Reducing the Uncertainty in AR4 Rainfall Projections for the Murray-Darling Basin Australia with applications to runoff estimation

Elise chandler

School of Earth Sciences, The University of Melbourne, Carlton, VIC 3010, Australia

Projections of the regional distribution of rainfall patterns are characterised by a high level of uncertainty and this is often magnified when the information is used to drive impacts models, for example, hydrological models. This uncertainty in rainfall projections will not necessarily decrease with the availability of new model results. Instead, increasing complexity in models as well as additional feedback processes may amplify model responses and therefore potentially widen the range of sample results in the future. Thus synthesizing currently available model results is a useful way to extract better information and narrow the uncertainty for regional projections.

Since the regional simulations from the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4) Global Climate Models (GCM) (CMIP3 multi-model database[1]) can vary substantially it is important to identify which models are likely to be more reliable. The approach which has been followed in this study to assess the modelled rainfall regime for the Australian region is proposed by Dessai *et* al. (2005). Given that the simulation of the current climate is important to the performance of future climate simulations, models which best reproduce features of the current climate are more likely to provide the best climate change simulations. Whetton *et al.* (2007) has also demonstrated that any clustering of projections amongst model results can be interpreted as evidence of less uncertainty or robustness.

The inequality amongst AR4 models in simulating key climate variables over the Australian continent has been assessed in various studies. Suppiah *et al.* (2007) and Watterson (2008) assessed AR4 models using seasonal averages, weighting models based on their skill in simulating the overall Australian climate. However this process leads to a relatively small range of weights, varying by a factor of approximately 2.3 (Watterson (2008)), and therefore having little impact on the resultant projections. Perkins *et al*. (2007) assessed models based on their ability to simulate daily variables and Maximo *et al.* (2007) assessed some of the AR4 models over the Murray Darling Basin (Figure 1) of south east Australia. Due to the poor performance of some models it makes little sense to include their results in regional climate change projections for the Murray-Darling Basin. Therefore the approach of this study is to exclude poor performing models rather than weighting them, developing improved projections of rainfall using a subset of model results from the A1B emission scenario. To be included each model must fulfil performance thresholds that include features of the current Australian rainfall regime; such as long-term averages at the grid point scale, spatial patterns over the Australian continent, the observed annual rainfall cycle (based on average monthly values) and interannual variability represented by ENSO in regions where this is important.

[1] www-pcmdi.llnl.gov/ipcc/about_ipcc.php

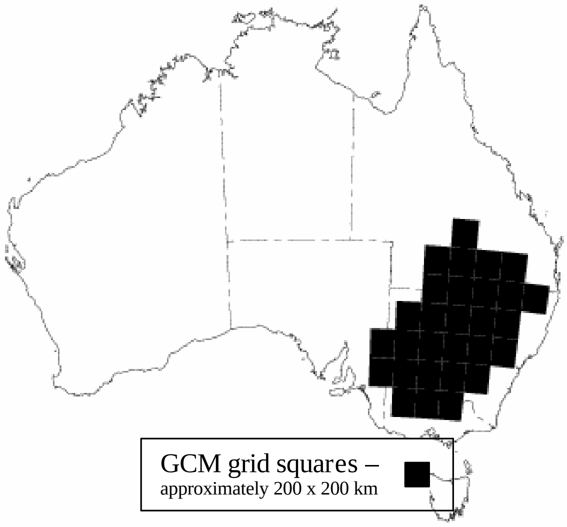

Figure 1. The area covered by the climate models for the Murray-Darling basin.

When these performance thresholds are applied to the Murray-Darling Basin, it is possible to demonstrate a clustering of results from the better performing models (Figure 2). These models indicate that rainfall changes expected as a result of anthropogenic warming to the end of this century are more likely to be at the drier end of the full set of model results under the A1B scenario. This occurs because the subset of better performing models indicate decreases in winter and spring rainfall that are significantly different to the changes indicated by the other models (Figure 3), and most importantly, this finding is not an artefact of a smaller sample size but represents a degree of consistency amongst the selected models (there is a 90% probability that the means from the two groups are significantly different according to Student's t-test). If a normal distribution is then fitted to the results (Figure 4), the subset of five models also indicate that there is only a small likelihood of there being an increase in annual rainfall within the Murray-Darling Basin as a response to increasing greenhouse gases for the A1B emission scenario, differing from the uncertainty apparent in the full set of AR4 results.

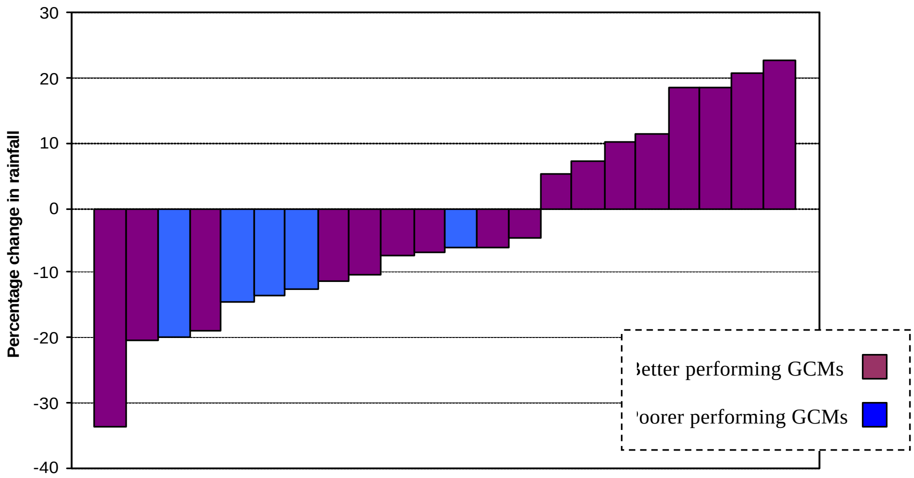

Figure 2. Predicted changes in rainfall by the models considered in this study.

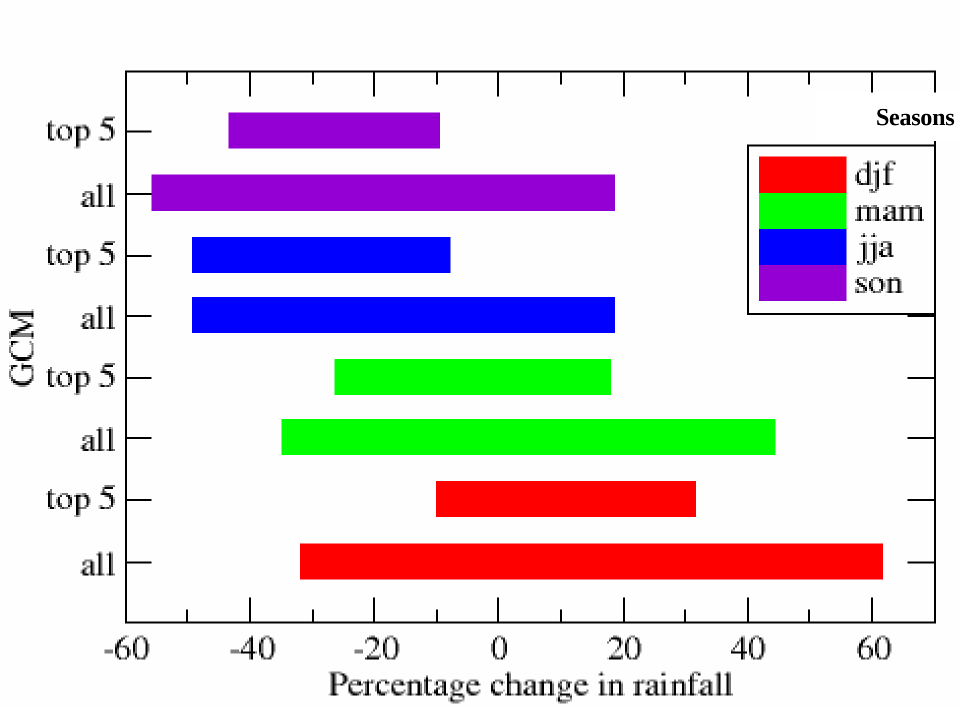

Figure 3. Differences in predicted rainfall changes by season: comparison of the best-performing models with all models.

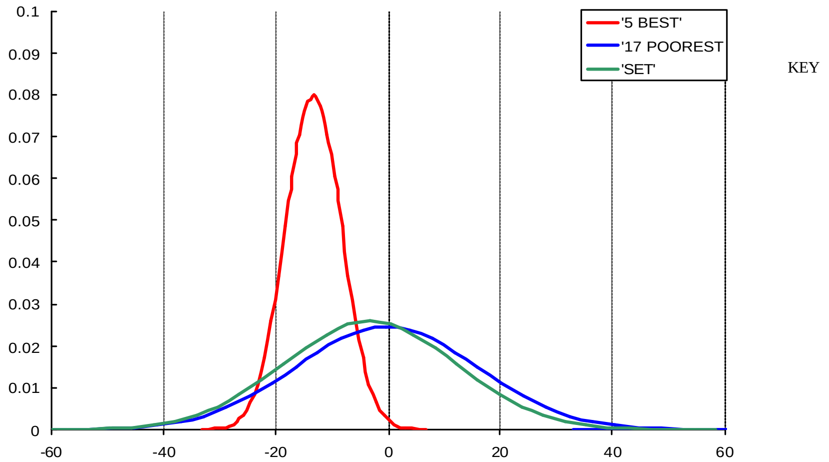

Figure 4. Distribution of predictions by the five best models compared to the rest.

A linear pattern scaling approach is then applied to decouple the regional change from the emission scenario underlying the global warming. Meehl *et* al. (2007) found this particularly useful later in the 21st century where regional climate changes can be regressed against the global warming average for the 21st century, where the slope of the regression equation gives the mean regional change per degree of warming. The results of pattern scaling for the MIROC3.2(hires) model simulations are shown in Figure 5. The projected percentage change in rainfall for the Murray-Darling Basin for each degree of warming is shown, including evidence of a distinct drying pattern which is most severe in the northern parts of the basin. Interestingly no part of the Murray-Darling Basin is likely to receive an increase in average precipitation by the end of the 21st century in this model.

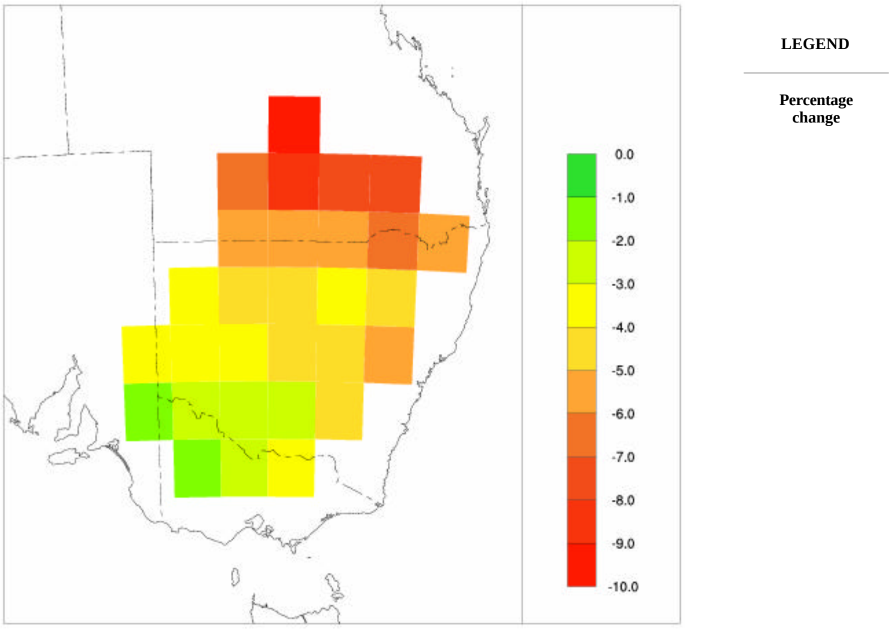

Figure 5. Rainfall change predicted by the MIROC3.2(hires) model over the study area by the end of the 21st century.

The results presented here indicate that dismissing some model results based on performance in simulating 20th century rainfall can significantly alter current projections and in the case of the Murray-Darling Basin more clearly define a negative direction of rainfall change. The simulated changes for annual rainfall over the Murray-Darling Basin from the subset of better performing models is statistically different from the remaining models and thus this approach towards model performance may be useful for rainfall projections in other regions especially where there is a large uncertainty.

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