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Interactive comment on "Projected impacts of climate change on hydropower potential in China" *by* Xingcai Liu et al.

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We are grateful for the thoughtful comments from the reviewer. We write responses to all comments point-by-point as provided below.

Review summary:
This manuscript uses multiple global hydrological models driven by multiple climate model data for two representative concentration pathways (RCPs) to estimate China's hydropower generation potential and the projected future changes based on the river flow estimated by these hydrological models. The study finds that the estimated present-day gross hydropower potential of China is comparable to previous estimates, and suggests that the hydropower potential will decrease in the short-term but will increase by the late 21st century. The study also suggests that these changes vary

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Discussion paper

significantly across different regions. The results presented are of high interest to the scientific community and beyond as the global society today is increasingly concerned about the use of carbon-intensive energy sources to meet the rising energy demands and hydropower could potentially play an important role in future energy mix toward reducing emissions and mitigating climate change, particularly in the rising economies such as China. Therefore, there is no doubt that the paper addresses an important topic but I feel that the study could be driven more by a central scientific finding with important socio-economic implications, rather than just presenting the changes in hydropower potential across different regions.

Response: Thanks for the comments. We have extended the Discussion section with more socioeconomic implications of the hydropower potential changes. The projected hydropower potential changes could be a reference for future hydropower development in China, e.g. to consider the climate change in the estimation of installed hydropower capacity. The increase of GHP in Southwest China may prompt the hydropower development in this region. The decrease of DHP in the hotspot regions implies possible lower power generation from current hydropower facilities. Some technologies, e.g. pumped-storage plants and joint reservoir regulations, may be options to mitigate increased seasonality in streamflow. It highlights the potential need to adapt the reservoir regulations to deal with the likely increasing competitive water uses in future. It should be noted that this study mainly focuses on hydropower potential rather than actual hydropower generation; future hydropower generation is also affected by the energy demand, electricity market, policies, economic conditions, technology development, etc., which are not addressed in the present study. Beyond mitigation and adaptation in river operations, a lower DHP would most likely need to be balanced by energy production from other sources, likely from costlier technologies, implying regional economic impact. Nevertheless, the assessment of hydropower potential in this study can be a fundament for the further investigation of socioeconomic interests of hydropower variation caused by climate change. As a matter of fact, the regional assessment performed in this study provides the necessary information for integration into regional version of integrated assessment models (IAM) in order to improve their water-energy management and expansion representation while taking into account socio-economic factors for national sustainable mitigation and adaptation policy making.

Specific comments: (1) I suggest the authors to revise the introduction. The first paragraph doesn't read very well. Also, it is important to highlight the objectives of the study and the key questions addressed at the end of introduction.
Response: Thanks for the comments. We have revised the introduction and extended the last two paragraphs to further clarify the key questions and objectives in the revised manuscript.

(2) While the gross generation potential provides useful information on the potential future changes, it is not an indicator of actual power generation potential. So, it will be important to consider whether the available flows can be utilized to the fullest as well as various locational and technological constraints. The study doesn't provide any information on this aspect.
Response: We agree that the gross hydropower potential (GHP) is far from the actual power generation potential, and have further clarified this in the revised manuscript. Different hydropower potentials exist, namely gross hydropower potential, technical potential, economic potential and exploitable potential (Zhou et al., 2015), which address the multiple constraints of water resources, hydropower technology, economy and environmental protection. However, it is difficult to project the changes of all these potentials (except for GHP, which is constrained only by discharge change) in the future without the use of an integrated assessment model to predict the future economy and technology developments. We focus on the impact of future climate change on the hydropower potential in the present study, and expect to provide a primary reference for the assessment of the impacts of climate change on actual hydropower generation.

Zhou, Y., Hejazi, M., Smith, S., Edmonds, J., Li, H., Clarke, L., Calvin, K. and Thomson, A. (2015) A comprehensive view of global potential for hydro-generated electricity. Energy Environ. Sci., 8(9): 2622-2633.

(3) Moreover, the analysis low flows would provide further insights on how the run-off-the-river hydropower generation capacity would be affected in the future. The annual mean and seasonal changes do not necessarily reflect such effects unless all runoff will be captured in reservoirs.

Response: Thanks for the suggestion. We agree with the reviewer that regional results may be affected by the non-representation of the run-of-the-river plants. We did not consider the run-of-the-river stations for lack of hydropower station types in the current database. According to https://en.wikipedia.org/wiki/List_of_run-of-the-river_hydroelectric_power_stations, there are 10 run-of-the-river power plants over 100MW in China presently. The large projects represent a total maximum generating capacity of 4,884 MW, i.e. 2% of the installed 220GW capacity. Many projects under 10MW power plants are not reported within an updated, consistent and exhaustive database across regions. We clarify in the manuscript that we do not take into consideration those run-of-the-river plants. We have added low flow changes in the DHP analysis in the revised manuscript.

(4) In page 4, line 2 it is noted the reservoir module is similar to the one in van Vliet et al. (2016). What are the differences in the findings? It may be worthwhile highlighting the differences.

Response: Thanks for the suggestion. We definitely build out of van Vliet et al. (2016) analysis. We specify in the literature review section the scientific gaps between van Vliet et al. and other papers, with respect to the overall objective of the paper, which is to support the sustainable regional development of hydropower in China. In brief, changes of hydropower potentials of reservoirs in China projected by this study and van Vliet et al. (2016) show similar conclusions. According to the objectives of the paper, we complement other's paper findings with the following: First, we used multi-model simulations but van Vliet et al. (2016) used only one global hydrological model which allows us to provide a more exhaustive uncertainty quantification. Secondly, the potential hydropower generation is assessed only over the existing plants in van Vliet et al. (2016), while in this study we assess the hydropower potential generation over different potential development scenarios (installed, gross). Finally, our analysis focuses on regional variability, which is important for development consideration.

(5) Page 5, Line 25: Do all models use the same reservoir operation module?
Response: Yes. We specify that the reservoir operations are tuned for each individual reservoir characteristics, i.e. reservoir capacity, and mean annual inflow in particular.

(6) Page 6, Line 24: Change "great" to "high".
Response: Changed.

(7) Page 6, Line 12: Why and how were these 447 reservoirs selected?
Response: We used as many reservoirs as possible in the study. Those chosen are mostly large reservoirs/dams with key information (i.e. location, storage capacity, dam height) were selected from the GRanD database. This is consistent with other large managed hydrology studies (Hanasaki et al 2008, Döll et al, 2009; van Vliet et al. 2016)

Hanasaki, N., Kanae, S., Oki, T., Masuda, K., Motoya, K., Shirakawa, N., Shen, Y., and Tanaka, K.: An integrated model for the assessment of global water resources – Part 2: Applications and assessments, Hydrol. Earth Syst. Sci., 12, 1027-1037, 10.5194/hess-12-1027-2008, 2008.
Döll, P., Fiedler, K., and Zhang, J.: Global-scale analysis of river flow alterations due to water withdrawals and reservoirs, Hydrol. Earth Syst. Sci., 13, 2413-2432, 10.5194/hess-13-2413-2009, 2009.
van Vliet, M. T. H., Wiberg, D., Leduc, S., and Riahi, K.: Power-generation system vulnerability and adaptation to changes in climate and water resources, Nature Clim. Change, 6, 375-380, 10.1038/nclimate2903, 2016.

(8) Page 7, Line 19: Expand this section or delete this line.
Response: Removed.

(9) Section 3: I see that a lot of information is provided as supplementary material. For completeness, I suggest the authors to bring some of these tables to the manuscript

itself.
Response: Thanks for the suggestion. We have presented the Table S4, S7 and S10, which show the ensemble means of multimodel, in the revised manuscript.

(10) Page 7, Line 27: change "is" to "are"
Response: Corrected.

(11) Page 12, Line 11: Change "great" to "large"
Response: Changed.

(12) What is the rationale behind the use of different alpha, beta, and K values? This needs to be discussed in relation to the implications on results.
Response: We have clarified the rationale of the sensitivity tests in the revised manuscript. The different values of the parameters in Eq. (1) represent different regulation efficiencies of reservoirs. We performed experiments with different parameter values to show the sensitivity of the results to the regulation coefficients.

(13) Evaporation from water retention behind large dams could increase largely under warmer future climate which can reduce runoff. Is this considered in the present study?
Response: Thanks for the comment. We agree that evaporation from reservoir water surface is not negligible and it will be considered in the future work. We did not consider it yet in the present study as the annual evaporation from reservoir surface usually accounts for a relatively small portion of the annual release of large reservoirs (Fekete et al. 2010). According to Liu et al. (2015), evaporation amount from reservoirs is $2.8\times10^{10} m^3$ in total, only 0.62% of the total runoff in China and is much smaller than the uncertainty range estimated from the different hydrology models in this study.

Fekete, B. M., Wisser, D., Kroeze, C., Mayorga, E., Bouwman, L., Wollheim, W. M., and Vörösmarty, C.: Millennium Ecosystem Assessment scenario drivers (1970–2050): Climate and hydrological alterations, Global Biogeochem. Cycles, 24, GB0A12, 10.1029/2009GB003593, 2010.
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mand challenges water sector, Scientific Reports, 5, 11446, 10.1038/srep11446, 2015.

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