Author's response letter for "Sensitivity of future Continental United States water deficit projections to General Circulation Model, evapotranspiration estimation method, and greenhouse gas emission scenario" by 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.

Referee #1

Index		Comments
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, ET_0 and water deficit (defined here as P- ET_0) projections to choice of GCM, ET_0 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 sub-sections, 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 ET_0 method has important implications when making future ET_0 projections and future water deficit projections (Fig. 8). Kingston et al. (2009) recommended the use of different ET_0 equations to evaluate global ET_0, and Wang et al. (2015) found that although different methods predict similar future ET_0, there are important differences in uncertainties due to ET_0 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 ET_0 estimation methods should be used to understand potential future water availability and water deficit due to climate change.*"
5	Referee	According to the IPCC AR4 Glossary

	review	(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 ET_0 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.