Session 1

Extension of the SLR tracking network and its potential for the realization of Terrestrial Reference Frames

Kehm A., Bloßfeld M., Seitz F.

The Global Geodetic Observing System (GGOS) aims at a realization of accuracies of 1 mm for positions and 0.1 mm/yr for velocities. In order to deliver these accuracies, there is a necessity of highly stable and precise reference frames. SLR is the unique technique that allows for a common estimation of Earth Orientation Parameters (EOP), station coordinates/velocities as well as the Stokes coefficients of the Earth's gravity field in one common adjustment. As it is one of the properties of GGOS to integrate over a wide range of the parameter space, SLR is one of the key techniques for its realization.

The current SLR tracking network suffers from a disadvantageous network geometry due to a lack of stations especially on the southern hemisphere with 80% of the active tracking network being located on the northern hemisphere. Previous simulation studies have shown that the extension of the global SLR tracking network is indispensable for reaching the accuracy goals of the Terrestrial Reference Frames of the future. The simulation studies have put focus on a determination of the locations where additional SLR stations are most valuable for the realization of the estimated geodetic parameters.

Within the present simulation studies, different possibilities for an extended global SLR tracking network have been compared by following two different approaches. In a first scenario, SLR stations which are already under consideration have been added to the existing network (Figure 1). In a second scenario, we performed a simulation of a set of stations distributed equally over the globe and comparing different solutions, always adding one of these simulated stations to the real SLR station network. This approach has been chosen in order to be able to investigate the deficiencies of the existing SLR network and to judge in which regions on the globe an additional SLR station could be valuable for the improvement of certain geodetic parameters of SLR-derived reference frames.

The simulations have been performed in such a way that SLR normal points (NPs) have been simulated as two-way measurements. Afterwards, a noise with a standard deviation of 1 cm has been added, including the assumed NP accuracy of < 1 mm as well as other random errors. Systematic errors in the models have been simulated by switching between different models for the Earth's gravity field as well as tidal effects between the simulation and the processing step.

The basis for the results of the present study is an assumed 5-satellite setup including LAGEOS-1, LAGEOS-2, Etalon-1, Etalon-2, and LARES. The simulated NPs have been reduced to a station-specific performance (i.e. number of passes observed w.r.t. number of possible passes) as well as to an observation scheduling with three NPs at the beginning, mid, and end of each observed pass. The station-specific performances have been determined empirically and reflect the average performance of a station between 01/2014 and 02/2015, excluding longer periods of station inactivity (> 1 GPS week). The values range from 3% to 54% with an average of 13%.

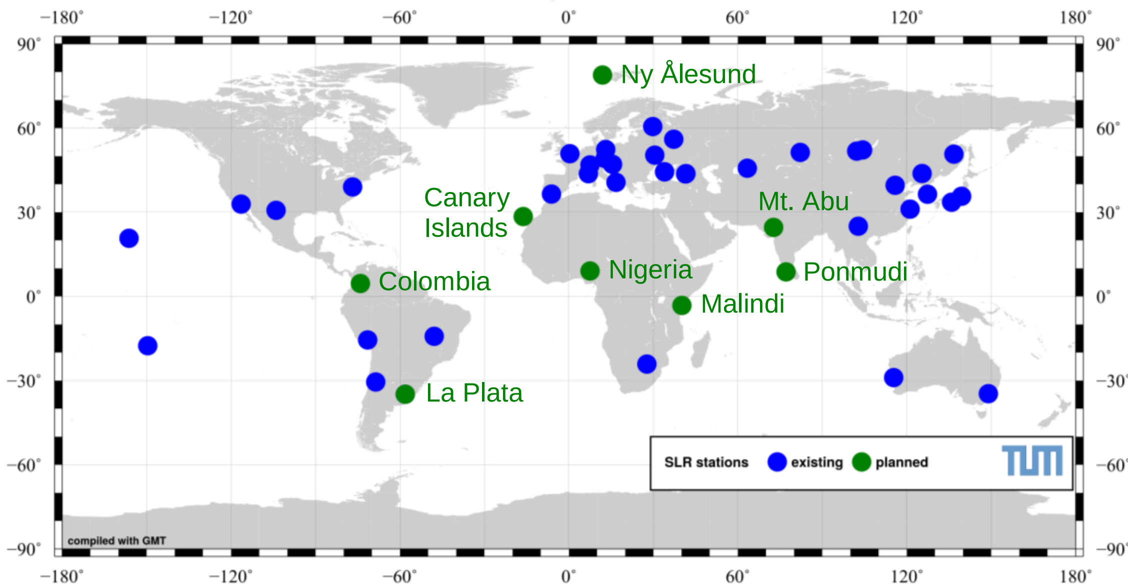

Figure 1: Existing and planned SLR stations considered within this study.

The solutions have been calculated on a weekly basis. The processing of the simulated observation has been performed in the same way the solutions from real observations are processed. In a first step, a single-satellite pre-processing takes place in order to reduce or eliminate all parameters not required in the combination. Afterwards, the satellite-specific NEQs are stacked into one common weekly NEQ and solved for station coordinates and EOP.

The impact of additional stations on the estimated parameters has been quantified in terms of the improvement of the WRMS of the weekly solutions w.r.t. the a priori TRF and EOP.

Table 1: Effect of the eight additional stations on the estimated parameters

Effect of	Helmert parameters (reference: SLRF)					EOP (ref.: IERS C04)		
	WRMS				RMS of residuals	WRMS		
	t_x	t_y	t_z	M		x_{Pol}	y_{Pol}	LoD
Geometry (+ 8 Stations)	18 %	20 %	24 %	20 %	6 %	4 %	5 %	2 %

Table 1 gives the values for the case of the network extended by eight stations as shown in Figure 1.

We can conclude that

- Adding eight stations to the existing network will lead to a **significant improvement of the estimated datum parameters**.
- The scatter of the realized origin of the TRF is reduced by up to 24%.
- The WRMS of the EOPs is reduced by up to 5% in the pole coordinates and 2% in LOD.
- Details: Kehm et al. (2017).

The results shown before refer to stations in certain predefined locations only. This leads us to the question in which geographical location an additional station can bring the largest benefit, independently from any predefined locations. Hence, simulations have been performed assuming a global network of equal-area distributed SLR stations. In each simulation scenario, one of these stations has been added to the existing SLR network and the impact of the solution on the estimated geodetic parameters has been determined. This scenario has been performed with a simple error modelling taking into account only a white observation noise of 1 cm in order to put focus on the errors caused by the spatio-temporal distribution of the observations.

The largest potential of improvement by additional stations can be found in North and South America for the z-translation of the reference frame (Figure 2) and in Central America and the Western Andes as well as East Asia for an improvement of y-pole.

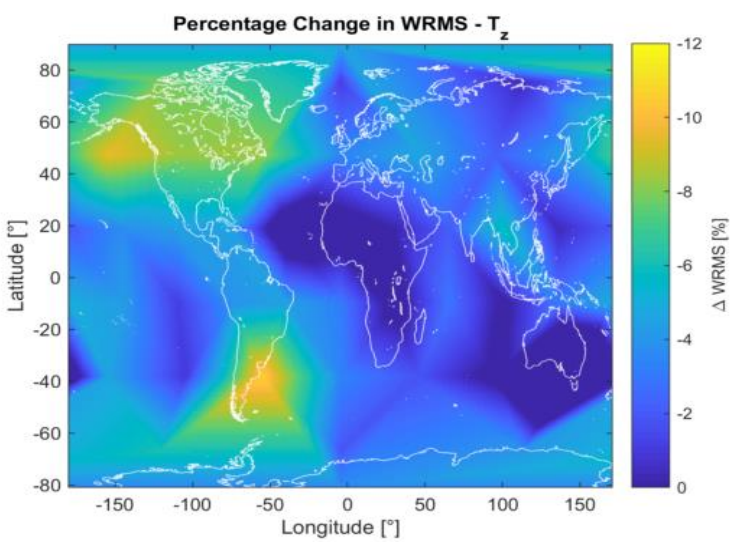

Figure 2: The z-translation is improved predominantly by additional stations in North and South America.

The following conclusions can be drawn from the two simulation scenarios presented here:

- Extending the existing SLR network for a more homogeneous station distribution helps to improve all estimated geodetic parameters.
- Under realistic error assumptions, we could show that an SLR network extended by eight stations can significantly improve the datum realization (>20 % in TRF, ~5% in EOP).
- A purely geometric approach omitting systematic errors in a-priori models confirms the assumption that the network at the southern hemisphere needs to be extended; further studies with refined modelling are currently ongoing.