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Modelling the morphodynamic development of intertidal shoals and sea-level rise adaptation

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Abstract

Introduction

Intertidal shoals are key features of estuarine environments worldwide. Climate change poses questions regarding the sustainability of intertidal areas under sea-level rise (SLR). In contrast to mudflats, sandy shoals have drawn limited attention in recent research. Inspired by channel-shoal systems such as the Wadden Sea (The Netherlands), our research investigates the mechanisms that drive the long-term morphodynamic development of sandy shoals and its SLR adaptation.

Methods

We apply a high-resolution (35×65 m) process-based model (Delft3D) to simulate the evolution of a sandy channel-shoal system in a schematized (20×2.5 km) tidal basin. An initial, mildly sloping bathymetry is subjected to constant semi-diurnal (M_2) tidal forcing, sediment supply, and small wind-generated waves (10-20 cm) modeled by SWAN.

Results

A positive morphodynamic feedback between hydrodynamics, sediment transport, and morphology causes the emergence of large-scale channel-shoal patterns (Figure 1). Over centuries, a steady morphological state develops by a balance between tides, sediment supply, and wave action.

SLR leads to increased flood dominance which triggers sediment import into the system. Shoals accrete in response to SLR. Seaward shoals near the open boundary sediment source have higher accretion rates compared to landward shoals. Similarly, on a shoal-scale, the highest accretion rates occur at the shoal edges near the channel sediment source. Waves help redistribute sediment supplied from the channels over the shoals by inducing resuspension. Mud fractions lead to faster, more uniform, accretion and muddier shoals under SLR.

Discussion

The morphodynamic adaptation lags behind SLR which eventually leads to intertidal area loss and increased shoal inundation. Implementing a large-scale, high-resolution approach, allowed for highlighting spatial variations in the morphological response. Short-term shoal dynamics by wind waves are of high relevance for the long-term morphological adaptation to SLR.

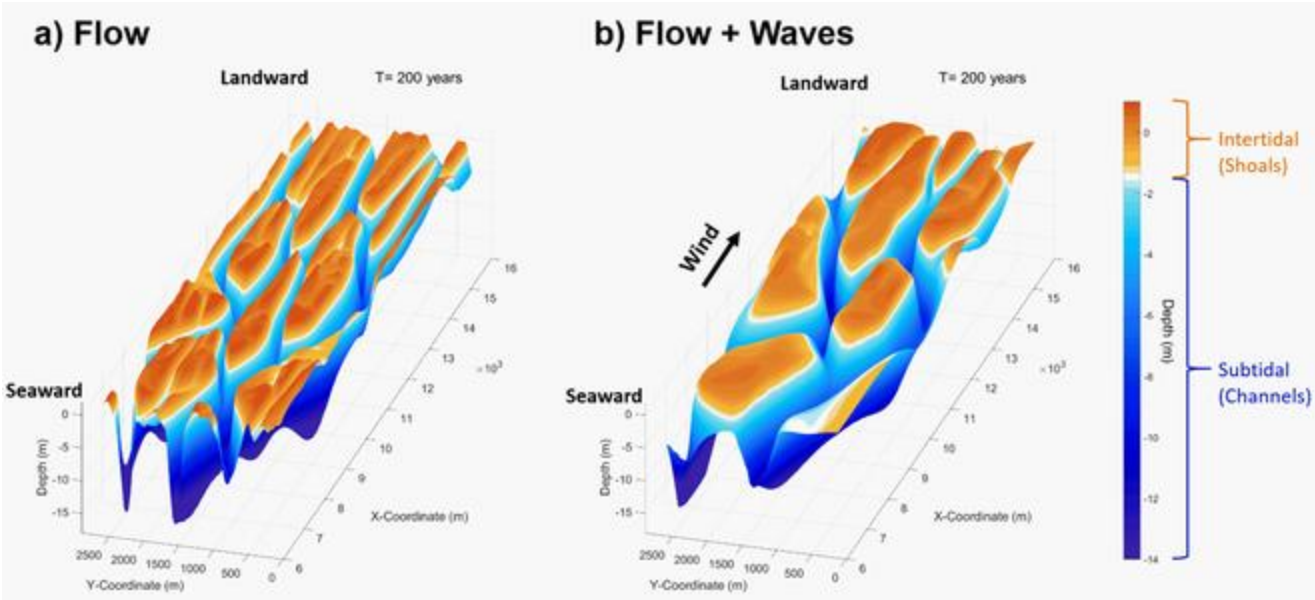

Figure 1. Modelled channel-shoal system under forcing conditions (a) without, and (b) with wave action.

Keywords

Intertidal, Morphology, Modelling, Sea-level rise