

MODELLING HYDROLOGICAL EXTREMES IN THE SEVERN UPLANDS

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Introduction

Global repercussions of a changing climate are likely to induce an increase in the frequency and magnitude of hydrological extremes (Cunderlik and Simonovic, 2005). There is evidence to suggest that both precipitation and flow extremes have increased in the UK over the last 30-40 years (DEFRA, 2001; Osborn *et al.*, 2000; Fowler and Kilsby, 2003). Flooding is the most damaging and costly natural hazard in the UK, costing the nation billions of pounds every year (Brown and Damery, 2002). Extreme floods such as those experienced in 1998, 2000 and 2007 are likely to occur more frequently due to changes in precipitation and accurately modelling these extreme periods is essential if future extremes under a changing climate are to be evaluated.

Methods

There is a need for a great deal of research into how precipitation forecasts can be effectively presented to hydrologists and how they can be used in combination with hydrological models to provide indications of future flows and river levels. For the majority of flood risk studies one-dimensional modelling is usually considered appropriate. Rainfall-runoff models are one-dimensional models which represent the conversion process of rainfall to river flows using observational data as the model driver. The quality of forecasts will, in general, depend on the quality of the simulation model, the accuracy of the precipitation and boundary forecasts, and the efficiency of the data assimilation procedure. However, complete replication of reality is impossible and accuracy is limited accordingly. Recent efforts in fluvial forecasting have focused on quantifying rainfall amounts from radar images. As the resolution of spatially distributed gridded data has increased it has become more desirable to incorporate gauge-corrected radar imagery into hydrological modelling to increase accuracy.

HEC-HMS is a 1-D rainfall-runoff model produced by the US Army Corps. The model separates a hydrological catchment into manageable sections linking up individual subbasins. Rainfall inputs were used to drive the hydrological model and subbasin and river routing parameters acted in transforming rainfall into runoff. Model performance was then assessed according to data input quality and the optimisation of hydrological parameters. Hydrological model calibration often improves the accuracy of predictions by optimising parameters in relation to observational data. Calibration for this research is over a time period of extreme precipitation and flow values. Calibrating model parameters for extreme conditions is essential as future research will investigate the impact of climate change scenarios on extreme conditions. The gauge- and radar-driven model predictions were calibrated independently to provide a comparison between optimal parameters for the two model inputs.

Study site and data

The Severn Uplands, an area approximately 2000 km², lies at the headwaters of the River Severn, UK. The catchment is bordered by the Cambrian mountains in the west where rainfall is high and runoff regimes are flashy. Towards the east of the basin rainfall reduces and drastic reductions in elevation give way to a wider fluvial system which meanders through low-lying floodplains.

During the summer of 2007 many parts of the UK were inundated following a series of unseasonably low depression systems throughout June and July. Rainfall intensity was high and June was one of the wettest months on record in the UK. Two main sources of precipitation data are available in the UK; (i) gauged data recorded by the Environment Agency and (ii) Nimrod radar imagery sourced from the Met Office. Precipitation records from both gauge and radar sources were used to simulate river flows for Summer 2007.

Preliminary results

Time-series analysis of precipitation and flow records in the Severn Uplands using non-parametric trend detection techniques has identified a change in extremes from 1977 to 2006. Generally, heavy precipitation extremes were found to be increasing in autumn and winter, and decreasing in spring and summer. High-flows have increased in winter and decreased in spring. These detected trends may be linked to various environmental indices affecting climate regimes within the catchment. With a change in extremes detected, progression was made to model the Summer 2007 extreme rainfall-runoff event using HEC-HMS.

River flows generated with HEC-HMS for sites in the Severn Uplands were compared to observational records under uncalibrated conditions. Accuracy was found to differ between outputs produced by the two data sources. The main finding was that radar data increased the accuracy of the flow predictions, particularly in respect to increasing the accuracy of predicted peak flows. The correlation, R^2 , between observed and simulated flows was large (>0.7) for both methods, suggesting that data sources were comparable in simulation accuracy. However, the root mean-squared error (RMSE) shows that radar data significantly reduces error, generally by over half compared to gauge-data simulations, indicating substantial differences in the bias of the simulations. Overall, a more accurate spatial distribution of where precipitation is falling was achieved given a higher spatial and temporal resolution of input precipitation data.

Model calibration to optimise parameters is currently under investigation and subsequent results and analysis will be presented.

References

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