PREDICTING FLOWS IN UNGAUGED UK CATCHMENTS

A collaborative project between Imperial College London[1] and the Centre for Ecology and Hydrology[2]

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Objectives

- An improved method for predicting daily flows in ungauged catchments using continuous-time rainfall-runoff models
- Identification of conceptual model structures which are suitable for regionalisation over the whole of UK
- Evaluate traditional methods of regionalisation based on regression of parameters against catchment descriptors
- Development and testing of a new, improved method, which includes ensemble modelling for uncertainty analysis

Prediction of flows in ungauged basins

Stream and river flow data are needed for many water management applications, for example flood design and drought planning. Rainfall-runoff modelling allows simulation of flows as a function of input climate.

Ideally, rainfall-runoff model parameters should be calibrated using several years of gauged climate and flow. Although we have more than 1000 stream flow gauging stations in the UK, there are still thousands of sites which are ungauged, for which model calibration is not an option. Instead, regionalisation is used to transfer models from gauged sites.

The standard method of regionalisation uses gauged catchments to identify a relationship between model parameters and catchment descriptors (e.g. Lee et al. 2006, Wagener and Wheater 2006), so then ungauged catchment model parameters can be estimated.

In theory, the regression method is flawed (McIntyre et al. 2005) and it has had limited success in producing accurate flow predictions over a wide range of catchments. Hence, a new method was developed, as presented below.

Data set and modelling tools

Flow and climate data for 273 gauged catchments were available (Fig. 1) representing a wide range of catchment types over Great Britain. Of these, 127 non-urban catchments with the best quality data, spanning over 20 years at a daily time-step, were selected for the modelling.

The modelling software used was the Rainfall-Runoff Modelling Toolkit (RRMT) developed at Imperial (Wagener et al. 2002). This includes a library of rainfall-runoff models, and model optimisation tools. The most applicable model structure was found to be the probability distributed model with two parallel linear reservoirs to represent routing processes (Lee et al. 2005).

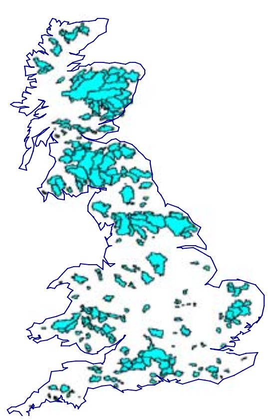

Fig. 1. Locations of 273 catchments

Method of regionalisation

The method consisted of: A) calibrating the model for each of the catchments using a 10-year data period and testing prediction performance on a seperate 10-year period, B) testing performance on the same periods using regionalised parameters rather than the locally calibrated parameter sets, C) comparison of the regionalised result (i.e. assuming catchment is ungauged) with the calibrated result (i.e. assuming it to be gauged) for each catchment.

The calibration was done using a standard method, uniform random sampling. The regionalisation was done using two methods – the standard regression method, and also a new 'similarity weighted averaging' (SWA) method.

$$E_{i,j} = \sqrt{\frac{1}{2}\left(\frac{\ln A_j - \ln A_i}{\sigma(\ln \mathbf{A})}\right)^2 + \left(\frac{\ln R_j - \ln R_i}{\sigma(\ln \mathbf{R})}\right)^2 + \left(\frac{B_j - B_i}{\sigma(\mathbf{B})}\right)^2} \quad \text{Eq. 1}$$

$$D_{i,j} = \sqrt{\left(NORTH_j - NORTH_i\right)^2 + \left(EAST_j - EAST_i\right)^2} \quad \text{Eq. 2}$$

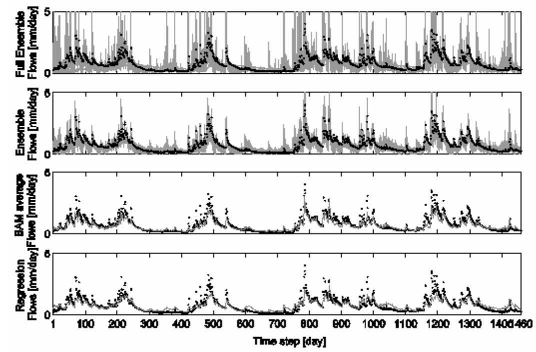

Fig. 2. SWA, ensemble and regression results on one test catchment

The new SWA method is a pooling group method. For each ungauged catchment, a pool of *S* similar gauged catchments are identified. For example Eq. 1 measures similarity between a gauged catchment *i* and an ungauged catchment *j*, based on differences in area (A), wetness (R) and base flow index estimated from soil type (B). **A**, **R** and **B** are the vectors of these descriptors over all catchments, and σ signifies standard deviation. Alternatively, Eq. 2 bases similarity on spatial proximity (N is northing coordinate and E is easting).

The calibrated models of the *S* pooled gauged catchments are each then individually applied to the climate inputs for the ungauged catchment to generate an ensemble of *S* flow time-series. The average of these series is taken as the best flow prediction, and the ensemble represents prediction uncertainty (Fig. 2). The method has been extended to include more than one parameter set from each pooled catchment, different similarity measures, and weighting of the pooled catchment models.

Results

Fig. 3. plots the performance of the calibrated model to observed data (x-axes), versus performance of the regionalised model, using our SWA method with Eq. 2 and *S*=10. A traditional performance statistic, NSE (plotted as 1-NSE), and a low-flow fit statistic, FSBM, are used. Results are shown seperately for permeable catchments (H) and less permeable catchments (L), and for designated calibration and test periods (cal and val). The more points lying below the diagonal lines, the better the SWA result.

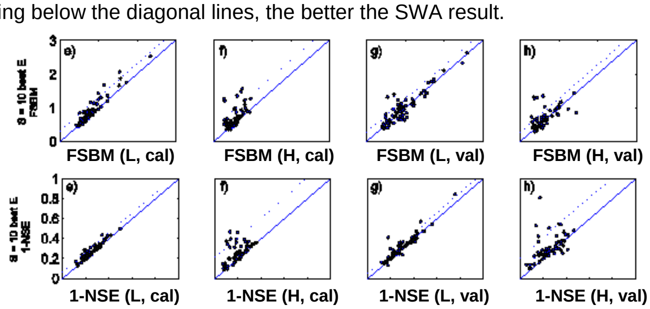

Fig. 3. Calibrated model performance vs. regionalised model performance

Results show that the SWA method works well especially in the more permeable catchment types (in 30% of cases it actually out-performs the calibrated model in the test period). When the same comparison is done between SWA results and those of the regression method (Lee et al. 2006), SWA is slightly better for NSE and much better for FSBM. Fig. 2 shows results for one example catchment. Using Eq. 2 produced poorer results.

Conclusions

A new method of predicting flows in ungauged catchments has been developed based on similarity weighted averaging and ensemble modelling. The method has proven to perform better than standard regression methods

Find out more…

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