Large scale instability of sandy coastlines under very oblique wave incidence.

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ABSTRACT

Breaking waves incident with certain angle with respect to the shore-normal drive an alongshore current that transports sediment along sandy coasts. Departures with respect to alongshore uniformity in the morphology cause gradients in the current and in the sediment flux feeding back into the morphology. Ashton et al. [1] showed that this coupling may be unstable in case of large angles of incidence (> 42^o in deep water) leading to the formation of large scale patterns (O(10-10^2 km)). The smallest among these patterns are relatively subtle shoreline undulations known as shoreline sand waves. They may go on growing and eventually develop into larger scale features known as capes or sandy spits. This instability was first studied by Ashton et al. [1] by using a cellular model. Although their model nicely shows the cascading in time of the instability towards such large scale features and reproduces some of the observed morphologies along some coasts, it is based on very crude simplifications that make it only valid for the limit of large wavelengths. As a result, it is unable of predicting any wavelength selection at the onset of the instability. Linear stability for this problem is not straightforward as the governing equation in the most simplified framework (one-line shoreline modelling) is a diffusion one with negative diffusivity. Falqués and Calvete [2] improved the classical one-line modelling obtaining a non-local governing equation where short wavelengths are damped. By linear stability analysis they determined the initially dominant wavelength O(1-10 km), the characteristic growth time O(1-10 yr) and the alongshore propagation celerity O(0.1-1 km/yr) of the emerging sand waves. Because the conditions for instability are difficult to meet in nature, in most of the unstable cases the system is just above the threshold developing just sand waves but not capes and spits. In such cases the predictions of linear stability analysis hold quite well and data from some coasts including The Netherlands, Spain, Brazil and Namibia are consistent with them. More recently, the linear stability model has been extended with a nonlinear model that reproduces the formation of shoreline sand waves from small perturbations of the rectilinear shoreline. The length and time scales of the linear stability analysis are reproduced and sand waves of wavelength about 3-5 km which grow up to 250 m amplitude within about 10 yr are obtained. With respect to the study of Ashton et al. [1] our work shows that the conditions for instability are more uncommon than initially foreseen: i) the critical angle of 42^o must be in relatively shallow water (~ 5-10 m) rather than in deep water, a condition difficult to meet due to wave refraction as waves approach the coast and ii) in real wave climates where wave angles vary in time, the frequency of high angles must be very large in order to have instability. Furthermore, the wavelength selection at the initial stage of development, which seems to be confirmed by observations, is totally new with respect to their study.

REFERENCES

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