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National Report of Germany

Compiled by

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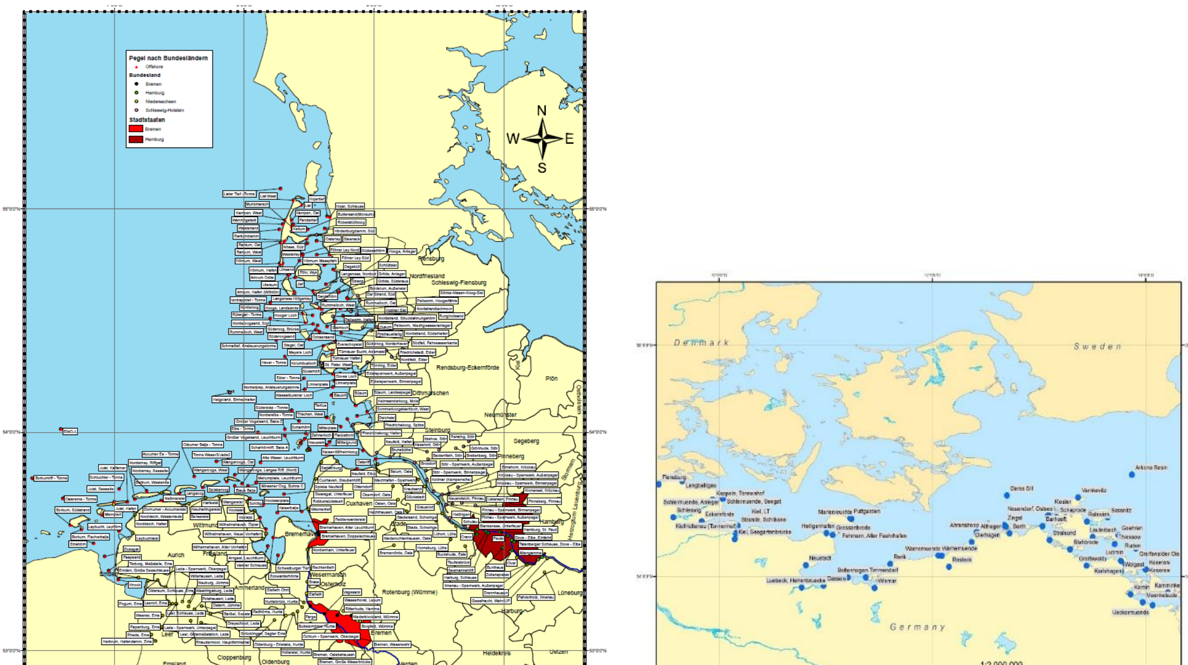
Within the federal system of Germany, responsibilities for waters bodies are divided between national and federal authorities. Two federal agencies are dedicated to hydrological and environmental matters concerning the coastal waters. Both institutions are higher federal authorities.
The *Bundesamt für Seeschifffahrt und Hydrographie* – Federal Maritime and Hydrographic Agency of Germany (BSH) is the public institution for maritime tasks. This concerns tasks such as averting dangers at sea, issuing official nautical charts and surveying tasks in the North Sea and Baltic Sea, maritime spatial planning as well as forecasting tides, water levels and storm surges.
The *Bundesanstalt für Gewässerkunde* – German Federal Institute of Hydrology-(BfG) is responsible for the German waterways in federal ownership. In this position it has a central mediating and integrating function. The BfG advises federal ministries, such as the Federal Ministry for Digital and Transport (BMDV), and the Federal Waterways and Shipping Administration (WSV) in matters regarding the utilisation and management of the German federal waterways. In this context, the WSV operates a network of gauging stations both in coastal and inland waters. Additionally, the federal states of Germany and some harbour authorities operate their own tide gauges.

The coastal tide-gauge network

The tide-gauge network is briefly described below. A list of selected stations can be found in the appendix. There are about 160 tide gauges along the coasts of Germany. About 100 of them are located on tidal rivers such as the Elbe, the Weser, and the Ems. Figure 1 gives an overview of all coastal tide gauges and GNSS (Global Navigation Satellite System) - stations.
The stations Sassnitz, Warnemünde, and Kiel Holtenau, that are located on the Baltic Sea and the tide gauges Hörnum, Helgoland-Binnenhafen, and Borkum-Fischerbalje on the North-Sea are regional extensions to the GLOSS core network. Cuxhaven-Steubenhöft is the German contribution to the GLOSS core network.
A number of tide gauges in the North Sea contribute to the **I**ntergovernmental **C**oordination **G**roup for the **T**sunami **E**arly **W**arning and **M**itigation **S**ystem in the **N**orth-**E**astern **A**tlantic, the Mediterranean and Connected Seas (ICG/NEAMTWS). The BSH is the national Tsunami Warning Focal Point (TWFP) for the NEAMTWS in Germany.



Figures 1a and b: German coastlines with tide gauges along the North Sea and Baltic Sea coast.

All tide gauges transmitting in NRT started off as a float system in a stilling well. The mechanical signal of the float was transformed by an angle decoder into electrical signals for the data transmission. In the course of time the demand for data of high-frequency, high accuracy and high availability has risen constantly.
In December 2007 the ministerial decree WS 14/52.06.01-01 introduced a 'Manual on Modern Gauges' with the subsequent implementation plan.

The Manual on Modern Gauges holds a number of criteria and instructions concerning the need of a gauge, the equipment, data transfer and archiving, inventory and geodesy (e.g. datum point). To fulfil the demands on frequency, accuracy and availability from the technical side, it was decided to equip gauges with two physically independent measuring units per gauge, two independent data lines between the data storage at the gauge and the central servers, high-performance batteries for a secured energy supply, automated system diagnosis, for immediate error report, triggering further action (e.g. repair, unblocking, etc), an enhanced rate of data transfer and automatic switching from the primary system to the secondary system in case of failure of sensors or data lines.
Because of the tide gauges being located in very diverse environments and thus different requirements, sensors or other equipment are not specified. Thus, sensors and other equipment are selected as appropriate by the responsible Federal Waterways and Shipping Department. It is to state that most of the gauges were additionally equipped with radar sensors or pressure sensors.

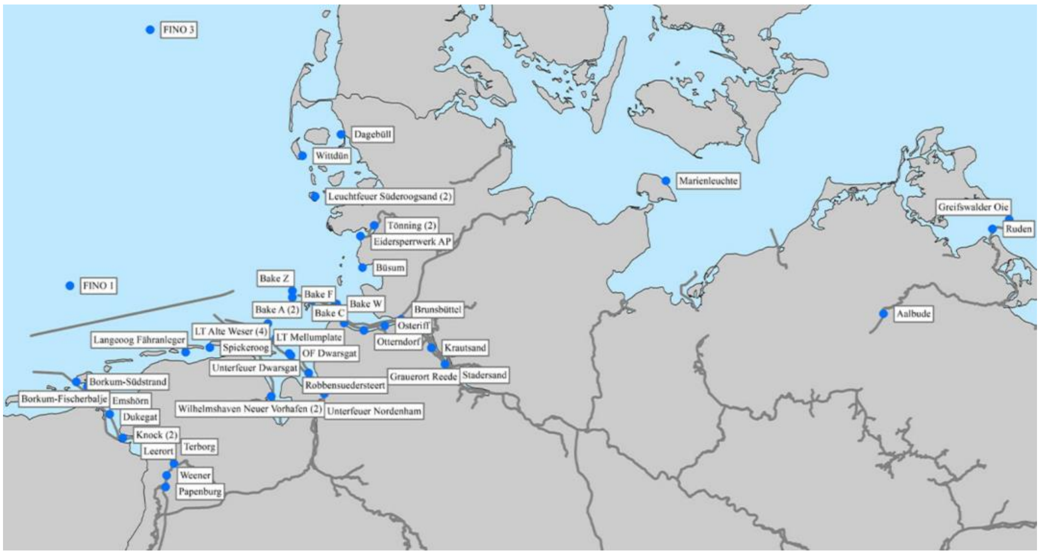


Figure 2: GNSS-Network (Status as of 01/2024), Source BfG

Data delivery to international databases

Data Type	Stations	Institution	Resolution
NRT Raw Data	Borkum Cuxhaven Helgoland Hörnum LT Kiel Warnemünde Sassnitz	Sea Level Station Monitoring Facility VLIZ, Oostende	1 Minute
High Frequency Fast Mode	Cuxhaven	University of Hawaii Sea Level Center UHSLC	Hourly Values Daily Values
High Frequency Delayed Mode Research Quality	Borkum Cuxhaven Helgoland Hörnum Kiel Holtenau Warnemünde Sassnitz	British Oceanographic Data Centre BODC, Liverpool	6-Minutes Hourly Values
High Frequency Research Quality	Cuxhaven	Joint Archive for Sea Level, UHSLC	Hourly Values Daily Values
Research Quality	Borkum Cuxhaven Wittdün Kiel Holtenau Travemünde Wismar Warnemünde Sassnitz Koserow	Permanent Service for Mean Sea Level Liverpool	Monthly Mean Annual Mean

The seven tide gauges, which also serve the national Tsunami Warning Focal Point (TWFP) for the ICG/NEAMTWS are available at the 'IOC Sea level data facility' http://www.ioc-sealevelmonitoring.org/. and are depicted in figure 2.

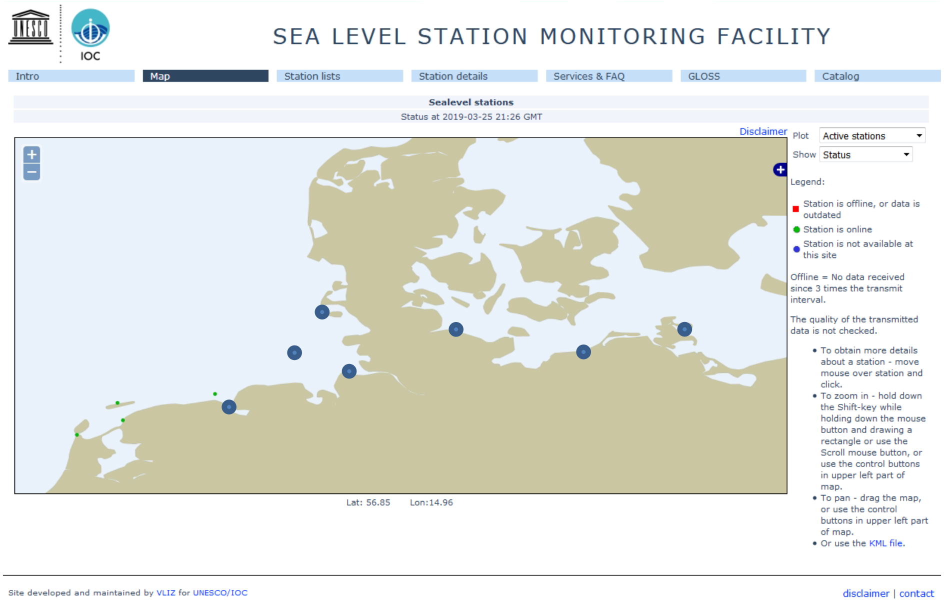


Figure 3: German tide gauges available through the ´IOC Sea level data facility´

Data availability and access

A web portal links the most important websites providing information and data access to relevant hydrological data as well as sea level data. In figure 3, as depicted from left to right, following websites can be accessed and are described below: 1. Hydrological yearbooks, 2. Current flood situation, depicted in figure 4, 3. Access to various free geospatial data provided by the Federal States of Germany, 4. Website providing raw data and meta data for fluvial and coastal stations and 5. Website dedicated to low water levels, leading to websites of regional networks.

Figure 4: Gauge portal at: https://www.pegelportal.de/

1. The website https://dgj.de/ provides access to information on individual gauging stations by map or lists, download of hydrological yearbooks, reports on special events and guidelines. The website is only available in German.

2. The website https://www.hochwasserzentralen.de/ provides mainly high or low water warnings for river and coastal gauges; it also provides access to the German regional tide gauge networks as well as to the gauge networks of neighbouring countries, i.e. Czech Republic or the Netherlands. Recently, flood warnings, including storm surge warnings for the North Sea and the Baltic Sea, severe weather warnings and precipitation radar features were included. The site is now available also in English, French, Dutch, Italian and Russian.

3. The website https://www.pegelportal.de/datendownload/ leads to a bouquet of freely accessible data, among them geospatial and environmental data. No other language than Germany is offered.

4. Raw sea-level data are available at 1-minute intervals for the previous 30 days at: https://www.pegelonline.wsv.de/gast/start , please refer to figures 6 and 7.

The website provides a number of services water level and other hydrological parameters.

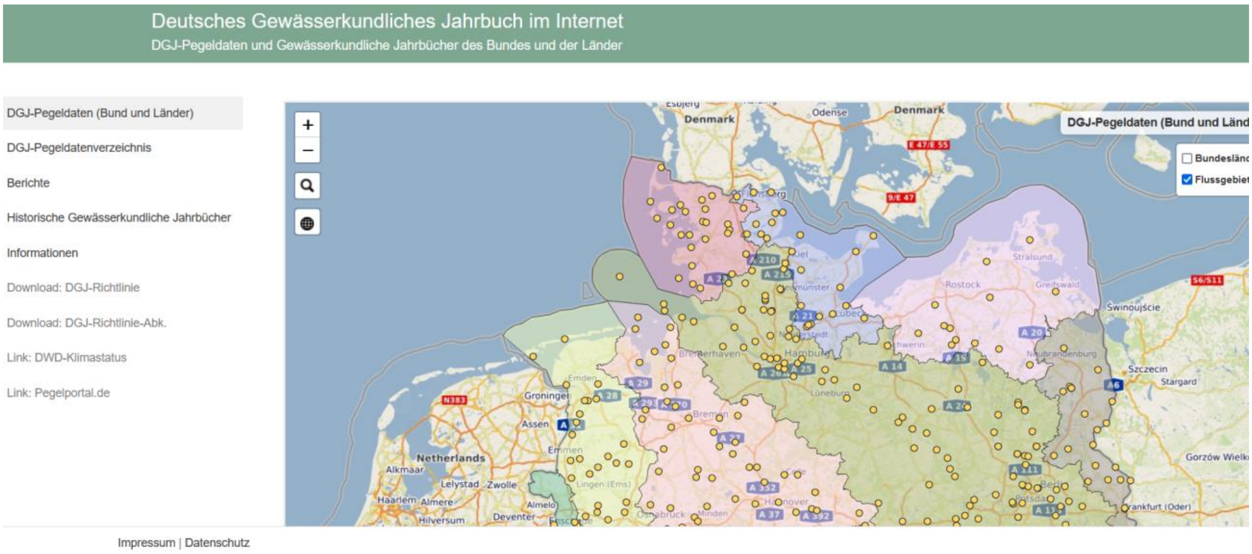


Figure 5: Website on hydrological yearbooks https://dgj.de/

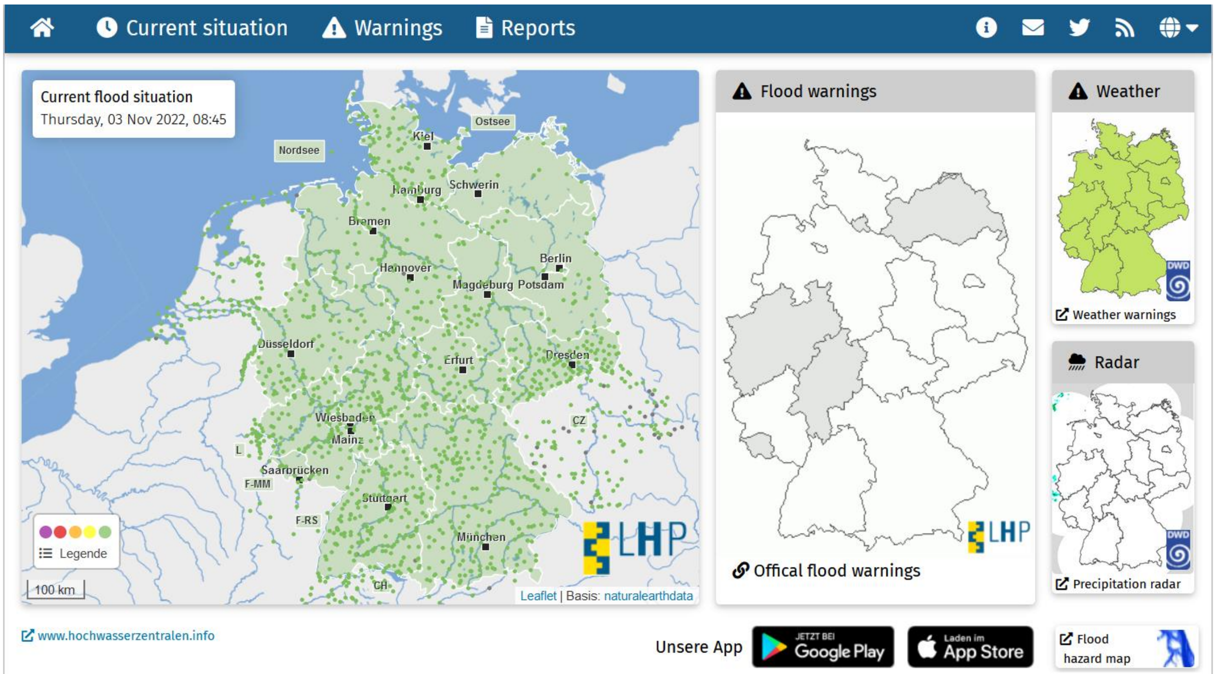


Figure 6: Website ´Hochwasserportal´

Figure 7: Homepage of PegelOnline, https://www.pegelonline.wsv.de/gast/start

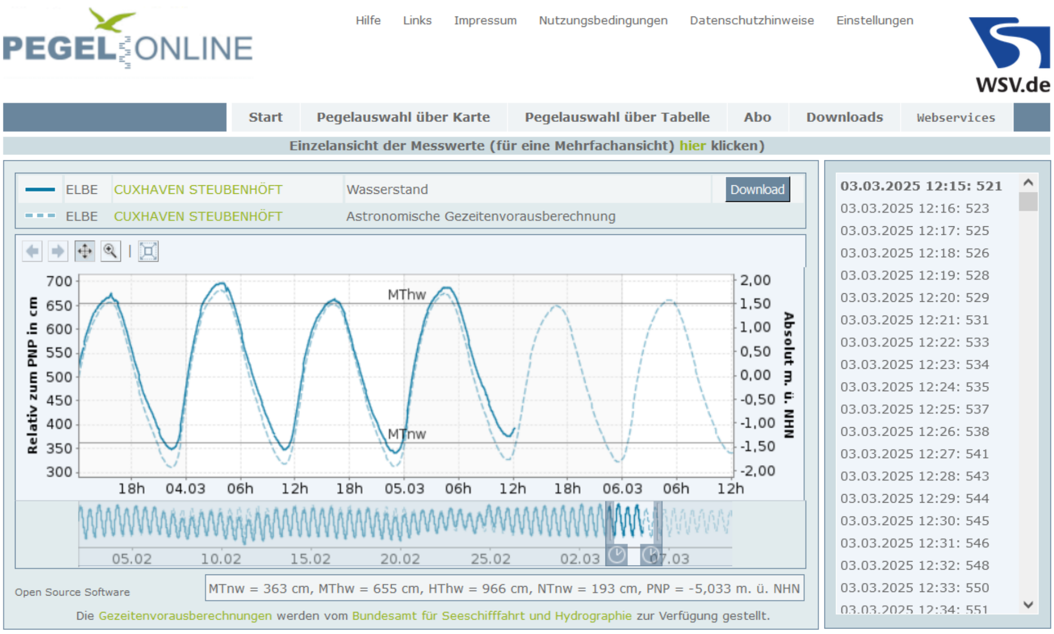


Figure 8: Example of observed data (solid line) in reference to the astronomical tide curve (dashed line) for Cuxhaven. Data for the last 30 days can be downloaded directly from this window.

Raw data are also used by the BSH for the prediction of tides, water levels, storm surges, and currents. The tidal prediction data used in PegelOnline is provided by the BSH.

Tidal predictions (high and low water) by the BSH can be downloaded for the current and, from August each year, for the following year. The data can be accessed through: https://gezeiten.bsh.de/

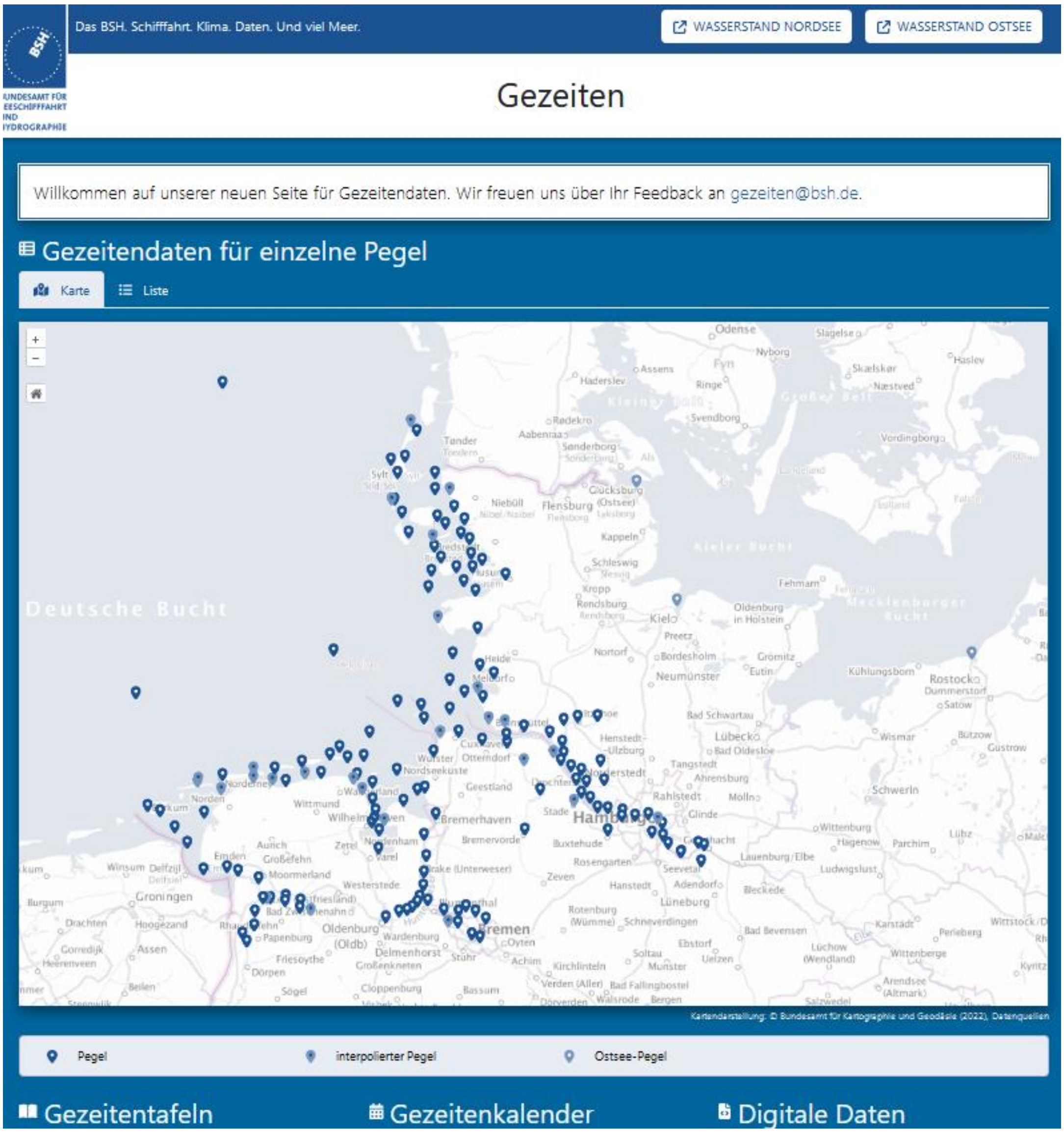


Figure 9: Website for tidal information, products and digital products, launched in February 2025

Regional tide gauge networks

Due to the federal structure of Germany, the coastal federal states Lower Saxony, Schleswig-Holstein and Mecklenburg-Western Pomerania support their own regional gauge networks, including the coastal area as well as rivers and other bodies of water. Some are accessible through the above mentioned PegelOnline website, but PegelOnline does not cover all of the gauges. Websites for the regional networks are only available in German.
Data from Lower Saxony can be viewed and retrieved from https://www.pegelonline.nlwkn.niedersachsen.de/Start (see Figure 9).

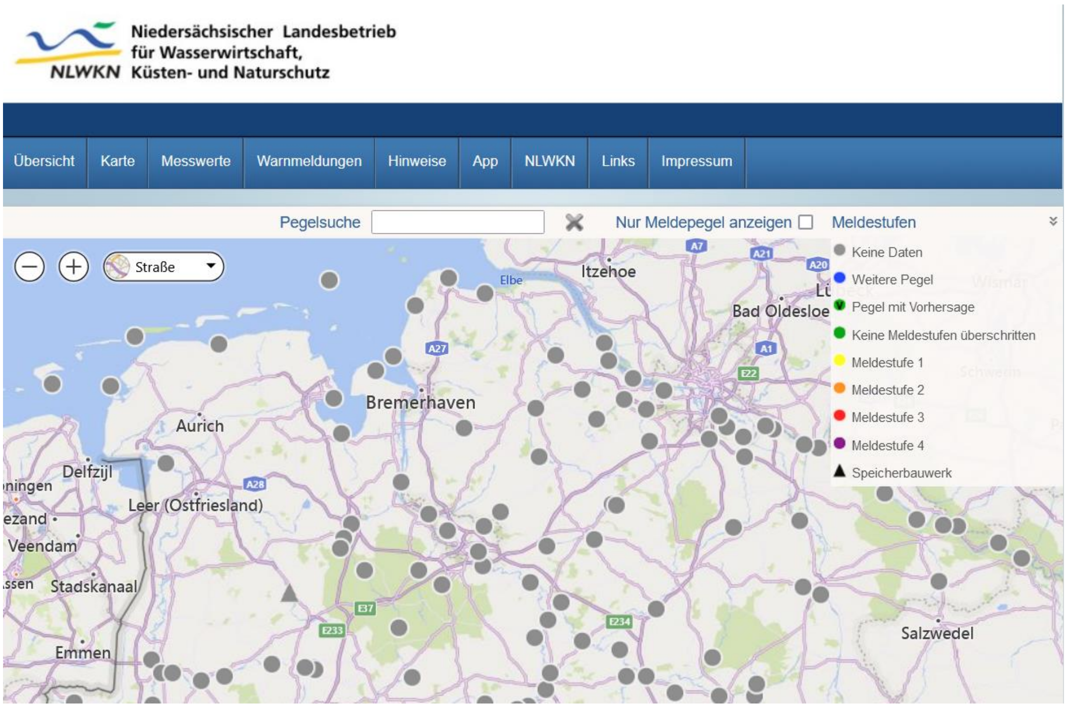


Figure 10: Gauges in Lower Saxony

For Schleswig-Holstein, data can be viewed and retrieved through the website https://umweltportal.schleswig-holstein.de/portal/ (Figure 10).

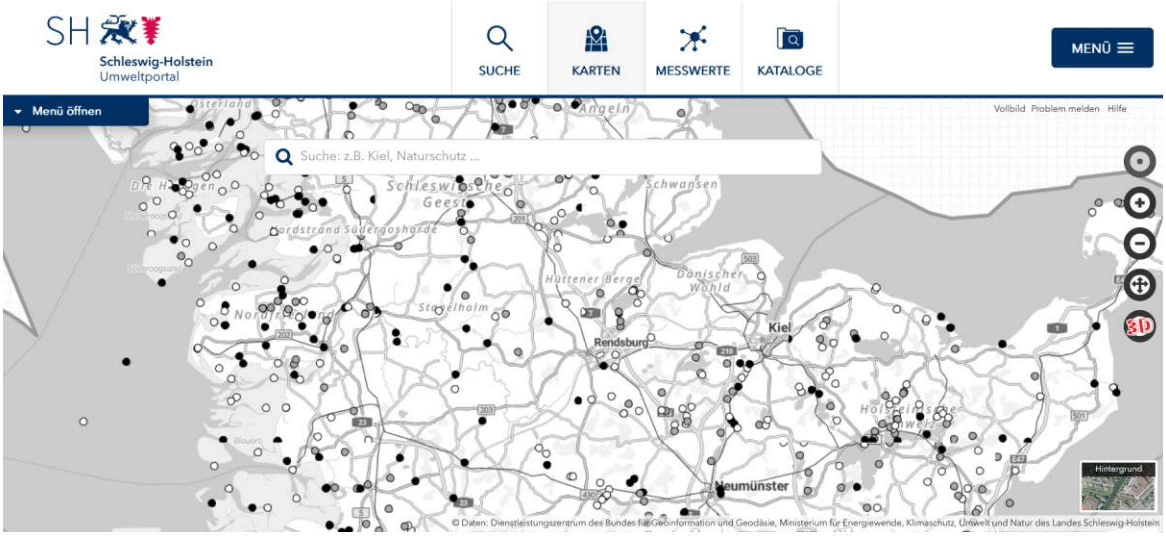


Figure 11: Gauges in Schleswig-Holstein

For data from Mecklenburg-Western Pomerania, refer to the webpage https://pegelportal-mv.de/pegel-mv/pegel_mv.html (Figure 12).

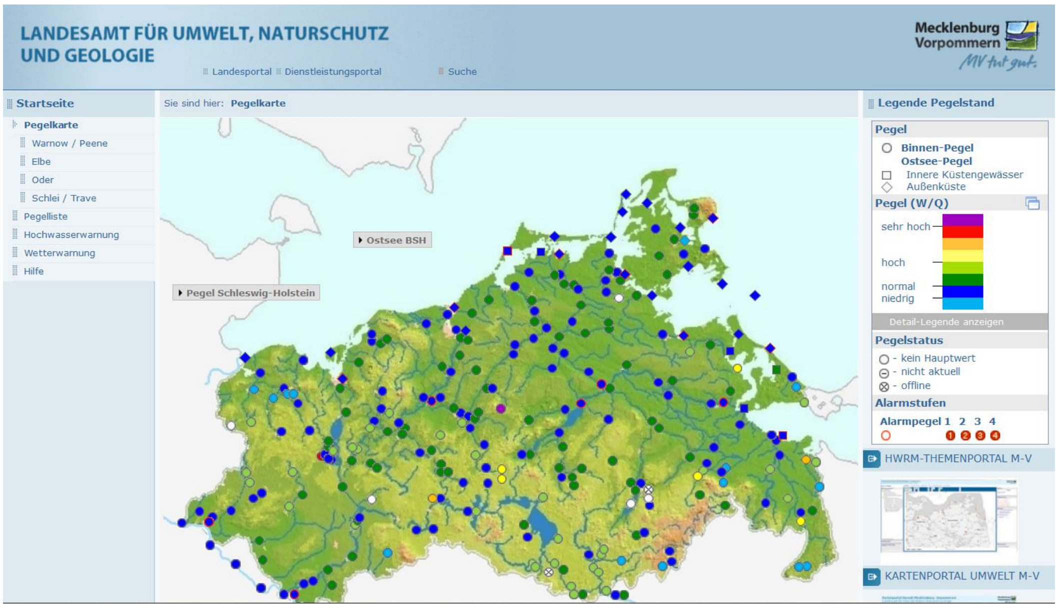


Figure 12: Gauges in Mecklenburg-Western Pomerania

For the federal states of Bremen and Hamburg, although not situated directly on the coast, data from tidaly influenced sea level stations are available.
For Bremen and the tide gauges along the river Weser:
https://umwelt.bremen.de/umwelt/hochwasser-und-kuestenschutz-quantitative-wasserwirtschaft/aktuelle-hochwassersituation-31626 or directly through the PegelOnline website described before.

Figure 13: Website for the current flooding situation in Bremen.

For Hamburg: https://hydroonline.hpanet.de/tide/map

Figure 14: Tide gauges on the river Elbe, Hamburg

Sea level measurements by radar

The BSH-MARNET monitoring network consists of various measuring stations in the German Bight and the western Baltic Sea. They automatically record marine data such as temperature, salinity and surface currents. The three FINO research platforms are equipped with radar sensors, measuring water level as well as 2D wave spectra. The location of the stations given in Figure 15.

Figure 15: Stations of the MARNET network

The research initiative RAVE carries out research and development work on the offshore test field alpha ventus**.** In the scope of RAVE seven radar sensors were installed offshore in the North Sea.
Data can be accessed through the BSH InSitu-Portal (https://login.bsh.de/fachverfahren/) which offers to view and download real-time data of the monitoring network stations after registration. Sea Level data is available in 1 min or 10 min resolution.

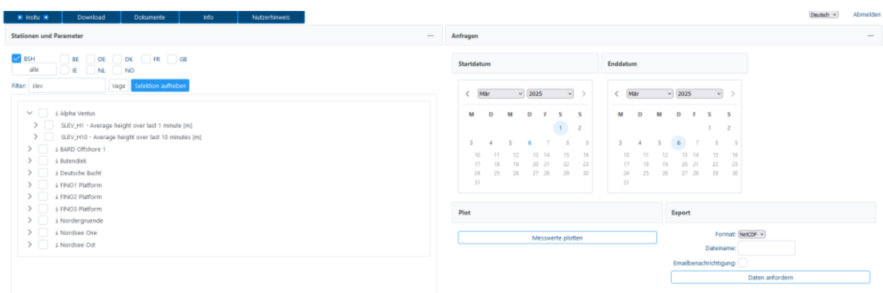


Figure 16: BSH InSitu-Portal

Data Archaeology

Last year, sea level data from ten countries was rediscovered in the BSH archives. The sea level data comes from the first half of the last century, mainly from the 1930s and 1940s. The data are hourly or quarter-hourly measurements, which are listed on index cards, as well as high and low water values and times. It is currently unknown to what extent this data is known, and the sources are not documented.

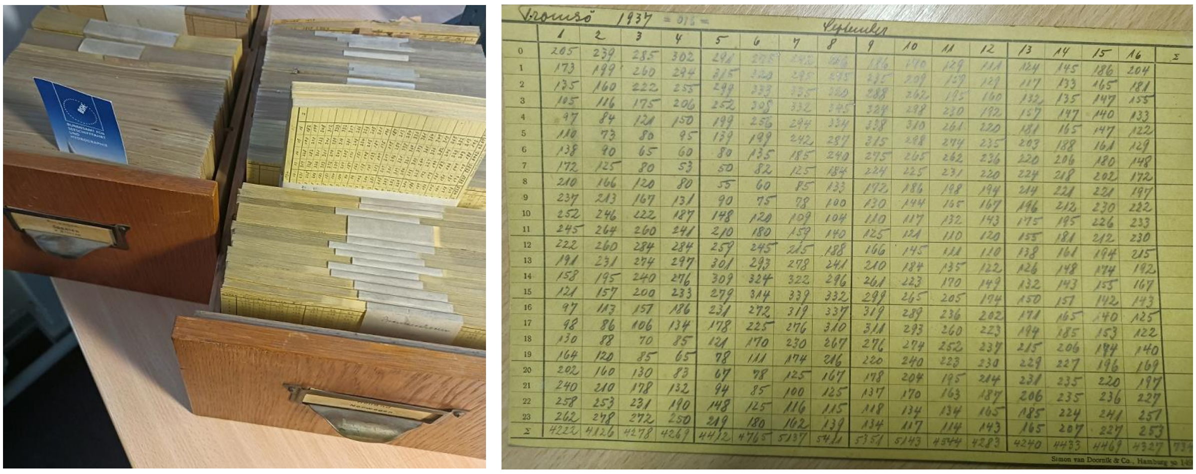


Figure 17 a and b: a) Drawers containing index cards with data lists. b) Example for houly data from, Tromsø, Norway

The current situation of sea level rise on the German coasts

The latest scientific studies on rise of the historical mean sea level (MSL) at the German coasts are based on data sets of sea level observations tide gauge observations covering a period from 1900 to 2015 (Dangendorf et al. 2022; Kelln et al. 2022), thus knowledge of the current development is already 9 years old.
The German DAS-Service "Climate and Water" is a service for climate adaptation, providing standardized information for users from different sectors, among them transportation, water and energy management, constructions, coastal, marine and civil protection. More information can be found at: https://www.das-basisdienst.de. The BfG (Federal Institute for Hydrology), being partner in the DAS-Service, aims to improve the historical database of the observed water levels in the coastal area and operationally calculates the current MSL for several tide gauge tide gauge locations on the German coast. For selected tide gauges, these calculations are forwarded to the Permanent Service of Mean Sea Level. Moreover, the geocentric sea level rise is calculated. For this purpose, information on the land movement from more than 30 permanently operated GNSS stations can be used; these stations are assembled with the tide gauges.
At the same time, the existing database will be further expanded and also independently quality-assured. Quality-assured time series of around 150 years or longer are now available for several gauging locations. The timeseries in the tide gauge location Cuxhaven begins 239 years ago, even if there is a long gap at the beginning of the 19th century, this is one of the

longest time series worldwide. However, not all time series at all tide gauge locations always fulfill the requirements for the long-term observation of the MSL. In the past, the tide gauges were built as harbor gauges, hence for navigation purposes or design tasks, but there were not build to document the rise in MSL caused by climate change.
An example of this are the tide gauges at sluices (Emden, Husum), or tide gauges where sea levels have changed considerably due to local anthropogenic impact. Another example is the Bremerhaven gauge, where the MSL was relatively lowered due to the deepening of the Weser (Ebener et al. 2021). A success of the quality assurance of the last years, for example by checking of the tide gauge zero point is, that the Cuxhaven and Travemünde tide gauges can once again be used in their entirety for sea level rise studies. For reasons of doubt about the quality of this time series, Dangendorf et al. (2022), had removed these gauges completely or partially from their investigations.
Figure 17 shows the development of the MSL since 1786 at the tide gauge locations Cuxhaven and Travemünde. These two locations were selected because they are the longest time series on the German North Sea and Baltic Sea coasts. A comparison with other gauges shows that both gauges are sufficiently accurate to represent the German coast. As expected, the interannual MSL fluctuations in Cuxhaven are around 50 % greater than those in Travemünde. It can also be seen that until the first half of the 20th century, multidecadal variability in the order of around 10 cm is the dominant MSL change over time. Only from then on, the climate change as cause of the rise in sea level prevails. Due to the overlapping multi-decadal fluctuations, a tipping point cannot be found.

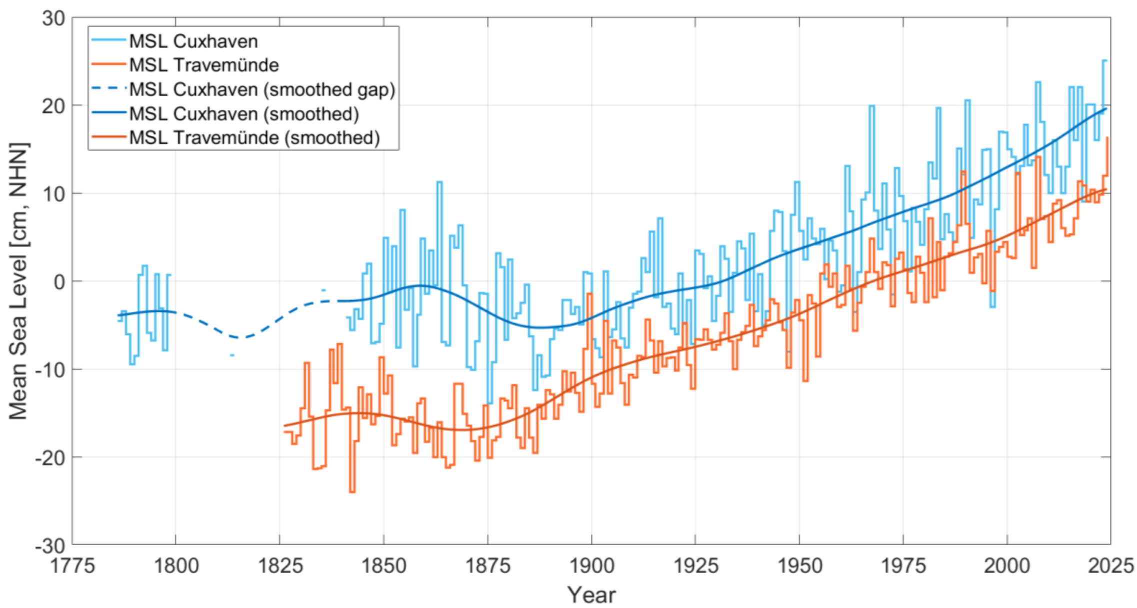


Figure 18: The development of MSL at the Cuxhaven and Travemünde gauging stations since 1786.

Both, the recalculation of some historical sea level zero points and the development of the MSL in recent years indicate a significant acceleration in sea level rise at both tide gauge locations. This is new, previous studies (Hein et al., 2013, Dangendorf et al. 2022) found no or at least no significant acceleration of sea level rise on the German coast. The last two years in particular, 2023 and 2024, stand out. In Cuxhaven, the highest MSL since the beginning of sea

level measurements was observed in 2023; in 2024, the MSL is only slightly lower. The highest MSL was observed at the Travemünde gauge in 2024.
The long-term trend in MSL in Cuxhaven and Travemünde is slightly below the global increase in MSL. The global trend between 1900 and 2018 is about 1.7 mm/a (Dangendorf et al. 2024). In Cuxhaven, an increase of 1.4 mm/a in the relative rise was measured in the same period. If the land subsidence in Cuxhaven of 0.3 mm/a - 0.5 mm/a is considered, a geocentric MSL rise of around 1 mm/a can be assumed over the period. The situation is similar in Travemünde, where a relative rise of 1.7 mm/a was measured. However, it is difficult to determine the land subsidence in Travemünde due to the lack of a permanent GNSS station.
If we look at the current situation since 2015, we can see that the global MSL has risen by more than 4 mm/a (https://www.aviso.altimetry.fr/en/data/products/ocean-indicators-products/mean-sea-level/data-acces.html). In Cuxhaven, the geocentric sea level has risen by around 1.5 mm/a to 2.5 mm/a. However, such a local observation over such a short period of time must be interpreted very cautiously.

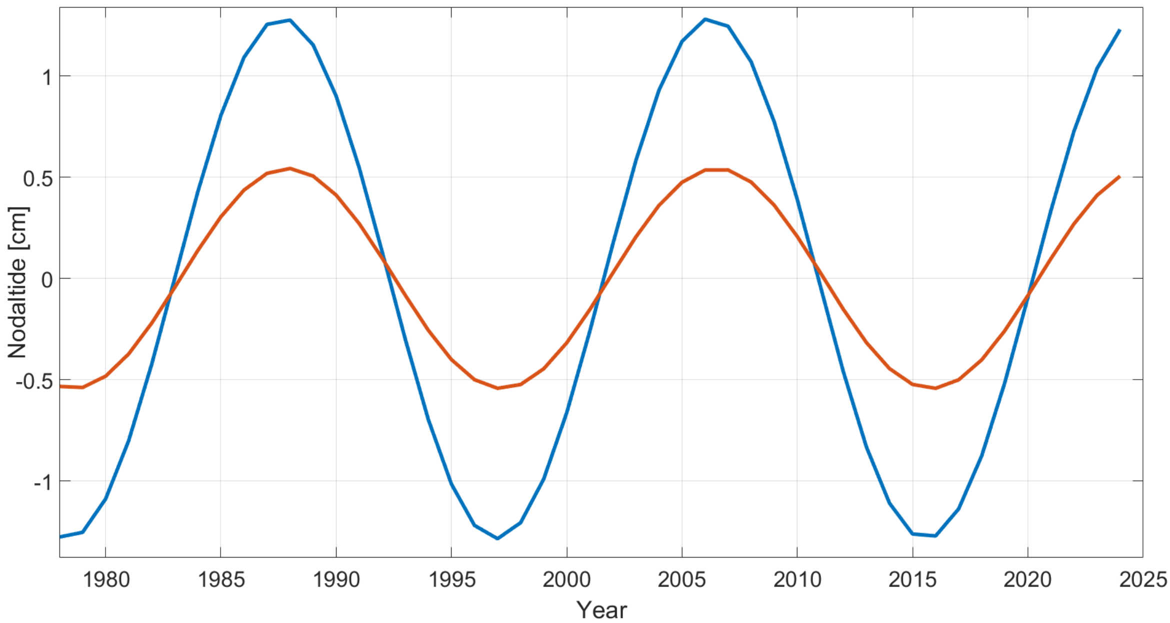


Figure 19: The nodal tide in the MSL at the gauging stations Cuxhaven (blue line) and Travemünde (red line).

One cause of the high MSL is certainly the accelerating global rise in the MSL. Another reason, especially for the development since 2015, can be found in the nodal tide. In 2015, a minimum nodal tide was observed, and in 2024, nine years later, a maximum nodal tide occurred (Figure 18). In Cuxhaven, this means a corresponding MSL increase of just under 3 cm due to the nodal tide, and just over 1 cm in Travemünde. Another reason was certainly the unusually warm sea surface temperatures in the North Atlantic in 2023 (Huang et al., 2024).

References:

Kelln, J., Dangendorf, S., Gräwe, U., Steffen, H., Jensen, J., für Wasserbau, B., & Lantmäteriet, S. (2022). Entwicklung des mittleren Meeresspiegels entlang der südwestlichen Ostseeküste. *Die Küste*, *91*, 181-220.

Dangendorf, S.; Kelln, J.; Arns, A.; Gräwe, U.; Steffen, H.; Jensen, J. (2022): Untersuchungen zur Rekonstruktion des Meeresspiegels und vertikaler Landbewegungen an den deutschen Küsten. In: Die Küste, 91, https://doi.org/10.18171/1.090103, 2022.

Dangendorf, S., Sun, Q., Wahl, T., Thompson, P., Mitrovica, J. X., & Hamlington, B. (2024). Probabilistic reconstruction of sea-level changes and their causes since 1900. *Earth System Science Data Discussions*, *2024*, 1-37.

Ebener, A., Bender, J., Eberle, M., Hein, H., Jensen, J., Mudersbach, C., & Rieken, M. (2021) Entwicklung der Tidekennwerte in den deutschen Nordseeästuaren Ems, Weser und Elbe unter dem Einfluss der Tidedynamik in der Nordsee und den Oberwasserzuflüssen. | DOI: 10.5675/HyWa_2021.5_1.

Huang, B., Yin, X., Carton, J. A., Chen, L., Graham, G., Hogan, P., ... & Zhang, H. M. (2024). Record high sea surface temperatures in 2023. *Geophysical Research Letters*, *51*(14), e2024GL108369.

Hein, H., Mai, S., Barjenbruch, U. (2014): Klimabedingt veränderte Tidekennwerte und Seegangsstatistik in den Küstengewässern. Schlussbericht KLIWAS-Projekt 2.03. KLIWAS-33/2014. DOI: 10.5675/Kliwas_33/2014_2.03.

The text was partially translated with Deepl.

Appendix

List of selected stations

Coordinate Reference System (CRS): DE_ETRS89_Lat- Lon

		Latitude			Longitude			
Station name	**Station-ID**	**Deg**	**Min**	**Sec**	**Deg**	**Min**	**Sec**	**Agency**
North Sea								
Büsum	9510095	54	07	12	08	51	35	WSA Tönning
Helgoland, Binnenhafen	9510070	54	10	33	07	53	29	WSA Tönning
Husum	9530020	54	28	20	09	01	34	WSA Tönning
List	9570070	55	00	60	08	26	31	WSA Tönning
Hörnum	9570050	54	45	29	08	17	51	WSA Tönning
Wittdün	9570010	54	37	55	08	23	07	WSA Tönning
Brunsbüttel	5970055	53	53	15	09	07	33	WSA Cuxhaven
Cuxhaven-Steubenhöft	5990020	53	52	04	08	43	03	WSA Cuxhaven
LT Großer Vogelsand	9510050	53	59	44	08	28	36	WSA Cuxhaven
Zehnerloch	9510010	53	57	20	08	39	30	WSA Cuxhaven
Bake A (Scharhörnriff)	9510063	53	59	04	08	18	55	WSA Cuxhaven
Bake Z (Großer Vogelsand)	9510066	54	00	49	08	18	53	WSA Cuxhaven
Scharhörn	9510060	53	58	12	08	28	05	WSA Cuxhaven
Mittelgrund	9510132	53	56	31	08	38	10	WSA Cuxhaven
Otterndorf	5990010	53	50	03	08	52	08	WSA Cuxhaven
Osteriff	5970095	53	51	19	09	01	46	WSA Cuxhaven
Brokdorf	5970050	53	51	46	09	19	03	WSA Hamburg
Glückstadt	5970035	53	47	04	09	24	39	WSA Hamburg
Bremerhaven, Alter LT	4990010	53	32	42	08	34	11	WSA Bremerhaven
Alte Weser, Leuchtturm	9460040	53	51	48	08	07	44	WSA Bremerhaven
Dwarsgat, Unterfeuer	9460020	53	43	07	08	18	33	WSA Bremerhaven
Robbensüdsteert	9460010	53	38	21	08	26	48	WSA Bremerhaven
Nordenham, Unterfeuer	4970040	53	27	52	08	29	22	WSA Bremerhaven
Rechtenfleth	4970030	53	22	52	08	30	07	WSA Bremerhaven
Wangerooge, Nord	9420030	53	48	23	07	55	45	WSA Wilhelmshaven
Wangerooge, Ost	9420020	53	46	02	07	59	06	WSA Wilhelmshaven
Mellumplate, Leuchtturm	9420010	53	46	18	08	05	33	WSA Wilhelmshaven
Schillig	9430030	53	41	57	08	02	50	WSA Wilhelmshaven
Hooksielplate	9430020	53	40	09	08	08	55	WSA Wilhelmshaven
Voslapp	9430010	53	36	39	08	07	22	WSA Wilhelmshaven
Wilhelmshaven, Ölpier	9430040	53	33	31	08	10	03	WSA Wilhelmshaven
Wangerooge, West	9420040	53	46	35	07	52	05	WSA Wilhelmshaven
Borkum, Fischerbalje	9340020	53	33	27	06	44	58	WSA Emden
Norderney, Riffgat	9360010	53	41	47	07	09	21	WSA Emden
Spiekeroog	9410010	53	44	57	07	41	00	WSA Emden
Langeoog	9390010	53	43	15	07	40	56	WSA Emden
Memmert	9350010	53	37	29	06	54	30	WSA Emden
Borkum, Südstrand	9340030	53	34	37	06	39	46	WSA Emden
Dukegat	3990020	53	26	01	06	55	39	WSA Emden
Emshörn	9340010	53	29	37	06	50	33	WSA Emden
Knock	3990010	53	19	38	07	01	56	WSA Emden

Coordinate Reference System (CRS): DE_ETRS89_Lat- Lon

Station name	Station-ID	Latitude Deg	Latitude Min	Latitude Sec	Longitude Deg	Longitude Min	Longitude Sec	Agency
Baltic Sea								
Flensburg	9610010	54	47	42	09	26	04	WSA Lübeck
Langballig	9610015	54	49	24	09	39	20	WSA Lübeck
Schleimünde Seepegel	9610025	54	40	22	10	02	17	WSA Lübeck
Eckernförde	9610045	54	28	29	09	50	15	WSA Lübeck
Kappeln	9610035	54	39	52	09	56	22	WSA Lübeck
LT Kiel	9610050	54	29	59	10	16	29	WSA Lübeck
Kiel-Holtenau	9610066	54	22	20	10	09	30	WSA Lübeck
Heiligenhafen	9610070	54	22	23	11	00	25	WSA Lübeck
Marienleuchte	9610075	54	29	48	11	14	25	WSA Lübeck
Travemünde	9620085	53	57	29	10	52	25	WSA Lübeck
LT Kalkgrund	9610020	54	49	29	09	53	22	WSA Lübeck
Althagen	9650024	54	22	18	12	25	08	WSA Stralsund
Barhöft	9650040	54	26	04	13	01	56	WSA Stralsund
Barth	9650030	54	22	16	12	43	23	WSA Stralsund
Greifswald Eldena	9650072	54	05	33	13	26	46	WSA Stralsund
Kloster	9670050	54	35	05	13	06	41	WSA Stralsund
Koserow	9690093	54	03	37	14	00	02	WSA Stralsund
Lauterbach	9670063	54	20	25	13	30	08	WSA Stralsund
Neuendorf Hafen	9670046	54	31	28	13	05	37	WSA Stralsund
Ruden	9690077	54	12	15	13	46	19	WSA Stralsund
Sassnitz	9670065	54	30	39	13	38	35	WSA Stralsund
Thiessow	9690077	54	16	50	13	42	35	WSA Stralsund
Warnemünde Tonnenhof	9640002	54	10	11	12	06	12	WSA Stralsund
Greifswalder Oie	9690078	54	14	28	13	54	26	WSA Stralsund
Karlshagen	9690085	54	06	28	13	48	27	WSA Stralsund