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Discussion

Comment on "On the development of large-scale cuspate features on a semi-reflective beach: Carchuna beach, Southern Spain," by M. Ortega Sanchez, M.A. Losada and A. Baquerizo [Mar. Geol. 198 (2003) 209–223]

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Ortega Sanchez et al. (2003) discuss mechanisms that could be responsible for the formation and maintenance of irregular, kilometer-scale cuspate features along Carchuna beach on the southern coast of Spain. The authors mention that one of the possible formation mechanisms for this cuspate shoreline is a recently highlighted instability in shoreline shape due to highly oblique waves that can lead to the self-organization of cuspate shoreline features (Ashton et al., 2001). However, the authors dismiss the long-term prospects for this process to affect Carchuna beach, citing the common misconception that the instability in shoreline shape requires the angle between the *breaking* wave crests and the shoreline ('wave angle') to be greater than 45° (Wang and Le Mehaute, 1980). We would like to clarify that the fundamental instability in shoreline shape that can form cuspate shorelines should occur whenever waves approach a shoreline with *deep water* wave angles greater than approximately 45° ('high angles'), even if breaking-wave angles are much smaller.

The common misconception that the maximum in alongshore sediment transport along a shoreline will occur when waves break at angles of 45° probably arises because most formulations for alongshore sediment transport (Q_s) are expressed in terms of breaking wave quantities, such as the common formula:

$$Q_s = KH_b^{5/2}\sin(\alpha_b)\cos(\alpha_b), \tag{1}$$

where H_b is the breaking-wave height, α_b is the breaking-wave angle and K is a constant (Komar, 1971). In this formulation, for a given breaking wave height, Q_s is maximized when waves break at an angle of 45°. However, along a natural shoreline, as waves approach shore they shoal and refract, which changes both their angle and height. Because the amount of refraction depends on the shoreline orientation (relative to the wave's deep-water approach angle), both breaking-wave angle and breaking-wave height will vary along an undulating shoreline (Ashton et al., 2001; Falques, 2003). Longuet-Higgins (1970) demonstrated that the flux of momentum that drives the alongshore current ($\propto H^2\sin(\alpha)\cos(\alpha)$) is constant as waves shoal and refract over shore-parallel contours. Accordingly, Eq. (1) can be transformed to (assuming $\cos^{1/5}(\alpha_b) \approx 1$):

$$Q_s = K'\, H_0^{12/5}\sin(\alpha_0)\cos^{6/5}(\alpha_0), \tag{2}$$

in terms of deep-water wave height (H_0) and angle (α_0). Unlike breaking-wave height, deep-water wave

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height can be considered constant along a stretch of shoreline. Eq. (2) predicts that for given deep-water wave conditions, the combination of breaking-wave height and angle that maximizes alongshore sediment transport will correspond to waves with a deep-water wave angle of approximately 45° (actually closer to 43°) (Ashton et al., 2001). (For example, for 2m, 10s waves, the maximum in Q_s would occur when waves that approach at a deep-water angle of 43° break at an angle of approximately 13°.)

Ortega Sanchez et al. (2003) describe Carchuna beach as having a south-facing shoreline trend dominantly affected by strong waves approaching from the W, WSW, SW, E, and ESE, all of which represent directions where the deep-water wave angle is greater than or equal to 45°. Although we have not studied Carchuna beach and its wave climate, the information provided by the authors suggests that this cuspate shoreline is a likely location for the instability in shoreline shape due to high-angle waves to occur. We believe that a thorough investigation of the wave climate (such as has been performed for the North Carolina (Ashton et al., 2003a) and Dutch (Ashton et al., 2003b) coasts) should be completed before the high wave-angle instability can be dismissed as a factor in the evolution of this beach.

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