DETERMINATION OF EARTH ROTATION (UT0-UTC AND VARIATION OF LATITUDE) BY ANALYZING LUNAR LASER RANGING DATA

FSG 95 M 01

J.Mueller, M.Schneider, U.Schreiber
Forschungseinrichtung Satellitengeodaesie (FSG), Technical University Munich
80290 Munich, Germany

M.Soffel, H.Ruder
Theoretical Astrophysics, University Tuebingen
Auf der Morgenstelle 10, 72076 Tuebingen, Germany

We have analyzed Lunar Laser Ranging (LLR) data acquired between 1970 and January, 1995. The observations are taken from the usual five sites: McDonald (three locations), Grasse and Haleakala; some normal points from Wettzell are added. All in all more than 9200 LLR measurements are used.

The constants adopted for the computations are those of the IAU recommendations resp. the IERS standards (McCarthy, 1992). For the 9-year, the annual, the half-year and the half-month period we used the values of Zhu *et al.* (1990).

The station coordinates have been corrected for plate motion (NUVEL NNR-1 model); the base epoch for plate motion is December 10, 1991 (MJD 48600).

The input Earth orientation parameters are taken from a solution generated by R. Gross called COMB94; the tidally driven diurnal and semidiurnal UT1 variations have been added to the input UT1 file (Herring, 1993).

We determined the parameters of the Earth-Moon system by a least-squares fit to weighted observations. For the determination of a correction to the luni-solar precession constant and the four (two in-phase and two out-of-phase) coefficients of the 18.6 year nutation period, constraints indicated in Williams *et al.* (1991) have been used.

The post-fit residuals are analyzed by the daily-decomposition method (Dickey *et al.*, 1985) to obtain improved values for UT0-UTC and variation of latitude (VOL) for each reflector station pair on every night for which sufficient data are available. 1612 pairs were found. After having removed the bad ones the others have been smoothed using a spline filter. The series of Earth rotation parameters (UT0-UTC and VOL) have been provided to the IERS Central bureau, designated EOP(FSG) 95 M 01.

These improved values for the Earth rotation have been used in a further iteration of the global adjustment of the LLR data. The final results for the station coordinates have been provided to the IERS Central Bureau. Its designation is SSC(FSG) 95 M 01.

Besides the parameters mentioned above, relativistic quantities have been determined: two metric parameters, the Nordtvedt parameter (strong equivalence principle), the geodetic precession of the lunar orbit, the time variation of the gravitational constant, one parameter for testing Newton's inverse square law, one parameter indicating a violation of special relativity and one parameter which indicates the validity of the strong equivalence principle in the coupling of dark matter to the different compositions of Earth and Moon.

Values for all parameters are available on request.

Acknowledgements. We wish to acknowledge and thank the staffs of Cerga, Haleakala, and McDonald Observatory for providing the normal points. We wish to thank R. Gross from JPL for providing his series of Earth rotation parameters. Support from the Deutsche Forschungsgemeinschaft is gratefully acknowledged.

References

Dickey, J.O., Newhall, X X, Williams, J.G., 1985: Earth Orientation from Lunar Laser Ranging and an Error Analysis of Polar Motion Services, *J. Geophys. Res.*, **90**, No. B11, 9353-9362.

Herring, T.A., 1993: Diurnal and Semidiurnal Variations in Earth Rotation, in: *Advances in Space Research,* **13,** No. 11., M. Feissel (ed.), Pergammon, Great Britain, 147-156.

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

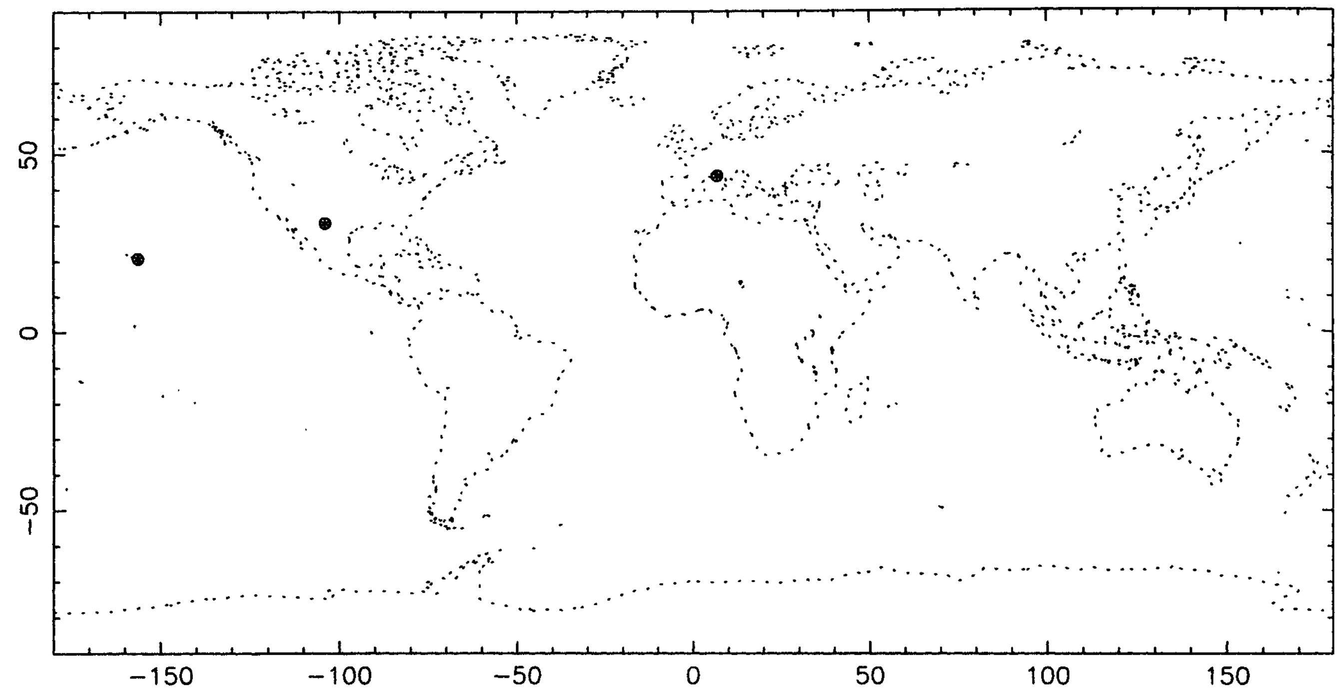
Mueller, J., Schneider, M., Soffel, M., Ruder, H., 1992: New results for relativistic parameters from the analysis of LLR measurements, in: *Relativistic Gravity Research - With Emphasis on Experiments and Observations*, Bad Honnef, Germany, Sept. 2-6, 1991, J. Ehlers and G. Schaefer (eds.), Berlin, *Lecture Notes in Physics,* **410**, Springer, 87-99.

Williams, J.G., Newhall, X X, Dickey, J.O., 1991: Luni-Solar Precession: Determination from Lunar Laser Ranges, *Astron. Astrophys,* **241**, L9-L12.

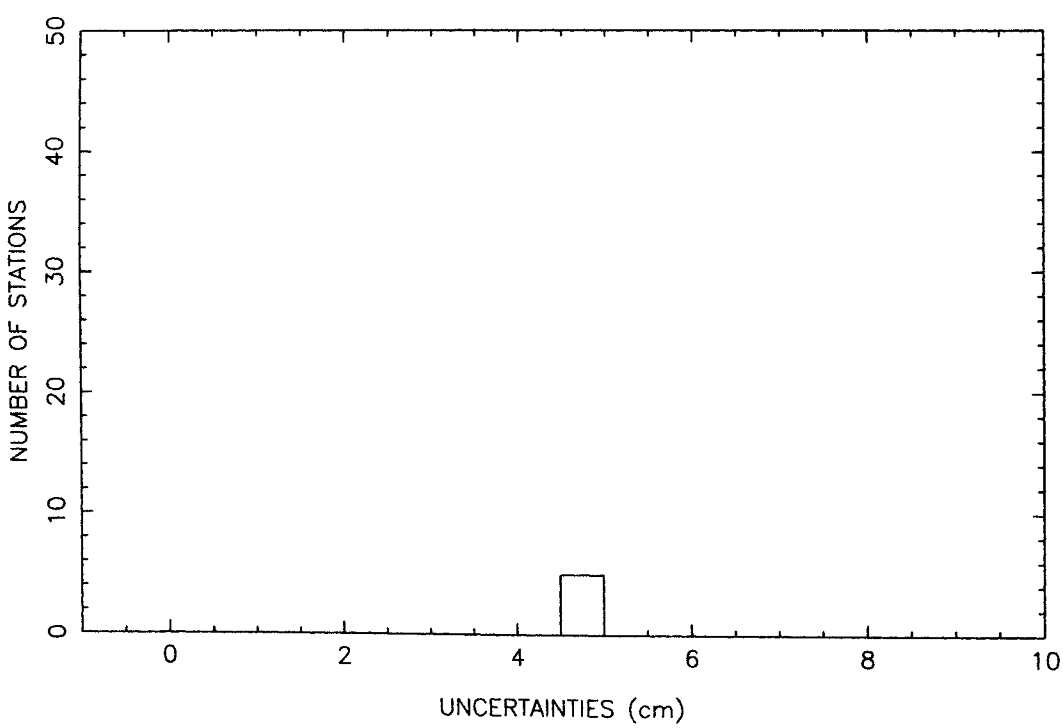
Zhu, S.Y., Groten, E., Reigber, Ch., 1990: Various Aspects of Numerical Determination of Nutation Constants, *Astron. J.*, **99,** No. 3, 1024-1044.

Technical description of solution FSG 95 M 01

1 - Technique:	LLR
2 - Analysis Center:	FSG/Techn. Univ. Munich
3 - Software used:	FSG LLR software
4 - Data span:	April 1970 - Jan 1995
5 - Celestial Reference Frame:	
a - Nature:	dynamical; own ephemeris program (initial values from DE200)
b - Definition of the Orientation:	referred to the equator and equinox of J2000 through the ephemeris
6 - Terrestrial Reference Frame:	SSC(FSG) 95 M 01
a - Relativity scale:	LE: relativistic geocentric frame
b - Velocity of light:	299792458 m/s
c - Geogravitational constant:	adjusted: 3.98600448 m^3/s^2 (geocentric)
d - Permanent tidal correction:	No
e - Definition of the origin:	by the geocenter through c10=0, c11=0, s11=0
f - Definition of the orientation:	EOP from 1970 to 1995 taken from a file of R. Gross (COMB94) which is aligned with the IERS system; daily corrections for UT0 and VOL are determined after the global fit
g - Reference epoch:	december 10, 1991 (MJD 48600)
h - Tectonic plate model:	NNR-NUVEL1
i - Constraint for time evolution:	fixed plate motion model (NNR-NUVEL1); estimation of UT1 and polar motion rates during the global solution
7 - Earth Orientation:	EOP(FSG) 95 M 01
a - A priori nutation model:	IAU(1980), values for the coefficients of the 9-year, annual, half-year and half-month period from Zhu et al. (1990)
b - Short-period tidal variations in x, y, UT1:	diurnal and semidiurnal tidal variations (M2, S2, N2, K1, O1, P1) in UT1 have been added (Herring, 1993), not in x and y
8 - Estimated parameters:	
a - Celestial Frame:	orbit of the Earth-Moon barycenter (X0, Y0, Z0, Xdot, Ydot, Zdot); lunar orbit (X0, Y0, Z0, Xdot, Ydot, Zdot)
b - Terrestrial Frame:	cartesian coordinates (X0, Y0, Z0); rates fixed (NNR-NUVEL1)
c - Earth Orientation:	UT0-UTC and variation of latitude VOL; luni-solar precession constant and the amplitudes of the 18.6-year nutation period (2 in-phase and 2 out-of-phase); rates for x, y, and UT1
d - Others:	lunar librations; reflector coordinates; lunar gravity; mass of the Earth-Moon system; lunar Love number and dissipation parameter; lag angle (lunar tidal acceleration); relativistic parameters



Distribution of the 3 sites of the terrestrial frame SSC(FSG) 95 M 01



Distribution of the uncertainties (quadratic mean of σ_x, σ_y, σ_z) for the 5 stations of the terrestrial frame SSC(FSG) 95 M 01.

EOP(FSG) 95 M 01 From Oct 1970 to Jan 1995

Number of measurements per year and median uncertainties
Units : 0.001" for φ; 0.0001s for UT0

YEAR	φ		UT0	
	Nb	Sigma	Nb	Sigma
1970	8	15.00	8	10.00
1971	21	15.00	21	10.00
1972	62	10.31	62	3.77
1973	105	15.00	105	10.00
1974	68	15.00	68	10.00
1975	82	15.00	82	10.00
1976	77	15.00	77	6.84
1977	70	15.00	70	10.00
1978	57	15.00	57	10.00
1979	62	15.00	62	10.00
1980	68	15.00	68	10.00
1981	29	15.00	29	10.00
1982	3	7.73	3	3.43
1983	6	15.00	6	10.00
1984	77	7.91	77	4.61
1985	175	7.84	175	3.45
1986	42	4.09	42	1.65
1987	39	3.87	39	1.27
1988	49	1.27	49	0.86
1989	51	1.34	51	0.87
1990	98	1.15	98	0.67
1991	63	1.36	63	0.62
1992	81	1.69	81	1.14
1993	100	1.53	100	0.80
1994	95	1.05	95	0.69
1995	13	0.88	13	0.69