

CHALMERS

To Martin Lidberg
Enhetschef för Geodetisk infrastruktur
Lantmäteriet
Gävle

2025-11-24

Geoscience activity plan for 2026–2028

Introduction:

The Onsala Space Observatory (OSO) is Sweden's geodetic fundamental site and an international geodetic core site. The geoscientific work at Onsala includes a number of activities with major importance for geodesy and geosciences, both on national and international level. OSO is both a member of the Space Geodesy network of the Global Geodetic Observing System (GGOS), as well as partner of the United Nations Global Geodetic Center of Excellence (UN-GGCE). Below we shortly describe what is planned for 2026–2028.

Changes since last year:

The plan for 2026–2028 basically agrees with and follows last year's plan. We continue aiming at increasing our activities for geodetic VLBI to follow the VGOS development. This step-by-step increase is in line with the international roll-out and further development of VGOS and appears possible, provided an increased level of automation. We also consider to become more active in VLBI data correlation, for the local data collected at OSO, but eventually even for global IVS sessions. While continuing to investigate possibilities at the Nordic level for VGOS-correlation, i.e. with our partners in Norway and Finland, we also want to investigate whether a VGOS-correlator can be established at Chalmers with support from the Swedish National Space Agency (SNSA). During 2025 we had initial discussions with SNSA and there is potential interest, but more detailed discussions in the beginning of 2026 are necessary. Concerning our source flux-monitoring program, we plan to continue and extend it in upcoming years, and complement it with near real-time flux monitoring, as well as extend it by including international partner stations. First steps in that direction have been taken during 2025 and we want to continue these. We describe the situation concerning frequency standards at the observatory (vital for both Geo- and Astro-VLBI operations) and the need for investment in a new frequency standard, e.g. a Hydrogen-maser, including procurement during 2026, followed by possible delivery in 2027. The new microwave radiometer, installed in mid 2023 at OSO, successfully delivers data on atmospheric attenuation which is important for both Geo- and

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Astro-activities at OSO and thus provides a synergy gain for the whole observatory. We plan to develop a system to include the atmospheric data obtained from the microwave radiometer into the radio telescope observation scheme and log-files. Concerning gravimetry, we want to continue investigating the possibility, as a long term goal, of installing a modern quantum gravimeter.

Geodetic Very Long Baseline Interferometry – VLBI:

OSO is an important partner in the international VLBI cooperation that is coordinated by the IVS (International VLBI Service for Geodesy and Astrometry). The IVS is a service for both IAG (International Association of Geodesy) and IAU (International Astronomical Union) and is crucial for the creation and maintenance of the International Terrestrial Reference Frame (ITRF), the International Celestial Reference Frame (ICRF), as well as observations of Earth Orientation Parameters (EOPs).



Figure 1: Telescopes at the Onsala Space Observatory that are used for geodetic VLBI observations: the 20 m telescope (middle) and the twin telescopes (left and right).

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OSO has the longest observational history of all active IVS sites, and during the last two decades OSO participated on average in 40–50 IVS-sessions every year with the 20 m telescope and its S/X-system. These observations form among other things the fundament for the ICRF. The IVS has a strong desire to maintain the S/X contribution to the ICRF, in combination with building up a multi-frequency ICRF in the long run. As a consequence of this, the IVS will continue in the future to coordinate international VLBI sessions using S/X frequencies. We plan to contribute to these IVS S/X-sessions with OSO's 20 m telescope, and we expect for 2026–2028 about 40–50 of these 24 hour long S/X sessions every year.

During the last years the next generation VLBI system for geodesy and astrometry, called VGOS (VLBI Global Observing System), has been developed in an international cooperation. VGOS is an important contribution to IAG's flagship GGOS (Global Geodetic Observing System). In connection to this, we installed the Onsala twin telescopes (OTT), two identical VLBI systems for VGOS. The OTT were inaugurated 2017, commissioned during 2018/2019, and has been fully operational since January 2020. They are the first operationally active VGOS twin telescopes in the IVS network. Since 2020 the twin telescopes observe in IVS' operational VGOS series, which had 2020 and 2021 one session of 24 hour duration every 2nd week, and in 2022 on a weekly basis. However, the IVS correlation capacity was not sufficient to keep this pace, so since the last quarter of 2022, the IVS went back to VGOS observations every 2nd week only. Beginning with the 4th quarter of 2023, there were 3 VGOS weekly sessions in a row, followed by a week without. This operation cadence has been followed in 2024 and 2025. For 2026, the IVS plans to increase again to weekly VGOS observations.

In general, the IVS plans to slowly increase the number of VGOS sessions in the future in order to eventually come up to 24/7 observations, i.e. in principle observations every day. The bottleneck still is insufficient data transfer and correlation capacity, leading to rather long turn-around times, i.e. the time between the actual observation and the final databases that can be analysed to derive geodetic and astrometric products. However, there is hope that the situation will improve eventually. For 2026, weekly VGOS sessions are planned. Reducing the latency between observation and final database that is available for data analysis is of high priority for the IVS. It is important for the actual geodetic results, but also to give feedback to the observing stations. Thus, for 2026, the IVS plans to introduce a number of so-called "VGOS-rapid" sessions with the aim to achieve a turn-around of less than 14 days. Also, a data cap approach for the 24 h VGOS sessions will be introduced, to restrict the amount of data to be transferred to the correlators. For 2027 and 2028 the expectation is to increase the number of VGOS sessions further to 2–3 every week, depending on available correlator capacity. In addition to these standard VGOS operational sessions, the IVS organises a number of "VGOS research and development", or "VR" sessions. These VR sessions aim at further developing VGOS by testing various aspects, such as shorter scan lengths, alternative frequency setups, or special radio source catalogues. An important recent research topic was to test and identify optimal VGOS

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frequency setups in order to be able to apply for frequency protection at the ITU. Other aspects of R&D are increasing the number of radio sources observed and optimizing scan length. We plan to contribute with the OTT to all these international VGOS sessions. One important topic for the 2026 R&D sessions is preparations for the observation of ESA's Genesis satellite. Already in 2025 there were first fringe-tests performed to test the future frequency setup for Genesis. These tests were done first at Onsala only, then with international networks. Based on the experience gained in 2025, further Genesis-tests are planned for 2026, including a full 24 h session with a global network of VGOS stations.

Besides these global 24 hour long VGOS sessions with partner stations worldwide, we also cooperate with our European VGOS partners and observe European VGOS sessions. The aim of these so-called EU-VGOS sessions is to test different aspects of the VGOS systems and to refine, improve and further develop VGOS. A proposal-based system for EU-VGOS sessions was introduced in 2022, and we plan to cooperate with our European VGOS partner stations during 2026–2028 with the primary goal to develop the VGOS system further.

In 2022 OSO started operational VGOS intensive observations in cooperation with the VGOS station Ishioka (Japan). These VGOS-B and -C sessions are 1 hour long observations intended to be observed on Saturdays and Sundays with the aim to determine the Earth rotation parameter UT1-UTC. Already in 2020 and 2021, we successfully observed about 30 such sessions, however not on weekends. Since 2022 we perform these sessions operationally during weekends. The data correlation is done in Japan, and the data analysis is carried out by several IVS Analysis Centres, amongst them OSO. Since April 2025 we usually observe 4 VGOS-INT sessions at 00 UT and 12 UT on Saturdays and Sundays. We plan to continue this activity with our Japanese partners in 2026 and the following years.

We also plan to continue local interferometric observations between the two VGOS antennas for radio source flux monitoring (FM). The data of the FM-sessions are correlated and analysed at OSO, in connection with the academic research group on space geodesy and geodynamics and our colleagues at Lantmäteriet. During 2025 first steps were taken to implement a real-time correlation system for flux monitoring and these efforts will be continued in 2026. Experience gained from this will be evaluated with the aim to even become active in correlation of IVS sessions in the upcoming years.

We think that within the next 2–3 years a Nordic or Swedish IVS correlator should be built up to share part of the correlation burden within the IVS. In 2025 we had initial discussions with the Swedish National Space Agency for a joint SNSA-LM-OSO project on VGOS-correlation, and we hope the project can be realized in the near future. This can be the basis to develop a coordinated Nordic effort in the field.

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Gravimeter laboratory:

Since more than 10 years OSO operates a superconducting gravimeter, GWR 054. It is operated continuously and delivers gravity data with high quality and reliability. We analyse and quality control the observed measurements and send the data to international databases such as IGETS (International Geodynamics and Earth Tide Service).

The gravimeter laboratory at OSO maintains the gravity reference and is used as a calibration facility for visiting absolute gravimeters. On average there are 1–3 visits per year by absolute gravimeters by, e.g., national land survey institutes in the Nordic countries or research groups at European universities. During 2022, OSO hosted an international metrology campaign to compare absolute gravimeters, including modern quantum gravimeters. International gravity groups from several European countries visited OSO and performed measurement in the gravimeter laboratory. We plan to continue this activity 2026–2028 as preformed during the last decade and to support campaigns with visiting absolute gravimeters. In 2025 the meteorology sensors of the gravimeter laboratory had to be replaced since the old ones had been destroyed by lightning. Since mid 2025 we have a new employee (Luciana Fenoglio) who takes care of the gravimeter operations and analysis. The long-term ambition for the gravimeter laboratory is, provided funding, to purchase a modern quantum gravimeter, once these instruments are fully developed and reliable. To start, we aim at trying to organize test measurements with a quantum gravimeter in collaboration with the European EQUIP-G project.

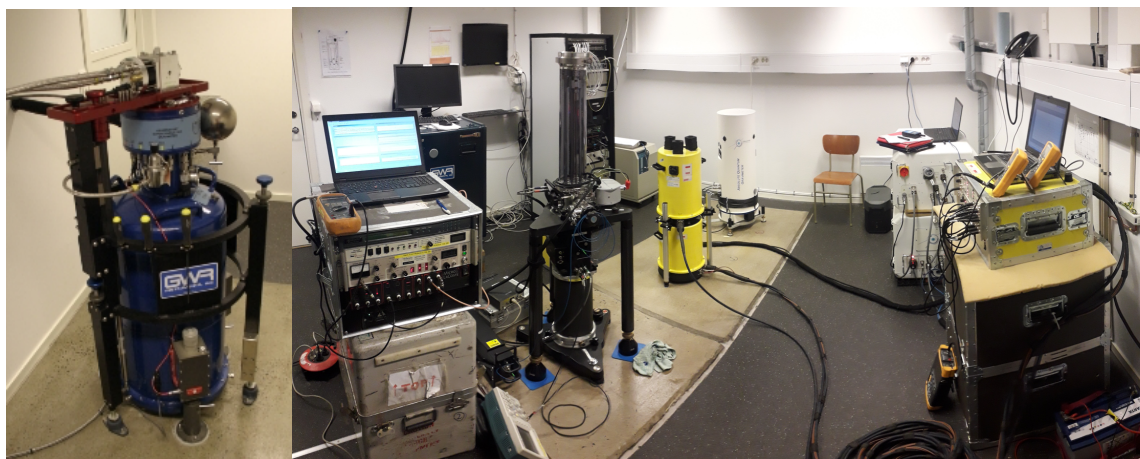


Figure 2: OSO's superconducting gravimeter GWR 054 (left) and visiting absolute gravimeters (right).

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Seismometer station:

OSO is the host for a seismometer that is part of Swedish National Seismic Network (SNSN) at Uppsala university (UU). We archive the data locally at OSO and use these data, amongst other things, to calibrate the superconducting gravimeter and to reduce noise in the measurements performed with absolute gravimeters. The seismometer station has thus an important role in supporting the gravimeter laboratory. We plan to continue with this activity 2026–2028.

GNSS stations:

All GNSS stations at OSO contribute in principle to SWEPOS, the GNSS network of Lantmäteriet, and most of the receivers and antennas are owned by Lantmäteriet. The most important installations include ONSA that was established in the early 1990's and serves as a reference station for the IGS (International GNSS Service) as well as EUREF Permanent Network (EPN). In addition ONS1, which was installed in 2012 as a backup for ONSA, also contributes to the same international networks. Furthermore, there are six GNSS stations installed around the twin telescopes. Among these, OTT5 is a specially designed station to study effects caused by multipath propagation and how these effects can be minimized. We plan to continue the GNSS activities during 2026–2028.



Figure 3: Some of the GNSS installations at OSO.

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Tide gauges:

Since 2015 OSO operates a tide gauge that is part of the national network for sea level monitoring of the Swedish Meteorological and Hydrological Institute (SMHI). The tide gauge is equipped with several sensors, among them radar, laser and pressure sensors, in order to guarantee reliable and robust observations and time series. At least once per year we perform levelling campaigns and check and document the tide gauge sensors' heights in RH2000. The tide gauge data are sent to SMHI and from there to international databases, e.g. PSMSL (Permanent Service for Mean Sea Level). Besides the traditional tide gauge we operated for many years a GNSS-based tide gauge that uses reflected GNSS signals. We receive multi-GNSS signals with two receivers that are connected to one antenna each, located above the sea surface, one upward-looking right-hand circular polarized (RHCP) and one downward-looking left-hand circular polarized (LHCP) antenna, respectively. The recorded signals are analysed with various analysis methods. We perform differential phase delay analysis, called GNSS reflectometry (GNSS-R), using data from both antennas together. We also perform signal-to-noise analysis, called GNSS interferometric reflectometry (GNSS-IR), using the upward-looking one. Using both approaches, sea level and its variations are determined. In 2024 we installed a second, similar installation, however here both antennas are RHCP and one of them is tilted by 90°, facing the sea surface. The new installation is meant for GNSS-IR. We plan to continue operating the OSO tide gauges during 2026–2028.

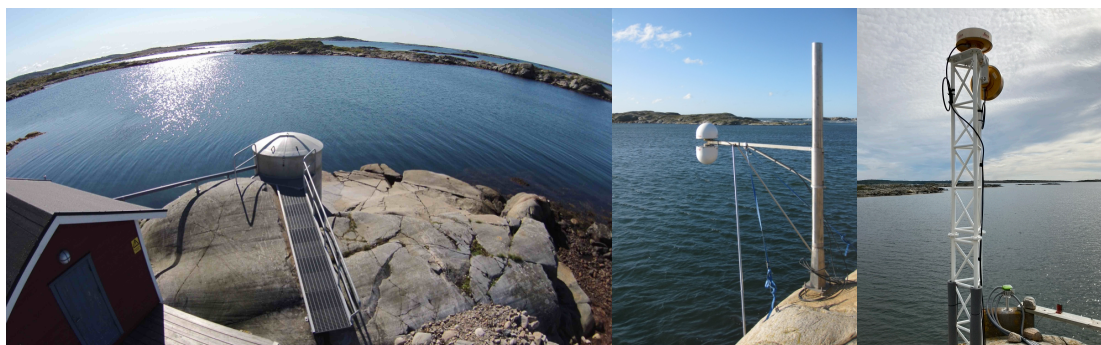


Figure 4: OSO's traditional tide gauge (left picture) and GNSS-R/-IR tide gauge (middle picture) and the new GNSS-IR tide gauge installed in 2024 (right picture).

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Microwave radiometry:

OSO operates several microwave radiometers to measure the amount of water vapor in the troposphere. This parameter and its variation in time and space are important factors that influence space geodetic measurements that work in the radio frequency regime, e.g., GNSS and VLBI. In both the analysis of GNSS and VLBI data so-called tropospheric parameters are estimated, and it is important to compare these results with independently derived information from microwave radiometers. An interesting spin-off product of geodetic GNSS and VLBI data analysis are accurate time series of tropospheric water vapor, which is of interest for climate research. A new radiometer, HATPRO, was delivered and installed in May 2023, replacing an old and broken one that had been installed in the 1980 and unfortunately could not be repaired. The new radiometer is working fine, and we work on, e.g., exploiting various operation modes, such as traditional sky-mapping, but also line-of-sight observations to GNSS satellites, as well as following VLBI schedules.

In addition to these radiometers, 3 mm wavelength radiometry is carried out at OSO. Even if the costs for this are not included in the contract with Lantmäteriet, there are synergy effects concerning microwave water vapour radiometry at Onsala and those observations. The latter observes water vapour, carbon monoxide and ozone in the mesosphere, which is important for research on atmospheric dynamics, climate change and global warming. These data are also sent to international databases. We plan to continue operating the OSO 3 mm wavelength radiometers for these purposes.



Figure 5: OSO's microwave radiometers to measure the amount of water vapor in the troposphere. Left: Konrad, operating since 1999. Right: Greta, installed in 2023.

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Time and frequency laboratory:

OSO's time and frequency laboratory is equipped with a H-maser that is needed for VLBI observations, and as well contributes in collaboration with RISE to the generation of UTC in Sweden. Furthermore, RISE owns another H-maser and a Cesium clock that are located in OSO's time and frequency laboratory. Both H-masers are Russian products and need urgently to be maintained, which is unfortunately not possible in the current political situation. We are also in contact with RISE concerning the development of a time and frequency distribution system via optical fibre. OSO has allocated 6 Mkr of capital in the OSO long term budget to cover the cost of a new H-maser. We propose to make a final decision, based on the progress or not of the alternative frequency distribution solution, on ordering a new H-maser during 2026.

There are at Onsala also several GNSS time receivers, which together with the Hydrogen masers make up the Onsala time and frequency laboratory, which is a crucial resource for supporting basically all observations that are performed at OSO, in particular for geodetic and astronomic VLBI, but also for the GNSS-receivers that make use of external frequency information provided by the H-masers. We plan to continue this activity 2026–2028 and develop modern techniques for time and frequency distribution via optical fibres in order to increase, amongst other things, robustness, reliability and accuracy.

InSAR:

During 2021 two retroreflectors for InSAR were installed at OSO. As part of a bachelor thesis in collaboration with Frankfurt University of Applied Sciences, the retroreflectors were surveyed and included in the local geodetic network at OSO. We still consider to use the OTT as InSAR reflectors when they are not used for VLBI observations. However, this would require testing of blinds to protect the sensitive OTT receivers.

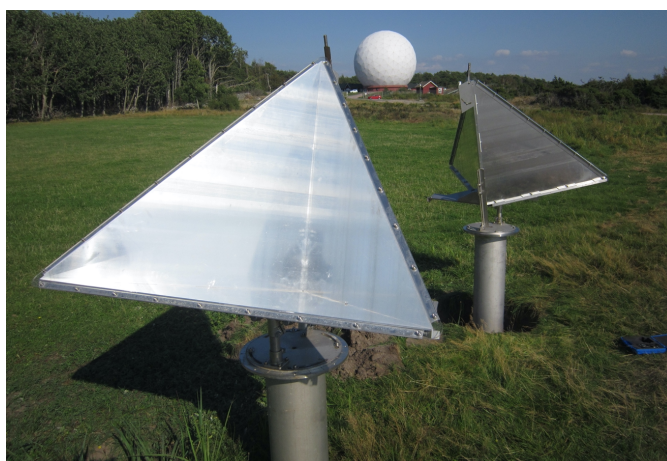


Figure 6: Retroreflectors for InSAR at OSO, installed 2021.

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Local maintenance including "local ties":

All instruments at OSO that are used for geoscientific observations are inspected and maintained on a regular basis so that accurate measurements can be done in an as reliable and robust way as possible. In late 2023 the OTT were equipped with invar systems to monitor thermal variations of the telescope towers. We also plan for temperature sensors on the reflectors and telescope cabin and structure. Corresponding data shall be collected to be able to model the thermal deformation of the OTT.

It is also very important to survey and monitor the local vectors between the instrument's reference points, the so-called "local ties". We do this through regular campaigns that are often organized as student projects in cooperation with other universities, and with support by Lantmäteriet. During 2025 we had a collaboration with Frankfurt University of Applied Sciences and Bochum University of Applied Sciences to characterize the reflector surface of the western Onsala twin telescope. We will continue corresponding local maintenance activity during 2026–2028.

Data access:

All data collected with the geoscientific instruments at OSO are accessible at databases at OSO and/or international databases, e.g. IVS, IGETS, IGS, SMHI, and are freely accessible to Swedish and international researchers. We follow the FAIR principles for scientific data.

Onsala, 2025-11-24
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