A stochastic generator for high-resolution spatio-temporal extreme rainfall

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Abstract

Stochastic precipitation generators are essential tools for urban flood risk analysis. We propose a framework for modeling the distribution and the spatio-temporal dependence of high-resolution rainfall using data from Montpellier's Urban Observatory rain gauge network collected since 2019. This dataset is complemented by 1 km hourly radar reanalysis data from Meteo-France, available for a longer time period of almost 20 years. A neural network downscaling approach will be applied to reanalysis data for local-scale marginal distributions to obtain a rich catalogue of space-time extreme precipitation events at high spatiotemporal resolution, for a longer period and with wider spatial coverage by leveraging information from the two data sources. For univariate modeling, at the point level, the Extended Generalized Pareto Distribution (EGPD) is used to capture both moderate and extreme rainfall without explicit threshold selection, simplifying parameter estimation. Spatio-temporal dependence is modeled with an r-Pareto process based on an underlying Gaussian dependence structure. Unlike max-stable processes, which focus on block maxima, r-Pareto processes offer greater flexibility by using the Peaks Over Threshold (POT) framework. By incorporating a non separable spatio-temporal variogram with advection, we account for the possible horizontal movement of precipitation clouds, enabling realistic simulations of spatio-temporal rainfall patterns. Variogram parameters are estimated using a novel composite likelihood approach based on bivariate joint exceedance indicators. This methodology will form the core of a stochastic precipitation generator for simulating high-resolution rainfall events on the Montpellier region, which will be integrated into a mechanistic water flow model for flood risk analysis.

Keywords: Stochastic generator, extremes, precipitation, EGPD, r Pareto process, high spatiotemporal resolution

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