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Compound risk of extreme pluvial and fluvial floods

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Extreme precipitation events often lead to flash floods, in particular in urban environments dominated by impervious surfaces. Likewise, excessive rainfall over an extended period or heavy snowmelt may lead to extreme river floods, which historically have caused loss of many lives, extensive damages to human and natural systems, and displacement of millions of people. Risk assessments generally consider the potential hazards from pluvial and fluvial floods as separate events. This can lead to a significant underestimation of the risks. Thus, the physical processes (e.g. precipitation) that drive these extreme events may interact and/or exhibit a spatial or temporal dependency, which could lead to an intensification of the hazard or modify the associated vulnerability and/or exposure. This is, e.g., the case of Budapest, where the urban drainage system relies on gravity flows. At about 3 m above the normal water level, rain water is not able to drain into the river without pumping, changing the operational conditions of the drainage system and potentially increasing the risk of urban flooding if this is coincident with an extreme precipitation event.

Here, we analyse the coincidence of compound pluvial and fluvial flood events for both a current and future climate, including the potential physical links between extreme precipitations events, and larger scale rainfall in the Danube catchment. For this analysis, we use the Future Danube Model (FDM), representing a full catastrophe model compliant with the insurance industry standards. The model considers four members of the Euro-CORDEX regional climate model ensemble and their historical and future simulations- 30-year time slices (e.g. 2071-2100) are extracted from each simulation, which are first bias-corrected and then statistically inflated using the IMAGE weather generator to yield spatially distributed daily time series covering 10.000 model years with the same overall statistical properties as the underlying Euro-CORDEX model but with an enhanced representation of rare (precipitation) extremes across the entire catchment of the Danube. This time series feed into a detailed hydrological/ hydrodynamic model for the river catchment, based on a combination of the SWIM eco-hydrological model and a modified version of the CaMa-Flood hydrodynamic model, from where we estimate the discharge levels and fluvial flood risk at the location of the city of Budapest. For the pluvial flood modelling, we use a modified version of the approach described in Kaspersen et al. (2017), forced by the same four Euro-CORDEX models as used in the SWIM hydrological model, to infer recurrence periods and intensities for present and future heavy to extreme rainfall events.

Considering the seasonality of the pluvial and fluvial flood risk, respectively, we find a significantly enhanced risk of compound events happening during the summer period, and that for most periods the compound risk is exacerbated by climate change. Given that the urban drainage system in Budapest already today is worn down and lacking the necessary capacity to deal with major flash floods, this suggests that new potentially nature-based approaches for dealing with storm water should be considered and that significant investments in updated urban drainage infrastructure is urgently needed.