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Modelling high angle wave instability and the generation of large scale shoreline sand waves

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Sandy coasts are dynamic systems, shaped by the continuous interaction between hydrodynamics and morphology. On a large time and spacial scale it is commonly assumed that the diffusive action of alongshore wave driven sediment transport dominates and maintains a stable and straight shoreline. Ashton et. al. (2001) however showed with a cellular model that for high angle off-shore wave incidence a coastline can be unstable and that shoreline sand waves can develop due to the feedback of shoreline changes into the wave field. These shoreline undulations can migrate and merge to form large scale capes and spits. Falqués and Calvete (2005) confirmed the mechanism of shoreline instability and shoreline sand wave formation with a linear stability analysis. They found a typical wavelength in the range 4-15 km and a characteristic growth time of a few years. Both studies however have there limitations. Ashton et. al. (2001) assume rectilinear depth contours and an infinite cross-shore extent of shoreline changes in the bathymetry. The linear stability analysis by Falqués and Calvete (2005) can only be applied for small amplitude shoreline changes. Both studies neglect cross-shore dynamics as bathymetric changes associated to shoreline changes are assumed to be instantaneous.

In the current study, a nonlinear morphodynamic model is used. In this model the bathymetric lines are curvilinear and the cross-shore extent of shoreline changes in the bathymetry is dynamic due to the introduction of cross-shore dynamics. The cross-shore dynamics are parameterized by assuming a relaxation to an equilibrium cross-shore profile. The relaxation is controlled by a diffusivity which is proportional to wave energy dissipation. The new model is equivalent to N-lines models but applies sediment conservation like 2DH models instead of just moving contour lines.

The main objective of this study is to extend the work of Falqués and Calvete (2005) and to study in more detail the mechanism of high angle wave instability. In specific we look at the effect of wave incidence angle, wave height and period, the role of cross-shore dynamics and initial conditions. As a default case we use a 20 km long beach with a Dean-type cross-shore profile, unidirectional waves (Hs=1.4 m, Tp=6 s, incidence angle 60 deg) and random bathymetric perturbations of 0.1 m. Preliminary results show that for high angle offshore wave incidence shoreline sand waves develop from the random perturbations. For lower wave incidence angles the shoreline remains stable and no shoreline undulations develop. Instability only develops when the incidence angle at the depth of closure, the most off-shore extent of the shoreline changes, is higher then the critical value of 42 degrees. This is in contrast with Ashton et. al. (2001) who evaluate this critical angle at deep water, which makes a coastline more prone to instability. The dominating wavelength of the sand waves is between 3 and 4 km and this is in agreement with the results of Falqués and Calvete (2005). Shoreline instability increases with higher off-shore wave height and shorter wave periods. Studies on the effect of the initial perturbations and the effect of varying wave conditions (bimodal and alternating stable and unstable conditions) are still in progress.

References

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