Comparing tracking scenarios to LAGEOS and Etalon by simulating realistic SLR observations

EGU General Assembly 2017
Open Session in Geodesy - focus on Relativistic Geodesy
24 - 28 April 2017, Vienna, Austria

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Introduction

The operational International Laser Ranging Service (ILRS) standard solution provides an important contribution to the International Terrestrial Reference Frame (ITRF). It supplies solutions for station and geocenter coordinates, as well as Earth rotation parameters (ERPs). As of today, these contributions are based on observations to the LAGEOS and Etalon satellites only (an extension to LARES is under consideration). There are currently 79 active targets supported by the ILRS, but in the near future the ILRS will provide tracking data to around 100 satellites while stations are already tracking close to their maximum capacity. On the other hand, in 2016 about 490000 normal points (NPs, binned full-rate data) were collected, roughly a third of these are observations to two satellites, LAGEOS1 and LAGEOS2. Based on this, the effect of reducing the NPs to LAGEOS on the ITRF contributions was studied using simulated observation scenarios and based on this further on a scenario with increased number of observations to Etalon was investigated because typically only 10% of observations come from these two satellites.

Simulation of observations

The simulation is based on the geometric distances derived from the station-satellite geometry using a set of weekly apriori station coordinates and orbits from a standard SLR analysis. It includes the typical corrections for relativistic effects, center of mass offset and so on. All time and range biases are assumed to be zero for the simulation. Taking this geometric distance, a pseudo random white noise function that is scaled according to the derived noise characteristics of each station-satellite pair from real measurements, as shown in Figure 1, is added. More details on the simulation can be found in Andritsch et. al (2016).

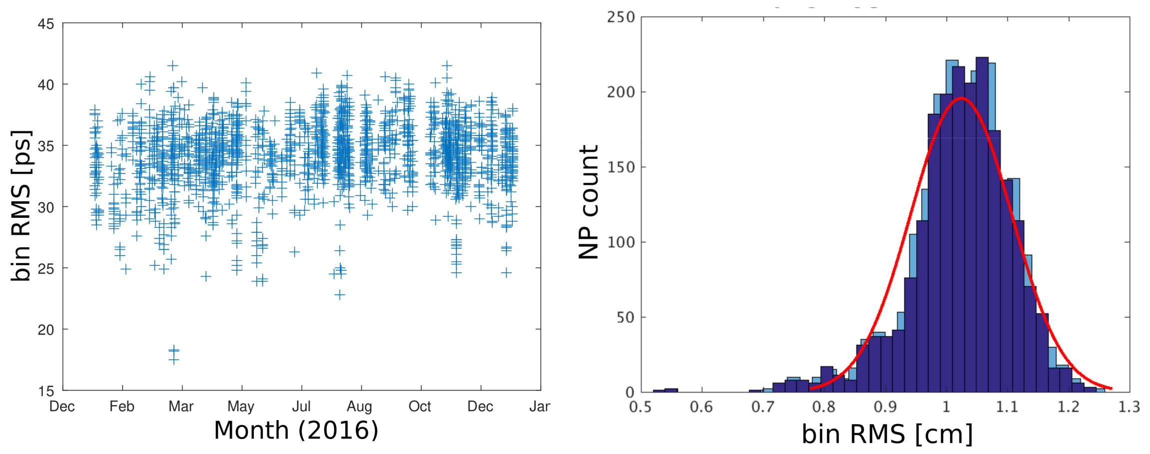

Figure 1: Modelling the noise characteristics of observations from station 7839 (Graz) to LAGEOS 2. The same procedure was conducted for each pair of station and satellite.

Assumed tracking scenarios

The observations taken by all the SLR tracking stations to the LAGEOS and Etalon satellites during the year 2016 have been used as a base scenario. They then have been replaced by synthetic observations from the simulation tool and are reduced step by step up to 30% (see Figure 2). The reductions were distributed equally on all stations.

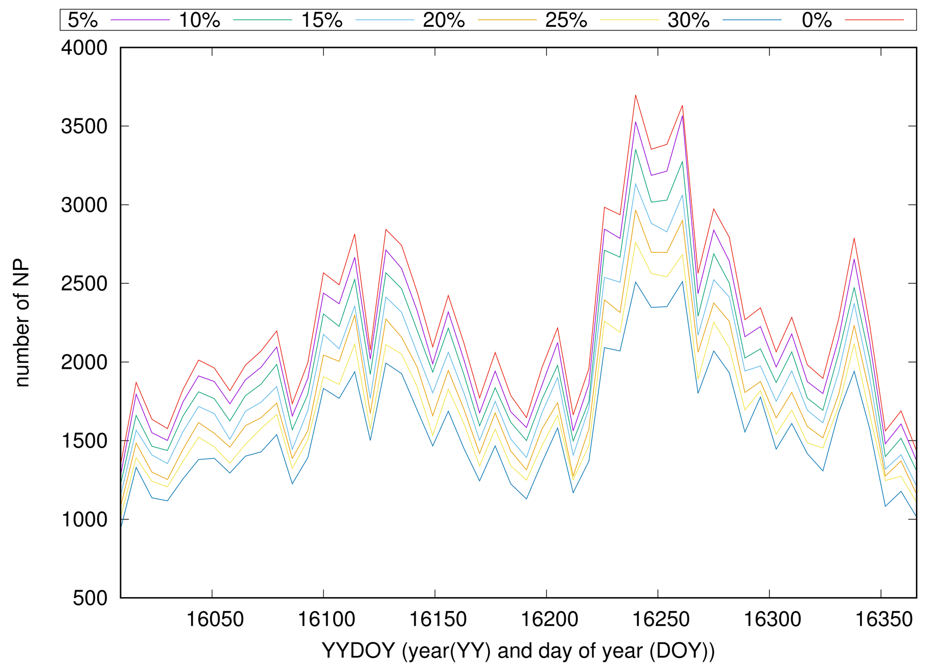

Figure 2: Number of NPs for LAGEOS for the different scenarios.

Comparing truth and simulation

First, the reference scenario (0% reduction of LAGEOS observations) solution was compared to the solution derived from the real (actual) observations. In a weekly SLR routine processing a set of station coordinates, ERPs and satellite orbits are calculated from the simulated NPs.
A comparison of the station coordinates with the assumed geometry results in a yearly mean RMS of the Helmert transformation of 3.4 mm. The translation and rotation parameters as well as the scale are insignificant. When simulating the same observations with a different initial seed for the pseudo random noise, the Helmert parameters are of the same magnitude. This defines the noise-threshold of the solution resulting from the simulated observations.

Comparing the scenarios

Similarly the station and geocenter coordinates, ERPs and orbits of all the scenarios with reduced tracking of the LAGEOS satellites were compared with respect to the reference solution to see when the errors get significantly worse in terms of the noise threshold given by the simulation.

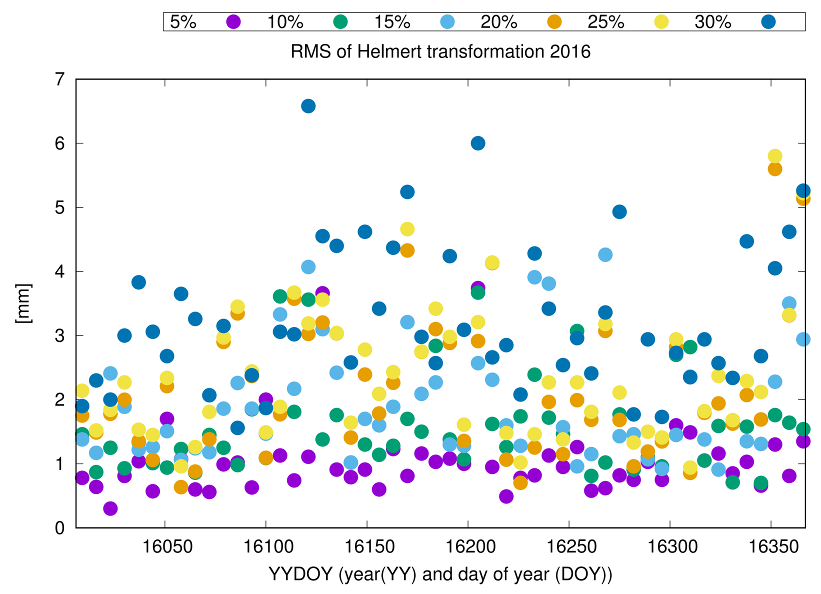

Figure 3: RMS of Helmert between resulting station coordinates and reference solutions.

Figure 3 shows that with each 5% reduction step the RMS of the Helmert transformation increases by $0.4-0.5$ mm. The noise of the scenarios reducing the measurements of up to 20% show an RMS for the Helmert parameters that are below the RMS in the coordinates when varying the noise of the observations. When comparing the geocenter coordinates a mean value of $0.1-0.5$ cm difference depending on the considered component and scenario can be observed. However the spread of the differences and bigger outliers increases from 5-30% reduction.

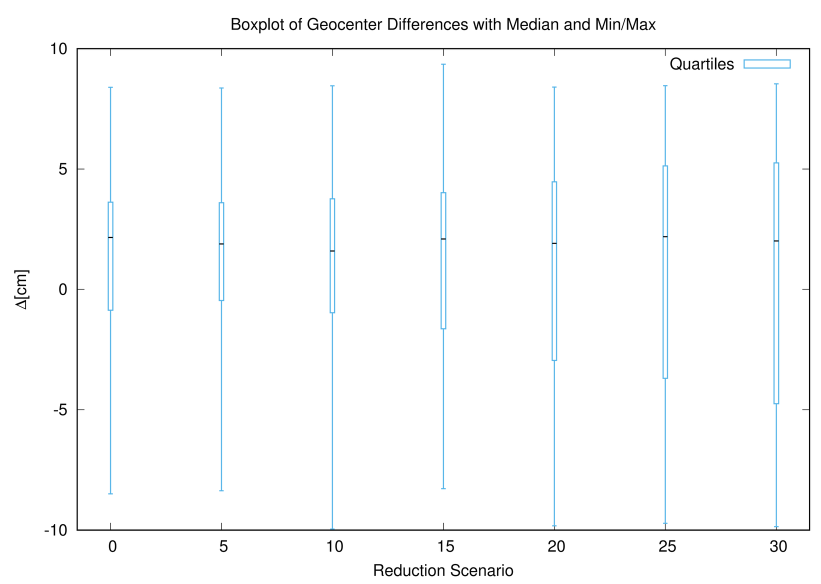

Figure 4: Spread of X coordinate geocenter differences for the various scenarios.

The few biggest outliers with more than 10 cm difference were neglected for this comparison as they appeared in all scenarios due to a limited number or unfortunately distributed measurements. The median is quite constant for all scenarios. Starting with the scenario with 15% reduction the noise increases. This is consistent for all three coordinate components. The same can be observed in the comparison of the scale factors.
Therefore we chose the 10% reduction scenario for the next simulation experiment.

Increasing the number of Etalon observations

By reducing the tracking activity to LAGEOS by 10% free capacity to track other satellites is gained for all stations. In a next step the tracking capacity is used to provide more tracking data for Etalon which is an integral part of the ILRS standard solution. The total number of NPs provided by each station hereby remains the same. In particular this increases the number of Etalon observations from 10% to 20% of the NPs compared to LAGEOS in the processing.

Comparison of the main parameters

It is important to show that introducing new observations does not decrease the quality of the parameters of the solution and study the effect of having twice as many Etalon NPs.

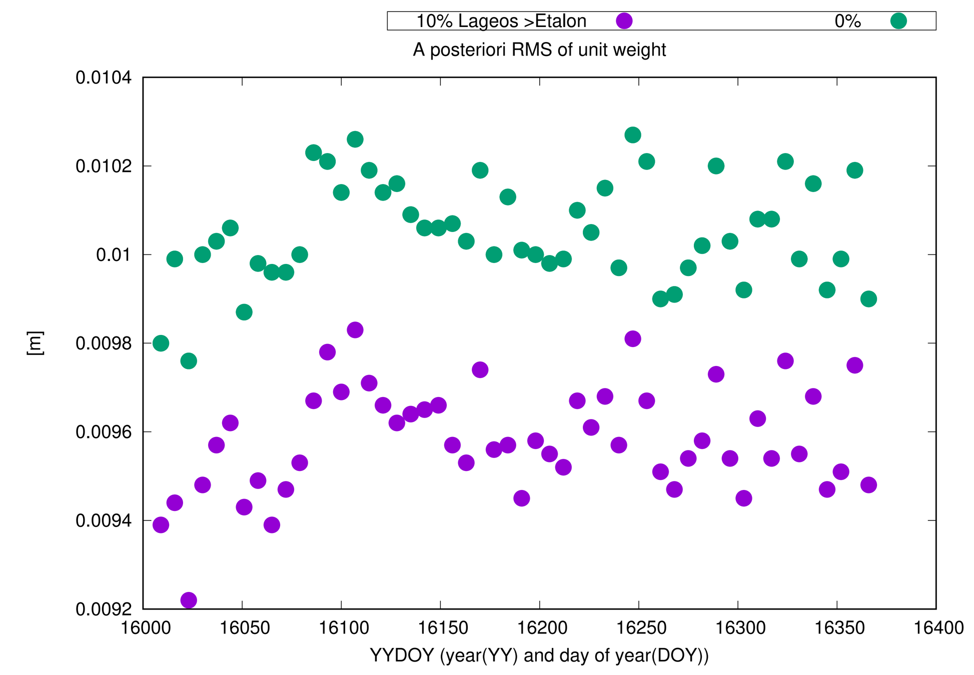

Figure 5: A posteriori RMS of unit weight.

The a posteriori RMS of unit weight is 5% lower than in the reference solution in average (see Figure 5). It has to be pointed out that this was achieved with the same total number of NPs, shifting the tracking capacity of the stations from the LAGEOS to the Etalon satellites.

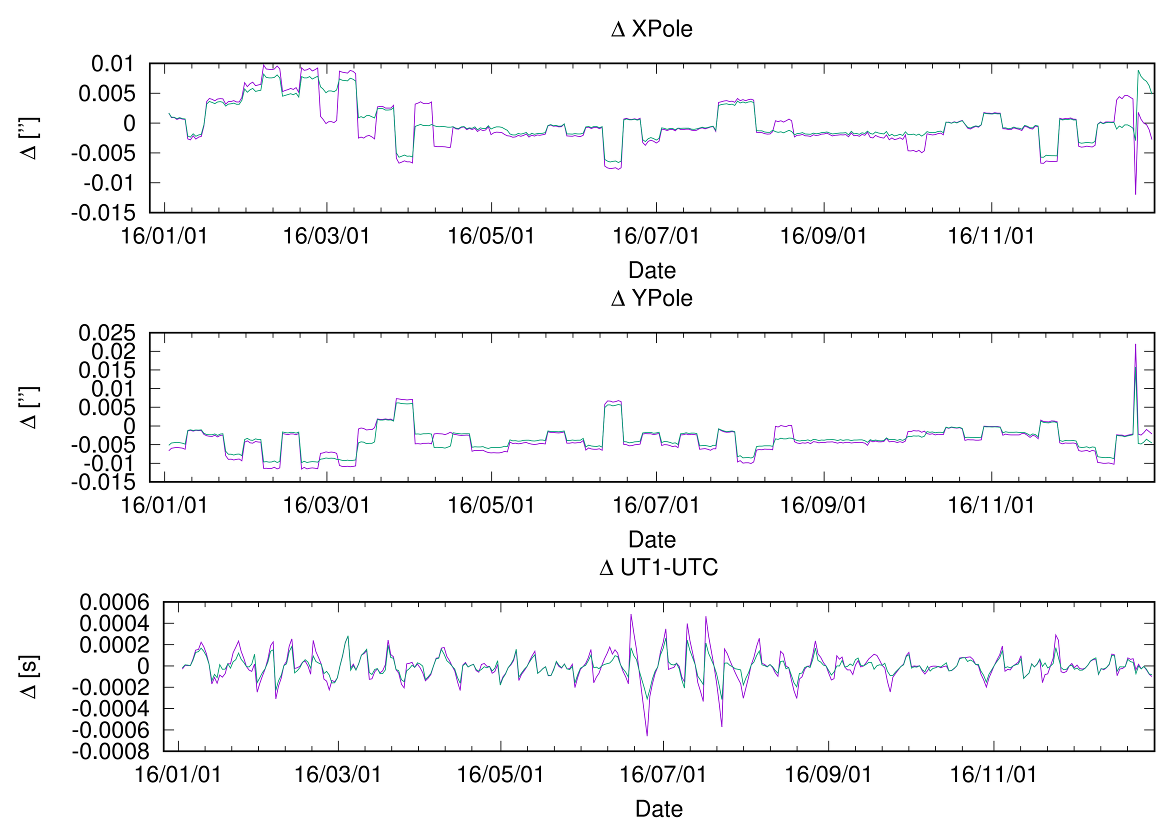

Figure 6: Comparison to an independent ERP solution for the reference scenario and the increased Etalon scenario.

By adding more Etalon observations the ERPs introduced into the solution can be recovered better than with the reference scenario (Figure 6).

Finally, considering the station coordinates, again the parameters of the Helmert transformation between the reference solution and the scenario with more Etalon observations are studied. The yearly average RMS of the Helmert transformation for the station coordinates is on the level of 2.9 mm. The translation and rotation parameters are not significant in Figures 7 and 8.

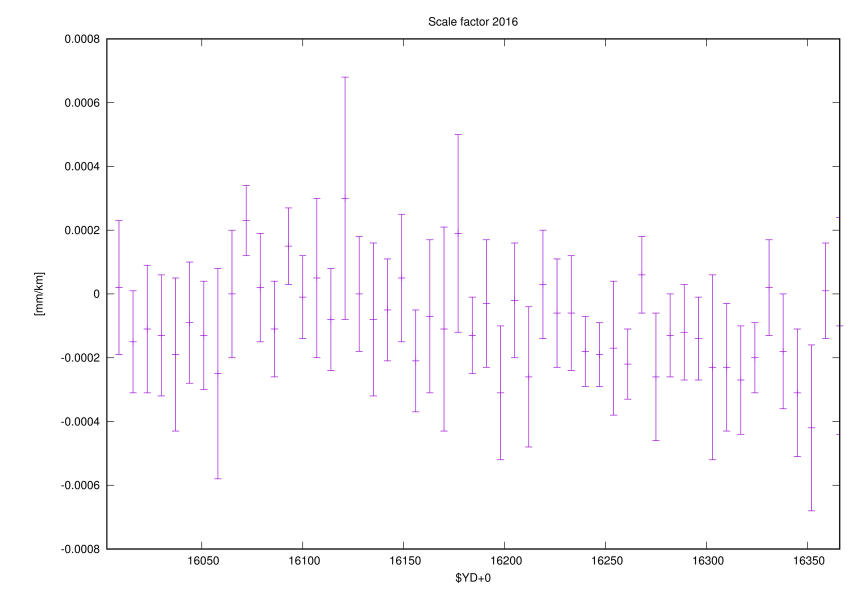

Figure 7: Scale of Helmert transformation.

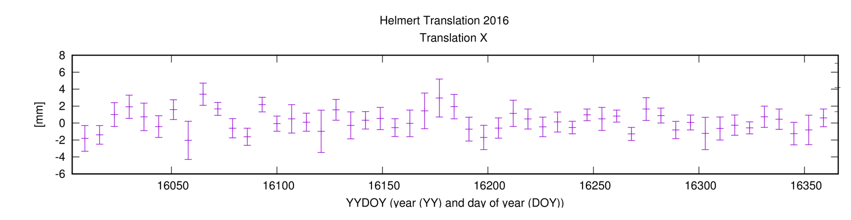

Figure 8: Translation of Helmert transformation in X. Y and Z component analog.

The geocenter coordinates are barely affected (see Figure 9) and show the same results as well as the scale factor of the Helmert transformation.

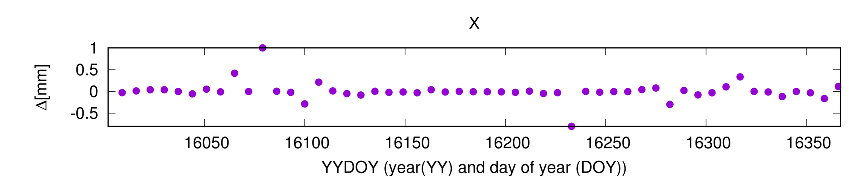

Figure 9: Differences of geocenter X coordinate to reference solution.

Conclusions

Simulation: The simulation can be used to produce synthetic observations for satellites even if they were not tracked by a specific station at a given epoch. The synthetic observations can be used in a standard SLR analysis and the results compared to both, the solutions of other simulated scenarios as well as the truth from actual observations.

Scenarios: Comparing simulated tracking scenarios for LAGEOS and Etalon show that the quality of the ILRS contribution to the ITRF does not show a significant decrease by reducing the number of NPs to the LAGEOS satellites by up to 10%. This amounts to more than 1000 NPs of tracking time per month which other targets could benefit from.

Increasing the number of Etalon observations: Using these "free observation slots" to increase for example the number of NPs to Etalon does not change the obtained geocenter or station coordinates significantly. The a posteriory error of unit weight can be reduced by including more NPs to Etalon. The difference in ERPs to an independent time series show a small improvement. Thus it can be beneficial to reduce tracking to LAGEOS and increase the number of observations to Etalon.

References

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