Vienna Analysis Center Report 2021–2022

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Abstract The IVS Analysis Center VIE is jointly run by the Technische Universität Wien (TU Wien) and the Bundesamt für Eich- und Vermessungswesen (Federal Office of Metrology and Surveying, BEV) since 2018. During the last two years, we contributed to the realization of the International Terrestrial Reference Frame 2020 with the reanalysis of VLBI sessions. Beside the regular operational analysis of VLBI sessions and estimation of global terrestrial and celestial reference frames along with Earth orientation parameters, we work on a variety of topics. For example, we focused on the optimization of scheduling and analysis of simulated data to satellites, on studies regarding Intensive sessions, and on an extended Earth rotation parameterization with continuous piecewise linear functions.

1 General Information

Technische Universität Wien (TU Wien) and the Federal Agency of Metrology and Surveying (BEV) are jointly running the VLBI Analysis Center VIE in Vienna as agreed upon in the summer of 2018 by signing a memorandum of understanding. At TU Wien the Analysis Center is attached to the Research Unit Higher Geodesy (HG), which is one of eight Research Units within the Department of Geodesy and Geoinformation (GEO). Besides VLBI, the research focus of Higher Geodesy is on satellite navigation and studies in the field of the Earth system. At BEV the Analysis Center is attached to the Department of Control Survey, which, e.g., is running the satellite positioning service APOS. Figure 1 shows members of the Research Unit Higher Geodesy and the BEV during the retreat in Payerbach-Reichenau. Since that time (September 2022) Hana Krásná has been chairing the VLBI Analysis Center VIE in Vienna.

1. Technische Universität Wien
2. Bundesamt für Eich- und Vermessungswesen

VIE Analysis Center

IVS 2021+2022 Biennial Report

2 Activities during the Past Two Years

2.1 Vienna VLBI and Satellite Software

The label VieVS (Vienna VLBI and Satellite Software for Geodesy and Astrometry, [1]) embraces all software developed and maintained by the HG group. Free access to all VLBI-related modules is offered via our GitHub account at https://github.com/TUW-VieVS. We provide VLBI analysis software, a VLBI raw data simulator VieRDS [2], and the VLBI scheduling tool VieSched++ [3], which is now continued and further developed by Matthias Schartner at ETH Zürich with ongoing cooperation in the field of satellite observations. The latest version of VieVS-VLBI (after release tag V3.3) incorporates ITRF2020 [4] site positions, velocities, and post-seismic deformation and can handle vgosDB files with the new naming convention (master file version 2). More information about VieVS can be found on our revamped Wiki page https://vievswiki.geo.tuwien.ac.at and at the VieVS YouTube channel.

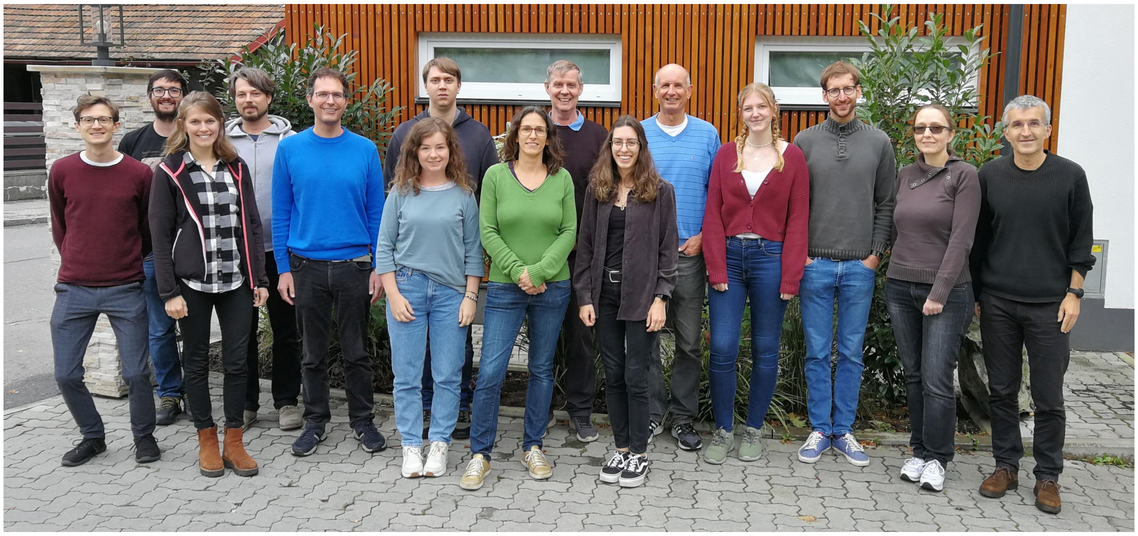

Fig. 1 Members of the Research Unit Higher Geodesy and BEV at the retreat in Payerbach-Reichenau (Austria) in September 2022.

Table 1 VIE members ordered alphabetically with their main tasks related to VLBI.

Leo Baldreich (since 01/2022)	Operational VLBI processing, student assistant
Johannes Böhm	Reference frames, Chair of HG
Sigrid Böhm	VieVS administrator, Earth orientation
Jakob Gruber	Correlation and fringe-fitting, raw data simulation
Andreas Hellerschmied	Operational VLBI processing
Frédéric Jaron	EU-VGOS, correlation and fringe-fitting
Lisa Kern	Intensive sessions, Earth orientation
Hana Krásná	Reference frames, VLBI global solutions
David Mayer	Operational VLBI processing, ITRF2020 submission
Axel Nothnagel	Consultant
Olivia Panzenböck	Analysis of EU-VGOS sessions, student assistant
Helene Wolf	VLBI observations to satellites, website

2.2 VLBI Observations to Satellites

In the last few years, the software VieSched++ was equipped with a satellite scheduling module that enables the planning of satellite observations in a schedule together with quasar observations, either manually or automatically [5].

Further, so-called Dilution of Precision (DOP) factors were introduced representing the sensitivity of a satellite observation with VLBI towards the components of the satellite position in the local orbital frame with the normal, tangential, and cross-track directions [6]. The results demonstrated that the normal component is significantly worsely determinable compared to the tangential and cross-track components. The highest sensitivities towards the tangential and cross-track directions arise if the satellite track and the observing baseline are parallel or orthogonal, respectively. These DOP factors could be used as an optimization criterion during the scheduling process of a satellite scan.

Additionally, the software package VieVS was equipped with the estimation of piecewise linear offsets of the individual components of the satellite position and the orbital elements, i.e., right ascension of the ascending node as a first test. For this, schedules were created using VieSched++ and simulated and analyzed using VieVS, and the results were assessed based on the repeatabilities and mean formal errors [7].

2.3 EU-VGOS

The EU-VGOS project [8, and references therein] was initiated in 2019 with the aim of investigating methods for the post-processing of Level-1 VGOS data. VGOS telescopes observe in dual-linear polarization mode. One of the main purposes of the EU-VGOS project is to explore how to best combine the two linear polarizations to Stokes *I*. EU-VGOS is currently a collaboration of about 50 individuals from different research institutes, mainly located in Europe but also beyond. The EU-VGOS collaboration has observed a number of research and development sessions, which are available for analysis. The network of these sessions consists of the European VGOS stations (i.e., Oe, Ow, Ws, and Yj at the time of observation) and is sometimes joined by Is in Japan.

At TU Wien we investigate how to best make use of these sessions in the framework of a geodetic analysis with VieVS with a special focus on tropospheric parameter estimation and with Earth orientation parameters being the estimated parameters of interest. This will help in the future to enable the investigation of differences between databases created from fringe-fitting *pseudo*-Stokes *I* data (generated by the Haystack VGOS pipeline) and data that have been calibrated and converted to circular polarization using the PolConvert software [9].

2.4 Earth Orientation and Intensive Sessions

At TU Wien, we routinely analyze the IVS VLBI sessions. In the last few years, we have refined our automatic processing of VLBI Intensive sessions and reprocessing of 24h sessions. This includes an iterative analysis with VieVS and an automated generation of an EOP file on a daily basis (current version *vie2022b.eopi* available at https://www.vlbi.at/products). A daily updated *.eoxy* file, including the EOP from standard 24h sessions, can also be found on our website.

Furthermore, studies regarding VLBI Intensive sessions and their performance have been carried out at TU Wien. It has been shown that the orientation of the single baseline, the selection and distribution of observed sources, especially in right ascension, the scheduling optimization strategy as well as the accuracy of the a priori values have a high impact on the accuracy of the UT1 estimate [10, 11, 12]. Additionally, a study regarding the Southern Intensives (SI) program, initiated by our group in late 2019, has been published. On the basis of 53 sessions from 2020 and 2021 observed between Hartebeesthoek (HART15M, Ht), Yarragadee (YARRA12M, Yg), and Hobart (HOBART12, Hb), we were able to show the competitiveness of the SI sessions in comparison to regularly observed Intensive sessions [13].

2.5 Extended Earth Rotation Parameterization with Continuous Piecewise Linear Functions

Continuous piecewise linear functions are a helpful way of parameterizing time series in least-squares adjustments employing a Gauss-Markov model. This approach is investigated for extended Earth rotation parameterization in collaboration of several IVS Analysis Centers under the lead of TU Wien [14]. The current approach of Earth rotation parameter estimation with 24-hour offsets and rates has deficits stemming from the mismatch of tabulated a priori EOP values at day boundaries and the two-calendar-day spanning of contemporary IVS observing sessions. In addition, the current EOP parameterization causes a mismatch of the IVS-derived EOPs labeled with “24 hours” with the daily EOPs derived from other space-geodetic techniques.

The project provided the first results in 2022 concluding that differences between celestial pole offset estimates and fixed modeled a priori values lead to systematics in the sub-daily piecewise linear polar motion estimates. A solution for handling celestial pole offsets in a rigorous way for operational purposes is under investigation.

2.6 Vienna VLBI Contribution to the ITRF2020

The VIE group contributed to the generation of the ITRF2020 by submitting sessions to the IVS Combination Center. More than 6000 sessions were analyzed including, for the first time, the new VGOS sessions. A state-of-the-art VLBI analysis was performed with the ITRF2014 [15] and ICRF3 [16] as a priori reference frames and the IERS EOP 14C04 series [17] as a priori EOP. The IERS Conventions 2010 [18] were used to calculate the computed delay. Since the creation of the ITRF2014, a couple of new models have emerged. The following new models were included in the contribution to the ITRF2020:

- New mean pole-tide model
- New high-frequency EOP model [19]
- Galactic aberration
- Gravitational deformation of VLBI antennas [20]

The VIE solution is the only VLBI submission that uses piecewise linear offsets for the parameterization of the EOP. After initial complications the combination with the other submissions was successful.

2.7 Reference Frames

At VIE we generate our own global terrestrial and celestial VLBI reference frames. The solutions are created in a common least-squares adjustment using the software VieVS. The recent solution VIE2022b [21] contains observations until June 2022 (with and without VGOS sessions), and together with the Earth orientation parameters, it is publicly available at https://www.vlbi.at/products. Within the established VLBI Working Group on TRF Scale, several possible reasons for the present discrepancy between the scale of the ITRF2020 and the scale coming from VLBI observations have been investigated. Furthermore, Hana Krásná analyzes K-band (24 GHz) VLBI observations and compares the resulting CRF and EOP with solutions provided by David Gordon at the United States Naval Observatory.

3 Future Plans

In addition to the continuation of the work described above, we have plans for new research:

- Under the umbrella of VieVS, we are going to develop stand-alone Python software for the combination of VLBI sessions. At a later stage, this software will also allow the combination with other space-geodetic techniques.
- The regular update of the reference frames at VIE is foreseen.
- In project SOFT, approved by the Austrian Science Fund, we will concentrate on source structure in VGOS fringe-fitting.

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