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Conditional probability of rainfall extremes across multiple durations

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The conditional probability that extreme rainfall will occur at one location given that it is occurring at another location is critical in engineering design and management circumstances including planning of evacuation routes and the sitting of emergency infrastructure. A challenge with this conditional simulation is that in many situations the interest is not so much the conditional distributions of rainfall of the same duration at two locations, but rather the conditional distribution of flooding in two neighbouring catchments, which may be influenced by rainfall of different critical durations. To deal with this challenge, a model that can consider both spatial and duration dependence of extremes is required.

The aim of this research is to develop a model that can take account both spatial dependence and duration dependence into the dependence structure of extreme rainfalls. To achieve this aim, this study is a first attempt at combining extreme rainfall for multiple durations within a spatial extreme model framework based on max-stable process theory. Max-stable processes provide a general framework for modelling multivariate extremes with spatial dependence for just a single duration extreme rainfall. To achieve dependence across multiple timescales, this study proposes a new approach that includes addition elements representing duration dependence of extremes to the covariance matrix of max-stable model. To improve the efficiency of calculation, a re-parameterization proposed by Koutsoyiannis et al. (1998) is used to reduce the number of parameters necessary to be estimated. This re-parameterization enables the GEV parameters to be represented as a function of timescale. A stepwise framework has been adopted to achieve the overall aims of this research. Firstly, the re-parameterization is used to define a new set of common parameters for marginal distribution across multiple durations. Secondly, spatial interpolation of the new parameter set is used to estimate marginal parameters across the full spatial domain. Finally, spatial interpolation result is used as initial condition to estimate dependence parameters via a likelihood function of max-stable model for multiple durations.

The Hawkesbury-Nepean catchment near Sydney in Australia was selected as case study for this research. This catchment has 25 sub-daily rain gauges with the minimum record length of 24 years over a region of 300 km $\times$ 300 km area. The re-parameterization was applied for each station for durations from 1 hour to 24 hours and then is evaluated by comparing with the at-site fitted GEV. The evaluation showed that the average R2 for all station is around 0.80 with the range from 0.26 to 1.0. The output of re-parameterization then was used to construct the spatial surface based on covariates including longitude, latitude, and elevation. The dependence model showed good agreements between empirical extremal coefficient and theoretical extremal coefficient for multiple durations. For the overall model, a leave-one-out cross-validation for all stations showed it works well for 20 out of 25 stations. The potential application of this model framework was illustrated through a conditional map of return period and return level across multiple durations, both of which are important for engineering design and management.