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Effects of mean sea level rise and tidal flat growth on tides and storm surge events in the Elbe estuary

Effects of mean sea level rise and tidal flat growth on tides and storm surge events in the Elbe estuary

BMVI Network of Experts
Knowledge Ability Action

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Introduction

Global mean sea level rise (SLR) will influence tidal dynamics and storm surge events in estuaries. Due to tidal flat morphodynamics (Friedrichs 2011), SLR can likely change the bathymetry of a coastal area. Tidal flats can grow to a certain amount with SLR, if sediment availability is sufficient (Dissanayake 2012). This study investigates the influence of SLR and different tidal flat growth scenarios on tides and storm surge events in the Elbe estuary by schematically changing the topography in a hydrodynamic-numerical model. A detailed description of methods, results and discussion will be available in Mahavadi et al. (in prep.). The findings might enable a better understanding of future changes in the Elbe estuary and help planning adaptation options to reduce the impacts of climate change.

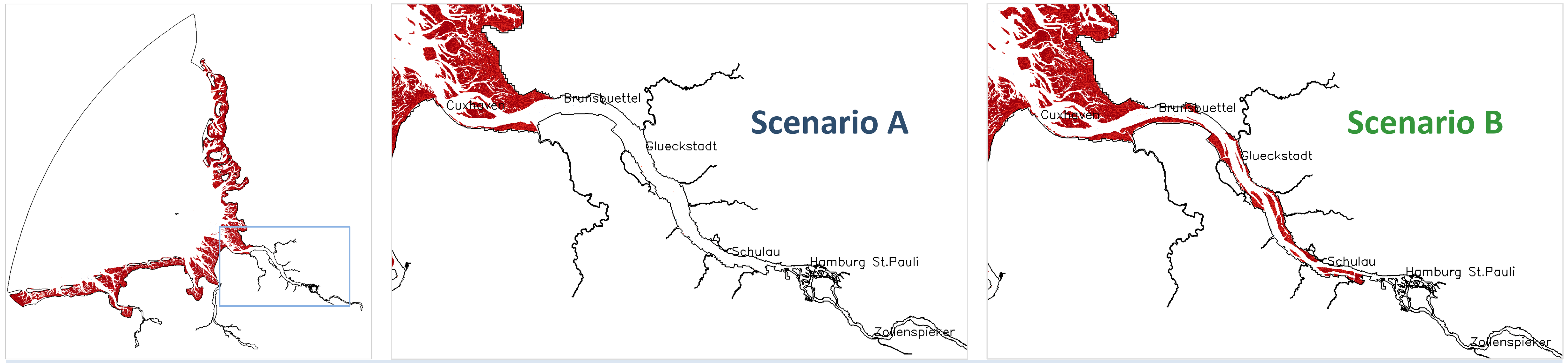

Figure 2: Elevated tidal flats in the model (left), section Elbe estuary scenario A (middle), section Elbe estuary scenario B (right)

Methods

The study was conducted using the hydrodynamic-numerical model UnTRIM² (Casulli 2008).

Scenarios:

Scenario	SLR	Change in Topography
Reference	-	-
SLR	+110 cm	-
Scenario A	+110 cm	tidal flat elevation of 110 cm in the German Bight and the outer Elbe estuary
Scenario B	+110 cm	tidal flat elevation of 110 cm in the German Bight and the entire Elbe estuary

SLR of 110 cm was added at the model boundary.

Events:

- **EH:** Extreme high storm surge event from a climate projection based on emission scenario B1 (Grabemann et al. 2020) with discharge of 600 m³/s into the Elbe estuary
- **SN2013:** Spring-neap-cycle in July 2013 with discharge of 600 m³/s into the Elbe estuary

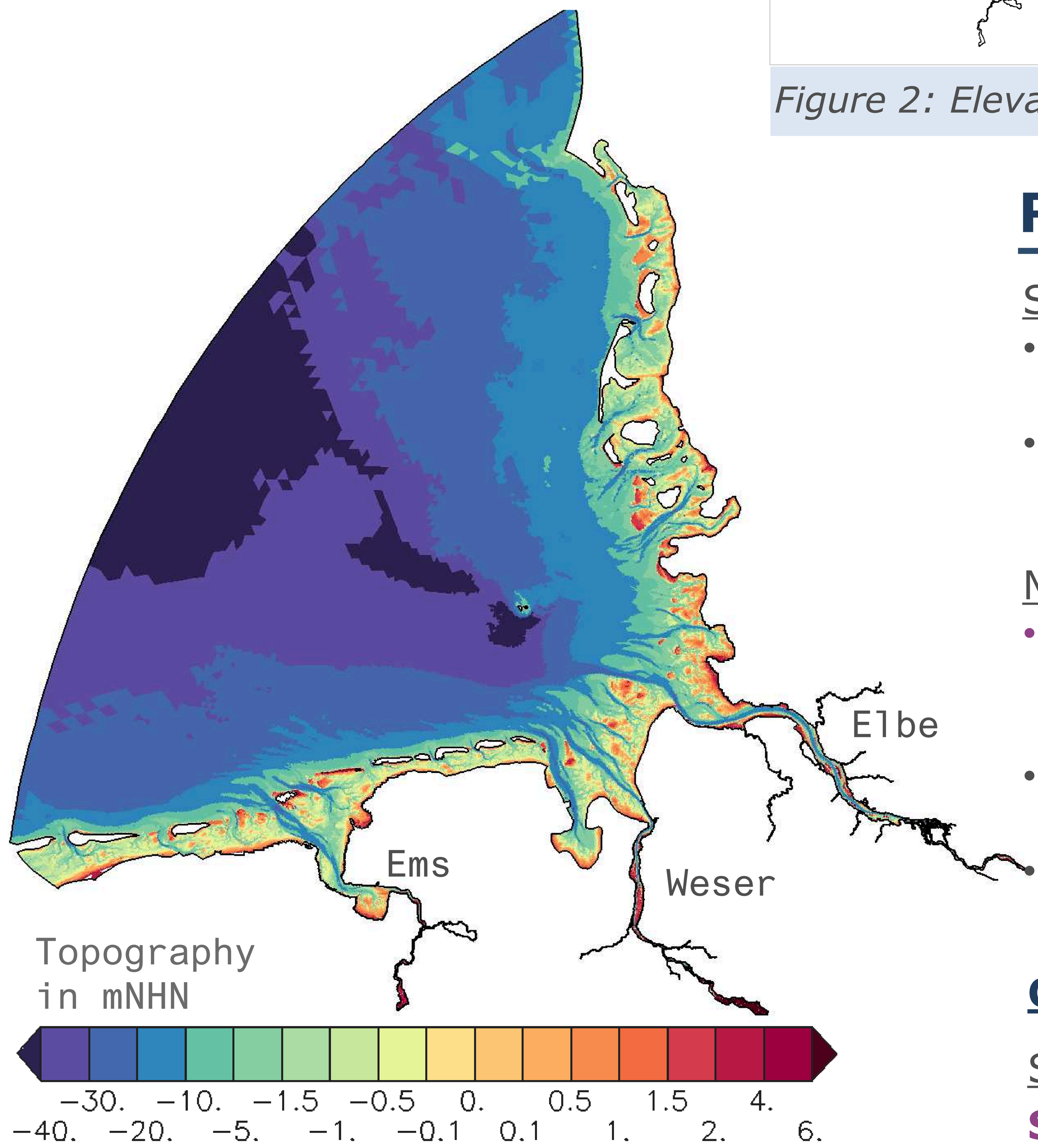

Figure 1: Model domain of the German Bight (North Sea) with its estuaries Ems, Weser and Elbe and their tributaries

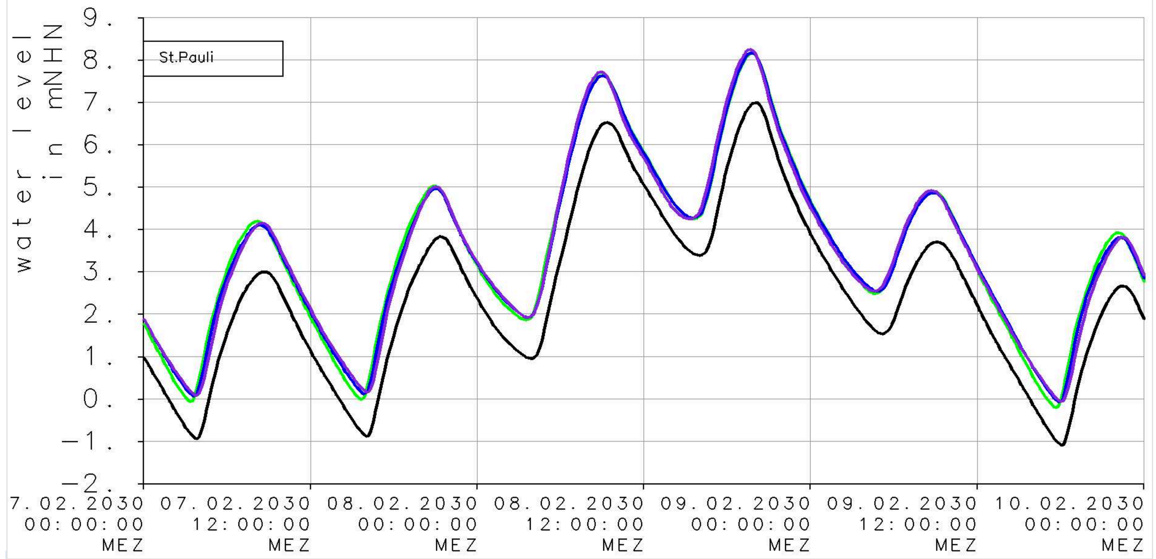

*Figure 3: Water level at St. Pauli during **EH**, black: reference condition, purple: SLR, blue: scenario A, green: scenario B*

Results and Discussion

Storm surge peak water level along Elbe estuary:

- Due to **SLR** alone, storm surge peak water level **increases** up to 15 cm higher than SLR
- Tidal flat growth of scenario **A** and **B** with SLR **decreases** peak water levels relative to sole SLR up to 9 cm

Mean tidal range along Elbe estuary:

- **SLR** of 110 cm **increases** mean tidal range as mean tidal low water decreases and mean tidal high water increases
- Tidal flat growth of scenario **A** with SLR **decreases** tidal range relative to sole SLR
- Tidal flat growth of scenario **B** with SLR **increases** tidal range relative to sole SLR

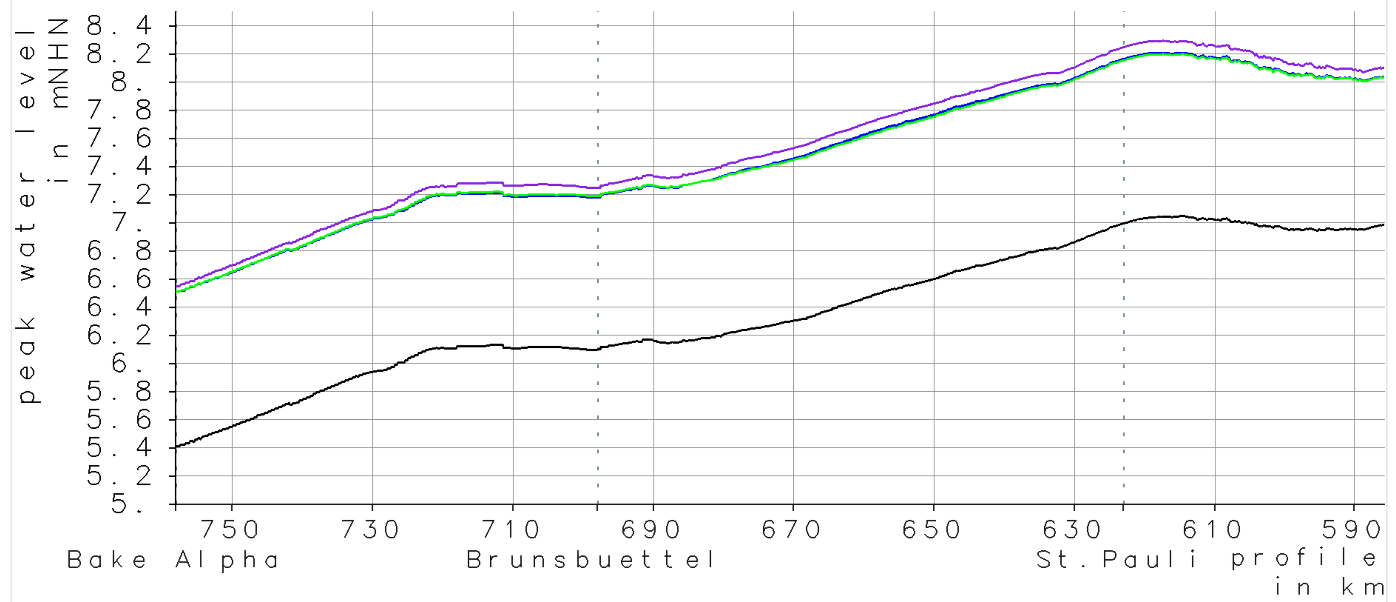

*Figure 4: peak water level of **EH** along the Elbe estuary, black: reference condition, purple: SLR, blue: scenario A, green: scenario B*

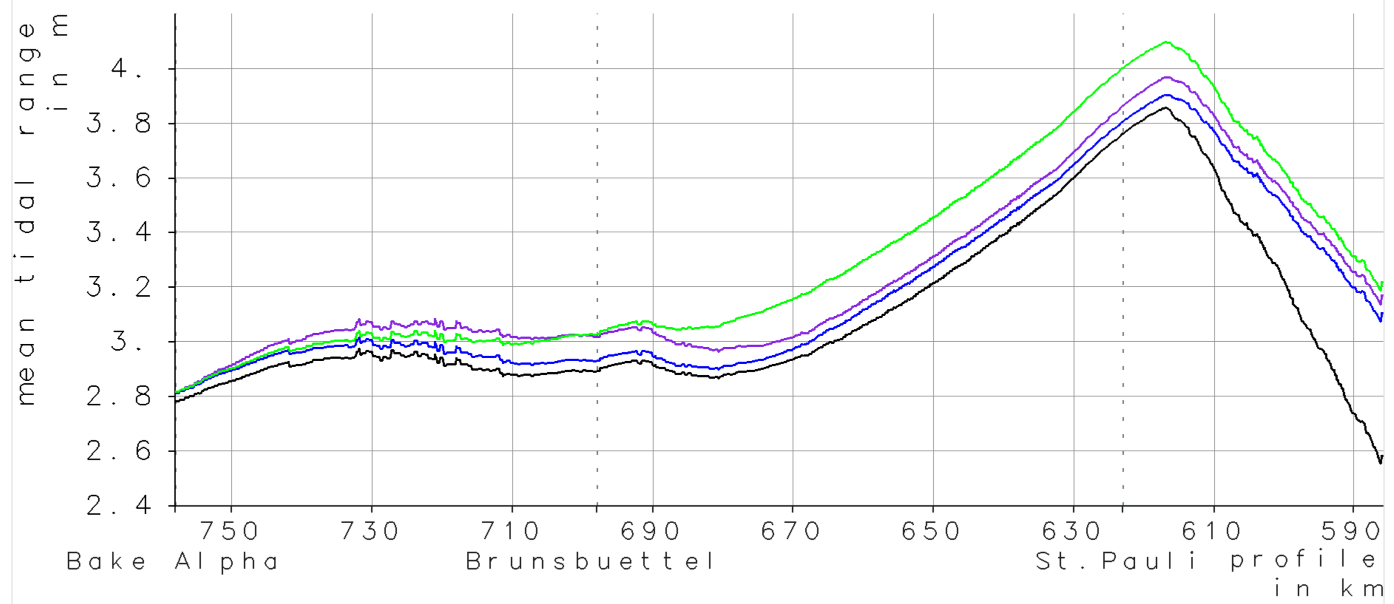

*Figure 5: Mean tidal range of **SN2013** along the Elbe estuary, black: reference condition, purple: SLR, blue: scenario A, green: scenario B*

Causes for these changes

Storm surge peak water level along Elbe estuary:

SLR alone causes an increase in water depth during storm surge events, reducing energy dissipation and therefore causing a larger tidal amplitude and higher peak water level. Additionally, **SLR** alone results in a stronger upstream convergence of the cross-sectional-flow area leading to an increase in tidal amplitude. Tidal flat growth of scenarios **A** and **B** counteracts both of these changes and therefore reduces peak water levels.

Mean tidal range along Elbe estuary:

SLR alone does not generally increase mean water depth of the estuary channels, as shallow previously intertidal areas at the channel sides become part of the channel. **SLR** causes a stronger upstream convergence of cross-sectional-flow area in the Elbe estuary and therefore increases tidal amplitude. Tidal flat elevation of scenario **A** decreases convergence to be close to reference condition and therefore reduces tidal range relative to sole SLR. Tidal flat elevation of scenario **B** causes an increase in mean water depth of the estuary channels and therefore reduces energy dissipation and causes an increase in tidal range.

References

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