PREDICTIONS OF SAND BANKS IN THE NORTH SEA

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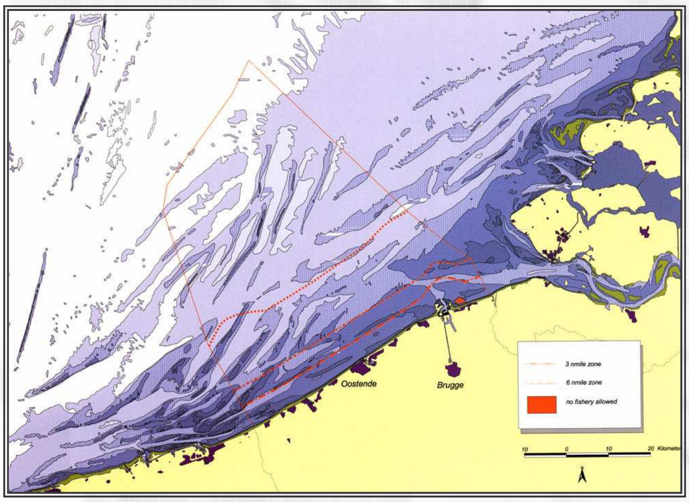
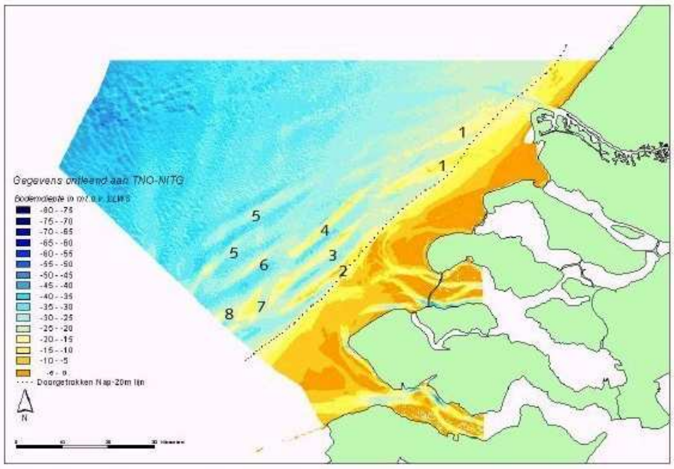


Sand Banks in the North Sea offshore the Belgian coast (Hommes, 2004)

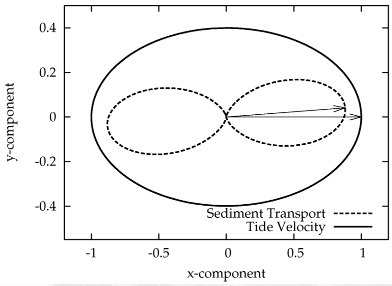
In shallow seas dominated by strong tidal currents, large scale periodic bottom forms, named sand banks, characterize the sea bed profile. Sand banks are long sand ridges, typically tens of meters high and tens of kilometers long, characterized by a spacing (crest to crest distance) of a few kilometers (Dyer & Huntley, 1999). The crests of sand banks are almost aligned with the major axis of the tidal ellipse.

A possible mechanism which leads to the formation of sand banks was first pointed out by Huthnance (1982) and later investigated by Hulscher et al. (1993) and Hulscher (1996) by using the shallow water approximation. Because of the Coriolis force and bottom frictional effects, an oscillatory tidal flow interacting with a bottom waviness counter-clockwise rotated (in the Northern Hemisphere) with respect to the main direction of the tidal current, causes the formation of a significant clockwise horizontal residual circulation around the crests. Consequently, flow velocities on the upstream side of the crests are slightly higher than those on the downstream side during both flood and ebb tide phases.



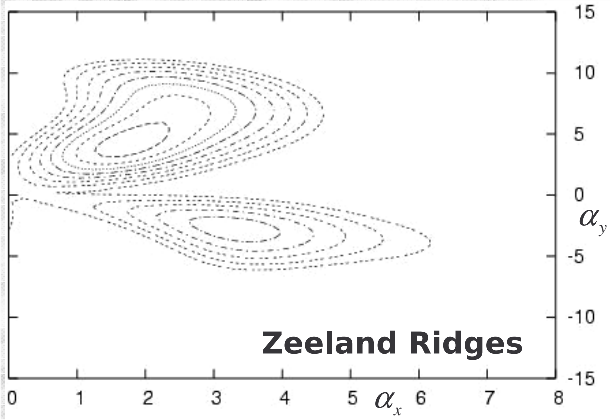
Bathymetry of Zeeland Ridges (Hommes, 2004)

Since sediment transport increases/decreases with increasing/decreasing velocities, the sediment tends to accumulate at the crests of the bottom waviness. Such a physical mechanism can explain only the appearance of sand banks counter-clockwise rotated with respect to the direction of the tidal current. However, Besio et al. (2006), using a full 3D model, have pointed out that clockwise rotated sand banks can be generated too: the velocity close to the bottom deviates from the direction of the depth averaged velocity. Therefore, even though no steady component of the depth averaged velocity is generated in the direction orthogonal to the crests of the bottom forms, a residual steady velocity orthogonal to the bed form crests does exist close to the sea bed, which drags the sediment from the troughs towards the crests of the bottom forms and induces their growth. Moreover, Besio et al. (2006) have shown that sand banks tend to be clockwise rotated with respect to the major axis of the tidal ellipse when the tidal velocity vector rotates in the counter-clockwise direction and viceversa, even though, for a unidirectional tidal current, no difference is present between a clockwise and a counter-clockwise rotating tidal velocity.



In the present study, the sand bank formation is investigated by means of the shallow water approximation and using a depth averaged approach. Because a depth averaged approach cannot predict the sediment transport rate deviation from the depth averaged velocity direction, a heuristic correction is added to the sediment transport predictor to account for this three-dimensional effect (De Swart & Hulscher, 1995).

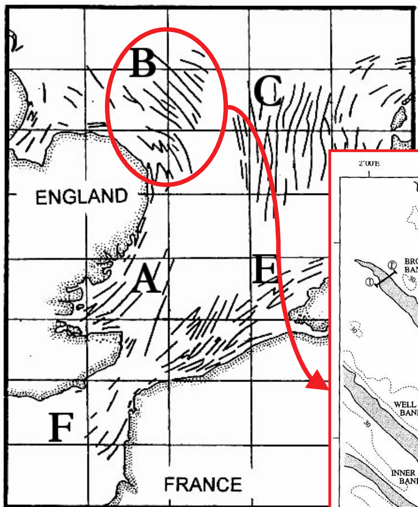
Zeeland Ridges	Observed wavelength	Predicted wavelength
Depth: 25 meters Tide: 0.4 m/s Tide Ratio: 0.4 Counter-clockwise tide	2 – 3 km	4.4 km



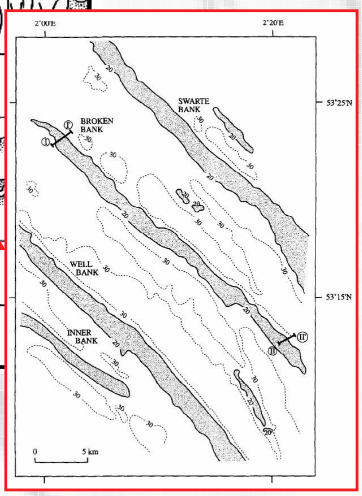
$$(Q_x, Q_y) = \left[\frac{(U\cos\varphi - V\sin\varphi, V\cos\varphi + U\sin\varphi)}{|\mathrm{U}|} - \frac{c_\lambda}{\hat{r}}\left(\frac{\partial h}{\partial x}, \frac{\partial h}{\partial y}\right)\right]\alpha|\mathrm{U}|^b$$

$$\alpha_x = \frac{2\pi}{L_x}\frac{U_0}{\omega}$$

$$\alpha_y = \frac{2\pi}{L_y}\frac{U_0}{\omega}$$



Sand Banks in the North Sea (Dyer & Huntley, 1999)



Norfolk Sand Banks (Collins et al., 1995)

Norfolk Sand Banks
Depth: 30 meters Tide: 0.7 m/s Tide Ratio: 0.2 Clockwise tide

Observed wavelength	Predicted wavelength
4 – 10 km	7.2 km