Vienna Special Analysis Center Annual Report 2013

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Abstract The main activities in 2013 of the VLBI group at the Department of Geodesy and Geoinformation of the Vienna University of Technology were related to scheduling and simulations of VLBI observations, global solutions with the determination of celestial and terrestrial reference frames, and satellite observations with VLBI radio telescopes. A highlight was certainly the fourth VieVS User Workshop in September 2013 in Vienna with the release of VieVS Version 2.1.

1 General Information

The Department of Geodesy and Geoinformation (GEO) in the Faculty of Mathematics and Geoinformation of the Vienna University of Technology is divided into seven research groups. One of those, the research group Higher Geodesy (*Höhere Geodäsie*) with about 15 members, is focusing on satellite geodesy, system Earth, and geodetic VLBI.

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 the university and partly by project money.

1. Vienna University of Technology
2. GeoForschungsZentrum Potsdam
3. Shanghai Astronomical Observatory

VIE Analysis Center

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Fig. 1 Members of the Vienna VLBI group in front of the VLBI radio telescope in Metsähovi during the EVGA Working Meeting 2013 (from left): Caroline Schönberger (Master student), Matthias Madzak, Johannes Böhm, Hana Krásná, Lucia Plank, Benedikt Soja, Kamil Teke (Hacettepe University).

3 Activities during the Past Year

3.1 Global Solutions with VieVS

Our latest realizations of global reference frames are the VieTRF13b terrestrial reference frame, the VieCRF13b celestial reference frame, and the corresponding Earth orientation parameters (EOP) VieEOP13b, all of them being provided at http://vievs.geo.tuwien.ac.at/results/ and made available as an input option in VieVS. In addition to the "operational" generation of reference frames and EOP, the global solution in VieVS was extended by

Table 1 Staff members ordered alphabetically.

Johannes Böhm	VGOS, atmospheric effects
Sigrid Böhm	VieVS Chair (until 06/2013), Earth orientation
Andreas Hellerschmied (since 11/2013)	Satellite observations with radio telescopes
Armin Hofmeister (since 05/2013)	Ray-traced delays in VLBI analysis
Hana Krásná	VieVS Chair (since 06/2013), global solution, celestial and terrestrial reference frames
Matthias Madzak	GUIs and special files in VieVS, Earth rotation
David Mayer (since 11/2013)	Scheduling and simulation
Lucia Plank	Satellite tracking with VLBI
Benedikt Soja (until 04/2013)	Sun corona studies with VLBI
Jing Sun (until 01/2013)	Development of scheduling options
Claudia Tierno Ros (until 04/2013)	European VLBI sessions, simulations

the ability to estimate amplitudes of seasonal station motions at annual and semi-annual periods. We not only compared those variations against hydrological models, but we used that tool to investigate the propagation of neglected seasonal station movements to radio source positions (Krásná et al. 2014, [4]) and we assessed the impact on EOP by the analysis of real and artificial VLBI observations (Krásná and Böhm 2013, [2]). Several other parameters, such as antenna axis offsets or atmosphere pressure loading regression coefficients were also added to the normal equation system in VieVS.

Furthermore, the global solution in VieVS was used to analyze the European VLBI sessions. Krásná et al. (2013, [3]) published the velocities of geodetic VLBI sites as derived from all European VLBI sessions, including a comparison with two global tectonic plate models, NUVEL-1A and MORVEL, with an earlier study of European crustal motion from VLBI data presented by Haas et al. (2003, [1]), and with velocities derived from Global Navigation Satellite Systems (GNSS) observations.

3.2 Ray-traced Delays in the Atmosphere for Geodetic VLBI

Within the project RADIATE VLBI, funded by the Austrian Science Fund (FWF), we developed new ray-tracing software, which is capable of determining slant path delays for the complete history of VLBI observations. With the use of real meteorological weather data delivered by numerical weather models, e.g. from the European Centre for Medium-range Weather Forecasts (ECMWF), it is possible to determine the actual ray path and calculate the slant path delay for each observation. In 2013, we successfully set up the routines for global grids of meteorological data (0.125^o) and validated the delays against those from an international comparison campaign of ray-tracing software (Nafisi et al., 2012, [5]).

3.3 VLBI Observations to Satellites

At GEO Vienna, research on VLBI observations to satellites is ongoing. Within the research project $D-VLBI$, which is part of the DFG Research Unit *Space-Time Reference Systems for Monitoring Global Change and for Precise Navigation in Space*, a number of simulation studies using VLBI observations to Earth satellites were performed. The goal of these investigations was to determine station position repeatabilities from either weekly or session-wise VLBI satellite observations. After certain amendments of VieVS, such observations can now also be integrated into routine VLBI sessions, and a combined analysis, e.g. estimating common clocks and the troposphere, is possible. As documented in several publications on this topic, we identified observation strategies to determine station position repeatabilities at the sub-centimeter level, respectively frame ties in terms of Helmert parameters between the GNSS frame and the VLBI frame of better than 1 millimeter (Plank, 2013, [6]; Plank et al., 2013, [7]).

Although some satellite observation experiments have been conducted in the recent years, it has not become a routine operation. To overcome that limitation, Andreas Hellerschmied in his Master thesis has expanded the current Vienna VLBI Software by adding a module capable of generating satellite observation schedules, where the observation plan is set up in an interactive process. The schedule files (VEX format) can then be used to perform real experiments. During this project a close cooperation with the Geodetic Observatory Wettzell (http://www.bkg.bund.de/Wettzell) evolved. This collaboration made it possible to perform tests on site and to prove the viability of the developed software utilizing the instruments at this station.

3.4 Assessing the Sun Corona with VLBI

By using the observational data of twelve dedicated VLBI experiments in 2011 and 2012, the electron density of the solar corona was determined. It was the first time that VLBI data was used for this purpose. The results agree well with those obtained by different techniques such as spacecraft tracking (Soja et al., 2013, [8]). The effect of the coronal plasma had to be separated from other dispersive effects caused by the ionosphere and hardware delays. As a byproduct of our investigations, a procedure to estimate the ionospheric total electron content of each radio telescope was implemented into VieVS.

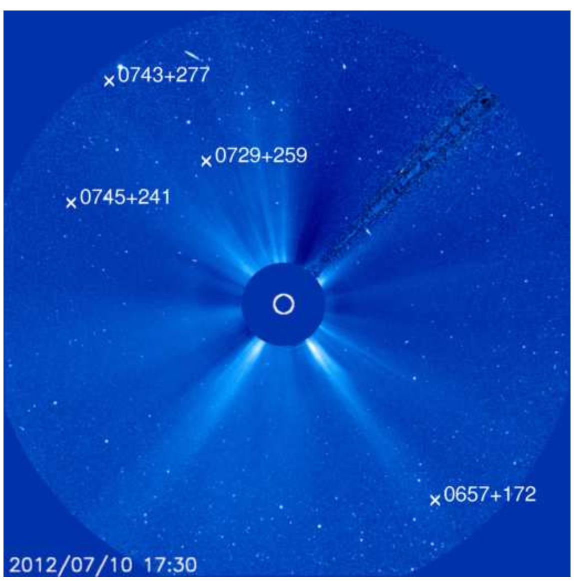

Fig. 2 Constellation of Sun corona and close radio sources on 10 July 2012 at 17:30 UT.

3.5 Scheduling and Simulations

Scheduling and simulations with VieVS have played a very important role for the Vienna VLBI group in 2013. This is certainly based on the close cooperation with Jing Sun who returned to Shanghai Astronomical Observatory in February 2013. She has made further amendments to the scheduling tool of VieVS, e.g. by providing the tag-along mode capability and other refinements. The scheduling tool in VieVS (Vie_SCHED, Sun et al., 2014, [9]) is now used operationally to schedule the AUSTRAL VLBI sessions.

Additionally, Vie_SCHED has been used to schedule the continuous VLBI campaign in November/December 2013 with stations in Australia, New Zealand, and South Africa. This campaign has been carried out to demonstrate the capabilities of the southern stations and to investigate the influence of sources with high structure index on geodetic results. Figure 3 shows simulation results of source coordinate estimates in right ascension for “good sources” (structure index 1) and “bad sources” (structure index 4). Furthermore, there have been studies with the scheduling and simulation tools in VieVS to demonstrate the importance of specific VLBI sites. For example, we evaluated the importance of the Hartebeesthoek Radio Astronomy Observatory (HartRAO) for the current and future VLBI network. The results suggest that HartRAO is of high importance for the estimation of

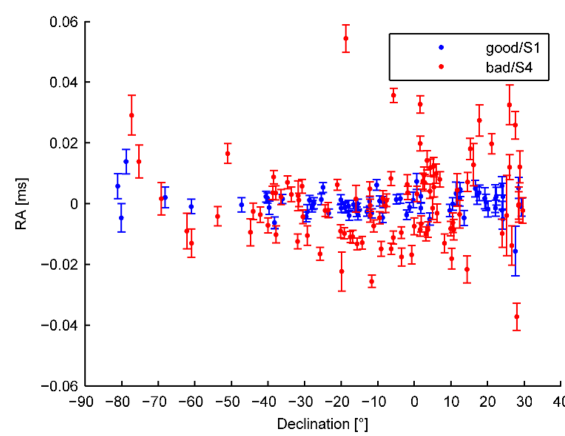

Fig. 3 Simulation results of estimates of source positions in right ascension as derived from simulations for the 15 day continuous VLBI campaign with stations in Australia, New Zealand, and South Africa.

EOP. In particular polar motion and nutation estimates benefit from HartRAO's remote location. Based on scheduling and simulation analysis of the VLBI2010 network, an upgrade from the current antenna to a fast slewing VLBI2010 antenna was recommended.

4 Future Plans

In 2014, we will continue the development of VieVS, with special focus on satellite tracking, scheduling, and the estimation of terrestrial and celestial reference frames. In particular, we will contribute to the ITRF2013, and we will organize the 5th VieVS User Workshop in September 2014.

Acknowledgements

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