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Systematic assessment of the impact of a planned channel deepening on estuarine physics, the example of the Weser estuary (North Sea)

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Introduction

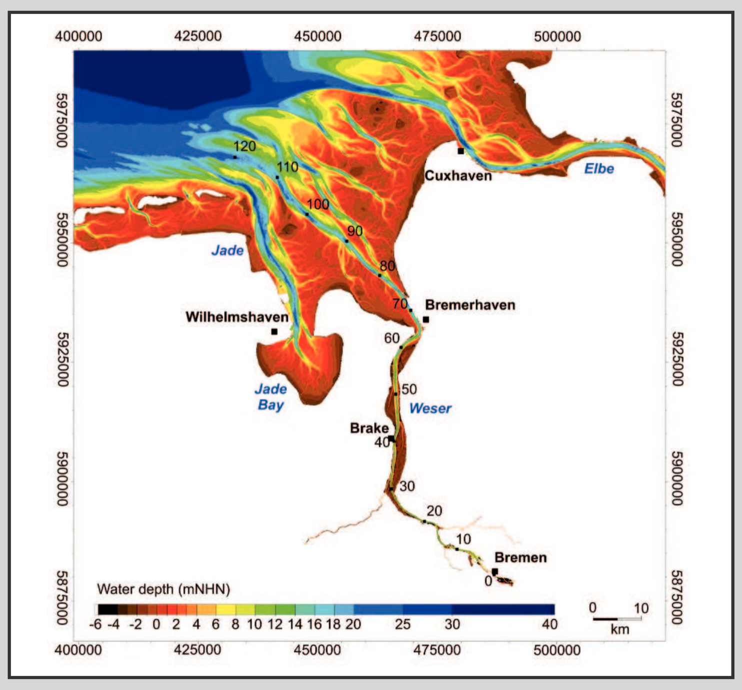

Figure 1: *Morphology of the Weser estuary (German Bight, North Sea). Numbers denote the distance along the main shipping channel.*

Many estuaries experience strong anthropogenic pressure as they contain approach channels for economically important harbors. At the same time, they represent ecologically valuable habitats which need to be protected in order to ensure a proper functioning of their ecosystem services. Therefore, the careful assessment of the environmental impact of human interventions such as a channel deepening has become increasingly important.
The planned adaption of the Weser Estuary (German Bight, North Sea) is taken as an example to illustrate challenges for the interpretation of numerical modelling results in order to obtain reliable predictions for adaption related changes in hydrodynamics and salinity.

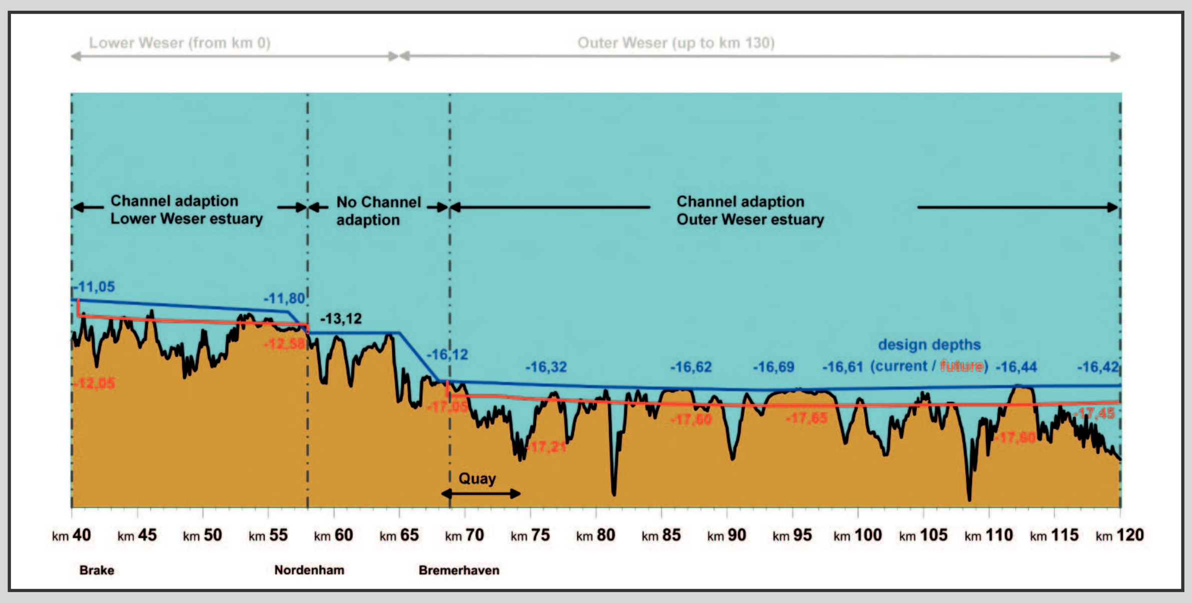

Figure 2: *Planned increases of design depths of the Weser (two separate adaptions of the Lower Weser and Outer Weser) in along stream direction.*

Methods

An Environmental Impact Assessment (EIA) for large coastal engineering projects usually contains a detailed numerical modelling study comparing the present-day situation (baseline) with the future situation including the planned channel adaption (scenario).
The numerical model applied here was UnTRIM in a high resolution 3D set-up.

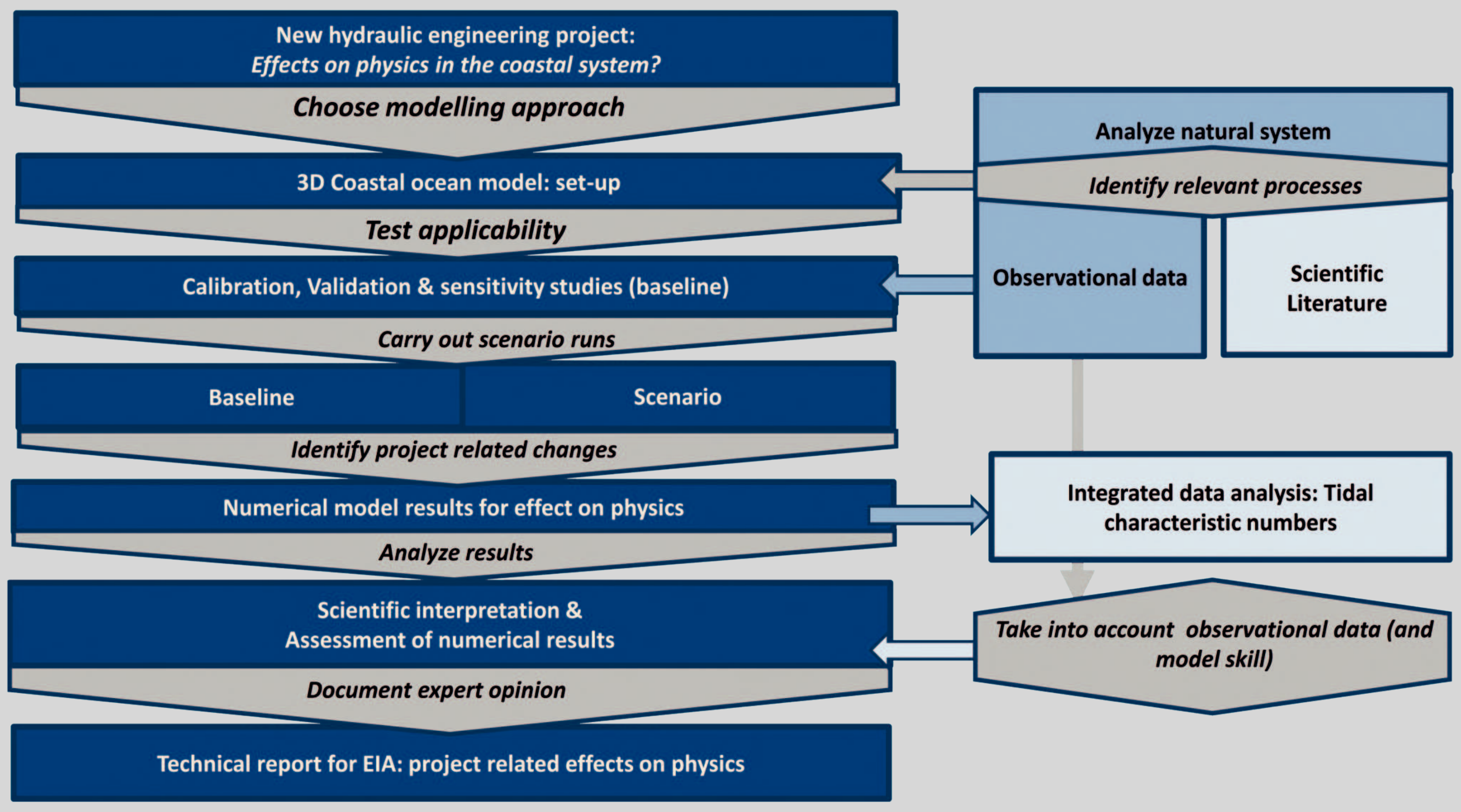

Figure 3: *Flow chart of the hydrodynamic modelling part of an EIA study.*

Research Question

The underlying estuarine physics of the effects of a channel deepening are well understood, but quantifying changes due to the channel deepening alone is less straightforward. This becomes especially evident when trying to identify changes due to anthropogenic interventions based on measurements in highly variable natural systems, e.g. for salt intrusion.

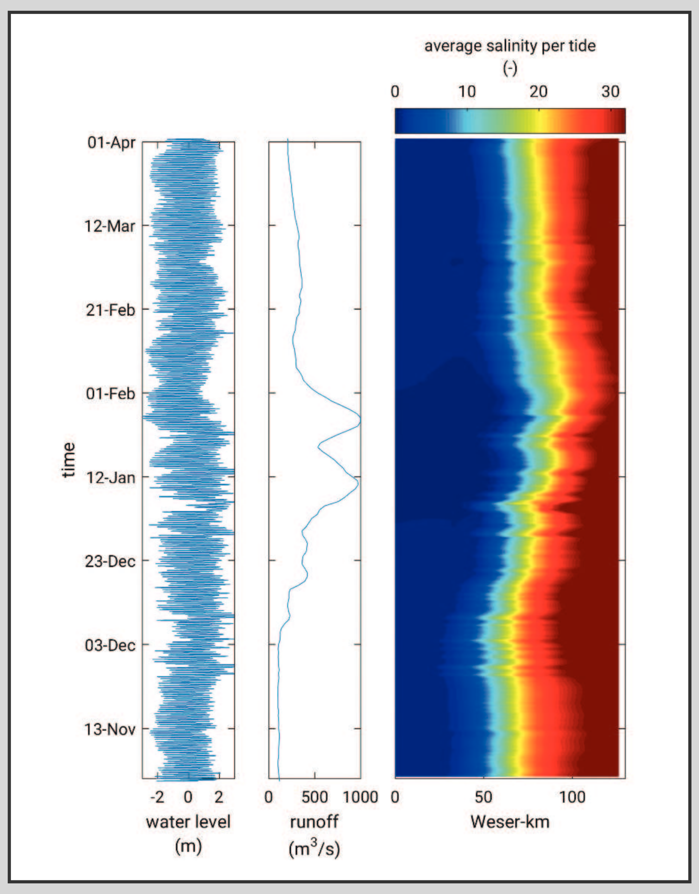

Figure 4: *Hovmöller diagram of salinity in along stream direction (right) and forcing due to changing water levels (left) and river runoff (middle).*

Changes due to the channel deepening in tidal high water may be different for spring and neap tides or the effects on salinity may be different for different hydrological situations. In the past commonly a representative spring-neap-cycle for specific scenarios (e.g. low or high river runoff) was chosen in order to assess adaption related changes. This approach was extended in order to overcome the need for specifying certain scenarios but rely on natural variability itself.
As the quantification of adaption-related changes is the basis for ecological or financial compensation measures in the following EIA, they need to be highly reliable and specific ("one number"). As an example, farmers may get compensation for the adverse effect of higher salinity in riverine water which is used for feeding their cattle.

Figure 5: *Typical landscape and agricultural land use in the Weser estuary.*

Mechanisms

The general physical mechanisms of a channel deepening consist among other things of a reduction of effective roughness. Less flow resistance yields an increase of tidal energy input into the estuary and results in higher current velocities, a stronger intrusion of saline water and frequently an increased accumulation of fine sediments.

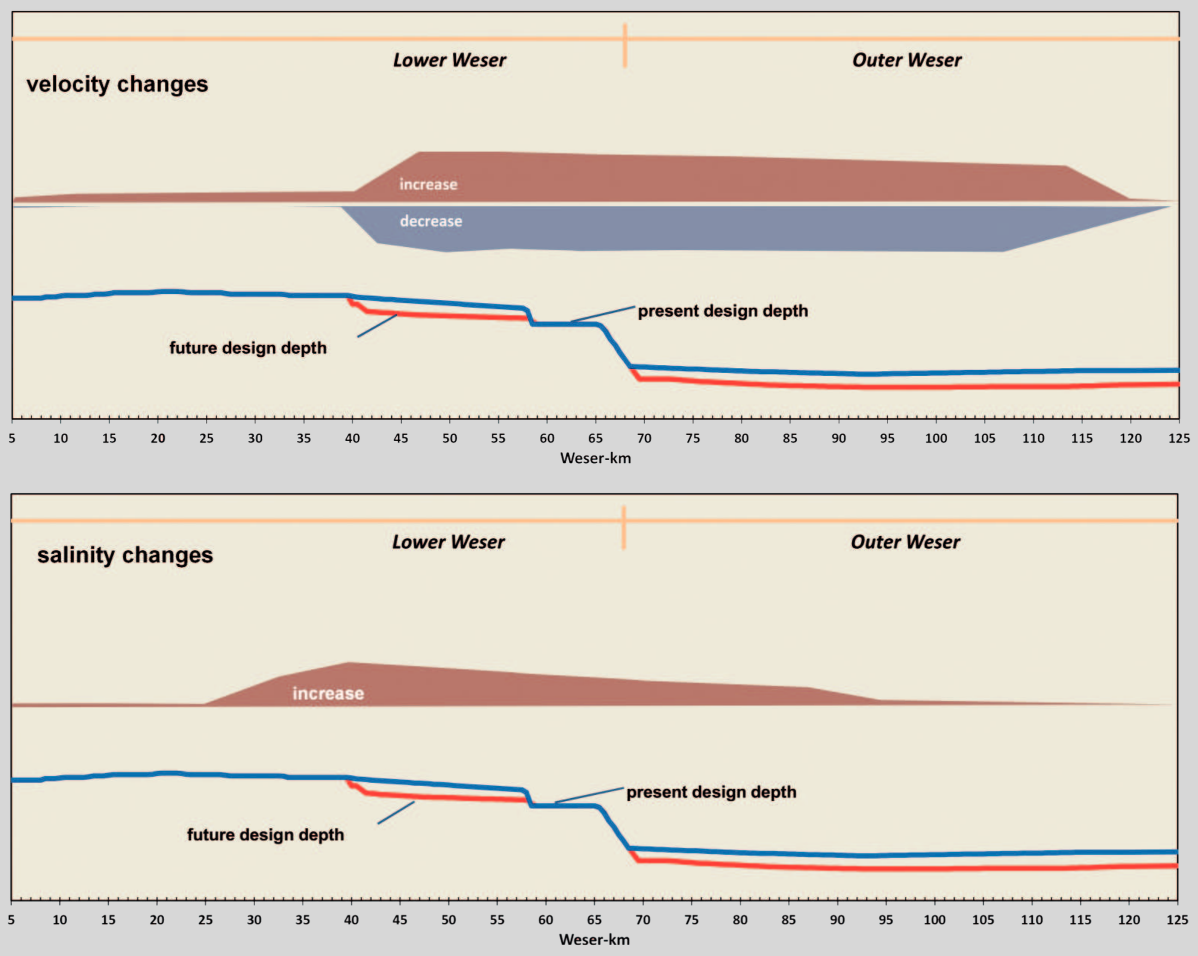

Figure 6: *Schematic changes due to the channel deepening for current velocity (upper) and salinity (lower)*

Results

For the EIA of the Weser Estuary, the numerical modeling results cover a full hydrological year with its natural variability. In order to get a robust estimate for the mean value of adaption related changes, the 5%- and 95%-percentiles of the whole year are computed which serve as upper and lower bound of the mean.
Interestingly, the results suggest, that adaption related changes of some tidal characteristic values such as tidal high water are largely insensitive to the specific hydrological situation (spring vs. neap tide). Therefore the results can be also seen as a corroboration of the previous approach where estimates were based on shorter model simulations.

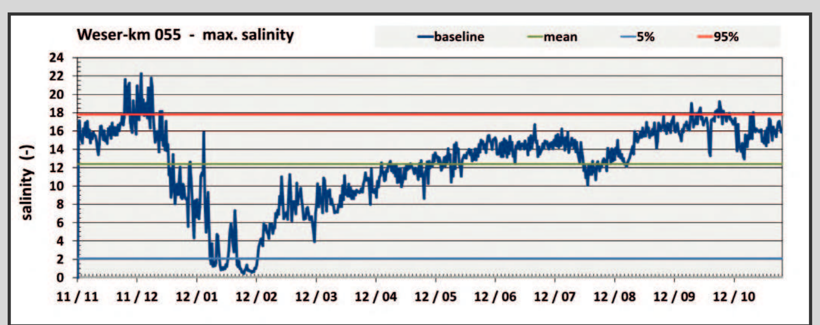

Figure 7: *Time-series of max. salinity per tide at Weser-km 55 over a hydrological year for the baseline togehther with mean, 5%- and 95%-percentile. The location is in the mixing zone of the Weser.*

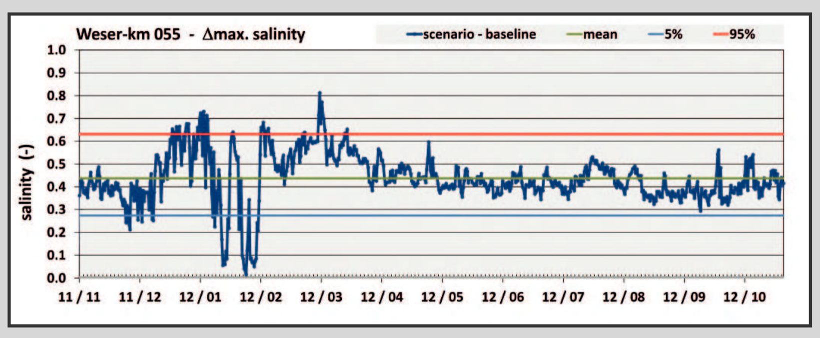

Figure 8: *Time-series of adaption related changes (scenario - base line) of max. salinity per tide at Weser-km 55. Note the robust changes over most of the time covered.*

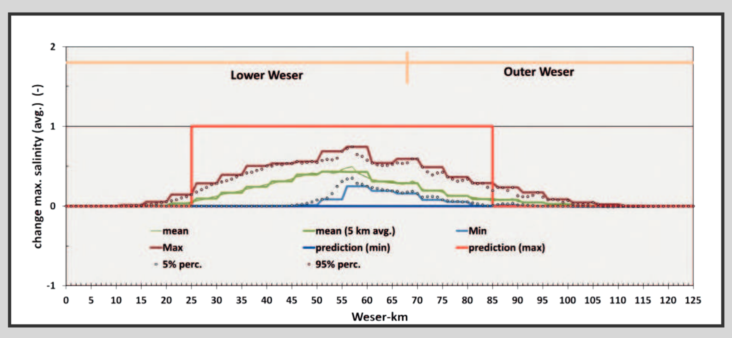

Figure 9: *Robust predictions of changes in salinity based on numerical modelling results (red) for use in the EIA.*

Conclusions

Numerical modelling studies for Environmental Impact Assessments (EIA) for large coastal engineering projects usually rely on relatively short modelled time series (i.e. a spring-neap cycle). This requires a careful definition of relevant scenarios to be considered (e.g. low river runoff). This approach was extended here by modelling a full year and analyzing natural variability instead of specific scenarios.
From these data robust predictions for channel adaption related changes in hydrodynamics have been obtained based on higher statistical percentiles. On the one hand this may be an approach for future studies as the dependence on specific scenarios is reduced. On the other hand, the results suggest that anthropogenic changes (of average conditions) are not very sensitive to specific hydrological conditions.

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