Extreme rainfall frequency analysis using the four-parameter Kappa distribution: separating storm intensities and arrival rate

Declan O'Shea[1], Rory Nathan[1], Ashish Sharma[2] and Conrad Wasko[1]

(1) *Department of Infrastructure Engineering, The University of Melbourne, Parkville, Victoria 3010, Australia*
(2) *School of Civil and Environmental Engineering, University of New South Wales, Sydney, New South Wales 2052, Australia*

Rainfall frequency analysis and the estimation of extreme rainfall quantiles is an essential part of engineering design for flood mitigation and disaster response. Here we show how quantile estimation can be improved by fitting the four-parameter Kappa distribution to a peaks-over-threshold (POT) series. We introduce a two-step approach to fit the Kappa distribution to POT data which separates the processes of rainfall intensity and storm arrival rate. In the first fitting step a Generalised Pareto distribution is fitted to describe rainfall intensity, followed by fitting a Binomial distribution for storm arrival rate.

The two-step Kappa is tested against existing methods of rainfall frequency analysis. We show that by leveraging the additional information from the POT series in the two-step Kappa dramatically improves quantile estimation and reduces uncertainty compared to fitting either the GEV or Kappa distributions models to an annual maxima series. We also show that in situations where the GEV is a poor approximation of the skew-kurtosis values of extreme rainfalls, the two-step Kappa yields unbiased quantiles under while use of GEV fitted using either a POT or annual maxima series leads to biased quantile estimates.

Based on these results we believe the two-step Kappa approach can be useful for both at-site and regional rainfall frequency analyses, particularly when the GEV distribution is shown to be a poor approximation of annual rainfall extremes.

Given that rainfall extremes are expected to increase with climate change, it is prudent to account for these increases in engineering design procedures. Methods of non-stationary frequency analysis are common in the literature; however, they can lack a physically justifiable basis. We believe that separation of storm intensity and storm arrival rate make this two-step method attractive for modelling non-stationary frequency curves under climate change.