Determining sub-daily ERPs using GNSS

Michael Meindl[1], Gerhard Beutler[2], Rolf Dach[2], Markus Rothacher[1]

[1] Department of Civil, Environmental and Geomatic Engineering, ETH Zurich, Switzerland
[2] Astronomical Institute, University of Bern, Switzerland

Subdaily polar motion

- Polar motion (PM) with two or more parameters of each type (*x*, *y*, UT1-UTC) per day is called subdaily.
- Subdaily PM parameters are highly correlated with the orbit parameters Ω (RA of ascending node) and *i* (inclination).
- As opposed to constraining retrograde diurnal circular polar motion to zero in the parameter estimation, we estimated PM without any constraints (free solutions) and deal with these correlation effects a posteriori.
- Unconstrained PM time series (resolution of 1.5 h) have been generated for 2008−2011 based on a global GNSS network.

Unconstrained subdaily PM and nutation

- The transformation between the Earth-fixed and quasi-inertial system is defined by the five angles *x*, *y*, sidereal time *Θ* (UT1-UTC), and the nutation angles *ξ* and *η*, whereas only three would be needed.
- In case of high-resolution PM one may therefore either solve for *x*, *y* or *ξ*, *η*. The two parameterizations are connected by:

$$\begin{aligned} \xi &= +x\ \cos\Theta + y\ \sin\Theta \\ \eta &= -x\ \sin\Theta + y\ \cos\Theta \end{aligned} \quad \text{and} \quad \begin{aligned} x &= \xi\ \cos\Theta - \eta\ \sin\Theta \\ y &= \xi\ \sin\Theta + \eta\ \cos\Theta \end{aligned}$$

- The subdaily PM part is extracted by subtracting the (interpolated) daily PM values from the 1.5 h high-resolution series.
- Figure 1 shows these differences for 10 days in the Earth-fixed (left) as well as in the inertial system (right) for GPS (top) and GLONASS (bottom).

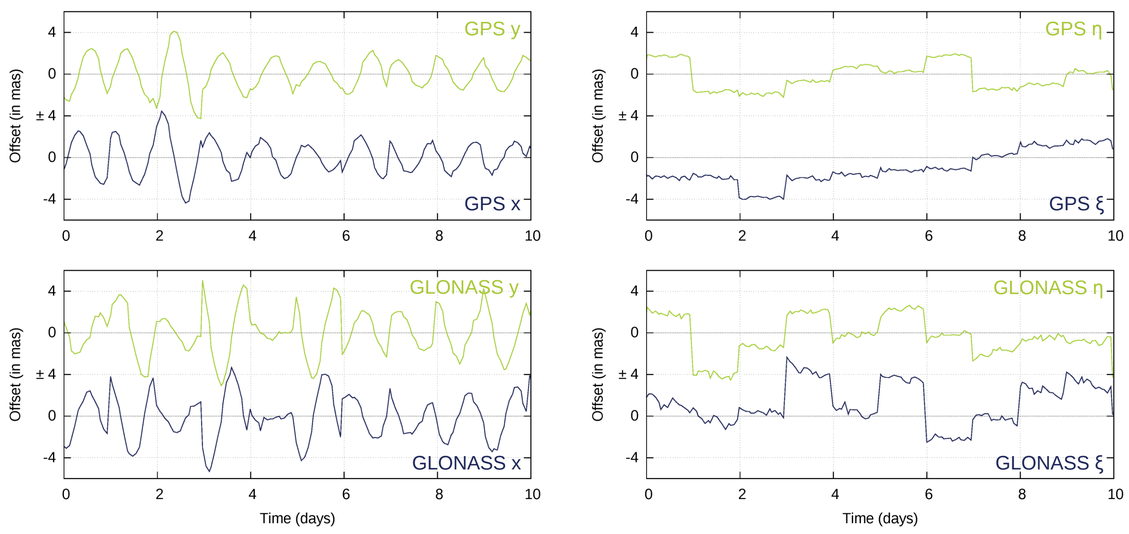

Fig. 1 Subdaily PM from GPS (top) and GLONASS (bottom) in the Earth-fixed (left) and inertial system (right) for 2010/001−010.

- The figures on the left nicely show the well-known retrograde daily circles of the pole (with radii of a few mas).
- The nutation parameters (right) are almost constant over one day for GPS. Significant rates occur for GLONASS.

References / scientific heritage

- Rothacher M (1998): *Recent contributions of GPS to Earth Rotation and Reference Frames*. Habilitationsschrift, Phil.-nat Fakultät Universität Bern.
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- Hefty J, Rothacher M, Springer TA, Weber R, Beutler G (2000): *Analysis of the first year of Earth rotation parameters with a sub-daily time resolution gained at the CODE processing center of the IGS*. J Geod 74:479−487.
- Rothacher M, Beutler G, Weber R, Hefty J (2001): *High-frequency variations in Earth rotation from Global Positioning System data*. J Geophys Res 106: 13711−13738.

Retro- and prograde PM spectra

- The subdaily PM series are de-correlated a posteriori by subtracting the best-fitting diurnal circular motion from the original high-resolution series.
- The circle is estimated from the *x* and *y* pole offsets using:

$$x = (\rho + \dot{\rho})\ \cos(\omega t + \phi) \quad \text{and} \quad y = (\rho + \dot{\rho})\ \sin(\omega t + \phi)$$

- Not only the circle radius ρ but also the rate $\dot{\rho}$ of the radius can be estimated from the PM for the de-correlation process.
- Figure 2 shows the impact of de-correlating with an estimated radius (left) and with an additional radius rate (right) for GPS and GLONASS.

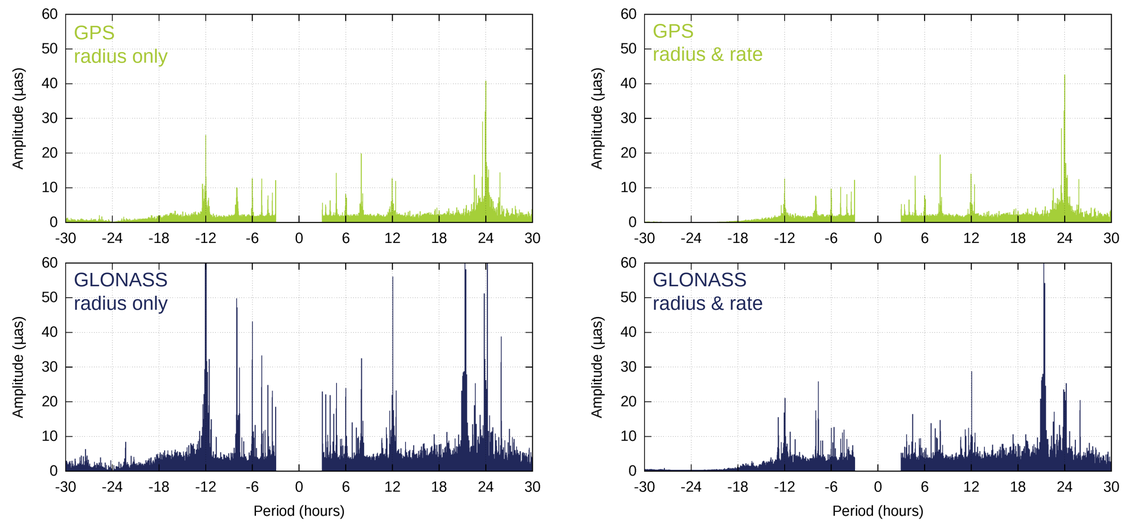

Fig. 2 Retro- and prograde spectra of subdaily PM (2009−2011) for GPS (top) and GLONASS (bottom): constant radius (left), radius and rate (right).

- The GLONASS spectrum on the left (radius-only) shows a series of spectral lines with linearly decreasing amplitudes at harmonics of 24 hours (typical for a saw tooth function with daily period). The de-correlation with an additional rate (right) removes these lines.
- GLONASS shows a spectral line at +21 hours which may be attributed to once-per-revolution perturbations in the orbit.

Orbits estimated with free subdaily PM

- Figure 3 compares two orbits in the Earth-fixed system
  - one orbit estimated together with 2 PM parameters per component and day (approach of IGS)
  - the other with subdaily PM (17 parameters per component and day, i. e. with a resolution of 1.5 h).
- The RMS of the 3-D position differences of all GPS satellites at the start, center and end of each orbital arc are on the level of a few centimeters.
- The RMS of a Helmert transformation (3 rotations and their rates) is around 2 cm. The estimated rotations are only a few µas (< 1 mm at the orbital height).
- The orbits are not sensitive to the resolution of the polar motion parameters if compared in an Earth-fixed system.

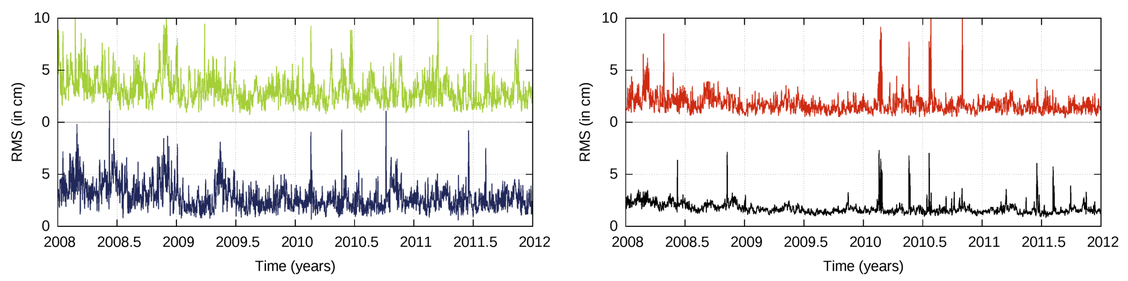

Fig. 3 Comparison (in Earth-fixed system) of orbits estimated with daily and sub-daily PM. RMS w.r.t. start (green), center (red) and end (blue) of each orbital arc. RMS of Helmert transformation (black).

michael.meindl@ethz.ch
Mathematical and Physical Geodesy
ETH Zurich, Switzerland