National assessment of change in river flows

Author/Organisation

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What is the overall aim of the work?

The aim of the work is to estimate changes in river flow across the river network of Britain.

Which UKCP09 products were used?

We used the 11-member Regional Climate Model (RCM) data directly as input to a grid-based hydrological model, G2G (Bell *et al*. 2007). The 25 km gridded Regional Climate Model (RCM) output is available for each of the 11 ensemble members across the UK for the period 1960–2099 for the A1B (medium) emissions scenario.

Why were these outputs used?

Our hydrological model (G2G) is run on a 1 km resolution grid across the UK. For each 1 km grid-cell, runoff is generated from the G2G and routed along river-pathways to produce an estimate of river flow.

This application requires input driving climate data for a large area (the whole of the UK) in the form of spatially consistent hourly and/or daily time-series.

The requirement for hourly and/or daily time-series meant that the UKCP09 probabilistic climate projections were not suitable, since they provide information on changes in monthly, seasonal and annual conditions for 30 yr time periods as a whole.

The requirement for spatial consistency precludes the use of the UKCP09 weather generator to provide the driving rainfall and potential evaporation (PE), because although weather generator data are available for specific locations, they are not currently available as spatially-consistent data for large areas.

How were the outputs used?

We used 25 km RCM data (rainfall and potential evaporation (PE) variables) for a region covering the whole of the UK. Our requirement for PE from vegetation was not directly available from the RCM, so further calculation was required to convert four related RCM variables, including open water PE, into a good approximation of PE from vegetation.

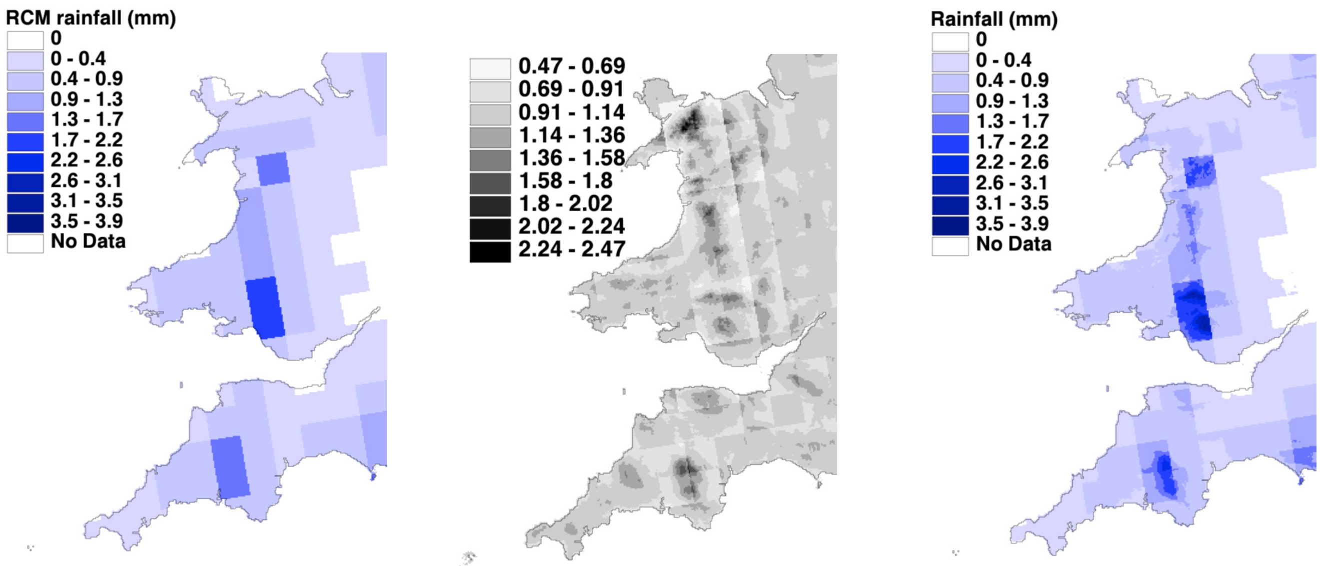
There are a number of different ways to calculate PE, but we used a method that emulates the Penman-Monteith equation for PE using the following RCM variables (where the number preceding the variable description is the internal Met Office identifier, also knows as the variable's STASH code):

03259	CANOPY CONDUCTANCE M/S
03313	SOIL MOISTURE AVAILABILITY FACTOR
03312	POTENTIAL EVAPORATION RATE KG/M2/S
03510	POTENTIAL EVAPOTRANSPIRATION FACTOR1

This method has the advantage of taking into account the likely effects of projected climate change (particularly carbon dioxide levels) on how much the vegetation leaf stomata open and close. An alternative method could use RCM variables for radiation, temperature, humidity and wind speed as input to the Penman-Monteith scheme and assume constant values for the resistance of the canopy to evaporation.

The RCM data (rainfall and PE) were used to drive the 1 km G2G Model, after down-scaling the rainfall from the 25 km resolution of the RCM to the 1 km resolution of the G2G (Figure 1). The down-scaling procedure adopted here uses high resolution information from a standard average annual rainfall (SAAR) dataset, which is typically calculated from observed rainfall on a 1 km grid (http://www.metoffice.gov.uk/climatechange/science/monitoring/ukcp09/)

Figure 1: An illustration of the use of SAAR rainfall weights to transform 25 km RCM output into 1 km rainfall fields.



For this case study, data were extracted for both baseline (1961–1990) and future (2070-2099; the 2080s) time periods for the A1B emissions scenario. Eleven ensemble members were available, which we used to produce 11 different estimates of river flow at locations across the UK for both time periods. An example is shown in the figure below which indicates that RCM-derived flow simulations have similar characteristics to observed flows at that location (although they would never be expected to match).

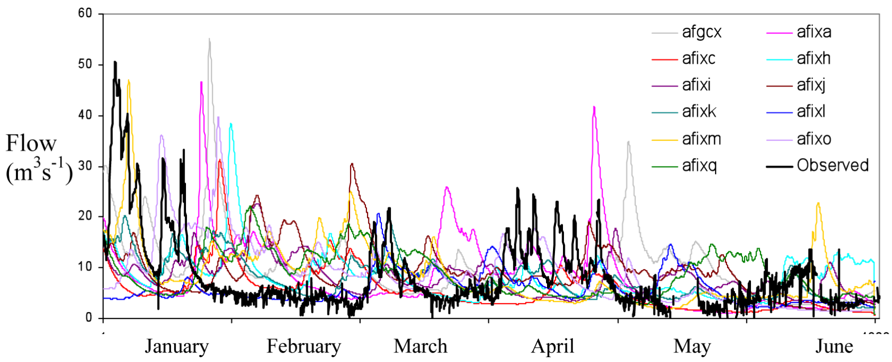


Figure 2: The 11 different estimates of river flow at a single location in the UK, based on different regional climate model outputs. The 5-letter acronyms refer to the different ensemble members. An example of observed river flow for the location is also shown.

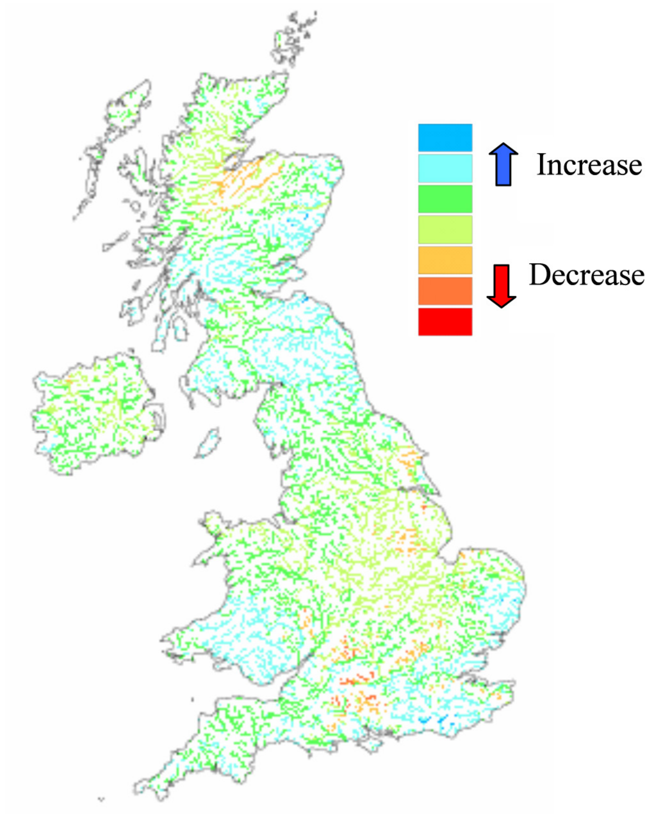


Figure 3: The change in peak river flows at the 2-year return period, between the baseline and the 2080s, for a single regional climate model ensemble member.

From these time series, statistics of changes in flow indices at all points of the resolved UK river network may be calculated. For example, the map in Figure 3, which shows estimated future change in average annual peak flow, illustrates the type of output we can produce using a single RCM ensemble member.

We get a different result (map) for each of the 11 ensemble members. The challenge is to combine all this information in a sensible way so we can estimate future changes in UK river flow with as much confidence as possible.

Describe any difficulties or limitations associated with using probabilistic information such as UKCP09

- A limitation of the 11-member RCM output is the extent to which they (and A limitation of the 11-member RCM output is the extent to which they (and the 11 sets of results produced) explore uncertainties in the modelling process. The spread of results provided by the 11 regional climate models does provide some quantification of the uncertainty associated with the Hadley Centre climate model. However, unlike the UKCP09 probabilistic climate projections, the 11-member RCM output does not incorporate the results of other global climate models or include any consideration of relative likelihood or probabilities of certain outcomes.

- Furthermore, 11-member RCM output is only available for a single emissions scenario (A1B; UKCP09 medium) meaning that the effects of emissions uncertainty is not addressed.

- The main difficulty encountered was the sheer volume of data. Sixty years-worth of hourly data required 3.6 Gbyte of storage for one variable for each ensemble member. Thus our data storage requirement was approximately 200 Gbyte just for the input data for our models.

- Another issue was that the data are stored in a specific Met Office binary format which can be read using Met Office software routines. Some knowledge of this software is essential which means this process can seem complicated at first but runs like clockwork once you get it all sorted out. Either this or another binary data format will be used for the RCM data when they are made available at BADC.

- It is also important to note that the climate models assume a year contains 360 days (12 months of 30 days). The viewing program xconv (http://badc.nerc.ac.uk/help/software/xconv/) is a quick and easy way of looking at the data-files.

Describe the lessons learned regarding the use of UKCP09 information

The main learning curve has related to the use of an ensemble of RCMs, giving us a set of 11 possible future changes in river flows. In our previous work (Bell *et al*. 2007) we had just one set of results to analyse which provided an indication of how river flows may change under a plausible future climate. Here, additional expertise will be required to enable us to judge the relative merits of the projected changes from the 11 regional climate models in order to provide some guidance on the likelihood of the resulting projected changes in river flows.

How would you communicate the results to your target audience?

Our target audience consists of customers such as Defra and the Environment Agency for whom we communicate results through reports and publications in refereed scientific journals.

Combining all the river flow results from 11 RCMs has provided us with a challenge which we are still working on. At present there is little guidance about which of the 11 regional climate models are most reliable. Instead, we are currently illustrating the full range of regional climate model output (e.g. Figure 2), and then presenting the mean of all the RCM-derived river flow results alongside the full range of results. The next step, which is work in progress, is to put the regional climate model changes in the context of the full IPCC AR4 likely range of changes allowing us either to draw firmer conclusions or indicate where more detailed research is required.

Links to sources of more information

UKCIP09 RCM data are available from the LINK website maintained by BADC (British Atmospheric Data Centre)

Tools for manipulating the data are also available from BADC: http://badc.nerc.ac.uk/help/software/xconv/

Reference

Bell, V.A., Kay, A.L., Jones, R.G., Moore, R.J. (2007) Use of a grid-based hydrological model and regional climate model outputs to assess changing flood risk. *Int. J. Climatol.*, **27**, 1657-1671. doi:10.1002/joc.1539.

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