NOAA Technical Memorandum ERL ARL-81

AIR RESOURCES LABORATORIES ATMOSPHERIC TRANSPORT AND DISPERSION MODEL (ARL-ATAD)

Jerome L. Heffter

Air Resources Laboratories
Silver Spring, Maryland
February 1980

noaa NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION / Environmental Research Laboratories

NOAA Technical Memorandum ERL ARL-81

AIR RESOURCES LABORATORIES ATMOSPHERIC TRANSPORT AND DISPERSION MODEL (ARL-ATAD)

Jerome L. Heffter

Air Resources Laboratories
Silver Spring, Maryland
February 1980

UNITED STATES DEPARTMENT OF COMMERCE
Philip M. Klutznick, Secretary

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
Richard A. Frank, Administrator

Environmental Research Laboratories
Wilmot N. Hess, Director

NOTICE

The Environmental Research Laboratories do not approve, recommend, or endorse any proprietary product or proprietary material mentioned in this publication. No reference shall be made to the Environmental Research Laboratories or to this publication furnished by the Environmental Research Laboratories in any advertising or sales promotion which would indicate or imply that the Environmental Research Laboratories approve, recommend, or endorse any proprietary product or proprietary material mentioned herein, or which has as its purpose an intent to cause directly or indirectly the advertised product to be used or purchased because of this Environmental Research Laboratories publication.

TABLE OF CONTENTS

ABSTRACT

The Air Resources Laboratories Atmospheric Transport and Dispersion Model (ATAD) is oriented toward practical application for pollution studies. ATAD calculates trajectories of 5 days duration from any number of origins, starting every 6 hours during any selected period (e.g., a day, month, or season), moving either forward or backward in time. Each trajectory is calculated using transport winds averaged in a vertical layer. Dispersion calculations are made for the forward trajectories. Standard model output includes tables of transport layer depth, maximum vertical wind shear in the transport layer, and trajectory positions. Optional output includes trajectory plots and maps of time averaged surface air concentrations and deposition amounts.

This report discusses the input data, describes the transport and dispersion techniques used in ATAD, and gives examples of model output. The report also describes the input meteorological data format and data tape availability and gives ATAD operating instructions and how to obtain the model program.

AIR RESOURCES LABORATORIES
ATMOSPHERIC TRANSPORT AND DISPERSION MODEL
(ARL-ATAD)

Jerome L. Heffter

1. INTRODUCTION

The Air Resources Laboratories (ARL) Regional-Continental Scale Transport and Dispersion Model (Heffter, et al., 1975) has been used for several years to evaluate long-term pollution problems and also to investigate individual pollution episodes. A revised version of this model, called the ARL Atmospheric Transport and Dispersion Model (ATAD), is presented here. ATAD is oriented toward practical application for both short and long-term pollution studies.

The main revisions to the former model include: 1) elimination of the gridded wind input option for a simpler and more efficient operational model using only observed meteorological data over land areas; 2) time interpolation of the input winds to provide additional resolution at the four daily observation times; 3) model calculation of a variable transport layer, using vertical temperature profiles along a trajectory, replacing a climatological value input by the user; and 4) the use of the "puff" concept to simulate both short and long-term dispersion eliminating the need to define a mean wind in long-term "plume" equations.

ATAD calculates trajectories of 5 days duration from any number of origins, starting every 6 hours during any selected period (e.g., a day, month, or season), moving either forward or backward in time. Each trajectory is calculated using transport winds averaged in a vertical layer. Diffusion and deposition calculations are made for the forward trajectories.

The model requires two types of input information; a selection of parameter values that describe an individual run, and the meteorological input data for that run.

Model output includes:

a) A listing of the selected input parameter values that describe the run.

b) A listing of dates from the meteorological input.

c) A table of transport layer depth along each trajectory.

d) A table of maximum vertical wind shear in the transport layer along each trajectory.

e) A table of trajectory positions at 6-hour intervals.

f) Individual trajectories plotted on any desired map scale.

g) Maps of time-averaged surface air concentrations and deposition amounts at grid points.

This report discusses the input data, describes the transport and dispersion techniques used in ATAD, and gives examples of model output. The report also includes an appendix describing the input meteorological data format and data tape availability, an appendix with ATAD operating instructions, and an appendix for obtaining the model program.

2. DESCRIPTIVE INPUT DATA

ATAD requires certain user supplied descriptive input information for each operational run. Parameter values are punched on data cards for the location of the pollutant origin, start date and time period for which calculations are desired, direction of the run in time, and map boundaries for meteorological input data and for printed output. Standard ATAD output lists these descriptive parameters (including the trajectory duration) for run identification purposes (see Table 1). The sample run described in Table 1 is for Dayton, Ohio, starting July 27, 1975. One day of forward trajectories is designated, each of 5 days duration, with the latitude and longitude of the map boundaries as indicated.

Table 1. Standard ATAD Output of Discriptive Run Parameters.

```
INPUT DATA
    ORIGIN ******************************** DTN(39.80  84.20)

    START DATE **************************** 27 JUL 75
    NUMBER OF DAYS ************************  1
    DIRECTION IN TIME ******************** FORW
    TRAJECTORY DURATION IN DAYS *********  5
    MAP BOUNDARIES
    TOP AND BOTTOM LATITUDES ************    45.    35.
    LEFT AND RIGHT LONGITUDES ***********    88.    70.
```

3. METEOROLOGICAL INPUT DATA

Global upper air observed meteorological data are collected by the U.S. Air Force, sorted by synoptic time, and stored on magnetic tape (one month of data on 2 tapes). ARL extracts data in the lower atmosphere from these tapes for specific geographical areas of interest. A data base, called NAMER-WINDTEMP, has been created that contains upper air winds, temperatures, and heights from rawinsonde and pibal stations for North America (excluding Alaska) from the surface to 500 mb. Station identification information, including an average terrain height at each station (Smith, et al., 1966), and observed meteorological data are recorded for four observation times per day (00, 06, 12, and 18Z). One year of NAMER-WINDTEMP data is stored on two to three magnetic tapes. Five years of data (1975 through 1979) are presently archived for input to ATAD or other models. Detailed format information and availability of this data base are given in Appendix A.

Standard ATAD output for identifying the meteorological data used in an individual run lists beginning and ending dates (see Table II). The one day of trajectories of 5 days duration each, starting on July 27, as described in Table I, uses meteorological data through Aug 2-00Z from as many as 17 reporting stations within the meteorological data map boundaries also described in Table I.

Table II. Standard ATAD Output of Meteorological Data Identification.

```
              INPUT METEOROLOGY
              TIME PERIOD         TYPE
FROM 1975 JUL 27- 0Z          WIND
FROM 1975 JUL 27- 0Z          TEMP
  TO 1975 AUG  2- 0Z          WIND
  TO 1975 AUG  2- 0Z          TEMP

MAXIMUM NUMBER OF STATIONS 17
```

4. TRANSPORT

Four trajectories per day are calculated starting at 00, 06, 12, and 18Z. A trajectory is composed of a series of 3-hour segments. The duration of the trajectory (5 days in ATAD) determines the number of segments to be calculated (40). Each segment calculation is based on an average wind in a transport layer whose depth is determined by model calculation.

4.1 Average Wind

The average wind in a layer at a rawinsonde station is computed from winds linearly weighted with respect to the depth between mid reporting levels. If winds at the station are missing at an observation time (e.g., 06Z), the average wind is linearly interpolated from computed average winds at the station for 6 hours before and after observation time (e.g., 00Z and 12Z). For computation purposes, the observed or interpolated winds are assumed to persist from 3 hours before to 3 hours after an observation time (e.g., 06Z winds are used for computations during the period 03Z to 09Z).

4.2 Transport Layer Depth

The transport layer depth (TLD) is calculated using two techniques, depending on whether the trajectory begins during the day or at night.

For trajectories beginning during the day the following daytime technique is used for the entire duration of the trajectory. The TLD is determined by converting a temperature sounding at a rawinsonde station (temperatures at all mandatory and significant reporting heights) to potential temperatures (θ). The converted temperature sounding is scanned upward from 300 m above average terrain at the station to locate the lowest critical inversion. A critical inversion must satisfy the following criteria:

1. $\Delta\theta/\Delta Z \geq .005^{o}K/m$

2. $\theta_{TOP} - \theta_{BASE} \geq 2^{o}K$

where $\Delta\theta/\Delta Z$ is the potential temperature lapse rate and θ_{TOP} and θ_{BASE} refer to the top and base of a layer. When both criteria are satisfied,

$$TLD = TLH - ATH$$

where TLH, the transport layer height, is the height in the critical inversion layer where the temperature is $2^{o}K$ above the temperature at the inversion base and ATH is the average terrain height at the station (see Figure 1). TLH, rather than the height of the inversion base, is used to determine the TLD thus allowing for additional vertical expansion into a weaker critical inversion. For a strong inversion the difference between the two is negligible for all practical purposes. When no critical inversion exists, the TLD is assumed to be 3000 m.

Since a sounding may not adequately represent conditions throughout the night in the first few hundred meters above the surface, a Gaussian technique with average nighttime coefficients is used to calculate initial nighttime transport depths. For trajectories beginning at night, it is assumed that the TLD is approximated by $2\sigma_z$, twice the standard deviation of the vertical Gaussian pollutant distribution. In terms of K_z, the vertical coefficient of eddy diffusion,

$$TLD = 2(2K_z t)^{\frac{1}{2}}.$$

In ATAD, $K_z = 1\ m^2/sec$ which is an average value determined during stable nighttime conditions (Draxler, 1979). This technique is used throughout the night after which the daytime technique is assumed to apply for the remainder of the trajectory. Night is presently programmed into ATAD for the central and eastern U.S. and extends from 00Z to 12Z; therefore, the first four 3-hour segments of a trajectory beginning at 00Z and the first two 3-hour segments of trajectory beginning at 06Z use the nighttime technique.

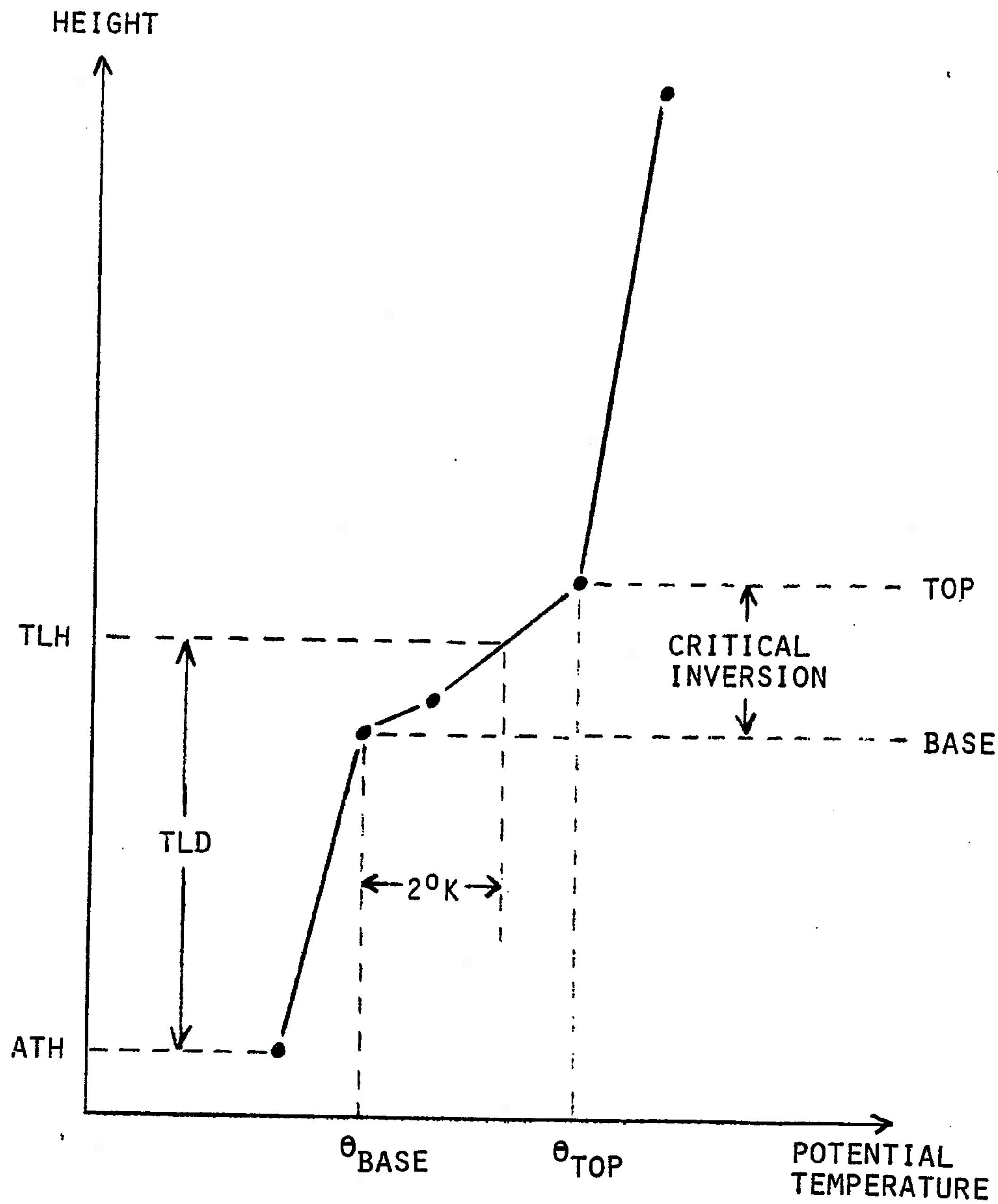


Figure 1. Schematic diagram for determining the transport layer depth (TLD). TLH refers to the transport layer height and ATH to the average terrain height.

Provision is made for minimizing surface frictional effects for both day and night transport by assuming the transport layer base to be 150 m above terrain.

4.3 Advection Calculation

A trajectory segment is determined from the average wind in the transport layer at each reporting station within a chosen radius of the segment origin as follows (see Figure 2):

$$S = \sum^{R} D_i A_i S_i / \sum^{R} D_i A_i$$

where,

S is the trajectory segment,

$\sum^{R}$ indicates the summation from each reporting station, i, within radius R. In ATAD, R = 560 km (300 naut. mi.),

S_i is the contribution from station i equal to $W_i\,\Delta t$ where W_i is the average wind at the station and the time increment Δt = 3 hrs,

D_i is the distance weighting factor equal to d_i^{-2} where d_i is the distance from a station to the midpoint of S_i,

A_i is the alignment weighting factor equal to $1 - .5|\mathrm{SIN}\theta_i|$ where θ_i is the angle between S_i and a line from the segment origin to the station.

A trajectory segment calculation can be made if 1) at least one wind level at a reporting station is included within, or no more than 600 m above the transport layer and 2) at least two reporting stations are within R (560 km) or one station is within R/2 (280 km). If these conditions are not satisfied, the trajectory calculation is terminated.

4.4 Output

An option is provided to output vertical potential temperature profiles for each rawinsonde station that contributes to determining an individual trajectory segment. The output option also lists observed wind components as a function of height and includes a plotted wind hodograph (see Figures 3a and 3b).

Standard output includes a table of TLD values along each trajectory for successive 3-hour segments (see Table III). A constant TLD may be specified by the user. In this case, no TLD table will be output but the base and top of the constant layer will appear in the listing of parameters that identify each individual run.

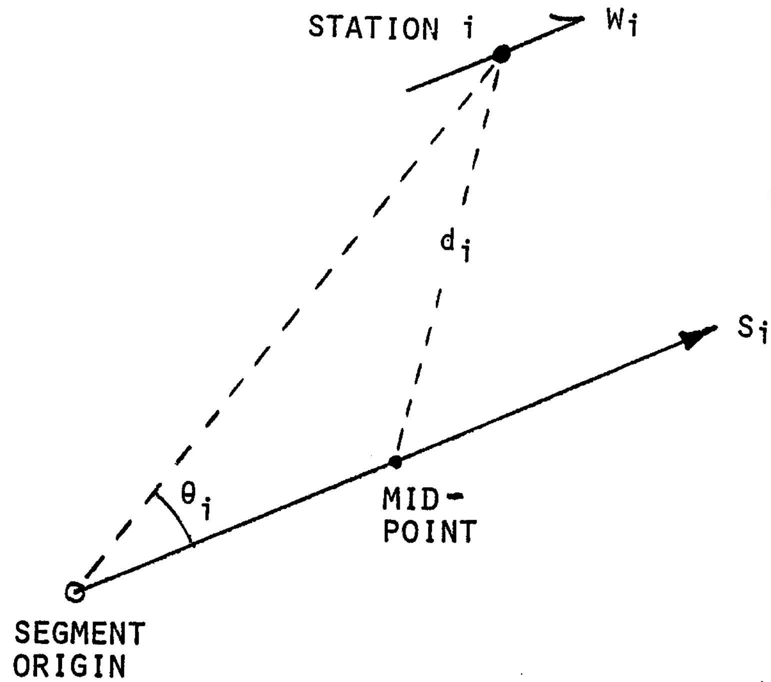
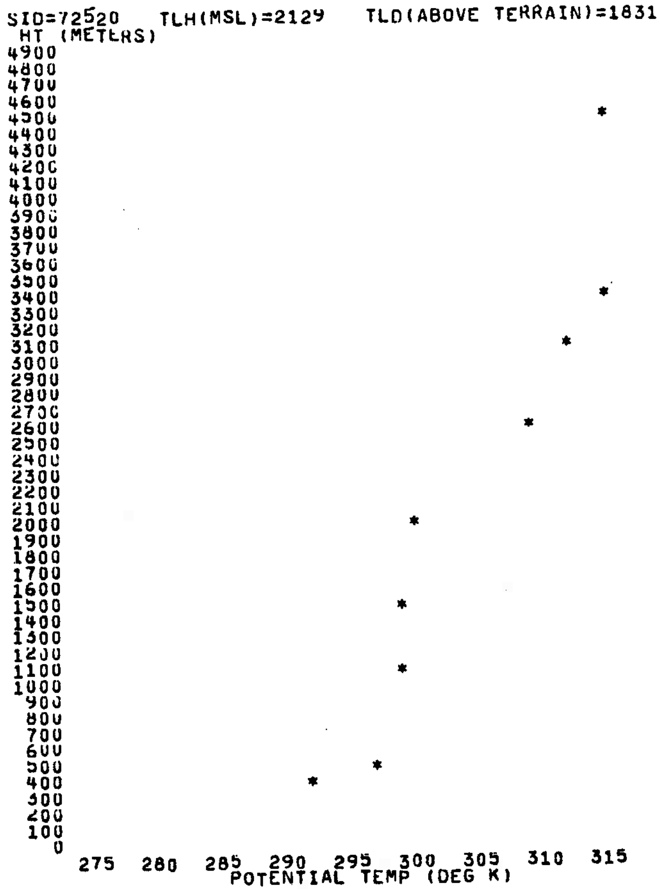


Figure 2. Configuration for determining the contribution S_i in a trajectory segment calculation from average wind W_i at station i.

a)



HT CODED	HT M	XW M/S	YW M/S
R	5820	11.6	-5.4
Q	5486	12.6	-5.9
P	4877	14.0	-5.1
N	4267	11.1	-2.0
M	3962	8.7	0.0
L	3658	8.7	0.0
K	3128	9.2	-0.8
J	2743	9.7	-0.8
I	2438	8.1	-1.4
H	2134	6.5	-1.7
G	1829	5.9	-1.6
F	1524	5.9	-1.6
E	1513	6.6	-1.2
D	1219	8.1	1.4
C	914	8.2	3.0
B	610	4.7	3.9
A	359	1.0	1.1

b)

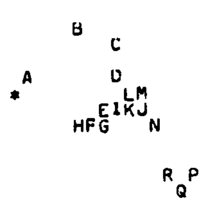


Figure 3. Optional ATAD output of: a) Vertical potential temperature profiles for individual rawinsonde stations, b) Vertical wind component structure and wind hodograph. In this example the station identification (SID) is Pittsburgh, PA (72520). TLH refers to the transport layer height and TLD to the transport layer depth. XW and YW, respectively, are the east-west and north-south components. The asterisk on the hodograph is the station location and North is vertical.

Table III. Standard ATAD Output Listing Transport Layer Depth Values Along Each Trajectory (trajectory termination is indicated by 99).

TRANSPORT LAYER DEPTH
(HUNDREDS OF METERS ABOVE TERRAIN)

DURATION (HOURS)

START DATE-TIME JUL 75	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48	51	54	57	60
27- 0Z	2	4	5	5	16	18	19	26	24	18	14	7	6	18	17	28	28	29	99	99
27- 6Z	2	4	15	17	17	16	21	21	19	16	13	27	24	28	28	25	25	99	99	99
27-12Z	16	16	17	16	16	20	20	21	20	28	29	26	25	24	24	21	23	99	99	99
27-18Z	16	21	18	17	17	20	25	28	27	25	23	16	16	12	13	13	13	18	18	19

START DATE-TIME JUL 75	63	66	69	72	75	78	81	84	87	90	93	96	99	102	105	108	111	114	117	120
27- 0Z	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99
27- 6Z	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99
27-12Z	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99
27-18Z	20	22	23	19	19	16	17	17	18	18	18	20	20	21	22	99	99	99	99	99

Standard output also includes a table of the maximum vertical wind shear in the transport layer for each segment (i.e., MAX $\Delta V/\Delta L$, where the V values are winds at successive reporting levels, L, in the transport layer) (see Table IV). A maximum shear value can be used as a guide to evaluating how well the computed average wind represents transport throughout the transport layer. As an example, a tabular value of 1 (.01 sec^{-1}), which might reflect a maximum shear of, perhaps, 3 m sec^{-1}/300 m, would indicate that the calculated average wind used to determine the segment at the indicated duration was well representative of the transport layer. Larger tabular values would suggest the average wind to be less representative of the actual pollutant transport. In Table IV all trajectories seem equally well representative.

The main output table in ATAD lists the latitude and longitude of trajectory positions at 6-hour intervals (see Table V). Other intervals divisible by 3 may be selected by the user, since the program retains each 3-hour position.

Another option provided is a plot of calculated trajectories on a computer page, using a Mercator map projection with a scale selected by the user (see Figure 4). Four trajectories (one day) are plotted on one page with a code to the plotted symbols provided for each computer run (inset in the figure).

5. DISPERSION

5.1 Diffusion

A pollutant plume is represented by a series of puffs, where each puff diffuses and deposits as it is transported at discrete time intervals along a trajectory path. The time intervals for each trajectory segment are determined by model calculation and may vary from several minutes to 3 hours. Puffs are emitted every hour. Puffs emitted between trajectory start-times follow interpolated trajectory paths. Each puff, which is assumed to have a Gaussian horizontal distribution and to be vertically mixed through the transport layer, diffuses according to:

$$C = (Q/2\pi\sigma_H{}^2 Z)\ \exp(-r^2/2\sigma_H{}^2)$$

where,

C = air concentration in the transport layer,

Q = emission amount per puff,

σ_H = horizontal standard deviation,

Z = transport layer depth (TLD),

r = distance from the puff center.

Table IV. Standard ATAD Output Listing Maximum Vertical Wind Shear Values Along Each Trajectory (trajectory termination is indicated by 99).

VERTICAL WIND SHEAR
(PER SECOND * 100)

START DATE-TIME JUL 75	DURATION (HOURS) 3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48	51	54	57	60	63	66	69	72	75	78	81	84	87	90	93	96	99	102	105	108	111	114	117	120
27- 0Z	0	0	0	0	1	1	1	2	2	1	1	1	1	1	1	1	1	1	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99
27- 6Z	0	0	1	1	1	2	2	1	1	1	1	1	1	2	1	1	1	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99
27-12Z	1	1	1	1	2	1	1	1	1	1	1	2	2	1	1	1	1	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99
27-18Z	1	1	1	1	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1	99	99	99	99	99

Table V. Standard ATAD Output Listing the Latitude and Longitude of Trajectory Positions (trajectory termination is indicated by 9990).

LATITUDE AND LONGITUDE OF TRAJECTORY POSITIONS (DEGREES*100)

START DATE-TIME JUL 75	DURATION (HOURS) 6 66 LAT	LON	12 72 LAT	LON	18 78 LAT	LON	24 84 LAT	LON	30 90 LAT	LON	36 96 LAT	LON	42 102 LAT	LON	48 108 LAT	LON	54 114 LAT	LON	60 120 LAT	LON
27- 0Z	4038	8385	4096	8255	4137	8054	4213	7780	4274	7524	4261	7295	4254	7102	4320	6897	4381	6642	9990	9990
	9990	9990	9990	9990	9990	9990	9990	9990	9990	9990	9990	9990	9990	9990	9990	9990	9990	9990	9990	9990
27- 6Z	4022	8346	4049	8176	4114	7955	4161	7705	4144	7479	4123	7276	4142	7080	4161	6866	9990	9990	9990	9990
	9990	9990	9990	9990	9990	9990	9990	9990	9990	9990	9990	9990	9990	9990	9990	9990	9990	9990	9990	9990
27-12Z	4006	8252	4065	8042	4106	7821	4086	7613	4058	7418	4063	7242	4059	7067	4005	6907	9990	9990	9990	9990
	9990	9990	9990	9990	9990	9990	9990	9990	9990	9990	9990	9990	9990	9990	9990	9990	9990	9990	9990	9990
27-18Z	3993	8247	4018	8051	3988	7896	3948	7725	3943	7571	3938	7440	3884	7323	3817	7248	3759	7208	3705	7132
	3663	7209	3628	7259	3589	7327	3542	7390	3491	7446	3428	7495	3346	7529	9990	9990	9990	9990	9990	9990

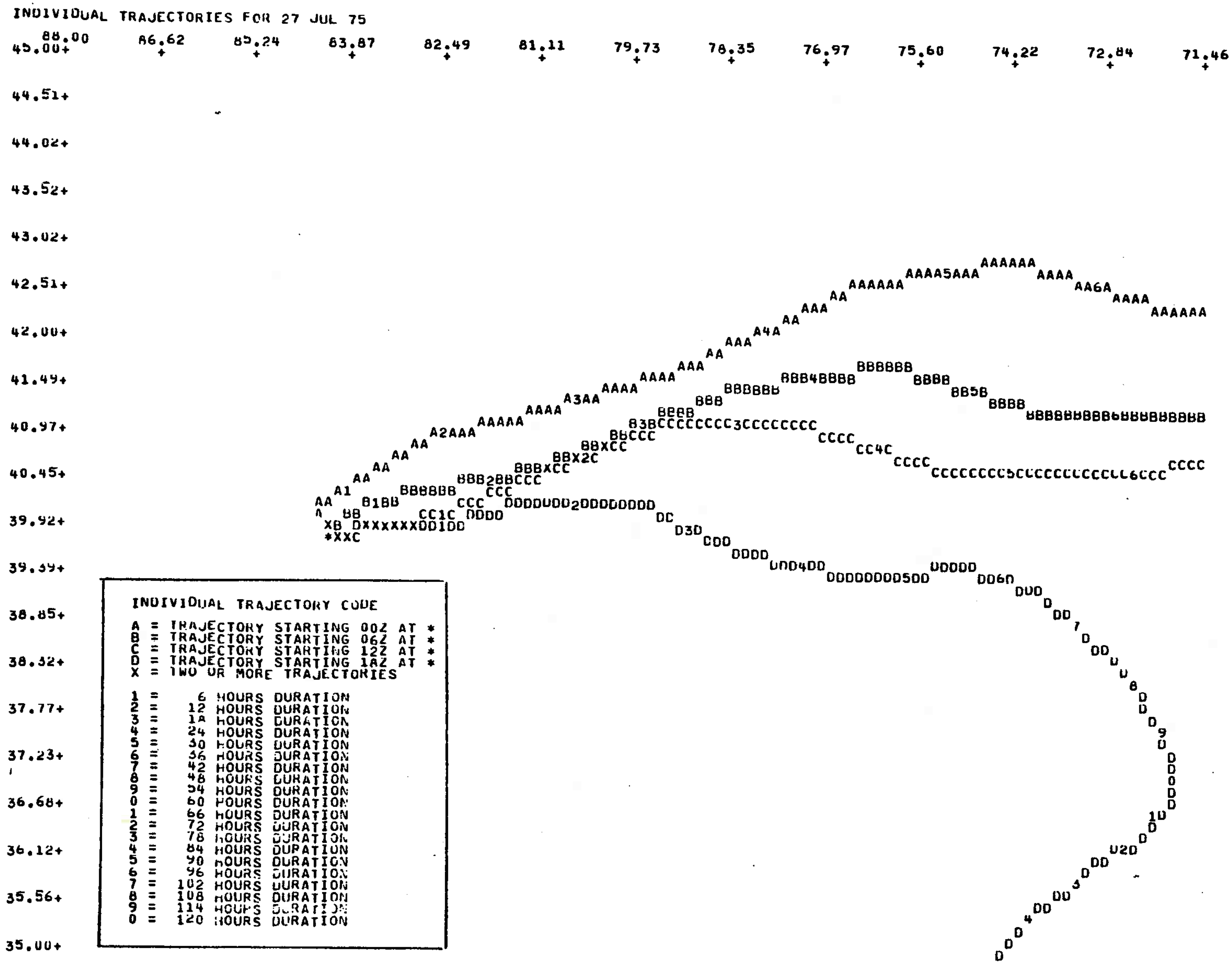


Figure 4. Optional ATAD Output of Individual Trajectory Plots.

A value of $\sigma_H(m) = .5t(sec)$ is used in ATAD for diffusion calculations. This approximation is based on measurements for several hours to several days as summarized by Heffter (1965) in a graph of σ versus time. It should be noted that when the TLD decreases with time, Z remains constant so there is no compression of the pollutant due to vertical mixing. When the TLD increases again, Z increases proportionally.

5.2 Deposition

The concept of a deposition velocity is used to calculate dry deposition along a trajectory and an empirical scavenging ratio is used for wet deposition.

The mass deposited per unit area by dry deposition from the transport layer during the time interval Δt is $CV_d\Delta t$ where V_d is the dry deposition velocity. The total mass per unit area in the layer before deposition is CZ. Thus, the fraction of mass deposited from the layer by dry deposition during the interval Δt is

$$f_d = V_d \Delta t/Z.$$

The mass deposited per unit area by wet deposition is proportional to EP where E is the scavenging ratio and P is the precipitation rate. In ATAD, $E = 4.2 \times 10^5$ (by volume), which is a reasonable average of values measured by Engelmann (1970). The height of the precipitation layer, Z_p, is assumed to be 4000 m as a climatological average. Engelmann assumes that the pollutant is uniformly mixed through the precipitation layer. Since the height of the variable transport layer is always lower than the height of the precipitation layer, scavenging takes place in Z/Z_p of the precipitation layer and the mass deposited is, therefore, $CEP\Delta tZ/Z_p$. Thus the fraction of mass deposited by wet deposition during the interval Δt is

$$f_w = EP\Delta t/Z_p.$$

When the effects of both wet and dry deposition are incorporated into the model, the air concentration depleted by deposition is

$$C(1-f_d)(1-f_w) = C(1-V_d\Delta t/Z)(1-EP\Delta t/Z_p).$$

The calculations for the total dry and wet deposition assume the processes act independently, so the mass available for wet deposition after dry deposition has occurred is $C(1-f_d)$. The amount of dry and wet deposition is, therefore,

$$CV_d\Delta t + C(1-V_d\Delta t/Z)EP\Delta tZ/Z_p.$$

Values used in ATAD for deposition calculations are $V_d = .01$ m/sec and $p = 3.2 \times 10^{-8}$ m/sec (40 in/yr).

Diffusion and deposition calculations are made for each Δt time interval along each trajectory or interpolated trajectory position. Air concentration values are averaged and deposition amount are summed (for time periods of 12 hours or more as designated by the user) at grid points on a map identical to the trajectory map. A computer plot of the results can include:

1) Average surface air concentrations without deposition (see Figure 5).

2) Average surface air concentrations with deposition,

3) Total deposition.

The average source term and a code to the plotted symbols are provided for each computer run (inset in Figure 5).

6. OPERATIONS

For one origin, one month of individual forward trajectories of 5 days duration with maps of monthly average surface air concentration and deposition amounts can be run on an IBM 360/195 in about 2 minutes. Each additional origin adds about 20 seconds to the run. Detailed operating instructions for ATAD are given in Appendix B. Output from the sample run described in the appendix is the basis for the tables and figures of this report.

Card images of the FORTRAN program have been written on magnetic tape. The meteorological data set used in the sample run of Appendix B has also been written on the tape. This allows the user to compare his output with the tables and figures of this report for check-out purposes. Detailed format information and the availability of this tape are given in Appendix C.

7. ACKNOWLEDGMENTS

This work was supported by the Office of Health and Environmental Research, Department of Energy.

8. REFERENCES

Draxler, R.R., 1979: Estimating Vertical Diffusion from Routine Meteorological Tower Measurements, Atmos. Environ., 13, pp. 1559-1564.

Engelmann, R.J., 1970: Scavenging Prediction Using Ratios of Concentrations in Air and Precipitation, Proc. Symposium on Precipitation Scavenging, AEC Symposium Series 22, pp. 475-485.

Heffter, J.L., A.D. Taylor, and G.J. Ferber, 1975: A Regional-Continental Scale Transport, Diffusion, and Deposition Model, NOAA Tech. Memo. ERL ARL-50, Air Resources Labs., Silver Spring, MD 20910, 29 pp.

Heffter, J.L., 1965: The Variation of Horizontal Diffusion Parameters with Time for Travel Periods of One Hour or Longer, J. Appl. Meteorol., 4(1): 153-156.

Smith, S.M., H.W. Menard, and G. Sharmin, 1966: World Wide Ocean Depth and Land Elevations Averaged for One Degree Squares of Latitude and Longitude, Scripps Institute of Oceanography, La Jolla, CA. (Available from NOAA Library and Information Services Division, 6009 Executive Blvd., Rockville, MD 20852.)

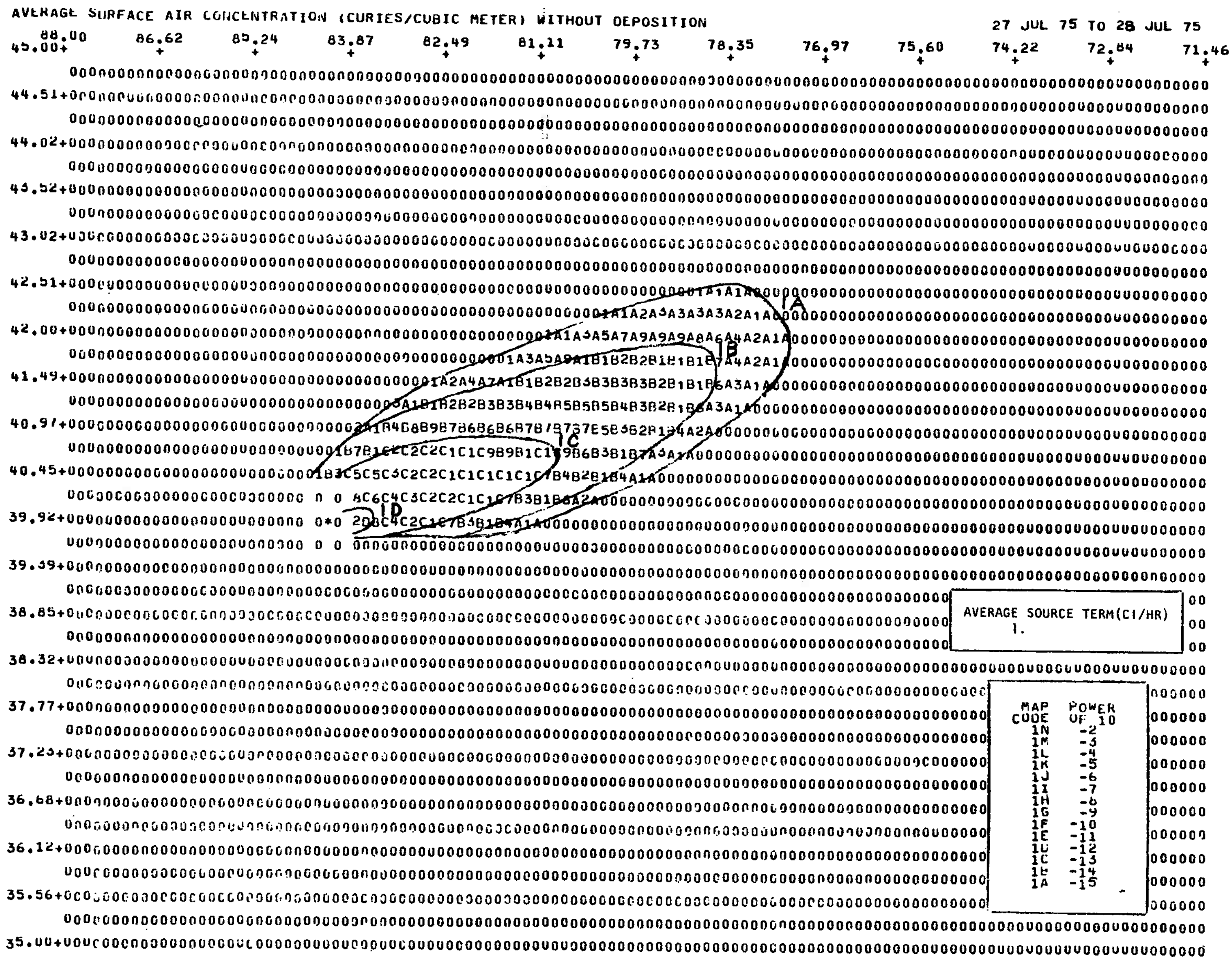


Figure 5. ATAD Output of Average Surface Air Concentration Coded Values. (The analysis is hand drawn.)

APPENDIX A

NAMER-WINDTEMP DATA MAGNETIC TAPE FORMAT

NAMER-WINDTEMP data tapes contain rawinsonde and pibal observations for North America (excluding Alaska) from the surface to 500 mb.

TAPE CHARACTERISTICS

```
TYPE          -  9 track, 1600 bpi, EBCDIC
LABEL         -  None
RECORD FORMAT -  FB
RECORD LENGTH -  30
BLOCK SIZE    -  12000
```

TAPE ORGANIZATION

All reporting stations, in block-station sequence, are compiled for each sequential observation time.

```
4 observation times per day (0,6,12,18 GMT)
2 files per month (day 01 to 15; day 16 to last)
12 files per tape (6 months) (overlap onto another tape may occur
                              at the end of a year)
```

DATA ORGANIZATION FOR EACH OBSERVATION TIME

```
TIME REC (FOR WINDS)
          STA REC (STATION 1)
                 WIND REC (HEIGHT 1)
                 WIND REC (HEIGHT 2)
                 ETC.
          STA REC (STATION 2)
                 WIND REC (HEIGHT 1)
                 WIND REC (HEIGHT 2)
                 ETC.
          ETC.
TIME REC (FOR TEMPERATURES)
          STA REC (STATION 1)
                 TEMP REC (HEIGHT 1)
                 TEMP REC (HEIGHT 2)
                 ETC.
          STA REC (STATION 2)
                 TEMP REC (HEIGHT 1)
                 TEMP REC (HEIGHT 2)
                 ETC.
          ETC.
```

DATA FORMAT

TIME REC:	MONTH (1ST 3 LETTERS) A3	YEAR I4	DAY I2	HOUR I2	NUMBER OF REPORTS I4	NUMBER OF RECORDS I5	MET FIELDS A1 {W = WINDS, T = TEMPS}

STA REC:	BLOCK STATION I5	LATITUDE (DEG*100) I5	LONGITUDE (DEG*100) I7	STATION HGT (M,MSL) I5	AVG TERRAIN HGT (M,MSL) I5	NUMBER OF LEVELS I2

WIND REC:	WIND HGT (M,MSL) I5	WIND DIRECTION (DEG) I3	WIND SPEED (M/S*10) I4

TEMP REC:	TEMPERATURE HGT (M,MSL) I4	PRESSURE (Mb*10) I5	TEMPERATURE (DEG K*10) I4

NAMER-WINDTEMP data tapes starting for the year 1975 (refer to TD-9743) are available at:

National Climatic Center, NOAA
Digital Products Section
Federal Building
Asheville, NC 28801

APPENDIX B

ARL-ATAD OPERATING INSTRUCTIONS

Instructions for Input Data

A data card is necessary for each set of parameters as shown below. An example for each parameter set is given in italics with an explanation included. These sample parameter values are used for the run whose output is given in the figures and the tables of this report (see Table 1).

ON EACH INPUT CARD IN THE DESIGNATED FORMAT, STARTING IN COLUMN 1, PUNCH:
NUMBER OF ORIGINS(NN)

1 NN
01

The computer run will be made for 1 origin (note the leading 0 or blank that must be punched for proper input alignment under the designated code both here and in the following entries). Additional files must be allocated for more than one origin (NN>1). The computer program requires the files allocated on units 20+1, 20+2, ...20+NN.

2 ORIGIN ID(III-LETTERS) LAT(LL.LL) LON(LLL.LL) IN WHOLE DEGREES AND HUNDREDTHS
III LL.LL LLL.LL
DTN *39.80 084.20*

Trajectories originate at Dayton, Ohio, latitude 39.80°N, longitude 84.20°W. (A card must be punched for each origin so the number of cards here must equal the number of origins on card 1).

3 START DAY(DD) MONTH(MMM-FIRST THREE LETTERS) YEAR(YY)
DD MMM YY
27 JUL 75

Computations begin for trajectories starting July 27, 1975.

4 NUMBER OF DAYS(NN) TO BE RUN
NN
01

Four trajectories per day will be run for one day, July 27. (It should be noted that if complete 5-day backward trajectories are desired for the one-day period, the start day on card 3 should be 5 days earlier, or 22 Jul 75, to provide input data for complete trajectory calculations. The number of days to be run should then be increased to 5+1, or 6 days.) The maximum number of days that can be run is 31. (If more days are desired, the first three dimension statements in the main program must be changed as indicated in the program comments.)

5 FORWARD(FORW) OR BACKWARD(BACK) IN TIME(UNDER XXXX)
XXXX
FORW

Trajectories are to be run forward in time.

6 TRANSPORT LAYER BASE(BBBB) AND TOP(TTTT) IN METERS ABOVE TERRAIN
BLANK CARD FOR DETERMINATION BY THE MODEL
BBBB TTTT
blank card

A blank card will designate the transport layer to be determined by model calculations. Otherwise, winds will be averaged through any desired constant transport layer designated here by the user.

7 MAP BOUNDARIES TOP LAT(TT) BOTTM LAT(BB) LEFT LON(LLL) RIGHT LON(RRR)
TT BB LLL RRR
45 35 088 070

Meteorological data within the map area bounded by 35°N to 45°N and 70°W to 88°W are extracted from the NAMER-WINDTEMP data tapes for use in model calculations. A smaller than necessary area may limit calculations terminating trajectories prematurely. A larger than necessary area may include unneeded data and waste computation time. Individual requirements and experience will dictate reasonable values to be chosen. It is suggested that (LLL-RRR) $\cong$ 1.7 (TT-BB) for reasonable computer map display purposes in card 9 below.

8 TO PRINT VERTICAL TEMPERATURE AND WIND PROFILES FOR A TRAJECTORY POSITION
TRAJECTORY DAY(DD)
TRAJECTORY START HOUR(ZZ-00 06 12 18)
TIME AFTER START OF TRAJECTORY(TT) IN HOURS
BLANK CARD FOR NO PROFILES
DD ZZ TT
27 00 12

Vertical temperature and wind profiles will be printed during the computation for the trajectory starting July 27 at 00Z. The profiles are those used for computation at a time period 12 hours after start time (the trajectory position at 12Z). A blank card will cause no profiles to be printed.

9 CODE 1 FOR TRAJECTORY MAPS OR 0 FOR NO MAPS(UNDER T)
CODE 1 FOR CONCENTRATION AND DEPOSITION MAPS OR 0 FOR NO MAPS(UNDER C)
T C
1 1

The number 1 under T will designate trajectories to be printed on a latitude-longitude grid within the area indicated by the input map boundaries. The number 0 will designate no trajectories to be printed. The number 1 under C will designate concentration and deposition calculations to be made and printed on grids similar to the trajectory grid (for forward in time trajectories only). The number 0 will designate no dispersion calculations are to be made (always to be used with backward in time trajectories). If dispersion calculations are desired, three additional cards are required as input:

9-1 AVERAGE SOURCE TERM IN CURIES PER HOUR(QQQ)
QQQ
001

An average source of 1 Ci/hr is designated.

9-2 SAMPLING PERIOD DURATION IN HOURS(DDD)
DDD
024
A sampling period will be 24 hours in duration.

9-3 NUMBER OF SAMPLING PERIODS(NNN)
NNN
001
One sampling period of 24 hours is designated.

Description of Output Data

Standard and optional output data are listed according to computer printed headings. A description is included for each heading.

INPUT DATA

Standard output includes a run descriptive input data table printed as a check on pertinent punched card values and as a permanent record for the run. A trajectory duration of 5 days has been programmed into the model and appears here. (For other durations, the first two dimension statements in the main program and the statement defining NDYDUR in SUBROUTINE INPUT must be changed as indicated in the program comments). If the transport layer is determined by the model, no layer information will appear here.

INPUT METEOROLOGY
TIME PERIOD TYPE

Standard output includes tabular values of the input meteorological data time period and type (read directly from the input tapes) as a check that proper data are being used in the calculations. (Backward in time runs will list the time periods in reverse chronological order.) The maximum number of rawinsonde stations used in the calculations is also printed.

SID= TLH= TLD=

Optional profiles of vertical temperatures are printed for the previously indicated trajectory and time period. Profiles are identified by the block-station number (SID) of the contributing rawinsonde station. In addition, the computed transport layer height (TLH) in meters above mean sea level (MSL) and the transport layer depth (TLD) in meters (above terrain) are given.

CODE HT XW YW

A wind profile is included with each optional temperature profile. The height (HT) in meters above MSL of the X-wind component (XW) and Y-wind component (YW) is given here. A wind hodograph, using tabular coded height values, is also plotted for viewing convenience. The station location is indicated by an asterisk and North is vertical toward the top of the printout.

TRANSPORT LAYER DEPTH
(HUNDREDS OF METERS ABOVE TERRAIN)

Standard output includes a table of transport layer depth given when the layer is determined by the model. The printed values are averages along each trajectory for successive 3-hour intervals. The coded number 99 indicates the trajectory computation terminated due to a lack of sufficient meteorological data. No table is printed when the user designates transport layer values.

VERTICAL WIND SHEAR
(PER SECOND*100)

Standard output includes the maximum vertical shear in the transport layer for successive 3-hour intervals. The coded number 99 indicates trajectory termination.

LATITUDE AND LONGITUDE OF TRAJECTORY POSITIONS (DEGREES*100)

Standard output includes tabular values along each trajectory at 6-hour intervals. The coded number 9990 indicates trajectory termination. Other intervals divisible by 3 may be substituted by changing the LAT LON PRINTING INTERVAL IN HOURS (IHRINP) in SUBROUTINE INPUT.

INDIVIDUAL TRAJECTORY CODE AND PLOTS

An individual trajectory code precedes optional plots of 4 individual trajectories per day identified by date.

AVERAGE SOURCE TERM

MAP CODE

AVERAGE SURFACE AIR CONCENTRATION (CURIES/CUBIC METER) WITHOUT DEPOSITION.

AVERAGE SURFACE AIR CONCENTRATION (CURIES/CUBIC METER) WITH DEPOSITION.

DEPOSITION (CURIES/SQUARE METER)

Average source term and codes for optional concentration and deposition plots identified by averaging dates.

APPENDIX C

ATAD LISTING AND SAMPLE METEOROLOGICAL DATA

TAPE ORGANIZATION

- FILE 1 ATAD Listing.
- FILE 2 Sample meteorological data input for the run used in this report.

TAPE CHARACTERISTICS

TYPE	9 track, 1600 bpi, EBCDIC
LABEL	None
RECORD FORMAT	F
RECORD LENGTH	80
BLOCK SIZE	80

An ATAD listing and sample meteorological data tape (refer to TD-9743) is available at:

National Climatic Center, NOAA
Digital Products Section
Federal Building
Asheville, NC 28801