Modeling of systematic effects in SLR observations to Swarm satellites for determination of global geodetic parameters

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The ESA low Earth orbit (LEO) satellites Swarm-A/B/C are equipped with Global Navigation Satellite System (GNSS) receivers and retroreflectors for Satellite Laser Ranging (SLR). Most commonly, the SLR technique is used to validate the Precise Orbit Determination (POD) products based on GNSS. The SLR observations to LEOs are currently not considered for the realization of terrestrial reference frames. The increasing accuracy of laser observations to LEOs, including Swarm satellites together with high-quality POD products allow for the utilization of SLR observations for various purposes, including identifying systematic effects in SLR data and determination of SLR station coordinates and global geodetic parameters.

We reduce systematic effects affecting the SLR residuals to LEO Swarm satellites by incorporating GPS-based POD products and special handling of SLR systematic errors emerging from tropospheric delay modeling. The Swarm POD products are based on ionosphere-free linear combinations, fixed ambiguities, and satellite macro-models used for modeling non-gravitational forces.

We test solutions incorporating the estimation of range biases, station coordinate corrections, tropospheric biases, and horizontal gradients. We propose estimating a daily correction to troposphere delay in the zenith direction w.r.t. the a priori tropospheric delays based on the Mendes and Pavlis (2004) model and meteorological observations collected at the SLR stations. Applying tropospheric bias correction in SLR allows obtaining orbit validation twice better than for solutions without modeling systematic effects. The solutions with modeling of tropospheric bias corrections show validation results better by 3 mm than solutions considering present methods of range bias handling. We use corrected SLR observations and orbits of Swarm satellites for the determination of SLR station and geocenter coordinates, the length-of-day parameter, and pole coordinates. We compare our estimates with LAGEOS-based solutions and evaluate the consistency of results based on active and passive satellites tracked by SLR.