DGFI-TUM Analysis Center Biennial Report 2019+2020

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Abstract This report describes the activities of the DGFI-TUM Analysis Center (AC) in 2019 and 2020. Besides regular IVS submissions, DGFI-TUM reprocessed nearly all past VLBI sessions that were selected for the ITRF2020. In connection with the latter, our analysis software DOGS-RI was extensively enhanced to consider the new geophysical models and technical details to cope with all legacy S/X and new VGOS sessions. An additional research focus was set on the application of non-tidal loading at different levels of the parameter estimation process.

1 General Information

DGFI-TUM has been serving as an IVS AC since the establishment of the IVS in 1999. Since November 2008, we are an operational AC regularly submitting datum-free normal equations for the rapid turnaround sessions in the SINEX format. Since 2008, we are also involved in the BKG/DGFI-TUM Combination Center by maintaining the combination software DOGS-CS (DGFI Orbit and Geodetic parameter estimation Software – Combination and Solution).

DGFI-TUM is an institute of the Technische Universität München (TUM) since January 2015 and located in the city center of Munich, Germany. The research performed at DGFI-TUM covers many different fields of geodesy (e.g., reference systems, satellite altimetry, or Earth system modeling) and includes contributions to national and international scientific services and research projects, as well as various functions in scientific organizations (see http://www.dgfi.tum.de).

Deutsches Geodätisches Forschungsinstitut der Technischen Universität München (DGFI-TUM)

DGFI-TUM Analysis Center

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2 Staff

At the beginning of 2019, Matthias Glomsda took over the operational IVS analysis from Younghee Kwak, who left DGFI-TUM at that time. Michael Gerstl retired in 2018 but is still supporting the software development of our VLBI analysis software DOGS-RI (Radio Interferometry). Table 1 lists all VLBI-related staff members.

Table 1 Staff members and their main areas of activity.

Name	Tasks
Detlef Angermann	Group leader of *Reference Systems*
Michael Gerstl	Software development
Matthias Glomsda	Operational data analysis; software development
Manuela Seitz	CRF/TRF combination; combination of different space geodetic techniques

3 Current Status and Activities

In 2019, we worked on two major topics. First, we investigated the impact of non-tidal loading, a geophysical effect that is currently only partly considered in VLBI analysis. Next to the non-tidal atmospheric loading, which is already included for the IVS solutions, we also applied non-tidal oceanic and hydrological loading, both individually and as a whole. Furthermore, we

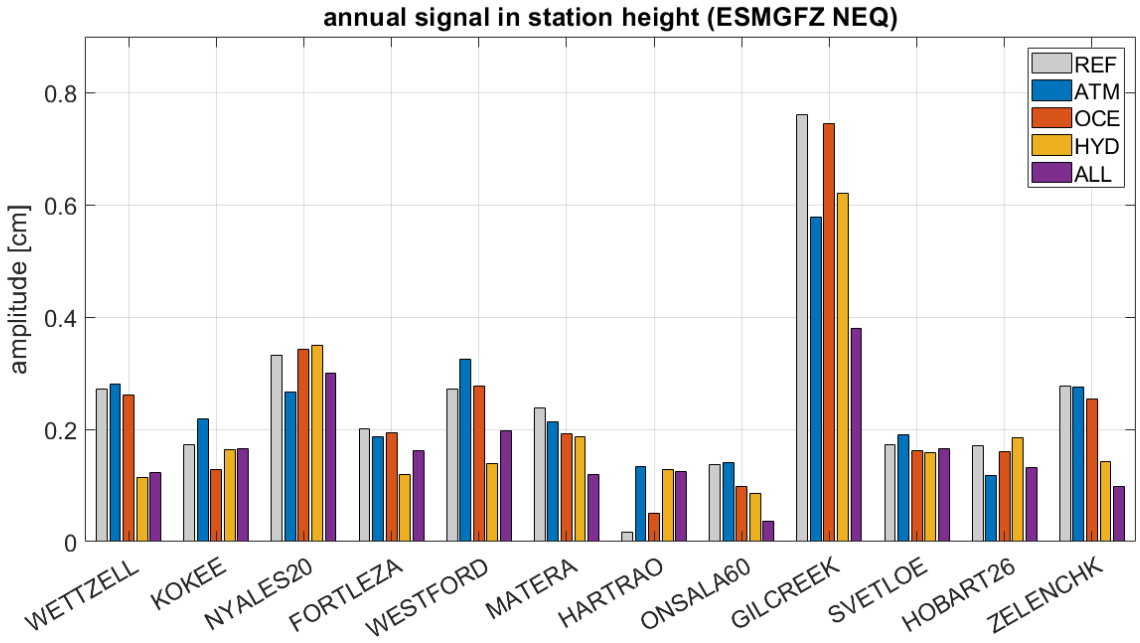

Fig. 1 We analyzed more than 4,000 sessions between 1984 and 2017. For each of them, five different setups were used: no non-tidal loading (REF), non-tidal atmospheric loading only (ATM), non-tidal oceanic loading only (OCE), hydrological loading only (HYD), and all non-tidal loading types at once (ALL). Here, we compare the amplitudes of the annual signal in the time series of station heights for all distinct setups and observe that the signals are often reduced when hydrological loading is applied (HYD, ALL). The non-tidal loading data was taken from the Earth System Modelling group of the Deutsches GeoForschungsZentrum and applied at the normal equation level.

examined two application levels: the observation and the normal equation level. We showed that considering non-tidal loading at either level is beneficial for various geodetic parameters, e.g., by reducing the scatter and/or periodic signals in their time series (compare, for instance, Figure 1, which is taken from [1]). Thereby, all three loading types are relevant and should be applied jointly.

Secondly, we had to prepare DOGS-RI for the upcoming realization of the International Terrestrial Reference System (ITRS), the ITRF2020 (International Terrestrial Reference Frame 2020). The most important modifications were the implementation of:

- the secular pole function as agreed upon at the Unified Analysis Workshop (UAW) 2017,
- the Desai and Sibois [2016] model for sub-daily EOP variation,
- the usage of Galactic Aberration in connection with the latest realization of the International Celestial Reference System (ICRF3), and
- the empirical model for the gravitational deformation of selected VLBI antennas.

All these new models also had to be considered for the official IVS solutions starting from January 2020.

In 2020, we hence released our new IVS contribution of datum-free normal equations for the rapid turnaround sessions (*dgf2020a*). Furthermore, we started to reprocess VLBI observations for the ITRF2020. The list of relevant sessions comprises basically all VLBI experiments with at least three antennas, many of which had never been analyzed at DGFI-TUM before. As a consequence, we had to handle almost 2,000 “new” VLBI sessions in 2020. These sessions also comprise the new session series of the next-generation VLBI system, the so-called VLBI Global Observing System (VGOS) sessions. The latter make use of smaller, fast-moving antennas with broadband receivers, and hence the analysis approach had to be augmented in comparison to the legacy S/X sessions.

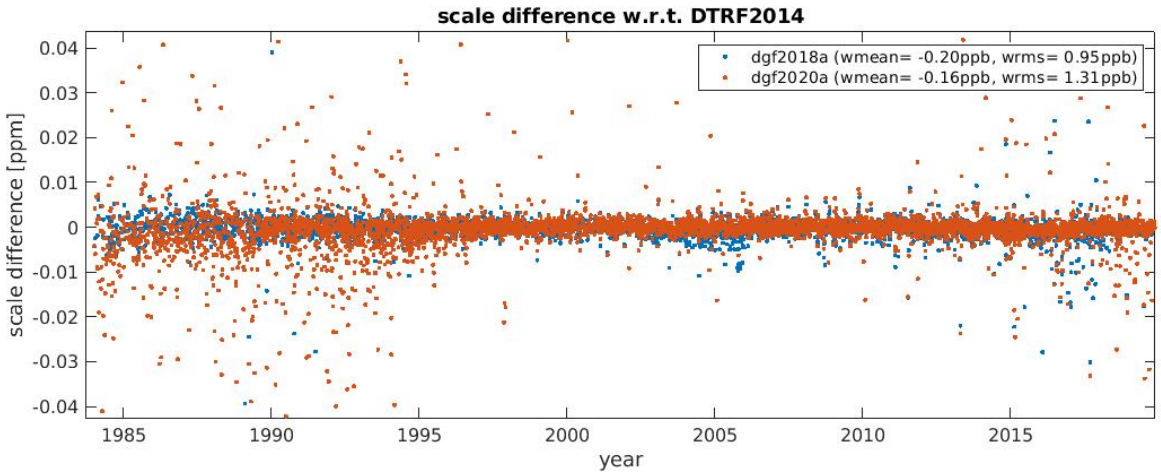

Fig. 2 Time series of the scale parameter in a Helmert transformation with respect to the DTRF2014, DGFI-TUM's realization of the ITRS with data as available through 2014. The session-wise transformations are based on VLBI station positions obtained from the solutions *dgf2018a* (blue) and *dgf2020a* (red).

To process all "new" VLBI experiments, DOGS-RI needed a few more modifications. By the end of 2020, we managed to complete almost all relevant ITRF2020 sessions, and we created a first global VLBI solution by combination of the single-session normal equations.

In the context of the ITRF2014 computation, the discussion on the consistency of the scales realized by VLBI and Satellite Laser Ranging (SLR) played an important role. For the ITRF2020, the analysis and comparison of the realized scales will still be of high interest, especially since—not only for VLBI, but also for SLR—changes in modeling and parameterization have been implemented (compare above). At DGFI-TUM, we have thus performed some initial analyses of the scale parameter in a Helmert transformation with respect to the DTRF2014 (see [3]). Figure 2 shows the corresponding time series derived for solution *dgf2020a* and its predecessor *dgf2018a*, which did not contain the four new models for the ITRF2020. It can be clearly seen that no significant change in the mean scale, scale rate, or RMS is caused by the changes in VLBI modeling.

Finally, we continued our research on non-tidal loading effects, and a second paper was submitted (see [2]). It contains a rather theoretical assessment and confirms, amongst others, that the differences between the application at the observation and normal equation levels are mainly driven by the temporal resolution of the loading data.

4 Future Plans

The year 2021 will be dominated by the generation of the ITRF2020. DGFI-TUM's reprocessed normal equations will be part of the combined IVS contribution, and probably some further tasks will arise from that. In particular, we want to establish and analyze a combined CRF/TRF solution from our VLBI data.

With respect to software development, we want to make DOGS-RI fully capable of performing simulations, and we plan to routinely process Intensive sessions next to the rapid turnarounds.

Acknowledgements

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References

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