SATELLITE LASER RANGING

EARTH ORIENTATION PARAMETERS AND STATION COORDINATES FROM CENTRAL LABORATORY FOR GEODESY

CLG 92 L 01, L 02, L 03, L 04

Ivan Georgiev and Valentin Kotzev, Central Laboratory for Geodesy,
Bulgarian Academy of Sciences , Sofia

CLG 92 L 01, 02, 03 and 04 are four years LAGEOS solutions derived by the SLRP-2 (Satellite Laser Ranging data Processor) computer program system from laser tracking data, acquired by the international laser tracking network during the period from January 1984 to December 1987.

1. MODELS

The models and constants underlying the CLG 92 solutions follow the IERS Standards:

Reference frame

CIS:	Mean equator and equinox of J2000.0
Precession:	IAU 1976
Nutation:	IAU 1980 + Herring 1987 correction
Planetary ephemeris:	JPL DE200/LE200
Initial Earth orientation:	BIH, Circular D
Initial station coordinates:	ITRF 89
Time evolution:	AM0-2 plate motion model
Equatorial radius of the Earth:	6378136 m
Eccentricity 1/f :	298.257

Dynamical model

Gravity model:	NASA/GSFC GEM-T1, truncated at 20 x 20, with GM =398600.436 km^3/s^2 and a =6378137m as scale parameters with the geopotential coefficients and GM =398600.440 km^3/s^2 with the two-body term.
C(2,1), S(2,1):	Applied according to IERS Standards.
Third body:	Sun, Moon, Mercury, Venus, Mars, Jupiter and Saturn.
Direct solar radiation pressure :	Occultation by Earth and Moon
Ocean tides:	Wahr model (IERS Standards)
Solid tides:	Schwiderski model (IERS Standards)
Empirical drag acceleration:	CT nominal value -3.1

Relativistic motion equation correction:	Applied according to IERS Standards
Air drag:	Not applied
Albedo:	Not applied

Measurement model

Marini-Murray Refraction Model:	IERS Standards
Solid Earth tidal displacement:	IERS Standards
Ocean loading site displacement:	Applied for stations 1181, 7086, 7090, 7105, 7109, 7110, 7112, 7121, 7122, 7210, 7400, 7401, 7805, 7810, 7833, 7834, 7835, 7837, 7838, 7839, 7840, 7886, 7907, 7939, 8833
Pole tide:	Applied
Relativistic propagation correction:	Applied

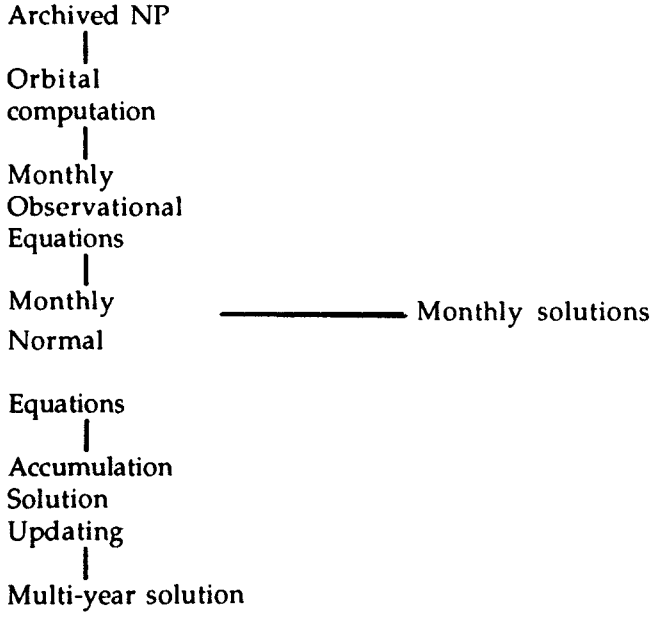
2. DATA

LAGEOS normal points used, were received from GAOUA. The entire 4.0 years period contains about 200 000 normal points. All the data is equally weighted.

3. ANALYSIS PROCESS

The analysis was performed by the SLRP-2 computer program system. It consists of two main modules: the orbit computation module and the parameter estimation module. The processing sequence is schematically shown in the figure below.

All other parameters undergo unconstrained free adjustment.



4. SOLUTION CONSTRAINTS

There were two a priori constraints: (1) the first 5 days value of UT1-UTC in each arc was fixed to its BIH, Circular D value and (2) the orientation of the terrestrial reference frame was constrained by fixing the latitude of 7210 (Hawaii) and the latitude and longitude of 7907 (Arequipa) stations.

5. ADJUSTED PARAMETERS

The differences between the four solutions, outlined in Table 1, are in the intervals of validity of the following parameters: solar radiation pressure coefficient CR; along track acceleration CT; pole coordinates xp and yp and LODR.

Table 1.

Solution	Interval in days		
	CR	CT	xp, yp and LODR
L 01	30	30	5
L 02	15	15	5
L 03	15	15	3
L 04	30	30	3

The adjusted parameters are:

Geogravitational parameter:	GM
A selected set of geopotential coefficients:	C(2,0), C(3,0), C(4,0), C(2,1), S(2,1), C(3,1), S(3,1), C(4,1), S(4,1), C(2,2), S(2,2), S(3,2), S(3,2), C(4,2), S(4,2)
Direct solar radiation pressure coefficient:	CR
Along track acceleration coefficient:	CT
Orbital state vector:	6 parameters per monthly arc
EOP:	xp, yp and LODR
Station coordinates:	Geodetic coordinates

Arc-dependent parameters have been reduced in the monthly normal equations before combining the normal equations for a multi-year solution.

6. RESULTS

The SSC, geocentric x, y an z coordinates, and EOP results obtained in each solution have been provided to the IERS Central Bureau. All coordinates are referred to the optical axis of the ranging systems. The time span of each station is calculating by summing up all days in which it is tracked (one or more passes). The correlation matrices of the estimated station coordinates are also available.

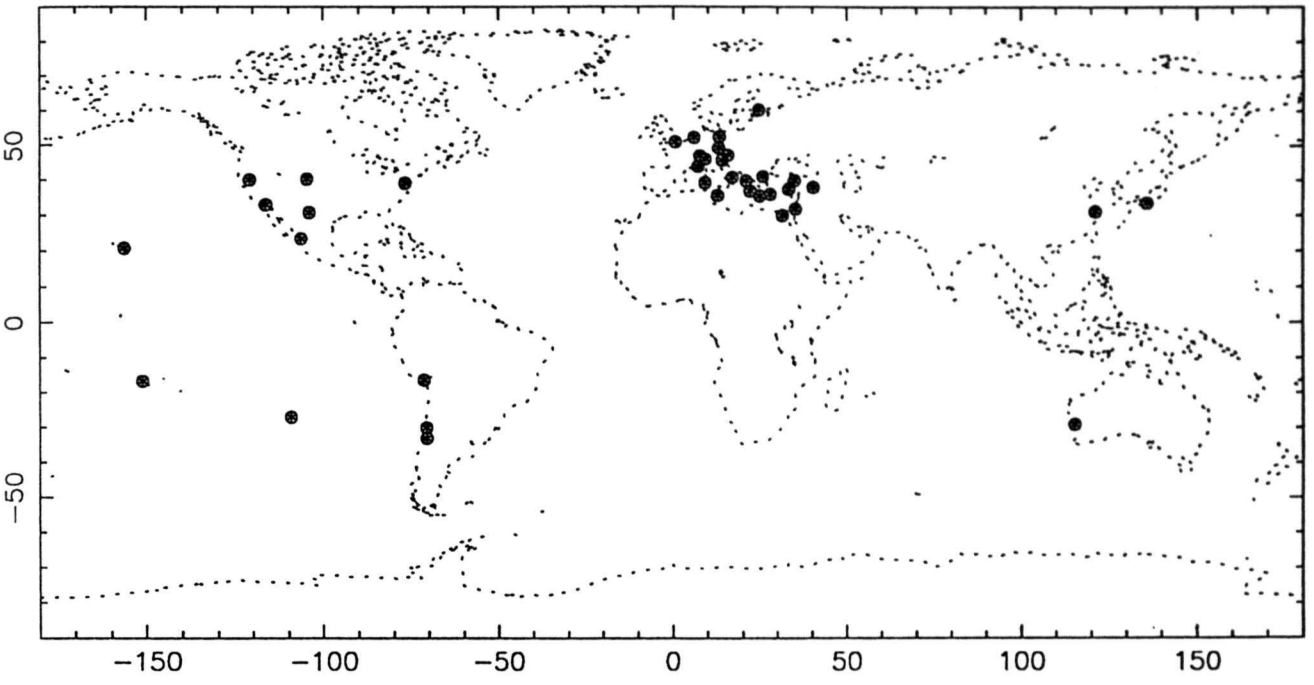
For LODR the reported epoch have to be decreased by the half of the tabulating interval since the LODR values were formed as forward differences of the estimated UT1-UTC series.

References

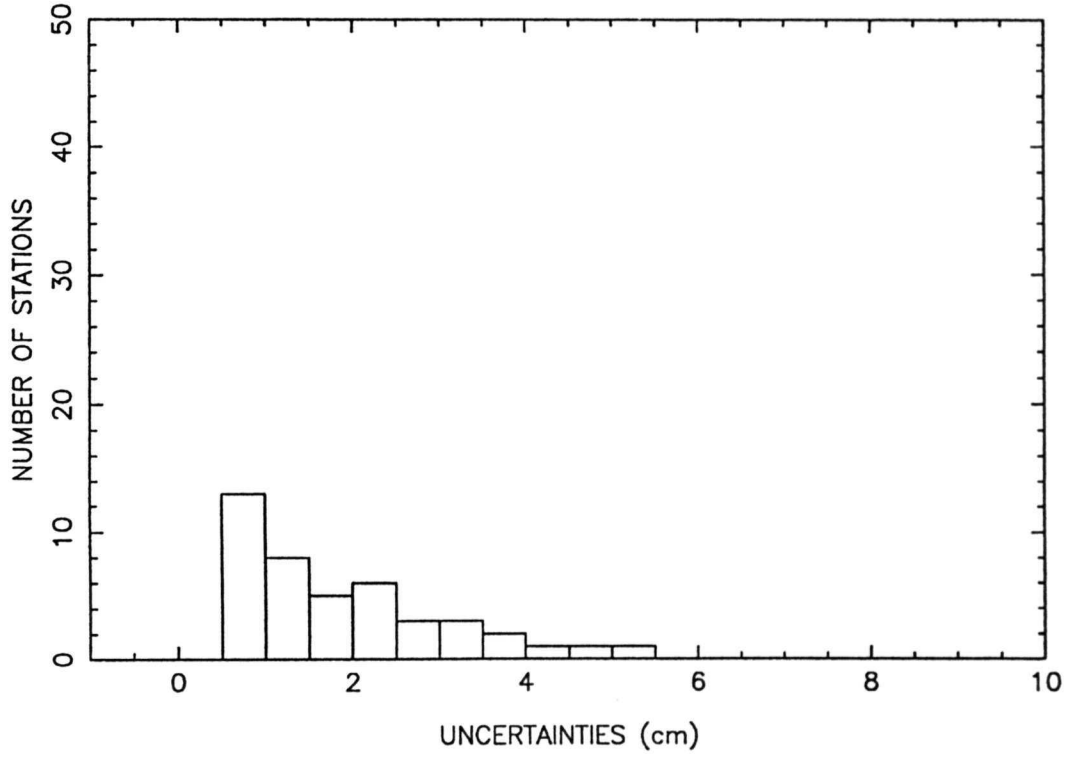
McCarthy (ed.), D.D., 1989: IERS Standards 1989, *IERS Tech. Note 3*, Observatoire de Paris, Paris.

Summary description of the terrestrial system attached to the set of station coordinates SSC(CLG) 93 L 01, 02, 03, 04.

1 - Technique:	SLR
2 - Analysis Center:	Central Laboratory for Geodesy (CLG)
3 - Solution identifier:	CLG 92 L 01, 02, 03, 04
4 - Software used:	SLRP-2
5 - Relativity Scale:	Geocentric (LE)
6 - Permanent tidal correction on station:	YES
7 - Tectonic plate motion model:	AM0-2
8 - Velocity of light (c):	299792458 m/s
9 - Geogravitational constant (GM):	398600.440 m^3/s^2 (solved for parameter)
10 - Reference epoch:	1984.0
11 - Adjusted parameters	
Coordinates:	Epoch 1984.0 geodetic station position coordinates. All positions are for the optical axis of the laser ranging system.
Orbit:	Cartesian coordinates and velocities solved for every 30 or 31 days
EOP:	xp, yp and LODR (see Table 1)
CR and CT:	see Table 1
Geogravitational constant:	GM
Geopotential coefficients:	A selected number of the low degree and order geopotential coefficients.
12 - Definition of the origin:	Geocentric, C(1,0), C(1,1), S(1,1)
13 - Definition of the orientation:	Fixed latitude for 7210. Fixed longitude and latitude for 7907.
14 - Constraint for time evaluation:	Fixed AM0-2 plate motion model



Distribution of the 38 sites of the terrestrial frame SSC(CLG) 93 L 01.



Distribution of the uncertainties (quadratic mean of σ_x, σ_y, σ_z) for the 45 stations of the terrestrial frame SSC(CLG) 93 R 01. 2 stations with uncertainties larger than 10 cm are not shown.

EOP(CLG) 93 L 01 From Jan 1984 to Dec 1987

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
1984	72	0.69	72	0.66	52	0.25
1985	81	0.60	81	0.57	52	0.23
1986	77	0.68	77	0.59	53	0.23
1987	78	0.58	78	0.56	56	0.21

EOP(CLG) 93 L 03 From Jan 1984 to Dec 1987

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
1984	107	0.86	107	0.76	87	0.44
1985	119	0.74	119	0.68	87	0.40
1986	115	0.85	115	0.71	91	0.42
1987	117	0.72	117	0.71	95	0.42

EARTH ORIENTATION AND SITE COORDINATES FROM THE CENTER FOR SPACE RESEARCH CSR 93 L 01

R. J. Eanes and M. M. Watkins
Center for Space Research, University of Texas at Austin, Austin TX 78712

Earth orientation parameters were derived from a combination of Lageos full rate and quick look data. Full rate data was used from 1976 until the end of June, 1991, and quicklook data was used for July 1991 through February 1993.

Mean positions for all sites were adjusted and horizontal site velocities were adjusted for 47 sites with good observing histories. For all other sites, velocities were held fixed to those predicted by the NNR-NUVEL1 model.

The force and measurement models used for this solution conform generally to the IERS Standards, with the following exceptions:

1) The apriori gravity field was JGM-1, a state of the art gravity field derived as a joint effort by the Goddard Space Flight Center and the Center for Space Research. Selected coefficients of this field were adjusted simultaneously with the stations positions.

2) The ocean tide model was an enhanced version of the Schwiderski model extrapolated to include 80 consituents complete through degree and order 20, assuming admittances which vary linearly with frequency. Some ocean tide coefficients were adjusted using Lageos-1 tracking data.

3) The solid tide model has been expanded to include third degree and fourth degree terms.

4) The geogravitational constant, GM, was 398600.4415 km^3/s^2.

5) The nominal plate motion model was NNR-NUVEL1.

6) The free core nutation period has been changed from 460 to 430 days.

The data was weighted in a piecewise continuous, linearly interpolated model to reflect the improvement in laser hardware over the data span. The weights are larger than the true random component of the laser ranges in order to reflect unmodelled systematic errors, and are thus scaled so that the formal uncertainties on the Earth orientation parameters are consistent with their internal precision.

The solutions for orbit elements and Earth orientation parameters were computed using residuals from a long arc fit spanning the period from 7 May 1976 through 06 February 1993, a period of 16.8 years. The short arc adjustments were made at 3 day intervals subject to the constraint that the posteriori uncertainties were less than specified values, to allow for the change in data quantity over time. If the solution for a given 3 day interval yielded unacceptably large uncertainties on the adjusted parameters, the interval was extended by 3 days and the solution repeated. Thus, each final interval is a multiple of 3 days. For each interval, regardless of length, 6 Keplerian mean elements and xp and yp were solved. The UT1 estimates are obtained from the Lageos node residuals, with the constraint that they follow the JPL SPACE92 series at periods longer than about 60 days [Gross, 1993].

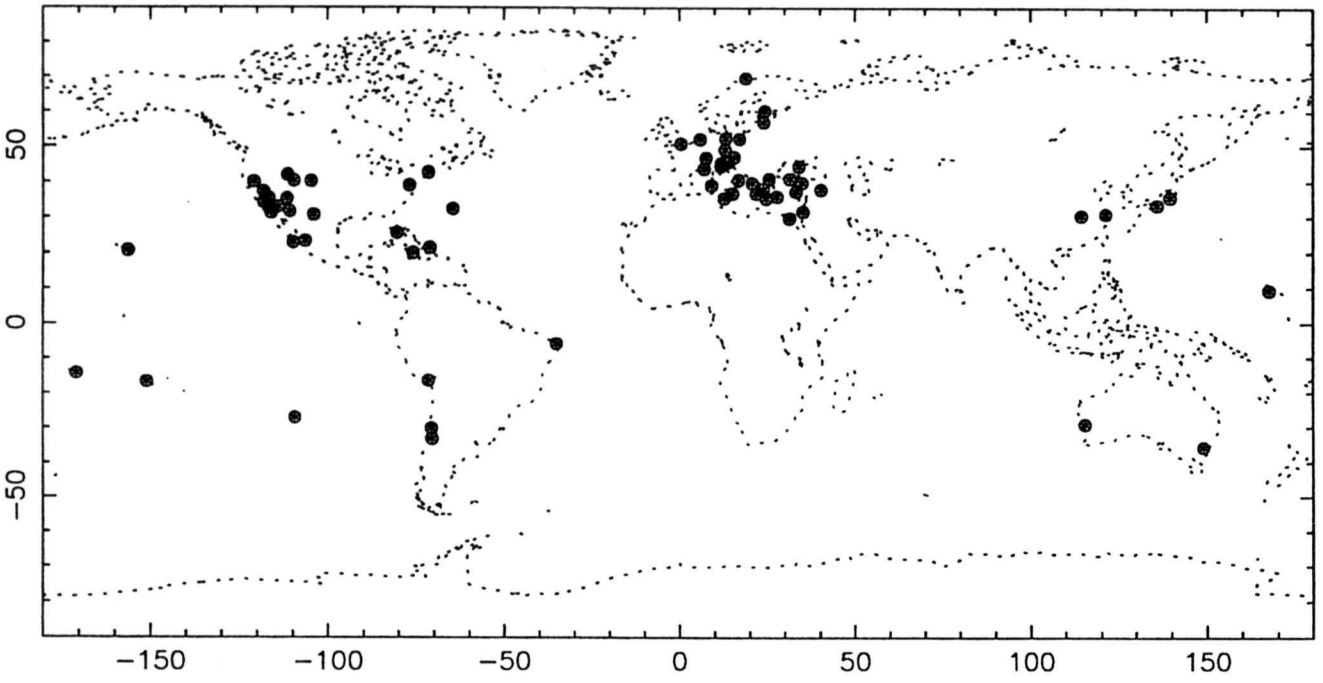
References

Gross, R.S. 1993: A Combination of Earth Orientation Data: SPACE92, *IERS Tech. Note 14*, Observatoire de Paris, Paris, p. C-1.

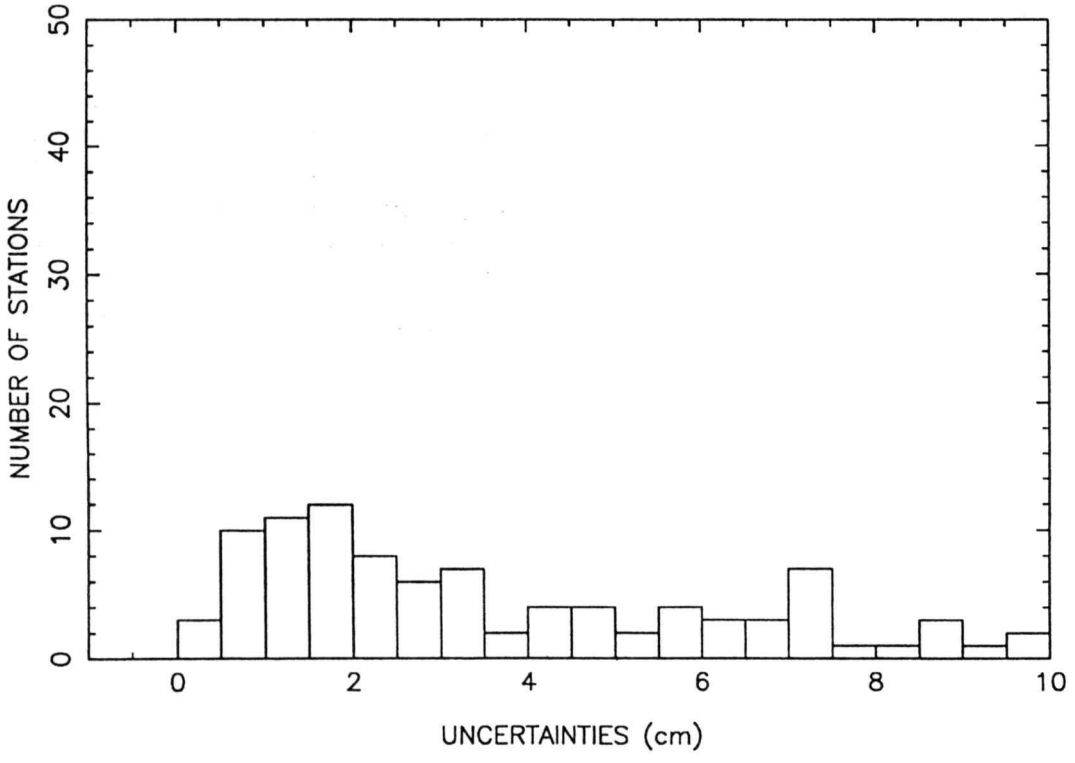
Summary description of the terrestrial system attached to the set of station coordinates SSC(CSR) 93 L 01

1 - Technique:	SLR
2 - Analysis Center:	CSR
3 - Solution Identifier:	SSC(CSR) 93 L 01
4 - Software Used:	UTOPIA
5 - Relativity Scale:	Geocentric (LE)
6 - Permananent Tidal Correction on Station:	Tidal correction has nonzero mean. Positions do not reflect true mean.
7 - Tectonic Plate model:	NNR-NUVEL1
8 - Velocity of light (C) :	299792458 m/sec
9 - Geogravitational constant (GM) :	398600.4415 km^3/s^2
10 - Reference Epoch :	1988.0
11 - Adjusted Parameters: Coordinates:	Epoch 1988.0 position for all sites in cartesian coordinates solved one time for entire data span. Horizontal velocities adjusted for 47 selected sites.

Site dependent biases:	Adjusted where necessary.
Geopotential coefficients:	Selected coefficients were adjusted.
Orbit:	6 Keplerian mean element corrections to long arc orbit solved every 3 days throughout span subject to constraint that posteriori uncertainties were less than specified values. If not satisfied, interval was extended in multiples of 3 days until solution was acceptable.
EOP:	x, y and UT1 (UT1 constrained by JPL SPACE92) were solved at the same intervals as the orbit.
12 - Definition of the origin:	Geocentric, C10 = C11 = S11 = 0.0
13 - Definition of the orientation:	System oriented to agree with SPACE92 in a mean sense over period 1981-1992, maintained through fixing the latitude and longitude of site 7210 (HOLLAS) and the latitude of site 7105 (GRF105). This definition was enforced by applying offsets to the adjusted polar motion. This adjustment could create a closure error between the origins implied by the EOP and the SSC.
14 - Constraint for time evolution:	Latitude and longitude rate of site 7210 (HOLLAS) and latitude rate of site 7105 (GRF105) fixed to NNR-NUVEL1 velocities. Horizontal site velocities adjusted with a priori sigma of 100 mm/yr for the other sites with sufficient data. Because of weak SLR data from Mojave (7288) and Owens Valley (7853) their velocity adjustment was constrained using a priori sigma of 5 mm/yr.



Distribution of the 68 sites of the terrestrial frame SSC(CSR) 93 L 01.



Distribution of the uncertainties (quadratic mean of σ_x, σ_y, σ_z) for the 111 stations of the terrestrial frame SSC(CSR) 93 L 01. 17 stations with uncertainties larger than 10 cm are not shown.

EOP(CSR) 93 L 01 From May 1976 to Feb 1993

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
1976	32	12.54	32	14.29	32	7.29
1977	72	12.83	72	12.04	72	6.77
1978	72	12.04	72	10.21	72	6.49
1979	76	9.28	76	9.58	76	5.95
1980	117	5.46	117	3.48	117	3.04
1981	112	5.40	112	3.20	112	2.65
1982	113	3.60	113	2.76	113	2.30
1983	118	3.07	118	2.67	118	1.75
1984	121	1.22	121	1.08	121	0.94
1985	121	1.05	121	0.89	121	0.73
1986	122	0.87	122	0.80	122	0.68
1987	122	0.60	122	0.55	122	0.46
1988	122	0.48	122	0.52	122	0.39
1989	121	0.52	121	0.51	121	0.43
1990	122	0.49	122	0.52	122	0.40
1991	122	0.62	122	0.62	122	0.46
1992	122	0.61	122	0.58	122	0.47
1993	12	0.79	12	0.77	12	0.88

EARTH ROTATION AND STATION COORDINATES COMPUTED FROM SLR OBSERVATIONS ON LAGEOS-1 DUT 93 L 02

R. Noomen, B.A.C. Ambrosius, D.C. Kuyper, H. Leenman, G.J. Mets, K.F. Wakker
Delft University of Technology, Faculty of Aerospace Engineering,
Kluyverweg 1, 2629 HS Delft, The Netherlands

The solution ERP/SSC(DUT) 93 L 02 consists of a coherent set of Earth Rotation Parameters (ERPs), determined at 5-day intervals, and coordinates of a global laser station network. The original solution was computed from laser range observations on the geodetic satellite LAGEOS-1, taken during the periods September 1983 through May 1985 and January 1986 through December 1992. Only ERP solutions for epochs since January 1986 are included in this contribution.

For the analysis, the 9.3-year data interval was divided into a total of 38 sub-periods, with a length of 13 weeks on average. The actual analysis was performed in a 2-step approach.

First, a continuous but mutually independent series of 38 global network and ERP solutions was computed by analyzing each batch of observations. The parameter estimation was based on a least-squares fit of the satellite orbit to the SLR observations. To limit the effect of potential dynamic model errors, the analysis programs GEODYN-2 and SOLVE-2 were executed in a so-called multi-arc mode, where each sub-period was further divided into a series of 7-day data arcs and satellite parameters (state-vector at epoch, a constant along-track acceleration and a 1-cpr radial acceleration) were estimated for each data arc. To prevent computational singularities, the parameters were constrained in a Bayesian way. The a priori standard deviation of the pole position and UT1 were assigned values of 0.1 arcsec and 0.01 s, respectively, with a priori values taken from the monthly IERS Bulletins B. The initial station coordinates, computed during a preliminary data screening run, were given an a priori uncertainty of 1 m. The ascending nodes of the satellite state-vectors were kept fixed at the values determined in the data screening.

The computation model is summarized in Table 1. The model closely follows the IERS Standards, with few exceptions: (i) the JGM-1 solution, both for the gravity field and for the ocean tides, was used instead of the advised GEM-T1 and Schwiderski models; (ii) the effect of ocean loading and atmospheric pressure loading on station positions was not applied; (iii) no plate motion was applied during each "13-week" sub-period; and (iv) new values for GM, ae and the flattening of the Earth were used.

The second step was primarly aimed at bringing coherency into the series of parameter solutions. This was done by fitting a model for tectonic deformations to the series of individual station coordinates, while eliminating systematic differences. This model consist of initial station coordinates at a reference epoch and the time-derivati-

ves of these coordinates. A priori values for these time-derivatives were taken from the NUVEL-1 No Net Rotation model, and either kept fixed for a sub-set of 12 SLR stations, which are known to follow the motions described by this model, or estimated for the remainder of the stations. Next, the resulting model for instantaneous station positions was back-substituted into the GEODYN/SOLVE data reduction programs. Finally, new solutions for the ERPs were computed without application of any constraint, and keeping the station positions (and the ascending nodes) fixed. The computation model is identical to the one for step 1, already listed in Table 1.

The resulting series of ERP solutions and the station coordinates have been provided to the IERS Central Bureau. The effect of short-term perturbations in UT1, caused by zonal tides, has been removed. The solution for each station consists of the cartesian monument coordinates at epoch, the corresponding standard deviations (both in m), the apparent motions and the standard deviations of the latter (in m/yr). The reference epoch of the solution is January 1, 1988.

Table 1: Models and constants.

DYNAMIC MODEL:

Gravity field:	NASA/GSFC JGM-1 model, truncated at 20x20
GM:	398600.4415 km^3/s^2
c :	299792.458 km/s
ae :	6378.1363 km
1/f :	298.2564
Solar and lunar attraction :	JPL DE-200 ephemeris
Solid earth tides:	Wahr model
Ocean tides:	NASA/GSFC JGM-1 model
Solar radiation:	CR fixed at 1.13; occultation by Earth and Moon; umbra and penumbra
Along-track acceleration:	constant value; adjusted
Radial acceleration:	sine and cosine term; adjusted
Third body attraction:	Sun, Moon, Venus, Mars, Jupiter, Saturn; positions from JPL DE200/LE200 ephemeris
Pole tide (dynamic part) :	applied

REFERENCE FRAME:

Station coordinates:	adjusted (step 1); modelled with NNR-NUVEL1 (step 2)
Earth rotation:	adjusted at 5-day intervals; a priori values from IERS EOP 90 C 04
CIS:	mean equator and equinox of J2000.0
Precession :	IAU 1976 (Lieske model)
Nutation:	IAU 1980 (Wahr model)
Plate motion:	not applied
Tidal uplift :	h2 = 0.609, l2 = 0.0852
Pole tide (geometric part) :	applied

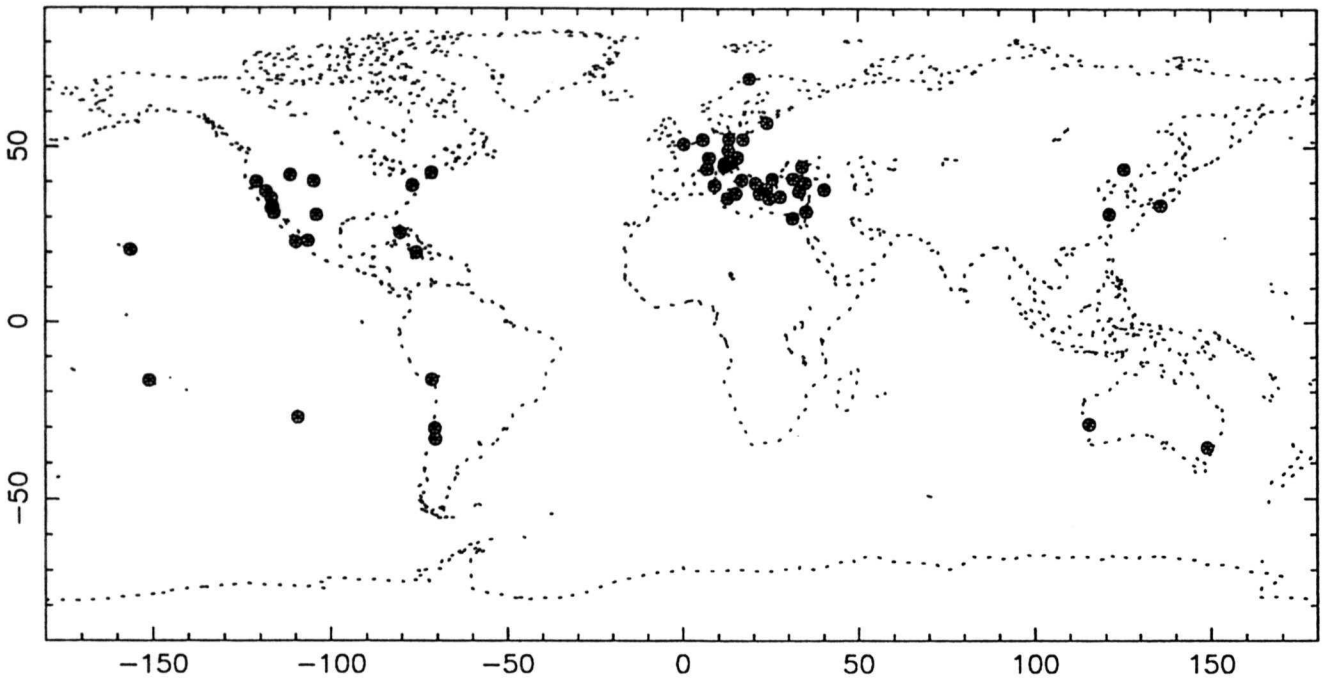
Ocean loading : not applied
Atmospheric pressure loading: not applied

MEASUREMENT MODEL:

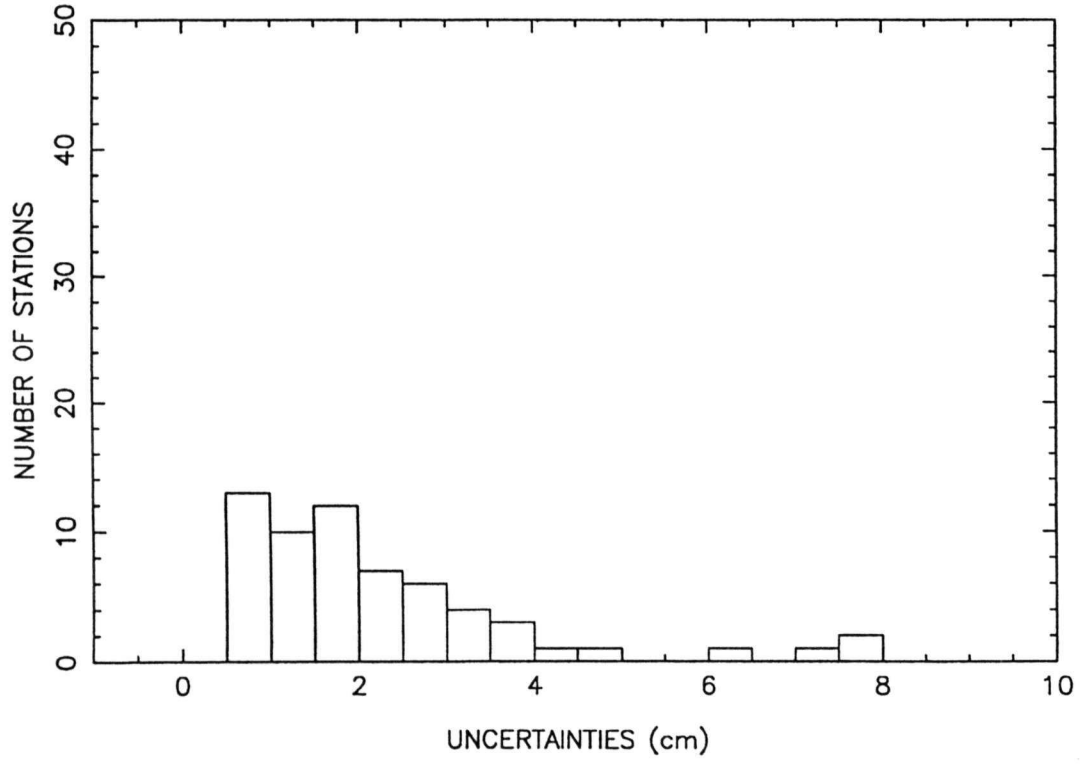
Observations :	Release B normal points, computed at NASA (September 1983 - May 1985), DGFII (January - October 1986, 1987), DUT (November, December 1986) and Bendix (1988 - March 1992); Release A normal points, computed at Bendix (April 1992 - June 1992); quick-look normal points (July 1992 - December 1992)
Data weighting :	Determined from overall model accuracy and system characteristics
Tropospheric refraction :	Marini-Murray model

Summary description of the terrestrial system attached to the set of station coordinates SSC(DUT) 93 L 02

1 - Technique :	SLR
2 - Analysis center :	DUT
3 - Solution identifier:	SSC(DUT) 93 L 02
4 - Software used :	GEODYN-2/SOLVE-2
5 - Relativity scale :	local Earth
6 - Tidal uplift :	yes
7 - Tectonic plate model :	NNR-NUVEL1 for selected sites (Yarragadee, Easter Island, Greenbelt, Platteville, Huahine, Mazatlan, Maui, Wettzell, Graz, RGO, Orroral Valley, Kootwijk); DUT solutions derived for the remainder of the stations, determined w.r.t. a reference frame moving according to NNR-NUVEL1
8 - Velocity of light :	299792.458 km/s
9 - Gravitational constant :	398600.4415 km^3/s^2
10 - Reference epoch :	January 1, 1988
11- Adjusted parameters :	X0, Y0, Z0 (for selected stations); X0, Y0, Z0, $\dot{X}$, $\dot{Y}$, $\dot{Z}$ (remainder)
12- Origin definition :	C(1,0) = C(1,1) = S(1,1) = 0
13- Orientation definition :	Initial coordinates at reference epoch
14- Evolution constraint :	NNR-NUVEL1 (for selected stations); DUT apparent motions (remainder)



Distribution of the 56 sites of the terrestrial frame SSC(DUT) 93 L 02.



Distribution of the uncertainties (quadratic mean of σ_x, σ_y, σ_z) for the 68 stations of the terrestrial frame SSC(DUT) 93 L 02. 7 stations with uncertainties larger than 10 cm are not shown.

EOP(DUT) 93 L 02 From Jan 1986 to Dec 1992

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
1986	72	0.23	72	0.19	72	0.17
1987	72	0.19	72	0.17	72	0.16
1988	73	0.20	73	0.19	73	0.17
1989	73	0.18	73	0.17	73	0.15
1990	73	0.16	73	0.16	73	0.14
1991	73	0.19	73	0.18	73	0.15
1992	72	0.19	72	0.18	72	0.15

EARTH ORIENTATION AND STATION COORDINATES FROM LAGEOS SLR OBSERVATIONS

GAOUA 93 L 01

V.N. Salyamov, V.K. Tarady, A.I. Yemets
Main Astronomical Observatory of Ukrainian, Academy of Sciences, Kiev
Dept. of Space Geodynamics

Solution GAOUA 93 L 01 consists of the sets of 73 station cartesian coordinates, 45 station velocities having a good observing history, and Earth Orientation Parameters. Kiev-Geodynamics - 4 software package has been used for the analysis and Lageos SLR normal points, spanning the period from September 1983 through April 1993 have been taken as input data.

The models and constants used for this solution are those recommended by the IERS Standards with the following exceptions:

1. The GEM-T1 ocean tide model was used instead of Schwiderski model.
2. Tidal variations in UT1 due to zonal tides with periods exceeding 35 days were not applied.
3. Nutation corrections were taken according to McCarthy *et al.* (1991)
4. Only variations of radial components of site positions were taken into account when modelling ocean loading effect.

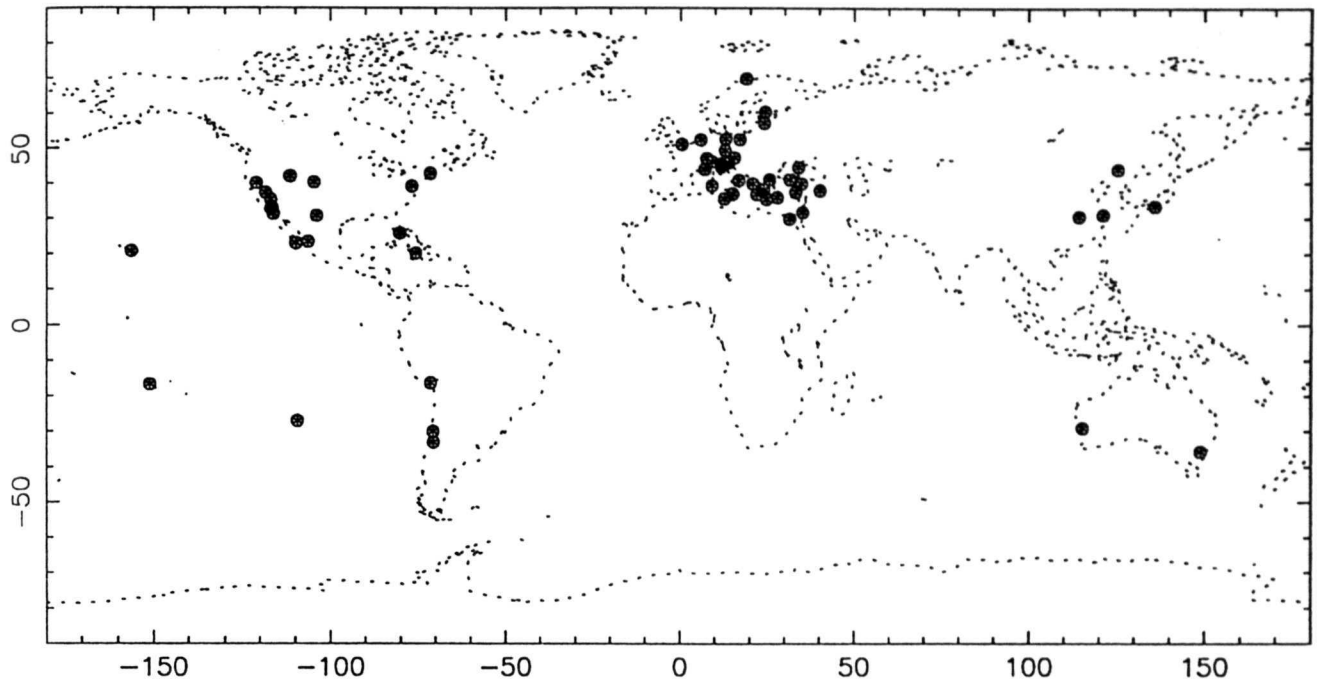
The solution was obtained in two steps. First, the whole data interval was divided in 15 day sub-intervals and 6 Keplerian mean elements were estimated on each of them. Next, the combination of all sub-intervals yielded the estimation of global and local parameters listed in summary sheet.

Rather simple weighting procedure was applied during the analysis. All the third generation laser station data were given the weights 3 with respect to those of the second generation.

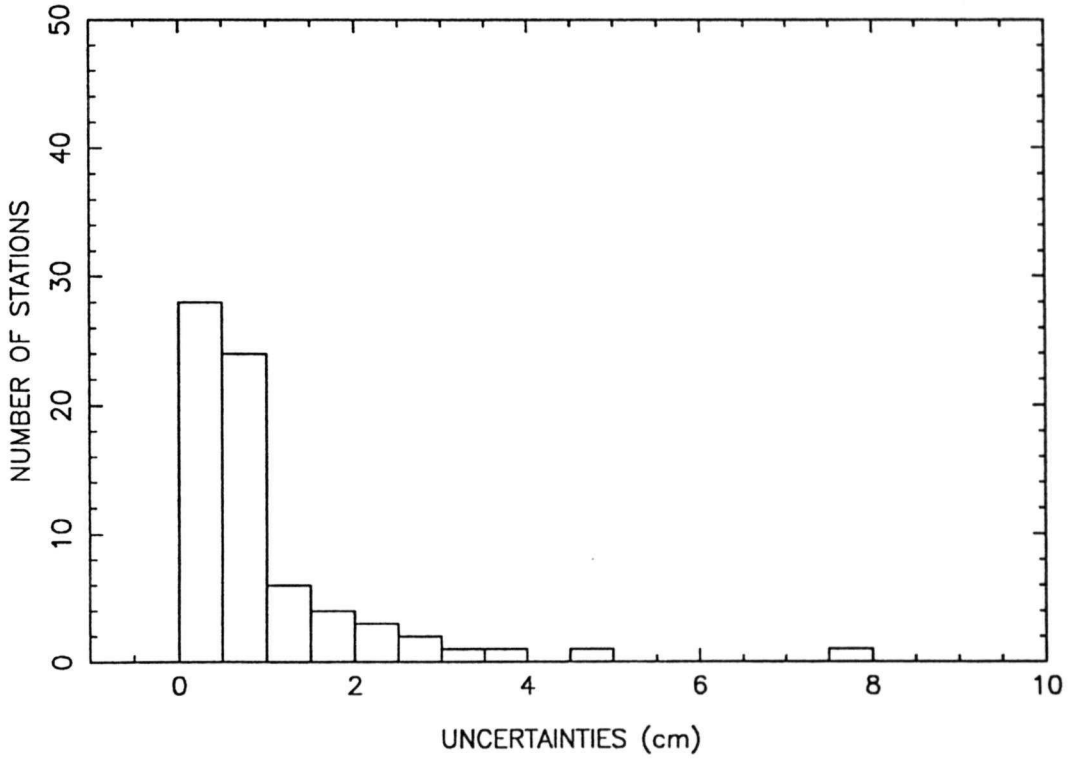
The reference system is attached to ITRF91 by fixing the latitude of station 7105 and the longitude and latitude of station 7210. Time evolution of the system is modelled by NNR-NUVEL1 for sites with either poor data distribution or short-term activity periods. The velocities of the other sites have been estimated and linked to NNR-NUVEL1 through fixing the latitude change rate of station 7210 and the longitude and latitude change rates of station 7105.

Summary description of the terrestrial system attached to the set of station coordinates SSC(GAOUA) 93 L 01

1 - Technique :	SLR
2 - Analysis Center :	GAOUA
3 - Solution identifier :	SSC(GAOUA) 93 L 01
4 - Software used :	KIEV-GEODYNAMICS - 4
5 - Relativity scale :	LE
6 - Permanent tidal correction on station :	NO
7 - Tectonic plate model :	NNR-NUVEL1
8 - Velocity of light (C) :	299 792 458
9 - Geogravitational constant (GM) :	$3.9860\ 04418\ 10^{14}$
10 - Reference epoch :	MJD 47161 (1988.0)
11 - Adjusted parameters :	
Coordinates:	X, Y ,Z for 73 stations $\dot{X}$, $\dot{Y}$, $\dot{Z}$ for 45 stations
Orbit :	5 keplerian mean elements estimated every 5 days, Ct and Cr every 15 days
EOP :	Xp, Yp, UT1R every 5 days
12 - Definition of the origin :	C10 = C11 = S11 = 0
13 - Definition of the orientation :	ERP values from BIH Annual reports and IERS Bulletin B. Longitude and latitude of station 7105 and latitude of station 7210 fixed.
14 - Constraint for time evolution :	Fixed plate motion model for selected stations. Latitude and longitude change rates of station 7105 and latitude change rate of station 7210 fixed to NNR-NUVEL1 velocities.



Distribution of the 59 sites of the terrestrial frame SSC(GAOUA) 93 L 01.



Distribution of the uncertainties (quadratic mean of σ_x, σ_y, σ_z) for the 73 stations of the terrestrial frame SSC(GAOUA) 93 L 01. 2 stations with uncertainties larger than 10 cm are not shown.

EOP(GAOUA)93 L 01 From Sep 1983 to Apr 1992

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
1983	24	1.15	24	0.80	24	0.80
1984	73	0.80	73	0.60	73	0.70
1985	73	0.60	73	0.40	73	0.50
1986	73	0.40	73	0.30	73	0.30
1987	73	0.40	73	0.20	73	0.30
1988	73	0.30	73	0.20	73	0.30
1989	73	0.60	73	0.40	73	0.50
1990	73	0.50	73	0.40	73	0.50
1991	73	0.70	73	0.50	73	0.50
1992	24	0.65	24	0.40	24	0.60

EARTH ROTATION PARAMETERS AND STATION COORDINATES BY LAGEOS LASER RANGING DATA UPDATED TILL MID-SEPTEMBER, 1992 GFZ 93 L 01, L 02, 03, 04, 05

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

SUMMARY

In continuation of the former years solutions two new Sets of Station Coordinates (SSC) were determined, the SSC(GFZ) 93 L 01 which includes the estimation of the site motions and the SSC(GFZ) 93 L 02 which fixed the site motions to the NUVEL-1 model. Comparing with the last year solutions, the series of Earth Rotation Parameters (ERP) were expanded by a 1-day resolution series (L 04). The others have a time resolution of 5 days (L 01 and L 05), 3 days (L 02) and 2 days (L 03).

DATA AND MODEL PARAMETERS

Using the further improved software package and the Satellite Laser Ranging (SLR) data to Lageos, two Sets of Station Coordinates (SSC) and 5 Sets of Earth Rotation Parameters (ERP) were determined. The data used concern SLR normal points of the global station net from the beginning of 1980 (MJD 44238) until September 14, 1992 (MJD 48879), in all 44208 passes from 101 stations. A statistical summary (r.m.s. station fits for 5-day orbit adjustments together with the number of passes and observations) for the time interval from March, 1991 to September, 1992 is given in Table 1.

The constants and model parameters used for these solutions conform to the IERS Standards (McCarthy, 1992) with the following exceptions:

- tidal variations in UT1 caused by zonal tides with periods larger than 35 days not considered
- nutation corrections derived by VLBI model.

In a multistage-multiarc procedure different parameters were solved for as given in the summary sheet. Here also details on the adopted model for the terrestrial system are stated.

STATION COORDINATES AND VELOCITIES

For the main solution SSC(GFZ) 93 L 01 the coordinates of all sites were adjusted simultaneously with site velocities using data from the whole time interval. For 45 stations (69 markers; colocated markers at one station were constrained to have the same velocity) the data distribution was good enough to determine site velocities, whereas the velocities of the other stations were held fixed to those of the NUVEL-1

model (De Mets *et al.*, 1990). In a second variant (additional solution SSC(GFZ) 93 L 02) all site velocities were fixed to that predicted by NUVEL-1 rigid plate model.

The site positions were refered to epoch 1988.0. The origin of the reference system was defined by C10 = C11 = S11 = 0. The orientation was constrained by fixing the latitude and longtitude of the station 7840 and the latitude of the station 7105. Additionally, no common net rotation were permitted in relation to the reference coordinate set SSC(GFZ) 92 L 01 (ITRF89). Corrections due to the permanent tidal deformation of the Earth were applied.

The station coordinates and the adjusted velocities for the 69 sites mentioned above have been provided to the IERS Central Bureau. The given errors have been scaled with a factor 5, because the calculated errors seem to be too optimistic.

EARTH ROTATION PARAMETERS

For the ERP (pole coordinates and length of day - LOD) two sets with 5-day time resolution were computed. The main solution ERP(GFZ) 93 L 01 refers to the SSC(GFZ) 93 L 01 with adjusted site velocities and the ERP(GFZ) 93 L 05 is based on SSC(GFZ) 93 L 02 with motions fixed to NUVEL-1. The two series with a time resolution of 3 days (ERP(GFZ) 93 L 02) and 2 days (ERP(GFZ) 93 L 03) were continued. Because of a new data release, several months in 1991 (March to September) were re-analysed. The series beginning in 1980 are now updated till mid-September 1992. Additionally, a series with a time resolution of 1 day (ERP(GFZ) 93 L 04) was produced starting in June 1983 and extending up to September 1992.

Whereas in the 5-day solutions the LOD values were estimated directly, in the L02, L03 and L04 solutions UT1 values were solved for instead of LOD. These UT1 results were converted into LOD. That means that the time scales for the ERP(GFZ) 93 L 02, L 03 and L 04 have to be transferred for the LOD values by -1.5 d, -1.0 d and -0.5 d, respectively.

Generally, the SLR data were weighted according to their estimated accuracy. In addition, several non-permanent stations were given smaller weights in order to reduce the influence of the change of the station distribution. No post-adjustment smoothing or filtering procedure was applied to the ERP series.

The standard deviations of the pole coordinates are about 0.1 mas for the series with a time resolution of 5 days and 3 days, 0.15 mas for the 2-day time resolution series, and 0.3 mas for the 1-day time resolution series. The accuracy was estimated to be about 1 mas to 2 mas. For the directly derived LOD results (5-day resolution) an extremely optimistic estimation was obtained for the formal standard deviations; therefore they were scaled by a factor of 4. Then the standard deviations are about 0.008 ms for the 5-day and 3-day time resolution series, 0.01 ms for the 2-day time resolution series and 0.02 ms to 0.03 ms for the 1-day time resolution series. The accuracy is in the order of 0.1 ms to 0.2 ms. All the accuracy is influenced by the data density and distribution. Mainly because of this data effect, the accuracy was significantly increased in the course of the last ten years.

In cases of poor data distribution the errors can be several times larger. Then also the correlation between the estimated ERP becomes very high. Therefore the correlation was used as an automatical elimination criterion (where higher than 0.9). This way about 3% of the results with a resolution of 2 days and about 15% of the results with a resolution of 1-day were eliminated; due to the station distribution the number of eliminated results for yp is twice as large as for xp.

The results show a good agreement with the previously reported series and with IERS results in the overlapping zones. The differences between the ERP results obtained on the basis of adjusted site velocities and on those obtained with NUVEL-1 site velocities are not significant.

References

DeMets, C., Gordon., R.G., Argus, D.F. and Stein, S., 1990: Current plate motions, *Geophys. J. Int.*, **101**, 425.

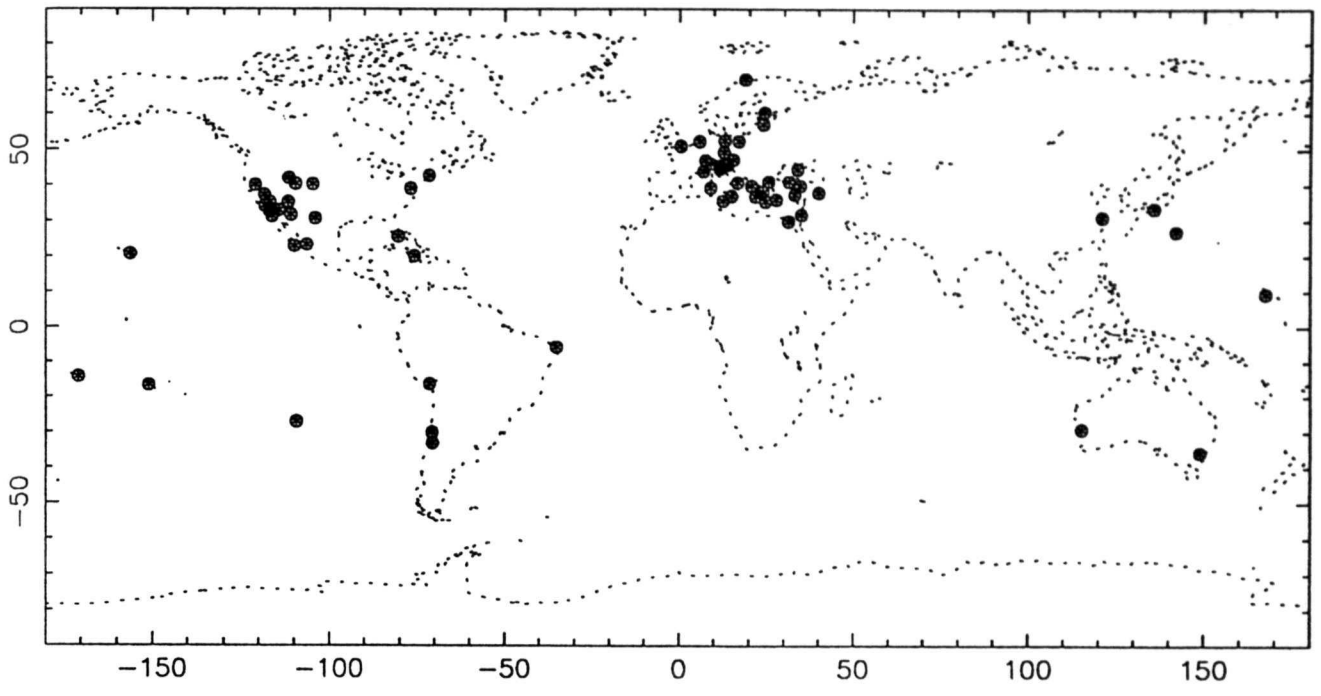
McCarthy, D.D. (ed.), 1992: IERS Standards. *IERS Tech. Note 13*, Observatoire de Paris, Paris.

TABLE 1. Summary of statistical information for 3/1991 to 9/1992

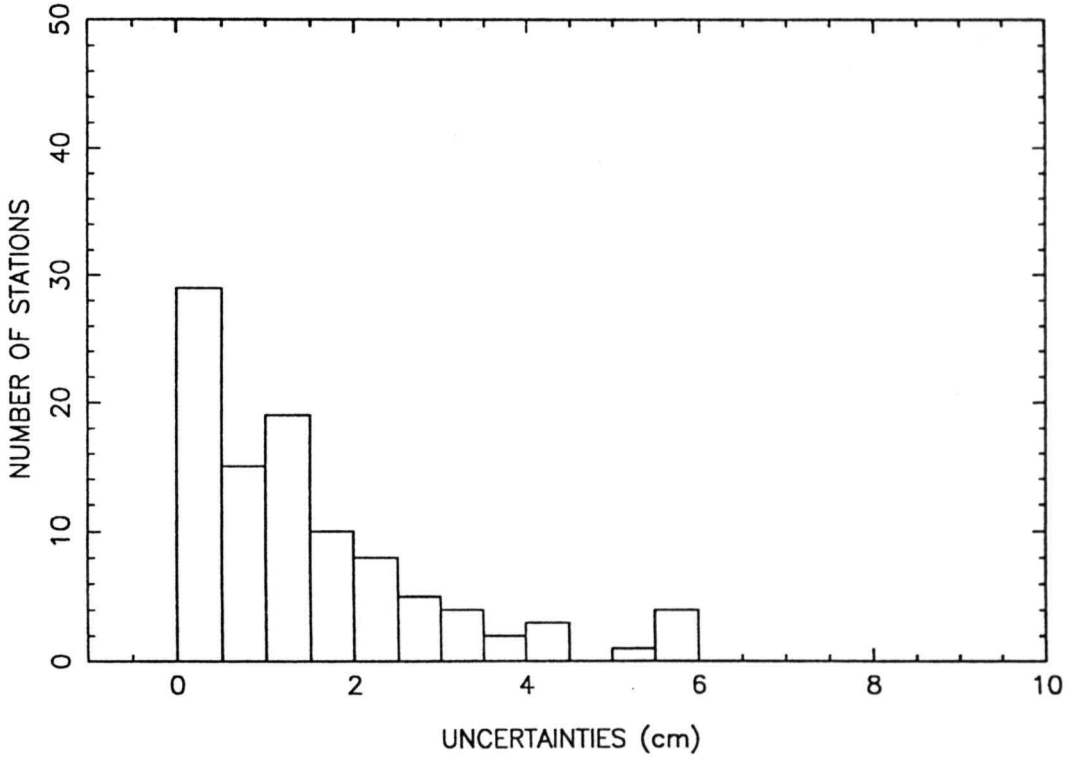
station	Number of passes	obs.	mean rms (m)	station	Number of passes	obs.	mean rms (m)
118101	20	100	0.165	7542	16	137	0.029
187301	57	427	0.146	7560	8	51	0.032
188401	92	1222	0.115	7561	50	648	0.044
189301	31	310	0.140	7587	8	67	0.034
195301	9	29	0.250	7810	294	3306	0.043
7046	60	858	0.026	781102	18	138	0.093
7080	234	2405	0.032	7831	205	1757	0.050
7090	364	5314	0.031	7835	509	6548	0.039
7097	45	539	0.039	7837	169	1512	0.078
7105	269	3774	0.028	7838	136	1720	0.054
7109	289	3697	0.021	7839	311	4708	0.033
7110	442	6255	0.027	7840	691	7683	0.033
7112	48	615	0.046	7843	15	141	0.109
7122	21	294	0.025	7882	41	592	0.026
7123	63	691	0.049	7883	50	645	0.036
7210	432	6160	0.029	7907	96	1010	0.101
7295	18	198	0.034	7918	15	207	0.029
7403	152	1888	0.041	7939	253	2729	0.071
7510	4	19	0.251	883401	565	5814	0.056
7512	58	615	0.041				
7517	44	533	0.035				
7525	43	471	0.028				

Summary description of the terrestrial systems attached to the sets of station coordinates SSC(GFZ) 93 L 01 and 92 L 02

1 - Technique:	SLR
2 - Analysis Center:	GFZ
3 - Solution Identifier:	SSC(GFZ) 93 L 01 and SSC(GFZ) 93 L 02
4 - Software Used:	EPOS.P.V1
5 - Relativity Scale:	Geocentric (LE)
6 - Permanent Tidal Correction on station:	Yes
7 - Tectonic Plate model:	Adjusted (L 01), resp. NUVEL-1 (L 02)
8 - Velocity of light (C):	299792458 m/sec
9 - Geogravitational constant (GM) :	Adjusted to 398600.4420 km^3/s^2
10 - Reference Epoch:	1988.0 (MJD 47160.)
11 - Adjusted Parameters:	
Coordinates :	Radius, longitude and latitude for all sites plus velocities in each of the coordinates, all solved one time for the whole data span (L 02: velocities are fixed to NUVEL-1)
Orbit:	6 Keplerian mean elements for intervals of 5 days
EOP:	x, y and LOD, solved at 5-day intervals (the same as orbit) x, y and UT1, solved at 1-, 2- and 3-day intervals.
12 - Definition of the origin:	Geocentric, C10 = C11 = S11 = 0
13 - Definition of the orientation:	System oriented by fixing: - the latitude of 7105 ,7840 - the longitude of 7840
14 - Constraint for time evolution:	L 01 - no net rotation by fixing the velocities of: - the latitude of 7105, 7840 - the longitude of 7840



Distribution of the 66 sites of the terrestrial frame SSC(GFZ) 93 L 01.



Distribution of the uncertainties (quadratic mean of σ_x, σ_y, σ_z) for the 101 stations of the terrestrial frame SSC(GFZ) 93 L 01. 1 station with uncertainty larger than 10 cm is not shown.

EOP(GFZ) 93 L 01 From Jan 1980 to Sep 1992

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
1980	66	0.46	66	0.25	66	0.15
1981	65	0.40	65	0.22	65	0.13
1982	70	0.34	70	0.19	70	0.12
1983	70	0.23	70	0.20	70	0.09
1984	73	0.14	73	0.11	73	0.06
1985	73	0.10	73	0.08	73	0.04
1986	73	0.11	73	0.09	73	0.04
1987	73	0.10	73	0.08	73	0.04
1988	73	0.10	73	0.09	73	0.04
1989	73	0.10	73	0.09	73	0.04
1990	73	0.08	73	0.09	73	0.04
1991	73	0.10	73	0.09	73	0.04
1992	51	0.10	51	0.10	51	0.04

EOP(GFZ) 93 L 02 From Jul 1983 to Sep 1992

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
1983	56	0.24	56	0.22	56	0.08
1984	121	0.19	121	0.16	121	0.07
1985	122	0.14	122	0.11	122	0.05
1986	121	0.14	121	0.12	121	0.05
1987	122	0.13	122	0.12	122	0.05
1988	121	0.13	121	0.12	121	0.05
1989	122	0.14	122	0.13	122	0.05
1990	120	0.11	120	0.12	120	0.05
1991	122	0.13	122	0.13	122	0.05
1992	86	0.15	86	0.13	86	0.06

EOP(GFZ) 93 L 03 From Jul 1983 to Sep 1992

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
1983	78	0.30	78	0.26	78	0.15
1984	178	0.23	178	0.19	178	0.12
1985	176	0.17	176	0.14	177	0.09
1986	177	0.17	177	0.14	176	0.09
1987	180	0.16	180	0.15	180	0.10
1988	175	0.16	175	0.14	175	0.09
1989	177	0.17	177	0.16	177	0.10
1990	180	0.13	180	0.15	181	0.09
1991	172	0.15	172	0.15	171	0.08
1992	124	0.18	124	0.16	124	0.10

EOP(GFZ) 93 L 04 From Jul 1983 to Sep 1992

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
1983	124	0.36	124	0.32	124	0.31
1984	303	0.28	303	0.23	303	0.28
1985	314	0.21	314	0.16	314	0.20
1986	309	0.21	309	0.17	309	0.20
1987	295	0.20	295	0.17	295	0.21
1988	287	0.19	287	0.17	287	0.20
1989	305	0.21	305	0.19	305	0.22
1990	328	0.17	328	0.17	329	0.20
1991	294	0.18	294	0.17	293	0.18
1992	225	0.22	225	0.20	225	0.23

EARTH ORIENTATION PARAMETERS FROM GSFC SOLUTION SL8.2 GSFC 93 L 01

D.E. Smith and R. Kolenkiewicz
NASA/Goddard Space Flight Center, Greenbelt MD 20771

P.J. Dunn, S. M.Klosko, J.W. Robbins, M.H. Torrence and R.G. Williamson
Hughes/ S T Systems Corp., Lanham MD 20706

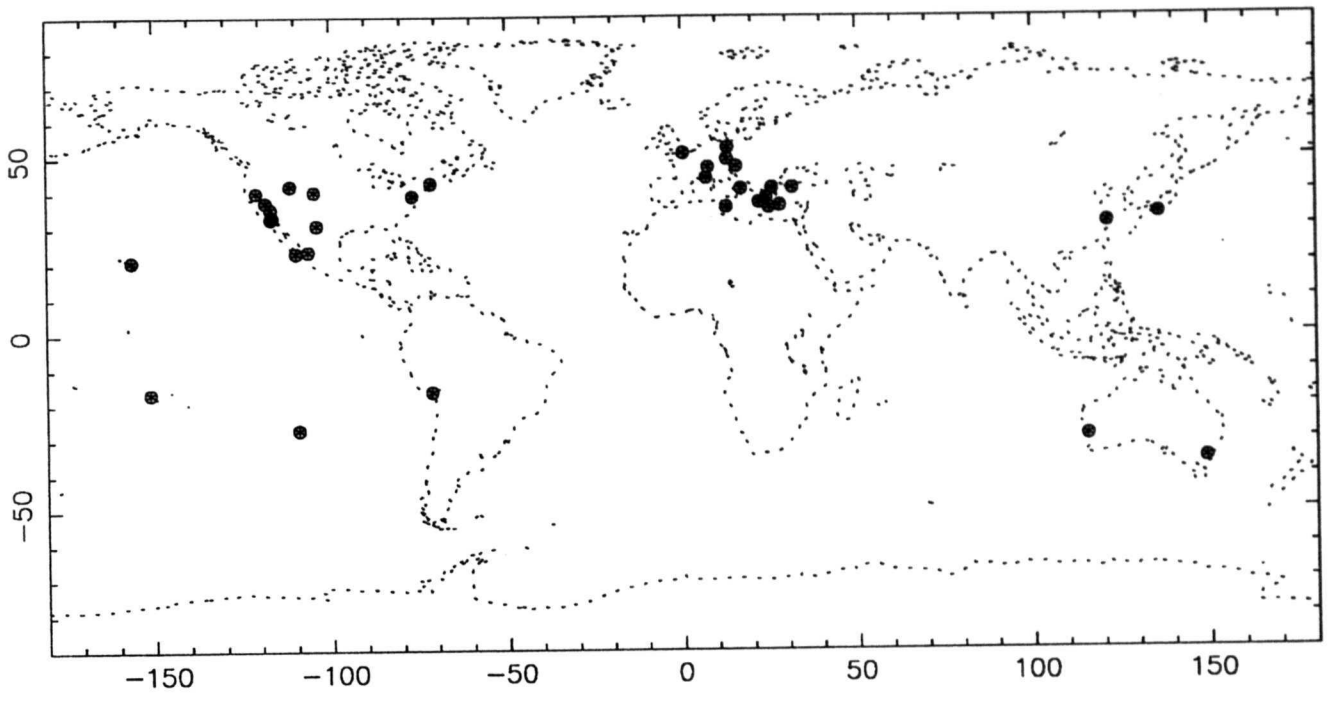
E.C. Pavlis
U. of Md. Dept. of Astronomy and NASA/GSFC, Greenbelt MD 20771

The SL8 solution was obtained by fitting the orbit of LAGEOS in 30 day (and once per year, 35 day) arcs using normal points from the global SLR tracking network between January 1980 and December 1992. The monthly arcs were combined to form a solution for a set of station positions at epoch 910101, and station velocities. Orbit and force model parameters were adjusted at the intervals listed below. Earth Orientation Parameters were estimated as independent values of time and polar motion at daily intervals since January 1983, and at 5 day intervals up to December 1982. The IERS standards were followed with the exception that the GEM-T3 gravity field with expanded ocean tidal terms was adopted and the value of the geogravitational constant was employed as listed below.

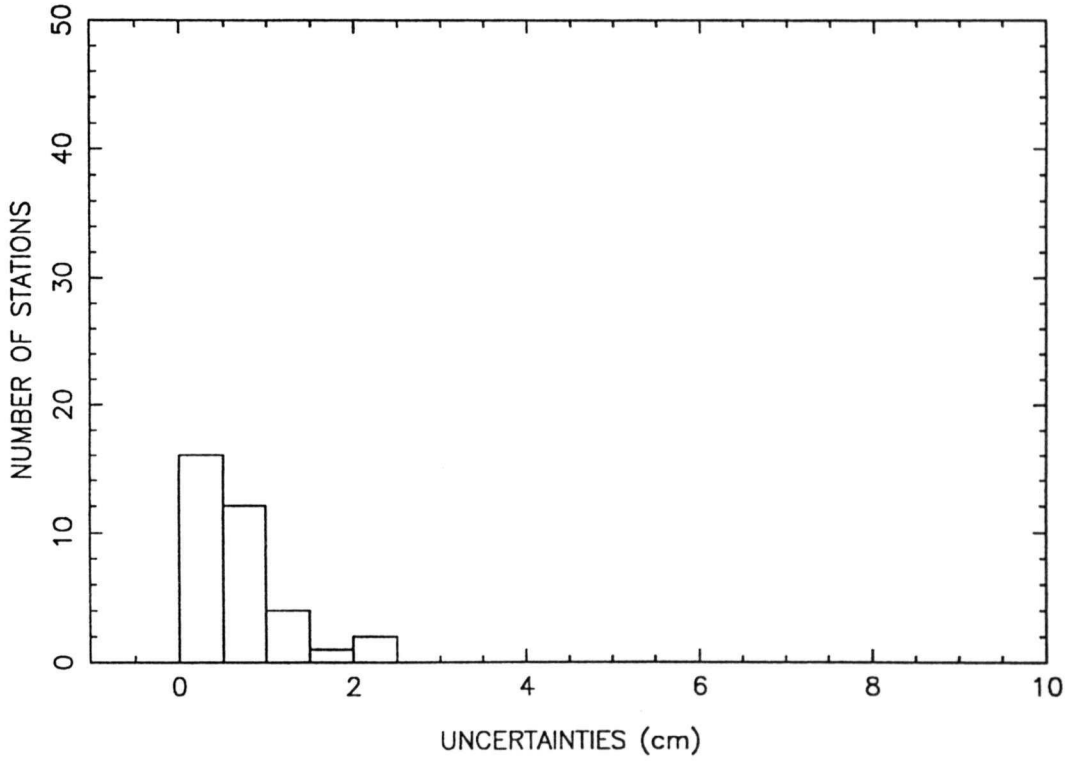
The EOP series that are attached to this submission were "Vondrak"-smoothed using an epsilon value of 0.05. The reason for the smoothing was the elimination of some spurious values due to lack of observations during the averaging interval. This only occured at a few instances, about 4% of the data have been edited in this fashion. The smoothing replaces these aberrant values with interpolated values based on those before and after the spurious point. The LODR series were obtained from the forward differencing of the UT1R series with IERS-nodes at arc-length intervals. The differencing was performed on the weakly smoothed UT1R series to minimize the noise amplification. Examination of the rms differences between the raw and the smoothed series indicates that given the accuracy of the series, the smoothing has not compromised its signal content.

Summary description of the terrestrial system attached to the set of station coordinates SSC(GSFC) 93 L 01

1 - Technique:		SLR to LAGEOS 1
2 - Analysis Center:		NASA/GSFC
3 - Solution Identifier:		GSFC SL8.2
4 - Software Used		GEODYN II and SOLVE II
5 - Relativity Scale:		Local Earth
6 - Station Tidal Correction:		Earth tides and Ocean loading (Scherneck)
7 - Tectonic plate model:		GSFC SL8.2
8 - Velocity of light:		299792458 m/s
9 - GM:		398600.4415 km^3/s^2
10 - Reference epoch:		88 01 01
11 - Adjusted Parameters	Orbit:	6 elements every 30(35) days along track accel. every 15 days once per rev. accel. every 15 days
	Stations:	position and velocity estimated except lat, lon of 7105 and lat of 7210 and lat, lon rate of 7105 and lat rate of 7210
	EOP:	X, Y, UT1 every 5 days from 80 01 01 to 82 12 28 every day from 82 12 29 to 91 12 31 one UT1 value fixed at IERS each month
12 - Definition of Origin:		Geocentric
13 - Definition of Orientation:		a priori ERP from IERS 90 C 04 and fixed station components
14 - Constraint for time evolution:		latitude and longitude rates of 7105 and latitude rate of 7210.



Distribution of the 34 sites of the terrestrial frame SSC(GSFC) 93 L 01.



Distribution of the uncertainties (quadratic mean of σ_x, σ_y, σ_z) for the 35 stations of the terrestrial frame SSC(GSFC) 93 L 01.

EOP(GSFC) 93 L 01 From Jan 1980 to Dec 1992

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
1980	74	1.31	74	0.52	61	0.90
1981	73	0.61	73	0.35	62	0.40
1982	76	0.74	75	0.63	64	0.70
1983	365	0.92	365	0.91	347	0.70
1984	366	0.56	366	0.49	354	0.50
1985	365	0.52	365	0.45	350	0.40
1986	365	0.50	365	0.44	349	0.50
1987	365	0.42	365	0.39	352	0.40
1988	366	0.44	366	0.43	354	0.40
1989	364	0.45	364	0.42	350	0.40
1990	365	0.39	365	0.41	351	0.40
1991	365	0.55	365	0.52	347	0.50
1992	365	0.52	365	0.50	353	0.80