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Dual wave farms for energy production and coastal protection

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ABSTRACT

The synergetic application of wave farms, i.e., arrays of wave energy converters (WECs), for protecting the coast in addition to their main objective of generating carbon-free energy can place this renewable resource as a major element in ocean and coastal management. In particular, their ability to mitigate coastal erosion by reducing the amount of wave power reaching the coast will be put to use – and this is the motivation for this work. We propose a new approach in which the wave farm has a dual purpose: to generate carbon-free energy and to contribute to coastal erosion management. We illustrate this approach by means of a case study: a dual-purpose wave farm off Xago, a beach-dune system in Asturias (N Spain) subject to severe erosion – manifested dramatically in the retreat of the dune – and located in the area earmarked for the first wave farm in Spain. The objective of this work is to establish whether or not the wave farm may be useful to counter the erosion of the beach-dune system. To this end a wave propagation model is coupled with a state-of-the-art coastal processes model and applied to analyse the response of the system under storm conditions in two scenarios: with and without the farm. The efficiency of the wave farm in mitigating erosion is determined by comparing the results in both scenarios by means of a series of coastal indicators defined *ad hoc*. We find that the farm reduces storm-induced erosion particularly where it is most acute, in the dune front, and thus contributes to alleviate the current erosive trends. This opens up exciting possibilities of using dual wave farms in lieu of, or as a complement to, coastal structures or beach nourishment. As wave energy develops into a major renewable energy source in the coming decades, dual wave farms are poised to constitute a breakthrough in coastal erosion management.

1. Introduction

The current status of wave energy is similar to that of wind energy in the early 80's. With a vast resource and a very active R&D community, wave energy is expected to become a major renewable in the coming decades, with wave farms deployed in a number of coastal regions throughout the world (Bernhoff et al., 2006; Cornett, 2008; Folley and Whittaker, 2009; Guedes Soares et al., 2014; Iglesias and Carballo, 2009, 2010b; Pontes et al., 1998; Veigas and Iglesias, 2013, 2014; Vicinanza et al., 2013). In previous work it was established that the extraction of wave energy by a nearshore wave farm results in a milder wave climate in its lee (Carballo and Iglesias, 2013; Iglesias and Carballo, 2014; Mendoza et al., 2014; Millar et al., 2007; Palha et al., 2010; Ruol et al., 2011; Smith et al., 2012; Veigas et al., 2014a, 2014b; Vidal et al., 2007; Zanuttigh and Angelelli, 2013). The scientific hypothesis of this work is that this reduction in wave energy can be used for coastal erosion management, in particular in the case of a beach-dune system. To test the hypothesis, a case study is carried out on Xago Beach, in the area proposed by FAEN (*Fundación Asturiana de la Energía*, Asturian Energy Foundation) for the deployment of the first wave farm in Spain. Previous studies of relevance for this work include the characterisation of the wave resource in the region (Iglesias and Carballo, 2010a) and the geological and geotechnical study for wave farm development (Flor-Blanco et al., 2011), in which two areas off the beaches of Xago and Llumeres (Fig. 1) were recommended.

The Xago beach-dune system constitutes an ideal case study, for it has experienced significant erosion in recent years. This is revealed particularly by the dune toe, which receded up to 11.5 m over a relatively short period of time, 2011–2014 (Fig. 2) (Flor-Blanco et al., 2013; Flor et al., 2015). The conventional approach to defending the coast against flooding and erosion involves coastal structures: stone-armour or concrete-unit revetments, seawalls, groynes, detached breakwaters, etc. – this is the so-called “hard engineering” approach. The downsides of this approach are well known: it results in armoured coastlines,

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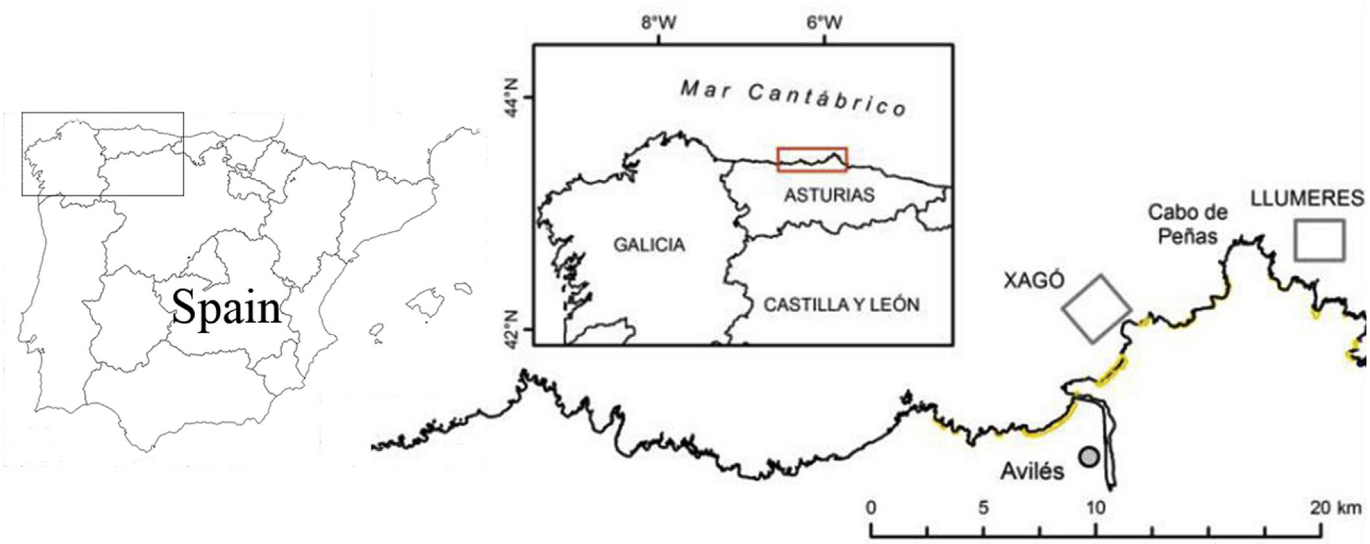

Fig. 1. Location of the Xago beach-dune system in Asturias, N Spain. The squares on the right-hand side of the figure delimit the areas selected for the deployment of wave farms: Xago and Llumeres (Flor-Blanco et al., 2011).

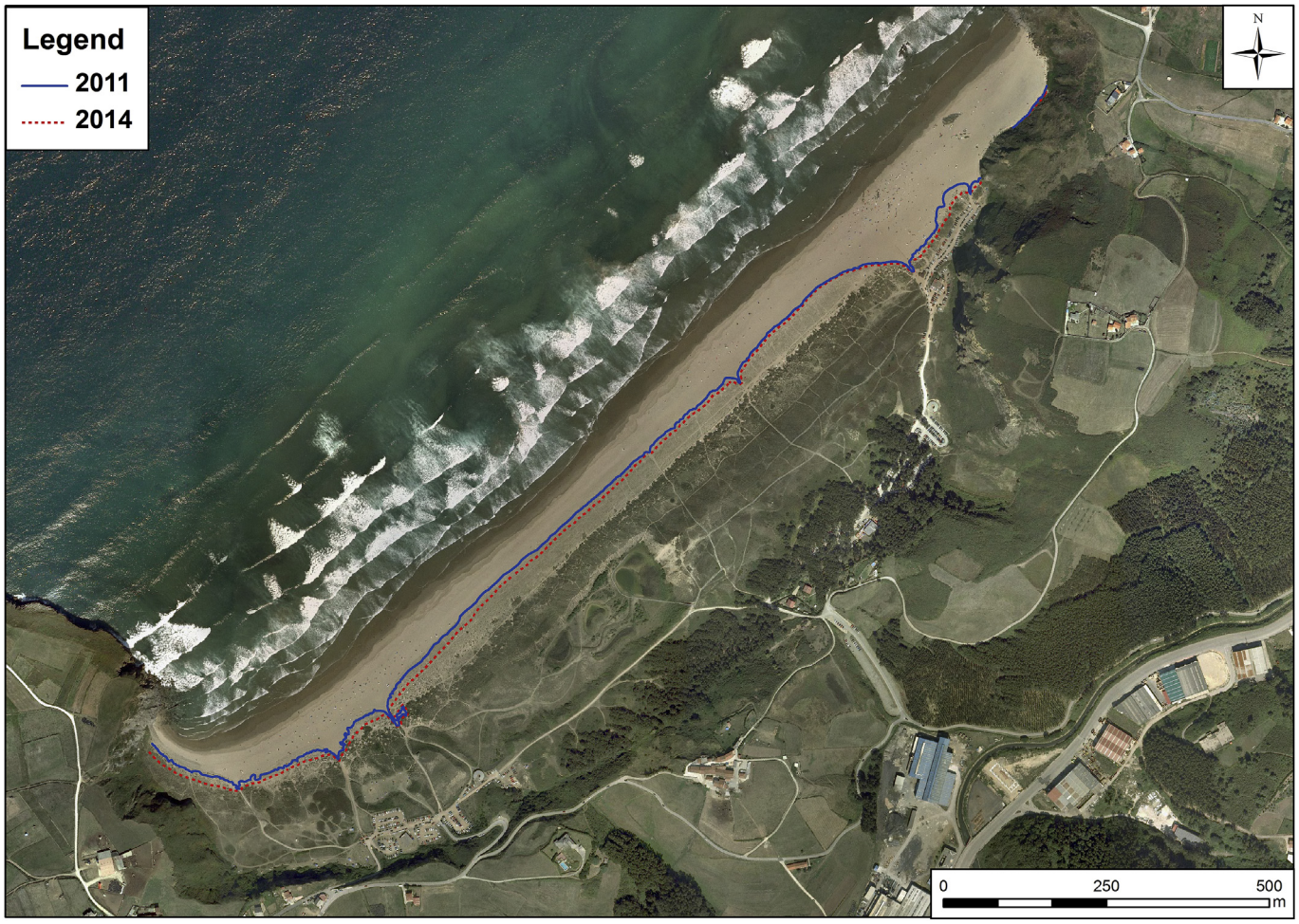

Fig. 2. Dune toe recession at Xago.

which bear little resemblance to their natural counterparts. Structures such as seawalls tend to have high wave reflection coefficients (far higher than those of beaches), which implies larger wave heights in front of the structure and often loss of sediment. Moreover, in the current context of climate change and transition coasts, the inability of structures to adapt to sea-level rise poses a problem. Indeed, there have been recently many cases of coastal structures failing to cope with the increased pressures of climate change (Castelle et al., 2015; Kendon and McCarthy, 2015; Senechal et al., 2015). These examples of failures of coastal structures – due to either structural collapse or excessive