Impact of SLR Tracking of GNSS Constellations on Science

Summary of Session to Discuss Position Paper 6

The presentations in this session demonstrated a number of ways that SLR tracking to GNSS can significantly impact science results. These can be partitioned into three broad areas; (1) validation and calibration of the GNSS orbit quality, either through passing GNSS-based orbits through the SLR tracking or by comparison with orbits determined independently from the SLR tracking, and (2) improvement of the GNSS-based results through direct ingestion of the SLR data at the observation level, and (3) improvement in the determination of the SLR reference frame by including laser ranging to GNSS satellites with the lower LAGEOS satellites.

The independent SLR tracking provides the opportunity to validate various aspects of the GNSS modeling. In some cases, such as the GPS and COMPASS satellites, the SLR tracking is rather sparse, and accurate independent orbits are more difficult to determine. However, even in the case of sparse tracking, the microwave-based orbits can be passed through the SLR data to distinguish modeling improvements at the cm level. For example, it was shown that when the GNSS modeling was improved to include Earth radiation pressure and the transmit power recoil, the residual bias of ~4 cm in the SLR tracking was reduced to ~2 cm. In another presentation, larger SLR residuals were observed during shadowing, indicating that there may be significant mismodeling of the satellite yaw during these periods. If the yaw modeling is modified, it should be clear in the SLR residuals whether the model is an improvement. When independent orbits can be accurately determined from the SLR tracking, it was shown that such orbits could reveal systematic orbit errors, such as cross-track orbit errors that may be correlated with clock errors, that cannot be resolved using the microwave data alone. Finally, the GNSS spacecraft center of mass (CoM) models can be validated with the SLR tracking to the few mm level. This has already been demonstrated for the Jason-1 altimeter satellite, where a 13±1 mm offset in the X-axis was confirmed with the SLR data, while the ~40 mm offset seen only in the GPS data could be shown to be incorrect (now known to be due to the incorrect, at the time, modeling of the GPS transmit antenna phase center).

The second contribution of the SLR tracking would be to incorporate the absolute range information with the GNSS data at the observation level. This allows the estimation of some of the GNSS biases that cannot be separated using GNSS data only. This approach was demonstrated to significantly improve the overall quality of the GNSS-based reference frame, particularly in sorting out biases that can affect the scale of the GNSS-based terrestrial reference frame (TRF). While SLR uniquely provides the origin of the TRF, and SLR/VLBI provide the scale, it is essential that this origin and scale be accurately transferred to the GNSS frame. This is especially important since GNSS is generally the only disseminator of the TRF to the users; there will typically be no SLR or VLBI site next to a tide gauge, for example. The combination of laser ranging and microwave tracking to the same target was demonstrated to provide a stronger link between the SLR and GNSS-based frames. This can help compensate for the lack of precise local ties at some ground stations or provide an independent assessment of the accuracy of existing survey ties. All this should lead to more accurate and internally consistent determinations of the TRF based on the various contributions of SLR, VLBI, GNSS and DORIS.

The third impact of SLR tracking of GNSS satellites would be the improvement of the SLR contribution to the terrestrial reference frame, especially in terms of scale. Because SLR tracking provides a measurement of the absolute distance to the satellite, it is able to simultaneously determine the satellite orbit, the reference frame scale, the Earth's mass (GM) and even the ranging biases; biased range measurements such as GNSS and DORIS cannot. Consequently, the GNSS analysis 'inherits' the scale of the geocentric frame from SLR. However, absolute knowledge of the satellite's center of mass must be known, and the current uncertainty in determining GM is limited at the few mm level by possible systematic errors in the LAGEOS CoM model. Because of the effect of scale on estimating GM, the SLR tracking of GNSS satellites, if the CoM is known to a few mm, may be able to improve the estimate of GM by perhaps a factor of two or more. The SLR tracking of the lower satellites would benefit from this improved estimate of GM, helping to sort out the CoM issues for the lower satellites and improve the TRF scale as determined by SLR.

In addition to improving the estimation of GM, simulations were presented that demonstrated the direct improvement in determining the terrestrial reference frame when laser ranging to a constellation of GNSS satellites was included in the SLR-based solution. While the error models for this initial simulation were relatively simple, the results demonstrate the potential for SLR to GNSS satellites to help achieve the part in 10^{10} level that is the current goal for the terrestrial reference frame for precise geodetic applications.