

AUA047: Students at TU Wien Organize Their own VLBI Session

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Abstract At Technische Universität Wien (TU Wien) students had the chance to fully organize the official IVS session AUA047. We will give an overview of the individual parts of this course, including, scheduling, large-scale Monte Carlo simulations, an correlation exercise and analysis. The workflow of carrying out the AUA047 VLBI session using the Vienna VLBI and Satellite Software (VieVS) and the new scheduling tool VieSched++ is described. We provide, as well, the scheduling statistics achieved with VieSched++ and the results of the analysis.

Keywords IVS, scheduling · Large-scale Monte Carlo simulations · Correlation · Analysis · VieSched++ · VieVS

1 Introduction

As part of the lecture “Space Geodetic Techniques” at TU Wien, students organized an official VLBI session of the International VLBI Service for Geodesy and Astrometry (IVS) (Nothnagel et al., 2017). The experiment is part of the AUSTRAL VLBI program (Plank et al., 2017) with the session code AUA047. Observation start was the 4th of December 2018. More than 30 students participated in this course and worked independently in groups to perform all necessary steps, in-

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cluding large-scale Monte-Carlo simulations, scheduling, correlation and analysis. As a result of a cooperation with the University of Tasmania, it was possible to observe the VLBI session successfully with Australian telescopes. The participating stations were Hobart (26 m), Katherine and Yarragadee, shown in Figure 1.

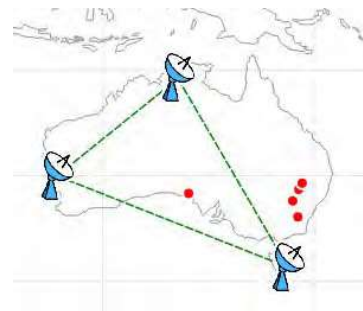


Fig. 1: The network of the AUA047 session consisting of Hobart (26m), Katherine and Yarragadee.

2 Scheduling

Schedules were created by each group independently using the software VieSched++ (Schartner and Böhm, 2019). The students could decide if they want to optimize the schedule for a geodetic, astrometric or intensive-like purpose. For this optimization the VieSched++ multi-scheduling tool was used. The students investigated the impact on the schedule of using different optimization criteria such as, number of observations, sky coverage, scan duration, maximum allowed idle time and minimum number of stations per scan. Additionally, the individual weights of the



Fig. 2: VieSched++ statistics tool for comparing created schedules using the multi-scheduling tool. The bars symbolise the relative value of parameters such as, number of scans (blue), number of observations (green) and weight factors (red, orange, purple).

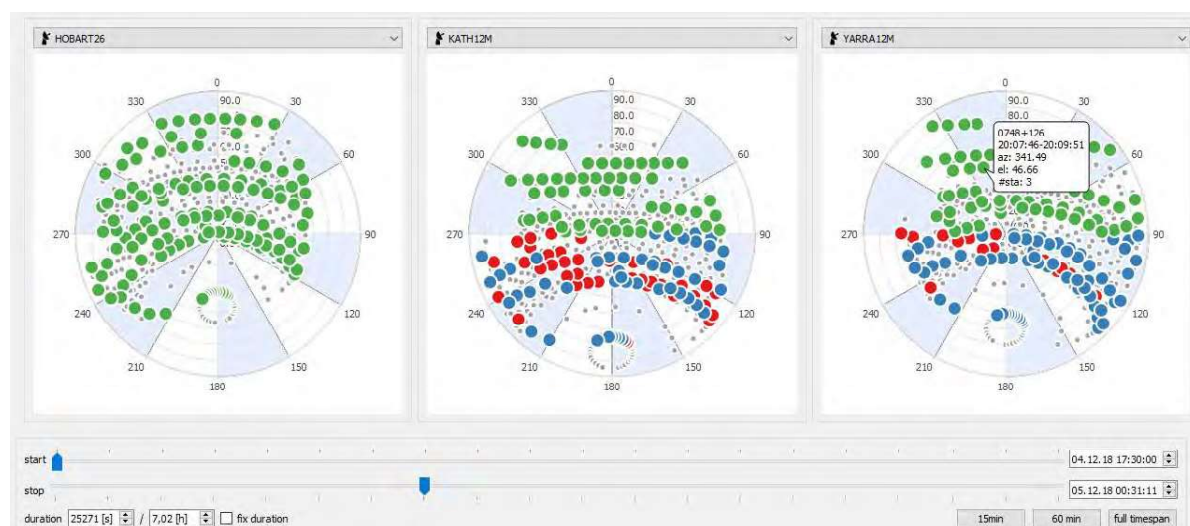


Fig. 3: VieSched++ Analyzer displaying the sky coverage of the in the session included stations, with dots representing observed sources, color-coded by the different cable wraps, counterclockwise (red), neutral (green) and clockwise (blue). The smaller grey dots represent the sources which are not observed in the selected time span.

stations were investigated with focus on the station Hobart, as this is the slowest but most sensitive station.

Figure 2 shows the VieSched++ statistics tool which was used for comparing the statistics of the created schedules. This tool allows the ranking of the schedules according to different properties, like for example, number of scans or number of observations.

The evaluation of a schedule was also done using the VieSched++ Analyzer, shown in Figure 3. This tool displays the sky coverage of the involved stations.

Therefore it allows a comparison of the created schedules based on the distribution of observed sources.

In total, several hundred schedules were created and further simulated and analysed using the Vienna VLBI and Satellite Software (VieVS) (Böhm et al., 2018). The schedule from one group was selected based on simulated repeatability values and successfully observed with the Australian telescopes.

Table 1 shows the achieved scheduling statistics of the observed schedule. It is worth mentioning that the students optimized the schedule, so that the antennas in

Table 1: Scheduling statistics of the observed schedule created using VieSched++

AUA047	
number of scans	513
number of observations	1358
number of scheduled sources	66
average observing time	58.65 %
average slew time	30.11 %
average idle time	1.77 %

average idle just for 1.77 % and observe for 58.65 % of the time.

3 Simulation

Simulations of the produced schedules were carried out for assessing the accuracy of the earth orientation parameters (EOP) and station coordinates. These large-scale Monte Carlo simulations were performed using VieVS (Pany et al., 2011). The clock accuracy was set to an Allan standard deviation (ASD) of 1×10^{-14} at 50 min (Herring et al., 1990), and a white noise of 30 ps was used. The refractive index structure constant of the troposphere C_n was set to $1.8 \times 10^{-7} m^{-1/3}$ with a scale height of 2 km (Nilsson et al., 2007). In total, several tens of thousands of simulations were generated and analyzed.

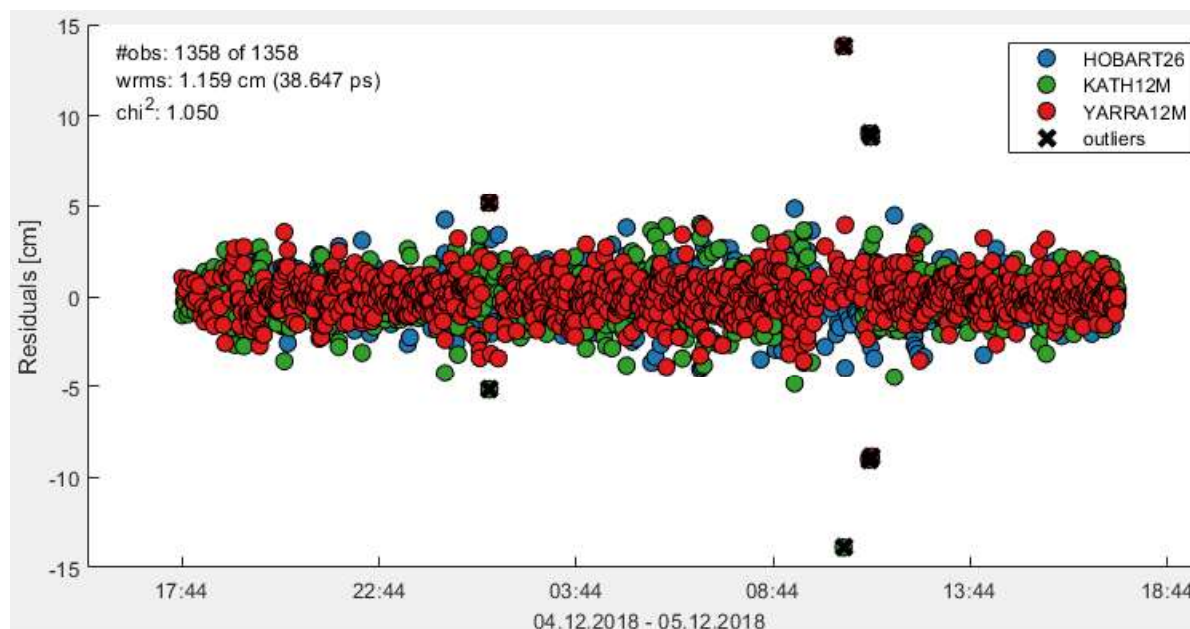


Fig. 4: Residuals in cm for AUA047 for all stations after removing clock breaks. Detected outliers, marked with a black cross, were removed in a next step.

4 Correlation

After the session was observed, the students got an introduction of the correlation of VLBI sessions with the Distributed FX-style correlator (DiFX) (Deller et al., 2007) and a presentation of the correlation on the Vienna Scientific Cluster (VSC-3).

During this course the students had to work on exercises to calculate the expected data size, transfer time and correlation time for AUA047. In order to enable the students to get a brief insight into the procedure of correlation, the students had to develop a FX- and a XF-style correlator in MATLAB and to compare the processing times.

5 Analysis

The analysis was done with VieVS using the vgosDB format. The students found and removed four clock breaks at the station Yarragadee. Further, outlier detection was performed, shown in Figure 4.

The optimising analysis was done by each group independently based on their scientific goal. The students varied for example, zenith wet delay intervals, constraints and the mapping functions. Finally, a session fit of 38.6 ps was achieved.

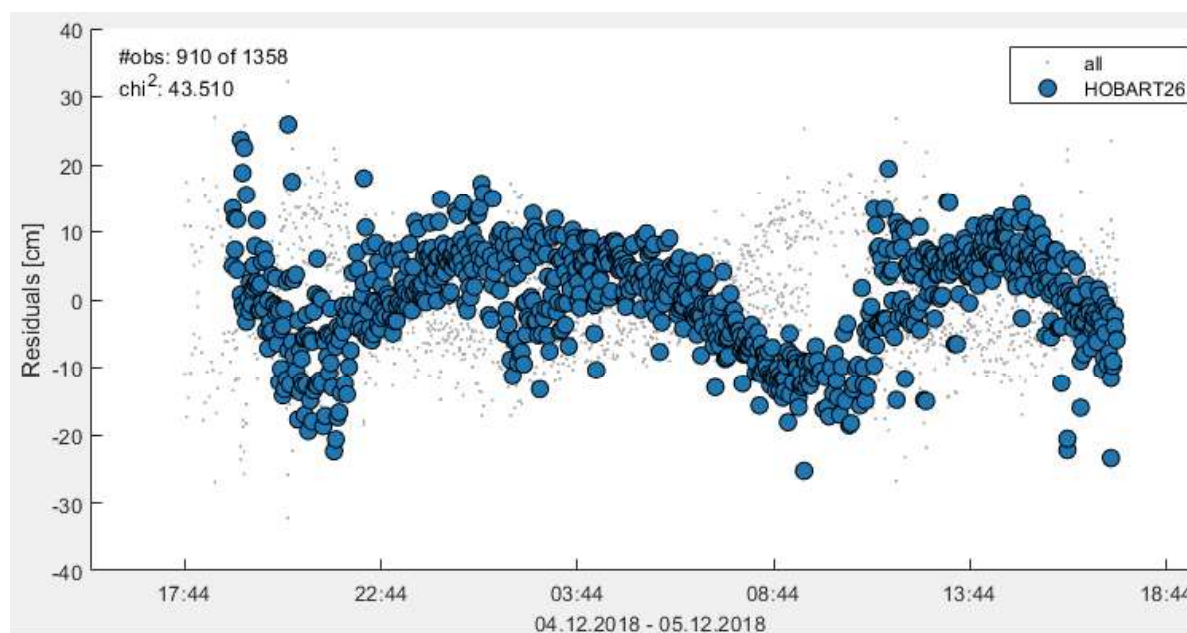


Fig. 5: Residuals in cm for AUA047 at station Hobart showing the effect of not considering the a priori model of solid earth tides.

To demonstrate the effect of a priori models like solid earth tides, tidal atmospheric loading and tidal ocean loading, the students investigated the residuals of the analysis without including these models separately and compared their results with the results obtained by applying the models. Figure 5 shows the effect of solid earth tides at station Hobart.

6 Conclusion

The official IVS session AUA047 was fully organized by students at TU Wien. All necessary steps, including scheduling, large-scale Monte Carlo simulations, correlation and analysis were done by each group independently. This shows that both software packages, VieSched++ and VieVS, are understandable and easy to use. The students got an insight into VLBI through the practical tasks and exercises. Next to the success in university teaching this course delivered scientific results as any other VLBI session does, like station coordinates and earth orientation parameters.

References

- Böhm J, Böhm S, Boisits J, et al. (2018) Vienna VLBI and Satellite Software (VieVS) for Geodesy and Astrometry. *PASP*, 130, 044503, doi:[10.1088/1538-3873/aaa22b](https://doi.org/10.1088/1538-3873/aaa22b)
- Deller A T, Tingay S J, Bailes M, et al. (2007) DiFX: A software correlator for very long baseline interferometry using multi-processor computing environments. *PASP*, 119, 318–336, doi:[10.1086/513572](https://doi.org/10.1086/513572)
- Herring T, Davis J, Shapiro I (1990) Geodesy by radio interferometry: The application of Kalman Filtering to the analysis of very long baseline interferometry data. *J Geophys Res*, 95, 12561–12581, doi:[10.1029/JB095iB08p12561](https://doi.org/10.1029/JB095iB08p12561)
- Nilsson T, Haas R, Elgered G (2007) Simulations of atmospheric path delays using turbulence models. *Proc. 18th EVGA Working Meeting*, 175–180
- Nothnagel A, Artz T, Behrend D, et al. (2017) International VLBI Service for Geodesy and Astrometry. *J Geod*, 91, 711–721, doi:[10.1007/s00190-016-0950-5](https://doi.org/10.1007/s00190-016-0950-5)
- Pany A, Böhm J, MacMillan D, et al. (2011) Monte Carlo simulations of the impact of troposphere, clock and measurement errors on the repeatability of VLBI positions. *J Geod*, 85, 39–50, doi:[10.1007/s00190-010-0415-1](https://doi.org/10.1007/s00190-010-0415-1)
- Plank L, Lovell J, McCallum J, et al. (2017) The AUSTRAL VLBI observing program *J Geod*, 91, 803–817, doi:[10.1007/s00190-016-0949-y](https://doi.org/10.1007/s00190-016-0949-y)
- Schartner M, Böhm J (2019) VieSched++: A New VLBI Scheduling Software for Geodesy and Astrometry. *PASP*, 131, 084501, doi:[10.1088/1538-3873/ab1820](https://doi.org/10.1088/1538-3873/ab1820)