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Benthos as a key driver of morphological change in coastal regions

Peter Arlinghaus et al.

Correspondence to: Peter Arlinghaus (peter.arlinghaus@hereon.de) and Wenyan Zhang (wenyan.zhang@hereon.de)

Supplement

Implementation of storm impact

In order to implement the impact of storm events, elevation data at the Lighthouse Alte Weser gauge station (Fig. 1; Wasserstraßen- und Schifffahrtsverwaltung des Bundes WSV) were used. First, storm events were identified based on peak water levels in a 24h averaged time series (green line in Fig. S1). In the model, the elevation was increased on the boundary for 48 hours before and after such a peak, according to the difference between measured and modeled data, combined with a ramp up and a ramp down function (Fig. S1). The impact of storm events was implemented in terms of water level change at the open boundary. Other changes like wind-wave height were not considered.

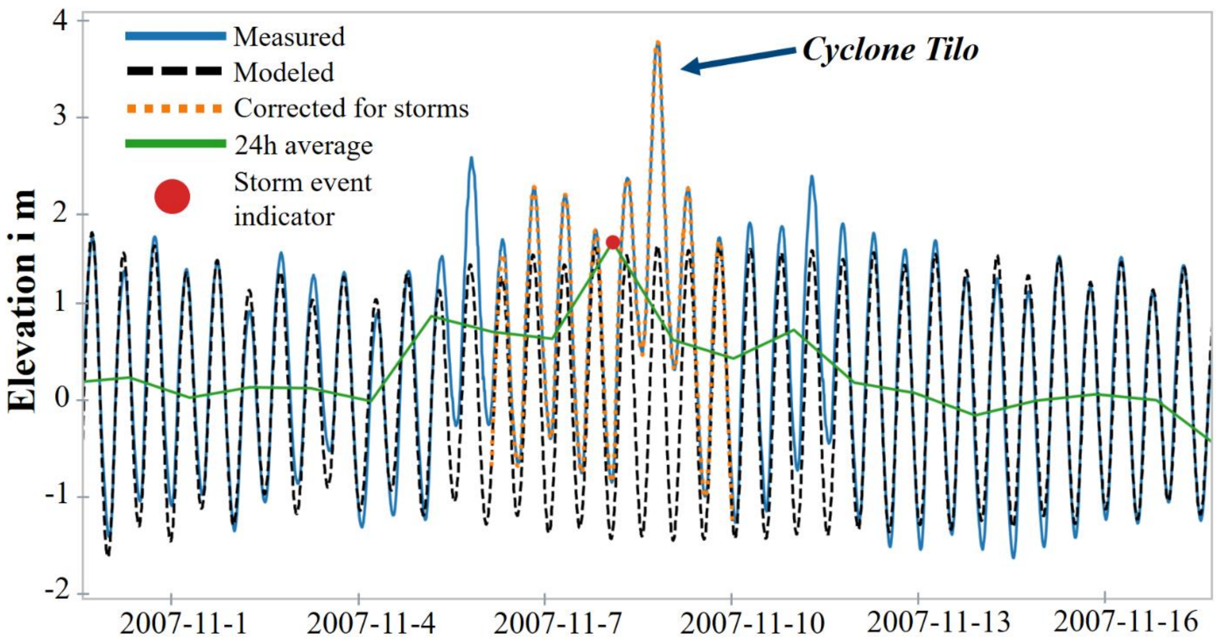

Figure S1. Measured and modeled elevation at Lighthouse Alte Weser gauge station. Strong peaks (red) in average elevation (green) are identified as storm events. The orange line indicates the corrected elevation values imposed on all open boundaries 48 hours before and after a storm event.

SAM model

Based on benthos abundance and biomass in sub- and intertidal areas at 160 stations in the Jade Bay (NLWKN, Schückel and Krönkcke, 2012) a species abundance model was build based on decision trees. The *ExtraTreesRegressor* function from the *scikit-learn* (Pedregosa et al., 2011) was chosen to both derive a species abundance and a species biomass map in the study area. The results are shown in Fig. 2.

The model was trained with 90% of the stations as training data and 10% as testing data. This process was repeated 30 times, each time picking random samples from the data. The average deviation in percent between modeled and testing data for each station was calculated. The model generating smallest error was chosen for this study. The deviations are displayed in Fig. S2. For *Hediste diversicolor*, *Macoma balthica* and *Cerastoderma Edule* at the majority of the stations the deviations are well below 20%. For *Peringia ulvae* and *Tubificoides benedii* approximately 2/3 of the data points lie below 20% deviation while the other data points can have very strong deviations.

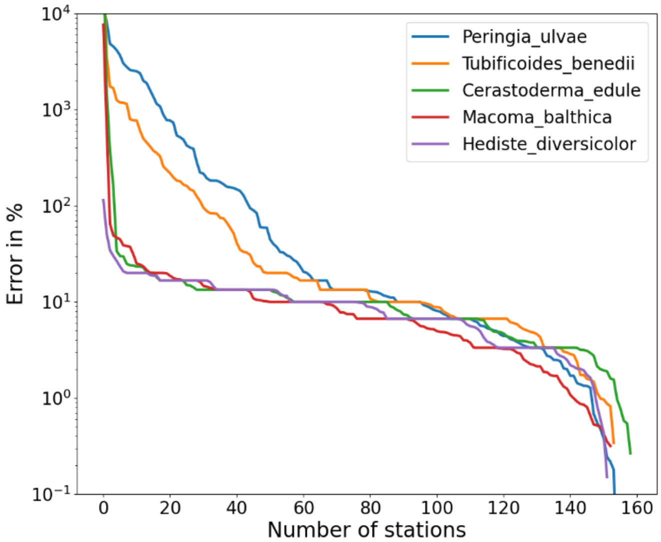

Figure S2. Deviations in percent between the modeled data and the testing data for each of the five macrobenthos species ordered from highest to lowest.

Benthos scaling

Figure S3 shows the scaling factor for erosion rate (a) and shear stress (b) depending on biomass, abundance and resulting metabolic rate according to Cozzoli et al. (2019). A detailed description of the calculation is given in the main text in chapter 3.2.1. g_d and p_d cover values between 0 and a positive real number where the values between 0 and 1 indicate an decrease in the value of erosion rate E_r or critical shear stress τ_c respectively and the values above 1 an increase. Since the whole range of decreasing values is depicted by a unit length of 1 while the range of increasing values is much larger, only in this plot, the values between 0 and 1 are inverted an multiplied by -1. As an example:

$$p_{d,plot} = 3 \quad \rightarrow \quad \tau_c = \tau_c^0 \cdot p_d = \tau_c^0 \cdot 3$$

$$p_{d,plot} = -3 \quad \rightarrow \quad \tau_c = \tau_c^0 \cdot p_d = \tau_c^0 \cdot 1/3$$

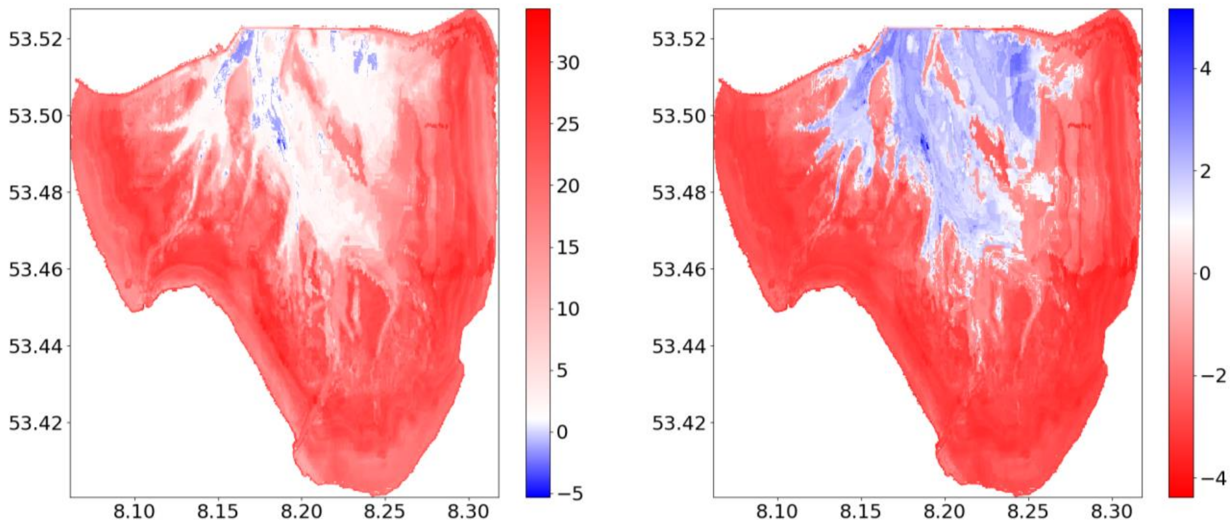

Figure S3. Estimated values for bioturbation functions g_d (left) and p_d (right) for the Jade Bay. Blue color indicates stabilization effect and red color destabilization effect.

Sediment origin

Figure S4 shows the origin of sand and mud in the main channel and tidal basin in the biotic modeling scenario, respectively. Figure S4a shows the origin of deposited material in the main channels. The origin of sand which enters the main channel from the Jade-Weser region is small, and a few points within the Jade Bay have a particularly high contribution to the deposition in the main channel. Figure S4b shows that around 70% of the mud which ends up in the tidal basin originates from the tidal flats from the Jade and Weser region.

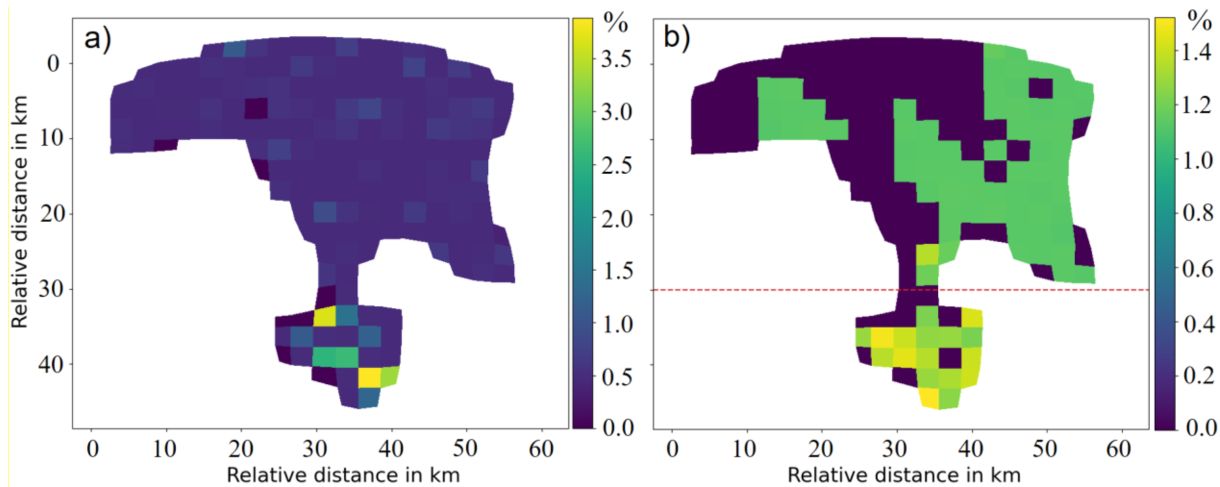

Figure S4. Areas of origin of sand accumulating in the main channel (a) and of mud accumulating in the tidal basin (b) in the biotic scenario.

Change in flow field due to seagrass

The ratio between flood and ebb volume flux is depicted in Figure S5a & b. It shows that in both the scenario with seagrass (b) and the reference scenario (a) the main channel is flood dominated while the tidal flats are mostly ebb dominated, indicating that the majority of water enters the basin through the main channels and leaves through the tidal flats. However, it can be clearly seen, that in the areas with seagrass present the ebb domination is strongly enforced. The change in percent between a) and b) is shown in Figure S5c. Despite the strong changes in currents in the aforementioned areas the main channel experiences a decrease in flood dominance which can be ascertained to the additional friction cause by the seagrass meadows, leading to increased outflow through the main channel. The change in mud content seen in Figure 9c coincides with the change in flood by ebb current depicted in Figure S5c.

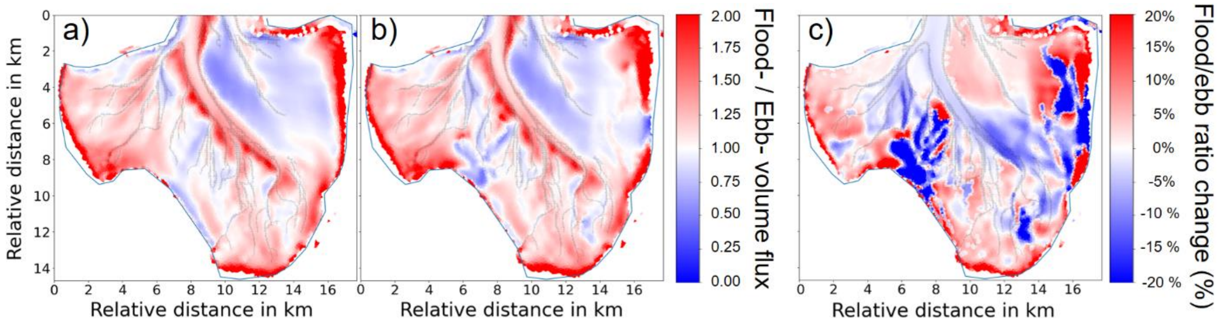

Figure S5. Ratio of the flood current to the ebb current in the Jade Bay in run abio_no_TS_10 (a) and gra_no_TS_10 (b). Plot c) shows the changes between a) and b) in percentage.

Morphological change on channels and tidal flats

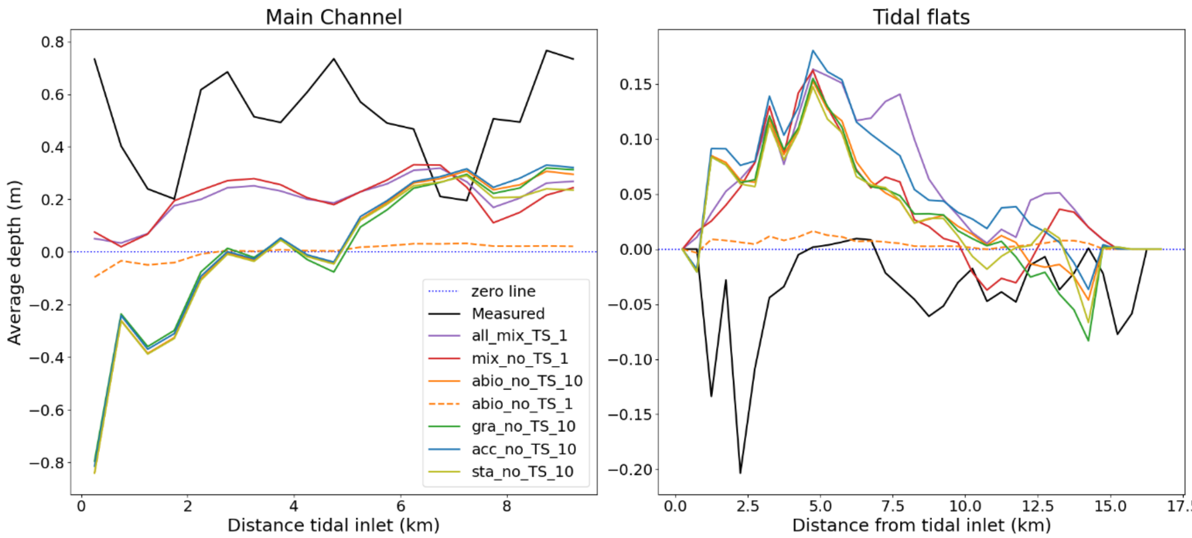

Figure S6. Average depth change in the main channel (a) and the entire bay excluding the main channel (b) calculated from the measured data and seven representative model experiments between 2001 and 2009. The 0 km in the x-axis marks the position of the inlet directed into the basin. Note that the measured value for the tidal flats is mostly within the measurement uncertainty (represented by the standard deviation of difference between the 2001 and 2009 field data).

Sediment concentration

Simulation results for sediment concentration (Fig. S7) are in the same range as measurements from the Jade Bay which range from 40-90 mg/l with peak values of 200 mg/l, measured over a 6 hour flood period (Becker, 2011). Other modeling studies from the Jade Bay show comparable amounts of suspended sediment as found in our simulation of Jade Bay (Kahlfeld and Schüttrumpf, 2006).

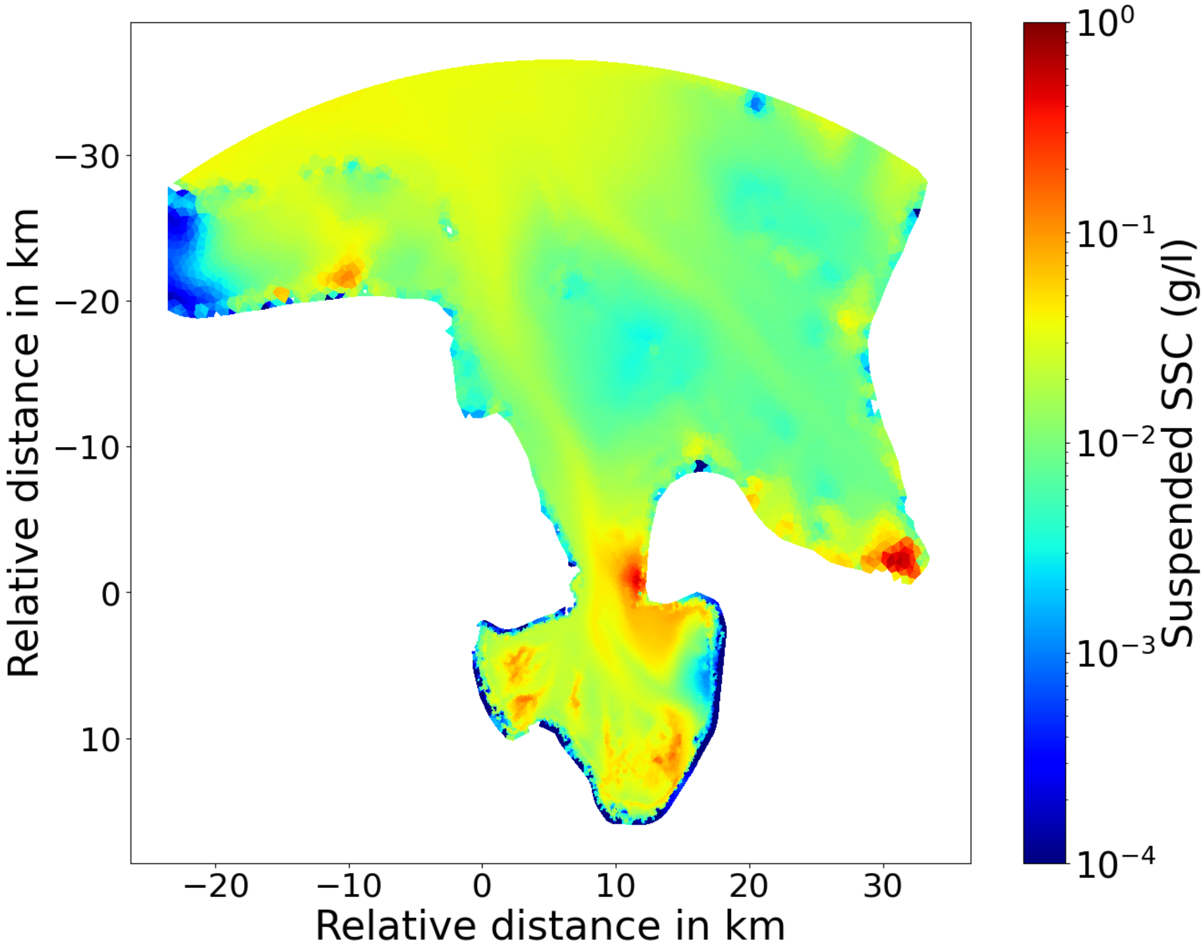

Figure S7. Averaged sediment concentration in Jade Bay in simulation all_mix_TS_1.

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