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Multivariate Statistical Modelling of Compound Events via Pair-Copula Constructions: Analysis of Floods in Ravenna

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Compound events are multivariate extreme events in which the individual contributing variables may not be extreme themselves, but their joint - dependent - occurrence causes an extreme impact. The conventional univariate statistical analysis cannot give accurate information regarding the multivariate nature of these events. We develop a conceptual model, implemented via pair-copula constructions, which allows for the quantification of the risk associated with compound events in present day and future climate, as well as the uncertainty estimates around such risk. The model includes meteorological predictors which provide insight into both the involved physical processes, and the temporal variability of CEs. Moreover, this model provides multivariate statistical downscaling of compound events. Downscaling of compound events is required to extend their risk assessment to the past or future climate, where climate models either do not simulate realistic values of the local variables driving the events, or do not simulate them at all. Based on the developed model, we study compound floods, i.e. joint storm surge and high river runoff, in Ravenna (Italy). To explicitly quantify the risk, we define the impact of compound floods as a function of sea and river levels. We use meteorological predictors to extend the analysis to the past, and get a more robust risk analysis. We quantify the uncertainties of the risk analysis observing that they are very large due to the shortness of the available data, though this may also be the case in other studies where they have not been estimated. Ignoring the dependence between sea and river levels would result in an underestimation of risk, in particular the expected return period of the highest compound flood observed increases from about 20 to 32 years when switching from the dependent to the independent case.