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Towards global stochastic flood modelling

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Hydraulic modelling at large spatial scales is a field of enquiry approaching a state of maturity, with the flood maps produced beginning to inform wide-area planning decisions, insurance pricing and emergency response. These maps, however, are typically ‘static’; that is, are a spatially homogeneous representation of a given probability flood. Actual floods vary in their extremity across space: if a given location is extreme, you may expect proximal locations to be similarly extreme and distal locations to be decreasingly extreme. Methods to account for this stochastically can, broadly speaking, be split into: (i) continuous simulation via a meteorological-hydrological-hydraulic model cascade and (ii) fitting statistical dependence models to samples of river gauges, generating a synthetic event set of streamflows and simulating the hydraulics from these. The former has the benefit of total spatial coverage, but the drawbacks of high computational cost and the low skill of large-scale hydrological models in simulating absolute river discharge. The latter enables higher-fidelity hydraulics in simulating the extremes only and with more accurately defined boundary conditions, yet it is only possible to execute (ii) in gauge-rich regions – excluding most of the planet.

In this work, we demonstrate that a hybrid approach of (i) & (ii) offers a promising path forward for stochastic flood modelling in gauge-poor areas. Inputting simulated streamflows from large-scale hydrological models to a conditional exceedance model which characterises the spatial dependence of discharge extremes produces a very different set of plausible flood events than when observed flows are used as boundary conditions. Yet, if the relative exceedance probability of simulated flows – internal to the hydrological model – are used in place of their absolute values (i.e. a return period instead of a value in m^3s^{-1}), the observation- and model-based dependence models produce similar events in terms of the spatial distribution of return periods. In the context of flood losses, when using Fathom-US CAT (a state-of-the-art large-scale stochastic flood loss model), the risk of an example portfolio is indistinguishable between the gauge- and model-driven framework given the uncertainty in vulnerability alone. This is providing the model-based event return period is matched up with a hydraulic model of the same return period, yet where the latter is characterised via a gauge-based approach.