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Improving the SLR network calibration through GPS-based precise orbit determination of LEO satellites

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Satellite laser ranging (SLR) measurements are widely applied for validating GPS-based precise orbit determination (POD) solutions of satellites in low Earth orbit (LEO). Considering only high-quality stations within the International Laser Ranging Service (ILRS), representative SLR residuals of 15 mm (RMS) have been achieved in many geodetic and remote sensing missions over the last decade. While LEO POD has long been considered a limiting factor for the achieved level of SLR residuals, we show that the current performance is in fact driven by uncertainties in the station coordinates and the station range bias calibrations. Corrections to the a priori values of these parameters can be obtained in a least-squares adjustment from SLR residuals of LEO POD solutions over a sufficiently long data arc.

Within the presentation, we introduce the concept of residuals-based parameter estimation and discuss the capability to separate orbit and station errors. Using a dedicated set of ambiguity-fixed reduced dynamic orbit solutions for the Swarm-A/B/C, TerraSAR-X, Sentinel-3, and Jason-2 satellites, we demonstrate a substantial reduction of SLR residuals down to the 5-mm (1-sigma) level for the best ILRS stations after adjusting the site position and range bias. While SLRF2014 already provides a notable improvement over SLRF2008, station coordinate and bias corrections at the 1-cm level are still required for numerous ILRS stations. In various extreme cases of stations with poor tracking performance, corrections at the dm level are obtained.

Aside from confirming the high quality of ambiguity-fixed POD solutions, the results contribute to an improved understanding of the ILRS station performance. While the introduction of kilohertz laser systems has enabled a clear reduction in the noise of individual normal points, the calibration and stability of range biases presents a persistent challenge and may ultimately limit the geodetic performance of the SLR technique. The routine analysis of GNSS-based LEO orbits is suggested as a complementary means for monitoring and calibration of the ILRS network and can serve as a new contribution to the SLR-GNSS frame tie.