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Discussion

Reply to Comment on "On the development of large scale features on a semi-reflective beach: Carchuna beach, Southern Spain" by A. Ashton and A. Brad Murray

M. Ortega Sanchez*, M.A. Losada, A. Baquerizo

Grupo de Puertos y Costas, Centro Andaluz de Medio Ambiente, Universidad de Granada, Avda. Del Mediterraneo s/n, Granada 18071, Spain

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1. Introduction

First of all, the authors want to thank Ashton and Murray for their interest and comments about the work, which have broadened the possible approaches to the problem.

They also want to emphasize that the work by Ashton et al. (2001) was pioneering in this topic and provides a plausible justification for the growth of large scale features. This is the reason why their work was cited in the article and considered as one of the possible mechanisms involved in the generation of the horns of Carchuna. However, after a detailed analysis that was not included in the article because of space limitations, it was concluded that the instability mechanism was not suitable for this particular case.

The discussion by Ashton and Murray (2004) offers the authors the opportunity to justify why the mechanisms proposed in the discussion were not considered.

The reply is organized as follows: first, the physical processes observed after the installation of an ARGUS station at Carchuna beach is exposed. Next, the main hypothesis of the one-line model and its limitations are summarized. Then, an explanation is offered as to why the instability mechanism is not likely to be involved in the formation of Carchuna's horns in comparison to the effect of wave height scattering during refraction. Finally, some other possible explanations for the generation of Carchuna morphology, with which the authors are now working, are presented.

2. Carchuna beach morphodynamic data

Data from the ARGUS Station installed in Carchuna in December 2002 show that in the vicinity of the horns, the breaking surf width and the type of wave breaking varies with time (Fig. 1) depending on the wave incidence (H,T,ϑ), that is, on the characteristics of the sea state. These results seem to confirm the explanation given by Ortega Sanchez et al. (2003) about the littoral processes associated with two of the three sea states of wave energy levels presented there.

In Fig. 1(a), the wave refraction due to the horns generates two opposite wave fronts that produce a circulation pattern which reinforces the horns. On the

* Corresponding author. Fax: +34-958-132479.
E-mail address: miguelos@ugr.es (M. Ortega Sanchez).

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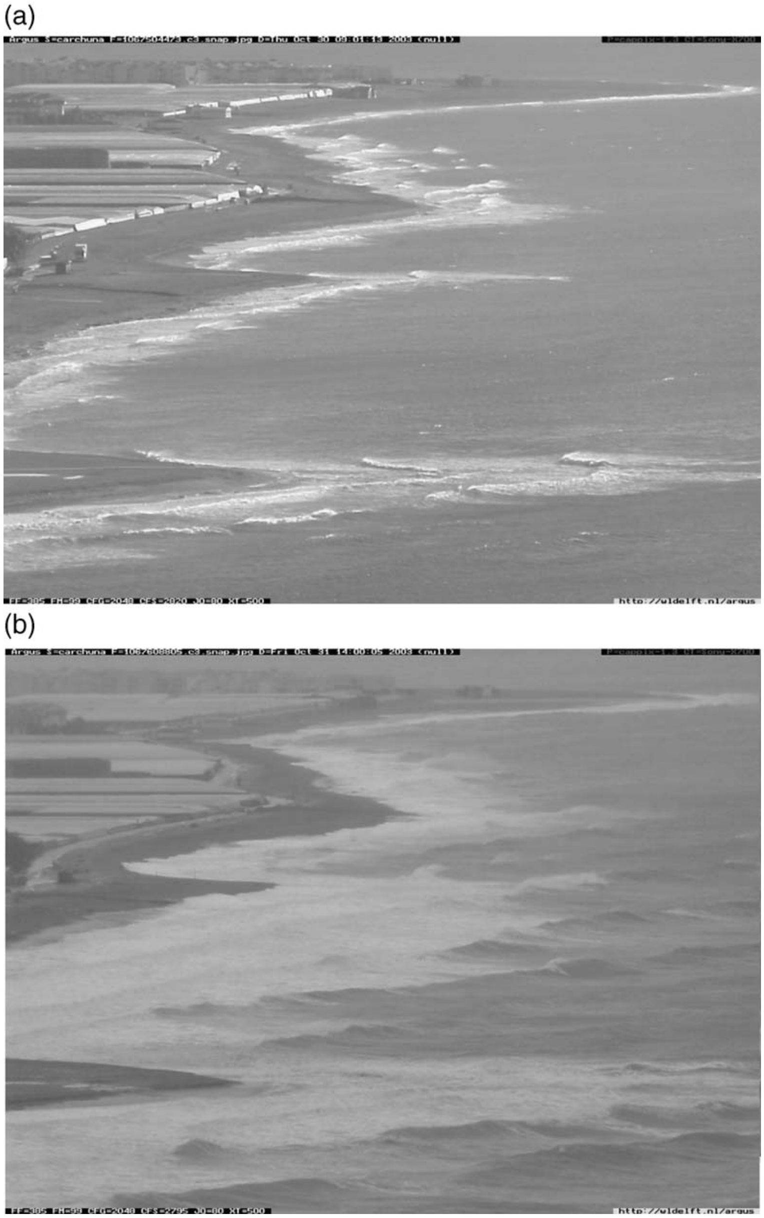

Fig. 1. Images from the ARGUS Station installed at Carchuna (SW wave incoming direction) under (a) mild wave conditions and (b) storm conditions.

contrary, in Fig. 1(b), waves propagate and break over the horns, eroding them and transporting the sediment to the East. Comparing both pictures, it can also be observed that the surf zone width is clearly different and that there is an important alongshore gradient of the breaking wave height and obliquity.

3. Application of Ashton et al. (2001) model to Carchuna

The model by Ashton et al. (2001) is a so-called one-line model type. It consists of a linear diffusion equation with an initial condition and two boundary conditions. The governing equation is obtained by assuming that the sediment transport occurs mainly alongshore induced by the mean current velocity driven by oblique breaking waves. The cross-shore sediment transport is neglected or included as a source term in the conservation equation. In addition, it is implicitly assumed that the current associated with alongshore gradients of the wave height at breaking can be neglected, that is, it is assured that $\partial H/\partial y = 0$.

This alongshore wave height gradient appears in the term $(\partial S_{yy})/(\partial y)$ in the momentum conservation equation

$$\frac{\partial S_{xy}}{\partial x} + \frac{\partial S_{yy}}{\partial y} = T_y + R_y \tag{1}$$

where S_{xy} and S_{yy} are the components of the radiation stress tensor (x and y are the shore-normal and shore-parallel coordinates) and T_y and R_y are the terms including the variation of the mean water level and the frictional terms, respectively. This gradient may play an important role at places where there are strong changes in coastal alignment.

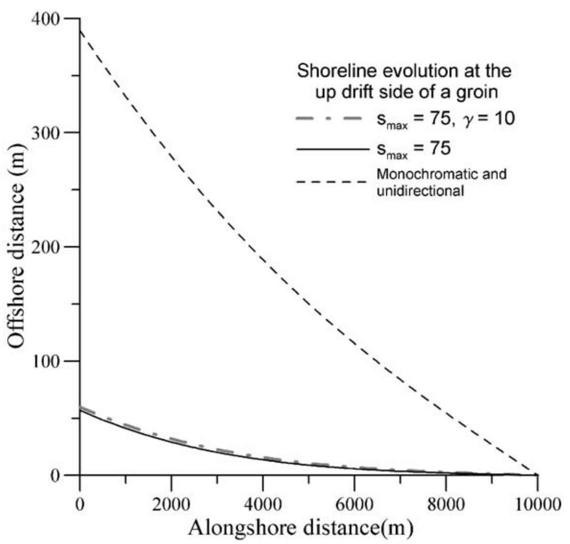

Fig. 2. Shoreline evolution at the up drift side of a groin for an initially straight beach. Two solutions for irregular swell forcing waves versus monochromatic and unidirectional forcing waves (adopted from Payo et al., 2003).

The importance of this component in the alongshore velocity is well known, in fact, Komar and Inman (1970) showed that the superposition of both gradient terms can even produce a reversal in the alongshore current. Therefore, any explanation of the formation of the horns should work with models that include the contribution of both terms. Furthermore, the variation of the breaking type and the breaking surf width should also be considered.

On the other hand, Payo et al. (submitted for publication) have recently showed that the classical one-line model forced by a multi-directional and multi-frequential wave energy spectrum gives solutions which evolve more slowly than those forced by a monochromatic wave train (Fig. 2).

In the authors' opinion, the application of a one-line model for the analysis of the long term evolution of large scale horns is not suitable for those in Carchuna and, consequently, results derived from it would not be reliable enough.

4. Formation of the horns due to instabilities

So far, the question of whether or not Carchuna's horns are generated by an instability mechanism has still not been addressed. For an affirmative answer, it would be necessary that the circulatory system associated with the unstable modes were also involved in the existence of the submerged fluvial valleys in the topography. These valleys would then refract the waves reinforcing the circulatory system, thereby generating a self-organized system.

According to the knowledge of the authors, there is no available model to explain or justify the formation of the valleys down to a depth of 70 m by means of a circulatory system induced by wave breaking. On the other hand, the analysis of the emerged and submerged topography shows the concomitance of the actual river net and the paleo-valleys, suggesting that those valleys were developed before the formation of the horn-embayment system as explained in the work by Ortega Sanchez et al. (2003). This was the main reason why the authors focused their work on the justification of the generation of the Carchuna's morphology starting from the alongshore variation of the wave height by refraction on the paleo-valleys.

5. Other possible generating mechanisms

In the authors' opinion, further analysis of the formation of Carchuna's horns is still needed to account for the action of other climatic agents like the wind which, in this case, may play an important role. With the aid of video images from the ARGUS station and developing an ad-hoc model, the authors are now working on the effect of the circulatory system due to the wind on the generation of horns, by looking for relationships between the horns spacing and the circulation pattern induced by the predominant wind. The authors are seeking cell circulations with length scales of the order of the continental shelf width that would be strong enough to reach 70-m depth and, consequently, to initiate the self-organized pattern.

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