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THE ROLE OF SURFACE ROLLERS ON THE FORMATION OF SURFZONE TRANSVERSE SAND BARS

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1. Introduction

Patches of transverse sand bars have been observed in the surf zone of several beaches. These bars are spaced with a remarkable alongshore periodicity (from 20 to 200 m). A patch of transverse bars with a wavelength of *45* m, observed during September 2002 at Noordwijk beach (the Netherlands), is shown in Figure 1a (Ribas and Kroon, 2007). The bar crests deviated some 30^o from the shore-normal against the longshore current flow (up-current orientation).

A possible explanation for the formation of this type of up-current oriented bars is based on the concept of morphodynamic self-organization. Topographic perturbations superimposed on an alongshore uniform beach induce hydrodynamic perturbations, which can lead to convergence of sand transport over the bars, hence producing a positive feedback. Stability analysis is a convenient tool to investigate the possible feedbacks, yielding information about the shape, the growth rate and the migration speed of the initially emerging modes. The study of Ribas and Kroon (2007) used the field observations at Noordwijk to test the predictions of the existing idealized self-organization models for transverse bar formation. Considering that Noordwijk bars were up-current oriented and that they emerged during periods of clearly oblique wave incidence, only the 'bed-flow mechanism' described by Ribas et al. (2003) remained as a viable explanation for their formation. Their crucial assumption is related to the cross-shore distribution of the depth-averaged volumetric sediment concentration, C_{da}. Only when C_{da} decreases seaward in the inner surf zone, up-current oriented bars can emerge.

The aim of the present contribution is to model and understand the role of surface rollers on the formation of up-current oriented surfzone bars using a more realistic model. Rollers can play a crucial role because they create turbulent bores that can lead to significant sediment resuspension in the inner surf zone. This may give a cross-shore distribution of C_{da} that could explain the formation of up-current bars. We use the up-to-date self-organization model described in Calvete et al. (2005), based on stability analysis, after extending it to include rollers and bore resuspension in the inner surf zone.

2. Model

The model describes the feedback between wave and roller dynamics, depth-averaged currents and bed evolution, so that self-organized processes can develop. Wave heights are supposed to be randomly distributed. Wave evolution is described using linear theory and a wave energy balance equation (with wave-current interactions). The roller energy balance equation is modelled following Reniers et al. (2004). The large-scale fluid motions are governed by the momentum and mass conservation equations, where the radiation stresses due to wave and roller propagation are included. All equations and quantities are wave- and depth-averaged. Finally, the depth-averaged sediment transport in the bed evolution equation is modelled following the widely accepted Soulsby and van Rijn formula. We have extended it to include the extra contribution to C_{da} due to the sediment stirring

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created by the bore induced turbulence. We follow Roelvink and Stive (1989), who assumed that this extra C_{da} was proportional to the dissipation of roller energy.

Firstly, the equilibrium solution is computed using a reference beach profile measured at Noordwijk. Then, stability analysis is applied in a standard way. Starting from arbitrary initial conditions, the dynamics after some time will be dominated by the fastest growing mode.

3. Results and conclusions

The model is applied to the specific wave and bathymetric conditions measured at Noordwijk. Realistic positive feedback leading to formation of bars like those observed only occurs if the stirring of sediment due to bore turbulence is included in the model. In that case, the depth-averaged sediment concentration C_{da} decreases seaward across the inner surf zone. This, in combination with an offshore-directed flow over the up-current oriented bars, leads to accretion of sediment in the crest areas. Thereby, our results confirm that the bed-flow interaction, described in Ribas et al. (2003), can cause the development of transverse bars in Noordwijk.

The up-current oriented shape (with an orientation of some 60^o), the wavelength (around *60* m) and the growth rate (of the order of half a day) of the modelled bars are in good agreement with observations at Noordwijk. However, modelled migration speeds (from tens to a few hundreds of meters per day) are significantly higher than those measured in the field. Figure 1c shows the fastest growing mode obtained for the conditions measured during the event shown in Figure 1a.

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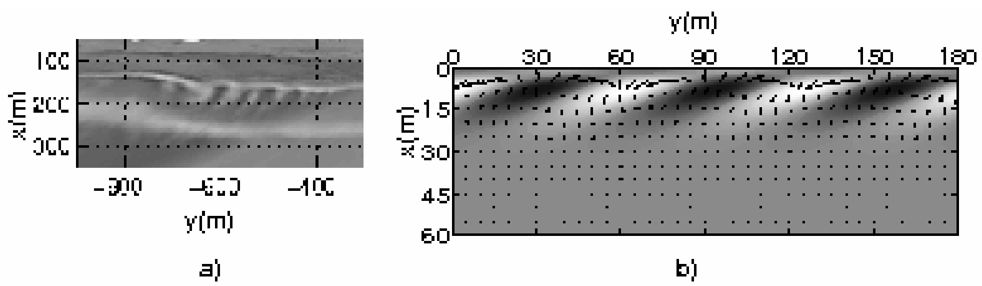

Figure 1. a) Observed transverse sand bars, in a 10-minute average of video images that shows a clear white signal over the bars due to predominant wave breaking; b) Modelled transverse sand bars, in an image with the topographic perturbations (white areas stand for shallow regions) and the current perturbations in small arrows.