BUNDESAMT FÜR SEESCHIFFFAHRT UND HYDROGRAPHIE

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Within the federal system of Germany, responsibilities for waters are divided between national and federal authorities. Two federal agencies are dedicated to hydrological and environmental matters concerning the coastal waters. Both institutions are supreme federal agencies.

The *Bundesamt für Seeschifffahrt und Hydrographie* – Federal Maritime and Hydrographic Agency of Germany- (BSH) is the maritime partner for business, science, and environmental organisations. The BSH offers a wide range of services such as: - prediction of tides, water levels, and storm surges, - monitoring of the marine environment, - prosecution of environmental offences, - and improvement of the knowledge of the oceans. 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, Building and Urban Affairs (BMVBS), 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 present report deals with the coastal tide-gauge (TG) network of the WSV on the North Sea and on the Baltic Sea and the use of their data and products. There are about 160 TGs 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 TGs 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 ESEAS stations. Cuxhaven-Steubenhöft is the German contribution to the GLOSS core network. The North-Sea stations contributed also their know-how 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), while the BSH is the national Tsunami Warning Focal Point (TWFP) for the NEAMTWS.

Bundesamt für Kartographie und Geodäsie

bfg Bundesanstalt für Gewässerkunde

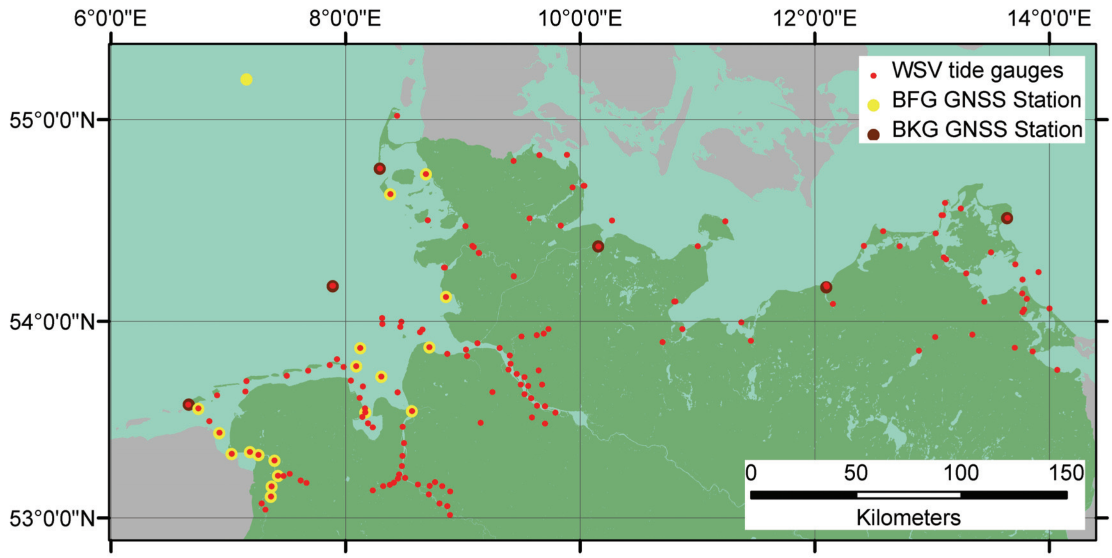

Figure 1: German coastline with tide gauges and GNSS-stations on federal waterways

The forecast of water levels and storm surges is one of the major task of the BSH. During the last years advanced methods and tools for predicting water levels and storm surges have been developed intensively. This lies in the availability of more information, both in the sampling rate of sea-level measurements and in the use of a variety of numerical model-chains. The measured time-series are accessible directly online from the TGs. The applied model-chains yield information about the atmosphere with forecasts of wind and air pressure on global and regional scales. Figure 2 gives an overview of the sub-methods and shows the flow of information in water-level and storm-surge warning via forecasting of wind set-up.

One of the central tools is the BSH-MOS; its name stands for the in-house tool of BSH and Model Output Statistics. It calculates in operational mode hourly forecast of wind set-up at the tide gauge Cuxhaven. To run this tool, information is required directly from the Global Forecast System (GFS). GFS is an atmospheric model from the National Oceanic Atmospheric Administration (NOAA) of the United States of America.

Additional inputs to BSH-MOS are results from the BSHcmod/BSHsmod, which is a water-level shelf-model that needs information about the wind-speed and air-pressure as input. The German National Weather Service (DWD) provides these data from its national weather forecast. Specific moisture and total coverage of clouds are other model input parameters that allow to calculate heat-fluxes above the sea surface.

Tide predictions and online water-level data directly from the TGs will be the third source of inputs to BSH-MOS in a next step. Both these inputs are needed to detect the crest of the tide automatically and calculate the wind set-up.

The next step is the Man-Machine-Interface, before the water-level forecast and the possible storm-surge warming can be sent out. The results will be send out to coastal authorities and relevant administration units, usually four times per day, but as often as needed in the event of *storm surge*. This information is available via internet http://www.bsh.de.

A complete description of the entire procedure is given in Müller-Navarra (2009).

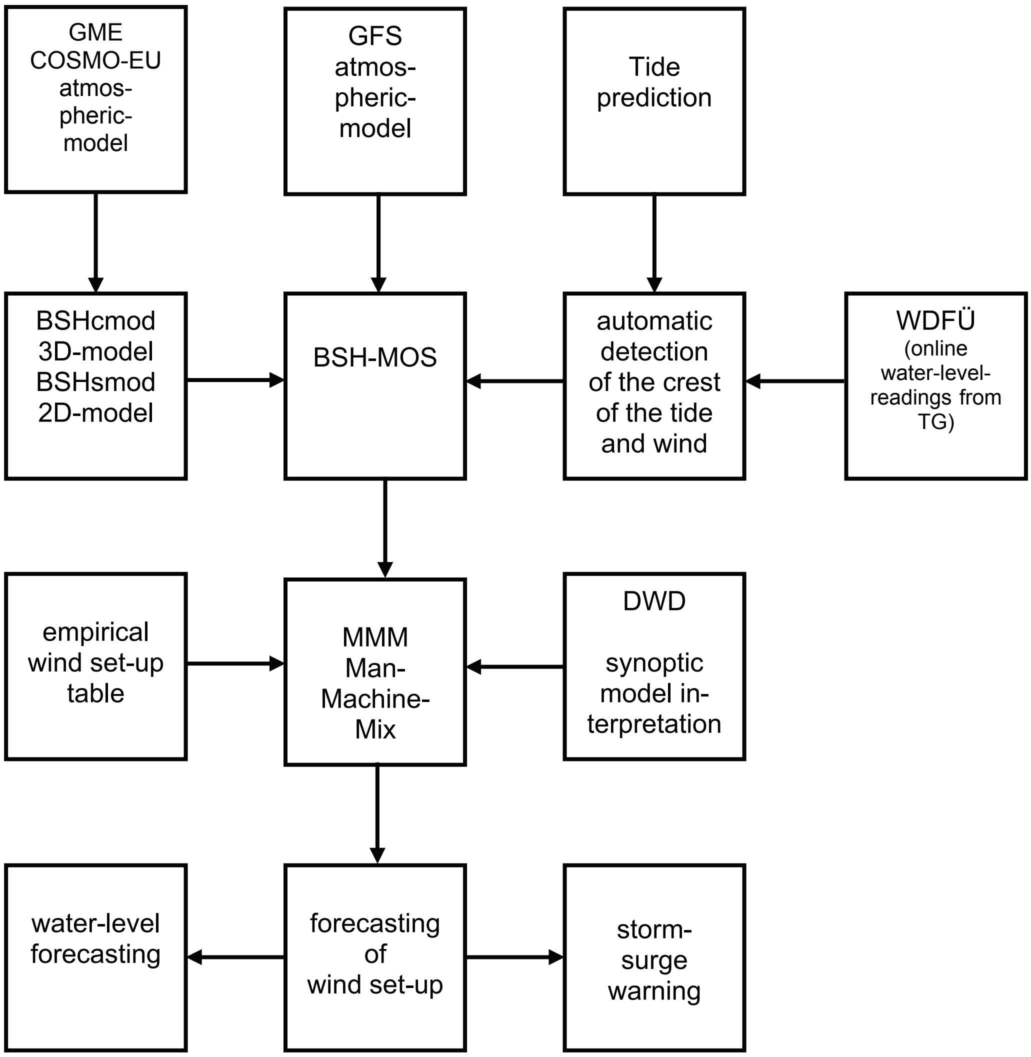

Figure 2: Methods and flow of information in water-level forecasting and storm-surge warning via wind set-up. Translated from (Müller-Navarra, 2009)

The above-mentioned procedure needs, beside the model-chains, water-level readings directly from the TGs. Therefore, more attention has to be paid to improve the quality of raw data. This can be achieved by more reliable sensors like radar-systems. In addition, the number of water-level sensors and their connection to the main frame of data processing can be doubled. Thus, it can be ensured that gaps and missing values will go down to zero. Furthermore, to improve the quality of online data, direct control with intelligent tools is another option. All these briefly described approaches can be summarized under the headline of Quality Management of Hydrological Data. The local offices of the WSV are responsible for maintaining the TGs and the collected data. The Federal Institute of Hydrology (BfG), as the scientific and technical consultant for the WSV, will assist them in this new challenge. One of the first approaches is the plausibility check of raw data and their fitting. The time series have to be analysed with mathematical methods in order to have a better overview of the ongoing physical processes and to identify and exclude unwanted phenomena like capillary-waves, swell, sea-state, and wave reflections. Now, the gained time series are treated for further studies like the estimation of crests of tide. First results are summarized in (Barjenbruch, U. & C.J. Blasi, 2011).

Sea state itself is a phenomena which plays an important role not only in sea-level measurements, but also regarding many coastal engineering works. Therefore, their physical properties, like power, direction, and height are the main parameters of further investigation. To assess the direction of the sea state, a new research project has to be set up. It is worth to mention that the inclusion of the direction of sea state will be an improvement to mathematical models. The project will be run from the year 2012 until 2014. The required data about the direction should be measured with the help of three sea-state sensors, which are straightforward radar-sensors. This triangle of sensors is the basic measurement device of the project. With the help of mathematical methods, like cross-correlation, Fourier- and wavelet-transformation, an algorithm has to be developed to calculate the spectrum of the sea-state direction. The results, will have to be analysed and checked under laboratory condition. The readings of the measurement triangle should be analysed also with the idea of improving the water-level measurements. Research about wave-height distribution and interactions of wind-waves and currents in estuaries, which were also a motive for the new project, is described in Hein, H. et al, (2010) and Mai, S. et al, (2010).

Selected list of 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

Coordinate Reference System (CRS): DE_ETRS89_Lat- Lon

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

All TGs measure the water level with a float-system in a stilling well. The mechanical signal of the float is transformed by an angle decoder into electrical signals for the data transmission. During the last year, a working group dealt with the optimisation and modernisation of the whole tide-gauge network in Germany. By taking economic, hydrologic, oceanographic and hydrometric aspects into account, it was ascertained that the network should retain its size and number of TGs. Nevertheless an upgrading of the network started in the year 2011. New technology, such as radar sensors, the doubling the number of sensors, and the connection to the main frame of data processing, will be introduced at important TGs.

In the past, the BfG and the Federal Waterways and Shipping Offices (WSA) monitored the altitudes of the tide-gauge zero points by geometric and hydrostatic levellings. The altitude of the tide-gauge zero points was related to a local network of benchmarks as well as to the nation-wide ordnance datum of the German Federal States. To distinguish between vertical recent land movements and long-term sea-level variations, permanent monitoring of the tide gauges is necessary. This can be done with the GNSS-technology.

In 2001, the *Bundesamt für Kartographie und Geodäsie* – Federal Agency for Cartography and Geodesy- (BKG) started the installation of GNSS-stations at the Baltic-Sea tide gauges Sassnitz, Warnemünde, Kiel-Holtenau and at the North-Sea tide gauges Hörnum, Helgoland, and Borkum-Fischerbalje (Figure 1). The GNSS stations are part of the German GNSS Reference Network (GREF) as well as several international GNSS networks (IGS, EPN, ESEAS, TIGA-PP). These stations are equipped with GPS/GLONASS receivers. The real-time data are transferred via Internet. The eccentricities between GNSS-antennae and tide-gauges are monitored regularly (precise spirit levelling) by the BfG, BKG and / or the Federal Waterways and Shipping Offices.

In 2008, the BfG began to establish a network of continuously operating GNSS-tide gauge sites in the area of the German Bight (Figure 1). These stations are equipped with geodetic GPS/GLONASS receivers. Their operation and the processing of the data are realized by the BfG. The results (including the altitudes of the tide-gauge zero points) are related to global reference frames (e.g. ITRF2005, IGS05), thus making world-wide comparisons of water-levels possible. These network might become integrated into the IGS-TIGA-PP-Network.

Data availability

- Tide gauges:
The raw sea-level data are available at 1-minute intervals (the last 30 days only) and can be retrieved from: http://www.pegelonline.wsv.de/. Tide gauges, which serve the national Tsunami Warning Focal Point (TWFP) for the NEAMTWS are available at the 'IOC Sea level data facility' http://www.ioc-sealevelmonitoring.org/. The raw data are also used by the BSH for the prediction of tides, water levels, storm surges, and currents. There are plans to improve the availability of verified sea-level data via *Web Services* to transfer the sea-level data to the GLOSS Data Centres. Hydrological data processing is done by the local offices of the WSV who are also responsible for operating and maintaining the tide gauges.

- GNSS (BKG):
Geodetic information from the BKG are available as follows:

TGs Borkum, Helgoland and Hörnum:	ftp://igs.bkg.bund.de/EUREF/
TGs Warnemünde, Sassnitz:	ftp://igs.bkg.bund.de/IGS/
TGs Kiel:	ftp://igs.bkg.bund.de/GREF/

- GNSS (BFG):
GNSS observation, metadata and results are available from (for password please contact: sudau@bafg.de):
ftp://gnss-gast@ftp.bafg.de
Geometric relations between GNSS-site and gauge datum
http://geoportal.bafg.de/kliwas/pegel202/00_gnss.html

Further geodetic information are available from:

- DGFI: http://www.dgfi.badw.de/
- EUREF: http:///www.epncb.oma.be/

Literature

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