2022/7/18

Reply to Reviewer 1

Manuscript title: A global terrestrial evapotranspiration product based on the three-temperature model with fewer input parameters and no calibration requirement

Reviewer: 1

General Comments:

This manuscript addresses a useful but challenging topic. Although there are many remotely sensed global or regional evapotranspiration (ET) datasets, their performances varied across different biomes or regions due to high uncertainty exist in ET estimates. The current manuscript provides a good try to retrieve a land ET product in 2001-2020 using a three-temperature model without resistance and parameter calibration, which is different from the available ET products generated by methods including Penman-Monteith equation-based and surface-energy-balance-residual-based methods. The validation performed at different scales sound good. The intent of the manuscript is worthy and significant, and the topic generally fits the scope of the Earth System Science Data. The manuscript is well-written, and the methods, results, and discussion are clearly presented. Seeing the potential of this, I am in general supportive of publication after minor revision.

Responses:

Thank you for appreciating our work and considering that the studied topic is a much-needed idea. With the help of your constructive comments and suggestions, we believe that our manuscript will be improved substantially.

NOTE: In this revision, the newly added content is in blue, and the revised content is in red.

The following are the answers to every question/comment.

Specific Comments:

1. It may be better to clearly state the temporal resolution and duration of the product.

Responses:

Thank you very much for the valuable suggestion. The specific temporal resolution and duration of the product have been stated in the abstract as follows:

Abstract. Accurate global terrestrial evapotranspiration (ET) estimation is essential to better understand Earth's energy and water cycles. Although several global ET products exist, recent studies indicate that ET estimates exhibit high uncertainty. With the increasing trend of extreme climate hazards (e.g., droughts and heat waves), accurate ET estimation under extreme conditions remains challenging. To overcome these challenges, we used 3-hour and 0.25° Global Land Data Assimilation System (GLDAS) datasets (net radiation, land surface temperature (LST), and air temperature) and a three-temperature (3T) model, without resistance and parameter calibration, in global terrestrial ET product development. The results demonstrated that the 3T model-based ET product agreed well with both global eddy covariance (EC) observations at daily (root mean square error (RMSE) = 1.1 mm day^{-1}, N=294058) and monthly scales (RMSE = 24.9 mm $month^{-1}$, N=9632) and basin-scale water balance observations (RMSE =116.0 mm yr^{-1}, N=34). The 3T model-based global terrestrial ET product was comparable to other common ET products, i.e., MOD16, P-LSH, PML, GLEAM, GLDAS, and Fluxcom, retrieved from various models, but the 3T model performed better under extreme weather conditions in croplands than did the GLDAS, attaining 9.0–20% RMSE reduction. The proposed daily and 0.25° ET product covering the period of 2001-2020, could provide periodic and large-scale information to support water cycle-related studies. The dataset is freely available at the Science Data Bank (http://doi.org/10.57760/sciencedb.o00014.00001, Xiong et al., 2022).

2. Please add the data points used for validation.

Responses:

Thank you. The missing information has been added to the abstract as well as to related figures. Please see details in our previous reply to comment 1.

3. "the energy balance product" is better changed to "the ET product".

Responses:

The words have been revised as suggested:

Several global ET estimates have been developed over the past two decades based on various theories, including 1) surface energy balance residual methods, e.g., the ET product based on the Surface Energy Balance System (SEBS) (EB) (Chen et al., 2021);

4. PMLv2 → PML. Missing a PT-based ET product, GLASS.

Responses:

The "PMLv2" has been changed to "PML" in the revised manuscript. The ET product, GLASS, produced using multiple methods, including the PT equation, has been added in this revision as follows:

2) Penman–Monteith (PM) and Priestley–Taylor (PT) equation-based methods, e.g., MOD16 (Mu et al., 2011), P-LSH (Zhang et al., 2015), PML (Zhang et al., 2019), and GLEAM (Martens et al., 2017; Miralles et al., 2011); 3) land surface models, e.g., the Global Land Data Assimilation System (GLDAS) (Rodell et al., 2004); 4) multimodel ensemble approach, e.g., GLASS (Yao et al., 2014), Hi-GLASS (Yao et al., 2017), and a synthesized ET product (Elnashar et al., 2021); and 5) empirical methods, e.g., Fluxcom (Jung et al., 2019).

Reference:

Yao, Y., Liang, S., Li, X., Hong, Y., Fisher, J. B., Zhang, N., Chen, J., Cheng, J., Zhao, S., and Zhang, X.: Bayesian multimodel estimation of global terrestrial latent heat flux from eddy covariance, meteorological, and satellite observations, J. Geophys. Res.: Atmos., 119, 4521-4545, https://doi.org/10.1002/2013JD020864, 2014.

Yao, Y., Liang, S., Li, X., Zhang, Y., Chen, J., Jia, K., Zhang, X., Fisher, J. B., Wang, X., and Zhang, L.: Estimation of high-resolution terrestrial evapotranspiration from Landsat data using a simple Taylor skill fusion method, J. Hydrol., 553, 508-526, https://doi.org/10.1016/j.jhydrol.2017.08.013, 2017.

5. Fluxcom also has no value in some arid regions.

Responses:

Thank you very much for your suggestion. The reference for the ET product Fluxcom has been added to the sentence as follows:

Consequently, ET in these arid regions has usually been assumed as zero in certain ET products (Mu et al., 2011; Jung et al., 2019).

6. It is better to provide a journal article as the thesis may not be available.

Responses:

Thank you very much for your suggestion. The thesis has been replaced with a journal article as follows: This model mainly utilizes net solar radiation, surface temperature and air temperature as model inputs. In this model, the resistance terms in the energy balance equation are eliminated via the introduction of a dry surface without evaporation or transpiration, as detailed in Qiu et al., (1999).

Reference:

Qiu, G. Y., Ben-Asher, J., Yano, T., and Momii, K.: Estimation of soil evaporation using the differential temperature method, Soil Sci. Soc. Am. J., 63, 1608-1614, https://doi.org/10.2136/sssaj1999.6361608x, 1999.

7. "G equals to 0.315Rn" may be misleading.

Responses:

Thank you very much for your suggestion. The sentence "which equals $0.315\times R_{n.}$" has been revised and moved to Section 2.2 as follows:

The ground heat flux (G) can be directly extracted from net radiation R_n according to Su (2002).

Reference:

Su, Z.: The surface energy balance system (SEBS) for estimation of the turbulent heat fluxes, Hydrol. Earth Syst. Sci., 6 (1), 85–99, https://doi.org/ 10.5194/hess-6-85-2002, 2002.

8. The subscript l is not consist with those in equations 10 and 11.

Responses:

Thank you very much for your careful reading. The inconsistency has been revised as follows:

$$R_{n,sr} = \overline{R_{n,s}\left[T_{s,upper5\%}\right]} = \text{mean}\left(R_{n,s1}, R_{n,s2}, \ldots, R_{n,sj}\right) \quad , \tag{10}$$

$$R_{n,cr} = \overline{R_{n,c}\left[T_{c,upper5\%}\right]} = \text{mean}\left(R_{n,c1}, R_{n,c2}, \ldots, R_{n,cj}\right) \quad , \tag{11}$$

where $R_{n,sj}$ and $R_{n,cj}$ denote the soil and vegetation net radiation values, respectively, corresponding to pixel j (j=1, 2, 3…) of the upper 5% T_s and T_c values, respectively, within the same subregion.

9. Order of the section title was wrong as well as the following section. The authors should proof read the manuscript to avoid such mistakes.

Responses:

Thank you very much. We carefully checked our manuscript, and the order of the section title has been corrected as follows:

2.3.2 Evaluation considering the water budget in global main catchments

2.3.3 Evaluation via comparison to other commonly used global ET products

10. TWSC is better replaced with ΔS. In L171, it is better to use annual TWSC.

Responses:

Thank you very much for your suggestion. The TWSC has been replaced with ΔS as suggested, as follows:

$$ET_{wb} = P - R - \Delta S \quad , \qquad (12)$$

where P, R and ΔS are the precipitation (mm yr^{-1}), runoff (mm yr^{-1}) and terrestrial water storage change (mm yr^{-1}), respectively, in a given catchment. Annual ΔS can be calculated as the terrestrial water storage anomaly (TWSA) difference between Decembers of the target year and its previous year.

11. Typos (the unit). The authors should proof read the manuscript to avoid such mistakes.

Responses:

Thank you very much for your careful reading. The unit "mm yr-1" has been corrected as follows:

The estimated mean ET value was 514.5 mm yr^{-1}, with a standard deviation of 211 mm yr^{-1}, whereas the mean ET_{wb} value reached 476.5 ± 280 mm yr^{-1}.

12. The value 133 mm/yr was from what data?

Responses:

The value was derived from the water balance equation. The sentence has been modified for clarity as follows:

These river basins were mainly located at high latitudes (approximately 60° North) with relatively low ET_{wb} values (133 ± 50 mm yr^{-1}).

13. It seems the ET should be removed.

Responses:

We carefully checked the manuscript, and the comment may be related to "Nonetheless, the above results generally suggest that the 3T model performance was comparable to that of the water balance ET equation". We deleted ET in this revision as follows:

Nonetheless, the above results generally suggest that the 3T model performance was comparable to that of the water balance equation.

14. PMLv2 looks curious. "v2" may be the version number, suggesting delete it across the entire manuscript but remain a statement somewhere.

Responses:

Thank you very much for your suggestion. The version of ET products PML, "v2", has been removed across the entire manuscript, except in section 2.3.3, where we introduced the ET products as follows:

Among the selected ET products, three products were based on the PM model with varying resistance parameterization schemes, i.e., MOD16 (version 6, Mu et al., 2011), P-LSH (Zhang et al., 2015), and PML (version 2, Zhang et al., 2019), while the remaining three products were based on the PT model (GLEAM version 3.5a; Miralles et al., 2011; Martens et al., 2017), land surface models (GLDAS-Noah version 2.1; Beaudoing and Rodell, 2020; Rodell et al., 2004), and machine learning (Fluxcom; Jung et al., 2019).

15. It is better to clearly state that the EC datasets are the same as those used in figure 2.

Responses:

Thank you very much for your suggestion. The caption of Figure 4 has been improved as follows:

Figure 5: Validation of 6 commonly used ET products (GLDAS, PML, P-LSH, GLEAM, Fluxcom, and MOD16) against EC tower observations. The data are monthly average ET values over the 2003–2013 period and are the same as those used in Fig. 3a.

16. Texts in the figures are too small to read. I suggest the authors enlarge these texts to improve their quality and readability.

Responses:

We tried our best to improve the quality of the figures, including the enlarged text in Figures 2, 4, and 5. Figure 2 shows an example as follows:

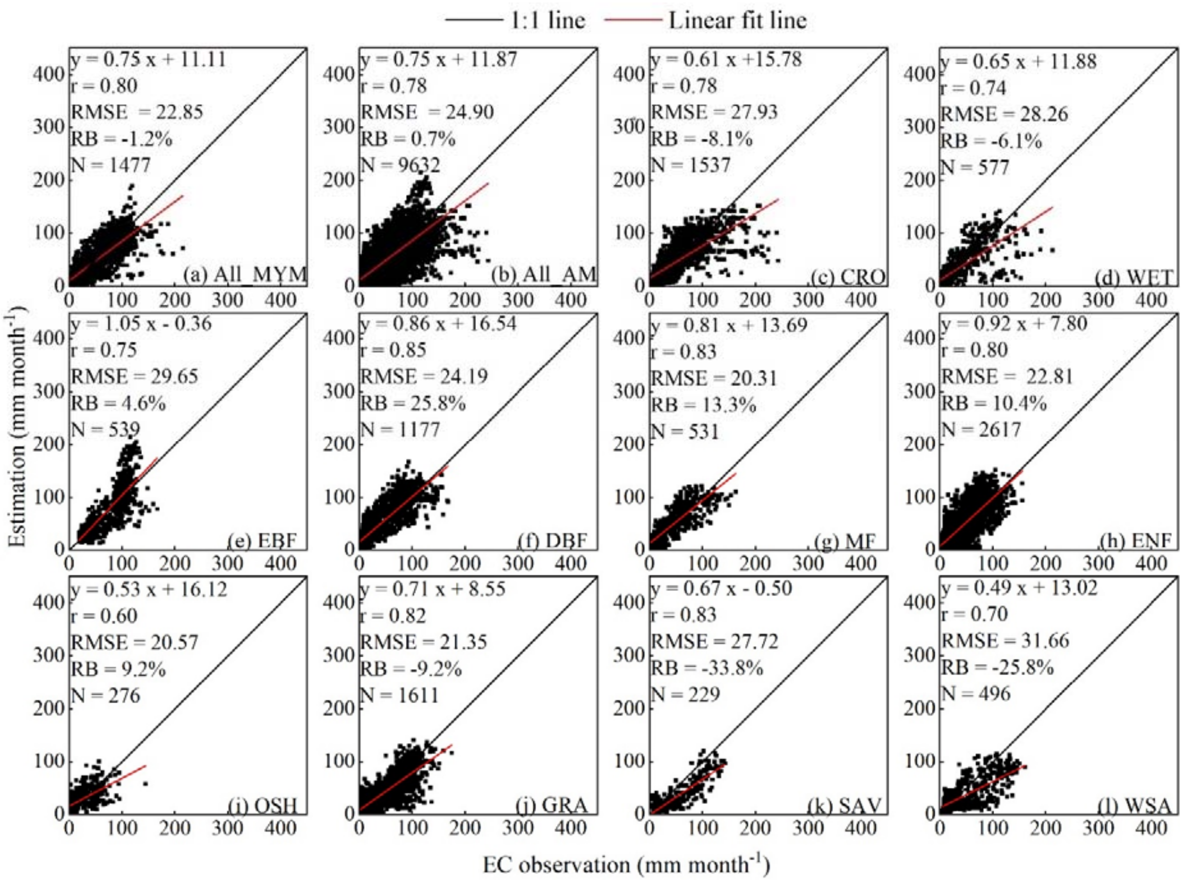

Figure 3: Comparison of the estimated (3T model) and measured (EC tower) monthly ET values from 2003–2013, where (a) shows the data for all 126 sites on a multi-year monthly mean (MYM) scale and (b) shows the data for all sites on an annual mean (AM) monthly scale. (c)-(l) show all land use/land cover

types on an annual monthly scale. The abbreviations in (c)-(l) are the same as those in Fig. 1.

17. What does "PFT" mean? Please consider define such abbreviation.

Responses:

"PFT" in Figures 11-13 has been removed and replaced by "Land use land cover" in the revised manuscript.

18. "the whiskers indicate the extreme values" should be "the whiskers indicate the outlier values".

Responses:

The "extreme" in the caption of Figure 11 has been replaced by "outlier" in the revised manuscript.

Figure 11: Monitoring performance of the 3T model-based terrestrial ET product under extreme heat conditions in the different biomes. The daily ET is shown in energy units. In the box plot (a), the black point indicates the mean, while central line in the box indicates the median value. The edges of the box indicate the 25th and 75th percentiles, and the whiskers indicate the outlier values. In the violin plot (b), the white point indicates the median value, and a wider violin plot indicates denser data for the same RMSE value. N denotes the number of data points.

19. Area of the Antarctica should be wrong.

Responses:

The area of Antarctica is 0.14×10^8 km^2 and has been corrected as follows:

Table 3: Multi-year (2003–2013) average ET values considering the water depth (mm yr^{-1}) and volume (km^3 yr^{-1}) of the different products used in this study for the global land surface.

ET products	ET rate (mm yr^{-1})	ET volume ($\times10^3$ km^3 yr^{-1})
3T	546 ± 22	73.8 ± 3.0
Fluxcom	549 ± 3	74.2 ± 0.4
GLDAS	551 ± 10	74.5 ± 1.3
GLEAM	544 ± 6	73.6 ± 0.7
MOD16	468 ± 6	63.3 ± 0.8
P-LSH	551 ± 8	74.5 ± 1.0
PML	542 ± 12	73.2 ± 1.7

Note: global land surface has an area of 1.35×10^8 km^2, excluding Antarctica.