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

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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 (30.01.1976)
- **Fig. 3:** Storm surge type SF94 (24.01.1994)

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)

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 air 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 a 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.