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The influence of GNSS model changes on gravity field recovery using spaceborne GPS

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Abstract

We derive gravity field parameters using a strict two step procedure: In a first step a kinematic trajectory of a LEO (Low Earth Orbiting) satellite is computed using the GPS data from the on-board receiver. In this procedure the orbits and clock corrections of the GPS satellites as well as the Earth orientation parameters are introduced as known (PPP-approach, PPP: Precise Point Positioning).
In the second step this kinematically derived trajectory is represented by a gravitational force model and pseudo-stochastic parameters to compensate for the non-gravitational forces. The gravity field model AIUB-CHAMP01S, based on one year of CHAMP data from 2002/2003, was generated by AIUB using this strict Celestial Mechanics approach.

The GPS satellite orbits and clock corrections, which have been introduced for the generation of the kinematic trajectory of CHAMP, were taken from the official contribution of the CODE (Center for Orbit Determination in Europe) analysis center to the IGS (International GNSS Service) final product line. Since 2003 many improvements have taken place in the GNSS (Global Navigation Satellite System) data processing. There are therefore good reasons to initiate a reprocessing of the GPS data to obtain state-of-the-art GPS satellite orbits and clock corrections as input for the kinematic POD (Precise Orbit Determination) of the LEOs for that time.
From this newly generated GPS products new kinematic trajectories of the CHAMP satellite are derived for the same time interval covered by the gravity field model AIUB-CHAMP01S. From the updated LEO trajectories gravity field parameters are determined in exactly the same way as for the original LEO orbits. This allows us to study the impact of the new LEO orbits on the derived gravity field parameters.

Model changes

Since 2003 numerous improvements in modeling of the GPS observations have been implemented. The most important ones are:

- Absolute instead of relative antenna phase center modeling
- Global pressure/temperature model and global mapping function instead of Niell mapping function
- Updated CODE radiation pressure model
- Center of mass correction and Hardisp interpolation applied to ocean tidal loading

GPS orbit reprocessing

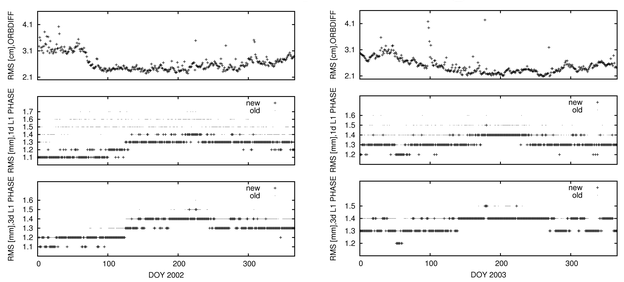

Fig. 1: Comparison between old and new solutions for 2002 and 2003. Top: RMS of orbit difference old and new GPS orbits. Middle / Bottom: comparison of the post fit RMS errors (L1 phase RMS) of the least squares adjustment for 1-day / 3-day solutions.

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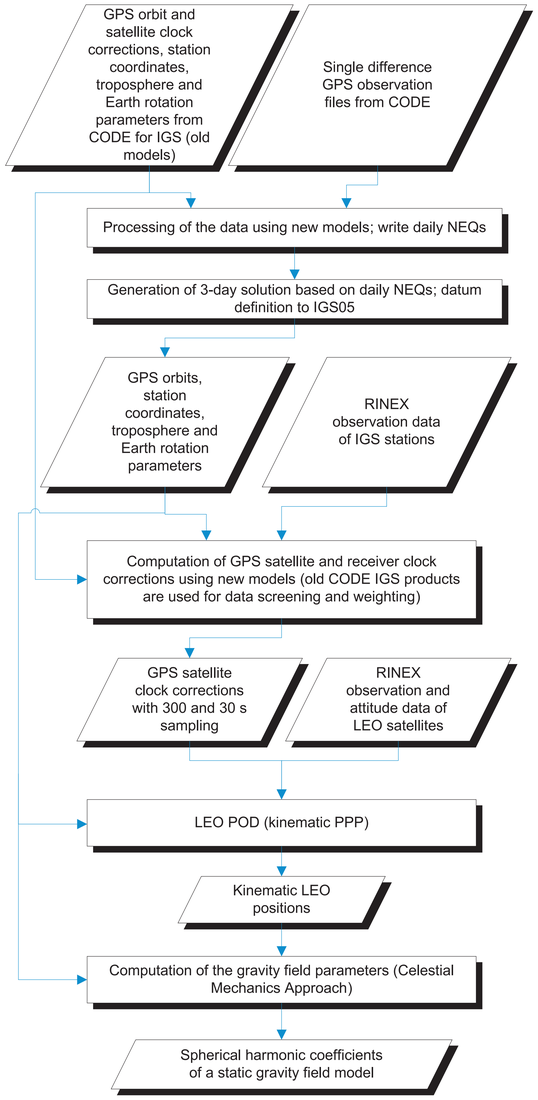
Processing scheme



The orbit reprocessing is a modified excerpt of the processing scheme for the IGS at CODE. In a first step 1-day solutions of the GPS orbits, Earth rotation parameters, troposphere parameters, and station coordinates are computed. In a second step the final solutions are computed from the normal equations (NEQs) of three consecutive days.

=> The post fit RMS error (L1 phase RMS) of the least squares adjustment could be reduced by a significant level (at least 0.1 mm) for 202 days in 2002 and for 147 days in 2003. In the remaining days of the years 2002 and 2003 the RMS error did not change significantly.

GPS clock correction reprocessing

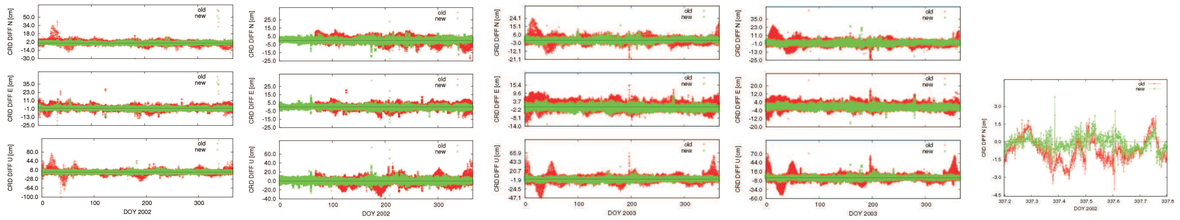


Fig. 2: Differences between PPP derived kinematic coordinates and static coordinates for the IGS station Zimmerwald in the years 2002 and 2003 when using old or new GPS clock corrections. (From left to right: 5 min clock corr. 2002, 30s clock corr. 2002, 5 min clock corr. 2003, 30 s clock corr 2003, zoom in for North component of day 337 in 2002)

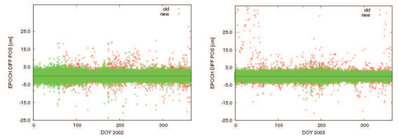


Fig. 3: Epoch to epoch differences of kinematic positions when using old and new 30s GPS satellite clock corrections.

The GPS clock reprocessing is a modified version of the processing scheme, which is used to generate clock corrections at the CODE IGS analysis center with an improved data screening. The computed 5 minute and 30 second GPS satellite clock corrections are validated by performing a kinematic precise point positioning of several static IGS ground stations. The conclusions of the PPP validation are:

- Significant improvement of the PPP accuracy for ground stations (Fig. 2)
- But only slight reduction of high frequency noise for the PPP solutions (Fig. 3)

CHAMP orbit reprocessing

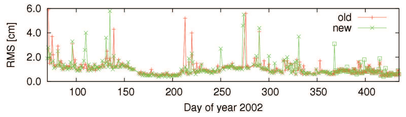


Fig. 4: RMS errors of the difference between kinematic and reduced dynamic orbits for old and reprocessed orbits. There are a few more days with kinematic positions available after the reprocessing. But the additional days usually have only a low number of observations resulting in low quality of the kinematic positions.

The CHAMP kinematic orbits were processed in the same way as the orbits used for the generation of the AIUB-CHAMP01S gravity field model. This time the newly generated GPS satellite orbits and clock corrections as well as the new models were used. The CHAMP orbits have been processed for the same time interval as the old CHAMP orbits (DOY 70, 2002 to DOY 70, 2003).

- Number of processed days within the 1-year time interval: 349 (old) / 354 (new)
- The quality of the old and new kinematic orbits is very similar: the mean RMS error of difference between reduced dynamic and kinematic orbit is 1.39 cm (old) and 1,38 cm (new)

Gravity field reprocessing

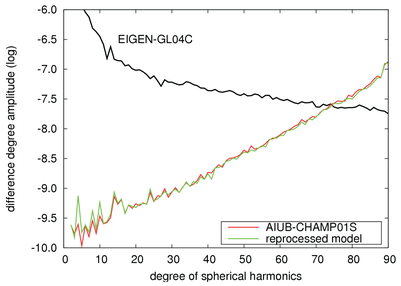


Fig. 5:Comparison of the reprocessed gravity field with the AIUB-CHAMP01S model.

The gravity field coefficients were processed in nearly the same way as the coefficients of the AIUB-CHAMP01S gravity field model using the Celestial Mechanics Approach. Only the screening procedure of the pseudo observations has been simplified. The newly processed and screened CHAMP kinematic orbit positions and the reprocessed Earth rotation parameters were used to generate daily normal equations (NEQs). The NEQs were combined to a 1-year solution.

- The comparison shows that the new gravity field solution is slightly better in the degrees above 30 (Fig. 5)
- The new gravity field model has deficiencies in the degrees below 30
- The a posteriori RMS errors of the solutions are 3.1 mm (old) and 3.5 mm (new)
- The total number of kinematic pseudo observations was 2829705 (old) and 2889288 (new)

Conclusions

- The kinematic PPP of ground stations can profit from the reprocessed GPS orbits and clock corrections (Fig. 2)
- The epoch to epoch noise of a kinematic PPP could not be reduced significantly by the reprocessing (Fig. 3)
- Thus the GPS orbit and clock reprocessing did not improve our gravity field solution significantly (Fig. 5)
- The limited quality of the new gravity field solution in the low degree spherical harmonics will be subject to further investigation (inconsistency?)

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