EARTH ROTATION PARAMETERS DERIVED FROM SLR DATA ON LAGEOS-1

B.A.C. AMBROSIUS, D.C. KUYPER, H. LEENMAN, G.J. METS, R. NOOMEN, K.F. WAKKER
Delft University of Technology
Faculty of Aerospace Engineering
Kluyverweg 1
2629 HS Delft
The Netherlands

ABSTRACT. This paper describes the computation of ERP(DUT) 93L05A, the contribution of Delft University of Technology to the SEARCH'92 Campaign. The analysis is based on satellite laser range observations to LAGEOS-1. The resulting 5-daily solutions for x, y and UT1 agree with IERS EOP90C04 at a level of 0.4 and 0.8 marcsec and 0.045 ms, respectively.

1. Introduction

The orbital characteristics of the geodetic satellite LAGEOS-1 (altitude 5900 km, inclination 109 degrees) make it a highly visible target for Satellite Laser Ranging (SLR) observatories around the world. Combined with the fact that the trajectory of the satellite can be modeled with an unparalleled accuracy, LAGEOS-1 is an ideal instrument to study a variety of global geodetic phenomena. Delft University of Technology (DUT) has been involved in the analysis of SLR data on this satellite since 1977. The analysis effort is aimed at crustal deformations and earth rotation in particular. Here, the computation of Earth Rotation Parameters (ERPs) for the SEARCH'92 Campaign (June 21 - September 22, 1992) will be discussed. The emphasis of this paper is on the computation procedure.

2. Technique

The computation of crustal deformations is a primary goal of the analysis of LAGEOS-1 SLR measurements at DUT. Serving this objective, the observations are processed in batches of 13 weeks on average. The deformations are then computed from the differences between the resulting consecutive network solutions.

The computation of the ERPs is performed in three steps. First, solutions for all global parameters (station coordinates and 5-daily ERPs) are computed for each of the quarterly intervals independently. The model that is used for the analysis is summarized in Table 1. It closely follows the IERS Standards (McCarthy, 1992), with a few exceptions: (i) the NASA/GSFC JGM-1 solution for the representation of the gravity field and ocean tides, including constants like GM, a_e and the flattening of the Earth and time-dependent terms, is used instead of the advised GEM-T3 and Schwiderski models; (ii) the effect of atmospheric pressure loading and ocean loading on station positions is not taken into account; and (iii) no plate motion is applied during each 13-week sub-interval. The orbital analysis and parameter estimation is performed using the GEODYN-II/SOLVE-II software package (Eddy et al., 1990; Majer, 1986). To limit the effect of potential dynamic errors in the computation model, each sub-interval is divided into a number of consecutive 1-week data arcs, and the trajectory of LAGEOS-1 is fitted to the observations for each data arc independently, adjusting a state-vector at epoch and a few force-scaling parameters only. It is important to realize that, to

avoid the inversion becoming numerically singular, the longitudes of the ascending nodes of each week arc are kept fixed at values derived in a preliminary data analysis, where polar motion is not adjusted but kept fixed at the a priori (IERS 90C04) values. Consequently, it is to be expected that the UT1 solutions presented here will very closely follow the IERS values, and cannot be considered as a very meaningfull analysis result.

In the second step, the series of individual, independent 13-week solutions for the global network of laser stations are converted into a model for the position of each individual station as a function of time. In this way, it is possible to eliminate potential systematic differences between the global network solutions, and bring coherency into the terrestrial reference frame. The model for the station positions includes an initial position at a reference epoch and a simple linear time-dependency for each position component. Although the SEARCH'92 Campaign is limited to 3 months in 1992 only, the analysis was actually performed on LAGEOS-1 observations acquired in the 1983-1992 time frame. The length of this time frame guarantees that very accurate solutions for the tectonic motions for each station can be derived. To eliminate numerical singularities in this step, the motion of a total of 12 globally well-distributed stations was kept fixed at the value given by the NUVEL-1 No Net Rotation model (DeMets et al., 1990). These stations (Yarragadee, Easter Island, Greenbelt, Platteville, Huahine, Mazatlan, Maui, Wettzell, Graz, RGO, Orroral Valley and Kootwijk) are located on the rigid part of 5 of the major tectonic plates, and have a good tracking history.

Finally, the model for station positions as a function of time is then back-substituted and provides the means to bring coherency into the series of ERP solutions. The latter are adjusted without any constraint, whereas the station positions (and the longitudes of the ascending nodes of the weekly satellite state-vectors) are kept fixed at the interpolated values of step 2. Since the normal equations that were already generated for step 1 are being used here, the computation model is the same as the one described in Table 1.

3. Results

The resulting ERP solutions are presented in Table 2. The solution is designated ERP(DUT) 93L05A. It represents an improved version of the ERP(DUT) 93L02 solution, which was submitted to the IERS Central Bureau for inclusion in the 1992 Annual Report. Column 4 provides UT1-UTC values. The standard deviations are 1-σ formal uncertainties. The number in the final column indicates the sub-interval, from which the solutions were taken. For the SEARCH'92 Campaign, only intervals 36 and 37 are relevant.

Statistics of the differences with respect to the a priori values (IERS EOP90C04) are shown in Table 3. After subtraction of the mean difference, the pole position solutions show an agreement of 0.39 and 0.81 marcsec, which is about 3-4 times the formal uncertainty provided along with the solutions here. As for the UT1 values, the agreement is about 0.045 ms, which exceeds the formal uncertainties by a factor of 3-4 also.

4. References

DeMets, C., R.G. Gordon, D.F. Argus and S. Stein, Current plate motions, *Geophys. J. Int.*, **101**, 425-478, 1990.

Eddy, W.F., J.J. McCarthy, D.E. Pavlis, J.A. Marshall, S.B. Luthke, L.S. Tsaoussi, G. Leung and D.A. Williams, GEODYN-II system operations manual Vol. 1-5, contractor report, ST System Corp., Lanham MD, USA, 1990.

Majer, V., SOLVE program mathematical description, NASA contractor report, Business and Technological Systems, Inc., Seabrook MD, USA, Dec., 1986.
McCarthy, D.D., (ed.), IERS Standards (1992), *IERS Technical Note 13*, Observatoire de Paris, France, July, 1992.

Table 1: Models and constants applied in the analysis.

Dynamic model:	
Gravity field	NASA/GSFC JGM-1 model, truncated at 20x20
GM	398600.4415 km^3/s^2
c	299792.458 km/s
a_e	6378.1363 km
1/f	298.2564
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 1cpr 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); SSC(DUT) 93L05 (step 3)
Earth rotation	adjusted at 5-day intervals; IERS EOP90C04 a priori values
CIS	mean equator and equinox of J2000.0
Precession	IAU 1976 (Lieske model)
Nutation	IAU 1980 (Wahr model)
Plate motion	not applied
Tidal uplift	$h_2 = 0.609$; $l_2 = 0.0852$
Pole tide (geometric part)	applied
Atmospheric, ocean loading	not applied
Measurement model:	
Observations	release A normal points, computed at Bendix (June); quick-look normal points (July-September)
Data weighting	overall model accuracy plus system characteristics
Tropospheric refraction	Marini-Murray model

Table 2: The solution ERP(DUT) 93L05A. Only parameters for the interval June 21 - September 22, 1992, are selected here.

date (mjd)	x (marcsec)	y (marcsec)	UT1-UTC (s)	σ(x) (marcsec)	σ(y) (marcsec)	σ(UT1-UTC) (s)	interval
48794	-152.90	356.19	-0.54265923	0.48	0.44	0.00003646	36
48799	-146.66	367.30	-0.55079802	0.29	0.23	0.00002428	36
48804	-141.85	380.24	-0.55816557	0.33	0.26	0.00002062	36
48809	-135.73	390.83	0.43571062	0.28	0.22	0.00001770	36
48814	-127.29	402.32	0.42957544	0.23	0.19	0.00001554	36
48819	-124.15	412.26	0.42320903	0.19	0.19	0.00001493	36
48824	-112.47	424.05	0.41646921	0.18	0.18	0.00001461	36
48829	-101.18	433.90	0.40893665	0.17	0.20	0.00001693	36
48834	-91.95	443.70	0.40174805	0.16	0.19	0.00001461	36
48839	-81.60	455.29	0.39408749	0.15	0.17	0.00001306	36
48844	-71.63	466.30	0.38579321	0.16	0.17	0.00001594	36
48849	-61.92	478.40	0.37731885	0.22	0.21	0.00001678	36
48854	-48.83	486.10	0.36840449	0.15	0.15	0.00001287	36
48859	-33.21	491.68	0.35904445	0.19	0.17	0.00001446	36
48864	-17.61	501.74	0.34899572	0.34	0.27	0.00002395	36
48869	-6.38	503.10	0.33930739	0.27	0.21	0.00001772	37
48874	5.92	506.21	0.33025067	0.16	0.14	0.00001375	37
48879	17.88	507.84	0.32037788	0.19	0.15	0.00001389	37
48884	29.54	509.15	0.31051683	0.14	0.13	0.00001094	37

Table 3: Statistics of the differences between ERP(DUT) 93L05A and IERS EOP90C04. The numbers in the column "rms difference" are obtained before and after subtraction of the mean value, respectively.

quantity	number of solutions	rms difference
x	19	0.52/0.39 marcsec
y	19	1.70/0.81 marcsec
UT1-UTC	19	0.064/0.045 ms