Review comments

Sun et al. provide a valuable estimate of global potential evapotranspiration (PET), which is highly beneficial for various research applications. The authors have taken into account various factors that influence PET estimation and have prepared multiple datasets to derive the PET values. The manuscript is well-structured, with clear method descriptions, data processing procedures, and explanations. Overall, the manuscript could be accepted with some comments to further enhance its quality.

Major comments

1. What are the valid temporal resolutions (e.g., hourly, monthly) for the inputs used in different models (i.e., equations)

   Different meteorological datasets have varying temporal resolutions, such as 3-hourly for MSWX and monthly for others. When equations are used to calculate PET and related variables (e.g., D, Rn) to derive PET, it is important to consider whether these equations, as presented in the main text and supplementary materials, are valid for different temporal resolution inputs (e.g., 3-hourly vs. monthly). For example, can the SW equation be applied to different temporal resolution inputs (e.g., hourly or mothly)? It would be helpful to provide information on the validity of the equations for different temporal resolutions of inputs, whenever applicable.

   Additionally, the SW model was calibrated based on daily inputs (as shown in Figure 3). However, when applying the SW model globally, monthly inputs were used. The question arises whether it is appropriate to use a daily calibrated model for monthly inputs application.

2. It would be highly valuable if the authors could provide the datasets that were used to derive PET. This would include the following:

   - EC related datasets, e.g., the original datasets after quality control, selected datasets with no soil water limits, etc.

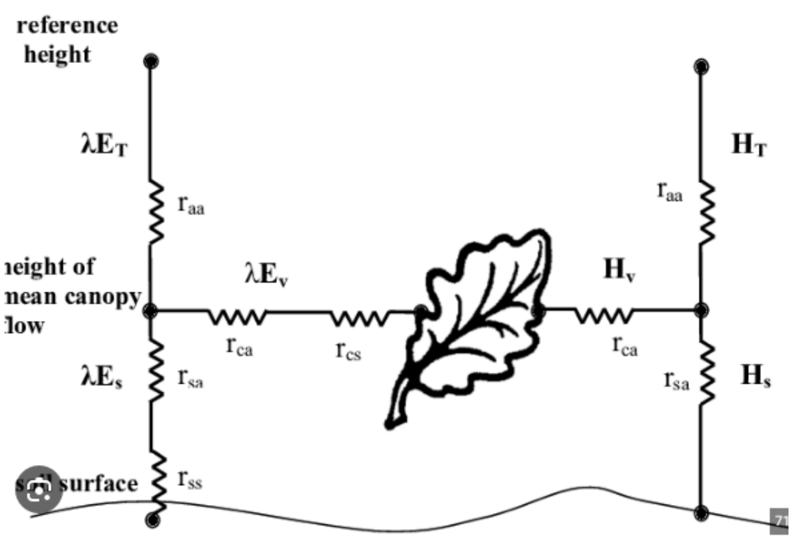
- Finally processed canopy height, and/or its source datasets.
- Land use/land cover, LAI, saturated water content in soil, and the CO2 concentration

Question for the CO2 concentration, the seasonal cycle of CO2 is different among different locations, e.g., between south and north hemisphere, will this affect your PET estimation?

3. About SW model:

   1) How about you add a concept diagram to show the structure of SW and related equation variables. One example for your reference, Figure 5 in

      - Kochendorfer, J. P. and Ramírez, J. A.: Modeling the monthly mean soil-water balance with a statistical-dynamical ecohydrology model as coupled to a two-component canopy model, Hydrol. Earth Syst. Sci., 14, 2099–2120, https://doi.org/10.5194/hess-14-2099-2010, 2010.



   2) EQ 1a, should the Cc be removed. Why not the total latent heat doesn't equal the sum of canopy and vegetation latent heat fluxes, but need multiply the coefficients, could you add some explanation?

      λET = ~~Cc~~PMc + ~~Cs~~PMs ?

   3) It would be helpful if the authors could provide an explanation for the calculation of LAIe in EQ2b and clarify the reasoning behind this approach. What is the underlying assumption or basis for this equation?

- When you calibrate the SW model using EC data with filtering out the rain effects, so most of the LAI should be likely effective (no rain coverage over the leaves), why the LAIe is still calculated in EQ2b (i.e., LAIe is less than LAI when LAI>2)?
- When you apply the calibrated SW model for global, the effective LAI should be considered due the reasons of rain. The LAIe should be related to different conditions (e.g., different rainfall intensity) but not considered in the EQ2b
- It seems there is inconsistence. When calibrating SW model using no-rain effects data, but applying effective LAI (i.e., from EQ2) when the rain effects is small. But the same LAIe equation are used for the global application, when under some conditions rain effects may be large. The PET calculation should also include the maximum ET during rain or after rain events, right?
- I wonder how to consider the LAIe for PET calculation at EC site level and global grid. How is the SW PET sensitivity to LAIe?
- Here I only say rain effects on LAIe, but other factors may also effect LAIe calculations, e.g., snow.

4. It would be beneficial to have a clear explanation of how PT and PE are calculated differently. Currently, there are no specific equations provided to illustrate the calculations for PE and PT. It appears that PT is derived from PMc, while PE is also derived from PMc. It is important to clarify this distinction and explicitly mention that PT and PE are derived from PMc in the text. Additionally, please review the sentence in line 238 that states "while PMc and PMs are the soil and vegetation latent heat fluxes (W/m2)" to ensure the correct explanation of parameters and variables throughout the equations.

   Furthermore, it is worth considering the inclusion of discussions on the explicit consideration of plant hydraulics in recent land surface models (e.g., CLM5 in 2019, NOAH-MP in 2021, CoLM in 2022) as it relates to transpiration simulations. I am interested to know whether the SW model implicitly incorporates plant hydraulics or if there are potential improvements that could be made to the PET estimation by integrating plant hydraulics within the framework of the SW model. Section 4.2 would be an appropriate place to include such discussions.

Related references:

- https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2018MS001500
- https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2020MS002214

5. You have presented the trends of PET, PE, and PT, as well as the contributions of changes in PE and PT to changes in PET. I am curious to know which factors, such as changes in meteorological forcings, contribute to the observed changes in PET, PE, or PT. For instance, could the global temperature increase be a significant driver?

   Furthermore, it would be valuable to include a discussion on how the phenomenon of Earth greening, such as an increase in LAI, may influence your trend analysis. Consider commenting on the potential impacts of Earth greening on the observed trends in PET, PE, and PT.

Minor comments

1. In the introduction, the authors mentioned different types of models to calculate the PET, and give examples for each type model (e.g., Penman-Monteith). It would be great if the authors can also provide the equations for these example models in the supplementary, so the readers can better compare them. Also please provide the information about the common temporal resolutions of the inputs for these models, hourly or daily or, …
2. In the supplementary, where is "EQ. S7a", should be EQ S4a ?. Bold the titles of "The ERA-5 D" and "The MERRA-2 D"
3. Lang et al. has another dataset from the webpage: https://langnico.github.io/globalcanopyheight/, what is the difference between this version of data and the Lang data you used in your study. Should this new data better than what the Lang data you used. You may add some discussion of this.

It seems that the canopy height is temporally static, but the LULC changes yearly. How to make the consistence for each year's LULC's canopy height for a given grid if LULC changes happens.

4. L230, r_{smin} should be defined when it first appears.
5. How are the averages of PET, PE, PT are calculated based on grid average or area average? Please mention it in the text.
6. Check the Figure 8, the colors for scatters and PE PT lines are not consistent.
7. For the calibration of r_smin, it would be helpful to know the range of variation among the 10 r_smin values for each specific plant functional type (PFT) site.