3.6.2.6 GeoForschungsZentrum Potsdam (GFZ)

Introduction

Most of the work related to the IERS CRC at GFZ is embedded in the project "GGOS-D" (see Section 3.7.2 "WG on Combination" for more details). The major features of this project are the high degree of standardization of the modeling and parameterization between the software packages used, the consistent reprocessing of all observations and the exchange of datum-free normal equation systems (NEQs). Thus, the resulting time series of parameters are very homogeneous and a rigorous combination of the individual contributions is possible. The following topics were studied in 2007:

- Subdaily Earth rotation parameters from GPS and VLBI
- SLR combination including low-degree harmonics of the Earth's gravity field
- Combined Earth Orientation Parameters
- Combination of the GPS ground network and Low Earth Orbiters (LEOs)

Subdaily Earth Rotation Parameters from GPS and VLBI

The space geodetic techniques GPS and VLBI are able to observe subdaily variations in Earth rotation that are mainly caused by ocean tides. As the periods of these tides are well-known, their amplitudes can be estimated in a weighted least squares adjustment using subdaily ERP time series as pseudo-observations. Such subdaily ERP models were determined from homogeneously reprocessed GPS and VLBI longtime series. The GPS series (Steigenberger et al., 2006) covers the time period January 1994 till October 2005 with an ERP spacing of 2 hours. The VLBI solution was computed by Goddard Space Flight Center from 3804 VLBI sessions between 1980 and 2007 with a parameter spacing of 1 hour. The largest tidal amplitudes of the GPS and VLBI subdaily ERP models estimated from these series as well as the IERS2003 model (McCarthy and Petit, 2004) are shown in Fig. 1. The polar motion amplitudes in general agree on the level of 4.2 to 9.4 µas, the UT1 amplitudes differences are between 0.5 and 1.1 µs. The maximum differences can reach up to 16.9 µas and 2.4 µs, respectively.

As the GPS and VLBI subdaily ERP models discussed above showed a high level of consistency, a simple combined GPS/VLBI model has been computed. Tab. 1 lists the RMS differences of the GPS and VLBI single-technique models and the combined model w.r.t. the IERS2003 model. A significant RMS reduction of 15 and 40 % could be achieved for diurnal and semidiurnal prograde polar motion, respectively. For retrograde polar motion, the RMS differences of the combined model are slightly worse compared to the GPS model but smaller by a factor of almost two compared to the VLBI model. For UT1, the impact of the combination is smaller: the

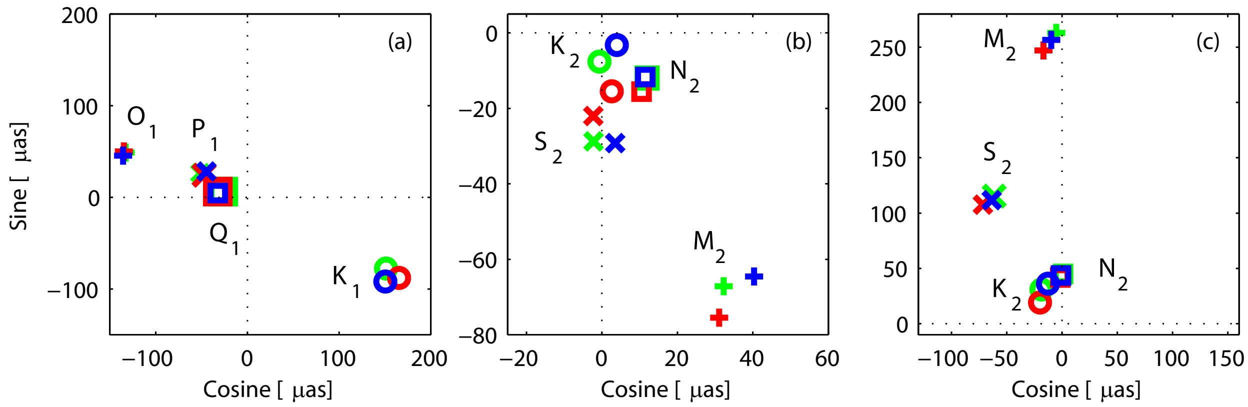

Fig. 1: Major tidal amplitudes in polar motion from GPS (blue), VLBI (red) and the IERS2003 model (green): (a) diurnal prograde polar motion; (b) semidiurnal prograde polar motion; (c) semidiurnal retrograde polar motion.

diurnal RMS differences of the combined model are slightly larger than that of the single-technique solutions whereas for semidiurnal UT1, the RMS values of the combined model are almost the same as for the GPS-only model.

Table 1: Mean RMS differences of the GPS and VLBI single-technique and the combined subdaily ERP models w.r.t. the IERS2003 model.

	GPS	VLBI	Combined
Prograde diurnal polar motion [µas]	4.2	4.3	3.7
Prograde semidiurnal polar motion [µas]	2.7	3.3	2.0
Retrograde semidiurnal polar motion [µas]	2.8	5.8	3.1
Diurnal UT1 [µs]	0.38	0.38	0.44
Semidiurnal UT1 [µs]	0.60	0.67	0.59

Combined Earth Orientation Parameters

Since the space-geodetic techniques GPS and VLBI now have a long history of data, the time series of Earth orientation parameters (EOP) that can be estimated covers more than a decade. Although computing a solution for the entire time span including station coordinates, velocities and all EOPs in only one step yields the most consistent parameters, it may be very time consuming. Therefore, the question arises how large the differences are compared to the full solution if the time series of EOP is computed from sub-intervals of data, e.g., one day, one week, one year, etc.

We compared time series of EOPs derived from daily solutions with the time series derived from a full solution for the time span 1994 until 2006. Figure 2 shows the differences exemplarily for the x-pole in case of a combined GPS-VLBI solution (WRMS of the differences: 76.7 µas). It becomes clear that the largest differences are visible in the early years, whereas only marginal differences are present for epochs later than approximately 1997. Similar comparisons were done for the GPS-only time series and the VLBI-only time series. As regards the GPS-only time series, the results look similar to those for the combined time series (WRMS of the differences: 70.7 µas), whereas the comparison between the daily VLBI solutions and the multi-year VLBI solution shows differences of the same size for the whole time span (WRMS of the differences: 177.8 µas) that are in the order of the differences seen for the early years of the combined time series (Fig. 2). From this behavior it can be concluded, that time series of EOP derived from daily solutions differ most from a multi-year solution if the observing network of the corresponding day is clearly weaker than the full network of the multi-year solution.

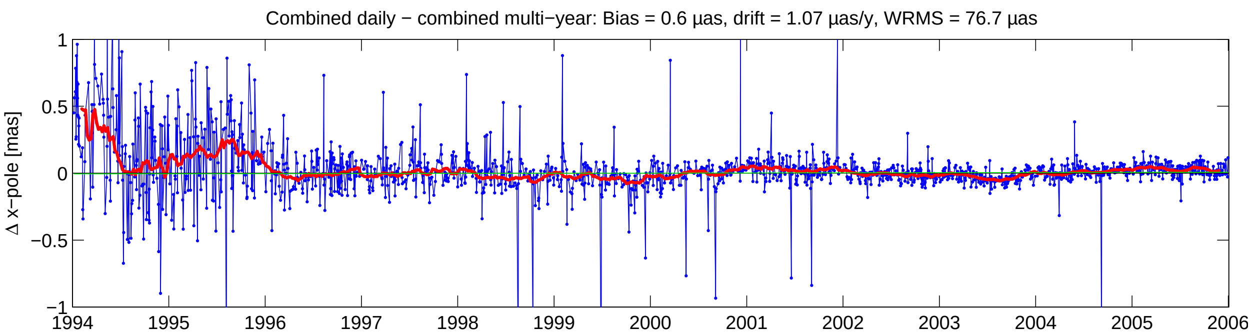

Fig. 2: Comparison of time series of x-pole derived from daily solutions with the time series derived from a full solution for the time span 1994 until 2006 (combined GPS-VLBI solution).

SLR Combination Including Low Degree Harmonics of the Earth's Gravity Field

Weekly SLR solutions for the years 1993–2007 with estimated low degree gravity field coefficients were used to check the correspondence between the geometric translations and the degree one gravity field coefficients. Both sets of parameters represent the same phenomenon – the motion of the geocenter – and should give approximately the same result. We calculated two multiyear-solutions – in the first one, the gravity field coefficients were fixed to their a priori values and the geometric translations were set up as parameters and estimated. In the second solution, the degree one gravity field coefficients were estimated. In Figs. 3–5 the time series of the parameters are presented. There is a good agreement between the geometric translations and the gravity field coefficients, the discrepancy seen in the time series of the Y-translation and the S11 coefficient might be caused by the influence of the a priori reference frame and by crustal deformations. The correlation between these two sets of parameters is on the level of 0.97–0.99.

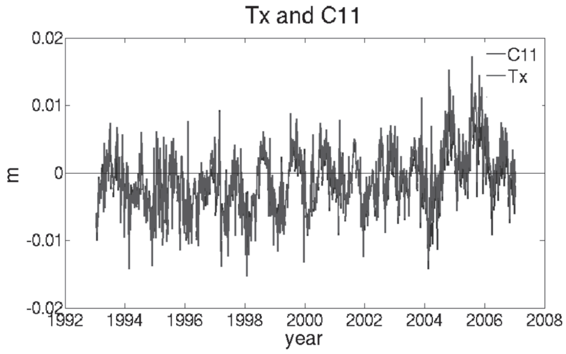

Fig. 3: X-translation and gravity field coefficient C11.

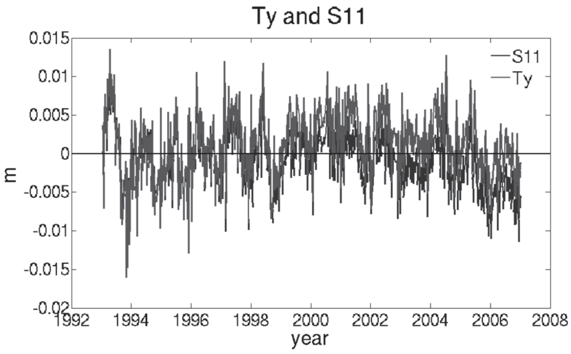

Fig. 4: Y-translation and gravity field coefficient S11.

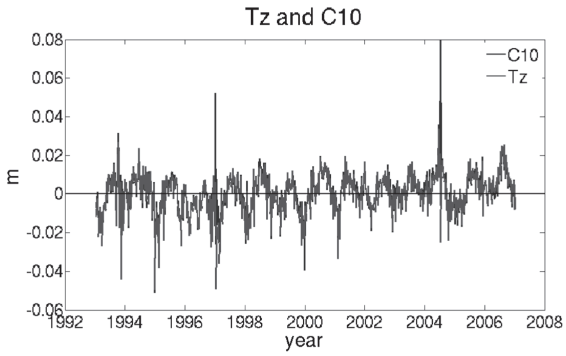

Fig. 5: Z-translation and gravity field coefficient C10.

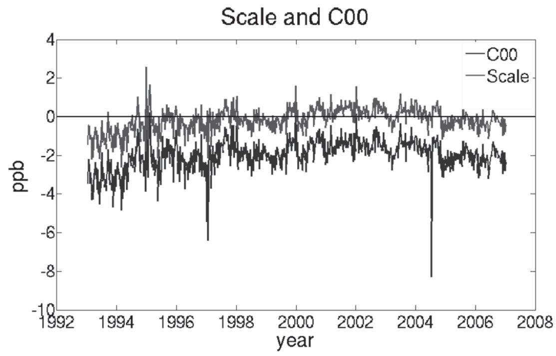

Fig. 6: Scale and gravity field coefficient C00.

The C00 gravity field coefficient and the geometric scale were compared in the same way, the result is shown in Fig. 6. Since the correspondence between geometric scale and C00 is not as direct as in the case of translations and degree one gravity field coefficients, it is likely that these parameters can be estimated simultaneously. Indeed in the normal equation system the correlation between them is on the level of 0.006, which means that they are separable. In the long term we see in Fig. 6, however, that besides a constant bias of about 1.8 ppb, a high correlation of about 0.93 exist between the time series.

Combination of the GPS Grund Network and Low Earth Orbiters (LEOs)

The IERS CRC at GFZ has continued determining station positions, Earth Orientation Parameters (EOPs), and spherical harmonic gravity field coefficients of low degree in the integrated mode using its EPOS software, see Zhu et al. (2004). The advantage of the integrated approach is the simultaneous and consistent processing of all available observational data and the estimation of all parameters including those needed to accurately account for the deficiencies of dynamic, geometric and observational models. The constellation processed comprises GPS ground stations of the IGS- and GFZ-networks, the GPS satellites, as well as the Low Earth Orbiters (LEOs) CHAMP and GRACE. The observational data include GPS and SLR tracking data to the GPS and LEO satellites, as well as accelerometer, attitude, and K-Band inter-satellite measurements collected on-board the LEOs, where the K-Band data are specific to GRACE. The dense and accurate CHAMP and GRACE data allow a high resolution of the sought for reference frame parameters.

Processing the data of the year 2004 in the framework of GGOS-D, it could be proved in terms of reduced residuals and reduced scatter of parameter time series that the integrated mode delivers more accurate results than the commonly applied sequential processing of the GPS and the LEO constellations. With a rather loose datum definition and solving for the aforementioned parameters, the integrated mode directly gives insight into the correlations and the separability of the estimated parameters. Thus it became clear that the possibility exists of estimating the geometric and the dynamic reference frame in one step. The results have been compared to time series derived independently from pure SLR observations to the LAGEOS satellites and to routine products from the GRACE mission.

The combination of LAGEOS and GRACE on the normal equation level was analyzed for the generation of low-degree harmonics. In addition, preparations were made for a new LEO mission, the TerraSAR-X mission, which also carries the GPS two-frequency receiver of type CHAMP and GRACE. TerraSAR-X POD results produced operationally indicate few centimeter orbit accuracies in the sequential processing mode.

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