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Nonlinear modelling of nearshore sand bars from self organization processes: a 'Global Analysis'

R. Garnier (1), N. Dodd (1), D. Calvete (2) and A. Falques (2)

(1) School of Civil Engineering, University of Nottingham, Nottingham, UK, (2) Applied Physics Department, Universitat Politecnica de Catalunya, Barcelona, Spain.
(Roland.Garnier@nottingham.ac.uk/Fax: +44-115-951-3898)

It is nowadays increasingly recognized that different types of nearshore sand bars emerge from self organization processes of the coupling between the hydrodynamics and the evolving topography. As an example of such patterns, a crescentic bar system associated with rip current system can develop from the instability of an initially uniform alonshore bar beach. A number of numerical modelling studies simulate the formation or the initial stages of the evolution of these features. Here, the nonlinear numerical model MORFO55 based on a wave and depth averaged shallow water equations solver with wave driver, sediment transport and bed updating is used to extend their evolution to the long term behaviour.

In particular, we found that the growth of the bars saturates, marking the transition between the linear and the nonlinear regime. In the latter, we observe merging/splitting in bars and variation of bar height until the bar wavelength and height stabilize so that the beach system reach eventually a dynamical equilibrium state. For oblique wave incidence the longshore current induces the migration of bars, thus, at equilibrium, bars are advected down-current.

To understand the dynamics of the rip channel systems, we introduce the concept of 'Global Analysis', previously seen in the case of transverse bars (*Garnier et al. 2006, J. Fluid Mech.*), which means that the beach dynamics are analysed from the whole domain, i.e. by using integrated variables over the cross-shore and the longshore axis. In this sense the 'bar amplitude' (A) is defined, and a decomposition of the sediment transport formulation gives two variables: the ‘production’ ($P > 0$) from the advective part and the ‘damping’ ($\Delta < 0$) from the bed-slope transport. We show that the growth rate of the instabilities can be approximated by the relation: $(P + \Delta)/(A^2)$. Another formula can be obtained for the bar migration celerity.

The Global Analysis will be firstly used to understand the bar dynamics in the linear regime. Based on the idea that the bars develop if the production dominates over the damping (i.e., positive growth rate), some aspects observed in previous modelling/observation studies will be explained, e.g. why do the bars not appear for high wave angle ?

Secondly, we will show that the nonlinear regime begins when the growth rate decreases and that one condition for the equilibrium is that the growth rate is zero. We will also explain why the final bar amplitude does not necessarily depend on the growth rate.