Selecting members of the 'QUMP' perturbed-physics ensemble for use with PRECIS

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Isn't one model enough…?

Downscaling a single GCM projection can provide us with some information about what type and magnitude of changes we might expect under a given emissions scenario for our region of interest, but it does not provide us with much information about how confident we should be in that projection. Exploring the range or spread of projections from different GCMs enables us to gain a better understanding of the uncertainties in climate change scenarios that arise from differences in model formulation. The Met Office Hadley centre is now able to provide boundary data from our 17-member perturbed-physics ensemble (HadCM3Q0-Q16, known as 'QUMP') for use with PRECIS in order to allow users to generate an ensemble of high-resolution regional simulations. Running 17 PRECIS experiments may be beyond the computing capacity of many institutions, in which case users might select a smaller sub-set from the 17. The sub-selection must be undertaken carefully because it is import to avoid biasing the resulting climate scenarios towards outcomes not consistent with the full range of evidence from the QUMP ensemble and other available multi-model ensembles. This document provides some advice on how this might be done.

What is a 'perturbed physics' ensemble?

Perturbed physics ensembles (PPE) can be designed by varying uncertain parameters in the model's representation of important physical and dynamical processes. The ensemble can then be used to capture some major sources of modelling uncertainty by running each member using identical climate forcings. This provides an alternative to using GCMs developed at different modelling centres around the world (a multi-model ensemble, MME), like those in the CMIP3 (Coupled Model Intercomparison Project 3) ensemble that was widely used in the IPCC Assessment Report 4.

The Hadley Centre's PPE includes 17 members which are formulated to systematically sample parameter uncertainties under the A1B emissions scenario – this is referred to as the QUMP (Quantifying Uncertainties in Model Projections) ensemble. The QUMP ensemble was designed for use in the UK's own climate projections and is described in detail in the UKCP report available online at
http://ukclimateprojections.defra.gov.uk/content/view/944/500/.

Globally, and for many regions and variables, the range of climate futures projected by the QUMP PPE is equivalent or greater than those based on the CMIP3 MME. Although a PPE cannot sample the so-called 'structural' uncertainties that occur due to different choices in model formulation between different modelling centres, the PPE approach allows us more control over the experimental design of the ensemble. This means that we can systematically sample the parameter uncertainties, exploring a wider range of possible variation in the formulation of a single model, which potentially leads to a wider range of physically plausible future climate outcomes than the MME. However, this is not always the case when we look at the future climate outcomes in a specific region; it is important to remember that neither a MME or a PPE accounts for all of the sources of model uncertainty. For this reason, we recommend that modelling results with the QUMP PPE are interpreted with reference to a range of results from the IPCC CMIP3 ensemble – this will enable you to assess whether there are physically plausible climate outcomes for your region that the QUMP PPE may not be able to simulate. Equally, this may also highlight future outcomes that the CMIP3 MME may not have indicated.

Sub-selecting QUMP members for use with PRECIS

Global monthly fields from control and future simulations from each of the 17 GCMs will be downloadable from the British Atmospheric Data Centre (BADC) at: *http://badc.nerc.ac.uk/browse/badc/hadcm3/data/PRECIS/ (NB: you will need to register with BADC and request access to this dataset).* PRECIS users who are considering using PRECIS with the QUMP ensemble should use this dataset to assess the QUMP GCMs for:

a) their performance in simulating the climate of the present day, to ensure that you select models which represent the climate of the region of interest realistically, and
b) the range or spread of future outcomes, in order to ensure that you select models which sample the full range of outcomes simulated by the 17 members.

Note also that every sub-set from the QUMP ensemble should include HadCM3Q0 – this the standard, unperturbed model which uses the original parameter settings as applied in the atmospheric component of HadCM3, itself a member of the CMIP3 ensemble.

We illustrate below some analyses that we at the Hadley Centre have undertaken in order to select QUMP members for use in PRECIS simulations in Vietnam based on these criteria. This may provide you with some ideas about how to proceed with a similar selection process for your region.

We ask PRECIS users to provide an explanation of the QUMP member selection when requesting boundary data from those models. We will provide those boundary data if we are confident that the selection has been made with appropriate consideration of the above criteria. Alternatively, we are happy to collaborate on this model selection if resources allow.

An example of QUMP sub-set selection for Vietnam

The selection of a sub-set of the 17 available QUMP members for Vietnam was done by examining simulations from each of the GCMs against the following criteria:

(a) Performance in simulating key aspects of the regional climate in baseline simulations for the period 1961-1990, when compared with observational datasets. Specifically, we are interested in the behaviour of the Asian summer monsoon as the major driver of the timing, magnitude and variability of wet-season rainfall and its extremes;

(b) Regional projections. Simulations of climate for the period 2070-2100 were examined to look at the range of magnitudes and patterns of response in south-east Asia to forcing from the A1B emission scenario. Specifically, we were interested in the magnitude of temperature changes, the magnitude and direction of rainfall changes, and changes in the timing or magnitude of the Asian Summer monsoon.

This analysis indicated that:

1) All the members gave a good representation of the key characteristics of the region's climate. An example of this is shown in figure 1, in which we can see that all the QUMP members represent the timing and onset of the summer monsoon reliably. Although the intensity of the monsoon circulation can be a little too high in the models, the good representation of the characteristics such as timing and geographical location of key features can give us confidence in their simulations of the future.

   We did not find enough difference between the realism of the models, in this region, to distinguish any models as 'poor' and eliminate them from our selection for use with PRECIS.

2) 4 perturbed members listed below, plus the standard Q0 model, represented a good range of future climate outcomes. The 4 members were selected to span a range of sensitivities (figure 2), characteristics of rainfall response (figures 3 and 4) and monsoon response (figure 4).

   The recommended model members for Vietnam were:
   - Q0 – The standard (unperturbed) model
   - Q3 – A low sensitivity model
   - Q13 – A high sensitivity model

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Q10 – A model which simulates rainfall decreases in the future in Vietnam (Fig 2)
Q11 – A model which simulates rainfall increases in the future in Vietnam (Fig 2)

Q10 and Q13 also represent two different spatial patterns of rainfall change (Fig 3), and different characteristics of monsoon response (Fig 4).

3) Comparison of the range of physically plausible outcomes simulated by the QUMP PPE with those simulated by the CMIP3 MME demonstrated some differences between the two ensembles. While both ensembles consistently indicate increases in wet season (JJAS) rainfall over the whole region, consistent with an increase in monsoon intensity, in DJF the QUMP models generally project a decrease whilst all the CMIP3 models indicate increases. This leads to a difference in the consensus achieved between the two ensembles in total annual rainfall change.

This highlights some important points for consideration when using ensemble results:

- Ensemble consensus does not necessarily imply confidence: we should only place confidence in those aspects of simulated future climate in which we are confident that we have a good understanding of the mechanisms that drive that change. We have some confidence that the model consensus in wet-season rainfall increases under a warmer climate because these changes are driven by changes in the Asian Summer monsoon, which we can model realistically. The drivers of the changes in DJF rainfall are less clear, and the apparent, but opposing, consensus achieved by each of the ensembles is mis-leading.

- It is important to interpret the range of outcomes indicated by the QUMP ensemble in the context of the range of outcomes indicated by the CMIP3 MME. This comparison can highlight plausible future outcomes not accounted for by the QUMP ensemble. Equally, the QUMP ensemble can indicate plausible outcomes that are not accounted for by the CMIP3 models. An overview of the projections of the IPCC CMIP3 ensemble, on a region by region basis can be found in Chapter 11 of the WG I IPCC fourth assessment report.

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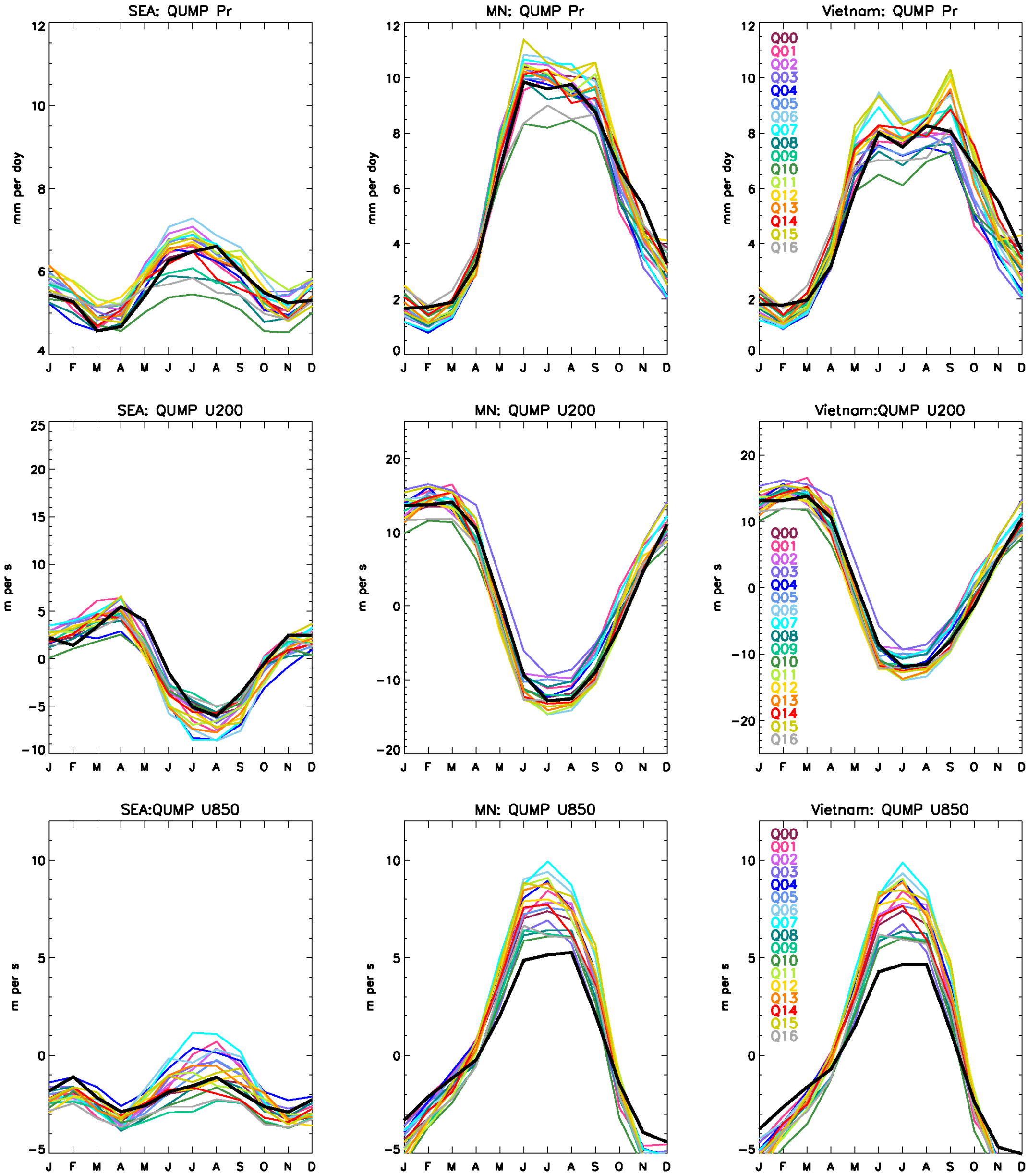

Figure 1: The Asian summer monsoon represented by the annual cycle of precipitation, U200 and U850 winds as a spatial average over each of the three regions (south-east asia, SEA, Monsoon region MN and Vietnam, VN) for observations from CMAP and ERA40 (Black) and the 17-member QUMP perturbed physics ensemble (colours).

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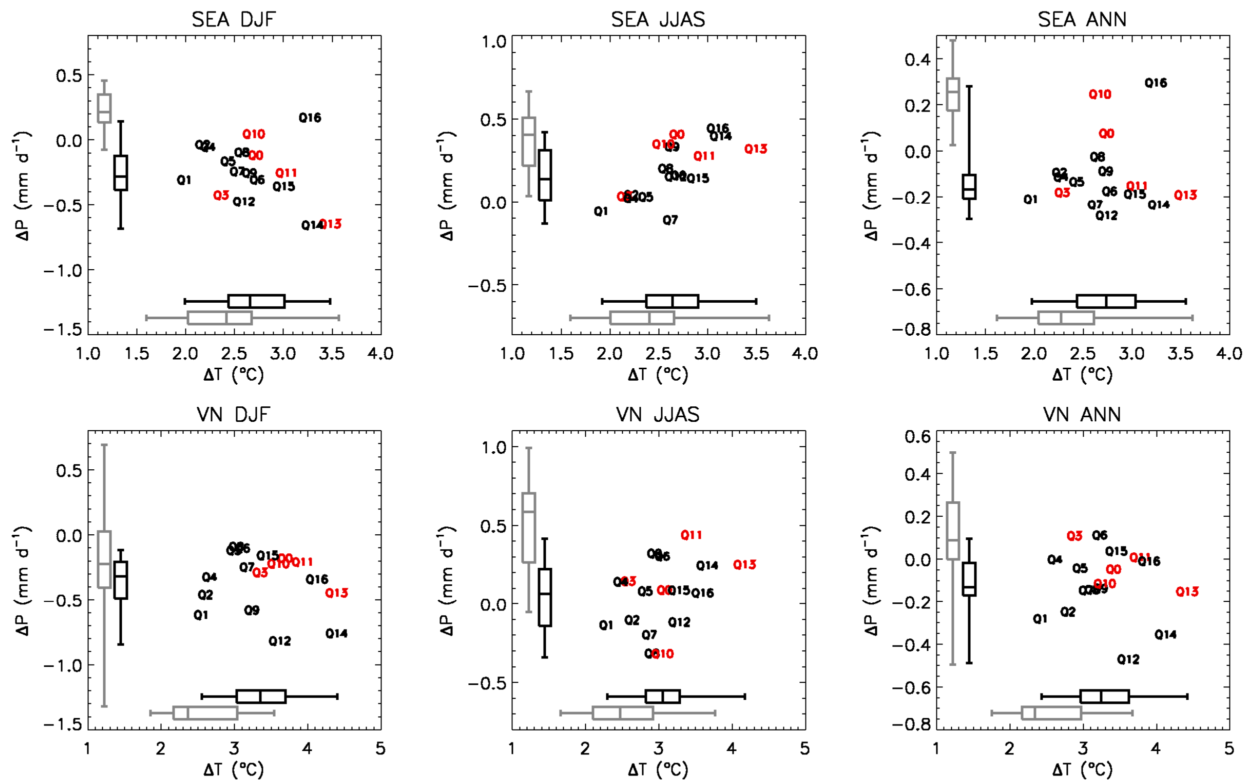

Figure 2: Magnitude of changes in average temperature (ΔT), and the average change in precipitation amount (ΔP) by the 2080s with respect to 1961-90 under SRES scenario A1B as indicated by the 17 members of the QUMP PPE (Q0-16) and the range of members of the CMIP3 multi-model ensemble shown also in grey for comparison. The selected 5 QUMP members are shown in red. Top figures show results averaged over south-east Asia (SEA), and bottom figures for a smaller area over Vietnam (VN).

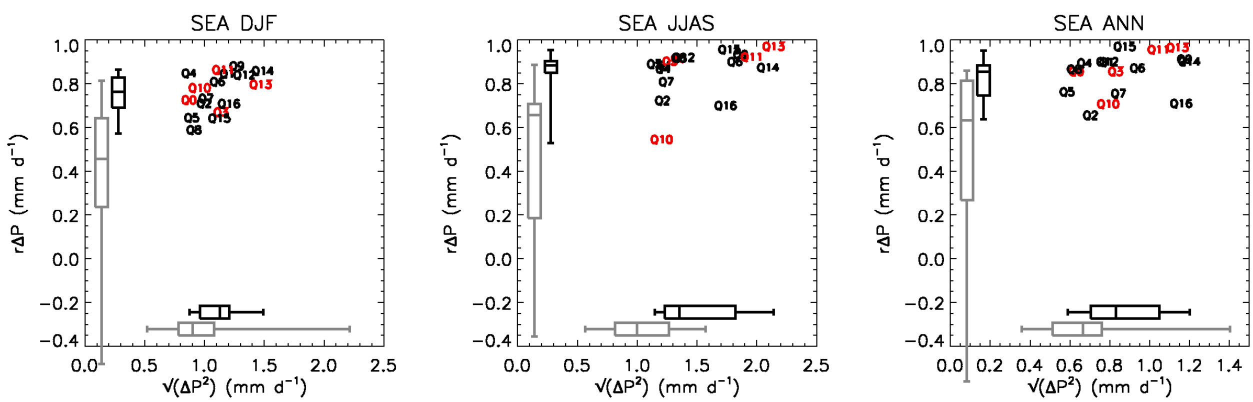

Figure 3: Spatial characteristics of changes in precipitation (rΔP is the spatial correlation of the changes in each model with those of the ensemble mean in order to identify 'typical' and 'atypical' patterns of change in the ensemble) by the 2080s with respect to 1961-90 under SRES scenario A1B as indicated by the 17 members of the QUMP PPE (Q0-16) and range from the members of the IPCC's CMIP3 MME in grey.

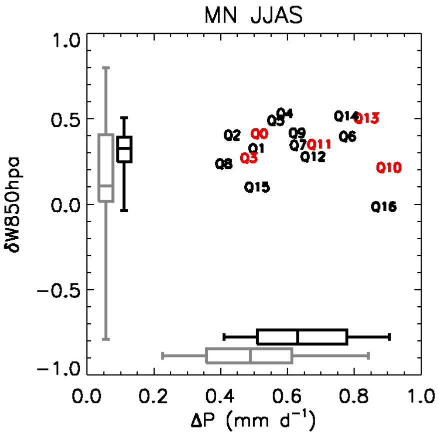

Figure 4: Changes in 850hpa wind speed mean daily rainfall in Monsoon region by the 2080s with respect to 1961-90 under SRES scenario A1B as indicated by the 17 members of the QUMP PPE (Q0-16) and the range of members of the IPPC CMIP3 multi-model ensemble shown also in grey for comparison). The selected 5 QUMP members are shown in red.

Useful References

Murphy, J. et al (2009). UKCP09: Climate Change Projections. http://ukclimateprojections.defra.gov.uk/content/view/824/500/

Christensen, HJ et al (2007). Regional Climate Projections. In: Climate Change: the Physical Science Basis: Report of Working group I to the Intergovernmental panel on Climate Change. Cambridge University Press, Cambridge, UK.

McSweeney et al, (In preparation). Selecting a sub-set of perturbed physics ensemble members for downscaling experiments with PRECIS in south-east Asia

Acknowledgements

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