Capturing flood risk dynamics with a coupled agent-based and hydraulic modelling framework

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Floods are one of the costliest natural hazards worldwide, affecting millions of people every year. To plan flood risk reduction strategies, there is a need to understand how risk changes over time. In traditional flood risk assessment, vulnerability is often unrealistically considered constant in time, which does not reflect patterns observed in the real world. The coupled human and natural flood system is complex and determined by two-way interactions between the two subsystems. Floodplain dynamics may affect human behavior (e.g. by triggering the implementation of protection measures at different scales) which changes exposure and vulnerability, while they are also in turn influenced by human activities (e.g. land-use changes or flood protection structures). Here we explore how these two-way interactions influence changes in flood risk over time, with a focus on the role of individual and governmental decision-making, by developing a coupled agent-based and hydraulic modelling framework.

In our framework, household agents are located in a floodplain protected by a levee system. Individual behavior is based on Protection Motivation Theory and it comprises (as a response to floods) the options to do nothing, invest in private flood protection measures, or file a complaint to the government. The governmental decision making process about the implementation of technical flood protection measures, i.e. reinforcing the levee system, is a compromise between a Cost-Benefit-Analysis and relative number of filed complaints from the households. The agents take decisions at every time step of a long time series of annual maximum water levels: in case of levee breach, the floodplain water level is estimated by the LISFLOOD 2D hydraulic model, which is dynamically coupled into the agent-based model.

We show that this coupled model is capable of replicating adaptation and levee effects, which have been empirically observed by several scholars in numerous floodplains around the world. Thus, our framework provides a useful explanatory tool for assessing different spatial and temporal dynamics of flood risk in a socio-hydrological system. Moreover, the new modelling approach can explicitly simulate the spatial distribution of flood risk which allows for the analysis of conflicting interests in neighbouring communities. First, efforts have been made to include farmer agents into the model to simulate conflicts between urban and rural areas. Further, we exploit data from the real world in order to assess the credibility of our model and, lastly, use the
model to investigate the effects of different climate scenarios on these types of conflicts.