Contributions of Onsala Space Observatory to GGOS

R. Haas, G. Elgered, T. Hobiger, H.-G. Scherneck, J. Johansson

Abstract The Onsala Space Observatory (OSO) on the Swedish west coast is the fundamental geodetic station of Sweden and operates several co-located geodetic and geophysical infrastructures that contribute to the GGOS. Currently, work is ongoing to establish a twin telescope to be part of the VGOS network.

Keywords GGOS, VLBI, GNSS, tide gauges, gravimetry, atmospheric measurements, time and frequency

1 Introduction

The Onsala Space Observatory (OSO) is the National Facility for Radioastronomy in Sweden and has the task to provide equipment and expertise in radio astronomy and geosciences to the Swedish as well as the international scientific community. In this role it is also the fundamental geodetic station of Sweden.

Already since the 1960ies radio telescopes are operated at OSO for geodetic Very Long Baseline Interferometry. Since the 1990ies, also equipment for GNSS is operated at OSO. A number of geodetic and geophysical research instruments have been installed during the last decades, including microwave radiometers for atmospheric research, a superconducting gravimeter, a seismometer, and several tide gauges. With its variety of co-located instrumentation used for geoscience observations, OSO contributes to several of the services of the International Association for Geodesy (IAG), such as the International VLBI Service for Geodesy and Astrometry (IVS), the International GNSS Service (IGS), and the Global Geodynamics Program (GGP), and thus to the Global Geodetic Observing System (GGOS). Figure 1 depicts an aerial photo of OSO and indicates the location of the different instruments.

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2 VLBI

OSO has the longest VLBI observational record in Europe, going back to April 1968 (Scherneck et al., 1998; Elgered and Haas, 2000). Currently, about 40 to 50 sessions per year are observed in IVS programs. OSO participated successfully in all CONT campaigns and performed CONT11 and CONT14 in ultra-rapid mode together with the Tsukuba station in Japan. During these continuous campaigns UT1-UTC was derived in near real-time. The left photo in Fig. 2 shows the radome-enclosed 20 m radio telescope that currently is used for geodetic VLBI observations. The right photo in Fig. 2 shows the 25 m radio telescope that occasionally is used to do VLBI with GNSS signals, see e.g. Haas et al. (2014, 2015).

In 2012 we received funding for a twin telescope (Haas, 2013), to be part of the VGOS network. Two VGOS-type telescopes with 13.2 m diameter have been ordered in late 2014 from the company MT Mechatronics. Currently the necessary infrastructure work at OSO is ongoing, including the construction of two concrete towers. As an example, Fig. 3 depicts the form for the

Fig. 1 Aerial photo of OSO: (1) the radome-enclosed 20 m radio telescope, (2) the microwave radiometer ”Konrad”, (3) the GNSS-station ONSA, (4) the microwave radiometer ”Astrid’, (5) the location of the northern telescope of the future Onsala Twin Telescope, (6) the location of the southern telescope of the future Onsala Twin Telescope, (7) the tide gauge station, (8) the 25 m radio telescope, (9) the GNSS-R based tide gauge, (10) the seismometer, (11) the six-station GNSS-array around the OTT, (12) the GNSS-station ONS1, (13) the gravimeter laboratory with the superconducting gravimeter, (14) the time and frequency laboratory.

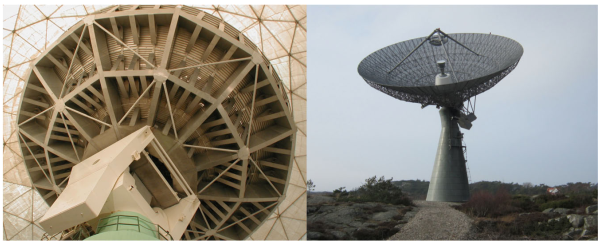

Fig. 2 Left: The radome-enclosed 20 m radio telescope at OSO that is used for VLBI observations in the IVS programs. Right: The 25 m radio telescope that is used primarily for astronomy VLBI but occasionally also to track GNSS satellites.

Fig. 3 The form for the concrete pouring of the bottom floor of the northern OTT tower.

concrete pouring of the northern tower. The telescopes themselves will be delivered in early 2016 and installed during the summer of 2016. The signal chain will be installed in late 2016. It is expected that first test observations with the Onsala Twin Telescope (OTT) can be started in early 2017, and that OTT becomes fully operational 1–2 years later. Figure 4 depicts an artist’s view on the future OTT.

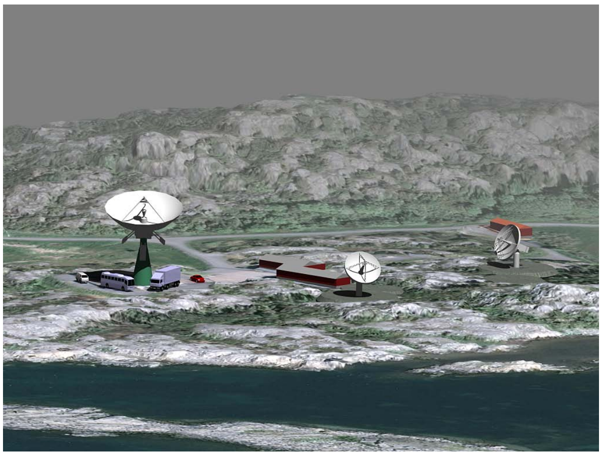

Fig. 4 An artist's view on the future OTT.

3 GNSS

In collaboration with Lantmäteriet, the Swedish Mapping, Cadastral and Land Registration Authority, OSO operates the IGS stations ONSA and ONS1, see Fig. 5. Data of ONSA are used for both geodynamical research, e.g. Johansson et al. (2002), and atmospheric research, e.g. Ning et al. (2012). A new GNSS array consisting of six additional stations is under construction in the area around the OTT. Its baselines are of the order of hundreds of metres, and this network will also be operated together with Lantmäteriet. Currently we are in discussion with ESA to investigate the possibility to include one of these array stations in ESA's ionospheric monitoring network.

Fig. 5 The pillar and antenna of the IGS station ONSA (left), and the mast and antenna of the IGS station ONS1 (right).

4 Gravimetry

Since 2009 OSO operates a gravimeter laboratory for relative and absolute gravity measurements which is equipped with a superconducting gravimeter. It has been operated continuously since then with a reliability well above 99 %. Data are available via a webpage and are sent to the archive of the Global Geodynamics Project (GGP). In collaboration with the University of Uppsala, a seismometer is operated that is part of the Swedish National Seismic Network (SNSN). A screen-shot of the webpage presenting near real-time results from the superconducting gravimeter is shown in Fig. 6. The OSO superconducting gravimeter also supports studies with visiting absolute gravimeters, e.g. Timmen et al. (2015).

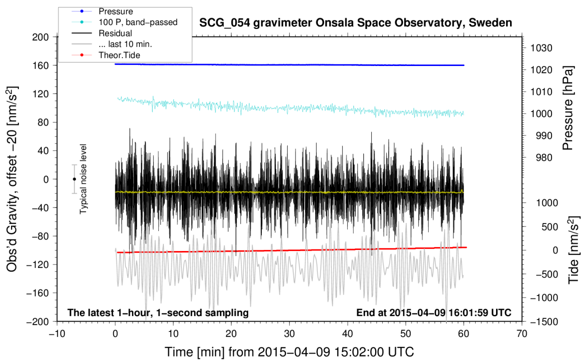

Fig. 6 An example of near real-time data results from observations of the superconducting gravimeter.

5 Tide gauges

Since 2011 GNSS-R tide gauge is operated at OSO, utilizing reflected signals from multiple GNSS, see Fig. 7 right. Signals of several GNSS are used to determine time series of sea level, e.g. Löfgren and Haas (2014); Hobiger et al. (2014). Additionally, in 2013 and 2014 several pneumatic and bubbler sensors and a radar-based sensor have been installed in a dedicated tide gauge well, see Fig. 7 left. The latter installation was inaugurated officially in September 2015 and is operated together with the Swedish Meteorological and Hydrological and Institute (SMHI). It is now an official site in the national sea level monitoring network.

Figure 8 depicts a comparison of sea level time series derived from GNSS-R and the traditional tide gauge.

Fig. 7 The traditional tide gauge (left) equipped with a radar and several bubbler sensors in the well, and the GNSS-R based tide gauge (right).

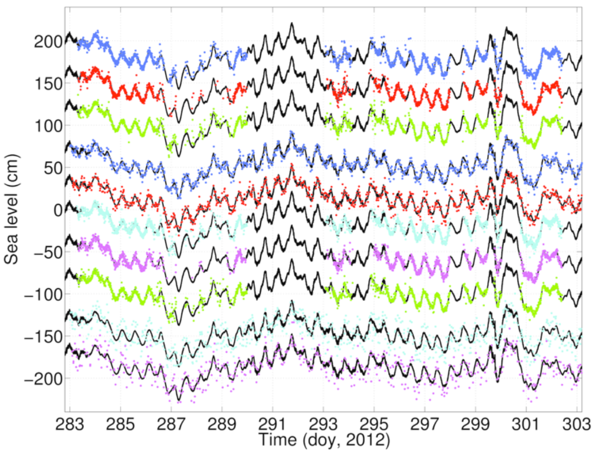

Fig. 8 Sea level derived from the GNSS-R tide gauge at OSO during 20 days in 2012 (Oct. 9 to 29). From top to bottom the sea level times series are derived from: GPS phase (L1), GLONASS phase (L1), GPS and GLONASS phase (L1), GPS SNR (L1), GLONASS SNR (L1), GPS phase (L2), GLONASS phase (L2), GPS and GLONASS phase (L2), GPS SNR (L2) and GLONASS SNR (L2). Each time series is paired with the independent sea level observations from the co-located tide gauge (black line). A mean is removed from each time series and the pairs are displayed with an offset of 40 cm to improve visibility.

6 Atmospheric measurements

Several ground-based microwave radiometers for atmospheric research are operated at OSO. The two microwave radiometers "Astrid" and "Konrad" are shown in Fig. 9. They are used to infer the time delay caused by atmospheric water vapour. This information is used to validate atmospheric parameters estimated from the space geodetic techniques, i.e. VLBI and GNSS, see e.g. Teke et al. (2013), but is also used for in meteorological studies, e.g. Elgered and Jarlemark (1998). A new microwave radiometer is currently under development and will be installed in the near future in the OTT area.

Fig. 9 The microwave radiometers Konrad (left) and Astrid (right).

7 Time and frequency

In collaboration with SP Technical Research Institute of Sweden, OSO operates a time and frequency laboratory with two H-masers, a cesium clock, and several GNSS time receivers. These instruments are used for the local time and frequency distribution for the scientific equipment at OSO, and to support the Swedish UTC realization. Based on VLBI and GNSS observations, we perform intercontinental frequency-transfer between OSO's time laboratory and international partner institutions, see Hobiger et al. (2015).

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