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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 maritime partner to shipping and a supporter of environmental conservation efforts and maritime uses. The BSH offers a wide range of maritime services such as: prediction of tides, water level forecast and storm surge warning service, monitoring of the sea, nautical information systems, and maritime spatial planning in the German Exclusive Economic Zone. 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 of Transport and Digital Infrastructure (BMVI), 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. Additionally, 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.

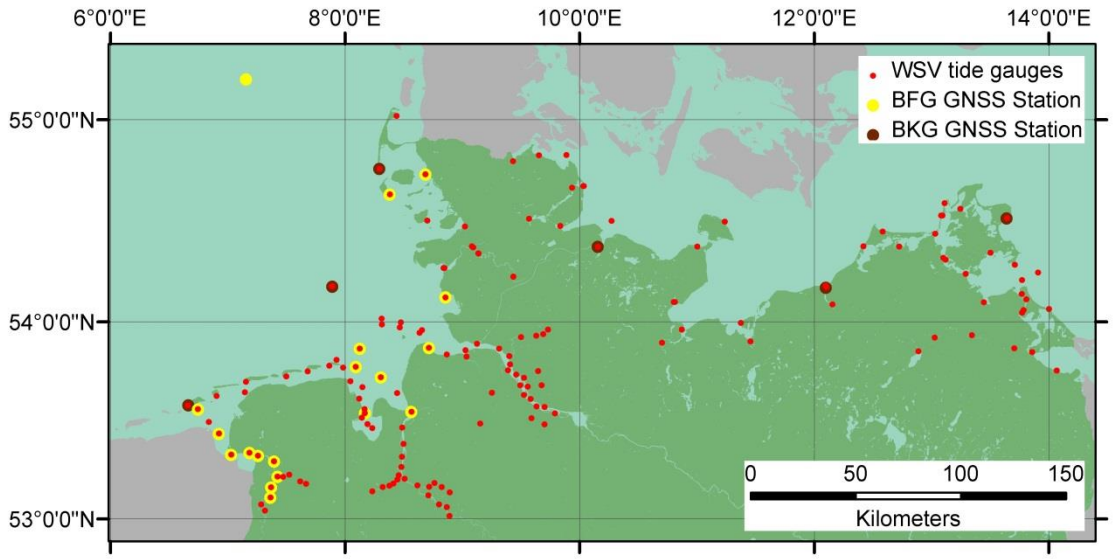

Figure 1: German coastline with tide gauges and GNSS-stations on federal waterways

All tide gauges transmitting in NRT consisted of 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 fulfill the demands on frequency, accuracy and availability from the technical side, it was to 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 were not prescribed. Thus, sensors and other equipment were chosen by the responsible Federal Waterways and Shipping Department as appropriate. It is to state that most of the gauges were additionally equipped with radar sensors or pressure sensors.

Data availability and access

Raw sea-level data are available at 1-minute intervals for the previous 31 days at: https://www.pegelonline.wsv.de/gast/start
The website provides a number of services water level and other hydrological parameters.

Figure 2: Homepage of PegelOnline

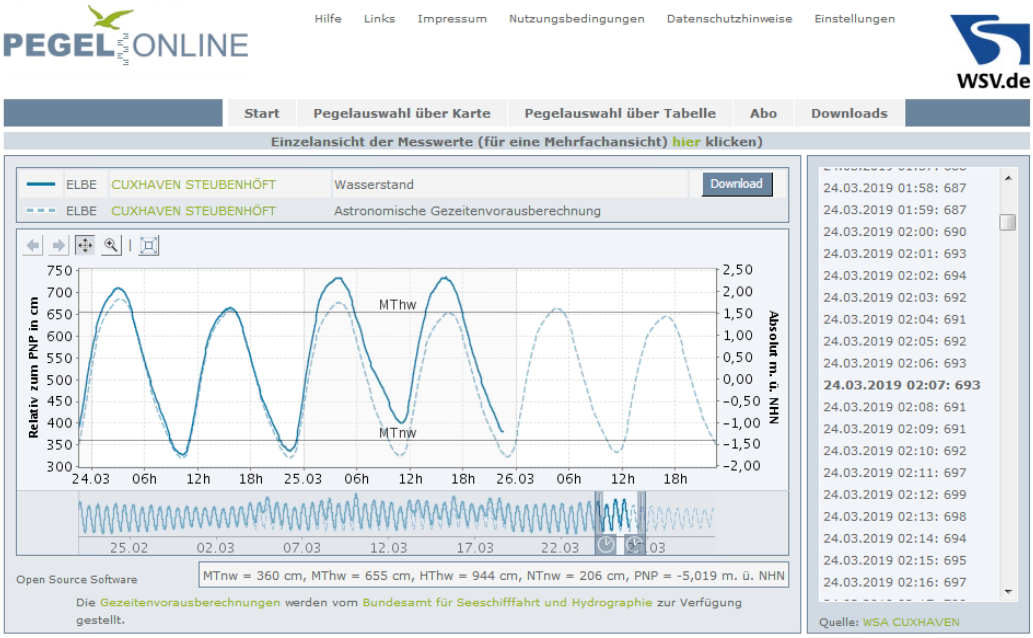

Figure 3: Example of observed data (solid line) in reference to the astronomical tide curve (dashed line) for Cuxhaven. Data for the last 31 days can be directly downloaded from this window.

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 prediction (high and low water) for the following seven days and can be accessed through: https://www.bsh.de/DE/DATEN/Gezeiten/gezeiten_node.html

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 4.

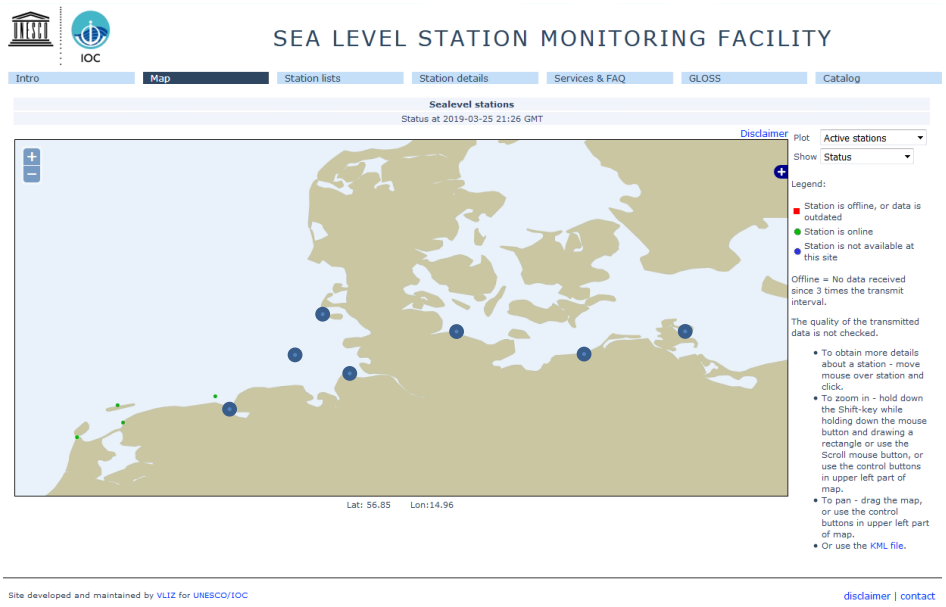

Figure 4: German tide gauges available through the ´IOC Sea level data facility´

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 5).

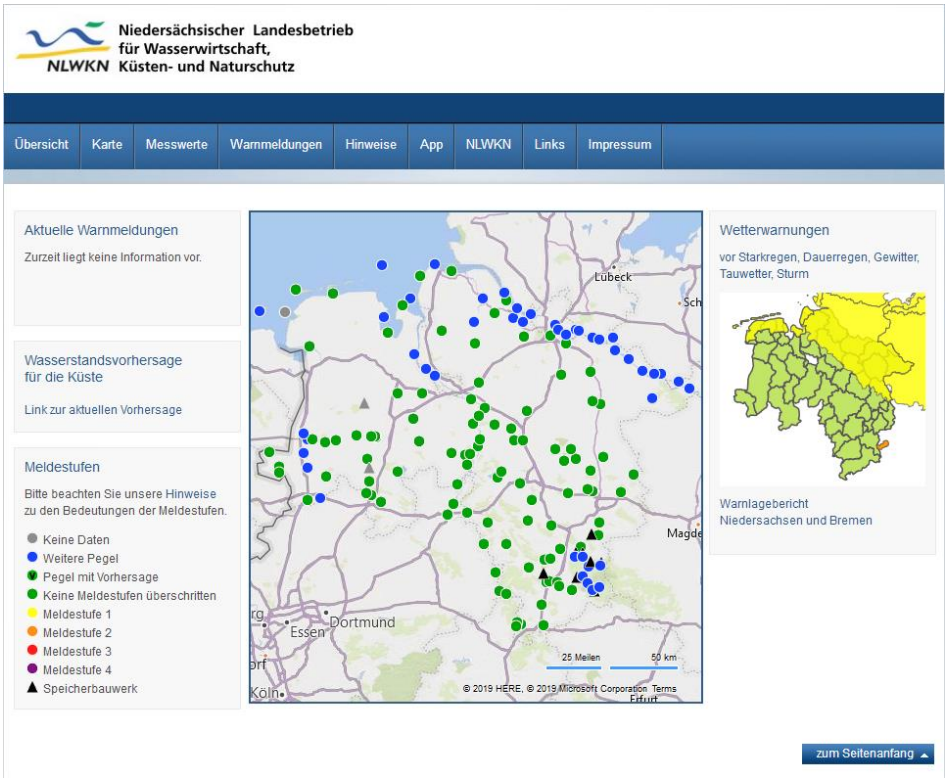

Figure 5: Gauges in Lower Saxony

For Schleswig-Holstein data can be viewed and retrieved through the website https://www.umweltdaten.landsh.de/public/hsi/index.html (Figure 6).

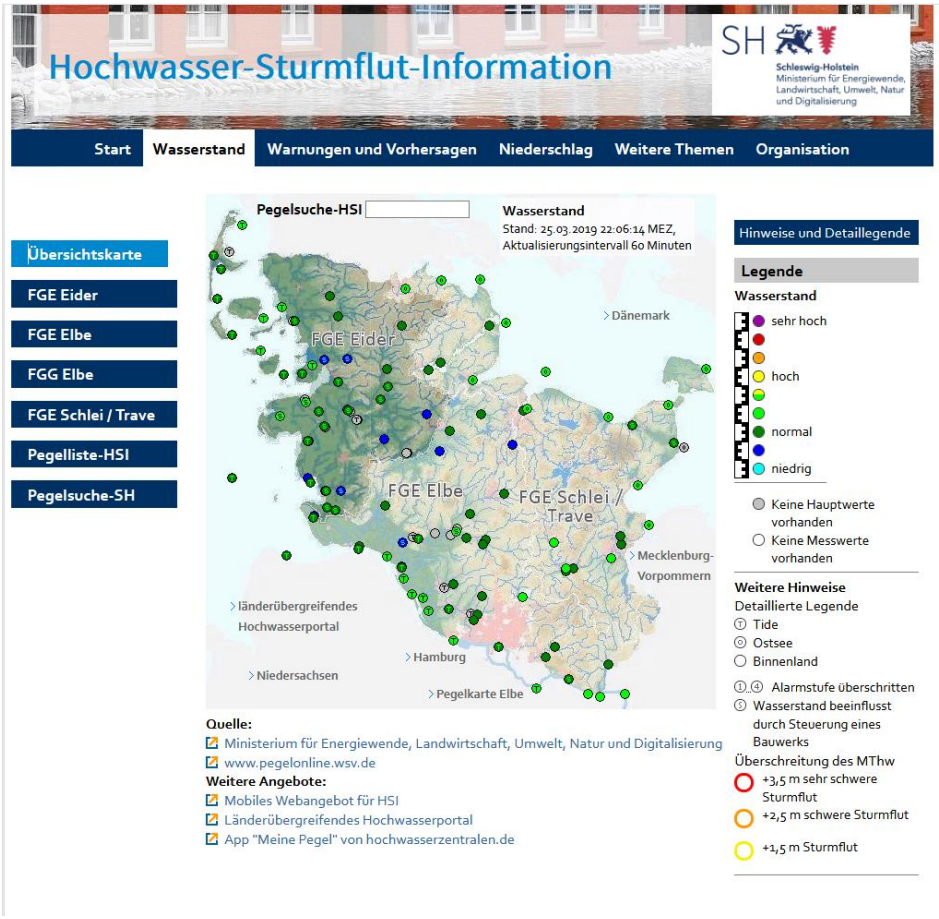

Figure 6: Gauges in Schleswig-Holstein

For data from Mecklenburg-Western Pomerania refer to the webpage https://pegelportal-mv.de/pegel-mv/pegel_mv.html (Figure 7).

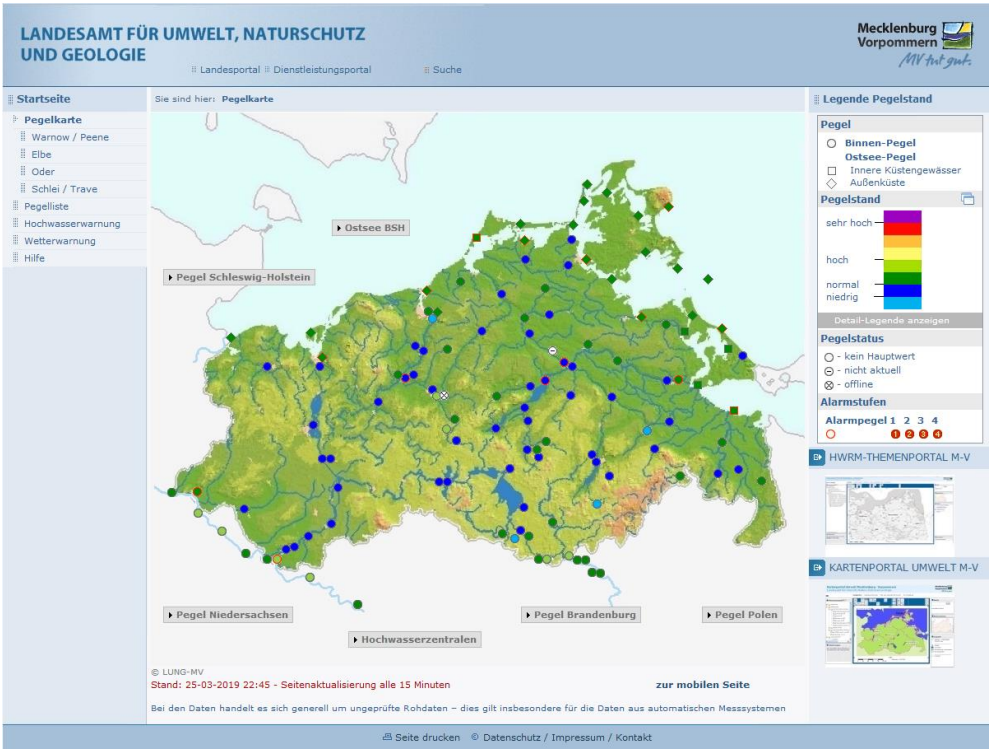

Figure 7: Gauges in Mecklenburg-Western Pomerania

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.

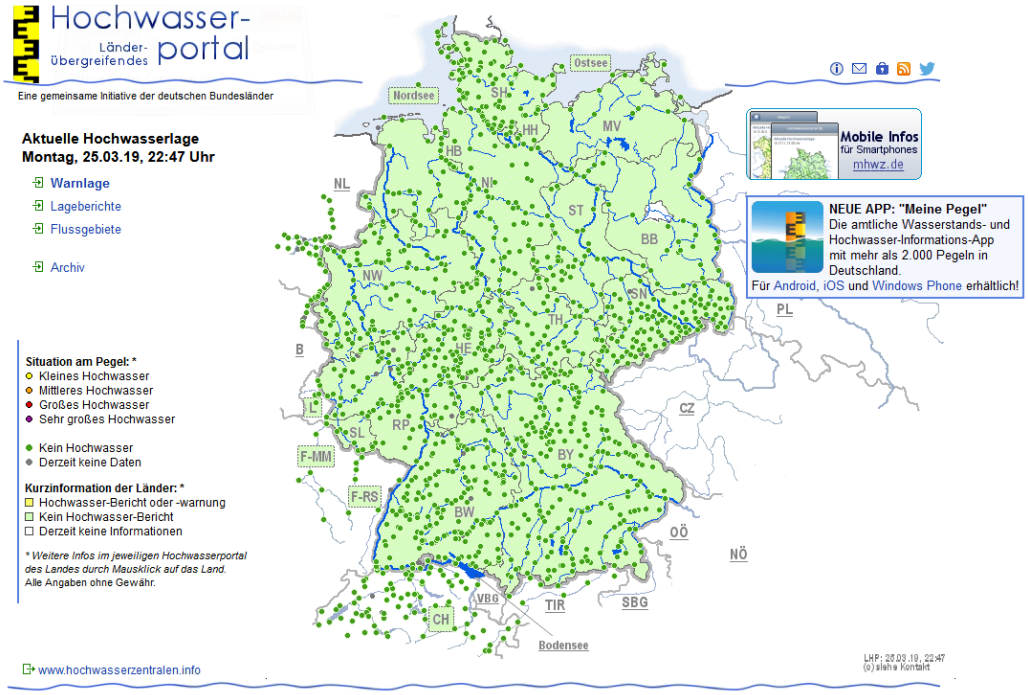

Figure 8: Website ´Hochwasserportal´

Uncertainty in water level measurements with Radar level gauges

The German Federal Institute of Hydrology together with the University of Applied Science Mainz started investigations into the uncertainty in water level measurements, with regards to difference between tide gauges in a river and tide gauges at sea (Mai et al., 2019). The free water surface is significantly influenced by wind or ship waves, while the movement of the water surface is damped in a stilling well, which is on the other side influenced by wave diffraction and the Bernoulli Effect.
Due to the redundancy in the equipment of hydrological gauges along the German federal waterways the uncertainties in water level measurements become apparent. For about twenty years, non-contact sensors, such as ultrasonic sensors or radar level sensors, have been used in addition to the traditional, contact sensors for continuous measurement of the water level, such as floats, pneumatic levels or pressure probes. In contrast to ultrasound measurements, the related distance measurements based on radar waves, underlie only very small and negligible uncertainties by the meteorological conditions along the measurement path.

Figure 1: Radar-Array at the tide Gauge Borkum-Südstrand (S.Rüten, BfG)

Therefore radar level sensors are preferably used for non-contact measurement. In Germany the Waterways and Shipping Administration (WSV) often uses radar level sensors, especially

for the intended, redundant equipment of levels. The longest, redundantly measured on federal waterways with radar level sensor and float water level time series are available in the coastal area at the gauge level "Borkum-Südstrand" (out of the estuary of the river Ems, since 2002) and at a river side at the gauge level in Mainz (river Rhine, since 2005). In the study the float gauges in the stilling well and the outside attached radar level sensor mismatches for the two sites were statistically analysed and examined for possible correlations with hydrological parameters such as sea state and runoff.

A comparison of water level measurements, collected with the floater in the stilling well and radar level sensors at the gauges in Mainz and Borkum-Südstrand, reveals a standard deviation of the valid data points of 1.7 cm in case of 15-minute data (Mainz) and 4.2 cm in case of 1-minute data (Borkum). The deviation of floater and radar sensor relates in part to intrinsic errors (Mai et al., 2019).
At Borkum-Südstrand the intrinsic error of radar level sensors is determined by an array of four identical radar level sensors. Figure 1 shows the radar array. They provide an internal resolution of 2 Hz, which means the possibility to observe sea state and the influence of sea state on the water levels. The uncertainty related to mostly to the sea state amounts to 0.5 cm during calm water conditions. However, during stormy sea the uncertainty increases to 2.5 cm (Mai et al., 2019).

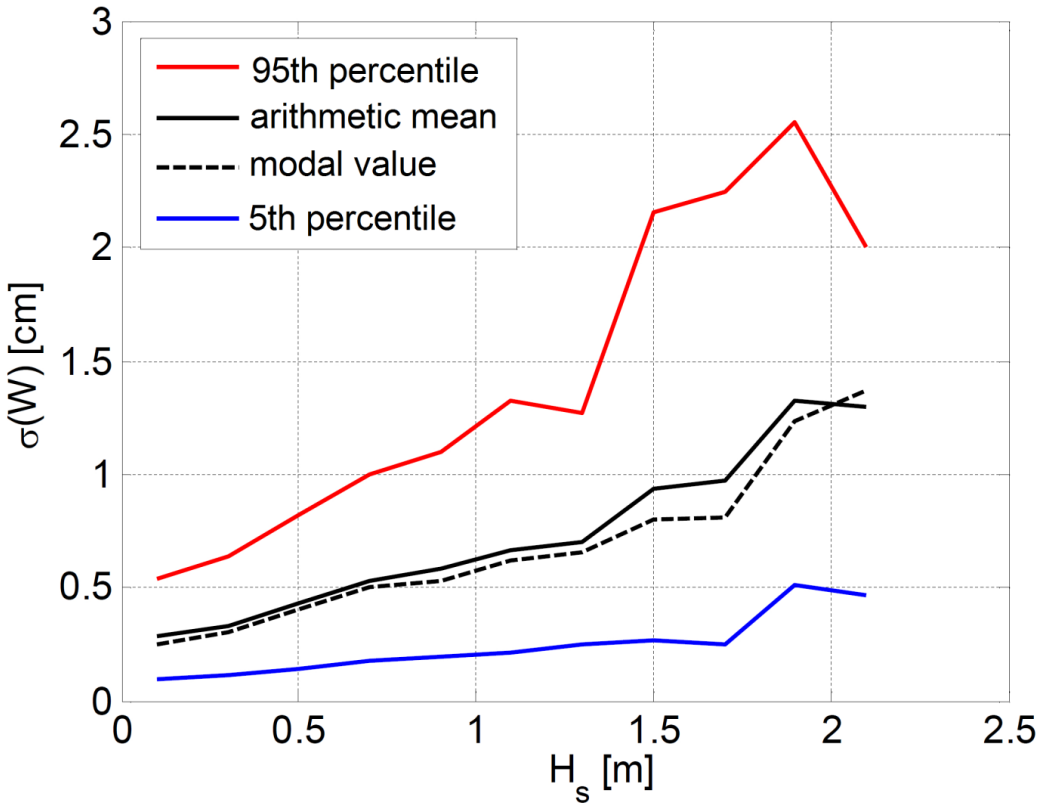

Figure 2: Uncertainty between the different radar sensors at the tide Gauge Borkum-Südstrand (Mai et al., 2019).

Radar level sensors provide a simple possibility to observe water levels, without the construction of a stilling well. The long-term expertise with radar sensors makes it possible to estimate the uncertainties. Even without the use of a stilling well, adequately accurate water levels can be measured. In today's digital world with the possibility of processing large amounts of data, measurements should be as high-resolution as possible, i.e. up to 2 Hz - or even higher. This would allow at the same time the detection of water level and sea state and also the detection of ship waves. Particularly for sedimentological or biological investigations, additional knowledge of both types of waves is of importance.

Mai S., Hein, H. and Wilhelmi, J., 2019: Unsicherheiten in der Wasserstandmessung mit Radarfüllstandsensoren, in German, accepted in WasserWirtschaft, 2019

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			Longitude			Agency
		Deg	Min	Sec	Deg	Min	Sec	
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