# Improved rainfall frequency analysis through separation of storm intensity and storm arrival frequency

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**Abstract:** Accurate estimation of Annual Exceedance Probabilities (AEPs) of extreme rainfalls through rainfall frequency analysis (RFA) is a critical step in the production of intensity-frequency duration relationships, which are used to inform engineering design for flood mitigation and disaster response. The most common approach to rainfall frequency analysis used in both academic literature and industry practice is to fit the three parameter Generalised Extreme Value (GEV) distribution to a series of annual maximum (AMS) rainfalls. Motivated by empirical evidence that rainfall AMS in the United States (Karlovits & Schaefer, 2020) and Australia (Nathan et al., 2016) are not well represented by the GEV distribution we explore fitting the more flexible four-parameter Kappa distribution. Use of the Kappa distribution in hydrology has been largely limited to regional studies that pool data from many sites owing to the data requirements of fitting the Kappa's two shape parameters. As an alternative we present a two-step approach for fitting the Kappa distribution to peaks-over-threshold (POT) series based on maximum likelihood estimation. The approach separately models storm intensity and the arrival frequency. First, a Generalized Pareto distribution describing storm intensity is fitted, followed by a Binomial distribution for storm arrivals. We compare the performance of this two-step Kappa approach to an analogous two-step GEV approach, and to Kappa and GEV distributions fitted to AMS, using both synthetic and real-world data representative of Australian climatic conditions. Our results show that the two-step Kappa approach performs better than the GEV distribution at estimating extreme rainfall quantiles over a wide range of parent distributions (O'Shea et al., 2023).

It is widely recognised that increasing global temperatures caused by anthropogenic climate change are causing rainfall to become more intense. Non-stationary RFA is an increasingly well studied design tool to investigate the risk of extreme rainfalls under climate change. A key issue with non-stationary RFA is what structure the non-stationary models should take. While many studies evaluate different model structures by comparing their performance in reproducing observed data it is widely accepted that for models to be robust when extrapolated to a future climate, they need to be representative of the underlying physical processes responsible for the non-stationarity. POT approaches to non-stationary RFA have the advantage that they separately model storm intensity and storm arrival frequency. This separation approximates the separation of thermodynamic (related to temperature change) and dynamic (related to atmospheric circulation) drivers of rainfall, the two primary mechanisms responsible for changes in extreme rainfall due to climate change. We explore how simple, physically motivated models of non-stationary rainfall intensity and arrival frequency can be incorporated in the two-step Kappa approach. Our results demonstrate that accurate quantile estimation when extrapolating to future climates is only possible when the non-stationary model correctly represents the underlying non-stationary process present in the rainfall record.

## REFERENCES

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