DACH Operation Center 2021–2022 Report

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Abstract The Operation Center DACH is responsible for the IVS observing programs AUS-AST, IVS-CRDS, IVS-CRF, IVS-INT-2, IVS-INT-3, IVS-INT-S, IVS-OHIG, IVS-T2, IVS-T2P, VGOS-INT-B, VGOS-INT-C, VGOS-INT-S, VGOS-INT-Y, and VGOS-RD, as well as other research and development sessions. Together, this accumulated to 205 sessions in 2021 and 376 sessions in 2022. The vast majority of these sessions are scheduled fully automatically. Besides scheduling, OC DACH performs sophisticated quality control. The fully automated scheduling pipeline is operating based on Monte Carlo simulations and well-defined scientific goals for each session to reduce human biases.

1 General Information

The Operation Center (OC) DACH is a joint endeavor of ETH Zurich (Switzerland), the Federal Agency for Cartography and Geodesy in Germany (BKG; Germany), and TU Wien (Austria). The motivation behind the OC DACH is to combine expertise in VLBI scheduling with expertise in VLBI operations. Furthermore, with the help of this cooperation, the long-term existence of the Operation Center can be ensured. A fully automated scheduling pipeline (*VieSched++ AUTO*) was established within OC DACH. It is a Python framework, running on top of the VLBI scheduling software *VieSched++* [6]. This pipeline is currently used for the observing programs (OPs) AUS-AST [4], IVS-INT-2 [7], IVS-INT-3 [7], IVS-INT-S [1], IVS-OHIG, IVS-T2, VGOS-INT-B [3], VGOS-INT-C, VGOS-INT-S [8], and VGOS-INT-Y, as well as some BKG internal OPs. Furthermore, most of the remaining IVS OPs are also scheduled automatically for quality control.

Besides the fully automated operational scheduling, some further observing programs require manual scheduling due to their research and development characteristics (OP: VGOS-RD [5], VGOS-24INT-S) or because special adjustments to the input catalogs, or a manual fine tuning of the scheduling, is necessary (OP: IVS-CRDS, IVS-CRF, IVS-T2P).

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2 Activities during the Past Two Years

Sessions

The OC DACH is responsible for a variety of OPs, listed in Table 1.

The number of sessions assigned to OC DACH increased drastically over the last few years. While in 2019, only 22 and, in 2020, only 73 official IVS sessions were scheduled at OC DACH, the number increased to 205 in 2021. In 2022, the number further increased to 376 schedules. Ensuring high-quality results for this huge workload could only be achieved through rigorous automation. The majority of the current sessions are scheduled fully automatically. It was proven that the automated scheduling approach is very robust. So far, no significant errors have been reported. Furthermore, the Python-based framework proves to be

Table 1 Number of sessions processed by the OC DACH per OP. OPs marked with * are scheduled fully automatically.

OP	2021	2022
AUS-AST*	12	12
IVS-CRDS	6	6
IVS-CRF	6	6
IVS-INT-2*	93	102
IVS-INT-3*	43	36
IVS-INT-S*	0	49
IVS-OHG*	6	6
IVS-T2*	5	5
IVS-T2P	2	2
VGOS-24INT-S	0	6
VGOS-INT-B*	17	46
VGOS-INT-C*	8	42
VGOS-INT-S*	3	36
VGOS-INT-Y*	0	13
VGOS-RD	1	6
other	3	3
Total	205	376

very flexible and easy to extend. So far, changes in the scheduling strategy or adjustments to the derived output files could be implemented easily.

Intensives

The majority of the sessions assigned to the OC DACH are VLBI Intensive sessions for the rapid determination of the Earth's phase of rotation, expressed as the time difference UT1-UTC.

By changing the scheduling strategy, the formal errors of the IVS-INT-2 sessions could be decreased by 11% for baseline IsWz, 32% for baseline KkWz, and 42% for baseline MkWz [7]. Similar improvements of up to 45% were also achieved for IVS-INT-3 sessions.

Besides the SX-Intensive programs IVS-INT-2, IVS-INT-3, and IVS-INT-S, the OC DACH is also scheduling the VGOS Intensive programs VGOS-INT-B, VGOS-INT-C, VGOS-INT-S, and VGOS-INT-Y. These programs test new baselines (VGOS-INT-B/C: IsOeOw, VGOS-INT-S: MgWs, and VGOS-INT-Y: GsYj) as well as slight modifications to the scheduling strategy. Within VGOS-INT-C the source selection is avoiding observations aligned with the direction of the source jet. Within VGOS-INT-S, a rapid alternation between high- and low-elevation scans is implemented, allowing for an increased sampling of the zenith wet delay during analysis.

VGOS-RD

Over the years 2021 and 2022, seven 24-hour VGOS research and development (VGOS-RD) sessions have been scheduled and observed. Some of these sessions required significant extensions in the VLBI scheduling software VieSched++. For example, the parameterization of the station sky coverage was extended to support individual parameters per station. Furthermore, the support for calibrator scans was extended. During

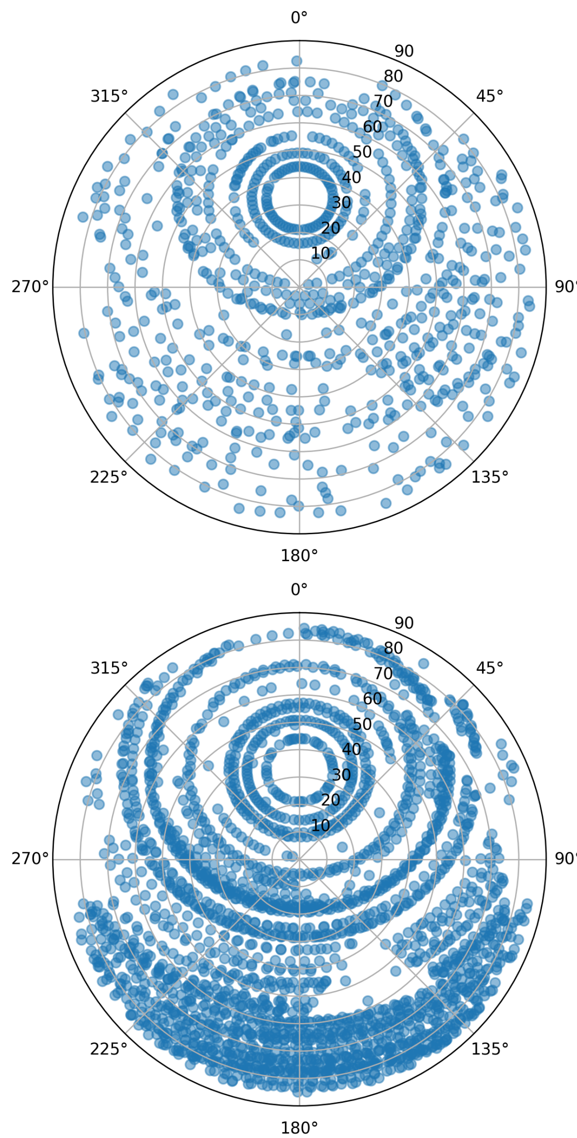

Fig. 1 Sky coverage of station ONSA13SW (Ow) for VO2132 (2022-05-12; top) and VR2303 (2022-05-19; bottom).

scheduling, the calibration scans are fixed in the first step. The calibration scans can now be chosen based on the full network (ignoring tag-along mode) to ensure that also tag-along stations are properly included in these scans. This is especially important for the new southern-hemisphere VGOS stations for which calibration scans are especially important. After the calibration scans are fixed, the actual scheduling starts by filling the time between the calibrator scans. Finally, support for a new four-band VGOS flux catalog and refined scheduling strategies were implemented as well. Due to these changes, SNR-based scheduling for VGOS sessions was utilized for the first time. With this SNR-based scheduling approach, the integration time could be reduced to 7–20 seconds, instead of using a fixed integration time of 30 seconds independent of the station sensitivity and source flux density, as is the case in the VGOS-OPS sessions. It was proven that the SNR-based integration time works. The percentage of usable observations in VGOS-RD is close to the VGOS-OPS sessions with the additional benefit that the number of observations is increased by up to a factor of two [5], while the total amount of recorded data is reduced by up to 30%. The latter point is especially important to reduce the latency of deriving VGOS results—one of the main challenges of today's VGOS sessions—because fewer bytes have to be transferred and processed. Figure 1 depicts the ONSA13SW sky coverage of VGOS-RD session VR2303 compared to the VGOS-OPS session VO2132 from the week before. A significant improvement w.r.t. the number of observed scans can be seen. The total number of scans for ONSA13SW increased by a factor of 3.2, from 797 to 2,470.

IVS-CRDS / IVS-CRF

The IVS-CRDS and IVS-CRF sessions continue to be scheduled manually. The objective of these sessions is to focus on observing ICRF3-defining sources [2]. Therefore, the source list is adapted for each session individually. Besides astrometry, astronomical source imaging is a further essential objective for these sessions, requiring special treatment during scheduling. But imaging is not possible for all sessions, due to the lack of VLBI stations in the southern hemisphere and the resulting smaller VLBI networks in some of the sessions. Besides, some southern-hemisphere stations have only low sensitivity, posing another difficulty for these sessions. Due to these obstacles (few stations in general with some of them having low sensitivity), the IVS-CRDS sessions are among the most challenging sessions to schedule.

3 Current Status

The number of sessions assigned to OC DACH has again increased for 2023. As of January 2023, we will support over 400 sessions, and it is expected that the number will rise further during the year. The scheduling pipeline is now based on the IVS master file format version 2.0. It is publicly available under `https://github.com/TUW-VieVS/VieSchedpp_AUTO`. Similarly, the VieSched++ scheduling software is available under `https://github.com/TUW-VieVS/VieSchedpp`.

The basic principle of the scheduling pipeline is that it relies on well-defined scientific goals for each session combined with large-scale Monte Carlo simulations. For each session, several hundred to a thousand different schedules are generated. Each session is further simulated a thousand times using varying tropospheric conditions, clock drifts, and measurement errors. Based on comparing the analysis results of these simulations with the scientific goals of the session, the best-performing schedule is selected. The best-performing schedule, along with vivid statistics and charts, is automatically distributed by email for human inspection. After some days, it is automatically uploaded to the IVS servers in case no human intervention is necessary. In the following days, the software checks if the upload was successful and if the station network was changed after the session was submitted. Changes are reported via email, and it is decided on a case-by-case basis whether or not a new schedule should be generated and uploaded.

4 Future Plans

It is planned to further enhance the scheduling software, as well as the automatic scheduling pipeline. This includes more options regarding the scheduling of twin telescopes, as well as enhanced support of satellite scheduling and active satellite avoidance. For twin telescopes (or multiple telescopes on one site in general), currently, it is supported that multiple telescopes can share and optimize one common sky-coverage. But it is planned to add further options to especially favor observation constellations where the twin telescopes are observing different sub-netting scans simultaneously. Furthermore, it should be supported that twin telescopes are counted as being only one station for various statistics and optimization criteria, e.g., for imaging or closure delays. Here, it is not yet clear if it is best to implement this behavior directly within the scheduling routines or if a special form of tag-along mode is more appropriate. As of right now, in some VGOS sessions including twin telescopes, one telescope is scheduled in tag-along mode. This ensures that each scan is scheduled with at least three independent telescopes. But the downside of this approach is that during the tag-along mode, the tag-along station tends to simply follow the observations of its twin telescope and is thus not contributing to improved tropospheric sampling.

We also plan to further improve the quality control of our scheduling pipeline to ensure the release of high-quality schedules. This includes extending the quality control metrics to not only compare scheduling-related statistics but also statistics from the analysis.

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