Geocenter Coordinates and Subdaily Polar Motion Estimated From a Multi-GNSS Data Analysis

International GNSS Service
Workshop 2012
July 23-27, 2012, Olsztyn (Poland)

M. Meindl[1], R. Dach[1], D. Thaller[1], S. Schaer[2], G. Beutler[1], A. Jaeggi[1]
[1] Astronomical Institute, University of Bern, Bern, Switzerland
[2] Federal Office of Topography swisstopo, Wabern, Switzerland

Introduction

We have computed high-quality GPS-only, GLONASS-only, and combined GPS/GLONASS solutions. All our experiments are based on observation data from a network of 92 globally distributed GPS/GLONASS-combined tracking stations. The data was continuously recorded for the years 2008 through 2011.

GNSS-specific artifacts are present in the geocenter as well as polar motion time-series. The artifacts can be explained by perturbation theory.

Artifacts in the Time-Series

Geocenter coordinates

Figure 1 (top) shows the components of the estimated geocenter coordinates (GCC) for 2008-2011. The GCC X- and Y-coordinates of the GPS- and GLONASS-only solutions are highly correlated. The combined solution is very close to the GPS-only solution. The GLONASS-derived GCC Z-coordinates, however, are much larger (peak-to-peak variations of about 30 cm) than those emerging from GPS.

The middle and the bottom row of Fig. 1 show the GPS- and GLONASS-only results (blue) together with the elevation β_0 (green) of the Sun above the single orbital planes. There is an eye-catching correlation between the large excursions of the GLONASS-only geocenter Z-component and the maximum values of β_0.

This is a strong indication that these extreme excursions are artifacts and caused by the correlation of the geocenter Z-coordinate and one or a linear combination of orbit parameters.

Polar motion

Figure 3 shows the amplitude spectra of GPS- and GLONASS-derived subdaily (1.5h resol.) polar motion time-series (in red and blue). The comparison reveals GNSS-specific spectral lines. Lines which are not common to both systems are most probably artifacts.

Explanation of GNSS-specific Artifacts

When interested in the correlations between GCC Z-coordinates/polar motion and orbit parameters, one has to study only the impact of a force perpendicular to the orbital plane (W-direction). Other components can not affect the orbital plane (i.e., the elements i, Ω, and ω). In order to further simplify the problem we assume circular orbits. The perturbation equations give the effect of a force in W-direction as

$$\Delta i = \frac{W}{n^2 a}\sin u,\ \Delta\Omega = \frac{W}{n^2 a \sin i}(\cos u - 1),\ \Delta u = \frac{W}{n^2 a \tan i}(\cos u - 1)$$

Geocenter coordinates

These perturbations of the orbital elements imply that all the satellites seemingly move on orbits which are parallel shifted by W/n^2. The most important part of the empirical orbit model causing a force in W-direction is the direct radiation pressure D_0 (W=D_0sin ß).

The correlation of the GCC Z-coordinate and the direct solar radiation pressure parameter for all $k = 1,\dots, n_p$ orbital planes is given by

$$\delta Z = \frac{1}{n^2 \cos i} \cdot \sum_{k=1}^{n_p} D_k \sin\beta_k$$

where D_k and β_k are mean values over all satellites of the particular orbital plane k.

We have estimated D_0 parameters from two solutions: one with estimated GCC and one without. The GCC Z-coordinate can be reconstructed from the difference of the two sets of D_0 using the above equation. Figure 2 shows the estimated (blue) and the reconstructed (red) GCC Z-coordinate: The curves coincide to a very high degree for both GNSS.

The geocenter Z-coordinate obviously compensates the orbit shift caused by an additional D_0-component of the radiation pressure model.

Polar Motion

The orbit perturbations Δi, $\Delta\Omega$, and Δu are simple trigonometric functions of the argument of latitude u and multiples thereof. They cause errors in the inertial reference frame as realized by the satellites.

The relation between a perturbed and an unperturbed orbit is given by three rotations

$$\begin{aligned} r'(t) = {} & R_3(-\Delta u \cos i - \Delta\Omega) \\ & R_2(-\Delta i \sin\Omega + \Delta u \sin i \cos\Omega) \\ & R_1(-\Delta i \cos\Omega - \Delta u \sin i \sin\Omega)\, r(t) \end{aligned}$$

The rotation angles contain terms sin u and cos u. They may be interpreted as superposition of pro-/retrograde circular motions which translate into spectral lines in polar motion as

$$x = \rho\cos(\Theta + mu),\ y = \rho\sin(\Theta + mu)$$

Figures 4 and 5 show the polar motion spectra for GPS and GLONASS solutions together with spectral lines computed from the above equation (using the mean motion of the satellites and various factors m). The predicted lines match the observed lines very well. These GNSS-specific lines (basic period is revolution period) are artifacts caused by the estimation of D_0.

Conclusions

The direct radiation pressure causes perturbations in the orbital elements. The perturbations in i, Ω and u change the orientation of the orbital planes. The correlation between the D_0 parameters and these orbital elements is the reason for GNSS-specific artifacts in the GCC Z-coordinate (30 cm for GLONASS!) as well as spurious periods in subdaily polar motion time-series.

As long as direct radiation pressure parameters must be estimated in the GNSS analysis, there is no possibility to get rid of these GNSS-specific errors. Even updated radiation pressure models will not solve this problem as long as they contain D_0-like parameters.

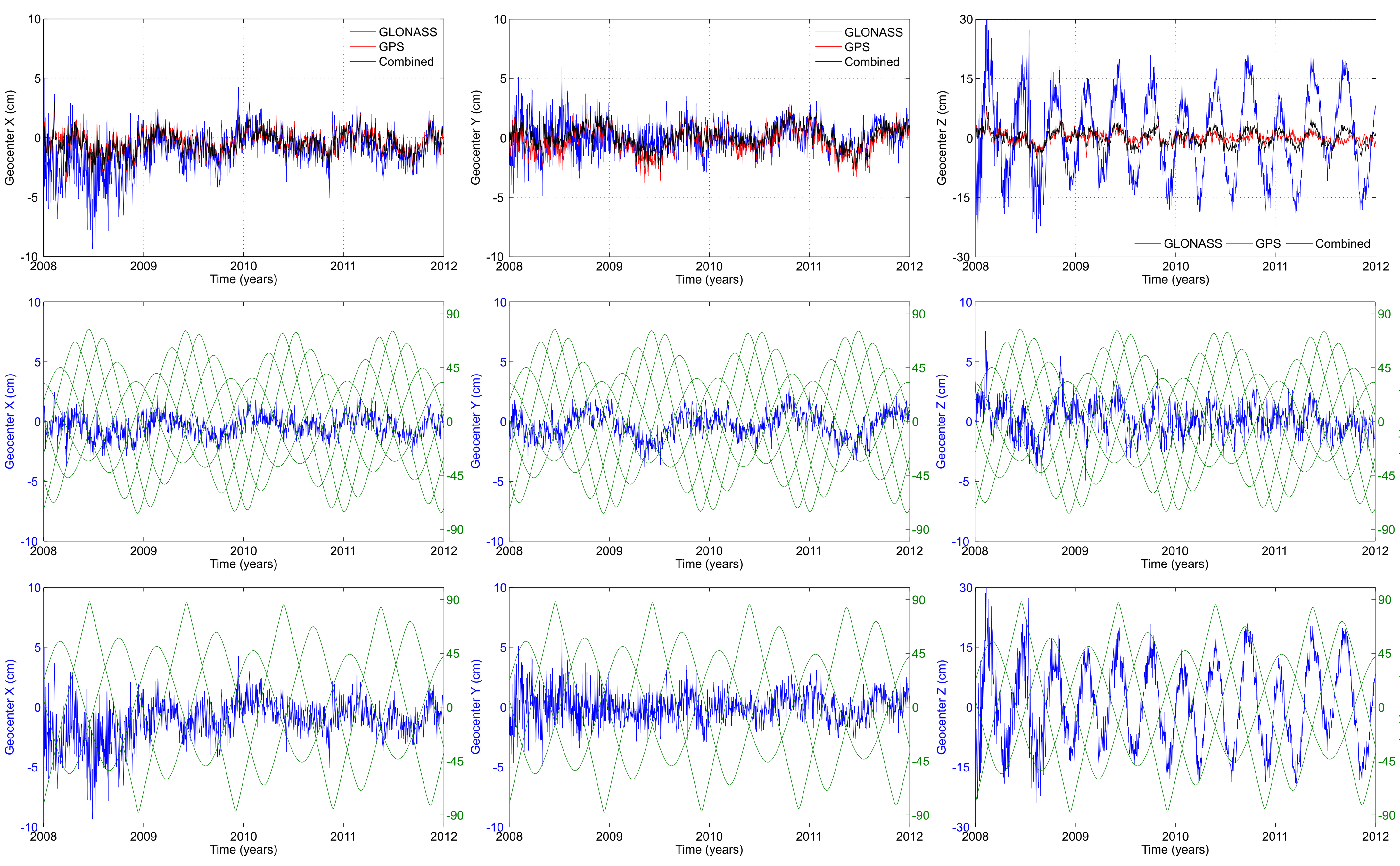

Figure 1: Geocenter X- (left), Y- (center), and Z-coordinates (right).
Top Comparison of GPS-only (red), GLONASS-only (blue), and combination (black).
Middle GPS-only geocenter coordinates and elevation β_0 of the Sun above orbital planes.
Bottom GLONASS-only geocenter coordinates and elevation β_0 of the Sun above orbital planes.

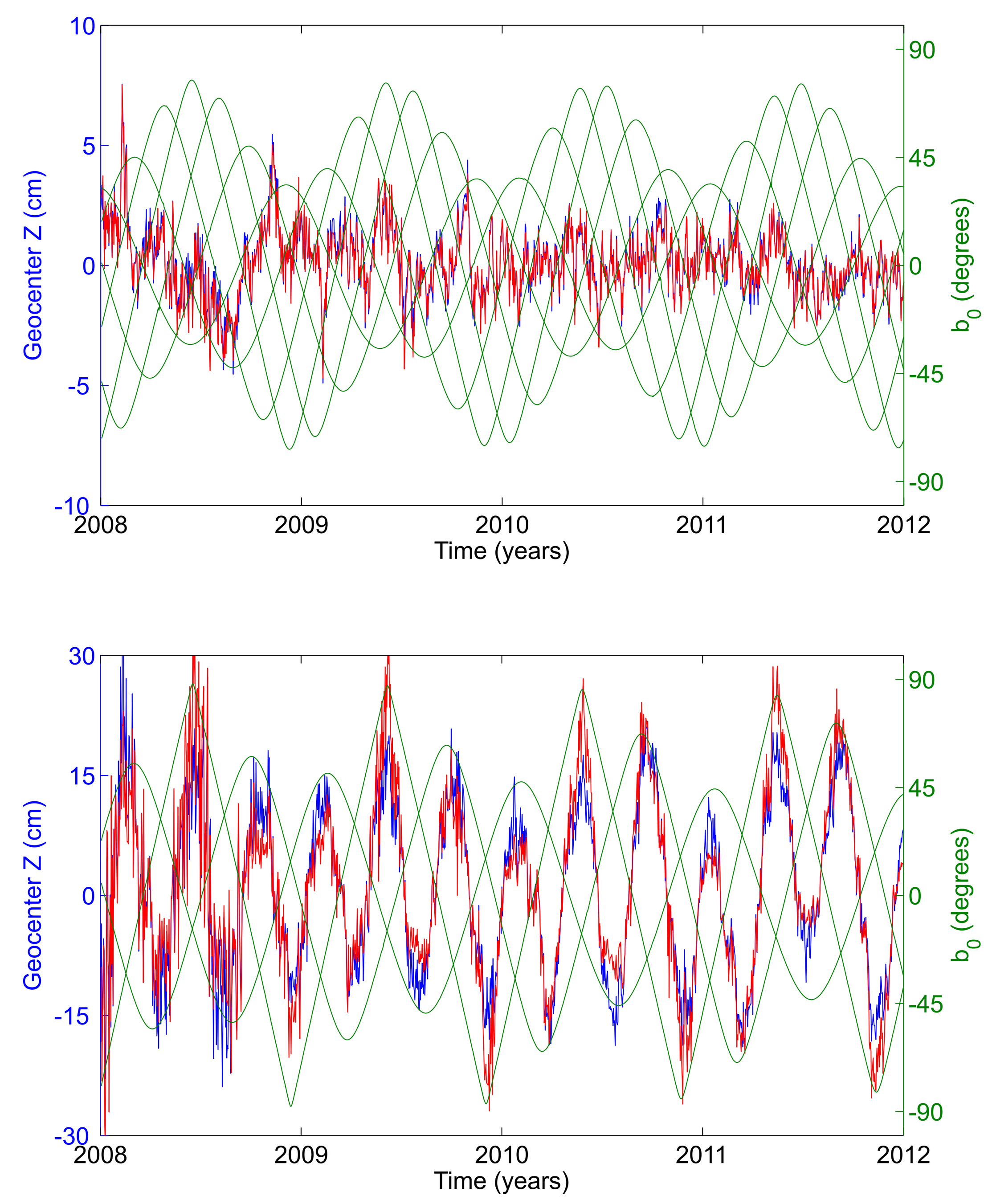

Figure 2: Estimated (blue) and reconstructed (red) geocenter Z-coordinate.
Top GPS
Bottom GLONASS

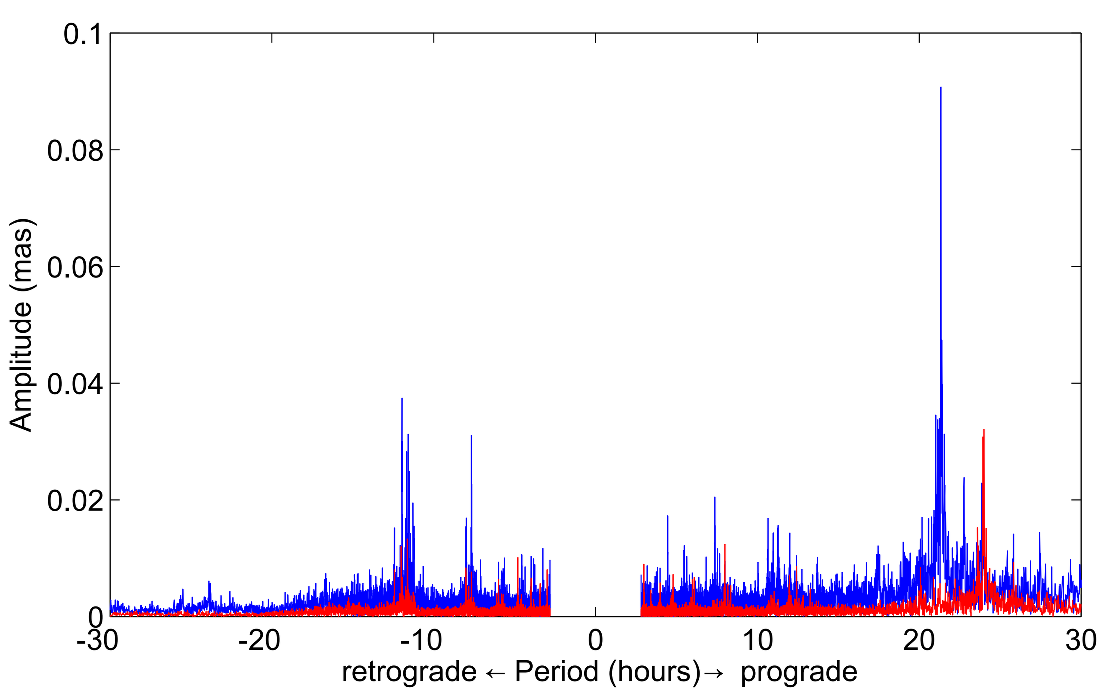

Figure 3: Spectrum of subdaily polar motion
red: GPS, blue: GLONASS

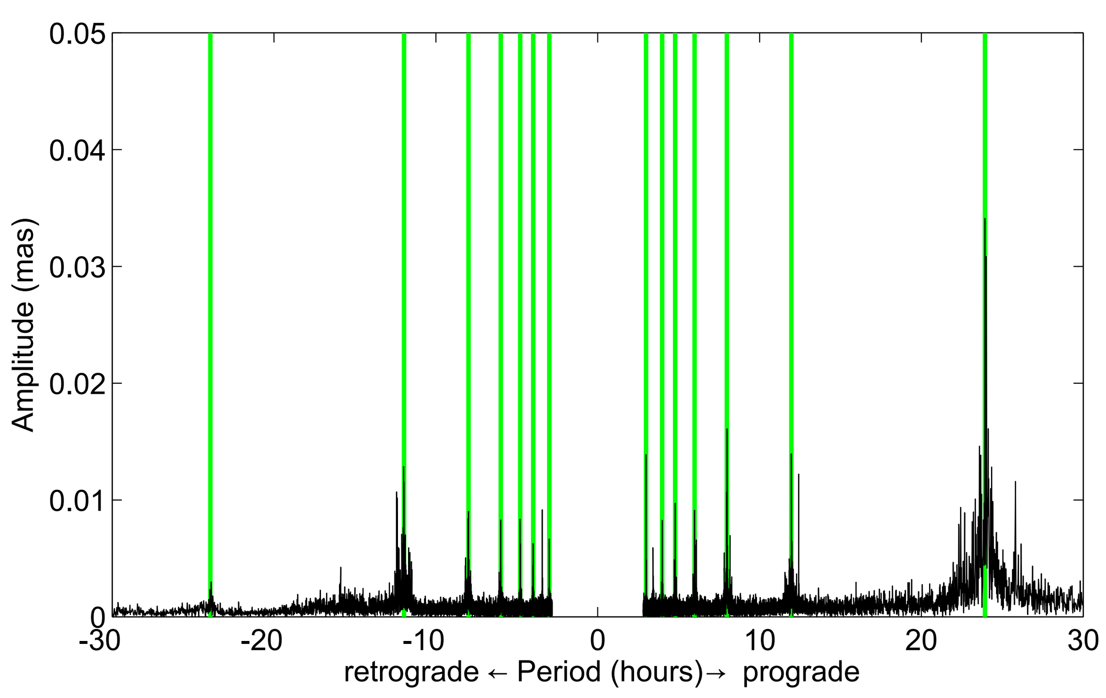

Figure 4: Spectrum of subdaily polar motion, GPS
green: predicted periods

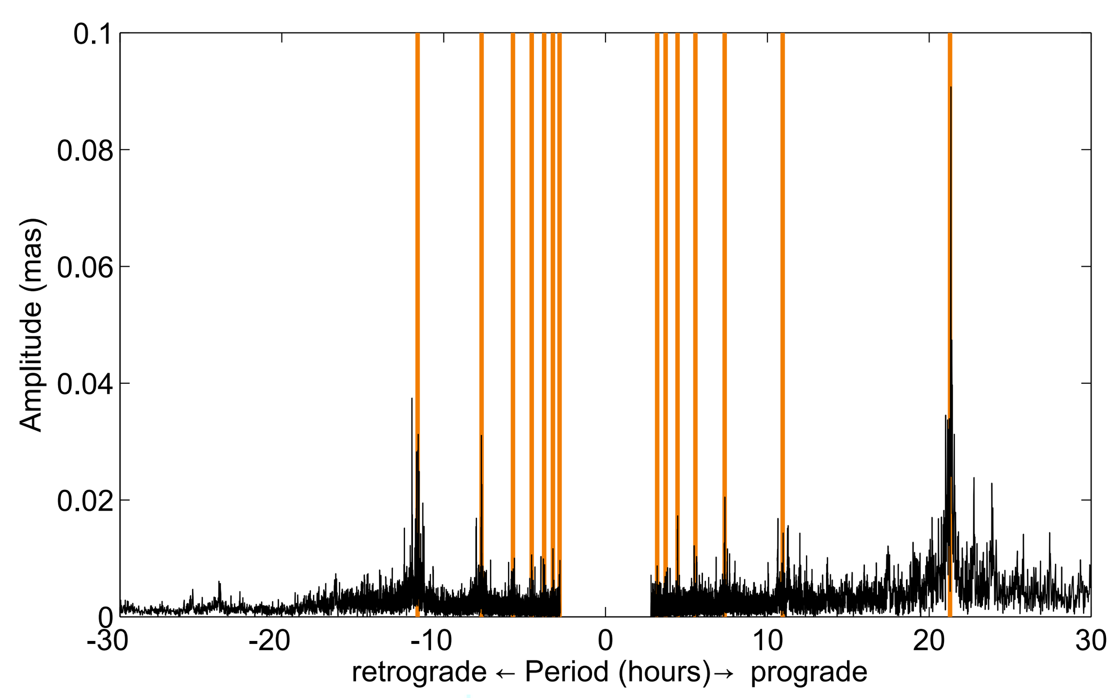

Figure 5: Spectrum of subdaily polar motion, GLONASS
orange: predicted periods

AIUB
Poster compiled by M. Meindl, June 2012
Astronomical Institute, University of Bern, Bern
michael.meindl@aiub.unibe.ch