

PROBABILISTIC SHORELINE CHANGE PROJECTIONS FOR THE CATALAN COAST (SPAIN): A PCR MODEL APPLICATION.

Rut Romero-Martín, Universitat Politècnica de Catalunya· BarcelonaTech, rut.romero@upc.edu

Johan Reyns, IHE Delft Institute for Water Education, j.reyns@un-ihe.org

Ali Dastgheib, IHE Delft Institute for Water Education, IMDC, a.dastgheib@un-ihe.org

Roshanka Ranasinghe, IHE Delft Institute for Water Education, r.ranasinghe@un-ihe.org

José A. Jiménez, Universitat Politècnica de Catalunya· BarcelonaTech, jose.jimenez@upc.edu

INTRODUCTION

Shoreline change due to climate change poses a significant challenge for the future management of beaches globally. Despite its recognized importance, determining the extent of these coastline changes remains a subject of debate, primarily because a universally accepted, reliable, easy-to-use predictive model is lacking.

The Bruun rule, despite its uncertainties, is the most commonly employed model - mainly due to its simplicity. Different alternative models have been proposed, among which the Probabilistic Coastline Recession (PCR) model (Ranasinghe et al., 2012) is one that has been used in many parts of the world. This physics-based model evaluates coastline recession by considering the combined impacts of storms and SLR in probabilistic terms while allowing beach recovery between storm events.

Despite its increasing application in coastal locations worldwide (e.g., Wainwright et al., 2015; Dastgheib et al., 2018; Le Cozannet et al., 2019; Dastgheib et al., 2022), like many existing models for estimating climate change driven shoreline change, PCR would benefit from applications in different environments. In this sense, it is pertinent to apply the model to various geomorphological environments experiencing diverse forcing regimes. Additionally, it's insightful to conduct intercomparisons with other widely used models, such as the Bruun rule, to determine if previously observed differences in estimations are site-specific or follow a common pattern of variation.

In this context, the primary objective of this study is to project 21st century shoreline change using the PCR model in two distinct coastal regions of Catalonia (NW Mediterranean). The selected sites, the Llobregat delta and the Maresme coast, are representative of the geomorphological variability on the coast. The Llobregat delta features a fine sediment coastline with gentle-sloped beaches, while the Maresme coast consists of coarse sediment and steep beaches. Both locations are situated within a microtidal environment, primarily influenced by wave-driven storm impacts, with storm surges playing only a minor role. The differing coastline orientations of these sites result in variations in storm characteristics affecting the separate coastline sections.

METHODOLOGY

These study sites are chosen not only due to their

contrasting geomorphological features and wave forces but also with regard to the potential repercussions of shoreline retreat. The Llobregat delta encompasses areas of natural significance while also hosting urbanized sections and critical infrastructure. Conversely, the Maresme coast is considerably constrained due to the presence of a coastal railway, which exacerbates the issue of coastal squeeze, as there is limited accommodation space available.

The PCR model has been applied according to the steps described as follows:

1. Generation of synthetic storm long-time series (in the order of 100 years). This has been done by using the synthetic storm generator JPM (Callaghan et al., 2008). Original wave climates used to generate multiple storm time series were obtained from 23-year-long hindcast data at points in front of the Llobregat delta and Maresme.
2. Estimation of SLR at the time of each storm impact during the synthetic time series. This has been done by using the AR6 IPCC SLR projections under the SSP1.2-6 and SSP5-8.5 scenarios.
3. Assessment of induced shoreline retreat for each storm in the generated storm time series, due to the combined effect of the storm and SLR at the time of each storm, while allowing for the recovery of the profile between storms. In this application, we have used the analytical erosion model of Mendoza & Jiménez (2006). To this end, representative values of sediment grain sizes (0.26 mm, and 0.64 mm respectively) and beach profiles of the two study sites have been used.
4. Quantify the extent of shoreline potential retreat by subtracting the initial position from its final computed position. In this work, we have used the averaged shoreline retreat over the last 3 years of the simulation to indicate the shoreline retreat.
5. Steps 1-4 are repeatedly executed until the model's results converge, with exceedance probabilities reaching or surpassing a predefined threshold, here set at 0.01%.

The PCR model was implemented by running 100,000 simulations of 80 years for each considered SLR scenario.

The Bruun rule has been applied following the approach adopted by Jiménez et al. (2017) to assess future shoreline change in the area. In this way to reduce the uncertainties associated to the selection of the closure depth, we assume that the induced retreat is inversely proportional to the slope of the upper shoreface representative of coastal stretches with an alongshore, homogeneous, inner-shelf slope. This slope has been calculated from the shoreline to 10 m water depth and, thus extending deeper than the medium-term closure depth of the area. To account for the potential variability introduced by geomorphology, we have calculated the values of the shoreface slope at different locations along the area, and thus, the estimations of the shoreline retreat are obtained in terms of a median value and a standard deviation.

RESULTS

Fig. 1 shows the CDFs of the last 3 years-averaged shoreline retreat in the Llobregat delta by 2100 under the AR6 SPSS1-2.5 and SSP5-8.5 SLR scenarios with respect to the year 2020. Also, the CDF corresponding to current conditions is shown, without SLR. Thus, for instance, if we select the 50% probability to represent the projected SLR-induced retreat in the area, the PCR model results indicate that the shoreline will retreat about 64 m and 83 m with respect to 2020 under the SPSS1-2.5 and SSP5-8.5 scenarios, respectively.

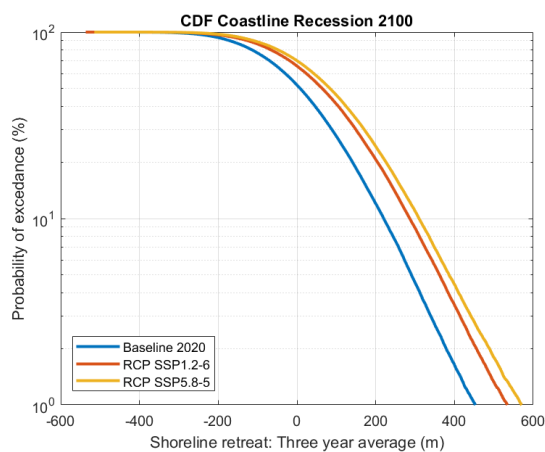


Figure 1 - CDF of coastline recession (relative to 2020) for SSP1.2-6 and SSP5-8.5 SLR projections scenarios obtained with PCR model in the Llobregat delta.

The median Bruun rule projections of shoreline retreat by 2100 in the Llobregat delta are 44 m and 70 m for SPSS1-2.5 and SSP5-8.5, respectively.

We provide a comprehensive analysis, comparing the performance of the PCR model at both study sites. Furthermore, the predictions will be compared with the results derived from Bruun rule. Finally, and as a local application, the probability of future exposure of existing infrastructures in both study sites will be estimated from PCR results.

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