Applying Machine Learning to Predict Typhoon-Induced Storm Surges in Vietnam

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Abstract

The primary objective of this research is to develop, implement, and rigorously assess a hybrid storm surge forecasting framework that integrates physical and data-driven modeling approaches. The proposed system leverages the predictive capabilities of Long Short-Term Memory (LSTM) neural networks to enhance the accuracy and operational relevance of storm surge forecasts derived from the Regional Ocean Modeling System (ROMS).

The specific goals of this study are:

1. To design and optimize an LSTM-based deep learning model capable of capturing nonlinear temporal dependencies in sea level data, with a focus on storm surge dynamics at strategically selected coastal stations.
2. To train the LSTM model using a fused dataset composed of historical water level observations and ROMS outputs, thereby enabling the model to learn and correct systematic biases inherent in physics-based numerical forecasts.
3. To quantitatively evaluate and compare the forecast skill of the LSTM-enhanced predictions versus standalone ROMS outputs, across multiple lead times (e.g., 1 to 72 hours), using statistical performance metrics such as MAE, RMSE, and correlation coefficients.
4. To assess the generalizability and robustness of the LSTM model under varying storm conditions and geographic locations, with the goal of informing future integration into operational coastal flood warning systems.

We show our approach provides excellent predictions of storm surge during typhoons and in most cases it performs better than the ROMS ocean model.