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Wave Energy Patterns under Different Sea Level Rise (SLR) Probabilities in the Andalusian Atlantic coast

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ABSTRACT

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Sea Level Rise (SLR) derived impacts in coastal areas has become a subject of increasing concern particularly in low-lying coastal stretches. Synergetic effects with increasing storminess and wind-wave climate variability is expected to force sandy coastlines to accommodate to new forcing conditions. Previous studies have used SLR scenarios to evaluate expected changes in shoreline position and to create flooding vulnerability maps, among others applications. Less common are the studies that use a combine approach to determine the expected changes of certain wave hydrodynamics parameters based on a single probability value of $P = 0.5$ in order to determine future SLR changes. Nevertheless, SLR scenarios developed by IPCC involve a probability model with centrality and dispersion parameters that allow matching probability values and future SLR and therefore to derive different site-specific probability scenarios. In the this work we present an integrated approach that assess the influence of different sea level rise scenarios (calculated based on local probabilities) on wave energy patterns using a wave propagation model in a mesotidal coast in southwestern Spain. The local probabilities spectrum is calculated through the integration of the observed sea level rise trends from the local tide gauge and by using the centrality and deviation parameters of the IPCC scenario RCP8.5. Five SLR probabilities were used in the nearshore wave simulations, corresponding to $P < 0.99$ (+0.20 m), $P < 0.75$ (+0.56 m), $P < 0.5$ (+0.7 m), $P < 0.25$ (+0.86 m), $P < 0.01$ (+1.20 m) and $P = 1$ as the current sea level. These five scenarios were run under modal and high energy wave conditions established from 15-year long wave time series. The results show a diverse hydrodynamic behavior that seems to be driven by a combination of factors such as the morphological conditions, beach orientation and platform steepness. Further, the presence of cross-shore rocky platforms influences wave energy propagation patterns for the different analyzed probability cases. The study helps to understand future coastal behavior under a SLR scenario though some limitations are acknowledged as the approach does not include the continuous morphological adaptation of the site to sea level rise.

ADDITIONAL INDEX WORDS: *Wave energy, sea level rise, climate change, probability.*

INTRODUCTION

According to IPCC global mean sea level is rising and accelerating due to the sum of glacier and ice sheet contributions, increasing to 3.6 mm / year over the period 2005-2015 (IPCC, 2019). Erosion, flooding and salinization risks are expected to significantly increase by the end of the 21st century. The retreat of shorelines, due to submersion or coastal erosion, will cause deep changes in a wide range of different processes like tidal patterns, wave propagation or currents, as well as in their interactions with human structures. Previous studies that have addressed the impact of future sea level rise (SLR) on shoreline changes (Passeri *et al*., 2015), flooding (Neumann *et al*., 2015) and tides (Pickering *et al.,* 2017), did not take into account changes in the wave climate. Whereas studies that have addressed the impact of waves and related morphological changes do not consider changes in sea level focusing on a hydrodynamic analysis (by adding projected rise to the existing mean sea level as in Friedrichs, Aubrey, and. Speer (1990)).

A shortfall in the approach of any of these works is that morphological adaptation of the hydrodynamic conditions to the new positions of sea level is not considered. Only recently, the combination of sea level rise with expected shoreline behaviour in two microtidal beaches has been assessed (Enriquez *et al.,* 2016).

On the other hand, a common approach for SLR studies is the use of different scenarios to determine a wide range of possible conditions that can be used to set different hydrodynamic parameters for the future. The most common approach is to use a single probability value of $P = 0.5$, ignoring the full spectrum of probability from 0 to 1. However, the use of centrality and dispersion parameters in different models such as those of the IPCC supports their use in estimating future SLR from a probabilistic point of view (Fraile-Jurado *et al.,* 2017).

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work dealing with the uncertainties of climate change should consider the full spectra of probabilities, otherwise a wide range of possible events might be lost.

Nevertheless, the results proved that there will be deep changes in the parameters related to the wave energy independently of the probability, meaning that there is an almost certainty that these changes will take place. Therefore, shore protection and coastal management should be planned taking into account that even the most optimistic probabilities consider that SLR will involve dramatic changes from an energetic point of view.

Planning adaptation measures should be aware of uncertainties derived by the choice of scenario, the accuracy of input data (waves and bathymetry), the efficiency of shore protection measures, the future subsidence levels, the coastal morphological changes (topobathymetry), among others key variables when analyzing impacts of SLR in coastal areas.

Particularly, one of the main limitations of the present study is that it does not include future wave climate projections to assess wave climate variability associated to global change but only a high-energy scenario. Furthermore, resilience and adaptation of present coastlines to sea level rise are expected and could change the results obtained here. Therefore, future studies should implement a synergetic approach that integrates the dynamic interactions between physical (geomorphologic and hydrodynamic), social (presence of defenses and level of alteration) and ecological resilience to better predict the impacts of SLR on coastal systems.

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