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Earth Surface Dynamics Discussions

Interactive comment on "Effects of mud supply on large-scale estuary morphology and development over centuries to millennia" *by* Lisanne Braat et al.

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We would like to thank anonymous referee 2 for the constructive review. The comments related to the description of the model help to make the paper much clearer.

The first comment drew our attention to the point that long term morphological simulations with a morphological factor and mud were never tested before in the literature. However, during the earlier modelling stages of this research we did some tests with other morphological acceleration values (10 to 1000) with only sand and different types of morphological acceleration factors, for example related to the sedimentation and erosion of one tidal cycle. We initiated this because we found it problematic that by using a morphological factor in tidal systems the tidal half-period over which sediment is transported in one direction is basically multiplied as well. Nevertheless, with these tests we found that the most widely used morphological factor we now use in the paper is actually the least different from runs with lower factors in these types of models (Roelvink, 2006 and pers. comm. 2016). In the next manuscript two additional model runs with lower morphological acceleration factors will be included as an appendix.

For the development of bended channels in the 2DH model, the second comment, we indeed used a parameterisation for the deflection of the bed shear stress vector depending on the spiral flow that is calculated from local curvature. We added this to the methods section under numerical model description.

The third comment suggests that section 3.6 should be moved to the discussion. We agree that this section includes some interpretation, but we think this subsection includes new results that were not described in earlier paragraphs. Furthermore, the results are not connected to any literature or larger context. Therefore, we would like to leave this section at the end of the results just before the discussion.

In the next part, italic sentences are comments of the reviewer that we want to address individually.

P3, L2: Le Hir et al., (2011) and I'm sure others already performed sediment transport simulations with sand and mud mixtures, please be more careful with "always". For instance, the authors missed a couple of paper by Geleynse (e.g. Geleynse et al., 2011) where Delft3D is applied to idealized deltas and where both sand and silts are considered. These studies might also be considered for the discussion in section 3.2. - We specified the situation where we used always. The paper of Geleynse et al. (2011) does not contain mud, and is therefore less relevant than the other delta papers that were mentioned. In this paper we focus on estuaries, but because limited studies were done on estuaries with mud we added a few delta papers that work with mud.

P5, L24: if Delft3D is used in 2DH, then the Saint-Venant equations are solved, which correspond to the depth integrated Navier-Stokes equations. Also, not that, as written, *eqs. (1) to (3) do not represent the effect of short waves.* - We believe Saint-Venant equations are 1D, not 2D. We will refer equation (1) to (3) as the shallow water equation in the next manuscript. The effect of short waves is solved separately in SWAN and this effect is therefore not included in these equations.

P7, eq. (4): how is solved the Exner equation to compute bottom change from the divergence of bedload transport? How are treated transition zones between where Pm<Pm,cr and Pm>Pm,cr? - We will clarify the bottom change. The transition zone of the critical mud content is quite abrupt as explained in last paragraph of section 2.1.

P8, Table2: "transverse slope parameter", do you mean a slope limiter? - No, these are the parameters for equation 7 in which sediment transport on transverse slopes is deflected as a function of slope and sediment mobility.

P10, L5-9: with such a coarse resolution and small waves, wave-induced processes cannot be represented properly. As a rough guideline, the grid should have a least 5 elements across the surfzone to represent properly wave-induced currents and setup. Here I assume that only wave stirring of sediment is represented in the model, and possibly a slight increase in bed shear stress. Please verify and clarify. - Correct, we only used the waves for wave stirring to bring the mud in suspension; we clarified this more clearly in the method section. Initially we wanted to simplify the model by ignoring waves in all model runs, but the mud deposition at the borders (with a marine source of mud) generated instabilities as visible in Fig. A1. Therefore, it was necessary to add wave stirring to prevent deposition in these locations. Properly modelled wave-induced transport is very difficult to use in combination with the Engelund-Hansen transport equation that we use now. Wave processes are more commonly used in combination with the Van Rijn transport equations, but these equations produce less realistic patterns in long-term morphological simulations. Basically, we did not want to sacrifice bar-channel pattern for realistic wave transport.

P14, L4: there is indeed a phase difference of Pi/2 between water levels and velocities.

Do you mean that this phase lag does not vary too much along the estuary? This is not that clear on figure 4. - I think there is no phase lag, because when water levels are maximal or minimal, the velocity is exactly zero as you would expect without a phase lag.

P21, section 3.4: this is only a thought but is that possible that an estuary that imports mud from the sea has no mud import from the river? - The reason for this scenario is to develop understanding of sediment provenance. However, it is also realistic as one could see this as a case with an upstream dam which is a common cause of starvation of deltas and saltmarshes. The use of this scenario will be clarified in section 3.4.

P22, L12-13: is that realistic that the estuary closes in the absence of waves? I think that in reality, the only estuaries that are closed are wave-dominated. - We agree, that the formation of a spit by waves is the most likely reason that an estuary will close, but if the velocities generated by the tidal flow are very low and enough sediment is available closure without waves should be possible as well. We interpret our modelling to show there is a continuum from river-dominated estuaries to deltas, where the transition to a delta means that the estuary is mostly closed except for a channel with approximately the same width as the upstream river.

P22, L21-24: this is not clear at all why waves would rise high water level and increase tidal range. According to previously published studies (e.g. Wargula et al., 2014; Dodet et al., 2013), wave breaking on the ebb shoal rises the water level in the estuary/lagoon by about 10% of the significant wave height at breaking. Since surf zone can hardly be represented with the resolution employed in this study, I don't see how waves can have any effect other than stirring sediments and, marginally, increase bed shear stress. Please clarify this section. - We will look into the cause of these higher water levels. We cannot give a good explanation yet. For now it seems that the waves are not directly the cause but it is an effect of morphology caused by the waves because the difference does not occur at the beginning of the model.

P24, figure 9: how can an estuary without mud supply have large surface areas covered by mud? - This is not the case. There is probably some confusion about the blue and brown lines. The brown lines indicate mud-related parameters, blue lines are related to the shape and size of the estuary as explained in the caption. In (d) and (g) the brown line starts at zero. We checked whether the text in the manuscript was clear.

P28, L15-19: in reality, tides big enough to develop estuaries imply that the associated oceanic basin is large enough to have significant short-waves as well. Short waves tend to limit ebb-dominance and subsequent estuary enlargement. If required, you'll find a review in the introduction of Wargula et al. (2014). - We will add the effect of waves on ebb-dominance as a point of attention when interpreting the results.

Finally, all other minor comments were implemented in the new version of the manuscript.

References:

Geleynse, N., Storms, J. E., Walstra, D. J. R., Jagers, H. A., Wang, Z. B., and Stive, M. J. (2011). Controls on river delta formation; insights from numerical modelling. Earth and Planetary Science Letters, 302(1), 217-226.

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