Scheduling VLBI observations to satellites with VieVS

A. Hellerschmied[1], J. Böhm[1], L. Plank[2], A. Neidhardt[3], J. Kodet[3], R. Haas[4]

[1]Vienna University of Technology, Austria
[2]University of Tasmania, Australia
[3]Technische Universität München, Geodetic Observatory Wettzell, Germany
[4]Chalmers University of Technology, Onsala Space Observatory, Sweden

1. Introduction

Observations of satellites with Very Long Baseline Interferometry (VLBI) radio telescopes provide a variety of new possibilities and promote the integration of different geodetic techniques, which is one of the main purposes of GGOS, the Global Geodetic Observing System of the IAG. Promising applications can be found, among others, in the field of inter-technique frame ties. A number of test observations (Tornatore et al. 2014) and studies (Plank et al. 2014) have been carried out in recent years. With the standard scheduling and observing software not being prepared for this so far, such observations were complicated for careful manual interaction to the standard interchange files. The newly developed satellite scheduling module of the Vienna VLBI Software (VieVS; Böhm et al., 2012) for the planning of satellite observations with VLBI antennas offers a solution to this.

2. VieVS satellite scheduling module

This new VieVS extension provides the possibility to schedule satellites as targets for VLBI observations. The results are schedule files in the VEX data format, which can be used to control the VLBI antennas and the station equipment in order to carry out real satellite observation experiments. The existing schedule module VIE_SCHED (Sun et al. 2014) was extended to integrate the new satellite scheduling functions to the VieVS package. The integration into the graphical user interface (GUI) of VieVS provides an easy and comfortable handling.

3. Workflow

After preparing the required input data and defining the general observation setup in the GUI (3.1.), the software calculates the available observation times for each selected satellite and provides this information to the user (3.2.). After assembling the observation schedule via a simple interface, the corresponding schedule files are generated (3.3.).

3.1. Scheduling parameters & data input

→ User sets parameter in GUI:
- a. Station network
- b. Observation time
- c. Satellites
- d. Output options
- e. Restrictive parameters
  - Cut-off elevation
  - Min. sun distance
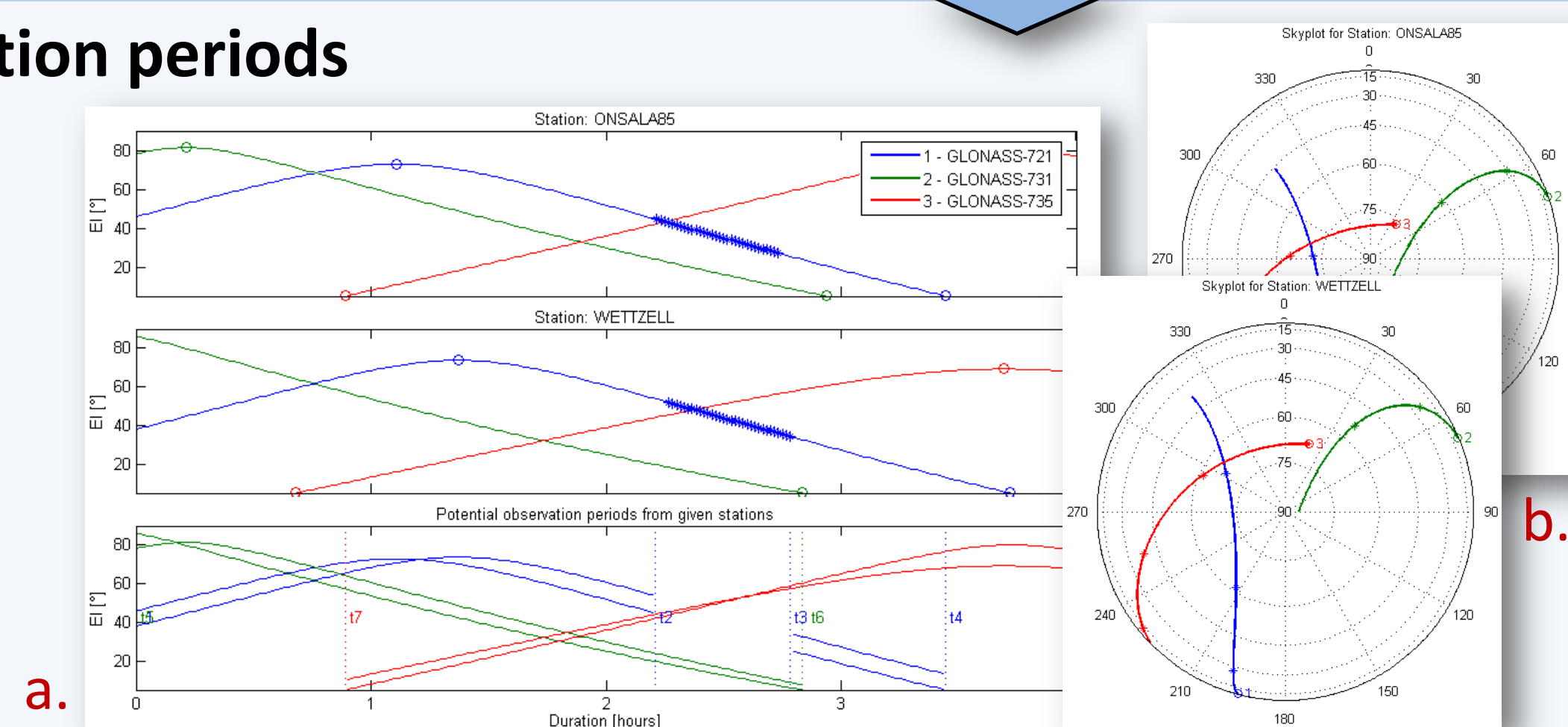
→ Input data is loaded by VieVS.
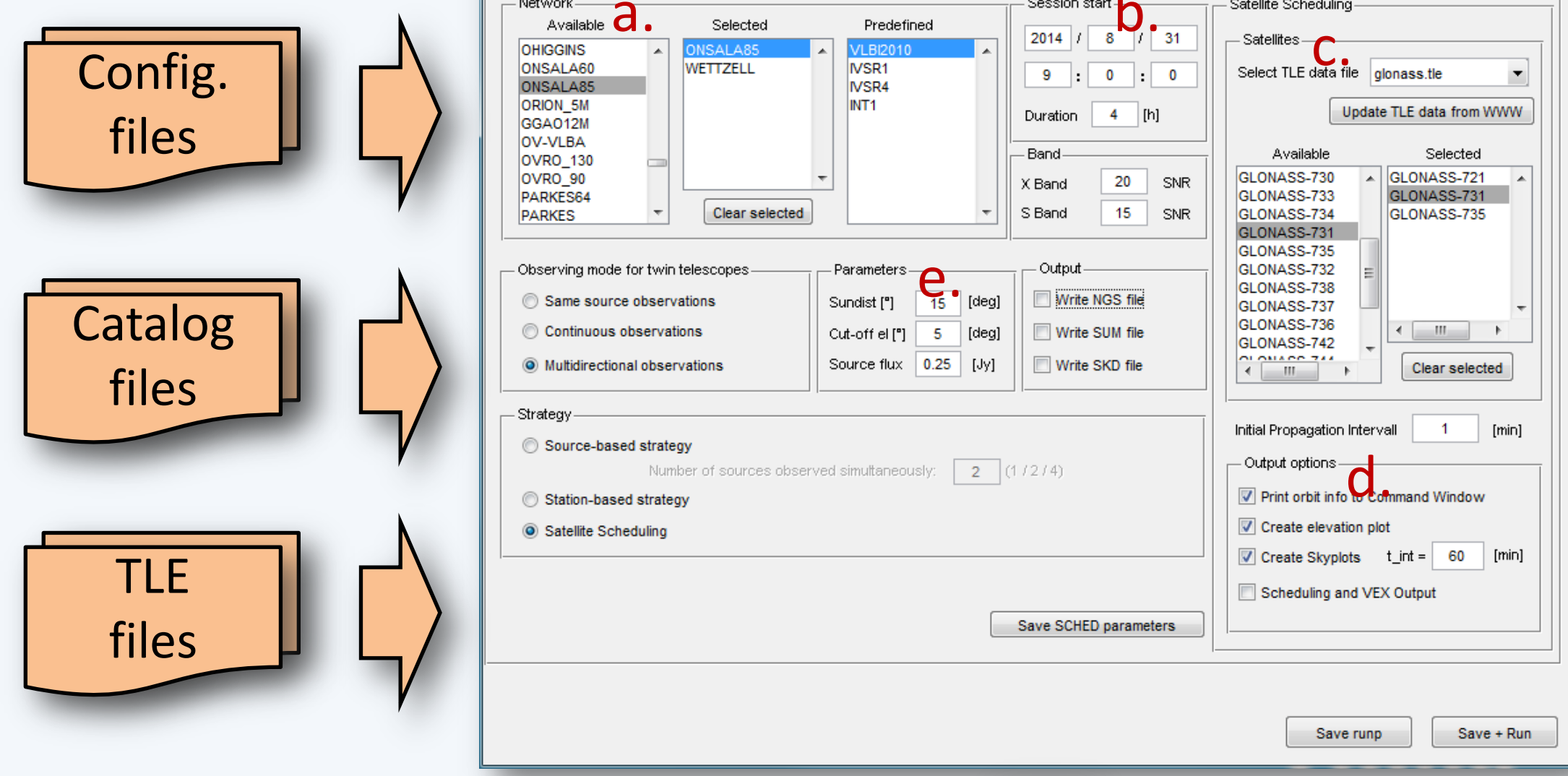
3.2. Calculation of available observation periods

→ VieVS calculates the available observation periods of all selected satellites for the defined observation constellation.

→ Information on satellite overpasses is provided to the user:
- a. Elevation plot
- b. Skyplots per station

3.3. Compilation of the observation schedule & generation of VEX files

→ The user defines any number of consecutive satellite scans by selecting the satellite and the corresponding observation period via a simple user interface.

→ After preparing the complete schedule, VEX files are generated.


User interface

4. Program details

4.1. Required input data

→ NORAD Two Line Element (TLE) data
- Datasets for satellite orbit determination by dedicated analytical models (Hoots & Röhrich 1988)
- Widely available on a daily basis over the internet; update function provided in the VieVS GUI

→ Catalog files
- Provide the required station data (antenna and receiver properties, coordinates, etc.)

→ Configuration files
- Define the setup of receiver/station equipment used for actual satellite observations

4.2. Implementation of satellite tracking using VEX files (1.5b1)

→ "Stepwise" satellite tracking approach:
- Satellite orbits are converted to a series of distinct topocentric equatorial positions (right ascension & declination)
- Antenna is repositioned in a defined time interval (e.g. 15 sec) to follow the satellite
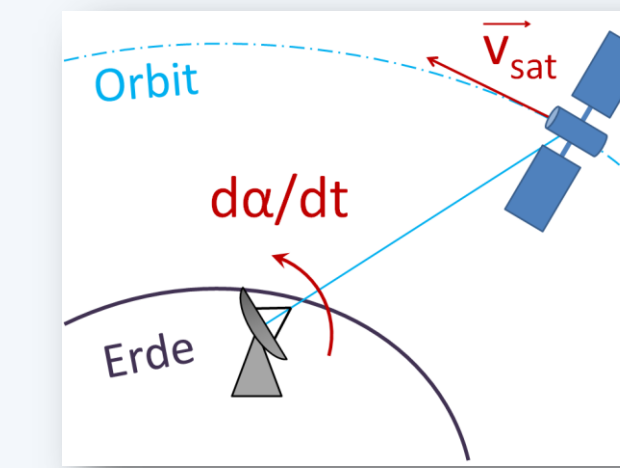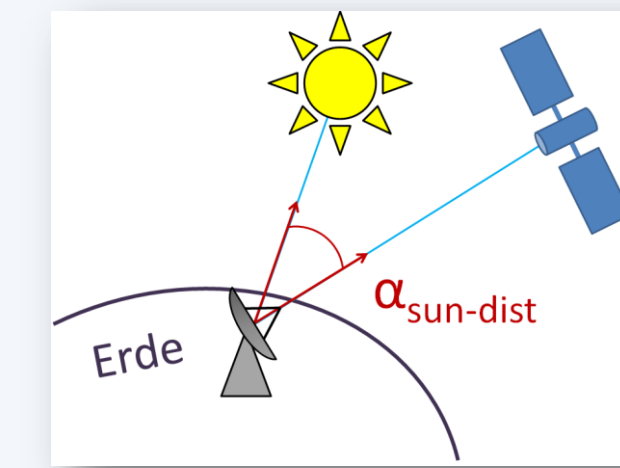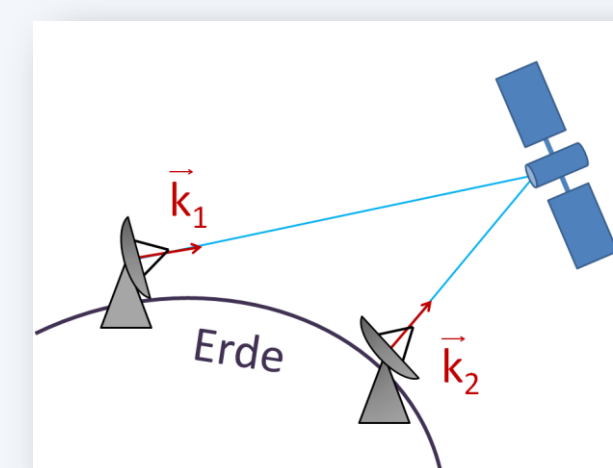- Feasible for standard IVS radio antennas
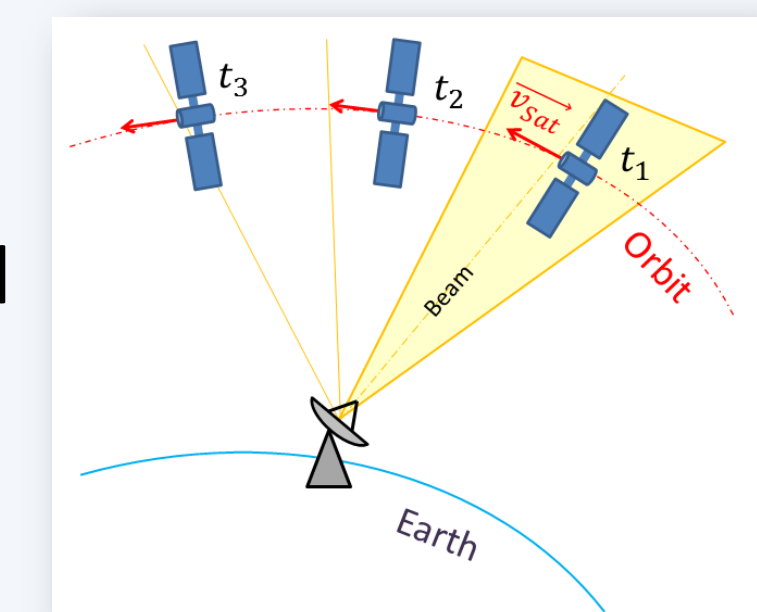
Tracking principle

4.3. Conditions for a valid satellite scan

→ The following conditions are checked by VieVS in order to decide if a satellite is observable:

1. Satellite visible from all participating stations?
2. Distance between sun and satellite above threshold?
3. Antenna slew speeds large enough to keep track?

5. Satellite observation experiments: Onsala – Wettzell

Observations

During several experiments planned with VieVS the new satellite scheduling capabilities could be tested.

- Baseline: Wettzell – Onsala
- Observation of several GLONASS satellites (L1-band)
- Four sessions with one hour duration each
  - 16th January 2014:   G140116a, G140116b
  - 21st January 2014:   G140121a, G140121b
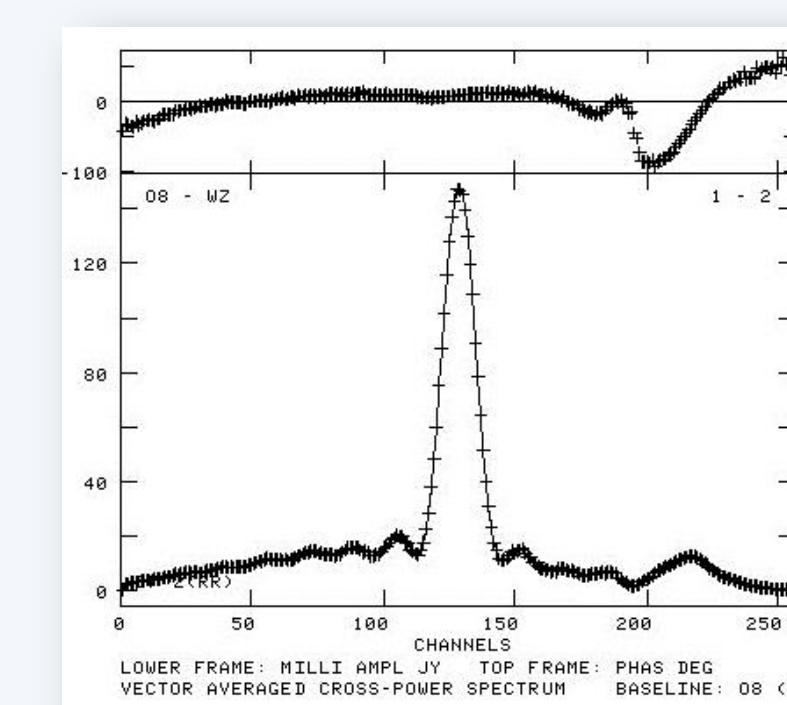
25 m antenna
L-band receiver

20 m antenna
L1 GNSS receiver

Station network

Results

- Preliminary data analysis by R. Haas
- Correlation of the acquired data with the DiFX software

Correlation result for GLONASS-732. Data acquired during the G140121a session.

→ Continuous phases and strong amplitudes were found for all observed satellites!

6. Summary & Outlook

→ The **VieVS satellite scheduling module** provides a flexible tool for scheduling real VLBI satellite observations and generating schedule files in the VEX format.
  - ✓ For any orbit types (LEO, MEO, etc.) and various station networks (nevertheless, observation restrictions occur due to the limited frequency bands observable with current VLBI antennas)
  - ! No scheduling optimization so far
  - ! No combination with classical observations to quasars yet

→ **Satellite tracking based on VieVS schedule files** in the current data format (VEX 1.5b1) is implemented using the described stepwise tracking approach.
  - ! The proposed VEX 2.0 format will support the definition of satellite orbits in terms of TLE data, which will provide further tracking possibilities in the future.

→ Several **successful satellite observation experiments** carried out in January 2014 on the baseline Wettzell – Onsala showed the viability of the new satellite scheduling module.

✉ Contact: andreas.hellerschmied@geo.tuwien.ac.at

References

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Plank L et al. (2014), Precise station positions from VLBI observations to satellites: a simulation study, J Geod, 88: 659-673 , DOI: 10.1007/s00190-014-0712-1.
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