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Modelling high-resolution rainfall extremes in a changing climate

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Stochastic modelling is an increasingly popular method to generate long rainfall time series as input for the subsequent hydrological applications, such as the design of urban drainage system. It aims to resemble the physical process of rainfall using parameters with physical meanings, instead of its statistical features. There are, however, two main challenges yet to be overcome in stochastic rainfall modelling. These are 1) reproduction of rainfall extremes at sub-hourly timescales, and 2) incorporation of the impact of climate change.

Some recent breakthroughs have been made to address the first challenge. Onof and Wang (2020) reformulated the equations of the randomised Bartlett-Lewis rectangular pulse (BLRP) models and showed that the improved models can well preserving rainfall extremes at sub-hourly (5- and 10-min) and hourly timescales.

The second challenge is however yet to be explored. Cross et al. (2020) recently presented a multivariate regression method that associates BLRP parameters to temperature estimates on a monthly basis, attempting to capture the dynamics of the underlying climate. However, the concept of 'calendar month' - an artificial period of time - was still employed to represent natural seasonality. This may fail capturing the natural shift and length difference of seasons between years. To address the above drawback, it is critical to 'relax' the concept of calendar month, so that the most similar climate conditions between different years can be better identified.

An innovative approach is proposed in this work to circumvent the above drawback, where two main improvements are implemented. First, instead of following calendar month, we slice the original rainfall time series using an overlapping moving window with 30-day window width and 10-day step size. This enables a stronger continuity in representing climate variations. Second, the dynamic time warping (DTW) algorithm is employed to quantify the similarity of climate conditions between different years. DTW is a widely-used algorithm in measuring the similarity between two time series, and is known to be less sensitive to the distortion in time axis as compared to the Euclidean distance metrics. Then, based upon DTW measures, we can identify the historical periods with the most similar climate conditions to the target ones. The statistical properties of the local gauge data for these specific periods are used to build the BLRP model in a dynamic fashion.

Selected atmospheric variables (including geopotential, temperature, U-component of wind, and V-component of wind) from the ERA5 re-analysis datasets and five-minute rainfall data from 6 long recording rain gauges in Germany (one with 69 years of data; others with 49 years) are used to test the impact of the proposed approach. Preliminary results show that the statistical behaviours of newly identified periods of data are more analogous to the target period as compared to those identified from the traditional method relying on calendar month. This demonstrates the potential to use the proposed new approach to better incorporating the impact of climate change into stochastic rainfall time series modelling.