Drivers and Prediction of Compound Flooding Using a Physics-Informed Risk Index

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In the past 20 years, flooding has been the most common natural disaster worldwide, accounting for 43% of all recorded events, and causing tremendous loss of life and property. The North Carolina coast is particularly vulnerable due to the interactions between river basins and oceans, placing communities at a heightened risk of flooding. Existing NOAA flood thresholds rely solely on fixed sea-level values, limiting forecasting effectiveness. This study investigates compound flooding, which occurs when two or more drivers interact, using a three-stage approach. First, 30 years of hydrologic and oceanographic data from NOAA and USGS stations in Wilmington, Beaufort, and Little Washington were analyzed to identify compound flooding events. Results show that the current single-variable detection system is less than 50% accurate in predicting compound flood events. Second, 25 years of GLOFAS and ERA5 data were used to calculate the relative influence of sea level, river discharge, precipitation, soil moisture, and wave height across 20 coastal counties. Hydrologic drivers were found to dominate compound flooding, with precipitation and soil moisture exhibiting correlations exceeding 80% in most counties. Finally, this study develops a compound flood risk index (CFRI) that integrates lagged upstream river discharge, coastal water level extremes, and a nonlinear interaction term to predict future compound events. Compared to traditional models, the new index provides an average of 60 hours of advance warning with a 94% precision rate. Overall, this study contributes to the advancement of predictive hydrological modeling and holds the potential to inform future compound flooding management strategies.

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