CRANIUM
Climate change Risk Assessment: New Impact and Uncertainty Methods

Working with probabilistic climate change scenarios – the challenges for the users and developers

Briefing note and key questions

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An introduction to climate scenario uncertainties

Uncertainties in climate scenarios are related to:

- The forcing emissions scenarios, i.e., inter-scenario variability
- The response of different climate models, i.e., inter-model variability
- Different realizations of a given forcing scenario with a given climate model, i.e., internal or intra-model variability (which is, in part, a reflection of natural climate variability)
- Sub-grid-scale forcings and processes, i.e., uncertainties due to downscaling method (applicable whether dynamical and/or statistical methods are used).

These sources of uncertainty were recognised a number of years ago and are sometimes referred to as the cascade or explosion of uncertainty. Techniques for handling them have also been identified and recommended. Inter-scenario variability, for example, can be represented by using multiple emissions scenarios and the pattern scaling technique. Intra-model variability can be explored using intra-model ensembles, in which the same model is run a number of times, with a different starting point or parameter values each time.

Despite the recognition of these uncertainties and ways of representing them, in practice these techniques have not been widely or comprehensively used, particularly with respect to regional climate scenarios. The UKCIP02 scenarios, for example, are based on four emissions scenarios and a single suite of climate models, hence they only reflect a small part of the uncertainty range.

The growing availability of large climate model ensembles permits a more comprehensive approach to the assessment of uncertainty. The size of these ensembles reflects the complexity and computing time required to run the different types of climate model. Multi-model ensembles encompassing dozens of regional climate model runs were performed during the European Union-funded PRUDENCE project (http://prudence.dmi.dk/), for example. Larger ensembles are possible for coarser scale global climate models - encompassing hundred of runs in the case of the Hadley Centre ‘perturbed physics’ QUMP (Quantifying Uncertainties in Model Predictions) simulations, and thousands of runs in the case of the climateprediction.net initiative (http://www.climateprediction.net/).

These large ensembles permit the construction of probabilistic climate scenarios, which are now acknowledged by the climate modelling and scenario community as the way forward. The UKCIPnext scenarios will, for example, be probabilistic. This approach is also being pursued in the European Union-funded ENSEMBLES project (http://www.ensembles-eu.org/).

This briefing note concludes with an example of probabilistic scenarios of extreme weather events for a single UK location, constructed as part of the BKCC CRANIUM project.

Exploring inter-model uncertainties in scenarios of UK weather extremes using a daily weather generator – an example from CRANIUM

In this example, constructed by the UEA team as part of the CRANIUM project, inter-model scenario uncertainties are explored using output from 10 different European regional climate models (RCMs). The RCM runs were undertaken as part of the PRUDENCE project. Most of the RCMs were forced by the Hadley Centre global climate model (the model used in UKCIP02), but three of the RCMs were also forced by a different global model – giving a total of 13 RCM runs, all for the IPCC SRES A2 emissions scenario (equivalent to the UKCIP02 medium high scenario). Changes in mean temperature and precipitation, together with changes in their variability, were taken from each RCM run for the grid square nearest to each UK location of interest, and used to perturb the parameters of the CRU weather generator developed for the BETWIXT project (see BETWIXT Technical Briefing Notes 1 and 4). For each of the 13 RCM runs, the weather generator was run 100 times. Seasonal indices of extremes (as used in BETWIXT) were then constructed from the daily time series.

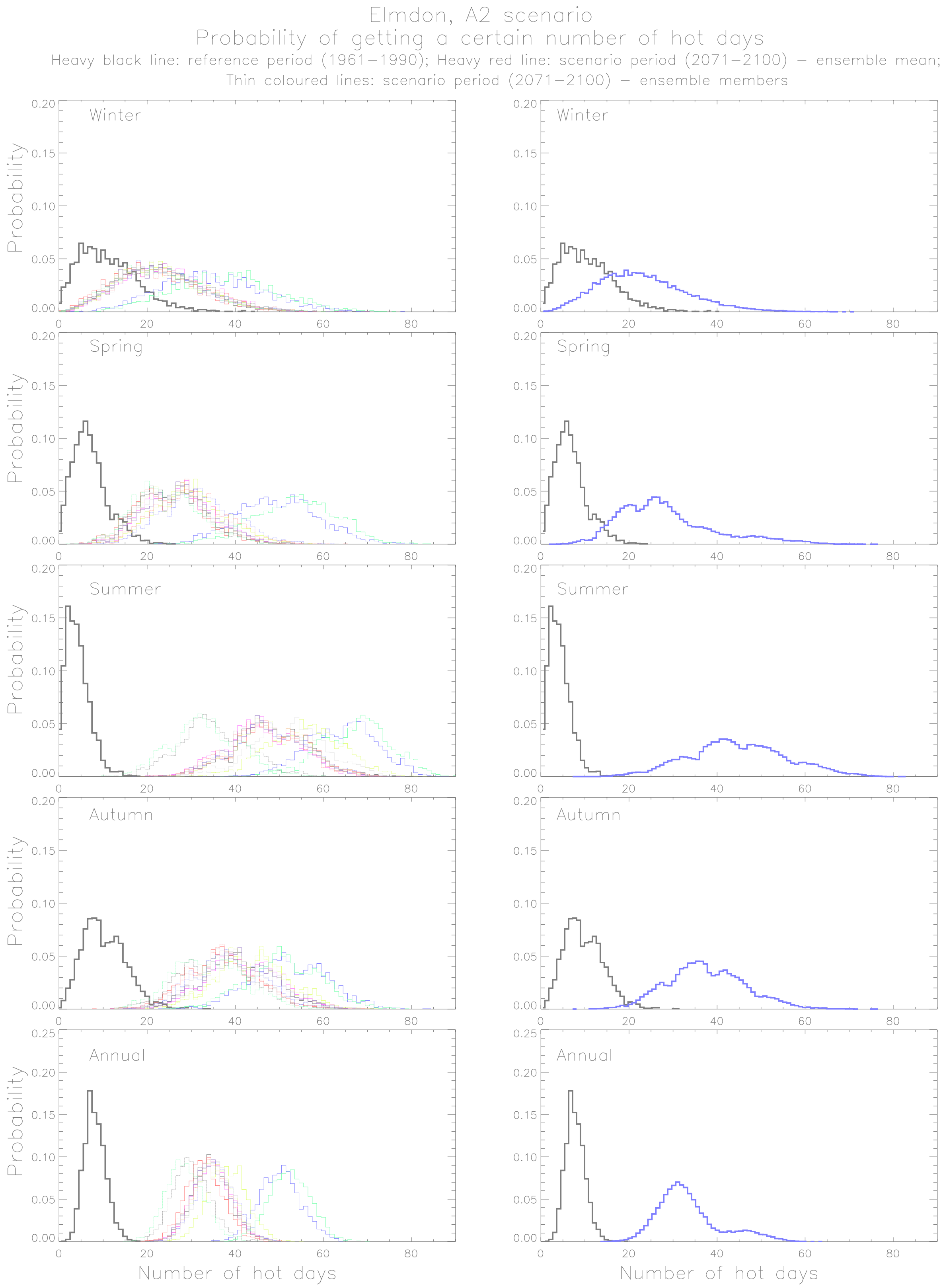
The results are plotted as probability distribution functions (PDFs), with the number or magnitude of extreme events on the horizontal axis and the probability of the event occurring in any one season on the vertical axis. Each individual PDF is constructed using 3000 values (i.e., 30 years x 100 weather generator runs).

The example shows the probability of getting a certain number of hot days (defined as Tmax > 90^{th} percentile) for Elmdon (Birmingham). The heavy black line in both left- and right-hand panels shows the weather generator results based on observations for the reference period 1961-1990. In the left-hand panel, each of the 13 coloured lines represents weather generator results for the 2080s based on a different RCM run. In the right-hand panel, the blue line shows the ensemble average, i.e., the average of the 13 coloured lines.

For all RCM runs, the PDF shifts to the right – indicating an increased probability of more frequent hot days in the 2080s for the A2 emissions scenario. This shift to the right is greater in summer than other seasons. The left-hand panel indicates the spread across results based on individual RCM runs. Two RCM runs give larger changes than the others – these are forced with two different global climate models to the others. This indicates the importance of considering inter-model uncertainty in the forcing model as well as the downscaling model.

As well as being shifted to the right, the future PDFs are broader, indicating the range of uncertainty in the projections. If we just consider the mode or centre point of the distribution, however, the ensemble average indicates a change in summer (middle right-hand PDF) from around 5 hot days (i.e., days with Tmax > 24.3°C in this case) in the reference period to about 40 days in the 2080s. This represents a major increase in the risk of occurrence of hot days. For comparison, the results for Elmdon produced as part of the BETWIXT project (based on the Hadley Centre RCM – a slightly different version of which is used here), indicate an average of 45.6 summer hot days.

A journal paper describing this work is in preparation. Probabilistic scenarios have been constructed for all 10 stations used in the BETWIXT project. Figures for other extreme events and stations will be made available from the CRANIUM web site shortly.


Elmdon, A2 scenario
Probability of getting a certain number of hot days
Heavy black line: reference period (1961–1990); Heavy red line: scenario period (2071–2100) – ensemble mean;
Thin coloured lines: scenario period (2071–2100) – ensemble members
Winter
Spring
Summer
Autumn
Annual
Probability
Number of hot days

Further reading

Dessai, S. and Hulme, M., 2004: Does climate adaptation policy need probabilities? *Climate Policy*, **4**, 107-128.

Ekström, M., Hingray, B., Mezghani, A. and Jones, P.D., 2005: Regional climate model data used within the SWURVE project 2: addressing uncertainty in regional climate model data for five European case study areas, *Hydrology and Earth Systems Science*, accepted for publication.

Giorgi, F. and Mearns, L.O., 2003: Probability of regional climate change based on the Reality Ensemble Averaging (REA) method, *Geophysical Research Letters*, **30**, doi:10.1029/2003GL017131.

Jenkins, G. and Lowe, J., 2003: *Handling uncertainties in the UKCIP02 scenarios of climate change*, Hadley Centre technical note 44: http://www.met-office.gov.uk/research/hadleycentre/pubs/HCTN/HCTN_44.pdf

Murphy, J.M., Sexton, D.M.H., Barnett, D.N., Jones, G.S., Webb, M.J. and Collins, M., 2004: Quantification of modelling uncertainties in a large ensemble of climate change simulations, *Nature*, **430**, 768-772.

Qunying, L., Jones, R.N., Williams, M., Bryan, B. and Bellotti, W., 2005: Probabilistic distributions of regional climate change and their application in risk analysis of wheat production, *Climate Research*, **29**, 41-52.

Räisänen, J. and Palmer, T.N., 2001: A probability and decision-model analysis of a multimodel ensemble of climate change simulations, *Journal of Climate*, **14**, 3212-3226.

Rowell, D.P., 2004: *An initial estimate of the uncertainty in UK predicted climate change resulting from RCM formulation*, Hadley Centre technical note 49: http://www.met-office.gov.uk/research/hadleycentre/pubs/HCTN/HCTN_49.pdf

Wigley, T.M.L. and Raper, S.C.B., 2001: Interpretation of high projections for global mean warming, *Science*, **293**, 451-454.

Wilby, R.L. and Harris, I., 2005: A framework for assessing uncertainties in climate change impacts: low flow scenarios for the River Thames, UK, *Water Resources Research*, submitted.

Web sites

BETWIXT: http://www.cru.uea.ac.uk/cru/projects/betwixt/
CRANIUM: http://www.ncl.ac.uk/cranium/
PRUDENCE: http://prudence.dmi.dk/
ENSEMBLES: http://www.ensembles-eu.org/

Key Questions

Probabilistic scenarios are the best way of making use of new information emerging from climate modelling. Dealing with probabilistic climate projections will, however, involve more work, with a steep learning curve for both developers and users. The following key questions have emerged from preliminary discussions with CRANIUM researchers and stakeholders:

1. What uncertainties should be represented in climate scenarios for impacts assessments?
   - what uncertainties can we reasonably expect to be represented in climate scenarios for impacts assessments?
     - and what underlying assumptions will still have to be made?
     - what guidance can we provide to help users take account of uncertainty?
     - how explicit do we need to be about the nature of the various uncertainties and how they are (or are not represented)?
     - will emissions scenario uncertainty have to be handled separately (i.e., each set of probabilistic scenarios will be conditional on a particular emissions scenario)?

2. Are probability distribution functions (PDFs) the most appropriate way of representing the uncertainties? What are the alternatives (e.g., probability bounds, two- or three-dimensional response surfaces)? What if users want maps?

3. Are industry approaches to climate variability sufficiently advanced to cope with new probabilistic information on climate change? Are there any examples of industry using (or preparing to use) probabilistic information on climate change?

4. How might industry make use of new probabilistic information:
   - what are the advantages and disadvantages, compared with non-probabilistic scenarios?
   - how important is synthetic time-series data?
   - can climate change impacts be described in probabilistic terms?
   - how does this information fit with current decision-making processes (and attitudes to risk) and what changes to these processes will be needed?
   - how will users access the information? How can it be presented most usefully to different audiences – eg., for impacts users, for decision-makers, for less technical users?
   - what communications/visualisation challenges and opportunities will all this bring?

The views of the broader BKCC researcher and stakeholder community on these key questions are sought. They will be discussed at the IF and ShF meetings on 17 and 21 November respectively. It is anticipated, however, that participants will want more time to reflect on these issues. Thus comments on and responses to these key questions are requested by ***16 January 2006****. They should be sent to Clare Goodess (c.goodess@uea.ac.uk; Climatic Research Unit, School of Environmental Sciences, UEA, Norwich, NR4 7TJ).*