National report of Norway 2025: The Norwegian Tide Gauge Network

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Content

Overview of the network

The Norwegian Mapping Authority operates the Norwegian sea level observing system, consisting of tide gauges and GNSS receivers along the Norwegian coast.

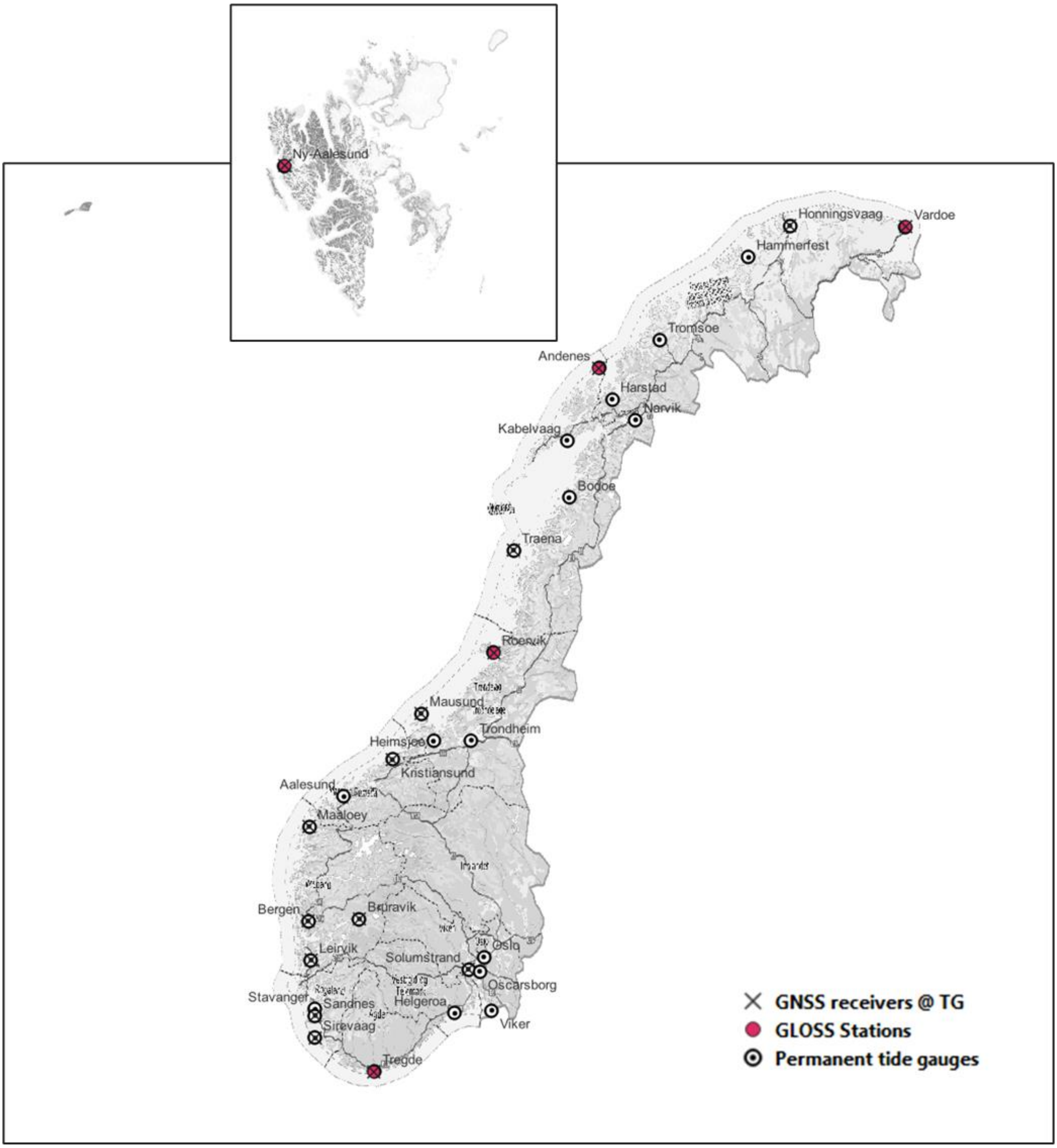


Figure 1: Overview of Norwegian permanent tide gauges, GLOSS stations and GNSS receivers co-located with tide gauges

The permanent tide gauge network

There are, as of March 2025, 29 tide gauges along the Norwegian coast and one in Ny-Ålesund in Svalbard, see Figure 1 and Table 1. Five of these tide gauges are GLOSS-stations: Tregde, Rørvik, Andenes, Vardø and Ny-Ålesund.

New permanent tide gauges

Over the last couple of years, the Norwegian tide gauge network has been expanded, with 6 new tide gauges since 2021. Four new stations have been installed since the last GLOSS-meeting in November 2022. Two new stations, in Leirvik and Bruravik were installed in November 2022. These stations are located between the existing stations of Stavanger and Bergen, and aim to cover the Hardanger fjord, which has a complicated tidal pattern. The Bruravik tide gauge currently serves as a test-site for sensor testing. A report will be issued when the testing is finished.

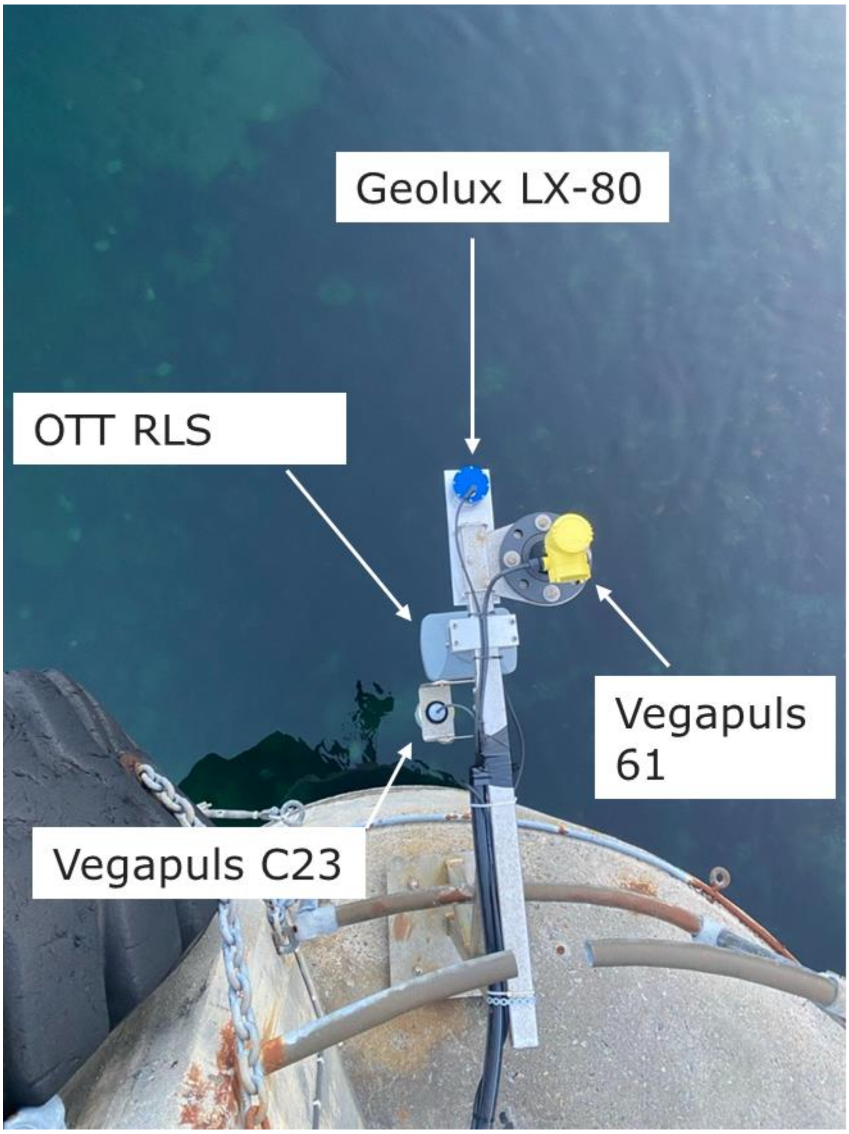


Figure 2: Setup of radar sensors on test-site.

In October 2023 a tide gauge was installed at the island of Træna, on the northern Norwegian coast, between Rørvik and Bodø. This tide gauge is installed on one of the outermost islands in the area, and will, in addition to the regular products and services, help to tie models from altimetry to the coastal tide gauge-based models.

In November 2023 a tide gauge was installed in Solumstrand, in the eastern city of Drammen. This tide gauge is place in the Drammensfjord on the inside of a narrow strait separating the fjord from the open ocean. This strait which causes a large delay in the water level propagation, as well as an important river coming out in the city, makes the Drammensfjord difficult to predict and the city vulnerable to flooding – both from river and sea.

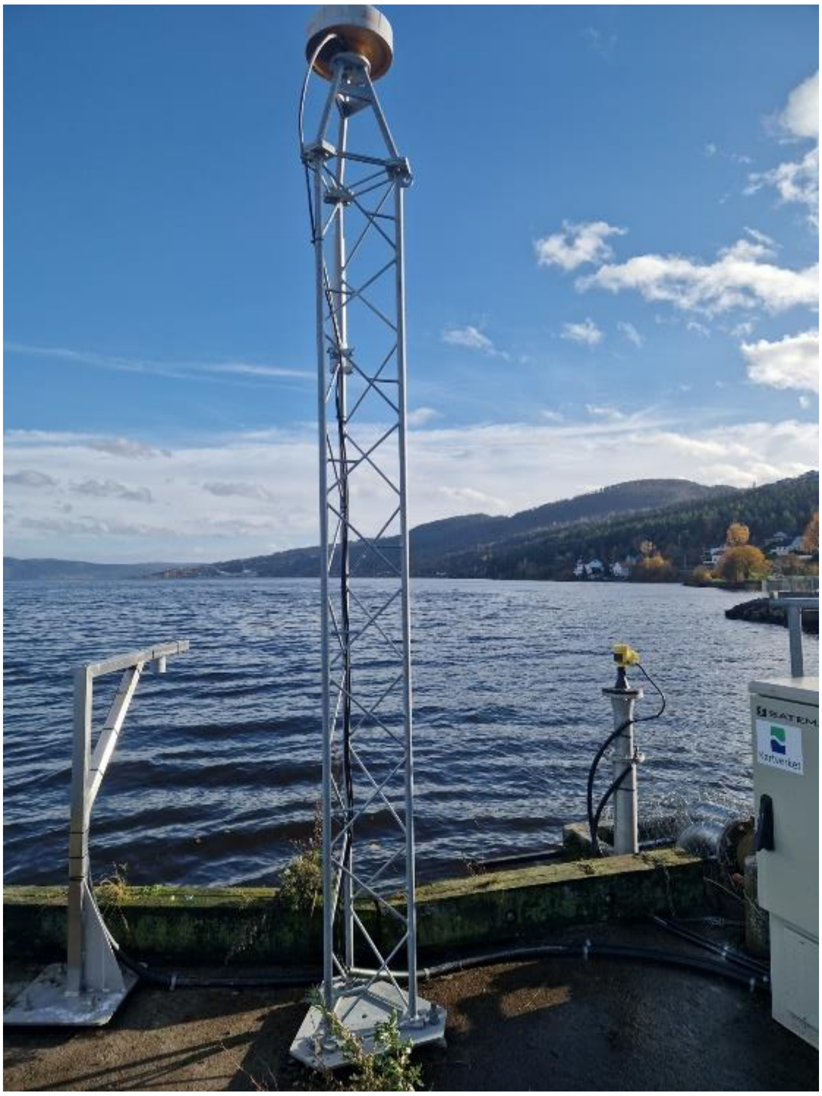


Figure 3: Tide gauge in Solumstrand

Sensors and data collection

All the new tide gauges, as well as the Hammerfest tide gauge have two radar sensors, a Vegapuls 61 and a Vegapuls C23. At the Solumstrand tide gauge, the Vegapuls 61 is mounted inside a tube, on the rest of the stations both sensors are inn open air.

The tide gauges installed before 2021 (except Hammerfest) are all float gauges with a stilling well. In these, a secondary system consisting of level switches is also in place for control and monitoring of the float.

Most of the gauges (both radar and float) have a sampling frequency of 1 Hz, and 1-minute averages are transferred to the Norwegian Mapping Authority in near real-time and stored in a database. The one-minute values are quality controlled using an automatic routine. If the data pass the quality control successfully, they are low pass filtered (Butterworth filter) and decimated to produce ten-minute values. The ten-minute values are directly available online (API and website). If the data do not pass the automatic quality control, a manual control is required. Software developed in-house is used for data control, processing, and analysis.

Most of the gauges are mounted on solid rock and are levelled with about three years intervals. The Norwegian Mapping Authority is responsible for the levelling.

Changes to the network

Kristiansund

Due to port renovation the tide gauge in Kristiansund was moved in the autumn of 2024. The station was moved less than 100m to the east. The gauge is still a float gauge.

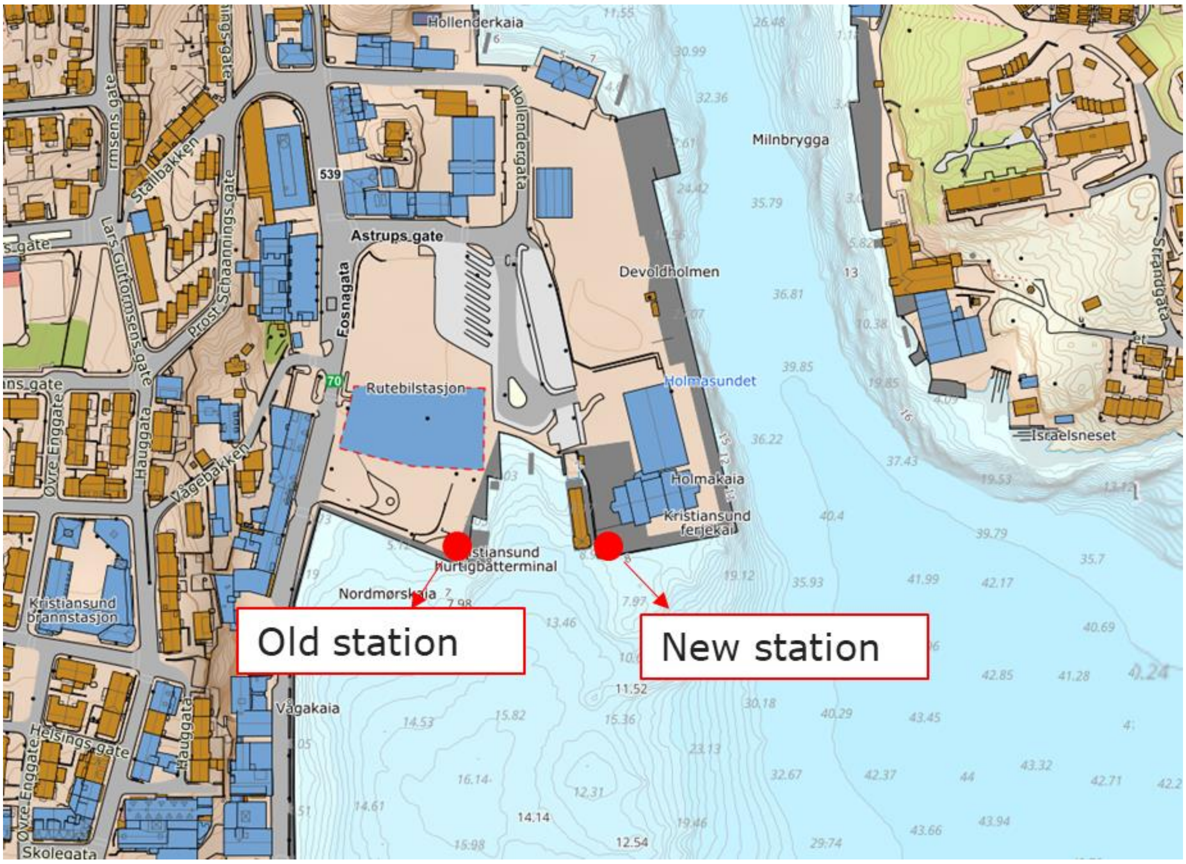


Figure 4: Location of old and new tide gauge in Kristiansund

From January 3rd, 2025, the data from the new station is the official data from Kristiansund and available online. All benchmarks are levelled and vertical datums have been transferred.

Sandnes

Due to port renovation the tide gauge in Sandnes had to be disconnected and removed in January 2025. The tide gauge will be reinstalled in proximity to the old location when the work on the quays is finished, estimated in early 2026.

The temporary tide gauge network

In addition to the permanent tide gauge network the Mapping Authority operates a network of temporary tide gauges. This network consists of shorter time series spanning from a couple of days to a few years. Lately, these campaign measurements have had a duration of at least one year, to account for any seasonal variations. The data is now mainly used for improving models (tide and water level, vertical datums) and in relation to work done by the coastal administration. For a long time, pressure sensors have typically been used for this type of measurements, but the Norwegian Mapping Authority is currently working on a system, using radar gauges also for shorter measuring campaigns.

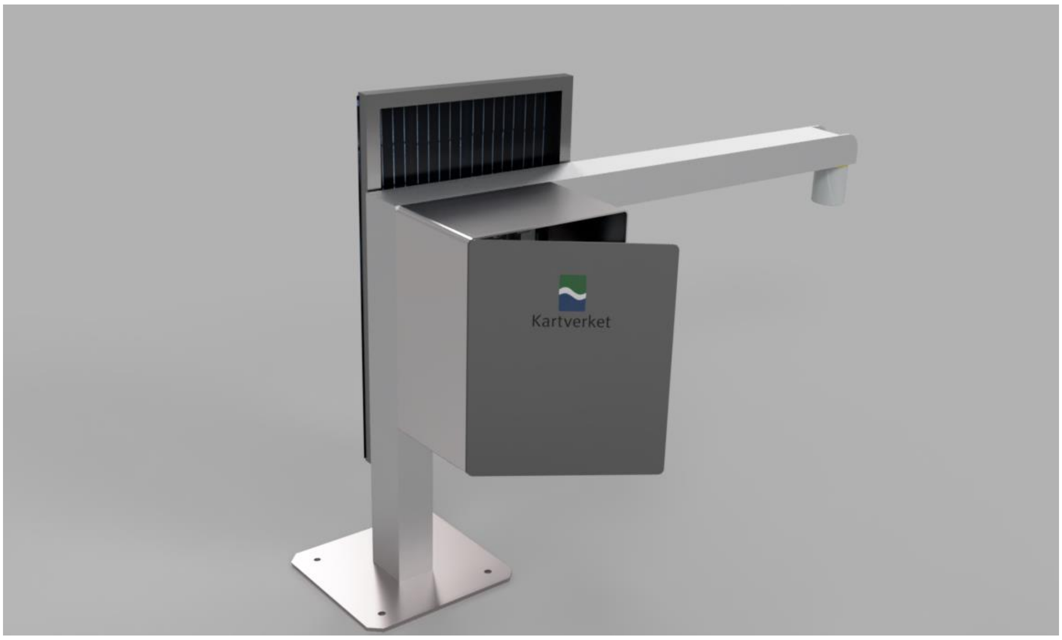


Figure 5: Illustration of a possible new concept for shorter measuring campaigns (Illustration: Kjetil Ydstebø)

Every year the Norwegian Mapping Authority is carrying out hydrographic mapping around Svalbard. Typically, water level measurements have been carried out simultaneously to correct the bathymetry to Chart datum. As the hydrographic measurements are now referenced to the Ellipsoid, and there is no longer a need for simultaneous water level measurements, we see a switch where the importance of high-quality models is increased. We are therefore looking for new ways of obtaining these models in this harsh and environmentally vulnerable territory, and will explore the use of altimetry, GNSS-IR and different types of tide gauges to obtain this.

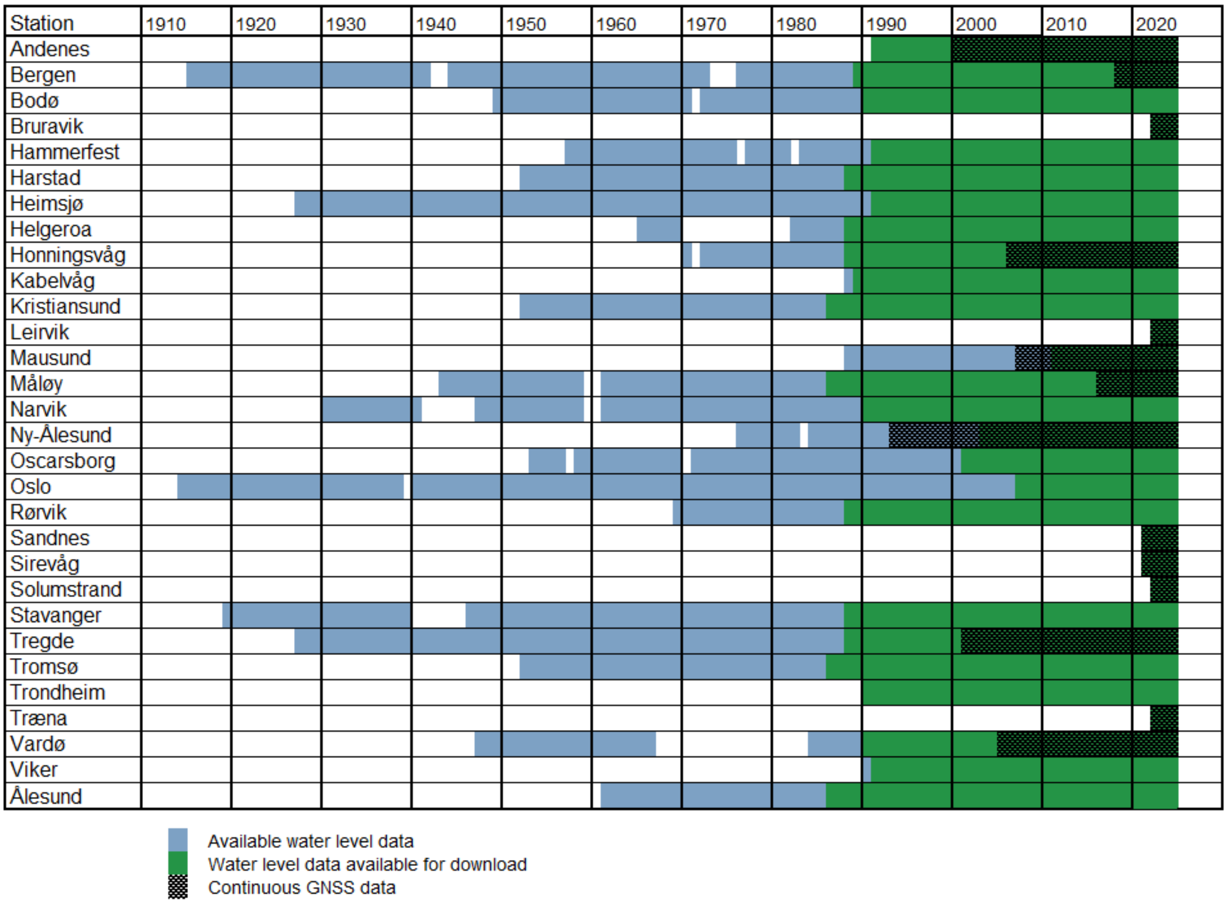
GNSS measurements

By March 2025, seventeen continuous GNSS receivers (CGPS) are installed at or in proximity of sixteen Norwegian tide gauges, see Figure 1. In Vardø, Andenes, Tregde, Bruravik, Træna, Leirvik and Sandnes the antennas are installed directly at the tide gauge, on the other stations the GNSS receivers are several hundred meters away. In Ny-Ålesund the GNSS receivers are installed near the old VLBI-station (Very Long Baseline Interferometry), which is located about 1.5 km from the tide gauge. In some locations the tie between the tide gauge and the GNSS receiver is difficult due to the placement of the GNSS receiver. The Norwegian Mapping Authority is responsible for the continuous GNSS measurements and analyses of the data.

Distribution of data and products

Data availability and distribution

Figure 6 shows the data available from the permanent tide gauges. All data available online can be retrieved directly from an API-service (https://vannstand.kartverket.no/tideapi_no.html) free of charge. Data not available online, both from the temporary and the permanent network, can be obtained on request.



Kartverket

Figure 6: Availability of data from permanent tide gauges. GNSS availability from the stations Kristiansund and Rørvik has not been updated on this figure.

Data from the permanent tide gauges is distributed to international data portals.

Website

In addition to the API-service, the Norwegian Mapping Authority makes data and information available on the website Se havnivå.

The following products are available:

- Water level observations (from around 1990 to now), for all permanent tide gauges.
- Historical monthly and annual means, for all permanent tide gauges and from the start of the time series (1914-1991 depending on station)
- Water level estimations, residuals, tidal predictions, vertical datums and water level prognosis (based on a model from the Norwegian Meteorological Institute) for almost all positions along the coast

- Projections of future sea level change in Norway for almost all positions along the coast

The official Norwegian tide tables are no longer published as a separate online publication (as of 2021), but the tide tables are still available for download at the website.

The web tool Se havnivå i kart (Visualize sea level) visualizes present-day storm surge levels and future sea level rise. The data and maps illustrate the potential scale of inundation along the Norwegian coast. The tool is used for preparedness and prevention in risk management and adaption to climate change and was updated in 2024 to reflect the newest projections of sea level rise and recommendations from the authorities. The tool has, since its launch in 2018, been used extensively – both by community planners, in the media and by the general public.

All data and products available online are free of charge

Other activities

Separation models

The data from the Norwegian tide gauge network are an important data source for the official gridded national separation models. These models make it possible to convert directly between different vertical datums for given positions and were first made public in 2021. The models were updated in 2024, with more tide gauge measurements and improved computational methods. The models describe the relationship between the geoid, Mean sea level, Chart datum, and the ellipsoid (EUREF89). They facilitate seamless terrain models from the deepest fjords to the highest mountains, coastal zone management, and Ellipsoidally Referenced Surveying (ERS). At this point, the models are valid from the coast to the territorial border, but work is in progress to calculate models for the entire Norwegian economic zone. The extension of the model domain requires that the tide gauge measurements are combined with observations from satellite altimetry and that a refined computational framework is developed.

Altimetry and tide gauges - Assessment of SWOT altimetry by tide gauge measurements

The NMA has recently assessed the performance of measurements from the new generation altimetry satellite Surface Water and Ocean Topography (SWOT) along the Norwegian coast. The assessment has been based on comparisons with in-situ measurements from the network of permanent tide gauges.

The comparisons show promising preliminary results and suggest that SWOT resolves the mean dynamic topography (MDT) along the coast with a standard deviation of 3.6 cm when compared to tide gauges. Furthermore, a spatial Spearman correlation of 0.8 was calculated between MDT at tide gauges and MDT calculated from SWOT observations within 20 km from each tide gauge. These results are significantly better than 4.3 cm (standard deviation) and 0.61 (correlation) obtained for Sentinel-3A/B in a previous similar study

The study demonstrates the importance of tide gauges tied to a global geodetic reference frame. In Norway, all tide gauges have levelled heights in the national height system, and heights in the International Terrestrial Reference Frame (ITRF) are obtained by a height reference surface. The ability to make this transformation is a fundamental need for calculating sea surface heights that can be compared to satellite measurements.

The goal of the study was to assess to what extent measurements from SWOT are sufficiently accurate to contribute to NMA's coastal mean sea surface, separation models, and ultimately, reduce the need for in-situ campaign measurements from tide gauges. The study has not been conclusive on these questions, and further research will be accomplished in the near future.

New projections on sea level and extremes along the Norwegian coast

Sea level projections for Norway were updated in 2024 following the release of the IPCC's Sixth Assessment Report. The work was commissioned by the Norwegian Environment Agency and resulted in the report «Sea-Level Rise and Extremes in Norway». The purpose of the report is to provide a knowledge base for policy and decision makers working with mitigation and adaptation strategies for coastal planning in Norway. In addition to sea level projections, new return levels for storm surges have been calculated. The new projections have been made available through the website Se havnivå and as an official basic map dataset for use by municipalities for planning and building purposes.

Use of GNSS-IR for water level measurements

The Norwegian Mapping Authority is responsible both for the geodetic network and the tide gauge network and there is a common interest in whether GNSS-IR can be used for water level measurements. A small study was therefore carried out in 2024 to see if there was a potential for using the technology for any of the products related to water level observation. One of the objectives was to see whether any existing geodetic stations, not co-located with a tide gauge, could be used to obtain water level information, hence closing the gap between the permanent tide gauges. The study showed that there is a small offset in the GNSS-IR data, which presently makes it difficult to use the data for vertical datums and mean sea level. This must be investigated further. On the other hand, there were promising results regarding tidal analysis, which means that the tidal amplitude and phase could be better resolved between the ordinary tide gauges. At present, GNSS-IR is not considered to be a possible replacement of a tide gauge, but the Norwegian Mapping Authority will continue the work on this technology.

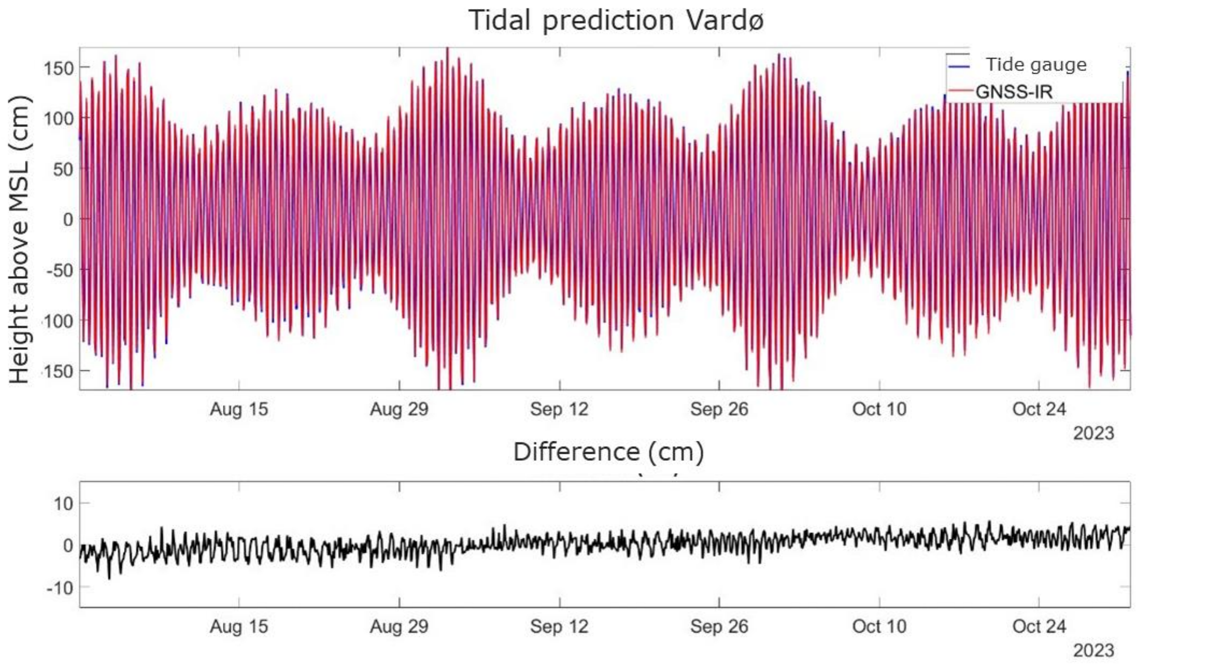


Figure 7: Illustration of the difference in the tidal predictions on data from a tide gauge and data from GNSS-IR

Data archeology

The Norwegian Mapping Authority, Hydrographic Service, where the tide gauge archive has been located, is moving in March 2025. This led to the start of a data archiving project.

The work is separated in several steps. Currently, a simple inventory is finished, and the archives are being shipped to the Mapping Authority's headquarters for proper storing. An important step is to get an official decision from the Norwegian National Archives on whether the material must be archived (according to the Norwegian law). This process is also ongoing. When these steps are finished, we will proceed to making a plan on how and when the material can be sorted (according to archiving procedures), scanned and digitized. Finally, parts of the paper documents will be delivered to the National Archives.

Most of the data from the permanent tide gauge network has already been partly digitized/collected as hourly values. More details could be obtained and a new quality control could be performed if the data was digitized with better resolution (both spatial and temporal). In addition, we have retrieved data not currently available in the water level database, for instance about 30 years from the Oslo data series (from the end of the 19th century). Finally, as well as the tide gauge data themselves, there are numerous documents related to metadata and operating procedures that should be taken care of, as these can be important both for data quality and for research into societal matters.

Appendix

Station	PSMSL ID	GLOSS ID	Latitude	Longitude	Water level data available from	GNSS station ID	GNSS available from
Viker	1759		59°02' N	10°57' E	1990		
Oslo	62		59°54' N	10°44' E	1914		
Oscarsborg	33		59°41' N	10°37' E	1953		
Solumstrand			59°43' N	10°16'	2023	SOLU	2023
Helgeroa	1113		59°00' N	09°52' E	1965		
Tregde	302	321	58°00' N	07°34' E	1927	TGDE	2001
Sirevåg	2401		58°30' N	05°47' E	2022	SIRC	
Stavanger	47		58°58' N	05°44' E	1919		
Sandnes	2398		58°52' N	05°40' E	2021	SNES	2021
Leirvik	2402		59°46' N	5°30' E	2022	STRD	2022
Bruravik	2400		60°30' N	6°54' E	2022	BRUR	2022
Bergen	58		60°24' N	05°18' E	1915	BERH	2019
Måløy	486		61°56' N	05°07' E	1943	MALO	
Ålesund	509		62°28' N	06°09' E	1961		
Kristiansund	682		63°07' N	07°44' E	1952	KRSU	
Heimsjø	313		63°26' N	09°07' E	1928		
Mausundvær	2271		63°52' N	08°40' E	1988	FROC	2007
Trondheim	34		63°26' N	10°24' E	1989		
Rørvik	1241	234	64°52' N	11°15' E	1969	VIKC	
Træna			66°30' N	12°5' E	2023	TRAE	2023
Bodø	562		67°18' N	14°24' E	1949		
Kabelvåg	45		68°13' N	14°30' E	1988		
Narvik	312		68°26' N	17°25' E	1931		
Harstad	681		68°48' N	16°33' E	1952		
Andenes	425	322	69°19' N	16°09' E	1991	ANDE	2000
Tromsø	680		69°39' N	18°58' E	1952		
Hammerfest	758		70°40' N	23°41' E	1957		
Honningsvåg	1267		70°59' N	25°59' E	1970	HONS	2006
Vardø	524	323	70°20' N	31°06' E	1947	VARS	2005
Ny-Ålesund	1421	345	78°56' N	11°57' E	1976	NYA1 NYAL	1997 1993

Table 1: List of Norwegian tide gauges with information on co-located GNSS receivers. GLOSS-stations are highlighted