UNDERSTANDING 3D SAND WAVE DYNAMICS FOR ENGINEERING PURPOSES

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Due to ambitious green energy goals the pressure on the offshore area is increasing at an unprecedented pace. These offshore developments, such as wind farms, require detailed bed level predictions. However, the uncertainty in these predictions increases dramatically when dynamic bed forms, such as sand waves, are present. This is the case in many areas, such as the North Sea, Taiwan Strait and the Banks Strait Australia. Sand waves can grow up to 25% of the water depth, have wavelengths of hundreds of meters and migrate with several meters per year. Due to their dynamic nature and size they may pose a threat to offshore activities, such as the construction and maintenance of wind farms and ship navigation. Cables and pipelines may become exposed and foundation could become unstable, due to the migration and/or shape changes of sand waves. Currently data-driven methods are applied to predict future bed levels (see Figure 1). The use of process-based numerical models could improve the accuracy of these predictions and help quantifying uncertainties over time. Additionally, these models give insight into the effects of extreme events and human interventions, and provide a solution for data-scarce areas.

The application of numerical models to real-life sand wave cases is still in its infancy. It comes with various challenges, such as the need for small horizontal and vertical grid sizes. Previous model cases are often idealized, including sinusoidal sand waves along a 2DV transect, instead of a 3D sand wave field (e.g. Campmans et al., 2018). Here, little variation in the along crest direction of sand waves is assumed. However, in reality

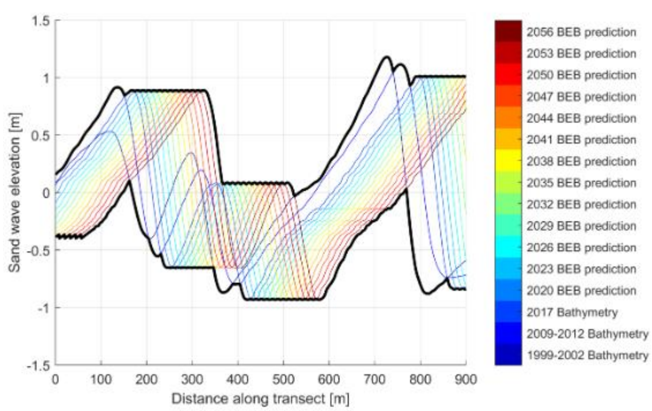

Figure 1 – Data-driven bed level predictions for sand wave dynamics: Best Estimate Bathymetry (BEB) for a transect at windfarm development site in the North Sea, based on historic sand wave measurements (Deltares, 2019)

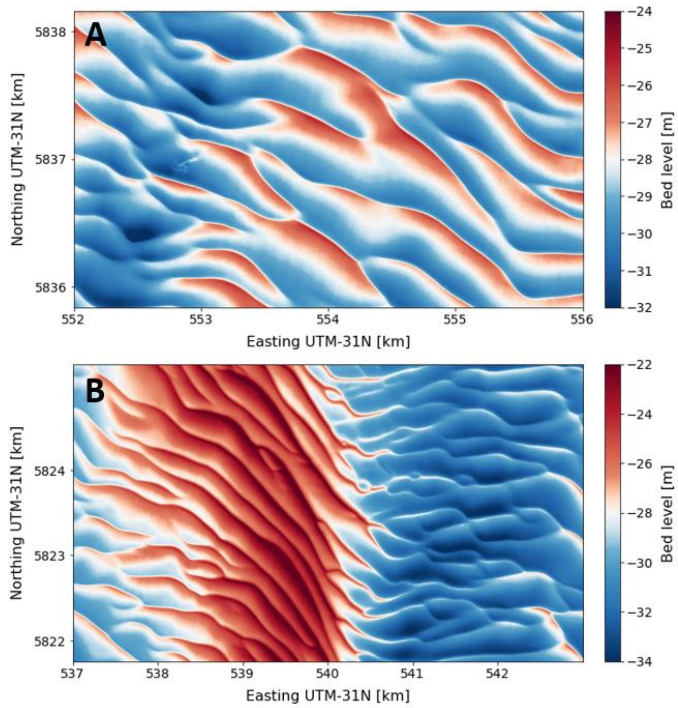

Figure 2 – Measured sand wave bathymetries in the North Sea including sand wave bifurcations and amplitude variations (A) and an underlying sand bank (B)

sand wave fields do show various amounts of 3D features, such as bifurcations and along crest changes in direction and amplitude (see Figure 2A). Although these features are found in sand wave fields around the world, much is still unknown about their development and behavior.

The current 2DV model set-up does not allow for inclusion of these 3D features. Moreover, the influence of underlying sand banks on sand wave shape (see Figure 2B) and migration cannot be simplified to, or predicted with, a 2DV model domain. Leenders et al. (2021) found that the presence of sand banks could even lead to opposing sand wave migration directions over small areas. Additionally, most engineering interventions, such as cable trenching, cannot be included in 2DV models.

The aim of this study is to increase our understanding of 3D sand wave systems through simulations using the newly developed Delft3D Flexible Mesh (FM) model. This model offers various opportunities to better represent the local hydrodynamics, while lowering computational efforts (e.g. new types of boundary conditions, unstructured grids and a dynamic timestep). Multiple locations with varying amounts of 3D sand wave features are chosen. There 3D sand wave models are set-up, with initial bathymetries based on measurements (see Figure 3). The models include four open boundaries, forced with both water levels and current velocities. The results of these process-based model simulations give insight into the interaction between the 3D morphology and the local tidal currents. The development of these features, as influenced by various hydrodynamic conditions, is studied. The simulations show the ability of the model to predict decadal bed level evolution for these sand wave fields.

Based on the model results we conclude that the inclusion of a third dimension spatial is of key importance to correctly predict bed level changes in sand wave fields.

Our 3D model offers us an opportunity to increase our understanding of highly 3D cases, as well as the impact of offshore engineering applications, such as the fill-up of a cable trench.

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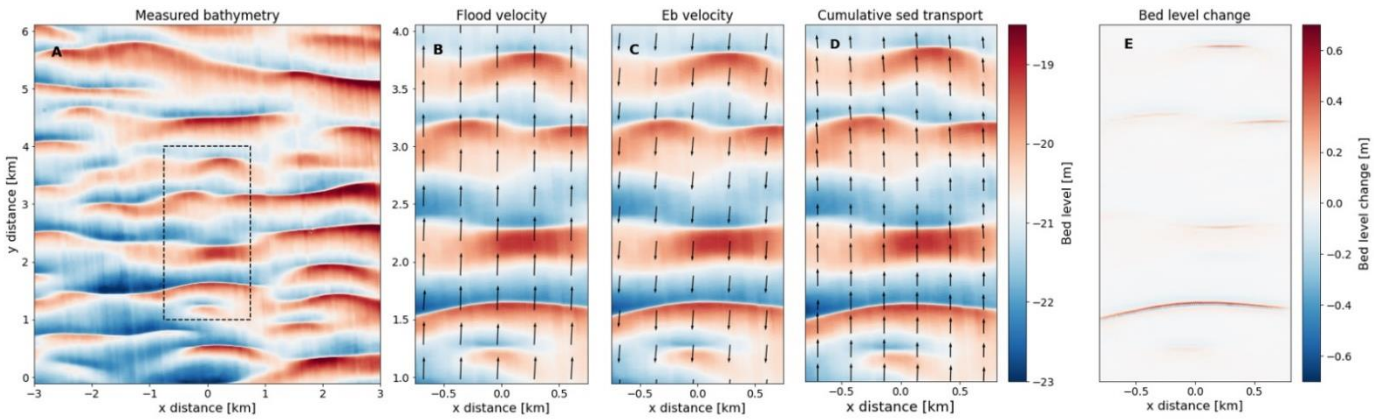

Figure 3 – [A] Measured sand wave bathymetry and locally modelled near bed [B] peak flow velocity, [C] peak eb velocity, [D] cumulative sediment transport (indicated by arrows, colors indicate bed level) and [E] bed level changes over 1 year