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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 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.

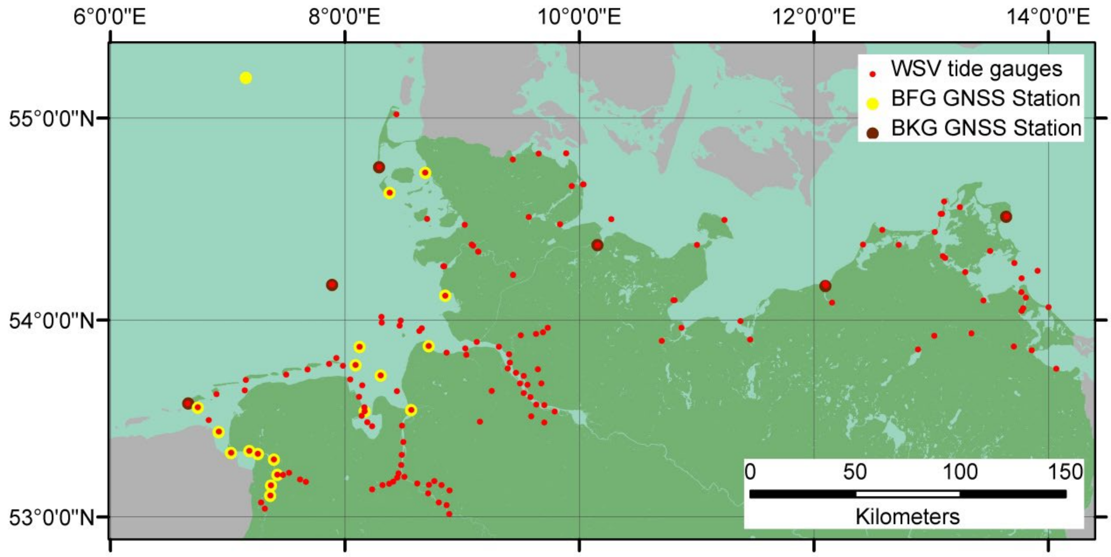

Figure 1: German coastline with tide gauges and GNSS-stations on federal waterways

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.

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.

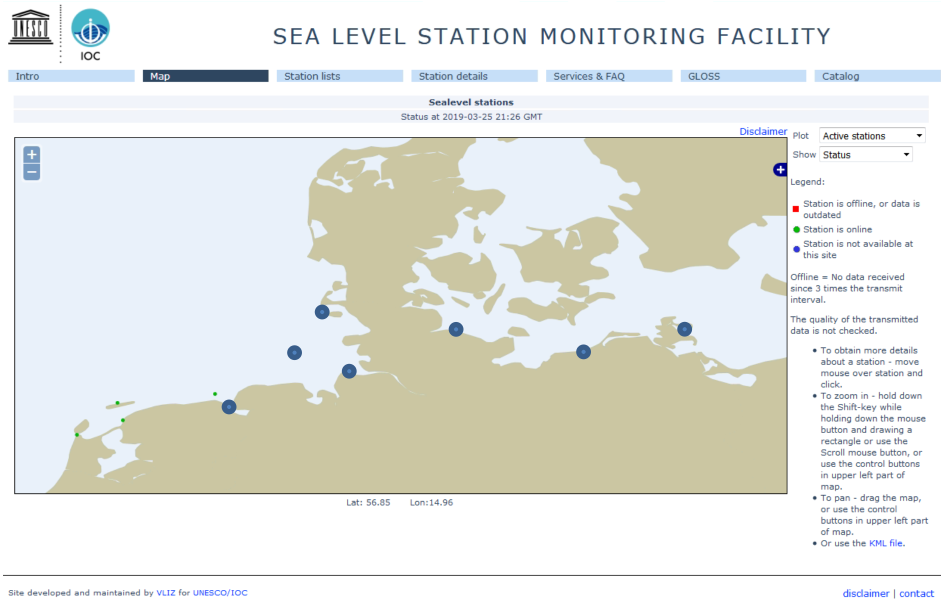

Figure 2: German tide gauges available through the ´IOC Sea level data facility´

Data availability and access

A new portal comprises 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 (access restricted), 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 base data for fluvial and coastal stations and 5. Website for low water level, leading to websites of regional networks.

Figure 3: Gauge portal at: https://www.pegelportal.de/

1. As the access to the website of the hydrologic yearbooks is restricted it is hence not described.

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 in English, French and Dutch.

3. This site 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 5 and 6.

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

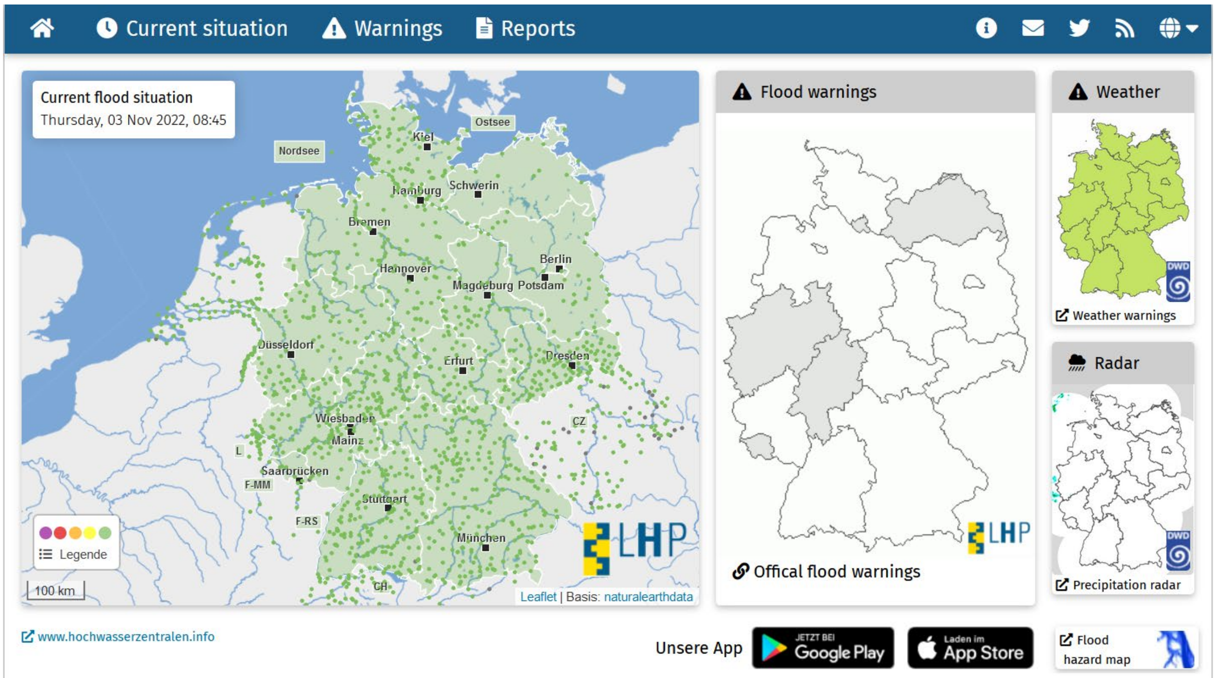

Figure 4: Website ´Hochwasserportal´

Figure 5: Homepage of PegelOnline

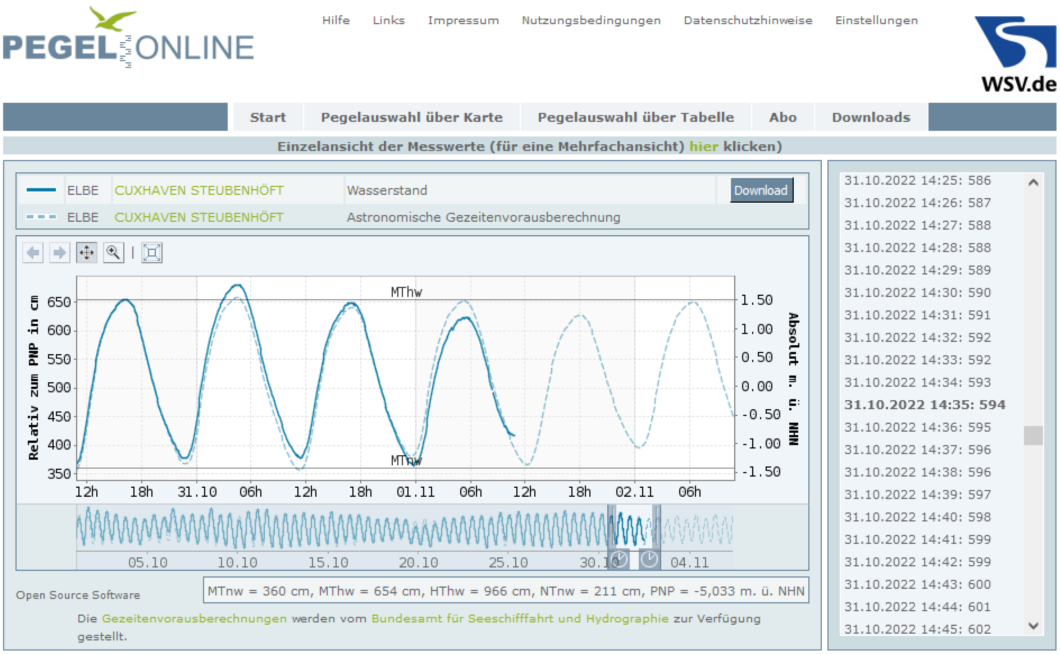

Figure 6: Example of observed data (solid line) in reference to the astronomical tide curve (dashed line) for Cuxhaven. Data for the last 30 days can be downloaded directly from this window.

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.
Since January 2022, tidal predictions (high and low water) by the BSH can be downloaded for the current and, around summer, for the following year and are not subject to any fee unlike before. The data can be accessed through:
https://www.bsh.de/DE/DATEN/Gezeiten/gezeiten_node.html.

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. Webpages 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 7).

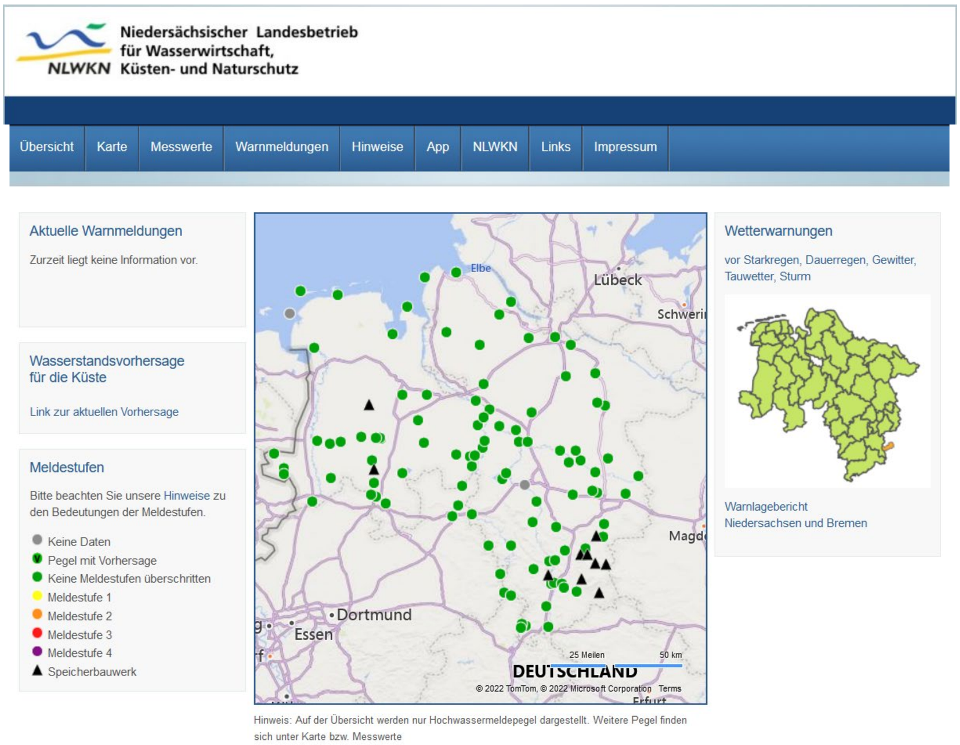

Figure 7: Gauges in Lower Saxony

For Schleswig-Holstein, data can be viewed and retrieved through the website https://www.umweltdaten.landsh.de/public/hsi/index.html (Figure 8).

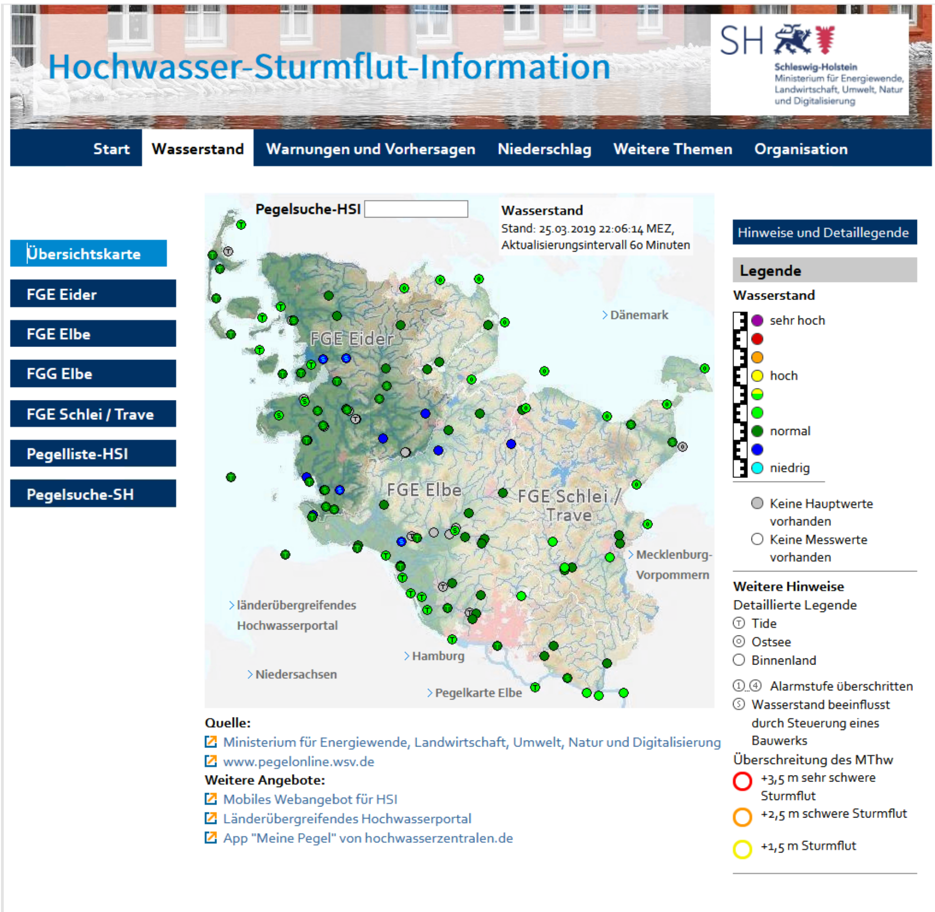

Figure 8: Gauges in Schleswig-Holstein

For data from Mecklenburg-Western Pomerania, refer to the webpage https://pegelportal-mv.de/pegel-mv/pegel_mv.html (Figure 9).

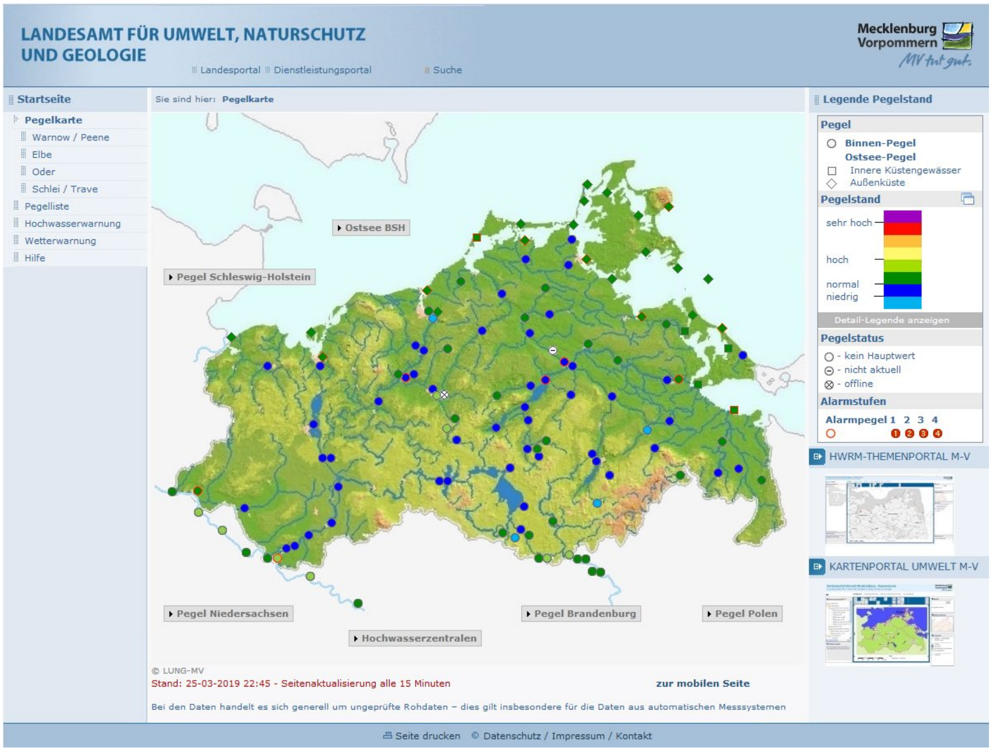

Figure 9: Gauges in Mecklenburg-Western Pomerania

Activities on Historical Sea Levels

Since November 2020, the German DAS--Service "Climate and Water" provides standardized information for users from different sectors, among them transportation, water and energy management, constructions, coastal, marine and civil protection. With the help of this data, the effects of climate change can be evaluated and adaptation strategies may be developed, ensuring a climate-resilient and sustainable infrastructure. 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. The investigation of the sea level development has been one of the original tasks of the, then newly established, BfG, leading to the recognition of coastal subsidence at the German North Sea coast. For this purpose, geodetic levelling and observations from tide gauges were applied. As part of the service, a new GNSS (Global Navigation Satellite System) network has been set up so that today the vertical movements of the tide gauges can be determined. Figure 10 shows a first result of the GNSS Network. The red dots indicate the subsidence of tide gauges, which can be found in almost the entire area of the German Bight. However, this still includes the sinking of the tide gauge itself, which may overlay the coastal subsidence.

Figure 10: Results from the BfG-GNSS Network. Red dots indicate subsidence of the tide gauges.

The knowledge of the past is now being retrieved from the archives and the existing digital historical sea level data is collected from various sources and subjected to renewed quality assurance. When recalculating the data series, the respective history of the tide gauges itself is considered. Historic tide gauges in Germany were usually harbor gauges, not built to monitor long-term sea-level changes, but rather for hydraulic engineering measures, navigational matters and operation of sluices.

In the course of time, the locations of many tide gauges have changed repeatedly. For example, individual gauges have been relocated repeatedly from one harbor basin to another. In addition, a number of construction measures, e.g. for coastal protection, were carried out in the vicinity of the tide gauges. Furthermore, it is essential to know the gauge zero at each point in time. For some areas in Germany, this is possible because securing the gauge datum with a benchmark has been mandatory since 1810 (Deutsch, 2010). If the climate-related development of water levels is to be determined, all of these circumstances have to be taken into consideration. That implies that each gauge has its own history, which needs to be documented best possible.

The tide gauge Cuxhaven, the most important tide gauge in the German Bight, has an interesting history. The tide gauge was built in 1786, on a quay called "Alte Liebe" (engl. “Old Love”). Since the constructor of the tide gauge -Reinhard Woltman- was already into the matter of long-term development of sea levels, it can be assumed that this tide gauge was set up to observe longer time series (Hein et al, 2023). This tide gauge was technically advanced compared to other contemporary tide gauges. For example, it was mounted in a box to be protected against wave impact and for better reading. At the same time, high tide levels were fixed with a special construction so that high tide levels could also be observed at night (Woltman, 1788).

The results of the observations were regularly published by Mr. Woltman between 1786 and 1799. These publications have recently been found in archives and the quality of the sea level observations is being examined. Since the gauge zero of the tide gauge defined the gauge zero of the entire region until the end of the 19th century, it is very likely that the gauge datum of the tide gauge may be traced back to the beginning. The tide gauge was also relocated twice and is now located at the "Steubenhöft" quay. The first results of the investigations of the historical data look promising, indicating that soon the historical development of the sea level can be traced, albeit with gaps, for more than 236 years.

The new datasets and additional information will be published on a new website (https://ws-klimaportal.bafg.de). Figure 11 shows an example from the website. The blue curve shows the observed curve of the tidal high water averaged over 19 years. The green dots indicate years for which there are no direct observations. The blue-grey band in the figure shows the uncertainty of the level observations, which is mainly determined by interannual variability. The historical data was validated against different tide gauges. Water levels are given relative to the coast. Therefore, part of the increase can be explained by land subsidence.

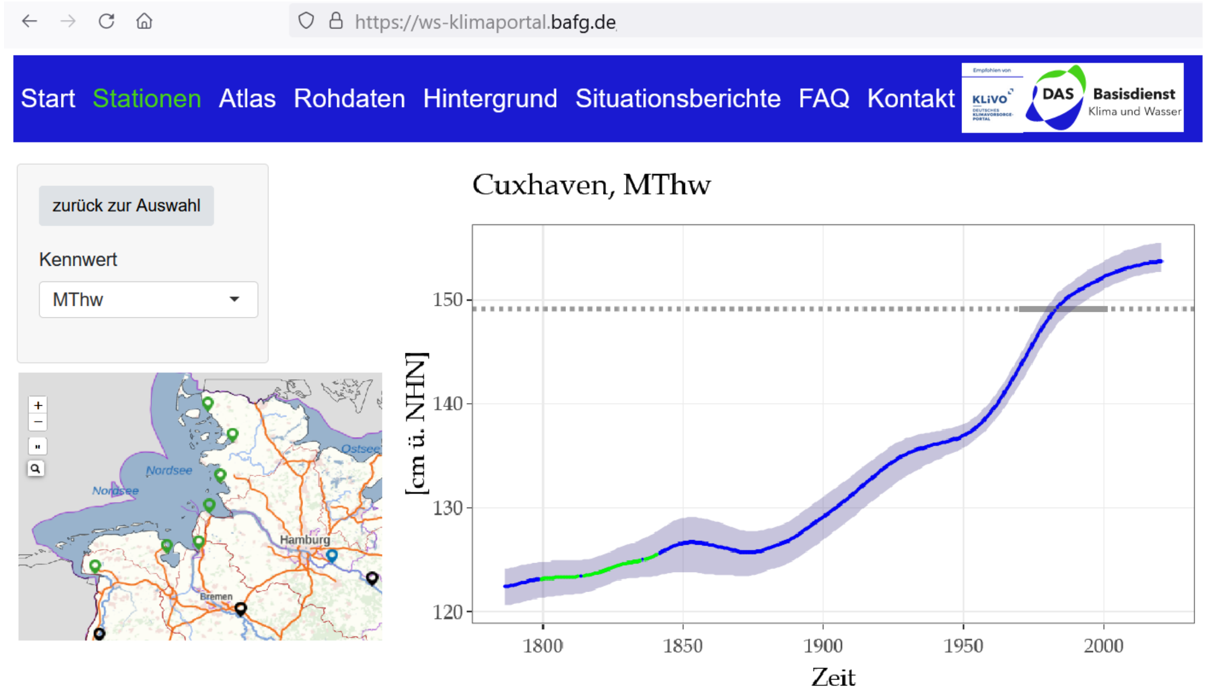

Figure 11: 19-yearly mean tidal high water in Cuxhaven since 1786, as shown in the WS-Portal.

References:

Deutsch, M. (2010). Zur Geschichte des preußischen Pegelwesens im 19. Jahrhundert (Remarks on the history of the Prussian waterlevel gauging system in the 19th century). *Hydrologie und Wasserbewirtschaftung*, *200*, 65-74.

Hein, H., Helmke, P., Scheufen, T. (2023). Woltman, die „Alte Liebe“ und der Meeresspiegel. *In prep.*

Woltman, R. (1788). Resultate aus zweitjährigen Beobachtungen der Fluth und Ebbe zu Cuxhaven. Hannoverisches Magazin, 26, 1788.

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

		Latitude			Longitude			
Station name	**Station-ID**	**Deg**	**Min**	**Sec**	**Deg**	**Min**	**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