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Precise Orbit Determination of Low Earth Orbiting Satellites Including Uncertainty Estimation

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Precise Orbit Determination (POD) is indispensable for many spaceborne Earth science applications, including Global Navigation Satellite System (GNSS) Radio Occultation (RO). RO is a highly valuable observation technique providing accurate atmospheric profiling measurements in the troposphere and stratosphere regions with global coverage, long-term stability, and virtually all-weather capability. During an occultation event the GNSS signals scan the atmosphere in limb sounding geometry and arrive with a time delay at the receiving RO satellite, which is due to the signal's refraction in the Earth's atmosphere. Key atmospheric variables such as temperature, pressure, and tropospheric water vapor, can in turn be retrieved from the raw measurements. In order to enable high accuracy of RO derived profiles, highly accurate orbit positions and velocities as well as clock estimates of the GNSS transmitter satellites and RO receiver satellites in low Earth orbit (LEO) need to be determined.

Using GPS orbit and clock data from the GNSS orbit data archives of CODE and IGS, and employing Bernese (v5.2) and Napeos (v3.3.1) software packages for the LEO orbit determination of RO satellite missions, we perform a mutual consistency check including estimates of systematic uncertainty bounds and propagated random uncertainties. Furthermore, the obtained orbit products are inter-validated with external orbit solutions from other processing centers and, as possible, to radial position estimates from satellite-laser ranging. Resulting monthly statistics in general show a consistency within RO orbit uncertainty target specifications of 5 cm in position and 0.05 mm/s in velocity for MetOp-A/-B, GRACE, and CHAMP missions. However, degraded observation data, detected by the rigorous consistency evaluation of the quality of the calculated orbits and clocks, can at times lead to decreased accuracy estimates. In particular COSMIC RO satellite orbits show decreased accuracy estimates near 20 cm in position and 0.2 mm/s in velocity, due to less favorable attitude behavior and restrictions in processing observations from two antennas.