Subdaily Earth rotation model and GPS solutions

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Introduction

Short-period variations in Earth rotation are caused by ocean tides, direct gravitational torques from Sun and Moon, atmospheric tides and non-tidal atmospheric and oceanic effects. In processing of geodetic observations these variations are taken into account by an a priori subdaily model for the Earth rotation parameters (ERPs) containing terms in polar motion (PM) and Universal Time (UT1) on tidal frequencies. Different models can be used in processing: there is the standard subdaily model recommended by the International Earth Rotation Service (IERS) which may be additionally changed if libration terms are taken into account, and there is a number of empirical models which can be found in literature. The choice of a subdaily model used in processing influences the obtained solutions systematically, time series of parameter differences between solutions computed with different subdaily ERPs models show periodic signals with the periods close to the aliased tidal term periods.
In this study we present a mechanism how errors of the subdaily tidal model are propagated into the GPS solution.

Data

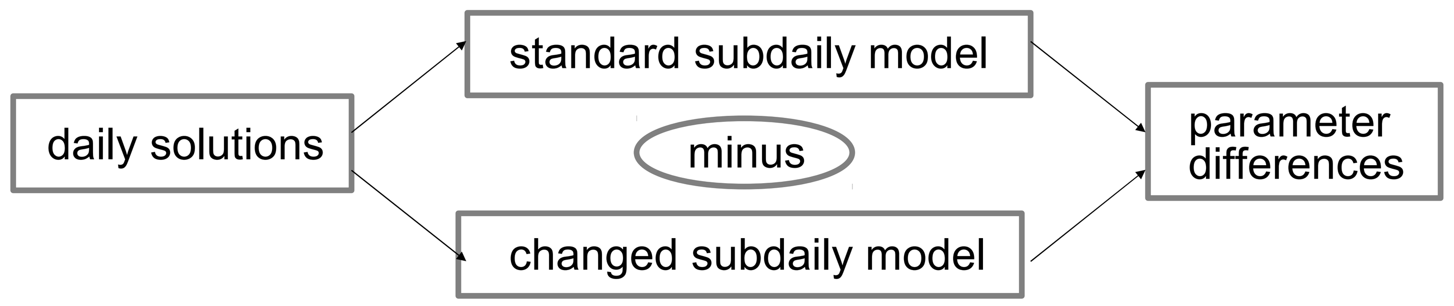
Free daily normal equations obtained within GGOS-D project were used.
Covered time span: 19994—2007
Explicitly present parameters: station coordinates, GPS orbits, ERPs with 1 hour resolution

Procedure

To see the effect of individual tidal terms on the GPS solution, we computed daily solutions with the standard subdaily ERP model (IERS2010) and with the same model where the amplitude of one tidal term was changed by 100 µas. Only a change in polar motion (PM) was considered here. Then the time series of parameter differences are considered.

The procedure of obtaining GPS solutions with a changed subdaily model is the following:

- 1-hour ERPs are transformed into tidal terms
- a priori values of one selected tidal term are changed by 100 µas
- amplitudes of all tidal terms are fixed to their a priori values
- GPS solution is computed where station coordinates, GPS orbits and ERPs are estimated daily



The parameter differences considered here:
1) Helmert transformation parameters between GPS orbits computed with the standard subdaily model and with a changed subdaily model to see the effect of the subdaily model on the reference frame realized by the GPS orbits
2) 24-hours Earth rotation parameters

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Error propagation: subdaily model ⟷ GPS solution

Change in ampitude of one tidal term in the subdaily model leads to a change in the a priori ERPs, this ERP change can be seen as a wave with the period of the changed tidal term. We consider here only a change in polar motion.

The additional subdaily wave in the a priori polar motion can be absorbed by the estimated parameters. To see which parameters and to which extent are absorbing the change in the a priori polar motion, we represent the wave in the ERPs by the following model:

subdaily wave in PM = prograde daily term + retrograde daily term + linear trend in x- and y-pole

Where:
- prograde daily term reflects a translation of the orbital plane for each GPS satellite (needs some constraints)
- (fictive) retrograde daily term reflects a rotation of the orbital plane
- linear trend in x- and y-pole reflects offset and rate differences between solutions with different subdaily models

Rotations of the GPS orbits

There are systematic rotations in x- and y-directions between GPS orbits computed with the standard and the changed subdaily models, what can be seen in the time series of computed Helmert rotations (see Fig.1). Orientation of the orbital plane in the inertial space is defined by nutation, which was kept fixed in the processing. Observed rotations of the GPS orbits caused by a change in the subdaily model can be explained if a part of the prograde signal contained in the subdaily model is mistaken for a retrograde diurnal signal. This is possible for a 1- day solution due to too short time span.

In figures 1 and 2 we show the agreement between the retrograde daily term in modeled subdaily ERPs and rotations of the GPS orbits. Fig. 1 shows the case where S1 term in polar motion was changed by 100 µas, fig.2 shows the case where O1 term (25.2h) in polar motion was changed by 100 µas.

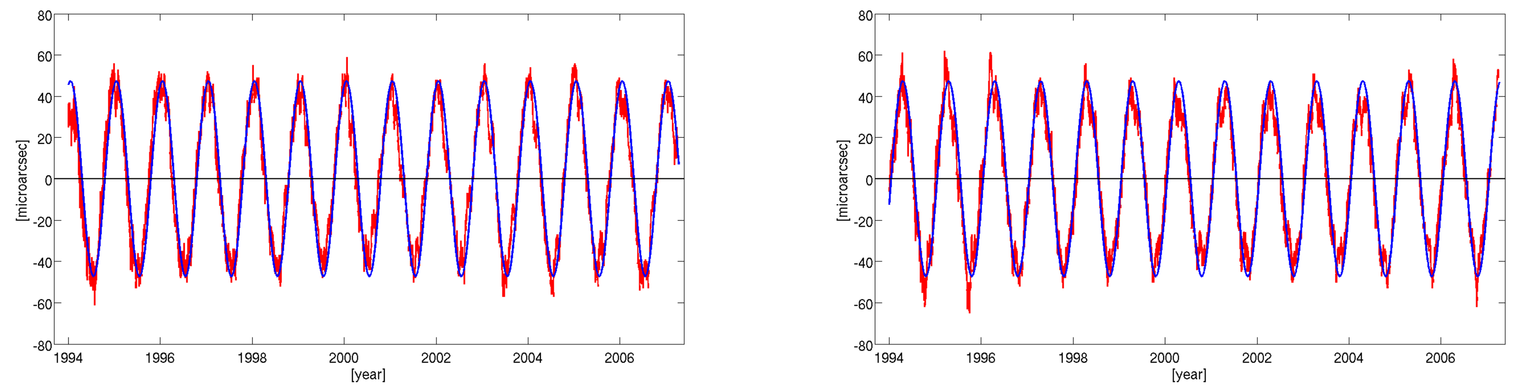

Fig. 1. Retrograde diurnal term (blue) and Helmert rotations (red) between GPS orbits computed with the standard subdaily model and with a subdaily model where S1 (24h) term in polar motion was changed by 100 µas.

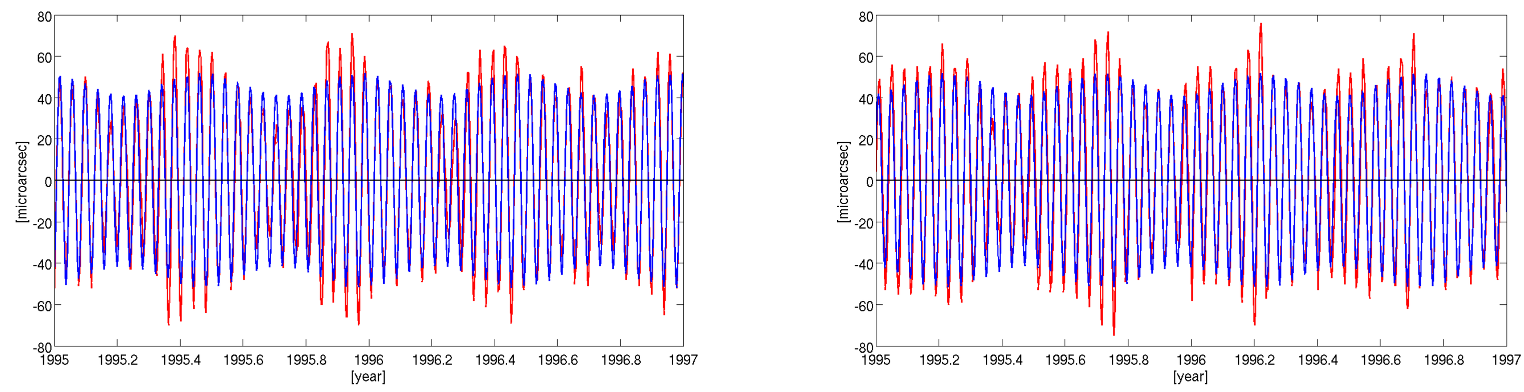

Fig. 2. Retrograde diurnal term (blue) and Helmert rotations (red) between GPS orbits computed with the standard subdaily model and with a subdaily model where O1 (25.2h) term in polar motion was changed by 100 µas.

Differences in polar motion offset and rate

A change in the subdaily ERP model influences the estimated daily ERPs , especially affected are the estimated rates. In figures 3-6 we present a comparison of the estimated from GPS polar motion differences and the linear trend estimated by the least squares adjustment from the modeled subdaily ERPs computed for the changed tidal term. The tidal terms changed in the subdaily model are S1 (24h) (fig.3-4) and O1 (25.2h) (fig.5-6). As can be seen, the rates agree very well, but the offsets agree only for y-pole and noticeably disagree for x-pole, what requires additional investigation.

Fig. 3. pole offset differences, S1 (24h) term changed, x-pole (left), y-pole (right): GPS solution (red), subdaily ERP model (blue).

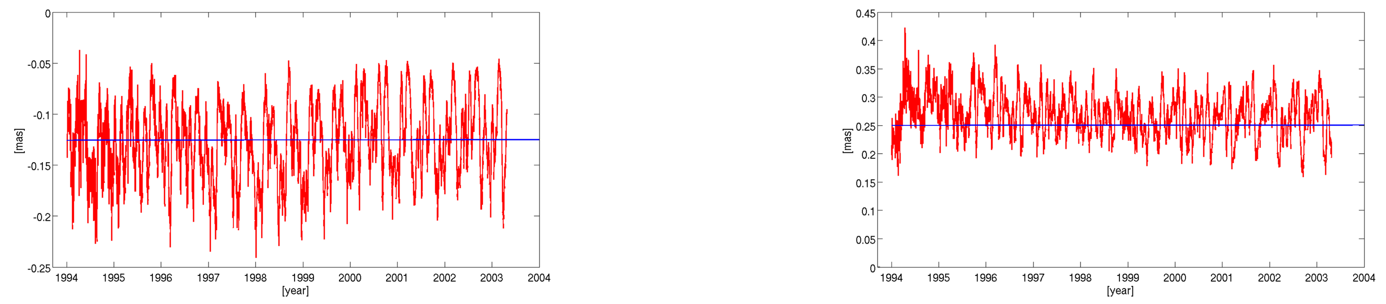

Fig. 4. pole rate differences, S1 (24h) term changed, x-pole (left), y-pole (right): GPS solution (red), subdaily ERP model (blue).

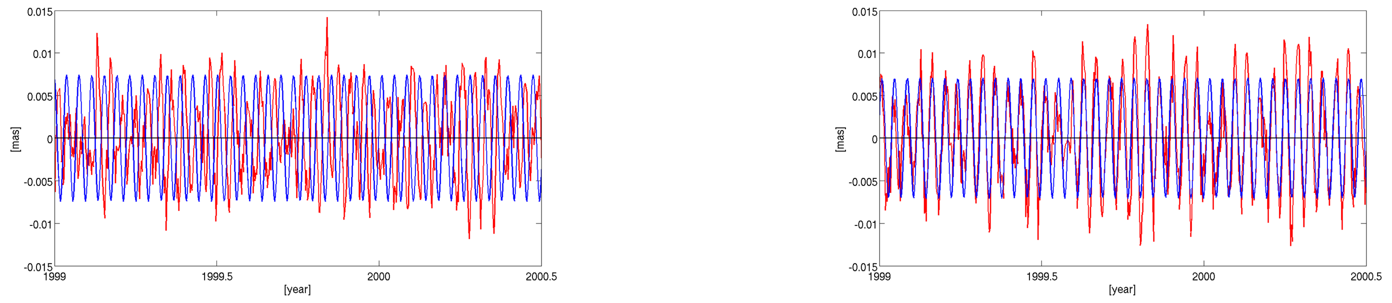

Fig. 5. pole offset differences, O1 (25.2h) term changed, x-pole (left), y-pole (right): GPS solution (red), subdaily ERP model (blue).

Fig. 6. pole rate differences, O1 (25.2h) term changed, x-pole (left), y-pole (right): GPS solution (red), subdaily ERP model (blue).

Conclusions

For a 1-day GPS solution the change in the a priori polar motion caused by a change in the a priori subdaily ERP model can be represented as a sum of prograde daily term, retrograde daily term and a linear trend in x- and y-pole. The prograde term corresponds to a translation of the orbital plane for each GPS satellite, the retrograde term corresponds to a nutation and reflects a change in the orientation of the GPS constellation. The retrograde daily term and the Helmert rotations between GPS orbits computed with the standard subdaily model and with a model where one tidal term in polar motion was changed by 100 µas are in a good agreement, what justifies the suggested model.

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