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Formation and migration of sandy shoals on ebb-tidal deltas: observations and modelling

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Abstract

Ebb-tidal deltas are bodies of sand that are located seaward of tidal inlets. Many of these deltas feature coherent, sandy shoals that cyclically form and migrate towards the coast. The average period between successive shoals that attach to the coast varies among different inlets. In this contribution, a quantitative assessment of the cyclic behaviour of such shoals is presented, and the processes that cause the formation and migration of shoals on ebb-tidal deltas are identified.

First, results are presented of the average period between successive shoals and the migration speed of individual shoals at inlets worldwide, including all inlets of the Wadden Sea. It will also be discussed to what extent these characteristics depend on external tide and wave conditions, thereby extending earlier work of Gaudiano & Kana (2001).

As the amount of field data is limited, additional insight into shoal dynamics is obtained from model simulations. For this, a numerical morphodynamic model with an idealized geometric set-up is employed. The model computes the bed-level evolution due to local erosion and deposition of sand driven by tides and waves. Results are shown of runs in which the water motion is forced by different wave heights (including seasonal variations and storms) and different tidal ranges. This approach is similar to that of Nahon et al. (2012) and Dastgheib (2012); differences concern the geometry of the inlet system, the applied forcing and the fact that in this contribution the focus is on unravelling the physical mechanisms that are responsible for the shoal dynamics.

Analysis of model results shows that shoals form when there is a local imbalance between the local bathymetry and the wave conditions. There are thresholds for shoal formation that depend on the distribution of the sand and the incident wave energy. Wave refraction over the shoals leads to focusing of wave energy and increased wave energy dissipation around the location of the local minimum water depth. This generates residual currents over the shoal and increased skin friction towards the local minimum water depth, which together create a sand transport pattern that induces the growth and migration of the shoal. Sand transport due to asymmetric waves contributes to keeping the shoal a coherent structure. It was found that shoal migration speed increases with increasing incident wave energy and decreasing tidal prism, as is illustrated in Figure 1 (see next page). The latter is because tidal residual currents oppose wave-driven currents that cause shoal migration.

References

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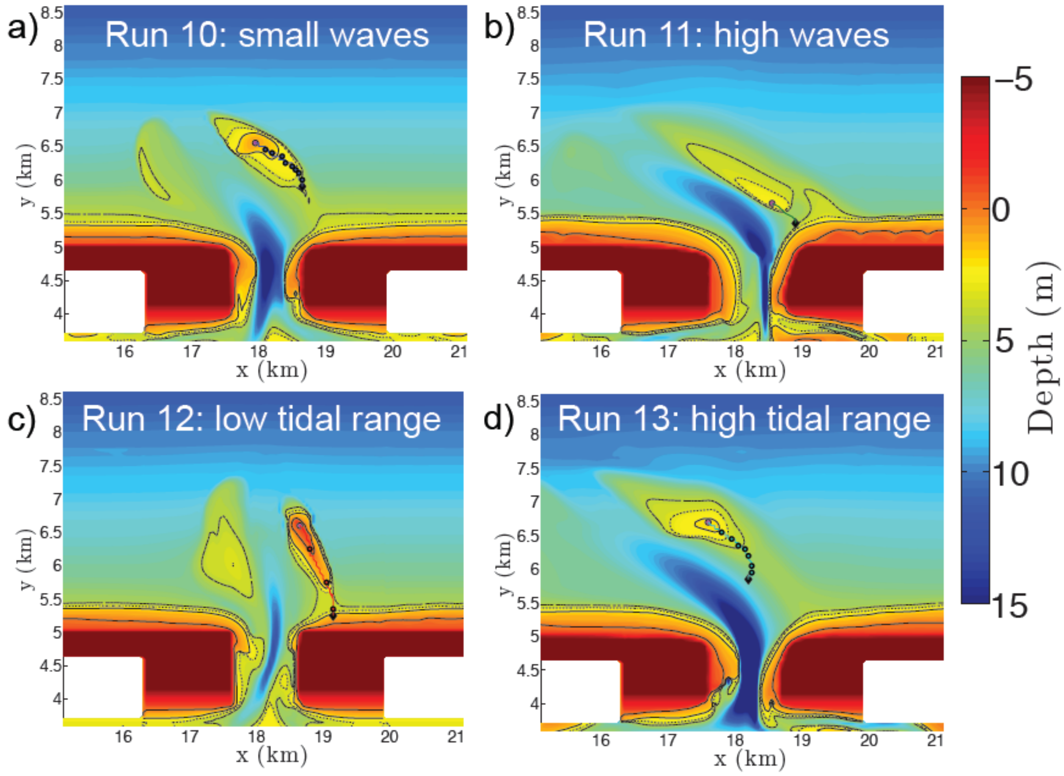

Figure 1: Bathymetry 200 days after the bathymetry was perturbed in a) with relatively small waves (H_s=0.75 m, default value is 1.2 m), b) large waves (H_s=1.75 m), c) with a small tidal range (0.75 m, compared to default value of 1 m) and d) with a high tidal range (1.5 m). The magenta dot indicates the location of the minimum water depth above the shoal. The colored lines indicate the path that the shoal follows until it reaches its most landward location (black diamond). The additional dots indicate the position of the shoal every 200 days.