DETERMINATION OF EARTH ROTATION FROM LASER RANGING TO LAGEOS AND RELATED RESEARCHES

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ABSTRACT. The Kiev-Geodynamics-2 program complex was used for determination of earth-rotation parameters and station coordinates from the full set of the MERIT SLR data. The results have been compared with other realizations that have been reported to the Coordinating Centre at the BIH. Other researches in the reduction of SLR data and in instrumen-tation are considered.

1. DETERMINATION OF ERP AND SSC

The Kiev-Geodynamics-2 program complex, which is based on numerical-integration techniques for satellite-orbit computation, was used for determining the Earth-Rotation Parameters (ERP) and the Set of Station Coordinates (SSC) during the MERIT Campaign (Yatskiv et al., 1985). The results of the analysis of LAGEOS SLR data obtained during the interval September 1983 - May 1984 were reported to the BIH (Yatskiv et al, 1986). After receiving in Kiev the full set of MERIT SLR data (14-months interval) we repeated our analysis. At the first stage the station coordinates and orbital elements were adjusted simultaneously, taking for the initial values of the station coordinates those reported to the BIH. The latitude and longitude of the Arequipa station (code number 7907) were held fixed. At the second stage the orbital elements and the ERP were adjusted. This final solution, which is denoted by (GAOUA)86L01, resulted in an orbital fit with a standard deviation of 6 to 11 cm. Figure 1 contains comparisons with the results obtained by other centres for the coordinates of the pole and for the length of day.

2. COMPARISON OF DIFFERENT REALIZATIONS OF SSC AND ERP

We have compared our results of the analysis of LAGEOS ranging data with those reported to the Coordinating Centre at the BIH (Cholij, 1987). In total, 8 sets of station coordinates were used for this purpose. We take the general relationship between two vectors R_j and R_i of a station k referred to terrestrial frames S_j and S_i, respectively, in the form

$$R_{jk} = B \cdot R_{ik} + T + R_{ik} \qquad (1)$$

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where B is a rotation matrix and T is a translation vector. Transformation parameters between different SSC were derived. They show that the systematic differences are small. In Table 1 the transformation parameters between SSC(GAOUA)86L01 and SSC(CSR)85L01 are given. Averaged values of the uncertainties of the determination of the relative transformation parameters are in the range

rotation,	$\pm$ 0.001	to $\pm$ 0.003	arcsec
translation	$\pm$ 0.01	to $\pm$ 0.05	m
scaling	$\pm 1\times10^{-9}$	to $\pm 3\times10^{-10}$	

Table 1. Transformation parameters between SSC(GAOUA)86L01 and SSC(CSR)85L01.

Units: arcsec for B1, B2, B3, m for T1, T2, T3, and 10^{-9} for D.

Rotation			Translation			Scaling
B1	B2	B3	T1	T2	T3	D
0.001	0.010	0.091	-0.012	-0.013	-0.048	2.5

We evaluated the root-mean-square errors of different realization of SSC and derived the internal precisions of each SSC; Table 2 shows the results obtained; SSC(GSFC)85L01 was excluded from the analysis because of large systematic differences.

Table 2. Root-mean-square errors of difference realizations of SSC.

SSC(ZIPE)85L02	0.045 m	SSC(ESOC)85L01	0.046 m
SSC(NAL)85101	0.048 m	SSC(DGFII)85L04	0.046 m
SSC(GAOUA)86L01	0.049 m	SSC(CSR)85L01	0.027 m
SSC(UPAD)85L02	0.061 m		

For the comparison of the pole coordinates obtained by different analysis centres, the initial data have been smoothed by the Vondrak-method, using different values of smoothing ($\varepsilon_1 = 10^{-5}$; $\varepsilon_2 = 10^{-6}$). The residuals $\Delta x = x_{in} - x_{sm}$ and $\Delta y = y_{in} - y_{sm}$ were derived and their power spectra were estimated in the frequency range of 0.02 to 0.1 cycles per day. These spectra showed common features at the periods of 11, 19, 40 days. On the basis of estimates of spectra of Δx and Δy, and taking into account the frequency response of the filters, the estimates of the standard deviations R_i for each series of pole coordinates were derived. Using these estimates of R_i at the first stage the weighted mean values of the pole coordinates $\bar{x}$ and $\bar{y}$ were derived.

Then the differences $x_{sm} - \bar{x}$ and $y_{sm} - \bar{y}$ were formed and analysed. On

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the basis of this analysis the standard errors of each set of ERP were derived; they are given in Table 3.

Table 3. Standard errors of pole coordinates.
Units: 0".001

Series	$\varepsilon = 10^{-6}$		$\varepsilon = 10^{-5}$	
	x	y	x	y
ERP(CSR)85L07	1.42	0.58	1.37	0.58
ERP(DGFII)85L04	1.31	0.73	1.23	0.81
ERP(GAOUA)86L01	0.91	0.90	0.95	1.26
ERP(GRGS)85L01	12.77	3.14	13.10	3.06
ERP(NAL)85L02	1.32	0.54	1.28	0.59
ERP(SHA)85L02	1.56	1.13	1.60	1.30
ERP(UPAD)85L01	2.63	1.93	2.85	2.34
ERP(ZIPE)85L01	1.19	0.62	1.13	0.65

3. RELATED RESEARCHES

3.1 Research in the reduction of SLR data

3.11 Study of Plate Motions. One of the factors which can affect earth-rotation results is the motion of the tectonic plates which make up the Earth's surface. It has been shown on the basis of Doppler satellite observations and astronomical latitude and longitude observations that the geophysical plate-motion model RM2 can be used for the reduction purpose (Yatskiv et al., 1985). We have continued this analysis using additional observational data, namely: LAGEOS laser ranging data and VLBI data (Christodoulidis, 1985; Tapley, 1985; Ryan, 1985). Averaged values of the squares of the observed rates of change in latitude, longitude and baselines were compared with those of differences between observed and predicted by Minster-Jordan model values. We estimated the relative rotation vectors from LAGEOS SLR data and VLBI data by a least-squares adjustment.

The results lead to the general conclusion that the determinations of plate motions from the modern techniques of precise geodetic positioning appear to be consistent with the average rates over the last few million years derived by Minster and Jordan from the geological record and other geophysical information.

3.12 Investigations of the horizontal refractivity gradients. The accuracy of Marini and Murray's and Saastamoinen's range-correction formulae were investigated by comparisons with corrections obtained by ray tracing through spherically-symmetric refractivity profiles (Yatskiv et al., 1985). The systematic errors can result from the horizontal refractivity gradients. Group refractivities were measured by four simultaneously released radiosondes located approximately at 150 to 200 km from each other. The investigations indicate that radiosonde measurement errors are not the primary source of the observed differences of group refractivity and that the departure of the refractivity profiles from spherical symmetry is real. Terrain features such as mountains, large bodies of water, and vegetative cover probably have an influence on horizontal refractivity gradients near the ground.

3.13 Satellite centre of mass corrections. The range corrections for extrapolating laser range measurements to the centre of gravity of the satellites and their variations with satellite orientation were investigated. The centre-of-mass corrections are as follows:

LAGEOS	(24.13 ± 0.09) cm
STARLETTE	(7.34 ± 0.65) cm
GEOS-3	$1.367 \cos(\phi - 21^{\circ}.579)$ m

where ϕ is the angle between the line of sight and the local vertical (in degrees).

3.14 Solid-tide effects. The vector displacements of the stations due to tidal deformation, including the third-degree tides, were computed using two different program complexes. One of them uses the tide-generating potential development by D. Cartwright and R Tayler. The other complex is based on the direct computation of the geocentric vectors to the Moon and Sun. Both techniques use frequency-dependent Love and Shida numbers. The variations of the station coordinates computed by both program complexes coincide with an accuracy of 3 mm.

3.2 Research in instrumentation

Experimental observations are being performed with first-generation laser-ranging devices ("Intercosmos" type). Typical passes for low satellites with the 25-ns laser pulses have standard deviations from smoothed curves of 75 cm. At present second-generation laser transportable stations ("Crimean" type) are being prepared.

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