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A MACHINE LEARNING APPROACH FOR HURRICANE-INDUCED FLOOD DEPTH ESTIMATION: A CASE STUDY ON HURRICANE HARVEY

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ABSTRACT

Urban flooding, resulting from the combined effect of extreme precipitation and storm surge, is a growing threat to coastal cities. It requires reliable and efficient modelling tools for risk mitigation and emergency response. In this context, recent advancements in machine learning (ML) techniques have opened new avenues for enhanced flood hazard assessment in such complex scenarios, characterized by a non-linear interplay of several diverse factors influencing inundation characteristics.

This study leverages Hurricane Harvey as an emblematic case study of compound flooding in coastal regions. In August 2017, the Houston Metro region experienced an unprecedented amount of rainfall, with accumulations of 900-1200 mm over a 5-day period, coupled with a storm surge ranging from 0.8 to 1.3 m. These extreme conditions led to catastrophic flooding across numerous areas in Harris and Galveston counties (Blake & Zelinsky, 2018).

The abundance of observed data from this event facilitates the investigation on the application of ML approaches for predicting water depths and analyzing the relative importance of the various factors governing inundation phenomena in hurricane-induced flooding. In detail, we sampled flood depth in 5,000 locations from the FEMA dataset compiled for Harvey damage assessment (FEMA, 2023). To capture the potential factors influencing flooding mechanisms, we enriched the dataset with information on the built and natural environment, as well as morphological and land-use features sourced from open-data and processed in a GIS framework. Hazard-related data, including storm surge and rivers' stages, were also incorporated as explanatory variables.

The methodology involved the application of Extra Trees and Random Forests algorithms to the elaborated dataset, using different combinations of the predictive features as input. The accuracy of the developed ML models in predicting flood depths was benchmarked against previous studies that employed traditional physically-based models for the same case study.

Our findings demonstrate satisfactory accuracy, reporting similar or even surpassing benchmark prediction errors in the literature, and also yield valuable insights into the major physical drivers influencing flooding during hurricanes. Furthermore, this study highlights the practical benefits of these advancements in flood risk management, suggesting the potential integration of ML predictions into real-time flood monitoring systems and enhanced early warning mechanisms.

References

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