GFZ Analysis Center 2013 Annual Report

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Abstract This report briefly provides general information and a component description of the recently established IVS Analysis Center at GFZ and outlines the planned activities.

1 General Information

Helmholtz Center Potsdam, GFZ German Research Center for Geosciences is the national research center for Earth sciences in Germany. The main tasks of GFZ according to its website (www.gfz-potsdam.de) are:

> *System Earth—Research Focus of the GFZ German Research Center for Geosciences*
>
> *The Earth is a dynamic planet. Under the influence of external and internal forces, it is continuously changing. The solid Earth, the atmosphere, the hydrosphere and the things living within them are always interacting. In short, the Earth is a complex system, with forces and interactions between many different partners. To understand the world in which we live, from our regional environment to the entire planet, it is necessary to understand how the System Earth works in all details. In the analysis, we have to include the activities of mankind and their influence on the natural processes in this complex, nonlinear system, which in turn affects the environment we live in.*
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> *The overarching research aim of the GFZ is one of developing strategies and demonstrating practical options, e.g. to preserve natural resources and to exploit them in an environmentally friendly way, to guard against natural catastrophes, to assess changes in the climate and the environment and man's impact on these, and to research and utilise our world below ground, all based on a comprehensive understanding of systems and processes.*

At this research facility within Department 1 'Geodesy and Remote Sensing' and its Section 1.1 'GPS/GALILEO Earth Observation,' a VLBI group was established in November 2012.

2 Component Description

Since December 2012, GFZ has been an associate Analysis Center (AC) of IVS. We are installing and automating our VLBI analysis process in preparation for becoming an operational AC. We will analyze all incoming geodetic/astrometric types of sessions and provide interim results in the SINEX format within 24 hours after the provision of database files of version 4 or higher at IVS Data Centers. At the end of 2013 we started a complete re-processing of all available IVS databases to get prepared for a contribution to ITRF2013. We are also performing as an IVS Combination Center for tropospheric products. In 2013 the IVS rapid combination product was determined at GFZ, while results and written output were still provided via the Deutsches Geodätisches Forschungsinstitut (DGFI) webpage. In 2014, we will finish the migration of the IVS troposphere Combination Center from DGFI to GFZ.

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3 Staff

At the GFZ IVS AC, the operational work is done by Robert Heinkelmann, Tobias Nilsson, and Julian Mora-Diaz. In addition, Maria Karbon and Benedikt Soja work within project VLBI-ART about the application of Kalman filtering to VLBI analysis, and Virginia Raposo-Pulido works on the ICRF and related systematic effects. Liu Li and Minghui Xu are guest PhD students from Shanghai, China, and Cuixian Lu is a guest PhD student from Wuhan, China. Harald Schuh is managing our group and, as long as his schedule allows, he is still very active for the IVS. A photo of us is shown in Figure 1.

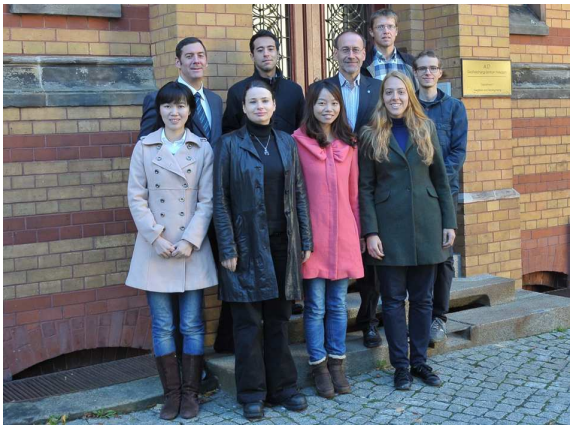

Fig. 1 The GFZ VLBI group in October 2013.

4 Current Status and Activities

- IVS Associate Analysis Center at GFZ
  At GFZ we use VieVS for VLBI data analysis starting at DB version 4 or higher. Together with the IVS Analysis Center at the Department of Geodesy and Geoinformation, Vienna University of Technology, we develop VieVS.
- Space applications
  Our scientific work focuses on VLBI applications in space, on GNSS observations using VLBI antennas, and on co-location in space of the various space geodetic techniques (VLBI, GNSS, SLR, and DORIS). One of the next steps will be the development of the differential VLBI (D-VLBI) method and its application for geodetic purposes.
- VLBI data analysis using Kalman filtering
  Within the project VLBI-ART (VLBI Analysis in Real-Time, [1]) we plan to implement a Kalman filter solution in the Vienna VLBI Sotware (VieVS) [2], as an alternative to the classical least squares solution (LSQ). The aim of the Kalman filter solution is that it should be able to analyze VLBI data in near real-time. Thus, the software will be ready for a possible future scenario where the VLBI observations are available with a much shorter latency than today.
  An advantage of a Kalman filter is that the parameters can be modeled as stochastic processes instead of with the piece-wise linear parametrization normally used in the LSQ solution. This allows better modeling of the random variations in e.g. the tropospheric delays. Furthermore, a Kalman filter requires less computer memory compared to the LSQ method, what will be an advantage for VLBI2010 where the amount of data will increase by several magnitudes. We will also investigate the possibility of including data from other sensors in the Kalman filter. These could for example be data on geophysical excitations of Earth rotations (e.g. from numerical weather prediction models), tropospheric delays from water vapor radiometers or GNSS, or Earth rotation parameters from GNSS and ring laser gyroscopes.
  As a first step we have performed various investigations in which we applied Kalman filtering for combining VLBI results (produced with the LSQ solution in VieVS) with results from other techniques. For example we made several tests combining VLBI data with atmospheric excitations from numerical weather prediction models. Furthermore, we combined hourly EOP estimated from VLBI and GNSS [3].
  An interesting possibility is to use a Kalman filter to combine UT1-UTC parameters estimated from the VLBI Intensive sessions with Length of Day (LOD) data obtained from GNSS [4]. The LOD from GNSS provides precise information about the short term (one week or less) UT1-UTC variations, while the VLBI Intensives have the long-term stability. In addition, other parameters common to both VLBI and GNSS can be combined in the Kalman filter, i.e. polar motion, station coordinates,

and tropospheric delays. Because correlations between the VLBI UT1-UTC estimates and errors of other parameters exist, this will additionally help to improve the UT1-UTC results. As an example, Figure 2 shows UT1-UTC from 2008-2010 estimated when also combining the tropospheric delays in the Kalman filter, compared to when not doing this. We found that the WRMS differences relative to the UT1-UTC values estimated from normal IVS-R1/R4 sessions slightly decreased from 27.1 μs to 26.1 μs.

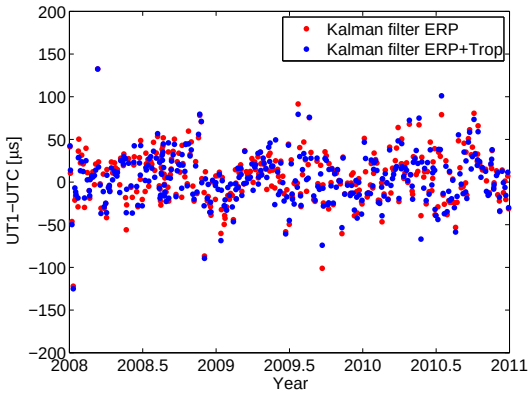

Fig. 2 UT1-UTC estimated from a Kalman filter combination of the results of the VLBI Intensive sessions and the GNSS LOD estimates, relative to estimates from the IVS-R1/R4 sessions. Shown are the results obtained when combining the UT1-UTC/LOD and polar motion, as well as the case when also combining the tropospheric delay estimates.

- Long-term troposphere combined product
  It is planned to generate a new updated version of the long-term tropospheric combination product including the most recent observational data.

5 Future Plans

- IVS Operational Analysis Center at GFZ
  At GFZ we would like to become an operational Analysis Center of IVS. Therefore we are installing and automating the standard VLBI data processing using VieVS in least squares estimation mode. Once we have finished a complete re-processing of all available IVS databases of version 4 or higher, we will submit our solution to IVS, applying to become operational.

Acknowledgements

The VLBI-ART project is funded by the Austrian Science Fund (FWF), project number P24187-N21.

References

1. M. Karbon, T. Nilsson, C. Tierno Ros, R. Heinkelmann, and H. Schuh. VLBI-Art: VLBI analysis in real-time. In N. Zubko and M. Poutanen, editors, *Proceedings 21th Meeting of the European VLBI Group for Geodesy and Astrometry*, pages 95–97, Espoo, Finland, 2013.
2. J. Böhm, S. Böhm, T. Nilsson, A. Pany, L. Plank, H. Spicakova, K. Teke, and H. Schuh. The new Vienna VLBI software. In S. Kenyon, M. C. Pacino, and U. Marti, editors, *IAG Scientific Assembly 2009*, number 136 in International Association of Geodesy Symposia, pages 1007–1011, Buenos Aires, Argentina, 2012. Springer.
3. T. Nilsson, M. Karbon, and H. Schuh. A Kalman filter for combining high frequency Earth rotation parameters from VLBI and GNSS. In N. Zubko and M. Poutanen, editors, *Proceedings 21th Meeting of the European VLBI Group for Geodesy and Astrometry*, pages 117–120, Espoo, Finland, 2013.
4. T. Nilsson, M. Karbon, B. Soja, V. Raposo-Pulido, R. Heinkelmann, J. Mora-Diaz, C. Lu, L. Liu, and H. Schuh. Rapid UT1 estimation by combining VLBI Intensives with GNSS. In *Proceedings of the IAG Scientific Assembly*, Potsdam, Germany, 2013. submitted.