Cohesive sediment in scale-experiments of estuaries

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1. Introduction

Mud plays an important role in alluvial estuaries in relation to ecological restoration and harbour maintenance but is rarely considered in long-term models of these systems. Over the past years, substantial progress has been made in long-term, morphological, numerical modelling with mud (Braat et al., in prep), however, physical experiments of estuaries have proven to be difficult. Recently, a novel tidal facility, 'the Metronome', was built in which self-evolving estuaries can be studied (pilot: Kleinhans et al., 2015). After successful experiments with sand we also started physical experiments with cohesive sediment. Our objective is to study the effects of cohesive sediment on the large-scale morphology of estuaries. We compare an experiment without cohesive sediment supply to one with cohesive sediment supply.

2. Methodology

The Metronome drives tidal flow by periodically tilting of the flume. By tilting the flume we exaggerate bed slope to create realistic sediment mobility on a small scale. To simulate the effects of cohesive mud we used 0.2 mm nutshell grains, because it has a low density and is therefore transported in suspension. Moreover, it becomes slightly cohesive, but less then real mud that would fixate the bed (van de Lageweg et al., 2016).

The experiments started with a flat sand bed with an exponential converging channel of 3 cm deep. 0.15 ml/s nutshell was supplied with a river discharge of 0.1 l/s during ebb. Waves were generated at the sea side during the flood phase. The maximum tilting slope was 0.004 m/m with a period of 40 s.

Bathymetry was collected every 500 to 1000 tidal cycles using Structure from Motion. Time lapse images were taken every tidal cycle from which we could obtain water depth by extracting the blueness of the water. In total the experiments ran for 15000 cycles.

3. Results and Discussion

At the start of the experiment morphological changes are fast, an alternate bar pattern develops and the initial shape starts widening. Within 300 cycles ebb-flood dominated channels develop as well (Fig. 1). The nutshell initially deposits on top of the bars but is later also found at the sides of the estuary and in abandoned channels. These deposition areas are generally near high water level and experience low flow velocities. Preliminary measurements suggest that due to nutshell deposition on bars, bars become higher in the run with cohesive sediment supply (Fig. 1). At the start of the experiment nutshell is only deposited upstream and then spreads downstream, though the concentration remains larger upstream which might be representable for hyper turbid conditions in real estuaries.

Due to the cohesiveness of the nutshell deposits, we observe the formation of steep banks and sides of bars that are subjected to undercutting. The cohesion increases the critical shear stress for erosion and influences the morphology. Widening of the estuary is less, or less rapid. Furthermore, overall dynamics of the estuary with cohesive sediment supply is lower than the experiment without supply. We observe less chutes and less migration.

4. Conclusions

The cohesive sediment was mainly deposited on bars and in smaller amount in abandoned channels and along the sides of the estuary. The overall width decreased and bars became slightly higher compared to the run without nutshell. Furthermore, cohesive sediment decreased morphodynamics and caused steeper banks to form.

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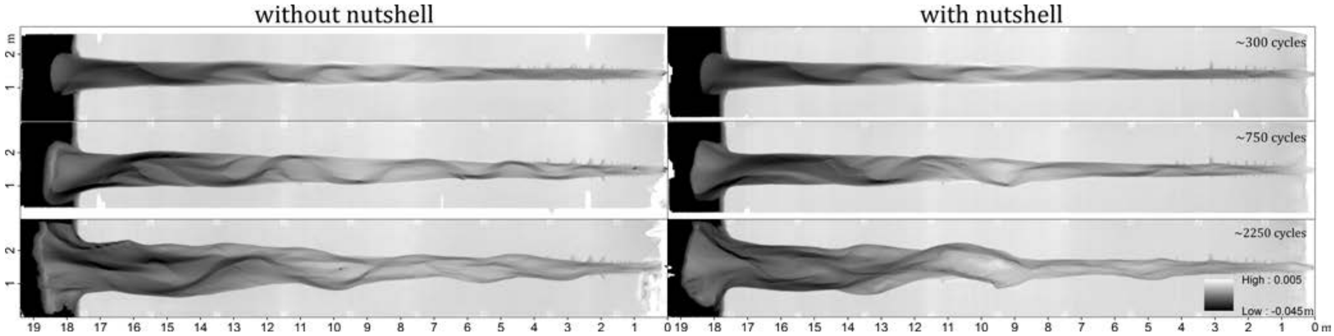

Figure 1. Bathymetry at three time steps of an experiment with (right) and without (left) cohesive sediment supply.