Revision notes for "Attribution of climate change and human activities to streamflow variations with a posterior distribution of hydrological simulations"

(hess-2021-528)

We would like to thank the editors and reviewers for the constructive feedback. We appreciate the valuable and thoughtful comments, which have certainly helped to improve the presentation and quality of our manuscript. We have updated our paper according to your comments and the detailed responses to the comments are described as follows.

Answers to the reviewers in blue.
Modifications of the manuscript in orange.

To Reviewer #1:

General Comments:

Runoff change attribution is an interesting research topic. In this manuscript, the authors proposed a novel framework to quantitatively evaluate the contributions of climate change and human activities to runoff changes in the Lancang River Basin. It provides an optional method for attribution of runoff changes on watershed scale, which is valuable. Generally, the manuscript is well organized and presented interesting results, but the description of the innovation of the study should be enhanced.

Responses to comments one by one:

1. The authors did not present the advantages of the proposed method clearly. Please clarify what's the innovation of this study.

Response: Thanks very much for your comments. Hydrological simulation is the main method to quantify the contribution rate (CR) of climate change (CC) and human activities (HAs) to the change of streamflow in the basin, and there is a phenomenon of "equifinality for different parameters" in hydrological simulation. Therefore, the main scientific contribution (innovation) of our study is to reduce the impact of "Equifinality" in using hydrological simulation to quantify the CRs of the CC and HAs. The accurate quantitative results have important scientific value for the development of effective water resources utilization and ecological flow regulation policies in the basin. In the abstract, we modified a part of the content to strengthen the innovation of this study in Page 1 Line 14-16, which as follows:

In our new quantitative framework, the uncertainty of hydrological simulations is first considered to quantify the impact of "equifinality for different parameters", which is common in hydrological simulations.

2. Line 171. I suggest the authors clarify the reasons for selecting the dataset in the study (GMSWU). Is it because of the higher accuracy of the data set, difficult to obtain other field data or some other reasons?

Response: Thank you very much for your comments. You are right that the main reasons for selecting the dataset in the study (GMSWU) are that it is difficult to collect water withdrawal data related to human activities in the Lancang River basin. Therefore, after referring to some published related literatures (Han et al., 2019, Huang et al., 2018), we choose the GMSWU dataset for related calculations. We also added a description of the reasons for choosing the GMSWU dataset in the revised manuscript. The added content (Page 6, Line 180-181) is as follows:

This dataset is used in this study because it is difficult to collect water withdrawal data related to human activities in the LR Basin, and this dataset has been successfully applied in this basin in other studies (Han et al., 2019).

References:

Han, Z., Long, D., Fang, Y., Hou, A., Hong, Y., 2019. Impacts of climate change and human activities on the flow regime of the dammed Lancang River in Southwest China. J Hydrol, 570: 96-105.

Huang, Z., Hejazi, M., Li, X., Tang, Q., Vernon, C., Leng, G., Liu, Y., Döll, P., Eisner, S., Gerten, D., Hanasaki, N., Wada, Y., 2018. Reconstruction of global gridded monthly sectoral water withdrawals for 1971–2010 and analysis of their spatiotemporal patterns. Hydrol. Earth Syst. Sci., 22(4): 2117-2133.

3. Line 181: It is not "avoid the common phenomenon of ‘equifinality for different parameters’ in hydrological simulation", in fact, the phenomenon of "equifinality for different parameters" in hydrological simulation is unavoidable. Suggest to revise it to "reduce the impact of "equifinality for different parameters" in hydrological simulation".

Response: Thanks very much for your suggestion. We acknowledge that " equifinality for different parameters" in hydrological simulation cannot be completely avoided. We run the model 1000 times, which is not to reduce the equifinality, but to quantify them and better to separate the CC and HA impacts on streamflow. The phenomenon of “Equifinality” in hydrological simulation means that different parameter combinations have similar objective function values in the simulation process, which was originally introduced to hydrology by Beven (1993). Our study is to solve the possible impact of “Equifinality” in hydrological simulation on the quantitative results, and proposes a new quantitative framework to reduce this impact. Therefore, we also compared the effect of "Equifinality" on the quantification results in Section 5.1 (5.1 How does parameter uncertainty affect the quantitative results?), and found that the quantization results of the two simulations with the same objective function value are completely opposite. In the revised manuscript, we have corrected this descriptive error you pointed out, and the modified content is as follows (Page 8, Line 191-193):

In this section, we will introduce a new quantitative framework to reduce the influence of the common phenomenon of "equifinality for different parameters" in hydrological simulation on the quantitative results, by constructing the posterior distribution of streamflow simulations during the implementation process.

References:

Beven, K., 1993. Prophecy, reality and uncertainty in distributed hydrological modelling. Adv Water Resour, 16(1): 41-51.

4. Line 245, If multiple break points are detected for the annual runoff time series, how to select the break points and divide the whole period to natural period and impacted period? The authors should clarify this in the text.

Response: Thank you very much for your useful comments. In fact, for the time period division of the runoff series, we selected three break point testing methods for cross-validation (Fig. 1). As shown in Fig. 1, all three methods indicated that the annual runoff sequence of the Yunjinghong station changed abruptly in 2005. Therefore, for brevity, we only show the result of the MK break point test in the paper.

As described in section 3.2 of Dey et. al (2017), if there are multiple break points in the annual streamflow time series, multiple points need to be screened according to the types of main human activities within the study area. In this study, there is only one break point in the annual streamflow time series. In addition, Dey et. al pointed out that "*Historical records like time of construction of dam/diversion structures also help in selection of representative change point.*" In the Lancang River Basin, the construction of the Xiaowan Hydropower Station began in December 2004, so it is reasonable to choose 2005 as the break point in this study. Likewise, in Section 5.4 of our revised manuscript, we added some content to explain how to select a single break point when multiple break points exist (Page 34, Line 752-756).

First, if there are multiple break points in the annual streamflow sequence, then when selecting the unique break point, it is necessary to consider the abrupt change points of the time series of other meteorological elements (precipitation, temperature, etc.) in the basin. At the same time, the impact of strong human activities (reservoir construction, large-scale water transfer project construction, etc.) on the abrupt change of streamflow in the basin should also be considered (Dey and Mishra, 2017).

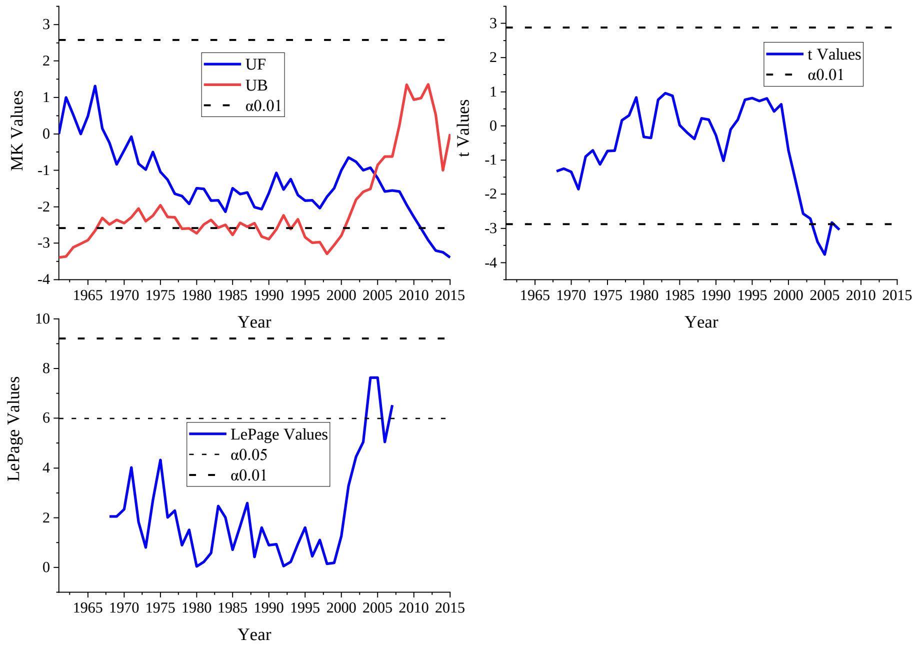

Fig. 1. Results of MK test, Moving t test and LePage test of the annual streamflow at Yunjinghong station from 1961 to 2015

References:

Dey, P., Mishra, A., 2017. Separating the impacts of climate change and human activities on streamflow: A review of methodologies and critical assumptions. J Hydrol, 548: 278-290.

5. Line 290-303, The proposed method of quantifying the contributions of climate change and human activities to watershed runoff changes may not guarantee that the sum of the contributions equals to 100% (e.g., equations 6 and 7). This is to say, there is an intersection between climate change and human activities. It is recommended that the authors should give explanations about this issue in the discussion section.

Response: Thanks very much for your comments. We admit that there are uncertainties in the method to separate the contribution rate of climate change and human activities to streamflow change, because it does not consider the mutual influence and overlap between the two impact factors. However, since the impacts of climate change and human activities on the hydrological process of the basin are very complied and interacted, it is still a challenge to completely separate the impacts of climate change and human activities on streamflow variations. Therefore, in this revised manuscript, we have revised the discussion of uncertainty about this method in Section 5.4.

The revised discussion in Section 5.4 is described in Page 33 - 34, Line 738 - 764, which is as follows:

A new quantitative framework for calculating the CR of CC and HAs to watershed streamflow variations was proposed in this study, and it was successfully applied to the

LR Basin with relatively accurate results. From our perspective, this method can effectively reduce the influence of the "equifinality for different parameters" that may exist in the use of hydrological simulation methods to quantify the CR of CC and HAs. At the same time, we also believe that this framework can be applied to other watersheds based on the following aspects. First, in the section 4.4, the Budyko framework and sectional water withdrawal data within the basin were used to compare with the new framework. Second, the results of the comparison with published research on the LR Basin (Han et al., 2019) also proved that the framework has good accuracy and applicability. Third, in the process of comparing with the new framework, we fully considered the impact of various HAs within the study area, including five types of water withdrawals (i.e., irrigation, livestock, living, mining, and manufacturing), the impact of reservoir storage and the land use/land cover change. Of course, due to the highly nonlinear relationship between the parameters of the hydrological model, we suggest that readers ensure that the selected simulation results with NSEs greater than 0.75 are large enough when applying the novel framework in other research areas (this study had 500 simulations). It is undeniable that this method still has certain uncertainties and limitations when it is applied to other watersheds. First, if there are multiple break points in the annual streamflow sequence, then when selecting the unique break point, it is necessary to consider the abrupt change points of the time series of other meteorological elements (precipitation, temperature, etc.) in the basin. At the same time, the impact of strong human activities (reservoir construction, large-scale water transfer project construction, etc.) on the abrupt change of streamflow in the basin should also be considered (Dey and Mishra, 2017). Finally, a unique break point is selected to divide the research time series into a natural period and an impacted period, and then the quantitative framework proposed in this study can be applied. Second, because the SWAT model has good applicability at the Yunjinghong station in the LR Basin, it can meet the 500 best simulation requirements set by the framework proposed in this study, but the hydrological model may have different applicability in different research areas. Therefore, the application of this framework in other research areas may have limitations, which need to be further verified. Third, because this study uses the parameter combinations obtained by the natural period to input the meteorological element data of the impacted period for calculation, this may also bring uncertainty to the calculation results, which is usually called “transferability” (Fu et al., 2018).

References:

Dey, P., Mishra, A., 2017. Separating the impacts of climate change and human activities on streamflow: A review of methodologies and critical assumptions. J Hydrol, 548: 278-290.

Fu, G., Charles, S.P., Chiew, F.H., Ekström, M., Potter, N.J., 2018. Uncertainties of statistical downscaling from predictor selection: Equifinality and transferability. Atmospheric research, 203: 130-140. DOI: 10.1016/j.atmosres.2017.12.008

Han, Z., Long, D., Fang, Y., Hou, A., Hong, Y., 2019. Impacts of climate change and human activities on the flow regime of the dammed Lancang River in Southwest China. J Hydrol, 570: 96-105.

6. Line 475, Why the authors present the normalized runoff process of the Yunjinghong station? Please clarify the reasons.

Response: Thanks a lot for your comments. Because the Lancang-Mekong River is a cross-border river in Southeast Asia, the runoff data was standardized in accordance with the requirements of the Information Center of the Ministry of Water Resources of the People's Republic of China, the provider of the runoff data in this study. In the revised manuscript, we have also made relevant explanations. The added explanatory content is on Line 482-484, Page 20, as shown below.

According to the requirements of the Information Center of the Ministry of Water Resources, the data provider, this study standardized the observed and simulated runoff curves of the Yunjinghong station.

7. Section 4.4, In this section, the authors compared the results of the new quantitative framework proposed by the manuscript with two simpler methods. What's the advantage of the proposed method over the two methods? please clarify.

Response: Thanks very much for your comments. In this study, we used two methods to compare with the calculation results of the novel quantitative framework proposed in this study. We have discussed the shortcomings of these two simple methods compared with the quantitative analysis framework of this study in Section 3.5 to highlight the innovation of this paper. The revised content is described in Page 16, Line 382 – 386, which is as follows:

It should be pointed out that here we use two seemingly simpler methods to verify the computational results of the new framework proposed in this study. However, this does not reduce the innovation of this study, as the new framework has the following significant advantages over the other two methods: 1) The new framework can perform quantitative calculations on the annual and monthly scales; 2) It has relatively less data requirements; 3) It has a more explicit physical meaning.

8. Fig 15, (1) How did you produce land use maps? Please clarify the satellite data that you used. (2) The presented land use maps in 1980, 2000, 2010 and 2015 look like similar, no obvious land use changes can be identified. (3) Figure 15 shows 6 types of land use while table 9 shows 7 types. They should be consistent.

Response: Thank you very much for your comments. (1) The land use dataset used in this study is downloaded from the Geographic Information Monitoring Cloud Platform (http://www.dsac.cn/), with a spatial resolution of 30 meters, providing land use information in the whole range of China. This study uses ArcGIS software to intercept the land use data in the Lancang River Basin. (2) In the revised manuscript, we have replaced the Figure 15, and only put the land use data of the Lancang River Basin in

2015 for display. (3) In Figure 15, the land use information we show is the first-level type information of the Lancang River Basin, while the permanent glacier in Table 5 is second-level type and belong to water in Figure 15.

For the above three comments, we have also made corresponding revisions in the revised manuscript. The modified content is as follows:

(1) Page 7, Line 173-176

In this study, to analyze the land use change in the LR during the historical period, we collected five periods of land use data in the 1980s, 1990s, 2000s, and from 2010 to 2015, and this data set was downloaded from the Geographic Information Monitoring Cloud Platform (http://www.dsac.cn/), with a spatial resolution of 30 meters.

(2) Page 32

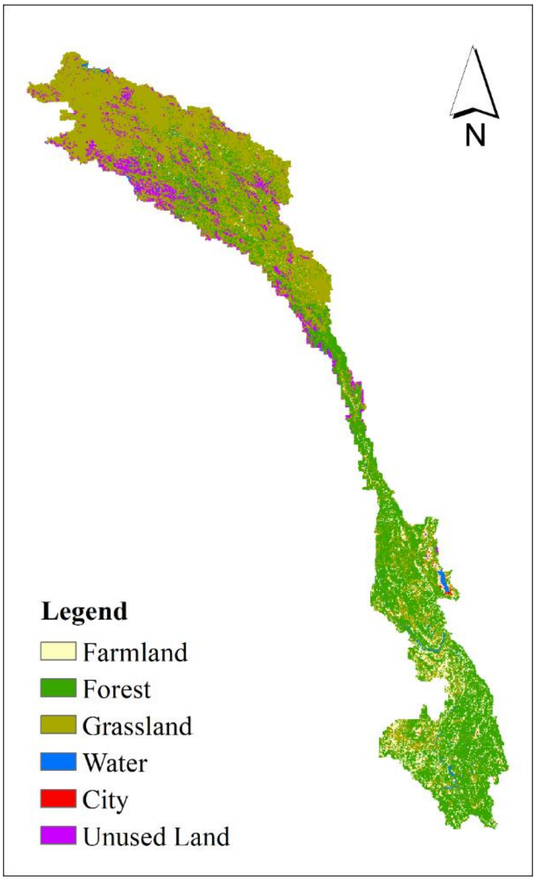

Fig. 15. Land use classification in the Lancang River Basin in 2015.

(3) We added an explanation for this comment in Page 31, Line 704.

(Nation: Permanent glacier in Table 5 is second-level type which belong to Water)

Technical corrections:

9. In addition, the format of the listed references is not uniform. For example, some references have DOI information, but some do not (Lines 831, 846, 915, etc).

Response: Thanks very much for your suggestion. We have performed a detailed review of the reference format in the revised manuscript, and added missing DOIs to ensure a consistent format for all the listed references.

10. If some nouns have been abbreviated in the manuscript, please use the abbreviation after the first occurrence and keep consistent throughout the whole text. For example, in line 13, please replace "contribution rate" with "CR". The same problem exists in other noun expressions in the manuscript. Please review the full text in detail and make consistent revisions (Line 16: human activities, Line 19: Lancang River Basin, etc.).

Response: Thank you very much for your comments. We have carefully checked all the abbreviations of nouns throughout the manuscript to ensure that they are full names the first time they occur, and all abbreviations thereafter.

11. Table 5, The titles of the hydrometeorological elements in the table should be consistent. At the moment, some of them are full names, and some of them are abbreviations.

Response: Thanks very much for your suggestion. We have modified Table 5 in the revised manuscript.

The revised Table 5 is as follows (Page 23):

Table 5 Hydrological and meteorological elements in the natural (1963 - 2004) and impacted periods (2005 - 2015) of the LR Basin and their changes during the two periods

Hydro-meteorological element	Streamflow (m^3/s)	Streamflow (mm)	Precipitation (mm)	Potential evapotranspiration (mm)	Temperature (℃)
Natural period	1801.5	398.6	863.8	832.5	5.8
Impacted period	1405.5	312.1	838.8	885.8	6.7
Amount of change	-396	-86.5	-25	53.3	0.9
Relative change (%)	-22.0	-22.0	-2.9	6.4	15.9