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How representative is the spread of climate projections from the 5 CMIP5 GCMs used in ISI-MIP?

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ABSTRACT

In many studies that use data from Coupled Model Inter-comparisons Project Five (CMIP5) the large number of models included prohibits the use of data from all models. Studies based on small subsets of CMIP5 may therefore exclude a significant fraction of the plausible range of future climate changes. In the Inter-sectoral Impact Model Inter-comparison Project (ISI-MIP), a subset of five CMIP5 models is used in global climate impact studies. We find that the fraction of the full range of future projections captured across different regions and seasons by the ISI-MIP subset varies from 0.5 to 0.9 for temperature (median 0.75) and 0.3 to 0.8 for precipitation (median 0.55). The implication of this is that for many regions and seasons, this subset can be expected to underestimate both the total uncertainty in future climate impact, and the proportion of total uncertainty that is attributable to the use of different GCMs. The fraction of climate model uncertainty sampled could be improved only marginally by using a strategically selected global optimal subset of 5. In order to capture > 0.8 (0.9) of the range in >75% or more of regions and seasons, at least 13 (20) models would be required. However, the use of regionally optimised subsets could significantly improve the range of regional precipitation changes captured by a subset of restricted size. The results of impact studies based on subsets of CMIP5 could be presented alongside information about how well the subset captures uncertainties in future climate to aid interpretation of impact uncertainty ranges.

Practical implications

The degree of usefulness of information about future climate from climate model projections often depends heavily on the accessibility and robustness of accompanying information about uncertainty. The spread in model projections from different climate models for a given region represents a significant component of future climate uncertainty. This uncertainty is typically represented by the range of climate futures indicated by the CMIP5 ensemble of projections from around 36 GCMs based on a common scenario (RCP8.5) and experimental set up.

In impacts studies and downscaling activities where downstream modelling activities are involved, incorporating the uncertainty information from the CMIP5 ensemble is challenging due to the size of the ensemble and the resources required for each impact model run. The Inter-Sectoral Impact Model Inter-comparison Project (ISI-MIP) approached this issue by using a subset of 5 CMIP5 models to represent GCM uncertainty in order to achieve a feasible experimental set up. In thestudy we assessed how well the 5 models used represented the full CMIP5 ensemble range for the major land regions of the world, and considered the implications of this for (1) the interpretation of results from ISI-MIP and other studies based on subsets of CMIP5, and (2) the design of future impact studies which hope to sample climate model uncertainty with a subset of CMIP5.

The results shown here from the ISI-MIP study provide an example of an issue affecting numerous studies and will apply similarly to any study based on an ensemble subset. These results therefore have wide ranging implications for those designing and using climate impact assessments based on subsets of CMIP5, or earlier generation CMIP datasets, and similarly for those using downscaled datasets (for example, CORDEX), which are inevitably based on a restricted subset of global models.

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Our results lead to the following practical implications:

1. We found that the fraction of uncertainty in seasonal mean changes in climate captured by the 5 models is low for a large proportion of the global land areas: varying from 0.5 to 0.9 for temperature (median 0.75) and 0.3 to 0.8 for precipitation (median 0.55). The implications of this are that for many regions and seasons, this subset can be expected to underestimate both the total uncertainty in future climate impact, and the relative proportion of uncertainty that is attributable to the use of different GCMs.
2. The potentially low fraction captured, and the wide regional variation in the fraction of model uncertainty captured makes interpreting ISI-MIP results, and those from other studies based on ensemble subsets, challenging. However, authors of such studies could usefully provide quantitative information about how the subset used spans the range of changes in key variables for the region of interest using freely available CMIP5 data – for example in a mapped format as in Fig. 1, or scatter plots in supplementary information. This information would provide very useful context for interpreting the results, and facilitate comparison of results across different impact studies which may be based on different ensemble subsets.
3. We have demonstrated that a greater fraction of the ensemble range can be captured if a strategic and regionally focussed approach is employed to sample uncertainty. Where there is scope to select the models used, these results presented here may influence the approaches to sub-selection used in future studies, and the number of models considered.
4. This study illustrates limits on the fraction of the range that we can expect to capture with a small subset, particularly in studies with a global scope. Where studies are restricted to a small number of models, or limited to a pre-existing subset which may have poor coverage, the usefulness of the results can be maximised by providing the kind of contextual information recommended above, in point number 2.

Introduction

A key product of the information from multiple Global Climate Models (GCMs) that is gathered via the Coupled Model Intercomparison Projects (CMIP) is the degree of spread in future climate projections from different GCMs. A large spread in projections occurs in some regions and variables due to a combination of variations in the climate sensitivity that determines the magnitude of the average global response, and large variations in the spatial patterns of change – particularly for precipitation. How this information about model spread from a multi-model ensemble should be used and interpreted has been discussed in numerous publications (e.g. Knutti et al., 2010; McSweeney and Jones, 2013; Stainforth et al., 2007; Tebaldi et al., 2011), but it is clear that when exploring the potential impact of climate change scenarios, ensemble spread provides some important, if incomplete, information about the range of plausible future climate changes. This uncertainty information significantly improves the usefulness of climate projection and impact information by (a) allowing policy makers to consider a plausible range of eventualities and (b) informing the appropriate use of uncertain climate projections.

In many studies or experiments that make use of the data from CMIP5 GCMs (Taylor et al., 2012), the large number of models included in CMIP5 prohibits the inclusion of data from all GCMs. The

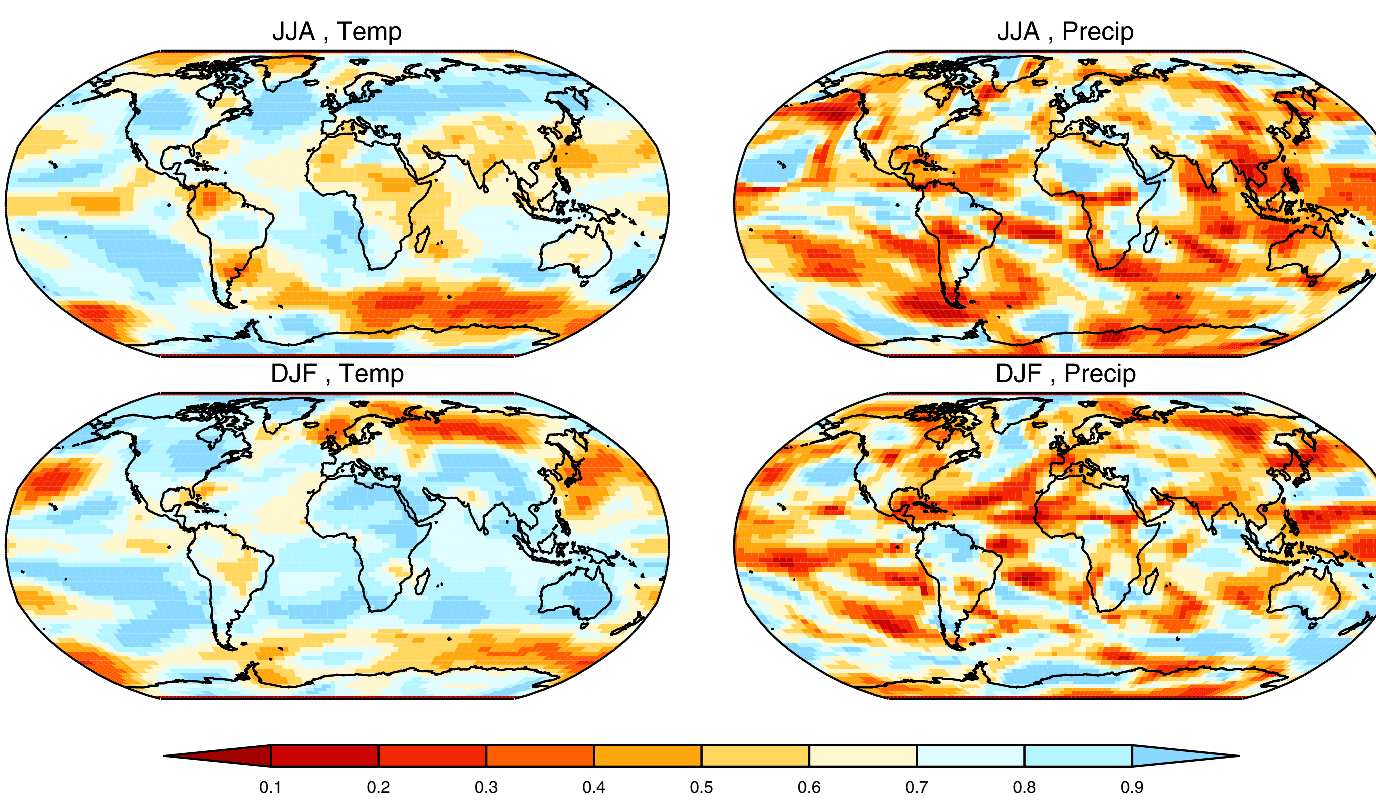

Fig. 1. Fractional range coverage (FRC) globally for the 5 GCMs (of 36 for which data were available) used in the ISI-MIP project for both mean temperature and precipitation in December, January February (DJF) and June, July, August (JJA). Changes in climate are those under the RCP8.5 scenario by 2071–2100 with respect to 1961-90.