Some Aspects of BKG's SLR Contribution to ITRF2020

Daniel Koenig (1), Claudia Flohrer (1), Sadegh Modiri (1), Ulrich Meyer (2), Rolf Dach (2), Daniela Thaller (1)

(1) Federal Agency for Cartography and Geodesy (BKG), Germany (daniel.koenig@bkg.bund.de)
(2) Astronomical Institute of the University of Berne (AIUB), Switzerland

Abstract

BKG as one of the Analysis Centres of the ILRS participated in the ILRS contribution to ITRF2020 by submitting its series of loosely constrained weekly SLR normal equations. For evaluation purposes BKG derived from its weekly submissions a series of weekly Minimum Constraints solutions that are presented here. Mainly the ground network's scale, range biases of selected stations, local ties measurements at the Wettzell fundamental station as well as some statistical figures are discussed. Special focus is put on disturbing influences on the ground network's scale as well as on comparisons to ITRF2020 and BKG's VLBI solutions.

1. Introduction

The solution presented here, henceforward called "BKG-SLR-2020", follows in principle the guidelines the Analysis Centres had to meet for the ILRS contribution to ITRF2020. This means that "BKG-SLR-2020", covering the time span 1993-2020, includes only the LAGEOS satellites from 1993 to 1999 and the LAGEOS plus both Etalon satellites from 2000 to 2020. Whereas in the submission to ITRF2020 loose-constraints of 1 m are applied to all parameters estimated "BKG-SLR-2020" is a series of minimum constraint solutions with NNR-conditions imposed on the core stations only. "BKG-SLR-2020" consists of a time series of 1468 weekly solutions containing station positions, ERP (LOD, Polar Motion) as well as range biases. In parallel, at BKG the VLBI solution series "BKG-VLBI-2020" has been produced in the context of BKG's VLBI contribution to ITRF2020 as a minimum constraint solution, too. Besides a characterization of the SLR solution comparisons between the SLR and the VLBI solution will be presented here.

2. Solution Statistics

In order to characterize the solutions obtained the a-posteriori RMS is considered as well as the number of observations used, and the number of stations involved. The corresponding time series are shown in Fig. 1.

The RMS reveals a stable quality of the solutions as of 2000 on the level of 10 mm. It is a bit higher and more unstable before most probable due to the relatively low number of observations in that period.

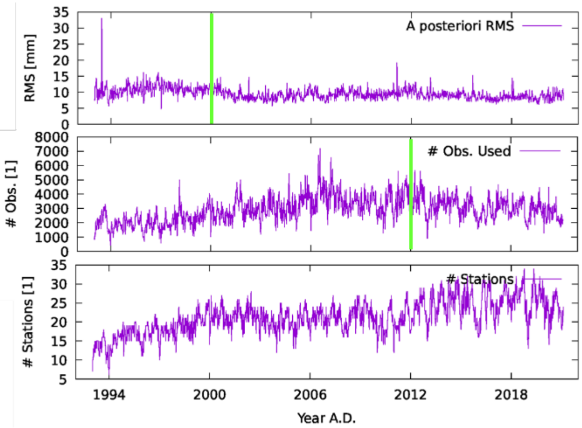

Figure 1. A-posteriori RMS, number of observations used, and number of stations of weekly solutions. The green lines mark a change in the behavior of the time series (see text).

Moreover, the low level of the RMS is supported by a steadily increasing number of stations reaching roughly 20 on average as of 2000 and 25 as of 2012. Concerning the number of observations it has not been investigated whether the decrease as of 2012 is due to an overall decline in SLR activity or due to an increasing number of observations screened. On the other hand, this effect seems to have no impact on the solutions' quality.

3. Geodetic Parameters

In view of a comparison to "BKG-VLBI-2020" the most interesting geodetic parameters to look at are the Earth Rotation Parameters (ERP) as well as the station network's scale.

3.1 ERP

Within "BKG-SLR-2020", the ERP estimated consist of LOD and Polar Motion. For ERP it is quite worthwhile to consider the differences w.r.t. C04 based on ITRF2014 (called "C04" in the following) in order to assess their quality.

In Fig. 2, the differences of the weekly LOD values w.r.t. C04 are shown for both the VLBI and SLR solutions. The WRMS for VLBI is 0.028 ms/d, and 0.048 ms/d in case of SLR. Overall, both time series do not reveal a significant bias, neither w.r.t. C04 nor w.r.t. each other. Higher scatter at annual periods may be seen for SLR as of 2013. The reason for this effect has still to be investigated.

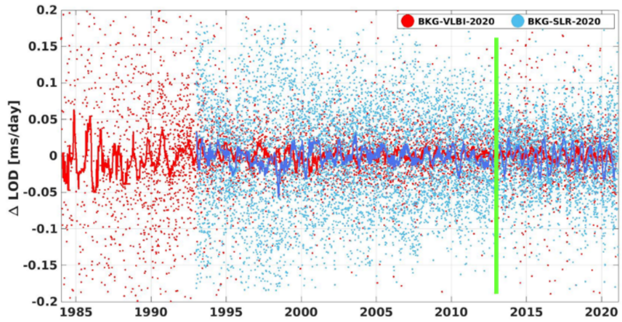

Figure 2. LOD: time series of difference w.r.t. C04. Solid lines: moving median filter (90 d). The green line marks a change in the behavior of the time series (see text).

Concerning Polar Motion, the differences of the weekly values are plotted in Fig. 3 for the x-component, and in Fig. 4 for the y-component.

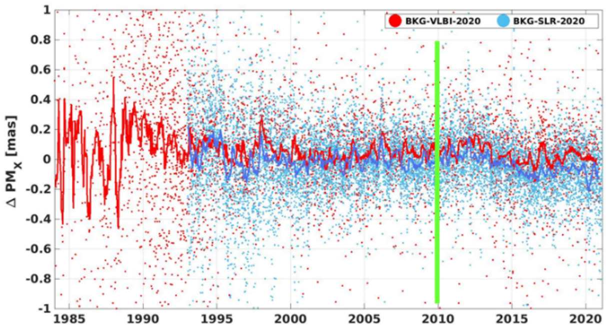

Figure 3. Polar Motion X: time series of difference w.r.t. C04. Solid lines: moving median filter (90 d). The green line marks a change in the behavior of the time series (see text).

For both components, the scatter is quite similar over the common time span. This is underlined by WRMS values for the x-component of 0.208 mas (VLBI) and 0.185 mas (SLR) as well as 0.266 mas (VLBI) and 0.187 mas (SLR) in case of the y-component. On the other hand, as of 2010, there is a significant bias between VLBI and SLR whereas the time series agree quite well before.

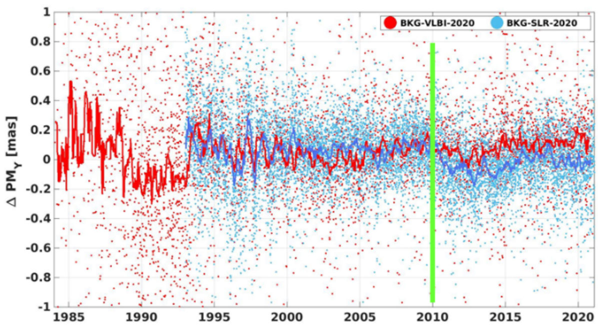

Figure 4. Polar Motion Y: time series of difference w.r.t. C04. Solid lines: moving median filter (90 d). The green line marks a change in the behavior of the time series (see text).

3.2 Scale w.r.t. ITRF2014

In order to derive the scale difference w.r.t. ITRF2014, Helmert transformations are carried out between the estimated station coordinates and those of ITRF2014 for every weekly solution. The whole set of three translations, three rotations, and a scale parameter is estimated using the core stations within each Helmert transformation.

In Fig. 5 the time series of some statistical figures are shown for characterizing the quality of the Helmert transformations. The RMS of transformation reveals a stable quality as of 2002 with low scatter. However, the mean level of the RMS is slightly degrading as of 2012, which seems to be related to a decreasing number of observations. On the other hand, the overall good quality of the Helmert transformations is supported by a stable amount of core stations on the level of about 10 per weekly solution.

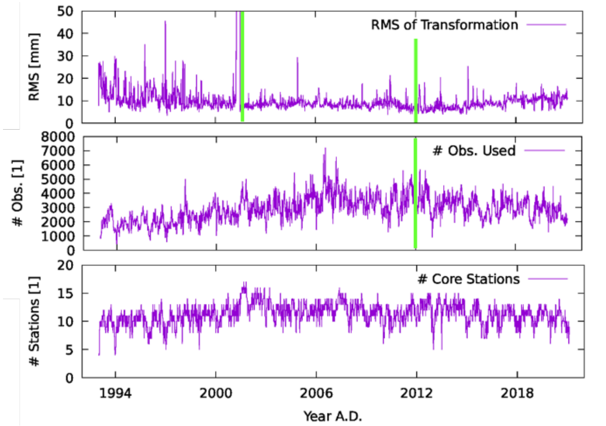

Figure 5. Time series of statistics of Helmert transformations. "# Obs. Used" is the number of Normal Point observations used (same as in Fig. 1), "#Core Stations" is the number of core stations the transformation parameters are estimated for. The green lines mark a change in the behavior of the time series (see text).

The time series of the resulting scale are plotted in Fig. 6 for both the VLBI as well as the SLR solution. Both time series show good agreement revealing similar scatter and no significant bias. This means that both techniques produce a network's scale that is quite similar and, therefore, reliable.

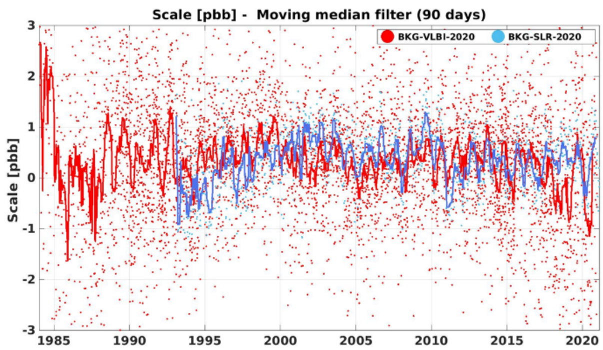

Figure 6. Scale difference w.r.t. ITRF2014: time series. Solid lines: moving median filter (90 d).

4. Local Ties

At BKG's Wettzell fundamental station, there are four observing sites for VLBI and SLR, namely RTW and TTW1 (both VLBI) as well as WLRS and SOSW (both SLR, ILRS-SOD: 8834, 7827), that are connected by local tie measurements and whose observations contributed to ITRF2020. Thus, for these sites, it is possible to compare the results of the local tie terrestrial surveying to the distances calculated based on the estimated coordinates. In Fig. 7, the layout of the local ties in question is shown.

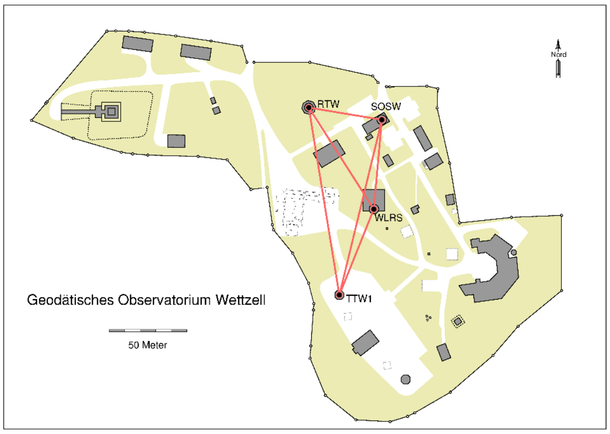

Figure 7. Local tie network between RTW, TTW1, WLRS, SOSW at Wettzell fundamental station.

Based on the solutions BKG-VLBI-2020 as well as BKG-SLR-2020, the distances for each pair of the aforementioned four observing sites are calculated per week. For each pair of observing sites, the resulting mean value is listed in Table 1, along with the value from the terrestrial surveying. It can be seen that the calculated distances are determined with a standard deviation (STD) of 10 mm or better, with the lowest STD for the pairs of the same technique (RTW-TTW1, 3.3 mm; SOSW-WLRS, 5.9 mm). Moreover, the calculated distances match quite well those of the terrestrial surveying. Here, the maximum difference is 4 mm (TTW1-WLRS) and the lowest is 0 (SOSW-WLRS). This underlines the good agreement between the BKG-VLBI-2020 and the BKG-SLR-2020 solutions.

Table 1 Local ties distances at Wettzell fundamental station.

Pair	Calculated from BKG-SLR-2020 BKG-VLBI-2020	Terrestrial Surveying	Difference 1-2
	Mean [m] ± STD [mm]		[mm]
	1	2	3
RTW-TTW1	123.309 ± 3.3	123.307 ± 0.8	2
RTW-WLRS	77.357 ± 10.0	77.358 ± 0.8	-1
RTW-SOSW	48.192 ± 6.4	48.191 ± 0.6	1
TTW1-WLRS	61.014 ± 9.8	61.010 ± 0.7	4
TTW1-SOSW	118.285 ± 10.1	118.283 ± 0.7	2
SOSW-WLRS	58.445 ± 5.9	58.445 ± 0.7	0

5. Conclusions

In order to evaluate BKG's SLR and VLBI submissions to ITRF2020, a time series of weekly minimum constraint solutions for both techniques have been derived. The SLR solutions exhibit a stable quality expressed by an a-posteriori RMS roughly on the level of 10 mm. Furthermore, there is a good agreement between the VLBI and the SLR solutions concerning the estimated LOD and the networks' scale. Additionally, a special view at the local ties of Wettzell fundamental station reveals good agreement between both solutions, too, with the maximum difference between the calculated distances and those from terrestrial surveying not exceeding 4 mm.