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The effect of mesh size and bed roughness on the simulation of sediment transport off the east coast of Norfolk

The effect of mesh size and bed roughness on the simulation of sediment transport off the east coast of Norfolk

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Abstract

The choice of mesh size and friction factors have been shown to be major sources of uncertainty in flow and morphodynamic modelling (See for example Villaret et al, TUC 2014). In order to reduce this uncertainty, we propose to use the robust finite element mesh generator qmesh (www.qmesh.org) developed by Avdis and Hill. (Renewable Energy, 2018) to test different mesh sizes and assess their influence on both flow and sediment transport rates. We also propose here a new approach based on physical ground to estimate the bed roughness from a high resolution dataset.

The Norfolk coastal area

The region of interest extends 100 km offshore of the east coast of Norfolk, including the elongated Norfolk sand banks (Cross Sands/ Cockle Gateway). This highly dynamic area is an ideal modelling test case for reasons which include:

- A considerable amount of publicly available hydrodynamic and sediment transport data exist, including flow and velocity data from the SNS2 2001 survey, that can be used for model validation.
- Morphodynamic features are reported with interactions at different scales and include the Norfolk banks parallel to the shore line with characteristic length scales of 5-10 km and smaller bedforms down to mega-ripples ripples in the near shore zone.
- Finally, an understanding of flow and sediment transport processes has commercial applications of relevance to this area, which include offshore renewables, oil & gas and power infrastructure and decommissioning operations.

Bathymetry data – DEM construction

Two different sources of raw bathymetry were used: (1) EMODnet (portal.emodnet-bathymetry.eu) regionally continuous data gridded at approximately 180m, and (2) Several higher resolution but smaller extent bathymetric datasets were mosaiced into a 25m grid using data from the UKHO data portal (aws2.caris.com/ukho) which ranged from 1981 to 2017. Initial preparation requires interpolation to avoid inconsistencies between the different data sets.

Meshing tool

The model domain includes the shoreline portion between Cromer and Lowestoft and extends approximately 50 km offshore to include the Norfolk offshore banks. We built a Telemac model using qmesh in a QGIS representation. In addition to the coarse mesh (baseline model) we built a high-resolution model (170 000 elements and 80 000 grid nodes).

The mean bed level and bed roughness were estimated from the EMODnet data sets for the coarse mesh and using the high-resolution DEM for the fine mesh. The mean bathymetry was obtained by applying a filtering length (ideally of the order of the mesh size) representative of the mean bed level, averaged over the mesh scale. In a second step, the bed roughness is determined as proportional to the bedforms heights, simply by applying the same filtering length to the differential DEM (local filtered). As a final step, both geometry files (coarse and fine mesh) were constructed using pputils, to include the mesh, mean bed level and bed roughness. The grain diameter was also included as a function of water depth, based on expert knowledge.

Tidal flow

The TPXO database was used to impose the flow (free surface and velocity) at the boundary nodes. Harmonics analysis of the flow model over 4 months were compared for the 4 main tidal gauges (M2, S2, N2 and M4). Both the coarse and fine mesh were able to capture the tidal flow variation in comparison with the tidal gauges although a more detailed calibration is needed (by varying the tidal amplitude at the offshore node). However, the general agreement is best with the fine mesh.

Morphodynamic Assessment

Morphodynamic model results obtained after 1 year of bed evolution are extremely different between the coarse and fine mesh. Only the fine mesh resolution is able to capture the mesoscale features (sand waves). A comparison between the high resolution model and the high resolution datasets gives an indication on the direction and celerity of sand waves by following individual crest lines across repeat surveys. Although the picture is complex there appears a north/south divide offshore Caister and Winterton.

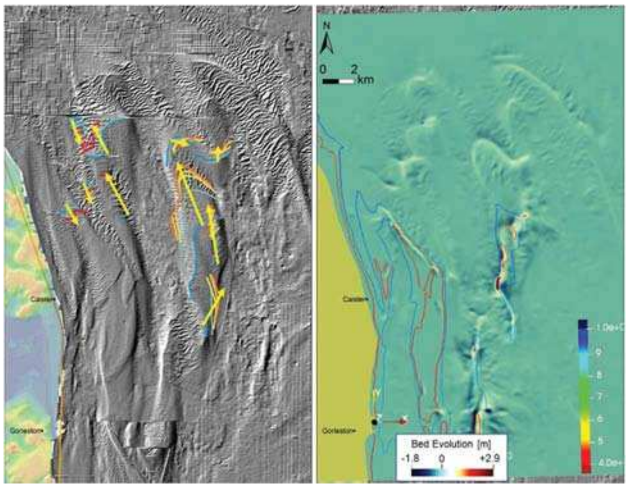

Figure 1: repeat survey analysis of bedforms (left) and comparison with 300 day bed evolution modelling (right)

Conclusion

This paper discusses the role of the mesh and initial treatment of the bathymetry datasets in the construction of the geometry file. We propose a new method to directly estimate the bed roughness from high resolution bathymetry. Although a coarse mesh gives a relatively rough estimate of the tidal flow, the morphodynamics results are completely unrealistic. The preliminary morphodynamics model results using the fine mesh resolution show realistic features (with greater evolution ranges along the crest of sand banks) and emerging sand waves. The approach proposed for the bed roughness estimation based on physical ground (from bathymetry analysis) needs to be further improved using a variable filtering length (consistent with the spatially varying mesh size). Results are however globally consistent with the bed roughness predictions using Van Rijn (2001) decomposition of bed roughness in terms of megaripples and dunes.