Kinematic versus highly reduced-dynamic LEO orbits for global gravity field recovery

Introduction

We compare different high-low GPS-SST precise orbit determination (POD) methods for Low Earth Orbiters (LEOs) in a simulation study to assess their capability to provide LEO position solutions for a subsequent gravity field recovery (GFR).

Method 1 is an undifferenced GPS phase kinematic POD method [Sveva, 2004]. The LEO positions are derived independently from a priori gravity field information, but they are affected by rather large noise.

Method 2 is a differenced GPS phase reduced-dynamic POD method [Jäggi, 2005]. The LEO positions are less affected by noise, but they depend to some extent on a priori gravity field information.

We show where the trade-off between a desirable noise reduction and an acceptable prior field dependencies can be found for method 2 for the purpose of GFR, and compare the results with those obtained from method 1.

Simulation of CHAMP GPS data: EIGEN-2 [Reigber, 2003] up to deg. 90 served as the a priori gravity field model for Method 2, which is indicated by a vertical line (see also Fig. 4).

GFR with the synthetic CHAMP positions: The synthetic CHAMP positions were computed for the different scenarios defined by Tables 1 and 2. EIGEN-2 truncated at deg. 20, and with slightly erroneous coefficients up to deg. 20 (according to RMS errors provided with the synthetic CHAMP orbit) served as the a priori model for Method 2, which is indicated by a vertical line in the corresponding figures to show the transition.

GFR with the synthetic CHAMP positions: The synthetic CHAMP positions were used as uncorrelated pseudo-observations for GFR performed in the course of orbit determination (24h arcs, 6 Keplerian elements as arc-specific parameters).

30s vs. 10s GPS data

Figure 1: Spectra of orbit differences due to Err.A and Err.x (see Tables 1 and 2) for the 30s and 10s solutions. The plots are vertically offset by the full ordinate 30s (top) and 10s (bottom) sampling. Only the bottom solution of type 2a is presented. The spectrum of Err.A is dominated by noise at least in position noise (see Fig. 1 (top)). The solution is still dominated by Err.A, but a significant contribution due to Err.x can be observed already. As a matter of fact, Err.A would become dominant if more than about 20 daily batches had been accumulated.

Solution 2b is partially dominated by Err.A as pulses compensate significantly worse for force model deficiencies than accelerations [Jäggi, 2006]. The spectrum performs worse than the solution 2a.

Solution 2c is completely dominated by Err.A and thus useless for GFR, even if Err.A is greatly decreased due to the longer acceleration intervals.

Conclusion: The solutions 2a, 2b, and 2c based on 30s GPS data are not suitable to derive unbiased gravity field information. Nonetheless, the reduced-high-frequency position noise for the solutions 2a x and Err.A is reduced by the presence of much larger systematic effects, e.g., due to a mismodeling of non-gravitational accelerations.

Summary and Conclusions

Reduced-dynamic LEO POD methods based on pseudo-stochastic parameters have been compared with the kinematic point positioning method in view of subsequent GFR. It was shown that reduced-dynamic LEO orbits require at least a spanning of 30s pseudo-stochastic parameters to be competitive to kinematic orbits for subsequent GFR. Such reduced-dynamic orbits are, however, equivalent to 30s kinematic orbits, if 30s GPS observations only are available. One thus do not offer advantages over the kinematic orbits.

When processing 10s GPS observations, reduced-dynamic LEO orbits based on 30s accelerations are at least equally well if not slightly better suited than the kinematic orbits for all probed GFR position sampling techniques in terms of noise. Even the small impact of the deficient a priori gravity field solution in 2a, which could be overcome in the solutions 2aa or 2aa+x, would probably not matter in reality as GFR is very likely to be dominated by the presence of much larger systematic effects, e.g., due to a mismodeling of non-gravitational accelerations.

References


Figure 2: Deviations per degree of the estimated (fully normalized) spherical harmonics w.r.t. the true gravity field coefficients for the solutions 1, 2a, and 2b.

Figure 3: Deviations per degree of the estimated (fully normalized) spherical harmonics w.r.t. the true gravity field coefficients for the solutions 1, 2a, and 2b.

Figure 4: Ratio between the difference degree amplitudes of a 2-day and a 4-day solution of type 2a (see Table 2) due to Err.A only or due to Err.A+Err.x. Observe that the impact of Err.A is reduced by the expected square root of 2 for terms above deg. 60, whereas the more pronounced reduction for deg. 20-60 is due to the still inhomogeneous 2-day to 4-day ground back time between the two sampling intervals. The impact of Err.A cannot be reduced by the accumulation of data, which becomes relevant in this simulation (and only) if Err.A is reduced to a similar level by accumulation.

Figure 5: Ratio between the difference degree amplitudes of a 2-day and a 4-day solution of type 2a (see Table 2) due to Err.A only or due to Err.A+Err.x. Observe that the impact of Err.A is reduced by the expected square root of 2 for terms above deg. 60, whereas the more pronounced reduction for deg. 20-60 is due to the still inhomogeneous 2-day to 4-day ground back time between the two sampling intervals. The impact of Err.A cannot be reduced by the accumulation of data, which becomes relevant in this simulation (and only) if Err.A is reduced to a similar level by accumulation.