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Statistical Modelling of Compound Floods

Emanuele Bevacqua (1), Douglas Maraun (1), Mathieu Vrac (2), Martin Widmann (3), and Colin Manning (3)

(1) Wegener Center for Climate and Global Change, University of Graz, Graz, Austria., (2) Laboratoire des Sciences du Climat et de l'Environnement, IPSL, CNRS, Centre d'Etude de Saclay, Gif-sur-Yvette, France., (3) School of Geography, Earth and Environmental Sciences, University of Birmingham, Birmingham, UK.

In the recent special report of the Intergovernmental Panel on Climate Change (IPCC) on extreme events it has been highlighted that an important class of extreme events has received little attention so far: so-called compound events (CEs) (Seneviratne et al., 2012). Compound events (CEs) are multivariate extreme events in which the individual contributing events might not be extreme themselves, but their joint occurrence causes an extreme impact. Following Leonard et al., 2013, we define events as CEs only when the contributing events are statistically dependent. For many events analysed so far, the contributing events have not been statistically dependent (e.g. the floods in Rotterdam, Van den Brink et al., 2005). Two typical examples of CEs are severe drought in conjunction with a heatwave, and storm surges coinciding with heavy rain that cause the so-called Compound Floods in the lower section of a river. We develop a multivariate statistical model to represent and analyse the physical mechanisms driving CEs, and to quantify the risk associated with these events. The model is based on pair-copula construction theory, which has the advantage of building joint probability distributions modeling the marginal distributions separately from the dependence structure among variables. This allows to analyse the individual contributing variables underlying the CE separately to their dependence structure. Here is presented an application of the statistical model for Compound Floods, based on a conceptual case study. For these particular events it is not trivial to find satisfying data. Usually, water level stations are not present in the area of the river where both the influence of the sea and river are seen. The main reason being that this critical area is small and stakeholders have little interest in measuring both effect from the sea and from the river. For these reasons we have developed a conceptual case study which allows us to vary the system's physical parameters of interest. This is based on real data for River discharge (Y'_{RIVER}) and Sea level (Y_{SEA}), from the River Têt in south of France. The impact of the compound flood is the water level in the area between the River and Sea station, which we define here as $h = \alpha Y_{RIVER} + (1 - \alpha) Y_{SEA}$. Here we show the sensitivity of the system to a changes in the two physical parameters. Through variations in α we can study the system in one or two dimensions which allows for the assessment of the risk associated with either of the two variables alone or with a combination of them. Varying instead the second parameter, i.e. the dependence among the variables Y_{RIVER} and Y_{SEA}, we show how an apparently weak dependence can increase the risk of flooding significantly with respect to the independent case. The model can be applied to future climate inserting predictors into the statistical model as additional conditioning variables. Through conditioning the simulation of the statistical model on the predictors obtained for future projections from Climate Models, both the change of the risk and characteristics of compound floods for the future can be analysed.