Numerical study to quantify the role of morphological parameters in the coastal flooding: Zarautz beach

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ABSTRACT

The interaction of hydrodynamic conditions and beach morphology may modify the coastal flooding and hence the hazard level for natural values and coastal facilities. So far, the knowledge on how the hydrodynamic and beach morphology interactions affect the coastal flooding is scarce. Here, the performance of a process-based hazard level forecasting modelling chain is assessed and then applied to different storm scenarios and morphological profile configurations in a highly urbanized beach (Zarautz, Basque coast). The aim of the present study is twofold; first, the validation of the modelling chain and its application to obtain a database of compound flooding scenarios; and second, the quantification of the influence of morphological parameters on the coastal flooding intensity under different storm scenarios through statistical approaches.

1. Introduction

The coastal flooding associated to storms represents a critical challenge with significant consequences for both natural environments and human societies. By comprehensively understanding the parameters that influence coastal flooding and their interaction, decision-makers can develop more effective strategies to mitigate and manage the consequences of coastal flooding. The difficulties associated with acquiring and maintaining flooding field data over large periods derive into the use of alternative approaches. For instance, de Santiago et al., 2024 shows that process-based numerical models could generate reliable flooding results as they consider the influence of climatic and morphologic parameters including the presence of coastal defenses.

The aim of the present study is to validate a modelling chain and implement it for different compound flooding ("compound" in the sense of compound influence of beach morphology and hydrodynamics) scenarios to obtain the associated hazard levels and quantify the influence of morphological parameters on the coastal flooding intensity under different storm scenarios through statistical approaches.

2. Study site and dataset

Zarautz beach is a 2 km long highly urbanized beach located on the Basque coast (northern Spain). This embayed beach is divided into two distinct sectors: i) a natural zone formed by sand dunes and ii) an urban zone backed by a vertical seawall that is used as a promenade (Fig. 1b). The latter will be the object of study.

Hydrodynamic data is based on hourly measurements from 2004 until 2023 of offshore directional wave spectrums available at the Bilbao-Vizcaya wave buoy, moored in 580 m water depth and water level (WL) from the Bilbao-Vizcaya tide gauge. Morphological data is obtained analysing the evolution of coastal videometry indicators along 13 years of data (Liria et al., 2021), such as the berm height (BH), dry beach width (DBW), the foreshore slope (tanB) and sandbars position (SP), and from measured topobathymetric data (3 Mar 2021) of the study site from the promenade until 30 m depth. Hazard level data is obtained by means of coastal videometry through the number of overtopping events detected at timestacks images (Gaztelumendi et al., 2016). The modelling chain is composed by 3 modules: (1) a spectral wave model (SWAN) to propagate offshore wave conditions up to 19 m depth off the study site, (2) a process-based phase-resolving model

(XBeach NH) to compute the mean overtopping discharge in a 1D profile at the promenade and (3) a hazard level estimation table based on the computed mean overtopping discharge (Garzon et al., 2023).

3. Methods

The modelling chain is validated by comparing the computed hazard levels (inputting the measured topobathymetric profile and offshore wave directional spectrums) against the observed hazard levels by the videometry station during 28 observed events between 23 Feb 2021 – 1 Apr 2021. The hazard levels are described as: 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.

Then a compound flooding database is generated by running the validated modelling chain for different storm scenarios and synthetic morphological profiles. Storm scenarios are identified offshore between 2004 and 2023 following the methodology proposed by Gaztelumendi et al., 2016. Since the modelling chain coastal hazard computation for each identified storm scenario offshore would be computationally expensive, these are clustered into bins, in a 3D rectangular grid, represented by Hs, Tp and WL values. Synthetic morphological profiles are generated through the combination of the previously described morphological parameters.

4. Preliminary results

The modelling chain validation is shown in Fig. 1a for the 28 observed storms. The validation shows accurate forecasting of hazard levels with a recall of 0.6, precision of 0.75, accuracy of 0.89 and f1 score of 0.66 for calibrated parameters. There is a single case where the computed hazard level underestimates by 2 the observations. It corresponds to the storm 25 (red rectangle in Fig. 1a), the unique storm that occurs when the subaerial zone of the morphological profile is eroded (Fig. 1b, the red rectangle shows a berm height decrease from storm 24 to 25). In this storm, because of not inputting the eroded “real” pre-storm profile into the modelling chain, it underestimates the observed hazard level, highlighting therefore the need of considering morphological changes to compute with accuracy the coastal flooding.

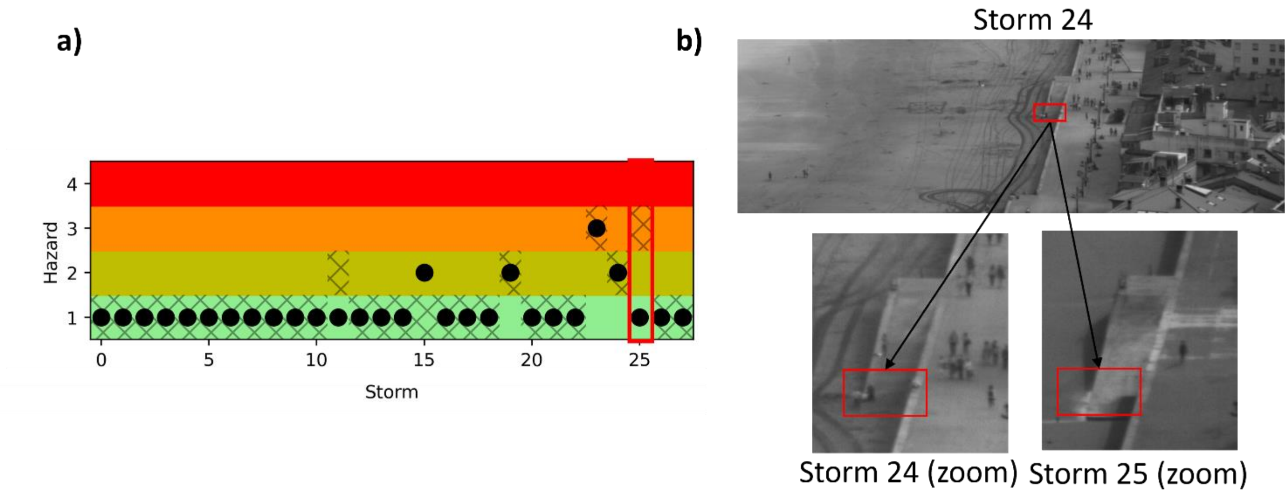

Fig. 1. Modelling chain validation with observed hazard levels at the observed 28 storms (23 Feb 2021 – 1 Apr 2021). a) Hazard levels comparison. Black dots represent the hazard level computed through the modelling chain. Hatched lines represent the hazard level observed through coastal videometry. b) Snap images of the study area the moment before storms 24 and 25. Red rectangles represent the same position.

The validated modelling chain will be implemented to obtain the hazard level at 27 identified offshore storm scenarios with different Hs, Tp and WL combined with 3 synthetic profile configurations composed by different BH, DBW, tanB and SP. This will lead into a compound flooding database of 81 simulations. This database will then be assessed obtaining the significance of each morphological parameter into coastal flooding under different storm scenarios through a statistical approach.

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