Hydrol. Earth Syst. Sci. Discuss., 9, C3863–C3871, 2012
www.hydrol-earth-syst-sci-discuss.net/9/C3863/2012/

Hydrology and Earth System Sciences Discussions

Interactive comment on "Future changes in Mekong River hydrology: impact of climate change and reservoir operation on discharge" *by* H. Lauri et al.

H. Lauri et al.

matti.kummu@iki.fi

Received and published: 17 August 2012

We appreciate a lot the careful work of the anonymous reviewer #1 and her/his thoughtful comments on the manuscript. The manuscript has been revised following the comments and suggestions, as detailed below. We believe that these revisions have led to a significant improvement of our manuscript.

REVIEWER#1: 1. General comments In this paper, a model chain is used to assess future changes in hydrology of the Mekong river including reservoir operation of future dams. In order to assess the impact of different climate change scenarios, the authors

choose to use an ensemble of coupled general circulation models (GCMs). The hydrology of the basin is modelled with only one model, though. Calibration is performed mainly for one station in the lower basin and the efficiency coefficients yield very good results. It is found that the impact of dam operation is stronger than the impact of climate change in the hydrology of the Mekong River. Even counting in all the model related and scenario related uncertainties, dam operation seem to have a significant impact in both dry and wet season. The paper is in general well written and presents an important contribution to the current discussion around the topic of future change in the hydrology of the Mekong River. It should be published, after a few minor comments are addressed.

RESPONSE: We appreciate a lot reviewer's excellent comments and we have addressed those as follows below.

REVIEWER#1: 2. Specific comments 2.1 The calibration was performed mainly based on one time series (discharge at Stung Treng). However, tributaries in the basin contribute very differently to total runoff during dry and wet season. For example, an important contribution to the flood hydrograph comes from the sub-catchments on the mountain range along the border between Vietnam and Laos. One can imagine that any of your CC scenarios will cause a change in spatial precipitation patterns, which may reinforce or weaken the importance of these sub-catchments (Eastham 2008). Since you did not present any measure of the efficiency for tributaries, it is impossible for the reader to know if the spatial heterogeneous climate change signal will be well translated into the hydrology of the basin. In simpler terms, there is an equifinality problem that has to be accounted for in the final uncertainty estimation, or at least discussed more thoroughly.

RESPONSE: The calibration and validation of the model was done not only for Stung Treng but also the other five main river stations from Chiang Saen to Pakse (see Table 3), as stated in Section 3.2. In all of those stations the model performs well (Nash-Sutcliffe efficiency coefficient varied from 0.819 to 0.922 during the calibration period

and from 0.779 to 0.941 during the validation period; see Table 3).

Due to the very sporadic discharge data in the Mekong tributaries, we were not able to validate the model in those in detail within this project. In a separate ongoing project, we have validated with updated VMod model application to the Mekong (with 1 km model grid) the model performance in three tributaries with data for more than ten years (Ban Tha Kok Daeng, Sebang Fai, Ban Kamphun). Attached (Fig 1 of the response attachments) is the summary of the results.

In these tributaries the model performed rather well. This is, however, yet unpublished data and we cannot refer to it yet. But we believe that those validation results in six mainstream stations together with this preliminary information from three tributaries confirm that the model is performing well in all the sections of the basin.

To enhance the spatial understanding of the model performance and climate change impacts on hydrology, we added a new tile to Fig. 3 (Fig. 3C), where we present spatially the simulated runoff and how the climate change impacts on it. This gives much better picture on the heterogeneity of the issue. Moreover, we added a spatial pattern for average temperature (Fig 3A) and average precipitation (Fig 3B). The new Fig 3 is attached to this response as Fig 2. The runoff results are also briefly discussed in the main text and basin wide change in runoff due to climate change is summarised in Table 5.

REVIEWER#1: 2.2 Model chain - The authors seem to want to stress the novelty of including GCM uncertainty into CC impact assessment. That is a valuable contribution to the present discussion of CC impacts in the Mekong hydrology, but your manuscript falls short of a quantification, discussion or comparison with other sources of uncertainty. For example, comparing different hydrological model parametrizations (also related with the problem of equifinality discussed above) or different kinds of climate downscaling methods.

RESPONSE: We have added a short note on sources of hydrological model uncertainty

to the end of discussion section. Rigorous uncertainty estimation was left for further studies, as a single model run requires now rather long time to compute, and typical uncertainty estimation methods require thousands of model runs.

We have added a short discussion on the influence of different downscaling techniques and its contribution to uncertainty in the results. See the following text: "(...) we used one particular downscaling technique, whilst there are many other appropriate methods available, both statistical (e.g. Teutschbein et al., 2011) and dynamical (e.g. Giorgi, 2006). However, uncertainty resulting from different downscaling techniques is generally smaller than from different GCMs (Prudhomme and Davies (2009). "

REVIEWER#1: - If there is no critical appraisal of the statistical downscaling of GCM data, its description should be reduced to a minimum: there are enough papers out there dealing with this topic.

RESPONSE: We have reduced the description of the downscaling as suggested to the following: "As the spatial resolution of GCMs is too coarse for basin-scale hydrological modelling, we downscaled the climate parameters (precipitation and temperature) using a delta method (see, e.g. Diaz-Nieto and Wilby, 2005; Choi et al., 2009). Changes in the monthly GCM data between a baseline (1981-2005) and future period were calculated using a moving window of 25 years for each month (i.e. January, February, March, etc.). Delta factors were calculated using Eq. 1 and 2.

Δ_TMP=(T ÌĚ_(series,i)-T ÌĚ_(ref,i))/σ_(ref,i) (Eq 1)

Δ_PRE=P ÌĚ_(series,i)/P ÌĚ_(ref,i) (Eq 2)

In Eq. 1 and 2, T ÌĚ_(series,i) and P ÌĚ_(series,i)are the (25 year) average for month i of a particular month in the GCM time series; T ÌĚ_(ref,i) and P ÌĚ_(ref,i) are the (25 year) averages for temperature and precipitation for the reference period 1981-2005 for month i; and σ_(ref,i) is the standard deviation of the monthly average temperature during the reference period for month i.

These delta factors were used to perturb a daily time-series created by replicating the observed 25 years. The delta factor for a specific month was used to adjust all daily data in that month. Temperatures were increased by the amount of standard deviations denoted by the delta factor and precipitation was multiplied with the delta factor. The average temperature, minimum temperature, and maximum temperature were all adjusted using the delta factor found in the GCM data for the average temperature. "

REVIEWER#1: 2.3 Manuscript structure There are several papers and reports dealing with climate change impacts and water management in the Mekong basin. The strengths of this particular manuscript are a) the use of an ensemble of GCMs and b) in the author's own words "novel reservoir operation optimization algorithm". a) is sufficiently discussed, but the authors seem to forget b) in the structure of the paper and relegate it to the supplement. This method deserves more attention and should be included in the main manuscript.

To compensate, some parts could be presented in the supplement and not in the main manuscript (or even deleted). The description of the meteorological data including Fig. 1 could be moved to the supplementary material. The spatial distribution of the stations is normally important, but you don't present any model result concerning spatially distributed variables, so you don't need to show the spatially distributed input. Instead, you should present a spatially distributed model result, like soil moisture or annual runoff in order to strengthen the model validation. The same applies to the description of the statistical downscaling methodology. There are enough papers out there dealing with this topic and unless you discuss the contribution of the downscaling to the uncertainty of your estimations (which you should) you don't need to describe it and may move it to the supplement (or simply delete it).

RESPONSE: The reservoir operation optimization algorithm is now presented in more detail in the main text whereas we still kept a large part of it in the supplement as in our opinion the equations etc. go into too much detail.

We felt that it is important to keep Fig 1 in the main text to show the density of the observation stations (temperature and precipitation). Moreover, it is necessary to show the locations of the discharge measurement stations against which we have calibrated and validated the hydrological model.

We agree that it is good to also include spatially distributed model results. We thus added the following figures to the paper - Baseline for temperature and precipitation to Fig 3A and Fig 3B, respectively - New tile to Fig 3 (Fig. 3C), where spatial runoff map and impact of climate change on runoff are presented

We have rewritten the description of the statistical downscaling methodology (see above).

REVIEWER#1: 3 Technical Corrections

- page 6570, line 8: "we downscaled the output"

- page 6574, line 20: "precipitation"

- page 6592, lines 15-23: is this really relevant to this paper? Remember that the paper is already too long and you did not discuss reservoir operation in the main text.

- page 6594, line 15: "(...) uncertain. We see (...)"

- page 6595, line 12: "Maa-ja vesitekniikan (...)" this is not english, maybe you should consider writing it italics.

RESPONSE:

- corrected

- corrected

- we agree that this paragraph is not necessarily needed in the paper and thus it is deleted from the revised paper

- corrected

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 9, 6569, 2012.

Sub-catchment	NS	computed discharge m^3/s	measured discharge m^3/s	computed/ measured discharge	Comparison period
Ban Tha Kok Daeng	0.535	100	147	0.68	04/1986-03/2002
Sebang Fai	0.713	308	313	0.98	04/1985-03/2005
Ban Kamphun	0.669	1158	1346	0.86	04/1985-03/2005

Fig. 1. Table where tributary validation of hydrological model is presented

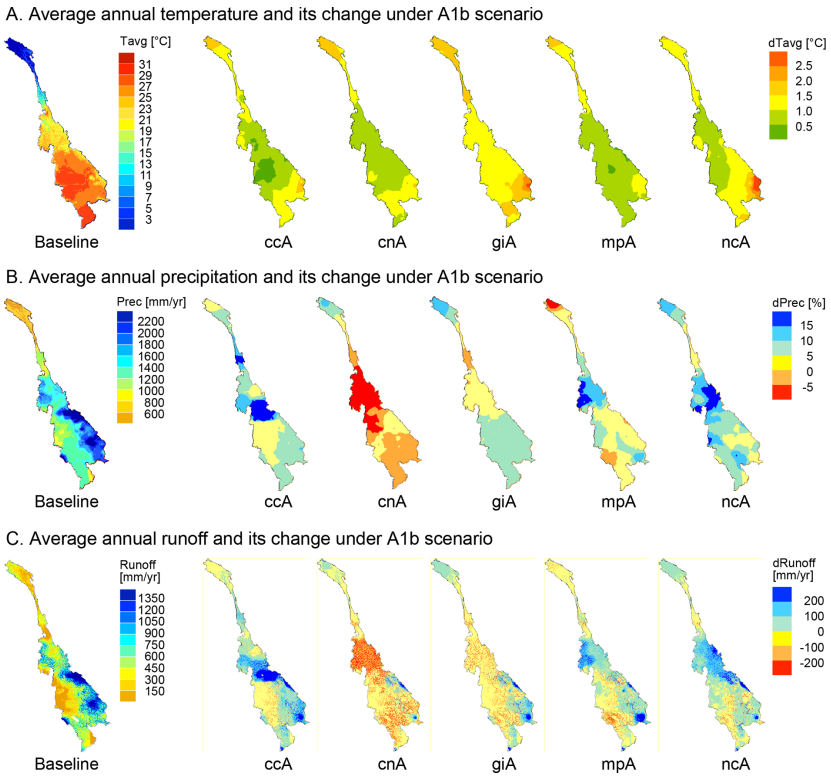

Fig. 2. new Fig 3 for the main text