GLOBAL POSITIONING SYSTEM

1994 ANNUAL REPORT OF THE CODE PROCESSING CENTER OF THE IGS

CODE 95 P 01, 02

M. Rothacher, G. Beutler, E. Brockmann, L. Mervart, R. Weber (Astronomical Institute, Bern), U. Wild, A. Wiget (Federal Office of Topography, Wabern), H. Seeger (Institute for Applied Geodesy, Frankfurt), C. Boucher (Institut Géographique National, Paris)

CODE, the Center for Orbit Determination in Europe, is a joint venture of four European Institutions. It is located at the University of Bern, the computations are performed on a cluster of VAX/ALPHA processors. The software used is the Bernese GPS Software Version 3.6, which is continuously improved to meet the steadily growing demands of the IGS processing.

Markus Rothacher is the head of the CODE processing and development team, Robert Weber is responsible for the CODE solutions since July 1993. We refer to (Rothacher *et al*, 1994) for a general description of the processing at the CODE processing center. Here we only present the development which took place in 1994.

Again the number of stations included in our processing was considerably growing (from 38 stations at the end of 1993 to 49 stations at the end of 1994). The fact that 17 of "our" 49 stations lie in Europe underlines that CODE puts the emphasis on Europe in its contribution to the ITRF. The ERP series and the coordinates sent to the IERS in 1995 are based on the ITRF93. The same 13 stations were kept fixed in 1994 as in 1993 to produce the ERPs results (Rothacher *et al.*, 1994).

The program ADDNEQ, our routine stacking normal equations (Rothacher *et al*, 1994) was considerably generalized in 1994. Today it is the central tool of the CODE processing center of the IGS:

- ADDNEQ may now be used to form n-day arcs, n >= 2, from one-day arcs (Beutler *et al*, 1995). This new development saves many hours of CPU in the daily routine.

- More troposphere parameters (12 per station and day) are set up in the one-day solutions. ADDNEQ allows it to produce solutions based on 2-, 4- ,6- ,12-, and 24-hour troposphere intervals (per station and day).

- ADDNEQ may now handle nutation parameters: First derivatives of $d\varepsilon$ and $d\psi$ may be extracted from ADDNEQ. Time series are (internally) available since 1 January 1994.

- The capabilities to change the reference frame (e.g. from ITRF92 to ITRF93) are now fully implemented and active. As soon as a new reference frame becomes available new solutions (coordinates, orbits, etc) may be extracted easily from ADDNEQ back to day 200 of year 1993.

It is also worth mentioning that since 1 January 1994 the troposphere parameters are stored in a user-friendly form. They are available for atmosphere studies.

Ambiguity resolution on long baselines was studied by Mervart (1994), a solution based on about 70%-80% fixed ambiguities is produced in a fully automatic way in parallel to our official solutions since October 1994.

The orbit model was studied already in 1993 (Beutler *et al.*, 1994). The program ORBIMP, using an improved radiation pressure model, is used for the long arc analysis by the IGS analysis center coordinator (Beutler *et al.*, 1993). At present we are systematically analysing the mean orbital elements, the series of radiation pressure parameters, and the series of stochastic parameters generated since mid 1992. We expect that this analysis will contribute to a new IGS radiation pressure model in 1995.

References

Beutler, G., Brockmann, E., Gurtner, W., Hugentobler, U., Mervart, L., Rothacher, M., Verdun, A., 1994: Extended Orbit Modelling Techniques at the CODE Processing Center of the IGS: Theory and Initial Result, *Manuscripta Geodaetica,* **19**, 367-386.

Beutler, G., Brockmann, E., Hugentobler, U., Mervart, L., Rothacher, M., Weber, R., 1995: Combining n Consecutive One-Day-Arcs into one n-Days-Arc, Submitted for publication to *Manuscripta Geodaetica,* October 1994.

Beutler, G., Kouba, J., Springer, T., 1993: Combining the Orbits of IGS Processing Centers, *Proceedings of the IGS Analysis Center Workshop,* October 12-14, 1993, J. Kouba (ed.), NRCan, Ottawa, Canada, p. 20-56, also in *Bulletin Geodesique* (accepted for publication).

Mervart, L., 1995: Ambiguity Resolution Techniques in Geodetic and Geodynamic Applications of the Global Positioning System, Ph.D. Thesis, Druckerei der Universitaet Bern.

Rothacher, M., Beutler, G., Brockmann, E., Gurtner, W., Mervart, L., Weber, R., Wild, U., Wiget, A., Seeger, H., Boucher, C., 1994: Annual Report of the CODE Analysis Center for 1993, *IERS Technical Note 17,* Observatoire de Paris, Paris, p. P-1 - P-14.

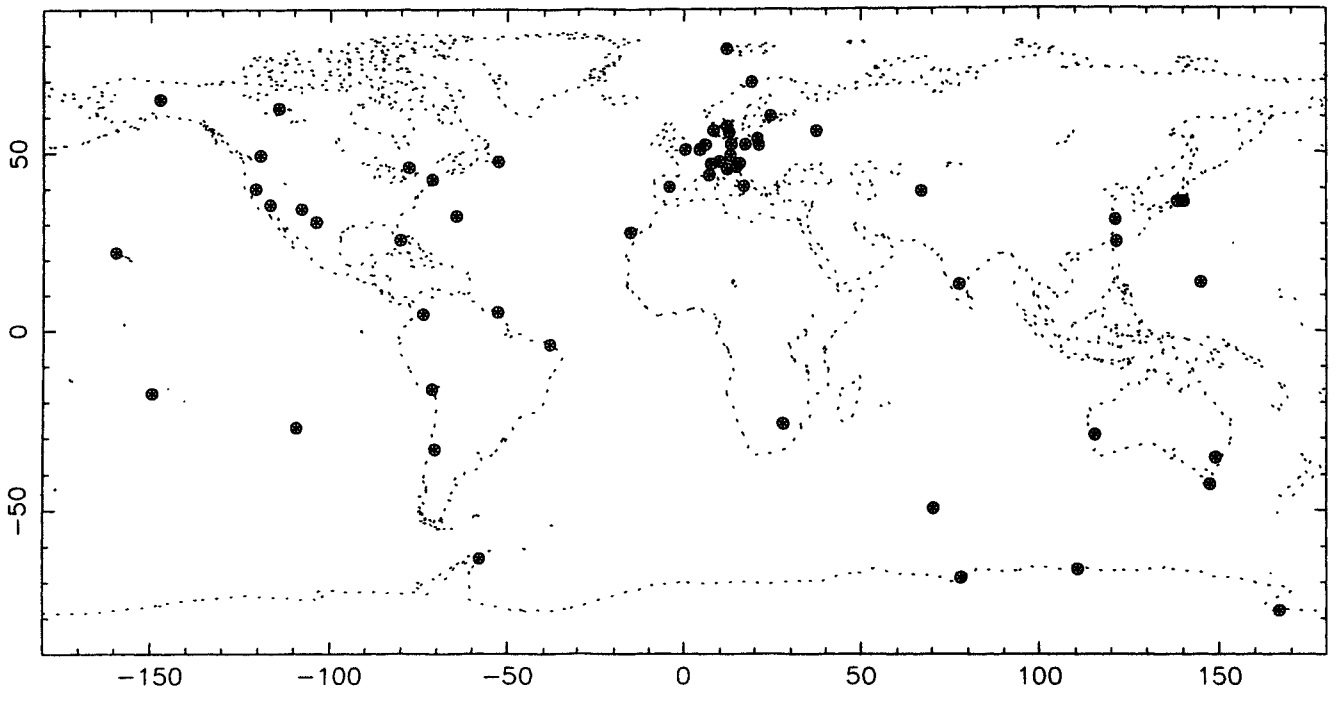
Technical description of solution CODE 95 P 01

1 - Technique:	GPS
2 - Analysis Center:	CODE
3 - Software used:	Bernese GPS Software Version 3.6
4 - Data span:	19 July 1993 (doy 200) - 1 March 1995
5 - Celestial Reference Frame:	
a - Nature:	dynamical
b - Definition of the orientation:	---
6 - Terrestrial Reference Frame:	SSC(IERS) 94 C 02
a - Relativity scale:	Local Earth
b - Velocity of light:	299792458 m/s
c - Geogravitational constant:	398.6004415 10^{12} m^3/s^2
d - Permanent tidal correction:	yes
e - Definition of origin:	origin of ITRF93
f - Definition of orientation:	non-rotation constraint
g - Reference epoch:	---
h - Tectonic plate model:	ITRF93 velocity field
i - Constraint for time evolution:	ITRF93 velocity field
7 - Earth orientation:	EOP(CODE) 95 P 01
a - A priori nutation model:	IAU 1980
b - Short-period tidal variations in x, y, UT1:	none
8 - Estimated Parameters:	
a - Celestial Frame:	---
b - Terrestrial Frame:	coordinates of free stations

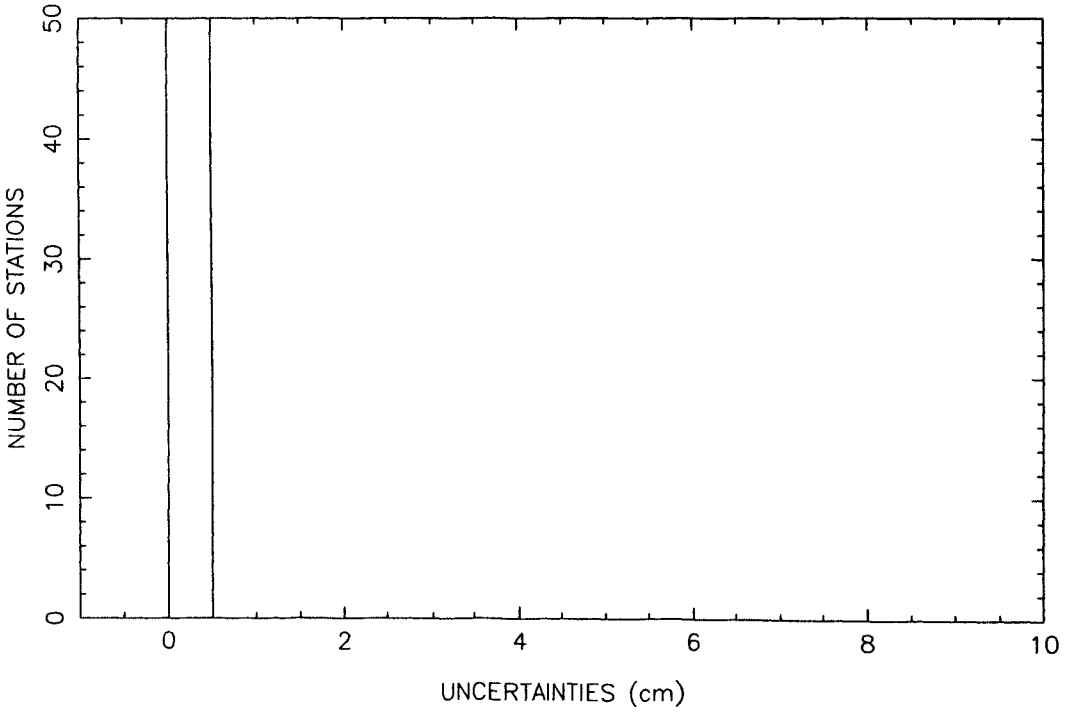
c - Earth Orientation:	x, y, UT1-UTC drift, and drifts in x, y
d - Others:	zenith troposphere delays (4 per day and station), orbit parameters (8 per satellite), ambiguities, stochastic acceleration parameters for eclipsing satellites.

Technical description of solution CODE 95 P 02

1 - Technique:	GPS
2 - Analysis Center:	CODE
3 - Software used:	Bernese GPS Software Version 3.6
4 - Data span:	01 April 1993 (doy 091) - 1 March 1995
5 - Celestial Reference Frame:	
a - Nature:	dynamical
b - Definition of the orientation:	---
6 - Terrestrial Reference Frame:	SSC(CODE) 95 P 02
a - Relativity scale:	Local Earth
b - Velocity of light:	299792458 m/s
c - Geogravitational constant:	398.6004415 10^{12} m^3/s^2
d - Permanent tidal correction:	yes
e - Definition of origin:	origin of ITRF93
f - Definition of orientation:	non-rotation constraint
g - Reference epoch:	16 March 1994
h - Tectonic plate model:	horizontal component estimated, vertical component used from ITRF93
i - Constraint for time evolution:	WETT fixed on ITRF93 velocity, stations with a short observation period are constrained to ITRF93
7 - Earth orientation:	EOP(CODE) 95 P 02
a - A priori nutation model:	IAU 1980
b - Short-period tidal variations in x, y, UT1: none	
8 - Estimated Parameters:	
a - Celestial Frame:	---
b - Terrestrial Frame:	coordinates and velocities of all stations
c - Earth Orientation:	x, y, UT1-UTC drift, and drifts in x, y
d - Others:	zenith troposphere delays (4 per day and station), orbit parameters (8 per satellite), ambiguities, stochastic acceleration parameters for eclipsing,satellites.



Distribution of the 60 sites of the terrestrial frame SSC(CODE) 95 P 02.



Distribution of the uncertainties (quadratic mean of σ_x, σ_y, σ_z) for the 69 stations of the terrestrial frame SSC(CODE) 95 P 02.

EOP(CODE) 95 P 01 From Jul 1993 to Jul 1995

Number of measurements per year and median uncertainties
Units : 0.001" for X,Y; 0.0001s for UT1

YEAR	X		Y		UT1	
	Nb	Sigma	Nb	Sigma	Nb	Sigma
1993	166	0.04	166	0.04	166	0.03
1994	365	0.04	365	0.03	365	0.03
1995	210	0.02	210	0.03	210	0.02

1995 GPS DATA PROCESSING AT THE EMR ANALYSIS CENTRE

EMR 95 P 02

J. Kouba, R. Ferland, P. Tetreault, J. Popelar, Geodetic Survey Division (GSD), Geomatics Canada, Natural Resources Canada (NRCan) (Formerly: Energy Mines and Resources (EMR)), 615 Booth St., Ottawa, Ont. K1A OE9

Since August 1992 the GSD's Master Active Control System (MACS) Centre has been processing GPS data from six Canadian ACS stations augmented by up to 16 stations of the International GPS Service for Geodynamics (IGS) global station network. Typically there were 25 GPS satellites observed and their precise ephemeris generated daily during 1994. The GIPSY II/ OASIS GPS software system developed by the Jet Propulsion Laboratory has been adapted to obtain daily orbit, EOP and station coordinate solutions. As recommended by IGS, 13 stations (ALGO, YELL, FAIR, GOLD, SANT, TROM, KOSG, WETT, MADR, HART, HART, TIDB, YAR1) were constrained at the ITRF92 coordinates of the date, utilizing the ITRF92 station velocities. The adopted constants, gravity and radiation pressure models conform to the IGS/IERS standards (McCarthy, 1992). The global ocean loading model due to Pagiatakis (1982) has been adopted.

Daily 1994 GPS Processing:

The EMR processing is based on undifferenced phase and smoothed pseudorange data at 7.5 minutes sampling intervals using 15 degree elevation angle cut off. Both phase and pseudorange observations are considered uncorrelated and weighted using an exponential elevation angle function. Some stations (e.g. STJO, YELL) have higher pseudorange noise due to multipath and are being weighted accordingly. We have also enhanced the GIPSY II software to facilitate different weighting of satellites data, data segment deletion and corrections of satellite dependent pseudorange biases. This improved results for AS pseudorange data since AS was permanently introduced on Jan. 31, 1994.

The daily solutions generate 24h arcs without any overlap. For each 24h arc the initial a priori state vector is taken from the previous day solution and propagated to the beginning of the current day and augmented by stochastic orbit sigmas of about 0.2m and 0.1mm/s, making the estimation process self contained. Broadcast orbits are used only when introducing or re-introducing a satellite. This approach also facilitates an estimation of UT1-UTC. Due to collinearity between UT1 and the R.A. of the ascending orbit nodes, the estimated UT1-UTC may contain both the UT1 changes as well as the orbit node errors common to all satellites, with sigmas and correlation characteristic of a random walk process. Jan. 2, 1994 UT1-UTC was initialized to a Bull. A value and a continuous UT1-UTC series has been maintained since.

The terrestrial reference frame position/orientation, and to a large extend the scale of the EMR orbit/EOP solutions are nominally those of ITRF92 (current epoch) as realized through the set of the 13 stations constrained at the ITRF92 SSC and SSV. The reported EOP sigmas are the formal sigmas as obtained from the adjustment. The repeatability of position solutions indicates that the formal sigma may be too optimistic, and need to be multiplied by a factor of 2 or 3. More information on the EMR daily processing is provided in Tetreault *et al.* (1995).

Batch Reprocessing:

All the archived 1994 daily solutions were retrieved and subjected to additional statistical testing/editing with emphasis on improving daily station solutions. The a priori (ITRF92) coordinate and sigma constraints at the 13 stations were rigorously removed and 10m sigma constraints were introduced to prevent numerical instability. These unconstrained variance-covariance matrices and the solutions for station coordinates, EOP were then combined into a single annual solution for station coordinates, velocities and daily EOP. The orbit state vector and other unknowns contained in the daily solutions were first rigorously eliminated from the solutions. The final solution is practically unconstrained and approximates a rigorous addition of the reduced normal matrices. It produced a consistent set of station coordinates (at the epoch 1994.0), new daily EOP and the corresponding station velocities, all based on the 1994 GPS data only.

Since it is not possible to submit a single solution for the EOP and SSC, the solution and the corresponding variance-covariance matrix were divided into an EOP part with standard deviations (EOP(EMR) 95 P 02) and the station positions and velocities (SSC(EMR) 95 P 02), which includes a complete variance-covariance matrix. For this submission we have applied small shifts and rotations to make the EOP, SSC and SSV solutions consistent with the 13 station ITRF93 SSC and SSV. The ITRF93 station velocities of the 13 stations were then highly constrained (at 0.01 times the ITRF93 SSV sigmas) to provide the reference for the time series of EOP and SSC as well as for the remaining station velocity solutions.

The EOP(EMR) 95 P 02 solution is reported in the IGS EOP format; the SSC(EMR) 95 P 02 solution uses parts of the proposed SINEX (Software INdependent EXchange) format, and includes complete information on a priori values, the antenna height offsets used, etc. More information on this batch reprocessing at NRCan is provided in Ferland *et al.* (1995).

References

Ferland, R., Kouba, J., Tetreault, P., Popelar J., and Dragert, H. 1995: Variation in EOP and station Coordinates Solution for Canadian Active Control System (CACS), A paper to be presented at the XXI General Assembly of IUGG, July 2-14, Boulder, Colo. (in prep.)

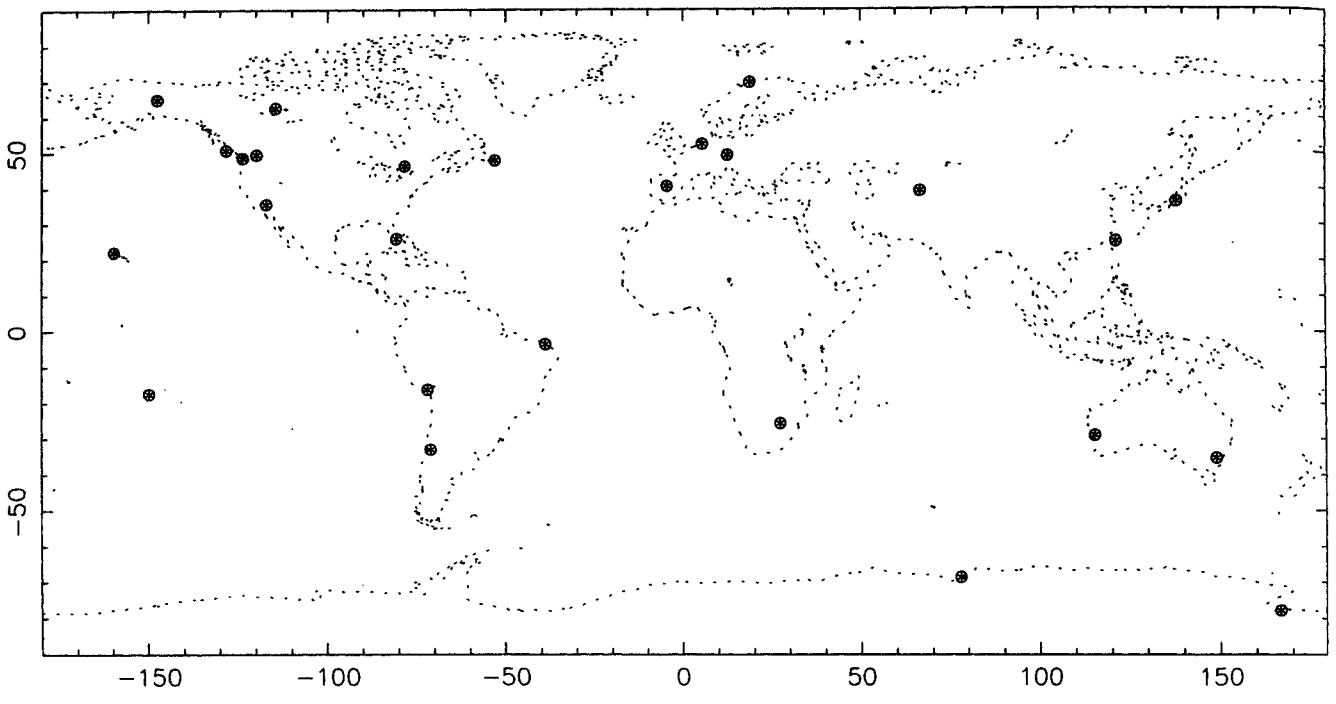
McCarthy, D.D. (ed), 1992: IERS Standards (1992), *IERS Technical Note 13,* Observatoire de Paris, Paris.

Pagiatakis, S.D., 1982: Ocean loading, body tides and polar motion effects on very long baseline interferometry, UNB Technical Rep. No. 2, Dept. of Surv. Engineering, Univ. of New Brunswick, Fredericton, N.B..

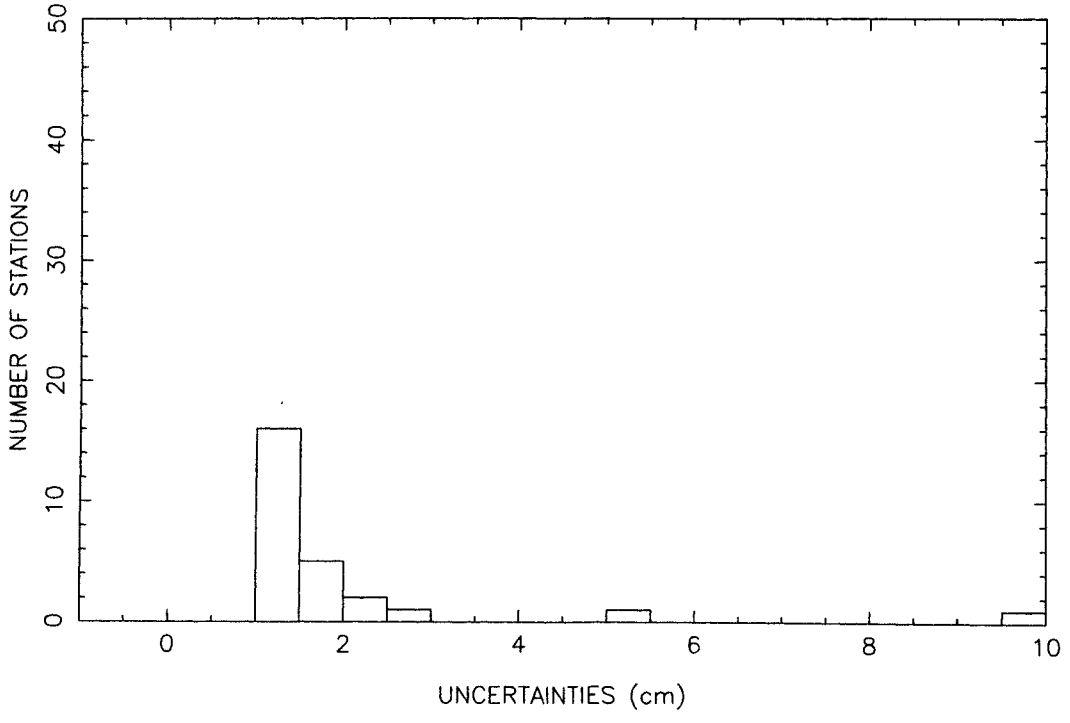
Tetreault, P., Kouba, J., Ferland, R., Popelar, J. 1995: NRCan (EMR) Analysis Report, 1994 IGS Annual Report (in prep.)

Technical description of solution EMR 95 P 02

1 - Technique:	GPS
2 - Analysis Center:	NRCan (Formerly EMR)
3 - Software used:	GIPSY II/ OASIS
4 - Data span:	Jan. 02-Dec. 31, 1994
5 - Celestial Reference Frame:	None
a - Nature:	25-26 GPS satellites
b - Definition of the orientation:	UT1-UTC (Bull. A) on Jan 2, 1994; 13 ITRF93 station velocities
6 - Terrestrial Reference Frame:	SSC(EMR) 95 P 02
a - Relativity scale:	LE
b - Velocity of light:	299 792 458 m/s
c - Geogravitational constant:	$3.986004415\ 10^{14}\ m^3/s^2$
d - Permanent tidal correction:	Yes
e - Definition of origin:	C10=0, C11=0, S11=0 (a coordinate shift, consistent with the 13 ITRF93 stations applied)
f - Definition of orientation:	ITRF93 (the 13 station coordinates)
g - Reference epoch:	1994.0
h - Tectonic plate model:	13 station ITRF93 coord. velocities
i - Constraint for time evolution:	13 station ITRF93 coord. velocities fixed (to ITRF93 SSV sigmas times 0.01)
7 - Earth orientation:	EOP(EMR) 95 P 02
a - A priori nutation model:	IAU (1980)
b - Short-period tidal variations in x, y, UT1:	No daily and sub-daily tidal variations applied
8 - Estimated Parameters:	
a - Celestial Frame:	Satellite states, X, Y, Z and Xdot, Ydot, Zdot (a priori sigmas: 1 km/0.005m/s or about 0.2m/sqrt (day); 0.1mm/s/sqrt (day))
b - Terrestrial Frame:	Station X0, Y0, Z0, Xdot, Ydot, Zdot (a priori sigmas: 10m for X0,Y0,Z0; the 13 station ITRF93 vel. sigmas times 0.01)
c - Earth Orientation:	x,y, UT1-UTC, LOD (since MJD 49515) (a priori sigmas: equivalent to 3m in x,y and UT1-UTC; 86 s/day for LOD)
d - Others:	Satellite and station clocks (a priori sigmas: 1ms and 1s resp.) Tropo Z. Delay (a constant and random walk with a priori sigmas: 0.2m and 0.01m/sqrt(h)) Sol. radiation press.: Gx, Gz and Gy (a priori sigmas: 10% for Gx, Gz and $0.5\ 10^{-9}\ m/s^2$ for Gy) Initial phase ambiguities (a priori sigmas: 300 000 km)



Distribution of the 26 sites of the terrestrial frame SSC(EMR) 95 P 02.



Distribution of the uncertainties (quadratic mean of σ_x, σ_y, σ_z) for the 26 stations of the terrestrial frame SSC(EMR) 95 P 02.

EOP(EMR) 95 P 02 From Jan 1994 to Dec 1994

Number of measurements per year and median uncertainties
Units : 0.001" for X,Y; 0.0001s for UT1

YEAR	X		Y		UT1	
	Nb	Sigma	Nb	Sigma	Nb	Sigma
1994	362	0.07	362	0.07	362	0.39

ANNUAL REPORT FROM THE ESOC IGS ANALYSIS CENTRE TO THE IERS FOR 1994

ESOC 94 P 01, 95 P 01

T. J. Martin Mur, J. M. Dow, J. Feltens (1), C. Garcia Martinez (2)
ESA / European Space Operations Centre (ESOC)
(1) mbp at ESOC, (2) GMV at ESOC

The ESOC contribution to the IERS for 1994 consists of a daily Earth Orientation Parameter solution, EOP(ESOC) 94 P 01, and a GPS station coordinate solution, SSC(ESOC) 95 P 01. The EOP solution has been obtained with the daily processing of GPS data for the IGS and the station coordinate solution has been obtained from 274 arcs of GPS observation equations from 1994.

Changes in 1994 in the EOP(ESOC) 94 P 01 series

For 1994 the terrestrial reference frame has been defined by fixing a set of 13 ground stations to the values given by the IERS and by using the ITRF92 velocity field. A continuous UT1R-TAI series is also provided. It has been obtained by the integration of the LODR solution.

Description of the GPS station coordinate solution SSC(ESOC) 95 P 01

Sites included
The stations that were included in the analysis were those stations that the ESOC/IGS Analysis Centre used for its 1994 daily IGS processing. They included all the 13 stations that are kept fixed in daily analysis, all the ESA receivers and additional receivers to obtain an evenly distributed tracking of the GPS satellites. All these stations are equipped with Rogue, MiniRogue, or TurboRogue precise geodetic GPS receivers connected to stable atomic frequency standards.

Arcs included
The periods of data used are 274 arcs of 1994. Observation equations were produced for the complete year, but other arcs are not used due to data or modelling problems. All GPS satellites were used, except those doing manoeuvres during each particular arc. For most of the stations we have used data from the whole year. The exceptions are KERG, KIT3, MATE and VILL, that were introduced in the daily ESOC analysis only for the last part of the year.

Initial station coordinates
Initial station coordinates were obtained from the ITRF93 station coordinate solution. Station positions were calculated at the different epochs using the velocities of the ITRF93. To obtain the velocities of those stations not included in the ITRF93 the NNR-NUVEL1 velocity field was used. Occupancies and antenna heights were obtained from the file localtie.tab maintained by the IGS Central Bureau.

Departures from IERS (1992) Standards

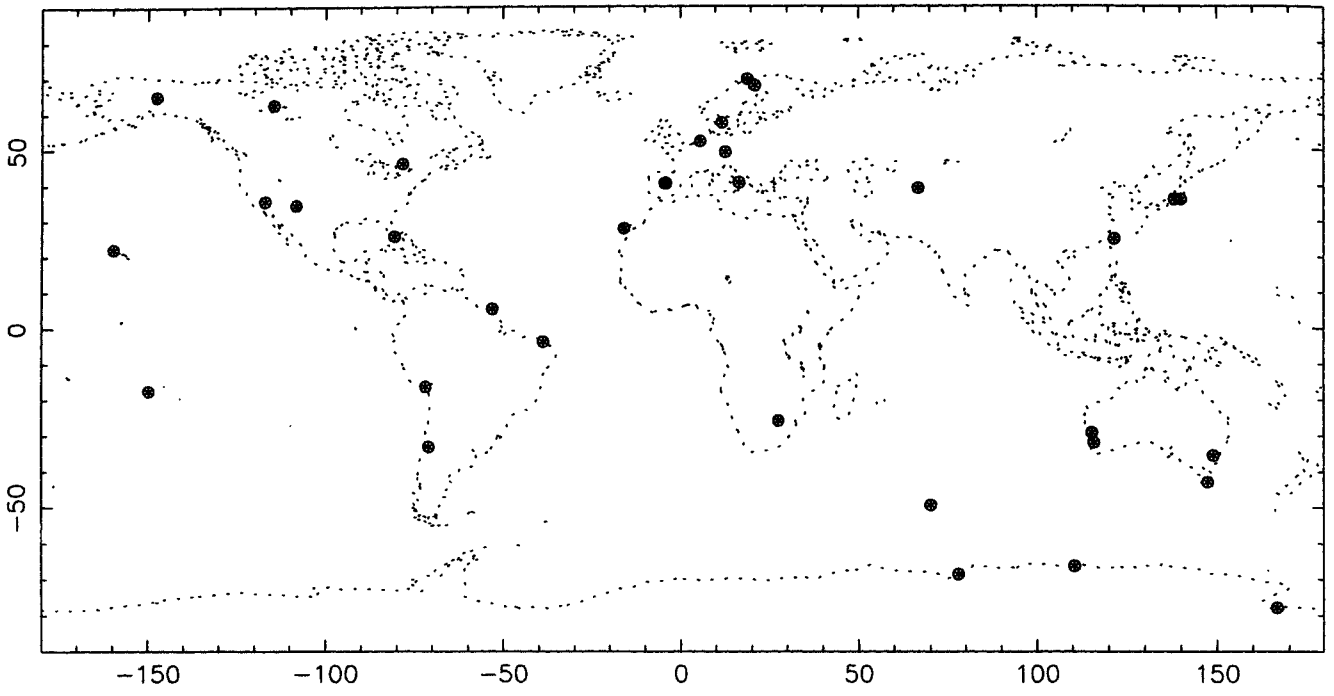
Relativistic corrections to the acceleration and to the propagation not applied. Ocean loading site displacement not applied.

Technical description of solution EOP(ESOC) 94 P 01

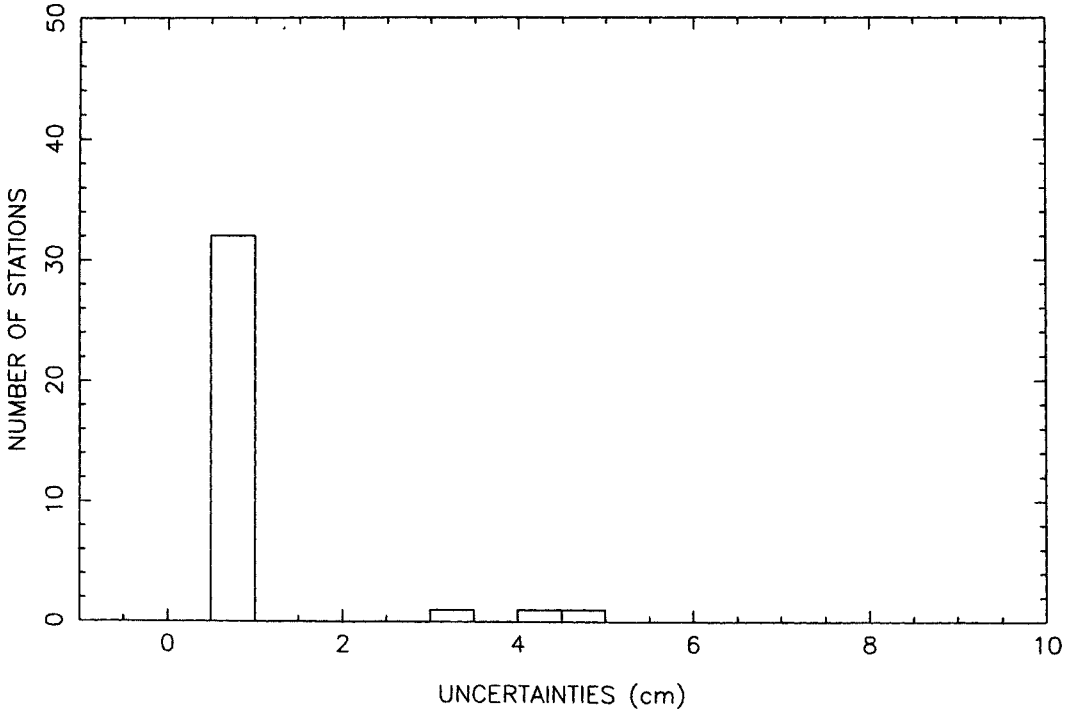
1 - Technique:	GPS
2 - Analysis Center:	ESA/European Space Operations Centre (ESOC)
3 - Software used:	GPSOBS/BAHN-V5
4 - Data span:	Dec 93 - Dec 94
5 - Celestial Reference Frame:	Mean Geocentric Equatorial System of 2000.0
a - Nature:	Dynamical
b - Definition of the orientation:	Using the IERS conventional models for precession and nutation, including celestial pole offsets.
6 - Terrestrial Reference Frame:	SSC(IERS) 93 C 04
a - Relativity Scale:	LE
b - Velocity of light:	299 792 458 m/s
c - Geogravitational constant:	$3.986004415\ 10^{14}\ m^3/s^2$
d - Permanent tidal correction:	No
e - Definition of origin:	Geocentre through C10=0, C11=0, S11=0.
f - Definition of orientation:	By fixing the coordinates of 13 fiducial stations to the SSC(IERS) 93 C 04 values.
g - Reference epoch:	1993.0
h - Tectonic plate model:	ITRF92 + NNR-NUVEL1
i - Constraint for time evolution:	by fixing 13 station coordinates and velocities to the ITRF92 solution.
7 - Earth Orientation:	EOP(ESOC) 94 P 01
a - A priori nutation model:	IAU(1980), corrected for celestial pole offsets from IERS Bulletin B.
b - Short-period tidal variations in x, y, UT1:	x, y and UT1R rate estimated as constants for 24 hours intervals. Short period UT1 variations modelled using Yoder (1981) model.
8 - Estimated parameters:	
a - Celestial Frame:	None
b - Terrestrial Frame:	Coordinates for stations that are not fixed.
c - Earth Orientation:	One set of pole coordinates xp, yp and LODR per day.
d - Others:	Satellite parameters per spacecraft: - one orbital state at start epoch. - one scaling factor for radiation pressure ROCK4 T10 or T20 model. - one Y-bias acceleration. Station related parameters per ground station: - every 6 hours an atmospheric zenith delay and a shape parameter. - clock biases and clock drifts as needed. - double-differenced phase ambiguities as real-valued parameters.

Technical description of solution SSC(ESOC) 95 P 01

1 - Technique:	GPS
2 - Analysis Center:	ESA / European Space Operations Centre (ESOC)
3 - Software used:	GPSOBS/BAHN-V5/MULTIARC
4 - Data span:	Jan 94 - Dec 94
5 - Celestial Reference Frame:	Mean Geocentric Equatorial System of 2000.0
a - Nature:	Dynamical
b - Definition of the orientation:	Using the IERS conventional models for precession and nutation, including celestial pole offsets.
6 - Terrestrial Reference Frame:	SSC(ESOC) 95 P 01
a - Relativity Scale:	LE
b - Velocity of light:	299 792 458 m/s
c - Geogravitational constant:	$3.986004415\ 10^{14}\,m^3s^2$
d - Permanent tidal correction :	No
e - Definition of origin:	Geocentre through C10=0, C11=0, S11=0.
f - Definition of the orientation:	By using the IERS Bulletin B Earth rotation parameters and applying a loose constraint to station positions and horizontal velocities.
g - Reference epoch:	1994.0
h - Tectonic plate model:	For those stations for which the velocity is not estimated NNR-NUVEL1 is used.
i - Constraint for time evolution:	By using the IERS Bulletin B Earth rotation parameters and applying a loose constraint to station horizontal velocities.
7 - Earth Orientation:	IERS Bulletin B
a - A priori nutation model:	IAU(1980), corrected for celestial pole offsets from IERS Bulletin B.
b - Short-period tidal variations in x, y, UT1:	linear x, y and UT1R in 24 hour intervals. Short period UT1 variations modelled using Yoder (1981) model.
8 - Estimated parameters:	
a - Celestial Frame:	None
b - Terrestrial Frame:	Coordinates of 35 IGS stations. Horizontal velocities of 30 IGS sites.
c - Earth Orientation:	None.
d - Others:	None.



Distribution of the 34 sites of the terrestrial frame SSC(ESOC) 95 P 01.



Distribution of the uncertainties (quadratic mean of σ_x, σ_y, σ_z) for the 35 stations of the terrestrial frame SSC(ESOC) 95 P 01.

EOP(ESOC) 94 P 01 From Dec 1993 to Dec 1994

Number of measurements per year and median uncertainties
Units : 0.001" for X,Y; 0.0001s for D

YEAR	X		Y		D	
	Nb	Sigma	Nb	Sigma	Nb	Sigma
1993	6	0.08	6	0.08	6	0.15
1994	365	0.10	365	0.10	365	0.15

EARTH ROTATION PARAMETERS, STATION COORDINATES AND VELOCITIES FROM GPS DATA

GFZ 95 P 02, 03

G. Gendt, G. Dick, Ch. Reigber, W. Sommerfeld, Th. Nischan
GeoForschungsZentrum (GFZ) Potsdam

A global Set of Station Coordinates (SSC(GFZ) 95 P 02) and Earth Rotation Parameters (EOP(GFZ) 95 P 02) are computed from the 1993/1994 global GPS data set using the GFZ analysis software package EPOS.P.V2. Additionally results from simultaneous adjustment of station coordinates and velocities are presented (SSC(GFZ) 95 P 03).

Data

The initial data acquired at the GFZ-IGS Center are the 30 sec RINEX data from the IGS stations collected at the global data centers CDDIS and IGN.

For the analysis itself undifferenced ionospheric free phases with a sampling rate of 6 minutes were used. RINEX data sessions of 32 hours in length were formed, which overlap by 8 hours from day to day. P-code data were entered into the analysis to preset the ambiguities. The identified ambiguities were constrained to the expected P-code accuracy. Consecutive data segments of 32 hours were formed to carry out the solutions including a quality assessment in overlapping orbital segments. The number of sites used varies from 23 in 1993 to 42 in 1994.

Analysis

The solutions were obtained by using GFZ EPOS.P.V2 Software package, which is adapted to the IERS Standards with the few exceptions indicated below. The adjusted parameter set results from a HELMERT blocking. For each parameter the resolution time can be chosen freely. The orbital elements are adjusted independently from day to day. To get a stable reference for the pole parameter determination a set of 12 stations was fixed for this purpose. The nominal values for these sites vary within the two years (in 1994 it was the ITRF92 system). The whole series is homogenized to compensate for jumps originating from these changes.

The Earth Rotation Parameters (pole coordinates and length of day) were adjusted as daily values (first 24 hours of each session). These values are practically independent from day to day. The accuracy is 0.25 mas for the pole position (difference to the mean of all IGS series) and 0.06 ms for LODR (compared to Bulletin B).

For the determination of station coordinates fiducial-free normal equations were archived. These normal equations were combined into a two-year system to derive the global station position solution SSC(GFZ) 95 P 02. To define the orientation three horizontal site parameters were fixed. The site velocities were fixed to the ITRF93 values (SSC(IERS) 94 C 01). A small net rotation to ITRF93 was eliminated by a 7-parameter similarity transformation.

A second solution for the reference frame, SSC(GFZ) 95 P 03, was determined where the site positions and the horizontal site velocities were adjusted simultaneously. Velocities for sites with less than 6 months of data were fixed.

The internal consistency of the determined reference frame is in the sub-cm level and reaches the mm level for the denser parts of the network . Results from a Helmert transformation are given in the table below (units in mm) .

data set A	data set B	Stations compared	#sta	with ITRF93 velocities North	East	Up	with GFZ velocities North	East	Up
P01	ITRF93	global	24	4.2	4.0	9.1			
1993	1994	global	24	4.2	5.4	4.6	2.3	2.8	5.0
1993	1994	NoAmerika&Europe	16	2.7	2.3	3.3	0.9	0.9	3.7
1993	1994	Europe	8	1.4	1.2	2.3	0.6	0.5	2.5

The geocenter differs between the yearly solutions in the range of a few cm.

References

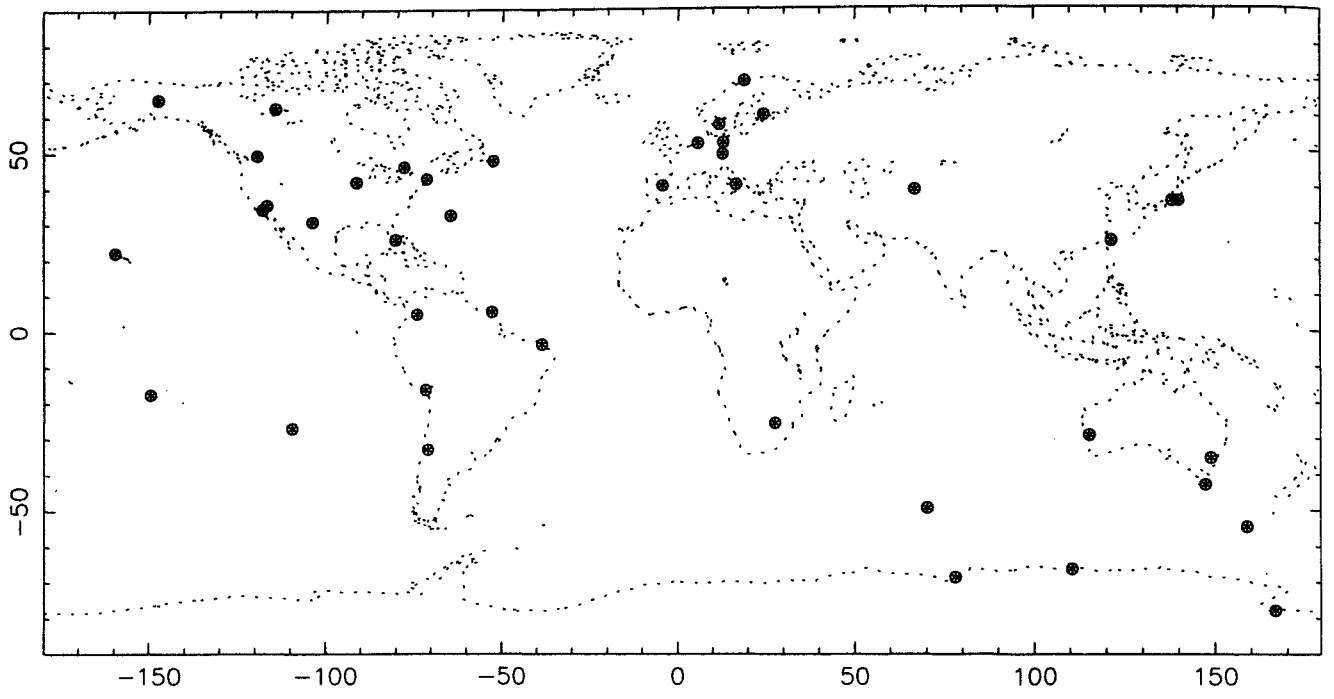
Reigber, Ch., Dick, G., Galas, R., Gendt, G., Montag, H., Zhu, S.Y., 1993: Investigation of high resolution Earth rotation parameters as determined from SLR and GPS data at Potsdam, Paper presented at IAG General Meeting, Beijing, August 8-13,1993

Gendt, G., Dick, G., Mai, W., Reigber, Ch., Nischan, Th., 1994: Earth Rotation Parameters and Station Coordinates from GPS Data, *IERS Technical Note 17,* P. Charlot (ed.), Observatoire de Paris, Paris, pp. P-37 - P-41.

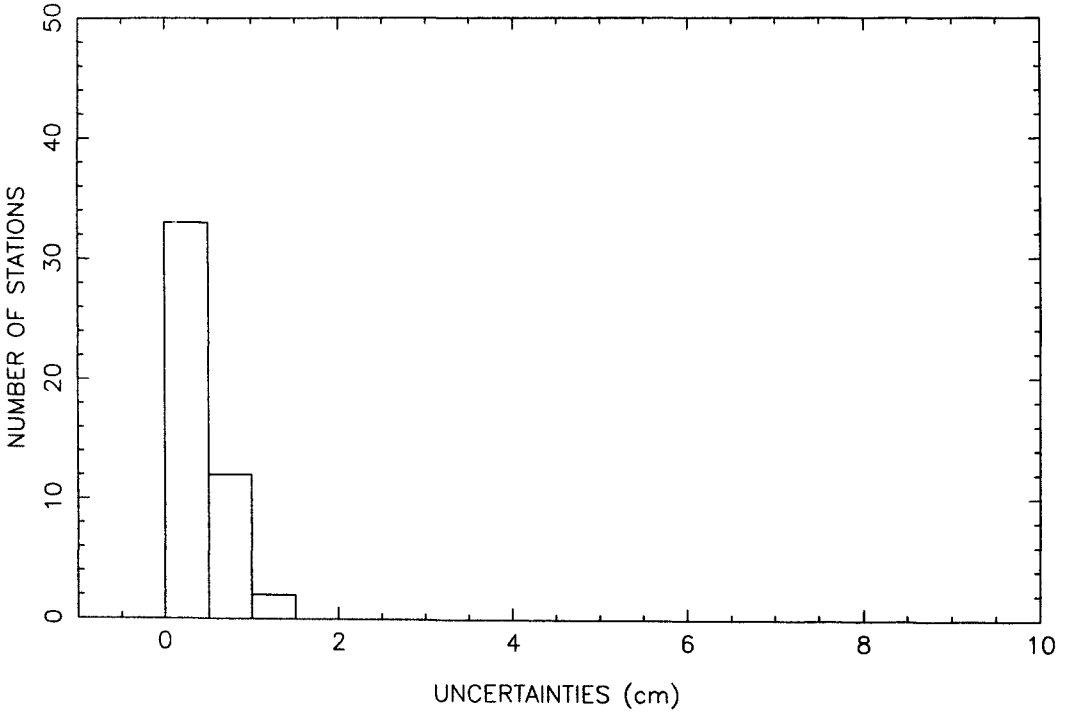
Gendt, G., Dick, G., Reigber, Ch., 1994: Plate Motions on a Global Scale Derived from GPS Data of the IGS Core Network, Paper presented at AGU Fall Meeting, Dec. 5-9, 1994 San Francisco, Abstract in EOS, Nov.1, 1994, p. 162 (G21A-5).

Technical description for solutions GFZ 95 P 02 and 95 P 03

1 - Technique :	GPS
2 - Analysis Center :	GFZ
3 - Software used :	EPOS.P.V2
4 - Data span:	Jan 93 - Dec 94
5 - Celestial reference frame :	
a - Nature :	dynamical
b - Definition of orientation :	aligned to UT1 form IERS Bulletin B
6 - Terrestrial Reference Frame :	SSC(GFZ) 95 P 02 and SSC(GFZ) 95 P 03
a - Relativity Scale :	none
b - Velocity of light :	299 792 458 m/s
c - Geogravitational constant:	$3.986004418\ 10^{14}\ m^3/s^2$
d - Permanent tidal correction:	yes (permanent tide not in listed coordinates)
e - Definition of origin :	C(1,0)=C(1,1)=S(1,1)=0
f - Definition of orientation :	longitude, latitude of ALGO fixed, latitude of WETT fixed, plus alignment to ITRF93 SSC(IERS) 94 C 01 by similarity transformation
g - Reference epoch :	1994.0 (MJD 49352)
h - Tectonic plate model :	ITRF93 Velocities
i - Constraint of time evolution:	a) SSC(GFZ) 95 P 02: fixed to ITRF93 Velocities b) SSC(GFZ) 95 P 03: vel_longitude, vel_latitude of ALGO, fixed vel_latitude of WETT fixed, plus alignment to ITRF93 Velocities by similarity transformation
7 - Earth Orientation :	EOP(GFZ) 95 P 02 (for SSC(GFZ) 95 P 02)
a - A priori nutation model :	IAU(1980)
b - Short-period tidal variations in x, y, UT1 :	UT1 zonal tides with periods < 35 days
8 - Estimated parameters :	
a - Celestial Frame :	none
b - Terrestrial Frame :	longitude, latitude, radius (vel_longitude, vel_lati for SSC(GFZ) 95 P 03)
c - Earth Orientation :	daily x, y and LODR
d - Others :	Orbit - 6 orbital parameters for 32-hour intervals - Reflectance coefficient, y-bias for 32 h - Tropospheric zenith path delay for 4-hour intervals - Ambiguities - Epoch time parameters



Distribution of the 41 sites of the terrestrial frame SSC(GFZ) 95 P 02.



Distribution of the uncertainties (quadratic mean of σ_x, σ_y, σ_z) for the 47 stations of the terrestrial frame SSC(GFZ) 95 P 02.

EOP(GFZ) 95 P 02 From Jan 1993 to Jan 1995

Number of measurements per year and median uncertainties
Units : 0.001" for X,Y; 0.0001s for D

YEAR	X		Y		D	
	Nb	Sigma	Nb	Sigma	Nb	Sigma
1993	360	0.04	360	0.03	360	0.40
1994	365	0.03	365	0.03	365	0.40
1995	3	0.03	3	0.03	3	0.40

COORDINATES, VELOCITIES, AND EOP FROM THE JET PROPULSION LABORATORY USING GPS

JPL 95 P 02

M. Heflin, M. Watkins, D. Jefferson, F. Webb, and J. Zumberge
Jet Propulsion Laboratory, California Institute of Technology, Pasadena, USA

Velocities and positions have been computed for 46 separate GPS monuments. The 16348 station days of data span four years from January 22, 1991 through January, 27 1995. Daily estimation was carried out by the Jet Propulsion Laboratory's geodetic analysis team. Past and present participants include Geoffrey Blewitt, Michael Heflin, David Jefferson, Yvonne Vigue, Michael Watkins, Frank Webb, and James Zumberge. The analysis strategies generally adhered to IERS/IGS standards and are described by Zumberge and Jefferson (1992), Heflin *et al.* (1992, 1994), Blewitt *et al.* (1992), Vigue *et al.* (1994), and Bar-Sever *et al.* (1995). Mean daily repeatability for all sites was determined to be 6 mm, 8 mm, and 13 mm for latitude, longitude, and height respectively.

Antenna heights were corrected on each day by comparing the value used during analysis to the official value listed at the IGS central bureau. Next, the daily solutions were combined, using their full covariance matrices, to obtain position and velocity estimates for each site. Formal errors were scaled by 1.8 to make chi-squared per degree of freedom equal to one. Finally, the reference frame was defined by application of internal constraints and rotation into ITRF93. The geocenter and scale were left at their GPS derived values.

The updated site position and velocity solution was then backsubstituted into the full information matrices (when available) for the daily Earth orientation parameters and station positions. This yielded a consistent EOP series spanning the period from mid 1992 through early 1995. Significant outliers were edited relative to a light smoothing. Because of gaps in the series, length of day has not been integrated in to UT1, and hence only x and y pole are included in this report. The resulting series demonstrates internal precision on the order of 0.2 to 0.3 mas. A scaling of approximately 2.5 will make the formal errors reported for the EOP series consistent with the internal precision.

Acknowledgements

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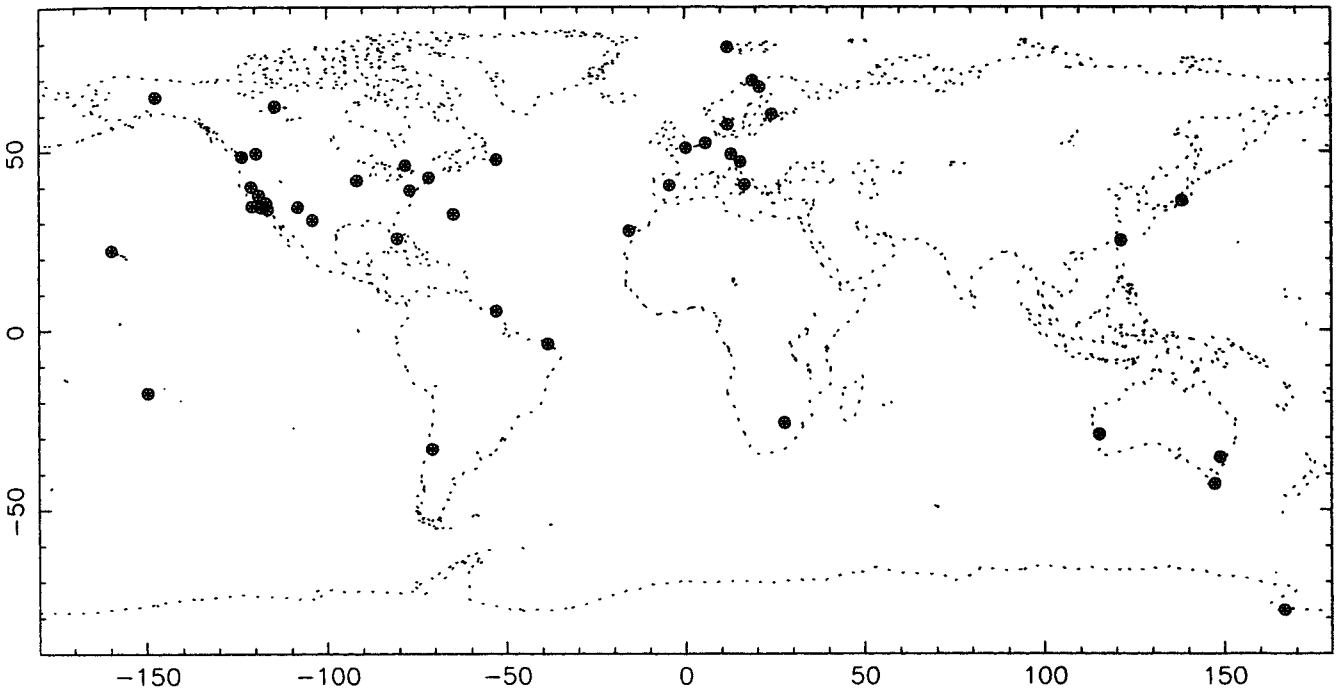
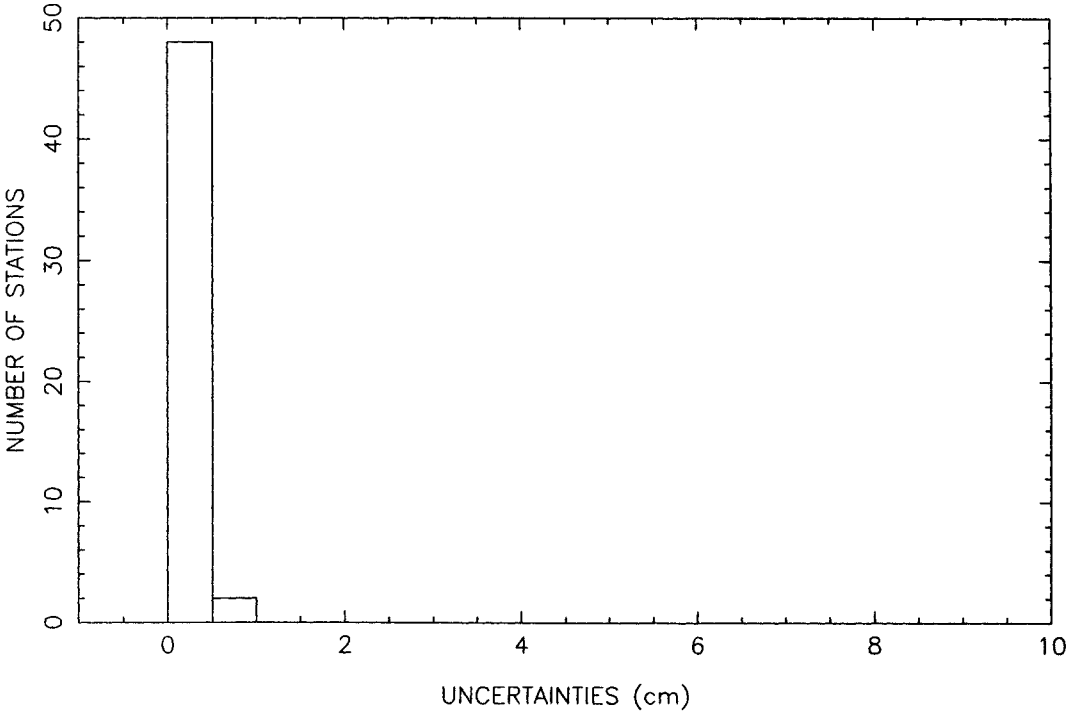
Zumberge, J., and Jefferson, D., 1992: An Analysts Guide to FLINN Reduction of GPS Data, IOM 335.4P92P013 (JPL internal document), Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA.

Technical description of solution JPL 95 P 02

1 - Technique:	GPS
2 - Analysis Center:	Jet Propulsion Laboratory, California Institute of Technology
3 - Software used:	GIPSY-OASIS II
4 - Data span:	January 22, 1991 - January 27, 1995 16348 station days
5 - Celestial Reference Frame:	not applicable
a - Nature:	Dynamical, GPS spacecraft
b - Definition of the orientation:	
6 - Terrestrial Reference Frame:	SSC(JPL) 95 P 02
a - Relativity scale:	Local Earth
b - Velocity of light:	C = 299792458 m/sec
c - Geogravitational constant:	GM0 = 3.986004415 10^{14} m^3 s^{-2}
d - Permanent tidal correction:	No
e - Definition of origin:	Defined by GPS s/c dynamics through C10=0,C11=0,S11=0
f - Definition of orientation:	No net rotation with respect to ITRF93
g - Reference epoch:	1993.0
h - Tectonic plate model:	None
i - Constraint for time evolution:	No net rotation rate with respect to ITRF93
7 - Earth orientation:	EOP(JPL) 95 P 02
a - A priori nutation model:	IAU(1980)
b - Short-period tidal variations in x, y, UT1:	Sub-daily tidal variations not subtracted from reported series, sub-daily tidal variations modelled beginning December 10, 1994
8 - Estimated Parameters:	
a - Celestial Frame:	Satellite initial conditions, yaw rate, and empirical accelerations
b - Terrestrial Frame:	X0, Y0, Z0, Xdot, Ydot, Zdot
c - Earth Orientation:	x, y (LOD estimated but not included in EOP(JPL) 95 P 02)
d - Others:	Satellite and site clocks adjusted each epoch, phase biases estimated as real valued parameters, tropospheric zenith delay adjusted stochastically at each site.



Distribution of the 43 sites of the terrestrial frame SSC(JPL) 95 P 02.



Distribution of the uncertainties (quadratic mean of σ_x, σ_y, σ_z) for the 50 stations of the terrestrial frame SSC(JPL) 95 P 02.

EOP(JPL) 95 P 02 From Jun 1992 to Jan 1995

Number of measurements per year and median uncertainties
Units : 0.001" for X,Y

YEAR	X		Y	
	Nb	Sigma	Nb	Sigma
1992	131	0.15	131	0.17
1993	340	0.11	340	0.12
1994	344	0.08	344	0.08
1995	27	0.09	27	0.09