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Prof. Wilco Hazeleger
Editor
Geoscientific Model Development

Dear Prof. Wilco,

Thank you for your help on manuscript titled:

"Climate patterns scaling set for an ensemble of 22 GCMs - adding uncertainty to the IMOGEN impacts system"

At the last paper version, we had answered both reviewers' comments to their acceptable level, except for the additional request to test the modelling framework for mean changes and spread in a key impact (Referee #2). Almost all of the climate models have available gridbox mean runoff, and so we used that quantity to answer this final query.

We are grateful for being asked to do this, as it does allow a new perspective on the pattern-scaling approach. In general, we find similarities between IMOGEN projections (which although spanning GCMs emulated, have the common land surface model JULES), and those from direct GCM estimates of runoff. However there are sufficient differences for us to conclude that future efforts on pattern-scaling could include direct scaling of variables such as runoff. That is in addition to the meteorological drivers.

As you know of course, there is presently much interest in global warming pathways to stabilisation at 1.5 and 2.0°C. Unfortunately very few GCM simulations are available that target those precise final temperatures. Pattern-scaling provides a mechanism to achieve that, by interpolating from existing GCM simulations. Hence we hope use will be made of this manuscript, and the related parameters and patterns that are available for download, to advise on expect impacts for either final warming level.

I am sorry it has taken us over two months to respond with this final analysis. This is in part because it took time to return to the original GCM simulations, and to extract the extra runoff variable. On behalf of myself and co-authors, I very much hope our revised manuscript can now be considered acceptable for publication in Geoscientific Model Development. Our full response to reviewer is given below. Changes in the manuscript are highlighted in blue.

With kind regards,

Prof. Chris Huntingford

Dear Reviewer 2 – thank you for your additional request below for manuscript **“Climate patterns scaling set for an ensemble of 22 GCMs - adding uncertainty to the IMOGEN impacts system".** This has allowed us to have a new perspective on IMOGEN pattern-scaling capability.

Reviewer #2 writes:
“Please show an application where all the patterns (i.e. all the CMIP3 models) are used, and show that on average the errors between true and pattern-scaled input to the impact models is within the original multi-model variability/uncertainty from the CMIP3 ensemble. That, in my opinion, is the correct way to validate the utility of this implementation. And if I had to bet, given the variance among CMIP3 models, the application will successfully demonstrate its "accuracy" within the CMIP3 universe of projections.”

We have chosen to answer this request via the quantity total gridbox-mean runoff (mm/day). This has led to a new Figure 7 and associated text in the paper. These additional paper components are listed below, and please accept these as our responses. We conclude that the land surface model has a strong influence on runoff projection changes, including the variance. We conclude that future pattern-scaling activities could include direct scaling of variables such as runoff, rather than just surface-level meteorological changes.

New figure and Caption:

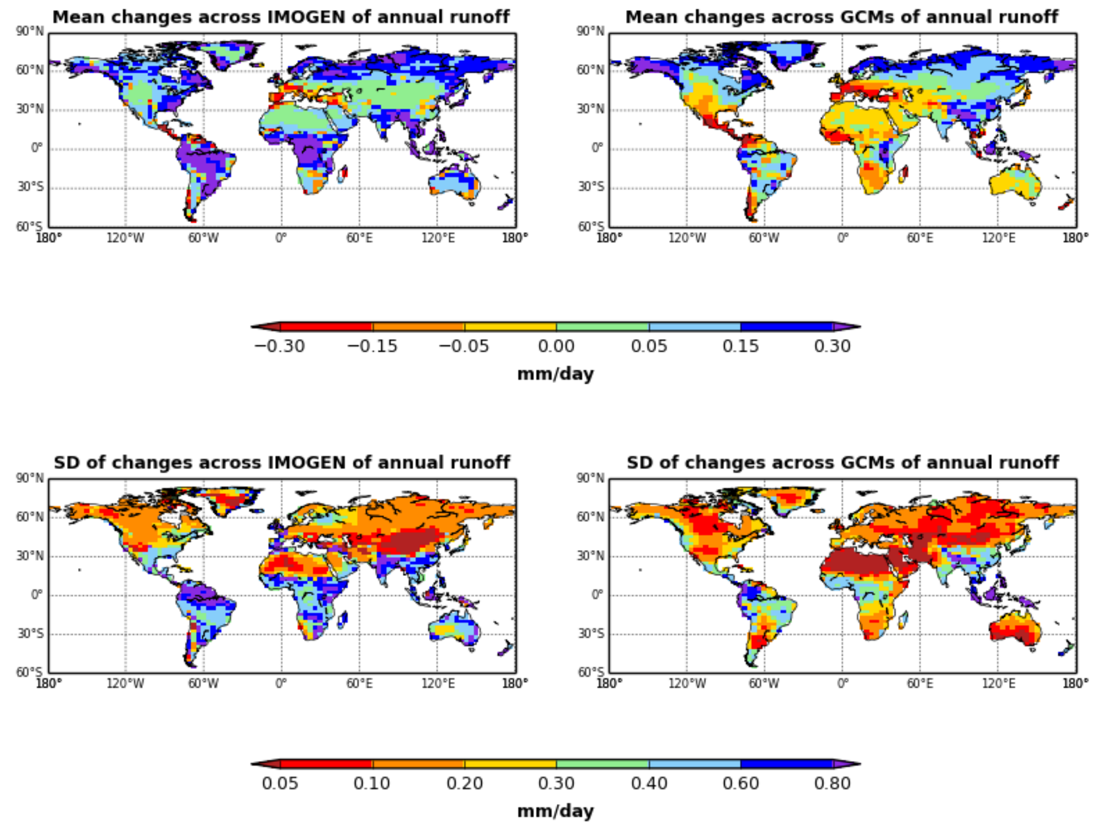

Figure 7. Comparison of IMOGEN and GCM estimates of annual mean runoff changes (20 years centred 2090 minus 20 years centred 1900), and for emissions scenario SRESA1B. Top left panel is the mean changes in runoff across GCMs emulated in the IMOGEN system, all forcing the JULES land surface model. Top right panel is the mean changes in runoff as taken directly from the GCMs themselves. In the bottom left panel, at each gridbox, presented is the SD of changes in runoff for IMOGEN, again across GCMs emulated. Bottom right panel is SD of changes in runoff taken directly from the GCMs.

Text for main paper:

In Figure 7, for SRESA1B emissions scenario, we consider the ability of IMOGEN to project runoff changes and compare the result to such changes taken directly from the GCMs themselves. Hence this is comparing the IMOGEN simulations that emulate multiple GCMs but with a single land surface model (JULES), versus runoff values directly from the GCMs. The latter therefore contain alternative estimates of climate change, and additionally the responses of different land surface models. During modelled pre-industrial period, and modelled period centred on year 2090, total runoff values are recorded for each GCM (both emulated in IMOGEN, and directly from GCMs). Then in each case the change is calculated. In the top panels, the mean of these changes are shown, whilst the bottom panels are the standard deviations of these change values. Although there are similarities between left and right-hand panels (over northern latitudes, in particular), there are important differences too (notably the drying signal in GCM output for Africa and Australia is not reflected by the IMOGEN framework). For SDs, in some locations there is higher variability for IMOGEN than for the GCMs themselves; however, this pertains mainly to the regions where IMOGEN predicts higher runoff. The latter may be surprising, as considering that GCMs directly introduce another level of uncertainty i.e. inter-land surface model differences. Our finding is suggestive that JULES has a particularly sensitive response of runoff to imposed climatic changes. Looking ahead to new forms for IMOGEN, one possibility to additionally capture the different land surface responses is to pattern-scale directly impact variables of interest such as runoff.