Modelling and Forecasting of Compound Coastal-Fluvial Floods in Urban Built Environment

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Abstract

Floods are amongst the most common and deadly weather-related natural disasters and there is an urgent need locally, nationally and globally to better forecast floods. However, flood forecasting along coastline faces often complex challenges due to the compound nature of coastal-fluvial floods and complexities of built environments. Involving the combination or successive occurrence of two or more flood drivers, compound flooding can amplify flood impacts in coastal/estuarine regions. The forecasting efforts so far show that there is a need for an integrated multi-hazard approach to compound flood forecasting.

This research aims to address current forecasting challenges by developing a coastal-fluvial flood prediction system utilising advanced process- and data-driven models. The compound flood forecasting system proposed here is a state-of-the-art hybrid hydrodynamic-ML-based model system. In the two-model cascade, the hydrodynamic model (MSN_Flood) of urban riverine-estuarine hydrological domain and its city-wide floodplains is used to simulate floods and provide hazard maps of various probability events. The fluvial and coastal boundary conditions of the model combined with the corresponding flood depths across floodplains provide the training, validation and testing data for machine learning algorithms. Ultimately, the best performing ML model is used to forecast the states of water levels across urban floodplains at ultra-high spatial for a given set of river discharges and sea water levels upstream and downstream, respectively. Unlike traditional models, this system integrates multi-model multihazard approaches where multiple data sources such as meteorological predictions, tidal records, river flow measurements, satellite products and historical flood events are aggregated in the modelling framework to simulate coastal-riverine flows and associated floods over coastal cities.

The system performance is demonstrated for a coastal city of Cork, second largest city in Ireland frequently subject to coastal floods. Results show that a number of ML models can reproduce and forecast coastal urban flooding, when trained by the hydrodynamic model outputs for a wide spectrum of river conditions. From total of 11 ML models, the RBF model is particularly suitable and demonstrates a very high forecasting accuracy. This new system gives an advantage of ML model for flood forecasting over the traditionally used hydrodynamic model.

The presented here two-step system can be incorporated into a flood early warning system, which is vital for preventing/reducing risks of flood-driven disaster in coastal cities and increasing resilience of coastal communities.