# To-SEAlert project. Wave overtopping and flooding in coastal and port areas: Tools for an early warning, emergency planning and risk management system

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## 1. INTRODUCTION

The To-SEAlert project (Fortes et al. 2019) aims to include a set of tools/methodologies into the Early Warning System (EWS) HIDRALERTA (Poseiro, 2019, Fortes et al., 2021, Santos et al., 2020, Zózimo et al., 2021, Ferreira, et al. 2021a) to make it more efficient, reliable and robust. The final goal is to implement a system capable of supporting the authorities responsible for monitoring, preventing and managing emergency situations, allowing for the prevention and management of emergency situations, adding value and potential benefits to the areas under their control. responsibility.

HIDRALERTA system 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-hour forecasts with a 3-hour time step of wave characteristics, mean overtopping discharges and risk levels associated with specific port activities and coastal receptors. HIDRALERTA is developed in a python framework and takes approximately 1 hour to generate the daily forecasts for the following 72h. 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.

To-SeAlert project is a Foundation of Sciences and Technology (FCT) financial project, developed between 2018 and 2022. It involves 6 institutions, namely LNEC, NOVA University of Lisbon, Dom Luis Institute of the faculty of Science of the University of Lisbon, The High Institute of Engineering of Lisbon and University of Cantábria (Spain).

The project is divided into 7 main tasks and uses different tools, namely: satellite and video imagery, numerical and physical modelling, quantitative and probabilistic methods for risk assessment and emergency planning,

to improve efficiency and reliability in the system, as well as to provide validation. The case studies are Costa da Caparica coastal area and Ericeira port along the West Coast Portuguese.
This present article describes the main objectives and tasks, and the final goals of the project.

**2. OBJECTIVES AND TASKS**

In order to improve HIDRALERTA, the project intends to: 1) implement methodologies for forecasting overtopping and delimiting the flooded zone and 2) support the response to emergency situations involving overtopping. For that six tasks are previewed, namely:
Implement methodologies for forecasting overtopping and delimiting the flooded zone

1. the validation of numerical models for modelling coastal flooding from satellite images (T1), from video monitoring results (T2) and from the results of tests in a physical model (T3),
2. the implementation and validation of procedures for simulating overtopping and flooding in coastal and port areas (T4),

Support the response to emergency situations involving overtopping

1. implementation of quantitative methodologies to assess exposure, vulnerability, consequences and risk of ocean overtopping and consequent flooding in terms of costs for strategic infrastructure (T5),
2. the development of a geographic information system that includes all the information from the previous tasks (T6) and
3. the implementation and validation of the To-SEAlert prototype in the coastal zone of Costa da Caparica and in the port of Ericeira (T7).

These tasks are described below:

- T1. Satellite image methodologies: the initial objectives of this task were the identification of floods caused by overtopping waves in the Costa da Caparica case study and the characterization of unrest conditions on the Portuguese coast. The conclusions drawn from the completion of the milestone “catalog of flood events associated with the storm Hercules on the beach of Costa da Caparica” forced a reformulation of the work to be developed, because due to the ephemeral characteristics of coastal flooding, it was not possible to identify floods in the images of post-event satellite available. Consequently, two new objectives were defined for T1: i) articulation with the European Copernicus Program (https://www.copernicus.eu/pt-pt) and ii) study to detect changes between pre-event and post-event;
- T2. Integration of video monitoring: implementation of video monitoring systems in the study areas, to enable the characterization of overtopping and flooded areas (Andriolo, 2018), observation in time of this phenomenon and the construction of long data series to support the calibration and validation of numerical models;
- T3. Physical modelling: the construction and exploration of a two-dimensional physical model and a three-dimensional physical model, both of the port of Ericeira, for the characterization of the overtopped volume and the flooded area in controlled situations;
- T4. Numerical models: the main objective is the implementation and validation of new procedures for simulating overtopping and flooding in coastal and port areas. For coastal areas, the XBEACH model will be implemented and validated, which considers changes in the beach profile in determining the volume of water overtopped and the consequent flooding. In port areas, the SWASH model (Manz, 2021), based on non-linear shallow water equations, and the IHFOAM model, based on the RANS equations (Reynolds Averaged Navier Stokes);
- T5. Risk assessment and emergency plans: the goal is the implementation of quantitative methodologies to assess the exposure, vulnerability, consequences and risk of ocean overtopping and consequent flooding in terms of costs for strategic infrastructures. In the construction of vulnerability maps, the vulnerability perceived by the population will be incorporated, Ferreira et al. 2021b;

- T6. WebGIS tool: development of a geographic information system that includes all the information from the previous tasks. Special attention will be given to the system's robustness and flexibility so that it can be applied in other coastal and port areas;
- T7. Test cases: the To-SEAlert prototype will be implemented and validated in the coastal area of Costa da Caparica and in the port of Ericeira.

## 3. RESULTS

The innovation of the To-SEAlert project results from the combination, interconnection and validation of the aforementioned methodologies, the use of the most advanced numerical models of overtopping and flooding, of new methods to validate/calibrate the simulation of overtopping (e.g. satellite images and video) , as well as a new emergency planning and risk assessment module.

The main results of the project will be the following: i) system for monitoring, forecasting and early warning, as well as for emergency response planning and risk assessment associated with ocean overtopping and the consequent flooding of neighboring areas; ii) methodologies to assess ocean overtopping and flooded areas from video images and numerical models; iii) methodologies for processing video images that are versatile enough for prototype applications and reduced physical models; iv) a validated numerical model to simulate overtopping and flooding; v) a set of quantitative methodologies for risk assessment; vi) a new emergency planning system on a WebGIS platform; vii) operational and validated prototypes for the port of Ericeira and for the coastal area of Costa da Caparica.

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