AEOLIS: MODELLING AEOLIAN SEDIMENT TRANSPORT PROCESSES FOR PREDICTING DUNE DEVELOPMENT AND NBS DESIGN

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Aeolian sediment transport in the coastal zone plays an important role in shaping the morphological development of beaches, coastal dunes and their surroundings. While aeolian transport is a potential nuisance for coastal infrastructure, aeolian transport is also increasingly considered important for the development of Nature Based Solutions (NBS) such as coastal nourishments and foredune notching (Figure 1).

Figure 1, Dune development at the Zandmotor NBS including foredune notching at the far right.

The lack of reliable predictions of aeolian transport and (long-term) coastal evolution of morphology at sandy beaches and dunes compromises the application of NBS in coastal engineering. A validated numerical tool that accounts for relevant local physical (e.g., grain size, beach shape) and environmental conditions (e.g., wind climate, tides) can help assess the long-term effectiveness of NBS for specific sites.

We present a two-dimensional , open-source numerical area model (AeoLiS) that calculates aeolian sediment transport based on:

1. a (detailed) simulation of wind shear.
2. a simulation of the conditions at the sediment surface

In this paper we demonstrate the advanced capabilities of the open-source AeoLiS model by presenting a selection of recent simulation results of typical natural coastal landforms and NBS. These example cases highlight the need for accounting for complex spatial processes such as vegetation effects, topographic influence on wind flow dynamics, and sediment supply for resolving the complex evolution of coastal landforms. These capabilities enable the ability to explore NBS implementation for a range of coastal management objectives involving wind-driven processes and dune evolution.

METHODS

AeoLiS calculates gradients in wind driven sediment transports that cause morphological changes at the sediment bed based on continuity. Morphological feedback exists between the morphological change and the wind shear (due to steering effects) and sediment surface characteristics (due to sedimentation and erosion). Figure 2 shows the flowchart of the modelling structure that includes modules to account numerous supply limiters related to grain size and moisture effects.

Various physical and ecological variables and processes that influence aeolian sediment transport in the coastal zone can be simulated. Moisture content of the sediment at and around the sediment surface related to water level variations and precipitation may limit the erodibility of the sediment bed (Hallin et. al. 2023). Grain size differences that may be influenced by coastal nourishments can lead to the selective transport resulting in erosion and sedimentation of different grain sizes (van IJzendoorn et. al. 2023). The presence of vegetation (natural or planted) can break the wind forcing causing gradients in sediment transport that may lead to sediment accumulation in the form of coastal foredunes (Derijckere et. al. 2023). The combination of these governing processes can now be used to assess the morphological development of coastal zones (for safety or biodiversity), up to climate timescales.

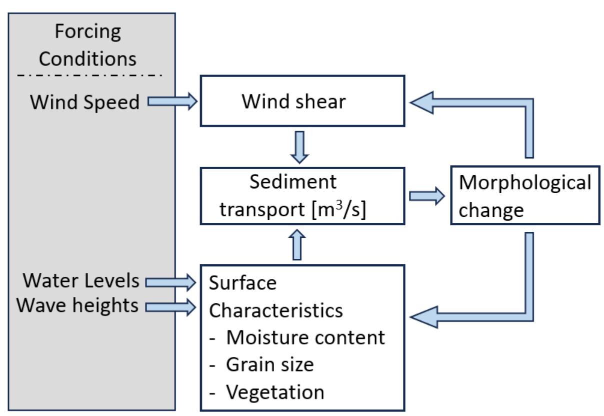

Figure 2, Flowchart of the AeoLiS modelling structure where spatiotemporally varying sediment transports and morphological changes are calculated based on a combined simulation of spatiotemporally varying wind shear and spatiotemporally varying surface characteristics.

RESULTS

One of the most challenging landforms to simulate is the parabolic dune, as it requires a delicate balance between vegetation growth that is related to sediment burial, topographic shear stress steering, and limited supply due to a non-erodible layer. Being able to numerically reproduce how parabolic dunes appear in nature (Figure 3), demonstrates AeoLiS' ability to incorporate all these aforementioned eco-morphodynamic processes and their interactions.

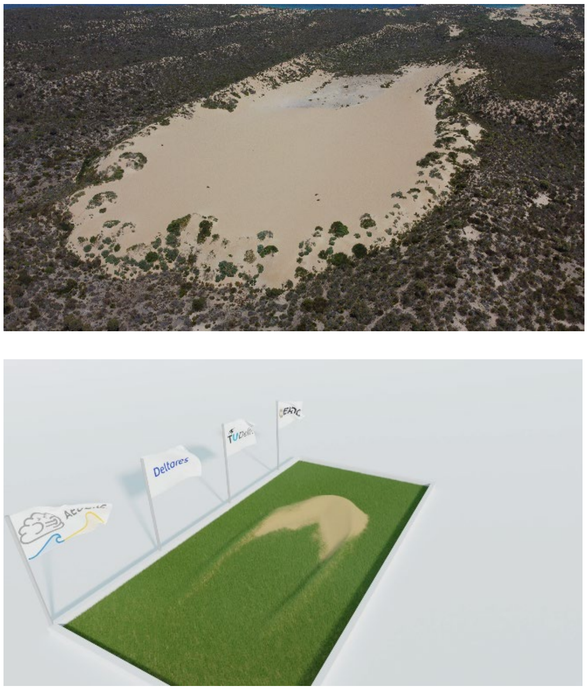

Figure 3, top panel shows an aerial figure of parabolic dune for reference, bottom panel shows an AeoLiS simulation where sediment transport, vegetation growth and morphological feedback are simulated.

Our second simulation displays AeoLiS's ability to simulate real life applications of NBS (Figure 4). Morphological development of the Sand Engine mega nourishment is calculated during a period of 5 years producing realistic results. Also, in this simulation, AeoLiS is coupled to a Delft3D simulation through a BMI interface such as described by Van Westen et. al. (in review). This work pushes the boundaries for time and spatial scales that process-based numerical models can be used to inform NBS design and effectiveness.

CONCLUSION

This contribution gives a detailed display of the assumptions and results that are generated with the AeoLiS model. The model stands out because of its ability to provide simulations of the wind-driven sediment transport capacity, including the influence of time and space evolving bed properties (e.g., grain size, moisture) on local transport rates. In addition to inclusion of ecological capabilities, the combination of processes including in AeoLiS make the model suitable for a broad range of coastal engineering applications.

The AeoLiS model is developed in the open domain (de Vries et al., 2023), is being actively development by a collaborative international team, and includes an increasing list of process capabilities. Combined with the low threshold of usability (user documentation, training materials) enables this modeling framework to be included in NBS-focused coastal engineering projects.

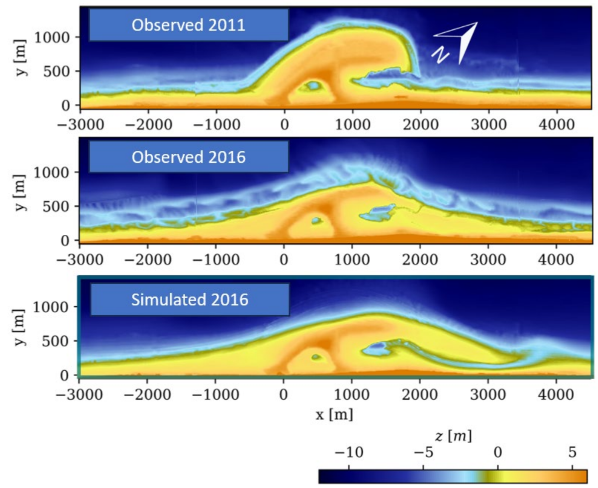

Figure 4. Top panel and middle panels indicate the observed morphology of the Zandmotor NBS in 2011 and 2016. Bottom panel shows the simulated morphology in 2016.

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