Extreme water level and their impact on the German Baltic coast

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1. Introduction

Extreme water level at the coast may cause substantial economic and ecological damages. At the German Baltic Sea coast, storm surges are defined as water levels of 1 m or more above and low sea levels as 1 m and lower below mean sea level (MSL), respectively. The BSH gives short term warnings (1–3 days in advance) for such events, mainly based on numerical forecasts. But to be prepared for such events and in order to minimize their consequences, coastal protection and shipping agencies, e.g., need knowledge about potential strengths and recurrence probabilities as well as possible impacts. In this context the duration of the events is similar important, while tides in the Baltic Sea are negligible in contrast.

2. Data

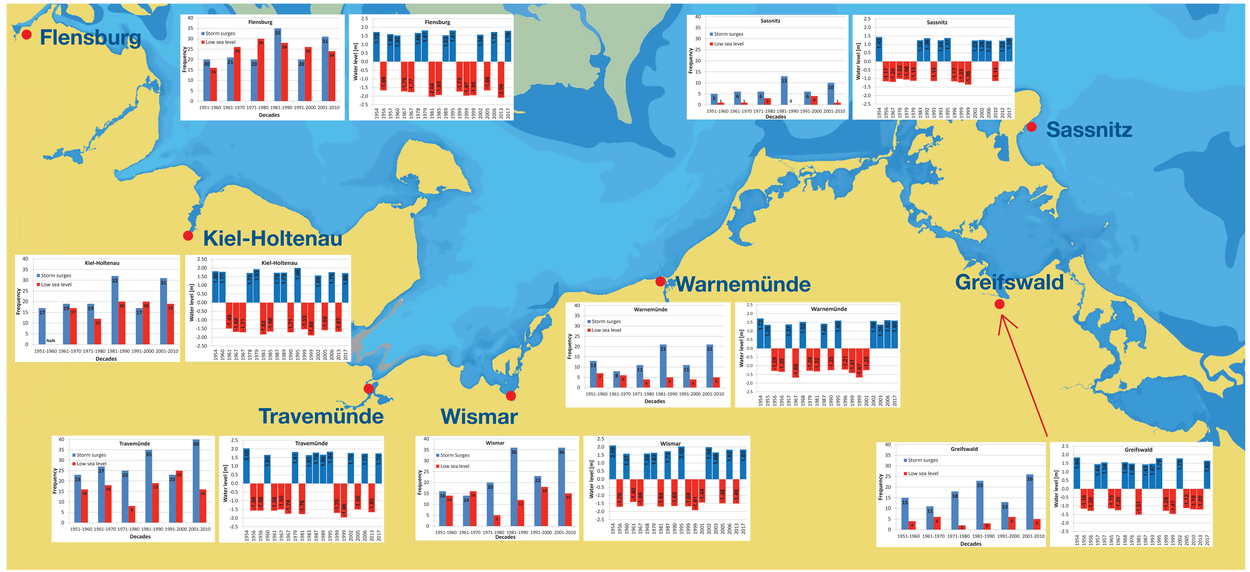
Here we use a subset of quality proofed water gauge measurements along the German coast, namely the stations Flensburg, Kiel-Holtenau, Travemünde, Wismar, Warnemünde, Sassnitz and Greifswald. We extracted dates and highest/lowest water level for extreme water events from annual Hydrology books (mainly before 1950), manually digitized water level graphs (starting around 1950) or from digital gauge data (since 1995) provided by the Waterway and Shipping Authority. In general, data since the 1950s have at least hourly resolution. Recurrence periods were calculated based on the full length of available data sets using Gumbel statistic. All other calculations were made based on data after 1950.

3. Conclusions

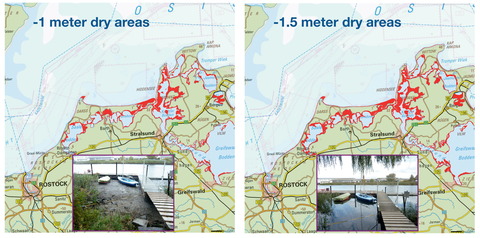
- The risk of extreme water levels increases towards the west, an alternative view is that extreme levels tend to be higher in the west than in the east.
- Severe storm surges (>1.5 m above MSL) occur each 10–20 years (in the east) to 5–10 years (in the west) on average.
- Almost all extreme cases occur between autumn and spring (although the rare summer events can carry higher damage potential).
- Longer duration at same water levels causes higher damages.

4. Outlook

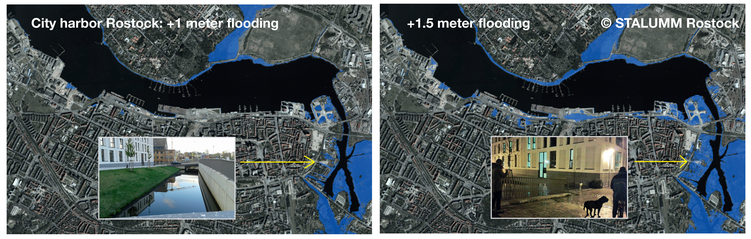
- Subdividing the time series will be used to estimate trends in the recurrence periods.
- Older paper gauge records (~1900 to 1950) will be digitized to produce longer term statistics which also include storm surge duration.



Top ten of highest and lowest extreme water levels since 1950. Frequency of storm surges and low sea levels in decades.

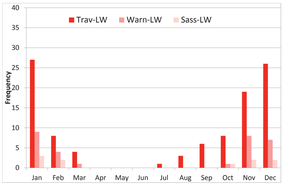


Map of Mecklenburg-West Pomerania. Red areas show potential dry falling areas during low water level events, exemplarily for water levels of 1 m and 1.5 m below MSL, respectively. Photo left shows the impact of low sea level, photo right MSL.

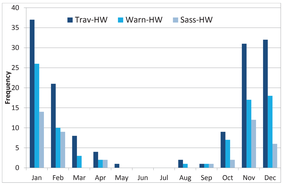


City map of Rostock. Blue fields show potential flooding areas during storm surge events, exemplarily for water levels of 1 m and 1.5 m above MSL, respectively. Photo left shows MSL+15 cm and the right photo shows impact of storm surge in January 2017.

For the impact of low water level, simulation of dry areas have been created using the GeoSeaPortal and sea floor survey data from BSH.



Low sea level: Monthly distribution for the gauges Travemünde, Warnemünde and Sassnitz



Storm surges: Monthly distribution for the gauges Travemünde, Warnemünde and Sassnitz

Gauge / years	5	10	20	50	100
Flensburg (96)	-1.57	-1.75	-1.93	-2.15	-2.32
Kiel-Holtenau (96)	-1.40	-1.56	-1.71	-1.90	-2.05
Travemünde (81)	-1.39	-1.54	-1.69	-1.88	-2.03
Wismar (104)	-1.38	-1.53	-1.69	-1.88	-2.03
Warnemünde (112)	-1.20	-1.33	-1.46	-1.63	-1.75
Sassnitz (112)	-0.93	-1.05	-1.17	-1.32	-1.43
Greifswald (81)	-1.07	-1.18	-1.29	-1.44	-1.55

Gauge / years	5	10	20	50	100
Flensburg (97)	1.45	1.63	1.80	2.02	2.18
Kiel-Holtenau (97)	1.45	1.64	1.82	2.05	2.23
Travemünde (82)	1.50	1.69	1.87	2.11	2.28
Wismar (105)	1.50	1.69	1.87	2.10	2.28
Warnemünde (114)	1.29	1.45	1.60	1.81	1.96
Sassnitz (113)	1.13	1.27	1.40	1.58	1.71
Greifswald (82)	1.35	1.51	1.66	1.96	2.01

Recurrence period in years and meters for high (right panel) and low (left panel) water levels at particular stations along the German Baltic Sea coast. Numbers in parenthesis give the length of a the data record in years.

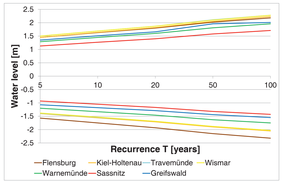
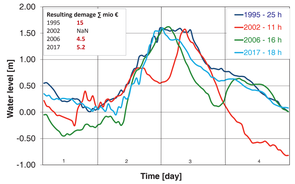


Illustration of recurrence period in years and meters for high/low water levels along the German Baltic Sea coast.



Development and duration of different high water level events observed in Warnemünde. Duration of more then tidal period is possible as tides in the Baltic Sea are negligible.

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