Generation of spatially-consistent rainfall fields for rainfall-runoff modelling

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In the last decade, radar data have become routinely available for the UK, providing a means of observing spatial rainfall. Although radar has limitations with respect to performance and long records of continuous data are not yet available, it represents an important source of information which allows, for the first time, the continuous spatial distribution of rainfall to be studied. In parallel, new research into spatial rainfall modelling has produced a range of tools with potential for hydrological application. However, most methods of representing rainfall for hydrological design and simulation are relatively primitive. There is a need, therefore, to combine the strengths of new data sources and new modelling methods to produce a new generation of rainfall modelling tools to support hydrological practice. Results of a major study for MAFF (Wheater et al., 2000) are briefly reported.

Spatial-temporal models

A family of stochastic models has been developed in which rainfall is modelled in continuous space and time and hence can be aggregated to any required spatial or temporal scale. A simplified conceptual representation of rainfall processes is based on simple statistical assumptions which lead to highly parameter efficient models. The model parameters represent observable rainfall features and can be used to simulate physical precipitation processes. The approach is based on single-site models developed by Rodriguez-Iturbe *et al.,* (1987, 1988), in which storm arrivals are modelled using a Poisson process and associated with each storm arrival is a random number of cells, of random duration and intensity. The framework for extension to spatial-temporal modelling was developed by Cox and Isham (1988, 1994), with further recent development by Northrop (1998).

A major thrust of this study has been to investigate the potential applicability of this family of models for continuous simulation. The primary source of continuous spatial data has been a radar data set from the Wardon Hill radar in south-west England, available for the period October 1993 to March 1997. Overall the model has performed extremely well in reproducing basic statistical properties over different space and time-scales, including temporal and spatial autocorrelations. The proportions of wet pixels (averaged over space and time) are also very well reproduced across the range of space and time-scales examined. Only limited evaluation of extreme value properties has been possible, but the results, in terms of intercomparison of the model and the radar data set, are most encouraging.

Generalized Linear Models (GLMs)

A current limitation of the above models is that spatial and temporal stationarity is assumed, although seasonal variability is incorporated. The GLM approach represents point rainfall at a number of locations by what is essentially an extension of a multiple regression approach (spatial correlation is introduced through a model for the noise). In this way, any important explanatory variables can be included (for example elevation, rainshadow effects, distance from the sea) as well as temporal dependence (e.g. previous rainfall). The model is thus extremely flexible, and can incorporate spatial non-stationarity as well as long term climate effects. Once the underlying independent controls on spatial non-stationarity have been defined, it can be used to simulate rainfall at any location within the modelled field. In addition, its efficient model identification structure allows for possible long-term trend or periodicity to be rigorously investigated, and included in simulations as appropriate. However, given the complexity of the spatial-temporal rainfall process, such models have so far only been applied at the daily time-scale.

An extensive study of Irish rainfall data (Chandler and Wheater, 1998a,b) demonstrates that although the daily rainfall data are extremely noisy, subtle spatial and temporal effects can be detected and quantified. The capacity to simulate long sequences of daily rainfall under a changing climate regime is demonstrated. The model performance in simulating daily and 3-monthly rainfall is good. Forecasting the probability of rainfall occurrence at a site is excellent and the basic statistical properties of point rainfall time-series, including autocorrelation and the proportion of wet days, are well reproduced. Considering simulation performance at pairs of sites, there is a slight under-representation of the proportion of days when both sites are wet, but the inter-site correlation for wet days is excellent. Other examples investigated include the Brue and Blackwater catchments.

Hybrid Modelling Approaches

For situations of limited spatial data, a hybrid approach has been developed, using the concept of spatial-temporal disaggregation. The general problem considered is as follows: given daily rainfall data (observed or simulated) from a number of locations, and one or more sub-daily data sets (again, observed or simulated, but in the latter case constrained to be consistent with the daily values), can an appropriate spatially-distributed sub-daily set of values be generated? A new method has been developed and tested for the Brue catchment; preliminary results are most encouraging.

In summary, a comprehensive suite of rainfall modelling tools has been developed, with wide applicability to provide inputs to distributed or lumped rainfall-runoff models based on radar or raingauge data. Some further work is required to test the simpler approaches more extensively and provide a UK-wide capability; the main limitation to the full spatial-temporal model is the quality of radar data and as yet a lack of long data records. However this latter method has considerable potential for wide-spread applicability in the medium-term. The suite of models and their performance are more fully described in Wheater et al., 2000. Further information is available from h.wheater@ic.ac.uk or valerie@stats.ucl.ac.uk . The support of MAFF and NERC is gratefully acknowledged.

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