Hydrol. Earth Syst. Sci. Discuss.,
https://doi.org/10.5194/hess-2018-162-AC2, 2018

Hydrology and Earth System Sciences Discussions
Open Access

Interactive comment on "A simple tool for refining GCM water availability projections, applied to Chinese catchments" *by* Joe M. Osborne and F. Hugo Lambert

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Received and published: 20 July 2018

Thank you for taking the time to review our paper and helping to significantly improve it, particularly with regards the way the methodology is presented. Our responses to your comments are in bold font.

1. The term "biased correction" is not defined thoroughly in the study. I read the article but I could not relate the biased calculations with the methodology described by the authors. It was just hard to follow. A proper explanation of what specific "biases" are the author trying to correct is missing. For instance, are the authors trying to correct the CMIP5 Q data with a Budyko-type equation (Eq. 2). If this is it, I do not understand why

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are there using so many ways of calculating Q and related changes (climate, human, GCM-LSM, Qa, Qh, below combined) in the context of this study. Please explain this clearly.

The only "conventional" bias correction performed in this study is in section 3.2, using equation 10. This is used to correct P and E_p in the CMIP5 models so that they are in the correct part of the Budyko space, prior to accounting for changes. These corrected variables (which become P' and E_p') are then used to calculate Q^*, the Budyko corrected runoff, which is defined on page 7, line 30. We think some of the misunderstanding of this and the other methodology that you list in your other comments comes down to conflating methods, data and equations that are used for the historical 20th century analysis with those that are used for the projected CMIP5 analysis. The second referee has also commented that the methodological approach could be explained better. We will therefore add a flow chart (Figure 1) to the end of the introduction section in the revised manuscript to serve as an overview for the subsequent breakdown of the paper.

The key message from this is that the Budyko curve, or rather the updated Fu version (equation 3), can be used to both attribute past changes and help refine future changes. These two strands share common ideology but are attempting to tackle different problems and therefore use different equations. The flow chart more clearly emphasises this and even lists the equations that are used in each application. We will also divide the Data (section 2.1) and Methods (section 2.2) subsections into further subsections to more clearly differentiate the two applications.

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Also regarding what I just mentioned, if the authors are trying to perform this bias correction of CMIP5 data, I must say that I have a feeling that CMIP5 data for Q is already biased-corrected. For bias corrected I mean that it is made at least consistent in Budyko space (0<ET/P<1 and PET/P>0 and PET/P>ET/P) for most basins in the world. Strangely, the direct CMIP5 ET data does not comply with this (all over Budyko space), and hence I assume there has been some type of "bias correction" in this sense for CMIP5 Q data. The authors should check Q and ET data from CMIP5 data for their two basins and if so, please update.

The models will be coded in such away to avoid values that are not physically consistent, but we are almost certain that Q output from CMIP5 models is not biased corrected. It should just be a direct output. We check Q as directly available for 28 models with water balance-derived Q and do not see any sensitivity to this, stating "These findings are not sensitive to using directly simulated runoff instead (Fig. 10 and Table 1)." Further, we do not perform direct bias correction on Q, only P and E_p. The "correction" of Q is within the Budyko framework which also ensures that any values are physically consistent.

2. The authors describe the methods partly in the introduction, partly under "Data" and partly under "methods". This was confusing, and hard to follow in general. I would describe the methodology in chronological order and only under "Methods". In this way, you would also clear much needed space to expand the literature review which is now limited. Please mention the several studies that use the Budyko framework to understand water changes in Chinese basins. I mention here a few. The authors say that there is "little consensus on the contributions of these two components to the decrease in Q". I would say that there is plenty, mainly afforestation and/or flow regulation. And what is the Qh have to do with the bias correction. Again, please expand on this.

We think a lot of the methodology section will become more clear though incorporating the changes listed above in response to your comment 1, particularly with the inclusion of the flow chart. However, we do feel that the introduction as it is contains only information that is crucial to introduce the overarching ideas and, namely, the Budyko framework. While used in the methodology, the water

balance (equation 1) is introduced here because it is critical in discussing the partitioning of P into Q and E and how the Budyko formula helps to understand this. While we refer to equations 2-3 in the methodology to derive further equations, they are not directly used in any calculations in the form presented in the introduction. The data section only contains information on the data used, with equation 4 simply stating that we calculate E_p in the CMIP5 models directly from net surface radiation. Also the methods section is currently in chronological order in the sense that one needs to determine ω (equation 5), before calculating Q_a (equation 6), before Q_a can be used in the decomposition of Q_m in equation 7 (with Q_h also detailed in the section above equation 7). On top of the improvements to the structure of the methodology suggested above we will add some specific additional information to make things easier to follow, such as the following sentence to the paragraph underneath equation 8:

"In Eq. (8) we use ω values calculated using observed data and Eq. (5) for the 1951–2000 period (1.77 and 2.44 for the Yangtze and Yellow, respectively)."

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Of the Budyko-China basins studies that you list, only one is related to the Budyko framework. However, we agree that we should mention this study and some other high profile paper that we found. To the page 3, line 10 paragraph we will add:

"There is a wealth of literature that uses the Budyko framework to understand water changes in other Chinese basins (Yang et al., 2007; Xu et al., 2014; Liang et al., 2015)."

References:

Liang, W., Bai, D., Wang, F., Fu, B., Yan, J., Wang, S., Yang, Y., Long, D., and Feng, M.: Quantifying the impacts of climate change and ecological restoration on streamflow changes based on a Budyko hydrological model in China's Loess Plateau, Water Resour. Res., 51, 6500–6519, https://doi.org/10.1002/2014WR016589, 2015.

Xu, X., Yang, D., Yang, H., and Lei, H.: Attribution analysis based on the Budyko hypothesis for detecting the dominant cause of runoff decline in Haihe basin, J. Hydrol., 510, 530–540, https://doi.org/10.1016/j.jhydrol.2013.12.052, 2014.

Yang, D., Sun, F., Liu, Z., Cong, Z., Ni, G., and Lei, Z.: Analyzing spatial and temporal variability of annual water-energy balance in nonhumid regions of China using the Budyko hypothesis, Water Resour. Res., 43, W04 426, https://doi.org/10.1029/2006WR005224, 2007.

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With regards the "little consensus on the contributions of these two components to the decrease in Q", we think you are correct. Most papers suggest that human impacts have had a significant influence on runoff. We will change this sentence and add the useful references you provided:

"Most studies suggest a significant contribution of direct human impacts, including afforestation and land-use change (Huang et al., 2003; Liu et al., 2008; Zhang et al., 2008; Qiu et al., 2011), although methods and attributed contributions vary."

References:

Huang, M., Zhang, L., and Gallichand, J.: Runoff responses to afforestation in a watershed of the Loess Plateau, China, Hydrol. Processes, 17, 2599–2609, https://doi.org/10.1002/hyp.1281, 2003.

Liu, M., Tian, H., Chen, G., Ren, W., Zhang, C., and Liu, J.: Effects of land use and land cover change on evapotranspiration and water yield in China during the 20th century, J. Am. Water Resour. Assoc., 44, 1193–1207,

https://doi.org/10.1111/j.1752-1688.2008.00243.x, 2008.

Qiu, G. Y., Yin, J., Tian, F., and Geng, S.: Effects of the "Conversion of Cropland to Forest and Grassland Program" on the water budget of the Jinghe River catchment in China, J. Environ. Qual., 40, 1745–1755, https://doi.org/10.2134/jeq2010.0263, 2011.

Zhang, X., Zhang, L., Zhao, J., Rustomji, P., and Hairsine, P.: Responses of streamflow to changes in climate and land use/cover in the Loess Plateau, China, Water Resour. Res., 44, W00A07, https://doi.org/10.1029/2007WR006711, 2008.

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3. I tried to understand the methods:

a. You calculate historical Q from GRDC data (1951-2000) b. You calculate E as P-Q from a) (1951-2000) c. You calculate Ep from Penman-Monteith (1951-2000) d. You calculate Q from LPJ-LSM (1951-2000). Here I could not understand what is this estimate trying to represent? Is it land-use driven Q, climatic Q, combined Q, or what? It was hard to follow, the explanation of the multiple runs. e. You calculate Q from the CMIP5 data (2006-2100) as P-E. Here see my comment 1, specially regarding the statement of line 31 Page 5, “Conclusions should. . .” f. You calculate Ep from the CMIP5 data (2006-2100) g. Calibrate Eq. 2 to obtain w. How did you do that? I would do it as: *Wang, D. and Hejazi, M.: Quantifying the relative contribution of the climate and direct human impacts on mean annual streamflow in the contiguous United States, Water Resources Research, 47(10), n/a–n/a, doi:10.1029/2010WR010283, 2011. h. You calculate Qa i. You calculate Qh, I could not understand why nor how. What does Qh have to do with the biased correction? j. Now you calculate changes in all Q components. k. Then you compare Qa with Q from LPJ LSM. Again, it is hard to know what this comparison should result in, since it is not clear what Q from LPJ LSM really represent. l. I got lost in what Q* psychically means. If this is the main purpose of the study, then I cannot understand why the authors go through a to k.

a. We do not use GRDC data. The first line of section 2.1 states "We use the Dai et al. (2009) Global River Flow and Continental Discharge Dataset..." b-c. Yes, for the historical 20th century analysis, which will be more clearly separated in the revised manuscript. d. This is stated in the page 7, line 20 paragraph. e-f. Yes, although we actually use 1951–2100 (page 7, line 30 paragraph). g. This is explained in the page 6, line 10 paragraph and we actually use equation 5. h-i. Yes. The calculation of Q_h is explained at the bottom of page 6/top of page 7. It has nothing to do with the bias correction, which concerns the projected CMIP5 analysis. This will be more clear when we produce the flow chart and clean up the methodology section as described above. j-k. Yes. The LJP LSM runoff should be a proxy for Q_a calculated via the Budyko framework as detailed in the text (page 7, line 20 and supplementary Sect. S3). l. Again, this is concerning the projected 21st century CMIP5 analysis, which will become much clearer in the revised manuscript.

The authors need to mention what calculations are related with the bias-correction, and which ones are related with the aim of calculating the human component of Q (Qh). So, is this the chronological order of calculations? If not, please modify. Also, where is the correction bias coming into these methods, I could not see it, until maybe the calculation of Q*. Please specify.

The revised layout of the methodology will make this much clearer. We have included the equations that are used in each calculation and in each application in Figure 1.

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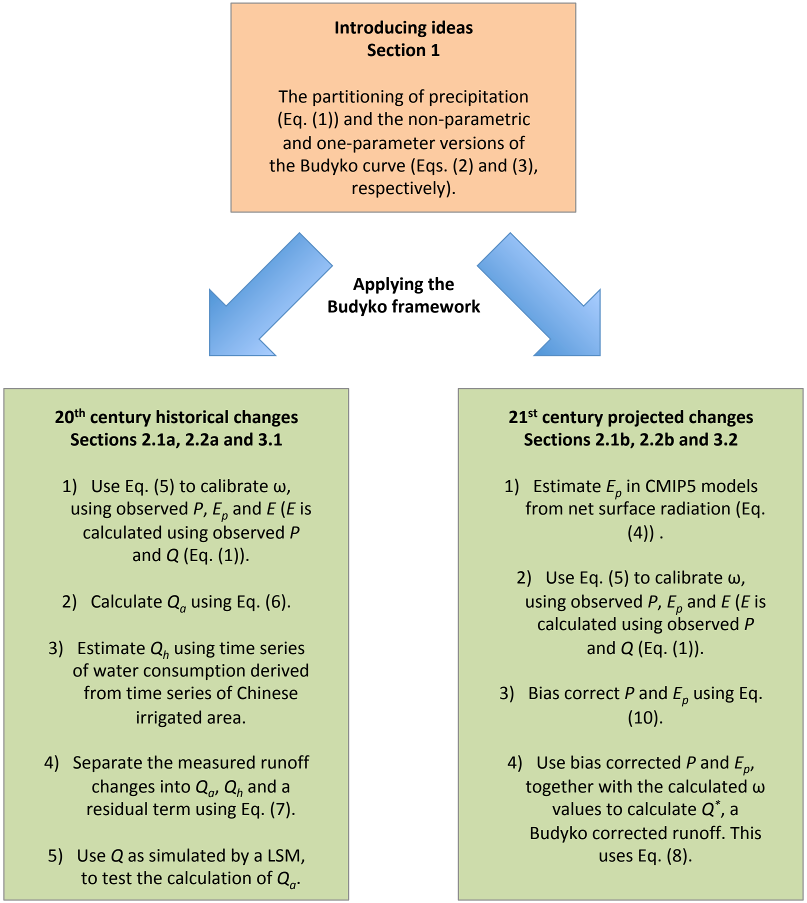

Fig. 1. Schematic of how the Budyko framework is used to improve our understanding of 20th-century historical changes and 21st-century projected changes.

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