The space tie between GNSS and SLR

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Introduction

It is important to know exactly the "space tie" for connecting the two space-geodetic techniques GNSS and SLR in space (i.e., at the satellites). The space tie consists of two components: the location of the phase center of the microwave transmitting antenna w.r.t. the center-of-mass (CoM) of the satellite on one hand (i.e., the satellite antenna offset, SAO), and the location of the center of the laser retro-reflector array (LRA) w.r.t. the CoM on the other hand. The accurate knowledge of these three-dimensional vectors is necessary for the SLR validation of microwave-based orbits as well as for a combined GNSS-SLR analysis. Thaller et al. (2011) demonstrated already that the estimation of corrections for the SAO within a combined GNSS-SLR solution yields SAO values which are consistent with the scale defined by SLR. We present hereafter an estimation of the LRA offsets for GLONASS and GPS satellites tracked by SLR.

Determination of the LRA offset from SLR data only

In the case of newly launched satellites, it can happen that microwave data as well as SLR tracking data are available but the offset of the LRA is not known. This was the situation with the first GLONASS-K satellite (GLONASS-125) launched in February 2011: SLR data were available since April, but the LRA offset was published end of June. In order to include the satellite in the SLR analysis, we wanted to determine the LRA offset based on the SLR tracking data. We first computed the SLR residuals w.r.t. the microwave-based orbit by setting the LRA offset to zero. The mean of the SLR residuals was -1394.2mm (from altogether 306 SLR normal points, see Table 1).

Assuming that the major part of the residuals corresponds to the LRA z-offset, we used this mean residual as a priori value for an estimation of the LRA z-offset: The satellite orbit and the corresponding Earth rotation parameters were taken from the microwave solution computed at the IGS analysis center CODE, the positions of the SLR stations were fixed to SLRF2008, and only the LRA offset was estimated (assuming no range biases). In one solution type, only the offset in z-direction (i.e., nadir direction) was estimated, whereas offsets in all three directions were estimated in a second solution type. These two solution types were computed several times during May and June 2011 by considering the steadily increasing number of SLR normal points. The results are summarized in Table 1. It becomes clear that the estimated offsets change by a few centimeters with increasing number of SLR data. The differences of the z-offsets between the two solution types are comparably small and well within the uncertainty of the estimates.

The official value published end of June 2011 is 1473.02mm for nadir direction, thus, about 2cm different from our estimation. It must be kept in mind, however, that our estimation considers the microwave-based orbits as truth, but at that time the location of the microwave phase center of the satellite antenna was not known (similar to the LRA offset), i.e., in the first months the z-offset of the microwave antenna was set to 0 instead of using 1.75m as published later on. This situation explains why the mean SLR residual based on the official LRA offset was about 37mm in June 2011, but decreases to 3.5mm only when considering all data until October 2012 with improved microwave orbits and SAO values as the basis.

Date	# SLR normal points	Mean residual and std.dev. [mm]	Solution 1	Solution 2		
			Z-offset [mm]	Z-offset [mm]	X-offset [mm]	Y-offset [mm]
May 30, 2011	306	-1394.2 ± 112.5	Assuming zero offsets for all components			
May 30, 2011	306	-	1400 ± 20	1393 ± 20	-127 ± 196	-85 ± 141
June 5, 2011	383	-	1417 ± 13	1402 ± 17	-231 ± 155	-30 ± 118
June 12, 2011	494	-	1442 ± 5	1432 ± 6	-148 ± 52	-19 ± 43
June 21, 2011	577	-1.6 ± 135.5	1451 ± 5	1448 ± 7	-55 ± 59	+81 ± 48
June 21, 2011	577	37.1 ± 133.5	Considering the official LRA offset (z = 1473.02)			
Oct. 2012	2658	3.5 ± 52.0	Considering the official LRA offset (z = 1473.02)			

Table 1: Estimation of the LRA offsets for GLONASS-125 based on SLR tracking data only and mean of SLR residuals when considering a specific LRA offset.

The estimation of x- and y-offsets is more difficult, especially for the LRA mounted on GLONASS-125 which is thought to be centered on the z-axis (i.e., a ring of corner cubes around the microwave antenna).

Validation of the LRA offsets within a combined GNSS-SLR analysis

A combined GNSS-SLR analysis with all parameters of interest estimated together (i.e., especially satellite orbits and offsets for the space tie) overcomes the problem described in the previous section, that the estimation of the LRA offsets depends on the microwave-based orbit solution. We combined microwave and SLR observations to GPS and GLONASS satellites together with SLR data to LAGEOS and Etalon. Station coordinates, Earth rotation parameters, geocenter coordinates, satellite orbits, SAO and LRA offsets were set up as parameters. For the determination of the SAO and LRA corrections, a multi-year solution covering the time span 2000-2010 was computed.

Figure 1 shows the estimated corrections for the LRA z-offset w.r.t. the official values. The estimation confirms the official offsets for the GPS satellites, but reveals differences of up to 3cm for the GLONASS satellites, with a mean correction of -16mm.

The corrections estimated for the SAO are clearly bigger: in average -86.1mm and -110.4mm for the GPS and GLONASS satellites, respectively. This corresponds to a scale difference between SLR and the SAO values given in igs08.atx (Schmid, 2012) by about 0.67-0.86ppb (see Thaller et al., 2012).

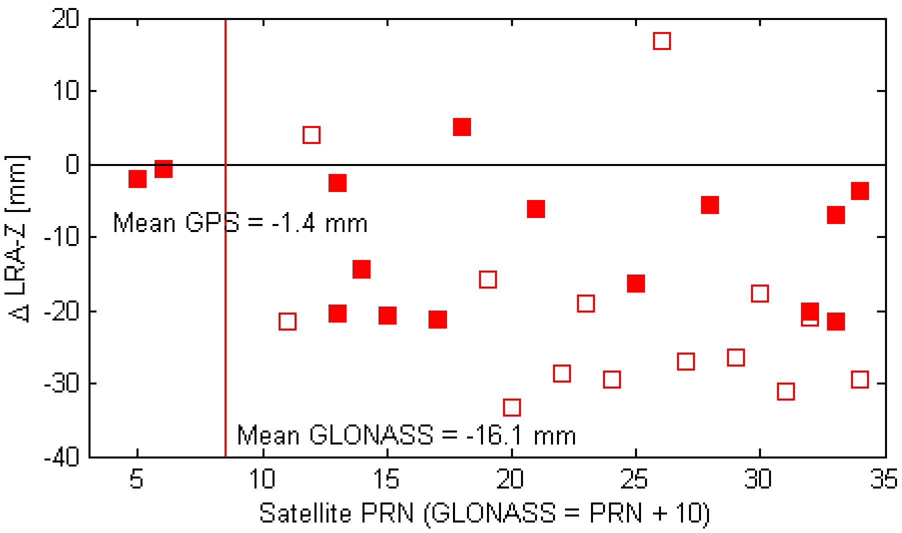

Figure 1: Corrections for the LRA z-offsets estimated within an 11-year combined GNSS-SLR solution. Filled markers: satellites tracked by all SLR sites; open markers: satellites tracked by Herstmonceux only.

Summary and conclusions

We demonstrated that the LRA z-offset of the GLONASS satellites can be determined from SLR data only with an uncertainty of about 2cm as soon as a few hundreds of normal points are available. However, the accuracy of the estimation strongly depends on the quality of the satellite orbit used as the truth. This procedure is especially applicable for new satellites. A determination of the LRA offsets within a fully combined GNSS-SLR analysis is preferable, of course, but a long time span is needed. In our 11-year solution, we estimate a correction for the LRA z-offset of -1.6mm and -16.1mm for GPS and GLONASS, respectively.

References

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