Response to Reviewers' comments

We greatly appreciate the anonymous referee for providing valuable and constructive comments that are of great help for us to improve the quality of the manuscript. We have fully considered the comments and will revise the manuscript accordingly. The point-to-point responses to the comments and our plans for revision are listed below.

Replies to the General Comments:

1. *This manuscript improves satellite-based algorithm for estimating soil evaporation by adding the frameworks for quantifying moisture constraints to ET into P-LSH model, and assesses the impact of moisture constraint uncertainty on the estimated ET. Mechanism studies about ET and their components (e.g., transpiration, soil evaporation etc) in alpine barren areas, especially for Tibetan Plateau (TP), are very limited, and this study of ET mechanism in TP region is quite necessary. There are still some issues should be addressed before a publication.*

Response:

Thanks for your positive evaluation and encouraging comments on our manuscript. Our point-to-point responses to your comments are listed below.

2. *The authors have paid more attention to soil evaporation, and neglected the vegetation transpiration. For example, in line 538-539 of page 23, "On the barrens of the TP, vegetation is sparse, and only soil evaporation exists". This addressing is not very rigorous. Grasslands account for 20.2% in Qaidam basin and 39.7% in Qiangtang Plateau, respectively, and Nelson et al (2020) indicate that transpiration in grasslands accounts for 40%-60% ET during growing seasons. I think that the authors should pay some attentions to transpiration estimation by considering the uncertainties of some others vegetation canopy conductance models. And, it is not clear the canopy conductance is calculated by which model; is it the empirical relationship between conductance and climatic variables, or the Jarvis-Stewart model? If the later, Jarvis model has poor performances in capturing the responses of conductance to climatic variables (e.g. air temperature), compared to other models such as Ball-Berry model, Ball-Berry-Leuning model and Mdelyn model. The uncertainties caused by choice of conductance model on ET may result in 32%-53% errors (Zhao et al., 2020). Therefore, I suggest the authors can also consider the influences of vegetation conductance model on estimated ET in TP.*

Response:

Thanks for your comments and suggestions. There is a misunderstanding here. I indeed estimated transpiration in this study. However, the objective of this study is to improve the soil evaporation algorithm in the existing P-LSH algorithm. We have optimized our transpiration algorithm in another recent study. In this study, the estimation of ET is conducted on the pixel scale and then aggregated to a basin. For these vegetated pixels, ET is estimated by the existing optimized P-LSH algorithm.

The barren is a kind of non-vegetated land cover, so we reasonably think that only soil evaporation exists on barrens.

In grassland pixels, we took the revised P-LSH algorithm to estimate transpiration. The calculation of canopy conductance takes from an NDVI-based Jarvis–Stewart-type, with NDVI quantifying the biome-dependent potential canopy conductance and with temperature, VPD, CO_2, shortwave radiation, and soil moisture reducing to the actual value. The method was developed and validated with flux towers in Tibetan grassland in a previous manuscript, and the transpiration estimations from our revised canopy conductance framework show considerable agreement with observations from flux towers (see Figure R1). The manuscript describing the transpiration improvement was just accepted by Journal of Hydrology and will be published online soon. The authors understand and agree on the significance of canopy conductance and the associated uncertainty analysis, but it is not the key part of this study because the vegetation is not the major part of the basins that we selected.

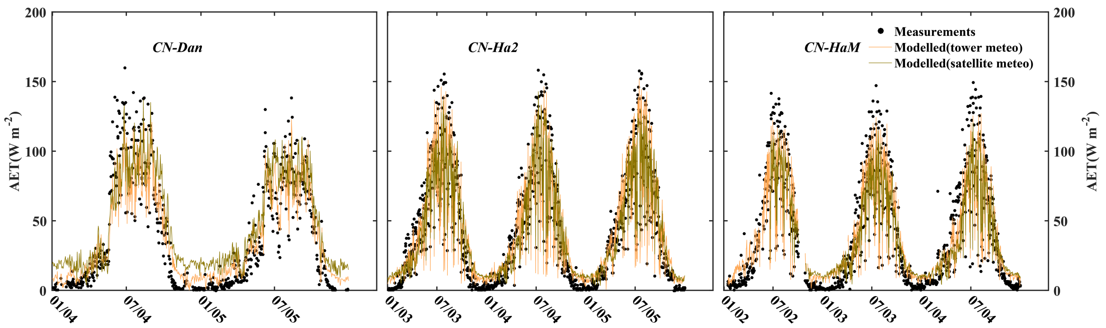

Figure R1. Time series of daily measured and modelled evapotranspiration (AET: W m^{-2}) using the improved P-LSH algorithm driven by tower-measured and reanalysis meteorology for three grassland flux towers. The time series and statistics of modelled AET driven by tower-measured and reanalysis meteorology are marked in orange and brown, respectively.

3. *The method description for estimating soil evaporation is not clear in section 3. The authors introduced five existing soil evaporation algorithms and then proposed two improvements. In each algorithm, descriptions of main parameters are needed. For example, how the biome-specific constants are determined in the PM-Brust soil evaporation algorithm?*

Response:

Thanks for your suggestion. In six existing and two improved soil evaporation algorithms, there are parameter k in A3, parameters rbl_{max}, rbl_{min}, VPD_{open}, VPD_{close} in A5, parameters k and r_{tot} in A6, and parameter r_{tot} in P-LSH_{θ} (in P-LSH_P it takes the same value as that in P-LSH_{θ}). Only parameters k and r_{tot} in A6 are precalibrated values, other parameters lack prior values for the barren type. The parameter k in A3, parameter r_{tot} in P-LSH_{θ}, and parameters rbl_{max}, rbl_{min}, VPD_{open}, VPD_{close} in A5 are calibrated. Actually, we listed the parameter values in the Results section (Lines 345, 350, 352, 367, and 404-406), and we will add more descriptions in the Methodology part in the revised manuscript.

4. *What is the difference between P-LSH soil evaporation algorithm (P-LSH$_p$) and PML soil evaporation algorithm? How the potential evaporation was calculated? Actually, it is not fair to compare soil evaporation algorithms with different potential evaporation equations. If the authors use the same equations, it is reasonable to compare soil evaporation algorithms. And, the difference between P-LSH soil evaporation algorithm (P-LSH$_\theta$) and PML soil evaporation algorithm is fwet. Why the authors do not add the fwet into P-LSH$_\theta$?*

Response:

Thanks for your question. The soil evaporation in P-LSH$_P$ takes a similar structure as that in PML, their sole discrepancy focuses on the estimation of the equilibrium (that is potential) evaporation, which both controls the soil evaporation and moisture constraint. The PML takes the simplified Priestley-Taylor-type equation as the equilibrium values, while P-LSH$_P$ takes the Penman-Monteith-type equation that considers the effect of the vapor pressure and resistance on equilibrium evaporation.

We conducted the comparison for the following reasons. Firstly, we think the two algorithms are comparable because both of them produce the actual values, and they are evaluated by a benchmark. Besides, we want to know with a similar structure, whether a theoretical better estimation of the equilibrium evaporation could contribute to the estimation of actual evaporation and moisture constraint, and it indeed turned out that way. By comparing the two, we can also separate the impact of potential evaporation on actual values.

For the latter question, we guess that there is a typo. The reviewer probably means that "And, the difference between P-LSH soil evaporation algorithm (P-LSH$_\theta$) and PM-Brust soil evaporation algorithm is fwet". Actually, the discrepancy between P-LSH$_\theta$ and PM-Brust is not only in f_{wet} but also in the estimation of the terms g_{a_s} and g_{totc} (a correction item of r_{tot}). In the P-LSH$_\theta$, the r_{tot} is a sensitive parameter that is estimated by calibration, while in PM-Brust, the r_{tot} is determined by VPD and four biome-specific constants. In the estimation of the term g_{a_s}, the conductance to convective heat transfer (g_{ch}) is a biome-specific constant in the P-LSH$_\theta$, while in the PM-Brust, it is assumed to be equal to r_{tot}. We will make a clearer description in the revised manuscript.

In terms of f_{wet}, it is a term to divide the saturated surface and moist surface, and takes a value of 0 if the relative humidity is lower than 70% (Mu et al., 2011). It is always dry in the Tibetan Plateau, and about 97% of the pixels and days have a relative humidity below 70% in our study areas, this indicates the f_{wet} mostly does not impact the calculation. Nevertheless, for the integrity of the algorithm, we will add it to the revised manuscript.

5. *Figure 3 and 4 have showed the results of A1-A6 for five existing soil evaporation algorithms. I suggest that two improvement soil evaporation algorithms proposed by the authors should be added into the comparisons.*

Response:

Thanks. We will add them in the revised version.

<u>Replies to the Specific Comments:</u>

1. *Line 68: "32 days" is right?*

<u>Response:</u>

In Zhang et al. (2010), they summed precipitation and equilibrium evaporation over four periods prior and four periods after the current period to estimate *f*, with each period constituted of 8 days. Later they simplified the estimation and only considered the previous 32 days (in the supplementary information of Zhang et al. (2019)). Thanks for your suggestion. We will modify the description as follows: "Zhang et al. (2019) selected the cumulative precipitation and cumulative equilibrium evaporation rates over the past 32 days to estimate *f*, based on which a continuous ET dataset including each component was generated."

2. *Sometimes, the logical relationship between some context sentences is not strong. For example, line 110-111: "Saline lakes and deserts cover approximately one-quarter and one-third of the Qaidam Basin, respectively. This region is thus very dry.".*

<u>Response:</u>

Thanks for your suggestion, we will delete the sentence "*This region is thus very dry.*" and thoroughly check the logicality throughout the whole manuscript.

3. *Figure 1 should include scale bar and compass.*

<u>Response:</u>

Thanks for your suggestion, we will add them in the revised version.

4. *Line 301: the description "vegetation evapotranspiration" is not right.*

<u>Response:</u>

Thanks for your mention. Here we do not just refer to the transpiration process of vegetation, instead, it is the total evapotranspiration framework including canopy transpiration and soil evaporation in a vegetation pixel.

Reference:

Mu, Q., Zhao, M., and Running, S. W.: Improvements to a MODIS global terrestrial evapotranspiration algorithm, Remote Sensing of Environment, 115, 1781-1800, https://doi.org/10.1016/j.rse.2011.02.019, 2011.

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Zhang, Y., Kong, D., Gan, R., Chiew, F. H. S., McVicar, T. R., Zhang, Q., and Yang, Y.: Coupled estimation of 500 m and 8-day resolution global evapotranspiration and gross primary production in 2002-2017, Remote Sensing of Environment, 222, 165-182, https://doi.org/10.1016/j.rse.2018.12.031, 2019.