Bundesamt für Kartographie und Geodäsie

A combined solution of SLR, SLR to GNSS and GNSS at Normal Equations Level: Preliminary results and facts

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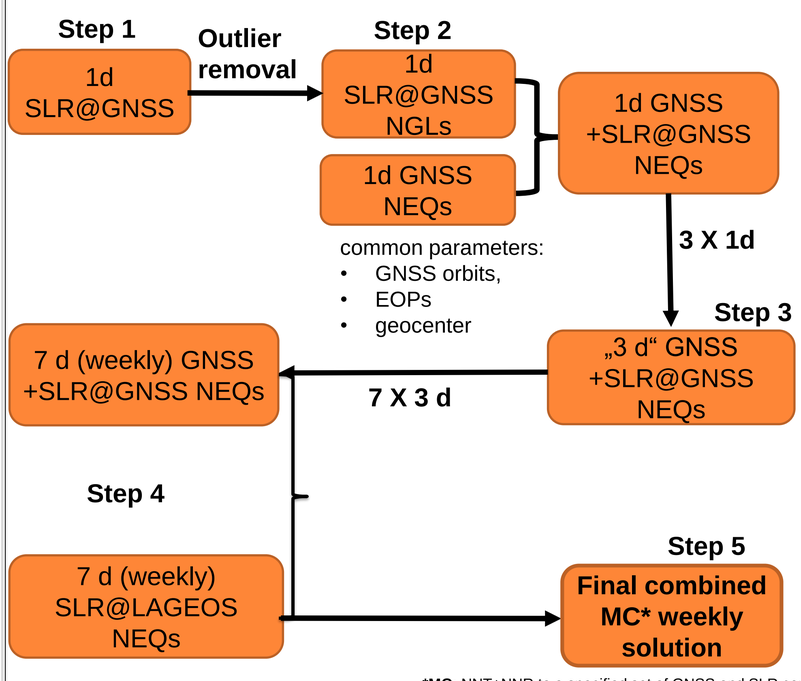
1. Introduction

The aims of our BKG project called "*Establishment of assessment methodologies for the consistent realization of the global reference systems"* (**KoKoRef**) are the following:

- Combination at NEQ level of the Space Techniques
- Consistency of the scale factor of the Space Techniques (SLR, GNSS und VLBI)
- Geocenter motion
- Consistent estimation of the Earth Orientation Parameters (EOPs)
- SLR: Investigation of the Range Biases (RGB) to GNSS satellites

We use 3 different types of observations, namely: I. SLR at LAGEOS, II. GNSS and III. SLR at GNSS satellites. The analysis was done using the Bernese GNSS Software SLR Development Version per observation type. The individual contributions were subsequently considered at datum-free NEQ level.

2. The analysis scheme



***MC:** NNT+NNR to a specified set of GNSS and SLR core sites

Figure 1: The analysis scheme to derive combined SLR-GNSS weekly solutions

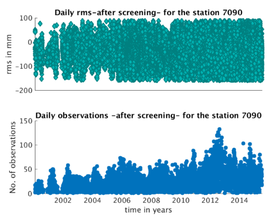


Figure 2a: The screened SLR@GNSS daily observations for station 7090

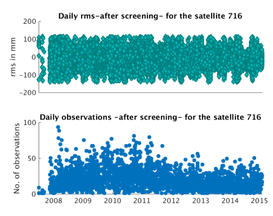


Figure 2b: The screened SLR@GNSS daily observations for GLONASS satellite 716

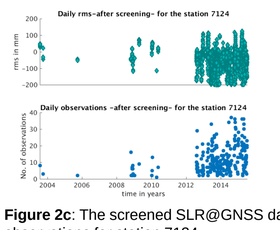


Figure 2c: The screened SLR@GNSS daily observations for station 7124

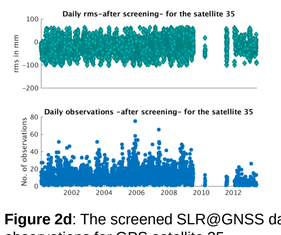


Figure 2d: The screened SLR@GNSS daily observations for GPS satellite 35

3. The global SLR+GNSS network

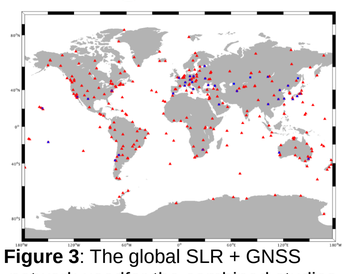


Figure 3: The global SLR + GNSS network usedfor the combined studies

358 GNSS stations,
58 stations SLR@LAGEOS,
43 stations SLR@GNSS

Time Span: 2000-2010, 2013-2014

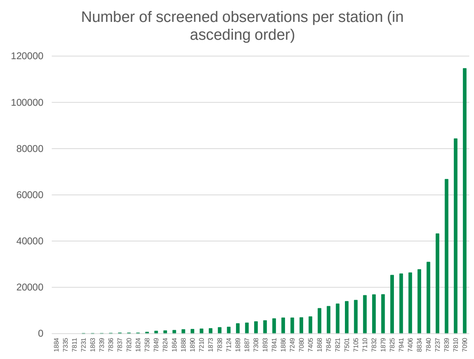


Figure 4: The total number of screened daily GNSS@SLR observations per station

4. Preliminary Results

Initially, we apply two different scenarios for estimating range biases RGB:

1. Without RGB: RGsB to GNSS satellites are not estimated at all.
2. One RGB per station and per GNSS satellite: We estimate the RGB (on a weekly basis) for each GNSS satellite which passes over a specified station

For both scenarios, we take into account the Non-Tidal Atmospheric Loading (NTAL), Non-Tidal Ocean Loading (NTOL) and the Continental Water Storage Loading (CWSL), using the geophysical models provided by GFZ (https://isdc.gfz-potsdam.de/esmdata/loading/).

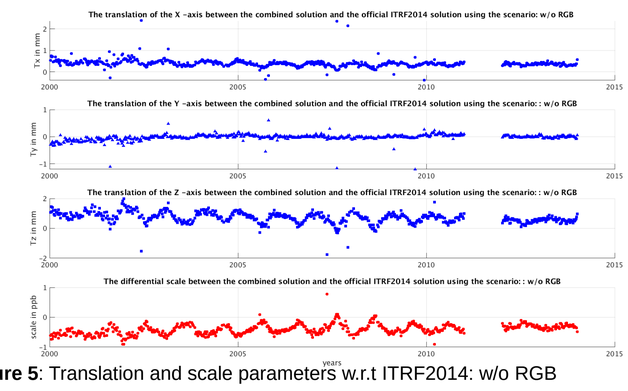


Figure 5: Translation and scale parameters w.r.t ITRF2014: w/o RGB

Table 1: statistics of the translation and scale parameters vs ITRF2014 : w/o RGB scenario (mm for translations, ppb for scale, resp.)

	min	max	mean	std
Tx	-0.39	2.38	0.40	0.19
Tx	-1.20	0.60	-0.03	0.12
Tz	-1.77	1.98	0.71	0.37
scale	-0.91	0.78	-0.4	0.17

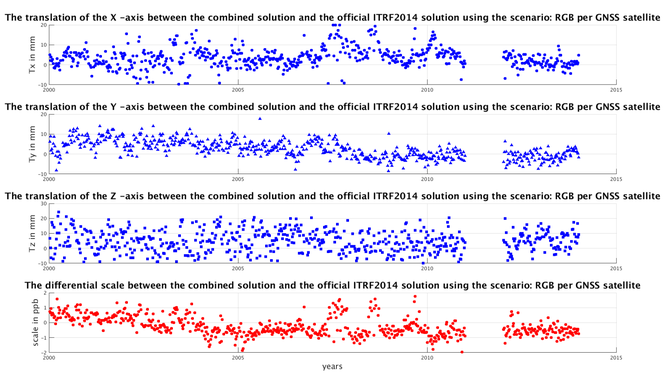


Figure 6: Translation and scale parameters w.r.t ITRF2014: RGB estimated per station and per satellite

Table 2: statistics of the translation and scale parameters vs ITRF2014:RGB per sat. scenario vs (mm for translations, ppb for scale, resp.)

	min	max	mean	std
Tx	-9.77	20.00	3.57	4.85
Tx	-8.60	17.53	2.39	4.36
Tz	-9.91	24.32	**4.91**	**7.08**
scale	-1.96	1.77	-0.25	0.63

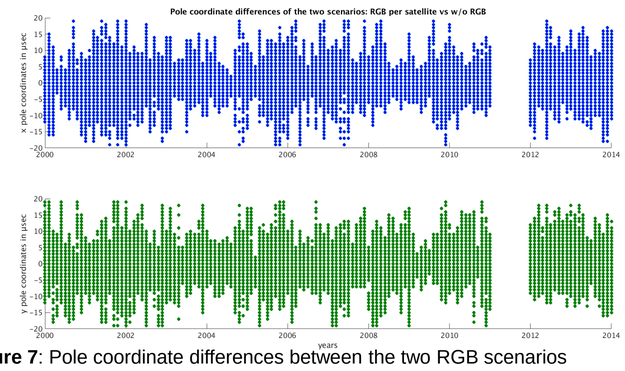


Figure 7: Pole coordinate differences between the two RGB scenarios

Table 3: statistics of pole coordinate differences: w/o RGB scenario vs RGB per satellite (μas.)

	min	max	mean	std
dxp	-19	19	0	6.3
dyp	-19	19	1	6.4

Table 4: statistics of LOD differences: w/o RGB scenario vs RGB per satellite (0.1 μas.)

	min	max	mean	std
dLOD	-29	27	-4	7

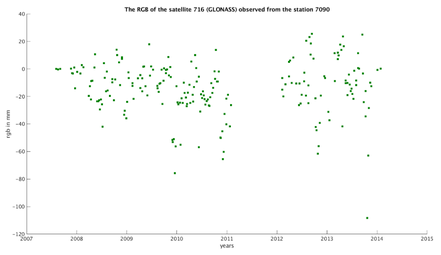


Figure 8a: The estimeted RGB of GLONASS satellite 716 for the station 7090 (**mean=-14.1 mm**, **std=19.4 mm**)

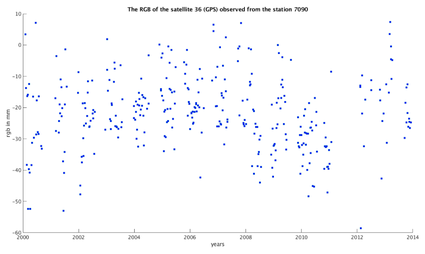


Figure 8b: The estimeted RGB of GPS satellite 36 for the station 7090 (**mean=-21.9 mm**, **std=11.6 mm**)

5. Conclusions

- According to our first results, it seems that the inclusion of the RGB estimation **affects the translations** of the network w.r.t the ITRF2014. The differences between the two scenarios for the translation reach **4.20 mm** (regarding the mean value) for the Z, **3.17 mm** for the X and **2.42 mm** for the Y axes, respectively. The standard deviations for the RGB per station and per GNSS satellite scenario (full scenario) show significantly larger values. **This implies, that the reliable RGBs should be estimated on multiyear (long term) time span instead of weekly**.
- On the other hand, the scale difference is at the level of **0.15 ppb** (0.96 mm), **relatively smaller than the translation effect**. Again the full RGB scenario shows greater dispersion (0.63 vs 0.17 ppb). In addition, we observe a tilt of the scale factor for the years 2000-2004 (for the full RGB scenario). The mean scale after 2004 is biased about **-0.37** ppb, which is practically the same as the scale bias of the w/o RGB scenario.
- For the case of the ERPs, we can observe that the two scenarios **do not differ significantly** (mean difference 0.1 μas for the pole coordinates and 0.4 μsec for the LOD).