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Simulating cross-shore material exchange at decadal scale. Model application

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ABSTRACT

A model developed to describe long-term cross-shore (CS) exchange of sand and resulting profile evolution at regional scale was employed to simulate the evolution at three different sites. The model consists of modules for calculating dune erosion and overwash, bar-berm material exchange, and dune build-up by wind-blown sand transport, as described in detail in a companion paper (Larson et al., 2016). Selected study sites represent coastal stretches influenced by beach nourishment (Barra in Portugal), overwash and breaching (Macaneta spit in Mozambique), and dune development (Ängelholm in Sweden). The model applications showed overall good performance and the results of the simulations are promising. Due to limitations in data availability in Ängelholm and Macaneta, values on calibration parameters were mainly determined based on previous studies. For Barra, where more field measurements were available, the application showed good agreement between the simulated results and observations. The CS-model proved to be a useful tool to predict long-term evolution of beach-dune systems in a time perspective from years to decades. However, additional efforts should be directed towards improving the schematized model profile so that it can better represent other beach shapes such as a sloping berm or a barrier shape.

1. Introduction

Beach erosion is threatening coastal societies, economical values, and valuable nature worldwide (Bird, 1985). The European project EUROSION concluded that 20% of the European coastline suffers from erosion and that the direct loss of land is a small problem compared to the flood risk associated with undermining of coastal dunes and other sea defenses (Doody et al., 2004). Sea level rise is expected to increase erosion rates and extend the problems to areas that are not yet affected (Leatherman et al., 2000). As development of coastal areas continues, population and economical values that are threatened by erosion are expected to increase significantly (Line et al., 2014).

Sustainable planning of coastal areas requires long-term predictions of beach-dune system evolution, since dunes often serve as flood defense for low-lying hinterlands and as a sediment reserve for the beach. For simulation of shoreline evolution at large temporal (decades) and spatial scales (kilometers) models based on the one-line theory, first introduced by Pelnard-Considere (1956), are typically used. Some examples are GENESIS (Hanson, 1988), Unibest CL+ by Deltares, and LITPACK by DHI. In the one-line theory, beach profiles are assumed to maintain an equilibrium shape. As a consequence, morphological cross-shore changes due to *e.g.* storm erosion, seasonal variations, and sea level rise are neglected.

Models for cross-shore sediment transport, on the other hand, are commonly focusing on short-term changes due to storm erosion (hours to days), *e.g.* SBEACH (Larson and Kraus, 1989) and XBEACH (Roelvink et al., 2009), or short to medium term (month to year) simulations like Unibest TC by Deltares. Aeolian processes are typically not included.

To simulate long-term evolution of beach-dune systems, a computationally efficient, semi-empirical model for cross-shore sediment transport (hereafter referred to as the CS model) has been developed. In a companion paper by Larson et al. (in review), the theoretical foundation of the model is described in detail together with validation of the included model components against field and wave tank data.

The CS model takes into account processes of dune erosion, overwash, dune build-up from wind, and berm-bar exchange. The longshore sediment transport gradient is here accounted for as a

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continuous source or sink; but may be coupled to simulations of changes in the shoreline position, *e.g.*, a one-line shoreline evolution model.

The main objective of this study is to evaluate model performance by applying the CS model to three sites with different characteristics and purpose of application. The study sites are located at Barra in Portugal, Macaneta spit in Mozambique, and Ängelholm beach in Sweden. At Barra the CS model is applied to simulate the effect of nourishments, at Macaneta overwash and breaching, and at Ängelholm dune development at different longshore sediment transport gradients. Study sites with variation in morphology, tidal regimes and wave climate were chosen to test the general applicability of the model.

2. Methodology

The methodology adopted for the implementation of the CS model comprises four different stages, specifically: (1) specification of initial morphological conditions; (2) assignment of values for input parameters and forcing; (3) specification of model parameters and calibration; and (4) model forecasting with output of sediment transport and morphological changes. The specifics of each stage are illustrated in Fig. 1, and developed in the following paragraphs. Adopted notation and corresponding units are summarized in a list of symbols exhibited at the end of the article.

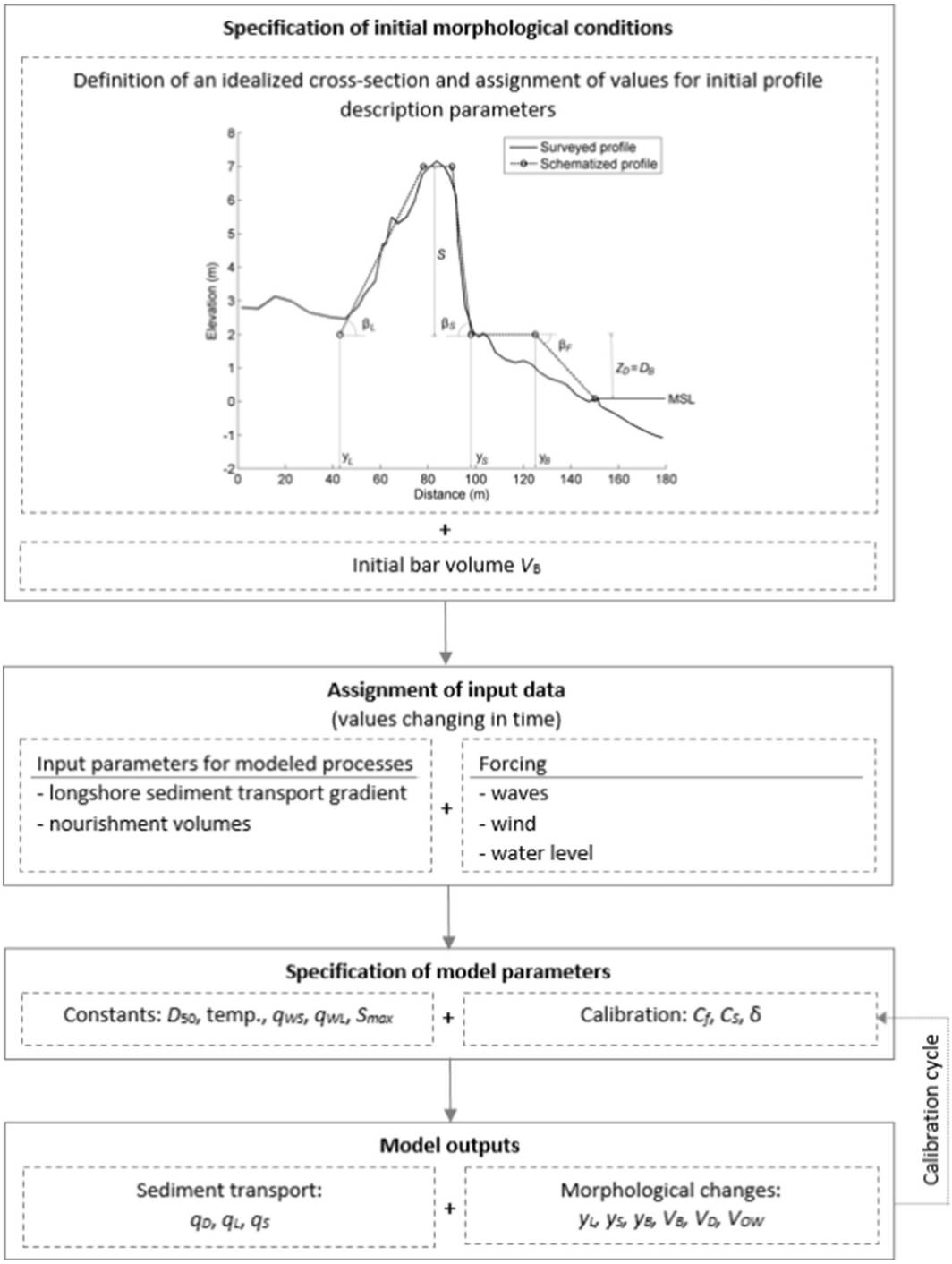

Fig. 1. Cross-shore model implementation stages.