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Earth System Dynamics
Discussions

Interactive comment on "Global meteorological drought and severe drought affected population in 1.5 °C and 2 °C warmer worlds" *by* Wenbin Liu et al.

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This article talks about the drought evolution (duration, intensity and frequency) due to the climate change in a 1.5 (2oC) scenarii defined by the COP21. It gives an estimation of the impacted people around the world. To obtain these results, the article uses outputs from eleven CMIP5 GCMs with the RCP4.5 and 8.5, the gridded population from SSP1 scenario and the Palmer drought severity index (PDSI). The transdisciplinary of this article is very interesting and show the human impacts due to the climate change. This paper is divided in 5 parts: an introduction that clearly defines the drought importance on the human society and the 1.5oC (2oC) scenario. The second part describes the data and the method but in this section, some corrections are required (see below). The results are well described and the discussion is interesting but some justifications

could improve the limits of the method. I suggest publishing this article in ESD with major revision. The different remarks and suggestions are described below.

Thank you. In the revised manuscript, we clarified the justifications and methodology of this manuscript. In the acknowledgement section, we added: "We thank the Editor (Michel Crucifix), Dimitri Defrance and another anonymous reviewer for their helpful comments". (Line 486-488 in the latest clean version).

Major comment on the methodology That is the major comment on your article and the bigger correction I demand. First, I find that you don't give enough details to justify the choose to use eleven-CMIP5 models and only 2 RCP scenarios (4.5 and 8.5). Data are available on about 30 models for RCP8.5 (e.g. Famien et al. ESD discussion November 2017) and available for RCP2.6 and 6 but with a reduced number of models. Are more simulations not better? I would like a justification of the models use.

We could have clarified the justification on the selection of climate models and climate scenarios as part of the methodology in the original version of this manuscript. A key step in current study is computation of PDSI using climate model outputs. It requires monthly simulated outputs, i.e., surface mean air temperature, surface minimum air temperature, surface maximum air temperature, air pressure, precipitation, relatively humidity, surface downwelling longwave flux, surface downwelling shortwave flux, surface upwelling longwave flux and surface upwelling shortwave flux; daily simulated outputs, i.e., surface zonal velocity component and meridional velocity component. Whilst a large number of climate models are available in the CMIP5 archive, we made use of those fully satisfied our data requirement. Among the RCP scenarios (i.e., RCP2.6, RCP4.5, RCP6, RCP8.5), the climate models under RCP4.5 and RCP8.5 scenarios are more complete relative to those under RCP2.6 and RCP4.5 scenarios (the reviewer also noticed this). In fact, recent studies have confirmed that the impacts of similar global mean surface temperature (i.e., +1.5oC, +2oC worlds) among the RCP scenarios are quite similar, implying that the global and regional responses to temperature and are independent of the RCP scenarios (Hu et al., 2017; King et al., 2017).

These provide the scientific justification for using the climate models under the RCP4.5 and RCP8.5 scenarios in current study. We settled at using 11 CMIP5 models under these scenarios.

In response, we clarified the justification of climate models and climate scenarios used in Line 129-137, as follows,

"...Recent studies have confirmed that the impacts of similar global mean surface temperature (i.e., +1.5oC and +2oC worlds) among the Representative Concentration Pathways (RCPs) are quite similar, implying that the global and regional responses to temperature and are independent of the RCPs (Hu et al., 2017; King et al., 2017). Following this idea, we settled at using 11 CMIP5 models which satisfied the data requirement of PDSI calculation (see paragraph above) under RCP4.5 and RCP8.5. Following Wang et al. (2017) and King et al. (2017), we use the ensemble mean of these CMIP5 models and climate scenarios (RCP4.5, RCP8.5) to composite the composite the warming scenarios (+1.5oC and +2oC worlds)..."

Reference: King, A.D., Karoly, D.J., and Henley, B.J.: Australian climate extremes at 1.5oC and 2oC of global warming, Nat. Clim. Change, 7, 412-416, doi:10.1038/nclimate3296, 2017.

Schleussner, C., Lissner, T.K., Fischer, E.M., Wohland, J., Perrette, M., Golly, A., Rogelj, J., Childers, K., Schewe, J., Frieler, K., Mengel, M., Hare, W., and Schaeffer, M.: Differential climate impacts for policy-relevant limits to global warming: the case of 1.5oC and 2oC, Earth Syst. Dynam., 7, 327-351, doi: 10.5194/esd-7-327-2016, 2016.

Wang, Z.L., Lin, L., Zhang, X.Y., Zhang, H., Liu, L.K., and Xu, Y.Y.: Scenario dependence of future changes in climate extremes under 1.5oC and 2oC global warming, Sci. Rep., 7:46432, doi:10.1038/srep46432, 2017.

Hu, T., Sun, Y., and Zhang, X.B.: Temperature and precipitation projection at 1.5 and 2oC increase in global mean temperature (in Chinese), Chin. Sci. Bull., 62, 3098-3111,

2017.

Secondly, in your study, all models have the same ponderation but if a model is a reverse signal, this result is not visible, to avoid this problem you can use a classification of model type as in Monerie et al, 2016 (10.1007/s00382-016-3236-y) or in Sgubin et al., 2017 (10.1038/ncomms14375.375). I think that the use of a classification is important to improve your results robustness.

Whilst it is possible to perform classification study, we have concern that it would shift away from the main focus of current study and our target audience (i.e., international policy-makers). This manuscript is prepared to inform climate policy-making hence we generalized the impacts as much as possible. We also performed sufficient uncertainty analyses. For example, we first generalized the multi-model results using the multi-model ensemble mean (the left panels in Figures 3, 5, 7 and 9), as many other studies did (i.e., Mo et al., 2015; He and Soden, 2016). We then quantified the different results/uncertainty among climate models using model consistency (the right panels in Figures 3, 5, 7 and 9) and boxplots (Figures 4, 6, 8 and 10). We characterized different impacts of severe droughts on population at continental scales using the multi-model ensemble mean and the corresponding uncertainty among climate models in Figures 11-13. We also discussed the uncertainties of this study in Section 4 (Line 408-427 in the latest clean version)

Reference: Mo, K.C. and Lyon, B.: Global Meteorological drought prediction using the North American Multi-Model ensemble, J. Hydrometero., 16, 1409-1424, 2015.

He, J., and Soden, B.: A re-examination of the projected subtropical precipitation decline, Nature Climate Change, 17, 53-57

My other remark (the more important correction) is due to your impacted study. You write in the discussion that the uncertainty of the model is important and the use of several models weaks the error. That is true but not sufficient. In some region, I think about West Africa, no models have the correct precipitations pattern. This problem is maybe present in other regions. I think this problem lead to a wrong result for the impact and this part must be corrected. The best solution is to unbiase the outputs of the model with e.g. a quantile/quantile method (univariate or multivariate) and observations. These outputs maybe exist now and can improve your interesting results. Another way is better describe the errors between the models and the current observations to be able to determine a confidence index for all regions. With a correction of the output or with a discussion of the local error from the model, the results will be robuster and you can eject the area where the confidence index is not sufficient.

We could have explained better about the methodology and the rational in the original version of the manuscript. Please note that the focus of this study is about the change in climate impact/risk (i.e., global meteorological droughts in this study) under +1.5oC and +2oC worlds. In this case, application of bias correction method(s) towards the historical and future periods would be somewhat redundant. The reason is because the change between the bias-corrected results of historical and future is more or less similar to that without bias-correction (e.g., Sun et al., 2011, WRR; Maraun, 2016). In addition, our methodology requires meteorological information (i.e., short- and long-wave radiation, wind, air temperature, humidity, air pressure, precipitation) that is consistent with the energy balance of the climate model (refer to Equation 3 in Section 2.3), hence we have concern about the ability of bias-correction method(s) in maintain the energy balance of the climate models. In terms of confidence index, we rigorously presented model consistency/agreement of these projected changes in climate impact/risk under +1.5oC and 2oC worlds (Figures 3, 5, 7, 9). This kind of confidence index has been widely applied for characterizing multi-model climate projections (e.g., Hirabayashi et al., 2013; Koirala et al., 2014).

In response, we revised Section 2.3 to clarify the rational of our methodology. We also discussed the feasibility using bias-correction approaches and alternative confidence indices (combine with thoughts kindly put forward by the reviewer) in Section 4. Thank you.

Reference: Sun,F., Roderick, M.L., Lim, W.H., and Farquhar, G.D.: Hydroclimatic projections for the Murray-Darling Basin based on an ensemble derived from Intergovernmental Panel on Climate Change AR4 climate models, Water Resource Research, 47, W00G02, 2011

Maraun, D.: Bias correcting climate change simulations – a critical review, Current Climate Change Reports, 2, 211-220, 2016

Hirabayashi, Y., Mahendran, R., Korala, S., Konoshima, L., Yamazaki, D., Watanabe, S., Kim, H. and Kanae, S.: Global flood risk under climate change, Nature Climate Change, 3, 816-821, 2013

Koirala, S., Hirabayashi, Y., Mahendran, R., Kanae, S.: Global assessment of agreement among streamflow projections using CMIP5 model outputs, Environmental Research Letters, 9, 064017 (11pp), 2014

Some questions/remarks In the abstract: I suggest adding some numerical results from the results and discussion part because of now the abstract is too qualitative.

Good point. In response, we added more quantitative results in the abstract (Line 32-45 in the latest clean version). Thank you.

Line 84: maybe add a reference for the longer duration

Done. Thank you.

Reference: McKee, T.B., Doesken, N.J. and Kleist, J.: The relationship of drought frequency and duration of time scales, Eighth Conference on Applied Climatology, American Meteorological Society, Jan 17-23, Anaheim CA, PP. 179-186, 1993.

Line 101: Why do you use only the SSP1 scenario? That is right this is compatible with the 1.5o scenarios (Line 135) but other SSP scenarios are also compatible with your climatic scenario. Have you an idea of the impacts of the different SSP scenarios on your results?

Also refer to our response to the second comment of the reviewer.

We used SSP1 scenario because it describes the storyline of a green growth paradigm with sustainable development and low challenges for adaptation and mitigation (O'Neill et al., 2014, Climatic Change). The +1.5oC and +2oC worlds clearly fit in this description and thus considered under the Paris Agreement 2015 (UNFCCC Conference of the Parties 2015).

Reference: O'Neill et al.: A new scenario framework for climate change research: the concept of shared socioeconomic pathways, Climatic Change, 122, 387-400, 2014. UNFCCC Conference of the Parties 2015: Adoption of the Paris Agreement, FCCC/CP/2015/10Add.11-32Paris

Line 153: Why do you use +-0.2 around the 1.5oC and 2oC ?

This study applied continuous time series for identification of drought duration, intensity and severity. From the climate model projections, we noticed that inter-annual variation of global mean air temperature is common and its magnitude differs with different climate models. To account for it, we followed King et al. (2017), in which the 1.5oC (2oC) world was defined as all years in the 2006-2100 scenario simulations when average temperatures are between 1.3 - 1.7oC (1.8 - 2.2oC) warmer than the pre-industrial levels.

In response, we explained the rational of using +/- 0.2 in Line 157-163.

Reference: King, A.D., Karoly, D.J., and Henley, B.J.: Australian climate extremes at 1.5oC and 2oC of global warming, Nat. Clim. Change, 7, 412-416, doi:10.1038/nclimate3296, 2017.

Line 207: Can you define the used threshold to define the drought duration/ intensity?

We added the used threshold (PDSI< -1) for defining the drought duration/intensity/ severity in the revised manuscript. Thank you.

Line 216: That is better to describe a little more the SSP1 scenario for the evolution of the rural/urban people. Your results explain the different trends but we don't know the evolution of the population.

Good point. In response, we added more descriptions about the evolution of population under the SSP1 scenario as follows (Line 255-262 in the latest clean version),

"...In this pathway, the world population will peak at around 2050s and then decline (van Vuuren et al., 2017). The environmentally friendly living arrangements and human settlement design in this scenario leads to fast urbanization in all countries. More in-migrants from rural areas are attracted to cities due to more adequate infrastructure, employment opportunities and convenient services for their residents (Cuaresma, 2012). The world urban population will gradually increase while rural population will correspondingly decline in the future under SSP1 scenario..."

Line 336: I suggest putting this paragraph before the SSP1 results. I think that is more logical to determine the role of the climate on the population exposure with a current population and after you add the role of the demographic trend.

Done. Thank you.

Technical notes Line 87: (PDSI) in place of, PDSI, Line 236: (more drought-prone)? Line 280: a "." To delete

Done. Thank you.

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