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MOSAIC.pt – A novel methodology and Web GIS portal for flood, erosion and overtopping risk management in coastal regions

Anabela Oliveira[1], Alberto Azevedo[1], Gonçalo de Jesus[1], Ricardo Martins[1], Miguel Rocha[1], Alphonse Nahon[1], André B. Fortunato[1], João Rogeiro[1] and Paula Freire[1]

[1] LNEC, Av. Do Brasil 101, 1700-066 Lisbon, Portugal
aoliveira@lnec.pt

Abstract. Coastal flooding, erosion and overtopping resulting from the combination of energetic wave conditions, storm surges and high spring-tide levels are the major hazards affecting coastal zones. To address these hazards in short (emergency) and long-term (planning) time scales, a combination of field data and numerical modeling tools is necessary to address risk adequately. Herein we propose a methodology to combine data from multiple sources with high-resolution numerical modeling of all processes at stake to address the risks of coastal flooding, erosion and structure or coastal defenses overtopping. The methodology and all its related information supports a novel WebGIS platform demonstrated in multiple observatories along the central west coast of Portugal. The WebGIS tool is generic and can be applied elsewhere if numerical models are established for each site, based on the forecasting framework WIFF that is extended herein to account for morphodynamic processes. The geographic data infrastructure behind the WebGIS accommodates historical and targeted field campaign data, real-time sensors and remote sensing from both cameras and satellites. Herein we focus on the data infrastructure and on the processing workflow for the remote sensing data. All data products can be applied in any coastal site and support the extensive application of coastal observatories as fundamental tools for management support.

Keywords: Geographic data infrastructure, WebGIS, Flooding, Camera, Satelite.

1 Introduction

Coastal flooding and overtopping resulting from the combination of energetic wave conditions, storm surges and high spring-tide levels are the major hazards affecting coastal zones, whose impacts is increasing due to climate change. Often these hazards also entail severe erosion processes that endanger coastal structures and margin occupation. Emergency response and long-term planning of coastal interventions and occupation require thus a combination of real-time information and risk indicators that identify the vulnerability of each coastal stretch to the combinations of hazards that lead to severe events.

To address this challenge, computational frameworks and their associated interfaces have been developed to address flooding and related issues [1]. Herein we present the application of a new methodology to address coastal flood, erosion and overtopping risks, anchored on a suite of state-of-the-art numerical models and real-time data. The methodology is based on a downscaling of processes, coastal features and forcings from the global/regional dimension to the local scale of the coastal sites. Data and model results are made available through a dedicated WebGIS portal.

This paper presents a brief overview of the blocks composing the new tool, focusing on the data infrastructure that includes in-situ and remote data sources.

2 The MOSAIC platform and its application to the Portuguese west coast

WebGIS platforms have been gaining popularity as a user-friendly way to convey complex information to non-expert personnel and aggregate complex data into indicators that can easily be used to support coastal management. [2]) and [3]) are examples of comprehensive WebGIS for coastal floods

The MOSAIC.pt platform constitutes a complete repository of hazard information to support end-users for emergency and long-term risk planning actions. It is organized into three sections: Historical data of past events, Regional hydrodynamic forcings and Observatory data. In the Observatory folder, the user can access the near real-time in-situ and Sentinel remote sensing data, the field campaigns´ data, the local model predictions and risk analysis outputs.

The modeling suite in the MOSAIC.pt methodology follows a cascading procedure. First, wave generation and propagation are simulated at the North Atlantic scale using model WW3 forced by global atmospheric models. These waves, combined with tides (from the global tidal model FES2014) and atmospheric forcings are then used to force the combined wave/circulation model SCHISM at an intermediate scale (10-100 km). Finally, results from SCHISM force an implementation of the model XBeach to simulate the hydro and morphodynamics at the scale of a beach. This infrastructure has been presented in detail in [1] and will not be further detailed here.

The data infrastructure comprises real-time observations, field campaigns data, and processed information from remote cameras and satellites. Each of these data sources plays a role in the quality control and assimilation procedure proposed in the MOSAIC.pt methodology to improve the daily forecasts of hydro and morphodynamics. Remote sensing data from Sentinel images were processed as follows:1) download images from Sentinel repository; 2) Extracts the necessary bands (B2-blue, B3-green, B4-red, B8-nir, B11-swir, B12-swir2), crops to the region of interest coordinates and resamples to 10 m, 3) Merges images, if the area includes images from different satellite orbits, 4) Processing images. Workflow as follows: a) generates an RGB image for uploading in the portal; b) calculates the normalized water index

(NDWI), c) calculates the automatic threshold; and d) divides the images in white (above threshold) and black (below threshold) pixels.

3 Results

MOSAIC.pt´s platform is currently applied to 3 observatories on the Portuguese west coast [4]. Herein, we illustrate results from S. Pedro de Moel for the camera data processing and from Cova-Gala observatory for the Sentinel satellite data. In addition, in-situ data are also available for the Cova-Gala: near real-time radar-based water level (Fig 1a,b) provides sea elevation for the SCHISM forecast on-the-fly validation.

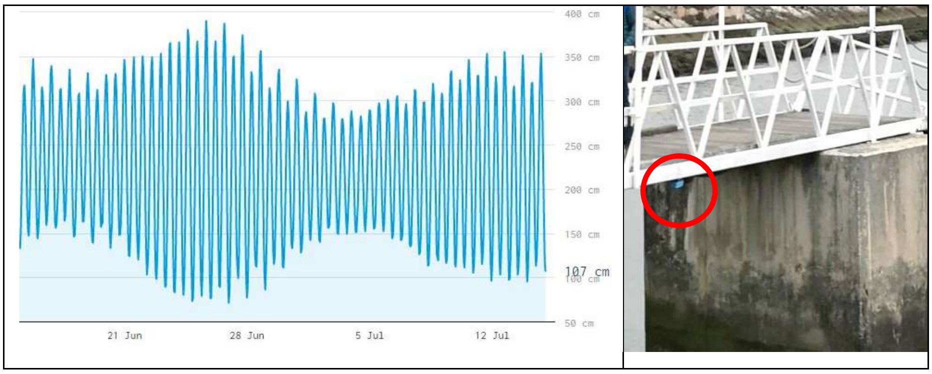

Fig. 1. Real-time sensor: a) elevation time series b) sensor location in the Marina (red mark).

To address the spatial variability of inundation, the results from the Sentinel data workflow were analyzed (illustrated in Fig. 2). Despite the relatively coarse resolution of this data source (10m) relative to the scale of the processes at the beach, some water/land interface patterns can be identified to be used to validate the predictions.

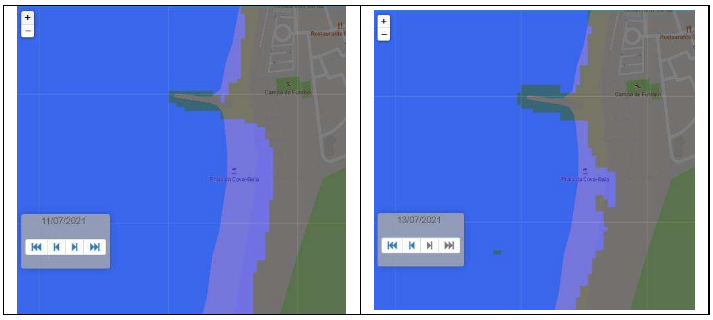

Fig. 2. Zoom–in on snapshots of satellite processed images: a) 11 and b) 13 of July 2021.

A high-resolution camera was installed in S. Pedro de Moel, to gather information on the beach hydrodynamics and monitor inundation events. The processing of the images through averaging the second-apart images and applying the K-Means segmentation allowed extracting (Fig. 3) the several relevant interfaces.

4 Discussion and Conclusions

Today, the MOSAIC.pt risk platform provides the means to anticipate coastal flooding events in coastal observatories, with the erosion component to be added in shortly. Morphodynamic simulations with XBeach were performed successfully, the integration with the forecasting component being underway. Herein, we focused on the data infrastructure and its nearfield and remote components with details on the camera and satellite image data processing.

The most complex challenge remaining is to assimilate the data into the forecasting simulation accounting for all relevant processes and spatial dimensions. The camera information is very rich but only includes a portion of the spatial dimension. Thus, multiple cameras should be used to monitor simultaneously the several fingerprints in the nearshore waters and the inundation at the downtown center in S. Pedro de Moel.

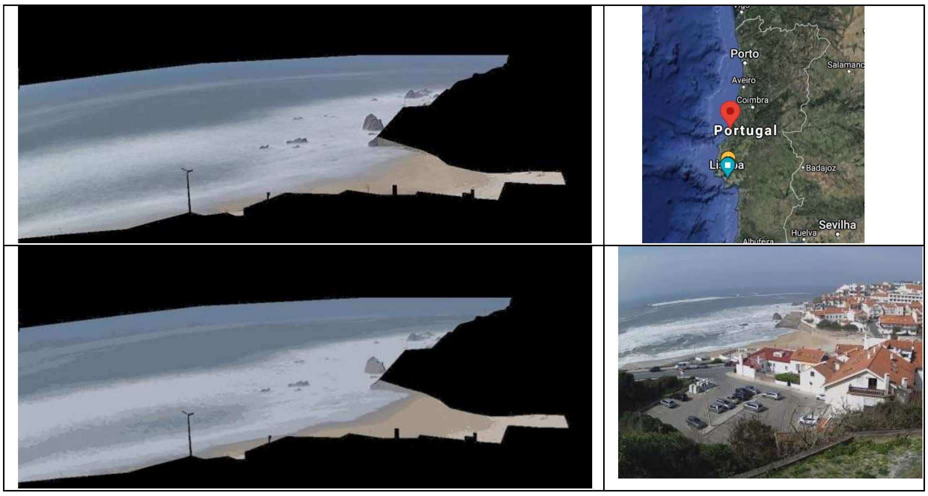

Fig. 3. Camera average image and Kmeans (top & bottom left) results for images of 2020/03/11@14h19, site location (red mark) and unprocessed camera image (bottom right).

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