3.6   ITRS Combination Centres

3.6.1   Deutsches Geodätisches Forschungsinstitut der TU München (DGFI-TUM)

In 2017, the ITRS Combination Centre at DGFI-TUM focuses on further comparisons of the three ITRS realizations, the ITRF2014 (IGN, France; Altamimi et al. 2016), the JTRF2014 (JPL, USA; Abbondanza et al. 2017) and the DTRF2014 (DGFI-TUM, Germany; Seitz et al. 2016). This report comprises the three following topics: (1) SLR and VLBI scale investigations, (2) comparison of the three ITRS realizations by Precise Orbit Determination (POD) of SLR satellites, and (3) consistent realization of the terrestrial and celestial reference systems.

SLR and VLBI scale investigations

At DGFI-TUM, detailed investigations on the scale of the terrestrial reference frame which is realized by a weighted mean of SLR and VLBI observations have been performed. This was largely motivated by the fact that a scale bias of 1.37 ppb between SLR and VLBI has been found in the ITRF2014 solution (Altamimi et al., 2016) which is not visible in the DTRF2014 solution (Seitz et al., 2016). The results of the scale investigations were presented at the IAG-IASPEI 2017 Scientific Assembly in Kobe, Japan, and are published in the corresponding IAG-IASPEI Symposia Proceedings (Bloßfeld et al., 2018). A summary of the outcome of these investigations is given below.

As recommended by the IERS Directing Board, in a first step, the long-term single-technique SLR and VLBI solutions provided by DGFI-TUM and IGN were compared directly. It was found that no scale bias is visible in the SLR and VLBI intra-technique solutions of IGN and DGFI-TUM. The results of 14-parameter Helmert transformations between the IGN and DGFI solutions show a scale agreement within 0.2–0.3 ppb for the single-technique VLBI and SLR solutions. This indicates that the effects might be caused by the inter-technique combination. Furthermore, two different test scenarios were applied to compare the individual SLR and VLBI solutions of DGFI-TUM: (i) direct comparison by using the available co-location sites between both techniques, and (ii) an indirect comparison of VLBI and SLR via GNSS co-locations. The results of these tests confirmed that the DTRF2014 does not show a significant bias between the SLR and VLBI scale (see Bloßfeld et al. 2018 for more details).

To further investigate the scale bias between VLBI and SLR, the three ITRS realizations were compared with the combined VLBI and SLR solutions obtained by the Combination Centres (CC) of the IVS and ILRS, respectively. Fig. 1 shows epoch-wise estimated scale parameters

of the IVS combined solutions (VLBI-only) w.r.t. several TRF realizations. It is clearly visible that the DTRF2008, the DTRF2014, the JTRF2014, and the quarterly VLBI-only TRF solution VTRF2015q2 agree quite well with the IVS combined solutions showing a mean value close to 0. The ITRF2008 as well as the ITRF2014 show a mean bias of about -0.5 ppb. Similar investigations have been performed for SLR by the primary ILRS CC located at ASI (Italy). Fig. 2 displays the epoch-wise estimated scale parameters of the combined ILRSA solutions w.r.t. the most recent ITRS realizations. Again, the DTRF2014 as well as the JTRF2014 do not show a long-term mean offset w.r.t. the SLR-only solutions, whereas the ITRF2014 shows a mean offset of about 0.7 ppb. Thus, the DTRF2014 and the JTRF2014 do not distort the scale of the VLBI and SLR subnets.
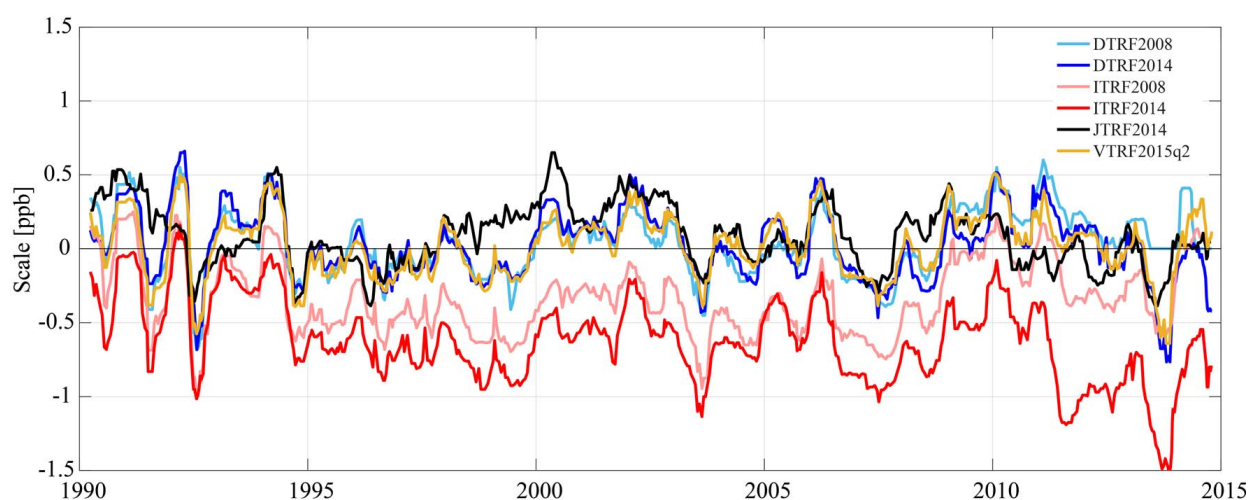

Fig. 1: *Scale of the combined IVS solutions w.r.t. different TRF realizations. This plot has been kindly provided by S. Bachmann in July 2017 (IVS CC at BKG, Germany).*

Comparison of ITRF2014, JTRF2014, DTRF2014, and SLRF2008 by POD of SLR satellites

The three ITRS realizations ITRF2014, DTRF2014 and JTRF2014 have been evaluated by using their station positions as apriori values within Precise Orbit Determination (POD) for SLR satellites. This study was based on POD of ten geodetic satellites at high (with an altitude more than 2000 km) and low (with an altitude below this value) Earth orbiting geodetic satellites in total over 24 years from 1993.0 to 2017.0 using SLR-only orbit determination (see Rudenko et al., 2018). In this report, we present as an example of this POD study some results for the SLR satellites Lageos-1 and Starlette (see Fig. 3). The results revealed almost the same accuracy level for the ITRF2014, JTRF2014 and DTRF2014, and all of them performed better than the previous realization for SLR, the SLRF2008. It was found from this analysis that the JTRF2014 (after an editing done for SLR stations Conception and Zimmerwald) and DTRF2014+NTL (with non-tidal loading corrections
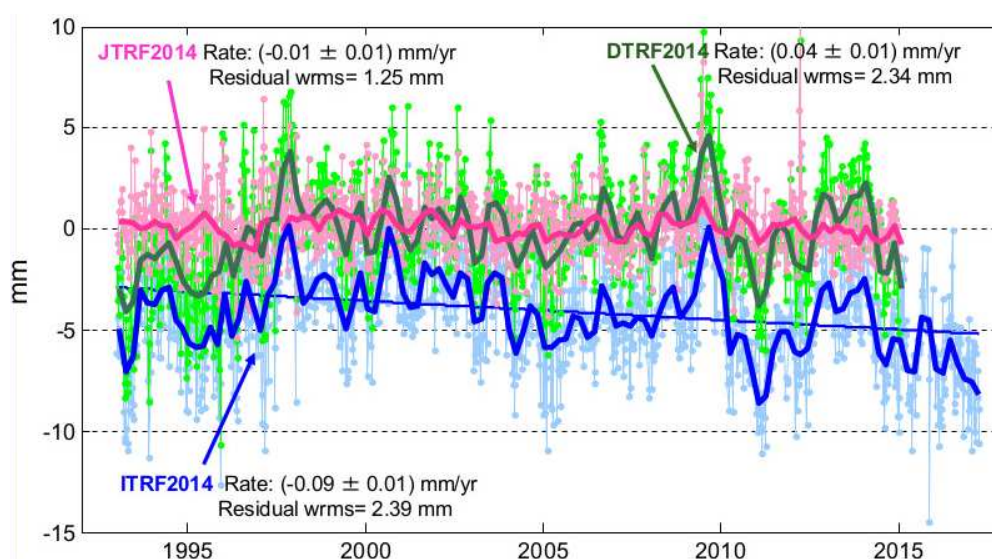
Fig. 2: *Scale of the combined ILRSA solutions w.r.t. different TRF realizations. This plot has been kindly provided by C. Luceri in July 2017 (ILRS CC at ASI, Italy).*

applied) showed the best performance, however, the differences be-tween the ITRS realizations obtained from the POD studies are only at (or below) the mm-level. The SLRF2008 and ITRF2008 cause a 0.2 – 0.3 mm/y trend in the mean of SLR fits in the time span 2001.0 – 2017.0. Further details on these studies can be found in Rudenko et al. (2018).
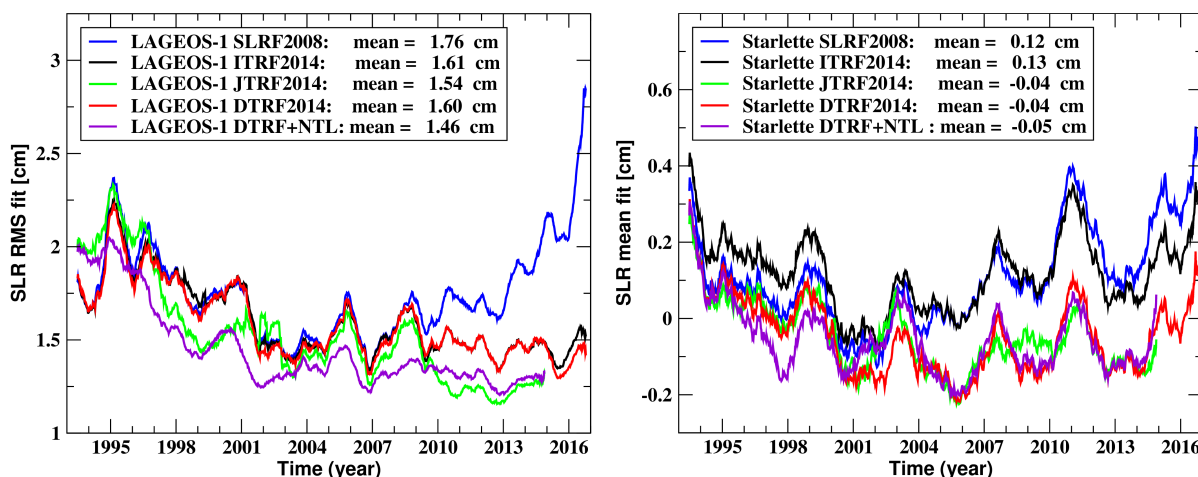

Fig. 3: *(Left) 50-week running averages of the RMS fits of SLR observations (in cm) for LAGEOS-1 orbits derived using SLRF2008, ITRF2014, JTRF2014, DTRF2014 linear, and DTRF2014+NTL. (Right) 50-week running averages of the mean fits of SLR observations (in cm) for Starlette orbits derived using SLRF2008, ITRF2014, JTRF2014*
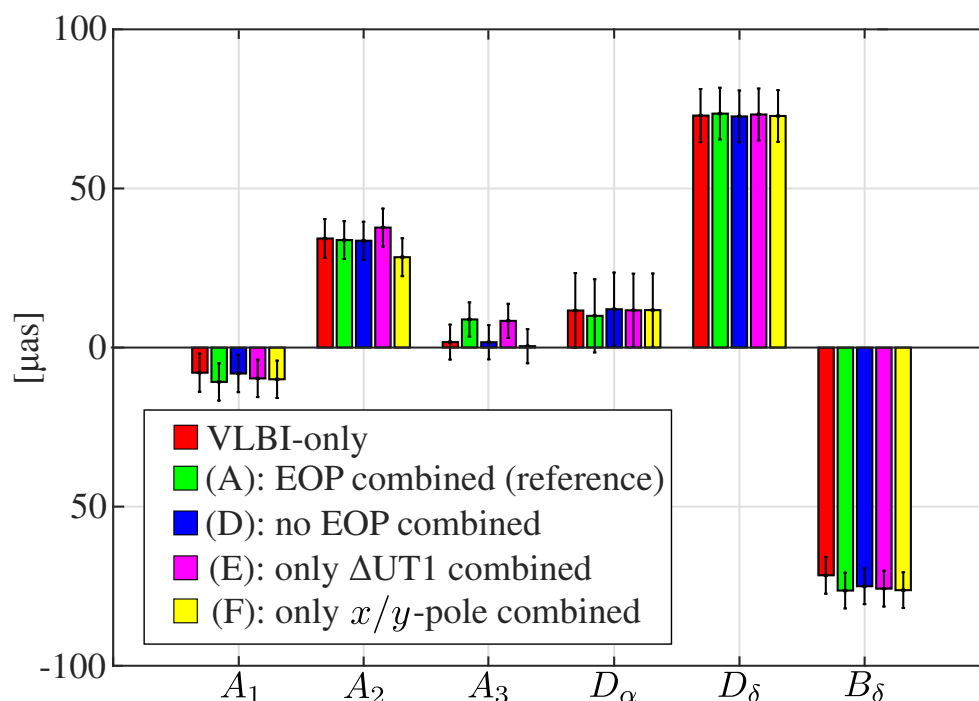
Fig. 4: *CRF transformation parameters and their standard deviations (error bars) of VLBI-only and different EOP combination setups w.r.t. ICRF2. A_1, A_2 and A_3 denote the rotations between two CRFs w.r.t. the three axes, D_α, D_δ represent the drifts of right ascension and declination, and B_δ means a bias in declination.*

Consistent realization of the terrestrial and celestial reference systems

With the Resolution No. 3 of the International Union of Geodesy and Geophysics (IUGG) adopted by the General Assembly in 2011, the IUGG urged "that highest consistency between the ICRF, the ITRF, and the EOP as observed and realized by the IAG and its components such as the IERS should be a primary goal in all future realizations of the ICRS". So far, the highest consistency could not be achieved, as three independent IERS product centers are in charge of computing the terrestrial and celestial reference frame as well as the EOP. At DGFI-TUM, various studies and test combinations have been performed to estimate all three components (CRF, TRF and EOP) in a common adjustment. In 2017, within the project "Consistent celestial and terrestrial reference frames by improved modelling and combination" as part of the DFG Research Unit FOR1503 "Space-time reference systems for monitoring global change and for precise navigation in space", a simultaneous and consistent realization of TRF, CRF and EOP (Kwak et al., 2018) in accordance with the IUGG Resolution was obtained. The joint parameter estimation was based on homogeneously processed VLBI, GNSS, and SLR single-technique solutions for 11 years (2005.0–2016.0). Several types of combined solutions were computed following the selections of different local ties, EOP combination setups, and different weights of the techniques. The impacts of the different combination setups on

CRF, TRF, and EOP were investigated. The following conclusions were derived (more details are reported in Kwak et al., 2018):

- The combination of different space geodetic techniques improves the precision of the estimated parameters due to the larger number of observations.

- The CRF benefits from the precise terrestrial x/y-pole coordinates estimated by GNSS (Fig. 4).

- The combination of ΔUT1 from VLBI and the satellite techniques affects the right ascension and therefore the CRF z-rotation (Fig. 4).

- It became evident that the common determination of TRF, CRF and EOP systematically influences future CRF computations at the level of several μas.

References

Abbondanza C., Chin T., Gross R., Heflin M., Parker J., Soja B., van Dam T., Wu X.: JTRF2014, the JPL Kalman filter and smoother realization of the International Terrestrial Reference System, J. Geophys. Res. Solid Earth, doi:10.1002/2017JB014360, 2017

Altamimi, Z., P. Rebischung, L. Metivier, and C. Xavier: ITRF2014: A new release of the International Terrestrial Reference Frame modeling nonlinear station motions, J. Geophys. Res. Solid Earth, 121, doi:10.1002/2016JB013098, 2016

Bloßfeld M., Angermann D., Seitz M.: DGFI-TUM analysis and scale investigations of the latest terrestrial reference frame realizations, IAG-IASPEI Symposia Proceedings, Springer, 2018

Kwak Y., Bloßfeld M., Schmid R., Angermann D., Gerstl M., Seitz M.: Consistent realization of celestial and terrestrial reference frames. J. Geod., doi:10.1007/s00190-018-1130-6, 2018

Rudenko S., Bloßfeld M., Müller H., Dettmering D., Angermann D., Seitz M.: Evaluation of DTRF2014, ITRF2014 and JTRF2014 by Precise Orbit Determination of SLR Satellites. IEEE T. Geosci. Remote, 56(6), 3148–3158, doi:10.1109/TGRS.2018.2793358, 2018

Seitz M., Bloßfeld M., Angermann D., Schmid R., Gerstl M., Seitz F.: The new DGFI-TUM realization of the ITRS: DTRF2014 (data). Deutsches Geodätisches Forschungsinstitut, Munich, doi:10.1594/PANGAEA.864046, 2016

Detlef Angermann, Mathis Bloßfeld, Manuela Seitz,
Younghee Kwak, Sergei Rudenko