Formation and destruction events of shoreline sand waves

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1. Introduction

Alongshore rhythmic morphological patterns at different length scales are quite common along sandy beaches. Well known examples are mega-cusps and crescentic bars/rip channel systems with alongshore wavelengths ~ 100-1000 m. At larger scales (~1-10 km or more) there are the km-scale shoreline sand waves (KSSW). During the last two decades there has been much research to unravel the origin of such intriguing patterns and to get insight into their dynamics. The hypothesis that they are self-organized and they emerge out of positive feedbacks between hydrodynamics and morphology has been amply confirmed by mathematical modelling. In particular, the potential role of high-angle wave incidence (HAWI) has been investigated (Ashton et al., 2001; van den Berg et al., 2012; Kaergaard & Fredsoe, 2013). However, the large spatial and temporal scales of these patterns have proven a major constraint to contrast the hypothesis with nature. This is because these tests would require detailed measurements of the bathymetry and the wave conditions during their formation from a featureless morphology. Such data are not reported in the literature and at best there are sites, such as the coast of Namibia, with already fully formed KSSW. The aim of this contribution is to test the HAWI mechanism by comparing model results with high-quality observations of KSSW along a stretch of coast in England.

2. Site

Dungeness is a cuspate foreland at the English shore of the Dover straight. It is a quite steep gravel beach without shore-parallel bars. Data from a wave buoy at 43 m depth show a bimodal wave climate with incident waves mainly from the South-West (SW) and from the North-East (NE). The former are dominant (Fig. 1, left), 35% vs 65% from 2006 to 2015). Focusing on the NE coast (green square in Fig. 1, left) and because of the shape of the cape, the SW waves are very oblique (high-angle waves) and the NE waves are nearly shore-normal (low-angle waves).

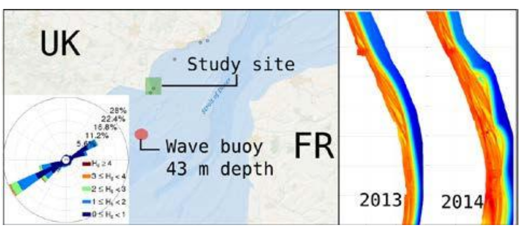

Fig. 1 Study site, wave rose and 5-m-depth bathymetries on 2013 and 2014.

3. Formation and destruction events

The formation of shoreline undulations has been clearly observed in the NE coast by means of bathymetric surveys between October 2013 and December 2014 (Fig. 1, right). There are bathymetric surveys roughly every year and three/four profile surveys every year. We extract 36 shorelines from profile surveys between 2003 and 2016 at the NE shoreline. These data are obtained from the U.K. Channel Coastal Observatory. Shoreline undulations appear in 2007 and 2014 with a wavelength of about 0.5 km. The 2007 undulations ended up being smoothed while the 2014 ones persist until 2016 migrating to the N. To quantify the dominance of SW waves at the NE shoreline, i.e., high-angle waves relative to this shoreline, we compute the SW/NE wave-energy-ratio as a function of time, t_0, (Fig. 2) during the interval between two extracted shorelines, Δt: $R(t_0)=E_{SW}(t_0)/E_{NE}(t_0)$ where

$$E_{SW}(t_0)=\int_{135}^{315} d\theta \int_{t_0}^{t_0+\Delta t} H^{5/2} dt$$

and a similar expression is used for E_{NE} with an integral from -45° to 135°. It is found that the formation events correlate with large R values (e.g., 2007 and 2014) and for low R values the shoreline remains relatively smooth with only small-scale undulations (e.g., 2009-2011). This suggests that HAWI is playing an important role in the formation of the large-scale undulations. The clear formation events and the 2007-destruction event provide a unique opportunity to compare observations with the outputs of morphodynamic models (e.g., van den Berg et al., 2012). This comparison is under way in order to test the self-organization hypothesis (HAWI).

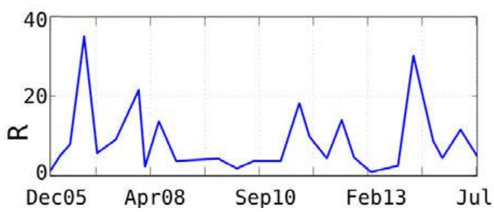

Fig. 2 SW/NE wave-energy-ratio during the intervals of extracted shorelines.

Acknowledgements

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References

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