SCALDIS-COAST: AN INTEGRATED NUMERICAL MODEL FOR THE SIMULATION OF THE BELGIAN COAST MORPHODYNAMICS

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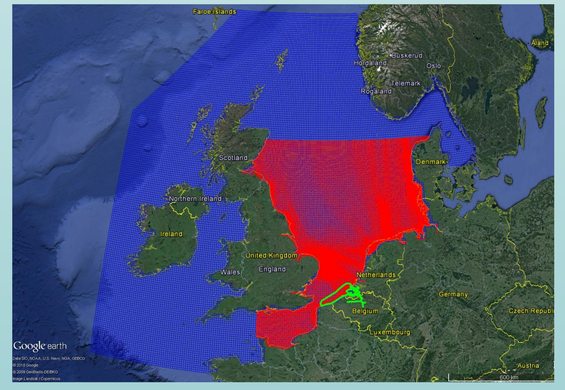
Introduction

State-of-the-art numerical modelling tools are employed for the prediction of the long-term evolution of hydrodynamics and morphodynamics, in order to contribute to the strategic decision-making for the protection of the Belgian Coast from (extreme) sea level rise and climate change. To this end, a complex coastal model, which is referred as the Scaldis-Coast model, is being developed by use of TELEMAC-MASCARET, an open source suite of solvers for free surface flows.

Modelling Strategy

The simulations are conducted in three levels: First a continental shelf model (CSM) is run in order to provide the boundary conditions of the second-level nested model (ZUNO), which includes the southern North Sea and the Channel. In turn, the latter model feeds the Scaldis-Coast coastal model.



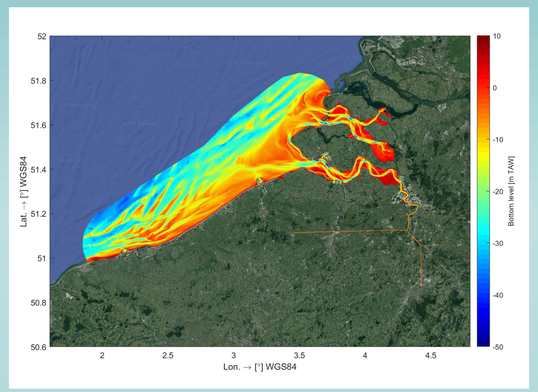
Computational grids of the implemented three-level modelling. The blue grid corresponds to the CSM, the red one to ZUNO model and the green outline to the Scaldis-Coast boundaries.

Methods & Formulation

The SIMONA software (Rijkswaterstaat, 2013) is used for the simulations of the two larger-scale models, CSM and ZUNO. The depth-averaged flow is calculated by solving the shallow water equations. The Scaldis-Coast hydrodynamic simulations are performed by means of TELEMAC2D module, which solves the shallow water equations (Saint-Venant) using the finite element method. Wave modelling is performed by the TOMAWAC module which solves the balance equation of the action density directional spectrum. Sediment transport and morphology simulations are conducted by means of SISYPHE module. Bed load transport is calculated by using classical formulas from literature, while for the suspended load the advection-diffusion equation for the sediment concentration is solved. The bed evolution results from the Exner equation.

Model Set-up

The computational grid of Scaldis-Coast, constructed using the finite element grid generator GMSH (Geuzaine & Remacle, 2009), consists of a broad range of element sizes, from kilometres (offshore) to a few meters (nearshore), which makes it suitable for the complex geometries of our study area. The grid consists of 258,390 nodes with the maximum resolution of 25 m being along the Belgian coastline and the minimum resolution of 750 m being along the offshore boundary.



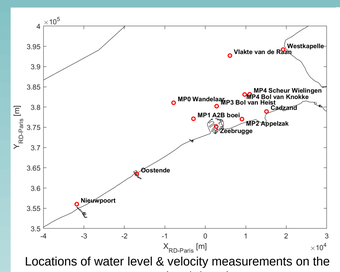
The computational domain and the bathymetry of Scaldis-Coast model.

The automatic local mesh refinement is based on the geometry of the coastline (including coastal structures) and the local bathymetric slopes. The latter attribute allows for the better representation of gullies and sand banks, which characterize the Belgian coast.

Part of the computational grid of Scaldis-Coast model where the element size is adapted to the bathymetric slopes of the existing sand banks of the Belgian coast.

Validation

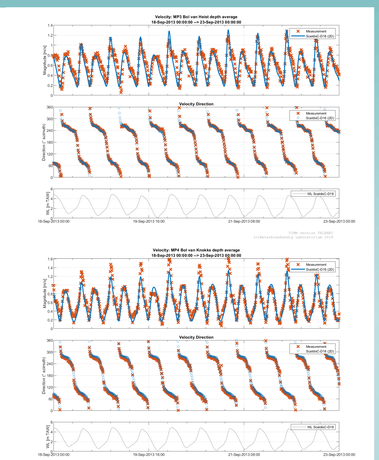
The hydrodynamic module of Scaldis-Coast is validated by comparison of the numerically predicted water levels and velocities against measured water levels and velocities at several locations at the Belgian coast. Then, the coupled hydrodynamic-wave model is validated by reproducing successfully the wave propagation and transformation at the western part of the Belgian coast, where sand banks parallel to the shoreline are encountered.

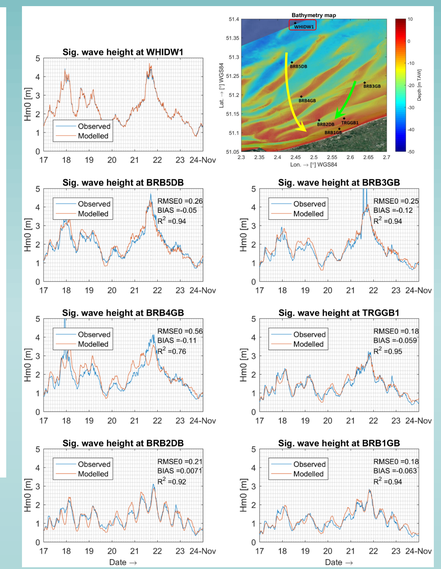


Locations of water level & velocity measurements on the computational domain.

Station	BIAS [m]	RMSE [m]	RMSE_0 [m]
Vlakte van de Raan	0.01	0.08	0.08
Westkapelle	0.02	0.09	0.08
Cadzand	0.03	0.09	0.08
Zeebrugge	-0.07	0.11	0.08
Oostende	-0.05	0.10	0.09
Nieuwpoort	-0.01	0.09	0.09
MP0 Wandelaar	0.01	0.07	0.07
MP1 A2B boei	-0.05	0.09	0.08
MP2 Appeltzak	0.03	0.09	0.08
MP3 Bol van Heist	0.02	0.08	0.08
MP4 Scheur Wielingen	0.02	0.08	0.08
Total	**0.00**	**0.09**	**0.08**

Main statistical parameters for the water level time-series.

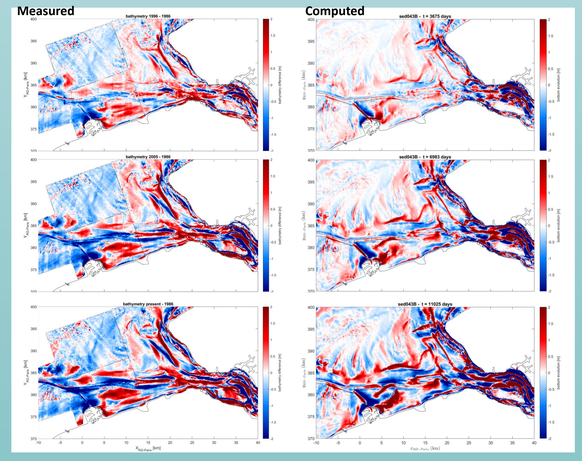




Morphological hindcasting

- The bathymetry of the year 1986 (Zeebrugge port expansion) is considered at the temporal starting point (t=0) of the simulation.
- A schematized tidal forcing consisting of successive representative tides of total duration of 3 years, was applied in the hydrodynamic module.
- Morphological acceleration factor equal to 10 was considered in the morphological module, resulting to a simulation period of about 30 morphological years.

- The erosion & sedimentation patterns around port of Zeebrugge are generally captured by the model.
- The model predicts accumulation of sand in the navigational channels. Dredging & damping module is under investigation.
- Sedimentation/erosion at the area of Vlakte van de Raan are reasonably reproduced by the model.
- Strong morphodynamic activity observed at the channels and banks of Western Scheldt is roughly represented.



Measured and numerically predicted sedimentation/erosion patterns of the bed evolution after 10 years (top figures), 19 years (middle figures) and 30 years (bottom figures).

References:

Geuzaine, C. and Remacle, J.-F. (2009). Gmsh: A 3-D finite element mesh generator with built-in pre- and post-processing facilities. Int. J. Numer. Meth. Engng., 79: 1309–1331. doi:10.1002/nme.2579.

Rijkswaterstaat (2013): User's guide WAQUA: General information, Rijkswaterstaat, The Netherlands.