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Using Machine Learning Surrogate Models Trained from Physics-Based Model for Real-time Street-scale Flood Forecasting in Urban Coastal Communities

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Abstract: Coastal communities have been threatened by increased frequency and severity of flooding in recent years, which is likely to worsen due to climate change. Flood prediction models are essential tools to help reduce the socio-economic disruptions caused by escalating flood events. However, traditional flood prediction approaches require powerful computing machines and have long run-times because they employ 1D/2D dual drainage models. Therefore, these models are unsuitable for real-time street flood forecasting. Since machine learning models can have smaller computational costs and fast run-times, they may have the potential to be used as an alternative approach. This study demonstrates the use of a machine learning algorithm, Random Forest, as a surrogate model to emulate flood depth on streets from a high-fidelity 1D pipe/2D overland flow physics-based model, TUFLOW. The Random Forest surrogate model was trained and evaluated using the top 20 storm events from 2016 to 2018 in the coastal city of Norfolk, VA, USA. The surrogate model uses topographic (e.g. elevation, topographic wetness index, depth to water) and environmental (e.g. rainfall, tide) features for 17,000 road segments in the city as input. Hourly water depth on streets simulated by the TUFLOW model is used as the surrogate model output. Results show that the surrogate model can match the duration and depth of flooding on streets from the TUFLOW model with high accuracy while reducing the computational time by a factor of 1,500. The surrogate model also exhibits the potential to identify problem spots in the physics-based model. In summary, this study shows how machine learning models trained on detailed physics-based models can provide a computationally efficient solution for real-time, street-scale flood warning within urban contexts.

***Keywords**: Machine Learning; Urban Flooding; Real-time Flooding; Random Forest, Surrogate Models