Reference levels, charts and water level

Swedish Maritime Administration 2025-06-27

Thomas Hammarklint





What is a reference level?

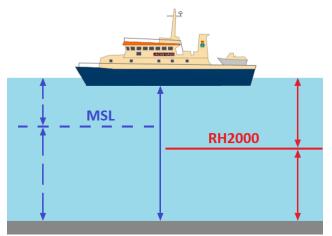
The depth information on a chart should be interpreted as the depth measured from the water surface to the bottom. The challenge is that the water surface level is constantly changing - winds, currents, air pressure, salinity, seiches and tides affect the level of the water surface. Variations of 3-4 decimeters during a day is normal. To be able to calculate the current depth at a given position a quick and well-defined reference level for the water surface is needed. This is particularly important if you are operating in shallow waters with small margins relative to the vessel's draught.

In addition to the fact that the level of the water surface varies, the depth is also affected by the elevation of the land. It is greatest along parts of the Norrland coast, about 1 cm per year. For charts of the Norrland coast produced in the 1960's, the depths have decreased by around half a metre.

Which reference level?



The water depth is unchanged when you change the reference level!

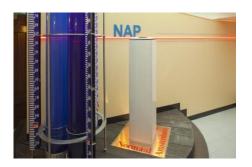




National height systems







RH00 National height system 1900

Official national height system until 1970 Zero-level definied by: Normal height point in Stockholm from 1886 Placed +11,800 m above mean sea level in Stockholm 1900

> RH70 National height system 1970

Official national height system 1970-2005 Zero-level defined by: Normaal Amsterdams Peil (NAP), a reference point in Varberg placed +4,234 m above NAP

> RH 2000 National height system 2000

"Baltic Sea Chart Datum 2000 (BSCD2000)"
Official national height system since 2005
Zero-level definied by:
NAP is the reference point in the European Vertical Reference
System (EVRS)
Epoch year 2000



What different reference levels are used today?

Mean sea level (MSL) or mean sea surface (MVY)

An estimated reference level used in older Swedish charts, based on observed mean sea level and a certain reference year (epoch) or year of publication. The level changes over time depends on the land and sea level rise, i.e. the "apparent" or relative land uplift, which is observed using tide gauges (water level stations). A table showing the mean sea level for the present year in different height systems and land uplift rates at all measurement locations around the coast can be found here.

Baltic Sea Chart Datum 2000 (BSCD2000) or the zero-level in Swedish national height system 2000 (RH 2000)

The realization in each country of the European Vertical Reference System (EVRS). The height reference surface of BSCD2000 is the equipotential surface of the Earth's gravity field. The reference level thus refers to a surface that is only affected by the Earth's gravitational field and does not change significantly over time. The zero level of BSCD2000 is in accordance with the Normaal Amsterdams Peil (NAP). The level is used also for heights on land. The member states around the Baltic have an agreement to switch to <u>BSCD2000</u> in charts and water level information. The work is coordinated by the BSHC Chart Datum, Water level and Currents Working Group (<u>CDWCWG</u>). In Sweden the transition was completed for water levels in June 2019. The transition in all Swedish charts (<u>Swedish Chart Improvement Project</u>) is expected to be completed by 2030 at the latest.

Lowest Astronomical Tide (LAT) – not used in Swedish charts

The lowest calculated tide, based on at least 18.6 years of water level observations, to account for all tidal components. Used as a chart datum in sea areas with significant tidal variations, e.g. in the North Sea. The variations depend on the gravitational pull of the moon and sun, depth and topography. On the Swedish west coast, the largest difference between the highest (flood) and lowest (ebb) water levels amounts to approx. 0.8 m (tidal range), in conjunction with full or new moon.

Information about which reference level is used in a specific chart can be found on the right in the upper margin of the printed charts. Example of how it looks in a newer Swedish chart, where BSCD2000 is used:

CHART DATUM: Mean Sea Level (Baltic Sea Chart Datum 2000^{RH2000})
REFERENSNIVÅ: Medelvattenyta (Baltic Sea Chart Datum 2000^{RH2000})
SYMPOLS and APPREVIATIONS: sea INT 1

SYMBOLS and ABBREVIATIONS: see INT 1

BETECKNINGAR och FÖRKORTNINGAR: se KORT 1





Nautical charts with chart datum MSL or BSCD2000

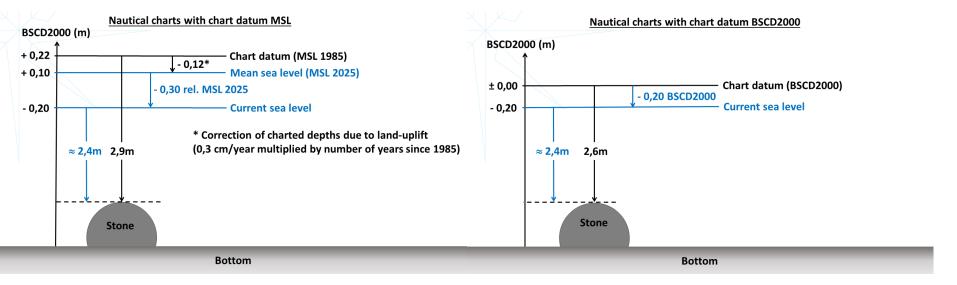
CHART DATUM: Mean Sea Level (MSL) 1985
REFERENSNIVÅ: Medelvattenyta (MVY) 1985
LAND UPLIFT/LANDHÖJNING 0.3 cm annually / per år
SYMBOLS and ABBREVIATIONS: see INT 1
BETECKNINGAR och FÖRKORTNINGAR: se KORT 1

CHART DATUM: Mean Sea Level (Baltic Sea Chart Datum 2000 REFERENSNIVÅ: Medelvattenyta (Baltic Sea Chart Datum 2000 2000)

SYMBOLS and ABBREVIATIONS: see INT 1

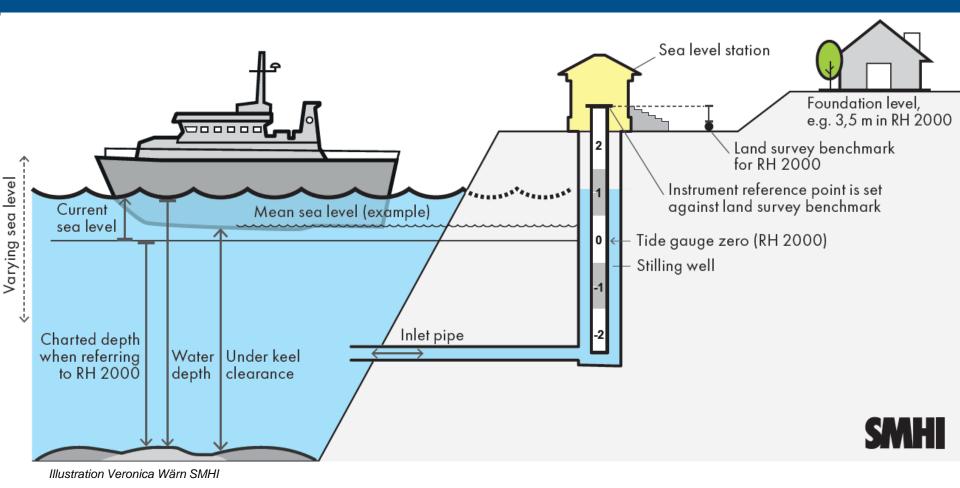
BETECKNINGAR och FÖRKORTNINGAR: se KORT 1







A uniform reference system from land to sea





Notices to Mariners (NtM)

* 14040

Sweden. not area bound. New reference system for sea level, nautical charts and warnings. BSCD2000 / RH 2000.

Expired notices: 2019:754/13917

See: 2018:716/13140

As of June 3, 2019, the Swedish national height system 'Rikets Höjdsystem 2000', or RH 2000 (international name 'Baltic Sea Chart Datum 2000', BSCD2000) will constitute the reference level for observations and forecasts of the water level in Swedish waters.

The zero level in RH 2000 is fixedly linked to land, and is not affected by land uplift, changes in sea level or geographical variations.

The change means that observations, forecasts, and warnings in the Swedish Maritime Administration's and Swedish Meteorological and Hydrological Institute's (SMHI) viewing services from 3 June 2019, or soon thereafter, refer to the new reference level and no longer to the 'mean sea level'.

The Swedish Maritime Administration is gradually adapting the charts to the new reference system. This is a time consuming process which will take several years to complete. During the transition period, it is important to know which reference level is used in the different charts. If the text 'Baltic Sea Chart Datum 2000', or 'BSCD2000' is printed in the chart, the update has been performed.

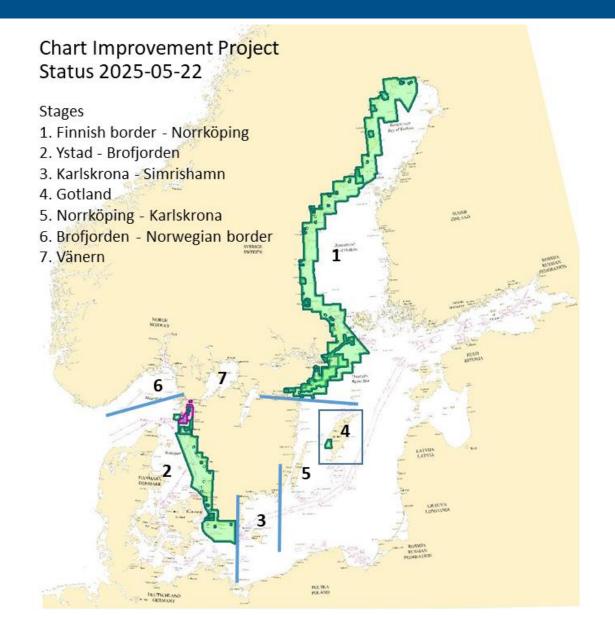
More information: www.sjofartsverket.se/RH2000 and www.smhi.se

www.sjofartsverket.se/RH2000 www.smhi.se

SMHI och Sjöfartsverket. Publ. 15 May 2019

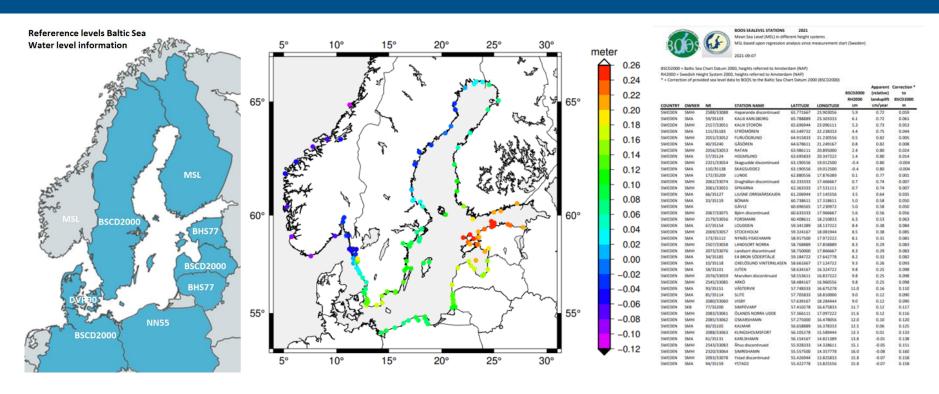


Status transition from MSL to BSCD2000 in nautical charts





Reference levels in the Baltic Sea



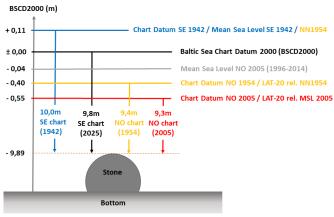
Reference levels used in the Baltic Sea and differences with respect to the Baltic Sea Chart Datum 2000 (BSCD2000). In Sweden and Finland, the old reference levels are equal to Mean Sea Level (MSL) transferred to year 2025 (according to different national conventions). The values from Norway shows the MSL over the period 1996-2014, relative NN2000/BSCD2000. In Estonia, Latvia and Lithuania, the Kronstadt datum was previously used as chart datum. In Poland, the local Polish Height System Amsterdam NN_{55} was used as chart datum. Notice how postglacial rebound reduces the magnitude of the MSL in the Bay of Bothnia. The values are shown in this <u>Table</u>.

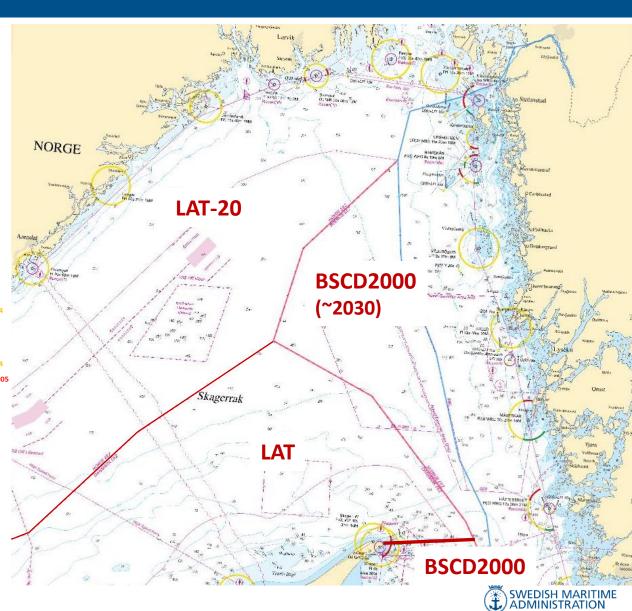


Reference levels in Skagerrak

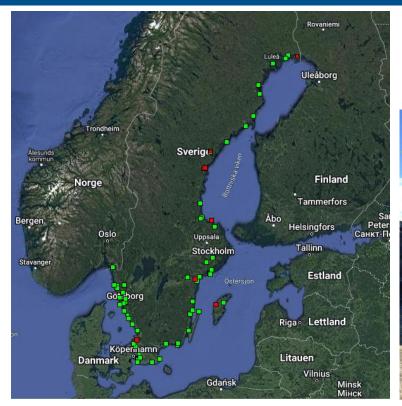
- Norwegian reference datum (LAT-20) ca 50-60 cm below BSCD2000
- Danish LAT ca 30 cm below BSCD2000

Chart datum Skagerrak (Swedish-Norwegian border)





Swedish Sea Level Network



- Class I Upgrade with battery backup
- Class II Upgrade without battery backup
- Class III Unchanged, temporary

- Real-time data relative BSCD2000 from 60 stations
- 1-minute values with 1 cm accuracy
- Real-time and delayed mode quality control





27 stations (23 SMHI, 3 SMA, 1 CTH)

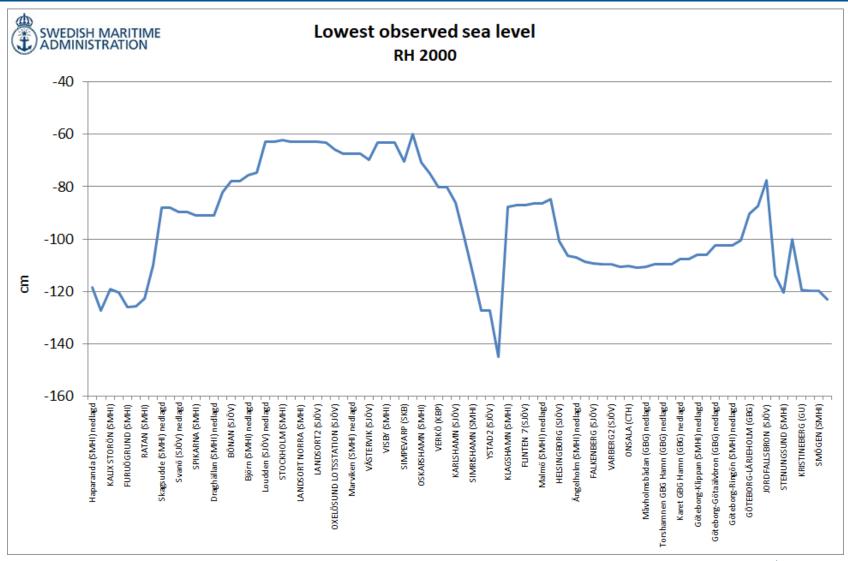
27 stations (23 SMA, 3 GBG, 1 SKB)

6 stations (6 SMA)

Present water level information are shown in Wind- and Water Information (ViVa)

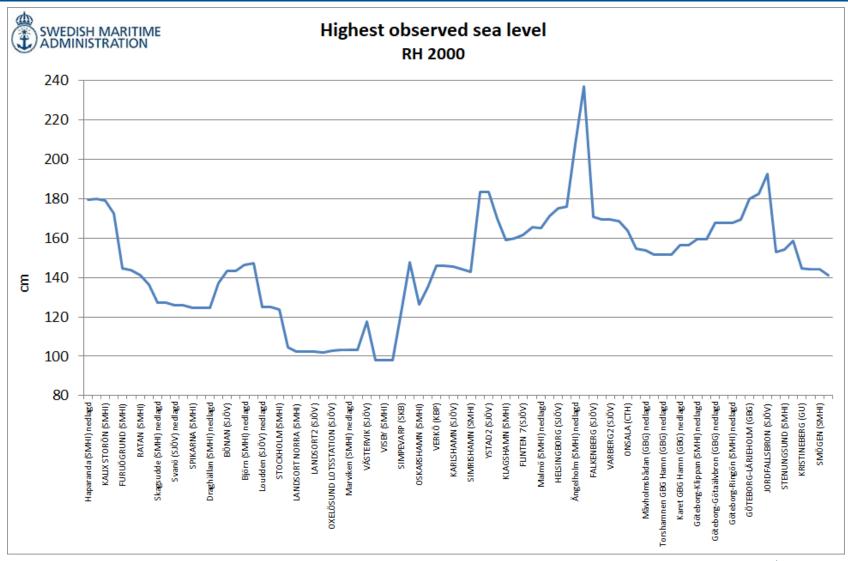


Lowest observed sea level



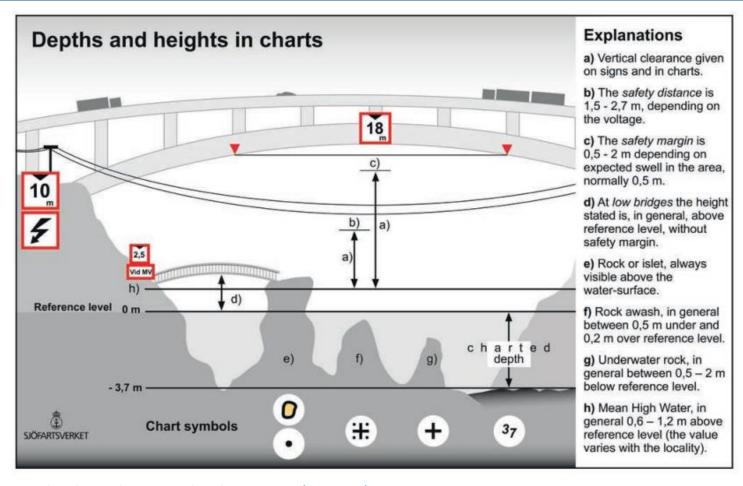


Highest observed sea level





Vertical clearance and mean high water

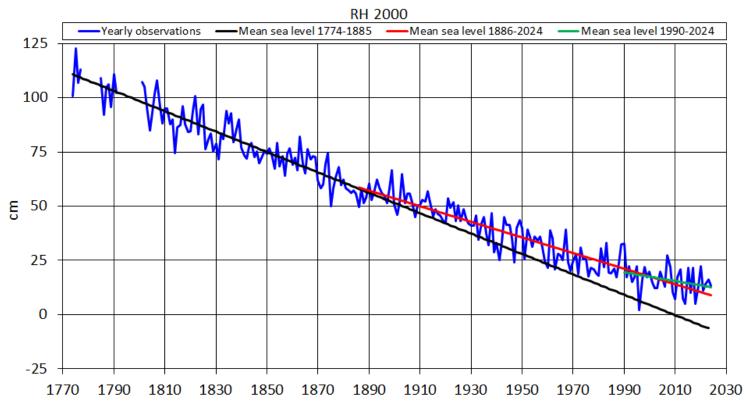


<u>Calculated mean high water (MHW)</u>



Stockholm "World's longest sea level record"

Stockholm 1774 - 2024







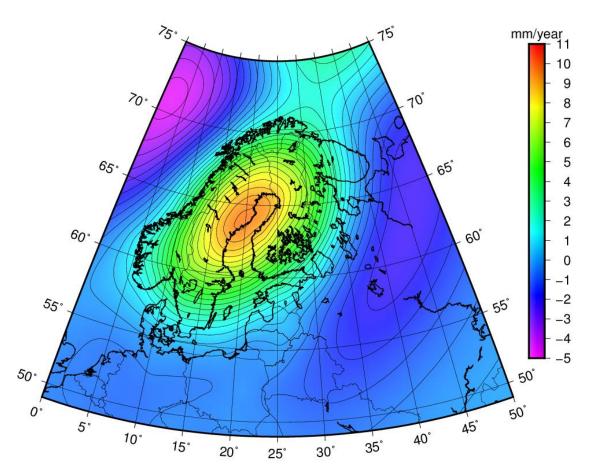








Land-uplift

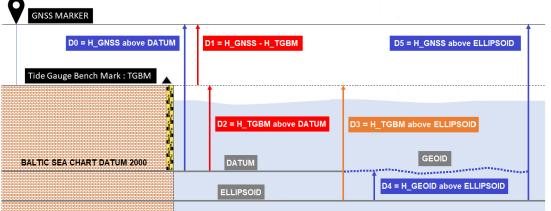


Levelled land-uplift (relative the geoid, NKG2016LU_lev) from the Nordic Geodetic Commission's (NKG) land-uplift model NKG2016LU



Co-location of sea level stations and GNSS

RESPONSIBLE AGENCY		TIDE GAUG	E COORDINA	ATCO-LOCATED INSTRUMENTS			GNSS COORDI	NATES	CO-LOCATED CRITERIA	LEVELING INFORMATION	
RESPONSIBLE FOR GNSS	RESPONSIBLE FOR TG	LON	LAT	TIDE_GAUGE	GNSS_SONEL	GNSS_SWEPOS	LON	LAT	INSTALLED GNSS->TG HORIZONTAL DISTANCE (m)	TGBM_ID	DATUM DEFINITION
SWEPOS-LMV	SMHI	20.895031	63.986056	RATAN	RATO	RATA.0	20.89556580	63.98558831	2006-06-09 58	h	BSCD2000/RH2000
SWEPOS-LMV	SMHI	18.081944	59.324167	STOCKHOLM	<u>omos</u>	MOSE.0	18.07420578	59.31842324	2013-07-11 373	a (LMV 108*2*6503)	BSCD2000/RH2000
SWEPOS-LMV	SMHI	16.960556	58.484167	ARKO	0ARK	ARKO.1	16.96265021	58.48327049	2019-08-26 158	101	BSCD2000/RH2000
SWEPOS-LMV	SMHI	15.589444	56.105278	KUNGSHOLMSFORT	KUN0	KUNG.0	15.58903022	56.10423868	2004-12-31 108	a (LMV 035*2*3704)	BSCD2000/RH2000
SWEPOS-LMV	Chalmers	11.919167	57.391944	ONSALA	ONSA	ONSA.0	11.92551310	57.39529604	1993-07-01 533	827a	BSCD2000/RH2000
SWEPOS-LMV	Chalmers	11.919167	57.391944	ONSALA	ONS1	ONSA.1	11.92453692	57.39533058	2012-01-28 496	827a	BSCD2000/RH2000
SWEPOS-LMV	SMHI	11.217778	58.353611	<u>SMOGEN</u>	SMO0	SMOG.0	11.21792382	58.35346156	2002-08-26 18	g	BSCD2000/RH2000
4											

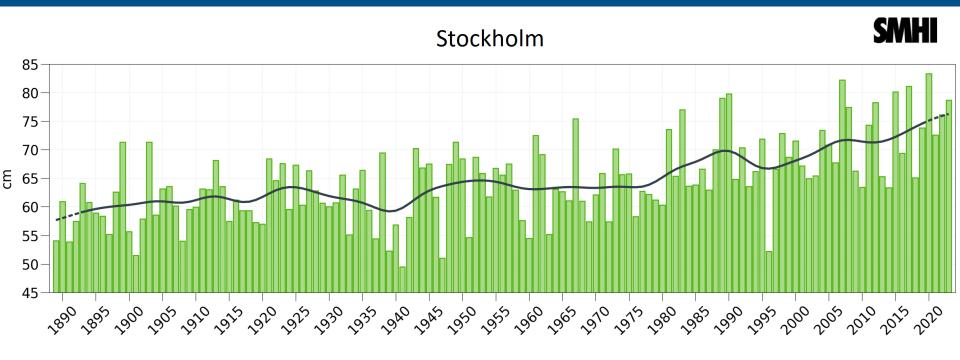




GNSS@TG < 1000.0 m for Sweden 25°E 67°N30' 67°N30 65°N 65°N 62°N30' 62°N30 57°N30' 55°N 55°N 52°N30' 52°N30 10°E



Sea level rise



Observed sea level change in Stockholm since 1889

Sea level corrected for the land-uplift (glacial isostatic adjustment)

The black line shows the gauss-filtered (smoothed) average



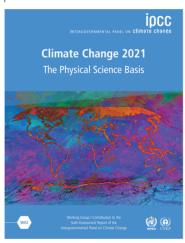
Future sea levels



PM

Thomas Hammarklint Hydrographic Office Published 2019-11-30 Updated 2024-08-16 1(10)

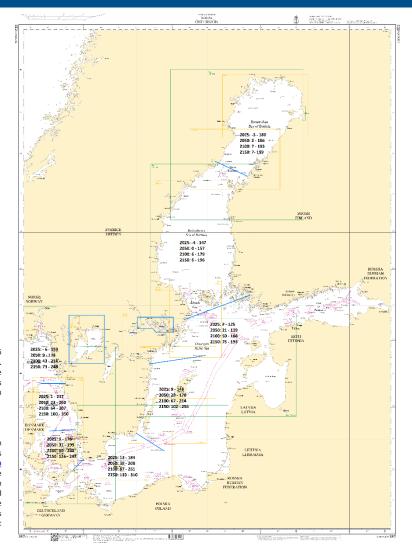
Future sea levels in Sweden



In 2021, the Intergovernmental Panel on Climate Change (IPCC) released the Sixth Assessment Report; AR6 Interim Report 1 - The Physical Science Basis [IPCC, 2021: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change] (AR6 WG1), where they present the latest calculations, including on future sea levels. SMHI has compiled data for probable projections for the years 2050, 2100 and 2150 municipality by municipality on its website (SMHI Future mean sea levels), which has been used in the calculations in this memorandum.

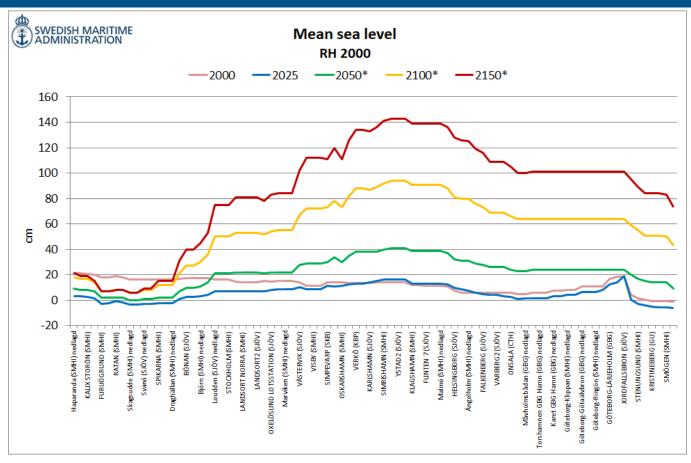
Summary

Calculations of mean sea levels and highest sea levels for the years 2024, 2050, 2100 and 2150 have been conducted for 86 Swedish stations (Figures 5, 6, 7 and Appendix Table 1). The results are based on analysis of historical observational data from 1886 through 2023 (SMHI Open Data Service, Availability Swedish sea levels) and extreme levels calculated at SMHI (SMHI Extreme levels) regional data on global sea level rise from the SSP5-8.5 projection (Figure 4, median values, likely scenario) in the Intergovernmental Panel on Climate Change (IPCC) projections presented in AR6 Interim Report 1 - The Scientific Basis ((AR6 WG1) and total (aggregated) land uplift data compiled by SMHI (SMHI Future mean sea levels), which is based on the Nordic Commission for Geodesy (NKG) land uplift model (NKG2016LU). All results are reported in Sweden's national reference system for depths, heights and water levels; Land Survey Datum 2000 (RH 2000) or Baltic Sea Chart Datum 2000 (BSCD2000).





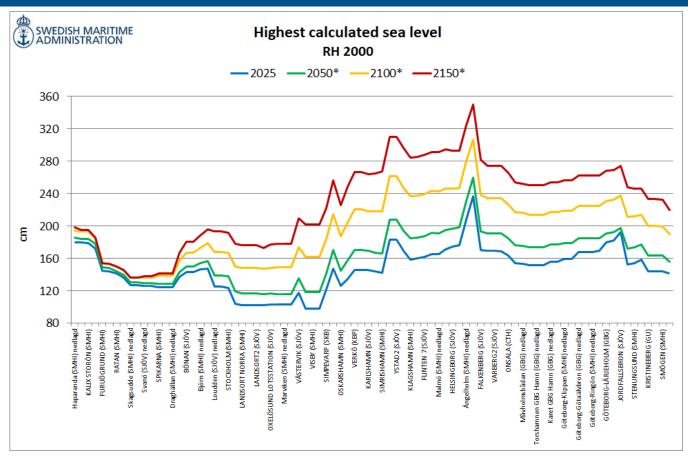
Mean sea level



Calculated mean sea level in RH 2000 (cm) for the years 2000, 2025, 2050*, 2100* and 2150* at 86 Swedish stations, * incl. sea level rise according to IPCC's projection SSP5-8.5 median values (IPCC, AR6 WG1) and total land uplift (SMHI Future mean sea levels)



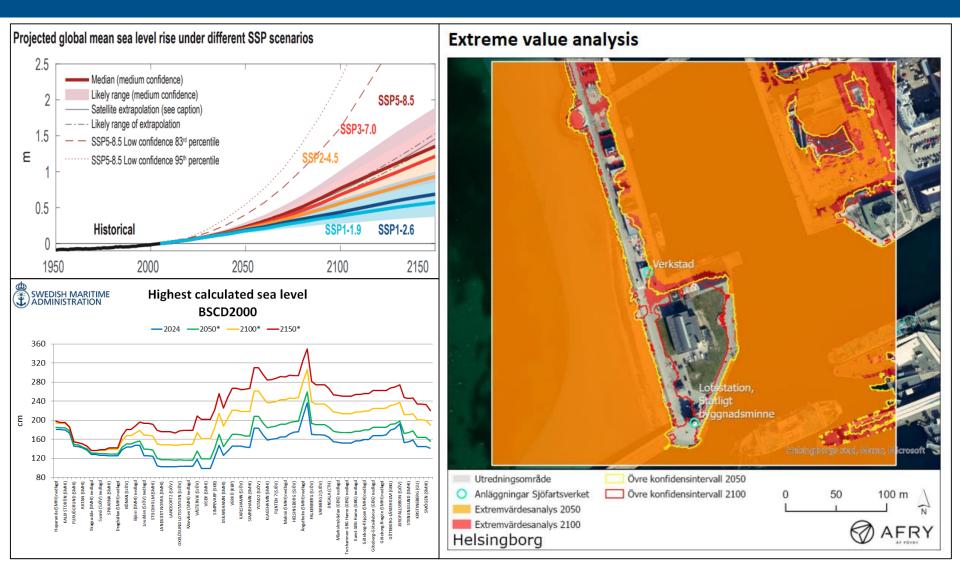
Highest calculated sea level



Highest calculated sea level in RH 2000 (cm) for the years 2025, 2050*, 2100* and 2150*, at 86 Swedish stations * incl. sea level rise according to IPCC's projection SSP5-8.5 median values (IPCC, AR6 WG1) and total land uplift (SMHI Future mean sea levels)

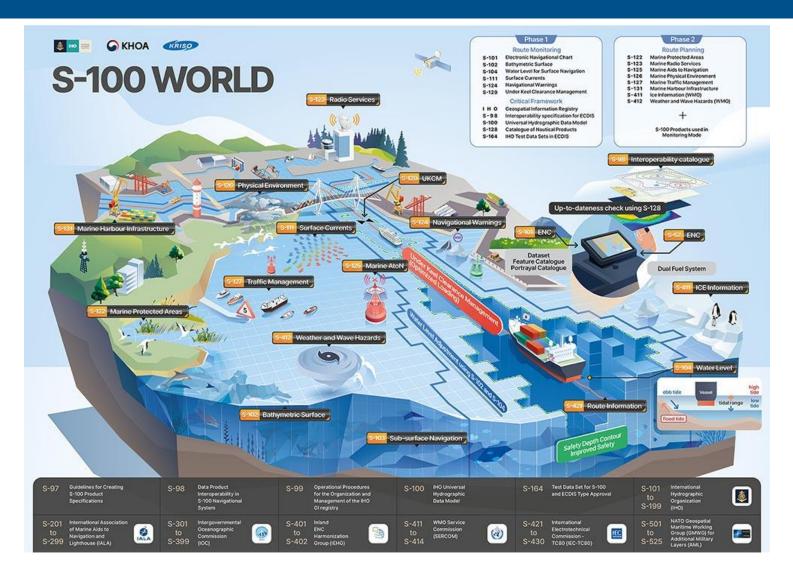


Future sea levels / climate adaptation



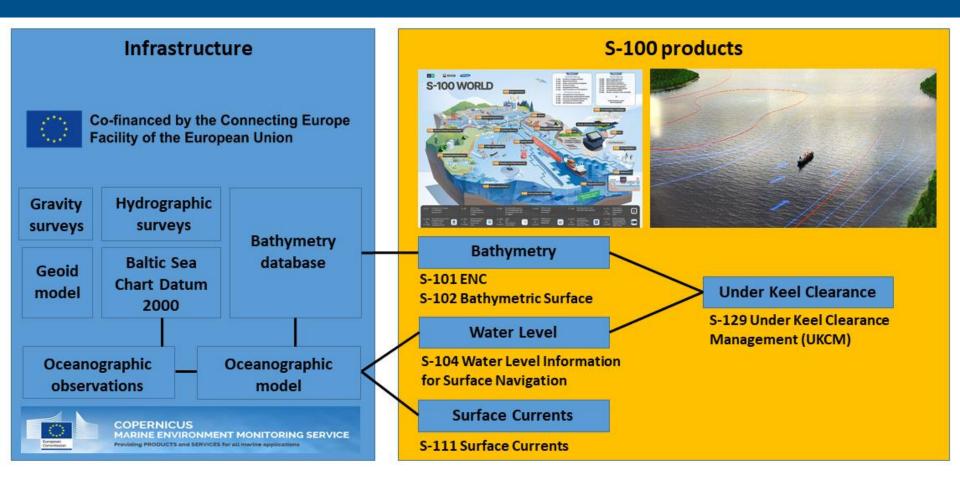


Future Maritime Services S-100





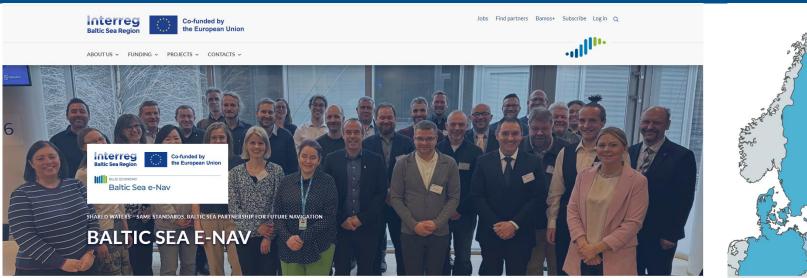
Real Time Hydrographic and Environmental Information Service





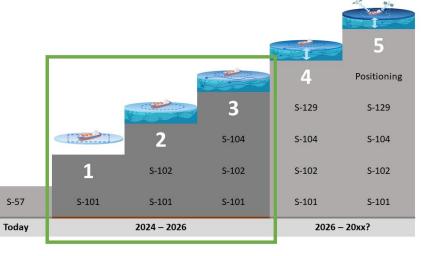
Baltic Sea e-Nav Interreg project 2023-2026





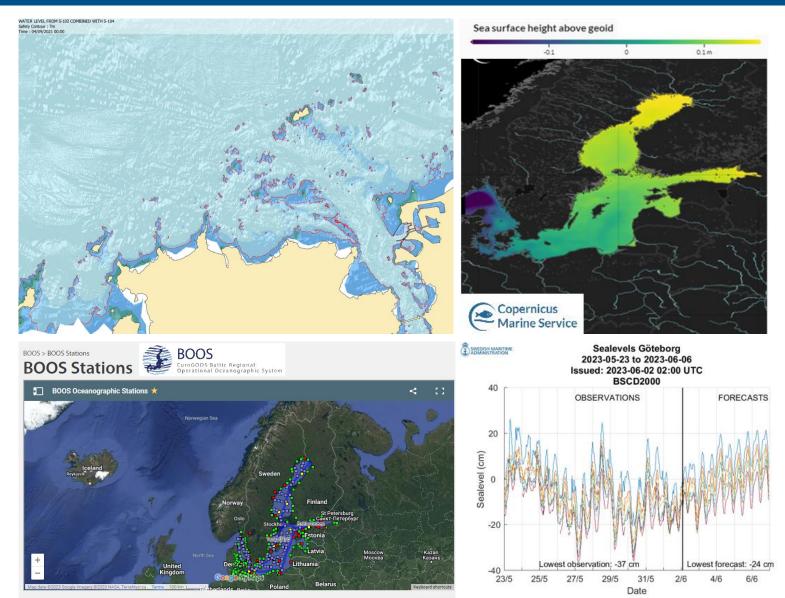


Goal	Period
Develop production capabilities for S-101 ENC, S-102 bathymetry and to some extent S-104 water level	2023-2025
Establish harmonization rules for S-10x- products, under the BSHC umbrella	2024-2026
Test, evaluate and refine the S-10x products	2025
Commercial rollout for S-101 and S-102 in the Baltic Sea. S-104 in parts of FI.	2026





S-104 Water Level





S-111 Surface Currents





Future navigation

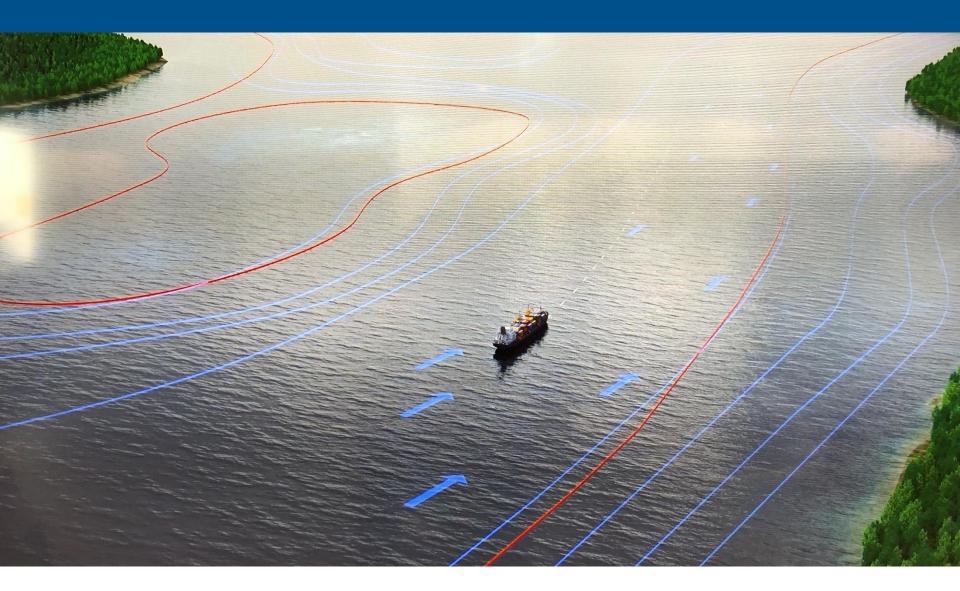




Chart Datum, Water level and Currents Working Group (CDWCWG)

Chart Datum, Water level and Currents Working Group (CDWCWG)

"To implement a common reference system, S-104 and S-111 in the Baltic Sea"



Photo: Chart Datum, Water level and Currents Working Group 2nd meeting, 25-26 March 2025, Tallinn, Estonia

https://www.bshc.pro/working-groups/cdwcwg

Members of CDWCWG:

Denmark Mr Kristian Villadsen Kristmar

Estonia Mrs Gabriela Kotsulim
Finland Mr Jyrki Mononen
Finland Mrs Anni Jokiniemi
Germany Dr Patrick Westfeld
Latvia Mr Bruno Špēls

Lithuania Mr Mindaugas Zakarauskas

Poland Mr Witold Stasiak
Poland Mrs Alicja Olszewska
Russia Mr Leonid Shalnov
Russia Dr Sergey V. Reshetniak

Sweden Mr Thomas Hammarklint (Chair)

Sweden Mr Henrik Tengbert

Observers and Experts:

Estonia Prof. Artu Ellmann Estonia Dr Sander Varbla

Estonia Dr Nicole Camille Delpeche-Ellmann

Finland Mr Jarmo Mäkinen
Finland Dr Jani Särkkä

Finland Dr Mirjam Bilker-Koivula

Finland Dr Timo Saari Germany Dr Xaver Lange Mr Thorben Knoop Germany Germany Dr Gunter Liebsch Germany Dr Joachim Schwabe Mr Armands Murans Latvia Latvia Mr Krists Dzenis Lithuania Mr Emilis Tertelis

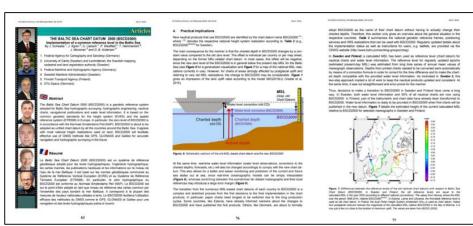
Lithuania Mr Romuald Obuchovski
Norway Mr Aksel Voldsund
Poland Mr Krzysztof Pyrchla
Poland Dr Monika Wilde-Piórko
Poland Dr Malgorzata Szelachowska

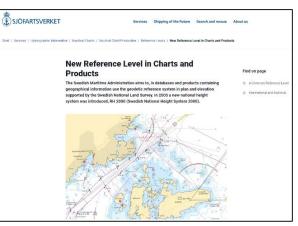
Sweden Dr Jonas Ägren
Sweden Dr Per-Anders Olsson
Sweden Mrs Johanna Linders



More information

Articles, fact-sheets and web pages about Baltic Sea Chart Datum 2000:

















Thanks!



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