National Report of Denmark, Greenland and the Faroe Islands 2025

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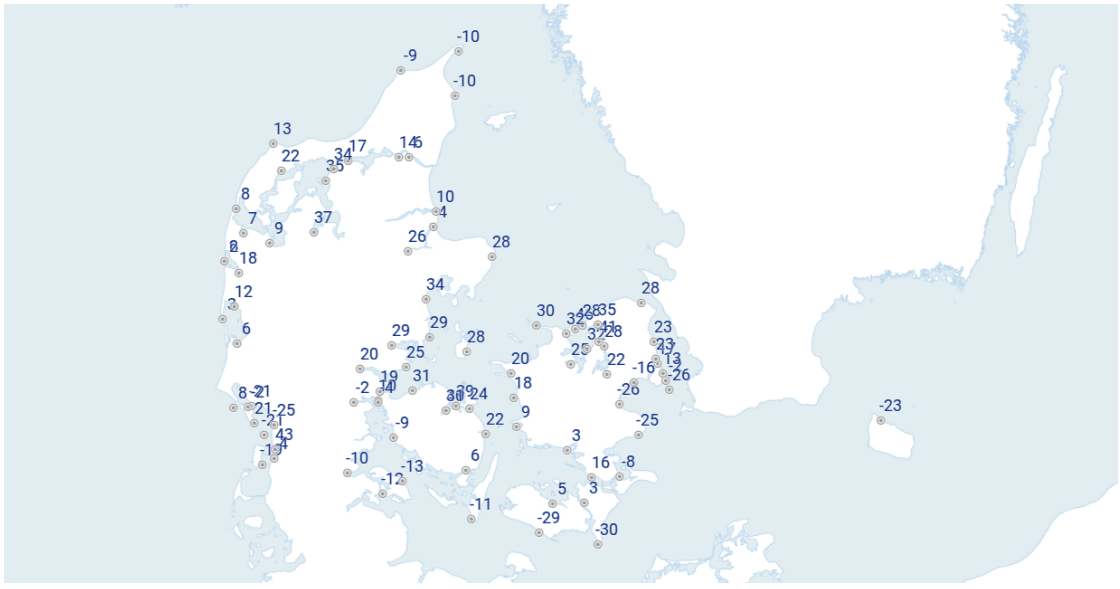
Denmark

DMI (https://dmi.dk) and the Danish Coastal Authority (https://kyst.dk) operate together with local harbour authorities tide gauge instruments at more than 80 sites along the Danish coast.

All data are collected in real time and the instantaneous sea level observations are displayed in real time at DMI's webpage: https://www.dmi.dk/vandstand/
In addition, the data from DMI and the Danish Coastal Authority are available for download at this Free Data Portal: https://opendatadocs.dmi.govcloud.dk/DMIOpenData
Please, notice that observations available in real time is only quality-controlled in a very basic way.



Instruments:
Different types of tide gauge instruments are in operation in Denmark:

- acoustic type
- TD instrument
- Bobble sensor
- pulse radar

Data delivery to international databases:

Data to PSMSL:
Data from the following 17 Danish stations, operated by DMI, are available through PSMSL. These mean sea level calculations are uploaded with a few years delay and a more thorough data quality have been applied.

These 14 tide gauges are operational stations:

130/001 Gedser	54 34 N	11 56 E
130/011 Rødbyhavn	54 39 N	11 21 E
130/016 Tejn	55 15 N	14 50 E
130/021 København	55 42 N	12 36 E
130/031 Hornbæk	56 06 N	12 28 E
130/041 Korsør	55 20 N	11 08 E
130/051 Slipshavn	55 17 N	10 50 E
130/062 Fynshav	55 00 N	09 59 E
130/071 Fredericia	55 34 N	09 45 E
130/081 Aarhus	56 09 N	10 13 E
130/091 Frederikshavn	57 26 N	10 34 E
130/101 Hirtshals	57 36 N	09 58 E
130/111 Hanstholm	57 07 N	08 36 E
130/121 Esbjerg	55 28 N	08 26 E

These three tide gauges have stopped and but the historical data are available:

130/018 Hammerhavn	55 17 N	14 45 E
130/019 Christiansø	55 19 N	15 11 E
130/061 Mommark	54 56 N	10 03 E

Data for NEAMTWS:
Data from the tide gauge station in Hirtshals (North Sea coast) are available for the IOC Sea Level Station Monitoring Facility in real time. Sampling interval is 10 minutes.

Data for EU's Copernicus Marine Service:
All tide gauge data from DMI and the Danish Coastal Authority are uploaded in real time into the Coperncius Marine Service (https://marine.copernicus.eu/)

Collocation with GNSS:

Eight tide-gauge station located in Denmark are collocated with GNSS (distance < 1 km)

CMEMS_NAME	LONG (deg)	LAT (deg)	GNSS ID	DIST (m)
Esbjerg	8.456821	55.493563	ESB5	0
Ferring Strand	8.118271	56.523018	FER5	258
Fynshav	9.986253	54.993634	FYHA	85
Gedser	11.922922	54.574427	GESR	276
Havnebyen	11.355311	55.971841	HABY	885
Hirtshals	9.967542	57.591097	HIRS	620
Arhus Havn	10.222640	56.146600	TA01	2
Tejn	14.83934	55.248420	TEJH	200

ESB5 has replaced ESBH.

Greenland

DTU Space operates five tide-gauge stations in Greenland:
- Qaqortoq (PSMSL 980/045).
- Thule. Since 2001 and upgraded to international standards in 2006.
- Illoqqortoormiit. Since 2006.
- Nuuk since 2014 (GLOSS ID 225).
- Upernavik since 2023.

At all five stations are collocated with permanent GNSS.

Instrumentation:
During 2020 DTU was granted money for the Greenland Integrated Observing system (GIOS) where DTU space should establish and updating the existing sea level measurement network in Greenland. The establishment of the new sea level recorders was planned along with the renovation of the existing 4 aging tide gauges: Nuuk (NUUK), Qaqortoq (QAQO), Ittoqqortoormiit (SCOR) and Pituffik Space Base (THUL).

In 2022 a new separate pipe and pressure sea level recorder (NUK1 was established to run in parallel with the existing Anderaa pressure recorder in Nuuk. For the new pressure sensor we selected the Valeport MIDAS CTD+. Also, during 2022 the Qaqortoq tide gauge (QAQO) in southern Greenland was updated from the Anderaa to the Velport MIDAS CTD+ pressure gauge. In 2023 a new pipe with a Valeport MIDAS CTD+ sensor were established in Upernavik and the existing tide gauge in Ittoqqortoormiit was upgraded to a Valeport MIDAS CTD+ as well.

Data for GLOSS:
All four stations contribute to the GLOSS Core network, currently only to the fast delivery data center:

225 NUUK	64 11N	051 43W
315 SCORESBYSUND	70 29N	021 59W
343 THULE	76 N	068 W
344 QAQORTOQ	60 43N	046 02W
UPERNAVIK	70 29N	021 59W

Delivery of research quality data to UHSLC as well as PSMSL are in progress.

Data for NEAMTWS:
Data from all five tide-gauge station in Greenland are available for the IOC Sea Level Station Monitoring Facility in real time. Sampling interval is 5 minutes.

Faroe Islands

The GLOSS station (GCN 237) Torshavn (DMI):
Historical data from the station, a floating/well device type, are available from 1957 until the operation stopped in 2006.

GNSS-IR experiments in Greenland:

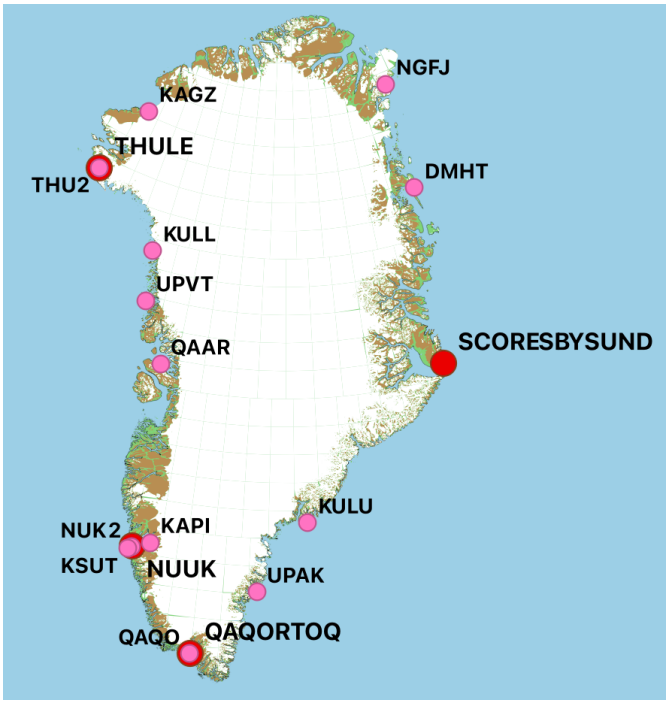
In 2022 a GNSS-IR station (NUK2) was established to run in parallel with the existing Anderaa pressure recorder in Nuuk. For the GNSS-IR measurements we selected the Tallysman VP6150 VeraPhase Full GNSS Antenna and Septentrio PolaRx5 GNSS receiver. Also, during 2022 a new GNSS-IR site (QAQO) was installed near the existing sea level pipe with the same type of antenna and receiver used in Nuuk. On the east coast where conventional gauges are close to impossible because of the lack of suitable infrastructure, we installed a standard GNSS-IR system at Danmarkshavn.

In addition, existing geodetic GNSS station in the Greenland network GNET has been assessed to select coastal sites that may be suited for GNSS-IR.

In total GNSS-IR experiments are carried out at the following 14 sites:

Overview of Stations Used for GNSS-IR in Greenland						
Station ID	Latitude	Longitude	Ellipsoidal Height	Operational Time	Antenna Type	Performance (1-5)
NGFJ	80° 34' 6"	-16° 50' 28"	34	2024 →	LEICA AR20	4
UPAK	63° 5' 44"	-41° 18' 57"	120	2024 →	LEICA AR20	4
QAQO	60° 42' 55"	-46° 2' 52"	74	2012 →	LEICA AR20	4
QAAR	70° 44' 25"	-52° 41' 18"	26	2007 →	LEICA AR20	4
KULL	74° 34' 50"	-57° 13' 37"	72	2007 →	LEICA AR20	3
THU2	76° 32' 13"	-68° 49' 30"	21	1998 →	LEICA AR20	4
PLPK	66° 53' 52"	-34° 1' 60"	66	2007 →	LEICA AR20	3
UPVT	72° 47' 19"	-56° 8' 47"	31	2024 →	Tallysmann	5
NUK2	64° 10' 16"	-51° 43' 13"	51	2024 →	Tallysmann	5
KSUT	64° 4' 15"	-52° 0' 28"	41	2023 →	LEICA AR20	1
KAPI	64° 25' 56"	-50° 16' 16"	44	2008 →	LEICA AR20	4
KULU	65° 34' 46"	-37° 8' 58"	17	1996 →	LEICA AR20	2
DMHT	76° 46' 7"	-18° 40' 14"	43	2024 →	Tallysmann	5
KAGZ	79° 7' 55"	-65° 51' 11"	73	2007 →	LEICA AR20	3

Table 2: Overview of the GNSS sites used for GNSS-IR estimations in Greenland. All sites with the Antenna type: AR20 are GNET sites. The remaining are GNSS-IR only sites. The performance measure is defined as a subjective angle on the performance of retrieving continuous time series.



Map showing locations of the GNSS-IR experiments together with locations of the tide-gauge stations. (Please note that an additional tide gauge is located at UPVT)

Preliminary results:

Comparison of conventional and GNSS-IR tide gauges observations in Nuuk.
In this analysis, GNSS-R-derived water levels are evaluated in relation to water levels measured with the traditional pressure gauge. The two stations are called "Nuuk_GNSS" and "Nuuk_TG" hereafter.

It should be noted that water level data from GNSS reflectometry is different from water level data from traditional gauges. Partly, because reflections occur at times when signals from GNSS satellites are available in directions where reflections may occur, partly because the reflection points are not at the same point as with traditional measurement. In addition, the data has been interpolated at 5 min intervals using splines.

In the preparation of data for this analysis, data is selected from Nuuk_TG every 5 minutes as before. Furthermore, only data is included for the period where data from both Nuuk_GNSS and Nuuk_TG are available. Thus, data in the period from 26 April 2023 to 30 September 2023 is included in the analysis.

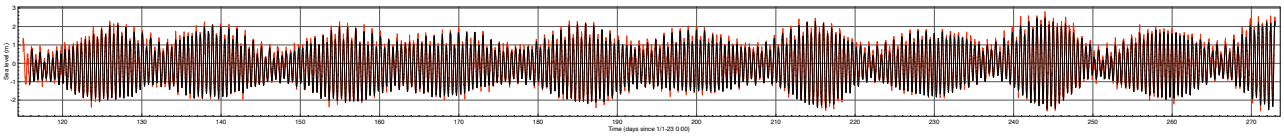


Figure 1. Sea-level time series from the Nuuk GNSS-R station (red) and the Nuuk pressure gauge (black).

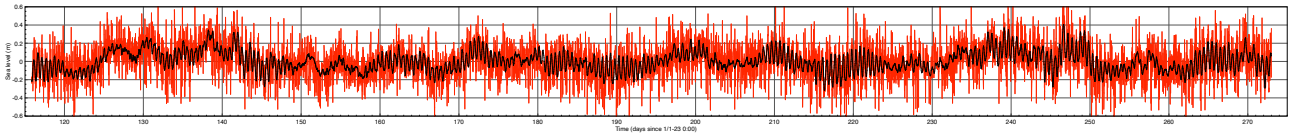


Figure 2. Sea-level time series where the tidal signal has been removed from the Nuuk GNSS-R station (red) and the Nuuk pressure gauge (black).

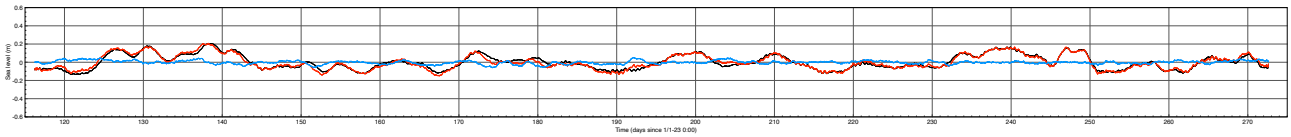


Figure 3. Sea-level time series where the tidal signal has been removed and smoothed over 1-day intervals from the Nuuk GNSS-R station (red) and the Nuuk pressure gauge (black). The blue curve shows the differences.

Table. Standard deviations of sea-level data, tidal model, residuals, and 1-day smoothed residuals for the Nuuk GNSS-R, the pressure gauge and their differences in meters.

Standard deviation	Nuuk_GNSS	Nuuk_TG	Differences
Observations	1.047	1.024	0.163
Tide Model	1.031	1.018	0.070
Residuals	0.183	0.109	0.148
24 hour averages	0.078	0.077	0.019

The conclusion of this analysis is that GNSS-R clearly gives promising results. The measurements are noisier than the measurements from the traditional pressure gauge, which can be explained by the fact that the GNSS-R measurements are made at nearby reflection points and not at the same point. The analysis of the measurements shows, however, that the results of calculations of tidal constituents as well as calculation of daily averages of the water levels correspond to results from the analysis of measurements from the pressure gauge within very small deviations. The reference level of the GNSS-R measurements provides a direct link to the ITRF, which remains to be verified.