Numerical models used for the PEZ sediment transport calculations

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1. The hydrodynamic model mu-BCS

The twodimensional hydrodynamic model mu-BCS calculates the depth-integrated water currents and elevation on the model grid under the influence of tides and meteorological influences. The long wave equations are calculated using a semi-implicit finite difference method on a Arakawa-C model grid. (Yu *et al.,* 1989, 1990; Ozer *et al.,* 1990; Yang *et al.,* 1991; Ozer, 1994). The bottom shear stress is calculated using a quadratic friction law.

The model is implemented on a model grid that comprises the entire Belgian Continental Shelf. The resolution is 5'/21=14.29'' in longitude (272 m – 278 m) and 2.5'/18 = 8.33'' in latitude (257 m). The model has 538 x 396 grid cells. The bathymetry is shown in **Error! Reference source not found.**. At the open sea boundaries, the model is coupled with the OMNECS model, with a resolution of 5' in longitude and 2,5' in latitude (5.83 km x 4.63 km on 51°N). The model comprises the complete Northwest European Continental Shelf froml 48°N to 62°N and from 12°W to 13°O. The westside of the model is the 200m contour line. The model is driven by four semi-diurnal (M2, S2, N2, K2) and four diurnal (O1, K1, P1, Q1) harmonic components.

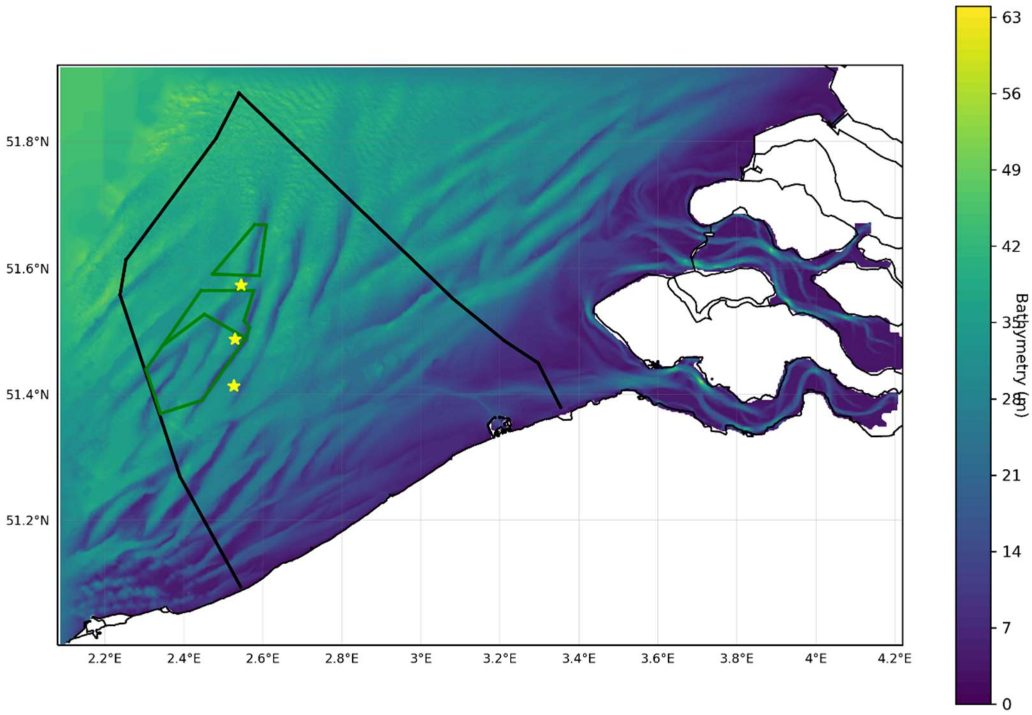

Figure 1: Bathymetry of the two-dimensional mu-BCS model. The green polygons are the PEZ area.

2. The wave model WAM

For the calculation of the waves, the implementation of the WAM model for the Belgian coastal waters is used. The WAM model is a third generation wave model, developed by the WAMDI Group (1988) and described by Günther *et al.* (1992). The WAM model is used both for research and for operational wave forecasting. It includes 'state-of-the-art' formulations for the description of the physical processes involved in the wave evolution. In comparison with the second generation model, the wave spectrum has no restrictions and the wind sea and the swell spectrum are not treated separately.

At RBINS, the model is running on three coupled model grids. A Coarse model grid comprises the entire North Sea, the Fine model models the central North Sea and the Local model calculates the waves in the Southern Bight. More information can be found in Van den Eynde (2013).

3. The sedimenttransport model mu-SEDIM

The MU-SEDIM sediment transport model is implemented on the same grid as the mu-BCS hydrodynamic model and calculates the total load under the influence of the local hydrodynamic and wave conditions. The current bottom stress, one of the most important driving forces, is a function of the depth-averaged current velocity, the wave parameters and of the Nikuradse bottom roughness. For the calculation of the Nikuradse bottom roughness, a distinction was made between the skin friction and the total friction. The skin friction is the roughness experienced by the sediments at the bottom and is calculated by using the expression of Engelund and Hansen (1967). The total friction is the friction experienced by the currents and is influenced by the bottom load and the bed forms (Smith and McLean, 1977). The calculation is based upon Grant and Madsen (1982). The bottom stress under the influence of currents and waves is based upon the formula of Bijker (1966). The formula of Ackers and White (1973) was used for the sediment transport calculations, because it yielded the best results in a comparison carried out by Sleath (1984). This equation was adapted by Swart (1976, 1977) to include the effects of waves on sediment transport.

Finally, the model calculates the evolution of the bottom (erosion/sedimentation), using a continuity equation for the bottom sediments (Djenidi and Ronday, 1992). More details on the equations implemented in the MU-SEDIM model can be found in Van den Eynde and Ozer (1993) or in Van den Eynde (2003).

One of the the input parameters for the MU-SEDIM transport model is the median grain size diameter *D50* (and some derived grain sizes). The *D50* was taken from Verfaillie et al. (2006). and refined in the framework of the TILES project (Van Lancker et al., 2019). The map of the *D50* for the entire Belgian Continental Shelf (BCS) and for the PEZ is shown in **Error! Reference source not found.** and **Error! Reference source not found.**.

The MU-SEDIM model has already been applied at the kink of the Westhinder Bank, a sandbank at the Belgian continental shelf, north of the Kwinte Bank (Deleu et al., 2004) and the model results agreed well with the transport pathways, derived from the observations, *e.g.*, from the asymmetry of the sand dunes. The model was applied to model the effect of sand extraction on sand banks (Van den Eynde et al., 2010; Giardino et al., 2010) and in the framework of the MAREBASSE project (Van Lancker et al., 2007).

More recently, new calculation of the bottom shear stress were implemented in the model, based on measurements of the bottom shear stress (Van den Eynde, 2015, 2016a, 2016b, 2017). It was shown that the Bijker model doesn't give realistic results for the bottom shear stress under the influence of waves with very small currents.. Additionally, no formulation was given for the mean bottom shear stress over a wave cycle, taking intoaccount the increase in mean bottom shear stress under the influence of currents, when waves are available. Furthermore, recently, more realistic and simple models for the combined bottom shear stress were proposed in literature. Therefore, three new formulations were implemented and tested: the Soulsby (1995), Soulsby and Clarke (2005) and Malarkey and Davies (2012) were implemented. These last two models also give a formulation for the maximal bottom shear stress during a wave cycle, and the mean bottom shear stress, averaged over a wave cycle. Furthermore, the theory was developed, both for flow over rough and over smooth bottom. Also more methods to calculate the ripple configuration and the bottom roughness were implemented. The first model uses the ripple geometry, proposed by Soulsby (1997) for the current-dominated ripples and the ripple geometry, proposed by Grant and Madsen (1982) for the wave-dominated ripples. More recently, a new ripple predictor was proposed by Soulsby and Whitehouse (2005). More information can be found in Van den Eynde (2015).

Validation of the different methods using measurements of bottom shear stresses (Van den Eynde, 2015, 2016a, 2016b) showed that similar results were obtained with the different models, but the best results seems to be given by the Soulsby (1995) model. Furthermore, the best results were obtained with a bottom roughness of 0.01 m, which is relatively high. In the present exercise, the Soulsby (1995) model is used with a bottom roughness of 0.01 m.

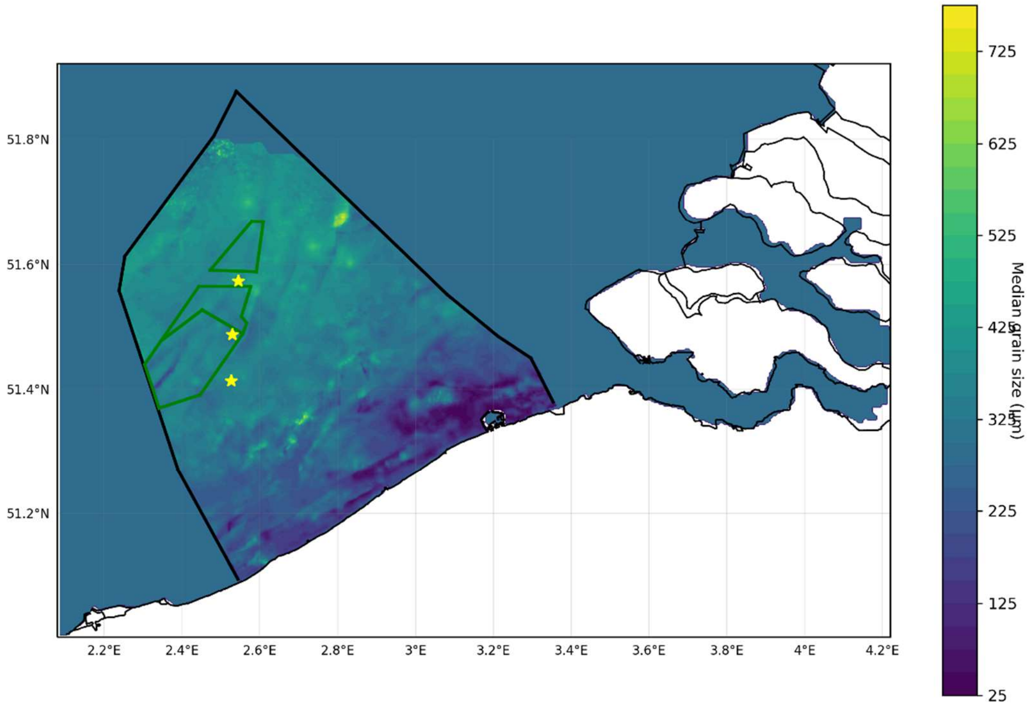

Figure 2: Median grain size diameter on the Belgian Continental Shelf. The green polygons are the PEZ area.

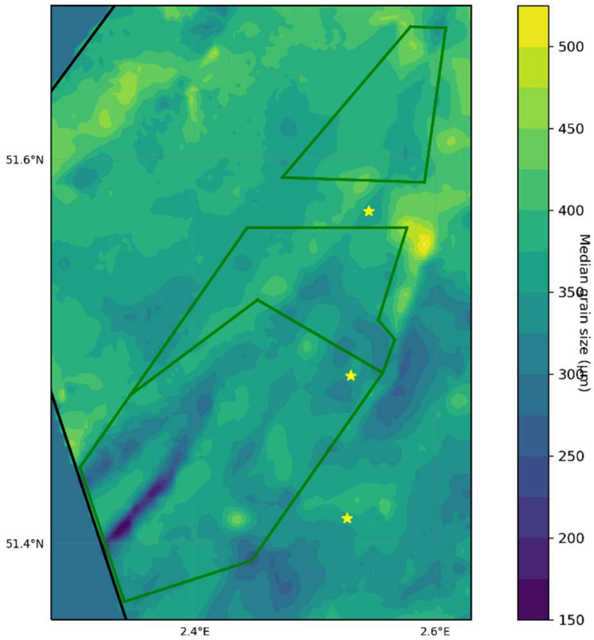

Figure 3: Median grain size diameter around the PEZ. The green polygons are the PEZ area.

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