Response to Referee #2

We would like to thank Referee #2 for the comments and thoughts. We will improve on the issues in a revised version of the manuscript and give thorough thought about the ideas of the referee. Below, we address the comments of Referee #2, with the referee comments written in italics.

(1) I appreciate the thorough assessment of differences occurring due to the use of different projections. However, from my point of view, there is a different understanding in the interpretation of the n-value between the two projections per se. The n-value has no apriori physical interpretation and is, technically, a mere mathematical entity. That means there is no necessity for the n-value to be invariant under different projections. Or is there? As much as I appreciate the illustration of your results using real-world data, I think a more mathematically-based discussion of the issue is also needed.

We agree with the referee that the n-value does not have a real physical meaning and can be considered a mathematical entity. However, many authors relate it to physical variables and attempt to give a physical explanation to the parameter. For example, several studies relate the parameter n to vegetation, such as Zhang et al. (2001), Yang et al. (2009) or Ning et al. (2017). Donohue et al. (2012) related this parameter even to a larger set of variables including local rooting depths, storm depths and soil water storage capacities. Moreover, Roderick and Farquhar (2011) argued that this parameter reflects all local catchment properties combined (except for climate). We discuss the meaning of n and the notion that n should be constant as catchment properties or vegetation stays constant more in our accompanying manuscript (Nijzink and Schymanski, 2022). Nevertheless, if n is indeed related to physical variables (we do not assess this in this technical note and do not take a stand on this), these n-values should be the same for the different projections. At least, we would like to emphasize that if n-values are compared between studies, authors should keep in mind that their values may depend on the projections used.

We will also add a more mathematically-based discussion. Technically, the two projections can be re-written into another and we will mathematically illustrate that for any combination of E, Ep, and P, the n-value is the same regardless of the projection. In this way, we believe that the meaning of the n-parameter should not change.

(2) A similar comment can be made concerning the deviations from the curve and the limits. The interpretation of deviations within the E/P and the E/Ep space is different per se. In other words, I do not expect similar deviations in terms of E/P and E/Ep. If this has been used interchangeably within the literature, I think it needs to be highlighted in your manuscript by providing more references and a more in-depth discussion of the issue.

We thank the referee for this important point and will clarify in the revised manuscript that the distance to E/Ep=1 indicates decreased energy use efficiency, whereas the distance to E/P=1 indicates decreased rain use efficiency by evapo-transpiration. This will also strengthen our argument that it is more meaningful to look at the non-contracted part of the Budyko-space only, as in the contracted part, a value of 1 cannot be achieved due to other constraints. We will highlight this more and add a more in-depth discussion about this.

Abstract: Even though it is a Technical Note, the abstract is a bit too technical (and a bit too long) in my opinion. I would appreciate it if you try to condense some of the methodologies and put more emphasis on the interpretation of your results.

We will shorten the abstract and condense it in the revised version of the manuscript.

Introduction: You introduce the Budyko framework as being super popular in recent years (which is true). However, most of your references are at least 10 years old or older. I would appreciate a slightly more extensive introduction outlining more recent references, highlights, and applications of the Budyko framework and how this connects to the objective of your manuscript.

We will elaborate more on recent applications of the Budyko framework and connect this to the issues raised in our manuscript.

p.5, l. 8: Would be great to acutally provide the number of arid/humid catchments.

There are 247 arid catchments and 110 humid catchments, we will add this to the text.

Fig. 2: Maybe consider adjusting the y-axis of the plots to better highlight the differences. Given the current scale, the differences seem rather unremarkable.

Thank you for the suggestion, we will adjust the axes.

Sec. 3.2: Deviations from the curve and the limits can be larger for water-limited catchments by design. For energy-limited catchments, the total range is always smaller than 1. You highlight that in your discussion of the contracted vs. the uncontracted side. However, I was just wondering if you would obtain similar results if you just assess randomly distributed numbers within the Budyko space.

This is an interesting thought experiment that we tried out. We sampled the x-values of Ep/P from a uniform distribution (100,000 samples between a value of 0 and 2). In the next step, we sampled an n-value for each realization of Ep/P from a truncated normal distribution (similar to Greve et al., 2015), truncated at 0.0 to avoid negative n-values, with a mean of 1.9 and standard deviation of 0.5 . In this way, we determined the accompanying Ea/P and Ea/Ep values by using the Budyko equation with a certain realization of n. With this set of data, we repeated our analysis and fitted a curve (i.e this curve will be close to the curve obtained with the mean of the n-values of the distribution used to create the data).
The results in Figure 1 mainly confirm that energy-limited catchments always have a smaller distance to the curve in a projection based on a dryness index compared to a projection based on a wetness index. Moreover, it can be seen that the distances of water-limited catchments with an aridity close to 2.0, doubles when changing from a projection with a wetness index to a projection with a dryness index.

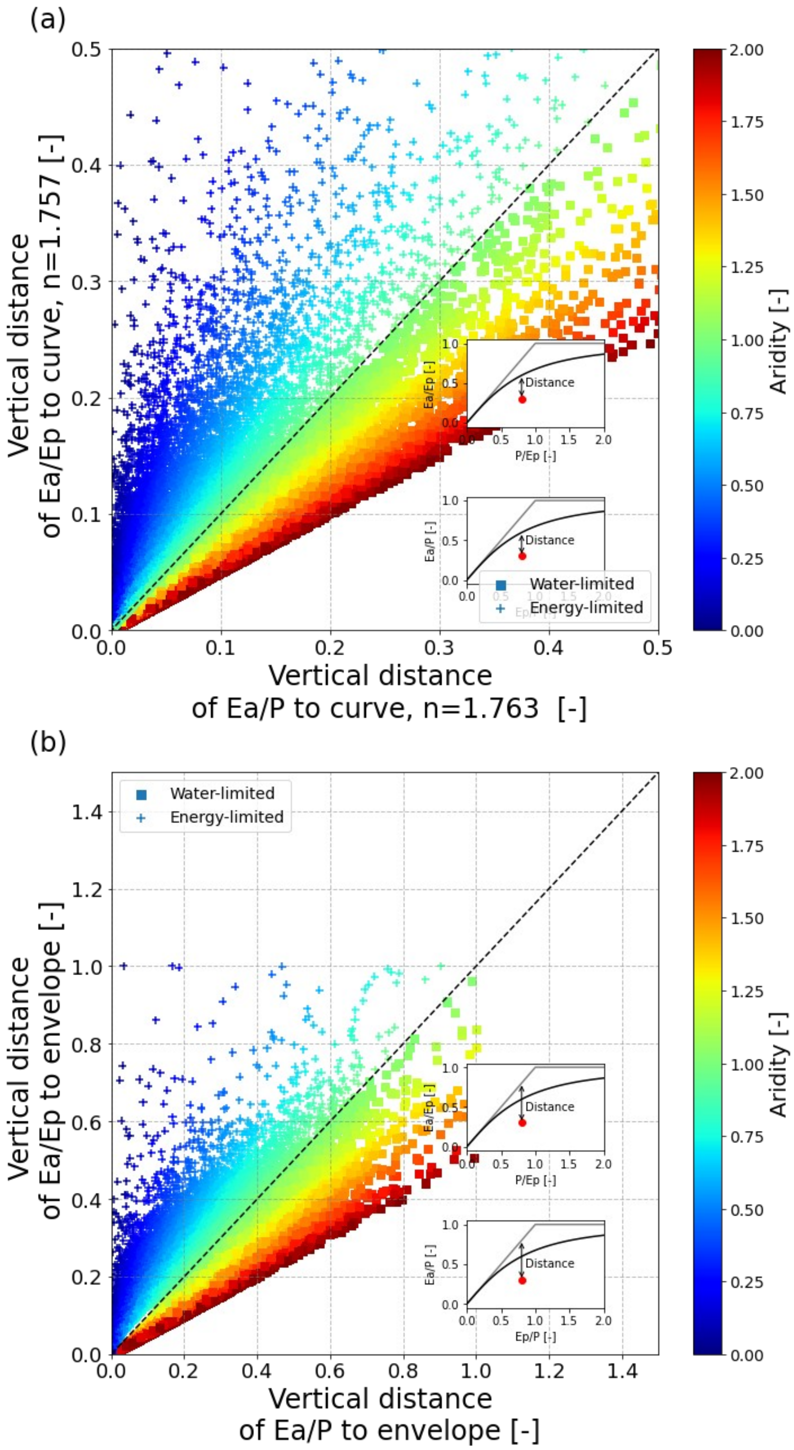

Figure 1. Vertical distances to a) the envelope of the physical limits of the Budyko framework and b) vertical distances to the fitted Budyko curve, both for projections normalized by precipitation (x-axes) and potential evaporation (y-axes). Ep/P-data is sampled from a uniform distribution with values between 0.0 and 2.0, n-values are sampled from a truncated normal distribution with a mean of 1.9 and standard deviation of 0.5, the distribution was truncated at 0. 100,000 data points were sampled. Water-limited catchments (Ep/P >1) are shown with stars, whereas energy-limited catchments are shown with crosses. The colorscale indicates the aridity of the catchments.

References

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