DEVELOPMENT AND VALIDATION OF A MODELLING CHAIN TO QUANTIFY COASTAL FLOODING EXPOSURE AT AN ENGINEERED BEACH

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INTRODUCTION

The coastal flooding associated to storms can represent a critical challenge with significant consequences for both natural environments and human societies. This phenomenon could have far-reaching repercussions, impacting ecosystems, infrastructure, economies, and public safety in various ways what could result in substantial economic losses, displacement of communities, and disruption of daily life. The generation of databases associated to coastal flooding could enhance the knowledge into this phenomenon, helping decision-makers to develop more effective strategies to mitigate and manage the consequences of coastal flooding.

MOTIVATION AND OBJECTIVES

Coastal flooding field data is scarce and focused over short and specific periods due to the difficulties associated with acquiring and maintaining it over large periods. Alternative approaches such as the application of empirical formulations, neural networks or process-based numerical models have often been used to complement or even replace the coastal flooding field data. Due to their fast computation, the former two approaches are more akin to be used as Early Warning Systems (Stokes et al., 2021, Garzon et al., 2023). The latter approach is more computationally expensive. However, it allows to study the response of a beach to different storm conditions by explicitly considering the influence of climatic and geomorphologic parameters including the presence of coastal defenses.

The present study aims to develop and validate a modelling chain allowing to quantify the coastal flooding exposure at an engineered beach. This modelling chain is based on 3 modules: (1) a spectral wave model (SWAN), (2) a process-based phase-resolving model (XBeach NH) and (3) a hazard level estimator.

STUDY SITE AND DATASET

Our study site is the beach of Zarautz a 2 km long highly urbanized and engineered beach located on the Basque coast (norther Spain, Figure 1a). This embayed beach is composed of two sectors: i) a natural stretch backed by sand dunes and ii) an urban stretch formed by a vertical seawall that is used as a promenade. The latter is the object of this study (Figure 1b).

The validation of the modelling chain is based on a field data set including hydrodynamic, topobathymetric and videometry data collected for one month (23 Feb 2021 – 1 Apr 2021). Hydrodynamic data are based on hourly hydrodynamic measurements of wave characteristics (Hs, Tp, Dir) and water level (WL) at 19 m depth (awac and seabird, Figure 1a) off the study site. Offshore wave characteristics were provided by the Bilbao-Vizcaya wave buoy moored in 580 m water depth. A total of 28 storms with a duration of 6 hours, occurring at high tide, were identified along the study period. Topobathymetric data were measured between the 3rd and 4th of March covering the study site from the promenade until 30 m depth. A video monitoring station collected, snap, timex and timestack images of the beach (Figure 1b) at 30 to 10 min time intervals depending on wave conditions. Snap and timex images are used to estimate changes of sandbars position and/or the evolution of the supratidal zone of the beach. The timestack images provide the number of overtoppings that is converted into a hazard level through a methodology based on monetary damage data provided by the Spanish Insurance Consortium during 2000-2015 (Gaztelumendi et al., 2016c). Level 0 (green) represents no damage, Level 1 (yellow) no major damage expected, Level 2 (orange) severe damage to non-structural elements and Level 3 (red) structural damage.

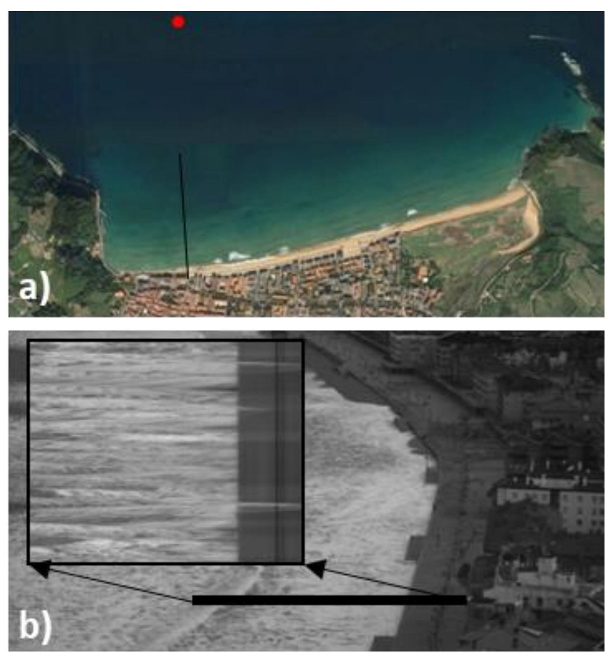

Figure 1 - Study site: Zarautz beach (Spain). a) Aerial image with the location of hydrodynamic measurement tools in red and the timestack position in black. b) Snap and timestack images of the engineered stretch recorded by the videometry station.

RESULTS

SWAN simulations are forced at the offshore boundary with wave spectra measured at the Bilbao Vizcaya wave buoy during the field campaign. The comparisons between measurements, carried out in 19m depth off the study site, and SWAN results give a RMSE below 0.18 m, 2.08 s and 8.15º for Hs, Tp and Dir, respectively. The transformation of waves in the nearshore zone and the flow discharge during overtopping events are computed with the non-hydrostatic version of the XBeach model that has been proven to be a good predictor of swash (De Beer et al., 2021) and mean overtopping discharge (Roelvink et al., 2018).

The complete modelling chain is then validated simulating the 28 observed storms. The SWAN model is used to propagate offshore wave conditions measured at the Bilbao-Vizcaya wave buoy up to 19 m depth off the study site. The SWAN spectrum is then used to force the XBNH in 1D to compute the mean overtopping discharge over a measured topobathymetric profile located at the most exposed location of the beach (Figure 1b). The hazard level is finally estimated for each storm through the maximum mean overtopping discharge (Garzon et al., 2023) among 10 simulations allowing to account for the influence of incident random phases. The validation shows a recall of 0.6, precision of 0.75, accuracy of 0.89 and f1 score of 0.66 (Figure 2) for calibrated parameters.

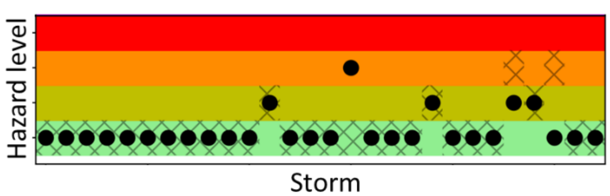

Figure 2 – Modelling chain validation for the 28 storms. Black dots represent the hazard level estimated through the modelling chain. Hatched lines represent the hazard level measured through coastal videometry.

CONCLUSION

The study shows that the proposed modelling chain represents adequately the hazard level according to the validation data source. A single case with a hazard level of difference has been found in the results, being the simulation underestimating the hazard level but close to the yellow-orange hazard threshold. Two exceptions have been found with two hazard levels of difference. The model overestimation occurs at the storm with the highest wave height registered during the study period, what might be related to the overall energetical overestimation in 1D simulations. The model underestimation is related to the unique storm that, compared to the measured topobathymetric profile used in all the XBNH simulations, presents a decrease in the berm height (characterized through coastal videometry). The obtained results could be therefore improved through 2D simulations and accounting for morphological changes between different storms. This tool has therefore the potential to be applied to generate a coastal flooding storm impact database considering a series of storm scenarios and geomorphological configurations representative of our study site.

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REFERENCES

Stokes, K., et al (2021). Forecasting coastal overtopping at engineered and naturally defended coastlines. Coastal Engineering, vol. 164, p. 103827.

Garzon, J. L., et al. (2023). Development of a Bayesian networks-based early warning system for wave-induced flooding. International Journal of Disaster Risk Reduction, vol. 96, p. 103931.

Gaztelumendi, S., et al. (2016c). The new Euskalmet coastal-maritime warning system. Advances in Science and Research, vol. 13, p. 91-96.

Garzon, J. L., et al. (2023). Conceptual and quantitative categorization of wave-induced flooding impacts for pedestrians and assets in urban beaches. Scientific reports, 2023, vol. 13, no 1, p. 7251.

De Beer, A. F., et al. (2021). Simulating wave runup on an intermediate-reflective beach using a wave-resolving and a wave-averaged version of XBeach. Coastal Engineering, 163, p. 103788.

Roelvink, D., et al. (2018). Improving predictions of swash dynamics in XBeach: The role of groupiness and incident-band runup. Coastal Engineering, vol. 134, p. 103-123.