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Discussions

# *Interactive comment on* "Sensitivity of future water availability projections to Global Climate Model, evapotranspiration estimation method, and greenhouse gas emission scenario" *by* S. Chang et al.

**S. Chang et al.**

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We appreciate the thoughtful comments from the reviewers, which have helped us to improve the original manuscript. We explain in detail how we responded to each of the reviewer's comments, with line numbers referring to the revised manuscript unless otherwise noted. We changed our title to "Sensitivity of future Continental United States water deficit projections to General Circulation Model, evapotranspiration estimation method, and greenhouse gas emission scenario" in response to reviewers comment.



In addition, we upload revised manuscript and responses to reviewers as our supplemental material.

[1] Referee review: Abstract, first sentence, and elsewhere. The authors need to clarify immediately that in this case, water availability refers to the meteorological water balance (i.e. P-PET). Particularly in a hydrology-related journal such as HESS, water availability implies surface hydrological processes as well – in which case future water availability would depend on many other factors as well (e.g. irrigation abstractions, land use, water management strategies).

Author's response: We agree this could have been confusing. We replaced the term "water availability" by "water deficit" throughout the manuscript, and defined it early in the abstract and in body of the manuscript in order to clarify this.

[2] Referee review: The Introduction section needs to better acknowledge that method-based PET uncertainty under climate change has been explored beyond just the meteorological water balance, to consider river flow as well (via hydrological models). Such studies include: Bae, D.H., Jung, I.W. & Lettenmaier, D.P. 2011 Hydrologic uncertainties in climate change from IPCC AR4 GCM simulations of the Chungju Basin, Korea. Journal of Hydrology 401 90-105. Kay, A.L. & Davies, H.N. 2008 Calculating potential evaporation from climate model data: A source of uncertainty for hydrological climate change impacts. Journal of Hydrology 358 221-239. Koedyk, L.P. & Kingston, D.G. 2016, Potential evapotranspiration method influence on climate change impacts on river flow: a mid-latitude case study. Hydrology Research DOI: 10.2166/nh.2016.152. Thompson, J.R., Green, A.J. & Kingston, D.G. 2014 Potential evapotranspiration related uncertainty in climate change impacts on river flow: An assessment for the Mekong River basin. Journal of Hydrology 510 259-279.

Author's response: We introduced the references suggested in the introduction section and discussed differences among these studies and our study in the discussion section. For example after line 19 on page 4 we added: "Kay and Davies (2008) compared the performance of the Penman-Monteith equation and a simple temperature-based evapotranspiration method using climate data from five global and eight regional climate models over Britain. They found that the two methods showed very different changes in potential evapotranspiration for the period 2071-2100 under the A2 emission scenario, and different flow predictions for three catchments when the data were used to force a rainfall-runoff model. Kay and Davies results suggest that hydrological prediction uncertainty due to potential evapotranspiration formulation was smaller than that due to GCM structure or RCM structure for their study region. Bae et al. (2011) evaluated the uncertainty contributed by choice of GCM and hydrologic model for the Chungju Dam basin, Korea. They found that hydrologic model structural differences contributed greater uncertainty than GCM selection to winter runoff prediction. Koedyk and Kingston (2016) found that for the Waikaia River, New Zealand potential evapotranspiration method contributed more uncertainty than GCM selection when predicting potential evapotranspiration, but that runoff predictions were more sensitive to GCMs than to potential evapotranspiration methods. Thompson et al. (2014) evaluated the effect of using different GCMs and different potential evapotranspiration methods on discharge predictions for the Mekong River in Southeast Asia and found that GCM-related uncertainty was greater than the potential evapotranspiration method related uncertainty. Our study adds to the literature by comprehensively evaluating the relative sensitivity of future P, ET0 and water deficit (defined here as P- ET0) projections to choice of GCM, ET0 method and RCP trajectory over the continental US."

[3] Referee review: The results and discussion are combined into a single section. Although I generally prefer these to be separated, the section is well written. At the very least, I would like to see the different aspects of the analysis divided into subsections, to help the reader follow the steps in the analysis.

Author's response: We divided the previously combined section into separate results and discussion sections as suggested.

[4] Referee review: P11, line 13: referring back to point 2 – yes, hydrological modelling



studies that use only one PET method effectively ignore PET uncertainty, but there have been a series of studies that explicitly investigate this.

Author's response: In addition to the revisions to the introductions noted in point 2 above, we changed the sentence on line 13, page 11 from "Many hydrological models use a single evapotranspiration method for simulation, which may substantially increase the uncertainty, and reduce the reliability of future projections." to "Similar to the results of Kay and Davies (2008) and Bae et al. (2011) the results of our GSA show that the choice of ET0 method has important implications when making future ET0 projections and future water deficit projections (Fig. 8). Kingston et al. (2009) recommended the use of different ET0 equations to evaluate global ET0, and Wang et al. (2015) found that although different methods predict similar future ET0, there are important differences in uncertainties due to ET0 estimation methods and input data reliability. Currently many hydrological models use a single evapotranspiration method for simulation, which may substantially increase the uncertainty and reduce the reliability of future projections. Our results strongly indicate that an ensemble of ET0 estimation methods should be used to understand potential future water availability and water deficit due to climate change."

[5] Referee review: According to the IPCC AR4 Glossary (http://www.ipcc.ch/pdf/assessmentreport/ar5/wg1/WG1AR5_AnnexIV_FINAL.pdf), the acronym GCM stands for General Circulation Model. I suggest avoiding the term Global Climate Model and replacing with General Circulation Model.

Author's response: We replaced 'Global Climate Model' with 'General Circulation Model' throughout the manuscript.

[6] Referee review: P4, line 9: Priestley-Taylor is misspelt.

Author's response: We replaced 'Preistly-Taylor' with 'Priestley-Taylor'.

[8; There's no 7th comment in the review note.] Referee review: P5, line 27: Priestley-

Taylor is a radiation based method – it only requires the slope of the vapour pressure curve (derived from temperature) and net radiation.

Author's response: We changed the classification of the Priestley-Taylor method to a radiation based method.

[9] Referee review: P6, line 3: RET is not defined in the paper. I presume RET means reference ET, but the commonly used abbreviation for this is ET0 (as used in the Table 1 caption).

Author's response: We have changed the abbreviation for reference ET to ET0 throughout the manuscript.

[10] Referee review: P6. On line 3 precipitation is abbreviated to P; on line 5 it is abbreviated pr.

Author's response: The paragraph on P.6 line 3 explains the CMIP5 archive. In the CMIP5 archive they use different abbreviations for precipitation and other climate variables than are conventionally used in hydrology and than we use in this manuscript. We have revised the paragraph to note these differences. "Variables directly used from the CMIP5 monthly model output included precipitation (pr, P in this study), maximum and minimum temperature (tasmax and tasmin), radiation (rlds, rlus, rsds, and rsus), air pressure (psl and ps), and wind speed (sfcWind). The abbreviations for these variables are as defined in the CMIP5 archive and explained in the PCMDI server (Program For Climate Model Diagnosis and Intercomparison, http://cmip-pcmdi.llnl.gov/cmip5/docs/standard_output.pdf)."

[11] Referee review: P7, line 11: spell out the number in this instance: nine, not 9 climate regions.

Author's response: We replaced '9' with 'nine'.

[12] Referee review: P10, line 15: typo: "sKingston".



Author's response: We replaced 'sKingston' with 'Kingston'.

[13] Referee review: P11, line 11: the acronym GSA is undefined.

Author's response: We defined GSA in the revised introduction section. "Global sensitivity analysis (GSA) apportions the total output uncertainty simultaneously onto all the uncertain input factors described by marginal probability density functions, and thus is preferred over local, one factor at a time, sensitivity analysis (Homma and Saltelli, 1996; Saltelli, 1999)."

[Additional Literature cited] Bae, D. H., Jung, I. W. and Lettenmaier, D. P.: Hydrologic uncertainties in climate change from IPCC AR4 GCM simulations of the Chungju Basin, Korea, J. Hydrol., 401(1-2), 90–105, doi:10.1016/j.jhydrol.2011.02.012, 2011. Homma, T. and Saltelli, A.: Importance measures in global sensitivity analysis of nonlinear models, Reliab. Eng. Syst. Saf., 52(1), 1–17, doi:10.1016/0951-8320(96)00002-6, 1996. Kay, A. L. and Davies, H. N.: Calculating potential evaporation from climate model data: A source of uncertainty for hydrological climate change impacts, J. Hydrol., 358(3-4), 221–239, doi:10.1016/j.jhydrol.2008.06.005, 2008. Kingston, D. G., Todd, M. C., Taylor, R. G., Thompson, J. R. and Arnell, N. W.: Uncertainty in the estimation of potential evapotranspiration under climate change, Geophys. Res. Lett., 36(20), L20403, doi:10.1029/2009GL040267, 2009. Koedyk, L. P. and Kingston, D. G.: Potential evapotranspiration method influence on climate change impacts on river flow: a mid-latitude case study, Hydrol. Res., doi:10.2166/nh.2016.152, 2016. Saltelli, A.: Sensitivity analysis: Could better methods be used?, J. Geophys. Res., 104(D3), 3789, doi:10.1029/1998JD100042, 1999. Thompson, J. R., Green, A. J. and Kingston, D. G.: Potential evapotranspiration-related uncertainty in climate change impacts on river flow: An assessment for the Mekong River basin, J. Hydrol., 510, 259–279, doi:10.1016/j.jhydrol.2013.12.010, 2014. Wang, W., Xing, W. and Shao, Q.: How large are uncertainties in future projection of reference evapotranspiration through different approaches?, J. Hydrol., 524, 696–700, doi:10.1016/j.jhydrol.2015.03.033, 2015.

Please also note the supplement to this comment:
http://www.hydrol-earth-syst-sci-discuss.net/hess-2015-408/hess-2015-408-AC1-supplement.zip

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