Comparison and Combination of SLR Solutions Including Gravity Field Coefficients and Range Biases

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Abstract

Within the GGOS-D project SLR solutions containing station coordinates, Earth rotation parameters (ERPs), range biases and low-degree gravity field coefficients were generated by GFZ and DGFI for the time span 1993-2007. We used these two long-term weekly solutions to study the impact of estimating different parameter sets on the solution. First, all gravity field coefficients were fixed to an accurate a priori gravity field model and the influence of range biases on the station coordinates and ERPs of the weekly solutions was considered. In the second step we considered the influence of estimation of gravity field coefficients of degree one on the solution.

Introduction

Analysis Centres at GFZ and DGFI obtained within the GGOS-D project weekly SLR solutions (Koenig and Mueller, 2006) where in addition to usually estimated from SLR observations parameters (satellite orbits, station coordinates, Earth rotation parameters, range biases etc.) low-degree gravity field coefficients up to degree and order 2 were set up and estimated. The generated weekly solutions cover the time span 1993-2007. The processing strategy, models and parameterization used by GFZ and DGFI were selected to be as consistent as possible to insure the compatibility of the solutions for future combination studies. Differences in the processing strategies within GGOS-D project at DGFI and GFZ concern mainly the cut-off elevation angle and the observations screening procedure what lead to different level of noise in the resulting solutions. Also the list of stations with range biases shows some differences. In principle, range biases are estimated for some stations and for some stations the known values of range biases are applied in the processing. The ILRS lists of stations for which range biases should be applied or estimated are changed from time to time, so the compatibility of different solutions concerning the range biases cannot be always ensured. In this contribution we focus on the properties of individual and combined GGOS-D SLR solutions. We show the influence of range biases and low-degree harmonics on the solution.

GFZ and DGFI SLR solutions

Both GFZ and DGFI GGOS-D weekly solutions contain station coordinates, range biases for some stations and gravity field coefficients for the middle of the week and daily Earth Rotation Parameters (x-pole, y-pole and UT1). Starting from the free normal equations from both analysis centres we computed weekly SLR solutions using Bernese GPS Software (Dach et al., 2007). All the gravity field coefficients were first fixed to the model EIGEN-GL04C (Foerste et al., 2006). In this case we need to constrain only the rotations of the whole network to adjust it to a certain terrestrial reference frame, because SLR observations provide direct access to the Earth's center of mass and the scale. The no-net-rotation condition was applied over a set of stable stations (6-9 stations for each week). Since in these solutions UT1 was set up as a parameter and not LOD which can only be directly estimated from satellite observations, we also always fixed the first daily UT1 estimate to the a priori value and the other daily UT1 parameters within a week were estimated as piece-wise linear functions. As a priori coordinates we used re-scaled ITRF2005 for SLR, and for a priori ERPs IERS time series C04 was used.

Figures 1 and 2 show as an example time series of ERPs w.r.t. a priori C04 values. DGFI solution is noticeably noisier than GFZ solution because it includes about 10% more observations due to the different cut-off elevation angle (1° for DGFI solution, 10° for GFZ) and different screening of the observations. Nevertheless the weighted root-mean-square values for x-pole, y-pole and UT1 estimates are on approximately the same level for both solutions, as can be seen from Table 1. To get an idea about possible systematic differences in the coordinates, we computed Helmert transformation parameters between GFZ and DGFI solutions. We do not show here pictures for the time series of transformation parameters, because there are no systematic components and all the parameters are scattered around zero. Differences between ERPs time series also do not show any systematic effects. Combined GFZ-DGFI solution shows a little bit better WRMS values for polar motion and somewhat worse value for UT1, what is seen from Table 1.

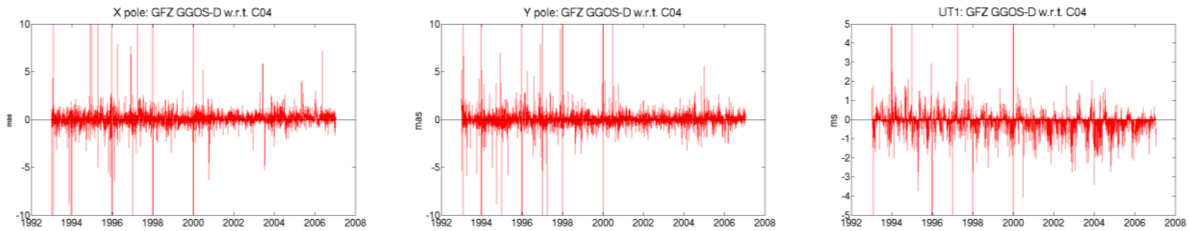

Figure 1. GFZ solution, x-pole (left), y-pole (middle), UT1 (right) w.r.t. C04

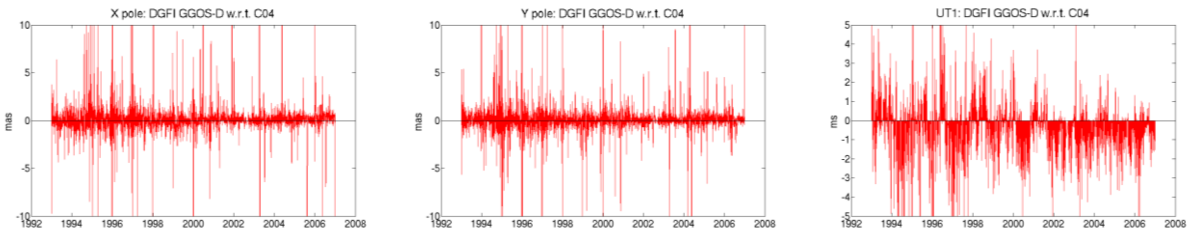

Figure 2. DGFI solution, x-pole (left), y-pole (middle), UT1 (right) w.r.t. C04

At the same time a comparison of GFZ GGOS-D weekly solutions with GFZ solutions for the ILRS shows some systematic differences both for the coordinates and ERPs. Weekly GFZ ILRS solutions, containing station coordinates and daily ERPs, were also re-processed starting from the free normal equations applying only no-net-rotation condition over the same set of stations as for GGOS-D solution. In Fig. 3 we show time series of scale parameter between GFZ GGOS-D and GFZ ILRS solutions, a clear periodic component is well-seen. Fig. 4 shows x-pole differences between the solutions, here we can see a systematic shift of about 0.2 mas. Y-pole differences do not show a systematic shift. The possible reasons for these systematic effects could be different processing options, such as using different a priori models and different parameter sets. DGFI GGOS-D and ILRS solutions, although again more scattered than GFZ solutions, do not show these clear systematic differences.

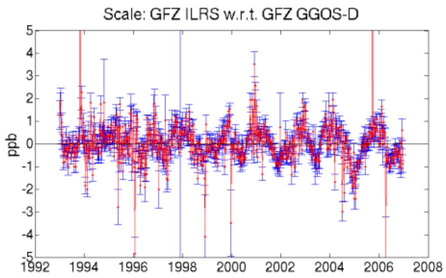

Figure 3. Scale between GFZ GGOS-D and GFZ ILRS weekly solutions

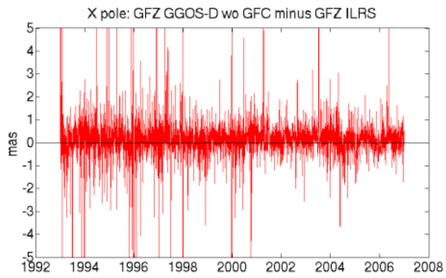

Figure 4. X-pole differences between GFZ GGOS-D and GFZ ILRS weekly solutions

Influence of range biases

Fig.5 shows an example of range biases estimates from GFZ solution for station Riga 1884. To get a general impression of the influence of range biases on the solution we computed a test GFZ solution where all the estimated range biases were fixed to zero. This test solution was compared to the normal GFZ solution with estimated range biases. Since the estimated values of range biases can vary from some millimetres to more than 10 cm, we can expect significant differences. Fig. 6 shows ERP differences between these solutions, it can be seen that the differences are more noticeable for the first part of time series, when the number of estimated range biases was also larger – about 4-8 till 1998, and about 1-2 afterwards. Helmert transformation parameters between the solutions show similar picture – more scatter in the first part of the time series and no noticeable systematic components, we do not show the corresponding graphics here. For the stations with range biases the coordinate difference between the solutions amounts to the range bias value, which is significant. This means that solutions obtained with different lists of range biases cannot be combined without distorting the solution.

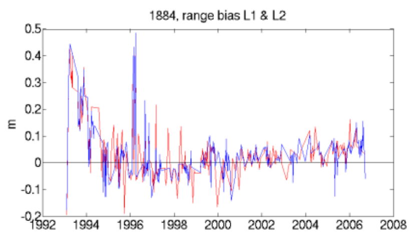

Figure 5. Range biases for station 1884 from GFZ GGOS-D solution.

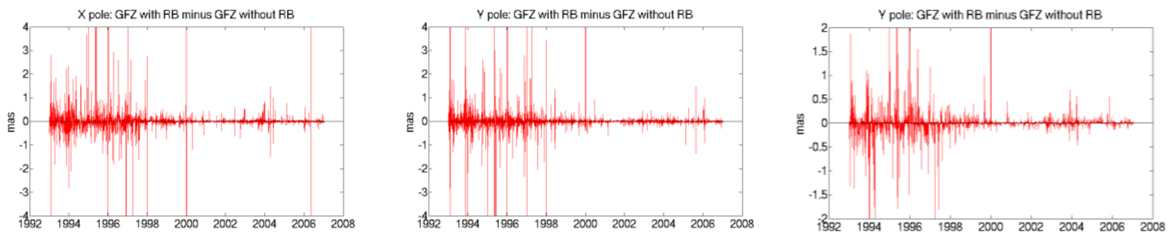

Figure 6. ERP differences for GFZ solutions with range biases estimated and range biases fixed to zero, x-pole (left), y-pole (middle), UT1 (right)

While computing a combined weekly solution we can estimate range biases from the individual solutions separately or we can stack them within a week. To estimate a possible influence of stacking range biases, we made a comparison between combined GFZ-DGFI weekly solutions with range biases stacked (separately for Lageos I and II) and with range biases estimated for both individual solutions. Fig. 7-9 show Helmert transformation parameters between these two combined solutions. As can be seen the coordinate differences are larger for the first part of the time series, what corresponds to the greater number of stations with range biases in the solutions, but still even for the most affected by range biases Z-translation the differences do not amount to 1 mm, so they can be considered negligible. The differences in the ERPs, which are not shown here, are also not significant. When we in addition stack range biases from Lageos I and II, the differences become more noticeable and amount for Tz component to 4-5 mm.

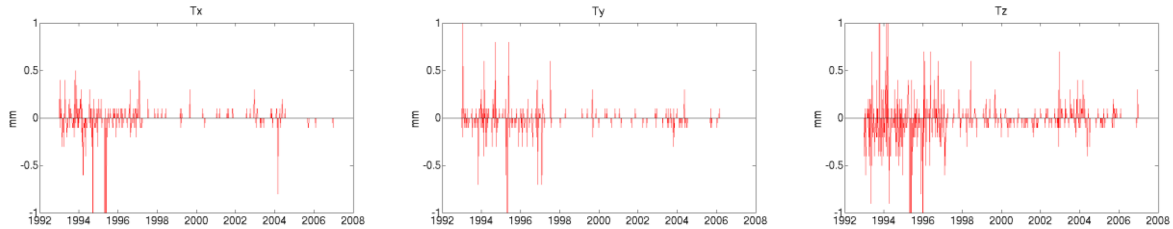

Figure 7. Translations between GFZ-DGFI combined weekly solutions with range biases stacked and not stacked

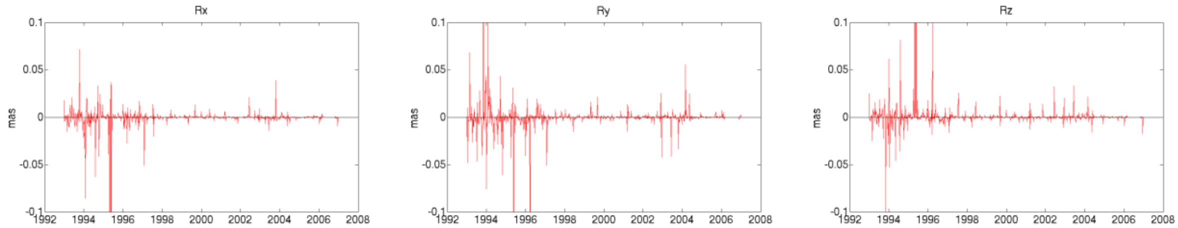

Figure 8. Rotations between GFZ-DGFI combined weekly solutions with range biases stacked and not stacked

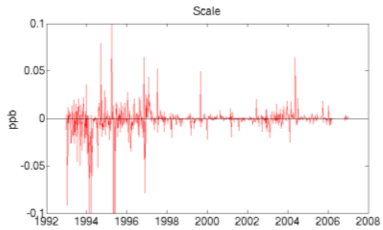

Figure 9. Scale between GFZ-DGFI combined weekly solutions with range biases stacked and not stacked

Estimation of 1st degree gravity field coefficients

To have a look at the influence of estimation in addition low degree harmonics on the solution we computed test GFZ GGOS-D weekly solutions where 1st degree gravity field coefficients (GFC) were estimated. In this case we need to apply (in addition to no-net-rotation condition) a no-net-translation condition to fix the solution to the ITRF. Gravity field coefficient C00 and all the coefficients of 2nd degree were kept fixed to a priori values to avoid the correlations with other parameters. The random errors of the ERPs from this solution remain on the same level as for the solution without GFC (see Table 1). The differences in ERPs between the solutions with estimated GFC and fixed GFC are shown in Fig. 10. Some periodic components can be seen there. The transformation parameters between these two solutions should directly correspond to the estimated first degree gravity field coefficients, C11 corresponds to Tx, S11 to Ty and C10 to Tz (e.g. Cretaux et al., 2002). In the Fig. 11 and 12 we show translations between the solutions, the high level of correlation with the GFC is well seen. The annual and semiannual signals presented in Table 2 also show a good level of agreement. This periodic geocenter motion agrees quite well with the results from (Angermann et al, 2002), where the annual amplitudes were estimated to be 2.82 mm in Tx, 3.04 mm in Ty, 5.09 mm in Tz, and semiannual amplitudes 0.57 mm in Tx, 0.53 mm in Ty and 1.07 mm in Tz.

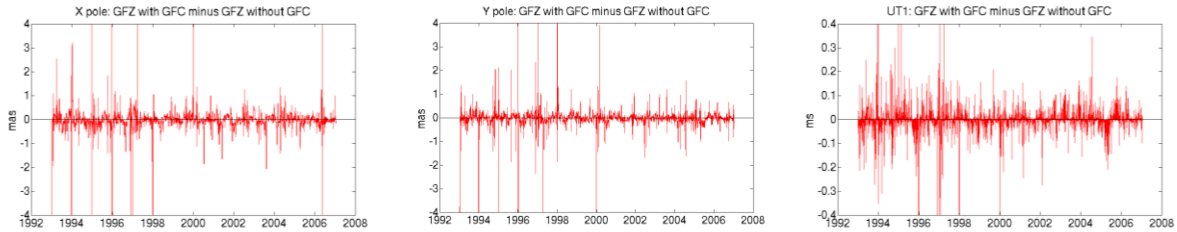

Figure 10. ERP differences between GFZ GGOS-D solutions with fixed gravity filed coefficients and estimated ones: x-pole (left), y-pole (middle), UT1 (right)

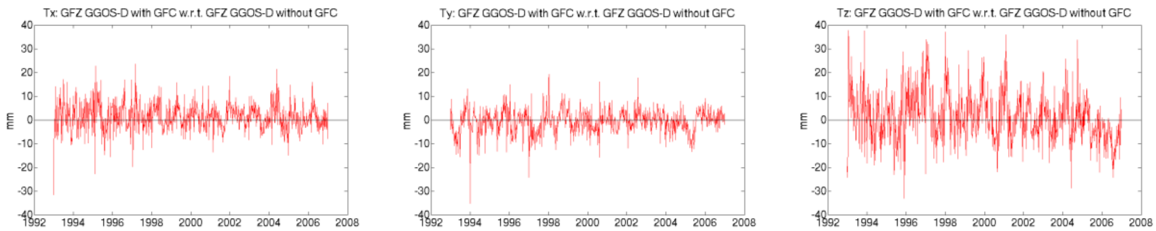

Figure 11. Translations between GFZ GGOS-D solutions with fixed gravity filed coefficients and estimated ones: Tx (left), Ty (middle), Tz (right)

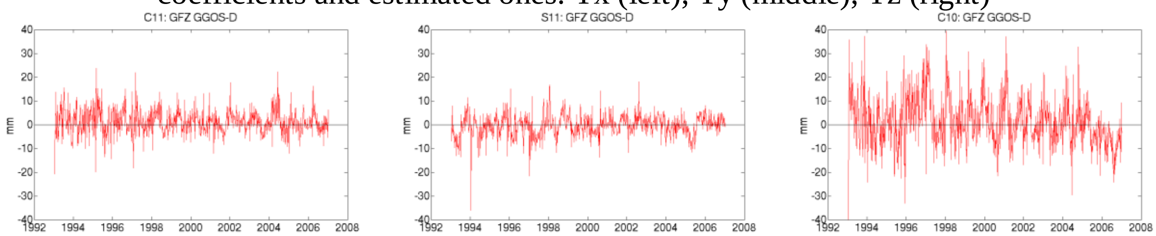

Figure 12. 1st degree gravity field coefficients: C11 (left), S11 (middle), C10 (right)

Table 1. Weighted RMS of ERPs from GFZ, DGFI and a combined solution

	GFZ, no GFC	DGFI, no GFC	comb, no GFC	GFZ, 1st deg. GFC	DGFI, 1st deg. GFC	comb, 1st deg. GFC
Xp, mas	0.35	0.38	0.33	0.37	0.38	0.35
Yp, mas	0.35	0.37	0.31	0.34	0.36	0.32
UT1, µs	0.11	0.12	0.14	0.11	0.12	0.15

Table 2. Annual and semiannual amplitudes (mm) in translation parameters and 1st degree gravity field coefficients.

	Annual amplitude, mm	Semiannual amplitude, mm
Tx	2.3 ± 0.3	0.6 ± 0.3
C11	1.9 ± 0.3	0.6 ±0.3
Ty	2.5 ± 0.2	0.3 ± 0.2
S11	2.2 ± 0.2	0.3 ± 0.2
Tz	4.8 ± 0.5	1.2 ± 0.5
C10	4.6 ± 0.5	1.3 ± 0.5

Conclusions

Within the GGOS-D project SLR weekly solutions including low-degree harmonics were generated by GFZ and DGFI. The standards adopted for these solutions were different than those used for ILRS Analysis Centre processing, what causes systematic differences in station coordinates and ERP between GGOS-D and ILRS solutions. The comparison shows no systematic differences between DGFI and GFZ GGOS-D solutions. Tests performed on these solutions concerning the stacking of range biases within a week showed no significant influence on the combined GFZ-DGFI solutions, although the differences in range biases applied in the processing will cause a distortion of station network. Estimating in addition 1st degree gravity field coefficients doesn't change the random error of the obtained parameters, but it introduces a periodic systematic difference in the station coordinates due to geocenter motion.

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