KLIMZUG-NORD
Regional strategies concerning climate changes in the metropolitan area of Hamburg

Effects of climate change on storm surges in the Elbe estuary – a sensitivity study

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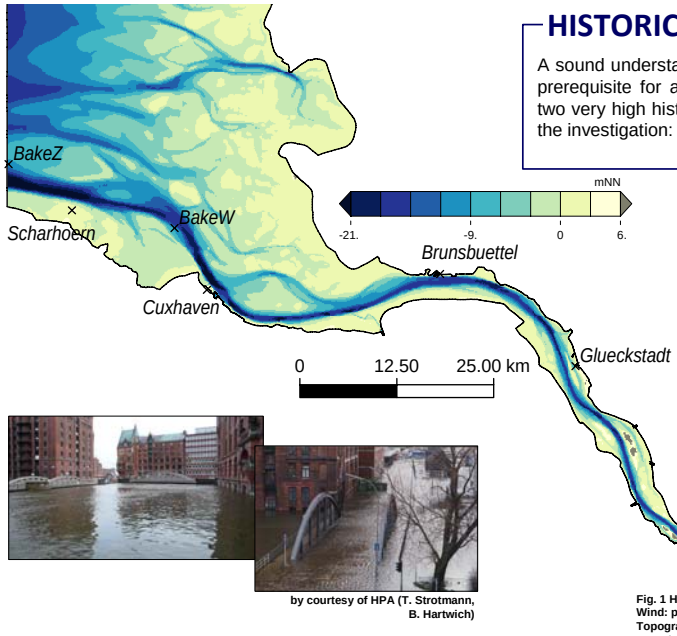

by courtesy of HPA (T. Strotmann, B. Hartwich)

Fig. 1 HN-Model UnTRIM
Wind: provided by DWD using MKW
Topography: 2002
Open boundary to the North Sea:
North Sea model BAW

HISTORICAL STORM SURGES IN THE ELBE

A sound understanding of the actual and historical situation in the estuary is a prerequisite for analysing future situations under climate change. Therefore, two very high historical storm surge events are analysed and used as basis of the investigation:

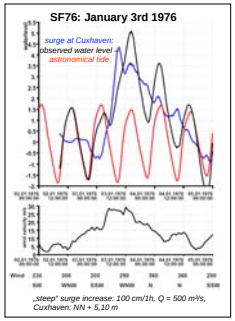

Fig. 2: Storm surge type SF76 (03.01.1976) top: water levels at Cuxhaven, bottom: wind situation at Scharhoern

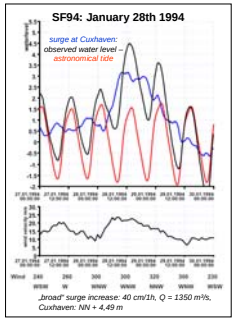

Fig. 3: Storm surge type SF94 (28.01.1994) top: water levels at Cuxhaven, bottom: wind situation at Scharhoern

MOTIVATION

As widely discussed, climate will change in the near and far future. However, it is unclear how a changing climate might influence the characteristics of storm surges along the German Bight and which steps must be undertaken to mitigate the risk for people's safety, economy and nature. A case of special significance plays the Elbe estuary in Northern Germany. Here, the problem is complex due to various interests (container harbour, navigation channel to the North Sea, metropolitan area of Hamburg, nature reserves).

We propose a concept to investigate the impact of a changing climate on storm surge conditions along the Tidal Elbe by means of sensitivity studies carried out with a 3D hydrodynamical numerical model and an analysis of characteristic numbers. The results of this study will be used to develop adaptation strategies for the metropolitan region of Hamburg. The presented work is embedded and financed by the KLIMZUG-Nord project.

INVESTIGATED SCENARIOS UNDER CLIMATE CHANGE

The development and intensity of a storm surge in the Elbe estuary is determined by the water level at the boundary of the North Sea, the river runoff into the estuary and the local wind field over the estuary. In science, various global and regional climate models exist which are run for several climate projections in numerous realisations. The outcomes exhibit a wide scatter of probable climate futures. Effective adaptation strategies for storm surges must cover this range while at the same time, must remain applicable in practice. To this aim, our concept proposes the use of historical storm surges as reference in combination with sensitivity studies in which the key parameters influencing storm surges are varied systematically according to the current knowledge about expected changes in a future climate:

- sea level changes in the North Sea (Fig. 4 and 6)
- variations in river runoff into the estuary (Fig. 5 and 6)
- increase in the local wind over the estuary (Fig. 7)

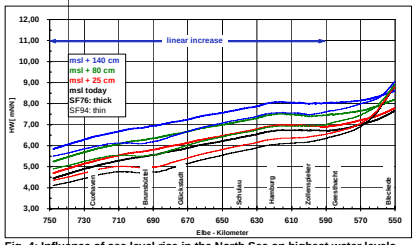

Fig. 4: Influence of sea level rise in the North Sea on highest water levels during storm surge types SF76 and SF94 along the Elbe estuary

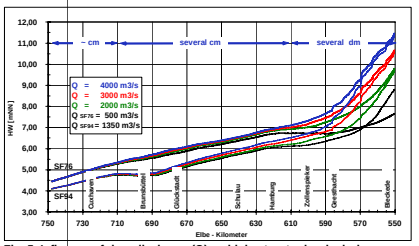

Fig. 5: Influence of river discharge (Q) on highest water levels during storm surge types SF76 and SF94 along the Elbe estuary

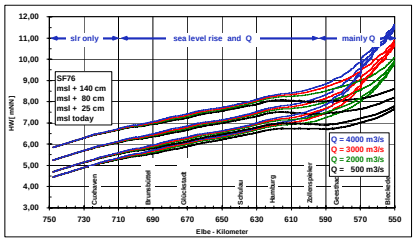

Fig. 6: Influence of sea level rise (slr) and river discharge (Q) on highest water levels along the Elbe estuary exemplarily during storm surge SF76

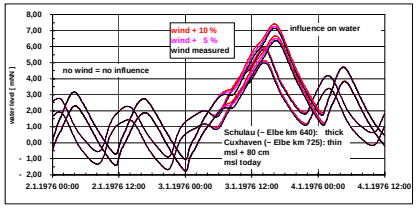

Fig. 7: Influence of wind speed increase over the Elbe estuary on water levels exemplarily during storm surge SF76 for locations Schulau and Cuxhaven

RESULTS

Characteristic numbers such as highest water levels, duration of high water and highest water times have been analysed for more than 50 parameter variations. Regarding both storm surge types, a sea level rise (*slr*) in the North Sea results in a linear increase in highest water levels (*HW*) along the estuary until the port of Hamburg (**Fig. 4**). Upstream of Hamburg instead, the increase in *HW* is additionally influenced by the magnitude of river discharge (*Q*) into the estuary.

The Tidal Elbe exhibits three zones during storm surge where highest water levels *HW* are more or less sensitive to river discharge *Q* (**Fig. 5**).

Three zones can also be determined when assuming storm surges at different river discharges and sea level rise (*slr*, **Fig. 6**): The increase in *HW* is dominated by *slr* in the mouth of the estuary while in the upstream part instead, the influence of *slr* decreases.

Finally, it can be observed that a probable increase in wind speed over the estuary leads to an increase in water levels along the estuary by several centimeters (**Fig. 7**) in addition to an increase by sea level rise.

CONCLUSIONS

The storm surge characteristics along the Tidal Elbe are significantly influenced by an increase in mean sea level in the North Sea, in wind speed over the estuary and by variations of the river discharge. Areas have been identified where the parameters investigated have different influence on the water levels during storm surge:

- mouth to Hamburg: dominated by conditions in the North Sea (slr, wind, etc.)
- Hamburg: influenced by conditions both in the North Sea and in the river
- upstream Hamburg: dominated by conditions in the river

The range of parameter variations offers a first indication of probable storm surge characteristics under a future climate.

The study provides the physical elements for vulnerability studies in KLIMZUG-Nord and enables the work on adaptation and risk mitigation necessitated under probable climate change.

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