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Simulating intra-event return period co-occurrences in short-duration intense precipitation events

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Design storms mimicking extreme rainfall events are essential for planning drainage networks and managing flood risks, as they serve as input to estimate the resulting flood hydrograph. They are typically characterized by high return periods of intensity-duration relationships, which are estimated from historical records. However, current methods for estimating design storms, such as block-maxima, fail to account for observed return period co-occurrence over different durations within rainfall events and tend to oversimplify and overestimate the total rainfall amount. Focusing on short-duration intense precipitation events recorded in Zurich (Switzerland), we investigated the dependencies between critical precipitation intensities over several duration intervals, namely over the 10-, 30-, 60-, 180-, and 360-min intervals. Our analysis reveals strong dependencies, with maximum and average pairwise return period Kendall's τ rank correlation coefficients over two of these duration intervals of 0.69 and 0.39, respectively. We model these multivariate relationships with a vine copula, which is then used to simulate critical precipitation intensities over different duration intervals, thus respecting the observed dependencies within rainfall events. These intensities are used to constrain a micro-canonical cascade model that produces the corresponding precipitation hyetographs. With the new introduced approach, we find a reduction of 29% on average in total storm volume compared to a common block-maxima approach for events with a 10-year return period on the 60-min interval. Yet, we also find that 10% of these events show an increase in the 10-min interval precipitation intensity. The new method allows for the simulation of extreme precipitation events that reflect observed intra-event return period co-occurrence and the results suggest potential implications for hydrological applications demanding realistic design storms.

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