Extreme storm surges
A method to calculate extreme events at the North Sea Coast

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Introduction

Usually, methods to determine extreme storm surges only look at the peak values of storm surge events. The approach chosen here looks at the whole storm surge curve. The components of a storm surge, tide, wind surge and external surge as well as their non-linear interactions are analysed.

Pilot sites

The analyses are conducted for one location at the open coast (Island of Sylt) and another, which is situated in an estuarine area (city of Hamburg). The study sites allow for transferability of the developed methods to other coastal or estuarine areas.

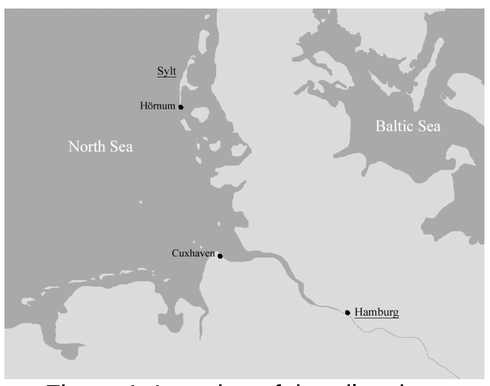

Figure 1: Location of the pilot sites

The methodological approach

Non-linear interaction between tide and wind surge

To determine the ratio between wind surge height around low water and around high water the relations between wind surge, the respective wind speed and tide are analysed. At tidal gauge Cuxhaven, the wind surge at high tide accounts for 82 to 94 percent of the wind surge around low tide. This analysis can be transferred to the astronomical dissimilarity. Hence the amount of reduction of wind surge due to shifting from low water to high water can be adapted to make out the reduction of effects of spring tide on storm surge water levels. Because there is a connection between overall water level and reduction, the calculation of the astronomical dissimilarity‘s decrease has to be made including wind surge.

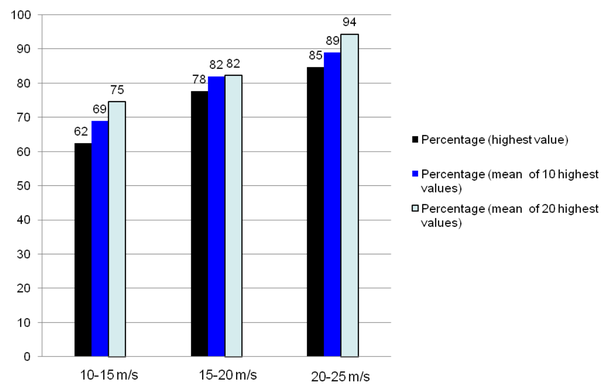

Figure 3: Difference of wind surge at high tide and low tide at tidal gauge Cuxhaven

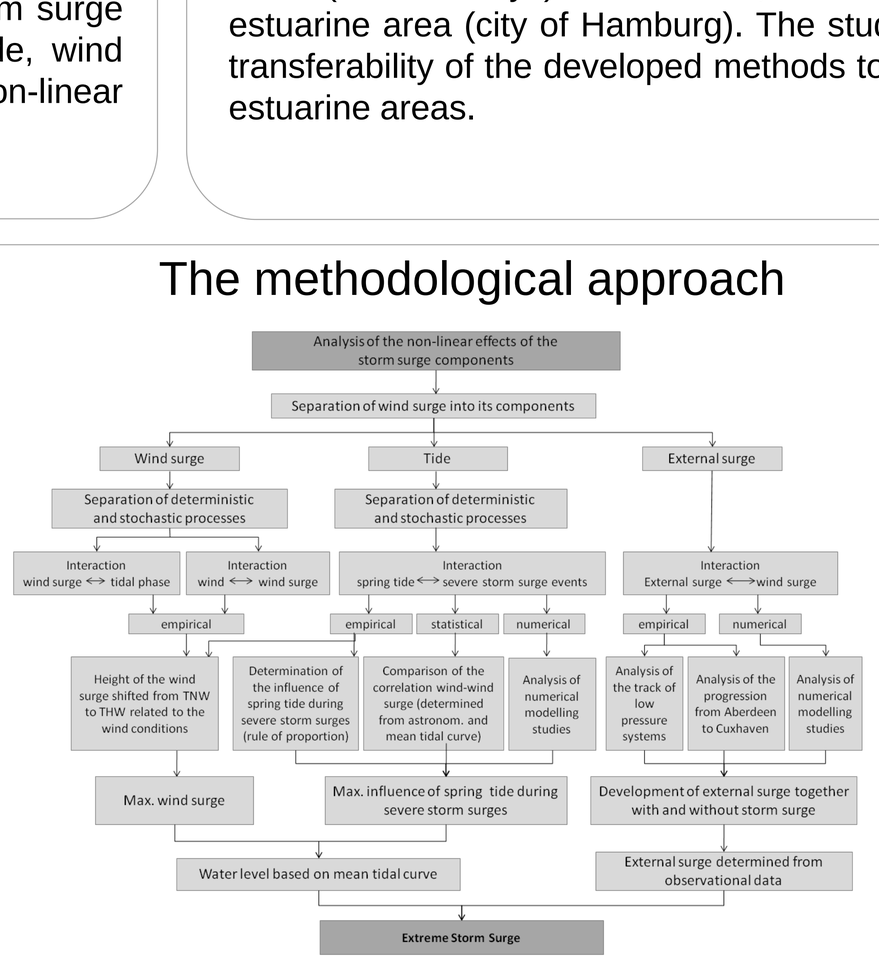

Figure 2: Methods to estimate the non-linear effects

In the course of a comprehensive analysis the components are firstly scrutinized separately and secondly their interaction is investigated with empirical, statistical and numerical methods. The consistence of the different methods’ results allows an optimal ascertainment of the physical context and a validation of the used methods.

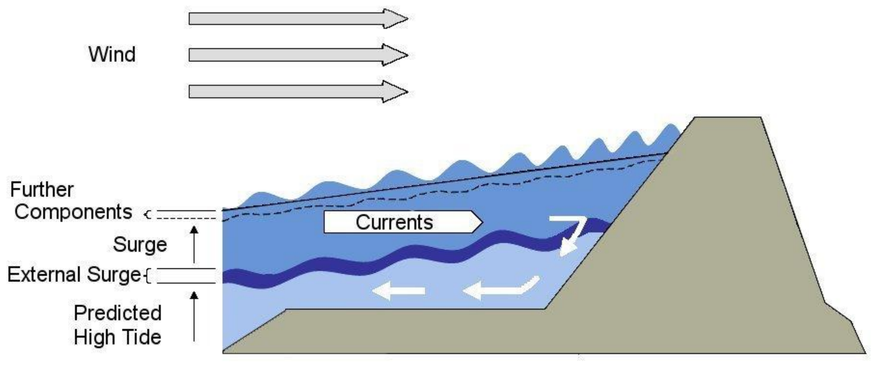

Figure 4: The components of a storm surge

Non-linear interaction between storm surge and external surge

The cyclone that causes an external surge in the Atlantic Ocean has negligible to substancial effects on the water level in the North Sea, depending on the cyclone‘s track. When the cyclone features a southern track the water level in the North Sea can for instance be affected by effects of air pressure and air pressure variations over the sea as well as additional wind. To avoid that the peak of the external surge combined with the extreme storm surge contains alterations of the water level due to these influences, only the external surges are taken into account that occurred without a coinciding storm surge. The average decrease of these external surges between Aberdeen and Cuxhaven is about 30 percent.

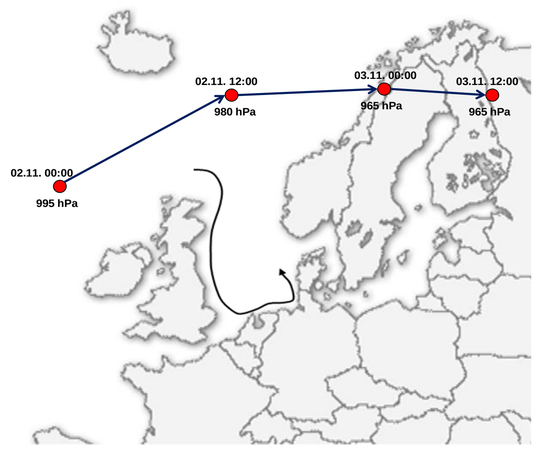

Figure 5: External surge at tidal gauge Cuxhaven (3.11.1971 14:00 MET)

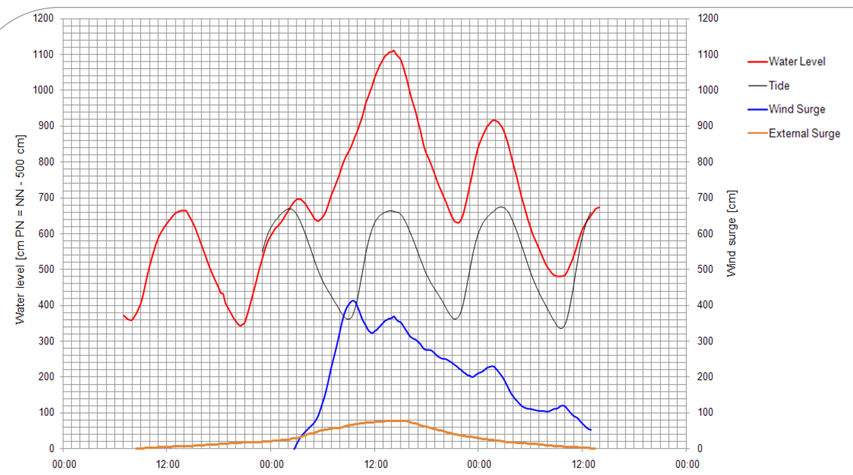

Figure 6: The extreme storm surge and ist components at tidal gauge Cuxhaven

Calculation of an extreme storm surge event

The extreme storm surge is calculated by adding the highest observed values of each storm surge component in due consideration of their non-linear interaction investigated in this study and adding the resulting value to the mean high tide.

Results

This paper presents an empirical approach to determine extreme storm surges at different tidal gauges. Statistical and numerical methods are brought in to validate the empirical methods.

The presented approach is developed at tidal gauge Cuxhaven because of its continuous time series that reaches back to 1900. It is then transferred to tidal gauge Hörnum. The implementation at this second tidal gauge showed that, provided that an adequate series of data is available, the approach can be transferred to other study areas.

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