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Geoscientific Model Development Discussions

Interactive comment on "Climate pattern scaling set for an ensemble of 22 GCMs – adding uncertainty to the IMOGEN impacts system" *by* Przemyslaw Zelazowski et al.

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Comment 3.1. As it stands, this paper is a simple implementation of the idea of pattern scaling and EMB calibration to a multi-model ensemble. I do not think any of this is new per se, and the choice of presenting this work based on a by now obsolete CMIP ensemble, CMIP3, does not help making the case for publication as is. That said, I think the value of the work resides in the provision of a multivariate set of fields/patterns, for the use in impact work, effectively exemplified by the motivating application through the IMOGEN system. This is in my opinion the real contribution of this work, but the focus of the paper is not adequately trained on this aspect. I would recommend major revisions, but I would hope that my request would not be a show stopper: what I would

like to see is the application section expanded, not because I want to see the results of the impact analysis for their own value, but because I think we need to see how the pattern scaling performs in the application context, compared to results obtained from using the actual GCM output (by the way, I do think the use of ESM here is not appropriate, I don't think any of the CMIP3 models was an ESM in the sense of including a representation of the carbon cycle). My main concern is to be able to assess how the differential performance of the pattern scaling approach across variables and across models impacts the results of a multi-model impact assessment. I do not think the application section at this time addresses that.

Response 3.1. We thank the Referee for this constructive criticism. First, on notation and similar to the request of referee one, we have dropped the use of "Earth System Model" description in the case of the analysed CMIP3 data.

Based on this comment, we have expanded significantly Section 4 "Applications" in which we undertake an assessment of IMOGEN performance in terms of ability to project changes to impacts. The focus is placed on mean annual total runoff, and making a direct comparison to GCM estimates of change. We also added a new Figure 7. The new diagram, its caption and associated new text in main body of the paper is repeated below.

Figure 7 (Caption – figure below): Estimates of gridbox mean annual total runoff, RTot (mm/day). These are: top panel, for IMOGEN and year 1860: middle panel, IMOGEN estimates and year 2090 calculations of RTot minus those of year 1860: bottom panel, HadCM3 estimates and mean of year 2080-2099 calculations of RTot minus those of mean of last 20 years of pre-industrial control simulation.

New text: "We additionally undertake an assessment of IMOGEN performance in terms of ability to project changes to impacts, and when compared directly to GCM estimates of change. Many of the components of the land surface component of IMOGEN, i.e. JULES, remain similar to those operated in the HadCM3 GCM. Hence we evaluate an

IMOGEN simulation operated with the HadCM3 patterns, by assessing performance against terrestrial diagnostics directly from the HadCM3 model. For both IMOGEN and HadCM3 simulations, this is with SRESA2 CO2 emissions and estimated non-CO2 radiative forcing also for that scenario, and with the GCM calculations drawn from the CMIP3 database. The variable we select is total runoff, which is the combination of surface and subsurface runoff calculations. This is available from both IMOGEN and HadCM3, and here presented as annual gridbox mean value, RTot (mm day-1).

Runoff provides a challenge for comparison, as it is frequently a relatively small number between two larger fluxes of precipitation and evapotranspiration (transpiration, plus soil evaporation and interception loses) and so sensitive to change in those fluxes. Direct comparison also needs to account for IMOGEN being initialised with a climatology based on the CRU dataset, and temporal dis-aggregation to sub-daily drivers of JULES having not been calibrated against any particular GCM. Nevertheless, to be a useful tool for impacts assessment, then IMOGEN must capture the general features of GCM projections when operated for similar emissions scenarios.

In Figure 7, we compare IMOGEN versus HadCM3 projections of change in RTot. The top panel is modelled year 1860 values, from IMOGEN. The middle panel is the change in RTot, again for IMOGEN, and between years 1860 and 2090. The bottom panel is the change in RTot for HadCM3, comparing the last 20 years of the pre-industrial control simulation against the last 20 years of SRES-A2 forced simulation, which for the latter is 2080-2099. Multi-year averages are derived to remove any inter-annual variability, which as yet, IMOGEN does not represent. Although there are apparent local differences, and recognising the caveats above, then at its most general many dominant geographical features of change in IMOGEN do have similarities to those of HadCM3."

C.3.2. A particular concern is how the performance on individual variables translates into a performance across variables, i.e., in their joint behavior, for different models' output. In fact, in this regard, even the section about "Explanatory power of linear

approximation" needs a better description: What is the meaning of the sentence (and I summarize) "Overall, climate patterns explain one third of regional climate change". How is the joint variability/covariability of the variables evaluated? Is the covariance patterns among all variables taken into account? I would like to see a more rigorous and formal definition of how the variance of the joint set of variables is represented by the emulation.

R.3.2. We agree that the issue of co-variability is important, and are aware of the studies that look in to more complex pattern-scaling models which partly address this issue (e.g. Frieler et al 2012, now cited in this manuscript). We request, that on this one issue, this is beyond the scope of this presentation of the IMOGEN 2.0 model.

However we do acknowledge some poor wording in the paper. First, the section of concern is now titled: "3.3. Performance of linear approximation assumption in "pattern-scaling" for individual variables". Then, in that Section, we now write more clearly, adding "when per-variables results are averaged" as: "Overall (i.e. when per-variable results are averaged, without considering co-variance), climate patterns explain one-third of regional climate change (PVE 34.25$\pm$5.21)"

C.3.3. If the authors are willing to show how the use of the pattern scaling solution compares to the use of the original output from the multi-model ensemble I think the article will become more informative and valuable to the impact research community, within and beyond IMOGEN users. In this respect I also agree with Dr. Emori that the potential is larger than just the IMOGEN application and it would be good to point that out.

R.3.3. We agree, and have expanded extensively our Section 4 "Applications", with a focus on change in mean annual total runoff. This is by a direct comparison between GCM estimates of change (for HadCM3), and IMOGEN estimates. Please see our response to query C.3.1. above, including listing of new diagram, caption and additional text within the manuscript.

C.3.4. Last, two very minor points: I think throughout the paper the word “assembly” has been erroneously substituted for “ensemble”, my guess because of an auto-correct program.

R.3.4. Corrected – thank you very much for noticing this mistake.

C.3.5. The other word, which I think is used instead deliberately but I question, is “meteorology”. I think what the pattern scaling approach produces is still “climatology”. These are after all ten-year means. The use of a weather generator may then produce meteorology at the time scale needed by the impact model, but that is an add-on to the method that this paper focuses on.

R.3.5. We agree that “climatology” is more accurate and would like to explain that originally we referred to “meteorology” because of IMOGEN‘s weather generator. Six instances of “meteorology” have been changed throughout the text to “climatology”.

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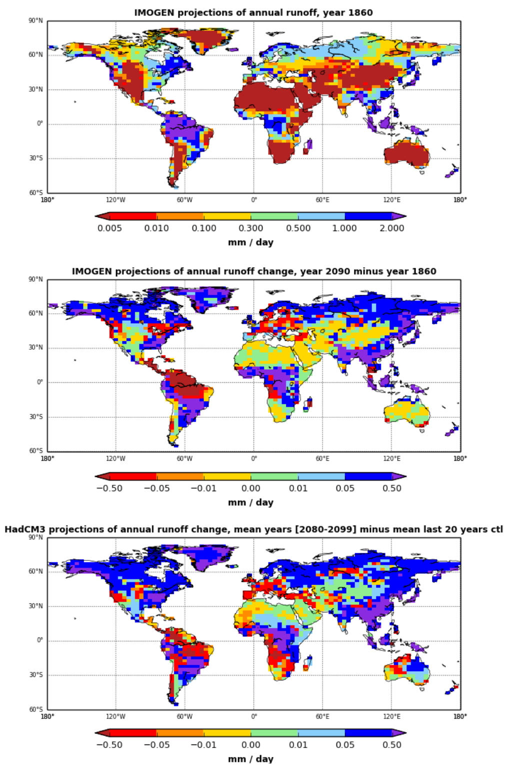

Fig. 1. Figure 7: Estimates of gridbox mean annual total runoff, RTot (mm/day). These are: top panel, for IMOGEN and year 1860: middle panel, IMOGEN estimates and year 2090 calculatio