ENHANCE DUNE-BUILDING PROCESSES WITH NATURE-BASED NOURISHMENT DESIGN

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INTRODUCTION

Vast coastal stretches around the world rely on dunes for flood protection. At the same time, the protection level of many dune systems can be undermined due to coastal erosion, sea-level rise, and greater population densities. To enhance dune building processes and the growth of coastal dunes, nature-based solutions, such as multi-purpose sand nourishments, are increasingly being implemented. However, the performance of the nourishment projects in terms of dune growth do not always match the expectations due to unforeseen supply-limiting factors (Hoonhout and de Vries, 2019).

Sediment on a beach should be within a site-specific range of grain sizes to be available for pick up by the wind and deposition in the dunes. However, the grain-size characteristics do also influence several other supply-limiting factors, *e.g.*, surface moisture, crust development, and beach slope, making nourishment design complicated. The process-based model Aeolis has been developed to predict aeolian transport rates considering several supply limiting factors. In this study, we introduce a new surface moisture functionality in Aeolis and demonstrate how the model can be used to optimize nourishment designs with respect to dune build-up. A number of test cases are presented to illustrate how grain size, sorting, and beach morphology are influencing aeolian transport rates.

METHOD

The process-based numerical model AeoLis (Hoonhout and de Vries, 2016), simulates aeolian transport and sediment availability. Multi-fraction aeolian sediment transport is implemented through an advection scheme with grain-size selective pick-up and deposition. Since finer grains are more easily picked up the wind, lag deposits of coarser grains may form that inhibit the aeolian transport. Aeolis includes wave runup and a hydraulic mixing scheme of sediments (Masselink et al., 2017); finer grains that are available for transport are exposed at the top layer through the mixing of the surface sand layers.

For this study, Aeolis was extended with a new surface moisture module. If the sand surface is wet, the critical shear velocity is assumed to increase with increasing moisture content (Belly, 1964). Surface moisture due to capillary rise from the groundwater table is described by a soil water retention relationship (van Genuchten, 1980), including hysteresis. When moving between wetting and drying conditions, the soil moisture content follows an intermediate retention curve, a so-called scanning curve (Mualem, 1974). The groundwater table is computed through a numerical solution of the Boussinesq equation (Raubenheimer et al., 1999), with an empirical description of the overheight due to runup (Nielsen et al., 1988). Runup and precipitation are assumed to infiltrate the sand resulting in a moisture content equivalent to the field capacity. Evaporation is implemented through the Penman equation (Shuttleworth, 1993).

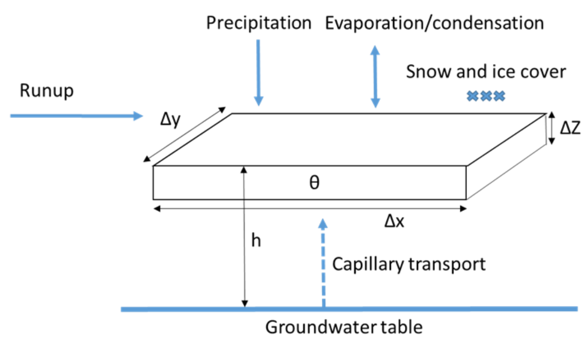

Figure 1 - Conceptual model of the moisture content on the beach surface.

EXAMPLE OF RESULTS

The model was applied to a number of test cases with varying grain size, sorting, and beach height. For the most common wind speeds, finer grains are more easily entrained, which should render larger transport rates. However, if surface moisture is considered, the transport may reduce since beaches with finer grain sizes are subject to larger capillary forces and typically more low-lying with shallower groundwater tables. Also, a high beach with lower soil moisture content does not necessarily mean larger transport rates. A high beach is less frequently subject to wave runup that can break up armouring lag deposits through hydraulic mixing. These effects can be simulated with Aeolis when including the processes of multi-fraction sediment transport, hydraulic mixing, and surface moisture.

DISCUSSION

To optimize dune-building processes, nourishments could be designed to promote supply and avoid restrainment of the aeolian transport capacity. The results show that the volumetric dune evolution is sensitive to both grain size and sorting. With nature-based designs being applied more frequently to stimulate natural processes, the need for design tools is increasing. The results of this study indicate that a process-based aeolian transport model can be used to explore complex relationships of supply and transport limiting factors. However, nourishment design for annual to decadal timescales should also consider sediment sorting due to cross-shore and longshore marine transport processes. Additionally, future studies should focus on the coupling between marine and aeolian processes.

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