Vienna IGG Special Analysis Center Annual Report 2011

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Abstract

The main activities of the VLBI group at the Institute of Geodesy and Geophysics (IGG) of the Vienna University of Technology in 2011 were related to the development of the Vienna VLBI Software VieVS (http://vievs.hg.tuwien.ac.at/). The number of external VieVS users further increased to about twenty, and some of them took part in the second VieVS User Workshop which was held at our institute in September 2011. In the last year, the tools for the VLBI global solutions were further refined and extended, and investigations on scheduling as well as on spacecraft and satellite tracking have been intensified. Furthermore, studies on VLBI2010 simulations, Earth rotation, and geodynamical parameters from VLBI have been continued.

1. General Information

The Institute of Geodesy and Geophysics (IGG) is part of the Faculty of Mathematics and Geoinformation of the Vienna University of Technology. It is divided into three research units, one of them focusing on advanced geodesy (mathematical and physical geodesy, space geodesy). Within this research unit, one group (out of three) is dealing with geodetic VLBI.

Figure 1. Members of the VLBI group participating in the EVGA meeting in Bonn: Hana Spicakova, Tobias Nilsson, Harald Schuh, Johannes Böhm, Lucia Plank, Jing Sun, and Claudia Tierno Ros in front of the radio telescope in Effelsberg.

2. Staff

Personnel at IGG associated with the IVS Special Analysis Center in Vienna are Harald Schuh (Head of IGG, Chair of the IVS Directing Board), and eleven scientific staff members. Their main research fields are summarized in Table 1.

Table 1. Staff members ordered by their main focus of research.

Johannes Böhm	VLBI2010, atmospheric effects
Jing Sun	VLBI2010, scheduling of VLBI observations
Tobias Nilsson	VLBI2010, turbulence, Earth orientation
Andrea Pany (until 07/2011)	VLBI2010, simulation
Sigrid Böhm	Earth orientation, tidal influences
Lucia Plank	Spacecraft and satellite tracking with VLBI
Benedikt Soja	Relativistic effects of solar system bodies
Matthias Madzak	Ray-tracing, VieVS graphical user interfaces
Hana Spicakova	Global solution, geodynamical parameters
Vahab Nafisi (until 09/2011)	Ray-traced delays for VLBI
Claudia Tierno Ros	External ionospheric delays

3. Current Status and Activities

- **Vienna VLBI Software VieVS**
  Most of the activities were related to the development of the Vienna VLBI Software (VieVS, http://vievs.hg.tuwien.ac.at/). For example, tools for the VLBI global solutions were updated in the latest release (Version 1d), and investigations into spacecraft and satellite tracking have been continued. Furthermore, studies on VLBI2010 simulations, scheduling, Earth rotation, and geodynamical parameters from VLBI were carried out, and the second VieVS User Workshop was held in September 2011.

- **Complex demodulation**
  By applying the so-called complex demodulation, high-frequency variations in a time series can be shifted to low frequencies, preserving thereby the original amplitudes. This enables the estimation of diurnal and subdiurnal variations with merely diurnal parameter sampling. The features of the complex demodulation were used in an extended parameterization of polar motion and universal time which was implemented in a dedicated version of VieVS. The functionality of the approach was evaluated by comparing amplitudes and phases of harmonic variations at tidal periods (diurnal/semidiurnal) as derived from demodulated Earth rotation parameters (ERP) to the terms of the conventional model for ocean tidal effects in Earth rotation (see Böhm et al., 2012 [1]).

- **External ionospheric delays in VieVS**
  A new module that allows the use of external ionospheric delay corrections calculated from Global Navigation Satellite Systems (GNSS) maps of Total Electron Content (TEC) has been implemented in VieVS. It has been shown that the use of GNSS TEC maps is certainly useful

in the case of single-frequency VLBI observations or when lacking ionospheric information due to measurement errors.

- **Global solutions with VieVS**
  VieVS allows a global adjustment of normal equations from single sessions in a separate module called *vie_glob*. It allows the estimation of terrestrial reference frames (station positions and velocities assuming linear motion of stations), celestial reference frames (source positions) and Earth orientation parameters. We analyzed all 24-hour IVS sessions from 1984.0 to 2011.0 and estimated our new terrestrial and celestial reference frames (VieTRF10a and VieCRF10a; see Spicakova et al. (2012, [4])). Furthermore, we examined the effect of tropospheric delay modeling on the estimated reference frames (see Figure 2).

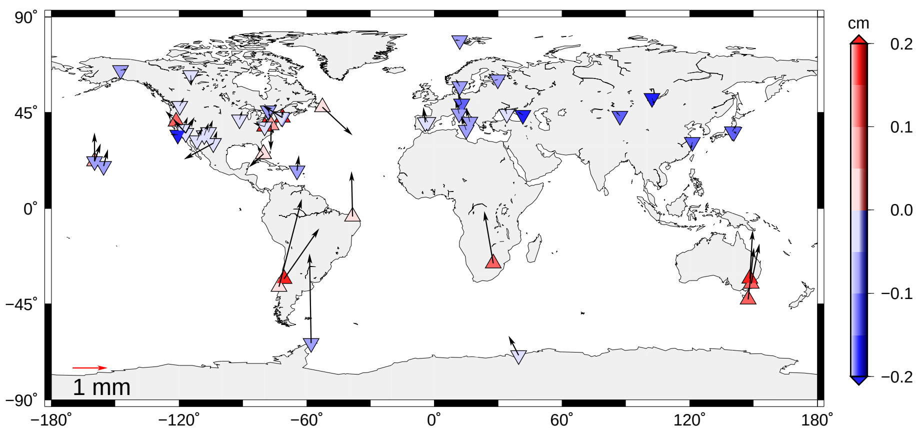

Figure 2. Influence of a priori gradients on station coordinates at epoch 2000.0. In both cases, tropospheric gradients were estimated as piecewise linear offsets every six hours with 1 mm absolute and 0.5 mm relative constraints. We show the differences in the sense *DAO apriori gradients* minus *zero a priori gradients*. Horizontal position changes are shown as arrows, vertical changes by color-coded triangles pointing in the direction of change (from Spicakova et al. (2012, [4]).

- **VLBI for space applications**
  The efforts of implementing the processing of VLBI observations of artificial sources within the solar system into VieVS have been continued. Same-beam differential VLBI observations of the Japanese lunar mission SELENE were analyzed with VieVS, and the results were successfully verified by comparison with those obtained by the National Astronomical Observatory (NAOJ), Mizusawa. Additionally, investigations regarding atmospheric effects, as well as the estimation of spacecraft coordinates, were performed. More recently the focus was put on VLBI tracking of satellites orbiting the Earth. This covers delay solutions of GNSS satellites in single mode, GNSS satellites in differential mode with a close-by quasar, and studies of simulated GNSS observations with a four station network.

- **General relativistic delay in VLBI observations**
  In terms of the accuracy requirements for the VLBI delay model nowadays and for VLBI2010, the significance of the relativistic effect due to the major celestial bodies was investigated. Therefore, the gravitational time delay for the Earth, the Sun, the Moon, and the planets was calculated for the observational configurations of all R1 and R4 sessions from 2002-2010.

According to our results, besides the Sun and the Earth, we recommend including the effects of Saturn, the Moon, and possibly also Venus in the delay modeling.

- **Scheduling with VieVS**
  The module *vie_sched* is the part of VieVS which designs the new scheduling algorithms to fully exploit the possibilities of the future VLBI2010 system. It considers a more uniform network and fast moving antennas. To support the development of *vie_sched*, it is directly connected to VieVS to provide feedback on the quality of the schedules by thorough and realistic simulations (see Sun et al., 2011 [3]).

- **Combination with ringlaser**
  We have combined data from the "G" ring laser gyroscope in Wettzell with VLBI observations in order to estimate Earth orientation parameters with hourly resolution. The details about the combination procedure and the results were summarized by Nilsson et al. (2012, [2]). Since the accuracy of the ring laser currently is about one order of magnitude worse than that of VLBI, the ring laser data normally do not contribute significantly to the combination, and the results are not improved compared to using only VLBI data. However, the combination with ring laser data would significantly improve the results if the accuracy of the ring laser was higher and/or data from more than one ring laser was used.

4. Future Plans

In 2012 we will continue the development of VieVS, with special focus on spacecraft tracking and scheduling. Additionally, we will contribute to the ongoing activities within VLBI2010 and Earth orientation, and reference system studies will be carried out. Other goals are to organize a third VieVS User Workshop and to equip VieVS with a Kalman filter solution.

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References

[1] Böhm, S., Brzezinski, A., Schuh, H., Complex demodulation in VLBI estimation of high frequency Earth rotation components, Journal of Geodynamics, published online, doi: 10.1016/j.jog.2011.10.002, 2012.

[2] Nilsson, T., Böhm, J., Schuh, H., Schreiber, U., Gebauer, A., Klügel, T., Combining VLBI and ringlaser observations for determination of high frequency earth rotation variation, J. Geodyn., submitted 2012.

[3] Sun, J., Pany, A., Nilsson, T., Böhm, J., Schuh, H., Status and future plans for the VieVS scheduling package, in: W. Alef, S. Bernhart, A. Nothnagel (eds.) Proceedings of the 20th Meeting of EVGA, pp. 44-48, 2011.

[4] Spicakova, H., Böhm, J., Plank, L., Nilsson, T., Schuh, H., Atmospheric Effects on VLBI-derived Terrestrial and Celestial Reference Frames, in: P. Willis (ed.) Proceedings of the IAG Symposium 2011, Melbourne, submitted 2012.