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Improved GRACE kinematic orbit determination using GPS receiver clock modeling

Ulrich Weinbach (1,2) and Steffen Schön (1,2)

(1) Institut für Erdmessung, Leibniz Universität Hannover, Germany (weinbach@ife.uni-hannover.de), (2) Centre for Quantum Engineering and Space-Time Research (QUEST), Hannover, Germany

Recently, kinematic positioning of Low Earth Orbiters (LEOs) equipped with GPS receivers has attracted much interest, as a tool that complements the well established methods of reduced dynamic orbit determination. The main advantage of kinematic orbits can be seen in the fact that no a priori information regarding the Earth's gravity field is introduced. On the other hand, tracking of at least 5 GPS satellites at any time is necessary to compute a precise and reliable position. This requirement often causes gaps in the computed orbit.

The most simple and efficient way for kinematic orbit determination of LEO satellites is Precise Point Positioning (PPP). In PPP, advantage is taken from precise orbits and clock corrections for the GNSS satellites derived from a global reference network, e.g. provided by the IGS. In contrast, the receiver clock correction has to be solved for as part of the point positioning problem. Due to the limited stability of the receiver's internal oscillator, the offset of the receiver clock with respect to the system time has to be estimated for every observation epoch. If, in contrast, the internal oscillator of the receiver is replaced by a highly stable clock the receiver clock correction can be modeled rather than estimated on an epoch-by-epoch basis.

In this contribution, we will discuss the technical requirements for GNSS receiver clock modeling at the carrier phase level and we will analyze its impact on the precision of kinematic PPP positions for the two GRACE satellites using both simulated and real data. We will demonstrate that a piece-wise linear parameterization is adequate to model the receiver clock of the Blackjack GPS receivers onboard of the GRACE satellites, which derive their frequency reference from an Ultra Stable Oscillator (USO). Adopting such a clock model, allows reliable positions estimation even if the number of usable GPS observations drops to 4. This increases the availability of kinematic positions significantly. Furthermore, simulations and code-only solutions indicate an improvement of the satellite trajectory of approximately 55 % in the along-track and radial direction and approximately 35 % in the cross-track direction when clock modeling is applied. For PPP with real GRACE data, however, the improvements of both absolute position and inter-satellite distance compared to the K-band ranging system were found to be significantly smaller. Among the reasons for this discrepancy are remaining systematic errors and a relaxation of the clock constraints due to the large number of float ambiguities that need to be estimated in the LEO PPP case. In this context, the impact of ambiguity fixing will also be discussed.