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Understanding the Effects of Local Hydrodynamic Components on Sand Wave Dynamics: A North Sea Case Study

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Large parts of the sandy seabed of shallow seas are covered with rhythmic bed patterns, such as tidal sand waves. Due to their dynamic nature and size, sand waves may pose a threat to offshore development, such as wind farm construction. Decadal predictions of seabed dynamics are thus required, which are currently determined using data-driven methods. Process-based models could be used to increase the accuracy of bed level predictions in these environments. Moreover, these tools could provide a solution for data scarce areas and show the effects of extreme events and human interventions.

The complex, process-based numerical model Delft3D-4 has been used to model sand wave dynamics in idealized settings (e.g. Borsje et al., 2013) and more recently for realistic cases (Krabbendam et al., 2021). In the current model set-up, the hydrodynamic boundary conditions are imposed at 20 km from the sand wave area. A flat buffer area is created to enable the flow to adapt and keep boundary effects away from the area of interest. As an undesired consequence of this the hydrodynamic forcing at the boundaries is now different from what is simulated in the sand wave area, making it difficult to define realistic forcing. The newly developed Delft3D Flexible Mesh (FM) model, the successor of Delft3D-4, shows the ability to drastically reduce this buffer area. Through a new, more comprehensive, type of boundary condition more accurate hydrodynamics can be imposed, by defining water level and flow velocity profile over depth simultaneously at inflow boundaries.

In this study the Delft3D FM model is applied to multiple transects in the North Sea, where the accuracy of the hydrodynamics is validated using a large-scale model and measurement data. By splitting the hydrodynamic signal into tidal components and non-tidal currents, the contribution of the various local hydrodynamic components to sand wave dynamics is determined.

This study shows the importance of accurate representation of local hydrodynamics for understanding sand wave dynamics. It is for example found that minor changes in residual currents will significantly alter the bed level changes over the considered time periods. Using the Delft3D FM model more realistic boundary conditions can easily be defined. Combined with a reduction of computation times of over 50%, compared to Delft3D-4, the first steps towards engineering applications of numerical models for predictions of sand wave dynamics are made.

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