Variability and Extremes of Rainfall at Different Spatial Scales

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Implications for model evaluation, climate scenarios and hydrological impact assessment

Aims and Objectives of the Research…

- investigate the relationships between precipitation variability and extremes at a range of spatial scales
- develop guidance on how dense an observation station network needs to be in order to allow reliable assessment of simulations of precipitation from climate models
- apply transformations between spatial scales for evaluating climate model simulations.
- apply the relationships to scenarios of future climate to generate the appropriate statistical characteristics of precipitation for any spatial scale required, in order to identify changes in variability under changed climate conditions (including whether the spatial scale of rainfall might change i.e. by a shift from frontal to more frequent convective events).
- apply the relationships to scenarios of future climate at appropriate spatial and temporal scales for application to flood estimation.

Introduction:

This poster presents some initial work for a PhD with the Climatic Research Unit UEA and CEH Wallingford (see 'Aims and Objectives').

Issues of spatial scale present a number of problems in the evaluation and application of climate model output. Whilst the mean is unaffected by spatial scale, the **distribution** of daily rainfall totals will alter depending on the size of the area represented such that the variance, for example, of daily rainfall observations at a point will be greater than that of a regional average surrounding that station (see Figure 1).

It is generally accepted that climate models generate output which represents the grid-box scale, which presents us with a mismatch between

a) the point observations used to evaluate model output; and
b) the resolution of scenarios required for many areas of climate impact assessment.

The high degree of spatial and temporal variability in precipitation, and the particular interest in the magnitude of that variability and extremes of the rainfall process, mean that this issue is of particular importance in assessments of model skill and future scenarios of change in precipitation regimes.

Model Evaluation:

A 'true' grid-box mean would be the mean of an infinite number of point observations from within that area. The areal averages constructed from a finite number of observation stations are therefore affected by the number of stations (***n***) which make up that mean (Figure 1). The statistics tend to level off as ***n*** increases, allowing the characteristics of a series constructed from an infinite number of stations (***n*=∞**) can be estimated from a finite number of stations.

… how many stations are needed to estimate the properties of an n=∞ mean series?

- The rate of change of these statistics with ↑***n*** is related to the degree of spatial correlation between the stations.
- Spatial correlation is related to separation distance, regional characteristics (e.g. topography and climate) and season.
- For variance, a theoretical relationship can be applied to relate the mean inter-station correlation (***mean r***) with the reduction of variance in an ***n***-station mean (Osborn and Hulme, 1997)
- However, there is not such a commonly known relationship for other statistical parameters…for example, skewness…

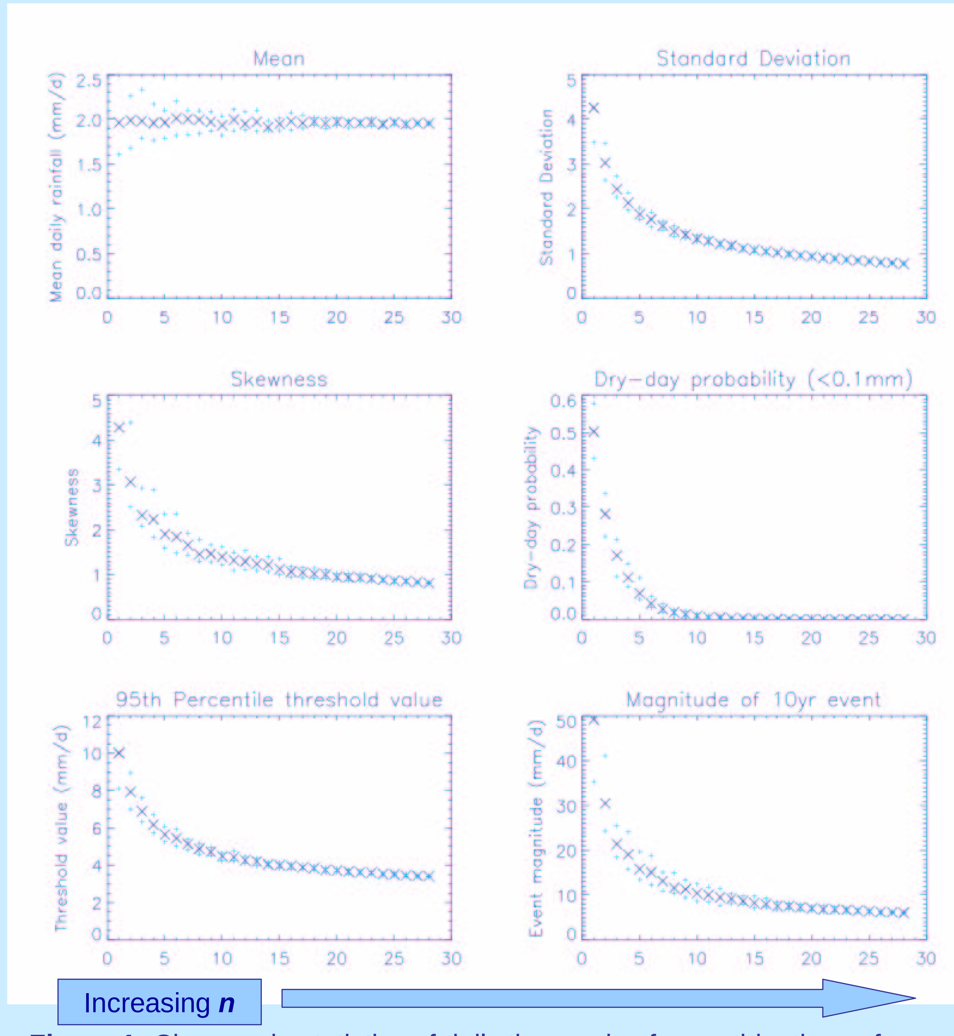

Figure 1: Changes in statistics of daily time series for combinations of *n* stations from a 5°x7.5° grid box covering Southern England.

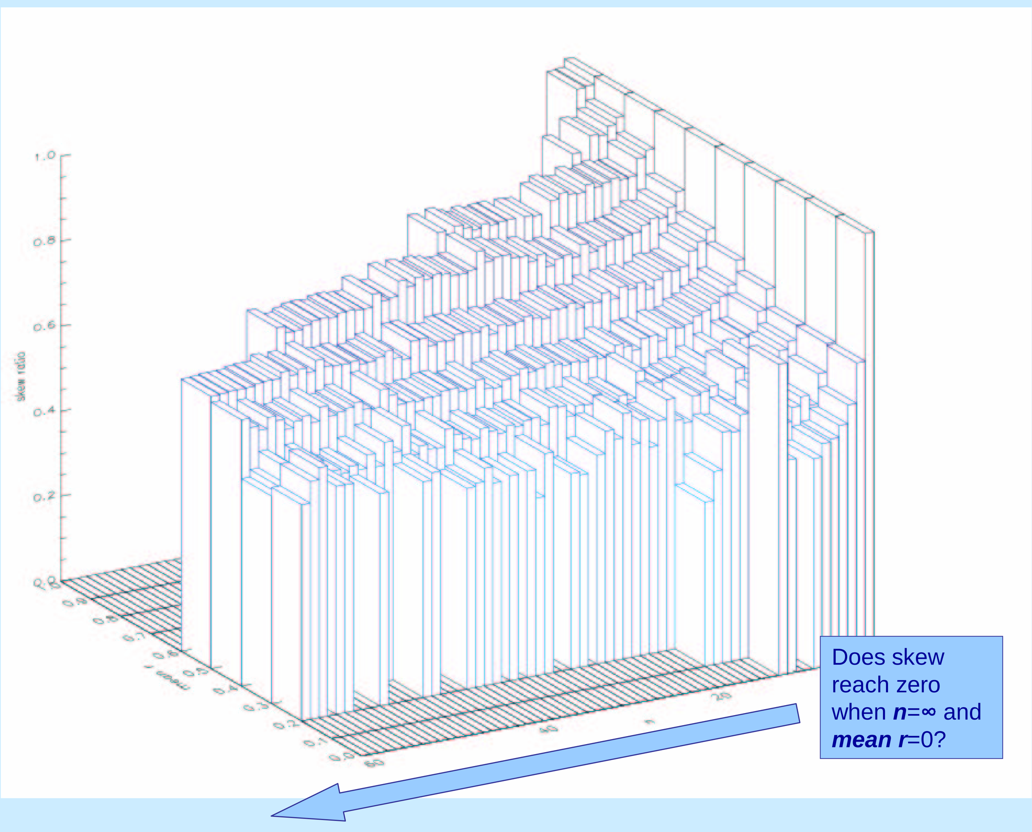

Figure 2: Observed ratio of skew of an *n*-station mean to skew of a single station, for a range of station combinations with different *mean r* values. Missing data regions occur where there is a shortage of examples of very high or low correlations for larger ***n*** combinations.

Skewness and Spatial Correlation:

An empirical approach, using random combinations of ***n*** stations, is used to relate the ratio of skewness in an ***n***-station series and a single station series (***skew n/skew 1***) to the mean inter-station correlation (***mean r***). Shown as a surface plot in Figure 2, the different rates of decline with increasing ***n*** for different ***mean r*** values might be used to extrapolate to obtain values for ***n*=∞**.

…Is 'mean r' an appropriate measure of spatial dependence?

Stations with ***mean r*** of 0 may not be completely independent. Rainfall events vary in their areal coverage, and there may be a tendency for more intense, convective events to cover a smaller region than synoptic events which are less intense but larger in geographical extent (see Figure 3). The ***r*** value for two stations therefore indicates the proportion of shared variance across **all** events, which can be useful in estimating variance in n-station means, but may be less appropriate for looking at particular subsets of events such as extremes or dry-days.

This also affects the skewness, which depends critically on the number of dry days (<0.1mm) and the extremes in the series. For any number of perfectly correlated stations (***mean r*** = 1), we would not expect averaging to change the skewness at all, whilst if an infinite number of independent stations were averaged, the skewness in the mean series would become zero (in accordance with the Central Limit Theorem) (Skaugen *et al*., 1996).

This may not be the case, however, because even with ***mean r*** =0 (for the full time series), the coincidence of dry or very low rainfall days may be more frequent than would be expected for truly independent series. Hence, using ***mean r*** may underestimate the preservation of these low values and the skewness of the mean series.

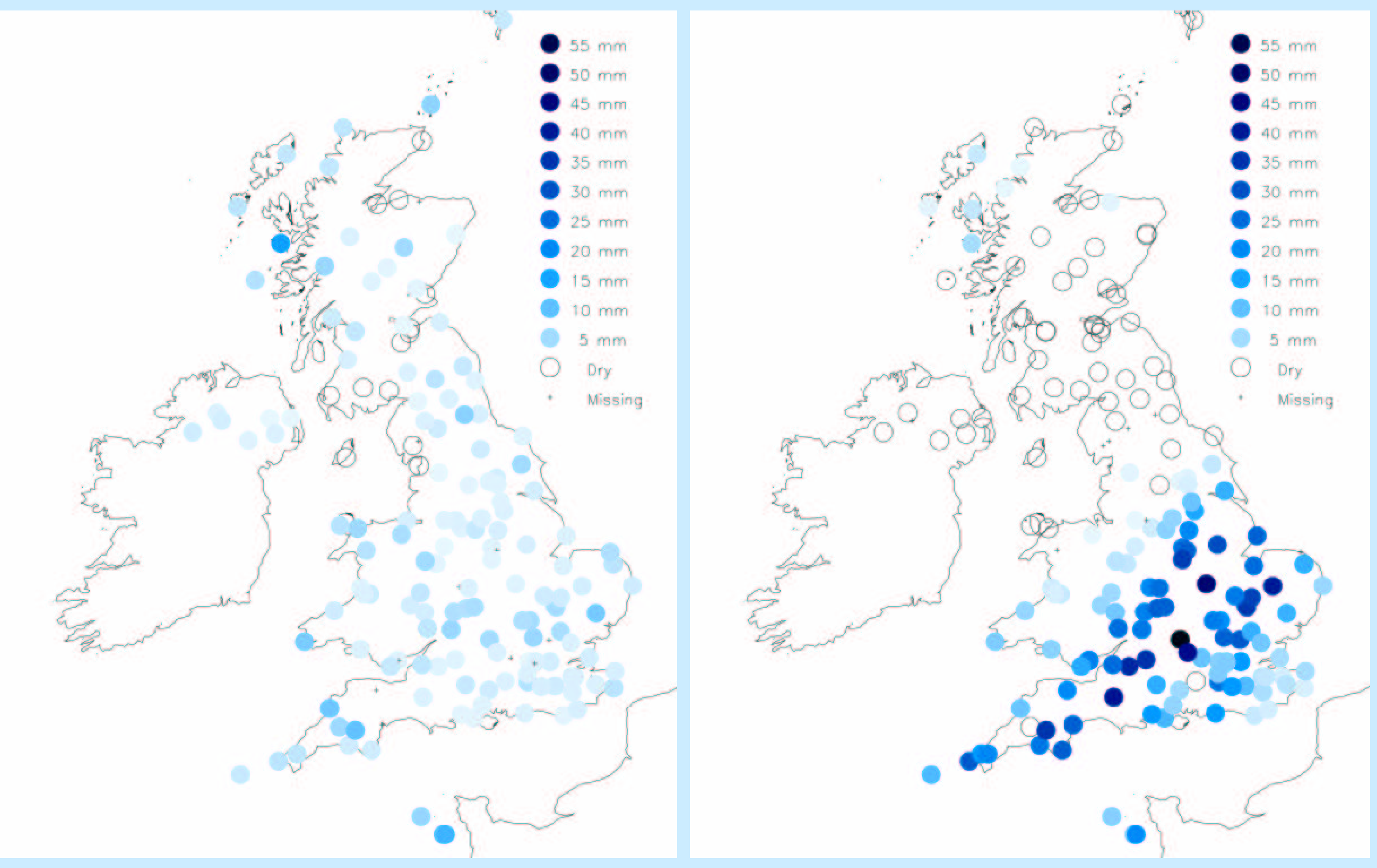

Figure 3: Two examples of spatial distribution of point daily rainfall intensities in the UK, illustrating the difference in areal coverage which might occur for events of different intensities.

Future direction of research…

These relationships between rainfall at point and areal scale might will be useful for assessing future changes in precipitation regimes at scales smaller than can currently be represented by General Circulation Models. However, it cannot be assumed that the spatial correlation structure will remain constant under warmer climatic conditions –in fact we expect that the spatial variability will increase if we experience the shift to more intense, convective rainfall that has been suggested by climate simulations (Frei *et al*., 1998; McGuffie *et al*, 1999).

The future stages of this research will involve investigation of the possible changes in areal extent and spatial variability of rainfall, and apply these changes to the generation of precipitation scenarios for flood estimation.

Acknowledgements:

The daily station data for the UK were collected by the UK Meteorological Office and were provided by the British Atmospheric Data Centre.

The work is funded by a NERC studentship, with CASE partner CEH Wallingford.

References:

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