**A non-stationary bivariate analysis of significant wave height and storm surge extremes in the English Channel, integrating teleconnection patterns and climate change**

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**Abstract**

The monthly maxima of a significant wave height (Hs) and five storm surge time series spanning the English Channel are analyzed. The margins of these variables are modelled by non-stationary generalized extreme values (GEV), with up to seven covariates per GEV parameter. These covariates are five climate indexes: the surface sea level (SST), sea level pressure (SLP), zonal wind (ZW), North Atlantic Oscillation (NAO) and the Atlantic Multi-decadal Oscillation (AMO), and two temporal variables corresponding to the linear time and the annual cycle. The dependence structure between the Hs and storm surge monthly maxima is modelled by dynamic copulas, with the same indexes as covariates. As the high number of covariates considered for each of the three GEV parameters result in many possible combinations, an automated process based on likelihood ratio was used to fit the nested non-stationary GEV models by iteratively adding covariates, thus gradually increasing the complexity of the model. A similar approach was used for the dynamic copulas. The bivariate distributions obtained from the GEV and copula models are used to calculate effective joint return levels for several return periods. These return levels are calculated separately for winter and summer, as the seasonality is a major source of variability for the Hs and storm surge monthly maxima. The results show that the dependence between Hs and storm surge weakens as the return period increases. However, for two of the five stations this dependence strengthens during period of high wind stress, resulting in greater probability of compound hazards, with both variables reaching an extreme level simultaneously. Overall the risk of extreme event of either variable is much higher during winter, so calculating the return levels separately for winter and summer improves the risk assessment.