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Biological influences on morphology and bed composition of an intertidal flat

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Abstract

Biological activity is known to influence sediment strength at bed–water interfaces. However, its precise effect on geomorphology and on bed composition is not known. This paper proposes a parameterization of sediment destabilizing and stabilizing organisms on three parameters that describe the erosion and mixing processes of the sediment bed, namely the critical bed shear stress, the erosion coefficient and the bioturbation coefficient. This parameterization is included in a 3D sand–mud morphodynamic model to form the *sand–mud–bio* model. The performance of the *sand–mud–bio* model is demonstrated by testing it on the Paulinapolder intertidal flat in the Western Scheldt estuary of The Netherlands. Model results show that biological influences on sediment strength result in significant morphological change and bed composition variations. Destabilizing organisms always cause a significant decrease in mud content in the bed and an increase of erosion. On the other hand, stabilizing organisms can, but do not necessarily, cause an increase of mud content and additional sedimentation.

Keywords: biological activity; erosion; sedimentation; modeling; sand/mud; geomorphology; Paulinapolder; Western Scheldt

1. Introduction

Biogeomorphology deals with the study of the interaction between organisms and the bed they are living on or living in. For water management purposes, it is important to predict the geomorphological effects of human interventions or natural changes of an estuarine system. A better understanding of the geomorphological behaviour of estuarine systems requires better knowledge about the physical processes involved, the performance of geomorphological modelling techniques, the interaction between biology and geomorphology, and the biological influences on bed composition. Widdows and Brinsley (2002) state that, at present, "…lack of knowledge of the precise nature of biological-sediment interaction coupled with a poor understanding of how to parameterize biological effects so that they can be incorporated into numerical sediment transport and geomorphological models is a major impediment to progress".

Experiments on different mudflats in the Western Scheldt estuary (De Brouwer et al., 2000; Widdows et al., 2000a; Widdows and Brinsley, 2002), the Humber estuary (Widdows et al., 1998, 2000b; De Deckere et al., 2001; Widdows and Brinsley, 2002), the Danish Wadden Sea (Austen et al., 1999), and the laboratory

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(Quaresma et al., 2004) have shown that sediment strength parameters are influenced by several orders of magnitude when biological activity is high. Using an onshore–offshore 1D model of cohesive sediment erosion and deposition, Wood and Widdows (2002) have shown that biotic influences on sediment transport within the intertidal zone are significant.

This paper addresses the question of whether biological influences on three critical sediment strength parameters cause significant changes in geomorphology and vertical bed composition (namely sand/mud distribution). To date, adequate parameterization of biological influences for the purpose of sediment transport modelling is lacking. This paper introduces parameterization of such biological influences. Stabilization and destabilization effects of biota on erosion, and bioturbation have been parameterized on the basis of experimental data published by Widdows et al. (1998, 2000a,b) and Widdows and Brinsley (2002). This parameterization is incorporated in a process-based sand–mud model (Van Ledden and Wang, 2001; Van Ledden, 2002, 2003; Van Ledden et al., 2004b) to form the *sand–mud–bio* model.

The performance of the *sand–mud–bio* model is demonstrated by testing it on the Paulinapolder, a small intertidal flat located on the southern shore of the Western Scheldt estuary, approximately 6 km northeast of Terneuzen (51°25′N, 3°40′E) of the Western Scheldt estuary, The Netherlands (Fig. 1). A reference situation free of biological activity is set-up, which in general agrees with hydrodynamical data and agrees with the expected morphological behaviour of the flat. Then, three test cases are analyzed to study the biological influences on morphological change and bed composition.

2. Biostabilization and biodestabilization

Earlier researchers such as Jumars and Nowell (1984) recognized the effect of benthos on sediment transport. It has become clear that benthic species can stabilize the sediment by physically covering it (e.g. mussel beds) or by binding it by roots. Biostabilization can also result from extracellular polymeric substances (EPS) excreted by diatoms that cohere sediment (Austen et al., 1999; De Brouwer et al., 2000; Decho, 2000; Paterson et al., 2000; Riethmüller et al., 2000). During a bloom period in spring, large amounts of diatoms are known to form diatom mats, which are sometimes visible as a brownish jelly-like layer on the sediment (De Brouwer et al., 2000; Widdows et al., 2000b).

Some species that live on or below the surface (for instance Mudsnail, Cockle, Lugworm) destabilize the sediment due to deposit feeding activity or increased mixing (bioturbation, see e.g. Boudreau, 1997). This causes increased porosity and changing sediment composition (De Brouwer et al., 2000; De Deckere et al., 2001; Reise, 2002), which may result in less stable sediment (Widdows et al., 2000a,b).

Biostabilization and biodestabilization influence two sediment transport parameters in particular: the critical

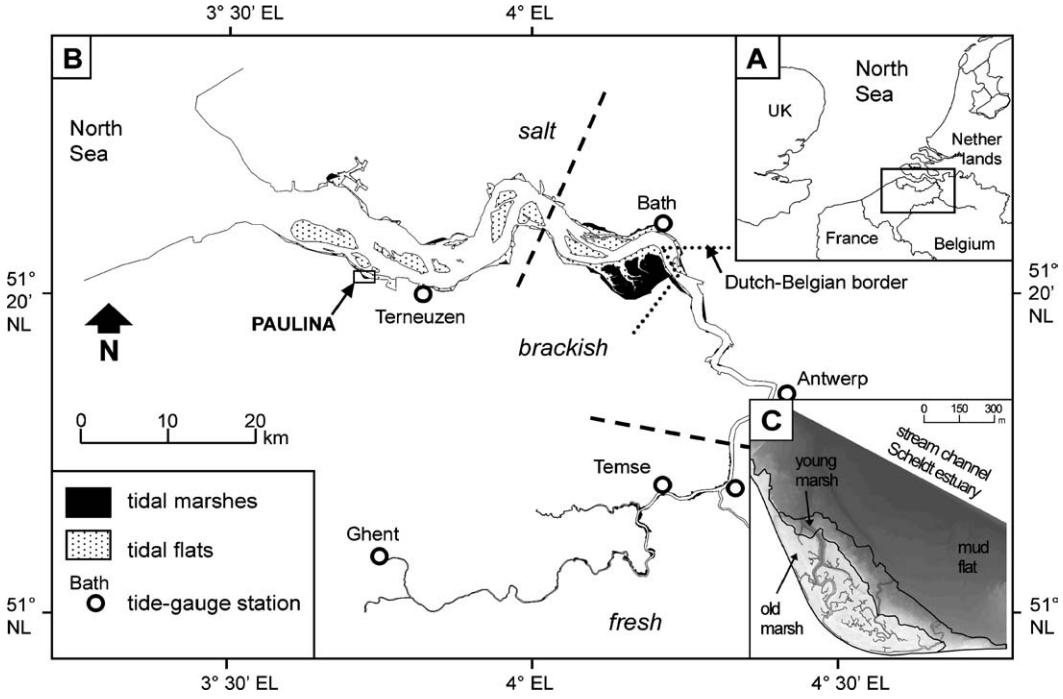

Fig. 1. Location of the Paulinapolder (c) in the Western Scheldt estuary (b) of The Netherlands (a). Figure modified from Temmerman et al. (2003).