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Interactive comment on "Redressing the balance: quantifying net intercatchment groundwater flows" *by* Laurène Bouaziz et al.

Anonymous Referee #1

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"General Comments":

This paper covers a very timely topic and would be a nice addition to HESS. The concept of quantification of Inter-catchment Groundwater Flow (IGF) is still in its infancy, but its relevance to the modeling and process understanding regarding water quality and quantity is obvious. The study summarized in this paper applies a three step approach to quantify IGF that relies on the (1) comparison and analysis of observed water balance data within the Budyko framework, (2) applying a suite of different conceptual hydrological models and (3) remote sensing based estimates of actual evaporation. Their analyses suggest that IGF varies annually, and at the scale of the headwaters, IGF can make up a relatively large proportion of the water balance. At the same time, as detailed in the comments below, I do have some substantial concerns. After these

issues are resolved, I believe this paper will make a nice and impactful contribution to HESS.

"Specific comments"

Introduction

1) The introduction falls short in acknowledging recent research on the quantification of IGF. Gleeson and Manning [2008], Welch and Allen [2012] and Ameli et al. [2018] used physically-based approaches to explicitly quantify IGF. These works also explored factors controlling the IGF. It might also be useful to cite some previous works which used Budyko framework to estimate watershed-scale groundwater recharge/discharge or IGF.

2) As it is in the introduction now, the importance of the understanding of IGF is limited to improving conceptual models. In addition to that, IGF impacts (1) water quality in the higher-order streams (2) the fate and biogeochemical alteration of non-point source agricultural pollution (3) the water replenishment in economically important aquifers within arid and semi-arid mountainous regions (4) the generation and migration of petroleum and mineral deposits, and (5) the ecological functioning of the watershed. These points have been discussed in Ameli et al. [2018].

3) The current introduction did not clearly state how the current paper goes beyond the status quo and why we have to use the proposed approach to quantify IGF. As stated above, recent works explicitly quantified IGF using sophisticated physically-based hydrological models. In my opinion, the advantage of the proposed approach in this paper is to use a simple framework and widely available observations to estimate IGF. While previous approaches used extensive tracer and hydrometric observations, which are rarely available in most landscapes, to explicitly quantify IGF.

Limitations and Advances

It is good that the author explained some of the limitations of the proposed framework.

However, I think this part still should be extended to provide the readers with a better understanding of the applicability and limitation of the proposed framework.

1) Although the proposed framework worked well in the Muse basin with high percentage of steep hillslopes, it ignores surface storage of water in lakes and wetlands. Surface storage of water is an important element of water budget in flat lake/wetland-dominated watersheds. Water retains in these storages for decades without reaching the stream. Ignoring this element when using the proposed approach can lead to a wrong estimation of actual evaporation and IGF.

2) As the authors acknowledged, the Budyko framework is subject to uncertainties in the data used to calculate long term averages of precipitation, discharge and potential evaporation. In addition, this paper used data from different sources at different watersheds. These uncertainties limit the ability of the framework to compare the estimated IGF between watersheds. This should be clarified in this section. Having said that, the comparison made in figure 9 (lower panel) might not be robust given the different sources of data in different watersheds used in the Budyko analysis. Off course that part of the comparison made using the conceptual model is valid.

3) Similarly, the proposed framework has limited ability to estimate IGF for different scenarios of land use and climate change. IGF is a slow process with transit time of over hundreds of years (cf [Ameli et al., 2018]), and is not rapidly sensitive to most environmental changes. So it takes long time that the changes in climate and land use impact the amount of IGF (but the Budyko framework may suggest in a different manner as Q/P changes).

4) Also please clarify that the Budyko framework is only able to estimate long-term IGF and not annual IGF.

"Minor comments"

P2-L15. Delete extra period.

P2L33. It is true for some but not all types of solutes. Ameli et al. [2017] compared the degree to which the residence time and concentration of different solutes are corresponded.

P3L1. Gleeson and Manning [2008] used water budget analyses to calculate the actual rates of intercatchment groundwater exchanges

P3L6. Provide examples of these models and their citations

P5L2. Perhaps this last sentence could come earlier in the paragraph

P6L24. Explain the Turc-Pike framework and its assumptions

P10L24. But previous research showed different conclusions (see Ameli et al. [2018] and Gleeson and Manning [2008]). As the watershed slope increases, the water table depth increases on average, leading to more regional GW and thus more intercatchment GF.

P13L19 Use annually in the entire paper and figure labels/captions

P14L33. This is too general statement. This value may be significantly larger or smaller for different types of geological settings and watershed slope.

Reference Cited

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