Manuscript Details:

Effects of snow ratio on annual runoff within Budyko framework (HESS-2014-557)

Authors:

D. Zhang, Z. Cong, G. Ni, D. Yang, and S. Hu

Response to Referee Comments by Anonymous Referee #2

Referee comments in Italics

General comments

This study provides an analytical extension of Budyko framework to account for the role of snow on annual water balance at the catchment scale, validates this extension in China against historical observations, and predicts the future streamflow based on CMIP5 projected forcings and this new extension. I feel that this is a very valuable contribution to catchment hydrology in general and this special issue in particular. The analysis is overall robust and the logic of presentation flows well. The writing could be improved further as pointed out by the 1st reviewer, although I think it is already good enough for most of the readers to easily follow.

We thank a lot the reviewer for the positive comments. According to the suggestions of the reviewer, we will thoroughly go through the manuscript and further improve the grammars and wording.

Specific comments

1. *A friendly suggestion: be more positive when citing/referring to a very relevant work by Berghuijs et al., 2014, which no doubt has a lot of merits. For example, at Page 941, L5, you could state that "Berghuijs et al. 2014 show that higher snowfall fraction is statistically associated with increased annual streamflow at pristine catchments, but they also pointed out that mechanistic understanding of this phenomenon is still lacking", and "inspired by Berghuijs et al. 2014, in this study we aim to provide more insight into this phenomenon using a new analytical approach based on the Budyko hypothesis". At Page951, L16, you could say that you are providing another way to quantify the sensitivity of annual runoff to snow ratio etc.*

Thanks for suggestions of the reviewer. The work by *Berghuijs et al. 2014* did inspire us a lot to put forward this study. We are more positive when citing the relevant work in the revision according to the advices.

2. *P947, L18. Please rephrase for better readability.*

Agreed. We changed it into: Given that the frozen ground has extremely low permeability, the surface flow is preferred during the snow melting period (Dunne and Black, 1971).

3. *Fig. 7, the quality of this figure, including legend, is really poor. Please improve.*

Thanks for your comments. We will submit high-quality figures for satisfying the publishing requirement of HESS in the revision.

4. *P947, L22, please pay great attention to the preciseness of the language when you are introducing a key assumption. In your study, most of the snow ratio values fall within 0.10, so it is likely that your assumption is only valid when snow ratio is significant but small enough. Reviewer 1 did point to significant evap. loss when snow ratio is high (0.4 or larger) in MOPEX basins. Even further, I believe adding some discussion on the limitations of your current work and possible directions of improvements in the last section, as suggested by Reviewer 1, would in fact enhance your paper.*

Good point. We acknowledge that the assumption that there is no evap. loss proposed in P947, L22 is ideal. This simple assumption is a compromise between obtaining a concise expression and our lack of understanding on the role of snow on annual water balance at present. When snow ratio is not very large, the error introduced can be negligible. When the snow ratio is large, this assumption may be out of place. In the revision, we have added some discussion on the limitation of this assumption and the potential efforts to improve the proposed Budyko framework in the last section.

4.6 limitation of revised Budyko framework

It should be noted that the assumption of no evapotranspiration loss in snowmelt adopted in Section 3.1 is not universally applicable. In small catchments, after snowfall is melt and the concrete frozen ground inhibits snowmelt infiltration, the snow water can flow away quickly though channels without evaporation loss. However, if the location of accumulated snow is far away from channels, or the snowfall amount is large, it will take longer for melt water to run off than the frozen soil thaws. In these cases, a part of snow infiltrates into the ground and later is available for evaporation (Dripps, 2012; Jasechko et al., 2014). In fact, it may be more suitable to introduce $k \cdot (1-r_s) \cdot P$ as "effective available water" for evapotranspiration, where *k* is a loss parameter requiring further investigation. To better understand and parameterize the snowmelt loss by evapotranspiration, the site-specific modeling and isotope-based field observations may provide tools for more detailed modeling in the future.

Apart from limitation of the assumption, the accurate estimation of snow ratio is also important for this framework. However, direct snow observation records are not available for the case study watersheds in this manuscript and the MOPEX watersheds used by Berguhijs et al. (2014). Mean annual snowfall is estimated by the air temperature-based empirical method. The threshold temperature is critical for calculating the snowfall amount. A higher threshold temperature will overestimate the snow ratio that may lead to an unreasonable conclusion under the framework in our

study. According to the sensitivity analysis of catchment parameter estimation, it shows that a small variation in snow ratio can lead to a significant change in catchment parameter when snow ratio is large enough to be comparable to runoff index. Thus, the accuracy of snow ratio is important to this framework especially when the snow ratio is large, which limits the applicability of this framework in those catchments.

We thank anonymous Referee #2 for the insightful and helpful comments.

D. Zhang, Z. Cong, G. Ni, D. Yang, and S. Hu

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