Onsala Space Observatory – IVS Network Station Activities during 2017—2018

Rüdiger Haas, Thomas Hobiger, Gunnar Elgered, Niko Kareinen, Grzegorz Klopotek, Joakim Strandberg, Periklis-Konstantinos Diamantidis, Hans-Georg Scherneck, Maxime Mouyen, Peter Forkman

Abstract During 2017 and 2018 we participated in 88 legacy S/X sessions with the Onsala 20 m telescope. Additionally, we observed a number of VGOS test sessions with one or both of the Onsala twin telescopes.

1 General Information

The Onsala Space Observatory is the national facility for radio astronomy in Sweden with the mission to support high-quality research in radio astronomy and geosciences. The geoscience instrumentation at Onsala includes equipment for geodetic VLBI, GNSS, a superconducting gravimeter, a platform for visiting absolute gravimeters, several microwave radiometers for atmospheric measurements, both GNSS based and conventional tide gauge sensors, and a seismometer. The Onsala Space Observatory can thus be regarded as a fundamental geodetic station.

During the last years the Onsala twin telescopes (OTT) were installed. The telescopes were inaugurated in connection to the 23th Working Meeting of the European VLBI Group for Geodesy and Astrometry, held in Gothenburg 14–16 May 2017. A ceremonial event with more than 200 international and national guests was held on 18 May 2017, see Figure 1.

On the Thursday 18 April, 2018, the observatory arranged an event to celebrate the first transatlantic geodesy VLBI, 50 years earlier. A corresponding activity was carried out at Haystack Observatory. At Onsala retired colleagues that participated in the first experiment were invited, see Figure 2. Bert Hansson gave a lecture, describing both the extensive preparations as well as the execution of this first experiment.

Fig. 1 The inauguration of the Onsala twin telescopes was held on 18 May 2017.

The staff members associated with the IVS Network Station at Onsala are listed in Table 1.

2 Legacy S/X VLBI Observations

In total, we participated in 51 and 37 legacy S/X sessions during 2017 and 2018, respectively, see Table 2. The majority were standard IVS session, but there was a small number of special sessions, too. During 2018 a lower number of sessions were observed, since in January the subreflector control electronics were replaced, and between June and the mid of August the control room was rebuild. All sessions were recorded

Chalmers University of Technology, Department of Space, Earth and Environment, Onsala Space Observatory

Onsala IVS Network Station

IVS 2017+2018 Biennial Report

Table 1 Staff members associated with the IVS Network Station at Onsala. All e-mail addresses have the ending @chalmers.se, and the complete telephone numbers start with the prefix +46-31-772.

Function	Name	e-mail	telephone
Responsible P.I.s for geodetic	Rüdiger Haas	rudiger.haas	5530
VLBI observations	Thomas Hobiger (–2018.06.30)	thomas.hobiger	5549
Ph.D. students involved in geodetic VLBI	Niko Kareinen (–2018.08.15)	niko.kareinen	5566
	Grzegorz Klopotek	grzegorz.klopotek	5575
	Joakim Strandberg (–2018.05.31)	joakim.strandberg	5566
	Periklis-Konstantinos Diamantidis (2018.01.15–)	periklis.diamantidis	5575
Responsible for the VLBI Field System	Michael Lindqvist	michael.lindqvist	5508
	Rüdiger Haas	rudiger.haas	5530
Responsible for the VLBI equipment	Karl-Åke Johansson	karl-ake.johansson	5571
	Leif Helldner	leif.helldner	5576
Responsible for the VLBI operators and	Roger Hammargren	roger.hammargren	5551
data recording and transfer equipment	Simon Casey	simon.casey	5529
Telescope scientist	Henrik Olofsson	henrik.olofsson	5564
Software engineer	Mikael Lerner	mikael.lerner	5581
Responsible for gravimetry	Hans-Georg Scherneck (–2018.09.30)	hans-georg.scherneck	5556
	Maxime Mouyen (2018.10.01–)	maxime.mouyen	5549
Responsible for tide gauge and radiometry	Gunnar Elgered	gunnar.elgered	5565
Responsible for aeronomy and radimetry	Peter Forkman	peter.forkman	5577
Observatory director	John Conway	john.conway	5503

with the DBBC2/Flexbuff system and the data were e-transferred for correlation.

At the end of the last of the CONT17 sessions the 20 m telescope got stuck in elevation. This caused the last 4.5 h of this session to be lost. During one of the R1 sessions in 2018 we lost the last 10 h of data since the Fila10G had stopped working and thus no data were recorded.

Fig. 2 Onsala veterans involved in the first transatlantic geodetic VLBI experiment in early April 1968. Left to right: Anders Winnberg, Lars-Göran Gunnarsson, Christer Andersson, Bert Hansson, Gustaf Rydbeck, Göran Netzler, Magne Hagström, Monica Hansen with her dog Moss, Ingvar Samulesson.

3 VGOS Observations

In September 2017 we started to participate in VGOS test sessions, see Table 3. Most of these sessions were observed with ONS13NE (OE), but some also with ONSA13SW (OW), or both systems. We participated in international VGOS sessions (VT), European VGOS session (VGT), and sessions together with Kashima where we used the Japanese VGOS setup (OK). We experienced a steep learning curve, both in terms in terms of the new technical equipment, but also concerning VGOS operations as such. The majority of the sessions was affected by different technical problems, e.g. due to the PCAL systems, the DBBC3, or recording. Our ambitious goal to already participate in the VGOS CONT17 could unfortunately not be achieved. However, improvements and fine-tuning of the VGOS systems lead to a stabilisation so that at the end of 2018 finally rather successful and reliable VGOS observations could be performed.

4 Monitoring Activities

We continued with monitoring activities:

Calibration of pressure sensor.

The ground pressure sensor at the observatory is continuously monitored and compared with a “travelling” barometer in order to maintain traceability to SI. The travelling barometer was calibrated at the SMHI main office in Norrköping on 16 January 2018. The differences were ≤ 0.1 hPa in the interval 950 – 1050 hPa.

The comparisons between the two sensors at the observatory, carried out during the two years since the last biennial report, are shown as the differences in Figure 3 and the dynamical range is illustrated in Figure 4. A very weak systematic change of about 0.1 hPa over the two years can be seen, but we find this acceptable because an uncertainty of 1 hPa corresponds to 2.3 mm in the zenith hydrostatic delay.

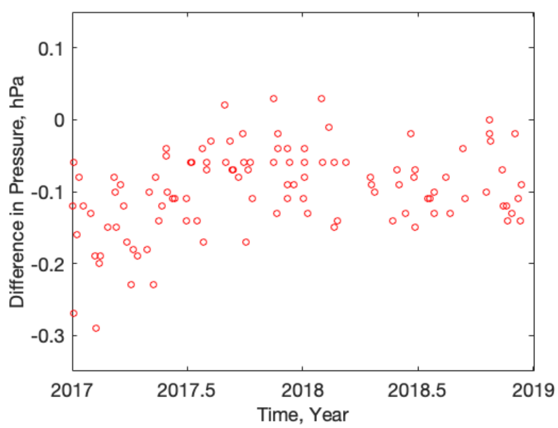

Fig. 3 Time series of pressure differences between the VLBI pressure sensor at the 20 m telescope and the calibrated pressure sensor from SMHI.

Vertical changes of the 20 m telescope tower.

We continued to monitor the vertical changes of the telescope tower using the invar rod system at the 20 m telescope. The measurements are available at `http://wx.oso.chalmers.se/pisa/`.

The local geodetic network.

During 2018 six geodetic survey pillars were installed around the twin telescopes. The extended local geodetic network at the observatory was thereafter surveyed in the summer by colleagues from

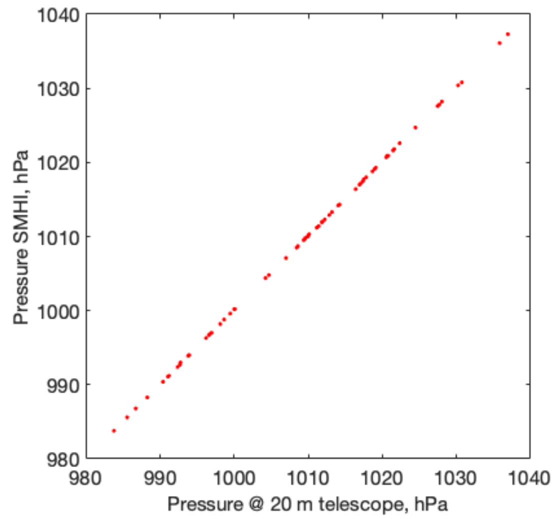

Fig. 4 The dynamical range of the comparisons during 2017–2018 between the VLBI pressure sensor at the 20 m telescope and the calibrated pressure sensor from SMHI.

the Frankfurt University of Applied Sciences (UAS), Germany.

Gravitational deformation of the OTT.

In the summer of 2018 photogrammetric measurements were performed to determine the gravitational deformation of the OTT. This work was done in collaboration with Frankfurt UAS and involved photogrammetry with a drone. A popular science video summarizing this work is available at `https://www.youtube.com/watch?v=sNnHvBaQ3_w`.

Superconducting gravimetry.

The superconducting gravimeter operated continuously and produced a highly accurate record of gravity variations. Tide solutions were prepared on a weekly basis and results are available on the SCG homepage (`http://holt.oso.chalmers.se/hgs/SCG/toe/toe.html`).

Absolute gravimetry.

Lantmäteriet, the Swedish mapping, cadastral and land registration authority, visited the observatory twice with their FG5 instrument. Measurement campaigns were performed in 2017 and 2018.

Table 2 Geodetic VLBI observations at Onsala during 2017 and 2018. The third and sixth columns give some general remarks and information on the percentage of the scheduled Onsala (On) observations that were used in the analysis (as reported on the web pages for the IVS session analyses), compared to the station average (StAv) percentage per experiment.

Exp.	Date	Remarks	Exp.	Date	Remarks
R1.773	17.01.03	OK: 87.1 % (StAv 79.1 %)	R1.829	18.02.12	OK: 96.0 % (StAv 94.2 %)
R1.774	17.01.10	OK: 77.7 % (StAv 54.0 %)	T2.123	18.02.13	OK: 76.4 % (StAv 56.1 %)
R1.776	17.01.23	OK: 84.4 % (StAv 69.8 %)	EUR.147	18.02.14	OK
RV.121	17.01.31	OK: 93.0 % (StAv 87.1 %)	R1.830	18.02.19	OK: 77.4 % (StAv 54.3 %)
R1.778	17.02.06	OK: 82.5 % (StAv 72.3 %)	RV.128	18.02.20	OK: 81.1 % (StAv 65.6 %)
T2.116	17.02.07	OK	R1.831	18.02.26	OK: 87.6 % (StAv 86.0 %)
EURD.01	17.02.08	OK	R1.832	18.03.05	OK: 84.3 % (StAv 60.1 %)
R1.780	17.02.21	OK: 70.5 % (StAv 55.9 %)	R1.834	18.03.19	OK: 77.5 % (StAv 73.6 %)
WHISP.6	17.02.22	OK	R1.836	18.04.03	OK: 77.5 % (StAv 86.1 %)
R1.785	17.03.27	OK: 73.0 % (StAv 68.7 %)	RV.129	18.04.04	OK: 94.2 % (StAv 75.2 %)
R1.788	17.04.18	OK: 77.7 % (StAv 71.2 %)	R1.839	18.04.23	OK: 96.6 % (StAv 95.1 %)
RD.17.05	17.04.19	OK	T2.124	18.04.24	OK: 64.0 % (StAv 49.6 %)
R1.789	17.04.24	OK: 85.5 % (StAv 69.3 %)	R1.840	18.05.02	OK: 86.9 % (StAv 75.4 %)
RV.122	17.04.25	OK: 84.1 % (StAv 65.6 %)	EURD.05	18.05.07	OK
R1.790	17.05.02	OK: 93.4 % (StAv 89.9 %)	T2.125	18.05.15	OK: 58.5 % (StAv 70.5 %)
R1.793	17.05.22	OK: 90.8 % (StAv 77.8 %)	R1.843	18.05.22	OK: 54.8.5 % (StAv 77.9 %) (10 h lost)
R1.798	17.06.26	OK: 93.0 % (StAv 90.4 %)	R1.856	18.08.20	OK: 79.5 % (StAv 65.3 %)
RV.123	17.06.28	OK: 88.8 % (StAv 75.0 %)	RD.18.03	16.04.20	not correlated yet
R1.799	17.07.03	OK: 91.8 % (StAv 89.2 %)	RV.130	18.08.21	OK: 55.1 % (StAv 72.8 %)
WHISP.7	17.07.05	OK	RD.18.06	18.08.22	not correlated yet
R1.800	17.07.10	OK: 85.0 % (StAv 81.8 %	R1.857	18.08.27	OK: 58.1 % (StAv 48.2 %)
T2.119	17.07.11	OK	R1.858	18.09.03	OK: 62.8 % (StAv 45.4 %)
R1.808	17.09.05	OK: 90.0 % (StAv 85.7 %	T2.127	18.09.04	not correlated yet
R1.809	17.09.11	OK: 95.0 % (StAv 93.9 %)	EUR.148	18.09.05	not correlated yet
T2.120	17.09.12	OK: 78.6 % (StAv 64.8 %)	R1.859	18.09.10	OK: 83.8 % (StAv 67.2 %)
EURD.02	17.09.13	OK	R1.863	18.10.08	OK: 88.0 % (StAv 80.3 %)
R1.811	17.09.25	OK: 82.7 % (StAv 67.8 %)	EURD.07	18.10.09	OK: 94.8 % (StAv 93.2 %)
RD.17.10	17.10.04	OK: 84.8 % (StAv 75.4 %)	R1.868	18.11.12	OK: 81.8 % (StAv 69.0 %)
AUA.029	17.10.07	OK	T2.128	18.11.13	not correlated yet
R1.814	17.10.16	OK: 96.4 % (StAv 91.6 %)	RV.132	18.11.14	OK: 82.8 % (StAv 69.9 %)
T2.121	17.10.17	OK: 52.9 % (StAv 34.4 %)	VT.007	18.11.23	not correlated yet
R1.819	17.11.20	OK: 92.5 % (StAv 91.2 %)	R1.870	18.11.26	OK: 90.3 % (StAv 87.3 %)
R4.819	17.11.21	OK: 87.3 % (StAv 81.0 %)	R1.872	18.12.10	OK: 84.6 % (StAv 80.5 %)
EURD.03	17.11.23	OK	EURD.08	18.12.11	not correlated yet
C17.01	17.11.28	OK: 92.3 % (StAv 86.4 %)	RD.18.10	18.12.12	not correlated yet
C17.02	17.11.29	OK: 94.1 % (StAv 90.7 %)	R1.873	18.12.17	OK: 83.8 % (StAv 67.4)
C17.03	17.11.30	OK: 81.6 % (StAv 75.0 %)	T2.129	18.12.18	not correlated yet
C17.04	17.12.01	OK: 80.6 % (StAv 61.7 %)			
C17.05	17.12.02	OK: 87.8 % (StAv 77.8 %)			
C17.06	17.12.03	OK: 83.2 % (StAv 74.0 %)			
C17.07	17.12.04	OK: 76.5 % (StAv 68.7 %)			
C17.08	17.12.05	OK: 90.7 % (StAv 87.4 %)			
C17.09	17.12.06	OK: 86.3 % (StAv 81.1 %)			
C17.10	17.12.07	OK: 80.6 % (StAv 72.0 %)			
C17.11	17.12.08	OK: 78.7 % (StAv 68.3 %)			
C17.12	17.12.09	OK: 94.9 % (StAv 89.6 %)			
C17.13	17.12.10	OK: 91.0 % (StAv 85.7 %)			
C17.14	17.12.11	OK: 80.6 % (StAv 72.4 %)			
C17.15	17.12.12	OK: 78.8 % (StAv 88.9 %) (4.5 h lost)			

Table 3 VGOS observations at Onsala during 2017 and 2018. We participated in international VGOS test sessions (VT), European VGOS test sessions (VGT), and a few test sessions with the Japanese interpretation of VGOS (OK). The filled circles indicate which VGOS system was used, ONSA13NE (ON) and/or ONSA13SW (OW).

Session	Date	h	OE	OW	Comment
VT7268	17.09.25	24	•	○	PCAL problems, weak fringes
MC7277	17.10.04	24	•	•	PCAL problems, weak fringes
MC7278	17.10.05	24	•	•	PCAL problems, weak fringes
VT7303	17.10.30	24	•	•	PCAL and ampl. problems
VT7317	17.11.13	24	•	○	PCAL and ampl. problems
VT7331	17.11.27	24	○	•	PCAL and ampl. problems
VT8039	18.02.08	24	○	•	band-A and -D problems
OK8051	18.02.20	1	○	•	fringes found
VT8060	18.03.01	24	•	○	OK, but variable amplitudes
OK8065	18.03.06	1	•	○	wrong recording, failed
VT8067	18.03.08	24	•	○	DBBC3 problems, data lost
OK8074	18.03.15	1	•	○	OK, fringes found
VT8078	18.03.19	24	•	○	DBBC3 problems, data lost
OK8086	18.03.27	19	•	○	OK
VGT095	18.04.05	4	•	○	problems with band-A Y-pol
VT8095	18.04.05	24	•	○	DBBC3 problems, data lost
VGT109	18.04.19	4	•	○	OK, but variable amplitudes
VT8109	18.04.19	24	•	○	DBBC3 problems, data lost
VT8123	18.05.03	24	•	○	DBBC3 problems, data lost
VGT134	18.05.14	4	•	○	
VT8134	18.05.14	24	•	○	DBBC3 problems, data lost
OK8138	18.05.16	1	•	○	OK
OK8141	18.05.21	20	•	○	OK
VGT149	18.05.29	4	•	○	
VT8149	18.05.29	24	•	○	DBBC3 problems, data lost
VGT162	18.06.11	24	•	○	
VT8162	18.06.11	24	•	○	DBBC3 problems, data lost
VT8249	18.09.06	24	•	○	DBBC3 problems, data lost
VGT260	18.09.17	4	•	○	
VT8260	18.09.17	24	•	○	DBBC3 problems, data lost
VGT274	18.10.01	4	•	○	
VT8274	18.10.01	24	•	○	recording problems, data lost
VGT288	18.10.15	4	•	○	
VT8288	18.10.15	24	•	○	completely correlated ?
VGT302	18.10.29	4	•	○	
VT8302	18.10.29	24	•	○	DBBC3 problems, data lost
VGT319	18.11.15	4	•	○	
VT8319	18.11.15	24	•	○	DBBC3 problems, data lost
VT8330	18.11.26	24	•	○	DBBC3 problems, lost
VT8347	18.11.26	24	•	•	OK

Seismological observations.

The seismometer owned by Uppsala University and the Swedish National Seismic Network (SNSN) was operated throughout the two-year period.

Water vapour radiometry.

The two radiometers Astrid and Konrad have been operated at the observatory. During 2017 Astrid was operating continuously from July through December, and Konrad was operating for $\approx$ 300 days. However, unfortunately CONT17 was only covered by Konrad observations for $\approx$ 5 days. During 2018 both radiometers were operating continuously with some data loss ($<$ 5 %). In addition to these data losses data acquired during rain, which are not sufficiently accurate for our applications in geodesy VLBI, shall be ignored. Rain or rain clods are typically present $\approx$ 10 % of the time.

Sea-level.

The inauguration of the Onsala tide gauge station was reported in the last IVS biennial report. Since then the main sensor, a Campbell CS476 radar, has been operated continuously. A status report was presented at the recent EVGA meeting [1].

The GNSS-R based tide gauge was operated continuously and the recorded data were analyzed.

5 Future Plans

- In the coming two years we plan to participate in about 50 IVS legacy S/X sessions per year with the 20 m telescope.
- We plan to participate in as many as possible VGOS test session in 2019 and plan to become fully operational with the OTT by 2020.
- We will work on connecting the OTT with the 20 m telescope through interferometric measurements and also derive local tie vectors from classical observations.
- The monitoring activities reported above will be continued.

References

1. Elgered G, Wahlbom J, Wennerbäck L, Pettersson L, Haas R (2019). The Onsala Tide Gauge Station: Experiences from the first three years of operation. Manuscript in preparation for *Proc. 24th European VLBI Group for Geodesy and Astrometry Working Meeting*, Las Palmas, Gran Canaria, Spain, 17-19 March, 2019.