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3.6 ITRS Combination Centres

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

In 2018, the ITRS Combination Centre at DGFI-TUM focused on the investigation of the impact of considering non-tidal loading corrections on ITRS realizations, in particular on the geodetic datum parameters and the station positions. Furthermore, the institute focused on the continuation of the research activities on the consistent realization of ITRS and ICRS.

Considering non-tidal loading signals in ITRS realizations

The DTRF2014 solution is the first ITRS realization considering non-tidal atmospheric and hydrological loading corrections. According to the combination strategy of DGFI-TUM, the correction values are applied at the normal equation level. The atmospheric and hydrological model values are based on the NCEP and the GLDAS model, respectively, and are provided by Tonie van Dam (GGFC). As the non-tidal signals possess in particular dominant annual and semi-annual signals, a significant effect on the estimated positions and velocities of stations with short observations time spans must be expected. The left panel of Figure 1 shows a global overview of the station the observation time intervals of the DTRF2014 solution. The majority of stations contributed continuous observations over more than 2000 days to the DTRF2014, whereas in some regions (e.g. Japan, right panel of Figure 1) due to e.g., earthquakes, the DTRF2014 is based on rather short observation intervals. In order to validate the impact of the non-tidal loading corrections on the DTRF2014 solution, we compared station positions and velocities computed with and without the corrections. Figure 2 shows the position and velocity differences for all DTRF2014 stations. In particular stations with very short observation time spans ($<< 2.5\,yr$) benefit from the achieved strong smoothing of the station position time series. Position changes of up to 40 mm and velocity changes of up to 4 mm/yr are reached.

Due to the characteristics of the non-tidal loading signals which are dominated by annual and semi-annual periods with a phase lag of half a year between the Northern and Southern hemisphere, the consideration of the non-tidal loading also impacts the datum parameters, i.e. the origin and scale. We performed Fast Fourier Transform analysis (FFT analysis) of the datum parameter time series and found that the typical annual signal disappears when atmospheric and hydrological loading corrections are applied (see Figure 3).

Similar investigations are made for VLBI analysis, in which considering all three loading components (atmospheric, hydrological and oceanic loading) on observation level. For the scale time series the same result as above was obtained: the annual signal vanishes completely when all loading components are considered. The correction of atmospheric loading only, however, leads just to a small smoothing of the signal. Besides the station positions and the datum parameters, the baseline length repeatabilities and also the a posteriori variance factor improved, quantifying the overall improvement of the TRF solution.

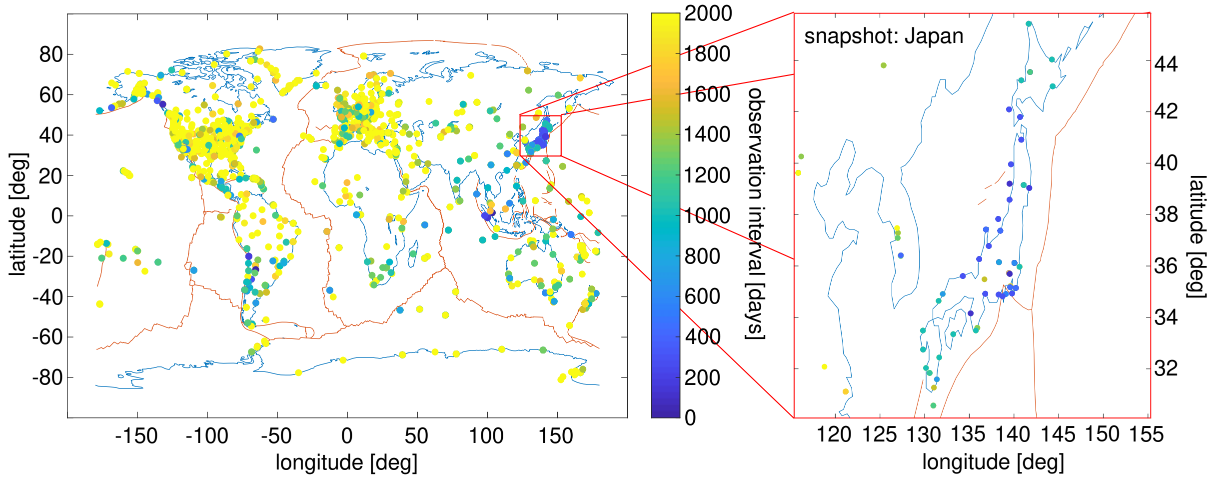

Fig. 1: *DTRF2014 station observation intervals (left panel: global plot, right panel: snapshot of Japan).*

Consistent realization of ITRS and ICRS

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 centres are in charge of computing the terrestrial and celestial reference frame as well as the EOP, and the products are computed from different input data series.

At DGFI-TUM, various studies and test combinations have been performed to estimate all three components (CRF, TRF and EOP) in a common adjustment. The joint parameter estimation was based on 11 years (2005.0–2016.0) of homogeneously processed VLBI, GNSS, and SLR single-technique solutions. Several types of combined solutions were computed varying the selections of local ties, the EOP combination setups, and the weighting of the techniques in order to be able to obtain conclusive results. The impacts of the different combination setups on the TRF, the EOP and finally the CRF were investigated.

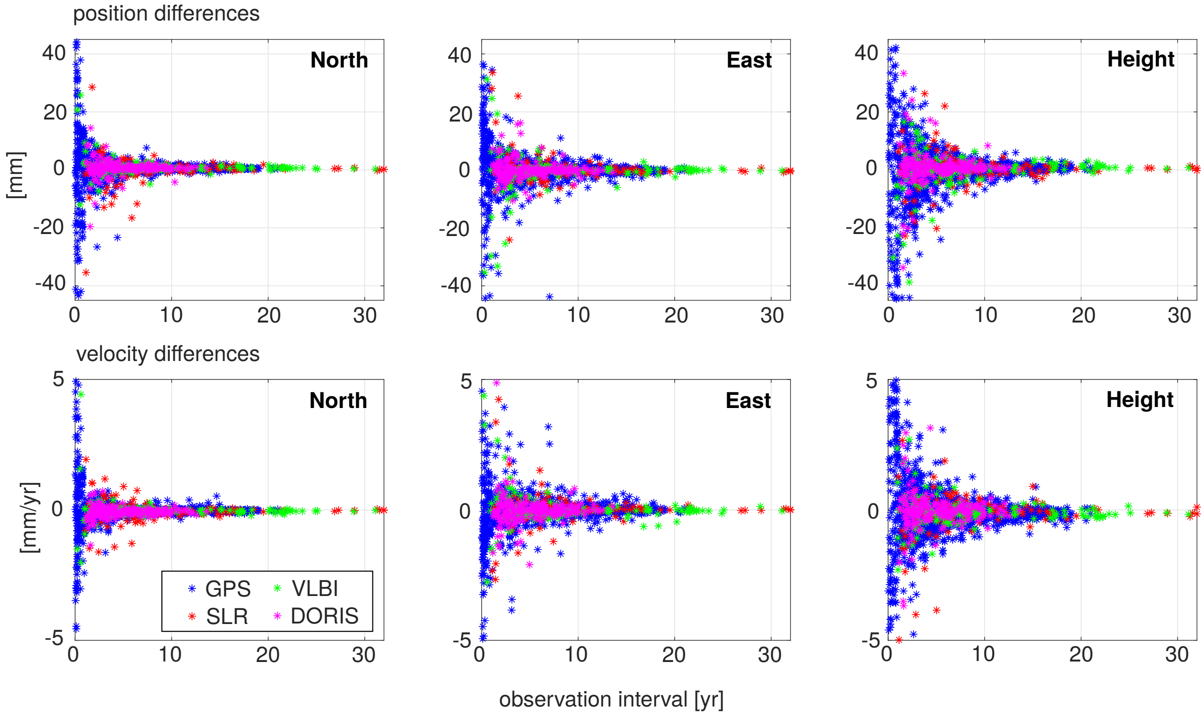

Fig. 2: *Station position and velocity differences for DTRF2014 solutions with considering non-tidal loading (official solution) and without applying the corrections.*

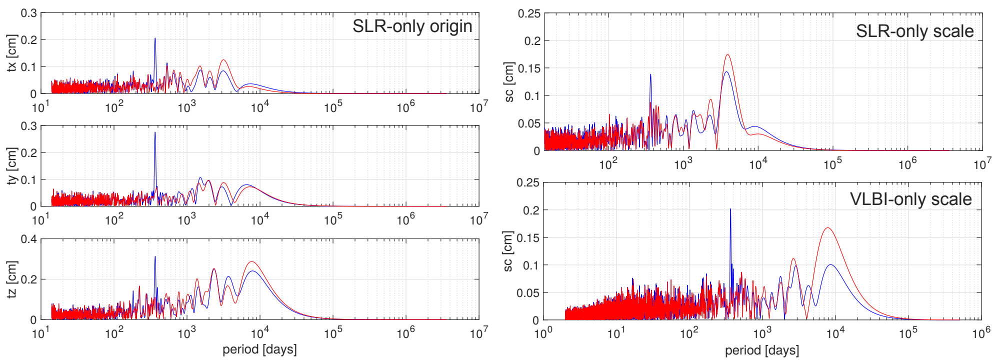

Fig. 3: *Amplitude spectra of the Fast Fourier Transform analysis of translation and scale parameter time series of DTRF2014 input data. The weekly SLR and session-wise VLBI solutions are computed with and without the correction of non-tidal loading signals.*

The results are published in Kwak et al., 2018. A key aspect is the impact of the combination on the CRF, which is realized from VLBI obsevations only, up to now. Figure 4 demonstrates the benefits of source positions w.r.t. a VLBI-only solution. In particular, the declinations of the VLBA Calibrator Survey (VCS) sources and newly added sources (not included in ICRF2) are improved significantly as demonstrated by decreasing standard deviations. As the standard deviations of the non-VCS sources including defining sources are much smaller than those of the VCS sources, their changes are hardly recognizable in Figure

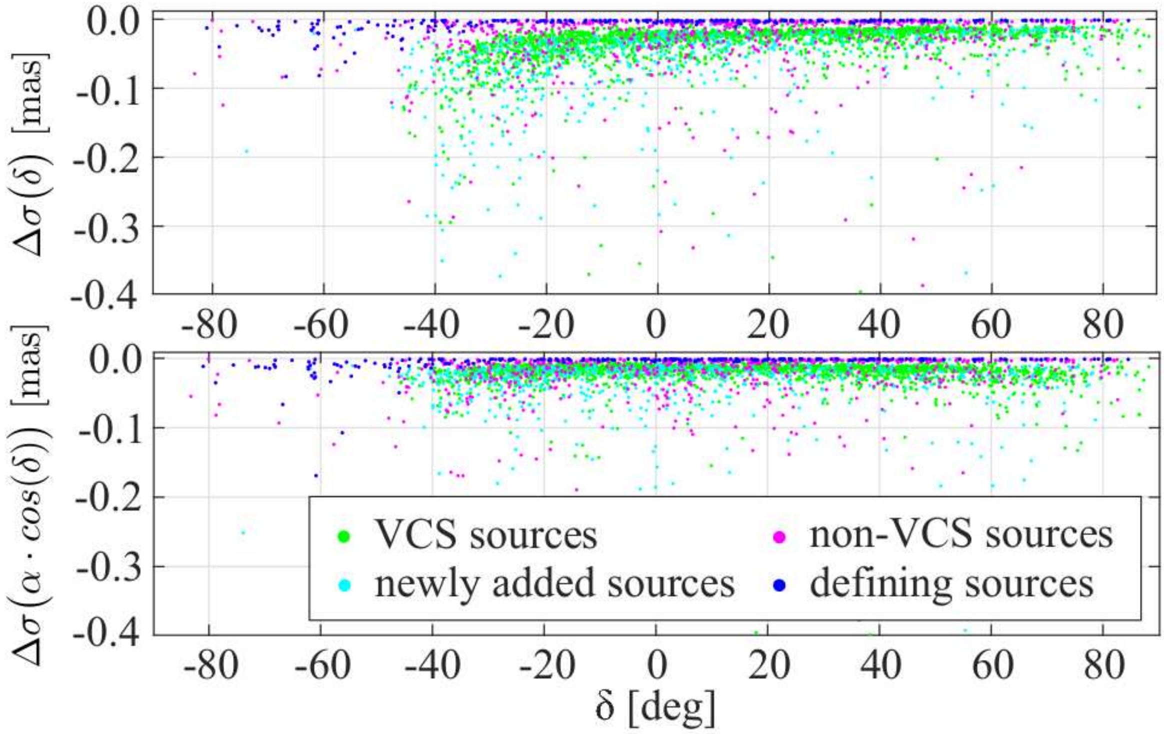

Fig. 4: *Differences of radio source declination and right ascension standard deviations of the combined VLBI, GNSS and SLR solution in comparison to the VLBI-only solution. The standard deviations of the VCS sources (green) and newly added sources (cyan), which were not included in ICRF2, are improved significantly, which is indicated by the negative differences displayed in the figure.*

4. However, they improve also in particular for the higher southern latitudes.

References

Bloßfeld M., Angermann D., Seitz M.: DGFI-TUM analysis and scale investigations of the latest Terrestrial Reference Frame realizations. In: J. T. Freymueller, L. Sánchez (Eds.), International Symposium on Advancing Geodesy in a Changing World, International Association of Geodesy Symposia Vol. 149, doi: 10.1007/1345_2018_47, 2018

Bloßfeld M., Rudenko S., Kehm A., Panafidina N., Müller H., Angermann D., Hugentobler U., Seitz M.: Consistent estimation of geodetic parameters from SLR satellite constellation measurements. Journal of Geodesy, 92(9), 1003–1021, doi: 10.1007/s00190-018-1166-7, 2018

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

Nothnagel A., Angermann D., Heinkelmann R.: Investigations of reference systems for monitoring global change and for precise navigation in space: preface to the special issue on reference systems. Journal of Geodesy, doi: 10.1007/s00190-018-1179-2, 2018

Panafidina N., Hugentobler U., Seitz M.: Influence of subdaily model for polar motion on the estimated GPS satellite orbits. Journal of Geodesy, 229–240, doi: 10.1007/s00190-018-1153-z, 2018

Panafidina N., Hugentobler U., Krásná H., Schmid R., Seitz M.: Mechanism of error propagation from the subdaily Universal Time model into the celestial pole offsets estimated by VLBI. Advances in Space Research, doi: 10.1016/j.asr.2018.08.007, 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 Transactions on Geoscience and Remote Sensing, 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

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Younghee Kwak, Sergei Rudenko, Matthias Glomsda