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Compound Coastal Flooding Drivers in the Pacific Northwest: Understanding Precipitation-Surge-Wave Interactions and Projected Changes

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Coastal regions face escalating threats under climate change, necessitating a comprehensive understanding of compound flooding dynamics. This study aims to investigate the interplay between precipitation, wind waves, and meteorologically-driven storm surge, assessing their joint behavior leading to compound coastal flood risks in the Pacific Northwest. We examined two approaches to capture all possible drivers leading to compound events, which may not necessarily result from the extreme conditions of individual marginal variables. First, we used a conditional approach and assessed the block maxima (BM) of each variable in conjunction with the corresponding values of the other variables. Second, a peak-over-threshold (POT) investigation was conducted to generate datasets where all variables exceed their 95th percentiles. To calculate the joint return period of coastal flooding drivers, we used the most appropriate marginal distributions commonly used in coastal engineering, including the Generalized Pareto Distribution (GPD) for the POT-based approach and the Generalized Extreme Value (GEV) distribution for the BM. Subsequently, we computed the joint probability distribution by fitting the best-suited copula to the datasets to capture the interdependencies between the drivers. Moreover, as meteorological drivers may change under global warming, we extended our analysis to consider future projections of surge, waves, and precipitation. This enabled us to examine changes in the aforementioned dependencies and return periods. Sub-daily time series of surge and wave heights were obtained from the Canadian Coastal Climate Risk Information System (CCCRIS) (https://cccris.ca/), which provides high-resolution (~250 m along coastlines) simulations driven by ERA5 reanalysis and future projections until 2100 under the RCP8.5 emission scenario driven by four different combinations of global and regional models, namely, CanESM2.CanRCM4, CanESM2.CRCM5-QUAM, MPI-ESM-MR.CRCM5-QUAM, and GFDL-ESM2M.WRF. For each grid point, the corresponding precipitation data is obtained from the nearest grid point of the respective climate models. We assessed the degree to which each driver contributed to the overall change in the joint return period of concurring extremes in coastal flooding. We also conducted an analysis to quantify the respective contributions of each driver's projection and their dependence structure to the uncertainty in changes of return periods. This study leveraged high-resolution data that encapsulated the regional dynamic responses, which is pivotal for precisely evaluating climatic

hazards and developing efficient adaptation schemes, thereby ensuring a more informed decision-making process for coastal management and engineering applications.