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Comment on esurf-2021-66

Olivier Gourgue et al.

Author comment on "Biogeomorphic modeling to assess the resilience of tidal-marsh restoration to sea level rise and sediment supply" by Olivier Gourgue et al., Earth Surf. Dynam. Discuss., https://doi.org/10.5194/esurf-2021-66-AC1, 2021

We thank both referees for their careful review of our manuscript. We hereby provide a detailed response to all their major comments.

Response to Anonymous Referee #1

Comment #1 (on sea level rise rates)

IPCC sea level rise rate projections for the period 2005-2055 at the estuary mouth range between 4.8 and 6.3 mm/yr. These are median projections for Representative Concentration Pathways (RCP) 2.6 and 8.5 (IPCC, 2019). This is very much consistent with the reference value of 6 mm/yr used in our study. However, we also explain in the manuscript that this value of 6 mm/yr rather corresponds to the average rate of mean high-water level rise observed in the Scheldt Estuary over the last century, likely influenced by both global sea level rise and human-induced changes in the geomorphology of the estuary, such as dredging and dike construction (Section 2.3.1). These local IPCC projections also illustrate that our two additional scenarios (i.e., 0 and 12 mm/yr) are rather extreme. We can therefore reasonably assume that our study covers the range of possible future sea level rise rates in the area. We will clarify this in the revised manuscript.

Comment #2 (on O'Brien's law)

We agree that we should not refer to O'Brien's law in our analysis of channel cross-section surface area vs. overmarsh tidal prism. To remain consistent with the observations against which we compare our model results, we here follow the approach used by Vandenbruwaene et al. (2013, 2015) who argue that overmarsh tides (i.e., which overtop the mash platform level) are especially relevant in such analysis for tidal marsh channels, because maximum channel flow velocities typically occur when the surrounding platform is flooded and drained (Bayliss-Smith et al., 1979; Pethick, 1980; French and Stoddart, 1992). We will remove all references to O'Brien's law in the revised manuscript.

Comment #3 (on suspended sediment transport)

We agree and will remove these sentences from the revised manuscript.

Comment #4 (on vegetation input parameters)

We have explored the model sensitivity to various vegetation input parameters, including the lateral expansion rate, but not in a systematic way for the present study. This is a very relevant topic, but we have already addressed it in a previous paper (Schwarz et al., 2018) and we further explore it in another paper in preparation. In general, fast colonizers (characterized by high number of establishing seedlings that produce homogeneous vegetation patterns) favor stabilization of pre-existing channels and consolidation of the landscape configuration, while slow colonizers (characterized by low number of establishing seedlings able to expand laterally, resulting in patchy vegetation patterns) facilitate the formation of new channels and thereby actively facilitates further landscape self-organization (Schwarz et al., 2018).

However, the scope of the present paper is on tidal marsh restoration and how different restoration design options can impact the biogeomorphic development of tidal marshes. That is why our model scenarios focus on real-life restoration design options (i.e., the size of the created tidal inlets), using fixed vegetation parameter values that are representative for the species that are present in the area. Adding model scenarios with various vegetation parameter values would be an interesting theoretical model experiment, but not relevant for real-life marsh restoration, and hence would deviate from the scope of this paper. Nevertheless, for the sake of completeness, we will incorporate some examples as supplementary material of the revised manuscript, which illustrate that vegetation input parameters have rather limited impact on the long-term morphodynamics in the case studied here.

The vegetation module is implemented such as each species can have a different mean expansion rate. In this study, the mean expansion rates for middle-marsh (*Scirpus maritimus*) and high-marsh (*Phragmites australis*) vegetation are determined based on remote sensing and literature data (see Table S3). This is pure coincidence if both species end up with the same value. However, that does not mean that both species have the same competitive ability, as the vegetation module is implemented in a hierarchical way (see Section S1.2 and Table 3). Higher-rank species can displace lower-rank species, but not the other way around. Lower-rank species can only colonize after higher-rank species have died off. On the long term, high-marsh vegetation (rank 3) will therefore always outcompete middle-marsh vegetation (rank 2) in its own niche.

The grid resolution for vegetation dynamics is indeed dependent on the imposed expansion rate and numerical timestep. The number of iterations in the vegetation module (i.e., the ratio between the simulated period – one year – and the numerical time step) is determined as a function of the grid resolution and the mean expansion rate, by means of Equations S16 to S19 (supplementary material).

Response to Anonymous Referee #2

Comment #1 (on the threshold value for shear stress)

The critical shear stress for bed erosion is 0.5 N/m^2 for the fresh layer (i.e., sediments deposited during the simulation) and 0.8 N/m^2 for the compacted layer (i.e., the sediment bed soil already present before marsh restoration; see Table S2). This approach is consistent with a previous study on consolidation of accretional mudflats for the same tidal marsh restoration project (Zhou et al., 2016). We will clarify this in the revised manuscript.

Comment #2 (on the biological component of accretion)

Sediment accretion in marshes of the Scheldt Estuary is dominated by the external supply by tides of suspended sediments, mostly of mineral nature, while organic matter only accounts for about 10% of the measured accretion rates (Temmerman et al., 2004). For this reason, our model does not explicitly simulate organic matter accretion locally produced by vegetation. However, organic matter accretion can be considered as implicitly compensated for by model calibration for total sediment accretion on vegetated platforms (Section 2.4.1). The calibration is indeed based on observed elevation changes, hence total accretion rates, including both mineral and organic contributions. We will clarify this in the revised manuscript.

Comment #3 (on deposition of fine sediments)

The existence of a minimum depositional velocity (or shear stress) below which fine particles remain in suspension is debated in the literature. In our model, we follow one of the well-established arguments that such threshold does not exist, and that it rather represents a threshold for erosion of freshly deposited sediments (Winterwerp, 2007). This approach agrees with field observations in the Chesapeake Bay (Sanford and Halka, 1993) and is often adopted in recent biogeomorphic models (e.g., Adams et al., 2016; Bryan et al., 2017; Mariotti, 2018; Zhang et al., 2019; Brückner et al., 2020). We will clarify this in the supplementary material of the revised manuscript, where the hydro-morphodynamic module is described in detail.

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