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Comment on hess-2021-174

Anonymous Referee #3

Referee comment on "Exploring the role of soil storage capacity for explaining deviations from the Budyko curve using a simple water balance model" by Jan Bondy et al., Hydrol. Earth Syst. Sci. Discuss., https://doi.org/10.5194/hess-2021-174-RC3, 2021

The Authors present a study to assess the role that the soil water storage might have in determining the water balance of catchments. The work is in the context of the Budyko framework, which uses a formula to relate the dryness index, ETp/P, to the evaporative ratio, ETa/P, where ETp, ETa and P are long-term averages of annual potential evapotranspiration, actual evapotranspiration, and precipitation. The Authors use a lumped hydrological model, based on the HBV model, applied to 16 catchments across Europe, the USA and Peru, with the goal of using the root soil water storage parameters to explain the difference between ETa/P expected from the Budyko curve and the modelled ones.

Although addressing a problem of likely interest to the readers of HESS, I believe the study presents several weaknesses that require attention. I have listed below some specific comments that I hope will help improve the manuscript.

1. Context: there is already a lot of work done on the Budyko framework and the role of soil storage in determining the location of catchments in the Budyko space. The Authors refer to the work by Milly (1993; https://doi.org/10.1029/93WR01934) dismissing all the contributions following that study. The model by Milly (1993) was further developed by Porporato et al. (2004; https://doi.org/10.1086/424970), who improved the description of ETa as a function of soil moisture leading to a better representation of the Budyko curve. Donohue et al. (2012; https://doi.org/10.1016/j.jhydrol.2012.02.033) used the model by Porporato et al. (2004) and the formula by Choudhury (1999; https://doi.org/10.1016/S0022-1694(98)00293-5) to analyze the role of root zone soil properties on the water balance of catchments in Australia. The work by Donohue et al. (2012) was further extended by Yang et al. (2016; https://doi.org/10.1002/2016WR019392). These studies were reviewed and compared by Daly et al. (2019a; https://doi.org/10.1016/j.advwatres.2019.103435). Daly et al. (2019b; https://doi.org/10.1029/2019WR025952) proposed a different scaling of variables based on the soil storage and showed that the Budyko space might not be the best to look at the water balance of catchments that are not very large.

When looking at this existing body of work, it becomes difficult to see the novel contribution of the study presented here. Additionally, the HBV model is very similar to the models by Milly (1993) and Porporato et al. (2004), with the exception of a better routing for the calculation of Q. However, HBV requires numerical simulations that make its application difficult for a large number of catchments. For example, the Authors limited their study to 8 catchments within the MOPEX dataset, while Daly et al. (2019b) were able to use the full MOPEX dataset.

2. Approach: as I understand, the main goal is to see how different values of soil storage parameters in the model drive the difference between the model results and the Budyko curve. This, which I believe is similar to Gentine et al. (2012; https://doi.org/10.1029/2012GL053492), seems to imply that the Budyko curve defines the expected behaviour of a catchment. However, because the Budyko framework only applies to very large catchments (see the book by Budyko, 1974), it is not surprising that smaller catchments do not follow the Budyko curve. Looking at the large body of literature on the Budyko framework and the models (parametric and non-parametric) developed to locate catchments within the Budyko space, it is not very clear what the study presented here is adding to generate new knowledge.

Minor suggestions:

- Lines 124-125: not clear how this is achieved without data of storage. It would be good to explain how the 5% error is evaluated.

- Table 2: it would be good to explain the meaning of the parameters and what they do within the model.

- Fig. 5: the ration S_{max}/P seems similar to the non-dimensional parameter introduced by Milly et al. (1993). This should be acknowledged.

- Lines 366: not clear what second-order means here.

- Lines 435-436: the number of rainy days, or rainfall frequency, has been used often in water balance models in the context of the Budyko framework. See, for example, Milly (1993), Porporato et al. (2004) and Daly et al. (2019a, b). This should be acknowledged.