Hoang et al. Mekong River flow and hydrological extremes under climate change

Responses to reviewer#2 comments

By Long Phi Hoang

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We highly appreciate Reviewer#2 for his/her dedicated reviews and constructive comments on the manuscript. We have revised the manuscript following the comments and suggestions, as described below.

This article discussed the climate change impacts on river flow and hydrological extremes in Mekong river basin. The topic is important and has been studied by many researchers. Compared to previous studies, this work attempted to reduce the uncertainty involved in climate projection using the CMIP5 data, and also highlighted the influences on extreme events. In general, its organization is straightforward, the methodology looks reasonable, and results were clearly explained.

A few limitations:

Comment#1. This study was motivated to reduce the uncertainty involved in previous studies. However, was this goal achieved in this paper? I'd say very limited. The authors used the most recent climate projection data, ran them with established models, and then performed analysis. The only advance s compared to previous studies is the climate data, which results the paper less innovative.

Response: We acknowledge Reviewer#2's point to focus more on uncertainties in climate and hydrological impact projections in the manuscript. We have done further analyses to illustrate that our CMIP5-based assessment exhibit lower uncertainties compared to similar CMIP3-based assessments, both in climate change and hydrological impact signals. We compared our results with four CMIP3-based assessments for the Mekong region, including Eastham et al. (2008), Kingston et al. (2011), Lauri et al. (2012) and Thompson et al. (2013). These studies include multiple GCMs and provide results that can be reasonably compared to our results. We have added a separate section (*5.1 Comparison: Impact signal and improvements in uncertainties*) to illustrate and discuss improvements in uncertainties relating to climate and hydrological impact projection. We also added one table (*Table 4*) to the manuscript present the cross-studies comparison.

Table 4. Comparing projected precipitation and discharge changes across studies. Signal agreement is indicated by number of GCM/scenarios projecting a reducing signal over the total GCMs/scenarios considered.

	Eastham et al. 2008	*Kingston et al. 2011*	*Lauri et al. 2012*	*Thompson et al. 2013*	***Hoang et al. 2015 (this study)***
Annual precipitation change range	*0.5% to 36% (A1B)*	*-3% to 10% (up to 6°C warming)*	*-2.5% to 8.6% (A1B)* *1.2% to 5.8% (B1)*	*-3% to 12.2% (2°C warming)*	***3% to 4% (RCP4.5)*** ***-3% to 5% (RCP8.5)***
Annual precipitation signal agreement	*Not available*	*3 out of 7*	*1 out of 10*	*3 out of 7*	***1 out of 10***
Annual discharge change range	*Not available*	*-5.4% to 4.5% (up to 6°C warming)*	*-10.6% to 13.4% (A1B)* *-6.9% to 8.1 % (B1)*	*-14.7% to +8.2% (2°C warming)*	***3% to 8% (RCP4.5)*** ***-7% to 11% (RCP8.5)***
Annual discharge change signal agreement	*Majority of GCMs show increasing trend*	*3 out of 7*	*3 out of 10*	*4 out of 7*	***1 out of 10***

Next to using updated climate data, we have revised the abstract, discussion and conclusion sections to highlight another important innovative aspect regarding its focus on changes in hydrological extremes (both low and high flow conditions). We found robust evidences of increases in hydrological extremes, and therefore recommend a shift in research focus and water management, towards better attention to low-probability but high-damage events. We have also included these to the revised abstract:

Added text:

"*The scenarios ensemble, however, show reduced uncertainties in climate projection and hydrological impacts compared to earlier CMIP3-based assessments.*"

"*Climate change induced hydrological changes will have important implications for safety, economic development and ecosystem dynamics and thus require special attention in climate change adaptation and water management.*"

Comment#2. The authors also mentioned the missing human part in the discussion. Anthropogenic factors such as land use change and hydropower operation affect the results significantly. It would greatly improve the value of the study if some of the effects can be integrated with the model.

Response: We fully agree with Reviewer#2's point on the potential impacts of anthropogenic factors on the Mekong's hydrology. Acknowledging these, we plan to implement a follow-up study, where land use change, particularly agricultural land expansion, and hydropower dams development in the Mekong basin are exclusively included. Regarding the current study, we focus solely on climate change in order to highlight the importance of this particular factor, as well as to establish the required physical boundary condition for further considering other anthropogenic factors. Furthermore, we have added more text to the manuscript to further acknowledge and discuss the possible impacts of anthropogenic factors on the Mekong's hydrology including land use change.

Specific comments:

Comment Page 11654, line 13: suggest revising the sentence

Response: Following Reviewer#2's suggestion, we have revised the sentence to improve readability: "*Notably, all earlier studies used the SRES emission scenarios (Nakicenovic et al., 2000), which were developed for the Climate Models Inter-comparison Project phase 3(CMIP3).*"

Comment Page 11658, line 3: do you consider land use change for the two calibration periods and how?

Response: We agree with Reviewer#2 that land use change in the past might have impacts on the river flow and including this factor could potentially improve calibration and validation results. However, we could not include land use change when calibrating and validating the hydrological model due to several technical reasons. Our calibration and validation cover the 1981-2001 period, when land use and land use change data is still rather limited for the Mekong region. Given unavailable temporally-continuous data, introducing different land use layers for different points in time will likely result in abrupt shifts in the simulated river flow, which is undesirable in our climate change impact assessment study. Given relatively good performance of the hydrological model during calibration and validation, we believe that the modelling setup is sufficiently reliable for our research objective.

Comment Page 11659, line 21: It is biased to assume that GCMs perform well in producing historical data would also do great in projection. If that is true, you don't need to select 5 GCMs.

Response: We agree with Reviewer#2 that well-performing GCMs for the historic period do not always imply good projection capacity. However, we believe that GCMs selection based on historic performance, which is a common choice amongst recent studies (e.g. Västilä et al., 2010; Lauri et al., 2012), is a relatively efficient and reliable approach. In particular, good performance for historic climate is an indication of better parameterizations, thus better capacity to capture the climatic features (e.g. monsoon driven precipitation) in the Mekong basin.

We have added extra information to the method section to explain this: "*We selected those GCMs that better reproduce historic tropical temperature and precipitation conditions, implying their suitability to be used in the Mekong region.*"

Comment Line 11660, line 9: what do you mean by "high climate change scenario"?

Response: Thank you for checking the manuscript very carefully! We have revised the sentence to "*The RCP8.5 is a high radiative forcing scenario assuming a rising radiative forcing leading to 8.5W/m2 by 2100 (Riahi et al., 2011).*"

Comment Suggest revision Figures: I'd suggest adding a spatial map showing discharge changes like figure 4 so as to better illustrate the results

Response: We thank Reviewer#2 for the suggestion. However, we think it is best to restrain from producing such maps for several reasons. We believe that spatial differences across the basin have been adequately reported throughout the manuscript, mostly by Table 3 (discharge changes at seven representative locations); Figures 5; 6; 7 and 8 (discharge changes at three locations representing upper, middle and lower sub-basins). Furthermore, presenting spatial data would require averaging data so as to avoid having too many figure panels. This averaging does not really match with our objective to present results on hydrological extremes, which are better presented at representative locations.

Comment: Land use is an important factor in hydrological modelling and expects to change with time. Do you include this in your model?

Response: Our hydrological model does account for land use situation in the modelled river basin, as mentioned in the methodology section. Regarding land use change, we agree with Reviewer#2 that this factor can have implications for hydrological change in the Mekong basin. However, in this paper we focus solely on climate change in order to highlight the importance of this particular factor, as well as to establish the required physical boundary condition for further considering other anthropogenic factors. Please also refer to our responses to your comment#2 above on this matter.