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Robust detection of changes in extreme rainfall?

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A large body of research now supplements the IPCC's Fourth Assessment Report indicating that it is likely that rainfall patterns are changing with extreme events becoming more intense, although changes in their frequency are less clear. In considering changes in these extremes, a statistician might ask whether extreme events are becoming more frequent; while in contrast, an hydrologist might ask whether extreme events are becoming more intense. Several studies have examined changes in extreme rainfall where individual events are subset, or binned, either in relation to the frequency of events or in relation to volumetric exceedances over a series of equally distributed thresholds (quantiles).

This study focused on the information obtained from quantile rainfall contributions which may not be deduced intuitively from physical processes. The question was not which method of binning is more useful, or whether trends exist, but whether trends in either approach could tell us something we did not expect. We believe that as the distribution of rainfall is changing, it should be unsurprising that trends exist in the upper quantiles. Thus, we contend that approaches centred on changes in the upper quantile bins may not be as robust as they first appear.

The method employed daily records from long duration gauges to compare rainfall properties between two sites in the North West and the South East of the UK. We were principally concerned with changes in the intensity of extreme events, rather than frequency as the latter method has been examined in some depth by others. We derived thresholds for each site from the respective observations based on a selection of different base periods, including the entire record length of approximately 110 years. The results demonstrated that the selection of base period has a marked influence on the threshold for the upper quantile with only a short change in duration of record, giving 24.9mm (1961-1995) and 26mm (1971-2000).

Daily rainfall records tend to follow a gamma distribution, which is heavy tailed and replicates the high frequency of very low rainfall amounts, through regular occurrences to the 'tail events' of annual maxima and greater. We hypothesised that as rainfall patterns are changing, the corresponding gamma distribution is also changing. Therefore, we fitted a gamma distribution to each of the observed data series obtaining, as expected, a highly left skewed fit for South East England and a lesser skew for North West Scotland. Two random series, of length 10,000, were then generated from each of these distributions to assess whether changes in the upper quantile are disproportionate to changes in precipitation distribution.

The analysis was performed using thresholds derived for each series from the gauged observations between 1961-1990. We simulated an increase of 10% in all events by multiplying the original series by 1.1, and a 10% increase in frequency through extending the randomly generated series by 1,000. Results are expressed in terms of the fractional contribution to each of ten quantiles. While the result for increased frequency differed little from that of the base period (both 0.052 in the 10th quantile), the increased intensity resulted in a contribution of 0.074. Therefore, for a trend in upper quantile rainfall to be considered significant, the increased fractional contribution would need to be >50% for a commensurate 10% increase in total rainfall.

It is concluded from the comparison of empirically and theoretically derived quantiles that sub-setting data in relation to some threshold is inappropriate. We also conclude that without comparison to some further metric, such as total annual rainfall, trends in the upper quantiles are not meaningful.