HIGH RESOLUTION EARTH ROTATION PARAMETERS AS COMPUTED FROM SLR AND GPS DATA

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ABSTRACT. Earth rotation parameters with a daily and sub-daily resolution were determined using SLR and GPS data. Although both techniques can deliver highly accurate results the GPS data have clear advantages because of the better data distribution.

1. Introduction

The daily and sub-daily resolution of the Earth Rotation Parameters (ERP's) with an aimed accuracy of 0.1 mas and 0.01 ms, respectively, is currently an area of intensive investigations, particularly also of the SEARCH'92 Campaign. Both the higher time resolution and accuracy will essentially contribute to a further improvement of the understanding of the interaction of outer and inner forces with the Earth's rotational behaviour.

One of the problems of all methods of determining high-frequency ERP's is the decomposition of EOP's and nutation terms. In the case of satellite methods the correlation with orbital elements has an additional influence (Montag et al. (1993)). Therefore, the high resolution of ERP's requires high-accurate measurements and modelling. Furtheron the data should be fairly even distributed around the whole day. This latter condition can be better fulfilled by GPS measurements than by Satellite Laser Ranging (SLR). On the other side using dense distributed SLR data for certain time intervals high-accurate ERP's results can be obtained as an independent reference for comparisons.

2. Model Parameters, Data and Reference Frame

The analyses were performed by means of the GFZ orbital program packages EPOS.P.V1 for SLR and EPOS.P.V2 for GPS data. The model parameters used are according to IERS standards, generally. The exceptions are:

GM	398600.440 km^3s^{-2} (initial, adjusted)
Lageos:	
Cross-section to mass relation	0.000694 m^2/kg
Nominal reflectance coefficient	c_R = 1.12 (adjusted)
Empirical acceleration	c_e (adjusted)
GPS	
Tropospheric correction	Saastamoinen, 1973
Solar radiation pressure	ROCK 4 and 42 including thermal reradiation
Vehicle masses	Fliegel (1992), Feltens (1991)

Lageos data were analysed since 1980. The typical orbital fit for a 5-day arc is ± 4 cm.
In the case of GPS undifferenced ionospheric-free phases were analysed since the IGS '92 campaign. The sampling rate is 6 minutes and the arc length 32 hours. Different parameters were adjusted for different time intervals (Gendt et al (1993 a, b)), namely:

SLR:

c_e, c_R	-	global, every 30 days
Orbital parameters	-	5- or 6-day intervals
ERP's	-	5, 3, 2 days; for selected intervals further 1d, 12h, 6h
Station coordinates	-	quarterly, semiannual or for longer time intervals

GPS:

Orbital parameters	-	32-hour arcs
c_R and y-bias	-	32-hour arcs
ERP's	-	1d, 12h
Tropospheric zenith path delay	-	e. g. 4h
Ambiquities		
Epoch time parameters		

As a result of the analyses two sets of station coordinates were obtained. The laser station coordinate set SSC (GFZ) 93L01 consists of 101 monument positions. The average accuracy is better than ± 2 cm. The comparison after a 7-parameter similarity (Helmert) transformation with the combined ITRF solution is shown in Table 1. Besides the position for 69 monuments also the motion velocities were adjusted (the other sites were fixed to the NUVEL-1 model motions).

The fiducial-free GPS station coordinate set SSC (GFZ) 93G01 shows a similar accuracy (Tab. 1).

TABLE 1. Comparison with combined ITRF-SSC

	rms (cm)	Scale (10^{-8})	Translation of geocenter (x, y. z; in cm)		
SSC (GFZ)93G01 - SSC (ITRF)93C01	1.6	.38	8.3	2.6	- 2.2
SSC(GFZ)93L01 - SSC (ITRF) 91	1.9	.01	- .4	-0.3	2.8

3. Results for the ERP's

3.1. ERP's BASED ON SLR DATA

It was shown that generally a high accuracy for highly resolved ERP's can be obtained too if at least SLR data from 4 relevant passes for each of the pole coordinates are available (Montag (1989)). But it can happen that even one well measured relevant satellite pass delivers high accurate results too. By means of numerical investigations a better criterion was found in the use of correlation between the solved-for ERP's. These correlations depend mainly from the data distribution and the sampling time interval for the solve-for-ERP's. If the correlation is higher than 0.9, certain parameters are deleted in the following way:

correlation > 0.9 between	deleted parameters
x_P, y_P x_P, UT (LOD) y_P, UT (LOD) x_P, UT (LOD) and y_P, UT (LOD)	x_P and y_P x_P y_P x_P, y_P, UT (LOD)

TABLE 2. Percentage of deleted pole coordinates and average correlation between ERP's after deletion

Time resolution		2d	1d	12h	6h
Percentage deleted	x_P y_P	1... 2 5...10	5...10 20	25 40	45-50 55-60
Mean correlation between ERP's		0.25	0.3	0.4...0.5	0.6

TABLE 3. R.m.s. difference between high resolution solution and 3-day solution (constant offset neglected)

Time resolution	R.m.s. differences in pole coordinates in mas		
	Example 1	Example 2 average data distrib.	dense data distrib.
1 d	0.9	1.4	0.3
12 h	1.4	2.2	0.9
6 h	2.5	3.3	1.6

TABLE 4. R.m.s. difference between 3- resp. 5-day solution and 1-day solution of ERP's (constant offset neglected)

Time resolution of reference	R.m.s. differences in pole coordinates in mas.		
	over 2 years (from 6.90 to 9.92)	over 90 days Example 1	Example 2
3 day	1.2	0.9	1.4
5 day	1.4	1.0	1.8

Using this criterion ERP's were computed with different time resolutions. For sub-daily resolution (12h, 6h) two examples were analysed:

- Example 1: 90 days from Dec. 1990 to March 1991 (incl. GIG'91 Campaign)
- Example 2: 90 days from June 1992 to Sept. 1992 (SEARCH'92 Campaign).

The percentage of pole coordinate results eliminated in this way is shown in Table 2 as a function of the time resolution. This Table further indicates that for the remaining results the average correlation ranges between 0.25 for the 2d solution and 0.6 for a resolution of 6h.

Several results having different time resolutions are displayed in Figure 1 to 3 (as corrections to IERS combined solution) together with the number of station and passes observed per day.

Figure 1 shows a part of the results of the Example 1 as correction to IERS, namely the 1d solutions for x and y, and the 12h solutions for the y component of the pole coordinates. The 3d solution is included as reference. The dependence of the scattering and the number of deleted points on the number of the stations and the observed passes is evident, especially for the 12h results. The effect of Christmas - New Year time (45249 - 257) is also clear visible.

More detailed results are shown for Example 2 (SEARCH'92 Campaign) in Figures 2 and 3. Here one can see the results for both the x- (Fig. 2) and y-component (Fig. 3) with a time resolution of 1d, 12h and 6h together with the 5d and 3d results as references. Comparing with Example 1 the scattering of the Example 2 is apparently higher. This is confirmed numerically in Table 3. It shows the r.m.s. differences (constant offset neclected) between the 3d solution on the one side and the 1d, 12h and 6h solution on the other. For an average data distribution the r.m.s. differences are in all cases significantly higher for the SEARCH'92 campaign. For the 1d resolution pole coordinates this is confirmed also using the 5d solution as a reference (Table 4). Table 4 also displays the r.m.s. differences between the 1d solution and the 3d and 5d solution for a time span of two years. Because the quality and quantity of the observations are nearly the only cause for the amount of these differences one can conclude, that apparently the SLR observing activity was during the GIG'91 campaign better, but during the SEARCH'92 campaign even worse than in average.

Selecting only time intervals with a dense data distribution the results can be much better (Table 3). The r.m.s. differences are about 0.3 mas for the 1 d resolution and still better than 1 mas (0.9) for the 12h resolution.

TABLE 5. R.m.s. difference to the smoothed mean 1-day curve (time period 1993, Jan. - June)

Time resolution	Center	Pole coordinates in mas	
		x-pole	y-pole
1d	JPL	0.71	0.73
1d	SIO	0.36	0.49
1d	EMR	0.53	0.43
1d	GFZ	0.34	0.29
12h	GFZ	0.35	0.36

3.2. ERP's BASED ON GPS

Using the GPS data of the SEARCH Campaign ERP's were determined with a time resolution of 1d (Zhu et al. (1993)). Besides the 1d resolution for 1993 also ERP's with a time resolution of 12h were analysed. A section of these results is presented in Figure 4 together with the corresponding solution of SIO. Apparently the scattering of the GPS results is generally smaller than that of SLR results. Numerically this is confirmed in Table 5. Here the r.m.s. differences to the smoothed 1d curve are shown (not to the 3d or 5d solution as in the case of SLR; this makes the GPS results somewhat more optimistic). It is clearly visible from this table that most of the IGS Analysis Centers have reached a 0.5

Figure 1. Diurnal and semidiurnal SLR polar motion results (Example 1)
3d solution (–) as reference

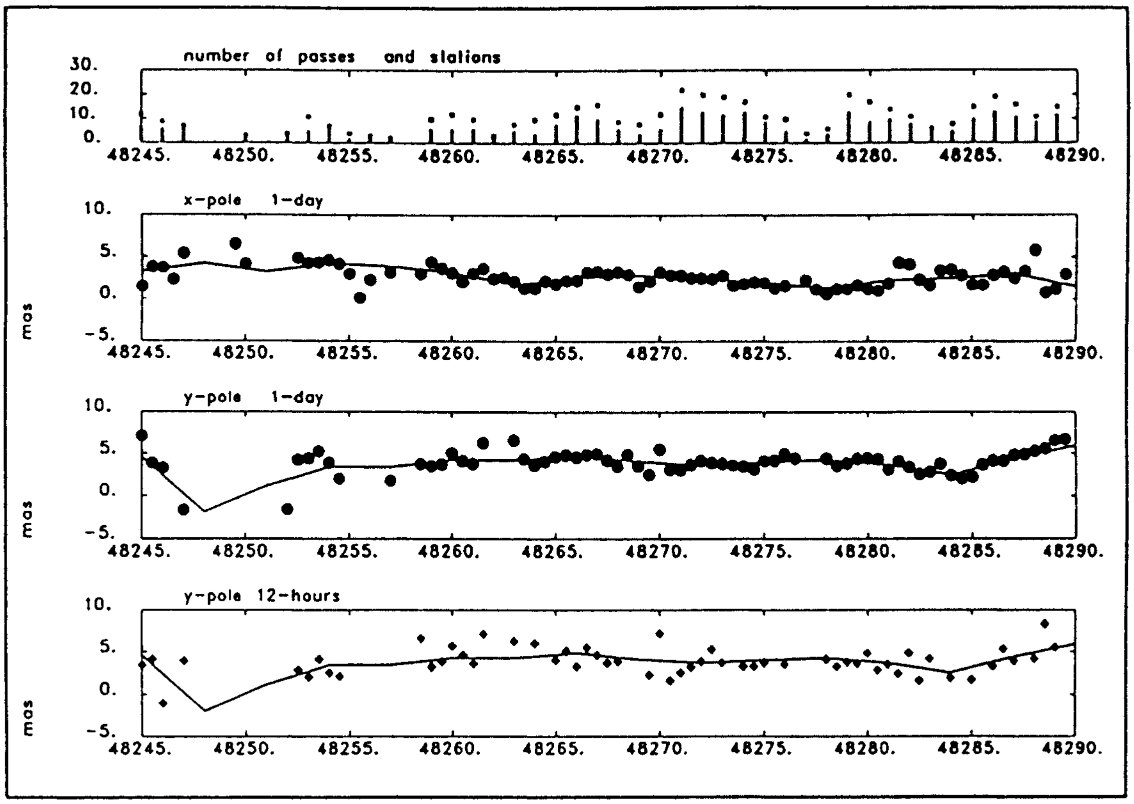


Figure 2. Highly resolved SLR x-pole (Example 2)
5d (—) and 3d (–) solution as reference

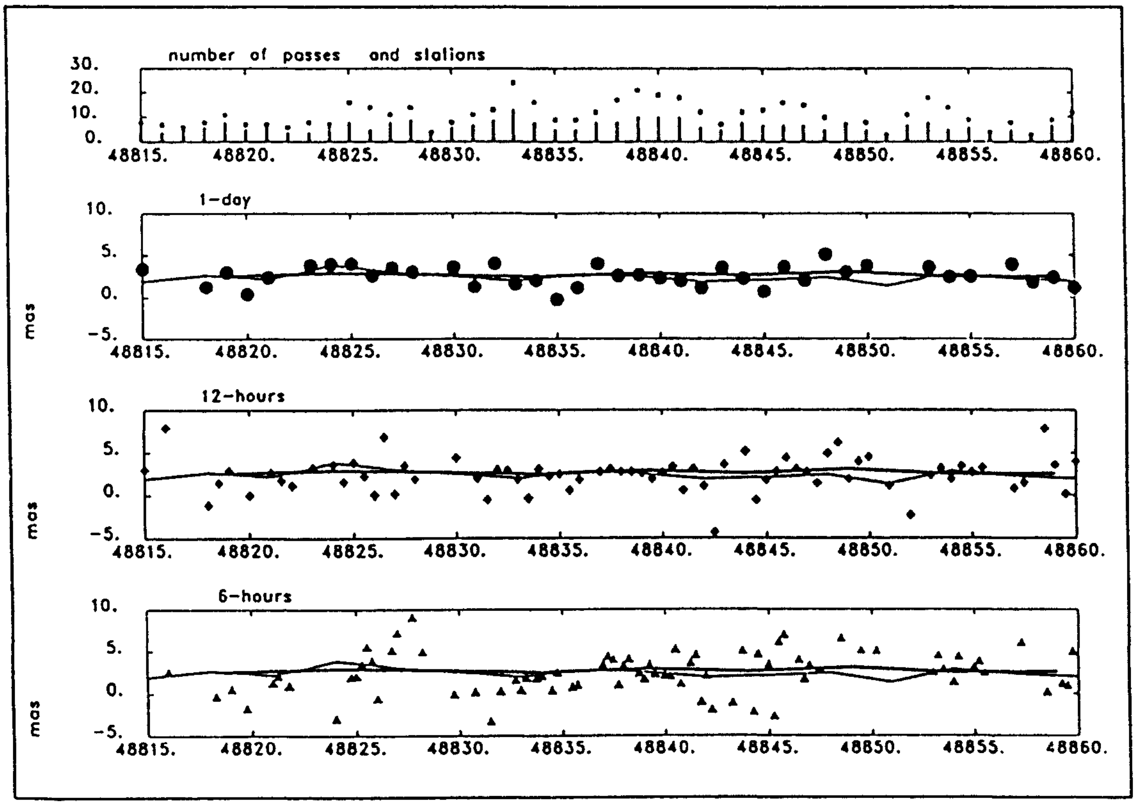


Figure 3. Highly resolved SLR y-pole (Example 2)
5d (↔) and 3d (–) solution as reference

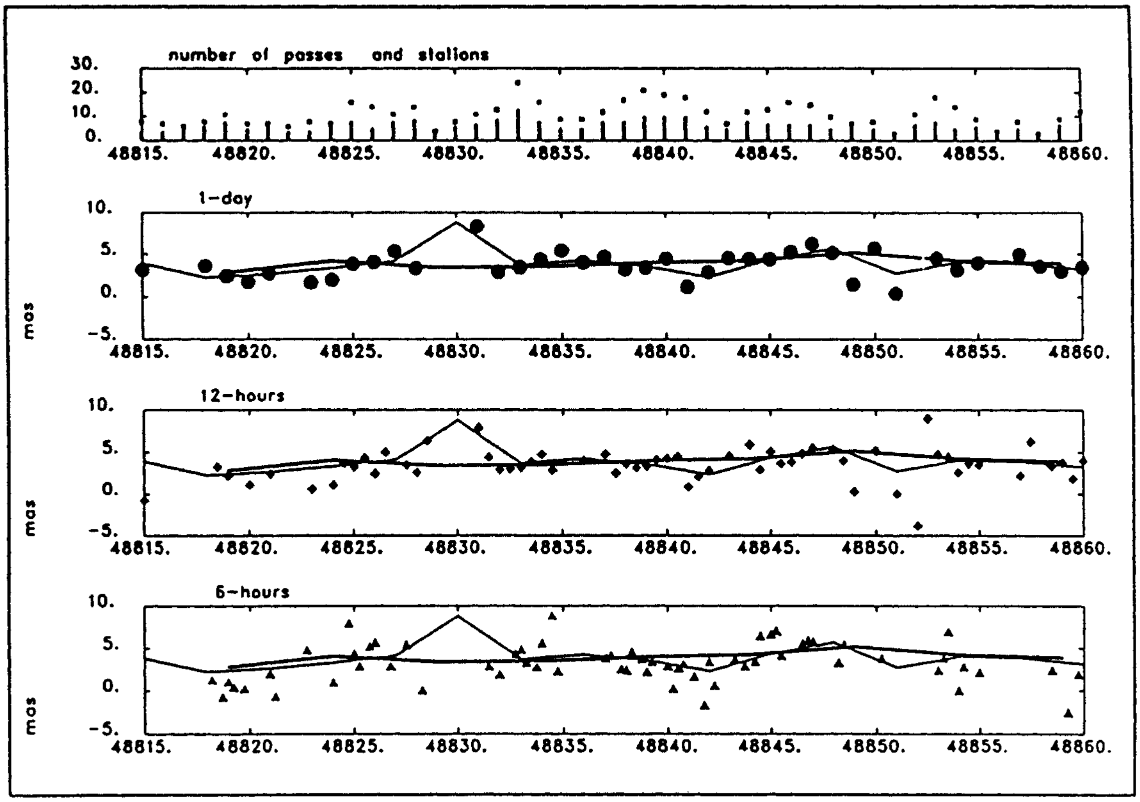
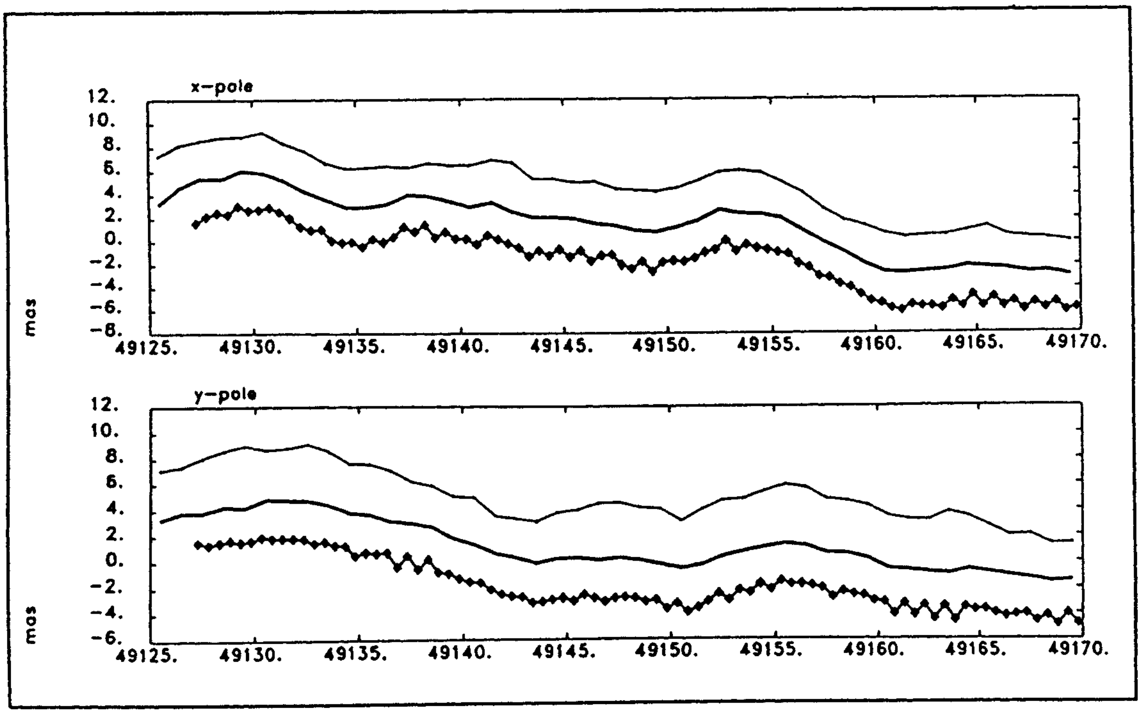


Figure 4. Highly resolved polar motion from GPS
1d GFZ (↔), 1d SIO (–), 12h GFZ (◆)



mas precision for their daily products. An increase in the time resolution only slightly increases the uncertainty of the GPS derived ERP's.

4. Conclusions

For highly resolved ERP's, generally, the GPS data have advantages because of the dense data distribution (all weather capability, good coverage and geometry). This holds especially for the sub-daily products where a precision of better than 0.5 mas can be obtained for a 12h resolution.

In certain time intervals with well distributed and accurate SLR data the ERP's results also reach a precision of better than 0.5 mas, but up to a resolution of 1d only. In the sub-daily region the precision is several times worse, generally. Therefore both SLR and GPS can complement each other for the determination of ERP's with a lower time resolution (e. g. from 5d to 1d). Here the SLR results can serve as independent reference series for the investigation of systematic errors (bias, drift). On this basis ERP's with a sub-daily resolution should be derived from GPS data in the future.

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