Can estuarine circulation save the tidal flats?

Morphodynamic response of the Wadden Sea to climate change

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In Short

- Sea-level rise threatens the tidal flats.
- Estuarine circulation and tidal straining generally import sediment into a tidal basin.
- 3D morphodynamic simulations are needed to include these processes.

The Wadden Sea in the German Bight (Fig. 1), stretching from Den Helder in The Netherlands to Skallingen in Denmark, is a prototype for a coastal region under threat by sea-level rise. Over 50% of the Wadden Sea area consists of intertidal flats, which are submerged by water only during a part of the tidal cycle. This shapes the unique coastal ecosystem of the Wadden Sea, which could survive the sea-level rise of the last centuries by accumulating sediment from the North Sea at a rate which made the intertidal flat level keeping pace with sea-level rise.

***Figure 1:** The Wadden Sea in the German Bight.*

The key question is up to which rate of increased sea-level rise the sediment accumulation in the Wadden Sea will be sufficient. This is a complex question since the sediment fluxes into the Wadden Sea depend on the rate of sea-level rise itself, on other consequences of climate change as well as on sediment availability in a highly non-linear way.

It is known that net sediment fluxes are driven by tidal asymmetries caused by non-linear overtides and horizontal density differences due to net-precipitation and run-off as well as cooling or heating of the Wadden Sea [1]. The characteristics of non-linear overtides depend on sea-level rise (more energetic tides, increased tidal range) and the horizontal density gradients may substantially alter with climate-related changes in precipitation/evaporation and cooling/heating. Furthermore, sediment fluxes are sensitive to wind intensity and direction, which are also susceptible to climate change.

Although the knowledge about sediment dynamics in the coastal zone allows for realistic model simulations of sediment transport in the Wadden Sea, projections of morphodynamic change are still using highly simplified, vertically integrated (2D) models [2]. The knowledge gained from such models is therefore strongly limited.

The leading objective of this project is therefore to assess possible morphological responses of the Wadden Sea to increased sea-level rise and other aspects of climate change under conditions of changed sediment availability, using a process-based three-dimensional (3D) model. With this, the major driving forces for sediment transport in the Wadden Sea are included.

First, these simulations were carried out in a systematic way using idealised bathymetries, identifying the most critical processes of morphodynamic change in the Wadden Sea. Using these bathymetries, impacts of sea-level rise on the sediment accumulation can be assessed in combination with other changes of external forcing (precipitation-evaporation, cooling-heating, wind-wave forcing).

Second, the morphodynamic evolution of a realistic tidal basin, the Sylt-Rømø bight, is going to be simulated with a 3D model. The results of previous, 2D simulations are presented in Fig. 2. The left panel shows the initial bathymetry, the upper panel the simulated bathymetry after 90 years without sea-level rise (reference scenario, REF) and the lower panel the same with a high sea-level rise (HSLR) of about one meter per century. The right panel illustrates their difference, i.e. the effect of high sea-level rise compared to no sea-level rise: Red colour marks erosion, blue accretion of the sea bed. The accretion is less than one meter (light blue) on the tidal flats, which indicates that the flats are likely to drown for a sea-level rise higher than one meter per century [2].

We expect the results of the 3D simulations to be

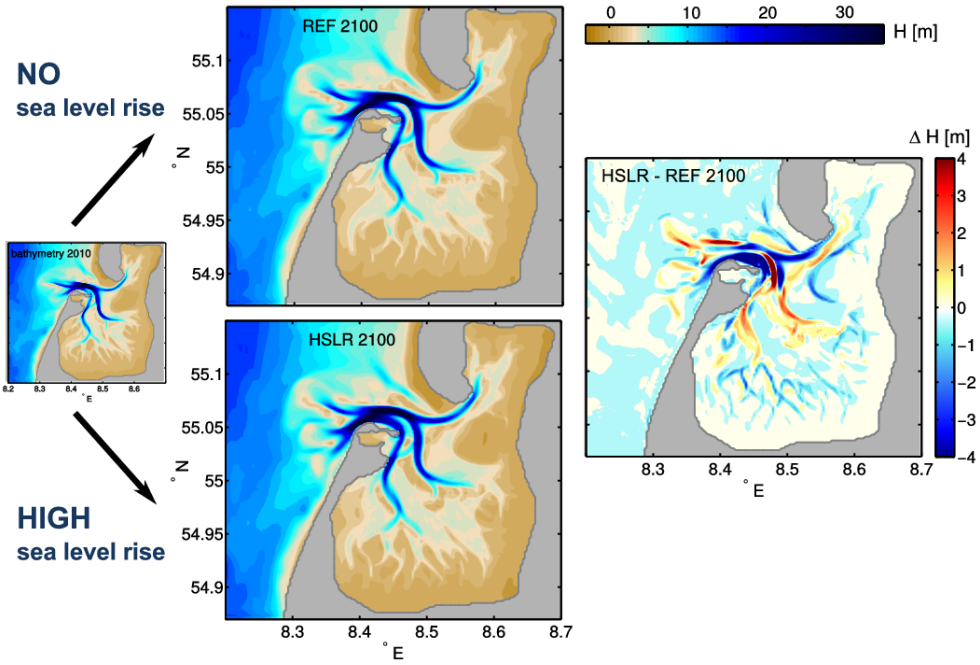

Figure 2: *Results of 2D simulations of the Sylt-Rømø bight [2]. See text for description.*

more optimistic. As they include processes like estuarine circulation and tidal straining, more sediment import into the tidal basin and thus more accretion of the sea bed can be anticipated.

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More Information

[1] J. Becherer, G. Flöser, L. Umlauf, and H. Burchard: Estuarine circulation versus tidal pumping: Sediment transport in a well-mixed tidal inlet. *J. Geophys. Res.* **121**(8): 6251–6270 (2016) doi:10.1002/2016JC011640.

[2] J. Becherer, J. Hofstede, U. Gräwe, K. Purkiani, E. Schulz, and H. Burchard: The Wadden Sea in transition - consequences of sea-level rise. *Ocean Dynam.* **68**(1): 131–151 (2018) doi:10.1007/s10236-017-1117-5.

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