EFFECTS OF STOCHASTIC WAVE FORCING ON EQUILIBRIUM SHORELINE RESPONSE ACROSS THE 21st CENTURY INCLUDING SEA-LEVEL RISE

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INTRODUCTION

Chronic erosion of sandy shorelines is a great concern for coastal communities, and its associated risks can be exacerbated by sea-level rise (SLR). Probabilistic long-term predictions of shoreline change are crucial to an informed adaptation planning. While scientists are moving towards ensemble-based approaches to address uncertainties on shoreline evolution, they rarely account for the stochastic nature of wave conditions across a several temporal scales (e.g., daily, seasonal, and interannual). In this work, we investigate the effects of the inherent variability of wave conditions in relation to other uncertain factors (e.g. future SLR) on multi-decadal shoreline evolution at the cross-shore transport dominated beach of Truc Vert (France). The analysis also includes the comparison of two different wave-driven equilibrium models response to the variability of wave conditions.

METHOD

We address probabilistic Truc Vert shoreline trajectories across the 21st century using two equilibrium shoreline models (Yates et al., 2009 and Splinter et al., 2014) and the Bruun (1962) model, including uncertainties in free model parameters, variability of wave conditions and SLR projections for two future representative greenhouse-gas concentration (RCP) scenarios. The uncertainties of each input variable are synthetized by their respective probability density distribution. For both shoreline models, we use the Simulated Annealing algorithm (Bertsimas and Tsitsiklis, 1993) to identify all the realistic combinations of model free parameters leading to a skillful hindcast against 8 years of in situ shoreline data. A Gaussian distribution is assigned to the yearly probabilistic SLR estimates based on the SROCC projections to 2100. We generate an ensemble of synthetic wave forcing conditions using the climate-based stochastic wave emulator developed by Cagigal et al. (2020), and considered these time series uniformly distributed (equally probable). Finally, we address the relative impact of the uncertain input variables on the results using new tools for Global Sensitivity Analysis (Owen, 2014). The contributions of uncertain inputs to the uncertainties on model results are quantified by calculating the Shapley Effects (Iooss and Prieur, 2019) which account for possible correlations and interactions among the input variables.

MAIN RESULTS AND IMPLICATIONS

The results show that the modelled shoreline variance is primarily driven by the uncertain wave chronology until mid-21st century while the uncertainties on future sea-level rise become dominant after 2060 in the simulated scenarios (Figure 1). This has implications for future research priorities and decision-making in climate change adaptation planning where coastal settings are similar to Truc Vert beach. Consistently with Vitousek et al. (2021), we find that the equilibrium shoreline models respond differently to ensemble wave forcing, so that the choice of the modelling approach is critical to long-term modelled shoreline variations and the related uncertainties. The application of Shapley Effects within the Global Sensitivity Analysis showed that the effects of interactions and interdependence among uncertain input variables can have a significant role in the uncertainty analysis (Figure 2). This indicates that while the intrinsic uncertainty of wave variability cannot be reduced, acting on the epistemic uncertainties (e.g. model choice, calibration data) may also attenuate the effects of the intrinsic uncertainties on the results.

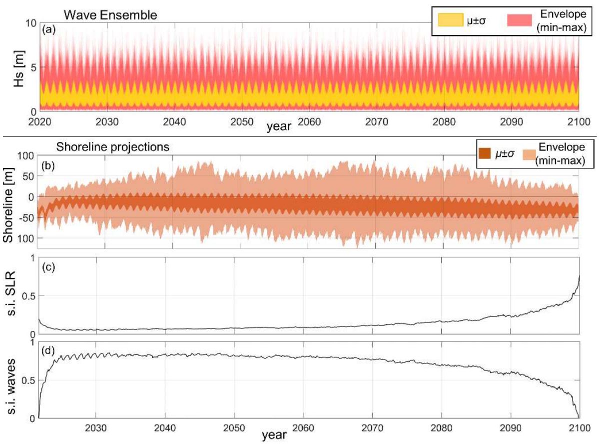

Figure 1 - (a) Envelope (red) and mean±σ interval (yellow) of 200 H_s time series of the wave forcing ensemble; (b) Envelope (light-shaded area) and mean±σ interval (dark-shaded area) of shoreline projections across the 21st century; and measures of model sensitivity to uncertainties on (c) SLR and (d) inherent variability of wave events.

Figure 2 – Comparison between Shapley Effects and first-order sensitivity indices that do not account for interactions and statistical dependence for (a, b) Splinter et al. (2014) model parameters, and (c) wave chronology.

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