Answers to Reviewer 02 Comments

Note: Reviewers comments in **bold**, answers in *italics* type.

The manuscript is very well written and easy to follow.

The authors thank the reviewer for these encouraging words. The authors acknowledge the fact that this regional study relies on a simplified understanding of the complex hydrological processes in the topographically highly diverse region. We believe that the approach followed here is warranted given the regional scope of this impact study which relies on data that we had put together of 221 catchments throughout the region covering an area of more than 400'000 km^2. Such a unified view of this highly fragile yet fascinating world region has never been carried out before and we believe that our thorough study contributes in an essential manner to better prepare local stakeholders and populations for future changes.

We are sure that the detailed answers below to observations and questions from the reviewer help to address his/her skepticism towards the approach.

A very simplified water balance model is applied with numerous assumptions that require more discussions and comparisons with data sets like:

- **Evaporation (including transpiration) depends only on potential evaporation, what about water availability?**
- **The partitioning of runoff and evaporation is it dependent on the topography?**
- **Parameters k1 and k2 (equation (17)) are set to 100 and 5. In Oudin et al. (2005) quoted by the authors, these parameters have to be calibrated with values depending on the hydrological model... Values of 100 and 5 are based on the water catchments they studied, which are different from the catchements addressed here.**
- **Concerning the rooting depth, it is assumed that data from Fan et al. (2017) are a good compromise, but it is not explained why ....**
- **Equation (18) is an oversimplified model that needs to be checked versus data.**

The authors mentioned most of these simplifications.

The model used here is a well-established stochastic soil moisture dynamics model. As in the main text, we refer to it as PSM model. Good, comprehensive overviews of the PSM *model and its applications globally are available*[1]*. The PSM model has also been applied in arid and semi-arid contexts. We would like to clarify the raised issues above one by one.*

- *Lines 161 and following explain the dependence of actual evaporation on potential evaporation. We clearly state that actual evaporation depends on effective relative soil moisture x(t) and thus on water availability in each of the studied subcatchments in the PSM model.*
- *The partitioning of available water into runoff and evaporation is shown in Equations (4) – (6) and the difference between the PSM model and the Budyko model is highlighted in Equations (7) and (8). The PSM model main variables are the basin aridity index ϕ and the basin storage index γ. As for the aridity index ϕ, it depends on the basin potential evaporation which itself depends on temperature. The dependence of ϕ on topography thus enters via the temperature lapse rate. As for γ, the dependence on topography comes from reduced rooting depth at high altitudes.*
- *We totally agree with the reviewer that these parameters are generic and not necessarily suitable for the catchments under consideration. In fact, we show the bias of potential evaporation computed using k1 = 100 and k2 = =5 in the left plate in Figure 5. We therefore use a bias correction method to harmonize these Ep values with the cones computed via Penman in the Chelsa V21 dataset. The reviewer is kindly requested to check the discussion starting on lines 338 – 353.*
- *In relation to soil data, we spent a considerable amount of time to access and compare different global datasets. This is evidenced in Section 2.5 in the article. For rooting depth, we compared three global datasets (see lines 356 – 357). We believe that the data from Fan et al., 2017 provides a good compromise product when compared with the other products as it is neither biased to the low nor to the high ends in the spectrum of available data (lines 365 – 368 and Figures B2 – B4).*
- *We agree that the model presented in Equation (18) is a simple linear model relating rooting depth to temperature (see also comment above). The data for fitting the linear model are shown in the left plate of Figure 8 that shows the clear dependence of the rooting depth on mean temperatures. These data are used for fitting the linear model. We hope that the discussion in the main text is sufficient in motivating our choice of the model.*

Because these simplifications are very strong and sometimes not consistent with our knowledge, they must be checked by comparisons with existing data (at least, at the scale of one water catchment). Without that checking, there is no possibility to verify the plausibility of the results and the paper appears like a modelling exercise not suitable for HESS.

We thank the reviewer for sharing these concerns. We would like to point out that we spent a lot of time collecting a consistent dataset for the entire region. The resulting manuscript

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[1] Porporato and Yin, *Ecohydrology: Dynamics of Life and Water in the Critical Zone*; Rodríguez-Iturbe and Porporato, *Ecohydrology of Water-Controlled Ecosystems: Soil Moisture and Plant Dynamics*.

draft by Marti, B. S., Yakovlev, A., Karger, D. N., Ragettli, S., Zhumabaev, A., Wakil, and Siegfried, T.: Geo-Located Discharge Time Series for Mountainous Rivers in Central Asia: A Novel Dataset for Water Balance Modelling and Runoff Forecasting, Rev., 2023 has just been accepted for publication in the journal Nature Scientific Data. This is the first time such dataset has been put together and used in a comprehensive way for a hydro-climatological impact assessment of global change. HESS is well known to public important contributions in this field, and we believe that our contribution adds in a targeted manner to ongoing discussions in this field.

We hope that the replies to the reviewer's comments/suggestions are satisfactory to her/him.

Kind regards, Tobias Siegfried (on behalf of all the co-authors).