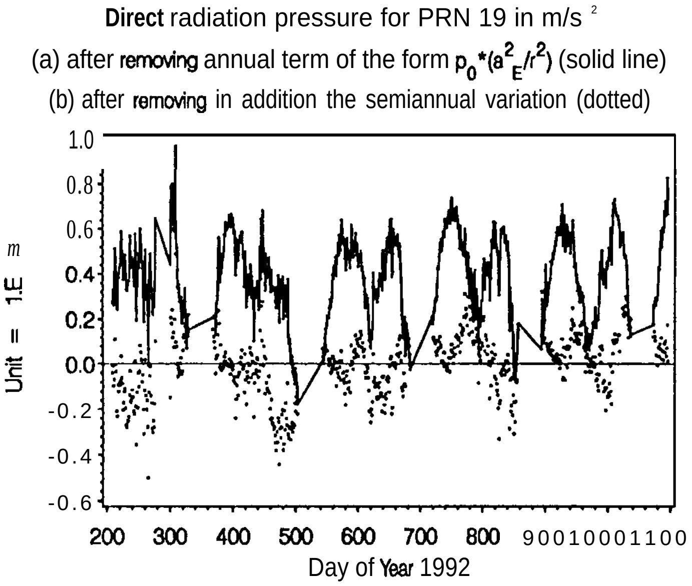

Figure 13. Direct radiation pressure after removing the annual term (solid line) and the semiannual term (dots),

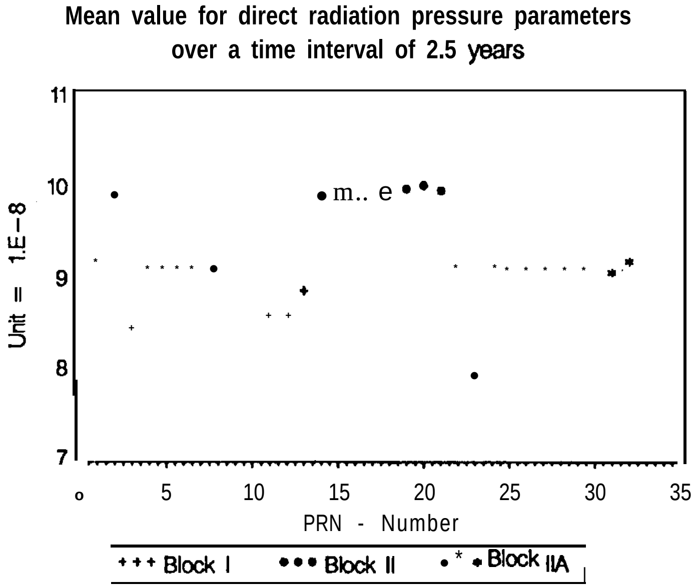

Figure 14. Mean values for direct radiation pressure parameters over a time interval of 2.5 years.

Table 6 summarizes the mean radiation pressure parameters corresponding to the ROCK4/42 T-model. This reconstruction was done by taking out the mean value of the S-models over one revolution and by adding the mean value corresponding to the T-models.

Table 6 contains in condensed form one of our a *priori* radiation pressure model files. There are two more of these files available, one for the ROCK4/42 S-model and one for the Z-model (based on a pure direct radiation pressure along the line sun-satellite). The actual radiation pressure has to be computed by adding to the ROCK4/42 T-model values (based on the masses in the above table) the term in column "DPO" in Table 6; the resulting (vectorial) sum has to be scaled by the current value of r^2_0/r^2, where *r.* is the mean distance sun–satellite (astronomical unit), and *r* is the actual distance sun–satellite. For the sake of completeness we also include in Table 6 the mean values of the y-biases as computed over the time period mentioned.

Table 6. A priori radiation pressure model referring to the ROCK4/42 T-models. Established on an analysis based on the alai/y estimates of p. and p_2 by the CODE processing center.

Satellite Specific Data 08-Mar-95

Radiation Pressure Model: T9501O1 (Rock Model T, Fliegel et al., 1992)

IPRN	Block No.	Mass (Kg)	DPO (1.E-8)	P2 (1.E-8)	Rock Mode (T=1,S=2)
1	3	975.0	+0.2132	-0.5640	1
2	2	878.2	-0.0169	-0.3178	1
3	1	521.8	-0.1788	-0.2655	1
4	3	975.0	+0.1072	-0.7666	1
5	3	975.0	+0.1145	-0.4401	1
6	1	453,8	0.0000	0.0000*)	1
6	3	975.0	+0.1410	-0.8875	1
7	3	975.0	+0.0807	-0.8180	1
8	1	440.9	0.0000	0.0000*)	1
9	1	462.6	0.0000	0,0000*)	1
9	3	975.0	+0.0835	-0.6081	1
11	1	522.2	-0.0385	-0.3159	1
12	1	519.8	-0.0475	-0.1326	1
13	1	520.4	+0.2326	+0.0332	1
14	2	887.4	+0.0859	-0.7411	1
15	2	885.9	+0.0450	-0.5184	1
16	2	883.2	-0.0033	-0.5385	1
17	2	883.2	+0.0009	-0.4713	1
18	2	883.2	+0.0321	-0.6809	1
19	2	883.2	+0.0924	-0.4080	1
20	2	887.4	+0.1929	-0.2303	1
21	2	883.9	+0.0601	-0.1410	1
22	3	975.0	+0.1479	-0.4627	1
23	3	972.9	-1.0906	-0.8189	1
24	3	975.0	+0.2121	-0.8389	1
25	3	975.0	+0.1 196	-0.5758	1
26	3	975.0	+0.0943	-0.6713	1
27	3	975.0	+0.0709	-0.6201	1
28	3	975.0	+0.1 557	-0.5162	1
29	3	975.0	+0.1210	-0.7231	1
31	3	975.0	+0.0959	-0.3349	1

Block number: Block 1=1, Block II=2, Block IIA=3

*) No information available for these block I satellites (out of operation prior to the start of the IGS).

It is instructive to inspect the daily estimates of the y-bias parameter p_2. We include the estimates for PRN 19 in Figure 15. Again we exclude the estimates during the shadow periods (there are severe correlations between the y-bias and the pseudo-stochastic pulses in S-direction). We clearly see a periodic pattern with the angle 2γ, where y is the angle between the normal to the orbital plane and the direction earth-sun. We also see that the pattern changed considerably around June 1994. The reason for this change might be correlated with the change of the attitude control. This behaviour also shows that the mean values in Table 6 have to be interpreted rather carefully.

Attempts were made at CODE to improve the force model for GPS satellites. One result is the program ORBIMP, which allows to solve for empirical force terms as they were suggested by Colombo (1989), for the parameters of a new radiation pressure model, for albedo parameters, and for the resonance terms of the geopotential. ORBIMP uses the satellite positions of the precise ephemerides files (SP3-Format) as pseudo-observations. Beutler *et al.* (1994) suggested to decompose radiation pressure into three orthogonal components, namely an acceleration in the direction sun-satellite, an acceleration along the space-body

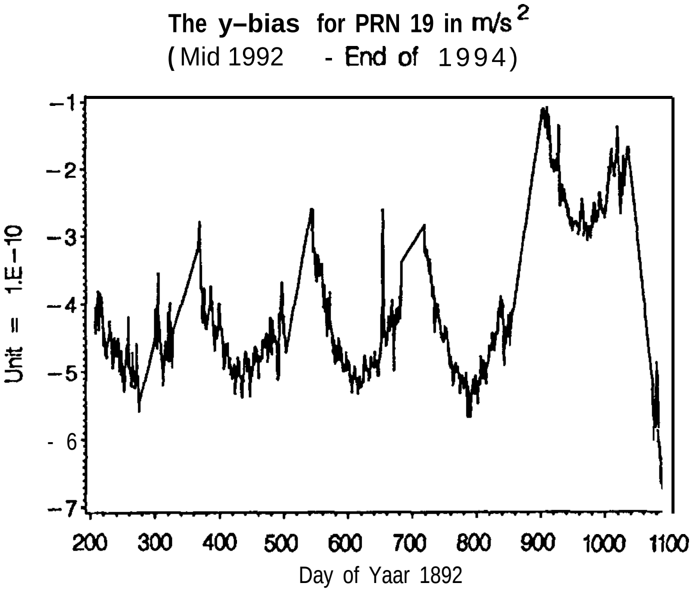

Figure 15. The y-bias estimates for PRN 19 over a time interval of 2.5 years.

fixed y-axis, and the third acceleration normal to the first two accelerations. Each component is then modeled by a trigonometric series using the argument of latitude u_0 as an independent argument. If these series are truncated after the terms of first order, 9 radiation pressure parameters have to be solved for, The fit of 7- to 14-day arcs to satellite positions of precise ephemerides files as produced by the IGS analysis centers is of the order of 10–20 cm, which is very close to the actual accuracy of these orbits. More information maybe found in Beutler *et al.* (1994).

ORBIMP is used by the IGS Analysis Center Coordinator for the so-called long-arc analyses. The same program is also used at CODE to check the quality of the daily orbit files before they are sent to the IGS data centers. Let us include in Figure 16 the rms per satellite coordinate for all satellites for GPS week 789 using the G1- (=one day) and the H3- (=the official) solution. PRN 23, showing (as usual) an abnormal behaviour, was excluded from Figure 16. We can see that the 3-day solution H3 is slightly superior to the G1 solution.

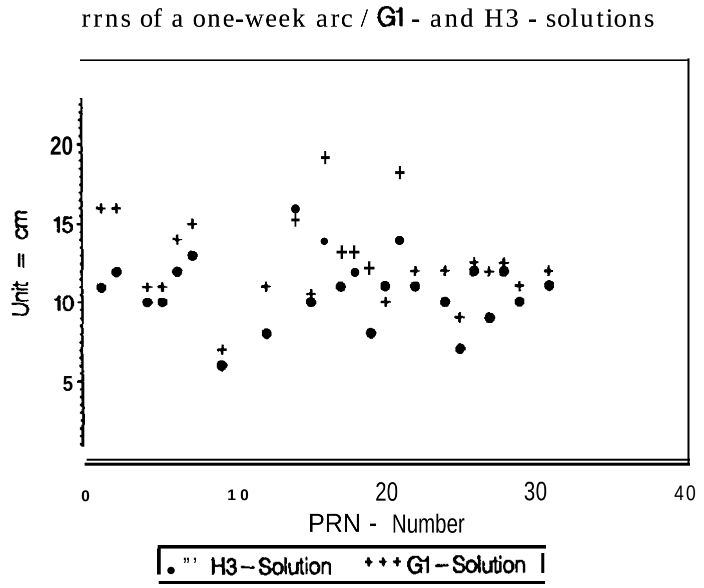

Figure 16. Rms of a one-week arc through the G1 - and the H3- solutions.

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The ESA/ESOC IGS Analysis Centre

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Introduction

ESOC is the satellite control center of the European Space Agency (ESA). It is responsible for the operations of the ESA satellites, its ground stations, and its communications network. In order to operate the satellites that are under control of ESA, ESOC has to be able to precisely determine their orbits, the position of the possible tracking stations, and other geodetic parameters. A state of the art software package has been developed over a number of years at ESOC and before the IGS campaign started it was already well proven through extensive processing of data from many satellites, including satellite laser ranging (SLR) from Lageos and Starlette. Although not able to handle GPS data types (pseudo-range and phase) at that time, a multi-satellite solution capability was already implemented. After submitting the proposal for ESOC participation as an IGS Analysis Centre a major effort was undertaken to develop GPS capabilities in our software. Important aspects of the use of the ESOC orbit and geodetic parameter estimation software are that this software is independent from other packages in use for GPS analysis, and the possibility of consistent processing of other geodetic satellite data with a single package (SLR, Doris, GPS, altimetry, PRARE, . ..).

ESOC is preparing for the use of GPS or other GNSS in operational and precise orbit determination. Some European spacecraft have already been equipped with GPS receivers and it is foreseen that some ESA spacecraft will also use GPS. An additional application of GPS of interest for ESOC is the use of GPS receivers located in our ground stations to obtain ionospheric corrections for single-frequency ranging.

We have been participating as an IGS Analysis Centre from the beginning of the IGS. Our first solutions for orbital and polar motion parameters were transmitted to the CDDIS on 24 July 1992, about one month after the start of the Epoch 92 campaign. By early August the delay with respect to real time was reduced to about 10 days. Along with several other centers, ESOC continued to process IGS data after the decision of the IGS Campaign Committee in October 1992 to continue the IGS activity in the form of an "IGS Pilot Service" and then in January 1994 as the IGS Operational Service. These series have guaranteed continuity of the IGS activities after the success of the first campaign.

ESOC IGS Analysis

ESOC is using the observation of most of the Rogue and TurboRogue receivers in the IGS network. Those that are always used are the 13 fixed stations and our own stations. Additional receivers up to a total of about forty are added to improve the global distribution of observations. We use phase double differences as our basic observable, because they are especially well-suited for batch estimation. With double differences the satellite and clock biases for every epoch do not need to be estimated with the same accuracy as that of the measurement, so the total number of parameters to be estimated is greatly reduced. Precise clock biases areproduced in post-processing, after the orbits have been determined.

Preprocessing

Preprocessing is done with the program GPSOBS. GPSOBS reads RINEX observation files and obtains independent ionospheric-free double-difference phase combinations. An elevation cut-off angle of 20 degrees is used. Cycle slip detection is performed using two-integer, almost-ionospheric-free combinations, the 4L1 - 3L2 and the 5L1 - 4L2. Satellite center of mass and phase wind-up corrections are performed at this step. For the satellite center-of-mass correction the following values are used:

- Block I: 0.210, 0.000, 0.854m in satellite x, y, z.
- Block II/IIA: 0.279, 0.000, 1.026m in satellite x, y, z.

GPSOBS also estimates the station clock biases to correct the time tags of the measurements. Double-difference phase measurements are output every six minutes. Observations of eclipsing satellites are excluded during eclipse and 30 minutes after it. We are not modeling the biased-satellite yaw model because it does not fully predict the attitude of the satellite.

Orbit and Geodetic Parameter Estimation

Orbit and geodetic parameter estimation is performed using the program BAHN. BAHN is a batch least-squares estimator for dynamic orbit determination. We use a 48-hour arc in order to obtain the precise orbit and erps for each day, with 12 hours before and after the central day.

Measurement Models

- Velocity of light: 299792.458 km/s
- Troposphere: Willmann model.
- Ionosphere: first-order term removed by using the so-called ionospheric-free combination.
- Plate motions: ITRF values used when available, if not Nuvel-NNR.
- Tidal displacements: Wahr model used for solid earth tidal displacement. Pole tide and ocean and atmospheric loading are not modeled.
- Ground antenna phase center calibration: not used. Only Rogue and TurboRogue receivers with Dorne-Margolin choke-ring antennas used.

Dynamic Models

- Geopotential: GEM-T3 up to degree and order 8 with the GM (398 600.4415 km^3/s^2), C21 and S21 from the IERS standards.
- Third-body forces: Sun, Moon and four planets regarded as point masses. Ephemeris form JPL DE200, GM of Sun 132712440000.0 km^3/s^2, GM of Moon 4902.7991 km^3/s^2.
- Solar radiation pressure: ROCK4 and ROCK42 approximations denoted as TIO and T20 used for Block I and Block 11 satellites. One scale factor and one Y-bias estimated per arc.
- Tidal forces: Wahr model for solid earth tides, Schwiderski for ocean tides.

Reference Frames

- Inertial: Geocentric, mean equator and equinox of 2000 Jan. 1 at 12:00 (J2000.0).
- Terrestrial: ITRF reference frame realized through a set of 13 station coordinates and site velocities.
- Interconnection: Precession, IAU 1976 Precession Theory; Nutation, IAU 1980 Nutation Theory; Celestial pole offsets from IERS Bulletin B; relation between UT1 and GMST, Aoki 1982; Pole and LODR estimated as constants for 24-hour intervals; Tidal variations in UT1, Yoder model.

Numerical Integration

Adams-Bashforth/Adams-Moulton predictor-corrector of order 8 started with a Runge-Kutta/Shanks of order 8. Integration step of 6 minutes.

Estimated Parameters

- Station coordinates: 13 stations fixed to the agreed ITRF positions. Remaining station positions estimated.
- Orbital parameters: Initial position and velocity, solar radiation pressure-scale factor and y-bias estimated as constant through the 48-hour orbital arc.
- Double-difference phases ambiguities estimated as real values.
- Earth rotation parameters: x and y pole and LODR estimated as constants for 24-hour intervals. LODR is the excess of the length of the day regularized as described in the IERS standards.
- Receiver clock biases and drifts estimated as constant parameters between clock resets.
- Maneuvers estimated as instantaneous velocity changes.
- Tropospheric zenith delay and shape parameter estimated linear in 6-hour intervals.

Precise Clock Bias Estimation

The Rogue and TurboRogue receivers used for our IGS Analysis can track the P code when Anti-Spoofing (AS) is not activated. When AS is activated they track the CA code and the cross-correlation between the codes in L1 and L2. With these two measurements a code in L1 is directly obtained (CA code) and a code in L2 can be reconstituted by adding the cross-correlation delay to the CA code. We have observed that these receivers have a bias between the P and the CA code. This bias can be clearly observed when the receiver is tracking simultaneously P and CA code (e.g., for a satellite that is not performing AS). The value of the bias depends on the particular receiver and its software and can be as big as 60 meters. In order to calculate the clock biases the values of the CA pseudo-range biases have to be estimated. This has to be done every day because of unannounced receiver changes.

We are using the daily average of double difference pseudo-range residuals as the basic observable to estimate the CA biases. For most of the receivers these biases do not depend on the PRN number, but for others we have to calculate a bias for every satellite.

The precise clock bias values are estimated from pseudo-ranges and carrier phase by using the CA pseudo-range biases and the parameters estimated in BAHN to correct the measurements.

The clock bias estimation is separated into a clock drift estimation using carrier phase and a clock bias estimation that uses the estimated clock drifts and pseudo-ranges. Satellite clock bias values are constrained to the Navigation Message values to produce values aligned with the GPS system time. The evolutions of the drift of receivers connected to hydrogen masers is also constrained to stabilize the drift and clock estimates.

Precise values are obtained every 60 seconds and can be used to interpolate the satellite clock value at any time.

Post-Processing and Quality Control

The orbits obtained with BAHN are combined with the precise clocks and output every 15 minutes in a file with the sp3 format. The erps are output to a file with the IERS format.

Quality control is performed by checking the following:

- Post-fit double-difference phase measurement residuals per station and satellite.
- Orbit overlaps between consecutive days.
- Pseudo-range residuals after calculating the clock biases.
- Agreement of the estimated clocks with the values contained in the Navigation Message.

Multi-Arc Parameter Estimation

BAHN can output the observation equations to a file. These equations can be accumulated for a number of arcs in order to obtain a multi-arc solution using the MULTIARC package. Our typical sequence for this is:

- An unconstrained run of BAHN to produce observation equations for all the parameters of interest, including positions and velocities for all the stations.
- Generation of normal equations from the observation equations.
- Elimination of those parameters that are not of interest in a multi-arc solution. The parameters that are eliminated are the ambiguities, the tropospheric parameters, the clock parameters and the satellite state vectors.
- Accumulation of the normal equations in a free-network solution for station coordinates, site velocities and erps.
- Check of the free-network solution by obtaining constrained solutions.

Recently we have developed the capability to generate station coordinate solutions in the Sinex format, that will be used for IERS and IGS submissions.

Products

Our routine products are the following:

- Daily orbits and clocks in the sp3 file: esawwwwd.sp3, wwww being the gps week and d the day of the week (O-6). These are values at 15 minute intervals and include the accuracy codes.
- weekly eop (pole, LODR) solutions in IERS format: esawwww7.erp.
- weekly summaries: esawwww7.sum.

We are also producing and archiving satellite clock bias files at 60 minute intervals. For these we are using our own internal format. They are available on request.

We have provided the IERS with several solutions, including more recently the following:

- EOP (ESOC) 94 P 01: an eop solution, including the integration of the LODR values to obtain a continuous UT1 series.
- SSC (ESOC) 95 P 01: a free network station coordinate and velocity solution based in 274 days of observations in 1994. It is referred to the IERS terrestrial reference frame by fixing the EOP at their Bulletin B values and by loose constraints on the positions and velocities to the ITRF92 values.

Outlook

We are planning to produce weekly free-network station coordinate solutions in the Sinex format. Other developments of interest for the IGS that we are planning to implement this year are the generation of ionospheric TEC models, the use of ocean loading to calculate station position displacements and the study of new models for satellite radiation forces.

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IGS Analysis Center at GFZ Potsdam

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Abstract

The GeoForschungsZentrum Potsdam (GFZ) operates as Analysis Center in the International GPS Service for Geodynamics (IGS). For automated data analysis the software package EPOS.P.V2 was developed at GFZ which has been in use permanently since 1993. The main features of the analysis software and the technology of automated data processing for IGS as well as achieved results are presented in this article.

Introduction

The GPS technology has become one of the most important geodetic techniques for regional and global studies of the Earth's kinematics. To support high-precision geodetic and geophysical research activities using GPS the concept of the "International GPS Service for Geodynamics (IGS)" was developed. The official IGS, founded under the auspices of the International Association of Geodesy, started its routine operation on January 1, 1994.

One of the *seven* IGS Analysis Centers was implemented at the GeoForschungsZentrum (GFZ) Potsdam. It has participated in the IGS from the very beginning. For this purpose the automated GPS Analysis Software package EPOS.P.V2 was developed, being operational since 1993. It was used for the first time in the IGS Pilot Service and since January 1, 1994 in the IGS routine analysis. The software was improved steadily to meet the increasing requirements of the IGS routine processing (new estimation parameters, growing number of stations, etc.).

The activities of the IGS Analysis Center at GFZ and some of the main features of the developed software package, the data processing and the results are described in the following sections.

Software and Processing Technique

The EPOS.P.V2 software package is dedicated to the processing of undifferenced phase observations from the GPS configuration.

Basic Equations and Main Software Features

Using undifferenced phase measurements to GPS satellites the basic observation equations for simultaneous analysis of any number of stations and satellites after ignoring atmospheric, relativistic and noise effects can be written in a simplified form as follows (Landau, 1988):

$$s_i^j(t) = L_i^j(t) + A_i^j + cT_i(t) - c\,t^j(t) \qquad (1)$$

where: s - distance between station i and satellite j
L - distance from measured beat-phase (single frequency or any linear combination)
T - station clock error
τ - satellite clock error
A - unknown time-independent ambiguity
t - epoch of measurement
c - velocity of light

All receivers measure at the same epoch t. The clock errors T_i are supposed to be small enough to be neglected in their influence on the satellite clock error t^j; e.g., $(d\,t^j / dt)\,T_i$ are negligible and all stations will have the same satellite clock. For sampling rates of typically 2 to 6 minutes the clocks have to be treated as white noise processes. Therefore for each epoch one clock parameter must be solved for each station and each satellite. Due to a linear dependency between all clock parameters one clock must be chosen as reference and has to be fixed; e.g., T_1=O, and all clock parameters have to be determined relative to this reference clock. (It is reasonable but not necessary to fix the same reference at all epochs.) As reference, a stable station or satellite clock should be selected. Having masers for a lot of IGS stations, one of these could be chosen as reference.

After setting T_1=O there is still a linear dependence between the satellite clocks t^j and the ambiguities A_1^j, as it can easily be seen from (l). It can be solved by using the reference station/reference satellite concept (Goad, 1985), where all ambiguities connected with a reference station or satellite have to be set to zero; e.g., A_1^j = A_il = o. It can be shown that the remaining ambiguities are equivalent to those of double differencing. Such an algorithm will be much more complicated for the real data because each cycle slip requires a new ambiguity.

In the GFZ software another concept is used which handles the rank defect in a simpler way. In our implementation only one reference clock is fixed and all ambiguities are solved for. There are two possibilities to handle the remaining rank defect: (i) to align the ambiguities to the P-code distances, to use these values as *a priori* values and to constrain them in the adjustment according to the accuracy of the P-code; (ii) to adjust phases and P-codes simultaneously. Here the clocks t^j and the ambiguities A_i^j can be separated with the accuracy of P-code.

The normal equations system consequently has numerical instabilities being of two different kinds: fictitious instability due to unfavorable units, and real instability arising from the clock-ambiguity problem or from free-network adjustment. To solve this problem we use a normalization of the normal equation matrix for the first kind of instability and a regularization after Tichonov (Kunert, 1976) for the real instability. Regularization after Tichonov is applied as follows by the addition of regularization coefficients a_{ii} to the main diagonal of normal equations:

$$(N + a)\,dx = b \qquad (2)$$

with $v^T P^{-1} u + dx^T a\, dx$ —> minimum,
a is a main diagonal matrix,

where regularization **coefficients** a_{ii} **have** to be as small as possible to have no significant influence on the minimization function VT $P^{-1}v \longrightarrow$ min (UT P^{-1} u >> $dx^{T}a\, dx$).

The described observation equations are taken as a basis for the main algorithms of the **EPOS.P.V2** software package. Compared to the **double**-difference principle, the processing of undifferenced phase and/or P-code observations has the following advantages: (i) possibility to estimate clock behavior of stations and satellites relative to reference clock; (ii) identical time parameters for P-code and phase observations; (iii) estimation of post-fit residuals for each satellite-station pair; (iv) simple algorithm for data selection; (v) no special treatment of correlations. The amount of data which enters into the analysis is bigger than for double-difference analysis, especially if rather isolated stations are used. This was of some advantage in the beginning of IGS when the network was sparse in some regions. After getting a more densified IGS core network this, of course, is less important. In the following, the main components of the data flow and all steps of the automated data processing for IGS will be described.

Communication and Data Holding

Every night an automatic procedure compares the content of our data holding with those of Data Centers:

Crustal Dynamics Data Information System **(CDDIS),**
Institut fuer Angewandte Geodaesie **(IfAG)** and
Institut Geografique National **(IGN).**

To minimize the transatlantic data transfer IfAG and IGN are the preferred data acquisition centers. New or updated files are then copied from the according data center. The files are accepted only if they pass an integrity check, including numerous simple tests (correct formal data structure, plausible ionospheric effects, etc.).

Preprocessing and Cleaning

Raw RINEX data of each day are processed station by station. As a result RINEX files with sampled original data (normally 6-rein intervals) and a **LOG**-file for each station are produced. With the sole exception of the sampling rate, the GPS measurements remain in their original form during the processing. In the LOG-files cycle-slips (identified and corrected if possible), **outliers,** and short data intervals (smaller than one hour between two ambiguities) are marked.

Cleaning the data with a station by station technique has some limitations, especially for Anti-Spoofing (AS) data. Therefore a double-difference cleaning procedure is used in parts of the network data where double differences can be formed. In order to get clean undifferenced data all possible double differences are formed to identify an erroneous station-satellite pair in case of a jump. It proved to be useful to execute such double-difference cleaning with a much higher sampling rate (e.g., 60 see) to get rid of strong ionospheric disturbances under AS conditions. This first cleaning step identifies cycle slips up to 10 cm even under AS.

Post-fit data cleaning is necessary in the regular analysis in order to identify the small remaining jumps as well as jumps in those parts of the data where double differencing cannot be performed. Looking at series of residuals for station-satellite pairs one can easily recognize jumps in the residuals. Because of the correlations between the clocks such jumps can be seen in **all** station-satellite residuals at the same epoch and the problem is to identify the erroneous station-satellite pair.

Analysis

The analysis is an iterative process where the following programs from *Merge* to *Clean* are used to determine the solution. The first iterations perform data cleaning. After obtaining clean data some additional iterations are necessary to get the final convergence for the parameters to be adjusted (satellite state vectors, ERP, and clocks).

Merge. The RINEX data are merged to a RINEX-like file including all selected stations and satellites, taking into account the LOG-files, the elevation height and the simultaneity of the data (for one epoch at least two satellites for each station and two stations for each satellite).

Orbit: first part. The satellite motion equations and variational equations are integrated and stored in a data base. Usually the initial state is predicted from the previous day, but can also be taken from broadcast messages. For the integration of the satellite motion an implicit single-step method integrating directly second order differential equations (Everhart, 1974) is used which automatically controls the step size. The variational equations are integrated by a multi-step method of Stoermer-Cowell (Stiefel and Scheifele, 1971), which integrates the large number of equations in a more effective way.

Orbit: second part. The orbits and partial derivatives from the variational equations are interpolated to epochs of the actual GPS data. The residuals and partial derivatives are computed and observation equations are formed and stored in a file (input for the Solve part). First tests of data quality are done and first clock determinations using P-code measurements are performed.

All dynamic and geometric models in this program are based on the IERS Standards (McCarthy, 1992). The main model parameters are given in Table 1.

Solve. In this part the parameters selected by the user are estimated by a HELMERT blocking method, i.e. each parameter can be eliminated for an arbitrarily chosen time interval and then estimated by backward substitution. At the beginning, normal equations of selected linear combination (i.e. ionospheric free L3) are built from the observation equations. The effective construction of normal equations for P-code measurement is made by eliminating the ambiguity parameter in the already-built normal equations for phase measurements. Normal equations are accumulated for one measurement epoch. At the end of each epoch the time parameters are eliminated, and the reduced normal equations are accumulated to the end of the first selected time interval. Ambiguities are eliminated at the end of each session. Finally a normal equation matrix with global parameters (e.g., station coordinates, GM, etc.) remains, which is stored in a data base for further processing (input for *Combination* program). This matrix is stored without any constraints; it can be used in different variants later in the *Combination* part. After inversion of the stored matrix all eliminated parameters are estimated by backward substitution. The estimated parameter corrections as well as post-fit residuals are stored in files for use in the next iteration.

Clean. Data cleaning is performed in two different ways. If large cycle-slips still exist, the stored post-fit residuals from the Solve part enter again into the

Table 1. Main parameters of EPOS.P. V2.

Reference frame	
CIS:	mean equator and equinox of J2000.0
Precession:	IAU 1976
Nutation:	IAU 1980
Tectonic plate model:	NNR NUVEL-1 or individual ITRF velocities
Solid earth tides:	Wahr model, h2=0.609, l=0.0852, permanent tide included
Ocean loading site displacement:	coefficients from Scherneck (Scherneck, 1991)
Dynamic model	
Gravity field:	**JGM2**
GM:	**398600.4418** km3/s2
Velocity of light:	299792.458 km/s
Earth tides:	Wahr model
Ocean tides:	Schwiderski model
Corrections to rotational deformations:	C(2,0), C(2,1), S(2,1)
Indirect perturbation of oblateness of the Earth:	applied
Third body effects:	Sun, Moon, Jupiter, Venus
Solar radiation:	ROCK4 and ROCK42, including thermal reradiation (TIO, T20 formulation of Fliegel et al., 1992)
Relativistic equation of motion:	no
Tidal variations in UT1:	zonal tides with periods <35 days
Measurement model	
Tropospheric model:	Saastamoinen
Relativistic clock corrections:	applied

double-difference cleaning program already used in the preprocessing. Otherwise undifferenced single station-satellite cleaning for detection of small outliers and cycle-slips is done. During the iterations for data cleaning the orbit integration is not repeated in every step, unless the remaining jumps in the residuals are very small. The new information from each cleaning step is stored in the LOG-files for the next iteration which starts with the *Merge* part.

Combination. During the last iteration the normal equation matrix with the global parameters (e.g., station coordinates) is stored in the Solve part. These normal equations can be accumulated over longer time intervals in different variants. Selection of various constraints, fiducials, etc. is possible. This way normal equations are combined for longer time intervals (semiannually, yearly solutions) to derive the global station coordinate solutions with fixed or adjusted site velocities.

This software is also used for control of solution quality by computing daily or weekly repeatability of station coordinates. This way the consistency of marker information is checked.

Operational IGS Data Processing at GFZ

Beginning with the 1992 IGS Campaign the observations of the global IGS network (recently about 80 stations) permanently flow into the Data Centers: CDDIS, IGN, IfAG, and S10 (Scripps Institution of Oceanography). From these centers the data files are copied via ftp to the GFZ data archives from which the analysis is started on a daily basis. The generated products for GPS week 'wwww' and day of week 'n' (n=0,1,2,...,6) are

GFZwwwwn.SP3	daily files with GPS ephemeris/clock information at 15 min intervals in SP3 format, including accuracy codes computed from the orbit overlaps
GFZwwww7.ERP	weekly ERP (pole coordinates, length of day - LODR)
GFZwwww7.SUM	weekly processing summary.

Being an official IGS Analysis Center, GFZ generates its products weekly and transmits them to the data centers at IGN and CDDIS with a delay of only a few days after data acquisition. The delivered orbit files are included in the combination of all submitted individual orbit solutions, so they contribute to the official IGS precise orbit product. All GFZ products as well as IGS precise orbits are available via ftp from the GFZ anonymous account as well as from the CDDIS and IGN data centers. The ERP products are also submitted to the International Earth Rotation Service (IERS) and to the U.S. Naval Observatory (USNO).

Solve-for Parameters

The adjustment part of EPOS.P.V2 chooses an arbitrary time interval for parameter estimation. Usually the following time intervals for parameter estimation are used in our routine analysis:

Satellite state:	32-h interval
Reflectance coefficient and y-bias:	32-h interval
ERP (pole and LOD):	24-h interval
Tropospheric zenith path delay:	4-h interval
Ambiguities	
Epoch time parameters	

The arc length of 32 h was chosen so that at least two satellite revolutions could be observed at any site. Each arc starts at midnight. Only the ERP solutions from 24-h intervals are used (Figure 1). In order to control the accuracy of adjusted orbits the rms values of differences between two adjacent arcs are calculated for an overlapping interval of 6 h.

Sites and Satellites Analyzed

At the end of 1994 about 45 sites were analyzed at GFZ AC. The distribution of the sites is given in Figure 6. Information about the initial coordinates (ITRF, GFZ) and velocities (ITRF, NUVEL, GFZ) for each site is given in Table 2. Here also the fiducial sites (fixed to the initial values) as well as the number of days with observations in 1993 and 1994 are given. All usable satellites were analyzed. Satellite information is given in Table 3.

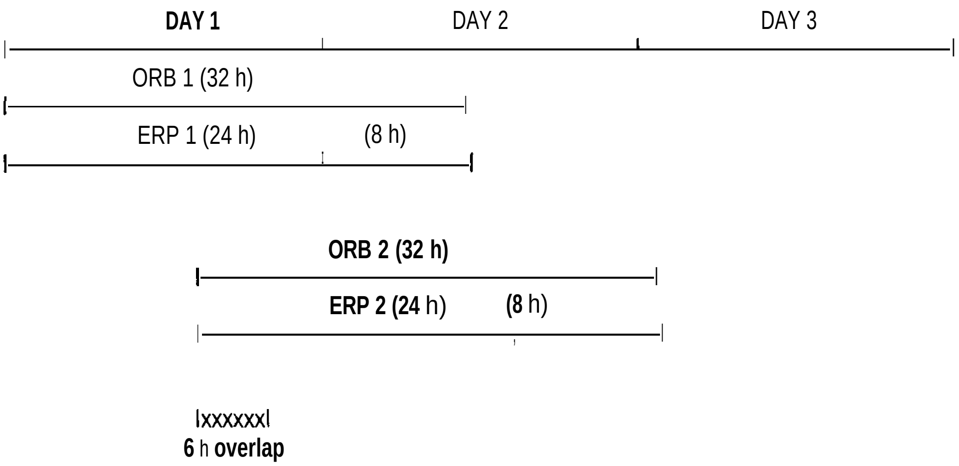


Figure 1. Scheme for parameter estimation.

Data and Computer Resources

For the daily analysis undifferenced ionospheric free phases with a sampling rate of 60 sec (preprocessing with double-difference cleaning) and 6 min (analysis itself) are used. The routine analysis of such amounts of data demands rather large processing times and computer resources. One iteration takes 20 min on a CONVEX machine, so that one data segment of 32 h with Anti-Spoofing data of 45 sites is usually ready after 2.5 to 3 h. The computer memory is maximally used for the *Solve* part which requires 60-MB main memory and 100-MB disc space. Permanent data files are in the order of 20 MB for one day.

Results and Comparisons

This section presents various results and comparisons, achieved in the first two years of GFZ participation in the IGS. These results give a first impression about the possibilities of the GPS software package and the obtained accuracies.

Determination of global reference frame

From the globally distributed station network and a data span of 2 years it is possible to determine the global reference frame with very high accuracy. The consistency of the coordinate solution can be seen from daily and weekly repeatabilities. They serve also for the quality check of data as well as for the control of marker information (e.g., eccentricities of antenna positions for different epochs).

A fiducial-free global set of coordinates for 40 IGS stations has been determined. In Figure 2 the weekly repeatability for selected European stations relative to the fixed station Wettzell is given for longitude, latitude and height. The accuracies depend on the distance to Wettzell and are of&2 to ±4 mm for the horizontal component and of ±5 to ±11 mm in the height. For the whole wide-scale European network with 5000-km extension the weekly repeatability gives ±5.2 mm in the height, and about ±2 mm in the horizontal components (Figure 3).

Such level of accuracy is reachable for all regions with a sufficiently dense site distribution, i.e. for Europe, North America, and Australia. For isolated stations the accuracies are worse: the variations are three to five times larger.

Table 2. Site Information.

Site	Fixed	up to 94/365		from 95/		days in	days in
		Coordinates	Velocities	Coordinates	Velocities	1993	1994
ALGO	F	ITRF92	ITRF92	ITRF93	ITRF93	365	365
AREQ		GFZ	NUVEL	GFZ	ITRF93		329
BOGT		GFZ	NUVEL	GFZ	NUVEL		55
BRMU		GFZ	NUVEL	ITRF93	ITRF93		56
CAS1		GFZ	NUVEL	GFZ	NUVEL		56
DAV1		GFZ	NUVEL	GFZ	NUVEL		166
DRAO		ITRF92	ITRF92	ITRF93	ITRF93	272	365
EISL		GFZ	ITRF92	GFZ	ITRF93		157
FAIR	F	ITRF92	ITRF92	ITRF93	ITRF93	365	365
FORT		GFZ	NUVEL	GFZ	ITRF93	153	365
GOLD	F	ITRF92	ITRF92	ITRF93	ITRF93		365
GUAM		GFZ	NUVEL	GFZ	NUVEL		
HART	F	ITRF92	ITRF92	ITRF93	ITRF93	365	348
HOB1		GFZ	ITRF92	ITRF93	ITRF93	365	218
HOB2		GFZ	ITRF92	GFZ	ITRF93		154
JPLM		ITRF92	ITRF92	ITRF93	ITRF93	365	365
KERG		GFZ	NUVEL	GFZ	NUVEL		42
KIT3		GFZ	NUVEL	GFZ	NUVEL		126
KOKB	F	ITRF92	ITRF92	ITRF93	ITRF93	365	365
KOSG	F	ITRF92	ITRF92	ITRF93	ITRF93	365	365
KOUR		ITRF92	ITRF92	ITRF93	ITRF93	272	365
MAC1		GFZ	NUVEL	GFZ	NUVEL		55
MADR	F	ITRF92	ITRF92	ITRF93	ITRF93	365	365
MASP	F	ITRF92	ITRF92	GFZ	ITRF93	365	253
MASI		ITRF92	ITRF92	GFZ	ITRF93		211
MATE	F	GFZ	ITRF92	ITRF93	ITRF93	365	365
MCMU		ITRF92	NUVEL	ITRF93	ITRF93	335	352
MCM4		ITRF92	NUVEL	ITRF93	ITRF93		
MDO1		GFZ	NUVEL	GFZ	ITRF93		56
METS		ITRF92	NUVEL	ITRF93	ITRF93	270	365
NLIB		GFZ	NUVEL	ITRF93	ITRF93		56
OHIG		GFZ	NUVEL	GFZ	NUVEL	365	365
ONSA		ITRF92	ITRF92	ITRF93	ITRF93	272	365
PAMA		ITRF92	NUVEL	ITRF93	ITRF93	365	340
POTS		GFZ	NUVEL	GFZ	GFZ		164
RCM2		GFZ	NUVEL	GFZ	ITRF93	229	
RCM4	F	GFZ	NUVEL	GFZ	ITRF93	33	
RCM5	F	GFZ	NUVEL	GFZ	ITRF93	27	365
SANT	F	ITRF92	ITRF92	ITRF93	ITRF93	365	365
STJO		ITRF92	NUVEL	ITRF93	ITRF93	365	365
TAIW	F	ITRF92	NUVEL	GFZ	ITRF93	365	365
TIDB	F	GFZ	ITRF92	ITRF93	ITRF93	365	365
TROM	F	ITRF92	NUVEL	ITRF93	ITRF93	365	365
TSKB		GFZ	NUVEL	GFZ	ITRF93		56
USUD		GFZ	NUVEL	GFZ	ITRF93	365	365
WES2		GFZ	NUVEL	ITRF93	ITRF93	272	365
WETT	F	ITRF92	NUVEL	ITRF93	ITRF93	365	365
YAR1	F	ITRF92	NUVEL	ITRF93	ITRF93	365	365
YELL		ITRF92	NUVEL	ITRF93	ITRF93	365	365

Table 3. Satellite information.

Center-of-mass corrections: IERS Standards
Block 1: x=0.210 m, z=0.854 m
Block 2: x=0.279 m, z=1.023 m

GPS space vehicle masses: from Fliegel *et al.* (1992) and Feltens (1991)
972.90 kg for PRN 14567922-32
878.15 kg for PRN 2
521.81 kg for PRN 3
440.89 kg for PRN 8
522.16 kg for PRN 11
519.82 kg for PRN 12
520.42 kg for PRN 13
887.36 kg for PRN 14
885.90 kg for PRN 15
883.23 kg for PRN 16171819
887.36 kg for PRN 20
883.90 kg for PRN 21

Weekly variations of the geocenter in x and y are of the order of ±2 to ±4 cm and in z of ±12 cm. The scale has an accuracy of $\pm1\times10^{-9}$.

Another way to estimate the accuracy of the determined reference frame is by 7-parameter similarity (HELMERT) transformations between two annual solutions and between our global solution and ITRF93 (label SSC(IERS)94C01) (Table 4). The two annual solutions of 1993 and 1994 coincide within ±2 to ±4 mm in the north, ±2 to ±5 mm in the east and ±5 mm in the height component dependent of which velocities have been used—ITRF or GFZ ones (Gendt *et al.*, 1995). A comparison with ITRF gives ±4 mm in the horizontal and ±9 mm in the height component.

Baseline Rates and Site Velocities

Due to the high accuracy of the GPS technique it is possible to determine global tectonic motions from time intervals of only a few years.

In the routine IGS analysis the daily, fiducial-free, and unconstrained normal equations for station coordinates are stored into a data base for further analysis. Investigations over long time intervals demands an effective technology for combining of solutions. To reduce the computing times and the amount of files, computation and archiving of weekly normal equations have been performed. By combining daily normal equations into weekly ones, the combination software produces homogeneous sets of equations based on the same *given* initial values for station coordinates, eccentricity values, and tectonic model. This way it is easy (i) to introduce new initial coordinates, (ii) to use the most recent eccentricities values for the solution, (iii) to change the tectonic model for the coordinate determination. The errors of chosen *a priori* site velocities are negligible for such short time intervals (one week or even one month, if, in future, data over many years have to be analyzed), The combined normal equations can be extended by parameters for site velocities.

The tectonic motions have been determined in two variants:

1. Baseline rates from weekly coordinate solutions. The advantage of this method is the control of data quality and eccentricities as well as a good evaluation of solution stability and accuracy. Episodic motions remain visible.

Figure 2. ***Weekly repeatability of station coordinates. Variations of north, east, and height components relative to the fixed site Wettzell (distance to Wettzell is given).***

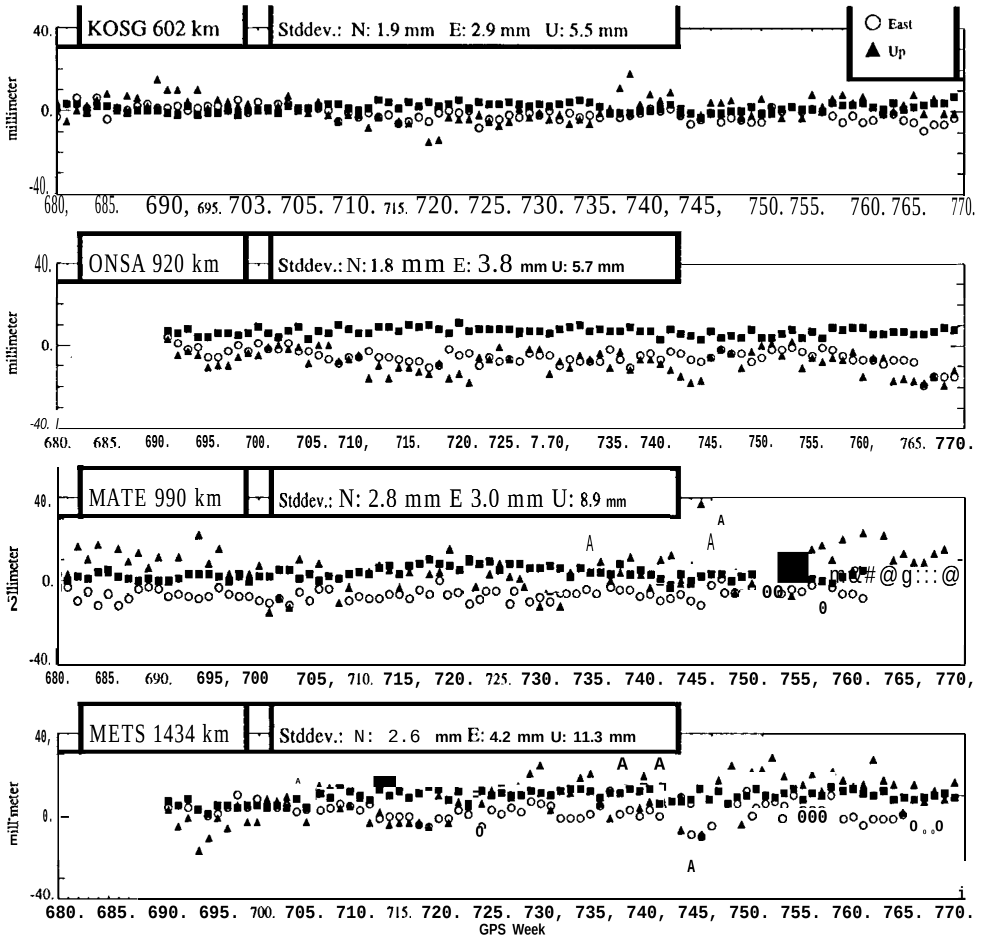


Figure 3. ***Stability in the European network (residuals of Helmert transformations between solutions of adjacent weeks).***

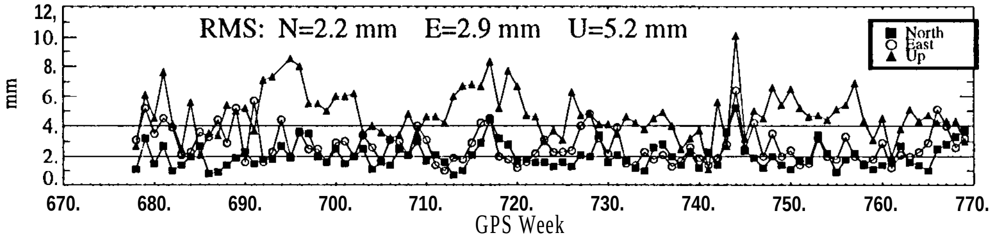


Table 4. Helmert transformations of global coordinate solutions using ITRF or GFZ velocities.

(Unit: mm)

Variant	No. of sites	ITRF velocities N	ITRF velocities E	ITRF velocities H	GFZ velocities N	GFZ velocities E	GFZ velocities H
GFZ93–GFZ94	24	4.2	5.4	4.6	2.3	2.8	5.0
alto., only Europe & N. America	16	2.7	2.3	3.3	0.9	0.9	3.7
alto., only Europe	8	1.4	1.2	2.3	0.6	0.5	2.5
GFz93/94-ITRF93	24	4.2	4.0	9.1			

2. Simultaneous adjustment of station coordinates and their velocities from the whole data set. This method gives optimum weighting of the data. Correlations between coordinates and velocities are automatically taken into account. Episodic motions cannot be seen. In this variant the accuracies are too optimistic and have to be scaled according to the first variant.

Some of the baseline rates derived from the first variant together with determined slopes are shown in Figure 4. The slope values from the ITRF are given for comparison. For baselines of about 1000 km (WETB-MATE) the scattering is ±3 mm, for longer baselines the scattering increases by 1.5 to 2 mm per each 1000 km. The plate tectonic motion can be seen clearly. Figure 5 gives the baseline rates from KOKB and WETB to their neighboring sites. The accuracies of the shorter baselines in Europe are ±1 mm/yr. In regions where we have a good site distribution (Europe, North America) even for longer baselines accuracies of ±2 mm/yr can be obtained. In these cases the agreement with the velocities from NUVEL or ITRF are in the range of a few mm/yr. For isolated stations, especially in the Southern hemisphere, the accuracy is about ±5 mm/yr. Even here we have a close agreement to other models.

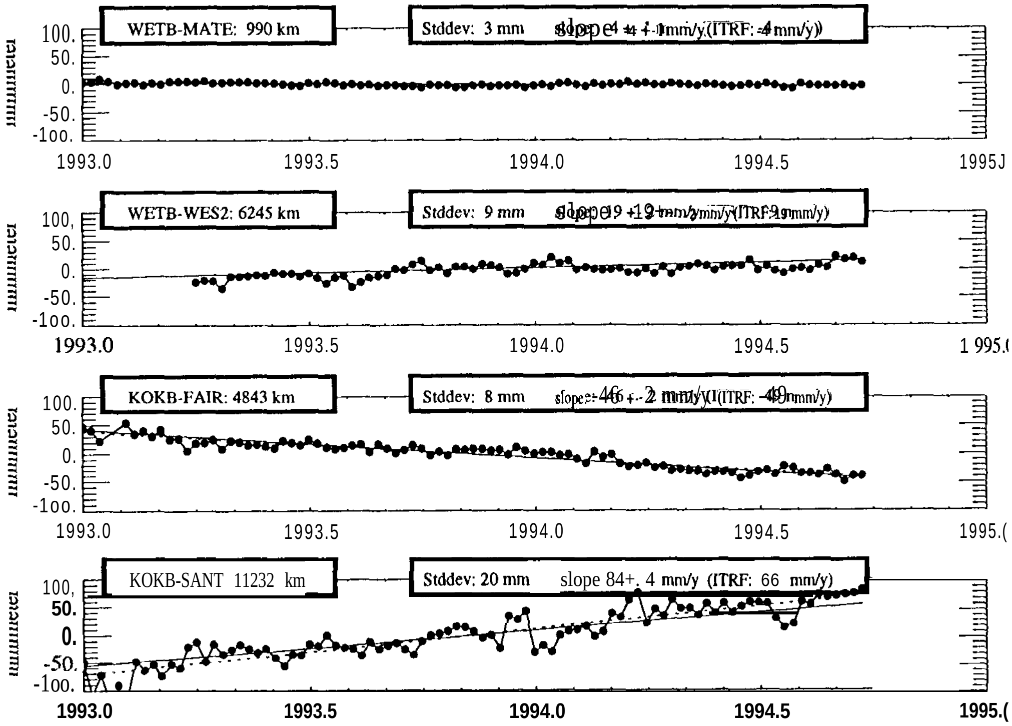


Figure 4. Baseline rates from weekly coordinate solutions (----: ITRF value for comparison).

Figure 6 shows the velocities as resulting from the global simultaneous adjustment of coordinates and velocities. Here again, the agreement with NUVEL and ITRF velocities for Europe and North America is obvious. In the Australian region a small net rotation can be observed, which probably originates from a relatively weak connection to the global network.

In the Southern hemisphere recently a lot of new sites became available. So we can expect to have an accuracy of ±2 to ±3 mm/yr in a global scale within the next few years.

Figure 5. Baseline rates of KOKB and WETB to neighboring sites (ITRF values are given in parentheses).

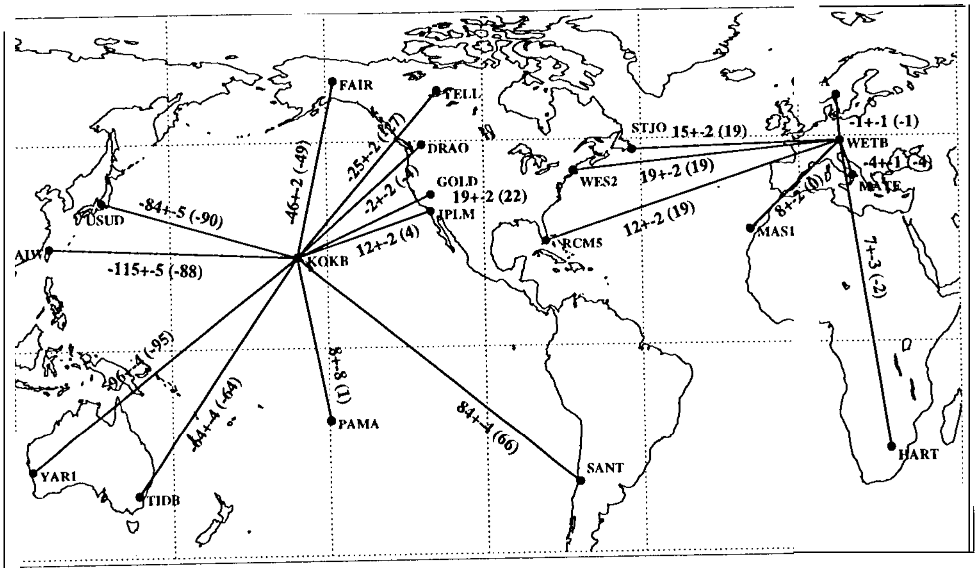
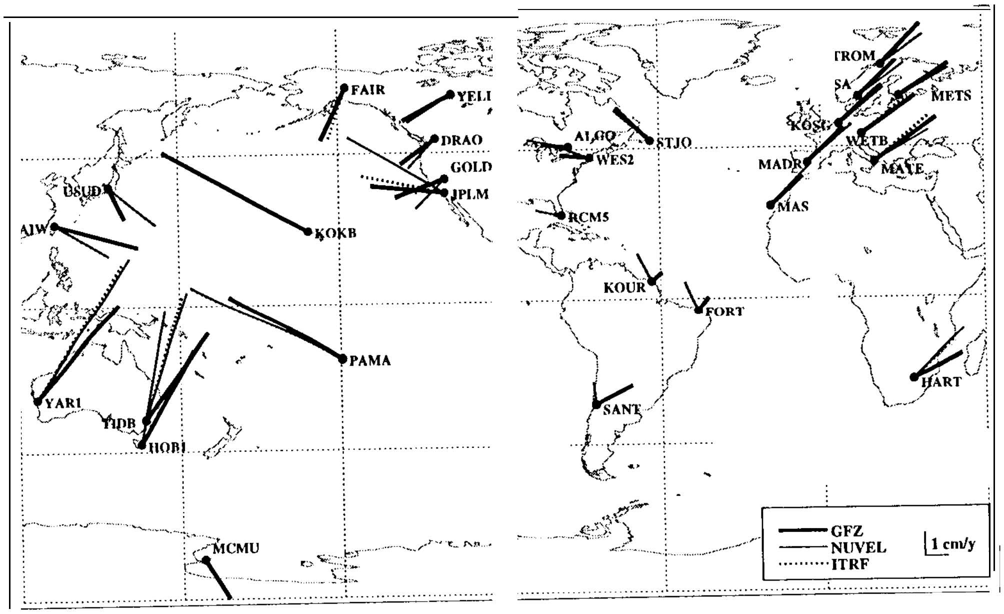


Figure 6. Site velocities from 2 years of IGS data (NUVEL-1 and ITRF values are given for comparison).



Our results show that data of only two years yield accuracies comparable to hose from analysis of SLR and VLBI data over 5 to 10 years. This demonstrates he advantage and great potential of the GPS technique for global applications. Because we will have a densification of the network in the near future which is unlikely for the SLR and VLBI techniques, the importance of the GPS technique becomes very obvious.

Determination of Earth Rotation Parameters

The adjustment part of our software package gives the possibility to choose an arbitrary time interval for parameter estimation. Besides the estimation of diurnal ERP (pole and LOD) in the routine IGS analysis, ERPs with semidiurnal resolution were calculated and analyzed. To assess the stability and accuracy of our ERP results, comparisons with solutions of other IGS analysis centers and with results from other techniques were performed.

To estimate the accuracy of the ERP series for each single IGS Analysis center the smoothed mean of all these solutions was taken. The differences of all solutions to the mean curve for 1993 and 1994 are shown in Figure 7. It is clear that the scattering of the solutions has significantly improved from the beginning of 1993 to the end of 1994. The most recent accuracy is about ±0.3 mas. Such an improved accuracy is due to better site distribution, a more precise reference system, and good data cleaning. The most results of daily estimations of length of day (LODR) from 32-h arcs have an accuracy of ±0.06 ms compared to Bulletin B (Figure 8).

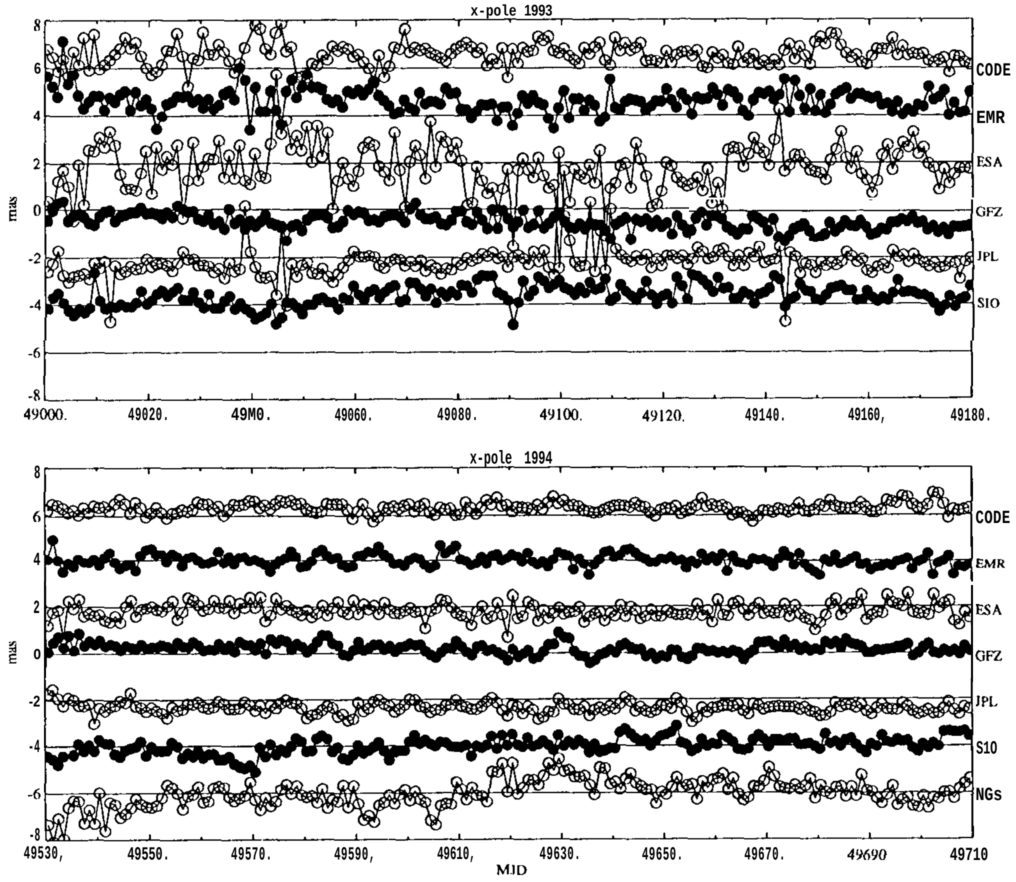


Figure 7. Daily polar motion results of IGS Analysis Centers (x-component). Differences to smoothed mean of all solutions. Improvement of accuracy of solutions from the beginning of 1993 to the end of 1994.

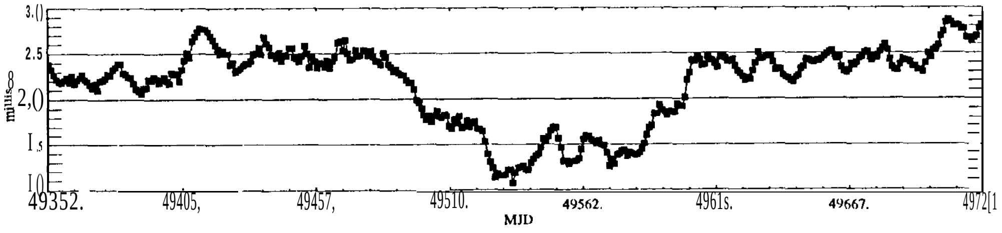


Figure 8. Daily LODR values for the year 1994 compared with IERS Bulletin B solution.

To evaluate the accuracy of GPS derived polar motion a comparison with results from other techniques have been performed. For this purpose one ERP series from VLBI determined by National Oceanic and Atmospheric Administration (NOAA, USA) and three series from SLR computed by GFZ and by the Center for Space Research/University of Texas (CSR) were chosen (Figure 9). The high short periodic stability of GPS results can clearly be seen (Figure 9 a,b). There is an excellent agreement to the SLR result with three days resolution. Highly resolved SLR curves have a considerably higher scattering caused by the unhomogeneous data distribution in smaller data intervals. GPS is today the only technique which can deliver routinely a high quality series of polar motion with daily resolution.

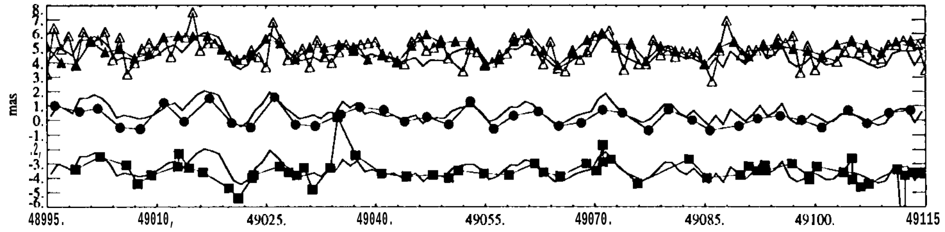


Figure 9. Daily polar motion from GPS (_-ERP (GFZ)94P01) compared with results from other techniques (x-pole, differences to IERS Bulletin B, arbitary origin): (▲,△) - SLR, ERP (GFZ)94L03/04, resolution of 2 and 1 days; (■) - VLBI, EOP(NOAA)93R07, 24-h-Sessions; (o) - SLR, EOP (CSR)94L01, resolution of 3 days.

To demonstrate the accuracy of GPS in the subdaily ERP determination, polar motion with 12-h resolution was computed (Gendt *et al.*, 1994). Compared to the daily resolution, there is a difference of ±0.25 and ±0.27 mas for X and Y-poles, respectively. In the computation of subdaily ERP's, of course, all constant disturbances of the inertial system, such as orbital errors and nutation errors, are absorbed by diurnal periods in the ERP's. This can clearly be seen from the alternating differences to the daily series in some intervals (Figure 10). Nevertheless, this example demonstrates the high accuracy of highly resolved ERP from GPS.

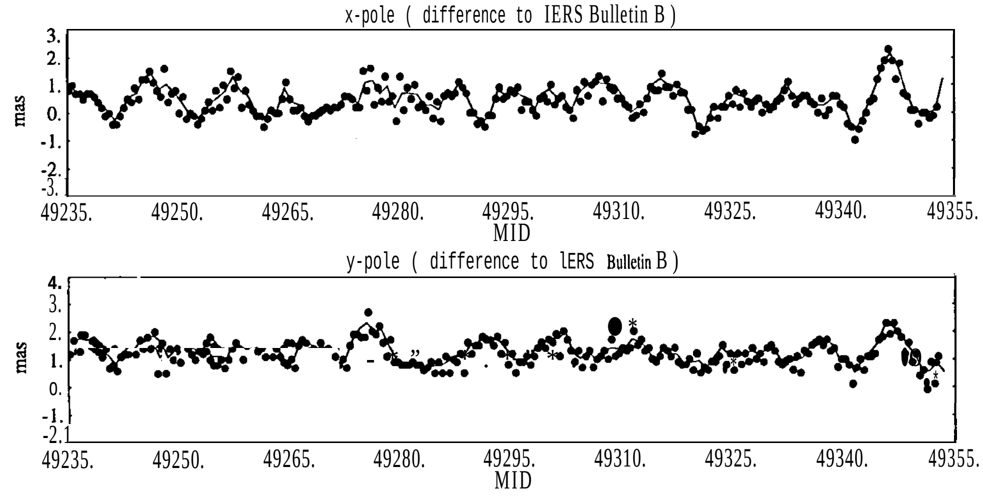


Figure 10. Highly-resolved GPS polar motion (differences to IERS). Semidiurnal results ERP(GFZ)94P02 compared with diurnal polar motion ERP(GFZ)94P01.

The GFZ orbits are computed on a daily basis using 32-h arcs. Simultaneously with the orbital state vector the reflectance coefficient and the Y-bias are adjusted for. Even for such a small interval as two revolutions the reflectance coefficient is very stable. The same holds for the Y-bias for non-eclipsing orbits. The quality of the orbits can be assessed by orbit overlapping and by comparisons with the results of other analysis centers as well as with the official IGS orbits (mean of all centers). Such a comparison for 1994 is shown in Figure 11. It can be stated that the GFZ orbits with an accuracy of better than 15 cm are among the best IGS orbits.

Satellite clocks are adjusted for each epoch and represent a part of the orbit products. The stability of clock determination was of ±0.6 ns for non-AS days. Since the AS was permanently switched on January 31, 1994 the accuracy of clock estimation was decreased.

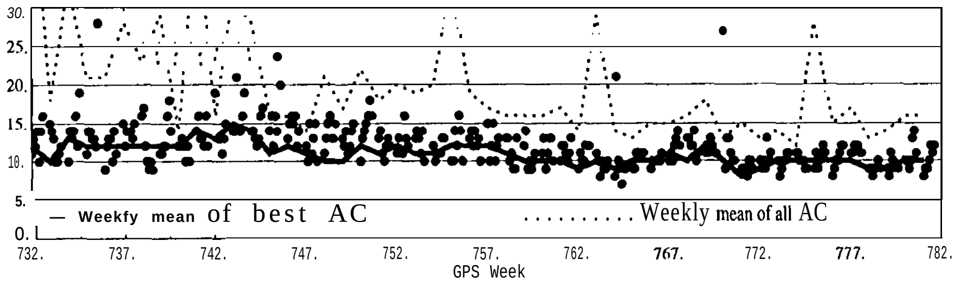


Figure 11. Differences of GFZ orbits to the official IGS orbits (daily mean of all satellites). For comparison weekly means of the differences of the best Analysis Centers (AC's) and of all AC's are shown.

Conclusions

The results presented here from a relatively short data span of 2 years show the considerable contribution of GPS to many areas of geodetic and geodynamic research. For the determination of pole coordinates GPS currently yields the highest precision and highest resolution among all techniques. For the future a combination of GPS and VLBI seems to be the best choice where VLBI would provide the link to inertial reference frames (e.g., UT1) that are inaccessible for satellite techniques.

Also GPS will play a major role for realizing and maintaining the global reference frame and its changes in time. The densification of the IGS Network will provide accuracies of ±2 to ±3 mm/yr for all regions of the Earth within the next 2 to 3 years. Global control networks maybe installed by SLR and VLBI to investigate possible systematic effects of the GPS technique and to obtain a high precision in defining the geocenter (SLR).

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Jet Propulsion Laboratory IGS Analysis Center 1994 Annual Report

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Background

Members of the Tracking Systems and Applications Section in the Telecommunications and Engineering Division of Caltech's Jet Propulsion Laboratory (JPL), are funded by the National Aeronautics and Space Administration (NASA) to participate as an Analysis Center (AC) for the International GPS Service for Geodynamics (IGS).

The Section is comprised of several Groups, of which four are concerned primarily with GPS technology, data, and analysis. These are (i) the GPS Networks and Operations (GNO) Group, supervised by U. J. Lindqwister; (ii) the Earth Orbiter Systems (EOS) Group, supervised by S. M. Lichten; (iii) the GPS Systems Group, supervised by L. Young; and (iv) the Space Geodesy and Geodynamics Systems (SGGS) Group, supervised by M. M. Watkins.

While members from all of these Groups contribute at least indirectly to JPL's IGS AC efforts, members from the SGGS Group (Heflin, Watkins, Webb, Zumberge) and the EOS Group (Jefferson) are most directly involved. The SGGS Group has been involved in the analysis of data from a globally-distributed network of GPS receivers beginning with the first Global International GPS experiment in 1991 (Heflin *et al.*, 1992).

Evolution in 1994

Beginning June 21, 1992, JPL began to analyze data from the global network on a daily basis. For details on the evolution of strategy in 1992 and 1993 see, respectively, Zumberge *et al.* (1993a) and Zumberge *et al.* (1994). Additional general information on the JPL IGS Analysis Center maybe found in Zumberge (1993b).

Pre-AS Strategy

At the beginning of 1994, anti-spoofing (AS), the encryption of P-code, was not yet implemented full time. Our analysis strategy at that point consisted of using the ionosphere-free combination of both pseudorange and carrier phase, with data noise values of 1 cm and 1 m, respectively. Data below 15 degrees elevation were excluded. The phase data were decimated to 7.5 minutes, and the pseudorange data were carrier-smoothed over the same interval.

Data corresponding to each GPS day were analyzed in 30-hour batches centered on GPS noon. Estimated parameters were satellite state vectors and solar radiation pressure (srp), receiver coordinates, zenith wet troposphere delay at each receiver site, station and satellite clock offsets, carrier phase ambiguities, and Earth orientation. Satellite x- and y- srp parameters were allowed to vary stochastically by 10%, and the y bias by 10^{-13} km/s^2. Zenith wet troposphere delay was modeled as a random walk with 1 cm^2/hr variance derivative.

The Williams solid Earth tide model was used; it differs from the IERS standards by an insignificant amount. Pole tide and the Love number variation at K1 frequency were modeled according to IERS Technical Note 13 (McCarthy, 1992). Ocean loading was modeled according to Scherneck (1991). The Earth's gravity field was described by the JGM2 12x12 multipole expansion using terms up through degree and order 12 (Nerem *et* al., 1994). The value of GM used was 398600.4415 km^3/s^2 (Ries *et al.*, 1992).

Nominal values of the parameters for each GPS satellite [3 each for position and velocity, and two for solar radiation pressure (srp)] were from the broadcast ephemeris. Weak a *priori* constraints of 1 km and 10 mm/s for position and velocity, respectively, were imposed. The T10-T20 solar radiation pressure model was used for srp (Fliegel, 1992).

As an example, the analysis of January 21 included data from 43 stations and 25 satellites. There were nearly 60,000 phase and pseudorange measurements each, from which 1556 parameters were determined. (Parameters allowed to vary stochastically are counted only once. These include station and satellite clocks, station zenith wet troposphere delay, and satellite srp.) The rms post-fit residuals for the phase measurements were typically a few mm. Those measurements with more than 5 cm post-fit residual for phase, or 5 m for pseudorange, were considered outliers and excluded.

Anti Spoofing

With the onset of full-time AS on January 31, our strategy was altered in three major ways, In retrospect two of these changes were in fact an overreaction to the difficulties associated with AS, and were imposed largely because the effect of the third in mitigating those difficulties was not yet fully realized.

The reactive changes were (1) elimination of pseudorange altogether in the parameter-estimation phase of analysis (pseudorange was still used for pre-fit data editing) and (2) an increase of the minimum elevation angle from 15 degrees to 20 degrees. Both of these steps were taken to reduce the amount of high-noise data, the major effect of which is the introduction of undetected phase breaks.

Clearly the more beneficial change was to improve the detection of phase breaks. To this end, we began to insert phase bias parameters for any station-satellite pair at any time for which the temporal discontinuity in post-fit residual exceeded 10 cm. That is, consider a given station-satellite pair with measurements x_i and post-fit model values z_i. Denote by t_i the time Of measurement i. In the event that

$$|x_{i+1} - z_{i+1} - x_i + z_i| > 10 \text{ cm},$$

a new phase bias parameter is introduced for that station-satellite pair at time t_{i+1}. This was the third change.

Although computationally expensive, requiring as it does an extra parameter estimation step, it was the single most effective change in dealing with noisy AS data. (More recently, by requiring temporal continuity in L1–L2, we have improved our pre-fit data editing so that, even with AS, the number of undetected phase breaks prior to parameter estimation has been significantly reduced, although not entirely eliminated.)

The stochastic treatment of satellite srp parameters was also eliminated, in the belief that the data were too noisy to reliably estimate these parameters.

Following these initial changes, there were a number of modifications to the strategy throughout the year (Table 1). The most noteworthy of these were:

- reintroduction of pseudorange data from TurboRogue receivers
- implementation of a yaw model and estimating yaw-rate parameters for eclipsing GPS satellites (Bar-Sever *et al.*, 1995)
- routine analysis of essentially *all* IGS stations, by first determining satellite parameters (orbits and clocks) with a 3 l-station global network, then fixing those parameters and analyzing all other stations, one at a time (Zumberge *et al.*, 1995)
- improved detection of potential problem stations by analysis of baseline loops (Figure 1)
- return to 15-degree elevation angle cutoff
- return to moderate (l%) stochastic variation in satellite srp

The current strategy is summarized on the Central Bureau information System, available on the World Wide Web (WWW) at location `http://igscb.jpl.nasa.gov/`; choose “Analysis Centers” and fetch the file `jpl.acn`.

Table 1. **Strategy *Evolution, 1994.***

Action	date
nominal non-AS strategy	Jan 1
initial AS strategy: no pseudorange, 20-degree elevation angle cutoff, post-fit data editing	Jan 31
include pseudorange from 8 TurboRogues (10-m data noise)	May 22
include P-code from all TurboRogues (l O-m data noise)	Jun 16
incorporate loop baseline preprocessing	Aug 29
eliminate phase breaks at day boundaries	Sep 9
analyze global network, then other sites with fixed transmitter parameters	Sep 20
implement GPS yaw-attitude model	Sep 20
reduce data interval from 7.5 to 5 minutes	Sep 20
Change to JGM3 12x12 gravity field (Watkins e: al. , 1994)	Ott 9
Use 1% srp stochastic variation on x and y, 1 e-14 km/s^2 on y bias.	Ott 9
reduce data noise on pseudorange to 1 m (don't use pseudorange from CASA, MCMU, RCM5)	Ott 9
edit rinex files with broadcast orbits and clocks	Ott 1 3
lower elevation angle cutoff to 15 degrees (but not Ott 18)	Ott 1 7
Use extended UTPM model (Herring, 1994)	Dec 10

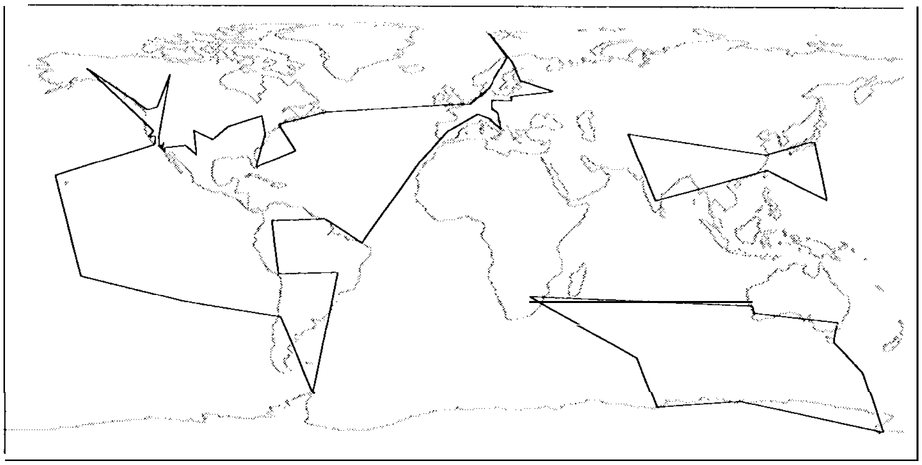

Figure 1. Each IGS site is included in one of three polygons. Using broadcast orbits, each baseline corresponding to an edge of the polygon is analyzed. If the results for a pair of connected baselines are anomalous, the site corresponding to the common vertex is excluded.

Fiducial Errors

To define the reference frame of our orbit product, coordinates and velocities of sites listed in Table 2 were fixed at their ITRF-92 values (Boucher *et al.*, 1993; see also IGS mail messages 421 and 430). Also indicated in Table 2 are errors and periods affected in our assumed monument coordinates and/or antenna heights.

Access to Products

Nine files are distributed weekly to two public areas. The files for a given GPS week are indicated in Table 3, and include a summary file, a file containing estimated Earth orientation parameters, and one file for each day of the week

Table 2. Fiducial Errors, 1994.

Site			error (cm)	dates affected (1994)
ALGO	Algonquin Park	Canada	-8.2	Feb 16
FAIR	Fairbanks	US		
GOLD	Goldstone	us		
HART	Harteebesthoek	South Africa	-3.2	Jan 01 - Dec 31
KOKE	Kokee Park	us		
KOSG	Kootwijk	Netherlands		
MADR	Madrid	Spain	7.0	Apr 20 – Dec 31
SANT	Santiago	Chile		
TIDB	Tidbinbilla	Australia	16.9	Apr 23 – Dec 31
TROM	Tromso	Norway		
WETT	Wetzzell	Germany	-7.0	Jan 01 - Apr 09
YAR1	Yaragadee	Australia		
YELL	Yellowknife	Canada		

Table 3. IGS Products.

filename	contents
jpl⟨wwww⟩7.sum	narrative summary
jpl⟨wwww⟩7.erp	Earth rotation parameters for GPS week wwww
jpl⟨wwww⟩⟨d⟩.sp3	GPS ephemerides for GPS week wwww, day d, sp3 format

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- reintroduction of pseudorange data from TurboRogue receivers
- implementation of a yaw model and estimating yaw-rate parameters for eclipsing GPS satellites (Bar-Sever *et al.*, 1995)
- routine analysis of essentially *all* IGS stations, by first determining satellite parameters (orbits and clocks) with a 31-station global network, then fixing those parameters and analyzing all other stations, one at a time (Zumberge *et* al., 1995)
- improved detection of potential problem stations by analysis of baseline loops (Figure 1)
- return to 15-degree elevation angle cutoff
- return to moderate (1%) stochastic variation in satellite srp

The current strategy is summarized on the Central Bureau information System, available on the World Wide Web (WWW) at location `http://igscb.jpl.nasa.gov/`; choose "Analysis Centers" and fetch the file `jpl.acn`.

***Table 1.* Strategy Evolution, 1994.**

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implement GPS yaw-attitude model	Sep 20
reduce data interval from 7.5 to 5 minutes	Sep 20
Change to JGM3 12x12 gravity field (Watkins *et* al., 1994)	Oct 9
Use 1% srp stochastic variation on x and y, 1.e-14 km/s^2 on y bias.	Oct 9
reduce data noise on pseudorange to 1 m (don't use pseudorange from CASA, MCMU, RCM5)	Oct 9
edit rinex files with broadcast orbits and clocks	Oct 13
lower elevation angle cutoff to 15 degrees (but not Oct 18)	Oct 17
Use extended UTPM model (Herring, 1994)	Dec 10

with estimated satellite positions. All of these are available from each of the IGS Global Data Centers (located at Goddard Space Flight Center, Scripps Institution of Oceanography, and Institut Géographique National).

The files are available from JPL using anonymous ftp to

`sideshow. jpl.nasa.gov`

in directory

`pub/jpligsac/⟨wwww⟩`

where ⟨wwww⟩ is the 4-digit GPS week. For example, for GPS week 780, the files to be found in pub/ jpligsac/0780 are

```
jpl07800.sp3.Z
jpl07801.sp3.Z
jpl07802.sp3.Z
jpl07803.sp3.Z
jpl07804.sp3.Z
jpl07805.sp3.Z
jpl07806.sp3.Z
jpl07807.erp.Z
jpl07807.sum.Z
```

Note that the day numbers in the sp3 files range from O for Sunday through 6 for Saturday. (For weeks 717—Ott 3, 1993 through Ott 9, 1993—and earlier, there is often a single sp3 file for the entire week, in which case the day digit is 7.) The definition of the sp3 ephemerides format can be found in the IGS Central Bureau Information System (`igscb.jpl .nasa. gov`), under `igscb/data/ format`.

In addition to the official IGS products, a one-line "engineering" record for each day and site analyzed in the current calendar year is kept in the file

`pub/jpligsac/ytd.eng`

Engineering data from earlier years can be found in ⟨yyyy⟩. eng, where ⟨yyyy⟩ is the four-digit calendar year. An excerpt from ytd. eng is given in Table 4.

Additionally, files specific to the GIPSY software (Lichten, 1990; Meehan *et al.*, 1992; Blewitt, 1993; Webb and Zumberge, 1993) are available in

```
date
 |          site ('.' means point-positioned)
 |          |     number of time tags for which clock solution is valid
 |          |     |   rms deviation from straight line of clock solution (ns)
 |          |     |   |         ift of clock solution (parts per trillion)
 |          |     |   |         |          clock solution at noon (usec)
 |          |     |   |         |          |        # of pseudorange mess
 |          |     |   |         |          |        |    rms (cm)
 |          |     |   |         |          |        |    |   # of phase mess.
 |          |     |   |         |          |        |    |   |      rms (mm)
 |          |     |   |         |          |        |    |   |      |  orig
 |          |     |   |         |          |        |    |   |      |  |   tot
 |          |     |   |         |          |        |    |   |      |  <-breaks->
 ________   |__   |_  |         |__________|_______ |___ |_ |____  |_ |_     |_
1995-01-01 ALBH  360     3.88      0.986       2.52 1933  54  1932   4  43   51
1995-01-01 BOR1. 360     1.97      0.399      -1.25 1993  41  1973  11  35   35
1995-01-01 FAIR  360   0.0654    -0.0423      -0.16    0   .  2047   7  60   71
1995-01-01 GPS10 360     1.01      -25.4       -233 2256  59  4113   9  66  100
1995-01-01 GPS13 338     79.5      -2.37       -134 3025  56  4682  10 111  232
1995-04-15 WLSN. 287     91.6      0.421        1.3 1658  66  1648   9  53   55
```

Table 4. Sample records of engineering data.

pub/ `gipsy_products`, where yearly directories exist. Within each yearly directory are two subdirectories, orbits and clocks. For example, for April 1, 1995, the files

```
pub/gipsy_products/1995/clocks/1995-04-01CLOCK.Z
pub/gipsy_products/1995/clocks/1995-04-01badCLOCK.Z
pub/gipsy_products/1995/orbits/1995-04-01.att.Z
pub/gipsy_products/1995/orbits/1995-04-01.eci.Z
pub/gipsy_products/1995/orbits/1995-04-01tpeo.nml.Z
```

contain information on, respectively, precise GPS clock solutions, times and satellites for which precise clock solutions are unavailable, information on the attitudes of eclipsing GPS spacecraft, precise satellite ephemerides in an Earth-centered inertial reference frame, and Earth orientation information. More information can be obtained from `gipsy@cobra.jpl.nasa.gov`.

Finally, WWW pages located at

http://sideshow.jpl.nasa.gov/mbh/series html

provide graphical time series of station coordinates.

Results

Results for station coordinates and Earth orientation, independent of errors in fiducial coordinates, are described by **Heflin** *et al.* **(1995)** from which Figure 2 is an example.

The performance of the operational Earth orientation series with respect to the IERS Bulletin B Final values is summarized in Table 5. A plot of excess

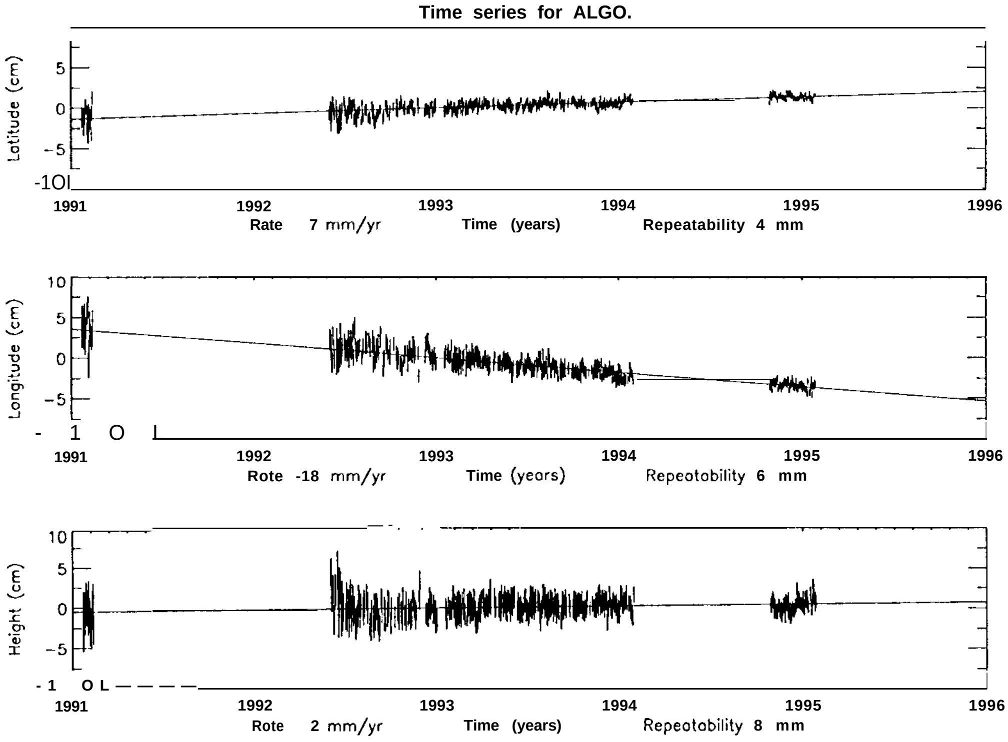

Figure 2. An example of a time series from the JPL IGS Analysis Center. Plots like this can be accessed on the World Wide Web at location http://sideshow.jpl.nasa.gov/mbh/series.html.

Table 5. Operational Earth orientation series.

quantity	bias	sigma
X (mas)	0.21	0.46
Y (mas)	1.37	0.44
LODR (usec)	-61	87
(after Ott 9:	-3	40)

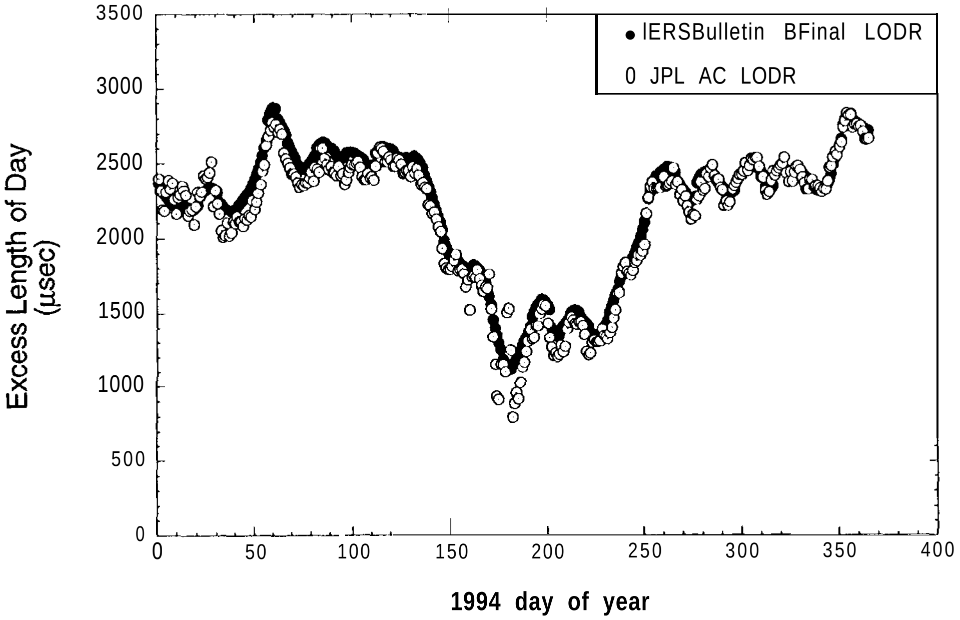

Figure 3. Operational length-of-day series during 1994, compared with IERS Bulletin B Final values.

length of day versus 1994 day number is given in Figure 3.

Our single most important measure of orbit quality is the extent to which estimated values of a satellite's position near midnight agree with similar estimates based on data from adjacent days. For a given satellite and day we define

$$Q^2 \equiv \Sigma_t \{ |x(t) - x_-(t)|^2 \} + \Sigma_t \{ |x(t) - x_+(t)|^2 \},$$

where $x(t), x_-(t), x_+(t)$ are the vector estimates of the satellite's position at time t using data from the current, previous, and subsequent days, respectively. In the first sum t ranges over the first three hours of the current day, while in the second sum it ranges over the last three hours of the day.

Shown in Figure 4 is a plot of the daily median value of Q, over all satellites. The daily variability of Q was typically 28 cm before October 9, and was reduced to 14 cm afterwards. The reduction in Q, both in its daily median and variability, is associated with the events in Table 1.

Finally, shown in Figure 5 is the distribution in the delay between data acquisition and product delivery. Our nominal goal is to deliver a week's worth of products on Friday (or earlier) following the Saturday that marked the close of the previous GPS week.

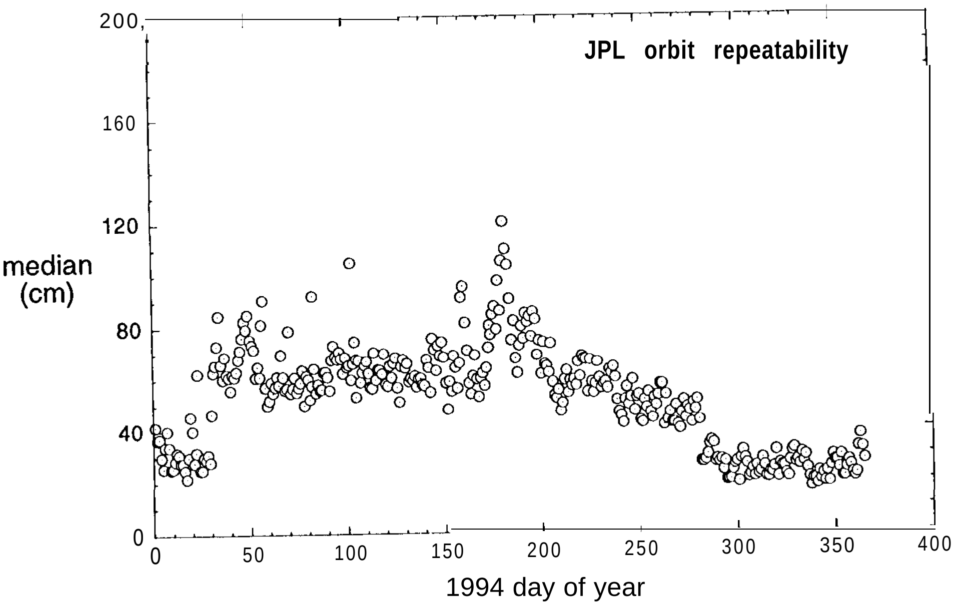

Figure 4. Orbit repeatability during 1994.

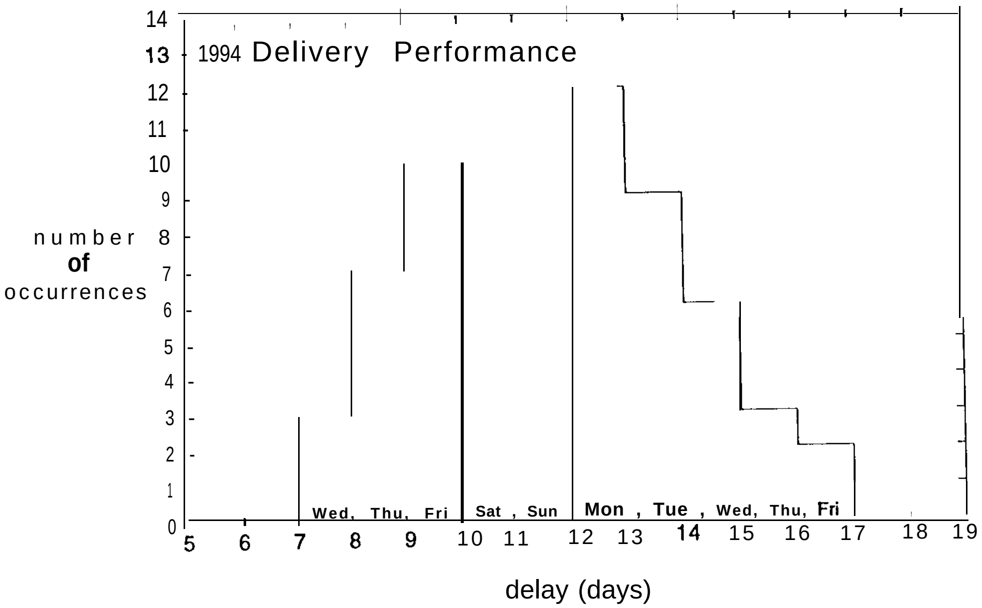

Figure 5. Delivery performance during 1994.

New for 1995

Site Selection *and Precise Point Positioning*

Because of the continuing expansion of the global IGS network during 1994, we have recently implemented a site-selection algorithm as follows:

- include Yellowknife and Algonquin (the two TurboRogue receivers that are IGS fiducials)

- from the set of remaining TurboRogue receivers, include successively the next 15 most isolated (those that are furthest away from the current set of included sites)

- include the remaining 11 IGS fiducials

- include the next 3 most isolated sites, without regard to receiver type

- choose an additional 3 sites at random

This algorithm provides a total of 34 sites, of which 31 have been chosen to be well distributed globally. Of the 31, a subset of 15 are well-distributed TurboRogues, allowing good determination of satellite clocks. (As new receivers are added in isolated regions, we will increase the number of sites in the global analysis.)

The remaining sites are analyzed with satellite parameters fixed at their just-determined values from the global solution.

The precise-point-positioning strategy has allowed us to analyze data from essentially all IGS sites, with horizontal repeatabilities at the few-mm level, and vertical repeatabilities at the cm level. We believe that this strategy is the key to analyzing dense networks of hundreds of receivers.

To avoid the consequences of errors in fiducial coordinates, we have recently (April 2, 1995) begun to compute free-network orbits and clocks, and use these in every day's precise point positioning. Thus, coordinates of these sites will be in the same reference frame as those used in that day's free-network global solution. The inclusion of 3 sites at random in the global solution means that all sites will occasionally participate in the global solution, allowing a comparison with precise point positioning results.

The WWW page at

http: `//sideshow.jpl.nasa.gov/mbh/point.html`

provides the time series of free-network point position results.

Automation

Beginning in April 1995, an automated process developed by Ron Muellerschoen of the EOS Group provides rapid precise orbits and clocks, within about a day of the end of data collection. These orbits are accurate to a few tens of cm, and, very valuable in their timeliness.

A second automated process periodically looks for new data files from IGS sites. If satellite parameters from the rapid orbit service are available for the corresponding day, such data are analyzed with precise point positioning. Both engineering data and site coordinates are saved. This process runs asynchronously with the rapid orbit service.

These automated processes will be used to develop before-the-fact quality control procedures for the normal AC operation.

Densification of the Terrestrial Reference Frame

As one of the seven AC's in the IGS, JPL will start submitting weekly coordinate solutions to the Global Data Centers sometime in calendar 1995. Additionally, we will expand our analyses to include comparison of such coordinate solutions among all AC's, as described by Blewitt (1995).

Acknowledgments

Geoffrey Blewitt served as Supervisor of the SGGS Group until January 1994. Our success in participating as an IGS Analysis Center owes much to Geoff.

The authors appreciate the efforts of the GNO Group in ensuring that data from the global network are made available for analysis in a timely fashion.

Our AC benefits from cooperation and collaboration with members of the EOS Group, in particular Yoaz Bar-Sever, Winy Bertiger, and Ron Muellerschoen.

It is a pleasure to be involved with the international community of IGS participants. We particularly acknowledge fruitful exchanges with Yehuda Bock, John Dow, Gerd Gendt, Jan Kouba, Gerry Mader, and Markus Rothacher.

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GPS Orbit and Earth Orientation Parameter Production at NOAA for the International GPS Service for Geodynamics for 1994

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Introduction

The GPS orbits and eop solutions submitted to the IGS by the National Geodetic Survey (NGS) are a joint effort between NGS and the Geosciences Laboratory (GL). The GL is responsible for the development of the processing software and techniques while NGS is responsible for the operational production. NGS and GL are both activities within the National Ocean Service (NOS) of NOAA (National Oceanic and Atmospheric Administration) which ensures a close working relationship between the two groups.

Station Network

NGS used an average of about 32 tracking stations for the GPS orbit and Earth orientation solutions that have been submitted to the IGS. This list of included stations is not static but changes occasionally to include new stations that offer a more favorable geometry or new geographical coverage and to drop stations in regions where the tracking density is greater or redundant, Generally, the number of included stations will probably be maintained between 35 and 40. Additional stations do not appear to noticeably improve the orbit solutions. This number also appears adequate to provide overall tracking network stability that is relatively insensitive to daily tracking irregularities within the total global tracking network.

Table 1 summarizes the tracking stations used during 1994. All stations that were used are listed along with the date at which their use began in order to highlight those new stations that were added during the year. The date at which stations were dropped from our daily orbit solutions are also indicated. From this list, 30 stations were used during the entire year while 7 stations were added and 3 stations were dropped. At the end of the year, 2 additional stations were dropped as the 1995 processing began.

Table 1 also shows which station positions were held fixed for the orbit and eop solutions. NGS began 1994 fixing only the 13 reference sites agreed upon by the IGS to their ITRF92 positions. All other sites were unconstrained. The effect of daily tracking dynamics on these 13 stations meant that on any given day, 1 or 2 stations were frequently missing. This had a severely deleterious effect on the orbit and eop results as shown later in this report. Consequently, in July we began also fixing all the stations that we were regularly using and for which an ITRF92 position was reported. These additional constraints, indicated in the table, had an immediate beneficial effect on the orbit and eop results.

Table 1. 1994 Selected NGS fiducial sites for precise GPS orbit computations.

Abbrev	*Ref Frame(*)*	*Station*	*Used*	*Dropped*
algo	ITRF92	Algonquin	01 JAN94	
areq	UNCONSTR	Arequipa	16AUG94	
brmu	UNCONSTR	Bermuda	01 JAN94	
cas1	UNCONSTR	Casey Station	02AUG94	
dav1	UNCONSTR	Davis	14JUL94	
drao	ITRF92(*)	Penticton	01 JAN94	
eisl	UNCONSTR	Easter Island	15AUG94	
fair	ITRF92	Fairbanks	01 JAN94	
for-t	UNCONSTR	Fortaleza	01 JAN94	
gold	ITRF92	Goldstone	01 JAN94	
hart	ITRF92	Hartebeesthoek	01 JAN94	
hers	ITRF92(*)	Herstmonceux	01 JAN94	15AUG94
hobl	UNCONSTR	Hobart	01 JAN94	31 JUL94
hob2	UNCONSTR	Hobart	16JUL94	
kerg	UNCONSTR	Kerguelen	10 DEC94	
kit3	UNCONSTR	Kitab	21 OCT94	
kokb	ITRF92	Kokee Park	01 JAN94	
kosg	ITRF92	Kootwijk	01 JAN94	
kour	ITRF92(*)	Kourou	01 JAN94	
macl	UNCONSTR	McQuarrie Is.	02AUG94	31 DEC94
madr	ITRF92	Madrid	01 JAN94	
masl	ITRF92(*)	Maspalomas	16JUL94	
masp	ITRF92(*)	Maspalomas	01 JAN94	15JUL94
mate	ITRF92(*)	Matera	01 JAN94	
mcmu	UNCONSTR	McMurdo	15JAN94	15JAN95
mdo1	ITRF92(*)	McDonald	01 JAN94	
mets	ITRF92(*)	Metsahovi	01 JAN94	
nlib	ITRF92(*)	North Liberty	01 JAN94	15AUG94
nyal	ITRF92(*)	Ny Alesund	01 JAN94	
onsa	ITRF92(*)	Onsala	01 JAN94	
pama	UNCONSTR	Pamatai	01 JAN94	09APR94
rcm5	UNCONSTR	Richmond	01 JAN94	
sant	ITRF92	Santiago	01 JAN94	
stjo	ITRF92(*)	St Johns	01 JAN94	
taiw	ITRF92(*)	Taiwan	01 JAN94	
tidb	ITRF92	Tidbinbilla	01 JAN94	
trom	ITRF92	Tromsoe	01 JAN94	
tskb	UNCONSTR	Tsukuba	01 JAN95	
usual	ITRF92(*)	Usuda	01 JAN94	31 DEC94
wes2	UNCONSTR	Westford	01 JAN94	
wett	ITRF92	Wettzell	01 JAN94	
yarl	ITRF92	Yarragadee	01 JAN94	
yell	ITRF92	Yellowknife	01 JAN94	

Notes:
1.) REF FRAME(*) Added constraints starting on 20Jul94.
2.) Switched to ITRF 1993 (epoch 1995.0) on 01 JAN95.

Product Delivery

NGS is the primary source of precise GPS orbits for the U.S. civil surveying community. Because of their need for precise orbits as near to real time as possible, NGS has made a commitment to deliver daily orbit products no later than 6 days after any given day. This commitment to timeliness has so far precluded the use of multiday arcs that would require waiting for following data, The delivery delay of NGS orbit products to the U.S. Coast Guard Navigation Information Service Bulletin Board and to the CDDIS is shown in Figure 1. The number of days it took to deliver an orbit is plotted for each day of 1994. Figure 2 shows this same data plotted as a histogram. The mean delivery delay in 1994 was a little longer than 4 days.

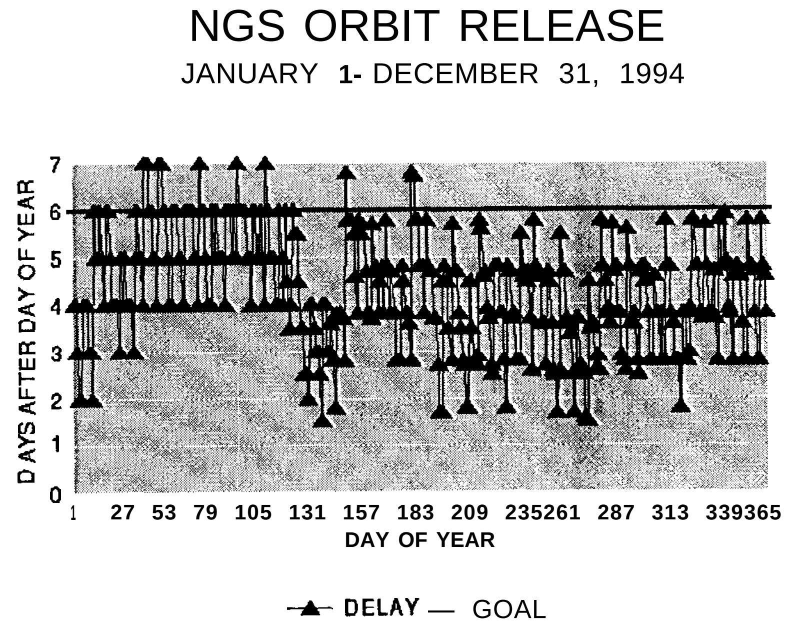


Figure 1. The number of days delay in delivering GPS ephemerides is shown for each day of the year for 1994.

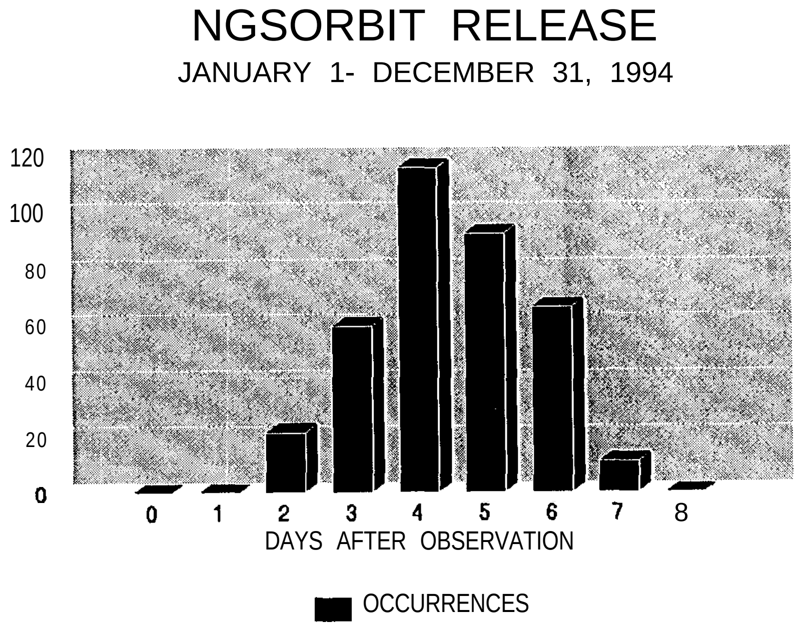


Figure 2. The frequency of occurrence of the delay for each day's orbit in 1994 is shown as a histogram. The mean ephemeris delivery time was just over 4 days.

On only 11 days (3%) were orbits delivered with a lag time greater than 6 days. Most of these delays occurred shortly after AIS was turned on requiring a greater than usual amount of manual data editing. These particular problems were solved by mid-year. The greatest factor contributing to the delay of NGS'S orbit computation is the late arrival of tracking data from stations within our computational network to the data centers, This is especially noticeable around holidays. These delays are partly responsible for certain stations being dropped from our list of usable stations. These delays are also responsible for increasing our station list to 35–40 stations while fixing about 25 stations in an effort to make the solutions less sensitive to this short but variable list of each day's missing stations.

Processing Summary

The procedures used by NGS for orbit and eop processing are summarized in Table 2. This table is reproduced and updated from that submitted to the IGS as a survey of all analysis center procedures. Changes to our processing during the year are indicated in the table.

Table 2. Analysis Center Questionnaire.

	GENERAL INFORMATION
Analysis Center	National Oceanic and Atmospheric Administration (NOAA) National Geodetic Survey (NGS) SSMC3 1315 East West Highway Silver Spring, MD 20910 USA Phone: 3017133205, Fax: 3017134322
Contact Person(s)	Mark Schenewerk email: mark@ tony. grdl.noaa.gov phone: 3017132854 William Kass email: billk@buster. rigs. noaa.gov phone :3017133208 Gerald Mader email: gerry@mozart.grdl. noaa.gov phone: 3017132854 Paul Spofford email: pauls@dancer. rigs. noaa.gov phone: 3017133205
Software Used	PAGE3 developed at NOAA
IGS Products generated for GPS week 'wwww' day of week 'n' (n=0,1,...,6)	NGSwwwwn.EPH GPS ephemeris/clock files in 7 daily files at 15 min intervals in SP3 format, including accuracy codes computed from the formal orbit errors of the solution NGSwwwwn.ERP (pole estimates and a priori UT1 UTC) in 7 daily files NGSwwwwn.SUM Processing summary in 7 daily files
Preparation Date	July 18, 1994

Table 2. (cont.)

MEASUREMENT MODELS	
Preprocessing	Phase preprocessing in a baseline by baseline mode using doubledifferences. In most cases cycle slips are fixed automatically looking simultaneously at different linear combinations of LI and L2. Manual reediting is done if any baseline shows larger than normal postfit RMS statistics in the all base combined solution. At that time, bad data points are removed or new ambiguities are set up.
Basic Observable	Carrier phase, code only used for receiver clock sync. Elevation angle cutoff : 20 degrees Sampling rate : 30 seconds Weighting : Uniform
Modelled observable	Double differences, ionosphere-free linear combination.
RHC phase rotation corr.	None
Ground antenna phase center	Elevation dependent phase center corrections are applied to all antenna types.
Troposphere	A priori model: Saastamoinen “dry” zenith with the CfA 2.2 **mapping function plus the Saasamoinen ‘(wet” with the Chao “wet” mapping function.** **Estimation : zenith delays in 6 hour intervals.**
Ionosphere	**Not modeled (ionosphere eliminated by forming the ionosphere** free linear combination of **L1 and** L2**)**
Plate motions	ITRF92 **station velocities fixed (see** IGSMAIL#421)
Tidal displacements	Solid earth tidal displacement: Melchion (1978) Pole tide: not applied Ocean loading: not applied
Atmospheric load.	Not applied
Satellite center of mass correction	Block I x,y,z: 0.2110, 0.0000, 0.8540 m Block II/IIA x,y,z: 0.2790,0.0000, 1.0230 m
Satellite phase center calibrat.	Not applied

Table 2. (cont.)

ORBIT MODELS	
Geopotential	GEMT3 model up to degree and order 8
	GM= 398600.4418 km**3/sec**2 (Jan 1- Aug 17) 398600.4415 km**3/sec**2 (Aug 18- present)
	AE = 6378.1363 km
Third body	Sun and Moon as point masses
	Ephemeris: Generated from the MIT PEP program
	GMsun = 132712440000 km**3/sec**2
	GMmoon = 4902.7989 km**3/sec**2
Solar radiation pressure	Direct radiation: ROCK4 and ROCK42 approximations (T10 and T20) for Block I and II sat.
	Satellite masses used: all Block I = 520.0 kg all Block II= 885.0 kg
	One scale factor and the ybias estimated per arc
	Earth shadow model includes: umbra and penumbra
	Reflection radiation: not included
	New GPS satellite attitude model: not applied
Tidal forces	Solid earth tides: not applied
	Ocean tides: not applied
Relativity	Not applied
Numerical Integration	11th order Adams-Moulton Predictor-corrector
	Integration step: 22.5 minutes
	Starter procedure: Initial conditions taken from the previous day at 24:00 (from broadcast under special conditions).
	Arc length: 24 hours of data are used to adjust a 31-hour integrated arc centered on the day of interest. The 3.5-hour extensions are used in house for quality control and are removed before submission to the IGS.

Table 2. (cont.)

ESTIMATED PARAMETERS (APRIORI VALUES& SIGMAS)	
Adjustment	Least-squares algorithms
Rejection Criter.	No rejection during parameter estimation procedure. Outliers are marked during preprocessing step
Station coordinates	13 stations absolutely fixed to the ITRF92 positions as given in IGSMAIL#430, the remaining are estimated The ITRF92 velocities are used for daily coordinate updates. Other site positions defined in IGSMAIL#421.
Orbital parameters	6 element state vector at IC, solar radiation and ybias scaling factors estimated as constants for one arc. No *a priori* sigmas used.
Troposphere	Zenith delays estimated once per 6 hours for each station.
Ionospheric correction	Not estimated
Ambiguity	Estimated as real values with no *a priori* constraints
ERP	X and Ypole coordinates. *A priori values* taken from IERS Rapid Service Bull. A
Satellite clock bias	Satellite clock biases are not estimated but eliminated by forming double differences.
Receiver clock bias	Receiver clock corrections are estimated during the preprocessing using code measurements.
Other parameters	None

REFERENCE FRAMES	
Inertial	Geocentric; mean equator and equinox of Besselian year 1950 (B1 950.0)
Terrestrial	ITRF92 reference frame realized through a set of 13 station coordinates and velocities as given in IGSMAIL #430 as well as the antenna offsets for the above stations given in /igscb/station/tie/localtie.tab available from IGS CB (igscb.jpl.nasa.gov). Beginning with data from July 20, 1994, an additional 12 sites were fixed.

Table 2. (cont.)

Interconnection	Precession: IAU 1976 Precession Theory Nutation: IAU 1980 Nutation Theory Relationship between UT1 and GMST: USNO **Circular No. 163 (IAU Resolution)** *A priori* ERP values from IERS Rapid Service Bull. A

References

Fliegel, H., T. Gallini and E. Swift (1992), Global Positioning System radiation force **model for geodetic applications,** *J. Geophys. Res.* 97(B1), pp. 559-568, January 1992.

McCarthy, D.D. (cd.) (1992). IERS Standards (1992), *IERS Technics/Note 73,* Observatoire de Paris, July 1992.

Melchion, P (1978), “The Tides of the Planet Earth,” Pergamon Press, pp. 109–121.

Schenewerk, M. S., MacKay, J. R., Kass, W., Miranda, C., and Mader, G., (1993), Rapid Turnaround GPS Ephemerides from the National Geodetic Survey, Proceedings of the ION GPS 93, Institute of Navigation, pp. 247-255.

Orbit and EOP Evaluation

NGS continuously monitors the quality of its GPS orbits and eop parameters by comparison with those produced by other analysis centers and the IGS combined products and by examining the repeatability of long baselines. Figure 3 shows the difference for 1994 of the x and y pole positions generated by NGS with respect to the IERS pole positions. The same figure also shows the RMS difference between the NGS orbits and the IGS combined orbits for all satellites after a 7-parameter transformation.

The RMS difference between the NGS orbits and those of the other analysis centers and the IGS combined orbits was typically 30–35 cm prior to the commencement of A/S on January 31, 1994. The onset of A/S had a significant effect on the quality of the solutions emerging from our automatic processing procedures. The typical RMS difference between the NGS and IGS combined orbit rose to about 50 cm with numerous severe outliers. In spite of these differences, NGS remained committed to its production schedule since it appeared that the orbit quality was still well within the specifications required by the surveying community. Meanwhile, efforts were simultaneously underway to modify our software and processing procedures in response to A/S. The results of these efforts were largely in place by May 1994.

The next major increment in improving the NGS orbits occurred on July 23 when we began fixing about 24 instead of the previous 13 stations. This brought the RMS difference between the NGS orbits and the IGS combined orbits to about 20 cm. The improvement seen in the GPS orbits was mirrored in the NGS polar motion results (see Figure 3). Throughout the first half of the year, the RMS residual was about 0.9 mas for the x pole and 1.1 mas for they pole. After constraining the additional stations, the polar motion performance improved by

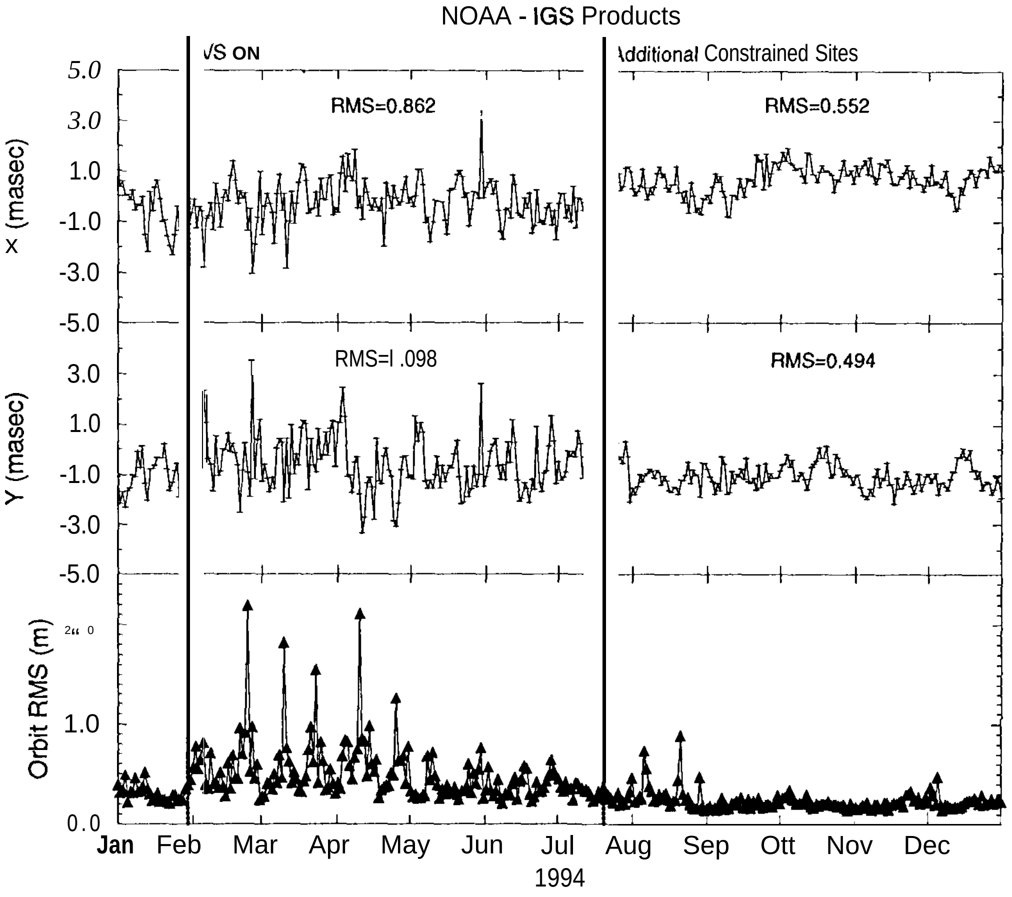


Figure* 3. *The NGS- determined x and y pole positions with respect to the IGS pole positions are plotted for each day of 1994. The overall RMS comparison between the NGS orbit and the combined IGS orbit is also shown for all 1994. The onset of A/S had a significant effect on NGS orbit quality. These problems were resolved by mid-year with a resulting 20-cm average agreement between NGS and IGS.

about a factor of two. Similar results can be seen from the weekly reports distributed by the USNO.

NGS and GL monitor the repeatability of long baselines, representative of those used within NOAA, using NGS as well as GPS orbits from other IGS analysis centers. This is done by producing daily estimates of site coordinates to assess the overall quality of GPS-derived geodetic solutions as end users would perceive it. This analysis is intended to monitor the contribution of the NGS orbits to the quality of these representative solutions by comparison with other orbits. It is not intended as a more thorough orbit analysis which would be done with longer baselines.

Three sites (two baselines) were selected for the baseline repeatability analysis presented here. These sites were chosen to meet the following requirements.

1. one baseline should be predominately north–south; one baseline should be predominately east–west.
2. reasonably reliable data should be available for all of 1994.
3. the sites should be part of the IGS network but not included in the NOAA orbit adjustments.
4. both baselines should be longer than 1000 km,

The site selection was also confined to North America to be coincident with the area containing most of NOAA's operational activities. The sites selected were Albert Head, McDonald, and JPL. Pertinent information regarding these sites, as specified in the IGS/IERS documentation and in the ITRF93 reference frame, is shown in Table 3. The baseline analysis presented here is in addition to routine baseline comparisons conducted by NGS on other baselines throughout the year. These results were compiled in early 1995 and consequently use the ITRF93 coordinates for the selected stations. All the orbits used for this analysis used ITRF92 coordinates and were downloaded from the CDDIS. Except for small deviations from the *a priori* coordinates, this difference in reference frames has no effect on the analysis.

Table 3. Sites Selected for Baseline Repeatability Analysis,

Albert Head, Victoria, BC, Canada				
albh	x	Y	z	
	-2341332.869 m	-3539049.487 m	4745791.402 m	monument
	-0.0240 m/yr	0.0014 m/yr	-0.0103 m/yr	velocity,
JPL Mesa, Pasadena, CA, USA				
jpl1	x	Y	z	
	-2493304.112 m	-4655215.532 m	3565497.360 m	monument
	-0.0353 m/yr	0.0227 m/yr	0.0076 m/yr	velocity,
McDonald VLBA, Fort Davis, TX, USA				
mdo1	x	Y	z	
	-1329998.656 m	-5328393.385 m	3236504.241 m	monument
	-0.0166m/yr	0.0008 m/yr	-0.0041 m/yr	velocity
	x	Y	z	Length
albh-jpl1	151971.243 m	1116166.045 m	1180294.042 m	1631568.547 m
mdo1-jpl1	1163305.456 m	-673177.853 m	-328993.119 m	1383721.243 m.

The data were processed with the Geosciences Laboratory's PAGE3 software, using the indicated precise ephemeris with no further orbit adjustment. The data were edited automatically. Approximately 10% of the days required additional, hand editing. Phase biases, 1 hour piece wise, continuous, linear tropo scaling factors, and daily positions were estimated. jpl1 was used as the reference site and held fixed.

Hardware information for each site were taken from the site logs available from the Central Bureau. Pertinent changes during 1994 are:

1	01/16/94	albh	ROGUE SNR 8C replaced with ROGUE SNR 8000
2	04/14/94	albh	antenna height change: Dome Margolin B replaced with Dome Margolin T
3	05/09/94	jpl1	firmware upgrade in ROGUE SNR 8: 7.5 to 7.8
4	06/14/94	jpl1	ROGUE SNR 8 replaced with ROGUE SNR 8100
5	06/14/94	jpl1	antenna height change: Dome Margolin R replaced with Dome Margolin T
6	10/12/94	jpl1	firmware upgrade in ROGUE SNR 8100: 2.8.32.1 to 3.0
7	11/23/94	mdo1	firmware upgrade in ROGUE SNR 8000: 2.8 to 3.0

These events are indicated in Figure 4 with dashed vertical lines labeled with the number from the first column. The following events also occurred during 1994 and are noteworthy for their possible effects on baseline repeatability:

A	01/1'7/94	jpl1	Northridge earthquake
B	01131194		AIS on continuously
C	07120/94		NOAA increase number of fixed orbit tracking sites.

Figure 4 shows the north, east, and up estimated adjustments to the *a priori* site coordinates from daily solutions using the IGS precise ephemerides. The events described above are indicated with dashed lines at the appropriate epoch and labeled using the corresponding number or letter. Four days had insufficient data from these baselines to yield meaningful solutions. The period from January 31 through June 14 (A/Son through the replacement of the ROGUE at JPL) had significant data loss presumably because of the poor performance of the older ROGUE receivers with A/S on. Using a criterion of 80% of the normal number of double difference observations for a baseline (80% normal = 10,000 observations given the baseline lengths, elevation cutoff, and observation interval) 37% of the days during this period failed this criterion as compared with 10% for the other periods. This data loss predictably resulted in larger scatter and outliers. Table 4 lists the RMS scatter (weighted by the formal errors from the solution) for each baseline component using the IGS and NOAA precise ephemerides. The results for January 31–June 13, and all other days are broken out revealing the disparate receiver performance during these two periods. All values are in centimeters.

Eliminating the days with 80% or fewer observations yielded slightly improved baseline repeatabilities. Since the receiver performance in the first half of 1994 for these baselines was anomalous and not representative of current or expected future performances, in the subsequent discussion, only the June 14–December 31 period will be considered.

The June 14–December 31 data were then reprocessed using ephemerides generated by the other analysis centers. All other aspects of the processing were identical. The estimated adjustments to the *a priori* baseline components for

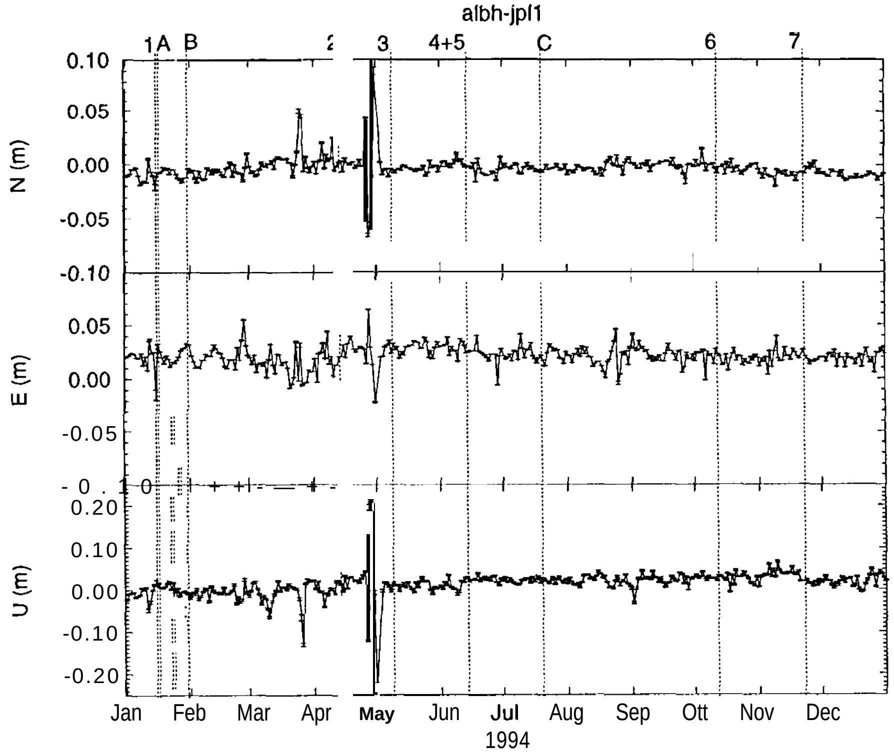


Figure 4. *The displacement of the north, east, and up position of albh with respect to jpl1 from the IGS* a priori *coordinates is shown for each day of 1994 using the IGS combined orbits. Significant events described in the text and indicated by the dashed lines.*

Table 4. Baseline Repeatability Using All Data (all **values in** *centimeters).*

EPH	DATES	albh-jpl1			mdo1-jpl1		
		N	E	U	N	E	u
IGS	All 1994	0.65	0.82	1.92	0.55	0.87	2.29
	Jan 31-Jun 13	0.83	1.09	2.58	0.64	0.99	3.40
	Jan & Jun 14-Dec 31	0.57	0.63	1.38	0.49	0.72	1.56
NGS	All 1994	1.06	1.14	2.12	0.61	1.58	2.19
	Jan 31 -Jun 13	1.17	1.49	3.03	0.72	1.49	3,22
	Jan & Jun 14-Dec 31	0.57	0.83	1.58	0.51	1.16	1,58

each orbit type and for each day are shown in the Figures 5–10. Each baseline component is shown separately with each Analysis Center and the IGS as sub-panels in the figure. The horizontal scales are identical in all figures; the vertical component figure scales have the same span but, by necessity, offsets from a zero mid-point. The mean displacement of albh and mdol, with respect to jpl1, from their *a priori* values and the RMS of their repeatability for each orbit type are shown in Figure 11 and summarized in Tables 5 and 6.

Conclusions

During 1994, NGS maintained an average delay for precise GPS orbit delivery of just over 4 days. The orbit processing procedure suffered significantly with the onset of AIS. Modifications to the automated software and procedures and the constraining of additional stations have produced an average agreement of about 20 cm with the IGS orbits. Baseline repeatability analyses using all the analysis center orbits as well as the combined IGS orbits do not show any significant variation between the baselines determined using NGS orbits and the other orbits. As a direct result of the analysis center questionnaire, the Geosciences Laboratory modified some of the physical constants used in the NGS processing. These modifications brought the previously large scale factor difference seen for the NGS orbits more in line with those of the other analysis centers.

In the coming year NGS and GL will examine possible revisions to some of the models and procedures used in our processing software and analysis. In particular, we expect to include the effect of Earth tides on the geopotential and to examine the production of orbits derived from multiday arcs as an additional orbit product. The current treatment of both these effects distinguishes the NGS orbit from most of the other analysis centers and maybe contributing significant factors to the differences between the NGS orbits and the IGS combined orbits. We also expect to add the effects of ocean loading using empirically determined coefficients.

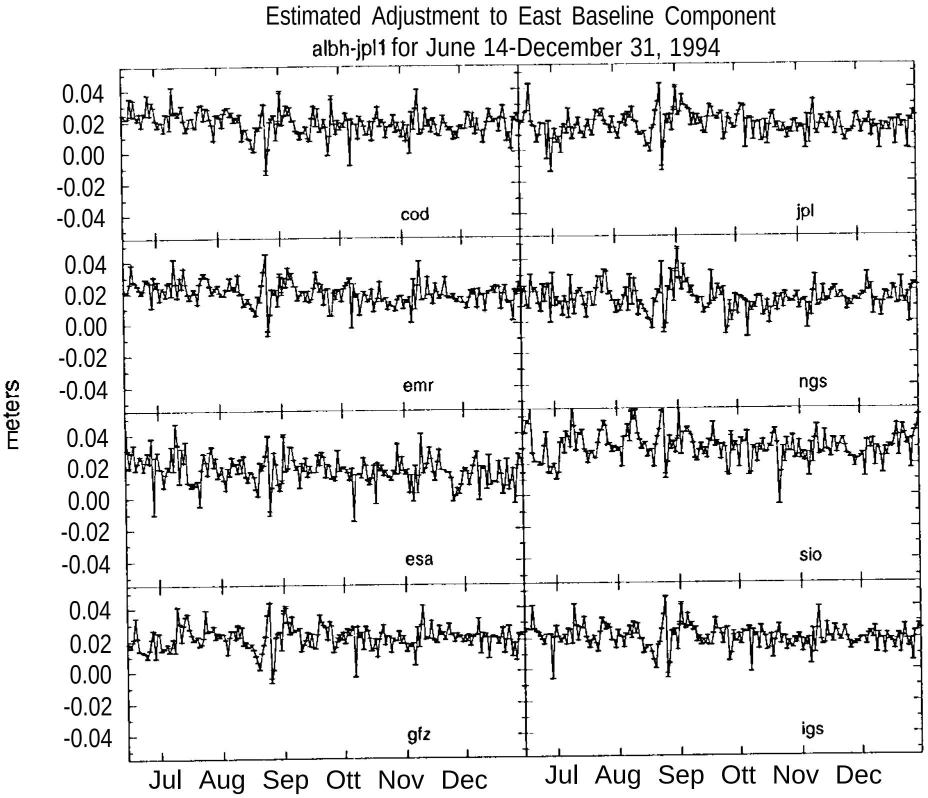


Figure 5. The east displacement of albh from its a priori value from June 14 to December 31 using each orbit type. All other details of the processing are identical.

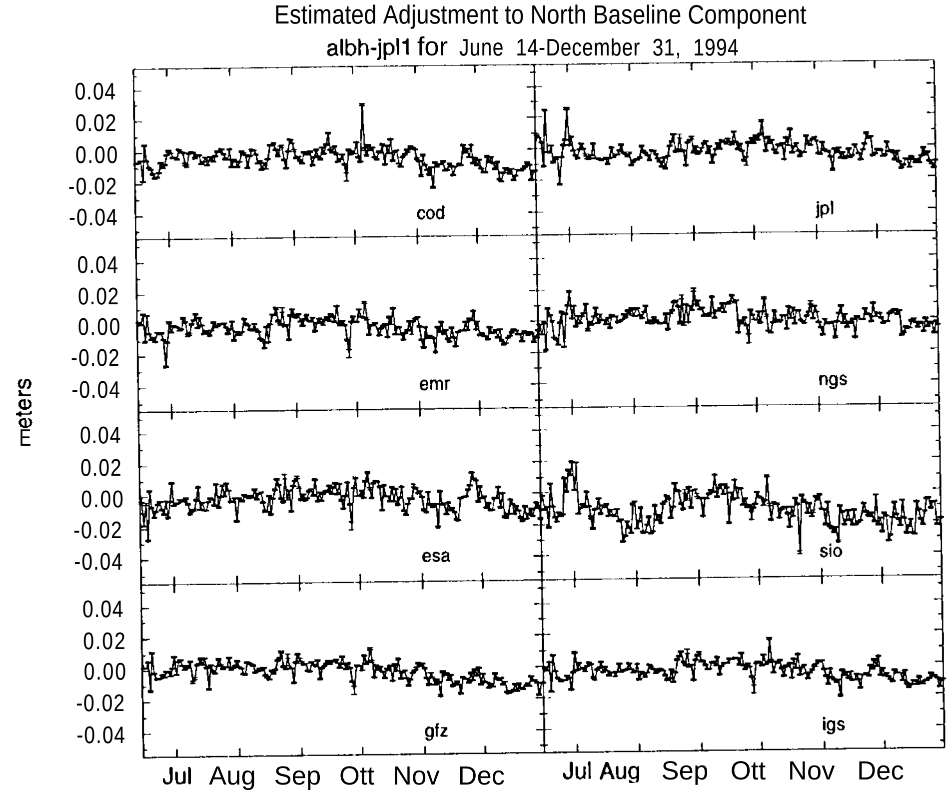


Figure 6. The north displacement of albh from its a priori value from June 14 to December 31 using each orbit type. All other details of the processing are identical.

Figure 7. The vertical displacement of albh from its a priori value from June 14 to December 31 using each orbit type. All other details of the processing are identical.

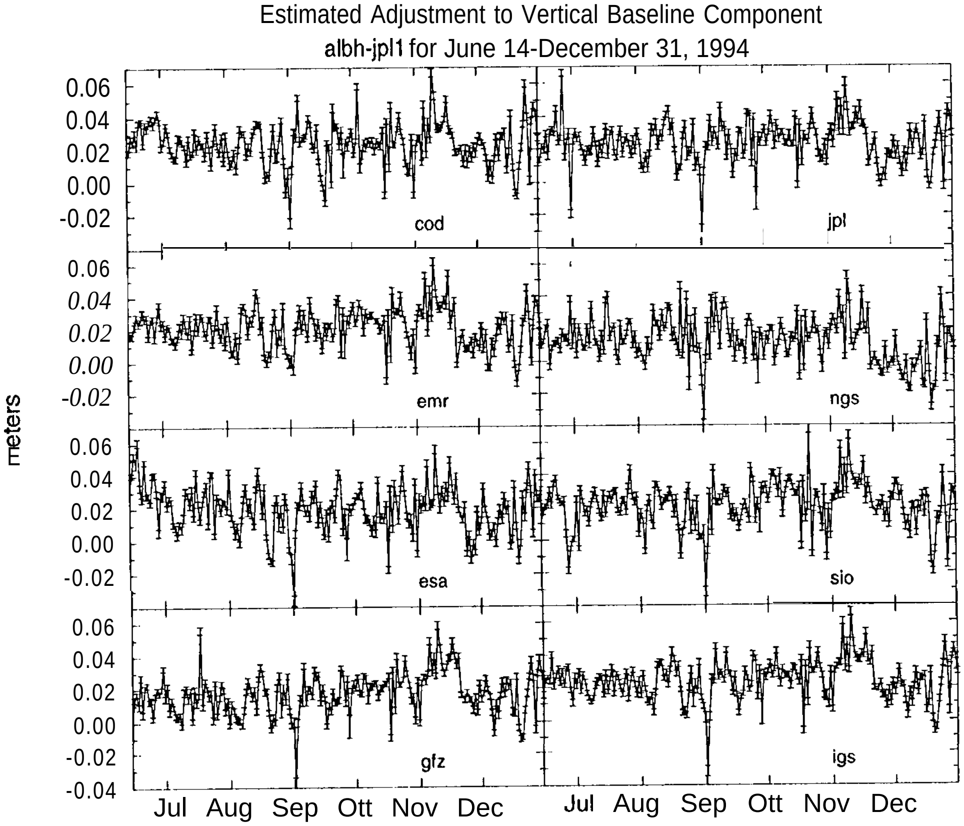
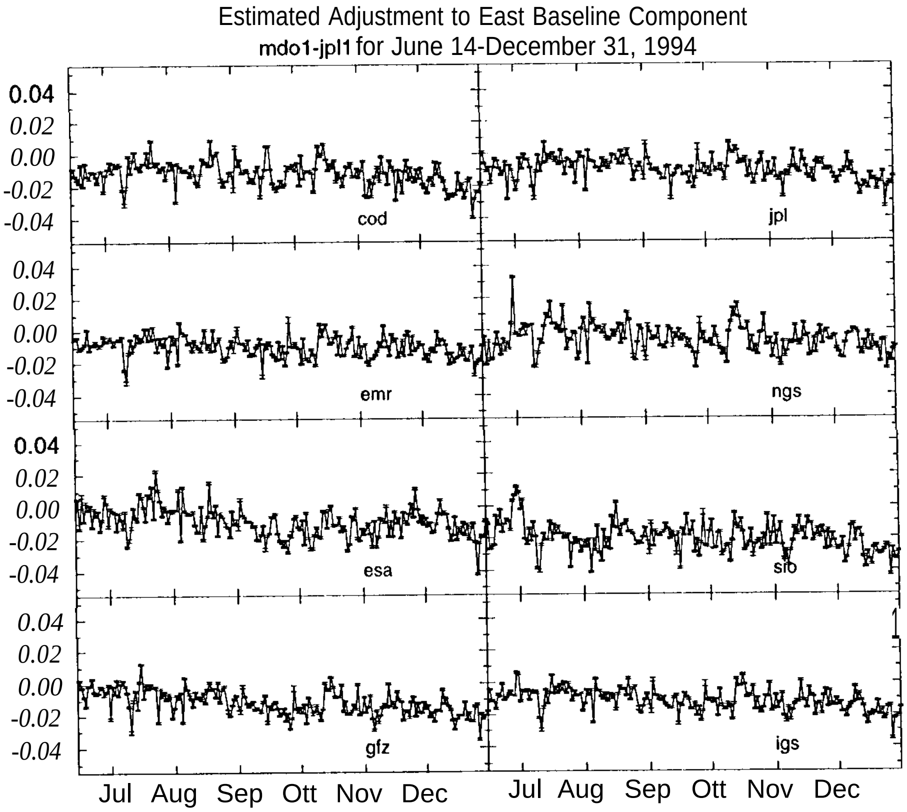


Figure 8. The east displacement of mdo 1 from its a priori value from June 14 to December 31 using each orbit type. All other details of the processing are identical.



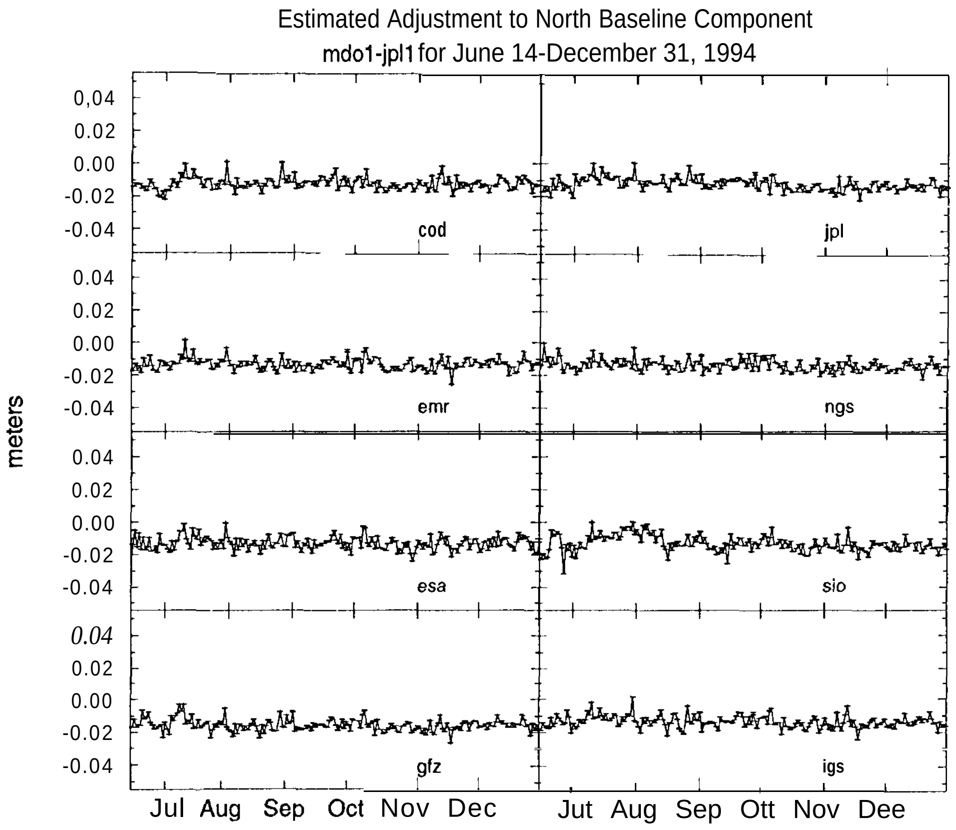


Figure 9. The north displacement of mdo 1 from its a priori ***value from June 14 to December 31 using each orbit type. All other details of the processing are identical.***

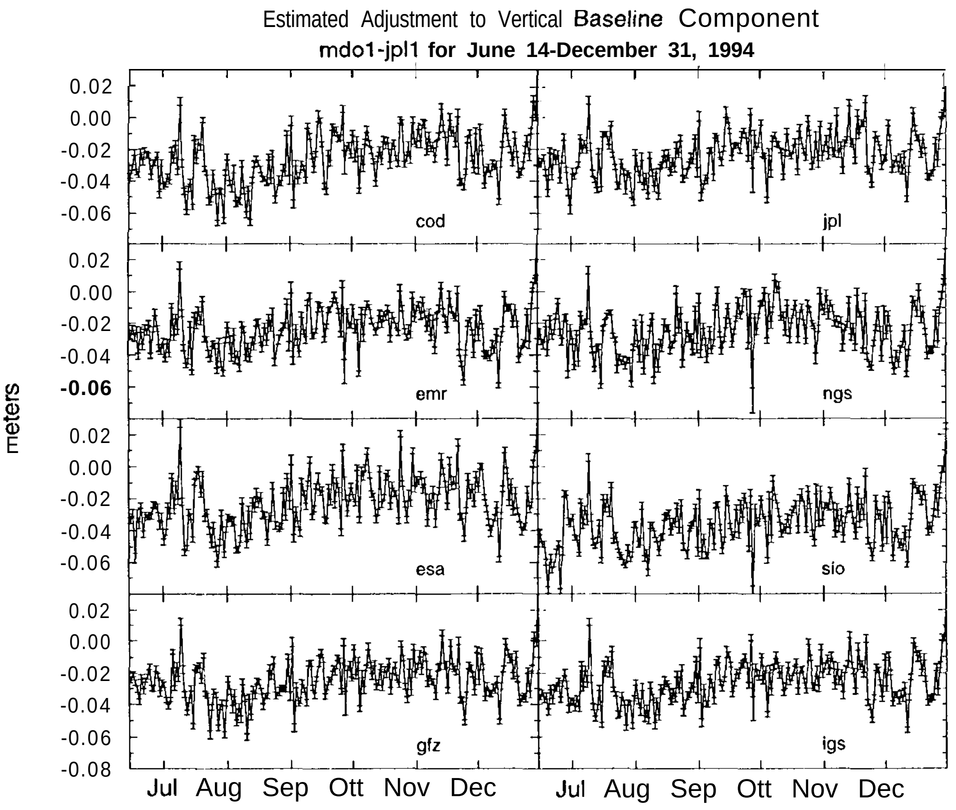


Figure 10. The vertical displacement of mdo 1 from its a priori ***value from June 14 to December 31 using each orbit type. All other details of the processing are identical.***

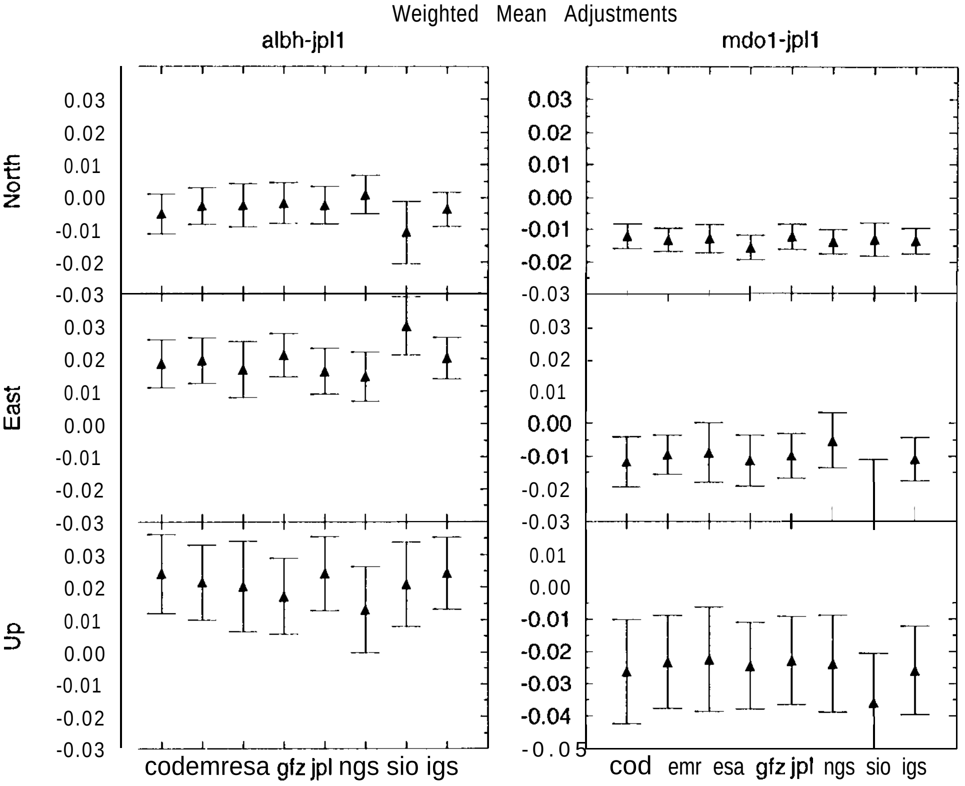


Figure 11. The mean north, east and vertical displacements for albh and mdo 1 for each orbit type. The error bars indicate the RMS repeatability for each orbit type.

Table 5. RMS Baseline Repeatability (cm).

	albh-jpl1			mdo1-jpl1		
	n	e	u	n	e	u
cod	0.63	0.74	1.21	0.37	0.77	1.61
emr	0.58	0.70	.15	0.35	0.61	1.44
esa	0.69	0.87	.39	0.42	0.91	1.63
gfz	0.65	0.67	.17	0.37	0.79	1.35
jpl	0.59	0.71	.14	0.38	0.69	1.37
ngs	0.60	0.76	.32	0.36	0.84	1.51
sio	0.96	0.89	.30	0.50	0.90	1.55
igs	0.54	0.64	1.10	0.38	0.67	1.37

Table 6. Mean Displacement (cm).

	albh-jpl1			mdo1-jpl1		
	n	e	u	n	e	u
cod	-0.51	1.85	2.42	-1.21	-1.18	-2.62
emr	-0.26	1.95	2.15	-1.32	-0.96	-2.33
esa	-0.24	1.67	2.03	-1.28	-0.90	-2.25
gfz	-0.17	2.12	1.72	-1.55	-1.14	-2.45
jpl	-0.24	1.45	2.42	-1.22	-0.99	-2.29
rigs	-0.09	1.45	1.31	-1.37	-0.53	-2.38
sio	-1.08	3.01	2.09	-1.30	-1.99	-3.60
igs	-0.37	2.02	2.43	-1.35	-1.09	-2.59

NRCan (EMR) Analysis Report

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Introduction

In August 1992, the Geodetic Survey Division (GSD) of Natural Resources Canada (NRCan) joined the IGS pilot service as its seventh analysis center known as EMR (Energy, Mines and Resources). Since then, EMR has been generating precise orbits, clocks, and EOP parameters on a daily basis. EMRs participation in IGS was a natural extension of GSD and Geological Survey of Canada (GSC) effort to create a GPS based Canadian Active Control System (CACS) (Delikaraoglou *et al.*, 1986; Kouba and Popelar, 1990). From the conception of the CACS in 1986 to the start of the Epoch92 campaign in July 1992, EMR had been contributing data to the international GPS effort by participating in several major GPS campaigns such as CASA'S, GOTEX, and GIG91 and by continuously operating the Yellowknife and Algonquin fiducial stations. By the start of the Epoch92 campaign, EMR had acquired the necessary hardware and software for the computation of precise GPS orbits. Participation in the IGS pilot service that evolved from Epoch92 was, therefore, an excellent opportunity for EMR to continue contributing to and benefiting from this international cooperative GPS effort.

In the following report, EMR's GPS analysis which includes generation of precise orbits, clocks, EOPS and station coordinates is reviewed and some of the results presented.

EMR GPS Analysis

Software

In view of EMR's limited resources and of the complexity of GPS global software, it was decided early on that an existing software had to be adapted for the CACS orbit computation. In 1989 EMR acquired the MicroCosm (Van Martin Systems Inc., 1990) and GIPSY/OASIS (Lichten, 1990; Webb and Zumberge, 1993) software packages. Initially, both packages were modified to increase operational flexibility and to accommodate new requirements. The software results for test data sets showed good agreement and provided information on achievable precision (Ferland and Lahaye, 1990). Currently EMR daily orbit computations capability is based on HP9000 UNIX platforms and the GIPSY/OASIS software.

Data

From the beginning the EMR orbit computation strategy has been to provide precise orbits optimized over Canada in the shortest time possible. To achieve this goal EMR has automated the GIPSY/OASIS procedures and used the minimum number of stations required to provide geometric network strength to process 24-hour arcs with no data overlaps.

During 1994, EMR used 6 Canadian CACS stations augmented by up to 16 global IGS sites. To enhance the data quality, given the relatively small number of stations, undifferenced pseudo-range and carrier-phase observations decimated at 7.5 minutes are used. The two types of observations are assumed independent, although the pseudo-range observations are smoothed using carrier-phase measurements. Most estimated parameters are constrained using realistic bounds corresponding to their daily variance and many parameters are sufficiently predictable to use previous day results as *a priori* values. For example, initial satellite states and stations' tropospheric delays are initialized using the previous day's solution. *A priori* values for solar pressure parameters are estimated using a moving weighted average of the previous days' solutions. Table 1 lists the parameters estimated daily, along with their *a priori* values and standard deviations.

Table 1. Summary of estimated parameters,* a priori *values and sigmas (as of December 1994).

Parameter	Estimation	*A priori* Value	*A priori* Sigma
Stations (X,Y,Z)	mean value	IGS/ITRF92 (of date)	**see Table 2 / 50m**
Pole (x,y)	mean value	IGS/USNO Bull. A	**3m**
DUT1	mean value	IGS/USNO Bull. A	**3m / fixed**
LOD	mean value	IGS/USNO Bull. A	0.5m/sec
Trop. Zenit. Delay	mean value	previous day estim.	**3cm**
Satellite States (X, Y, Z,dX,dY,dZ)	mean value	previous day estim.	see Table4
Sol. Rad. Press. (GX,GZ)	mean value	previous days estim.	10%
Sol. Rad. Press. (GY)	mean value	previous days estim.	0.5d-09m/s**2
Phase Ambiguity	mean value	pseudorange estim.	300000km
Tropospheric Bias	rand. walk	0.0km	0.01 m/sqrt(hr)
Station Clock	white noise	point positioning	1 sec
Satellite Clock	white noise	broadcast	1 sec

Reference Frame

As recommended by IGS, the ITRF is used in all EMRs solutions. This is realized by constraining a prescribed set of ITRF coordinates and velocities. Table 2 lists the 13 stations and the constraining standard deviations for their ITRF coordinates used since January 1994. Table 2 also gives the percentage of days since January 1994 when listed stations have not been included in EMRs daily solution due to either data unavailability or data problems. EMR's processing is typically performed within three to five days after the time of observation.

On January 1, 1995, in accordance with IGS recommendations, ITRF92 station coordinates were updated to ITRF93. This reference frame change introduced a small discontinuity in EMRs solutions. Table 3 shows the seven parameters for the 13 station ITRF92/ITRF93 transformation as well as transformations derived from EMRs daily solutions for GPS week 782. The small differences between the transformations are due to variations in data quality, fiducial stations used, and solution geometry.

Processing Strategy

The basic processing strategy (Kouba *et al.*, 1993) had been developed and implemented by October 1992, two months after EMR had commenced

Table 2. Constraining sigmas (X, Y,Z) for 1994 and 1995 EMR solutions.

Station	ITRF92 Sigma (mm)	ITRF93 Sigma (mm)	Exclusion* (%)
ALGO	5, 5,5	3, 3, 3	3.0
FAIR	6,6,6	3,3,3	2.1
GOLD	8, 8,8	4, 5, 5	1.4
HART	10, 10, 10	4,4,4	10.5
KOKB	6, 6, 6	3,3,3	7.0
KOSG	7,7,7	5, 5,3	6.0
MADR	6, 6, 6	3,3,2	1.4
SANT	0, 10, 10	4,4,4	9.8
TIDB	1,11,11	4,4,4	1.9
TROM	6,6,6	4, 4,4	2.3
WETT	6, 6, 6	3, 3, 2	3.5
YAR1	9,9,9	5,5,4	0.7
YELL	6,6,6	3,3,4	0.7

(*) Fiducial stations may have been excluded from EMR daily solutions due to receiver not tracking, data not available at time of estimation or data rejected. Percentage are given with respect to all days stations have been in operation from January 02, 1994 to March 04, 1995.

Table 3. Differences between EMR solutions based on ITRF92 and ITRF93 for GPS week 782.

Transformation	T1	T2	T3	Sc	R1	R2	R3
	sig	sig	sig	sig	sig	sig	sig
	(cm)	(cm)	(cm)	(ppb)	(mas)	(mas)	(mas)
ITRF93 to ITRF92 for the	2.0	0.8	0.3	-0.1	1.32	0.82	0.55
13 IGS fiducial stations	0.4	0.5	0.4	0.6	0.18	0.16	0.16
EOP and station coordinate	1.4	1.6	-0.1	0.4	1.48	0.96	0.48
solution based on ITRF92 and ITRF93	0.1	0.1	0.1	0.2	0.06	0.05	0.06
Orbit solution based on	0.2	1.1	0.5	0.0	1.42	0.81	0.63
ITRF92 and ITRF93	0.04	0.04	0.04	0.02	0.01	0.01	0.01

contributing to IGS. The main characteristic of this strategy is to compute a 24-hour arc without data overlap and with most of the *a priori* information obtained from the previous day solution. Using properly weighted previous day orbital information ensures day-to-day solution continuity. To minimize nonlinearity problems, UT1-UTC (DUT1) estimation is reset, typically hi-weekly, to the VLBI-derived value (IERS, Bull A). For days when a reset takes place two solutions are computed, one with the old a *priori* DUT1 and one with the new. This facilitates maintenance of a continuous UT1-UTC series since January 2, 1994. The satellite state vector constraints are relaxed whenever DUT1 is reset and fixed. A summary of EMRs processing strategy is given in Appendix A.

The processing strategy has been modified on five occasions. In January 1993 the period between a *priori* DUT1 resets to Bulletin A values was extended from one to two weeks. In January 1994 EMR implemented a stochastic daily update of the orbital parameters. Since then, orbital constraints for day(n) are derived from the satellites state vector solution of day(n-1) with the corresponding variance-covariance matrix augmented using a stochastic model. Stochastic modeling of the state vectors, as described in Table 4, facilitates estimation of both DUT1 and LOD since it effectively constrains the right ascension of the ascending nodes.

Table 4. Orbit stochastic modeling employed in EMR daily analysis.

Parameter	Modeling	Steady State Sigma	DUT1
semi-major axis	randomwalk	0.10m/sqrt(day)	estimated
eccentricity	randomwalk	0.12m/sqrt(day)	estimated
inclination	randomwalk	0.06m/sqrt(day)	estimated
right ascencion	randomwalk	0.06m/sqrt(day)	estimated
argument of perigee	randomwalk	0.16m/sqrt(day)	estimated
mean anomaly	randomwalk	0.16m/sqrt(day)	estimated
dX, dY, dZ (non-eclip)	whitenoise	5.0d-08mm/sec	estimated
dX, dY, dZ (eclipsing)	whitenoise	1.0d-07mm/sec	estimated
GX, GZ	whitenoise	1070	estimated / fixed
GY	whitenoise	0.5d-09 m/s**2	estimated / fixed
x, Y, z	whitenoise	1km	fixed
dX, dY, dZ	whitenoise	0.1m	fixed

The activation of anti-spoofing (AS) on all GPS Block 11 satellites in February 1994 resulted in a degradation of EMRs orbit and clock solution quality. Table 5 shows the impact of AS on EMRs results. AS was especially harmful to EMRs processing because precise GPS pseudo-range observations were no longer available for clock estimation. Under AS, the older generation of Rogue receivers produced cross-correlated pseudo-range observations that were biased and up to 10 times noisier than P-code observations. Furthermore, the pseudo-range biases of the reconstructed observations were time dependent and thus could not be properly calibrated nor combined with carrier-phase observations. The AS problems were somewhat mitigated by the introduction of the Meenix 7.8 receiver software and by using stations equipped with TurboRogue receivers. AS pseudo-range observations for TurboRogues and Rogues with the Meenix 7.8 or later software were still biased by about 1 m or 20 to 50 m, respectively. The receiver hardware and software updates, however, made it possible to estimate satellite dependent biases at each station and use again both carrier-phase and properly weighted pseudo-range observations in daily processing.

In June 1994 LOD estimation was implemented.”' The yaw rate attitude model (Bar-Sever, 1994) was implemented in October 1994. EMR currently does not estimate the yaw rates; instead the best available nominal values are used. Tracking data of satellites emerging from the earth’s shadow, which used to be rejected, can now be properly modeled and included in EMRs estimation. At the same time, the antenna phase center offset of Block II satellites was changed from 0.952 m to 1,023 m to be consistent with the 1992 IERS standards. No

Table 5. Impact of anti-spoofing on EMR results.

GPS Week	Pseudo-Range RMS (cm)	EMR Clock RMS IGS Combination (nanosecond)	EMR Orbit RMS IGS Combination (cm)
732-733 (pre-AS)	17	0.5	10
736-737(early AS)	60	10	15
780-781	45	1	12

change in scale has been noted, indicating that the 7-cm difference is being absorbed by other solution parameters.

Two additional enhancements were introduced for the 1995 processing. Stations GUAM, EISL, and KERG, recently added to the IGS global network, have been included to provide the needed geometrical strength in the southern hemisphere. Station USUD was replaced by station TSKB in January 1995 and since February 26, 1995, IERS Bulletin A celestial pole (CP) corrections are added to the IAU 1980 a *priori* nutation model.

Clock Estimation

Precise satellite clock corrections have been included in EMRs SP3 files since August 1992. The clock corrections are estimated simultaneously with the orbital, EOP, and station parameters using both phase and pseudo-range observations. One station's clock is selected as a reference in the estimation process. The ALGO station, which is equipped with an hydrogen maser (HM), has served with few exceptions as the EMR reference clock. The ALGO HM typically drifts about 20 ns per day or less.

Since no integer phase ambiguity fixing is employed, precise pseudo-range observations are essential for clock estimation with nanosecond precision. Calibration of pseudo-range biases is required whenever AS is in effect and Cl and cross-correlated P2 observations are used. Since a single reference station clock is used, a strong network geometry is required to ensure that precise clock solutions are obtained for all GPS satellites over the 24-hour arcs. Figures 1 and 2 show typical results of station clock variations with respect to ALGO. Figure 2 also shows the effect of ionospheric disturbances on station clock estimation at YELL. The common signature is due to the ALGO HM used as the reference. Discontinuities between consecutive days are typically less than one nanosecond and represent the bias of the independent daily solutions. Other discontinuities are sometimes present within the daily solution. They may be caused by a variety of factors ranging from GPS receiver clock resets to pseudo-range bias changes when a station receiver configuration is modified or tracking is interrupted.

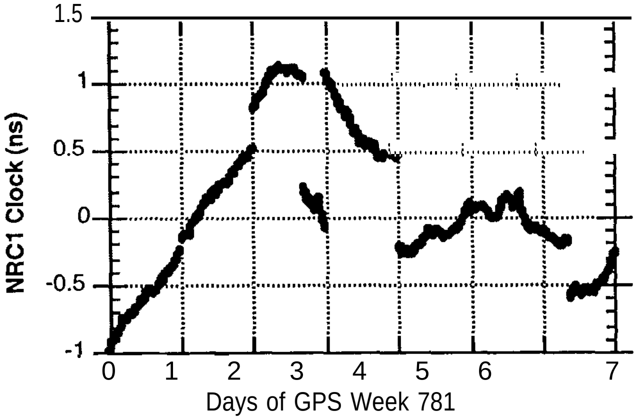


Figure 1. NRC1 hydrogen maser clock offsets with respect to AL GO obtained from EMR daily GPS solutions.

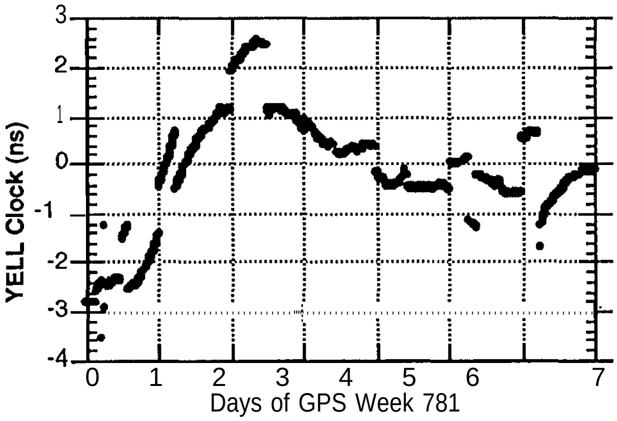


Figure 2. YELL hydrogen maser clock offsets with respect to AL GO obtained from EMR daily GPS solutions.

Combination of Daily Solutions

For 1993 and 1994 EMR has combined all daily solutions and derived new station coordinates. For 1994, EOP and station velocities were also included in the combined solution. Specifically, all the archived 1994 daily solutions were retrieved and subjected to additional statistical testing and editing to remove outliers. The *a priori* ITRF92 coordinate constraints for the 13 fiducial stations were rigorously removed and 10-m sigma introduced. Orbit state vectors and other unknowns contained in the daily solutions were also eliminated. The loosely constrained variance-covariance matrices were then combined into a single annual solution for station coordinates, velocities and daily EOP. The velocities for the 13 fiducial stations were constrained to their ITRF93 values. The combined solution produced a consistent set of station coordinates and velocities (at the epoch 1994.0) and new daily EOP, all based on ITRF93 and the 1994 EMR daily solutions only. The EMR 1994 station and velocity solutions are free of daily variations resulting from inconsistencies of data from fiducial sites.

Appendix 2 lists the coordinate and velocity differences between the EMR 1994 combined solution and the ITRF93. Table 6 lists RMS differences for both EMR 1994 EOP daily solutions, the original and the recomputed, with respect to IERS Bulletin B. In 1995 EMR has begun to combine daily solutions to produce weekly estimates of station coordinates and EOP as part of an IGS pilot project.

Table 6. Mean and RMS differences between IERS Bull Band EMR 1994 EOP estimates (original estimates submitted to IGS and recomputed estimates submitted to IERS).

Difference	Pole X mean/rms (mas)	Pole Y mean/rms (mas)	UT1 - UTC * mean/rms (ins)
Original (ITRF92)- Bull B	0.45 / 0.39	1.24 / 0.50	0.1 16/ 0.566
Recomputed (ITRF93) - Bull B	-0.20 / 0.37	-0.40 / 0.35	0.151/0.564

* DUT1 modeled as (UT1-UTC) + 455μs + 9.945μs/d * DOY

Operational Procedures

Data Acquisition and Validation

The acquisition and validation of the data for all stations used in EMRs daily analysis is highly automated and performed by the Data Acquisition and Validation group which also manages the CACS sites (Duval, 1995), RINEX files for the non-Canadian IGS sites are retrieved daily either from CDDIS or JPL. The data are validated by performing pseudo-range point positioning, generating a satellite tracking table and creating a clock file for each station. The tracking table is useful for detection of unusual events such as a AS-free Block II satellite and the clock files provide indication of the station's and satellites' clock performance. Validation data files for all stations used in EMR daily solutions are available to station operators and users.

Orbit Computation

Orbits are currently computed using one of two processing strategies, one for days when DUT1 is reset and new *a priori* EOP are input and one for all other days. Figure 3 depicts the steps performed before initiating the EMR GIPSY/ OASIS automated processing. The complete daily orbit computation including the generation of SP3 ephemeris, clock and EOP files for 25 GPS satellites using data from 22 stations takes about 6 hours on an HP9000/735 computer and requires close to 200 Mb of run-time on-line storage. Each processed day currently requires about 30 Mb of storage for archiving. Figure 4 shows the stations which have been included in EMR daily solutions since August 1992, while Figure 5 shows days when satellites were excluded or were not operational.

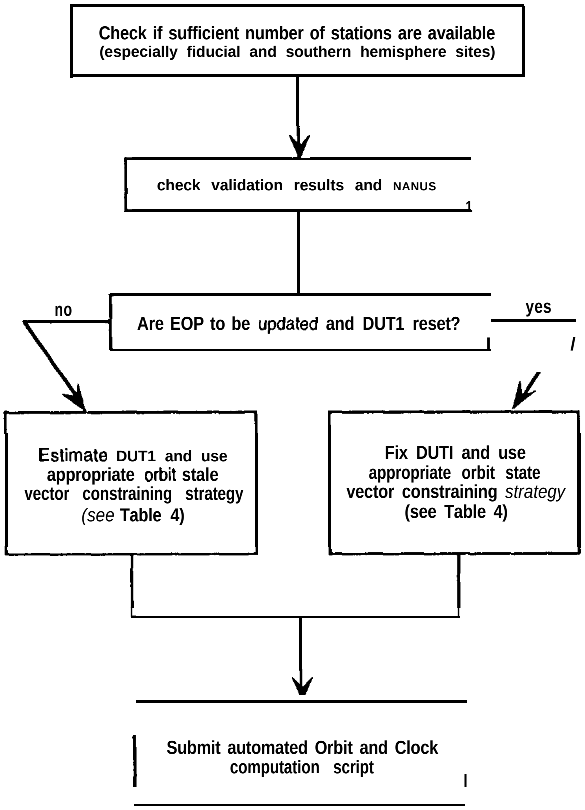


Figure 3. Processing steps performed before starting automated daily EMR GPS analysis.

Figure 4. Stations included in EMR daily solutions.

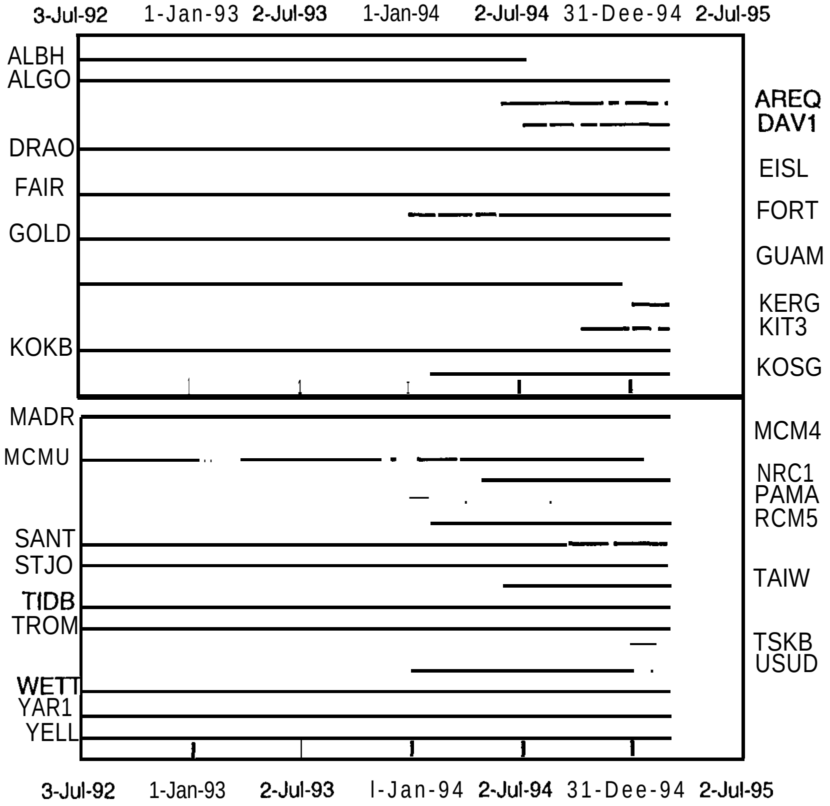
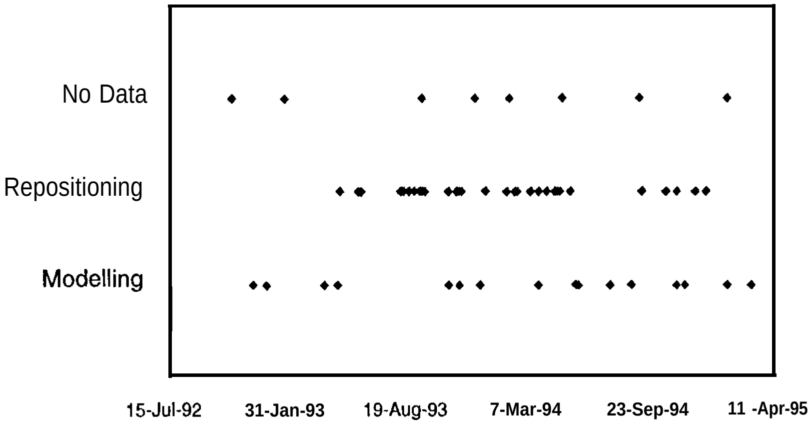


Figure 5. Days with a missing or deleted satellite in EMR daily solutions.



Quality Control (QC)

The QC is divided into pre- and post-processing verifications. Pre-processing QC includes data quality, quantity and GPS constellation status verification in order to prevent eventual problems such as satellite maneuvers. Post-processing QC, by a minimum of two EMR team members, is performed on each daily solution before it is transferred to the IGS data center. It includes verifications of the post-processing carrier-phase and pseudo-range observation residuals for stations and satellites; estimated corrections and sigmas for satellite states, station coordinates and EOP. Pseudo-range biases are also verified and updated as required. Final QC and feedback are provided weekly by the IGS orbit and clock combination and the IERS Rapid GPS EOP combinations.

Conclusions

The short history of the IGS so far, regardless of the AS setback, has been one of continuous progress and productive international collaboration. EMR participation in the IGS has also been a successful one. As of March 31, 1995 EMR had processed and submitted to the IGS 972 daily GPS ephemerides and EOP solutions, one for every day since the first contribution of August 2, 1992. In return, the Canadian Active Control System has been integrated within the ITRF. Access to a global reference frame and precise GPS satellite orbits and clocks are some of the tools EMR has acquired through its participation in the IGS. These tools are essential to provide Canadian users with a modern spatial reference system.

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Appendix A

Measurement and Orbit Models used in EMR GPS Analysis

MEASUREMENT MODELS

Preprocessing	single station type, using L1-L2 phase and pseudorange data, editing most cycle slips, computes smoothed pseudoranges at requested intervals (7.5min), introduces and initializes real phase ambiguities
Basic observable	carrier phase and smoothed pseudo-range elevation angle cutoff : 15 degrees sampling rate : 7.5 minutes weighting : exponential, station/satell. specific. Rejection criteria : 5 (aposteriori) sigmas
Modelled observable	undifferenced, corrected for ionosphere (L3, P3), CA pseudoranges corrected for CA-PI biases whenever applicable
RHO Polar. phase rotation corr.	applied (Wu et al., 1993)
Ground antenna phase centre cal.	not applied
Troposphere	Zenith delay: treated as a random walk process Mapping function: Lanyi mapping function Met. data input : Global constant values
Ionosphere	not modelled (ionospheric corrections applied using dual frequency observations, see above)
Plate motions	13 ITRF93 station velocities fixed (see IGSMAIL#819)
Tidal displacement	Solid earth tidal displacement: applied (IERS, 1992) Correction applied to remove permanent tide not applied Nominal h2 and l2 values 0.609 , 0.0852 dh periodic change (IERS,1992, eqn. (7), p. 57) applied (IERS, 1992) Pole tide applied (IERS, 1992) Ocean loading : Pagiatakis (1982) model
Atmospheric load.	not applied
Satellite center of mass correction	Block I x,y & z: (0.210, 0, 0.854m) Block II/IIA x,y & z : (0.279,0, 1.0229 m)
satellite phase centre calibrat.	not applied
Relativity	periodic term applied

ORBIT MODELS

Geopotential	GEM T3 + C21+S21 model up to degree and order 8
	GM=398600.4415 km**3/sec**2
	AE = 6378.137 km
Third-body	Sun, Moon and planets regarded as point masses
	ephemerides: JPL DE200
	GMsun = 132712439935.4842 km**3/sec**2
	GMmoon = 4902.7991 km**3/sec**2
Solar radiation pressure	direct radiation: ROCK4 and ROCK42T models for Block I and II satellites, resp. area, specularities and reflectivity used: see Tables 1,2, (Fliegel and Gallini, 1992, JGR(97)B1,P562) satellite masses used: PRN 12 519.8kg PRN 01 880.0kg PRN 21-22 883.9 02 878.2 23 972.9 14 887.4 24-31 880.0 15 885.9 04-06 972.9 16-19 883.2 07 883.9 20 887.4 09 972.9
	x,z, scale and y- radiation biases: taken into account
	Earth shadow model includes: penumbra and atmospheric refraction/attenuation effects
	reflection radiation: not applied
	new GPS satellite attitude model: applied(IGSMAIL#591) geometrical effects : applied orbit dynamic (integration) eff. : not applied yaw rates(estimated/nominal) : NOMINAL
Tidal forces	solid earth tides: frequency independent Love's number K2= 0.300
	Ocean tides: UT CSR model from Schwiderski
Numerical integration	variable (high) order Adams predictor-corrector with direct integration of second-order equations
	integration step : variable (typically < 1000s)
	starter procedure: Runge-Kutta
	arc length : 24 hours

ESTIMATED PARAMETERS (APRIORI VALUES & SIGMAS)

Adjustment	square-root information filter (SRIF) [Bierman, 1977]
Station coordinates	13 stations constrained to the ITRF93 positions (using ITF93 sigmas) as given in IGSMAIL#819, the remaining stations estimated (50m apriori sigmas) . The ITRF93 velocities are used for daily updating of coordinates In POSTPROCESSING and station combination, Apriori station constraints are rigorously removed for input into combined station solutions (adding the reduced normal matrices)
Satellite clock bias	modelled as white noise process and solved for at each epoch. (1ms appriori sigmas, apriori values from broadcast message) . Thus each epoch solution is independent and based on both phase and pseudorange observations. WARNING: no L1-L2 **satellite calibration applied, so the satellite clocks include the** L1-L2 **calibration delays**
Receiver clock bias	a **white noise process** (with large 1 s apriori sigmas, apriori values from preprocessing) . One Hydrogen Maser clock fixed and used as a time reference, usually ALGO. Thus each epoch solution is independent and based on both phase and pseudorange observations. WARNING: no P1-P2 receiver calibration applied, so the receiver clocks include the P2-P1 cal. delays (i.e. Rogues SNR8-800)
Orbital parameters	initial position and velocity, solar radiation pressure scales in x, z and y-bias considered constant through the orbital arc. Orbit states modelled as a random walk process between adjacent 24h orbit arcs. Apriori orbits, extrapolated from previous arc are assigned the following stochastic sigmas (for convenience Keplerian elements are used, then transformed into the x,y, z frame of reference used for processing) : semi-major axis (a) : 10m/sqrt (day) eccentricity (e) : .12m/sqrt (day) inclin., node(i, RA) : . 06m/sqrt (day) perigee, M.A (P, MA) : . 16m/sqrt (day) velocity (DX, DY, DZ) : . 00005 m/s/sqrt (day) non eclipsing . 0001m/s/sqrt (day) eclipsing Gx scale : .10 (white noise) Gy scale : .10 (white noise) Gy bias : .5d-09 m/s**2 (" ")
Troposphere	estimated as a random walk with about O. 01m/sqrt (hr) sigma. Previous day solution is used as apriori value with O. 03m sigmas to initiate the random walk process.
Phase Ambiguities	real, estimated as needed with apriori values from pseudorange observation, sigmas 3. ODO 8m
EON	x & y pole, UT1-UTC and LOD. Current IERS Bulletin A, (updated every two weeks only) and used as apriori. Constant during a 24h period, solutions refer to 12:00h UT. Apriori sigmas used: x,y pole 100 mas UT1-UTC 7 ms LOD 86400 ins/day. Note: In postprocessing the EOP and station coordinate apriori sigmas can be rigorously removed or changed
Other parameters	C1-P1 Pseudorange biases periodically updated as necessary from post fit pseudorange residuals

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Appendix B

Differences between EMR 1994 Combined Station Coordinate/ Velocity Solutions** and ITRF93 at epoch 1994.0

Coordinate Differences

Site	X(mm)	Y(mm)	Z(mm)	N(mm)	E(mm)	H(mm)
ALBH	-19.0	55.5	-59.7	-13.1	-46.5	-68.4
ALGO	-9.0	25.6	-12,1	10.8	-3.5	-27.4
AREQ	1.3	-6.0	-7.3	-5.3	-0.7	7.9
DRAO	.6	20.7	-7.8	8.7	-9.7	-17.9
FAIR	-1.7	9.5	.2	3.4	-8.9	-1.4
FORT	-6.2	-2.4	4.9	4.6	-5.7	-3.7
GOLD	-7.1	11.1	6.7	9.3	-11.4	-1.6
HART	23.6	7.6	18.9	27.6	-4.2	13.8
KOKB	9.3	-13.0	1.6	3.1	15.4	-3.3
HOLB	-23.7	-21.2	31.1	-4.4	-5.6	43.9
KOSG	-2.4	-7.4	2.5	4.0	-7.1	.0
MADR	-4.1	-4.5	-8.4	-4.0	-4.8	-8.3
MCM2	11.7	-5.3	28.4	-6.3	2,5	-30.4
RCM5	-9.3	-30.1	43.0	26.7	-14.2	43.9
SANT	15.4	-25.4	-10.9	6.7	6.1	30.3
STJO	-10.6	11.0	-.3	11.0	-1.8	-10.5
TAIW	7.0	-22.4	35.4	41.7	5.7	-5.8
TIDB	2.0	-9.5	15.0	8.4	7.1	-14.1
TROM	-7.3	-6.0	-10.5	4.6	-3.3	-12.9
USUD	6.8	-13.8	9.7	16.2	5.8	-5.8
WETT	-2.5	-6.7	-4.6	-.1	-6.0	-6.0
YARI	-12.8	6.6	12.0	16.0	8.7	4.2
YELL	-4.9	4.7	12.8	7.9	-6.4	10.3
mean	-0.2	-2.0	6.9	9.7	-2.3	-1.0
sigma	8.7	14.2	14.2	10.6	7.3	16.6
mean*	0.1	-0.6	1.8	7.5	-1.4	-1.3
sigma*	9.9	12.6	10.3	7.5	7.7	13.3

• For the 13 IGS fiducial stations

Velocity Differences

Site	Vx mm/y	Vy mm/y	Vz mm/y	VN mm/y	VE mm/y	VH mm/y
ALBH	6.2	15.1	-0.7	11.5	-3.2	-11.2
AREQ	2.9	-17.8	-8.4	-3.0	-2.9	-19.4
DRAO	1.8	8.3	-10.2	-.6	-2.5	-13.0
FORT	21.1	-1.5	-4.8	-3.6	12.0	17.7
HOLB	-4.7	-6.3	18.9	6.0	0.2	19.6
MCM2	-11.9	-3.0	-33.2	3.6	5.6	34.7
RCM5	.5	-13.3	7.0	.7	-1.7	14.9
STJO	.6	17.7	-18.6	-2.5	11.2	-23.0
TAIW	3.2	5.4	11.1	8.9	-5.6	7.3
USUD	-22.0	-21.2	.3	-1.1	30.5	2.0
mean	-4.8	2.1	-8.4	-1.8	-0.3	2.4
sigma	12.7	20.4	22.6	5.2	17.7	28.8

•* EMR solutions obtained with ITRF93 Velocities Fixed for the 13 Fiducial Stations

Appendix C

Example EMR Weekly Reports

Analysis Report

EMR ANALYSIS REPORT GPS-WEEK 0791 Dates: 95mar05 to 95marl 1

NRCan (Natural Resources Canada, formerly Energy, Mines and Resources (EMR))
615 Booth Street, Ottawa, Canada K1 A OE9
e-mail: kouba@geod.emr.ca, pierre@geod.emr.ca
tel: (613)992-2678 (Jan Kouba)
(613)992-2218 (Pierre Tétreault)
fax: (61 3)995-321 5

PRODUCTS GENERATED:
The following products are generated and uploaded into CDDIS@NASA/GSFC

EMR07910-6.SP3	GPS ephem. files for days O-6, week #0791 in sp3 format
EMR07917.ERP	pole x,y and DUT1 solutions for week #0791
EMR07917.SUM	name of this text summary file

REMARKS on EMR's products:

1. ALGO receiver clock used as reference. In the sp3 EPH file sat. epochs with no reference (e.g. ALGO not observing a satellite) have a value of 99999,999999 microseconds. ALGO clock error & drift were about -260 ns (49781) & -22 ns/day w.r.t. GPS time,
2. PRN28 is operating in AS free mode since February 20.
3. No data for PRN28 observed on Day 02 (Mar07/95) and only a little data observed on Day 3 (Mar08/95)
4. Starling with week 0791 we have added in our ERP report the apriori corrections to the celestial pole (dpsi and deps) that are used in our orbit processing.

SOLUTION CHARACTERISTICS

1. Solution identifier	Submission 950316
2. Software used	GIPSY/OASIS II (UNIX)
3. Definition of Terrestrial frame:	
origin and orientation	Nominally ITRF93
reference epoch	current date
GM	398600.4415 km^3/s^5
gravity model	GEMT3(8,8) +C21+S21
ocean loading	Pagiatakis, global model

4. Solution characteristics:
   undifferenced phase and smoothed pseudorange data > 15 degrees @ 7.5 min.; single day (24h) arc with 6 IC and 3 rad. parameters per satellite
5. See IGS Mail#655 (June 30, 1994) and IGS Report#1488 (January 16, 1995) for more details.

CARRIER PHASE / PSEUDO RANGE STATISTICS

Note: F indicates a constrained fiducial site
E indicates an eclipsing satellite

Carrier Phase Statistics
rms (cm)/ # obs

		95mar05	95mar06	95mar07	95mar08	95mar09	95mar1O	95marl1
ALBH		.42/1147	.42/1136	.00/0	.00/0	.00/0	.40/1141	.36/1144
ALGO	F	.53/1182	.56/1167	.65/1124	.67/1153	.56/1153	.57/1185	.57/1183
AREQ		.40/1013	.00/0	.37/185	.43/1036	.41/1033	.00/0	.00/0
DAV1		.49/1097	.48/904	.49/1101	.47/1085	.49/1048	.49/1050	.55/1003
DRAO		.44/1118	.39/1111	.40/1110	.43/1103	.41/1170	.47/1167	.43/1169
FAIR	F	.82/1141	.70/1182	.83/1112	.81/1025	.8611055	.79/1004	.82/1003
FORT		1.25/1054	1.32/994	1.29/1029	1.28/1061	1.25/1009	1.19/964	1.28/1031
GUAM		.60/967	.65/1088	.57/1009	.70/1077	.47/1094	.49/1062	.61/1102
GOLD	F	.55/1156	.43/1153	.43/1107	.40/1116	.46/1152	.38/970	.57/1062
HART	F	.62/1151	.56/1140	.53/1029	.55/1051	.55/1097	.55/1154	.55/1162
KERG		.57/1014	.61/1136	.61/1083	.59/1083	.51/1047	.61/1144	.60/1143
KIT3		.99/1058	.92/1109	.89/1051	.97/1058	.84/1063	.88/1087	.95/1075
KOKB	F	1.47/1066	1.13/1165	1.10/1102	1.1311080	1.03/1156	1.03/1118	1.10/1183
KOSG	F	.4711158	.43/1138	.41/1065	.42/1113	.41/1092	.37/1064	.39/1083
MADR	F	.53/1113	.56/1120	.46/1076	.5211096	.45/1089	.48/1132	.49/1022
MCM4		.45/1160	.45/1203	.54/1170	.54/1167	.56/1112	.49/1173	.58/1166
NRC1		.34/1170	.38/1167	.40/1133	.40/1174	.40/1185	.35/1175	.37/1188
RCM5		.80/1113	.84/1141	.83/1126	.99/1112	.69/1152	.73/1168	.80/1145
SANT	F	.00/0	.50/319	.48/1065	.50/1114	.49/1181	.49/1180	.48/1168
STJO		.41/1190	.54/1181	.43/1146	.4711194	.46/1171	.49/1193	.45/1182
TAIW		.51/1165	.50/1148	.49/1077	.57/1093	.54/1159	.47/1170	.57/1110
TIDB	F	.97/1068	.93/1081	1.02/1087	1.08/1083	1.04/1107	.97/1127	.96/1115
TROM	F	.79/1085	.76/1210	.80/1160	.82/1167	.79/1095	.85/1090	.88/1022
TSKB		.53/1155	.55/1152	.51/1083	.59/930	.471795	.58/1068	.61/1182
WETT	F	.22/98	.50/1146	.15/97	.49/1104	.12/58	.46/1151	.52/1153
YAR1	F	.44/1184	.42/1192	.44/1098	.46/1098	.39/998	.46/1039	.54/1037
YELL	F	.61/1011	.61/1156	.63/1052	.62/1135	.66/1132	,64/1042	.70/962
PRNO1		.75/1089	.71/1149	.71/1083	.6611157	.71/1113	.5811094	.68/1132
PRN02		.70/1114	.60/1127	.64/1105	.64/1142	.59/1082	.61/1169	.67/1188
PRN04		.65/1043	.64/1154	.65/1090	.69/1152	.61/1081	.64/1217	.63/1193
PRN05		.65/1142	.63/1133	.62/1091	,67/1197	.62/1164	.59/1170	.68/1160
PRN06	E	.68/1202	,91/1113	.73/1108	.68/1148	.69/1137	.69/1182	.76/1183
PRN07	E	.71/1043	.65/1203	.69/1115	.69/1205	.68/1032	.61/1161	.70/1190
PRN09		.63/1121	.58/1126	.62/1119	.62/1168	.60/1119	.60/1161	.59/1108
PRN12		,40/1122	,40/1135	.39/1085	.4411128	.39/1063	.40/1113	.40/1060
PRN14		.72/1093	.60/1203	.64/1142	.74/1212	.62/1157	.62/1168	.68/1166
PRN15		.79/1063	.62/1166	.66/1088	.68/1189	.60/1069	.56/1121	.60/1117
PRN16		.67/1099	.72/1160	.77/1139	.97/1172	.70/1109	.76/1211	.70/1206
PRN17		.64/1150	.72/1140	.63/1122	.68/1186	.69/1140	.59/1141	.6911146
PRN18	E	.65/1123	.64/1135	.66/1013	.65/1137	.64/1067	.62/1153	.65/1073
PRN19		.62/1086	.65/1148	.64/1105	.67/1133	.63/1119	.62/1177	.67/1158
PRN20		.66/1090	.62/1096	.62/1093	.66/1121	.62/1053	.60/1108	.61/1135
PRN21		.74/1099	.67/1145	.77/1041	.70/1176	.62/1037	.70/1135	.72/1136
PRN22		.69/1188	.70/1179	.75/1156	.76/1211	.73/1188	.70/1216	.72/1209
PRN23		.57/1032	.65/1107	.65/1042	.65/1088	.61/1058	.59/1162	.80/1118
PRN24		.67/1104	.66/1138	.62/1149	.71/1226	.60/1028	.60/1168	.65/1195
PRN25		.71/1190	.69/1199	.7411164	.71/1215	.69/1169	.66/1161	.75/1216
PRN26	E	.74/1190	.76/1145	.70/1087	.79/1193	.78/1121	.73/1106	.78/1143
PRN27		.67/1155	.68/1143	.68/1152	.64/1238	.65/1141	.71/1187	.67/1214
PRN28	E	.77/1151	.63/1108	.00/0	.55/330	.60/929	.63/1041	.63/1061
PRN29	E	.62/1153	.62/1152	.70/1113	.69/1206	.72/1154	.70/1170	.70/1134
PRN31	E	.95/992	.64/1135	.7711075	.73/1178	.62/1073	.64/1126	.70/1154

Pseudo Range Statistics
rms (cm)/ # obs

		95mar05	95mar06	95mar07	95mar08	95mar09	95marl O	95marl 1
ALBH		25/1 149	27/1151	0/0	0/0	0/0	26/1 145	28/1 146
ALGO	F	31/1183	32/1 179	40/1 129	37/1 180	29/1182	32/1 187	32/1 184
AREQ		43/1 046	0/0	44/1 84	43/1 057	41/1033	0/0	0/0
DAVI		11/38	10/56	12/38	23/59	1 3/34	12/39	1 3/31
DRAO		32/1 120	33/1 118	35/1 114	32/1 104	29/1 169	32/1170	33/1 170
FAIR	F	53/1 176	56/1 193	59/1 118	56/1 040	51/1056	52/1 049	51/1056
FORT		41/1165	43/1 171	44/1 127	42/1 142	41/1133	44/1 017	41/1136
GUAM		51/1035	54/1 097	54/1 057	57/1 106	58/1 115	59/1 074	53/1 106
GOLD	F	83/1 158	78/1 156	77/1 109	85/1 119	81/1150	65/970	93/1 063
HART	F	66/1171	70/1151	71/1040	67/1061	73/1 113	67/1161	68/1 174
KERG		1 7/43	1 7/43	18/42	16/43	18/42	16143	17/42
KIT3		59/1 111	62/1131	72/1091	70/1 094	70/1 119	93/1 126	101/1105
KOKB	F	56/1 197	57/1 211	62/1 172	60/1 143	59/1200	58/1 198	57/1 222
KOSG	F	53/1 158	56/1 152	53/1 067	57/1 114	59/1 112	51/1068	60/1 083
MADR	F	63/1 120	64/1121	65/1 079	66/1 098	61/1095	63/1 133	65/1 030
MCM4		39/1 187	35/1 203	41/1174	40/1 175	38/1 122	37/1 177	35/1 170
NRCI		36/1 171	3511169	37/1 134	37/1 176	36/1 185	37/1177	35/1 189
RCM5		35/1 160	36/1 163	39/1 137	35/1 161	34/1 159	36/1 172	32/1 158
SANT	F	0/0	61/321	57/1 068	89/1 122	77/1 183	54/1 186	58/1 177
STJO		68/1 192	63/1 193	84/1 149	70/1 194	59/1 194	53/1 196	58/1 193
TAIW		65/1 174	59/1 154	1 30/1 034	69/1 125	65/1 187	57/1 177	81/1104
TIDB	F	53/1 135	52/1 118	60/1 131	53/1 122	58/1 155	57/1 174	60/1 154
TROM	F	27/48	21 /57	21/55	19/56	1 9/49	1 3/45	1 5/43
TSKB		62/1 178	67/1 193	94/1 116	1 01/933	78/800	1 00/1 070	94/1 184
WETT	F	67/98	68/1 146	58/97	70/1 104	51/58	69/1 148	67/1151
YAR1	F	36/1 197	39/1 198	46/1 098	39/1 099	36/1 005	40/1 045	42/1 053
YELL	F	34/1 119	33/1171	33/1 116	35/1 137	35/1 155	37/1 106	36/1 089
PRNO1		55/1 033	58/1 041	731966	65/1 055	66/977	5311003	63/1 026
PRN02		54/986	55/1 006	63/946	63/1013	59/960	68/1 023	68/1 041
PRN04		47/984	49/1 024	60/953	57/1041	53/983	53/1 085	53/1 082
PRN05		52/1 037	54/1 041	61/965	60/1 086	55/1 040	54/1 069	54/1 056
PRN06	E	57/1 105	54/1 034	62/1 006	60/1 064	60/1 031	54/1 075	53/1 077
PRN07	E	55/973	55/1 053	62/984	67/1 056	62/996	64/1 050	67/1061
PRN09		49/999	49/998	62/995	63/1 048	57/993	51/1034	57/1 013
PRN12		40/1 121	33/1135	34/1 072	36/1 136	42/1 053	31/1 114	35/1 061
PRN14		51/997	54/1 076	62/1015	58/1 090	54/1 081	57/1 083	60/1 076
PRN15		53/999	49/1 049	64/957	58/1 071	66/959	61/1036	61/1030
PRN16		54/1 006	5511073	66/1 094	70/1 101	61/1029	57/1 119	64/1 092
PRN17		55/1 039	58/1 034	61/979	61/1038	64/1 003	57/1 011	59/1 040
PRN18	E	51/1009	58/1 019	67/937	66/1 019	61/963	62/1 051	61/1012
PRN19		51/1010	54/1 035	66/978	65/1 057	61/1004	58/1 040	62/1 047
PRN20		51 /974	51/977	65/961	54/1 025	52/943	48/993	55/1021
PRN21		54/987	58/1 015	77/938	62/1031	61/931	60/1 006	63/1 030
PRN22		53/1 095	53/1 097	68/1 053	60/1 094	55/1 074	57/1 099	58/1 108
PRN23		53/933	56/979	71/904	521923	53/901	53/1 003	61/1015
PRN24		50/972	57/989	58/1 002	6411085	561967	56/1 036	57/1 063
PRN25		53/1 059	53/1 083	78/1 025	62/1 120	57/1 044	55/1 037	58/1 095
PRN26	E	53/1 068	54/1 075	54/991	61/1073	56/1 007	54/997	67/1018
PRN27		51/1059	4811057	62/1 027	63/1 098	60/1 025	62/1 076	60/1 098
PRN28	E	38/1051	42/1 044	0/0	30/330	40/872	40/939	44/960
PRN29	E	46/1 032	56/1 045	65/974	6411063	64/1 017	62/1 033	65/1 058
PRN31	E	59/1 001	56/1 037	64/954	59/1 047	62/952	63/1041	69/1 033

Station Clock Solutions at 0hour UTC
(microsecond)

	95mar05	95mar06	95mar07	95mar08	95mar09	95mar10	95mar11
ALBH	1.733	1.840	---	---	---	2.419	2.534
ALGO	REF	REF	REF	REF	REF	REF	REF
AREQ	.751	...	---	.694	.755	---	...
DAV1	...	-.267*	10.294'	23.905'	37,693*	---	65.346'
DRAO	-1.318	-1.214	-1.107	-1.004	-.893	-.782	-.669
FAIR	-.506	-.516	-.524	-.532	-.540	-.549	-.560
FORT	.190	.229	.269	.309	.349	.389	.430
GUAM	---	..-	...	---	...	---	---
GOLD	-.745	-.731	-.716	-.699	-.682	-.664	-.646
HART	-.302	-.032	.375	.752	.899	1.089	1.153
KERG	10.870	8.721	6.767	4.379	3.124	.370	-2.729
KIT3	---	...	...	...	...	---	...
KOKB	1.894	1.776	1.657	1.538	1.418	1.296	1.173
KOSG	.847	.929	1.029	1.199	1.397	1.638	1.896
MADR	-2.750	-2.721	-2.689	-2.655	-2.623	-2.591	-2.562
MCM4	---	...	...	...	...	...	---
NRC1	-1.049	-1.036	-1.022	-1.007	-.993	-.979	-.965
RCM5	.512	.523	.536	.552	.565	.576	.587
SANT	---	---	-5.163	-5.111	-5.064	-5.013	-4.963
STJO	39.685	69.898	100.059	130.287	160.534	190.960	221.484
TAIW	2422.103	2481.754	2541.429	2601.139	2660.921	2720.724	2780.492
TIDB	.067	.076	.086	.097	.109	.120	.129
TROM	1124.693	1132.811	1140.968	1149.175	1157.405	1165.733*	1173.969
TSKB	71.256	71,306	71.361	71.417	71.474	71.533	380.837
WETT	1.922*	2.117	2.338'	2.536	2.745	2.952	3.074
YARI	3.664	3.695	4.315	4.344	4.361	4.364	4.357
YELL	-.070	-.096	-.120	-.144	-.173	-.201*	-.233

Note: * indicates a non-0hour UTC epoch

EOP Report

SUMMARY OF CANADIAN EMR SOLUTION

1. Analysis center : Geodetic Survey Division (GSD), SMRSS, EMR
2. Solution identifier : Submission 950315
3. Software used : GIPSY/OASIS II (UNIX)
4. Definition of Terrestrial frame:
   origin ‘(Nominally ITRF93
   orientation (“
   reference epoch : current date
   velocity of light : 299792458 m/s
   GM 398600.4415 km^3/s^5
   gravity model : GEMT3(8,8) +C21+S21
   permanent tide corr: None
   ocean loading : Pagiatakis, global model
5. Adjusted parameters:
   - undifferenced phase and smoothed pseudorange data > 15 degrees @ 7.5 min.;
     single day (24 h) arc with 6 IC and 3 rad. parameters per satellite
   - trop. zenith delay corr. parameter augmented with random walk stoch. process;
     initial phase ambiguity parameters (1 for each satellite/station pass or initial phase);
   - station positions X,Y,Z, up to 23 stations. ALGO, FAIR, GOLD, HART, KOSG, TROM, WETT, YELL, MADR, MCMU, SANT, TIDB and YAR1 are constrained;
     x, y pole position, once a day (DUT1 fixed/solved; DUT1 ,x,y *a priori* sigma = 3m), LOD *(a priori* sigma 86400 ins/day);
     station clock biases once per each epoch/station (except for ALGO h. maser which provides the time reference) with sigma 1 s;
   - **satellite clock biases once per each epoch/satellite with 1 ms sigma.**

EOP SOLUTION

MJD	X	Y	UT1-UTC	LOD	Xsig	Ysig	UTsig	LODsig	Nr	Nf	Nt	Xrt	Yrt	dpsi	deps
	(10**-5")		usec	us/d	(1 O*	● -5)	usec	us/d				10**-5"/d		10**-5"/d	
49781.50	-4572	53741	227360	2882	9	11	29	11	26	12	25	322	114	-2331	-620
49782.50	-4225	53841	224542	2766	9	10	14	10	26	13	25	318	103	-2312	-634
49783,50	-3891	53945	221823	2591	8	10	17	11	26	13	24	313	93	-2299	-645
49784.50	-3644	54078	219206	2527	8	10	19	11	26	13	25	306	80	-2292	-652
49785.50	-3379	54226	216586	2602	8	10	21	12	26	13	25	299	67	-2289	-657
49786.50	-3164	54314	213901	2672	8	10	22	10	26	13	25	296	58	-2286	-659
49787.50	-2964	54381	211159	2762	8	10	23	11	26	13	25	296	52	-2279	-657

Scripps Orbit and Permanent Array Center Report to the IGS—1995

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Scripps Institution of Oceanography, University of California San Diego
La Jolla, California

Introduction

The Scripps Orbit and Permanent Array Center (SOPAC) at Scripps Institution of Oceanography has been providing precise GPS satellite ephemerides and Earth orientation parameter (EOP) estimates on a daily and weekly basis since August 1991. The motivation for this activity is the development and support of regional GPS permanent arrays for geophysical applications, in particular, the Southern California Integrated GPS Network (SCIGN) which includes the regional-scale Permanent GPS Geodetic Array (PGGA) and a dense array in the Los Angeles Basin. One of our primary goals is the development of a very-near-real-time system for monitoring crustal deformation, atmospheric processes, engineering structures, and moving geophysical platforms.

SOPAC functions as both an IGS Global Data Center and Global Analysis Center in our role as the UNAVCO Orbit Facility. We work closely with the MIT group (R. W. King, T. A. Herring and S. McClusky), including the development of the GAMIT/GLOBK software and orbit-determination strategies.

In this report, we emphasize recent progress towards a very near real time system including rapid orbits, rapid polar motion, rapid tropospheric mapping and global ionospheric TEC mapping.

Global and Operational Data Center

SOPAC is one of the three Global Data Centers, along with CDDIS and IGN, archiving IGS products and a complete set of RINEX data for the global tracking network. In addition, it serves as a Regional Data Center, archiving and analyzing all continuous GPS data collected in southern and Baja California (Figures 1-2) for the Southern California Earthquake Center (SCEC). SOPAC is responsible currently for the operations and data downloading of 19 SCIGN/ PGGA/DGGA stations, in collaboration with the U.S. Geological Survey Office in Pasadena (K. Hudnut). Furthermore, SOPAC archives data from the northern California Bay Area Deformation Array (BARD) and the Continuously Operating Reference Stations (CORS) network operated by the U.S. National Geodetic Survey.

SOPAC distributes by electronic mail a weekly data bulletin which catalogs the tracking data in the archive as well as provides a rudimentary quality check indicator. An example of a recent week is given in Table 1. A World Wide Web (WWW) Home Page also provides access to these bulletins (http://jon.ucsd.edu). The SOPAC archive has a three-tiered hierarchical structure as indicated in Figure 3 with a total of 120 Gb available for on-line data storage.

Southern California Integrated GPS Network (SCIGN)

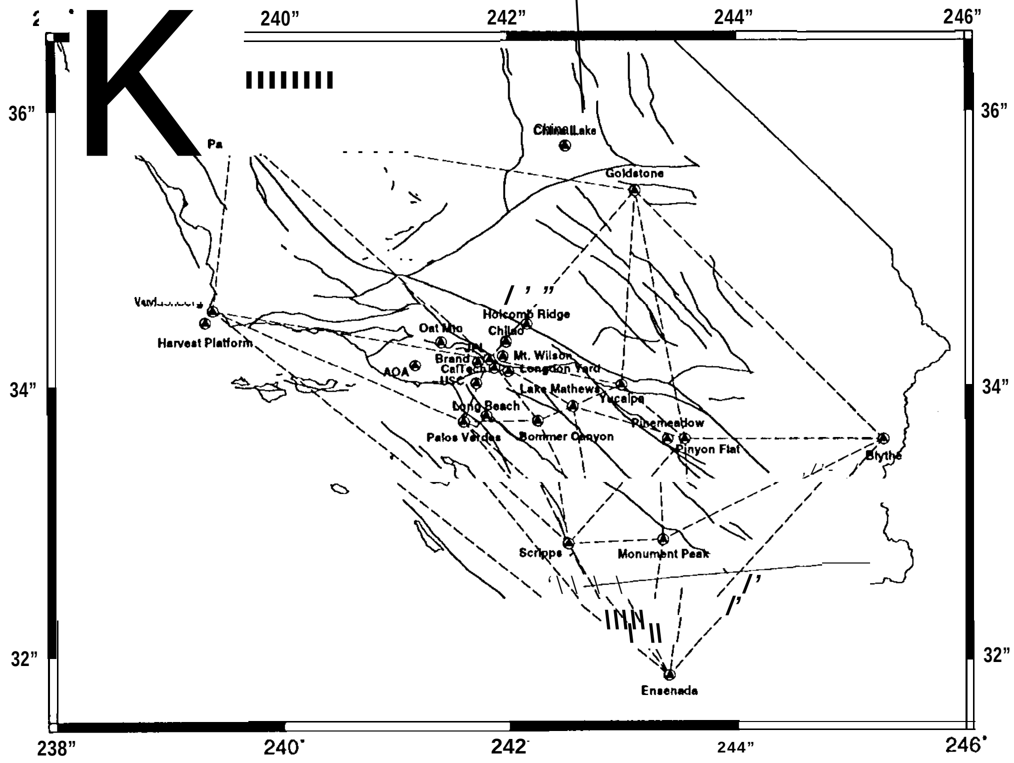

Figure 1. Southern California Integrated GPS Network. Map of southern California permanent GPS array for near real-time monitoring of crustal deformation. See Figure 2 for a complete site map of Los Angeles Basin stations.

Dense GPS Geodetic Array (DGGA) - Los Angeles Basin

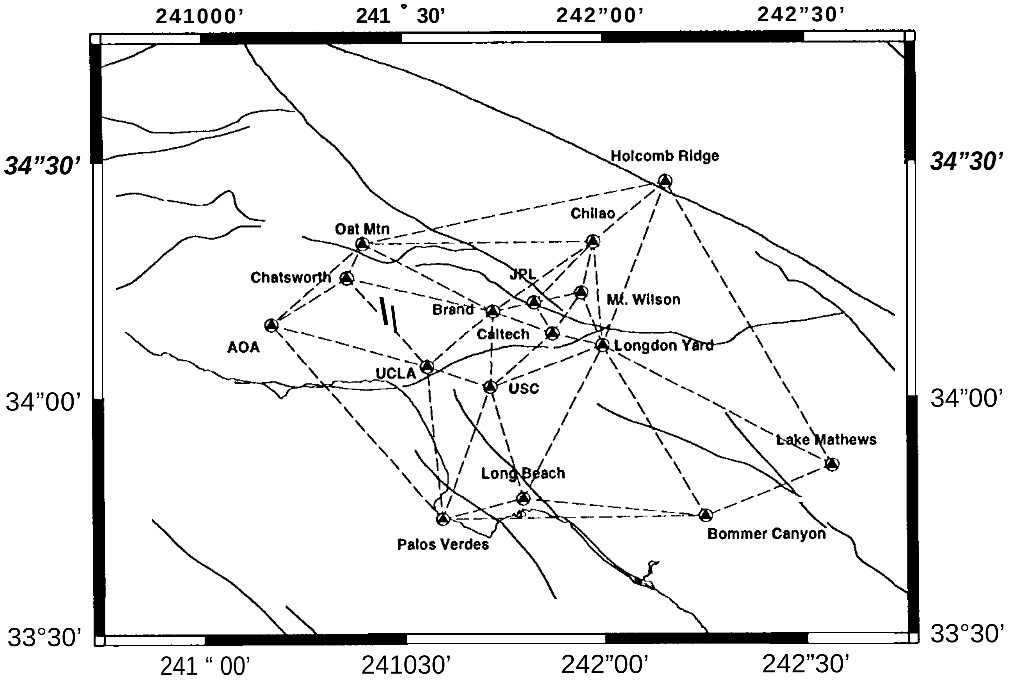

Figure 2. Dense GPS Geodetic Array in the Los Angeles Basin. Sites operational as of May.

Table 1. SOPAC Global Data Center Report — GPS Week 0810.

Submitted by: Yehuda Bock, Jeff Behr and Peng Fang
Scripps Orbit and Permanent Array Center (SOPAC)
Institute of Geophysics and Planetary Physics (IGPP)
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Geodesy lab tel: (619) 534-7692

To access SOPAC GARNER archive:
ftp toba. ucsd. edu (132.239.152.80)
login: anonymous
password: your name
directories: rinex, raw
Direct problems to: pgga@pgga. ucsd. edu

```
Data Holdings as of 07/26/95 03:49:11 UTC

                    PGGA & GLOBAL TRACKING DATA
                    (GPS DATA ARCHIVED AT SOPAC )
  GPS WEEK #810        Jul 16,95 - Jul 22,95           DOY 197 - DOY 203

                                                                Day Number
                                                           1   1   1   2   2   2   2
                                  S10  IGS  TYPE OF        9   9   9   0   0   0   0
SITE_NAME                         CODE CODE RECEIVER       7   8   9   0   1   2   3
--------------------------------------------------------------------   ---   ---   -

Blythe [ PGGA] , CA, USA          blyt blyt ASHTECH Z-X113     B   B   B   B   B   B   B
Yucaipa [PGGA], CA, USA           crfp crfp ASHTECH Z-X113     B   B   B   B   B   B   B
Lake Mathews [ PGGAI , CA, uSA    math math TRIMBLE 4000 SSE   B   B   B   B   B   B   B
Monument Peak [ PGGA] , CA, USA   monp monp ASHTECH Z-XI 13   R5   B   B   B   B   B   B
Pinyon 1 [PGGA] , CA, USA         pin1 piny ASHTECH Z-X113     B   B   B   B   B   B   B
Pales Verdes [PGGA] , CA, USA     pvep pvep TRIMBLE 4000 SSE   B   B   B   B   B   B   B
Scripps 3 [PGGA] , CA, USA        sio3 sio3 ASHTECH z-X113     B   X   B   B   B   B   B
Bommer Canyon [ PGGA ] , CA, USA  trak trak ASHTECH Z-X113     B   X   B   B   B   B   B
Vandenberg [ PGGA] , CA, USA      vndp vndp ASHTECH Z-X113     B   B   B   B   B   B   B
Brand Basin [DGGA] , CA, USA      bran bran ASHTECH LPZ-XI ID  BBR6   -    -    -    -
Brand Basin [DGGA] , CA, USA      bran bran ROGUE SNR-8000     -   -   -   B   B   B   B
Chilao [DGGA] , CA, USA           chil chil ASHTECH LPZ-XIID   B   B   B   B   B   B   B
Claremont [DGGA] , CA, USA        clar clar ASHTECH LPZ-XIID   B   B   B   B   B   B   B
Firecamp 9 [DGGA] , CA, USA       cmp9 cmp9 ASHTECH LPZ-XIID   B   B   B   B   B   B   B
Pearblossom [DGGA] , CA, USA      hole hole ASHTECH LPZ-XIID   B   B   B   B   B   B   B
Hollydale [DGGA] , CA, USA        help help ASHTECH LPZ-XIID   B   B   B   B   B   B   B
Mt. Lee [DGGA] , CA, USA          leep leep ASHTECH LPZ-XIID   B   B   B   B   B   B   B
Longdon Yard [DGGA] , CA, USA     long long ASHTECH LPZ-XI ID  B   B   B   B   B   B   B
Rocketdyne [DGGA] , CA, USA       rock rock ASHTECH LPZ-XIID   B   B   B   B   B   B   B
Allen Osborne [DGGA] , CA, USA    aoal aoal ROGUE SNR- 8000    X   x   x   x   x   x   x
Parkfield [PGGA] , CA, USA        carr carr ROGUE SNR-8000     X   x   x   x   x   x   x
Mammoth Lakes, CA, USA            casa casa ROGUE SNR- 8000    X   X   X   X   X   9   X
Catalina Island [DGGA] , CA, USA  cat1 catl ROGUE SNR -8000    -   -   -   -   x   x   x
Enseneda [ PGGA] , BC, Mexico     cice cice ROGUE SNR- 8000    X   x   x   x   x   x   x
Cal tech [ PGGA] , CA, USA        cit1 citl ROGUE SNR- 8000    xxx   x    x    x    x
Goldstone [PGGA] , CA, USA        ds10 gold ROGUE SNR- 8       X    9    6    9   XXX
Harvest Platform [PGGA] , CA, USA harv harv ROGUE SNR- 8000    X   x   x   x   x   x   x
JPL Mesa [PGGA] , CA, USA         jpl1 jplm ROGUE SNR-800 0    X   X   X   X   X   1   6
Long Beach [DGGA] , CA, USA       lbch lbch ROGUE SNR-8000     X   x   x   x   x   x   x
Oat Mt new [DGGA] , CA, USA       0at2 0at2 ROGUE SNR-800 0    X   x   x   x   x   x   x
Quincy [PGGA] , CA, USA           quin quin ROGUE SNR - 8000   xxx   x    x    x    x
Saddle Peak [DGGA] , CA, USA      spkl spkl ROGUE SNR-8000     2   7   3   2   4   6   6
UCLA [DGGA] , CA, USA             uclp uclp ROGUE SNR- 8000    x    x   xx    x    xx
USC [DGGA] , CA, USA              usc1 usc1 ROGUE SNR- 8000    X   x   x   x   x   x   x
Whittier College [DGGA] ,CA, USA  whc1 whcl ROGUE SNR-800 0    X   x   x   x   x   x   x
Whittier Library [DGGA] , CA, USA whil whil ROGUE SNR-8000     x   9   5   8   9   9   8
Mt. Wilson [DGGA] , CA, USA       wlsn wlsn ROGUE SNR- 8000    X   x   x   x   x   x   x
Briones [BARD] , CA, USA          brib brib ASHTECH Z-XI 13    X   x   x   x   x   x   x
Chabot [BARDI , CA, USA           chab chab ASHTECH Z-X113     X   x   x   l   x   x
Columbia [BARDI , CA, USA         cmbb cmbb ASHTECH Z-XI 13    X   x   x   x   x   x   x
Farallon [BARD I , CA, USA        farb farb ASHTECH Z-X113     X   x   x   x   x   x   x
Molate [BARDI , CA, USA           mola mola TRIMBLE 4000 SSE       x   x
Nunes [BARD] , CA, USA            nune nune TRIMBLE 4000 SSE       x   x
Tiburon [BARDI , CA, USA          tibb tibb ASHTECH Z -XI 13   X   x   x   x   x   x   x
Winton [BARDI , CA, USA           wint wint ASHTECH Z-X113     x    xx    2    xx
Denver [CORS] , CO, USA           dent dent TRIMBLE 4000 SSE   X   x   x   x   x   x   x
Hillsboro [CORS] , KS, USA        hbrk hbrk TRIMBLE 4000 SSE
Haskell [CORS] , OK, USA          hklo hklo TRIMBLE 4000 SSE   X   x   x   x   x   x   x
Lament [CORS] , OK, USA           lmno lmno TRIMBLE 4000 SSE   X   x   x   x   x   x   x
```

Platteville [CORS] , CO, USA	pltc	pltc	TRIMBLE 4000 SSE	X x x x 9 X X
Sterling. [CORS] , CO, USA	strl	strl	ROGUE SNR-800 0	X x x x x x x
Table Mt. [CORS] , CO, USA	tmgo	tmgo	ROGUE SNR - 8000	X x x x x x x
Vici [CORS] , OK, USA	vcio	vcio	TRIMBLE 4000 SSE	X x x x x x x
Wallops. [CORS] , CO, USA	wlps	wlps	ROGUE SNR-8000	X x x x x x x
white Sands [CORS] , NM, USA	wsmn	wsmn	TRIMBLE 4000 SSE	X x x x x x x
Albert Head, Victoria B.C.	albh	albh	ROGUE SNR - 8000	X x x x x x x
Algonquin, Canada	algo	algo	ROGUE SNR-8000	X x x x x x x
Arequipa, Peru	arel	areq	ROGUE SNR-8000	X x x x x x x
Bogota, Colombia	bogt	bogt	ROGUE SNR-8000	X x x x x x x
Borowiec, Poland	borl	borl	ROGUE SNR-8000	X x x x x o x
Brasilia, Brazil	braz	braz	ROGUE SNR- 8000	X x x x x x x
Bermuda	brmu	brmu	ROGUE SNR- 8000	x X x x x6 x
Brussels, Belgium	brus	brus	ROGUE SNR- 8000	X x x x x x x
Casey, Antarctica	casl	cas1	ROGUE SNR-810 0	8 7x x
Davis, Antarctica	dav1	dav1	ROGUE SNR-810 0	3 2 1 2
Easter Island, Chile	eisl	eisl	ROGUE SNR - 8000	X x x x x x x
Fairbanks, AR, USA	fair	fair	ROGUE SNR-8000	x 3 4 X X X X
Fortaleza, Brazil	fort	fort	ROGUE SNR-8000	x 7 X x x x x
Goddard SFC, MD, USA	gode	gode	ROGUE SNR-8100	X x x x x x x
Graz, Austria	graz	graz	ROGUE SNR - 8	X x x x x x x
Guam, USGS Observatory	guam	guam	ROGUE SNR- 8000	1 4 2 1 x x x
Hartebeesthoek, S. Africa	hart	hart	ROGUE SNR- 8	X x x x x x x
Herstmonceux, UK	hers	hers	ROGUE SNR- 8A	X x x x x x x
Hobart [Tasmania] , Australia	hob2	hob2	ROGUE SNR- 8100	
Bangalore, India	iisc	iisc	TRIMBLE 4000 SSE	
Jozefoslaw, Poland	joze	joze	TRIMBLE 4000 SSE	x x x x x x6
Kerguelen Islands	kerg	kerg	ROGUE SNR- 8c	X x x x x x x
Kiruna, Sweden	kiru	kiru	ROGUE SNR-8100	x
Kitab, Uzbekistan	kit3	kit3	ROGUE SNR- 8000	x X x x x x
Kokee Park, HI, USA	kokr	kokb	ROGUE SNR- 8000	X x x x x x x
Kootwi jk Obs. , Netherlands	kosg	kosg	ROGUE SNR- 8000	X x x x x x x
Kourou, Fr. Guyana	kour	kour	ROGUE SNR- 8 C	x x x x x
Lhasa, Tibet	lhas	lhas	ROGUE SNR- 8000	X x x x x x x
La Plata, Argentina	lpgs	lpgs	ROGUE SNR-800 0	X x x x x x
Macca, Antarctica	macl	mac1	ROGUE SNR-8100	X X 9 X
Madrid DSN, Spain	ds60	madr	ROGUE SNR-8	x x 9 9 X X X
Maspalomas, Canary Is.	mas1	masl	ROGUE SNR-810 0	X x x x x x x
Matera, Italy	mate	mate	ROGUE SNR- 8	X x x x x x
McDonald Obs, TX, USA	mdo 1	mdo1	ROGUE SNR- 8000	X x x x x x x
McMurdo, Antarctica new	mcm4	mcm4	ROGUE SNR- 8000	X x x x x x x
Metsahovi, Finland	mets	mets	ROGUE SNR- 8C	X x x x x x x
North Liberty, Iowa, USA	nlib	nlib	ROGUE SNR - 8000	X x x x x x x
NY Alesund, Norway	nail	nyal	ROGUE SNR - 8	X x x x 8 x x
O'Higgins, Antarctica	ohig	ohig	ROGUE SNR-8000	
Onsala, Sweden	onsa	onsa	ROGUE SNR- 8000	x 9 9 9 X 8 X
Pamatai, Tahiti	pama	pama	ROGUE SNR- 800	2 x x x3
Penticton, Canada	drao	drao	ROGUE SNR- 8000	X x x x x x x
Perth, Australia	pert	pert	ROGUE SNR- 8100	0
Pie Town, NM, USA	piel	piel	ROGUE SNR- 8000	X x x x x x x
Pot sdam, Germany	pots	pots	ROGUE SNR-800 0	X x x x x x x
Richmond, FL, USA	rcm5	rcm5	ROGUE SNR-8000	9 X X X X 9 X
Santiago, Chile	sant	sant	ROGUE SNR-8	x l 7 0 3 0
Saint John's, Canada	stjo	stjo	ROGUE SNR- 8000	X x x x x x x
Shanghai Observatory, China	shao	shao	ROGUE SNR-8100	X x x x x x x
Taiwan, Taipei	taiw	taiw	ROGUE SNR-8000	8 x x x x x
Thule, Greenland	thu1	thu1	ROGUE SNR-8000	
Tidbinbilla, Australia	ds42	tidb	ROGUE SNR-8	X X 6 X 8 X X
Tromso, Norway	trom	trom	ROGUE SNR-8	X x x x x x x
Tsukuba-Kashima, Japan	tskb	tskb	ROGUE SNR-8000	X x x x x x x
Usuda, Japan	usu3	usual	ROGUE SNR-8000	X x x x x x x
Villa franca, Spain	vill	vill	ROGUE SNR-8100	x 7
West ford, MA, USA	wes2	wes2	ROGUE SNR-8000	X x x x x x x
Wettzell, Germany	wtz1	wett	ROGUE SNR-8000	X x x x x x x
Yarragadee, Australia	yar1	yarl	ROGUE SNR-8	X x x x x x x
Yell owkni f e, Canada	yell	yell	ROGUE SNR-8000	X x x x x x x
Zimmerwald, Switzerland	zimm	zimm	TRIMBLE 4000 SSE	X x x x x x x
Zwenigorod, Russia	zwen	zwen	ROGUE SNR - 8000	x x x

1. The following 19 sites are downloaded by SOPAC: BLYT, BRAN, CHIL, CHTP, CLAR CMP9 , CRFP, HOLC, HOLP, LEEP, LONG, MATH, MONP, PIN1 , PVEP, ROCK, S103 , TRAK, VNDP .
2. All other data are copied from CDDIS/JPL/NOAA/ CIC/AUSLIG/IGN/EMR
3. From GPS week 747, we record above the approximate percentage of data for each file computed by a RINEX file checker (e.g. 9 = 85-95%)
4. PGGA is the acronym for the southern California Permanent GPS Geodetic Array. It is now the regional component of the Southern California Integrated GPS Network (SCIGN) operated by SOPAC, USGS and JPL and which includes a

dense array in the Los Angeles Basin referred to as the DGGA (Dense GPS Geodetic Array) . SCIGN is administered under the umbrella of the Southern California Earthquake Center (SCEC) .

5. BARD (Bay Area Regional Deformation Array) is the acronym for the Northern California permanent GPS array. RINEX data can be also accessed from tbe Northern California Seismic Data Center (NCSDC) via anonymous ftp [login: brkseis20. Berkeley. edu (128.32.146.106) 1 cd /pub/ gps/rinex/YYYY/ YYYY. DDD (YYYY= current year, DDD. Jul ian day)
6. CORS (Continuously Operating Reference Stations) is tbe acronym for tbe U. S National GPS Network. RINEX and meteorological data can also be accessed from the National Geodetic Survey (NGS) , Silver Spring, MD via anonymous ftp [login: proton .ngs. noaa. gov (140.90.111.134)1 SOPAC archives both RINEX and meteorological data (e.g. , vici1550.95m) .
7. Ashtech Low Power z-12 is indicated by LPZ-XII3 .
8. Ashtech z-12 series receiver in combination with new Ashtech Dome Margolin with choke ring antenna is indicated by a trailing 'D' , i .e. , Z-XII3D.
9. Receiver change at BRAN on day 199, Ashtech replaced by TruboRogue SNR-8000.
10. New DGGA site on Catalina Island from day 201.
11 .S103 & TRAK raw data lost on day 198 due to operator error.
12. CARR & CASA data are a mix of 30 second and 1 second sampling on day 200.

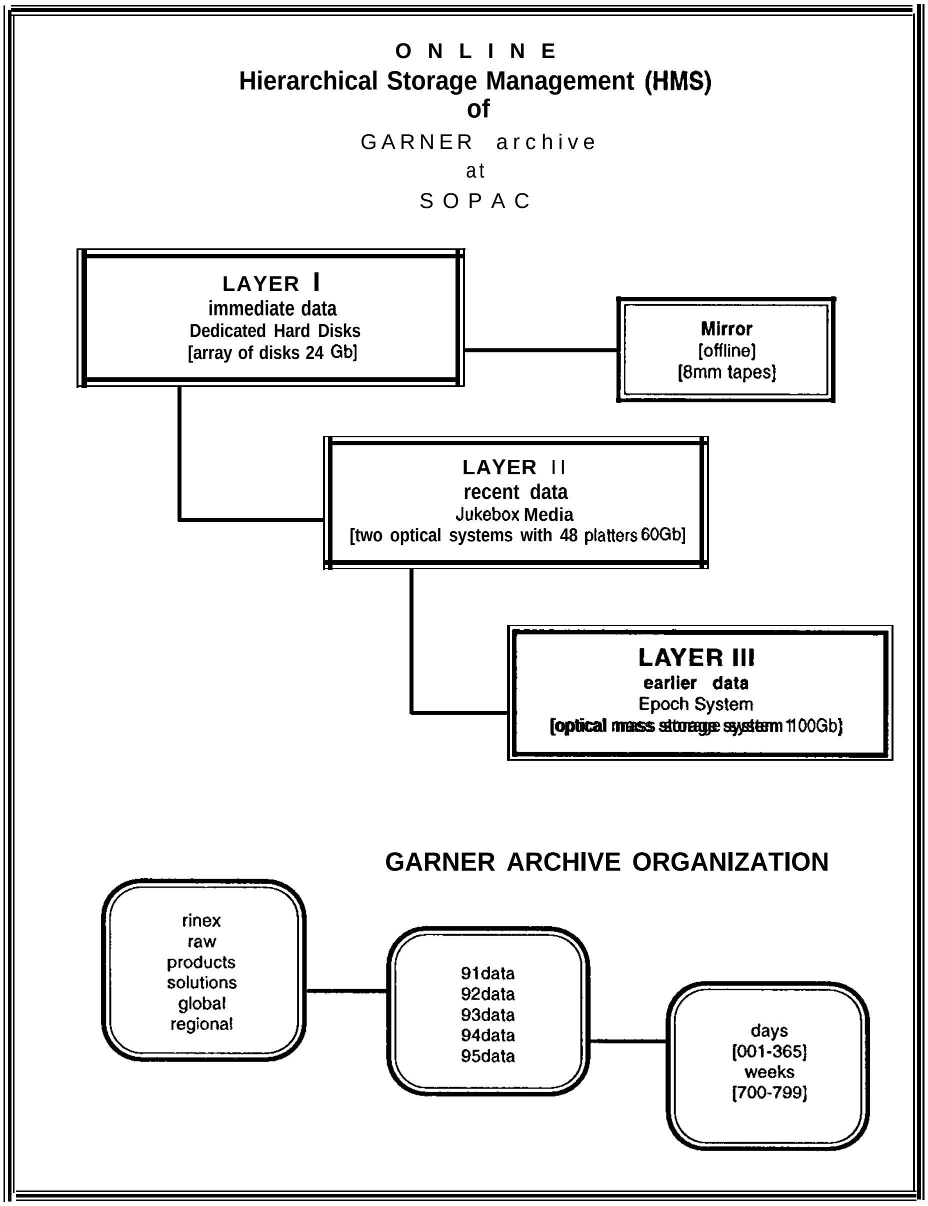


Figure 3. Hierarchical Structure of the SOPAC GARNER Archive.

SOPAC Global Analysis Center

SOPAC Rapid Products

Due to increasing demands for near real time applications, SOPAC has been generating rapid orbit and Earth orientation estimates since the beginning of GPS week 0783 (8 January, 1995). These products in standard IGS format are generally available over anonymous ftp within 18 hours of the end of a 24-hr observation collection window (0-24h UTC). In addition, we compute our regular daily and weekly orbits and Earth orientation estimates. The weekly products are contributed currently to the IGS combined orbit. In addition we have been experimenting with a predicted orbit which is extrapolated 24 hours by numerical integration of the daily rapid orbits. We rely on HP700 series workstations to meet the increasing demand on data analysis. The procedure that we follow for the rapid orbital products are outlined in the next section.

In order to cope with the heavy computational load problem with processing an increasing number of global stations, SOPAC has conducted some experiments with distributed solution schemes, which have proven very successful in regional applications (Zhang *et al.*, 1995). In one of these schemes, we divide the global stations into two groups so that the stations are interleaving. In order to strengthen the connection between the two networks, 3 stations are chosen to be common to both subnetworks. In another scheme, we divide the network into northern and southern subnetworks (P. Tregoning, personal communication). With these schemes, the computation load can be distributed and the efficiency is greatly increased. Moreover, a longer observation time span can be used and more unknown parameters (e.g., zenith delays) can be estimated without an increase in computational time.

Temporal variations in atmospheric refraction are of interest to geodesy and atmospheric physics. SOPAC has begun mapping global total electron content (TEC) and plans to provide TEC maps, time series, and/or spherical harmonic coefficients as additional rapid products. Initial results and procedures are given in the results section. SOPAC has already begun producing rapid precipitable water maps for the U.S. CORS/NOAA stations.

Analysis Procedures

Daily and Weekly Regular Orbit Service. An automatic ftp procedure retrieves RINEX observation files from various data-collecting agencies around the world every 4 hours. Within 4-7 days after data retrieval, an analysis procedure is initiated using 24 hours of data (0-24h). This procedure first performs a series of checks for adequate global station coverage and observation length. When an individual RINEX file is less than 50% of normal size, it is excluded. At present, 32-36 global stations are used in each 24-hour solution. The procedure then sets up auxiliary files and converts the RINEX files into GAMIT (King and Bock, 1994) internal format. A driver program generates a set of batch jobs running sequentially according to a predefine strategy. In the case of the IGS daily solution, parameters to be solved for include station positions, satellite orbits (8 initial conditions: satellite state vector, direct solar radiation pressure and y-bias for each satellite), polar motion position and rate, UT1 rate, tropospheric zenith delays (piecewise continuous once every 2 hours per site), and phase ambiguities. We use the ionosphere-free linear combination of phase sampled at 2-minute intervals. The data processing starts with the best available satellite ephemerides, normally from our rapid solution, a *priori* Earth orientation parameters from the IERS rapid service, *a priori* tracking station coordinates according to the ITRF93 specification (Boucher, Altamimi, and Duhem, 1994), and previous SOPAC solutions. Among the *a priori* values, only the best known station coordinates and UT1 are tightly constrained. The data processing is iterated on a model-clean-solution cycle 3 times. The solution is of the weighted least squares type. Data cleaning is a crucial step in the process. Bad observation rejecting, cycle slip fixing, and phase ambiguity flagging are performed by an automatic cleaning procedure that relies on the progressively improved (orbital) modeling during the iterations. In the final stage of the processing, a loosely constrained (of all parameters) solution (SINEX-like) file is produced, of which the full covariance matrix will be saved for later weekly solution use.

A weekly solution of 7 daily solutions (according to GPS week) are carried out with the GLOBK (Herring, 1994) software package which is of Kalman filter type. The *a priori* and constrained setups in the weekly solutions are identical to that of daily solutions. A forward filter solution computes a weekly estimate of station coordinates. These are fixed in a back solution which estimates daily orbital initial conditions and earth orientation parameters (pole, pole rate, UT1 rate).

Orbit and EOP estimates from the SOPAC regular weekly solution are reported regularly to the IGS AC coordinator and USNO. The SOPAC orbits agree with the rapid IGS orbits to about 20 cm after a 7-parameter similarity transformation (rotation, translation, and scale). S10 pole-x/y position series agree with IERS Bulletin B to about 0.13 miliarcseconds (Gambis) after offsets are removed.

Daily Rapid Service. The basic procedure for the rapid solution is very similar to the regular daily solution described above. The data processing is launched by computer automatically 13 hours (6am local time) after the end of data collection time (00:00 UTC). According to our experience, most of the key stations, typically 20 at least, will become available at this time. If the total number of stations is less than 18, the rapid processing will sleep for 30 minutes, then wake up to check data availability until enough data are ready. This processing uses the predicted orbit from the previous day, or from the broadcast ephemerides if one of the satellites was repositioned on the previous day. The major difference between rapid processing and regular processing is that the automatic cleaning procedure is more strict, that is, any observations of poor quality or in question are removed to assure full automation. When cleaning in the strict mode, about 10% more data are excluded compared to the regular editing. The total processing time is about 6 hours.

These differences are in an absolute sense, that is the no translation, rotation, or offset are taken into account. There are some high values around day 20 to 50, that indicate the solution suffer from tightly constrained a *priori* UT values which are predictions and in error. Such errors lead to the serious rotation in the orbits. Figure 4a shows the S10 rapid orbit and EOP estimate availability time after data collection ending time (at end of a day in GMT time). The dark horizontal time represents the nominal processing starting time (13 hours after data collection end time). Except for the first 10 days, those delayed ones are normally due to external data source down and occasionally our local network or computer system problem. Figure 4b shows the number of stations included in the rapid solution. On the average, about 26 stations are available for the rapid solutions. Figure 5 shows the rms and offset of SOPAC rapid pole-x and pole-y comparing with USNO-A. Figure 6 compares the SOPAC rapid orbits and the IGS “rapid” orbits. Figure 7 shows baseline precision obtainable with the SOPAC rapid orbits.

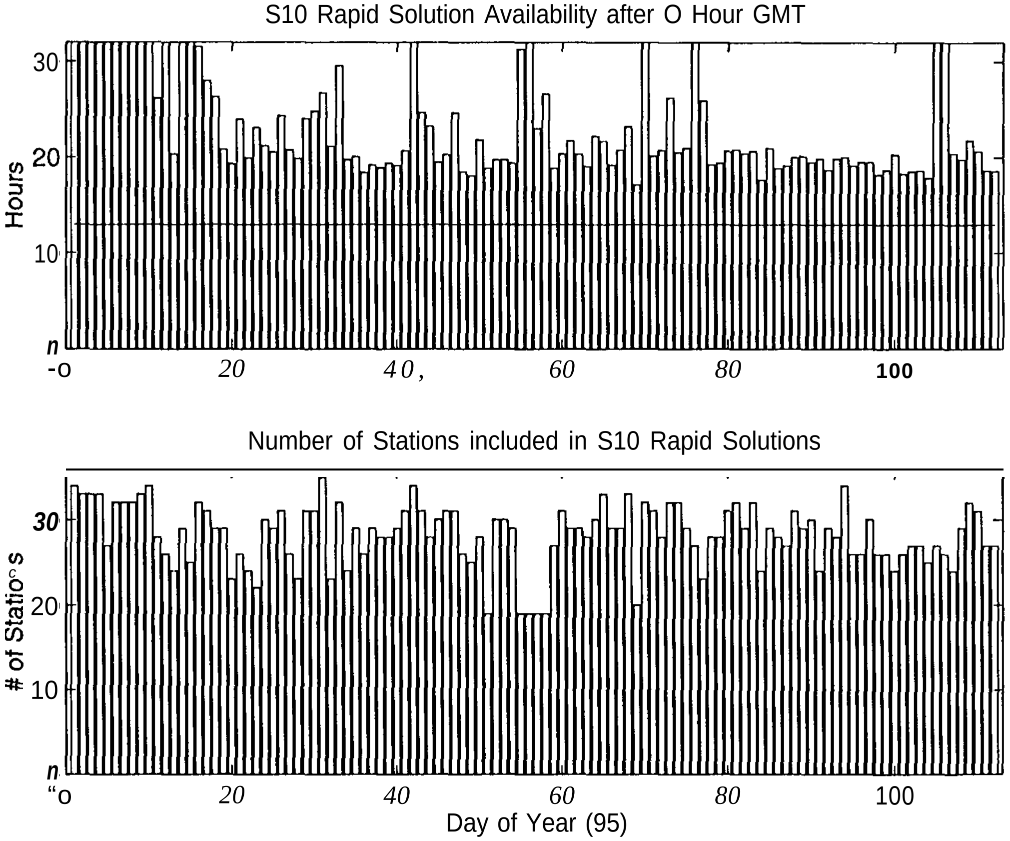


Figure 4. SOPAC Rapid Orbit Statistics. Solution availability time and the number of stations included in the rapid SOPAC orbit and EOP solutions. The solid horizontal line in the upper graph represents the nominal processing start time. The first 10 days were later processed for evaluation purposes. Typical reasons for delays are network and computer facility problems.

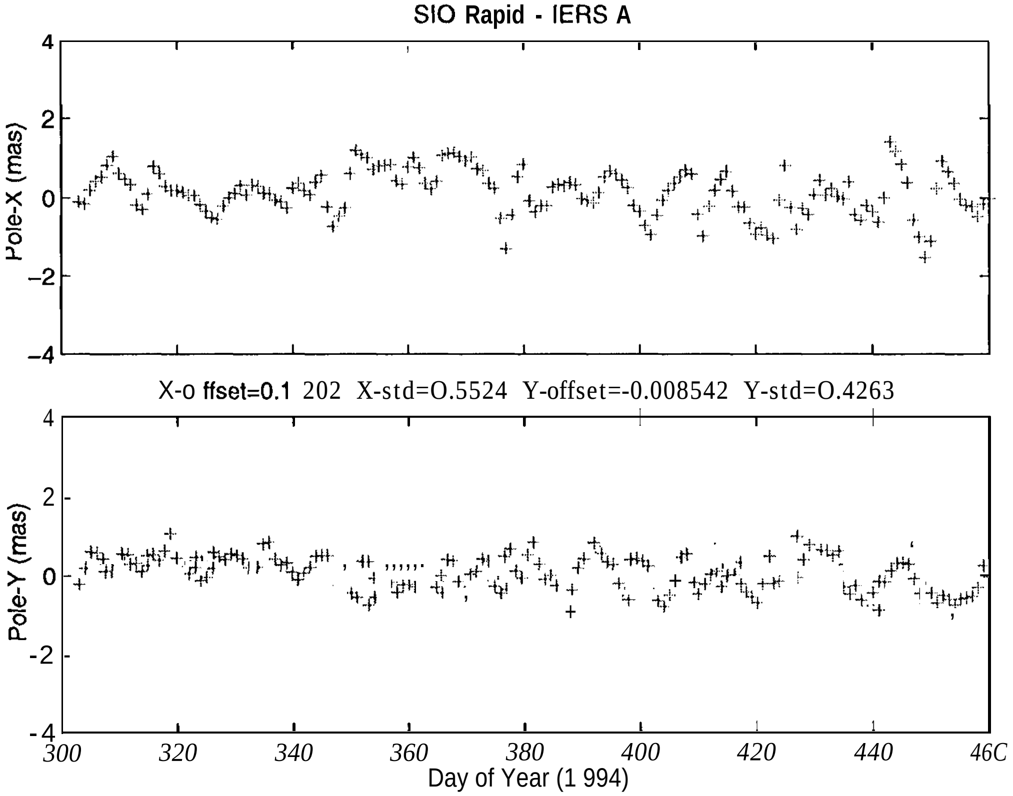


Figure 5. Comparison of SIO rapid polar motion and IERS Bulletin A.

24 Hour Orbit Overlap Difference between SIO Rapid& IGS

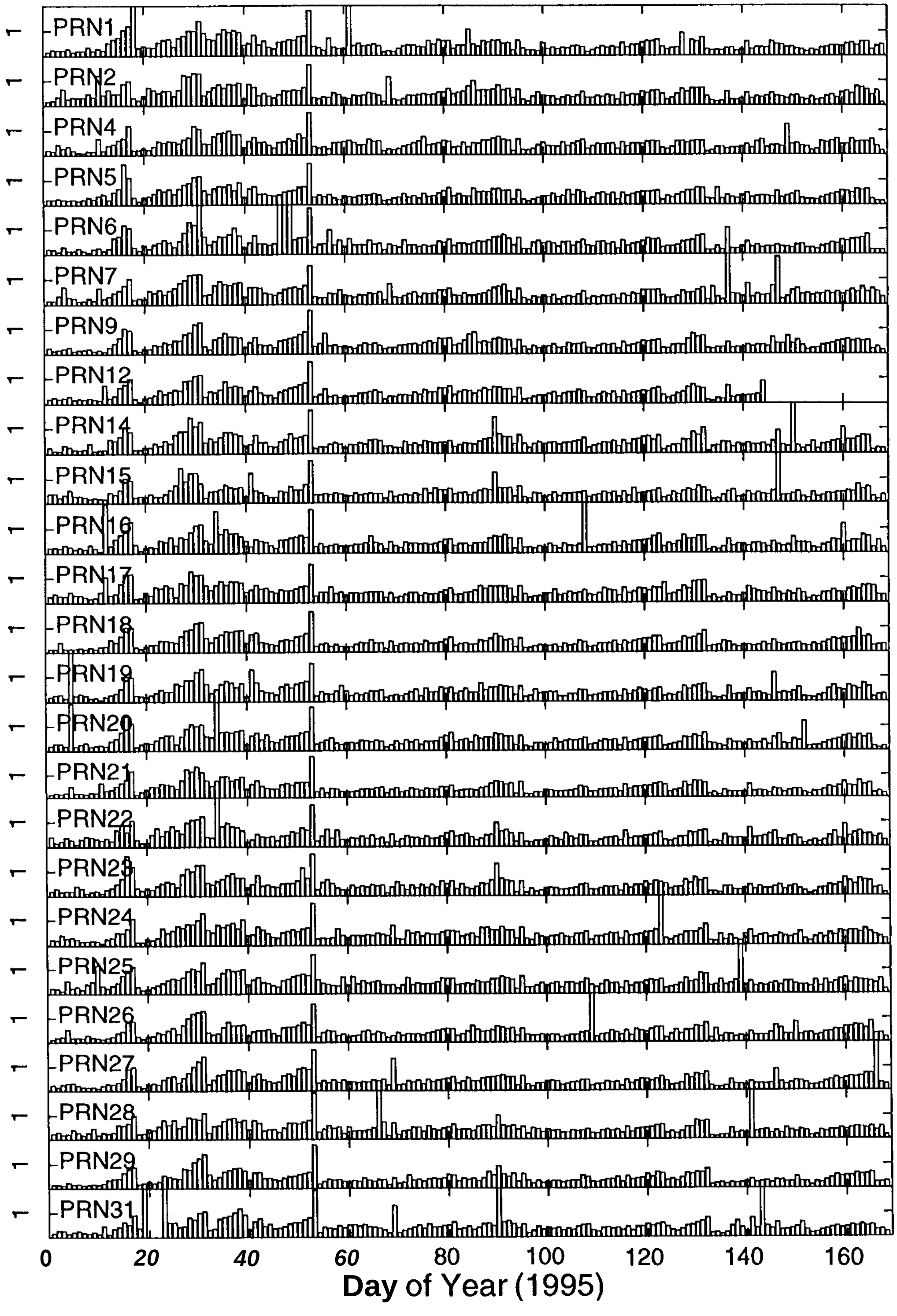


Figure 6. Comparison of SOPAC rapid orbits with IGS. Time series of absolute overlap differences for 24-hour periods between S10 rapid orbits and combined IGS orbits.

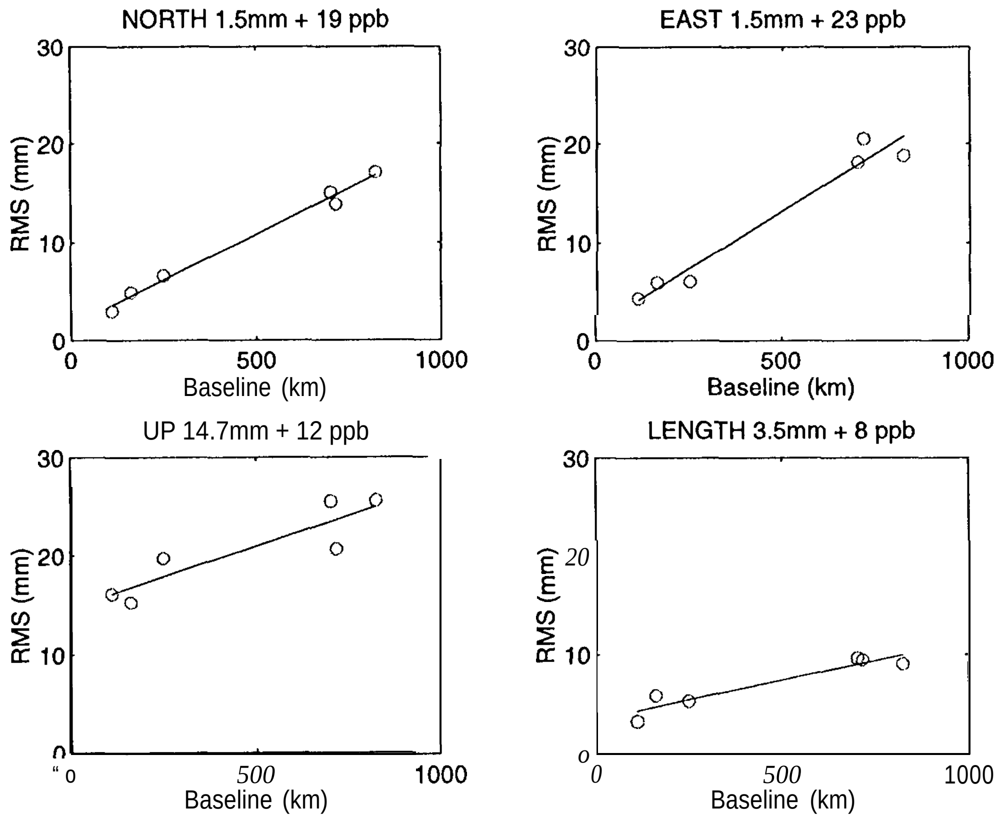


Figure 7. Baseline precision using SIO rapid orbits. The rms of individual components are based on 120 days of 24-hour solutions of 4 California stations with no overlapping stations with IGS.

Mapping Global Total Electron Content

Mapping global TEC is carried out with conventional methods using GPS L1 and L2 carrier phase observable assisted by PI and P2 pseudoranges for resolving ambiguities. The TEC can be estimated from pseudorange in an absolute sense but the noise level is very high (Figure 8 upper graph) while TEC can be estimated from phase with very high accuracy in a relative sense. By offsetting the phase estimates, absolute TEC at high precision can be obtained (Figure 8 middle graph). The scatter over smooth-fitting lines is about 10-16e/m2 level in TEC. Figure 8 shows the obvious nighttime low and daytime high. The TEC curves do not overlap at a given time because they are different estimates in space (Figure 9). These points are computed assuming that the centroid height of ionosphere is 350 km on the Earth with mean radius of 6371 km. As shown, the TEC estimates cover a very wide region which makes the global mapping possible. Figure 10 shows a series of 2-hour averaged TEC global maps over a 24-hour period. It can be clearly seen that the solar-activated high TEC region (light area) is moving westwards in time.

Mapping Rapid Tropospheric Precipitable Water

We have begun to routinely produce daily, rapid precipitable water estimates for the NOAA CORS stations equipped with meteorological sensors. All North American IGS stations (only Goldstone in California), including the CORS stations are analyzed using the GAMIT software as soon as the SOPAC rapid

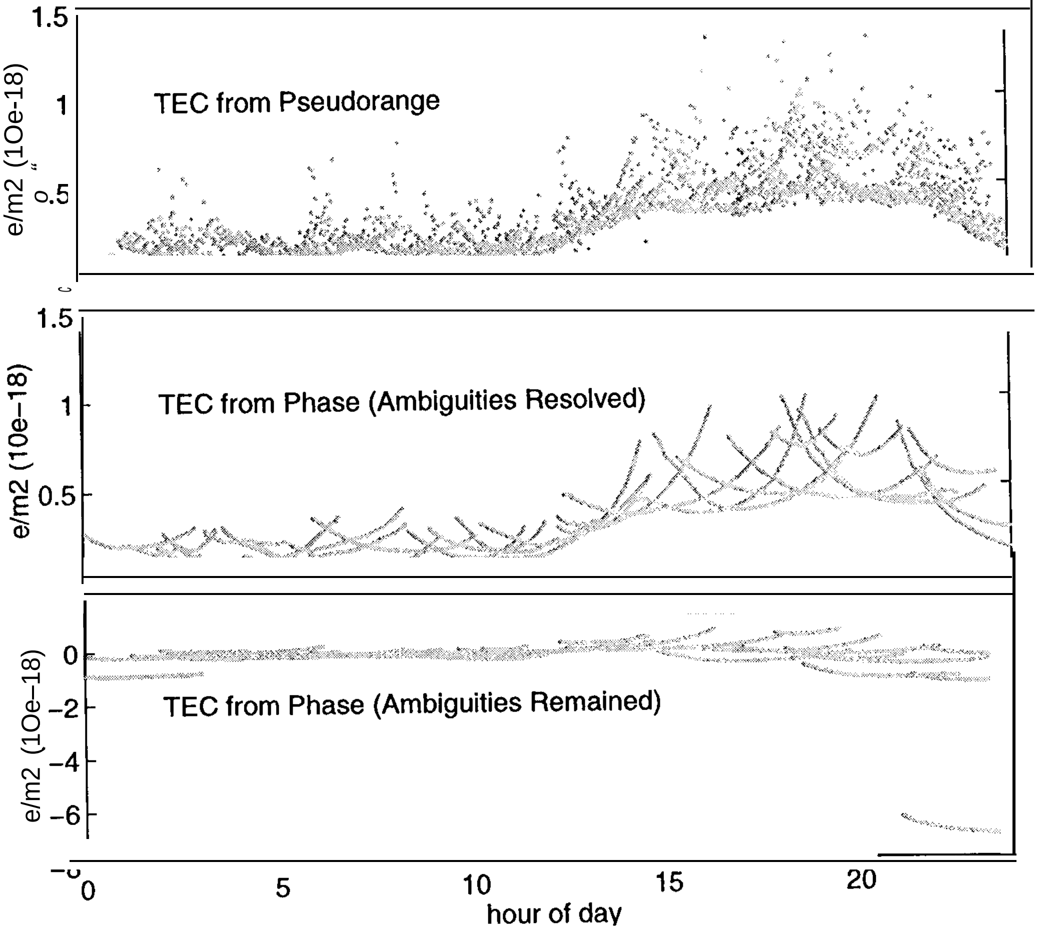


Figure 8. TEC estimates at ALGO. Time series of TEC estimates over a 24-hour period from all satellites observed at station ALGO.

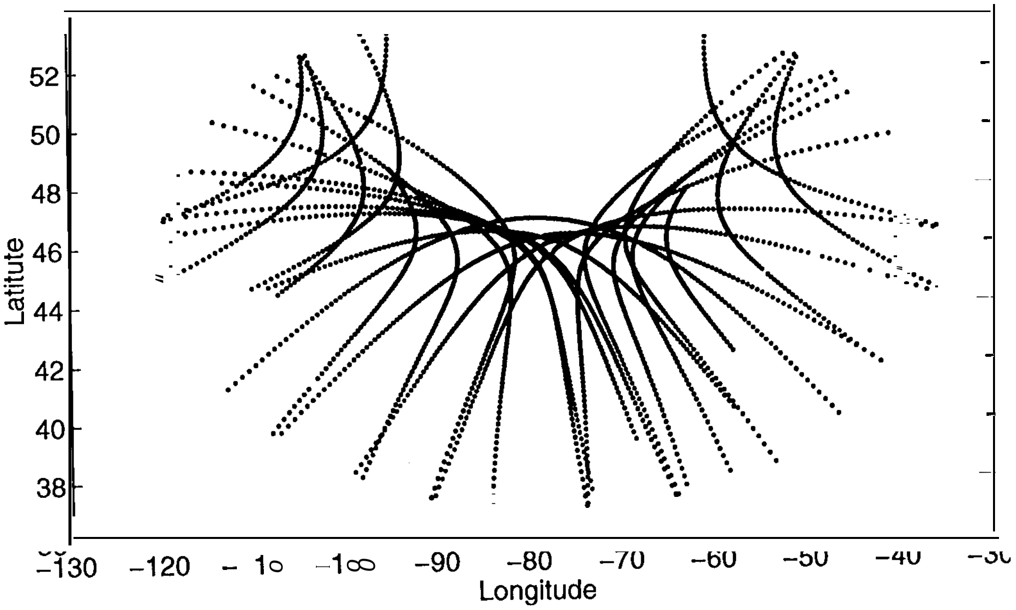
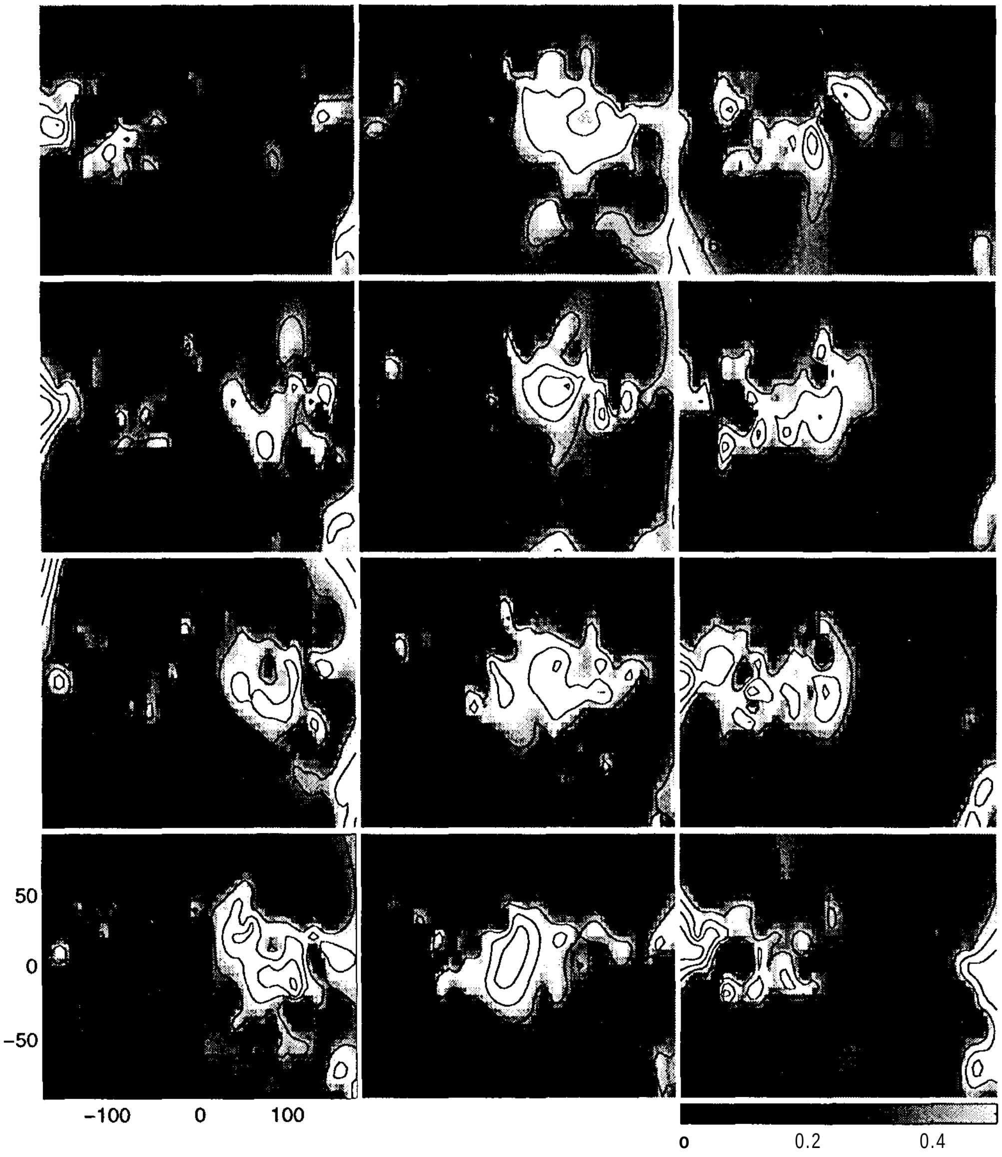


Figure 9. Subionsophere points at ALGO. Subionosphere points during a 24-hour period at station ALGO.

Figure 10. Two-hour averaged global TEC mapping. X-axis is longitude and Y-axis is latitude. Gray scale is in 1018 e/m2.



orbit is generated. The station coordinates and satellite orbits are tightly constrained. Total zenith delay parameters (ZND - zenith neutral delay) are estimated under the assumption that they behave as a first-order Gauss-Markov process. The process correlation time is set to 100 hours, the process standard deviation to 2.5 mm, and the ZND is estimated every 30 minutes at each station. We use the CfA mapping function [Davis, *et al.*, 19851. The zenith wet delay (ZWD) is recovered from the ZND estimates by subtracting the ZHD time series computed using surface pressure measurements. The ZWD estimates are then transformed into PW estimates as described in Duan *et al.* [1995]. The uncertainty in the PW estimate derives almost entirely from the uncertainty in the earlier estimate of ZWD [Bevis *et al.*, 19941.

Figure 11 shows a 30-day time series of PW for the CORS/NOAA site in Denver, Colorado using the rapid SOPAC orbits and the procedure just described, including a comparison with water vapor radiometer (WVR) determinations of PW. The differences in PW when using the rapid and regular SOPAC orbits is

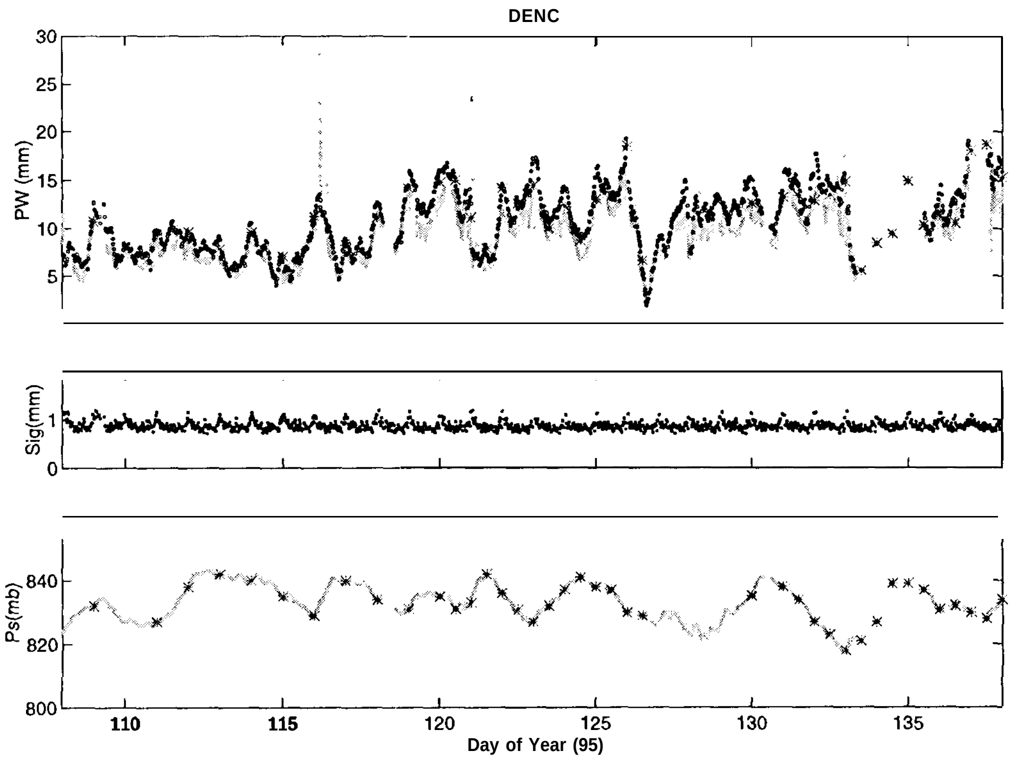


Figure 11. GPS PW series at Denver NOAA CORS station. Solid circles are GPS estimates using 'pure GPS approach' with SOPAC near-real-time orbits. Light dots are WVR estimates. The '*' are balloon sounding (radiosonde) estimates. Note that there is a small offset (under 1 mm) between WVR, GPS, and Radiosonde measurements. This is probably due to miscalibration of WVR.

generally below the 1-mm level. These results indicate that PW can be monitored rapidly and automatically using GPS meteorology with about 1–2-mm accuracy.

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The SIRGAS Project

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The SIRGAS Project was established during the International Conference on the Definition of a South American Geocentric Datum, during the period October 4–7, 1993, in Asuncion, Paraguay, by an invitation of the sponsoring entities: International Association of Geodesy (IAG), Pan-American Institute of Geography and History (PAIGH), and United States Defense Mapping Agency (DMA). Representatives of each sponsoring entity and of almost all South American countries participated in that Conference.

The objectives established for the project are the following: to define a reference system for South America; to establish and maintain a reference network; and to define and establish a geocentric datum. The goals to be achieved are: to reach the defined objectives in 1997 coinciding with the Scientific Assembly of the International Association of Geodesy (with the exception of maintenance that has a permanent character); to promote and coordinate the work of each South American country in order to get the defined objectives; to establish a high precision GPS network; to concentrate the attention at the beginning on the Horizontal Datum; and to facilitate the connection of pre-existing networks.

Objectives related to the definition of the reference system and of the geocentric datum for the continent have been achieved in the Asuncion Conference, the plenary having chosen the following:

- SIRGAS reference system: IERS (International Earth Rotation Service) Terrestrial Reference Frame (ITRF);
- geocentric datum: coordinate axes based on the SIRGAS reference system and parameters of “Geodetic Reference System (GRS) of 1980” ellipsoid.

The development of the SIRGAS Project encompasses the activities needed for the adoption on the continent of a reference network of precision compatible with the up-to-date positioning techniques, mainly those associated with the Global Positioning System (GPS). Considering the proliferation of GPS utilization, to tie these new surveys to an existing geodetic structure, basically carried out by the use of classical methods (triangulation, traverse, trilateration, etc.), whose precision is at least ten times worse than that easily obtained with the GPS, implies at least a waste of resources. Besides, the multiplicity of classical geodetic systems, adopted by the South American countries, makes the solution of technically simple problems, such as the definition of international borders, very difficult. On the other hand, the adoption of the ITRF as reference system, besides guaranteeing the homogenization of the results internally to the continent, will allow the consistent integration with the networks of other continents, contributing more and more to the effective developing of a “global” geodesy.

During 1994, important progress was achieved towards the establishment of a geocentric reference system for South America. From this point of view, the first meeting of the Working Group II “Geocentric Datum”, held during the period 20 through 22 April 1994, in Bogota, Colombia, and the first one of the Working Group I “Reference System” and the second one of the Working Group II, both held during the period October 24–28, 1995, in La Plata, Argentina, have contributed a lot. During the WG I meeting, the SIRGAS GPS campaign was scheduled for May 26 to June 4, 1995, when about 52 stations (Table 1), which will form the SIRGAS reference network, will observe the GPS satellites 24 hours per day. From this high precision frame, the WG 11 will integrate the GPS networks available in each country, using and encouraging the establishment of the necessary international ties. The classical network integration, as Resolution No. 2 of the first WG II meeting, will occur according to the interest of each country. It is important to mention that, among those 52 stations, around eight are IGS stations already functioning in South America, which will guarantee the necessary tie between the SIRGAS reference network and IGS (Figure 1).

Besides the meetings mentioned above, two other events where resolutions that specifically deal with and support the SIRGAS project were adopted should be emphasized: Meeting XXX of the PAIGH Directing Council, through Resolution No. VIII, and Meeting XI of the Directors of South American, Spanish and Portuguese Geographic Institutes, through Resolution No. 8.

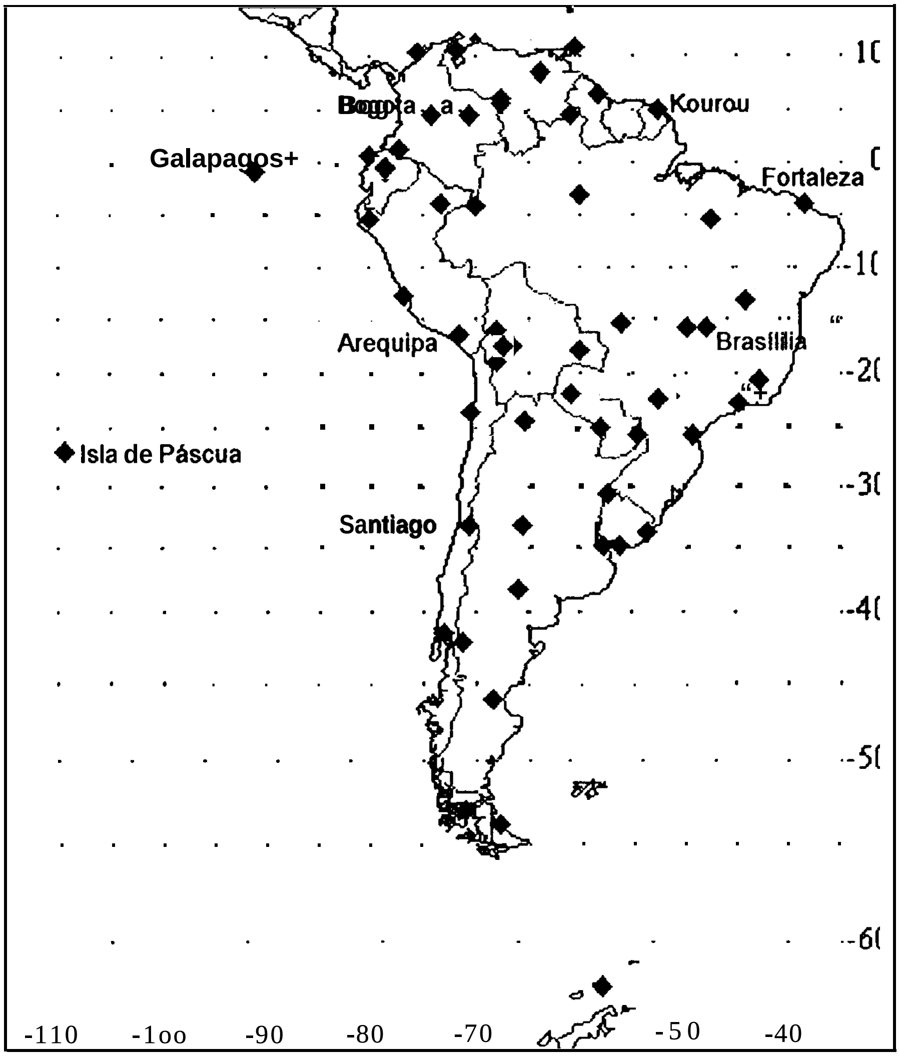
The efforts that have been carried out by various groups and project collaborators, including the sponsoring entities and the IGS community, besides the steps that were already carried out by the Working Groups, have been generating a continually greater participation of various South American countries, establishing the necessary conditions for the achievement of the project objectives.

Detailed information about the project structure, composition, Working Group I and II meetings, including data and processing centers can be found in SIRGAS Project Newsletters #1 and #2, available upon request or under ftp.dgfi.badw-muenchen.de or deged.ibge.gov.br (name: anonymous, passwd: <own e-mail address>, directory: pub/gps/sirgas).

Table 1. Stations of the SIRGAS Reference Network.

SIRGAS stations (10.Jan.1 995)				Instr.	Institution
ISLA REY JORGE	Antarctica	-62,3	-58.	(Z12/SSE)	IGM Chile
CHURCAL	Argentina	-24.31	-65.34		Univ. Tucuman
EL MAITEN	Argentina	-42.01	-71.21	Leica	Cat. Rio Negro
LA PLATA	Argentina	-34.91	-57,93	T. Rogue	Ohs. La Plata/GFZ
LOTE 10B	Argentina	-46.04	-66.47	(SSE/Z12)	Cat. Chubut
LOTE 24	Argentina	-38.13	-66.09	SSE	UAGG Mendoza
MORRO	Argentina	-33.27	-65.48	Z12	UAGG Mendoza
PUERTO IGUAZU	Argentina	-25.60	-54.59		IGM Argentina
RIO GRANDE	Argentina	-53.79	.67.75	T. Rogue	Oba. La Plata / GFZ
AZANAQUES	Bolivia	-19.	-66.	SSE	IGM Bolivia
EL ALTO	Bolivia	-16.	-66.	SSE	IGM Bolivia
SURUTUVIA	Bolivia	-16.	-60.	SSE	IGM Bolivia
VILLA TUNARI	Bolivia	-17.5	-66.5	SSE	IGM Bolivia
BOM JESUS LAPA	Brazil	-13.25	-43.42	(SSE/Z12)	·
BRASÍLIA	Brazil	-15.95	-47.66	T. Rogue	IGS (IBGE / JPL)
CACHOEIRA	Brazil	.22.69	-44.96	(SSE/Z12)	·
CUIABÁ	Brazil	-15.55	-56.07	(SSE/Z12)	·
CURITIBA	Brazil	-25.45	-49.23	(SSE/Z12)	·
FORTALEZA	Brazil	.03.66	-36.43	T. Rogue	IGS
IMPERATRIZ	Brazil	-05.50	-47,47	(SSE/Z12)	‘ - {IBGE/IfE/
MANAUS	Brazil	-03.12	-60.06	(SSE/Z12)	/UFPR/USP/
PRES. PRUDENTE	Brazil	-22.12	-51.41	(SSE/Z12)	/UNESP/UFV/
VIÇOSA	Brazil	-20.75	-42.90	(SSE/Z12)	UFPE}
ANTOFAGASTA	Chile	-23.5	-70.5	T. Rogue	IGM Chile/GFZ
ISLA DE PASCUA	Chile	-26.99	-109.36	T. Rogue	IGS
PUERTO MONTT	Chile	-41.5	-73.	T. Rogue	IGM Chile/GFZ
PUNTA ARENAS	Chile	-53.	-71.		IGM Chile
SANTIAGO	Chile	.33.15	-70.67	T. Rogue	IGS
BOGOTA	Colombia	+04.64	-74.06	T. Rogue	IGS
CARTAGENA	Colombia	+10.5	-75.5	Leica	Agustin Codazzi
LETICIA	Colombia	-04.1	-69.9	Laica	Agustin Codazzi
PASTO	Colombia	+01 .2	-77.2	Leica	Agustin Codazzi
PTO. CARRENO	Colombia	+06. 1	-67.5	Leica	Agustin Codazzi
GALAPAGOS	Ecuador	-01.	-91.	T. Rogue	IGS
LATACUNGA	Ecuador	-01.0	-76.6		IGM Ecuador
MUISNE	Ecuador	+00.6	-60.		IGM Ecuador
KOUROU	Fr. Guiana	+05.13	-52.62	T. Rogue	ESA / IGS
TIMEHRI	Guyana	+06.51	-56.26		Lands & Surv. Dept.
ASUNCIÓN	Paraguay	-25.	-5B.		DSGM Paraguay
M ESTIGARRIBIA	Paraguay	-22.	-61.		DSGM Paraguay
AREQUIPA	Peru	-16.45	-71.48	T. Rogue	IGS
IGUITOS	Peru	-03.9	-73.3	(SSE)	“ - {IGN Peru/
LIMA	Peru	-12.8	-76.8	(SSE)	/Univ. FA RFA)
PIURA	Peru	-05.3	-60.2	(SSE)	·
TOBAGO	Trinidad	+11.	-60.5		
CERRO VIGIA	Uruguay	-33.72	-53,58	Z12	{SGM Uruguay/
MONTEVIDEO	Uruguay	-34.06	-56.27	Z12 + Leica	/Fac. Ing
YACARE	Uruguay	-30.60	-57.42	Z12	Univ. de la Rap.)
LA CANOA	Venezuela	+8.57	-63.85	Leica	{DCN/
MARACAIBO	Venezuela	+10.77	-71.67	Leica	/EIG/
PTO. AYACUCHO	Venezuela	+05.7	-67.6	Leica	/DIGECAFA/
STA. ELENA	Venezuela	+04.7	-61.	Leica	/DGFI}

Figure 1. Stations of the SIRGAS Reference Network (the IGS ones are named)



The Contribution of the EUREF Subcommission to IGS

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The EUREF Subcommission (EUropean REference Frame) is a body within the IAG Commission X, "Continental Networks". Its task is to establish and maintain a three-dimensional geometric reference frame for the whole of Europe. Starting in 1989 the subcommission has covered the major part of Europe with a GPS network. While the older parts have an accuracy of 3 to 5 cm horizontally and somewhat worse vertically, the new campaigns reach centimeter accuracy. The subcommission, or more specifically its Technical Working Group, has formulated strict rules on how to process the campaigns and how to establish and operate permanent GPS stations, to be accepted as EUREF stations. The EUREF Subcommission has expressed its will to establish a regional densification of the IGS network in Europe and endorsed this with resolution 3 of the Helsinki meeting:

> The IAG Subcommission for the European Reference Frame *endorses* the guidelines for a EUREF network of permanent GPS stations presented by the EUREF Technical Working Group, asks the EUREF Technical Working Group to implement and co-ordinate such a permanent network, *requests* the EUREF members to take the necessary actions to support these activities and *proposes* to the International GPS Service for Geodynamics (IGS) that the EUREF network be the regional densification for Europe of the global IGS network.

AUSLIG Associate Analysis Centre

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Summary for the IGS Annual Report 1994

AUSLIG Geodesy has been doing global GPS solutions using about 20 IGS sites. Station coordinates, pole position, and eight satellite parameters are estimated. A comparison of the GPS satellite trajectories—generated from the estimated GPS orbit parameters—with the ephemeris produced by the individual IGS Analysis and the IGS combined ephemeris is currently underway. The estimated coordinates of the IGS core sites show very good agreement with the ITRF values.

Regional solutions are being done for the Australian Regional Network (Australia & Antarctica). These computations are performed using both the locally determined satellite orbits and the IGS combined orbit.

The global GPS sites being processed are: Fairbanks, Yellowknife, Algonquin, Goldstone, Kokee Park, Pamate, Easter Island, Santiago, Fortaleza, Madrid, Maspalomas, Ny Alesund, Metsahovi, Hartebeesthoek, Kerguelen, Kitab, Yaragadee, Taipei, Usuda, Tidbinbilla, McMurdo, Casey, and Davis.

Plans are to continue this work in preparation to function as a Type-1 Associate Analysis Centre.

SLR data are being routinely processed.

The Central European Initiative and Its Relation to IGS

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Introduction

At present, the following eight countries are members of the Central European Initiative (CEI): Austria, Croatia, Czech Republic, Hungary, Italy, Poland, Slovakia, and Slovenia. Within the framework of CEI, the Committee of Earth Sciences section C looks after the field of geodesy. Based on earlier proposals, the Central Europe Regional Geodynamics Project (CERGOP), initiated by Hungarian and Polish scientists, can be considered as a logical continuation of earlier geodynamic activities in the Central European area, now based on modern space techniques and *on* a flexible and reliable organization. CERGOP was approved by the CEI Section C conference in Ksiaz Castle, Poland in May 1993. A detailed concept of CERGOP was introduced during the last IGS workshop in Potsdam (Pesec, 1995). The following condensed summary is given.

The Main Objectives of CERGOP

The main objectives of CERGOP are described in detail in Sledzinski (1994a). They can be summarized as follows: (1) collection of satellite, geodetic, astronomical and gravimetric data for the analysis and interpretation of the geodynamic interactions in the region of Central Europe; (2) investigation of geodynamic processes and geotectonic features in the Central European region, in particular the Teisseyre-Tornquist zone and the Carpathian and Subalpine Orogeny; (3) provision and monitoring of a precise geodetic reference in order to accomplish these tasks; (4) collection of materials for providing a geoid map with centimeter accuracy for Central Europe.

Concept and Realization

The scientific concept of CERGOP is based on the *merging* of on-going national activities in the field of geodynamic research which are supplemented by international projects. Specifically this means that most of the financial burden has to be carried by the national institutions. By now three additional countries have joined the project: Germany, Romania, and Ukraine. Each country is represented by a National Investigator (NI). They constitute the International Project Working Group (IPWG), headed by the CERGOP Management Group (NIs of Germany, Hungary, Italy, and Poland).

The tasks of IPWG include the organization of observation campaigns, the supervising of the study groups' activities, the performance control of the data center and the processing centers, and the liaison with overlapping international projects. Besides the overall project tasks, the members of IPWG disseminate information, and keep and establish contacts with existing international projects and organizations (e.g., IGS, EUREF, WEGENER, IDNDR, EUROPROBE, Baltic Sea Level Project, Extended SAGET, and others). IPWG is chaired by the NI of Hungary and co-chaired by the NI of Poland.

One of the first important steps was the establishment of a Central European GPS Geodynamic Reference Network, which serves as the common basis for all scientific projects. It consists not only of the mere sites but also of the complete infrastructure which enables a proper operation (instrumentation, maintenance, communication, observing personnel). Financial support for covering part of the maintenance of CEGRN during the next three years was given by the European Community.

During the last year altogether 11 CERGOP study groups (CSGs) were proposed by the national representatives. They are formed by the collaboration of scientists from two or more member countries and are designed for carrying out research in a particular field. This field may cover objectives directly related to CERGOP (co-research) or only linked to CERGOP (associated research). Some CSGS have started their work recently, and some are just in the stage of being developed (Sledzinski, 1994b).

The CERGOP working group meets twice a year at different places in the member countries. Detailed summaries of the national activities are supplemented by the reports of the data center, the processing centers, and the individual study groups. All reports are compiled and published (presently in the "Reports on Geodesy" of the Warsaw University of Technology).

Central European GPS Geodynamic Reference Network (CEGRN)

In order to keep the number of sites at a reasonable level IPWG decided to appoint-after consultation—to each member country a restricted number of stations which are served within CERGOP—even if they are upgraded to a permanent station. At present CEGRN comprises 31 sites (Pesec, 1995), which are obliged to take part in a five-day epoch campaign every year.

The data center at Graz is responsible for archiving all incoming data (permanent stations, epoch campaigns), checking and distributing the data to other organizations, and providing continuous access to the stored data sets. It is organized similar to the IGS data centers and can be queried via anonymous FTP and dial-up modem. Up to 3-GByte disc memory is at disposal for data storage; older data are stored on magneto-optical discs.

By now four processing centers are in operation:

- Institute of Geodesy and Geodetic Astronomy, Warsaw, Poland;
- Institute for Space Research, Graz, Austria;
- Research Institute of Geodesy, Zdiby, Czech Republic;
- FOMI Satellite Geodetic Observatory, Pent, Hungary.

IFAG Frankfurt indicated its interest to act as an additional processing center in the future.

The main task of the processing centers is to compute an annual set of coordinates for all CEGRN stations. All processing centers are currently using the Bernese software package; CSG 4 determines and recommends the official set of coordinates. In addition, the determination of daily coordinate sets for the permanently recording stations is on the schedule.

The products placed at disposal by the data center for further use are station descriptions (including receiver types and eccentricities), relevant sets of coordinates and the respective covariance matrices, and in future, specific data of the station environment like 4-D meteorological data and multipass information.

Possible Relations of CERGOP to IGS

CEGRN can be regarded as a regional reference frame, which was established according to the guidelines of IGS. A considerable part of the reference stations was observed during the IGS Epoch'92 campaign giving a first link to the global IGS frame. CEGRN contains the VLBI/SLR/GPS fundamental station Wettzell (FRG) and the SLR/GPS stations Graz (Austria), Borowiec (Poland) and Potsdam (FRG) operating as European core stations of IGS as well. In addition, the permanently operating stations Jozefoslaw and Lamkowko (Poland), Pecny (Czech Republic), Padova (Italy) and Hafelekar (Innsbruck, Austria) make their data available—via Internet or Modem—to the CERGOP data center at Graz, which transfers all collected data to the regional IGS data center at IFAG Frankfurt on a daily basis. At present, altogether eight stations of the CEGRN network monitor the CERGOP reference frame on a permanent basis; their data are included in the daily solution of the IGS orbit determination center CODE at the University of Berne.

It should be stressed that, according to the present plans, some more stations will receive a permanent status in the near future (after solving some communication problems). Daily solutions computed at the CERGOP processing centers and referred to ITRF will be routinely available. At least one complete set of coordinates per year is at disposal for all CEGRN stations which can be incorporated into regional and global solutions.

Conclusions

The Central Europe Regional Geodynamic Project takes a considerable part of national geodynamic investigations of 11 countries under a common umbrella. Mutual assistance promotes the use of modern space techniques for attaining accuracies of coordinates in the sub-centimeter region which is required for geodynamic research. Through accepted procedures the products can be incorporated in continental and global solutions. The activities are controlled by the International Project Working Group. However, the main tasks have to be fulfilled and financed by the underlying national organizations. Some financial support has been given by the European Community within “Copernicus” for the next three years,

References

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Lamkowko Satellite Observatory

Lubomir W. Baran
Olsztyn University of Agriculture and Technology
Olsztyn, Poland

The Satellite Observatory of the Olsztyn University of Agriculture and Technology was established in 1961 on initiative of the Committee for International Geophysical Cooperation of the Polish Academy of Sciences. The Observatory was located at the area of the University Campus Kortowo, in the southern part of Olsztyn. It was registered in COSPAR as an International Satellite Tracking Station, number 1151.

In the years 1961–78 visual observations of artificial Earth satellites were carried out, at the beginning only in the framework of the Ephemeridal Service, and since 1964 also within international programs of study of the upper parts of the Earth atmosphere (INTEROBS, EUROBS, ATMOSPHERE). Observations of low satellites were carried out with special telescopes having large fields of view (AT-1, TZK) as their feature. Specially adopted theodolites were used for this purpose. Also a digital theodolite TEOSAT was built at the Observatory to meet these requirements.

In 1978 the Observatory was moved to the little village of Lamkowko, located nearly 30 km to the northeast of Olsztyn. At the *new* location, a camera, AFU-75, for photo observations of artificial Earth satellites was installed. The observations performed with it were used for realization of the research programs ATMOSPHERE and PHOTODOPPLER, coordinated by INTERCOSMOS.

In the 1980s, theoretical and then also practical activities took place at the Observatory, aiming at application of the Doppler observations to regional geodynamic studies as well as to realization of various engineering tasks. The observations were performed taking advantage of the Doppler receiver DOG-3, designed and constructed in Poland.

The Satellite Observatory in Lamkowko got its own GPS receivers (ASHTECH MD-XII) in February 1991. Thanks to that the Observatory was able to take part in the first IGS observational campaign (July 25–August 8, 1992) as a Fiducial Station. In the years 1992 through 1994 the Observatory participated in many other observational campaigns connected, for example, with extending the EUREF network to the territory of Poland and Baltic States (EUREF-POL and EUREF-BAL), as well as with regional geodynamical studies (projects: Baltic Sea Level, Central Europe Regional Geodynamics Project, Geodynamics of Ukrainian Carpathians).

Since 1994 the Observatory has owned a Turbo Rogue SNR-8000 receiver. It enabled permanent observations to start from 1 December 1994 in the framework of the International GPS Service for Geodynamics.

Support of the CNES GPS Tracking Network to the IGS

Loic Boloh
Centre National d'etudes Spatiales
Toulouse, France

Introduction

Since 1991, CNES, the French Space Agency, has been contributing to the International GPS Service for Geodynamics. Through its Toulouse Operational Center, CNES currently manages four stations which are part of the International Network:

- Grasse, France
- Hartebeesthoek, Rep. of South Africa
- Kerguelen Islands, Southern Indian Ocean
- Pamatai, Tahiti Island, French Polynesia

CNES sites are equipped with permanently installed receivers, which are dedicated to continuous GPS satellites tracking.

Toulouse Operational Center

An Operational Center at CNES in Toulouse performs Network management, which includes tasks such as data management, network maintenance, and users' interface.

The four CNES stations have access to direct communications links with the Toulouse Operational Center. GPS raw data, along with meteorological surface measurements (HART and PAMA), are transmitted daily to Toulouse. The data are also stored at each site for backup. CNES personnel in Toulouse:

- overview data transfer from the stations to Toulouse,
- assess performance of the data taken by the stations of the network,
- ensure data are made available to the users within the proper time delay,
- meet special requirements from the users in term of data availability,
- manage data storage at the Toulouse Operational Center.

At the Toulouse Operational Center, data are uncompressed and rinexed; data completeness is checked and a quality control is performed. Rinexed data are then stored on a workstation to be retrieved by users. Every day data are transferred from Toulouse to the IGN Global Data Center in Paris which provides on-line access to the community.

Besides data formatting and validation, the Toulouse Operational Center performs Network maintenance:

- to assist station personnel for first-level maintenance,
- to perform diagnosis on GPS receivers in case of anomalies,
- to direct and coordinate equipment shipment if maintenance cannot be performed on-site,

- to provide the interface between the network and the industrial maker when required to perform maintenance actions,
- to ensure that the necessary equipment to perform first-level maintenance is available or can be secured for each station.

Grasse

In February 1995 a Turbo Rogue (SNR-81OO) was installed near Grasse, southeast of France, at the Calern Observatory which is part of Observatoire de la Côte d'Azur (OCA). It is collocated with SLRS and LLRs; the GPS antenna, which is stationed close to a mobile VLBI mark, is mounted on a dedicated concrete pillar on bedrock with forced centering plate.

The GPS receiver is operated and monitored by OCA personnel; data are retrieved daily by the Toulouse Operational Center through the Internet.

Hartebeesthoek

The Rogue SNR-8 at Hartebeesthoek, Rep. of South Africa, has been continuously tracking GPS satellites since January 1991. The receiver is set up at the CNES satellite tracking station, near the radio observatory of Hartebeesthoek, which provides a VLBI reference point.

This GPS station was part of the 6-station Global Network for the TOPEX-Poseidon project. It is operated and monitored by Satellite Applications Center personnel from CSIR, who also staff the CNES satellite tracking station 24 hours a day. Raw data are transferred daily to Toulouse through a permanent link set up for satellite tracking applications. The allocated bandwidth for GPS data is 9600 bps.

Kerguelen

A Rogue SNR-8C (mini-rogue) has been operational since mid-November 1994 in the Kerguelen islands, in the southern Indian Ocean. The site is located on the main island, at Port-aux-Français, in IFRTP (Institut Français pour la Recherche et la Technologies Polaires) facilities and close to a CNES satellite tracking station.

The receiver is operated and monitored by IFRTP personnel from the Geophysics Laboratory. Raw data are transferred daily to Toulouse through a permanent link set up for satellite tracking applications. The allocated bandwidth for GPS data is 9600 bps.

Pamatai

The Rogue SNR-800 at Pamatai on the French Polynesian island of Tahiti has been continuously tracking GPS satellites since January 1992. The receiver is set up in the facilities of the CEA (Commissariats à L'Énergie Atomique) Geophysics Laboratory (LDG).

The receiver is operated and monitored by LDG personnel. Raw data are transferred daily to Toulouse through a NUMERIS type link (64 bps). NUMERIS is a service for data transfer offered to general customers by France Telecom.

Receiver Tracking Performance

During the year 1994, two major anomalies occurred, which degraded network tracking performance.

The first anomaly occurred in July at Pamatai when the receiver software was upgraded to Meenix 7.8; 7 days of tracking were lost. The second anomaly occurred in December at Hartebeesthoek, when lightning struck and damaged the GPS antenna. Tracking was interrupted on December 17 and resumed after the antenna was changed on January 27.

No anomaly was recorded at Kerguelen from mid-November to December 31, 1994. For 1994, the overall tracking success rates are the following:

HARTEBEESTHOEK	95.6 %
KERGUELEN	***100 %***
PAMATAI	97,6 %

Contribution from GPS Station in Brussels (BRUS)

Carine Bruyninx
Observatoire Royal de Belgique
Brussels, Belgium

The Royal Observatory of Belgium (ROB) has a long tradition of collaboration in astronomical and geodetic international campaigns. The ROB participated in the BIH observations for time and latitude determinations and in the first European geodetic network (WEST) developed for satellite observations, from 1966 to 1971. From 1972 to 1993, as a station of the DMANTC TRANET network, permanent tracking of Transit satellites was conducted at ROB. From 1989, GPS measurements were carried out in the frame of the international EUREF89, EUREF-NORTH, EPOCH92, EUREF-L-D-B94 campaigns and different national GPS campaigns.

A TurboRogue receiver, permanently operating at the ROB in Brussels, has been included in the IGS network since November 1993. The data are processed by the CODE processing center.

In support of the deployment of a GPS zero-order geodetic network (30 stations), by the Belgian Geographical Institute, and due to a growing interest of the Belgian GPS user community, three more permanent TurboRogue receivers were installed in Belgium during 1994. All four receivers are now operating permanently and the data are processed daily at the ROB with the Bernese software and self-developed programs. Besides the objective defined above, the principal goals are the study of the ionosphere and the determination of precise station coordinates in an international reference frame, allowing the study of correlations between the coordinate variations and other geophysical phenomena.

The IGS station in Brussels is very interesting from a geophysical point of view because of the collocation with other geophysical instruments, A TRANET station was operating on the same site from 1972 to October 1993, showing better than 90% agreement between ionospheric disturbances calculated from Doppler measurements and earlier GPS measurements. A superconducting gravimeter has been continuously recording at the ROB and until now absolute gravity measurements were carried out twice a year. In 1996 an absolute gravimeter is expected to be operating on a regular basis. Ground water level variations are monitored and seismic measurements are continuously made on site. At the same site, the Belgian Royal Meteorological Institute measures the meteorological parameters which influence the GPS signal several times a day. Precise frequency is made available to the GPS receiver by an H-maser.

Until now the three permanent stations (beside Brussels) have only been included in the EUREF-L-D-B-94 network; the calculation of precise ETRF89 coordinates is in progress. In the meantime all four sites were included in the national densification of ETRF89 (1994). In this way the four permanent stations are the backbone of the Belgian national zero-order geodetic network based on GPS measurements. Thanks to their permanent character the calculation of their ITRF coordinates and associated changes are now in progress.

The Belgian fundamental point for leveling is located at the ROB and the GPS station is a fundamental part of the national zero-order GPS network.

In this way the GPS station at the ROB combines the national and international aspect of GPS and offers collocation with a variety of other geophysical instrumentation.

University of Padova (UPAD)

Alessandro Caporali
University of Padova
Padova, Italy

The station UPAD started tracking activities at the experimental level in January 1994, with the official start of the IGS. The antenna of the Trimble 4000SSE receiver was originally mounted above the dome of an unused astronomical observatory in downtown Padova, on the roof of the University's main building. This site was selected because of its unobstructed horizon, nominal quality of the GPS data and logistic facilities provided by the University. The site was assigned the DOMES number 12750M001.

Late in 1994 the radio frequency environment worsened to the extent that the data became unusable. Fortunately it turned out that it was sufficient to move the antenna just few meters apart from the DOMES 12750M001 location to re-establish normal tracking conditions. The new site was monumented and a new site description was submitted to the IGS. The DOMES number of this new site, in effect since January 1995, is 12750 MO02.

In 1994 extensive work was done to improve communications. The receiver was interfaced to a PC via an RS232 port at 38.4 Kbaud. From the PC the data were originally sent to the VAX of the University Computer Center, via modem connection through the local phone network of the University. The download process required almost two hours daily but proved reliable and gave a lot of experience on automating procedures via modem. Late in 1994 an Ethernet connection with the VAX was cabled up to the receiver and data download improved in speed considerably. It was decided to keep the modem procedure as a backup.

As of February 1995 we considered the experimental phase concluded. Daily RINEX files are compressed in accordance with the IGS standards, are checked with the QC program of UNAVCO, and are sent to the regional Data Center of the Italian Space Agency in Matera, where they arrive normally between 00:30 and 00:45 UTC. From there they are relayed to IfAG in Frankfurt.

Besides the contribution to the IGS, support to local projects is provided in the following fields:

- applied geology: in the Euganei Hills, about 15 km from Padova, water pumping results in subsidence. A structural model of the deformation uses height changes determined by a local network of GPS receivers which make reference to the IGS site UPAD;
- cadastral survey: roving single-frequency GPS receivers are used by surveyors to map borders of plots of land. Updated measurements of the areas are obtained in support of the management of agricultural resources. The UPAD station serves as unique reference for all local surveys;
- aircraft navigation: two single frequency stations are operated in cooperation with the Local Command of the Air Traffic Control to experiment on the procedures for monitoring the integrity of the GPS signals by repeated computation of the baselines joining the receivers to the UPAD site.

Future plans include the improvement of the capability to provide, at the UPAD site, GPS related services to the local community, such as GPS data and ephemeris, gravity, trigonometric and leveling data, geoidal undulations and digital terrain models.

GL/NOAA Operational Data Center

Miranda Chin
National Oceanic and Atmospheric Administration
Silver Spring, Maryland

BERMUDA

4_Char_Id: BRMU IERS DOMES Number: 42501S004

Geographical Location: The station is located at the Bermuda Biological Station for Research of Bermuda Island.

Operation Agency: GL/NOAA Operational Data Center (GODC)

Site Description: The GPS station is located in the Wright Hall building. The tracking system was established on March 12, 1993.

GPS Tracking System Configuration

Receiver (type: Rogue SNR-8000, serial #: T307, firmware: 3.2)
Antenna (type: Dome Margolin T, serial #: 148)
PC (type: 386)
Uninterrupted power supply (UPS)
High speed modem (type: Telebit Trailblazer+)

System Installation

Antenna Installation: The antenna is mounted on the roof of the Wright Hall building.

Receiver Installation: The receiver is located inside an office of the building and is connected to a UPS unit, The operation remote control and the data communication to the receiver are provided by a PC which directly connects to the receiver via an RS232 cable.

```
                                        Operation Remote Control
1---------1         1-----1                   1-----1
|antenna|--||---|   U P S  |---|     |-------|modem|----------|
1---------1  I  I   1-----1  I  I         1-----1              |
      |----------          1---------1
      |  receiver  <----->|  On_site  |                 1---------1
      1----------    RS232  | PC      1--------------------[  GODC |
                           1---------1    Internet      1---------1
                                        Data Communication Route
```

Tracking Configuration

The *receiver* is operating in fixed position mode and is continuously recording measurements every 30 seconds onto the flash card. The clock steering capability is enabled.

Data Communication

The daily tracking data are downloaded from the receiver to the on-site PC at 00:10 UTC; then the data are forwarded to GODC for rinexing and distribution.

```
1----------1 00:10 |------------| Inter|---------|Inter 1-------1
| Receiver |------->| on_site  PC |<------| GODC |----->| CDDIS |
1----------1 RS232 1------------1 Net 1---------1 Net 1-------1
```

Data Availability

On-line data sets: Copies of the raw and RINEX data sets are available on-line through GODC; the access information can be found inthe GODCreport.

Off-line data sets: Two copies of data sets collected more than 200 days prior are stored on optical disks and DAT tapes.

Other Geodetic Measurements

Mobile Laser, Mobile VLBI

FORTALEZA

4_Char_Id: FORT IERS DOMES Number: 41602M001
Monument Inscription: SAT92009

Geographical Location: The station is located at the Instituto National de Pesquisas Espaciais (INPE) site in Eusebio which is approximately 22.7 km southeast of the city of Fortaleza in the state of Ceara on the Atlantic coast of northeastern Brazil.

Operation Agencies: The daily operation is provided by INPE at Fortaleza, Brazil and by GL/NOAA Operational Data Center (GODC).

Site Description: The GPS site was established on May 13, 1993. A local control survey was conducted in September 1993. In this survey vectors between the GPS monument, the VLBI reference point, and four additional geodetic control points were determined.

GPS Tracking System Configuration

Receiver (type: Rogue SNR-8000, serial #: T119, firmware v: 2.8)
Antenna (type: Dome Margolin T, serial #: 119)
PC (type: Compaq 386/20)
External frequency standard (type: Hydrogen maser)
Uninterrupted power supply (UPS)
High speed modem (type: Telebit Trailblazer+)

System Installation

Monument location and description: The monument is a standard IBGE disk star-drilled in the concrete roof of the eastern-most observatory building. It is about 0.4 m south of the north edge of the building and 0.4 m east of the west edge of the building.

Antenna Installation: The Dome Margolin T chokering antenna is located on top of an aluminum platform. The platform is supported by two sides of the building and a pole. A fiber plastic cone shape dome is used for covering the antenna.

Receiver Installation: The Rogue SNR-8000 is located inside the main office building. A 5-MHz output from a maser clock is connected to the receiver lpps input. The data communication is provided by a PC which directly connects to the receiver via an RS232 cable.

```
                                  1-----1
                               ---|UPS |-----|
     1---------1               |   |-----|   |
     | antenna |-------1  |                   |
     1---------1        1----------1 RS232 1-------1       1-----1
                        | receiver |<------>|on_site|---->|modem|
                        1----------1        | PC    |      1-----1
       |-------            | lpps           1-------1
       | maser  --------                    Data Communication
       |-------|   5MHz
```

Tracking Configuration

The receiver is operating in fixed position mode and is continuously recording measurements every 30 seconds onto the flash card. The digital potentiometer is disabled.

Data Communication

Step 1. The daily tracking data are downloaded from the receiver to the on-site PC at 00:10 UTC. Then the data are forwarded to the computer at the Federal University of Ceara in Fortaleza (UFC) via a high speed modem.

```
1----------1  00:10 1------------1       1-----1
| Receiver |------->| on_site PC|------>| UFC |
1----------1  RS232 1------------1 modem|-----|
```

Step 2. The computer at ATSME/INPE gets the data from UFC and then transfers them to the HP 755 computer at GODC via the Internet for data processing and distribution.

```
|------| Internet |----------|Internet |---------|     1-------1
| UFC  |<--------- |ATSME/INPE| -------->| GODC    |---->| CDDIS |
1------1            1----------1          1---------1    1-------1
```

Data Availability

On-line data sets: Copies of the raw and RINEX data sets are available on-line through GODC; the access information can be found in the GODC report.

Off-line data sets: Two copies of data sets collected 200 days prior are stored on optical disks and DAT tapes.

Other Geodetic Measurements

VLBI, Absolute Gravity

RICHMOND

4_Char_Id: RCM5 IERS DOMES Number: 40499S018

Geographical Location: The station is located at the U.S. Naval Observatory Time Service Substation in Perrine which is approximately 25 miles south of Miami, Florida.

Operation Agency: GL/NOAA Operational Data Center (GODC)

Site Description: A number of GPS systems have been installed at this station since February 1988. The current system was established on October 11, 1993.

GPS Tracking System Configuration

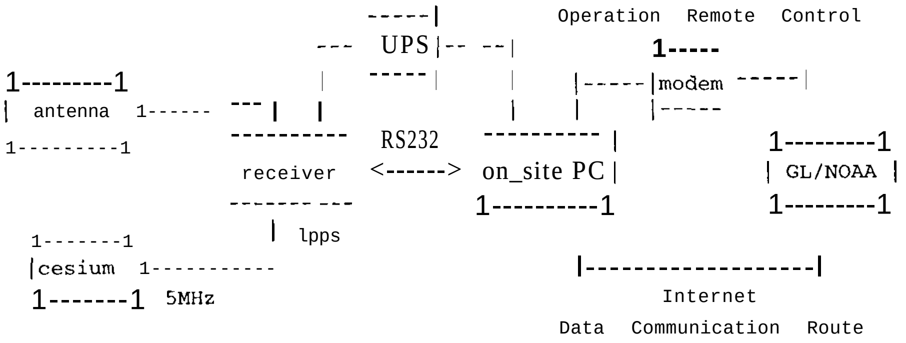
Receiver (type: Rogue SNR-8000, serial #: T160, firmware: 3.0.32.2)
Antenna (type: Dome Margolin T, serial #: 148)
PC (type: 386)
External frequency standard (type: cesium)
Uninterrupted power supply (UPS)
High speed modem (type: Telebit Trailblazer+)

RCM5 *System Installation*

Monument location and description: The monument is located at the east end of the main office building and is a combination of a ground plane and a galvanized pipe. The ground plane is made of a one meter square plate of aluminum. A punch hole in the center marks a permanent location for mounting the antenna. This ground plane is mounted on top of a galvanized pipe. The pipe is held by two brackets to the wall of the building, set in cement in the ground.

Antenna Installation: The antenna is held in place by a 48-cm stainless steel ring. A spike is used to position the antenna to the punch hole in the center of the ground plane. Then the ring is held onto the ground plane by three stainless steel studs which are also used to level the antenna. In addition, four tabs are used to reinforced the antenna onto the ring.

Receiver Installation: The receiver is located inside the main office building. A 5-MHz line from a cesium clock is connected to the receiver 1pps input. The operation remote control and the data communication to the receiver are provided by a PC which directly connects to the receiver via an RS232 cable.



Tracking Configuration

The receiver is operating in fixed position mode and is continuously recording measurements every 30 seconds onto the flash card. The clock steering capability is disabled.

Data ***Communication***

The daily tracking data are downloaded from the receiver to the on-site PC at 00:10 UTC; then the data are forwarded to GODC for rinexing and distribution.

```
1----------1 00:10 |------------| Inter |---------  |Inter 1-------1
| Receiver |------->| on_site PC |<------| GODC     |----->| CDDIS |
1----------1 RS232 1------------1 Net 1---------1 Net 1-------1
```

Data Availability

On-line data sets: Copies of the raw and RINEX data sets are available on-line through GODC; the access information can be found in the GODC report.

Off-line data sets: Two copies of data sets collected more than 200 days prior are stored on optical disks and DAT tapes.

Other Geodetic Measurements

VLBI – From December 1983 to August 1992.
Absolute Gravity – Measurements were taken in 1989, 1990, and 1991.
SLR - Mobile Laser
DORIS

WESTFORD

4_Char_Id: WES2 IERS DOMES Number: 40440S020

Geographical Location: The station is located at the Haystack Observatory in Westford which is about 48 km northwest of Boston, Massachusetts.

Operation Agency: GL/NOAA Operational Data Center (GODC)

Site Description: The GPS station is on the right side of the road after entering the Observatory. Various GPS systems have been installed at the site since October 1986. The current system was established on February 8, 1993; the antenna position, WES2, was surveyed to the local control points and also determined by the global GPS tracking network.

GPS Tracking System Configuration

Receiver (type: Rogue SNR-8000, serial #: T109, firmware: 3.0.32.2)
Antenna (type: Dome Margolin T, serial #: 145)
PC (type: COMPAQ 386)
External frequency standard (type: maser)
Uninterrupted power supply (UPS)
High speed modem (type: Telebit Trailblazer+)

System Installation

Antenna Installation: The antenna was mounted on a steel tower about 60 m away from the northeast corner of the Westford VLBI office building.

Receiver Installation: The receiver is located inside the Westford office building. The 5-MHz output from a maser is plugged into the lpps input in the back of the receiver panel. The data communication and the operation monitoring of the receiver are provided by the PC which directly connects to the receiver via an RS232 cable.

```
                           1-----1            Operation Remote Control
                         |--| UPS |-----|             1-----1
 1-----"----1            |  |-·---|     |    |-------|modem|-----|
 | antenna |------||                     |    |        1-----1     |
 1---------1        |----------  RS232  1----------1          1---------1
                    | receiver  <------>|on_site PC|              GODC
                    1----------         1----------1          1---------1
  1-------1           | lpps                    1----------1
  | maser |-------                       |------| Haystack |------|
  |-------| 5MHz                          LAN | network | Internet
                                                1---------'-1
                                          Data Communication Route
```

Tracking Configuration

The receiver is operating infixed position mode andiscontinuously recording measurements every30 seconds ontotheflash card. The clock steering capability is disabled.

Data Communication

The daily tracking data are downloaded from the receiver to the on-site PC at 00:10 UTC. From the PC the data are transferred to a Haystack computer then forwarded to GODC for processing and distribution.

```
 1---------1       |---------         1-----------1      |------
    TR     |00:10 | On_site                GODC             | IGS/
 | Receiver |------>| P C          |-->|             |---->|CDDIS
 |----------|RS232 1---------      | 1-----------1      |------
                                   | Internet         Internet
                 LAN          --------
                             | Haystack
                         --->| network
                             1--------
```

Data Availability

On-line data sets: Copies of the raw and RINEX data sets are available on-line through GPDC; the access information can be found in the GODC report.

Off-line data sets: Two copies of data sets collected more than 200 days prior are stored on optical disks and DAT tapes.

Other Geodetic Measurements

VLBI, Absolute Gravity, Mobile Laser

NRCan (GSD) Operational Stations

Robert Duval
Geodetic Survey Division, Natural Resources Canada
Ottawa, Ontario

Algonquin

Station:	ALGO
Full Name:	ALGONQUIN
GSD No:	883160
Domes No:	401 04M002
CDP No:	N/A
Location:	Algonquin Park, Ontario, Canada
Lat:	N 45°57'20.8"
Long:	W 78°04'16.9"
Agency:	Geodetic Survey Division Natural Resources Canada 615 Booth Street Ottawa, Ontario Canada K1A 0E9
Contact:	Robert Duval
Telephone:	(613) 947-2786
E-mail:	duval@geod.nrcan.gc.ca

ALGO is collocated with the permanent VLBI installation (46-m dish) located on the property of Algonquin Space Complex in the Algonquin Park approximately 160 km west of Ottawa, Ontario. The GPS station has been in operation since January 1991. In addition to GPS observations and VLBI experiments, Satellite Laser Ranging and absolute gravity observations have been carried out at the site. ALGO is located on the North American plate.

The GPS reference mark consists of a brass plate with a forced centring stainless steel bolt embedded on top of a 2-m concrete pier, 40 cm in diameter. The concrete pier is anchored to exposed bedrock by a steel casing to a depth of 10 m.

A local reference network of 14 points within a 200-m radius is used to monitor the offsets between the GPS marker and the collocated system markers as well as for studies of the site stability through periodic resurvey. These surveys are carried out by conventional surveying techniques according to special order specifications. This local network is linked to four stations within a 10-km radius that provide connection to the Canadian Geodetic control network for monitoring of regional stability.

As of March 1995 ALGO is equipped with a dual-frequency, eight-channel AOA SNR-8000 TurboRogue GPS receiver. The Dome Margolin antenna with choke rings is mounted to the reference mark using a 10-cm-high anodized aluminum cylinder. This mount provides a constant height above the reference mark and also allows the antenna to be oriented. Reference frequency is provided by an external Hydrogen Maser frequency standard shared with the VLBI installation. A meteorological sensor unit records data every 15 minutes.

Data communication to the site is provided through the wide-area Anikom 200 satellite link operated by Telesat Canada using CCITT standard X.25

asynchronous packet data communications. At the site, a X.25 packet assembler disassembler (PAD) interfaces with the receiver and the met sensor unit. From Telesat facilities in Ottawa data is routed to GSD via DATAPAC, a public packet switching network.

Technical Summary

As of March 31, 1995:

GPS Receiver:	ROGUE SNR-8000 Rcvr s/n 226
Firmware:	Version 3.0.32.2
Antenna:	AOA Dome Margolin T s/n 173
Antenna Height:	0.100 m (from reference mark to base of antenna assembly)
Clock:	Hydrogen Maser
Meteorological data:	Temperature, humidity and pressure recorded every 15 minutes
Collocation:	VLBI (CDP no 7282, DOMES no 40104S001, GSD no 683100) SLR (CDP no 7410, GSD no 933000) Absolute Gravity (Geological Survey of Canada)

St. John's

Station:	STJO
Full Name:	ST. JOHN'S
GSD No:	920000
Domes No:	401 01M001
CDP No:	N/A
Location:	St. John's, Newfoundland, Canada
Lat:	N 47°35'42.8"
Long:	W 52°40'39.9"
Agency:	Geodetic Survey Division Natural Resources Canada 615 Booth Street Ottawa, Ontario Canada KIA OE9
Contact:	Robert Duval
Telephone:	(613) 947-2786
E-mail:	duval@geod.nrcan.gc.ca

STJO is located at the Geological Survey of Canada (NRCan) geomagnetic observing station in St. John's, Newfoundland. The GPS station has been in operation since May 1992. STJO is located on the North American plate.

The GPS reference mark consists of a brass plate with a forced centring stainless steel bolt embedded on top of a 1.5-m concrete pier, 40 cm in diameter. The concrete pier is anchored to exposed bedrock by stainless steel reinforcing bars to a depth of 3 m.

A local reference network of three points within a 150-m radius is used for monitoring the local stability of the site through periodic resurvey. These surveys are carried out by conventional surveying techniques according to special order specifications.

As of March 1995 STJO is equipped with a dual-frequency, eight-channel AOA SNR-8000 TurboRogue GPS receiver. The Dome Margolin antenna with choke rings is mounted to the reference mark using a 10-cm-high anodized aluminum cylinder. This mount provides a constant height above the reference mark and also allows the antenna to be oriented. Reference frequency is provided by an external Rubidium frequency standard.

Data communication to the site uses high-speed modems over terrestrial data lines.

Technical Summary

As of March 31, 1995:

GPS Receiver:	ROGUE SNR-8000 Rcvr s/n 161
Firmware:	Version 3.0.32.2
Antenna:	AOA Dome Margolin T s/n 171
Antenna Height:	0.100 m (from reference mark to base of antenna assembly)
Clock:	AOA Rubidium frequency standard s/n 116
Meteorological data:	None
Collocation:	Geomagnetic observatory (Geological Survey of Canada)

Yellowknife

Station:	YELL
Full Name:	YELLOWKNIFE
GSD No:	889201
Domes No:	40127MO03
CDP No:	N/A
Location:	Yellowknife, N. W. T., Canada
Lat:	N 62°28'51.2"
Long:	W 114°28'50.4"
Agency:	Geodetic Survey Division Natural Resources Canada 615 Booth Street Ottawa, Ontario Canada K1A 0E9
Contact:	Robert Duval
Telephone:	(613) 947-2786
E-mail:	duval@geod.nrcan.gc.ca

YELL is collocated with the semi-permanent VLBI installation (MV-1 mobile unit, 9-m dish) located at the Geological Survey of Canada Geophysical Laboratory (Seismic Station) in Yellowknife, N.W.T. The GPS station has been in operation since January 1991. In addition to GPS and VLBI installations, a DORIS transmitting station, an absolute gravity station, a permanent geomagnetic observatory and a seismic array are located at the site. YELL is located on the North American plate.

The GPS reference mark consists of a brass plate with a forced centring stainless steel bolt embedded on top of a 1.8-m concrete pier, 40 cm in diameter. The concrete pier is anchored to exposed bedrock by steel reinforcing bars to a depth of 50 cm.

A local reference network of 12 points within a 350-m radius is used to monitor the offsets between the GPS marker and the collocated system markers as well as for studies of the site stability through periodic resurvey. These surveys are carried out by conventional surveying techniques according to special order specifications. This local network is linked to the Canadian geodetic control network.

As of March 1995 YELL is equipped with a dual-frequency, eight-channel AOA SNR-8000 TurboRogue GPS receiver. A Dome Margolin antenna with choke rings is mounted to the reference mark using a 10-cm-high anodized aluminum cylinder. This mount provides a constant height above the reference mark and also allows the antenna to be oriented. Reference frequency is provided by an external Hydrogen Maser frequency standard shared with the VLBI installation. A meteorological sensor unit records data every 15 minutes.

Data communication to the site is provide through the wide-area Anikom 200 satellite link operated by Telesat Canada using CCITT standard X.25 asynchronous packet data communications. At the site, a X.25 packet assembler disassembler (PAD) interfaces with the receiver and the met sensor unit. From Telesat facilities in Ottawa data is routed to GSD via DATAPAC, a public packet switching network.

Technical Summary

As of March 31, 1995:

GPS Receiver:	ROGUE SNR-8000 Rcvr s/n 302
Firmware:	Version 2.8.32.1
Antenna:	AOA Dome Margolin T s/n 273
Antenna Height:	0.100 m (from reference mark to base of antenna assembly)
Clock:	Hydrogen Maser
Meteorological data:	Temperature, humidity and pressure recorded every 15 minutes
Collocation:	VLBI (CDP no 7296, DOMES no.40127MO04, GSD no 909012) VLBI (CDP no.7285, DOMES no.40127M001, GSD no 829098) DORIS Absolute Gravity Seismic Array Geomagnetic Observatory

Sites in Kitab and Potsdam

Roman Galas and Christoph Reigber
Department of Kinematics and Dynamics of the Earth, GeoForschungsZentrum
Potsdam, Germany

Kitab

The Kitab (Uzbekistan) IGS Core Station (KIT3) has been jointly operated by GFZ and the Kitab Latitude Station since October 2, 1994. The GPS antenna is placed a few meters apart from the Visual Zenith Telescope, which was operated in the International Polar Motion Service for about 80 years and was used, together with four other stations, for the definition of the CIO 1900-05.

Two other satellite tracking systems are permanently colocated with the GPS, a PRARE ground station and a DORIS beacon.

The station is equipped with:

- Turbo Rogue SNR 8000 receiver, S/W Version 2.8.32.1X
- Automatic meteorologic sensor
- Inmarsat A Mobile Terminal
- Computer with modems and software for automatic data download and for HSD (64k) transfer via Inmarsat A service.

In 1994 the station was operating nearly automatically. A permanently running program on the Inmarsat-computer downloads the GPS data (CONAN Binary Format) every midnight. After compression, they are routed to the Inmarsat Earth Station in Eik (Norway). From there the data reach the Base Station in Potsdam through ISDN. The transfer of one day's data, including establishing the connections, takes about 1 minute. After decoding and converting the data, in the GFZ Operational Data Center to the RINEX format, the daily files are sent to the Regional Data Center in IfAG (Frankfurt) and to the Global Data Center CDDIS (Greenbelt).

Potsdam

The IGS station in Potsdam (POTS) is located in the campus of the GeoForschungsZentrum on the Telegrafenberg, and has also been operating in the IGS since October 2, 1994.

The station is equipped with:

- TurboRogue receiver, SNR-8000
- PC computer with interface to the LAN of GFZ.

The GPS antenna is placed on the geodetic pillar (old triangulation point on the roof of old Geodetic Institute (Building A17). The station operates in a fully automatic mode. Every midnight the data from the previous day is downloaded (CONAN Binary Format) and the RINEX daily files are sent through the Internet to the IGS Data Centers.

An SLR (7836) and PRARE system are also operating permanently, near the GPS, with known differential coordinates to the GPS Mark.

Some construction work on the geodetic/GPS pillar caused the station to be out of service between days 287 and 300 of 1994, and the antenna height was changed as follows:

Between the days 275–286:	h = 0.168 m
From day 301 onwards:	h = 0.046 m

In December 1994 the receiver software version was updated:

Between the days 275–353:	2.8.32.1X
From day 354 onwards:	***3.0***

Since October 2, 1994 the data from both stations, **Kitab** and **Potsdam,** are available at the CDDIS, IfAG, and IGN Data Centers with average delay of **1** day. Starting with day 275 of 1994 RINEX files are also available directly from Potsdam. The GFZ Operational Data Center is easily accessible through anonymous ftp at the Internet address 139.17.1.7 under the directory pub/home/**kg/gpsdata**.

The GPS Receiver Network of ESOC: Maspalomas, Kourou, Kiruna, Perth, and Villafranca

C. Garcia-Martinez, J. M. Dow, T. Martin-Mur, J. Feltens, and M. A. Bayona-Perez
European Space Operations Center
Darmstadt, Germany

ESOC is currently involved in the establishment of a network of high-precision geodetic receivers on ESA ground sites. So far, five installations have been carried out at the sites of Maspalomas, Kourou, Kiruna, Perth, and Villafranca. The establishment of this network is one of the objectives of the ESA GPS-TDAF (Tracking and Data Analysis Facility). Figure 1 shows the geographical distribution of the receivers.

ESOC GPS RECEIVERS

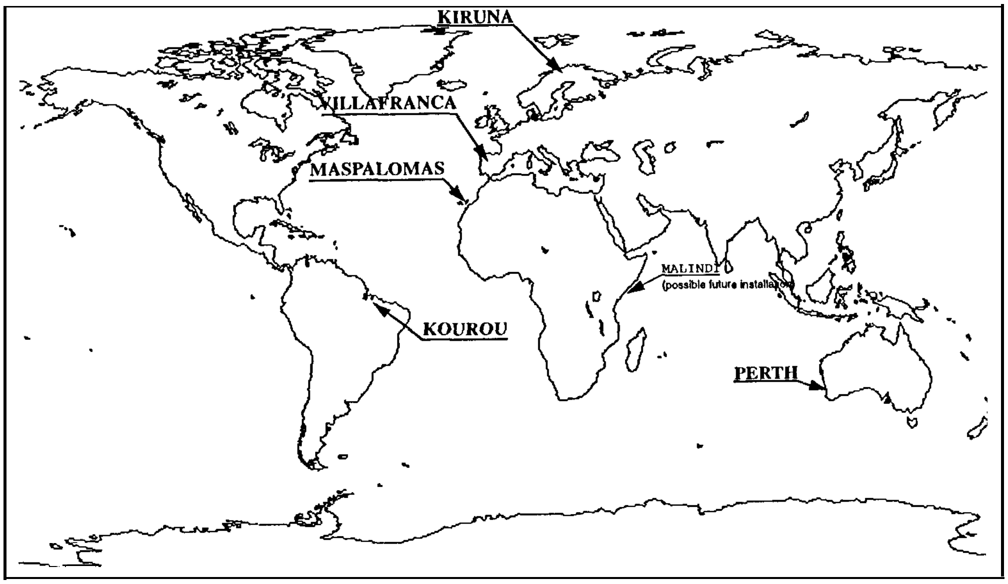


Figure 1.

Location of the Receivers

The ESOC receivers are being installed at the ESA ground stations. In this way they can take advantage of the facilities that the stations provide. They are integrated in racks in rooms with temperature and humidity control, connected to the frequency standards of the stations and to the permanent communication links between the stations and the control center at ESOC. They also provide, along with the rest of the GPS-TDAF, several additional services. Examples are the monitoring of the behavior of the timing system, the 1PPS output, and the ionosphere monitoring over the station.

Maspalomas

The GPS receiver is installed at the Maspalomas ground station, the property of the Spanish institute INTA. It is located in the southern part of the Gran Canaria Island, municipal district of San Bartolome de Tirajana, Spain. The site is approximately 1750 m from the coast.

Kourou

The GPS receiver is installed at the ESA Kourou Diane station located about 27 km from the town of Kourou, in French Guiana.

Kiruna

The GPS receiver is installed in the ESA Kiruna ground station, located at Salmijarvi, 38 km east of Kiruna in northern Sweden.

Perth

The receiver is located at the ESA Perth station, approximately 20 km north of the city of Perth on the western coast of Australia. The station is situated on the Perth International Telecommunications Centre Complex, operated by Telstra Corporation Limited,

Villa franca

The receiver is situated in the Villafranca (VILSPA) ground station, located in Villafranca del Castillo, 30 km west of Madrid, Spain.

History and Evolution

The development of the network started at the beginning of 1992 when two MiniRogues (SNR-8C), the most advanced receiver then, were ordered from AOA. After a period of testing in ESOC, the first installation was completed in the week before the start of the IGS campaign at Maspalomas. Data were available from June 22, 1992. The antenna was mounted on a monument, belonging to the Spanish IGN, that participated in several geodetic campaigns with the marker name MPA1. For IGS the selected marker name was MASP.

ESOC constructed another monument and on April 11, 1994 installed a new GPS system with a TurboRogue SNR-81OO. Both systems were operated in parallel for several weeks until the decommission of the old receiver. The marker name of the new monument is MAS1 and the IERS DOMES Number 31303MO02 was assigned to it.

The second of the MiniRogues was installed late July 1992 at Kourou. Initially the data were downloaded directly from the receiver to ESOC using Telebit modems, Unfortunately the quality of the public telephone lines between Europe and French Guiana were very irregular. The data were obtained for a period of 10 days in August, and sporadically thereafter. Attempts made from Pasadena to dial up the Kourou modem were also unsuccessful. The low transfer rates and the irregular quality of the telephone lines made very problematic the completion of the file transfers using XMODEM. A new solution had to be implemented. It was based on the permanent links between the station and the control center ESOC shared by several ESA projects. The regular operation of the receiver started on October 18, 1992 when the connection to the new data link was completed. During the period when communications were not possible, a permanent concrete monument was constructed for the antenna there (see IGS mail No. 144). The antenna was moved by about -3.0 m, -1.1 m, 1.1 m in longitude, latitude, and height, respectively, from its previous position. The software of the MiniRogue was upgraded to version 7.8 on October 6, 1994. The receiver has been operated permanently without hardware problems for almost two-and-a-half years.

Another set of five receivers, this time TurboRogues, was ordered at the end of 1992. After the testing period in ESOC, the first receiver was dispatched to Kiruna and installed in July 1993. The receiver was placed in a building several meters away from the main building of the station. From here the distance to the monument is shorter. The monument is on top of a slope surrounded by trees.

The second TurboRogue installation was performed on August 13, 1993 at Perth. Unfortunately, a few days after the beginning of the operation, the receiver was damaged during a lightning storm on September 3, 1993. A new receiver was immediately delivered. The grounding of the antenna has been improved to avoid the same problem happening again. The original receiver and antenna were repaired and reinstalled on April 27, 1994.

The last installation was Villafranca, on November 12, 1994. At this site the cabling from the monument to the racks of the main building, where the receiver is integrated, is about 150 meters long. This is 50 m longer than the standard setup of the receiver. This made necessary the installation of an additional line amplifier close to the antenna. With this modification the signal level has nominal values.

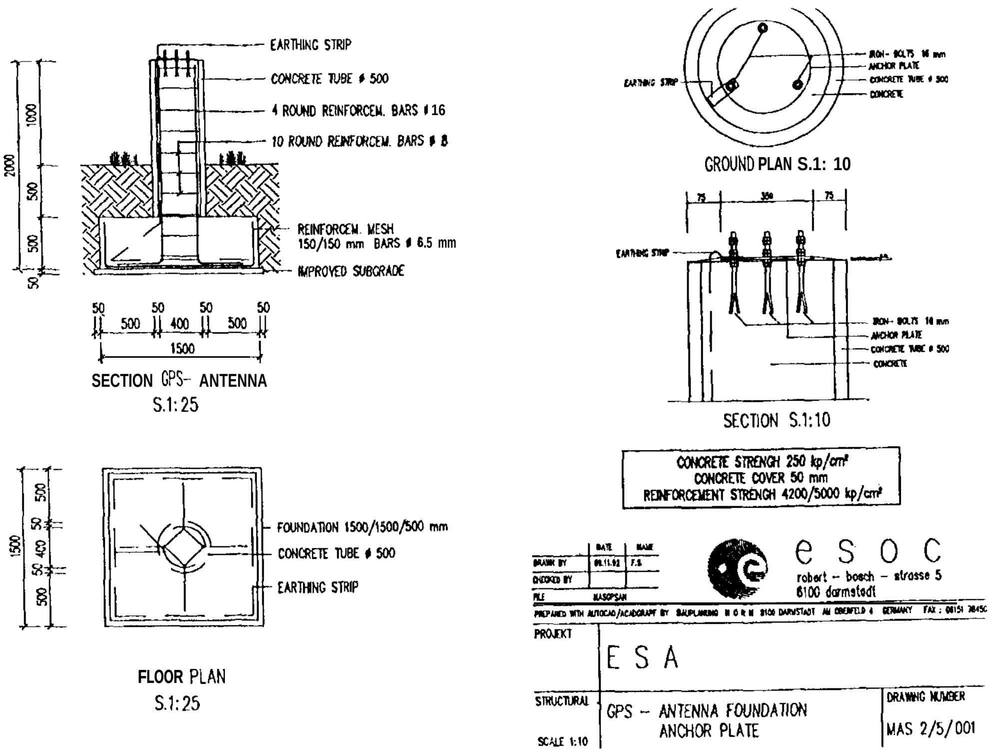


figure 2.

Monumentation

Figure 2 shows the monument specially developed for the GPS-TDAF. It is basically a reinforced concrete cylinder 50 cm in diameter that is situated over a foundation. On top of the cylinder there is an embedded horizontal metal plate. The marker is the center of this plate, on the upper surface.

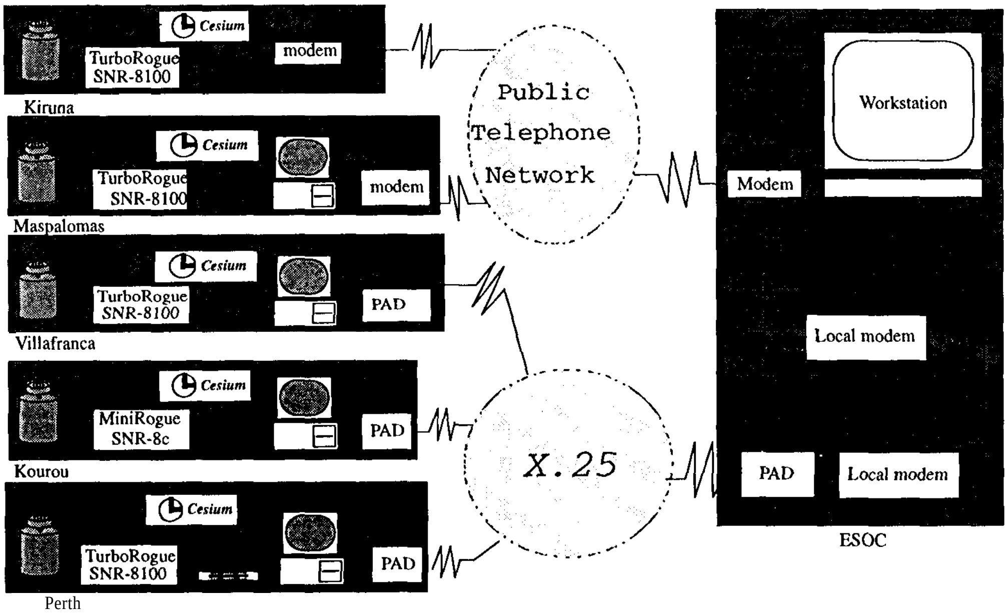
Three iron bolts fix the antenna mounting in a horizontal position. The antenna is screwed to the mounting.

Equipment

The physical configuration of all the equipment involved in the remote stations part of the GPS TDAF is summarized in Figure 3. The remote stations are continuously tracking the GPS satellites. The antenna is connected to the receiver normally with a standard 100-m RG-214 coaxial cable. Only Villafranca has a cable 150-m long, as remarked in the last section.

Figure 3.

GPS TDAF Pilot System Configuration



The timing system of the stations use a 5-MHz reference frequency. They are cesiums manufactured by OSCILLOQUARTZ with long-term drift controlled by timing GPS system.

There are two different receivers in the ESA stations. The MiniRogue SNR-8C, currently only at Kourou, and the TurboRogue SNR8100 at the rest of the stations. An effort is made to try to update them with the latest well-tested software releases. All the TurboRogues are currently (March 1995) running software version 2.8. The MiniRogue of Kourou runs Meenix 7.8 and Ruse 4.2.

One of the serial ports of the receivers is connected to a device that provides for communications and optionally for data storage. This device is a PC that runs a script of a communications package. Shortly after 00:00 UTC the PC downloads the data from the receiver with the XMODEM protocol, waits the remainder of the day for the call from the ESOC control center and allows the remote control of the computer.

There are two main reasons for the necessity of the intermediate device. First it buffers data. Several months of data can be stored on the disk. In addition it allows the data transfer to ESOC using a wide range of protocols. The XMODEM protocol, the only one supported by the receivers, is not suitable for the packet-switched networks that are sometimes involved in the communications with the control center. It also provides flow control with the DCE (Data Communication Equipment).

The communication with the receiver uses the same line that is used for data downloading. The commands are sent to the PC that stores them and immediately changes the active comm port to the one connected to the receiver, sends them, waits for the answer, and stores it. The active port is swapped, again to the one connected to the communication device and the answer of the receiver is echoed. Several attempts have been made with a secondary line (PAD or modem) connected to the free port of the receiver for interaction with it in terminal mode, but the system has been shown to be more reliable without this secondary link.

For the communications with ESOC the permanent links between ESOC and the stations are used whenever possible. They are very reliable and do not introduce additional costs due to the small amounts of data involved.

At ESOC there is one workstation with two serial ports. One is attached to a Telebit modem and the other to an internal LAN of ESOC that gives access to the ESA ground station via X.25/PAD. This workstation retrieves, decompresses, reformats, validates, archives, recompresses, and distributes the data automatically every day. The nominal time when all the processes are finished is 02:00 UTC.

The data are available to the IGS community in RINEX format via the official data centers.

In Maspalomas the receiver is a TurboRogue SNR-81OO. The antenna, Dome Margolin T, is mounted over a monument located several meters east of the main equipment room. The antenna height is 0.033 m. The data retrieval is performed with a Telebit T2500 modem. A PAD (Packet Assembler-Disassembler) that runs over a 64-Kbit/s line has been used in the past.

Kourou is the only one of the ESA stations with a MiniRogue SNR-8C. The antenna is Dome Margolin B with a height of 0.132 m and is located about 25 *m* from the main control room building.

Kiruna has a TurboRogue SNR-81OO and a Dome Margolin T antenna with a height of 0.062 m. The communications are performed with a Telebit T2500 that is directly connected to the TurboRogue. There are future plans for using a PAD and a remote PC as in the other ESA stations.

The TurboRogue of Perth is connected to a Dome Margolin T antenna with a height of 0.0595 m. The communications are carried out by means of a PAD that is situated in a different building of the station. To overcome this problem, two local modems had to be used. They provide for communications between PC and PAD.

Villafranca has also a TurboRogue with a Dome Margolin T antenna. The antenna height is in this case 0.0437 m.

Plans for the Future

There are currently three ESA sites that offer possibilities for future installations. They are Malindi (Kenya), Odenwald (Germany), and Redu

(Belgium). Because of its geographical position Malindi is the most interesting one for IGS. Nevertheless the other two sites, located in Europe, are also quite interesting for ESA. Currently there are very encouraging plans for the improvement of the communications with Malindi and a test with a receiver is being planned for May 1995.

References

GPS TDAF Stations Configuration Manual, Version 1.0, March 1993, ESOC.

Tsukuba

Yuki Hatanaka
Geographical Survey Institute
Tsukuba, Japan

Station Name: Tsukuba

4 char ID: TSKB
IERS DOMES Number: 21730S005

Site Specifications
  GPS Receiver
    Receiver Type: Rogue SNR-81OO (TurboRogue)
    Serial Number: 102
    Firmware Version: 2.8
  GPS Antenna
    Antenna Type: Dome Margolin T (with filter)
    Serial Number: 105
  Vertical Antenna Height: 0.0 m (Dee.15,1993-)
  Antenna Reference Point: Bottom of preamplifier
  Frequency Standard: Cesium 5 MHz
  Address: Kitasato-1, Tsukuba-shi, Ibaraki-ken, 305 Japan

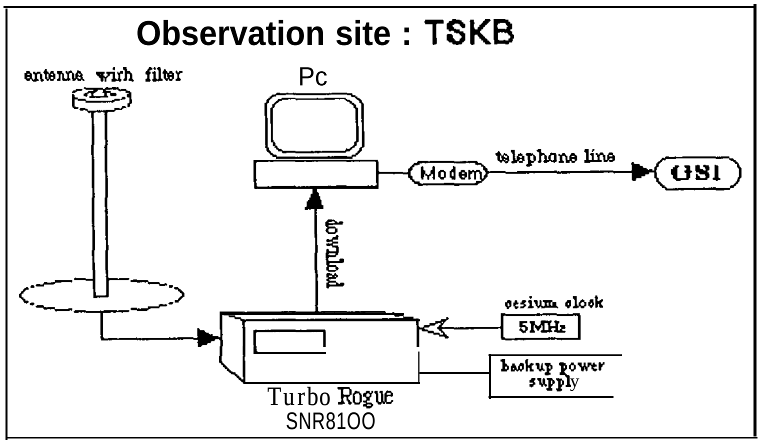


Figure 1.

Site problems in 1994

date	doy	description	IGS mail No.
Aug. 14–15	226–227	Antenna failure	0707
Oct. 22–23	295–296	Outage	0724

Point of Contact
  Agency: Geographical Survey Institute
  Contact: HATANAKA, Yuki
  Address: Kitasato-1, Tsukuba-shi, Ibaraki-ken 305, Japan
  Telephone: 81-298-64-1111 ex.4357
  E-mail: gps@geos.gsi-mc.go.jp
  Fax: 81-298-64-1802

AUSLIG Operational Data Center

Martin Hendy
Australian Surveying and Land Information Group
Belconnen, Australia

GPS Site at Casey Station in Antarctica

A permanent GPS receiver was installed at the Australian Antarctic Research Station Casey, in Wilkes Land, Antarctica in 1994. The monument *is* a concrete pad set in rock at ground level, 200 m west of the nearest station building. The site was chosen using aerial photography and station plans, such that the antenna had the best possible horizon, was away from any potential multipath from station buildings, was free of any potential snow drifts, and was within feasible distance of a building that could house the receiver and associated equipment. This is a permanent installation and was installed by AUSLIG field staff with the assistance of the Australian Antarctic Division.

The GPS antenna is permanently located on the new monument and is covered with an acrylic dome. Low-loss heliax antenna cable was used. The GPS system consists of a PC running the Linux operating system, a modem, and multiplexer. The PC logs data from the GPS receiver continuously and sends them back to Canberra using tcp/ip protocols over the Antarctic Division satellite link. Data are also stored on the receiver flashcard as per usual.

The remote system is fully automated and except for occasional firmware upgrades and system maintenance does not require human intervention. It is housed in the communications room at Casey and is supported by the station UPS system.

Due to the remote location of this site, and the infrequent resupply of the site, GPS receiver firmware upgrades and other system maintenance can only be done once a year during the Antarctic summer.

Station information as was submitted by email to IGS in July 1994 is as follows:

Station Information

Installation Date: July, 1994
Monument Mark: 16 mm stub in center of stainless steel plate set in concrete
Receiver Type: Rogue SNR-8100 (Turbo Rogue rackmount)
Receiver Software: V2.8.1.2
Frequency Reference: external rubidium
Antenna Height: 0.001 m (arp = base of antenna)
Approximate Station Coordinates:
(ITRF from an unconstrained global solution)

Lat: S 66” 17’ 00.0840”
Long: E 110" 31' 10.9385"
Ht : 22.741 m
x : - 901776.2558 m
Y: 2409383.7338 m
Z: -5816748.5915 m

Data Availability

Data for this site are available from:

```
ftp.auslig.gov.au
user = ftp
passwd = email address
cd gps/nnn          where nnn is the day of the year (1...366)
```

The site identifier is casl and the files are held in UNIX compressed format on a Sun Workstation.

GPS Site at the Australian Research Station Davis, Antarctica

A permanent GPS receiver has been installed at the Australian Antarctic Research Station–Davis, in Princess Elizabeth Land Antarctica. The monument is a stainless steel platform set in rock and raised off the rock by approximately 12 cm to prevent any drifting of snow. The GPS antenna is a permanent installation and is covered by an acrylic dome. It is located on a hill 60 m from the Atmospheric Physics Laboratory. Since the antenna is within a magnetic quiet zone due to the proximity of a sensitive magnetometer, the antenna platform was fabricated using a special high-grade stainless steel.

The site was chosen using aerial photography and station plans, such that the antenna had the best possible horizon, was away from any potential multipath from station buildings, was free of any potential snow drifts, and was within feasible distance of a building that could house the receiver and associated equipment. This is a permanent installation and was installed by Australian Antarctic Division expeditioners for AUSLIG.

RG214 antenna cable was used and is protected by above ground conduit. The GPS system consists of a PC running the Linux operating system, a modem and multiplexer. The PC logs data from the GPS receiver continuously and sends them back to Canberra using tcp/ip protocols over the Antarctic Division satellite link. Data are also stored on the receiver flashcard as per usual.

The remote system is fully automated and except for occasional firmware upgrades and system maintenance does not require human intervention. It is housed in the Atmospheric Physics Laboratory at Davis and is supported by the station UPS system.

Due to the remote location of this site, and the infrequent resupply of the site, GPS receiver firmware upgrades and other system maintenance can only be done once a year during the Antarctic summer.

Brief station information follows and a site report has been submitted to IGSCB.

Station Information

Installation Date: July 1994
Monument Mark: stainless steel plate set in concrete pillar
Receiver Type: Rogue SNR-8100 (Turbo Rogue rackmount)
Receiver Software: V2.8.1.2
Frequency Reference: external rubidium
Antenna Height: 0.0035 m (arp = base of antenna)
Approximate Station Coordinates:
(ITRF from an unconstrained global solution)

Lat: S 68° 34' 38.3552"
Long: E 77° 58' 21.4245"
Ht: 44.696 m
X: 486854.441 m
Y: 2285099.620 m
Z: -5914955.885 m

Data Availability

Data for this site are available from:

ftp.auslig.gov.au
user = ftp
passwd = email address
cd gps/nnn where nnn is the day of the year (1 . ..366)

The data are held on a Sun workstation in UNIX compressed RINEX files.

GPS Site at MacQuarie Island Research Station in the Sub-Antarctic

A permanent GPS receiver has been installed at the Australian Sub-Antarctic Research Station on MacQuarie Island, in the Southern Ocean. MacQuarie island is located at the boundary of the Australian and Antarctic plates. It is a small island with a very high rainfall and maritime climate.

The monument is a concrete pillar 1.2 m high and approximately 30 m from the Atmospheric Physics Laboratory. This is a permanent location.

The GPS antenna failed during 1994 due to corrosion damage and a new one was installed in June 1995 on a stainless steel mount which covers the top 200 mm of the pillar and which locates the GPS antenna precisely over the existing survey mark. The antenna will be protected by an acrylic dome and RG214 antenna cable was used.

The GPS system consists of a PC running the Linux operating system, a modem and multiplexer. The PC logs data from the GPS receiver continuously and sends them back to Canberra using tcp/ip protocols over the Antarctic Division satellite link. Data are also stored on the receiver flashcard as per usual.

The remote system is fully automated and except for occasional firmware upgrades and system maintenance does not require human intervention. It is housed in the Atmospheric Physics Laboratory and is supported by a UPS system.

Due to the remote location of this site, and the infrequent resupply of the site, GPS receiver firmware upgrades and other system maintenance can only be done once a year during the Antarctic summer.

Brief station information follows and a site report has been submitted to IGSCB.

Station Information

Installation Date: July 1994
Monument Mark: 16 mm stub in centre of stainless steel plate set in concrete pillar
Receiver Type: Rogue SNR-8100 (Turbo Rogue rackmount)
Receiver Software: V2.8.33.2

Frequency Reference: external rubidium
Antenna Height: 0.0675 m (arp = base of antenna)
Approximate Station Coordinates:
(ITRF from an unconstrained global solution)

Lat: S 54° 29' 58.3197"
Long: E 158" 56' 8.9915"
Ht: -6.590 m
X: -3464038.4828 m
Y: 1334172.9560 m
Z: -5169224.5040 m

Data Availability

Data forthis site are available from:

ftp.auslig.gov.au
user = ftp
passwd = email address
cd gps/nnn where nnnisthedayofyear (1 . ..366)

The data are held on a Sunworkstation in UNIXcompressed RINEX files.

GPS Site at Hobart, Tasmania, Australia

A permanent GPS receiver has been installed at the Mt. Pleasant VLBI observatory in Hobart, Tasmania, Australia. This receiver is approximately 150 m away from the previous CIGNET antenna location and the VLBI dish.

The site was chosen to minimize multipath effects from the VLBI dish and observatory, such that the antenna had the best possible horizon, and was within feasible distance of a building that could house the receiver in close proximity to the hydrogen maser clock. This is a permanent installation and was installed by AUSLIG field staff in collaboration with the Departments of Physics and Surveying at the University of Tasmania.

The GPS antenna is permanently located on the new monument and is covered with an acrylic dome. Low-loss heliax antenna cable was used. The GPS system consists of a PC! running the Linux operating system, a modem, and multiplexer. The PC logs data from the GPS *receiver* continuously and sends them back to Canberra using tcp/ip protocols over a national Internet network. Data are also stored on the receiver flashcard as per usual.

The observatory is located approximately 30 km from the University of Tasmania which is the nearest Internet node, and a dedicated data landline is leased to connect the observatory and the university. Data are transferred from the observatory to the university from where they are transferred using the Internet to Canberra.

The remote system is fully automated and except for occasional firmware upgrades and system maintenance does not require human intervention. It is housed in the observatory control room and is supported by a UPS system. Remote control of all parts of the system is possible.

Brief station information follows and a site report has been submitted to IGSCB.

Station Information

Installation Date: June 1994
Monument Mark: stainless steel plate set in concrete pillar
Receiver Type: Rogue SNR-81OO (Turbo Rogue rackmount)
Receiver Software: V3.0.33.2
Frequency Reference: external hydrogen maser
Antenna Height: 0.000 m (arp = base of antenna)
Approximate Station Coordinates:

Lat: S 42” 48’ 16.9846”
Long: E 147” 26’ 19.4293”
Ht: 41.249 m
x: -3950071.268 m
Y: -2522415.236 m
z: -4311638.625 m

DataAvailability

Data forthis site are available from:

```
ftp.auslig.gov.au
user = ftp
passwd = email address
cd gps/nnn      where nnnisthedayofthe year (1 . ..366)
```

Thedata areheld on a Sunworkstation running SunOS 4.1.3 and the files are UNIX compressed RINEX files.

GPS Station in Borowiec, Poland

Waldemar Jaks
AstroGeodynamical Observatory
Space Research Centre, Polish Academy of Sciences
Kornik, Poland

The Observatory was founded in 1955 to begin astronomical observations for Earth rotation research. Observations started in the International Geophysical Year 1957 using Transit Instruments and Visual Zenith Telescopes. In the 1980s, the astronomical observations were replaced with satellite methods. The Observatory takes part in several international projects including: DOSE, IGS, WEGENER, and IERS.

SLR Station Borowiec (12205M001) started operating in May, 1988. The main instrument is the third generation laser transmitter CONTINUUM PY-62-1O which is able to achieve about 3 cm accuracy. From 1981 to 1991 the observatory handled measurements using Doppler methods of the TRANSIT system in international campaigns and researches: WEDOC-1, WEDOC-2, MERIT, MEDOC, FINPOLDOC, and ICDOC.

The permanent GPS observations started in September 1993 using TurboRogue SNR-8000 on the BOR1 marker. The receiver is linked to the cesium frequency standard EUDICS 3020 and to the automatic meteorological measurement system HPTL3A (NAVI Ltd., Poland). The Borowiec GPS station has been participating as a permanent IGS project since June 1994. Observations are checked by Quality Check v 3.0 and sent to the Graz IGS Data Center using the Internet. The Observatory computes and analyzes observations gathered in almost all international campaigns. Results of the Baltic Sea Level 1990 and 1993 campaigns were calculated using BERNESE 3.4 software. Coordinates of BORO (EUREF 0216) and BOR1 markers were computed from the EPOCH 1992 project. The Time Laboratory of Borowiec Observatory has carried the GPS comparisons to BIPM time scale since 1991. Currently, there are two cesium frequency standards: EUDICS 3020 and the XSC (Rhode & Schwartz).

Status Report of the IGS GPS Station at Metsahovi

Matti Paunonen
Finnish Geodetic Institute
Helsinki, Finland

A permanent GPS receiver has been in continuous operation at the Metsahovi Geodetic Observatory since May 1, 1991. The present MiniRogue SNR-8C receiver started up on April 30, 1992 and it has delivered data also to the IGS (International GPS Service for Geodynamics) from the very beginning in June 1992. The antenna is mounted on top of a 20-m steel tower using an electrically isolated, vertically floating mount.

The height of the antenna is kept fixed by an invar bar anchored to the bedrock (Paunonen, 1993). A 5-MHz external frequency from a hydrogen maser feeds the receiver. Statens Kartverk, Norway, retrieves the data directly from the receiver by a modem. An archive copy is kept at the observatory. The system has operated without physical changes, excluding receiver firmware updates. The height of the antenna has been found stable within 1 mm in all inspections. For monitoring the horizontal position, a 20-m plumb line inside a tube was permanently installed in the tower in September 1993, and regular checks have been made since then. The mean position has remained within 1 mm and its rms variation well within 1 mm in 187 determinations. As expected, direct sunshine has some effect on the position because of uneven elongation of the guy wires due to variable illumination conditions. The worst case movement, 3 mm, happened during a hot (26 degrees C), clear day in July 1994.

The MiniRogue has shown increased susceptibility to pseudo-range multipath effects (1-2 m) after the implementation of anti-spoofing. This is not due to the GPS environment around the tower, because unaffected satellites still give less than 20-cm multipath. Code measurements have sometimes shown irregularities which disturb ionospheric studies. In April 1995 the present receiver will be replaced by a TurboRogue SNR-8100 receiver. The GPS receiver has close site connections to a satellite laser rangefinder (50 *m*), a mobile VLBI point, and a DORIS orbitography beacon (about 3 km) (Paunonen, 1993 and 1994). A superconducting gravimeter, GWR TT70, started operation at the observatory in August 1994.

Paunonen, M., Height-stabilized 20-meter antenna mounting system of the CIGNET GPS station at Metsahovi, Newsletter of Space Geodetic Measurements Sites Subcommission (SGMS), IAG, IUGG, International Coordination of Space Techniques for Geodesy and Geodynamics (CSTG), Vol. 4, No. 1, May 1993, pp. 7–10.

Paunonen, M., Comparison of globally and locally determined site ties for the Metsahovi GPS station, Proc. of the 1993 IGS Workshop (Eds. G. Beutler and E. Brockmann), IAG, IUGG, International GPS Service for Geodynamics (IGS), March 25–26, 1993, Astronomical Institute, University of Bern, Switzerland, pp. 310-317.

Paunonen, M., Evaluation of the site tie between the IGS GPS station and the mobile VLBI point at Metsahovi. A poster paper presented at it the IERS and IGS Workshop in Paris and Saint Mande, March 21–28, 1994.

The IGS Station Graz-Lustbuehel—Status Report

Peter Pesec
Institute for Space Research
Dept. Satellite Geodesy Austrian Academy of Sciences
Graz, Austria

Introduction

The observatory Graz-Lustbuehel represents the basic Austrian geodynamic reference point, First optical satellite measurements were initiated in 1967, in the framework of the West European densification network. Starting in 1976 the observatory served as the primary Austrian Doppler reference site during various Doppler campaigns on the European scale. From 1979 to 1983 continuous Doppler observations were carried out and gave valuable contributions to the establishment of WGS-84 and the Austrian Geoid. During the years 1979 to 1982 a precise satellite laser ranging facility was built up; this has been in continuous operation since that time and shows up, presently, as one of the most accurate SLR systems all over the world. GPS was introduced in 1986 (TI-41OO) and permanent observations started in early 1990 (with short interruptions). The observatory has contributed to the IGS since June 1992 without any interruptions.

Geodynamic Observatory Graz-Lustbuehel (GRAZ)

The geodynamic observatory Graz-Lustbuehel (GRAZ) (Latitude: N 47”04’; Longitude: E 15030’; Height: 483 m) is located in the eastern outskirts of the city of Graz at a height of about 130 m above the city level consisting of tertiary sediments with a thickness of about 400 m. The basement rock is formed by the “Graz Paleozoic” of the Eurasian plate. The central marker is fixed to the roof of a stable concrete building; local control is maintained by monitoring the ties to the laser pillar of l-m diameter, which extends 12 m below the ground surface. Further control is maintained by local ties to three fiducial points fixed in bedrock at distances of about 16 km (measured every year) and five adjacent sites of the Austrian Geodynamic Reference Frame (AGREF) at distances of about 40 km, being remeasured every 3 years.

The department currently operates the most accurate European Satellite Laser Ranging System. Capable of observing all types of satellites up to geostationary orbits; it has a leading position in multi-color SLR techniques. The time laboratory TUG (operated by the Institute of Wave Propagation and Communications) provides the required reference frequencies. The central marker is connected to the national height system by precise leveling, and absolute gravity measurements will be carried out at the observatory during the current year (at present only a relative connection to the absolute gravity point situated at the Graz University of Technology exists).

Starting with June 1992 (IGS pilot campaign) GPS observations have been continuously carried out on the main reference point (GRAZ) of the observatory. Data have been acquired by a MiniRogue SNR-8C receiver connected to the time laboratory TUG. Its ownership is shared by the Federal Office for Metrology and Surveying in Vienna and the Institute for Space Research (Department of Satellite Geodesy). The excellent reliability of this receiver is revealed by the fact that, altogether, only about 12 days of observations are missing from the start, corresponding to an efficiency of 99%. The main reasons were internal receiver software problems during weekends, which could not be corrected immediately, as well as logistic gaps (hardware replacements, for example).

The whole system is monitored by a PC-based automatic time-scheduling menu, which simply defines and sets the timely order of the specific independent tasks. It operates in close connection with an IBM workstation (5 GByte, connected by thin-wire ethernet), which acts as the local data center and FTP server for international access. In this context it should be mentioned that this menu also monitors data downloading and data transfer of additional remotely controlled GPS stations in Austria (see chapter 3) as well as the control and protection of data currently coming in from five permanent stations of the CEI (Central European Initiative).

The downloading of GRAZ GPS data is carried out twice a day at 12:01 UTC and 00:01 UTC. If possible, binary data are immediately transferred to JPL via FTP (unfortunately the access to JPL is frequently blocked by lacking memory/ connection resources). The binary data are saved, converted to Rinex format, merged to a daily file, and transferred to the workstation, which distributes the data set of specific stations to the regional data center IFAG Frankfurt via FTP at 03:00 UTC. In addition, all data collected during the last ten days are available via anonymous FTP (129.27.194.14) on the directory cei/outdata/LAST-TEN.DAYS. All data of the GRAZ local data center are stored on magneto-optical discs for later use.

Meteorological data for GRAZ are likewise available. At present, dry temperature and humidity are automatically collected in half-hour samples. The installation of a precise remotely controlled pressure-sensor is under way. Starting in August 1995 GRAZ will transfer meteorological data in Rinex format together with the daily data files.

Further Potential IGS Stations in Austria

Following the concept of the total coverage of the Austrian territory by permanently recording GPS stations with mutual distances of not more than 200 km the establishment of four additional stations is foreseen.

The geodynamic site Hafelekar (HFLK) (near Innsbruck; Lat: N 47018’; Len: E 11023’; H: 2335 m) is located on top of the Hafelekarspitze north of Innsbruck. Comprehensive safety precautions shelter the antenna from storms (up to 200 km/h) and keep the equipment (Rogue SNR-8C) from lightning and other influences. Regular observations started end of January 1995. Data are collected via Trailblazer modem on a daily basis and transferred to IFAG Frankfurt.

The geodynamic site Reisseck (GRMS) (Grosser Muehldorfer See; (Lat: N 46”54’; Len: E 13021’; H: 2287 m) hopefully will start its operation during autumn 1995 (Rogue SNR-8000). It is accessible by an inclined hoist, followed by a short railway line and 15 minutes on foot. The layout of the station will correspond to the site Hafelekar.

The geodynamic site Hutbiegl (HUTB) (Lower Austria) (Lat: N 48”39’; Len: E 15”36’; H: 411 m) is located in Lower Austria and serves as the main height reference point of Austria. The pillar is connected to bedrock (gneiss). The site is accessible by car. However, no electricity is available which complicates the logistics for permanent observations. Despite this, the possibility of making this station permanent during 1996 is being investigated.

Finally, the site Pfaender in Vorarlberg which is shared, as a first order triangulation point, by Austria, Germany and Switzerland is a potential candidate.

NRCan (GSC) Operational Stations

Michael Schmidt
Geological Survey of Canada, Natural Resources Canada
Sidney, British Columbia

Albert Head

STATION:	ALBH
GEODETIC MARK	927000
FULL NAME:	Albert Head
CLASS:	WCDA, CORE2
DOMES No.:	40129-M003
CDP No.:	n/a
LOCATION:	Victoria, B. C., Canada
COORDINATES:	Latitude N 48° 23’23.2” (prelim. 93/01/07) Longitude E 236°30’45.1” (prelim. 93/01/07) Ellipsoid Height 32.01 m (prelim. 93/01/07) Orthometric Height 50.05 m (prelim. 93/01/07)
COLLOCATION:	Mobile VLBI - CDP No.: 7289 - DOMES No.: 40129-M001 - Geodetic Mark: 907001

ALBH is located on the property of Canadian Forces Base Albert Head south of the city of Victoria (Vancouver Island), British Columbia, Canada. ALBH is one of seven GPS trackers in the Western Canada Deformation Array (WCDA) operated by the Geological Survey of Canada (GSC). ALBH is also part of the Canadian Active Control System (ACS) as well as the provincial (B. C.) ACS. Mobile VLBI, absolute gravity, precise tri-lat and precise levels have been carried out at ALBH in addition to the GPS observations. ALBH is located on the North American plate.

ALBH was the second permanent GPS tracker established by the GSC in western Canada. The first crustal dynamics measurements took place in 1990 (VLBI); the GPS tracker commenced operation in May 1992; absolute gravity measurements have been carried out three times (1992, 1994, and 1995). All markers on site (GPS, VLBI and local references) are tied into local vertical control through special order leveling surveys carried out by the Geodetic Survey Division (GSD), Geomatics Canada. Between 1990 and 1992 the VLBI marker was utilized as a GPS base station for the GPS surveys of several crustal strain networks on Vancouver Island as well as the first MAGEX (Marine Geodetic Experiment)—a cooperative project between S10, JPL, GSC.

Instrumentation As of July 1995 ALBH is equipped with a dual-frequency, eight-channel AOA SNR-8000 TurboRogue GPS receiver. The antenna is attached to a brass forced-centered plate (embedded in the concrete pier) via a 10-cm-high anodized aluminum base. This base provides a constant height above the brass plates and also permits the antenna to be referenced to north. The antenna and choke-ring assembly are protected by an acrylic dome. The reference frequency is provided by an external cesium beam frequency standard. The GPS equipment uses local grid power backed up by an uninterruptible power supply (UPS) capable of sustaining the site for up to 45 minutes. Two high-speed modems are used (1) to access the receiver for instrument control and data recovery and (2) to access the UPS to monitor and control power to the GPS instrumentation. The current (March 1995) data rate is 30 seconds.

Monumentation The AOA TurboRogue GPS antenna is located on top of a high concrete pier anchored to bedrock with steel reinforcement bars. The internal reference network consists of four markers surrounding the pier; these are used to monitor long-term stability of the GPS pier as well as to maintain the offsets between the GPS marker and the VLBI marker through periodic resurvey(s) of the reference network. An external GPS reference network is maintained and consists of four stations within a 10-km radius of ALBH. These four sites also belong to the joint GSC-USGS Juan de Fuca crustal strain network spanning the Strait of Juan de Fuca.

Data Handling The GPS data from all WCDA sites are retrieved automatically from a central data collection and validation platform located at the Pacific Geoscience Centre (PGC) in Sidney, B.C. Data retrieval commences at 00:00 hrs UTC daily and relies on high-speed modems over local telco data lines. Upon completion of downloads the data are validated using two routines developed at GSD, GIMP8, and DCRAP7. The validation routines issue both warning and error flags. In the event of an error condition the data are automatically downloaded again and validated. The IGS Quality Assurance program is run on the RINEX files. Any warnings or errors are captured in a daily log file along with summaries from all data validation programs. Both native CONAN Binary and RINEX files are available from a public FTP directory. The GSD (Ottawa) currently retrieves the GPS data files from the PGC FTP site, validates and forwards RINEX files to CDDIS.

ALBH Station Summary March 31, 1995:

```
GPS RECEIVER:      - 95/01/11 (95.011) 22:15UT ROGUE  SNR-8000  Rcvr s/n 292
FIRMWARE :         - 95/07/21 (95.202) 19:26UT Vers. 3.2  link  1995/03/09
                                               12:37:24 G050  JPL
ANTENNA :            95/06/07 (95.158) 20:52UT AOA  Dome Margolin T p/n 7490582-1
                                               s/n 95-174 (with acrylic dome)
ANTENNA HEIGHT :   - 95/01/11 (95.011) 22:15   0.100 m   (10 cm)
                     vertical distance measured to antenna reference point(ARP)
CLOCK:               95/01/23 (95.023) 20:54UT HP 5061A Cesium s/n 2340 A02226
STATUS :           - 92/05/04 (92.125)   Operational
AGENCY :           Geological Survey of Canada, NRCan
CONTACT :          Michael Schmidt
                   Pacific Geoscience Centre
                   Geological Survey of Canada
                   PO Box 6000, Sidney, B.C. , Canada, V8L 4B2
                   TEL (604) 363-6760
                   FAX (604) 363-6565
                   INTERNET  schmidt@pgc .nrcan. gc. ca or schmidt@pgc. emr. ca
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Penticton

STATION ID:	DRAO
GEODETIC MARK	887006
FULL NAME:	DRAO WCDA ACP
CLASS:	WCDA, CORE1
DOMES No.:	401 O5-MOO2
CDP No.:	nJa
LOCATION:	Dominion Radio Astrophysical Observatory (DRAO) Penticton, B. C., Canada
COORDINATES:	Latitude N 49”19’21.4” Longitude E 240°22’30.1” Ellipsoid Height 542.5 m
COLLOCATION:	Mobile VLBI - CDP No.: 7283 - DOMES No.: 401 O5-MOO1 - Geodetic Mark: 837030

DRAO is located on the property of the Dominion Radio Astrophysical Observatory (DRAO), south of the town of Penticton, B. C., Canada. DRAO is one of seven GPS trackers in the Western Canada Deformation Array operated by the Geological Survey of Canada (GSC). DRAO is also part of the Canadian Active Control System (ACS) as well as the provincial (B. C.) ACS. Mobile VLBI, absolute gravity, precise tri-lat and precise levels have been carried out at DRAO in addition to the GPS observations. DRAO is located on the North American plate.

DRAO was the first permanent GPS tracker established by the GSC in Western Canada. The first crustal dynamics measurements took place in 1984 (VLBI: MV-2) followed by repeated VLBI occupations in 1985 and 1990; a TI-4100 GPS receiver was run at the current GPS pier for the GIG ’91 experiment. The GPS tracker commenced operation (Rogue SNR-8) in February 1991; absolute and precise relative gravity measurements are carried out at regular intervals. All markers on site (GPS, VLBI and local references) are tied into local vertical control through special order leveling surveys carried out by the Geodetic Survey Division (GSD), Geomatics Canada. A broadband seismometer is collocated at the site.

Instrumentation As of July1995 DRAO is equipped with a dual-frequency, eight-channel AOA SNR-8000 TurboRogue GPS receiver. The antenna is attached to a brass forced-centered plate (embedded in the concrete pier) via a 10-cm-high anodized aluminum base. This base provides a constant height above the brass plates and also permits the antenna to be referenced to north. Reference frequency is provided by an external cesium beam (super tube) frequency standard. The GPS equipment uses local grid power backed up by an uninterruptible power supply (UPS) capable of sustaining the site for up to 45 minutes. Two high-speed modems are used (1) to access the receiver for instrument control and data recovery and (2) to access the UPS to monitor and control power to the GPS instruments. The instrumentation is enclosed in a special RFI / EMI-shielded cabinet in order to eliminate any potential interference disruptive to the radio astronomy program at DRAO. The current (March 1995) data rate is 30 seconds.

Monumentation The AOA TurboRogue GPS antenna is located on top of a concrete pier anchored to bedrock with steel reinforcement bars. The internal reference network consists of four markers surrounding the pier; these are used to monitor long-term stability of the GPS pier as well as to maintain the offsets between the GPS marker and the VLBI marker through periodic resurvey(s) of the reference network. An external GPS reference network is maintained and consists of six stations within a 10-km radius of DRAO.

Data Handling The GPS data from all WCDA sites are retrieved automatically from a central data collection and validation platform located at the Pacific Geoscience Centre (PGC) in Sidney, B.C. Data retrieval commences at 00:00 hrs UTC daily and relies on high-speed modems over local telco data lines. Upon completion of downloads the data are validated using two routines developed at GSD, GIMP8, and DCRAP7. The validation routines issue both warning and error flags. In the event of an error condition the data are automatically downloaded again and validated. The IGS Quality Assurance program is run on the RINEX files. Any warnings or errors are captured in a daily log file along with summaries from all data validation programs. Both native CONAN Binary and RINEX files are available from a public FTP directory. The GSD (Ottawa) currently picks up the data from the PGC FTP site, validates them and forwards RINEX files to CDDIS.

DRAO Station Summary April 12, 1995

```
GPS  RECEIVER:  - 95/04/12  (95.102)  17:05UT ROGUE SNR 8000 Rcvr S/n 347
FIRMWARE :      - 95/07/17  (95.198)  17:23UT 3.2  link  1995/03/09  12:37:24
                                              G050  JPL
ANTENNA :         95/04/12  (95.102)  17:05UT AOA  Dome  Margolin T p/n  7490582-1
                                              s/n  95-172
ANTENNA HEIGHT : - 95/04/12  (95.102)  17:05UT 0.100  m    (10 cm)
                  vertical  distance  measured  to  antenna  reference  point  (ARP)
CLOCK :           94/01/04 (94.006) 23:07uT HP 5061B 003 004 Cesium Super Tube
                                              s/n 2624 A00154
STATUS :        - 91/02/27 (91.058)           Operational
AGENCY :        Geological  Survey  of  Canada,  NRCan
CONTACT :       Michael  Schmidt
                Pacific  Geoscience  Centre
                Geological  Survey  of  Canada
                PO  Box  6000,  Sidney,  B.C.  ,  Canada,  V8L  4B2
                TEL  (604)  363-6760
                FAX  (604)  363-6565
                INTERNET   schmidt@pgc.nrcan.gc.ca or schmidt@pgc.emr.ca
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Herstmonceux GPS ROGUE Receiver General Site Description

Andrew Sinclair
Royal Greenwich Observatory
Cambridge, England

The site of the GPS Rogue receiver at Herstmonceux, England, is in the grounds of Herstmonceux Castle, and is located about 3 km from the village of Herstmonceux and about 8 km from the south coast of England. It is the former site of the Royal Greenwich Observatory, until it moved to Cambridge in 1990. The site is now owned by Queen's University of Canada, and is used as an international study center and conference center. The principal geodetic instrument operated at the site is the UK Satellite Laser Ranging System. This has been in continuous operation since October 1983. It was decided not to move it to Cambridge when the Observatory moved, and it is now operated by a local team of 6 people as an outstation of the Royal Greenwich Observatory, with a further 2 people at Cambridge for management and data analysis activities. An SNR-8A mini-ROGUE GPS receiver was put into operation at the site in September 1991, and the receiver was replaced by an SNR-8C in March 1992, which has been in operation since then.

The local site manager is Dr. Roger Wood, based at Herstmonceux, and the overall manager of the project is Dr. Andrew Sinclair, based at Cambridge.

Report on IGS Global Station Jozefoslaw

Janusz Sledzinski
Institute of Geodesy and Geodetic Astronomy
Warsaw University of Technology
Warsaw, Poland

The IGS station Jozefoslaw (JOZE) is located at the Astrogeodetic Observatory of the Institute of Geodesy and Geodetic Astronomy of the Warsaw University of Technology established in 1959. At present three permanent services are maintained at this station:

- Astrometric latitude observations have been carried out since 1959 in the frame of international cooperation with BIH and IPMS; now the observations are being used by Shanghai Observatory (international coordinator of the optical astrometry) and GOSTSTANDARD, Moscow. These observations are also used for the analyses of the time variations of the plumb line.

- Gravimetric permanent tidal measurements using LaCoste & Romberg mod. G gravity meter have been carried out since November 1993. The Observatory Jozefoslaw is one of the fundamental points of the Polish national gravimetric network; many absolute gravity determinations have been performed. A special meridional gravimetric baseline, 26 km long, was established at the observatory in 1976; periodic observations are made four times a year. The observations are used jointly with astrometric determinations for studies of the changes in the vertical.

- GPS permanent service has been maintained since August 1993. The station participated earlier in the IGS Epoch'92 campaign. The Trimble 4000SSE receiver serial No. 3249A02090, antenna Trimble Geodetic L1/L2 N0.3247A66429 is used. Three rubidium frequency standards are available at the station; one of them is used as an external standard for IGS service. On January 1, 1995 the second GPS receiver, a TurboRogue SNR 8000, serial No. 339, antenna type Dome Margolin T No. 439, was installed at the station. The permanent GPS IGS service will be maintained by both receivers (Trimble 4000SSE and TurboRogue SNR 8000). The Trimble 4000SSE will serve as the main receiver and its observations will still be transmitted to the international data centers. The observations of the TurboRogue SNR 8000 receiver will be soon available upon request for all interested centers for scientific research.

Monumentation of the reference point was made according to the IGS standards. Control points are available. Due to the geological situation the pillar could not be monumented on the bedrock. Station Jozefoslaw is the reference point of several international GPS networks: EUREF, EXTENDED SAGET, CEGRN (Central European GPS Reference Network), and BSL (Baltic Sea Level). The eccentricity of the EUREF point with respect to that of other campaigns is: X = 0.079 m, Y = 0.030 m, Z = 0.108 m. Since the 1960s the

Observatory has also participated in other international astrometric and satellite campaigns (photographic, Doppler, GPS).

The IGS Associate Analysis Centre was organized at the Institute with the aim of processing data from IGS and other GPS campaigns in Central Europe used for geodynamic studies of the Teisseyre-Tornquist contact zone, the Carpathian and Subalpine regions. The day-to-day coordinates of several IGS permanent stations from Central Europe are computed at the Centre in the cooperation with the CODE Berne Centre. Also IGS products, e.g., GPS satellite orbits and Earth rotation parameters, are archived. The Centre is also responsible for daily data transmission from the Astrogeodetic Observatory Jozefoslaw to the international data centers.

JPL-Supported Permanent Tracking Stations

G. Franklin, B. Iijima, P. Kroger, U. Lindqwister, T. Lockhart, A. Mikolajcik, M. Smith, and K. Stark
Jet Propulsion Laboratory
Pasadena, California

The following sites are permanent installations currently operated or supported by JPL. Latitude and longitude are in degrees, heights are in meters.

AREQ — NASA Laser Tracking Station, Arequipa, Peru
Lat: -16.4655
Long: 288.5070
Ht.: 2496.421

The TurboRogue at Arequipa is collocated with the Satellite Laser Ranging station in Arequipa. The original installation was done in January 1994 at an existing monument and was moved to a new installation in March of that year.

BOGT — INGEOMINAS, Bogota, Columbia
Lat: 4.64
Long: 285.91
Ht.: 2573.0

The TurboRogue receiver at Bogota shares an office phone line in order to transfer the data back to JPL.

BRAZ — IBGE, Brasilia, Brazil
Lat: -15.9474
Long 312.1219
Ht.: 1106.1887

The TurboRogue receiver at Brazil is currently uploaded using a standard phone line, but it will soon switch over to using the Internet to transfer the data to JPL.

CASA — Mammoth, California
Lat: 37.6446
Long: 241.1034
Ht.: 2384.8

The TurboRogue Receiver was installed as part of a DOSE funded project headed up by Frank Webb, Tim Dixon, and Marcus Bursik, to measure uplift in the Mammoth Lakes region. It is located at the United States Geological Survey offices in Mammoth.

CICE — CICESE, Ensenada, Mexico
Lat: 31.8712
Long: 243.3326
Ht.: 96.0994

This site was installed by the University of Miami, UNAVCO, JPL and CICESE in early 1995. It uses radio data modems to offload the GPS data.

EISL — Easter Island, Chile
Lat: –27.1482
Long: -109.3832
Ht.: 116.9770

Easter Island is located off of the coast of Chile. The TurboRogue installed there is collocated with the Satellite Laser Ranging facility on the island.

FAIR — NASA Fairbanks Observatory, Fairbanks, Alaska
Lat: 64.9780
Long: 212.5011
Ht.: 320.3149

Big Red, as the monument at Fairbanks is often called, is installed at the Gilmore Creek observatory in Fairbanks. A Rogue SNR-8 is currently in operation at this site.

GODE — Goddard Space Flight Center, Maryland
Lat: 39.0217
Long: 283.173
Ht.: 19.81

The TurboRogue Receiver at the Goddard Space Flight Center is using a steel pillar monument. It is using an external maser frequency standard.

GUAM — Guam Seismic Observatory, Dededo, Guam
Lat: 13.5893
Long: 144.8683
Ht.: 204.9137

The TurboRogue receiver is installed at the Observatory along with an IRIS/ USGS seismometer.

HARV — Harvest Oil Platform, California
Lat: 34.4694
Long: -120.6821
Ht.: 19.1620

The Harvest Oil Platform is located 8 km off the coast of Vandenberg Air Force Base in Southern California. Data communications to the TurboRogue receiver at Harvest are accomplished using commercial cellular communications to the platform.

KOKB — Kokee Park, Kokee, Hawaii
Lat: 22.1262
Long: 200.3354
Ht.: 1189.9162

The Rogue SNR-8 at Kokee is located on top of a small concrete building at the Kokee Park Observatory. It is using an external Hydrogen Maser frequency reference.

MCM4 — McMurdo, Antarctica
Lat: -77.8383
Long: 166.6693
Ht.: 102.3635

There are two sites that have been used at McMurdo. There is currently a TurboRogue receiver operating at the MCM4 mark, There is a local Macintosh that uploads the receiver at the site. The data are offloaded from the Macintosh using Internet.

MDO1 — McDonald Laser Observatory, Fort Davis, Texas
Lat: 30.6805
Long: 255.9849
Ht.: 2094.9

Table 1. Data Access Information.

Short Name:	JPL
Institution:	Jet Propulsion Laboratory
Function within IGS:	Special Data Center
Mail Address:	4800 Oak Grove Drive Pasadena, CA 91109, USA
Contact:	Keith F. Stark
Telephone:	(81 8) 3545922
Fax:	(81 8) 3934965
E-Mail:	stark@logos.jpl.nasa.gov (internet)
Telnet Access:	None
FTP Access:	bodhi.jpl.nasa.gov (128.149.70.66) anonymous
Computer Operating System:	HP 9000/715 HP-UX, VAX/VMS
Amount of data on line:	120 days
Access to off-line data:	Special arrangements

Table 2. Directory Structure.

directory specifications are for our guest computer BODHI.

Directory	Subdirectory	Description
pub		top level
	/rinex	rinex area indexed by day of year
	/raw	raw data area indexed by day of year
	/docs	supporting documentation and IGS MAIL
	/software	supporting software
	/topex	Topex orbit data

The TurboRogue at McDonald Laser Observatory uses a steel pillar monument located on the grounds of the Observatory.

NLIB — North Liberty VLBA Station, North Liberty, Iowa
Lat: 41.7716
Long: 268.4252
Ht.: 216.635

This installation is collocated with the VLBA site in North Liberty. The monument is comprised of a steel pillar on a concrete mount placed in the ground just outside of the VLBA compound. The TurboRogue receiver is using the VLBA maser as a clock reference.

PIE1 — Pie Town VLBA Station, Pie Town, New Mexico
Lat: 34.3015
Long: 251.8814
Ht.: 2353.50

This installation is collocated with the VLBA site in Pie Town. The monument is comprised of a steel pillar on a concrete mount placed in the ground just outside of the VLBA compound. The TurboRogue receiver is using the VLBA maser as a clock reference.

QUIN — Mobile Laser Tracking Station, Quincy, California
Lat: 39.9746
Long: 239.0559
Ht.: 1080.3

The TurboRogue receiver at Quincy is located at the Mobile Laser Tracking Station (Moblas) #8 in Northern California.

SHAO — Shanghai Observatory, Shanghai, China
Lat: 31.0996
Long: 121.2004
Ht.: 23.16

The TurboRogue receiver at Shanghai is hosted by the Chinese Academy of Science at the Shanghai observatory. The receiver is using the local maser as its clock reference.

THU1 — Thule, Greenland
Lat: 76.5372
Long: 291.2120
Ht.: 94.7687

This receiver is a 12-channel TurboRogue to ensure ample channel availability for the increased number of visible low elevation GPS satellites.

YAR1 — Mobile Laser Tracking Station, Yaragadee, Australia
Lat: –29.0376
Long: 115.3487
Ht.: 2165.49

The Rogue SNR-8 at Yaragadee has been operating there since late 1990.

DSN sites *and TOPEX*

GOLD — Goldstone DSN Station, California
Lat: 35.4252
Long: -116.8892
Ht.: 986.7163

The monument and antenna used by the Rogue SNR-8 receiver at Goldstone is installed on the top of a Microwave tower at the Deep Space Network station. The data is transferred back from the site using the NASCOM lines back to JPL.

MADR — Madrid DSN Station, Spain
Lat: 40.4292
Long: -4.2497
Ht.: 829.4512

The Rogue SNR-8 receiver located here uses an monument mounted on the roof of a building at the Madrid Deep Space Network facility. The data are transferred back from the site using the NASCOM lines back to JPL.

SANT — University of Chile, Santiago, Chile
Lat: –33.1502
Long: –70.6682
Ht.: 725.6814

This installation uses a Macintosh computer in Santiago to upload the data from the Rogue SNR-8 receiver. The data are then transferred back to JPL via the Internet.

USUD — Usuda, Japan
Lat: 36.1331
Long: 138.3621
Ht.: 1504.5

The monument at Usuda is mounted on the roof of the two-story control room at the Usuda Tracking Station. The TurboRogue receiver is using an external frequency.

TIDB — Tidbinbilla DSN Station, Australia
Lat: –35.3992
Long: 148.98
Ht.: 665.4018

The Rogue SNR-8 receiver at Tidbinbilla uses an antenna mounted on JPL-style reinforced concrete pillar monument. The data are transferred back from the site using the NASCOM lines back to JPL.

Southern California

The following sites were installed as a part of the Southern California Integrated GPS Network (SCIGN), which uses a regional array of permanent GPS receivers for seismic studies in Southern California. SCIGN is currently composed of 30 permanent sites operated by various agencies in Southern

California. JPL currently retrieves data from the following 12 sites which are equipped with TurboRogue receivers:

AOA1 — Allen Osborne Associates, Westlake Village, California
Lat: 34.1575
Long: 241.1697
Ht.: 249.1509

Allen Osborne Associates, the manufacturer of the TurboRogue receiver, hosts this TurboRogue installation on the roof of their offices in Westlake Village.

CARR — Parkfield, California
Lat: 35.8883
Long: 239.5693
Ht.: 466.2229

Parkfield, California has long been known as one of the most seismically interesting places on earth due to its history of regularly repeating earthquakes. A TurboRogue receiver is permanently operating on a site with a long history of campaign occupations.

CIT1 — Caltech, Pasadena, California
Lat: 34.1367
Long: 241.8727
Ht.: 216.877

Located only a few miles south of JPL, Caltech is closely tied with the operation of the Laboratory. The TurboRogue receiver installed at Caltech is located on the roof of the North Mudd building on the Caltech campus.

JPLM — Jet Propulsion Laboratory, Pasadena, CA
Lat: 34.2050
Long: 241.8266
Ht.: 461.1171

The site here at JPL is located on the mesa directly north of the JPL Oak Grove complex in Pasadena. This receiver is one of the longest permanently operating receivers, having been installed in early 1990. A TurboRogue has replaced the Rogue SNR-8 that was originally installed there.

LBCH — Long Beach, California
Lat: 33.7877
Long: 241.7966
Ht.: 44.0

The TurboRogue receiver here uses a roof-mount monument on the Electronic System Communication building at the Bureau of Public Services.

OAT2 — ATT Microwave Facility, Oat Mountain, California
Lat: 34.3301
Long: 241.3986
Ht.: 1016.1

The name of the original site, OATT, included the acronym for the operators of the facility where it was located. The name change to OAT2 was required when the monument used by the TurboRogue receiver was moved from the ground to the roof of the facility in early 1995.

SPK1 — Fire Camp 8, Saddle Peak, California
Lat: 34.0592
Long: 241.3539
Ht.: 438.6513

Saddle Peak is located in the hills north of Malibu and currently has a TurboRogue receiver installed there.

UCLP — University California at Los Angeles, Westwood, California
Lat: 34.0691
Long: 241.5581
Ht.: 113.0

The TurboRogue receiver and the roof mount monument are installed at a building on the University of California at Los Angeles campus.

USC1 — University of Southern California, Los Angeles, California
Lat: 34.024
Long: 241.715
Ht.: 31.205

This TurboRogue installation consists of a steel pillar monument located at a power vault on the campus of the University of Southern California.

WHC1 — Whittier College, Whittier, California
Lat: 33.97
Long: 241.96
Ht.: 68.14

The TurboRogue receiver and the roof mount monument are installed at a building on the Whittier College Campus.

WHI1 — Whittier Library, Whittier, California
Lat: 33.97
Long: 241.97
Ht.: 68.14

The TurboRogue receiver and the roof mount monument are installed on the Whittier Library.

WLSN — Mt. Wilson Observatory, Mt. Wilson, California
Lat: 34.2261
Long: 241.9441
Ht.: 1695.1

The TurboRogue receiver is located at the NRL/MIT interferometry site northeast of JPL in the San Gabriel Mountains.

References

Additional information about the GPS Global Tracking Network and the SCIGN Network maybe obtained via the World Wide Web at the following addresses:

1. JPL's Global GPS Time Series Data:
   http://sideshow.jpl.nasa.gov/mbh/series.html

2. JPL's contribution to the Southern California Dense Array:
   http://milhouse.jpl.nasa.gov/

The KOSG IGS Station

Danny Van Loon
Kootwijk Observatory for Satellite Geodesy
Delft University of Technology
Delft, Netherlands

The KOSG IGS-station (acronym for Kootwijk Observatory for Satellite Geodesy) is located in the eastern part, while the Delft University of Technology itself, owner of KOSG, is in the western part of the Netherlands. KOSG has operated its ROGUE SNR-8 GPS receiver since the start of IGS after a successful GIG-91 campaign. An external HP rubidium frequency standard is connected to the receiver, while a PC takes care of the automatic download of the data in the compressed (crop) Rogue data format, using the Procomm Plus communication software. This takes place every day at 00:00 UTC. The PC is inserted in a local network of which its HP-server is connected to the Internet.

At 01:00 UTC the Kootwijk data handling job at the Delft University of Technology is started. The start is scheduled using the UNIX "crontab" command. The first action is an ftp to Kootwijk to download the Rogue data file. This file is checked for its size and after approval it is copied to the anonymous ftp account at Delft (dutlru6.tudelft.nl or 130.161.164. 175) in the directory /pub/ rogue. Also it is sent (using ftp) to the Jet Propulsion Laboratory (JPL). If no cmp file was found at Kootwijk or if the size is not large enough, the data handling stops and sends an e-mail message to both the operators at Kootwijk and Delft.

After successful download of the data file the conversion to RINEX starts. Here care is taken to concatenate the navigation file to contain only messages between 0:00 and 24:00 UTC of this day. The observations always span from 0:00 to 24:00 hours UTC so no special actions are required here. After the RINEX conversions, using the Bernese RGRINEX program for the IBM-RS6000 AIX, the RINEX file is also copied to the Delft anonymous ftp account. Furthermore the data are distributed, using ftp, for the IGS to the IfAG data center. In case of an ftp error when transmitting the file to IfAG the data will be put to the CODE IGS Analysis Center in Berne. In case of any errors during the ftp sessions an e-mail message will be sent to both operators.

After conversion of the raw Rogue data, the RINEX data are processed using parts of the Gipsy and Bernese software. With both softwares an orbit integration is performed to see if anything is wrong with the navigation messages. Up to now no errors have been detected here in over two years of operation. The observation data are run through the "ninja" program of the Gipsy software with the TurboEdit algorithm, to get an idea of the data quality. From the Bernese software we use the program "RxSTATUS" and "RNXGRA" to get a graphical overview of the observations. Furthermore, a single-point-positioning solution is made using the code observations. Here both the observation and the navigation files are used. This code single-point positioning is done twice; once estimating only a clock offset and a clock drift and once estimating a clock offset for every epoch. The difference between the sigmas of the residuals of these two runs gives us an idea of the quality of the external frequency used in Kootwijk. Furthermore the rms of the residuals is a control on the quality of the code observations.

Finally the log sheet of the data processing is sent by e-mail to both operators and the output of the RNXGRA program (pseudo graphic of the RINEX observations) is put to Kootwijk using ftp.

Italian Space Agency

Francesco Vespe
Italian Space Agency
Matera, Italy

Matera Core Station

The activities of the Matera Core Station are now completely automated. The GPS fixed-station Rogue SNR-8 was installed in 1990. In 1992 our station was included among the core stations of the IGS service. The operational mode of the Rogue receiver is the following:

- Time acquisition: 24 hour/day
- Sample rate: 30 sec
- Elevation cutoff 15°
- 5-MHz external reference on Hydrogen Maser

The collected data are sent daily through the Internet in raw format to JPL/NASA and in Rinex compressed format to IfAG. In Figure 1 we show the data flow configuration used.

The Raw and RINEX compressed data are also archived at CGS.

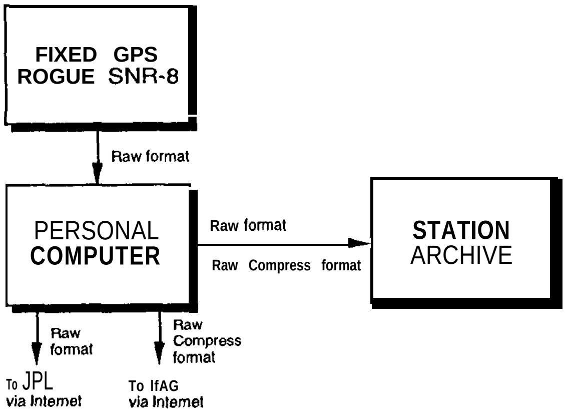

Figure 1. Data flow configuration of the GPS fixed station at Matera.

A New Fixed GPS Station at Padova

The University of Padova, in collaboration with CGS, installed a fixed station last October. The-data are collected on a daily basis and through modem are sent to CGS. As for the core stations, the data are then distributed to IfAG (RINEX) and to JPL (raw).

Following is a summary of the main features of the new GPS fixed station in Padova:

Type of Receiver:	Trimble 4000 SSE
Frequency Standard:	Internal
Coordinates of the site:	45°24’25” N 11°40’52” E 90 m
Vertical antenna height:	1.962 m (on bottom of Preamplifier)
On site point of contact:	Prof. Caporali, Dr. Galgaro Dept. of Geology and Geophysics, University of Padova

The Permanent GPS Tracking Station Zimmerwald

Urs Wild
Federal Office of Topography
Wabern, Switzerland

Introduction

The Federal Office of Topography has been operating a permanent GPS receiver since the beginning of the IGS Test Campaign (June 1992) at the SLR station Zimmerwald of the Astronomical Institute of the University of Berne (AIUB).

The station is located 10 km south of Berne at an altitude of about 900 m. The station consists of the old astronomical and the newer SLR dome and a building with offices and accommodations for the SLR observers. The GPS antenna is installed on top of a 9-m steel mast.

Local ties have been established between the axis intersection point of the SLR telescope, the GPS antenna on the mast, older GPS points on the roof of the main building, and a first-order triangulation point in the vicinity of the station. All local surveys were carried out by the Swiss Federal Office of Topography with an accuracy at the 1-mm level.

Permanent GPS Tracking

The technical specifications of the GPS receiver in Zimmerwald are:

Receiver type	Trimble Geodetic System Surveyor 4000SSE
NP software	Version 6.10
SP software	Version 1.26
Internal memory	2.5 MB
Number of channels	9 + 9
Observable	L1 and L2 phase / P-code on L1 and L2 / Cross-correlation under AS
RTCM	Output (used for DGPS service)
1 PPS	Installed (used for SLR)

The Trimble 4000SSE is connected to a laptop computer, which is connected through a LAN to the station computer (VAXStation 4000/90). The receiver and the steering laptop computer are protected against power failure with a 24-V DC power supply and may be operated up to 6 hours independently from the AC current.

A special setup for the permanent GPS tracking has been chosen because Zimmerwald is not only an IGS station, but is also a reference station for national surveys and for high-precision aircraft navigation for airborne photogrammetry. It was therefore our goal not to be limited to the 30-s sampling rate commonly used for the IGS.

On the laptop computer (running under MS-DOS) the program DESQview has been installed in order to have multitask capability. Three programs are running permanently on the laptop:

- Data Logging (using the program LOGST from TRIMBLE)
- FTP server (allowing file transfer from/to the laptop)
- CRON (Job Scheduler)

The program LOGST downloads data to the laptop continuously, i.e. no data is stored in the internal receiver memory. The sampling rate is 1 s.

Every full hour the data are converted from the disk-image format to the Trimble raw data format (DAT/EPH/ION/MES). The data are automatically reduced from 1-s to 30-s data rate, unless 1-s data are explicitly requested (i.e. in a time table) for special applications such as photogrammetric flights.

Producing l-h files would also allow hourly distribution of RINEX files (even at a higher data rate than 30 s) over the Internet, in order to achieve the near real-time requirements in the future.

Every day all l-h data files are concatenated and converted to the RINEX format. The original Trimble raw data files are compressed (PKZIP) into one file. All data of the last 24 h are then downloaded to the station computer (VAXStation 4000/90), where the RINEX files are compressed and sent to the IGS European Data Center (IfAG, Frankfurt) and to CODE (Center for Orbit Determination in Europe) at the AIUB. Normally the files (in the RINEX format) are available at IfAG and CODE within a few hours after midnight.

Twenty-one days of data are available on-line from the station computer; data older than 21 days are automatically deleted from the disk every day. Data backup is performed on a magneto-optical disk (with a capacity of approximately one year of tracking data).

The quality of the tracking data is checked daily using the QC program (UNAVCO) and by computing a single-point positioning solution.

Swiss GPS Information System

The Swiss GPS Information System was installed on the station computer at Zimmerwald. The information system maybe accessed by computer networks (Internet) or by telephone modem. The use of the system is free of charge.

The main options are:

- The **GPS-Status files of the USNO GPS Information system** are downloaded daily and may be displayed.

- The status of the permanent GPS receiver in Zimmerwald may be displayed (Table 1). The same file (updated half hourly) is also available at the IGS Central Bureau Information System.

- Different types of **orbit data** are available: for campaign planning purposes the actual EPH files of the Trimble receiver are available; for high-precision GPS applications the precise orbits of the CODE maybe obtained.

- **Application programs:** Coordinate transformations between WGS-84 / ITRF and the national coordinate system (and others) maybe computed. Another program allows the computation of the deflections of the vertical and geoidal heights (for the Swiss geoid) of sites within Switzerland.

Table 1. Permanent GPS tracking status at Zimmerwald.

Date / Time 1995/05/26 15:04 UT
Day of the Year : 146 GPS - Week: 802

Tr	SV	Azi	El	AS	URA	H	Tr	SV	Azi	El	AS	URA	H
	1			Y	32.0	H	*	19	314	11	Y	32.0	H
	2			Y	32.0	H		20			Y	32.0	H
	4			Y	32.0	H	*	21	154	40	Y	32.0	H
	5			Y	32.0	H	*	22	200	57	Y	32.0	H
	6			Y	32.0	H	*	23	98	49	Y	32.0	H
	7			Y	32.0	H		24			Y	32.0	H
	9			Y	32.0	H		25			Y	32.0	H
	12			N	2.8	U	*	26	46	5	Y	32.0	H
	14			Y	32.0	H		27			Y	32.0	H
	15			Y	4.0	H	*	28	308	66	N	4.0	H
	16			Y	32.0	H		29			Y	32.0	H
*	17	56	34	Y	32.0	H	*	31	292	23	Y	32.0	H
	18			Y	32.0	H		–					

Tr: Tracking flag (*: satellite tracked)
Sv: Satellite Number
Azi: Azimuth
El: Elevation
AS: Y: AS on / N: AS off
URA: User Range Accuracy
H: Satellite Health (H: healthy, U: unhealthy)

DGPS Service (Pilot project)

The Swiss Federal Office of Topography and the SwissTELECOM are establishing a nationwide DGPS service over FM/RDS (Radio Data System) using the RTCM corrections generated by the Trimble 4000SSE of the Permanent Tracking Station Zimmerwald. During the pilot project (September 1995-1997) the RTCM corrections are broadcasted over four major FM stations which cover about 70% of the more densely populated area of Switzerland.

First field tests have shown accuracies of 1 to 5 meters in real-time, depending on the receiver type used.

Pine Meadow PGGA

Frank Wyatt
Scripps Institution of Oceanography
San Diego, California

Form

Prepared by (full name)	: Frank Wyatt, Hadley Johnson, and Yehuda Bock
Date	: November 21, 1994
Report type	: NEW

Site Identification of the GPS Monument

Site Name	: Pinemeadow PGGA
4 char ID	: ROCH
Monument Inscription	: None

Threaded stainless steel rod (2 cm diameter, 9 cm long), set vertically in hole drilled in large granite outcropping on side of hill. Rod set in granite with epoxy.

IERS DOMES Number	40486MO01
CDP Number	None
Date	April 19, 1991 (installed)
Additional information	PGGA - Permanent GPS Geodetic Array

Site Location

Town	Pinemeadow
Country	California, USA
Tectonic Plate	Pacific-North America plate boundary
Additional information	ITRF92 coordinates (m) — X -2382183.199 Y -4755085.173 Z 3511367.704 Epoch 1993.000

GPS Receiver

a-c) Type	Trimble 4000 SST
Serial Number	0496
Firmware Version	4.11
Date	April 19, 1991
Note	First measurements

```
               Trimble: 4000ST  L1/L2 GEOD

                       ----+----                         <-- 0.070 L1
                    /      +      \                      <-- 0.068 L2
++---------------+---------------  +----------------++  <-- 0.063  TGP
++--------------+----------------  -+---------------++  <--  0.060  BGP
                |                   |
                                   |
                  |
                  +------x------+                   <-  0.000   ARP=BPA

                  <--  0.140 -->                          BPA
               <--     0.155      -->                     TPA
 <--                   0.467                  -->         NOTCHES
<--                    0.483                   ->         EOGE
```

Figure 1. Antenna graphics.

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Scripps Institution of Oceanography
San Diego, California

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X -2382183.199
Y -4755085.173
Z 3511367.704
Epoch 1993.000

GPS Receiver

a-c) Type	Trimble 4000 SST
Serial Number	0496
Firmware Version	4.11
Date	April 19, 1991
Note	First measurements

GPS Antenna

a)	Type	Trimble 4000ST L1/L2 GEOD
	Serial Number	0038
	Vertical Antenna Height	: 0.2465 m
	Antenna Reference Point	: BPA (Bottom of Preamplifier)
	Date	April 19, 1991
b)	Type	Trimble 4000ST L1/L2 GEOD
	Serial Number	0038
	Vertical Antenna Height	: 0.2475 m
	Antenna Reference Point	: BPA (Bottom of Preamplifier)
	Date	May 15, 1991
c)	Type	Trimble 4000ST L1/L2 GEOD
	Serial Number	: **0038**
	Vertical Antenna Height	: **0.2440** m
	Antenna Reference Point	: BPA (Bottom of Preamplifier)
	Date	July 3, 1992

Note: Antenna always oriented to true North

Frequency Standard

Frequency Standard	: Internal
Other (specify)	: Rogue SNR-8 uses external rubidium standard
Date	: April 19, 1991

Collocation

Other GEOPHYSICAL Instrumentation (specify): Continuous strain, tilt and gravity instruments, seismic array

Other (specify) : Environmental sensors

On-site, Point of Contact Agency Information

Agency	Scripps Institution of Oceanography
Contact	Frank Wyatt / Hadley Johnson
Address	IGPP 0225, Scripps Institution of Oceanography 9500 Gilman Drive, La Jolla, CA 92093-0225
Telephone	(619) 534-2411,534-2019
E-mail	fwyatt@ucsd.edu, hjohnson@ucsd.edu
Fax	(619) 534-5332

```
                Trimble: 4000ST  L1/L2 GEOD

                         ----+----                          <-- 0.070 L1
                      /       +       \                     <-- 0.068 L2
++----------------- ------------------+ ------------------++  <-- 0.063  TGP
++-----------------+ -------------------+ ------------------++  <-- 0.060  BGP
                   |                    |
                    |                  |
                     |                |
                      +-------x------+                   <-- 0.000  ARP=BPA

                      <--   0.140 -->                             BPA
                  <--        0.155        -->                     TPA
 <--                         0.467                    ->          NOTCHES
<--                          0.483                    -->         EDGE
```

Figure 1. *Antenna graphics.*

National Aeronautics and
Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

JPL Publication 95-18 9/95

International GPS Service for Geodynamics

Association Internationale de Géodésie
Union Géodésique et Géophysique
Internationale

International Association of Geodesy
International Union of Geodesy and
Geophysics