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Satellite co-locations for combined GNSS and SLR analyses

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The combination of Global Navigation Satellite System (GNSS) and Satellite Laser Ranging (SLR) data is done commonly by using the connection at co-located GNSS-SLR sites (station coordinates together with local ties) and by common Earth rotation parameters (ERP). Co-location of GNSS and SLR on ground is in general taken into account, co-location at the satellites is, however, generally ignored. Using satellite co-location implies that one common set of orbit parameters is estimated based on GNSS microwave and SLR observations together (apart from other common parameters, e.g., ERP, geocenter coordinates). Thus, satellite co-locations provide a very strong link between both techniques.

When speaking of satellite co-locations for combining GNSS and SLR, there are in principle two different types of co-locations, namely, the one due to GNSS satellites equipped with laser retroreflector arrays (LRA) and the one due to Low Earth Orbiting (LEO) satellites equipped with GNSS antennas and an LRA.

We will show that satellite co-locations are not only an additional connection to that provided by the ground stations, but that they offer even an adequate alternative to ground-based co-locations. Such an alternative is of special interest because the problems related to the local ties and their discrepancies with the coordinate differences at co-located sites are well known although the reasons are still not fully understood.

Furthermore, the estimation of common orbit parameters allows it to transfer the scale directly from SLR to GNSS. Due to uncertainties in the phase center modeling for the GNSS antennas, GNSS alone cannot provide the absolute scale information, and it is often assumed that the necessity to estimate range biases may reduce the potential of SLR to deliver the scale. However, we intend to demonstrate that the SLR-derived scale does not suffer from estimating range biases. Therefore, a combined GNSS-SLR analysis using satellite co-locations at GNSS satellites allows the estimation of the satellite antenna phase center offsets (SAO) for the GNSS antennas without fixing the scale of the a priori reference frame. The resulting GNSS SAOs are consistent with the SLR scale, what is actually not the case for the official IGS values provided in the file “igs05.atx”.

We will address the aspects mentioned above by combining normal equations generated at the Center for Orbit Determination in Europe (CODE) from GPS and GLONASS observations on one hand, and SLR observations to GNSS satellites on the other hand. A rigorous combined analysis includes the usage of consistent a priori models for the GNSS and SLR observations as well as a consistent set-up of all common parameters (satellite orbits, ERP, geocenter). We use the Bernese GPS Software for the analysis of both observation types, which guarantees the highest possible consistency and compatibility.