Development of natural seabed forms and their interaction with off shore wind farms - DTU Orbit (03/12/2018)

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Large, coherent bedforms are often found in the sea, straits and along coasts. The bed forms are generated by sediments, accumulated by a continuous deposition of sand, which is transported by tides, surges and waves. Areas with large bedforms are a favorite target for extraction of sand, gravel and stone for use in construction. Elevated bedforms and reefs are also attractive in the construction of offshore wind farms.

The formation of large, sandy bedforms on the sea floor has been studied in the past using linear stability analyses. These analyses are commonly conducted analytically and therefore require simplifications in the governing equations. This thesis presents a two-dimensional horizontal Matlab model that can simulate the morphodynamics of large-scale bedforms. The model was used to conduct a numerical linear stability analysis, intended to identify the likely emergence of dominant finite sized bedforms, as a function of governing parameters. The model includes separate formulations for bed load, featuring bed load correction due to a sloping bed and modeled helical flow effects as well as suspended load in a pseudo-3D description. Horizontal gradients are computed with spectral accuracy, which proves to be highly efficient for the analysis. The flow velocity, resistance and sediment grain size were varied in a parametric study.

The simulations yielded the emergence of bed forms due to an intrinsic instability of the morphodynamic system. The results support the importance of bed load correction due to bed slope, and also the role that the helical flow has on the characteristics of bedform growth rates, orientation, and in particular its balance with the Coriolis effect, in line with previous analytical studies. Moreover, the results suggest that the inclusion of suspended transport increases, rather than decreases, the unstable growth rate. This outcome stands in contrast to previous studies utilizing simpler suspended transport descriptions and suggests that suspended transport should be included when looking for quantitative accuracy. The linear stability analysis gave both quantitative and qualitative predictions, which served as inputs in a morphologic study of large-scale bedforms and helped with the interpretation of its results. The morphologic study shows that the linear growth rate is predicted accurately in the early development stages, but the migration rate is overestimated. One of the theories behind a linear stability analysis is to associate the wavelength of the fastest growing bed form with the final wavelength of bedforms kept in maintenance. This study shows that by using doubly periodic boundaries, resembling far offshore situations, the final bedform can attain a different final form due to non-linear interaction of all there solved wavelengths within the domain. Comparing the outcome of the bed morphology between a steady current and a tidal flow showed that differences were predominantly quantitative. Offshore wind farms were then added to the morphological study as subgrid elements in order to simulate their interaction with the bedforms. This addition showed that the wind farms could affect the bedforms by increasing their height and slowing their migration rate. However, for large-scale sandbanks in the order of kilometers, the time scale of the changes is very slow and spans over centuries. The morphological development over timescales with the water depth. Thus, a conceptual simulation at very shallowwaters indicated that a wind farm turbine could perturb a stable bed and cause the formation of new bedforms developing over timescales comparable to the designed lifespan of offshore wind farms.

Finally, a developer version of MIKE 3 by DHI was modified and used to simulate various cases in 3D. MIKE 3 is a shallow water model that uses σ-coordinates to resolve the water vertically, and the used version includes non-hydrostatic pressure terms. It is crucial to use vertical resolution to simulate bedforms like sandwaves, which are perpendicular to the flow direction and are of shorter wavelengths than sandbanks. Sandwaves are migrating at faster rates than sandbanks and can pose a great nuisance for the structural integrity of offshore structures and cables by migrating and altering the seabed levels up to several meters. The model successfully simulated full-scale morphological development of sandwaves, the scouring process around a monopile and the interaction between the migrating sandwaves and a monopile. Time limitations did not allow for a thorough analysis of these, but the model provided results that are generally of comparable nature to the literature on the subject and hence look promising for future studies.

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