Onsala Space Observatory – IVS Analysis Center Activities during 2019–2020

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Abstract This report briefly summarizes the activities of the IVS Analysis Center at the Onsala Space Observatory during 2019–2020 and gives examples of results of ongoing work.

1 General information

We concentrate on research topics that are relevant for space geodesy and geosciences. These research topics are related to data observed with geodetic VLBI and complementing techniques.

2 Activities during the Past Two Years

We worked primarily on the following topics:

- VGOS Intensives
- Short-baseline interferometry
- Adaption of the ASCOT software
- VLBI to near-field radio sources
- Deformation of radio telescopes
- Atmospheric delays in space geodesy
- Radio telescopes as InSAR reflectors
- Coastal GNSS reflectometry
- Gravimetry
- Ocean tide loading

3 VGOS Intensives

We investigated the scheduling of VLBI Intensive sessions with modern VGOS stations. This included both the use of twin telescope VGOS stations [3] as well as a new approach based on mixed-integer linear programming [4]. In both cases, the focus was on the impact of the new scheduling on the estimated UT1–UTC parameter, as well the local troposphere parameters at the participating stations and was based on extensive simulations. These studies show that the inclusion of twin telescopes in INT sessions promises to improve the precision of UT1–UTC determinations, as compared to legacy S/X Intensives. Estimated tropospheric parameters were, however, only slightly improved [3]. Mixed-integer linear programming for scheduling slightly increased the number of observations as well as the precision of the derived UT1–UTC parameters [4].

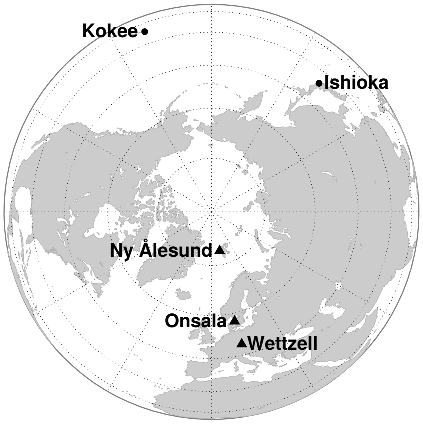

Fig. 1 Network geometry of simulations of Intensive sessions where the VGOS twin telescope sites Onsala and Wettzell were included. Figure taken from [3].

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Succeeding these scheduling and simulation investigations, we observed twelve VGOS Intensives during December 2019 through February 2020, involving the VGOS twin telescopes at Onsala [8] and the VGOS station Ishioka. These so-called VGOS-B sessions were observed simultaneously to standard legacy S/X Intensives that were primarily using Wettzell and Kokee. The VGOS-B sessions were correlated and analyzed at Onsala to derive UT1–UTC [9]. The results show that the VGOS-B sessions achieve 3–4 times lower formal uncertainties for the UT1–UTC results than the simultaneously observed legacy S/X-band INT sessions. The comparison to UT1–UTC of the final IERS Bulletin B shows a slightly better RMS agreement for the VGOS-B results than for the simultaneously observed legacy S/X-band INT1 results. To study the topic further, a new series of VGOS-B sessions was started in late 2020.

4 Short-baseline Interferometry

We performed 25 short-baseline interferometry sessions with the three geodetic stations of the Onsala telescope cluster, i.e., On, Oe, and Ow. The aim was to connect the Onsala twin telescopes, Oe and Ow, with the legacy S/X station On. The observations were performed at X-band only, using dual-linear polarization for the OTT and one circular polarization for On. The sessions were planned, scheduled, observed, correlated, fringe-fitted, and post-processed at Onsala. Both group delay and phase delay solutions were performed, resulting in precise coordinates for Oe and Ow in VTRF2020b [23].

5 Adoption of the ASCOT Software

After the unfortunate closure of the VLBI group at the University of Bonn, we adopted the VLBI data analysis software ASCOT [1] that had been developed in Bonn during the last decade. ASCOT is now available at `https://github.com/varenius/ascot` and will be further developed by the Onsala VLBI Analysis Center. This software was used for the analysis of the VGOS-B sessions [9], the short-baseline interferometry sessions [23], as well as for the Onsala contribution to the IVS ITRF2020 solution.

6 VLBI with Near-field Radio Sources

We continued our work on VLBI with near-field radio sources. This included both analysis of real data of the OCEL (Observations of the Chang'E Lander) sessions [12], as well as a simulation study for precise orbit determination of Earth satellites [13]. For the latter, VLBI observations of medium earth orbiting satellites were simulated using both the actual CONT17 legacy S/X schedules, as well as simulated schedules for a hypothetical international VGOS network with 16 globally distributed stations. Various different scheduling options were studied, and different analysis strategies were tested with Monte Carlo simulations. The simulations of observations for Galileo satellites with a 16-station VGOS network show that satellite orbits can be determined with a precision of a few centimeters, see Figure 2. Furthermore, the results for the traditional VLBI parameters, in particular the polar motion and UT1–UTC, are not degraded by including observations to satellites. However, careful scheduling appears to be of major importance to balance the ratio of observing natural radio sources and satellites.

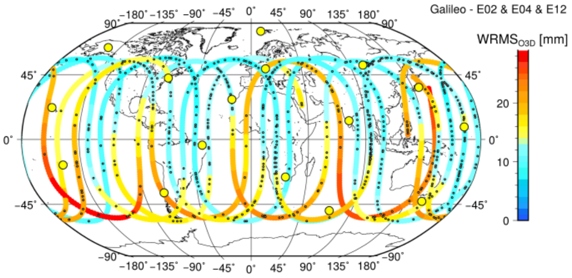

Fig. 2 Location-dependent 3-dimensional weighted root-mean square (WRMS) deviation (i.e., precision) of the orbit solutions for observations of three Galileo satellites (E02, E04, and E12) with a 16-station VGOS network (yellow dots). The figure is taken from [13].

7 Deformation of Radio Telescopes

During the last two years, we worked on studying deformations of the radio telescopes at Onsala. This includes both the gravitational deformation of the 20-m radio telescope [2, 16], as well as the Oe, one of the Onsala twin telescopes [14, 15].

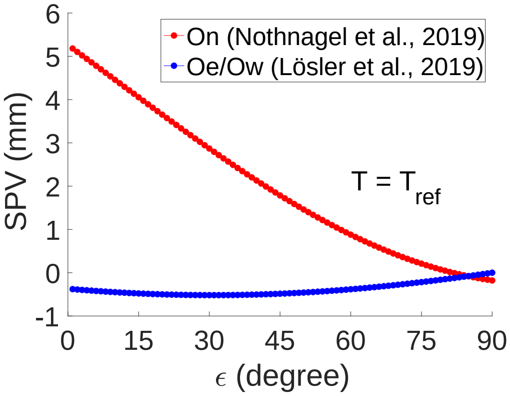

Fig. 3 Signal path variation (SPV) models for the Onsala 20-m telescope (On, red) and the Onsala twin telescopes (Oe, Ow, blue). The same temperature as the Onsala reference temperature was used in the modeling.

For the 20-m telescope, the gravitational stability of the telescope's reference point was studied using data acquired with a terrestrial laser scanner [11]. A gravitational deformation model was developed [16] that is recommended now by the IVS for regular data analysis. The signal path variation is more than 5 mm between 90° and 0° elevation, see the red curve in Figure 3.

The gravitational deformation model for the Onsala twin telescopes was derived from a photogrammetric survey [15]. The signal path variation is about -0.5 mm between 90° and 0° elevation (blue curve in Figure 3) and can easily be modeled.

8 Atmospheric Delays in Space Geodesy

We continued our research efforts concerning atmospheric delay effects in space geodesy. This included both the study of zenith wet delays [10] as well as horizontal gradients [5]. The horizontal gradients were estimated for the CONT14 campaign (6–20 May 2014) and compared to the corresponding results obtained from GNSS and microwave radiometry. Correlations from 0.56 to 0.71 were obtained when VLBI gradients were compared to the others using a temporal resolution of 6 hours. The temporal resolution can be increased with a better agreement for the use of the twin telescopes with faster slewing speeds and thereby an improved sampling of the atmosphere.

9 Radio Telescopes as InSAR Reflectors

In collaboration with Australian colleagues, we studied the possibility of using radio telescopes as reflectors for InSAR satellite signals [17]. While protecting the delicate receiving systems of the OTT, we tracked the European remote sensing satellites Sentinel-1a/b with the radio telescopes. Using radio telescopes with tracking capability provides the opportunity to achieve many more reflections, even at low elevations, than using dedicated fixed corner cube reflectors. Figure 4 shows an example of OTT reflections obtained for an ascending satellite track.

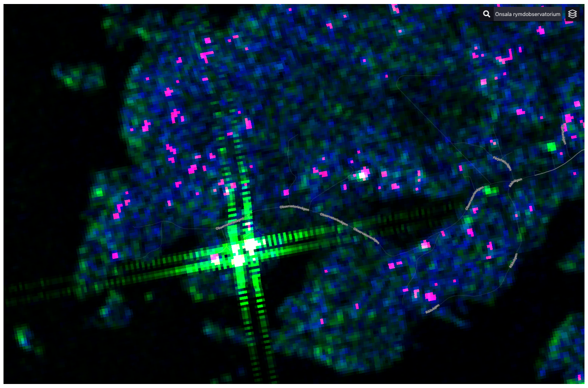

Fig. 4 InSAR picture of Onsala from an ascending track of Sentinel-1. The OTT had been tracking the satellite, resulting in strong reflection signals.

10 Coastal GNSS Reflectometry

We continued our research in the field of GNSS reflectometry. Besides investigating a real-time approach based on Kalman filter analysis [21], we also investigated the use of rather low-cost sensors for GNSS-R instead of high-end geodetic equipment [22].

Furthermore, we investigated the uncertainty level of GNSS-R for sea level observations [18], as well participated in an international comparison campaign on GNSS-R [7]. For the latter, one year of data from the Onsala GNSS-R installations was used.

11 Gravimetry

We assessed one decade of continuous measurements with the Onsala superconducting gravimeter (SG) and sixteen visiting absolute gravity (AG) campaigns [6, 19, 20]. The combined analysis of these data sets guarantees the long-term gravity reference better than 10 μGal [20].

12 Ocean Tide Loading

The Automatic Ocean Tide Loading service was operated throughout the year. It is heavily used by the international scientific community. Both new ocean models and new Green's functions were included during the last two years, see `http://holt.oso.chalmers.se/loading/`.

13 Future Plans

The IVS Analysis Center at the Onsala Space Observatory will continue its efforts to work on specific topics relevant to space geodesy and geosciences. We plan to intensify our work in particular concerning tropospheric parameters sensed by space geodetic techniques, as well as monitoring radio source flux density with local interferometry. We also plan in close collaboration with Lantmäteriet—the Swedish mapping, cadastral, and land registration authority—to analyze the global VLBI data set on a more regular basis and to contribute, for instance, to the IVS quarterly solutions.

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