Morphological evolution of estuary mouths with wave-current interactions modelled over centuries

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1. Introduction

Estuaries are formed and evolve over centuries through complex interactions between inherited geology, marine and fluvial hydrodynamics, sediment supply and biota (Vos, 2015). However, long term modelling efforts have been performed under rather simplified settings that usually focus on simplistic boundary conditions (*e.g.*, Van der Wegen and Roelvink, 2008). Thereafter, this study combined effects of river inflow, tidal currents and waves on large-scale evolution of estuaries and effects of initial valley and coastal plain morphology thereon.

2. Methods

Idealised Delft3D model scenarios were based on spatial and temporal high-resolution geological reconstructions of Dutch estuaries (Figure 1) and their initial and boundary conditions (de Haas *et al.*, *submitted*). Initial bathymetry, tidal components (including full tides based on North Sea harmonics), river discharge and wave action have been tested combined. Especial attention was devoted into the effects of waves on sediment stirring, littoral drift and onshore transport on the estuary. Those processes were investigated by specifying offshore wave climate driving sediment transport for currents and waves interaction. The results were presented considering tides and river discharge with and without waves (see Figure 2). Tentative results were compared to geological reconstructions of the Dutch estuaries and to physical experiments performed in the Metronome, *i.e.* a 20x3m tilting flume where entire estuaries can be formed.

3. Results

The inclusion of waves created a wave dominant zone on both estuary flanks, in agreement with Davis (2012). Within this zone, sediment was transported into de river mouth, which was not observed when only tides and river discharge were considered. Therefore, net flood sediment transport into the estuary appears to be highly controlled by wave action, as shown in Figure 2B. This behaviour corroborates from hypothesis derived from our geological reconstructions as well as from physical experiments.

4. Conclusions

Sediment transported by alongshore littoral drift and onshore directed transport was observed inside the estuary due to wave action.

Nonetheless, our geological reconstructions show that relative importance of waves and fluvial input on estuary mouth development remains unclear. However, the combined effort among high resolution geological reconstructions, comprehensive numerical modelling and physical experiments were able to identify the effects of wave hydrodynamics and related transport that promotes flood directed net sediment transport that can lead to estuary closure or infilling. Combined with river discharge decline and sediment supply, this tentatively explains the closure of Holocene estuaries along the Dutch coast.

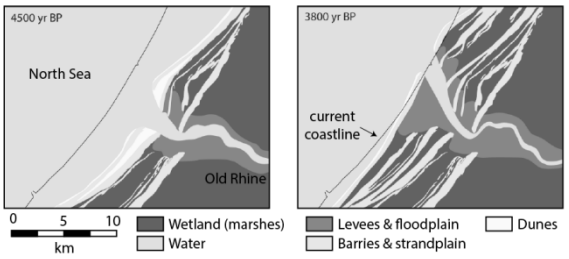

Figure 1. Geological reconstruction of Old Rhine river estuary (modified from de Haas *et al.*, *submitted*).

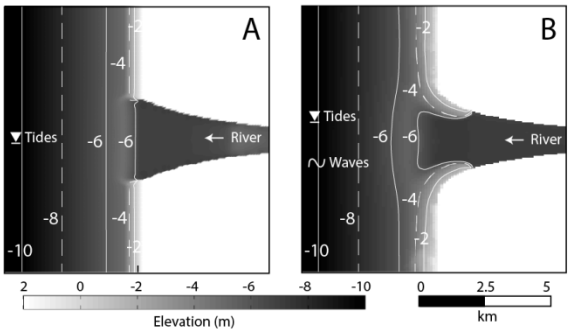

Figure 2. Preliminary numerical simulation of estuaries with tides and river discharge without waves (A) and with waves (B). Panel B shows the wave induced sediment transport on both flanks that are absent in (A).

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