Onsala Space Observatory – IVS Network Station Activities during 2015–2016

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Abstract During 2015 and 2016 we participated in 98 IVS sessions. Additionally, we observed a small number of experimental sessions.

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 with a platform for visiting absolute gravimeters, several microwave radiometers for atmospheric measurements, both GNSS-based and pressure-based tide gauges, and a seismometer. The Onsala Space Observatory can thus be regarded as a fundamental geodetic station.

In January 2015, the Onsala Twin Telescopes (OTT) project officially started with infrastructure work, i.e., building concrete towers for the telescopes, concrete installation platforms, road work, and a computer and fiber network. The OTT telescopes were delivered in June 2016 and the assembly and installation continued until the end of November.

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

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

Onsala IVS Network Station

IVS 2015+2016 Biennial Report

2 Geodetic VLBI Observations

In total, we participated in 45 and 53 IVS sessions during 2015 and 2016, respectively (see Table 2).

All sessions were recorded with the DBBC/Mark 5B+ system. The sessions to be correlated at the Bonn correlator were recorded in parallel in mk5b-format on the FlexBuff. These data were then e-transferred to Bonn for correlation. For a few sessions the Flexbuff-recording failed and thus the data recorded on Mark 5B-modules were read out and e-transferred to the correlator.

In 2015, two sessions suffered from a wrong setup and a power failure, respectively, causing data loss for several hours. Also in 2016, one session was affected by a technical problem that caused several hours of data loss, and we lost one complete session due to communication and planning mistakes.

In addition to the IVS sessions, we observed a few test experiments together with Wettzell, for atmospheric studies and to observe the APOD satellite.

3 Monitoring Activities

We continued with the monitoring activities as described in previous annual reports:

Local tie vector at Onsala.

In the autumn of 2015, we performed an experimental campaign together with Metsähovi to simultaneously monitor the telescope reference points with automated monitoring systems during ongoing VLBI experiments and to perform local tie measurements using classical measurements and GNSS.

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 VLBI observations	Rüdiger Haas Thomas Hobiger	rudiger.haas thomas.hobiger	5530 5549
Observatory director	John Conway	john.conway	5503
Head of department	Gunnar Elgered	gunnar.elgered	5565
Ph.D. students involved in geodetic VLBI	Niko Kareinen Grzegorz Klopotek (2015.04.01–) Joakim Strandberg (2015.10.10–)	niko.kareinen grzegorz.klopotek joakim.strandberg	5566 5575 5566
Responsible for the VLBI Field System	Michael Lindqvist Rüdiger Haas	michael.lindqvist rudiger.haas	5508 5530
Responsible for the VLBI equipment	Karl-Åke Johansson Leif Helldner	karl-ake.johansson leif.helldner	5571 5576
Responsible for the VLBI operators	Roger Hammargren	roger.hammargren	5551
Telescope scientist	Henrik Olofsson	henrik.olofsson	5564
Software engineer	Mikael Lerner	mikael.lerner	5581
Responsible for gravimetry	Hans-Georg Scherneck	hans-georg.scherneck	5556

The data analysis is still ongoing and a corresponding publication is in preparation.

Vertical height changes of the telescope tower.

We continued to monitor the vertical height 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/`.

Calibration of pressure sensor.

We continued to calibrate the Onsala pressure sensor using a transportable Vaisala barometer borrowed from the Swedish Meteorological and Hydrological Institute (SMHI). This latter instrument was installed at Onsala in late 2002. It has since then been calibrated regularly at the SMHI main facility in Norrköping with traceability to SI. The last calibration occurred on September 29, 2015. At this occasion, the largest deviation was 0.05 hPa over the input range from 800 hPa to 1100 hPa. The VLBI pressure sensor that had failed in late December 2014 was replaced by an identical one in February 2015. In the mean time a spare sensor mounted at a different height was used. The new sensor appears, however, to have a small offset compared to the one that failed in 2014 (see Figure 1).

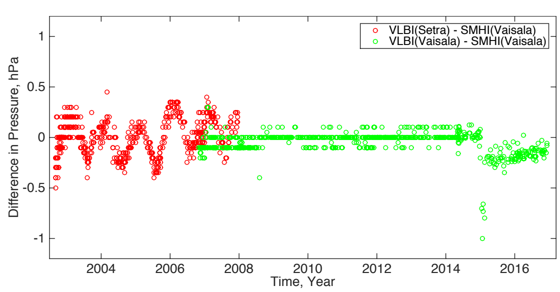

Fig. 1 Time series of pressure differences between the VLBI pressure sensors and the calibrated pressure sensor from SMHI.

Microwave radiometry.

The older water vapor radiometer (WVR), Astrid, was operating continuously from May to the end of December 2015 but with a data gap from mid-August to mid-September. During 2016, Astrid was operating from mid-February to the end of June and from early August to mid-December. During the first of these two periods the temperature regulation failed but the data may still be useful. The Konrad WVR was operating from February to end of June 2015. It started to operate again in May 2016 until the end of the year.

The data analysis for both WVRs is not completed and therefore a final check of the data quality has not occurred yet.

Table 2 Geodetic VLBI observations at Onsala during 2015 and 2016. The third and sixth column gives 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
EUR.133	15.01.19	OK	R1.723	16.01.18	OK: 93.7 % (StAv 90.3)
R1.671	15.01.20	OK: 86.4 % (StAv 67.1 %)	RV.115	16.01.19	OK: 88.2 % (StAv 75.6)
RV.109	15.01.28	OK: 78.7 % (StAv 59.8 %)	RD.16.01	16.01.20	not correlated yet
R1.673	15.02.02	OK: 80.5 % (StAv 63.0 %)	EUR.139	16.01.25	OK
RD.15.01	15.02.03	OK: 84.4 % (StAv 71.9 %)	R1.724	16.01.26	OK: 90.3 % (StAv 77.9)
R1.675	15.02.16	OK: 92.8 % (StAv 78.6 %)	R1.726	16.02.08	OK: 85.4 % (StAv 67.7)
T2.102	15.02.17	OK	RV.116	16.02.09	OK: 87.0 % (StAv 77.4)
R1.681	15.03.30	OK: 75.4 % (StAv 61.3 %)	R1.727	16.02.15	OK: 84.2 % (StAv 71.9)
R1.682	15.04.07	OK: 68.3 % (StAv 56.5 %)	T2.109	16.02.16	OK
RD.15.02	15.04.08	OK: 87.2 % (StAv 75.0 %)	R1.732	16.03.21	OK: 90.8 % (StAv 75.2)
R1.684	15.04.20	OK: 93.1 % (StAv 87.8 %)	EUR.140	16.03.22	OK
T2.103	15.04.21	not correlated yet	R1.733	16.03.29	OK: 85.3 % (StAv 83.0)
RV.111	15.04.22	OK: 93.3 % (StAv 80.4 %)	R1.734	16.04.04	OK: 80.0 % (StAv 59.3)
R1.685	15.04.27	OK: 89.0 % (StAv 86.0 %)	T2.110	16.04.05	OK
R1.686	15.05.04	OK: 91.7 % (StAv 85.2 %)	EUR.141	16.04.06	OK
EUR.135	15.05.05	OK	R1.736	16.04.18	OK: 85.5 % (StAv 71.4)
RD.15.03	15.05.06	OK: 84.9 % (StAv 63.3 %)	RV.117	16.04.19	OK: 93.5 % (StAv 93.1)
R1.689	15.05.26	23.1 % (StAv 61.0 %) (16 h wrong setup)	RD.16.03	16.04.20	OK: 81.3 % (StAv 71.3)
R1.694	15.06.29	OK: 90.4 % (StAv 78.6 %)	R1.737	16.04.26	OK: 82.7 % (StAv 61.1)
T2.104	15.06.30	OK	R1.740	16.05.17	OK: 85.9 % (StAv 75.0)
R1.695	15.07.06	OK: 54.6 % (StAv 52.1 %	RD.16.04	16.05.18	not correlated yet
RD.15.05	15.07.07	not correlated yet	R1.746	16.06.27	OK: 89.6 % (StAv 85.3)
RD.15.06	15.07.29	not correlated yet	RD.16.05	16.06.28	OK: 84.7 % (StAv 78.9)
R1.700	15.08.11	OK: 88.6 % (StAv 86.9 %)	R1.747	16.07.04	OK: 79.8 % (StAv 69.4)
R1.701	15.08.17	OK: 80.3 % (StAv 56.8 %)	RV.118	16.07.06	OK: 86.4 % (StAv 76.7)
R1.702	15.08.24	OK: 68.3 % (StAv 57.7 %)	R1.748	16.07.11	OK: 83.5 % (StAv 81.7)
T2.105	15.08.25	OK	R1.749	16.07.18	OK: 86.3 % (StAv 84.9)
RD.15.07	15.08.26	not correlated yet	R1.750	16.07.25	OK: 89.9 % (StAv 81.3)
R1.703	15.08.31	OK: 89.1 % (StAv 72.7 %	R1.754	16.08.22	OK: 94.5 % (StAv 91.6)
EUR.137	15.09.07	OK	T2.112	16.08.23	OK
R1.704	15.09.08	OK: 79.6 % (StAv 65.2 %)	RD.16.07	16.08.24	OK: 85.1 % (StAv 78.1)
RV.113	15.09.09	OK: 90.3 % (StAv 76.9 %)	R1.755	16.08.29	OK: 77.6 % (StAv 60.7)
R1.706	15.09.21	55.1 % (StAv 67.1) (8 h power failure)	EUR.143	16.09.05	OK: but 45 min lost
R1.709	15.10.13	OK: 77.3 % (StAv 64.1 %)	R1.756	16.09.06	OK: 81.1 % (StAv 68.2)
R1.713	15.11.09	OK: 74.7 % (StAv 61.4 %)	RD.16.08	16.09.07	49.8 % (StAv 59.4) (11 h lost)
T2.107	15.11.10	OK	R1.757	16.09.12	OK: 88.8 % (StAv 65.4)
R1.715	15.11.23	OK: 86.2 % (StAv 68.3 %)	RD.16.09	16.09.13	not correlated yet
RD.15.09	15.11.25	OK: 80.6 % (StAv 61.7 %)	RV.119	16.09.14	OK: 90.3 % (StAv 84.8)
RD.15.10	15.12.01	not correlated yet	R1.758	16.09.19	OK: 88.6 % (StAv 82.8)
R1.717	15.12.07	OK: 93.9 % (StAv 81.4 %)	R1.759	16.09.26	OK: 76.4 % (StAv 59.0)
R1.718	15.12.14	OK: 91.2 % (StAv 82.0 %)	R1.760	16.10.04	OK: 62.0 % (StAv 39.7)
T2.108	15.12.15	OK	RD.16.10	16.10.05	OK: 82.1 % (StAv 58.7)
EUR.138	15.12.16	OK	T2.113	16.10.18	OK
R1.719	15.12.21	OK: 92.6 % (StAv 88.2 %)	R1.767	16.11.21	OK: 75.7 % (StAv 45.8)
R1.720	15.12.28	OK: 90.0 % (StAv 82.6 %)	EUR.144	16.11.24	OK
			R1.768	16.11.28	OK: 63.6 % (StAv 44.7)
			RD.16.11	16.11.29	not correlated yet
			RV.120	16.11.30	OK: 91.0 % (StAv 86.7)
			T2.215	16.12.06	lost
			R1.770	16.12.12	OK: 86.4 % (StAv 66.5)
			RD.16.12	16.12.13	not correlated yet
			RD.16.13	16.12.19	not correlated yet
			R1.771	16.12.20	OK: 93.3 % (StAv 91.0)

Sea-level monitoring.

The GNSS-R based tide gauge was operated continuously and data were analyzed [1, 2]. The new (traditional) tide gauge station with a radar sensor and pressure sensors, inside and outside the well, was inaugurated officially in September 2015. It is now part of the national tide gauge monitoring network of the Swedish Meteorological and Hydrological Institute (SMHI).

Fig. 2 The Onsala super tide gauge inaugurated in September 2015 and since then operated together with SMHI.

Superconducting gravimetry.

The superconducting gravimeter operated continuously and produced a highly precise record of gravity variations. No data were lost in 2015 and 2016. 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.

In 2015, we supported a visiting absolute gravity measurement campaign with two gravimeters operating in parallel, a novel quantum gravimeter from the Humboldt University in Berlin, Germany, and a traditional FG5 instrument from Leibniz University, Hannover, Germany [3]. In 2016 we had another visit from Lantmäteriet, the Swedish mapping, cadastral, and land registration authority, with a traditional FG5 instrument.

Seismological observations.

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

4 Future Plans

- In the coming two years we plan to participate in about 50 IVS sessions per year with the 20-m telescope. We aim at becoming a “VDIF-only” station, i.e., to record data exclusively in VDIF-format.
- The Onsala Twin Telescopes (OTT), see Figure 3, will be commissioned during 2017. The official inauguration is planned for 18 May 2017. The goal is to start as soon as possible in 2017 to participate in VGOS test sessions and to be part of the CONT17 campaign with the OTT. For 2018 we expect to ramp up the VGOS observations considerably.
- A new GNSS reference station will be built in 2017 in the vicinity to the OTT. Also monuments for local tie measurements and telescope reference point monitoring will be established in 2017.
- In the summer of 2017 we will start tests with a newly developed microwave radiometer. In the long run it is likely to be located close to the OTT.
- The monitoring activities reported above will be continued.

References

1. Hobiger T, Haas R, Löfgren J (2016) Software-Defined Radio Direct Correlation GNSS Reflectometry by Means of GLONASS. *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, 9(10), 4834–4842, doi:10.1109/JSTARS.2016.2529683
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3. Freier C, Hauth M, Schkolnik V, Leykauf B, Schilling M, Wziontek H, Scherneck H-G, Müller J, Peters A (2016). Mobile quantum gravity sensor with unprecedented stability *Journal of Physics – Conference Series*, 723, Art. no. 012050, doi:10.1088/1742-6596/723/1/012050

Fig. 3 The Onsala telescope cluster in 2016 with the new Onsala Twin Telescopes in the center of the photo. The new VGOS radio telescopes are equipped with reflectors of 13.2-m diameter. The radio telescope on the left hand side is the 25.6-m telescope installed in 1964, which is the first European telescope ever to be involved in VLBI. First geodetic VLBI measurements were performed already in 1968. The white radome on the right side of the picture houses the 20-m radio telescope installed in 1976, which was used with the Mark III geodetic VLBI system since 1979 and has the longest time series in the International VLBI Service for Geodesy and Astrometry (IVS) database. Close to the radome, but not visible in the photo, is the GNSS station ONSA, which was established already 1987 in the CIGNET network, several years before the International GNSS Service (IGS) was founded. ONSA had a pioneering role in the early days of GNSS, and has the longest continuous time series in the IGS network. There is also a gravimeter laboratory with a superconducting gravimeter. Shown in the picture foreground is the Onsala super tide gauge inaugurated in 2015. The observatory is one of the unique fundamental space geodetic sites that have a direct access to the sea level and co-locate VLBI, GNSS, gravimetry, and sea level monitoring. It is thus an important co-location site for the Global Geodetic Observing System (GGOS).