Dynamical Constraints and Their Impact on the Mean Leveling of GOCE Precise Orbit Determination Results

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Abstract
Reduced dynamic and kinematic orbit determination results for the GOCE mission obtained with the GPS High Precision Orbit Determination Tools (GHOST) are compared with the operational GOCE Precise Science Orbit (PSO) product. Systematic biases of about 3 cm in the antenna offset vector relative to the center-of-gravity (CoG) are identified from the analysis. A CoG mismatch is indicated by comparison with satellite laser ranging (SLR) measurements.

Data Sets
12 days of GPS data collected between 28 March and 8 April 2010 with both the main (front) and redundant (back) antenna (Fig. 1) were provided for the analysis. The original RINEX files were preprocessed to remove discontinuities at data dump boundaries and decimated to 10s intervals. GPS orbit and clock products at 30s intervals were provided by the Center for Orbit Determination in Europe (CODE).

Processing
The PSO is created at AIUB using the Bernese GPS Software [1]. A strongly reduced dynamic model is applied, in which a global set of unconstrained accelerations in radial (R), along-track (T) and cross-track (N) direction is adjusted along with constrained RTN accelerations at 6 min intervals.

The GHOST reduced dynamic orbit determination software [2] employs a priori models for non-gravitational forces (drag (deactivated for GOCE), radiation pressure) and adjusts piecewise constant RTN accelerations at 10 min intervals. Kinematic GHOST orbits are obtained by a precise point positioning technique and do not depend on orbit models.

Positions of the GPS antennas, laser reflector/laser and CoG for the time of interest are based on established GOCE processing standards [3] and are summarized in Table 1.

For the GPS processing, L1 & L2 phase center offsets (PCOs) from the ground calibration [3] are employed along with empirical phase center variations (PCV) for the ionosphere-free L1+L2 combination from an in-flight calibration [4]. The PCVs have been derived by AIUB using a residuals stacking approach and are free of mean PCO shifts. PCV maps for both antennas are shown in Fig. 2.

Orbit Comparison
PSO products for the main antenna and GHOST reduced dynamic orbit solutions exhibit daily rms position differences with a median value of 4.0 cm. Median rms values for the radial, along-track, and cross-track direction amount to 3.0 cm, 2.1 cm, and 1.5 cm, respectively. The radial component is dominated by a mean offset that varies between 2 cm and 3 cm on the various days. The precise science orbits are systematically lower than the GHOST RD orbits (Fig. 4).

The kinematic GHOST orbits exhibit mean radial offsets of ±1 mm with respect to the respective PSO products but are likewise offset from the GHOST RD solutions by 2.4 cm (see Fig. 4).

The results demonstrate that the PSO orbit height is essentially unconstrained due to the free adjustment of a radial acceleration parameter in the Bernese SW [5].

As an alternative to the CoG shift, an empirical acceleration in radial direction might be introduced to achieve a consistent modeling of all observations in the reduced dynamic orbit determination. However, the required value of 140 nm/s² is incompatible with the expected uncertainty of the employed dynamical model.

A comprehensive interagency comparison of GOCE precise orbit products based on different processing strategies is therefore encouraged along with a critical review of manufacturer supplied CoG and sensor coordinates.

References

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