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Earth System Dynamics Discussions

Interactive comment on "Climate change impact on available water resources obtained using multiple global climate and hydrology models" *by* S. Hagemann et al.

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This study presents multi-model ensemble simulation results of global daily average evapotranspiration (ET) and runoff (R) fields for the future (2071-2100). Three GCMs are used, and after applying a statistical bias-correction to the model output of P and T, eight global hydrological models (GHM) are forced to produce output. The study shows that there is considerable variability arising from the choice of models used for impact assessment. Another important conclusion is the critical role of representing ET which can cause considerable uncertainty in water resources assessment.

The manuscript is well written and its general objective of assessing future water resources is of scientific importance. However, the approach of forcing hydrological models with (modified) GCM outputs is not new and also not critically discussed. The novelty is that the variability which arises due to the choice of different models is assessed. However, this variability is hard to judge, as other sources of uncertainty (parameter, initial conditions) are not available. Hence, the paper could benefit if reliability of the results is checked with regard to their physical consistency. This involves in particular the consistency of mass and energy balances of the GCM-bias-correction-GHM model chain. Also a more detailed assessment of the impacts of the bias correction should be included.

In summary, a more comprehensive presentation of the results (i) with regard to the hydro-climatology and (ii) a critical evaluation of the general methodology would clearly improve the value of the manuscript.

1 Major Remarks

1.1 Does bias-correction result in higher ensemble mean changes in ET and R?

On P1330L11 it is noted that bias-correction reduces the spread of the change signals. Further, the GCM-GHM model chain results in larger average changes, while the non-corrected GCMs show less significant changes. Hence, the GCM-GHM simulation results suggest more confidence in the change signal.

This is an important result, which should be taken with care with regard to the inherent assumptions of the general approach. For me the following questions arise:

- To which extent are the changes in ET and R caused by the bias-correction or the use of different GHMs?

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- Does the bias-correction procedure retains consistent mass and energy balances?
- To which extent does bias-correction changes hydrological behavior? For example changes in precipitation falling as snow or rain.
- Please elaborate the statement on P1330L21 "the consistency between variables is not necessarily the case due to the bias correction".
- Why and how do you arive at that statement P1330L24: "...these results show another advantage of the chosen model setup compared to the direct use of GCM data for impact assessment, ..."?

I see that there are references provided on that topic, however, for judging the results of this manuscript, I think this needs to be discussed.

1.2 How useful are decoupled ET estimates in a climate simulation setting?

A major result in my mind is the large variability in ET induced by the 8 GHMs. The authors point to the uncertainty in ET formulations. However, I miss a critical assessment of the methodology in simulating global ET with an impact model. This might introduce a large conceptual uncertainty: ET is part of the water and energy balances of the hydrological cycle and the atmosphere. If the mass and energy flux of ET is not feed back into the atmospheric part, I expect that water and energy balances are not closed. It would be nice if the authors could prove me wrong.

1.3 Hydro-climatological assessment

The manuscript (without supplement) shows 24 global maps, but there is no assessment of the simulated changes with respect to the current hydro-climatology which

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largely influences the sensitivity of ET and R to climate change (Arora, 2002; Roderick and Farquhar, 2011; Renner and Bernhofer, 2012). Hence, an assessment of the simulated changes in the partitioning of water fluxes with respect to the aridity of the climate and the hydrological response of river basins could be beneficial. This might also provide a way to reduce the amount of maps.

1.4 Temporal scale of changes daily vs. annual

The results are presented as mm/day. The reference, however, is a 30yr average. From my point of view, I would rather use the scale of long-term annual averages (mm/yr) for presenting the results.

2 Minor Comments

- abstract, I miss the mentioning that bias-correction is employed
- P1323L5: please be more detailed on the differences between hydrological models
- section 2.1 models: please give an brief overview with respect to the main differences of the GCM models; this task should not be left for the reader
- bias-correction: please be more detailed on the pitfalls of bias-correction; this is a major modeling step and should be clearly reflected for the reader
- please be more detailed on the GHMs; maybe a table for input data, ET formulation and other important processes would be beneficial; As the use of 8 different models is the stated novelty of this manuscript, their differences should be discussed.

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- section 2.2: so ET is derived by the GHMs; Is there a check for consistency of the (surface) energy balance and water balance within the GCM-GHM model chain?

- P1326L6ff: for the precipitation change results, is the GCM output shown, or the bias-corrected output?

- P1326L20 To which extent are ET and R driven by precipitation changes? How important are changes in other forcing variables such as net radiation and temperature? What are the spatial patterns, hydro-climatological patterns of the changes?

- P1327L8-23: In general I like the idea of separating the differences induced by the climate or the hydrological models. Further, please indicate how exactly you defined the coloring.

- P1328L8-12 "Over the high latitudes ..." unclear sentence

- P1328L16-18: First, it is stated that maximum spread is important to judge the robustness for average changes. However, in Fig. 4 the standard deviation is used. Hence, I would like to see the maximal spread of projected changes and not the sd.

- P1329L19-23: the text only repeats the colors of the corresponding figure

- P1330 Original GCM output means that there is no bias correction? If so, this should be noted explicitly.

- Fig. 1 Is that bias corrected output? Panel b) by using the CV, dry regions are overly emphasized, while for more wet regions the map suggests high confidence.

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- Fig.: 2 The 8 global maps are hardly readable. Especially the legend is too small. The authors should remove some of these maps or make separate figures, if important.
- Fig. 4 try to increase the readability of the figures (colors, too much overlay). Please display the full spread and not only the standard deviation (requires non-skewed samples).
- Fig. 5 I would rather like to see a scatterplot comparing the changes / or absolute ensemble means than the maps. It is enough to state that spatial patterns are similar.
- Fig.6 Similar as Fig.5 and unclear units used in the legend

References

Arora, V.: The use of the aridity index to assess climate change effect on annual runoff, Journal of Hydrology, 265, 164–177, 2002.

Renner, M. and Bernhofer, C.: Applying simple water-energy balance frameworks to predict the climate sensitivity of streamflow over the continental United States, Hydrology and Earth System Sciences, 16, 2531–2546, doi:10.5194/hess-16-2531-2012, 2012.

Roderick, M. and Farquhar, G.: A simple framework for relating variations in runoff to variations in climatic conditions and catchment properties, Water Resources Research, 47, W00G07, doi:10.1029/2010WR009826, 2011.

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