Generating realistic storms using a joint return period sampling of intense precipitation

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Project aims

- Determine the joint distribution of return periods over various durations within storms
- Compare observed dependencies with the common design storm guidelines

Design storms

- Design storms mimic extreme precipitation events. They are widely used as inputs to hydrodynamic models to develop flood hazard maps or plan flood mitigation measures.

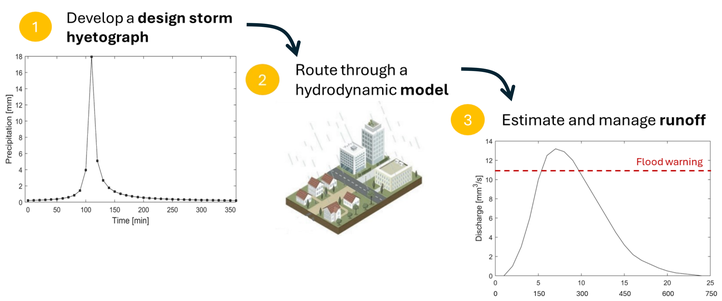


Figure 1: Conceptual diagram of design storm use in hydrological modelling applications.

- The most common methods for constructing design storms, e.g., Chicago (CDS) or Euler Type II design storms, assume a constant return period across all durations throughout the event.
- These methods overlook the observed correlations between return periods for different duration intervals within storms and may thereby lead to under- or overestimation of the flood risk.

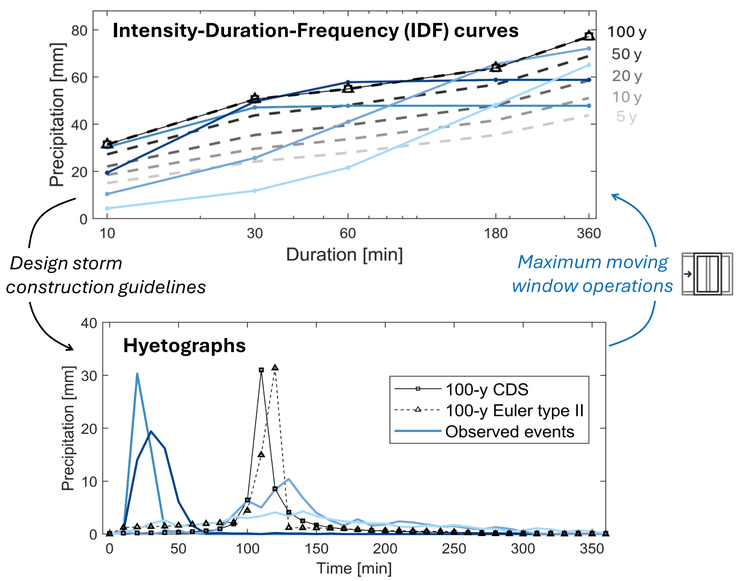


Figure 2: Return periods across different durations (top) and hyetographs (bottom) for observed events and 100-y design storms in Zurich (Switzerland).

Methods

Figure 3: Methodology workflow.

Model highlights

- We introduce a model that can simulate extreme precipitation events with **realistic duration-frequency dependencies**.
- The results highlight the **overestimation of total precipitation volumes by the common design storm sampling methods**.
- The model can support improved flood risk assessment by providing more realistic design storms and intensity patterns.

Results

Dependencies analysis

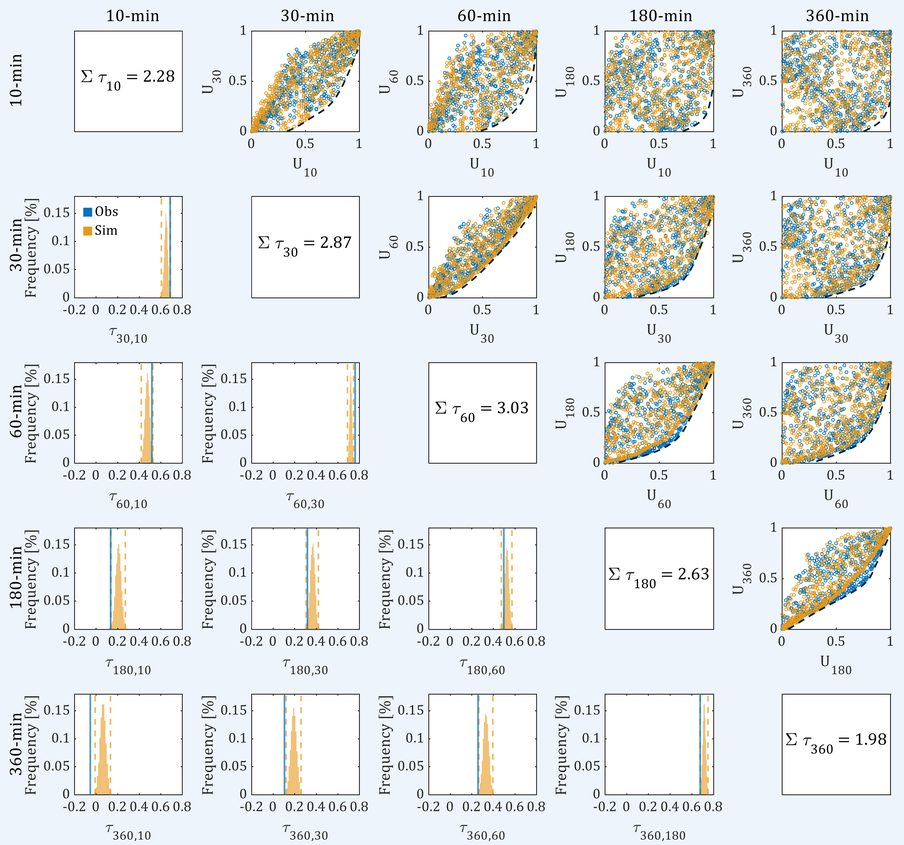


Figure 4: Above the diagonal: Scatter plots of the normalised ranks of accumulated precipitation volumes on the 10-min, 30-min, 1-h, 3-h and 6-h duration intervals. The dashed black curves show the limits of the infeasible regions. Below the diagonal: Histograms of the pairwise Kendall's τ rank correlation coefficients based on 10,000 simulations, where the 99% confidence interval bounds are shown by the dashed yellow lines and the rank correlation of the observations are shown by the vertical blue line. Along the diagonal: Estimates of the pairwise dependencies, as the sum of Kendall's τ coefficients.

- The pairwise dependencies are asymmetric, with infeasible regions, due to the following constraint:
$$Pr_{d1} > Pr_{d2} \ \ if \ \ d1 > d2.$$
- Copulas can be used to reproduce the joint distributions between return periods of accumulated precipitation volumes across different duration intervals within precipitation events.

Multivariate distribution modelling

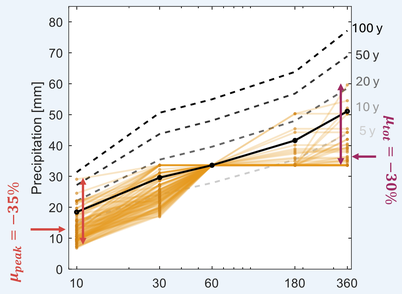
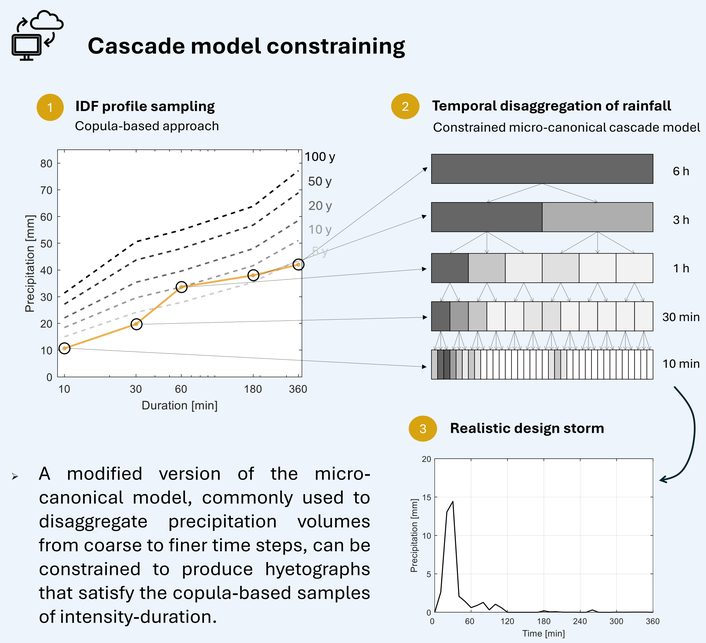


Figure 5: IDF profiles for 100 events with 10-y return period on the 1-h duration interval.

- Realistic intensity-duration samples can be generated from the multivariate joint distribution.
- We compared design storms from standard methods with design storms that reproduce observed intensity-duration dependencies:
  - the relative difference in total storm volume is on average 30%,
  - the relative difference in peak storm intensity is on average 35%.

Cascade model constraining



- A modified version of the micro-canonical model, commonly used to disaggregate precipitation volumes from coarse to finer time steps, can be constrained to produce hyetographs that satisfy the copula-based samples of intensity-duration.