Vienna Special Analysis Center Annual Report 2014

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Abstract The main activities in 2014 of the VLBI group at the Department of Geodesy and Geoinformation of the Vienna University of Technology were related to the application and the further development of the Vienna VLBI Software (VieVS). For example, we scheduled VLBI observations of the AUSTRAL sessions as well as observations to satellites with radio telescopes. Furthermore, we contributed to the ITRF2014 by providing normal equations for more than 5,000 sessions, and we assessed the impact of various ways of troposphere delay modeling on geodetic parameters. The highlight from an organizational point of view was the fifth VieVS User Workshop in September 2014 in Vienna with the release of VieVS version 2.2.

1 General Information

The Department of Geodesy and Geoinformation (GEO) in the Faculty of Mathematics and Geoinformation of Technische Universität Wien (TU Wien) is divided into seven research groups. One of those, the research group Höhere Geodäsie (Advanced Geodesy) with about 15 members, is focusing on satellite geodesy, system Earth, and geodetic VLBI.

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2 Staff

Personnel at GEO associated with the IVS Special Analysis Center in Vienna (VIE) and their main research fields and activities are summarized in Table 1. The staff members are partly paid by TU Wien and partly they are funded by the Austrian Science Fund (FWF) within several projects.

3 Activities during the Past Year

3.1 Global Solutions and Reference Frames

Axis offset models have to be applied for VLBI telescopes if the pointing axes do not intersect. We estimated the axis offsets for VLBI antennas in a global adjustment of suitable IVS 24-hour sessions (1984.0 — 2014.0) with the Vienna VLBI Software (VieVS) (Krásná et al., 2015, [3]). In particular, we focused on the two radio telescopes of the Hartebeesthoek Radio Astronomy Observatory (HartRAO) in South Africa where a comparison with axis offset estimates from other geodetic techniques, such as GNSS and conventional local survey, was made. Furthermore, we assessed the influence of differences in the axis offsets on the estimated geodetic parameters, such as station coordinates or Earth orientation parameters.

VLBA Calibrator Survey (VCS) observing sessions with ten radio telescopes in North America were carried out with the primary goal of densifying the International Celestial Reference Frame. We investigated the impact of Earth orientation parameters

Fig. 1 Members of the Vienna VLBI group and participants at the 5th VieVS User Workshop in September 2014.

Table 1 Staff members ordered alphabetically.

Johannes Böhm	Reference frames, atmospheric effects
Sigrid Böhm (on maternity leave)	Earth orientation
Anastasia Girdiuk (since 12/2014)	Earth orientation
Andreas Hellerschmied	Satellite observations with radio telescopes, VieVS admin since 12/2014
Armin Hofmeister	Ray-traced delays in VLBI analysis
Hana Krásná (on maternity leave since 12/2014)	Global solutions, VieVS admin until 11/2014
Younghee Kwak (since 03/2014)	Hybrid GNSS-VLBI observations
Daniel Landskron (since 06/2014)	Troposphere delay models for VLBI
Matthias Madzak	GUIs and special files in VieVS, Earth rotation
David Mayer	Reference frames and scheduling, e.g. AUSTRAL sessions
Caroline Schönberger (since 12/2014)	Simulation of twin telescopes

on the estimated source positions. For that purpose we applied the combined IERS C04 08 series as well as Earth rotation parameters from GNSS observations alone and compared the source coordinates to those estimated in VLBI-only solutions.

We contributed more than 5,000 SINEX files to the IVS Combination Center at BKG (Frankfurt, Germany) for the International Terrestrial Reference Frame 2014 (ITRF2014).

3.2 Troposphere Delays

Within the project RADIATE VLBI, which is funded by the Austrian Science Fund (FWF), there is ongoing development and enhancement of our new ray-tracing program RADIATE (Hofmeister and Böhm, 2015, [2]). With the use of real meteorological data provided by the European Centre for Medium-Range Weather Forecasts (ECMWF) via numerical weather models with horizontal resolutions as high as 0.125° times 0.125°, our program RADIATE is able to determine slant path delays for VLBI observations. In 2014, after the successful validation of our first ray-traced delays from RADIATE against the delays from an international comparison campaign of ray-tracing software (Nafisi et al., 2012, [5]), we further enhanced our ray-tracing program. A major step in the past year was the application of the ray-traced delays in VLBI analysis and the validation of the results. For this task we used the CONT11 campaign and calculated our ray-traced slant delays. Using VieVS for the analysis, we investigated the impact of our ray-traced delays on the VLBI solution by assessing baseline length repeatabilities.

In terms of improving troposphere delay models, two aspects were considered in 2014: (1) an improvement of the coefficients of the Vienna Mapping Function 1 (VMF1) and (2) the development of a new horizontal gradient formula in order to better consider az-

imuthal asymmetries. The latter approach uses expansions of the gradient formula based on spherical harmonics in order to compensate for the impact on the delays which is caused by the non-spherical shape of the Earth's atmosphere, which is flatter at the poles and thicker at the equator.

3.3 Simulation of Twin Telescopes

The Vienna VLBI Software was used to schedule and simulate a global VLBI network following the example of the CONT11 campaign, with the existing ONSALA60 telescope or with a Twin Telescope in Onsala. Different scheduling approaches (e.g., source-based scheduling with two or four sources at a time, multidirectional or continuous mode) (Sun et al., 2014, [7]) were compared by evaluating the numbers of observations and scans as well as baseline length repeatabilities, station positions, Earth orientation parameters, atmospheric parameters, and clock estimates.

3.4 Scheduling VLBI Sessions

The VieVS scheduling module is used operationally to schedule sessions for the AuScope VLBI network. This is done in close cooperation with the University of Tasmania. The AuScope VLBI network consists of three almost identical small (12-m) antennas distributed over Australia. Other telescopes from New Zealand (12-m) and South Africa (15-m) contribute on a regular basis. For special experiments, the two big (26-m) telescopes in Australia and South Africa are used as well. In 2014 the number of sessions observed with the Australian telescopes increased tremendously with a continuous campaign over two weeks in September and 57 regular Australian sessions. The schedules are created on a relatively short notice, which allows us to adjust to the current conditions and apply changes fast. Furthermore, more features were built into the software to fit the specific needs, and the GUI was updated slightly for more user-friendliness.

3.5 VLBI Observations to Satellites

Observations of GNSS satellites with large VLBI radio antennas enable the realization of inter-technique ties and seem to be a promising approach to accomplish a vital interconnection between dynamical and kinematical reference frames (Plank et al., 2014 [6]). Although several satellite observation experiments have been carried out in recent years, this approach is still far away from being applied operationally. Limitations have already emerged at the observation planning level, because suitable scheduling software has not been available. On that account the current Vienna VLBI Software was upgraded by adding a module capable of creating satellite observation schedules (Hellerschmied et al., 2015 [1]). The generated VEX-formatted schedule files can be used directly to carry out satellite observations, where the satellites are tracked by repositioning the VLBI antennas stepwise to define celestial coordinates. The first successful observations to GLONASS satellites based on VieVS schedules were carried out in January 2014 on the baseline Onsala—Wettzell. The new VieVS satellite scheduling module provides a flexible tool to generate suitable schedule files for satellite observations, which is particularly important to promote further research and development in this specific field.

3.6 GPS-VLBI Hybrid Observation for Geodesy

We started project *GPS-VLBI Hybrid Observation for Geodesy (Hybrid GPS-VLBI)*, funded by the Austrian Science Fund (FWF), which combines GPS and VLBI at the observation level. In 2014, we developed and validated the delay model of GPS satellites according to the GPS-VLBI (GV) hybrid observation concept and implemented it in VieVS. As a test of VieVS for GPS delays, we set up a global GV hybrid network with several IVS CONT11 sites, which are stable and homogeneously distributed and moreover simultaneously acquire GPS data. GPS delays were created by differencing post-processed range measurements from a precise point positioning (PPP) GPS solution with the C5++ software because we currently do not have any real observation data. The data were successfully processed

in VieVS, and we found centimeter-level accuracy of the models (Kwak et al., 2015, [4]). Compared to GPS PPP solutions, the accuracy is still worse, which needs to be further investigated. In 2015, we will combine VLBI and GPS data, estimate common parameters at the sites, and assess the impact of the GV hybrid combination solution on the geodetic parameters.

3.7 Development of VieVS

We have set up and maintained a wiki for the Vienna VLBI Software. This wiki is accessible at http://vievswiki.geo.tuwien.ac.at/ and contains a lot of useful information, not just for VieVS users. We organized the 5th VieVS User Workshop from 17 to 18 September 2014 in Vienna. Additionally, Hana Krásná held a VieVS training course at Hartebeesthoek Radio Astronomy Observatory (HartRAO), South Africa, from 15 to 17 April 2014.

4 Future Plans

In 2015, we will continue the development of VieVS, with special focus on satellite tracking, scheduling, and the estimation of terrestrial and celestial reference frames. We also plan to become an operational Analysis Center of the IVS. Moreover, we will organize the 6th VieVS User Workshop in September 2015.

Acknowledgements

We are very grateful to the Austrian Science Fund (FWF) for supporting our work by projects P23143 (Integrated VLBI), P25320 (RADIATE VLBI), P24813 (SPOT), M1592 (Hybrid GPS-VLBI), and I1479 (ASPIRE). We also acknowledge the German Research foundation (DFG) for funding project D-VLBI (SCHU 1103/4-1).

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