Assessment of wave-induced flooding risk under current and future conditions

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1. INTRODUCTION

Disaster risk reduction measures are crucial to minimize the loss of lives and livelihoods, and to enhance community resilience and preparedness to extreme climate-related events. Within the *"EW-Coast"* project, an innovative system based on a combination of numerical modelling (XBeach, Roelvink *et al.*, 2009) and Bayesian Networks (BNs) was used to address wave-induced flooding at three hotspots of Portugal. This system allows informing civil protection authorities about risks for coastal receptors, namely pedestrians, vehicles and properties. In this study, oceanic conditions from previous storms along with sea-level rise projections from the IPCC (Assessment Report 6, AR6) are used to condition the BNs and evaluate changes in risks on those receptors at Costa da Caparica, Praia de Faro and Quarteira. This allows understanding how the storm-related impacts will change in the future if no further protection measurements are implemented and being better prepared for storms that currently might not induce any risks in these coastal communities.

2. STUDY AREAS

Praia de Faro (PF) and Quarteira (QT) are located on the south coast of Portugal, and Costa da Caparica (CC) is located at the west coast, near Lisbon. In PF, a natural open sandy beach, the area investigated is in front of a parking lot, where a walking wooden path marks the edge of the urbanized area. The elevation of this path is 4.6 m above mean sea level (MSL) and the beach width is approximately 40 m. These features make this site highly vulnerable to wave overtopping (Almeida *et al.*, 2012), and it is periodically overwashed. QT is an urban beach with a width of more than 60 m (Garzon *et al.*, 2020), limited laterally by 150 m long rock armoured groins and at the backside by a promenade with an elevation of 5.5 m above MSL. Several touristic facilities are located beyond the promenade including restaurants, hotels and supermarkets.

The coastal stretch of CC is approximately 2.7 km long and has been severely modified with a longshore rock armoured seawall and a groin field that creates six sandy cells. Seawall crest levels is approximately 6 m above MSL. This area has several beach facilities (e.g. bars and restaurants) located on the seawall crest.

3. METHODS

A dataset of hourly oceanic conditions (23.5 years for PF and QT and 25 years for CC) was used to force the BNs and assess the average number of hours per year (h/yr) with risks for pedestrians, vehicles and property under current conditions. Then, sea-level rise (SLR) projections from IPCC (Masson-Delmotte *et al.*, 2021) were added to the astronomical tide to compute the average number of h/yr with risks by 2050, 2070 and 2100. The BNs risk model has three levels of risk (based on mean overtopping discharge thresholds) for each receptor: "Low Risk", "Moderate Risk" and "High Risk".

The average number of h/yr with risk conditions was evaluated for present conditions and for future conditions (2050, 2070 and 2100) with both the SSP2-4.5 (intermediate future Greenhouse Gas Emissions scenario) and the SSP5-8.5 (very high future Greenhouse Gas Emissions scenario) scenarios.

The projected SLR for SSP2-4.5 is 0.23 m, 0.37 m and 0.59 m for 2050, 2070 and 2100, respectively, for all considered beaches. The projected SLR for SSP5-8.5 for 2050 is approximately 0.25 m for the three sites, for 2070 is 0.43 m for the three study areas and for 2100 is 0.79 m for CC and 0.80 m for PF and QT. Wave parameters and surge stationarity were considered, and the same dataset of oceanographic conditions were used to calculate

the h/yr for future conditions.

4. RESULTS

For the study sites at the Algarve (PF and QT):

- The present risk for pedestrians is of 6 h/yr for PF and 0.6 h/yr for QT. For pedestrians in 2100, the high-risk level is expected to occur at 38 h/yr for the SSP2-4.5 scenario and 52 h/yr for the SSP5-8.5 scenario for PF, and in 3 h/yr in QT for both scenarios;
- For vehicles, the current risk is of 5 h/yr in PF and of 0.2 h/yr in QT. The highest total h/yr of risk is less than 1 for QT for all scenarios analyzed, while for PF it is predicted, at 2100, for the SSP5-8.5 scenario, 22 h/yr of low risk and 16 h/yr of high risk;
- Regarding properties, the current total h/yr of risk is less than 1 for QT, while for PF it is already 14.6 h/yr. For PF, in 2070, it is expected to have 24 h/yr of high-risk level under the SSP5-8.5 scenario and near 21 h/yr under the SSP2-4.5, while in 2100 one can expect 49 h/yr of high-risk level for SSP5-8.5 scenario and more than 35 h/yr for the SSP2-4.5 scenario. For QT, the foreseen total hours of risk will not exceed 4 h/yr, regardless of the scenario and time horizon.

For the study site at the west coast (CC):

- Pedestrians: from less than 5 h/yr of total hours of risk at present conditions, the risk will increase up to 29 h/yr, 36 h/yr and 22 h/yr in 2100 for the SSP5-8.5 scenario for low, moderate and high-risk levels, respectively;
- Vehicles: at 2100, one can expect to have 13 h/yr of low risk and 5 h/yr of high risk for the SSP2-4.5 scenario and 23 h/yr of low risk and 8 h/yr of high risk for the SSP5-8.5 scenario;
- Properties: the low risk level can increase from 3 h/yr to 37 h/yr at 2100 for the SSP5-8.5 scenario. At 2100 for the SSP5-8.5 scenario, the hours of moderate risk will be less than 5 h/yr, but the high-risk level will increase from less than 1 h/yr in present conditions to near 20 h/yr.

5. CONCLUSIONS

For the Algarve, the average number of h/yr of risk are much higher in PF than in QT, for all the receptors and emission scenarios analyzed. For CC, while the risk for pedestrians at present is less than at PF, proportionally, the future increase in h/yr of risk will be higher at CC than at PF, specially for low and moderate risk levels. The total number of risk hours per year will increase for all the study cases and for both scenarios, indicating a real increase in risk hours per year, and not simply a shift of hours between different levels of risk.

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