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Hydrology and Earth System Sciences
Discussions

Interactive comment on "Shift of annual water balance in the Budyko space for a catchment with groundwater dependent evapotranspiration" *by* X.-S. Wang and Y. Zhou

Anonymous Referee #3

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The paper by Wang and Zhou addresses the special case in which groundwater contributes to evapotranspiration within a catchment. This additional water leads to occurrences of evapotranspiration exceeding precipitation in dry years. The authors present here an approach on how to incorporate shallow groundwater into a modified Budyko framework. It is utterly important to point out that under conditions of groundwater-driven E the traditional Budyko framework is not valid (and does not need to be valid since it is not defined and designed for such circumstances). The foundation of the framework is that E is limited by both available energy and available water supplied through precipitation. This is not the case if groundwater is available to E. The concept of a supply limit is hence obsolete. To me, the main result is thus not the occurrence

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of E/P>1 if groundwater is available to E, but is the new, modified Budyko formulation (Eq. 23) that is able to explicitly represent the contribution of groundwater. The new formulation provides an extension/modification of the traditional Budyko hypothesis and should be presented as such (e.g. as E/P = F(Φ,ΔG) with E<P+ΔG, where G is shallow groundwater).

It is my assessment that the manuscript by Wang and Zhou provides an interesting contribution to the field, but some rewording and restructuring is necessary to avoid misconceptions.

Major comments

1. In your conclusions you write about the Budyko hypothesis: "This hypothesis is robust for long-term mean annual water balance but is dubious for the inter-annual variations in catchment with varying dryness." (P. 11633, l. 19-20). I'm not happy with the word "dubious" in this context. It is important to note (again) that the original Budyko hypothesis is defined at climatological, catchment scales with no changes in storage. Hence, under conditions of additional water supply from groundwater the Budyko framework is not "dubious", it is simply not valid. That observations thus show occurrences of E/P>1 is not a surprise. I would therefore like to see a revised manuscript putting the focus more on the modification of the framework, rather than pointing out several times that the traditional framework is not valid. The modified framework itself does, however, pretty well represent occurrences of E/P>1 by simply including the fraction of catchment area with shallow groundwater.

2. Your modified approach (Eq. 23) does include the area fraction α of shallow groundwater and provides a rather flexible mathematical formulation that allows to represent cases of E/P>1. You discussed several limitations of your approach in section 4.4. However, since groundwater provides just one additional source of water (among soil moisture, snow storage, etc.), I think the limitations are rather strong. I would love to see a comment on the use and applicability of the modified approach.

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3. I do miss a convincing line of argument on why you don't directly use and show the observations. Of course, you need the model to make the difference between deep groundwater and shallow groundwater. But this is not so clear from the manuscript. I would also like to see the data cloud of the observations within the Budyko space (Fig. 7a) to have a better comparison and feel for the "natural" model in the context of Budyko.

4. How does the modified Budyko formulation provided by Eq. 23 and shown in Figure 8 actually look like for the HRC. It would be beneficial to see the modified curve in Fig. 7A to have a direct comparison to the data points of the "natural model". What value of α would you get if you estimate it directly from the observations and Eq. 23? How would you explain differences in the α-estimates are different?

Specific Comments

P.11633, l.17-19: The Budyko hypothesis as formulated in Eq. 1, E/P= F(Φ), does only assume that the Budyko curve is determined by Φ and not an additional catchment specific parameter.

Fig.5: You can't really see the crosses and dots in Fig. 5a. Is the R-square value for the runoff or the groundwater discharge.

Fig. 7: Why is it "Including irrigation" in a) and "Observations" in b) ?

Fig. 8: Could you please explain in more detail how you separate between zone-1 and zone-2 evapotranspiration. Is this based on equation 17 and simply the particular fraction of E?

Fig. 8 and 9: Some lines are very wriggly.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 12, 11613, 2015.