A SYSTEMATIC APPROACH TO ASSESS WAVE OVERTOPPING AT A REGIONAL SCALE: THE NORTHERN PORTUGUESE COAST.

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ABSTRACT
This study presents a comprehensive methodology for assessing wave overtopping risks along the Northern Portuguese Coast, spanning from Viana do Castelo to Aveiro. A Python-based algorithm was developed to analyse a 2m resolution Digital Terrain Model (DTM) of the coast, capturing a spatial extent approximately 400m seaward and 600m landward. By generating transects at 100m intervals that conform to the coast's geometry and orientation, key coastal parameters such as the beach slope (derived from the intertidal range) and the critical overtopping threshold were extracted. Utilizing an empirical formula using genetic-programming based algorithm, wave run-up estimations were calculated for specific sea states. The resulting data was integrated into an interactive map, effectively highlighting the region’s most susceptible to wave overtopping and potential coastal flooding. This innovative approach not only facilitates an understanding of the present coastal vulnerability but also provides an invaluable tool for future coastal engineering and management endeavours in the region.

INTRODUCTION
The Northern Portuguese coast is profoundly influenced by one of the world's most energetic wave climates, while also facing an intense anthropogenic stress, with its main public and private infrastructures located in this area, as well as housing roughly three quarters of the Portuguese population. Despite the extensive engineering measures like groins, breakwaters, seawalls, and artificial nourishments in many parts of this coast, vulnerabilities to coastal flooding persist. Recent decades have witnessed an alarming upsurge in such episodes (Tavares et al. 2021), posing threats to both human settlements and economic assets. The current challenges are exacerbated when considering the impacts of climate change, which predict augmented risks through both sea-level rise and the intensification of extreme weather events. With such context, this study embarks on a systematic approach to assess and visualize wave overtopping levels, aiming to support the region against these impending threats.

MATERIALS AND METHODS
This work adopts an adaptation of the regional wave model introduced by (Ramos et al. 2017), encompassing the full extension of the Portuguese coast. The computational domain spans approximately 115,000km2 and employs a structured grid with resolution of 2x2m. Wave boundary conditions are derived from the Spanish State Port Authority (Puertos del Estado) via the SIMAR-44 datasets. These sets are derived from the synergy of the high-resolution atmospheric model REMO, and the spectral wave model WAM. This time-series have a time resolution of one hour and span a 30-years long period from 1990 to 2020. Sea-level measurements were collected from an in-situ equipment located in a port within the domain (Leixoes).
Local topography data was obtained through the Diretorio Nacional do Territorio (DGT), that makes available a 2 m resolution Digital Terrain Model, including both bathymetric and topographic surveys together, roughly 400 m to land, 600 m to sea, and is in the PT-TM06/ETRS89 reference system with the altimetric datum of Cascais Helmert 38. Transects of 250m of length were extracted at 100 m interval. They are perpendicular to the coast, assuming the characteristic orientation of the coast. An example of these transects orientation are presented in Figure 1, a short zoom at a particular section of the study.

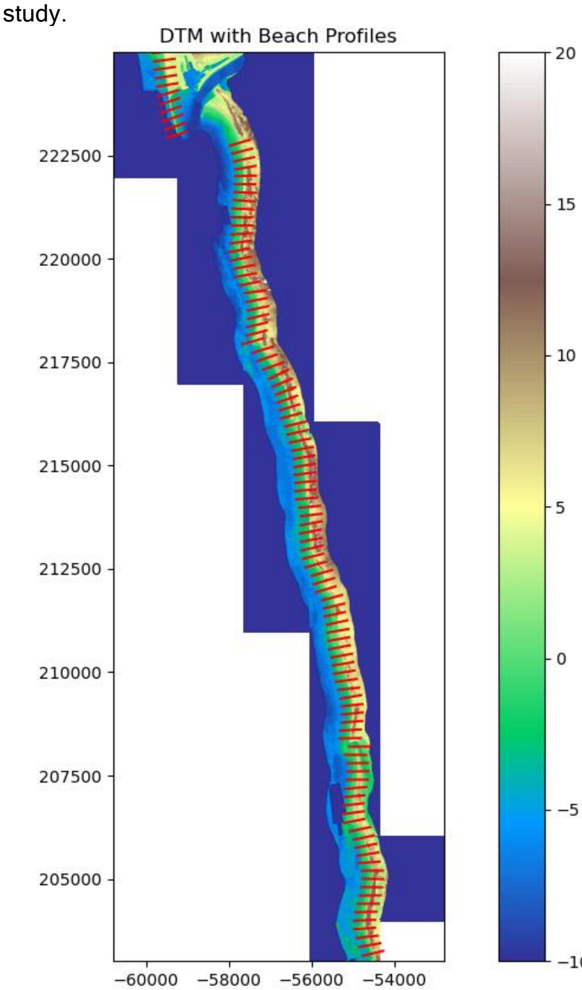

Figure 1 - Transects of the profiles and their orientation at a particular section of the study domain.

Important parameters were extracted from this DTM, namely the beach slope, hereby characterized by the intertidal variation plus two standard deviations, and the critical threshold, i.e., the heights of points where flooding starts (dune crests or maximum height of defence structures). Figure 2, shows an example of the profiles with the beach slope and critical threshold highlighted.

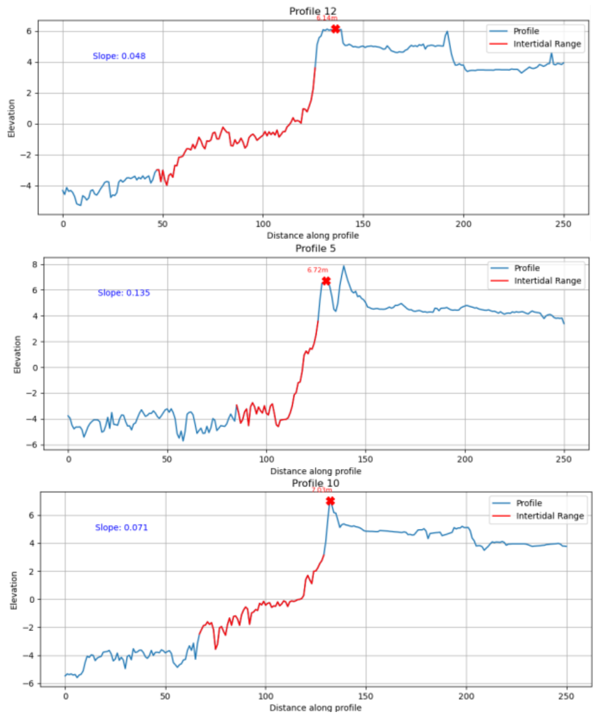

Figure 2 - Example of cross-shore profiles extracted from the DTM, highlighting the intertidal range where the beach slope was calculated (red), and the critical threshold (red cross).

With the local characteristics of each profile together with the ocean conditions, it was possible to implement a genetic-based algorithm to calculate wave run-up (Power et al. 2019), which was already validated for one of the spots of the domain (Carneiro-Barros et al. 2023). It essentially has 4 inputs: significant wave height (H_0), wavelength (L_0), beach slope (β), and roughness coefficient (r). Therefore, the wave run-up for each profile was calculated for representative sea-states, added to sea-level scenarios according to a tide hindcast, and, finally, an interactive map was developed presenting the areas most susceptible or potentially more at risks on the Northern Portuguese coast.

RESULTS AND DISCUSSION

Preliminary results considering a typical extreme weather condition ($H_0 = 9{,}0\,m;\ Tp = 19{,}0s$), excluding the tide component, and considering a single roughness coefficient for the whole domain, are presented in Figure 3. The map is interactive and each 'blob' has stored the local characteristics, displaying the local beach slope, critical threshold height, wave overtopping height, and coordinates. The color bar indicates the points where most wave overtopping levels were found (red).

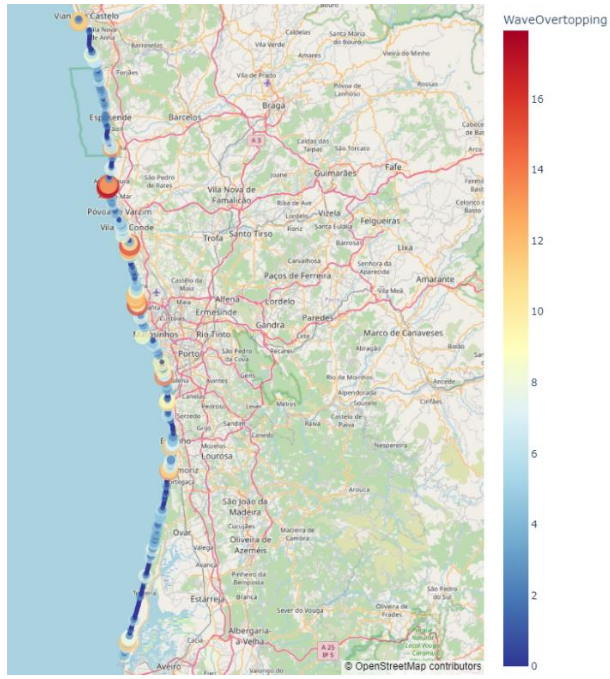

Figure 3 - Interactive map displaying levels of wave overtopping (in meters) along the Northern Portuguese coast.

CONCLUSION

Even without a thorough validation and calibration of the methodology, the initial outcomes are promising, indicating a "sweet-spot" between a global analysis (Almar et al. 2021) and detailed local studies that demand significant computational resources. With further tuning and enhancement, this methodology has the potential to become a highly effective tool for evaluating wave overtopping on a regional scale.

REFERENCES

Almar, Ranasinghe, Bergsma, Diaz, Melet, Papa, Vousdoukas, et al. (2021). A Global Analysis of Extreme Coastal Water Levels with Implications for Potential Coastal Overtopping. Nature Communications 12 (1).
Carneiro-Barros, Plomaritis, Fazeres-Ferradosa, Rosa-Santos, and Taveira-Pinto (2023). Coastal Flood Mapping with Two Approaches Based on Observations at Furadouro, Northern Portugal. Remote Sensing 15 (21): 5215.
Power, Gharabaghi, Bonakdari, Robertson, Atkinson, and Baldock (2019). Prediction of Wave Runup on Beaches Using Gene-Expression Programming and Empirical Relationships. Coastal Engineering. Vol. 144.
Ramos, Taveira-Pinto, and Rosa-Santos (2017). Influence of the Wave Climate Seasonality on the Performance of a Wave Energy Converter: A Case Study. Energy 135: 303-16.
Tavares, Barros, Freire, Santos, Perdiz, and Fortunato (2021). A Coastal Flooding Database from 1980 to 2018 for the Continental Portuguese Coastal Zone. Applied Geography 135