EWS_CoCoFlood: AN EARLY WARNING SYSTEM FOR PREDICTION OF COMPOUND FLOOD EVENTS

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INTRODUCTION

Coastal flooding is one of the most threatening and detrimental natural disasters affecting coastal areas (Tsoukala et al., 2016, Chondros et al., 2021a), mainly caused by Sea Level Rise (SLR) due to astronomical tide and storm surge, along with the concurrent wave action. The risk increases further in coastal areas with presence of river or stream outflows, potentially leading under extreme conditions to the inundation of even larger domains, a phenomenon defined as a compound flood event.

The simultaneous occurrence of extreme river discharge and storm surge can cause extreme damages far exceeding the ones those events would cause separately. Many real-life examples worldwide, have shown the destructive capabilities and importance of such events (e.g. Juarez et al., 2022). The imminent threat posed by climate change and its effect on increasing the frequency of compound flood events along with the mean sea level rise, are projected to further increase the damages caused by floods. According to Feyen et al., 2020, for the case of high emissions scenario, a significant proportion of the gross domestic product (GDP) of several countries in the end of the century is projected to be dedicated to tackle the damages caused by compound flood events. While many studies have focused on analyzing the long-term impact and examine the occurrence of compound flood events, to this day, few research efforts have tackled the near-real time prediction of such events, to help communities prepare for the hazardous climate change related flood events and facilitate the proper adaptation measures.

The scope of this paper is to present a highly innovative methodological framework to design an Early Warning System (EWS_CoCoFlood hereafter) deriving data from open metocean databases and based on Artificial Neural Networks and numerical modelling predictions, capable of warning coastal communities about the imminent threat of compound coastal flooding considering the impact of climate change, thus increasing their resilience.

MATERIALS AND METHODDOLOGY

The study area is located in the city of Pyrgos, Ilis in southwestern Greece and encompasses the surrounding coast in each side of the Alfeios River mouth (extending about 4.5 km) and the riverbank. The hinterland is characterized by several low-lying areas and residencies with close proximity to the coastline, while the sea bottom slope is relatively mild. Upstream Alfeios river, a hydroelectric dam is situated which however can be overtopped and can act as a spillway. The study area and the position of the Alfeios river dam is shown in Figure 1.

The methodology to develop the EWS has as follows:

- Gathering of offshore sea-state wave characteristics and sea level data from hindcast simulations (https://marine.copernicus.eu/) and projections incorporating climate change impacts (https://cds.climate.copernicus.eu/).
- Employment of a Fuzzy C-Means clustering algorithm to define several combinations (about 5000 total) of sea-state wave characteristics, sea level rise and scenarios of flow discharge, provided by the dam operator.
- Carrying out a multitude of nearshore wave propagation simulations in the nearshore area utilizing a parabolic mild slope (PMS) wave model (Chondros et al., 2021b) and calculation of wave runup/overtopping at distinct coastal profile cross sections.
- Utilizing the point wave runup/ overtopping discharges obtained through the simulations with Maris PMS and the water discharges downstream the Alfeios river dam, simulations of compound coastal flooding are carried out with the hydrodynamic model HEC-RAS (USACE, 2020). Calibration and validation of the numerical models is undertaken utilizing data from flood events in the study area occurring in 2003 and 2019. The simulations also serve the purpose of identifying the most vulnerable areas to the threat of compound flooding.
- The results of the numerical simulations regarding the flow water depth are provided as input to a properly trained Artificial Neural Network (ANN), capable of predicting the water depth of the compound flood event, for an arbitrary combination of offshore sea-state wave characteristics, sea level rise and discharge due to rainfall, providing a reliable Early Warning System for the particular study area.

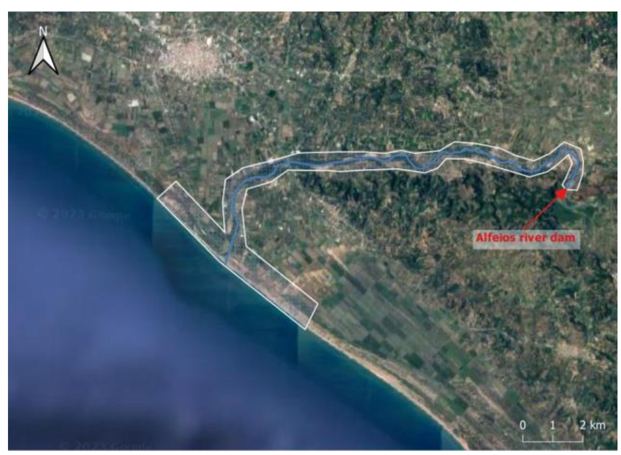

Figure 1 – Study area and flooding prone areas (within the closed polygon) along the bank of Alfeios river

RESULTS AND DISCUSSION

Results of nearshore wave propagation for an extreme incident sea-state with Hs = 5 m and Tp = 9 s propagating from the West-SouthWest direction, as simulated with the PMS model is showcased in Figure 2. Due to the mild sea bottom slopes in the vicinity of the Alfeios river mouth, a wide breaker zone, with an average width of about 120 m, can be observed. Figure 3 shows the flooded areas due to compound flooding event for the sea-state with the characteristics mentioned above, an outflow discharge with a value of 1500 m^3/s, as specified by the dam operator.

As is evident from Figure 3, the most flood prone areas are identified northwestern the mouth of Alfeios river, where a previously situated reservoir has dried up. Since the elevation of these areas lies beneath the mean sea level and they have a close proximity to the coastline, they are extremely vulnerable to the imminent threat of compound flooding.

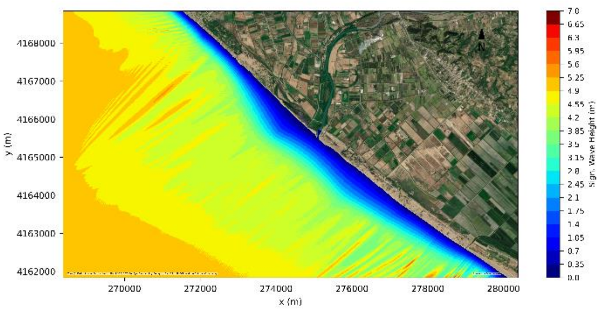

Figure 2 – Nearshore wave height field at the coastal zone of Alfeios river mouth for an extreme incident wave from the West-SouthWest direction (Hs = 5m and Tp = 9s)

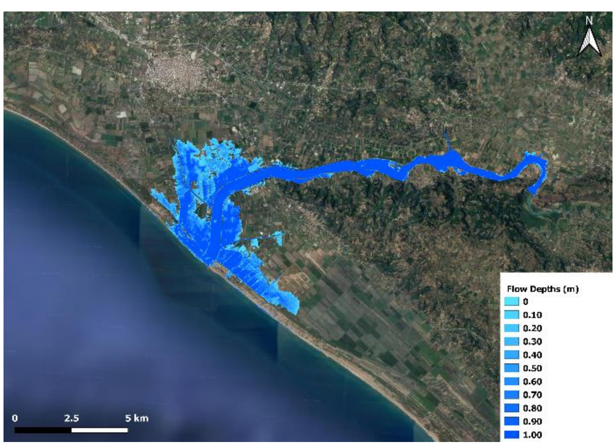

Figure 3 – Flooded area due a compound flood event with the following characteristics: (Hs = 5m and Tp = 9s, outflow of 1500 m^3/s)

The numerical models have been calibrated using data from past flood events that occurred in the study area in the years 2003 and 2019. After performing several trials, a multilayer Feed-Forward Artificial Neural Network has been selected as the optimal architecture, comprised of two hidden layers with 12 units (neurons) and capable of predicting the water depths due to imminent compound flood events. Finally, a training/validation split of 80%/20% has been implemented during the training procedure of the ANN.

CONCLUSIONS AND FUTURE RESEARCH

In this paper, the methodological framework and initial results of the development of an Early Warning System for the accurate and timely prediction of the possible imminent compound flooding in a coastal area in Pyrgos, Greece are presented. The developed Early Warning System represents a novel tool, leveraging advanced numerical simulations of waves and hydrodynamics, alongside open databases and Artificial Neural Networks. This system is poised to serve as a valuable tool in enhancing the resilience of coastal areas, against the impending threat of compound river and coastal flooding. The ongoing and subsequent phases of the research are centered on the integration of rainfall-induced flooding dynamics and incorporation of storm-induced erosion, aiming to culminate in the development of a comprehensive and seamlessly integrated system, poised to function as a web-based application, able to provide near-real-time and accurate forecasts.

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