GEOCENTER VARIATIONS DERIVED FROM GPS DATA

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1. ESTIMATION METHOD

For a 14 months period (95.06.01 - 96.07.31) geocenter positions were solved in a two-step procedure: In a first step, only GPS data were used for orbit determination, with the station coordinates being treated as unknowns, yet with tight constraints (0.5 cm a priori sigma for 'core' stations, 5-10 cm or more for the other stations). In the second step, the geocenter correction was explicitly solved for by using the GPS orbits of step one as fixed, together with all other station coordinates. In order to avoid singularity, weak constraints were applied (10 m a priori sigma).

The theoretically possible explicit computation of geocenter corrections in one complete simultaneous adjustment was not carried out because the application of weak constraints leads to unstable solutions. Tests of this procedure with given 2 cm artificial geocenter variations led, due to the weak constraint, to recovered values of 1.7 cm, whereas with the two-step approach the recovered value was 1.9 cm. (To recover exactly 2 cm in the two-step method is not possible as well because the restituted orbit is affected by the constraint, too.)

2. MAJOR ERROR SOURCES

(a). *Error in GPS orbits.* Parameters like GM value, gravity model or third body model are sufficiently accurate. We have modified the GM value by 10^{-8}, and used the GRIM4 instead of the JGM3 gravity model. By doing so, the translation parameters of the orbit were changed only by less than 1 mm. By employing or neglecting models like an albedo model, solid earth tide model, or ocean tide model, the geocenter variation is also only insignificantly (by less than 1 mm) effected. As regards the solar radiation model, we solved the scales in x and z direction separately and afterwards used the same scale for these two directions with effects on the translation parameters of a few mm up to centimeter level. This indicates that potential mismodeling influencing the geocenter estimation might occur in connection with radiation pressure, especially when the satellites are located in the shadow. Regulatives as once-per-revolution empirical forces can be used to absorb this error. Applying an empirical force model or not can affect the orbit translation parameter (corresponding to geocenter estimation error) by a few cm up to 10 cm. Once applied, the effect of GPS orbit errors on the geocenter estimation is at a few mm level. The following is a typical example. Data of Oct. 24-26, 1995 were used to form two 2-day arcs. The empirical force model was utilized in these two solutions. Table 1 gives the overlap orbit differences.

Table 1. The overlap differences of two adjacent orbits.

Translation in x, y, z (m):	.006	-.001	.007
scale (10-8):	-.03		
Rotation (x,y,z) (mas):	.0	.1	.1
Overall rms difference (cm):	8		

RMS per Satellite (cm)

sat	1	2	4	5	6	7	9	12	14	15	16	17	18
RMS	7	14	9	7	7	9	8	12	7	7	7	8	11

sat	19	20	21	22	23	24	25	26	27	28	29	31
RMS	5	4	7	5	8	7	4	8	5	6	9	5

(b). *Inaccuracy of station coordinates.* The estimated geocenter (gc) position is the actual gc position plus the common (mean weight) correction of the station coordinates. Assuming the models and observations being without errors and the approximate coordinates having inaccuracies dX, their influence on gc is

$$dGC = F\,(dX_j, j = 1, \ldots, n) = \Sigma\,(p_j * dX_j)$$

with p acting as a weight factor. If the station combination and geometry do not change, dGC will be more or less constant. Its effect on the gc variation estimation is negligible. Actually, the station combination and with this the geometry change from time to time. In order to reduce this effect on gc, one should try to keep dX as small as possible. An error in the a-priori values of station velocity has a similar effect.

3. RESULTS AND DISCUSSION

Fig. 1 shows the time series of our solved geocenter variation from the two-step approach. Besides the annual and semi-annual periods, the spectral analysis given in Fig. 2 displays other periodicities. Peaks are visible at periods of about 140 days, 60-70 days, 20 days and 14 days. We solved the annual and semi-annual terms together with the linear trend (and constant term) from the series in Fig. 1. The results are given in Table 2. The second line for each component indicates the sigma of the corresponding solution. The amplitudes of both the annual and semi-annual terms are for all components at a few mm level. The sigmas of the amplitudes are around 1 mm. The phase results are, however, less reliable. The daily x and y geocenter components are estimated with a repeatability of better than 1.5 cm, for the z-component with better than 1.8 cm.

Using other techniques such as satellite laser ranging, the geocenter can be estimated with better repeatability, but those are 12-days or even monthly solutions. If we convert our solution into 12-days or monthly values, the repeatability is also at the few mm level. On the other hand, daily solutions are preferable because they contain more high-frequency information (e.g., 14-day period variations). GPS is presently the most suitable technique for daily geocenter estimations.

Comparing with the sigma, the trends in X and Y direction are significant. But bearing in mind that the data span used is less than two years, to distinguish the possible quasi long period terms (periods of at least several years) from linear trends is a question too intricate, although it is obvious that such trend and/or quasi-long period terms exist.

Table 2. Amplitude and phase of annual and semi-annual terms (phases in degree, amplitude in cm).

	rms	const	trend	amp (annu)	pha (annu)	amp (semi)	pha (semi)
X:	1.47	-0.226	-1.286	0.430	34.8	0.274	237.5
		0.070	0.138	0.092	12.0	0.088	18.8
Y:	1.39	1.684	-2.536	0.917	186.5	0.475	21.2
		0.066	0.130	0.088	5.2	0.085	10.0
Z:	1.80	-0.880	0.164	0.676	210.3	0.522	85.1
		0.086	0.169	0.113	9.3	0.107	12.2

Series of station positions are generated as by-products. The comparison of our station coordinates with ITRF96 at epoch 1996.0 is given in Table 3. The difference in height is larger than for the horizontal components, possibly because of incorrect information on the antenna height at some stations.

Table 3. Difference between ITRF 96 and GFZ_GC solution for common GPS Stations.

	H	N	E	DP	DX	DY	DZ
RMS [mm]	**9.7**	**3.8**	**3.8**	**11.1**	**6.4**	**6.7**	**6.1**

mean RMS = 6.6 mm

Helmert transformation parameters

dx=	.0028 m	± .0015 m
dy=	-.0044 m	± .0015 m
dz=	.0042 m	± .0014 m
scale:	-.0033 D-06	± .0002 D-06
rotz =	.00025 arcsec	± .00005
roty =	-.00105 arcsec	± .00006
rotx =	-.00030 arcsec	± .00006

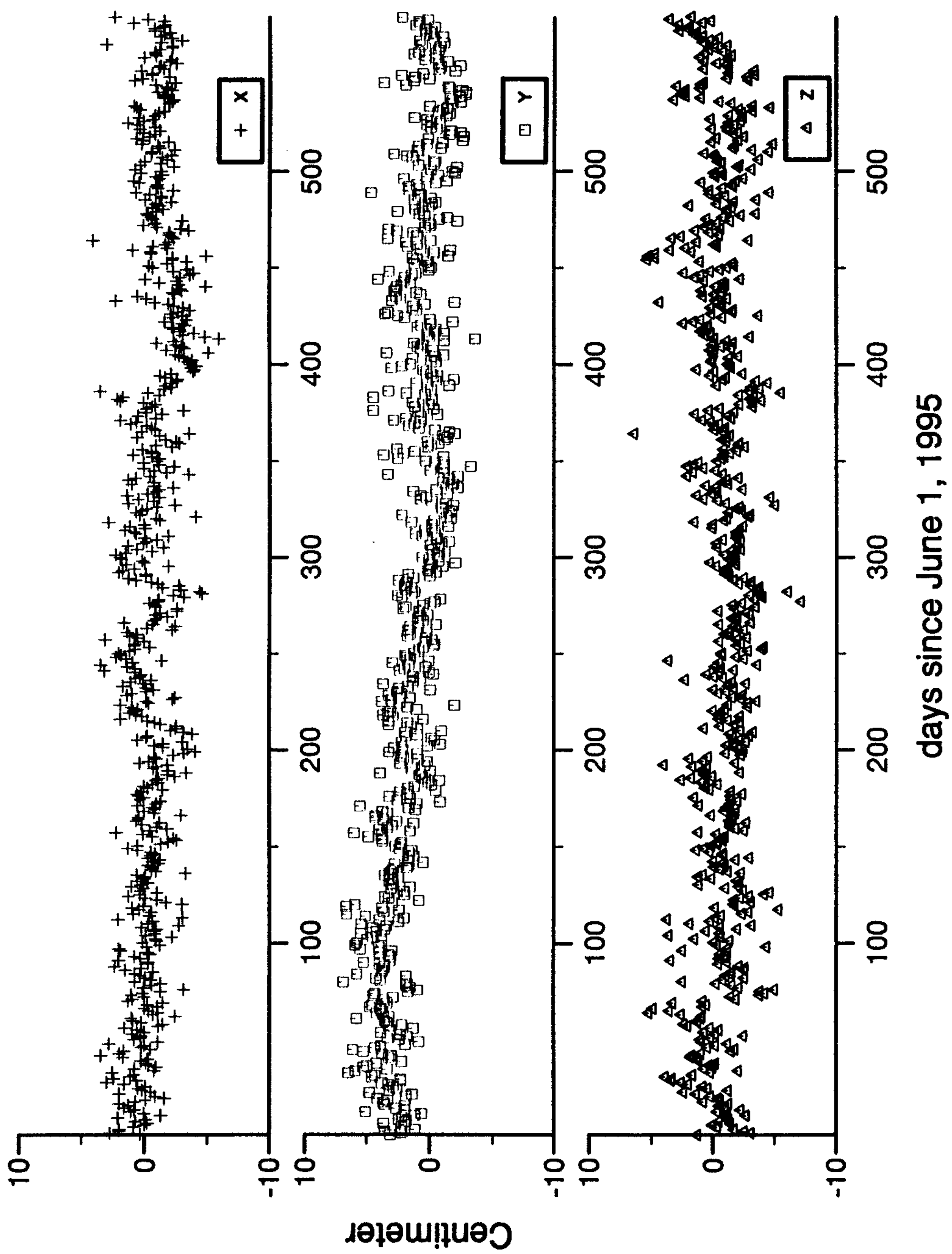

Fig.1 Daily geocenter variations

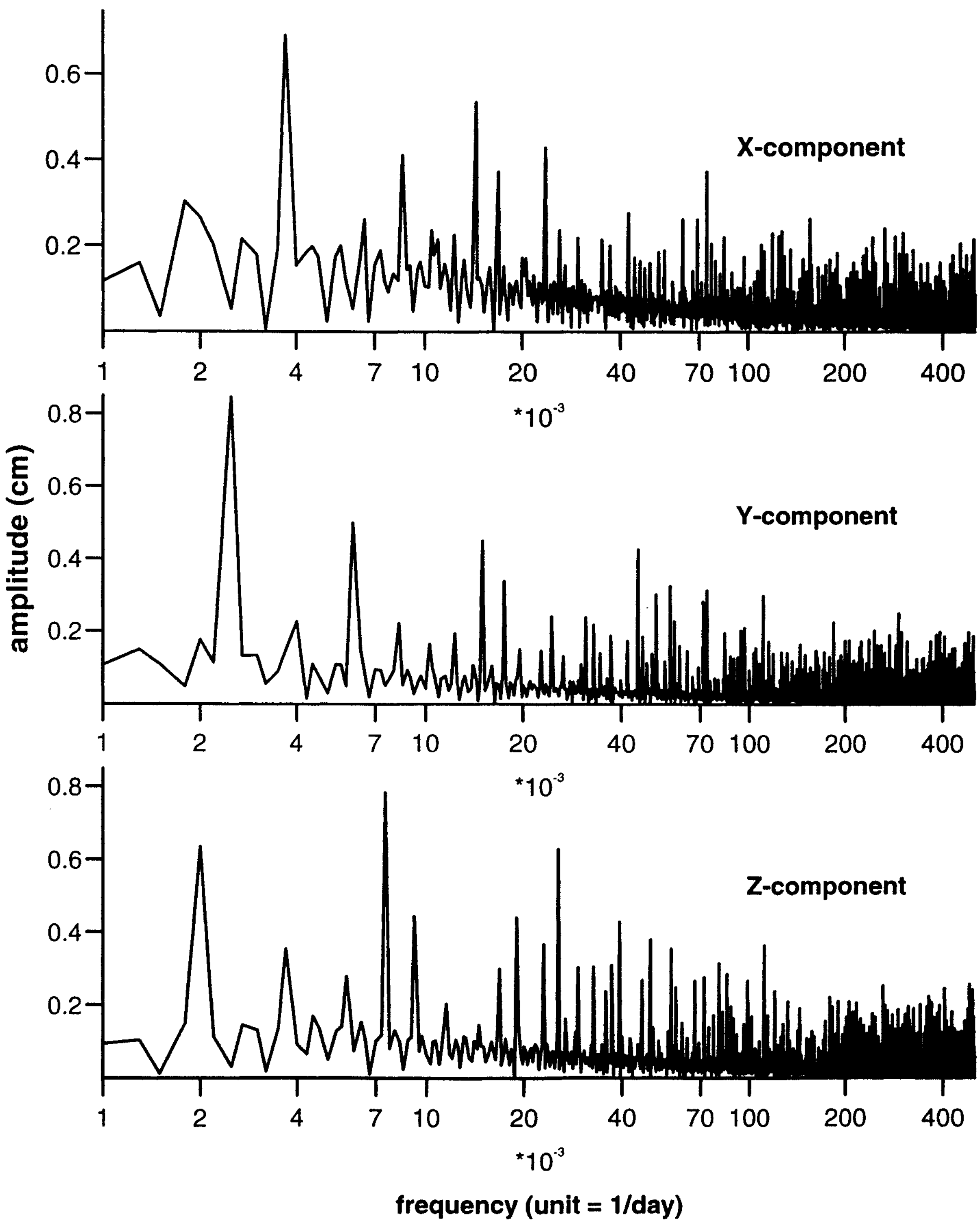

Fig.2 Spectrum of geocenter variations