Ph.D. DISSERTATION DEFENSE

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Title: Enhancing Flood Forecasting Systems through the Integration of Machine Learning and Advanced Sensing and Modeling Techniques

Chairperson: Dr. Marouane Temimi, Department of Civil, Environmental & Ocean Engineering, Charles V. Schaefer, Jr. School of Engineering & Science

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ABSTRACT

In the realm of weather-related research, challenges persist in optimizing reservoir management, streamflow prediction, nowcasting methodologies, and effective weather communication. These challenges impede accurate forecasting, hydrological understanding, and informed decision-making in the face of extreme weather events. This thesis addresses these challenges through a multidisciplinary approach, encompassing machine learning, nowcasting techniques, and natural language processing (NLP). By leveraging innovative methodologies, the thesis aims to a) enhance weather prediction capabilities through the development of a very short term rainfall forecast, commonly known as rainfall nowcast, b) improve streamflow estimation by using data-driven methods, and c) and foster efficient communication of weather-related information by leveraging machine learning-based Natural Language Processing (NLP) methods.

This research demonstrated that the use of the long short-term memory (LSTM) model, a data-driven model, can significantly enhance streamflow estimations at the continental and local scales, particularly in the case of natural flow. In addition, the LSTM model showed a potential to accurately infer reservoir management decisions in the case study of Hackensack River Watershed. Furthermore, the incorporation of vegetation Greenness Fraction (GF) into LSTM models led to an improved streamflow simulation across diverse watersheds and seasonal dynamics. The resultant LSTM-GF models adjusted to specific watershed conditions and their seasonality, augmenting streamflow simulation accuracy.

A comprehensive assessment of deterministic and probabilistic nowcasting models over the New York City metropolitan area using the Multi-Radar Multi-Sensor (MRMS) data showed higher nowcasting performance with the Lagrangian Integro-Difference equation model with Autoregression (LINDA)

algorithmic especially in the case of extreme weather events which is essential for short term contingency planning.

Moreover, by employing sentiment analysis, NLP techniques, and topic modeling, valuable insights from mobile weather mobile applications reviews were inferred. Users' sentiments during extreme weather events were inferred and key application attributes that influence user experiences and communication effectiveness were identified. In conclusion, this thesis encapsulates a multidimensional exploration of weather-related domains, contributing to refining weather forecasting methodologies, enriching hydrological understanding, and bolstering effective public engagement. The outcomes hold potential to impact decision-making and disaster mitigation efforts in the face of extreme weather events.