HARPO

A Versatile Three-Dimensional Hamiltonian Ray-Tracing Program for Acoustic Waves in an Ocean with Irregular Bottom

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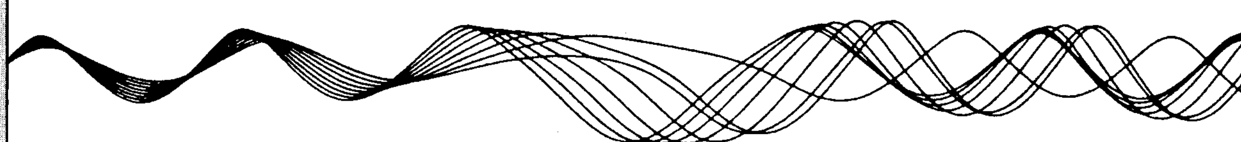

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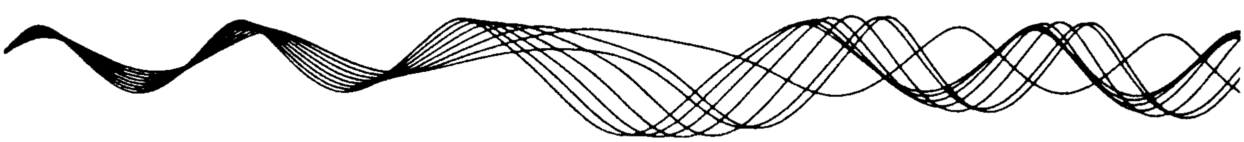
Wave Propagation Laboratory
Boulder, Colorado

October 1986



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The program documented in this report is offered "as is," with no performance guarantees. The authors make no claim that it is suitable for any particular application, or that it will run on any computing system without modification. If you encounter true "bugs," please report them to the authors. If you have specific applications that require consultation or program modification, the authors are willing to discuss arrangements for meeting your specific need.

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Errata for HARPO report (17 June 2005)

page 47, line 7: Add "with a copy of the input data file" after "raysets".

page 50, Figure 2.25: Change "Col.74-79" to "Col.74-77".

page 158, Table 7.25: Change "XMIN0,YB" to "YMIN0,YB"

page 158, Table 7.25: Change "XMAX0,YT" to "YMAX0,YT"

page 214: The sentence "Superimpose these raypath plots on the graph of the previous runset:" should read "Superimpose these raypath plots on the graph of the next runset:"

page 223, 6th line from bottom should read:
the fractional increase of C with depth, epsilon sub 1 = ________(W158)

page 223, last line should read:
the fractional increase of C with depth, epsilon sub 2 = ________(W163)

page 223: The formula for [Greek letter eta] should contain a minus sign.

page 224, 6th line from bottom should read:
the fractional increase of C with depth, epsilon sub 1 = ________(W158)

page 224, last line should read:
the fractional increase of C with depth, epsilon sub 2 = ________(W163)

page 224: The formulas for [Greek letter eta sub 1 and eta sub 2] should contain minus signs.

page 225: Change "W200" to "W150", "W201" to "W151", and "W202" to "W152".

page 235: Change the model check number for subroutine RBOTM to "2.0".

page 236: Change the model check number for subroutine RVERT to "3.0".

page 240: 9th line from the bottom, change "HARPA" to "HARPO".

page 248: After line RAQC1670 of PROGRAM RAYTRC, insert

```
      LHDRPG = LINES/LINSPP*LINSPP                                  RAQC1675
```

@begin[comment]
page 256, line REZ11620 in SUBROUTIN READW1 sets GP(N1-1) to have a fractional value, but line GTLH0490 in SUBROUTINE GTANH on page 415 tests to see whether it is a multiple of 3. (See the equivalence statement in line CB8 0060 on page 413.)
@end[comment]
page 261: line REXW0290 in FUNCTION READW should read:

```
      PARAMETER (MXCMTS=83,BIGVAL=1.E9)                             REXW0290
```

@begin[comment]
page 261: Change line REXW0360 in FUNCTION READW to

```
      LOGICAL NWOK,AB,UUCON,UCON,SETUCON                            REXW0360
```
@end[comment]

page 261: line REXW0360 in FUNCTION READW should read:

```
      LOGICAL NWOK,AB,UCON,UUCON,SETUCON                            REXW0360
```

page 264: line REXW1980 in FUNCTION READW should read:

```
      UUCON=SETUCON(X.Y,Z)                                          REXW1980
```

```
@BEGIN[COMMENT]
Page 265:  line REXW2090
    The variable SKIP should not be set to be the largest possible REAL value,
        because on page 270, line TRWE0450, it is stored in an integer variable.

page 268:  SETUCON is an entry point in a logical function, but there are places
        where the program uses CALL SETUCON, as though it were a subroutine.

@END[COMMENT]
page 271: line TRWE0730 in SUBROUTINE TRACE should read:

      IF(THERE.AND.FDOT.EQ.0.) RSIGN = SIGN(1.0,D2Z)                    TRWE0730

page 273: In line TRWE1870 of SUBROUTINE TRACE, change SSURF TO ASURF.

page 295: Line COPK0610 in SUBROUTINE CONBLK should read:
        DATA CUEF/1.d0,8.31436d-3,1.4d0/                                  COPK0610

@begin[comment]
page 311: In line OCBD1370 in SUBROUTINE OCNHD, the format allows for 134
        columns, which may not be allowed on some computers.
@end[comment]
page 311: line OCBD1370 in SUBROUTINE OCNHD should read:

1000  FORMAT(A1/A80,21X,2A10,' PAGE',I4)                                OCBD1370

page 311: in line OCBD1540 in SUBROUTINE OCNHD, change "F12.6" to "F18.6".

page 330: Change lines LAOT0750 and LAOT0760 to
C     LOOP FOR 9 MODELS AND PERTURBATIONS
      DO 1700 K=1,18

          Insert the following 4 lines after line LAOT0880
      IF(I.EQ.7) WRITE(LABEL,1600) (MODT(J),J=J1,J2)
      IF(I.EQ.8 .AND. J1.EQ.1)
     1 WRITE(LABEL,1600) (MODM(J),J=J1,J2)
      IF(I.EQ.9) WRITE(LABEL,1600) (MODP(J),J=J1,J2)

page 335: Replace lines DRYS014 through DRYS019 in SUBROUTINE DRAWTKS with

      IF(DTICV.GT.0.) THEN
         YBP=YMID-AINT((YMID-YB)/DTICV)*DTICY
         NTICX=(XR-XL)/DTICH+1.5
      ELSE
         YBP=YB
         NTICX=2
      ENDIF
C
      nticy=2
      IF(DTICV.GT.0.d0) NTICY=(YT-YBP+DTICV)/DTICV+0.5 ! added .5

page 337: Change line PLGB0360 in SUBROUTINE PLTLB to
      WRITE(ANNOT,50)
     &     IDINT((V-EARTHR)*F*dsign(1.d0,hb) +
     & dsign(.5, (V-EARTHR)*F*dsign(1.d0,hb) ))

page 337: Change line PLGB0400 in SUBROUTINE PLTLB to
60    WRITE(ANNOT,80) SNGL((V-EARTHR)*F*dsign(1.d0,hb))

page 338: Change lines ARPC0100 and ARPC0110 in SUBROUTINE ARCTIC to

      IF(TIC.NE.0.) NTIC=1.5+(THMAX-THMIN)/TIC                          ARPC0100
      NLINE=MAX0(3,100/NTIC)                                            ARPC0110

page 364: Line WGZ20140 in SUBROUTINE WGAUSS2 should be
```

```
      DATA RECOGU/8.0/                                              WGZ20140
```

page 381: Change line CSS10140 in SUBROUTINE CSMUNK1 to

```
C     ETA = -2(Z-ZA)/H                                              CSS10140
```

page 384: Change line CSS20140 in SUBROUTINE CSMUNK2 to

```
C     ETA = -2(Z-ZA)/H                                              CSS20140
```

@BEGIN[GROUP]page 389: (SUBROUTINE CTABLE)

Line CTUE0180, change CMX to CPX.
Line CTUE0190, change CNTBL to CQTBL.
Line CTUE0200, change CITBL to CLTBL.
Line CTUE0210, change CFRMTBL to CIRMTBL.

After line CTUE0210:

Insert a copy of line CSS10370 through CSS10460 (from SUBROUTINE CSMUNK1) on page 383.
@END[GROUP]

page 393: In lines CB2 0020 and CB2 0050 in SUBROUTINE NPSPEED, change B2 to B4.

page 415: Change lines GTLH0490 and GLTH0500 in SUBROUTINE GTANH to comments.

page 428: Change line RVRT0190 in SUBROUTINE RVERT to

```
      DATA RECORR/3.0/                                              RVRT0190
```

We thank Arthur Newhall of WHOI for pointing out many of these errors.

CONTENTS

FIGURES

TABLES

ACKNOWLEDGMENTS

Part of the organization of this program into subroutines follows that of the program of Dudziak (1961). Also, the coordinate transformation in subroutine PRINTR and the method for data input via the W array are taken from the program of Dudziak (1961). The term "rayset," the idea of outputting computer-readable results of each hop for each ray trace, and the idea of automatically plotting raypaths come from the program of Croft and Gregory (1963). Subroutine RKAM1 is a modification of subroutine RKAMSUB, written by G. J. Lastman, and is available through the CDC CO-OP library (the CO-OP identification is D2 UTEX RKAMSUB). Subroutine GAUSEL was written by L. David Lewis, NOAA Space Environment Laboratory. Judith Stephenson wrote much of the original ionospheric ray-tracing program, upon which HARPO is based. Richard Lindzen devised the method upon which models CSTANH, CTANH, and GTANH are based. We also thank the many users of earlier versions of the program who provided helpful feedback. Special thanks go to the Editorial Staff of Publication Services for extensive help in clarifying the expression of our ideas, and to Ms. Mildred Birchfield for her excellent typing and layout of the manuscript.

HARPO -- A VERSATILE THREE-DIMENSIONAL HAMILTONIAN RAY-TRACING PROGRAM FOR ACOUSTIC WAVES IN AN OCEAN WITH IRREGULAR BOTTOM

R. Michael Jones, J. P. Riley, and T. M. Georges

ABSTRACT

HARPO stands for Hamiltonian Acoustic Ray-tracing Program for the Ocean. This FORTRAN computer program traces the three-dimensional paths of acoustic rays through model oceans by numerically integrating Hamilton's equations, which are a differential expression of Fermat's principle. The user specifies an ocean model by writing closed-form formulas for its three-dimensional current and sound-speed distribution, and by defining the depth of the bottom as a function of geographic latitude and longitude. Some general-purpose models are provided, or users can easily design their own.

Because it uses continuous models, the Hamiltonian method avoids the false caustics and discontinuous raypath properties encountered in conventional ray-tracing methods, which use layers or cells where each acoustic-raypath segment can be computed in closed form. Furthermore, computational speed can be traded for accuracy, without changing the model of the medium, by specifying the maximum allowable integration error per step.

In addition to computing the geometry of each raypath, the program can calculate pulse travel time, phase time, Doppler shift (if the ocean varies in time), absorption, and geometrical path length. Amplitude is not explicitly computed, but the contributions by absorption, reflection losses, and focusing are separately available for each ray. Only geometrical effects are accounted for; that is, no diffraction or partial-reflection corrections are applied. The program prints out a step-by-step account of each ray's progress, and it can plot the projection of a set of rays on any horizontal or vertical plane. Furthermore, it can output each ray's properties in machine-readable form for further processing (amplitude and eigenray calculations, for example).

This report describes the ray-tracing equations and the structure of the program and provides complete instructions for using it, illustrated by a sample

case. The program is modular and can be adapted to model propagation through other media by changing the routine that defines the medium's dispersion relation.

PART I: WHAT THIS RAY-TRACING PROGRAM CAN DO

1. Introduction to Hamiltonian Ray Tracing

1.1 Rationale

Many practical problems in ocean acoustics submit to a straightforward application of geometrical acoustics, or ray theory. No other propagation-modeling tool provides such an intuitive and graphic portrayal of the paths that acoustic energy follows through inhomogeneous media. Even in situations where ray theory does not strictly apply, a picture of the acoustic raypaths often provides a useful first look at where sound goes in the ocean, and it gives insight into where higher order computations may be required. Some calculations cannot be easily made in any other way, for example, computing multipath pulse travel time or showing which parts of the ocean affect each pulse arrival.

Yet most of the ray-tracing computer programs in common use fail to take full advantage of the power of geometrical acoustics. Many are essentially automated versions of graphical techniques that patch together closed-form raypath solutions for layers or cells with simple refractive-index gradients (Roberts, 1974; Cornyn, 1973). In such models, gradient discontinuities at cell boundaries can introduce false caustics and cause discontinuous behavior of ray properties as launch angle varies (Pedersen, 1961). Furthermore, it is difficult to extend such models to three-dimensional oceans, to account for currents, and to compute reflections from complicated bottom models.

This report describes a general-purpose underwater acoustic ray-tracing program called HARPO -- for Hamiltonian Acoustic Ray-tracing Program for the Ocean -- that we have designed to overcome these limitations. It computes acoustic raypaths by numerically integrating Hamilton's equations, which are a differential expression of Fermat's principle. The user defines an ocean model by writing closed-form expressions for its sound-speed and current distribution in three dimensions, and by defining the bottom depth (or bathymetry) as a function of latitude and longitude. Several simple but generally useful models with user-specifiable parameters are described in this report; users can pattern their own models after them.

HARPO is the companion to a similar program we have developed for the atmosphere, known as HARPA. The main differences between the two programs are in the models available for the two media, and in provisions for reflections from an upper surface (in the ocean case). HARPA is documented in a separate report (Jones et al., 1986b).

1.2 What Is Ray Tracing?

Although ray tracing has a long history, many people outside the field do not know what ray tracing is or what it can do. In ray theory, waves are treated like particles (photons of light, phonons of sound) that travel along geometric trajectories called rays. In material media, the particles travel at a speed determined by the medium's "refractive index." Gradients in refractive index bend rays, giving rise to the problem of computing ray trajectories through a known spatial distribution of refractive index. Ray tracing is any method, graphical or numerical, for solving that problem.

Originally, lensmakers used ray tracing to find out how light rays travel through optical systems. They used graphical techniques based on Snell's law to compute the bending that light rays suffer when they encounter abrupt changes in refractive index, as at the surface of a lens. By constructing bundles of such rays, lensmakers could simulate the magnification, reduction, and focusing of their lens designs without actually building them.

Modern ray-tracing applications, whether acoustic or electromagnetic, serve basically the same function: they allow one to simulate the propagation of waves through media whose refractive-index structure varies in a complicated way, without actually performing the physical measurement. Modern ray-tracing computations are usually performed by programs written for digital computers that can graphically display the results of their computations in informative ways.

Today's ray-tracing programs do much more than compute how rays bend as they cross interfaces; they can model media whose refractive index varies continuously in space and even with time. In dissipative media, they integrate absorption along the raypath. They can also integrate phase and pulse travel time, as well as wave amplitude. In time-varying media, they can integrate the rate of change of phase, or Doppler shift. Some programs (including HARPO) produce machine-readable output so that the results of many raypath computations can be processed by other programs to display field observables, such as amplitude.

The most advanced applications of ray-tracing computer programs have been in the fields of ionospheric radiowave propagation, seismic wave propagation, and the propagation of acoustic or sound waves in the ocean and the atmosphere. In the Hamiltonian formalism, the ray-tracing equations for acoustic, seismic, and electromagnetic waves are identical. To go from one kind of ray-tracing program to another, all you have to do is change the modules that describe the wave dispersion relation and how the medium varies in space.

1.3 What Approximations Are Involved in Ray Tracing?

Solving a wave equation with arbitrary boundary conditions is still an impractical task, even for the most modern computers. Therefore, practical problems in wave propagation are often solved by making simplifying approximations to the wave equation. Examples of such approximations are the parabolic-equation (P.E.) method (Tappert, 1977), normal-mode theory (Tolstoy and Clay, 1966; Pierce, 1965), fast-field methods for numerical integration of the wave equation in range-independent environments (Raspet et al., 1985), and ray theory.

Ray theory, sometimes called the WKB or eikonal method, results from making a high-frequency approximation in the solution of arbitrary elliptic or hyperbolic partial differential equations (Budden, 1961). Ray tracing is related to the "method of characteristics" for solving such equations because the acoustic raypaths are the bi-characteristic rays of the differential equations in the infinite-frequency, infinite-wave-number limits. In some fields, ray tracing is called the "shooting method" because (as with shooting a gun) the location of the end point is found by trial and error while the initial conditions of a ray are varied.

In the case of the wave equation, the approximation gives rise to the fields of geometrical acoustics or geometrical optics, which are concerned with the trajectories of bundles of acoustic or electromagnetic energy radiated in infinitesimal angular beams. Such rays experience no diffraction but produce sharp shadow boundaries when they encounter solid objects. Ray theory can be extended to include the effects of diffraction, for example, by using the Geometrical Theory of Diffraction (GTD) (Keller, 1962).

In ray theory, one assumes conservation of energy within a bundle of rays called a flux tube, so that wave intensity is inversely proportional to the cross-sectional area of the flux tube. When that cross-sectional area becomes zero (a "caustic"), ray theory predicts infinite energy density. (This does not prevent rays from being traced through caustics, however.) Higher order corrections to ray theory can give more accurate field estimates near caustics when needed. For example, the field near a surface caustic can be calculated in terms of Airy functions (Ludwig, 1966; White and Pedersen, 1981).

Without such corrections, ray tracing accounts only for refraction by large-scale gradients in the medium and not for diffraction and scattering by changes in the medium over scales that are small compared to a Fresnel zone. Even so, ray theory provides a useful first look at many complicated propagation problems and gives a kind of graphical insight lacking in other propagation models.

1.4 When Should You Use Ray Tracing?

Ray tracing is best suited to modeling sound propagation in oceans whose refractive index can be described deterministically in one, two, or three dimensions, and where changes in refractive index are small within an acoustic Fresnel zone (this is the WKB criterion). (This means that ray models are most accurate at high frequencies.) In such environments, ray tracing gives accurate information about the geometrical paths followed by acoustic rays (energy), about shadow boundaries and reflections from surfaces, and about phase, intensity, pulse travel time, absorption and Doppler shift (for time-varying media) integrated along those paths.

In models where multiple rays reach a receiver location of interest, additional computations, external to the ray tracing, may be required to combine field information from multiple rays. When the number of multipath rays becomes large, alternative formulations of the problem (P.E. or normal-mode theory, for example) are more appropriate for continuous-wave amplitude calculations. For pulse transmissions, ray theory is useful for describing the distinct geometric paths corresponding to each pulse arrival and for computing multipath travel times.

In situations where the applicability of ray theory is doubtful, a raypath picture can tell which regions must be treated with higher order methods, such as GTD or the Airy-function approximation to the field near a caustic. Furthermore, there are standard formulas to estimate how close to a caustic amplitude calculations are accurate (Budden, 1961; 1972).

Even when ray calculations of one wave quantity become inaccurate, they can give useful estimates of others. For example, when amplitude estimates break down (as at surface caustics), other information, such as travel time or phase, may still be reliable and can be tracked through caustics. Furthermore, Budden (1961, pp. 325-326) shows that the ray-computed phase must be advanced by 90° every time a ray passes through a surface caustic.

1.5 What Is Hamiltonian Ray Tracing?

An alternative to cellular methods requires the ocean to be modeled as a continuous three-dimensional function with continuous gradients and computes each raypath by numerically integrating Hamilton's equations with a different set of initial conditions. This method has been called Hamiltonian ray tracing. Hamilton's equations are the same for all kinds of wave propagation; only the definition of the Hamiltonian varies when going from one wave type to another.

Although Hamilton's equations are more familiar in mechanics, they have a long history of application to more general problems, including wave propagation. There, the point of view is that in a high-frequency limit, waves behave like particles and travel along rays, according to equations that exactly parallel those governing changes of position and momentum in mechanical systems (Lighthill, 1978, Sec. 4.5). Two steps show that integrating Hamilton's equations can lead to approximate solutions of a wave equation:

(1) The first step is to show that solutions to the wave equation are related to paths that satisfy a particular stationary principle, usually called

Fermat's principle. There are at least two standard methods for demonstrating that relation.

(a) First is the method of characteristics (see, for example, Courant and Hilbert, 1962; Garabedian, 1964), in which the solution is related to initial-value data chosen on some appropriate surface. Specifying a surface and constructing a solution requires first constructing the characteristic surfaces that are wave fronts of the wave. These characteristic surfaces can be constructed by first constructing bi-characteristic rays that satisfy a stationary principle. The bi-characteristic rays are the same as the geometrical raypaths whenever all terms in the wave equation are proportional to a derivative of the wave function, or in the limit of infinite frequency and wave number.

(b) Second is the path-integral method (see, for example, Feynman and Hibbs, 1965), in which a solution to the wave equation is constructed as an integral over all possible paths (not just raypaths) that connect the source and observer. Making a saddlepoint (or stationary phase) approximation to the path integral finds the paths that contribute most to the path integral. Such paths are those for which the action (phase) is stationary for variations of the path; that is, they satisfy Fermat's principle.

(2) The second step is to show that Hamilton's equations can be integrated to construct paths that satisfy a variational principle, such as Fermat's principle. This is done in standard texts (for example, Lighthill, 1978). First, the variational principle is expressed as an integral of a Lagrangian along the path (specified in terms of generalized coordinates, q_i). This determines the form of the Lagrangian for the problem, which for the wave equation is usually some simple function of the phase refractive index. Then the generalized momenta p_i are defined, which for the wave equation correspond to components k_i of the wave number vector. Then a Hamiltonian $H(q_i,p_i)$ is constructed from the Lagrangian. For the wave equation, the Hamiltonian is usually a function that gives the dispersion relation for the wave in question when it is set to zero. Integrating Hamilton's equations then gives a path that satisfies the variational (Fermat's) principle.

In Cartesian coordinates, Hamilton's equations take the particularly simple form (Lighthill, 1978)

$$\frac{dx_i}{d\tau} = \frac{\partial H}{\partial k_i} \quad ; \quad \frac{dk_i}{d\tau} = -\frac{\partial H}{\partial x_i} \quad , \quad i = 1 \text{ to } 3 \quad , \tag{1.1}$$

where τ is a parameter (sometimes proportional to time) whose physical meaning depends on the how the Hamiltonian, H, is defined, k_i are the wave-number components, and x_i are the coordinates of a point on the raypath. Transforming to spherical polar coordinates complicates the equations considerably. The full set of equations for spherical coordinates can be found in Chapter 6.

To solve (1.1) for the raypath, one chooses initial values for the six quantities x_i and k_i and performs a numerical integration of the system (1.1) of six total differential equations. For acoustic waves in the ocean, the Hamiltonian (which is constant along a raypath) is defined as

$$H(x_i, k_j) = [\omega - \vec{k}\cdot\vec{V}(x_i)]^2 - C^2(x_i)\, k^2 = 0 \ , \tag{1.2}$$

where $\vec{V}(x_i)$ is the ocean current, $C(x_i)$ is the sound-speed field, and ω is the angular wave frequency ($\vec{V}$ and C may also depend on time). Thus, the effects of a three-dimensional vector-current field are automatically included in the definition of the Hamiltonian.

There is an alternative to Hamilton's equations for a differential form of the ray equation, namely the eikonal equation (see, for example, Garabedian, 1964, p. 166; Felsen and Marcuvitz, 1973, p. 126). The eikonal equation is derived by first assuming an approximate solution to the wave equation in terms of an asymptotic series. Substituting the asymptotic series into the wave equation leads to the eikonal equation, which determines the raypaths, and a transport equation, which determines an approximate solution to the wave equation. The eikonal equation is equivalent to Hamilton's equations for determining the raypath. The transport equation is equivalent to methods mentioned above for determining an approximate solution to the wave equation.

In addition to allowing continuous three-dimensional models of the refractive-index field and two-dimensional models of reflecting surfaces, Hamiltonian ray tracing by numerical integration permits the user to trade computing speed for accuracy by specifying the maximum allowed integration error per step. In other words, you can have a fast but crude ray trace or a slower and more accurate one. HARPO automatically adjusts the integration step length along the raypath to keep the error within specified bounds. In regions where the refractive index varies quickly, small steps are required, but where it varies slowly, large steps save computation. If the quantity being integrated varies monotonically along the raypath, the specified relative accuracy will be preserved in integrated quantities, such as travel time.

1.6 What This Program Does

HARPO computes the paths of acoustic rays, one at a time, through a user-defined model of the ocean, given initial conditions that include the source location (latitude, longitude, and depth), wave frequency, direction of transmission (elevation and azimuth), the receiver-surface model, and the maximum number of hops (intersections with the receiver surface). The input data specification forms in Chapter 2 illustrate the generality of acceptable input.

The mechanics of the raypath calculation have been completely separated from the modeling of the medium (sound-speed, current-velocity, and bottom models). This allows the user to select models from those we have developed or to develop new models simply by writing new (or altering existing) subroutines to define those models.

The modular structure of the program allows the user to extend the program easily to other types of geophysical ray tracing simply by substituting new subroutines for defining the Hamiltonian and the model of the medium.

The method for putting data into the program is easy to learn. The user simply specifies the magnitude and units of the elements of an Input Data File that correspond to physical or mathematical quantities that tell the program what models to use, what rays to trace, and in what form to present its results. We provide input parameter forms for making sure that all the required quantities are specified.

At the user's option, HARPO produces three kinds of output: (1) The printout reproduces the input data set and gives detailed information about each raypath computed, in columnar form, with each line corresponding to a "snapshot" of the ray's progress after a specified number of integration steps. (2) Computer-readable output permits further processing of raypath data by supplementary programs, without recomputing the raypaths. (3) The raypath plots show projections of any part of the raypaths on any vertical or horizontal plane, with any desired magnification. These plots give the user a quick view of the raypath geometries.

Chapter 2 illustrates more fully what the program does by going through the setup and execution of a representative application.

1.7 What This Program Does Not Do

HARPO's computations lie entirely within the scope of geometrical acoustics (ray theory). It applies no corrections for diffraction or partial reflections. The ocean model must be deterministic, not random.

There are no provisions built into HARPO for explicit computations of acoustic amplitude. This would normally be done with a supplementary program that processes HARPO's machine-readable output. Total amplitude at a receiver would be computed by combining flux-tube focusing, reflection losses, and absorption, and the user would normally decide whether to add coherently or incoherently the contributions of multipath rays. Because there are so many ways to compute amplitude, we think it is most useful to keep the various factors separate and let the users combine them however they wish.

Because the numerical integration of Hamilton's equations requires ocean models with continuous gradients, HARPO cannot presently handle refraction at discontinuities of refractive index or its gradients. If such discontinuities are included in a model, the integration routine will attempt to handle them by taking extremely small steps when a ray encounters a discontinuity, and the results may not be reliable. In general, one can approximate discontinuous functions with continuous functions to any desired accuracy, and HARPO will adjust its step length to accommodate them. Our algorithms for reflecting rays from arbitrary bottom surfaces could be generalized to compute refraction at discontinuities in refractive index.

HARPO is not now equipped to model penetration of rays into the bottom or to account for partial reflections from sub-bottom layers. However, the user can specify a complex (to account for phase and amplitude) bottom-reflection coefficient that is a function of frequency and angle of incidence. Since reflection coefficients do not affect the raypaths, their effects can be added (and varied) after raypath calculations.

HARPO cannot directly compute the raypaths that connect a specified source and receiver. To find such "eigenrays," one usually launches a fan of rays at small increments in elevation and/or azimuth angle and linearly interpolates for the rays that reach the desired receiver location (range, azimuth and depth). We have developed an eigenray program that processes the "rayset" output of HARPO, interpolating in elevation angle only, and that will be documented elsewhere. Some shortcuts for finding three-dimensional eigenrays when azimuthal deflections are small are described by Georges et al. (1986).

HARPO makes no checks to see if ocean models satisfy physical conservation laws and boundary conditions, or that current and sound-speed models are geostrophically consistent. (Accurate raypaths can be computed through physically impossible models.) It is the users' responsibility to make their models as physically realistic as their application demands.

1.8 History of the Program

HARPO has a long history of development. We started by learning from the programs of Dudziak (1961) and Croft and Gregory (1963). Jones (1966) documented our first version of a three-dimensional ray-tracing program for radio waves in the ionosphere, which included anisotropy caused by the earth's magnetic field. Jones (1968) documented improvements in the original program. Georges (1971) converted the ionospheric radio program to trace raypaths for acoustic-gravity waves in an atmosphere with winds and changed the ray-tracing equations into Hamiltonian form. Jones and Stephenson (1975) documented further significant improvements in the ionospheric program. Jones et al. (1982) documented a Hamiltonian acoustic ray-tracing program for an atmosphere over a spherical earth.

Through its history, HARPO and its predecessors have found application in the propagation of radio waves through the ionosphere (Georges, 1967; 1970; Georges and Stephenson, 1968; Stephenson and Georges, 1969), acoustic propagation through the atmosphere (Georges, 1972; Georges and Beasley, 1977) and acoustic propagation in the ocean (Georges et al., 1986; Jones et al., 1984, 1986a). In extending the utility of ray theory, Jones (1970) has treated ray propagation in lossy media (ray tracing in complex space), bending of rays in random, inhomogeneous media (Jones, 1981a), and the frequency shift suffered by pulses propagating in dispersive media (Jones, 1981b). Jones (1983) has also surveyed existing techniques for underwater acoustic ray tracing.

HARPO combines the improvements made by Jones and Stephenson with the acoustic-wave capability and ocean models developed by Georges, and it includes modularity features that make it easier to convert the program to trace rays in other media. It also includes algorithms developed by Jones (1982) for reflecting rays from arbitrary bottom surfaces. In addition, we have developed real-time graphics routines and improved access by time-share graphics terminals as that technology has advanced.

1.9 Scope of This Report

This report documents only the ray-tracing program HARPO, its supporting subroutines, and its various forms of input and output. The main intent of this report is to show what HARPO can do and to explain how to use it. We illustrate its capabilities with a comprehensive sample case. We also show how to extend and modify the program to the user's specific needs.

Not documented here are supplementary programs that we have designed to plot properties of the ocean models and to process the computer-readable output of HARPO. Examples of such programs are packages to compute eigenrays, to plot range vs. elevation angle of transmission, range vs. travel time, and amplitude calculations (Georges et al., 1986; Jones et al., 1984). We have not documented here our programs for editing input to HARPO or our procedure files for running it on our computer. Nevertheless, the package documented here is self-contained and has everything needed to compute and display raypaths through arbitrary three-dimensional model oceans.

Figure 1.1 shows an organization chart of HARPO in relation to its supporting modules. The dotted line encloses the portion documented in this report. Separate reports will document the remaining modules, which are the same for both HARPA and HARPO.

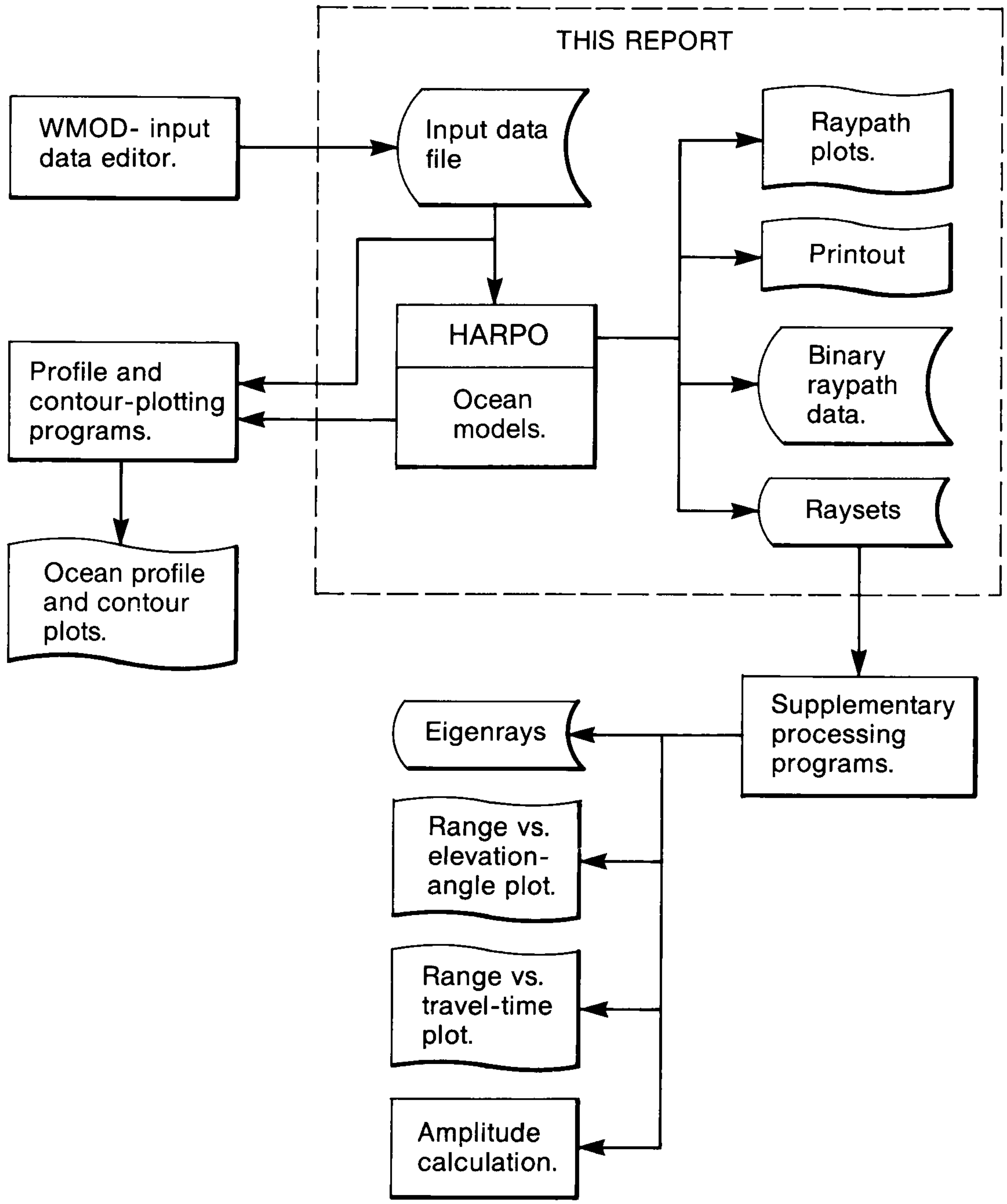


Figure 1.1. Relation of HARPO to its inputs and outputs, as well as its supporting and supplementary programs. The dashed line shows the scope of this report.

2. A Sample Run Illustrating an Application of HARPO

A sample case serves several purposes: it introduces new users to the capabilities of the program in terms of physical models they can understand; it shows the new user how to set up and run the program and what output to expect; and it provides a comprehensive test case to exercise the program and make sure everything works on a new machine. New users should run the sample case (provided with the program) first and make sure that the program's output is identical to that shown in this report. Varying the input parameters, one by one, from the sample case is an instructive way to explore the program's capabilities.

The usual procedure in defining models is to fill out "order forms" corresponding to the sound-speed, current, absorption and bottom models you want to use, then create an "Input Data File" from the information on the order forms. Models can be selected from the general-purpose ones we have created, or you can design your own. The following pages show filled-out forms for the models used by the sample case, and blank order forms for all our ocean models are supplied in Appendix B. We recommend that both beginning and advanced users fill out these forms, because they make sure that you specify all the required model parameters. They also help you keep track of the models you create.

2.1 The Ocean Model for the Sample Case

The ocean model described here is designed more to exercise features of the program than to represent any physically realistic situation. It combines a three-dimensional current and sound-speed field with a bottom model containing a Lorentzian-shaped ridge. The sample case also includes a simple absorption model that depends only on acoustic frequency.

Refer now to the FORM TO SPECIFY AN OCEAN MODEL (Figure 2.1). This form is filled in with the names of all the subroutines required to specify the ocean model for the sample case, including an ocean-bottom model, an ocean-surface model, and a receiver-surface model. Data-set ID numbers uniquely specify the particular set of parameter values used by each subroutine for the sample case. The entire set of models and parameters that constitute the ocean model for the sample case is also given a unique ID number, which is N01. The references to W

FORM TO SPECIFY AN OCEAN MODEL
(including bottom and upper surface model)

Name GEORGES Date 8-19-86 Model ID (3 characters) NØ1

Dispersion Relation
__ ANCNL ✓ AWCWL __ AWCNL __ ANCWL __ Other ________

Coordinates of the north pole pole of the computational coordinate system:
North geographic latitude = 90. rad, km, (deg) (W24)
East geographic longitude = 0. rad, km, deg (W25)

Data Set ID Model Subroutine Name (Model Check Number)

Current Velocity W102 (W100)	__	WLINEAR	(1.)	__	WGAUSS2	(8.)	
	3.	VVORTX3	(9.)	__	Other ______		( )
Current Perturbation W127 (W125)	0.	NPCURR	(0.)	__	Other ______		( )
Sound Speed W152 (W150)	__	CSTANH	(2.)	__	CSMUNK1	(5.)	
	__	CSSPOKE	(3.)	__	CSMUNK2	(6.)	
	__	CSSPOK2	(4.)	__	CTABLE	(8.)	
	1.	CTANH	(7.)	__	Other ______		( )
Sound-Speed Perturbation W177 (W175)	__	NPSPEED	(0.)	7.	CBLOB2	(2.)	
	__	CBLOB3	(3.)	__	Other ______		( )
Receiver Surface* (W275)	✓	RHORIZ	(1.)		RTERR	(2.)	
		RVERT	(3.)		Other ______		( )
Ocean Bottom W302 (W300)	__	GHORIZ	(1.)	__	GTANH	(2.)	
	3.	GLORENZ	(3.)	__	Other ______		( )
Ocean-Bottom Perturbation W327 (W325)	0.	NPBOTM	(0.)	__	Other ______		( )
Ocean Surface W352 (W350)	1.	SHORIZ	(1.)	__	Other ______		( )
Ocean-Surface Perturbation W377 (W375)	0.	NPSURF	(0.)	__	Other ______		( )
Absorption (loss) W502 (W500)	1.	SLLOSS	(1.)	__	Other ______		( )
Absorption Perturbation W527 (W525)	0.	NPABSR	(0.)	__	Other ______		( )
Graph Annotation* W75	__	SMPANN		.15	FULANN		

* The receiver-surface and graph-annotation models are not considered part of the ocean-model ID.

Figure 2.1. Sample of completed form to specify an ocean model, with entries for the sample case.

followed by numbers in these forms correspond to specific input data parameters, as described in Section 5.3.

The first subroutine name on this form specifies the acoustic-wave dispersion relation to be used. In the sample case, we specify AWCWL, which means "Acoustic, With Currents, With Losses." This means that we will use a model ocean with currents, and we will calculate acoustic absorption. More efficient versions of the dispersion relation should be selected when currents or absorption models are not used (Sec. 6.4). The remaining subroutine names filled out on this form refer to ocean model subroutines, to be discussed next.

Refer next to the FORM TO SPECIFY INPUT DATA FOR CURRENT VELOCITY MODEL VVORTX3 (Fig. 2.2). This current model represents a vortex with a vertical axis and a solid-rotating core blending with a potential-vortex velocity falloff beyond a specified radius. A gaussian height profile of vortex intensity is also allowed.

VVORTX3 requires the user to specify six parameters: U_o, r_o, ϕ_o, λ_o, W_H and h_{max}. For the sample case, we select the maximum tangential speed to be 1.02 m/s, the radius r_o of the vortex core (where the tangential velocity reaches its maximum value, U_o) to be 50 km, the latitude of the vortex center, $\lambda_o = 0$, the longitude of the vortex center, $\phi_o = 150$ km (that is, 150 km east of the prime meridian, as measured at the Equator), the gaussian width in height, $W_H = 1$ km, and the height of the maximum velocity, $h_{max} = -1$ km (1 km below mean sea level). The resulting current field is illustrated in the contour plots of Figures 2.3 and 2.4. (The program that provided these plots is part of a set of peripheral programs that will be documented in another report.) Because we use no current-perturbation model in the sample case, we select the do-nothing current-perturbation model NPCURR.

Refer next to the FORM TO SPECIFY INPUT DATA FOR BACKGROUND SOUND-SPEED MODEL CTANH (Fig. 2.5). We use this model to specify the background sound-speed field of the ocean, in this case a horizontally uniform sound channel with a surface layer. CTANH is a general-purpose model that fits tabular sound-speed profiles with linear segments that join smoothly to form an analytic function. The formula for the function is given on the CTANH order form. For the sample case, we fit six segments to an average profile derived from in-situ ocean

FORM TO SPECIFY INPUT DATA FOR
CURRENT-VELOCITY MODEL VVORTX3

This subroutine models a vortex with a viscous core and a Gaussian intensity profile in the vertical. The axis of the vortex is vertical and may be positioned above any geographic latitude and longitude. The vortex rotates anticlockwise looking down. The core (inside r_o) is essentially a solid-rotating fluid, while outside r_o, $|u|$ falls off as the inverse radius.

$$u_\theta = -\frac{1.397\ R_e U_o r_o}{r^2}\left(1 - e^{-1.26\ r^2/r_o^2}\right)(\phi - \phi_o)e^{-\left(\frac{h - h_{max}}{w_H}\right)^2}$$

$$u_\phi = \frac{1.397\ R_e U_o r_o}{r^2}\left(1 - e^{-1.26\ r^2/r_o^2}\right)(\theta - \theta_o)e^{-\left(\frac{h - h_{max}}{w_H}\right)^2} ,$$

where $\theta_o = \pi/2 - \lambda_o$ and r is the radial distance from the vortex center. The numerical constants normalize the function so that $|U| = U_o$ at $r = r_o$. R_e is the radius of the Earth, θ is the colatitude, ϕ is the longitude, and h is the height above sea level.

Specify--

the model check for VVORTX3 = 9.0 (W100)

the input data-format code = ________ (W101)

an input data-set identification number = 3. (W102)

an 80-character description of the model, including description of parameter values:

VORTEX AT LONGITUDE 150 KM E, UMAX = 1.02 M/S, R = 50 KM

the maximum tangential current, U_o = .00102 (km/s), m/s (W103)

the radius of the vortex core (to $u = U_o$), r_o = 50. km (W104)

the latitude of the vortex center, λ_o = 0. rad, deg, km N (W105)

the longitude of the vortex center, ϕ_o = 150. rad, deg, (km)E (W106)

the Gaussian width in height of the vortex, W_H = 1. (km) m (W107)

the height of the vortex, h_{max} = −1. (km) m (W108)

OTHER MODELS REQUIRED: Any current-perturbation model. Use NPCURR if no perturbation is desired.

Figure 2.2. Sample of completed form to specify ocean current model VVORTX3.

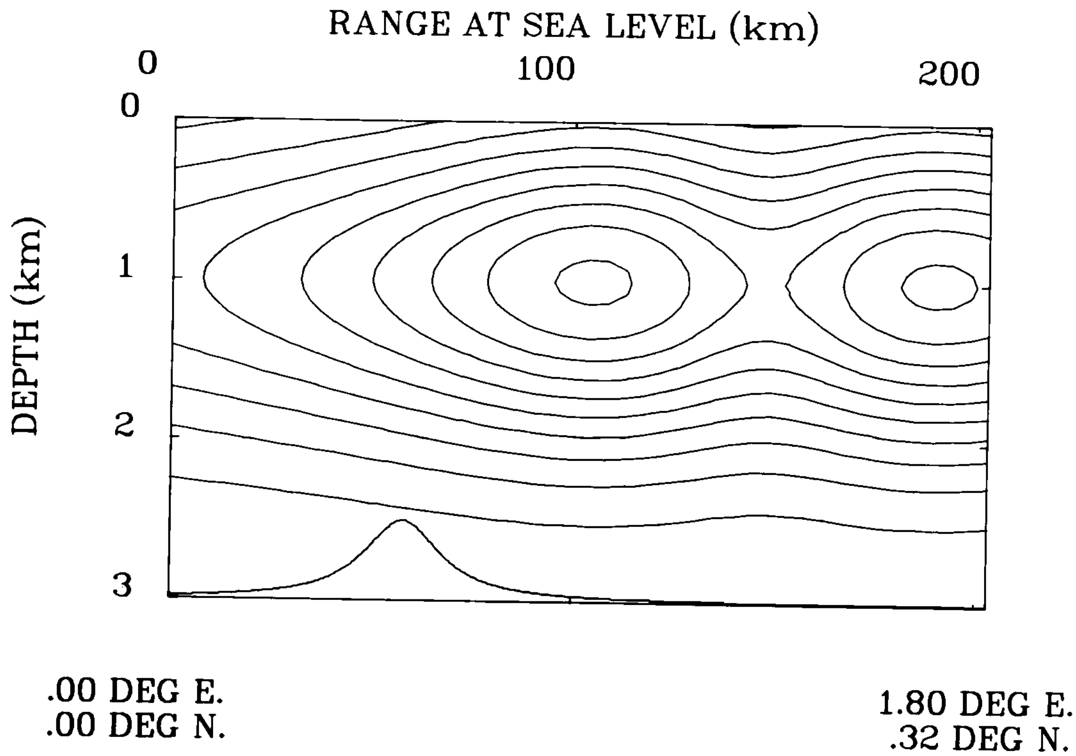


Figure 2.3. Contours of ocean current for model VVORTX3 in the vertical ray-transmission plane (Fig. 2.18).

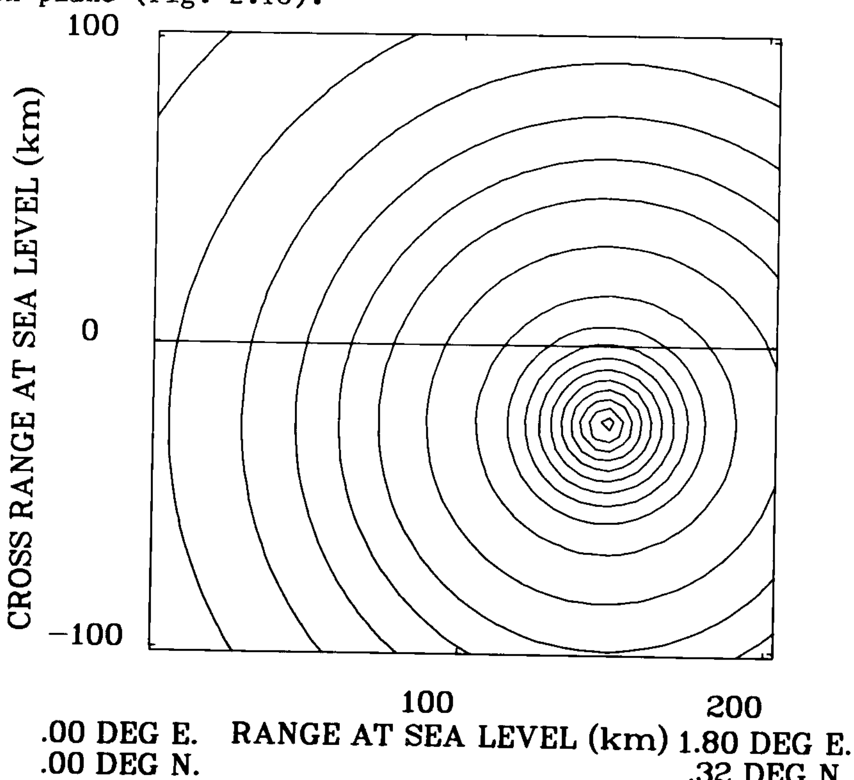


Figure 2.4. Contours of ocean current for model VVORTX3 in a horizontal plane at a depth of 1 km.

FORM TO SPECIFY INPUT DATA FOR BACKGROUND SOUND-SPEED MODEL CTANH

This model represents the sound-speed profile by a sequence of linear segments that are smoothly joined by hyperbolic functions:

$$C = C_o + \frac{b_1}{2}(z-z_o) + \sum_{i=1}^{n} \delta_i \left(\frac{b_{i+1} - b_i}{2}\right) \ln \left\{ \frac{\cosh\left(\frac{z-z_i}{\delta_i}\right)}{\cosh\left(\frac{z_i-z_o}{\delta_i}\right)} \right\} + \frac{b_{n+1}}{2}(z-z_o)$$

$$\frac{dC}{dz} = b_1 + \sum_{i=1}^{n} \left(\frac{b_{i+1} - b_i}{2}\right) \left\{\tanh\left(\frac{z-z_i}{\delta_i}\right) + 1\right\}$$

$$b_i = (C_i - C_{i-1})/(z_i - z_{i-1}) \quad .$$

$z = r - r_e$, where r_e is the Earth radius, and r is the radial coordinate of the ray point. Thus, δ_i is the half-thickness of a region centered at approximately z_i km, in which dC/dz changes from b_i to b_{i+1}. Start by drawing a profile with linear segments, and get C_i and z_i from the corners. Then select δ_i to round the corners. The final profile will not go through (C_i, z_i).

Specify--

the model check for CTANH = 7.0 (W150)

the input data-format code = ________ (W151)

an input data-set identification number = 1. (W152)

an 80-character description of the model with parameters:

EL NINO BACKGROUND SOUND-SPEED PROFILE

and the profile values:

the number of points in the profile -2 = n = 5

the profile:

i	z_i (km, m)	C_i (km/s, m/s)	δ_i (km, m)
0	0	1532.	0
1	-20.	1531.5	-7.
2	-50.	1509.	-20.
3	-250.	1503.	-40.
4	-450.	1485.	-300.
5	-1500.	1485.	-400.
6	-3000.	1508.	0

OTHER MODELS REQUIRED: Any sound-speed perturbation model. Use NPSPEED if no perturbation is desired. FUNCTION ALCOSH.

Figure 2.5. Sample of completed form to specify input data for ocean sound-speed model CTANH.

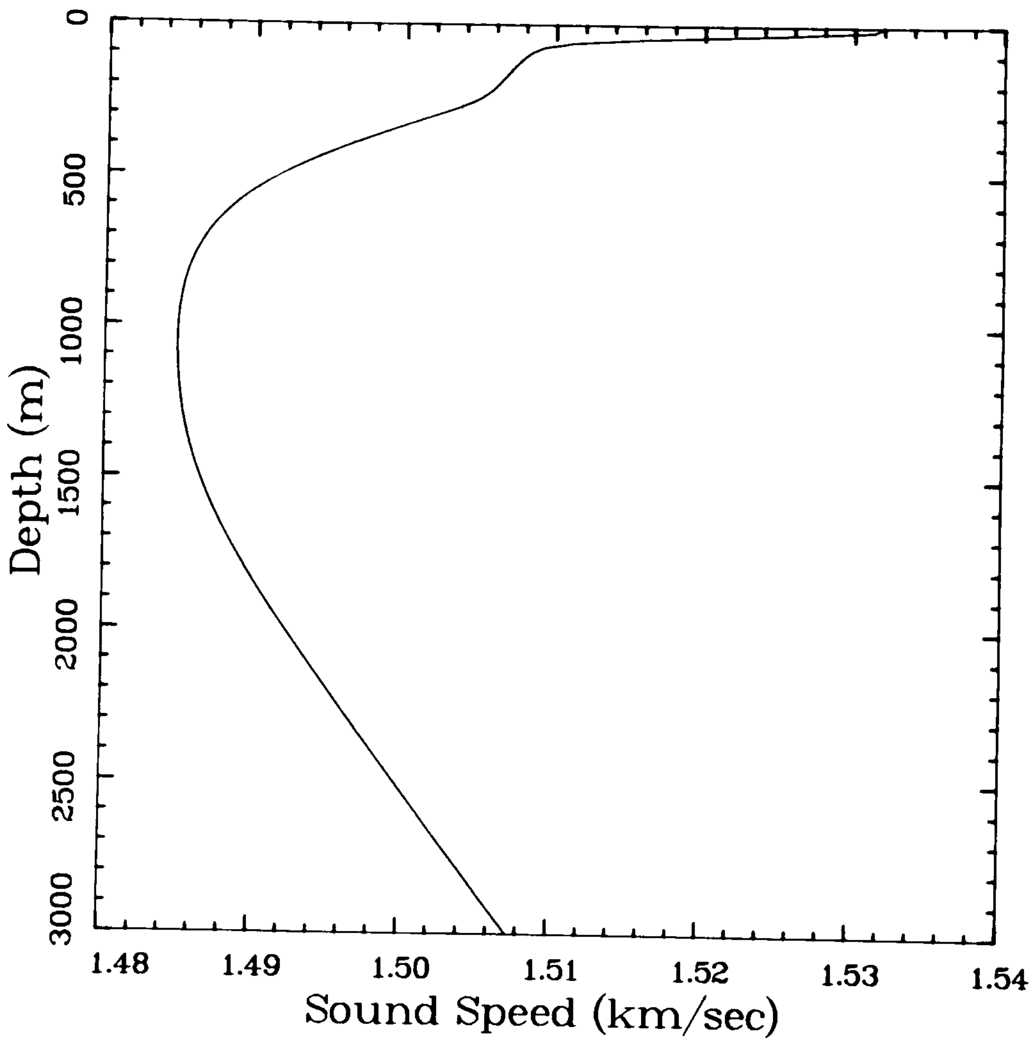


Figure 2.6. Sound-speed profile for model CTANH with parameters used in the sample case.

measurements made off the coast of Ecuador during the EPOCS exercise (NOAA, 1985). The resulting model profile is shown in Figure 2.6.

Refer next to the FORM TO SPECIFY INPUT DATA FOR SOUND-SPEED PERTURBATION MODEL CBLOB2 (Figure 2.7). CBLOB2 represents a local increase (or decrease) of sound speed that decays in a gaussian manner in all three spatial dimensions and can be located anywhere in the ocean. The perturbation model is superimposed on the background sound-speed model.

The user must specify seven input parameters: Δ, the strength of the fractional increase in squared sound speed, z_o, the height of the maximum effect; λ_o , the latitude of the maximum effect, ϕ_o, the longitude of the maximum effect; W_z, the gaussian width in height; W_θ, the gaussian width in the north-south direction; and W_ϕ, the gaussian width in the east-west direction. If any of the W's is given a zero value, the result is that there is no spatial variation in that direction. The formula is given on the CBLOB2 order form. For the sample case, we select $\Delta = 0.02$, $z_o = -1$ km, $\lambda_o = 0$, $\phi_o = 50$ km, $W_Z = 1$ km, $W_\theta = 50$ km, and $W_\phi = 50$ km. The location and scale of this perturbation are designed to coincide with the VVORTX3 current model just described. Figures 2.8 and 2.9 show total-sound-speed contours (including the background model) for the sample case.

Refer next to the FORM TO SPECIFY INPUT DATA FOR OCEAN ABSORPTION MODEL SLLOSS (Figure 2.10). This is a simple empirical model of absorption that depends only on the acoustic frequency according to the formula given on the SLLOSS order form. It requires no other ocean models, but other absorption models could be devised that depend on the concentrations of ocean constituents. Figure 2.11 shows the frequency dependence of this absorption model.

Refer next to the FORM TO SPECIFY INPUT DATA FOR OCEAN BOTTOM MODEL GLORENZ (Figure 2.12). This bottom model superimposes a Lorentzian ridge on a spherical surface at any height. The ridge, defined by the formula on the GLORENZ order form, runs along a latitude line, chosen to be 10 km N for the sample case. The other input parameters are z_o, the height of the ridge, chosen to be 0.5 km, and $\Delta\theta$, the width of the ridge, chosen to be 10 km for the sample case, and z_B, the height of the base of the ridge, chosen to be -3 km for the sample case.

FORM TO SPECIFY INPUT DATA FOR SOUND-SPEED
PERTURBATION MODEL CBLOB2

An increase (or decrease) in sound speed in a localized region that decays in a Gaussian manner in all three spatial directions.

$$C^2(r,\theta,\phi) = C_o^2(r,\theta,\phi)\left(1 + \Delta \exp\left\{-\left(\frac{z-z_o}{W_z}\right)^2 - \left(\frac{\theta-\theta_o}{W_\theta}\right)^2 - \left(\frac{\phi-\phi_o}{W_\phi}\right)^2\right\}\right)$$

$C_o^2(r,\theta,\phi)$ is the square of the sound speed specified by a sound-speed model. (r,θ,ϕ) are the coordinates of the ray point in an Earth-centered spherical polar-coordinate system. $\theta_o = \pi/2 - \lambda_o$ and $z = r - r_e$, where r_e is the Earth radius.

Specify--

the model check for subroutine CBLOB2 = 2.0 (W175)

the input data-format code = ____________ (W176)

an input data-set identification number = 7. (W177)

an 80-character description for the sound-speed perturbation model, including description of parameter values:

2% INCREASE IN C SQUARED AT 150 KM RANGE, 1 KM DEPTH, 50 KM WIDE

the strength of the fractional increase (or decrease), Δ = .02 (W178)

the height of maximum effect, z_o = -1. km (W179)

the latitude of maximum effect, λ_o = 0 rad, deg, km N (W180)

the longitude of maximum effect, ϕ_o = 150. rad, deg, (km) E (W181)

the Gaussian width in height of the effect, W_z = 1. km (W182)*

the meridional width of the effect, W_θ = 50. rad, deg, (km) (W183)*

the zonal width of the effect, W_ϕ = 50. rad, deg, (km) (W184)*

OTHER MODELS REQUIRED: none.

* Setting W_z, W_θ, or W_ϕ = zero results in no space variation in that direction.

Figure 2.7. Sample of completed form to specify sound-speed perturbation model CBLOB2.

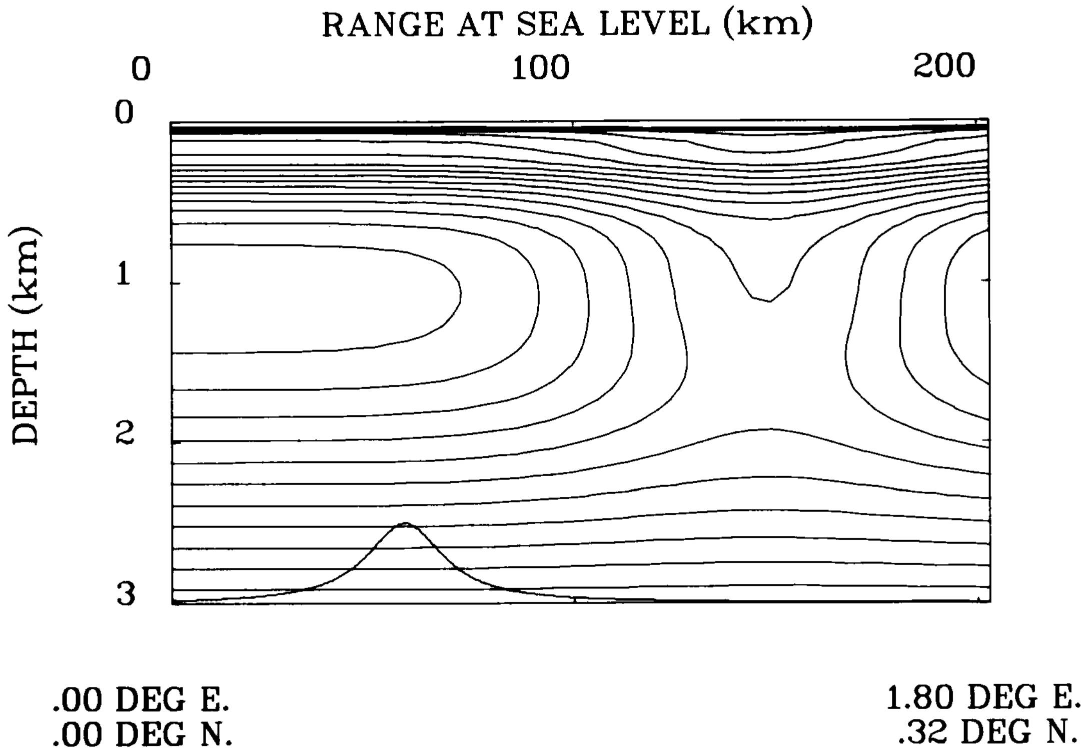


Figure 2.8. Contours of total sound speed in the vertical ray-transmission plane (Figure 2.18), using models CTANH and CBLOB2.

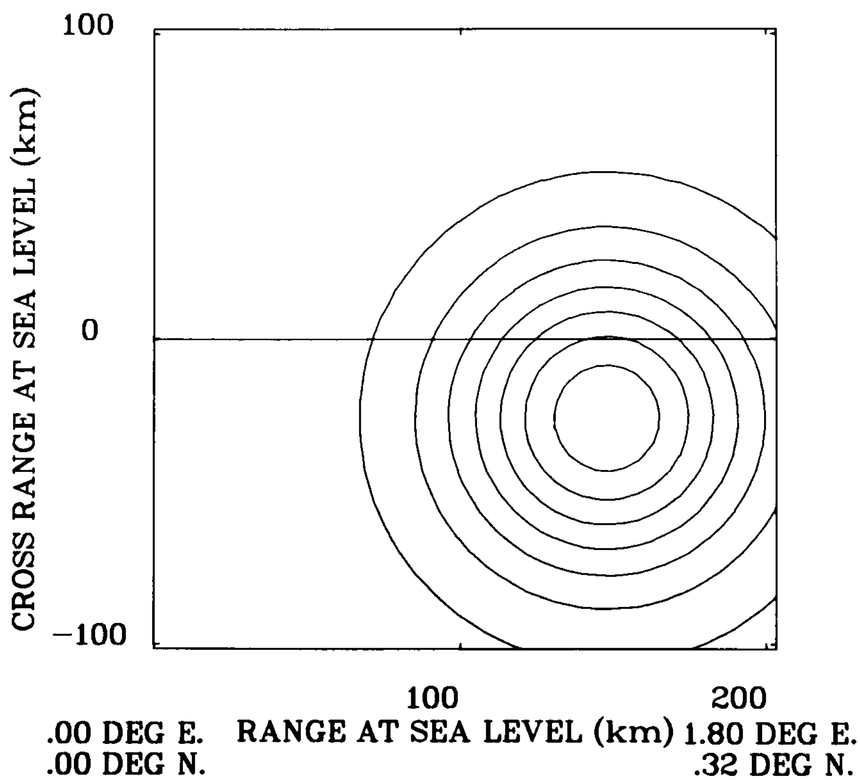


Figure 2.9. Contours of total sound speed in a horizontal plane at 1 km depth, corresponding to the sound-speed models of the sample case.

FORM TO SPECIFY INPUT DATA FOR
OCEAN ABSORPTION MODEL SLLOSS

This absorption model depends only on the acoustic wave frequency ω (rad/s), according to the formula

$$\alpha = a \frac{\omega^2}{\omega_1^2} + b \frac{\omega^2}{\omega_2^2 + \omega^2}$$

The following values for the coefficients correspond to the model of Skretting and Leroy (1971)*:

a = 0.006 dB/km ; ω_1 = 6283.2 rad/s (= 1000.0 Hz)

b = 0.2635 dB/km ; ω_2 = 10,681.4 rad/s (= 1700.0 Hz)

Specify--

the model check for SLLOSS = 1. (W500)

the input data-format code = ______ (W501)

an input data-set identification number = 1.0 (W502)

an 80-character description of the model, including parameter values:

SKRETTING- LEROY ABSORPTION FORMULA

a = 0.006 nepers/km, (dB/km) (W503)

b = 0.2635 nepers/km, (dB/km) (W504)

ω_1 = 1000 rad/s (Hz) (505)

ω_2 = 1700 rad/s (Hz) (W506)

Other models required: any absorption perturbation model. Use NPABSR if no perturbation is desired.

*see References.

Figure 2.10. Sample of completed form to specify absorption model SLLOSS.

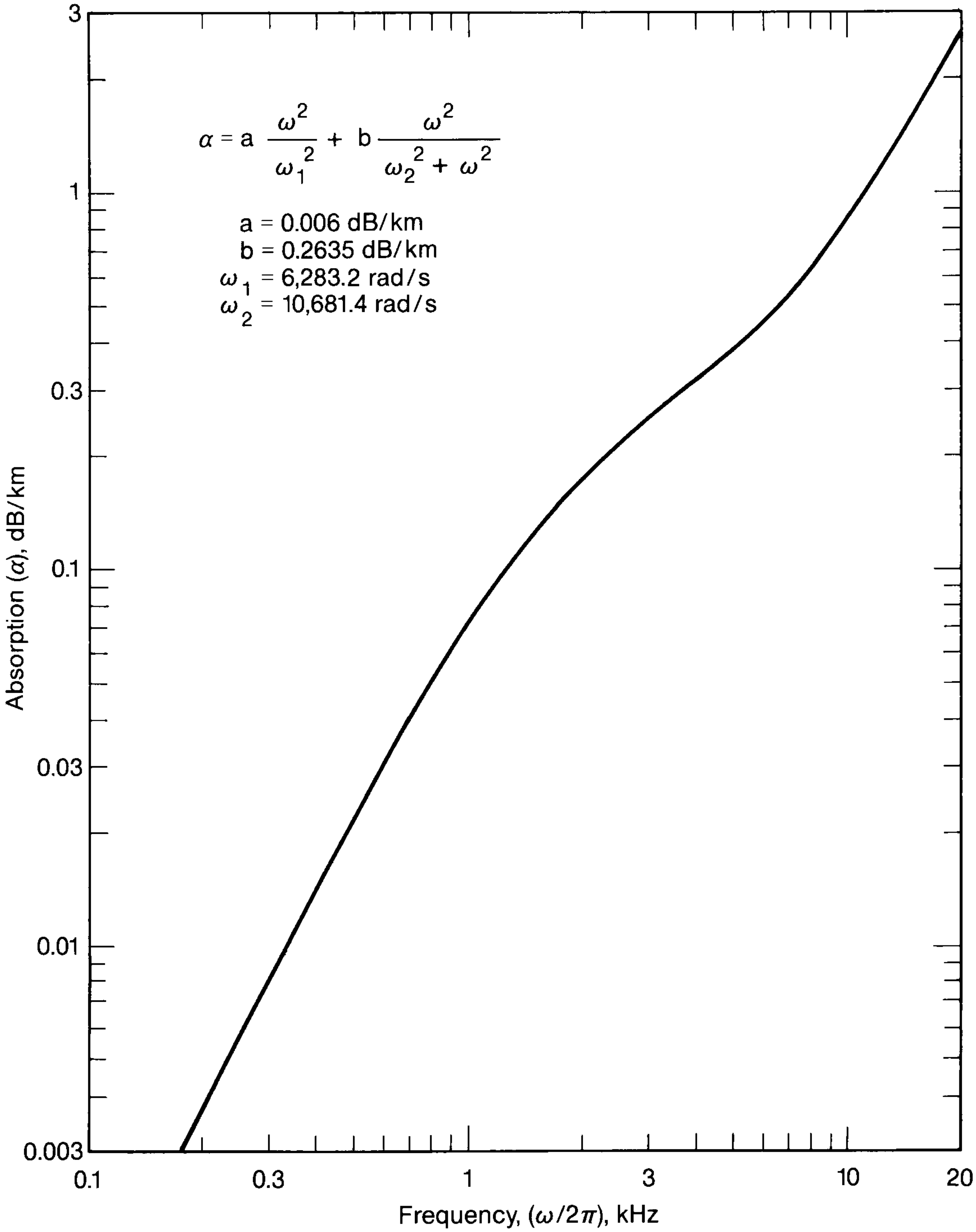


Figure 2.11. Frequency dependence of acoustic absorption with model SLLOSS, using the parameters indicated.

FORM TO SPECIFY INPUT DATA FOR
BOTTOM MODEL GLORENZ

An east-west Lorentzian-shaped ridge.

$$g(r,\theta,\phi) = h - z ,$$

where $h = r - r_e$,

$$z = z_o/(1 + ((\theta-\theta_o)/\Delta\theta)^2) + z_B$$

$$\theta_o = \pi/2 - \lambda_o ,$$

and r_e is the radius of the Earth.

Specify --

the model check number for GLORENZ = 4.0 (W300)

the data input format code number = ______ (W301)

the data set identification number = 3. (W302)

an 80-character description of the model including parameters:

RIDGE .5 KM HIGH, 2 KM WIDE AT 10KM LATITUDE, BASE = -3 KM

the height of the ridge, z_o = .5 (km) m (W303)

the latitude of the ridge center, λ_o = 10. rad, deg, (km) (W304)

the half-width of the ridge, $\Delta\theta$ = 2. rad, deg, (km) (W305)

the height above sea level of the base of the ridge (negative if below sea level) z_B = -3. m, (km) (W306)

OTHER MODELS REQUIRED: Any bottom perturbation model. Use NPBOTM if no perturbation is desired.

Figure 2.12. Sample of completed form to specify ocean bottom model GLORENZ.

Refer next to the FORM TO SPECIFY INPUT DATA FOR OCEAN SURFACE MODEL SHORIZ (Figure 2.13). This model specifies a spherical ocean surface at a specified height above mean sea level. For the sample case, the height is zero.

2.2 The Ray-Tracing Order Form for the Sample Case

Refer now to the FORM TO SPECIFY DATA FOR A THREE-DIMENSIONAL RAYPATH CALCULATION (Figure 2.14). The form has been filled out with values selected for the sample case. Let's go through each parameter specification on this form:

We choose a transmitter height of 2.0 km above the ocean bottom (as specified in the GLORENZ bottom model), at a latitude of zero, and a longitude of zero. (Alternatively, a transmitter depth below mean sea level (MSL, $r = r_e$) could be specified.) The acoustic frequency is 400 Hz, with no stepping in frequency. The azimuth angle of transmission is 80° (clockwise from north), with no stepping in azimuth. The elevation angle of transmission is stepped from 2° to 16° in steps of 2°. (If azimuth and frequency stepping are used, elevation angle stepping is performed first, then azimuth angle, then frequency.)

We want to keep track of all ray intersections with a receiver surface 1 km below MSL, and we want to stop tracing rays that go below 5 km depth or above 5 km above MSL. (Actually, neither event should happen unless something goes wrong in the bottom- or surface-reflection logic, so this is just a precaution.) We want to stop rays that go beyond 50 hops, a hop being defined as an intersection with the receiver surface, and those that go beyond 210 km range, measured at mean sea level.

Because we have selected a receiver surface at a fixed height above MSL, we also fill out the FORM TO SPECIFY INPUT DATA FOR RECEIVER SURFACE MODEL RHORIZ (Figure 2.15) and specify a height of -1.0 km. If we had wanted a receiver surface at a fixed height above the bottom, we would have specified the receiver surface model RBOTM.

FORM TO SPECIFY INPUT DATA
FOR OCEAN SURFACE MODEL SHORIZ

An ocean surface model that is a horizontal (i.e., a sphere concentric with the earth). The ocean surface is where the following function is zero.

$$s(r,\theta,\phi) = z_s - h$$

where

$$h = r - r_e$$

and

r_e is the earth radius

Specify--

the model check number for subroutine SHORIZ = 1.0 (W350)

the data input format code number = ________ (W351)

the data set identification number = 1.0 (W352)

an 80-character description of the model including parameters:

OCEAN SURFACE = SPHERE AT MSL

the height of the ocean surface above
mean sea level, z_s = 0.0 km, m (W353)

OTHER MODELS REQUIRED: Any surface-perturbation model. Use NPSURF if no perturbation is desired.

Figure 2.13. Sample of completed form to specify ocean surface model SHORIZ.

FORM TO SPECIFY INPUT DATA FOR A
THREE-DIMENSIONAL RAYPATH CALCULATION

Name ______________
Ocean ID (3 characters) NØ1 — Date AUG 19, 86

Title (77 characters) SAMPLE CASE FOR HARPO DOCUMENTATION

Transmitter: Height	2.	(km), nm, ft (W3)
	✓	above bottom
		above sea level
Latitude	0.	rad, deg, km (W4)
Longitude	0.	rad, deg, km (W5)
Frequency, initial	400.	rad/s, (Hz), s (W7)
final		(W8)
step		(W9)
Azimuth angle, initial	80.	rad, (deg) clockwise of north (W11)
final		(W12)
step		(W13)
Elevation angle, initial	2.	rad, (deg) (W15)
final	16.	(W16)
step	2.	(W17)
Receiver: Height	-1.	km, nm, ft (W20)
	✓	above sea level (rcvr model RHORIZ)
		above bottom (rcvr model RBOTM)
Distance from origin		rad, deg, km (W278) (rcvr model RVERT)
Latitude of origin		rad, deg, km (W279) (rcvr model RVERT)
Longitude of origin		rad, deg, km (W280) (rcvr model RVERT)
Stop elevation-angle stepping when ray goes out of bounds	0.	(W21 = 1.)
Stop ray if it hits the bottom	0.	(W19 = 1.)
Maximum height	5.	km (W26)
Minimum height	-5.	km (W27)
Maximum range	210.	km (W28)
Maximum number of hops	50.	(W22)
Maximum number of steps per hop	1000.	(W23)
Maximum allowable error per step	10^{-6}	(W42)
Additional calculations:		= 1. to integrate = 2. to integrate and print
Phase path	2.	(W57)
Absorption	2.	(W58)
Doppler shift	0.	(W59)
Path length	2.	(W60)
Printout:	Every 50.	steps of the ray trace (W71)
Computer readable output (raysets):	1.	(W72 = 1.)
Diagnostic printing:	0.	(W73 = 1.)
Suppress all printout	0.	(W74 = 1.)

Figure 2.14. Sample of completed form to specify a three-dimensional raypath calculation.

FORM TO SPECIFY INPUT DATA
FOR RECEIVER-SURFACE MODEL RHORIZ

A receiver-surface model that is a horizontal surface (i.e., a sphere concentric with the Earth).

$$f(r,\theta,\phi) = h - z_R \ ,$$

where

$$h = r - r_e$$

and

r_e is the Earth radius

$$\frac{\partial f}{\partial t} = \frac{\partial f}{\partial \theta} = \frac{\partial f}{\partial \phi} = 0$$

$$\frac{\partial f}{\partial r} = 1.0 \quad .$$

Specify--

the model check number for subroutine RHORIZ = 1.0 (W275)

the input data-format code number = ________ (W276)

an 80-character description of the model including parameters:

RECEIVER SURFACE = SPHERE 1 KM BELOW MSL

the receiver surface height, z_R = -1. km (W20)

OTHER MODELS REQUIRED: none.

Figure 2.15. Sample of completed form to specify receiver surface model RHORIZ.

We set the maximum number of steps per hop to 1000 (usually a large number that we don't expect to be exceeded under normal conditions but which guards against "accidents"). We set the maximum allowable integration error per step to 10^{-6}, which means that integrated quantities are computed with at least that relative accuracy. We want to integrate and print phase path, path length and absorption, but not to calculate Doppler shift (which would be zero for the sample case, which has no time-dependent models). The printed output will display the raypath status every 50th step, in addition to printing at special events, such as reflections, apogees and perigees (turning points). Machine-readable "raysets" will also be produced.

2.3 Rayplot Order Form for the Sample Case

Two kinds of raypath plots are available and are specified for the sample case on the FORM TO SPECIFY INPUT PARAMETERS FOR PLOTTING A PROJECTION OF THE RAY PATH (Figure 2.16 and Figure 2.17). The same form is used twice: once for a projection of raypaths on a vertical plane, and once for a projection on a horizontal plane.

The vertical plane is specified by the geographic coordinates of its left and right edges and the height above MSL for the bottom of the graph. In the sample case, we want the left edge to be at latitude zero, longitude zero; the right edge is to be at latitude 35.27 km (north), longitude 200 km (east). This makes the plane of the vertical projection coincide with the plane of initial ray transmission (azimuth 80°). The bottom of the graph is to be at -3 km, and the top of the graph is at sea level (0 km). Because rays in the ocean are nearly horizontal, rayplots are easier to see if we expand the vertical dimension. We select an expansion factor of 40. We want tick marks every 100 km along the horizontal axis, and every 1 km along the vertical.

The horizontal projection plane is specified by the location of the centers of its left and right edges. For the sample case, we select the left and right edges of the horizontal plot to coincide with the coordinates of the left and right edges of the vertical plot, as specified above.

FORM TO SPECIFY INPUT PARAMETERS FOR PLOTTING A
PROJECTION OF THE RAYPATH

Model ID: NØ1

Plot directly during raypath calculations ✓, or

plot from precomputed raypaths ____

in disk file ____

Normal or apogee plots:

Normal ✓ (W80=0.0)

Plot apogees only ____ (W80=1.0)

Projection:

Vertical plane, polar plot, rectangular expansion ____ (W81=1.0)

Horizontal plane, lateral expansion ____ (W81=2.0)

Vertical plane, polar plot, radial expansion ____ (W81=3.0)

Vertical plane, rectangular plot ✓ (W81=4.0)

Superimpose these raypath plots on the graph of the previous runset:

Yes ____ (W81 negative.)

No ✓ (W81 positive.)

Vertical or lateral expansion factor 40. (W82)

Coordinates of the left edge of the graph:

Latitude = 0. (rad, deg, km) north (W83)

Longitude = 0. (rad, deg, km) east (W84)

Coordinates of the right edge of the graph:

Latitude = 35.1 (rad, deg, (km)) north (W85)

Longitude = 200. (rad, deg, (km)) east (W86)

Distance between horizontal tick marks = 50. rad, deg, (km) (W87)

Height above sea level of bottom of graph = -3. km (W88)

Height above sea level of top of graph = 0. km (W89)

Distance between vertical tick marks = 1. km (W96)

Figure 2.16. Sample of completed form to specify a vertical rayplot projection.

FORM TO SPECIFY INPUT PARAMETERS FOR PLOTTING A PROJECTION OF THE RAYPATH

Model ID: NØ1

Plot directly during raypath calculations ✓, or

plot from precomputed raypaths ______

in disk file ______

Normal or apogee plots: Normal ✓ (W80=0.0)

Plot apogees only ______ (W80=1.0)

Projection:

Vertical plane, polar plot, rectangular expansion ______ (W81=1.0)

Horizontal plane, lateral expansion ✓ (W81=2.0)

Vertical plane, polar plot, radial expansion ______ (W81=3.0)

Vertical plane, rectangular plot ______ (W81=4.0)

Superimpose these raypath plots on the graph of the previous runset:

Yes ______ (W81 negative.)

No ✓ (W81 positive.)

Vertical or lateral expansion factor 40. (W82)

Coordinates of the left edge of the graph:

Latitude = 0. (rad, deg, km) north (W83)

Longitude = 0. (rad, deg, km) east (W84)

Coordinates of the right edge of the graph:

Latitude = 35.1 (rad, deg, (km)) north (W85)

Longitude = 200. (rad, deg, (km)) east (W86)

Distance between horizontal tick marks = 50. rad, deg, (km) (W87)

Height above sea level of bottom of graph = -1. km (W88)

Height above sea level of top of graph = 0. km (W89)

Distance between vertical tick marks = 1. km (W96)

Figure 2.17. Sample of completed form to specify a horizontal rayplot projection.

Figure 2.18 shows a plan view of the region of the earth's surface near latitude zero, longitude zero, including the transmitter location, the ray-launch azimuth, the locations of the centers of the CBLOB2 and VVORTX3 perturbations, the axis of the ridge at 10 km N, and the locations of the left and right edges of the two plot projections (L and R).

2.4 Setting Up the Input Data File (W Array) for the Sample Case

Now that we have defined all the parameters needed to specify the ocean model, the raypaths desired, as well as the printed, plotted and machine-readable output, we can look at how these input data are communicated to HARPO. To run HARPO, you have to create a file like the one shown for the sample case in Figure 2.19. (Such a file for the sample case comes with the program.) HARPO reads this file into an array named W(n), where n, the array subscript, is the first value on each line (columns 1-3), and W(n) is the second value on each line (columns 4-17).

The values of n corresponding to each input parameter are indicated on each of the input parameter forms we have just looked at. You will notice that not all values of n are listed in Figure 2.19 for the sample case; those not explicitly defined in the Input Data File assume an initial value that is usually (but not always) zero. The initialization scheme is explained in Section 5.3.1.

Besides the values of n and W(n), the table contains in columns 18-24 provisions for unit conversion on input, that is, for entering data in various units. For example, the notation AN KM means that a central-earth angle has been entered as a great-circle distance in kilometers and will be converted to radians by the program. For W(3), the height of the transmitter, a T in col. 17 implies that the height specified is a height above the bottom (as specified by the bottom model). Finally, in columns 25-80, descriptive comments identify the data for easy data entry.

The standard set of units used by the program are: angles in radians, distances in kilometers, and frequency in radians per second. It is important

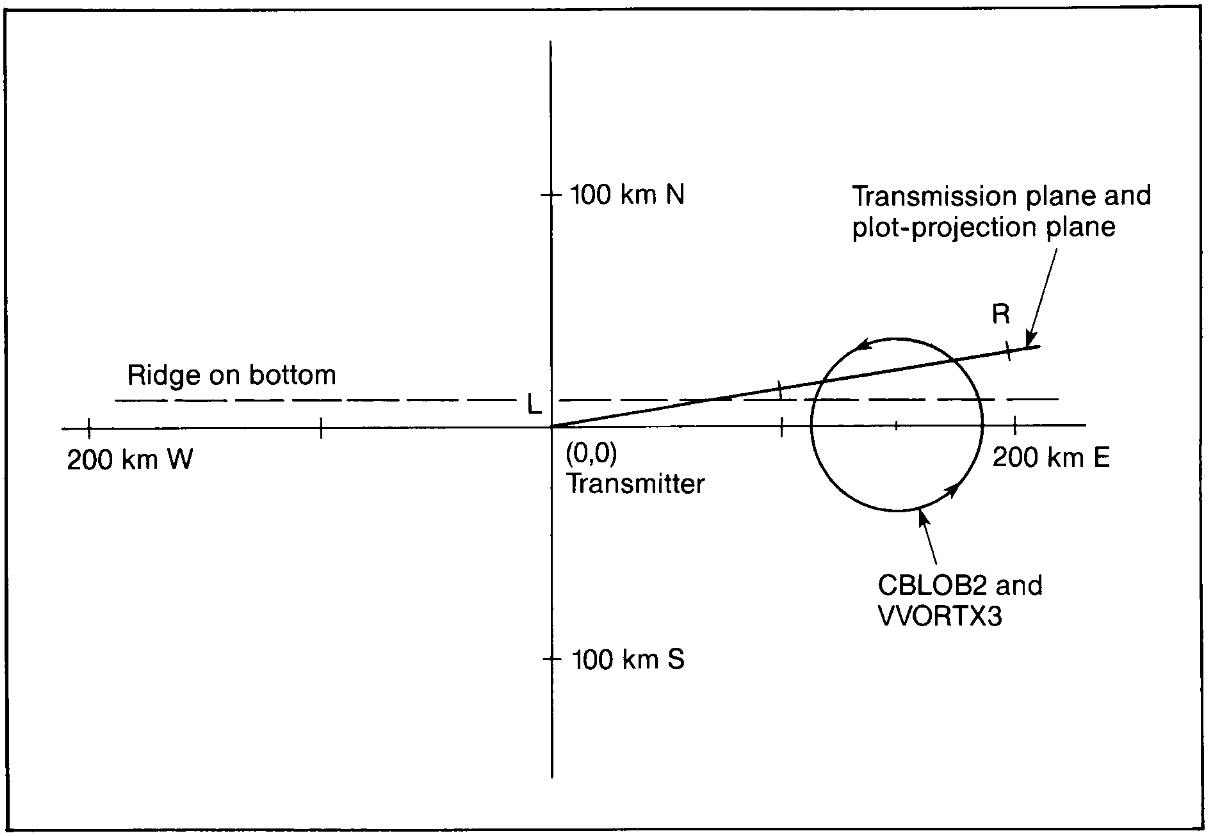


Figure 2.18. Plan view of the major features of the sample case model, the source location, the transmission plane, and the plot-projection plane.

```
col.    col.      col.      col.
1-3     4-17      18-24     25-80
 n      W(n)      UNITS     DESCRIPTION
--------------------------------------------------------------------------------
GEORGES    RB3    X6437
N01-1      SAMPLE CASE FOR HARPO DOCUMENTATION              REV. 8-19-86
  1     6370.               EARTH RADIUS TO MSL, KM (6370.)
  3        2.              TTRANSMITTER HEIGHT ABOVE MSL (T=ABOVE BOTTOM), KM
  4        0.     AN KM     N. TRANSMITTER LATITUDE, KM
  5        0.     AN KM     E. TRANSMITTER LONGITUDE, KM
  7      400.     FQ HZ     INITIAL FREQUENCY, HZ
 11       80.     AN DG     INITIAL AZIMUTH ANGLE, DEG
 15        2.     AN DG     INITIAL ELEVATION ANGLE, DEG
 16       16.     AN DG     FINAL   ELEVATION ANGLE, DEG
 17        2.     AN DG     STEP IN ELEVATION ANGLE, DEG
 19        0.               STOP RAYS THAT STRIKE BOTTOM (1=YES; 0=NO)
 20       -1.               RECEIVER HEIGHT ABOVE MSL, KM
 22       50.               MAXIMUM NUMBER OF HOPS (1.)
 23     1000.               MAXIMUM NUMBER OF STEPS PER HOP (1000.)
 26        5.               MAXIMUM RAY HEIGHT ABOVE MSL, KM
 27       -5.               MINIMUM RAY HEIGHT ABOVE MSL, KM
 28      210.               MAXIMUM RANGE AT MSL, KM
 29        0.               DO: EIGRAY/RNG-TIM/RNG-ELV/NEW-PROJ/RAYTRC/CONT/PROF
 33       20.               MAXIMUM ABSORPTION, DB (999.999)
 42        1.0E-06          MAXIMUM SINGLE-STEP INTEGRATION ERROR (1.0E-4)
 44        .1               INITIAL INTEGRATION STEP SIZE, KM (1.0)
 57        2.               PHASE PATH  (0=NO; 1=INTEGRATE; 2=INTEGRATE/PRINT)
 58        2.               ABSORPTION  (0=NO; 1=INTEGRATE; 2=INTEGRATE/PRINT)
 60        2.               PATH LENGTH (0=NO; 1=INTEGRATE; 2=INTEGRATE/PRINT)
 71       50.               NUMBER OF INTEGRATION STEPS PER PRINT [1.E31]
 72        1.               OUTPUT RAYSETS (1=YES; 0=NO)
 73        0.               DIAGNOSTIC PRINTOUT (1=YES; 0=NO)
 74        0.               PRINT EVERY W(71) RAY STEPS (0=YES; 1=NO)
 75      .15                FULANN PLOT LETTERING; HEIGHT= [0.15 IN]
 76        0.               BINARY RAY OUTPUT (1=YES; 0=NO)
 77       57.               LINES PER PAGE OF PRINTOUT (57.)
 81        4.               RAYPLOT PROJECTION PLANE (4 = VERT. RECTANGULAR)
 82       40.                PLOT-ORDINATE EXPANSION FACTOR [1.]
 83        0.     AN KM      N. LATITUDE OF LEFT PLOT EDGE, KM
 84        0.     AN KM      E. LONGITUDE OF LEFT PLOT EDGE, KM
 85      35.1     AN KM      N. LATITUDE OF RIGHT PLOT EDGE, KM
 86      200.     AN KM      E. LONGITUDE OF RIGHT PLOT EDGE, KM
 87       50.     AN KM      DISTANCE BETWEEN RANGE TICKS, KM (0 = AUTO)
 88       -3.                HEIGHT ABOVE MSL OF BOTTOM OF GRAPH, KM
 89        0.                HEIGHT ABOVE MSL OF TOP OF GRAPH, KM
 96        1.                DISTANCE BETWEEN DEPTH TICKS, KM (0 = AUTO)
100        9.               VVORTX3 MODEL CHECK NUMBER
102        3.                VVORTX3 BACKGROUND CURRENT DATA SET ID
103     1.02      LN   M     MAXIMUM TANGENTIAL CURRENT, M/S
104       50.                RADIUS OF VORTEX CORE, KM
105        0.     AN KM      LATITUDE OF VORTEX CENTER, KM
106      150.     AN KM      LONGITUDE OF VORTEX CENTER, KM
107        1.                VERTICAL HALF-WIDTH OF VORTEX, KM
```

Figure 2.19. Input Data File for the sample case.

```
108       -1.               HEIGHT OF VORTEX CENTER ABOVE MSL, KM
150        7.              CTANH SOUND SPEED MODEL CHECK NUMBER
152        1.               CTANH BACKGROUND SOUND SPEED DATA SET ID
175        2.              CBLOB2 SOUND SPEED PERTURBATION MODEL CHECK NUMBER
177        7.               CBLOB2 PERTURBATION SOUND SPEED DATA SET ID
178       .02               MAXIMUM FRACTIONAL INCREASE IN C SQUARED
179       -1.               HEIGHT OF MAX EFFECT ABOVE MSL, KM
180        0.     AN KM     LATITUDE OF MAX EFFECT, KM
181      150.     AN KM     LONGITUDE OF MAX EFFECT, KM
182        1.               VERTICAL HALF-WIDTH, KM
183       50.     AN KM     N-S  HALF-WIDTH, KM
184       50.     AN KM     E-W  HALF-WIDTH, KM
275        1.              RHORIZ RECEIVER MODEL CHECK NUMBER
300        4.              GLORENZ BOTTOM MODEL CHECK NUMBER
302        3.               GLORENZ BOTTOM MODEL DATA SET ID
303        .5               HEIGHT OF RIDGE, KM ABOVE BASE
304       10.     AN KM     N. LATITUDE OF RIDGE CENTER, KM
305        2.     AN KM     HALF-WIDTH OF THE RIDGE, KM
306       -3.               HEIGHT ABOVE MSL OF BASE OF RIDGE, KM
350        1.              SHORIZ MODEL CHECK NUMBER
352        1.               SHORIZ OCEAN SURFACE DATA SET ID
353        0.               HEIGHT OF OCEAN SURFACE ABOVE MSL, KM
500        1.              SLLOSS ABSORPTION MODEL CHECK NUMBER
502        1.               SLLOSS ABSORPTION DATA SET ID
503     0.006     AM DB     A COEFFICIENT, DB
504    0.2635     AM DB     B COEFFICIENT, DB
505     1000.     FQ HZ     OMEGA1, HZ
506     1700.     FQ HZ     OMEGA2, HZ
 -1                        DATA SUBSET FOR BACKGROUND CURRENT MODEL
  A  VORTEX AT LONGITUDE 150 KM E, UMAX= 1.02 M/S, R= 50 KM
  0        RETURN TO W-ARRAY DATA SET
 -2                        DATA SUBSET FOR PERTURBATION CURRENT MODEL
  A  NO CURRENT PERTURBATION
  0        RETURN TO W-ARRAY DATA SET
 -3                        DATA SUBSET FOR BACKGROUND SOUND-SPEED MODEL
  A  EL NINO BACKGROUND SOUND-SPEED PROFILE
  3      999.0
   LN  M          LN  M         LN  M
   0.             1532.         0.
   -20.           1531.5        -7.
   -50.           1509.         -20.
   -250.          1503.         -40.
   -450.          1485.         -300.
   -1500.         1485.         -400.
   -3000.         1508.         0.
   999.0
  0       RETURN TO W-ARRAY DATA SET
 -4                        DATA SUBSET FOR SOUND-SPEED PERTURBATION MODEL
  A  2% INCREASE IN C-SQUARED AT 150 KM LON., 1 KM DEPTH, 50 KM WIDE
  0       RETURN TO W-ARRAY DATA SET
 -8                        DATA SUBSET FOR RECEIVER-SURFACE MODEL
  A  RECEIVER SURFACE = SPHERE 1 KM BELOW MSL
  0       RETURN TO W-ARRAY DATA SET
 -9                        DATA SUBSET FOR BACKGROUND BOTTOM MODEL
  A  RIDGE .5 KM HIGH, 2 KM WIDE AT 10 KM N LATITUDE; BASE= -3 KM
```

Figure 2.19. Input Data File (continued).

```
  0        RETURN TO W-ARRAY DATA SET
-10
                        DATA SUBSET FOR BOTTOM PERTURBATION MODEL
  A   NO BOTTOM PERTURBATION
  0        RETURN TO W-ARRAY DATA SET
-11
                        DATA SUBSET FOR OCEAN SURFACE MODEL
  A   OCEAN SURFACE = SPHERE AT MSL
  0        RETURN TO W-ARRAY DATA SET
-12
                        DATA SUBSET FOR OCEAN SURFACE PERTURBATION MODEL
  A   NO OCEAN SURFACE PERTURBATION
  0        RETURN TO W-ARRAY DATA SET
-17
                        DATA SUBSET FOR OCEAN ABSORPTION MODEL
  A   SKRETTING-LEROY ABSORPTION FORMULA
  0        RETURN TO W-ARRAY DATA SET
-18
                        DATA SUBSET FOR PERTURBATION ABSORPTION MODEL
  A   NO ABSORPTION PERTURBATION
  0        RETURN TO W-ARRAY DATA SET
  0
                        **********  END OF RUN SET NUMBER 1  *********
N01-2      SAMPLE CASE FOR HARPO DOCUMENTATION        REV. 8-19-86
 71         0.          NUMBER OF INTEGRATION STEPS PER PRINT [1.E31]
 72         0.          OUTPUT RAYSETS (1=YES; 0=NO)
 73         1.          DIAGNOSTIC PRINTOUT (1=YES; 0=NO)
 81         2.          RAYPLOT PROJECTION PLANE (2 = HORIZONTAL)
 88        -1.          HEIGHT OF HORIZONTAL PLOT SECTION ABOVE MSL, KM
  0
                        **********  END OF RUN SET NUMBER 2  *********
```

Figure 2.19. Input Data File (continued).

to remember to convert the units of the spherical coordinates θ or ϕ when they are entered as distances. For example, entering CBLOB2 longitude ϕ_o in kilometers requires you to use the AN KM unit conversion.

There are special values of n (such as zero or negative values) that contain instructions for interpreting what follows in the Input Data File. They will be described in detail in Chapter 5. A negative number in col. 1-3 indicate that tabular or text data follow. A zero in col. 1-3 indicates the end of tabular data or the end of a "run set," which is the name we give to the input data for a set of ray calculations. For example, the rays for one run set will all appear on a single ray plot. A new run set is necessary to create different plots or to change model parameters. In Figure 2.19 new run sets start with the lines that begin with "N01." Each of the two run sets for the sample case generates a different ray plot projection. Only the W values that change from the previous run set need be specified; the others remain unchanged from the previous run set.

For now, you need only be aware of this tabular procedure for entering data into HARPO; you may find it instructive to verify that the values entered into the order forms for the sample case correspond to the entries in the W(n) input data listing.

When you run the program with this input data set, three kinds of output will be produced: a step-by-step printed account of each ray's progress, plots of the raypaths on vertical and horizontal planes, and machine-readable data, including "raysets."

2.5 Printed Output for the Sample Case

Appendix A shows the complete printed output, or "printout," for the sample case. Sections 2.5.1 and 2.5.2 define the terms and quantities used in the printout.

Page 1 of the printout contains the program title block and a list of all the models used for the first run set. The model list includes subroutine names, a number identifying the set of parameters defining that particular model, and comments describing each model.

Pages 2-4 of the printout reproduce the Input Data File for run set number 1.

Page 5 of the printout is a list of n and W(n) for all nonzero W(n). The values of W(n) have been converted to the units used by the program; for example, angles (like latitude and longitude) input in kilometers or degrees have been converted to radians.

Pages 6-10 of the printout are in a columnar format that gives a step-by-step account of each ray's progress, with each line showing important raypath quantities at user-specified intervals along the raypath. The meanings of the quantities printed out are explained in Section 2.5.1. The user can specify how often along the ray a line is printed (we specified every 50 integration steps). In addition, a line is printed out every time a ray experiences a "special event," such as a bottom or surface reflection, a turnover (apogee) or turnunder (perigee), intersections with the receiver surface, or a few other events. Section 2.5.2 explains the exact meanings of all the special events.

Each ray calculation terminates when one of the termination conditions is met, such as the maximum number of hops or maximum range, whichever occurs first. In the sample case, all of the rays terminate because they reached the maximum range specified. At the end of each ray calculation, the printout shows how much CPU time was used for that ray computation (1.736 s, in this case).

Look at page 1 of the printout in Appendix A. Verify that the models indicated at the bottom of the page coincide with those we specified as input. Verify that the wave frequency and initial azimuth and elevation angles on page 6 are what we want. Look down the first (ERROR) column of the tabular printout (page 6) and verify that none of the numbers in this column greatly exceeds the maximum allowable single-step integration error, W(42), which for the sample case is 10^{-6}. This means that the numerical integration is proceeding correctly.

Look at the first entries in the ELEVATION columns and verify that the ray starts at the correct height above the bottom (2.00 km in this case), as well as the correct height above MSL (slightly above -1 km in this case, because of the bottom model). The RANGE column should begin with zero range from the transmitter and indicate an increasing range from the transmitter with successive steps.

A general idea of the sequence of events along this ray can be read in the EVENT column. These notations mark the special events along the raypath, which cause printout regardless of the step number. Reading down this column, we see that the first ray begins at the transmitter (XMTR), then executes a series of APOGEE, WAVE REV, RCVR, PERIGEE, etc., indicating ray ducting in the sound channel. The ray apogee is at a depth of 0.77 km and its perigee is at a depth of 1.38 km. Notice that the apogee and perigee depths change because of the model's range dependence. The ray stops when it reaches the specified maximum range (210 km).

The numbers in the AZIMUTH DEVIATION columns indicate that the ray deviates from the azimuth of transmission because of sound-speed and current gradients. The ELEVATION ANGLE columns show changes in the local wave-normal direction and the elevation angle of the ray point measured from the transmitter.

PULSE TIME gives the time for a pulse or wave packet to reach that point, and PHASE TIME gives the time for a wave phase front to reach that point. The wave phase can be derived from PHASE TIME by multiplying by the wave frequency in appropriate units (cycles per second to get wave phase in cycles, etc.) and removing the integer part. The PATH LENGTH gives the physical length of the ray path (which cannot be directly measured).

The second run set shown in the sample-case printout uses the same initial ray conditions, but it changes the rayplot to a horizontal projection, and it adds diagnostic printout that can be useful for studying the details of ocean bottom or receiver-surface intersections.

2.5.1 Definitions of Quantities Listed in Printout (in Appendix A)

AZIMUTH ANGLE OF TRANSMISSION -- Azimuth angle (degrees clockwise from north) of the initial ray-launch direction.

ELEVATION ANGLE OF TRANSMISSION -- Elevation angle (degrees upward) between the initial ray-launch direction and local horizontal at the transmitter.

TRANSMITTER LATITUDE -- North geographic latitude of the transmitter.

TRANSMITTER LONGITUDE -- East geographic longitude of the transmitter.

FREQUENCY -- Acoustic wave frequency in hertz.

SINGLE-STEP ERROR -- Maximum allowable single-step integration error.

ERROR -- Normalized difference between the wave number k computed by numerical integration and k computed from the dispersion relation [Eq. (6.23)].

EVENT -- Nature of special event along the raypath (see Sec. 2.5.2).

HEIGHT -- Height of the ray point above mean sea level (or above the bottom).

RANGE -- Great-circle distance, measured at mean sea level, between the transmitter and the ray point.

AZIMUTH DEVIATION (XMTR) -- Azimuth angle of the direction of transmission in degrees clockwise from the great circle between the transmitter and the ray point.

AZIMUTH DEVIATION (LOCAL) -- Azimuth angle of the wave normal in degrees clockwise from the great circle between the transmitter and the ray point.

ELEVATION (XMTR) -- Elevation angle (degrees) of the ray point from local horizontal at the transmitter.

ELEVATION (LOCAL) -- Elevation angle (degrees) of the wave normal from the local horizontal at the ray point.

PULSE TIME -- The time (seconds) required for a wave packet (pulse) to travel from the transmitter to the ray point (Sec. 6.1).

PHASE TIME -- The time (seconds) required for a wave front to travel from the transmitter to the ray point (Sec. 6.1.1).

ABSORPTION -- Decrease in acoustic intensity (dB) from the transmitter to the ray point caused by volume dissipation only (Sec. 6.1.2).

PATH LENGTH -- Geometric length of the ray path (kilometers) from the transmitter to the ray point (Sec. 6.1.3).

2.5.2 Meanings of Special Events Along a Raypath

XMTR -- Ray is at the transmitter.

RCVR -- Ray is at the receiver surface.

BOTM REF -- Ray has reflected from the ocean bottom.

SURF REF -- Ray has reflected from the ocean surface.

APOGEE -- Ray has passed through a maximum in height.

PERIGEE -- Ray has passed through a minimum in height.

WAVE REV -- Vertical, southward, or eastward component of the wave-normal vector has changed sign.

MAX LAT -- Ray has passed through a maximum (or minimum) in latitude.

MAX LONG -- Ray has passed through a maximum (or minimum) in longitude.

EXTINC -- Absorption has exceeded the maximum allowable.

MAX HOP -- Ray has executed the requested number of hops (receiver-surface crossings).

MAX RANG -- Ray has exceeded the maximum allowable horizontal range.

MAX HT -- Ray has exceeded the maximum allowable height.

MIN HT -- Ray has gone below the minimum allowable height.

MIN DIST -- Ray has made a closest approach to the receiver surface.

BOTM ABS -- Total absorption of ray by ocean bottom.

ADDITIONAL EVENTS IN DIAGNOSTIC PRINTOUT

BACK UP0 -- At call to subroutine BACKUP.

BACK UP1 -- Before each numerical integration step in subroutine BACKUP.

GRAZE 0 -- At call to ENTRY point GRAZE in subroutine BACKUP.

GRAZE 1 -- Before each numerical integration step after ENTRY point GRAZE.

BACK UP2 -- After unsuccessfully trying to find a closest approach to the receiver surface.

BACK UP3 -- Before each numerical integration step after BACK UP2.

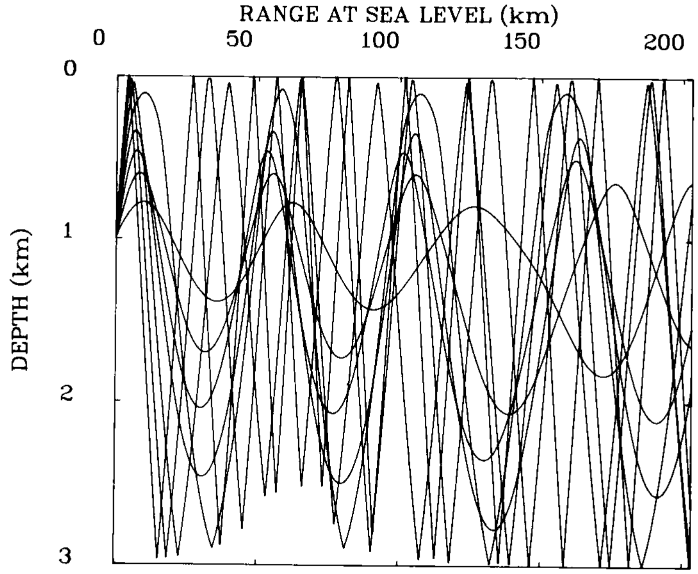
2.6 Rayplots for the Sample Case

We requested two rayplots, a projection on a vertical plane in rectangular coordinates and a projection on a horizontal plane. These two plots are shown in Figures 2.20 and 2.21. Because we selected the FULANN (full annotation) option in W(75), we have produced a plot with publication-quality lettering. This capability requires the DISSPLA plotting package.

Rayplots are often the most useful output from a ray-tracing program, particularly when the medium is complicated. Depending on the user's plotting and display facilities, rayplots can be produced on paper, microfilm, or video displays.

Because the ocean and bottom models used in the sample case cause the acoustic raypaths to behave in complicated ways, a few features of the two rayplot projections call for some explanation. Figure 2.18 shows how the planes of these plots are related to the transmitter location and the features of the ocean and bottom models. The letters L and R show the locations of the left and right edges of the two plots; the line connecting the L and R represents the plane of the vertical projection (Figure 2.20) as

1 SAMPLE CASE FOR HARPO DOCUMENTATION REV. 8-19-86
MODEL = N01 ,FREQ = 400.000 HZ, AZ = 80.000 DEG
EL = 2.00 DEG TO 16.00 DEG, STEP = 2.00 DEG
XMTR HT = -.98 KM ,LAT = .00 DEG, LONG = .00 DEG
ACOUSTIC WAVE *** WITH CURRENT *** WITH LOSSES



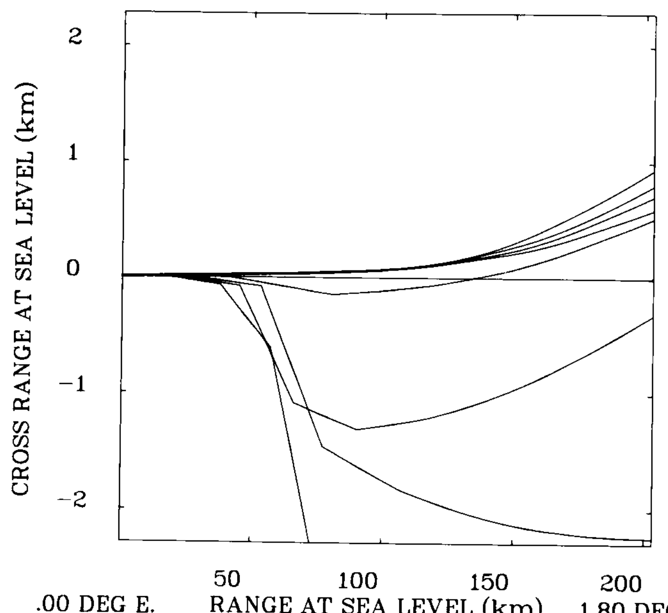
MODELS

VVORTX3 3.0
NPCURR .0
CTANH 1.0
CBLOB2 7.0
GLORENZ 3.0
NPBOTM .0
SLLOSS 1.0
NPABSR .0
RHORIZ .0
SHORIZ 1.0
NPSURF .0

86/09/05. 14.58.54.

Figure 2.20. Projection of the rays of the sample case onto the vertical plane shown in Figure 2.18.

2 SAMPLE CASE FOR HARPO DOCUMENTATION REV. 8-19-86
MODEL = N01 ,FREQ = 400.000 HZ, AZ = 80.000 DEG
EL = 2.00 DEG TO 16.00 DEG, STEP = 2.00 DEG
XMTR HT = -.98 KM ,LAT = .00 DEG, LONG = .00 DEG
ACOUSTIC WAVE *** WITH CURRENT *** WITH LOSSES



.00 DEG E. RANGE AT SEA LEVEL (km) 1.80 DEG E.
.00 DEG N. .32 DEG N.

MODELS

VVORTX3 3.0
NPCURR .0
CTANH 1.0
CBLOB2 7.0
GLORENZ 3.0
NPBOTM .0
SLLOSS 1.0
NPABSR .0
RHORIZ .0
SHORIZ 1.0
NPSURF .0

86/09/05. 14.58.54.

Figure 2.21. Projection of the rays of the sample case onto a horizontal plane whose axis is shown in Figure 2.18.

well as the line across the center of the horizontal projection (Figure 2.21).

The two rayplots show ray ducting in the sound channel, with rays launched at different elevation angles reaching different depths. The ray launched at 14° elevation angle reflects from the ocean surface on its third apogee. The horizontal projection shows the lateral deviations caused by the eddy model's sound-speed gradients and by reflections from the ridge on the ocean bottom. A more detailed picture of the effects of bottom reflections could be obtained by launching a dense fan of rays between 12° and 14°. This will be left as an exercise for the user.

Figure 2.22 shows an "apogee plot," a plotting option (see Fig. 2.16, W80) that gives only the loci of ray apogees and perigees. Such a diagram is useful for showing the ocean regions probed by a set of rays, without the clutter of intersecting raypaths.

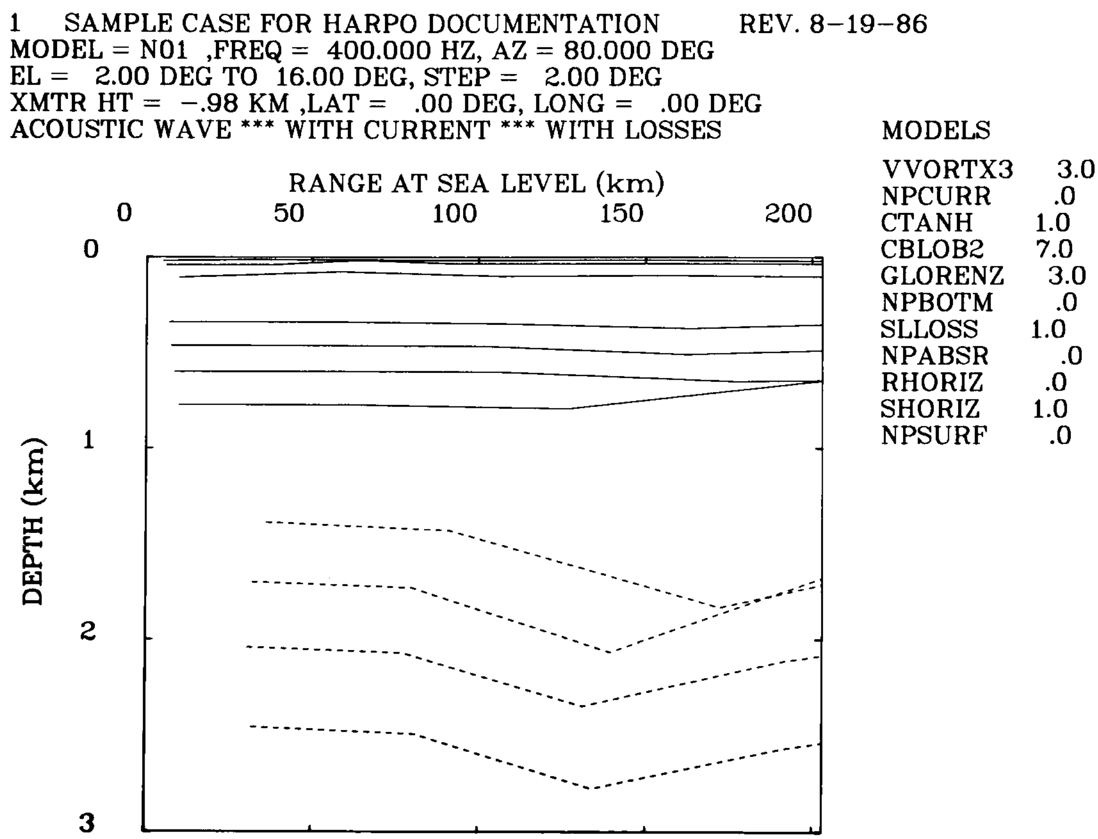


Figure 2.22. Ray-apogee plot for the sample case.

2.7 Machine-Readable Output for the Sample Case

HARPO produces two kinds of machine-readable output. One kind is called "raysets," which summarize in compressed form some useful ray parameters at each special event (as defined above in Section 2.5.2) along the raypath. The other kind of machine-readable output is called "binary raypath data," which permits a complete reconstruction of the raypaths by a supplementary processing program. When stored in machine-readable form (punched cards, magnetic tape, disk files), raysets (as a file named PUNCH) and binary raypath data (as a file named TAPE6) form the input to supplementary processing programs and extend the utility of ray-tracing calculations. Examples are supplementary programs to compute amplitude, to plot range versus elevation angle of transmission and range versus travel time, as well as programs that interpolate in elevation angle to estimate eigenrays that reach a specified range. These supplementary capabilities will be documented in other reports.

Figure 2.23 shows a portion of the printout of the raysets for the sample case. The complete rayset output for the sample case is given in Appendix A. Each ray begins with a "transmitter rayset," the lines beginning with "N01" in the example. Additional 80-column lines are produced whenever a ray reflects from the bottom or the ocean surface or crosses the receiver height and at the end of each ray trace. Because of the way hops are counted, two identical raysets are produced each time a ray executes a closest approach to the receiver surface.

The compressed rayset format is generally meant to be read by machines, not humans, so it can be rather difficult to inspect for information. However, since this is occasionally necessary (and to aid the user in designing supplementary programs to process raysets), Figures 2.24 and 2.25 provide the key for reading rayset printouts.

Notice that the last 3 items preceding the hop identifier in the receiver raysets contain all zeroes for the sample case. The first of these items is Doppler shift, which is zero because we did not use a time-varying ocean model. The transverse polarization is always zero for pure acoustic waves, but is nonzero for acoustic-gravity waves (Jones et al., 1982, Sec. 4.1).

```
N01-1     SAMPLE CASE FOR HARPO DOCUMENTATION          REV. 8-19-86
VVORTX3      3.0 NPCURR        .0    CTANH        1.0 CBLOB2      7.0
NO MODL       .0 NO MODL       .0    NO MODL       .0 NO MODL      .0
NO MODL       .0 NO MODL       .0    SLLOSS       1.0 NPABSR       .0
GLORENZ      3.0 NPBOTM        .0    RHORIZ        .0 NO MODL      .0
  VORTEX AT LONGITUDE 150 KM E, UMAX= 1.02 M/S, R= 50 KM
  NO CURRENT PERTURBATION
  EL NINO BACKGROUND SOUND-SPEED PROFILE
  2% INCREASE IN C-SQUARED AT 150 KM LON., 1 KM DEPTH, 50 KM WIDE
  RIDGE .5 KM HIGH, 2 KM WIDE AT 10 KM N LATITUDE; BASE= -3 KM
N013    -9808      0      0   -10000 25132741   8000000    200000         0   050T
   -10000  194734   -18    -20 -2022   1311291   1311291    288     0    0    0 1R
   -10000  520417   -16    -27  2010   3504472   3504471    769     0    0    0 2R
   -10000  723109   -15    -42 -1990   4868914   4868914   1069     0    0    0 3R
   -10000 1127595     6   -147  1418   7586966   7586966   1667     0    0    0 4R
   -10000 1406506    51   -324 -1281   9454219   9454219   2079     0    0    0 5R
   -10000 1941240   197   -503  3128  13036463  13036463   2870     0    0    0 6R
    -8511 2101960   240   -509 -2971  14116463  14116463   3108     0    0    0 7F
N013    -9808      0      0   -10000 25132741   8000000    400000         0   050T
   -10000  165446   -17    -19 -4012   1114351   1114351    245     0    0    0 1R
   -10000  468372   -15    -22  4001   3154502   3154502    693     0    0    0 2R
   -10000  637278   -14    -31 -3985   4291986   4291986    943     0    0    0 3R
   -10000  963209    -6    -74  3618   6484653   6484653   1425     0    0    0 4R
   -10000 1149018     7   -148 -3476   7731899   7731898   1700     0    0    0 5R
   -10000 1652653    91   -346  2658  11104455  11104455   2446     0    0    0 6R
   -10000 1864722   142   -439 -2819  12525535  12525535   2759     0    0    0 7R
   -15734 2105919   200   -455  1823  14145535  14145535   3116     0    0    0 8F
N013    -9808      0      0   -10000 25132741   8000000    600000         0   050T
   -10000  145209   -16    -17 -6008    978585    978585    215     0    0    0 1R
   -10000  458199   -12    -18  5996   3086200   3086200    679     0    0    0 2R
   -10000  605599   -13    -25 -5983   4079462   4079462    898     0    0    0 3R
   -10000  934379    -6    -55  5593   6291447   6291447   1385     0    0    0 4R
   -10000 1090494     1   -108 -5472   7340500   7340500   1616     0    0    0 5R
   -10000 1530604    52   -242  4301  10289292  10289292   2268     0    0    0 6R
   -10000 1709365    87   -352 -4402  11486110  11486110   2533     0    0    0 7R
   -10000 2087795   168   -388  5537  14026691  14026691   3093     0    0    0 8R
    -8578 2102600   171   -389  5404  14126691  14126691   3115     0    0    0 9F
```

Model Identification Header

Transmitter Raysets

Receiver Raysets

Figure 2.23. Portion of the rayset output for the first run set of the sample case.

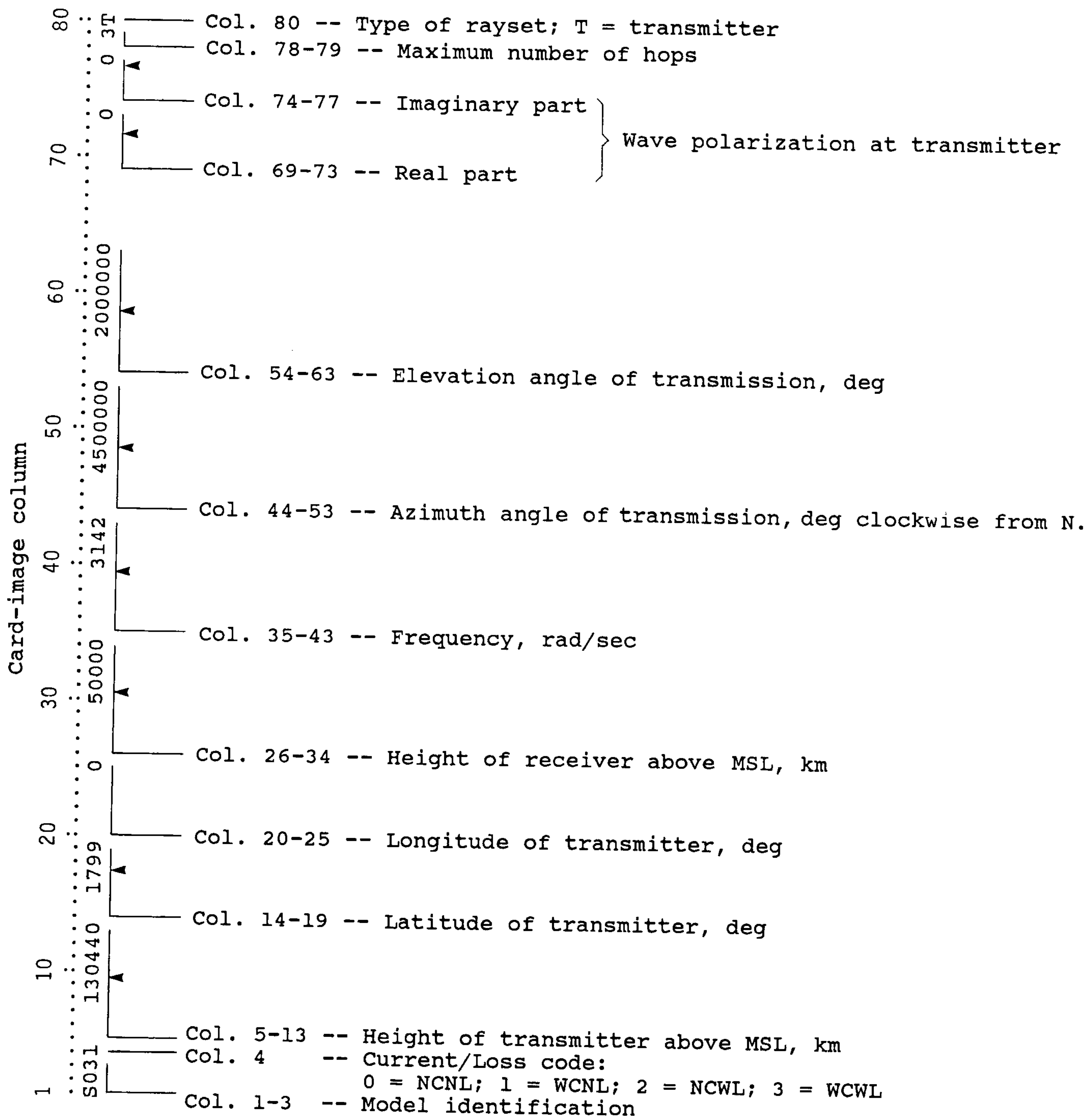


Figure 2.24. Definitions and format of a transmitter rayset.
▲ = implied decimal point.

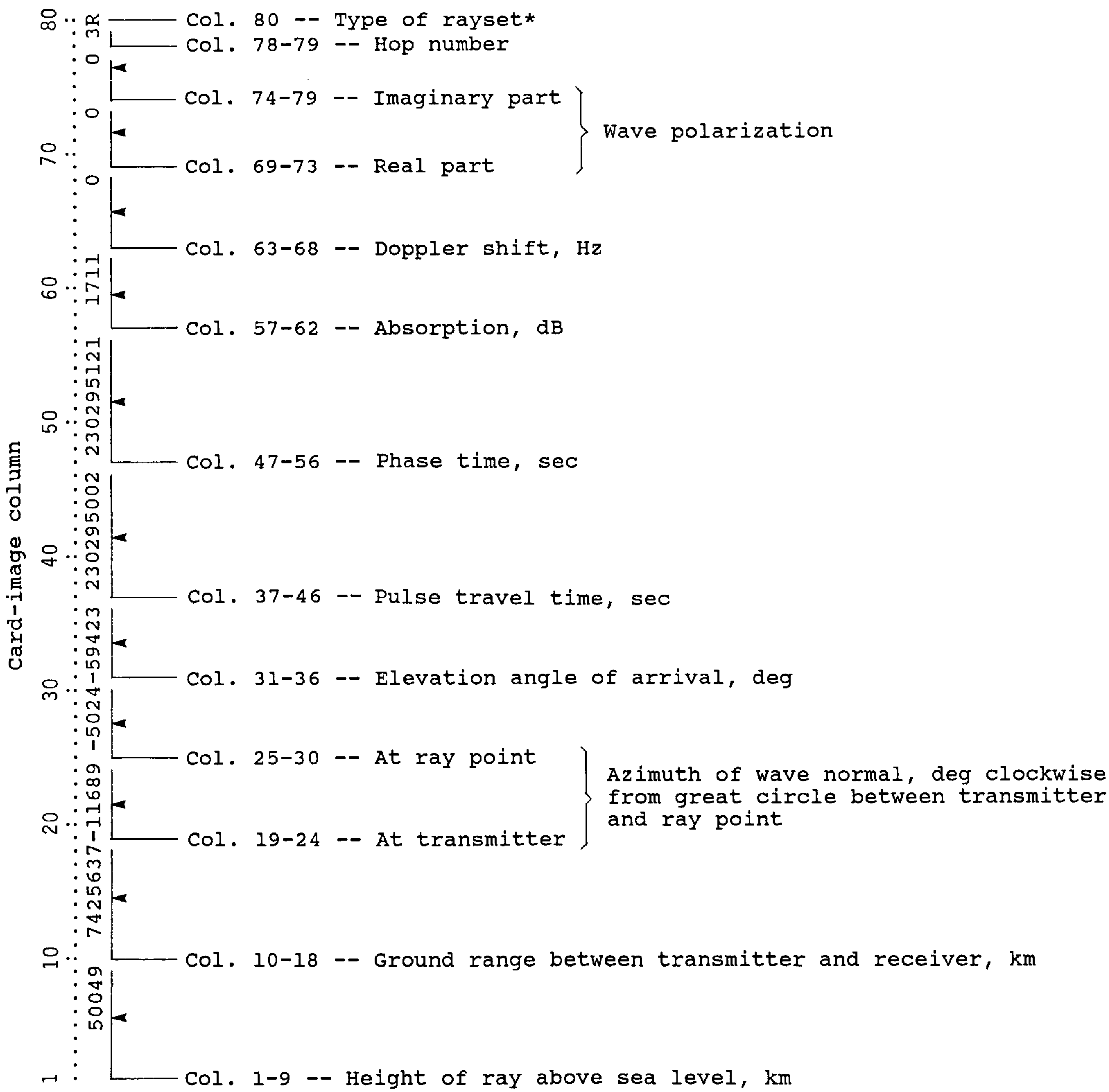


Figure 2.25. Definitions and format for a receiver rayset. * type of rayset: G = bottom reflection; M = closest approach to receiver height; R = at receiver height; S = maximum number of steps; E = extinction; F = exceeded maximum range; U = exceeded maximum height; D = went below minimum height; A = ocean-surface reflection; X = bottom absorption; ▲ = implied decimal point.

PART II: HOW TO USE THIS PROGRAM

3. How to Get This Program Running on Your Computer

This chapter explains how to get the FORTRAN program off the distribution tape and onto your computer, and how to get as far as running the sample case. It also deals with the machine-dependent aspects of running HARPO and suggests ways to deal with different computing environments.

3.1 How To Get a Copy of the Program

The FORTRAN program for the version of HARPO documented in this report and the Input Data File for the sample case are available on magnetic tape. For ordering information, contact the authors at the Wave Propagation Laboratory, Propagation Studies Program Area, 325 Broadway, Boulder, Colorado 80303.

The format of the distribution tape is 0.5 in × 700 ft, 9 track, 1600 bpi, ASCII character set, block size 1600 bytes, logical record length 80 bytes, no parity.

3.2 ANSI-FORTRAN 77 Compatibility

HARPO was designed to run on a Control Data Corp. (CDC) CYBER 700-800 series with a CDC FORTRAN 77 compiler. It should compile with any FORTRAN compiler that adheres to the ANSI FORTRAN 77 standard, including microcomputer FORTRAN compilers that claim such compatibility.

To ensure portability, we have made many changes in portions of the program that were written before the ANSI standard was established. However, where such changes would have been arduous, and where de facto standards that exist on many systems permit deviations from the ANSI standard, we have retained some non-ANSI code. Following are some exceptions to the ANSI standard:

(1) Some variable and subroutine names have seven characters (six is the ANSI standard).

(2) Some alphanumeric characters are stored eight characters per word in numeric (not character) variables and are output using A8 format.

(3) Some machine-dependent constants are entered in nonstandard format (see the following section).

(4) Sometimes a function is called as though it were a subroutine.

(5) Some real variables are EQUIVALENCEd to integer variables.

3.2.1 Machine- and System-Dependent Programming

We have tried to consolidate any machine- or operating-system-dependent code into two subroutines to make it easier to identify and adapt to new environments.

Before attempting to run HARPO, the user must modify SUBROUTINE DFCNST, which defines machine-dependent constants. The version supplied on the distribution tape is for the CYBER 700-800 series with NOS 2x. Instructions for modifying this routine for several popular machines are included as comments in SUBROUTINE DFCNST (Appendix D).

Another subroutine, DFSYS, contains some operating-system-dependent functions, such as clock and date functions and system-dependent I/O (input/output). Users should also check DFSYS and make changes appropriate to their own operating systems.

3.2.2 Word Length

Some problems may arise with machines that have word lengths shorter than the 60-bit word used in our CYBER 840. The numerical integration subroutine (RKAM1) uses double-precision arithmetic to accumulate numerically integrated quantities, but this is almost certainly not always necessary with a 60-bit word for ordinary precision requirements. We have not investigated what errors might occur if less precision were used. We recommend testing the precision on a different machine by running the sample case for smaller and smaller values of the single-step integration error, W(42), and verifying that the error value in the first column of the printout maintains at least the accuracy specified by W(42).

The level where that accuracy first breaks down is probably the precision limit imposed by the computer's word length.

3.2.3 Execution Speed

For many applications, HARPO runs fast enough on our CYBER 840 to allow virtually interactive (machine load permitting) ray tracing using a graphics terminal for editing program input and for viewing graphical output. Although HARPO may compile and run on smaller machines, its speed may be so slow that interactive ray tracing may no longer be practical. The run times shown on the printout (Appendix A) for the sample case (at the end of each ray) allow you to compare run times between your computer and ours. Tests on a CRAY XMP-48 indicate a speedup by a factor of about 7 over a CYBER 840.

3.2.4 Graphics

The graphics programs included with HARPO were designed to run on the CYBER series computer and use the DISSPLA graphics package (by ISSCO, Inc.) and the Information International Inc. Model FR-80 Microfilm Plotting Unit. However, HARPO will run regardless of the plotting facilities you have.

If you have DISSPLA, you can produce the graphic output by running the supplementary program TAPRD combined with DDSPLA subroutines, supplied as Files 6 and 7 of the distribution tape. This program reads a graphics file called TAPE5, which HARPO produces when plots are requested (see Fig. C1).

If you don't have DISSPLA, you can still run HARPO and get the printed and machine-readable outputs, but you won't get any graphics output. Just ignore the TAPE5 file. If you have other graphics devices, you can modify the DD-prefix plotting routines (in DDALT, supplied as File 8 of the distribution tape) to drive them. The functions of these routines and further details about the FR-80 plot package and the DISSPLA interface are given in Appendix C.

3.3 Unpacking the Program Tape and File Organization

The distribution tape contains the files listed in Section 3.3.1. Although HARPO continues to evolve, the source code on the distribution tape will always correspond exactly to the version described in this report. Updates and errata will be documented separately and included in a dated update tape file. Section 7.1 gives a list of the programs and subroutines on the distribution tape. Normally, you would transfer tape files 1-8 to punched cards or permanent disk files, depending on which medium you will use to run the program.

3.3.1 Files on the HARPO Distribution Tape

File #:

1. FORTRAN source code for the Sample Case, including its models, ready to compile, with common and data blocks included.
2. Input Data File for the Sample Case.
3. FORTRAN source code for the "Ray-tracing Core" programs, including plotting (graphics write) routines.
4. FORTRAN source code for four dispersion-relation routines.
5. FORTRAN source code for all ocean-model routines.
6. FORTRAN source code for graphics-file read routine TAPRD for reading the Graphics Output File (TAPE5).
7. FORTRAN source code for DDSPLA routines for users with DISSPLA.
8. FORTRAN source code for DDALT, a set of skeleton routines allowing users to insert plotting modules for their own plotting system.

3.3.2 Setting Up a Run Module

A run module is the subset of programs that you submit to your computer to run a particular application, along with input data and the job-control commands your computer needs to compile and/or run a program. Files 1 and 2 of the distribution tape constitute the run module (minus the job-control cards) for the sample case. It consists of core routines (Sec. 7.1.1) that must always be present to trace rays, and a set of selectable routines (Secs. 7.1.2 and 7.1.3) that describe the particular ocean model (those for the sample case in this example). Figure 3.1 shows the parts of a representative run module.

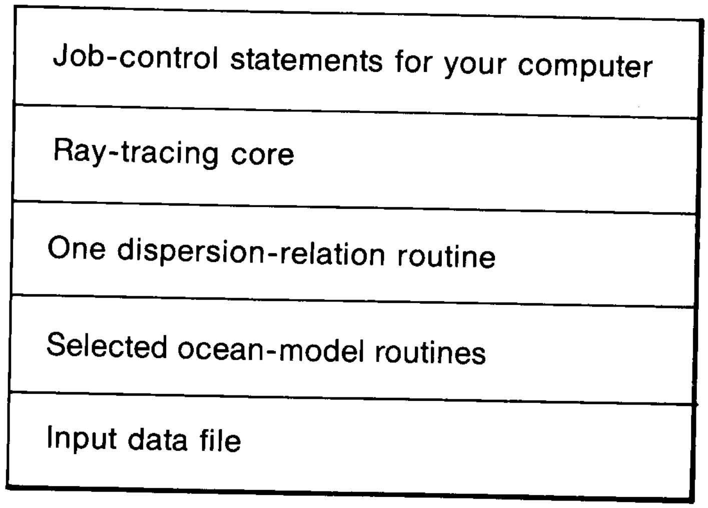


Figure 3.1. Configuration of a run module, assembled from parts consisting either of disk-file modules or punched-card decks.

The selectable part of the run module means that you select only the routines that describe the model you want to use. The run module must contain one and only one (with exceptions noted) of the following kinds of model routines:

- a dispersion-relation routine
- a background sound-speed model
- a background current model (if you use AWCWL or AWCNL dispersion-relation models)
- a background bottom model
- a background ocean-surface model
- a perturbation sound-speed model (NPSPEED does nothing)
- a perturbation current model (NPCURR does nothing) (if you use AWCWL or AWCNL dispersion-relation models)
- a perturbation bottom model (NPBOTM does nothing)
- a perturbation ocean-surface model (NPSURF does nothing)
- a receiver-surface model.
- a loss model (if you use ANCWL or AWCWL dispersion-relation models)

In addition, you need any other models that are called by any of the above routines. Look at the bottom of the model input parameter forms (Appendix B) to see what other models a given model needs.

3.3.3 If You Are Using Cards To Input Data

If you have no permanent disk storage on your computer, you can load a previously compiled version of HARPO (if you don't change the program itself) into your computer from tape each time you want to run it, and have it read the Input Data File from punched cards. For each run, you have to edit the Input Data File (Deck) by punching new cards for the data you change from a previous run. The Input Data File is arranged in an 80-column format with one input parameter per card so that the deck is easy to edit if you have the contents of the cards interpreted (printed across the card tops).

3.3.4 If You Are Using Permanent Disk Files

It is far more convenient to store both the program and the Input Data File in permanent disk files. A run module (Figure 3.1) can be constructed by a batch or procedure program that selects the appropriate routines from the HARPO "library." Procedure (or batch) programs also simplify the manipulation of HARPO input and output, but because they depend on the operating system you use, you will generally have to write your own procedures.

4. How to Construct An Ocean Model

The easy way to set up an ocean model is to select from a general-purpose set of models we have designed (Table 4.1) and choose the model parameters that fit your needs. This requires no programming whatsoever and we encourage that choice whenever possible. Alternatively, you can design your own ocean model by writing a FORTRAN subroutine that defines the ocean property and its spatial derivatives in a form that is compatible with the rest of the program. This chapter describes both ways.

4.1 Choosing From the Available Ocean Models

We have designed some generic ocean models that can be adapted to represent common ocean structures simply by selecting the appropriate model and its parameters in the Input Data File. They are closed-form expressions for an ocean property as a function of geographic latitude, longitude, and depth; some accept input parameters in tabular form. There are models for current and sound-speed fields, absorption, and top and bottom surfaces. Though not strictly considered part of the ocean model, three models for the receiver surface are also provided. All of these models are described in Appendix B.

Most of the models come in two kinds, "background" and "perturbation." Perturbation models generally superimpose more structure on a background model. Table 4.1 lists the ocean models that come with HARPO. To run HARPO, you always have to specify one background model and one perturbation model for each required ocean property, even if the perturbation is a do-nothing version.

To put together an ocean model from the subroutines we have supplied, first copy the FORM TO SPECIFY AN OCEAN MODEL from Appendix B and fill in the name of a model you want to use for each ocean parameter, selecting from the choices listed in Table 4.1. Full mathematical descriptions of each model can be found in Appendix B on the order form listed under the model name, and FORTRAN listings for the model subroutines can be found in Appendix D. For now, leave off the numbers of the Data Set ID column until you have selected the models' parameters.

Table 4.1--Available ocean models

Model type number	Start of W array parameter block	Model check number	Subroutine name	Description
1.	100			Background current models:
		1.	WLINEAR	Constant upward and northward current, linear eastward current profile
		9.	VVORTX3	Vertical, cylindrical current vortex
		8.	WGAUSS2	Localized (Gaussian) eastward current field
2.	125			Current-perturbation model:
		0.	NPCURR	Do-nothing version
				Sound-speed models:
3.	150	2.	CSTANH	Linear C^2 segments joined by hyperbolic functions
		3.	CSSPOKE	C^2 function of angle from horizontal
		4.	CSSPOK2	C^2 function of angle from horizontal
		7.	CTANH	Linear C segments, smoothly joined
		5.	CSMUNK1	Canonical sound channel; interpolates parameters
		6.	CSMUNK2	Canonical sound channel; interpolates C
		8.	CTABLE	Tabular sound-speed profile in cubic segments
4.	175			Sound-speed perturbation models:
		0.	NPSPEED	Do-nothing version
		2.	CBLOB2	Localized (Gaussian) sound-speed perturbations
		3.	CBLOB3	
8.	275			Receiver-surface models:
		1.	RHORIZ	A sphere concentric with the earth
		2.	RTERR	A fixed height above the bottom
		3.	RVERT	A vertical surface at a specified fixed range from a specified geographic point
9.	300			Bottom models:
		1.	GHORIZ	A sphere concentric with the earth
		3.	GTANH	A profile of linear segments joined by hyperbolic functions
		4.	GLORENZ	An east-west Lorentzian-shaped ridge

Table 4.1--Available ocean models (continued)

Model type number	Start of W array parameter block	Model check number	Subroutine name	Description
10.	325	0.	NPBOTM	Bottom perturbation: Do-nothing version
11.	350	1.	SHORIZ	Ocean-surface model: A sphere concentric with the earth
12.	375	0.	NPSURF	Ocean-surface perturbation model: Do-nothing version
17.	500	1.	SLLOSS	Ocean absorption model: Skretting-Leroy absorption formula
18.	525	0.	NPABSR	Ocean absorption perturbation model: Do-nothing version

Next, select and copy the blank Input Parameter Forms from Appendix B for the models you have selected and fill in the values of the variable parameters that you want. Next transfer the input parameters to a new Input Data File, either constructing one from scratch, according to the format shown in Figure 2.19, or modifying an old one. (If you use an old one, make sure that unused parameters are removed.) Remember to assign an input data-set identification number, which uniquely identifies that set of input parameters for each model, and to assign an Ocean Identification (ID) for the entire set of models. Put these ID numbers on the FORM TO SPECIFY AN OCEAN MODEL and save all these forms as a record of the models you have defined.

Here are a few guidelines for selecting models. If you want a model with no current, use no current model and select a dispersion-relation routine with no current (ANCNL or ANCWL). If you want no perturbation model for current, sound speed, ocean surface, bottom, or absorption, use the corresponding do-nothing perturbation models NPCURR, NPSPEED, NPSURF, NPBOTM, or NPABSR. If you are storing HARPO on a permanent disk file, you have to select only the subroutines that define your ocean model (and the correct dispersion-relation routine) and assemble them into a separate "run module" (Sec. 3.3.2). If you are storing the programs on punched cards, you should select and submit only the decks for the model subroutines you want to use. It is convenient to think of HARPO as consisting of a core of ray-tracing routines that are always used, and a set of selectable model-related routines from which you select the ones appropriate to the models you want. The specific routines that fall into each category are listed in Chapter 7.

4.1.1 Model Check Numbers

To guard against accidentally selecting the wrong model subroutine for a run module, each model is assigned a permanent Model Check Number, which is entered on each model input data form (Appendix B). If a model subroutine is selected whose Check Number does not match that specified in the Input Data File, then the program will stop and give an error message.

Another number, called the Input Data Format Code, is not now being used or checked, but may be used in the future.

4.1.2 Tabular Input to Models

Some models, like CTANH and CTABLE, can accept so many input parameters that it is inconvenient to specify each one as a separate line in the Input Data File, so a general provision has been made for entering data in tabular form. The use of CTANH in the sample case is an example. Tabular data are entered into the Input Data File in a special format illustrated by Figure 2.19 and described fully in Chapter 5.

4.2 Designing Your Own Models

HARPO will accept any ocean model specification that provides the desired ocean property as a continuous function of the earth-centered spherical-polar coordinates r,θ,ϕ and time t, as well as its first spatial and temporal derivatives. (Bottom models require specifying continuous second derivatives as well.) There are three important considerations in writing model subroutines: (a) All first spatial derivatives must be not only continuous but also analytically consistent with the formulas for the atmospheric property itself; any errors or approximations in those calculations will result in larger-than-desired integration errors, as displayed in the first column of the ray-tracing printout. (b) The input data for the models must come from the part of the W array assigned to that type of model (Table 4.1) and from the tabular-input common blocks assigned to those models (Table 4.2). (c) The output from the ocean model must go to the appropriate data-output common block (Table 4.3). Because the model routines are called many times, efficient programming here pays off in execution efficiency.

If you want a new model of current or sound speed that depends only on depth, you would normally design only a new background model. If you want a three-dimensional model, you could use one of the background models we have supplied and design only a new perturbation model. Conceivably, you could

Table 4.2--Allocation of common blocks for tabular input to the various ocean models*

Common block name	Ocean model
/B1/	Current velocity
/B2/	Perturbation to the current velocity
/B3/	Sound speed
/B4/	Perturbations to the sound speed
/B8/	Receiver surface
/B9/	Ocean bottom
/B10/	Ocean-bottom perturbation
/B11/	Ocean surface
/B12/	Ocean-surface perturbation
/B17/	Absorption
/B18/	Absorption perturbation

* In the first 31 elements of each of these common blocks, each ocean model indicates the structure of the rest of the common block. Subroutine READW1 stores input data that it reads starting in element 32 of the common block.

Table 4.3--Allocation of common blocks for output from the various ocean models

Common block name	Location of description (table number)	Ocean model
/UU/	7.33	Current velocity
/CC/	7.34	Sound speed
/RR/	7.37	Receiver surface
/GG/	7.38	Bottom
/LL/	7.35	Absorption (losses)
/SS/	7.36	Ocean surface

design both a new background and a new perturbation model, but the safe way to proceed is to do one at a time.

Those designing a new model should pattern their subroutine after a similar one that comes with HARPO. We will use the CTANH model (Fig. 4.1) as an example and discuss its structure in detail to illustrate how to write a model subroutine. In the following paragraphs, general statements will be followed in square brackets by the specific examples from CTANH.

There are no restrictions on naming models, but it is useful to assign a name that suggests the model's function. [CTANH is a sound-speed model that used TANH (hyperbolic tangent) functions to smooth sound-speed profiles that have linear segments.] Each model subroutine has three entry points whose standard names are given in Table 4.4. These names must be used when designing new subroutines. The first entry point [ENTRY SETSPD] is to transfer values from local variables to labeled common, since Fortran 77 forbids references in DATA statements to labeled-common variables. The second entry point [ENTRY IPSPEED], whose name begins with an "I," is for initialization after new input data have been read in, and that entry point is called each time new data are read before the second entry point [ENTRY SPEED] is called. The third entry point [ENTRY SPEED] enters the routine to compute the ocean parameter [CS] and its time and space derivatives [PCST, PCSR, PCSTH, PCSPH] according to the formulas given on the model order form.

```
      SUBROUTINE CTANH
C     SPEED PROFILE REPRESENTED BY A SEQUENCE OF LINEAR SEGMENTS
C     SMOOTHLY JOINED BY HYPERBOLIC FUNCTIONS. PARAMETERS ARE INPUT
C     AS TABULAR DATA WITH SLOPES COMPUTED FROM SPEED DATA.
C     REFERENCE SPEED C0 IS READ FROM TABULAR DATA.
C
      REAL C0(20), TM(19), Z(19), DL(19)
C
C     COMMON DECK "RKAM" INSERTED HERE
      REAL KR,KTH,KPH
      COMMON//R,TH,PH,KR,KTH,KPH,RKVARS(14),TPULSE,CSTEP,DRDT(20)
C     COMMON DECK "CC" INSERTED HERE
      REAL MODC
      COMMON/CC/MODC(4),CS,PCST,PCSR,PCSTH,PCSPH
C     COMMON DECK "WW" INSERTED HERE
      PARAMETER (NWARSZ=1000)
      COMMON/WW/ID(10),MAXW,W(NWARSZ)
      REAL MAXSTP,MAXERR,INTYP,LLAT,LLON
      EQUIVALENCE (EARTHR,W(1)),(RAY,W(2)),(XMTRH,W(3)),(TLAT,W(4)),
     1 (TLON,W(5)),(OW,W(6)),(FBEG,W(7)),(FEND,W(8)),(FSTEP,W(9)),
     2 (AZ1,W(10)),(AZBEG,W(11)),(AZEND,W(12)),(AZSTEP,W(13)),
     3 (BETA,W(14)),(ELBEG,W(15)),(ELEND,W(16)),(ELSTEP,W(17)),
     8   (RUNSUP,W(18)),(RCVRH,W(20)),
     4 (ONLY,W(21)),(HOP,W(22)),(MAXSTP,W(23)),(PLAT,W(24)),(PLON,W(25))
     5,(HMAX,W(26)),(RAYFNC,W(29)),(EXTINC,W(33)),
     6 (HMIN,W(27)),(RGMAX,W(28)),
     8 (INTYP,W(41)),(MAXERR,W(42)),(ERATIO,W(43)),
     6 (STEP1,W(44)),(STPMAX,W(45)),(STPMIN,W(46)),(FACTR,W(47)),
     7 (SKIP,W(71)),(RAYSET,W(72)),(PRTSRP,W(74)),(HITLET,W(75))
     9 ,(BINRAY,W(76)),(PAGLN,W(77)),(PLT,W(81)),(PFACTR,W(82)),
     1 (LLAT,W(83)),(LLON,W(84)),(RLAT,W(85)),(RLON,W(86))
     2,(TIC,W(87)),(HB,W(88)),(HT,W(89)),(TICV,W(96))
      REAL MMODEL,MFORM,MID
C
C     WIND          100-124
      EQUIVALENCE (W(100),UMODEL),(W(101),UFORM),(W(102),UID)
C
C     DELTA WIND          125-149
      EQUIVALENCE (W(125),DUMODEL),(W(126),DUFORM),(W(127),DUID)
C
C     SOUND SPEED 150-174
      EQUIVALENCE (W(150),CMODEL),(W(151),CFORM),(W(152),CID)
      EQUIVALENCE (W(153),REFC)
C
C     DELTA SOUND SPEED 175-199
      EQUIVALENCE (W(175),DCMODEL),(W(176),DCFORM),(W(177),DCID)
C
C     TEMPERATURE    200-224
      EQUIVALENCE (W(200),TMODEL),(W(201),TFORM),(W(202),TID)
C
C     DELTA TEMPERATURE    225-249
      EQUIVALENCE (W(225),DTMODEL),(W(226),DTFORM),(W(227),DTID)
C
C     MOLECULAR    250-274
      EQUIVALENCE (W(250),MMODEL),(W(251),MFORM),(W(252),MID)
C
C     RECEIVER HEIGHT   275-299
      EQUIVALENCE (W(275),RMODEL),(W(276),RFORM),(W(277),RID)
C
C     TOPOGRAPHY    300-324
      EQUIVALENCE (W(300),GMODEL),(W(301),GFORM),(W(302),GID)
C
C     DELTA TOPOGRAPHY    325-349
```

Figure 4.1. Listing for model sound-speed subroutine CTANH.

```
      EQUIVALENCE (W(325),GUMODEL),(W(326),GUFORM),(W(327),GUID)
C
C     ATMOSPHERIC SURFACE TOPOGRAPHY   350-374
      EQUIVALENCE (W(350),SMODEL),(W(351),SFORM),(W(352),SID)
C
C     ATMOSPHERIC SURFACE TOPOGRAPHY   375-399
      EQUIVALENCE (W(375),SUMODEL),(W(376),SUFORM),(W(377),SUID)
C     PLOT ENHANCEMENTS CONTROL PARAMETERS
C
      EQUIVALENCE (W(490),XFQMDL),(W(491),YFQMDL)
C     ABSORPTION         500-524
      EQUIVALENCE (W(500),AMODEL),(W(501),AFORM),(W(502),AID)
C
C     DELTA ABSORPTION         525-549
      EQUIVALENCE (W(525),DAMODEL),(W(526),DAFORM),(W(527),DAID)
C
C     PRESSURE         550-574
      EQUIVALENCE (W(550),PMODEL),(W(551),PFORM),(W(552),PID)
C
C     DELTA PRESSURE         575-599
      EQUIVALENCE (W(575),DPMODEL),(W(576),DPFORM),(W(577),DPID)
C
C     COMMON DECK "B3" INSERTED HERE
      INTEGER CMX,CNTBL,CITBL,CFRMTBL,IDSC(10)
      COMMON/B3/CMX,CNTBL(10),CITBL(10),CFRMTBL(10),CGP(512)
      EQUIVALENCE (CGP,IDSC),(ANC,CGP(11))
C
      EQUIVALENCE (Z0,CGP(12)),(TM,CGP(33))
      EQUIVALENCE (Z,CGP(13)),(CO,CGP(32)),(DL,CGP(53))
C
      INTEGER CPX    ,CQTBL(10),CLTBL(10),CIRMTBL(10)
      DATA RECOGC,N/7.0,0/
C
      DATA AQC/0.0/
      DATA CPX/2/
      DATA CQTBL/1,11,72,7*0/
      DATA CLTBL/1,20,8*0/
      DATA CIRMTBL/1,2,8*0/
C
      COSH (X) = (EXP (X) + 1. / (EXP (X))) / 2.
C
C
      ENTRY SETSPD
C
      ANC=AQC
      CMX=CPX
      CALL IMOVE(CNTBL,CQTBL,10)
      CALL IMOVE(CITBL,CLTBL,10)
      CALL IMOVE(CFRMTBL,CIRMTBL,10)
      CALL SETPSP
C
      RETURN
C
      ENTRY ISPEED
C
C     IF HAD PREVIOUS CALL BUT NOTHING THIS TIME, EXIT NOW
C     RETAINING PREVIOUS TABULAR DATA COUNT
C
      CALL IPSPEED
C
      IF(N.GT.0 .AND. ANC.EQ.0.0) RETURN
C
      IF(RECOGC .NE. CMODEL)
```

Figure 4.1. Listing for model sound-speed subroutine CTANH (continued).

```
     1    CALL RERROR('SPEED   ','WRNG MODEL',RECOGC)
C
      MODC(1)=7HCTANH
      MODC(2)=CID
C
      N=(ANC+1)/3 - 2
C
      IF(N.LE.0)
     1    CALL RERROR('CTANH','BAD N VALUE',FLOAT(N))
C
      ANC=0.0
C
C     CONVERT 'CGP' ARRAY INPUT(OVERLAYS 'C' ARRAY) TO 'C' ARRAY
C
      C0=CO(1)
      TIM1=C0
      ZIM1=Z0
      NP1=N+1
      DO 10 I=1,NP1
         TI=TM(I)
         ZI=Z(I)
         CO(I)=(TI-TIM1)/(ZI-ZIM1)
         TIM1=TI
10       ZIM1=ZI
C
      RETURN
C
      ENTRY SPEED
      H = R - EARTHR
      SUM = 0.
C
C     LOOP TO SUM OVER ALL COEFFICIENTS
C     USE SPECIAL FUNCTION 'ALCOSH' WHICH ALLOWS FOR LARGE ARGUMENTS.
      DO 1 I = 1, N
    1 SUM = SUM + DL(I) * (CO(I + 1) - CO(I)) / 2. *(ALCOSH((H - Z
     1(I)) / DL(I)) - ALCOSH((Z(I)-Z0) / DL(I)))
C
      C = C0 + SUM + (CO(1) + CO(N + 1)) * (H - Z0) * 0.5
C
      SUM = 0.
      DO 2 I = 1, N
    2 SUM = SUM + (CO(I + 1) - CO(I)) / 2. * (1. + TANH ((H - Z(I)) /DL
     1 (I)))
C
      CS=C*C
C
      PCST=0.0
      PCSR = 2.0*C*(CO(1) + SUM)
      PCSTH=0.0
      PCSPH=0.0
C
      CALL PSPEED
      RETURN
      END
```

Figure 4.1. Listing for model sound-speed subroutine CTANH (continued).

The input to each subroutine (geographic coordinates r,θ,ϕ) is through blank common, and output [sound speed squared and its derivatives] is through the labeled common blocks [/CC/], named for each kind of model and listed in Table 4.3. If you need more input parameters than will fit in the assigned

Table 4.4--Assignment of entry point names and input parameter blocks in the W array for the ocean models

Ocean model	Entry point names	Input parameter block in the W array
Current	SETWND, WINDR, IWINDR	100-124
Current perturbation	SETPWN, PWINDR, IPWINDR	125-149
Sound-speed	SETSPD, SPEED, ISPEED	150-174
Sound speed perturbation	SETPSP, PSPEED, IPSPEED	175-199
Receiver surface	SETRCV, RECVR, IRECVR	275-299
Bottom	SETTOP, TOPOG, ITOPOG	300-324
Bottom perturbation	SETPTP, PTOPOG, IPTOPOG	325-349
Ocean surface	SETSUR, SURFACE, ISURFAC	300-374
Ocean surface perturbation	SETPSR, PSURFC, IPSURFC	375-399
Absorption	SETABS, ABSRP, IABSRP	500-524
Absorption perturbation	SETPAB, PABSRP, IPABSRP	525-549

block of the Input Data Table [150-174], then you should use a tabular input format, which uses the labeled common blocks [/B3/] listed in Table 4.2. Tabular data are read into this common block from the Input Data File according to the format described in Chapter 5 and illustrated near the end of Figure 2.19 for the sample case.

4.2.1 How To Write an Ocean Model Subroutine So It Can Receive Tabular Data Read Into Common Blocks by Subroutine READW1

If you want to write an ocean model subroutine that uses tabular input data, then you have to observe some special precautions. In what follows, general statements are exemplified in square brackets for the case of the sound-speed subroutine. You can use this example as a guide in developing new model subroutines that use tabular data.

Tabular [sound-speed] data are read into a model-related common block [/B3/] by subroutine READW1. Table 4.2 gives the names of the common blocks associated with the different model types. The format of the tabular input data can be selected by the user and is determined by a format number [3] in columns 1-3 of the Input Data File (see Fig. 2.19). [In the case of CTANH, a three-column format makes sense because there are three input parameters for each profile point]. READW1 interprets this format number according to the formats listed in Table 5.3. The model subroutine [CTANH] must tell READW1 how it wants the tabular input data stored in the common block [/B3/] in an array [CGP]. It does so by setting (in DATA statements) the values in variable CMX and in arrays CNTBL, CITBL and CFRMTBL for sound speed models (or corresponding names for other model types, in which the first letter is different). The model variables [ZO,TM,C,DL] are EQUIVALENCEd to elements of a GP (for general-purpose) array [called CGP for sound-speed models]. The first element [ANC] of each numeric data block is set by SUBROUTINE READW1 to the number of data values actually read. Table 4.5 defines the structure of common block /B3/, which transmits these variables between READW1 and CTANH, and it explains how to set the data-block parameters.

4.2.2 Designing Your Own Ocean-Bottom and Ocean-Surface Models

An ocean-bottom model specifies a function $g(r,\theta,\phi)$ such that $g=0$ for a point (r,θ,ϕ) on the bottom, $g>0$ for a point (r,θ,ϕ) above the bottom, and $g<0$ for a point (r,θ,ϕ) below the bottom. To be an allowed model, g must be continuous through second derivatives. A subroutine for a background or perturbation bottom model must calculate g, its three first derivatives, and its six second derivatives for any values of r,θ,ϕ. All of our present bottom models define g to be the height above the bottom, but more general definitions are allowed to handle cliffs, overhangs, and caves. To design a simple model with a few parameters, follow the example of SUBROUTINE GLORENZ. To design a more elaborate model that needs tabular input data, follow the example of SUBROUTINE GTANH. Source-Code listings for these models are in Appendix D.

Models for the ocean surface follow the same rules as those for the bottom, with both background and perturbation models allowed. Ordinarily, the ocean surface is represented by a sphere at MSL (or some other radius), and we provide SUBROUTINE SHORIZ for this purpose. A do-nothing surface-perturbation model NPSURF is provided. Other ocean-surface models can be patterned after these examples.

Table 4.5--Definitions of the parameters in common block /B3/*

Position in common	Variable name	Definition	Value
1	CMX	Maximum number of data blocks in /B3/	2
2-11	CNTBL	An array that contains the beginning locations (in CGP array) of data blocks within the common block	
2	CNTBL(1)	Beginning location (in CGP array) of data block 1	1
3	CNTBL(2)	Beginning location (in CGP array) of data block 2	11
4	CNTBL(3)	Beginning location (in CGP array) of data block 3**	12 + number of data columns times the maximum number of rows of data
5 -11	CNTBL(4)-CNTBL(10)	Not used	0
12-21	CITBL	An array that contains the maximum number of rows of data in the data blocks (if there is more than one array in the data block, then this is the dimension of the arrays)	
12	CITBL(1)	Maximum number of rows in data block 1	1
13	CITBL(2)	Maximum number of rows in data block 2	= array dimension for data columns
14-21	CITBL(3)-CITBL(10)	Not used	0
22-31	CFRMTBL	An array that contains the input format type numbers for the data blocks within the common block	
22	CFRMTBL(1)	Format type*** for data block 1	1
23	CFRMTBL(2)	Format type*** for data block 2	2
24-31	CFRMTBL(3)-CFRMTBL(10)	Not used	0
32-	CGP	An array (of length at least CNTBL(3)-1) containing CMX number of data blocks for tabular input data for ocean models	
42	CGP(11)	The number of data values actually read into data block 2	roughly equal the number of data columns times the number of rows of data read

* The values of the first 31 elements in /B3/ define the block structure for the array CGP, and they are set in the ocean models and used in the data read-in routines READW and READW1. The common blocks /B1/, /B2/, /B4/, /B5/, /B6/, and /B7/ have the same structure as /B3/, but have different names for the variables.

** Only two data blocks are now available to use; however, the beginning location of the first data block not used must be specified to indicate the length of the last data block used.

*** Format type 1 implies format number A (see Table 5.3).
Format type 2 implies format numbers 1, 2, or 3 (see Table 5.3).

5. How to Specify the Input Data and Set Up an Input Data File

To give HARPO an ocean model and to tell it what rays to trace, you have to construct an Input Data File, like the one shown in Figure 5.1 (same as Figure 2.19, reproduced here for your convenience) for the sample case. An Input Data File may contain one or more "run sets," each of which can specify a different ocean model (but the same ocean-model subroutines), different plotting modes, or different initial ray conditions, but which will all be executed as a single computer run. The sample case contains two run sets. After the first run set, only the parameters whose values differ from those specified in the preceding run set need be specified.

After setting up an Input Data File, you run HARPO by combining the Input Data File with other ray-tracing modules to form a "run module," as explained in Section 3.3.2. All the necessary modules to run the sample case are contained in Files 1 and 2 of the distribution tape (Sec. 3.3.1).

5.1 Editing the Input Data File

Because HARPO contains no built-in way to construct or edit an Input Data File, you have to use a text editor of your own to do so. We have designed a specialized editor, called WMOD, for this purpose. It not only permits editing the Input Data File, but it also sets up a "run module" that includes appropriate ray-tracing and model routines and job-submission procedures for our computer. This program, which could run on a local microcomputer, will be documented in another report.

The Input Data File can take the form of either a deck of punched cards or a disk file to be read by HARPO. Some suggestions for those using punched cards are given in Section 3.3.3. Henceforth, we will assume that the Input Data File will be created as a disk file. There are no formal differences between the two methods, however.

Rather than start from scratch, we recommend that you modify an existing Input Data File. After you have run the sample case and have verified that its

```
col.     col.      col.          col.
1-3      4-17      18-24         25-80
 n       W(n)      UNITS         DESCRIPTION
-----------------------------------------------------------------------------

GEORGES    RB3     X6437
N01-1      SAMPLE CASE FOR HARPO DOCUMENTATION         REV. 8-19-86
  1     6370.              EARTH RADIUS TO MSL, KM (6370.)
  3        2.             TTRANSMITTER HEIGHT ABOVE MSL (T=ABOVE BOTTOM), KM
  4        0.      AN KM   N. TRANSMITTER LATITUDE, KM
  5        0.      AN KM   E. TRANSMITTER LONGITUDE, KM
  7      400.      FQ HZ   INITIAL FREQUENCY, HZ
 11       80.      AN DG   INITIAL AZIMUTH ANGLE, DEG
 15        2.      AN DG   INITIAL ELEVATION ANGLE, DEG
 16       16.      AN DG   FINAL   ELEVATION ANGLE, DEG
 17        2.      AN DG   STEP IN ELEVATION ANGLE, DEG
 19        0.              STOP RAYS THAT STRIKE BOTTOM (1=YES; 0=NO)
 20       -1.              RECEIVER HEIGHT ABOVE MSL, KM
 22       50.              MAXIMUM NUMBER OF HOPS (1.)
 23     1000.              MAXIMUM NUMBER OF STEPS PER HOP (1000.)
 26        5.              MAXIMUM RAY HEIGHT ABOVE MSL, KM
 27       -5.              MINIMUM RAY HEIGHT ABOVE MSL, KM
 28      210.              MAXIMUM RANGE AT MSL, KM
 29        0.              DO: EIGRAY/RNG-TIM/RNG-ELV/NEW-PROJ/RAYTRC/CONT/PROF
 33       20.              MAXIMUM ABSORPTION, DB (999.999)
 42        1.0E-06         MAXIMUM SINGLE-STEP INTEGRATION ERROR (1.0E-4)
 44        .1              INITIAL INTEGRATION STEP SIZE, KM (1.0)
 57        2.              PHASE PATH  (0=NO; 1=INTEGRATE; 2=INTEGRATE/PRINT)
 58        2.              ABSORPTION  (0=NO; 1=INTEGRATE; 2=INTEGRATE/PRINT)
 60        2.              PATH LENGTH (0=NO; 1=INTEGRATE; 2=INTEGRATE/PRINT)
 71       50.              NUMBER OF INTEGRATION STEPS PER PRINT [1.E31]
 72        1.              OUTPUT RAYSETS (1=YES; 0=NO)
 73        0.              DIAGNOSTIC PRINTOUT (1=YES; 0=NO)
 74        0.              PRINT EVERY W(71) RAY STEPS (0=YES; 1=NO)
 75      .15               FULANN PLOT LETTERING; HEIGHT= [0.15 IN]
 76        0.              BINARY RAY OUTPUT (1=YES; 0=NO)
 77       57.              LINES PER PAGE OF PRINTOUT (57.)
 81        4.              RAYPLOT PROJECTION PLANE (4 = VERT. RECTANGULAR)
 82       40.               PLOT-ORDINATE EXPANSION FACTOR [1.]
 83        0.      AN KM    N. LATITUDE OF LEFT PLOT EDGE, KM
 84        0.      AN KM    E. LONGITUDE OF LEFT PLOT EDGE, KM
 85       35.1     AN KM    N. LATITUDE OF RIGHT PLOT EDGE, KM
 86      200.      AN KM    E. LONGITUDE OF RIGHT PLOT EDGE, KM
 87       50.      AN KM    DISTANCE BETWEEN RANGE TICKS, KM (0 = AUTO)
 88       -3.               HEIGHT ABOVE MSL OF BOTTOM OF GRAPH, KM
 89        0.               HEIGHT ABOVE MSL OF TOP OF GRAPH, KM
 96        1.               DISTANCE BETWEEN DEPTH TICKS, KM (0 = AUTO)
100        9.              VVORTX3 MODEL CHECK NUMBER
102        3.               VVORTX3 BACKGROUND CURRENT DATA SET ID
103        1.02    LN  M    MAXIMUM TANGENTIAL CURRENT, M/S
104       50.               RADIUS OF VORTEX CORE, KM
105        0.      AN KM    LATITUDE OF VORTEX CENTER, KM
106      150.      AN KM    LONGITUDE OF VORTEX CENTER, KM
107        1.               VERTICAL HALF-WIDTH OF VORTEX, KM
```

Figure 5.1. Input Data File (W array) for the sample case.

```
108        -1.               HEIGHT OF VORTEX CENTER ABOVE MSL, KM
150         7.              CTANH SOUND SPEED MODEL CHECK NUMBER
152         1.               CTANH BACKGROUND SOUND SPEED DATA SET ID
175         2.              CBLOB2 SOUND SPEED PERTURBATION MODEL CHECK NUMBER
177         7.               CBLOB2 PERTURBATION SOUND SPEED DATA SET ID
178       .02                MAXIMUM FRACTIONAL INCREASE IN C SQUARED
179        -1.               HEIGHT OF MAX EFFECT ABOVE MSL, KM
180         0.     AN KM     LATITUDE OF MAX EFFECT, KM
181       150.     AN KM     LONGITUDE OF MAX EFFECT, KM
182         1.               VERTICAL HALF-WIDTH, KM
183        50.     AN KM     N-S  HALF-WIDTH, KM
184        50.     AN KM     E-W  HALF-WIDTH, KM
275         1.              RHORIZ RECEIVER MODEL CHECK NUMBER
300         4.              GLORENZ BOTTOM MODEL CHECK NUMBER
302         3.               GLORENZ BOTTOM MODEL DATA SET ID
303        .5                HEIGHT OF RIDGE, KM ABOVE BASE
304        10.     AN KM     N. LATITUDE OF RIDGE CENTER, KM
305         2.     AN KM     HALF-WIDTH OF THE RIDGE, KM
306        -3.               HEIGHT ABOVE MSL OF BASE OF RIDGE, KM
350         1.              SHORIZ MODEL CHECK NUMBER
352         1.               SHORIZ OCEAN SURFACE DATA SET ID
353         0.               HEIGHT OF OCEAN SURFACE ABOVE MSL, KM
500         1.              SLLOSS ABSORPTION MODEL CHECK NUMBER
502         1.               SLLOSS ABSORPTION DATA SET ID
503     0.006      AM DB     A COEFFICIENT, DB
504    0.2635      AM DB     B COEFFICIENT, DB
505     1000.      FQ HZ     OMEGA1, HZ
506     1700.      FQ HZ     OMEGA2, HZ
 -1                         DATA SUBSET FOR BACKGROUND CURRENT MODEL
 A  VORTEX AT LONGITUDE 150 KM E, UMAX= 1.02 M/S, R= 50 KM
 0        RETURN TO W-ARRAY DATA SET
 -2                         DATA SUBSET FOR PERTURBATION CURRENT MODEL
 A  NO CURRENT PERTURBATION
 0        RETURN TO W-ARRAY DATA SET
 -3                         DATA SUBSET FOR BACKGROUND SOUND-SPEED MODEL
 A  EL NINO BACKGROUND SOUND-SPEED PROFILE
 3     999.0
  LN  M         LN  M         LN  M
  0.            1532.         0.
  -20.          1531.5        -7.
  -50.          1509.         -20.
  -250.         1503.         -40.
  -450.         1485.         -300.
  -1500.        1485.         -400.
  -3000.        1508.         0.
  999.0
 0        RETURN TO W-ARRAY DATA SET
 -4                         DATA SUBSET FOR SOUND-SPEED PERTURBATION MODEL
 A  2% INCREASE IN C-SQUARED AT 150 KM LON., 1 KM DEPTH, 50 KM WIDE
 0        RETURN TO W-ARRAY DATA SET
 -8                         DATA SUBSET FOR RECEIVER-SURFACE MODEL
 A  RECEIVER SURFACE = SPHERE 1 KM BELOW MSL
 0        RETURN TO W-ARRAY DATA SET
 -9                         DATA SUBSET FOR BACKGROUND BOTTOM MODEL
 A  RIDGE .5 KM HIGH, 2 KM WIDE AT 10 KM N LATITUDE; BASE= -3 KM
```

Figure 5.1. Input Data File (W array) for the sample case (continued).

```
  0       RETURN TO W-ARRAY DATA SET
-10                      DATA SUBSET FOR BOTTOM PERTURBATION MODEL
  A  NO BOTTOM PERTURBATION
  0       RETURN TO W-ARRAY DATA SET
-11                      DATA SUBSET FOR OCEAN SURFACE MODEL
  A  OCEAN SURFACE = SPHERE AT MSL
  0       RETURN TO W-ARRAY DATA SET
-12                      DATA SUBSET FOR OCEAN SURFACE PERTURBATION MODEL
  A  NO OCEAN SURFACE PERTURBATION
  0       RETURN TO W-ARRAY DATA SET
-17                      DATA SUBSET FOR OCEAN ABSORPTION MODEL
  A  SKRETTING-LEROY ABSORPTION FORMULA
  0       RETURN TO W-ARRAY DATA SET
-18                      DATA SUBSET FOR PERTURBATION ABSORPTION MODEL
  A  NO ABSORPTION PERTURBATION
  0       RETURN TO W-ARRAY DATA SET
  0                      **********  END OF RUN SET NUMBER 1  *********
N01-2     SAMPLE CASE FOR HARPO DOCUMENTATION        REV. 8-19-86
 71        0.            NUMBER OF INTEGRATION STEPS PER PRINT [1.E31]
 72        0.            OUTPUT RAYSETS (1=YES; 0=NO)
 73        1.            DIAGNOSTIC PRINTOUT (1=YES; 0=NO)
 81        2.            RAYPLOT PROJECTION PLANE (2 = HORIZONTAL)
 88       -1.            HEIGHT OF HORIZONTAL PLOT SECTION ABOVE MSL, KM
  0                      **********  END OF RUN SET NUMBER 2  *********
```

Figure 5.1. Input Data File (W array) for the sample case (continued).

output agrees with that given in Appendix A, you can modify the Input Data File for the sample case to make the raypath calculations you want.

The best way to be sure you have input all the required data is to fill out the forms for specifying all the ocean-model and ray parameters, as discussed for the sample case in Chapter 2. Then translate the data from those forms into the format of the Input Data File. We provide blank forms for all models and procedures in Appendix B.

5.2 Input Data Formats

The Input Data File is read by a FORTRAN program and so must conform to precise format specifications. Originally, the Input Data File consisted of a deck of 80-column punched cards, with one input parameter per card, so the data format is still specified in terms of data fields in card-image columns, even though we no longer use cards. Figure 5.1 for the sample case is an example of the proper format.

Looking at Figure 5.1, you will notice that the first part of the file consists of a series of lines that begin with a positive integer. Each of these lines specifies an element of a Data Input Array, W(n). This format goes as far as the line that begins with 506. At the line beginning with -1, the data format changes to accept tabular input data. First, we will explain how to specify data to be read into W(n); then we will explain how to enter data in the tabular format.

5.3 Specifying the W-Array Input

The W-array input format consists of a single 80-column line with four data fields: n, W(n), unit conversion characters, and a description field.

The first three card-image columns contain the first data field in I3 format and specify the index, n, of the array W(n). The value of n must be between 0 and 999, and if there are fewer than three digits, the entry must be right-justified, or else FORTRAN will assume that trailing zeroes are appended to fill out the three columns. If two or more lines begin with the same value of n, the last one prevails.

The second field, columns 4-17, contains the value of W(n) in E14.7 format. The value can be entered in either E or F format, but if the E format is used, the exponent must be right-justified within the 14 spaces, or else zeroes will be appended.

The third field, columns 18-24, contains characters that tell the program to convert the units of the data, as input, to units used by the program. The present choices available for input in this field are given in Table 5.1; the characters must be input in exactly the columnar format shown.

Table 5.1--Units conversion on input

Units of input value*	Meaning	Conversion needed	Value stored by read-in routine
AN RD	Angle in radians	None	V_i
AN DG	Angle in degrees	deg to rad or deg/s to rad/s	$V_i\ \pi/180$**
AN KM	Central earth angle in kilometers	km to rad	V_i/r_e***
LN KM	Length in kilometers	None	V_i
LN M	Length in meters	m to km	$V_i/1000$
LN NM	Length in nautical miles	nmi to km	$1.852\ V_i$
LN FT	Length in feet	ft to km	$3.048006096 \times 10^{-4}\ V_i$
FQ HZ	Frequency in hertz	Hz to rad/s	$2\pi V_i$
FQ S	Frequency expressed as a period in seconds	Period in seconds to frequency in rad/s	$2\pi/V_i$
AM NP	Amplitude in nepers	None	V_i
AM DB	Amplitude in decibels	dB to nepers	$V_i\ \log_c 10/10$
T****	Transmitter height relative to bottom instead of mean sea level	Add bottom height to transmitter height	V_i (also, a flag is set)*****

* The five characters listed are to be put in card-image columns 18 through 22 of the W-array input value to be converted, or put above the data-input column of tabular input. For three-column tabular input, for example, the five characters should be in columns 1-13, 14-26, and 27-39. The five characters are automatically put in the appropriate place when using the WMOD editor.

** V_i is the input value.

*** r_e is the radius of the earth. The current value of W(1) in the W array is used for this conversion.

**** Applies only for input to W(3) (transmitter height). The "T" must be put in card-image column 24.

***** At the start of each ray, the status of the flag is checked. If the flag is set, then the bottom height (negative) at the longitude and latitude of the transmitter is added to the transmitter height. For general bottom models, the bottom height at a given longitude and latitude can only be estimated. For all of the presently available bottom models, the estimate gives an exact result, however, because $\partial g/\partial r$ is constant.

The fourth field (columns 25-80) contains descriptive comments, which aid the user in setting up the table. These comments are optional and arbitrary as far as HARPO is concerned, but for $n \geq 100$ and divisible by 25, the first word in the comment field is read when WMOD is used for editing and must be a valid model name. This convention will be described in a report about the supplementary programs. Where practical, the comments should describe the function of all acceptable values of the parameter, not just the present value, so that the comment would not have to be changed when the parameter is changed. We have included nonzero initial values in the comment field, where applicable. To make it easier to see the model groupings, we have adopted the convention of indenting the comments that describe model parameters.

5.3.1 Initialization of the Input Data Parameters

Before reading the Input Data File, the program initializes all of the input parameters, W(n). Most are set to zero, but a few are given nonzero initial values that correspond to common usage. An example is the latitude of the north pole of the computational coordinate system, W(24), which usually has a value of $\pi/2$. Section 5.3.2 denotes those nonzero initial values by parentheses. These initial values can be overridden by the Input Data File (including a value of zero), but if no value is specified for a W(n) in the Input Data File, then its initial value prevails.

In addition, some initial values are given "zero-override" priority, which means that W(n) assumes its nonzero initial value if no value is input, <u>but also if a zero is input</u>. This zero override operates when a zero value would produce meaningless results or cause difficulty in program execution. An example is the plot expansion factor, W(82). Fig. 5.1 and Sec. 5.3.2 denotes by square brackets the nonzero initial values that override zero.

To help the user keep track of the unit conversions and initializations, all nonzero W(n) values, in the units actually used by HARPO, are listed at the beginning of the printout (Appendix A). In the examples given above, if W(24) were given a value of zero in the Input Data File, no value would be printed for W(24), indicating that HARPO will use W(24) = 0. On the other hand, if W(82) is given a zero value in the Input Data File, a message is printed indicating "INPUT OVERRIDDEN," and the nonzero override value is printed.

5.3.2 Explanation of the Input Data Parameters

Because HARPO has evolved from ray-tracing programs for other media, some values of the input parameter index, n, are not used in HARPO, but may be used in other versions of the program. As far as possible, n is assigned consistently among the different versions, and blocks of n are assigned to groups of related parameters.

Following is a list of all the input parameters used by HARPO, with a description of their meanings and idiosyncrasies. Those with nonzero initial values need not be entered in the Input Data File, if the value is what you want. If no initial value is indicated, a zero will be assigned if you leave it out of the Input Data File. The default units given in parentheses are those which are assumed if no unit conversions are put into columns 18-24. Also included in the table is the FORTRAN name (where one exists) assigned (in EQUIVALENCE statements) to each variable in the program. Those labeled "not used" can be assigned to additional input parameters, but those labeled "used by other programs" or "used internally" should not be used.

W(1) EARTHR (6370.) -- Radius (kilometers) of the earth, r_e, to mean sea level (MSL). Can be set to a very large value for a "flat-earth" approximation.

W(2) RAY -- Used by other programs.

W(3) XMTRH -- Height (kilometers) of the transmitter (source) above mean sea level. Depth values are negative. If there is a T in column 24, it is the height above the ocean bottom.

W(4) TLAT -- North geographic latitude (radians) of the transmitter. Can be entered in kilometers (or degrees) by putting AN KM (or AN DG) beginning in column 18.

W(5) TLON -- East geographic longitude (radians) of the transmitter. Can be entered in kilometers (or degrees) by putting AN KM (or AN DG) beginning in column 18.

W(6) OW -- Used internally.

W(7) FBEG -- Initial acoustic wave frequency (rad/s). Can be entered in Hz (or period in seconds) by putting FQ HZ (or FQ S) beginning in column 18.

W(8) FEND -- Final frequency (rad/s). Can be entered in Hz (or period in seconds) by putting FQ HZ (or FQ S) beginning in column 18.

W(9) FSTEP -- Step in frequency (rad/s). Can be entered in Hz (or period in seconds) by putting FQ HZ (or FQ S) beginning in col 18. Set = 0 for no stepping.

W(10) AZ1 -- Used internally.

W(11) AZBEG -- Initial azimuth angle (radians east of north) of transmission. Can be entered in degrees by putting AN DG beginning in column 18.

W(12) AZEND -- Final azimuth angle (radians east of north) of transmission. Can be entered in degrees by putting AN DG beginning in column 18.

W(13) AZSTEP -- Step in azimuth angle (radians east of north) of transmission. Can be entered in degrees by putting AN DG beginning in column 18. Set = 0 for no stepping.

W(14) BETA -- Used internally.

W(15) ELBEG -- Initial elevation angle (radians above horizontal) of transmission. Can be entered in degrees by putting AN DG beginning in column 18.

W(16) ELEND -- Final elevation angle (radians above horizontal) of transmission. Can be entered in degrees by putting AN DG beginning in column 18.

W(17) ELSTEP -- Step in elevation angle (radians) of transmission. Can be entered in degrees by putting AN DG beginning in column 18. Set = 0 for no stepping.

W(18) -- Used internally.

W(19) -- Set = 1 to stop a ray when it strikes the ocean bottom, printing BOTM ABS.

W(20) RCVRH -- Height (kilometers) above sea level of the receiver surface when model RHORIZ is used; height of the receiver surface above the bottom when model RTERR is used.

W(21) ONLY -- Set = 1 to stop elevation-angle stepping when ray goes out of bounds.

W(22) HOP -- Maximum number of ray hops (intersections with or closest approaches to the receiver surface); ray calculation stops when reached, printing MAX HOPS. Closest approaches count as two hops.

W(23) MAXSTP (1000.) -- Maximum number of integration steps per hop; ray calculation stops when reached, printing STEP MAX.

W(24) PLAT ($\pi/2$) -- Geographic latitude (radians) of the north pole of the computational coordinate system.

W(25) PLON -- Geographic longitude (radians) of the north pole of the computational coordinate system.

W(26) HMAX (500.) -- Maximum ray height (kilometers) above MSL; ray calculation stops if exceeded, printing MAX HT.

W(27) HMIN -- Minimum ray height (kilometers) above MSL; calculation stops if ray goes below this height, printing MIN HT.

W(28) RGMAX -- Maximum ground range (kilometers at MSL) of the ray from the transmitter; ray calculation stops if exceeded, printing MAX RANG.

W(29) RAYFNC -- A seven-digit number used to select execution of HARPO and supplementary programs. To run HARPO, use 100. Setting = 0 is the same as all ones and will run HARPO.

W(30)-W(32) -- Used by other programs.

W(33) EXTINC (999.999) -- Maximum absorption (dB); ray calculation stops if value exceeded, printing EXTINC. Set = 0 for no maximum.

W(34)-W(40) -- Not used.

W(41) INTYP (3.) -- Integration type --
= 1 for Runge-Kutta integration without error checking;
= 2 for Adams-Moulton integration without error checking;
= 3 for Adams-Moulton integration with relative-error checking;
= 4 for Adams-Moulton integration with absolute-error checking.

W(42) MAXERR (1.E-4) -- Maximum allowable integration error per step. RKAM routine decreases step size to achieve this error.

W(43) ERATIO (50.) [50.] -- Ratio of maximum to minimum single-step integration error; RKAM increases step size when error is smaller than W(42) by this factor.

W(44) STEP1 (1.0) -- Initial integration step size (seconds).

W(45) STPMAX (100.) -- Maximum integration step size (seconds).

W(46) STPMIN (1.E-8) -- Minimum integration step size (seconds).

W(47) FACTR (.5) [0.5] -- Factor multiplying integration step size when decreasing step size.

W(48)-W(56) Not used.

W(57) -- Phase-time integration: 0 to not integrate; 1 to integrate; 2 to integrate and print.

W(58) -- Absorption integration: 0 to not integrate; 1 to integrate; 2 to integrate and print.

W(59) -- Doppler shift integration: 0 to not integrate; 1 to integrate; 2 to integrate and print.

W(60) -- Path-length integration: 0 to not integrate; 1 to integrate; 2 to integrate and print.

W(61)-W(70) -- Assigned to future integration options.

W(71) SKIP -- [1.E31] Number of integration steps between printed lines. Set = 1 to print every step; = 0 to suppress periodic printing.

W(72) RAYSET -- Write machine-readable raysets to file PUNCH: 1 = yes; 0 = no.

W(73) PCNTRW -- Add diagnostic printout lines: 1 = yes; 0 = no.

W(74) PRTSRP -- Produce normal printout every W(71) steps: 0 = yes; 1 = no. Also produces printout at special events.

W(75) HITLET [.15] -- Height (inches on our plotter) of lettering on graphs. "FULANN" in description field activates publication-quality lettering on graphs when read by WMOD. Any other comment in description field produces draft-quality lettering.

W(76) BINRAY -- Write binary raypath description to file TAPE6: 1 = yes; 0 = no.

W(77) PAGLIN (66.) -- Page length (lines) for printout.

W(78)-W(79) Not used.

W(80) APOG, PRIGEE - 0 for normal rayplots; 1 for apogee plots.

W(81) PLT -- Rayplot projection:
1 = vertical plane, polar projection, rectangular expansion;
2 = horizontal plane, lateral expansion;
3 = vertical plane, polar plot, radial expansion;
4 = vertical plane, rectangular plot.
Make W(81) negative to superimpose plot on that from previous runset.

W(82) PFACTW [1.] -- Vertical or lateral expansion factor for rayplot.

W(83) LLAT -- North latitude (radians) of left edge of plot. To enter in degrees (kilometers) put AN DG (AN KM) beginning in column 18.

W(84) LLON -- East longitude (radians) of left edge of plot. To enter in degrees (kilometers) put AN DG (AN KM) beginning in column 18.

W(85) RLAT -- North latitude (radians) of right edge of plot. To enter in degrees (kilometers) put AN DG (AN KM) beginning in column 18.

W(86) RLON -- East longitude (radians) of right edge of plot. To enter in degrees (kilometers) put AN DG (AN KM) beginning in column 18.

W(87) TIC -- Distance (radians) between tick marks on horizontal axis of plot. To enter in kilometers, put AN KM beginning in column 18.

W(88) HB -- Height (kilometers) of the bottom of the graph above MSL.

W(89) HT -- Height (kilometers) of the top of the graph above MSL.

W(90)-W(95) -- Used by other programs.

W(96) TICV -- Distance (kilometers) between tick marks on vertical axis of plot. Notice that the default units are kilometers for the vertical ticks and radians for the horizontal ticks.

W(97)-W(99) -- Used by other programs.

W(100) UMODEL -- Check number for background current model.

W(101) UFORM -- format code for background current model.

W(102) UID -- Data-set ID for background current model.

W(103)-W(124) Parameters for background current model.

W(125) DUMODEL -- Check number for perturbation current model.

W(126) DUFORM -- Format code for perturbation current model.

W(127) DUID -- Data-set perturbation current model.

W(128)-W(149) -- Parameters for perturbation model.

W(150) CMODEL -- Check number for background sound speed model.

W(151) CFORM -- Format code for background sound speed model.

W(152) CID -- Data-set ID for background sound speed model.

W(153)-W(174) -- Parameters for background sound speed model.

W(175) DCMODEL -- Check number for perturbation sound speed model.

W(176) DCFORM -- Format code for perturbation sound speed model.

W(177) DCID -- Data-set for perturbation sound speed model.

W(178)-W(199) -- Parameters for perturbation sound speed model.

W(275) RMODEL -- Check number for receiver surface model.

W(276) RFORM -- Format code for receiver surface model.

W(277) RID -- Data-set ID for receiver surface model.

W(278)-W(299) -- Parameters for receiver surface model.

W(300) GMODEL -- Check number for background bottom model.

W(301) GFORM -- Format code for background bottom model.

W(302) GID -- Data-set ID for background bottom model.

W(303)-W(324) -- Parameters for background bottom model.

W(325) DGMODEL -- Check number for perturbation bottom model.

W(326) DGFORM -- Format code for perturbation bottom model.

W(327) DGID -- Data-set ID for perturbation bottom model.

W(328)-W(349) -- Parameters for perturbation bottom model.

W(350) SMODEL -- Check number for background ocean surface model.

W(351) SFORM -- Format code for background ocean surface model.

W(352) SID -- Data-set ID for background ocean surface model.

W(353)-W(374) -- Parameters for background ocean surface model.

W(375) -- Check number for ocean-surface perturbation model.

W(376) -- Format code for ocean-surface perturbation model.

W(377) -- Data-set ID for ocean-surface perturbation model.

W(378)-(399) -- Parameters for ocean-surface perturbation model.

W(400)-W(500) -- Parameters for supplementary programs.

W(500) AMODEL -- Check number for absorption model.

W(501) AFORM -- Format code for absorption model.

W(502) AID -- Data-set ID for absorption model.

W(503)-W(524) -- Parameters for absorption model.

W(525) DAMODEL -- Check number for perturbation absorption model.

W(526) DAFORM -- Format code for perturbation absorption model.

W(527) DAID -- Data-set ID for perturbation absorption model.

W(528)-W(549) -- Parameters for perturbation absorption model.

5.4 Specifying Tabular Input

In addition to providing values to the W(n) array, the Input Data File lets you enter tabular data to be used by ocean model subroutines. In the following discussion, refer to the Input Data File for the sample case (Fig. 5.1) for examples of tabular data.

5.4.1 Changing to the Tabular Format

When the sign of the W-array index n is read (in columns 1-3), it is checked for a valid negative value, which signals a change in the format of the data to follow. Any valid negative value selects a corresponding "input common block" that has been dedicated to a particular model subroutine. Table 5.2 shows which values select which common blocks. The line in Figure 5.1 that begins with -1 and has the comment "ENTER DATA SUBSET FOR BACKGROUND CURRENT MODEL" is an example selecting common block /B1/ to receive data. Because this line must conform to the W-array format, comments must begin after column 24.

5.4.2 The Format Line

The line following the negative value of n begins with an integer that specifies the format of the data to follow. The formats are numbered according to the method shown in Table 5.3.

Format A is alphanumeric and lets you enter descriptive comments on the rest of the line that begins with the format number. That comment is reproduced at the beginning of the program printout. The comments in Figure 5.1 that follow an A in col. 3 are examples of brief model descriptions and correspond to those enetered on the forms specifying ocean models.

Formats 1 through 6 specify 1 to 6 columns, respectively, of floating-point data. If format 1 through 6 is selected, then columns 4-13 of the format line must contain an end-of-data terminator, such as 999.0 in the sample case. The rest of the format line should be blank.

Table 5.2--Description of the identifying numbers in the first three columns of the Input Data File

Code number	Prefix for common-block variables*	Description
1-999		Input to elements 1-999 of the W array as described in Table 4.4 and Section 5.3.2
-1	U	Signals start of tabular input to common block /B1/ (current velocity) (see Table 4.2)
-2	DU	Signals start of tabular input to common block /B2/ (perturbation current velocity)
-3	C	Signals start of tabular input to common block /B3/ (sound speed)
-4	DC	Signals start of tabular input to common block /B4/ (perturbation sound speed)
-8	R	Signals start of tabular input to common block /B8/ (receiver surface)
-9	G	Signals start of tabular input to common block /B9/ (bottom)
-10	DG	Signals start of tabular input to common block /B10/ (bottom perturbation)
-11	S	Signals start of tabular data input to common block /B11/ (ocean surface)
-12	DS	Signals start of tabular data input to common block /B12/ (ocean-surface perturbation)
-17	V	Signals start of tabular input to common block /B17/ (absorption)
-18	DV	Signals start of tabular input to common block /B18/ (absorption perturbation)
0		Signals end of tabular input to one of the above common blocks, or if that is not appropriate, end of the input data

* See Table 4.5.

Table 5.3--Tabular input data formats available*

Format number	Purpose of format	Number of data lines used	Line number	Format	Card columns	Data read
0	signify end of tabular input	1	1(return line)	I3	1 -3	format number (=0)
A	enter comments that describe the ocean model	1	1	A	1 -3	format number (=A)
					4 -80	descriptive comments
1-6	enter 1-6 column tabular data	variable	1	I3	1 -3	format number
				G13.6	4 -16	terminator
			2(units line)	A	1 -13	units conversion for first data column
				A	14-26	units conversion for second data column
				A	27-39	units conversion for third data column
				A	40-52	units conversion for fourth data column
				A	53-65	units conversion for fifth data column
				A	60-78	units conversion for sixth data column
			3-(data lines)	BZ,10G13.6	1 -78	up to 6 columns of data
			last	BZ,10G13.6	1 -78	terminator (in data column after the last data column, but not in a data column larger than the format number)

*Table 4.5 explains how the data is stored in a common block such as /B3/. The descriptive comments are stored in elements 32-41 of the common block. The number of tabular data elements read is stored in element 42 of the common block. The first data column is stored beginning in element 43 of the common block. The second data column is stored beginning in element number (= 43 + maximum allowed number of rows of tabular data) in the common block. The maximum number of rows of tabular data is set by the model subroutine (see Table 4.5).

5.4.3 The Units Line

Following the format line is a line containing unit-conversion specifications for the columnar data to follow. The conversion specifications follow the conventions described in Table 5.1. The 5 characters can be placed anywhere in the same 13-character columns as the tabular data to be converted, as long as at least one space separates adjacent conversion specifications.

5.4.4 The Data Lines

Any number of data lines can follow the format line. They must contain numeric data in the format specified in the format line (Table 5.3) and must be terminated with the number given in the format line as specifying end-of-data. Data values are read until the terminator is encountered. The data following the "EL NINO BACKGROUND SOUND-SPEED PROFILE" comment in Figure 5.1 is an example of 3-column data entry (format 3) into the common block /B3/, which contains data used by sound-speed model CTANH. If the number of data values read in exceeds the maximum allocated in the model subroutine, an error will occur, and the program will stop.

5.4.5 The Return Line

After the end-of-data number signifies the end of tabular input, you will usually enter a line beginning with a 0 in column 3 to return to the W-array data format.

PART III: HOW THE PROGRAM WORKS

6. The Ray-Tracing Equations

6.1 Hamilton's Equations in Spherical Polar Coordinates

HARPO calculates raypaths by numerically integrating Hamilton's equations. Lighthill (1965, 1978) gives Hamilton's equations in four dimensions (three spatial and one temporal) for Cartesian coordinates. Haselgrove (1954) gives Hamilton's equations in three dimensions for spherical polar coordinates, a more useful coordinate system for geophysical media. Combining the two gives Hamilton's equations in four dimensions in which the three spatial coordinates are earth-centered spherical polar (see Table 6.1 for a definition of the symbols):

$$\frac{dr}{d\tau} = \frac{\partial H}{\partial k_r} , \tag{6.1}$$

$$\frac{d\theta}{d\tau} = \frac{1}{r} \frac{\partial H}{\partial k_\theta} , \tag{6.2}$$

$$\frac{d\phi}{d\tau} = \frac{1}{r \sin\theta} \frac{\partial H}{\partial k_\phi} , \tag{6.3}$$

$$\frac{dt}{d\tau} = - \frac{\partial H}{\partial \omega} , \tag{6.4}$$

$$\frac{dk_r}{d\tau} = - \frac{\partial H}{\partial r} + k_\theta \frac{d\theta}{d\tau} + k_\phi \sin\theta \frac{d\phi}{d\tau} , \tag{6.5}$$

$$\frac{dk_\theta}{d\tau} = \frac{1}{r} \left(- \frac{\partial H}{\partial \theta} - k_\theta \frac{dr}{d\tau} + k_\phi r \cos\theta \frac{d\phi}{d\tau} \right) , \tag{6.6}$$

$$\frac{dk_\phi}{d\tau} = \frac{1}{r \sin\theta} \left(- \frac{\partial H}{\partial \phi} - k_\phi \sin\theta \frac{dr}{d\tau} - k_\phi r \cos\theta \frac{d\theta}{d\tau} \right) , \tag{6.7}$$

$$\frac{d\omega}{d\tau} = \frac{\partial H}{\partial t} . \tag{6.8}$$

The variables r, θ, ϕ are the (Earth-centered) spherical polar coordinates of a point on the raypath; k_r, k_θ, and k_ϕ are the local Cartesian components of the propagation vector (a vector whose magnitude,

Table 6.1--The more important symbols and their definitions

A	In Section 6.1.2, absorption in dB
C	Sound speed
C_{ref}	A reference sound speed
f	Wave frequency (in Hz)
Δf	Frequency shift of a wave due to a time-varying medium
H	Hamiltonian
k_r, k_θ, k_ϕ	Components of the propagation vector in the r, θ, ϕ directions--a vector normal to the wave front having a magnitude $2\pi/\lambda = \omega/v$
k_{disp}	Complex wave number determined by the dispersion relation
P	Phase path length, phase of the wave divided by the reference wave number ($2\pi/\lambda_o = \omega/C_{ref}$)
P'	Group path length $= C_{ref}t$
r, θ, ϕ	Spherical polar coordinates of a raypath point
s	Geometric raypath length
t	Time of travel of a wave packet (in some cases, used to express the time dependence of the propagation medium)
V	Current velocity
V_r, V_θ, V_ϕ	Components of the current velocity in the r, θ, ϕ direction
v	Wave phase velocity
θ	Colatitude in spherical polar coordinates
λ	Wavelength
$\lambda_o = (2\pi/\omega)C_{ref}$	Reference wavelength
τ	Independent variable in Hamilton's equations (no physical significance)
ϕ	Longitude in spherical polar coordinates
Ω	$= \omega - \vec{k}\cdot\vec{V}$, the intrinsic wave frequency, the wave frequency as seen by an observer moving with the medium
$\omega = 2\pi f$	Radian wave frequency
$\Delta\omega = 2\pi\Delta f$	Radian frequency shift

$$k = \sqrt{k_r^2 + k_\theta^2 + k_\phi^2} = 2\pi/\lambda \quad , \tag{6.9}$$

is the wave number, and that points in the wave normal direction) in the r, θ, and ϕ directions; t is time--in (6.4) it is the propagation time of a wave packet; in (6.8) it expresses the variation with time of a time-varying medium; τ is a parameter whose value depends on the choice of the Hamiltonian H. Section 6.4 explains how the Hamiltonian is defined.

For actual calculation, HARPO uses group path $P' = C_{ref}\, t$ (where C_{ref} is a standard reference speed) as the independent variable because the derivatives with respect to P' are independent of the choice of Hamiltonian, allowing the program to switch Hamiltonians in the middle of a path. This choice automatically causes the program to take smaller steps in real path length where the calculations are more critical, as when refractive index varies rapidly. These equations are obtained by dividing (6.1) through (6.8) by C_{ref} times (6.4):

$$\frac{dr}{dP'} = -\frac{1}{C_{ref}} \frac{\partial H/\partial k_r}{\partial H/\partial \omega} , \tag{6.10}$$

$$\frac{d\theta}{dP'} = -\frac{1}{rC_{ref}} \frac{\partial H/\partial k_\theta}{\partial H/\partial \omega} , \tag{6.11}$$

$$\frac{d\phi}{dP'} = -\frac{1}{rC_{ref} \sin\theta} \frac{\partial H/\partial k_\phi}{\partial H/\partial \omega} , \tag{6.12}$$

$$\frac{dk_r}{dP'} = \frac{1}{C_{ref}} \frac{\partial H/\partial r}{\partial H/\partial \omega} + k_\theta \frac{d\theta}{dP'} + k_\phi \sin\theta \frac{d\phi}{dP'} , \tag{6.13}$$

$$\frac{dk_\theta}{dP'} = \frac{1}{r} \left(\frac{1}{C_{ref}} \frac{\partial H/\partial \theta}{\partial H/\partial \omega} - k_\theta \frac{dr}{dP'} + k_\phi\, r \cos\theta \frac{d\phi}{dP'}\right) , \tag{6.14}$$

$$\frac{dk_\phi}{dP'} = \frac{1}{r \sin\theta} \left(\frac{1}{C_{ref}} \frac{\partial H/\partial \phi}{\partial H/\partial \omega} - k_\phi \sin\theta \frac{dr}{kP'} - k_\phi\, r \cos\theta \frac{d\theta}{dP'}\right) , \tag{6.15}$$

$$\frac{d(\Delta f)}{dP'} = \frac{1}{2\pi} \frac{d\Delta\omega}{dP'} = \frac{1}{2\pi} \frac{d\omega}{dP'} = -\frac{1}{2\pi} \frac{\partial H/\partial t}{\partial H/\partial \omega} . \tag{6.16}$$

Equation (6.16) for the frequency shift of a wave propagating through a time-varying medium follows directly from Hamilton's equations (6.4) and (6.8). An alternative derivation is given by Bennett (1967). Large frequency shifts should be accumulated along the raypath and the shifted frequency used in calculations at each point on the raypath. Equations (6.1) through (6.8) imply that all eight dependent variables vary along the path, and that at each point on the path the instantaneous value of all parameters (including frequency) is used in further evaluations of the equations. However, the time variation of the ocean due to natural causes is so slow that the resulting frequency shifts have negligible effect on the propagation. For this reason, HARPO calculates frequency shift to compare with frequency-shift measurements, but does not adjust the frequency of the wave used in the propagation calculations.

The first six differential equations, (6.10) through (6.15), are always integrated. By setting W(59), the user can choose whether to have the program integrate (6.16) to calculate the frequency shift.

6.1.1 Phase Path

Three other quantities can be calculated by integration along the raypath. The phase path P (phase divided by the reference wave number $2\pi/\lambda_o = \omega/C_{ref}$) is calculated by integrating

$$\frac{dP}{dP'} = \frac{C_{ref}}{\omega}\left(k_r \frac{dr}{dP'} + k_\theta \, r \frac{d\theta}{dP'} + k_\phi \, r \sin\theta \frac{d\phi}{dP'}\right)$$

$$= -\frac{1}{\omega} \frac{k_r \frac{\partial H}{\partial k_r} + k_\theta \frac{\partial H}{\partial k_\theta} + k_\phi \frac{\partial H}{\partial k_\phi}}{\partial H/\partial \omega} \quad . \qquad (6.17)$$

6.1.2 Absorption

If the absorption per wavelength is small (as it must be for this type of ray tracing to be valid), then an approximate formula can be integrated to give the absorption in decibels:

$$\frac{dA}{dP'} = - \frac{10}{\log_e 10} \frac{\omega}{C_{ref}} \frac{\text{imag } (k^2_{disp})}{k_r^2 + k_\theta^2 + k_\phi^2} \frac{dP}{dP'}$$

$$= \frac{10}{\log_e 10} \frac{\text{imag } (k^2_{disp})}{k_r^2 + k_\theta^2 + k_\phi^2} \frac{k_r \frac{\partial H}{\partial k_r} + k_\theta \frac{\partial H}{\partial k_\theta} + k_\phi \frac{\partial H}{\partial k_\phi}}{C_{ref} \; \partial H/\partial \omega} , \qquad (6.18)$$

where k_{disp} is the (complex) wave number determined by the dispersion relation.

There are two ways to calculate the imaginary part of K^2_{disp} to give the absorption in (6.18). Whenever possible, one calculates K^2_{disp} from a complex dispersion relation such as the Appleton-Hartree formula for radio waves in the ionosphere or from the Navier-Stokes equations for acoustic-gravity waves in the atmosphere. When that is not possible, one uses

$$K^2_{imag} = - \alpha \sqrt{K^2_{real}} , \qquad (6.19)$$

where α is an absorption coefficient in nepers per kilometer, derived either from a theoretical or empirical model or from measurements.

6.1.3 Path Length

The geometrical path length of the ray can be calculated by integrating

$$\frac{ds}{dP'} = \sqrt{\left(\frac{dr}{dP'}\right)^2 + r^2 \left(\frac{d\theta}{dP'}\right)^2 + r^2 \sin^2\theta \left(\frac{d\phi}{dP'}\right)^2}$$

$$= \frac{\sqrt{\left(\frac{\partial H}{\partial k_r}\right)^2 + \left(\frac{\partial H}{\partial k_\theta}\right)^2 + \left(\frac{\partial H}{\partial k_\phi}\right)^2}}{C_{ref} \left|\partial H/\partial \omega\right|} . \qquad (6.20)$$

The user can choose to integrate and print frequency shift, phase time, absorption, or path length using Equations (6.16), (6.17), (6.18), or (6.20) by setting the appropriate values of W(59), W(57), W(58), W(60), respectively, in the Input Data File (Figures 2.14 and 2.19).

The user can add other differential equations to the program by modifying HAMLTN, the subroutine that evaluates Hamilton's equations.

The Hamiltonian and its derivatives are calculated by one of the versions of dispersion-relation subroutine (with entry point DISPER), which also calculates k_{disp}^2.

6.2 Numerical Integration

Subroutines RKAM and RKAM1 integrate the differential equations numerically using an Adams-Moulton predictor-corrector method with a Runge-Kutta starter. RKAM1 was adapted from a program in the CDC CO-OP library called RKAMSUB, written by G. J. Lastman and dated March 1964. The program executes one integration step by one of four methods the user can specify using W(41). The subroutine is called once for each advance of the independent variable. The flow charts of Figures 6.1 through 6.5 show how the integration routine works.

Usually, RKAM1 is run in mode 3, that is, Adams-Moulton integration with relative-error checking. The user can trade execution time for accuracy by varying the single-step integration error, W(42). RKAM1 will increase or decrease the step length to maintain the specified error. Table 6.2 gives an

Table 6.2--Run time vs. accuracy

Maximum Integration Error, W(42)	Run Time Sec	Range error
10^{-9}	9.9	$<10^{-7}$
10^{-8}	7.1	$<10^{-7}$
10^{-7}	4.5	1×10^{-7}
10^{-6}	3.3	1×10^{-6}
10^{-5}	2.3	6×10^{-6}
10^{-4}	1.7	1.7×10^{-4}
10^{-3}	1.2	5.7×10^{-4}

Note: Data obtained using model OT2; elevation angle = 4.46°; range = 1000 km; computer: CYBER 750.

idea of how the tradeoff works for a single ray calculation using HARPO and a model of the ocean sound channel described by Georges et al. (1986).

The user can vary other parameters, W(43) - W(47), that control the way RKAM1 adjusts its step length and controls errors (see Sec. 5.3.2), but the initial values assigned in the sample case have been found to work best for most cases met in practice. If the scale of the model differs greatly from the sample case, the initial step length, W(44), should be adjusted.

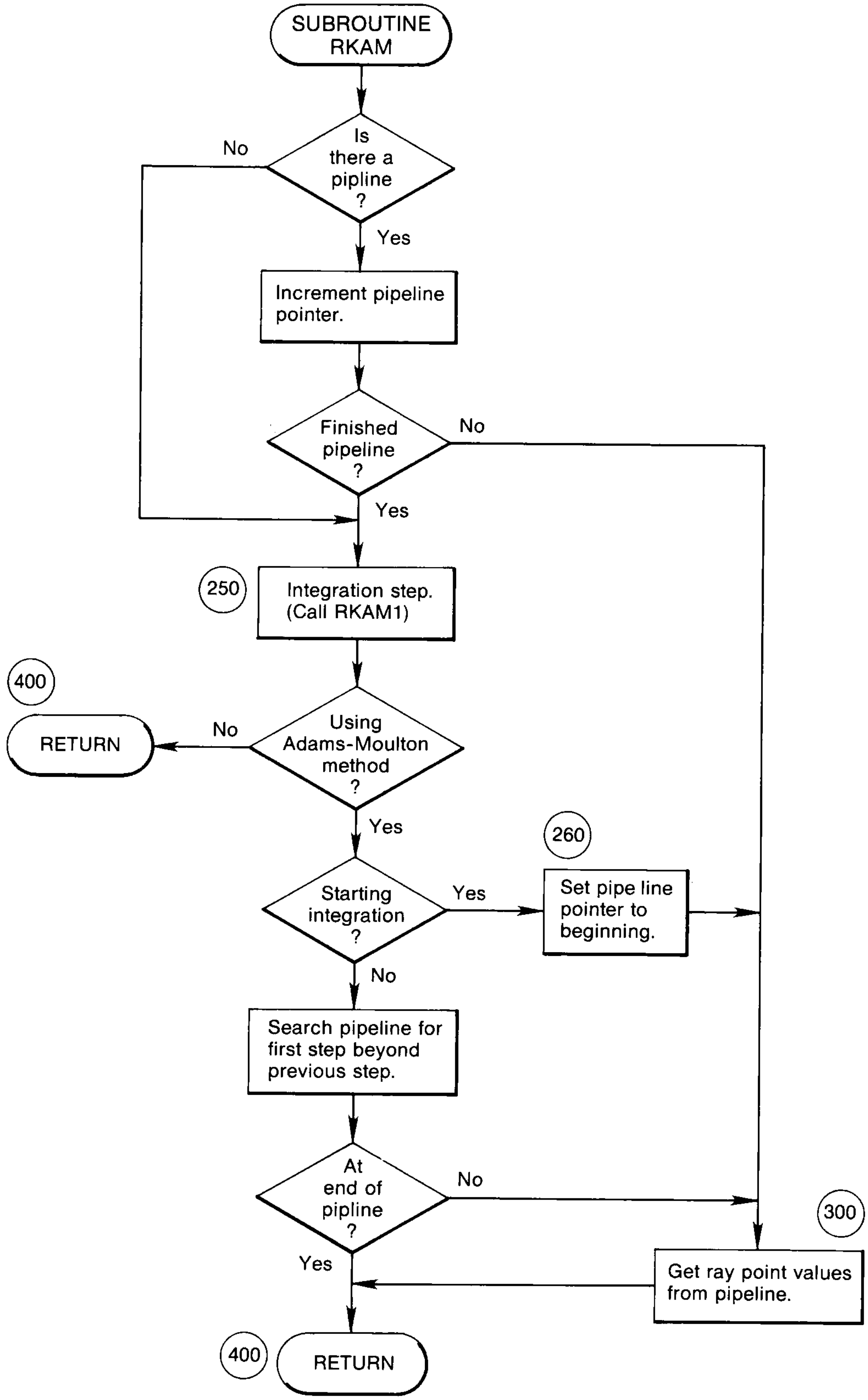


Figure 6.1. Flow chart for subroutine RKAM. The term "pipeline" refers to the sequence of four consecutive integration steps kept by the Adams-Moulton integration method. Circled numbers refer to program statement numbers.

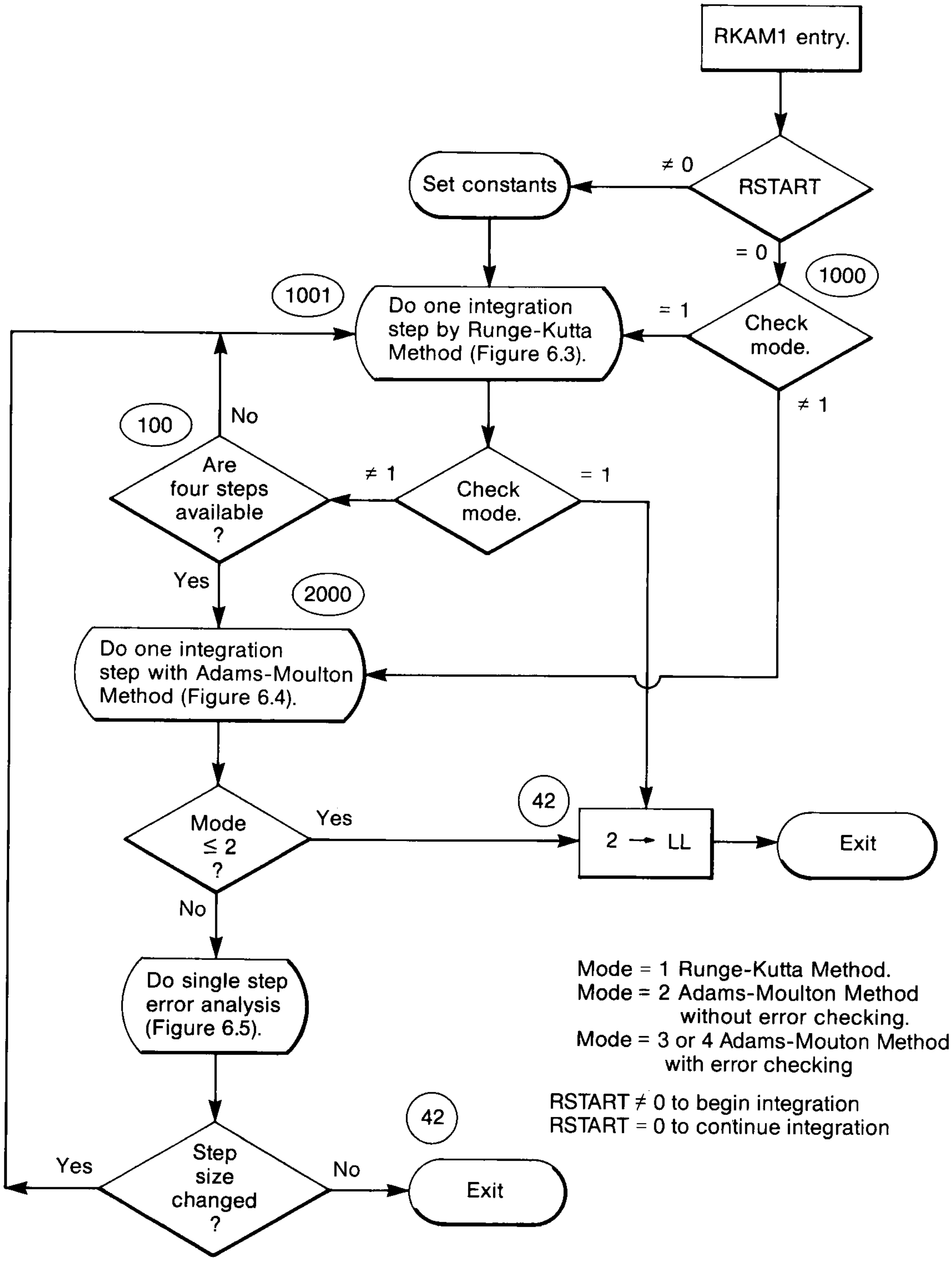


Figure 6.2. Flow chart for subroutine RKAM1. Circled numbers refer to program statement numbers.

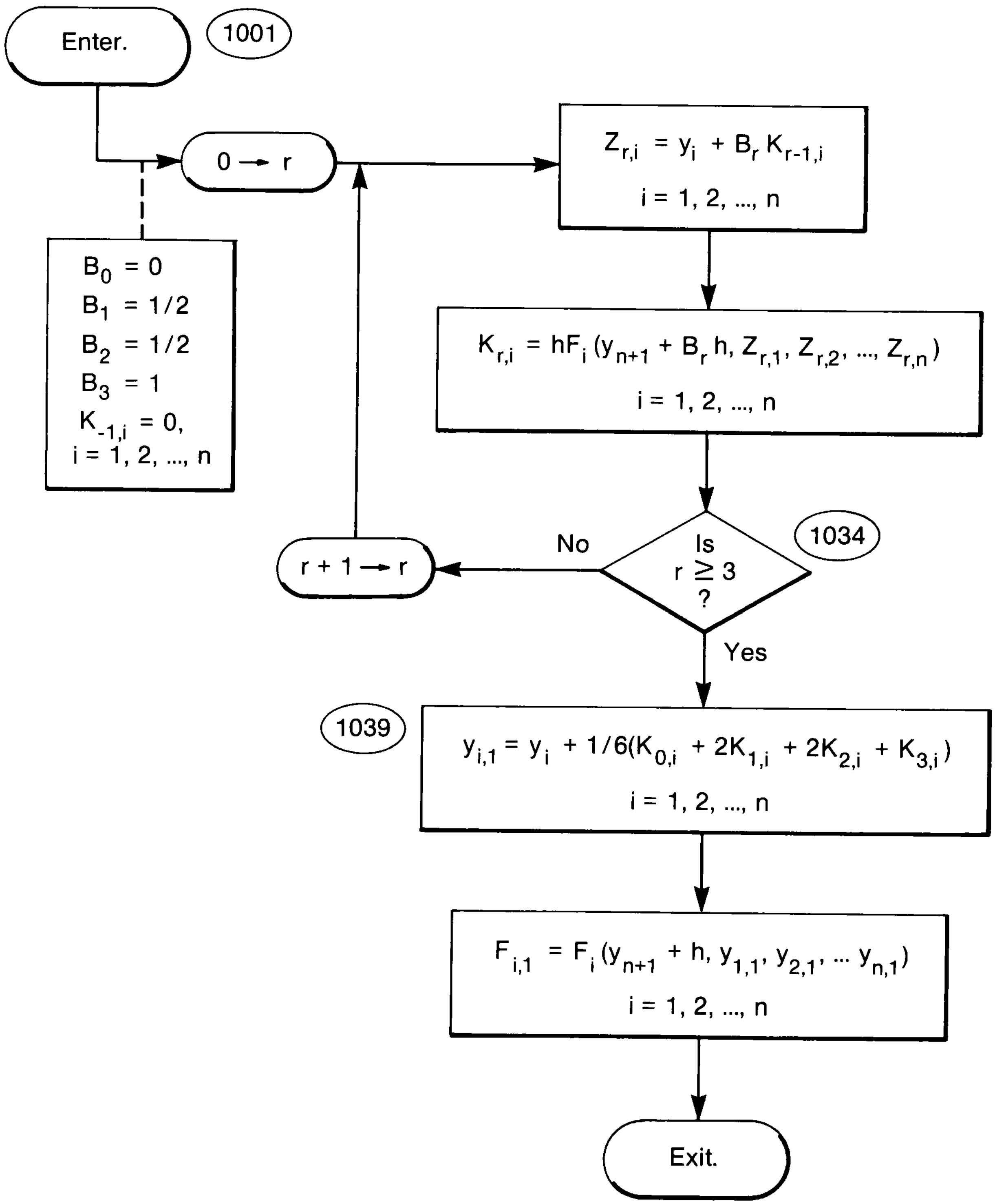


Figure 6.3. Flow chart for the Runge-Kutta procedure. The variables y_1, y_2, ... y_n are the dependent variables, n is the order of the system, and y_{n+1} is the independent variable. Circled numbers refer to program statement numbers. h is the step size. $F_{i,1}$ is the derivative of y_i. $Z_{j,i}$ are 4 estimates of y_i at the beginning, middle, and end of a step. $K_{j,i}$ is Δy_i estimated at $Z_{j,i}$.

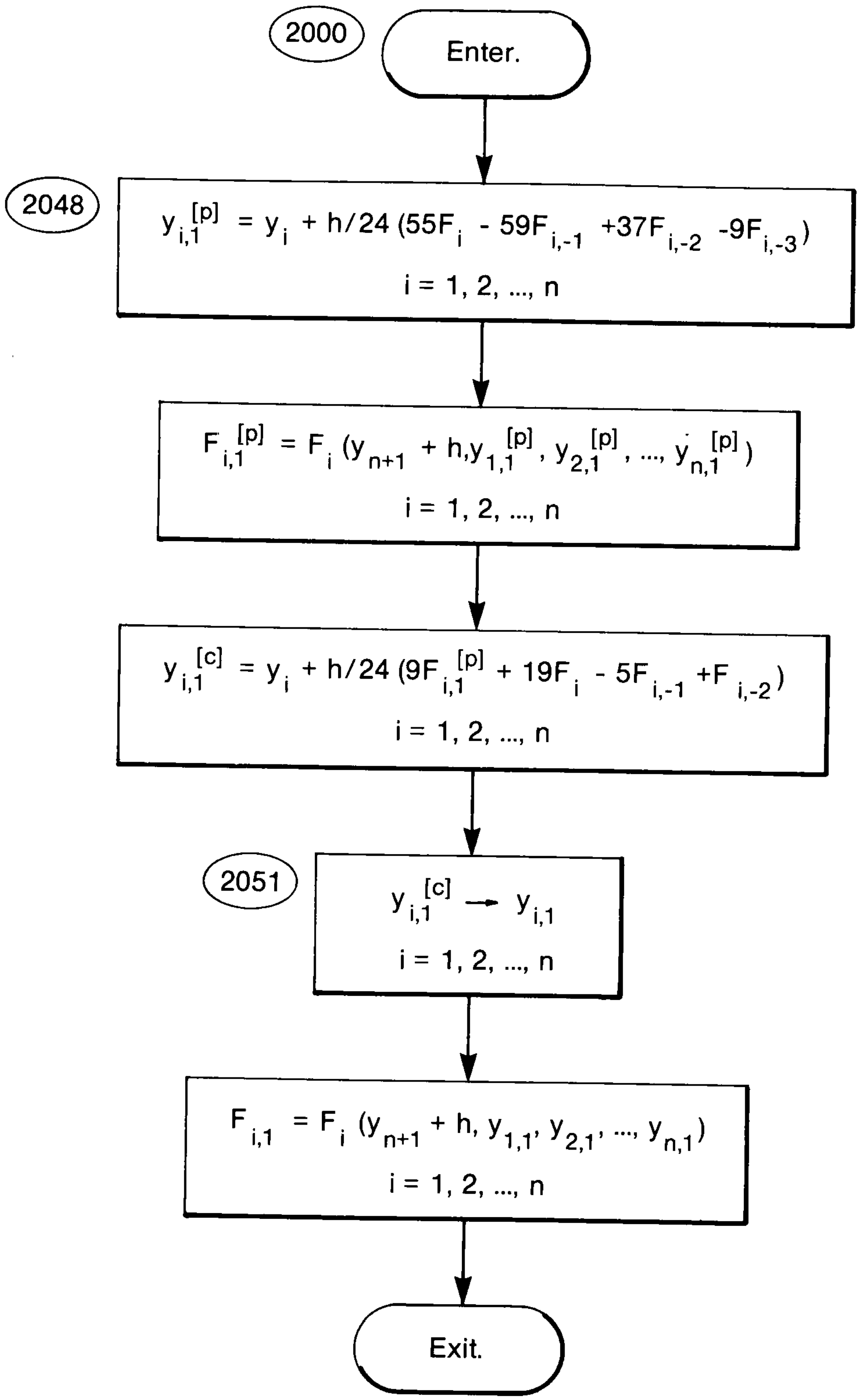


Figure 6.4. Flow chart for the Adams-Moulton integration method. The four starting values needed for this method are supplied by the Runge-Kutta method. Circled numbers refer to program statement numbers. [P] means predicted. [C] means corrected. n is the number of equations being integrated. $y_i \rightarrow y_n$ are the dependent variables. y_{n+1} is the independent variable. h is the step size. $F_{i,j}$ is the derivative of y_i j steps forward.

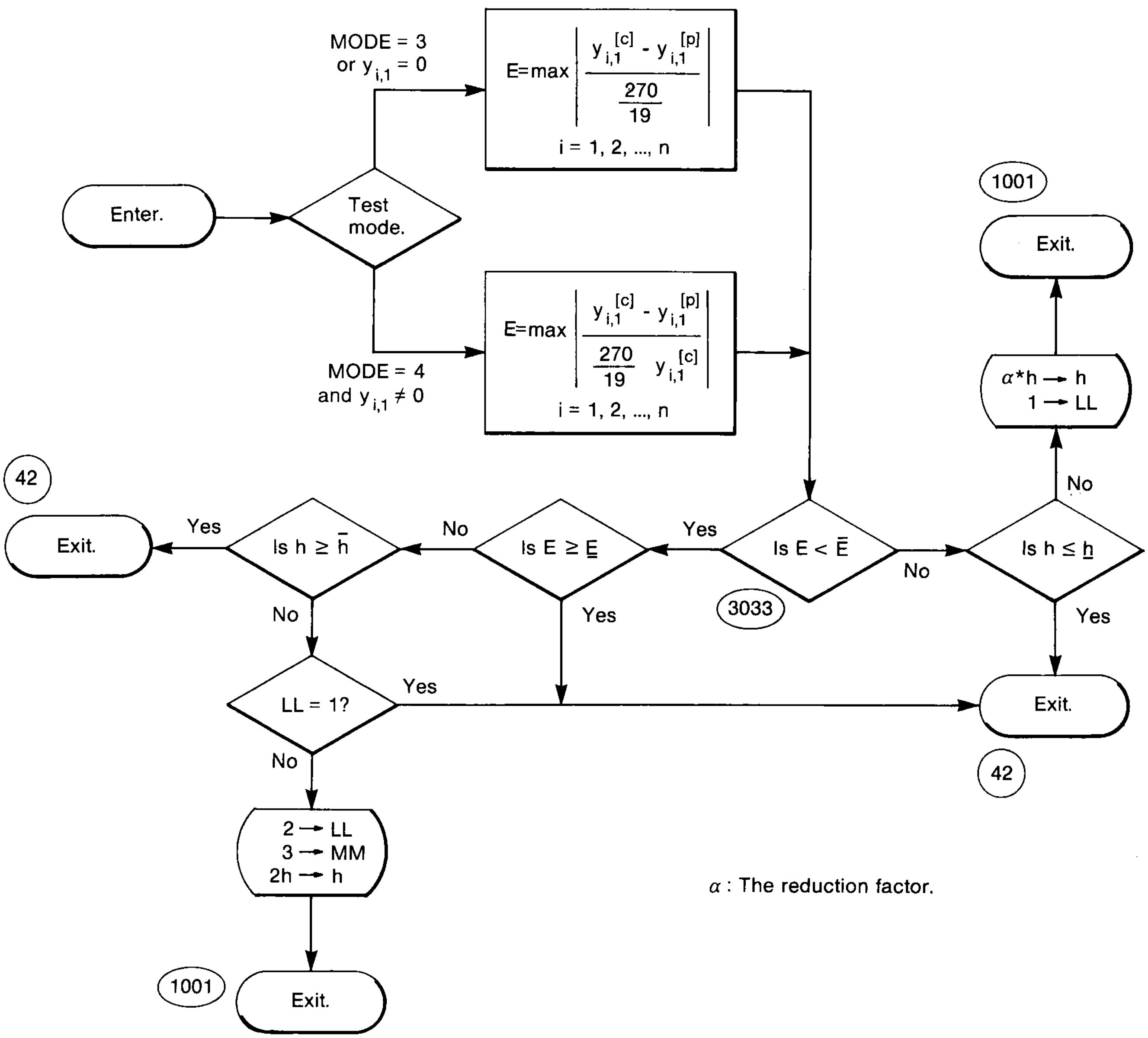


Figure 6.5. Flow chart for the single-step error analysis. The symbol E represents the single-step error, and $\bar{E}$, $\underline{E}$, $\bar{h}$, and $\underline{h}$ represent the maximum and minimum acceptable single-step error and the maximum and minimum mesh size, respectively. Circled numbers refer to program statement numbers.

6.3 The Ocean Sound-Speed Models

Ocean sound-speed models can be specified either directly as $C(r,\theta,\phi,t)$, or they can call models of other ocean variables (such as temperature, salinity and density) upon which sound speed depends. In this version of HARPO, we provide only $C(r,\theta,\phi,t)$ background and perturbation models.

6.4 Ocean Dispersion Relations

HARPO gains versatility without sacrificing speed by having several versions of some of the subroutines. For example, the four versions of the dispersion-relation subroutine allow the user to decide in making up a run module (Sec. 3.3.2) whether to include or ignore currents and absorption. If there are no currents (or absorption) in the calculation, it is much cheaper to leave them out of the equations than it is to make the full calculations with zero current or zero absorption.

The input to the dispersion-relation subroutine is through blank common and common blocks /UU/, /CC/ and /LL/. Output is through common block /RIN/. The dispersion-relation subroutine is called through the entry point DISPER. The subroutine names are used only for user identification.

HARPO has four versions of the dispersion-relation subroutine.

(1) ANCNL - Acoustic waves, No Current, No Losses
(2) AWCNL - Acoustic waves, With Current, No Losses
(3) ANCWL - Acoustic waves, No Current, With Losses
(4) AWCWL - Acoustic Waves, With Current, With Losses

All of these versions calculate a Hamiltonian and its derivatives and the square of the wave number that satisfies the dispersion relation. All of the above variables and some others are in the common block /RIN/ (described in Table 7.17), which has all of the output from the dispersion-relation subroutines.

6.4.1 ANCNL - Acoustic, No Current, No Losses

The dispersion relation for pure acoustic waves is

$$k^2 = k_r^2 + k_\theta^2 + k_\phi^2 = \frac{\omega^2}{C^2} , \tag{6.21}$$

where $C(t,r,\theta,\phi)$ is the speed of sound (provided by one of the sound-speed model subroutines).

At the beginning of the numerical integration, the magnitude of $\vec{k}$ is automatically set by the program so that the dispersion relation (6.21) is satisfied. During the numerical integration, the components of $\vec{k}$ are allowed to vary according to Hamilton's equations. Because of integration errors, there will be slight differences between k^2 and

$$k_{disp}^2 = \frac{\omega^2}{C^2} , \tag{6.22}$$

the value it would have according to the dispersion relation. As a check on the accuracy of the numerical integration and on the consistency of the equations, the quantity

$$\text{ERROR} \equiv \frac{k^2}{k_{disp}^2} - 1 \tag{6.23}$$

is printed at each step of the raypath calculation. It is possible, however, for ERROR to exceed somewhat the maximum allowable single-step integration error (W42) because k does not vary monotonically along the raypath. ERROR serves mainly as a check that the integration is proceeding correctly and that there are no errors in the formulas that compute derivatives in the model subroutines. If ERROR is generally smaller than W(42), then integrated quantities that vary monotonically (like travel time) will be computed with the accuracy given by W(42).

We use the following form of the dispersion relation for the Hamiltonian:

$$H(t,r,\theta,\phi,\omega,k_r,k_\theta,k_\phi) = \omega^2 - (k_r^2 + k_\theta^2 + k_\phi^2)\, C^2(t,r,\theta,\phi) \tag{6.24}$$

The partial derivatives of the Hamiltonian are

$$\frac{\partial H}{\partial t} = - k^2 \frac{\partial C^2}{\partial t} \quad (6.25)$$

$$\frac{\partial H}{\partial r} = - k^2 \frac{\partial C^2}{\partial r} \quad (6.26)$$

$$\frac{\partial}{\partial \theta} = - k^2 \frac{\partial C^2}{\partial \theta} \quad (6.27)$$

$$\frac{\partial H}{\partial \phi} = - k^2 \frac{\partial C^2}{\partial \phi} \quad (6.28)$$

$$\frac{\partial H}{\partial \omega} = 2\omega \quad (6.29)$$

$$\frac{\partial H}{\partial k_r} = - 2 C^2 k_r \quad (6.30)$$

$$\frac{\partial H}{\partial k_\theta} = - 2 C^2 k_\theta \quad (6.31)$$

$$\frac{\partial H}{\partial k_\phi} = - 2 C^2 k_\phi \quad (6.32)$$

$$k \cdot \frac{\partial H}{\partial k} = -2 C^2 k^2 \quad . \quad (6.33)$$

6.4.2 AWCNL - Acoustic, With Current, No Losses

The dispersion relation for pure acoustic waves in terms of the sound speed in the presence of currents is

$$\Omega^2 - C^2 k^2 = 0 \ , \quad (6.34)$$

where

$$k^2 = k_r^2 + k_\theta^2 + k_\phi^2 \quad (6.35)$$

and

$$\Omega = \omega - \vec{k} \cdot \vec{V} = \omega - k_r V_r - k_\theta V_\theta - k_\phi V_\phi \quad (6.36)$$

is the intrinsic frequency of the wave (the frequency seen by an observer moving with the current). $\vec{V}(t,r,\theta,\phi)$ is the current velocity (provided by a current velocity model subroutine).

At the beginning of the numerical integration, the magnitude of k is set by the program so that the dispersion relation (6.34) is satisfied. During the numerical integration, the components of $\vec{k}$ are allowed to vary according to Hamilton's equations. Because of integration errors, there will be slight differences between k^2 and

$$k^2_{disp} = \frac{\omega^2}{\left(C + \frac{\vec{k}\cdot\vec{V}}{k}\right)^2} , \qquad (6.37)$$

the value it would have according to the dispersion relation. Notice that

$$\frac{\vec{k}\cdot\vec{V}}{k} = \frac{k_r V_r + k_\theta V_\theta + k_\phi V_\phi}{\sqrt{k_r^2 + k_\theta^2 + k_\phi^2}} \qquad (6.38)$$

is independent of the magnitude of $\vec{k}$, as it should be.

As a check on the accuracy of the numerical integration and on the consistency of the equations, the quantity in (6.23) is printed at each step of the raypath calculation.

We use the following form of the dispersion relation for the Hamiltonian:

$$H(t,r,\theta,\phi,\omega,k_r,k_\theta,k_\phi) =$$
$$\Omega^2(t,r,\theta,\phi,\omega,k_r,k_\theta,k_\phi) - (k_r^2+k_\theta^2+k_\phi^2)\ C^2(t,r,\theta,\phi), \qquad (6.39)$$

where the intrinsic frequency Ω is given by (6.36)

The partial derivatives of the Hamiltonian are as follows.

$$\frac{\partial H}{\partial t} = 2\Omega\,\frac{\partial \Omega}{\partial t} - k^2\,\frac{\partial C^2}{\partial t} \qquad (6.40)$$

$$\frac{\partial H}{\partial r} = 2\Omega\,\frac{\partial \Omega}{\partial r} - k^2\,\frac{\partial C^2}{\partial r} \qquad (6.41)$$

$$\frac{\partial H}{\partial \theta} = 2\Omega\,\frac{\partial \Omega}{\partial \theta} - k^2\,\frac{\partial C^2}{\partial \theta} \qquad (6.42)$$

$$\frac{\partial H}{\partial \phi} = 2\Omega\,\frac{\partial \Omega}{\partial \phi} - k^2\,\frac{\partial C^2}{\partial \phi} \qquad (6.43)$$

$$\frac{\partial H}{\partial \omega} = 2\Omega \qquad (6.44)$$

$$\frac{\partial H}{\partial k_r} = -2(\Omega V_r + C^2 k_r) \tag{6.45}$$

$$\frac{\partial H}{\partial k_\theta} = -2(\Omega V_\theta + C^2 k_\theta) \tag{6.46}$$

$$\frac{\partial H}{\partial k_\phi} = -2(\Omega V_\phi + C^2 k_\phi) \tag{6.47}$$

$$k \cdot \frac{\partial H}{\partial k} = k_r \frac{\partial H}{\partial k_r} + k_\theta \frac{\partial H}{\partial k_\phi} + k_\phi \frac{\partial}{\partial k_\phi} = -2(\Omega \vec{k} \cdot \vec{V} + C^2 k^2) \ , \tag{6.48}$$

where

$$\frac{\partial \Omega}{\partial t} = -k_r \frac{\partial V_r}{\partial t} - k_\theta \frac{\partial V_\theta}{\partial t} - k_\phi \frac{\partial V_\phi}{\partial t} \tag{6.49}$$

$$\frac{\partial \Omega}{\partial r} = -k_r \frac{\partial V_r}{\partial r} - k_\theta \frac{\partial V_\theta}{\partial r} - k_\phi \frac{\partial V_\phi}{\partial r} \tag{6.50}$$

$$\frac{\partial \Omega}{\partial \theta} = -k_r \frac{\partial V_r}{\partial \theta} - k_\theta \frac{\partial V_\theta}{\partial \theta} - k_\phi \frac{\partial V_\phi}{\partial \theta} \tag{6.51}$$

$$\frac{\partial \Omega}{\partial \phi} = -k_r \frac{\partial V_r}{\partial \phi} - k_\theta \frac{\partial V_\theta}{\partial \phi} - k_\phi \frac{\partial V_\phi}{\partial \phi} \ . \tag{6.52}$$

6.4.3 ANCWL - Acoustic, No Currents, With Losses and AWCWL - Acoustic, With Currents, With Losses

Part of the transmission loss for acoustic waves in the ocean is caused by absorption due to various physical and chemical relaxation processes (Urick, 1967). This absorption is often modeled with empirical formulas that give absorption as a function only of acoustic frequency. One such formula is given by Skretting and Leroy (1971) and Wakeley (1978):

$$\alpha = .006\ f^2 + \frac{.155(1.7f^2)}{(1.7)^2 + f^2} \ , \tag{6.53}$$

where α is the absorption coefficient in dB/km, and f is the acoustic frequency in kHz. Other treatments of absorption are reviewed by Jones (1983).

Subroutine SLLOSS computes α from (6.53) when called by DISPER, DISPER calculates $k_{imag}{}^2$ using (6.19), and HAMLTN provides an equation (6.18) which when integrated gives the absorption along the raypath. Some kind of absorption subroutine, such as SLLOSS, is required whenever you use ANCWL or AWCWL.

6.5 Reflecting Rays From the Bottom

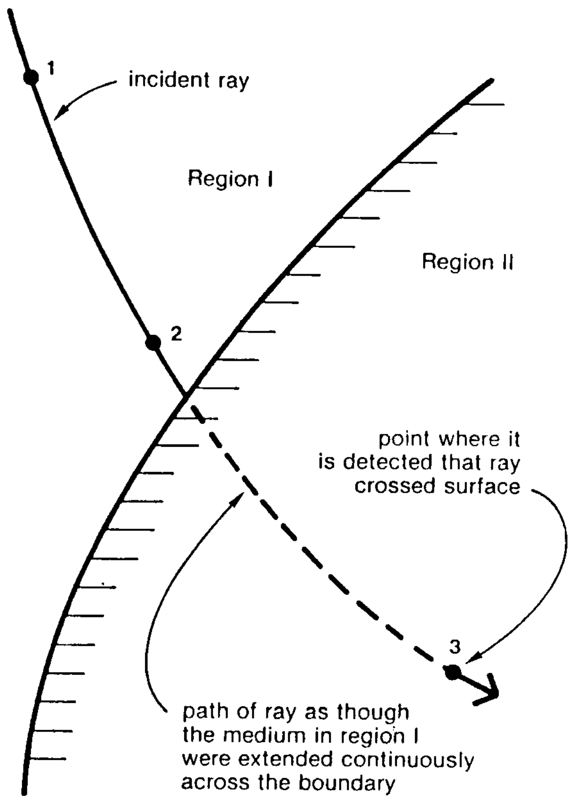
This section describes the method HARPO uses to find the intersections of a ray with any bottom surface and to compute the correct reflected ray, even in an anisotropic medium (an ocean with currents). A more detailed discussion of bottom-reflection algorithms is given in the report by Jones (1982). Essentially the same methods are used to detect receiver-surface crossings and to compute reflections from the ocean surface.

6.5.1 Detecting Ray Intersections With the Bottom

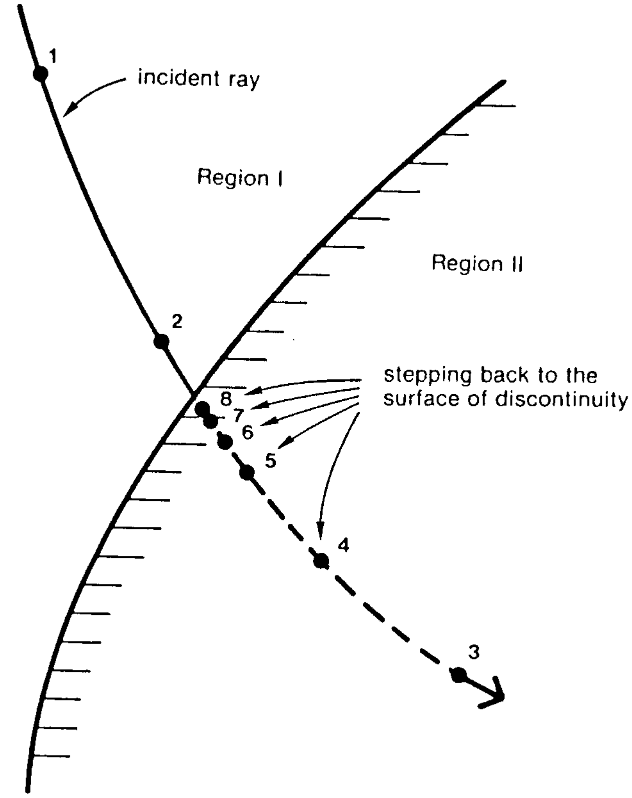
Detecting that the ray has crossed the bottom surface is straightforward for the simple case shown in Figure 6.6. Figure 6.7 shows a more difficult example in which the ray crosses the bottom surface twice. It is difficult to distinguish such a raypath from the example in Figure 6.8, knowing only the raypath coordinates and ray directions between the integration steps (shown by dots in Figures 6.7 and 6.8). A further difficulty is that iteration of the numerical integration in Figure 6.7 might lead to finding the wrong intersection with the surface of discontinuity, a problem shared by the example in Figure 6.9.

Although infrequent, the difficulties illustrated in Figures 6.7, 6.8 and 6.9 occur often enough that any useful algorithm must be able to handle them. These difficult cases obviously occur more often when large (relative to bottom structure) integration steps are used. This section derives algorithms that can handle these difficult cases in addition to the straightforward cases. Figure 6.10 illustrates cases that HARPO's intersection algorithm will not correctly handle unless step length is decreased or the bottom model is made smoother.

HARPO accepts only bottom models whose surface is continuous and whose slope and curvature are continuous. Thus, wedge-shaped surfaces, for example, are not allowed. Not only are diffraction effects important at such edges, but



a



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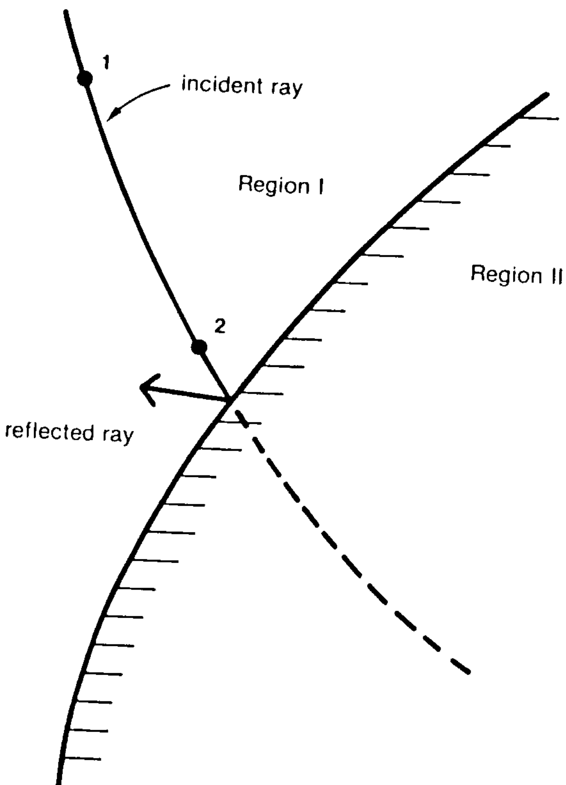

c

Figure 6.6. Three steps in calculating the intersection and reflection of a ray at a surface: (a) recognition that the ray has crossed the surface (numbers indicate successive positions of the ray after each integration step; the raypath is curved because the ocean is inhomogeneous); (b) iteration by numerical integration to find the intersection of the ray with the surface; and (c) computation of the reflected ray ready to start numerical integration in a new direction in the ocean. The same algorithm could be used to compute ray refraction at discontinuities of refractive index.

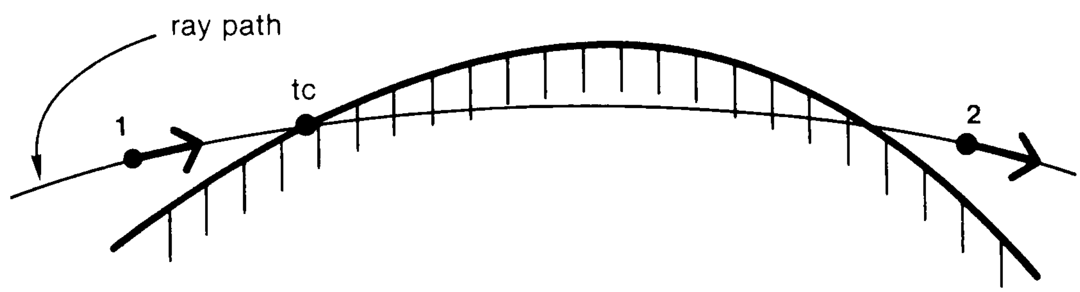

Figure 6.7. A ray crossing a bottom or receiver surface and crossing back again between integration steps. An algorithm that checked only to see if the ray at point 2 was in a different medium than point 1 would miss the intersections.

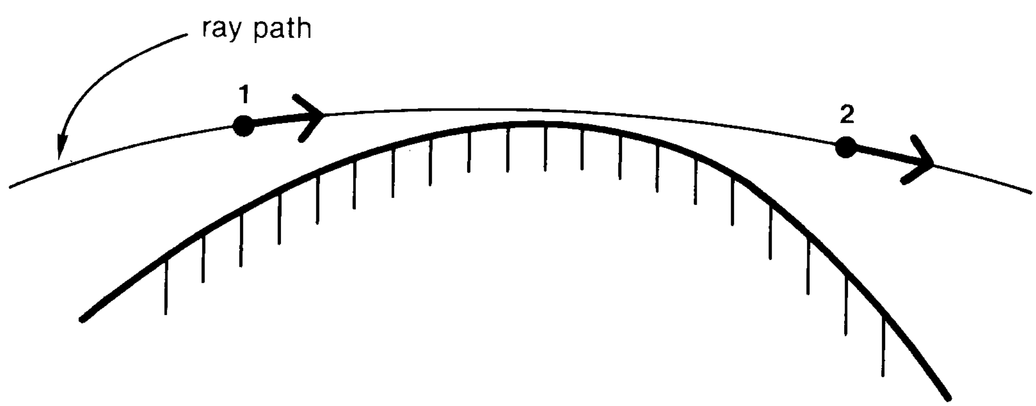

Figure 6.8. A ray that nearly intersects a bottom or receiver surface. A useful intersection algorithm must be able to distinguish this case from the one depicted in Figure 6.7.

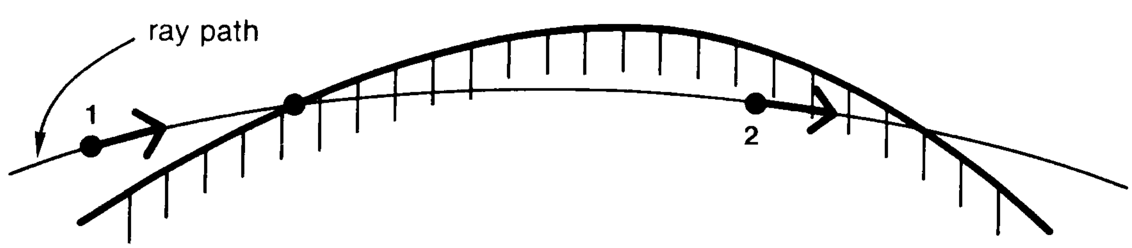

Figure 6.9. A ray crossing a bottom or receiver surface and ending closer to a second intersection. A useful algorithm must step backward and find the first intersection. HARPO will correctly handle the three cases on this page.

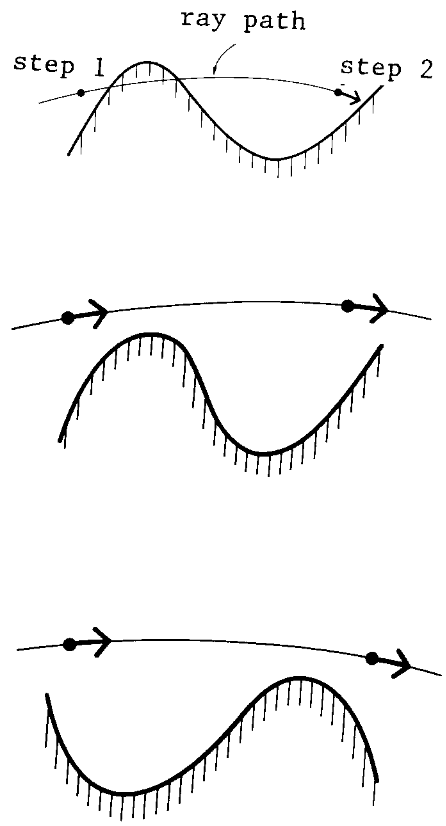

Figure 6.10. Examples of bottom (or receiver-surface) encounters that HARPO's intersection algorithm will not correctly handle. Step length must be decreased, or the bottom model must be smoothed.

some of the algorithms used by HARPO may not work properly for surfaces with edges. In addition, the algorithms used by HARPO may not always properly handle surfaces that contain caves or tunnels.

At each integration step in the raypath calculation, we assume that the following information is available:

(1) The position of the ray point (r, θ, ϕ) in spherical polar (Earth-centered) coordinates,

(2) The local Cartesian components (k_r, k_θ, k_ϕ) of the wave vector (a vector pointing in the wave-normal direction and normalized so that the magnitude equals the wave number),

(3) The accumulated group time delay, t, of the ray, (which is also the independent variable for the numerical integration), and

(4) The derivatives

$$\dot{r} \equiv dr/dt \tag{6.54}$$

$$\dot{\theta} \equiv d\theta/dt \tag{6.55}$$

$$\dot{\phi} \equiv d\phi/dt \tag{6.56}$$

$$\dot{k}_r \equiv dk_r/dt \tag{6.57}$$

$$\dot{k}_\theta \equiv dk_\theta/dt \tag{6.58}$$

$$\dot{k}_\phi \equiv dk_\phi/dt \; . \tag{6.59}$$

We assume also that the values of any of these variables can be saved from one step to the next for comparison. In particular, we make the following approximations,

$$\ddot{r} \approx (\dot{r}(t_2) - \dot{r}(t_1))/t_2 - t_1) \tag{6.60}$$

$$\ddot{\theta} \approx (\dot{\theta}(t_2) - \dot{\theta}(t_1))/(t_2 - t_1) \tag{6.61}$$

$$\ddot{\phi} \approx (\dot{\phi}(t_2) - \dot{\phi}(t_1))/(t_2 - t_1) \; , \tag{6.62}$$

which allow us to estimate the curvature of ray. In using these algorithms, it would probably be useful to incorporate a test of the validity of the above approximations by evaluating both sides of (6.60) - (6.62), but HARPO does not do that.

The simplest method for predicting whether an extension of the raypath from a point will intersect the bottom surface (or the receiver surface) is to extend the ray in a straight line and see if it meets the bottom when the surface is extended as a plane by using the local slope. However, whenever the curvature of the ray and the bottom surface are small enough for that approximation to be useful, the ray would probably eventually go below the bottom on one of the integration steps, and the prediction from the simplest algorithm would not be needed.

Because we want an algorithm sophisticated enough to estimate the time of nearest intersection (if one occurs) in cases like those in Figures 6.7 or 6.8, we should include at least the local curvature in any approximations. Also, because it would be difficult to deal with a higher order approximation, a quadratic approximation to both the ray and the bottom seems to be the best compromise.

In addition, when searching for an intersection with the bottom (or receiver) surface, the intersection must be in the correct direction. In the case of the bottom, the intersection will always be into the bottom. In the case of the receiver surface, the correct direction of crossing will alternate from one crossing to the next, but for each crossing, the direction will be known. For the purposes of the present development, it is useful to define a parameter S that is equal to +1 if the wanted crossing is upward and -1 if the wanted crossing is downward. Thus, the value of S will always be -1 for a bottom crossing.

6.5.2 The Surface Model

HARPO expresses an arbitrary model of a bottom, an ocean surface or a receiver surface in the form

$$f(r, \theta, \phi) = 0 \ . \tag{6.63}$$

Because f is zero only on the surface, it always has one sign on one side of the surface and the opposite sign on the other side. Let us call the side of the bottom surface that is underground the inside and the other side the outside. Then we can arbitrarily require that f be positive outside of the surface and negative inside the surface. We can similarly designate an inside and an outside for the receiver and ocean surfaces and make the same requirement on f.

Thus, we have

$$f(r, \theta, \phi) > 0 \tag{6.64}$$

outside the surface and

$$f(r, \theta, \phi) < 0 \tag{6.65}$$

inside the surface. The time derivative of f (which indicates the rate that the ray is moving away from the surface) is

$$\dot{f} = f_r \dot{r} + f_\theta \dot{\theta} + f_\phi \dot{\phi} \tag{6.66}$$

where a subscript indicates a partial derivative with respect to the subscript. The time derivative of (6.66) is

$$\ddot{f} = f_r \ddot{r} + f_\theta \ddot{\theta} + f_\phi \ddot{\phi} + f_{rr} \dot{r}^2 + f_{\theta\theta} \dot{\theta}^2 + f_{\phi\phi}\dot{\phi}^2 + 2f_{r\theta} \dot{r}\dot{\theta} + 2f_{r\phi} \dot{r}\dot{\phi} + 2f_{\theta\phi} \dot{\theta}\dot{\phi}. \tag{6.67}$$

Assuming that (6.67) is nearly constant locally, we have

$$f = f_1 + \dot{f}_1(t - t_1) + \frac{1}{2} \ddot{f}_1(t - t_1)^2 , \tag{6.68}$$

where the subscript 1 refers to the values at the time t_1. We want to find the value of t for which the ray intersects the surface, that is, where f = 0. Let t_c be the value for which f = 0. Then

$$0 = f_1 + \dot{f}_1(t_c - t_1) + \frac{1}{2} \ddot{f}_1(t_c - t_1)^2 . \tag{6.69}$$

For simplicity, let us drop the subscript 1 in (6.69), but remember that f and t without subscripts refer to the integration step on the raypath where we are trying to estimate the time t_c where the ray will intersect the surface. Then (6.69) becomes

$$0 = f + \dot{f}(t_c - t) + \frac{1}{2} \ddot{f}(t_c - t)^2 . \tag{6.70}$$

The solution of (6.70), for which the ray is crossing from inside to outside when S = +1 and crossing from outside to inside when S = -1, is

$$t_c - t = \frac{-\dot{f} + S\sqrt{\dot{f}^2 - 2f\ddot{f}}}{\ddot{f}} . \tag{6.71}$$

Within the approximation made here, the ray will intersect the surface if

$$\dot{f}^2 - 2f\ddot{f} > 0 \tag{6.72}$$

but will make a closest approach to the surface if

$$\dot{f}^2 - 2f\ddot{f} < 0 . \tag{6.73}$$

In the latter case, we can estimate the time t_p at which f is a minimum.

$$t_p - t = -\frac{\dot{f}}{\ddot{f}} . \qquad (6.74)$$

This is close to the time when the ray makes a closest approach to the surface. If the second derivative in (6.67) is very small, then the formula in (6.71) may be impractical. In that case, the solution

$$t_c - t = \frac{-2f}{\dot{f} + S\sqrt{\dot{f}^2 - 2f\ddot{f}}} \qquad (6.75)$$

is more useful. The advantage of (6.75) is that it is uniformly valid as $\ddot{f}$ approaches zero.

In HARPO, different formulas are used in different circumstances: statement 501 in TRACE uses (6.75) to estimate t_c. Subroutine BACKUP uses

$$t_c = t - f/\dot{f} \qquad (6.76)$$

when it is stepping to an intersection. Subroutine BACKUP uses (6.74) to step to a closest approach. When BACKUP has tried to step to a closest approach and fails after 10 tries, it tries to find an intersection. In that case, it uses (6.71) to give a first estimate for t_c, then uses (6.76) for iterating. Statement 30 in TRACE uses (6.74) to estimate the time of closest approach. See Section 7.3 for flow charts of these algorithms.

6.5.3 Reflecting the Ray From a Surface

Once the intersection with the ocean surface or bottom has been found, the ray must be properly reflected. For an isotropic medium, this is straightforward. The algorithm must first project the wave vector into the two components parallel to the surface and the component perpendicular to the surface. It then changes sign on the component perpendicular to the surface.

An anisotropic medium (such as an ocean with currents) is more difficult. The two components parallel to the surface remain unchanged, as before, but the component perpendicular to the surface must be changed so that the dispersion relation is satisfied. Although this principle is the same for all media, the solution depends on the dispersion relation. At this point, we must specialize to the particular medium of interest, namely, acoustic waves in the presence of currents.

We need to first separate the wave vector $\vec{k}$ into components perpendicular and parallel to the surface. Let $\vec{n}$ be a unit vector pointing out of the surface. Then the component of $\vec{k}$ normal to the surface is

$$k_\perp = \vec{k}\cdot\vec{n} \tag{6.77}$$

$$\vec{k}_\perp = (\vec{k}\cdot\vec{n})\ \vec{n} \tag{6.78}$$

and the part parallel to the surface is

$$\vec{k}_\parallel = \vec{k} - (\vec{k}\cdot\vec{n})\ \vec{n}\ . \tag{6.79}$$

The dispersion relation for acoustic waves in the presence of currents is

$$-\ \Omega^2 + C^2\ k^2 = 0\ , \tag{6.80}$$

where $$\Omega \equiv \omega - \vec{k}\cdot\vec{v} \tag{6.81}$$

is the intrinsic frequency, ω is the wave frequency, and $\vec{v}$ is the current velocity.

With the help of (6.81), we can separate (6.80) as follows:

$$-(\omega - \vec{k}_\perp\cdot\vec{v} - \vec{k}_\parallel\cdot\vec{v})^2 + C^2\ k_\perp{}^2 + C^2\ k_\parallel{}^2 = 0\ . \tag{6.82}$$

We want to solve (6.82) for $k_\perp$, assuming $\vec{k}_\parallel$ to be known. We can rewrite (6.80) as

$$(C^2 - v_\perp{}^2)\ k_\perp{}^2 + 2\ \Omega_\parallel\ v_\perp\ k_\perp - \Omega_\parallel{}^2 + C^2\ k_\parallel{}^2 = 0\ , \tag{6.83}$$

where

$$\Omega_\parallel \equiv \omega - \vec{k}_\parallel\cdot\vec{v} \tag{6.84}$$

and

$$\vec{v}_\perp \equiv (\vec{v}\cdot\vec{n})\ \vec{n} \quad , \quad v_\perp \equiv \vec{v}\cdot\vec{n} \tag{6.85}$$

is the component of current normal to the surface. The quadratic formula gives the solution to (6.83) as

$$k_\perp = \frac{-\Omega_\parallel v_\perp \pm C\sqrt{\Omega_\parallel^2 - k_\parallel^2 (C^2 - v_\perp^2)}}{C^2 - v_\perp^2} \quad . \tag{6.86}$$

One solution of (6.86) should be the normal component of $\vec{k}$ for the incident wave, the other the normal component of $\vec{k}$ for the reflected wave. To convert from the incident wave to the reflected wave, it is necessary simply to change the sign of

$$k_\perp + \frac{\Omega_\parallel v_\perp}{C^2 - v_\perp^2} \quad . \tag{6.87}$$

To do this, we can use (6.78) and (6.79) to write

$$\vec{k} = \vec{k} - (\vec{k}\cdot\vec{n})\vec{n} + (\vec{k}\cdot\vec{n})\vec{n} \ . \tag{6.88}$$

This is equivalent to

$$\vec{k} = \vec{k} - (\vec{k}\cdot\vec{n})\vec{n} - \frac{\Omega_\parallel v_\perp}{C^2 - v_\perp^2}\vec{n} + (\vec{k}\cdot\vec{n})\vec{n} + \frac{\Omega_\parallel v_\perp \vec{n}}{C^2 - v_\perp^2} \ . \tag{6.89}$$

Let us assume that (6.89) applies to the incident wave, that is,

$$\vec{k}_{inc} = \vec{k}_{inc} - (\vec{k}_{inc}\cdot\vec{n})\vec{n} - \frac{\Omega_\parallel v_\perp}{C^2 - v_\perp^2}\vec{n} + (\vec{k}_{inc}\cdot\vec{n})\vec{n} + \frac{\Omega_\parallel v_\perp \vec{n}}{C^2 - v_\perp^2} \ , \tag{6.90}$$

where the subscript inc signifies the incident wave. To get the wave vector for the reflected wave, we need only reverse the sign of the last two terms in (6.90), that is,

$$\vec{k}_{ref} = \vec{k}_{inc} - 2(\vec{k}_{inc}\cdot\vec{n})\vec{n} - 2\,\frac{\Omega_\parallel v_\perp \vec{n}}{C^2 - v_\perp^2} \ , \tag{6.91}$$

where the subscript ref signifies the reflected wave.

To be more explicit, we can write (6.91) in terms of components. We assume an earth-centered spherical polar-coordinate system (r, θ, ϕ). We then consider Cartesian components of $\vec{k}$, (k_r, k_θ, k_ϕ) in the r, θ, and φ directions. We also consider components of n, (n_r, n_θ, n_ϕ) in the r, θ, and φ directions. Then (6.91) is equivalent to

$$k_{r\ ref} = k_{r\ inc} - 2(\vec{k}_{inc} \cdot \vec{n})n_r - \frac{2\Omega_\parallel v_\perp}{C^2 - v_\perp^2} n_r \tag{6.92a}$$

$$k_{\theta\ ref} = k_{\theta\ inc} - 2(\vec{k}_{inc} \cdot \vec{n})n_\theta - \frac{2\Omega_\parallel v_\perp}{C^2 - v_\perp^2} n_\theta \tag{6.92b}$$

$$k_{\phi\ ref} = k_{\phi\ inc} - 2(\vec{k}_{inc} \cdot \vec{n})n_\phi - \frac{2\Omega_\parallel v_\perp}{C^2 - v_\perp^2} n_\phi \ . \tag{6.92c}$$

One might wonder whether it is realistic to allow a component of the current normal (or even parallel) to the ocean surface or bottom. Rather than debate this point here, we simply point out that HARPO does not check any models to see if they satisfy continuity, geostrophy, or physical boundary conditions (in fact, many of our models don't). This is the responsibility of those who design models, if such conditions are important in their applications. The last term in (6.92a,b,c) guarantees that the dispersion relation will be satisfied for the reflected wave, even if the current does not vanish at the surface.

6.5.4 Unit-Normal Directions From the Surface

The previous section requires unit normal directions to the surface. Because f is a constant along the surface, the gradient of f is in the same direction as the unit normal. That is

$$\vec{\nabla} f = f_r\, \hat{i}_r + \frac{f_\theta}{r}\, \hat{i}_\theta + \frac{f_\phi}{r \sin\theta}\, \hat{i}_\theta \propto \vec{n} \ . \tag{6.93}$$

Taking the ratio of components gives

$$n_\theta = \frac{f_\theta}{r\, f_r}\, n_r \tag{6.94}$$

and

$$n_\phi = \frac{f_\phi}{f_r \, r \sin\theta} n_r \; . \tag{6.95}$$

The solution of (6.94), and (6.95), while requiring $n_r^2 + n_\theta^2 + n_\phi^2 = 1$, is

$$n_r = \frac{f_r}{\sqrt{f_r^{\,2} + \frac{f_\theta^{\,2}}{r^2} + \frac{f_\phi^{\,2}}{r^2 \sin^2\theta}}} \; , \tag{6.96}$$

$$n_\theta = \frac{f_\theta}{r\sqrt{f_r^{\,2} + \frac{f_\theta^{\,2}}{r^2} + \frac{f_\phi^{\,2}}{r^2 \sin^2\theta}}} \; , \tag{6.97}$$

$$n_\phi = \frac{f_\phi}{r \sin\theta \sqrt{f_r^{\,2} + \frac{f_\theta^{\,2}}{r^2} + \frac{f_\phi^{\,2}}{r^2 \sin^2\theta}}} \; . \tag{6.98}$$

6.6 Coordinate Systems

HARPO uses two different earth-centered spherical polar-coordinate systems, one geographic and one computational, because it is easier to express some models in a different coordinate system. Input data for the coordinates of the transmitter, W(4) and W(5), and input data for the coordinates of the north pole of the computational coordinate system, W(24) and W(25), are entered in geographic coordinates. Setting W(25) equal to 0° and W(24) equal to 90° superimposes the two north poles and equates the two coordinate systems.

When the two coordinate systems do not coincide, the ocean models calculate current, sound speed, bottom surface, upper surface, and receiver surface in terms of the computational coordinate system. Dudziak (1961) describes the transformations between these coordinate systems.

For some long-range ray calculations in the ocean, a spherical model of the earth may not be accurate enough. Some applications may require ocean models to be expressed in geodetic (e.g., spheroidal) coordinates, which would be transformed to spherical coordinates for ray tracing. However, for paths of a few thousand kilometers and less, we would recommend using a spherical computational coordinate system with W(1) set to the local radius of curvature of the geoid in the propagation direction.

7. Structure of the Program

This chapter explains how the parts of HARPO work together, including a brief description of each program subroutine and detailed flow charts of the central ray-tracing parts. Also included are hierarchical or organization diagrams that show the calling sequences of the principal ray-tracing operations and details of the common-block structure and usage.

7.1 Description of the Subroutines

Following is a list of all the programs, subroutines, and functions that comprise HARPO, that is, the functions inside the dashed lines of Figure 1.1. They are listed in the order they appear in Files 3, 4, and 5 of the distribution tape and in the source-code listings of Appendix D. The routines are divided into a RAY-TRACING "CORE," the set of programs that is always required to do ray tracing, DISPERSION-RELATION ROUTINES, from which you must select one, and OCEAN MODEL SUBROUTINES, from which you select the routines that correspond to the ocean models you want to use. A more detailed description of the distribution-tape structure is given in Sec. 3.3.1.

7.1.1 Ray-Tracing Core (Tape File 3)

PROGRAM RAYTRC -- The main program; sets the initial conditions for each ray and calls TRACE.

SUBROUTINE DFSYS -- Contains system-dependent functions such as date, time (user must modify).

SUBROUTINE DFCNST -- Defines machine-dependent constants (user must modify).

SUBROUTINE READW1 -- Reads variable-length tabular data from input data table.

SUBROUTINE GTUNIT -- Interprets units line in tabular input data.

SUBROUTINE SREAD1 -- Handles unassigned labeled common blocks.

FUNCTION READW -- Reads input data table into W array, converting units.

SUBROUTINE CLEAR -- Sets n elements of an array to zero.

FUNCTION ND2B -- Converts decimal digits to positionally equivalent binary numbers when reading W(29).

FUNCTION UCON -- Provides keyword units conversion for input data.

SUBROUTINE TRACE -- Calculates a raypath for the requested number of hops.

FUNCTION PCROSS -- Tests whether ray crosses a surface.

SUBROUTINE RCROSS -- Estimates point where ray crosses a surface.

SUBROUTINE HAMLTN -- Calculates Hamilton's equations for ray tracing and other quantities to be integrated.

SUBROUTINE RKAM -- Keeps track of integration steps performed by RKAM1 and makes them available to calling subroutines.

SUBROUTINE RKAM1 -- Numerically integrates Hamilton's equations.

SUBROUTINE BACKUP -- Moves the ray point to the desired intersection with a surface.

FUNCTION REFLECT -- Computes normal and parallel components of k vector at reflections from a surface.

SUBROUTINE FIT -- Computes 3 types of parabolic fit to raypath relative to a surface.

FUNCTION GET -- Gets the value of a surface function and its derivatives; calls the surface model subroutine if necessary.

FUNCTION GET1 -- Second version of GET to avoid self-calls.

FUNCTION ITEST -- Passes integer values through for variables typed real.

FUNCTION ITOC -- Integer to character conversion.

SUBROUTINE CONBLK -- Data-initialization and file-opening service routine.

SUBROUTINE SETTRC -- Initializes /TRAC/ labeled common block.

FUNCTION WCHANGE -- Determines whether two W arrays are the same (needed for producing raysets).

FUNCTION RENORM -- Normalizes a vector to a specified magnitude.

SUBROUTINE SET2 -- Sets n components of vector to a specified single value.

SUBROUTINE PRINTR -- Prints details of the raypath calculation at specified intervals and produces computer-readable output (raysets).

SUBROUTINE OCNHD -- Prints page headings.

SUBROUTINE PUTDES -- Prints model information on printout header.

FUNCTION NUMSTG -- Converts a numeric value to a string.

SUBROUTINE SFILL -- Fills a string with n specified characters.

FUNCTION STRIM -- Determines position of last nonblank character of a string.

FUNCTION RERR -- Computes for subroutine PRINTR the largest relative integration error.

SUBROUTINE RERROR -- Reports error conditions and stops program.

SUBROUTINE STOPIT -- Prints error condition and stops program.

SUBROUTINE PUTKST -- Multiple ENTRY points to produce line-printer output while accounting for line count, new page, etc.

SUBROUTINE PUTKCT -- Put out a centered line and count.

SUBROUTINE OPNREP -- Either opens a new disk file or replaces an ole one, as necessary.

SUBROUTINE ZAPFIL -- Test for existence of file and delete.

SUBROUTINE OVERRD -- Tests for "zero-override" condition in input data (Sec. 5.3.1).

SUBROUTINE SFILTR -- Filters extraneous characters from plot labels.

FUNCTION ALCOSH -- Compute log(cosh(x)) and uses large-argument approximation.

SUBROUTINE GAUSEL -- Calculates coefficients of cubic functions to fit points in CTABLE.

[PLOTTING ROUTINES]

SUBROUTINE RAYPLT -- Main plotting program; initializes, reads input, plots projections of rays on a vertical or horizontal plane.

SUBROUTINE PLOT -- XY plotting routine, called by RAYPLT.

SUBROUTINE LABPLT -- Labels rayplots.

[TICK/ANNOTATION ROUTINES]

SUBROUTINE PLTHLB -- Plots horizontal ticks and annotation for rayplot.

SUBROUTINE PLTANH -- Generic horizontal tick annotation.

SUBROUTINE SETXY -- Plot initialization; sets projection parameters.

SUBROUTINE TIKLINE -- Draws straight line with ticks at intervals.

SUBROUTINE PLTANOT -- Puts general annotations on plots.

SUBROUTINE DRAWTKS -- Draws plot boundary, ticks, and labels for horizontal ray projection.

SUBROUTINE PLTLB -- Puts vertical tick annotations on rayplots.

SUBROUTINE ARCTIC -- Draws curved range axis for rayplot.

[GRAPHICS WRITE ROUTINES]

SUBROUTINE DDINIT -- Initializes plotting process (writes header line to TAPE5).

SUBROUTINE DDBP -- Sets a vector origin (writes IX,IY to TAPE5).

SUBROUTINE DDVC -- Plots a vector (writes IX,IY for vector end point to TAPE5).

SUBROUTINE DDTEXT -- Writes an array (character string) to TAPE 5 in tabular text mode.

SUBROUTINE DDTAB -- Sends instruction to TAPE5 that initializes tabular (text) plotting.

SUBROUTINE DDFR -- Sends instruction to TAPE5 to advance a microfilm frame.

SUBROUTINE DDEND -- Empties plot buffer and releases plotting command file to microfilm plot queue.

SUBROUTINE DASH -- Sets dashed-line mode; that is, all plotted curves will be dashed instead of solid after a call to subroutine DASH.

SUBROUTINE RESET('DASH') -- Sets solid-line mode; that is, all plotted curves will be solid lines after this call.

SUBROUTINE HEIGHT -- If you do not have the DISSPLA* plotting package, load SUBROUTINE SMPANN instead of SUBROUTINE FULANN, and you can ignore this routine.

SUBROUTINE MX1ALF -- If you do not have the DISSPLA* plotting package, load SUBROUTINE SMPANN instad of SUBROUTINE FULANN, and you can ignore this routine.

SUBROUTINE MX2ALF -- If you do not have the DISSPLA* plotting package, load SUBROUTINE SMPANN instead of SUBROUTINE FULANN, and you can ignore this routine.

SUBROUTINE SCMPLX -- If you do not have the DISSPLA* plotting package, load SUBROUTINE SMPANN instead of SUBROUTINE FULANN, and you can ignore this routine.

7.1.2 Dispersion Relation Routines (Tape File 4)

SUBROUTINE ANCNL -- Acoustic wave, no current, no losses.

SUBROUTINE AWCNL -- Acoustic wave, with current, no losses.

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* DISSPLA is the proprietary product of ISSCO, Inc.

SUBROUTINE ANCWL -- Acoustic wave, no current, with losses.

SUBROUTINE AWCWL -- Acoustic wave, with current, with losses.

7.1.3 Ocean Model Subroutines (Tape File 5)

SUBROUTINE WLINEAR -- Constant upward or northward background current; linear eastward current profile.

SUBROUTINE VVORTX3 -- Vertical vortex current model with viscous core and Gaussian height profile.

SUBROUTINE WGAUSS2 -- Eastward current model that decays in three dimensions (jet).

SUBROUTINE NPCURR -- Do-nothing current perturbation model.

SUBROUTINE CTANH -- Background sound-speed profile with linear segments joined smoothly.

SUBROUTINE CSTANH -- Background sound-speed-squared profile with linear segments joined smoothly.

SUBROUTINE CSSPOKE -- Background sound speed as a function of angle from horizontal.

SUBROUTINE CSSPOK2 -- Background sound speed as a function of angle from horizontal.

SUBROUTINE CSMUNK1 -- Canonical sound channel; linear parameters in longitude.

SUBROUTINE CSMUNK2 -- Canonical sound channel; linear C with longitude.

SUBROUTINE CTABLE -- Tabular C profile in cubic segments.

SUBROUTINE NPSPEED -- Do-nothing sound-speed-perturbation model.

SUBROUTINE CBLOB2 -- Sound-speed perturbation with Gaussian decay in three dimensions.

SUBROUTINE CBLOB3 -- Up to 3 blobs of C increase that decay in three dimensions.

SUBROUTINE CBLOB4 -- Up to 3 blobs of C^2 increase that decay in three dimensions.

[ABSORPTION MODELS]

SUBROUTINE SLLOSS -- Skretting-Leroy formula for acoustic absorption.

SUBROUTINE NPABSR -- Do-nothing absorption-perturbation model.

[BOTTOM, OCEAN-SURFACE, AND RECEIVER-SURFACE MODELS]

SUBROUTINE GHORIZ -- Bottom model = a sphere at fixed depth below MSL (mean sea level).

SUBROUTINE GLORENZ -- Lorentzian-ridge bottom model.

SUBROUTINE GTANH -- 2-D bottom model with a series of linear segments joined smoothly.

SUBROUTINE NPBOTM -- Do-nothing bottom-perturbation model.

SUBROUTINE SHORIZ -- Ocean surface = a sphere at fixed height above MSL.

SUBROUTINE NPSURF -- Do-nothing ocean-surface perturbation model.

SUBROUTINE RHORIZ -- Horizontal receiver-surface model.

SUBROUTINE RBOTM -- Receiver-surface model at fixed height above the bottom.

SUBROUTINE RVERT -- Vertical (conical) receiver surface at a fixed central-earth angle from a specified geographic location (latitude and longitude).

[ANNOTATION MODELS]

SUBROUTINE SMPANN -- Initializes plot in draft mode (must be used if you don't have DISSPLA).

SUBROUTINE FULANN -- Initializes plot in publication-quality mode (requires DISSPLA).

7.2 HARPO Organization Diagrams

This section contains hierarchical diagrams, Figures 7.1 through 7.4, that show how the principal subroutines are interrelated by calling sequences. These diagrams are not flow charts; they show how control passes among the program modules. Not all subroutines are shown, only the major ones that perform the ray-tracing function.

7.3 Flow Charts for Program RAYTRC and Subroutines TRACE and BACKUP

These three routines contain the central logic of the raypath calculations and so are described in detail in flow-chart form.

This ray-tracing program consists of various subroutines that perform specific tasks in calculating raypaths. The division of labor makes it easier to modify the program to solve specific problems. Often it may be necessary to change only one or two subroutines to convert the program to a different use.

The main program (RAYTRC) sets up the initial conditions (transmitter location, wave frequency, and direction of transmission) for each ray trace. In setting up the initial conditions for each ray trace, the main program (RAYTRC) steps frequency, azimuth angle of transmission, and elevation angle of transmission (see Figure 7.5). Then subroutine TRACE calculates one raypath for the requested number of crossings of the specified receiver height. Subroutine TRACE is the heart of the ray-tracing program. It is the most complicated subroutine included, but also the most important to understand. The flow charts in Figures 7.6, 7.7, and 7.8 explain how TRACE works.

Subroutine RKAM integrates the differential equations numerically using an Adams-Moulton predictor-corrector method with a Runge-Kutta starter. Subroutine HAMLTN evaluates the differential equations to be integrated. A subroutine with entry point DISPER calculates the Hamiltonian and its derivatives, the wave number from the dispersion relation, and the wave polarization. (Four versions of this subroutine are included, as noted in Sec. 6.4.) Subroutines with entry points WINDR, SPEED, RECVR, TOPOG, SURFACE and ABSRP calculate the ocean current velocity, sound speed, receiver surface, bottom, upper surface, and absorption. Several versions of these six subroutines are included, and it is straightforward to add more. Subroutine BACKUP finds an intersection of the ray with the receiver surface, ocean bottom, or upper surface. The flow charts in Figures 7.9 through 7.11 and Section 6.5 explain how BACKUP works.

Subroutine PRINTR prints information describing the raypath and outputs the results in computer-readable form (raysets). Subroutine RAYPLT plots the raypath. The block diagrams in Figures 7.1 through 7.4 show the relation among these (and other) subroutines.

The listings of most of the subroutines have comments that should help in understanding how they work. In addition, Tables 7.1 through 7.38 define the variables in the common blocks.

7.4 Common-Block Structure and Usage

We use common blocks instead of calling sequences to pass information between subroutines and functions because it is faster. However, the added complexity requires a detailed description of how those common blocks are organized, which blocks link which program modules, and the variables in each block.

Table 7.1 defines the variables in blank common. These are mostly the dependent variables in the numerical integration and their derivatives. Nearly all of the subprograms use this common block.

Table 7.2 describes the common block /MCONST/, which contains mathematical constants. Table 7.3 describes the common block /PCONST/, which contains physical constants.

Many common blocks are used to cummunicate among the various routines in the program. Table 7.4 lists those common blocks and shows which routines use those common blocks. Blank common, common block /WW/, and the model-related common blocks listed in Tables 4.2 and 4.3 are not included in Table 7.4. Table 7.5 lists the variable names in these common blocks that are used for input and output by each routine. Tables 7.6 through 7.32 list all of the variables in these common blocks and give the meanings of those variables.

Table 7.17 describes common block /RIN/, which contains parameters output by all of the versions of the dispersion relation subroutines (all of which have the entry point name DISPER). Tables 7.33 through 7.38 describe the common blocks /UU/, /CC/, /LL/, /SS/, /RR/, and /GG/, which contain the parameters output by the various ocean models.

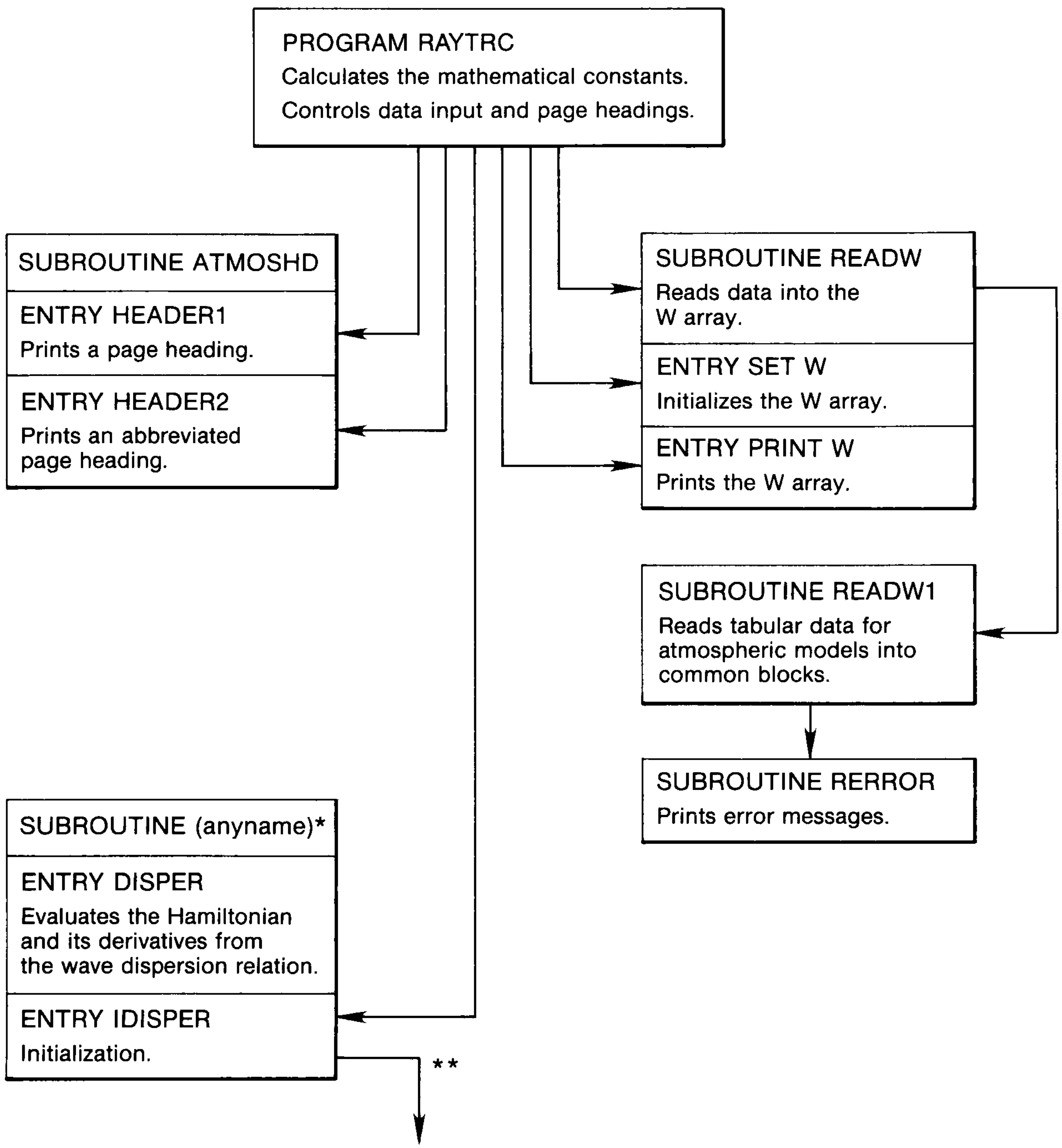

Figure 7.1. Block diagram (not a flow chart) of the ray-tracing program showing the relation (hierarchy, what calls what) of the main program to other subroutines during the initialization stage (immediately after new input data are read in).

* ANCNL (Acoustic, No Currents, No Losses), AWCNL (Acoustic, With Currents, No Losses), ANCWL, and AWCWL are the names of the versions of the dispersion-relation subroutines available.

** Figure 7.2 shows the continuation of this block diagram.

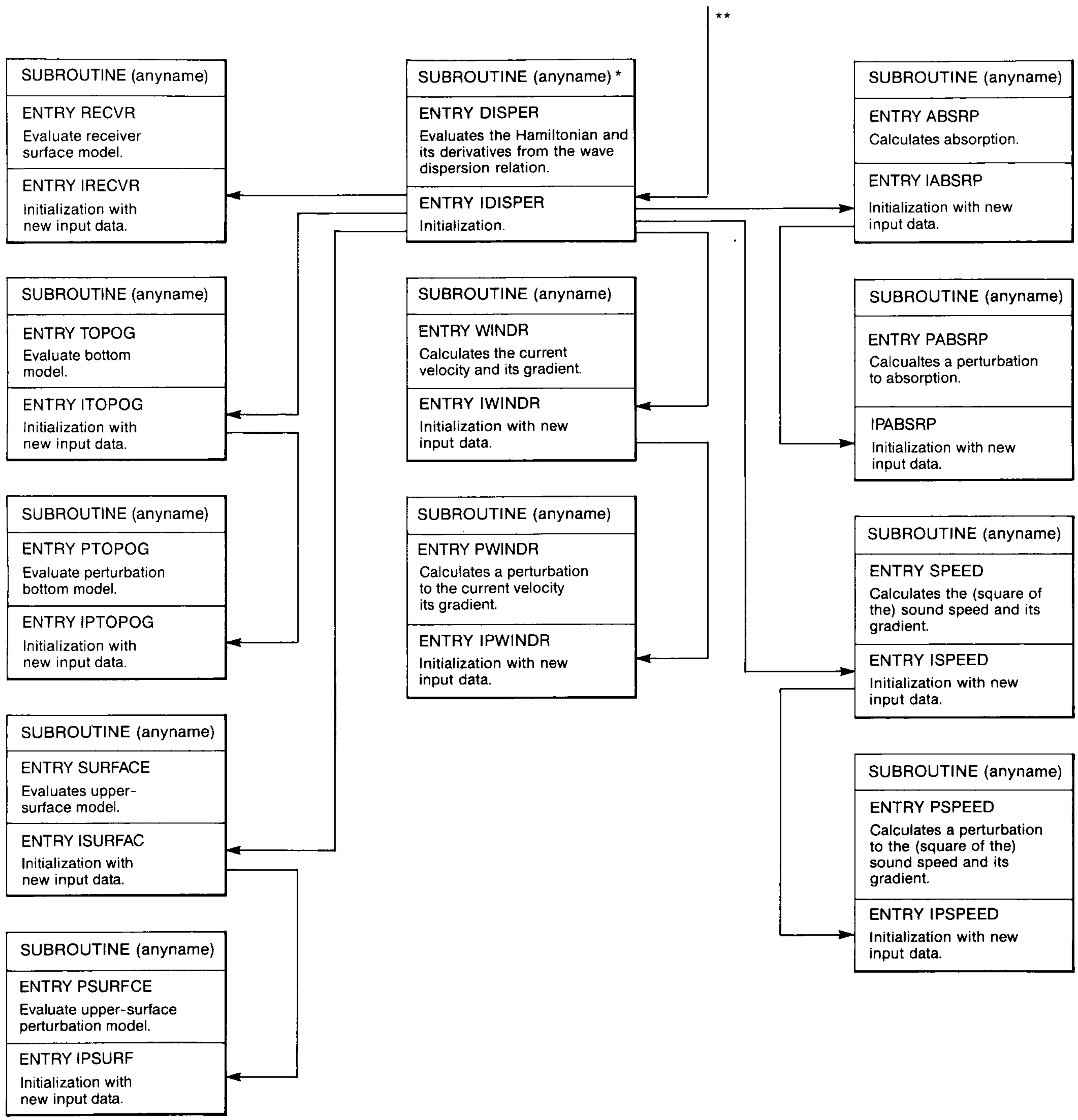

Figure 7.2. Continuation of the block diagram of the ray-tracing program (Fig. 7.1), showing the relations among the atmospheric model subroutines during the initialization stage (immediately after new input data are read in).

* ANCNL (Acoustic, No Currents, No Losses), AWCNL (Acoustic, With Currents, No Losses), ANCWL, and AWCWL are the names of the versions of the dispersion-relation subroutine available with this version of the program.

** Continued from Figure 7.1.

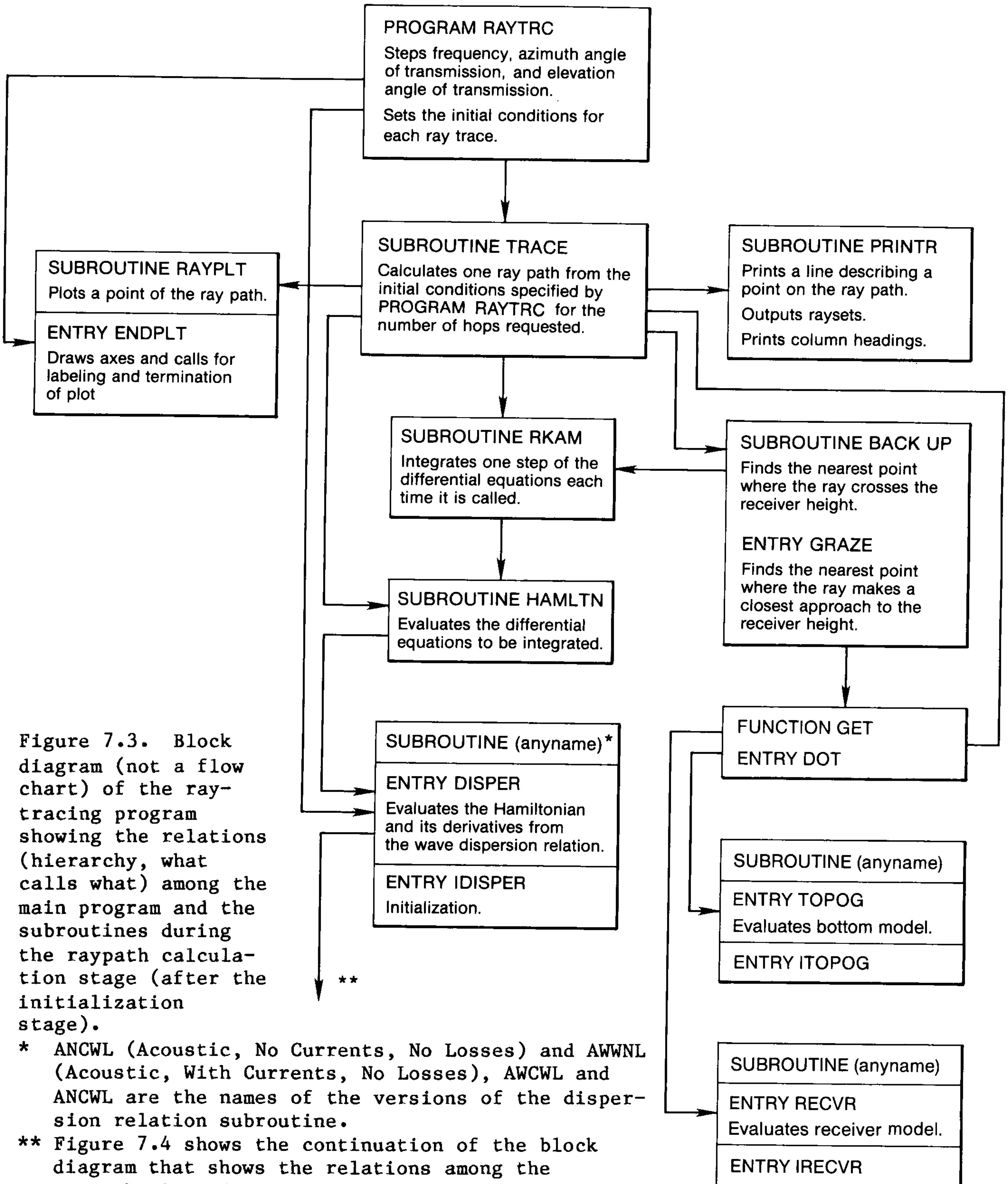

Figure 7.3. Block diagram (not a flow chart) of the ray-tracing program showing the relations (hierarchy, what calls what) among the main program and the subroutines during the raypath calculation stage (after the initialization stage).

* ANCWL (Acoustic, No Currents, No Losses) and AWWNL (Acoustic, With Currents, No Losses), AWCWL and ANCWL are the names of the versions of the dispersion relation subroutine.

** Figure 7.4 shows the continuation of the block diagram that shows the relations among the atmospheric model subroutines.

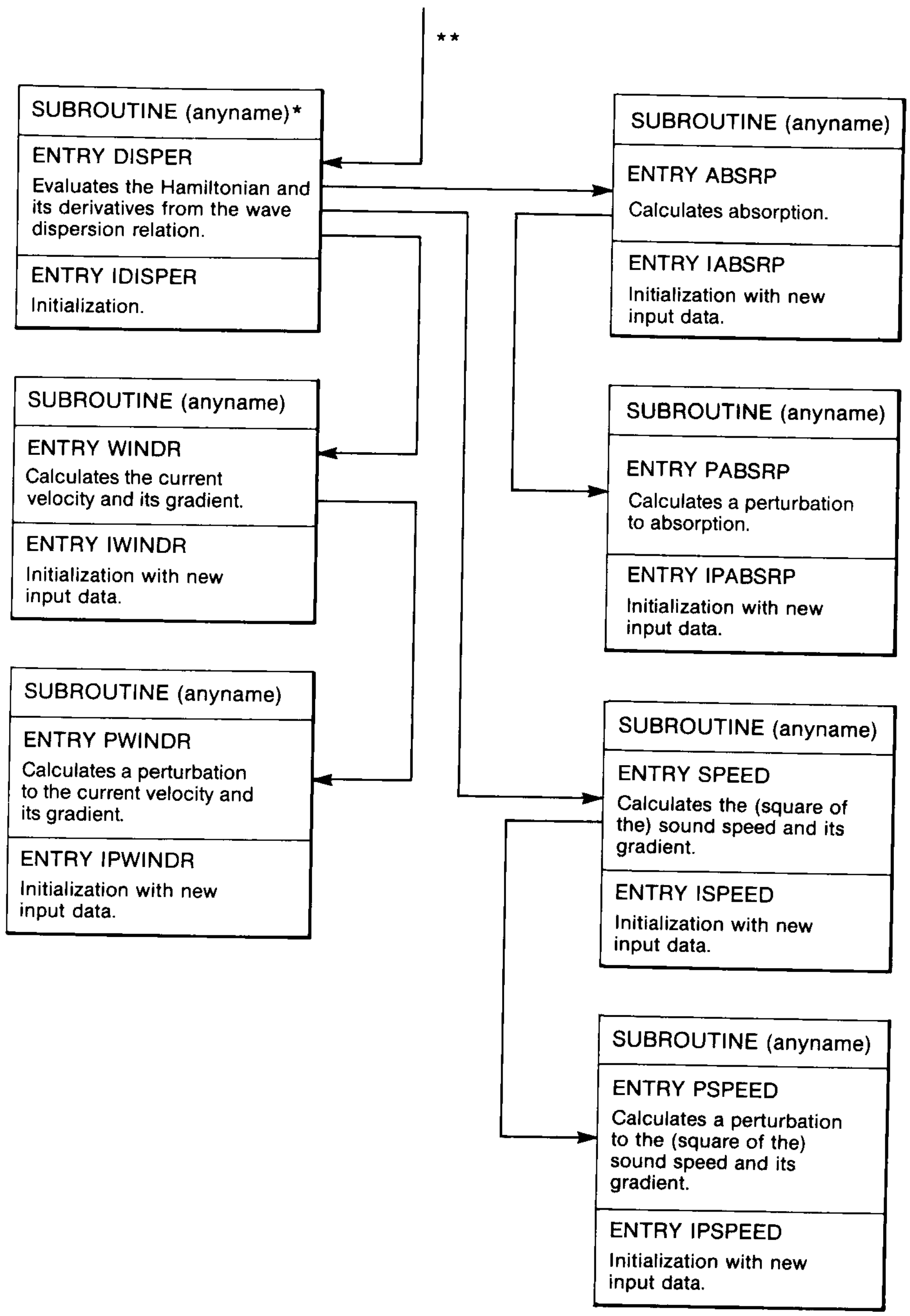

Figure 7.4. Continuation of the block diagram of the ray-tracing program (Fig. 7.3) that shows the relations (hierarchy, what calls what, a block diagram is not a flow chart) among the ocean model subroutines during the raypath calculation stage (after the initialization stage).

* ANCNL (Acoustic, No Currents, No Losses) and AWCNL (Acoustic, With Currents, No Losses), AWCWL and ANCWL are the names of the versions of the dispersion-relation subroutine.

** Continued from Figure 7.3.

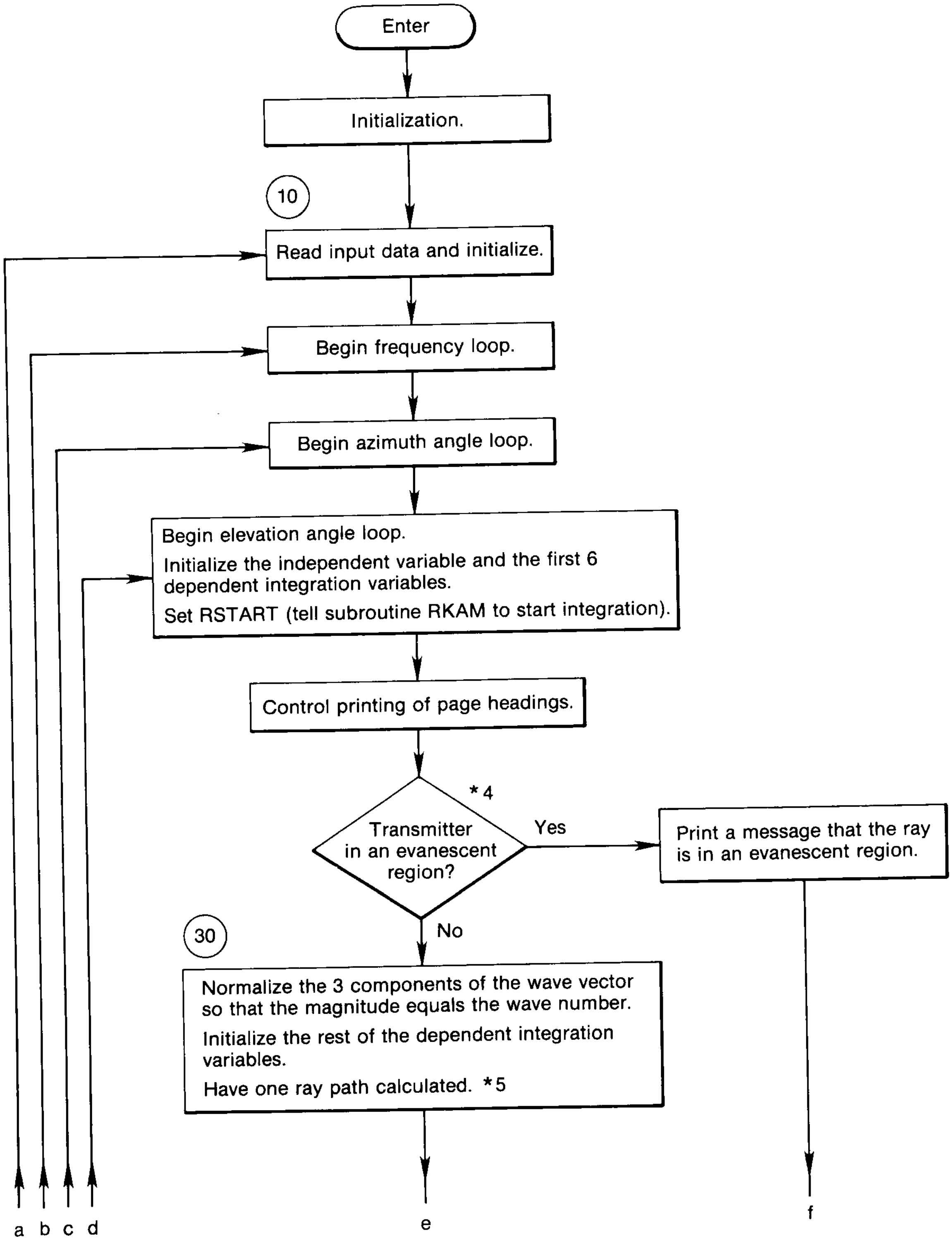

Figure 7.5. Flow chart for program RAYTRC. Circled block numbers correspond to program statement numbers.

*4 There are no evanescent regions for pure acoustic waves (with no cutoff frequency).

*5 Subroutine TRACE calculates one raypath.

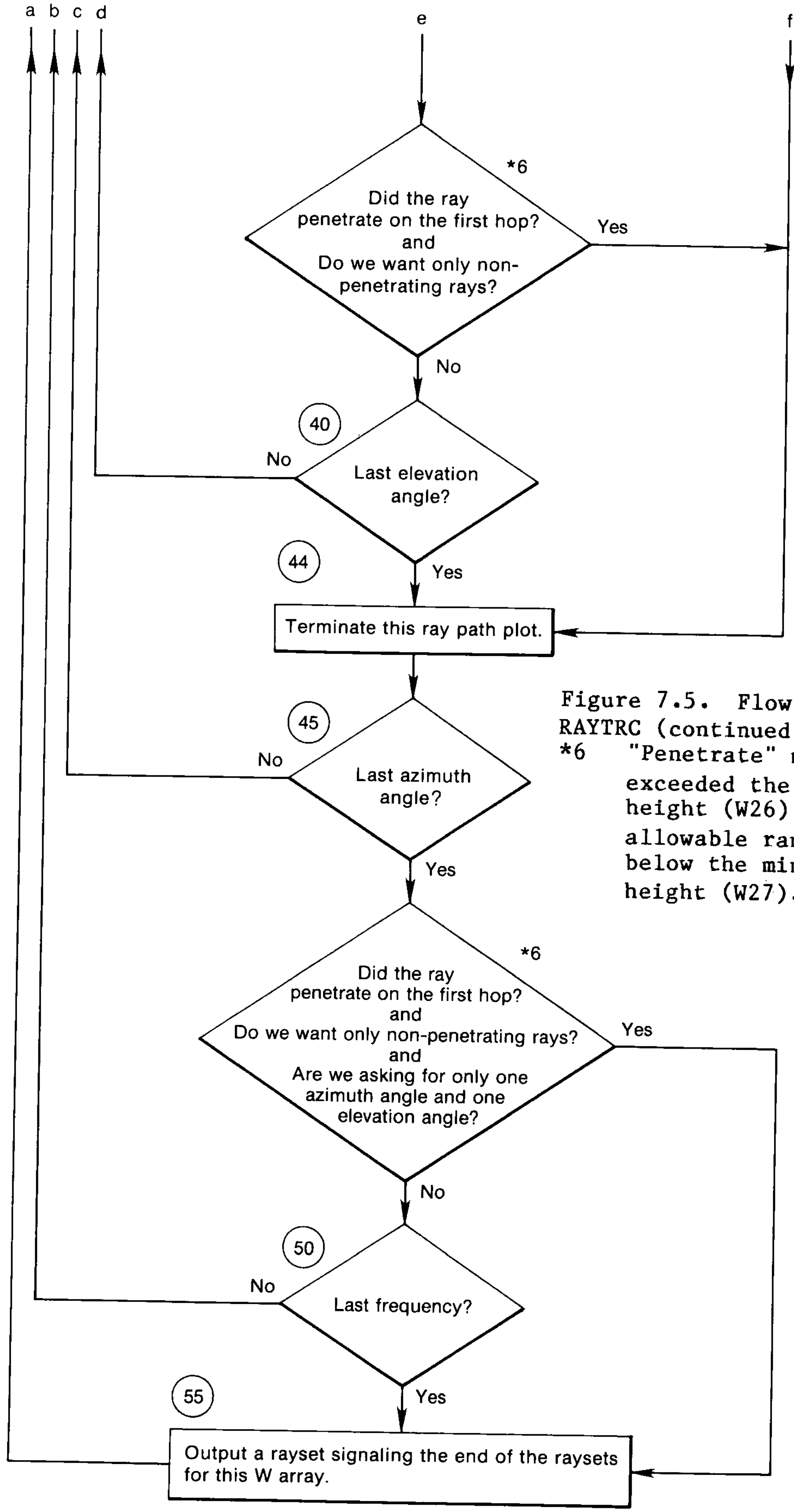

Figure 7.5. Flow chart for program RAYTRC (continued).

*6 "Penetrate" means the ray exceeded the maximum allowable height (W26) or the maximum allowable range (W28) or went below the minimum allowable height (W27).

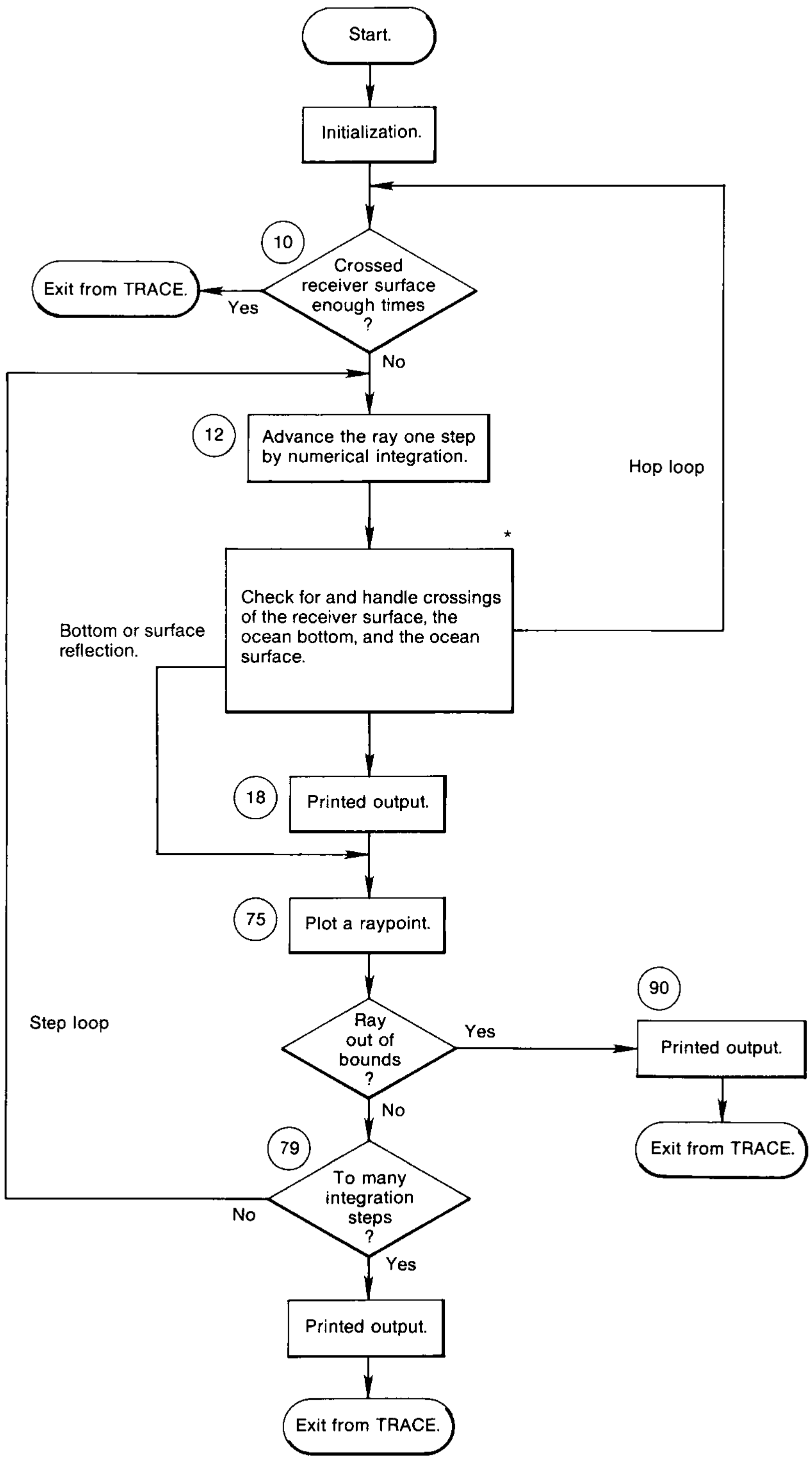

Figure 7.6. Flow chart for subroutine TRACE. Circled block numbers correspond to program statement numbers in subroutine TRACE.
* See Figure 7.7 for details.

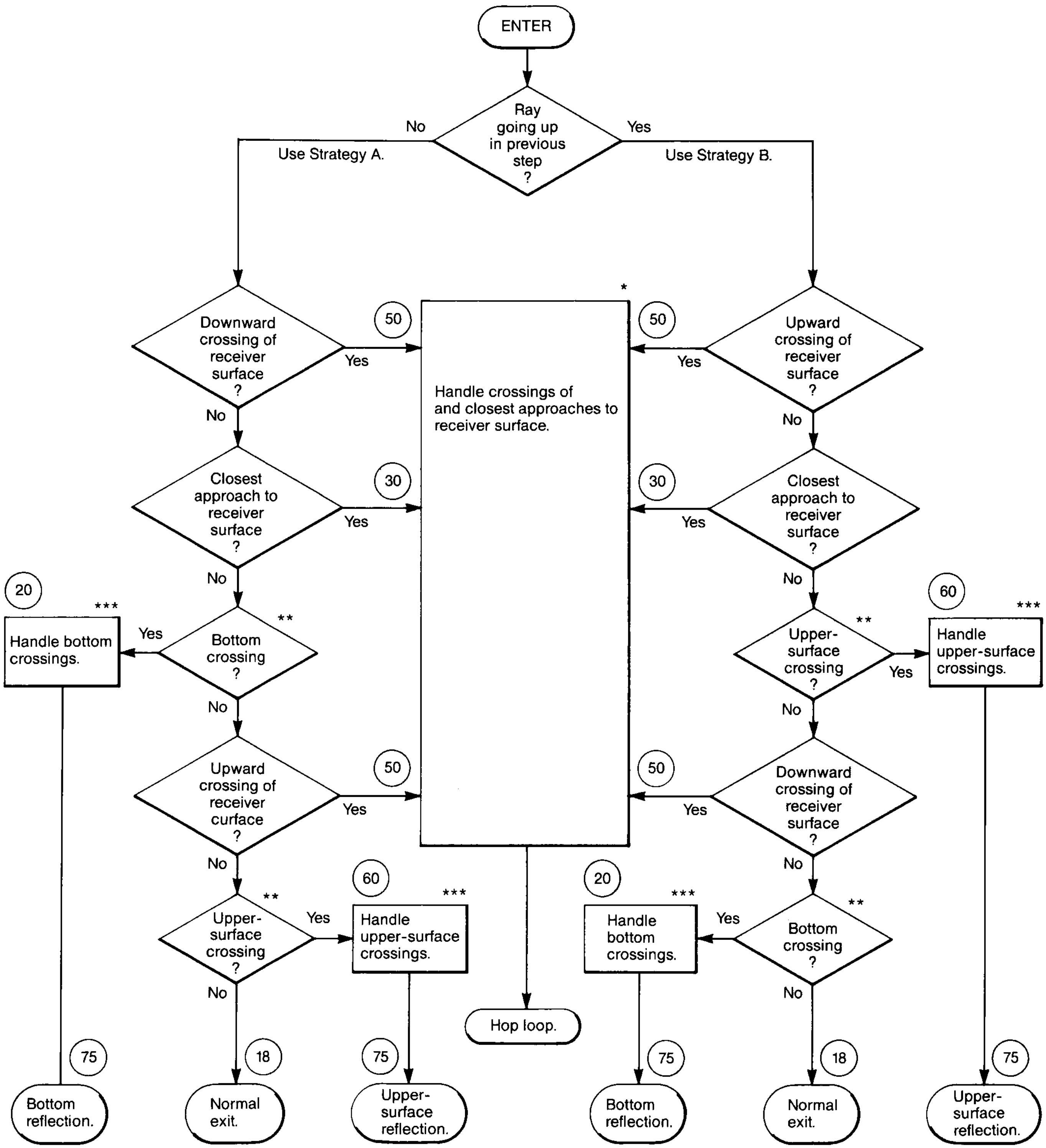

Figure 7.7. Flow chart for details of handling surface crossings in subroutine TRACE. Circled block numbers correspond to program statement numbers.

* See Figure 7.8 for details

** Logical function PCROSS estimates whether a bottom crossing or upper-surface crossing has occurred.

*** Subroutine RCROSS handles bottom crossings and upper-surface crossings.

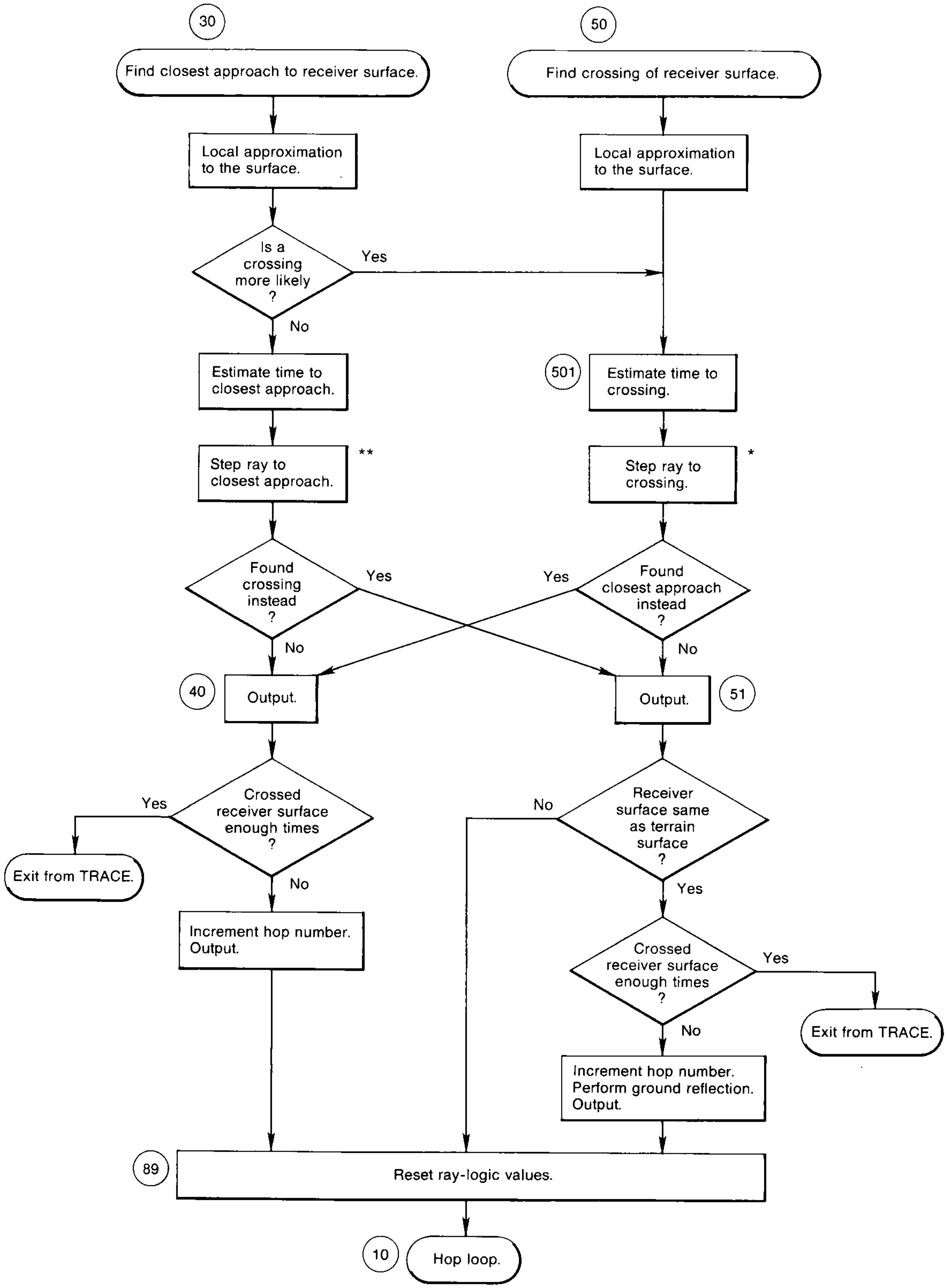

Figure 7.8. Details of finding crossings of and closest approaches to receiver surface. Circled block numbers correspond to program statement numbers in subroutine TRACE.

*   See Figure 7.9 for details (subroutine BACKUP).

** See Figure 7.9 for details (entry point GRAZE in subroutine BACKUP).

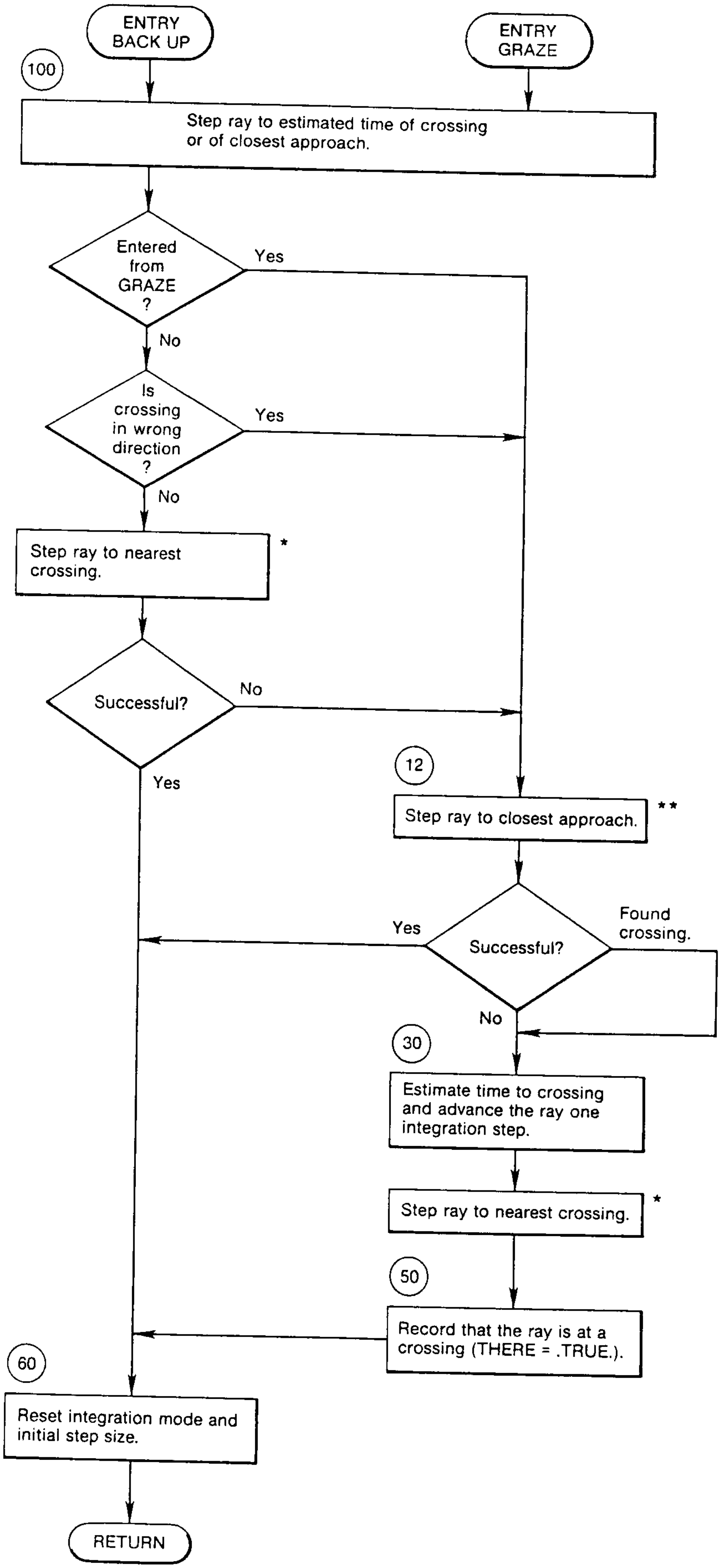

Figure 7.9. Flow chart for subroutine BACKUP. Circled block numbers correspond to program statement numbers. Entry BACKUP steps the ray to a crossing with a specified height. Entry GRAZE steps the ray to a point of closest approach to the specified surface. The calling routine (subroutine TRACE) specifies the height with which the ray is to intersect, the direction of crossing (up or down), and estimates the time of crossing (group time delay). Asterisks identify supplementary procedures.

* See Figure 7.10 for details of the algorithm that steps the ray by numerical integration to the nearest crossing of a specified height.

** See Figure 7.11 for details of the algorithm that steps the ray by numerical integration to a closest approach to a specified height.

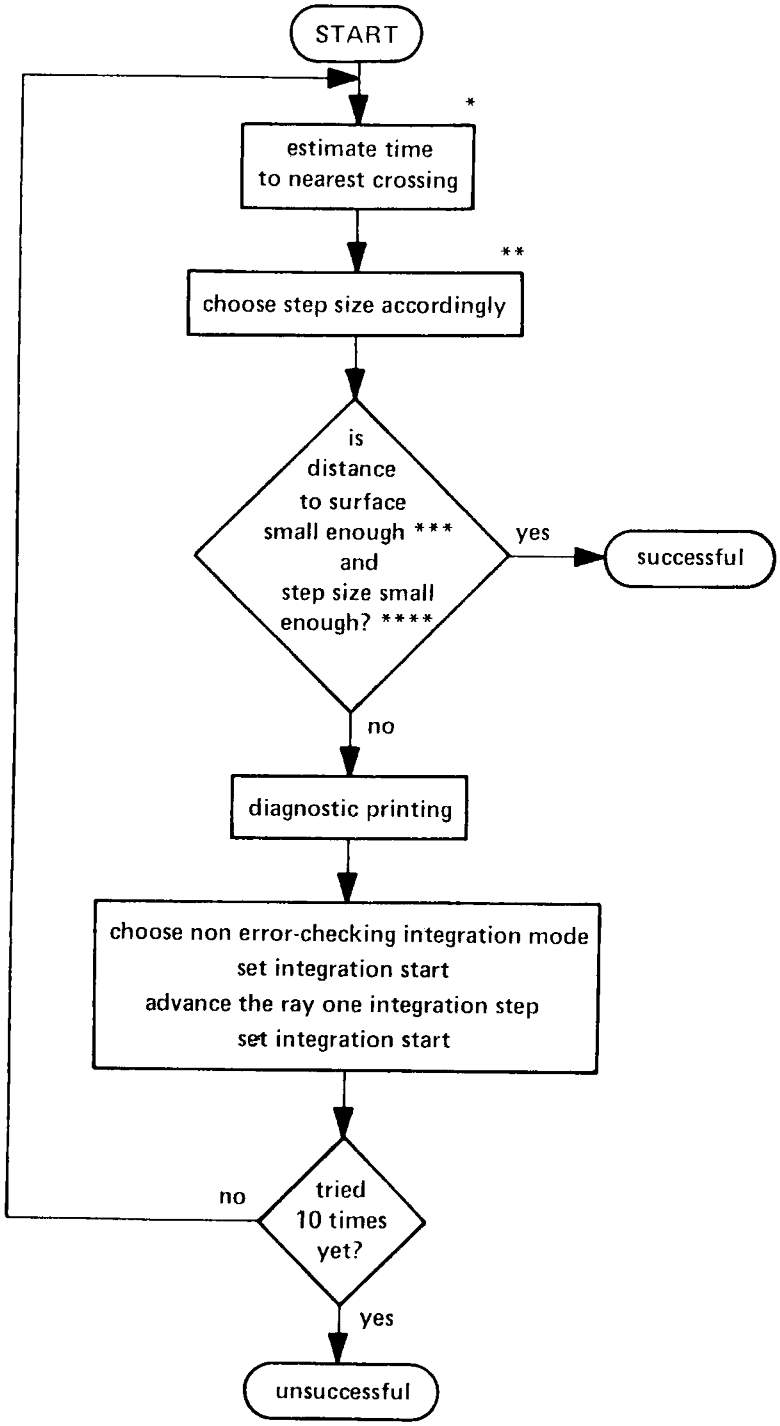

Figure 7.10. Flow chart for the algorithm that steps the ray by numerical integration to a crossing of a specified surface. Circled block numbers correspond to program statement numbers.

* See Equation (6.76) to estimate the time of the nearest crossing of the specified height.

** The step size should be no larger than that being used by the numerical integration routine to maintain accuracy in the error-checking mode.

*** 0.5×10^{-4} km.

**** Small enough to ensure the required accuracy and smaller than the smallest allowable step size.

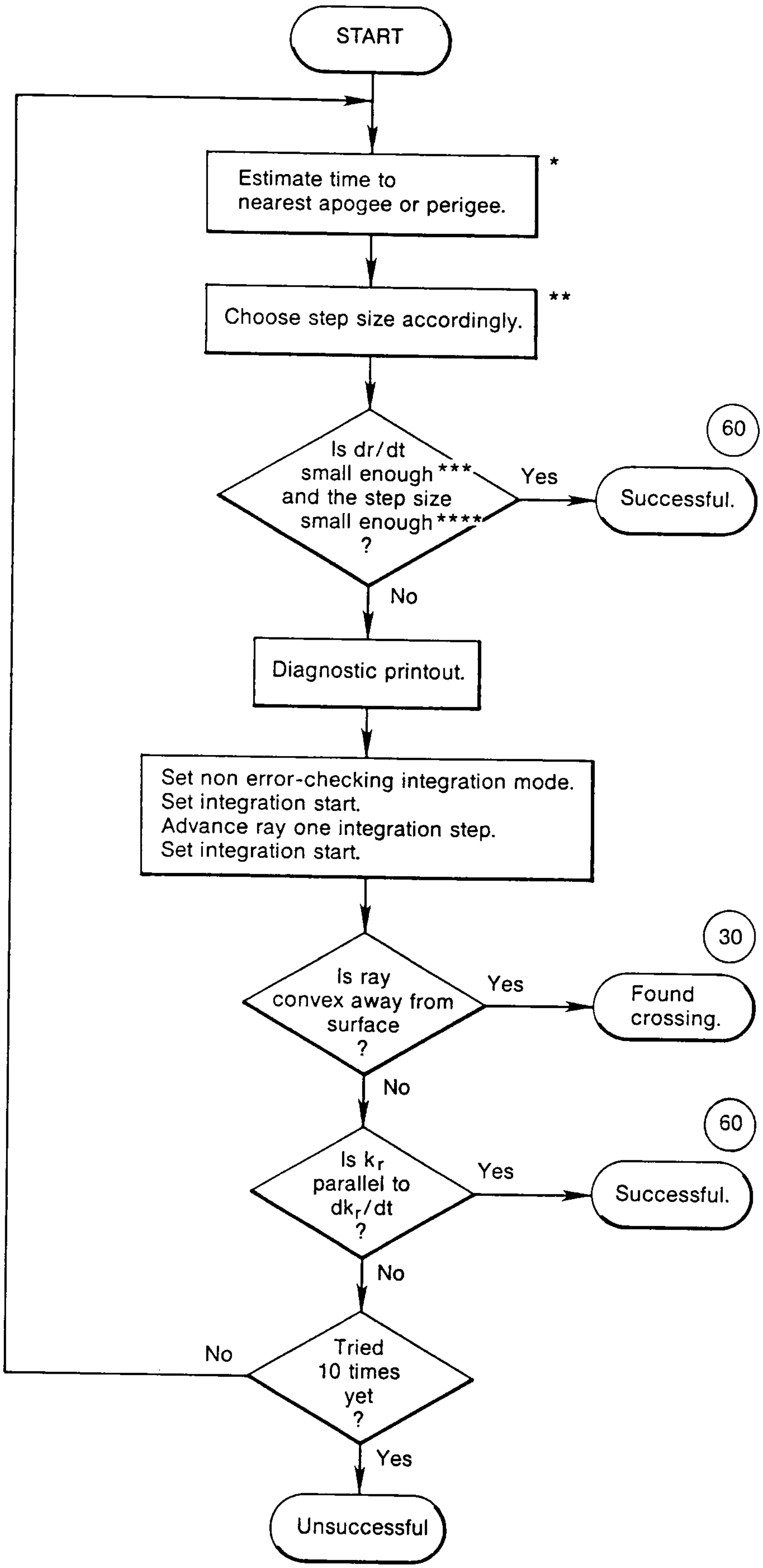

Figure 7.11. Flow chart for the algorithm that steps the ray by numerical integration to a point of closest approach to a specified surface. Circled block numbers correspond to program statement numbers.

* See Equation (6.74) to estimate the time of the specified surface.

** The step size should be no larger than that being used by the numerical integration routine to maintain accuracy in the error-checking mode.

*** 10^{-6} km/km.

**** Small enough to ensure the required accuracy and smaller than the smallest allowable step size.

Table 7.1--Definitions of the parameters in blank common

Position in common	Variable name	Definition
1-20	R	The dependent variables in the differential equations being integrated--the definitions of the first six are fixed, but the others may be varied by the program user
1	R(1) or R	r
2	R(2) or TH	θ
3	R(3) or PH	ϕ
4	R(4) or KR	k_r
5	R(5) or KTH	k_θ
6	R(6) or KPH	k_ϕ
7-12	R(7)-R(12) or RKVARS(1)-RKVARS(6)	Those variables the user has chosen to integrate, taken in the following order: P -phase path in kilometers A -absorption in decibels Δf -Doppler shift in hertz s -geometrical path length in kilometers
13-20	R(13)-R(20)	Reserved for future expansion
21	TPULSE	Group path length in kilometers (the independent variable in the differential equations)
22	CSTEP	Step length in group path
23-42	DRDT	The derivatives of the dependent variables with respect to the independent variable TPULSE

R and TPULSE are initialized in program RAYTRC and changed in subroutines TRACE, RKAM, and BACKUP.

CSTEP is calculated in subroutine RKAM.

DRDT is calculated in subroutine HAMLTN and used in subroutine RKAM.

Table 7.2--Definitions of the parameters in common block /MCONST/*

Position in common	Variable name	Definition
1	PI	π
2	PIT2	2π
3	PID2	$\pi/2$
4	DEGS	$180.0/\pi$
5	RAD	$\pi/180.0$
6	ALN10	$\log_e 10$

* These parameters are set in program RAYTRC.

Table 7.3--Definitions of the parameters in common block /PCONST/

Position in common	Variable name	Definition
1	CREF	A reference sound speed (1.500 km/s), used to convert group delay time in seconds to an equivalent group path length in kilometers, and to convert a phase time in seconds to an equivalent phase-path length in kilometers
2	RGAS	The gas constant, = 8.31436×10^{-3} kg (kg mole)$^{-1}$ km^2 s^{-2} K^{-1} (this value of the gas constant gives a sound speed in km/s). Used by HARPA.
3	GAMMA	γ, the ratio of specific heat at constant pressure to that at constant density, = 1.4. Used by HARPA.

Table 7.4--Common block usage by the core routines

Routine \ Common block	HDR	UCONC	UCONV	RKAMS	CGET	CRMACH	CRKTIME	TRLOCAL	RK	TRAC	FNDER	RIN	ERR	RAYDEV	FLGP	RINPL	FLG	HDRC	FILEC	PLT	RAYCON	ANNCTC	ANNCLL	LABCLT	DD	DDREZ	KNKN	DDLIM
RAYTRC	O								B			I	I	I	O		B	O	O									
CONBLK	O	O	O				O					O		B				O			O							
DFCNST						O																						
UCON		I	B																									
HAMLTN												I																
RKAM				B			B		B																			
RKAM1				O					B																			
TRACE							B	B	B	B							O											
PCROSS										I																		
RCROSS								O	O	B							O											
BACKUP									B	B																		
REFLECT										B	I																	
FIT										B	I																	
GET					O	I	I				O																	
GET1					O	I	I																					
READW1														I														
READW														I	I		I											
PRINTR									I			I	O				B											
OCNHD												I			I	I	B	I										
RAYPLT																	B		I	O								
PLOT																				B					O	O		
LABPLT												I						I							O			
PLTANH																					I			I	O			
SETXY																								O				
PLTANOT																						I	I	I	B			
PLTLB																								I	B			
PLOTBL																											O	O
DDBP																									I	B	B	B
DDVC																									I	B	B	B
DDTEXT																									I		B	

Notes:

1. "I" signifies that the routine uses information from the common block.
2. "O" signifies that the routine puts information into the common block.
3. "B" signifies that the routine both puts information into the common block and uses information from the common block.
4. Blank common, common blocks /MCONST/, /PCONST/, /WW/, and the common blocks listed in Tables 4.2 and 4.3 are not included in this table.

Table 7.5--Input and output variables to routines in common blocks other than blank common and labeled common blocks /MCONST/, /PCONST/, and /WW/ and other than the common blocks listed in Tables 4.2 and 4.3

Routine	Input parameters common block	Input parameters parameter name	Output parameters common block	Output parameters parameter name
RAYTRC	/FLG/	IHOP	/HDRC/	DAT
	/RIN/	KAY2	/HDRC/	INITID
	/FLG/	LINES	/FLG/	LINES
	/RK/	NEQS	/FLG/	NEWWP
	/ERR/	NERG	/FLG/	NEWWR
	/ERR/	NERP	/FILEC/	NPLTDP
	/ERR/	NERR	/FLGP/	NSET
	/ERR/	NERT	/HDR/	SEC
	/RAYDEV/	NRYIND	/HDRC/	TOD
	/RIN/	OMEGMAX	/RK/	RSTART
	/RIN/	OMEGMIN		
	/FLG/	PENET		
	/RIN/	SGN		
DFCNST			/CRMACH/	RMACH
READW1	/RAYDEV/	NDEVTMP		
	/RAYDEV/	NRYIND		
READW	/B1/→/B20/		/B1/→/B20/	
	/FLG/	LINES		
	/RAYDEV/	NDEVTMP		
	/RAYDEV/	NFRMAT		
	/RAYDEV/	NRYIND		
	/FLGP/	NSET		
UCON	/UCONC/	CNVC	/UCONV/	CNVV
	/UCONV/	CNVV		
	/UCONC/	PCV		
TRACE	/TRAC/	D2Z	/TRAC/	DROLD
	/TRAC/	GROUND	/RK/	E1MAX
	/CRKTIME/	IRKTIME	/RK/	E1MIN
	/TRAC/	RAD	/RK/	E2MAX
	/TRAC/	RAD1	/RK/	E2MIN
	/TRAC/	THERE	/RK/	FACT
	/TRAC/	ZDOT	/TRLOCAL/	FDOT
	/TRLOCAL/	RSIGN	/TRLOCAL/	GDOLD
	/TRLOCAL/	HOME	/TRLOCAL/	GDOT
	/TRLOCAL/	FDOT	/TRLOCAL/	GOLD
			/TRAC/	GROUND
			/TRAC/	HOME
			/FLG/	HPUNCH
			/FLG/	IHOP

Table 7.5--(continued)

Routine	Input parameters common block	Input parameters parameter name	Output parameters common block	Output parameters parameter name
TRACE (continued)			/CRKTIME/	IRKTIME
			/RK/	MODE
			/TRAC/	NEWRAY
			/FLG/	NEWTRC
			/FLG/	PENET
			/TRAC/	ROLD
			/TRLOCAL/	RSIGN
			/RK/	RSTART
			/RK/	STEP
			/TRAC/	THERE
			/TRAC/	TOLD
PCROSS	/TRAC/	OSMT		
	/TRAC/	SMT		
RCROSS	/TRAC/	RAD1	/TRLOCAL/	FDOT
	/TRAC/	ZDOT	/TRLOCAL/	HOME
			/FLG/	HPUNCH
			/TRLOCAL/	RSIGN
			/RK/	RSTART
HAMLTN	/RIN/			
RKAM	/RKAMS/	ALPHA	/RK/	E1MAX
	/RK/	E1MAX	/CRKTIME/	IRKTIME
	/RKAMS/	FV	/RKAMS/	MM
	/CRKTIME/	IRKTIME	/RK/	MODE
	/RKAMS/	MM	/RK/	NEQS
	/RK/	MODE	/RKAMS/	XV
	/RK/	NEQS		
	/RK/	RSTART		
	/RK/	STEP		
	/RKAMS/	XV		
	/RKAMS/	YU		
RKAM1	/RK/	E1MAX	/RKAMS/	ALPHA
	/RK/	E1MIN	/RKAMS/	EPM
	/RK/	E2MAX	/RK/	E1MIN
	/RK/	E2MIN	/RK/	FACT
	/RK/	FACT	/RKAMS/	FV
	/RK/	MODE	/RKAMS/	MM
	/RK/	NN	/RK/	RSTART
	/RK/	RSTART	/RKAMS/	XV
	/RK/	SPACE	/RKAMS/	YU

Table 7.5--(continued)

Routine	Input parameters common block	Input parameters parameter name	Output parameters common block	Output parameters parameter name
BACKUP	/TRAC/	DROLD	/RK/	MODE
	/TRAC/	D2Z	/RK/	RSTART
	/RK/	E1MAX	/RK/	STEP
	/RK/	E2MIN	/TRAC/	THERE
	/RK/	FACT	/TRAC/	TOLD
	/RK/	MODE	/TRAC/	ZDOT
	/TRAC/	RAD1		
REFLECT	/FNDER/	NPZPH		
	/FNDER/	NPZR		
	/FNDER/	NPZTH		
FIT	/TRAC/	DROLD	/TRAC/	D2Z
	/FNDER/	NPZPH	/TRAC/	OSMT
	/FNDER/	NPZPHPH	/TRAC/	RAD
	/FNDER/	NPZR	/TRAC/	RAD1
	/FNDER/	NPZRPH	/TRAC/	SMT
	/FNDER/	NPZRR	/TRAC/	ZDOT
	/FNDER/	NPZRTH		
	/FNDER/	NPZTH		
	/FNDER/	NPZTHPH		
	/FNDER/	NPZTHTH		
	/FNDER/	NZ		
	/TRAC/	TOLD		
GET	/CRKTIME/	IRKTIME	/FNDER/	NPZPH
	/CRKTIME/	RKTIME	/FNDER/	NPZPHPH
	/CRMACH/	RMACH	/FNDER/	NPZR
			/FNDER/	NPZRPH
			/FNDER/	NPZRR
			/FNDER/	NPZRTH
			/FNDER/	NPZTH
			/FNDER/	NPZTHPH
			/FNDER/	NPZTHTH
			/FNDER/	NSELECT
			/FNDER/	NTIME
			/FNDER/	NZ
			/CGET/	ZERO
GET1	/CRKTIME/	IRKTIME	/CGET/	ZERO
	/CRKTIME/	RKTIME		
	/CRMACH/	RMACH		
CONBLK	/RAYDEV/	NRYIND	/UCONC/	CNVC
			/UCONV/	CNVV
			/CRKTIME/	IRKTIME
			/RIN/	KVECT

Table 7.5--(continued)

Routine	Input parameters common block	Input parameters parameter name	Output parameters common block	Output parameters parameter name
CONBLK (continued)			/RIN/	LPOLAR
			/RAYCON/	MCONP
			/RAYDEV/	NDEVTMP
			/RAYDEV/	NFRMAT
			/RAYDEV/	NRYIND
			/RIN/	OMEGMAX
			/RIN/	OMEGMIN
			/UCONC/	PCV
			/RIN/	POLAR
			/RIN/	RAYNAME
			/HDRC/	DAT
			/HDRC/	INITID
			/PROCFL/	LIST
			/PROCFL/	PITBL
			/PROCFL/	PNTBL
			/HDR/	SEC
			/HDRC/	TOD
PRINTR	/FLG/	HPUNCH	/FLG/	LINES
	/FLG/	IHOP	/ERR/	NERG
	/RIN/	KAY2	/ERR/	NERP
	/FLG/	LINES	/ERR/	NERR
	/RK/	NEQS	/ERR/	NERT
	/FLG/	NTYP	/FLG/	NEWWP
	/RIN/	POLAR		
	/RIN/	TYPE		
OCNHD	/HDRC/	DAT	/FLG/	LINES
	/RINPL/	DISPM	/FLG/	NTYP
	/FLG/	LINES		
	/RIN/	MODRIN		
	/FLGP/	NSET		
	/RIN/	RAYNAME		
	/HDRC/	TOD		
PUTKST	/FLG/	LINES	/FLG/	LINES
RAYPLT	/FLG/	NEWTRC	/PLT/	ALPHA
	/FLG/	NEWWR	/PLT/	APLT
	/FILEC/	NPLTDP	/FLG/	NEWTRC
			/FLG/	NEWWR
			/PLT/	PRESET
			/PLT/	RMAX
			/PLT/	RMIN
			/PLT/	XL
			/PLT/	XR
			/PLT/	YB
			/PLT/	YT

Table 7.5--(continued)

Routine	Input parameters common block	Input parameters parameter name	Output parameters common block	Output parameters parameter name
PLOT	/PLT/	ALPHA	/DD/	IX
	/PLT/	APLT	/DD/	IY
	/PLT/	RESET	/PLT/	RESET
	/PLT/	RMAX	/DDREZ/	DDHIX
	/PLT/	RMIN	/DDREZ/	DDHIY
	/PLT/	XMAXO		
	/PLT/	XMINO		
	/PLT/	YMAXO		
	/PLT/	YMINO		
LABPLT	/HDRC/	DAT	/DD/	IOR
	/RIN/	MODRIN	/DD/	IS
			/DD/	IT
			/DD/	IX
			/DD/	IY
PLTANH	/RAYCON/	MCONP	/DD/	IOR
	/LABCLT/	PROJCT	/DD/	IX
	/LABCLT/	RMAX	/DD/	IY
	/LABCLT/	RMIN		
	/LABCLT/	THMAX		
	/LABCLT/	THMIN		
SETXY			/LABCLT/	PROJCT
			/LABCLT/	RMAX
			/LABCLT/	RMIN
			/LABCLT/	THMAX
			/LABCLT/	THMIN
PLOTANOT	/ANNCTC/	ANOTES	/DD/	IOR
	/ANNCTC/	HNOTES	/DD/	IX
	/DD/	IX	/DD/	IY
	/DD/	IY		
	/ANNCTL/	LENA		
	/ANNCTL/	LENHA		
	/LABCLT/	THMAX		
	/LABCLT/	THMIN		
PLTLB	/DD/	IX	/DD/	IOR
	/DD/	IY	/DD/	IX
	/LABCLT/	PROJCT		
	/LABCLT/	RMAX		
	/LABCLT/	RMIN		

Table 7.5--(continued)

Routine	Input parameters common block	Input parameters parameter name	Output parameters common block	Output parameters parameter name
PLOTBL			/KNKN/	
			/DDLIM/	
DDBP	/DD/	IX	/KNKN/	KNBP
	/DD/	IY	/DDLIM/	MNIX
	/KNKN/	KNBP	/DDLIM/	MNIY
	/DDLIM/	MNIX	/DDLIM/	MXIX
	/DDLIM/	MNIY	/DDLIM/	MXIY
	/DDLIM/	MXIX	/DDREZ/	DDHIX
	/DDLIM/	MXIY	/DDREZ/	DDHIY
	/DDREZ/	DDHIX		
	/DDREZ/	DDHIY		
DDVC	/DD/	IX	/KNKN/	KNVC
	/DD/	IY	/DDLIM/	MNIX
	/KNKN/	KNVC	/DDLIM/	MNIY
	/DDLIM/	MNIX	/DDLIM/	MXIX
	/DDLIM/	MNIY	/DDLIM/	MXIY
	/DDLIM/	MXIX	/DDREZ/	DDHIX
	/DDLIM/	MXIY	/DDREZ/	DDHIY
	/DDREZ/	DDHIX		
	/DDREZ/	DDHIY		
DDTEXT	/DD/	IOR	/KNKN/	KNDT
	/DD/	IX		
	/DD/	IY		
	/KNKN/	KNDT		

Table 7.6--Definitions of the parameters in common block /HDR/

Position in common	Variable name	Definition
1	SEC	Total elapsed computer calculation time at end of calculating previous raypath

Table 7.7--Definitions of the parameters in common block /UCONC/

Position in common	Variable name	Definition
1-4	PCV	List of valid unit types for units conversion: blank (no conversion), AN (angle), LN (length), FQ (frequency, AM (amplitude)
5-20	CNVC	An array of lists of valid physical units for each unit type for units conversion: blank (no conversion), M (meters), KM (kilometers), DG (degrees), etc

Table 7.8--Definitions of the parameters in common block /UCONV/

Position in common	Variable name	Definition
1-16	CNVV	An array of units conversion factors corresponding to the array CNVC in common block /UCONC/

Table 7.9--Definitions of the parameters in common block /RKAMS/

Position in common	Variable name	Definition
1-5	XV	Values of independent variable for 5 integration steps
6-85	FV	Values of the derivatives of the 20 dependent variables for 4 integration steps
86-285	YU	Values of the 20 dependent variables for 5 integration steps (in double precision)
286	EPM	The amount by which the independent variable changed during the previous call to SUBROUTINE RKAM1
287	ALPHA	Value of the independent variable at the beginning of the latest integration step
288	MM	Relative integration step number (varies from 1 to 4)

Table 7.10--Definitions of the parameters in common block /CGET/

Position in common	Variable name	Definition
1	ZERO	A great circle distance at sea level corresponding to a central earth angle that is twice the smallest floating point variable that can be stored in one single precision word in the computer being used

Table 7.11--Definitions of the parameters in common block /CRMACH/

Position in common	Variable name	Definition
1	RMACH(1)	Smallest positive magnitude = B**(EMIN-1)
2	RMACH(2)	Largest magnitude = B**EMAX*(1-B**(-T))
3	RMACH(3)	Smallest relative spacing = B**(-T)
4	RMACH(4)	Largest relative spacing = B**(1-T)
5	RMACH(5)	$Log_{10}B = Log_{10}2$

Notes: 1. B = the number base used by the computer (= 2 for most computers)
2. T = the number of bits in the mantissa of a floating point number
3. EMIN = the most negative allowable exponent
4. EMAX = the largest allowable positive exponent

Table 7.12--Definitions of the parameters in common block /CRKTIME/

Position in common	Variable name	Definition
1	IRKTIME	The number of times that SUBROUTINE RKAM has been called (used to compare FTIME or GTIME with to know whether F or G need to be updated)
1	RKTIME	Floating point name of IRKTIME

Table 7.13--Definitions of the parameters in common block /TRLOCAL/

Position in common	Variable name	Definition
1	RSIGN	+1 if next receiver-surface crossing is going up; -1 if going down
2	HOME	.TRUE. if ray is going away from receiver surface; .FALSE. otherwise
3	FDOT	Rate of change of distance of ray above the receiver surface
4	GDOT	Rate of change of distance of ray above the terrain
5	GOLD	Value of G at previous integration step (= distance of ray above terrain)
6	GDOLD	Value of GDOT at previous integration step

Table 7.14--Definitions of the parameters in common block /RK/*

Position in common	Variable name	Definition
1	N	The number of equations being integrated
2	STEP	The initial step in group path in kilometers
3	MODE	Defines type of integration used (same as W41), see Section 5.3.2
4	E1MAX	Maximum allowable single step error (same as W42)
5	E1MIN	Minimum allowable single step error (= W42/W43)
6	E2MAX	Maximum step length (same as W45)
7	E2MIN	Minimum step length (same as W46)
8	FACT	Factor to use to decrease step length (same as W47)
9	RSTART	Nonzero to initialize numerical integration, zero to continue integration

* These parameters are calculated in subroutine READW (some are temporarily reset in subroutine BACKUP) and are used in subroutine RKAM.

Table 7.15--Definitions of the parameters in common block /TRAC/*

Position in common	Variable name	Definition
1	GROUND	.TRUE. if the ray is on the ocean bottom
2	PERIGE	.TRUE. if the ray has just made a perigee
3	THERE	.TRUE. if the ray is at the receiver height
4	MINDIS	.TRUE. if the ray has just made a closest approach to the receiver height
5	NEWRAY	Not used in this version of the program
6	SMT	An estimation of the vertical distance to an apogee or perigee of the ray
7	OSMT	Value of SMT at previous integration step
8-27	ROLD	Value of R(1) (=r in r,θ,ϕ earth-centered spherical polar coordinate system) at previous integration step
28-47	DROLD	Value of dr/dt at previous integration step
48	TOLD	Value of t (= independent variable for numerical integration) at previous integration step
49	ZDOT	dZ/dt (= dF/dt or dG/dt, depending on the situation)
50	D2Z	d^2Z/dt^2 (= d^2F/dt^2 or d^2G/dt^2, depending on the situation)
51	RAD	$(dZ/dt)^2 - 2\ Z\ d^2Z/dt^2$
52	RAD1	$\sqrt{RAD}$

* These parameters are used for communication between subroutines TRACE and BACKUP.

Table 7.16--Definitions of the parameters in common block /FNDER/

Position in common	Variable name	Definition	Value
1-20	GY	Dummy variable to protect the other variables from being klobbered by the CRAY XMP computer	---
21	NZ	Relative position of F in common block /RR/ (or G in common block /GG/)	1
22	NPZR	Relative position of PFR in common block /RR/ (or PGR in common block /GG/)	2
23	NPZRR	Relative position of PFRR in common block /RR/ (or PGRR in common block /GG/)	3
24	NPZRTH	Relative position of PFRTH in common block /RR/ (or PGRTH in common block /GG/)	4
25	NPZRPH	Relative position of PFRPH in common block /RR/ (or PGRPH in common block /GG/)	5
26	NPZTH	Relative position of PFTH in common block /RR/ (or PGTH in common block /GG/)	6
27	NPZPH	Relative position of PFPH in common block /RR/ (or PGPH in common block /GG/)	7
28	NPZTHTH	Relative position of PFTHTH in common block /RR/ (or PGTHTH in common block /GG/)	8
29	NPZPHPH	Relative position of PFPHPH in common block /RR/ (or PGPHPH in common block /GG/)	9
30	NPZTHPH	Relative position of PFTHPH in common block /RR/ (or PGTHPH in common block /GG/)	10
31	NSELECT	Relative position of FSELECT in common block /RR/ (or GSELECT in common block /GG/)	11
32	NTIME	Relative position of FTIME in common block /RR/ (or GTIME in common block /GG/)	12

Table 7.17--Definitions of the parameters in common block /RIN/*

Position in common	Variable name	Definition
1-8	MODRIN	Description of version of DISPER in BCD
9-14	RAYNAME	Hollerith names of the characteristic rays in a birefringent medium (= blank for this version of the program)
15-17	TYPE	= Hollerith 1 or 3 if this version of DISPER includes wind, = Hollerith 2 or 3 if this version of DISPER includes losses
18	SPACE	TRUE, if the ray is in a homogeneous non-dissipative medium (Unconditionally set to FALSE in this version of the program)
19	OMEGMIN	Minimum frequency for nonevanescent propagation (= 0 for this version of the program)
20	OMEGMAX	Maximum frequency for nonevanescent propagation (not applicable for this version of the program, set to 0)
21,22	KAY2	k^2, square of the complex wave number
23,24	H	Hamiltonian (complex)
25,26	PHPT	$\partial H/\partial t$ (complex)
27,28	PHPR	$\partial H/\partial r$ (complex)
29,30	PHPTH	$\partial H/\partial \theta$ (complex)
31,32	PHPPH	$\partial H/\partial \phi$ (complex)
33,34	PHPOM	$\partial H/\partial \omega$ (complex)
35,36	PHPKR	$\partial H/\partial k_r$ (complex)
37,38	PHPKTH	$\partial H/\partial k_\theta$ (complex)
39,40	PHPKPH	$\partial H/\partial k_\phi$ (complex)
41,42	KPHPK	$\vec{k} \cdot \partial H/\partial \vec{k}$ (complex) $= k_r \partial H/\partial k_r + k_\theta \, \partial H/\partial k_\theta + k_\phi \, \partial H/\partial k_\phi$
43,44	POLAR	Characteristic transverse polarization of the wave (complex) (= 0 for this version of the program)
45,46	LPOLAR	Characteristic longitudinal polarization of the wave (complex) (= 1 for this version of the program)
47	SGN	= +1 or -1; used for ray tracing in complex space

* These parameters are calculated in subroutine DISPER and used in subroutine HAMLTN.

Note: In some subroutines, the real and imaginary parts of the complex variables have separate names.

Table 7.18--Definitions of the parameters in common block /ERR/

Position in common	Variable name	Definition
1	NERG	Index number for the dependent variable for the integration that gives G
2	NERR	Index number for the dependent variable for the integration that gives $\partial G/\partial r$
3	NERT	Index number for the dependent variable for the integration that gives $\partial G/\partial \theta$
4	NERP	Index number for the dependent variable for the integration that gives $\partial G/\partial \phi$

Table 7.19--Definitions of the parameters in common block /RAYDEV/

Position in common	Variable name	Definition
1	NRYIND	Device unit number for input data
2	NDEVTMP	Device unit number for temporary output and input
3	NFRMAT	Device unit number for secondary input file (not used by ray tracing program)
4	NDEVGRP	Device unit number for graphics output
5	NDEVBIN	Device unit number for binary raypath coordinate output

Table 7.20--Definitions of the parameters in common block /FLGP/

Position in common	Variable name	Definition
1	NSET	Runset number

Table 7.21--Definitions of the parameters in common block /RINPL/

Position in common	Variable name	Definition
1	DISPM	Character string identifier for the dispersion relation model

Table 7.22--Definitions of the parameters in common block /FLG/*

Position in common	Variable	Definition
1	NTYP	Wave polarization indicator (not used in this version of program)
2	NEWWR	Set equal to .TRUE. to tell subroutine RAYPLT there is a new W array
3	NEWWP	Set equal to .TRUE. to tell subroutine PRINTR there is a new W array
4	PENET	Set equal to .TRUE. if the ray left the allowed region of the ocean
5	LINES	Number of lines printed on the current page
6	IHOP	Hop number (at the beginning of each ray, subroutine TRACE sets this parameter to zero so that subroutine RAYPLT will begin a new line in plotting the raypath, and subroutine PRINTR will print column headings and punch a transmitter rayset)
7	HPUNCH	The height to be output on the raysets

* The parameters are used to communicate between various subroutines.

Table 7.23--Definitions of the parameters in common block /HDRC/

Position in common	Variable name	Definition
1	INITID	Character string for user name and phone number identifier for graphics output
2	DAT	Character string for the date of the computer run
3	TOD	Character string for the time of day of the computer run

Table 7.24--Definitions of the parameters in common block /FILEC/

Position in common	Variable name	Definition
1	NPLTDP	Set equal to the device unit number for binary raypath coordinate output (variable in position 5 of common block /RAYDEV/) if binary raypath coordinate output has been requested, set to zero otherwise

Table 7.25--Definitions of the parameters in common block /PLT/*

Position in common	Variable name	Definition
1	XMINO,XL	The x-coordinate of the left side of the plotting area in kilometers
2	XMAXO,XR	The x-coordinate of the right side of the plotting area in kilometers
3	XMINO,YB	The y-coordinate of the bottom of the plotting area in kilometers
4	XMAXO,YT	The y-coordinate of the top of the plotting area in kilometers
5	RESET	Set equal to one whenever the plotting area is changed

* These parameters are used for communication between subroutine RAYPLT and subroutine PLOT.

Table 7.26--Definitions of the parameters in common block /RAYCON/

Position in common	Variable name	Definition
1	MCONP	Set to zero for the raytracing program to indicate that the abscissa in raypath plots is a central-earth angle in radians, set non-zero for the contouring program to indicate that the abscissa in contour plots is a great-circle distance in kilometers

Table 7.27--Definitions of the parameters in common block /ANNCTC/

Position in common	Variable name	Definition
1-8	ANOTES	Character strings to label the ordinate of raypath plots
9-20	HNOTES	Character strings to label the abscissa of raypath plots

Table 7.28--Definitions of the parameters in common block /ANNCTL/

Position in common	Variable name	Definition
1-4	LENA	Lengths of the character strings that label the ordinate of raypath plots
5-7	LENHA	Lengths of the character strings that label the abscissa of raypath plots

Table 7.29--Definitions of the parameters in common block /LABCLT/

Position in common	Variable name	Definition
1	PROJCT	Number that indicates which type of projection is being used for raypath plots
2	THMIN	θ_{min}, minimum value of the abscissa of a raypath plot
3	THMAX	θ_{max}, maximum value of the abscissa of a raypath plot
4	RMIN	r_{min}, minimum value of the ordinate of a raypath plot
5	RMAX	r_{max}, maximum value of the ordinate of a raypath plot

Table 7.30a--Definitions of the parameters in common block /DD/

Position in common	Variable name	Definition
1	IN	Intensity IN = 0 specifies normal intensity IN = 1 specifies high intensity
2	IOR	Orientation IOR = 0 specifies upright orientation IOR = 1 specifies rotated orientation (90° counterclockwise)
3	IT	Italics (Font) IT= 0 specifies non-italic (Roman) symbols IT = 1 specifies italic symbols
4	IS	Symbol size IS = 0 specifies miniature size IS = 1 specifies small size IS = 2 specifies medium size IS = 3 specifies large size
5	IC	Symbol case IC = 0 specifies uppercase IC = 1 specifies lowercase
6	ICC	Character code, 0-63 (R1 format) ICC and IC together specify the symbol plotted
7	IX	X-coordinate, 0-1023
8	IY	Y-coordinate, 0-1023

Table 7.30b--Definitions of the parameters in common block /DDREZ/

Position in common	Variable name	Definition
1	DDHIX	X-coordinate (real), 0.0-1023.0
2	DDHIY	Y-coordinate (real), 0.0-1023.0

Table 7.31--Definitions of the parameters in common block /KNKN/

Position in common	Variable name	Definition
1	KNBP	Number of times SUBROUTINE DDBP was called
2	KNVC	Number of times SUBROUTINE DDVC was called
3	KNDT	Number of times SUBROUTINE DDTEXT was called

Table 7.32--Definitions of the parameters in common block /DDLIM/

Position in common	Variable name	Definition
1	MXIX	Maximum value of IX
2	MXIY	Maximum value of IY
3	MNIX	Minimum value of IX
4	MNIY	Minimum value of IY

Table 7.33--Definitions of the parameters in common block /UU/

Position in common	Variable name	Definition
1-4	MODU	Current-velocity model and parameter identification
1	MODU(1)	Name of current-velocity subroutine
2	MODU(2)	Current-velocity parameter identification number
3	MODU(3)	Name of current-velocity perturbation subroutine
4	MODU(4)	Current-velocity perturbation parameter identification number
5	V	$\|V\|$, current speed in km/s
6	PVT	$\partial \|V\|/\partial t$
7	PVR	$\partial \|V\|/\partial r$
8	PVTH	$\partial \|V\|/\partial \theta$
9	PVPH	$\partial \|V\|/\partial \phi$
10	VR	V_r, upward component of current velocity
11	PVRT	$\partial V_r/\partial t$
12	PVRR	$\partial V_r/\partial r$
13	PVRRTH	$\partial V_r/\partial \theta$
14	PVRPH	$\partial V_r/\partial \phi$
15	VTH	V_θ, southward component of current velocity
16	PVTHT	$\partial V_\theta/\partial t$
17	PVTHR	$\partial V_\theta/\partial r$
18	PVTHTH	$\partial V_\theta/\partial \theta$
19	PVTHPH	$\partial V_\theta/\partial \phi$
20	VPH	V_ϕ, eastward component of current velocity
21	PVPHT	$\partial V_\phi/\partial t$
22	PVPHR	$\partial V_\phi/\partial r$
23	PVPHTH	$\partial V_\phi/\partial \theta$
24	PVPHPH	$\partial V_\phi/\partial \phi$

Table 7.34--Definitions of the parameters in common block /CC/

Position in common	Variable name	Definition common
1-4	MODC	Sound-speed model and parameter identification
1	MODC(1)	Name of sound-speed subroutine
2	MODC(2)	Sound-speed parameter identification number
3	MODC(3)	Name of sound-speed perturbation subroutine
4	MODC(4)	Sound-speed perturbation parameter identification number
5	CS	C^2, square of sound speed in km^2/s^2
6	PCST	$\partial C^2/\partial t$
7	PCSR	$\partial C^2/\partial r$
8	PCSTH	$\partial C^2/\partial \theta$
9	PCSPH	$\partial C^2/\partial \phi$

Table 7.35--Definitions of the parameters in common block /LL/

Position in common	Variable name	Definition
1-4	MODL	Absorption model and parameter identification
1	MODL(1)	Name of absorption subroutine
2	MODL(2)	Absorption parameter identification number
3	MODL(3)	Name of absroption-perturbation subroutine
4	MODL(4)	Absorption-perturbation-parameter identification number
5	ALPHA	α, absorption coefficient in nepers per km

Table 7.36--Definitions of the parameters in common block /SS/

Position in common	Variable name	Definition
1-4	MODSURF	Ocean-surface model and parameter identification
1	MODSURF(1)	Name of ocean-surface subroutine
2	MODSURF(2)	Ocean surface parameter identification number
3	MODSURF(3)	Name of ocean surface perturbation subroutine
4	MODSURF(4)	Ocean surface perturbation parameter identification number
5	U	$u(r,\theta,\phi)$ defined in the same way as $f(r,\theta,\phi)$ in (6.72)-(6.74)
6	PUR	$\partial u/\partial r$
7	PURR	$\partial^2 u/\partial r^2$
8	PURTH	$\partial^2 u/\partial r \partial \theta$
9	PURPH	$\partial^2 u/\partial r \partial \phi$
10	PUTH	$\partial u/\partial \theta$
11	PUPH	$\partial u/\partial \phi$
12	PUTHTH	$\partial^2 u/\partial \theta^2$
13	PUPHPH	$\partial^2 u/\partial \phi^2$
14	PUTHPH	$\partial^2 u/\partial \theta \partial \phi$
15	USELECT	= "SURFACE"
16	UTIME	An integer that is initialized to equal -1 at the beginning of each raypath calculation and is incremented by 1 at each integration step so that it is possible to determine whether the variables in this common block are current

Table 7.37--Definitions of the parameters in common block /RR/

Position in common	Variable name	Definition
1-4	MODREC	Receiver-surface model and parameter identification
1	MODREC(1)	Name of receiver-surface subroutine
2	MODREC(2)	Parameter identification number for receiver-surface model
3	MODREC(3)	Unused now
4	MODREC(4)	Unused now
5	F	$f(r,\theta,\phi)$ defined in (6.72)-(6.74)
6	PFR	$\partial f/\partial r$
7	PFRR	$\partial^2 f/\partial r^2$
8	PFRTH	$\partial^2 f/\partial r \partial \theta$
9	PFRPH	$\partial^2 f/\partial r \partial \phi$
10	PFTH	$\partial f/\partial \theta$
11	PFPH	$\partial f/\partial \phi$
12	PFTHTH	$\partial^2 f/\partial \theta^2$
13	PFPHPH	$\partial^2 f/\partial \phi^2$
14	PFTHPH	$\partial^2 f/\partial \theta \partial \phi$
15	FSELECT	= "RECEIVER"
16	FTIME	An integer that is initialized to equal -1 at the beginning of each raypath calculation and is incremented by 1 at each integration step so that it is possible to determine whether the variables in this common block are current

Table 7.38--Definitions of the parameters in common block /GG/

Position in common	Variable name	Definition
1-4	MODG	Bottom model and parameter identification
1	MODG(1)	Name of terrain subroutine
2	MODG(2)	Bottom-parameter identification number
3	MODG(3)	Name of terrain-perturbation subroutine
4	MODG(4)	Bottom-perturbation parameter identification number
5	G	$g(r,\theta,\phi)$ defined in the same way as $f(r,\theta,\phi)$ in (6.72)-(6.74)
6	PGR	$\partial g/\partial r$
7	PGRR	$\partial^2 g/\partial r^2$
8	PGRTH	$\partial^2 g/\partial r \partial \theta$
9	PGRPH	$\partial^2 g/\partial r \partial \phi$
10	PGTH	$\partial g/\partial \theta$
11	PGPH	$\partial g/\partial \phi$
12	PGTHTH	$\partial^2 g/\partial \theta^2$
13	PGPHPH	$\partial^2 g/\partial \phi^2$
14	PGTHPH	$\partial^2 g/\partial \theta \partial \phi$
15	GSELECT	= "BOTTOM"
16	GTIME	An integer that is initialized to equal -1 at the beginning of each raypath calculation and is incremented by 1 at each integration step so that it is possible to determine whether the variables in this common block are current

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APPENDIX A: PRINTOUT AND RAYSET LISTING FOR THE SAMPLE CASE

This appendix contains the printout and rayset listing for the sample case. Users should compare their sample-case output with this printout to be sure they are identical. The meanings of the printed quantities are explained in Sections 2.5.1 and 2.5.2, and the meanings of rayset quantities are listed in Figures 2.24 and 2.25.

***** H A R P O *****
HAMILTONIAN ACOUSTIC RAY-TRACING PROGRAM FOR THE OCEAN

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RUN SET NUMBER 1

OCEAN MODEL ID — N01

OCEAN MODEL DESCRIPTION — SAMPLE CASE FOR HARPO DOCUMENTATION REV. 8-19-86

MODEL TYPE	SUBROUTINE NAME	DATA SET ID	DESCRIPTION
DISPERSION RELATION	AWCWL		ACOUSTIC WAVE *** WITH CURRENT *** WITH LOSSES
BACKGROUND CURRENT VELOCITY	VVORTX3	3.00	VORTEX AT LONGITUDE 150 KM E, UMAX= 1.02 M/S, R= 50 KM
CURRENT VELOCITY PERTURBATION	NPCURR	.00	NO CURRENT PERTURBATION
BACKGROUND SOUND SPEED	CTANH	1.00	EL NINO BACKGROUND SOUND-SPEED PROFILE
SOUND SPEED PERTURBATION	CBLOB2	7.00	2% INCREASE IN C-SQUARED AT 150 KM LON., 1 KM DEPTH, 50 KM WIDE
BACKGROUND BOTTOM	GLORENZ	3.00	RIDGE .5 KM HIGH, 2 KM WIDE AT 10 KM N LATITUDE; BASE= -3 KM
BOTTOM PERTURBATION	NPBOTM	.00	NO BOTTOM PERTURBATION
ABSORPTION	SLLOSS	1.00	SKRETTING-LEROY ABSORPTION FORMULA
ABSORPTION PERTURBATION	NPABSR	.00	NO ABSORPTION PERTURBATION
RECEIVER SURFACE	RHORIZ	.00	RECEIVER SURFACE = SPHERE 1 KM BELOW MSL
OCEAN SURFACE	SHORIZ	1.00	OCEAN SURFACE = SPHERE AT MSL
OCEAN SURFACE PERTURBATION	NPSURF	.00	NO OCEAN SURFACE PERTURBATION

INPUT DATA FILE FOR RUN SET NUMBER 1

```
N01-1     SAMPLE CASE FOR HARPO DOCUMENTATION        REV. 8-19-86
   1    6370.           EARTH RADIUS TO MSL, KM (6370.)
   3       2.          TTRANSMITTER HEIGHT ABOVE MSL (T=ABOVE BOTTOM), KM
   4       0.    AN KM  N. TRANSMITTER LATITUDE, KM
   5       0.    AN KM  E. TRANSMITTER LONGITUDE, KM
   7     400.    FQ HZ  INITIAL FREQUENCY, HZ
  11      80.    AN DG  INITIAL AZIMUTH ANGLE, DEG
  15       2.    AN DG  INITIAL ELEVATION ANGLE, DEG
  16      16.    AN DG  FINAL   ELEVATION ANGLE, DEG
  17       2.    AN DG  STEP IN ELEVATION ANGLE, DEG
  19       0.           STOP RAYS THAT STRIKE BOTTOM (1=YES; 0=NO)
  20      -1.           RECEIVER HEIGHT ABOVE MSL, KM
  22      50.           MAXIMUM NUMBER OF HOPS (1.)
  23    1000.           MAXIMUM NUMBER OF STEPS PER HOP (1000.)
  26       5.           MAXIMUM RAY HEIGHT ABOVE MSL, KM
  27      -5.           MINIMUM RAY HEIGHT ABOVE MSL, KM
  28     210.           MAXIMUM RANGE AT MSL, KM
  29       0.           DO: EIGRAY/RNG-TIM/RNG-ELV/NEW-PROJ/RAYTRC/CONT/PROF
  33      20.           MAXIMUM ABSORPTION, DB (999.999)
  42     1.0E-06        MAXIMUM SINGLE-STEP INTEGRATION ERROR (1.0E-4)
  44      .1            INITIAL INTEGRATION STEP SIZE, KM (1.0)
  57       2.           PHASE PATH  (0=NO; 1=INTEGRATE; 2=INTEGRATE/PRINT)
  58       2.           ABSORPTION  (0=NO; 1=INTEGRATE; 2=INTEGRATE/PRINT)
  60       2.           PATH LENGTH (0=NO; 1=INTEGRATE; 2=INTEGRATE/PRINT)
  71      50.           NUMBER OF INTEGRATION STEPS PER PRINT [1.E31]
  72       1.           OUTPUT RAYSETS (1=YES; 0=NO)
  73       0.           DIAGNOSTIC PRINTOUT (1=YES; 0=NO)
  74       0.           PRINT EVERY W(71) RAY STEPS (0=YES; 1=N0)
  75     .15            FULANN PLOT LETTERING; HEIGHT= [0.15 IN]
  76       0.           BINARY RAY OUTPUT (1=YES; 0=NO)
  77      57.           LINES PER PAGE OF PRINTOUT (57.)
  81       4.           RAYPLOT PROJECTION PLANE (4 = VERT. RECTANGULAR)
  82      40.            PLOT-ORDINATE EXPANSION FACTOR [1.]
  83       0.    AN KM   N. LATITUDE OF LEFT PLOT EDGE, KM
  84       0.    AN KM   E. LONGITUDE OF LEFT PLOT EDGE, KM
  85      35.1   AN KM   N. LATITUDE OF RIGHT PLOT EDGE, KM
  86     200.    AN KM   E. LONGITUDE OF RIGHT PLOT EDGE, KM
  87      50.    AN KM   DISTANCE BETWEEN RANGE TICKS, KM (0 = AUTO)
  88      -3.            HEIGHT ABOVE MSL OF BOTTOM OF GRAPH, KM
  89       0.            HEIGHT ABOVE MSL OF TOP OF GRAPH, KM
  96       1.            DISTANCE BETWEEN DEPTH TICKS, KM (0 = AUTO)
 100       9.           VVORTX3 MODEL CHECK NUMBER
 102       3.            VVORTX3 BACKGROUND CURRENT DATA SET ID
 103     1.02    LN  M   MAXIMUM TANGENTIAL CURRENT, M/S
 104      50.            RADIUS OF VORTEX CORE, KM
 105       0.    AN KM   LATITUDE OF VORTEX CENTER, KM
 106     150.    AN KM   LONGITUDE OF VORTEX CENTER, KM
 107       1.            VERTICAL HALF-WIDTH OF VORTEX, KM
 108      -1.            HEIGHT OF VORTEX CENTER ABOVE MSL, KM
 150       7.           CTANH SOUND SPEED MODEL CHECK NUMBER
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152       1.              CTANH BACKGROUND SOUND SPEED DATA SET ID
175       2.             CBLOB2 SOUND SPEED PERTURBATION MODEL CHECK NUMBER
177       7.              CBLOB2 PERTURBATION SOUND SPEED DATA SET ID
178      .02              MAXIMUM FRACTIONAL INCREASE IN C SQUARED
179      -1.              HEIGHT OF MAX EFFECT ABOVE MSL, KM
180       0.    AN KM     LATITUDE OF MAX EFFECT, KM
181     150.    AN KM     LONGITUDE OF MAX EFFECT, KM
182       1.              VERTICAL HALF-WIDTH, KM
183      50.    AN KM     N-S  HALF-WIDTH, KM
184      50.    AN KM     E-W  HALF-WIDTH, KM
275       1.             RHORIZ RECEIVER MODEL CHECK NUMBER
300       4.             GLORENZ BOTTOM MODEL CHECK NUMBER
302       3.              GLORENZ BOTTOM MODEL DATA SET ID
303       .5              HEIGHT OF RIDGE, KM ABOVE BASE
304      10.    AN KM     N. LATITUDE OF RIDGE CENTER, KM
305       2.    AN KM     HALF-WIDTH OF THE RIDGE, KM
306      -3.              HEIGHT ABOVE MSL OF BASE OF RIDGE, KM
350       1.             SHORIZ MODEL CHECK NUMBER
352       1.              SHORIZ OCEAN SURFACE DATA SET ID
353       0.              HEIGHT OF OCEAN SURFACE ABOVE MSL, KM
500       1.             SLLOSS ABSORPTION MODEL CHECK NUMBER
502       1.              SLLOSS ABSORPTION DATA SET ID
503    0.006    AM DB     A COEFFICIENT, DB
504   0.2635    AM DB     B COEFFICIENT, DB
505    1000.    FQ HZ     OMEGA1, HZ
506    1700.    FQ HZ     OMEGA2, HZ
 -1                      DATA SUBSET FOR BACKGROUND CURRENT MODEL
  A  VORTEX AT LONGITUDE 150 KM E, UMAX= 1.02 M/S, R= 50 KM
  0        RETURN TO W-ARRAY DATA SET
 -2                      DATA SUBSET FOR PERTURBATION CURRENT MODEL
  A  NO CURRENT PERTURBATION
  0        RETURN TO W-ARRAY DATA SET
 -3                      DATA SUBSET FOR BACKGROUND SOUND-SPEED MODEL
  A  EL NINO BACKGROUND SOUND-SPEED PROFILE
  3     999.0
   LN  M        LN  M        LN  M
   0.           1532.        0.
   -20.         1531.5       -7.
   -50.         1509.        -20.
   -250.        1503.        -40.
   -450.        1485.        -300.
   -1500.       1485.        -400.
   -3000.       1508.        0.
   999.0
  0       RETURN TO W-ARRAY DATA SET
 -4                      DATA SUBSET FOR SOUND-SPEED PERTURBATION MODEL
  A  2% INCREASE IN C-SQUARED AT 150 KM LON., 1 KM DEPTH, 50 KM WIDE
  0       RETURN TO W-ARRAY DATA SET
 -8                      DATA SUBSET FOR RECEIVER-SURFACE MODEL
  A  RECEIVER SURFACE = SPHERE 1 KM BELOW MSL
  0       RETURN TO W-ARRAY DATA SET
 -9                      DATA SUBSET FOR BACKGROUND BOTTOM MODEL
  A  RIDGE .5 KM HIGH, 2 KM WIDE AT 10 KM N LATITUDE; BASE= -3 KM
  0       RETURN TO W-ARRAY DATA SET
-10                      DATA SUBSET FOR BOTTOM PERTURBATION MODEL
```

```
  A  NO BOTTOM PERTURBATION
  0       RETURN TO W-ARRAY DATA SET
-11                           DATA SUBSET FOR OCEAN SURFACE MODEL
  A  OCEAN SURFACE = SPHERE AT MSL
  0       RETURN TO W-ARRAY DATA SET
-12                           DATA SUBSET FOR OCEAN SURFACE PERTURBATION MODEL
  A  NO OCEAN SURFACE PERTURBATION
  0       RETURN TO W-ARRAY DATA SET
-17                           DATA SUBSET FOR OCEAN ABSORPTION MODEL
  A  SKRETTING-LEROY ABSORPTION FORMULA
  0       RETURN TO W-ARRAY DATA SET
-18                           DATA SUBSET FOR PERTURBATION ABSORPTION MODEL
  A  NO ABSORPTION PERTURBATION
  0       RETURN TO W-ARRAY DATA SET
  0                           **********  END OF RUN SET NUMBER 1  *********
```

INITIAL VALUES FOR THE W ARRAY
ONLY NONZERO VALUES PRINTED — ALL ANGLES IN RADIANS

N	W(N)
1	.637000000000000E+04
3	-.980769230769170E+00
7	.251327412287184E+04
11	.139626340159545E+01
15	.349065850398864E-01
16	.279252680319091E+00
17	.349065850398864E-01
20	-.100000000000000E+01
22	.500000000000000E+02
23	.100000000000000E+04
24	.157079632679490E+01
26	.500000000000000E+01
27	-.500000000000000E+01
28	.210000000000000E+03
33	.200000000000000E+02
41	.300000000000000E+01
42	.999999999999997E-06
43	.500000000000000E+02
44	.100000000000000E+00
45	.100000000000000E+03
46	.100000000000000E-07
47	.500000000000000E+00
57	.200000000000000E+01
58	.200000000000000E+01
60	.200000000000000E+01
71	.500000000000000E+02
72	.100000000000000E+01
75	.150000000000000E+00
77	.570000000000000E+02
81	.400000000000000E+01
82	.400000000000000E+02
85	.551020408163264E-02
86	.313971742543171E-01
87	.784929356357927E-02
88	-.300000000000000E+01
96	.100000000000000E+01
100	.900000000000000E+01
102	.300000000000000E+01
103	.102000000000001E-02
104	.500000000000000E+02
106	.235478806907378E-01
107	.100000000000000E+01
108	-.100000000000000E+01
150	.700000000000000E+01
152	.100000000000000E+01
175	.200000000000000E+01
177	.700000000000000E+01
178	.200000000000000E-01
179	-.100000000000000E+01
181	.235478806907378E-01
182	.100000000000000E+01
183	.784929356357927E-02
184	.784929356357927E-02
275	.100000000000000E+01
300	.400000000000000E+01
302	.300000000000000E+01
303	.500000000000000E+00
304	.156985871271585E-02
305	.313971742543171E-03
306	-.300000000000000E+01
350	.100000000000000E+01
352	.100000000000000E+01
500	.100000000000000E+01
502	.100000000000000E+01
503	.138155106185094E-02
504	.606731174662869E-01
505	.628318530717958E+04
506	.106814150222053E+05

AZIMUTH ANGLE OF TRANSMISSION = 80.000000 DEG TRANSMITTER LATITUDE = .000000 DEG FREQUENCY = 400.000000 HZ
ELEVATION ANGLE OF TRANSMISSION = 2.000000 DEG TRANSMITTER LONGITUDE = .000000 DEG SINGLE STEP ERROR = 1.000000E-06

ERROR	EVENT	ELEVATION ABOVE SEA LEVEL KM	ELEVATION ABOVE TERRAIN KM	RANGE KM	AZIMUTH DEVIATION XMTR DEG	AZIMUTH DEVIATION LOCAL DEG	ELEVATION ANGLE XMTR DEG	ELEVATION ANGLE LOCAL DEG	PULSE TIME SEC	PHASE TIME SEC	ABSORPTION DB	PATH LENGTH KM
.00E+00	XMTR	-.9808	2.0000	.0000				2.000	.0000	.0000	.0000	.0000
.85E-09	APOGEE	-.7737	2.1992	9.5046	-.018	-.019	1.205	-.014	6.4000	6.4000	.1405	9.5061
.85E-09	WAVE REV	-.7737	2.1992	9.5046	-.018	-.019	1.205	-.014	6.4000	6.4000	.1405	9.5061
-.1E-07		-.9379	2.0238	17.6732	-.018	-.020	.060	-1.916	11.9000	11.9000	.2613	17.6757
-.2E-07	RCVR	-1.0000	1.9582	19.4734	-.018	-.020	-.144	-2.022	13.1129	13.1129	.2879	19.4767
-.1E-07	PERIGEE	-1.3869	1.5043	35.8077	-.017	-.023	-.811	.016	24.1129	24.1129	.5294	35.8134
-.1E-07	WAVE REV	-1.3869	1.5043	35.8077	-.017	-.023	-.811	.016	24.1129	24.1129	.5294	35.8134
-.1E-07		-1.1622	1.5593	47.3932	-.017	-.025	-.433	1.908	31.9129	31.9129	.7007	47.3992
-.2E-07	RCVR	-1.0000	1.5965	52.0417	-.016	-.027	-.255	2.010	35.0447	35.0447	.7694	52.0498
-.1E-07	APOGEE	-.7732	1.7938	62.2163	-.016	-.033	-.089	-.023	41.8947	41.8947	.9199	62.2261
-.1E-07	WAVE REV	-.7732	1.7938	62.2163	-.016	-.033	-.089	-.023	41.8947	41.8947	.9199	62.2261
-.3E-07	RCVR	-1.0000	1.8084	72.3109	-.015	-.042	-.340	-1.990	48.6891	48.6891	1.0691	72.3225
-.3E-07	PERIGEE	-1.4302	1.5166	91.0432	-.009	-.070	-.692	.029	61.2891	61.2891	1.3461	91.0571
-.3E-07	WAVE REV	-1.4302	1.5166	91.0432	-.009	-.070	-.692	.029	61.2891	61.2891	1.3461	91.0571
-.3E-07		-1.2877	1.6800	101.4652	-.004	-.098	-.630	1.332	68.2891	68.2891	1.5001	101.4781
-.3E-07	RCVR	-1.0000	1.9792	112.7595	.006	-.147	-.517	1.418	75.8697	75.8697	1.6671	112.7741
-.3E-07	APOGEE	-.7919	2.1946	126.4921	.024	-.226	-.483	-.038	85.0697	85.0697	1.8701	126.5068
-.3E-07	WAVE REV	-.7919	2.1946	126.4921	.024	-.226	-.483	-.038	85.0697	85.0697	1.8701	126.5068
-.3E-07		-.9275	2.0625	137.2533	.044	-.299	-.595	-1.160	92.2697	92.2697	2.0292	137.2677
-.3E-07	RCVR	-1.0000	1.9907	140.6506	.051	-.324	-.640	-1.281	94.5422	94.5422	2.0794	140.6653
-.3E-07		-1.8317	1.1635	171.7311	.135	-.469	-1.056	-.077	115.3422	115.3422	2.5390	171.7518
-.3E-07	PERIGEE	-1.8317	1.1635	172.3289	.136	-.470	-1.058	.068	115.7422	115.7422	2.5478	172.3494
-.3E-07	WAVE REV	-1.8317	1.1635	172.3289	.136	-.470	-1.058	.068	115.7422	115.7422	2.5478	172.3494
-.5E-07	RCVR	-1.0000	1.9967	194.1240	.197	-.503	-.879	3.128	130.3646	130.3646	2.8702	194.1592
-.4E-07	APOGEE	-.6456	2.3515	203.6491	.223	-.510	-.822	-.031	136.7646	136.7646	3.0112	203.6915
-.4E-07	WAVE REV	-.6456	2.3515	203.6491	.223	-.510	-.822	-.031	136.7646	136.7646	3.0112	203.6915
-.5E-07		-.7780	2.2193	208.7102	.236	-.510	-.883	-2.632	140.1646	140.1646	3.0860	208.7544
-.5E-07	MAX RANG	-.8511	2.1462	210.1960	.240	-.509	-.910	-2.971	141.1646	141.1646	3.1080	210.2419

THIS RAY CALCULATION TOOK 3.124 SEC

AZIMUTH ANGLE OF TRANSMISSION = 80.000000 DEG TRANSMITTER LATITUDE = .000000 DEG FREQUENCY = 400.000000 HZ
ELEVATION ANGLE OF TRANSMISSION = 4.000000 DEG TRANSMITTER LONGITUDE = .000000 DEG SINGLE STEP ERROR = 1.000000E-06

ERROR	EVENT	ELEVATION ABOVE SEA LEVEL KM	ELEVATION ABOVE TERRAIN KM	RANGE KM	AZIMUTH DEVIATION XMTR DEG	AZIMUTH DEVIATION LOCAL DEG	ELEVATION ANGLE XMTR DEG	ELEVATION ANGLE LOCAL DEG	PULSE TIME SEC	PHASE TIME SEC	ABSORPTION DB	PATH LENGTH KM
.00E+00	XMTR	-.9808	2.0000	.0000				4.000	.0000	.0000	.0000	.0000
.16E-07	APOGEE	-.5981	2.3760	8.2406	-.017	-.018	2.622	-.098	5.5500	5.5500	.1220	8.2504
.16E-07	WAVE REV	-.5981	2.3760	8.2406	-.017	-.018	2.622	-.098	5.5500	5.5500	.1220	8.2504
.15E-07		-.6839	2.2867	11.5129	-.016	-.018	1.425	-2.712	7.7500	7.7500	.1704	11.5238
-.4E-08	RCVR	-1.0000	1.9635	16.5446	-.017	-.019	-.141	-4.012	11.1435	11.1435	.2449	16.5649
-.4E-08	PERIGEE	-1.6999	1.2170	31.8384	-.015	-.019	-1.437	.069	21.4435	21.4435	.4712	31.8750
-.4E-08	WAVE REV	-1.6999	1.2170	31.8384	-.015	-.019	-1.437	.069	21.4435	21.4435	.4712	31.8750
.14E-07		-1.3886	1.4488	41.0550	-.014	-.020	-.754	3.453	27.6435	27.6435	.6075	41.0959
-.6E-07	RCVR	-1.0000	1.7344	46.8372	-.015	-.022	-.234	4.001	31.5450	31.5450	.6932	46.8901
-.4E-07	APOGEE	-.5978	1.9213	55.3751	-.015	-.026	.147	-.094	37.2950	37.2950	.8195	55.4384
-.4E-07	WAVE REV	-.5978	1.9213	55.3751	-.015	-.026	.147	-.094	37.2950	37.2950	.8195	55.4384
-.5E-07		-.7986	1.7342	60.7261	-.015	-.029	-.101	-3.572	40.8950	40.8950	.8987	60.7935
-.6E-07	RCVR	-1.0000	1.6081	63.7278	-.014	-.031	-.304	-3.985	42.9199	42.9199	.9432	63.8015
-.2E-07	PERIGEE	-1.7286	1.1645	79.7738	-.012	-.043	-.896	.058	53.7199	53.7199	1.1806	79.8643
-.2E-07	WAVE REV	-1.7286	1.1645	79.7738	-.012	-.043	-.896	.058	53.7199	53.7199	1.1806	79.8643
-.9E-08		-1.3278	1.6191	91.0825	-.008	-.059	-.628	3.420	61.3199	61.3199	1.3479	91.1790
-.6E-07	RCVR	-1.0000	1.9593	96.3209	-.006	-.074	-.445	3.618	64.8465	64.8465	1.4255	96.4267
-.5E-07	APOGEE	-.5997	2.3730	105.5524	-.001	-.106	-.268	-.032	71.0465	71.0465	1.5621	105.6674
-.5E-07	WAVE REV	-.5997	2.3730	105.5524	-.001	-.106	-.268	-.032	71.0465	71.0465	1.5621	105.6674
-.5E-07		-.7378	2.2395	110.3261	.003	-.125	-.370	-2.873	74.2465	74.2465	1.6327	110.4432
-.6E-07	RCVR	-1.0000	1.9806	114.9018	.007	-.148	-.526	-3.476	77.3190	77.3190	1.7004	115.0258
-.2E-07	PERIGEE	-2.0665	.9238	138.7830	.042	-.232	-1.072	.018	93.3190	93.3190	2.0538	138.9293
-.2E-07	WAVE REV	-2.0665	.9238	138.7830	.042	-.232	-1.072	.018	93.3190	93.3190	2.0538	138.9293
-.2E-07		-1.7343	1.2583	150.7473	.062	-.260	-.964	2.799	101.3190	101.3190	2.2307	150.8958
-.3E-07	RCVR	-1.0000	1.9945	165.2653	.091	-.346	-.750	2.658	111.0446	111.0446	2.4455	165.4295
-.3E-07	APOGEE	-.6490	2.3465	176.1659	.116	-.403	-.684	-.067	118.3446	118.3446	2.6068	176.3358
-.3E-07	WAVE REV	-.6490	2.3465	176.1659	.116	-.403	-.684	-.067	118.3446	118.3446	2.6068	176.3358
-.3E-07		-.7340	2.2618	180.4961	.127	-.419	-.733	-2.007	121.2446	121.2446	2.6708	180.6667
-.3E-07	RCVR	-1.0000	1.9962	186.4722	.142	-.439	-.845	-2.819	125.2554	125.2553	2.7592	186.6482
-.1E-07	PERIGEE	-1.6644	1.3327	205.2309	.188	-.458	-1.114	.087	137.8554	137.8553	3.0367	205.4174
-.1E-07	WAVE REV	-1.6644	1.3327	205.2309	.188	-.458	-1.114	.087	137.8554	137.8553	3.0367	205.4174
-.1E-07	MAX RANG	-1.5734	1.4239	210.5919	.200	-.455	-1.108	1.823	141.4554	141.4553	3.1159	210.7782

THIS RAY CALCULATION TOOK 2.467 SEC

AZIMUTH ANGLE OF TRANSMISSION = 80.000000 DEG TRANSMITTER LATITUDE = .000000 DEG FREQUENCY = 400.000000 HZ
ELEVATION ANGLE OF TRANSMISSION = 6.000000 DEG TRANSMITTER LONGITUDE = .000000 DEG SINGLE STEP ERROR = 1.000000E-06

ERROR	EVENT	ELEVATION ABOVE SEA LEVEL KM	ELEVATION ABOVE TERRAIN KM	RANGE KM	AZIMUTH DEVIATION XMTR DEG	AZIMUTH DEVIATION LOCAL DEG	ELEVATION ANGLE XMTR DEG	ELEVATION ANGLE LOCAL DEG	PULSE TIME SEC	PHASE TIME SEC	ABSORPTION DB	PATH LENGTH KM
.00E+00	XMTR	-.9808	2.0000	.0000				6.000	.0000	.0000	.0000	.0000
.64E-07	APOGEE	-.4612	2.5139	7.2720	-.016	-.016	4.055	-.170	4.9000	4.9000	.1078	7.2936
.64E-07	WAVE REV	-.4612	2.5139	7.2720	-.016	-.016	4.055	-.170	4.9000	4.9000	.1078	7.2936
.65E-07		-.5558	2.4167	9.8061	-.015	-.016	2.438	-3.882	6.6000	6.6000	.1453	9.8297
-.3E-07	RCVR	-1.0000	1.9667	14.5209	-.016	-.017	-.141	-6.008	9.7858	9.7858	.2153	14.5651
-.2E-07	PERIGEE	-2.0399	.8848	30.2627	-.013	-.016	-2.141	.056	20.3858	20.3858	.4486	30.3459
-.2E-07	WAVE REV	-2.0399	.8848	30.2627	-.013	-.016	-2.141	.056	20.3858	20.3858	.4486	30.3459
-.3E-07		-1.9737	.9313	33.8448	-.012	-.016	-1.833	2.055	22.7858	22.7858	.5016	33.9277
-.6E-07	RCVR	-1.0000	1.7566	45.8199	-.012	-.018	-.230	5.996	30.8620	30.8620	.6792	45.9421
.28E-07	APOGEE	-.4609	2.1032	53.2398	-.013	-.021	.320	-.089	35.8620	35.8620	.7892	53.3846
.28E-07	WAVE REV	-.4609	2.1032	53.2398	-.013	-.021	.320	-.089	35.8620	35.8620	.7892	53.3846
.30E-07		-.5837	1.9240	56.2203	-.013	-.023	.152	-4.288	37.8620	37.8620	.8333	56.3680
-.6E-07	RCVR	-1.0000	1.5297	60.5599	-.013	-.025	-.291	-5.983	40.7946	40.7946	.8977	60.7272
-.5E-07	PERIGEE	-2.0686	.7995	76.9038	-.010	-.033	-1.156	.085	51.7946	51.7946	1.1399	77.1109
-.5E-07	WAVE REV	-2.0686	.7995	76.9038	-.010	-.033	-1.156	.085	51.7946	51.7946	1.1399	77.1109
-.5E-07		-1.9934	.9072	80.7867	-.009	-.034	-1.082	2.116	54.3946	54.3946	1.1973	80.9934
-.7E-07	RCVR	-1.0000	1.9531	93.4379	-.006	-.055	-.432	5.593	62.9145	62.9145	1.3849	93.6828
-.5E-09	APOGEE	-.4648	2.5026	101.2476	-.003	-.078	-.163	-.072	68.1645	68.1645	1.5007	101.5133
-.5E-09	WAVE REV	-.4648	2.5026	101.2476	-.003	-.078	-.163	-.072	68.1645	68.1645	1.5007	101.5133
.66E-09		-.5476	2.4231	103.7882	-.002	-.086	-.228	-3.460	69.8645	69.8645	1.5382	104.0555
-.7E-07	RCVR	-1.0000	1.9762	109.0494	.001	-.108	-.501	-5.472	73.4050	73.4050	1.6163	109.3358
-.6E-07	PERIGEE	-2.3504	.6375	130.5265	.024	-.156	-1.188	.209	87.8050	87.8050	1.9345	130.8599
-.6E-07	WAVE REV	-2.3504	.6375	130.5265	.024	-.156	-1.188	.209	87.8050	87.8050	1.9345	130.8599
-.6E-07		-2.3469	.6412	131.1263	.025	-.156	-1.187	.467	88.2050	88.2050	1.9434	131.4594
-.2E-07	RCVR	-1.0000	1.9929	153.0604	.052	-.242	-.696	4.301	102.8929	102.8929	2.2682	153.4338
.17E-07	APOGEE	-.5077	2.4864	162.1001	.069	-.302	-.562	-.053	108.9429	108.9429	2.4021	162.4884
.17E-07	WAVE REV	-.5077	2.4864	162.1001	.069	-.302	-.562	-.053	108.9429	108.9429	2.4021	162.4884
.19E-07		-.5695	2.4249	164.6463	.074	-.316	-.597	-2.599	110.6429	110.6429	2.4397	165.0353
-.2E-08	RCVR	-1.0000	1.9950	170.9365	.087	-.352	-.775	-4.402	114.8611	114.8611	2.5329	171.3399
-.2E-07	PERIGEE	-2.1120	.8844	191.2150	.132	-.390	-1.199	.188	128.4611	128.4611	2.8332	191.6505
-.2E-07	WAVE REV	-2.1120	.8844	191.2150	.132	-.390	-1.199	.188	128.4611	128.4611	2.8332	191.6505
-.2E-07		-2.0668	.9298	194.2054	.138	-.388	-1.194	1.547	130.4611	130.4611	2.8774	194.6404
-.5E-07	RCVR	-1.0000	1.9972	208.7795	.168	-.388	-.944	5.537	140.2669	140.2669	3.0934	209.2537
-.5E-07	MAX RANG	-.8578	2.1395	210.2600	.171	-.389	-.912	5.404	141.2669	141.2669	3.1154	210.7408

THIS RAY CALCULATION TOOK 2.942 SEC

AZIMUTH ANGLE OF TRANSMISSION = 80.000000 DEG TRANSMITTER LATITUDE = .000000 DEG FREQUENCY = 400.000000 HZ
ELEVATION ANGLE OF TRANSMISSION = 8.000000 DEG TRANSMITTER LONGITUDE = .000000 DEG SINGLE STEP ERROR = 1.000000E-06

ERROR	EVENT	ELEVATION ABOVE SEA LEVEL KM	ELEVATION ABOVE TERRAIN KM	RANGE KM	AZIMUTH DEVIATION XMTR DEG	AZIMUTH DEVIATION LOCAL DEG	ELEVATION ANGLE XMTR DEG	ELEVATION ANGLE LOCAL DEG	PULSE TIME SEC	PHASE TIME SEC	ABSORPTION DB	PATH LENGTH KM
-.7E-14	XMTR	-.9808	2.0000	.0000				8.000	.0000	.0000	.0000	.0000
.13E-07	APOGEE	-.3379	2.6378	6.6740	-.015	-.015	5.473	-.090	4.5000	4.5000	.0992	6.7104
.13E-07	WAVE REV	-.3379	2.6378	6.6740	-.015	-.015	5.473	-.090	4.5000	4.5000	.0992	6.7104
.15E-07		-.3648	2.6099	7.7979	-.014	-.015	4.482	-2.630	5.2500	5.2500	.1158	7.8347
.30E-07	RCVR	-1.0000	1.9682	13.4059	-.015	-.016	-.142	-8.006	9.0405	9.0405	.1993	13.4802
.78E-07	PERIGEE	-2.4608	.4591	31.2440	-.010	-.013	-2.853	.258	21.0405	21.0405	.4641	31.3913
.78E-07	WAVE REV	-2.4608	.4591	31.2440	-.010	-.013	-2.853	.258	21.0405	21.0405	.4641	31.3913
.75E-07		-2.3208	.5684	36.0378	-.009	-.012	-2.292	3.086	24.2405	24.2405	.5349	36.1858
-.6E-07	RCVR	-1.0000	1.7001	48.2230	-.009	-.014	-.240	7.989	32.4673	32.4673	.7161	48.4435
-.5E-07	APOGEE	-.3378	2.1865	55.0449	-.010	-.018	.422	-.087	37.0673	37.0673	.8175	55.3032
-.5E-07	WAVE REV	-.3378	2.1865	55.0449	-.010	-.018	.422	-.087	37.0673	37.0673	.8175	55.3032
-.5E-07		-.3888	2.1152	56.6176	-.010	-.018	.344	-3.568	38.1173	38.1173	.8408	56.8768
-.3E-07	RCVR	-1.0000	1.5573	61.7971	-.010	-.022	-.296	-7.975	41.6204	41.6204	.9179	62.0931
.20E-07	PERIGEE	-2.4981	.3966	79.9390	-.007	-.026	-1.447	.143	53.8204	53.8204	1.1872	80.3095
.20E-07	WAVE REV	-2.4981	.3966	79.9390	-.007	-.026	-1.447	.143	53.8204	53.8204	1.1872	80.3095
.18E-07		-2.3999	.5206	84.1373	-.006	-.026	-1.345	2.527	56.6204	56.6204	1.2493	84.5076
-.7E-07	RCVR	-1.0000	1.9625	98.0715	-.004	-.048	-.452	7.435	66.0059	66.0059	1.4563	98.5132
-.6E-07	APOGEE	-.3456	2.6267	105.2099	-.002	-.072	-.127	-.050	70.8059	70.8059	1.5624	105.6865
-.6E-07	WAVE REV	-.3456	2.6267	105.2099	-.002	-.072	-.127	-.050	70.8059	70.8059	1.5624	105.6865
-.6E-07		-.3876	2.5863	106.7110	-.001	-.076	-.161	-3.102	71.8059	71.8059	1.5846	107.1882
-.5E-07	RCVR	-1.0000	1.9788	112.3615	.002	-.102	-.515	-7.311	75.6110	75.6110	1.6686	112.8725
-.4E-08	PERIGEE	-2.7759	.2131	134.1448	.024	-.134	-1.370	.298	90.2110	90.2110	1.9919	134.7405
-.4E-08	WAVE REV	-2.7759	.2131	134.1448	.024	-.134	-1.370	.298	90.2110	90.2110	1.9919	134.7405
-.5E-08		-2.7513	.2382	135.9504	.025	-.133	-1.358	1.260	91.4110	91.4110	2.0185	136.5455
-.3E-07	RCVR	-1.0000	1.9933	155.7112	.045	-.192	-.707	6.434	104.6557	104.6557	2.3118	156.3860
-.3E-07	APOGEE	-.3717	2.6225	163.4742	.056	-.242	-.522	-.149	109.8557	109.8557	2.4270	164.1784
-.3E-07	WAVE REV	-.3717	2.6225	163.4742	.056	-.242	-.522	-.149	109.8557	109.8557	2.4270	164.1784
-.2E-07		-.4361	2.5584	165.4268	.059	-.251	-.555	-3.517	111.1557	111.1557	2.4559	166.1322
-.2E-07	RCVR	-1.0000	1.9950	171.0190	.069	-.283	-.776	-6.530	114.9135	114.9135	2.5390	171.7528
.30E-08	PERIGEE	-2.5674	.4291	191.5992	.105	-.307	-1.336	.195	128.7135	128.7135	2.8443	192.4012
.30E-08	WAVE REV	-2.5674	.4291	191.5992	.105	-.307	-1.336	.195	128.7135	128.7135	2.8443	192.4012
.28E-08		-2.5636	.4329	192.1999	.106	-.306	-1.336	.521	129.1135	129.1135	2.8531	193.0017
-.1E-06	MAX RANG	-1.0281	1.9692	210.0554	.134	-.300	-.958	7.721	141.1135	141.1135	3.1182	210.9320

THIS RAY CALCULATION TOOK 3.476 SEC

AZIMUTH ANGLE OF TRANSMISSION = 80.000000 DEG
ELEVATION ANGLE OF TRANSMISSION = 10.000000 DEG

TRANSMITTER LATITUDE = .000000 DEG
TRANSMITTER LONGITUDE = .000000 DEG

FREQUENCY = 400.000000 HZ
SINGLE STEP ERROR = 1.000000E-06

ERROR	EVENT	ELEVATION ABOVE SEA LEVEL KM	ELEVATION ABOVE TERRAIN KM	RANGE KM	AZIMUTH DEVIATION XMTR DEG	AZIMUTH DEVIATION LOCAL DEG	ELEVATION ANGLE XMTR DEG	ELEVATION ANGLE LOCAL DEG	PULSE TIME SEC	PHASE TIME SEC	ABSORPTION DB	PATH LENGTH KM
-.7E-14	XMTR	-.9808	2.0000	.0000				10.000	.0000	.0000	.0000	.0000
.36E-07		-.2056	2.7708	5.9196	-.014	-.014	7.435	2.972	4.0000	4.0000	.0883	5.9749
.33E-07	APOGEE	-.1048	2.8679	9.6483	-.012	-.013	5.145	-.028	6.4750	6.4750	.1435	9.7053
.33E-07	WAVE REV	-.1048	2.8679	9.6483	-.012	-.013	5.145	-.028	6.4750	6.4750	.1435	9.7053
.33E-07		-.1089	2.8631	10.3268	-.011	-.012	4.780	-.652	6.9250	6.9250	.1535	10.3838
.37E-07		-.3567	2.6089	15.2873	-.011	-.012	2.269	-6.411	10.2250	10.2250	.2269	15.3521
.56E-07	RCVR	-1.0000	1.9585	19.3456	-.012	-.014	-.144	-10.005	12.9848	12.9848	.2877	19.4613
.15E-06	BOTM REF	-2.8979	.0000	34.8791	-.009	.232	-3.304	3.400	23.4576	23.4576	.5192	35.1183
.13E-06		-2.3562	.4852	40.8644	-.043	.197	-2.112	6.941	27.4576	27.4576	.6080	41.1266
-.2E-07	RCVR	-1.0000	1.6789	49.3788	-.080	.159	-.244	10.224	33.2447	33.2447	.7354	49.7475
.30E-07		-.1682	2.3537	55.6707	-.100	.136	.586	3.262	37.4947	37.4947	.8293	56.0996
.23E-07	APOGEE	-.0756	2.4244	58.2324	-.106	.129	.629	-.035	39.1947	39.1947	.8672	58.6633
.23E-07	WAVE REV	-.0756	2.4244	58.2324	-.106	.129	.629	-.035	39.1947	39.1947	.8672	58.6633
.23E-07		-.0757	2.4243	58.2890	-.106	.129	.627	-.194	39.2322	39.2322	.8681	58.7199
.34E-07		-.1931	2.3371	61.1890	-.113	.121	.462	-3.552	41.1572	41.1572	.9110	61.6225
.36E-07	RCVR	-1.0000	1.6805	67.0788	-.126	.105	-.318	-10.188	45.1390	45.1391	.9989	67.5716
.15E-06	BOTM REF	-2.8954	.0000	81.1497	-.145	-.210	-1.717	3.021	54.6401	54.6401	1.2089	81.7738
.13E-06		-2.3276	.6044	87.7358	-.129	-.195	-1.274	6.794	59.0401	59.0401	1.3066	88.3829
-.7E-07	RCVR	-1.0000	1.9576	96.4893	-.113	-.197	-.445	9.505	64.9763	64.9763	1.4374	97.2352
-.2E-07		-.2083	2.7599	102.7961	-.102	-.206	-.032	2.790	69.2263	69.2263	1.5315	103.5961
-.3E-07	APOGEE	-.0990	2.8741	106.9837	-.094	-.208	-.009	-.028	72.0013	72.0013	1.5934	107.7855
-.3E-07	WAVE REV	-.0990	2.8741	106.9837	-.094	-.208	-.009	-.028	72.0013	72.0013	1.5934	107.7855
-.3E-07		-.0995	2.8739	107.2103	-.094	-.208	-.011	-.224	72.1513	72.1513	1.5967	108.0120
-.4E-07		-.2706	2.7074	112.2643	-.085	-.213	-.142	-3.946	75.5013	75.5013	1.6715	113.0695
-.7E-08	RCVR	-1.0000	1.9817	117.6220	-.076	-.234	-.538	-9.212	79.1147	79.1147	1.7515	118.4782
.92E-07	BOTM REF	-2.9882	.0000	132.2094	-.048	-.265	-1.465	4.554	88.9443	88.9443	1.9691	133.2007
.14E-06		-2.0084	.9821	140.5627	-.032	-.259	-1.051	8.423	94.5443	94.5443	2.0934	141.6097
.23E-07	RCVR	-1.0000	1.9918	147.1174	-.019	-.295	-.669	8.695	98.9793	98.9793	2.1914	148.2400
.40E-07		-.2199	2.7730	153.7493	-.005	-.332	-.408	2.573	103.4293	103.4293	2.2902	154.9216
.36E-07	APOGEE	-.0959	2.8977	158.6998	.005	-.344	-.394	-.027	106.7043	106.7043	2.3634	159.8741
.36E-07	WAVE REV	-.0959	2.8977	158.6998	.005	-.344	-.394	-.027	106.7043	106.7043	2.3634	159.8741
.36E-07		-.0960	2.8976	158.7376	.006	-.344	-.395	-.057	106.7293	106.7293	2.3640	159.9119
.43E-07		-.2285	2.7657	163.7248	.017	-.355	-.473	-2.749	110.0293	110.0293	2.4377	164.9012
.58E-07	RCVR	-1.0000	1.9949	170.0700	.031	-.383	-.771	-8.865	114.2929	114.2929	2.5323	171.2967
.15E-06	BOTM REF	-2.9961	.0000	186.1151	.068	-.394	-1.458	3.353	125.0875	125.0875	2.7713	187.4683
.14E-06		-2.3201	.6764	193.2994	.083	-.382	-1.266	7.320	129.8875	129.8875	2.8780	194.6828
-.9E-07	RCVR	-1.0000	1.9969	201.7061	.100	-.384	-.913	9.692	135.5923	135.5923	3.0038	203.1913
-.5E-07		-.2011	2.7960	208.0081	.113	-.386	-.721	2.795	139.8423	139.8423	3.0978	209.5489
-.6E-07	MAX RANG	-.1257	2.8715	210.0424	.117	-.384	-.711	1.425	141.1923	141.1923	3.1278	211.5846

THIS RAY CALCULATION TOOK 5.659 SEC

AZIMUTH ANGLE OF TRANSMISSION = 80.000000 DEG TRANSMITTER LATITUDE = .000000 DEG FREQUENCY = 400.000000 HZ
ELEVATION ANGLE OF TRANSMISSION = 12.000000 DEG TRANSMITTER LONGITUDE = .000000 DEG SINGLE STEP ERROR = 1.000000E-06

ERROR	EVENT	ELEVATION ABOVE SEA LEVEL KM	ELEVATION ABOVE TERRAIN KM	RANGE KM	AZIMUTH DEVIATION XMTR DEG	AZIMUTH DEVIATION LOCAL DEG	ELEVATION ANGLE XMTR DEG	ELEVATION ANGLE LOCAL DEG	PULSE TIME SEC	PHASE TIME SEC	ABSORPTION DB	PATH LENGTH KM
-.7E-14	XMTR	-.9808	2.0000	.0000				12.000	.0000	.0000	.0000	.0000
.65E-07		-.1252	2.8521	4.8540	-.014	-.014	9.975	6.814	3.3000	3.3000	.0729	4.9310
.12E-06	APOGEE	-.0412	2.9353	5.7848	-.013	-.013	9.200	-.152	3.9188	3.9188	.0867	5.8661
.12E-06	WAVE REV	-.0412	2.9353	5.7848	-.013	-.013	9.200	-.152	3.9188	3.9188	.0867	5.8661
.12E-06		-.0446	2.9318	5.9175	-.013	-.013	8.964	-2.724	4.0063	4.0063	.0887	5.9989
.17E-06		-.2287	2.7462	7.5281	-.012	-.012	5.672	-7.461	5.0813	5.0813	.1126	7.6201
.46E-07	RCVR	-1.0000	1.9705	11.6447	-.013	-.014	-.147	-12.004	7.8897	7.8897	.1746	11.8093
.22E-06	BOTM REF	-2.9508	.0000	22.7433	-.010	.193	-5.054	7.184	15.4322	15.4322	.3412	23.0790
.19E-06		-1.7328	1.1932	30.1346	-.058	.144	-1.565	11.426	20.4322	20.4322	.4519	30.5691
-.7E-07	RCVR	-1.0000	1.9079	33.5994	-.075	.127	-.184	12.169	22.8150	22.8150	.5042	34.1099
.33E-07		-.1048	2.7643	38.5988	-.094	.107	1.127	6.968	26.2150	26.2150	.5794	39.1911
.71E-07	APOGEE	-.0394	2.8222	39.3422	-.096	.105	1.194	-.089	26.7087	26.7088	.5904	39.9378
.71E-07	WAVE REV	-.0394	2.8222	39.3422	-.096	.105	1.194	-.089	26.7087	26.7088	.5904	39.9378
.89E-07		-.0481	2.8112	39.5601	-.096	.104	1.173	-4.292	26.8525	26.8525	.5936	40.1559
.13E-06		-.2570	2.5826	41.2430	-.101	.099	.820	-8.014	27.9775	27.9775	.6187	41.8519
.64E-07	RCVR	-1.0000	1.7803	45.0772	-.111	.088	-.227	-12.165	30.5973	30.5973	.6764	45.7579
.26E-06	BOTM REF	-2.5790	.0000	53.2686	-.127	3.158	-1.959	11.314	36.1914	36.1914	.7997	54.0993
.46E-06		-1.1398	1.3625	59.5115	-.460	2.824	-.421	14.052	40.4914	40.4914	.8946	60.5132
.44E-06	RCVR	-1.0000	1.5006	60.0692	-.486	2.797	-.288	14.060	40.8789	40.8790	.9031	61.0887
.65E-06		-.1205	2.3975	64.0004	-.660	2.621	.482	10.070	43.5789	43.5790	.9627	65.1224
.61E-06		-.0188	2.5081	64.7692	-.691	2.590	.560	1.791	44.0914	44.0915	.9742	65.8995
.61E-06	APOGEE	-.0153	2.5149	65.0273	-.701	2.579	.558	-.032	44.2602	44.2602	.9780	66.1579
.61E-06	WAVE REV	-.0153	2.5149	65.0273	-.701	2.579	.558	-.032	44.2602	44.2602	.9780	66.1579
.61E-06		-.0215	2.5130	65.3427	-.714	2.567	.547	-2.690	44.4664	44.4665	.9827	66.4737
.70E-06		-.1440	2.4026	66.1744	-.746	2.534	.427	-10.169	45.0227	45.0227	.9951	67.3159
.47E-06		-.9233	1.6847	69.6713	-.875	2.403	-.266	-14.021	47.4227	47.4227	1.0481	70.9025
.48E-06	RCVR	-1.0000	1.6137	69.9780	-.885	2.392	-.330	-14.041	47.6356	47.6357	1.0528	71.2189
.34E-06	BOTM REF	-2.7472	.0000	77.6090	-1.122	-.362	-1.653	8.925	52.8837	52.8837	1.1686	79.0521
.49E-06		-1.4621	1.3883	84.3663	-1.094	-.338	-.706	12.251	57.4837	57.4837	1.2703	85.9295
-.3E-07	RCVR	-1.0000	1.8714	86.4716	-1.086	-.335	-.402	12.427	58.9327	58.9327	1.3021	88.0845
.12E-06		-.0930	2.8136	91.3049	-1.069	-.328	.146	7.760	62.2202	62.2202	1.3749	93.0040
.18E-06	APOGEE	-.0340	2.8762	91.9411	-1.067	-.327	.177	-.165	62.6420	62.6421	1.3843	93.6435
.18E-06	WAVE REV	-.0340	2.8762	91.9411	-1.067	-.327	.177	-.165	62.6420	62.6421	1.3843	93.6435
.21E-06		-.0448	2.8667	92.1690	-1.067	-.326	.167	-5.051	62.7920	62.7921	1.3877	93.8717
.29E-06		-.2739	2.6460	93.8128	-1.061	-.323	.010	-8.877	63.8920	63.8921	1.4122	95.5315
.29E-08	RCVR	-1.0000	1.9346	97.4114	-1.050	-.323	-.449	-12.356	66.3503	66.3503	1.4665	99.2029
-.5E-07	BOTM REF	-2.9598	.0000	107.4338	-1.020	-.497	-1.539	8.489	73.1776	73.1776	1.6175	109.4142
.18E-07		-1.6122	1.3583	114.8063	-.989	-.476	-.831	11.745	78.1776	78.1776	1.7282	116.9076
-.4E-06	RCVR	-1.0000	1.9735	117.7288	-.977	-.482	-.539	11.826	80.1784	80.1784	1.7724	119.8930
-.3E-06		-.0952	2.8826	122.7290	-.958	-.491	-.139	7.698	83.5659	83.5659	1.8475	124.9759
-.2E-06	APOGEE	-.0340	2.9443	123.3849	-.955	-.490	-.115	-.161	84.0003	84.0003	1.8573	125.6353
-.2E-06	WAVE REV	-.0340	2.9443	123.3849	-.955	-.490	-.115	-.161	84.0003	84.0003	1.8573	125.6353
-.2E-06		-.0431	2.9354	123.5942	-.954	-.490	-.121	-4.673	84.1378	84.1378	1.8604	125.8448
-.2E-06		-.2641	2.7155	125.2234	-.948	-.490	-.235	-8.485	85.2253	85.2253	1.8847	127.4891
-.3E-06	RCVR	-1.0000	1.9819	129.0483	-.934	-.502	-.589	-11.733	87.8248	87.8248	1.9422	131.3844
-.2E-06	BOTM REF	-2.9865	.0000	139.2201	-.896	-.541	-1.452	9.044	94.7420	94.7420	2.0954	141.7468
-.2E-06		-1.0505	1.9391	149.2267	-.859	-.545	-.698	11.551	101.5420	101.5420	2.2461	151.9372
-.3E-06	RCVR	-1.0000	1.9896	149.4738	-.858	-.546	-.680	11.543	101.7106	101.7106	2.2498	152.1894

-.2E-06		-.1072	2.8836	154.4643	-.839	-.565	-.371	7.760	105.0856	105.0856	2.3248	157.2604
-.1E-06	APOGEE	-.0338	2.9571	155.2048	-.837	-.565	-.348	-.071	105.5762	105.5762	2.3358	158.0053
-.1E-06	WAVE REV	-.0338	2.9571	155.2048	-.837	-.565	-.348	-.071	105.5762	105.5762	2.3358	158.0053
-.9E-07		-.0398	2.9512	155.3763	-.836	-.565	-.352	-3.853	105.6887	105.6887	2.3383	158.1769
-.4E-07		-.2519	2.7394	156.9699	-.830	-.566	-.440	-8.306	106.7512	106.7512	2.3621	159.7848
-.1E-06	RCVR	-1.0000	1.9920	160.9212	-.816	-.582	-.731	-11.578	109.4330	109.4331	2.4215	163.8067
-.8E-07	BOTM REF	-2.9935	.0000	171.3287	-.778	-.596	-1.444	8.749	116.5054	116.5054	2.5782	174.4020
-.1E-06		-1.1889	1.8057	180.7432	-.746	-.588	-.879	11.949	122.9054	122.9054	2.7199	183.9868
-.4E-06	RCVR	-1.0000	1.9946	181.6361	-.743	-.591	-.823	11.929	123.5170	123.5170	2.7334	184.8993
-.3E-06		-.1074	2.8877	186.5385	-.727	-.597	-.571	7.638	126.8420	126.8420	2.8070	189.8840
-.2E-06	APOGEE	-.0350	2.9601	187.2827	-.724	-.596	-.553	-.091	127.3358	127.3358	2.8181	190.6324
-.2E-06	WAVE REV	-.0350	2.9601	187.2827	-.724	-.596	-.553	-.091	127.3358	127.3358	2.8181	190.6324
-.2E-06		-.0398	2.9554	187.4350	-.724	-.596	-.555	-3.432	127.4358	127.4358	2.8204	190.7847
-.2E-06		-.2454	2.7499	189.0078	-.719	-.594	-.627	-8.296	128.4858	128.4858	2.8438	192.3712
-.4E-06	RCVR	-1.0000	1.9956	192.8983	-.706	-.597	-.873	-12.030	131.1364	131.1364	2.9024	196.3350
-.5E-06	BOTM REF	-2.9962	.0000	203.5948	-.673	-.588	-1.483	7.919	138.4099	138.4099	3.0633	207.2161
-.5E-06		-1.9368	1.0597	209.8062	-.655	-.572	-1.205	11.338	142.6099	142.6099	3.1564	213.5160
-.5E-06	MAX RANG	-1.8778	1.1188	210.0987	-.655	-.572	-1.190	11.474	142.8099	142.8099	3.1608	213.8144

THIS RAY CALCULATION TOOK 8.958 SEC

AZIMUTH ANGLE OF TRANSMISSION = 80.000000 DEG TRANSMITTER LATITUDE = .000000 DEG FREQUENCY = 400.000000 HZ
ELEVATION ANGLE OF TRANSMISSION = 14.000000 DEG TRANSMITTER LONGITUDE = .000000 DEG SINGLE STEP ERROR = 1.000000E-06

ERROR	EVENT	ELEVATION ABOVE SEA LEVEL KM	ELEVATION ABOVE TERRAIN KM	RANGE KM	AZIMUTH DEVIATION XMTR DEG	AZIMUTH DEVIATION LOCAL DEG	ELEVATION ANGLE XMTR DEG	ELEVATION ANGLE LOCAL DEG	PULSE TIME SEC	PHASE TIME SEC	ABSORPTION DB	PATH LENGTH KM
-.7E-14	XMTR	-.9808	2.0000	.0000				14.000	.0000	.0000	.0000	.0000
.18E-06		-.1184	2.8596	3.9008	-.014	-.014	12.450	9.917	2.6750	2.6750	.0591	3.9959
.96E-07		-.0202	2.9572	4.6611	-.013	-.013	11.624	1.442	3.1813	3.1813	.0704	4.7634
.96E-07	APOGEE	-.0187	2.9586	4.7902	-.013	-.013	11.335	-.054	3.2656	3.2656	.0723	4.8926
.96E-07	WAVE REV	-.0187	2.9586	4.7902	-.013	-.013	11.335	-.054	3.2656	3.2656	.0723	4.8926
.11E-06		-.0490	2.9279	5.2560	-.012	-.013	10.029	-8.283	3.5719	3.5719	.0792	5.3598
.28E-06		-.3004	2.6753	6.6651	-.012	-.012	5.799	-11.090	4.5219	4.5219	.1004	6.7911
.17E-07	RCVR	-1.0000	1.9727	9.6474	-.013	-.014	-.158	-14.003	6.5782	6.5782	.1457	9.8545
-.1E-06	BOTM REF	-2.9600	.0000	18.5493	-.010	.206	-6.176	10.186	12.6798	12.6798	.2804	18.9691
-.1E-06		-1.7236	1.2230	24.4126	-.061	.156	-1.853	13.542	16.6798	16.6798	.3690	24.9601
.74E-07	RCVR	-1.0000	1.9375	27.3220	-.079	.137	-.163	14.155	18.6970	18.6970	.4133	27.9576
.27E-06		-.1226	2.7988	31.2187	-.098	.117	1.434	10.151	21.3720	21.3720	.4724	31.9527
.20E-06		-.0182	2.8993	31.9974	-.102	.114	1.579	1.947	21.8908	21.8908	.4840	32.7392
.20E-06	APOGEE	-.0128	2.9026	32.4041	-.103	.112	1.565	-.017	22.1564	22.1564	.4900	33.1460
.20E-06	WAVE REV	-.0128	2.9026	32.4041	-.103	.112	1.565	-.017	22.1564	22.1564	.4900	33.1460
.20E-06		-.0144	2.8997	32.6338	-.104	.111	1.550	-.844	22.3064	22.3064	.4934	33.3757
.18E-06		-.0793	2.8309	33.3339	-.106	.109	1.399	-9.868	22.7689	22.7689	.5038	34.0799
.24E-06		-.4217	2.4771	35.1051	-.113	.102	.755	-12.532	23.9689	23.9689	.5305	35.8841
.48E-07	RCVR	-1.0000	1.8806	37.4756	-.120	.094	-.198	-14.153	25.6089	25.6089	.5665	38.3239
-.1E-06	BOTM REF	-2.7790	.0000	45.2665	-.138	2.653	-2.479	12.635	30.9631	30.9631	.6847	46.3144
-.4E-08		-1.6227	1.0820	49.9072	-.386	2.405	-.962	15.204	34.1631	34.1631	.7554	51.1002
.49E-07	RCVR	-1.0000	1.6618	52.1548	-.491	2.300	-.256	15.588	35.7338	35.7338	.7899	53.4340
.40E-06		-.0905	2.4992	55.7357	-.640	2.149	.665	11.971	38.2088	38.2088	.8446	57.1319
.32E-06		-.0065	2.5735	56.2362	-.659	2.130	.740	6.560	38.5432	38.5432	.8521	57.6400
.30E-06	SURF REF	.0000	2.5788	56.2926	-.661	2.128	.745	-6.517	38.5803	38.5803	.8529	57.6968
.31E-06		-.0488	2.5233	56.6468	-.675	2.114	.688	-10.794	38.8146	38.8146	.8582	58.0547
.54E-06		-.3052	2.2457	57.8238	-.718	2.070	.409	-13.112	39.6146	39.6146	.8760	59.2601
.17E-06	RCVR	-1.0000	1.5146	60.4317	-.808	1.979	-.290	-15.580	41.4271	41.4271	.9160	61.9605
.89E-07	BOTM REF	-2.5168	.0000	66.1771	-.981	-.413	-1.628	11.913	45.4148	45.4148	1.0038	67.9048
.29E-06		-1.0613	1.5984	72.2693	-.948	-.384	-.389	14.338	49.6148	49.6148	1.0964	74.1674
.28E-06	RCVR	-1.0000	1.6659	72.5091	-.947	-.383	-.341	14.335	49.7813	49.7813	1.1001	74.4149
.40E-06		-.1073	2.6484	76.4054	-.928	-.369	.311	10.473	52.4563	52.4563	1.1592	78.4130
.37E-06		-.0147	2.7542	77.0815	-.925	-.366	.371	3.080	52.9063	52.9063	1.1693	79.0962
.34E-06	SURF REF	.0000	2.7745	77.3854	-.924	-.365	.378	-2.616	53.1049	53.1049	1.1738	79.4004
.39E-06		-.0285	2.7550	77.8822	-.922	-.363	.350	-5.771	53.4299	53.4299	1.1811	79.8981
.53E-06		-.1877	2.6111	78.7936	-.918	-.359	.222	-10.778	54.0424	54.0424	1.1948	80.8236
.27E-06	RCVR	-1.0000	1.8466	82.2672	-.904	-.351	-.383	-14.302	56.4312	56.4312	1.2476	84.3914
.17E-06	BOTM REF	-2.9130	.0000	90.5056	-.872	-1.030	-1.630	10.348	62.0907	62.0908	1.3726	92.8480
.38E-06		-1.4652	1.4772	97.2370	-.802	-.967	-.723	13.513	66.6907	66.6908	1.4743	99.7329
.32E-06	RCVR	-1.0000	1.9482	99.1598	-.784	-.956	-.457	13.622	68.0193	68.0194	1.5036	101.7111
.50E-06		-.1302	2.8276	103.1436	-.747	-.934	.009	9.972	70.7443	70.7444	1.5639	105.7899
.41E-06		-.0204	2.9390	103.9411	-.740	-.928	.062	2.046	71.2756	71.2756	1.5758	106.5958
.41E-06	APOGEE	-.0169	2.9429	104.1662	-.738	-.926	.062	-.051	71.4225	71.4225	1.5791	106.8209
.41E-06	WAVE REV	-.0169	2.9429	104.1662	-.738	-.926	.062	-.051	71.4225	71.4225	1.5791	106.8209
.41E-06		-.0277	2.9328	104.5105	-.735	-.924	.052	-4.479	71.6475	71.6475	1.5842	107.1656
.55E-06		-.2094	2.7531	105.6202	-.726	-.917	-.057	-10.224	72.3912	72.3912	1.6009	108.2905
.30E-06	RCVR	-1.0000	1.9680	109.1722	-.697	-.904	-.501	-13.547	74.8237	74.8237	1.6547	111.9302
.16E-06	BOTM REF	-2.9775	.0000	118.0022	-.629	-.958	-1.500	10.589	80.8701	80.8701	1.7884	120.9783

.36E-06		-1.3162	1.6666	125.6139	-.571	-.921	-.718	13.227	86.0701	86.0701	1.9036	128.7684
.45E-06	RCVR	-1.0000	1.9835	126.9610	-.561	-.922	-.580	13.183	86.9964	86.9964	1.9240	130.1520
.63E-06		-.1308	2.8547	131.0325	-.533	-.922	-.218	9.947	89.7714	89.7714	1.9856	134.3163
.55E-06		-.0196	2.9662	131.8406	-.527	-.919	-.175	2.104	90.3089	90.3089	1.9977	135.1329
.55E-06	APOGEE	-.0149	2.9711	132.1571	-.525	-.918	-.176	-.035	90.5151	90.5152	2.0023	135.4495
.55E-06	WAVE REV	-.0149	2.9711	132.1571	-.525	-.918	-.176	-.035	90.5151	90.5152	2.0023	135.4495
.55E-06		-.0182	2.9678	132.4161	-.523	-.917	-.179	-1.642	90.6839	90.6839	2.0062	135.7085
.61E-06		-.1040	2.8823	133.1137	-.518	-.915	-.221	-9.862	91.1464	91.1464	2.0166	136.4123
.54E-06		-.5923	2.3950	135.5879	-.502	-.913	-.446	-12.752	92.8214	92.8214	2.0539	138.9348
.43E-06	RCVR	-1.0000	1.9879	137.3491	-.490	-.917	-.626	-13.126	94.0299	94.0299	2.0806	140.7425
.30E-06	BOTM REF	-2.9904	.0000	146.2585	-.433	-.926	-1.445	10.886	100.1225	100.1225	2.2155	149.8706
.47E-06		-1.5123	1.4795	152.9963	-.392	-.903	-.887	13.196	104.7225	104.7225	2.3175	156.7677
.43E-06	RCVR	-1.0000	1.9922	155.1897	-.379	-.910	-.705	13.086	106.2289	106.2289	2.3508	159.0199
.60E-06		-.1342	2.8587	159.2642	-.355	-.917	-.412	9.927	109.0039	109.0039	2.4124	163.1864
.51E-06		-.0195	2.9735	160.1005	-.350	-.916	-.376	1.968	109.5602	109.5602	2.4249	164.0316
.51E-06	APOGEE	-.0156	2.9775	160.3739	-.348	-.915	-.376	-.042	109.7383	109.7383	2.4289	164.3050
.51E-06	WAVE REV	-.0156	2.9775	160.3739	-.348	-.915	-.376	-.042	109.7383	109.7383	2.4289	164.3050
.51E-06		-.0215	2.9717	160.6807	-.346	-.915	-.381	-2.625	109.9383	109.9383	2.4334	164.6119
.59E-06		-.1441	2.8492	161.5250	-.342	-.913	-.430	-9.955	110.5008	110.5008	2.4461	165.4658
.34E-06		-.8617	2.1320	164.9413	-.322	-.917	-.700	-13.106	112.8258	112.8258	2.4977	168.9575
.37E-06	RCVR	-1.0000	1.9938	165.5342	-.319	-.919	-.751	-13.134	113.2332	113.2332	2.5067	169.5663
.13E-06	BOTM REF	-2.9948	.0000	174.5912	-.269	-.914	-1.446	10.549	119.4250	119.4250	2.6438	178.8397
.29E-06		-1.3307	1.6647	182.2004	-.231	-.891	-.929	13.422	124.6250	124.6250	2.7589	186.6280
.33E-06	RCVR	-1.0000	1.9956	183.5857	-.224	-.893	-.832	13.413	125.5800	125.5800	2.7800	188.0522
.55E-06		-.1330	2.8629	187.6118	-.204	-.891	-.585	9.843	128.3300	128.3300	2.8409	192.1718
.46E-06		-.0209	2.9751	188.4473	-.200	-.889	-.556	1.564	128.8863	128.8863	2.8533	193.0158
.46E-06	APOGEE	-.0192	2.9767	188.5766	-.199	-.889	-.556	-.040	128.9706	128.9707	2.8553	193.1451
.46E-06	WAVE REV	-.0192	2.9767	188.5766	-.199	-.889	-.556	-.040	128.9706	128.9707	2.8553	193.1451
.47E-06		-.0492	2.9468	189.0334	-.197	-.888	-.568	-8.228	129.2706	129.2707	2.8620	193.6034
.58E-06		-.2966	2.6994	190.4456	-.190	-.884	-.651	-10.778	130.2206	130.2207	2.8832	195.0373
.32E-06	RCVR	-1.0000	1.9963	193.5470	-.175	-.882	-.876	-13.489	132.3496	132.3497	2.9302	198.2177
.20E-06	BOTM REF	-2.9968	.0000	202.7494	-.134	-.862	-1.482	9.968	138.6453	138.6453	3.0694	207.6343
.24E-06		-1.6529	1.3442	209.2034	-.107	-.839	-1.125	13.342	143.0453	143.0453	3.1669	214.2261
.38E-06	MAX RANG	-1.4448	1.5522	210.0720	-.104	-.837	-1.071	13.577	143.6453	143.6453	3.1801	215.1191

THIS RAY CALCULATION TOOK 12.853 SEC

AZIMUTH ANGLE OF TRANSMISSION = 80.000000 DEG TRANSMITTER LATITUDE = .000000 DEG FREQUENCY = 400.000000 HZ
ELEVATION ANGLE OF TRANSMISSION = 16.000000 DEG TRANSMITTER LONGITUDE = .000000 DEG SINGLE STEP ERROR = 1.000000E-06

ERROR	EVENT	ELEVATION ABOVE SEA LEVEL KM	ELEVATION ABOVE TERRAIN KM	RANGE KM	AZIMUTH DEVIATION XMTR DEG	AZIMUTH DEVIATION LOCAL DEG	ELEVATION ANGLE XMTR DEG	ELEVATION ANGLE LOCAL DEG	PULSE TIME SEC	PHASE TIME SEC	ABSORPTION DB	PATH LENGTH KM
-.7E-14	XMTR	-.9808	2.0000	.0000				16.000	.0000	.0000	.0000	.0000
.20E-06		-.0835	2.8949	3.4327	-.014	-.014	14.634	12.436	2.3750	2.3750	.0525	3.5486
.17E-06		-.0050	2.9730	3.8770	-.013	-.014	14.111	7.448	2.6719	2.6719	.0591	4.0000
.15E-06	SURF REF	.0000	2.9780	3.9152	-.013	-.014	14.047	-7.420	2.6970	2.6970	.0597	4.0386
.15E-06		-.0555	2.9222	4.2683	-.013	-.013	12.213	-11.786	2.9314	2.9314	.0650	4.3961
.38E-06		-.3556	2.6210	5.5701	-.012	-.012	6.379	-14.064	3.8189	3.8189	.0847	5.7321
-.3E-07	RCVR	-1.0000	1.9745	7.8975	-.013	-.014	-.175	-16.003	5.4410	5.4410	.1204	8.1469
-.3E-06	BOTM REF	-2.9653	.0000	15.3961	-.010	.213	-7.416	12.811	10.6304	10.6304	.2350	15.8979
-.4E-07		-1.3042	1.6493	21.7624	-.075	.148	-.950	16.069	15.0304	15.0304	.3323	22.4762
-.4E-07	RCVR	-1.0000	1.9510	22.8151	-.083	.140	-.151	16.139	15.7682	15.7682	.3485	23.5718
.11E-06		-.0827	2.8586	26.2807	-.103	.119	1.839	12.606	18.1682	18.1682	.4015	27.1573
.16E-06		-.0031	2.9368	26.7249	-.105	.117	1.975	7.730	18.4651	18.4651	.4081	27.6088
.15E-06	SURF REF	.0000	2.9398	26.7475	-.105	.117	1.980	-7.714	18.4800	18.4800	.4085	27.6316
.14E-06		-.0596	2.8789	27.1094	-.107	.115	1.824	-12.156	18.7206	18.7206	.4139	27.9985
.38E-06		-.3785	2.5552	28.4642	-.113	.109	1.084	-14.413	19.6456	19.6456	.4345	29.3904
.46E-07	RCVR	-1.0000	1.9244	30.6799	-.122	.099	-.174	-16.138	21.1918	21.1918	.4685	31.6915
-.2E-06	BOTM REF	-2.8791	.0000	37.7222	-.143	1.485	-3.051	13.972	26.0731	26.0731	.5762	38.9792
-.2E-06		-1.4867	1.3450	42.7673	-.319	1.308	-.870	16.689	29.5731	29.5731	.6536	44.2132
-.3E-06	RCVR	-1.0000	1.8118	44.3760	-.367	1.260	-.224	16.889	30.7047	30.7047	.6784	45.8940
-.3E-06		-.0693	2.6918	47.7025	-.456	1.169	.880	13.415	33.0172	33.0172	.7295	49.3494
-.2E-06	SURF REF	.0000	2.7549	48.0587	-.465	1.161	.953	-9.230	33.2556	33.2556	.7349	49.7125
-.1E-06		-.0077	2.7463	48.1059	-.466	1.159	.943	-9.268	33.2869	33.2869	.7356	49.7604
-.2E-07		-.0989	2.6473	48.5373	-.477	1.149	.823	-13.665	33.5775	33.5775	.7421	50.2015
-.5E-06		-.8743	1.8155	51.3273	-.540	1.085	-.112	-16.849	35.5150	35.5150	.7849	53.0982
-.4E-06	RCVR	-1.0000	1.6806	51.7418	-.549	1.075	-.254	-16.886	35.8066	35.8066	.7914	53.5313
-.3E-06	BOTM REF	-2.5573	.0000	57.1345	-.652	5.462	-1.838	16.468	39.5718	39.5718	.8743	59.1442
-.5E-06		-1.1110	1.4095	61.6638	-1.055	5.057	-.398	18.382	42.7718	42.7718	.9449	63.9162
-.5E-06	RCVR	-1.0000	1.5183	61.9964	-1.083	5.030	-.297	18.383	43.0087	43.0087	.9501	64.2680
-.4E-06		-.0607	2.4436	65.0092	-1.318	4.793	.519	15.127	45.1274	45.1274	.9969	67.4348
-.4E-06	SURF REF	.0000	2.5035	65.2683	-1.337	4.774	.567	-11.851	45.3027	45.3027	1.0008	67.7019
-.5E-06		-.0188	2.4845	65.3570	-1.343	4.768	.549	-12.108	45.3620	45.3620	1.0022	67.7929
-.2E-06		-.2051	2.2966	66.0428	-1.393	4.718	.376	-15.817	45.8339	45.8339	1.0127	68.5059
-.9E-06	RCVR	-1.0000	1.5003	68.5421	-1.566	4.543	-.324	-18.376	47.5969	47.5969	1.0516	71.1365
-.7E-06	BOTM REF	-2.5168	.0000	73.2669	-1.861	1.370	-1.531	15.683	50.9337	50.9337	1.1251	76.1111
-.9E-06	RCVR	-1.0000	1.5937	78.2658	-1.950	1.277	-.366	17.518	54.4373	54.4373	1.2024	81.3353
-.7E-06		-.0628	2.5914	81.4574	-2.001	1.222	.279	14.213	56.6623	56.6623	1.2516	84.6628
-.8E-06	SURF REF	.0000	2.6597	81.7521	-2.005	1.217	.320	-10.579	56.8600	56.8600	1.2560	84.9642
-.7E-06		-.0186	2.6430	81.8509	-2.007	1.216	.305	-10.852	56.9256	56.9256	1.2575	85.0648
-.5E-06		-.1767	2.4966	82.4834	-2.016	1.206	.188	-14.797	57.3569	57.3569	1.2671	85.7170
-.9E-06	RCVR	-1.0000	1.7211	85.2403	-2.056	1.161	-.396	-17.499	59.2834	59.2834	1.3097	88.5949
-.8E-06	BOTM REF	-2.8039	.0000	91.2552	-2.133	-1.725	-1.555	13.679	63.4879	63.4879	1.4025	94.8744
-.6E-06		-1.1211	1.7570	97.4561	-2.024	-1.626	-.521	16.054	67.7879	67.7879	1.4975	101.3007
-.6E-06	RCVR	-1.0000	1.8817	97.8766	-2.017	-1.620	-.451	16.051	68.0819	68.0819	1.5040	101.7384
-.4E-06		-.0850	2.8212	101.3112	-1.963	-1.577	.051	12.950	70.4569	70.4569	1.5566	105.2944
-.5E-06		-.0008	2.9081	101.7598	-1.956	-1.571	.094	8.329	70.7569	70.7569	1.5633	105.7512
-.5E-06	SURF REF	.0000	2.9090	101.7652	-1.956	-1.571	.095	-8.326	70.7605	70.7604	1.5634	105.7567
-.5E-06		-.0680	2.8431	102.1449	-1.951	-1.566	.053	-12.749	71.0136	71.0136	1.5691	106.1427
-.3E-06		-.4618	2.4578	103.7530	-1.927	-1.546	-.180	-15.059	72.1136	72.1136	1.5936	107.7989

-.6E-06	RCVR	-1.0000	1.9283	105.6589	-1.899	-1.527	-.486	-16.008	73.4412	73.4412	1.6229	109.7798
-.9E-06	BOTM REF	-2.9512	.0000	112.8133	-1.803	-1.841	-1.508	13.397	78.3987	78.3987	1.7325	117.1962
-.7E-06		-1.1041	1.8610	119.7562	-1.696	-1.754	-.598	15.571	83.1987	83.1987	1.8387	124.3822
-.7E-06	RCVR	-1.0000	1.9656	120.1295	-1.691	-1.752	-.549	15.561	83.4584	83.4583	1.8445	124.7699
-.6E-06		-.0862	2.8842	123.6498	-1.641	-1.723	-.142	12.758	85.8834	85.8833	1.8983	128.4087
-.6E-06		-.0036	2.9674	124.0942	-1.635	-1.718	-.107	8.097	86.1803	86.1802	1.9049	128.8611
-.6E-06	SURF REF	.0000	2.9710	124.1192	-1.635	-1.718	-.105	-8.086	86.1967	86.1967	1.9053	128.8864
-.7E-06		-.0611	2.9103	124.4767	-1.630	-1.714	-.136	-12.375	86.4342	86.4342	1.9107	129.2493
-.5E-06		-.3875	2.5855	125.8629	-1.611	-1.701	-.296	-14.243	87.3780	87.3780	1.9317	130.6740
-.9E-06	RCVR	-1.0000	1.9752	128.1144	-1.581	-1.688	-.585	-15.517	88.9375	88.9375	1.9663	133.0082
-.1E-05	BOTM REF	-2.9809	.0000	135.4746	-1.489	-1.724	-1.455	13.598	94.0267	94.0266	2.0789	140.6313
-.9E-06		-1.6847	1.2991	140.4060	-1.428	-1.674	-.919	15.436	97.4267	97.4266	2.1543	145.7308
-.8E-06	RCVR	-1.0000	1.9850	142.8894	-1.399	-1.666	-.650	15.337	99.1495	99.1495	2.1924	148.3074
-.7E-06		-.0845	2.9020	146.4535	-1.358	-1.652	-.308	12.720	101.5995	101.5995	2.2468	151.9888
-.7E-06		-.0012	2.9855	146.9079	-1.353	-1.648	-.279	8.085	101.9027	101.9026	2.2537	152.4513
-.7E-06	SURF REF	.0000	2.9867	146.9161	-1.353	-1.648	-.278	-8.082	101.9081	101.9080	2.2538	152.4596
-.8E-06		-.0651	2.9217	147.2923	-1.349	-1.645	-.306	-12.469	102.1581	102.1580	2.2595	152.8417
-.5E-06		-.4230	2.5644	148.8073	-1.332	-1.637	-.454	-14.360	103.1893	103.1893	2.2825	154.3990
-.9E-06	RCVR	-1.0000	1.9881	150.9431	-1.309	-1.632	-.686	-15.335	104.6667	104.6667	2.3152	156.6119
-.1E-05	BOTM REF	-2.9902	.0000	158.3933	-1.231	-1.623	-1.439	13.562	109.8135	109.8135	2.4292	164.3244
-.1E-05		-1.7753	1.2160	163.0372	-1.184	-1.585	-1.012	15.427	113.0135	113.0135	2.5002	169.1249
-.9E-06	RCVR	-1.0000	1.9918	165.8384	-1.157	-1.578	-.752	15.416	114.9585	114.9585	2.5431	172.0318
-.7E-06		-.0842	2.9082	169.3993	-1.123	-1.568	-.459	12.642	117.4085	117.4085	2.5975	175.7102
-.8E-06		-.0024	2.9901	169.8489	-1.119	-1.565	-.434	7.931	117.7085	117.7085	2.6043	176.1675
-.8E-06	SURF REF	.0000	2.9925	169.8664	-1.119	-1.565	-.433	-7.923	117.7200	117.7200	2.6045	176.1853
-.8E-06		-.0620	2.9306	170.2334	-1.116	-1.562	-.456	-12.297	117.9638	117.9637	2.6100	176.5577
-.5E-06		-.3859	2.6069	171.6202	-1.103	-1.556	-.573	-14.144	118.9075	118.9075	2.6311	177.9824
-.9E-06	RCVR	-1.0000	1.9931	173.8890	-1.082	-1.551	-.788	-15.459	120.4791	120.4791	2.6659	180.3335
-.1E-05	BOTM REF	-2.9941	.0000	181.4326	-1.016	-1.525	-1.452	13.200	125.6912	125.6911	2.7812	188.1371
-.9E-06		-1.1587	1.8361	188.3780	-.959	-1.483	-.901	15.678	130.4912	130.4911	2.8874	195.3217
-.9E-06	RCVR	-1.0000	1.9949	188.9434	-.955	-1.482	-.856	15.669	130.8852	130.8852	2.8961	195.9090
-.8E-06		-.0845	2.9107	192.4767	-.927	-1.467	-.599	12.533	133.3227	133.3227	2.9501	199.5606
-.8E-06		-.0045	2.9908	192.9211	-.924	-1.465	-.578	7.682	133.6196	133.6195	2.9568	200.0125
-.8E-06	SURF REF	.0000	2.9953	192.9544	-.923	-1.464	-.577	-7.663	133.6416	133.6415	2.9573	200.0462
-.8E-06		-.0572	2.9381	193.3075	-.921	-1.462	-.596	-11.983	133.8759	133.8759	2.9626	200.4041
-.4E-06		-.3653	2.6301	194.6382	-.911	-1.455	-.694	-14.055	134.7822	134.7821	2.9828	201.7704
-.8E-06	RCVR	-1.0000	1.9956	196.9598	-.893	-1.446	-.891	-15.715	136.3953	136.3952	3.0184	204.1778
-.9E-06	BOTM REF	-2.9961	.0000	204.5749	-.838	-1.412	-1.485	12.804	141.6603	141.6602	3.1347	212.0512
-.7E-06	MAX RANG	-1.5880	1.4085	210.0885	-.801	-1.378	-1.110	15.626	145.4603	145.4602	3.2189	217.7421

THIS RAY CALCULATION TOOK 13.791 SEC

***** H A R P O *****
HAMILTONIAN ACOUSTIC RAY-TRACING PROGRAM FOR THE OCEAN

BY

R. M. JONES, J. P. RILEY AND T. M. GEORGES
WAVE PROPAGATION LABORATORY
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
BOULDER, COLORADO 80303

RUN SET NUMBER 2

OCEAN MODEL ID — N01

OCEAN MODEL DESCRIPTION — SAMPLE CASE FOR HARPO DOCUMENTATION REV. 8-19-86

MODEL TYPE	SUBROUTINE NAME	DATA SET ID	DESCRIPTION
DISPERSION RELATION	AWCWL		ACOUSTIC WAVE *** WITH CURRENT *** WITH LOSSES
BACKGROUND CURRENT VELOCITY	VVORTX3	3.00	VORTEX AT LONGITUDE 150 KM E, UMAX= 1.02 M/S, R= 50 KM
CURRENT VELOCITY PERTURBATION	NPCURR	.00	NO CURRENT PERTURBATION
BACKGROUND SOUND SPEED	CTANH	1.00	EL NINO BACKGROUND SOUND-SPEED PROFILE
SOUND SPEED PERTURBATION	CBLOB2	7.00	2% INCREASE IN C-SQUARED AT 150 KM LON., 1 KM DEPTH, 50 KM WIDE
BACKGROUND BOTTOM	GLORENZ	3.00	RIDGE .5 KM HIGH, 2 KM WIDE AT 10 KM N LATITUDE; BASE= -3 KM
BOTTOM PERTURBATION	NPBOTM	.00	NO BOTTOM PERTURBATION
ABSORPTION	SLLOSS	1.00	SKRETTING-LEROY ABSORPTION FORMULA
ABSORPTION PERTURBATION	NPABSR	.00	NO ABSORPTION PERTURBATION
RECEIVER SURFACE	RHORIZ	.00	RECEIVER SURFACE = SPHERE 1 KM BELOW MSL
OCEAN SURFACE	SHORIZ	1.00	OCEAN SURFACE = SPHERE AT MSL
OCEAN SURFACE PERTURBATION	NPSURF	.00	NO OCEAN SURFACE PERTURBATION

INPUT DATA FILE FOR RUN SET NUMBER 2

```
N01-2     SAMPLE CASE FOR HARPO DOCUMENTATION          REV. 8-19-86
 71         0.            NUMBER OF INTEGRATION STEPS PER PRINT [1.E31]
 72         0.            OUTPUT RAYSETS (1=YES; 0=NO)
 73         1.            DIAGNOSTIC PRINTOUT (1=YES; 0=NO)
 81         2.            RAYPLOT PROJECTION PLANE (2 = HORIZONTAL)
 88        -1.            HEIGHT OF HORIZONTAL PLOT SECTION ABOVE MSL, KM
  0                       **********  END OF RUN SET NUMBER 2  *********
```

INITIAL VALUES FOR THE W ARRAY
ONLY NONZERO VALUES PRINTED — ALL ANGLES IN RADIANS

N	W(N)	
1	.637000000000000E+04	
3	-.980769230769170E+00	
7	.251327412287184E+04	
11	.139626340159545E+01	
15	.349065850398864E-01	
16	.279252680319091E+00	
17	.349065850398864E-01	
20	-.100000000000000E+01	
22	.500000000000000E+02	
23	.100000000000000E+04	
24	.157079632679490E+01	
26	.500000000000000E+01	
27	-.500000000000000E+01	
28	.210000000000000E+03	
33	.200000000000000E+02	
41	.300000000000000E+01	
42	.999999999999997E-06	
43	.500000000000000E+02	
44	.100000000000000E+00	
45	.100000000000000E+03	
46	.100000000000000E-07	
47	.500000000000000E+00	
57	.200000000000000E+01	
58	.200000000000000E+01	
60	.200000000000000E+01	
71	.999999999999999E+30	INPUT OVERRIDDEN
73	.100000000000000E+01	
75	.150000000000000E+00	
77	.570000000000000E+02	
81	.200000000000000E+01	
82	.400000000000000E+02	
85	.551020408163264E-02	
86	.313971742543171E-01	
87	.784929356357927E-02	
88	-.100000000000000E+01	
96	.100000000000000E+01	
100	.900000000000000E+01	
102	.300000000000000E+01	
103	.102000000000001E-02	
104	.500000000000000E+02	
106	.235478806907378E-01	
107	.100000000000000E+01	
108	-.100000000000000E+01	
150	.700000000000000E+01	
152	.100000000000000E+01	
175	.200000000000000E+01	

N	W(N)
177	.700000000000000E+01
178	.200000000000000E-01
179	-.100000000000000E+01
181	.235478806907378E-01
182	.100000000000000E+01
183	.784929356357927E-02
184	.784929356357927E-02
275	.100000000000000E+01
300	.400000000000000E+01
302	.300000000000000E+01
303	.500000000000000E+00
304	.156985871271585E-02
305	.313971742543171E-03
306	-.300000000000000E+01
350	.100000000000000E+01
352	.100000000000000E+01
500	.100000000000000E+01
502	.100000000000000E+01
503	.138155106185094E-02
504	.606731174662869E-01
505	.628318530717958E+04
506	.106814150222053E+05

AZIMUTH ANGLE OF TRANSMISSION = 80.000000 DEG TRANSMITTER LATITUDE = .000000 DEG FREQUENCY = 400.000000 HZ
ELEVATION ANGLE OF TRANSMISSION = 2.000000 DEG TRANSMITTER LONGITUDE = .000000 DEG SINGLE STEP ERROR = 1.000000E-06

ERROR	EVENT	ELEVATION ABOVE SEA LEVEL KM	ELEVATION ABOVE TERRAIN KM	RANGE KM	AZIMUTH DEVIATION XMTR DEG	AZIMUTH DEVIATION LOCAL DEG	ELEVATION ANGLE XMTR DEG	ELEVATION ANGLE LOCAL DEG	PULSE TIME SEC	PHASE TIME SEC	ABSORPTION DB	PATH LENGTH KM
.00E+00	XMTR	-.9808	2.0000	.0000				2.000	.0000	.0000	.0000	.0000
.85E-09	APOGEE	-.7737	2.1992	9.5046	-.018	-.019	1.205	-.014	6.4000	6.4000	.1405	9.5061
.85E-09	WAVE REV	-.7737	2.1992	9.5046	-.018	-.019	1.205	-.014	6.4000	6.4000	.1405	9.5061
-.2E-07	BACK UP0	-1.0204	1.9367	20.0479	-.018	-.020	-.203	-2.037	13.5000	13.5000	.2964	20.0514
-.2E-07	BACK UP1	-1.0000	1.9582	19.4734	-.018	-.020	-.144	-2.022	13.1129	13.1129	.2879	19.4767
-.2E-07	RCVR	-1.0000	1.9582	19.4734	-.018	-.020	-.144	-2.022	13.1129	13.1129	.2879	19.4767
-.1E-07	PERIGEE	-1.3869	1.5043	35.8077	-.017	-.023	-.811	.016	24.1129	24.1129	.5294	35.8134
-.1E-07	WAVE REV	-1.3869	1.5043	35.8077	-.017	-.023	-.811	.016	24.1129	24.1129	.5294	35.8134
-.2E-07	BACK UP0	-.9965	1.5972	52.1429	-.016	-.027	-.252	2.007	35.1129	35.1129	.7709	52.1510
-.2E-07	BACK UP1	-1.0000	1.5965	52.0417	-.016	-.027	-.255	2.010	35.0447	35.0447	.7694	52.0498
-.2E-07	RCVR	-1.0000	1.5965	52.0417	-.016	-.027	-.255	2.010	35.0447	35.0447	.7694	52.0498
-.1E-07	APOGEE	-.7732	1.7938	62.2163	-.016	-.033	-.089	-.023	41.8947	41.8947	.9199	62.2261
-.1E-07	WAVE REV	-.7732	1.7938	62.2163	-.016	-.033	-.089	-.023	41.8947	41.8947	.9199	62.2261
-.3E-07	BACK UP0	-1.0158	1.7998	72.7647	-.015	-.042	-.355	-2.002	48.9947	48.9947	1.0759	72.7765
-.3E-07	BACK UP1	-1.0000	1.8084	72.3109	-.015	-.042	-.340	-1.990	48.6891	48.6891	1.0691	72.3225
-.3E-07	RCVR	-1.0000	1.8084	72.3109	-.015	-.042	-.340	-1.990	48.6891	48.6891	1.0691	72.3225
-.3E-07	PERIGEE	-1.4302	1.5166	91.0432	-.009	-.070	-.692	.029	61.2891	61.2891	1.3461	91.0571
-.3E-07	WAVE REV	-1.4302	1.5166	91.0432	-.009	-.070	-.692	.029	61.2891	61.2891	1.3461	91.0571
-.3E-07	BACK UP0	-.9993	1.9799	112.7886	.006	-.147	-.517	1.417	75.8891	75.8891	1.6676	112.8031
-.3E-07	BACK UP1	-1.0000	1.9792	112.7596	.006	-.147	-.517	1.418	75.8697	75.8697	1.6671	112.7741
-.3E-07	RCVR	-1.0000	1.9792	112.7595	.006	-.147	-.517	1.418	75.8697	75.8697	1.6671	112.7741
-.3E-07	APOGEE	-.7919	2.1946	126.4921	.024	-.226	-.483	-.038	85.0697	85.0697	1.8701	126.5068
-.3E-07	WAVE REV	-.7919	2.1946	126.4921	.024	-.226	-.483	-.038	85.0697	85.0697	1.8701	126.5068
-.3E-07	BACK UP0	-1.0043	1.9865	140.8411	.052	-.325	-.643	-1.287	94.6697	94.6697	2.0823	140.8559
-.3E-07	BACK UP1	-1.0000	1.9907	140.6506	.051	-.324	-.640	-1.281	94.5422	94.5422	2.0794	140.6653
-.3E-07	RCVR	-1.0000	1.9907	140.6506	.051	-.324	-.640	-1.281	94.5422	94.5422	2.0794	140.6653
-.3E-07	PERIGEE	-1.8317	1.1635	172.3289	.136	-.470	-1.058	.068	115.7422	115.7422	2.5478	172.3494
-.3E-07	WAVE REV	-1.8317	1.1635	172.3289	.136	-.470	-1.058	.068	115.7422	115.7422	2.5478	172.3494
-.5E-07	BACK UP0	-.9856	2.0111	194.3880	.198	-.504	-.876	3.118	130.5422	130.5422	2.8742	194.4236
-.5E-07	BACK UP1	-1.0000	1.9967	194.1240	.197	-.503	-.879	3.128	130.3646	130.3646	2.8702	194.1592
-.5E-07	RCVR	-1.0000	1.9967	194.1240	.197	-.503	-.879	3.128	130.3646	130.3646	2.8702	194.1592
-.4E-07	APOGEE	-.6456	2.3515	203.6491	.223	-.510	-.822	-.031	136.7646	136.7646	3.0112	203.6915
-.4E-07	WAVE REV	-.6456	2.3515	203.6491	.223	-.510	-.822	-.031	136.7646	136.7646	3.0112	203.6915
-.5E-07	MAX RANG	-.8511	2.1462	210.1960	.240	-.509	-.910	-2.971	141.1646	141.1646	3.1080	210.2419

THIS RAY CALCULATION TOOK 2.697 SEC

AZIMUTH ANGLE OF TRANSMISSION = 80.000000 DEG TRANSMITTER LATITUDE = .000000 DEG FREQUENCY = 400.000000 HZ
ELEVATION ANGLE OF TRANSMISSION = 4.000000 DEG TRANSMITTER LONGITUDE = .000000 DEG SINGLE STEP ERROR = 1.000000E-06

ERROR	EVENT	ELEVATION ABOVE SEA LEVEL KM	ELEVATION ABOVE TERRAIN KM	RANGE KM	AZIMUTH DEVIATION XMTR DEG	AZIMUTH DEVIATION LOCAL DEG	ELEVATION ANGLE XMTR DEG	ELEVATION ANGLE LOCAL DEG	PULSE TIME SEC	PHASE TIME SEC	ABSORPTION DB	PATH LENGTH KM
.00E+00	XMTR	-.9808	2.0000	.0000				4.000	.0000	.0000	.0000	.0000
.16E-07	APOGEE	-.5981	2.3760	8.2406	-.017	-.018	2.622	-.098	5.5500	5.5500	.1220	8.2504
.16E-07	WAVE REV	-.5981	2.3760	8.2406	-.017	-.018	2.622	-.098	5.5500	5.5500	.1220	8.2504
-.4E-08	BACK UP0	-1.0007	1.9629	16.5543	-.017	-.019	-.143	-4.012	11.1500	11.1500	.2450	16.5745
-.4E-08	BACK UP1	-1.0000	1.9635	16.5446	-.017	-.019	-.141	-4.012	11.1435	11.1435	.2449	16.5649
-.4E-08	RCVR	-1.0000	1.9635	16.5446	-.017	-.019	-.141	-4.012	11.1435	11.1435	.2449	16.5649
-.4E-08	PERIGEE	-1.6999	1.2170	31.8384	-.015	-.019	-1.437	.069	21.4435	21.4435	.4712	31.8750
-.4E-08	WAVE REV	-1.6999	1.2170	31.8384	-.015	-.019	-1.437	.069	21.4435	21.4435	.4712	31.8750
-.6E-07	BACK UP0	-.9898	1.7412	46.9831	-.015	-.023	-.222	3.996	31.6435	31.6435	.6953	47.0363
-.6E-07	BACK UP1	-1.0000	1.7344	46.8372	-.015	-.022	-.234	4.001	31.5450	31.5450	.6932	46.8901
-.6E-07	RCVR	-1.0000	1.7344	46.8372	-.015	-.022	-.234	4.001	31.5450	31.5450	.6932	46.8901
-.4E-07	APOGEE	-.5978	1.9213	55.3751	-.015	-.026	.147	-.094	37.2950	37.2950	.8195	55.4384
-.4E-07	WAVE REV	-.5978	1.9213	55.3751	-.015	-.026	.147	-.094	37.2950	37.2950	.8195	55.4384
-.6E-07	BACK UP0	-1.0181	1.5972	63.9874	-.014	-.031	-.321	-3.992	43.0950	43.0950	.9470	64.0617
-.6E-07	BACK UP1	-1.0000	1.6081	63.7278	-.014	-.031	-.304	-3.985	42.9199	42.9199	.9432	63.8015
-.6E-07	RCVR	-1.0000	1.6081	63.7278	-.014	-.031	-.304	-3.985	42.9199	42.9199	.9432	63.8015
-.2E-07	PERIGEE	-1.7286	1.1645	79.7738	-.012	-.043	-.896	.058	53.7199	53.7199	1.1806	79.8643
-.2E-07	WAVE REV	-1.7286	1.1645	79.7738	-.012	-.043	-.896	.058	53.7199	53.7199	1.1806	79.8643
-.6E-07	BACK UP0	-.9931	1.9664	96.4298	-.006	-.075	-.441	3.614	64.9199	64.9199	1.4271	96.5359
-.6E-07	BACK UP1	-1.0000	1.9593	96.3209	-.006	-.074	-.445	3.618	64.8465	64.8465	1.4255	96.4267
-.6E-07	RCVR	-1.0000	1.9593	96.3209	-.006	-.074	-.445	3.618	64.8465	64.8465	1.4255	96.4267
-.5E-07	APOGEE	-.5997	2.3730	105.5524	-.001	-.106	-.268	-.032	71.0465	71.0465	1.5621	105.6674
-.5E-07	WAVE REV	-.5997	2.3730	105.5524	-.001	-.106	-.268	-.032	71.0465	71.0465	1.5621	105.6674
-.6E-07	BACK UP0	-1.0116	1.9692	115.0917	.007	-.149	-.533	-3.482	77.4465	77.4465	1.7032	115.2161
-.6E-07	BACK UP1	-1.0000	1.9806	114.9018	.007	-.148	-.526	-3.476	77.3190	77.3190	1.7004	115.0258
-.6E-07	RCVR	-1.0000	1.9806	114.9018	.007	-.148	-.526	-3.476	77.3190	77.3190	1.7004	115.0258
-.2E-07	PERIGEE	-2.0665	.9238	138.7830	.042	-.232	-1.072	.018	93.3190	93.3190	2.0538	138.9293
-.2E-07	WAVE REV	-2.0665	.9238	138.7830	.042	-.232	-1.072	.018	93.3190	93.3190	2.0538	138.9293
-.3E-07	BACK UP0	-.9810	2.0135	165.6749	.091	-.349	-.745	2.644	111.3190	111.3190	2.4516	165.8395
-.3E-07	BACK UP1	-1.0000	1.9945	165.2653	.091	-.346	-.750	2.658	111.0446	111.0445	2.4455	165.4295
-.3E-07	RCVR	-1.0000	1.9945	165.2653	.091	-.346	-.750	2.658	111.0446	111.0446	2.4455	165.4295
-.3E-07	APOGEE	-.6490	2.3465	176.1659	.116	-.403	-.684	-.067	118.3446	118.3446	2.6068	176.3358
-.3E-07	WAVE REV	-.6490	2.3465	176.1659	.116	-.403	-.684	-.067	118.3446	118.3446	2.6068	176.3358
-.3E-07	BACK UP0	-1.0286	1.9676	187.0517	.143	-.441	-.856	-2.835	125.6446	125.6446	2.7678	187.2282
-.3E-07	BACK UP1	-1.0000	1.9962	186.4722	.142	-.439	-.845	-2.819	125.2553	125.2553	2.7592	186.6482
-.3E-07	RCVR	-1.0000	1.9962	186.4722	.142	-.439	-.845	-2.819	125.2554	125.2553	2.7592	186.6482
-.1E-07	PERIGEE	-1.6644	1.3327	205.2309	.188	-.458	-1.114	.087	137.8554	137.8553	3.0367	205.4174
-.1E-07	WAVE REV	-1.6644	1.3327	205.2309	.188	-.458	-1.114	.087	137.8554	137.8553	3.0367	205.4174
-.1E-07	MAX RANG	-1.5734	1.4239	210.5919	.200	-.455	-1.108	1.823	141.4554	141.4553	3.1159	210.7782

THIS RAY CALCULATION TOOK 2.438 SEC

AZIMUTH ANGLE OF TRANSMISSION = 80.000000 DEG TRANSMITTER LATITUDE = .000000 DEG FREQUENCY = 400.000000 HZ
ELEVATION ANGLE OF TRANSMISSION = 6.000000 DEG TRANSMITTER LONGITUDE = .000000 DEG SINGLE STEP ERROR = 1.000000E-06

ERROR	EVENT	ELEVATION ABOVE SEA LEVEL KM	ELEVATION ABOVE TERRAIN KM	RANGE KM	AZIMUTH DEVIATION XMTR DEG	AZIMUTH DEVIATION LOCAL DEG	ELEVATION ANGLE XMTR DEG	ELEVATION ANGLE LOCAL DEG	PULSE TIME SEC	PHASE TIME SEC	ABSORPTION DB	PATH LENGTH KM
.00E+00	XMTR	-.9808	2.0000	.0000				6.000	.0000	.0000	.0000	.0000
.64E-07	APOGEE	-.4612	2.5139	7.2720	-.016	-.016	4.055	-.170	4.9000	4.9000	.1078	7.2936
.64E-07	WAVE REV	-.4612	2.5139	7.2720	-.016	-.016	4.055	-.170	4.9000	4.9000	.1078	7.2936
-.3E-07	BACK UP0	-1.0022	1.9644	14.5418	-.016	-.017	-.150	-6.009	9.8000	9.8000	.2156	14.5861
-.3E-07	BACK UP1	-1.0000	1.9667	14.5209	-.016	-.017	-.141	-6.008	9.7858	9.7858	.2153	14.5651
-.3E-07	RCVR	-1.0000	1.9667	14.5209	-.016	-.017	-.141	-6.008	9.7858	9.7858	.2153	14.5651
-.2E-07	PERIGEE	-2.0399	.8848	30.2627	-.013	-.016	-2.141	.056	20.3858	20.3858	.4486	30.3459
-.2E-07	WAVE REV	-2.0399	.8848	30.2627	-.013	-.016	-2.141	.056	20.3858	20.3858	.4486	30.3459
-.6E-07	BACK UP0	-.9808	1.7719	46.0028	-.012	-.018	-.207	5.989	30.9858	30.9858	.6819	46.1260
-.6E-07	BACK UP1	-1.0000	1.7566	45.8199	-.012	-.018	-.230	5.996	30.8620	30.8620	.6792	45.9421
-.6E-07	RCVR	-1.0000	1.7566	45.8199	-.012	-.018	-.230	5.996	30.8620	30.8620	.6792	45.9421
.28E-07	APOGEE	-.4609	2.1032	53.2398	-.013	-.021	.320	-.089	35.8620	35.8620	.7892	53.3846
.28E-07	WAVE REV	-.4609	2.1032	53.2398	-.013	-.021	.320	-.089	35.8620	35.8620	.7892	53.3846
-.6E-07	BACK UP0	-1.0104	1.5212	60.6594	-.013	-.026	-.301	-5.986	40.8620	40.8620	.8992	60.8273
-.6E-07	BACK UP1	-1.0000	1.5297	60.5599	-.013	-.025	-.291	-5.983	40.7946	40.7946	.8977	60.7272
-.6E-07	RCVR	-1.0000	1.5297	60.5599	-.013	-.025	-.291	-5.983	40.7946	40.7946	.8977	60.7272
-.5E-07	PERIGEE	-2.0686	.7995	76.9038	-.010	-.033	-1.156	.085	51.7946	51.7946	1.1399	77.1109
-.5E-07	WAVE REV	-2.0686	.7995	76.9038	-.010	-.033	-1.156	.085	51.7946	51.7946	1.1399	77.1109
-.7E-07	BACK UP0	-.9884	1.9650	93.5567	-.006	-.055	-.425	5.588	62.9946	62.9946	1.3867	93.8021
-.7E-07	BACK UP1	-1.0000	1.9531	93.4379	-.006	-.055	-.432	5.593	62.9145	62.9145	1.3849	93.6828
-.7E-07	RCVR	-1.0000	1.9531	93.4379	-.006	-.055	-.432	5.593	62.9145	62.9145	1.3849	93.6828
-.5E-09	APOGEE	-.4648	2.5026	101.2476	-.003	-.078	-.163	-.072	68.1645	68.1645	1.5007	101.5133
-.5E-09	WAVE REV	-.4648	2.5026	101.2476	-.003	-.078	-.163	-.072	68.1645	68.1645	1.5007	101.5133
-.7E-07	BACK UP0	-1.0085	1.9678	109.1376	.001	-.108	-.505	-5.474	73.4645	73.4645	1.6176	109.4244
-.7E-07	BACK UP1	-1.0000	1.9762	109.0494	.001	-.108	-.501	-5.472	73.4050	73.4050	1.6163	109.3358
-.7E-07	RCVR	-1.0000	1.9762	109.0494	.001	-.108	-.501	-5.472	73.4050	73.4050	1.6163	109.3358
-.6E-07	PERIGEE	-2.3504	.6375	130.5265	.024	-.156	-1.188	.209	87.8050	87.8050	1.9345	130.8599
-.6E-07	WAVE REV	-2.3504	.6375	130.5265	.024	-.156	-1.188	.209	87.8050	87.8050	1.9345	130.8599
-.2E-07	BACK UP0	-.9874	2.0055	153.2275	.053	-.244	-.692	4.295	103.0050	103.0050	2.2707	153.6014
-.2E-07	BACK UP1	-1.0000	1.9929	153.0604	.052	-.242	-.696	4.301	102.8929	102.8929	2.2682	153.4338
-.2E-07	RCVR	-1.0000	1.9929	153.0604	.052	-.242	-.696	4.301	102.8929	102.8929	2.2682	153.4338
.17E-07	APOGEE	-.5077	2.4864	162.1001	.069	-.302	-.562	-.053	108.9429	108.9429	2.4021	162.4884
.17E-07	WAVE REV	-.5077	2.4864	162.1001	.069	-.302	-.562	-.053	108.9429	108.9429	2.4021	162.4884
-.2E-08	BACK UP0	-1.0209	1.9742	171.2073	.088	-.353	-.783	-4.411	115.0429	115.0429	2.5369	171.6114
-.2E-08	BACK UP1	-1.0000	1.9950	170.9365	.087	-.352	-.775	-4.402	114.8611	114.8611	2.5329	171.3399
-.2E-08	RCVR	-1.0000	1.9950	170.9365	.087	-.352	-.775	-4.402	114.8611	114.8611	2.5329	171.3399
-.2E-07	PERIGEE	-2.1120	.8844	191.2150	.132	-.390	-1.199	.188	128.4611	128.4611	2.8332	191.6505
-.2E-07	WAVE REV	-2.1120	.8844	191.2150	.132	-.390	-1.199	.188	128.4611	128.4611	2.8332	191.6505
-.5E-07	BACK UP0	-.9722	2.0251	209.0670	.168	-.388	-.938	5.525	140.4611	140.4611	3.0977	209.5425
-.5E-07	BACK UP1	-1.0000	1.9972	208.7795	.168	-.388	-.944	5.537	140.2669	140.2669	3.0934	209.2537
-.5E-07	RCVR	-1.0000	1.9972	208.7795	.168	-.388	-.944	5.537	140.2669	140.2669	3.0934	209.2537
-.5E-07	MAX RANG	-.8578	2.1395	210.2600	.171	-.389	-.912	5.404	141.2669	141.2669	3.1154	210.7408

THIS RAY CALCULATION TOOK 2.922 SEC

AZIMUTH ANGLE OF TRANSMISSION = 80.000000 DEG TRANSMITTER LATITUDE = .000000 DEG FREQUENCY = 400.000000 HZ
ELEVATION ANGLE OF TRANSMISSION = 8.000000 DEG TRANSMITTER LONGITUDE = .000000 DEG SINGLE STEP ERROR = 1.000000E-06

ERROR	EVENT	ELEVATION ABOVE SEA LEVEL KM	ELEVATION ABOVE TERRAIN KM	RANGE KM	AZIMUTH DEVIATION XMTR DEG	AZIMUTH DEVIATION LOCAL DEG	ELEVATION ANGLE XMTR DEG	ELEVATION ANGLE LOCAL DEG	PULSE TIME SEC	PHASE TIME SEC	ABSORPTION DB	PATH LENGTH KM
-.7E-14	XMTR	-.9808	2.0000	.0000				8.000	.0000	.0000	.0000	.0000
.13E-07	APOGEE	-.3379	2.6378	6.6740	-.015	-.015	5.473	-.090	4.5000	4.5000	.0992	6.7104
.13E-07	WAVE REV	-.3379	2.6378	6.6740	-.015	-.015	5.473	-.090	4.5000	4.5000	.0992	6.7104
.30E-07	BACK UP0	-1.0227	1.9453	13.5670	-.015	-.016	-.238	-8.010	9.1500	9.1500	.2017	13.6428
.30E-07	BACK UP1	-1.0000	1.9682	13.4059	-.015	-.016	-.142	-8.006	9.0405	9.0405	.1993	13.4802
.30E-07	RCVR	-1.0000	1.9682	13.4059	-.015	-.016	-.142	-8.006	9.0405	9.0405	.1993	13.4802
.78E-07	PERIGEE	-2.4608	.4591	31.2440	-.010	-.013	-2.853	.258	21.0405	21.0405	.4641	31.3913
.78E-07	WAVE REV	-2.4608	.4591	31.2440	-.010	-.013	-2.853	.258	21.0405	21.0405	.4641	31.3913
-.6E-07	BACK UP0	-.9643	1.7293	48.4777	-.009	-.014	-.199	7.977	32.6405	32.6405	.7199	48.7006
-.6E-07	BACK UP1	-1.0000	1.7001	48.2230	-.009	-.014	-.240	7.989	32.4673	32.4673	.7161	48.4435
-.6E-07	RCVR	-1.0000	1.7001	48.2230	-.009	-.014	-.240	7.989	32.4673	32.4673	.7161	48.4435
-.5E-07	APOGEE	-.3378	2.1865	55.0449	-.010	-.018	.422	-.087	37.0673	37.0673	.8175	55.3032
-.5E-07	WAVE REV	-.3378	2.1865	55.0449	-.010	-.018	.422	-.087	37.0673	37.0673	.8175	55.3032
-.3E-07	BACK UP0	-1.0406	1.5239	62.0868	-.010	-.022	-.334	-7.980	41.8173	41.8173	.9222	62.3855
-.3E-07	BACK UP1	-1.0000	1.5573	61.7971	-.010	-.022	-.296	-7.975	41.6204	41.6204	.9179	62.0931
-.3E-07	RCVR	-1.0000	1.5573	61.7971	-.010	-.022	-.296	-7.975	41.6204	41.6204	.9179	62.0931
.20E-07	PERIGEE	-2.4981	.3966	79.9390	-.007	-.026	-1.447	.143	53.8204	53.8204	1.1872	80.3095
.20E-07	WAVE REV	-2.4981	.3966	79.9390	-.007	-.026	-1.447	.143	53.8204	53.8204	1.1872	80.3095
-.7E-07	BACK UP0	-.9972	1.9653	98.0930	-.004	-.048	-.451	7.434	66.0204	66.0204	1.4566	98.5349
-.7E-07	BACK UP1	-1.0000	1.9625	98.0715	-.004	-.048	-.452	7.435	66.0059	66.0059	1.4563	98.5132
-.7E-07	RCVR	-1.0000	1.9625	98.0715	-.004	-.048	-.452	7.435	66.0059	66.0059	1.4563	98.5132
-.6E-07	APOGEE	-.3456	2.6267	105.2099	-.002	-.072	-.127	-.050	70.8059	70.8059	1.5624	105.6865
-.6E-07	WAVE REV	-.3456	2.6267	105.2099	-.002	-.072	-.127	-.050	70.8059	70.8059	1.5624	105.6865
-.5E-07	BACK UP0	-1.0370	1.9420	112.6498	.002	-.103	-.535	-7.319	75.8059	75.8059	1.6729	113.1631
-.5E-07	BACK UP1	-1.0000	1.9788	112.3615	.002	-.102	-.515	-7.311	75.6110	75.6110	1.6686	112.8725
-.5E-07	RCVR	-1.0000	1.9788	112.3615	.002	-.102	-.515	-7.311	75.6110	75.6110	1.6686	112.8725
-.4E-08	PERIGEE	-2.7759	.2131	134.1448	.024	-.134	-1.370	.298	90.2110	90.2110	1.9919	134.7405
-.4E-08	WAVE REV	-2.7759	.2131	134.1448	.024	-.134	-1.370	.298	90.2110	90.2110	1.9919	134.7405
-.3E-07	BACK UP0	-.9740	2.0193	155.9419	.045	-.194	-.699	6.426	104.8110	104.8110	2.3153	156.6182
-.3E-07	BACK UP1	-1.0000	1.9933	155.7112	.045	-.192	-.707	6.434	104.6557	104.6557	2.3118	156.3860
-.3E-07	RCVR	-1.0000	1.9933	155.7112	.045	-.192	-.707	6.434	104.6557	104.6557	2.3118	156.3860
-.3E-07	APOGEE	-.3717	2.6225	163.4742	.056	-.242	-.522	-.149	109.8557	109.8557	2.4270	164.1784
-.3E-07	WAVE REV	-.3717	2.6225	163.4742	.056	-.242	-.522	-.149	109.8557	109.8557	2.4270	164.1784
-.2E-07	BACK UP0	-1.0242	1.9708	171.2300	.069	-.284	-.785	-6.537	115.0557	115.0557	2.5422	171.9652
-.2E-07	BACK UP1	-1.0000	1.9950	171.0190	.069	-.283	-.776	-6.530	114.9135	114.9135	2.5390	171.7528
-.2E-07	RCVR	-1.0000	1.9950	171.0190	.069	-.283	-.776	-6.530	114.9135	114.9135	2.5390	171.7528
.30E-08	PERIGEE	-2.5674	.4291	191.5992	.105	-.307	-1.336	.195	128.7135	128.7135	2.8443	192.4012
.30E-08	WAVE REV	-2.5674	.4291	191.5992	.105	-.307	-1.336	.195	128.7135	128.7135	2.8443	192.4012
-.1E-06	MAX RANG	-1.0281	1.9692	210.0554	.134	-.300	-.958	7.721	141.1135	141.1135	3.1182	210.9320

THIS RAY CALCULATION TOOK 3.529 SEC

AZIMUTH ANGLE OF TRANSMISSION = 80.000000 DEG TRANSMITTER LATITUDE = .000000 DEG FREQUENCY = 400.000000 HZ
ELEVATION ANGLE OF TRANSMISSION = 10.000000 DEG TRANSMITTER LONGITUDE = .000000 DEG SINGLE STEP ERROR = 1.000000E-06

ERROR	EVENT	ELEVATION ABOVE SEA LEVEL KM	ELEVATION ABOVE TERRAIN KM	RANGE KM	AZIMUTH DEVIATION XMTR DEG	AZIMUTH DEVIATION LOCAL DEG	ELEVATION ANGLE XMTR DEG	ELEVATION ANGLE LOCAL DEG	PULSE TIME SEC	PHASE TIME SEC	ABSORPTION DB	PATH LENGTH KM
-.7E-14	XMTR	-.9808	2.0000	.0000				10.000	.0000	.0000	.0000	.0000
.33E-07	APOGEE	-.1048	2.8679	9.6483	-.012	-.013	5.145	-.028	6.4750	6.4750	.1435	9.7053
.33E-07	WAVE REV	-.1048	2.8679	9.6483	-.012	-.013	5.145	-.028	6.4750	6.4750	.1435	9.7053
.56E-07	BACK UP0	-1.0491	1.9088	19.6238	-.012	-.014	-.288	-10.009	13.1750	13.1750	.2919	19.7437
.56E-07	BACK UP1	-1.0000	1.9585	19.3456	-.012	-.014	-.144	-10.005	12.9848	12.9848	.2877	19.4613
.56E-07	RCVR	-1.0000	1.9585	19.3456	-.012	-.014	-.144	-10.005	12.9848	12.9848	.2877	19.4613
.15E-06	BACK UP0	-2.9064	-.0099	35.0706	-.009	-.012	-3.301	-2.477	23.5848	23.5848	.5220	35.3099
.15E-06	BACK UP1	-2.8979	.0000	34.8791	-.009	-.012	-3.304	-2.591	23.4576	23.4576	.5192	35.1183
.15E-06	BOTM REF	-2.8979	.0000	34.8791	-.009	.232	-3.304	3.400	23.4576	23.4576	.5192	35.1183
-.2E-07	BACK UP0	-.9966	1.6818	49.3975	-.080	.159	-.241	10.223	33.2576	33.2576	.7357	49.7665
-.2E-07	BACK UP1	-1.0000	1.6789	49.3788	-.080	.159	-.244	10.224	33.2447	33.2447	.7354	49.7475
-.2E-07	RCVR	-1.0000	1.6789	49.3788	-.080	.159	-.244	10.224	33.2447	33.2447	.7354	49.7475
.23E-07	APOGEE	-.0756	2.4244	58.2324	-.106	.129	.629	-.035	39.1947	39.1947	.8672	58.6633
.23E-07	WAVE REV	-.0756	2.4244	58.2324	-.106	.129	.629	-.035	39.1947	39.1947	.8672	58.6633
.36E-07	BACK UP0	-1.0048	1.6764	67.1054	-.126	.105	-.322	-10.189	45.1572	45.1572	.9993	67.5986
.36E-07	BACK UP1	-1.0000	1.6805	67.0788	-.126	.105	-.318	-10.188	45.1391	45.1391	.9989	67.5716
.36E-07	RCVR	-1.0000	1.6805	67.0788	-.126	.105	-.318	-10.188	45.1390	45.1391	.9989	67.5716
.15E-06	BACK UP0	-2.9053	-.0089	81.2985	-.145	.079	-1.722	-3.774	54.7390	54.7391	1.2111	81.9228
.15E-06	BACK UP1	-2.8954	.0000	81.1497	-.145	.079	-1.717	-3.861	54.6401	54.6401	1.2089	81.7738
.15E-06	BOTM REF	-2.8954	.0000	81.1497	-.145	-.210	-1.717	3.021	54.6401	54.6401	1.2089	81.7738
-.7E-07	BACK UP0	-.9843	1.9734	96.5829	-.113	-.197	-.436	9.501	65.0401	65.0401	1.4388	97.3300
-.7E-07	BACK UP1	-1.0000	1.9576	96.4893	-.113	-.197	-.445	9.505	64.9763	64.9763	1.4374	97.2352
-.7E-07	RCVR	-1.0000	1.9576	96.4893	-.113	-.197	-.445	9.505	64.9763	64.9763	1.4374	97.2352
-.3E-07	APOGEE	-.0990	2.8741	106.9837	-.094	-.208	-.009	-.028	72.0013	72.0013	1.5934	107.7855
-.3E-07	WAVE REV	-.0990	2.8741	106.9837	-.094	-.208	-.009	-.028	72.0013	72.0013	1.5934	107.7855
-.7E-08	BACK UP0	-1.0446	1.9373	117.8969	-.075	-.235	-.561	-9.220	79.3013	79.3013	1.7556	118.7567
-.7E-08	BACK UP1	-1.0000	1.9817	117.6220	-.076	-.234	-.538	-9.212	79.1147	79.1147	1.7515	118.4782
-.7E-08	RCVR	-1.0000	1.9817	117.6220	-.076	-.234	-.538	-9.212	79.1147	79.1147	1.7515	118.4782
.92E-07	BACK UP0	-3.0313	-.0430	132.7664	-.047	-.248	-1.482	-4.276	89.3147	89.3147	1.9774	133.7591
.92E-07	BACK UP1	-2.9882	.0000	132.2094	-.048	-.249	-1.465	-4.591	88.9443	88.9443	1.9691	133.2007
.92E-07	BOTM REF	-2.9882	.0000	132.2094	-.048	-.265	-1.465	4.554	88.9443	88.9443	1.9691	133.2007
.23E-07	BACK UP0	-.9627	2.0292	147.3613	-.019	-.297	-.656	8.687	99.1443	99.1443	2.1951	148.4868
.23E-07	BACK UP1	-1.0000	1.9918	147.1174	-.019	-.295	-.669	8.695	98.9793	98.9793	2.1914	148.2400
.23E-07	RCVR	-1.0000	1.9918	147.1174	-.019	-.295	-.669	8.695	98.9793	98.9793	2.1914	148.2400
.36E-07	APOGEE	-.0959	2.8977	158.6998	.005	-.344	-.394	-.027	106.7043	106.7043	2.3634	159.8741
.36E-07	WAVE REV	-.0959	2.8977	158.6998	.005	-.344	-.394	-.027	106.7043	106.7043	2.3634	159.8741
.58E-07	BACK UP0	-1.0199	1.9750	170.1974	.031	-.384	-.779	-8.869	114.3793	114.3793	2.5342	171.4256
.58E-07	BACK UP1	-1.0000	1.9949	170.0700	.031	-.383	-.771	-8.865	114.2929	114.2929	2.5323	171.2967
.58E-07	RCVR	-1.0000	1.9949	170.0700	.031	-.383	-.771	-8.865	114.2929	114.2929	2.5323	171.2967
.15E-06	BACK UP0	-2.9966	-.0005	186.1234	.068	-.392	-1.458	-3.356	125.0929	125.0929	2.7715	187.4766
.15E-06	BACK UP1	-2.9961	.0000	186.1151	.068	-.392	-1.458	-3.361	125.0875	125.0875	2.7713	187.4683
.15E-06	BOTM REF	-2.9961	.0000	186.1151	.068	-.394	-1.458	3.353	125.0875	125.0875	2.7713	187.4683
-.9E-07	BACK UP0	-.9762	2.0208	201.8456	.100	-.384	-.906	9.686	135.6875	135.6875	3.0059	203.3329
-.9E-07	BACK UP1	-1.0000	1.9969	201.7061	.100	-.384	-.913	9.692	135.5923	135.5923	3.0038	203.1913
-.9E-07	RCVR	-1.0000	1.9969	201.7061	.100	-.384	-.913	9.692	135.5923	135.5923	3.0038	203.1913
-.6E-07	MAX RANG	-.1257	2.8715	210.0424	.117	-.384	-.711	1.425	141.1923	141.1923	3.1278	211.5846

THIS RAY CALCULATION TOOK 5.782 SEC

AZIMUTH ANGLE OF TRANSMISSION = 80.000000 DEG TRANSMITTER LATITUDE = .000000 DEG FREQUENCY = 400.000000 HZ
ELEVATION ANGLE OF TRANSMISSION = 12.000000 DEG TRANSMITTER LONGITUDE = .000000 DEG SINGLE STEP ERROR = 1.000000E-06

ERROR	EVENT	ELEVATION ABOVE SEA LEVEL KM	ELEVATION ABOVE TERRAIN KM	RANGE KM	AZIMUTH DEVIATION XMTR DEG	AZIMUTH DEVIATION LOCAL DEG	ELEVATION ANGLE XMTR DEG	ELEVATION ANGLE LOCAL DEG	PULSE TIME SEC	PHASE TIME SEC	ABSORPTION DB	PATH LENGTH KM
-.7E-14	XMTR	-.9808	2.0000	.0000				12.000	.0000	.0000	.0000	.0000
.12E-06	APOGEE	-.0412	2.9353	5.7848	-.013	-.013	9.200	-.152	3.9188	3.9188	.0867	5.8661
.12E-06	WAVE REV	-.0412	2.9353	5.7848	-.013	-.013	9.200	-.152	3.9188	3.9188	.0867	5.8661
.46E-07	BACK UP0	-1.0051	1.9653	11.6687	-.013	-.014	-.172	-12.005	7.9063	7.9063	.1749	11.8339
.46E-07	BACK UP1	-1.0000	1.9705	11.6447	-.013	-.014	-.147	-12.004	7.8897	7.8897	.1746	11.8093
.46E-07	RCVR	-1.0000	1.9705	11.6447	-.013	-.014	-.147	-12.004	7.8897	7.8897	.1746	11.8093
.22E-06	BACK UP0	-2.9612	-.0106	22.8294	-.010	-.011	-5.062	-6.845	15.4897	15.4897	.3425	23.1658
.22E-06	BACK UP1	-2.9508	.0000	22.7433	-.010	-.011	-5.054	-6.896	15.4322	15.4322	.3412	23.0790
.22E-06	BOTM REF	-2.9508	.0000	22.7433	-.010	.193	-5.054	7.184	15.4322	15.4322	.3412	23.0790
-.7E-07	BACK UP0	-.9946	1.9131	33.6244	-.075	.127	-.175	12.168	22.8322	22.8322	.5046	34.1354
-.7E-07	BACK UP1	-1.0000	1.9079	33.5994	-.075	.127	-.184	12.169	22.8150	22.8150	.5042	34.1099
-.7E-07	RCVR	-1.0000	1.9079	33.5994	-.075	.127	-.184	12.169	22.8150	22.8150	.5042	34.1099
.71E-07	APOGEE	-.0394	2.8222	39.3422	-.096	.105	1.194	-.089	26.7087	26.7088	.5904	39.9378
.71E-07	WAVE REV	-.0394	2.8222	39.3422	-.096	.105	1.194	-.089	26.7087	26.7088	.5904	39.9378
.64E-07	BACK UP0	-1.0486	1.7275	45.3025	-.112	.087	-.290	-12.169	30.7525	30.7525	.6798	45.9883
.64E-07	BACK UP1	-1.0000	1.7803	45.0772	-.111	.088	-.227	-12.165	30.5973	30.5973	.6764	45.7579
.64E-07	RCVR	-1.0000	1.7803	45.0772	-.111	.088	-.227	-12.165	30.5973	30.5973	.6764	45.7579
.26E-06	BACK UP0	-2.5803	-.0016	53.2774	-.127	.071	-1.960	-8.780	36.1973	36.1973	.7999	54.1081
.26E-06	BACK UP1	-2.5790	.0000	53.2686	-.127	.071	-1.959	-8.785	36.1914	36.1914	.7997	54.0993
.26E-06	BOTM REF	-2.5790	.0000	53.2686	-.127	3.158	-1.959	11.314	36.1914	36.1914	.7997	54.0993
.44E-06	BACK UP0	-.9955	1.5051	60.0872	-.487	2.796	-.284	14.059	40.8914	40.8914	.9033	61.1072
.44E-06	BACK UP1	-1.0000	1.5006	60.0692	-.486	2.797	-.288	14.060	40.8789	40.8790	.9031	61.0887
.44E-06	RCVR	-1.0000	1.5006	60.0692	-.486	2.797	-.288	14.060	40.8789	40.8790	.9031	61.0887
.61E-06	APOGEE	-.0153	2.5149	65.0273	-.701	2.579	.558	-.032	44.2602	44.2602	.9780	66.1579
.61E-06	WAVE REV	-.0153	2.5149	65.0273	-.701	2.579	.558	-.032	44.2602	44.2602	.9780	66.1579
.48E-06	BACK UP0	-1.0314	1.5847	70.1034	-.890	2.388	-.357	-14.043	47.7227	47.7227	1.0547	71.3482
.48E-06	BACK UP1	-1.0000	1.6137	69.9780	-.885	2.392	-.330	-14.041	47.6356	47.6357	1.0528	71.2189
.48E-06	RCVR	-1.0000	1.6137	69.9780	-.885	2.392	-.330	-14.041	47.6356	47.6357	1.0528	71.2189
.34E-06	BACK UP0	-2.7903	-.0398	77.8333	-1.128	2.145	-1.682	-10.807	53.0356	53.0357	1.1720	79.2807
.34E-06	BACK UP1	-2.7472	.0000	77.6090	-1.122	2.151	-1.653	-10.938	52.8837	52.8837	1.1686	79.0521
.34E-06	BOTM REF	-2.7472	.0000	77.6090	-1.122	-.362	-1.653	8.925	52.8837	52.8837	1.1686	79.0521
-.3E-07	BACK UP0	-.9517	1.9216	86.6909	-1.085	-.335	-.371	12.417	59.0837	59.0837	1.3055	88.3091
-.3E-07	BACK UP1	-1.0000	1.8714	86.4716	-1.086	-.335	-.402	12.427	58.9327	58.9327	1.3021	88.0845
-.3E-07	RCVR	-1.0000	1.8714	86.4716	-1.086	-.335	-.402	12.427	58.9327	58.9327	1.3021	88.0845
.18E-06	APOGEE	-.0340	2.8762	91.9411	-1.067	-.327	.177	-.165	62.6420	62.6421	1.3843	93.6435
.18E-06	WAVE REV	-.0340	2.8762	91.9411	-1.067	-.327	.177	-.165	62.6420	62.6421	1.3843	93.6435
.29E-08	BACK UP0	-1.0292	1.9058	97.5448	-1.050	-.323	-.467	-12.359	66.4420	66.4421	1.4685	99.3395
.29E-08	BACK UP1	-1.0000	1.9346	97.4114	-1.050	-.323	-.449	-12.356	66.3503	66.3503	1.4665	99.2029
.29E-08	RCVR	-1.0000	1.9346	97.4114	-1.050	-.323	-.449	-12.356	66.3503	66.3503	1.4665	99.2029
-.5E-07	BACK UP0	-3.1293	-.1675	108.5873	-1.017	-.308	-1.622	-8.028	73.9503	73.9503	1.6347	110.5796
-.5E-07	BACK UP1	-2.9598	.0000	107.4338	-1.020	-.311	-1.539	-8.693	73.1776	73.1776	1.6175	109.4142
-.5E-07	BOTM REF	-2.9598	.0000	107.4338	-1.020	-.497	-1.539	8.489	73.1776	73.1776	1.6175	109.4142
-.4E-06	BACK UP0	-.9391	2.0348	118.0199	-.976	-.483	-.511	11.815	80.3776	80.3776	1.7768	120.1904
-.4E-06	BACK UP1	-1.0000	1.9735	117.7288	-.977	-.482	-.539	11.826	80.1784	80.1784	1.7724	119.8930
-.4E-06	RCVR	-1.0000	1.9735	117.7288	-.977	-.482	-.539	11.826	80.1784	80.1784	1.7724	119.8930
-.2E-06	APOGEE	-.0340	2.9443	123.3849	-.955	-.490	-.115	-.161	84.0003	84.0003	1.8573	125.6353
-.2E-06	WAVE REV	-.0340	2.9443	123.3849	-.955	-.490	-.115	-.161	84.0003	84.0003	1.8573	125.6353
-.3E-06	BACK UP0	-1.0001	1.9818	129.0489	-.934	-.502	-.589	-11.733	87.8253	87.8253	1.9423	131.3851

-.3E-06	RCVR	-1.0000	1.9819	129.0483	-.934	-.502	-.589	-11.733	87.8248	87.8248	1.9422	131.3844
-.2E-06	BACK UP0	-3.0530	-.0663	139.6415	-.894	-.501	-1.478	-8.849	95.0248	95.0248	2.1017	142.1732
-.2E-06	BACK UP1	-2.9865	.0000	139.2201	-.896	-.502	-1.452	-9.086	94.7420	94.7420	2.0954	141.7468
-.2E-06	BOTM REF	-2.9865	.0000	139.2201	-.896	-.541	-1.452	9.044	94.7420	94.7420	2.0954	141.7468
-.3E-06	BACK UP0	-.9906	1.9991	149.5198	-.858	-.546	-.676	11.541	101.7420	101.7420	2.2505	152.2364
-.3E-06	BACK UP1	-1.0000	1.9896	149.4738	-.858	-.546	-.680	11.543	101.7106	101.7106	2.2498	152.1894
-.3E-06	RCVR	-1.0000	1.9896	149.4738	-.858	-.546	-.680	11.543	101.7106	101.7106	2.2498	152.1894
-.1E-06	APOGEE	-.0338	2.9571	155.2048	-.837	-.565	-.348	-.071	105.5762	105.5762	2.3358	158.0053
-.1E-06	WAVE REV	-.0338	2.9571	155.2048	-.837	-.565	-.348	-.071	105.5762	105.5762	2.3358	158.0053
-.1E-06	BACK UP0	-1.0355	1.9565	161.0943	-.815	-.583	-.744	-11.584	109.5512	109.5512	2.4242	163.9834
-.1E-06	BACK UP1	-1.0000	1.9920	160.9212	-.816	-.582	-.731	-11.578	109.4330	109.4331	2.4215	163.8067
-.1E-06	RCVR	-1.0000	1.9920	160.9212	-.816	-.582	-.731	-11.578	109.4330	109.4331	2.4215	163.8067
-.8E-07	BACK UP0	-3.0227	-.0291	171.5190	-.777	-.583	-1.454	-8.655	116.6330	116.6331	2.5810	174.5945
-.8E-07	BACK UP1	-2.9935	.0000	171.3287	-.778	-.584	-1.444	-8.763	116.5054	116.5054	2.5782	174.4020
-.8E-07	BOTM REF	-2.9935	.0000	171.3287	-.778	-.596	-1.444	8.749	116.5054	116.5054	2.5782	174.4020
-.4E-06	BACK UP0	-.9419	2.0527	181.9110	-.742	-.591	-.806	11.917	123.7054	123.7054	2.7375	185.1802
-.4E-06	BACK UP1	-1.0000	1.9946	181.6361	-.743	-.591	-.823	11.929	123.5170	123.5170	2.7334	184.8993
-.4E-06	RCVR	-1.0000	1.9946	181.6361	-.743	-.591	-.823	11.929	123.5170	123.5170	2.7334	184.8993
-.2E-06	APOGEE	-.0350	2.9601	187.2827	-.724	-.596	-.553	-.091	127.3358	127.3358	2.8181	190.6324
-.2E-06	WAVE REV	-.0350	2.9601	187.2827	-.724	-.596	-.553	-.091	127.3358	127.3358	2.8181	190.6324
-.4E-06	BACK UP0	-1.0231	1.9725	193.0067	-.705	-.597	-.881	-12.033	131.2108	131.2108	2.9040	196.4457
-.4E-06	BACK UP1	-1.0000	1.9956	192.8983	-.706	-.597	-.873	-12.030	131.1364	131.1364	2.9024	196.3350
-.4E-06	RCVR	-1.0000	1.9956	192.8983	-.706	-.597	-.873	-12.030	131.1364	131.1364	2.9024	196.3350
-.5E-06	BACK UP0	-3.0224	-.0261	203.7839	-.672	-.582	-1.491	-7.816	138.5364	138.5364	3.0661	207.4069
-.5E-06	BACK UP1	-2.9962	.0000	203.5948	-.673	-.582	-1.483	-7.926	138.4099	138.4099	3.0633	207.2161
-.5E-06	BOTM REF	-2.9962	.0000	203.5948	-.673	-.588	-1.483	7.919	138.4099	138.4099	3.0633	207.2161
-.5E-06	MAX RANG	-1.8778	1.1188	210.0987	-.655	-.572	-1.190	11.474	142.8099	142.8099	3.1608	213.8144

THIS RAY CALCULATION TOOK 9.265 SEC

AZIMUTH ANGLE OF TRANSMISSION = 80.000000 DEG TRANSMITTER LATITUDE = .000000 DEG FREQUENCY = 400.000000 HZ
ELEVATION ANGLE OF TRANSMISSION = 14.000000 DEG TRANSMITTER LONGITUDE = .000000 DEG SINGLE STEP ERROR = 1.000000E-06

ERROR	EVENT	ELEVATION ABOVE SEA LEVEL KM	ELEVATION ABOVE TERRAIN KM	RANGE KM	AZIMUTH DEVIATION XMTR DEG	AZIMUTH DEVIATION LOCAL DEG	ELEVATION ANGLE XMTR DEG	ELEVATION ANGLE LOCAL DEG	PULSE TIME SEC	PHASE TIME SEC	ABSORPTION DB	PATH LENGTH KM
-.7E-14	XMTR	-.9808	2.0000	.0000				14.000	.0000	.0000	.0000	.0000
.96E-07	APOGEE	-.0187	2.9586	4.7902	-.013	-.013	11.335	-.054	3.2656	3.2656	.0723	4.8926
.96E-07	WAVE REV	-.0187	2.9586	4.7902	-.013	-.013	11.335	-.054	3.2656	3.2656	.0723	4.8926
.17E-07	BACK UP0	-1.0247	1.9479	9.7464	-.013	-.014	-.302	-14.006	6.6469	6.6469	.1472	9.9565
.17E-07	BACK UP1	-1.0000	1.9727	9.6474	-.013	-.014	-.158	-14.003	6.5782	6.5782	.1457	9.8545
.17E-07	RCVR	-1.0000	1.9727	9.6474	-.013	-.014	-.158	-14.003	6.5782	6.5782	.1457	9.8545
-.1E-06	BACK UP0	-3.0369	-.0777	18.9927	-.010	-.011	-6.266	-9.710	12.9782	12.9782	.2871	19.4189
-.1E-06	BACK UP1	-2.9600	.0000	18.5493	-.010	-.012	-6.176	-9.973	12.6798	12.6798	.2804	18.9691
-.1E-06	BOTM REF	-2.9600	.0000	18.5493	-.010	.206	-6.176	10.186	12.6798	12.6798	.2804	18.9691
.74E-07	BACK UP0	-.9700	1.9671	27.4412	-.080	.136	-.101	14.149	18.7798	18.7798	.4151	28.0804
.74E-07	BACK UP1	-1.0000	1.9375	27.3220	-.079	.137	-.163	14.155	18.6970	18.6970	.4133	27.9576
.74E-07	RCVR	-1.0000	1.9375	27.3220	-.079	.137	-.163	14.155	18.6970	18.6970	.4133	27.9576
.20E-06	APOGEE	-.0128	2.9026	32.4041	-.103	.112	1.565	-.017	22.1564	22.1564	.4900	33.1460
.20E-06	WAVE REV	-.0128	2.9026	32.4041	-.103	.112	1.565	-.017	22.1564	22.1564	.4900	33.1460
.48E-07	BACK UP0	-1.0218	1.8580	37.5620	-.121	.094	-.232	-14.155	25.6689	25.6689	.5679	38.4130
.48E-07	BACK UP1	-1.0000	1.8806	37.4756	-.120	.094	-.198	-14.153	25.6089	25.6089	.5665	38.3239
.48E-07	RCVR	-1.0000	1.8806	37.4756	-.120	.094	-.198	-14.153	25.6089	25.6089	.5665	38.3239
-.1E-06	BACK UP0	-2.8475	-.0754	45.6301	-.139	.074	-2.549	-10.561	31.2089	31.2089	.6901	46.6842
-.1E-06	BACK UP1	-2.7790	.0000	45.2665	-.138	.075	-2.479	-10.776	30.9631	30.9631	.6847	46.3144
-.1E-06	BOTM REF	-2.7790	.0000	45.2665	-.138	2.653	-2.479	12.635	30.9631	30.9631	.6847	46.3144
.49E-07	BACK UP0	-.9883	1.6727	52.1966	-.493	2.298	-.243	15.586	35.7631	35.7631	.7906	53.4774
.49E-07	BACK UP1	-1.0000	1.6618	52.1548	-.491	2.300	-.256	15.588	35.7338	35.7338	.7899	53.4340
.49E-07	RCVR	-1.0000	1.6618	52.1548	-.491	2.300	-.256	15.588	35.7338	35.7338	.7899	53.4340
.30E-06	BACK UP0	.0001	2.5789	56.2932	-.661	2.128	.745	6.516	38.5807	38.5807	.8529	57.6975
.30E-06	SURF REF	.0000	2.5788	56.2926	-.661	2.128	.745	-6.517	38.5803	38.5803	.8529	57.6968
.17E-06	BACK UP0	-1.0249	1.4888	60.5211	-.811	1.976	-.314	-15.583	41.4896	41.4896	.9173	62.0534
.17E-06	BACK UP1	-1.0000	1.5146	60.4317	-.808	1.979	-.290	-15.580	41.4271	41.4271	.9160	61.9605
.17E-06	RCVR	-1.0000	1.5146	60.4317	-.808	1.979	-.290	-15.580	41.4271	41.4271	.9160	61.9605
.89E-07	BACK UP0	-2.5211	-.0041	66.1951	-.982	1.803	-1.631	-13.349	45.4271	45.4271	1.0041	67.9233
.89E-07	BACK UP1	-2.5168	.0000	66.1771	-.981	1.803	-1.628	-13.359	45.4148	45.4148	1.0038	67.9048
.89E-07	BOTM REF	-2.5168	.0000	66.1771	-.981	-.413	-1.628	11.913	45.4148	45.4148	1.0038	67.9048
.28E-06	BACK UP0	-.9877	1.6794	72.5572	-.947	-.383	-.332	14.334	49.8148	49.8148	1.1008	74.4645
.28E-06	BACK UP1	-1.0000	1.6659	72.5091	-.947	-.383	-.341	14.335	49.7813	49.7813	1.1001	74.4149
.28E-06	RCVR	-1.0000	1.6659	72.5091	-.947	-.383	-.341	14.335	49.7813	49.7813	1.1001	74.4149
.34E-06	BACK UP0	.0005	2.7753	77.3972	-.924	-.365	.378	2.609	53.1126	53.1126	1.1739	79.4122
.34E-06	BACK UP1	.0000	2.7745	77.3854	-.924	-.365	.378	2.616	53.1049	53.1049	1.1738	79.4004
.34E-06	SURF REF	.0000	2.7745	77.3854	-.924	-.365	.378	-2.616	53.1049	53.1049	1.1738	79.4004
.27E-06	BACK UP0	-1.0133	1.8339	82.3193	-.903	-.351	-.393	-14.303	56.4674	56.4674	1.2483	84.4451
.27E-06	BACK UP1	-1.0000	1.8466	82.2672	-.904	-.351	-.383	-14.302	56.4312	56.4312	1.2476	84.3914
.27E-06	RCVR	-1.0000	1.8466	82.2672	-.904	-.351	-.383	-14.302	56.4312	56.4312	1.2476	84.3914
.17E-06	BACK UP0	-3.0095	-.0939	91.0097	-.871	-.326	-1.687	-10.699	62.4312	62.4312	1.3802	93.3610
.17E-06	BACK UP1	-2.9130	.0000	90.5056	-.872	-.328	-1.630	-10.993	62.0908	62.0908	1.3726	92.8480
.17E-06	BOTM REF	-2.9130	.0000	90.5056	-.872	-1.030	-1.630	10.348	62.0907	62.0908	1.3726	92.8480
.32E-06	BACK UP0	-.9750	1.9735	99.2631	-.783	-.955	-.443	13.618	68.0907	68.0908	1.5052	101.8174
.32E-06	BACK UP1	-1.0000	1.9482	99.1598	-.784	-.956	-.457	13.622	68.0193	68.0194	1.5036	101.7111
.32E-06	RCVR	-1.0000	1.9482	99.1598	-.784	-.956	-.457	13.622	68.0193	68.0194	1.5036	101.7111
.41E-06	APOGEE	-.0169	2.9429	104.1662	-.738	-.926	.062	-.051	71.4225	71.4225	1.5791	106.8209
.41E-06	WAVE REV	-.0169	2.9429	104.1662	-.738	-.926	.062	-.051	71.4225	71.4225	1.5791	106.8209

.30E-06	BACK UP0	-1.0149	1.9532	109.2339	-.696	-.904	-.509	-13.549	74.8662	74.8662	1.6556	111.9936
.30E-06	BACK UP1	-1.0000	1.9680	109.1722	-.697	-.904	-.501	-13.547	74.8237	74.8237	1.6547	111.9302
.30E-06	RCVR	-1.0000	1.9680	109.1722	-.697	-.904	-.501	-13.547	74.8237	74.8237	1.6547	111.9302
.16E-06	BACK UP0	-3.0477	-.0699	118.3782	-.626	-.857	-1.533	-10.470	81.1237	81.1237	1.7941	121.3606
.16E-06	BACK UP1	-2.9775	.0000	118.0022	-.629	-.859	-1.500	-10.685	80.8701	80.8701	1.7884	120.9783
.16E-06	BOTM REF	-2.9775	.0000	118.0022	-.629	-.958	-1.500	10.589	80.8701	80.8701	1.7884	120.9783
.45E-06	BACK UP0	-.9749	2.0086	127.0682	-.561	-.922	-.569	13.179	87.0701	87.0701	1.9257	130.2621
.45E-06	BACK UP1	-1.0000	1.9835	126.9610	-.561	-.922	-.580	13.183	86.9964	86.9964	1.9240	130.1520
.45E-06	RCVR	-1.0000	1.9835	126.9610	-.561	-.922	-.580	13.183	86.9964	86.9964	1.9240	130.1520
.55E-06	APOGEE	-.0149	2.9711	132.1571	-.525	-.918	-.176	-.035	90.5151	90.5152	2.0023	135.4495
.55E-06	WAVE REV	-.0149	2.9711	132.1571	-.525	-.918	-.176	-.035	90.5151	90.5152	2.0023	135.4495
.43E-06	BACK UP0	-1.0311	1.9569	137.4822	-.489	-.918	-.639	-13.131	94.1214	94.1214	2.0826	140.8793
.43E-06	BACK UP1	-1.0000	1.9879	137.3491	-.490	-.917	-.626	-13.126	94.0299	94.0299	2.0806	140.7425
.43E-06	RCVR	-1.0000	1.9879	137.3491	-.490	-.917	-.626	-13.126	94.0299	94.0299	2.0806	140.7425
.30E-06	BACK UP0	-3.0492	-.0587	146.5659	-.431	-.896	-1.468	-10.741	100.3299	100.3299	2.2202	150.1834
.30E-06	BACK UP1	-2.9904	.0000	146.2585	-.433	-.898	-1.445	-10.913	100.1225	100.1225	2.2155	149.8706
.30E-06	BOTM REF	-2.9904	.0000	146.2585	-.433	-.926	-1.445	10.886	100.1225	100.1225	2.2155	149.8706
.43E-06	BACK UP0	-.9683	2.0240	155.3259	-.378	-.911	-.694	13.082	106.3225	106.3225	2.3529	159.1598
.43E-06	BACK UP1	-1.0000	1.9922	155.1897	-.379	-.910	-.705	13.086	106.2289	106.2289	2.3508	159.0199
.43E-06	RCVR	-1.0000	1.9922	155.1897	-.379	-.910	-.705	13.086	106.2289	106.2289	2.3508	159.0199
.51E-06	APOGEE	-.0156	2.9775	160.3739	-.348	-.915	-.376	-.042	109.7383	109.7383	2.4289	164.3050
.51E-06	WAVE REV	-.0156	2.9775	160.3739	-.348	-.915	-.376	-.042	109.7383	109.7383	2.4289	164.3050
.37E-06	BACK UP0	-1.0315	1.9623	165.6690	-.318	-.919	-.763	-13.138	113.3258	113.3258	2.5087	169.7047
.37E-06	BACK UP1	-1.0000	1.9938	165.5342	-.319	-.919	-.751	-13.134	113.2332	113.2332	2.5067	169.5663
.37E-06	RCVR	-1.0000	1.9938	165.5342	-.319	-.919	-.751	-13.134	113.2332	113.2332	2.5067	169.5663
.13E-06	BACK UP0	-3.0789	-.0841	175.0485	-.267	-.900	-1.474	-10.298	119.7332	119.7332	2.6506	179.3045
.13E-06	BACK UP1	-2.9948	.0000	174.5912	-.269	-.903	-1.446	-10.560	119.4250	119.4250	2.6438	178.8397
.13E-06	BOTM REF	-2.9948	.0000	174.5912	-.269	-.914	-1.446	10.549	119.4250	119.4250	2.6438	178.8397
.33E-06	BACK UP0	-.9844	2.0111	183.6509	-.223	-.893	-.827	13.411	125.6250	125.6250	2.7810	188.1192
.33E-06	BACK UP1	-1.0000	1.9956	183.5857	-.224	-.893	-.832	13.413	125.5800	125.5800	2.7800	188.0522
.33E-06	RCVR	-1.0000	1.9956	183.5857	-.224	-.893	-.832	13.413	125.5800	125.5800	2.7800	188.0522
.46E-06	APOGEE	-.0192	2.9767	188.5766	-.199	-.889	-.556	-.040	128.9706	128.9707	2.8553	193.1451
.46E-06	WAVE REV	-.0192	2.9767	188.5766	-.199	-.889	-.556	-.040	128.9706	128.9707	2.8553	193.1451
.32E-06	BACK UP0	-1.0073	1.9890	193.5774	-.175	-.882	-.878	-13.490	132.3706	132.3707	2.9307	198.2490
.32E-06	BACK UP1	-1.0000	1.9963	193.5470	-.175	-.882	-.876	-13.489	132.3496	132.3497	2.9302	198.2177
.32E-06	RCVR	-1.0000	1.9963	193.5470	-.175	-.882	-.876	-13.489	132.3496	132.3497	2.9302	198.2177
.20E-06	BACK UP0	-2.9979	-.0011	202.7558	-.134	-.857	-1.482	-9.970	138.6496	138.6497	3.0695	207.6408
.20E-06	BACK UP1	-2.9968	.0000	202.7494	-.134	-.857	-1.482	-9.974	138.6453	138.6453	3.0694	207.6343
.20E-06	BOTM REF	-2.9968	.0000	202.7494	-.134	-.862	-1.482	9.968	138.6453	138.6453	3.0694	207.6343
.38E-06	MAX RANG	-1.4448	1.5522	210.0720	-.104	-.837	-1.071	13.577	143.6453	143.6453	3.1801	215.1191

THIS RAY CALCULATION TOOK 13.113 SEC

AZIMUTH ANGLE OF TRANSMISSION = 80.000000 DEG TRANSMITTER LATITUDE = .000000 DEG FREQUENCY = 400.000000 HZ
ELEVATION ANGLE OF TRANSMISSION = 16.000000 DEG TRANSMITTER LONGITUDE = .000000 DEG SINGLE STEP ERROR = 1.000000E-06

ERROR	EVENT	ELEVATION ABOVE SEA LEVEL KM	ELEVATION ABOVE TERRAIN KM	RANGE KM	AZIMUTH DEVIATION XMTR DEG	AZIMUTH DEVIATION LOCAL DEG	ELEVATION ANGLE XMTR DEG	ELEVATION ANGLE LOCAL DEG	PULSE TIME SEC	PHASE TIME SEC	ABSORPTION DB	PATH LENGTH KM
-.7E-14	XMTR	-.9808	2.0000	.0000				16.000	.0000	.0000	.0000	.0000
.15E-06	BACK UP0	.0012	2.9792	3.9245	-.013	-.013	14.031	7.414	2.7031	2.7031	.0598	4.0479
.15E-06	SURF REF	.0000	2.9780	3.9152	-.013	-.014	14.047	-7.420	2.6970	2.6970	.0597	4.0386
-.3E-07	BACK UP0	-1.0012	1.9733	7.9016	-.013	-.014	-.184	-16.003	5.4439	5.4439	.1205	8.1511
-.3E-07	BACK UP1	-1.0000	1.9745	7.8975	-.013	-.014	-.175	-16.003	5.4410	5.4410	.1204	8.1469
-.3E-07	RCVR	-1.0000	1.9745	7.8975	-.013	-.014	-.175	-16.003	5.4410	5.4410	.1204	8.1469
-.3E-06	BACK UP0	-3.0667	-.1021	15.8535	-.010	-.011	-7.569	-12.367	10.9410	10.9410	.2419	16.3661
-.3E-06	BACK UP1	-2.9653	.0000	15.3961	-.010	-.012	-7.416	-12.638	10.6304	10.6304	.2350	15.8979
-.3E-06	BOTM REF	-2.9653	.0000	15.3961	-.010	.213	-7.416	12.811	10.6304	10.6304	.2350	15.8979
-.4E-07	BACK UP0	-.9743	1.9765	22.9038	-.083	.140	-.087	16.135	15.8304	15.8304	.3498	23.6641
-.4E-07	BACK UP1	-1.0000	1.9510	22.8151	-.083	.140	-.151	16.139	15.7682	15.7682	.3485	23.5718
-.4E-07	RCVR	-1.0000	1.9510	22.8151	-.083	.140	-.151	16.139	15.7682	15.7682	.3485	23.5718
.15E-06	BACK UP0	.0008	2.9405	26.7533	-.105	.117	1.981	7.710	18.4838	18.4838	.4086	27.6375
.15E-06	SURF REF	.0000	2.9398	26.7475	-.105	.117	1.980	-7.714	18.4800	18.4800	.4085	27.6316
.46E-07	BACK UP0	-1.0119	1.9123	30.7211	-.123	.099	-.196	-16.140	21.2206	21.2206	.4691	31.7344
.46E-07	BACK UP1	-1.0000	1.9244	30.6799	-.122	.099	-.174	-16.138	21.1918	21.1918	.4685	31.6915
.46E-07	RCVR	-1.0000	1.9244	30.6799	-.122	.099	-.174	-16.138	21.1918	21.1918	.4685	31.6915
-.2E-06	BACK UP0	-2.9529	-.0766	38.0433	-.144	.077	-3.140	-12.847	26.2918	26.2918	.5811	39.3085
-.2E-06	BACK UP1	-2.8791	.0000	37.7222	-.143	.078	-3.051	-13.037	26.0731	26.0731	.5762	38.9791
-.2E-06	BOTM REF	-2.8791	.0000	37.7222	-.143	1.485	-3.051	13.972	26.0731	26.0731	.5762	38.9792
-.3E-06	BACK UP0	-.9705	1.8400	44.4731	-.370	1.257	-.187	16.885	30.7731	30.7731	.6799	45.9955
-.3E-06	BACK UP1	-1.0000	1.8118	44.3760	-.367	1.260	-.224	16.889	30.7047	30.7047	.6784	45.8940
-.3E-06	RCVR	-1.0000	1.8118	44.3760	-.367	1.260	-.224	16.889	30.7047	30.7047	.6784	45.8940
-.2E-06	BACK UP0	.0013	2.7560	48.0667	-.465	1.160	.954	9.224	33.2610	33.2610	.7350	49.7207
-.2E-06	BACK UP1	.0000	2.7549	48.0587	-.465	1.161	.953	9.230	33.2556	33.2556	.7349	49.7125
-.2E-06	SURF REF	.0000	2.7549	48.0587	-.465	1.161	.953	-9.230	33.2556	33.2556	.7349	49.7125
-.4E-06	BACK UP0	-1.0036	1.6768	51.7536	-.549	1.075	-.258	-16.887	35.8150	35.8150	.7915	53.5437
-.4E-06	BACK UP1	-1.0000	1.6806	51.7418	-.549	1.075	-.254	-16.886	35.8066	35.8066	.7914	53.5313
-.4E-06	RCVR	-1.0000	1.6806	51.7418	-.549	1.075	-.254	-16.886	35.8066	35.8066	.7914	53.5313
-.3E-06	BACK UP0	-2.6086	-.0553	57.3303	-.655	.968	-1.885	-14.626	39.7066	39.7066	.8773	59.3466
-.3E-06	BACK UP1	-2.5573	.0000	57.1345	-.652	.971	-1.838	-14.741	39.5718	39.5718	.8743	59.1442
-.3E-06	BOTM REF	-2.5573	.0000	57.1345	-.652	5.462	-1.838	16.468	39.5718	39.5718	.8743	59.1442
-.5E-06	BACK UP0	-.9704	1.5474	62.0851	-1.090	5.022	-.270	18.379	43.0718	43.0718	.9515	64.3618
-.5E-06	BACK UP1	-1.0000	1.5183	61.9964	-1.083	5.030	-.297	18.383	43.0087	43.0087	.9501	64.2680
-.5E-06	RCVR	-1.0000	1.5183	61.9964	-1.083	5.030	-.297	18.383	43.0087	43.0087	.9501	64.2680
-.4E-06	BACK UP0	.0009	2.5044	65.2726	-1.337	4.774	.568	11.848	45.3055	45.3055	1.0009	67.7063
-.4E-06	BACK UP1	.0000	2.5035	65.2683	-1.337	4.774	.567	11.851	45.3027	45.3027	1.0008	67.7019
-.4E-06	SURF REF	.0000	2.5035	65.2683	-1.337	4.774	.567	-11.851	45.3027	45.3027	1.0008	67.7019
-.9E-06	BACK UP0	-1.0466	1.4539	68.6820	-1.576	4.533	-.364	-18.378	47.6964	47.6964	1.0538	71.2844
-.9E-06	BACK UP1	-1.0000	1.5003	68.5421	-1.566	4.543	-.324	-18.376	47.5969	47.5969	1.0516	71.1365
-.9E-06	RCVR	-1.0000	1.5003	68.5421	-1.566	4.543	-.324	-18.376	47.5969	47.5969	1.0516	71.1365
-.7E-06	BACK UP0	-2.5438	-.0265	73.3576	-1.866	4.240	-1.551	-16.557	50.9969	50.9969	1.1265	76.2059
-.7E-06	BOTM REF	-2.5168	.0000	73.2669	-1.861	1.370	-1.531	15.683	50.9337	50.9337	1.1251	76.1111
-.9E-06	BACK UP0	-.9569	1.6394	78.4024	-1.952	1.275	-.335	17.512	54.5337	54.5337	1.2045	81.4786
-.9E-06	BACK UP1	-1.0000	1.5937	78.2658	-1.950	1.277	-.366	17.518	54.4373	54.4373	1.2024	81.3353
-.9E-06	RCVR	-1.0000	1.5937	78.2658	-1.950	1.277	-.366	17.518	54.4373	54.4373	1.2024	81.3353
-.8E-06	BACK UP0	.0015	2.6614	81.7602	-2.005	1.217	.321	10.574	56.8654	56.8654	1.2561	84.9725
-.8E-06	BACK UP1	.0000	2.6597	81.7521	-2.005	1.217	.320	10.579	56.8600	56.8600	1.2560	84.9642

-.8E-06	SURF	REF	.0000	2.6597	81.7521	-2.005	1.217	.320	-10.579	56.8600	56.8600	1.2560	84.9642
-.9E-06	BACK	UP0	-1.0329	1.6899	85.3445	-2.057	1.160	-.419	-17.502	59.3569	59.3569	1.3113	88.7042
-.9E-06	BACK	UP1	-1.0000	1.7211	85.2403	-2.056	1.161	-.396	-17.499	59.2834	59.2834	1.3097	88.5949
-.9E-06	RCVR		-1.0000	1.7211	85.2403	-2.056	1.161	-.396	-17.499	59.2834	59.2834	1.3097	88.5949
-.8E-06	BACK	UP0	-2.9199	-.1112	91.6847	-2.138	1.072	-1.624	-14.995	63.7834	63.7834	1.4091	95.3191
-.8E-06	BACK	UP1	-2.8039	.0000	91.2552	-2.133	1.077	-1.555	-15.243	63.4879	63.4879	1.4025	94.8744
-.8E-06	BOTM	REF	-2.8039	.0000	91.2552	-2.133	-1.725	-1.555	13.679	63.4879	63.4879	1.4025	94.8744
-.6E-06	BACK	UP0	-.9975	1.8842	97.8853	-2.017	-1.620	-.450	16.050	68.0879	68.0879	1.5041	101.7474
-.6E-06	BACK	UP1	-1.0000	1.8817	97.8766	-2.017	-1.620	-.451	16.051	68.0819	68.0819	1.5040	101.7384
-.6E-06	RCVR		-1.0000	1.8817	97.8766	-2.017	-1.620	-.451	16.051	68.0819	68.0819	1.5040	101.7384
-.5E-06	BACK	UP0	.0006	2.9096	101.7693	-1.956	-1.571	.095	8.324	70.7631	70.7631	1.5635	105.7608
-.5E-06	SURF	REF	.0000	2.9090	101.7652	-1.956	-1.571	.095	-8.326	70.7605	70.7604	1.5634	105.7567
-.6E-06	BACK	UP0	-1.0092	1.9192	105.6910	-1.899	-1.527	-.491	-16.009	73.4636	73.4636	1.6234	109.8132
-.6E-06	BACK	UP1	-1.0000	1.9283	105.6589	-1.899	-1.527	-.486	-16.008	73.4412	73.4412	1.6229	109.7798
-.6E-06	RCVR		-1.0000	1.9283	105.6589	-1.899	-1.527	-.486	-16.008	73.4412	73.4412	1.6229	109.7798
-.9E-06	BACK	UP0	-2.9664	-.0150	112.8754	-1.802	-1.447	-1.516	-13.645	78.4412	78.4412	1.7335	117.2602
-.9E-06	BACK	UP1	-2.9512	.0000	112.8133	-1.803	-1.447	-1.508	-13.681	78.3987	78.3987	1.7325	117.1962
-.9E-06	BOTM	REF	-2.9512	.0000	112.8133	-1.803	-1.841	-1.508	13.397	78.3987	78.3987	1.7325	117.1962
-.7E-06	BACK	UP0	-.9838	1.9819	120.1875	-1.690	-1.751	-.542	15.559	83.4987	83.4987	1.8454	124.8302
-.7E-06	BACK	UP1	-1.0000	1.9656	120.1295	-1.691	-1.752	-.549	15.561	83.4584	83.4583	1.8445	124.7699
-.7E-06	RCVR		-1.0000	1.9656	120.1295	-1.691	-1.752	-.549	15.561	83.4584	83.4583	1.8445	124.7699
-.6E-06	BACK	UP0	.0005	2.9715	124.1227	-1.635	-1.718	-.105	8.084	86.1990	86.1990	1.9054	128.8899
-.6E-06	SURF	REF	.0000	2.9710	124.1192	-1.635	-1.718	-.105	-8.086	86.1967	86.1967	1.9053	128.8864
-.9E-06	BACK	UP0	-1.0362	1.9391	128.2447	-1.580	-1.688	-.602	-15.522	89.0280	89.0280	1.9683	133.1434
-.9E-06	BACK	UP1	-1.0000	1.9752	128.1144	-1.581	-1.688	-.585	-15.517	88.9375	88.9375	1.9663	133.0082
-.9E-06	RCVR		-1.0000	1.9752	128.1144	-1.581	-1.688	-.585	-15.517	88.9375	88.9375	1.9663	133.0082
-.1E-05	BACK	UP0	-3.0907	-.1095	135.9303	-1.484	-1.619	-1.501	-13.415	94.3375	94.3375	2.0859	141.1000
-.1E-05	BACK	UP1	-2.9809	.0000	135.4746	-1.489	-1.624	-1.455	-13.672	94.0267	94.0266	2.0789	140.6313
-.1E-05	BOTM	REF	-2.9809	.0000	135.4746	-1.489	-1.724	-1.455	13.598	94.0267	94.0266	2.0789	140.6313
-.8E-06	BACK	UP0	-.9695	2.0156	143.0007	-1.398	-1.665	-.639	15.334	99.2267	99.2266	2.1941	148.4228
-.8E-06	BACK	UP1	-1.0000	1.9850	142.8894	-1.399	-1.666	-.650	15.337	99.1495	99.1495	2.1924	148.3074
-.8E-06	RCVR		-1.0000	1.9850	142.8894	-1.399	-1.666	-.650	15.337	99.1495	99.1495	2.1924	148.3074
-.7E-06	BACK	UP0	.0002	2.9869	146.9174	-1.353	-1.648	-.278	8.081	101.9089	101.9089	2.2538	152.4609
-.7E-06	SURF	REF	.0000	2.9867	146.9161	-1.353	-1.648	-.278	-8.082	101.9081	101.9080	2.2538	152.4596
-.9E-06	BACK	UP0	-1.0288	1.9594	151.0478	-1.308	-1.632	-.698	-15.339	104.7393	104.7393	2.3168	156.7206
-.9E-06	BACK	UP1	-1.0000	1.9881	150.9431	-1.309	-1.632	-.686	-15.335	104.6667	104.6667	2.3152	156.6119
-.9E-06	RCVR		-1.0000	1.9881	150.9431	-1.309	-1.632	-.686	-15.335	104.6667	104.6667	2.3152	156.6119
-.1E-05	BACK	UP0	-3.1140	-.1237	158.9115	-1.226	-1.581	-1.484	-13.297	110.1667	110.1667	2.4371	164.8571
-.1E-05	BACK	UP1	-2.9902	.0000	158.3933	-1.231	-1.586	-1.439	-13.590	109.8135	109.8135	2.4292	164.3244
-.1E-05	BOTM	REF	-2.9902	.0000	158.3933	-1.231	-1.623	-1.439	13.562	109.8135	109.8135	2.4292	164.3244
-.9E-06	BACK	UP0	-.9781	2.0137	165.9177	-1.156	-1.578	-.745	15.413	115.0135	115.0135	2.5444	172.1141
-.9E-06	BACK	UP1	-1.0000	1.9918	165.8384	-1.157	-1.578	-.752	15.416	114.9585	114.9585	2.5431	172.0318
-.9E-06	RCVR		-1.0000	1.9918	165.8384	-1.157	-1.578	-.752	15.416	114.9585	114.9585	2.5431	172.0318
-.8E-06	BACK	UP0	.0002	2.9927	169.8679	-1.119	-1.565	-.433	7.923	117.7210	117.7210	2.6046	176.1867
-.8E-06	SURF	REF	.0000	2.9925	169.8664	-1.119	-1.565	-.433	-7.923	117.7200	117.7200	2.6045	176.1853
-.9E-06	BACK	UP0	-1.0312	1.9619	174.0019	-1.081	-1.550	-.799	-15.462	120.5575	120.5575	2.6676	180.4506
-.9E-06	BACK	UP1	-1.0000	1.9931	173.8890	-1.082	-1.551	-.788	-15.459	120.4791	120.4791	2.6659	180.3335
-.9E-06	RCVR		-1.0000	1.9931	173.8890	-1.082	-1.551	-.788	-15.459	120.4791	120.4791	2.6659	180.3335
-.1E-05	BACK	UP0	-3.1262	-.1321	182.0027	-1.012	-1.504	-1.494	-12.885	126.0791	126.0791	2.7899	188.7222
-.1E-05	BACK	UP1	-2.9941	.0000	181.4326	-1.016	-1.508	-1.452	-13.213	125.6912	125.6911	2.7812	188.1371
-.1E-05	BOTM	REF	-2.9941	.0000	181.4326	-1.016	-1.525	-1.452	13.200	125.6912	125.6911	2.7812	188.1371
-.9E-06	BACK	UP0	-.9976	1.9973	188.9519	-.955	-1.482	-.855	15.669	130.8912	130.8911	2.8962	195.9179
-.9E-06	BACK	UP1	-1.0000	1.9949	188.9434	-.955	-1.482	-.856	15.669	130.8852	130.8852	2.8961	195.9090
-.9E-06	RCVR		-1.0000	1.9949	188.9434	-.955	-1.482	-.856	15.669	130.8852	130.8852	2.8961	195.9090

-.8E-06	BACK UP0	.0006	2.9959	192.9591	-.923	-1.464	-.576	7.660	133.6446	133.6445	2.9573	200.0509
-.8E-06	SURF REF	.0000	2.9953	192.9544	-.923	-1.464	-.577	-7.663	133.6416	133.6415	2.9573	200.0462
-.8E-06	BACK UP0	-1.0351	1.9605	197.0843	-.892	-1.446	-.902	-15.718	136.4822	136.4821	3.0203	204.3072
-.8E-06	BACK UP1	-1.0000	1.9956	196.9598	-.893	-1.446	-.891	-15.715	136.3953	136.3952	3.0184	204.1778
-.8E-06	RCVR	-1.0000	1.9956	196.9598	-.893	-1.446	-.891	-15.715	136.3953	136.3952	3.0184	204.1778
-.9E-06	BACK UP0	-3.0410	-.0449	204.7735	-.837	-1.402	-1.498	-12.696	141.7953	141.7952	3.1378	212.2548
-.9E-06	BACK UP1	-2.9961	.0000	204.5749	-.838	-1.403	-1.485	-12.811	141.6603	141.6602	3.1347	212.0512
-.9E-06	BOTM REF	-2.9961	.0000	204.5749	-.838	-1.412	-1.485	12.804	141.6603	141.6602	3.1347	212.0512
-.7E-06	MAX RANG	-1.5880	1.4085	210.0885	-.801	-1.378	-1.110	15.626	145.4603	145.4602	3.2189	217.7421

THIS RAY CALCULATION TOOK 13.562 SEC

END OF INPUT DATA

```
N01-1      SAMPLE CASE FOR HARPO DOCUMENTATION           REV. 8-19-86
VVORTX3       3.0 NPCURR         .0    CTANH         1.0 CBLOB2        7.0
NO MODL        .0 NO MODL        .0    NO MODL        .0 NO MODL        .0
NO MODL        .0 NO MODL        .0    SLLOSS        1.0 NPABSR         .0
GLORENZ       3.0 NPBOTM         .0    RHORIZ         .0 NO MODL        .0
  VORTEX AT LONGITUDE 150 KM E, UMAX= 1.02 M/S, R= 50 KM
  NO CURRENT PERTURBATION
  EL NINO BACKGROUND SOUND-SPEED PROFILE
  2% INCREASE IN C-SQUARED AT 150 KM LON., 1 KM DEPTH, 50 KM WIDE
  RIDGE .5 KM HIGH, 2 KM WIDE AT 10 KM N LATITUDE; BASE= -3 KM
N013    -9808      0      0    -10000 25132741   8000000    200000          0    050T
   -10000   194734    -18    -20 -2022    1311291   1311291    288     0    0    0 1R
   -10000   520417    -16    -27  2010    3504472   3504471    769     0    0    0 2R
   -10000   723109    -15    -42 -1990    4868914   4868914   1069     0    0    0 3R
   -10000  1127595      6   -147  1418    7586966   7586966   1667     0    0    0 4R
   -10000  1406506     51   -324 -1281    9454219   9454219   2079     0    0    0 5R
   -10000  1941240    197   -503  3128   13036463  13036463   2870     0    0    0 6R
    -8511  2101960    240   -509 -2971   14116463  14116463   3108     0    0    0 7F
N013    -9808      0      0    -10000 25132741   8000000    400000          0    050T
   -10000   165446    -17    -19 -4012    1114351   1114351    245     0    0    0 1R
   -10000   468372    -15    -22  4001    3154502   3154502    693     0    0    0 2R
   -10000   637278    -14    -31 -3985    4291986   4291986    943     0    0    0 3R
   -10000   963209     -6    -74  3618    6484653   6484653   1425     0    0    0 4R
   -10000  1149018      7   -148 -3476    7731899   7731898   1700     0    0    0 5R
   -10000  1652653     91   -346  2658   11104455  11104455   2446     0    0    0 6R
   -10000  1864722    142   -439 -2819   12525535  12525535   2759     0    0    0 7R
   -15734  2105919    200   -455  1823   14145535  14145535   3116     0    0    0 8F
N013    -9808      0      0    -10000 25132741   8000000    600000          0    050T
   -10000   145209    -16    -17 -6008     978585    978585    215     0    0    0 1R
   -10000   458199    -12    -18  5996    3086200   3086200    679     0    0    0 2R
   -10000   605599    -13    -25 -5983    4079462   4079462    898     0    0    0 3R
   -10000   934379     -6    -55  5593    6291447   6291447   1385     0    0    0 4R
   -10000  1090494      1   -108 -5472    7340500   7340500   1616     0    0    0 5R
   -10000  1530604     52   -242  4301   10289292  10289292   2268     0    0    0 6R
   -10000  1709365     87   -352 -4402   11486110  11486110   2533     0    0    0 7R
   -10000  2087795    168   -388  5537   14026691  14026691   3093     0    0    0 8R
    -8578  2102600    171   -389  5404   14126691  14126691   3115     0    0    0 9F
N013    -9808      0      0    -10000 25132741   8000000    800000          0    050T
   -10000   134059    -15    -16 -8006     904047    904047    199     0    0    0 1R
   -10000   482230     -9    -14  7989    3246733   3246733    716     0    0    0 2R
   -10000   617971    -10    -22 -7975    4162042   4162042    918     0    0    0 3R
   -10000   980715     -4    -48  7435    6600587   6600587   1456     0    0    0 4R
   -10000  1123615      2   -102 -7311    7561098   7561098   1669     0    0    0 5R
   -10000  1557112     45   -192  6434   10465570  10465570   2312     0    0    0 6R
   -10000  1710190     69   -283 -6530   11491347  11491347   2539     0    0    0 7R
   -10281  2100554    134   -300  7721   14111347  14111347   3118     0    0    0 8F
N013    -9808      0      0    -10000 25132741   8000000   1000000          0    050T
   -10000   193456    -12    -14-10005    1298480   1298480    288     0    0    0 1R
   -28979   348791     -9    232  3400    2345757   2345757    519     0    0    0 2G
   -10000   493788    -80    159 10224    3324473   3324474    735     0    0    0 2R
   -10000   670788   -126    105-10188    4513905   4513905    999     0    0    0 3R
   -28954   811497   -145   -210  3021    5464007   5464008   1209     0    0    0 4G
   -10000   964893   -113   -197  9505    6497632   6497633   1437     0    0    0 4R
   -10000  1176220    -76   -234 -9212    7911470   7911470   1751     0    0    0 5R
   -29882  1322094    -48   -265  4554    8894430   8894430   1969     0    0    0 6G
```

	-10000	1471174	-19	-295	8695	9897927	9897927	2191	0	0	0 6R
	-10000	1700700	31	-383	-8865	11429294	11429295	2532	0	0	0 7R
	-29961	1861151	68	-394	3353	12508746	12508747	2771	0	0	0 8G
	-10000	2017061	100	-384	9692	13559231	13559232	3004	0	0	0 8R
	-1257	2100424	117	-384	1425	14119231	14119232	3128	0	0	0 9F
N013		-9808	0	0	-10000	25132741	8000000	1200000		0	050T
	-10000	116447	-13	-14	-12004	788973	788973	175	0	0	0 1R
	-29508	227433	-10	193	7184	1543215	1543216	341	0	0	0 2G
	-10000	335994	-75	127	12169	2281500	2281500	504	0	0	0 2R
	-10000	450772	-111	88	-12165	3059732	3059733	676	0	0	0 3R
	-25790	532686	-127	3158	11314	3619144	3619144	800	0	0	0 4G
	-10000	600692	-486	2797	14060	4087894	4087895	903	0	0	0 4R
	-10000	699780	-885	2392	-14041	4763564	4763565	1053	0	0	0 5R
	-27472	776090	-1122	-362	8925	5288367	5288368	1169	0	0	0 6G
	-10000	864716	-1086	-335	12427	5893266	5893268	1302	0	0	0 6R
	-10000	974114	-1050	-323	-12356	6635033	6635035	1467	0	0	0 7R
	-29598	1074338	-1020	-497	8489	7317761	7317763	1617	0	0	0 8G
	-10000	1177288	-977	-482	11826	8017840	8017842	1772	0	0	0 8R
	-10000	1290483	-934	-502	-11733	8782483	8782485	1942	0	0	0 9R
	-29865	1392201	-896	-541	9044	9474203	9474204	2095	0	0	010G
	-10000	1494738	-858	-546	11543	10171061	10171063	2250	0	0	010R
	-10000	1609212	-816	-582	-11578	10943305	10943306	2422	0	0	011R
	-29935	1713287	-778	-596	8749	11650537	11650538	2578	0	0	012G
	-10000	1816361	-743	-591	11929	12351703	12351704	2733	0	0	012R
	-10000	1928983	-706	-597	-12030	13113644	13113645	2902	0	0	013R
	-29962	2035948	-673	-588	7919	13840989	13840989	3063	0	0	014G
	-18778	2100987	-655	-572	11474	14280989	14280989	3161	0	0	014F
N013		-9808	0	0	-10000	25132741	8000000	1400000		0	050T
	-10000	96474	-13	-14	-14003	657818	657818	146	0	0	0 1R
	-29600	185493	-10	206	10186	1267978	1267978	280	0	0	0 2G
	-10000	273220	-79	137	14155	1869704	1869704	413	0	0	0 2R
	-10000	374756	-120	94	-14153	2560890	2560890	567	0	0	0 3R
	-27790	452665	-138	2653	12635	3096309	3096309	685	0	0	0 4G
	-10000	521548	-491	2300	15588	3573382	3573382	790	0	0	0 4R
	0	562926	-661	2128	-6517	3858025	3858026	853	0	0	0 5S
	-10000	604317	-808	1979	-15580	4142711	4142711	916	0	0	0 5R
	-25168	661771	-981	-413	11913	4541478	4541479	1004	0	0	0 6G
	-10000	725091	-947	-383	14335	4978134	4978134	1100	0	0	0 6R
	0	773854	-924	-365	-2616	5310488	5310489	1174	0	0	0 7S
	-10000	822672	-904	-351	-14302	5643124	5643125	1248	0	0	0 7R
	-29130	905056	-872	-1030	10348	6209075	6209075	1373	0	0	0 8G
	-10000	991598	-784	-956	13622	6801934	6801935	1504	0	0	0 8R
	-10000	1091722	-697	-904	-13547	7482368	7482369	1655	0	0	0 9R
	-29775	1180022	-629	-958	10589	8087007	8087008	1788	0	0	010G
	-10000	1269610	-561	-922	13183	8699639	8699640	1924	0	0	010R
	-10000	1373491	-490	-917	-13126	9402993	9402995	2081	0	0	011R
	-29904	1462585	-433	-926	10886	10012246	10012248	2216	0	0	012G
	-10000	1551897	-379	-910	13086	10622890	10622893	2351	0	0	012R
	-10000	1655342	-319	-919	-13134	11323316	11323318	2507	0	0	013R
	-29948	1745912	-269	-914	10549	11942496	11942499	2644	0	0	014G
	-10000	1835857	-224	-893	13413	12558001	12558004	2780	0	0	014R
	-10000	1935470	-175	-882	-13489	13234962	13234965	2930	0	0	015R
	-29968	2027494	-134	-862	9968	13864530	13864534	3069	0	0	016G
	-14448	2100720	-104	-837	13577	14364530	14364534	3180	0	0	016F
N013		-9808	0	0	-10000	25132741	8000000	1600000		0	050T

0	39152	-13	-14	-7420	269703	269703	60	0	0	0 1S
-10000	78975	-13	-14	-16003	544103	544103	120	0	0	0 1R
-29653	153961	-10	213	12811	1063042	1063042	235	0	0	0 2G
-10000	228151	-83	140	16139	1576821	1576820	348	0	0	0 2R
0	267475	-105	117	-7714	1847998	1847998	408	0	0	0 3S
-10000	306799	-122	99	-16138	2119176	2119176	468	0	0	0 3R
-28791	377222	-143	1485	13972	2607306	2607306	576	0	0	0 4G
-10000	443760	-367	1260	16889	3070471	3070471	678	0	0	0 4R
0	480587	-465	1161	-9230	3325562	3325562	735	0	0	0 5S
-10000	517418	-549	1075	-16886	3580665	3580664	791	0	0	0 5R
-25573	571345	-652	5462	16468	3957184	3957184	874	0	0	0 6G
-10000	619964	-1083	5030	18383	4300867	4300866	950	0	0	0 6R
0	652683	-1337	4774	-11851	4530267	4530267	1001	0	0	0 7S
-10000	685421	-1566	4543	-18376	4759688	4759688	1052	0	0	0 7R
-25168	732669	-1861	1370	15683	5093370	5093369	1125	0	0	0 8G
-10000	782658	-1950	1277	17518	5443729	5443728	1202	0	0	0 8R
0	817521	-2005	1217	-10579	5685999	5685998	1256	0	0	0 9S
-10000	852403	-2056	1161	-17499	5928338	5928337	1310	0	0	0 9R
-28039	912552	-2133	-1725	13679	6348794	6348792	1403	0	0	010G
-10000	978766	-2017	-1620	16051	6808190	6808188	1504	0	0	010R
0	1017652	-1956	-1571	-8326	7076045	7076043	1563	0	0	011S
-10000	1056589	-1899	-1527	-16008	7344119	7344117	1623	0	0	011R
-29512	1128133	-1803	-1841	13397	7839875	7839872	1733	0	0	012G
-10000	1201295	-1691	-1752	15561	8345838	8345835	1844	0	0	012R
0	1241192	-1635	-1718	-8086	8619674	8619671	1905	0	0	013S
-10000	1281144	-1581	-1688	-15517	8893751	8893748	1966	0	0	013R
-29809	1354746	-1489	-1724	13598	9402668	9402664	2079	0	0	014G
-10000	1428894	-1399	-1666	15337	9914954	9914949	2192	0	0	014R
0	1469161	-1353	-1648	-8082	10190808	10190803	2254	0	0	015S
-10000	1509431	-1309	-1632	-15335	10466671	10466666	2315	0	0	015R
-29902	1583933	-1231	-1623	13562	10981354	10981349	2429	0	0	016G
-10000	1658384	-1157	-1578	15416	11495851	11495845	2543	0	0	016R
0	1698664	-1119	-1565	-7923	11772004	11771998	2605	0	0	017S
-10000	1738890	-1082	-1551	-15459	12047914	12047908	2666	0	0	017R
-29941	1814326	-1016	-1525	13200	12569117	12569111	2781	0	0	018G
-10000	1889434	-955	-1482	15669	13088524	13088517	2896	0	0	018R
0	1929544	-923	-1464	-7663	13364155	13364148	2957	0	0	019S
-10000	1969598	-893	-1446	-15715	13639529	13639522	3018	0	0	019R
-29961	2045749	-838	-1412	12804	14166026	14166018	3135	0	0	020G
-15880	2100885	-801	-1378	15626	14546026	14546017	3219	0	0	020F

APPENDIX B: BLANK INPUT-PARAMETER FORMS

This appendix provides blank Input Parameter Forms for all of the ocean models (including bottom and receiver-surface models) that we have developed for HARPO. The forms describe each model mathematically and list the variable input parameters you have to specify. We recommend reproducing these forms and filling them out when setting up ocean models for HARPO. The filled-out forms should then be saved as a record of the models you have defined.

The FORTRAN source codes for the corresponding model subroutines are listed in Appendix D under the model name. No forms are given for the do-nothing versions NPSPEED, NPBOTM, NPCURR, etc. The forms are arranged as follows:

FORM TO SPECIFY INPUT DATA FOR A
THREE-DIMENSIONAL RAYPATH CALCULATION

Name________________
Date________________

Ocean ID (3 characters)_____

Title (77 characters)____

Transmitter: Height ________km, nm, ft (W3)
________above bottom
________above sea level
Latitude ________rad, deg, km (W4)
Longitude ________rad, deg, km (W5)
Frequency, initial ________rad/s, Hz, s (W7)
final ________ (W8)
step ________ (W9)
Azimuth angle, initial ________rad, deg clockwise of north (W11)
final ________ (W12)
step ________ (W13)
Elevation angle, initial________rad, deg (W15)
final ________ (W16)
step ________ (W17)

Receiver: Height ________km, nm, ft (W20)
________above sea level (rcvr model RHORIZ)
________above bottom (rcvr model RBOTM)
Distance from origin ________rad, deg, km (W278) (rcvr model RVERT)
Latitude of origin ________rad, deg, km (W279) (rcvr model RVERT)
Longitude of origin ________rad, deg, km (W280) (rcvr model RVERT)

Stop elevation-angle stepping
when ray goes out of bounds ________(W21 = 1.)
Stop ray if it hits the bottom ________(W19 = 1.)

Maximum height ________km (W26)
Minimum height ________km (W27)
Maximum range ________km (W28)
Maximum number of hops ________(W22)
Maximum number of steps per hop ________(W23)
Maximum allowable error per step ________(W42)

Additional calculations:
= 1. to integrate
= 2. to integrate and print
Phase path ________(W57)
Absorption ________(W58)
Doppler shift ________(W59)
Path length ________(W60)

Printout: Every________steps of the ray trace (W71)

Computer readable output (raysets): ________(W72 = 1.)
Diagnostic printing: ________(W73 = 1.)
Suppress all printout ________(W74 = 1.)

FORM TO SPECIFY INPUT PARAMETERS FOR PLOTTING A PROJECTION OF THE RAYPATH

Model ID:__________

Plot directly during raypath calculations______________, or

plot from precomputed raypaths______________

in disk file______________

Normal or apogee plots: Normal__________(W80=0.0)

Plot apogees only__________(W80=1.0)

Projection:

Vertical plane, polar plot, rectangular expansion__________(W81=1.0)

Horizontal plane, lateral expansion __________(W81=2.0)

Vertical plane, polar plot, radial expansion __________(W81=3.0)

Vertical plane, rectangular plot __________(W81=4.0)

Superimpose these raypath plots on the graph of the previous runset:

Yes__________(W81 negative.)

No __________(W81 positive.)

Vertical or lateral expansion factor __________(W82)

Coordinates of the left edge of the graph:

Latitude = __________(rad, deg, km) north (W83)

Longitude = __________(rad, deg, km) east (W84)

Coordinates of the right edge of the graph:

Latitude = __________(rad, deg, km) north (W85)

Longitude = __________(rad, deg, km) east (W86)

Distance between horizontal tick marks = __________rad, deg, km (W87)

Height above sea level of bottom of graph = __________km (W88)

Height above sea level of top of graph = __________km (W89)

Distance between vertical tick marks = __________km (W96)

FORM TO SPECIFY AN OCEAN MODEL
(including bottom and upper surface model)

Name____________________ Date__________ Model ID (3 characters)_________

Dispersion Relation

__ ANCNL __ AWCWL __AWCNL __ANCWL __Other ________________

Coordinates of the north pole pole of the computational coordinate system:

North geographic latitude = ____________rad, km, deg (W24)

East geographic longitude = ____________rad, km, deg (W25)

Data Set ID	Model Subroutine Name (Model Check Number)						
Current Velocity W102 (W100)	__	WLINEAR	(1.)	__	WGAUSS2	(8.)	
	__	VVORTX3	(9.)	__	Other __________		( )
Current Perturbation W127 (W125)	__	NPCURR	(0.)	__	Other __________		( )
Sound Speed W152 (W150)	__	CSTANH	(2.)	__	CSMUNK1	(5.)	
	__	CSSPOKE	(3.)	__	CSMUNK2	(6.)	
	__	CSSPOK2	(4.)	__	CTABLE	(8.)	
	__	CTANH	(7.)	__	Other __________		( )
Sound-Speed Perturbation W177 (W175)	__	NPSPEED	(0.)	__	CBLOB2	(2.)	
	__	CBLOB3	(3.)	__	Other __________		( )
Receiver Surface* (W275)		RHORIZ	(1.)		RTERR	(2.)	
		RVERT	(3.)		Other __________		( )
Ocean Bottom W302 (W300)	__	GHORIZ	(1.)	__	GTANH	(2.)	
	__	GLORENZ	(3.)	__	Other __________		( )
Ocean-Bottom Perturbation W327 (W325)	__	NPBOTM	(0.)	__	Other __________		( )
Ocean Surface W352 (W350)	__	SHORIZ	(1.)	__	Other __________		( )
Ocean-Surface Perturbation W377 (W375)	__	NPSURF	(0.)	__	Other __________		( )
Absorption (loss) W502 (W500)	__	SLLOSS	(1.)	__	Other __________		( )
Absorption Perturbation W527 (W525)	__	NPABSR	(0.)	__	Other __________		( )
Graph Annotation* W75	__	SMPANN		__	FULANN		

* The receiver-surface and graph-annotation models are not considered part of the ocean-model ID.

FORM TO SPECIFY INPUT DATA FOR
CURRENT-VELOCITY MODEL WLINEAR

This subroutine specifies constant radial (upward), eastward and southward currents, allowing a linear height gradient of the eastward component.

$$U_\theta = U_{\theta o}$$

$$U_\phi = U_{\phi o} + \frac{du_\phi}{dz} z$$

$$u_r = U_{ro}$$

$z = r - r_e$, where r_e is the Earth radius, and r is the radial coordinate of ray point.

Specify--

the model check for WLINEAR = ___1.0___ (W100)

the input data-format code = __________ (W101)

an input data-set identification number = __________ (W102)

an 80-character description of the current-velocity profile:

____

the constant upward current, U_{ro} = __________ km/s, m/s (W103)

the constant southward current, $U_{\theta o}$ = __________ km/s, m/s (W104)

the ground value of the eastward current, $U_{\phi o}$ = __________ km/s, m/s (W105)

the height gradient of u_ϕ, du_ϕ/dz = __________ km/s/km, m/s/km (W106)

(This subroutine can be used with its input parameters zero when no current field is desired.)

OTHER MODELS REQUIRED: Any current-perturbation model. Use NPCURR if no perturbation is desired.

FORM TO SPECIFY INPUT DATA FOR
CURRENT-VELOCITY MODEL VVORTX3

This subroutine models a vortex with a viscous core and a Gaussian intensity profile in the vertical. The axis of the vortex is vertical and may be positioned above any geographic latitude and longitude. The vortex rotates anticlockwise looking down. The core (inside r_o) is essentially a solid-rotating fluid, while outside r_o, $|u|$ falls off as the inverse radius.

$$u_\theta = -\frac{1.397\ R_e U_o r_o}{r^2}\left(1 - e^{-1.26\ r^2/r_o^2}\right)(\phi - \phi_o)e^{-\left(\frac{h - h_{max}}{w_H}\right)^2}$$

$$u_\phi = \frac{1.397\ R_e U_o r_o}{r^2}\left(1 - e^{-1.26\ r^2/r_o^2}\right)(\theta - \theta_o)e^{-\left(\frac{h - h_{max}}{w_H}\right)^2},$$

where $\theta_o = \pi/2 - \lambda_o$ and r is the radial distance from the vortex center. The numerical constants normalize the function so that $|U| = U_o$ at $r = r_o$. R_e is the radius of the Earth, θ is the colatitude, ϕ is the longitude, and h is the height above sea level.

Specify--

the model check for VVORTX3 = 9.0 (W100)

the input data-format code = __________ (W101)

an input data-set identification number = __________ (W102)

an 80-character description of the model, including description of parameter values:

____

the maximum tangential current, U_o = __________ km/s, m/s (W103)

the radius of the vortex core (to $u = U_o$), r_o = __________ km (W104)

the latitude of the vortex center, λ_o = __________ rad, deg, km N (W105)

the longitude of the vortex center, ϕ_o = __________ rad, deg, km E (W106)

the Gaussian width in height of the vortex, W_H = __________ km, m (W107)

the height of the vortex, h_{max} = __________ km, m (W108)

OTHER MODELS REQUIRED: Any current-perturbation model. Use NPCURR if no perturbation is desired.

FORM TO SPECIFY INPUT DATA FOR
CURRENT-VELOCITY MODEL WGAUSS2

This subroutine specifies a zonal (eastward) current field whose intensity decays in a Gaussian manner in all three space dimensions.

$$u_\phi = U_{\phi o} \exp\left\{-\left(\frac{z-z_o}{w_z}\right)^2 - \left(\frac{\theta-\theta_o}{W_\theta}\right)^2 - \left(\frac{\phi-\phi_o}{W_\phi}\right)^2\right\}$$

$z = r - r_e$, where r_e is the Earth radius, $\theta_o = \pi/2 - \lambda_o$, and r is the radial coordinate of the ray point. θ is the colatitude. ϕ is the longitude. Notice that this current field does not satisfy continuity if $W_\phi \neq 0$.

Specify--

the model check for WGAUSS2 = 8.0 (W100)

the input data-format code = ______(W101)

an input data-set identification number = ______(W102)

an 80-character description of the model, including description of parameter values:

____

the maximum value of u_ϕ, $U_{\phi o}$ = ______km/s, m/s (W103)

the height where u_ϕ, maximizes, z_o = ______km (W107)

the Gaussian width in height of u_ϕ, W_z = ______km (W104)*

the latitude where u_ϕ maximizes, λ_o = ______rad, deg, km N (W108)

the meridional width of u_ϕ, W_θ = ______rad, deg, km (W105)*

the longitude where u_ϕ, maximizes, ϕ_o = ______rad, deg, km E (W109)

the zonal width of u_ϕ, W_ϕ = ______rad, deg, km (W106)*

OTHER MODELS REQUIRED: Any current-perturbation model. Use NPCURR if no perturbation is desired.

*Setting W_z, W_θ or W_ϕ = 0 results in no space variation in that direction.

FORM TO SPECIFY INPUT DATA FOR BACKGROUND
SOUND-SPEED MODEL CTANH

This model represents the sound-speed profile by a sequence of linear segments that are smoothly joined by hyperbolic functions:

$$C = C_o + \frac{b_1}{2}(z-z_o) + \sum_{i=1}^{n} \delta_i \left(\frac{b_{i+1} - b_i}{2}\right) \ell n \left\{ \frac{\cosh\left(\frac{z-z_i}{\delta_i}\right)}{\cosh\left(\frac{z_i-z_o}{\delta_i}\right)} \right\} + \frac{b_{n+1}}{2}(z-z_o)$$

$$\frac{dC}{dz} = b_1 + \sum_{i=1}^{n} \left(\frac{b_{i+1} - b_i}{2}\right) \left\{\tanh\left(\frac{z-z_i}{\delta_i}\right) + 1\right\}$$

$$b_i = (C_i - C_{i-1})/(z_i - z_{i-1}) \quad .$$

$z = r - r_e$, where r_e is the Earth radius, and r is the radial coordinate of the ray point. Thus, δ_i is the half-thickness of a region centered at approximately z_i km, in which dC/dz changes from b_i to b_{i+1}. Start by drawing a profile with linear segments, and get C_i and z_i from the corners. Then select δ_i to round the corners. The final profile will not go through (C_i, z_i).

Specify--

the model check for CTANH = ____7.0____(W150)

the input data-format code = ____________(W151)

an input data-set identification number = ____________(W152)

an 80-character description of the model with parameters:

____

and the profile values:

the number of points in the profile -2 = n = ____________

the profile: i z_i (km,m) C_i (km/s, m/s) δ_i (km,m)

OTHER MODELS REQUIRED: Any sound-speed perturbation model. Use NPSPEED if no perturbation is desired. FUNCTION ALCOSH.

FORM TO SPECIFY INPUT DATA FOR
SOUND-SPEED MODEL CSTANH

This model represents the sound-speed (squared) profile by a sequence of linear segments that are smoothly joined by hyperbolic functions:

$$C^2 = C_o^2 + \frac{b_1}{2}(z-z_o) + \sum_{i=1}^{n} \delta_i \left(\frac{b_{i+1} - b_i}{2}\right) \ln \frac{\cosh\left(\frac{z-z_i}{\delta_i}\right)}{\cosh\left(\frac{z_i-z_o}{\delta_i}\right)} + \frac{b_{n+1}}{2}(z-z_o)$$

$$\frac{dC^2}{dz} = b_1 + \sum_{i=1}^{n} \left(\frac{b_{i+1} - b_i}{2}\right) \left\{\tanh\left(\frac{z-z_i}{\delta_i}\right) + 1\right\}$$

$$b_i = (C_i^2 - C_{i-1}^2)/(z_i - z_{i-1}) \quad .$$

$z = r - r_e$, where r_e is the Earth radius, and r is the radial coordinate of the ray point. Thus, δ_i is the half-thickness of a region centered at approximately z_i km, in which dC^2/dz changes from b_i to b_{i+1}. Start by drawing a profile with linear segments, and get C_i^2 and z_i from the corners. Then select δ_i to round the corners. The final profile will not go through (C_i^2, z_i).

Specify--

the model check for CSTANH = 2.0 (W150)

the input data-format code = ____________ (W151)

an input data-set identification number = ____________ (W152)

an 80-character description of the model with parameters:

____

and the profile values:

the number of points in the profile -2 = n = ____________

the profile:	i	z_i (km,m)	C_i (km/s, m/s)	δ_i (km,m)

OTHER MODELS REQUIRED: Any sound-speed-perturbation model. Use NPSPEED if no perturbation is desired. FUNCTION ALCOSH.

FORM TO SPECIFY INPUT DATA FOR
SOUND SPEED MODEL CSSPOKE

This model represents the sound speed (squared) as a function of the angle α from a horizontal line at a specified height and latitude. The dependence of C^2 on α is as a sequence of linear segments joined by hyperbolic functions.

$$C^2 = C_o^2 + \frac{b_1}{2}(\alpha-\alpha_o) + \sum_{i=1}^{n} \delta_i \left(\frac{b_{i+1} - b_i}{2}\right) \ln \left\{ \frac{\cosh\left(\frac{\alpha-\alpha_i}{\delta_i}\right)}{\cosh\left(\frac{\alpha_i-\alpha_o}{\delta_i}\right)} \right\} + \frac{b_{n+1}}{2}(\alpha-\alpha_o)$$

$$\frac{dC^2}{dz} = b_1 + \sum_{i=1}^{n} \left(\frac{b_{i+1} - b_i}{2}\right) \left\{\tanh\left(\frac{\alpha-\alpha_i}{\delta_i}\right) + 1\right\} ,$$

where $b_i = (C_i^2 - C_{i-1}^2)/(\alpha_i - \alpha_{i-1})$, $\alpha = \sin^{-1}((r \cos(\theta-\theta_o) - r_o)/D)$, $D = (r_o^2 + r^2 - 2 r r_o \cos(\theta-\theta_o))^{1/2}$, $r_o = r_e + h_o$, $\theta_o = \pi/2 - \lambda_o$, r_e is the Earth radius, r is the radial coordinate of the ray point and θ is the colatitude of the ray point. Thus, δ_i is the half-thickness of a region centered at approximately α_i, in which $dC^2/d\alpha$ changes from b_i to b_{i+1}.

Specify--

the model check for CSSPOKE = ___3.0___ (W150)

the input data format code = ________ (W151)

an input data set identification number = ________ (W152)

an 80-character description of the model with parameters:

____

the reference sound speed, C_{ref} = ________ km/s (W153)

the height of the horizontal line, h_o = ________ km, m (W154)

the latitude of the horizontal line, λ_o = ________ rad, deg, km (W155)

and the profile values:

the number of points in the profile, n = ________

the profile:

i	z_i (km)	C_i (km/sec)	δ_i (km)

OTHER MODELS REQUIRED: Any sound-speed perturbation model. Use NPSPEED if no perturbation is desired. FUNCTION ALCOSH.

FORM TO SPECIFY INPUT DATA FOR
SOUND SPEED MODEL CSSPOK2

This model represents the sound speed (squared) as a function of the angle α from a horizontal line at a specified height and latitude. The dependence of C^2 on α is as a sequence of linear segments joined by hyperbolic functions.

$$C^2 = C_o^2 + \frac{b_1}{2}(\alpha-\alpha_o) + \sum_{i=1}^{n} \delta_i \left(\frac{b_{i+1} - b_i}{2}\right) \ln \left\{ \frac{\cosh\left(\frac{\alpha-\alpha_i}{\delta_i}\right)}{\cosh\left(\frac{\alpha_i-\alpha_o}{\delta_i}\right)} \right\} + \frac{b_{n+1}}{2}(\alpha-\alpha_o)$$

$$\frac{dC^2}{dz} = b_1 + \sum_{i=1}^{n} \left(\frac{b_{i+1} - b_i}{2}\right) \left\{\tanh\left(\frac{\alpha-\alpha_i}{\delta_i}\right) + 1\right\} ,$$

where $b_i = (C_i^2 - C_{i-1}^2)/(\alpha_i - \alpha_{i-1})$, $\alpha = \tan^{-1}((r - r_o)/r_e(\theta - \theta_o)))$, $r_o = r_e + h_o$, $\theta_o = \pi/2 - \lambda_o$, r_e is the Earth radius, r is the radial coordinate of the ray point and θ is the colatitude of the ray point. Thus, δ_i is the half-thickness of a region centered at approximately α_i, in which $dC^2/d\alpha$ changes from b_i to b_{i+1}.

Specify--

the model check for CSSPOK2 = ___4.0___(W150)

the input data format code = __________(W151)

an input data set identification number = __________(W152)

an 80-character description of the model with parameters:

____

the reference sound speed, C_{ref} = __________km/s (W153)

the height of the horizontal line, h_o = __________km, m (W154)

the latitude of the horizontal line, λ_o = __________rad, deg, km (W155)

and the profile values:

the number of points in the profile, n = __________

the profile: i	z_i (km)	C_i (km/sec)	δ_i (km)

OTHER MODELS REQUIRED: Any sound-speed perturbation model. Use NPSPEED if no perturbation is desired. FUNCTION ALCOSH.

FORM TO SPECIFY INPUT DATA FOR
OCEAN SOUND-SPEED MODEL CSMUNK1*

This subroutine specifies the "canonical" model for a sound channel derived by Munk. The four parameters of the model can vary linearly with longitude, ϕ. The user specifies values for the four parameters at two longitudes, ϕ_1, and ϕ_2, and the program interpolates linearly to get the values at other longitudes.

$$C = C_A[1 + \varepsilon(\eta + e^{-\eta} - 1)] ,$$

where

$$\eta = 2/H (z - z_A) ,$$

$$C_A = C_{A1} + (C_{A2} - C_{A1})(\phi - \phi_1)/(\phi_2 - \phi_1) ,$$

$$z_A = z_{A1} + (z_{A2} - z_{A1})(\phi - \phi_1)/(\phi_2 - \phi_1) ,$$

$$H = H_1 + (H_2 - H_1)(\phi - \phi_1)/(\phi_2 - \phi_1) ,$$

$$\varepsilon \pm \varepsilon_1 + (\varepsilon_2 - \varepsilon_1)(\phi - \phi_1)/(\phi_2 - \phi_1) ,$$

and $z = r - r_e$, where r_e is the earth radius.

Specify--

the model check for subroutine CSMUNK1 = 5. (W150)
the input data format code = ________ (W151)
an input data set identification number = ________ (W152)
an 80-character description for the sound-speed model, including description of parameter values:

____

the reference sound speed, C_0 = ________ km/s, m/s (W153)

longitude of first profile, ϕ_1 = ________ rad, deg, km (W154)

the sound speed on the axis, C_{A1} = ________ km/s, m/s (W155)

the height of the axis, z_{A1} = ________ km, m (W156)

the scale depth, H_1 = ________ km, m (W157)

the fractional increase of C with depth, η = ________ (W158)

longitude of second profile, ϕ_2 = ________ rad, deg, km (W159)

the sound speed on the axis, C_{A2} = ________ km/s, m/s (W160)

the height of the axis, z_{A2} = ________ km, m (W161)

the scale depth, H_2 = ________ km, m (W162)

the fractional increase of C with depth, η = ________ (W163)

Other models required: Any sound-speed perturbation model. Use NPSPEED if no perturbation is desired.

*Munk, W. H., (1974), Sound channel in an exponentially stratified ocean, with application to SOFAR, J. Acoust. Soc. Amer. 55, 220-226.

FORM TO SPECIFY INPUT DATA FOR
OCEAN SOUND-SPEED MODEL CSMUNK2*

This subroutine specifies the "canonical" model for a sound channel derived by Munk. The sound speed varies linearly with longitude, ϕ. The user specifies values for the four parameters at two longitudes, ϕ_1 and ϕ_2.

$$C = C_1 + (C_2 - C_1)(\phi - \phi_1)/(\phi_2 - \phi_1) ,$$

where

$$C_1 = C_{A1}[1 + \varepsilon_1(\eta_1 + e^{-\eta_1} - 1)] ,$$

$$C_2 = C_{A2}[1 + \varepsilon_2(\eta_2 + e^{-\eta_2} - 1)] ,$$

$$\eta_1 = (2/H_1)(z - z_{A1}) ,$$

$$\eta_2 = (2/H_2)(z - z_{A2}) ,$$

and $z = r - r_e$, where r_e is the earth radius.

Specify--

the model check for subroutine CSMUNK2 = ____6.____(W150)
the input data format code = __________(W151)
an input data set identification number = __________(W152)
an 80-character description for the sound-speed model, including description of parameter values:

____

the reference sound speed, C_0 = __________km/s, m/s (W153)

longitude of first profile, ϕ_1 = __________rad, deg, km (W154)

the sound speed on the axis, C_{A1} = __________km/s, m/s (W155)

the height of the axis, z_{A1} = __________km, m (W156)

the scale depth, H_1 = __________km, m (W157)

the fractional increase of C with depth, η = __________(W158)

longitude of second profile, ϕ_2 = __________rad, deg, km (W159)

the sound speed on the axis, C_{A2} = __________km/s, m/s (W160)

the height of the axis, z_{A2} = __________km, m (W161)

the scale depth, H_2 = __________km, m (W162)

the fractional increase of C with depth, η = __________(W163)

Other models required: Any sound-speed perturbation model. Use NPSPEED if no perturbation is desired.

*Munk, W. H., (1974), Sound channel in an exponentially stratified ocean, with application to SOFAR, J. Acoust. Soc. Amer. 55, 220-226.

FORM TO SPECIFY INPUT DATA FOR
OCEAN SOUND-SPEED MODEL CTABLE

This model represents the sound-speed profile by a sequence of cubic segments such that the sound-speed gradient is continuous through each profile point. This is not a cubic spline; the coefficients of the cubic fit in each segment depend on only the four nearest profile points.

The coefficients of the cubic are calculated as follows: each set of three successive points in the profile is first fit with a quadratic. The slope of that quadratic at the middle profile point is then assigned to that profile point. This procedure assigns a slope to every profile point except the first and last. A slope of zero is assigned to the first and last point. Between each pair of profile points the coefficients of the cubic are chosen so that the curve goes through the two points and matches the assigned slope at the two points. Those four conditions determine the four coefficients. Both the sound-speed and its gradient are continuous throughout the profile, even at the profile points.

Specify--

the model check number for CTABLE = ____8.0____ (W200)

the input data-format code = __________ (W201)

an input data-set identification number = __________ (W202)

an 80-character description of the profile:

____

and the profile values:

the number of points in the profile, n = __________ (w 153)

the profile: height (km, m) Sound speed (Km/s, m/s)

OTHER MODELS REQUIRED: Subroutine GAUSEL and any sound-speed-perturbation model. Use NPSPEED if no perturbations are desired.

FORM TO SPECIFY INPUT DATA FOR SOUND-SPEED PERTURBATION MODEL CBLOB2

An increase (or decrease) in sound speed in a localized region that decays in a Gaussian manner in all three spatial directions.

$$C^2(r,\theta,\phi) = C_o^2(r,\theta,\phi)\left(1 + \Delta \exp\left\{-\left(\frac{z-z_o}{W_z}\right)^2 - \left(\frac{\theta-\theta_o}{W_\theta}\right)^2 - \left(\frac{\phi-\phi_o}{W_\phi}\right)^2\right\}\right)$$

$C_o^2(r,\theta,\phi)$ is the square of the sound speed specified by a sound-speed model. (r,θ,ϕ) are the coordinates of the ray point in an Earth-centered spherical polar-coordinate system. $\theta_o = \pi/2 - \lambda_o$ and $z = r - r_e$, where r_e is the Earth radius.

Specify--

the model check for subroutine CBLOB2 = ___2.0___(W175)

the input data-format code = __________(W176)

an input data-set identification number = __________(W177)

an 80-character description for the sound-speed perturbation model, including description of parameter values:

____

the strength of the fractional increase (or decrease), Δ = ______(W178)

the height of maximum effect, z_o = __________km (W179)

the latitude of maximum effect, λ_o = __________rad, deg, km N (W180)

the longitude of maximum effect, ϕ_o = __________rad, deg, km E (W181)

the Gaussian width in height of the effect, W_z = __________km (W182)*

the meridional width of the effect, W_θ = __________rad, deg, km (W183)*

the zonal width of the effect, W_ϕ = __________rad, deg, km (W184)*

OTHER MODELS REQUIRED: none.

---

* Setting W_z, W_θ, or W_ϕ = zero results in no space variation in that direction.

FORM TO SPECIFY INPUT DATA FOR SOUND-SPEED PERTURBATION MODEL CBLOB3

An increase (or decrease) in sound speed in up to three localized regions that decays in a Gaussian manner in all three spatial directions.

$$C\,(r,\theta,\phi) = C_o(r,\theta,\phi)\{1 + \sum_{i=1}^{n} \Delta_i \exp[-(\frac{z-z_i}{W_{zi}})^2 - (\frac{\theta-\theta_i}{W_{\theta i}})^2 - (\frac{\phi-\phi_i}{W_{\phi i}})^2]\}$$

$C_o(r,\theta,\phi)$ is a background sound-speed model, (r,θ,ϕ) are Earth-centered spherical-polar coordinates. $z = r - r_e$, where r_e is the Earth's radius. $\lambda_i = \pi/2 - \theta_i$ is the latitude.

Specify--

the model check number for subroutine CBLOB3 = ___3.___(W175)

the input data format code = ________(W176)

an input data set identification number = ________(W177)

an 80-character description for the sound-speed perturbation model, including description of parameter set:

____

the number of Gaussian blobs, n = ________(W178)

Δ_1 = ________(W179), Δ_2 = ________(W180), Δ_3 = ________(W181)

z_1 = ________(W182), z_2 = ________(W183), z_3 = ________(W184)

λ_1 = ________(W185), λ_2 = ________(W186), λ_3 = ________(W187)rad,deg,km N

ϕ_1 = ________(W188), ϕ_2 = ________(W189), ϕ_3 = ________(W190)rad,deg,km E

*W_{z1} = ________(W191), W_{z2} = ________(W192), W_{z3} = ________(W193)km

*$W_{\theta 1}$ = ________(W194), $W_{\theta 2}$ = ________(W195), $W_{\theta 3}$ = ________(W196)rad,deg,km

*$W_{\phi 1}$ = ________(W197), $W_{\phi 2}$ = ________(W198), $W_{\phi 3}$ = ________(W199)rad,deg,km

OTHER MODELS REQUIRED: None.

*Setting a W = 0 results in no space variation in that direction.

FORM TO SPECIFY INPUT DATA FOR SOUND-SPEED PERTURBATION MODEL CBLOB4

An increase (or decrease) in squared sound speed in up to three localized regions that decays in a Gaussian manner in all three spatial directions.

$$C^2(r,\theta,\phi) = C_o^2(r,\theta,\phi)\{1 + \sum_{i=1}^{n} \Delta_i \exp[-(\frac{z-z_i}{W_{zi}})^2 - (\frac{\theta-\theta_i}{W_{\theta i}})^2 - (\frac{\phi-\phi_i}{W_{\phi i}})^2]\}$$

$C_o(r,\theta,\phi)$ is a background sound-speed model, (r,θ,ϕ) are Earth-centered spherical-polar coordinates. $z = r - r_e$, where r_e is the Earth's radius. $\lambda_i = \pi/2 - \theta_i$ is the latitude.

Specify--

the model check number for subroutine CBLOB4 = ___4.___(W175)

the input data format code = ________(W176)

an input data set identification number = ________(W177)

an 80-character description for the sound-speed perturbation model, including description of parameter set:

____

the number of Gaussian blobs, n = ________(W178)

Δ_1 = ________(W179), Δ_2 = ________(W180), Δ_3 = ________(W181)

z_1 = ________(W182), z_2 = ________(W183), z_3 = ________(W184)

θ_1 = ________(W185), θ_2 = ________(W186), θ_3 = ________(W187)rad,deg,km N

ϕ_1 = ________(W188), ϕ_2 = ________(W189), ϕ_3 = ________(W190)rad,deg,km E

*W_{z1} = ________(W191), W_{z2} = ________(W192), W_{z3} = ________(W193)km

*$W_{\theta 1}$ = ________(W194), $W_{\theta 2}$ = ________(W195), $W_{\theta 3}$ = ________(W196)rad,deg,km

*$W_{\phi 1}$ = ________(W197), $W_{\phi 2}$ = ________(W198), $W_{\phi 3}$ = ________(W199)rad,deg,km

OTHER MODELS REQUIRED: None.

*Setting a W = 0 results in no space variation in that direction.

FORM TO SPECIFY INPUT DATA FOR
OCEAN ABSORPTION MODEL SLLOSS

This absorption model depends only on the acoustic wave frequency ω (rad/s), according to the formula

$$\alpha = a \frac{\omega^2}{\omega_1^2} + b \frac{\omega^2}{\omega_2^2 + \omega^2}$$

The following values for the coefficients correspond to the model of Skretting and Leroy (1971)*:

a = 0.006 dB/km ; ω_1 = 6283.2 rad/s (= 1000.0 Hz)

b = 0.2635 dB/km ; ω_2 = 10,681.4 rad/s (= 1700.0 Hz)

Specify--

the model check for SLLOSS = ____1.____(W500)

the input data-format code = __________(W501)

an input data-set identification number = __________(W502)

an 80-character description of the model, including parameter values:

____

a = __________ nepers/km, dB/km (W503)

b = __________ nepers/km, dB/km (W504)

ω_1 = __________ rad/s Hz (505)

ω_2 = __________ rad/s Hz (W506)

Other models required: any absorption perturbation model. Use NPABSR if no perturbation is desired.

*see References.

FORM TO SPECIFY INPUT DATA FOR
OCEAN-BOTTOM MODEL GHORIZ

A constant-height bottom model, i.e., a sphere concentric with the Earth.

$$g(r,\theta,\phi) = h - z_o ,$$

where $h = r - r_e$,

$$\frac{\partial g}{\partial r} = 1 , \frac{\partial g}{\partial \theta} = 0 , \frac{\partial g}{\partial \phi} = 0 ,$$

$$\frac{\partial^2 g}{\partial r^2} = \frac{\partial^2 g}{\partial r \partial \theta} = \frac{\partial^2 g}{\partial \theta \partial r} = \frac{\partial^2 g}{\partial r \partial \phi} = \frac{\partial^2 g}{\partial \phi \partial r} = \frac{\partial^2 g}{2 \theta 2} = \frac{\partial^2 g}{\partial \theta \partial \phi} = \frac{\partial^2 g}{\partial \phi \partial \theta} = \frac{\partial^2 g}{\partial \phi^2} = 0 ,$$

and r_e is the radius of the Earth.

Specify --

The model check number for GHORIZ = ____1.0____ (W300)

The input data-format code number = ____________ (W301)

The input data-set identification number = ____________ (W302)

an 80-character description of the model including parameters:

____

The constant bottom height, z_o = ____________ km, (W303)

(negative if below mean sea level)

OTHER MODELS REQUIRED: Any bottom-perturbation model. Use NPBOTM if no perturbation is desired.

FORM TO SPECIFY INPUT DATA FOR
OCEAN-BOTTOM MODEL GLORENZ

An east-west Lorentzian-shaped ridge.

$$g(r,\theta,\phi) = h - z ,$$

where $h = r - r_e$,

$$z = z_o/(1 + ((\theta-\theta_o)/\Delta\theta)^2) + z_B$$

$$\theta_o = \pi/2 - \lambda_o ,$$

and r_e is the radius of the Earth.

Specify --

the model check number for GLORENZ = ____4.0____ (W300)

the data input format code number = __________ (W301)

the data set identification number = __________ (W302)

an 80-character description of the model including parameters:

____

the height of the ridge, z_o = __________ km, m (W303)

the latitude of the ridge center, λ_o = __________ rad, deg, km (W304)

the half-width of the ridge, $\Delta\theta$ = __________ rad, deg, km (W305)

the height above sea level of the
base of the ridge (negative if below sea level) z_B = __________ m,km (W306)

OTHER MODELS REQUIRED: Any bottom perturbation model. Use NPBOTM if no perturbation is desired.

FORM TO SPECIFY INPUT DATA FOR
OCEAN-BOTTOM MODEL GTANH

This model represents the ocean bottom by a sequence of linear segments that are smoothly joined by hyperbolic functions:

$$g(r,\theta,\phi) = h - z(\theta), \text{ where}$$

$$z(\theta) = z_o + \frac{c_1}{2}(\theta-\theta_o) - \sum_{i=1}^{n} \delta_i \left(\frac{c_{i+1} - c_i}{2}\right) \ln \left\{ \frac{\cosh\left(\frac{\theta-\theta_i}{\delta_i}\right)}{\cosh\left(\frac{(\theta_i-\theta_o)}{\delta_i}\right)} \right\} + \frac{c_{n+1}}{2}(\theta-\theta_o)$$

$$\frac{dz}{d\theta} = c_1 + \sum_{i=1}^{n} \left(\frac{c_{i+1} - c_i}{2}\right) \left\{- \tanh\left(\frac{\theta-\theta_i}{\delta_i}\right) + 1\right\}$$

$$c_i = (z_i - z_{i-1})/(\theta_i - \theta_{i-1})$$

$h = r - r_e$, where r_e is the Earth radius, and r is the radial coordinate of the ray point. $\theta_i = \pi/2 - \lambda_i$. Thus, δ_i is the half-thickness of a region centered at approximately θ_i, in which $dz/d\theta$ changes from c_i to c_{i+1}. Start by drawing a profile using linear segments, and θ_i and z_i from the corners. Then select δ_i to round the corners. The final profile will not go through (θ_i, z_i).

Specify--

the model check for GTANH = ___3.0___ (W300)

the input data-format code = ________ (W301)

an input data-set identification number = ________ (W302)

an 80-character description of the model with parameters:

____

and the profile values:

the number of points in the profile -2 = n = ________

the profile: i	λ_i (rad,deg)	z_i (km,m)	δ_i (rad,deg)

OTHER MODELS REQUIRED: Any bottom-perturbation model. Use NPBOTM if no perturbation is desired. FUNCTION ALCOSH.

FORM TO SPECIFY INPUT DATA
FOR OCEAN SURFACE MODEL SHORIZ

An ocean surface model that is a horizontal (i.e., a sphere concentric with the earth). The ocean surface is where the following function is zero.

$$s(r,\theta,\phi) = z_s - h$$

where

$$h = r - r_e$$

and

r_e is the earth radius

Specify--

the model check number for subroutine SHORIZ = ___1.0___(W350)

the data input format code number = __________(W351)

the data set identification number = __________(W352)

an 80-character description of the model including parameters:

____

the height of the ocean surface above
mean sea level, z_s = __________km, m (W353)

OTHER MODELS REQUIRED: Any surface-perturbation model. Use NPSURF if no perturbation is desired.

FORM TO SPECIFY INPUT DATA
FOR RECEIVER-SURFACE MODEL RHORIZ

A receiver-surface model that is a horizontal surface (i.e., a sphere concentric with the Earth).

$$f(r,\theta,\phi) = z_R - h \ ,$$

where

$$h = r - r_e$$

and

r_e is the Earth radius

$$\frac{\partial f}{\partial t} = \frac{\partial f}{\partial \theta} = \frac{\partial f}{\partial \phi} = 0$$

$$\frac{\partial f}{\partial r} = 1.0 \quad .$$

Specify--

the model check number for subroutine RHORIZ = ____1.0____ (W275)

the input data-format code number = ____________ (W276)

an 80-character description of the model including parameters:

____

the receiver surface height, z_R = ____________ km (W20)

OTHER MODELS REQUIRED: none.

FORM TO SPECIFY INPUT DATA
FOR RECEIVER-SURFACE MODEL RBOTM

A receiver-surface model in which the receiver surface is a fixed height above the ocean bottom.

$$f(r,\theta,\phi) = g(r,\theta,\phi) + z_R$$

$$\frac{\partial f}{\partial r} = \frac{\partial g}{\partial r}, \quad \frac{\partial f}{\partial \theta} = \frac{\partial g}{\partial \phi}, \quad \frac{\partial f}{\partial \phi} = \frac{\partial g}{\partial \phi},$$

where $g(r,\theta,\phi)$ and its derivatives are specified in common block /GG/ by the terrain model.

Specify--

the model check number for subroutine RBOTM = ~~3.0~~ 2.0 (W275)

the input data-format code number = ____________ (W276)

an 80-character description of the model including parameters:

____

the height of the receiver surface above the ocean bottom, z_R = _____ km (W20)

OTHER MODELS REQUIRED: Any ocean-bottom model.

FORM TO SPECIFY INPUT DATA FOR
RECEIVER-SURFACE MODEL RVERT

A receiver surface that is a vertical (conical) surface a constant distance from a given origin on the Earth's surface

$$f(r,\theta,\phi) = \sin\lambda_o \cos\theta + \cos\lambda_o \sin\theta \cos(\phi-\phi_o) - \cos\alpha_o$$

$$\frac{\partial f}{\partial t} = \frac{\partial f}{\partial r} = 0$$

$$\frac{\partial f}{\partial \theta} = - \sin\lambda_o \sin\theta + \cos\lambda_o \cos\theta \cos(\phi-\phi_o)$$

$$\frac{\partial f}{\partial \phi} = - \cos\lambda_o \sin\theta \sin(\phi-\phi_o) .$$

Specify--

the model check number for subroutine RVERT = ~~2.0~~ 3.0 (W275)

the input data-format code number = __________(W276)

an 80-character description of the model including parameters:

____

the distance of the surface from the origin,

α_o = __________rad, deg, km (278)

the latitude of the origin, λ_o = __________rad, deg, km N (W279)

the longitude of the origin, ϕ_o = __________rad, deg, km E (W280)

OTHER MODELS REQUIRED: none.

APPENDIX C: FR-80 PLOT PACKAGE AND DISSPLA INTERFACE

This appendix describes the plotting commands used by DDPLOT, our local microfilm plotting system, and also an interface called DDSPLA to the DISSPLA* plot package in common use. Figure C1 shows the steps necessary to obtain graphical output from HARPO, if you have DISSPLA. File 6 of the distribution tape contains PROGRAM TAPRD, which reads the graphics data file. File 7 of the distribution tape contains the DISSPLA interface routines DDSPLA. If you do not have DISSPLA and want graphical output on your own plotting system, you will have to insert the equivalent instructions used by your system into the skeleton graphics interface routines DDALT (tape file 8). This information was taken with permission from "User's Guide to Cathode-Ray Plotter Subroutines" by L. David Lewis, ESSA Technical Memorandum ERL TM-ORSS5, January 1970. The routines used in this version of HARPO assume DISSPLA version 9.0 and are listed in Appendix D.

The Information International Inc. FR-80 Microfilm Recorder, under control of the NOAA Boulder CDC-CYBER 840 computer, plots data on the face of a high-resolution cathode ray tube, which is photographed onto standard size, perforated, 35-mm film.

The plotting area, called a frame, is a square. Plotting positions are described in rectangular coordinates. Coordinate values are integers in the range 0 - 1023; (0,0) is the "lower left-hand corner."

Plotting specifications are transmitted to the DDPLOT/DDSPLA interface routines via the following two COMMON blocks.

```
COMMON/DD/IN,IOR,IT,IS,IC,ICC,IX,IY
COMMON/DDREZ/DDHIX,DDHIY
```

---

*DISSPLA is the proprietary product of ISSCO, Inc.

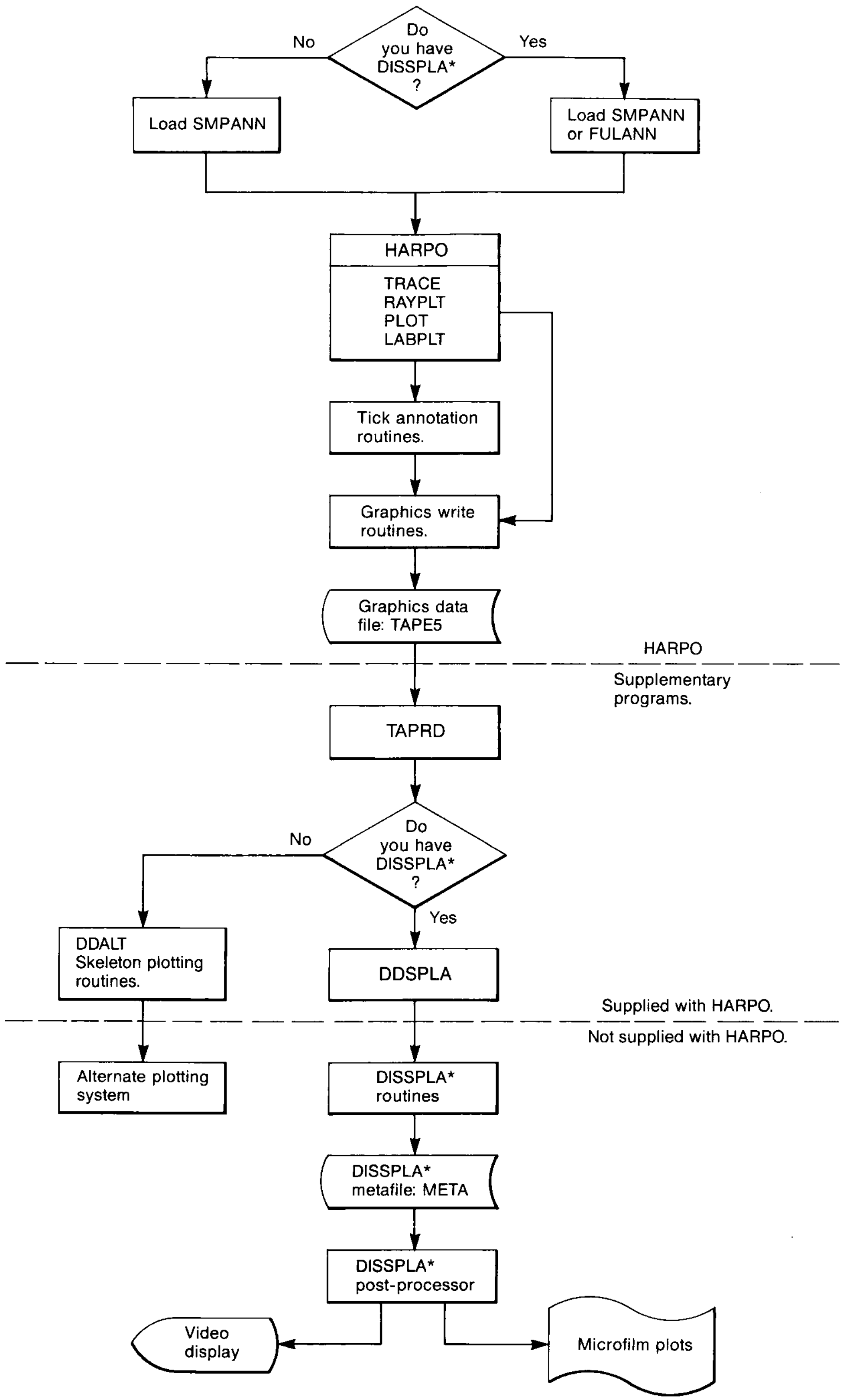

Figure C1. An organization chart that shows how graphical output is produced by a series of programs, some of which are a part of HARPO, and others of which are either supplied along with HARPO or are commerical packages.

The usage of each of the ten variables is listed below, followed by an explanation of the subroutine calls.

IN	Intensity. IN=0 specifies normal intensity. IN=1 specifies high intensity.
IOR	Orientation IOR=0 specifies upright orientation. IOR=1 specifies rotated orientation (90° counter-clockwise).
IT	Italics (Font). IT=0 specifies non-italic (Roman) symbols. IT=1 specifies italic symbols.
IS	Symbol size. IS=0 specifies miniature size. IS=1 specifies small size. IS=2 specifies medium size. IS=3 specifies large size.
IC	Symbol case. IC=0 specifies uppercase. IC=1 specifies lowercase.
ICC	Character code, 0-63 (R1 format). ICC and IC together specify the symbol plotted.
IX(DDHIX)	X-coordinate, 0-1023 (X-coordinate, real value, 0.0-1023.0)
IY(DDHIY)	Y-coordinate, 0-1023 (Y-coordinate, real value, 0.0-1023.0).

CALL DDINIT (N,ID) is required to initialize the plotting process.

ID is a string of characters to identify the person getting the plot and giving the telephone extension and the place to deliver the microfilm plot.

N is the number of characters in the string "ID."

CALL DDBP — defines a vector origin in position IX, IY.

CALL DDVC — plots a vector (straight line), with intensity IN, from the vector origin defined by the previous DDBP or DDVC call, to the vector end position at IX, IY. A single call to DDBP followed by successive calls to DDVC (with changing IX and IY) plots connected vectors.

CALL DDTAB — Initializes tabular plotting.

CALL DDTEXT (N,NT) plots a given array in a tabular mode after initiating tabular plotting by using DDTAB, as described above. NT is an array of length N, containing "text" for tabular plotting. Text consists of character codes, packed eight per word (A8 Format). Text characters are plotted as tabular symbols until the command character ≠ (octal code 14, card code 4,8, or the alphabetic shift counterpart of the = on the keypunch) occurs. The command character is not plotted. DDTEXT interprets the next character as a command; after the command is processed, tabular plotting resumes until ≠ is again encountered. ≠ means end of text: DDTEXT returns to the calling routine.

CALL DDFR causes a frame advance operation. Plotting on the current frame is completed, and the film advances to the next frame.

CALL DDEND empties the plot buffer and releases the plotting command file to the microfilm plot queue.

DISSPLA CALLS

HARPO calls the following DISSPLA routines directly, rather than through the DDPLOT package. Therefore, if you want to do plotting with a plotting package other than DISSPLA, you will have to convert the following DISSPLA calls to corresponding calls in your plotting package.

CALL DASH sets dashed-line mode. That is, all plotted curves will be dashed instead of solid.

CALL RESET('DASH') sets solid-line mode. That is, all plotted curves will be solid lines after this call.

HARPO calls a routine named SETANN. SETANN is an entry point in SUBROUTINE FULANN and also in SUBROUTINE SMPANN. When running HARPA, you must make a choice whether to load FULANN or SMPANN. If you do not have the DISSPLA plotting package, then load SMPANN because it makes no special character-generating calls to DISSPLA routines. If you do have the DISSPLA plotting package, then load FULANN. SUBROUTINE FULANN calls the following DISSPLA subroutines directly. If you have the DISSPLA plotting package, then the manual will explain the meaning of these routines. If you do not have the DISSPLA plotting package, then load SMPANN, and ignore the routines HEIGHT, MX1ALF, MX2ALF, and SCMPLX.

Following is a list of the routines on Files 6, 7 and 8 of the distribution tape.

- TAPRD -- Graphics File Read Routine (Tape File 6)

PROGRAM TAPRD -- Program to read graphics output file and call graphics interface routines.

- DDSPLA -- DISSPLA Interface Routines (Tape File 7)

SUBROUTINE MYJSUB -- Intercepts transmission of titles and axis labels so that minus signs on axis labels can be removed.

SUBROUTINE DDINIT -- Initializes plotting process.

SUBROUTINE DDBP -- Sets a vector origin.

SUBROUTINE DDVC -- Plots a vector.

SUBROUTINE DDEND -- Emties plot buffer and releases plotting command file to microfilm plot queue.

SUBROUTINE DDTEXT -- Writes an array (character string) in tabular text mode.

SUBROUTINE DDTAB -- Sends instruction that initializes tabular (text) plotting.

SUBROUTINE DDFR -- Sends instruction to advance a microfilm frame.

- DDALT -- Skeleton Graphics Interface Routines (Tape File 8)

SUBROUTINE DDINIT -- Initializes plotting process.

SUBROUTINE DDBP -- Sets a vector origin.

SUBROUTINE DDVC -- Plots a vector.

SUBROUTINE DDEND -- Empties plot buffer and releases plotting command file to microfilm plot queue.

SUBROUTINE DDTEXT -- Writes an array (character string) in tabular text mode.

SUBROUTINE DDTAB -- Sends instruction that initializes tabular (text) plotting.

SUBROUTINE DDFR -- Sends instruction to advance a microfilm frame.

SUBROUTINE DASH -- Sets dashed-line mode; that is, all plotted curves will be dashed instead of solid after a call to subroutine DASH.

SUBROUTINE RESET('DASH') -- Sets solid-line mode; that is, all plotted curves will be solid lines after this call.

SUBROUTINE SCMPLX -- If you do not have the DISSPLA plotting package, load SUBROUTINE SMPANN instead of SUBROUTINE FULANN, and you can ignore this routine.

SUBROUTINE MX1ALF -- If you do not have the DISSPLA plotting package, load SUBROUTINE SMPANN instead of SUBROUTINE FULANN, and you can ignore this routine.

SUBROUTINE MX2ALF -- If you do not have the DISSPLA plotting package, load SUBROUTINE SMPANN instead of SUBROUTINE FULANN, and you can ignore this routine.

SUBROUTINE HEIGHT -- If you do not have the DISSPLA plotting package, load SUBROUTINE SMPANN instead of SUBROUTINE FULANN, and you can ignore this routine.

The following routines are not used by HARPO, but "dummy" versions must be present when loading TAPRD because they are referred to by the general-purpose TAPRD program.

COMPRS, GRACE, PHYSOR, PAGE, SCLPIC, XREVTK, YREVTK, INTAXS, TITLE, FRAME, GRAF, MARKER, SYSTEM, CURVE, ENDPL, DONEPL, XTICKS, YTICKS, MYJACT, NOBRDR, GRAFB, AREA2D, STRTPT, CONNPT, ANGLE, MESSAG, XNONUM, YNONUM, XGRAXS, and YGRAXS.

APPENDIX D: FORTRAN SOURCE CODE LISTING

This appendix contains the FORTRAN source-code listing for HARPO, including all of its subroutines and atmospheric models. Their order is the same as the order of the programs in Files 3 through 7 of the distribution tape and the list in Section 7.1. Table D1 lists the routines in alphabetical order and the page where the source code can be found.

****
WARNING: THIS LISTING IS PROVIDED FOR INFORMATION PURPOSES ONLY. THOSE WHO WANT TO USE THE PROGRAM MUST OBTAIN THE SOURCE CODE ON MAGNETIC TAPE FROM THE AUTHORS (SEE SECTION 3.1). COPYING THE CODE LISTED HERE WILL NOT PRODUCE A USABLE PROGRAM.
****

Table D1 -- Alphabetical List of Source-Code Modules

Module Name	Page	Module Name	Page
ALCOSH	316	NPSURF	420
ANCNL	343	NUMSTG	312
ANCWL	349	OCNHD	306
ARCTIC	337	OPNREP	315
AWCNL	346	OVERRD	316
AWCWL	352	PCROSS	275
BACKUP	282	PLOT	324
CBLOB2	393	PLTANH	330
CBLOB3	396	PLTANOT	333
CBLOB4	399	PLTHLB	330
CLEAR	267	PLTLB	336
CONBLK	292	PRINTR	298
CSMUNK1	381	PUTDES	311
CSMUNK2	384	PUTKCT	314
CSSPOK2	377	PUTKST	313
CSSPOKE	374	RAYPLT	319
CSTANH	370	RAYTRC	245
CTABLE	387	RBOTM	424
CTANH	367	RCROSS	275
DASH	341,440	READW	259
DDBP	338,435,439	READW1	253
DDEND	341,436,439	REFLECT	284
DDFR	341,437,440	RENORM	298
DDINIT	338,435,439	RERR	312
DDTAB	340,437,440	RERROR	313
DDTEXT	340,436,439	RESET	341,440
DDVC	339,436,439	RHORIZ	422
DFCNST	251	RKAM	278
DFSYS	249	RKAM1	280
DRAWTKS	335	RVERT	427
FIT	286	SCMPLX	342,440
FULANN	430	SET2	298
GAUSEL	317	SETTRC	297
GET	289	SETXY	332
GET1	287	SFILL	312
GHORIZ	407	SFILTR	316
GLORENZ	409	SHORIZ	418
GRAFB	437	SLLOSS	403
GTANH	412	SMPANN	429
GTUNIT	257	SREAD1	258
HAMLTN	276	STOPIT	313
HEIGHT	342,441	STRIM	312
ITEST	291	TAPRD	432
ITOC	291	TIKLINE	332
LABPLT	326	TITLEW	437
MX1ALF	342,440	TRACE	269
MX2ALF	342,441	UCON	267
MYJSUB	435	VVORTX3	359
ND2B	267	WCHANGE	297
NPABSR	405	WGAUSS2	362
NPBOTM	415	WLINEAR	357
NPCURR	365	ZAPFIL	315
NPSPEED	391		

D.1 RAY-TRACING CORE (Tape File 3)

```
      PROGRAM RAYTRC
C     MAIN PROGRAM FOR THE RAY TRACING PACKAGE.                         RAQC0020
C          SETS THE INITIAL CONDITIONS FOR EACH RAY AND CALLS TRACE     RAQC0030
C                                                                       RAQC0040
C     COMMON DECK "RAYDEV" INSERTED HERE                                RAQC0050
C     DEVICE ASSIGNED TO RAYTRC INPUT FILE                              CRAY0020
      COMMON/RAYDEV/NRYIND,NDEVTMP,NFRMAT,NDEVGRP,NDEVBIN                CRAY0040
      LOGICAL WCHANGE,FIRST                                             CRAY0050
      REAL WS(400)                                                      RAQC0070
C     COMMON DECK "FILEC" INSERTED HERE                                 RAQC0080
      COMMON /FILEC/NPLTDP                                              CFIL0020
C     COMMON DECK "CERR" INSERTED HERE                                  CFIL0040
      COMMON/ERR/NERG,NERR,NERT,NERP                                    CERR0020
C     COMMON DECK "GG" INSERTED HERE                                    CERR0030
      REAL MODG                                                         CGG 0020
      COMMON/GG/MODG(4)                                                 CGG 0040
      COMMON/GG/G,PGR,PGRR,PGRTH,PGRPH                                  CGG 0050
      COMMON/GG/PGTH,PGPH,PGTHTH,PGPHPH,PGTHPH,GSELECT,GTIME            CGG 0060
C     COMMON DECK "HDR" INSERTED HERE                                   CGG 0070
      CHARACTER*10 INITID*80,DAT,TOD                                    CHDR0020
      COMMON/HDR/SEC                                                    CHDR0040
      COMMON/HDRC/INITID,DAT,TOD                                        CHDR0050
C     COMMON DECK "CONST" INSERTED HERE                                 CHDR0060
      COMMON/PCONST/CREF,RGAS,GAMMA                                     CCON0020
      COMMON/MCONST/PI,PIT2,PID2,DEGS,RAD,ALN10                         CCON0040
C     COMMON DECK "FLAG" INSERTED HERE                                  CCON0050
      LOGICAL NEWWR,NEWWP,NEWTRC,PENET                                  CFLA0020
      COMMON /FLG/ NTYP,NEWWR,NEWWP,NEWTRC,PENET,LINES,IHOP,HPUNCH      CFLA0040
      COMMON/FLGP/NSET                                                  CFLA0050
C     COMMON DECK "RINPLEX" INSERTED HERE                               CFLA0060
      REAL KAY2,KAY2I                                                   CRIN0020
      COMPLEX PNP,POLAR,LPOLAR                                          CRIN0040
      LOGICAL SPACE                                                     CRIN0050
      CHARACTER DISPM*6                                                 CRIN0060
      COMMON/RINPL/DISPM                                                CRIN0070
      COMMON /RIN/ MODRIN(8),RAYNAME(2,3),TYPE(3),SPACE                 CRIN0080
      COMMON/RIN/OMEGMIN,OMEGMAX,KAY2,KAY2I                             CRIN0090
      COMMON/RIN/PNP(10),POLAR,LPOLAR,SGN                               CRIN0100
C     COMMON DECK "RK" INSERTED HERE                                    CRIN0110
C     DEFINE SIZE REQUIRED FOR RAY STATE SAVE ARRAY                     CRK 0020
      PARAMETER (LRKAMS=87+2*100,NXRKMS=12+LRKAMS,MXEQPT=21)            CRK 0040
      PARAMETER (NRKSAV=NXRKMS+MXEQPT-1)                                CRK 0050
      COMMON /RK/ NEQS,STEP,MODE,E1MAX,E1MIN,E2MAX,E2MIN,FACT,RSTART    CRK 0060
C     COMMON DECK "RKAM" INSERTED HERE                                  CRK 0070
      REAL KR,KTH,KPH                                                   RKAM0020
      COMMON//R,TH,PH,KR,KTH,KPH,RKVARS(14),TPULSE,CSTEP,DRDT(20)       RKAM0040
C     COMMON DECK "WWR" INSERTED HERE                                   RKAM0050
      PARAMETER (NWARSZ=1000)                                           CWWR0020
      COMMON/WW/ID(10),MAXW,W(NWARSZ)                                   CWW10030
      REAL MAXSTP,MAXERR,INTYP,LLAT,LLON                                CWW10040
      EQUIVALENCE (EARTHR,W(1)),(RAY,W(2)),(XMTRH,W(3)),(TLAT,W(4)),    CWW20020
     1 (TLON,W(5)),(OW,W(6)),(FBEG,W(7)),(FEND,W(8)),(FSTEP,W(9)),      CWW20030
     2 (AZ1,W(10)),(AZBEG,W(11)),(AZEND,W(12)),(AZSTEP,W(13)),          CWW20040
     3 (BETA,W(14)),(ELBEG,W(15)),(ELEND,W(16)),(ELSTEP,W(17)),         CWW20050
     8   (RUNSUP,W(18)),(RCVRH,W(20)),                                  CWW20060
                                                                        CWW20070
```

```
     4 (ONLY,W(21)),(HOP,W(22)),(MAXSTP,W(23)),(PLAT,W(24)),(PLON,W(25))CWW20080
     5,(HMAX,W(26)),(RAYFNC,W(29)),(EXTINC,W(33)),                      CWW20090
     6 (HMIN,W(27)),(RGMAX,W(28)),                                      CWW20100
     8 (INTYP,W(41)),(MAXERR,W(42)),(ERATIO,W(43)),                     CWW20110
     6 (STEP1,W(44)),(STPMAX,W(45)),(STPMIN,W(46)),(FACTR,W(47)),       CWW20120
     7 (SKIP,W(71)),(RAYSET,W(72)),(PRTSRP,W(74)),(HITLET,W(75))        CWW20130
     9 ,(BINRAY,W(76)),(PAGLN,W(77)),(PLT,W(81)),(PFACTR,W(82)),        CWW20140
     1 (LLAT,W(83)),(LLON,W(84)),(RLAT,W(85)),(RLON,W(86))              CWW20150
     2,(TIC,W(87)),(HB,W(88)),(HT,W(89)),(TICV,W(96))                   CWW20160
C                                                                       RAQC0190
      CHARACTER TMP80*80                                                RAQC0200
C                                                                       RAQC0210
      DATA FIRST/.TRUE./                                                RAQC0220
C                                                                       RAQC0230
C   SET CONSTANTS , INITITALIZE FILES  AND MAKE SYSTEM CALLS            RAQC0240
      CALL SYSINI                                                       RAQC0250
      CALL CONBLK                                                       RAQC0260
      CALL SETDSP                                                       RAQC0270
      CALL STDINI                                                       RAQC0280
C     INITIALIZE LINE COUNTS FOR CURRENT AND LAST HEADER                RAQC0290
      LINES=0                                                           RAQC0300
      LHDRPG=0                                                          RAQC0310
C                                                                       RAQC0320
      REWIND NRYIND                                                     RAQC0330
C  INITIALIZE RAYSET FILE                                               RAQC0340
5     READ(NRYIND,'(A)',END=8) TMP80                                    RAQC0350
      WRITE(9,'(A)') TMP80                                              RAQC0360
      GO TO 5                                                           RAQC0370
C                                                                       RAQC0380
8     WRITE(9,'(A)') '****SOFT EOF***+++++'                             RAQC0390
      REWIND NRYIND                                                     RAQC0400
C     READ IN USERS NAME AND TELEPHONE EXTENSION FOR IDENTIFYING        RAQC0410
C     MICROFILM PLOTS.                                                  RAQC0420
C                                                                       RAQC0430
C     REPOSITION DINP AFTER IDENTIFIER                                  RAQC0440
      READ(NRYIND,'(A)',END=6000) TMP80                                 RAQC0450
C                                                                       RAQC0460
C********* READ W ARRAY AND PRINT NON-ZERO VALUES                       RAQC0470
      IRUN=0                                                            RAQC0480
      NSET=0                                                            RAQC0490
C                                                                       RAQC0500
10    CALL READW                                                        RAQC0510
      NSET=NSET+1                                                       RAQC0520
      ICODE=ND2B(INT(RAYFNC))                                           RAQC0530
C PROCESS RAYPATH CALCULATIONS ONLY IF W(29) IS BEING USED              RAQC0540
      IF((RAYFNC.NE.0.).AND.(AND(ICODE,4).EQ.0)) GO TO 10               RAQC0550
C                                                                       RAQC0560
C********* LET ROUTINES PRINTR AND RAYPLT KNOW THERE IS A NEW W ARRAY    RAQC0570
      NEWWP=.TRUE.                                                      RAQC0580
      NEWWR=.TRUE.                                                      RAQC0590
      IRUN=IRUN+1                                                       RAQC0600
C                                                                       RAQC0610
C     SET BINARY RAY FILE UNIT TO ZERO IF NO OUTPUT WANTED              RAQC0620
      NPLTDP=0                                                          RAQC0630
      IF(BINRAY.NE.0.0) NPLTDP=NDEVBIN                                  RAQC0640
```

```
C
C******** INITIALIZE THE MODELS VIA 'DISPER'
      CALL IDISPER
C
      IF(FIRST.AND.PLT.NE.0.) CALL DDINIT(8,INITID)
      IF(PLT.NE.0.) FIRST=.FALSE.
C
      OW=0.
      BETA=0.
      AZ1=0.
C
      CALL HEADER1
C
C********* PRINT OUT THE CONTENTS OF THE 'W' ARRAY
C********* DETERMINE TRANSMITTER LOCATION IN COMPUTATIONAL COORDINATE
C********* SYSTEM (GEOMAGNETIC COORDINATES IF DIPOLE FIELD IS USED)
      SP=SIN (PLAT)
      CP=SIN (PID2-PLAT)
      SDPH=SIN (TLON-PLON)
      CDPH=SIN (PID2-(TLON-PLON))
      SL=SIN (TLAT)
      CL=SIN (PID2-TLAT)
      ALPHA=ATAN2(-SDPH*CP,-CDPH*CP*SL+SP*CL)
      TH0=ACOS (CDPH*CP*CL+SP*SL)
      PH0=ATAN2(SDPH*CL,CDPH*SP*CL-CP*SL)
C
      R=EARTHR
      TH=TH0
      PH=PH0
      CALL TOPOG
C
C     OBTAIN ABSOLUTE HEIGHT OF THE TRANSMITTER.
C     IF IT WAS SPECIFIED AS RELATIVE TO THE TERRAIN, THEN REMOVE
C     THE FLAG VALUE 10**40 WHICH WAS ADDED AT INPUT.
C
      TMP=XMTRH
      IF(XMTRH .EQ. 1.E-40) XMTRH=0.0
      IF( ABS(XMTRH) .GE. 1.E20 ) XMTRH=XMTRH*1.E-40
      IF(TMP.NE.XMTRH) XMTRH=XMTRH-G/PGR
C
C     CHECK THAT TRANSMITTER IS ABOVE TERRAIN.
C
      IF(-G/PGR .LE. XMTRH) GO TO 655
C
      PRINT 640, IRUN
      WRITE(3,640) IRUN
640   FORMAT('0****** TRANSMITTER BELOW TERRAIN. RUN ',I3
     1 ,' TERMINATED.'/'SEE W-ARRAY PRINTOUT. INPUT CONTINUES.'//)
      CALL SETOVR
      CALL PRINTW
      GO TO 10
C
C     PREVENT RERUNNING SAME MODEL CASES
655   IF(IRUN.EQ.1) GO TO 12
      IF(RUNSUP.NE.0.0 .AND. .NOT.WCHANGE(WS(1),W(1))) THEN
```

```
         PRINT *,'SUPPRESSING REDUNDANT RUNSET #',NSET
         GO TO 10
      ENDIF
C
12    PRINT *,'PROCESSING FOR RUNSET #',NSET
C
      CALL RMOVE(WS,W,400)
C
      CALL SETOVR
      CALL PRINTW
      CALL IPRINTR
C******** INITIALIZE PRINT CONTROL PARAMTERS
      LINSPP=PAGLN
      LNPHPG=LINSPP/2
      IF(LNPHPG.LT.40) LNPHPG=LINSPP
C
C********* LOOP ON FREQUENCY, AZIMUTH ANGLE, AND ELEVATION ANGLE
      NFREQ=1
      IF (FSTEP.NE.0.) NFREQ=(FEND-FBEG)/FSTEP+1.5
      NAZ=1
      IF (AZSTEP.NE.0.) NAZ=(AZEND-AZBEG)/AZSTEP+1.5
      NBETA=1
      IF (ELSTEP.NE.0.) NBETA=(ELEND-ELBEG)/ELSTEP+1.5
      DO 50 NF=1,NFREQ
      OW=FBEG+(NF-1)*FSTEP
      DO 45 J=1,NAZ
      AZ1=AZBEG+(J-1)*AZSTEP
      AZA=AZ1*DEGS
      GAMMA1=PI-AZ1+ALPHA
      SGAMMA=SIN (GAMMA1)
      CGAMMA=SIN (PID2-GAMMA1)
      DO 40 I=1,NBETA
      BETA=ELBEG+(I-1)*ELSTEP
      EL=BETA*DEGS
      CBETA=SIN (PID2-BETA)
      R=EARTHR+XMTRH
      TH=TH0
      PH=PH0
      KR=SIN (BETA)
      KTH=CBETA*CGAMMA
      KPH=CBETA*SGAMMA
      TPULSE=0.
      RSTART=1.
C********* THE FOLLOWING LINE NEEDED FOR RAY TRACING IN COMPLEX SPACE
      SGN=1.0
C********* CALL MODELS
      CALL DISPER
C
      LINPG=LINES-LHDRPG
      IF(I.EQ.1  .OR.  LINPG.GE.LINSPP-20) THEN
C
C     PUT OUT SUBHEADERS FROM MEDIA AND PRINTR ROUTINES
         CALL HEADER2
         CALL PRNHD1(' ')
C
```

```
C       COMPUTE LINE COUNT OF THIS HEADER
           LHDRPG=LINES/LINSPP*LINSPP
        ELSEIF(LINPG.GE.LNPHPG-10 .AND. LINPG.LE.LNPHPG) THEN
C       PUT OUT PAGE FEED WITH SUBHEADER IF AT HALF PAGE
           CALL PRNHD2('1')
        ELSE
C       PUT OUT SUBHEADER
           CALL PRNHD2(' ')
        ENDIF
C
        IF (KAY2.GT.0.) GO TO 30
        WRITE(3,2900) OMEGMIN,OMEGMAX
 2900 FORMAT (58H0TRANSMITTER IN EVANESCENT REGION, TRANSMISSION IMPOSSI
     1BLE/20H0MINIMUM FREQUENCY =,E17.10,20H MAXIMUM FREQUENCY =,E17.10)
        GO TO 44
 30     CALL RENORM(KR,KAY2,3)
        CALL CLEAR(RKVARS,NEQS-6)
        CALL TOPOG
        IF(NERG.GT.0) RKVARS(NERG)=G
        IF(NERR.GT.0) RKVARS(NERR)=PGR
        IF(NERT.GT.0) RKVARS(NERT)=PGTH
        IF(NERP.GT.0) RKVARS(NERP)=PGPH
C
C       CALCULATE ONE RAY PATH
        CALL TRACE
        OSEC=SEC
        CALL SYSSEC(SEC)
        DIFF=SEC-OSEC
C
C       ADD TO LINES COUNT FOR ELAPSED TIME REPORT
        LINES=LINES+2
        WRITE(3,3500) DIFF
3500    FORMAT (/T93,'THIS RAY CALCULATION TOOK ',F8.3,' SEC')
C
        IF (PENET.AND.ONLY.NE.0..AND.IHOP.EQ.1) GO TO 44
   40 CONTINUE
44      IF(PLT.GT.0.AND.(NAZ.LE.1.OR.NBETA.GT.1)) CALL ENDPLT
   45 CONTINUE
        IF(PLT.GT.0.AND.NAZ.GT.1.AND.NBETA.LE.1)CALL ENDPLT
        IF(PENET.AND.ONLY.NE.0..AND.IHOP.EQ.1.AND.NAZ.EQ.1.AND.NBETA.EQ.1)
     1 GO TO 55
   50 CONTINUE
  55    IF (RAYSET.NE.0.) WRITE(9,5000)
 5000 FORMAT (78X,1H-)
        GO TO 10
6000    PRINT *,'DINP EMPTY OR NOT FOUND'
        STOP
        END


        SUBROUTINE DFSYS
        CHARACTER DAT*(*),DATX*10
```

```
      CHARACTER TIM*(*),TIMX*10
C
C     ALL ROUTINES WHICH RELY ON SYSTEM BASED FUNCTIONS, SUCH AS TIME
C     OF DAY OR MAY BENEFIT FROM SYSTEM AVAILABLE ROUTINES FOR BETTER
C     PERFORMANCE, SUCH AS 'RMOVE' HAVE BEEN COLLECTED IN THIS ROUTINE.
C
      ENTRY RMOVE(X,Y,N)
C     MOVE 'N' COMPONENTS OF ARRAY 'Y' TO ARRAY 'X'.
C     THIS LOGIC WILL HANDLE OVERLAP CASES ONLY FOR X(M)=X(M+N1)
C     WITH N1>0, M=1,N.
      REAL X(N),Y(N)
C
C      DO 10 I=1,N
C10    X(I)=Y(I)
C     RETURN
C
C     ENTRY IMOVE(IX,IY,N)
      ENTRY IMOVE(X,Y,N)
C     SPECIAL ENTRY FOR INTEGER ARRAYS FOR MACHINES HAVING DIFFERENT
C     WORD SIZES FOR INTEGERS THAN REALS.
C     INTEGER IX(N),IY(N)
C
      IF(N.LE.0) RETURN
C     USE CYBER BUILT-IN ROUTINE
      CALL MOVLEV(Y,X,N)
C
C     THE EQUIVALENT FORTRAN CODING FOR THIS ROUTINE ARE THE FOLLOWING
C     TWO LINES.
C      DO 20 I=1,N
C20    IX(I)=IY(I)
C
      RETURN
      ENTRY SYSSEC(SECS)
C
C     OBTAIN CURENT TIME OF DAY IN SECONDS FROM SYSTEM ROUTINE
C      SECS=0
C     SYSTEM CALL NEEDED FOR THE CYBER NOS OP SYS
      CALL SECOND(SECS)
C     SYSTEM CALL NEEDED FOR CRAY COMPUTER UNDER CTSS
C      CALL TIMEUSED(ICPU,IO,ISYS,MEM)
C      SECS=ICPU/1.E6
      RETURN
C
      ENTRY SYSTIM(TIM)
C
C     OBTAIN CURENT TIME OF DAY AS A CHARACTER STRING FROM SYSTEM ROUTI
C      TIM='TIME'
C     SYSTEM CALL NEEDED FOR THE CYBER NOS OP SYS
      CALL TIME(TIM)
C     SYSTEM CALL NEEDED FOR THE CRAY CTSS OP SYS
C     CALL TIMEDATE(TIM,DATX,MACH)
      RETURN
C
      ENTRY SYSDAT(DAT)
C
```

```
C     OBTAIN CURENT DATE AS A CHARACTER STRING FROM SYSTEM ROUTINE
C      DAT='DATE'
C     SYSTEM CALL NEEDED FOR THE CYBER NOS OP SYS
      CALL DATE(DAT)
C     SYSTEM CALL NEEDED FOR THE CRAY CTSS OP SYS
C     CALL TIMEDATE(TIMX,DAT,MACH)
      RETURN
C     STANDARD SYSTEM INITIALIZATION TO BE CALLED FROM MAIN PROGRAM
      ENTRY SYSINI
C     SYSTEM INITIALIZATION CALL FOR CTSS ON CRAY COMPUTER
C     CALL LINK("READ5,UNIT5=TTY,PRINT6,UNIT6=TTY//")
      RETURN
C
      ENTRY MORTEM
      STOP 'POST MORTEM'
      END
```

```
      SUBROUTINE DFCNST(DRMACH,MAX)
      REAL DRMACH(MAX)
C     RETURN MAX MACHINE CONSTANTS(OR THE NUMBER AVAILABLE)
C     IN ARRAY DRMACH.

C     THIS MODULE PROVIDES CONSTANTS WHICH ARE EXPLICITLY DEPENDENT
C     ON MACHINE ARCHITECTURE AND SHOULD BE EXAMINED WHEN MAKING ANY
C     MIGRATION OF THE RAY TRACING ROUTINES.
C
C
      REAL RMACH(5)
C
C     SINGLE PRECISION MACHINE CONSTANTS
C      (SEE DIGITAL SIGNAL PROCESSING, IEEE PRESS 1979 P S-7)
C
C     THE CONSTANTS ARE DERIVED FROM THE FOLLOWING
C     FORM FOR FLOATING POINT NUMBERS:
C
C        SIGN (B**E)*( (X(1)/B) + ... + (X(T)/B**T) )
C     FOR MOST MACHINES THE BASE B=2.
C     FOR THE CYBER 60-BIT MACHINES
C        T=48, EMIN=-974 AND EMAX=1070.
C     FOR THE PDP-11 AND VAX-11 MACHINES
C        T=24, EMIN=-127 AND EMAX=127
C
C     RMACH(1)  SMALLEST POSITIVE MAGNITUDE = B**(EMIN-1)
C     RMACH(2)  LARGEST MAGNITUDE           = B**EMAX*(1-B**(-T))
C     RMACH(3)  SMALLEST RELATIVE SPACING   = B**(-T)
C     RMACH(4)  LARGEST RELATIVE SPACING    = B**(1-T)
C     RMACH(5)                              = LOG10(B=2)
C
C     CONSTANTS HERE ARE FOR CDC 6000/7000/CYBER SERIES COMPUTERS
C     PLEASE SUBSTITUTE FOR OTHER MACHINES
C
```

```
C
C      INTEGER SMALL(2)
C      INTEGER LARGE(2)
C      INTEGER RIGHT(2)
C      INTEGER DIVER(2)
C      INTEGER LOG10(2)
CC
C      EQUIVALENCE (RMACH(1),SMALL(1))
C      EQUIVALENCE (RMACH(2),LARGE(1))
C      EQUIVALENCE (RMACH(3),RIGHT(1))
C      EQUIVALENCE (RMACH(4),DIVER(1))
C      EQUIVALENCE (RMACH(5),LOG10(1))
C
C     MACHINE CONSTANTS FOR CYBER 170/180 COMPUTERS
C
      DATA RMACH(1) / O"00014000000000000000" /
      DATA RMACH(2) / O"37767777777777777777" /
      DATA RMACH(3) / O"16404000000000000000" /
      DATA RMACH(4) / O"16414000000000000000" /
      DATA RMACH(5) / O"17164642023241175720" /
C
C***REFERENCES  FOX, P.A., HALL, A.D., SCHRYER, N.L, *FRAMEWORK FOR
C                 A PORTABLE LIBRARY*, ACM TRANSACTIONS ON MATHE-
C                 MATICAL SOFTWARE, VOL. 4, NO. 2, JUNE 1978,
C                 PP. 177-188.
C***ROUTINES CALLED  XERROR
C***END PROLOGUE  R1MACH
C     MACHINE CONSTANTS FOR VAX 11/780
C     (EXPRESSED IN INTEGER AND HEXADECIMAL)
C    ***THE HEX FORMAT BELOW MAY NOT BE SUITABLE FOR UNIX SYSYEMS***
C    *** THE INTEGER FORMAT SHOULD BE OK FOR UNIX SYSTEMS***
C
C     DATA SMALL(1), SMALL(2) /       128,           0 /
C     DATA LARGE(1), LARGE(2) /    -32769,          -1 /
C     DATA RIGHT(1), RIGHT(2) /      9344,           0 /
C     DATA DIVER(1), DIVER(2) /      9472,           0 /
C     DATA LOG10(1), LOG10(2) /  546979738,  -805796613 /
C
C     DATA SMALL(1), SMALL(2) / Z00000080, Z00000000 /
C     DATA LARGE(1), LARGE(2) / ZFFFF7FFF, ZFFFFFFFF /
C     DATA RIGHT(1), RIGHT(2) / Z00002480, Z00000000 /
C     DATA DIVER(1), DIVER(2) / Z00002500, Z00000000 /
C     DATA LOG10(1), LOG10(2) / Z209A3F9A, ZCFF884FB /
C
C   MACHINE CONSTANTS FOR VAX 11/780 (G-FLOATING)
C     (EXPRESSED IN INTEGER AND HEXADECIMAL)
C    ***THE HEX FORMAT BELOW MAY NOT BE SUITABLE FOR UNIX SYSYEMS***
C    *** THE INTEGER FORMAT SHOULD BE OK FOR UNIX SYSTEMS***
C
C     DATA SMALL(1), SMALL(2) /        16,           0 /
C     DATA LARGE(1), LARGE(2) /    -32769,          -1 /
C     DATA RIGHT(1), RIGHT(2) /     15552,           0 /
C     DATA DIVER(1), DIVER(2) /     15568,           0 /
C     DATA LOG10(1), LOG10(2) /  1142112243, 2046775455 /
C
```

```
C     DATA SMALL(1), SMALL(2) / Z00000010, Z00000000 /               DFRT0910
C     DATA LARGE(1), LARGE(2) / ZFFFF7FFF, ZFFFFFFFF /               DFRT0920
C     DATA RIGHT(1), RIGHT(2) / Z00003CC0, Z00000000 /               DFRT0930
C     DATA DIVER(1), DIVER(2) / Z00003CD0, Z00000000 /               DFRT0940
C     DATA LOG10(1), LOG10(2) / Z44133FF3, Z79FF509F /               DFRT0950
C                                                                    DFRT0960
C     MACHINE CONSTANTS FOR THE CRAY 1                               DFRT0970
C                                                                    DFRT0980
C     DATA SMALL(1) / 201354000000000000000B /                       DFRT0990
C     DATA SMALL(2) / 000000000000000000000B /                       DFRT1000
C                                                                    DFRT1010
C     DATA LARGE(1) / 577767777777777777777B /                       DFRT1020
C     DATA LARGE(2) / 000007777777777777774B /                       DFRT1030
C                                                                    DFRT1040
C     DATA RIGHT(1) / 376434000000000000000B /                       DFRT1050
C     DATA RIGHT(2) / 000000000000000000000B /                       DFRT1060
C                                                                    DFRT1070
C     DATA DIVER(1) / 376444000000000000000B /                       DFRT1080
C     DATA DIVER(2) / 000000000000000000000B /                       DFRT1090
C                                                                    DFRT1100
C     DATA LOG10(1) / 377774642023241175717B /                       DFRT1110
C     DATA LOG10(2) / 000007571421742254654B /                       DFRT1120
C                                                                    DFRT1130
      CALL RMOVE(DRMACH,RMACH,MIN0(MAX,5))                           DFRT1140
C                                                                    DFRT1150
      END                                                            DFRT1160


      SUBROUTINE READW1(AB,NWOK,MSET,MX,NTBL,ITBL,FRMTBL,GP)         REZ10020
C     HANDLES INPUT OF TABULAR DATA REQUIRED BY SOME MODELS.         REZ10030
C     COMMON DECK "RAYDEV" INSERTED HERE                             CRAY0020
C     DEVICE ASSIGNED TO RAYTRC INPUT FILE                           CRAY0040
      COMMON/RAYDEV/NRYIND,NDEVTMP,NFRMAT,NDEVGRP,NDEVBIN             CRAY0050
C     COMMON DECK "CUCON" INSERTED HERE                              CUCO0020
      COMMON/UCONV/CNVV(5,4)                                         CUCO0040
      CHARACTER PCV*3,CNVC*2                                         CUCO0050
      COMMON/UCONC/PCV(5),CNVC(5,4)                                  CUCO0060
C     COMMON DECK "CONST" INSERTED HERE                              CCON0020
      COMMON/PCONST/CREF,RGAS,GAMMA                                  CCON0040
      COMMON/MCONST/PI,PIT2,PID2,DEGS,RAD,ALN10                      CCON0050
C     COMMON DECK "WWR" INSERTED HERE                                CWWR0020
      PARAMETER (NWARSZ=1000)                                        CWW10030
      COMMON/WW/ID(10),MAXW,W(NWARSZ)                                CWW10040
      REAL MAXSTP,MAXERR,INTYP,LLAT,LLON                             CWW20020
      EQUIVALENCE (EARTHR,W(1)),(RAY,W(2)),(XMTRH,W(3)),(TLAT,W(4)), CWW20030
     1 (TLON,W(5)),(OW,W(6)),(FBEG,W(7)),(FEND,W(8)),(FSTEP,W(9)),   CWW20040
     2 (AZ1,W(10)),(AZBEG,W(11)),(AZEND,W(12)),(AZSTEP,W(13)),       CWW20050
     3 (BETA,W(14)),(ELBEG,W(15)),(ELEND,W(16)),(ELSTEP,W(17)),      CWW20060
     8   (RUNSUP,W(18)),(RCVRH,W(20)),                               CWW20070
     4 (ONLY,W(21)),(HOP,W(22)),(MAXSTP,W(23)),(PLAT,W(24)),(PLON,W(25))CWW20080
     5,(HMAX,W(26)),(RAYFNC,W(29)),(EXTINC,W(33)),                   CWW20090
     6 (HMIN,W(27)),(RGMAX,W(28)),                                   CWW20100
```

```
     8 (INTYP,W(41)),(MAXERR,W(42)),(ERATIO,W(43)),                     CWW20110
     6 (STEP1,W(44)),(STPMAX,W(45)),(STPMIN,W(46)),(FACTR,W(47)),       CWW20120
     7 (SKIP,W(71)),(RAYSET,W(72)),(PRTSRP,W(74)),(HITLET,W(75))        CWW20130
     9 ,(BINRAY,W(76)),(PAGLN,W(77)),(PLT,W(81)),(PFACTR,W(82)),        CWW20140
     1 (LLAT,W(83)),(LLON,W(84)),(RLAT,W(85)),(RLON,W(86))              CWW20150
     2,(TIC,W(87)),(HB,W(88)),(HT,W(89)),(TICV,W(96))                   CWW20160
      LOGICAL NWOK,AB                                                   REZ10080
C                                                                       REZ10090
      CHARACTER LINE*80,ALPHA*3,FBUF*3                                  REZ10100
      PARAMETER (NVAR=6,ALPHA='  A',NACDE=-1,NFIELD=13)                 REZ10110
      INTEGER IPV(NVAR),NTBL(10),ITBL(10),FRMTBL(10)                    REZ10120
      CHARACTER*8 PU(NVAR)                                              REZ10130
      REAL GP(*),V(NVAR),CONV(NVAR)                                     REZ10140
C                                                                       REZ10150
C     THE DATA STRUCTURE EXPECTED BY THIS PROGRAM FOR A DATA BLOCK IS   REZ10160
C     SPECIFIED FOR A GIVEN MODEL BY THE THREE ARRAYS NTBL,ITBL,FRMTBL. REZ10170
C     THE TYPE OF DATA EXPECTED FOR A GIVEN FORMAT GROUP IS TAKEN FROM  REZ10180
C     ARRAY FRMTBL. IT MUST HAVE AN ENTRY FOR A GIVEN TYPE OF FORMAT    REZ10190
C     WHICH IS EITHER ZERO, IF THAT FORMAT IS NOT ALLOWED OR AN ENTRY   REZ10200
C     WHOSE VALUE IS EQUAL TO THAT FORMAT TYPE. CURRENTLY ONLY TWO      REZ10210
C     FORMAT TYPES ARE ALLOWED, 1 FOR ALPHA AND 2 FOR NUMERIC.          REZ10220
C     TO ALLOW MORE FLEXIBLITY IN THE INPUT FILE THE NUMERIC FORMAT     REZ10230
C     TYPE IN TURN ALLOWS FOR 3 DIFFERENT DATA FORMATS, SEE BELOW.      REZ10240
C                                                                       REZ10250
C     OFFSETS INTO THE GENERAL ARRAY 'GP' FOR EACH FORMAT ARE GIVEN     REZ10260
C     IN THE ARRAY 'NTBL'. THE SPACING BETWEEN DATA VALUES IN EACH LINE REZ10270
C     READ IS GIVEN IN ARRAY 'ITBL'. THIS SCHEME DOES NOT ALLOW FOR X,Y REZ10280
C     ,Z CYCLES BUT RATHER SEPARATE ARRAYS OF X VALUES, THEN Y VALUES,  REZ10290
C     AND THEN Z VALUES(ETC. UP TO 'NVAR' VARIABLES).                   REZ10300
C                                                                       REZ10310
      NWOK=.TRUE.                                                       REZ10320
C                                                                       REZ10330
C     INITIALIZE ANY ALPHANUMERIC ARRAYS TO BLANKS                      REZ10340
      IF(FRMTBL(1).EQ.1) CALL SET2(GP(NTBL(1)),1H ,NTBL(2)-NTBL(1))     REZ10350
C                                                                       REZ10360
C     BEGIN MULTI-FORMAT LOOP                                           REZ10370
5     READ(NRYIND,'(A,A)',END=200) FBUF,LINE                            REZ10380
      IF(NDEVTMP.GT.0) WRITE(NDEVTMP,'(A,A)') FBUF,LINE                 REZ10390
      IF(FBUF.EQ.ALPHA) THEN                                            REZ10400
         NFRM=NACDE                                                     REZ10410
      ELSE                                                              REZ10420
         READ(FBUF,10) NFRM                                             REZ10430
      ENDIF                                                             REZ10440
10    FORMAT(BZ,I3,A)                                                   REZ10450
      IF(NFRM .EQ. 0) RETURN                                            REZ10460
C                                                                       REZ10470
C     FORMAT #1 IS ASSIGNED TO ALPHANUMERIC INPUT AND LARGER NUMBERS    REZ10480
C     FOR NUMERIC INPUT.                                                REZ10490
C                                                                       REZ10500
C     CHECK NOW FOR NUMERICAL FORMATS.                                  REZ10510
C     THESE ARE PROVIDED FOR EASE OF INPUT OF TABULATED DATA            REZ10520
C     AND ARE PARTLY 'TRANSPARENT' TO THE MODEL INVOLVED. I.E.          REZ10530
C     THE USER HAS THE OPTION OF SPECIFING THE NUMBER OF DATA COLUMNS.  REZ10540
C     INPUT FORMAT NUMBER SPECIFIES THE NUMBER OF COLUMNS OF INPUT DATA REZ10550
C     I.E. FOR VALUE 1 A SINGLE DATA COLUMN IS EXPECTED, FOR A VALUE    REZ10560
```

```
C      2 TWO DATA COLUMNS ARE EXPECTED, ETC.
C
C      DETERMINE FORMAT NUMBER
       IF(NFRM.EQ.NACDE) THEN
          IT=1
C      ALPHANUMERIC FORMATS MUST BE FIRST IN LIST
C      SINCE NO OFFSET SPECIFIER IS ALLOWED IN A FULL ALPHA LINE
          IF(FRMTBL(1).EQ.1) GO TO 100
       ELSE
          READ(LINE,'(I2)') IT
          IT=MAX0(IT,2)
          IF(IT.LE.MX) GO TO 100
       ENDIF
C
15     AB=.TRUE.
       PRINT 20, MSET,NFRM,MX
20     FORMAT(' FOR SET',I5,' FORMAT NUMBER',I5,' EXCEEDS LIMIT OF',I5)
C       ERROR IN INPUT DATA , STOP HERE
       STOP
C
C      THE 'NTBL' TABLE PROVIDES A LIST OF OFFSETS TO VARIABLE GROUPS IN
C      MODEL ARRAYS, 'ITBL' GIVES ELEMENT SEPARATION TO ALLOW FOR 2-
C      DIMENSIONAL ARRAYS AND 'FRMTBL' SPECIFIES THE INPUT FORMAT.
C
100    N1=NTBL(IT)
       N3=ITBL(IT)
       N2=NTBL(IT+1)-N3
C
       IF(NFRM.NE.NACDE) GO TO 110
C
       READ(LINE,1010)((GP(I+J-1),I=N1,N2,N3),J=1,N3)
1010   FORMAT(10A8)
       GO TO 5
C
110    IF(NFRM.LT.1 .OR. NFRM.GT.NVAR) GO TO 200
C      HANDLE NUMERIC FORMATS
C
C      N1 IS STARTING ELEMENT WHICH WILL BE AFTER THE DATA COUNT
C      VALUE(NEED NELS*N3+1 TOTAL ELEMENTS)
       N1=N1+1
       N=0
C
C      # ELEMENTS IS EQUAL TO FORMAT NUMBER
       NELS=NFRM
C      READ UNITS CONVERSION SPECIFICATION LINE
       READ(LINE,1018) (PU(I),I=1,3)
       IF(PU(2).NE.' ') READ(LINE,2024) DELIM
       IF(PU(2).EQ.' ') READ(LINE,1020) DELIM,(PU(I),I=1,NELS)
C
C  ALLOW FOR BLANK CONVERSION LINE PRODUCED BY EIGENRAY ROUTINE
       IF(DELIM.EQ.0) READ(LINE,2024) DELIM
C
C      READ NEXT LINE AND EXTRACT UNIT CONVERSION SPECS IF PRESENT
C      IN FLOATING FORMAT
       READ(NRYIND,'(A)') LINE
```

```
      CALL GTUNIT(LINE,PU,NFIELD,NELS, NCARY)
C     CARRY COUNT IS ZERO IF LINE CONTAINED UNITS SPECIFIERS
      IF(NCARY.EQ.0.AND.NDEVTMP.GT.0) WRITE(NDEVTMP,'(A)') LINE
C
1018  FORMAT(10(A,5X))
1020  FORMAT(BZ,3X,G10.3,8X,10A)
2024  FORMAT(T43,G10.3)
1025  FORMAT(BZ,10G13.6)
C
C     LOOK UP CONVERSION CONSTANTS
      DO 2030 I=1,NELS
2030  CALL UCON(IPV(I),PU(I),CONV(I))
C
C     DELIMITOR TESTING REQUIRES THE INNER LOOP BE EXECUTED
C     AT LEAST ONCE
      NX=MAX0(1,N3)
      N2=MAX0(N2,N1)
C     BEGIN SINGLE DATA FORMAT LOOP
      DO 150 J=0,10000
         IF(NELS.GT.1) THEN
            IF(NCARY.EQ.0) READ(NRYIND,'(A)') LINE
            NCARY=0
            IF(NDEVTMP.GT.0) WRITE(NDEVTMP,'(A)') LINE
            READ(LINE,1025) (V(I),I=1,NELS)
         ENDIF
         K=0
         DO 145 I=N1+J,N2+J,NX
               K=K+1
               IF(NELS.EQ.1) THEN
                  IF(NCARY.EQ.0) READ(NRYIND,'(A)',END=10000) LINE
                  NCARY=0
                  IF(NDEVTMP.GT.0) WRITE(NDEVTMP,'(A)') LINE
C     FOR SINGLE COLUMN CASE READ NOW
                  READ(LINE,1020) V(K)
               ENDIF
               IF(V(K) .EQ. DELIM) GO TO 160
C
C           APPLY ANY SCALING CONVERSIONS
               IF(CONV(K).GE.0.0) THEN
                  V(K)=V(K)*CONV(K)
               ELSEIF(V(K).NE.0.0) THEN
                  V(K)=-CONV(K)/V(K)
      ENDIF
               IF(J.LT.N3) GP(I)=V(K)
145            N=N+1
150   CONTINUE
C
10000 IF(V(1).NE.DELIM) CALL RERROR('READW1','NO DELIM',FLOAT(MSET))
C
C     SAVE NUMBER OF VALUES AND ELEMENTS(AS FRACTIONAL PART)
160   IF(N1.GT.1) GP(N1-1)=N+NELS/10.
C
C     CONTINUE MULTI-FORMAT LOOP
      GO TO 5
C
```

```
200   CALL RERROR('READW1','BAD FORMAT',FLOAT(MSET))
C
      END
```

```
      SUBROUTINE GTUNIT(LINE,PU,NFIELD,NVAR, LN)
C     GTUNIT IS USED TO EXTRACT UNIT CONVERSION SPECIFIERS FROM TABULAR
C     DATA INPUT.
C     CONVERSION SPECIFICATIONS ARE TAKEN FROM 'LINE' INPUT STRING.
C     A FLOATING FORMAT FALLING WITHIN SUCCESSIVE FIELDS OF
C     LENGTH 'NFIELD' IS PROVIDED FOR.
C     OUTPUT IS TO UNIT SPECIFIER ARRAY 'PU' FOR A MAXIMUM OF 'NVAR'
C     FIELDS. FOR A SUCCESS/FAIL RETURN VALUE, 'LN' GIVES THE NUMBER
C     OF NON-BLANK CHARACTERS USEFUL FOR UNIT DECODING, ZERO IMPLIES
C     NO USEFUL UNIT INFORMATION WAS FOUND.
C
      PARAMETER (MAXLN=130)
      CHARACTER*(*) LINE,PU(NVAR),TMP*(MAXLN),TMP1*(MAXLN)
      INTEGER STRIM
C
      LN=STRIM(LINE)
      IF(LN.LT.1) THEN
         DO 5 I=1,NVAR
5           PU(I)=' '
         RETURN
      ENDIF
C
      TMP=' '
      CALL SFILTR(LINE,TMP,' 0123456789+-.E')
      IF(STRIM(TMP).LT.1) RETURN
C     SIGNIFY WE CONSUMED THIS LINE
      LN=0
C
      TMP1=LINE
C     PLACE INTER-SPECIFIER DELIMITORS
      DO 10 I=NFIELD,NFIELD*NVAR,NFIELD
         IF(TMP1(I:I).NE.' ') THEN
            IF(TMP1(I+1:I+1).NE.' ') THEN
C     IF NO ROOM FOR A BLANK, ITS AN ERROR
               CALL RERROR('GTUNIT','FORMAT ER1',FLOAT(I))
            ELSE
               TMP1(I+1:I+1)='#'
            ENDIF
         ELSE
            TMP1(I:I)='#'
         ENDIF
10    CONTINUE
C
C     NOW SQUEEZE OUT THE BLANKS
      CALL SFILTR(TMP1,TMP,' ')
C     HOPEFULLY SOMETHING LEFT
C
```

```
      NL=STRIM(TMP)
      ILIN=1
      DO 20 I=1,NVAR
C     CHECK FOR EMPTY CONVERSIONS
         IF(TMP(ILIN:ILIN).EQ.'#') THEN
            ILIN=ILIN+1
            PU(I)=' '
            GO TO 20
         ENDIF
C     GET NEXT UNIT TYPE
         PU(I)(1:2)=TMP(ILIN:ILIN+1)
C     GET NEXT PHYSICAL UNIT(BLANKS HAVE BEEN REMOVED)
C     SHORT PHRASE IF A BLANK WAS REMOVED
         IF(TMP(ILIN+3:ILIN+3).NE.'#') THEN
            IF(TMP(ILIN+4:ILIN+4).NE.'#') THEN
C     IF INCORRECT GROUPING OF LETTERS, ITS AN ERROR
               CALL RERROR('GTUNIT','FORMAT ER2',FLOAT(ILIN))
            ELSE
C     ADD TWO LETTER UNIT
               PU(I)(3:5)=' '//TMP(ILIN+2:ILIN+3)
               ILIN=ILIN+5
            ENDIF
         ELSE
C     ADD ONE LETTER UNIT
            PU(I)(3:5)='  '//TMP(ILIN+2:ILIN+2)
            ILIN=ILIN+4
         ENDIF
20    CONTINUE
C
C     SHOULD HAVE USED UP ALL THE TEXT BY NOW
      IF(ILIN.LE.NL) CALL RERROR('GTUNIT','FORMAT ER3',FLOAT(ILIN))
      END
```

```
      SUBROUTINE SREAD1(AB,NWOK,NW)
C     THIS IS THE FALLTHROUGH FEATURE FOR READW WHEN ENCOUNTERING
C     A NON STANDARD LABELED COMMON BLOCK. SREAD1 WILL ADD TABULAR
C     DATA TO THE DEFAULT GP ARRAY PGP AND INCLUDE INDEX OFFSET
C     VALUES TO A LOOKUP ARRAY 'LIST'.
C     COMMON DECK "CPROCFL" INSERTED HERE
      INTEGER PMX,PNTBL,PITBL,PFRMTBL,IDSP(10)
C     PARAMETER DECK "PGROUPS"
      PARAMETER (NCHPG1=11,NWPV=250,NSPGP=NCHPG1+2*NWPV+1)
      PARAMETER (MNGRP=9,MXGRP=69,MXLIST=MXGRP-MNGRP+2)
      COMMON/PROCFL/LIST(MXLIST)
      COMMON/PROCFL/PMX,PNTBL(10),PITBL(10),PFRMTBL(10),PGP(NSPGP)
      EQUIVALENCE (PGP,IDSP)
C
      CHARACTER ITOC*7
C
      INTEGER PPX    ,PQTBL(10),PLTBL(10),PIRMTBL(10)
C
```

```
      DATA PPX/2/
      DATA PQTBL/1,NCHPG1,NSPGP,7*0/
      DATA PLTBL/1,NWPV,8*0/
      DATA PIRMTBL/1,2,8*0/
C
      NWA=IABS(NW)-(MNGRP-2)
      IF(NWA.LT.2 .OR. NWA.GT.MXLIST) CALL STOPIT
     1  ( 'SREAD1 NW='//ITOC(NW)//',LIST(1)='//ITOC(LIST(1)) )
C
      CALL READW1(AB,NWOK,NW,PMX,PNTBL,PITBL,PFRMTBL,PGP)
C
C     UPDATE THE LIST, LIST(1)=MAXIMUM USED ELEMENT
      LIST(1)=MAX0(LIST(1),NWA)
      LIST(NWA)=PNTBL(1)
C
C     GET NEXT NUMERICAL INDEX FROM THE POINTER ARRAY
      NLN=PNTBL(2)
C
C     NUMBER OF VALUES IS INTEGRAL PART OF FIRST ELEMENT
      NPTS=PGP(NLN)
C     NUMBER OF ROWS IS KEPT AS FRACTIONAL PART
      NELS=(PGP(NLN)-NPTS)*10.+.5
      N2=NPTS/NELS
      NMX=PITBL(2)
C     MAKE ADJUSTMENTS TO LENGTHS AND OFFSETS
      PITBL(2)=NMX-N2-(NCHPG1-1)
      NUP=NPTS+NCHPG1
      PNTBL(1)=PNTBL(1)+NUP
      PNTBL(2)=PNTBL(2)+NUP
      NLN=NLN+1
C
C     LOOP TO MOVE NELS-1 ROWS OF PGP(NMX,NELS) TO PGP(N2,NELS)
C     THUS MAKING PGP A CONTIGUOUS ARRAY
      NTO=NLN+N2
      NFRM=NLN+NMX
      DO 100 I=2,NELS
      IF(NTO.GT.0 .AND. NFRM+N2-1.LE.NSPGP)
     1         CALL RMOVE(PGP(NTO),PGP(NFRM),N2)
      NTO=NTO+N2
100   NFRM=NFRM+NMX
      RETURN
C
      ENTRY SETSRD
      CALL ISET2(LIST,0,MXLIST)
      PMX=PPX
      CALL IMOVE(PNTBL,PQTBL,10)
      CALL IMOVE(PITBL,PLTBL,10)
      CALL IMOVE(PFRMTBL,PIRMTBL,10)
      END



      FUNCTION READW(XX)
```

```
C     READS W ARRAY MAKING ANY NECESSARY CONVERSION OF UNITS.             REXW0030
C     VARIABLE LENGTH 'TABULAR' DATA IS READ BY SUBROUTINE 'READW1'       REXW0040
C     WHICH IS CALLED FOR NEGATIVE W-ARRAY INDICES.                       REXW0050
C                                                                         REXW0060
C     COMMON DECK "CONST" INSERTED HERE                                   CCON0020
      COMMON/PCONST/CREF,RGAS,GAMMA                                       CCON0040
      COMMON/MCONST/PI,PIT2,PID2,DEGS,RAD,ALN10                           CCON0050
C     COMMON DECK "WWR" INSERTED HERE                                     CWWR0020
      PARAMETER (NWARSZ=1000)                                             CWW10030
      COMMON/WW/ID(10),MAXW,W(NWARSZ)                                     CWW10040
      REAL MAXSTP,MAXERR,INTYP,LLAT,LLON                                  CWW20020
      EQUIVALENCE (EARTHR,W(1)),(RAY,W(2)),(XMTRH,W(3)),(TLAT,W(4)),      CWW20030
     1 (TLON,W(5)),(OW,W(6)),(FBEG,W(7)),(FEND,W(8)),(FSTEP,W(9)),        CWW20040
     2 (AZ1,W(10)),(AZBEG,W(11)),(AZEND,W(12)),(AZSTEP,W(13)),            CWW20050
     3 (BETA,W(14)),(ELBEG,W(15)),(ELEND,W(16)),(ELSTEP,W(17)),           CWW20060
     8   (RUNSUP,W(18)),(RCVRH,W(20)),                                    CWW20070
     4 (ONLY,W(21)),(HOP,W(22)),(MAXSTP,W(23)),(PLAT,W(24)),(PLON,W(25))CWW20080
     5,(HMAX,W(26)),(RAYFNC,W(29)),(EXTINC,W(33)),                        CWW20090
     6 (HMIN,W(27)),(RGMAX,W(28)),                                        CWW20100
     8 (INTYP,W(41)),(MAXERR,W(42)),(ERATIO,W(43)),                       CWW20110
     6 (STEP1,W(44)),(STPMAX,W(45)),(STPMIN,W(46)),(FACTR,W(47)),         CWW20120
     7 (SKIP,W(71)),(RAYSET,W(72)),(PRTSRP,W(74)),(HITLET,W(75))          CWW20130
     9 ,(BINRAY,W(76)),(PAGLN,W(77)),(PLT,W(81)),(PFACTR,W(82)),          CWW20140
     1 (LLAT,W(83)),(LLON,W(84)),(RLAT,W(85)),(RLON,W(86))                CWW20150
     2,(TIC,W(87)),(HB,W(88)),(HT,W(89)),(TICV,W(96))                     CWW20160
C     COMMON DECK "B1" INSERTED HERE                                      CB1 0020
      INTEGER UMX,UNTBL,UITBL,UFRMTBL,IDSU(10)                            CB1 0040
      COMMON/B1/UMX,UNTBL(10),UITBL(10),UFRMTBL(10),UGP(10)               CB1 0050
      EQUIVALENCE (UGP,IDSU)                                              CB1 0060
C     COMMON DECK "B2" INSERTED HERE                                      CB2 0020
      INTEGER DUMX,DUNTBL,DUITBL,DUFRMTB,IDSDU(10)                        CB2 0040
      COMMON/B2/DUMX,DUNTBL(10),DUITBL(10),DUFRMTB(10),DUGP(10)           CB2 0050
      EQUIVALENCE (DUGP,IDSDU)                                            CB2 0060
C     COMMON DECK "B3" INSERTED HERE                                      CB3 0020
      INTEGER CMX,CNTBL,CITBL,CFRMTBL,IDSC(10)                            CB3 0040
      COMMON/B3/CMX,CNTBL(10),CITBL(10),CFRMTBL(10),CGP(512)              CB3 0050
      EQUIVALENCE (CGP,IDSC),(ANC,CGP(11))                                CB3 0060
C     COMMON DECK "B4" INSERTED HERE                                      CB4 0020
      INTEGER DCMX,DCNTBL,DCITBL,DCFRMTB,IDSDC(10)                        CB4 0040
      COMMON/B4/DCMX,DCNTBL(10),DCITBL(10),DCFRMTB(10),DCGP(10)           CB4 0050
      EQUIVALENCE (DCGP,IDSDC)                                            CB4 0060
C     COMMON DECK "B5" INSERTED HERE                                      CB5 0020
      INTEGER TMX,TNTBL,TITBL,TFRMTBL,IDST(10)                            CB5 0040
      COMMON/B5/TMX,TNTBL(10),TITBL(10),TFRMTBL(10),TGP(262)              CB5 0050
      EQUIVALENCE (TGP,IDST),(ANT,TGP(11))                                CB5 0060
C     COMMON DECK "B6" INSERTED HERE                                      CB6 0020
      INTEGER DTMX,DTNTBL,DTITBL,DTFRMTB,IDSDT(10)                        CB6 0040
      COMMON/B6/DTMX,DTNTBL(10),DTITBL(10),DTFRMTB(10),DTGP(10)           CB6 0050
      EQUIVALENCE (DTGP,IDSDT)                                            CB6 0060
C     COMMON DECK "B7" INSERTED HERE                                      CB7 0020
      INTEGER MMX,MNTBL,MITBL,MFRMTBL,IDSM(10)                            CB7 0040
      REAL MGP                                                            CB7 0050
      COMMON/B7/MMX,MNTBL(10),MITBL(10),MFRMTBL(10),MGP(10)               CB7 0060
      EQUIVALENCE (MGP,IDSM)                                              CB7 0070
C     COMMON DECK "B9" INSERTED HERE                                      CB8 0020
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      INTEGER GMX,GNTBL,GITBL,GFRMTBL,IDSG(10)                      CB8 0040
      COMMON/B9/GMX,GNTBL(10),GITBL(10),GFRMTBL(10),GGP(113)        CB8 0050
      EQUIVALENCE (GGP,IDSG),(ANG,GGP(11))                          CB8 0060
C                                                                   REXW0170
C     COMMON DECK "B10" INSERTED HERE                               CB9 0020
      INTEGER DGMX,DGNTBL,DGITBL,DGFRMTB,IDSDG(10)                  CB9 0040
      COMMON/B10/DGMX,DGNTBL(10),DGITBL(10),DGFRMTB(10),DGGP(10)    CB9 0050
      EQUIVALENCE (DGGP,IDSDG)                                      CB9 0060
C                                                                   REXW0190
C     COMMON DECK "B8" INSERTED HERE                                CB100020
      INTEGER RMX,RNTBL,RITBL,RFRMTBL,IDSR(10)                      CB100040
      COMMON/B8/RMX,RNTBL(10),RITBL(10),RFRMTBL(10),RGP(10)         CB100050
      EQUIVALENCE (RGP,IDSR)                                        CB100060
C                                                                   REXW0210
C     COMMON DECK "CB11" INSERTED HERE                              CB110020
      INTEGER SMX,SNTBL,SITBL,SFRMTBL,IDSS(10)                      CB110040
      COMMON/B11/SMX,SNTBL(10),SITBL(10),SFRMTBL(10),SGP(11)        CB110050
      EQUIVALENCE (SGP,IDSS),(ANS,SGP(11))                          CB110060
C     COMMON DECK "CB12" INSERTED HERE                              CB120020
      INTEGER DSMX,DSNTBL,DSITBL,DSFRMTB,IDSDS(10)                  CB120040
      COMMON/B12/DSMX,DSNTBL(10),DSITBL(10),DSFRMTB(10),DSGP(11)    CB120050
      EQUIVALENCE (DSGP,IDSDS),(ANDS,DSGP(11))                      CB120060
C     COMMON DECK "CB17" INSERTED HERE                              CB170020
      INTEGER VMX,VNTBL,VITBL,VFRMTBL,IDSV(10)                      CB170040
      COMMON/B17/VMX,VNTBL(10),VITBL(10),VFRMTBL(10),VGP(53)        CB170050
      EQUIVALENCE (VGP,IDSV),(ANV,VGP(11))                          CB170060
C     COMMON DECK "CB18" INSERTED HERE                              CB180020
      INTEGER DVMX,DVNTBL,DVITBL,DVFRMTB,IDSDV(10)                  CB180040
      COMMON/B18/DVMX,DVNTBL(10),DVITBL(10),DVFRMTB(10),DVGP(11)    CB180050
      EQUIVALENCE (DVGP,IDSDV),(ANDV,DVGP(11))                      CB180060
C     COMMON DECK "CB19" INSERTED HERE                              CB190020
      INTEGER PRMX,PRNTBL,PRITBL,PRFRMTB,IDSPR(10)                  CB190040
      COMMON/B19/PRMX,PRNTBL(10),PRITBL(10),PRFRMTB(10),PRGP(11)    CB190050
      EQUIVALENCE (PRGP,IDSPR),(ANP,PRGP(11))                       CB190060
C     COMMON DECK "CB20" INSERTED HERE                              CB200020
      INTEGER DPMX,DPNTBL,DPITBL,DPFRMTB,IDSDP(10)                  CB200040
      COMMON/B20/DPMX,DPNTBL(10),DPITBL(10),DPFRMTB(10),DPGP(11)    CB200050
      EQUIVALENCE (DPGP,IDSDP),(ANDP,DPGP(11))                      CB200060
C                                                                   REXW0280
      PARAMETER (MXCMTS=83,BIGVAL=1.E30)                            REXW0290
      CHARACTER*38 WFRMT,WNOTES(2)                                  REXW0300
      CHARACTER*80 LINEX,NUMSTG                                     REXW0310
      CHARACTER*100 STMP1,STMP2                                     REXW0320
      INTEGER STRIM,WCOMTS(MXCMTS)                                  REXW0330
      CHARACTER*1 DEG,KM,NM,FEET,CYCLE,PER,MSKMS                    REXW0340
C     COMMON DECK "RAYDEV" INSERTED HERE                            CRAY0020
C     DEVICE ASSIGNED TO RAYTRC INPUT FILE                          CRAY0040
      COMMON/RAYDEV/NRYIND,NDEVTMP,NFRMAT,NDEVGRP,NDEVBIN            CRAY0050
      LOGICAL NWOK,AB,UCON                                          REXW0360
C                                                                   REXW0370
C     COMMON DECK "FLAG" INSERTED HERE                              CFLA0020
      LOGICAL NEWWR,NEWWP,NEWTRC,PENET                              CFLA0040
      COMMON /FLG/ NTYP,NEWWR,NEWWP,NEWTRC,PENET,LINES,IHOP,HPUNCH  CFLA0050
      COMMON/FLGP/NSET                                              CFLA0060
C                                                                   REXW0390
```

```
      CHARACTER PC*1
C
      INTEGER XMX,XNTBL(10),XITBL(10),XFRMTBL(10)
      REAL XGP(11)
C
      DATA XMX/2/
      DATA XNTBL/1,11,12,7*0/
      DATA XITBL/1,9*0/
      DATA XFRMTBL/1,2,8*0/
C
      DATA WCOMTS,WNOTES/MXCMTS*1, ' ',' INPUT OVERRIDDEN'/
C
      AB=.FALSE.
      READW=0.0
C
      IF(NDEVTMP.GT.0) REWIND NDEVTMP
C
      READ(NRYIND,1000,END=3) ID
 1000 FORMAT (BZ,10A8)
      IF(NDEVTMP.GT.0) WRITE(NDEVTMP,1000) ID
      GO TO 4
C
3     READW=1.0
      IF(NFRMAT.LT.0) RETURN
C
      PRINT 1040
      WRITE(3,1040)
1040  FORMAT(' END OF INPUT DATA')
      CALL ENDPLT
33    IF(PLT.NE.0.0) CALL DDEND
      STOP
C
4     READ(NRYIND,'(A)',END=10001) STMP1
C
      READ(STMP1,1100) NW,WWW,LINEX
1100  FORMAT (BZ,I3,E14.7,A)
      IF(NDEVTMP.GT.0.AND.(NFRMAT.NE.-2.OR.NW.LT.0))
     1       WRITE(NDEVTMP,'(A)') STMP1
10001 IF (NW.EQ.0) GO TO 10
      IF(NW.GT.MAXW) GO TO 3400
C
      IF (NW.LE.MAXW .AND. NW.GT.0) GO TO 5
C     TABULAR INPUT DATA
      NWOK=.FALSE.
C 'OPEN' THE TEMP FILE
1150  FORMAT(I3,T18,A)
      NWP=-NW
      IF(NFRMAT.EQ.-2) THEN
C     USE DUMMY ARRAYS TO ABSORB TABULAR DATA
         CALL READW1(AB,NWOK,NW,XMX,XNTBL,XITBL,XFRMTBL,XGP)
      ELSEIF(NWP.EQ.1) THEN
         CALL READW1(AB,NWOK,NW,UMX,UNTBL,UITBL,UFRMTBL,UGP)
      ELSEIF(NWP.EQ.2) THEN
         CALL READW1(AB,NWOK,NW,DUMX,DUNTBL,DUITBL,DUFRMTB,DUGP)
      ELSEIF(NWP.EQ.3) THEN
```

```
         CALL READW1(AB,NWOK,NW,CMX,CNTBL,CITBL,CFRMTBL,CGP)
      ELSEIF(NWP.EQ.4) THEN
         CALL READW1(AB,NWOK,NW,DCMX,DCNTBL,DCITBL,DCFRMTB,DCGP)
      ELSEIF(NWP.EQ.5) THEN
            CALL READW1(AB,NWOK,NW,TMX,TNTBL,TITBL,TFRMTBL,TGP)
      ELSEIF(NWP.EQ.6) THEN
         CALL READW1(AB,NWOK,NW,DTMX,DTNTBL,DTITBL,DTFRMTB,DTGP)
      ELSEIF(NWP.EQ.7) THEN
         CALL READW1(AB,NWOK,NW,MMX,MNTBL,MITBL,MFRMTBL,MGP)
      ELSEIF(NWP.EQ.8) THEN
         CALL READW1(AB,NWOK,NW,RMX,RNTBL,RITBL,RFRMTBL,RGP)
      ELSEIF(NWP.EQ.9) THEN
         CALL READW1(AB,NWOK,NW,GMX,GNTBL,GITBL,GFRMTBL,GGP)
      ELSEIF(NWP.EQ.10) THEN
         CALL READW1(AB,NWOK,NW,DGMX,DGNTBL,DGITBL,DGFRMTB,DGGP)
      ELSEIF(NWP.EQ.11) THEN
         CALL READW1(AB,NWOK,NW,SMX,SNTBL,SITBL,SFRMTBL,SGP)
      ELSEIF(NWP.EQ.12) THEN
         CALL READW1(AB,NWOK,NW,DSMX,DSNTBL,DSITBL,DSFRMTB,DSGP)
      ELSEIF(NWP.EQ.17) THEN
         CALL READW1(AB,NWOK,NW,VMX,VNTBL,VITBL,VFRMTBL,VGP)
      ELSEIF(NWP.EQ.18) THEN
         CALL READW1(AB,NWOK,NW,DVMX,DVNTBL,DVITBL,DVFRMTB,DVGP)
      ELSEIF(NWP.EQ.19) THEN
         CALL READW1(AB,NWOK,NW,PRMX,PRNTBL,PRITBL,PRFRMTB,PRGP)
      ELSEIF(NWP.EQ.20) THEN
         CALL READW1(AB,NWOK,NW,DPMX,DPNTBL,DPITBL,DPFRMTB,DPGP)
      ELSE
         CALL SREAD1(AB,NWOK,NW)
      ENDIF
      IF(NWOK) GO TO 4
C
3400  WRITE(3,4000) NW,MAXW
4000  FORMAT(15H1THE SUBSCRIPT ,I3,  ' ON THE W-ARRAY INPUT IS OUT OF BO
     1UNDS.  ALLOWABLE VALUES ARE -8 THROUGH,',I4,'.' )
      CALL EXIT
C
5     READ(LINEX,70) DEG,KM,NM,FEET,CYCLE,PER,MSKMS
70    FORMAT(7A)
      W(NW)=WWW
C
C     CHECK FOR A 'TERRAIN RELATIVE' HEIGHT SPECIFICATION.
C     IF SO ADD FLAG VALUE 10**40 TO BE TESTED FOR LATER IN 'RAYTRC'
C
      IF(MSKMS.EQ.'T' .AND. WWW.EQ.0.0) W(NW)=1.E-40
      IF(WWW.EQ.0.0) GO TO 4
      IF(MSKMS.EQ.'T') WWW=WWW*1.E40
C
C     CHECK FOR KEYWORD UNITS SPECIFICATION, IF SO PERFORM CONVERSION
C
      IF(.NOT.UCON(KU,LINEX(:10),CONV)) GO TO 60
75    IF(CONV.GE.0.0) THEN
         W(NW)=WWW*CONV
      ELSEIF(W(NW).NE.0.0) THEN
         W(NW)=-CONV/W(NW)
```

```
      ENDIF
      GO TO 4
C
60    IF (DEG.EQ.'1') WWW=WWW*RAD
      IF (KM.EQ.'1') WWW=WWW/EARTHR
      IF (NM.EQ.'1') WWW=WWW*1.852
      IF (FEET.EQ.'1') WWW=WWW*3.048006096E-4
      IF(CYCLE.EQ.'1') WWW=WWW*PIT2
      IF(PER.EQ.'1') WWW=PIT2/WWW
      IF(MSKMS.EQ.'1') WWW=WWW*1.E-3
      W(NW)=WWW
      GO TO 4
C
10    IF(.NOT.AB) RETURN
      PRINT 1200
1200  FORMAT(' A DATA FORMATTING ERROR PREVENTS CONTINUED EXECUTION')
      CALL EXIT
C
      ENTRY SETW(XX)
C     THIS ENTRY IS CALLED ONCE BEFORE THE FIRST RUN SET IS READ
C
C INITIALIZE SOME MATHEMATICAL CONSTANTS
      PI=4.0*ATAN(1.0)
      PIT2=2.*PI
      PID2=PI/2.
      DEGS=180./PI
      RAD=PI/180.
      ALN10=ALOG(10.)
CC********* INITIALIZE SOME VARIABLES IN THE W ARRAY
      MAXW=NWARSZ
      CALL CLEAR(W,MAXW)
      PLON=0.
      PLAT=PID2
      EARTHR=6370.
      INTYP=3.
      MAXERR=1.E-4
      ERATIO=50.
      STEP1=1.
      STPMAX=100.
      STPMIN=1.E-8
      FACTR=0.5
      HITLET=.15
      MAXSTP=1000.0
      HOP=1.
      HMAX=500.0
      EXTINC=999.999
      PAGLN=66.0
C
      CALL SETUCON
C
      RETURN
C
      ENTRY SETOVR(XX)
C     THIS ENTRY IS CALLED AFTER EACH RUN SET IS READ
C
```

```
C     PERFORM OVERRIDE ASSIGNMENTS TO W-ELEMENTS
      CALL OVERRD(MAXSTP,0.0,1000.0,WCOMTS(23),2,1)
      CALL OVERRD(ERATIO,0.0,50.0,WCOMTS(43),2,1)
      CALL OVERRD(FACTR,0.0,0.5,WCOMTS(47),2,1)
      CALL OVERRD(SKIP,0.0,BIGVAL,WCOMTS(71),2,1)
      CALL OVERRD(HITLET,0.0,.15,WCOMTS(75),2,1)
      IF(PAGLN.LT.30.0) PAGLN=0.0
      CALL OVERRD(PAGLN,0.0,66.0,WCOMTS(77),2,1)
      CALL OVERRD(PFACTR,0.0,1.0,WCOMTS(82),2,1)
      RETURN
C
      ENTRY PRINTW(XX)
C     THIS ENTRY IS CALLED AFTER EACH RUN SET IS READ
C     TO PRINT VALUES OF THE W-ARRAY IN A FORMAT WHICH SHOWS
C     FULL ACCURACY AND THE EFFECTS OF ANY CONVERSIONS OR OVERRIDES.
C
C     GO TO NEXT PAGE, PUT OUT COPY OF INPUT DATA FOR THIS RUN SET
C     ASSUMING WE HAD A TEMPORARY FILE TO USE
C
      IF(NDEVTMP.LE.0) GO TO 1065
      CALL NEWPAG(NPAG,INT(PAGLN),PC)
      LNSXPG=LINES+INT(PAGLN)
      CALL PUTHDR(3,PC,NPAG)
      CALL PUTDVR(3)
      CALL PUTKBK(3,1)
      CALL PUTKCT(3,'INPUT DATA FILE FOR RUN SET NUMBER'
     1  //NUMSTG(NSET,1,'(I5)'))
      CALL PUTKBK(3,1)
      CALL PUTDVR(3)
      CALL PUTKBK(3,1)
      REWIND NDEVTMP
C
1060  READ(NDEVTMP,'(A)',END=1065) LINEX
      IF(LINES.GE.LNSXPG) THEN
         CALL NEWPAG(NPAG,INT(PAGLN),PC)
         LNSXPG=LINES+INT(PAGLN)
         CALL PUTHDR(3,PC,NPAG)
         CALL PUTKBK(3,1)
      ENDIF
      CALL PUTKST(3,' '//LINEX)
      GO TO 1060
1065  CONTINUE
C
C     GO TO NEXT PAGE, PUT OUT W-ELEMENTS SHOWING FULL PRECISION
C     USE A TWO COLUMN FORMAT
C
      CALL NEWPAG(NPAG,INT(PAGLN),PC)
      CALL PUTHDR(3,PC,NPAG)
      CALL PUTDVR(3)
      CALL PUTKBK(3,1)
      CALL PUTKCT(3,'INITIAL VALUES FOR THE W ARRAY')
      CALL PUTKCT(3,'ONLY NONZERO VALUES PRINTED'
     1  //' -- ALL ANGLES IN RADIANS')
      CALL PUTKBK(3,1)
      CALL PUTDVR(3)
```

```
      LINSPP=INT(PAGLN)-7                                               REXW2600
C                                                                       REXW2610
      WFRMT='(BZ,I3,E14.7,A)'                                           REXW2620
      IF(NFRMAT.EQ.0) WFRMT='(I4,E24.15,A)'                             REXW2630
C                                                                       REXW2640
      NWE=0                                                             REXW2650
C     ALLOW MAXIMUM OF 10 PAGES OF OUTPUT(1 IS ENOUGH)                  REXW2660
      DO 18 NPGS=1,10                                                   REXW2670
C     ALLOW 3 LINES FOR INSIDE HEADER(SEE BELOW)                        REXW2680
         LINSPP=LINSPP-3                                                REXW2690
C     NEXT ELEMENT TO SCAN IS ONE MORE THAN LAST ONE                    REXW2700
         LWE=NWE+1                                                      REXW2710
C                                                                       REXW2720
C     INITIALIZE SECOND COLUMN START INDEX                              REXW2730
         NXCL=0                                                         REXW2740
C     INITIALIZE TOTAL ELEMENT COUNTER                                  REXW2750
         NELS=0                                                         REXW2760
C     LOOP TO FIND BREAK POINTS FOR FIRST/SECOND COLUMNS                REXW2770
         DO 14 I=LWE,MAXW                                               REXW2780
            IF(W(I).EQ.0.0) GO TO 14                                    REXW2790
            NWE=I                                                       REXW2800
            NELS=NELS+1                                                 REXW2810
            IF(NELS.EQ.LINSPP) NXCL=I                                   REXW2820
            IF(NELS.EQ.2*LINSPP) GO TO 15                               REXW2830
14       CONTINUE                                                       REXW2840
15    IF(NELS.EQ.0) GO TO 22                                            REXW2850
C                                                                       REXW2860
         IF(NPGS.GT.1) THEN                                             REXW2870
            CALL NEWPAG(NPAG,INT(PAGLN),PC)                             REXW2880
            CALL PUTHDR(3,PC,NPAG)                                      REXW2890
            LINSPP=INT(PAGLN)-1                                         REXW2900
         ENDIF                                                          REXW2910
C                                                                       REXW2920
C     INSERT 'INNER' HEADER                                             REXW2930
         CALL PUTKBK(3,2)                                               REXW2940
         STMP1=' N              W(N)'                                   REXW2950
         CALL PUTKST(3,STMP1(:65)//' '//STMP1)                          REXW2960
C                                                                       REXW2970
       NX=NXCL-1                                                        REXW2980
       IF(NX.LT.LWE) NX=NWE                                             REXW2990
       DO 17 NW=LWE,NX                                                  REXW3000
       NCOMT=MIN0(NW,MXCMTS)                                            REXW3010
       IF(W(NW).NE.0) THEN                                              REXW3020
         WRITE(STMP1,WFRMT) NW,W(NW),WNOTES(WCOMTS(NCOMT))              REXW3030
         STMP2=' '                                                      REXW3040
         IF(NXCL.EQ.0) GO TO 23                                         REXW3050
         DO 19 I=NXCL,MAXW                                              REXW3060
         IF(W(I).NE.0) THEN                                             REXW3070
           NCOMT=MIN0(I,MXCMTS)                                         REXW3080
           WRITE(STMP2,WFRMT) I,W(I),WNOTES(WCOMTS(NCOMT))              REXW3090
           NXCL=I+1                                                     REXW3100
           GO TO 23                                                     REXW3110
         ENDIF                                                          REXW3120
19       CONTINUE                                                       REXW3130
23       CALL PUTKST(3,STMP1(:65)//' '//STMP2)                          REXW3140
```

```
       ENDIF                                                    REXW3150
 17     CONTINUE                                                REXW3160
      IF(NELS.EQ.0) GO TO 22                                    REXW3170
 18   CONTINUE                                                  REXW3180
C                                                               REXW3190
 22   CONTINUE                                                  REXW3200
      END                                                       REXW3210
```

```
      SUBROUTINE CLEAR(A,N)                                     CLYR0020
C     SET N ELEMENTS OF ARRAY A TO ZERO                         CLYR0030
      REAL A(N)                                                 CLYR0040
      IF(N.LE.0) RETURN                                         CLYR0050
      DO    10 I=1,N                                            CLYR0060
 10   A(I)=0.0                                                  CLYR0070
      RETURN                                                    CLYR0080
      END                                                       CLYR0090
```

```
      FUNCTION ND2B(INDEC)                                      ND2B0020
C                                                               ND2B0030
C     CONVERT A NUMERIC DECIMAL DIGIT STRING TO A BIT STRING    ND2B0040
C     WITH EACH BIT SET BY A CORRESPONDING DECIMAL DIGIT.       ND2B0050
C                                                               ND2B0060
      ND2B=0                                                    ND2B0070
      IF(INDEC.LE.0) RETURN                                     ND2B0080
      M=INDEC                                                   ND2B0090
      MB=1                                                      ND2B0100
C                                                               ND2B0110
 10   IF(MOD(M,10).NE.0) ND2B=ND2B+MB                           ND2B0120
      MB=MB*2                                                   ND2B0130
      M=M/10                                                    ND2B0140
      IF(M.GT.0) GO TO 10                                       ND2B0150
      END                                                       ND2B0160
```

```
      LOGICAL FUNCTION UCON(JC1,U,CONV)                         UCON0020
      LOGICAL SETUCON                                           UCON0030
C     PROVIDES KEYWORD UNITS CONVERSION FOR W-ARRAY INPUT.      UCON0040
C     UNITS SPECIFICATION MUST BE IN THE FORM 'DV UN' WHERE DV IS THE   UCON0050
C     TYPE OF VARIABLE(SUCH AS AN FOR ANGLE) AND UN IS THE UNITS CHOICE UCON0060
C     SUCH AS RD FOR RADIANS). RETURN VALUE IS THE CONVERSION FACTOR.   UCON0070
C     COMMON DECK "CUCON" INSERTED HERE                         CUCO0020
      COMMON/UCONV/CNVV(5,4)                                    CUCO0040
      CHARACTER PCV*3,CNVC*2                                    CUCO0050
      COMMON/UCONC/PCV(5),CNVC(5,4)                             CUCO0060
```

```
C     COMMON DECK "CONST" INSERTED HERE                                  CCON0020
      COMMON/PCONST/CREF,RGAS,GAMMA                                      CCON0040
      COMMON/MCONST/PI,PIT2,PID2,DEGS,RAD,ALN10                          CCON0050
C     COMMON DECK "WWR" INSERTED HERE                                    CWWR0020
      PARAMETER (NWARSZ=1000)                                            CWW10030
      COMMON/WW/ID(10),MAXW,W(NWARSZ)                                    CWW10040
      REAL MAXSTP,MAXERR,INTYP,LLAT,LLON                                 CWW20020
      EQUIVALENCE (EARTHR,W(1)),(RAY,W(2)),(XMTRH,W(3)),(TLAT,W(4)),     CWW20030
     1 (TLON,W(5)),(OW,W(6)),(FBEG,W(7)),(FEND,W(8)),(FSTEP,W(9)),       CWW20040
     2 (AZ1,W(10)),(AZBEG,W(11)),(AZEND,W(12)),(AZSTEP,W(13)),           CWW20050
     3 (BETA,W(14)),(ELBEG,W(15)),(ELEND,W(16)),(ELSTEP,W(17)),          CWW20060
     8   (RUNSUP,W(18)),(RCVRH,W(20)),                                   CWW20070
     4 (ONLY,W(21)),(HOP,W(22)),(MAXSTP,W(23)),(PLAT,W(24)),(PLON,W(25))CWW20080
     5,(HMAX,W(26)),(RAYFNC,W(29)),(EXTINC,W(33)),                       CWW20090
     6 (HMIN,W(27)),(RGMAX,W(28)),                                       CWW20100
     8 (INTYP,W(41)),(MAXERR,W(42)),(ERATIO,W(43)),                      CWW20110
     6 (STEP1,W(44)),(STPMAX,W(45)),(STPMIN,W(46)),(FACTR,W(47)),        CWW20120
     7 (SKIP,W(71)),(RAYSET,W(72)),(PRTSRP,W(74)),(HITLET,W(75))         CWW20130
     9 ,(BINRAY,W(76)),(PAGLN,W(77)),(PLT,W(81)),(PFACTR,W(82)),         CWW20140
     1 (LLAT,W(83)),(LLON,W(84)),(RLAT,W(85)),(RLON,W(86))               CWW20150
     2,(TIC,W(87)),(HB,W(88)),(HT,W(89)),(TICV,W(96))                    CWW20160
      CHARACTER U*(*),PU*3,PV*2                                          UCON0110
C                                                                        UCON0120
      DATA NPV,NPU/5,4/                                                  UCON0130
      UCON=.FALSE.                                                       UCON0140
      CONV=1.0                                                           UCON0150
C                                                                        UCON0160
      READ(U,100) PU,PV                                                  UCON0170
100   FORMAT(A,A)                                                        UCON0180
C                                                                        UCON0190
      DO 2010 J=1,NPV                                                    UCON0200
2010     IF(PU.EQ.PCV(J)) GO TO 2015                                     UCON0210
      JC1=4                                                              UCON0220
      RETURN                                                             UCON0230
2015  JC1=J                                                              UCON0240
      DO 2020 K=1,NPU                                                    UCON0250
2020     IF(PV.EQ.CNVC(J,K)) GO TO 2025                                  UCON0260
      JC1=4                                                              UCON0270
      RETURN                                                             UCON0280
2025  UCON=.TRUE.                                                        UCON0290
      CONV=CNVV(JC1,K)                                                   UCON0300
      IF(CONV.EQ.-1.0) CONV=1.0/EARTHR                                   UCON0310
      RETURN                                                             UCON0320
C                                                                        UCON0330
C     INITIAL CONVERSION CONSTANTS                                       UCON0340
      ENTRY SETUCON(JC1,U,CONV)                                          UCON0350
      SETUCON=.TRUE.                                                     UCON0360
C                                                                        UCON0370
      CNVV(1,2) = RAD                                                    UCON0380
C     USE TAG -1 FOR DYNAMIC USE OF EARTHR                               UCON0390
      CNVV(1,3) = -1.0                                                   UCON0400
      CNVV(2,2) = 1.0E-3                                                 UCON0410
      CNVV(2,3) = 3.048006096E-4                                         UCON0420
      CNVV(2,4) = 1.852                                                  UCON0430
      CNVV(3,2) = PIT2                                                   UCON0440
```

```
      CNVV(3,3) = PIT2*1.0E3
      CNVV(3,4) = -PIT2
      CNVV(4,1) = 1.0/4.3429448
      END
```

```
      SUBROUTINE TRACE
C
C     CALCULATES ONE RAYPATH FOR THE REQUESTED NUMBER OF HOPS
C     (CROSSINGS OR CLOSEST APPROACH TO RECEIVER SURFACE; A CLOSEST
C     APPROACH COUNTS AS TWO HOPS).
      REAL NORYST
      PARAMETER (NORYST=0.0,MXPRGS=200)
C
C     COMMON DECK "SS" INSERTED HERE
      REAL MODSURF
      COMMON/SS/ MODSURF(4)
      COMMON/SS/U,PUR,PURR,PURTH,PURPH
      COMMON/SS/PUTH,PUPH,PUTHTH,PUPHPH,PUTHPH,USELECT,UTIME
C     COMMON DECK "RK" INSERTED HERE
C     DEFINE SIZE REQUIRED FOR RAY STATE SAVE ARRAY
      PARAMETER (LRKAMS=87+2*100,NXRKMS=12+LRKAMS,MXEQPT=21)
      PARAMETER (NRKSAV=NXRKMS+MXEQPT-1)
      COMMON /RK/ NEQS,STEP,MODE,E1MAX,E1MIN,E2MAX,E2MIN,FACT,RSTART
C     COMMON DECK "FLAG" INSERTED HERE
      LOGICAL NEWWR,NEWWP,NEWTRC,PENET
      COMMON /FLG/ NTYP,NEWWR,NEWWP,NEWTRC,PENET,LINES,IHOP,HPUNCH
      COMMON/FLGP/NSET
C     COMMON DECK "TRAC" INSERTED HERE
      LOGICAL GROUND,SURF,PERIGE,THERE,MINDIS,NEWRAY
      COMMON /TRAC/ GROUND,SURF,PERIGE,THERE,MINDIS,NEWRAY,SMT,OSMT
      COMMON/TRAC/ROLD(20),DROLD(20),TOLD,ZDOT,D2Z,RAD,RAD1
C     COMMON DECK "RR" INSERTED HERE
      REAL MODREC
      COMMON/RR/ MODREC(4)
      COMMON/RR/F,PFR,PFRR,PFRTH,PFRPH
      COMMON/RR/PFTH,PFPH,PFTHTH,PFPHPH,PFTHPH,FSELECT,FTIME
C     COMMON DECK "GG" INSERTED HERE
      REAL MODG
      COMMON/GG/MODG(4)
      COMMON/GG/G,PGR,PGRR,PGRTH,PGRPH
      COMMON/GG/PGTH,PGPH,PGTHTH,PGPHPH,PGTHPH,GSELECT,GTIME
C     COMMON DECK "RKTIME" INSERTED HERE
      COMMON/CRKTIME/RKTIME
C     COMMON DECK "RINPLEX" INSERTED HERE
      REAL KAY2,KAY2I
      COMPLEX PNP,POLAR,LPOLAR
      LOGICAL SPACE
      CHARACTER DISPM*6
      COMMON/RINPL/DISPM
      COMMON /RIN/ MODRIN(8),RAYNAME(2,3),TYPE(3),SPACE
      COMMON/RIN/OMEGMIN,OMEGMAX,KAY2,KAY2I
```

```
      COMMON/RIN/PNP(10),POLAR,LPOLAR,SGN                              CRIN0110
      COMMON R(20),T,STP,DRDT(20)                                      TRWE0180
C     COMMON DECK "WWR" INSERTED HERE                                  CWWR0020
      PARAMETER (NWARSZ=1000)                                          CWW10030
      COMMON/WW/ID(10),MAXW,W(NWARSZ)                                  CWW10040
      REAL MAXSTP,MAXERR,INTYP,LLAT,LLON                               CWW20020
      EQUIVALENCE (EARTHR,W(1)),(RAY,W(2)),(XMTRH,W(3)),(TLAT,W(4)),   CWW20030
     1 (TLON,W(5)),(OW,W(6)),(FBEG,W(7)),(FEND,W(8)),(FSTEP,W(9)),     CWW20040
     2 (AZ1,W(10)),(AZBEG,W(11)),(AZEND,W(12)),(AZSTEP,W(13)),         CWW20050
     3 (BETA,W(14)),(ELBEG,W(15)),(ELEND,W(16)),(ELSTEP,W(17)),        CWW20060
     8   (RUNSUP,W(18)),(RCVRH,W(20)),                                 CWW20070
     4 (ONLY,W(21)),(HOP,W(22)),(MAXSTP,W(23)),(PLAT,W(24)),(PLON,W(25))CWW20080
     5,(HMAX,W(26)),(RAYFNC,W(29)),(EXTINC,W(33)),                     CWW20090
     6 (HMIN,W(27)),(RGMAX,W(28)),                                     CWW20100
     8 (INTYP,W(41)),(MAXERR,W(42)),(ERATIO,W(43)),                    CWW20110
     6 (STEP1,W(44)),(STPMAX,W(45)),(STPMIN,W(46)),(FACTR,W(47)),      CWW20120
     7 (SKIP,W(71)),(RAYSET,W(72)),(PRTSRP,W(74)),(HITLET,W(75))       CWW20130
     9 ,(BINRAY,W(76)),(PAGLN,W(77)),(PLT,W(81)),(PFACTR,W(82)),       CWW20140
     1 (LLAT,W(83)),(LLON,W(84)),(RLAT,W(85)),(RLON,W(86))             CWW20150
     2,(TIC,W(87)),(HB,W(88)),(HT,W(89)),(TICV,W(96))                  CWW20160
C    THE FOLLOWING IS A LOCAL COMMON ONLY                              TRWE0200
C     COMMON DECK "TRLOCAL" INSERTED HERE                              CTRL0020
      COMMON/TRLOCAL/RSIGN,HOME,FDOT,GDOT,GOLD,GDOLD,UDOT,UOLD,UDOLD   CTRL0040
      LOGICAL PCROSS,HOME,WASNT                                        TRWE0220
      LOGICAL LAUNCH,APOGEE,PLTENB,EXTON                               TRWE0230
      EQUIVALENCE (R(2),TH),(R(3),PHI)                                 TRWE0240
C                                                                      TRWE0250
      CHARACTER*10 XCOND,DEFCND                                        TRWE0260
      PARAMETER (DEFCND=' MAX HOPS')                                   TRWE0270
C                                                                      TRWE0280
      REAL PRGHST(3,MXPRGS)                                            TRWE0290
      EQUIVALENCE(RKTIME,IRKTIME), (APOG,PRIGEE,W(80))                 TRWE0300
      EQUIVALENCE (BOTABS,W(19))                                       TRWE0310
C                                                                      TRWE0320
C     INCREMENT EVENT COUNT                                            TRWE0330
      IRKTIME=IRKTIME+1                                                TRWE0340
      PLTENB=APOG.EQ.0.0                                               TRWE0350
C     ENABLE EXTINCTION TEST IF LIMIT IS SET AND VARIABLE IS BEING INTE TRWE0360
      EXTON=(EXTINC.GT.0.0) .AND. (W(58).NE.0.0)                       TRWE0370
C     POINT INDEX TO ABSORTION VARIABLE                                TRWE0380
      NR=7                                                             TRWE0390
      IF(W(57).NE.0.0) NR=8                                            TRWE0400
      RMAX=HMAX+EARTHR                                                 TRWE0410
      RMIN=HMIN+EARTHR                                                 TRWE0420
      NHOP=HOP                                                         TRWE0430
      MAX=MAXSTP                                                       TRWE0440
      NSKIP=SKIP                                                       TRWE0450
C********* INITIALIZE PARAMETERS FOR INTEGRATION SUBROUTINE RKAM        TRWE0460
      MODE=INTYP                                                       TRWE0470
      STEP=STEP1                                                       TRWE0480
      E1MAX=MAXERR                                                     TRWE0490
      E1MIN=MAXERR/ERATIO                                              TRWE0500
      E2MAX=STPMAX                                                     TRWE0510
      E2MIN=STPMIN                                                     TRWE0520
      FACT=FACTR                                                       TRWE0530
```

```
      RSTART=1.
      CALL HAMLTN
      FDOT=DOT(F)
C
C     CHECK FOR EQUALITY WITH RECEIVER HEIGHT WITHIN MACHINE PRECISION
      THERE=F.EQ.0.0
C
      HOME=FDOT*F.GE.0.
C********* IHOP=0 TELLS PRINTR TO PRINT HEADING AND PUNCH A TRANSMITTER
C********* RAYSET AND NEWTRC=TRUE TELLS RAYPLT TO START A NEW RAY
      NEWTRC=.TRUE.
      IHOP=0
C********* RESET PERIGEE PLOT COUNTER
      NPRGS=0
C     USE CURRENT RELATIVE POSITION OF RAY TO PREDICT
C     SIGN OF NEXT INTERSECTION OF RAY WITH RECEIVER HEIGHT
C     (WILL SOON BE REVERSED).
      RSIGN=SIGN(1.0,F)
C     IF RAY IS LAUNCHED FROM RECEIVER HEIGHT, USE DIRECTION INSTEAD
      IF(THERE) RSIGN=SIGN(1.0,FDOT)
      UDOT=DOT(U)
      GDOT=DOT(G)
C     TEST CASE FOR RECEIVER ON THE GROUND
      IF(F.EQ.G) RSIGN=1.0
C     IF RECEIVER IS ON TERRAIN THEN DIRECTION OF FIRST
C     RECEIVER CROSSING IS DOWNWARD
      CALL PRINTR('TXMTR',RAYSET)
      IF (PLTENB) CALL RAYPLT
      NEWRAY=.TRUE.
      STH0=SIN(TH)
      CTH0=COS(TH)
      PHI0=PHI
C
C     SET DEFAULT RAY EVENTS FOR 'PRINTR'
      XCOND=DEFCND
      XSET=NORYST
C
C********* LOOP ON NUMBER OF HOPS
10    IHOP=IHOP+1
C      REVERSE SIGN AT EACH CROSSING OF RECEIVER HEIGHT
      RSIGN=-RSIGN
      IF (IHOP.GT.NHOP) GO TO 100
      PENET=.FALSE.
C********* LOOP ON MAXIMUM NUMBER OF STEPS PER HOP
      DO 79 J=1,MAX
C     LAUNCH=TRUE ONLY WHEN TRANSMITTER ON GROUND WITH DOWNWARD
C     TRANSMISSION(POSSIBLE ONLY ON 1ST STEP).
      LAUNCH=G.EQ.0.0 .AND. GDOT.LT.0.0
C
C     SAVE CURRENT STATE VALUES FOR LATER COMPARISONS
C     RESTORE RAY STATE IF NEEDED
12    DO 13 L=1,6
      ROLD(L)=R(L)
13    DROLD(L)=DRDT(L)
      FDOLD=FDOT
```

```
      GDOLD=GDOT
      UDOLD=UDOT
      FOLD=F
      GOLD=G
      UOLD=U
      TOLD=T
C
C     PROCESS NEXT RAY POINT
      CALL RKAM
      FDOT=DOT(F)
      WASNT=.NOT.HOME
      HOME=FDOT*F.GE.0.
C
C     CHOOSE STRATEGY A OR B
      IF(DROLD(1).GT.0.0) GO TO 15
C
C     BEGIN STRATEGY A
C
C     LOOK FOR DOWNGOING CROSSING OF RECEIVER SURFACE
      IF(.NOT.LAUNCH.AND.F.LT.0.0.AND.RSIGN.LT.0.0) GO TO 50
C     CHECK FOR CASE OF CLOSEST APPROACH
      IF (HOME.AND.WASNT) GO TO 30
C     DETERMINE IF A GROUND CROSSING HAS OCCURED
      IF(PCROSS(G,GDOT)) GO TO 20
C     LOOK FOR UPGOING CROSSING OF RECEIVER SURFACE
      IF(.NOT.LAUNCH.AND.F.GT.0.0.AND.RSIGN.GT.0.0) GO TO 50
C     CROSSED UPPER SURFACE?
      IF(PCROSS(U,UDOT)) GO TO 60
      GO TO 18
C
C     BEGIN STRATEGY B
C
C     LOOK FOR UPGOING CROSSING OF RECEIVER SURFACE
15    IF(.NOT.LAUNCH.AND.F.GT.0.0.AND.RSIGN.GT.0.0) GO TO 50
C     CHECK FOR CASE OF CLOSEST APPROACH
      IF (HOME.AND.WASNT) GO TO 30
C     CROSSED UPPER SURFACE?
      IF(PCROSS(U,UDOT)) GO TO 60
C     LOOK FOR DOWNGOING CROSSING OF RECEIVER SURFACE
      IF(.NOT.LAUNCH.AND.F.LT.0.0.AND.RSIGN.LT.0.0) GO TO 50
C     DETERMINE IF A GROUND CROSSING HAS OCCURED
      IF(PCROSS(G,GDOT)) GO TO 20
C
C     RAY HAS NOT CROSSED ANY SURFACE OF DISCONTINUITY
C     OR RECEIVER SURFACE. PRINT OUT ANY SPECIAL CONDITIONS
C     OF THE RAY.
C
C     CHECK FOR PERIGEE CONDITION
18    IF (DROLD(1).GE.0..OR.DRDT(1).LE.0.) GO TO 25
      CALL PRINTR(' PERIGEE ',NORYST)
      IF(PRIGEE.EQ.0.0) GO TO 25
C
      IF(NPRGS.GE.MXPRGS) CALL STOPIT('PRG LIMIT')
      NPRGS=NPRGS+1
      CALL RMOVE(PRGHST(1,NPRGS),R,3)
```

```
C
25    APOGEE=DROLD(1).GT.0..AND.DRDT(1).LT.0.
      PLTENB=APOG.EQ.0.0.OR.APOGEE
C
      IF(APOGEE) CALL PRINTR(' APOGEE  ',NORYST)
      IF (DROLD(2)*DRDT(2).LT.0.) CALL PRINTR(' MAX LAT ',NORYST)
      IF (DROLD(3)*DRDT(3).LT.0.) CALL PRINTR(' MAX LONG',NORYST)
      DO 14 I=4,6
      IF (ROLD(I)*R(I).LT.0.) CALL PRINTR(' WAVE REV',NORYST)
   14 CONTINUE
      GO TO 75
C********* RAY WENT UNDERGROUND
C     USE 'FULL' REGULAR PARABOLIC FIT(ENTRY 'FIT')
20    IF(BOTABS.NE.0.0) THEN
         CALL RCROSS(-1.,G,GDOT,'XBOTM ABS',GROUND)
         XCOND=' '
      ELSE
         CALL RCROSS(-1.,G,GDOT,'GBOTM REF',GROUND)
      ENDIF
C
      GO TO 75
C********* RAY WENT THROUGH UPPER SURFACE
C     USE 'FULL' REGULAR PARABOLIC FIT(ENTRY 'FIT')
60    CALL RCROSS(1.,U,UDOT,'SSURF REF',SURF)
      GO TO 75
C********* RAY MAY HAVE MADE A CLOSEST APPROACH
C     USE 'FULL' REGULAR PARABOLIC FIT
30    CALL FIT(F,FOLD,FDOLD)
      IF(RAD.GE.0.0) GO TO 501
C     ESTIMATE TIME OF CLOSEST APPROACH
      TP=T-ZDOT/D2Z
      CALL GRAZE(F,RSIGN,TP)
      FDOT=ZDOT
      IF (THERE) GO TO 51
C
C     SET DRDT(1)=0 TO AVOID INCORRECT APOGEE OR PERIGEE PRINTOUT, A NEW
C     VALUE WILL BE COMPUTED BEFORE FURTHER ANALYSIS IS DONE
40    DRDT(1)=0.
      HPUNCH=R(1)-EARTHR
      CALL PRINTR('MMIN DIST',RAYSET)
      IF(PLTENB) CALL RAYPLT
      IF (IHOP.GE.NHOP) GO TO 100
      IHOP=IHOP+1
      RSIGN=-RSIGN
      CALL PRINTR ('MMIN DIST',RAYSET)
      GO TO 89
C********* RAY CROSSED RECEIVER HEIGHT
50    CALL FIT(F,FOLD,FDOLD)
C     ESTIMATE GROUP TIME WHEN RAY CROSSES RECEIVER HEIGHT
C     (IN THE CORRECT DIRECTION).
501   TC=T-2.0*F/(ZDOT+SIGN(RAD1,RSIGN))
      CALL BACKUP(F,RSIGN,TC)
      FDOT=ZDOT
      IF(.NOT.THERE) GO TO 40
51    HPUNCH=R(1)-EARTHR
```

```
      CALL PRINTR('RRCVR    ',RAYSET)                                   TRWE2190
      IF (PLTENB) CALL RAYPLT                                           TRWE2200
      IF (GET(F).NE.GET(G)) GO TO 89                                    TRWE2210
C                                                                       TRWE2220
C     RECEIVER IS ON TERRAIN                                            TRWE2230
      IF (IHOP.GE.NHOP) GO TO 100                                       TRWE2240
      IHOP=IHOP+1                                                       TRWE2250
      RSIGN=-RSIGN                                                      TRWE2260
C********* GROUND REFLECT                                               TRWE2270
      CALL REFLECT(G)                                                   TRWE2280
      CALL HAMLTN                                                       TRWE2290
      FDOT=DOT(F)                                                       TRWE2300
      RSTART=1.                                                         TRWE2310
      HPUNCH=R(1)-EARTHR                                                TRWE2320
      CALL PRINTR('GBOTM REF',RAYSET)                                   TRWE2330
      THERE=.TRUE.                                                      TRWE2340
      HPUNCH=R(1)-EARTHR                                                TRWE2350
      CALL PRINTR ('RRCVR    ',RAYSET)                                  TRWE2360
      GO TO 89                                                          TRWE2370
C*********                                                              TRWE2380
75    IF (PLTENB) CALL RAYPLT                                           TRWE2390
      PLTENB=APOG.EQ.0.0                                                TRWE2400
      IF(EXTON) THEN                                                    TRWE2410
         IF (R(NR).GE.EXTINC) XCOND='EEXTINC'                           TRWE2420
      ENDIF                                                             TRWE2430
      IF (R(1).GT.RMAX.AND.F.GT.0.0.AND.FDOT.GT.0.) XCOND='UMAX HT'     TRWE2440
      IF (R(1).LT.RMIN.AND.F.LT.0.0.AND.FDOT.LT.0.) XCOND='DMIN HT'     TRWE2450
      RANGE=EARTHR*ACOS(COS(TH)*CTH0+SIN(TH)*STH0*COS(PHI-PHI0))        TRWE2460
      IF(RGMAX.GT.0.0.AND.RGMAX.LT.RANGE) XCOND='FMAX RANGE'            TRWE2470
      IF(XCOND.NE.DEFCND) GO TO 90                                      TRWE2480
C                                                                       TRWE2490
      IF (MOD(J,NSKIP).EQ.0) CALL PRINTR('          ',NORYST)           TRWE2500
79    CONTINUE                                                          TRWE2510
C********* EXCEEDED MAXIMUM NUMBER OF STEPS                             TRWE2520
      HPUNCH=R(1)-EARTHR                                                TRWE2530
      CALL PRINTR('SSTEP MAX',RAYSET)                                   TRWE2540
      GO TO 100                                                         TRWE2550
C                                                                       TRWE2560
C*********                                                              TRWE2570
89    HOME=.TRUE.                                                       TRWE2580
      GDOT=DOT(G)                                                       TRWE2590
      GO TO 10                                                          TRWE2600
C********* RAY PENETRATED COMPUTATIONAL AREA BOUNDARY AND WAS HEADING OUTRWE2610
90    PENET=.TRUE.                                                      TRWE2620
      HPUNCH=R(1)-EARTHR                                                TRWE2630
      XSET=RAYSET                                                       TRWE2640
C                                                                       TRWE2650
C     NORMAL EXIT                                                       TRWE2660
100   IF(XCOND.NE.' ') CALL PRINTR(XCOND,XSET)                          TRWE2670
      IF(NPRGS.LE.0) RETURN                                             TRWE2680
C                                                                       TRWE2690
      CALL DASH                                                         TRWE2700
      NEWTRC=.TRUE.                                                     TRWE2710
      DO 110 I=1,NPRGS                                                  TRWE2720
      CALL RMOVE(R,PRGHST(1,I),3)                                       TRWE2730
```

```
110    CALL RAYPLT
C
       CALL RESET('DASH')
       END


       LOGICAL FUNCTION PCROSS(Z,ZDT)
C      RETURNS 'TRUE' IF PARABOLIC 'FIT2'(SEE 'FIT' ROUTINE)
C      INDICATES CROSSING OF SURFACE 'Z'.
       REAL ZDT(3)
C      COMMON DECK "TRAC" INSERTED HERE
       LOGICAL GROUND,SURF,PERIGE,THERE,MINDIS,NEWRAY
       COMMON /TRAC/ GROUND,SURF,PERIGE,THERE,MINDIS,NEWRAY,SMT,OSMT
       COMMON/TRAC/ROLD(20),DROLD(20),TOLD,ZDOT,D2Z,RAD,RAD1
C
C      USE SPECIAL PARABOLIC FIT GIVING 'SMT' AND 'OSMT'
       ZDT(1)=DOT(Z)
       PCROSS=.TRUE.
       IF(Z.LT.0.0) GO TO 20
       IF(ZDT(1).LE.0.0.OR.ZDT(3).GE.0.0) GO TO 15
       CALL FIT2(Z,ZDT(2),ZDT(3))
       IF(SMT.GT.Z.OR.OSMT.GT.ZDT(2)) GO TO 20
C
15     PCROSS=.FALSE.
20     RETURN
       END


       SUBROUTINE RCROSS(S,Z,ZDT,EVENT,QMODE)
C      FIND ESTIMATED CROSSING POINT OF SURFACE 'Z' THEN USE
C      ROUTINE 'BACKUP' TO GO THERE AND PERFORM A RAY REFLECTION
C      WITH ROUTINE 'REFLECT'.
C      EXTENDS RAY PROPAGATION TO INTERSECTION WITH REFLECTING SURFACE
C      Z AND CALLS 'REFLECT' TO OBTAIN VECTOR COMPONENTS.
C
       CHARACTER EVENT*8
       REAL ZDT(3)
       LOGICAL QMODE
C      COMMON DECK "TRAC" INSERTED HERE
       LOGICAL GROUND,SURF,PERIGE,THERE,MINDIS,NEWRAY
       COMMON /TRAC/ GROUND,SURF,PERIGE,THERE,MINDIS,NEWRAY,SMT,OSMT
       COMMON/TRAC/ROLD(20),DROLD(20),TOLD,ZDOT,D2Z,RAD,RAD1
C      COMMON DECK "RR" INSERTED HERE
       REAL MODREC
       COMMON/RR/ MODREC(4)
       COMMON/RR/F,PFR,PFRR,PFRTH,PFRPH
       COMMON/RR/PFTH,PFPH,PFTHTH,PFPHPH,PFTHPH,FSELECT,FTIME
C      COMMON DECK "WWR" INSERTED HERE
       PARAMETER (NWARSZ=1000)
```

```
      COMMON/WW/ID(10),MAXW,W(NWARSZ)                                   CWW10040
      REAL MAXSTP,MAXERR,INTYP,LLAT,LLON                                CWW20020
      EQUIVALENCE (EARTHR,W(1)),(RAY,W(2)),(XMTRH,W(3)),(TLAT,W(4)),    CWW20030
     1 (TLON,W(5)),(OW,W(6)),(FBEG,W(7)),(FEND,W(8)),(FSTEP,W(9)),      CWW20040
     2 (AZ1,W(10)),(AZBEG,W(11)),(AZEND,W(12)),(AZSTEP,W(13)),          CWW20050
     3 (BETA,W(14)),(ELBEG,W(15)),(ELEND,W(16)),(ELSTEP,W(17)),         CWW20060
     8   (RUNSUP,W(18)),(RCVRH,W(20)),                                  CWW20070
     4 (ONLY,W(21)),(HOP,W(22)),(MAXSTP,W(23)),(PLAT,W(24)),(PLON,W(25))CWW20080
     5,(HMAX,W(26)),(RAYFNC,W(29)),(EXTINC,W(33)),                      CWW20090
     6 (HMIN,W(27)),(RGMAX,W(28)),                                      CWW20100
     8 (INTYP,W(41)),(MAXERR,W(42)),(ERATIO,W(43)),                     CWW20110
     6 (STEP1,W(44)),(STPMAX,W(45)),(STPMIN,W(46)),(FACTR,W(47)),       CWW20120
     7 (SKIP,W(71)),(RAYSET,W(72)),(PRTSRP,W(74)),(HITLET,W(75))        CWW20130
     9 ,(BINRAY,W(76)),(PAGLN,W(77)),(PLT,W(81)),(PFACTR,W(82)),        CWW20140
     1 (LLAT,W(83)),(LLON,W(84)),(RLAT,W(85)),(RLON,W(86))              CWW20150
     2,(TIC,W(87)),(HB,W(88)),(HT,W(89)),(TICV,W(96))                   CWW20160
C     COMMON DECK "FLAG" INSERTED HERE                                  CFLA0020
      LOGICAL NEWWR,NEWWP,NEWTRC,PENET                                  CFLA0040
      COMMON /FLG/ NTYP,NEWWR,NEWWP,NEWTRC,PENET,LINES,IHOP,HPUNCH      CFLA0050
      COMMON/FLGP/NSET                                                  CFLA0060
      COMMON R(20),T,STP,DRDT(20)                                       TRWE3090
      COMMON /RK/ N,STEP,MODE,E1MAX,E1MIN,E2MAX,E2MIN,FACT,RSTART       TRWE3100
      LOGICAL HOME                                                      TRWE3110
C     COMMON DECK "TRLOCAL" INSERTED HERE                               CTRL0020
      COMMON/TRLOCAL/RSIGN,HOME,FDOT,GDOT,GOLD,GDOLD,UDOT,UOLD,UDOLD    CTRL0040
C                                                                       TRWE3130
      IF(QMODE) GO TO 60                                                TRWE3140
      CALL FIT(Z,ZDT(2),ZDT(3))                                         TRWE3150
      TC=T-2.0*Z/(ZDOT-RAD1)                                            TRWE3160
      CALL BACKUP(Z,-1.,TC)                                             TRWE3170
C********* GROUND REFLECT                                               TRWE3180
60    CALL REFLECT(Z)                                                   TRWE3190
      CALL HAMLTN                                                       TRWE3200
      ZDT(1)=DOT(Z)                                                     TRWE3210
      FDOT=DOT(F)                                                       TRWE3220
      HOME=FDOT*F.GE.0.0                                                TRWE3230
      RSTART=1.                                                         TRWE3240
      HPUNCH=R(1)-EARTHR                                                TRWE3250
      CALL PRINTR(EVENT,RAYSET)                                         TRWE3260
      IF(F.NE.Z) RETURN                                                 TRWE3270
C     AVOID RECEIVER CROSSING AT THE TRANSMITTER IF RECEIVER ON TERRAIN TRWE3280
      RSIGN=S                                                           TRWE3290
      HOME=.TRUE.                                                       TRWE3300
      END                                                               TRWE3310


      SUBROUTINE HAMLTN                                                 HAKN0020
C********* CALCULATES HAMILTONS EQUATIONS FOR RAY TRACING               HAKN0030
C     AND OTHER QUANTITIES TO BE INTEGRATED                             HAKN0040
C     COMMON DECK "GG" INSERTED HERE                                    CGG 0020
      REAL MODG                                                         CGG 0040
      COMMON/GG/MODG(4)                                                 CGG 0050
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      COMMON/GG/G,PGR,PGRR,PGRTH,PGRPH                                  CGG 0060
      COMMON/GG/PGTH,PGPH,PGTHTH,PGPHPH,PGTHPH,GSELECT,GTIME            CGG 0070
C     COMMON DECK "CONST" INSERTED HERE                                 CCON0020
      COMMON/PCONST/CREF,RGAS,GAMMA                                     CCON0040
      COMMON/MCONST/PI,PIT2,PID2,DEGS,RAD,ALN10                         CCON0050
C     COMMON DECK "RINREAL" INSERTED HERE                               CRIN0020
      LOGICAL SPACE                                                     CRIN0040
      REAL LPOLAR,LPOLRI,KPHK,KPHKI,KAY2,KAY2I                          CRIN0050
      CHARACTER DISPM*6                                                 CRIN0060
      COMMON/RINPL/DISPM                                                CRIN0070
      COMMON /RIN/ MODRIN(8),RAYNAME(2,3),TYPE(3),SPACE                 CRIN0080
      COMMON/RIN/OMEGMIN,OMEGMAX,KAY2,KAY2I,                            CRIN0090
     1              H,HI,PHT,PHTI,PHR,PHRI,PHTH,PHTHI,PHPH,PHPHI        CRIN0100
     2, PHOW,PHOWI,PHKR,PHKRI,PHKTH,PHKTI, PHKPH,PHKPI                  CRIN0110
     3 ,KPHK,KPHKI,POLAR,POLARI,LPOLAR,LPOLRI,SGN                       CRIN0120
      COMMON R(20),T,STP,DRDT(20)                                       HAKN0080
      PARAMETER (NWARSZ=1000)                                           CWW10030
      COMMON/WW/ID(10),MAXW,W(NWARSZ)                                   CWW10040
      EQUIVALENCE (TH,R(2)),(PH,R(3)),(KR,R(4)),(KTH,R(5)),(KPH,R(6)),  HAKN0100
     1 (DTHDT,DRDT(2)),(DPHDT,DRDT(3)),(DKRDT,DRDT(4)),(DKTHDT,DRDT(5)),HAKN0110
     2 (DKPHDT,DRDT(6)),(HMAX,W(26)),(OW,W(6))                          HAKN0120
      REAL KR,KTH,KPH                                                   HAKN0130
      STH=SIN(TH)                                                       HAKN0140
      CTH=SIN(PID2-TH)                                                  HAKN0150
      RSTH=R(1)*STH                                                     HAKN0160
      RCTH=R(1)*CTH                                                     HAKN0170
      CALL DISPER                                                       HAKN0180
      DENPHC=1.0/(PHOW*CREF)                                            HAKN0190
      DRDT(1)=-PHKR*DENPHC                                              HAKN0200
      DTHDT=-PHKTH*DENPHC/R(1)                                          HAKN0210
      DPHDT=-PHKPH*DENPHC/RSTH                                          HAKN0220
      DKRDT=PHR*DENPHC+KTH*DTHDT+KPH*STH*DPHDT                          HAKN0230
      DKTHDT=(PHTH*DENPHC-KTH*DRDT(1)+KPH*RCTH*DPHDT)/R(1)              HAKN0240
      DKPHDT=(PHPH*DENPHC-KPH*STH*DRDT(1)-KPH*RCTH*DTHDT)/RSTH          HAKN0250
      NR=6                                                              HAKN0260
C********* PHASE PATH                                                   HAKN0270
      IF (W(57).EQ.0.) GO TO 10                                         HAKN0280
      NR=NR+1                                                           HAKN0290
      DRDT(NR)=-      KPHK/PHOW/OW                                      HAKN0300
C********* ABSORPTION                                                   HAKN0310
   10 IF (W(58).EQ.0.) GO TO 15                                         HAKN0320
      NR=NR+1                                                           HAKN0330
      DRDT(NR)= 10./ALN10*KPHK*KAY2I/(KR*KR+KTH*KTH+KPH*KPH)*DENPHC     HAKN0340
C********* DOPPLER SHIFT                                                HAKN0350
   15 IF (W(59).EQ.0.) GO TO 20                                         HAKN0360
      NR=NR+1                                                           HAKN0370
      DRDT(NR)=-PHT*DENPHC/PIT2                                         HAKN0380
C********* GEOMETRICAL PATH LENGTH                                      HAKN0390
   20 IF (W(60).EQ.0.) GO TO 25                                         HAKN0400
      NR=NR+1                                                           HAKN0410
      DRDT(NR)=SQRT(PHKR**2+PHKTH**2+PHKPH**2)*ABS(DENPHC)              HAKN0420
C********* TERRAIN FUNCTION AS COMPLETE INTEGRAL                        HAKN0430
25    IF(ABS(W(61))+ABS(W(62))+ABS(W(63))+ABS(W(64)).EQ.0.0) GO TO 45   HAKN0440
      CALL TOPOG                                                        HAKN0450
C                                                                       HAKN0460
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```
      IF(W(61).EQ.0.) GO TO 30                                          HAKN0470
      NR=NR+1                                                           HAKN0480
      DRDT(NR)=PGR*DRDT(1)+PGTH*DTHDT+PGPH*DPHDT                        HAKN0490
C********* TERRAIN TIME DERIVATIVES AS COMPLETE INTEGRALS                HAKN0500
   30 IF(W(62).EQ.0.) GO TO 35                                          HAKN0510
      NR=NR+1                                                           HAKN0520
C     DERIVATIVE WITH RESPECT TO R                                      HAKN0530
      DRDT(NR)=PGRR*DRDT(1)+PGRTH*DTHDT+PGRPH*DPHDT                     HAKN0540
   35 IF(W(63).EQ.0.) GO TO 40                                          HAKN0550
      NR=NR+1                                                           HAKN0560
C     DERIVATIVE WITH RESPECT TO THETA                                  HAKN0570
      DRDT(NR)=PGRTH*DRDT(1)+PGTHTH*DTHDT+PGTHPH*DPHDT                  HAKN0580
   40 IF(W(64).EQ.0.) GO TO 45                                          HAKN0590
      NR=NR+1                                                           HAKN0600
C     DERIVATIVE WITH RESPECT TO PHI                                    HAKN0610
      DRDT(NR)=PGRPH*DRDT(1)+PGTHPH*DTHDT+PGPHPH*DPHDT                  HAKN0620
C********* OTHER CALCULATIONS                                            HAKN0630
45    CONTINUE                                                          HAKN0640
      RETURN                                                            HAKN0650
         END                                                            HAKN0660
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      SUBROUTINE RKAM                                                   RKAM0020
C     KEEPS TRACK OF INTERNAL INTEGRATION STEPS PERFORMED BY THE RKAM1  RKAM0030
C     ROUTINE AND MAKES THEM AVAILABLE TO CALLING ROUTINES.             RKAM0040
      COMMON/RKAMS/XV(5),FV(4,20),YU(5,20),EPM,ALPHA,MM                 RKAM0050
C     COMMON DECK "RK" INSERTED HERE                                    CRK 0020
C     DEFINE SIZE REQUIRED FOR RAY STATE SAVE ARRAY                     CRK 0040
      PARAMETER (LRKAMS=87+2*100,NXRKMS=12+LRKAMS,MXEQPT=21)            CRK 0050
      PARAMETER (NRKSAV=NXRKMS+MXEQPT-1)                                CRK 0060
      COMMON /RK/ NEQS,STEP,MODE,E1MAX,E1MIN,E2MAX,E2MIN,FACT,RSTART    CRK 0070
C     COMMON DECK "RKTIME" INSERTED HERE                                CRKT0020
      COMMON/CRKTIME/RKTIME                                             CRKT0040
      COMMON Y(20),T,SPACE,DYDT(20)                                     RKAM0080
      REAL RV(1)                                                        RKAM0090
      DOUBLE PRECISION YU                                               RKAM0100
      EQUIVALENCE(RKTIME,IRKTIME),(RV,R)                                RKAM0110
C                                                                       RKAM0120
      REAL SVBUF(NRKSAV)                                                RKAM0130
      LOGICAL SAVED                                                     RKAM0140
C                                                                       RKAM0150
      DATA SAVED/.FALSE./                                               RKAM0160
C     PERFORM CLOCK ADVANCE(SEE 'GET' ROUTINE)                          RKAM0170
      IRKTIME=IRKTIME+1                                                 RKAM0180
C                                                                       RKAM0190
      IF(RSTART.NE.0.0 .OR. MODE.LE.2) GO TO 250                        RKAM0200
C                                                                       RKAM0210
      NV=NV+1                                                           RKAM0220
      IF(NV.LE.4) GO TO 300                                             RKAM0230
C                                                                       RKAM0240
250   TOLD=T                                                            RKAM0250
C     PERFORM NUMERICAL INTEGRATION TO TIME 'T'                         RKAM0260
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      CALL RKAM1
      IF(MODE.LE.2) GO TO 400
      IF(RSTART.NE.0.0) GO TO 260
C     SEARCH FOR REQUESTED VALUE IN PIPELINE
C     TAKING SIGN OF 'STEP' INTO ACCOUNT.
      TUP=TOLD+.25*STEP
      DO 150 NV=1,3
      IF(SPACE.GT.0.0.AND.TUP.LT.XV(NV)) GO TO 300
      IF(SPACE.LT.0.0.AND.TUP.GT.XV(NV)) GO TO 300
150   CONTINUE
C     GOT IT ALREADY, RETURN
      GO TO 400
C
260   NV=1
C     RETRIEVE REQUESTED VALUES FROM PIPELINE
300   T=XV(NV)
      DO 350 I=1,NEQS
      Y(I)=YU(NV,I)
350   DYDT(I)=FV(NV,I)
C
C     STANDARD EXIT SEQUENCE
400   RETURN
C
      ENTRY RKSAVE(SVBUF)
C
      SVBUF(1)=NV
      SVBUF(2)=NEQS
      SVBUF(3)=MM
      SVBUF(4)=SPACE
      SVBUF(5)=MODE
      CALL RMOVE(SVBUF(6),E1MAX,6)
      CALL RMOVE(SVBUF(12),XV,LRKAMS)
      CALL RMOVE(SVBUF(NXRKMS),Y,MXEQPT)
C
      SAVED=.TRUE.
      RETURN
      ENTRY RKRSTR(SVBUF)
C
      IF(.NOT.SAVED) RETURN
C
      NV=SVBUF(1)
      NEQS=SVBUF(2)
      MM=SVBUF(3)
      SPACE=SVBUF(4)
      MODE=SVBUF(5)
      CALL RMOVE(E1MAX,SVBUF(6),6)
      CALL RMOVE(XV,SVBUF(12),LRKAMS)
      CALL RMOVE(Y,SVBUF(NXRKMS),MXEQPT)
C
      WRITE(3,*) 'RESTORING NV,NEQS,MM,ALPHA,T='
     1    ,NV,NEQS,MM,ALPHA,T
      RETURN
      END
```

```
      SUBROUTINE RKAM1
C        NUMERICAL INTEGRATION OF DIFFERENTIAL EQUATIONS
C     THIS ROUTINE IS A MODIFICATION OF RKAMSUB, WHICH WAS WRITTEN
C     BY G.J. LASTMAN AND IS AVAILABLE THROUGH THE CDC CO-OP LIBRARY
C     AS 'D2 UTEX RKAMSUB'.
      COMMON /RK/ NN,SPACE,MODE,E1MAX,E1MIN,E2MAX,E2MIN,FACT,RSTART
      COMMON Y(20),T,STEP,DYDT(20)
      COMMON/RKAMS/XV(5),FV(4,20),YU(5,20),EPM,ALPHA,MM
      DIMENSION DELY(4,20),BET(4)
      DOUBLE PRECISION YU
C
      IF (RSTART.EQ.0.) GO TO 1000
      LL=1
      MM=1
      IF (MODE.EQ.1) MM=4
      ALPHA=T
      EPM=0.0
      BET(1)=0.5
      BET(2)=0.5
      BET(3)=1.0
      BET(4)=0.0
      STEP=SPACE
      R=19.0/270.0
      XV(MM)=T
      IF (E1MIN.LE.0.) E1MIN=E1MAX/50.
      IF (FACT.LE.0.) FACT=0.5
      CALL HAMLTN
      DO 320 I=1,NN
      FV(MM,I)=DYDT(I)
  320 YU(MM,I)=Y(I)
      RSTART=0.
      GO TO 1001
 1000 IF (MODE.NE.1) GO TO 2000
C
C          RUNGE-KUTTA
 1001 DO 1034 K=1,4
      DO 1350 I=1,NN
      DELY(K,I)=STEP*FV(MM,I)
      Z=YU(MM,I)
 1350 Y(I)=Z+BET(K)*DELY(K,I)
      T=BET(K)*STEP+XV(MM)
      CALL HAMLTN
      DO 1034 I=1,NN
 1034 FV(MM,I)=DYDT(I)
      DO 1039 I=1,NN
      DEL=(DELY(1,I)+2.0*DELY(2,I)+2.0*DELY(3,I)+DELY(4,I))/6.0
 1039 YU(MM+1,I)=YU(MM,I)+DEL
      MM=MM+1
      XV(MM)=XV(MM-1)+STEP
      DO 1400 I=1,NN
 1400 Y(I)=YU(MM,I)
      T=XV(MM)
```

```
      CALL HAMLTN
      IF (MODE.EQ.1) GO TO 42
      DO 150 I=1,NN
  150 FV(MM,I)=DYDT(I)
      IF (MM.LE.3) GO TO 1001
C
C          ADAMS-MOULTON
 2000 DO 2048 I=1,NN
      DEL=STEP*(55.*FV(4,I)-59.*FV(3,I)+37.*FV(2,I)-9.*FV(1,I))/24.
      Y(I)=YU(4,I)+DEL
 2048 DELY(1,I)=Y(I)
      T=XV(4)+STEP
      CALL HAMLTN
      XV(5)=T
      DO 2051 I=1,NN
      DEL=STEP*(9.*DYDT(I)+19.*FV(4,I)-5.*FV(3,I)+FV(2,I))/24.
      YU(5,I)=YU(4,I)+DEL
 2051 Y(I)=YU(5,I)
      CALL HAMLTN
      IF (MODE.LE.2) GO TO 42
C
C          ERROR ANALYSIS
      SSE=0.0
      DO 3033 I=1,NN
      EPSIL=R*ABS(Y(I)-DELY(1,I))
      IF (MODE.EQ.3.AND.Y(I).NE.0.) EPSIL=EPSIL/ABS(Y(I))
      IF (SSE.LT.EPSIL) SSE=EPSIL
 3033 CONTINUE
      IF (E1MAX.GT.SSE) GO TO 3035
      IF (ABS(STEP).LE.E2MIN) GO TO 42
      LL=1
      MM=1
      STEP=STEP*FACT
      GO TO 1001
 3035 IF (LL.LE.1.OR.SSE.GE.E1MIN.OR.E2MAX.LE.ABS(STEP)) GO TO 42
      LL=2
      MM=3
      XV(2)=XV(3)
      XV(3)=XV(5)
      DO 5363 I=1,NN
      FV(2,I)=FV(3,I)
      FV(3,I)=DYDT(I)
      YU(2,I)=YU(3,I)
 5363 YU(3,I)=YU(5,I)
      STEP=2.0*STEP
      GO TO 1001
C
C          EXIT ROUTINE
   42 LL=2
      MM=4
      DO 12 K=1,3
      XV(K)=XV(K+1)
      DO 12 I=1,NN
      FV(K,I)=FV(K+1,I)
   12 YU(K,I)=YU(K+1,I)
```

```
      XV(4)=XV(5)                                                       RKK11090
      DO 52 I=1,NN                                                      RKK11100
      FV(4,I)=DYDT(I)                                                   RKK11110
   52 YU(4,I)=YU(5,I)                                                   RKK11120
      IF (MODE.LE.2) RETURN                                             RKK11130
      E=ABS(XV(4)-ALPHA)                                                RKK11140
      IF (E.LE.EPM+.25*STEP) GO TO 2000                                 RKK11150
      EPM=E                                                             RKK11160
      RETURN                                                            RKK11170
         END                                                            RKK11180
```

```
      SUBROUTINE BACKUP(Z,RSIGN,TC)                                     BAQP0020
C     MOVES THE RAY TO THE CLOSEST INTERSECTION WITH THE RECEIVER       BAQP0030
C     OR TERRAIN SURFACE(VARIABLES 'FSELECT' OR 'GSELECT' IN LABELED    BAQP0040
C     COMMONS /RR/ OR /GG/, RESPECTIVELY, TELL WHICH KIND OF SURFACE).  BAQP0050
C                                                                       BAQP0060
      CHARACTER*9 NBAK,NGRAZ,NTRY                                       BAQP0070
C                                                                       BAQP0080
      PARAMETER (PRNZTL=0.5E-4,PRNDZTL=1.E-6)                           BAQP0090
C                                                                       BAQP0100
      COMMON /RK/ N,STEP,MODE,E1MAX,E1MIN,E2MAX,E2MIN,FACT,RSTART       BAQP0110
C     COMMON DECK "TRAC" INSERTED HERE                                  CTRA0020
      LOGICAL GROUND,SURF,PERIGE,THERE,MINDIS,NEWRAY                    CTRA0040
      COMMON /TRAC/ GROUND,SURF,PERIGE,THERE,MINDIS,NEWRAY,SMT,OSMT     CTRA0050
      COMMON/TRAC/ROLD(20),DROLD(20),TOLD,ZDOT,D2Z,RAD,RAD1             CTRA0060
      COMMON R(20),T,STP,DRDT(20)                                       BAQP0130
      PARAMETER (NWARSZ=1000)                                           CWW10030
      COMMON/WW/ID(10),MAXW,W(NWARSZ)                                   CWW10040
      EQUIVALENCE (EARTHR,W(1)),(INTYP,W(41)),(STEP1,W(44))             BAQP0150
      REAL KR                                                           BAQP0160
      EQUIVALENCE (KR,R(4)),(DKRDT,DRDT(4))                             BAQP0170
      REAL INTYP                                                        BAQP0180
      LOGICAL PCNTRL                                                    BAQP0190
      DATA NBAK,NGRAZ/' BACK UP0', ' GRAZE 1'/                          BAQP0200
C                                                                       BAQP0210
      NTRY=NBAK                                                         BAQP0220
      GO TO 100                                                         BAQP0230
C                                                                       BAQP0240
      ENTRY GRAZE(Z,RSIGN,TC)                                           BAQP0250
      NTRY=NGRAZ                                                        BAQP0260
C                                                                       BAQP0270
C     DEFINE BASE STEP SIZE                                             BAQP0280
100   STPB=STP                                                          BAQP0290
C                                                                       BAQP0300
C     DEFINE BACKUP LOCATION TOLERANCES BASED ON INTEGRATION MODE       BAQP0310
C                                                                       BAQP0320
      IF(MODE.LT.3) THEN                                                BAQP0330
         TOL=STEP1                                                      BAQP0340
      ELSEIF(MODE.EQ.3) THEN                                            BAQP0350
         TOL=ABS(E1MAX*STPB)                                            BAQP0360
      ELSE                                                              BAQP0370
```

```
          TOL=E1MAX
       ENDIF
C      USE THIS OR MINIMUM STEP SIZE WHICHEVER IS LESS
       TOL=AMIN1(TOL,FACT*E2MIN)
C
       PCNTRL=W(73).NE.0.0
       THERE=.TRUE.
C       STEP TO ESTIMATED CROSSING AT TC.
C********* DIAGNOSTIC PRINTOUT
       IF(PCNTRL) CALL PRINTR (NTRY,0.)
       STEP=TC-T
       STEP=SIGN(AMIN1(ABS(STPB),ABS(STEP)),STEP)
       MODE=1
       RSTART=1
       TOLD=T
       CALL RMOVE(DROLD,DRDT,3)
       ZDOLD=DOT(Z)
       CALL RKAM
       RSTART=1.0
       ZDOT=DOT(Z)
       IF(NTRY.EQ.NGRAZ .OR. RSIGN*ZDOT.LE.0.0) GO TO 12
C
C********* FIND NEAREST INTERSECTION OF RAY WITH THE HEIGHT HS
       DO 10 I=1,10
       STEP=-Z/ZDOT
       STEP=SIGN(AMIN1(ABS(STPB),ABS(STEP)),STEP)
       IF (ABS(Z).LT.PRNZTL .AND. ABS(STEP).LT.TOL) GO TO 60
C********* DIAGNOSTIC PRINTOUT
       IF(PCNTRL) CALL PRINTR(' BACK UP1',0.)
       MODE=1
       RSTART=1.
       TOLD=T
       CALL RMOVE(DROLD,DRDT,3)
       ZDOLD=ZDOT
       CALL RKAM
       ZDOT=DOT(Z)
   10  RSTART=1.
C
C********* FIND NEAREST CLOSEST APPROACH OF RAY TO THE HEIGHT HS
12     THERE=.FALSE.
       DO 20 I=1,10
C      DO 'LOCAL' PARABOLIC FIT
       CALL FIT3(Z,ZOLD,ZDOLD)
       STEP=-ZDOT/D2Z
       STEP=SIGN(AMIN1(ABS(STPB),ABS(STEP)),STEP)
       IF (ABS(ZDOT).LE.PRNDZTL .AND. ABS(STEP).LT.TOL) GO TO 60
C********* DIAGNOSTIC PRINTOUT
       IF(PCNTRL) CALL PRINTR (' GRAZE 1 ',0.)
       MODE=1
       RSTART=1.
       TOLD=T
       CALL RMOVE(DROLD,DRDT,3)
       ZOLD=Z
       ZDOLD=ZDOT
       CALL RKAM
```

```
      RSTART=1.                                                          BAQP0930
      IF (D2Z*Z.LT.0.) GO TO 30                                          BAQP0940
      IF(KPARLEL(Z).EQ.0.0) GO TO 60                                     BAQP0950
   20 CONTINUE                                                           BAQP0960
      WRITE(3,350)                                                       BAQP0970
350   FORMAT(' ****** COULDN''T FIND CLOSEST APPROACH IN 10 STEPS')      BAQP0980
      GO TO 60                                                           BAQP0990
C                                                                        BAQP1000
   30 CONTINUE                                                           BAQP1010
C********* DIAGNOSTIC PRINTOUT                                           BAQP1020
      IF(PCNTRL) CALL PRINTR (' BACK UP2',0.)                            BAQP1030
      MODE=1                                                             BAQP1040
C********* ESTIMATE DISTANCE TO NEAREST INTERSECTION GOING THE RIGHT     BAQP1050
C********* DIRECTION OF RAY WITH HEIGHT HS                               BAQP1060
      CALL FIT3(Z,ZOLD,ZDOLD)                                            BAQP1070
      STEP=(-ZDOT+RSIGN*RAD1)/D2Z                                        BAQP1080
      RSTART=1.                                                          BAQP1090
      CALL RKAM                                                          BAQP1100
      RSTART=1.                                                          BAQP1110
C********* FIND NEAREST INTERSECTION OF RAY WITH HEIGHT HS               BAQP1120
      DO 40 I=1,10                                                       BAQP1130
      ZDOT=DOT(Z)                                                        BAQP1140
      STEP=-Z/ZDOT                                                       BAQP1150
      STEP=SIGN(AMIN1(ABS(STPB),ABS(STEP)),STEP)                         BAQP1160
      IF (ABS(Z).LT.PRNZTL .AND. ABS(STEP).LT.TOL) GO TO 50              BAQP1170
C********* DIAGNOSTIC PRINTOUT                                           BAQP1180
      IF(PCNTRL) CALL PRINTR (' BACK UP3',0.)                            BAQP1190
      MODE=1                                                             BAQP1200
      RSTART=1.                                                          BAQP1210
      CALL RKAM                                                          BAQP1220
   40 RSTART=1.                                                          BAQP1230
   50 THERE=.TRUE.                                                       BAQP1240
C********* RESET STANDARD MODE AND INTEGRATION TYPE                      BAQP1250
   60 MODE=INTYP                                                         BAQP1260
      STEP=STPB                                                          BAQP1270
      RETURN                                                             BAQP1280
         END                                                             BAQP1290
```

```
      FUNCTION REFLECT(Z)                                                REST0020
C     COMPUTES NORMAL AND PARALLEL COMPONENTS OF THE K-VECTOR AT         REST0030
C     REFLECTION POINTS TO A SURFACE. WIND EFFECTS ARE INCLUDED.         REST0040
C                                                                        REST0050
      REAL Z(12),KPARLEL,KNORM                                           REST0060
C     COMMON DECK "CC" INSERTED HERE                                     CCC 0020
      REAL MODC                                                          CCC 0040
      COMMON/CC/MODC(4),CS,PCST,PCSR,PCSTH,PCSPH                         CCC 0050
C     COMMON DECK "WWR" INSERTED HERE                                    CWWR0020
      PARAMETER (NWARSZ=1000)                                            CWW10030
      COMMON/WW/ID(10),MAXW,W(NWARSZ)                                    CWW10040
      REAL MAXSTP,MAXERR,INTYP,LLAT,LLON                                 CWW20020
      EQUIVALENCE (EARTHR,W(1)),(RAY,W(2)),(XMTRH,W(3)),(TLAT,W(4)),     CWW20030
```

```
     1 (TLON,W(5)),(OW,W(6)),(FBEG,W(7)),(FEND,W(8)),(FSTEP,W(9)),
     2 (AZ1,W(10)),(AZBEG,W(11)),(AZEND,W(12)),(AZSTEP,W(13)),
     3 (BETA,W(14)),(ELBEG,W(15)),(ELEND,W(16)),(ELSTEP,W(17)),
     8   (RUNSUP,W(18)),(RCVRH,W(20)),
     4 (ONLY,W(21)),(HOP,W(22)),(MAXSTP,W(23)),(PLAT,W(24)),(PLON,W(25))
     5,(HMAX,W(26)),(RAYFNC,W(29)),(EXTINC,W(33)),
     6 (HMIN,W(27)),(RGMAX,W(28)),
     8 (INTYP,W(41)),(MAXERR,W(42)),(ERATIO,W(43)),
     6 (STEP1,W(44)),(STPMAX,W(45)),(STPMIN,W(46)),(FACTR,W(47)),
     7 (SKIP,W(71)),(RAYSET,W(72)),(PRTSRP,W(74)),(HITLET,W(75))
     9 ,(BINRAY,W(76)),(PAGLN,W(77)),(PLT,W(81)),(PFACTR,W(82)),
     1 (LLAT,W(83)),(LLON,W(84)),(RLAT,W(85)),(RLON,W(86))
     2,(TIC,W(87)),(HB,W(88)),(HT,W(89)),(TICV,W(96))
C     COMMON DECK "RKAM" INSERTED HERE
      REAL KR,KTH,KPH
      COMMON//R,TH,PH,KR,KTH,KPH,RKVARS(14),TPULSE,CSTEP,DRDT(20)
C     COMMON DECK "UU" INSERTED HERE
      REAL MODU
      COMMON/UU/MODU(4)
     1  ,V  ,PVT  ,PVR  ,PVTH  ,PVPH
     2  ,VR ,PVRT ,PVRR ,PVRTH ,PVRPH
     3  ,VTH,PVTHT,PVTHR,PVTHTH,PVTHPH
     4  ,VPH,PVPHT,PVPHR,PVPHTH,PVPHPH
C     COMMON DECK "FNDER" INSERTED HERE
      COMMON/FNDER/GY(20),NZ,NPZR,NPZRR,NPZRTH,NPZRPH,NPZTH
      COMMON/FNDER/NPZPH,NPZTHTH,NPZPHPH,NPZTHPH,NSELECT,NTIME
C
      REAL NR,NTH,NPH,KRNR,KPARR,KPARTH,KPARPH
C
      IENTRY=1
      REFLECT=0.0
      GO TO 5
C
      ENTRY KPARLEL(Z)
      KPARLEL=0.0
      IENTRY=2
      GO TO 5
C
      ENTRY KNORM(Z)
      KNORM=0.0
      IENTRY=3
C
5     Z(1)=GET(Z)
      NR=Z(NPZR)
      NTH=Z(NPZTH)/R
      NPH=Z(NPZPH)/(R*SIN(TH))
C
      CALL RENORM(NR,1.0,3)
C     COMPUTE THE NORMAL COMPONENT OF K-VECTOR TO SURFACE
      KRNR=KR*NR+KTH*NTH+KPH*NPH
      IF(IENTRY.NE.3) GO TO 8
C     IF ENTRY 3 THEN WE ARE DONE
      REFLECT=KRNR
      RETURN
C
```

```
C     COMPUTE THE PARALLEL VECTOR COMPONENT
8     KPARR=KR-KRNR*NR
      KPARTH=KTH-KRNR*NTH
      KPARPH=KPH-KRNR*NPH
C
      IF(IENTRY.NE.2) GO TO 10
      REFLECT=ABS(KPARR)+ABS(KPARTH)+ABS(KPARPH)
      RETURN
C
10    OWIPAR=OW-KPARR*VR-KPARTH*VTH-KPARPH*VPH
      VNR=VR*NR+VTH*NTH+VPH*NPH
C
      FCTR=2.0*(KRNR+OWIPAR*VNR/(CS-VNR*VNR))
      KR=KR-FCTR*NR
      KTH=KTH-FCTR*NTH
      KPH=KPH-FCTR*NPH
      END
```

```
      SUBROUTINE FIT(Z,ZOLD,ZDOLD)
C     COMPUTES THREE TYPES OF PARABOLIC FITS TO RAY PATH RELATIVE
C     TO TERRAIN.
C
      REAL Z(12)
C     COMMON DECK "RKAM" INSERTED HERE
      REAL KR,KTH,KPH
      COMMON//R,TH,PH,KR,KTH,KPH,RKVARS(14),TPULSE,CSTEP,DRDT(20)
C     COMMON DECK "TRAC" INSERTED HERE
      LOGICAL GROUND,SURF,PERIGE,THERE,MINDIS,NEWRAY
      COMMON /TRAC/ GROUND,SURF,PERIGE,THERE,MINDIS,NEWRAY,SMT,OSMT
      COMMON/TRAC/ROLD(20),DROLD(20),TOLD,ZDOT,D2Z,RAD,RAD1
C     COMMON DECK "FNDER" INSERTED HERE
      COMMON/FNDER/GY(20),NZ,NPZR,NPZRR,NPZRTH,NPZRPH,NPZTH
      COMMON/FNDER/NPZPH,NPZTHTH,NPZPHPH,NPZTHPH,NSELECT,NTIME
C
      REAL D2(3)
C
C     USE FIT OF APPENDIX 'J' OF REPORT 'WPL-103' WHICH USES
C     WEIGHTED ESTIMATE OF 1ST DERIVATIVE.
C
      IENTRY=1
      GO TO 5
C
C     USE MODIFIED FIT REQUIRING HEIGHTS OF PARABOLA VERTICES FROM
C     CURRENT AND PREVIOUS RAY POINTS.
      ENTRY FIT2(Z,ZOLD,ZDOLD)
      IENTRY=2
      GO TO 5
C
C     USE FIT OF APPENDIX U(LOCAL VALUE OF 1ST DERIVATIVE)
      ENTRY FIT3(Z,ZOLD,ZDOLD)
      IENTRY=3
```

```
C
5     ZDOT=DOT(Z)
C
      DTI=1.0/(TPULSE-TOLD)
      DO 10 I=1,3
10    D2(I)=(DRDT(I)-DROLD(I))*DTI
C
      D2Z=Z(NPZR)*D2(1)+Z(NPZTH)*D2(2)+Z(NPZPH)*D2(3)
     1          +Z(NPZRR)*DRDT(1)*DRDT(1)
     1          +Z(NPZTHTH)*DRDT(2)*DRDT(2)
     1          +Z(NPZPHPH)*DRDT(3)*DRDT(3)
     1   +2.0*(Z(NPZRTH)*DRDT(1)*DRDT(2)
     1          +Z(NPZRPH)*DRDT(1)*DRDT(3)
     1          +Z(NPZTHPH)*DRDT(2)*DRDT(3)  )
C
C     THE STATEMENTS FROM HERE TO 'END FIT' IMPLEMENT THE
C     PARABOLIC FITS IN EQUATIONS J.1 AND U.3 OF THE TEXT.
C
      IF(IENTRY.NE.2) GO TO 30
      SMT=0.
      IF (D2Z.NE.0.) SMT=0.5*ZDOT*ZDOT/D2Z
C     USE FIT U.3 AT THE PREVIOUS POINT OF RAY PATH
      OSMT=0.
      IF (D2Z.NE.0.) OSMT=0.5*ZDOLD*ZDOLD/D2Z
      GO TO 2000
C
C     IMPLEMENTATION OF FIT FOR EQUATION J.1
C
30    IF(IENTRY.EQ.3) GO TO 1000
      ZDOTM=.5*(ZDOT+ZDOLD)
C     IMPLEMENT TESTS OF EQUATIONS J.2 AND J.3
      IF(ABS(ZDOTM).LE..05*ABS(ZDOT)) GO TO 1000
      FCTR=(Z(NZ)-ZOLD)*DTI/ZDOTM
      D2Z=FCTR*D2Z
      ZDOT=FCTR*ZDOT
C     END FIT
C
C     COMMON CODE FOR FIT AND FIT3
1000  RAD=ZDOT*ZDOT-2.0*Z(NZ)*D2Z
      RAD1=SQRT(AMAX1(RAD,0.0))
C
2000  CONTINUE
C
      END
```

```
      FUNCTION GET1(Z)
C     FUNCTIONALLY THE SAME AS 'GET' PROGRAM, SEE DOCUMENTATION THERE
C     NEEDED BECAUSE RECEIVER MODELS WILL CALL GET TO OBTAIN TERRAIN VA
C     BUT THEY THEMSELVES ARE CALLED VIA GET. HENCE HAVE RE-ENTRANCE
C     PROBLEM.
C
```

```
      REAL Z(*)                                                         GET 0080
      REAL PF(10),PG(10)                                                GET 0090
C     COMMON DECK "SS" INSERTED HERE                                    CSS 0020
      REAL MODSURF                                                      CSS 0040
      COMMON/SS/ MODSURF(4)                                             CSS 0050
      COMMON/SS/U,PUR,PURR,PURTH,PURPH                                  CSS 0060
      COMMON/SS/PUTH,PUPH,PUTHTH,PUPHPH,PUTHPH,USELECT,UTIME            CSS 0070
C     COMMON DECK "RKAM" INSERTED HERE                                  RKAM0020
      REAL KR,KTH,KPH                                                   RKAM0040
      COMMON//R,TH,PH,KR,KTH,KPH,RKVARS(14),TPULSE,CSTEP,DRDT(20)       RKAM0050
C     COMMON DECK "FNDER" INSERTED HERE                                 CFND0020
      COMMON/FNDER/GY(20),NZ,NPZR,NPZRR,NPZRTH,NPZRPH,NPZTH             CFND0040
      COMMON/FNDER/NPZPH,NPZTHTH,NPZPHPH,NPZTHPH,NSELECT,NTIME          CFND0050
C     COMMON DECK "RR" INSERTED HERE                                    CRR 0020
      REAL MODREC                                                       CRR 0040
      COMMON/RR/ MODREC(4)                                              CRR 0050
      COMMON/RR/F,PFR,PFRR,PFRTH,PFRPH                                  CRR 0060
      COMMON/RR/PFTH,PFPH,PFTHTH,PFPHPH,PFTHPH,FSELECT,FTIME            CRR 0070
C     COMMON DECK "GG" INSERTED HERE                                    CGG 0020
      REAL MODG                                                         CGG 0040
      COMMON/GG/MODG(4)                                                 CGG 0050
      COMMON/GG/G,PGR,PGRR,PGRTH,PGRPH                                  CGG 0060
      COMMON/GG/PGTH,PGPH,PGTHTH,PGPHPH,PGTHPH,GSELECT,GTIME            CGG 0070
C     COMMON DECK "RKTIME" INSERTED HERE                                CRKT0020
      COMMON/CRKTIME/RKTIME                                             CRKT0040
C                                                                       GET 0160
C     COMMON DECK "RMACH" INSERTED HERE                                 CRMA0020
      COMMON/CRMACH/RMACH(5)                                            CRMA0040
      EQUIVALENCE(RKTIME,IRKTIME)                                       GET 0180
C     COMMON DECK "WWR" INSERTED HERE                                   CWWR0020
      PARAMETER (NWARSZ=1000)                                           CWW10030
      COMMON/WW/ID(10),MAXW,W(NWARSZ)                                   CWW10040
      REAL MAXSTP,MAXERR,INTYP,LLAT,LLON                                CWW20020
      EQUIVALENCE (EARTHR,W(1)),(RAY,W(2)),(XMTRH,W(3)),(TLAT,W(4)),    CWW20030
     1 (TLON,W(5)),(OW,W(6)),(FBEG,W(7)),(FEND,W(8)),(FSTEP,W(9)),      CWW20040
     2 (AZ1,W(10)),(AZBEG,W(11)),(AZEND,W(12)),(AZSTEP,W(13)),          CWW20050
     3 (BETA,W(14)),(ELBEG,W(15)),(ELEND,W(16)),(ELSTEP,W(17)),         CWW20060
     8   (RUNSUP,W(18)),(RCVRH,W(20)),                                  CWW20070
     4 (ONLY,W(21)),(HOP,W(22)),(MAXSTP,W(23)),(PLAT,W(24)),(PLON,W(25))CWW20080
     5,(HMAX,W(26)),(RAYFNC,W(29)),(EXTINC,W(33)),                      CWW20090
     6 (HMIN,W(27)),(RGMAX,W(28)),                                      CWW20100
     8 (INTYP,W(41)),(MAXERR,W(42)),(ERATIO,W(43)),                     CWW20110
     6 (STEP1,W(44)),(STPMAX,W(45)),(STPMIN,W(46)),(FACTR,W(47)),       CWW20120
     7 (SKIP,W(71)),(RAYSET,W(72)),(PRTSRP,W(74)),(HITLET,W(75))        CWW20130
     9 ,(BINRAY,W(76)),(PAGLN,W(77)),(PLT,W(81)),(PFACTR,W(82)),        CWW20140
     1 (LLAT,W(83)),(LLON,W(84)),(RLAT,W(85)),(RLON,W(86))              CWW20150
     2,(TIC,W(87)),(HB,W(88)),(HT,W(89)),(TICV,W(96))                   CWW20160
C                                                                       GET 0200
      COMMON/CGET/ZERO                                                  GET 0210
C                                                                       GET 0220
      IENTRY=1                                                          GET 0230
      GO TO 5                                                           GET 0240
C                                                                       GET 0250
      ENTRY DOT1(Z)                                                     GET 0260
      IENTRY=2                                                          GET 0270
```

```
 5      CONTINUE
        IF(ZERO.EQ.0.0) ZERO=EARTHR*RMACH(3)*2.0
 C
        IF(ITEST(Z(NTIME)).EQ.IRKTIME) GO TO 10
 C
        IF(Z(NSELECT).EQ.USELECT) CALL SURFACE
        IF(Z(NSELECT).EQ.FSELECT) CALL RECEVER
        IF(Z(NSELECT).EQ.GSELECT) CALL TOPOG
        Z(NTIME)=RKTIME
 C      REMOVE MACHINE ROUND OFF NOISE FROM EXACT RECEIVER LOCATIONS
        IF(ABS(Z(NZ)).LE.ZERO) Z(NZ)=0.0
 C
 10     IF(IENTRY.NE.1) GO TO 20
        GET1=Z(NZ)
        RETURN
 C
 20     GET1=Z(NPZR)*DRDT(1)+Z(NPZTH)*DRDT(2)+Z(NPZPH)*DRDT(3)
        RETURN
        END


        FUNCTION GET(Z)
 C      'GET' AND ENTRY 'DOT' PROVIDE A CONTROL METHOD FOR AVOIDING
 C      REDUNDANT CALLS TO THE TERRAIN AND RECEIVER MODELS. THE VALUES
 C      RETURNED ARE THE FUNCTION VALUES FOR 'F' OR 'G' OR THEIR DERIVATI
 C      (VIA 'DOT' ENTRY). UNNECESSARY CALLS ARE ELIMINATED THROUGH USE
 C      OF 'TIME OF CALL' VARIABLES WHICH ARE COMPARED WITH THE CURRENT
 C      LAST CALL TIME MAINTAINED BY THE 'RKAM' PROGRAM. WHEN VALUES ARE
 C      NOT CURRENT THEY ARE UPDATED BY CALLS TO THE APPROPRIATE ROUTINES
 C
        REAL Z(*),PF(10),PG(10)
 C      COMMON DECK "SS" INSERTED HERE
        REAL MODSURF
        COMMON/SS/ MODSURF(4)
        COMMON/SS/U,PUR,PURR,PURTH,PURPH
        COMMON/SS/PUTH,PUPH,PUTHTH,PUPHPH,PUTHPH,USELECT,UTIME
 C      COMMON DECK "RKAM" INSERTED HERE
        REAL KR,KTH,KPH
        COMMON//R,TH,PH,KR,KTH,KPH,RKVARS(14),TPULSE,CSTEP,DRDT(20)
 C      COMMON DECK "FNDER" INSERTED HERE
        COMMON/FNDER/GY(20),NZ,NPZR,NPZRR,NPZRTH,NPZRPH,NPZTH
        COMMON/FNDER/NPZPH,NPZTHTH,NPZPHPH,NPZTHPH,NSELECT,NTIME
 C      COMMON DECK "RR" INSERTED HERE
        REAL MODREC
        COMMON/RR/ MODREC(4)
        COMMON/RR/F,PFR,PFRR,PFRTH,PFRPH
        COMMON/RR/PFTH,PFPH,PFTHTH,PFPHPH,PFTHPH,FSELECT,FTIME
 C      COMMON DECK "GG" INSERTED HERE
        REAL MODG
        COMMON/GG/MODG(4)
        COMMON/GG/G,PGR,PGRR,PGRTH,PGRPH
        COMMON/GG/PGTH,PGPH,PGTHTH,PGPHPH,PGTHPH,GSELECT,GTIME
```

```
C     COMMON DECK "RKTIME" INSERTED HERE                                CRKT0020
      COMMON/CRKTIME/RKTIME                                             CRKT0040
C                                                                       GET 0630
C     COMMON DECK "RMACH" INSERTED HERE                                 CRMA0020
      COMMON/CRMACH/RMACH(5)                                            CRMA0040
      EQUIVALENCE(RKTIME,IRKTIME)                                       GET 0650
C                                                                       GET 0660
C     COMMON DECK "WWR" INSERTED HERE                                   CWWR0020
      PARAMETER (NWARSZ=1000)                                           CWW10030
      COMMON/WW/ID(10),MAXW,W(NWARSZ)                                   CWW10040
      REAL MAXSTP,MAXERR,INTYP,LLAT,LLON                                CWW20020
      EQUIVALENCE (EARTHR,W(1)),(RAY,W(2)),(XMTRH,W(3)),(TLAT,W(4)),    CWW20030
     1 (TLON,W(5)),(OW,W(6)),(FBEG,W(7)),(FEND,W(8)),(FSTEP,W(9)),      CWW20040
     2 (AZ1,W(10)),(AZBEG,W(11)),(AZEND,W(12)),(AZSTEP,W(13)),          CWW20050
     3 (BETA,W(14)),(ELBEG,W(15)),(ELEND,W(16)),(ELSTEP,W(17)),         CWW20060
     8   (RUNSUP,W(18)),(RCVRH,W(20)),                                  CWW20070
     4 (ONLY,W(21)),(HOP,W(22)),(MAXSTP,W(23)),(PLAT,W(24)),(PLON,W(25))CWW20080
     5,(HMAX,W(26)),(RAYFNC,W(29)),(EXTINC,W(33)),                      CWW20090
     6 (HMIN,W(27)),(RGMAX,W(28)),                                      CWW20100
     8 (INTYP,W(41)),(MAXERR,W(42)),(ERATIO,W(43)),                     CWW20110
     6 (STEP1,W(44)),(STPMAX,W(45)),(STPMIN,W(46)),(FACTR,W(47)),       CWW20120
     7 (SKIP,W(71)),(RAYSET,W(72)),(PRTSRP,W(74)),(HITLET,W(75))        CWW20130
     9 ,(BINRAY,W(76)),(PAGLN,W(77)),(PLT,W(81)),(PFACTR,W(82)),        CWW20140
     1 (LLAT,W(83)),(LLON,W(84)),(RLAT,W(85)),(RLON,W(86))              CWW20150
     2,(TIC,W(87)),(HB,W(88)),(HT,W(89)),(TICV,W(96))                   CWW20160
C                                                                       GET 0680
      COMMON/CGET/ZERO                                                  GET 0690
C                                                                       GET 0700
      REAL PI(10),PJ(10)                                                GET 0710
      COMMON/TMP1/NC,NSZR    ,NSZRR    ,NSZRTH                          GET 0720
     1 ,NSZRPH    ,NSZTH    ,NSZPH    ,NSZTHTH    ,NSZPHPH    ,NSZTHPH  GET 0730
     2 ,NVELECT    ,NWIME                                               GET 0740
C                                                                       GET 0750
      DATA PI,PJ/1.0,9*0.0,1.0,9*0.0/                                   GET 0760
      DATA NC,NSZR,NSZRR,NSZRTH,NSZRPH,NSZTH,NSZPH,NSZTHTH,NSZPHPH      GET 0770
     1   ,NSZTHPH,NVELECT,NWIME/1,2,3,4,5,6,7,8,9,10,11,12/             GET 0780
      DATA FWIME,GWIME,FVELECT,GVELECT/2*-1.0,8HRECEIVER ,7HTERRAIN /   GET 0790
      DATA UWIME,UVELECT/-1.0,7HSURFACE /                               GET 0800
      DATA ZHRO/0.0/                                                    GET 0810
C                                                                       GET 0820
      IENTRY=1                                                          GET 0830
      GO TO 5                                                           GET 0840
C                                                                       GET 0850
      ENTRY SETGET                                                      GET 0860
C                                                                       GET 0870
      CALL RMOVE(PF,PI,10)                                              GET 0880
      CALL RMOVE(PG,PJ,10)                                              GET 0890
      CALL IMOVE(NZ,NC,12)                                              GET 0900
      FTIME=FWIME                                                       GET 0910
      GTIME=GWIME                                                       GET 0920
      FSELECT=FVELECT                                                   GET 0930
      GSELECT=GVELECT                                                   GET 0940
      UTIME=UWIME                                                       GET 0950
      USELECT=UVELECT                                                   GET 0960
      ZERO=ZHRO                                                         GET 0970
```

```
C
      RETURN
C
      ENTRY DOT(Z)
      IENTRY=2
5     CONTINUE
C
C     THE FOLLOWING THREE ASSIGNMENT STATEMENTS ARE NEEDED TO REPAIR
C     ARRAY ELEMENTS OVERWRITTEN ON THE CRAY VERSION OF THIS PROGRAM.
C     THE ADDITIONAL ARRAY 'GY' HAS ALSO BEEN ADDED TO THE /FNDER/
C     LABELED COMMON TO ACT AS A BUFFER AREA.
C     NO CAUSE FOR THIS PROBLEM HAS YET BEEN FOUND. THESE STATEMENTS
C     ARE NOT NEEDED ON OTHER MACHINES AS FAR AS IS KNOWN.
      NZ=1
      NPZR=2
      NPZRR=3
      IF(ZERO.EQ.0.0) ZERO=EARTHR*RMACH(3)*2.0
C
      IF(ITEST(Z(NTIME)).EQ.IRKTIME) GO TO 10
C
      IF(Z(NSELECT).EQ.USELECT) CALL SURFACE
      IF(Z(NSELECT).EQ.FSELECT) CALL RECEVER
      IF(Z(NSELECT).EQ.GSELECT) CALL TOPOG
      Z(NTIME)=RKTIME
C     REMOVE MACHINE ROUND OFF NOISE FROM EXACT RECEIVER LOCATIONS
      IF(ABS(Z(NZ)).LE.ZERO) Z(NZ)=0.0
C
10    IF(IENTRY.NE.1) GO TO 20
      GET=Z(NZ)
      RETURN
C
20    GET=Z(NPZR)*DRDT(1)+Z(NPZTH)*DRDT(2)+Z(NPZPH)*DRDT(3)
      RETURN
      END
```

```
      FUNCTION ITEST(I)
C     USED TO PASS INTEGER VALUES THROUGH FOR VARIABLES TYPED REAL
C     (AS IN MIXED REAL/INTEGER ARRAYS)
      ITEST=I
      END
```

```
      FUNCTION ITOC(N)
C     RETURN 7 CHARACTER STRING REPRESENTATION OF INTEGER N
C     IF NUMBER IS TOO LARGE OR SMALL USE FLOATING POINT FORMAT
      CHARACTER ITOC*7
      IF(N.LT.-9999.OR.N.GT.99999) GO TO 100
      ITOC=' '
```

```
      WRITE(ITOC,'(I7)',ERR=100) N                                  ITOC0080
      RETURN                                                        ITOC0090
100   WRITE(ITOC,'(2PG7.0)') FLOAT(N)                               ITOC0100
      END                                                           ITOC0110


      SUBROUTINE CONBLK                                             COPK0020
C     DATA INITIALIZATION AND FILE OPENING SERVICE ROUTINE          COPK0030
C                                                                   COPK0040
C     COMMON DECK "RMACH" INSERTED HERE                             CRMA0020
      COMMON/CRMACH/RMACH(5)                                        CRMA0040
C     COMMON DECK "HDR" INSERTED HERE                               CHDR0020
      CHARACTER*10 INITID*80,DAT,TOD                                CHDR0040
      COMMON/HDR/SEC                                                CHDR0050
      COMMON/HDRC/INITID,DAT,TOD                                    CHDR0060
C                                                                   COPK0070
C     COMMON DECK "CPROCFL" INSERTED HERE                           CPRO0020
      INTEGER PMX,PNTBL,PITBL,PFRMTBL,IDSP(10)                      CPRO0040
C     PARAMETER DECK "PGROUPS"                                      PGRO0020
      PARAMETER (NCHPG1=11,NWPV=250,NSPGP=NCHPG1+2*NWPV+1)          PGRO0030
      PARAMETER (MNGRP=9,MXGRP=69,MXLIST=MXGRP-MNGRP+2)             PGRO0040
      COMMON/PROCFL/LIST(MXLIST)                                    CPRO0060
      COMMON/PROCFL/PMX,PNTBL(10),PITBL(10),PFRMTBL(10),PGP(NSPGP)  CPRO0070
      EQUIVALENCE (PGP,IDSP)                                        CPRO0080
C     COMMON DECK "CC" INSERTED HERE                                CCC 0020
      REAL MODC                                                     CCC 0040
      COMMON/CC/MODC(4),CS,PCST,PCSR,PCSTH,PCSPH                    CCC 0050
C     COMMON DECK "GG" INSERTED HERE                                CGG 0020
      REAL MODG                                                     CGG 0040
      COMMON/GG/MODG(4)                                             CGG 0050
      COMMON/GG/G,PGR,PGRR,PGRTH,PGRPH                              CGG 0060
      COMMON/GG/PGTH,PGPH,PGTHTH,PGPHPH,PGTHPH,GSELECT,GTIME        CGG 0070
C     COMMON DECK "RR" INSERTED HERE                                CRR 0020
      REAL MODREC                                                   CRR 0040
      COMMON/RR/ MODREC(4)                                          CRR 0050
      COMMON/RR/F,PFR,PFRR,PFRTH,PFRPH                              CRR 0060
      COMMON/RR/PFTH,PFPH,PFTHTH,PFPHPH,PFTHPH,FSELECT,FTIME        CRR 0070
C     COMMON DECK "TT" INSERTED HERE                                CTT 0020
      REAL MODT                                                     CTT 0040
      COMMON/TT/MODT(4), T,PTT,PTR,PTTH,PTPH                        CTT 0050
C     COMMON DECK "UU" INSERTED HERE                                CUU 0020
      REAL MODU                                                     CUU 0040
      COMMON/UU/MODU(4)                                             CUU 0050
     1  ,V  ,PVT  ,PVR  ,PVTH  ,PVPH                                CUU 0060
     2  ,VR ,PVRT ,PVRR ,PVRTH ,PVRPH                               CUU 0070
     3  ,VTH,PVTHT,PVTHR,PVTHTH,PVTHPH                              CUU 0080
     4  ,VPH,PVPHT,PVPHR,PVPHTH,PVPHPH                              CUU 0090
C                                                                   COPK0140
C     COMMON DECK "RAYDEV" INSERTED HERE                            CRAY0020
C     DEVICE ASSIGNED TO RAYTRC INPUT FILE                          CRAY0040
      COMMON/RAYDEV/NRYIND,NDEVTMP,NFRMAT,NDEVGRP,NDEVBIN            CRAY0050
C     COMMON DECK "CUCON" INSERTED HERE                             CUCO0020
```

```
      COMMON/UCONV/CNVV(5,4)                                            CUCO0040
      CHARACTER PCV*3,CNVC*2                                            CUCO0050
      COMMON/UCONC/PCV(5),CNVC(5,4)                                     CUCO0060
C                                                                       COPK0170
C     COMMON DECK "SS" INSERTED HERE                                    CSS 0020
      REAL MODSURF                                                      CSS 0040
      COMMON/SS/ MODSURF(4)                                             CSS 0050
      COMMON/SS/U,PUR,PURR,PURTH,PURPH                                  CSS 0060
      COMMON/SS/PUTH,PUPH,PUTHTH,PUPHPH,PUTHPH,USELECT,UTIME            CSS 0070
C     COMMON DECK "CONST" INSERTED HERE                                 CCON0020
      COMMON/PCONST/CREF,RGAS,GAMMA                                     CCON0040
      COMMON/MCONST/PI,PIT2,PID2,DEGS,RAD,ALN10                         CCON0050
C     COMMON DECK "WWR" INSERTED HERE                                   CWWR0020
      PARAMETER (NWARSZ=1000)                                           CWW10030
      COMMON/WW/ID(10),MAXW,W(NWARSZ)                                   CWW10040
      REAL MAXSTP,MAXERR,INTYP,LLAT,LLON                                CWW20020
      EQUIVALENCE (EARTHR,W(1)),(RAY,W(2)),(XMTRH,W(3)),(TLAT,W(4)),    CWW20030
     1 (TLON,W(5)),(OW,W(6)),(FBEG,W(7)),(FEND,W(8)),(FSTEP,W(9)),      CWW20040
     2 (AZ1,W(10)),(AZBEG,W(11)),(AZEND,W(12)),(AZSTEP,W(13)),          CWW20050
     3 (BETA,W(14)),(ELBEG,W(15)),(ELEND,W(16)),(ELSTEP,W(17)),         CWW20060
     8   (RUNSUP,W(18)),(RCVRH,W(20)),                                  CWW20070
     4 (ONLY,W(21)),(HOP,W(22)),(MAXSTP,W(23)),(PLAT,W(24)),(PLON,W(25))CWW20080
     5,(HMAX,W(26)),(RAYFNC,W(29)),(EXTINC,W(33)),                      CWW20090
     6 (HMIN,W(27)),(RGMAX,W(28)),                                      CWW20100
     8 (INTYP,W(41)),(MAXERR,W(42)),(ERATIO,W(43)),                     CWW20110
     6 (STEP1,W(44)),(STPMAX,W(45)),(STPMIN,W(46)),(FACTR,W(47)),       CWW20120
     7 (SKIP,W(71)),(RAYSET,W(72)),(PRTSRP,W(74)),(HITLET,W(75))        CWW20130
     9 ,(BINRAY,W(76)),(PAGLN,W(77)),(PLT,W(81)),(PFACTR,W(82)),        CWW20140
     1 (LLAT,W(83)),(LLON,W(84)),(RLAT,W(85)),(RLON,W(86))              CWW20150
     2,(TIC,W(87)),(HB,W(88)),(HT,W(89)),(TICV,W(96))                   CWW20160
C     COMMON DECK "B9" INSERTED HERE                                    CB8 0020
      INTEGER GMX,GNTBL,GITBL,GFRMTBL,IDSG(10)                          CB8 0040
      COMMON/B9/GMX,GNTBL(10),GITBL(10),GFRMTBL(10),GGP(113)            CB8 0050
      EQUIVALENCE (GGP,IDSG),(ANG,GGP(11))                              CB8 0060
C     COMMON DECK "B2" INSERTED HERE                                    CB2 0020
      INTEGER DUMX,DUNTBL,DUITBL,DUFRMTB,IDSDU(10)                      CB2 0040
      COMMON/B2/DUMX,DUNTBL(10),DUITBL(10),DUFRMTB(10),DUGP(10)         CB2 0050
      EQUIVALENCE (DUGP,IDSDU)                                          CB2 0060
C     COMMON DECK "B4" INSERTED HERE                                    CB4 0020
      INTEGER DCMX,DCNTBL,DCITBL,DCFRMTB,IDSDC(10)                      CB4 0040
      COMMON/B4/DCMX,DCNTBL(10),DCITBL(10),DCFRMTB(10),DCGP(10)         CB4 0050
      EQUIVALENCE (DCGP,IDSDC)                                          CB4 0060
C     COMMON DECK "B6" INSERTED HERE                                    CB6 0020
      INTEGER DTMX,DTNTBL,DTITBL,DTFRMTB,IDSDT(10)                      CB6 0040
      COMMON/B6/DTMX,DTNTBL(10),DTITBL(10),DTFRMTB(10),DTGP(10)         CB6 0050
      EQUIVALENCE (DTGP,IDSDT)                                          CB6 0060
C     COMMON DECK "B1" INSERTED HERE                                    CB1 0020
      INTEGER UMX,UNTBL,UITBL,UFRMTBL,IDSU(10)                          CB1 0040
      COMMON/B1/UMX,UNTBL(10),UITBL(10),UFRMTBL(10),UGP(10)             CB1 0050
      EQUIVALENCE (UGP,IDSU)                                            CB1 0060
C     COMMON DECK "B3" INSERTED HERE                                    CB3 0020
      INTEGER CMX,CNTBL,CITBL,CFRMTBL,IDSC(10)                          CB3 0040
      COMMON/B3/CMX,CNTBL(10),CITBL(10),CFRMTBL(10),CGP(512)            CB3 0050
      EQUIVALENCE (CGP,IDSC),(ANC,CGP(11))                              CB3 0060
C     COMMON DECK "B5" INSERTED HERE                                    CB5 0020
```

```
      INTEGER TMX,TNTBL,TITBL,TFRMTBL,IDST(10)                          CB5 0040
      COMMON/B5/TMX,TNTBL(10),TITBL(10),TFRMTBL(10),TGP(262)            CB5 0050
      EQUIVALENCE (TGP,IDST),(ANT,TGP(11))                              CB5 0060
C     COMMON DECK "B7" INSERTED HERE                                    CB7 0020
      INTEGER MMX,MNTBL,MITBL,MFRMTBL,IDSM(10)                          CB7 0040
      REAL MGP                                                          CB7 0050
      COMMON/B7/MMX,MNTBL(10),MITBL(10),MFRMTBL(10),MGP(10)             CB7 0060
      EQUIVALENCE (MGP,IDSM)                                            CB7 0070
C     COMMON DECK "RINPLEX" INSERTED HERE                               CRIN0020
      REAL KAY2,KAY2I                                                   CRIN0040
      COMPLEX PNP,POLAR,LPOLAR                                          CRIN0050
      LOGICAL SPACE                                                     CRIN0060
      CHARACTER DISPM*6                                                 CRIN0070
      COMMON/RINPL/DISPM                                                CRIN0080
      COMMON /RIN/ MODRIN(8),RAYNAME(2,3),TYPE(3),SPACE                 CRIN0090
      COMMON/RIN/OMEGMIN,OMEGMAX,KAY2,KAY2I                             CRIN0100
      COMMON/RIN/PNP(10),POLAR,LPOLAR,SGN                               CRIN0110
C     COMMON DECK "MM" INSERTED HERE                                    CMM 0020
      REAL M,MODM                                                       CMM 0040
      COMMON/MM/MODM(4),M,PMT,PMR,PMTH,PMPH                             CMM 0050
C     COMMON DECK "PP" INSERTED HERE                                    CPP 0020
      REAL MODP                                                         CPP 0040
      COMMON/PP/MODP(4),P,PPT,PPR,PPTH,PPPH                             CPP 0050
C     COMMON DECK "AA" INSERTED HERE                                    CAA 0020
      REAL MODA                                                         CAA 0040
      REAL MU,MUPT,MUPR,MUPTH,MUPPH                                     CAA 0050
      REAL KAP,KAPPT,KAPPR,KAPPTH,KAPPPH                                CAA 0060
      COMMON/AA/MODA(4),MU,MUPT,MUPR,MUPTH,MUPPH                        CAA 0070
      COMMON/AA/KAP,KAPPT,KAPPR,KAPPTH,KAPPPH                           CAA 0080
C     COMMON DECK "CB11" INSERTED HERE                                  CB110020
      INTEGER SMX,SNTBL,SITBL,SFRMTBL,IDSS(10)                          CB110040
      COMMON/B11/SMX,SNTBL(10),SITBL(10),SFRMTBL(10),SGP(11)            CB110050
      EQUIVALENCE (SGP,IDSS),(ANS,SGP(11))                              CB110060
C     COMMON DECK "CB12" INSERTED HERE                                  CB120020
      INTEGER DSMX,DSNTBL,DSITBL,DSFRMTB,IDSDS(10)                      CB120040
      COMMON/B12/DSMX,DSNTBL(10),DSITBL(10),DSFRMTB(10),DSGP(11)        CB120050
      EQUIVALENCE (DSGP,IDSDS),(ANDS,DSGP(11))                          CB120060
C     COMMON DECK "LL" INSERTED HERE                                    CLL 0020
      REAL MODL                                                         CLL 0040
      COMMON/LL/MODL(4),APH,APHPT,APHPR,APHPTH,APHPPH                   CLL 0050
C     COMMON DECK "FLAG" INSERTED HERE                                  CFLA0020
      LOGICAL NEWWR,NEWWP,NEWTRC,PENET                                  CFLA0040
      COMMON /FLG/ NTYP,NEWWR,NEWWP,NEWTRC,PENET,LINES,IHOP,HPUNCH      CFLA0050
      COMMON/FLGP/NSET                                                  CFLA0060
C     COMMON DECK "RKTIME" INSERTED HERE                                CRKT0020
      COMMON/CRKTIME/RKTIME                                             CRKT0040
C                                                                       COPK0380
      COMMON/RAYCON/MCONP                                               COPK0390
C                                                                       COPK0400
      EQUIVALENCE(RKTIME,IRKTIME)                                       COPK0410
C                                                                       COPK0420
C     COMMON DECK "B10" INSERTED HERE                                   CB9 0020
      INTEGER DGMX,DGNTBL,DGITBL,DGFRMTB,IDSDG(10)                      CB9 0040
      COMMON/B10/DGMX,DGNTBL(10),DGITBL(10),DGFRMTB(10),DGGP(10)        CB9 0050
      EQUIVALENCE (DGGP,IDSDG)                                          CB9 0060
```

```
C     COMMON DECK "B8" INSERTED HERE                                    CB100020
      INTEGER RMX,RNTBL,RITBL,RFRMTBL,IDSR(10)                          CB100040
      COMMON/B8/RMX,RNTBL(10),RITBL(10),RFRMTBL(10),RGP(10)             CB100050
      EQUIVALENCE (RGP,IDSR)                                            CB100060
C     COMMON DECK "CB17" INSERTED HERE                                  CB170020
      INTEGER VMX,VNTBL,VITBL,VFRMTBL,IDSV(10)                          CB170040
      COMMON/B17/VMX,VNTBL(10),VITBL(10),VFRMTBL(10),VGP(53)            CB170050
      EQUIVALENCE (VGP,IDSV),(ANV,VGP(11))                              CB170060
C     COMMON DECK "CB18" INSERTED HERE                                  CB180020
      INTEGER DVMX,DVNTBL,DVITBL,DVFRMTB,IDSDV(10)                      CB180040
      COMMON/B18/DVMX,DVNTBL(10),DVITBL(10),DVFRMTB(10),DVGP(11)        CB180050
      EQUIVALENCE (DVGP,IDSDV),(ANDV,DVGP(11))                          CB180060
C     COMMON DECK "CB19" INSERTED HERE                                  CB190020
      INTEGER PRMX,PRNTBL,PRITBL,PRFRMTB,IDSPR(10)                      CB190040
      COMMON/B19/PRMX,PRNTBL(10),PRITBL(10),PRFRMTB(10),PRGP(11)        CB190050
      EQUIVALENCE (PRGP,IDSPR),(ANP,PRGP(11))                           CB190060
C     COMMON DECK "CB20" INSERTED HERE                                  CB200020
      INTEGER DPMX,DPNTBL,DPITBL,DPFRMTB,IDSDP(10)                      CB200040
      COMMON/B20/DPMX,DPNTBL(10),DPITBL(10),DPFRMTB(10),DPGP(11)        CB200050
      EQUIVALENCE (DPGP,IDSDP),(ANDP,DPGP(11))                          CB200060
      COMMON/KNKN/KNBP,KNVC,KNDT                                        COPK0490
      COMMON/DDLIM/MXIX,MXIY,MNIX,MNIY                                  COPK0500
C                                                                       COPK0510
      REAL KVECT(22)                                                    COPK0520
      REAL VSET(20)                                                     COPK0530
      EQUIVALENCE(KVECT,KAY2),(VSET,V)                                  COPK0540
C                                                                       COPK0550
      REAL CUEF(3)                                                      COPK0560
      INTEGER NUYIND(5)                                                 COPK0570
C                                                                       COPK0580
      CHARACTER PFV(5)*3,CQVC(5,4)*2                                    COPK0590
C                                                                       COPK0600
      DATA CUEF/1.0,1.4,8.31436E-3/                                     COPK0610
      DATA NUYIND/8,4,0,10,11/                                          COPK0620
      DATA PFV/'AN','LN','FQ','AM',' '/                                 COPK0630
      DATA CQVC/'RD' ,'KM' ,'RD' ,'DB',' '                              COPK0640
     1         ,'DG' ,' M' ,'HZ' ,'NP',' '                              COPK0650
     2         ,'KM' ,'FT' ,'KH' ,2*' '                                 COPK0660
     3         ,'  ' ,'NM' ,'DG' ,2*' '/                                COPK0670
C                                                                       COPK0680
      CALL SET2(KVECT,0.0,22)                                           COPK0690
      CALL SET2(RAYNAME,1H , 6)                                         COPK0700
      CALL SET2(VSET,0.0,20)                                            COPK0710
      CALL SET2(OMEGMIN,0.0,2)                                          COPK0720
      MXIX=-1000                                                        COPK0730
      MXIY=-1000                                                        COPK0740
      MNIX=1000                                                         COPK0750
      MNIY=1000                                                         COPK0760
      KNBP=0                                                            COPK0770
      KNVC=0                                                            COPK0780
      KNDT=0                                                            COPK0790
      IRKTIME=0                                                         COPK0800
C     SET TRACE-BACKUP VARIABLES                                        COPK0810
      CALL SETTRC                                                       COPK0820
      MCONP=0                                                           COPK0830
```

```
      POLAR=0.0
      LPOLAR=1.0
      CALL RMOVE(CREF,CUEF,3)
      CALL IMOVE(NRYIND,NUYIND,5)
      CALL SET2(CNVV,1.0,20)
      DO 10 I=1,5
        PCV(I)=PFV(I)
        DO 10 J=1,4
10       CNVC(I,J)=CQVC(I,J)
C     DEFAULT WIND AND ABSORBSION IDENTIFIERS
      MODU(1)=1H
      MODU(2)=0.0
      MODU(3)=1H
      MODU(4)=0.0
      MODL(1)=1H
      MODL(2)=0.0
      MODL(3)=1H
      MODL(4)=0.0
C
C     INITIALIZE MODEL DESCRIPTIONS TO BLANKS
      CALL SET2(IDSDC,1H ,10)
      CALL SET2(IDSDT,1H ,10)
      CALL SET2(IDSDU,1H ,10)
      CALL SET2(IDSC,1H ,10)
      CALL SET2(IDSM,1H ,10)
      CALL SET2(IDST,1H ,10)
      CALL SET2(IDSU,1H ,10)
      CALL SET2(IDSG,1H ,10)
      CALL SET2(IDSDG,1H ,10)
      CALL SET2(IDSV,1H ,10)
      CALL SET2(IDSDV,1H ,10)
      CALL SET2(IDSPR,1H ,10)
      CALL SET2(IDSDP,1H ,10)
      CALL SET2(IDSR,1H ,10)
      CALL SET2(IDSS,1H ,10)
      CALL SET2(IDSDS,1H ,10)
C
C     GET MACHINE CONSTANTS
      CALL DFCNST(RMACH,5)
      RETURN
C
      ENTRY STDINI
      CALL OPNREP(NDEVTMP,'TAPE4')
      CALL OPNURP(NDEVBIN,'TAPE6')
      CALL OPNREP(9,'PUNCH')
C
      ENTRY STDINT
      OPEN(UNIT=NRYIND,FILE='DINP',STATUS='OLD',ERR=1000)
      REWIND NRYIND
      CALL OPNREP(2,'OUTPUT')
      CALL OPNREP(3,'DOUTP')
      CALL OPNURP(NDEVGRP,'TAPE5')
C
C  INITIALIZE RAYSET FILE
      READ(NRYIND,'(A)',END=1000) INITID
```

```
      CALL SETW                                                         COPK1390
      CALL SETGET                                                       COPK1400
      CALL SYSDAT(DAT)                                                  COPK1410
      CALL SYSTIM(TOD)                                                  COPK1420
      CALL SYSSEC(SEC)                                                  COPK1430
C     INITIALIZE POINT MODEL LIST                                       COPK1440
      LIST(1)=1                                                         COPK1450
      LIST(2)=0                                                         COPK1460
C     FILL FORMAT CONTROL ARRAYS                                        COPK1470
      PNTBL(1)=1                                                        COPK1480
C     ALLOW FOR AN 80 CHARACTER IDENT STRING(A8)                        COPK1490
      PNTBL(2)=NCHPG1                                                   COPK1500
C     ALLOW MAXIMUM 250 WORD PER VARIABLE                               COPK1510
      PITBL(2)=NWPV                                                     COPK1520
C     FOR BOTH X AND Y PLUS 1 FOR NUMBER OF VARIABLES                   COPK1530
      PNTBL(3)=NSPGP                                                    COPK1540
      RETURN                                                            COPK1550
1000  STOP 'DINP FORMAT ERROR'                                          COPK1560
      END                                                               COPK1570


      SUBROUTINE SETTRC                                                 COPK1580
C     INITIALIZE /TRAC/ LABELED COMMON                                  COPK1590
C     COMMON DECK "TRAC" INSERTED HERE                                  CTRA0020
      LOGICAL GROUND,SURF,PERIGE,THERE,MINDIS,NEWRAY                    CTRA0040
      COMMON /TRAC/ GROUND,SURF,PERIGE,THERE,MINDIS,NEWRAY,SMT,OSMT     CTRA0050
      COMMON/TRAC/ROLD(20),DROLD(20),TOLD,ZDOT,D2Z,RAD,RAD1             CTRA0060
      GROUND=.FALSE.                                                    COPK1610
      SURF=.FALSE.                                                      COPK1620
      END                                                               COPK1630


      LOGICAL FUNCTION WCHANGE(W1,W2)                                   WCZE0020
      REAL W1(400),W2(400)                                              WCZE0030
C                                                                       WCZE0040
C WCHANGE PROVIDES A TEST AGAINST TWO W-ARRAYS                          WCZE0050
C     IF BOTH WOULD PRODUCE THE SAME SET OF RAYS BY RAYTRC THEN RESULT  WCZE0060
C     IS <FALSE>.                                                       WCZE0070
C                                                                       WCZE0080
      INTEGER NDX(8)                                                    WCZE0090
C                                                                       WCZE0100
      DATA NGRPS,NDX/8, 1,17, 21,26, 41,47, 100,399/                    WCZE0110
C                                                                       WCZE0120
      WCHANGE=.FALSE.                                                   WCZE0130
      DO 20 N=1,NGRPS,2                                                 WCZE0140
         N1=NDX(N)                                                      WCZE0150
         N2=NDX(N+1)                                                    WCZE0160
      DO 20 I=N1,N2                                                     WCZE0170
         WCHANGE=W1(I).NE.W2(I)                                         WCZE0180
```

```
         IF(WCHANGE) RETURN                                            WCZE0190
20    CONTINUE                                                          WCZE0200
      END                                                               WCZE0210
```

```
      FUNCTION RENORM(VECTOR,NNORM,NCOMPS)                              RELM0020
C     NORMALIZES 'NCOMPS' COMPONENT VECTOR 'VECTOR' TO MAGNITUDE        RELM0030
C     'NNORM' AND RETURNS SQUARE ROOT OF FACTOR NEEDED.                 RELM0040
      REAL NNORM,VECTOR(*)                                              RELM0050
C                                                                       RELM0060
      RENORM=0.0                                                        RELM0070
      IF(NNORM.LE.0.0) RETURN                                           RELM0080
C                                                                       RELM0090
      RENORM=0.0                                                        RELM0100
      DO 10 I=1,NCOMPS                                                  RELM0110
10    RENORM=RENORM+VECTOR(I)*VECTOR(I)                                 RELM0120
      IF(RENORM.EQ.0.0) RETURN                                          RELM0130
C                                                                       RELM0140
      RENORM=SQRT(NNORM/RENORM)                                         RELM0150
      DO 20 I=1,NCOMPS                                                  RELM0160
20    VECTOR(I)=VECTOR(I)*RENORM                                        RELM0170
C                                                                       RELM0180
      RETURN                                                            RELM0190
      END                                                               RELM0200
```

```
      SUBROUTINE SET2(A,V,N)                                            SET20020
C     SETS N COMPONENTS OF VECTER TO SINGLE VALUE V                     SET20030
      ENTRY ISET2(A,V,N)                                                SET20040
C     SPECIAL ENTRY FOR INTEGER ARRAYS FOR MACHINES HAVING DIFFERENT    SET20050
C     WORD SIZES FOR INTEGERS THAN REALS.                               SET20060
C                                                                       SET20070
      REAL A(N)                                                         SET20080
C                                                                       SET20090
      DO 100 I=1,N                                                      SET20100
100   A(I)=V                                                            SET20110
      END                                                               SET20120
```

```
      SUBROUTINE PRINTR(EVENT,CARD)                                     PRVR0020
C                                                                       PRVR0030
      CHARACTER EVENT*9,NWHY*8,CC*1,PC*1,TMP*9                          PRVR0040
C                                                                       PRVR0050
C     PRINTS OUTPUT AND OUTPUTS RAYSETS(MACHINE READABLE OUTPUT)        PRVR0060
C     WHEN 'CARD' ARGUMENT NONZERO.                                     PRVR0070
      REAL KNORM                                                        PRVR0080
```

```
      DIMENSION G0(3,3),G1(3,3)                                          PRVR0090
      CHARACTER*12 HEADRS(20),HEAD(20),UNITS(20),UNIT(20)                PRVR0100
      DIMENSION RPRINT(20),NPR(20)                                       PRVR0110
C     COMMON DECK "RK" INSERTED HERE                                     CRK 0020
C     DEFINE SIZE REQUIRED FOR RAY STATE SAVE ARRAY                      CRK 0040
      PARAMETER (LRKAMS=87+2*100,NXRKMS=12+LRKAMS,MXEQPT=21)             CRK 0050
      PARAMETER (NRKSAV=NXRKMS+MXEQPT-1)                                 CRK 0060
      COMMON /RK/ NEQS,STEP,MODE,E1MAX,E1MIN,E2MAX,E2MIN,FACT,RSTART     CRK 0070
C     COMMON DECK "CERR" INSERTED HERE                                   CERR0020
      COMMON/ERR/NERG,NERR,NERT,NERP                                     CERR0030
C     COMMON DECK "GG" INSERTED HERE                                     CGG 0020
      REAL MODG                                                          CGG 0040
      COMMON/GG/MODG(4)                                                  CGG 0050
      COMMON/GG/G,PGR,PGRR,PGRTH,PGRPH                                   CGG 0060
      COMMON/GG/PGTH,PGPH,PGTHTH,PGPHPH,PGTHPH,GSELECT,GTIME             CGG 0070
C     COMMON DECK "CONST" INSERTED HERE                                  CCON0020
      COMMON/PCONST/CREF,RGAS,GAMMA                                      CCON0040
      COMMON/MCONST/PI,PIT2,PID2,DEGS,RAD,ALN10                          CCON0050
C     COMMON DECK "FLAG" INSERTED HERE                                   CFLA0020
      LOGICAL NEWWR,NEWWP,NEWTRC,PENET                                   CFLA0040
      COMMON /FLG/ NTYP,NEWWR,NEWWP,NEWTRC,PENET,LINES,IHOP,HPUNCH       CFLA0050
      COMMON/FLGP/NSET                                                   CFLA0060
C     COMMON DECK "RINPLEX" INSERTED HERE                                CRIN0020
      REAL KAY2,KAY2I                                                    CRIN0040
      COMPLEX PNP,POLAR,LPOLAR                                           CRIN0050
      LOGICAL SPACE                                                      CRIN0060
      CHARACTER DISPM*6                                                  CRIN0070
      COMMON/RINPL/DISPM                                                 CRIN0080
      COMMON /RIN/ MODRIN(8),RAYNAME(2,3),TYPE(3),SPACE                  CRIN0090
      COMMON/RIN/OMEGMIN,OMEGMAX,KAY2,KAY2I                              CRIN0100
      COMMON/RIN/PNP(10),POLAR,LPOLAR,SGN                                CRIN0110
C     COMMON DECK "RKAM" INSERTED HERE                                   RKAM0020
      REAL KR,KTH,KPH                                                    RKAM0040
      COMMON//R,TH,PH,KR,KTH,KPH,RKVARS(14),TPULSE,CSTEP,DRDT(20)        RKAM0050
C     COMMON DECK "WW" INSERTED HERE                                     CWW 0020
      PARAMETER (NWARSZ=1000)                                            CWW10030
      COMMON/WW/ID(10),MAXW,W(NWARSZ)                                    CWW10040
      REAL MAXSTP,MAXERR,INTYP,LLAT,LLON                                 CWW20020
      EQUIVALENCE (EARTHR,W(1)),(RAY,W(2)),(XMTRH,W(3)),(TLAT,W(4)),     CWW20030
     1 (TLON,W(5)),(OW,W(6)),(FBEG,W(7)),(FEND,W(8)),(FSTEP,W(9)),       CWW20040
     2 (AZ1,W(10)),(AZBEG,W(11)),(AZEND,W(12)),(AZSTEP,W(13)),           CWW20050
     3 (BETA,W(14)),(ELBEG,W(15)),(ELEND,W(16)),(ELSTEP,W(17)),          CWW20060
     8   (RUNSUP,W(18)),(RCVRH,W(20)),                                   CWW20070
     4 (ONLY,W(21)),(HOP,W(22)),(MAXSTP,W(23)),(PLAT,W(24)),(PLON,W(25))CWW20080
     5,(HMAX,W(26)),(RAYFNC,W(29)),(EXTINC,W(33)),                       CWW20090
     6 (HMIN,W(27)),(RGMAX,W(28)),                                       CWW20100
     8 (INTYP,W(41)),(MAXERR,W(42)),(ERATIO,W(43)),                      CWW20110
     6 (STEP1,W(44)),(STPMAX,W(45)),(STPMIN,W(46)),(FACTR,W(47)),        CWW20120
     7 (SKIP,W(71)),(RAYSET,W(72)),(PRTSRP,W(74)),(HITLET,W(75))         CWW20130
     9 ,(BINRAY,W(76)),(PAGLN,W(77)),(PLT,W(81)),(PFACTR,W(82)),         CWW20140
     1 (LLAT,W(83)),(LLON,W(84)),(RLAT,W(85)),(RLON,W(86))               CWW20150
     2,(TIC,W(87)),(HB,W(88)),(HT,W(89)),(TICV,W(96))                    CWW20160
      REAL MMODEL,MFORM,MID                                              CWW30020
C                                                                        CWW30030
C     WIND          100-124                                              CWW30040
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```
      EQUIVALENCE (W(100),UMODEL),(W(101),UFORM),(W(102),UID)            CWW30050
C                                                                        CWW30060
C     DELTA WIND        125-149                                          CWW30070
      EQUIVALENCE (W(125),DUMODEL),(W(126),DUFORM),(W(127),DUID)         CWW30080
C                                                                        CWW30090
C     SOUND SPEED 150-174                                                CWW30100
      EQUIVALENCE (W(150),CMODEL),(W(151),CFORM),(W(152),CID)            CWW30110
      EQUIVALENCE (W(153),REFC)                                          CWW30120
C                                                                        CWW30130
C     DELTA SOUND SPEED 175-199                                          CWW30140
      EQUIVALENCE (W(175),DCMODEL),(W(176),DCFORM),(W(177),DCID)         CWW30150
C                                                                        CWW30160
C     TEMPERATURE    200-224                                             CWW30170
      EQUIVALENCE (W(200),TMODEL),(W(201),TFORM),(W(202),TID)            CWW30180
C                                                                        CWW30190
C     DELTA TEMPERATURE    225-249                                       CWW30200
      EQUIVALENCE (W(225),DTMODEL),(W(226),DTFORM),(W(227),DTID)         CWW30210
C                                                                        CWW30220
C     MOLECULAR   250-274                                                CWW30230
      EQUIVALENCE (W(250),MMODEL),(W(251),MFORM),(W(252),MID)            CWW30240
C                                                                        CWW30250
C     RECEIVER HEIGHT   275-299                                          CWW30260
      EQUIVALENCE (W(275),RMODEL),(W(276),RFORM),(W(277),RID)            CWW30270
C                                                                        CWW30280
C     TOPOGRAPHY   300-324                                               CWW30290
      EQUIVALENCE (W(300),GMODEL),(W(301),GFORM),(W(302),GID)            CWW30300
C                                                                        CWW30310
C     DELTA TOPOGRAPHY   325-349                                         CWW30320
      EQUIVALENCE (W(325),GUMODEL),(W(326),GUFORM),(W(327),GUID)         CWW30330
C                                                                        CWW30340
C     ATMOSPHERIC SURFACE TOPOGRAPHY   350-374                           CWW30350
      EQUIVALENCE (W(350),SMODEL),(W(351),SFORM),(W(352),SID)            CWW30360
C                                                                        CWW30370
C     ATMOSPHERIC SURFACE TOPOGRAPHY   375-399                           CWW30380
      EQUIVALENCE (W(375),SUMODEL),(W(376),SUFORM),(W(377),SUID)         CWW30390
C     PLOT ENHANCEMENTS CONTROL PARAMETERS                               CWW30400
C                                                                        CWW30410
      EQUIVALENCE (W(490),XFQMDL),(W(491),YFQMDL)                        CWW30420
C     ABSORPTION        500-524                                          CWW30430
      EQUIVALENCE (W(500),AMODEL),(W(501),AFORM),(W(502),AID)            CWW30440
C                                                                        CWW30450
C     DELTA ABSORPTION        525-549                                    CWW30460
      EQUIVALENCE (W(525),DAMODEL),(W(526),DAFORM),(W(527),DAID)         CWW30470
C                                                                        CWW30480
C     PRESSURE        550-574                                            CWW30490
      EQUIVALENCE (W(550),PMODEL),(W(551),PFORM),(W(552),PID)            CWW30500
C                                                                        CWW30510
C     DELTA PRESSURE        575-599                                      CWW30520
      EQUIVALENCE (W(575),DPMODEL),(W(576),DPFORM),(W(577),DPID)         CWW30530
C                                                                        CWW30540
      EQUIVALENCE(T,TPULSE),(PHI,PH),(TH,THETA)                          PRVR0200
      DATA                                                               PRVR0210
     2 HEADRS(7)/'  PHASE TIME'/,UNITS(7)/'   SEC'/                      PRVR0220
     3 ,HEADRS(8)/' ABSORPTION'/,UNITS(8)/'   DB '/                      PRVR0230
     4 ,HEADRS(9)/'   DOPPLER  '/,UNITS(9)/'  C/,S '/                    PRVR0240
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```
     5 ,HEADRS(10)/' PATH LENGTH'/,UNITS(10)/'   KM '/
     6 ,HEADRS(11)/' TERRAIN'/,UNITS(11)/' '/
     7 ,HEADRS(12)/' TERRAIN PGR'/,UNITS(12)/' '/
     8 ,HEADRS(13)/' TERRAIN PGT'/,UNITS(13)/' '/
     9 ,HEADRS(14)/' TERRAIN PGP'/,UNITS(14)/' '/
C
C      ROUND-OFF FUNCTION
      ROUND(X)=SIGN(ABS(X)+0.5,X)
C
      NWHY=EVENT(2:)
      GO TO 10
C
C     INITIALIZATION ENTRY POINT FOR PRINTR. CALLED FOR EACH NEW
C     W-ARRAY.
      ENTRY IPRINTR
C
C********* NEW W ARRAY -- REINITIALIZE
      NEWWP=.FALSE.
      SPL=SIN (PLON-TLON)
      CPL=SIN (PID2-(PLON-TLON))
      SP=SIN (PLAT)
      CP=SIN (PID2-PLAT)
      SL=SIN (TLAT)
      CL=SIN (PID2-TLAT)
C********* MATRIX TO ROTATE COORDINATES
      G0(1,1)=CPL*SP*CL-CP*SL
      G0(1,2)=SPL*SP
      G0(1,3)=-SL*SP*CPL-CL*CP
      G0(2,1)=-SPL*CL
      G0(2,2)=CPL
      G0(2,3)=SL*SPL
      G0(3,1)=CL*CP*CPL+SP*SL
      G0(3,2)=CP*SPL
      G0(3,3)=-SL*CP*CPL+SP*CL
      DENM=G0(1,1)*G0(2,2)*G0(3,3)+G0(1,2)*G0(3,1)*G0(2,3)
     1   +G0(2,1)*G0(3,2)*G0(1,3)-G0(2,2)*G0(3,1)*G0(1,3)
     2   -G0(1,2)*G0(2,1)*G0(3,3)-G0(1,1)*G0(3,2)*G0(2,3)
C********* THE MATRIX G1 IS THE INVERSE OF THE MATRIX G
      G1(1,1)=(G0(2,2)*G0(3,3)-G0(3,2)*G0(2,3))/DENM
      G1(1,2)=(G0(3,2)*G0(1,3)-G0(1,2)*G0(3,3))/DENM
      G1(1,3)=(G0(1,2)*G0(2,3)-G0(2,2)*G0(1,3))/DENM
      G1(2,1)=(G0(3,1)*G0(2,3)-G0(2,1)*G0(3,3))/DENM
      G1(2,2)=(G0(1,1)*G0(3,3)-G0(3,1)*G0(1,3))/DENM
      G1(2,3)=(G0(2,1)*G0(1,3)-G0(1,1)*G0(2,3))/DENM
      G1(3,1)=(G0(2,1)*G0(3,2)-G0(3,1)*G0(2,2))/DENM
      G1(3,2)=(G0(3,1)*G0(1,2)-G0(1,1)*G0(3,2))/DENM
      G1(3,3)=(G0(1,1)*G0(2,2)-G0(2,1)*G0(1,2))/DENM
      R0=EARTHR+XMTRH
C********* CARTESIAN COORDINATES OF TRANSMITTER
      XR=R0*G0(1,1)
      YR=R0*G0(2,1)
      ZR=R0*G0(3,1)
      CTHR=G0(3,1)
      STHR=SIN (ACOS (CTHR))
      PHIR=ATAN2(YR,XR)
```

```
      ALPH=ATAN2(G0(3,2),G0(3,3))
C*********
      NR=0
      NP=0
      NERG=0
      NERR=0
      NERT=0
      NERP=0
C     INSURE NO GARBLE IN HEADERS
      HEAD(1)=' '
      UNIT(1)=' '
C
      DO 7 NN=7,20
      IF (W(NN+50).EQ.0.) GO TO 7
C********* DEPENDENT VARIABLE NUMBER NN IS BEING INTEGRATED
C********* NR IS THE NUMBER OF DEPENDENT VARIABLES BEING INTEGRATED
      NR=NR+1
C     ENABLE SELECTED RELATIVE ERROR PRINTOUTS FOR TERRAIN(G) OR
C     ITS DERIVATIVES WITH RESPECT TO (R)ANGE, (T)HETA OR (P)HI.
      IF(NN.EQ.11) NERG=NR
      IF(NN.EQ.12) NERR=NR
      IF(NN.EQ.13) NERT=NR
      IF(NN.EQ.14) NERP=NR
      IF (W(NN+50).NE.2.) GO TO 7
C********* DEPENDENT VARIABLE NUMBER NN IS BEING INTEGRATED AND PRINTED.
C********* NP IS THE NUMBER OF DEPENDENT VARIABLES BEING INTEGRATED AND
C********* PRINTED
      NP=NP+1
C********* SAVE THE INDEX OF THE DEPENDENT VARIABLE TO PRINT
      NPR(NP)=NR
      HEAD(NP)=HEADRS(NN)
      HEAD(NP)=HEADRS(NN)
      UNIT(NP)=UNITS(NN)
    7 CONTINUE
      NPM=MIN0(NP,3)
      NP1=NPM+1
      P=0.0
      ABSORB=0.0
      DOPP=0.0
      NEQS=NR+6
      RETURN
C
      ENTRY PRNHD1(CC)
C     PRINT PRINTR HEADER 1
C   IF NO OUTPUT NEEDED EXIT NOW
      IF(PRTSRP.NE.0.0) RETURN
C
C     ADD NUMBER OF LINES NEEDED FOR THIS HEADER
      PC=CC
      IF(CC.EQ.'1') CALL NEWPAG(NPAG,INT(PAGLN),PC)
      LINES=LINES+3
C********* PRINT COLUMN HEADINGS
C
      WRITE(3,1100) PC,(HEAD(NN),NN=1,NPM)
C
```

```
1100  FORMAT (   A,T25,'ELEVATION',T54,'AZIMUTH',T71,'ELEVATION'/
     3 ,T20,2('ABOVE',6X),T53,'DEVIATION',T72,'ANGLE'/'  ERROR   EVENT'
     4  ,T20,'SEA LEVEL  TERRAIN     RANGE',4X,2('XMTR   LOCAL',5X),
     5  'PULSE TIME',3A12)
C
      WRITE(3,1150) (UNIT(NN),NN=1,NPM)
 1150 FORMAT(13X,3(8X,'KM'),2X,2(6X,'DEG',5X,'DEG'),T88
     1 ,'SEC',3X,3(3X,A7,2X))
C
      RETURN
C
      ENTRY PRNHD2(CC)
C     PRINT PRINTR HEADER 1
C   IF NO OUTPUT NEEDED EXIT NOW
      IF(PRTSRP.NE.0.0) RETURN
C     PAGE BY HALF LENGTH
      LINSPP=PAGLN/2
      IF(LINSPP.LT.40) LINSPP=PAGLN
      PC=CC
      IF(CC.EQ.'1') CALL NEWPAG(NPAG,LINSPP,PC)
C     ADD NUMBER OF LINES NEEDED FOR THIS SUBHEADER
      LINES=LINES+1
C
      IF(ELEND.GE.ELBEG+ELSTEP) THEN
         WRITE(3,'(A,''ELEVATION ANGLE OF TRANSMISSION =''
     1    ,F10.4,'' DEG'')') PC,BETA*DEGS
      ELSEIF(AZEND.GE.AZBEG+AZSTEP) THEN
         WRITE(3,'(A,''AZIMUTH ANGLE OF TRANSMISSION =''
     1    ,F10.4,'' DEG'')') PC,AZ1*DEGS
      ENDIF
      RETURN
C
C     IF PRINTING SUPPRESSED AND RAYSETS OFF NOTHING TO DO
10    IF(PRTSRP.NE.0.0 .AND. CARD.EQ.0.0) RETURN
      CALL DISPER
      IF (CARD.EQ.0.0 .OR. IHOP.NE.0) GO TO 12
C********* OUTPUT A TRANSMITTER RAYSET
C        NOTE: THIS IS A SPECIAL CASE, ALL OTHER RAY EVENTS ARE
C           OUTPUT AT CODE 'PUNCH A RAYSET' BELOW.
C
      TLOND=TLON*DEGS
      IF (TLOND.LT.0.) TLOND=TLOND+360.
      TLATD=TLAT*DEGS
      IF (TLATD.LT.0.) TLATD=TLATD+360.
      AZ=AZ1*DEGS
      EL=BETA*DEGS
      NHOP=HOP
      NXMTRH=ROUND(XMTRH*1.E4)
      NTLATD=ROUND(TLATD*1.E3)
       NTLOND=ROUND(TLOND*1.E3)
      NRCVRH=ROUND(RCVRH*1.E4)
       NF=ROUND(OW*1.E4)
      NAZ=ROUND(AZ*1.E5)
       NEL=ROUND(EL*1.E5)
      NPOLAR1=ROUND(REAL(POLAR)*1.E2)
```

```
       NPOLAR2=ROUND(AIMAG(POLAR)*1.E2)
      WRITE(9,1201) ID(1),TYPE(NTYP),NXMTRH,NTLATD,NTLOND,NRCVRH,NF,NAZ
     1 ,NEL,NPOLAR1,NPOLAR2,NHOP,'T'
 1201 FORMAT(A3,A1,I9,2I6,2I9,2I10,5X,I5,I4,I2,A1)
C*********
12    V=1.E10
C     OBTAIN THE WORST ERROR OF THOSE ENABLED.
      IF (KAY2.NE.0.) V=(KR**2+KTH**2+KPH**2)/KAY2-1.
      ERT=1HK
      V=RERR(V,ERT,'G',NERG,G)
      V=RERR(V,ERT,'R',NERR,PGR)
      V=RERR(V,ERT,'T',NERT,PGTH)
      V=RERR(V,ERT,'P',NERP,PGPH)
C
      H=R-EARTHR
      STH=SIN (THETA)
      CTH=SIN (PID2-THETA)
C********* CARTESIAN COORDINATES OF RAY POINT, ORIGIN AT TRANSMITTER
      XP=R*STH*SIN (PID2-PHI)-XR
      YP=R*STH*SIN (PHI)-YR
      ZP=R*CTH-ZR
C********* CARTESIAN COORDINATES OF RAY POINT, ORIGIN AT TRANSMITTER AND
C********* ROTATED
      EPS=XP*G1(1,1)+YP*G1(1,2)+ZP*G1(1,3)
      ETA=XP*G1(2,1)+YP*G1(2,2)+ZP*G1(2,3)
      ZETA=XP*G1(3,1)+YP*G1(3,2)+ZP*G1(3,3)
      RCE2=ETA**2+ZETA**2
      RCE=SQRT (RCE2)
C********* GROUND RANGE
      RANGE=EARTHR*ATAN2(RCE,EARTHR+EPS+XMTRH)
C********* ANGLE OF WAVE NORMAL WITH LOCAL HORIZONTAL
      ELL=ATAN2(KR,SQRT (KTH**2+KPH**2))*DEGS
C********* STRAIGHT LINE DISTANCE FROM TRANSMITTER TO RAY POINT
      SR=SQRT (RCE2+EPS**2)
C********* TERRAIN RELATIVE HEIGHT
      GRH=GET(G)/PGR
C     REPORT GROUP TIME AS FIRST 'OPTION'
      RPRINT(1)=T
      IF (NP1.LT.2) GO TO 16
C     ADD MORE OPTIONS IF REQUESTED
      DO 15 I=2,NP1
      NN=NPR(I-1)
   15 RPRINT(I)=RKVARS(NN)
C
16    IF(V.GE.0.0) THEN
         WRITE(TMP,'(A1,0PE7.2)') ERT,V
      ELSE
         WRITE(TMP,'(A1,0PE7.1)') ERT,V
      ENDIF
C     DETERMINE WHERE TO PUT A SPACE
C     AT BEGINNING OR END OF 1ST 2 VALUES
      KT=1
      IF(TMP(1:1).EQ.'K') KT=2
C
C     TEST IF NEED NEW PAGE
```

```
      CALL TSTPAG(3)
      IF (SR.GE.1.E-6) GO TO 20
C********* TOO CLOSE TO TRANSMITTER TO CALCULATE DIRECTION FROM
C********* TRANSMITTER
      IF(PRTSRP.EQ.0.0)
     1 WRITE(3,1500)TMP(KT:9),NWHY,H,GRH,RANGE,ELL,(RPRINT(NN),NN=1,NP1)
 1500 FORMAT (1X,A8,A8,2F10.4,F11.4,26X,F8.3,4F12.4)
C     SET RAYSET VARIABLES TO UNDEFINDED VALUES FOR FLAGS
      AZDEV=999.0
      AZA=999.0
      GO TO 40
C********* ELEVATION ANGLE OF RAY POINT FROM TRANSMITTER
   20 EL=ATAN2(EPS,RCE)*DEGS
      IF (RCE.GE.1.E-6) GO TO 30
C********* NEARLY DIRECTLY ABOVE OR BELOW TRANSMITTER. CAN NOT CALCULATE
C********* AZIMUTH DIRECTION FROM TRANSMITTER ACCURATELY
      IF(PRTSRP.EQ.0.0)
     1   WRITE(3,2500)TMP(KT:9),NWHY,H,GRH,RANGE,EL,ELL
     2   ,(RPRINT(NN),NN=1,NP1)
 2500 FORMAT (1X,A8,A8,2F10.4,F11.4,17X,F9.3,F8.3,
     1 4F12.4)
      GO TO 40
C********* AZIMUTH ANGLE OF RAY POINT FROM TRANSMITTER
   30 ANGA=ATAN2(ETA,ZETA)
      AZDEV=180.-AMOD(540.-(AZ1-ANGA)*DEGS,360.)
      IF (KTH.NE.0..OR.KPH.NE.0.) GO TO 34
C********* WAVE NORMAL IS VERTICAL, SO AZIMUTH DIRECTION CANNOT BE
C********* CALCULATED
      IF(PRTSRP.EQ.0.0)
     1 WRITE(3,3000)TMP(KT:9),NWHY,H,GRH,RANGE,AZDEV,EL,ELL,(RPRINT(NN),
     1 NN=1,NP1)
 3000 FORMAT (1X,A8,A8,2F10.4,F11.4,F9.3,8X,F9.3,F8.3,
     1 4F12.4)
      GO TO 40
   34 ANA=ANGA-ALPH
      SANA=SIN (ANA)
      SPHI=SANA*STHR/STH
      CPHI=-SIN (PID2-ANA)*SIN (PID2-(PHI-PHIR))+SANA*SIN (PHI-PHIR)
     1 *CTHR
      AZA=180.-AMOD (540.-(ATAN2(SPHI,CPHI)-ATAN2(KPH,KTH))*DEGS,360.)
      IF(PRTSRP.EQ.0.0)
     1   WRITE(3,3500)TMP(KT:9),NWHY,H,GRH,RANGE,AZDEV,AZA,EL,ELL
     2   ,(RPRINT(NN),NN=1,NP1)
 3500 FORMAT (1X,A8,A8,2F10.4,F11.4,2(F9.3,F8.3),
     1 4F12.4)
C*********
   40 LINES=LINES+1
      IF (NP.LE.3) GO TO 45
C********* ADDITIONAL LINE TO PRINT REMAINING DEPENDENT INTEGRATION
C********* VARIABLES
      IF(PRTSRP.EQ.0.0)
     1   WRITE(3,4000) (RPRINT(NN),NN=4,NP)
 4000 FORMAT (99X,3F12.4)
      LINES=LINES+1
C
```

```
C     IF NO 'CARDS' WANTED OR AT TRANSMITTER, NO RAYSET OUTPUT
C
45    IF (CARD.EQ.0.0 .OR. IHOP.LT.1) RETURN
C
C********* PUNCH A RAYSET
      IF (AZDEV.LT.-90.) AZDEV=AZDEV+360.
      IF (AZA.LT.-90.) AZA=AZA+360.
      NR=0
      IF (W(57).EQ.0.) GO TO 47
C********* PHASE PATH
      NR=NR+1
      P=RKVARS(NR)
   47 IF (W(58).EQ.0.) GO TO 48
C********* ABSORPTION
      NR=NR+1
      ABSORB=RKVARS(NR)
C********* DOPPLER SHIFT
   48 IF (W(59).NE.0.) DOPP=RKVARS(NR+1)
      NHPUNCH=ROUND(HPUNCH*1.E4)
       NRANGE=ROUND(RANGE*1.E4)
      NAZDEV=ROUND(AZDEV*1.E3)
       NAZA=ROUND(AZA*1.E3)
       NELL=ROUND(ELL*1.E3)
      IF(NWHY.EQ.'GRND REF') NELL =
     1 ROUND((PID2 - ACOS(KNORM(G)/SQRT(KR*KR+KTH*KTH+KPH*KPH)))
     2   *DEGS*1.E3)
      NABSORB=AMIN1(999999.0,ROUND(ABSORB*1.E3))
       NDOPP=ROUND(DOPP*1.E3)
      NPOLAR1=ROUND(REAL(POLAR)*1.E2)
       NPOLAR2=ROUND(AIMAG(POLAR)*1.E2)
      JP=ROUND(P*1.E5)
      JT=ROUND(T*1.E5)
      WRITE(9,4501) NHPUNCH,NRANGE,NAZDEV,NAZA,NELL,JT,JP,NABSORB
     1 ,NDOPP,NPOLAR1,NPOLAR2,IHOP,EVENT(1:1)
 4501 FORMAT(2I9,3I6,2I10,2I6,I5,I4,I2,A1)
      RETURN
      END
```

```
      SUBROUTINE OCNHD
C     PRINTS PAGE HEADINGS
C     IF W(72) IS NEGATIVE, ONLY ONE HEADER OUTPUT IS INCLUDED IN RAYSE
      CHARACTER PCC*1,PC*1,BLANKS*100,DIVIDR*132,BANNER(8)*80
      CHARACTER NUMSTG*80,STMP*80
      LOGICAL NOPUNCH
      INTEGER STRIM
C
C     TWO ENTRY POINTS ARE PROVIDED. ONE FOR THE FIRST PAGE HEADER
C     OF THE COMPUTATIONAL PRINTOUT AND FOR THE RAYSET FILE. THE
C     SECOND ENTRY IS FOR ALL SUBSEQUENT PAGES OF THE COMPUTATIONAL
C     PRINTOUT.
C
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```
C     COMMON DECK "LL" INSERTED HERE                                    CLL 0020
      REAL MODL                                                         CLL 0040
      COMMON/LL/MODL(4),APH,APHPT,APHPR,APHPTH,APHPPH                   CLL 0050
C     COMMON DECK "PP" INSERTED HERE                                    CPP 0020
      REAL MODP                                                         CPP 0040
      COMMON/PP/MODP(4),P,PPT,PPR,PPTH,PPPH                             CPP 0050
C                                                                       OCBD0170
C     COMMON DECK "SS" INSERTED HERE                                    CSS 0020
      REAL MODSURF                                                      CSS 0040
      COMMON/SS/ MODSURF(4)                                             CSS 0050
      COMMON/SS/U,PUR,PURR,PURTH,PURPH                                  CSS 0060
      COMMON/SS/PUTH,PUPH,PUTHTH,PUPHPH,PUTHPH,USELECT,UTIME            CSS 0070
C     COMMON DECK "CONST" INSERTED HERE                                 CCON0020
      COMMON/PCONST/CREF,RGAS,GAMMA                                     CCON0040
      COMMON/MCONST/PI,PIT2,PID2,DEGS,RAD,ALN10                         CCON0050
C     COMMON DECK "WWR" INSERTED HERE                                   CWWR0020
      PARAMETER (NWARSZ=1000)                                           CWW10030
      COMMON/WW/ID(10),MAXW,W(NWARSZ)                                   CWW10040
      REAL MAXSTP,MAXERR,INTYP,LLAT,LLON                                CWW20020
      EQUIVALENCE (EARTHR,W(1)),(RAY,W(2)),(XMTRH,W(3)),(TLAT,W(4)),    CWW20030
     1 (TLON,W(5)),(OW,W(6)),(FBEG,W(7)),(FEND,W(8)),(FSTEP,W(9)),      CWW20040
     2 (AZ1,W(10)),(AZBEG,W(11)),(AZEND,W(12)),(AZSTEP,W(13)),          CWW20050
     3 (BETA,W(14)),(ELBEG,W(15)),(ELEND,W(16)),(ELSTEP,W(17)),         CWW20060
     8   (RUNSUP,W(18)),(RCVRH,W(20)),                                  CWW20070
     4 (ONLY,W(21)),(HOP,W(22)),(MAXSTP,W(23)),(PLAT,W(24)),(PLON,W(25))CWW20080
     5,(HMAX,W(26)),(RAYFNC,W(29)),(EXTINC,W(33)),                      CWW20090
     6 (HMIN,W(27)),(RGMAX,W(28)),                                      CWW20100
     8 (INTYP,W(41)),(MAXERR,W(42)),(ERATIO,W(43)),                     CWW20110
     6 (STEP1,W(44)),(STPMAX,W(45)),(STPMIN,W(46)),(FACTR,W(47)),       CWW20120
     7 (SKIP,W(71)),(RAYSET,W(72)),(PRTSRP,W(74)),(HITLET,W(75))        CWW20130
     9 ,(BINRAY,W(76)),(PAGLN,W(77)),(PLT,W(81)),(PFACTR,W(82)),        CWW20140
     1 (LLAT,W(83)),(LLON,W(84)),(RLAT,W(85)),(RLON,W(86))              CWW20150
     2,(TIC,W(87)),(HB,W(88)),(HT,W(89)),(TICV,W(96))                   CWW20160
C     COMMON DECK "GG" INSERTED HERE                                    CGG 0020
      REAL MODG                                                         CGG 0040
      COMMON/GG/MODG(4)                                                 CGG 0050
      COMMON/GG/G,PGR,PGRR,PGRTH,PGRPH                                  CGG 0060
      COMMON/GG/PGTH,PGPH,PGTHTH,PGPHPH,PGTHPH,GSELECT,GTIME            CGG 0070
C     COMMON DECK "RR" INSERTED HERE                                    CRR 0020
      REAL MODREC                                                       CRR 0040
      COMMON/RR/ MODREC(4)                                              CRR 0050
      COMMON/RR/F,PFR,PFRR,PFRTH,PFRPH                                  CRR 0060
      COMMON/RR/PFTH,PFPH,PFTHTH,PFPHPH,PFTHPH,FSELECT,FTIME            CRR 0070
C     COMMON DECK "B9" INSERTED HERE                                    CB8 0020
      INTEGER GMX,GNTBL,GITBL,GFRMTBL,IDSG(10)                          CB8 0040
      COMMON/B9/GMX,GNTBL(10),GITBL(10),GFRMTBL(10),GGP(113)            CB8 0050
      EQUIVALENCE (GGP,IDSG),(ANG,GGP(11))                              CB8 0060
C     COMMON DECK "B2" INSERTED HERE                                    CB2 0020
      INTEGER DUMX,DUNTBL,DUITBL,DUFRMTB,IDSDU(10)                      CB2 0040
      COMMON/B2/DUMX,DUNTBL(10),DUITBL(10),DUFRMTB(10),DUGP(10)         CB2 0050
      EQUIVALENCE (DUGP,IDSDU)                                          CB2 0060
C     COMMON DECK "B4" INSERTED HERE                                    CB4 0020
      INTEGER DCMX,DCNTBL,DCITBL,DCFRMTB,IDSDC(10)                      CB4 0040
      COMMON/B4/DCMX,DCNTBL(10),DCITBL(10),DCFRMTB(10),DCGP(10)         CB4 0050
      EQUIVALENCE (DCGP,IDSDC)                                          CB4 0060
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C     COMMON DECK "B6" INSERTED HERE                                    CB6 0020
      INTEGER DTMX,DTNTBL,DTITBL,DTFRMTB,IDSDT(10)                      CB6 0040
      COMMON/B6/DTMX,DTNTBL(10),DTITBL(10),DTFRMTB(10),DTGP(10)         CB6 0050
      EQUIVALENCE (DTGP,IDSDT)                                          CB6 0060
C     COMMON DECK "B1" INSERTED HERE                                    CB1 0020
      INTEGER UMX,UNTBL,UITBL,UFRMTBL,IDSU(10)                          CB1 0040
      COMMON/B1/UMX,UNTBL(10),UITBL(10),UFRMTBL(10),UGP(10)             CB1 0050
      EQUIVALENCE (UGP,IDSU)                                            CB1 0060
C     COMMON DECK "B3" INSERTED HERE                                    CB3 0020
      INTEGER CMX,CNTBL,CITBL,CFRMTBL,IDSC(10)                          CB3 0040
      COMMON/B3/CMX,CNTBL(10),CITBL(10),CFRMTBL(10),CGP(512)            CB3 0050
      EQUIVALENCE (CGP,IDSC),(ANC,CGP(11))                              CB3 0060
C     COMMON DECK "B5" INSERTED HERE                                    CB5 0020
      INTEGER TMX,TNTBL,TITBL,TFRMTBL,IDST(10)                          CB5 0040
      COMMON/B5/TMX,TNTBL(10),TITBL(10),TFRMTBL(10),TGP(262)            CB5 0050
      EQUIVALENCE (TGP,IDST),(ANT,TGP(11))                              CB5 0060
C     COMMON DECK "B7" INSERTED HERE                                    CB7 0020
      INTEGER MMX,MNTBL,MITBL,MFRMTBL,IDSM(10)                          CB7 0040
      REAL MGP                                                          CB7 0050
      COMMON/B7/MMX,MNTBL(10),MITBL(10),MFRMTBL(10),MGP(10)             CB7 0060
      EQUIVALENCE (MGP,IDSM)                                            CB7 0070
C     COMMON DECK "HDR" INSERTED HERE                                   CHDR0020
      CHARACTER*10 INITID*80,DAT,TOD                                    CHDR0040
      COMMON/HDR/SEC                                                    CHDR0050
      COMMON/HDRC/INITID,DAT,TOD                                        CHDR0060
C     COMMON DECK "RINPLEX" INSERTED HERE                               CRIN0020
      REAL KAY2,KAY2I                                                   CRIN0040
      COMPLEX PNP,POLAR,LPOLAR                                          CRIN0050
      LOGICAL SPACE                                                     CRIN0060
      CHARACTER DISPM*6                                                 CRIN0070
      COMMON/RINPL/DISPM                                                CRIN0080
      COMMON /RIN/ MODRIN(8),RAYNAME(2,3),TYPE(3),SPACE                 CRIN0090
      COMMON/RIN/OMEGMIN,OMEGMAX,KAY2,KAY2I                             CRIN0100
      COMMON/RIN/PNP(10),POLAR,LPOLAR,SGN                               CRIN0110
C     COMMON DECK "CC" INSERTED HERE                                    CCC 0020
      REAL MODC                                                         CCC 0040
      COMMON/CC/MODC(4),CS,PCST,PCSR,PCSTH,PCSPH                        CCC 0050
C     COMMON DECK "MM" INSERTED HERE                                    CMM 0020
      REAL M,MODM                                                       CMM 0040
      COMMON/MM/MODM(4),M,PMT,PMR,PMTH,PMPH                             CMM 0050
C     COMMON DECK "FLAG" INSERTED HERE                                  CFLA0020
      LOGICAL NEWWR,NEWWP,NEWTRC,PENET                                  CFLA0040
      COMMON /FLG/ NTYP,NEWWR,NEWWP,NEWTRC,PENET,LINES,IHOP,HPUNCH      CFLA0050
      COMMON/FLGP/NSET                                                  CFLA0060
C     COMMON DECK "TT" INSERTED HERE                                    CTT 0020
      REAL MODT                                                         CTT 0040
      COMMON/TT/MODT(4), T,PTT,PTR,PTTH,PTPH                            CTT 0050
C     COMMON DECK "UU" INSERTED HERE                                    CUU 0020
      REAL MODU                                                         CUU 0040
      COMMON/UU/MODU(4)                                                 CUU 0050
     1  ,V  ,PVT  ,PVR  ,PVTH  ,PVPH                                    CUU 0060
     2  ,VR ,PVRT ,PVRR ,PVRTH ,PVRPH                                   CUU 0070
     3  ,VTH,PVTHT,PVTHR,PVTHTH,PVTHPH                                  CUU 0080
     4  ,VPH,PVPHT,PVPHR,PVPHTH,PVPHPH                                  CUU 0090
C                                                                       OCBD0380
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C     COMMON DECK "B10" INSERTED HERE
      INTEGER DGMX,DGNTBL,DGITBL,DGFRMTB,IDSDG(10)
      COMMON/B10/DGMX,DGNTBL(10),DGITBL(10),DGFRMTB(10),DGGP(10)
      EQUIVALENCE (DGGP,IDSDG)
C     COMMON DECK "B8" INSERTED HERE
      INTEGER RMX,RNTBL,RITBL,RFRMTBL,IDSR(10)
      COMMON/B8/RMX,RNTBL(10),RITBL(10),RFRMTBL(10),RGP(10)
      EQUIVALENCE (RGP,IDSR)
C     COMMON DECK "CB11" INSERTED HERE
      INTEGER SMX,SNTBL,SITBL,SFRMTBL,IDSS(10)
      COMMON/B11/SMX,SNTBL(10),SITBL(10),SFRMTBL(10),SGP(11)
      EQUIVALENCE (SGP,IDSS),(ANS,SGP(11))
C     COMMON DECK "CB12" INSERTED HERE
      INTEGER DSMX,DSNTBL,DSITBL,DSFRMTB,IDSDS(10)
      COMMON/B12/DSMX,DSNTBL(10),DSITBL(10),DSFRMTB(10),DSGP(11)
      EQUIVALENCE (DSGP,IDSDS),(ANDS,DSGP(11))
C     COMMON DECK "CB17" INSERTED HERE
      INTEGER VMX,VNTBL,VITBL,VFRMTBL,IDSV(10)
      COMMON/B17/VMX,VNTBL(10),VITBL(10),VFRMTBL(10),VGP(53)
      EQUIVALENCE (VGP,IDSV),(ANV,VGP(11))
C     COMMON DECK "CB18" INSERTED HERE
      INTEGER DVMX,DVNTBL,DVITBL,DVFRMTB,IDSDV(10)
      COMMON/B18/DVMX,DVNTBL(10),DVITBL(10),DVFRMTB(10),DVGP(11)
      EQUIVALENCE (DVGP,IDSDV),(ANDV,DVGP(11))
C     COMMON DECK "CB19" INSERTED HERE
      INTEGER PRMX,PRNTBL,PRITBL,PRFRMTB,IDSPR(10)
      COMMON/B19/PRMX,PRNTBL(10),PRITBL(10),PRFRMTB(10),PRGP(11)
      EQUIVALENCE (PRGP,IDSPR),(ANP,PRGP(11))
C     COMMON DECK "CB20" INSERTED HERE
      INTEGER DPMX,DPNTBL,DPITBL,DPFRMTB,IDSDP(10)
      COMMON/B20/DPMX,DPNTBL(10),DPITBL(10),DPFRMTB(10),DPGP(11)
      EQUIVALENCE (DPGP,IDSDP),(ANDP,DPGP(11))
C
      PARAMETER (NBNRLS=8,NBLNS=8)
C
      DATA BLANKS/' '/
      DATA BANNER/
     1 '***** H A R P O *****'
     2 ,'HAMILTONIAN ACOUSTIC RAY-TRACING PROGRAM FOR THE OCEAN'
     3 ,' '
     4 ,'BY'
     5 ,'R. M. JONES,  J. P. RILEY  AND  T. M. GEORGES'
     6 ,'WAVE PROPAGATION LABORATORY'
     7 ,'NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION'
     8 ,'BOULDER, COLORADO 80303'/
      DATA NOPUNCH/.FALSE./
      DATA IBLK/1H /
C
      ENTRY HEADER1
C
C     COMPUTE EFFECTIVE LINES COUNT BASED ON FIXED PAGE SIZE
      CALL NEWPAG(NPAG,INT(PAGLN),PC)
      CALL SFILL(DIVIDR,LEN(DIVIDR),'-')
      DIVIDR(1:1)=' '
      NTYP=2
```

```
      IF(RAY.NE.0.0) NTYP=2.0+SIGN(1.0,RAY)
C
1600  FORMAT(2(2(A8,F7.1,1X),2X))
      CALL PUTKST(3,'1'
     1  //DAT//TOD//BLANKS(:100)//'PAGE'//NUMSTG(NPAG,1,'(I5)'))
      CALL PUTKST(3,DIVIDR)
      CALL PUTKBK(3,1)
      DO 15 I=1,NBNRLS
15    CALL PUTKCT(3,BANNER(I))
      CALL PUTKBK(3,1)
      CALL PUTKST(3,DIVIDR)
      CALL PUTKBK(3,NBLNS)
C
      CALL PUTKST(3,BLANKS(:57)//'RUN SET NUMBER'
     1  //NUMSTG(NSET,1,'(I5)'))
      CALL PUTKBK(3,1)
      WRITE(STMP,'(10A8)') ID
      CALL PUTKST(3,BLANKS(:52)//'OCEAN MODEL ID -- '//STMP(:3))
      CALL PUTKBK(3,1)
      CALL PUTKST(3,
     1 BLANKS(:25)//'OCEAN MODEL DESCRIPTION -- '//STMP(7:))
      CALL PUTKBK(3,1)
C
      WRITE(STMP,'(2A8)') (RAYNAME(I,NTYP),I=1,2)
      CALL PUTKST(3,STMP)
      CALL PUTKBK(3,1)
      CALL PUTKST(3,DIVIDR)
      CALL PUTKBK(3,1)
      CALL PUTKST(3,
     1  BLANKS(:8)//'MODEL                    SUBROUTINE    DATA SET'
     1  //'         DESCRIPTION')
      CALL PUTKST(3,
     1  BLANKS(:8)//'TYPE                          NAME          ID')
      CALL PUTKBK(3,1)
      CALL PUTKST(3,DIVIDR)
      CALL PUTKBK(3,1)
      CALL PUTKST(3,' DISPERSION RELATION            '//DISPM
     1  //BLANKS(:16)//NUMSTG(MODRIN,8,'(8A8)'))
      CALL PUTDES(3,'BACKGROUND CURRENT VELOCITY',MODU,IDSU)
      CALL PUTDES(3,'CURRENT VELOCITY PERTURBATION',MODU(3),IDSDU)
      CALL PUTDES(3,'BACKGROUND SOUND SPEED',MODC,IDSC)
      CALL PUTDES(3,'SOUND SPEED PERTURBATION',MODC(3),IDSDC)
      CALL PUTDES(3,'BACKGROUND BOTTOM',MODG,IDSG)
      CALL PUTDES(3,'BOTTOM PERTURBATION',MODG(3),IDSDG)
      CALL PUTDES(3,'ABSORPTION',MODL,IDSV)
      CALL PUTDES(3,'ABSORPTION PERTURBATION',MODL(3),IDSDV)
      CALL PUTDES(3,'RECEIVER SURFACE',MODREC,IDSR)
      CALL PUTDES(3,'OCEAN SURFACE',MODSURF,IDSS)
      CALL PUTDES(3,'OCEAN SURFACE PERTURBATION',MODSURF(3),IDSDS)
      CALL PUTKST(3,DIVIDR)
C
      NOPUNCH=NOPUNCH.AND.RAYSET.LT.0.0
      IF(NOPUNCH) RETURN
      NOPUNCH=RAYSET.LT.0.0
C
```

```
      WRITE(9,1200) ID,DAT,TOD
      WRITE(9,1600) MODU,MODC,MODG,MODL,MODREC(1),MODREC(2),MODSURF
C
      IF(IDSU(1) .NE. IBLK) WRITE(9,1200) IDSU
      IF(IDSDU(1) .NE. IBLK) WRITE(9,1200) IDSDU
      IF(IDSC(1) .NE. IBLK) WRITE(9,1200) IDSC
      IF(IDSDC(1) .NE. IBLK) WRITE(9,1200) IDSDC
      IF(IDST(1) .NE. IBLK) WRITE(9,1200) IDST
      IF(IDSDT(1) .NE. IBLK) WRITE(9,1200) IDSDT
      IF(IDSM(1) .NE. IBLK) WRITE(9,1200) IDSM
      IF(IDSG(1) .NE. IBLK) WRITE(9,1200) IDSG
C
 1000 FORMAT (A1,10A8,24X,2A,' PAGE',I4)
1200  FORMAT(10A8,2(A8,2X))
C
      RETURN
C
      ENTRY HEADER2
C
C     COMPUTE EFFECTIVE LINES COUNT BASED ON FIXED PAGE SIZE
      CALL NEWPAG(NPAG,INT(PAGLN),PC)
      LINES=LINES+5
C
      WRITE(3,1000) PC,ID,DAT,TOD,NPAG
      WRITE(3,2400) AZ1*DEGS,TLAT*DEGS,OW/PIT2,BETA*DEGS
     1         ,TLON*DEGS,MAXERR
 2400 FORMAT (
     1  /' AZIMUTH ANGLE OF TRANSMISSION   =',F12.6,' DEG'
     2  ,'        TRANSMITTER  LATITUDE  =',F12.6,' DEG'
     3  ,'     FREQUENCY =',F12.6,' HZ'
     4  /' ELEVATION ANGLE OF TRANSMISSION =',F12.6,' DEG'
     5  ,'        TRANSMITTER  LONGITUDE =',F12.6,' DEG'
     6  ,'     SINGLE STEP ERROR =',1PG13.6/)
C
      RETURN
C
      ENTRY PUTDVR(NUNIT)
      CALL PUTKST(NUNIT,DIVIDR)
      RETURN
C
      ENTRY PUTHDR(NUNIT,PCC,NP)
      CALL PUTKST(NUNIT,
     1  PCC//DAT//TOD//BLANKS(:100)//'PAGE'//NUMSTG(NP,1,'(I5)'))
      RETURN
      END
```

```
      SUBROUTINE PUTDES(NUNIT,DES,MOD,ID)
C     TITLING AID, OUTPUT MODULE DESCRIPTION AS HOLLERITH NAME
C     AND NUMERIC IDENTIFIER
      CHARACTER DES*(*),TITLE*30,SMODL*20,NUMSTG*80
      REAL MOD(2),ID(10)
```

```
      TITLE=DES                                                         PUQS0070
      WRITE(SMODL,'(A8,F10.2)') MOD                                     PUQS0080
      CALL PUTKST(NUNIT, ' '//TITLE//SMODL//NUMSTG(ID,10,'(10A8)'))     PUQS0090
      END                                                               PUQS0100
```

```
      FUNCTION NUMSTG(V,N,FRM)                                          NUNG0020
C     CONVERTS A NUMERIC VALUE TO A STRING                              NUNG0030
C     USING FORMAT PROVIDED IN CALL                                     NUNG0040
      CHARACTER NUMSTG*80,FRM*(*)                                       NUNG0050
      INTEGER V(N)                                                      NUNG0060
C                                                                       NUNG0070
      NUMSTG=' '                                                        NUNG0080
      WRITE(NUMSTG,FRM) V                                               NUNG0090
      RETURN                                                            NUNG0100
      END                                                               NUNG0110
```

```
      SUBROUTINE SFILL(STG,LN,C)                                        SFSL0020
C     FILLS A STRING WITH N SPECIFIED CHARACTERS                        SFSL0030
      CHARACTER STG*(*),C*1                                             SFSL0040
C                                                                       SFSL0050
      DO 10 I=1,LN                                                      SFSL0060
10    STG(I:I)=C                                                        SFSL0070
      RETURN                                                            SFSL0080
      END                                                               SFSL0090
```

```
      INTEGER FUNCTION STRIM(C)                                         STEM0020
C     DETERMINES POSITION OF LAST NONBLANK CHARACTER OF A STRING        STEM0030
      CHARACTER*(*) C                                                   STEM0040
C                                                                       STEM0050
      L=LEN(C)                                                          STEM0060
      DO 100 I=L,1,-1                                                   STEM0070
100   IF(C(I:I) .NE. ' ') GO TO 200                                     STEM0080
      I=0                                                               STEM0090
200   STRIM=I                                                           STEM0100
      END                                                               STEM0110
```

```
      FUNCTION RERR(V,ERT,ELAB,NKV,PREF)                                RERR0020
C     RETURNS RELATIVE ERROR OF VARIABLE RKVAR(NKV) IF PREF<>0 AND      RERR0030
C     THE ERROR IS GREATER THAN PREVIOUS ERROR 'V'.                     RERR0040
```

```
C     COMMON DECK "RKAM" INSERTED HERE
      REAL KR,KTH,KPH
      COMMON//R,TH,PH,KR,KTH,KPH,RKVARS(14),TPULSE,CSTEP,DRDT(20)
C
      RERR=V
      IF(NKV.LE.0) RETURN
      IF(PREF.EQ.0.) RETURN
      V1=RKVARS(NKV)/PREF-1.
      IF(ABS(V1).LT.ABS(V)) RETURN
C
      ERT=ELAB
      RERR=V1
      END
```

```
      SUBROUTINE RERROR(ROUTIN,STR,VAL)
C     REPORTS ERROR CONDITIONS AND STOPS PROGRAM.
C
      PRINT 10,ROUTIN,STR,VAL
10    FORMAT(39H ERROR CONDITION IN RAYTRACE ROUTINE <
     1  ,A8,10H> DUE TO " ,A10,9H", VALUE=  ,F8.2)
      STOP
      END
```

```
      SUBROUTINE STOPIT(A)
C     PRINTS CONDITION AND STOPS PROGRAM
C     AFTER CALLING THE SYSTEM POST MORTEM DUMP.
C
      CHARACTER A*(*)
C
      PRINT 100, A
      CALL MORTEM
100   FORMAT('*** STOPIT WITH CONDITION <',A,'>')
      STOP
      END
```

```
      SUBROUTINE PUTKST(NUNIT,STRG)
C     WRITE LINE OF OUTPUT TO PRINTER UNIT ADDING TO LINE COUNT
C
      CHARACTER STRG*(*)
      INTEGER STRIM
C
C     COMMON DECK "FLAG" INSERTED HERE
      LOGICAL NEWWR,NEWWP,NEWTRC,PENET
```

```
      COMMON /FLG/ NTYP,NEWWR,NEWWP,NEWTRC,PENET,LINES,IHOP,HPUNCH
      COMMON/FLGP/NSET
C
C     PUT OUT A STRING WITH LINE COUNT INCREMENT
      LINES=LINES+1
      LN=MAX0(1,MIN0(STRIM(STRG),132))
      WRITE(NUNIT,'(A)') STRG(1:LN)
      RETURN
      END
C



      SUBROUTINE PUTKCT(NUNIT,STRG)
C     PUT OUT A CENTERED LINE AND COUNT
      CHARACTER STRG*(*)
      CHARACTER BLANKS*100,STMP*80
      INTEGER STRIM
      CHARACTER PC*1
C
C     COMMON DECK "FLAG" INSERTED HERE
      LOGICAL NEWWR,NEWWP,NEWTRC,PENET
      COMMON /FLG/ NTYP,NEWWR,NEWWP,NEWTRC,PENET,LINES,IHOP,HPUNCH
      COMMON/FLGP/NSET
C
      DATA BLANKS/' '/
C
      NTRM=MAX0(1,STRIM(STRG))
      NBLKS=66-(NTRM+1)/2
      LINES=LINES+1
      LN=MIN0(NTRM,132-NBLKS)
      STMP=STRG
      WRITE(NUNIT,'(A)') BLANKS(:NBLKS)//STMP(:LN)
      RETURN
C
      ENTRY PUTKBK(NUNIT,NBKS)
C     PUT NBLKS BLANK LINES TO UNIT NUNIT
C
      LINES=LINES+1
      DO 100 I=1,NBKS
100      WRITE(NUNIT,'(1X)')
      RETURN
C
      ENTRY NEWPAG(NXP,LIP,PC)
C     THIS ENTRY COMPUTES NEXT PAGE NUMBER AND LINE COUNT TO END
C     OF CURRENT PAGE
C     RETAIN LINES PER PAGE FOR USE BY TSTPAG ENTRY
      LINSPP=LIP
C     THE LOGIC HERE ASSUMES THAT A FORM FEED IS ALWAYS NEEDED.
C     A MORE SOPHISTICATED VERSION WOULD DETERMINE IF A NEW PAGE
C     IS NEEDED AND RETURN PC=' ' IF NOT. THE CALLING PROGRAM COULD
C     USE OR IGNORE.
      PC='1'
```

```
C     COMPUTE CURRENT PAGE NUMBER
      NPAG=(LINES+LINSPP-1)/LINSPP
C     COMPUTE LINE COUNT AT END OF CURRENT PAGE
      LINES=NPAG*LINSPP
      NXP=NPAG+1
C     COMPUTE LINE COUNT AT END OF NEXT PAGE
      LNSXPG=LINES+LINSPP-1
      RETURN
C
      ENTRY TSTPAG(NUNIT)
C     OUTPUT HEADER IF HAVE REACHED LAST LINE OF PAGE
      IF(LINES.GE.LNSXPG) THEN
C     COMPUTE CURENT PAGE NUMBER
         NPAG=(LINES+LINSPP-1)/LINSPP
C     AND ITS LAST LINE
         LINES=NPAG*LINSPP
         LNSXPG=LINES+LINSPP-1
         NPAG=NPAG+1
         CALL PUTHDR(NUNIT,'1',NPAG)
         WRITE(NUNIT,'(1X)')
         LINES=LINES+1
      ENDIF
      END
```

```
      SUBROUTINE OPNREP(IUN,FNAME)
C     THIS OPEN OPERATION ALLOWS FOR AN EXISTING VERSION OF
C     A FILE. IF THE FILE EXISTS IT IS OVERWRITTEN.
C     THE LOGIC USED IS HOPEFULLY MACHINE INDEPENDENT.
      CHARACTER*(*) FNAME
      CALL ZAPFIL(IUN,FNAME)
      OPEN(IUN,FILE=FNAME,STATUS='NEW')
      REWIND IUN
      RETURN
      ENTRY OPNURP(IUN,FNAME)
      CALL ZAPFIL(IUN,FNAME)
      OPEN(IUN,FILE=FNAME,STATUS='NEW',FORM='UNFORMATTED')
      REWIND IUN
      END
```

```
      SUBROUTINE ZAPFIL(IUN,FNAME)
C     TEST FOR EXISTENCE OF FILE AND DELETE
      CHARACTER FNAME*(*)
      LOGICAL EX
      INQUIRE(FILE=FNAME,EXIST=EX)
      IF(EX) THEN
         OPEN(UNIT=IUN,FILE=FNAME,STATUS='OLD')
         CLOSE(UNIT=IUN,STATUS='DELETE')
```

```
      ENDIF
      END
```

```
      SUBROUTINE OVERRD(VAR,TST,DEFT,NFLG,NFVLEQ,NFVLNE)
C
C     OVERRIDE SUPPORT ROUTINE
C     TEST 'VAR' AGAINST 'TST', IF EQUAL SET TO DEFAULT 'DEFT'
C     AND ALSO SET INTEGER FLAG 'NFLG' TO VALUE 'NFVLEQ' ELSE 'NFVLNE'
C
      IF(VAR.EQ.TST) THEN
         VAR=DEFT
         NFLG=NFVLEQ
      ELSE
         NFLG=NFVLNE
      ENDIF
      RETURN
      END
```

```
      SUBROUTINE SFILTR(C,S,KSET)
C     FILTERS EXTRANEOUS CHARACTERS FROM PLOT LABELS
      CHARACTER*(*) C,S,KSET
C
      LN=LEN(C)
      J=0
      DO 10 I=1,LN
        IF(INDEX(KSET,C(I:I)).EQ.0) THEN
           J=J+1
           S(J:J)=C(I:I)
        ENDIF
10    CONTINUE
      RETURN
      END
```

```
      FUNCTION ALCOSH(X)
C     COMPUTE LOG(COSH(X)) AND USE LARGE ARGUMENT APPROXIMATION
C     WHEN POSSIBLE.
      DATA ALOG2/.6931471806/
C
      IF(ABS(X).GT.50.0) GO TO 10
      EX=EXP(X)
      ALCOSH=ALOG((EX+1.0/EX)*.5)
      RETURN
10    ALCOSH=ABS(X)-ALOG2
```

```
      END                                                               ALRH0120


      SUBROUTINE GAUSEL (C,NRD,NRR,NCC,NSF)                             GAKL0020
C     MATRIX INVERSION BY METHOD OF GAUSSIAN PIVOT                      GAKL0030
C     SOLVES NCC-NRR SETS OF NRR EQUATIONS                              GAKL0040
C********* SAME AS SUBROUTINE GAUSSEL WRITTEN BY L. DAVID LEWIS ********GAKL0050
      DIMENSION C(NRD,NCC),L(128,2)                                     GAKL0060
C           BITS = 2.**-18                                              GAKL0070
      DATA BITS/3.8146972656E-6/                                        GAKL0080
      NR=NRR                                                            GAKL0090
      NC=NCC                                                            GAKL0100
      IF(NC.LT.NR.OR.NR.GT.128.OR.NR.LE.0) CALL EXIT                    GAKL0110
C                                                                       GAKL0120
C           INITIALIZE.                                                 GAKL0130
      NSF=0                                                             GAKL0140
      NRM=NR-1                                                          GAKL0150
      NRP=NR+1                                                          GAKL0160
      D=1.                                                              GAKL0170
      LSD=1                                                             GAKL0180
      DO 1 KR=1,NR                                                      GAKL0190
      L(KR,1)=KR                                                        GAKL0200
1     L(KR,2)=0                                                         GAKL0210
      IF(NR.EQ.1) GO TO 42                                              GAKL0220
C                                                                       GAKL0230
C           ELIMINATION PHASE.                                          GAKL0240
      DO 41 KP=1,NRM                                                    GAKL0250
      KPP=KP+1                                                          GAKL0260
      PM=0.                                                             GAKL0270
      MPN=0                                                             GAKL0280
C                                                                       GAKL0290
C           SEARCH COLUMN KP FROM DIAGONAL DOWN FOR MAX PIVOT.          GAKL0300
      DO 2 KR=KP,NR                                                     GAKL0310
      LKR=L(KR,1)                                                       GAKL0320
      PT=ABS(C(LKR,KP))                                                 GAKL0330
      IF(PT.LE.PM) GO TO 2                                              GAKL0340
      PM=PT                                                             GAKL0350
      MPN=KR                                                            GAKL0360
      LMP=LKR                                                           GAKL0370
2     CONTINUE                                                          GAKL0380
C                                                                       GAKL0390
C           IF MAX PIVOT IS ZERO, MATRIX IS SINGULAR.                   GAKL0400
      IF(MPN.EQ.0) GO TO 9                                              GAKL0410
      NSF=NSF+1                                                         GAKL0420
      IF(MPN.EQ.KP) GO TO 3                                             GAKL0430
C                                                                       GAKL0440
C           NEW ROW NUMBER KP HAS MAX PIVOT.                            GAKL0450
      LSD=-LSD                                                          GAKL0460
      L(KP,2)=L(KP,1)                                                   GAKL0470
      L(MPN,1)=L(KP,1)                                                  GAKL0480
      L(KP,1)=LMP                                                       GAKL0490
C                                                                       GAKL0500
```

```
C          ROW OPERATIONS TO ZERO COLUMN KP BELOW DIAGONAL.
3       MKP=L(KP,1)
        P=C(MKP,KP)
        D=D*P
        DO 41 KR=KPP,NR
        MKR=L(KR,1)
        Q=C(MKR,KP)/P
        IF(Q.EQ.0.) GO TO 41
C
C          SUBTRACT Q * PIVOT ROW FROM ROW KR.
        DO 4 LC=KPP,NC
        R=Q*C(MKP,LC)
        C(MKR,LC)=C(MKR,LC)-R
4       IF(ABS(C(MKR,LC)).LT.ABS(R)*BITS) C(MKR,LC)=0.
41      CONTINUE
C
C          LOWER RIGHT HAND CORNER.
42      LNR=L(NR,1)
        P=C(LNR,NR)
        IF(P.EQ.0.) GO TO 9
        NSF=NSF+1
        D=D*P*LSD
        IF(NR.EQ.NC) GO TO 8
C
C          BACK SOLUTION PHASE.
        DO 61 MC=NRP,NC
        C(LNR,MC)=C(LNR,MC)/P
        IF(NR.EQ.1) GO TO 61
        DO 6 LL=1,NRM
        KR=NR-LL
        MR=L(KR,1)
        KRP=KR+1
        DO 5 MS=KRP,NR
        LMS=L(MS,1)
        R=C(MR,MS)*C(LMS,MC)
        C(MR,MC)=C(MR,MC)-R
5       IF(ABS(C(MR,MC)).LT.ABS(R)*BITS) C(MR,MC)=0.
6       C(MR,MC)=C(MR,MC)/C(MR,KR)
61      CONTINUE
C
C          SHUFFLE SOLUTION ROWS BACK TO NATURAL ORDER.
        DO 71 LL=1,NRM
        KR=NR-LL
        MKR=L(KR,2)
        IF(MKR.EQ.0) GO TO 71
        MKP=L(KR,1)
        DO 7 LC=NRP,NC
        Q=C(MKR,LC)
        C(MKR,LC)=C(MKP,LC)
7       C(MKP,LC)=Q
71      CONTINUE
C
C          NORMAL AND SINGULAR RETURNS.  GOOD SOLUTION COULD HAVE D=0.
8       C(1,1)=D
        GO TO 91
```

```
9     C(1,1)=0.                                                           GAKL1060
   91 RETURN                                                              GAKL1070
      END                                                                 GAKL1080
```

```
      SUBROUTINE RAYPLT                                                   RANT0020
C     MAIN PLOTTING PROGRAM; INITIALIZES, READS INPUT, PLOTS              RANT0030
C     PROJECTIONS OF RAYS ON A VERTICAL OR HORIZONTAL PLANE.              RANT0040
C        ABS(PLT)=1. PLOTS PROJECTION OF RAYPATH ON VERTICAL PLANE        RANT0050
C                    RECTANGULAR EXPANSION BY FACTOR 'PFACTR'             RANT0060
C                =2. PLOTS PROJECTION OF RAYPATH ON GROUND                RANT0070
C                =3. VERICAL PROJECTION USING RADIAL EXPANSION BY FACTO RANT0080
C                    'PFACTR'                                             RANT0090
C     COMMON DECK "FILEC" INSERTED HERE                                   CFIL0020
      COMMON /FILEC/NPLTDP                                                CFIL0040
      COMMON /PLT/ XL,XR,YB,YT,PRESET                                     RANT0110
      COMMON/PLT/RMIN,RMAX,ALPHA,APLT                                     RANT0120
C                                                                         RANT0130
C     COMMON DECK "CONST" INSERTED HERE                                   CCON0020
      COMMON/PCONST/CREF,RGAS,GAMMA                                       CCON0040
      COMMON/MCONST/PI,PIT2,PID2,DEGS,RAD,ALN10                           CCON0050
C     COMMON DECK "FLAG" INSERTED HERE                                    CFLA0020
      LOGICAL NEWWR,NEWWP,NEWTRC,PENET                                    CFLA0040
      COMMON /FLG/ NTYP,NEWWR,NEWWP,NEWTRC,PENET,LINES,IHOP,HPUNCH        CFLA0050
      COMMON/FLGP/NSET                                                    CFLA0060
C     COMMON DECK "RKAM" INSERTED HERE                                    RKAM0020
      REAL KR,KTH,KPH                                                     RKAM0040
      COMMON//R,TH,PH,KR,KTH,KPH,RKVARS(14),TPULSE,CSTEP,DRDT(20)         RKAM0050
C     COMMON DECK "WW" INSERTED HERE                                      CWW 0020
      PARAMETER (NWARSZ=1000)                                             CWW10030
      COMMON/WW/ID(10),MAXW,W(NWARSZ)                                     CWW10040
      REAL MAXSTP,MAXERR,INTYP,LLAT,LLON                                  CWW20020
      EQUIVALENCE (EARTHR,W(1)),(RAY,W(2)),(XMTRH,W(3)),(TLAT,W(4)),      CWW20030
     1 (TLON,W(5)),(OW,W(6)),(FBEG,W(7)),(FEND,W(8)),(FSTEP,W(9)),        CWW20040
     2 (AZ1,W(10)),(AZBEG,W(11)),(AZEND,W(12)),(AZSTEP,W(13)),            CWW20050
     3 (BETA,W(14)),(ELBEG,W(15)),(ELEND,W(16)),(ELSTEP,W(17)),           CWW20060
     8   (RUNSUP,W(18)),(RCVRH,W(20)),                                    CWW20070
     4 (ONLY,W(21)),(HOP,W(22)),(MAXSTP,W(23)),(PLAT,W(24)),(PLON,W(25))CWW20080
     5,(HMAX,W(26)),(RAYFNC,W(29)),(EXTINC,W(33)),                        CWW20090
     6 (HMIN,W(27)),(RGMAX,W(28)),                                        CWW20100
     8 (INTYP,W(41)),(MAXERR,W(42)),(ERATIO,W(43)),                       CWW20110
     6 (STEP1,W(44)),(STPMAX,W(45)),(STPMIN,W(46)),(FACTR,W(47)),         CWW20120
     7 (SKIP,W(71)),(RAYSET,W(72)),(PRTSRP,W(74)),(HITLET,W(75))          CWW20130
     9 ,(BINRAY,W(76)),(PAGLN,W(77)),(PLT,W(81)),(PFACTR,W(82)),          CWW20140
     1 (LLAT,W(83)),(LLON,W(84)),(RLAT,W(85)),(RLON,W(86))                CWW20150
     2,(TIC,W(87)),(HB,W(88)),(HT,W(89)),(TICV,W(96))                     CWW20160
      REAL MMODEL,MFORM,MID                                               CWW30020
C                                                                         CWW30030
C     WIND          100-124                                               CWW30040
      EQUIVALENCE (W(100),UMODEL),(W(101),UFORM),(W(102),UID)             CWW30050
C                                                                         CWW30060
C     DELTA WIND          125-149                                         CWW30070
```

```
      EQUIVALENCE (W(125),DUMODEL),(W(126),DUFORM),(W(127),DUID)        CWW30080
C                                                                       CWW30090
C     SOUND SPEED 150-174                                               CWW30100
      EQUIVALENCE (W(150),CMODEL),(W(151),CFORM),(W(152),CID)           CWW30110
      EQUIVALENCE (W(153),REFC)                                         CWW30120
C                                                                       CWW30130
C     DELTA SOUND SPEED 175-199                                         CWW30140
      EQUIVALENCE (W(175),DCMODEL),(W(176),DCFORM),(W(177),DCID)        CWW30150
C                                                                       CWW30160
C     TEMPERATURE    200-224                                            CWW30170
      EQUIVALENCE (W(200),TMODEL),(W(201),TFORM),(W(202),TID)           CWW30180
C                                                                       CWW30190
C     DELTA TEMPERATURE    225-249                                      CWW30200
      EQUIVALENCE (W(225),DTMODEL),(W(226),DTFORM),(W(227),DTID)        CWW30210
C                                                                       CWW30220
C     MOLECULAR   250-274                                               CWW30230
      EQUIVALENCE (W(250),MMODEL),(W(251),MFORM),(W(252),MID)           CWW30240
C                                                                       CWW30250
C     RECEIVER HEIGHT   275-299                                         CWW30260
      EQUIVALENCE (W(275),RMODEL),(W(276),RFORM),(W(277),RID)           CWW30270
C                                                                       CWW30280
C     TOPOGRAPHY   300-324                                              CWW30290
      EQUIVALENCE (W(300),GMODEL),(W(301),GFORM),(W(302),GID)           CWW30300
C                                                                       CWW30310
C     DELTA TOPOGRAPHY   325-349                                        CWW30320
      EQUIVALENCE (W(325),GUMODEL),(W(326),GUFORM),(W(327),GUID)        CWW30330
C                                                                       CWW30340
C     ATMOSPHERIC SURFACE TOPOGRAPHY   350-374                          CWW30350
      EQUIVALENCE (W(350),SMODEL),(W(351),SFORM),(W(352),SID)           CWW30360
C                                                                       CWW30370
C     ATMOSPHERIC SURFACE TOPOGRAPHY   375-399                          CWW30380
      EQUIVALENCE (W(375),SUMODEL),(W(376),SUFORM),(W(377),SUID)        CWW30390
C     PLOT ENHANCEMENTS CONTROL PARAMETERS                              CWW30400
C                                                                       CWW30410
      EQUIVALENCE (W(490),XFQMDL),(W(491),YFQMDL)                       CWW30420
C     ABSORPTION          500-524                                       CWW30430
      EQUIVALENCE (W(500),AMODEL),(W(501),AFORM),(W(502),AID)           CWW30440
C                                                                       CWW30450
C     DELTA ABSORPTION          525-549                                 CWW30460
      EQUIVALENCE (W(525),DAMODEL),(W(526),DAFORM),(W(527),DAID)        CWW30470
C                                                                       CWW30480
C     PRESSURE         550-574                                          CWW30490
      EQUIVALENCE (W(550),PMODEL),(W(551),PFORM),(W(552),PID)           CWW30500
C                                                                       CWW30510
C     DELTA PRESSURE         575-599                                    CWW30520
      EQUIVALENCE (W(575),DPMODEL),(W(576),DPFORM),(W(577),DPID)        CWW30530
C                                                                       CWW30540
      REAL LTIC                                                         RANT0180
      INTEGER IWDMP(411)                                                RANT0190
      EQUIVALENCE(IWDMP,ID)                                             RANT0200
C                                                                       RANT0210
      EXTERNAL PLOT,PLTLB,PLTLBN,PLTHLB                                 RANT0220
C                                                                       RANT0230
      DATA NWDSRK/4/                                                    RANT0240
C                                                                       RANT0250
```

```
      IF (.NOT.NEWWR) GO TO 8
      APLT=ABS(PLT)
C
C          NEW W ARRAY -- REINITIALIZE
      NEWWR=.FALSE.
      PRESET=1.
C     IF NO ACTIVE PLOTTING,WE ARE STILL DUMPING DATA
      IF(PLT.EQ.0) GO TO 5
C     INITIALIZE ANNOTATION MODEL
C  CONVERT COORDINATES OF VERTICAL PLANE FROM GEOGRAPHIC TO GEOMAGNETIC
      SW=SIN (PLAT)
      CW=SIN (PID2-PLAT)
      SLM=SIN (LLAT)
      CLM=SIN (PID2-LLAT)
      SRM=SIN (RLAT)
      CRM=SIN (PID2-RLAT)
      CDPHI=SIN (PID2-(LLON-PLON))
      PHL=ATAN2(SIN (LLON-PLON)*CLM,CDPHI*SW*CLM-CW*SLM)
      CTHL=CDPHI*CW*CLM+SW*SLM
      STHL=SIN (ACOS (CTHL))
      CDPHI=SIN (PID2-(RLON-PLON))
      PHR=ATAN2(SIN (RLON-PLON)*CRM,CDPHI*SW*CRM-CW*SRM)
      CTHR=CDPHI*CW*CRM+SW*SRM
      STHR=SIN (ACOS (CTHR))
      CLR=CTHL*CTHR+STHL*STHR*SIN (PID2-(PHL-PHR))
      ALPHA=.5*ACOS (CLR)
      SLR=SQRT (1.-CLR**2)
C
      IF (APLT.EQ.2.) GO TO 3
C
C     VERTICAL PROJECTIONS ONLY
      T=HB
      HB=AMIN1(T,HT)
      HT=AMAX1(T,HT)
      RMIN=EARTHR+HB
      YT1=YT
      RMAX=EARTHR+HT
C
      IF(APLT.NE.4.) GO TO 100
C
C     SCALE FOR CARTESIAN PROJECTION(=4)
      XR=ALPHA
      XR1=XR
      XL=-XR
      XL1=XL
      YB=RMIN
      YT=RMAX
      GO TO 5
C
C     PROJECTIONS 1 AND 3
100   XR1=RMIN*SIN (ALPHA)
      XL1=-XR1
      YB=RMIN*SIN (PID2-ALPHA)
      IF(APLT.EQ.3.) RMAX=RMIN+(RMAX-RMIN)*PFACTR
      XR=AMAX1(RMAX*SIN(ALPHA),(RMAX-YB)/2.)
```

```
      XL=-XR
      YT1=RMAX*(YB/RMIN)
      YT=2.0*XR
      IF(APLT.EQ.1) YT=YT/PFACTR
      YT=YT+YB
      GO TO 5
C
C     HORIZONTAL PROJECTION(=2)
3     ALPH1=ATAN2(STHR*SIN (PHR-PHL),(CTHR-CTHL*CLR)/STHL)
      XL=0.0
      XL1=0.0
      XR=EARTHR*2.0*ALPHA
      XR1=XR
C USE 90% OF X-RANGE FOR Y-RANGE
      RMAX=0.5*(0.90*XR)/PFACTR
      YT=RMAX
      RMIN=-RMAX
      YB=RMIN
C
5     IF(NPLTDP.LE.0) GO TO 8
      WRITE(NPLTDP) 1,NWDSRK,1,411
      WRITE(NPLTDP) (IWDMP(I),I=1,411)
C
8     NEW=0
      IF (NEWTRC) NEW=1
      NEWTRC=.FALSE.
C
      IF(NPLTDP.LE.0) GO TO 88
      IF(NEW.NE.1) GO TO 84
      WRITE(NPLTDP) 1,NWDSRK,17,25
      WRITE(NPLTDP) (IWDMP(I),I=17,25)
C
84    WRITE(NPLTDP) 3-NEW,R,TH,PH
C
88    IF(PLT.EQ.0) RETURN
C
      STH=SIN (TH)
      CTH=SIN (PID2-TH)
      CR=CTHR*CTH+STHR*STH*SIN (PID2-(PHR-PH))
      CL=CTHL*CTH+STHL*STH*SIN (PID2-(PHL-PH))
      CEA=ATAN2(CR-CL*CLR,CL*SLR)
C
      IF(APLT.NE.4.) GO TO 150
      CALL PLOT(CEA-ALPHA,R,NEW)
      RETURN
C
150   IF(APLT.EQ.2.) GO TO 10
      RX=R
      IF(APLT.EQ.3.) RX=RMIN+(R-RMIN)*PFACTR
      CALL PLOT(CEA-ALPHA,RX,NEW)
      RETURN
C
10    SL=SQRT(AMAX1(0.,1.-CL**2))
      TMP1=STH*SIN (PH-PHL)
      TMP2=(CTH-CTHL*CL)/STHL
```

```
      ALPH2=0.
      IF (TMP1.NE.0..OR.TMP2.NE.0.) ALPH2=ATAN2(TMP1,TMP2)
      CALL PLOT (EARTHR*CEA,EARTHR*ASIN(SL*SIN (ALPH1-ALPH2)),NEW)
      RETURN
C
C          DRAW AXES AND CALL FOR LABELING AND TERMINATION OF THIS PLOT
      ENTRY ENDPLT
C
C     IF NEWWR IS STILL TRUE, NO PLOTS WHERE PRODUCED
      IF(NEWWR) RETURN
      NEWWR=.TRUE.
C
C     SIGNAL END OF PLOT
      IF(NPLTDP.GT.0) WRITE(NPLTDP) 4,(NWDSRK,I=2,NWDSRK)
C
      IF(PLT.EQ.0) RETURN
C
      TICKX=0.01*(YT-YB)
      DTIC=TIC*EARTHR
      CALL SETXY(APLT,-ALPHA,RMIN,ALPHA,RMAX)
C
      IF(APLT.EQ.4.) GO TO 200
      IF(APLT.EQ.2.) GO TO 25
C
C     CURVLINEAR PROJECTIONS(=1,3)
      CALL ARCTIC(-ALPHA,ALPHA,RMIN,TICKX,PLTHLB)
      CALL ARCTIC(-ALPHA,ALPHA,RMAX,-TICKX,PLTHLB)
      GO TO 300
C
C     CARTESIAN PROJECTION PUT IN BOTTOM BOUNDARY
200   CALL TIKLINE(-ALPHA,RMIN,ALPHA,RMIN,TIC,-TICKX,PLTHLB)
C     PUT IN TOP BOUNDARY
      CALL TIKLINE(-ALPHA,RMAX,ALPHA,RMAX,TIC,TICKX,PLTHLB)
C
300   TIKL=.02*ALPHA
      LTIC=TICV
      IF(APLT.EQ.3.) LTIC=TICV*PFACTR
C     PUT IN LEFT BOUNDARY
      CALL TIKLINE(-ALPHA,RMIN,-ALPHA,RMAX,LTIC,TIKL,PLTLB)
C     PUT IN RIGHT BOUNDARY
      CALL TIKLINE(ALPHA,RMIN,ALPHA,RMAX,LTIC,-TIKL,PLTLBN)
C
      GO TO 50
C   DRAW TICKS, BOX FOR HORIZONTAL PLOT
25    CALL DRAWTKS(DTIC,TICV,XL,XR,YB,YT,PLOT)
C
50    IF(APLT.EQ.2.0) THEN
        CALL PLTANOT(ID,OW/PIT2,XFQMDL,YFQMDL,XL,YB,XR,YT,DEGS,
     2      LLAT,LLON,RLAT,RLON,HB,HT,APLT,DTIC,DTIC/PFACTR,PLOT)
      ELSE
        CALL PLTANOT(ID,OW/PIT2,XFQMDL,YFQMDL,-ALPHA,RMIN,ALPHA,RMAX,
     2      DEGS,LLAT,LLON,RLAT,RLON,HB,HT,APLT,DTIC,TICV,PLOT)
      ENDIF
C
      CALL LABPLT
```

```
      CALL PLTEND                                                       RANT1910
      RETURN                                                            RANT1920
      END                                                               RANT1930


      SUBROUTINE PLOT (X,Y,NEW)                                         PLOT0020
C     PLOTS ONE VECTOR FROM CURRENT PLOT POSITION TO POINT(X,Y)         PLOT0030
C     TAKING BORDER CROSSINGS INTO ACCOUNT.                             PLOT0040
      COMMON /PLT/ XMIN0,XMAX0,YMIN0,YMAX0,RESET                        PLOT0050
      COMMON/PLT/RMIN,RMAX,ALPHA,APLT                                   PLOT0060
      INTEGER REZFLG                                                    DDHI0020
      PARAMETER (REZFLG=2001)                                           DDHI0030
      COMMON/DDREZ/DDHIX,DDHIY                                          DDHI0040
      COMMON /DD/ INT,IOR,IT,IS,IC,ICC,IX,IY                            PLOT0080
C DEFINE NOMINAL PLOTTING AREA(ZERO SUFFIXES) AND AN                    PLOT0090
C OUTER CLIPPING BOUNDARY BEYOND WHICH NO VECTORS EXTEND.               PLOT0100
      DATA XOLD,YOLD/0.0,0.0/                                           PLOT0110
C 90% FOR Y RANGE                                                       PLOT0120
C                                                                       PLOT0130
C            COMPUTE SCALE FACTORS                                      PLOT0140
    1 IF (RESET.EQ.0.) GO TO 5                                          PLOT0150
      RESET=0.                                                          PLOT0160
      IF(APLT.EQ.2.) THEN                                               PLOT0170
         MRNGE=723                                                      PLOT0180
         MINX0=165                                                      PLOT0190
         MINY0=140                                                      PLOT0200
      ELSE                                                              PLOT0210
         MRNGE=813                                                      PLOT0220
         MINX0=165                                                      PLOT0230
         MINY0=140                                                      PLOT0240
      ENDIF                                                             PLOT0250
      IF(APLT.EQ.4.) MINY0=0                                            PLOT0260
C                                                                       PLOT0270
      MAXX0=MINX0+MRNGE                                                 PLOT0280
      MAXY0=MINY0+MRNGE                                                 PLOT0290
C                                                                       PLOT0300
      XSCALE=(MAXX0-MINX0)/(XMAX0-XMIN0)                                PLOT0310
      YSCALE=(MAXY0-MINY0)/(YMAX0-YMIN0)                                PLOT0320
      XMIN=XMIN0                                                        PLOT0330
      YMIN=YMIN0                                                        PLOT0340
      XMAX=XMAX0                                                        PLOT0350
      YMAX=YMAX0                                                        PLOT0360
      IF(APLT.EQ.2.) GO TO 5                                            PLOT0370
C                                                                       PLOT0380
      XMIN=-ALPHA                                                       PLOT0390
      XMAX=ALPHA                                                        PLOT0400
      YMIN=RMIN                                                         PLOT0410
      YMAX=RMAX                                                         PLOT0420
      IF(APLT.NE.4) GO TO 5                                             PLOT0430
      YSCALE=.85*YSCALE                                                 PLOT0440
      MINY0=MINY0+60                                                    PLOT0450
C                                                                       PLOT0460
```

```
C          START A NEW LINE
C          HORIZONTAL DISPLACEMENT
5      XS=X-XOLD
       YS=Y-YOLD
       S=1.0
       IF(NEW.EQ.0) GO TO 10
       IF(X.GE.XMIN.AND.X.LE.XMAX.AND.Y.GE.YMIN.AND.Y.LE.YMAX) GO TO 48
       GO TO 50
C
10     IF (XS) 11,12,16
C          NEGATIVE
   11  X1=XMAX
       X2=XMIN
       GO TO 20
C          ZERO
   12  IF (YS) 13,50,14
   13  S1=(YMAX-YOLD)/YS
       S2=(YMIN-YOLD)/YS
       GO TO 40
   14  S1=(YMIN-YOLD)/YS
       S2=(YMAX-YOLD)/YS
       GO TO 40
C          POSITIVE
   16  X1=XMIN
       X2=XMAX
C
C          VERTICAL DISPLACEMENT
   20  IF (YS) 21,22,26
C          NEGATIVE
   21  Y1=YMAX
       Y2=YMIN
       GO TO 30
C          ZERO
   22  S1=(X1-XOLD)/XS
       S2=(X2-XOLD)/XS
       GO TO 40
C          POSITIVE
   26  Y1=YMIN
       Y2=YMAX
C
   30  S1=AMAX1((X1-XOLD)/XS,(Y1-YOLD)/YS)
       S2=AMIN1((X2-XOLD)/XS,(Y2-YOLD)/YS)
C
C          PLOT LINE -- CHECKING FOR BORDER CROSSINGS
40     IF (S2.LT.0..OR.S1.GT.1.) GO TO 50
       IF (S1.LT.0.) GO TO 42
C          PREVIOUS POINT OFF GRAPH
       XP=XOLD+XS*S1
       YP=YOLD+YS*S1
       IF(APLT.EQ.2.0.OR.APLT.EQ.4.0) GO TO 41
       T=XP
       XP=YP*SIN(T)
       YP=YP*COS(T)
C
41     DDHIX=MINX0+(XP-XMIN0)*XSCALE+0.5
```

```
      DDHIY=MINY0+(YP-YMIN0)*YSCALE+0.5                                 PLOT1020
C     USE SPECIAL HI-REZ MODE                                           PLOT1030
      IX=REZFLG                                                         PLOT1040
      CALL DDBP                                                         PLOT1050
      GO TO 48                                                          PLOT1060
C                                                                       PLOT1070
42    IF (S2.GT.1.) GO TO 48                                            PLOT1080
C          CURRENT POINT OFF GRAPH                                      PLOT1090
      S=S2                                                              PLOT1100
C          CURRENT POINT ON GRAPH                                       PLOT1110
48    XP=XOLD+XS*S                                                      PLOT1120
      YP=YOLD+YS*S                                                      PLOT1130
      IF(APLT.EQ.2.0.OR.APLT.EQ.4.0) GO TO 49                           PLOT1140
      T=XP                                                              PLOT1150
      XP=YP*SIN(T)                                                      PLOT1160
      YP=YP*COS(T)                                                      PLOT1170
49    DDHIX=MINX0+(XP-XMIN0)*XSCALE+0.5                                 PLOT1180
      DDHIY=MINY0+(YP-YMIN0)*YSCALE+0.5                                 PLOT1190
C     USE SPECIAL HI-REZ MODE                                           PLOT1200
      IX=REZFLG                                                         PLOT1210
      IF(NEW.EQ.0) CALL DDVC                                            PLOT1220
      IF(NEW.NE.0) CALL DDBP                                            PLOT1230
C                                                                       PLOT1240
C          EXIT ROUTINE                                                 PLOT1250
   50 XOLD=X                                                            PLOT1260
      YOLD=Y                                                            PLOT1270
      RETURN                                                            PLOT1280
C                                                                       PLOT1290
C          TERMINATE THE CURRENT PLOT                                   PLOT1300
      ENTRY PLTEND(X,Y,NEW)                                             PLOT1310
      CALL DDFR                                                         PLOT1320
C                                                                       PLOT1330
      RETURN                                                            PLOT1340
         END                                                            PLOT1350
```

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      SUBROUTINE LABPLT                                                 LAOT0020
C          LABEL THE CURRENT PLOT                                       LAOT0030
      CHARACTER*80 LABEL,CHID                                           LAOT0040
      CHARACTER*4 ANGRANG,ANOTE                                         LAOT0050
C     COMMON DECK "LL" INSERTED HERE                                    CLL 0020
      REAL MODL                                                         CLL 0040
      COMMON/LL/MODL(4),APH,APHPT,APHPR,APHPTH,APHPPH                   CLL 0050
C     COMMON DECK "SS" INSERTED HERE                                    CSS 0020
      REAL MODSURF                                                      CSS 0040
      COMMON/SS/ MODSURF(4)                                             CSS 0050
      COMMON/SS/U,PUR,PURR,PURTH,PURPH                                  CSS 0060
      COMMON/SS/PUTH,PUPH,PUTHTH,PUPHPH,PUTHPH,USELECT,UTIME            CSS 0070
C     COMMON DECK "GG" INSERTED HERE                                    CGG 0020
      REAL MODG                                                         CGG 0040
      COMMON/GG/MODG(4)                                                 CGG 0050
      COMMON/GG/G,PGR,PGRR,PGRTH,PGRPH                                  CGG 0060
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```
      COMMON/GG/PGTH,PGPH,PGTHTH,PGPHPH,PGTHPH,GSELECT,GTIME            CGG 0070
C     COMMON DECK "RR" INSERTED HERE                                    CRR 0020
      REAL MODREC                                                       CRR 0040
      COMMON/RR/ MODREC(4)                                              CRR 0050
      COMMON/RR/F,PFR,PFRR,PFRTH,PFRPH                                  CRR 0060
      COMMON/RR/PFTH,PFPH,PFTHTH,PFPHPH,PFTHPH,FSELECT,FTIME            CRR 0070
C     COMMON DECK "UU" INSERTED HERE                                    CUU 0020
      REAL MODU                                                         CUU 0040
      COMMON/UU/MODU(4)                                                 CUU 0050
     1   ,V   ,PVT   ,PVR   ,PVTH   ,PVPH                               CUU 0060
     2   ,VR  ,PVRT  ,PVRR  ,PVRTH  ,PVRPH                              CUU 0070
     3   ,VTH,PVTHT,PVTHR,PVTHTH,PVTHPH                                 CUU 0080
     4   ,VPH,PVPHT,PVPHR,PVPHTH,PVPHPH                                 CUU 0090
C     COMMON DECK "CC" INSERTED HERE                                    CCC 0020
      REAL MODC                                                         CCC 0040
      COMMON/CC/MODC(4),CS,PCST,PCSR,PCSTH,PCSPH                        CCC 0050
C     COMMON DECK "TT" INSERTED HERE                                    CTT 0020
      REAL MODT                                                         CTT 0040
      COMMON/TT/MODT(4), T,PTT,PTR,PTTH,PTPH                            CTT 0050
C     COMMON DECK "MM" INSERTED HERE                                    CMM 0020
      REAL M,MODM                                                       CMM 0040
      COMMON/MM/MODM(4),M,PMT,PMR,PMTH,PMPH                             CMM 0050
C     COMMON DECK "HDR" INSERTED HERE                                   CHDR0020
      CHARACTER*10 INITID*80,DAT,TOD                                    CHDR0040
      COMMON/HDR/SEC                                                    CHDR0050
      COMMON/HDRC/INITID,DAT,TOD                                        CHDR0060
C     COMMON DECK "RINPLEX" INSERTED HERE                               CRIN0020
      REAL KAY2,KAY2I                                                   CRIN0040
      COMPLEX PNP,POLAR,LPOLAR                                          CRIN0050
      LOGICAL SPACE                                                     CRIN0060
      CHARACTER DISPM*6                                                 CRIN0070
      COMMON/RINPL/DISPM                                                CRIN0080
      COMMON /RIN/ MODRIN(8),RAYNAME(2,3),TYPE(3),SPACE                 CRIN0090
      COMMON/RIN/OMEGMIN,OMEGMAX,KAY2,KAY2I                             CRIN0100
      COMMON/RIN/PNP(10),POLAR,LPOLAR,SGN                               CRIN0110
      COMMON /DD/ INT,IOR,IT,IS,IC,ICC,IX,IY                            LAOT0160
C     COMMON DECK "CONST" INSERTED HERE                                 CCON0020
      COMMON/PCONST/CREF,RGAS,GAMMA                                     CCON0040
      COMMON/MCONST/PI,PIT2,PID2,DEGS,RAD,ALN10                         CCON0050
C     COMMON DECK "FLAG" INSERTED HERE                                  CFLA0020
      LOGICAL NEWWR,NEWWP,NEWTRC,PENET                                  CFLA0040
      COMMON /FLG/ NTYP,NEWWR,NEWWP,NEWTRC,PENET,LINES,IHOP,HPUNCH      CFLA0050
      COMMON/FLGP/NSET                                                  CFLA0060
C     COMMON DECK "WW" INSERTED HERE                                    CWW 0020
      PARAMETER (NWARSZ=1000)                                           CWW10030
      COMMON/WW/ID(10),MAXW,W(NWARSZ)                                   CWW10040
      REAL MAXSTP,MAXERR,INTYP,LLAT,LLON                                CWW20020
      EQUIVALENCE (EARTHR,W(1)),(RAY,W(2)),(XMTRH,W(3)),(TLAT,W(4)),    CWW20030
     1 (TLON,W(5)),(OW,W(6)),(FBEG,W(7)),(FEND,W(8)),(FSTEP,W(9)),      CWW20040
     2 (AZ1,W(10)),(AZBEG,W(11)),(AZEND,W(12)),(AZSTEP,W(13)),          CWW20050
     3 (BETA,W(14)),(ELBEG,W(15)),(ELEND,W(16)),(ELSTEP,W(17)),         CWW20060
     8   (RUNSUP,W(18)),(RCVRH,W(20)),                                  CWW20070
     4 (ONLY,W(21)),(HOP,W(22)),(MAXSTP,W(23)),(PLAT,W(24)),(PLON,W(25))CWW20080
     5,(HMAX,W(26)),(RAYFNC,W(29)),(EXTINC,W(33)),                      CWW20090
     6 (HMIN,W(27)),(RGMAX,W(28)),                                      CWW20100
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     8 (INTYP,W(41)),(MAXERR,W(42)),(ERATIO,W(43)),                     CWW20110
     6 (STEP1,W(44)),(STPMAX,W(45)),(STPMIN,W(46)),(FACTR,W(47)),      CWW20120
     7 (SKIP,W(71)),(RAYSET,W(72)),(PRTSRP,W(74)),(HITLET,W(75))       CWW20130
     9 ,(BINRAY,W(76)),(PAGLN,W(77)),(PLT,W(81)),(PFACTR,W(82)),       CWW20140
     1 (LLAT,W(83)),(LLON,W(84)),(RLAT,W(85)),(RLON,W(86))             CWW20150
     2,(TIC,W(87)),(HB,W(88)),(HT,W(89)),(TICV,W(96))                  CWW20160
      REAL MMODEL,MFORM,MID                                             CWW30020
C                                                                       CWW30030
C     WIND         100-124                                              CWW30040
      EQUIVALENCE (W(100),UMODEL),(W(101),UFORM),(W(102),UID)           CWW30050
C                                                                       CWW30060
C     DELTA WIND         125-149                                        CWW30070
      EQUIVALENCE (W(125),DUMODEL),(W(126),DUFORM),(W(127),DUID)        CWW30080
C                                                                       CWW30090
C     SOUND SPEED 150-174                                               CWW30100
      EQUIVALENCE (W(150),CMODEL),(W(151),CFORM),(W(152),CID)           CWW30110
      EQUIVALENCE (W(153),REFC)                                         CWW30120
C                                                                       CWW30130
C     DELTA SOUND SPEED 175-199                                         CWW30140
      EQUIVALENCE (W(175),DCMODEL),(W(176),DCFORM),(W(177),DCID)        CWW30150
C                                                                       CWW30160
C.    TEMPERATURE    200-224                                            CWW30170
      EQUIVALENCE (W(200),TMODEL),(W(201),TFORM),(W(202),TID)           CWW30180
C                                                                       CWW30190
C     DELTA TEMPERATURE    225-249                                      CWW30200
      EQUIVALENCE (W(225),DTMODEL),(W(226),DTFORM),(W(227),DTID)        CWW30210
C                                                                       CWW30220
C     MOLECULAR   250-274                                               CWW30230
      EQUIVALENCE (W(250),MMODEL),(W(251),MFORM),(W(252),MID)           CWW30240
C                                                                       CWW30250
C     RECEIVER HEIGHT   275-299                                         CWW30260
      EQUIVALENCE (W(275),RMODEL),(W(276),RFORM),(W(277),RID)           CWW30270
C                                                                       CWW30280
C     TOPOGRAPHY   300-324                                              CWW30290
      EQUIVALENCE (W(300),GMODEL),(W(301),GFORM),(W(302),GID)           CWW30300
C                                                                       CWW30310
C     DELTA TOPOGRAPHY   325-349                                        CWW30320
      EQUIVALENCE (W(325),GUMODEL),(W(326),GUFORM),(W(327),GUID)        CWW30330
C                                                                       CWW30340
C     ATMOSPHERIC SURFACE TOPOGRAPHY   350-374                          CWW30350
      EQUIVALENCE (W(350),SMODEL),(W(351),SFORM),(W(352),SID)           CWW30360
C                                                                       CWW30370
C     ATMOSPHERIC SURFACE TOPOGRAPHY   375-399                          CWW30380
      EQUIVALENCE (W(375),SUMODEL),(W(376),SUFORM),(W(377),SUID)        CWW30390
C     PLOT ENHANCEMENTS CONTROL PARAMETERS                              CWW30400
C                                                                       CWW30410
      EQUIVALENCE (W(490),XFQMDL),(W(491),YFQMDL)                       CWW30420
C     ABSORPTION         500-524                                        CWW30430
      EQUIVALENCE (W(500),AMODEL),(W(501),AFORM),(W(502),AID)           CWW30440
C                                                                       CWW30450
C     DELTA ABSORPTION         525-549                                  CWW30460
      EQUIVALENCE (W(525),DAMODEL),(W(526),DAFORM),(W(527),DAID)        CWW30470
C                                                                       CWW30480
C     PRESSURE         550-574                                          CWW30490
      EQUIVALENCE (W(550),PMODEL),(W(551),PFORM),(W(552),PID)           CWW30500
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C
C     DELTA PRESSURE          575-599                                     CWW30510
      EQUIVALENCE (W(575),DPMODEL),(W(576),DPFORM),(W(577),DPID)          CWW30520
C                                                                         CWW30530
C                                                                         CWW30540
C     COMMON DECK "AA" INSERTED HERE                                      LAOT0200
      REAL MODA                                                           CAA 0020
      REAL MU,MUPT,MUPR,MUPTH,MUPPH                                       CAA 0040
      REAL KAP,KAPPT,KAPPR,KAPPTH,KAPPPH                                  CAA 0050
      COMMON/AA/MODA(4),MU,MUPT,MUPR,MUPTH,MUPPH                          CAA 0060
      COMMON/AA/KAP,KAPPT,KAPPR,KAPPTH,KAPPPH                             CAA 0070
C     COMMON DECK "PP" INSERTED HERE                                      CAA 0080
      REAL MODP                                                           CPP 0020
      COMMON/PP/MODP(4),P,PPT,PPR,PPTH,PPPH                               CPP 0040
C                                                                         CPP 0050
      WRITE(LABEL,900) ID                                                 LAOT0230
900   FORMAT(10A8)                                                        LAOT0240
      CHID=LABEL                                                          LAOT0250
      LABEL=CHID(5:)                                                      LAOT0260
      IOR=0                                                               LAOT0270
      IT=0                                                                LAOT0280
      IS=2                                                                LAOT0290
      IX=0                                                                LAOT0300
      IY=1023                                                             LAOT0310
      CALL DDTEXT (8,LABEL)                                               LAOT0320
      IX=1090                                                             LAOT0330
      IY=0                                                                LAOT0340
      CALL DDTEXT (2,DAT)                                                 LAOT0350
      IY=1023                                                             LAOT0360
      F=OW/PIT2                                                           LAOT0370
      NANGLE=10                                                           LAOT0380
      ANGRANG='EL ='                                                      LAOT0390
      ANOTE='AZ ='                                                        LAOT0400
      ANEL=0.                                                             LAOT0410
      IF(ELSTEP.NE.0.0) ANEL=(ELEND-ELBEG)/ELSTEP+1.5                     LAOT0420
      IF(ANEL.GT.1.0.OR.PLT.LT.0.0) GO TO 100                             LAOT0430
         ANGRANG='AZ ='                                                   LAOT0440
         ANOTE='EL ='                                                     LAOT0450
         NANGLE=14                                                        LAOT0460
100   WRITE(LABEL,1300)  CHID(1:3),F,ANOTE,W(NANGLE)*DEGS                 LAOT0470
1300  FORMAT ('MODEL = ',A,'  ,FREQ =',F9.3,' HZ, ',A,F7.3,' DEG')        LAOT0480
      IX=0                                                                LAOT0490
      IY=IY-32                                                            LAOT0500
      CALL DDTEXT (7,LABEL)                                               LAOT0510
C                                                                         LAOT0520
C INDEX OF OPPOSITE ANGLE                                                 LAOT0530
      NANGLE=(10+14-NANGLE)+1                                             LAOT0540
      NANGLE2=NANGLE+2                                                    LAOT0550
      WRITE(LABEL,1400) ANGRANG,(W(I)*DEGS,I=NANGLE,NANGLE2)              LAOT0560
1400  FORMAT(A,F7.2,' DEG TO',F7.2,' DEG, STEP =',F7.2,' DEG')            LAOT0570
      IY=IY-32                                                            LAOT0580
      CALL DDTEXT (7,LABEL)                                               LAOT0590
C                                                                         LAOT0600
      WRITE(LABEL,1500) XMTRH,TLAT*DEGS,TLON*DEGS                         LAOT0610
1500  FORMAT('XMTR HT =',F6.2,' KM ,LAT =',F6.2,' DEG, LONG ='            LAOT0620
                                                                          LAOT0630
```

```
     1    ,F6.2,' DEG')
      IY=IY-32
      CALL DDTEXT (7,LABEL)
C
      IY=IY-32
      WRITE(LABEL,'(10A8)') MODRIN
      CALL DDTEXT(8,LABEL)
C
      IX=1050
      CALL DDTEXT(1,'MODELS')
      IY=IY-15
C     LOOP FOR 8 MODELS AND PERTURBATIONS
      DO 1700 K=1,12
      I=(K-1)/2+1
C     GENERATE ALTERNATING 1,2;3,4 SERIES FOR MODEL AND PERTURBATION
      J1=2*(K+1-I*2)+1
      J2=J1+1
      IF(I.EQ.1) WRITE(LABEL,1600) (MODU(J),J=J1,J2)
      IF(I.EQ.2) WRITE(LABEL,1600) (MODC(J),J=J1,J2)
C
      IF(I.EQ.3) WRITE(LABEL,1600) (MODG(J),J=J1,J2)
      IF(I.EQ.4) WRITE(LABEL,1600) (MODL(J),J=J1,J2)
      IF(I.EQ.5 .AND. J1.EQ.1)
     1     WRITE(LABEL,1600) (MODREC(J),J=J1,J2)
      IF(I.EQ.6) WRITE(LABEL,1600) (MODSURF(J),J=J1,J2)
1600  FORMAT(2(2(A8,2X,F5.1,1X),2X))
C
1610  IF(LABEL(1:1).EQ.' ') GO TO 1700
      IY=IY-32
      CALL DDTEXT(2,LABEL)
1700  LABEL(1:1)=' '
C
         END
```

```
      SUBROUTINE PLTHLB(X,Y,NC)
C     HORIZONTAL TICK ANNOTATION ROUTINE FOR RAYPLOT.
C
C
      EXTERNAL PLOT
C
      CALL PLTANH(X,Y,NC,PLOT)
      END
```

```
      SUBROUTINE PLTANH(X,Y,NC,PLOT)
C
C     TIC LABELING ROUTINE FOR HORIZONTAL PLOT PROJECTIONS
C
```

```
      CHARACTER ANNOT*10                                                PLRH0060
      COMMON/DD/IN,IOR,IT,IS,IC,ICC,IX,IY                               PLRH0070
C     COMMON DECK "WWR" INSERTED HERE                                   CWWR0020
      PARAMETER (NWARSZ=1000)                                           CWW10030
      COMMON/WW/ID(10),MAXW,W(NWARSZ)                                   CWW10040
      REAL MAXSTP,MAXERR,INTYP,LLAT,LLON                                CWW20020
      EQUIVALENCE (EARTHR,W(1)),(RAY,W(2)),(XMTRH,W(3)),(TLAT,W(4)),    CWW20030
     1 (TLON,W(5)),(OW,W(6)),(FBEG,W(7)),(FEND,W(8)),(FSTEP,W(9)),      CWW20040
     2 (AZ1,W(10)),(AZBEG,W(11)),(AZEND,W(12)),(AZSTEP,W(13)),          CWW20050
     3 (BETA,W(14)),(ELBEG,W(15)),(ELEND,W(16)),(ELSTEP,W(17)),         CWW20060
     8   (RUNSUP,W(18)),(RCVRH,W(20)),                                  CWW20070
     4 (ONLY,W(21)),(HOP,W(22)),(MAXSTP,W(23)),(PLAT,W(24)),(PLON,W(25))CWW20080
     5,(HMAX,W(26)),(RAYFNC,W(29)),(EXTINC,W(33)),                      CWW20090
     6 (HMIN,W(27)),(RGMAX,W(28)),                                      CWW20100
     8 (INTYP,W(41)),(MAXERR,W(42)),(ERATIO,W(43)),                     CWW20110
     6 (STEP1,W(44)),(STPMAX,W(45)),(STPMIN,W(46)),(FACTR,W(47)),       CWW20120
     7 (SKIP,W(71)),(RAYSET,W(72)),(PRTSRP,W(74)),(HITLET,W(75))        CWW20130
     9 ,(BINRAY,W(76)),(PAGLN,W(77)),(PLT,W(81)),(PFACTR,W(82)),        CWW20140
     1 (LLAT,W(83)),(LLON,W(84)),(RLAT,W(85)),(RLON,W(86))              CWW20150
     2,(TIC,W(87)),(HB,W(88)),(HT,W(89)),(TICV,W(96))                   CWW20160
C     COMMON DECK "CONST" INSERTED HERE                                 CCON0020
      COMMON/PCONST/CREF,RGAS,GAMMA                                     CCON0040
      COMMON/MCONST/PI,PIT2,PID2,DEGS,RAD,ALN10                         CCON0050
      COMMON/LABCLT/PROJCT,THMIN,THMAX,RMIN,RMAX                        PLRH0100
C                                                                       PLRH0110
      COMMON/RAYCON/MCONP                                               PLRH0120
C                                                                       PLRH0130
      DATA LNC/-100/                                                    PLRH0140
C                                                                       PLRH0150
      IF(NC.LE.0 .OR. NC.GT.2) GO TO 100                                PLRH0160
C                                                                       PLRH0170
C     NORMALIZE LETTER SIZE FACTOR TO .15 INCHES                        PLRH0180
      HLETF=HITLET/.15                                                  PLRH0190
C                                                                       PLRH0200
      IF(LNC.NE.NC) LICM=-100                                           PLRH0210
      LNC=NC                                                            PLRH0220
C                                                                       PLRH0230
      CALL PLOT(X,Y,1)                                                  PLRH0240
      IX=IX-80*HLETF                                                    PLRH0250
      ICM=IX                                                            PLRH0260
      IF(NC.GT.1) THEN                                                  PLRH0270
         ICM=IY                                                         PLRH0280
         IX=IX-40                                                       PLRH0290
      ENDIF                                                             PLRH0300
C                                                                       PLRH0310
C     INSURE THAT OVERLAPS OF ANNOTATIONS DO NOT OCCUR                  PLRH0320
      IF(IABS(ICM-LICM).LT.INT(80*HLETF)) GO TO 100                     PLRH0330
C                                                                       PLRH0340
      IF(PROJCT.EQ.2.0) GO TO 25                                        PLRH0350
      IF(HB.GE.0.0.AND.Y.GT.(RMIN+RMAX)/2) GO TO 100                    PLRH0360
      IF(HB.LT.0.0.AND.Y.LT.(RMIN+RMAX)/2) GO TO 100                    PLRH0370
C                                                                       PLRH0380
25    F=DEGS                                                            PLRH0390
      TMP=(THMAX-THMIN)*DEGS                                            PLRH0400
      IF(TMP.LT.10.) F =EARTHR                                          PLRH0410
```

```
      FT=F                                                              PLRH0420
      IF(PROJCT.EQ.2.0 .AND. MCONP.EQ.0) F=F/EARTHR                     PLRH0430
      V=X-THMIN                                                         PLRH0440
      IF(NC.GT.1) V=Y-(RMIN+RMAX)/2.                                    PLRH0450
      IF(ABS(AMOD(TIC*FT+.0001,1.)).GT..001) GO TO 60                   PLRH0460
C                                                                       PLRH0470
      WRITE(ANNOT,50) INT(V*F+SIGN(.5,V))                               PLRH0480
50    FORMAT(I5)                                                        PLRH0490
      GO TO 90                                                          PLRH0500
C                                                                       PLRH0510
60    WRITE(ANNOT,80) V*F                                               PLRH0520
80    FORMAT(F8.2)                                                      PLRH0530
C                                                                       PLRH0540
90    LICM=ICM                                                          PLRH0550
C     ALLOW 8 RASTERS FOR THE LETTER HEIGHT                             PLRH0560
      H=HB                                                              PLRH0570
      IF(PROJCT.EQ.2.0) H=0.                                            PLRH0580
      IF(NC.EQ.1) IY=IY-8*HLETF-SIGN(52.,H)                             PLRH0590
      IOR=0                                                             PLRH0600
95    FORMAT(3G13.6,2I5,1X,A10)                                         PLRH0610
99    FORMAT(2G13.6,5I5,1X,A10)                                         PLRH0620
      CALL DDTEXT(1,ANNOT)                                              PLRH0630
C                                                                       PLRH0640
100   CALL PLOT(X,Y,MIN0(1,NC))                                         PLRH0650
      END                                                               PLRH0660
```

```
      SUBROUTINE SETXY(PROJ,XMIN,YMIN,XMAX,YMAX)                        SEMY0020
C     PLOT INITIALIZATION; SETS PROJECTION PARAMETERS                   SEMY0030
C                                                                       SEMY0040
      COMMON/LABCLT/PROJCT,THMIN,THMAX,RMIN,RMAX                        SEMY0050
C                                                                       SEMY0060
C                                                                       SEMY0070
C   INITIAL ANNOTATION MODEL                                            SEMY0080
      CALL SETANN                                                       SEMY0090
C                                                                       SEMY0100
      PROJCT=PROJ                                                       SEMY0110
      THMIN=XMIN                                                        SEMY0120
      RMIN=YMIN                                                         SEMY0130
      THMAX=XMAX                                                        SEMY0140
      RMAX=YMAX                                                         SEMY0150
      END                                                               SEMY0160
```

```
      SUBROUTINE TIKLINE(XL1,YB,XL,YT1,TICV,TIKSZ,PLOT)                 TIYE0020
C     DRAWS STRAIGHT LINE WITH TICKS AT INTERVALS                       TIYE0030
C                                                                       TIYE0040
C                                                                       TIYE0050
      XDF=XL-XL1                                                        TIYE0060
```

```
      YDF=YT1-YB                                                        TIYE0070
      DST=SQRT(XDF*XDF+YDF*YDF)                                         TIYE0080
      TICE=DST                                                          TIYE0090
      T=0.0                                                             TIYE0100
      IF(TICV.EQ.0.0) GO TO 50                                          TIYE0110
      TICE=TICV                                                         TIYE0120
      T=TIKSZ/TICV                                                      TIYE0130
C                                                                       TIYE0140
50    TICVX=TICE*XDF/DST                                                TIYE0150
      TICVY=TICE*YDF/DST                                                TIYE0160
      TX=TICVY*T                                                        TIYE0170
      TY=-TICVX*T                                                       TIYE0180
      NTIC=1+DST/TICE                                                   TIYE0190
      CALL PLOT(XL1,YB,-1)                                              TIYE0200
      DO 100 I=0,NTIC-1                                                 TIYE0210
        X=XL1+I*TICVX                                                   TIYE0220
        Y=YB+I*TICVY                                                    TIYE0230
        CALL PLOT(X,Y,0)                                                TIYE0240
        CALL PLOT(X+TX,Y+TY,0)                                          TIYE0250
100   CALL PLOT(X,Y,1)                                                  TIYE0260
      CALL PLOT(XL,YT1,0)                                               TIYE0270
      CALL PLOT(XL,YT1,1)                                               TIYE0280
      END                                                               TIYE0290
```

```
      SUBROUTINE PLTANOT(ID,FREQ,XMF,YMF,XL,YB,XR,YT                    PLYT0020
     1     ,DEGS,LLAT,LLON,RLAT,RLON,ALTLOW,ALTHI,PLT,DTICH,DTICV,PLOT) PLYT0030
C     PUTS STANDARD ANNOTATIONS ON PLOTS                                PLYT0040
C                                                                       PLYT0050
      COMMON/LABCLT/PROJCT,THMIN,THMAX,RMIN,RMAX                        PLYT0060
      REAL LLAT,LLON                                                    PLYT0070
      CHARACTER LABEL*80                                                PLYT0080
      COMMON /DD/ INT,IOR,IT,IS,IC,ICC,IX,IY                            PLYT0090
C     COMMON DECK "ANNOT" INSERTED HERE                                 ANNO0020
      CHARACTER*10 ANOTES,HNOTES                                        ANNO0040
      COMMON/ANNCTL/LENA(4),LENHA(3)                                    ANNO0050
      COMMON/ANNCTC/ANOTES(2,4),HNOTES(4,3)                             ANNO0060
C                                                                       PLYT0110
      IF(PLT.EQ.2. .OR. XMF.LE.0.0 .OR. YMF.LE.0.0) GO TO 45            PLYT0120
      CALL PLOT(XL+XMF*(XR-XL),YB+YMF*(YT-YB),1)                        PLYT0130
      IF(FREQ.LE.0.0) GO TO 30                                          PLYT0140
C                                                                       PLYT0150
      WRITE(LABEL,25) FREQ                                              PLYT0160
25    FORMAT('FREQ =',F9.3)                                             PLYT0170
      CALL DDTEXT(2,LABEL)                                              PLYT0180
      IY=IY+40                                                          PLYT0190
C                                                                       PLYT0200
30    WRITE(LABEL,35) ID                                                PLYT0210
35    FORMAT('MODEL = ',A3)                                             PLYT0220
      CALL DDTEXT(2,LABEL)                                              PLYT0230
C                                                                       PLYT0240
45    NSPY=97                                                           PLYT0250
```

```
      IOR=0                                                             PLYT0260
C                                                                       PLYT0270
C FIRST THE LOW ALTITUDE-LATITUDE ANNOTATION                             PLYT0280
50    CALL PLOT(XL,YB,1)                                                PLYT0290
      IX=IX-155                                                         PLYT0300
      IY=IY-NSPY                                                        PLYT0310
      WRITE(LABEL,1840) DEGS*LLON                                       PLYT0320
      CALL DDTEXT(2,LABEL)                                              PLYT0330
      WRITE(LABEL,1850) DEGS*LLAT                                       PLYT0340
      IY=IY-32                                                          PLYT0350
      CALL DDTEXT(2,LABEL)                                              PLYT0360
C                                                                       PLYT0370
C NEXT THE RIGHT LATITUDE ANNOTATION                                    PLYT0380
      CALL PLOT(XR,YB,1)                                                PLYT0390
      IX=IX-130                                                         PLYT0400
      IY=IY-NSPY                                                        PLYT0410
      WRITE(LABEL,1840) DEGS*RLON                                       PLYT0420
      CALL DDTEXT(2,LABEL)                                              PLYT0430
      WRITE(LABEL,1850) DEGS*RLAT                                       PLYT0440
      IY=IY-32                                                          PLYT0450
      CALL DDTEXT(2,LABEL)                                              PLYT0460
C                                                                       PLYT0470
      XMID=(XL+XR)/2.0                                                  PLYT0480
      IF(PLT.EQ.2.0) GO TO 55                                           PLYT0490
C                                                                       PLYT0500
C PUT THE HORIZONTAL TIC LABEL                                          PLYT0510
      Y=YT                                                              PLYT0520
      IF(ALTLOW.GE.0.0) Y=YB                                            PLYT0530
      CALL PLOT(XMID,Y,1)                                               PLYT0540
C                                                                       PLYT0550
      IF(ALTLOW.LT.0.0) IY=IY+80                                        PLYT0560
      IF(ALTLOW.GE.0.0) IY=IY-95                                        PLYT0570
      GO TO 60                                                          PLYT0580
C                                                                       PLYT0590
55    CALL PLOT(XMID,YB,1)                                              PLYT0600
      IY=IY-95                                                          PLYT0610
C                                                                       PLYT0620
60    IX=IX-235                                                         PLYT0630
      NOTEA=1                                                           PLYT0640
      TMP=(THMAX-THMIN)*DEGS                                            PLYT0650
      IF(TMP.GT.10.) NOTEA=2                                            PLYT0660
C                                                                       PLYT0670
      CALL DDTEXT (LENHA(NOTEA),HNOTES(1,NOTEA))                        PLYT0680
C                                                                       PLYT0690
C PUT THE VERTICAL TIC LABEL                                            PLYT0700
      CALL PLOT(XL,(YB+YT)/2.0,1)                                       PLYT0710
      IOR=1                                                             PLYT0720
      IF(PLT.NE.2.) GO TO 100                                           PLYT0730
C                                                                       PLYT0740
C   HORIZONTAL PLOT  PUT Y-AXIS ANNOTATION                              PLYT0750
C                                                                       PLYT0760
      IX=IX-125                                                         PLYT0770
      IY=200                                                            PLYT0780
      CALL DDTEXT (LENHA(3),HNOTES(1,3))                                PLYT0790
      GO TO 200                                                         PLYT0800
```

```
C
100   IX=IX-125
      IY=IY-75
      NOTEA=1
      IF(ALTLOW.GE.0.0) NOTEA=3
      IF(ABS(ALTHI-ALTLOW).GE.1.) NOTEA=NOTEA+1
      CALL DDTEXT (LENA(NOTEA),ANOTES(1,NOTEA))
C
200   IOR=0
1840  FORMAT(F7.2,' DEG E.')
1850  FORMAT(F7.2,' DEG N.')
C
      END
```

```
      SUBROUTINE DRAWTKS(DTICH,DTICV,XLPR,XR,YBPR,YT,PLOT)
C
C     HORIZONTAL PLOT PROJECTION SUPPORT ROUTINE.
C     DRAW BOUNDARY TO PLOT AREA, TICS AND TIC LABELS.
C
      EXTERNAL PLOT
C
      XL=XLPR
      YB=YBPR
      YMID=.5*(YB+YT)
      TICX=.01*(YT-YB)
      TICY=.01*(XR-XL)
      YBP=YB
      IF(DTICV.GT.0.) YBP=YMID-AINT((YMID-YB)/DTICV)*DTICV
C
      NTICX=(XR-XL)/DTICH
      NTICY=1
      IF(DTICV.GT.0.) NTICY=(YT-YBP+DTICV)/DTICV
C&     PRINT *,"DRAWTKS ",XLPR,XR,YBPR,YBP,YT,DTICH,DTICV,NTICX,NTICY
      IOF=0
C
C     TWO PASSES BOTTOM AND LEFT THEN TOP AND RIGHT
      DO 100 J=1,2
      CALL PLOT(XL,YBPR,1)
      DO 30 I=1,NTICY
      Y=YBP+(I-1)*DTICV
      CALL PLOT(XL,Y,0)
      CALL PLOT(XL+TICY,Y,0)
30    CALL PLTANH(XL,Y,IOF+2,PLOT)
      CALL PLOT(XL,YT,0)
C
      CALL PLOT(XLPR,YB,1)
C
      DO 40 I=1,NTICX
      X=XLPR+I*DTICH
      CALL PLOT(X,YB,0)
      CALL PLOT(X,YB+TICX,0)
```

```
      CALL PLTANH(X,YB,IOF+1,PLOT)                                      DRYS0390
40    CALL PLOT(X,YB,1)                                                 DRYS0400
      CALL PLOT(XR,YB,0)                                                DRYS0410
      YB=YT                                                             DRYS0420
      XL=XR                                                             DRYS0430
      TICX=-TICX                                                        DRYS0440
      TICY=-TICY                                                        DRYS0450
100   IOF=10                                                            DRYS0460
C                                                                       DRYS0470
      CALL PLOT(XLPR,YMID,1)                                            DRYS0480
      CALL PLOT(XR,YMID,0)                                              DRYS0490
      END                                                               DRYS0500
```

```
      SUBROUTINE PLTLB(X,PY,NCP)                                        PLGB0020
C     PUT VERTICAL TIC ANNOTATIONS ON RAY PLOT                          PLGB0030
C     THIS IS A SPECIAL PURPOSE SUBSTITUTE FOR THE 'PLOT' ROUTINE       PLGB0040
C     IT COMPUTES THE NEAREST ROUNDED TIC POSITIONS FOR VERTICAL LINES. PLGB0050
C     WHEN THE NC PARAMETER IS > 0 AN ANNOTATION IS GENERATED           PLGB0060
C     AT THE TIC POSITION. THE ADDITIONAL NC VALUE < 0 ALLOWS FOR       PLGB0070
C     SIMPLE PEN UP MOTION TO THE X,Y POSITION.                         PLGB0080
C                                                                       PLGB0090
      CHARACTER ANNOT*10                                                PLGB0100
C                                                                       PLGB0110
C     COMMON DECK "WWR" INSERTED HERE                                   CWWR0020
      PARAMETER (NWARSZ=1000)                                           CWW10030
      COMMON/WW/ID(10),MAXW,W(NWARSZ)                                   CWW10040
      REAL MAXSTP,MAXERR,INTYP,LLAT,LLON                                CWW20020
      EQUIVALENCE (EARTHR,W(1)),(RAY,W(2)),(XMTRH,W(3)),(TLAT,W(4)),    CWW20030
     1 (TLON,W(5)),(OW,W(6)),(FBEG,W(7)),(FEND,W(8)),(FSTEP,W(9)),      CWW20040
     2 (AZ1,W(10)),(AZBEG,W(11)),(AZEND,W(12)),(AZSTEP,W(13)),          CWW20050
     3 (BETA,W(14)),(ELBEG,W(15)),(ELEND,W(16)),(ELSTEP,W(17)),         CWW20060
     8   (RUNSUP,W(18)),(RCVRH,W(20)),                                  CWW20070
     4 (ONLY,W(21)),(HOP,W(22)),(MAXSTP,W(23)),(PLAT,W(24)),(PLON,W(25))CWW20080
     5,(HMAX,W(26)),(RAYFNC,W(29)),(EXTINC,W(33)),                      CWW20090
     6 (HMIN,W(27)),(RGMAX,W(28)),                                      CWW20100
     8 (INTYP,W(41)),(MAXERR,W(42)),(ERATIO,W(43)),                     CWW20110
     6 (STEP1,W(44)),(STPMAX,W(45)),(STPMIN,W(46)),(FACTR,W(47)),       CWW20120
     7 (SKIP,W(71)),(RAYSET,W(72)),(PRTSRP,W(74)),(HITLET,W(75))        CWW20130
     9 ,(BINRAY,W(76)),(PAGLN,W(77)),(PLT,W(81)),(PFACTR,W(82)),        CWW20140
     1 (LLAT,W(83)),(LLON,W(84)),(RLAT,W(85)),(RLON,W(86))              CWW20150
     2,(TIC,W(87)),(HB,W(88)),(HT,W(89)),(TICV,W(96))                   CWW20160
      COMMON /DD/ IINT,IOR,IT,IS,IC,ICC,IX,IY                           PLGB0130
      COMMON/LABCLT/PROJCT,THMIN,THMAX,RMIN,RMAX                        PLGB0140
C                                                                       PLGB0150
      DATA LIY/-100/                                                    PLGB0160
C                                                                       PLGB0170
      NC=NCP                                                            PLGB0180
      GO TO 10                                                          PLGB0190
C                                                                       PLGB0200
      ENTRY PLTLBN(X,PY,NCP)                                            PLGB0210
      NC=0                                                              PLGB0220
```

```
C                                                                       PLGB0230
10    Y=PY                                                              PLGB0240
C                                                                       PLGB0250
      IF(NCP.LT.0) GO TO 200                                            PLGB0260
      F=1.                                                              PLGB0270
      IF(AMAX1(ABS(RMAX-EARTHR),ABS(RMIN-EARTHR)).LT.1.) F=1000.        PLGB0280
      Y=INT((Y-EARTHR)*F)/F+EARTHR                                      PLGB0290
      IF(NC.EQ.0) GO TO 100                                             PLGB0300
C                                                                       PLGB0310
      V=Y                                                               PLGB0320
      IF(PROJCT.EQ.3.) V=RMIN+(Y-RMIN)/PFACTR                           PLGB0330
      IF(ABS(AINT(TICV*F)-TICV*F).GT..001) GO TO 60                     PLGB0340
C                                                                       PLGB0350
      WRITE(ANNOT,50) INT(ABS(V-EARTHR)*F)                              PLGB0360
50    FORMAT(I3)                                                        PLGB0370
      GO TO 90                                                          PLGB0380
C                                                                       PLGB0390
60    WRITE(ANNOT,80) ABS(V-EARTHR)*F                                   PLGB0400
80    FORMAT(F6.2)                                                      PLGB0410
C                                                                       PLGB0420
90    CALL PLOT(X,PY,1)                                                 PLGB0430
      CALL PLOT(X,Y,1)                                                  PLGB0440
C     INSURE THAT OVERLAPS OF ANNOTATIONS DO NOT OCCUR                  PLGB0450
      IF(IABS(IY-LIY).LT.80) GO TO 100                                  PLGB0460
      LIY=IY                                                            PLGB0470
      IX=IX-100                                                         PLGB0480
      IOR=0                                                             PLGB0490
      CALL DDTEXT(1,ANNOT)                                              PLGB0500
C                                                                       PLGB0510
100   CALL PLOT(X,Y,NC)                                                 PLGB0520
      RETURN                                                            PLGB0530
C                                                                       PLGB0540
200   CALL PLOT(X,Y,1)                                                  PLGB0550
      RETURN                                                            PLGB0560
      END                                                               PLGB0570
```

```
      SUBROUTINE ARCTIC(THMIN,THMAX,HEIGHT,TICY,PLOT)                   ARPC0020
C     DRAW RANGE AXIS IN RAY TRACE PLOT. INCLUDES ANY CURVILINEAR       ARPC0030
C     PROJECTIONS PROVIDED IN DDGRAPH.                                  ARPC0040
C     COMMON DECK "WWR" INSERTED HERE                                   CWWR0020
      PARAMETER (NWARSZ=1000)                                           CWW10030
      COMMON/WW/ID(10),MAXW,W(NWARSZ)                                   CWW10040
      REAL MAXSTP,MAXERR,INTYP,LLAT,LLON                                CWW20020
      EQUIVALENCE (EARTHR,W(1)),(RAY,W(2)),(XMTRH,W(3)),(TLAT,W(4)),    CWW20030
     1 (TLON,W(5)),(OW,W(6)),(FBEG,W(7)),(FEND,W(8)),(FSTEP,W(9)),      CWW20040
     2 (AZ1,W(10)),(AZBEG,W(11)),(AZEND,W(12)),(AZSTEP,W(13)),          CWW20050
     3 (BETA,W(14)),(ELBEG,W(15)),(ELEND,W(16)),(ELSTEP,W(17)),         CWW20060
     8   (RUNSUP,W(18)),(RCVRH,W(20)),                                  CWW20070
     4 (ONLY,W(21)),(HOP,W(22)),(MAXSTP,W(23)),(PLAT,W(24)),(PLON,W(25))CWW20080
     5,(HMAX,W(26)),(RAYFNC,W(29)),(EXTINC,W(33)),                      CWW20090
     6 (HMIN,W(27)),(RGMAX,W(28)),                                      CWW20100
```

```
     8 (INTYP,W(41)),(MAXERR,W(42)),(ERATIO,W(43)),                CWW20110
     6 (STEP1,W(44)),(STPMAX,W(45)),(STPMIN,W(46)),(FACTR,W(47)),  CWW20120
     7 (SKIP,W(71)),(RAYSET,W(72)),(PRTSRP,W(74)),(HITLET,W(75))   CWW20130
     9 ,(BINRAY,W(76)),(PAGLN,W(77)),(PLT,W(81)),(PFACTR,W(82)),   CWW20140
     1 (LLAT,W(83)),(LLON,W(84)),(RLAT,W(85)),(RLON,W(86))         CWW20150
     2,(TIC,W(87)),(HB,W(88)),(HT,W(89)),(TICV,W(96))              CWW20160
      COMMON /DDSCALE/ XMIN,XMAX,YMIN,YMAX,MINX,MAXX,MINY,MAXY,SCX,SCY, ARPC0060
     1 NSCX,NXCY,MSCX,MSCY,ISCX,ISCY                               ARPC0070
C                                                                  ARPC0080
      NTIC=2                                                       ARPC0090
      IF(TIC.NE.0.) NTIC=1+(THMAX-THMIN)/TIC                       ARPC0100
      NLINE=MAX0(2,100/NTIC)                                       ARPC0110
C                                                                  ARPC0120
      TICN=TIC/(NLINE-2)                                           ARPC0130
      DO 10 I=1,NTIC                                               ARPC0140
      X=THMIN+(I-1)*TIC                                            ARPC0150
      CALL PLOT(X,HEIGHT+TICY,1)                                   ARPC0160
      DO 10 J=2,NLINE                                              ARPC0170
      XJ=X+(J-2)*TICN                                              ARPC0180
      IF(XJ.GT.THMAX) GO TO 15                                     ARPC0190
10    CALL PLOT(XJ,HEIGHT,0)                                       ARPC0200
C                                                                  ARPC0210
15    CALL PLOT(THMAX,HEIGHT,0)                                    ARPC0220
      CALL PLOT(THMAX,HEIGHT+TICY,1)                               ARPC0230
      RETURN                                                       ARPC0240
      END                                                          ARPC0250
```

```
      SUBROUTINE DDINIT(N,TEXT)                                    DDRT0020
C     INITIALIZES PLOTTING PROCESS(DDPLOT)                         DDRT0030
C     WRITE PARAMETERS TO GRAPHICS CALLS FILE                      DDRT0040
C     COMMON DECK "RAYDEV" INSERTED HERE                           CRAY0020
C     DEVICE ASSIGNED TO RAYTRC INPUT FILE                         CRAY0040
      COMMON/RAYDEV/NRYIND,NDEVTMP,NFRMAT,NDEVGRP,NDEVBIN           CRAY0050
      CHARACTER TEXT*(*)                                           DDRT0060
C                                                                  DDRT0070
      DATA IDD/0/                                                  DDRT0080
10    FORMAT(5A10)                                                 DDRT0090
      IF(IDD.EQ.0) REWIND NDEVGRP                                  DDRT0100
      IDD=1                                                        DDRT0110
      WRITE(NDEVGRP) 0,0,0                                         DDRT0120
      WRITE(NDEVGRP) M,LEN(TEXT),TEXT                              DDRT0130
      END                                                          DDRT0140
```

```
      SUBROUTINE DDBP                                              DDBP0020
C     SETS A VECTOR ORIGIN(DDPLOT)                                 DDBP0030
C     WRITE PARAMETERS TO GRAPHICS CALLS FILE                      DDBP0040
C     COMMON DECK "RAYDEV" INSERTED HERE                           CRAY0020
```

```
C     DEVICE ASSIGNED TO RAYTRC INPUT FILE
      COMMON/RAYDEV/NRYIND,NDEVTMP,NFRMAT,NDEVGRP,NDEVBIN            CRAY0040
      COMMON/DD/IN,IOR,IT,IS,IC,ICC,IX,IY                            CRAY0050
      INTEGER REZFLG                                                 DDBP0060
      PARAMETER (REZFLG=2001)                                        DDHI0020
      COMMON/DDREZ/DDHIX,DDHIY                                       DDHI0030
      COMMON/KNKN/KNBP,KNVC,KNDT                                     DDHI0040
      COMMON/DDLIM/MXIX,MXIY,MNIX,MNIY                               DDBP0080
C                                                                    DDBP0090
C     USE PRE-ASSIGNED FLAG VALUE FOR IX TO DETERMINE USE OF         DDBP0100
C     FLOATING POINT RASTER VALUES OF X AND Y USED IN DDBP AND DDVC  DDBP0110
C                                                                    DDBP0120
      IF(IX.EQ.REZFLG) THEN                                          DDBP0130
         IX=DDHIX                                                    DDBP0140
         IY=DDHIY                                                    DDBP0150
      ELSE                                                           DDBP0160
         DDHIX=IX                                                    DDBP0170
         DDHIY=IY                                                    DDBP0180
      ENDIF                                                          DDBP0190
C                                                                    DDBP0200
      MNIX=MIN0(MNIX,IX)                                             DDBP0210
      MXIX=MAX0(MXIX,IX)                                             DDBP0220
      MNIY=MIN0(MNIY,IY)                                             DDBP0230
      MXIY=MAX0(MXIY,IY)                                             DDBP0240
      IF(IX.LT.0.OR.IX.GT.1023.OR.IY.LT.0.OR.IY.GT.1023              DDBP0250
     1  ) PRINT 10,'DDBP ',KNBP,IX,IY                                DDBP0260
10    FORMAT(A10,3I5)                                                DDBP0270
      KNBP=KNBP+1                                                    DDBP0280
      WRITE(NDEVGRP) 1,DDHIX,DDHIY                                   DDBP0290
      END                                                            DDBP0300
                                                                     DDBP0310



      SUBROUTINE DDVC
C     PLOTS A VECTOR(DDPLOT)                                         DDVC0020
C     WRITE PARAMETERS TO GRAPHICS CALLS FILE                        DDVC0030
C     COMMON DECK "RAYDEV" INSERTED HERE                             DDVC0040
C     DEVICE ASSIGNED TO RAYTRC INPUT FILE                           CRAY0020
      COMMON/RAYDEV/NRYIND,NDEVTMP,NFRMAT,NDEVGRP,NDEVBIN            CRAY0040
      COMMON/DD/IN,IOR,IT,IS,IC,ICC,IX,IY                            CRAY0050
      INTEGER REZFLG                                                 DDVC0060
      PARAMETER (REZFLG=2001)                                        DDHI0020
      COMMON/DDREZ/DDHIX,DDHIY                                       DDHI0030
      COMMON/KNKN/KNBP,KNVC,KNDT                                     DDHI0040
      COMMON/DDLIM/MXIX,MXIY,MNIX,MNIY                               DDVC0080
C                                                                    DDVC0090
C     USE PRE-ASSIGNED FLAG VALUE FOR IX TO DETERMINE USE OF         DDVC0100
C     FLOATING POINT RASTER VALUES OF X AND Y USED IN DDBP AND DDVC  DDVC0110
C                                                                    DDVC0120
      IF(IX.EQ.REZFLG) THEN                                          DDVC0130
         IX=DDHIX                                                    DDVC0140
         IY=DDHIY                                                    DDVC0150
      ELSE                                                           DDVC0160
                                                                     DDVC0170
```

```
         DDHIX=IX                                                      DDVC0180
         DDHIY=IY                                                      DDVC0190
      ENDIF                                                            DDVC0200
C                                                                      DDVC0210
      MNIX=MIN0(MNIX,IX)                                               DDVC0220
      MXIX=MAX0(MXIX,IX)                                               DDVC0230
      MNIY=MIN0(MNIY,IY)                                               DDVC0240
      MXIY=MAX0(MXIY,IY)                                               DDVC0250
      IF(IX.LT.0.OR.IX.GT.1023.OR.IY.LT.0.OR.IY.GT.1023                DDVC0260
     1  ) PRINT 10,'DDVC ',KNVC,IX,IY                                  DDVC0270
10    FORMAT(A10,3I5)                                                  DDVC0280
      KNVC=KNVC+1                                                      DDVC0290
      WRITE(NDEVGRP) 2,DDHIX,DDHIY                                     DDVC0300
      END                                                              DDVC0310
```

```
      SUBROUTINE DDTEXT(N,TEXT)                                        DDXT0020
C     WRITES A CHARACTER ARRAY PACKED A10(DDPLOT)                      DDXT0030
C     WRITE PARAMETERS TO GRAPHICS CALLS FILE                          DDXT0040
C     COMMON DECK "RAYDEV" INSERTED HERE                               CRAY0020
C     DEVICE ASSIGNED TO RAYTRC INPUT FILE                             CRAY0040
      COMMON/RAYDEV/NRYIND,NDEVTMP,NFRMAT,NDEVGRP,NDEVBIN               CRAY0050
      CHARACTER TEXT*(*)                                               DDXT0060
      COMMON/DD/IN,IOR,IT,IS,IC,ICC,IX,IY                              DDXT0070
      COMMON/KNKN/KNBP,KNVC,KNDT                                       DDXT0080
100   FORMAT(A10,2I5,I2,1X,8A10)                                       DDXT0090
      KNDT=KNDT+1                                                      DDXT0100
      WRITE(NDEVGRP) 3,IX,IY                                           DDXT0110
      LN=MIN0(N*10,LEN(TEXT))                                          DDXT0120
      IF(LN.EQ.N*10) THEN                                              DDXT0130
         WRITE(NDEVGRP) IOR,N,N*10,(TEXT(I:I),I=1,LN)                  DDXT0140
      ELSE                                                             DDXT0150
         WRITE(NDEVGRP) IOR,N,N*10,(TEXT(I:I),I=1,LN)                  DDXT0160
     1    ,(' ',I=LN+1,N*10)                                           DDXT0170
      ENDIF                                                            DDXT0180
      END                                                              DDXT0190
```

```
      SUBROUTINE DDTAB                                                 DDQB0020
C     INITIALIZES TABULAR PLOTTING(DDPLOT)                             DDQB0030
C     WRITE PARAMETERS TO GRAPHICS CALLS FILE                          DDQB0040
C     COMMON DECK "RAYDEV" INSERTED HERE                               CRAY0020
C     DEVICE ASSIGNED TO RAYTRC INPUT FILE                             CRAY0040
      COMMON/RAYDEV/NRYIND,NDEVTMP,NFRMAT,NDEVGRP,NDEVBIN               CRAY0050
      END                                                              DDQB0060
```

```
      SUBROUTINE DDFR
C     ADVANCE ONE PLOTTING FRAME(DDPLOT)                                DDFR0020
C     WRITE PARAMETERS TO GRAPHICS CALLS FILE                           DDFR0030
C     COMMON DECK "RAYDEV" INSERTED HERE                                DDFR0040
C     DEVICE ASSIGNED TO RAYTRC INPUT FILE                              CRAY0020
      COMMON/RAYDEV/NRYIND,NDEVTMP,NFRMAT,NDEVGRP,NDEVBIN               CRAY0040
10    FORMAT(A10)                                                       CRAY0050
      WRITE(NDEVGRP) -2,0,0                                             DDFR0060
      END                                                               DDFR0070
                                                                        DDFR0080

      SUBROUTINE DDEND
C     EMPTIES PLOT BUFFER AND RELEASES PLOTTING COMMAND FILE(DDPLOT)    DDPD0020
C     WRITE PARAMETERS TO GRAPHICS CALLS FILE                           DDPD0030
C     COMMON DECK "RAYDEV" INSERTED HERE                                DDPD0040
C     DEVICE ASSIGNED TO RAYTRC INPUT FILE                              CRAY0020
      COMMON/RAYDEV/NRYIND,NDEVTMP,NFRMAT,NDEVGRP,NDEVBIN               CRAY0040
      COMMON/KNKN/KNBP,KNVC,KNDT                                        CRAY0050
      COMMON/DDLIM/MXIX,MXIY,MNIX,MNIY                                  DDPD0060
10    FORMAT(3A10,5I5)                                                  DDPD0070
      WRITE(NDEVGRP) -1,0,0                                             DDPD0080
      END                                                               DDPD0090
                                                                        DDPD0100

      SUBROUTINE DASH
C     ACTIVATE DASHED LINE CONNECTIONS(DISSPLA)                         DASH0020
C     WRITE PARAMETERS TO GRAPHICS CALLS FILE                           DASH0030
C     COMMON DECK "RAYDEV" INSERTED HERE                                DASH0040
C     DEVICE ASSIGNED TO RAYTRC INPUT FILE                              CRAY0020
      COMMON/RAYDEV/NRYIND,NDEVTMP,NFRMAT,NDEVGRP,NDEVBIN               CRAY0040
      WRITE(NDEVGRP) 37,0,0                                             CRAY0050
      END                                                               DASH0060
                                                                        DASH0070

      SUBROUTINE RESET(S)
C     RESETS AN OPTION TO ITS DEFAULT VALUE(DISSPLA)                    REUT0020
C     WRITE PARAMETERS TO GRAPHICS CALLS FILE                           REUT0030
C     COMMON DECK "RAYDEV" INSERTED HERE                                REUT0040
C     DEVICE ASSIGNED TO RAYTRC INPUT FILE                              CRAY0020
      COMMON/RAYDEV/NRYIND,NDEVTMP,NFRMAT,NDEVGRP,NDEVBIN               CRAY0040
      CHARACTER S*10                                                    CRAY0050
      WRITE(NDEVGRP) 38,0,0                                             REUT0060
      WRITE(NDEVGRP) S                                                  REUT0070
      END                                                               REUT0080
                                                                        REUT0090
```

```
      SUBROUTINE HEIGHT(H)                                              HEPT0020
C     SETS REFERENCE CHARACTER HEIGHT IN INCHES(DISSPLA)                HEPT0030
C     WRITE PARAMETERS TO GRAPHICS CALLS FILE                           HEPT0040
C     COMMON DECK "RAYDEV" INSERTED HERE                                CRAY0020
C     DEVICE ASSIGNED TO RAYTRC INPUT FILE                              CRAY0040
      COMMON/RAYDEV/NRYIND,NDEVTMP,NFRMAT,NDEVGRP,NDEVBIN                CRAY0050
      WRITE(NDEVGRP) 13,H,0                                             HEPT0060
      END                                                               HEPT0070
```

```
      SUBROUTINE MX1ALF(T1,T2)                                          MXIF0020
C     SPECIFY USE OF ALTERNATE CHARACTER SET NUMBER 1(DISSPLA)          MXIF0030
C     WRITE PARAMETERS TO GRAPHICS CALLS FILE                           MXIF0040
C     COMMON DECK "RAYDEV" INSERTED HERE                                CRAY0020
C     DEVICE ASSIGNED TO RAYTRC INPUT FILE                              CRAY0040
      COMMON/RAYDEV/NRYIND,NDEVTMP,NFRMAT,NDEVGRP,NDEVBIN                CRAY0050
      WRITE(NDEVGRP) 11,T1,T2                                           MXIF0060
      END                                                               MXIF0070
```

```
      SUBROUTINE MX2ALF(T1,T2)                                          MXJF0020
C     SPECIFY USE OF ALTERNATE CHARACTER SET NUMBER 2(DISSPLA)          MXJF0030
C     WRITE PARAMETERS TO GRAPHICS CALLS FILE                           MXJF0040
C     COMMON DECK "RAYDEV" INSERTED HERE                                CRAY0020
C     DEVICE ASSIGNED TO RAYTRC INPUT FILE                              CRAY0040
      COMMON/RAYDEV/NRYIND,NDEVTMP,NFRMAT,NDEVGRP,NDEVBIN                CRAY0050
      WRITE(NDEVGRP) 12,T1,T2                                           MXJF0060
      END                                                               MXJF0070
```

```
      SUBROUTINE SCMPLX                                                 SCJX0020
C     SPECIFY USE OF SIMPLEX CHARACTER SET(DISSPLA)                     SCJX0030
C     WRITE PARAMETERS TO GRAPHICS CALLS FILE                           SCJX0040
C     COMMON DECK "RAYDEV" INSERTED HERE                                CRAY0020
C     DEVICE ASSIGNED TO RAYTRC INPUT FILE                              CRAY0040
      COMMON/RAYDEV/NRYIND,NDEVTMP,NFRMAT,NDEVGRP,NDEVBIN                CRAY0050
      WRITE(NDEVGRP) 10,0,0                                             SCJX0060
      END                                                               SCJX0070
```

D.2 DISPERSION-RELATION ROUTINES (Tape File 4)

```
      SUBROUTINE ANCNL
C     DISPERSION RELATION FOR ACOUSTIC WAVES NO CURRENT, NO LOSSES      ANNL0020
C     COMMON DECK "RKAM" INSERTED HERE                                  ANNL0030
      REAL KR,KTH,KPH                                                   RKAM0020
      COMMON//R,TH,PH,KR,KTH,KPH,RKVARS(14),TPULSE,CSTEP,DRDT(20)       RKAM0040
C     COMMON DECK "CC" INSERTED HERE                                    RKAM0050
      REAL MODC                                                         CCC 0020
      COMMON/CC/MODC(4),CS,PCST,PCSR,PCSTH,PCSPH                        CCC 0040
C     COMMON DECK "CONST" INSERTED HERE                                 CCC 0050
      COMMON/PCONST/CREF,RGAS,GAMMA                                     CCON0020
      COMMON/MCONST/PI,PIT2,PID2,DEGS,RAD,ALN10                         CCON0040
C     COMMON DECK "RK" INSERTED HERE                                    CCON0050
C     DEFINE SIZE REQUIRED FOR RAY STATE SAVE ARRAY                     CRK 0020
      PARAMETER (LRKAMS=87+2*100,NXRKMS=12+LRKAMS,MXEQPT=21)            CRK 0040
      PARAMETER (NRKSAV=NXRKMS+MXEQPT-1)                                CRK 0050
      COMMON /RK/ NEQS,STEP,MODE,E1MAX,E1MIN,E2MAX,E2MIN,FACT,RSTART    CRK 0060
C     COMMON DECK "RINREAL" INSERTED HERE                               CRK 0070
      LOGICAL SPACE                                                     CRIN0020
      REAL LPOLAR,LPOLRI,KPHK,KPHKI,KAY2,KAY2I                          CRIN0040
      CHARACTER DISPM*6                                                 CRIN0050
      COMMON/RINPL/DISPM                                                CRIN0060
      COMMON /RIN/ MODRIN(8),RAYNAME(2,3),TYPE(3),SPACE                 CRIN0070
      COMMON/RIN/OMEGMIN,OMEGMAX,KAY2,KAY2I,                            CRIN0080
     1           H,HI,PHT,PHTI,PHR,PHRI,PHTH,PHTHI,PHPH,PHPHI           CRIN0090
     2, PHOW,PHOWI,PHKR,PHKRI,PHKTH,PHKTI, PHKPH,PHKPI                  CRIN0100
     3 ,KPHK,KPHKI,POLAR,POLARI,LPOLAR,LPOLRI,SGN                       CRIN0110
C     COMMON DECK "UU" INSERTED HERE                                    CRIN0120
      REAL MODU                                                         CUU 0020
      COMMON/UU/MODU(4)                                                 CUU 0040
     1  ,V  ,PVT  ,PVR  ,PVTH  ,PVPH                                    CUU 0050
     2  ,VR ,PVRT ,PVRR ,PVRTH ,PVRPH                                   CUU 0060
     3  ,VTH,PVTHT,PVTHR,PVTHTH,PVTHPH                                  CUU 0070
     4  ,VPH,PVPHT,PVPHR,PVPHTH,PVPHPH                                  CUU 0080
C     COMMON DECK "WW" INSERTED HERE                                    CUU 0090
      PARAMETER (NWARSZ=1000)                                           CWW 0020
      COMMON/WW/ID(10),MAXW,W(NWARSZ)                                   CWW10030
      REAL MAXSTP,MAXERR,INTYP,LLAT,LLON                                CWW10040
      EQUIVALENCE (EARTHR,W(1)),(RAY,W(2)),(XMTRH,W(3)),(TLAT,W(4)),    CWW20020
     1 (TLON,W(5)),(OW,W(6)),(FBEG,W(7)),(FEND,W(8)),(FSTEP,W(9)),      CWW20030
     2 (AZ1,W(10)),(AZBEG,W(11)),(AZEND,W(12)),(AZSTEP,W(13)),          CWW20040
     3 (BETA,W(14)),(ELBEG,W(15)),(ELEND,W(16)),(ELSTEP,W(17)),         CWW20050
     8    (RUNSUP,W(18)),(RCVRH,W(20)),                                 CWW20060
     4 (ONLY,W(21)),(HOP,W(22)),(MAXSTP,W(23)),(PLAT,W(24)),(PLON,W(25))CWW20070
     5,(HMAX,W(26)),(RAYFNC,W(29)),(EXTINC,W(33)),                      CWW20080
     6 (HMIN,W(27)),(RGMAX,W(28)),                                      CWW20090
     8 (INTYP,W(41)),(MAXERR,W(42)),(ERATIO,W(43)),                     CWW20100
     6 (STEP1,W(44)),(STPMAX,W(45)),(STPMIN,W(46)),(FACTR,W(47)),       CWW20110
     7 (SKIP,W(71)),(RAYSET,W(72)),(PRTSRP,W(74)),(HITLET,W(75))        CWW20120
     9 ,(BINRAY,W(76)),(PAGLN,W(77)),(PLT,W(81)),(PFACTR,W(82)),        CWW20130
     1 (LLAT,W(83)),(LLON,W(84)),(RLAT,W(85)),(RLON,W(86))              CWW20140
     2,(TIC,W(87)),(HB,W(88)),(HT,W(89)),(TICV,W(96))                   CWW20150
      REAL MMODEL,MFORM,MID                                             CWW20160
C                                                                       CWW30020
C     WIND        100-124                                               CWW30030
      EQUIVALENCE (W(100),UMODEL),(W(101),UFORM),(W(102),UID)           CWW30040
                                                                        CWW30050
```

```
C                                                                       CWW30060
C     DELTA WIND        125-149                                         CWW30070
      EQUIVALENCE (W(125),DUMODEL),(W(126),DUFORM),(W(127),DUID)        CWW30080
C                                                                       CWW30090
C     SOUND SPEED 150-174                                               CWW30100
      EQUIVALENCE (W(150),CMODEL),(W(151),CFORM),(W(152),CID)           CWW30110
      EQUIVALENCE (W(153),REFC)                                         CWW30120
C                                                                       CWW30130
C     DELTA SOUND SPEED 175-199                                         CWW30140
      EQUIVALENCE (W(175),DCMODEL),(W(176),DCFORM),(W(177),DCID)        CWW30150
C                                                                       CWW30160
C     TEMPERATURE    200-224                                            CWW30170
      EQUIVALENCE (W(200),TMODEL),(W(201),TFORM),(W(202),TID)           CWW30180
C                                                                       CWW30190
C     DELTA TEMPERATURE    225-249                                      CWW30200
      EQUIVALENCE (W(225),DTMODEL),(W(226),DTFORM),(W(227),DTID)        CWW30210
C                                                                       CWW30220
C     MOLECULAR   250-274                                               CWW30230
      EQUIVALENCE (W(250),MMODEL),(W(251),MFORM),(W(252),MID)           CWW30240
C                                                                       CWW30250
C     RECEIVER HEIGHT   275-299                                         CWW30260
      EQUIVALENCE (W(275),RMODEL),(W(276),RFORM),(W(277),RID)           CWW30270
C                                                                       CWW30280
C     TOPOGRAPHY   300-324                                              CWW30290
      EQUIVALENCE (W(300),GMODEL),(W(301),GFORM),(W(302),GID)           CWW30300
C                                                                       CWW30310
C     DELTA TOPOGRAPHY   325-349                                        CWW30320
      EQUIVALENCE (W(325),GUMODEL),(W(326),GUFORM),(W(327),GUID)        CWW30330
C                                                                       CWW30340
C     ATMOSPHERIC SURFACE TOPOGRAPHY   350-374                          CWW30350
      EQUIVALENCE (W(350),SMODEL),(W(351),SFORM),(W(352),SID)           CWW30360
C                                                                       CWW30370
C     ATMOSPHERIC SURFACE TOPOGRAPHY   375-399                          CWW30380
      EQUIVALENCE (W(375),SUMODEL),(W(376),SUFORM),(W(377),SUID)        CWW30390
C     PLOT ENHANCEMENTS CONTROL PARAMETERS                              CWW30400
C                                                                       CWW30410
      EQUIVALENCE (W(490),XFQMDL),(W(491),YFQMDL)                       CWW30420
C     ABSORPTION        500-524                                         CWW30430
      EQUIVALENCE (W(500),AMODEL),(W(501),AFORM),(W(502),AID)           CWW30440
C                                                                       CWW30450
C     DELTA ABSORPTION        525-549                                   CWW30460
      EQUIVALENCE (W(525),DAMODEL),(W(526),DAFORM),(W(527),DAID)        CWW30470
C                                                                       CWW30480
C     PRESSURE        550-574                                           CWW30490
      EQUIVALENCE (W(550),PMODEL),(W(551),PFORM),(W(552),PID)           CWW30500
C                                                                       CWW30510
C     DELTA PRESSURE        575-599                                     CWW30520
      EQUIVALENCE (W(575),DPMODEL),(W(576),DPFORM),(W(577),DPID)        CWW30530
C                                                                       CWW30540
C                                                                       ANNL0110
      REAL KS,MKS                                                       ANNL0120
      REAL KVECT(24)                                                    ANNL0130
      REAL VSET(20)                                                     ANNL0140
      EQUIVALENCE(KVECT,KAY2),(VSET,V)                                  ANNL0150
C                                                                       ANNL0160
```

```
      REAL MRDRIN(8)      ,TBPE( 3)
      CHARACTER DLSPM*5
C
      DATA MRDRIN/8HACOUSTIC ,8H WAVE ** ,8H** NO CU ,8HRRENT **
     1  ,8H* NO LOS ,3HSES ,2*1H /
      DATA DLSPM/'ANCNL'/
      DATA TBPE/3*1H0 /
C
C
      ENTRY SETDSP
C
      CALL RMOVE(MODRIN,MRDRIN,8)
      DISPM=DLSPM
      CALL RMOVE(TYPE,TBPE, 3)
C
      CALL SETSPD
      CALL SETRCV
      CALL SETTOP
      CALL SETSUR
      RETURN
C
      ENTRY IDISPER
      CALL ISPEED
      CALL IRECVR
      CALL ITOPOG
      CALL ISURFAC
      RETURN
C
      ENTRY DISPER
      ENTRY RINDEX
C
      SPACE=.FALSE.
C
      KS=KR*KR+KTH*KTH+KPH*KPH
C     SOUND SPEED
      CALL SPEED
      OWS=OW*OW
      KAY2=OWS/CS
C
      H=OW*OW - CS*KS
      MKS=-KS
      PHT=MKS*PCST
      PHR=MKS*PCSR
      PHTH=MKS*PCSTH
      PHPH=MKS*PCSPH
C
      PHOW=2.0*OW
      CS2=-2.0*CS
      PHKR=CS2*KR
      PHKTH=CS2*KTH
      PHKPH=CS2*KPH
      KPHK=CS2*KS
      RETURN
      END
```

```
      SUBROUTINE AWCNL                                                  AWNL0020
C     DISPERSION RELATION FOR ACOUSTIC WAVES WITH CURRENT, NO LOSSES    AWNL0030
C     COMMON DECK "RKAM" INSERTED HERE                                  RKAM0020
      REAL KR,KTH,KPH                                                   RKAM0040
      COMMON//R,TH,PH,KR,KTH,KPH,RKVARS(14),TPULSE,CSTEP,DRDT(20)       RKAM0050
C     COMMON DECK "CC" INSERTED HERE                                    CCC 0020
      REAL MODC                                                         CCC 0040
      COMMON/CC/MODC(4),CS,PCST,PCSR,PCSTH,PCSPH                        CCC 0050
C     COMMON DECK "CONST" INSERTED HERE                                 CCON0020
      COMMON/PCONST/CREF,RGAS,GAMMA                                     CCON0040
      COMMON/MCONST/PI,PIT2,PID2,DEGS,RAD,ALN10                         CCON0050
C     COMMON DECK "RK" INSERTED HERE                                    CRK 0020
C     DEFINE SIZE REQUIRED FOR RAY STATE SAVE ARRAY                     CRK 0040
      PARAMETER (LRKAMS=87+2*100,NXRKMS=12+LRKAMS,MXEQPT=21)            CRK 0050
      PARAMETER (NRKSAV=NXRKMS+MXEQPT-1)                                CRK 0060
      COMMON /RK/ NEQS,STEP,MODE,E1MAX,E1MIN,E2MAX,E2MIN,FACT,RSTART    CRK 0070
C     COMMON DECK "RINREAL" INSERTED HERE                               CRIN0020
      LOGICAL SPACE                                                     CRIN0040
      REAL LPOLAR,LPOLRI,KPHK,KPHKI,KAY2,KAY2I                          CRIN0050
      CHARACTER DISPM*6                                                 CRIN0060
      COMMON/RINPL/DISPM                                                CRIN0070
      COMMON /RIN/ MODRIN(8),RAYNAME(2,3),TYPE(3),SPACE                 CRIN0080
      COMMON/RIN/OMEGMIN,OMEGMAX,KAY2,KAY2I,                            CRIN0090
     1           H,HI,PHT,PHTI,PHR,PHRI,PHTH,PHTHI,PHPH,PHPHI           CRIN0100
     2, PHOW,PHOWI,PHKR,PHKRI,PHKTH,PHKTI, PHKPH,PHKPI                  CRIN0110
     3 ,KPHK,KPHKI,POLAR,POLARI,LPOLAR,LPOLRI,SGN                       CRIN0120
C     COMMON DECK "UU" INSERTED HERE                                    CUU 0020
      REAL MODU                                                         CUU 0040
      COMMON/UU/MODU(4)                                                 CUU 0050
     1  ,V   ,PVT  ,PVR  ,PVTH  ,PVPH                                   CUU 0060
     2  ,VR  ,PVRT ,PVRR ,PVRTH ,PVRPH                                  CUU 0070
     3  ,VTH,PVTHT,PVTHR,PVTHTH,PVTHPH                                  CUU 0080
     4  ,VPH,PVPHT,PVPHR,PVPHTH,PVPHPH                                  CUU 0090
C     COMMON DECK "WW" INSERTED HERE                                    CWW 0020
      PARAMETER (NWARSZ=1000)                                           CWW10030
      COMMON/WW/ID(10),MAXW,W(NWARSZ)                                   CWW10040
      REAL MAXSTP,MAXERR,INTYP,LLAT,LLON                                CWW20020
      EQUIVALENCE (EARTHR,W(1)),(RAY,W(2)),(XMTRH,W(3)),(TLAT,W(4)),    CWW20030
     1 (TLON,W(5)),(OW,W(6)),(FBEG,W(7)),(FEND,W(8)),(FSTEP,W(9)),      CWW20040
     2 (AZ1,W(10)),(AZBEG,W(11)),(AZEND,W(12)),(AZSTEP,W(13)),          CWW20050
     3 (BETA,W(14)),(ELBEG,W(15)),(ELEND,W(16)),(ELSTEP,W(17)),         CWW20060
     8   (RUNSUP,W(18)),(RCVRH,W(20)),                                  CWW20070
     4 (ONLY,W(21)),(HOP,W(22)),(MAXSTP,W(23)),(PLAT,W(24)),(PLON,W(25))CWW20080
     5,(HMAX,W(26)),(RAYFNC,W(29)),(EXTINC,W(33)),                      CWW20090
     6 (HMIN,W(27)),(RGMAX,W(28)),                                      CWW20100
     8 (INTYP,W(41)),(MAXERR,W(42)),(ERATIO,W(43)),                     CWW20110
     6 (STEP1,W(44)),(STPMAX,W(45)),(STPMIN,W(46)),(FACTR,W(47)),       CWW20120
     7 (SKIP,W(71)),(RAYSET,W(72)),(PRTSRP,W(74)),(HITLET,W(75))        CWW20130
     9 ,(BINRAY,W(76)),(PAGLN,W(77)),(PLT,W(81)),(PFACTR,W(82)),        CWW20140
     1 (LLAT,W(83)),(LLON,W(84)),(RLAT,W(85)),(RLON,W(86))              CWW20150
     2,(TIC,W(87)),(HB,W(88)),(HT,W(89)),(TICV,W(96))                   CWW20160
```

```
      REAL MMODEL,MFORM,MID
C
C     WIND          100-124
      EQUIVALENCE (W(100),UMODEL),(W(101),UFORM),(W(102),UID)
C
C     DELTA WIND          125-149
      EQUIVALENCE (W(125),DUMODEL),(W(126),DUFORM),(W(127),DUID)
C
C     SOUND SPEED 150-174
      EQUIVALENCE (W(150),CMODEL),(W(151),CFORM),(W(152),CID)
      EQUIVALENCE (W(153),REFC)
C
C     DELTA SOUND SPEED 175-199
      EQUIVALENCE (W(175),DCMODEL),(W(176),DCFORM),(W(177),DCID)
C
C     TEMPERATURE    200-224
      EQUIVALENCE (W(200),TMODEL),(W(201),TFORM),(W(202),TID)
C
C     DELTA TEMPERATURE    225-249
      EQUIVALENCE (W(225),DTMODEL),(W(226),DTFORM),(W(227),DTID)
C
C     MOLECULAR   250-274
      EQUIVALENCE (W(250),MMODEL),(W(251),MFORM),(W(252),MID)
C
C     RECEIVER HEIGHT   275-299
      EQUIVALENCE (W(275),RMODEL),(W(276),RFORM),(W(277),RID)
C
C     TOPOGRAPHY   300-324
      EQUIVALENCE (W(300),GMODEL),(W(301),GFORM),(W(302),GID)
C
C     DELTA TOPOGRAPHY   325-349
      EQUIVALENCE (W(325),GUMODEL),(W(326),GUFORM),(W(327),GUID)
C
C     ATMOSPHERIC SURFACE TOPOGRAPHY   350-374
      EQUIVALENCE (W(350),SMODEL),(W(351),SFORM),(W(352),SID)
C
C     ATMOSPHERIC SURFACE TOPOGRAPHY   375-399
      EQUIVALENCE (W(375),SUMODEL),(W(376),SUFORM),(W(377),SUID)
C     PLOT ENHANCEMENTS CONTROL PARAMETERS
C
      EQUIVALENCE (W(490),XFQMDL),(W(491),YFQMDL)
C     ABSORPTION          500-524
      EQUIVALENCE (W(500),AMODEL),(W(501),AFORM),(W(502),AID)
C
C     DELTA ABSORPTION          525-549
      EQUIVALENCE (W(525),DAMODEL),(W(526),DAFORM),(W(527),DAID)
C
C     PRESSURE          550-574
      EQUIVALENCE (W(550),PMODEL),(W(551),PFORM),(W(552),PID)
C
C     DELTA PRESSURE          575-599
      EQUIVALENCE (W(575),DPMODEL),(W(576),DPFORM),(W(577),DPID)
C
C
      REAL KS,KV
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```
      REAL KVECT(24)
      EQUIVALENCE(KVECT,KAY2)
C
      REAL MRDRIN(8)    ,TBPE( 3)
      CHARACTER DLSPM*5
C
      DATA MRDRIN/8HACOUSTIC ,8H WAVE ** ,8H* WITH C ,8HURRENT *
     1  ,8H*** NO L ,5HOSSES ,2*1H /
      DATA DLSPM/'AWCNL'/
      DATA TBPE/3*1H1 /
C
C
      ENTRY SETDSP
C
      CALL RMOVE(MODRIN,MRDRIN,8)
      DISPM=DLSPM
      CALL RMOVE(TYPE,TBPE, 3)
C
      CALL SETSPD
      CALL SETWND
      CALL SETRCV
      CALL SETTOP
      CALL SETSUR
      RETURN
C
      ENTRY IDISPER
      CALL ISPEED
      CALL IWINDR
      CALL IRECVR
      CALL ITOPOG
      CALL ISURFAC
      RETURN
C
      ENTRY DISPER
C
      SPACE=.FALSE.
C
      KS=KR*KR+KTH*KTH+KPH*KPH
C     WIND VELOCITY
      CALL WINDR
      KV=KR*VR+KTH*VTH+KPH*VPH
      VLS=KV*KV/KS
C     SOUND SPEED
      CALL SPEED
      OWS=OW*OW
      KAY2=OWS/(SQRT(CS)+KV/SQRT(KS))**2
C
      OWI=OW-KV
      H=OWI*OWI - CS*KS
      POWIT=-KR*PVRT - KTH*PVTHT - KPH*PVPHT
      PHT=2.0*OWI*POWIT - KS*PCST
      POWIR=-KR*PVRR - KTH*PVTHR - KPH*PVPHR
      PHR=2.0*OWI*POWIR - KS*PCSR
      POWITH=-KR*PVRTH - KTH*PVTHTH - KPH*PVPHTH
      PHTH=2.0*OWI*POWITH - KS*PCSTH
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      POWIPH=-KR*PVRPH - KTH*PVTHPH - KPH*PVPHPH                        AWNL0680
      PHPH=2.0*OWI*POWIPH - KS*PCSPH                                    AWNL0690
C                                                                       AWNL0700
      PHOW=2.0*OWI                                                      AWNL0710
      PHKR=-2.0*(OWI*VR + CS*KR)                                        AWNL0720
      PHKTH=-2.0*(OWI*VTH + CS*KTH)                                     AWNL0730
      PHKPH=-2.0*(OWI*VPH + CS*KPH)                                     AWNL0740
      KPHK=-2.0*(OWI*KV + CS*KS)                                        AWNL0750
      RETURN                                                            AWNL0760
      END                                                               AWNL0770


      SUBROUTINE ANCWL                                                  ANRL0020
C     DISPERSION RELATION FOR ACOUSTIC WAVES NO CURRENT, WITH LOSSES    ANRL0030
C     COMMON DECK "RKAM" INSERTED HERE                                  RKAM0020
      REAL KR,KTH,KPH                                                   RKAM0040
      COMMON//R,TH,PH,KR,KTH,KPH,RKVARS(14),TPULSE,CSTEP,DRDT(20)       RKAM0050
C     COMMON DECK "CC" INSERTED HERE                                    CCC 0020
      REAL MODC                                                         CCC 0040
      COMMON/CC/MODC(4),CS,PCST,PCSR,PCSTH,PCSPH                        CCC 0050
C     COMMON DECK "CONST" INSERTED HERE                                 CCON0020
      COMMON/PCONST/CREF,RGAS,GAMMA                                     CCON0040
      COMMON/MCONST/PI,PIT2,PID2,DEGS,RAD,ALN10                         CCON0050
C     COMMON DECK "RK" INSERTED HERE                                    CRK 0020
C     DEFINE SIZE REQUIRED FOR RAY STATE SAVE ARRAY                     CRK 0040
      PARAMETER (LRKAMS=87+2*100,NXRKMS=12+LRKAMS,MXEQPT=21)            CRK 0050
      PARAMETER (NRKSAV=NXRKMS+MXEQPT-1)                                CRK 0060
      COMMON /RK/ NEQS,STEP,MODE,E1MAX,E1MIN,E2MAX,E2MIN,FACT,RSTART    CRK 0070
C     COMMON DECK "RINREAL" INSERTED HERE                               CRIN0020
      LOGICAL SPACE                                                     CRIN0040
      REAL LPOLAR,LPOLRI,KPHK,KPHKI,KAY2,KAY2I                          CRIN0050
      CHARACTER DISPM*6                                                 CRIN0060
      COMMON/RINPL/DISPM                                                CRIN0070
      COMMON /RIN/ MODRIN(8),RAYNAME(2,3),TYPE(3),SPACE                 CRIN0080
      COMMON/RIN/OMEGMIN,OMEGMAX,KAY2,KAY2I,                            CRIN0090
     1            H,HI,PHT,PHTI,PHR,PHRI,PHTH,PHTHI,PHPH,PHPHI          CRIN0100
     2, PHOW,PHOWI,PHKR,PHKRI,PHKTH,PHKTI, PHKPH,PHKPI                  CRIN0110
     3 ,KPHK,KPHKI,POLAR,POLARI,LPOLAR,LPOLRI,SGN                       CRIN0120
C     COMMON DECK "UU" INSERTED HERE                                    CUU 0020
      REAL MODU                                                         CUU 0040
      COMMON/UU/MODU(4)                                                 CUU 0050
     1   ,V   ,PVT   ,PVR   ,PVTH   ,PVPH                               CUU 0060
     2   ,VR  ,PVRT  ,PVRR  ,PVRTH  ,PVRPH                              CUU 0070
     3   ,VTH,PVTHT,PVTHR,PVTHTH,PVTHPH                                 CUU 0080
     4   ,VPH,PVPHT,PVPHR,PVPHTH,PVPHPH                                 CUU 0090
C     COMMON DECK "WW" INSERTED HERE                                    CWW 0020
      PARAMETER (NWARSZ=1000)                                           CWW10030
      COMMON/WW/ID(10),MAXW,W(NWARSZ)                                   CWW10040
      REAL MAXSTP,MAXERR,INTYP,LLAT,LLON                                CWW20020
      EQUIVALENCE (EARTHR,W(1)),(RAY,W(2)),(XMTRH,W(3)),(TLAT,W(4)),    CWW20030
     1 (TLON,W(5)),(OW,W(6)),(FBEG,W(7)),(FEND,W(8)),(FSTEP,W(9)),      CWW20040
     2 (AZ1,W(10)),(AZBEG,W(11)),(AZEND,W(12)),(AZSTEP,W(13)),          CWW20050
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     3 (BETA,W(14)),(ELBEG,W(15)),(ELEND,W(16)),(ELSTEP,W(17)),          CWW20060
     8   (RUNSUP,W(18)),(RCVRH,W(20)),                                   CWW20070
     4 (ONLY,W(21)),(HOP,W(22)),(MAXSTP,W(23)),(PLAT,W(24)),(PLON,W(25))CWW20080
     5,(HMAX,W(26)),(RAYFNC,W(29)),(EXTINC,W(33)),                       CWW20090
     6 (HMIN,W(27)),(RGMAX,W(28)),                                       CWW20100
     8 (INTYP,W(41)),(MAXERR,W(42)),(ERATIO,W(43)),                      CWW20110
     6 (STEP1,W(44)),(STPMAX,W(45)),(STPMIN,W(46)),(FACTR,W(47)),        CWW20120
     7 (SKIP,W(71)),(RAYSET,W(72)),(PRTSRP,W(74)),(HITLET,W(75))         CWW20130
     9 ,(BINRAY,W(76)),(PAGLN,W(77)),(PLT,W(81)),(PFACTR,W(82)),         CWW20140
     1 (LLAT,W(83)),(LLON,W(84)),(RLAT,W(85)),(RLON,W(86))               CWW20150
     2,(TIC,W(87)),(HB,W(88)),(HT,W(89)),(TICV,W(96))                    CWW20160
      REAL MMODEL,MFORM,MID                                              CWW30020
C                                                                        CWW30030
C     WIND          100-124                                              CWW30040
      EQUIVALENCE (W(100),UMODEL),(W(101),UFORM),(W(102),UID)            CWW30050
C                                                                        CWW30060
C     DELTA WIND          125-149                                        CWW30070
      EQUIVALENCE (W(125),DUMODEL),(W(126),DUFORM),(W(127),DUID)         CWW30080
C                                                                        CWW30090
C     SOUND SPEED 150-174                                                CWW30100
      EQUIVALENCE (W(150),CMODEL),(W(151),CFORM),(W(152),CID)            CWW30110
      EQUIVALENCE (W(153),REFC)                                          CWW30120
C                                                                        CWW30130
C     DELTA SOUND SPEED 175-199                                          CWW30140
      EQUIVALENCE (W(175),DCMODEL),(W(176),DCFORM),(W(177),DCID)         CWW30150
C                                                                        CWW30160
C     TEMPERATURE    200-224                                             CWW30170
      EQUIVALENCE (W(200),TMODEL),(W(201),TFORM),(W(202),TID)            CWW30180
C                                                                        CWW30190
C     DELTA TEMPERATURE    225-249                                       CWW30200
      EQUIVALENCE (W(225),DTMODEL),(W(226),DTFORM),(W(227),DTID)         CWW30210
C                                                                        CWW30220
C     MOLECULAR   250-274                                                CWW30230
      EQUIVALENCE (W(250),MMODEL),(W(251),MFORM),(W(252),MID)            CWW30240
C                                                                        CWW30250
C     RECEIVER HEIGHT   275-299                                          CWW30260
      EQUIVALENCE (W(275),RMODEL),(W(276),RFORM),(W(277),RID)            CWW30270
C                                                                        CWW30280
C     TOPOGRAPHY   300-324                                               CWW30290
      EQUIVALENCE (W(300),GMODEL),(W(301),GFORM),(W(302),GID)            CWW30300
C                                                                        CWW30310
C     DELTA TOPOGRAPHY   325-349                                         CWW30320
      EQUIVALENCE (W(325),GUMODEL),(W(326),GUFORM),(W(327),GUID)         CWW30330
C                                                                        CWW30340
C     ATMOSPHERIC SURFACE TOPOGRAPHY   350-374                           CWW30350
      EQUIVALENCE (W(350),SMODEL),(W(351),SFORM),(W(352),SID)            CWW30360
C                                                                        CWW30370
C     ATMOSPHERIC SURFACE TOPOGRAPHY   375-399                           CWW30380
      EQUIVALENCE (W(375),SUMODEL),(W(376),SUFORM),(W(377),SUID)         CWW30390
C     PLOT ENHANCEMENTS CONTROL PARAMETERS                               CWW30400
C                                                                        CWW30410
      EQUIVALENCE (W(490),XFQMDL),(W(491),YFQMDL)                        CWW30420
C     ABSORPTION          500-524                                        CWW30430
      EQUIVALENCE (W(500),AMODEL),(W(501),AFORM),(W(502),AID)            CWW30440
C                                                                        CWW30450
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C     DELTA ABSORPTION        525-549                                  CWW30460
      EQUIVALENCE (W(525),DAMODEL),(W(526),DAFORM),(W(527),DAID)       CWW30470
C                                                                      CWW30480
C     PRESSURE        550-574                                          CWW30490
      EQUIVALENCE (W(550),PMODEL),(W(551),PFORM),(W(552),PID)          CWW30500
C                                                                      CWW30510
C     DELTA PRESSURE        575-599                                    CWW30520
      EQUIVALENCE (W(575),DPMODEL),(W(576),DPFORM),(W(577),DPID)       CWW30530
C                                                                      CWW30540
C                                                                      ANRL0110
C     COMMON DECK "LL" INSERTED HERE                                   CLL 0020
      REAL MODL                                                        CLL 0040
      COMMON/LL/MODL(4),APH,APHPT,APHPR,APHPTH,APHPPH                  CLL 0050
C                                                                      ANRL0130
C     COMMON DECK "PP" INSERTED HERE                                   CPP 0020
      REAL MODP                                                        CPP 0040
      COMMON/PP/MODP(4),P,PPT,PPR,PPTH,PPPH                            CPP 0050
C                                                                      ANRL0150
C     COMMON DECK "MM" INSERTED HERE                                   CMM 0020
      REAL M,MODM                                                      CMM 0040
      COMMON/MM/MODM(4),M,PMT,PMR,PMTH,PMPH                            CMM 0050
C                                                                      ANRL0170
      REAL KS,MKS                                                      ANRL0180
      REAL KVECT(24)                                                   ANRL0190
      REAL VSET(20)                                                    ANRL0200
      EQUIVALENCE(KVECT,KAY2),(VSET,V)                                 ANRL0210
C                                                                      ANRL0220
      REAL MRDRIN(8)     ,TBPE( 3)                                     ANRL0230
      CHARACTER DLSPM*5                                                ANRL0240
C                                                                      ANRL0250
      DATA MRDRIN/8HACOUSTIC ,8H WAVE ** ,8H** NO CU ,8HRRENT **       ANRL0260
     1  ,8H* WITH L ,5HOSSES ,2*1H /                                   ANRL0270
      DATA DLSPM/'ANCWL'/                                              ANRL0280
      DATA TBPE/3*1H2 /                                                ANRL0290
C                                                                      ANRL0300
C                                                                      ANRL0310
      ENTRY SETDSP                                                     ANRL0320
C                                                                      ANRL0330
      CALL RMOVE(MODRIN,MRDRIN,8)                                      ANRL0340
      DISPM=DLSPM                                                      ANRL0350
      CALL RMOVE(TYPE,TBPE, 3)                                         ANRL0360
C                                                                      ANRL0370
      CALL SETSPD                                                      ANRL0380
      CALL SETRCV                                                      ANRL0390
      CALL SETTOP                                                      ANRL0400
      CALL SETSUR                                                      ANRL0410
      RETURN                                                           ANRL0420
C                                                                      ANRL0430
      ENTRY IDISPER                                                    ANRL0440
      CALL ISPEED                                                      ANRL0450
      CALL IRECVR                                                      ANRL0460
      CALL ITOPOG                                                      ANRL0470
      CALL ISURFAC                                                     ANRL0480
C                                                                      ANRL0490
      CALL IABSRP                                                      ANRL0500
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      RETURN                                                            ANRL0510
C                                                                       ANRL0520
      ENTRY DISPER                                                      ANRL0530
      ENTRY RINDEX                                                      ANRL0540
C                                                                       ANRL0550
      SPACE=.FALSE.                                                     ANRL0560
C                                                                       ANRL0570
      KS=KR*KR+KTH*KTH+KPH*KPH                                          ANRL0580
C     SOUND SPEED                                                       ANRL0590
      CALL SPEED                                                        ANRL0600
      OWS=OW*OW                                                         ANRL0610
      KAY2=OWS/CS                                                       ANRL0620
C                                                                       ANRL0630
      H=OW*OW - CS*KS                                                   ANRL0640
      MKS=-KS                                                           ANRL0650
      PHT=MKS*PCST                                                      ANRL0660
      PHR=MKS*PCSR                                                      ANRL0670
      PHTH=MKS*PCSTH                                                    ANRL0680
      PHPH=MKS*PCSPH                                                    ANRL0690
C                                                                       ANRL0700
      PHOW=2.0*OW                                                       ANRL0710
      CS2=-2.0*CS                                                       ANRL0720
      PHKR=CS2*KR                                                       ANRL0730
      PHKTH=CS2*KTH                                                     ANRL0740
      PHKPH=CS2*KPH                                                     ANRL0750
      KPHK=CS2*KS                                                       ANRL0760
C                                                                       ANRL0770
      CALL ABSRP                                                        ANRL0780
      GMS=GAMMA-1.0                                                     ANRL0790
      KAY2I=-SQRT(KAY2)*APH                                             ANRL0800
      RETURN                                                            ANRL0810
      END                                                               ANRL0820
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      SUBROUTINE AWCWL                                                  AWRL0020
C     DISPERSION RELATION FOR ACOUSTIC WAVES WITH CURRENT, WITH LOSSES  AWRL0030
C     COMMON DECK "RKAM" INSERTED HERE                                  RKAM0020
      REAL KR,KTH,KPH                                                   RKAM0040
      COMMON//R,TH,PH,KR,KTH,KPH,RKVARS(14),TPULSE,CSTEP,DRDT(20)       RKAM0050
C     COMMON DECK "CC" INSERTED HERE                                    CCC 0020
      REAL MODC                                                         CCC 0040
      COMMON/CC/MODC(4),CS,PCST,PCSR,PCSTH,PCSPH                        CCC 0050
C     COMMON DECK "CONST" INSERTED HERE                                 CCON0020
      COMMON/PCONST/CREF,RGAS,GAMMA                                     CCON0040
      COMMON/MCONST/PI,PIT2,PID2,DEGS,RAD,ALN10                         CCON0050
C     COMMON DECK "RK" INSERTED HERE                                    CRK 0020
C     DEFINE SIZE REQUIRED FOR RAY STATE SAVE ARRAY                     CRK 0040
      PARAMETER (LRKAMS=87+2*100,NXRKMS=12+LRKAMS,MXEQPT=21)            CRK 0050
      PARAMETER (NRKSAV=NXRKMS+MXEQPT-1)                                CRK 0060
      COMMON /RK/ NEQS,STEP,MODE,E1MAX,E1MIN,E2MAX,E2MIN,FACT,RSTART    CRK 0070
C     COMMON DECK "RINREAL" INSERTED HERE                               CRIN0020
      LOGICAL SPACE                                                     CRIN0040
```

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      REAL LPOLAR,LPOLRI,KPHK,KPHKI,KAY2,KAY2I                          CRIN0050
      CHARACTER DISPM*6                                                 CRIN0060
      COMMON/RINPL/DISPM                                                CRIN0070
      COMMON /RIN/ MODRIN(8),RAYNAME(2,3),TYPE(3),SPACE                 CRIN0080
      COMMON/RIN/OMEGMIN,OMEGMAX,KAY2,KAY2I,                            CRIN0090
     1               H,HI,PHT,PHTI,PHR,PHRI,PHTH,PHTHI,PHPH,PHPHI       CRIN0100
     2, PHOW,PHOWI,PHKR,PHKRI,PHKTH,PHKTI, PHKPH,PHKPI                  CRIN0110
     3 ,KPHK,KPHKI,POLAR,POLARI,LPOLAR,LPOLRI,SGN                       CRIN0120
C     COMMON DECK "UU" INSERTED HERE                                    CUU 0020
      REAL MODU                                                         CUU 0040
      COMMON/UU/MODU(4)                                                 CUU 0050
     1  ,V  ,PVT  ,PVR  ,PVTH  ,PVPH                                    CUU 0060
     2  ,VR ,PVRT ,PVRR ,PVRTH ,PVRPH                                   CUU 0070
     3  ,VTH,PVTHT,PVTHR,PVTHTH,PVTHPH                                  CUU 0080
     4  ,VPH,PVPHT,PVPHR,PVPHTH,PVPHPH                                  CUU 0090
C     COMMON DECK "WW" INSERTED HERE                                    CWW 0020
      PARAMETER (NWARSZ=1000)                                           CWW10030
      COMMON/WW/ID(10),MAXW,W(NWARSZ)                                   CWW10040
      REAL MAXSTP,MAXERR,INTYP,LLAT,LLON                                CWW20020
      EQUIVALENCE (EARTHR,W(1)),(RAY,W(2)),(XMTRH,W(3)),(TLAT,W(4)),    CWW20030
     1 (TLON,W(5)),(OW,W(6)),(FBEG,W(7)),(FEND,W(8)),(FSTEP,W(9)),      CWW20040
     2 (AZ1,W(10)),(AZBEG,W(11)),(AZEND,W(12)),(AZSTEP,W(13)),          CWW20050
     3 (BETA,W(14)),(ELBEG,W(15)),(ELEND,W(16)),(ELSTEP,W(17)),         CWW20060
     8    (RUNSUP,W(18)),(RCVRH,W(20)),                                 CWW20070
     4 (ONLY,W(21)),(HOP,W(22)),(MAXSTP,W(23)),(PLAT,W(24)),(PLON,W(25))CWW20080
     5,(HMAX,W(26)),(RAYFNC,W(29)),(EXTINC,W(33)),                      CWW20090
     6 (HMIN,W(27)),(RGMAX,W(28)),                                      CWW20100
     8 (INTYP,W(41)),(MAXERR,W(42)),(ERATIO,W(43)),                     CWW20110
     6 (STEP1,W(44)),(STPMAX,W(45)),(STPMIN,W(46)),(FACTR,W(47)),       CWW20120
     7 (SKIP,W(71)),(RAYSET,W(72)),(PRTSRP,W(74)),(HITLET,W(75))        CWW20130
     9 ,(BINRAY,W(76)),(PAGLN,W(77)),(PLT,W(81)),(PFACTR,W(82)),        CWW20140
     1 (LLAT,W(83)),(LLON,W(84)),(RLAT,W(85)),(RLON,W(86))              CWW20150
     2,(TIC,W(87)),(HB,W(88)),(HT,W(89)),(TICV,W(96))                   CWW20160
      REAL MMODEL,MFORM,MID                                             CWW30020
C                                                                       CWW30030
C     WIND          100-124                                             CWW30040
      EQUIVALENCE (W(100),UMODEL),(W(101),UFORM),(W(102),UID)           CWW30050
C                                                                       CWW30060
C     DELTA WIND          125-149                                       CWW30070
      EQUIVALENCE (W(125),DUMODEL),(W(126),DUFORM),(W(127),DUID)        CWW30080
C                                                                       CWW30090
C     SOUND SPEED 150-174                                               CWW30100
      EQUIVALENCE (W(150),CMODEL),(W(151),CFORM),(W(152),CID)           CWW30110
      EQUIVALENCE (W(153),REFC)                                         CWW30120
C                                                                       CWW30130
C     DELTA SOUND SPEED 175-199                                         CWW30140
      EQUIVALENCE (W(175),DCMODEL),(W(176),DCFORM),(W(177),DCID)        CWW30150
C                                                                       CWW30160
C     TEMPERATURE     200-224                                           CWW30170
      EQUIVALENCE (W(200),TMODEL),(W(201),TFORM),(W(202),TID)           CWW30180
C                                                                       CWW30190
C     DELTA TEMPERATURE     225-249                                     CWW30200
      EQUIVALENCE (W(225),DTMODEL),(W(226),DTFORM),(W(227),DTID)        CWW30210
C                                                                       CWW30220
C     MOLECULAR    250-274                                              CWW30230
```

```
      EQUIVALENCE (W(250),MMODEL),(W(251),MFORM),(W(252),MID)           CWW30240
C                                                                       CWW30250
C     RECEIVER HEIGHT   275-299                                         CWW30260
      EQUIVALENCE (W(275),RMODEL),(W(276),RFORM),(W(277),RID)           CWW30270
C                                                                       CWW30280
C     TOPOGRAPHY   300-324                                              CWW30290
      EQUIVALENCE (W(300),GMODEL),(W(301),GFORM),(W(302),GID)           CWW30300
C                                                                       CWW30310
C     DELTA TOPOGRAPHY   325-349                                        CWW30320
      EQUIVALENCE (W(325),GUMODEL),(W(326),GUFORM),(W(327),GUID)        CWW30330
C                                                                       CWW30340
C     ATMOSPHERIC SURFACE TOPOGRAPHY   350-374                          CWW30350
      EQUIVALENCE (W(350),SMODEL),(W(351),SFORM),(W(352),SID)           CWW30360
C                                                                       CWW30370
C     ATMOSPHERIC SURFACE TOPOGRAPHY   375-399                          CWW30380
      EQUIVALENCE (W(375),SUMODEL),(W(376),SUFORM),(W(377),SUID)        CWW30390
C     PLOT ENHANCEMENTS CONTROL PARAMETERS                              CWW30400
C                                                                       CWW30410
      EQUIVALENCE (W(490),XFQMDL),(W(491),YFQMDL)                       CWW30420
C     ABSORPTION          500-524                                       CWW30430
      EQUIVALENCE (W(500),AMODEL),(W(501),AFORM),(W(502),AID)           CWW30440
C                                                                       CWW30450
C     DELTA ABSORPTION          525-549                                 CWW30460
      EQUIVALENCE (W(525),DAMODEL),(W(526),DAFORM),(W(527),DAID)        CWW30470
C                                                                       CWW30480
C     PRESSURE          550-574                                         CWW30490
      EQUIVALENCE (W(550),PMODEL),(W(551),PFORM),(W(552),PID)           CWW30500
C                                                                       CWW30510
C     DELTA PRESSURE          575-599                                   CWW30520
      EQUIVALENCE (W(575),DPMODEL),(W(576),DPFORM),(W(577),DPID)        CWW30530
C                                                                       CWW30540
C                                                                       AWRL0110
C     COMMON DECK "LL" INSERTED HERE                                    CLL 0020
      REAL MODL                                                         CLL 0040
      COMMON/LL/MODL(4),APH,APHPT,APHPR,APHPTH,APHPPH                   CLL 0050
C                                                                       AWRL0130
C     COMMON DECK "PP" INSERTED HERE                                    CPP 0020
      REAL MODP                                                         CPP 0040
      COMMON/PP/MODP(4),P,PPT,PPR,PPTH,PPPH                             CPP 0050
C                                                                       AWRL0150
C     COMMON DECK "MM" INSERTED HERE                                    CMM 0020
      REAL M,MODM                                                       CMM 0040
      COMMON/MM/MODM(4),M,PMT,PMR,PMTH,PMPH                             CMM 0050
C                                                                       AWRL0170
      REAL KS,KV                                                        AWRL0180
      REAL KVECT(24)                                                    AWRL0190
      EQUIVALENCE(KVECT,KAY2)                                           AWRL0200
C                                                                       AWRL0210
      REAL MRDRIN(8)     ,TBPE( 3)                                      AWRL0220
      CHARACTER DLSPM*5                                                 AWRL0230
C                                                                       AWRL0240
      DATA MRDRIN/8HACOUSTIC ,8H WAVE ** ,8H* WITH C ,8HURRENT *        AWRL0250
     1  ,8H** WITH  ,6HLOSSES ,2*1H /                                   AWRL0260
      DATA DLSPM/'AWCWL'/                                               AWRL0270
      DATA TBPE/3*1H3 /                                                 AWRL0280
```

```
C
C
      ENTRY SETDSP
C
      CALL RMOVE(MODRIN,MRDRIN,8)
      DISPM=DLSPM
      CALL RMOVE(TYPE,TBPE, 3)
C
      CALL SETSPD
      CALL SETWND
      CALL SETRCV
      CALL SETTOP
      CALL SETSUR
      CALL SETABS
      RETURN
C
      ENTRY IDISPER
      CALL ISPEED
      CALL IWINDR
      CALL IRECVR
      CALL ITOPOG
      CALL ISURFAC
C
      CALL IABSRP
      RETURN
C
      ENTRY DISPER
C
      SPACE=.FALSE.
C
      KS=KR*KR+KTH*KTH+KPH*KPH
C     WIND VELOCITY
      CALL WINDR
      KV=KR*VR+KTH*VTH+KPH*VPH
      VLS=KV*KV/KS
C     SOUND SPEED
      CALL SPEED
      OWS=OW*OW
      KAY2=OWS/(SQRT(CS)+KV/SQRT(KS))**2
C
      OWI=OW-KV
      H=OWI*OWI - CS*KS
      POWIT=-KR*PVRT - KTH*PVTHT - KPH*PVPHT
      PHT=2.0*OWI*POWIT - KS*PCST
      POWIR=-KR*PVRR - KTH*PVTHR - KPH*PVPHR
      PHR=2.0*OWI*POWIR - KS*PCSR
      POWITH=-KR*PVRTH - KTH*PVTHTH - KPH*PVPHTH
      PHTH=2.0*OWI*POWITH - KS*PCSTH
      POWIPH=-KR*PVRPH - KTH*PVTHPH - KPH*PVPHPH
      PHPH=2.0*OWI*POWIPH - KS*PCSPH
C
      PHOW=2.0*OWI
      PHKR=-2.0*(OWI*VR + CS*KR)
      PHKTH=-2.0*(OWI*VTH + CS*KTH)
      PHKPH=-2.0*(OWI*VPH + CS*KPH)
```

```
      KPHK=-2.0*(OWI*KV + CS*KS)
C
      CALL ABSRP
      GMS=GAMMA-1.0
      KAY2I=-SQRT(KAY2)*APH
      RETURN
      END
```

D.3 OCEAN MODEL ROUTINES (Tape File 5)

```
      SUBROUTINE WLINEAR                                                WLTR0020
C     LINEAR WIND VELOCITY PROFILE                                      WLTR0030
C     PROVIDES CONSTANT RADIAL, ZONAL AND MERIDONAL WINDS               WLTR0040
C     EXCEPT THAT A POSSIBLE LINEAR HEIGHT GRADIENT OF THE ZONAL        WLTR0050
C     COMPONENT IS ALLOWED.                                             WLTR0060
C     COMMON DECK "RKAM" INSERTED HERE                                  RKAM0020
      REAL KR,KTH,KPH                                                   RKAM0040
      COMMON//R,TH,PH,KR,KTH,KPH,RKVARS(14),TPULSE,CSTEP,DRDT(20)       RKAM0050
C     COMMON DECK "UU" INSERTED HERE                                    CUU 0020
      REAL MODU                                                         CUU 0040
      COMMON/UU/MODU(4)                                                 CUU 0050
     1  ,V   ,PVT   ,PVR   ,PVTH   ,PVPH                                CUU 0060
     2  ,VR  ,PVRT  ,PVRR  ,PVRTH  ,PVRPH                               CUU 0070
     3  ,VTH,PVTHT,PVTHR,PVTHTH,PVTHPH                                  CUU 0080
     4  ,VPH,PVPHT,PVPHR,PVPHTH,PVPHPH                                  CUU 0090
C     COMMON DECK "WW" INSERTED HERE                                    CWW 0020
      PARAMETER (NWARSZ=1000)                                           CWW10030
      COMMON/WW/ID(10),MAXW,W(NWARSZ)                                   CWW10040
      REAL MAXSTP,MAXERR,INTYP,LLAT,LLON                                CWW20020
      EQUIVALENCE (EARTHR,W(1)),(RAY,W(2)),(XMTRH,W(3)),(TLAT,W(4)),    CWW20030
     1 (TLON,W(5)),(OW,W(6)),(FBEG,W(7)),(FEND,W(8)),(FSTEP,W(9)),      CWW20040
     2 (AZ1,W(10)),(AZBEG,W(11)),(AZEND,W(12)),(AZSTEP,W(13)),          CWW20050
     3 (BETA,W(14)),(ELBEG,W(15)),(ELEND,W(16)),(ELSTEP,W(17)),         CWW20060
     8   (RUNSUP,W(18)),(RCVRH,W(20)),                                  CWW20070
     4 (ONLY,W(21)),(HOP,W(22)),(MAXSTP,W(23)),(PLAT,W(24)),(PLON,W(25))CWW20080
     5,(HMAX,W(26)),(RAYFNC,W(29)),(EXTINC,W(33)),                      CWW20090
     6 (HMIN,W(27)),(RGMAX,W(28)),                                      CWW20100
     8 (INTYP,W(41)),(MAXERR,W(42)),(ERATIO,W(43)),                     CWW20110
     6 (STEP1,W(44)),(STPMAX,W(45)),(STPMIN,W(46)),(FACTR,W(47)),       CWW20120
     7 (SKIP,W(71)),(RAYSET,W(72)),(PRTSRP,W(74)),(HITLET,W(75))        CWW20130
     9 ,(BINRAY,W(76)),(PAGLN,W(77)),(PLT,W(81)),(PFACTR,W(82)),        CWW20140
     1 (LLAT,W(83)),(LLON,W(84)),(RLAT,W(85)),(RLON,W(86))              CWW20150
     2,(TIC,W(87)),(HB,W(88)),(HT,W(89)),(TICV,W(96))                   CWW20160
      REAL MMODEL,MFORM,MID                                             CWW30020
C                                                                       CWW30030
C     WIND         100-124                                              CWW30040
      EQUIVALENCE (W(100),UMODEL),(W(101),UFORM),(W(102),UID)           CWW30050
C                                                                       CWW30060
C     DELTA WIND         125-149                                        CWW30070
      EQUIVALENCE (W(125),DUMODEL),(W(126),DUFORM),(W(127),DUID)        CWW30080
C                                                                       CWW30090
C     SOUND SPEED 150-174                                               CWW30100
      EQUIVALENCE (W(150),CMODEL),(W(151),CFORM),(W(152),CID)           CWW30110
      EQUIVALENCE (W(153),REFC)                                         CWW30120
C                                                                       CWW30130
C     DELTA SOUND SPEED 175-199                                         CWW30140
      EQUIVALENCE (W(175),DCMODEL),(W(176),DCFORM),(W(177),DCID)        CWW30150
C                                                                       CWW30160
C     TEMPERATURE     200-224                                           CWW30170
      EQUIVALENCE (W(200),TMODEL),(W(201),TFORM),(W(202),TID)           CWW30180
C                                                                       CWW30190
C     DELTA TEMPERATURE      225-249                                    CWW30200
      EQUIVALENCE (W(225),DTMODEL),(W(226),DTFORM),(W(227),DTID)        CWW30210
C                                                                       CWW30220
C     MOLECULAR   250-274                                               CWW30230
```

```
      EQUIVALENCE (W(250),MMODEL),(W(251),MFORM),(W(252),MID)           CWW30240
C                                                                       CWW30250
C     RECEIVER HEIGHT   275-299                                         CWW30260
      EQUIVALENCE (W(275),RMODEL),(W(276),RFORM),(W(277),RID)           CWW30270
C                                                                       CWW30280
C     TOPOGRAPHY   300-324                                              CWW30290
      EQUIVALENCE (W(300),GMODEL),(W(301),GFORM),(W(302),GID)           CWW30300
C                                                                       CWW30310
C     DELTA TOPOGRAPHY   325-349                                        CWW30320
      EQUIVALENCE (W(325),GUMODEL),(W(326),GUFORM),(W(327),GUID)        CWW30330
C                                                                       CWW30340
C     ATMOSPHERIC SURFACE TOPOGRAPHY   350-374                          CWW30350
      EQUIVALENCE (W(350),SMODEL),(W(351),SFORM),(W(352),SID)           CWW30360
C                                                                       CWW30370
C     ATMOSPHERIC SURFACE TOPOGRAPHY   375-399                          CWW30380
      EQUIVALENCE (W(375),SUMODEL),(W(376),SUFORM),(W(377),SUID)        CWW30390
C     PLOT ENHANCEMENTS CONTROL PARAMETERS                              CWW30400
C                                                                       CWW30410
      EQUIVALENCE (W(490),XFQMDL),(W(491),YFQMDL)                       CWW30420
C     ABSORPTION          500-524                                       CWW30430
      EQUIVALENCE (W(500),AMODEL),(W(501),AFORM),(W(502),AID)           CWW30440
C                                                                       CWW30450
C     DELTA ABSORPTION          525-549                                 CWW30460
      EQUIVALENCE (W(525),DAMODEL),(W(526),DAFORM),(W(527),DAID)        CWW30470
C                                                                       CWW30480
C     PRESSURE          550-574                                         CWW30490
      EQUIVALENCE (W(550),PMODEL),(W(551),PFORM),(W(552),PID)           CWW30500
C                                                                       CWW30510
C     DELTA PRESSURE          575-599                                   CWW30520
      EQUIVALENCE (W(575),DPMODEL),(W(576),DPFORM),(W(577),DPID)        CWW30530
C                                                                       CWW30540
C     COMMON DECK "B1" INSERTED HERE                                    CB1 0020
      INTEGER UMX,UNTBL,UITBL,UFRMTBL,IDSU(10)                          CB1 0040
      COMMON/B1/UMX,UNTBL(10),UITBL(10),UFRMTBL(10),UGP(10)             CB1 0050
      EQUIVALENCE (UGP,IDSU)                                            CB1 0060
      EQUIVALENCE (W(103),UR0)                                          WLTR0110
      EQUIVALENCE (W(104),UTH0),(W(105),UPH0),(W(106),PUPHZ0)           WLTR0120
C                                                                       WLTR0130
      INTEGER UPX    ,UQTBL(10),ULTBL(10),UIRMTBL(10)                   WLTR0140
      DATA RECOGU/1.0/                                                  WLTR0150
C                                                                       WLTR0160
      DATA UPX/1/                                                       WLTR0170
      DATA UQTBL/1,11,8*0/                                              WLTR0180
      DATA ULTBL/1,9*0/                                                 WLTR0190
      DATA UIRMTBL/1,9*0/                                               WLTR0200
C                                                                       WLTR0210
C                                                                       WLTR0220
      ENTRY SETWND                                                      WLTR0230
C                                                                       WLTR0240
      UMX=UPX                                                           WLTR0250
      CALL IMOVE(UNTBL,UQTBL,10)                                        WLTR0260
      CALL IMOVE(UITBL,ULTBL,10)                                        WLTR0270
      CALL IMOVE(UFRMTBL,UIRMTBL,10)                                    WLTR0280
      CALL SETPWN                                                       WLTR0290
C                                                                       WLTR0300
```

```
      RETURN
C
      ENTRY IWINDR
C
      IF(RECOGU .NE. UMODEL)
     1    CALL RERROR('SPEED   ','WRNG MODEL',RECOGU)
C
      MODU(1)=7HWLINEAR
      MODU(2)=UID
      CALL IPWINDR
C
      RETURN
C
       ENTRY WINDR
       H = R - EARTHR
C
      CALL CLEAR(V,20)
C
       VR = UR0
       VTH = UTH0
       VPH = (UPH0 + PUPHZ0 * H)
      V=SQRT(VR*VR+VTH*VTH+VPH*VPH)
      PVR=PUPHZ0
      IF(V.NE.0.0) PVR=VPH/V*PUPHZ0
      PVPHR = PUPHZ0
      CALL PWINDR
       RETURN
       END


      SUBROUTINE VVORTX3
C     WIND VELOCITY MODEL
C     VERTICAL VORTEX WIND PERTURBATION WITH VISCOUS CORE AND
C     MULTIPLIES VELOCITY FIELD BY A GUASSIAN HEIGHT PROFILE.
C
C     COMMON DECK "CONST" INSERTED HERE
      COMMON/PCONST/CREF,RGAS,GAMMA
      COMMON/MCONST/PI,PIT2,PID2,DEGS,RAD,ALN10
C     COMMON DECK "RKAM" INSERTED HERE
      REAL KR,KTH,KPH
      COMMON//R,TH,PH,KR,KTH,KPH,RKVARS(14),TPULSE,CSTEP,DRDT(20)
C     COMMON DECK "UU" INSERTED HERE
      REAL MODU
      COMMON/UU/MODU(4)
     1  ,V  ,PVT  ,PVR  ,PVTH  ,PVPH
     2  ,VR ,PVRT ,PVRR ,PVRTH ,PVRPH
     3  ,VTH,PVTHT,PVTHR,PVTHTH,PVTHPH
     4  ,VPH,PVPHT,PVPHR,PVPHTH,PVPHPH
C     COMMON DECK "WW" INSERTED HERE
      PARAMETER (NWARSZ=1000)
      COMMON/WW/ID(10),MAXW,W(NWARSZ)
      REAL MAXSTP,MAXERR,INTYP,LLAT,LLON
```

```
      EQUIVALENCE (EARTHR,W(1)),(RAY,W(2)),(XMTRH,W(3)),(TLAT,W(4)),     CWW20030
     1 (TLON,W(5)),(OW,W(6)),(FBEG,W(7)),(FEND,W(8)),(FSTEP,W(9)),       CWW20040
     2 (AZ1,W(10)),(AZBEG,W(11)),(AZEND,W(12)),(AZSTEP,W(13)),           CWW20050
     3 (BETA,W(14)),(ELBEG,W(15)),(ELEND,W(16)),(ELSTEP,W(17)),          CWW20060
     8   (RUNSUP,W(18)),(RCVRH,W(20)),                                   CWW20070
     4 (ONLY,W(21)),(HOP,W(22)),(MAXSTP,W(23)),(PLAT,W(24)),(PLON,W(25))CWW20080
     5,(HMAX,W(26)),(RAYFNC,W(29)),(EXTINC,W(33)),                       CWW20090
     6 (HMIN,W(27)),(RGMAX,W(28)),                                       CWW20100
     8 (INTYP,W(41)),(MAXERR,W(42)),(ERATIO,W(43)),                      CWW20110
     6 (STEP1,W(44)),(STPMAX,W(45)),(STPMIN,W(46)),(FACTR,W(47)),        CWW20120
     7 (SKIP,W(71)),(RAYSET,W(72)),(PRTSRP,W(74)),(HITLET,W(75))         CWW20130
     9 ,(BINRAY,W(76)),(PAGLN,W(77)),(PLT,W(81)),(PFACTR,W(82)),         CWW20140
     1 (LLAT,W(83)),(LLON,W(84)),(RLAT,W(85)),(RLON,W(86))               CWW20150
     2,(TIC,W(87)),(HB,W(88)),(HT,W(89)),(TICV,W(96))                    CWW20160
      REAL MMODEL,MFORM,MID                                              CWW30020
C                                                                        CWW30030
C     WIND          100-124                                              CWW30040
      EQUIVALENCE (W(100),UMODEL),(W(101),UFORM),(W(102),UID)            CWW30050
C                                                                        CWW30060
C     DELTA WIND          125-149                                        CWW30070
      EQUIVALENCE (W(125),DUMODEL),(W(126),DUFORM),(W(127),DUID)         CWW30080
C                                                                        CWW30090
C     SOUND SPEED 150-174                                                CWW30100
      EQUIVALENCE (W(150),CMODEL),(W(151),CFORM),(W(152),CID)            CWW30110
      EQUIVALENCE (W(153),REFC)                                          CWW30120
C                                                                        CWW30130
C     DELTA SOUND SPEED 175-199                                          CWW30140
      EQUIVALENCE (W(175),DCMODEL),(W(176),DCFORM),(W(177),DCID)         CWW30150
C                                                                        CWW30160
C     TEMPERATURE    200-224                                             CWW30170
      EQUIVALENCE (W(200),TMODEL),(W(201),TFORM),(W(202),TID)            CWW30180
C                                                                        CWW30190
C     DELTA TEMPERATURE    225-249                                       CWW30200
      EQUIVALENCE (W(225),DTMODEL),(W(226),DTFORM),(W(227),DTID)         CWW30210
C                                                                        CWW30220
C     MOLECULAR   250-274                                                CWW30230
      EQUIVALENCE (W(250),MMODEL),(W(251),MFORM),(W(252),MID)            CWW30240
C                                                                        CWW30250
C     RECEIVER HEIGHT   275-299                                          CWW30260
      EQUIVALENCE (W(275),RMODEL),(W(276),RFORM),(W(277),RID)            CWW30270
C                                                                        CWW30280
C     TOPOGRAPHY   300-324                                               CWW30290
      EQUIVALENCE (W(300),GMODEL),(W(301),GFORM),(W(302),GID)            CWW30300
C                                                                        CWW30310
C     DELTA TOPOGRAPHY   325-349                                         CWW30320
      EQUIVALENCE (W(325),GUMODEL),(W(326),GUFORM),(W(327),GUID)         CWW30330
C                                                                        CWW30340
C     ATMOSPHERIC SURFACE TOPOGRAPHY   350-374                           CWW30350
      EQUIVALENCE (W(350),SMODEL),(W(351),SFORM),(W(352),SID)            CWW30360
C                                                                        CWW30370
C     ATMOSPHERIC SURFACE TOPOGRAPHY   375-399                           CWW30380
      EQUIVALENCE (W(375),SUMODEL),(W(376),SUFORM),(W(377),SUID)         CWW30390
C     PLOT ENHANCEMENTS CONTROL PARAMETERS                               CWW30400
C                                                                        CWW30410
      EQUIVALENCE (W(490),XFQMDL),(W(491),YFQMDL)                        CWW30420
```

```
C     ABSORPTION          500-524
      EQUIVALENCE (W(500),AMODEL),(W(501),AFORM),(W(502),AID)
C
C     DELTA ABSORPTION          525-549
      EQUIVALENCE (W(525),DAMODEL),(W(526),DAFORM),(W(527),DAID)
C
C     PRESSURE          550-574
      EQUIVALENCE (W(550),PMODEL),(W(551),PFORM),(W(552),PID)
C
C     DELTA PRESSURE          575-599
      EQUIVALENCE (W(575),DPMODEL),(W(576),DPFORM),(W(577),DPID)
C
       EQUIVALENCE (U0,W(103)),(R0,W(104)),(TH0,W(105)),(PH0,W(106))
       EQUIVALENCE (HWIDTH,W(107)),(HVMAX,W(108))
C     COMMON DECK "B1" INSERTED HERE
      INTEGER UMX,UNTBL,UITBL,UFRMTBL,IDSU(10)
      COMMON/B1/UMX,UNTBL(10),UITBL(10),UFRMTBL(10),UGP(10)
      EQUIVALENCE (UGP,IDSU)
      INTEGER UPX    ,UQTBL(10),ULTBL(10),UIRMTBL(10)
      DATA RECOGU/9.0/
C
      DATA UPX/1/
      DATA UQTBL/1,11,8*0/
      DATA ULTBL/1,9*0/
      DATA UIRMTBL/1,9*0/
C
C
      ENTRY SETWND
C
      UMX=UPX
      CALL IMOVE(UNTBL,UQTBL,10)
      CALL IMOVE(UITBL,ULTBL,10)
      CALL IMOVE(UFRMTBL,UIRMTBL,10)
      CALL SETPWN
C
      RETURN
C
      ENTRY IWINDR
C
      IF(RECOGU .NE. UMODEL)
     1    CALL RERROR('SPEED   ','WRNG MODEL',RECOGU)
C
      MODU(1)=7HVVORTX3
      MODU(2)=UID
       DENOM=0.0
       IF(HWIDTH.NE.0.0) DENOM=1.0/HWIDTH**2
      CALL IPWINDR
C
      RETURN
C
       ENTRY WINDR
      CALL CLEAR(V,20)
      DR=R-EARTHR-HVMAX
       DTH = TH - (PID2-TH0)
       DPH = PH - PH0
```

```
      RAD2 = EARTHR * SQRT(DTH * DTH + DPH * DPH)                       VVX30510
      A = 1.397                                                         VVX30520
      B = - 1.26                                                        VVX30530
      EXPO=RAD2/R0                                                      VVX30540
      EXPO=B*EXPO*EXPO                                                  VVX30550
      EXB=0.0                                                           VVX30560
      IF(EXPO .GT. -675.0) EXB = EXP(EXPO)                              VVX30570
      FX=1.-EXB                                                         VVX30580
      DUM = A * EARTHR * U0 * R0 / RAD2 * * 2                           VVX30590
      FZ=EXP(-DR*DR*DENOM)                                              VVX30600
      DFDZ=-2.*DR*DENOM                                                 VVX30610
      DUM=FZ*DUM                                                        VVX30620
C                                                                       VVX30630
      DUX = FX / RAD2 + RAD2 * B * EXB / R0 * * 2                       VVX30640
      VTH = - DUM * FX * DPH                                            VVX30650
      VPH = DUM * FX * DTH                                              VVX30660
      V=SQRT(VTH*VTH + VPH*VPH)                                         VVX30670
      DUM2=2.*DUM*EARTHR*EARTHR                                         VVX30680
      PVTHTH = DUM2 * DTH * DPH / RAD2 * DUX                            VVX30690
      PVPHPH = - PVTHTH                                                 VVX30700
      PVTHPH = DPH**2 * DUM2 / RAD2 * DUX -DUM*FX                       VVX30710
      PVPHTH = - DTH**2* DUM2 / RAD2* DUX + DUM*FX                      VVX30720
C                                                                       VVX30730
      PVTH=(VTH*PVTHTH + VPH*PVPHTH)/V                                  VVX30740
      PVPH=(VTH*PVTHPH + VPH*PVPHPH)/V                                  VVX30750
C                                                                       VVX30760
      PVTHR=VTH*DFDZ                                                    VVX30770
      PVPHR=VPH*DFDZ                                                    VVX30780
      PVR=(VTH*PVTHR+VPH*PVPHR)/V                                       VVX30790
C                                                                       VVX30800
      CALL PWINDR                                                       VVX30810
      RETURN                                                            VVX30820
      END                                                               VVX30830


      SUBROUTINE WGAUSS2                                                WGZ20020
C     WIND VELOCITY MODEL                                               WGZ20030
C     EXPONENTIALLY DECAYING EFFECT IN ALL THREE DIRECTIONS.            WGZ20040
C     COMMON DECK "CONST" INSERTED HERE                                 CCON0020
      COMMON/PCONST/CREF,RGAS,GAMMA                                     CCON0040
      COMMON/MCONST/PI,PIT2,PID2,DEGS,RAD,ALN10                         CCON0050
C     COMMON DECK "RKAM" INSERTED HERE                                  RKAM0020
      REAL KR,KTH,KPH                                                   RKAM0040
      COMMON//R,TH,PH,KR,KTH,KPH,RKVARS(14),TPULSE,CSTEP,DRDT(20)       RKAM0050
C     COMMON DECK "UU" INSERTED HERE                                    CUU 0020
      REAL MODU                                                         CUU 0040
      COMMON/UU/MODU(4)                                                 CUU 0050
     1  ,V   ,PVT   ,PVR   ,PVTH   ,PVPH                                CUU 0060
     2  ,VR  ,PVRT  ,PVRR  ,PVRTH  ,PVRPH                               CUU 0070
     3  ,VTH,PVTHT,PVTHR,PVTHTH,PVTHPH                                  CUU 0080
     4  ,VPH,PVPHT,PVPHR,PVPHTH,PVPHPH                                  CUU 0090
C     COMMON DECK "WW" INSERTED HERE                                    CWW 0020
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      PARAMETER (NWARSZ=1000)
      COMMON/WW/ID(10),MAXW,W(NWARSZ)                                   CWW10030
      REAL MAXSTP,MAXERR,INTYP,LLAT,LLON                                CWW10040
      EQUIVALENCE (EARTHR,W(1)),(RAY,W(2)),(XMTRH,W(3)),(TLAT,W(4)),    CWW20020
     1 (TLON,W(5)),(OW,W(6)),(FBEG,W(7)),(FEND,W(8)),(FSTEP,W(9)),      CWW20030
     2 (AZ1,W(10)),(AZBEG,W(11)),(AZEND,W(12)),(AZSTEP,W(13)),          CWW20040
     3 (BETA,W(14)),(ELBEG,W(15)),(ELEND,W(16)),(ELSTEP,W(17)),         CWW20050
     8   (RUNSUP,W(18)),(RCVRH,W(20)),                                  CWW20060
     4 (ONLY,W(21)),(HOP,W(22)),(MAXSTP,W(23)),(PLAT,W(24)),(PLON,W(25))CWW20070
     5,(HMAX,W(26)),(RAYFNC,W(29)),(EXTINC,W(33)),                      CWW20080
     6 (HMIN,W(27)),(RGMAX,W(28)),                                      CWW20090
     8 (INTYP,W(41)),(MAXERR,W(42)),(ERATIO,W(43)),                     CWW20100
     6 (STEP1,W(44)),(STPMAX,W(45)),(STPMIN,W(46)),(FACTR,W(47)),       CWW20110
     7 (SKIP,W(71)),(RAYSET,W(72)),(PRTSRP,W(74)),(HITLET,W(75))        CWW20120
     9 ,(BINRAY,W(76)),(PAGLN,W(77)),(PLT,W(81)),(PFACTR,W(82)),        CWW20130
     1 (LLAT,W(83)),(LLON,W(84)),(RLAT,W(85)),(RLON,W(86))              CWW20140
     2,(TIC,W(87)),(HB,W(88)),(HT,W(89)),(TICV,W(96))                   CWW20150
      REAL MMODEL,MFORM,MID                                             CWW20160
C                                                                       CWW30020
C     WIND           100-124                                            CWW30030
      EQUIVALENCE (W(100),UMODEL),(W(101),UFORM),(W(102),UID)           CWW30040
C                                                                       CWW30050
C     DELTA WIND          125-149                                       CWW30060
      EQUIVALENCE (W(125),DUMODEL),(W(126),DUFORM),(W(127),DUID)        CWW30070
C                                                                       CWW30080
C     SOUND SPEED 150-174                                               CWW30090
      EQUIVALENCE (W(150),CMODEL),(W(151),CFORM),(W(152),CID)           CWW30100
      EQUIVALENCE (W(153),REFC)                                         CWW30110
C                                                                       CWW30120
C     DELTA SOUND SPEED 175-199                                         CWW30130
      EQUIVALENCE (W(175),DCMODEL),(W(176),DCFORM),(W(177),DCID)        CWW30140
C                                                                       CWW30150
C     TEMPERATURE    200-224                                            CWW30160
      EQUIVALENCE (W(200),TMODEL),(W(201),TFORM),(W(202),TID)           CWW30170
C                                                                       CWW30180
C     DELTA TEMPERATURE     225-249                                     CWW30190
      EQUIVALENCE (W(225),DTMODEL),(W(226),DTFORM),(W(227),DTID)        CWW30200
C                                                                       CWW30210
C     MOLECULAR    250-274                                              CWW30220
      EQUIVALENCE (W(250),MMODEL),(W(251),MFORM),(W(252),MID)           CWW30230
C                                                                       CWW30240
C     RECEIVER HEIGHT    275-299                                        CWW30250
      EQUIVALENCE (W(275),RMODEL),(W(276),RFORM),(W(277),RID)           CWW30260
C                                                                       CWW30270
C     TOPOGRAPHY    300-324                                             CWW30280
      EQUIVALENCE (W(300),GMODEL),(W(301),GFORM),(W(302),GID)           CWW30290
C                                                                       CWW30300
C     DELTA TOPOGRAPHY    325-349                                       CWW30310
      EQUIVALENCE (W(325),GUMODEL),(W(326),GUFORM),(W(327),GUID)        CWW30320
C                                                                       CWW30330
C     ATMOSPHERIC SURFACE TOPOGRAPHY    350-374                         CWW30340
      EQUIVALENCE (W(350),SMODEL),(W(351),SFORM),(W(352),SID)           CWW30350
C                                                                       CWW30360
C     ATMOSPHERIC SURFACE TOPOGRAPHY    375-399                         CWW30370
      EQUIVALENCE (W(375),SUMODEL),(W(376),SUFORM),(W(377),SUID)        CWW30380
                                                                        CWW30390
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C     PLOT ENHANCEMENTS CONTROL PARAMETERS                                CWW30400
C                                                                         CWW30410
      EQUIVALENCE (W(490),XFQMDL),(W(491),YFQMDL)                         CWW30420
C     ABSORPTION          500-524                                         CWW30430
      EQUIVALENCE (W(500),AMODEL),(W(501),AFORM),(W(502),AID)             CWW30440
C                                                                         CWW30450
C     DELTA ABSORPTION          525-549                                   CWW30460
      EQUIVALENCE (W(525),DAMODEL),(W(526),DAFORM),(W(527),DAID)          CWW30470
C                                                                         CWW30480
C     PRESSURE          550-574                                           CWW30490
      EQUIVALENCE (W(550),PMODEL),(W(551),PFORM),(W(552),PID)             CWW30500
C                                                                         CWW30510
C     DELTA PRESSURE          575-599                                     CWW30520
      EQUIVALENCE (W(575),DPMODEL),(W(576),DPFORM),(W(577),DPID)          CWW30530
C                                                                         CWW30540
C     COMMON DECK "B1" INSERTED HERE                                      CB1 0020
      INTEGER UMX,UNTBL,UITBL,UFRMTBL,IDSU(10)                            CB1 0040
      COMMON/B1/UMX,UNTBL(10),UITBL(10),UFRMTBL(10),UGP(10)               CB1 0050
      EQUIVALENCE (UGP,IDSU)                                              CB1 0060
      INTEGER UPX,UQTBL(10),ULTBL(10),UIRMTBL(10)                         WGZ20100
C                                                                         WGZ20110
      EQUIVALENCE (UPH0,W(103)),(WH,W(104)),(WTH,W(105))                  WGZ20120
      EQUIVALENCE  (WPH,W(106)),(H0,W(107)),(WGTH0,W(108)),(PH0,W(109))   WGZ20130
      DATA RECOGU/7.0/                                                    WGZ20140
      DATA UPX/1/                                                         WGZ20150
      DATA UQTBL/1,11,8*0/                                                WGZ20160
      DATA ULTBL/1,9*0/                                                   WGZ20170
      DATA UIRMTBL/1,9*0/                                                 WGZ20180
C                                                                         WGZ20190
      ENTRY SETWND                                                        WGZ20200
      UMX=UPX                                                             WGZ20210
      CALL IMOVE(UNTBL,UQTBL,10)                                          WGZ20220
      CALL IMOVE(UITBL,ULTBL,10)                                          WGZ20230
      CALL IMOVE(UFRMTBL,UIRMTBL,10)                                      WGZ20240
      CALL SETPWN                                                         WGZ20250
      RETURN                                                              WGZ20260
C                                                                         WGZ20270
      ENTRY IWINDR                                                        WGZ20280
C                                                                         WGZ20290
      IF(RECOGU .NE. UMODEL)                                              WGZ20300
     1    CALL RERROR('SPEED   ','WRNG MODEL',RECOGU)                     WGZ20310
C                                                                         WGZ20320
      MODU(1)=7HWGAUSS2                                                   WGZ20330
      MODU(2)=UID                                                         WGZ20340
      CALL IPWINDR                                                        WGZ20350
C                                                                         WGZ20360
      WIDH=0.0                                                            WGZ20370
      WIDTH=0.0                                                           WGZ20380
      WIDPH=0.0                                                           WGZ20390
      TH0= PID2-WGTH0                                                     WGZ20400
      IF(WH.NE.0.0) WIDH=1.0/WH                                           WGZ20410
      IF(WTH.NE.0.0) WIDTH=1.0/WTH                                        WGZ20420
      IF(WPH.NE.0.0) WIDPH=1.0/WPH                                        WGZ20430
      RETURN                                                              WGZ20440
C                                                                         WGZ20450
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       ENTRY WINDR                                                      WGZ20460
      CALL CLEAR(V,20)                                                  WGZ20470
       H = R - EARTHR                                                   WGZ20480
      DFH=(H-H0)*WIDH                                                   WGZ20490
      DFTH=(TH-TH0)*WIDTH                                               WGZ20500
      DFPH=(PH-PH0)*WIDPH                                               WGZ20510
      EXPO=-(DFH*DFH+DFTH*DFTH+DFPH*DFPH)                               WGZ20520
      EXPN=0.0                                                          WGZ20530
      IF(EXPO.GT.-200.0) EXPN=EXP(EXPO)                                 WGZ20540
       VPH = UPH0*EXPN                                                  WGZ20550
       PVPHR = - 2. * VPH * DFH*WIDH                                    WGZ20560
       PVPHTH = - 2. * VPH * DFTH*WIDTH                                 WGZ20570
       PVPHPH = - 2. * VPH * DFPH*WIDPH                                 WGZ20580
       END                                                              WGZ20590
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      SUBROUTINE NPCURR                                                 NPTR0020
C     DO-NOTHING CURRENT PERTURBATION MODEL                             NPTR0030
C     COMMON DECK "UU" INSERTED HERE                                    CUU 0020
      REAL MODU                                                         CUU 0040
      COMMON/UU/MODU(4)                                                 CUU 0050
     1  ,V  ,PVT  ,PVR  ,PVTH  ,PVPH                                    CUU 0060
     2  ,VR ,PVRT ,PVRR ,PVRTH ,PVRPH                                   CUU 0070
     3  ,VTH,PVTHT,PVTHR,PVTHTH,PVTHPH                                  CUU 0080
     4  ,VPH,PVPHT,PVPHR,PVPHTH,PVPHPH                                  CUU 0090
C     COMMON DECK "WW" INSERTED HERE                                    CWW 0020
      PARAMETER (NWARSZ=1000)                                           CWW10030
      COMMON/WW/ID(10),MAXW,W(NWARSZ)                                   CWW10040
      REAL MAXSTP,MAXERR,INTYP,LLAT,LLON                                CWW20020
      EQUIVALENCE (EARTHR,W(1)),(RAY,W(2)),(XMTRH,W(3)),(TLAT,W(4)),    CWW20030
     1 (TLON,W(5)),(OW,W(6)),(FBEG,W(7)),(FEND,W(8)),(FSTEP,W(9)),      CWW20040
     2 (AZ1,W(10)),(AZBEG,W(11)),(AZEND,W(12)),(AZSTEP,W(13)),          CWW20050
     3 (BETA,W(14)),(ELBEG,W(15)),(ELEND,W(16)),(ELSTEP,W(17)),         CWW20060
     8   (RUNSUP,W(18)),(RCVRH,W(20)),                                  CWW20070
     4 (ONLY,W(21)),(HOP,W(22)),(MAXSTP,W(23)),(PLAT,W(24)),(PLON,W(25))CWW20080
     5,(HMAX,W(26)),(RAYFNC,W(29)),(EXTINC,W(33)),                      CWW20090
     6 (HMIN,W(27)),(RGMAX,W(28)),                                      CWW20100
     8 (INTYP,W(41)),(MAXERR,W(42)),(ERATIO,W(43)),                     CWW20110
     6 (STEP1,W(44)),(STPMAX,W(45)),(STPMIN,W(46)),(FACTR,W(47)),       CWW20120
     7 (SKIP,W(71)),(RAYSET,W(72)),(PRTSRP,W(74)),(HITLET,W(75))        CWW20130
     9 ,(BINRAY,W(76)),(PAGLN,W(77)),(PLT,W(81)),(PFACTR,W(82)),        CWW20140
     1 (LLAT,W(83)),(LLON,W(84)),(RLAT,W(85)),(RLON,W(86))              CWW20150
     2,(TIC,W(87)),(HB,W(88)),(HT,W(89)),(TICV,W(96))                   CWW20160
      REAL MMODEL,MFORM,MID                                             CWW30020
C                                                                       CWW30030
C     WIND          100-124                                             CWW30040
      EQUIVALENCE (W(100),UMODEL),(W(101),UFORM),(W(102),UID)           CWW30050
C                                                                       CWW30060
C     DELTA WIND         125-149                                        CWW30070
      EQUIVALENCE (W(125),DUMODEL),(W(126),DUFORM),(W(127),DUID)        CWW30080
C                                                                       CWW30090
C     SOUND SPEED 150-174                                               CWW30100
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      EQUIVALENCE (W(150),CMODEL),(W(151),CFORM),(W(152),CID)          CWW30110
      EQUIVALENCE (W(153),REFC)                                        CWW30120
C                                                                      CWW30130
C     DELTA SOUND SPEED 175-199                                        CWW30140
      EQUIVALENCE (W(175),DCMODEL),(W(176),DCFORM),(W(177),DCID)       CWW30150
C                                                                      CWW30160
C     TEMPERATURE    200-224                                           CWW30170
      EQUIVALENCE (W(200),TMODEL),(W(201),TFORM),(W(202),TID)          CWW30180
C                                                                      CWW30190
C     DELTA TEMPERATURE    225-249                                     CWW30200
      EQUIVALENCE (W(225),DTMODEL),(W(226),DTFORM),(W(227),DTID)       CWW30210
C                                                                      CWW30220
C     MOLECULAR   250-274                                              CWW30230
      EQUIVALENCE (W(250),MMODEL),(W(251),MFORM),(W(252),MID)          CWW30240
C                                                                      CWW30250
C     RECEIVER HEIGHT   275-299                                        CWW30260
      EQUIVALENCE (W(275),RMODEL),(W(276),RFORM),(W(277),RID)          CWW30270
C                                                                      CWW30280
C     TOPOGRAPHY   300-324                                             CWW30290
      EQUIVALENCE (W(300),GMODEL),(W(301),GFORM),(W(302),GID)          CWW30300
C                                                                      CWW30310
C     DELTA TOPOGRAPHY   325-349                                       CWW30320
      EQUIVALENCE (W(325),GUMODEL),(W(326),GUFORM),(W(327),GUID)       CWW30330
C                                                                      CWW30340
C     ATMOSPHERIC SURFACE TOPOGRAPHY   350-374                         CWW30350
      EQUIVALENCE (W(350),SMODEL),(W(351),SFORM),(W(352),SID)          CWW30360
C                                                                      CWW30370
C     ATMOSPHERIC SURFACE TOPOGRAPHY   375-399                         CWW30380
      EQUIVALENCE (W(375),SUMODEL),(W(376),SUFORM),(W(377),SUID)       CWW30390
C     PLOT ENHANCEMENTS CONTROL PARAMETERS                             CWW30400
C                                                                      CWW30410
      EQUIVALENCE (W(490),XFQMDL),(W(491),YFQMDL)                      CWW30420
C     ABSORPTION         500-524                                       CWW30430
      EQUIVALENCE (W(500),AMODEL),(W(501),AFORM),(W(502),AID)          CWW30440
C                                                                      CWW30450
C     DELTA ABSORPTION          525-549                                CWW30460
      EQUIVALENCE (W(525),DAMODEL),(W(526),DAFORM),(W(527),DAID)       CWW30470
C                                                                      CWW30480
C     PRESSURE          550-574                                        CWW30490
      EQUIVALENCE (W(550),PMODEL),(W(551),PFORM),(W(552),PID)          CWW30500
C                                                                      CWW30510
C     DELTA PRESSURE          575-599                                  CWW30520
      EQUIVALENCE (W(575),DPMODEL),(W(576),DPFORM),(W(577),DPID)       CWW30530
C                                                                      CWW30540
C     COMMON DECK "B2" INSERTED HERE                                   CB2 0020
      INTEGER DUMX,DUNTBL,DUITBL,DUFRMTB,IDSDU(10)                     CB2 0040
      COMMON/B2/DUMX,DUNTBL(10),DUITBL(10),DUFRMTB(10),DUGP(10)        CB2 0050
      EQUIVALENCE (DUGP,IDSDU)                                         CB2 0060
      INTEGER DXMX     ,DXNTBL(10),DXITBL(10),DXFRMTB(10)              NPTR0070
      DATA RECOGDU/0.0/                                                NPTR0080
C                                                                      NPTR0090
      DATA DXMX/1/                                                     NPTR0100
      DATA DXNTBL/1,11,8*0/                                            NPTR0110
      DATA DXITBL/1,9*0/                                               NPTR0120
      DATA DXFRMTB/1,9*0/                                              NPTR0130
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C                                                                       NPTR0140
C                                                                       NPTR0150
      ENTRY SETPWN                                                      NPTR0160
C                                                                       NPTR0170
      DUMX=DXMX                                                         NPTR0180
      CALL IMOVE(DUNTBL,DXNTBL,10)                                      NPTR0190
      CALL IMOVE(DUITBL,DXITBL,10)                                      NPTR0200
      CALL IMOVE(DUFRMTB,DXFRMTB,10)                                    NPTR0210
C                                                                       NPTR0220
      RETURN                                                            NPTR0230
C                                                                       NPTR0240
      ENTRY IPWINDR                                                     NPTR0250
      IF(RECOGDU .NE. DUMODEL)                                          NPTR0260
     1    CALL RERROR('DWINDR ','WRNG MODEL',RECOGDU)                   NPTR0270
      MODU(3)=6HNPCURR                                                  NPTR0280
      MODU(4)=DUID                                                      NPTR0290
      RETURN                                                            NPTR0300
C                                                                       NPTR0310
      ENTRY PWINDR                                                      NPTR0320
      RETURN                                                            NPTR0330
      END                                                               NPTR0340



      SUBROUTINE CTANH                                                  CTLH0020
C     SPEED PROFILE REPRESENTED BY A SEQUENCE OF LINEAR SEGMENTS        CTLH0030
C     SMOOTHLY JOINED BY HYPERBOLIC FUNCTIONS. PARAMETERS ARE INPUT     CTLH0040
C     AS TABULAR DATA WITH SLOPES COMPUTED FROM SPEED DATA.             CTLH0050
C     REFERENCE SPEED C0 IS READ FROM TABULAR DATA.                     CTLH0060
C                                                                       CTLH0070
      REAL CO(20), TM(19), Z(19), DL(19)                                CTLH0080
C                                                                       CTLH0090
C     COMMON DECK "RKAM" INSERTED HERE                                  RKAM0020
      REAL KR,KTH,KPH                                                   RKAM0040
      COMMON//R,TH,PH,KR,KTH,KPH,RKVARS(14),TPULSE,CSTEP,DRDT(20)       RKAM0050
C     COMMON DECK "CC" INSERTED HERE                                    CCC 0020
      REAL MODC                                                         CCC 0040
      COMMON/CC/MODC(4),CS,PCST,PCSR,PCSTH,PCSPH                        CCC 0050
C     COMMON DECK "WW" INSERTED HERE                                    CWW 0020
      PARAMETER (NWARSZ=1000)                                           CWW10030
      COMMON/WW/ID(10),MAXW,W(NWARSZ)                                   CWW10040
      REAL MAXSTP,MAXERR,INTYP,LLAT,LLON                                CWW20020
      EQUIVALENCE (EARTHR,W(1)),(RAY,W(2)),(XMTRH,W(3)),(TLAT,W(4)),    CWW20030
     1 (TLON,W(5)),(OW,W(6)),(FBEG,W(7)),(FEND,W(8)),(FSTEP,W(9)),      CWW20040
     2 (AZ1,W(10)),(AZBEG,W(11)),(AZEND,W(12)),(AZSTEP,W(13)),          CWW20050
     3 (BETA,W(14)),(ELBEG,W(15)),(ELEND,W(16)),(ELSTEP,W(17)),         CWW20060
     8    (RUNSUP,W(18)),(RCVRH,W(20)),                                 CWW20070
     4 (ONLY,W(21)),(HOP,W(22)),(MAXSTP,W(23)),(PLAT,W(24)),(PLON,W(25))CWW20080
     5,(HMAX,W(26)),(RAYFNC,W(29)),(EXTINC,W(33)),                      CWW20090
     6 (HMIN,W(27)),(RGMAX,W(28)),                                      CWW20100
     8 (INTYP,W(41)),(MAXERR,W(42)),(ERATIO,W(43)),                     CWW20110
     6 (STEP1,W(44)),(STPMAX,W(45)),(STPMIN,W(46)),(FACTR,W(47)),       CWW20120
     7 (SKIP,W(71)),(RAYSET,W(72)),(PRTSRP,W(74)),(HITLET,W(75))        CWW20130
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     9 ,(BINRAY,W(76)),(PAGLN,W(77)),(PLT,W(81)),(PFACTR,W(82)),       CWW20140
     1 (LLAT,W(83)),(LLON,W(84)),(RLAT,W(85)),(RLON,W(86))             CWW20150
     2,(TIC,W(87)),(HB,W(88)),(HT,W(89)),(TICV,W(96))                  CWW20160
      REAL MMODEL,MFORM,MID                                            CWW30020
C                                                                      CWW30030
C     WIND          100-124                                            CWW30040
      EQUIVALENCE (W(100),UMODEL),(W(101),UFORM),(W(102),UID)          CWW30050
C                                                                      CWW30060
C     DELTA WIND          125-149                                      CWW30070
      EQUIVALENCE (W(125),DUMODEL),(W(126),DUFORM),(W(127),DUID)       CWW30080
C                                                                      CWW30090
C     SOUND SPEED 150-174                                              CWW30100
      EQUIVALENCE (W(150),CMODEL),(W(151),CFORM),(W(152),CID)          CWW30110
      EQUIVALENCE (W(153),REFC)                                        CWW30120
C                                                                      CWW30130
C     DELTA SOUND SPEED 175-199                                        CWW30140
      EQUIVALENCE (W(175),DCMODEL),(W(176),DCFORM),(W(177),DCID)       CWW30150
C                                                                      CWW30160
C     TEMPERATURE    200-224                                           CWW30170
      EQUIVALENCE (W(200),TMODEL),(W(201),TFORM),(W(202),TID)          CWW30180
C                                                                      CWW30190
C     DELTA TEMPERATURE    225-249                                     CWW30200
      EQUIVALENCE (W(225),DTMODEL),(W(226),DTFORM),(W(227),DTID)       CWW30210
C                                                                      CWW30220
C     MOLECULAR   250-274                                              CWW30230
      EQUIVALENCE (W(250),MMODEL),(W(251),MFORM),(W(252),MID)          CWW30240
C                                                                      CWW30250
C     RECEIVER HEIGHT   275-299                                        CWW30260
      EQUIVALENCE (W(275),RMODEL),(W(276),RFORM),(W(277),RID)          CWW30270
C                                                                      CWW30280
C     TOPOGRAPHY   300-324                                             CWW30290
      EQUIVALENCE (W(300),GMODEL),(W(301),GFORM),(W(302),GID)          CWW30300
C                                                                      CWW30310
C     DELTA TOPOGRAPHY   325-349                                       CWW30320
      EQUIVALENCE (W(325),GUMODEL),(W(326),GUFORM),(W(327),GUID)       CWW30330
C                                                                      CWW30340
C     ATMOSPHERIC SURFACE TOPOGRAPHY   350-374                         CWW30350
      EQUIVALENCE (W(350),SMODEL),(W(351),SFORM),(W(352),SID)          CWW30360
C                                                                      CWW30370
C     ATMOSPHERIC SURFACE TOPOGRAPHY   375-399                         CWW30380
      EQUIVALENCE (W(375),SUMODEL),(W(376),SUFORM),(W(377),SUID)       CWW30390
C     PLOT ENHANCEMENTS CONTROL PARAMETERS                             CWW30400
C                                                                      CWW30410
      EQUIVALENCE (W(490),XFQMDL),(W(491),YFQMDL)                      CWW30420
C     ABSORPTION          500-524                                      CWW30430
      EQUIVALENCE (W(500),AMODEL),(W(501),AFORM),(W(502),AID)          CWW30440
C                                                                      CWW30450
C     DELTA ABSORPTION          525-549                                CWW30460
      EQUIVALENCE (W(525),DAMODEL),(W(526),DAFORM),(W(527),DAID)       CWW30470
C                                                                      CWW30480
C     PRESSURE          550-574                                        CWW30490
      EQUIVALENCE (W(550),PMODEL),(W(551),PFORM),(W(552),PID)          CWW30500
C                                                                      CWW30510
C     DELTA PRESSURE          575-599                                  CWW30520
      EQUIVALENCE (W(575),DPMODEL),(W(576),DPFORM),(W(577),DPID)       CWW30530
```

```
C
C     COMMON DECK "B3" INSERTED HERE
      INTEGER CMX,CNTBL,CITBL,CFRMTBL,IDSC(10)
      COMMON/B3/CMX,CNTBL(10),CITBL(10),CFRMTBL(10),CGP(512)
      EQUIVALENCE (CGP,IDSC),(ANC,CGP(11))
C
      EQUIVALENCE (Z0,CGP(12)),(TM,CGP(33))
      EQUIVALENCE (Z,CGP(13)),(CO,CGP(32)),(DL,CGP(53))
C
      INTEGER CPX     ,CQTBL(10),CLTBL(10),CIRMTBL(10)
      DATA RECOGC,N/7.0,0/
C
      DATA AQC/0.0/
      DATA CPX/2/
      DATA CQTBL/1,11,72,7*0/
      DATA CLTBL/1,20,8*0/
      DATA CIRMTBL/1,2,8*0/
C
      COSH (X) = (EXP (X) + 1. / (EXP (X))) / 2.
C
C
      ENTRY SETSPD
C
      ANC=AQC
      CMX=CPX
      CALL IMOVE(CNTBL,CQTBL,10)
      CALL IMOVE(CITBL,CLTBL,10)
      CALL IMOVE(CFRMTBL,CIRMTBL,10)
      CALL SETPSP
C
      RETURN
C
      ENTRY ISPEED
C
C     IF HAD PREVIOUS CALL BUT NOTHING THIS TIME, EXIT NOW
C     RETAINING PREVIOUS TABULAR DATA COUNT
C
      CALL IPSPEED
C
      IF(N.GT.0 .AND. ANC.EQ.0.0) RETURN
C
      IF(RECOGC .NE. CMODEL)
     1    CALL RERROR('SPEED   ','WRNG MODEL',RECOGC)
C
      MODC(1)=7HCTANH
      MODC(2)=CID
C
      N=(ANC+1)/3 - 2
C
      IF(N.LE.0)
     1    CALL RERROR('CTANH','BAD N VALUE',FLOAT(N))
C
      ANC=0.0
C
C     CONVERT 'CGP' ARRAY INPUT(OVERLAYS 'C' ARRAY) TO 'C' ARRAY
```

```
C                                                                       CTLH0640
      C0=CO(1)                                                          CTLH0650
      TIM1=C0                                                           CTLH0660
      ZIM1=Z0                                                           CTLH0670
      NP1=N+1                                                           CTLH0680
      DO 10 I=1,NP1                                                     CTLH0690
         TI=TM(I)                                                       CTLH0700
         ZI=Z(I)                                                        CTLH0710
         CO(I)=(TI-TIM1)/(ZI-ZIM1)                                      CTLH0720
         TIM1=TI                                                        CTLH0730
10       ZIM1=ZI                                                        CTLH0740
C                                                                       CTLH0750
      RETURN                                                            CTLH0760
C                                                                       CTLH0770
      ENTRY SPEED                                                       CTLH0780
      H = R - EARTHR                                                    CTLH0790
      SUM = 0.                                                          CTLH0800
C                                                                       CTLH0810
C     LOOP TO SUM OVER ALL COEFFICIENTS                                 CTLH0820
C     USE SPECIAL FUNCTION 'ALCOSH' WHICH ALLOWS FOR LARGE ARGUMENTS.   CTLH0830
      DO 1 I = 1, N                                                     CTLH0840
    1 SUM = SUM + DL(I) * (CO(I + 1) - CO(I)) / 2. *(ALCOSH((H - Z      CTLH0850
     1(I)) / DL(I)) - ALCOSH((Z(I)-Z0) / DL(I)))                        CTLH0860
C                                                                       CTLH0870
      C = C0 + SUM + (CO(1) + CO(N + 1)) * (H - Z0) * 0.5               CTLH0880
C                                                                       CTLH0890
      SUM = 0.                                                          CTLH0900
      DO 2 I = 1, N                                                     CTLH0910
    2 SUM = SUM + (CO(I + 1) - CO(I)) / 2. * (1. + TANH ((H - Z(I)) /DL CTLH0920
     1 (I)))                                                            CTLH0930
C                                                                       CTLH0940
      CS=C*C                                                            CTLH0950
C                                                                       CTLH0960
      PCST=0.0                                                          CTLH0970
      PCSR = 2.0*C*(CO(1) + SUM)                                        CTLH0980
      PCSTH=0.0                                                         CTLH0990
      PCSPH=0.0                                                         CTLH1000
C                                                                       CTLH1010
      CALL PSPEED                                                       CTLH1020
      RETURN                                                            CTLH1030
      END                                                               CTLH1040
```

```
      SUBROUTINE CSTANH                                                 CSRH0020
C     SPEED PROFILE REPRESENTED BY A SEQUENCE OF LINEAR SEGMENTS        CSRH0030
C     SMOOTHLY JOINED BY HYPERBOLIC FUNCTIONS. PARAMETERS ARE INPUT     CSRH0040
C     AS TABULAR DATA WITH SLOPES COMPUTED FROM SPEED DATA.             CSRH0050
C                                                                       CSRH0060
      REAL ALC(20),Z(19),B(19),DL(19)                                   CSRH0070
C     COMMON DECK "RKAM" INSERTED HERE                                  RKAM0020
      REAL KR,KTH,KPH                                                   RKAM0040
      COMMON//R,TH,PH,KR,KTH,KPH,RKVARS(14),TPULSE,CSTEP,DRDT(20)       RKAM0050
```

```
C     COMMON DECK "B3" INSERTED HERE                                    CB3 0020
      INTEGER CMX,CNTBL,CITBL,CFRMTBL,IDSC(10)                          CB3 0040
      COMMON/B3/CMX,CNTBL(10),CITBL(10),CFRMTBL(10),CGP(512)            CB3 0050
      EQUIVALENCE (CGP,IDSC),(ANC,CGP(11))                              CB3 0060
C     COMMON DECK "CC" INSERTED HERE                                    CCC 0020
      REAL MODC                                                         CCC 0040
      COMMON/CC/MODC(4),CS,PCST,PCSR,PCSTH,PCSPH                        CCC 0050
C     COMMON DECK "CONST" INSERTED HERE                                 CCON0020
      COMMON/PCONST/CREF,RGAS,GAMMA                                     CCON0040
      COMMON/MCONST/PI,PIT2,PID2,DEGS,RAD,ALN10                         CCON0050
C     COMMON DECK "WW" INSERTED HERE                                    CWW 0020
      PARAMETER (NWARSZ=1000)                                           CWW10030
      COMMON/WW/ID(10),MAXW,W(NWARSZ)                                   CWW10040
      REAL MAXSTP,MAXERR,INTYP,LLAT,LLON                                CWW20020
      EQUIVALENCE (EARTHR,W(1)),(RAY,W(2)),(XMTRH,W(3)),(TLAT,W(4)),    CWW20030
     1 (TLON,W(5)),(OW,W(6)),(FBEG,W(7)),(FEND,W(8)),(FSTEP,W(9)),      CWW20040
     2 (AZ1,W(10)),(AZBEG,W(11)),(AZEND,W(12)),(AZSTEP,W(13)),          CWW20050
     3 (BETA,W(14)),(ELBEG,W(15)),(ELEND,W(16)),(ELSTEP,W(17)),         CWW20060
     8   (RUNSUP,W(18)),(RCVRH,W(20)),                                  CWW20070
     4 (ONLY,W(21)),(HOP,W(22)),(MAXSTP,W(23)),(PLAT,W(24)),(PLON,W(25))CWW20080
     5,(HMAX,W(26)),(RAYFNC,W(29)),(EXTINC,W(33)),                      CWW20090
     6 (HMIN,W(27)),(RGMAX,W(28)),                                      CWW20100
     8 (INTYP,W(41)),(MAXERR,W(42)),(ERATIO,W(43)),                     CWW20110
     6 (STEP1,W(44)),(STPMAX,W(45)),(STPMIN,W(46)),(FACTR,W(47)),       CWW20120
     7 (SKIP,W(71)),(RAYSET,W(72)),(PRTSRP,W(74)),(HITLET,W(75))        CWW20130
     9 ,(BINRAY,W(76)),(PAGLN,W(77)),(PLT,W(81)),(PFACTR,W(82)),        CWW20140
     1 (LLAT,W(83)),(LLON,W(84)),(RLAT,W(85)),(RLON,W(86))              CWW20150
     2,(TIC,W(87)),(HB,W(88)),(HT,W(89)),(TICV,W(96))                   CWW20160
      REAL MMODEL,MFORM,MID                                             CWW30020
C                                                                       CWW30030
C     WIND          100-124                                             CWW30040
      EQUIVALENCE (W(100),UMODEL),(W(101),UFORM),(W(102),UID)           CWW30050
C                                                                       CWW30060
C     DELTA WIND          125-149                                       CWW30070
      EQUIVALENCE (W(125),DUMODEL),(W(126),DUFORM),(W(127),DUID)        CWW30080
C                                                                       CWW30090
C     SOUND SPEED 150-174                                               CWW30100
      EQUIVALENCE (W(150),CMODEL),(W(151),CFORM),(W(152),CID)           CWW30110
      EQUIVALENCE (W(153),REFC)                                         CWW30120
C                                                                       CWW30130
C     DELTA SOUND SPEED 175-199                                         CWW30140
      EQUIVALENCE (W(175),DCMODEL),(W(176),DCFORM),(W(177),DCID)        CWW30150
C                                                                       CWW30160
C     TEMPERATURE     200-224                                           CWW30170
      EQUIVALENCE (W(200),TMODEL),(W(201),TFORM),(W(202),TID)           CWW30180
C                                                                       CWW30190
C     DELTA TEMPERATURE     225-249                                     CWW30200
      EQUIVALENCE (W(225),DTMODEL),(W(226),DTFORM),(W(227),DTID)        CWW30210
C                                                                       CWW30220
C     MOLECULAR   250-274                                               CWW30230
      EQUIVALENCE (W(250),MMODEL),(W(251),MFORM),(W(252),MID)           CWW30240
C                                                                       CWW30250
C     RECEIVER HEIGHT   275-299                                         CWW30260
      EQUIVALENCE (W(275),RMODEL),(W(276),RFORM),(W(277),RID)           CWW30270
C                                                                       CWW30280
```

```
C       TOPOGRAPHY   300-324
        EQUIVALENCE (W(300),GMODEL),(W(301),GFORM),(W(302),GID)
C
C       DELTA TOPOGRAPHY   325-349
        EQUIVALENCE (W(325),GUMODEL),(W(326),GUFORM),(W(327),GUID)
C
C       ATMOSPHERIC SURFACE TOPOGRAPHY   350-374
        EQUIVALENCE (W(350),SMODEL),(W(351),SFORM),(W(352),SID)
C
C       ATMOSPHERIC SURFACE TOPOGRAPHY   375-399
        EQUIVALENCE (W(375),SUMODEL),(W(376),SUFORM),(W(377),SUID)
C       PLOT ENHANCEMENTS CONTROL PARAMETERS
C
        EQUIVALENCE (W(490),XFQMDL),(W(491),YFQMDL)
C       ABSORPTION          500-524
        EQUIVALENCE (W(500),AMODEL),(W(501),AFORM),(W(502),AID)
C
C       DELTA ABSORPTION          525-549
        EQUIVALENCE (W(525),DAMODEL),(W(526),DAFORM),(W(527),DAID)
C
C       PRESSURE          550-574
        EQUIVALENCE (W(550),PMODEL),(W(551),PFORM),(W(552),PID)
C
C       DELTA PRESSURE          575-599
        EQUIVALENCE (W(575),DPMODEL),(W(576),DPFORM),(W(577),DPID)
C
C
        EQUIVALENCE (Z0,CGP(12)),(CS0,CGP(32)),(DL0,CGP(52))
        EQUIVALENCE (Z,CGP(13)),(B,CGP(33)),(DL,CGP(53))
C
        INTEGER CPX    ,CQTBL(10) ,CLTBL(10),CIRMTBL(10)
        DATA RECOGC,N/2.0,0/
C
        DATA PFST,PFSTH,PFSPH/3*0.0/
        DATA AQC/0.0/
        DATA CPX/2/
        DATA CQTBL/1,11,72,7*0/
        DATA CLTBL/1,20,8*0/
        DATA CIRMTBL/1,2,8*0/
C
C
        ENTRY SETSPD
C
        PCST=PFST
        PCSTH=PFSTH
        PCSPH=PFSPH
        ANC=AQC
        CALL IMOVE(CMX,CPX, 1)
        CALL IMOVE(CNTBL,CQTBL,10)
        CALL IMOVE(CITBL,CLTBL,10)
        CALL IMOVE(CFRMTBL,CIRMTBL,10)
        CALL SETPSP
C
        RETURN
C
```

```
      ENTRY ISPEED
C
      IF(REFC.GT.0.0) CREF=REFC
C
      CALL IPSPEED
C
C     IF HAD PREVIOUS CALL BUT NOTHING THIS TIME, EXIT NOW
C     RETAINING PREVIOUS TABULAR DATA COUNT
      IF(N.GT.0 .AND. ANC.EQ.0.0) RETURN
C
      IF(RECOGC .NE. CMODEL)
     1    CALL RERROR('SPEED  ','WRNG MODEL',RECOGC)
      MODC(1)=6HCSTANH
      MODC(2)=CID
      N=ANC/3
      IF(ANC.NE.3*N.OR.N.LE.0)
     1    CALL RERROR('CSTANH','BAD NUMBER',ANC+2.0)
      N=N-2
      ANC=0.0
C
C
C     CONVERT 'C' ARRAY INPUT(OVERLAYS 'B' ARRAY) TO 'B' ARRAY
C
      ZM1=Z0
      CS0=CS0*CS0
      CSM1=CS0
      NP1=N+1
      DO 10 I=1,NP1
         ZR=Z(I)
         ALC(I)=ALCOSH((ZR-Z0) / DL(I))
         CS=B(I)**2
         B(I)=(CS-CSM1)/(ZR-ZM1)
         ZM1=ZR
10       CSM1=CS
C
      RETURN
C
      ENTRY SPEED
C
      IF(N.LE.0)
     1    CALL RERROR('CSTANH','BAD N VALUE',FLOAT(N))
C
      ZR=R-EARTHR
      SUM = 0.
      PCSR=B(1)
      DO 1 I = 1, N
      SAV=0.5*(B(I+1)-B(I))
      PCSR= PCSR+ SAV * (1.+TANH ((ZR-Z(I)) /DL(I)))
    1 SUM = SUM+DL(I) * SAV *(ALCOSH((ZR-Z(I))/DL(I))-ALC(I))
      CS = CS0+SUM + 0.5*(B(1) + B(N + 1)) * (ZR-Z0)
C
      CALL PSPEED
      RETURN
      END
```

```
      SUBROUTINE CSSPOKE                                                CSTE0020
C     SOUND SPEED SQUARED IS MODELED AS A FUNCTION OF ANGLE 'ALPHA'     CSTE0030
C     ABOUT A HORIZONTAL LINE AT SPECIFIED HEIGHT AND LATITUDE. DEPENDE CSTE0040
C     ON 'ALPHA' IS AS A SEQUENCE OF LINEAR SEGMENTS JOINED BY HYPERBOL CSTE0050
C     TANGENTS.                                                         CSTE0060
C                                                                       CSTE0070
      REAL ALC(20),Z(19),BIN(19),B(19),DL(19),LAM0                      CSTE0080
C     COMMON DECK "RKAM" INSERTED HERE                                  RKAM0020
      REAL KR,KTH,KPH                                                   RKAM0040
      COMMON//R,TH,PH,KR,KTH,KPH,RKVARS(14),TPULSE,CSTEP,DRDT(20)       RKAM0050
C     COMMON DECK "B3" INSERTED HERE                                    CB3 0020
      INTEGER CMX,CNTBL,CITBL,CFRMTBL,IDSC(10)                          CB3 0040
      COMMON/B3/CMX,CNTBL(10),CITBL(10),CFRMTBL(10),CGP(512)            CB3 0050
      EQUIVALENCE (CGP,IDSC),(ANC,CGP(11))                              CB3 0060
C     COMMON DECK "CC" INSERTED HERE                                    CCC 0020
      REAL MODC                                                         CCC 0040
      COMMON/CC/MODC(4),CS,PCST,PCSR,PCSTH,PCSPH                        CCC 0050
C     COMMON DECK "CONST" INSERTED HERE                                 CCON0020
      COMMON/PCONST/CREF,RGAS,GAMMA                                     CCON0040
      COMMON/MCONST/PI,PIT2,PID2,DEGS,RAD,ALN10                         CCON0050
C     COMMON DECK "WW" INSERTED HERE                                    CWW 0020
      PARAMETER (NWARSZ=1000)                                           CWW10030
      COMMON/WW/ID(10),MAXW,W(NWARSZ)                                   CWW10040
      REAL MAXSTP,MAXERR,INTYP,LLAT,LLON                                CWW20020
      EQUIVALENCE (EARTHR,W(1)),(RAY,W(2)),(XMTRH,W(3)),(TLAT,W(4)),    CWW20030
     1 (TLON,W(5)),(OW,W(6)),(FBEG,W(7)),(FEND,W(8)),(FSTEP,W(9)),      CWW20040
     2 (AZ1,W(10)),(AZBEG,W(11)),(AZEND,W(12)),(AZSTEP,W(13)),          CWW20050
     3 (BETA,W(14)),(ELBEG,W(15)),(ELEND,W(16)),(ELSTEP,W(17)),         CWW20060
     8   (RUNSUP,W(18)),(RCVRH,W(20)),                                  CWW20070
     4 (ONLY,W(21)),(HOP,W(22)),(MAXSTP,W(23)),(PLAT,W(24)),(PLON,W(25))CWW20080
     5,(HMAX,W(26)),(RAYFNC,W(29)),(EXTINC,W(33)),                      CWW20090
     6 (HMIN,W(27)),(RGMAX,W(28)),                                      CWW20100
     8 (INTYP,W(41)),(MAXERR,W(42)),(ERATIO,W(43)),                     CWW20110
     6 (STEP1,W(44)),(STPMAX,W(45)),(STPMIN,W(46)),(FACTR,W(47)),       CWW20120
     7 (SKIP,W(71)),(RAYSET,W(72)),(PRTSRP,W(74)),(HITLET,W(75))        CWW20130
     9 ,(BINRAY,W(76)),(PAGLN,W(77)),(PLT,W(81)),(PFACTR,W(82)),        CWW20140
     1 (LLAT,W(83)),(LLON,W(84)),(RLAT,W(85)),(RLON,W(86))              CWW20150
     2,(TIC,W(87)),(HB,W(88)),(HT,W(89)),(TICV,W(96))                   CWW20160
      REAL MMODEL,MFORM,MID                                             CWW30020
C                                                                       CWW30030
C     WIND         100-124                                              CWW30040
      EQUIVALENCE (W(100),UMODEL),(W(101),UFORM),(W(102),UID)           CWW30050
C                                                                       CWW30060
C     DELTA WIND         125-149                                        CWW30070
      EQUIVALENCE (W(125),DUMODEL),(W(126),DUFORM),(W(127),DUID)        CWW30080
C                                                                       CWW30090
C     SOUND SPEED 150-174                                               CWW30100
      EQUIVALENCE (W(150),CMODEL),(W(151),CFORM),(W(152),CID)           CWW30110
      EQUIVALENCE (W(153),REFC)                                         CWW30120
C                                                                       CWW30130
C     DELTA SOUND SPEED 175-199                                         CWW30140
```

```
      EQUIVALENCE (W(175),DCMODEL),(W(176),DCFORM),(W(177),DCID)        CWW30150
C                                                                       CWW30160
C     TEMPERATURE    200-224                                            CWW30170
      EQUIVALENCE (W(200),TMODEL),(W(201),TFORM),(W(202),TID)           CWW30180
C                                                                       CWW30190
C     DELTA TEMPERATURE    225-249                                      CWW30200
      EQUIVALENCE (W(225),DTMODEL),(W(226),DTFORM),(W(227),DTID)        CWW30210
C                                                                       CWW30220
C     MOLECULAR   250-274                                               CWW30230
      EQUIVALENCE (W(250),MMODEL),(W(251),MFORM),(W(252),MID)           CWW30240
C                                                                       CWW30250
C     RECEIVER HEIGHT   275-299                                         CWW30260
      EQUIVALENCE (W(275),RMODEL),(W(276),RFORM),(W(277),RID)           CWW30270
C                                                                       CWW30280
C     TOPOGRAPHY   300-324                                              CWW30290
      EQUIVALENCE (W(300),GMODEL),(W(301),GFORM),(W(302),GID)           CWW30300
C                                                                       CWW30310
C     DELTA TOPOGRAPHY   325-349                                        CWW30320
      EQUIVALENCE (W(325),GUMODEL),(W(326),GUFORM),(W(327),GUID)        CWW30330
C                                                                       CWW30340
C     ATMOSPHERIC SURFACE TOPOGRAPHY   350-374                          CWW30350
      EQUIVALENCE (W(350),SMODEL),(W(351),SFORM),(W(352),SID)           CWW30360
C                                                                       CWW30370
C     ATMOSPHERIC SURFACE TOPOGRAPHY   375-399                          CWW30380
      EQUIVALENCE (W(375),SUMODEL),(W(376),SUFORM),(W(377),SUID)        CWW30390
C     PLOT ENHANCEMENTS CONTROL PARAMETERS                              CWW30400
C                                                                       CWW30410
      EQUIVALENCE (W(490),XFQMDL),(W(491),YFQMDL)                       CWW30420
C     ABSORPTION          500-524                                       CWW30430
      EQUIVALENCE (W(500),AMODEL),(W(501),AFORM),(W(502),AID)           CWW30440
C                                                                       CWW30450
C     DELTA ABSORPTION          525-549                                 CWW30460
      EQUIVALENCE (W(525),DAMODEL),(W(526),DAFORM),(W(527),DAID)        CWW30470
C                                                                       CWW30480
C     PRESSURE          550-574                                         CWW30490
      EQUIVALENCE (W(550),PMODEL),(W(551),PFORM),(W(552),PID)           CWW30500
C                                                                       CWW30510
C     DELTA PRESSURE          575-599                                   CWW30520
      EQUIVALENCE (W(575),DPMODEL),(W(576),DPFORM),(W(577),DPID)        CWW30530
C                                                                       CWW30540
      EQUIVALENCE (Z0,CGP(12)),(C0,CGP(32)),(DL0,CGP(52))               CSTE0140
      EQUIVALENCE (Z,CGP(13)),(BIN,CGP(33)),(DL,CGP(53))                CSTE0150
      EQUIVALENCE (REFH,W(154)), (LAM0,W(155))                          CSTE0160
C                                                                       CSTE0170
      INTEGER CPX     ,CQTBL(10) ,CLTBL(10),CIRMTBL(10)                 CSTE0180
      DATA RECOGC,N/2.0,0/                                              CSTE0190
C                                                                       CSTE0200
      DATA PFST,PFSTH,PFSPH/3*0.0/                                      CSTE0210
      DATA AQC/0.0/                                                     CSTE0220
      DATA CPX/2/                                                       CSTE0230
      DATA CQTBL/1,11,72,7*0/                                           CSTE0240
      DATA CLTBL/1,20,8*0/                                              CSTE0250
      DATA CIRMTBL/1,2,8*0/                                             CSTE0260
C                                                                       CSTE0270
C                                                                       CSTE0280
```

```
      ENTRY SETSPD
C
      PCST=PFST
      PCSTH=PFSTH
      PCSPH=PFSPH
      ANC=AQC
      CMX=CPX
      CALL IMOVE(CNTBL,CQTBL,10)
      CALL IMOVE(CITBL,CLTBL,10)
      CALL IMOVE(CFRMTBL,CIRMTBL,10)
      CALL SETPSP
C
      RETURN
C
      ENTRY ISPEED
C
      IF(REFC.GT.0) CREF=REFC
C
      CALL IPSPEED
C
C     IF HAD PREVIOUS CALL BUT NOTHING THIS TIME, EXIT NOW
C     RETAINING PREVIOUS TABULAR DATA COUNT
      IF(N.GT.0 .AND. ANC.EQ.0.0) RETURN
C
      IF(RECOGC .NE. CMODEL)
     1    CALL RERROR('SPEED   ','WRNG MODEL',RECOGC)
      MODC(1)=7HCSSPOKE
      MODC(2)=CID
      N=ANC/3
      IF(ANC.NE.3*N.OR.N.LE.0)
     1     CALL RERROR('CSSPOKE','BAD NUMBER',ANC+2.0)
      N=N-2
      ANC=0.0
      TH0=PID2-LAM0
C
      R0=EARTHR+REFH
C
C
C     CONVERT 'C' ARRAY INPUT(OVERLAYS 'B' ARRAY) TO 'B' ARRAY
C
      ZM1=Z0
      CS0=C0*C0
      CSM1=CS0
      NP1=N+1
      DO 10 I=1,NP1
         ZR=Z(I)
         ALC(I)=ALCOSH((ZR-Z0) / DL(I))
         CS=BIN(I)**2
         B(I)=(CS-CSM1)/(ZR-ZM1)
         ZM1=ZR
10       CSM1=CS
C
      RETURN
C
      ENTRY SPEED
```

```
C
      IF(N.LE.0)
     1    CALL RERROR('CSSPOKE','BAD N VALUE',N)
C
      COSTH=COS(THO-TH)
      SINTH=SIN(THO-TH)
      D=SQRT(R0*R0+R*R-2*R*R0*COSTH)
      X=(R*COSTH-R0)/D
      ZR=ASIN(X)
      SUM=0.
      PCSZ=B(1)
      DO 1 I = 1, N
      SAV=0.5*(B(I+1)-B(I))
      PCSZ= PCSZ+ SAV * (1.+TANH ((ZR-Z(I)) /DL(I)))
    1 SUM = SUM+DL(I) * SAV *(ALCOSH((ZR-Z(I))/DL(I))-ALC(I))
      CS = CS0+SUM + 0.5*(B(1) + B(N + 1)) * (ZR-Z0)
      PDR=(R-R0*COSTH)/D
      IF(CS.LT.0) CALL PMDSTOP
      PDTH=(-1.)*R*R0*SINTH/D
      PZR=(COSTH/D-(R*COSTH-R0)*PDR/(D*D))/SQRT(1.-X*X)
      PZTH=(R*SINTH/D-(R*COSTH-R0)*PDTH/(D*D))/
     1    SQRT(1.-X*X)
C
      PCSR=PCSZ*PZR
      PCSTH=PCSZ*PZTH
C
C
      CALL PSPEED
      RETURN
      END
```

```
      SUBROUTINE CSSPOK2
C     SOUND SPEED SQUARED IS MODELED AS A FUNCTION OF ANGLE 'ALPHA'
C     ABOUT A HORIZONTAL LINE AT SPECIFIED HEIGHT AND LATITUDE. DEPENDE
C     ON 'ALPHA' IS AS A SEQUENCE OF LINEAR SEGMENTS JOINED BY HYPERBOL
C     TANGENTS.
C
      REAL ALC(20),Z(19),BIN(19),B(19),DL(19),LAM0
C     COMMON DECK "RKAM" INSERTED HERE
      REAL KR,KTH,KPH
      COMMON//R,TH,PH,KR,KTH,KPH,RKVARS(14),TPULSE,CSTEP,DRDT(20)
C     COMMON DECK "B3" INSERTED HERE
      INTEGER CMX,CNTBL,CITBL,CFRMTBL,IDSC(10)
      COMMON/B3/CMX,CNTBL(10),CITBL(10),CFRMTBL(10),CGP(512)
      EQUIVALENCE (CGP,IDSC),(ANC,CGP(11))
C     COMMON DECK "CC" INSERTED HERE
      REAL MODC
      COMMON/CC/MODC(4),CS,PCST,PCSR,PCSTH,PCSPH
C     COMMON DECK "CONST" INSERTED HERE
      COMMON/PCONST/CREF,RGAS,GAMMA
      COMMON/MCONST/PI,PIT2,PID2,DEGS,RAD,ALN10
```

```
C     COMMON DECK "WW" INSERTED HERE                                    CWW 0020
      PARAMETER (NWARSZ=1000)                                           CWW10030
      COMMON/WW/ID(10),MAXW,W(NWARSZ)                                   CWW10040
      REAL MAXSTP,MAXERR,INTYP,LLAT,LLON                                CWW20020
      EQUIVALENCE (EARTHR,W(1)),(RAY,W(2)),(XMTRH,W(3)),(TLAT,W(4)),    CWW20030
     1 (TLON,W(5)),(OW,W(6)),(FBEG,W(7)),(FEND,W(8)),(FSTEP,W(9)),      CWW20040
     2 (AZ1,W(10)),(AZBEG,W(11)),(AZEND,W(12)),(AZSTEP,W(13)),          CWW20050
     3 (BETA,W(14)),(ELBEG,W(15)),(ELEND,W(16)),(ELSTEP,W(17)),         CWW20060
     8   (RUNSUP,W(18)),(RCVRH,W(20)),                                  CWW20070
     4 (ONLY,W(21)),(HOP,W(22)),(MAXSTP,W(23)),(PLAT,W(24)),(PLON,W(25))CWW20080
     5,(HMAX,W(26)),(RAYFNC,W(29)),(EXTINC,W(33)),                      CWW20090
     6 (HMIN,W(27)),(RGMAX,W(28)),                                      CWW20100
     8 (INTYP,W(41)),(MAXERR,W(42)),(ERATIO,W(43)),                     CWW20110
     6 (STEP1,W(44)),(STPMAX,W(45)),(STPMIN,W(46)),(FACTR,W(47)),       CWW20120
     7 (SKIP,W(71)),(RAYSET,W(72)),(PRTSRP,W(74)),(HITLET,W(75))        CWW20130
     9 ,(BINRAY,W(76)),(PAGLN,W(77)),(PLT,W(81)),(PFACTR,W(82)),        CWW20140
     1 (LLAT,W(83)),(LLON,W(84)),(RLAT,W(85)),(RLON,W(86))              CWW20150
     2,(TIC,W(87)),(HB,W(88)),(HT,W(89)),(TICV,W(96))                   CWW20160
      REAL MMODEL,MFORM,MID                                             CWW30020
C                                                                       CWW30030
C     WIND         100-124                                              CWW30040
      EQUIVALENCE (W(100),UMODEL),(W(101),UFORM),(W(102),UID)           CWW30050
C                                                                       CWW30060
C     DELTA WIND         125-149                                        CWW30070
      EQUIVALENCE (W(125),DUMODEL),(W(126),DUFORM),(W(127),DUID)        CWW30080
C                                                                       CWW30090
C     SOUND SPEED 150-174                                               CWW30100
      EQUIVALENCE (W(150),CMODEL),(W(151),CFORM),(W(152),CID)           CWW30110
      EQUIVALENCE (W(153),REFC)                                         CWW30120
C                                                                       CWW30130
C     DELTA SOUND SPEED 175-199                                         CWW30140
      EQUIVALENCE (W(175),DCMODEL),(W(176),DCFORM),(W(177),DCID)        CWW30150
C                                                                       CWW30160
C     TEMPERATURE    200-224                                            CWW30170
      EQUIVALENCE (W(200),TMODEL),(W(201),TFORM),(W(202),TID)           CWW30180
C                                                                       CWW30190
C     DELTA TEMPERATURE    225-249                                      CWW30200
      EQUIVALENCE (W(225),DTMODEL),(W(226),DTFORM),(W(227),DTID)        CWW30210
C                                                                       CWW30220
C     MOLECULAR   250-274                                               CWW30230
      EQUIVALENCE (W(250),MMODEL),(W(251),MFORM),(W(252),MID)           CWW30240
C                                                                       CWW30250
C     RECEIVER HEIGHT   275-299                                         CWW30260
      EQUIVALENCE (W(275),RMODEL),(W(276),RFORM),(W(277),RID)           CWW30270
C                                                                       CWW30280
C     TOPOGRAPHY   300-324                                              CWW30290
      EQUIVALENCE (W(300),GMODEL),(W(301),GFORM),(W(302),GID)           CWW30300
C                                                                       CWW30310
C     DELTA TOPOGRAPHY   325-349                                        CWW30320
      EQUIVALENCE (W(325),GUMODEL),(W(326),GUFORM),(W(327),GUID)        CWW30330
C                                                                       CWW30340
C     ATMOSPHERIC SURFACE TOPOGRAPHY   350-374                          CWW30350
      EQUIVALENCE (W(350),SMODEL),(W(351),SFORM),(W(352),SID)           CWW30360
C                                                                       CWW30370
C     ATMOSPHERIC SURFACE TOPOGRAPHY   375-399                          CWW30380
```

```
      EQUIVALENCE (W(375),SUMODEL),(W(376),SUFORM),(W(377),SUID)
C     PLOT ENHANCEMENTS CONTROL PARAMETERS
C
      EQUIVALENCE (W(490),XFQMDL),(W(491),YFQMDL)
C     ABSORPTION        500-524
      EQUIVALENCE (W(500),AMODEL),(W(501),AFORM),(W(502),AID)
C
C     DELTA ABSORPTION        525-549
      EQUIVALENCE (W(525),DAMODEL),(W(526),DAFORM),(W(527),DAID)
C
C     PRESSURE        550-574
      EQUIVALENCE (W(550),PMODEL),(W(551),PFORM),(W(552),PID)
C
C     DELTA PRESSURE        575-599
      EQUIVALENCE (W(575),DPMODEL),(W(576),DPFORM),(W(577),DPID)
C
      EQUIVALENCE (Z0,CGP(12)),(C0,CGP(32)),(DL0,CGP(52))
      EQUIVALENCE (Z,CGP(13)),(BIN,CGP(33)),(DL,CGP(53))
      EQUIVALENCE (REFH,W(154)), (LAM0,W(155))
C
      INTEGER CPX     ,CQTBL(10) ,CLTBL(10),CIRMTBL(10)
      DATA RECOGC,N/2.0,0/
C
      DATA PFST,PFSTH,PFSPH/3*0.0/
      DATA AQC/0.0/
      DATA CPX/2/
      DATA CQTBL/1,11,72,7*0/
      DATA CLTBL/1,20,8*0/
      DATA CIRMTBL/1,2,8*0/
C
C
      ENTRY SETSPD
C
      PCST=PFST
      PCSTH=PFSTH
      PCSPH=PFSPH
      ANC=AQC
      CMX=CPX
      CALL IMOVE(CNTBL,CQTBL,10)
      CALL IMOVE(CITBL,CLTBL,10)
      CALL IMOVE(CFRMTBL,CIRMTBL,10)
      CALL SETPSP
C
      RETURN
C
      ENTRY ISPEED
C
      IF(REFC.GT.0) CREF=REFC
C
      CALL IPSPEED
C
C     IF HAD PREVIOUS CALL BUT NOTHING THIS TIME, EXIT NOW
C     RETAINING PREVIOUS TABULAR DATA COUNT
      IF(N.GT.0 .AND. ANC.EQ.0.0) RETURN
C
```

```
      IF(RECOGC .NE. CMODEL)                                             CST20530
     1    CALL RERROR('SPEED   ','WRNG MODEL',RECOGC)                   CST20540
      MODC(1)=7HCSSPOK2                                                  CST20550
      MODC(2)=CID                                                        CST20560
      N=ANC/3                                                            CST20570
      IF(ANC.NE.3*N.OR.N.LE.0)                                           CST20580
     1     CALL RERROR('CSSPOKE','BAD NUMBER',ANC+2.0)                  CST20590
      N=N-2                                                              CST20600
      ANC=0.0                                                            CST20610
      TH0=PID2-LAM0                                                      CST20620
C                                                                        CST20630
      R0=EARTHR+REFH                                                     CST20640
C                                                                        CST20650
C                                                                        CST20660
C     CONVERT 'C' ARRAY INPUT(OVERLAYS 'B' ARRAY) TO 'B' ARRAY           CST20670
C                                                                        CST20680
      ZM1=Z0                                                             CST20690
      CS0=C0*C0                                                          CST20700
      CSM1=CS0                                                           CST20710
      NP1=N+1                                                            CST20720
      DO 10 I=1,NP1                                                      CST20730
         ZR=Z(I)                                                         CST20740
         ALC(I)=ALCOSH((ZR-Z0) / DL(I))                                  CST20750
         CS=BIN(I)**2                                                    CST20760
         B(I)=(CS-CSM1)/(ZR-ZM1)                                         CST20770
         ZM1=ZR                                                          CST20780
10       CSM1=CS                                                         CST20790
C                                                                        CST20800
      RETURN                                                             CST20810
C                                                                        CST20820
      ENTRY SPEED                                                        CST20830
C                                                                        CST20840
      IF(N.LE.0)                                                         CST20850
     1    CALL RERROR('CSSPOK2','BAD N VALUE',N)                         CST20860
C                                                                        CST20870
      X=(R-R0)/(EARTHR*(TH0-TH))                                         CST20880
      ZR=ATAN2(R-R0,EARTHR*(TH0-TH))                                     CST20890
      SUM=0.                                                             CST20900
      PCSZ=B(1)                                                          CST20910
      DO 1 I = 1, N                                                      CST20920
      SAV=0.5*(B(I+1)-B(I))                                              CST20930
      PCSZ= PCSZ+ SAV * (1.+TANH ((ZR-Z(I)) /DL(I)))                     CST20940
    1 SUM = SUM+DL(I) * SAV *(ALCOSH((ZR-Z(I))/DL(I))-ALC(I))            CST20950
      CS = CS0+SUM + 0.5*(B(1) + B(N + 1)) * (ZR-Z0)                     CST20960
      IF(CS.LT.0) CALL PMDSTOP                                           CST20970
C                                                                        CST20980
      F=X/(1.0+X*X)                                                      CST20990
      PZR=F/(R-R0)                                                       CST21000
      PZTH=-F/(TH-TH0)                                                   CST21010
C                                                                        CST21020
      PCSR=PCSZ*PZR                                                      CST21030
      PCSTH=PCSZ*PZTH                                                    CST21040
C                                                                        CST21050
C                                                                        CST21060
      CALL PSPEED                                                        CST21070
```

```
      RETURN                                                          CST21080
      END                                                             CST21090


      SUBROUTINE CSMUNK1                                              CSS10020
C SPEED MODEL BASED ON THE 'CANONICAL' MODEL FOR A SOUND CHANNEL      CSS10030
C DERIVED BY MUNK(J.ACOUSTICAL SOC. AM. 55,220-226).                  CSS10040
C THE FOUR PARAMETERS OF THE MODEL ARE ALLOWED TO VARY LINEARLY IN    CSS10050
C LONGITUDE, PH. THE USER SPECIFIES VALUES FOR THE FOUR PARAMETERS AT CSS10060
C TWO LONGITUDES, PH1 AND PH2, AND THE PROGRAM INTERPOLATES LINEARLY  CSS10070
C TO GET THE VALUES AT OTHER LONGITUDES.                              CSS10080
C                                                                     CSS10090
C     C = CA(1+EP(ETA+EXP(-ETA)-1))                                   CSS10100
C                                                                     CSS10110
C        WHERE                                                        CSS10120
C                                                                     CSS10130
C           ETA = 2(Z-ZA)/H                                           CSS10140
C                                                                     CSS10150
C           Z = R-EARTHR                                              CSS10160
C                                                                     CSS10170
C     COMMON DECK "CONST" INSERTED HERE                               CCON0020
      COMMON/PCONST/CREF,RGAS,GAMMA                                   CCON0040
      COMMON/MCONST/PI,PIT2,PID2,DEGS,RAD,ALN10                       CCON0050
C     COMMON DECK "RKAM" INSERTED HERE                                RKAM0020
      REAL KR,KTH,KPH                                                 RKAM0040
      COMMON//R,TH,PH,KR,KTH,KPH,RKVARS(14),TPULSE,CSTEP,DRDT(20)     RKAM0050
C     COMMON DECK "CC" INSERTED HERE                                  CCC 0020
      REAL MODC                                                       CCC 0040
      COMMON/CC/MODC(4),CS,PCST,PCSR,PCSTH,PCSPH                      CCC 0050
C     COMMON DECK "WW" INSERTED HERE                                  CWW 0020
      PARAMETER (NWARSZ=1000)                                         CWW10030
      COMMON/WW/ID(10),MAXW,W(NWARSZ)                                 CWW10040
      REAL MAXSTP,MAXERR,INTYP,LLAT,LLON                              CWW20020
      EQUIVALENCE (EARTHR,W(1)),(RAY,W(2)),(XMTRH,W(3)),(TLAT,W(4)),  CWW20030
     1 (TLON,W(5)),(OW,W(6)),(FBEG,W(7)),(FEND,W(8)),(FSTEP,W(9)),    CWW20040
     2 (AZ1,W(10)),(AZBEG,W(11)),(AZEND,W(12)),(AZSTEP,W(13)),        CWW20050
     3 (BETA,W(14)),(ELBEG,W(15)),(ELEND,W(16)),(ELSTEP,W(17)),       CWW20060
     8   (RUNSUP,W(18)),(RCVRH,W(20)),                                CWW20070
     4 (ONLY,W(21)),(HOP,W(22)),(MAXSTP,W(23)),(PLAT,W(24)),(PLON,W(25))CWW20080
     5,(HMAX,W(26)),(RAYFNC,W(29)),(EXTINC,W(33)),                    CWW20090
     6 (HMIN,W(27)),(RGMAX,W(28)),                                    CWW20100
     8 (INTYP,W(41)),(MAXERR,W(42)),(ERATIO,W(43)),                   CWW20110
     6 (STEP1,W(44)),(STPMAX,W(45)),(STPMIN,W(46)),(FACTR,W(47)),     CWW20120
     7 (SKIP,W(71)),(RAYSET,W(72)),(PRTSRP,W(74)),(HITLET,W(75))      CWW20130
     9 ,(BINRAY,W(76)),(PAGLN,W(77)),(PLT,W(81)),(PFACTR,W(82)),      CWW20140
     1 (LLAT,W(83)),(LLON,W(84)),(RLAT,W(85)),(RLON,W(86))            CWW20150
     2,(TIC,W(87)),(HB,W(88)),(HT,W(89)),(TICV,W(96))                 CWW20160
      REAL MMODEL,MFORM,MID                                           CWW30020
C                                                                     CWW30030
C     WIND        100-124                                             CWW30040
      EQUIVALENCE (W(100),UMODEL),(W(101),UFORM),(W(102),UID)         CWW30050
C                                                                     CWW30060
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```
C       DELTA WIND          125-149                                     CWW30070
        EQUIVALENCE (W(125),DUMODEL),(W(126),DUFORM),(W(127),DUID)      CWW30080
C                                                                       CWW30090
C       SOUND SPEED 150-174                                             CWW30100
        EQUIVALENCE (W(150),CMODEL),(W(151),CFORM),(W(152),CID)         CWW30110
        EQUIVALENCE (W(153),REFC)                                       CWW30120
C                                                                       CWW30130
C       DELTA SOUND SPEED 175-199                                       CWW30140
        EQUIVALENCE (W(175),DCMODEL),(W(176),DCFORM),(W(177),DCID)      CWW30150
C                                                                       CWW30160
C       TEMPERATURE    200-224                                          CWW30170
        EQUIVALENCE (W(200),TMODEL),(W(201),TFORM),(W(202),TID)         CWW30180
C                                                                       CWW30190
C       DELTA TEMPERATURE    225-249                                    CWW30200
        EQUIVALENCE (W(225),DTMODEL),(W(226),DTFORM),(W(227),DTID)      CWW30210
C                                                                       CWW30220
C       MOLECULAR   250-274                                             CWW30230
        EQUIVALENCE (W(250),MMODEL),(W(251),MFORM),(W(252),MID)         CWW30240
C                                                                       CWW30250
C       RECEIVER HEIGHT   275-299                                       CWW30260
        EQUIVALENCE (W(275),RMODEL),(W(276),RFORM),(W(277),RID)         CWW30270
C                                                                       CWW30280
C       TOPOGRAPHY   300-324                                            CWW30290
        EQUIVALENCE (W(300),GMODEL),(W(301),GFORM),(W(302),GID)         CWW30300
C                                                                       CWW30310
C       DELTA TOPOGRAPHY   325-349                                      CWW30320
        EQUIVALENCE (W(325),GUMODEL),(W(326),GUFORM),(W(327),GUID)      CWW30330
C                                                                       CWW30340
C       ATMOSPHERIC SURFACE TOPOGRAPHY   350-374                        CWW30350
        EQUIVALENCE (W(350),SMODEL),(W(351),SFORM),(W(352),SID)         CWW30360
C                                                                       CWW30370
C       ATMOSPHERIC SURFACE TOPOGRAPHY   375-399                        CWW30380
        EQUIVALENCE (W(375),SUMODEL),(W(376),SUFORM),(W(377),SUID)      CWW30390
C       PLOT ENHANCEMENTS CONTROL PARAMETERS                            CWW30400
C                                                                       CWW30410
        EQUIVALENCE (W(490),XFQMDL),(W(491),YFQMDL)                     CWW30420
C       ABSORPTION          500-524                                     CWW30430
        EQUIVALENCE (W(500),AMODEL),(W(501),AFORM),(W(502),AID)         CWW30440
C                                                                       CWW30450
C       DELTA ABSORPTION            525-549                             CWW30460
        EQUIVALENCE (W(525),DAMODEL),(W(526),DAFORM),(W(527),DAID)      CWW30470
C                                                                       CWW30480
C       PRESSURE          550-574                                       CWW30490
        EQUIVALENCE (W(550),PMODEL),(W(551),PFORM),(W(552),PID)         CWW30500
C                                                                       CWW30510
C       DELTA PRESSURE          575-599                                 CWW30520
        EQUIVALENCE (W(575),DPMODEL),(W(576),DPFORM),(W(577),DPID)      CWW30530
C                                                                       CWW30540
C                                                                       CSS10220
        EQUIVALENCE (W(154),PH1), (W(155),CA1) ,(W(156),ZA1)            CSS10230
        EQUIVALENCE (W(157),H1) ,(W(158),EP1)                           CSS10240
C                                                                       CSS10250
        EQUIVALENCE (W(159),PH2), (W(160),CA2) ,(W(161),ZA2)            CSS10260
        EQUIVALENCE (W(162),H2) ,(W(163),EP2)                           CSS10270
C                                                                       CSS10280
```

```
C     COMMON DECK "B3" INSERTED HERE                                    CB3 0020
      INTEGER CMX,CNTBL,CITBL,CFRMTBL,IDSC(10)                          CB3 0040
      COMMON/B3/CMX,CNTBL(10),CITBL(10),CFRMTBL(10),CGP(512)            CB3 0050
      EQUIVALENCE (CGP,IDSC),(ANC,CGP(11))                              CB3 0060
      INTEGER CPX     ,CQTBL(10),CLTBL(10),CIRMTBL(10)                  CSS10300
      DATA RECOGC/5.0/                                                  CSS10310
C                                                                       CSS10320
      DATA CPX/1/                                                       CSS10330
      DATA CQTBL/1,11,8*0/                                              CSS10340
      DATA CLTBL/1,9*0/                                                 CSS10350
      DATA CIRMTBL/1,9*0/                                               CSS10360
C                                                                       CSS10370
      ENTRY SETSPD                                                      CSS10380
C                                                                       CSS10390
      CMX=CPX                                                           CSS10400
      CALL IMOVE(CNTBL,CQTBL,10)                                        CSS10410
      CALL IMOVE(CITBL,CLTBL,10)                                        CSS10420
      CALL IMOVE(CFRMTBL,CIRMTBL,10)                                    CSS10430
      CALL SETPSP                                                       CSS10440
C                                                                       CSS10450
      RETURN                                                            CSS10460
C                                                                       CSS10470
      ENTRY ISPEED                                                      CSS10480
C                                                                       CSS10490
      IF(RECOGC .NE. CMODEL)                                            CSS10500
     1    CALL RERROR('SPEED  ','WRNG MODEL',RECOGC)                    CSS10510
      MODC(1)=7HCSMUNK1                                                 CSS10520
      MODC(2)=CID                                                       CSS10530
C                                                                       CSS10540
      DPH=PH2-PH1                                                       CSS10550
      DCA=CA2-CA1                                                       CSS10560
      DZA=ZA2-ZA1                                                       CSS10570
      DH=H2-H1                                                          CSS10580
      DEP=EP2-EP1                                                       CSS10590
C    COMPUTE PH DERIVATIVES OF CA,ZA,H,EP                               CSS10600
      PHPH=DH/DPH                                                       CSS10610
      PEPPH=DEP/DPH                                                     CSS10620
      PCAPH=DCA/DPH                                                     CSS10630
      PZAPH=DZA/DPH                                                     CSS10640
C                                                                       CSS10650
      IF(REFC.GT.0.) CREF=REFC                                          CSS10660
      CALL IPSPEED                                                      CSS10670
      RETURN                                                            CSS10680
C                                                                       CSS10690
      ENTRY SPEED                                                       CSS10700
C                                                                       CSS10710
C    INTERPOLATE FOR CA,ZA,H,EP                                         CSS10720
      FRACT=(PH-PH1)/DPH                                                CSS10730
      CA=CA1+FRACT*DCA                                                  CSS10740
      ZA=ZA1+FRACT*DZA                                                  CSS10750
      H=H1+FRACT*DH                                                     CSS10760
      EP=EP1+FRACT*DEP                                                  CSS10770
C    COMPUTE SOUND SPEED,C                                              CSS10780
      ETA=-2.*(R-EARTHR-ZA)/H                                           CSS10790
      EXETA1=EXP(-ETA)-1.                                               CSS10800
```

```
C                                                                        CSS10810
      PRODCT=CA*(ETA+EXETA1)                                             CSS10820
      C=CA+EP*PRODCT                                                     CSS10830
      CS=C*C                                                             CSS10840
C     COMPUTE DERIVATIVES OF C                                           CSS10850
      PCR=2.*CA*EP*EXETA1/H                                              CSS10860
      PCEP=PRODCT                                                        CSS10870
      PCCA=1.+(EP/CA)*PRODCT                                             CSS10880
      PCZA=-PCR                                                          CSS10890
      PCH=ETA/2.*PCR                                                     CSS10900
C     COMPUTE DERIVATIVES OF CS                                          CSS10910
      C2=C*2.                                                            CSS10920
      PCSTH=0.                                                           CSS10930
      PCST=0.                                                            CSS10940
      PCSR=C2*PCR                                                        CSS10950
C     CHAIN RULE TO GET PCS/PPH.                                         CSS10960
      PCSPH=C2*(PCH*PHPH+PCEP*PEPPH+PCZA*PZAPH+PCCA*PCAPH)               CSS10970
C                                                                        CSS10980
      CALL PSPEED                                                        CSS10990
      RETURN                                                             CSS11000
      END                                                                CSS11010
```

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      SUBROUTINE CSMUNK2                                                 CSS20020
C SPEED MODEL BASED ON THE 'CANONICAL' MODEL FOR A SOUND CHANNEL         CSS20030
C DERIVED BY MUNK(J.ACOUSTICAL SOC. AM. 55,220-226).                     CSS20040
C THE FOUR PARAMETERS OF THE MODEL ARE ALLOWED TO VARY LINEARLY IN       CSS20050
C LONGITUDE, PH. THE USER SPECIFIES VALUES FOR THE FOUR PARAMETERS AT    CSS20060
C TWO LONGITUDES, PH1 AND PH2, AND THE PROGRAM INTERPOLATES LINEARLY     CSS20070
C TO GET THE VALUES AT OTHER LONGITUDES.                                 CSS20080
C                                                                        CSS20090
C     C = CA(1+EP(ETA+EXP(-ETA)-1))                                      CSS20100
C                                                                        CSS20110
C        WHERE                                                           CSS20120
C                                                                        CSS20130
C           ETA = 2(Z-ZA)/H                                              CSS20140
C                                                                        CSS20150
C           Z = R-EARTHR                                                 CSS20160
C                                                                        CSS20170
C     COMMON DECK "CONST" INSERTED HERE                                  CCON0020
      COMMON/PCONST/CREF,RGAS,GAMMA                                      CCON0040
      COMMON/MCONST/PI,PIT2,PID2,DEGS,RAD,ALN10                          CCON0050
C     COMMON DECK "RKAM" INSERTED HERE                                   RKAM0020
      REAL KR,KTH,KPH                                                    RKAM0040
      COMMON//R,TH,PH,KR,KTH,KPH,RKVARS(14),TPULSE,CSTEP,DRDT(20)        RKAM0050
C     COMMON DECK "CC" INSERTED HERE                                     CCC 0020
      REAL MODC                                                          CCC 0040
      COMMON/CC/MODC(4),CS,PCST,PCSR,PCSTH,PCSPH                         CCC 0050
C     COMMON DECK "WW" INSERTED HERE                                     CWW 0020
      PARAMETER (NWARSZ=1000)                                            CWW10030
      COMMON/WW/ID(10),MAXW,W(NWARSZ)                                    CWW10040
      REAL MAXSTP,MAXERR,INTYP,LLAT,LLON                                 CWW20020
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```
      EQUIVALENCE (EARTHR,W(1)),(RAY,W(2)),(XMTRH,W(3)),(TLAT,W(4)),    CWW20030
     1 (TLON,W(5)),(OW,W(6)),(FBEG,W(7)),(FEND,W(8)),(FSTEP,W(9)),      CWW20040
     2 (AZ1,W(10)),(AZBEG,W(11)),(AZEND,W(12)),(AZSTEP,W(13)),          CWW20050
     3 (BETA,W(14)),(ELBEG,W(15)),(ELEND,W(16)),(ELSTEP,W(17)),         CWW20060
     8   (RUNSUP,W(18)),(RCVRH,W(20)),                                  CWW20070
     4 (ONLY,W(21)),(HOP,W(22)),(MAXSTP,W(23)),(PLAT,W(24)),(PLON,W(25))CWW20080
     5,(HMAX,W(26)),(RAYFNC,W(29)),(EXTINC,W(33)),                      CWW20090
     6 (HMIN,W(27)),(RGMAX,W(28)),                                      CWW20100
     8 (INTYP,W(41)),(MAXERR,W(42)),(ERATIO,W(43)),                     CWW20110
     6 (STEP1,W(44)),(STPMAX,W(45)),(STPMIN,W(46)),(FACTR,W(47)),       CWW20120
     7 (SKIP,W(71)),(RAYSET,W(72)),(PRTSRP,W(74)),(HITLET,W(75))        CWW20130
     9 ,(BINRAY,W(76)),(PAGLN,W(77)),(PLT,W(81)),(PFACTR,W(82)),        CWW20140
     1 (LLAT,W(83)),(LLON,W(84)),(RLAT,W(85)),(RLON,W(86))              CWW20150
     2,(TIC,W(87)),(HB,W(88)),(HT,W(89)),(TICV,W(96))                   CWW20160
      REAL MMODEL,MFORM,MID                                             CWW30020
C                                                                       CWW30030
C     WIND         100-124                                              CWW30040
      EQUIVALENCE (W(100),UMODEL),(W(101),UFORM),(W(102),UID)           CWW30050
C                                                                       CWW30060
C     DELTA WIND         125-149                                        CWW30070
      EQUIVALENCE (W(125),DUMODEL),(W(126),DUFORM),(W(127),DUID)        CWW30080
C                                                                       CWW30090
C     SOUND SPEED 150-174                                               CWW30100
      EQUIVALENCE (W(150),CMODEL),(W(151),CFORM),(W(152),CID)           CWW30110
      EQUIVALENCE (W(153),REFC)                                         CWW30120
C                                                                       CWW30130
C     DELTA SOUND SPEED 175-199                                         CWW30140
      EQUIVALENCE (W(175),DCMODEL),(W(176),DCFORM),(W(177),DCID)        CWW30150
C                                                                       CWW30160
C     TEMPERATURE    200-224                                            CWW30170
      EQUIVALENCE (W(200),TMODEL),(W(201),TFORM),(W(202),TID)           CWW30180
C                                                                       CWW30190
C     DELTA TEMPERATURE    225-249                                      CWW30200
      EQUIVALENCE (W(225),DTMODEL),(W(226),DTFORM),(W(227),DTID)        CWW30210
C                                                                       CWW30220
C     MOLECULAR   250-274                                               CWW30230
      EQUIVALENCE (W(250),MMODEL),(W(251),MFORM),(W(252),MID)           CWW30240
C                                                                       CWW30250
C     RECEIVER HEIGHT   275-299                                         CWW30260
      EQUIVALENCE (W(275),RMODEL),(W(276),RFORM),(W(277),RID)           CWW30270
C                                                                       CWW30280
C     TOPOGRAPHY   300-324                                              CWW30290
      EQUIVALENCE (W(300),GMODEL),(W(301),GFORM),(W(302),GID)           CWW30300
C                                                                       CWW30310
C     DELTA TOPOGRAPHY   325-349                                        CWW30320
      EQUIVALENCE (W(325),GUMODEL),(W(326),GUFORM),(W(327),GUID)        CWW30330
C                                                                       CWW30340
C     ATMOSPHERIC SURFACE TOPOGRAPHY   350-374                          CWW30350
      EQUIVALENCE (W(350),SMODEL),(W(351),SFORM),(W(352),SID)           CWW30360
C                                                                       CWW30370
C     ATMOSPHERIC SURFACE TOPOGRAPHY   375-399                          CWW30380
      EQUIVALENCE (W(375),SUMODEL),(W(376),SUFORM),(W(377),SUID)        CWW30390
C     PLOT ENHANCEMENTS CONTROL PARAMETERS                              CWW30400
C                                                                       CWW30410
      EQUIVALENCE (W(490),XFQMDL),(W(491),YFQMDL)                       CWW30420
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C     ABSORPTION           500-524                                        CWW30430
      EQUIVALENCE (W(500),AMODEL),(W(501),AFORM),(W(502),AID)             CWW30440
C                                                                         CWW30450
C     DELTA ABSORPTION          525-549                                   CWW30460
      EQUIVALENCE (W(525),DAMODEL),(W(526),DAFORM),(W(527),DAID)          CWW30470
C                                                                         CWW30480
C     PRESSURE             550-574                                        CWW30490
      EQUIVALENCE (W(550),PMODEL),(W(551),PFORM),(W(552),PID)             CWW30500
C                                                                         CWW30510
C     DELTA PRESSURE            575-599                                   CWW30520
      EQUIVALENCE (W(575),DPMODEL),(W(576),DPFORM),(W(577),DPID)          CWW30530
C                                                                         CWW30540
C                                                                         CSS20220
      EQUIVALENCE (W(154),PH1), (W(155),CA1) ,(W(156),ZA1)                CSS20230
      EQUIVALENCE (W(157),H1)  ,(W(158),EP1)                              CSS20240
C                                                                         CSS20250
      EQUIVALENCE (W(159),PH2), (W(160),CA2) ,(W(161),ZA2)                CSS20260
      EQUIVALENCE (W(162),H2)  ,(W(163),EP2)                              CSS20270
C                                                                         CSS20280
C     COMMON DECK "B3" INSERTED HERE                                      CB3 0020
      INTEGER CMX,CNTBL,CITBL,CFRMTBL,IDSC(10)                            CB3 0040
      COMMON/B3/CMX,CNTBL(10),CITBL(10),CFRMTBL(10),CGP(512)              CB3 0050
      EQUIVALENCE (CGP,IDSC),(ANC,CGP(11))                                CB3 0060
      INTEGER CPX    ,CQTBL(10),CLTBL(10),CIRMTBL(10)                     CSS20300
      DATA RECOGC/6.0/                                                    CSS20310
C                                                                         CSS20320
      DATA CPX/1/                                                         CSS20330
      DATA CQTBL/1,11,8*0/                                                CSS20340
      DATA CLTBL/1,9*0/                                                   CSS20350
      DATA CIRMTBL/1,9*0/                                                 CSS20360
C                                                                         CSS20370
C                                                                         CSS20380
      ENTRY SETSPD                                                        CSS20390
C                                                                         CSS20400
      CMX=CPX                                                             CSS20410
      CALL IMOVE(CNTBL,CQTBL,10)                                          CSS20420
      CALL IMOVE(CITBL,CLTBL,10)                                          CSS20430
      CALL IMOVE(CFRMTBL,CIRMTBL,10)                                      CSS20440
      CALL SETPSP                                                         CSS20450
C                                                                         CSS20460
      RETURN                                                              CSS20470
C                                                                         CSS20480
      ENTRY ISPEED                                                        CSS20490
C                                                                         CSS20500
      IF(RECOGC .NE. CMODEL)                                              CSS20510
     1   CALL RERROR('SPEED    ','WRNG MODEL',RECOGC)                     CSS20520
      MODC(1)=7HCSMUNK2                                                   CSS20530
      MODC(2)=CID                                                         CSS20540
      IF(REFC.GT.0) CREF=REFC                                             CSS20550
C                                                                         CSS20560
      DPH=PH2-PH1                                                         CSS20570
C                                                                         CSS20580
      CALL IPSPEED                                                        CSS20590
      RETURN                                                              CSS20600
C                                                                         CSS20610
```

```
      ENTRY SPEED
C
C     COMPUTE SOUND SPEED,C1, AT (PH1,Z)
C
      ETA1=-2.*(R-EARTHR-ZA1)/H1
      EXETA1=EXP(-ETA1)-1.
      PROD1=CA1*(ETA1+EXETA1)
      C1=CA1+EP1*PROD1
C
C     COMPUTE SOUND SPEED C2 AT (PH2,Z)
C
      ETA2=-2.*(R-EARTHR-ZA2)/H2
      EXETA2=EXP(-ETA2)-1.
      PROD2=CA2*(ETA2+EXETA2)
      C2=CA2+EP2*PROD2
C
C     COMPUTE VERTICAL GRADIENTS AT PH1,PH2
C
      PCR1=2.*CA1*EP1/H1*EXETA1
      PCR2=2.*CA2*EP2/H2*EXETA2
C
C     DIFFERENCES IN C AND ITS VERTICAL GRADIENT
C
      DPCR=PCR2-PCR1
      DC = C2-C1
C
C     INTERPOLATE FOR C AT (PH,Z)
C
      FRACT=(PH-PH1)/DPH
      C=C1+FRACT*DC
      CS=C*C
C
C     DERIVATIVES OF C AND CS
C
      PCPH=DC/DPH
      PCR=PCR1+FRACT*DPCR
      PCSR=2.*C*PCR
      PCSPH=2.*C*PCPH
      PCSTH=0.
      PCST=0.
C
C
      CALL PSPEED
      RETURN
      END


      SUBROUTINE CTABLE
C     TABULAR TEMPERATURE PROFILE THAT MAKES A CUBIC INTERPOLATION
C     BETWEEN POINTS TO INSURE A CONTINUOUS TERMPERATURE GRADIENT
      DIMENSION HPC(250),FN2C(250),ALPHA(250),TTBETA(250),GAMM(250),
     1 DELTA(250),SLOPE(250),MAT(4,5)
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```
      REAL MAT                                                          CTUE0070
C     COMMON DECK "CONST" INSERTED HERE                                 CCON0020
      COMMON/PCONST/CREF,RGAS,GAMMA                                     CCON0040
      COMMON/MCONST/PI,PIT2,PID2,DEGS,RAD,ALN10                         CCON0050
C     COMMON DECK "RKAM" INSERTED HERE                                  RKAM0020
      REAL KR,KTH,KPH                                                   RKAM0040
      COMMON//R,TH,PH,KR,KTH,KPH,RKVARS(14),TPULSE,CSTEP,DRDT(20)       RKAM0050
C     COMMON DECK "CC" INSERTED HERE                                    CCC 0020
      REAL MODC                                                         CCC 0040
      COMMON/CC/MODC(4),CS,PCST,PCSR,PCSTH,PCSPH                        CCC 0050
C     COMMON DECK "WW" INSERTED HERE                                    CWW 0020
      PARAMETER (NWARSZ=1000)                                           CWW10030
      COMMON/WW/ID(10),MAXW,W(NWARSZ)                                   CWW10040
      REAL MAXSTP,MAXERR,INTYP,LLAT,LLON                                CWW20020
      EQUIVALENCE (EARTHR,W(1)),(RAY,W(2)),(XMTRH,W(3)),(TLAT,W(4)),    CWW20030
     1 (TLON,W(5)),(OW,W(6)),(FBEG,W(7)),(FEND,W(8)),(FSTEP,W(9)),      CWW20040
     2 (AZ1,W(10)),(AZBEG,W(11)),(AZEND,W(12)),(AZSTEP,W(13)),          CWW20050
     3 (BETA,W(14)),(ELBEG,W(15)),(ELEND,W(16)),(ELSTEP,W(17)),         CWW20060
     8   (RUNSUP,W(18)),(RCVRH,W(20)),                                  CWW20070
     4 (ONLY,W(21)),(HOP,W(22)),(MAXSTP,W(23)),(PLAT,W(24)),(PLON,W(25))CWW20080
     5,(HMAX,W(26)),(RAYFNC,W(29)),(EXTINC,W(33)),                      CWW20090
     6 (HMIN,W(27)),(RGMAX,W(28)),                                      CWW20100
     8 (INTYP,W(41)),(MAXERR,W(42)),(ERATIO,W(43)),                     CWW20110
     6 (STEP1,W(44)),(STPMAX,W(45)),(STPMIN,W(46)),(FACTR,W(47)),       CWW20120
     7 (SKIP,W(71)),(RAYSET,W(72)),(PRTSRP,W(74)),(HITLET,W(75))        CWW20130
     9 ,(BINRAY,W(76)),(PAGLN,W(77)),(PLT,W(81)),(PFACTR,W(82)),        CWW20140
     1 (LLAT,W(83)),(LLON,W(84)),(RLAT,W(85)),(RLON,W(86))              CWW20150
     2,(TIC,W(87)),(HB,W(88)),(HT,W(89)),(TICV,W(96))                   CWW20160
      REAL MMODEL,MFORM,MID                                             CWW30020
C                                                                       CWW30030
C     WIND         100-124                                              CWW30040
      EQUIVALENCE (W(100),UMODEL),(W(101),UFORM),(W(102),UID)           CWW30050
C                                                                       CWW30060
C     DELTA WIND          125-149                                       CWW30070
      EQUIVALENCE (W(125),DUMODEL),(W(126),DUFORM),(W(127),DUID)        CWW30080
C                                                                       CWW30090
C     SOUND SPEED 150-174                                               CWW30100
      EQUIVALENCE (W(150),CMODEL),(W(151),CFORM),(W(152),CID)           CWW30110
      EQUIVALENCE (W(153),REFC)                                         CWW30120
C                                                                       CWW30130
C     DELTA SOUND SPEED 175-199                                         CWW30140
      EQUIVALENCE (W(175),DCMODEL),(W(176),DCFORM),(W(177),DCID)        CWW30150
C                                                                       CWW30160
C     TEMPERATURE    200-224                                            CWW30170
      EQUIVALENCE (W(200),TMODEL),(W(201),TFORM),(W(202),TID)           CWW30180
C                                                                       CWW30190
C     DELTA TEMPERATURE    225-249                                      CWW30200
      EQUIVALENCE (W(225),DTMODEL),(W(226),DTFORM),(W(227),DTID)        CWW30210
C                                                                       CWW30220
C     MOLECULAR   250-274                                               CWW30230
      EQUIVALENCE (W(250),MMODEL),(W(251),MFORM),(W(252),MID)           CWW30240
C                                                                       CWW30250
C     RECEIVER HEIGHT   275-299                                         CWW30260
      EQUIVALENCE (W(275),RMODEL),(W(276),RFORM),(W(277),RID)           CWW30270
C                                                                       CWW30280
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C     TOPOGRAPHY   300-324                                              CWW30290
      EQUIVALENCE (W(300),GMODEL),(W(301),GFORM),(W(302),GID)           CWW30300
C                                                                       CWW30310
C     DELTA TOPOGRAPHY   325-349                                        CWW30320
      EQUIVALENCE (W(325),GUMODEL),(W(326),GUFORM),(W(327),GUID)        CWW30330
C                                                                       CWW30340
C     ATMOSPHERIC SURFACE TOPOGRAPHY   350-374                          CWW30350
      EQUIVALENCE (W(350),SMODEL),(W(351),SFORM),(W(352),SID)           CWW30360
C                                                                       CWW30370
C     ATMOSPHERIC SURFACE TOPOGRAPHY   375-399                          CWW30380
      EQUIVALENCE (W(375),SUMODEL),(W(376),SUFORM),(W(377),SUID)        CWW30390
C     PLOT ENHANCEMENTS CONTROL PARAMETERS                              CWW30400
C                                                                       CWW30410
      EQUIVALENCE (W(490),XFQMDL),(W(491),YFQMDL)                       CWW30420
C     ABSORPTION          500-524                                       CWW30430
      EQUIVALENCE (W(500),AMODEL),(W(501),AFORM),(W(502),AID)           CWW30440
C                                                                       CWW30450
C     DELTA ABSORPTION          525-549                                 CWW30460
      EQUIVALENCE (W(525),DAMODEL),(W(526),DAFORM),(W(527),DAID)        CWW30470
C                                                                       CWW30480
C     PRESSURE          550-574                                         CWW30490
      EQUIVALENCE (W(550),PMODEL),(W(551),PFORM),(W(552),PID)           CWW30500
C                                                                       CWW30510
C     DELTA PRESSURE          575-599                                   CWW30520
      EQUIVALENCE (W(575),DPMODEL),(W(576),DPFORM),(W(577),DPID)        CWW30530
C                                                                       CWW30540
C     COMMON DECK "B3" INSERTED HERE                                    CB3 0020
      INTEGER CMX,CNTBL,CITBL,CFRMTBL,IDSC(10)                          CB3 0040
      COMMON/B3/CMX,CNTBL(10),CITBL(10),CFRMTBL(10),CGP(512)            CB3 0050
      EQUIVALENCE (CGP,IDSC),(ANC,CGP(11))                              CB3 0060
C                                                                       CTUE0130
      EQUIVALENCE (HPC,CGP(12)),(FN2C,CGP(262))                         CTUE0140
C                                                                       CTUE0150
      DATA RECOGC,NOC/8.0,0/                                            CTUE0160
      DATA ANC/0.0/                                                     CTUE0170
      DATA CMX/2/                                                       CTUE0180
      DATA CNTBL/1,11,512,7*0/                                          CTUE0190
      DATA CITBL/1,250,8*0/                                             CTUE0200
      DATA CFRMTBL/1,2,8*0/                                             CTUE0210
C                                                                       CTUE0220
      ENTRY ISPEED                                                      CTUE0230
C                                                                       CTUE0240
      CALL IPSPEED                                                      CTUE0250
C                                                                       CTUE0260
C     IF HAD PREVIOUS CALL BUT NOTHING THIS TIME, EXIT NOW              CTUE0270
C     RETAINING PREVIOUS TABULAR DATA COUNT                             CTUE0280
      IF(NOC.GT.0 .AND. ANC.LE.0.0) RETURN                              CTUE0290
C                                                                       CTUE0300
C         PRINT *,(CGP(I),I=11,30)                                      CTUE0310
      IF(RECOGC.NE.CMODEL)                                              CTUE0320
     1    CALL RERROR('SPEED  ','WRNG MODEL',RECOGC)                    CTUE0330
C                                                                       CTUE0340
        ANC=AINT(ANC)                                                   CTUE0350
      NOC=ANC/2                                                         CTUE0360
      IF(ANC.NE.2*NOC .OR. NOC.LE.1)                                    CTUE0370
```

```
    1     CALL RERROR('CTABLE','BAD NUMBER',ANC)
      ANC=0.0
C
      MODC(1)=6HCTABLE
      MODC(2)=CID
C
C           PRINT *,(HPC(I),I=1,10),(FN2C(I),I=1,10)
C
      SLOPE(1)=(FN2C(2)-FN2C(1))/(HPC(2)-HPC(1))
      SLOPE(NOC)=0.
      NMAX=1
      DO 6 I=2,NOC
      IF (FN2C(I).GT.FN2C(NMAX)) NMAX=I
      IF (I.EQ.NOC) GO TO 4
      DO 3 J=1,3
      M=I+J-2
      MAT(J,1)=1.
      MAT(J,2)=HPC(M)
      MAT(J,3)=HPC(M)**2
  3   MAT(J,4)=FN2C(M)
      CALL GAUSEL (MAT,4,3,4,NRANK)
      IF (NRANK.LT.3) GO TO 60
      SLOPE(I)=MAT(2,4)+2.*MAT(3,4)*HPC(I)
    4 DO 5 J=1,2
      M=I+J-2
      MAT(J,1)=1.
      MAT(J,2)=HPC(M)
      MAT(J,3)=HPC(M)**2
      MAT(J,4)=HPC(M)**3
      MAT(J,5)=FN2C(M)
      L=J+2
      MAT(L,1)=0.
      MAT(L,2)=1.
      MAT(L,3)=2.*HPC(M)
      MAT(L,4)=3.*HPC(M)**2
    5 MAT(L,5)=SLOPE(M)
      CALL GAUSEL (MAT,4,4,5,NRANK)
      IF (NRANK.LT.4) GO TO 60
      ALPHA(I)=MAT(1,5)
      TTBETA(I)=MAT(2,5)
      GAMM(I)=MAT(3,5)
    6 DELTA(I)=MAT(4,5)
C     HMAX=HPC(NMAX)
      NH=2
C
      RETURN
C
   60 PRINT 6000, I,HPC(I)
 6000 FORMAT(' THE',I4,'TH POINT IN THE TEMPERATURE PROFILE HAS'
     1,' THE HEIGHT',F8.2,' KM, WHICH IS THE SAME AS ANOTHER POINT.')
      CALL EXIT
C
      ENTRY SPEED
C
C          PRINT *,'ENTER CTABLE'
```

```
C                                                                       CTUE0930
      IF(NOC.LE.0)                                                      CTUE0940
     1    CALL RERROR('CTABLE','BAD N VALUE',FLOAT(NOC))                CTUE0950
C                                                                       CTUE0960
      H=R-EARTHR                                                        CTUE0970
      PCST=0.0                                                          CTUE0980
      PCSR=0.0                                                          CTUE0990
      PCSTH=0.0                                                         CTUE1000
      PCSPH=0.0                                                         CTUE1010
      IF (H.GE.HPC(1)) GO TO 12                                         CTUE1020
   11 NH=2                                                              CTUE1030
      T=FN2C(1)+SLOPE(1)*(H-HPC(1))                                     CTUE1040
        PCSR=2.*T*SLOPE(1)                                              CTUE1050
        CS=T*T                                                          CTUE1060
        CALL PSPEED                                                     CTUE1070
C         PRINT *,'LEAVE CTABLE1 ',R,C,PCSR                             CTUE1080
      RETURN                                                            CTUE1090
   12 IF (H.GE.HPC(NOC)) GO TO 18                                       CTUE1100
      NSTEP=1                                                           CTUE1110
      IF (H.LT.HPC(NH-1)) NSTEP=-1                                      CTUE1120
   15 IF (HPC(NH-1).LE.H.AND.H.LT.HPC(NH)) GO TO 16                     CTUE1130
      NH=NH+NSTEP                                                       CTUE1140
      GO TO 15                                                          CTUE1150
   16 T=(ALPHA(NH)+H*(TTBETA(NH)+H*(GAMM(NH)+H*DELTA(NH))))             CTUE1160
      PCSR=(TTBETA(NH)+H*(2.*GAMM(NH)+H*3.*DELTA(NH)))                  CTUE1170
C            PRINT *,NH,ALPHA(NH),TTBETA(NH),HPC(NH),FN2C(NH)           CTUE1180
         PCSR=2.*T*PCSR                                                 CTUE1190
         CS=T*T                                                         CTUE1200
         CALL PSPEED                                                    CTUE1210
C         PRINT *,'LEAVE CTABLE2 ',R,C,PCSR                             CTUE1220
      RETURN                                                            CTUE1230
   18 T=FN2C(NOC)                                                       CTUE1240
C                                                                       CTUE1250
      CALL PSPEED                                                       CTUE1260
         PCSR=2.*T*PCSR                                                 CTUE1270
         CS=T*T                                                         CTUE1280
C         PRINT *,'LEAVE CTABLE3 ',R,C,PCSR                             CTUE1290
      RETURN                                                            CTUE1300
         END                                                            CTUE1310
```

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      SUBROUTINE NPSPEED                                                NPPD0020
C     DO-NOTHING SOUND SPEED PERTURBATION MODEL                         NPPD0030
C     COMMON DECK "CC" INSERTED HERE                                    CCC 0020
      REAL MODC                                                         CCC 0040
      COMMON/CC/MODC(4),CS,PCST,PCSR,PCSTH,PCSPH                        CCC 0050
C     COMMON DECK "WW" INSERTED HERE                                    CWW 0020
      PARAMETER (NWARSZ=1000)                                           CWW10030
      COMMON/WW/ID(10),MAXW,W(NWARSZ)                                   CWW10040
      REAL MAXSTP,MAXERR,INTYP,LLAT,LLON                                CWW20020
      EQUIVALENCE (EARTHR,W(1)),(RAY,W(2)),(XMTRH,W(3)),(TLAT,W(4)),    CWW20030
     1 (TLON,W(5)),(OW,W(6)),(FBEG,W(7)),(FEND,W(8)),(FSTEP,W(9)),      CWW20040
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     2 (AZ1,W(10)),(AZBEG,W(11)),(AZEND,W(12)),(AZSTEP,W(13)),          CWW20050
     3 (BETA,W(14)),(ELBEG,W(15)),(ELEND,W(16)),(ELSTEP,W(17)),         CWW20060
     8   (RUNSUP,W(18)),(RCVRH,W(20)),                                  CWW20070
     4 (ONLY,W(21)),(HOP,W(22)),(MAXSTP,W(23)),(PLAT,W(24)),(PLON,W(25))CWW20080
     5,(HMAX,W(26)),(RAYFNC,W(29)),(EXTINC,W(33)),                      CWW20090
     6 (HMIN,W(27)),(RGMAX,W(28)),                                      CWW20100
     8 (INTYP,W(41)),(MAXERR,W(42)),(ERATIO,W(43)),                     CWW20110
     6 (STEP1,W(44)),(STPMAX,W(45)),(STPMIN,W(46)),(FACTR,W(47)),       CWW20120
     7 (SKIP,W(71)),(RAYSET,W(72)),(PRTSRP,W(74)),(HITLET,W(75))        CWW20130
     9 ,(BINRAY,W(76)),(PAGLN,W(77)),(PLT,W(81)),(PFACTR,W(82)),        CWW20140
     1 (LLAT,W(83)),(LLON,W(84)),(RLAT,W(85)),(RLON,W(86))              CWW20150
     2,(TIC,W(87)),(HB,W(88)),(HT,W(89)),(TICV,W(96))                   CWW20160
      REAL MMODEL,MFORM,MID                                             CWW30020
C                                                                       CWW30030
C     WIND          100-124                                             CWW30040
      EQUIVALENCE (W(100),UMODEL),(W(101),UFORM),(W(102),UID)           CWW30050
C                                                                       CWW30060
C     DELTA WIND          125-149                                       CWW30070
      EQUIVALENCE (W(125),DUMODEL),(W(126),DUFORM),(W(127),DUID)        CWW30080
C                                                                       CWW30090
C     SOUND SPEED 150-174                                               CWW30100
      EQUIVALENCE (W(150),CMODEL),(W(151),CFORM),(W(152),CID)           CWW30110
      EQUIVALENCE (W(153),REFC)                                         CWW30120
C                                                                       CWW30130
C     DELTA SOUND SPEED 175-199                                         CWW30140
      EQUIVALENCE (W(175),DCMODEL),(W(176),DCFORM),(W(177),DCID)        CWW30150
C                                                                       CWW30160
C     TEMPERATURE    200-224                                            CWW30170
      EQUIVALENCE (W(200),TMODEL),(W(201),TFORM),(W(202),TID)           CWW30180
C                                                                       CWW30190
C     DELTA TEMPERATURE    225-249                                      CWW30200
      EQUIVALENCE (W(225),DTMODEL),(W(226),DTFORM),(W(227),DTID)        CWW30210
C                                                                       CWW30220
C     MOLECULAR   250-274                                               CWW30230
      EQUIVALENCE (W(250),MMODEL),(W(251),MFORM),(W(252),MID)           CWW30240
C                                                                       CWW30250
C     RECEIVER HEIGHT   275-299                                         CWW30260
      EQUIVALENCE (W(275),RMODEL),(W(276),RFORM),(W(277),RID)           CWW30270
C                                                                       CWW30280
C     TOPOGRAPHY   300-324                                              CWW30290
      EQUIVALENCE (W(300),GMODEL),(W(301),GFORM),(W(302),GID)           CWW30300
C                                                                       CWW30310
C     DELTA TOPOGRAPHY   325-349                                        CWW30320
      EQUIVALENCE (W(325),GUMODEL),(W(326),GUFORM),(W(327),GUID)        CWW30330
C                                                                       CWW30340
C     ATMOSPHERIC SURFACE TOPOGRAPHY   350-374                          CWW30350
      EQUIVALENCE (W(350),SMODEL),(W(351),SFORM),(W(352),SID)           CWW30360
C                                                                       CWW30370
C     ATMOSPHERIC SURFACE TOPOGRAPHY   375-399                          CWW30380
      EQUIVALENCE (W(375),SUMODEL),(W(376),SUFORM),(W(377),SUID)        CWW30390
C     PLOT ENHANCEMENTS CONTROL PARAMETERS                              CWW30400
C                                                                       CWW30410
      EQUIVALENCE (W(490),XFQMDL),(W(491),YFQMDL)                       CWW30420
C     ABSORPTION          500-524                                       CWW30430
      EQUIVALENCE (W(500),AMODEL),(W(501),AFORM),(W(502),AID)           CWW30440
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C                                                                      CWW30450
C     DELTA ABSORPTION        525-549                                  CWW30460
      EQUIVALENCE (W(525),DAMODEL),(W(526),DAFORM),(W(527),DAID)       CWW30470
C                                                                      CWW30480
C     PRESSURE          550-574                                        CWW30490
      EQUIVALENCE (W(550),PMODEL),(W(551),PFORM),(W(552),PID)          CWW30500
C                                                                      CWW30510
C     DELTA PRESSURE          575-599                                  CWW30520
      EQUIVALENCE (W(575),DPMODEL),(W(576),DPFORM),(W(577),DPID)       CWW30530
C                                                                      CWW30540
C                                                                      NPPD0060
C     COMMON DECK "B2" INSERTED HERE                                   CB2 0020
      INTEGER DUMX,DUNTBL,DUITBL,DUFRMTB,IDSDU(10)                     CB2 0040
      COMMON/B2/DUMX,DUNTBL(10),DUITBL(10),DUFRMTB(10),DUGP(10)        CB2 0050
      EQUIVALENCE (DUGP,IDSDU)                                         CB2 0060
C                                                                      NPPD0080
      INTEGER DXMX    ,DXNTBL(10),DXITBL(10),DXFRMTB(10)               NPPD0090
C                                                                      NPPD0100
      DATA DXMX/1/                                                     NPPD0110
      DATA DXNTBL/1,11,8*0/                                            NPPD0120
      DATA DXITBL/1,9*0/                                               NPPD0130
      DATA DXFRMTB/1,9*0/                                              NPPD0140
C                                                                      NPPD0150
      DATA RECOGDC/0.0/                                                NPPD0160
C                                                                      NPPD0170
C                                                                      NPPD0180
      ENTRY SETPSP                                                     NPPD0190
C                                                                      NPPD0200
      DUMX=DXMX                                                        NPPD0210
      CALL IMOVE(DUNTBL,DXNTBL,10)                                     NPPD0220
      CALL IMOVE(DUITBL,DXITBL,10)                                     NPPD0230
      CALL IMOVE(DUFRMTB,DXFRMTB,10)                                   NPPD0240
C                                                                      NPPD0250
      RETURN                                                           NPPD0260
C                                                                      NPPD0270
      ENTRY IPSPEED                                                    NPPD0280
      IF(RECOGDC .NE. DCMODEL)                                         NPPD0290
     1    CALL RERROR('DSPEED ','WRNG MODEL',RECOGDC)                  NPPD0300
      MODC(3)=7HNPSPEED                                                NPPD0310
      MODC(4)=DCID                                                     NPPD0320
      RETURN                                                           NPPD0330
C                                                                      NPPD0340
      ENTRY PSPEED                                                     NPPD0350
      RETURN                                                           NPPD0360
      END                                                              NPPD0370



      SUBROUTINE CBLOB2                                                CBF20020
C     SOUND SPEED PERTURBATION MODEL                                   CBF20030
C     MULTIPLICATIVE PERTURBATION WITH EXPONENTIALLY DECAYING          CBF20040
C     EFFECT IN ALL THREE DIRECTIONS. GIVE LATITUDE                    CBF20050
C     INSTEAD OF CO-LATITUDE.                                          CBF20060
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C     COMMON DECK "CONST" INSERTED HERE                                 CCON0020
      COMMON/PCONST/CREF,RGAS,GAMMA                                     CCON0040
      COMMON/MCONST/PI,PIT2,PID2,DEGS,RAD,ALN10                         CCON0050
C     COMMON DECK "RKAM" INSERTED HERE                                  RKAM0020
      REAL KR,KTH,KPH                                                   RKAM0040
      COMMON//R,TH,PH,KR,KTH,KPH,RKVARS(14),TPULSE,CSTEP,DRDT(20)       RKAM0050
C     COMMON DECK "B4" INSERTED HERE                                    CB4 0020
      INTEGER DCMX,DCNTBL,DCITBL,DCFRMTB,IDSDC(10)                      CB4 0040
      COMMON/B4/DCMX,DCNTBL(10),DCITBL(10),DCFRMTB(10),DCGP(10)         CB4 0050
      EQUIVALENCE (DCGP,IDSDC)                                          CB4 0060
C                                                                       CBF20100
C     COMMON DECK "CC" INSERTED HERE                                    CCC 0020
      REAL MODC                                                         CCC 0040
      COMMON/CC/MODC(4),CS,PCST,PCSR,PCSTH,PCSPH                        CCC 0050
C     COMMON DECK "WW" INSERTED HERE                                    CWW 0020
      PARAMETER (NWARSZ=1000)                                           CWW10030
      COMMON/WW/ID(10),MAXW,W(NWARSZ)                                   CWW10040
      REAL MAXSTP,MAXERR,INTYP,LLAT,LLON                                CWW20020
      EQUIVALENCE (EARTHR,W(1)),(RAY,W(2)),(XMTRH,W(3)),(TLAT,W(4)),    CWW20030
     1 (TLON,W(5)),(OW,W(6)),(FBEG,W(7)),(FEND,W(8)),(FSTEP,W(9)),      CWW20040
     2 (AZ1,W(10)),(AZBEG,W(11)),(AZEND,W(12)),(AZSTEP,W(13)),          CWW20050
     3 (BETA,W(14)),(ELBEG,W(15)),(ELEND,W(16)),(ELSTEP,W(17)),         CWW20060
     8   (RUNSUP,W(18)),(RCVRH,W(20)),                                  CWW20070
     4 (ONLY,W(21)),(HOP,W(22)),(MAXSTP,W(23)),(PLAT,W(24)),(PLON,W(25))CWW20080
     5,(HMAX,W(26)),(RAYFNC,W(29)),(EXTINC,W(33)),                      CWW20090
     6 (HMIN,W(27)),(RGMAX,W(28)),                                      CWW20100
     8 (INTYP,W(41)),(MAXERR,W(42)),(ERATIO,W(43)),                     CWW20110
     6 (STEP1,W(44)),(STPMAX,W(45)),(STPMIN,W(46)),(FACTR,W(47)),       CWW20120
     7 (SKIP,W(71)),(RAYSET,W(72)),(PRTSRP,W(74)),(HITLET,W(75))        CWW20130
     9 ,(BINRAY,W(76)),(PAGLN,W(77)),(PLT,W(81)),(PFACTR,W(82)),        CWW20140
     1 (LLAT,W(83)),(LLON,W(84)),(RLAT,W(85)),(RLON,W(86))              CWW20150
     2,(TIC,W(87)),(HB,W(88)),(HT,W(89)),(TICV,W(96))                   CWW20160
      REAL MMODEL,MFORM,MID                                             CWW30020
C                                                                       CWW30030
C     WIND          100-124                                             CWW30040
      EQUIVALENCE (W(100),UMODEL),(W(101),UFORM),(W(102),UID)           CWW30050
C                                                                       CWW30060
C     DELTA WIND          125-149                                       CWW30070
      EQUIVALENCE (W(125),DUMODEL),(W(126),DUFORM),(W(127),DUID)        CWW30080
C                                                                       CWW30090
C     SOUND SPEED 150-174                                               CWW30100
      EQUIVALENCE (W(150),CMODEL),(W(151),CFORM),(W(152),CID)           CWW30110
      EQUIVALENCE (W(153),REFC)                                         CWW30120
C                                                                       CWW30130
C     DELTA SOUND SPEED 175-199                                         CWW30140
      EQUIVALENCE (W(175),DCMODEL),(W(176),DCFORM),(W(177),DCID)        CWW30150
C                                                                       CWW30160
C     TEMPERATURE    200-224                                            CWW30170
      EQUIVALENCE (W(200),TMODEL),(W(201),TFORM),(W(202),TID)           CWW30180
C                                                                       CWW30190
C     DELTA TEMPERATURE    225-249                                      CWW30200
      EQUIVALENCE (W(225),DTMODEL),(W(226),DTFORM),(W(227),DTID)        CWW30210
C                                                                       CWW30220
C     MOLECULAR   250-274                                               CWW30230
      EQUIVALENCE (W(250),MMODEL),(W(251),MFORM),(W(252),MID)           CWW30240
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C
C     RECEIVER HEIGHT   275-299
      EQUIVALENCE (W(275),RMODEL),(W(276),RFORM),(W(277),RID)
C
C     TOPOGRAPHY   300-324
      EQUIVALENCE (W(300),GMODEL),(W(301),GFORM),(W(302),GID)
C
C     DELTA TOPOGRAPHY   325-349
      EQUIVALENCE (W(325),GUMODEL),(W(326),GUFORM),(W(327),GUID)
C
C     ATMOSPHERIC SURFACE TOPOGRAPHY   350-374
      EQUIVALENCE (W(350),SMODEL),(W(351),SFORM),(W(352),SID)
C
C     ATMOSPHERIC SURFACE TOPOGRAPHY   375-399
      EQUIVALENCE (W(375),SUMODEL),(W(376),SUFORM),(W(377),SUID)
C     PLOT ENHANCEMENTS CONTROL PARAMETERS
C
      EQUIVALENCE (W(490),XFQMDL),(W(491),YFQMDL)
C     ABSORPTION          500-524
      EQUIVALENCE (W(500),AMODEL),(W(501),AFORM),(W(502),AID)
C
C     DELTA ABSORPTION            525-549
      EQUIVALENCE (W(525),DAMODEL),(W(526),DAFORM),(W(527),DAID)
C
C     PRESSURE          550-574
      EQUIVALENCE (W(550),PMODEL),(W(551),PFORM),(W(552),PID)
C
C     DELTA PRESSURE           575-599
      EQUIVALENCE (W(575),DPMODEL),(W(576),DPFORM),(W(577),DPID)
C
C
      EQUIVALENCE (C0,W(178)), (Z0,W(179)),(CBTH0,W(180))
      EQUIVALENCE (PH0,W(181)),(WZ,W(182)),(WTH,W(183)),(WPH,W(184))
      INTEGER DFMX     ,DFNTBL(10),DFITBL(10),DFFRMTB(10)
      DATA RECOGDC/2.0/
C
      DATA DFMX/1/
      DATA DFNTBL/1,11,8*0/
      DATA DFITBL/1,9*0/
      DATA DFFRMTB/1,9*0/
C
C
      ENTRY SETPSP
C
      DCMX=DFMX
      CALL IMOVE(DCNTBL,DFNTBL,10)
      CALL IMOVE(DCITBL,DFITBL,10)
      CALL IMOVE(DCFRMTB,DFFRMTB,10)
C
      RETURN
C
      ENTRY IPSPEED
      IF(RECOGDC .NE. DCMODEL)
     1    CALL RERROR('DSPEED ','WRNG MODEL',RECOGDC)
C
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      MODC(3)=6HCBLOB2                                                  CBF20380
      MODC(4)=DCID                                                      CBF20390
C                                                                       CBF20400
      FWZ=0.0                                                           CBF20410
      FWTH=0.0                                                          CBF20420
      FWPH=0.0                                                          CBF20430
      THO= PID2-CBTHO                                                   CBF20440
      IF(WZ.NE.0.0) FWZ=2.0/WZ/WZ                                       CBF20450
      IF(WTH.NE.0.0) FWTH=2.0/WTH/WTH                                   CBF20460
      IF(WPH.NE.0.0) FWPH=2.0/WPH/WPH                                   CBF20470
      RETURN                                                            CBF20480
C                                                                       CBF20490
      ENTRY PSPEED                                                      CBF20500
C                                                                       CBF20510
      IF(C0.EQ.0.0) RETURN                                              CBF20520
C                                                                       CBF20530
      DZ=R-EARTHR-Z0                                                    CBF20540
      DTH=TH-THO                                                        CBF20550
      DPH=PH-PHO                                                        CBF20560
      DEXPO=0.0                                                         CBF20570
      EXPO=-0.5*(DZ*DZ*FWZ+DTH*DTH*FWTH+DPH*DPH*FWPH)                   CBF20580
      IF(EXPO .GT. -200.0) DEXPO=C0*EXP(EXPO)                           CBF20590
      DEL=1.0+DEXPO                                                     CBF20600
C                                                                       CBF20610
      PCSR=PCSR*DEL-CS*DEXPO*FWZ*DZ                                     CBF20620
      PCSTH=PCSTH*DEL-CS*DEXPO*FWTH*DTH                                 CBF20630
      PCSPH=PCSPH*DEL-CS*DEXPO*FWPH*DPH                                 CBF20640
      CS=CS*DEL                                                         CBF20650
      RETURN                                                            CBF20660
      END                                                               CBF20670
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      SUBROUTINE CBLOB3                                                 CBF30020
C     SOUND SPEED PERTURBATION MODEL WITH MULTIPLE BLOBS EACH A         CBF30030
C     MULTIPLICATIVE PERTURBATION WITH EXPONENTIALLY DECAYING           CBF30040
C     EFFECT IN ALL THREE DIRECTIONS. THE FORM OF THE                   CBF30050
C     PERTURBATION IS:                                                  CBF30060
C                                                                       CBF30070
C     C = C(1+DEL)                                                      CBF30080
C     WHERE     DEL = SUM(DELSI)    AND I=1,2,3 FOR EACH BLOB.          CBF30090
C                                                                       CBF30100
C     GIVE LATITUDE INSTEAD OF CO-LATITUDE.                             CBF30110
C                                                                       CBF30120
C     COMMON DECK "CONST" INSERTED HERE                                 CCON0020
      COMMON/PCONST/CREF,RGAS,GAMMA                                     CCON0040
      COMMON/MCONST/PI,PIT2,PID2,DEGS,RAD,ALN10                         CCON0050
C     COMMON DECK "RKAM" INSERTED HERE                                  RKAM0020
      REAL KR,KTH,KPH                                                   RKAM0040
      COMMON//R,TH,PH,KR,KTH,KPH,RKVARS(14),TPULSE,CSTEP,DRDT(20)       RKAM0050
C     COMMON DECK "B4" INSERTED HERE                                    CB4 0020
      INTEGER DCMX,DCNTBL,DCITBL,DCFRMTB,IDSDC(10)                      CB4 0040
      COMMON/B4/DCMX,DCNTBL(10),DCITBL(10),DCFRMTB(10),DCGP(10)         CB4 0050
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      EQUIVALENCE (DCGP,IDSDC)                                          CB4 0060
C                                                                       CBF30160
C     COMMON DECK "CC" INSERTED HERE                                    CCC 0020
      REAL MODC                                                         CCC 0040
      COMMON/CC/MODC(4),CS,PCST,PCSR,PCSTH,PCSPH                        CCC 0050
C     COMMON DECK "WW" INSERTED HERE                                    CWW 0020
      PARAMETER (NWARSZ=1000)                                           CWW10030
      COMMON/WW/ID(10),MAXW,W(NWARSZ)                                   CWW10040
      REAL MAXSTP,MAXERR,INTYP,LLAT,LLON                                CWW20020
      EQUIVALENCE (EARTHR,W(1)),(RAY,W(2)),(XMTRH,W(3)),(TLAT,W(4)),    CWW20030
     1 (TLON,W(5)),(OW,W(6)),(FBEG,W(7)),(FEND,W(8)),(FSTEP,W(9)),      CWW20040
     2 (AZ1,W(10)),(AZBEG,W(11)),(AZEND,W(12)),(AZSTEP,W(13)),          CWW20050
     3 (BETA,W(14)),(ELBEG,W(15)),(ELEND,W(16)),(ELSTEP,W(17)),         CWW20060
     8   (RUNSUP,W(18)),(RCVRH,W(20)),                                  CWW20070
     4 (ONLY,W(21)),(HOP,W(22)),(MAXSTP,W(23)),(PLAT,W(24)),(PLON,W(25))CWW20080
     5,(HMAX,W(26)),(RAYFNC,W(29)),(EXTINC,W(33)),                      CWW20090
     6 (HMIN,W(27)),(RGMAX,W(28)),                                      CWW20100
     8 (INTYP,W(41)),(MAXERR,W(42)),(ERATIO,W(43)),                     CWW20110
     6 (STEP1,W(44)),(STPMAX,W(45)),(STPMIN,W(46)),(FACTR,W(47)),       CWW20120
     7 (SKIP,W(71)),(RAYSET,W(72)),(PRTSRP,W(74)),(HITLET,W(75))        CWW20130
     9 ,(BINRAY,W(76)),(PAGLN,W(77)),(PLT,W(81)),(PFACTR,W(82)),        CWW20140
     1 (LLAT,W(83)),(LLON,W(84)),(RLAT,W(85)),(RLON,W(86))              CWW20150
     2,(TIC,W(87)),(HB,W(88)),(HT,W(89)),(TICV,W(96))                   CWW20160
      REAL MMODEL,MFORM,MID                                             CWW30020
C                                                                       CWW30030
C     WIND        100-124                                               CWW30040
      EQUIVALENCE (W(100),UMODEL),(W(101),UFORM),(W(102),UID)           CWW30050
C                                                                       CWW30060
C     DELTA WIND        125-149                                         CWW30070
      EQUIVALENCE (W(125),DUMODEL),(W(126),DUFORM),(W(127),DUID)        CWW30080
C                                                                       CWW30090
C     SOUND SPEED 150-174                                               CWW30100
      EQUIVALENCE (W(150),CMODEL),(W(151),CFORM),(W(152),CID)           CWW30110
      EQUIVALENCE (W(153),REFC)                                         CWW30120
C                                                                       CWW30130
C     DELTA SOUND SPEED 175-199                                         CWW30140
      EQUIVALENCE (W(175),DCMODEL),(W(176),DCFORM),(W(177),DCID)        CWW30150
C                                                                       CWW30160
C     TEMPERATURE    200-224                                            CWW30170
      EQUIVALENCE (W(200),TMODEL),(W(201),TFORM),(W(202),TID)           CWW30180
C                                                                       CWW30190
C     DELTA TEMPERATURE    225-249                                      CWW30200
      EQUIVALENCE (W(225),DTMODEL),(W(226),DTFORM),(W(227),DTID)        CWW30210
C                                                                       CWW30220
C     MOLECULAR    250-274                                              CWW30230
      EQUIVALENCE (W(250),MMODEL),(W(251),MFORM),(W(252),MID)           CWW30240
C                                                                       CWW30250
C     RECEIVER HEIGHT   275-299                                         CWW30260
      EQUIVALENCE (W(275),RMODEL),(W(276),RFORM),(W(277),RID)           CWW30270
C                                                                       CWW30280
C     TOPOGRAPHY   300-324                                              CWW30290
      EQUIVALENCE (W(300),GMODEL),(W(301),GFORM),(W(302),GID)           CWW30300
C                                                                       CWW30310
C     DELTA TOPOGRAPHY   325-349                                        CWW30320
      EQUIVALENCE (W(325),GUMODEL),(W(326),GUFORM),(W(327),GUID)        CWW30330
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C                                                                       CWW30340
C     ATMOSPHERIC SURFACE TOPOGRAPHY   350-374                          CWW30350
      EQUIVALENCE (W(350),SMODEL),(W(351),SFORM),(W(352),SID)           CWW30360
C                                                                       CWW30370
C     ATMOSPHERIC SURFACE TOPOGRAPHY   375-399                          CWW30380
      EQUIVALENCE (W(375),SUMODEL),(W(376),SUFORM),(W(377),SUID)        CWW30390
C     PLOT ENHANCEMENTS CONTROL PARAMETERS                              CWW30400
C                                                                       CWW30410
      EQUIVALENCE (W(490),XFQMDL),(W(491),YFQMDL)                       CWW30420
C     ABSORPTION          500-524                                       CWW30430
      EQUIVALENCE (W(500),AMODEL),(W(501),AFORM),(W(502),AID)           CWW30440
C                                                                       CWW30450
C     DELTA ABSORPTION          525-549                                 CWW30460
      EQUIVALENCE (W(525),DAMODEL),(W(526),DAFORM),(W(527),DAID)        CWW30470
C                                                                       CWW30480
C     PRESSURE         550-574                                          CWW30490
      EQUIVALENCE (W(550),PMODEL),(W(551),PFORM),(W(552),PID)           CWW30500
C                                                                       CWW30510
C     DELTA PRESSURE         575-599                                    CWW30520
      EQUIVALENCE (W(575),DPMODEL),(W(576),DPFORM),(W(577),DPID)        CWW30530
C                                                                       CWW30540
C                                                                       CBF30190
      REAL C0(3),Z0(3),CBTH0(3),TH0(3),PH0(3)                           CBF30200
      REAL WZ(3),WTH(3),WPH(3)                                          CBF30210
      REAL FWZ(3),FWTH(3),FWPH(3)                                       CBF30220
C                                                                       CBF30230
      EQUIVALENCE (PN,W(178)),(C0,W(179)), (Z0,W(182)),(CBTH0,W(185))   CBF30240
      EQUIVALENCE (PH0,W(188)),(WZ,W(191)),(WTH,W(194)),(WPH,W(197))    CBF30250
      INTEGER DFMX     ,DFNTBL(10),DFITBL(10),DFFRMTB(10)               CBF30260
      DATA RECOGDC/3.0/                                                 CBF30270
C                                                                       CBF30280
      DATA DFMX/1/                                                      CBF30290
      DATA DFNTBL/1,11,8*0/                                             CBF30300
      DATA DFITBL/1,9*0/                                                CBF30310
      DATA DFFRMTB/1,9*0/                                               CBF30320
C                                                                       CBF30330
C                                                                       CBF30340
      ENTRY SETPSP                                                      CBF30350
C                                                                       CBF30360
      DCMX=DFMX                                                         CBF30370
      CALL IMOVE(DCNTBL,DFNTBL,10)                                      CBF30380
      CALL IMOVE(DCITBL,DFITBL,10)                                      CBF30390
      CALL IMOVE(DCFRMTB,DFFRMTB,10)                                    CBF30400
C                                                                       CBF30410
      RETURN                                                            CBF30420
C                                                                       CBF30430
      ENTRY IPSPEED                                                     CBF30440
      IF(RECOGDC .NE. DCMODEL)                                          CBF30450
     1    CALL RERROR('DSPEED ','WRNG MODEL',RECOGDC)                   CBF30460
C                                                                       CBF30470
      MODC(3)=6HCBLOB3                                                  CBF30480
      MODC(4)=DCID                                                      CBF30490
C                                                                       CBF30500
      NP=PN                                                             CBF30510
      DO 10 I=1,NP                                                      CBF30520
```

```
      FWZ(I)=0.0
      FWTH(I)=0.0
      FWPH(I)=0.0
      THO(I)= PID2-CBTHO(I)
      IF(WZ(I).NE.0.0) FWZ(I)=2.0/WZ(I)/WZ(I)
      IF(WTH(I).NE.0.0) FWTH(I)=2.0/WTH(I)/WTH(I)
      IF(WPH(I).NE.0.0) FWPH(I)=2.0/WPH(I)/WPH(I)
10    CONTINUE
      RETURN
C
      ENTRY PSPEED
C
      DEL=1.0
C     INITIALIZE PARTIALS OF DEL
      PDELR=0.0
      PDELTH=0.0
      PDELPH=0.0
C
      DO 20 I=1,NP
      DZ=R-EARTHR-Z0(I)
      DTH=TH-THO(I)
      DPH=PH-PHO(I)
      DEXPO=0.0
      EXPO=-0.5*(DZ*DZ*FWZ(I)+DTH*DTH*FWTH(I)+DPH*DPH*FWPH(I))
      IF(EXPO .GT. -200.0) DEXPO=C0(I)*EXP(EXPO)
C
      DEL=DEL+DEXPO
      PDELR=PDELR-DEXPO*FWZ(I)*DZ
      PDELTH=PDELTH-DEXPO*FWTH(I)*DTH
20    PDELPH=PDELPH-DEXPO*FWPH(I)*DPH
C
C     IN THIS MODEL WE ARE USING THE SQUARE OF DEL
C     AS THE CS PERTURBATION
C
      FTR=CS*2.0*DEL
      DEL=DEL*DEL
C
      CS=CS*DEL
      PCSR=PCSR*DEL+FTR*PDELR
      PCSTH=PCSTH*DEL+FTR*PDELTH
      PCSPH=PCSPH*DEL+FTR*PDELPH
      RETURN
      END
```

```
      SUBROUTINE CBLOB4
C     SOUND SPEED PERTURBATION MODEL WITH MULTIPLE BLOBS EACH A
C     MULTIPLICATIVE PERTURBATION WITH EXPONENTIALLY DECAYING
C     EFFECT IN ALL THREE DIRECTIONS. THE FORM OF THE
C     PERTURBATION IS:
C
C     CS = CS(1+DEL)
```

```
C     WHERE     DEL = SUM(DELSI)   AND I=1,2,3 FOR EACH BLOB.            CBF40090
C                                                                        CBF40100
C     GIVE LATITUDE INSTEAD OF CO-LATITUDE.                              CBF40110
C                                                                        CBF40120
C     COMMON DECK "CONST" INSERTED HERE                                  CCON0020
      COMMON/PCONST/CREF,RGAS,GAMMA                                      CCON0040
      COMMON/MCONST/PI,PIT2,PID2,DEGS,RAD,ALN10                          CCON0050
C     COMMON DECK "RKAM" INSERTED HERE                                   RKAM0020
      REAL KR,KTH,KPH                                                    RKAM0040
      COMMON//R,TH,PH,KR,KTH,KPH,RKVARS(14),TPULSE,CSTEP,DRDT(20)        RKAM0050
C     COMMON DECK "B4" INSERTED HERE                                     CB4 0020
      INTEGER DCMX,DCNTBL,DCITBL,DCFRMTB,IDSDC(10)                       CB4 0040
      COMMON/B4/DCMX,DCNTBL(10),DCITBL(10),DCFRMTB(10),DCGP(10)          CB4 0050
      EQUIVALENCE (DCGP,IDSDC)                                           CB4 0060
C                                                                        CBF40160
C     COMMON DECK "CC" INSERTED HERE                                     CCC 0020
      REAL MODC                                                          CCC 0040
      COMMON/CC/MODC(4),CS,PCST,PCSR,PCSTH,PCSPH                         CCC 0050
C     COMMON DECK "WW" INSERTED HERE                                     CWW 0020
      PARAMETER (NWARSZ=1000)                                            CWW10030
      COMMON/WW/ID(10),MAXW,W(NWARSZ)                                    CWW10040
      REAL MAXSTP,MAXERR,INTYP,LLAT,LLON                                 CWW20020
      EQUIVALENCE (EARTHR,W(1)),(RAY,W(2)),(XMTRH,W(3)),(TLAT,W(4)),     CWW20030
     1 (TLON,W(5)),(OW,W(6)),(FBEG,W(7)),(FEND,W(8)),(FSTEP,W(9)),       CWW20040
     2 (AZ1,W(10)),(AZBEG,W(11)),(AZEND,W(12)),(AZSTEP,W(13)),           CWW20050
     3 (BETA,W(14)),(ELBEG,W(15)),(ELEND,W(16)),(ELSTEP,W(17)),          CWW20060
     8   (RUNSUP,W(18)),(RCVRH,W(20)),                                   CWW20070
     4 (ONLY,W(21)),(HOP,W(22)),(MAXSTP,W(23)),(PLAT,W(24)),(PLON,W(25))CWW20080
     5,(HMAX,W(26)),(RAYFNC,W(29)),(EXTINC,W(33)),                       CWW20090
     6 (HMIN,W(27)),(RGMAX,W(28)),                                       CWW20100
     8 (INTYP,W(41)),(MAXERR,W(42)),(ERATIO,W(43)),                      CWW20110
     6 (STEP1,W(44)),(STPMAX,W(45)),(STPMIN,W(46)),(FACTR,W(47)),        CWW20120
     7 (SKIP,W(71)),(RAYSET,W(72)),(PRTSRP,W(74)),(HITLET,W(75))         CWW20130
     9 ,(BINRAY,W(76)),(PAGLN,W(77)),(PLT,W(81)),(PFACTR,W(82)),         CWW20140
     1 (LLAT,W(83)),(LLON,W(84)),(RLAT,W(85)),(RLON,W(86))               CWW20150
     2,(TIC,W(87)),(HB,W(88)),(HT,W(89)),(TICV,W(96))                    CWW20160
      REAL MMODEL,MFORM,MID                                              CWW30020
C                                                                        CWW30030
C     WIND          100-124                                              CWW30040
      EQUIVALENCE (W(100),UMODEL),(W(101),UFORM),(W(102),UID)            CWW30050
C                                                                        CWW30060
C     DELTA WIND          125-149                                        CWW30070
      EQUIVALENCE (W(125),DUMODEL),(W(126),DUFORM),(W(127),DUID)         CWW30080
C                                                                        CWW30090
C     SOUND SPEED 150-174                                                CWW30100
      EQUIVALENCE (W(150),CMODEL),(W(151),CFORM),(W(152),CID)            CWW30110
      EQUIVALENCE (W(153),REFC)                                          CWW30120
C                                                                        CWW30130
C     DELTA SOUND SPEED 175-199                                          CWW30140
      EQUIVALENCE (W(175),DCMODEL),(W(176),DCFORM),(W(177),DCID)         CWW30150
C                                                                        CWW30160
C     TEMPERATURE    200-224                                             CWW30170
      EQUIVALENCE (W(200),TMODEL),(W(201),TFORM),(W(202),TID)            CWW30180
C                                                                        CWW30190
C     DELTA TEMPERATURE    225-249                                       CWW30200
```

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      EQUIVALENCE (W(225),DTMODEL),(W(226),DTFORM),(W(227),DTID)         CWW30210
C                                                                        CWW30220
C     MOLECULAR   250-274                                                CWW30230
      EQUIVALENCE (W(250),MMODEL),(W(251),MFORM),(W(252),MID)            CWW30240
C                                                                        CWW30250
C     RECEIVER HEIGHT   275-299                                          CWW30260
      EQUIVALENCE (W(275),RMODEL),(W(276),RFORM),(W(277),RID)            CWW30270
C                                                                        CWW30280
C     TOPOGRAPHY   300-324                                               CWW30290
      EQUIVALENCE (W(300),GMODEL),(W(301),GFORM),(W(302),GID)            CWW30300
C                                                                        CWW30310
C     DELTA TOPOGRAPHY   325-349                                         CWW30320
      EQUIVALENCE (W(325),GUMODEL),(W(326),GUFORM),(W(327),GUID)         CWW30330
C                                                                        CWW30340
C     ATMOSPHERIC SURFACE TOPOGRAPHY   350-374                           CWW30350
      EQUIVALENCE (W(350),SMODEL),(W(351),SFORM),(W(352),SID)            CWW30360
C                                                                        CWW30370
C     ATMOSPHERIC SURFACE TOPOGRAPHY   375-399                           CWW30380
      EQUIVALENCE (W(375),SUMODEL),(W(376),SUFORM),(W(377),SUID)         CWW30390
C     PLOT ENHANCEMENTS CONTROL PARAMETERS                               CWW30400
C                                                                        CWW30410
      EQUIVALENCE (W(490),XFQMDL),(W(491),YFQMDL)                        CWW30420
C     ABSORPTION          500-524                                        CWW30430
      EQUIVALENCE (W(500),AMODEL),(W(501),AFORM),(W(502),AID)            CWW30440
C                                                                        CWW30450
C     DELTA ABSORPTION          525-549                                  CWW30460
      EQUIVALENCE (W(525),DAMODEL),(W(526),DAFORM),(W(527),DAID)         CWW30470
C                                                                        CWW30480
C     PRESSURE          550-574                                          CWW30490
      EQUIVALENCE (W(550),PMODEL),(W(551),PFORM),(W(552),PID)            CWW30500
C                                                                        CWW30510
C     DELTA PRESSURE          575-599                                    CWW30520
      EQUIVALENCE (W(575),DPMODEL),(W(576),DPFORM),(W(577),DPID)         CWW30530
C                                                                        CWW30540
C                                                                        CBF40190
      REAL C0(3),Z0(3),CBTH0(3),TH0(3),PH0(3)                            CBF40200
      REAL WZ(3),WTH(3),WPH(3)                                           CBF40210
      REAL FWZ(3),FWTH(3),FWPH(3)                                        CBF40220
C                                                                        CBF40230
      EQUIVALENCE (PN,W(178)),(C0,W(179)), (Z0,W(182)),(CBTH0,W(185))    CBF40240
      EQUIVALENCE (PH0,W(188)),(WZ,W(191)),(WTH,W(194)),(WPH,W(197))     CBF40250
      INTEGER DFMX    ,DFNTBL(10),DFITBL(10),DFFRMTB(10)                 CBF40260
      DATA RECOGDC/4.0/                                                  CBF40270
C                                                                        CBF40280
      DATA DFMX/1/                                                       CBF40290
      DATA DFNTBL/1,11,8*0/                                              CBF40300
      DATA DFITBL/1,9*0/                                                 CBF40310
      DATA DFFRMTB/1,9*0/                                                CBF40320
C                                                                        CBF40330
C                                                                        CBF40340
      ENTRY SETPSP                                                       CBF40350
C                                                                        CBF40360
      DCMX=DFMX                                                          CBF40370
      CALL IMOVE(DCNTBL,DFNTBL,10)                                       CBF40380
      CALL IMOVE(DCITBL,DFITBL,10)                                       CBF40390
```

```
      CALL IMOVE(DCFRMTB,DFFRMTB,10)
C
      RETURN
C
      ENTRY IPSPEED
      IF(RECOGDC .NE. DCMODEL)
     1    CALL RERROR('DSPEED ','WRNG MODEL',RECOGDC)
C
      MODC(3)=6HCBLOB4
      MODC(4)=DCID
C
      NP=PN
      DO 10 I=1,NP
      FWZ(I)=0.0
      FWTH(I)=0.0
      FWPH(I)=0.0
      THO(I)= PID2-CBTH0(I)
      IF(WZ(I).NE.0.0) FWZ(I)=2.0/WZ(I)/WZ(I)
      IF(WTH(I).NE.0.0) FWTH(I)=2.0/WTH(I)/WTH(I)
      IF(WPH(I).NE.0.0) FWPH(I)=2.0/WPH(I)/WPH(I)
10    CONTINUE
      RETURN
C
      ENTRY PSPEED
C
      DEL=1.0
C     INITIALIZE PARTIALS OF DEL
      PDELR=0.0
      PDELTH=0.0
      PDELPH=0.0
C
      DO 20 I=1,NP
      DZ=R-EARTHR-Z0(I)
      DTH=TH-TH0(I)
      DPH=PH-PH0(I)
      DEXPO=0.0
      EXPO=-0.5*(DZ*DZ*FWZ(I)+DTH*DTH*FWTH(I)+DPH*DPH*FWPH(I))
      IF(EXPO .GT. -200.0) DEXPO=C0(I)*EXP(EXPO)
C
      DEL=DEL+DEXPO
      PDELR=PDELR-DEXPO*FWZ(I)*DZ
      PDELTH=PDELTH-DEXPO*FWTH(I)*DTH
20    PDELPH=PDELPH-DEXPO*FWPH(I)*DPH
C
      FTR=CS
C
      CS=CS*DEL
      PCSR=PCSR*DEL+FTR*PDELR
      PCSTH=PCSTH*DEL+FTR*PDELTH
      PCSPH=PCSPH*DEL+FTR*PDELPH
      RETURN
      END
```

```
      SUBROUTINE SLLOSS
C     SLLOSS BACKGROUND ABSORPTION FORMULA                              SLLS0020
C                                                                       SLLS0030
C     COMMON DECK "WW" INSERTED HERE                                    SLLS0040
      PARAMETER (NWARSZ=1000)                                           CWW 0020
      COMMON/WW/ID(10),MAXW,W(NWARSZ)                                   CWW10030
      REAL MAXSTP,MAXERR,INTYP,LLAT,LLON                                CWW10040
      EQUIVALENCE (EARTHR,W(1)),(RAY,W(2)),(XMTRH,W(3)),(TLAT,W(4)),    CWW20020
     1 (TLON,W(5)),(OW,W(6)),(FBEG,W(7)),(FEND,W(8)),(FSTEP,W(9)),      CWW20030
     2 (AZ1,W(10)),(AZBEG,W(11)),(AZEND,W(12)),(AZSTEP,W(13)),          CWW20040
     3 (BETA,W(14)),(ELBEG,W(15)),(ELEND,W(16)),(ELSTEP,W(17)),         CWW20050
     8    (RUNSUP,W(18)),(RCVRH,W(20)),                                 CWW20060
     4 (ONLY,W(21)),(HOP,W(22)),(MAXSTP,W(23)),(PLAT,W(24)),(PLON,W(25))CWW20070
     5,(HMAX,W(26)),(RAYFNC,W(29)),(EXTINC,W(33)),                      CWW20080
     6 (HMIN,W(27)),(RGMAX,W(28)),                                      CWW20090
     8 (INTYP,W(41)),(MAXERR,W(42)),(ERATIO,W(43)),                     CWW20100
     6 (STEP1,W(44)),(STPMAX,W(45)),(STPMIN,W(46)),(FACTR,W(47)),       CWW20110
     7 (SKIP,W(71)),(RAYSET,W(72)),(PRTSRP,W(74)),(HITLET,W(75))        CWW20120
     9 ,(BINRAY,W(76)),(PAGLN,W(77)),(PLT,W(81)),(PFACTR,W(82)),        CWW20130
     1 (LLAT,W(83)),(LLON,W(84)),(RLAT,W(85)),(RLON,W(86))              CWW20140
     2,(TIC,W(87)),(HB,W(88)),(HT,W(89)),(TICV,W(96))                   CWW20150
      REAL MMODEL,MFORM,MID                                             CWW20160
C                                                                       CWW30020
C     WIND        100-124                                               CWW30030
      EQUIVALENCE (W(100),UMODEL),(W(101),UFORM),(W(102),UID)           CWW30040
C                                                                       CWW30050
C     DELTA WIND         125-149                                        CWW30060
      EQUIVALENCE (W(125),DUMODEL),(W(126),DUFORM),(W(127),DUID)        CWW30070
C                                                                       CWW30080
C     SOUND SPEED 150-174                                               CWW30090
      EQUIVALENCE (W(150),CMODEL),(W(151),CFORM),(W(152),CID)           CWW30100
      EQUIVALENCE (W(153),REFC)                                         CWW30110
C                                                                       CWW30120
C     DELTA SOUND SPEED 175-199                                         CWW30130
      EQUIVALENCE (W(175),DCMODEL),(W(176),DCFORM),(W(177),DCID)        CWW30140
C                                                                       CWW30150
C     TEMPERATURE    200-224                                            CWW30160
      EQUIVALENCE (W(200),TMODEL),(W(201),TFORM),(W(202),TID)           CWW30170
C                                                                       CWW30180
C     DELTA TEMPERATURE    225-249                                      CWW30190
      EQUIVALENCE (W(225),DTMODEL),(W(226),DTFORM),(W(227),DTID)        CWW30200
C                                                                       CWW30210
C     MOLECULAR   250-274                                               CWW30220
      EQUIVALENCE (W(250),MMODEL),(W(251),MFORM),(W(252),MID)           CWW30230
C                                                                       CWW30240
C     RECEIVER HEIGHT   275-299                                         CWW30250
      EQUIVALENCE (W(275),RMODEL),(W(276),RFORM),(W(277),RID)           CWW30260
C                                                                       CWW30270
C     TOPOGRAPHY    300-324                                             CWW30280
      EQUIVALENCE (W(300),GMODEL),(W(301),GFORM),(W(302),GID)           CWW30290
C                                                                       CWW30300
C     DELTA TOPOGRAPHY   325-349                                        CWW30310
      EQUIVALENCE (W(325),GUMODEL),(W(326),GUFORM),(W(327),GUID)        CWW30320
                                                                        CWW30330
```

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C                                                                       CWW30340
C     ATMOSPHERIC SURFACE TOPOGRAPHY   350-374                          CWW30350
      EQUIVALENCE (W(350),SMODEL),(W(351),SFORM),(W(352),SID)           CWW30360
C                                                                       CWW30370
C     ATMOSPHERIC SURFACE TOPOGRAPHY   375-399                          CWW30380
      EQUIVALENCE (W(375),SUMODEL),(W(376),SUFORM),(W(377),SUID)        CWW30390
C     PLOT ENHANCEMENTS CONTROL PARAMETERS                              CWW30400
C                                                                       CWW30410
      EQUIVALENCE (W(490),XFQMDL),(W(491),YFQMDL)                       CWW30420
C     ABSORPTION          500-524                                       CWW30430
      EQUIVALENCE (W(500),AMODEL),(W(501),AFORM),(W(502),AID)           CWW30440
C                                                                       CWW30450
C     DELTA ABSORPTION          525-549                                 CWW30460
      EQUIVALENCE (W(525),DAMODEL),(W(526),DAFORM),(W(527),DAID)        CWW30470
C                                                                       CWW30480
C     PRESSURE          550-574                                         CWW30490
      EQUIVALENCE (W(550),PMODEL),(W(551),PFORM),(W(552),PID)           CWW30500
C                                                                       CWW30510
C     DELTA PRESSURE          575-599                                   CWW30520
      EQUIVALENCE (W(575),DPMODEL),(W(576),DPFORM),(W(577),DPID)        CWW30530
C                                                                       CWW30540
C                                                                       SLLS0060
      EQUIVALENCE (W(503),ACOEF),(W(504),BCOEF),(W(505),OMEG1)          SLLS0070
      EQUIVALENCE (W(506),OMEG2)                                        SLLS0080
C                                                                       SLLS0090
C     COMMON DECK "RINREAL" INSERTED HERE                               CRIN0020
      LOGICAL SPACE                                                     CRIN0040
      REAL LPOLAR,LPOLRI,KPHK,KPHKI,KAY2,KAY2I                          CRIN0050
      CHARACTER DISPM*6                                                 CRIN0060
      COMMON/RINPL/DISPM                                                CRIN0070
      COMMON /RIN/ MODRIN(8),RAYNAME(2,3),TYPE(3),SPACE                 CRIN0080
      COMMON/RIN/OMEGMIN,OMEGMAX,KAY2,KAY2I,                            CRIN0090
     1              H,HI,PHT,PHTI,PHR,PHRI,PHTH,PHTHI,PHPH,PHPHI        CRIN0100
     2, PHOW,PHOWI,PHKR,PHKRI,PHKTH,PHKTI, PHKPH,PHKPI                  CRIN0110
     3 ,KPHK,KPHKI,POLAR,POLARI,LPOLAR,LPOLRI,SGN                       CRIN0120
C     COMMON DECK "CONST" INSERTED HERE                                 CCON0020
      COMMON/PCONST/CREF,RGAS,GAMMA                                     CCON0040
      COMMON/MCONST/PI,PIT2,PID2,DEGS,RAD,ALN10                         CCON0050
C     COMMON DECK "LL" INSERTED HERE                                    CLL 0020
      REAL MODL                                                         CLL 0040
      COMMON/LL/MODL(4),APH,APHPT,APHPR,APHPTH,APHPPH                   CLL 0050
C                                                                       SLLS0130
C     COMMON DECK "CB17" INSERTED HERE                                  CB170020
      INTEGER VMX,VNTBL,VITBL,VFRMTBL,IDSV(10)                          CB170040
      COMMON/B17/VMX,VNTBL(10),VITBL(10),VFRMTBL(10),VGP(53)            CB170050
      EQUIVALENCE (VGP,IDSV),(ANV,VGP(11))                              CB170060
C                                                                       SLLS0150
      INTEGER VPX    ,VQTBL(10),VLTBL(10),VIRMTBL(10)                   SLLS0160
C                                                                       SLLS0170
      DATA VPX/1/                                                       SLLS0180
      DATA VQTBL/1,11,8*0/                                              SLLS0190
      DATA VLTBL/1,9*0/                                                 SLLS0200
      DATA VIRMTBL/1,9*0/                                               SLLS0210
      DATA RECOGA/1.0/                                                  SLLS0220
C                                                                       SLLS0230
```

```
C                                                                       SLLS0240
      ENTRY SETABS                                                      SLLS0250
C                                                                       SLLS0260
      VMX=VPX                                                           SLLS0270
      CALL IMOVE(VNTBL,VQTBL,10)                                        SLLS0280
      CALL IMOVE(VITBL,VLTBL,10)                                        SLLS0290
      CALL IMOVE(VFRMTBL,VIRMTBL,10)                                    SLLS0300
      CALL SETPAB                                                       SLLS0310
C                                                                       SLLS0320
      RETURN                                                            SLLS0330
C                                                                       SLLS0340
      ENTRY IABSRP                                                      SLLS0350
      IF(RECOGA .NE. AMODEL)                                            SLLS0360
     1    CALL RERROR('ABSRP ','WRNG MODEL',RECOGA)                     SLLS0370
      MODL(1)=6HSLLOSS                                                  SLLS0380
      MODL(2)=AID                                                       SLLS0390
      CALL IPABSRP                                                      SLLS0400
      RETURN                                                            SLLS0410
C                                                                       SLLS0420
      ENTRY ABSRP                                                       SLLS0430
      OWS=OW*OW                                                         SLLS0440
      APH=ACOEF*(OW/OMEG1)**2 + BCOEF*OWS/(OMEG2**2+OWS)                SLLS0450
      CALL PABSRP                                                       SLLS0460
      END                                                               SLLS0470
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      SUBROUTINE NPABSR                                                 NPWR0020
C     DO-NOTHING ABSORPTION PERTURBATION MODEL                          NPWR0030
C     COMMON DECK "WW" INSERTED HERE                                    CWW 0020
      PARAMETER (NWARSZ=1000)                                           CWW10030
      COMMON/WW/ID(10),MAXW,W(NWARSZ)                                   CWW10040
      REAL MAXSTP,MAXERR,INTYP,LLAT,LLON                                CWW20020
      EQUIVALENCE (EARTHR,W(1)),(RAY,W(2)),(XMTRH,W(3)),(TLAT,W(4)),    CWW20030
     1 (TLON,W(5)),(OW,W(6)),(FBEG,W(7)),(FEND,W(8)),(FSTEP,W(9)),      CWW20040
     2 (AZ1,W(10)),(AZBEG,W(11)),(AZEND,W(12)),(AZSTEP,W(13)),          CWW20050
     3 (BETA,W(14)),(ELBEG,W(15)),(ELEND,W(16)),(ELSTEP,W(17)),         CWW20060
     8   (RUNSUP,W(18)),(RCVRH,W(20)),                                  CWW20070
     4 (ONLY,W(21)),(HOP,W(22)),(MAXSTP,W(23)),(PLAT,W(24)),(PLON,W(25))CWW20080
     5,(HMAX,W(26)),(RAYFNC,W(29)),(EXTINC,W(33)),                      CWW20090
     6 (HMIN,W(27)),(RGMAX,W(28)),                                      CWW20100
     8 (INTYP,W(41)),(MAXERR,W(42)),(ERATIO,W(43)),                     CWW20110
     6 (STEP1,W(44)),(STPMAX,W(45)),(STPMIN,W(46)),(FACTR,W(47)),       CWW20120
     7 (SKIP,W(71)),(RAYSET,W(72)),(PRTSRP,W(74)),(HITLET,W(75))        CWW20130
     9 ,(BINRAY,W(76)),(PAGLN,W(77)),(PLT,W(81)),(PFACTR,W(82)),        CWW20140
     1 (LLAT,W(83)),(LLON,W(84)),(RLAT,W(85)),(RLON,W(86))              CWW20150
     2,(TIC,W(87)),(HB,W(88)),(HT,W(89)),(TICV,W(96))                   CWW20160
      REAL MMODEL,MFORM,MID                                             CWW30020
C                                                                       CWW30030
C     WIND         100-124                                              CWW30040
      EQUIVALENCE (W(100),UMODEL),(W(101),UFORM),(W(102),UID)           CWW30050
C                                                                       CWW30060
C     DELTA WIND         125-149                                        CWW30070
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      EQUIVALENCE (W(125),DUMODEL),(W(126),DUFORM),(W(127),DUID)        CWW30080
C                                                                       CWW30090
C     SOUND SPEED 150-174                                               CWW30100
      EQUIVALENCE (W(150),CMODEL),(W(151),CFORM),(W(152),CID)           CWW30110
      EQUIVALENCE (W(153),REFC)                                         CWW30120
C                                                                       CWW30130
C     DELTA SOUND SPEED 175-199                                         CWW30140
      EQUIVALENCE (W(175),DCMODEL),(W(176),DCFORM),(W(177),DCID)        CWW30150
C                                                                       CWW30160
C     TEMPERATURE    200-224                                            CWW30170
      EQUIVALENCE (W(200),TMODEL),(W(201),TFORM),(W(202),TID)           CWW30180
C                                                                       CWW30190
C     DELTA TEMPERATURE    225-249                                      CWW30200
      EQUIVALENCE (W(225),DTMODEL),(W(226),DTFORM),(W(227),DTID)        CWW30210
C                                                                       CWW30220
C     MOLECULAR   250-274                                               CWW30230
      EQUIVALENCE (W(250),MMODEL),(W(251),MFORM),(W(252),MID)           CWW30240
C                                                                       CWW30250
C     RECEIVER HEIGHT   275-299                                         CWW30260
      EQUIVALENCE (W(275),RMODEL),(W(276),RFORM),(W(277),RID)           CWW30270
C                                                                       CWW30280
C     TOPOGRAPHY   300-324                                              CWW30290
      EQUIVALENCE (W(300),GMODEL),(W(301),GFORM),(W(302),GID)           CWW30300
C                                                                       CWW30310
C     DELTA TOPOGRAPHY   325-349                                        CWW30320
      EQUIVALENCE (W(325),GUMODEL),(W(326),GUFORM),(W(327),GUID)        CWW30330
C                                                                       CWW30340
C     ATMOSPHERIC SURFACE TOPOGRAPHY   350-374                          CWW30350
      EQUIVALENCE (W(350),SMODEL),(W(351),SFORM),(W(352),SID)           CWW30360
C                                                                       CWW30370
C     ATMOSPHERIC SURFACE TOPOGRAPHY   375-399                          CWW30380
      EQUIVALENCE (W(375),SUMODEL),(W(376),SUFORM),(W(377),SUID)        CWW30390
C     PLOT ENHANCEMENTS CONTROL PARAMETERS                              CWW30400
C                                                                       CWW30410
      EQUIVALENCE (W(490),XFQMDL),(W(491),YFQMDL)                       CWW30420
C     ABSORPTION          500-524                                       CWW30430
      EQUIVALENCE (W(500),AMODEL),(W(501),AFORM),(W(502),AID)           CWW30440
C                                                                       CWW30450
C     DELTA ABSORPTION          525-549                                 CWW30460
      EQUIVALENCE (W(525),DAMODEL),(W(526),DAFORM),(W(527),DAID)        CWW30470
C                                                                       CWW30480
C     PRESSURE          550-574                                         CWW30490
      EQUIVALENCE (W(550),PMODEL),(W(551),PFORM),(W(552),PID)           CWW30500
C                                                                       CWW30510
C     DELTA PRESSURE          575-599                                   CWW30520
      EQUIVALENCE (W(575),DPMODEL),(W(576),DPFORM),(W(577),DPID)        CWW30530
C                                                                       CWW30540
C     COMMON DECK "LL" INSERTED HERE                                    CLL 0020
      REAL MODL                                                         CLL 0040
      COMMON/LL/MODL(4),APH,APHPT,APHPR,APHPTH,APHPPH                   CLL 0050
C                                                                       NPWR0060
C     COMMON DECK "CB18" INSERTED HERE                                  CB180020
      INTEGER DVMX,DVNTBL,DVITBL,DVFRMTB,IDSDV(10)                      CB180040
      COMMON/B18/DVMX,DVNTBL(10),DVITBL(10),DVFRMTB(10),DVGP(11)        CB180050
      EQUIVALENCE (DVGP,IDSDV),(ANDV,DVGP(11))                          CB180060
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C                                                                       NPWR0080
      INTEGER DYMX    ,DYNTBL(10),DYITBL(10),DYFRMTB(10)                NPWR0090
C                                                                       NPWR0100
      DATA DYMX/1/                                                      NPWR0110
      DATA DYNTBL/1,11,8*0/                                             NPWR0120
      DATA DYITBL/1,9*0/                                                NPWR0130
      DATA DYFRMTB/1,9*0/                                               NPWR0140
C                                                                       NPWR0150
      DATA RECOGDA/0.0/                                                 NPWR0160
C                                                                       NPWR0170
C                                                                       NPWR0180
      ENTRY SETPAB                                                      NPWR0190
C                                                                       NPWR0200
      DVMX=DYMX                                                         NPWR0210
      CALL IMOVE(DVNTBL,DYNTBL,10)                                      NPWR0220
      CALL IMOVE(DVITBL,DYITBL,10)                                      NPWR0230
      CALL IMOVE(DVFRMTB,DYFRMTB,10)                                    NPWR0240
C                                                                       NPWR0250
      RETURN                                                            NPWR0260
C                                                                       NPWR0270
      ENTRY IPABSRP                                                     NPWR0280
      IF(RECOGDA .NE. DAMODEL)                                          NPWR0290
     1    CALL RERROR('DABSRP ','WRNG MODEL',RECOGDA)                   NPWR0300
      MODL(3)=7HNPABSR                                                  NPWR0310
      MODL(4)=DAID                                                      NPWR0320
      RETURN                                                            NPWR0330
C                                                                       NPWR0340
      ENTRY PABSRP                                                      NPWR0350
      RETURN                                                            NPWR0360
      END                                                               NPWR0370
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      SUBROUTINE GHORIZ                                                 GHJZ0020
C     TERRAIN MODEL USING FIXED OFFSET TO EARTHR'S SURFACE              GHJZ0030
C     COMMON DECK "GG" INSERTED HERE                                    CGG 0020
      REAL MODG                                                         CGG 0040
      COMMON/GG/MODG(4)                                                 CGG 0050
      COMMON/GG/G,PGR,PGRR,PGRTH,PGRPH                                  CGG 0060
      COMMON/GG/PGTH,PGPH,PGTHTH,PGPHPH,PGTHPH,GSELECT,GTIME            CGG 0070
C     COMMON DECK "WW" INSERTED HERE                                    CWW 0020
      PARAMETER (NWARSZ=1000)                                           CWW10030
      COMMON/WW/ID(10),MAXW,W(NWARSZ)                                   CWW10040
      REAL MAXSTP,MAXERR,INTYP,LLAT,LLON                                CWW20020
      EQUIVALENCE (EARTHR,W(1)),(RAY,W(2)),(XMTRH,W(3)),(TLAT,W(4)),    CWW20030
     1 (TLON,W(5)),(OW,W(6)),(FBEG,W(7)),(FEND,W(8)),(FSTEP,W(9)),      CWW20040
     2 (AZ1,W(10)),(AZBEG,W(11)),(AZEND,W(12)),(AZSTEP,W(13)),          CWW20050
     3 (BETA,W(14)),(ELBEG,W(15)),(ELEND,W(16)),(ELSTEP,W(17)),         CWW20060
     8   (RUNSUP,W(18)),(RCVRH,W(20)),                                  CWW20070
     4 (ONLY,W(21)),(HOP,W(22)),(MAXSTP,W(23)),(PLAT,W(24)),(PLON,W(25))CWW20080
     5,(HMAX,W(26)),(RAYFNC,W(29)),(EXTINC,W(33)),                      CWW20090
     6 (HMIN,W(27)),(RGMAX,W(28)),                                      CWW20100
     8 (INTYP,W(41)),(MAXERR,W(42)),(ERATIO,W(43)),                     CWW20110
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     6 (STEP1,W(44)),(STPMAX,W(45)),(STPMIN,W(46)),(FACTR,W(47)),        CWW20120
     7 (SKIP,W(71)),(RAYSET,W(72)),(PRTSRP,W(74)),(HITLET,W(75))         CWW20130
     9 ,(BINRAY,W(76)),(PAGLN,W(77)),(PLT,W(81)),(PFACTR,W(82)),         CWW20140
     1 (LLAT,W(83)),(LLON,W(84)),(RLAT,W(85)),(RLON,W(86))               CWW20150
     2,(TIC,W(87)),(HB,W(88)),(HT,W(89)),(TICV,W(96))                    CWW20160
      REAL MMODEL,MFORM,MID                                              CWW30020
C                                                                        CWW30030
C     WIND          100-124                                              CWW30040
      EQUIVALENCE (W(100),UMODEL),(W(101),UFORM),(W(102),UID)            CWW30050
C                                                                        CWW30060
C     DELTA WIND          125-149                                        CWW30070
      EQUIVALENCE (W(125),DUMODEL),(W(126),DUFORM),(W(127),DUID)         CWW30080
C                                                                        CWW30090
C     SOUND SPEED 150-174                                                CWW30100
      EQUIVALENCE (W(150),CMODEL),(W(151),CFORM),(W(152),CID)            CWW30110
      EQUIVALENCE (W(153),REFC)                                          CWW30120
C                                                                        CWW30130
C     DELTA SOUND SPEED 175-199                                          CWW30140
      EQUIVALENCE (W(175),DCMODEL),(W(176),DCFORM),(W(177),DCID)         CWW30150
C                                                                        CWW30160
C     TEMPERATURE    200-224                                             CWW30170
      EQUIVALENCE (W(200),TMODEL),(W(201),TFORM),(W(202),TID)            CWW30180
C                                                                        CWW30190
C     DELTA TEMPERATURE    225-249                                       CWW30200
      EQUIVALENCE (W(225),DTMODEL),(W(226),DTFORM),(W(227),DTID)         CWW30210
C                                                                        CWW30220
C     MOLECULAR   250-274                                                CWW30230
      EQUIVALENCE (W(250),MMODEL),(W(251),MFORM),(W(252),MID)            CWW30240
C                                                                        CWW30250
C     RECEIVER HEIGHT   275-299                                          CWW30260
      EQUIVALENCE (W(275),RMODEL),(W(276),RFORM),(W(277),RID)            CWW30270
C                                                                        CWW30280
C     TOPOGRAPHY   300-324                                               CWW30290
      EQUIVALENCE (W(300),GMODEL),(W(301),GFORM),(W(302),GID)            CWW30300
C                                                                        CWW30310
C     DELTA TOPOGRAPHY   325-349                                         CWW30320
      EQUIVALENCE (W(325),GUMODEL),(W(326),GUFORM),(W(327),GUID)         CWW30330
C                                                                        CWW30340
C     ATMOSPHERIC SURFACE TOPOGRAPHY   350-374                           CWW30350
      EQUIVALENCE (W(350),SMODEL),(W(351),SFORM),(W(352),SID)            CWW30360
C                                                                        CWW30370
C     ATMOSPHERIC SURFACE TOPOGRAPHY   375-399                           CWW30380
      EQUIVALENCE (W(375),SUMODEL),(W(376),SUFORM),(W(377),SUID)         CWW30390
C     PLOT ENHANCEMENTS CONTROL PARAMETERS                               CWW30400
C                                                                        CWW30410
      EQUIVALENCE (W(490),XFQMDL),(W(491),YFQMDL)                        CWW30420
C     ABSORPTION          500-524                                        CWW30430
      EQUIVALENCE (W(500),AMODEL),(W(501),AFORM),(W(502),AID)            CWW30440
C                                                                        CWW30450
C     DELTA ABSORPTION          525-549                                  CWW30460
      EQUIVALENCE (W(525),DAMODEL),(W(526),DAFORM),(W(527),DAID)         CWW30470
C                                                                        CWW30480
C     PRESSURE          550-574                                          CWW30490
      EQUIVALENCE (W(550),PMODEL),(W(551),PFORM),(W(552),PID)            CWW30500
C                                                                        CWW30510
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C       DELTA PRESSURE          575-599                                 CWW30520
        EQUIVALENCE (W(575),DPMODEL),(W(576),DPFORM),(W(577),DPID)      CWW30530
C                                                                       CWW30540
C       COMMON DECK "RKAM" INSERTED HERE                                RKAM0020
        REAL KR,KTH,KPH                                                 RKAM0040
        COMMON//R,TH,PH,KR,KTH,KPH,RKVARS(14),TPULSE,CSTEP,DRDT(20)     RKAM0050
C                                                                       GHJZ0070
        EQUIVALENCE (W(303), Z0)                                        GHJZ0080
C                                                                       GHJZ0090
C       COMMON DECK "B9" INSERTED HERE                                  CB8 0020
        INTEGER GMX,GNTBL,GITBL,GFRMTBL,IDSG(10)                        CB8 0040
        COMMON/B9/GMX,GNTBL(10),GITBL(10),GFRMTBL(10),GGP(113)          CB8 0050
        EQUIVALENCE (GGP,IDSG),(ANG,GGP(11))                            CB8 0060
C                                                                       GHJZ0110
        INTEGER GPX     ,GQTBL(10),GLTBL(10),GIRMTBL(10)                GHJZ0120
        DATA RECOGG/1.0/                                                GHJZ0130
C                                                                       GHJZ0140
C                                                                       GHJZ0150
        DATA GPX/1/                                                     GHJZ0160
        DATA GQTBL/1,11,8*0/                                            GHJZ0170
        DATA GLTBL/1,9*0/                                               GHJZ0180
        DATA GIRMTBL/1,9*0/                                             GHJZ0190
C                                                                       GHJZ0200
C                                                                       GHJZ0210
        ENTRY SETTOP                                                    GHJZ0220
C                                                                       GHJZ0230
        GMX=GPX                                                         GHJZ0240
        CALL IMOVE(GNTBL,GQTBL,10)                                      GHJZ0250
        CALL IMOVE(GITBL,GLTBL,10)                                      GHJZ0260
        CALL IMOVE(GFRMTBL,GIRMTBL,10)                                  GHJZ0270
        CALL SETPTP                                                     GHJZ0280
C                                                                       GHJZ0290
        RETURN                                                          GHJZ0300
C                                                                       GHJZ0310
        ENTRY ITOPOG                                                    GHJZ0320
        IF(RECOGG .NE. GMODEL)                                          GHJZ0330
     1      CALL RERROR('GHORIZ ','WRNG MODEL',RECOGG)                  GHJZ0340
        MODG(1)=6HGHORIZ                                                GHJZ0350
        MODG(2)=GID                                                     GHJZ0360
        CALL IPTOPOG                                                    GHJZ0370
        RETURN                                                          GHJZ0380
C                                                                       GHJZ0390
        ENTRY TOPOG                                                     GHJZ0400
        G=R-W(1)-Z0                                                     GHJZ0410
        PGR=1.0                                                         GHJZ0420
        CALL CLEAR(PGRR,8)                                              GHJZ0430
        END                                                             GHJZ0440


        SUBROUTINE GLORENZ                                              GLRZ0020
C       TERRAIN MODEL USING LORENZIAN SHAPED HORIZONTAL SURFACE LOCATED A GLRZ0030
C       ARBITRARY GEOGRAPHICAL LOCATION.                                GLRZ0040
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C                                                                       GLRZ0050
C     COMMON DECK "CONST" INSERTED HERE                                 CCON0020
      COMMON/PCONST/CREF,RGAS,GAMMA                                     CCON0040
      COMMON/MCONST/PI,PIT2,PID2,DEGS,RAD,ALN10                         CCON0050
C     COMMON DECK "B9" INSERTED HERE                                    CB8 0020
      INTEGER GMX,GNTBL,GITBL,GFRMTBL,IDSG(10)                          CB8 0040
      COMMON/B9/GMX,GNTBL(10),GITBL(10),GFRMTBL(10),GGP(113)            CB8 0050
      EQUIVALENCE (GGP,IDSG),(ANG,GGP(11))                              CB8 0060
C     COMMON DECK "RKAM" INSERTED HERE                                  RKAM0020
      REAL KR,KTH,KPH                                                   RKAM0040
      COMMON//R,TH,PH,KR,KTH,KPH,RKVARS(14),TPULSE,CSTEP,DRDT(20)       RKAM0050
C     COMMON DECK "GG" INSERTED HERE                                    CGG 0020
      REAL MODG                                                         CGG 0040
      COMMON/GG/MODG(4)                                                 CGG 0050
      COMMON/GG/G,PGR,PGRR,PGRTH,PGRPH                                  CGG 0060
      COMMON/GG/PGTH,PGPH,PGTHTH,PGPHPH,PGTHPH,GSELECT,GTIME            CGG 0070
C     COMMON DECK "B10" INSERTED HERE                                   CB9 0020
      INTEGER DGMX,DGNTBL,DGITBL,DGFRMTB,IDSDG(10)                      CB9 0040
      COMMON/B10/DGMX,DGNTBL(10),DGITBL(10),DGFRMTB(10),DGGP(10)        CB9 0050
      EQUIVALENCE (DGGP,IDSDG)                                          CB9 0060
C     COMMON DECK "WW" INSERTED HERE                                    CWW 0020
      PARAMETER (NWARSZ=1000)                                           CWW10030
      COMMON/WW/ID(10),MAXW,W(NWARSZ)                                   CWW10040
      REAL MAXSTP,MAXERR,INTYP,LLAT,LLON                                CWW20020
      EQUIVALENCE (EARTHR,W(1)),(RAY,W(2)),(XMTRH,W(3)),(TLAT,W(4)),    CWW20030
     1 (TLON,W(5)),(OW,W(6)),(FBEG,W(7)),(FEND,W(8)),(FSTEP,W(9)),      CWW20040
     2 (AZ1,W(10)),(AZBEG,W(11)),(AZEND,W(12)),(AZSTEP,W(13)),          CWW20050
     3 (BETA,W(14)),(ELBEG,W(15)),(ELEND,W(16)),(ELSTEP,W(17)),         CWW20060
     8   (RUNSUP,W(18)),(RCVRH,W(20)),                                  CWW20070
     4 (ONLY,W(21)),(HOP,W(22)),(MAXSTP,W(23)),(PLAT,W(24)),(PLON,W(25))CWW20080
     5,(HMAX,W(26)),(RAYFNC,W(29)),(EXTINC,W(33)),                      CWW20090
     6 (HMIN,W(27)),(RGMAX,W(28)),                                      CWW20100
     8 (INTYP,W(41)),(MAXERR,W(42)),(ERATIO,W(43)),                     CWW20110
     6 (STEP1,W(44)),(STPMAX,W(45)),(STPMIN,W(46)),(FACTR,W(47)),       CWW20120
     7 (SKIP,W(71)),(RAYSET,W(72)),(PRTSRP,W(74)),(HITLET,W(75))        CWW20130
     9 ,(BINRAY,W(76)),(PAGLN,W(77)),(PLT,W(81)),(PFACTR,W(82)),        CWW20140
     1 (LLAT,W(83)),(LLON,W(84)),(RLAT,W(85)),(RLON,W(86))              CWW20150
     2,(TIC,W(87)),(HB,W(88)),(HT,W(89)),(TICV,W(96))                   CWW20160
      REAL MMODEL,MFORM,MID                                             CWW30020
C                                                                       CWW30030
C     WIND         100-124                                              CWW30040
      EQUIVALENCE (W(100),UMODEL),(W(101),UFORM),(W(102),UID)           CWW30050
C                                                                       CWW30060
C     DELTA WIND        125-149                                         CWW30070
      EQUIVALENCE (W(125),DUMODEL),(W(126),DUFORM),(W(127),DUID)        CWW30080
C                                                                       CWW30090
C     SOUND SPEED 150-174                                               CWW30100
      EQUIVALENCE (W(150),CMODEL),(W(151),CFORM),(W(152),CID)           CWW30110
      EQUIVALENCE (W(153),REFC)                                         CWW30120
C                                                                       CWW30130
C     DELTA SOUND SPEED 175-199                                         CWW30140
      EQUIVALENCE (W(175),DCMODEL),(W(176),DCFORM),(W(177),DCID)        CWW30150
C                                                                       CWW30160
C     TEMPERATURE    200-224                                            CWW30170
      EQUIVALENCE (W(200),TMODEL),(W(201),TFORM),(W(202),TID)           CWW30180
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C
C     DELTA TEMPERATURE    225-249
      EQUIVALENCE (W(225),DTMODEL),(W(226),DTFORM),(W(227),DTID)
C
C     MOLECULAR   250-274
      EQUIVALENCE (W(250),MMODEL),(W(251),MFORM),(W(252),MID)
C
C     RECEIVER HEIGHT   275-299
      EQUIVALENCE (W(275),RMODEL),(W(276),RFORM),(W(277),RID)
C
C     TOPOGRAPHY   300-324
      EQUIVALENCE (W(300),GMODEL),(W(301),GFORM),(W(302),GID)
C
C     DELTA TOPOGRAPHY   325-349
      EQUIVALENCE (W(325),GUMODEL),(W(326),GUFORM),(W(327),GUID)
C
C     ATMOSPHERIC SURFACE TOPOGRAPHY   350-374
      EQUIVALENCE (W(350),SMODEL),(W(351),SFORM),(W(352),SID)
C
C     ATMOSPHERIC SURFACE TOPOGRAPHY   375-399
      EQUIVALENCE (W(375),SUMODEL),(W(376),SUFORM),(W(377),SUID)
C     PLOT ENHANCEMENTS CONTROL PARAMETERS
C
      EQUIVALENCE (W(490),XFQMDL),(W(491),YFQMDL)
C     ABSORPTION          500-524
      EQUIVALENCE (W(500),AMODEL),(W(501),AFORM),(W(502),AID)
C
C     DELTA ABSORPTION          525-549
      EQUIVALENCE (W(525),DAMODEL),(W(526),DAFORM),(W(527),DAID)
C
C     PRESSURE          550-574
      EQUIVALENCE (W(550),PMODEL),(W(551),PFORM),(W(552),PID)
C
C     DELTA PRESSURE          575-599
      EQUIVALENCE (W(575),DPMODEL),(W(576),DPFORM),(W(577),DPID)
C
      EQUIVALENCE (GCZAMP,W(303))
      EQUIVALENCE (GCLAMZ,W(304)) ,(GCTHDL,W(305))
      EQUIVALENCE (GCBASE,W(306))
C
      INTEGER GPX    ,GQTBL(10),GLTBL(10),GIRMTBL(10)
      DATA RECOGG/4.0/
C
      DATA GPX/1/
      DATA GQTBL/1,11,8*0/
      DATA GLTBL/1,9*0/
      DATA GIRMTBL/1,9*0/
C
      ENTRY SETTOP
C
      GMX=GPX
      CALL IMOVE(GNTBL,GQTBL,10)
      CALL IMOVE(GITBL,GLTBL,10)
      CALL IMOVE(GFRMTBL,GIRMTBL,10)
      CALL SETPTP
```

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C                                                                       GLRZ0310
      RETURN                                                            GLRZ0320
C                                                                       GLRZ0330
      ENTRY ITOPOG                                                      GLRZ0340
C                                                                       GLRZ0350
      IF(RECOGG .NE. GMODEL)                                            GLRZ0360
     1    CALL RERROR('GROUND ','WRNG MODEL',RECOGG)                    GLRZ0370
      MODG(1)=7HGLORENZ                                                 GLRZ0380
      MODG(2)=GID                                                       GLRZ0390
C                                                                       GLRZ0400
      GCTH0=PID2-GCLAMZ                                                 GLRZ0410
      GCINV=1.0/GCTHDL                                                  GLRZ0420
      CALL IPTOPOG                                                      GLRZ0430
      RETURN                                                            GLRZ0440
C                                                                       GLRZ0450
      ENTRY TOPOG                                                       GLRZ0460
C                                                                       GLRZ0470
      CALL CLEAR(PGRR,8)                                                GLRZ0480
C                                                                       GLRZ0490
      ETA=(TH-GCTH0)*GCINV                                              GLRZ0500
      ETA2=ETA*ETA                                                      GLRZ0510
      GBINOM=1.0/(1.0 + ETA2)                                           GLRZ0520
      Z=GCZAMP*GBINOM                                                   GLRZ0530
      G=R-EARTHR-Z-GCBASE                                               GLRZ0540
C                                                                       GLRZ0550
      PGR=1.0                                                           GLRZ0560
      GBINOMB=GBINOM*GCINV                                              GLRZ0570
      PGTH=2.0*Z*ETA*GBINOMB                                            GLRZ0580
      PGTHTH=2.0*Z*GBINOMB*GBINOMB*(1.0-3.0*ETA2)                       GLRZ0590
C                                                                       GLRZ0600
      RETURN                                                            GLRZ0610
      END                                                               GLRZ0620
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      SUBROUTINE GTANH                                                  GTLH0020
C     TERRAIN PROFILE REPRESENTED BY A SEQUENCE OF LINEAR SEGMENTS      GTLH0030
C     SMOOTHLY JOINED BY HYPERBOLIC FUNCTIONS. PARAMETERS ARE INPUT     GTLH0040
C     AS TABULAR DATA WITH SLOPES COMPUTED FROM TERRAIN DATA.           GTLH0050
C     COMMON DECK "CONST" INSERTED HERE                                 CCON0020
      COMMON/PCONST/CREF,RGAS,GAMMA                                     CCON0040
      COMMON/MCONST/PI,PIT2,PID2,DEGS,RAD,ALN10                         CCON0050
C     TERRAIN MODEL                                                     GTLH0070
      REAL C(49), LAM0,LMI,LMIM1,LM(49), DL(49),ALC(50)                 GTLH0080
C     COMMON DECK "RKAM" INSERTED HERE                                  RKAM0020
      REAL KR,KTH,KPH                                                   RKAM0040
      COMMON//R,TH,PH,KR,KTH,KPH,RKVARS(14),TPULSE,CSTEP,DRDT(20)       RKAM0050
C     COMMON DECK "GG" INSERTED HERE                                    CGG 0020
      REAL MODG                                                         CGG 0040
      COMMON/GG/MODG(4)                                                 CGG 0050
      COMMON/GG/G,PGR,PGRR,PGRTH,PGRPH                                  CGG 0060
      COMMON/GG/PGTH,PGPH,PGTHTH,PGPHPH,PGTHPH,GSELECT,GTIME            CGG 0070
C     COMMON DECK "B9" INSERTED HERE                                    CB8 0020
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      INTEGER GMX,GNTBL,GITBL,GFRMTBL,IDSG(10)                          CB8 0040
      COMMON/B9/GMX,GNTBL(10),GITBL(10),GFRMTBL(10),GGP(113)            CB8 0050
      EQUIVALENCE (GGP,IDSG),(ANG,GGP(11))                              CB8 0060
C     COMMON DECK "WW" INSERTED HERE                                    CWW 0020
      PARAMETER (NWARSZ=1000)                                           CWW10030
      COMMON/WW/ID(10),MAXW,W(NWARSZ)                                   CWW10040
      REAL MAXSTP,MAXERR,INTYP,LLAT,LLON                                CWW20020
      EQUIVALENCE (EARTHR,W(1)),(RAY,W(2)),(XMTRH,W(3)),(TLAT,W(4)),    CWW20030
     1 (TLON,W(5)),(OW,W(6)),(FBEG,W(7)),(FEND,W(8)),(FSTEP,W(9)),      CWW20040
     2 (AZ1,W(10)),(AZBEG,W(11)),(AZEND,W(12)),(AZSTEP,W(13)),          CWW20050
     3 (BETA,W(14)),(ELBEG,W(15)),(ELEND,W(16)),(ELSTEP,W(17)),         CWW20060
     8   (RUNSUP,W(18)),(RCVRH,W(20)),                                  CWW20070
     4 (ONLY,W(21)),(HOP,W(22)),(MAXSTP,W(23)),(PLAT,W(24)),(PLON,W(25))CWW20080
     5,(HMAX,W(26)),(RAYFNC,W(29)),(EXTINC,W(33)),                      CWW20090
     6 (HMIN,W(27)),(RGMAX,W(28)),                                      CWW20100
     8 (INTYP,W(41)),(MAXERR,W(42)),(ERATIO,W(43)),                     CWW20110
     6 (STEP1,W(44)),(STPMAX,W(45)),(STPMIN,W(46)),(FACTR,W(47)),       CWW20120
     7 (SKIP,W(71)),(RAYSET,W(72)),(PRTSRP,W(74)),(HITLET,W(75))        CWW20130
     9 ,(BINRAY,W(76)),(PAGLN,W(77)),(PLT,W(81)),(PFACTR,W(82)),        CWW20140
     1 (LLAT,W(83)),(LLON,W(84)),(RLAT,W(85)),(RLON,W(86))              CWW20150
     2,(TIC,W(87)),(HB,W(88)),(HT,W(89)),(TICV,W(96))                   CWW20160
      REAL MMODEL,MFORM,MID                                             CWW30020
C                                                                       CWW30030
C     WIND         100-124                                              CWW30040
      EQUIVALENCE (W(100),UMODEL),(W(101),UFORM),(W(102),UID)           CWW30050
C                                                                       CWW30060
C     DELTA WIND         125-149                                        CWW30070
      EQUIVALENCE (W(125),DUMODEL),(W(126),DUFORM),(W(127),DUID)        CWW30080
C                                                                       CWW30090
C     SOUND SPEED 150-174                                               CWW30100
      EQUIVALENCE (W(150),CMODEL),(W(151),CFORM),(W(152),CID)           CWW30110
      EQUIVALENCE (W(153),REFC)                                         CWW30120
C                                                                       CWW30130
C     DELTA SOUND SPEED 175-199                                         CWW30140
      EQUIVALENCE (W(175),DCMODEL),(W(176),DCFORM),(W(177),DCID)        CWW30150
C                                                                       CWW30160
C     TEMPERATURE    200-224                                            CWW30170
      EQUIVALENCE (W(200),TMODEL),(W(201),TFORM),(W(202),TID)           CWW30180
C                                                                       CWW30190
C     DELTA TEMPERATURE    225-249                                      CWW30200
      EQUIVALENCE (W(225),DTMODEL),(W(226),DTFORM),(W(227),DTID)        CWW30210
C                                                                       CWW30220
C     MOLECULAR    250-274                                              CWW30230
      EQUIVALENCE (W(250),MMODEL),(W(251),MFORM),(W(252),MID)           CWW30240
C                                                                       CWW30250
C     RECEIVER HEIGHT   275-299                                         CWW30260
      EQUIVALENCE (W(275),RMODEL),(W(276),RFORM),(W(277),RID)           CWW30270
C                                                                       CWW30280
C     TOPOGRAPHY   300-324                                              CWW30290
      EQUIVALENCE (W(300),GMODEL),(W(301),GFORM),(W(302),GID)           CWW30300
C                                                                       CWW30310
C     DELTA TOPOGRAPHY   325-349                                        CWW30320
      EQUIVALENCE (W(325),GUMODEL),(W(326),GUFORM),(W(327),GUID)        CWW30330
C                                                                       CWW30340
C     ATMOSPHERIC SURFACE TOPOGRAPHY   350-374                          CWW30350
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      EQUIVALENCE (W(350),SMODEL),(W(351),SFORM),(W(352),SID)           CWW30360
C                                                                       CWW30370
C     ATMOSPHERIC SURFACE TOPOGRAPHY   375-399                          CWW30380
      EQUIVALENCE (W(375),SUMODEL),(W(376),SUFORM),(W(377),SUID)        CWW30390
C     PLOT ENHANCEMENTS CONTROL PARAMETERS                              CWW30400
C                                                                       CWW30410
      EQUIVALENCE (W(490),XFQMDL),(W(491),YFQMDL)                       CWW30420
C     ABSORPTION          500-524                                       CWW30430
      EQUIVALENCE (W(500),AMODEL),(W(501),AFORM),(W(502),AID)           CWW30440
C                                                                       CWW30450
C     DELTA ABSORPTION          525-549                                 CWW30460
      EQUIVALENCE (W(525),DAMODEL),(W(526),DAFORM),(W(527),DAID)        CWW30470
C                                                                       CWW30480
C     PRESSURE          550-574                                         CWW30490
      EQUIVALENCE (W(550),PMODEL),(W(551),PFORM),(W(552),PID)           CWW30500
C                                                                       CWW30510
C     DELTA PRESSURE          575-599                                   CWW30520
      EQUIVALENCE (W(575),DPMODEL),(W(576),DPFORM),(W(577),DPID)        CWW30530
C                                                                       CWW30540
      EQUIVALENCE (LAM0,GGP(12)),(Z0,GGP(62)),(DL0,GGP(112))            GTLH0130
      EQUIVALENCE (LM,GGP(13)),(C,GGP(63)),(DL,GGP(113))                GTLH0140
C                                                                       GTLH0150
      INTEGER GPX    ,GQTBL(10),GLTBL(10),GIRMTBL(10)                   GTLH0160
      DATA RECOGG/3.0/                                                  GTLH0170
C                                                                       GTLH0180
      DATA AQG/0.0/                                                     GTLH0190
      DATA GPX/2/                                                       GTLH0200
      DATA GQTBL/1,11,162,7*0/                                          GTLH0210
      DATA GLTBL/1,50,8*0/                                              GTLH0220
      DATA GIRMTBL/1,2,8*0/                                             GTLH0230
C                                                                       GTLH0240
      ENTRY SETTOP                                                      GTLH0250
C                                                                       GTLH0260
      ANG=AQG                                                           GTLH0270
      GMX=GPX                                                           GTLH0280
      CALL IMOVE(GNTBL,GQTBL,10)                                        GTLH0290
      CALL IMOVE(GITBL,GLTBL,10)                                        GTLH0300
      CALL IMOVE(GFRMTBL,GIRMTBL,10)                                    GTLH0310
      CALL SETPTP                                                       GTLH0320
C                                                                       GTLH0330
      RETURN                                                            GTLH0340
C                                                                       GTLH0350
      ENTRY ITOPOG                                                      GTLH0360
C                                                                       GTLH0370
      CALL IPTOPOG                                                      GTLH0380
C                                                                       GTLH0390
C     IF HAD PREVIOUS CALL BUT NOTHING THIS TIME, EXIT NOW              GTLH0400
C     RETAINING PREVIOUS TABULAR DATA COUNT                             GTLH0410
      IF(N.GT.0 .AND. ANG.EQ.0.0) RETURN                                GTLH0420
C                                                                       GTLH0430
      IF(RECOGG .NE. GMODEL)                                            GTLH0440
     1   CALL RERROR('TOPO    ','WRNG MODEL',RECOGG)                    GTLH0450
      MODG(1)=5HGTANH                                                   GTLH0460
      MODG(2)=GID                                                       GTLH0470
      N=ANG/3                                                           GTLH0480
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```
      IF(ANG.NE.3*N.OR.N.LE.0)
     1      CALL RERROR('GTANH','BAD NUMBER',ANG+2.0)
      N=N-2
      ANG=0.0
C
C
C     CONVERT 'Z' ARRAY INPUT(OVERLAYS 'C' ARRAY) TO 'C' ARRAY
C
      ZM1=Z0
      LAM0=PID2-LAM0
      LMIM1=LAM0
      NP1=N+1
      DO 10 I=1,NP1
         Z=C(I)
         LMI=PID2-LM(I)
         LM(I)=LMI
         ALC(I)=ALCOSH((LMI-LAM0) / DL(I))
         C(I)=(Z-ZM1)/(LMI-LMIM1)
         ZM1=Z
10       LMIM1=LMI
C
      RETURN
C
      ENTRY TOPOG
C
      IF(N.LE.0)
     1     CALL RERROR('GTANH','BAD N VALUE',FLOAT(N))
C
      SUM = 0.
      DO 1 I = 1, N
    1 SUM = SUM + DL(I) * (C(I + 1) - C(I)) / 2. *(ALCOSH(((TH-LM
     1(I)) / DL(I))) - ALC(I))
      Z = Z0 - SUM + (C(1) + C(N + 1)) * (TH-LAM0) / 2.
      G=R-EARTHR-Z
      PGR=1.0
C
      PGTH = C(1)
      DO 2 I = 1, N
    2 PGTH= PGTH+ (C(I + 1) - C(I)) / 2. * (1. + TANH ((LM(I)- TH) /DL
     1 (I)))
      PGTH=-PGTH
      PGTHTH=0.0
      DO 3 I=1,N
3     PGTHTH=PGTHTH+
     1     (C(I+1)-C(I))/2.*(1.0-TANH((LM(I)-TH)/DL(I))**2)/DL(I)
C
      CALL PTOPOG
      RETURN
      END


      SUBROUTINE NPBOTM
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C     DO-NOTHING BOTTOM PERTURBATION MODEL                                  NPRM0030
C      COMMON DECK "GG" INSERTED HERE                                       CGG 0020
       REAL MODG                                                            CGG 0040
       COMMON/GG/MODG(4)                                                    CGG 0050
       COMMON/GG/G,PGR,PGRR,PGRTH,PGRPH                                     CGG 0060
       COMMON/GG/PGTH,PGPH,PGTHTH,PGPHPH,PGTHPH,GSELECT,GTIME               CGG 0070
C                                                                           NPRM0050
C      COMMON DECK "WW" INSERTED HERE                                       CWW 0020
       PARAMETER (NWARSZ=1000)                                              CWW10030
       COMMON/WW/ID(10),MAXW,W(NWARSZ)                                      CWW10040
       REAL MAXSTP,MAXERR,INTYP,LLAT,LLON                                   CWW20020
       EQUIVALENCE (EARTHR,W(1)),(RAY,W(2)),(XMTRH,W(3)),(TLAT,W(4)),       CWW20030
     1 (TLON,W(5)),(OW,W(6)),(FBEG,W(7)),(FEND,W(8)),(FSTEP,W(9)),          CWW20040
     2 (AZ1,W(10)),(AZBEG,W(11)),(AZEND,W(12)),(AZSTEP,W(13)),              CWW20050
     3 (BETA,W(14)),(ELBEG,W(15)),(ELEND,W(16)),(ELSTEP,W(17)),             CWW20060
     8   (RUNSUP,W(18)),(RCVRH,W(20)),                                      CWW20070
     4 (ONLY,W(21)),(HOP,W(22)),(MAXSTP,W(23)),(PLAT,W(24)),(PLON,W(25))CWW20080
     5,(HMAX,W(26)),(RAYFNC,W(29)),(EXTINC,W(33)),                          CWW20090
     6 (HMIN,W(27)),(RGMAX,W(28)),                                          CWW20100
     8 (INTYP,W(41)),(MAXERR,W(42)),(ERATIO,W(43)),                         CWW20110
     6 (STEP1,W(44)),(STPMAX,W(45)),(STPMIN,W(46)),(FACTR,W(47)),           CWW20120
     7 (SKIP,W(71)),(RAYSET,W(72)),(PRTSRP,W(74)),(HITLET,W(75))            CWW20130
     9 ,(BINRAY,W(76)),(PAGLN,W(77)),(PLT,W(81)),(PFACTR,W(82)),            CWW20140
     1 (LLAT,W(83)),(LLON,W(84)),(RLAT,W(85)),(RLON,W(86))                  CWW20150
     2,(TIC,W(87)),(HB,W(88)),(HT,W(89)),(TICV,W(96))                       CWW20160
       REAL MMODEL,MFORM,MID                                                CWW30020
C                                                                           CWW30030
C      WIND         100-124                                                 CWW30040
       EQUIVALENCE (W(100),UMODEL),(W(101),UFORM),(W(102),UID)              CWW30050
C                                                                           CWW30060
C      DELTA WIND         125-149                                           CWW30070
       EQUIVALENCE (W(125),DUMODEL),(W(126),DUFORM),(W(127),DUID)           CWW30080
C                                                                           CWW30090
C      SOUND SPEED 150-174                                                  CWW30100
       EQUIVALENCE (W(150),CMODEL),(W(151),CFORM),(W(152),CID)              CWW30110
       EQUIVALENCE (W(153),REFC)                                            CWW30120
C                                                                           CWW30130
C      DELTA SOUND SPEED 175-199                                            CWW30140
       EQUIVALENCE (W(175),DCMODEL),(W(176),DCFORM),(W(177),DCID)           CWW30150
C                                                                           CWW30160
C      TEMPERATURE    200-224                                               CWW30170
       EQUIVALENCE (W(200),TMODEL),(W(201),TFORM),(W(202),TID)              CWW30180
C                                                                           CWW30190
C      DELTA TEMPERATURE    225-249                                         CWW30200
       EQUIVALENCE (W(225),DTMODEL),(W(226),DTFORM),(W(227),DTID)           CWW30210
C                                                                           CWW30220
C      MOLECULAR   250-274                                                  CWW30230
       EQUIVALENCE (W(250),MMODEL),(W(251),MFORM),(W(252),MID)              CWW30240
C                                                                           CWW30250
C      RECEIVER HEIGHT   275-299                                            CWW30260
       EQUIVALENCE (W(275),RMODEL),(W(276),RFORM),(W(277),RID)              CWW30270
C                                                                           CWW30280
C      TOPOGRAPHY   300-324                                                 CWW30290
       EQUIVALENCE (W(300),GMODEL),(W(301),GFORM),(W(302),GID)              CWW30300
C                                                                           CWW30310
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C     DELTA TOPOGRAPHY   325-349                                        CWW30320
      EQUIVALENCE (W(325),GUMODEL),(W(326),GUFORM),(W(327),GUID)        CWW30330
C                                                                       CWW30340
C     ATMOSPHERIC SURFACE TOPOGRAPHY   350-374                          CWW30350
      EQUIVALENCE (W(350),SMODEL),(W(351),SFORM),(W(352),SID)           CWW30360
C                                                                       CWW30370
C     ATMOSPHERIC SURFACE TOPOGRAPHY   375-399                          CWW30380
      EQUIVALENCE (W(375),SUMODEL),(W(376),SUFORM),(W(377),SUID)        CWW30390
C     PLOT ENHANCEMENTS CONTROL PARAMETERS                              CWW30400
C                                                                       CWW30410
      EQUIVALENCE (W(490),XFQMDL),(W(491),YFQMDL)                       CWW30420
C     ABSORPTION          500-524                                       CWW30430
      EQUIVALENCE (W(500),AMODEL),(W(501),AFORM),(W(502),AID)           CWW30440
C                                                                       CWW30450
C     DELTA ABSORPTION          525-549                                 CWW30460
      EQUIVALENCE (W(525),DAMODEL),(W(526),DAFORM),(W(527),DAID)        CWW30470
C                                                                       CWW30480
C     PRESSURE          550-574                                         CWW30490
      EQUIVALENCE (W(550),PMODEL),(W(551),PFORM),(W(552),PID)           CWW30500
C                                                                       CWW30510
C     DELTA PRESSURE          575-599                                   CWW30520
      EQUIVALENCE (W(575),DPMODEL),(W(576),DPFORM),(W(577),DPID)        CWW30530
C                                                                       CWW30540
C     COMMON DECK "B10" INSERTED HERE                                   CB9 0020
      INTEGER DGMX,DGNTBL,DGITBL,DGFRMTB,IDSDG(10)                      CB9 0040
      COMMON/B10/DGMX,DGNTBL(10),DGITBL(10),DGFRMTB(10),DGGP(10)        CB9 0050
      EQUIVALENCE (DGGP,IDSDG)                                          CB9 0060
C                                                                       NPRM0080
      INTEGER DJMX    ,DJNTBL(10),DJITBL(10),DJFRMTB(10)                NPRM0090
C                                                                       NPRM0100
      DATA DJMX/1/                                                      NPRM0110
      DATA DJNTBL/1,11,8*0/                                             NPRM0120
      DATA DJITBL/1,9*0/                                                NPRM0130
      DATA DJFRMTB/1,9*0/                                               NPRM0140
C                                                                       NPRM0150
C                                                                       NPRM0160
      ENTRY SETPTP                                                      NPRM0170
C                                                                       NPRM0180
      DGMX=DJMX                                                         NPRM0190
      CALL IMOVE(DGNTBL,DJNTBL,10)                                      NPRM0200
      CALL IMOVE(DGITBL,DJITBL,10)                                      NPRM0210
      CALL IMOVE(DGFRMTB,DJFRMTB,10)                                    NPRM0220
C                                                                       NPRM0230
      RETURN                                                            NPRM0240
C                                                                       NPRM0250
      ENTRY IPTOPOG                                                     NPRM0260
C                                                                       NPRM0270
      MODG(3)=6HNPBOTM                                                  NPRM0280
      MODG(4)=GUID                                                      NPRM0290
      ENTRY PTOPOG                                                      NPRM0300
      END                                                               NPRM0310
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      SUBROUTINE SHORIZ                                                 SHJZ0020
C     SURFACE MODEL USING FIXED OFFSET TO EARTHR'S SURFACE.             SHJZ0030
C     COMMON DECK "RKAM" INSERTED HERE                                  RKAM0020
      REAL KR,KTH,KPH                                                   RKAM0040
      COMMON//R,TH,PH,KR,KTH,KPH,RKVARS(14),TPULSE,CSTEP,DRDT(20)       RKAM0050
C     COMMON DECK "SS" INSERTED HERE                                    CSS 0020
      REAL MODSURF                                                      CSS 0040
      COMMON/SS/ MODSURF(4)                                             CSS 0050
      COMMON/SS/U,PUR,PURR,PURTH,PURPH                                  CSS 0060
      COMMON/SS/PUTH,PUPH,PUTHTH,PUPHPH,PUTHPH,USELECT,UTIME            CSS 0070
C     COMMON DECK "WW" INSERTED HERE                                    CWW 0020
      PARAMETER (NWARSZ=1000)                                           CWW10030
      COMMON/WW/ID(10),MAXW,W(NWARSZ)                                   CWW10040
      REAL MAXSTP,MAXERR,INTYP,LLAT,LLON                                CWW20020
      EQUIVALENCE (EARTHR,W(1)),(RAY,W(2)),(XMTRH,W(3)),(TLAT,W(4)),    CWW20030
     1 (TLON,W(5)),(OW,W(6)),(FBEG,W(7)),(FEND,W(8)),(FSTEP,W(9)),      CWW20040
     2 (AZ1,W(10)),(AZBEG,W(11)),(AZEND,W(12)),(AZSTEP,W(13)),          CWW20050
     3 (BETA,W(14)),(ELBEG,W(15)),(ELEND,W(16)),(ELSTEP,W(17)),         CWW20060
     8   (RUNSUP,W(18)),(RCVRH,W(20)),                                  CWW20070
     4 (ONLY,W(21)),(HOP,W(22)),(MAXSTP,W(23)),(PLAT,W(24)),(PLON,W(25))CWW20080
     5,(HMAX,W(26)),(RAYFNC,W(29)),(EXTINC,W(33)),                      CWW20090
     6 (HMIN,W(27)),(RGMAX,W(28)),                                      CWW20100
     8 (INTYP,W(41)),(MAXERR,W(42)),(ERATIO,W(43)),                     CWW20110
     6 (STEP1,W(44)),(STPMAX,W(45)),(STPMIN,W(46)),(FACTR,W(47)),       CWW20120
     7 (SKIP,W(71)),(RAYSET,W(72)),(PRTSRP,W(74)),(HITLET,W(75))        CWW20130
     9 ,(BINRAY,W(76)),(PAGLN,W(77)),(PLT,W(81)),(PFACTR,W(82)),        CWW20140
     1 (LLAT,W(83)),(LLON,W(84)),(RLAT,W(85)),(RLON,W(86))              CWW20150
     2,(TIC,W(87)),(HB,W(88)),(HT,W(89)),(TICV,W(96))                   CWW20160
      REAL MMODEL,MFORM,MID                                             CWW30020
C                                                                       CWW30030
C     WIND         100-124                                              CWW30040
      EQUIVALENCE (W(100),UMODEL),(W(101),UFORM),(W(102),UID)           CWW30050
C                                                                       CWW30060
C     DELTA WIND          125-149                                       CWW30070
      EQUIVALENCE (W(125),DUMODEL),(W(126),DUFORM),(W(127),DUID)        CWW30080
C                                                                       CWW30090
C     SOUND SPEED 150-174                                               CWW30100
      EQUIVALENCE (W(150),CMODEL),(W(151),CFORM),(W(152),CID)           CWW30110
      EQUIVALENCE (W(153),REFC)                                         CWW30120
C                                                                       CWW30130
C     DELTA SOUND SPEED 175-199                                         CWW30140
      EQUIVALENCE (W(175),DCMODEL),(W(176),DCFORM),(W(177),DCID)        CWW30150
C                                                                       CWW30160
C     TEMPERATURE    200-224                                            CWW30170
      EQUIVALENCE (W(200),TMODEL),(W(201),TFORM),(W(202),TID)           CWW30180
C                                                                       CWW30190
C     DELTA TEMPERATURE    225-249                                      CWW30200
      EQUIVALENCE (W(225),DTMODEL),(W(226),DTFORM),(W(227),DTID)        CWW30210
C                                                                       CWW30220
C     MOLECULAR   250-274                                               CWW30230
      EQUIVALENCE (W(250),MMODEL),(W(251),MFORM),(W(252),MID)           CWW30240
C                                                                       CWW30250
C     RECEIVER HEIGHT   275-299                                         CWW30260
      EQUIVALENCE (W(275),RMODEL),(W(276),RFORM),(W(277),RID)           CWW30270
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C
C     TOPOGRAPHY   300-324
      EQUIVALENCE (W(300),GMODEL),(W(301),GFORM),(W(302),GID)
C
C     DELTA TOPOGRAPHY   325-349
      EQUIVALENCE (W(325),GUMODEL),(W(326),GUFORM),(W(327),GUID)
C
C     ATMOSPHERIC SURFACE TOPOGRAPHY   350-374
      EQUIVALENCE (W(350),SMODEL),(W(351),SFORM),(W(352),SID)
C
C     ATMOSPHERIC SURFACE TOPOGRAPHY   375-399
      EQUIVALENCE (W(375),SUMODEL),(W(376),SUFORM),(W(377),SUID)
C     PLOT ENHANCEMENTS CONTROL PARAMETERS
C
      EQUIVALENCE (W(490),XFQMDL),(W(491),YFQMDL)
C     ABSORPTION          500-524
      EQUIVALENCE (W(500),AMODEL),(W(501),AFORM),(W(502),AID)
C
C     DELTA ABSORPTION          525-549
      EQUIVALENCE (W(525),DAMODEL),(W(526),DAFORM),(W(527),DAID)
C
C     PRESSURE          550-574
      EQUIVALENCE (W(550),PMODEL),(W(551),PFORM),(W(552),PID)
C
C     DELTA PRESSURE          575-599
      EQUIVALENCE (W(575),DPMODEL),(W(576),DPFORM),(W(577),DPID)
C
C
      EQUIVALENCE (W(353),SHEIGHT)
C
C     COMMON DECK "CB11" INSERTED HERE
      INTEGER SMX,SNTBL,SITBL,SFRMTBL,IDSS(10)
      COMMON/B11/SMX,SNTBL(10),SITBL(10),SFRMTBL(10),SGP(11)
      EQUIVALENCE (SGP,IDSS),(ANS,SGP(11))
C
      INTEGER SPX    ,SQTBL(10),SLTBL(10),SIRMTBL(10)
      DATA RECOSS/1.0/
C
      DATA SPX/1/
      DATA SQTBL/1,11,8*0/
      DATA SLTBL/1,9*0/
      DATA SIRMTBL/1,9*0/
C
      ENTRY SETSUR
C
      SMX=SPX
      CALL IMOVE(SNTBL,SQTBL,10)
      CALL IMOVE(SITBL,SLTBL,10)
      CALL IMOVE(SFRMTBL,SIRMTBL,10)
      CALL SETPSR
C
      RETURN
C
      ENTRY ISURFAC
C
```

```
      IF(RECOSS .NE. SMODEL)                                             SHJZ0320
     1   CALL RERROR('SURFACE','WRNG MODEL', RECOSS)                     SHJZ0330
      MODSURF(1)=6HSHORIZ                                                SHJZ0340
      MODSURF(2)=SID                                                     SHJZ0350
C     CALL THE PERTURBATION INITIALIZATION                               SHJZ0360
      CALL IPSURF                                                        SHJZ0370
      RETURN                                                             SHJZ0380
C                                                                        SHJZ0390
      ENTRY SURFACE                                                      SHJZ0400
      U=-(R-EARTHR-SHEIGHT)                                              SHJZ0410
      PUR=-1.0                                                           SHJZ0420
      CALL CLEAR(PURR,8)                                                 SHJZ0430
C     CALL THE PERTURBATION                                              SHJZ0440
      CALL PSURFCE                                                       SHJZ0450
      END                                                                SHJZ0460
```

```
      SUBROUTINE NPSURF                                                  NPPF0020
C     DO-NOTHING SURFACE PERTURBATION MODEL                              NPPF0030
C     COMMON DECK "SS" INSERTED HERE                                     CSS 0020
      REAL MODSURF                                                       CSS 0040
      COMMON/SS/ MODSURF(4)                                              CSS 0050
      COMMON/SS/U,PUR,PURR,PURTH,PURPH                                   CSS 0060
      COMMON/SS/PUTH,PUPH,PUTHTH,PUPHPH,PUTHPH,USELECT,UTIME             CSS 0070
C     COMMON DECK "WW" INSERTED HERE                                     CWW 0020
      PARAMETER (NWARSZ=1000)                                            CWW10030
      COMMON/WW/ID(10),MAXW,W(NWARSZ)                                    CWW10040
      REAL MAXSTP,MAXERR,INTYP,LLAT,LLON                                 CWW20020
      EQUIVALENCE (EARTHR,W(1)),(RAY,W(2)),(XMTRH,W(3)),(TLAT,W(4)),     CWW20030
     1 (TLON,W(5)),(OW,W(6)),(FBEG,W(7)),(FEND,W(8)),(FSTEP,W(9)),       CWW20040
     2 (AZ1,W(10)),(AZBEG,W(11)),(AZEND,W(12)),(AZSTEP,W(13)),           CWW20050
     3 (BETA,W(14)),(ELBEG,W(15)),(ELEND,W(16)),(ELSTEP,W(17)),          CWW20060
     8   (RUNSUP,W(18)),(RCVRH,W(20)),                                   CWW20070
     4 (ONLY,W(21)),(HOP,W(22)),(MAXSTP,W(23)),(PLAT,W(24)),(PLON,W(25))CWW20080
     5,(HMAX,W(26)),(RAYFNC,W(29)),(EXTINC,W(33)),                       CWW20090
     6 (HMIN,W(27)),(RGMAX,W(28)),                                       CWW20100
     8 (INTYP,W(41)),(MAXERR,W(42)),(ERATIO,W(43)),                      CWW20110
     6 (STEP1,W(44)),(STPMAX,W(45)),(STPMIN,W(46)),(FACTR,W(47)),        CWW20120
     7 (SKIP,W(71)),(RAYSET,W(72)),(PRTSRP,W(74)),(HITLET,W(75))         CWW20130
     9 ,(BINRAY,W(76)),(PAGLN,W(77)),(PLT,W(81)),(PFACTR,W(82)),         CWW20140
     1 (LLAT,W(83)),(LLON,W(84)),(RLAT,W(85)),(RLON,W(86))               CWW20150
     2,(TIC,W(87)),(HB,W(88)),(HT,W(89)),(TICV,W(96))                    CWW20160
      REAL MMODEL,MFORM,MID                                              CWW30020
C                                                                        CWW30030
C     WIND         100-124                                               CWW30040
      EQUIVALENCE (W(100),UMODEL),(W(101),UFORM),(W(102),UID)            CWW30050
C                                                                        CWW30060
C     DELTA WIND         125-149                                         CWW30070
      EQUIVALENCE (W(125),DUMODEL),(W(126),DUFORM),(W(127),DUID)         CWW30080
C                                                                        CWW30090
C     SOUND SPEED 150-174                                                CWW30100
      EQUIVALENCE (W(150),CMODEL),(W(151),CFORM),(W(152),CID)            CWW30110
```

```
      EQUIVALENCE (W(153),REFC)
C
C     DELTA SOUND SPEED 175-199
      EQUIVALENCE (W(175),DCMODEL),(W(176),DCFORM),(W(177),DCID)
C
C     TEMPERATURE    200-224
      EQUIVALENCE (W(200),TMODEL),(W(201),TFORM),(W(202),TID)
C
C     DELTA TEMPERATURE    225-249
      EQUIVALENCE (W(225),DTMODEL),(W(226),DTFORM),(W(227),DTID)
C
C     MOLECULAR   250-274
      EQUIVALENCE (W(250),MMODEL),(W(251),MFORM),(W(252),MID)
C
C     RECEIVER HEIGHT   275-299
      EQUIVALENCE (W(275),RMODEL),(W(276),RFORM),(W(277),RID)
C
C     TOPOGRAPHY   300-324
      EQUIVALENCE (W(300),GMODEL),(W(301),GFORM),(W(302),GID)
C
C     DELTA TOPOGRAPHY   325-349
      EQUIVALENCE (W(325),GUMODEL),(W(326),GUFORM),(W(327),GUID)
C
C     ATMOSPHERIC SURFACE TOPOGRAPHY   350-374
      EQUIVALENCE (W(350),SMODEL),(W(351),SFORM),(W(352),SID)
C
C     ATMOSPHERIC SURFACE TOPOGRAPHY   375-399
      EQUIVALENCE (W(375),SUMODEL),(W(376),SUFORM),(W(377),SUID)
C     PLOT ENHANCEMENTS CONTROL PARAMETERS
C
      EQUIVALENCE (W(490),XFQMDL),(W(491),YFQMDL)
C     ABSORPTION         500-524
      EQUIVALENCE (W(500),AMODEL),(W(501),AFORM),(W(502),AID)
C
C     DELTA ABSORPTION           525-549
      EQUIVALENCE (W(525),DAMODEL),(W(526),DAFORM),(W(527),DAID)
C
C     PRESSURE            550-574
      EQUIVALENCE (W(550),PMODEL),(W(551),PFORM),(W(552),PID)
C
C     DELTA PRESSURE            575-599
      EQUIVALENCE (W(575),DPMODEL),(W(576),DPFORM),(W(577),DPID)
C
C     COMMON DECK "CB12" INSERTED HERE
      INTEGER DSMX,DSNTBL,DSITBL,DSFRMTB,IDSDS(10)
      COMMON/B12/DSMX,DSNTBL(10),DSITBL(10),DSFRMTB(10),DSGP(11)
      EQUIVALENCE (DSGP,IDSDS),(ANDS,DSGP(11))
      INTEGER DVMX     ,DVNTBL(10),DVITBL(10),DVFRMTB(10)
      DATA RECOGSU/0.0/
C
      DATA DVMX/1/
      DATA DVNTBL/1,11,8*0/
      DATA DVITBL/1,9*0/
      DATA DVFRMTB/1,9*0/
C
```

```
      ENTRY SETPSR                                                      NPPF0150
C                                                                       NPPF0160
      DSMX=DVMX                                                         NPPF0170
      CALL IMOVE(DSNTBL,DVNTBL,10)                                      NPPF0180
      CALL IMOVE(DSITBL,DVITBL,10)                                      NPPF0190
      CALL IMOVE(DSFRMTB,DVFRMTB,10)                                    NPPF0200
C                                                                       NPPF0210
      RETURN                                                            NPPF0220
C                                                                       NPPF0230
      ENTRY IPSURF                                                      NPPF0240
      IF(RECOGSU .NE. SUMODEL)                                          NPPF0250
     1    CALL RERROR('DSURF ','WRNG MODEL',RECOGSU)                    NPPF0260
      MODSURF(3)=6HNPSURF                                               NPPF0270
      MODSURF(4)=SUID                                                   NPPF0280
      RETURN                                                            NPPF0290
C                                                                       NPPF0300
      ENTRY PSURFCE                                                     NPPF0310
      RETURN                                                            NPPF0320
      END                                                               NPPF0330
```

```
      SUBROUTINE RHORIZ                                                 RHJZ0020
C     RECEIVER MODEL USING FIXED OFFSET TO EARTHR'S SURFACE.            RHJZ0030
C     COMMON DECK "RR" INSERTED HERE                                    CRR 0020
      REAL MODREC                                                       CRR 0040
      COMMON/RR/ MODREC(4)                                              CRR 0050
      COMMON/RR/F,PFR,PFRR,PFRTH,PFRPH                                  CRR 0060
      COMMON/RR/PFTH,PFPH,PFTHTH,PFPHPH,PFTHPH,FSELECT,FTIME            CRR 0070
C     COMMON DECK "WW" INSERTED HERE                                    CWW 0020
      PARAMETER (NWARSZ=1000)                                           CWW10030
      COMMON/WW/ID(10),MAXW,W(NWARSZ)                                   CWW10040
      REAL MAXSTP,MAXERR,INTYP,LLAT,LLON                                CWW20020
      EQUIVALENCE (EARTHR,W(1)),(RAY,W(2)),(XMTRH,W(3)),(TLAT,W(4)),    CWW20030
     1 (TLON,W(5)),(OW,W(6)),(FBEG,W(7)),(FEND,W(8)),(FSTEP,W(9)),      CWW20040
     2 (AZ1,W(10)),(AZBEG,W(11)),(AZEND,W(12)),(AZSTEP,W(13)),          CWW20050
     3 (BETA,W(14)),(ELBEG,W(15)),(ELEND,W(16)),(ELSTEP,W(17)),         CWW20060
     8   (RUNSUP,W(18)),(RCVRH,W(20)),                                  CWW20070
     4 (ONLY,W(21)),(HOP,W(22)),(MAXSTP,W(23)),(PLAT,W(24)),(PLON,W(25))CWW20080
     5,(HMAX,W(26)),(RAYFNC,W(29)),(EXTINC,W(33)),                      CWW20090
     6 (HMIN,W(27)),(RGMAX,W(28)),                                      CWW20100
     8 (INTYP,W(41)),(MAXERR,W(42)),(ERATIO,W(43)),                     CWW20110
     6 (STEP1,W(44)),(STPMAX,W(45)),(STPMIN,W(46)),(FACTR,W(47)),       CWW20120
     7 (SKIP,W(71)),(RAYSET,W(72)),(PRTSRP,W(74)),(HITLET,W(75))        CWW20130
     9 ,(BINRAY,W(76)),(PAGLN,W(77)),(PLT,W(81)),(PFACTR,W(82)),        CWW20140
     1 (LLAT,W(83)),(LLON,W(84)),(RLAT,W(85)),(RLON,W(86))              CWW20150
     2,(TIC,W(87)),(HB,W(88)),(HT,W(89)),(TICV,W(96))                   CWW20160
      REAL MMODEL,MFORM,MID                                             CWW30020
C                                                                       CWW30030
C     WIND         100-124                                              CWW30040
      EQUIVALENCE (W(100),UMODEL),(W(101),UFORM),(W(102),UID)           CWW30050
C                                                                       CWW30060
C     DELTA WIND         125-149                                        CWW30070
```

```
      EQUIVALENCE (W(125),DUMODEL),(W(126),DUFORM),(W(127),DUID)        CWW30080
C                                                                       CWW30090
C     SOUND SPEED 150-174                                               CWW30100
      EQUIVALENCE (W(150),CMODEL),(W(151),CFORM),(W(152),CID)           CWW30110
      EQUIVALENCE (W(153),REFC)                                         CWW30120
C                                                                       CWW30130
C     DELTA SOUND SPEED 175-199                                         CWW30140
      EQUIVALENCE (W(175),DCMODEL),(W(176),DCFORM),(W(177),DCID)        CWW30150
C                                                                       CWW30160
C     TEMPERATURE    200-224                                            CWW30170
      EQUIVALENCE (W(200),TMODEL),(W(201),TFORM),(W(202),TID)           CWW30180
C                                                                       CWW30190
C     DELTA TEMPERATURE    225-249                                      CWW30200
      EQUIVALENCE (W(225),DTMODEL),(W(226),DTFORM),(W(227),DTID)        CWW30210
C                                                                       CWW30220
C     MOLECULAR   250-274                                               CWW30230
      EQUIVALENCE (W(250),MMODEL),(W(251),MFORM),(W(252),MID)           CWW30240
C                                                                       CWW30250
C     RECEIVER HEIGHT   275-299                                         CWW30260
      EQUIVALENCE (W(275),RMODEL),(W(276),RFORM),(W(277),RID)           CWW30270
C                                                                       CWW30280
C     TOPOGRAPHY   300-324                                              CWW30290
      EQUIVALENCE (W(300),GMODEL),(W(301),GFORM),(W(302),GID)           CWW30300
C                                                                       CWW30310
C     DELTA TOPOGRAPHY   325-349                                        CWW30320
      EQUIVALENCE (W(325),GUMODEL),(W(326),GUFORM),(W(327),GUID)        CWW30330
C                                                                       CWW30340
C     ATMOSPHERIC SURFACE TOPOGRAPHY   350-374                          CWW30350
      EQUIVALENCE (W(350),SMODEL),(W(351),SFORM),(W(352),SID)           CWW30360
C                                                                       CWW30370
C     ATMOSPHERIC SURFACE TOPOGRAPHY   375-399                          CWW30380
      EQUIVALENCE (W(375),SUMODEL),(W(376),SUFORM),(W(377),SUID)        CWW30390
C     PLOT ENHANCEMENTS CONTROL PARAMETERS                              CWW30400
C                                                                       CWW30410
      EQUIVALENCE (W(490),XFQMDL),(W(491),YFQMDL)                       CWW30420
C     ABSORPTION          500-524                                       CWW30430
      EQUIVALENCE (W(500),AMODEL),(W(501),AFORM),(W(502),AID)           CWW30440
C                                                                       CWW30450
C     DELTA ABSORPTION          525-549                                 CWW30460
      EQUIVALENCE (W(525),DAMODEL),(W(526),DAFORM),(W(527),DAID)        CWW30470
C                                                                       CWW30480
C     PRESSURE          550-574                                         CWW30490
      EQUIVALENCE (W(550),PMODEL),(W(551),PFORM),(W(552),PID)           CWW30500
C                                                                       CWW30510
C     DELTA PRESSURE          575-599                                   CWW30520
      EQUIVALENCE (W(575),DPMODEL),(W(576),DPFORM),(W(577),DPID)        CWW30530
C                                                                       CWW30540
C     COMMON DECK "RKAM" INSERTED HERE                                  RKAM0020
      REAL KR,KTH,KPH                                                   RKAM0040
      COMMON//R,TH,PH,KR,KTH,KPH,RKVARS(14),TPULSE,CSTEP,DRDT(20)       RKAM0050
C                                                                       RHJZ0070
C     COMMON DECK "B8" INSERTED HERE                                    CB100020
      INTEGER RMX,RNTBL,RITBL,RFRMTBL,IDSR(10)                          CB100040
      COMMON/B8/RMX,RNTBL(10),RITBL(10),RFRMTBL(10),RGP(10)             CB100050
      EQUIVALENCE (RGP,IDSR)                                            CB100060
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C                                                                       RHJZ0090
      INTEGER RPX    ,RQTBL(10),RLTBL(10),RIRMTBL(10)                   RHJZ0100
      DATA RECORR/1.0/                                                  RHJZ0110
C                                                                       RHJZ0120
      DATA RPX/1/                                                       RHJZ0130
      DATA RQTBL/1,11,8*0/                                              RHJZ0140
      DATA RLTBL/1,9*0/                                                 RHJZ0150
      DATA RIRMTBL/1,9*0/                                               RHJZ0160
C                                                                       RHJZ0170
      ENTRY SETRCV                                                      RHJZ0180
C                                                                       RHJZ0190
      RMX=RPX                                                           RHJZ0200
      CALL IMOVE(RNTBL,RQTBL,10)                                        RHJZ0210
      CALL IMOVE(RITBL,RLTBL,10)                                        RHJZ0220
      CALL IMOVE(RFRMTBL,RIRMTBL,10)                                    RHJZ0230
C                                                                       RHJZ0240
      RETURN                                                            RHJZ0250
C                                                                       RHJZ0260
      ENTRY IRECVR                                                      RHJZ0270
C                                                                       RHJZ0280
      IF(RECORR .NE. RMODEL)                                            RHJZ0290
     1    CALL RERROR('RECEIVR','WRNG MODEL',RECORR)                    RHJZ0300
C                                                                       RHJZ0310
      MODREC(1)=6HRHORIZ                                                RHJZ0320
      MODREC(2)=RID                                                     RHJZ0330
      RETURN                                                            RHJZ0340
C                                                                       RHJZ0350
      ENTRY RECEVER                                                     RHJZ0360
      F=R-W(1)-W(20)                                                    RHJZ0370
      PFR=1.0                                                           RHJZ0380
      CALL CLEAR(PFRR,8)                                                RHJZ0390
      END                                                               RHJZ0400


      SUBROUTINE RBOTM                                                  RBIM0020
C     RECEIVER MODEL USING FIXED OFFSET TO TERRAIN HEIGHT               RBIM0030
C     COMMON DECK "RKAM" INSERTED HERE                                  RKAM0020
      REAL KR,KTH,KPH                                                   RKAM0040
      COMMON//R,TH,PH,KR,KTH,KPH,RKVARS(14),TPULSE,CSTEP,DRDT(20)       RKAM0050
C     COMMON DECK "WW" INSERTED HERE                                    CWW 0020
      PARAMETER (NWARSZ=1000)                                           CWW10030
      COMMON/WW/ID(10),MAXW,W(NWARSZ)                                   CWW10040
      REAL MAXSTP,MAXERR,INTYP,LLAT,LLON                                CWW20020
      EQUIVALENCE (EARTHR,W(1)),(RAY,W(2)),(XMTRH,W(3)),(TLAT,W(4)),    CWW20030
     1 (TLON,W(5)),(OW,W(6)),(FBEG,W(7)),(FEND,W(8)),(FSTEP,W(9)),      CWW20040
     2 (AZ1,W(10)),(AZBEG,W(11)),(AZEND,W(12)),(AZSTEP,W(13)),          CWW20050
     3 (BETA,W(14)),(ELBEG,W(15)),(ELEND,W(16)),(ELSTEP,W(17)),         CWW20060
     8   (RUNSUP,W(18)),(RCVRH,W(20)),                                  CWW20070
     4 (ONLY,W(21)),(HOP,W(22)),(MAXSTP,W(23)),(PLAT,W(24)),(PLON,W(25))CWW20080
     5,(HMAX,W(26)),(RAYFNC,W(29)),(EXTINC,W(33)),                      CWW20090
     6 (HMIN,W(27)),(RGMAX,W(28)),                                      CWW20100
     8 (INTYP,W(41)),(MAXERR,W(42)),(ERATIO,W(43)),                     CWW20110
```

```
      6 (STEP1,W(44)),(STPMAX,W(45)),(STPMIN,W(46)),(FACTR,W(47)),
      7 (SKIP,W(71)),(RAYSET,W(72)),(PRTSRP,W(74)),(HITLET,W(75))
      9 ,(BINRAY,W(76)),(PAGLN,W(77)),(PLT,W(81)),(PFACTR,W(82)),
      1 (LLAT,W(83)),(LLON,W(84)),(RLAT,W(85)),(RLON,W(86))
      2,(TIC,W(87)),(HB,W(88)),(HT,W(89)),(TICV,W(96))
       REAL MMODEL,MFORM,MID
C
C      WIND           100-124
       EQUIVALENCE (W(100),UMODEL),(W(101),UFORM),(W(102),UID)
C
C      DELTA WIND           125-149
       EQUIVALENCE (W(125),DUMODEL),(W(126),DUFORM),(W(127),DUID)
C
C      SOUND SPEED 150-174
       EQUIVALENCE (W(150),CMODEL),(W(151),CFORM),(W(152),CID)
       EQUIVALENCE (W(153),REFC)
C
C      DELTA SOUND SPEED 175-199
       EQUIVALENCE (W(175),DCMODEL),(W(176),DCFORM),(W(177),DCID)
C
C      TEMPERATURE       200-224
       EQUIVALENCE (W(200),TMODEL),(W(201),TFORM),(W(202),TID)
C
C      DELTA TEMPERATURE      225-249
       EQUIVALENCE (W(225),DTMODEL),(W(226),DTFORM),(W(227),DTID)
C
C      MOLECULAR    250-274
       EQUIVALENCE (W(250),MMODEL),(W(251),MFORM),(W(252),MID)
C
C      RECEIVER HEIGHT    275-299
       EQUIVALENCE (W(275),RMODEL),(W(276),RFORM),(W(277),RID)
C
C      TOPOGRAPHY    300-324
       EQUIVALENCE (W(300),GMODEL),(W(301),GFORM),(W(302),GID)
C
C      DELTA TOPOGRAPHY    325-349
       EQUIVALENCE (W(325),GUMODEL),(W(326),GUFORM),(W(327),GUID)
C
C      ATMOSPHERIC SURFACE TOPOGRAPHY    350-374
       EQUIVALENCE (W(350),SMODEL),(W(351),SFORM),(W(352),SID)
C
C      ATMOSPHERIC SURFACE TOPOGRAPHY    375-399
       EQUIVALENCE (W(375),SUMODEL),(W(376),SUFORM),(W(377),SUID)
C      PLOT ENHANCEMENTS CONTROL PARAMETERS
C
       EQUIVALENCE (W(490),XFQMDL),(W(491),YFQMDL)
C      ABSORPTION          500-524
       EQUIVALENCE (W(500),AMODEL),(W(501),AFORM),(W(502),AID)
C
C      DELTA ABSORPTION          525-549
       EQUIVALENCE (W(525),DAMODEL),(W(526),DAFORM),(W(527),DAID)
C
C      PRESSURE          550-574
       EQUIVALENCE (W(550),PMODEL),(W(551),PFORM),(W(552),PID)
C
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C     DELTA PRESSURE         575-599                                    CWW30520
      EQUIVALENCE (W(575),DPMODEL),(W(576),DPFORM),(W(577),DPID)        CWW30530
C                                                                       CWW30540
C     COMMON DECK "RR" INSERTED HERE                                    CRR 0020
      REAL MODREC                                                       CRR 0040
      COMMON/RR/ MODREC(4)                                              CRR 0050
      COMMON/RR/F,PFR,PFRR,PFRTH,PFRPH                                  CRR 0060
      COMMON/RR/PFTH,PFPH,PFTHTH,PFPHPH,PFTHPH,FSELECT,FTIME            CRR 0070
C     COMMON DECK "GG" INSERTED HERE                                    CGG 0020
      REAL MODG                                                         CGG 0040
      COMMON/GG/MODG(4)                                                 CGG 0050
      COMMON/GG/G,PGR,PGRR,PGRTH,PGRPH                                  CGG 0060
      COMMON/GG/PGTH,PGPH,PGTHTH,PGPHPH,PGTHPH,GSELECT,GTIME            CGG 0070
C                                                                       RBIM0080
C     COMMON DECK "B8" INSERTED HERE                                    CB100020
      INTEGER RMX,RNTBL,RITBL,RFRMTBL,IDSR(10)                          CB100040
      COMMON/B8/RMX,RNTBL(10),RITBL(10),RFRMTBL(10),RGP(10)             CB100050
      EQUIVALENCE (RGP,IDSR)                                            CB100060
C                                                                       RBIM0100
      INTEGER RPX    ,RQTBL(10),RLTBL(10),RIRMTBL(10)                   RBIM0110
C                                                                       RBIM0120
      DATA RPX/1/                                                       RBIM0130
      DATA RQTBL/1,11,8*0/                                              RBIM0140
      DATA RLTBL/1,9*0/                                                 RBIM0150
      DATA RIRMTBL/1,9*0/                                               RBIM0160
C                                                                       RBIM0170
      DATA RECORR/2.0/                                                  RBIM0180
C                                                                       RBIM0190
      ENTRY SETRCV                                                      RBIM0200
C                                                                       RBIM0210
      RMX=RPX                                                           RBIM0220
      CALL IMOVE(RNTBL,RQTBL,10)                                        RBIM0230
      CALL IMOVE(RITBL,RLTBL,10)                                        RBIM0240
      CALL IMOVE(RFRMTBL,RIRMTBL,10)                                    RBIM0250
C                                                                       RBIM0260
      RETURN                                                            RBIM0270
C                                                                       RBIM0280
      ENTRY IRECVR                                                      RBIM0290
C                                                                       RBIM0300
      IF(RECORR .NE. RMODEL)                                            RBIM0310
     1    CALL RERROR('RECEIVR','WRNG MODEL',RECORR)                    RBIM0320
      MODREC(1)=5HRBOTM                                                 RBIM0330
      MODREC(2)=RID                                                     RBIM0340
      RETURN                                                            RBIM0350
C                                                                       RBIM0360
      ENTRY RECEVER                                                     RBIM0370
C     GET CURRENT TERRAIN HEIGHT(MUST USE GET1 TO AVOID RECURSION       RBIM0380
C     SINCE WE ARE PROBABLY BEING CALLED BY GET RIGHT NOW)              RBIM0390
      F=GET1(G)-W(20)                                                   RBIM0400
      CALL RMOVE(PFR,PGR,9)                                             RBIM0410
      END                                                               RBIM0420
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      SUBROUTINE RVERT
C     VERTICAL(CONICAL) RECEIVER SURFACE AT A FIXED RADIUS FROM         RVRT0020
C     A SPECIFIED ORIGIN.                                               RVRT0030
C                                                                       RVRT0040
C     COMMON DECK "RKAM" INSERTED HERE                                  RVRT0050
      REAL KR,KTH,KPH                                                   RKAM0020
      COMMON//R,TH,PH,KR,KTH,KPH,RKVARS(14),TPULSE,CSTEP,DRDT(20)       RKAM0040
C     COMMON DECK "RR" INSERTED HERE                                    RKAM0050
      REAL MODREC                                                       CRR 0020
      COMMON/RR/ MODREC(4)                                              CRR 0040
      COMMON/RR/F,PFR,PFRR,PFRTH,PFRPH                                  CRR 0050
      COMMON/RR/PFTH,PFPH,PFTHTH,PFPHPH,PFTHPH,FSELECT,FTIME            CRR 0060
C     COMMON DECK "B8" INSERTED HERE                                    CRR 0070
      INTEGER RMX,RNTBL,RITBL,RFRMTBL,IDSR(10)                          CB100020
      COMMON/B8/RMX,RNTBL(10),RITBL(10),RFRMTBL(10),RGP(10)             CB100040
      EQUIVALENCE (RGP,IDSR)                                            CB100050
C     COMMON DECK "GAMANG" INSERTED HERE                                CB100060
      COMMON/SPHGAM/SINLM0,COSLM0,GPH0,COSPHD,SINTH,COSTH               CGAM0020
      COMMON/SPHGAM/GAMFUN,PGMTH,PGMPH,PGMTHTH,PGMPHPH,PGMTHPH          CGAM0040
C     COMMON DECK "WW" INSERTED HERE                                    CGAM0050
      PARAMETER (NWARSZ=1000)                                           CWW 0020
      COMMON/WW/ID(10),MAXW,W(NWARSZ)                                   CWW10030
      REAL MAXSTP,MAXERR,INTYP,LLAT,LLON                                CWW10040
      EQUIVALENCE (EARTHR,W(1)),(RAY,W(2)),(XMTRH,W(3)),(TLAT,W(4)),    CWW20020
     1 (TLON,W(5)),(OW,W(6)),(FBEG,W(7)),(FEND,W(8)),(FSTEP,W(9)),      CWW20030
     2 (AZ1,W(10)),(AZBEG,W(11)),(AZEND,W(12)),(AZSTEP,W(13)),          CWW20040
     3 (BETA,W(14)),(ELBEG,W(15)),(ELEND,W(16)),(ELSTEP,W(17)),         CWW20050
     8   (RUNSUP,W(18)),(RCVRH,W(20)),                                  CWW20060
     4 (ONLY,W(21)),(HOP,W(22)),(MAXSTP,W(23)),(PLAT,W(24)),(PLON,W(25))CWW20070
     5,(HMAX,W(26)),(RAYFNC,W(29)),(EXTINC,W(33)),                      CWW20080
     6 (HMIN,W(27)),(RGMAX,W(28)),                                      CWW20090
     8 (INTYP,W(41)),(MAXERR,W(42)),(ERATIO,W(43)),                     CWW20100
     6 (STEP1,W(44)),(STPMAX,W(45)),(STPMIN,W(46)),(FACTR,W(47)),       CWW20110
     7 (SKIP,W(71)),(RAYSET,W(72)),(PRTSRP,W(74)),(HITLET,W(75))        CWW20120
     9 ,(BINRAY,W(76)),(PAGLN,W(77)),(PLT,W(81)),(PFACTR,W(82)),        CWW20130
     1 (LLAT,W(83)),(LLON,W(84)),(RLAT,W(85)),(RLON,W(86))              CWW20140
     2,(TIC,W(87)),(HB,W(88)),(HT,W(89)),(TICV,W(96))                   CWW20150
      REAL MMODEL,MFORM,MID                                             CWW20160
C                                                                       CWW30020
C     WIND         100-124                                              CWW30030
      EQUIVALENCE (W(100),UMODEL),(W(101),UFORM),(W(102),UID)           CWW30040
C                                                                       CWW30050
C     DELTA WIND         125-149                                        CWW30060
      EQUIVALENCE (W(125),DUMODEL),(W(126),DUFORM),(W(127),DUID)        CWW30070
C                                                                       CWW30080
C     SOUND SPEED 150-174                                               CWW30090
      EQUIVALENCE (W(150),CMODEL),(W(151),CFORM),(W(152),CID)           CWW30100
      EQUIVALENCE (W(153),REFC)                                         CWW30110
C                                                                       CWW30120
C     DELTA SOUND SPEED 175-199                                         CWW30130
      EQUIVALENCE (W(175),DCMODEL),(W(176),DCFORM),(W(177),DCID)        CWW30140
C                                                                       CWW30150
C     TEMPERATURE     200-224                                           CWW30160
      EQUIVALENCE (W(200),TMODEL),(W(201),TFORM),(W(202),TID)           CWW30170
                                                                        CWW30180
```

```
C                                                                       CWW30190
C     DELTA TEMPERATURE    225-249                                      CWW30200
      EQUIVALENCE (W(225),DTMODEL),(W(226),DTFORM),(W(227),DTID)        CWW30210
C                                                                       CWW30220
C     MOLECULAR   250-274                                               CWW30230
      EQUIVALENCE (W(250),MMODEL),(W(251),MFORM),(W(252),MID)           CWW30240
C                                                                       CWW30250
C     RECEIVER HEIGHT   275-299                                         CWW30260
      EQUIVALENCE (W(275),RMODEL),(W(276),RFORM),(W(277),RID)           CWW30270
C                                                                       CWW30280
C     TOPOGRAPHY   300-324                                              CWW30290
      EQUIVALENCE (W(300),GMODEL),(W(301),GFORM),(W(302),GID)           CWW30300
C                                                                       CWW30310
C     DELTA TOPOGRAPHY   325-349                                        CWW30320
      EQUIVALENCE (W(325),GUMODEL),(W(326),GUFORM),(W(327),GUID)        CWW30330
C                                                                       CWW30340
C     ATMOSPHERIC SURFACE TOPOGRAPHY   350-374                          CWW30350
      EQUIVALENCE (W(350),SMODEL),(W(351),SFORM),(W(352),SID)           CWW30360
C                                                                       CWW30370
C     ATMOSPHERIC SURFACE TOPOGRAPHY   375-399                          CWW30380
      EQUIVALENCE (W(375),SUMODEL),(W(376),SUFORM),(W(377),SUID)        CWW30390
C     PLOT ENHANCEMENTS CONTROL PARAMETERS                              CWW30400
C                                                                       CWW30410
      EQUIVALENCE (W(490),XFQMDL),(W(491),YFQMDL)                       CWW30420
C     ABSORPTION           500-524                                      CWW30430
      EQUIVALENCE (W(500),AMODEL),(W(501),AFORM),(W(502),AID)           CWW30440
C                                                                       CWW30450
C     DELTA ABSORPTION           525-549                                CWW30460
      EQUIVALENCE (W(525),DAMODEL),(W(526),DAFORM),(W(527),DAID)        CWW30470
C                                                                       CWW30480
C     PRESSURE          550-574                                         CWW30490
      EQUIVALENCE (W(550),PMODEL),(W(551),PFORM),(W(552),PID)           CWW30500
C                                                                       CWW30510
C     DELTA PRESSURE          575-599                                   CWW30520
      EQUIVALENCE (W(575),DPMODEL),(W(576),DPFORM),(W(577),DPID)        CWW30530
C                                                                       CWW30540
      EQUIVALENCE (RVALPHO,W(278)) ,(RVLAMZ,W(279)), (RVPHO,W(280))     RVRT0110
C                                                                       RVRT0120
      INTEGER RPX    ,RQTBL(10),RLTBL(10),RIRMTBL(10)                   RVRT0130
C                                                                       RVRT0140
      DATA RPX/1/                                                       RVRT0150
      DATA RQTBL/1,11,8*0/                                              RVRT0160
      DATA RLTBL/1,9*0/                                                 RVRT0170
      DATA RIRMTBL/1,9*0/                                               RVRT0180
      DATA RECORR/(1.0 struck out)/                                     RVRT0190
C                3.0                                                    RVRT0200
      ENTRY SETRCV                                                      RVRT0210
C                                                                       RVRT0220
      RMX=RPX                                                           RVRT0230
      CALL IMOVE(RNTBL,RQTBL,10)                                        RVRT0240
      CALL IMOVE(RITBL,RLTBL,10)                                        RVRT0250
      CALL IMOVE(RFRMTBL,RIRMTBL,10)                                    RVRT0260
C                                                                       RVRT0270
      RETURN                                                            RVRT0280
C                                                                       RVRT0290
```

```
      ENTRY IRECVR                                                      RVRT0300
C                                                                       RVRT0310
      IF(RECORR .NE. RMODEL)                                            RVRT0320
     1    CALL RERROR(7HRECEIVR  ,10HWRNG MODEL ,RECORR)                RVRT0330
      MODREC(1)=7HRVERT                                                 RVRT0340
      MODREC(2)=RID                                                     RVRT0350
C                                                                       RVRT0360
      SINLMZ=SIN(RVLAMZ)                                                RVRT0370
      COSLMZ=COS(RVLAMZ)                                                RVRT0380
      COSALP=COS(RVALPH0)                                               RVRT0390
C                                                                       RVRT0400
      RETURN                                                            RVRT0410
C                                                                       RVRT0420
      ENTRY RECEVER                                                     RVRT0430
C                                                                       RVRT0440
      SINLM0=SINLMZ                                                     RVRT0450
      COSLM0=COSLMZ                                                     RVRT0460
      GPH0=RVPH0                                                        RVRT0470
C                                                                       RVRT0480
      CALL GAMANG(TH,PH)                                                RVRT0490
C                                                                       RVRT0500
      F=GAMFUN-COSALP                                                   RVRT0510
      PFR=0.0                                                           RVRT0520
      CALL RMOVE(PFTH,PGMTH,5)                                          RVRT0530
C                                                                       RVRT0540
      RETURN                                                            RVRT0550
      END                                                               RVRT0560
```

```
      SUBROUTINE SMPANN                                                 SMQN0020
C     ANNOTATION MODEL FOR MINIMUM GRAPHICS SUPPORT                     SMQN0030
C                                                                       SMQN0040
      CHARACTER*(*) S,C                                                 SMQN0050
C                                                                       SMQN0060
C     INITIALIZES PLOT IN DRAFT MODE(DOES NOT REQUIRE DISSPLA)          SMQN0070
C                                                                       SMQN0080
C     COMMON DECK "WWR" INSERTED HERE                                   CWWR0020
      PARAMETER (NWARSZ=1000)                                           CWW10030
      COMMON/WW/ID(10),MAXW,W(NWARSZ)                                   CWW10040
      REAL MAXSTP,MAXERR,INTYP,LLAT,LLON                                CWW20020
      EQUIVALENCE (EARTHR,W(1)),(RAY,W(2)),(XMTRH,W(3)),(TLAT,W(4)),    CWW20030
     1 (TLON,W(5)),(OW,W(6)),(FBEG,W(7)),(FEND,W(8)),(FSTEP,W(9)),      CWW20040
     2 (AZ1,W(10)),(AZBEG,W(11)),(AZEND,W(12)),(AZSTEP,W(13)),          CWW20050
     3 (BETA,W(14)),(ELBEG,W(15)),(ELEND,W(16)),(ELSTEP,W(17)),         CWW20060
     8   (RUNSUP,W(18)),(RCVRH,W(20)),                                  CWW20070
     4 (ONLY,W(21)),(HOP,W(22)),(MAXSTP,W(23)),(PLAT,W(24)),(PLON,W(25))CWW20080
     5,(HMAX,W(26)),(RAYFNC,W(29)),(EXTINC,W(33)),                      CWW20090
     6 (HMIN,W(27)),(RGMAX,W(28)),                                      CWW20100
     8 (INTYP,W(41)),(MAXERR,W(42)),(ERATIO,W(43)),                     CWW20110
     6 (STEP1,W(44)),(STPMAX,W(45)),(STPMIN,W(46)),(FACTR,W(47)),       CWW20120
     7 (SKIP,W(71)),(RAYSET,W(72)),(PRTSRP,W(74)),(HITLET,W(75))        CWW20130
     9 ,(BINRAY,W(76)),(PAGLN,W(77)),(PLT,W(81)),(PFACTR,W(82)),        CWW20140
```

```
     1 (LLAT,W(83)),(LLON,W(84)),(RLAT,W(85)),(RLON,W(86))              CWW20150
     2,(TIC,W(87)),(HB,W(88)),(HT,W(89)),(TICV,W(96))                   CWW20160
C      COMMON DECK "ANNOT" INSERTED HERE                                ANNO0020
       CHARACTER*10 ANOTES,HNOTES                                       ANNO0040
       COMMON/ANNCTL/LENA(4),LENHA(3)                                   ANNO0050
       COMMON/ANNCTC/ANOTES(2,4),HNOTES(4,3)                            ANNO0060
C                                                                       SMQN0110
       INTEGER LHNA(4) ,LHNHA(3)                                        SMQN0120
       CHARACTER*10 AQOTES(2,4),HQOTES(4,3)                             SMQN0130
C                                                                       SMQN0140
       DATA LHNA,AQOTES/2*1,2*2,'DEPTH (M)',' ','DEPTH (KM)',' ',       SMQN0150
     2 'HEIGHT (M)',' ','HEIGHT (KM',')'/                               SMQN0160
       DATA LHNHA,HQOTES/3,2,3, 'RANGE AT S','EA LEVEL (','KM)',' '     SMQN0170
     2       ,'RANGE (DEG',')',2*' '                                    SMQN0180
     3       ,'CROSS RANG','E AT SEA L','EVEL (KM)',' '/                SMQN0190
C                                                                       SMQN0200
       ENTRY SETANN                                                     SMQN0210
C                                                                       SMQN0220
       CALL IMOVE(LENA,LHNA,4)                                          SMQN0230
       CALL IMOVE(LENHA,LHNHA,3)                                        SMQN0240
       DO 10 I=1,2                                                      SMQN0250
       DO 10 J=1,4                                                      SMQN0260
10     ANOTES(I,J)=AQOTES(I,J)                                          SMQN0270
       DO 20 I=1,4                                                      SMQN0280
       DO 20 J=1,3                                                      SMQN0290
20     HNOTES(I,J)=HQOTES(I,J)                                          SMQN0300
C                                                                       SMQN0310
       RETURN                                                           SMQN0320
C                                                                       SMQN0330
       ENTRY ANNFIL(S,C)                                                SMQN0340
       CALL SFILTR(S,C,'#!')                                            SMQN0350
       END                                                              SMQN0360
```

```
       SUBROUTINE FULANN                                                FUPN0020
C      ANNOTATION MODEL SUITED FOR PUBLICATION QUALITY LETTERING        FUPN0030
C                                                                       FUPN0040
       CHARACTER*(*) S,C                                                FUPN0050
C                                                                       FUPN0060
C      INITIALIZES PLOT IN PUBLICATION-QUALITY MODE(REQUIRES DISSPLA)   FUPN0070
C                                                                       FUPN0080
C      COMMON DECK "WWR" INSERTED HERE                                  CWWR0020
       PARAMETER (NWARSZ=1000)                                          CWW10030
       COMMON/WW/ID(10),MAXW,W(NWARSZ)                                  CWW10040
       REAL MAXSTP,MAXERR,INTYP,LLAT,LLON                               CWW20020
       EQUIVALENCE (EARTHR,W(1)),(RAY,W(2)),(XMTRH,W(3)),(TLAT,W(4)),   CWW20030
     1 (TLON,W(5)),(OW,W(6)),(FBEG,W(7)),(FEND,W(8)),(FSTEP,W(9)),      CWW20040
     2 (AZ1,W(10)),(AZBEG,W(11)),(AZEND,W(12)),(AZSTEP,W(13)),          CWW20050
     3 (BETA,W(14)),(ELBEG,W(15)),(ELEND,W(16)),(ELSTEP,W(17)),         CWW20060
     8   (RUNSUP,W(18)),(RCVRH,W(20)),                                  CWW20070
     4 (ONLY,W(21)),(HOP,W(22)),(MAXSTP,W(23)),(PLAT,W(24)),(PLON,W(25))CWW20080
     5,(HMAX,W(26)),(RAYFNC,W(29)),(EXTINC,W(33)),                      CWW20090
```

```
     6 (HMIN,W(27)),(RGMAX,W(28)),                                          CWW20100
     8 (INTYP,W(41)),(MAXERR,W(42)),(ERATIO,W(43)),                         CWW20110
     6 (STEP1,W(44)),(STPMAX,W(45)),(STPMIN,W(46)),(FACTR,W(47)),           CWW20120
     7 (SKIP,W(71)),(RAYSET,W(72)),(PRTSRP,W(74)),(HITLET,W(75))            CWW20130
     9 ,(BINRAY,W(76)),(PAGLN,W(77)),(PLT,W(81)),(PFACTR,W(82)),            CWW20140
     1 (LLAT,W(83)),(LLON,W(84)),(RLAT,W(85)),(RLON,W(86))                  CWW20150
     2,(TIC,W(87)),(HB,W(88)),(HT,W(89)),(TICV,W(96))                       CWW20160
C     COMMON DECK "ANNOT" INSERTED HERE                                     ANNO0020
      CHARACTER*10 ANOTES,HNOTES                                            ANNO0040
      COMMON/ANNCTL/LENA(4),LENHA(3)                                        ANNO0050
      COMMON/ANNCTC/ANOTES(2,4),HNOTES(4,3)                                 ANNO0060
C                                                                           FUPN0110
      INTEGER LHNA(4) ,LHNHA(3)                                             FUPN0120
      CHARACTER*10 AQOTES(2,4),HQOTES(4,3)                                  FUPN0130
C                                                                           FUPN0140
      DATA LHNA,AQOTES/4*2,'DEPTH (#M!',')','DEPTH (#KM','!)',              FUPN0150
     2'HEIGHT (#M','!)','HEIGHT (#K','M!)'/                                 FUPN0160
      DATA LHNHA,HQOTES/3,2,4, 'RANGE AT S','EA LEVEL (','#KM!)',' '        FUPN0170
     2       ,'RANGE (#DE','G!)',2*' '                                      FUPN0180
     3       ,'CROSS RANG','E AT SEA L','EVEL (#KM!',')'/                   FUPN0190
      ENTRY SETANN                                                          FUPN0200
C                                                                           FUPN0210
      PRINT *,'FULL ANNOTATION MODEL'                                       FUPN0220
C                                                                           FUPN0230
      CALL SCMPLX                                                           FUPN0240
      CALL MX1ALF('STAND','!')                                              FUPN0250
      CALL MX2ALF('L/CSTD','#')                                             FUPN0260
      CALL HEIGHT(HITLET)                                                   FUPN0270
C                                                                           FUPN0280
      CALL IMOVE(LENA,LHNA,4)                                               FUPN0290
      CALL IMOVE(LENHA,LHNHA,3)                                             FUPN0300
      DO 10 I=1,2                                                           FUPN0310
      DO 10 J=1,4                                                           FUPN0320
10    ANOTES(I,J)=AQOTES(I,J)                                               FUPN0330
      DO 20 I=1,4                                                           FUPN0340
      DO 20 J=1,3                                                           FUPN0350
20    HNOTES(I,J)=HQOTES(I,J)                                               FUPN0360
C                                                                           FUPN0370
      RETURN                                                                FUPN0380
C                                                                           FUPN0390
      ENTRY ANNFIL(S,C)                                                     FUPN0400
      C=S                                                                   FUPN0410
      END                                                                   FUPN0420
```

D.4 TAPRD -- Graphics file read routine (Tape File 6)

```
      PROGRAM TAPRD
C     PROGRAM TO READ GRAPHICS OUTPUT FILE AND CALL GRAPHICS
C     INTERFACE ROUTINES.
      COMMON/DD/IN,IOR,IT,IS,IC,ICC,IX,IY
      COMMON/SUPNEG/IDEL,NMBS
C
      PARAMETER (LIMPTS=700,IUN=4)
      REAL XV(LIMPTS),YV(LIMPTS)
      CHARACTER*40 A,C,E
      LOGICAL COMPCL
      CHARACTER LINE*72,TEXT*80,S*10
      EQUIVALENCE (IX,XXX),(IY,YYY)
      DATA COMPCL/.TRUE./
      DATA KNT/0/
C
      OPEN(UNIT=IUN,FILE='TAPE5',FORM='UNFORMATTED')
      REWIND IUN
10    READ(IUN,END=100,ERR=100) IT,IX,IY
C     PRINT *,IT,XXX,YYY
      IF(IT.GT.20) THEN
         IF(COMPCL) THEN
            PRINT '(A,3(I4,1X),2G13.6)',
     1         'NO CALL TO ''COMPRS'' BEFORE---',IT,IX,IY,XXX,YYY
            STOP
            ENDIF
      ENDIF
      IF(IT.LT.-2 .OR. IT.GT.39) STOP 'CODE>39'
      KNT=KNT+1
      IF(IT.EQ.-1) THEN
         CALL DDEND
      ELSEIF(IT.EQ.-2) THEN
         CALL DDFR
      ELSEIF(IT.EQ.0) THEN
         READ(IUN) N,M,(TEXT(I:I),I=1,M)
         CALL DDINIT(N,TEXT)
         COMPCL=.FALSE.
      ELSEIF(IT.EQ.1) THEN
         CALL DDBP
      ELSEIF(IT.EQ.2) THEN
         CALL DDVC
      ELSEIF(IT.EQ.10) THEN
         CALL SCMPLX
      ELSEIF(IT.EQ.11) THEN
         CALL MX1ALF(IX,IY)
      ELSEIF(IT.EQ.12) THEN
         CALL MX2ALF(IX,IY)
      ELSEIF(IT.EQ.13) THEN
         IF(XXX.LE.0.0) THEN
            PRINT *,'HEIGHT OF ZERO!!'
            XXX=.15
         ENDIF
         CALL HEIGHT(XXX)
C
      ELSEIF(IT.EQ.20) THEN
         COMPCL=.FALSE.
```

```
            CALL COMPRS
         ELSEIF(IT.EQ.21) THEN
            CALL GRACE(IX,IY)
         ELSEIF(IT.EQ.22) THEN
            CALL PHYSOR(IX,IY)
         ELSEIF(IT.EQ.23) THEN
            CALL PAGE(IX,IY)
         ELSEIF(IT.EQ.24) THEN
            CALL SCLPIC(IX)
         ELSEIF(IT.EQ.25) THEN
            IF(IX.NE.0 .OR. IY.NE.0) STOP 'ERROR 1'
            READ(IUN) A,B,C,D,E,F,XAXIS,YAXIS
            CALL XREVTK
            CALL YREVTK
            CALL INTAXS
            CALL TITLE(A,B,C,D,E,F,XAXIS,YAXIS)
         ELSEIF(IT.EQ.26) THEN
            CALL FRAME
         ELSEIF(IT.EQ.27) THEN
            READ(IUN) W,X,Y,Z
            CALL GRAF(IX,IY,W,X,Y,Z,XAXIS,YAXIS)
         ELSEIF(IT.EQ.28) THEN
            CALL MARKER(IX)
         ELSEIF(IT.EQ.29) THEN
            IF(IX.GT.LIMPTS) CALL SYSTEM(52,'N>LIMPTS')
            READ(IUN)  (XV(I),I=1,IX),(YV(I),I=1,IX)
            CALL CURVE(XV,YV,IX,IY)
         ELSEIF(IT.EQ.30) THEN
            CALL ENDPL(IX)
         ELSEIF(IT.EQ.31) THEN
            CALL DONEPL
         ELSEIF(IT.EQ.32) THEN
            CALL XTICKS(IX)
         ELSEIF(IT.EQ.33) THEN
            CALL YTICKS(IX)
         ELSEIF(IT.EQ.34) THEN
            CALL MYJACT(IX)
         ELSEIF(IT.EQ.35) THEN
            CALL MYJACT('NUMBERS')
            IDEL=IX
            NMBS=IY
         ELSEIF(IT.EQ.36) THEN
            CALL NOBRDR
         ELSEIF(IT.EQ.37) THEN
            CALL DASH
         ELSEIF(IT.EQ.38) THEN
            READ(IUN) S
            CALL RESET(S)
         ELSEIF(IT.EQ.39) THEN
            READ(IUN) W,X,Y,Z
            CALL GRAFB(IX,IY,W,X,Y,Z,XAXIS,YAXIS)
         ENDIF
C
         IF(IT.NE.3) GO TO 10
         READ(IUN) IOR,N,M,(TEXT(I:I),I=1,M)
```

```
      CALL DDTEXT(N,TEXT)
C      PRINT 20,(TEXT(I),I=1,N)
20    FORMAT(8A10)
      GO TO 10
C
100   PRINT *,'NUMBER OF VECTORS=',KNT,IT
      STOP
      END
```

D.5 DDSPLA -- DISSPLA Interface Routines (Tape File 7)

```
      SUBROUTINE MYJSUB(IPAR,ITY,IMYJ)                                  DDLA0030
C     DSSPLA USER ROUTINE TO HANDLE SPECIAL ANNOTATIONS                 DDLA0040
      COMMON/SUPNEG/IDEL,NMBS                                           DDLA0050
      DATA IDEL,NMBS/0,100000/                                          DDLA0060
C                                                                       DDLA0070
C  WE ARE INTERESTED ONLY IN NUMERICAL VALUES CAUSED BY                 DDLA0080
C  A CALL MYJACT('NUMBERS')(IMYJ=5)                                     DDLA0090
C                                                                       DDLA0100
      IF(ITY.GE.0 .OR. IMYJ.NE.5) RETURN                                DDLA0110
C                                                                       DDLA0120
      IF(IDEL.GT.0) IDEL=IDEL-1                                         DDLA0130
C                                                                       DDLA0140
      IF(IDEL.LE.0.AND.NMBS.GT.0) THEN                                  DDLA0150
         NMBS=NMBS-1                                                    DDLA0160
         IPAR=IABS(IPAR)                                                DDLA0170
      ENDIF                                                             DDLA0180
      END                                                               DDLA0190



      SUBROUTINE DDINIT(N,TEXT)                                         DDLA0200
C     INITIALIZE PLOTTING PROCESS                                       DDLA0210
C                                                                       DDLA0220
      COMMON/PLOTCN/NPLOT,INABLE,FX,FY,OFFX,OFFY                        CPLO0020
      DATA OFFX,OFFY/0.0,0.0/                                           DDLA0240
      DATA NPLOT,INABLE,PLOTSZ,XAXIS,YAXIS/0,0,7.5,11.,8.5/             DDLA0250
C                                                                       DDLA0260
C     NO RE-INITIALIZATIONS BEFORE ENDPL'S                              DDLA0270
      IF(INABLE.GT.0) RETURN                                            DDLA0280
C                                                                       DDLA0290
      IF(NPLOT.GT.0) GO TO 10                                           DDLA0300
C                                                                       DDLA0310
       CALL COMPRS                                                      DDLA0320
      FY=PLOTSZ/1024.                                                   DDLA0330
      FX=FY                                                             DDLA0340
C                                                                       DDLA0350
10    NPLOT=NPLOT+1                                                     DDLA0360
      INABLE=1                                                          DDLA0370
      CALL NOBRDR                                                       DDLA0380
      CALL PAGE(XAXIS,YAXIS)                                            DDLA0390
      CALL PHYSOR(0.0,0.0)                                              DDLA0400
      CALL AREA2D(XAXIS,YAXIS)                                          DDLA0410
      CALL GRACE(0.0)                                                   DDLA0420
      RETURN                                                            DDLA0430
      END                                                               DDLA0440



      SUBROUTINE DDBP                                                   DDLA0450
C     DEFINE A VECTOR ORIGIN AT IX,IY                                   DDLA0460
      COMMON/PLOTCN/NPLOT,INABLE,FX,FY,OFFX,OFFY                        CPLO0020
```

```
      COMMON/DD/IN,IOR,IT,IS,IC,ICC,IX,IY                               CDDC0020
C                                                                       DDLA0490
C     MAKE IX AND IY REAL ONLY FOR DDBP AND DDVC                        DDLA0500
      REAL IX,IY                                                        DDLA0510
C     "DDPLOT" DOES NOT REQUIRE RE-INITIALIZATION AFTER EACH FRAME      DDLA0520
C     BUT "DISSPLA" DOES SO WE USE THE STATUS OF "INABLE" TO TELL US    DDLA0530
C     WHERE WE ARE.                                                     DDLA0540
      IF(INABLE.EQ.0) CALL DDINIT(-1,0)                                 DDLA0550
      CALL STRTPT(OFFX+IX*FX,OFFY+IY*FY)                                DDLA0560
      RETURN                                                            DDLA0570
      END                                                               DDLA0580


      SUBROUTINE DDVC                                                   DDLA0590
C     PLOT A STRAIGHT LINE WITH INTENSITY                               DDLA0600
      COMMON/PLOTCN/NPLOT,INABLE,FX,FY,OFFX,OFFY                        CPLO0020
      COMMON/DD/IN,IOR,IT,IS,IC,ICC,IX,IY                               CDDC0020
C                                                                       DDLA0630
C     MAKE IX AND IY REAL ONLY FOR DDBP AND DDVC                        DDLA0640
      REAL IX,IY                                                        DDLA0650
C     SEE "DDBP" FOR THE REASON FOR THIS TEST.                          DDLA0660
      IF(INABLE.EQ.0) CALL DDINIT(-1,0)                                 DDLA0670
      CALL CONNPT(OFFX+IX*FX,OFFY+IY*FY)                                DDLA0680
      RETURN                                                            DDLA0690
      END                                                               DDLA0700


      SUBROUTINE DDEND                                                  DDLA0710
C     EMPTY THE PLOT BUFFER AND RELEASE                                 DDLA0720
      COMMON/PLOTCN/NPLOT,INABLE,FX,FY,OFFX,OFFY                        CPLO0020
C     CHECK SYNCH, DDFR SHOULD HAVE BEEN CALLED BY NOW                  DDLA0740
      IF(INABLE.GT.0) CALL ENDPL(0)                                     DDLA0750
C                                                                       DDLA0760
      CALL DONEPL                                                       DDLA0770
C                                                                       DDLA0780
      INABLE=0                                                          DDLA0790
      RETURN                                                            DDLA0800
      END                                                               DDLA0810


      SUBROUTINE DDTEXT(N,TEXT)                                         DDLA0820
C     PLOT A GIVEN ARRAY IN A TABULAR MODE                              DDLA0830
      COMMON/PLOTCN/NPLOT,INABLE,FX,FY,OFFX,OFFY                        CPLO0020
      COMMON/DD/IN,IOR,IT,IS,IC,ICC,IX,IY                               CDDC0020
C                                                                       DDLA0860
      IF(INABLE.EQ.0) CALL DDINIT(-1,0)                                 DDLA0870
```

```
      IF(IOR.EQ.0) CALL ANGLE(0.0)
      IF(IOR.NE.0) CALL ANGLE(90.0)
      CALL MESSAG(TEXT,N*10,OFFX+IX*FX,OFFY+IY*FY)
      RETURN
      END


      SUBROUTINE DDTAB
C     INITIALIZE TABULAR TEXT PLOTTING
      RETURN
      END


      SUBROUTINE DDFR
C     ADVANCE ONE PLOTTING FRAME, WHEN PLOTTING IS COMPLETED.
      COMMON/PLOTCN/NPLOT,INABLE,FX,FY,OFFX,OFFY
      IF(INABLE.GT.0) CALL ENDPL(0)
      INABLE=0
      RETURN
      END


      SUBROUTINE GRAFB(XORIG,XSTP,XMAX,YORIG,YSTP,YMAX,XAXIS,YAXIS)
C     SPECIAL VERSION OF GRAF ROUTINE TO ENCLOSE PLOT AREA
C     IN BOX.
C
      CALL GRAF(XORIG,XSTP,XMAX,YORIG,YSTP,YMAX)
      CALL XNONUM
      CALL YNONUM
      CALL XGRAXS(XORIG,XSTP,XMAX,XAXIS,' ',-1,0.0,YAXIS)
      XR=XMAX-XORIG
      XAX=AINT(XR/XSTP)*XSTP*(XAXIS/XR)
      XAX=XAXIS
      PRINT *,XORIG,XMAX,XSTP,XAXIS,XAX
      CALL YGRAXS(YORIG,YSTP,YMAX,YAXIS,' ',-1,XAX,0.0)
      CALL RESET('XNONUM')
      CALL RESET('YNONUM')
      END


      SUBROUTINE TITLEW(A,B,C,D,E,F,G,H)
C     DUMMY ROUTINE ALLOWING SUBSTITUTION OF ALTERNATE TITLE PROGRAMS
      CALL TITLE(A,B,C,D,E,F,G,H)
```

END DDLA1230

D.6 DDALT -- Skeleton Graphics Interface Routines (Tape File 8)

```
      SUBROUTINE DDINIT(N,ID)                                           DDKT0030
C     INSERT YOUR OWN ROUTINE TO INITIALIZE PLOTTING PROCESS            DDKT0040
C     ID IS A HOLLERITH STRING OF CHARACTERS IDENTIFYING THE PERSON     DDKT0050
C     GETTING THE PLOT, PHONE NUMBER, ETC.                              DDKT0060
C     N IS THE NUMBER OF CHARACTERS IN THE STRING "ID"                  DDKT0070
      RETURN                                                            DDKT0080
      END                                                               DDKT0090


      SUBROUTINE DDBP                                                   DDKT0100
      COMMON/DD/IN,IOR,IT,IS,IC,ICC,IX,IY                               DDKT0110
C     INSERT YOUR OWN ROUTINE TO DEFINE A VECTOR ORIGIN AT IX,IY        DDKT0120
      RETURN                                                            DDKT0130
      END                                                               DDKT0140


      SUBROUTINE DDVC                                                   DDKT0150
      COMMON/DD/IN,IOR,IT,IS,IC,ICC,IX,IY                               DDKT0160
C     INSERT YOUR OWN ROUTINE TO PLOT A STRAIGHT LINE WITH INTENSITY    DDKT0170
C     "IN" FROM THE ORIGIN TO THE END POSITION IX,IY.  A SINGLE CALL    DDKT0180
C     TO DDBP FOLLOWED BY SUCCESSIVE CALLS TO DDVC (CHANGING IX,IY)     DDKT0190
C     PLOTS CONNECTED VECTORS.                                          DDKT0200
      RETURN                                                            DDKT0210
      END                                                               DDKT0220


      SUBROUTINE DDEND                                                  DDKT0230
C     CHECK SYNCH, DDFR SHOULD HAVE BEEN CALLED BY NOW                  DDKT0240
C     INSERT YOUR OWN ROUTINE TO EMPTY THE PLOT BUFFER AND RELEASE      DDKT0250
C     THE PLOTTING COMMAND FILE TO YOUR PLOTTING DEVICE.                DDKT0260
      RETURN                                                            DDKT0270
      END                                                               DDKT0280


      SUBROUTINE DDTEXT(N,NT)                                           DDKT0290
      COMMON/DD/IN,IOR,IT,IS,IC,ICC,IX,IY                               DDKT0300
C     INSERT YOUR OWN ROUTINE TO PLOT A GIVEN ARRAY IN A TABULAR MODE   DDKT0310
C     AFTER INITIALIZING TABULAR PLOTTING WITH DDTAB. NT IS AN ARRAY OF DDKT0320
C     LENGTH N, CONTAINING "TEXT" FOR TABULAR PLOTTING. SEE APPENDIX C. DDKT0330
      RETURN                                                            DDKT0340
      END                                                               DDKT0350
```

```
      SUBROUTINE DDTAB                                                  DDKT0360
      COMMON/DD/IN,IOR,IT,IS,IC,ICC,IX,IY                               DDKT0370
C     INSERT YOUR OWN ROUTINE TO INITIALIZE TABULAR TEXT PLOTTING       DDKT0380
C        SPECIFY IOR,IS,IX,IY.  TEXT WILL BEGIN AT IX,IY.               DDKT0390
      RETURN                                                            DDKT0400
      END                                                               DDKT0410


      SUBROUTINE DDFR                                                   DDKT0420
C     INSERT YOUR OWN ROUTINE TO ADVANCE ONE PLOTTING FRAME, WHEN       DDKT0430
C     PLOTTING IS COMPLETED.                                            DDKT0440
      RETURN                                                            DDKT0450
      END                                                               DDKT0460


      SUBROUTINE DASH                                                   DDKT0470
C     THIS IS A DUMMY ROUTINE TO SATISFY LOADER REFERENCES              DDKT0480
      STOP 'DASH SHOULD NOT HAVE BEEN CALLED'                           DDKT0490
      END                                                               DDKT0500


      SUBROUTINE RESET                                                  DDKT0510
C     THIS IS A DUMMY ROUTINE TO SATISFY LOADER REFERENCES              DDKT0520
      STOP 'RESET SHOULD NOT HAVE BEEN CALLED'                          DDKT0530
      END                                                               DDKT0540


      SUBROUTINE SCMPLX                                                 DDKT0550
C     THIS IS A DUMMY ROUTINE TO SATISFY LOADER REFERENCES              DDKT0560
      STOP 'SCMPLX SHOULD NOT HAVE BEEN CALLED'                         DDKT0570
      END                                                               DDKT0580


      SUBROUTINE MX1ALF                                                 DDKT0590
C     THIS IS A DUMMY ROUTINE TO SATISFY LOADER REFERENCES              DDKT0600
      STOP 'MX1ALF SHOULD NOT HAVE BEEN CALLED'                         DDKT0610
      END                                                               DDKT0620
```

```
      SUBROUTINE MX2ALF
C     THIS IS A DUMMY ROUTINE TO SATISFY LOADER REFERENCES
      STOP 'MX2ALF SHOULD NOT HAVE BEEN CALLED'
      END


      SUBROUTINE HEIGHT
C     THIS IS A DUMMY ROUTINE TO SATISFY LOADER REFERENCES
      STOP 'HEIGHT SHOULD NOT HAVE BEEN CALLED'
      END


      SUBROUTINE PHYSOR
C     THIS IS A DUMMY ROUTINE TO SATISFY LOADER REFERENCES
      STOP 'PHYSOR SHOULD NOT HAVE BEEN CALLED'
      END


      SUBROUTINE PAGE
C     THIS IS A DUMMY ROUTINE TO SATISFY LOADER REFERENCES
      STOP 'PAGE SHOULD NOT HAVE BEEN CALLED'
      END


      SUBROUTINE SCLPIC
C     THIS IS A DUMMY ROUTINE TO SATISFY LOADER REFERENCES
      STOP 'SCLPIC SHOULD NOT HAVE BEEN CALLED'
      END


      SUBROUTINE XREVTK
C     THIS IS A DUMMY ROUTINE TO SATISFY LOADER REFERENCES
      STOP 'XREVTK SHOULD NOT HAVE BEEN CALLED'
      END
```

```
      SUBROUTINE YREVTK                                                 DDKT0870
C     THIS IS A DUMMY ROUTINE TO SATISFY LOADER REFERENCES              DDKT0880
      STOP 'YREVTK SHOULD NOT HAVE BEEN CALLED'                         DDKT0890
      END                                                               DDKT0900

      SUBROUTINE INTAXS                                                 DDKT0910
C     THIS IS A DUMMY ROUTINE TO SATISFY LOADER REFERENCES              DDKT0920
      STOP 'INTAXS SHOULD NOT HAVE BEEN CALLED'                         DDKT0930
      END                                                               DDKT0940

      SUBROUTINE TITLE                                                  DDKT0950
C     THIS IS A DUMMY ROUTINE TO SATISFY LOADER REFERENCES              DDKT0960
      STOP 'TITLE SHOULD NOT HAVE BEEN CALLED'                          DDKT0970
      END                                                               DDKT0980

      SUBROUTINE FRAME                                                  DDKT0990
C     THIS IS A DUMMY ROUTINE TO SATISFY LOADER REFERENCES              DDKT1000
      STOP 'FRAME SHOULD NOT HAVE BEEN CALLED'                          DDKT1010
      END                                                               DDKT1020

      SUBROUTINE MARKER                                                 DDKT1030
C     THIS IS A DUMMY ROUTINE TO SATISFY LOADER REFERENCES              DDKT1040
      STOP 'MARKER SHOULD NOT HAVE BEEN CALLED'                         DDKT1050
      END                                                               DDKT1060

      SUBROUTINE SYSTEM                                                 DDKT1070
C     THIS IS A DUMMY ROUTINE TO SATISFY LOADER REFERENCES              DDKT1080
      STOP 'SYSTEM SHOULD NOT HAVE BEEN CALLED'                         DDKT1090
      END                                                               DDKT1100
```

```
      SUBROUTINE CURVE                                                  DDKT1110
C     THIS IS A DUMMY ROUTINE TO SATISFY LOADER REFERENCES              DDKT1120
      STOP 'CURVE SHOULD NOT HAVE BEEN CALLED'                          DDKT1130
      END                                                               DDKT1140

      SUBROUTINE ENDPL                                                  DDKT1150
C     THIS IS A DUMMY ROUTINE TO SATISFY LOADER REFERENCES              DDKT1160
      STOP 'ENDPL SHOULD NOT HAVE BEEN CALLED'                          DDKT1170
      END                                                               DDKT1180

      SUBROUTINE XTICKS                                                 DDKT1190
C     THIS IS A DUMMY ROUTINE TO SATISFY LOADER REFERENCES              DDKT1200
      STOP 'XTICKS SHOULD NOT HAVE BEEN CALLED'                         DDKT1210
      END                                                               DDKT1220

      SUBROUTINE YTICKS                                                 DDKT1230
C     THIS IS A DUMMY ROUTINE TO SATISFY LOADER REFERENCES              DDKT1240
      STOP 'YTICKS SHOULD NOT HAVE BEEN CALLED'                         DDKT1250
      END                                                               DDKT1260

      SUBROUTINE MYJACT                                                 DDKT1270
C     THIS IS A DUMMY ROUTINE TO SATISFY LOADER REFERENCES              DDKT1280
      STOP 'MYJACT SHOULD NOT HAVE BEEN CALLED'                         DDKT1290
      END                                                               DDKT1300

      SUBROUTINE GRAFB                                                  DDKT1310
C     THIS IS A DUMMY ROUTINE TO SATISFY LOADER REFERENCES              DDKT1320
      STOP 'GRAFB SHOULD NOT HAVE BEEN CALLED'                          DDKT1330
      END                                                               DDKT1340
```

```
      SUBROUTINE COMPRS
C     THIS IS A DUMMY ROUTINE TO SATISFY LOADER REFERENCES
      STOP 'COMPRS SHOULD NOT HAVE BEEN CALLED'
      END


      SUBROUTINE NOBRDR
C     THIS IS A DUMMY ROUTINE TO SATISFY LOADER REFERENCES
      STOP 'NOBRDR SHOULD NOT HAVE BEEN CALLED'
      END


      SUBROUTINE AREA2D
C     THIS IS A DUMMY ROUTINE TO SATISFY LOADER REFERENCES
      STOP 'AREA2D SHOULD NOT HAVE BEEN CALLED'
      END


      SUBROUTINE GRACE
C     THIS IS A DUMMY ROUTINE TO SATISFY LOADER REFERENCES
      STOP 'GRACE SHOULD NOT HAVE BEEN CALLED'
      END


      SUBROUTINE STRTPT
C     THIS IS A DUMMY ROUTINE TO SATISFY LOADER REFERENCES
      STOP 'STRTPT SHOULD NOT HAVE BEEN CALLED'
      END


      SUBROUTINE CONNPT
C     THIS IS A DUMMY ROUTINE TO SATISFY LOADER REFERENCES
      STOP 'CONNPT SHOULD NOT HAVE BEEN CALLED'
      END
```

```
      SUBROUTINE DONEPL                                              DDKT1590
C     THIS IS A DUMMY ROUTINE TO SATISFY LOADER REFERENCES           DDKT1600
      STOP 'DONEPL SHOULD NOT HAVE BEEN CALLED'                      DDKT1610
      END                                                            DDKT1620
```

```
      SUBROUTINE ANGLE                                               DDKT1630
C     THIS IS A DUMMY ROUTINE TO SATISFY LOADER REFERENCES           DDKT1640
      STOP 'ANGLE SHOULD NOT HAVE BEEN CALLED'                       DDKT1650
      END                                                            DDKT1660
```

```
      SUBROUTINE MESSAG                                              DDKT1670
C     THIS IS A DUMMY ROUTINE TO SATISFY LOADER REFERENCES           DDKT1680
      STOP 'MESSAG SHOULD NOT HAVE BEEN CALLED'                      DDKT1690
      END                                                            DDKT1700
```

```
      SUBROUTINE GRAF                                                DDKT1710
C     THIS IS A DUMMY ROUTINE TO SATISFY LOADER REFERENCES           DDKT1720
      STOP 'GRAF SHOULD NOT HAVE BEEN CALLED'                        DDKT1730
      END                                                            DDKT1740
```

```
      SUBROUTINE XNONUM                                              DDKT1750
C     THIS IS A DUMMY ROUTINE TO SATISFY LOADER REFERENCES           DDKT1760
      STOP 'XNONUM SHOULD NOT HAVE BEEN CALLED'                      DDKT1770
      END                                                            DDKT1780
```

```
      SUBROUTINE YNONUM                                              DDKT1790
C     THIS IS A DUMMY ROUTINE TO SATISFY LOADER REFERENCES           DDKT1800
      STOP 'YNONUM SHOULD NOT HAVE BEEN CALLED'                      DDKT1810
      END                                                            DDKT1820
```

```
      SUBROUTINE XGRAXS                                                 DDKT1830
C     THIS IS A DUMMY ROUTINE TO SATISFY LOADER REFERENCES              DDKT1840
      STOP 'XGRAXS SHOULD NOT HAVE BEEN CALLED'                         DDKT1850
      END                                                               DDKT1860
```

```
      SUBROUTINE YGRAXS                                                 DDKT1870
C     THIS IS A DUMMY ROUTINE TO SATISFY LOADER REFERENCES              DDKT1880
      STOP 'YGRAXS SHOULD NOT HAVE BEEN CALLED'                         DDKT1890
      END                                                               DDKT1900
```

APPENDIX E. ERRATA FOR HARPA REPORT

HARPA: A versatile Three-Dimensional Hamiltonian Ray-Tracing Program for Acoustic Waves in the Atmosphere Above Irregular Terrain" by R. Michael Jones, J. P. Riley, and T. M. Georges

2 February 1987

Page xi: change line 12 to:
Table 7.23 Definitions of the parameters in common block /HDRC/....157

Page 21: Following "The profile:" circle the units "km" in the columns labeled z_i and δ_i.

Page 31 and 199: At mid-page, change "stop frequency stepping" to "stop elevation-angle stepping," and change W30, W31, and W32 to W278, W279, and W280, respectively.

Page 33 and 221: Change the Model Check Number from 3.0 to 2.0.

Page 50: Change "Phase path, km" to Phase time, sec" and "Group path, km" to "Pulse travel time, sec."

Page 59: In Table 4.1, change "NPABS" to "NPABSR".

Page 69: Change the last two lines to read:
*** Format type 1 implies format number A (see Table 5.3).
*** Format type 2 implies format number 1, 2, or 3 (see Table 5.3).

Page 79: Change description following W(21) to read "Set = 1 to stop elevation-angle increment when the ray goes out of bounds."

Page 94-98: Add the following to the captions for Figures 6.1 through 6.5: "Circled block numbers correspond to program statement numbers."

Page 98: Change the comment near the lower branch of the "Test Mode" block to read: "MODE = 4 and $Y_{i,1} \neq 0$".

Page 101: In the last sentence of Section 6.4 change the table mentioned from Table 7.9 to Table 7.17.

Page 102: In the second line of the first full paragraph change the equation mentioned from Eq. (4.1) to Eq. (6.30).

Page 126 and 128: Change the captions so that the parenthetical expressions following ANWNL and AWWNL begin "(Acoustic, No Winds..." and "(Acoustic, With Winds...").

Page 127: Change the name of PROGRAM NITIAL to PROGRAM RAYTRC in the second block down.

Page 136: Change the first note in the caption of Figure 7.10 to read: "* See Equation (6.83) to estimate the time of nearest closest approach to the specified surface."

Page 155: Add the variable names NDEVGRP and NDEVBIN to Table 7.19.

Page 158: Replace Table 7.23 by:

Table 7.23--Definitions of the parameters in common block /HDRC/

Position in common	Variable name	Definition
1	INITID	Character string for user name and phone number identifier for graphics output
2	DAT	Character string for the date of the computer run
3	TOD	Character string for the time of day of the computer run

Page 168: In line 9, replace PGRKPH with PGRPH.
In line 11, replace $\partial g/\partial \theta$ by $\partial g/\partial \phi$.

Page 222: Change the Model Check Number from 2.0 to 3.0.

Make the following changes in <u>both</u> the source-code listing (Appendix D) and in the program itself:

Page 251: Following the line "UCON 30" in LOGICAL FUNCTION UCON, insert the line:

```
IF(CONV.EQ.-1.0) CONV = 1.0/EARTHR                         UCON305
```

Page 251: Replace line "UCON 38" in LOGICAL FUNCTION UCON by:

```
CNVV(1,3) = -1.0                                           UCON380
```

Page 361: Replace line "TTANH554" in SUBROUTINE TTANH5 by:

```
ZIM1 = Z0                                                  TTANH554
```

Page 395: Replace line "RVERT 21" in SUBROUTINE RVERT by:

```
DATA RECORR/3.0/                                           RVERT21
```

Add the following routine:

```
      FUNCTION ITOC(N)                                           ITOC0020
C     RETURN 7 CHARACTER STRING REPRESENTATION OF INTEGER N      ITOC0030
C     IF NUMBER IS TOO LARGE OR SMALL USE FLOATING POINT FORMAT  ITOC0040
      CHARACTER ITOC*7                                           ITOC0050
      IF(N.LT.-9999.OR.N.GT.99999) GO TO 100                     ITOC0060
      ITOC=' '                                                   ITOC0070
      WRITE(ITOC,'(I7)',ERR=100) N                               ITOC0080
      RETURN                                                     ITOC0090
100   WRITE(ITOC,'(2PG7.0)') FLOAT(N)                            ITOC0100
      END                                                        ITOC0110
```

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Index of HARPO entry point names

HARPO module and entry point list

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List of subroutines, functions and their entry points, if any, and their page numbers in the HARPO report.