The HIDRALERTA system: Peniche, Quarteira and Faro applications

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1. INTRODUCTION

Early warning systems (EWS) are a fundamental tool to reduce risks in coastal areas since they provide in advance the necessary information for the responsible authorities to mitigate the effects of possible emergency situations due to storms. Nevertheless, their development and current use are still in their early stages.

HIDRALERTA (Poseiro, 2019; Fortes *et al*., 2020; Pinheiro *et al*., 2020; Santos *et al*., 2020, Zózimo *et al*., 2021) is an EWS focused on forecast and risk assessment of wave overtopping in coastal zones. It enables the identification of emergency situations, prompting the responsible entities to adopt measures to avoid loss of lives and minimize damage. HIDRALERTA provides 72-hours forecasts with a 3-hour time step of wave characteristics, mean overtopping discharges and risk levels associated with specific port activities and coastal receptors. The system uses as input data ECMWF and Copernicus forecasts of wind and sea-wave/water level characteristics, or Puertos del Estado forecasts, to evaluate wave overtopping and flooding risks at the study areas.

Six prototypes of the HIDRALERTA system are already operational: Ericeira and Sines harbours and Costa da Caparica coastal zone at the mainland of Portugal, and Praia da Vitória, S. Roque do Pico and Madalena do Pico harbours in the Azores archipelago. Presently, HIDRALERTA is being extended to the port of Peniche and to Praia de Faro and Quarteira at mainland Portugal. These new prototypes introduced new numerical and probabilistic strategies, such as Bayesian Networks (BN), previously trained with results from the numerical model XBeach (Roelvink *et al*., 2010).

This work describes the recently developed prototypes of Peniche, Faro and Quarteira to illustrate the main capabilities of HIDRALERTA as an early warning system.

2. CASE STUDIES

Peniche is the westernmost harbour in mainland Europe and is located on an isthmus of the south coast of Peniche. It is equipped with a marina, a boat ramp, a dock and a shipyard, among other infrastructure. It is protected by two breakwaters, north and south, of 700 m and 415 m in length, respectively. The largest overtopping events occur on the north breakwater.

Praia de Faro is an open beach located in the Peninsula of Ancão. The area investigated includes a central parking lot and urbanized areas, partly separated from the beach by a wooden walking path. The elevation of this path (4.6 m above mean sea level (MSL)) and the beach width (approximately 40 m) make this site highly vulnerable to wave overtopping (Almeida *et al*., 2012).

Quarteira, an urban beach with rocky groins, is located 10 km NW from Praia de Faro, is limited by a promenade at the backside with an elevation of 5.5 m above MSL and has a beach width of more than 60 m (Garzon *et al*., 2021). Both Faro and Quarteira are relatively protected from E–SE and, therefore, only storms with directions greater than 180º N can create flood conditions (Ferreira *et al*., 2021).

3. THE HIDRALERTA SYSTEM

The HIDRALERTA system encompasses four main modules that can be adapted to any port or coastal zone, namely:

- Module I - Sea-state Characterization, where the offshore wave conditions are propagated to nearshore;
- Module II - Wave Run-up and Overtopping determination, using Artificial Neural Network tools (ANN), numerical models or empirical formulations;

- Module III - Risk Assessment, that defines the risk levels for the results of Module II;
- Module IV - Warning System, which integrates all the information and disseminates warnings.

HIDRALERTA is developed in a python framework and takes approximately 1 hour to generate the daily forecasts for the following 72h.

3.1. Module I – Sea-state Characterization

For Peniche area, the offshore boundary conditions are set by ECMWF forecasts (wind and wave characteristics) and are propagated into the port using numerical models, SWAN (SWAN Team, 2006) and DREAMS (Fortes, 2002). The astronomical tide is set with the XTIDE model (https://flaterco.com/xtide/). For Quarteira and Faro, wave conditions (heights, periods, directions) are obtained from Puertos del Estado at the location of Faro buoy, and are used as input to the BNs trained for those locations.

3.2. Module II – Wave Overtopping

For Peniche area, sea conditions, together with cross-section characteristics of the harbour's coastal structures, are used as input to the ANN tool named NN_OVERTOPPING2 (Coeveld *et al.*, 2005) to obtain an estimate of the mean overtopping discharge, q, at each structure cross-section.

The prototypes of Faro and Quarteira use BNs, which have been trained with XBeach results, using the non-hydrostatic mode, from a wide range of storm conditions. The overtopping and overwash are predicted at defined points.

3.3. Modules III and IV - Risk Assessment and Warning System

The Risk Assessment module generates risk maps using the data provided by Module II. Based on different thresholds of q, risk severity (four levels of risk) is evaluated for two coastal receptors in Peniche (pedestrians and vehicles) and three coastal receptors in Faro and Quarteira (pedestrians, buildings and vehicles). Warning levels and hazard signals are issued for each stretch whenever the pre-defined thresholds are exceeded.

3.4. Web user application

A web platform was developed to display results of the four modules, namely: forecasts of sea-wave conditions and wind fields, overtopping discharges and alerts, as well as continuous validations (using wave buoys observations). The system automatically sends daily reports with the forecasts and alerts to a mailing list comprising responsible entities.

4 . CONCLUSIONS

The HIDRALERTA system is operating and providing daily 72-hour forecasts for the port of Peniche and the beaches of Quarteira and Faro. The validation of the new prototypes is ongoing and will ensure the reliability of the system.

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