

# Vienna VLBI Software – Current release and plans for the future

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**Abstract** The Vienna VLBI Software (VieVS) is a geodetic Very Long Baseline Interferometry (VLBI) data analysis software which has been developed at the Vienna University of Technology since 2008. This paper gives an overview about its capabilities, including scheduling and simulation of VLBI observations. The latest release, version 2.1 includes a graphical user interface. A few results and planned future developments are presented as well.

**Keywords** VLBI, data analysis, Scheduling, Simulation

## 1 Introduction

To meet the requirements of future geodetic VLBI experiments, e.g. VLBI2010, the VLBI group at Vienna University of Technology has been developing and maintaining a VLBI data analysis software called VieVS (Vienna VLBI Software, Böhm et al., 2012). Several institutions worldwide use the software to perform various investigations. The code can be read and changed easily since it is written in Matlab. Therefore VieVS runs on all operating systems which are able to run Matlab.

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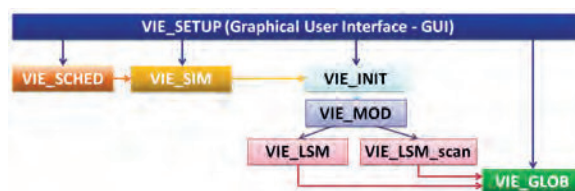
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In the latest release versions (2.0 and 2.1) we have focused on a new Graphical User Interface (GUI) which makes the use of the program even easier, for experienced users as well as for students. This GUI provides a consistent treatment of all capabilities of the software, i.e. single session analysis, scheduling, simulation and global parameter estimation. Furthermore the new version includes a plotting tool to visualize several useful information as well as the estimated parameters.

## 2 VieVS overview

The idea behind VieVS was to develop a new state-of-the-art VLBI data analysis software to perform single-session analysis. VieVS now is able to read NGS-files as well as openDB files in NetCDF format (Gipson, 2010) and includes the most recent IERS Conventions (Petit and Luzum, 2010). The parameter estimation is done in a least squares adjustment; clock parameters, zenith wet delays, tropospheric gradients, Earth Orientation Parameters (EOP), station and source coordinates can be estimated as piece-wise linear offsets at fractions of integer hours.

The structure and different modules are shown in Fig. 1.



**Fig. 1** VieVS structure and different modules of the software.

### 3 Graphical User Interface

All processing options and output settings can be modified in VIE.SETUP, the graphical user interface of VieVS (Fig. 2). It is built in Matlab as well and therefore allows easy manipulation.

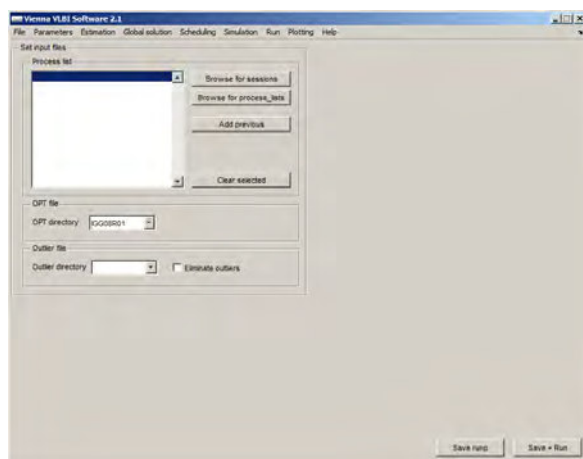


Fig. 2 Graphical user interface of VieVS.

The interface includes a plotting tool where estimated parameters, post-fit residuals and session information can be visualized. Observations can be marked as outliers, clock break information added, and solutions can be compared with each other (Fig. 3). Ana-

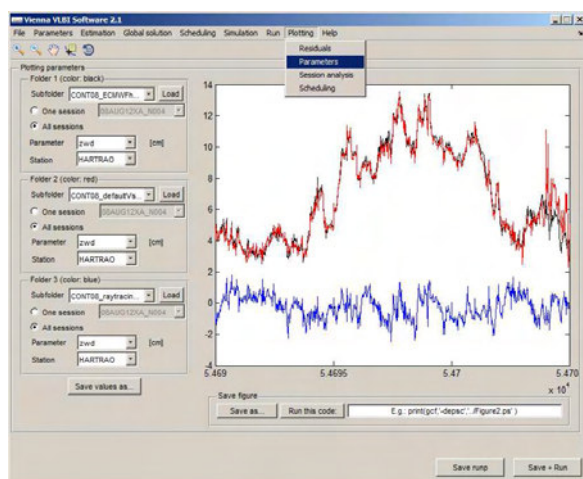


Fig. 3 Comparison of VLBI solutions using the VieVS plotting tool.

lysts can furthermore see the station network and the correlation matrix between estimated parameters, as well as plot the baseline length repeatabilities of up to four solutions.

### 4 Additional features

Besides single session analysis, VieVS has several other modules for geodetic VLBI applications.

- **Scheduling**  
Towards VLBI2010 (Petrachenko et al., 2009) new scheduling strategies have to be developed due to changing equipment at VLBI sites, for example fast-slewing antennas and Twin telescopes. Therefore we have developed VIE\_SCHED (Sun, 2013), a scheduling program as part of the VieVS software package. It creates observation schedules and has been used to schedule seven R&D sessions in 2012 to study the Sun corona. As an alternative to the classical 'station-based' algorithm, we can also use the 'source-based' strategy which is simpler and yields similar results as the classical approach. The idea behind the new strategy is to have a simple scheduling algorithm that still achieves a good sky-coverage for an accurate troposphere estimation (Sun, 2013). Using VIE\_SCHED we will schedule the AUSTRAL sessions in the second half of 2013.
- **Global solution**  
The global solution module, VIE\_GLOB (Krásná, 2013a), combines normal equations of several single sessions to estimate global parameters, such as Terrestrial Reference Frame (TRF) or Celestial Reference Frame (CRF) solutions. Fig. 4 shows horizontal position differences at epoch 2000.0 between our VieTRF10a (Krásná et al., 2013b) and VTRF2008 (Böckmann et al., 2010). Red arrows denote the datum stations and blue ones the remaining stations.

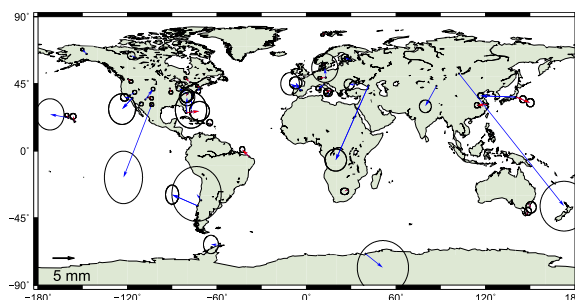


Fig. 4 Horizontal position differences between VieTRF10a and VTRF2008.

- **Simulation**  
This tool simulates artificial VLBI observations based on theoretical (model) delays plus simulated errors for the main error sources: wet troposphere

(Nilsson and Haas, 2010), clock errors as random walk plus integrated random walk process and white observation noise. Those delays can be written into NGS files and then analyzed like a standard VLBI session.

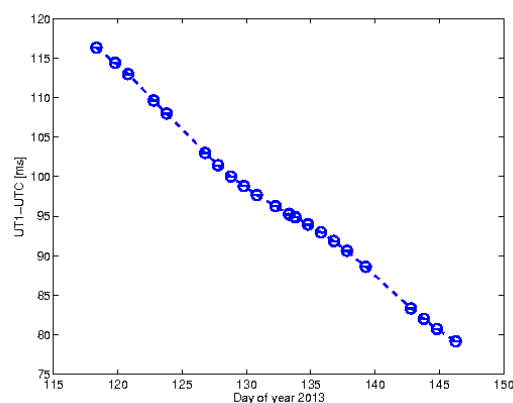
- **Spacecraft tracking**  
VieVS, with slight modifications, has successfully been used to process differential VLBI observations of the Japanese lunar spacecraft SELENE (Plank et al., 2013).
- **External delays**  
In order to make the program more flexible and the structure more similar to the one proposed by the Working Group 4 (Gipson, 2010), we use ASCII files containing tropospheric or ionospheric delays from external sources, such as ray-tracing, GNSS, or TEC-maps.
- **Main station/source file**  
Since version 2.0 we store all static station- or source-dependent information in a file which makes it easier for the different modules to use those information consistently. The station-file contains different TRF and antenna and equipment information as well as tidal loading coefficients. The source-file is more or less a translation table and includes different CRF.
- **Parallel computing**  
To decrease the processing time VieVS can run in parallel mode on a CPU with more than one core.
- **Documentation**  
Since version 2.1 there exists a user manual for the software. It includes a fundamentals chapter about VLBI analysis and exercises for beginners. The document can be downloaded from our webpage: <http://vievs.geo.tuwien.ac.at>.

## 5 Automatic processing and results

We have set up an automatic processing batch job which automatically downloads and processes all new VLBI sessions. A processing report including information about the session (e.g. date and participating stations), statistics as well as a residuals plot is sent to the analyst who decides if more action has to be taken to derive useful results. This procedure makes an operational analysis of VLBI sessions feasible.

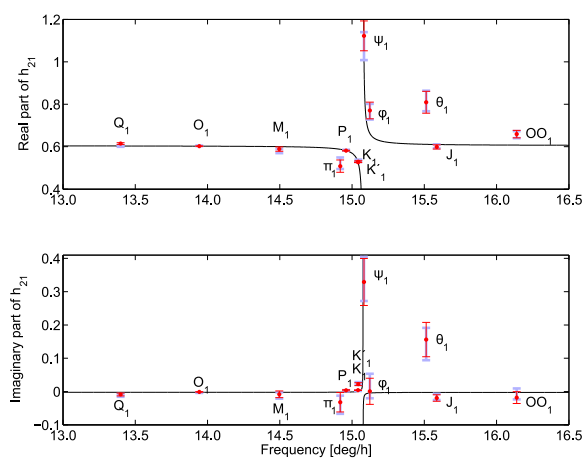
We also estimate UT1–UTC from VLBI Intensive sessions on an operational basis. The estimated values are shown in Fig. 5.

Several geodynamic and astronomical parameters have been estimated using the global solution mod-



**Fig. 5** UT1–UTC from VLBI Intensive sessions estimated with VieVS from April 28<sup>th</sup> to May 26<sup>th</sup> 2013.

ule VIE\_GLOB. Fig. 6 shows the real and imaginary parts of Love numbers for twelve diurnal tidal waves (Krásná et al., 2013c). The two solutions differ in the a priori ocean loading model, where the 'FES2004 solution' is plotted in red and the 'AG06a solution' in light blue. The black line denotes the theoretical values from the IERS Conventions 2010 (Petit and Luzum, 2010).



**Fig. 6** Real and imaginary parts of Love numbers for twelve diurnal tidal waves estimated with VIE\_GLOB.

## 6 Future plans

- **Kalman filter**  
As an additional estimation algorithm we will use a Kalman filter which allows to model the stochastic behaviour of e.g. clocks more accurately. Furthermore it may be used for real-time applications.

- **Spacecraft observations**  
At the moment, VieVS is extended for the possibility to process and simulate VLBI observations to near-Earth targets, e.g. satellites (Plank et al., this issue).
- **Group delay ambiguity resolution**  
We want to add the possibility to resolve group delay ambiguities, and calculating the ionospheric delay. Then we could use the correlator output to perform analyses earlier.
- **Source-structure**  
In a cooperation with the University of Tasmania we will include source-structure corrections in the Vienna VLBI Software. As a first step we will perform simulations to study the error due to the structure of sources.

## 7 Concluding remarks

VieVS is freely available for registered users. Registration and more information can be found at the VieVS webpage: <http://views.geo.tuwien.ac.at>.

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