Response to Anonymous Referee #1:

Dear reviewer, we sincerely appreciate your time and effort in reviewing our manuscript and providing valuable feedback to help improve our work. In the reply, the reviewer's comments are in black, our responses are in blue, and quotes from the revised manuscript are in *orange italics*.

General Comment

This paper describes a "globally seamless ET dataset…with remote sensing and reanalysis data". The data is openly available at the National Tibetan Plateau Data Center for the period 2001-2019. I believe that the paper requires a severe revision of its content, as it lacks most of the details behind the methodology adopted, details on the characteristics of the final products are difficult to find (is it monthly or daily? Is the model applied directly on monthly data or aggregated afterward?), and several key details on the validation are difficult to follow. In addition, numerous typos and unclear sentences can be found throughout the text (see examples in the specific comments below).

However, the most notable drawback of the dataset resides in its inception. The study claims that this is a "remote sensing based" dataset that "overcome the need for pre-defined parameters". Regarding the first point, I found really difficult to see this as a remote sensing product, as the vast majority of the inputs came from ERA5-land. The remote sensing contribution is limited to emissivity and albedo only. This would not have been a major issue (beside the need to reword some of the model descriptions), but it highlights the second major problem of this dataset. The method uses skin LST from ERA5-land. These data are not observed from satellite, but they are modelled within the land surface component of the reanalysis system. It means that skin temperature depends on the parameterization used in ERA5-Land, the same parameterization that you are claiming to avoid. Following this consideration, the relationships used (1-1 and 1-2) acts only as a simplified version of the PM approach, where the skin temperature is derived from the more complex (and heavily parameterized) H-TESSEL.

Overall, the dataset may still have some useful applications related to multi-model assessment, but three key points need to be address: 1) a much better contextualization of the modelling framework and scope in view of the above-mentioned issue; 2) a much better description of the methodology, including differences from already existing approaches, and 3) an improved (especially in consistency) evaluation of the dataset against other similar products (e.g., ET from ERA5-land itself).

Response: We sincerely thank you for providing such professional and constructive feedback on our manuscript. I deeply appreciate your comments which are invaluable in helping refine and strengthen our research. We have responded to your key comments and each specific comments individually.

The responses to general comments are as follows:

(1) The temporal scale of our model and dataset: The RSNP model estimate global monthly ET dataset with monthly inputs, and we have added corelated information where the dataset first mentioned in both Abstract and section '2.2 Framework of Global ET Estimation and Dataset':

a. Abstract: "*In this study, we improved the Remote Sensed Non-Parametric (RSNP) model based on the NP and SFE-NP method with remote sensing and reanalysis data, and estimated global monthly ET from 2001 to 2019 in the spatial resolution of 0.1°.*" (Line 21-23)

b. Section 2.2: "*Remote sensing data and reanalysis datasets with full coverage across the global land surface are used as the inputs of the RSNP model to estimate global land surface ET at monthly scale during 2001-2019…*" (Line 128-130)

c. Section 2.2: "*GLASS 8-day albedo and BBE data were firstly aggregated into monthly scale, …*" (Line 153)

(2) Description of the dataset: The RSNP ET dataset integrates both remote sensing and reanalysis data as inputs, with skin LST obtained from ERA5-Land, rather than direct satellite observations. In response to your comments, we have revised relevant descriptions to remove the term "remote sensing" to avoid any potential misunderstanding. We appreciate your insightful observations, which have helped improve the accuracy of our manuscript.

(3) Modelling of framework: We have reorganized the main structure of our manuscript. In the revised section '2.2 Framework of Global ET Estimation and Dataset', we present the framework together with the introduction of input data and their pre-processing. We also introduce the sequential steps involved in parameter derivation and estimation, ensuring a clear and logical flow of method introduction.

(4) Description of the methodology: We have revised the 'Introduction' and 'Methodology' with a much clearer description of the NP approach.

a. In the last paragraph of Introduction, we extend the basic thesis of the NP method and its development to SFE-NP method: "*Evaporation is the phase change process where water molecules transition from liquid to vapor, and thermal driving is the primary mechanism governing terrestrial evaporation. Hamilton's principle offers a physical insight into the macro-state processes to mechanics and describe thermodynamics. The original nonparametric (NP) method is based on the Hamiltonian principle that terrestrial ET follows in the macroscopic state, with surface temperature as a generalized coordinate of the Hamiltonian, and combining with the equilibrium ET (Liu et al., 2012), the original NP method is in a simple analytical form without parameterization of aerodynamic resistances. To address NP method's applicability in arid areas, the surface flux equilibrium (SFE) with relative humidity was introduced to develop the SFE-NP method (Pan et al., 2024).*" (Line 74-82)

b. In the section '2.1 Nonparametric approach for global ET Estimation', we have expanded on the basic principles, limitations of the NP method, and the basic principles of the SFE-NP method. We introduced the methods in more detail to enhance the readability of the paper.

(5) Comparison with ERA5-Land ET dataset: According to your suggestion, we acknowledge the importance of a more consistent and rigorous evaluation of the RSNP ET dataset, particularly in comparison to ERA5-Land (which has similar parameters). We have enhanced dataset evaluation by incorporating ERA5-Land monthly ET as a reference dataset, expanding the validation analysis to include accuracy assessment and spatial distribution comparisons.

a. Accuracy comparison: At in-situ EC sites, RSNP (R^2=0.65, RMSE=23.19 mm/month, bias=-3.81 mm/month) shows consistency with ERA5-Land (R^2=0.64, RMSE=23.94 mm/month, bias=-1.36 mm/month), and RSNP shows less underestimation than ERA5-Land. For different land cover, "*RSNP shows higher in-situ accuracy than ERA5-Land for vegetated land covers, and the accuracy improvement at the wetland sites is significant, with RMSE reducing from 65.21 mm/month to 20.6 mm/month*" (249-254). At the basin scale, RSNP (R^2=0.89, RMSE=113.04 mm/month, RE=0.16) explicit a slightly higher error than ERA5-Land (R^2=0.89, RMSE=101.02 mm/month, RE=0.13), but has the least overestimation among high ET basins (which higher than 1200 mm/yr).

b. Spatial distribution comparison: ERA5-Land provide global gap-free ET dataset, however, RSNP demonstrates superior capability of ET variations. For example, in the South America, ERA5-Land shows minimal spatial differentiation in ET among vegetation areas, while RSNP successfully captures the gradual transition of ET variation, better reflecting the actual surface heterogeneity. (383-385)

Further details regarding to these modifications can be found in response to specific comments.

Specific comments

Title: A seamless global…

Response: Thank you very much for your thoughtful review. We have corrected the grammar error, and we have revised "Seamless" to "Gap-free" to describe the dataset's continuous and uninterrupted characteristics. The revised title is "A Gap-free Global Terrestrial Evapotranspiration Dataset Estimated by the Nonparametric Approach with Remote Sensing and Reanalysis Datasets".

L17. Water exchange

Response: Thank you very much for your thoughtful review. We have corrected the phrase error. (Line 17)

L18-19. Hydrological, surface energy, and carbon cycles.

Response: Thank you for your thoughtful review. We have checked and corrected the grammatical error of this sentence. (Line 18)

L20. Resistances. This is difficult to follow out of context into an abstract. Please reword.

Response: Thank you for your thoughtful review. We have revised this sentence to indicate the aerodynamic resistances:

"*Different parameterization schemes of aerodynamic resistances might result in uncertainties in global ET dataset.*" (Line 19)

L27. Explain acronyms.

Response: We sincerely appreciate your valuable comments. We have revised this sentence, and the name of each ET dataset were removed in the Abstract section. Moreover, we have corrected all acronyms at their first appearance in the manuscript. Thank you again for your thoughtful review.

L40. To conduct.

Response: Thank you for your thoughtful review. We apologize for the error in grammar, and we have revised this sentence as *"The ability to perform periodic and repetitive observations over regions, coupled with its cost-effectiveness, enables remote sensing conducting global ET observation"*. (Line 43-45)

L41. Conducting. Repetition

Response: Thank you for your thoughtful review. We have rewritten this sentence to avoid the repetition used of "conduct". The revised sentence is:

"*The ability to perform periodic and repetitive observations over regions, coupled with its cost-effectiveness, enables remote sensing conducting global ET observation*". (Line 43-45)

L44. Sequentially?

Response: Thank you for your careful review. The word "sequentially" may confuse the meaning of the sentence, and we have revised this statement for clarity:

"*Some remote sensing models have been proposed based on hydrometeorological approaches (e. g. Penman-Monteith (PM) approach, Priestly-Taylor (PT) approach), such as the Surface Energy Balance System (SEBS), Surface Energy Balance Algorithms for Land (SEBAL), triangle approach (Bastiaanssen et al., 1998b; Bastiaanssen et al., 1998a; Su, 2002; Moran et al., 1994) and so on. They have been widely applied to retrieve ET in many regions*". (Line 45-50)

L50-53. Add references to these datasets.

Response: We sincerely appreciate your feedback on the statement. We had added refences to each global ET dataset to make sure the standardized of science writing.

"*Manny global ET datasets derived from remote sensing data and meteorological forcing data have been proposed, including MODIS-MOD16 dataset (Mu et al., 2011), Penman–Monteith–Leuning Version 2 (PML-V2) dataset (Zhang et al., 2019), the Operational Simplified Surface Energy Balance (SSEBop) dataset (Senay et al., 2020), Calibration-free (CR) dataset (Ma et al., 2021), ETMonitor dataset (Zheng et al., 2022), a simplified surface energy-water balance model based on proportionality hypothesis (PEW) dataset (Fu et al., 2022), three temperature (3T) dataset (Yu et al., 2022) and so on.*" (Line 54-59)

Reference:

Fu, J., Wang, W., Shao, Q., Xing, W., Cao, M., Wei, J., Chen, Z., and Nie, W.: Improved global evapotranspiration estimates using proportionality hypothesis-based water balance constraints, Remote Sens. Environ., 279, 113140, http://doi.org/10.1016/j.rse.2022.113140, 2022.

Ma, N., Szilagyi, J., and Zhang, Y.: Calibration - free complementary relationship estimates terrestrial evapotranspiration globally, Water Resour. Res., 57, e2021WR029691, https://doi.org/10.1029/2021WR029691, 2021.

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

Senay, G. B., Kagone, S., and Velpuri, N. M.: Operational global actual evapotranspiration: Development, evaluation, and dissemination, Sensors, 20, 1915, https://doi.org/10.3390/s20071915, 2020.

Yu, L., Qiu, G. Y., Yan, C., Zhao, W., Zou, Z., Ding, J., Qin, L., and Xiong, Y.: A global terrestrial evapotranspiration product based on the three-temperature model with fewer input parameters and no calibration requirement, Earth Syst. Sci. Data Discuss., 2022, 1-33, https://doi.org/10.5194/essd-14-3673-2022, 2022.

Zhang, Y., Kong, D., Gan, R., Chiew, F. H., 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 Sens. Environ., 222, 165-182, http://doi.org/10.1016/j.rse.2018.12.031, 2019.

Zheng, C., Jia, L., and Hu, G.: Global land surface evapotranspiration monitoring by ETMonitor model driven by multi-source satellite earth observations, J. Hydrol., 613, 128444, https://doi.org/10.1016/j.jhydrol.2022.128444, 2022.

L54. Use consistent units for pixel size.

Response: Thank you for your valuable feedback regarding pixel size units. To ensure clarity and consistency, we have converted 1° to approximately 111 km near the equator. Because the actual geographical distance corresponding to 1 radian varies with the geographical location, so we have standardized the spatial resolution description as follows:
"Among them, the spatial and temporal resolutions of global ET datasets varied from 500 meters to almost 1° (approximately 111 kilometers near the equator)…" (Line 60-61)

L58. Datasets available, they often…

Response: We sincerely appreciate your careful review, and we feel sorry for the writing error. In the revised version, we have removed the original sentence and revised this part to better connect our research focus. The revised statement is, *"Existing global ET datasets still leave room for improvement, primarily relate to the complex parametrization of resistances and the empirical determination of coefficients in global ET models, which affect the applicability and accuracy in the studies of hydrology, meteorology, and ecology. In addition, pixel gaps might lead to limitations in practical application (Chen et al., 2021)."* (Line 65-69)

L62. Metrology?

Response: Thank you for your careful review. We have corrected the word as "meteorology". (Line 67)

L62-63. In this sentence, it is not clear which problem (or problems) this dataset is trying to solve.

Response: Thank you for your insightful comments. We apologize for that the original text did not sufficiently highlight the specific scientific gaps addressed by our dataset. To better indicate our research objectives, we have revised the statement with reference to explicitly state that this study:
"*By evaluating 25 global ET datasets with site observations and their spatial patterns, Tang et.al refer that ET dataset produced based on similar algorithms tend to have high consistency in annual magnitude and spatial distribution (Tang et al., 2024). Therefore, developing a global ET dataset based on well-defined physical mechanisms remains a critical need in ET research.*" (Line 69-74)

Reference:

Tang, R., Peng, Z., Liu, M., Li, Z.-L., Jiang, Y., Hu, Y., Huang, L., Wang, Y., Wang, J., and Jia, L. J. R. S. o. E.: Spatial-temporal patterns of land surface evapotranspiration from global products, 304, 114066, https://doi.org/10.1016/j.rse.2024.114066, 2024.

L66. A lot of repetitions (non-parametric) and unclarified terms (what is the role of Hamilton's principle here).

Response: We sincerely thank you for your constructive comments. Your suggestions have helped us better introduce the ET estimation method. We have removed redundant mentions of "non-parametric" to improve readability. And we have also revised the statement to indicate the role of Hamilton's principle:

"*Hamilton's principle offers a physical insight into the macro-state processes. The original nonparametric (NP) method is based on the Hamiltonian principle that terrestrial ET follows in the macroscopic state, with surface temperature as a generalized coordinate of the Hamiltonian, and combining with the equilibrium ET (Liu et al., 2012), the original NP method is in a simple analytical form without parameterization of aerodynamic resistances.*" (Line 76-81)

L66-69. This sentence is unclear, please reword.

Response: Thank you for highlighting the need for greater clarity in this statement. We have revised this sentence to introduce to more clearly present the performance of NP approaches:

"*The evaluation of the NP and SFE-NP methods, compared with observed LE across EC sites, reveals that the RMSE ranges from approximately 11 to 34 W/m² at the daily scale (Pan et al., 2024).*" (Line 84-85)

L76. I suggest introducing the methodology first, as explaining the data used, without introducing for what they are used for, make difficult to follow.

Response: Thank you for your valuable suggestion and it helps us better organize the readability of this manuscript. We have reorganized Section2 to introduce "Methodology and Materials" with global ET model, model input dataset, and model validation dataset. As suggested, we have initially introduced the methodology, and then introduced the framework of RSNP model together with model inputs, finally introduced the validation datasets. The structure of Section2 is as follows:

2.Methodology and Materials
- 2.1 Nonparametric approach for global ET Estimation
- 2.2 Framework of Global ET Estimation and Model Forcing Data
- 2.3 Datasets for Evaluation
  - 2.3.1EC Observations from FLUXNET2015
  - 2.3.2Water-balance-based ET of Global Basins
  - 2.3.3Other Global ET Datasets

L78. As the inputs of

Response: Thank you for your careful review. We have corrected the grammatical error of this sentence. (Line 129)

L79. To estimate ET…. Daily? Monthly? Not clear.

Response: We sincerely appreciate your valuable suggestion regarding to the temporal resolution of the RSNP ET estimation. The temporal resolution of the ET dataset has been added in the revised sentence, and it locates in Section2.2:

"*Remote sensing data and reanalysis datasets are used as the inputs of the RSNP model to estimate global land surface ET at monthly scale during 2001-2019*". (Line 128-130)

L80. At a spatial resolution

Response: Thank you for your careful review, we apologize for the incorrect use of prepositions, and this statement have been revised according to the reorganization of Section2.

L81. Longwave radiation.

Response: Thank you for your careful review. We have corrected the term "surface thermal radiation downwards" to "longwave radiation" throughout the manuscript.

L87. Resempled… how? Especially land use, which is categorical.

Response: Thank you for your comments on the preprocessing of model inputs. In this paper, the GLASS data were resampled to a spatial resolution of 0.1° using the nearest neighbor resampling, and the land use type were aggregated to 0.1° by the maximum fraction method. We have modified the pre-processing of model inputs at section2.2:

"*The consistency of spatial and temporal resolution in the input images is crucial for ensuring the computability of multi-source remote sensing data. GLASS 8-day albedo and BBE were firstly aggregated into monthly albedo and BBE, considering there were still missing pixels of albedo and BBE which would result in missing value of ET result, the nearest day gap-filling method were used to directly fill the missing pixels at the monthly scale. And finally, the gap-filled global albedo and BBE, and global aridity index datasets were resampled to 0.1° using the nearest neighbor resampling. The land use type was aggregated to 0.1° by the maximum fraction method before adapted into the RSNP model.*" (Line 152-158)

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Table 1. This table is not referenced in the text, as far as I can tell.

Response: We sincerely appreciate your feedback. In the revised version, we added the reference of Table 1 at the beginning of scetion2.2, where these datasets were first mentioned in our manuscript. (Line 131)

Table 1. Please clarify which input is from remote sensing and which from reanalysis. Also, please separate the model inputs from other data used for validation and analysis. The "data usage" column may not be seen by a reader, especially when things are mixed (2 retrievals, then validation, then retrieval again, …).

Response: We sincerely appreciate your insightful suggestions for improving Table 1. We have added a column of "Data Type" to distinguish which input is from remote sensing and which from reanalysis. And according to the change of the manuscript's structure, the revised Table 1 only introduces model input data. The revised Tabel 1 is as follows:

Table 1 Remote sensing and reanalysis datasets used in the RSNP model

Dataset	Data Type	Variables	Spatial resolution	Temporal resolution
GLASS	Remote sensing data	Black sky Albedo White sky Albedo Broadband Emissivity (BBE)	0.05°×0.05°	8-day
ERA5-Land	Reanalysis data	Skin temperature Surface pressure Downward longwave radiation Downward shortwave radiation 2m Temperature 2m Dew point temperature	0.1°×0.1°	Monthly

MCD12Q1 The water-balance-based ET on dataset of large river basins of the world	Reanalysis data	Land cover type	1 km×1 km	Annual
Version 3 of the Global Aridity Index and Potential Evapotranspiration Database	Reanalysis data	Aridity Index	1 km×1 km	

Table 1. Aridity index.

Response: Thank you for your careful review. We have corrected 'arid index' to 'aridity index' throughout the manuscript.

L93. Was the closure forced on the data. Which method?

Response: Thank you for your comments which helps enhance our manuscript. FLUXNET2015 provide corrected by the energy closure correction factor, and the corrected data is 'LE_CORR'. To provide further clarification, we have added following statement for clarity:

"*ET observation offered from FLUXNET2015 were corrected by energy balance closure correction factor (Pastorello et al., 2020).*" (Line 175-176)

Reference:

Pastorello, G., Trotta, C., Canfora, E., and Papale, D.: The FLUXNET2015 dataset and the ONEFlux processing pipeline for eddy covariance data, Nature Publishing Group, https://doi.org/10.1038/s41597-020-0534-3, 2020.

L100. Some more details on this dataset are needed. A section (2.3) of just few lines is not acceptable.

Response: Thank you for your valuable feedback. In the revised manuscript, we have significantly expanded the description, provided a more comprehensive explanation of the methodology associated with the WBET dataset, as well as the selection of validation basins. We have expanded the revision as following (Section 2.3.2 in the revision):

"*This study applied the water-balance-based ET (WBET) of global typical large river basins dataset to validated global ET datasets at the annual scale (Ma, 2024). This dataset includes WBET data for fifty-six typical large river basins globally from 1983 to 2016, and it is based on measured runoff data from hydrological stations, four precipitation datasets, and three terrestrial water storage* *datasets. For each river basin under consideration, twelve WBET were generated. Subsequently, the Bayesian three-cornered hat method was employed for weighted averaging to derive the optimal combined WBET dataset. The uncertainty in ET estimation, calculated through error propagation methods, remains within 10% (Ma et al., 2024). This dataset was derived from National Tibetan Plateau Data Center (https://data.tpdc.ac.cn/en/data). We excluded basins that cover less than 2×10^5 km^2 and ultimately selected 38 basins, and the global distribution of these chosen basins is shown in Fig. 2.*" (Line 185-195)

Section 2.4. Same as before, some more details are needed. Modelling approach, main inputs, similarity in either inputs or methods, etc.

Response: We sincerely appreciate your valuable feedback and apologize for the insufficient description of the datasets, which indeed fell short of proper scientific writing standards. In response to this concern, we have thoroughly expanded the discussion of global ET datasets in the revised manuscript (Section 2.3.3), providing additional details on their modeling approaches and spatial resolutions to enhance clarity. (Line 200-224)

L116. Nearest neighbour method.

Response: We sincerely thank you for your valuable comments. We have addressed the spelling error throughout the manuscript.

L116. "the differences…" at which time scale? Daily? Monthly? Again, not clear.

Response: Thank you for your comments, and we feel sorry for the unclear description. We have revised this sentence which state comparison between RSNP and present ET datasets. The revised statement is as follows:

"*This study evaluated the accuracy of global ET datasets regarding the in-situ ET observations at monthly scale, as well as the regional applicability against WBET and the consistency and differences of their spatial and temporal characteristics at the annual scale.*" (Line 221-223)

Table 2. This table is not referenced in the text.

Response: Thank you for your comments. Table 2 has now been mentioned at the beginning of Section3.3, where the global ET datasets were first be mentioned. (Line200)

L130. Some more details on the formulations are need. The reader needs to understand the basis of this approach without the need to go reading another full paper. For instance, the first term (Rn-G) is related to the available energy, and it is in common in all ET approach, but what about the other terms? What (Ts4-Ta4) represents? And the logarithmic term with Gs?

Response: We sincerely appreciate your suggestions, which have greatly helped to enhance the clarity of our methodology. In response to your valuable comments, we have expanded Section 2.1 to provide a more comprehensive introduction to the methodology (Line 96-126). This includes an explanation of the foundation of the original NP method, the improvements introduced in the SFE-NP method, and how these methods are applied for global estimation. In addition, we also provided Appendix. A and Appendix. B, which detail the derivation of the NP method and the SFE-NP method, and the physical interpretation of each component is elaborated in the supplementary materials.

The meaning of $\varepsilon\sigma(T_s^4 - T_0^4)$ and $G_s ln\left(\frac{T_s}{T_0}\right)$ in Eq.1 and Eq.2 can be included in the introduction to the derivation:

When T_s serves as a generalized coordinate of the system, we can obtain Eq. A4,

$$\frac{\partial HA}{\partial T_s} = \frac{\partial\left(\int_{t_1}^{t_1}\int_A (G_s+H+LE+R_n)dAdt\right)}{\partial T_s} = 0 \,, \tag{A4}$$

and obviously we can have $\partial(G_s + H + LE + R_n)/\partial T_s = 0$. Among them, the partial derivative of R_n with respect to T_s is $\frac{\partial R_n}{\partial T_s} = -4\varepsilon\sigma T_s^3$. Under the constraint of a given R_n, the partial derivative of LE with respect to T_s is $\partial LE/\partial T_s = 0$ (Wang et al., 2004; Wang et al., 2007) according to the Lagrangian multiplier method. With the energy conservation equation and Fourier's law, further incorporating $\partial G_s/\partial T_s = G_s/T_s$ (Magyari et al., 1999). Consequently, we can obtain the partial derivation of H to T_s as Eq. A5,

$$\frac{\partial H}{\partial T_s} = 4\varepsilon\sigma T_s^3 - \frac{G_s}{T_s} \,, \tag{A5}$$

and when $T_s > 0$, $\partial H/\partial T_s$ is evidently a continuous function which can be expressed as Eq. A6 (where H_{T_0} is the heat flux referenced to surrounding environment when $T_s = T_0$).

$$\int_{T_0}^{T_s} \frac{\partial H}{\partial T_s} dT_s = H_{T_s} - H_{T_0} \,, \tag{A6}$$

Integrating from T_0 to T_s, we can obtain Eq. A7,

$$H_{T_s} = H_{T_0} + \varepsilon\sigma(T_s^4 - T_0^4) - G_s ln\left(\frac{T_s}{T_0}\right), \tag{A7}$$

among them, $\varepsilon\sigma(T_s^4 - T_0^4)$ and $G_s ln\left(\frac{T_s}{T_0}\right)$ is from the derivation and integrating of R_n and G_s, respectively.

Reference:

Wang, J., Salvucci, G. D., and Bras, R. L.: An extremum principle of evaporation, Water Resour. Res., 40, https://doi.org/10.1029/2004WR003087, 2004.

Wang, J., Bras, R. L., Lerdau, M., and Salvucci, G. D.: A maximum hypothesis of transpiration, J. Geophys. Res.: Biogeosci., 112, https://doi.org/10.1029/2006JG000255, 2007.

Eqs. (4) and (5) are not really needed, as they are basic physics. Please expand, instead, on the peculiarity of your method compared to other approaches. How do you "avoid parameters"?

Response: We sincerely appreciate your insightful comments. According to your suggestion, we have made following improvements:

(1) We have removed Eqs. (4) and (5) since they are basic equations for relative humidity and saturated water vapor estimation.

(2) We have added supplement to provide the derivation of both the NP and the SFE-NP method (Appendix A and Appendix B) without parametrization of resistances. Traditional methods such as the Penman-Monteith method was builds on the Penman formula by introducing surface resistance to describe the resistance to water vapor transfer between the surface and the near-surface atmosphere, and by using aerodynamic resistance to express the turbulent transfer resistance of heat and moisture in the near-surface atmosphere. In contrast, the reason for NP avoid parameterization

of resistance is that it treats terrestrial ET as a thermodynamic process in a macroscopic state based on Hamilton's principle. Net radiation is regarded as the potential energy of the system, and land surface temperature serves as a generalized coordinate reflecting the energy exchange between the surface and the atmosphere. The dynamics of the system are determined by the Lagrangian $L = K - P$, the difference between kinetic (K) and potential (P) energies. To a terrestrial ground surface layer, assumed to be isotropic and incompressible without lose of generality, Rn serves as the potential energy. Accordingly, the Lagrangian can be described as:

$$L = \int_{t_1}^{t_2} \int_A Udvdt + \int_{t_1}^{t_2} \int_A GdAdt + \int_{t_1}^{t_2} \int_A (H + LE)dAdt - \int_{t_1}^{t_2} \int_A R_n dAdt, \tag{A1}$$

where v is volume of the ground surface layer, A is the surface area, and t is the time interval from t_1 to t_2. The Hamiltonian (HA) HA is described as follows:

$$HA = \int_{t_1}^{t_2} \int_A Udvdt + \int_{t_1}^{t_2} \int_A GdAdt + \int_{t_1}^{t_2} \int_A (H + LE)dAdt + \int_{t_1}^{t_2} \int_A R_n dAdt, \tag{A2}$$

In the ground surface layer, the heat transfer is traditionally described with Fourier's equation. In the modern theory of general thermodynamics, the equation has been modified to be more general, known as the Maxwell–Cattaneo equation (Tarkenton and Cramer, 1994). On the surface, $\int_{t_1}^{t_2} \int_A Udvdt$ vanishes and G shifts to G_s in each equation. HA is described as follows:

$$HA = \int_{t_1}^{t_2} \int_A G_s dAdt + \int_{t_1}^{t_2} \int_A (H + LE)dAdt + \int_{t_1}^{t_2} \int_A R_n dAdt, \tag{A3}$$

By virtue of the Hamiltonian system, ground surface temperature (T_s) serves as a generalized coordinate of the dynamical system in phase space (Strauch, 2009). Based on the Hamiltonian principle, the motion of the system ($K + P$) remains constant. With respect to T_s, there has:

$$\frac{\partial HA}{\partial T_s} = \frac{\partial\left(\int_{t_1}^{t_1} \int_A (G_s+H+LE+R_n)dAdt\right)}{\partial T_s} = 0, \tag{A4}$$

And obviously, $\partial(G_s + H + LE + R_n)/\partial T_s = 0$.

On the basis of surface energy balance, and assuming that the air temperature is independent on land surface temperature, the partial derivative of R_n with respect to T_s is $\frac{\partial R_n}{\partial T_s} = -4\varepsilon\sigma T_s^3$, where ε is surface emissivity, and σ is the Stephan Boltzmann constant. Under the constraint of a given R_n, $\partial LE/\partial T_s = 0$ (Wang et al., 2004; Wang et al., 2007) according to the Lagrangian multiplier method. With the energy conservation equation and Fourier's law, further incorporating $\partial G_s/\partial T_s = G_s/T_s$ (Magyari et al., 1999), we obtain the following:

$$\frac{\partial H}{\partial T_s} = 4\varepsilon\sigma T_s^3 - \frac{G_s}{T_s}, \tag{A5}$$

When $T_s > 0$, $\frac{\partial H}{\partial T_s}$ is evidently a continuous function. Mathematically, we obtain the following equation:

$$\int_{T_0}^{T_s} \frac{\partial H}{\partial T_s} dT_s = H_{T_s} - H_{T_0}, \tag{A6}$$

where H_{T_s} is the sensible heat flux at T_s, and H_{T_0} is the heat flux referenced to surrounding environment when $T_s = T_0$. Subsequently, we obtain the following expression:

$$H_{T_s} = H_{T_0} + \varepsilon\sigma(T_s^4 - T_0^4) - G_s ln\left(\frac{T_s}{T_0}\right), \quad \text{(A7)}$$

Coupled with H_{T_0} is the terrestrial ET in the reference state (LE_{T_0}). An optional reference state is local thermal equilibrium (T_s= T_0) for ET. In the original NP method, the conventional equilibrium ET(LE_E) cane be expressed as:

$$LE_E = \frac{\Delta}{\Delta+\gamma}(R_n - G_s), \quad \text{(A8)}$$

where Δ is the slope of the saturated vapour pressure, and γ is the psychometric constant, was introduced. In practice, T_0 refers to the surface air temperature (T_a) measured using a standard meteorological instrument. The definition yields $H_{T_0} = \Delta/(\Delta + \gamma)(R_n - G_s)$ to satisfy the energy conservation correspondingly. Combined with Eq.5, the sensible heat flux can be expressed as:

$$Hs = \frac{\gamma}{\Delta+\gamma}(R_n - G_s) + \varepsilon\sigma(T_s^4 - T_a^4) - G_s ln\left(\frac{T_s}{T_a}\right), \quad \text{(A9)}$$

where *Ts* is the land surface temperature, *Ta* is the surface air temperature, ε is surface emissivity, and σ is the Stephan Boltzmann constant.

Then, the latent heat flux, LE, which is equivalent to the actual ET, can be estimated based on the energy budget, and the LE estimated by the original NP method is:

$$LE = \frac{\Delta}{\Delta+\gamma}(R_n - G_s) - \varepsilon\sigma(T_s^4 - T_a^4) + G_s ln\left(\frac{T_s}{T_a}\right), \quad \text{(A10)}$$

The derived formulas for sensible (Eq.A9) and latent heat fluxes (Eq.A10) contain only observable physical quantities, thus avoiding parameterization of resistance in the non-parametric approaches.

L156. Why is the resampling needed? Just for a different projection? Not clear.

Response: Thank you for your helpful comments. We are sorry for the mistake in this sentence, because the 0.05° GLASS were resampled to 0.1° instead of 0.05°, and we have revised this error. The revision is as follows:

"*And finally, the gap-filled global albedo and BBE, and global aridity index datasets were resampled to 0.1° using the nearest neighbor resampling.*" (Line 156-157)

L157. How where water bodies, etc. excluded?

Response: Thank you for your comments. The sentence has been rewritten to indicate that *"water bodies, and permanent ice and snow were excluded according to the classification of MCD12Q1 dataset of each year."*, and we hope the revised expression provides greater clarity and precision. (Line 130)

L158. Here there is the first reference to monthly scale, but it should be made clearer and it should be reported much earlier. Also, is the approach designed for monthly scale? Does eqs. 1-1 and 1-2 valid at monthly temporal scale?

Response: We sincerely thank you for your valuable comments about the clarification of the temporal scale of the RSNP ET dataset. The monthly scale should be explicitly stated earlier in the manuscript to avoid ambiguity, and we have made improvements:

a. According to your suggestion, we have introduced the temporal scale in the Abstract: "*we improved the Remote Sensed Non-Parametric (RSNP) model based on the NP and SFE-NP method with remote sensing and reanalysis data, and estimated global monthly ET from 2001 to 2019 in the spatial resolution of 0.1°.*" (Line 21-22)

b. We include our dataset was produced with monthly input images in the revised section '2.2 Framework of Global ET Estimation and Model Fording Data': "*GLASS 8-day albedo and BBE data were firstly aggregated into monthly scale,, ...*" (Line 153)

L162. Aridity index.

Response: Thank you for your careful review. The incorrect spelling of the word has been corrected.

L163. Aridity. Please fix throughout the text.

Response: Thank you for your thorough review, and we appreciate your attention to detail, which helps ensure the quality of our manuscript. The misspelling of "aridity" has been corrected throughout the manuscript.

L163-165. Why 0.65 is used? Please add some reference to support this choice.

Response: Thank you for your comments, which helps ensure the quality our manuscript. The United Nations Environment Program (UNEP) defines arid lands based on the aridity index, and when the aridity index is less than 0.65, it is classified as arid area. In the revised manuscript, we have added the references from both the Global Aridity Index dataset and from the UNEP to support this choice. (Line 147)

Reference:

Zomer, R. J., Xu, J., and Trabucco, A.: Version 3 of the global aridity index and potential evapotranspiration database, Sci. Data, 9, 409, http://doi.org/10.1038/s41597-022-01493-1, 2022.

UNEP: World Atlas of Desertification - Second Edition, 1997.

Fig. 3. The goal of the upper part of the figure (steps 1 to 5) is not clear. Is this just for gap filling? Very little is said about that in the main text.

Response: Thank you for your comments. The step 1 to 5 in original Fig.1 is the gap-filling of the GLASS albedo and BBE, and it is a pre-processing process of model inputs. In the revised Section 2.2, we have restructured the flowchart and rewritten the description of the gap - filling process to present it in a more logical manner:

"The consistency of spatial and temporal resolution in the input images is crucial for ensuring the computability of multi-source remote sensing data. GLASS 8-day albedo and BBE data were firstly aggregated into monthly scale, considering there were still missing pixels of albedo and BBE which would result in missing value of ET result, the nearest day gap-filling method were used to directly fill the missing pixels at the monthly scale." (Line 152-156)

L168. This sentence is unclear. How was this evaluated?

Response: We sincerely thank you for your comments on this statement. We have looked through the 8-day BBE images with missing values in South Africa, Asia, and Australia, but your comments made us realize that "without reference to" is unreasonable, so we have removed such an inappropriate expression.

L173-176. This part of the pre-processing is very confusing. It needs rewording and expanding.

Response: Thank you for your valuable suggestion on the statement of pre-processing. We have reorganized the description of the pre-processing in Section 2.2, and we also revised the flowchart according to the description. The revised description of pre-processing is as follows:

"*The consistency of spatial and temporal resolution in the input images is crucial for ensuring the computability of multi-source remote sensing data. GLASS 8-day albedo and BBE data were firstly aggregated into monthly scale, considering there were still missing pixels of albedo and BBE which would result in missing value of ET result, the nearest day gap-filling method were used to directly fill the missing pixels at the monthly scale. And finally, the gap-filled global albedo and BBE, and global aridity index datasets were resampled to 0.1° using the nearest neighbor resampling. The land use type was aggregated to 0.1° by the maximum fraction method before adapted into the RSNP model.*" (Line 152-158)

Section 3.3 I found this section mostly unnecessary.

Response: We sincerely thank your valuable comments on our manuscript regarding the organization of our manuscript. As you mentioned that the "Validation Method and Accuracy Metrics" is not the main part of this manuscript, and we have removed this section. In addition, the validation process and statistical metrics been contained along with the introduction of validation datasets (Section2.3), and is located at Line161-179:

"The performance of RSNP ET was evaluated through a multi-scale framework. At the site scale, RSNP monthly ET dataset were validated against in-situ EC observations to verify their accuracy against ground observations. While the mismatch between observational footprints and 0.1° pixel dimensions could lead to uncertainties in in-situ assessment (Liu et al., 2016), RSNP annual ET were evaluated with water-balance based ET at basins to access the model's effectiveness for the regional scale. Additionally, comprehensive cross-validation was conducted with multiple global ET datasets to examine the consistency and discrepancies in global spatio-temporal patterns. The statistical metrics of assessing the RSNP model including mean bias error (bias), relative error (RE), and Relative Mean Squared Error (RMSE) and Coefficient of determination (R^2)."

L182-183. This sentence is not clear.

Response: We sincerely thank you for your valuable feedback on this sentence. We have revised the description of cross-validation process to improve its clarity:

Section 2.3: *"Additionally, comprehensive cross-validation was conducted with multiple global ET datasets to examine the consistency and discrepancies in global spatiotemporal patterns."* (Line 165-167)

L186. This reference is not needed. These are standard metrics used in validation, not specifically introduced in that research.

Response: Thank you for your careful look through of our manuscript and the valuable feedback on this sentence. We have removed the reference of this metrics which is not a specifically point of this research.

L206. Absolute value

Response: We sincerely thank you for your careful review. The incorrect spelling of the word has been corrected as ‘value’. (L245)

L227-229. This appears to be just 1 point. What is the point to compare this case with all the others? This analysis is very weak.

Response: We sincerely appreciate the reviewer’s insightful comment regarding the comparison in Fig.7. We acknowledge that drawing conclusions based on a single point lacks statistical significance and weakens the analysis. To address this, we have removed this statement to ensure a more rigorous presentation of our findings. Thank you again for highlighting this important point.

Fig. 8. Differences among models seems mostly systematic, so what is the point of showing multiple years? Wouldn’t be better to show the average year? Regional results would also be useful. Global average data are somewhat difficult to analyze.

Response: Thank you for your insightful comments on the temporal comparison of global ET datasets, and we have made revisions according to your suggestion. In the original manuscript, the inter-annual variability is presented since the monthly ET values are the direct outputs of the RSNP model, and we compared monthly ET variations to cross-validate the performance of RSNP. According to your comments, we have revised Fig.8 to include ERA5-Land and GLEAM ET dataset for cross-validation, and Fig.8 shows that RSNP exhibits the closest inter-annual variation with GLEAM. In addition, we have also provided the annual variability over the 2003-2018 period in Appendix C (Figure S1) to address the performance of average year, and the Figure S1 reveals that ERA5-Land yields higher magnitudes than RSNP at annual scale, while PEW shows the lowest annual ET. All six global ET dataset showed a pronounced increase from 2009 to 2010. Furthermore, we also presented Africa (Appendix C. Figure S2) annual ET as regional results, for which ET values varied obviously among different ET datasets. RSNP (602.74 mm/yr) presented the highest average ET among Africa, while and other ET datasets ranged from 461.07 mm/yr (PEW) to 562.19 mm/yr (ETMonitor).

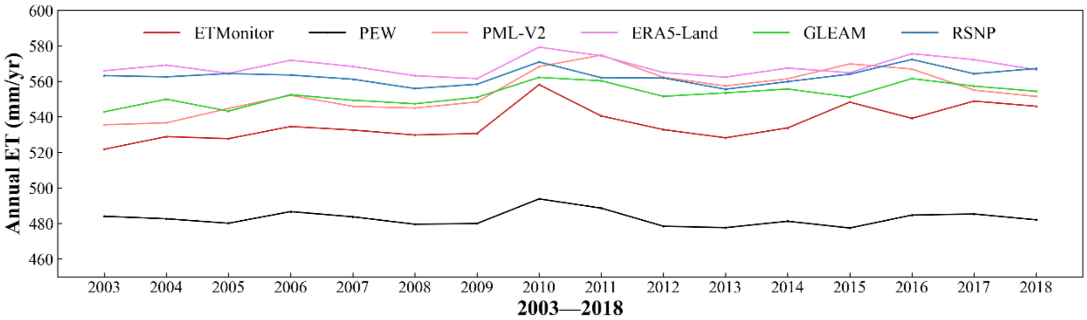

Figure S1: Global annual average ET (mm/year) of ETMonitor, PEW, PML-V2, ERA5-Land, GLEAM, and RSNP during 2003-2018.

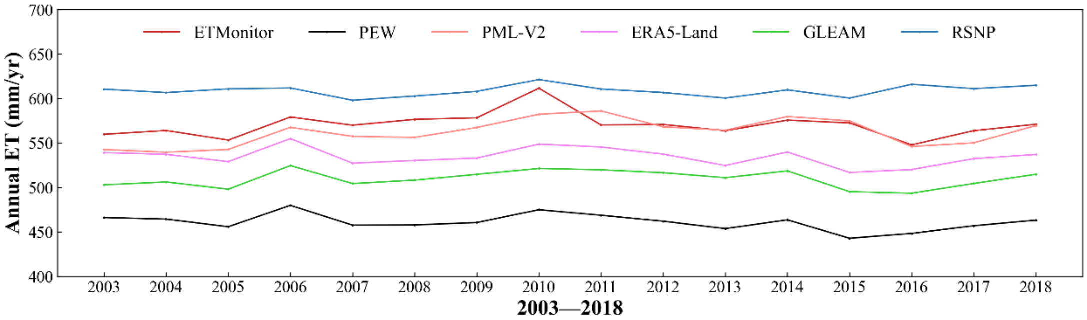

Figure S2: Global annual average ET (mm/year) of ETMonitor, PEW, PML-V2, ERA5-Land, GLEAM, and RSNP during 2003-2018 over Africa.

L260. What is the difference? Please quantify. This is true for the entire results section, where often qualitative statements such as "is higher" is not accompanied by quantification.

Response: We sincerely appreciate your thoughtful comments on our manuscript. We apologize for lacking quantification in our results section, where qualitative statements such as "is higher" are often made without accompanying numerical details. This indeed affects the precision and comparability of our results. We have extended quantification of difference in the highest ET of each dataset, such as in Section3.3.2:

a. *"In tropical rainforest areas, higher ET values are observed, with RSNP, PML-V2, PEW, and ERA5-Land showing annual ET values in the range of 1300-1500 mm/yr, while ETMonitor and GLEAM display values approximately 1400-1800mm/yr in these regions."* (Line 303-305)

b. *"For instance, the highest annual ET for RSNP, PML-V2, PEW, and ERA5-Land are located in the Malay Archipelago, exceeding 1500 mm/yr. Meanwhile, ETMonitor and GLEAM shows the highest annual ET over 1700mm/yr in both South America and Malay Archipelago."* (Line 306-309)

c. *"In both the Northern and Southern Hemispheres, the peak ET values of RSNP were observed near the equator (0° latitude), exceeding 1000mm/yr. As latitude increases, the average ET decreases sharply, dropping to nearly 500 mm/yr by around 30° latitude."* (Line 319-303)

In addition, we also revised other qualitative statements to clarify the details in results and discussions, thank you again for your insightful comments.

L262-265. From the map in Fig. 9, it is not clear this difference in your dataset compared to the other. Also, here and later, there is a lot on emphasis on ET over the desert (missing values, values different than 0, etc.). Is this really that important? Are you expecting notable difference in water budget over these regions.

Response: We sincerely appreciate your valuable feedback on this statement. According to your comments, since Fig.9 did not show the difference between RSNP and other datasets, we removed the previous statement, and we have also added Fig.S3 in the supplement to display the differences of annual ET among RSNP and other datasets. Additionally, except the north Africa, we also expanded quantitative comparison for Australia:

"*In Australia, PEW, GLEAM, and ERA5-Land showed annual ET lower than 300mm/yr in most areas, while RSNP, ETMonitor, and PML-V2 shows obvious ET variation from 300mm/yr to nearly 700 mm/yr.*" (Line 316-318)

In addition, ET value plays a crucial role in desert regions, serving as a key component of the water balance. Previous study across 25 basins in Africa revealed that precipitation ranges from ~0 to 300 mm/yr in North Africa's basin, while run-off was ~ 0mm/yr (Karamage et al., 2018). The water balance equation (P=R+E+S, where P is the precipitation, R is the run-off, E is the evapotranspiration, S is the water storage change) would become unbalanced if ET were excluded. Although ET values are typically low in arid regions, they remain an essential consideration in water budget analyses. We have also added related discussion in section 4.1:
"Karamage et al.'s research across Africa basins revealed that both precipitation and run-off varies over basins in North Africa (Karamage et al., 2018). Consequently, missing ET value can compromise the closure of annual water balance assessments." (Line 350-353)

Reference:
Karamage, F., Liu, Y., Fan, X., Francis Justine, M., Wu, G., Liu, Y., Zhou, H., and Wang, R.: Spatial relationship between precipitation and runoff in Africa, Hydrology Earth System Sciences Discussions, 2018, 1-27, https://doi.org/10.5194/hess-2018-424, 2018.

L274. Consistent behaviour with latitude.
Response: Thank you very much for your kind comments. The phrase has been revised as *"consistent behaviour with increasing latitude"* (Line 326)

L284. Seam?
Response: Thank you for your really helpful suggestion, we apologize for the indeed an inappropriate word usage here. We have replaced "Seam" with "Gap". (Line334)

L295-297. This result, and Fig. 10, raises the question: did you use the same dates for the analyses in Figs. 8 and 9 for all datasets? Average values should be computed on the same samples, so if you used a different number of dates for each dataset (based on availability or coverage) the results will be biased just for that and not for the differences in methodology.
As an example, if one dataset tends to have gaps during cloudy days, its average ET will be higher just because those cloudy days are not included. Please ensure consistency in the results reported.
Response: We sincerely appreciate your comments regarding spatial and temporal consistency for analyses. We have addressed these valuable concerns from three aspects:

(1) Fig.8 to Fig.10 is based on the same samples. We collected global monthly ET data of RSNP, ETMonitor, PML-V2, PEW, ERA5-Land, and GLEAM during the period from 2003 to 2018. Fig. 8 collected all available pixel for average monthly ET calculation, and Fig.9's annual ET is the sum of monthly ET. Fig. 10 displays the monthly pixel loss rate of each dataset on a global land surface. We have added statements in the front of Section 4.1 to clarify this issue: *"The analysis of temporal and spatial pattern presented in Fig.8 to Fig.10 were from ETMonitor, PEW, PML-V2, ERA5-Land, GLEAM, and RSNP global ET datasets over the 2003-2018 period."* (Line284-285)

(2) For monthly ET estimation, RSNP and other global ET datasets were obtained with clear-sky remote sensing data (albedo and BBE), which is gap-free at the monthly scale. Gaps in other ET datasets primarily from data storage format rather than cloud coverage, as noted in Chaolei Zheng's comments (Comment #3, who published the ETMonitor ET dataset).

(3) While clear-sky ET may slighter higher than all-sky ET, they are conventionally treated as representative of complete monthly values in applied research (Elnashar et.al, 2020; Liu et.al, 2023), as well as the accuracy comparison in similar researches (Ma et.al, 2021; Yu et.al, 2022). Accordingly, the evaluation of ET datasets was performed without all-sky/clear-sky normalization.

Reference:

Elnashar, A., Wang, L., Wu, B., Zhu, W., and Zeng, H.: Synthesis of global actual evapotranspiration from 1982 to 2019, Earth Syst. Sci. Data, 13, 447-480, http://doi.org/10.5194/essd-13-447-2021, 2021.

Liu, H., Xin, X., Su, Z., Zeng, Y., Lian, T., Li, L., Yu, S., and Zhang, H.: Intercomparison and evaluation of ten global ET products at site and basin scales, J. Hydrol., 617, 128887, https://doi.org/10.1016/j.jhydrol.2022.128887, 2023.

Ma, N., Zhang, Y., and Szilagyi, J.: Water-balance-based evapotranspiration for 56 large river basins: A benchmarking dataset for global terrestrial evapotranspiration modeling, J. Hydrol., 630, 130607, http://doi.org/10.1016/j.jhydrol.2024.130607, 2024.

Yu, L., Qiu, G. Y., Yan, C., Zhao, W., Zou, Z., Ding, J., Qin, L., and Xiong, Y.: A global terrestrial evapotranspiration product based on the three-temperature model with fewer input parameters and no calibration requirement, Earth Syst. Sci. Data Discuss., 2022, 1-33, https://doi.org/10.5194/essd-14-3673-2022, 2022.

L298-299. This statement is confusing. Mu refers to 24% of land surface. Where the 81% comes from? What is a middle-high latitude?

Response: Thank you for your valuable feedback. Mu et al. refers to deserts covering 24% of the global land area. The 81% represents the proportion of total global land area located in the Northern Hemisphere, which we derived from statistics. We are sorry that the original statement was unclear. We revised this sentence to better indicate land located northern of 30°N where the gap values mostly located. The revised statement is as follows:

"*Barren/deserts regions account for about 24% of the land surface (Mu et al., 2011), and land located north of 30°N latitude accounts approximately 45% of the Earth's total land area.*" (Line 349-350)

L302. Most of the missing values in the other datasets seems related to desert. How much the water balance can be compromised there when ET is mostly 0 anyway? The missing data is an important point, but it is more relevant in regions when ET is different than 0 when the data are missing. I will focus on these conditions to highlight your point.

Response: We sincerely appreciate your insightful comments regarding the discussion of missing values in desert regions. For the statistic of monthly ET, missing values located in both desert regions and above 30°N. The ET value is also important of water balance in arid regions, since previous research over 25 basins in Africa revealed precipitation ranges from ~0 to 300 mm/yr over North Africa's basin, while run-off was ~ 0mm/yr, which addressed the imbalance of water-balance (Karamage et al., 2018). We have also added related discussion to discussion:

"Karamage et al.'s research over Africa basins revealed that both precipitation and run-off varies over basins in North Africa (Karamage et al., 2018). Consequently, missing ET value can compromise the closure of annual water balance assessments." (Line 350-353)

Reference:

Karamage, F., Liu, Y., Fan, X., Francis Justine, M., Wu, G., Liu, Y., Zhou, H., and Wang, R.: Spatial relationship between precipitation and runoff in Africa, Hydrology Earth System Sciences Discussions, 2018, 1-27, https://doi.org/10.5194/hess-2018-424, 2018.

L305. Shifts.

Response: We thank you for catching this typo. The excessive full stop has been removed in the revised manuscript. (Line 357)

Fig. 11. Monthly availability… How is this monthly? Not clear.

Response: We sincerely appreciate your comment on Fig. 11, and thank you for pointing out the lack of clarity regarding the monthly representation. We have revised the title of Fig.11 as '*Figure 12: Spatial distribution of monthly ET pixels available ratio during 2003-2018 for global ET datasets (water, and permanent ice and snow were excluded).*' to clarify the time-span for analysis. (Line 361-362)

L317. This dataset is seamless because is not a remote sensing-based product. If you try to use skin LST from satellite, then you would have a RS dataset but with some gaps.

Response: We sincerely appreciate your valuable comments, which significantly helps to enhance the academic quality of our paper. To address your valuable comments, we have removed emphasis on "our remote sensing ET data" since we used both remote sensing and reanalysis data as model forcing. The revised statement refers to *"The RSNP model enables gap-free global ET estimation without reliance on calibration or parameterization."* (Line 374-375). Furthermore, the generation of long temporal scale (monthly/annual) LST composites involves aggregation of short temporal scale (instantaneous/daily) observations, with gap-filling applied during monthly compositing. Consequently, missing values in the model output ET datasets are not only attributed to LST data. Considering that recent studies have published high accuracy global gap-free LST datasets (Jia et al., 2023; Hong et al., 2021; Liu et al., 2023), we will further adopt remote sensing LST product to update the RSNP ET dataset, providing a more detailed estimation at a higher spatial resolution.

Reference:

Hong, F., Zhan, W., Göttsche, F.-M., Lai, J., Liu, Z., Hu, L., Fu, P., Huang, F., Li, J., and Li, H.: A simple yet robust framework to estimate accurate daily mean land surface temperature from thermal observations of tandem polar orbiters, Remote Sens. Environ., 264, 112612, https://doi.org/10.1016/j.rse.2021.112612, 2021.

Jia, A., Liang, S., Wang, D., Ma, L., Wang, Z., and Xu, S.: Global hourly, 5 km, all-sky land surface temperature data from 2011 to 2021 based on integrating geostationary and polar-orbiting satellite data, Earth Syst. Sci. Data, 15, 869-895, https://doi.org/10.5194/essd-15-869-2023, 2023.

Liu, X., Li, Z.-L., Li, J.-H., Leng, P., Liu, M., and Gao, M.: Temporal upscaling of MODIS 1-km instantaneous land surface temperature to monthly mean value: Method evaluation and product generation, IEEE Transactions on Geoscience Remote Sensing, 61, 1-14, http://doi.org/10.1109/TGRS.2023.3247428, 2023.

L320. This statement is very confusing to me, first because skin LST from ERA5-land relies on these resistances, and second because the methodology does not explain how the method get rid of the resistances.

Response: We sincerely appreciate your insightful comment regarding how our method eliminates resistances. We apologize for any confusion caused by the unclear statements in the original text. To address this, we will clarify the issue from the following aspects:

(1) We apologize for the incorrect description of this statement, and we have revised this statement to emphasize that the model is based on methods which avoid parameterization of resistances, and the revised statement is *"Conversely, the RSNP based on Hamiltonian principle and remains a diagnostic model independent from empirical resistance or calibration and is helpful for eliminating uncertainties in global terrestrial water-energy budget researches."*. (Line 396-399)

(2) To clarify the process of avoiding parameterization, we have added supplement to provide the derivation of both the NP and the SFE-NP method (Appendix A and Appendix B). Traditional methods such as the Penman-Monteith method was builds on the Penman formula by introducing surface resistance to describe the resistance to water vapor transfer between the surface and the near-surface atmosphere, and by using aerodynamic resistance to express the turbulent transfer resistance of heat and moisture in the near-surface atmosphere. In contrast, the reason for NP avoid parameterization of resistance is that it treats terrestrial ET as a thermodynamic process in a macroscopic state based on Hamilton's principle. Net radiation is regarded as the potential energy of the system, and land surface temperature serves as a generalized coordinate reflecting the energy exchange between the surface and the atmosphere. The derived formulas for sensible and latent heat fluxes only contain observable physical quantities. In the RSNP model, the model inputs include surface net radiation, soil heat flux, air temperature, land surface temperature, and relative humidity, they can directly be derived from remote sensing and reanalysis dataset.

(3) We sincerely appreciate your insightful comment regarding the potential uncertainties in the estimation accuracy of ERA5-Land skin LST due to its reliance on the parameterized H-TESSEL model. To address this, we would incorporate global gap-free remote sensing LST products (e.g., those developed by Hong et al., Jia et al., and Liu et al.) as model forcing in future improvements of the RSNP model. Furthermore, we have acknowledged the limitations of the LST input in the discussions as *"Additionally, utilizing gap-free global LST products as model inputs offers stronger physical foundations and reduced parametric dependence relative to reanalysis datasets, which would better controlling uncertainty at the data input level."* (Line 403-407). We hope these revisions could help to improve our dataset in the future.

L327. Our dataset…

Response: Thank you for pointing out the spelling error of the original manuscript. The statement have been improved in the revised manuscript, and we have checked and corrected spelling error throughout the whole manuscript. Thank you again for your attention to detail, which has helped improve the quality of our paper.

L328-332. This sentence is very confusing. Please reword.

Response: Thank you for your insightful comment regarding the clarity of our statements. We appreciate your feedback, and we have addressed the confusion in the sentence you pointed out. The revise sentence is as following:

"Moreover, the RSNP ET dataset, with a spatial resolution of 0.1°, provides more detailed ET information compared to PML-V2 (0.5 km), PEW (0.1°), and GLEAM (0.25°). This suggests that spatial resolution alone does not determine the accuracy of ET datasets (Stisen et al., 2008; Zheng et al., 2022)." (Line 385-388)

L333. ERA5-land has already an ET product. You should include in your analysis a comparison with that product, as it is based on mostly the same forcings and is produced together with the skin LST used in this study. What is the added value of your methodology compared with what is already there?

Response: Thank you for your valuable suggestions which are important for our manuscript.

In response to your suggestion regarding the necessity of the RSNP model's dependence on resistance parameters, we have included ERA-5Land ET dataset for cross-validation in the revised manuscript. Consequently, the results from cross-validation revealed that, RSNP performed better than ERA5-Land under vegetated and saturated land covers, *"RSNP shows higher in-situ accuracy than ERA5-Land for vegetated and saturated land covers, and the accuracy improvement at the wetland sites is significant, with RMSE reducing from 65.21 mm/month to 20.60 mm/month."* (Line 252). In addition, RSNP demonstrates superior performance in capturing spatial details of ET patterns, even ERA5-Land and RSNP share most of the model forcing at the same spatial resolution (0.1°). Corresponding comparison and discussion have been added to Section4.2, such as: *"For instance, in South America, ERA5-Land shows minimal spatial differentiation in ET between low and high vegetation areas, while RSNP successfully captures the gradual transition of ET variation, better reflecting the actual surface heterogeneity."* (Line 383-385). In conclusion, the added value of proposed RSNP model existed in both improve accuracy and reduce uncertainties in ET estimation. We have attached these importances in the discussion and we hope these revisions would improve our manuscript. Thank you again for these insightful suggestions.

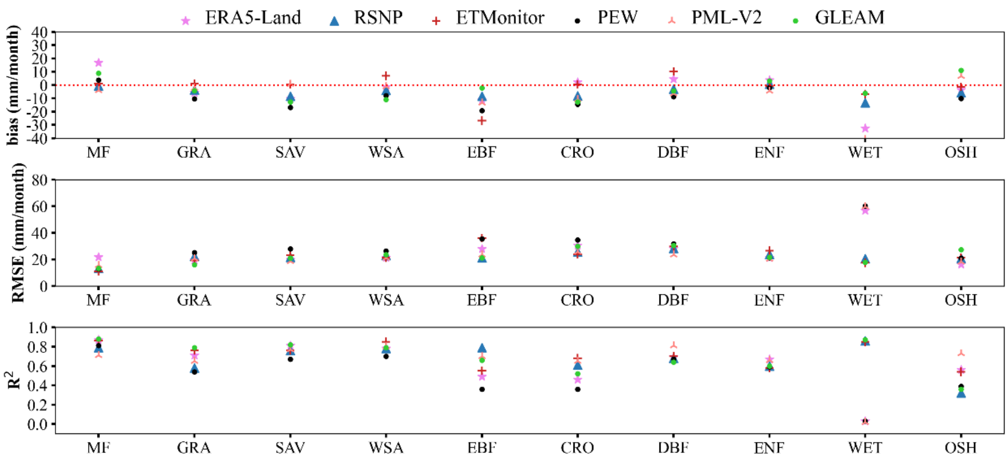

Figure 1: Comparison of estimated ET and observed ET over FLUXNET2015 sites at ten types of land covers, including MF (Mixed Forest), GRA (Grassland), SAV (Savanna), WSA (Woody

Savanna), EBF (Evergreen Broadleaf Forest), CRO (Cropland), DBF (Deciduous Broadleaf Forest), ENF (Evergreen Needleleaf Forest), WET (Wetland), OSH (Open Shrublands). The relative mean square error (RMSE) and bias are both in mm/month.

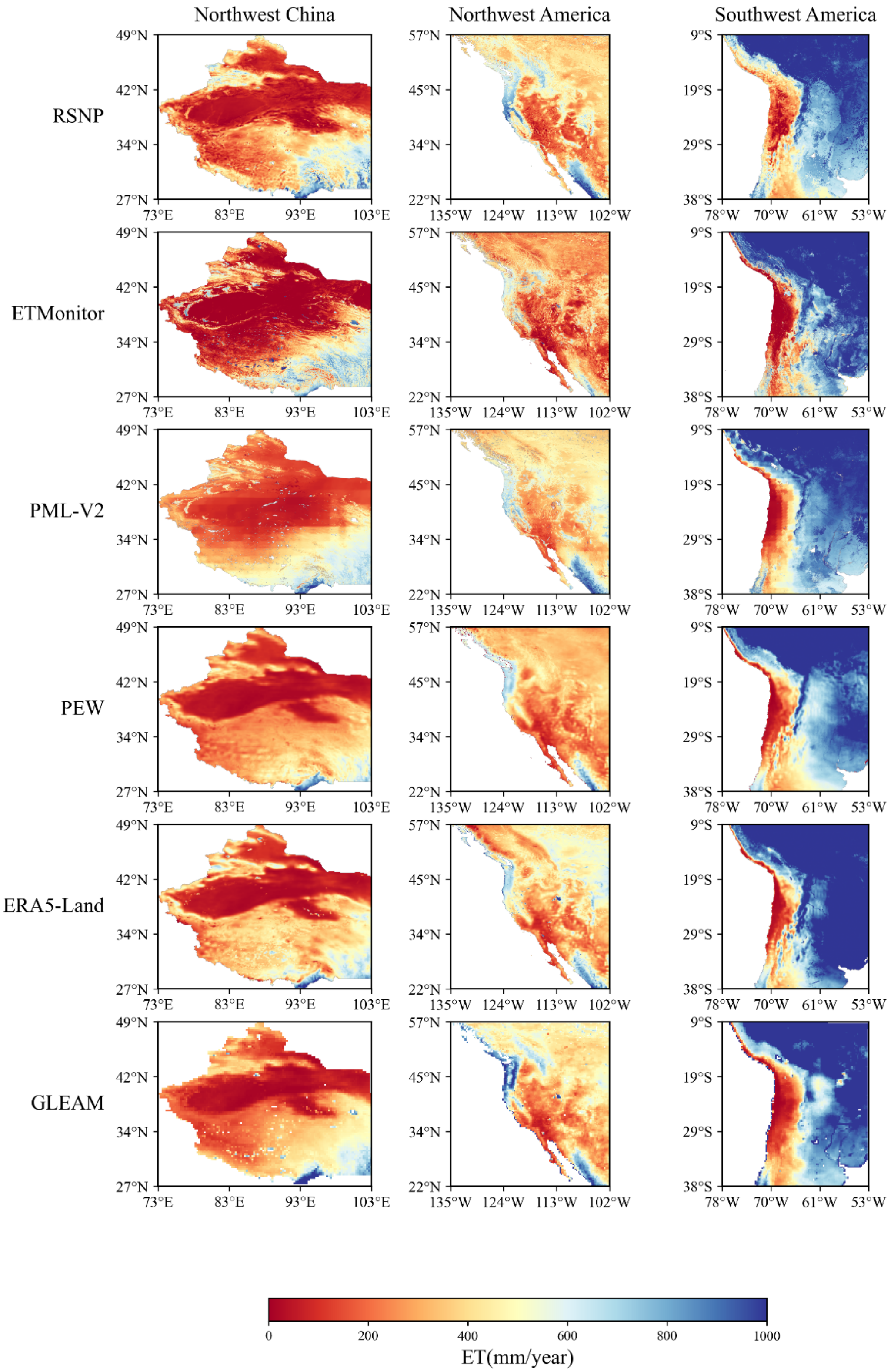

Figure 12: Spatial pattern of global ET datasets in typical regions in 2014. Columns from left to right: (a) Northwest China; (b) Northwest America; (c) Southwest America.

L337. Residual surface energy balance is neglected here, which is weird as it is the more "direct" method from remote sensing to assess ET.

Response: Thank you for your valuable feedback on this statement. we have included the surface energy balance residual methods to list as suggested.

"However, incorporating datasets faces a fundamental challenge which result from datasets sharing similar theoretical frameworks tend to exhibit correlated systematic biases (e. g. PM equation, PT equation, surface energy balance residual methods)." (Line 392-394)

L337. "…may have similar systematic uncertainty". Is your method so different from PM? A lot of the same factors plays a role in this method and in PM. In the text, you also confirm a lot of similarities between your dataset and the others. A better description of the methodology can help understanding the key differences and why it should not be affected by the same systematic differences as the other methods.

Response: We sincerely appreciate your insightful comment. The familiar terms in NP and PM equation are related to they are based on the same equilibrium evaporation equation (Eq. A8). In response, we have expanded descriptions in Section2.1 together with a supplement (Appendix A and Appendix B) to provide a detailed derivation of the NP and SFE-NP method based on Hamilton's principle, and we hope the extension in Methodology and supplement would improve the clarity of our approach. Additionally, we provide statement to illustrate the non-parametric estimation process:

Traditional methods such as the Penman-Monteith method was builds on the Penman formula by introducing surface resistance to describe the resistance to water vapor transfer between the surface and the near-surface atmosphere, and by using aerodynamic resistance to express the turbulent transfer resistance of heat and moisture in the near-surface atmosphere. In contrast, the reason for NP avoid parameterization of resistance is that it treats terrestrial ET as a thermodynamic process in a macroscopic state based on Hamilton's principle. Net radiation is regarded as the potential energy of the system, and land surface temperature serves as a generalized coordinate reflecting the energy exchange between the surface and the atmosphere. The dynamics of the system are determined by the Lagrangian $L = K - P$, the difference between kinetic (K) and potential (P) energies. To a terrestrial ground surface layer, assumed to be isotropic and incompressible without lose of generality, Rn serves as the potential energy. Accordingly, the Lagrangian can be described as:

$$L = \int_{t_1}^{t_2} \int_A \ Udvdt + \int_{t_1}^{t_2} \int_A \ GdAdt + \int_{t_1}^{t_2} \int_A \ (H + LE)dAdt - \int_{t_1}^{t_2} \int_A \ R_n dAdt, \quad \text{(A1)}$$

where v is volume of the ground surface layer, A is the surface area, and t is the time interval from t_1 to t_2. The Hamiltonian (HA) HA is described as follows:

$$HA = \int_{t_1}^{t_2} \int_A \ Udvdt + \int_{t_1}^{t_2} \int_A \ GdAdt + \int_{t_1}^{t_2} \int_A \ (H + LE)dAdt + \int_{t_1}^{t_2} \int_A \ R_n dAdt, \quad \text{(A2)}$$

In the ground surface layer, the heat transfer is traditionally described with Fourier's equation. In the modern theory of general thermodynamics, the equation has been modified to be more general, known as the Maxwell–Cattaneo equation (Tarkenton and Cramer, 1994). On the surface, $\int_{t_1}^{t_2} \int_A \ Udvdt$ vanishes and G shifts to G_s in each equation. HA is described as follows:

$$HA = \int_{t_1}^{t_2} \int_A G_s dAdt + \int_{t_1}^{t_2} \int_A (H + LE) dAdt + \int_{t_1}^{t_2} \int_A R_n dAdt, \quad \text{(A3)}$$

By virtue of the Hamiltonian system, ground surface temperature (T_s) serves as a generalized coordinate of the dynamical system in phase space (Strauch, 2009). Based on the Hamiltonian principle, the motion of the system ($K + P$) remains constant. With respect to T_s, there has:

$$\frac{\partial HA}{\partial T_s} = \frac{\partial\left(\int_{t_1}^{t_1} \int_A (G_s + H + LE + R_n) dAdt\right)}{\partial T_s} = 0, \quad \text{(A4)}$$

And obviously, $\partial(G_s + H + LE + R_n)/\partial T_s = 0$.

On the basis of surface energy balance, and assuming that the air temperature is independent on land surface temperature, the partial derivative of R_n with respect to T_s is $\frac{\partial R_n}{\partial T_s} = -4\varepsilon\sigma T_s^3$, where ε is surface emissivity, and σ is the Stephan Boltzmann constant. Under the constraint of a given R_n, $\partial LE/\partial T_s = 0$ (Wang et al., 2004; Wang et al., 2007) according to the Lagrangian multiplier method. With the energy conservation equation and Fourier's law, further incorporating $\partial G_s/\partial T_s = G_s/T_s$ (Magyari et al., 1999), we obtain the following:

$$\frac{\partial H}{\partial T_s} = 4\varepsilon\sigma T_s^3 - \frac{G_s}{T_s}, \quad \text{(A5)}$$

When $T_s > 0$, $\frac{\partial H}{\partial T_s}$ is evidently a continuous function. Mathematically, we obtain the following equation:

$$\int_{T_0}^{T_s} \frac{\partial H}{\partial T_s} dT_s = H_{T_s} - H_{T_0}, \quad \text{(A6)}$$

where H_{T_s} is the sensible heat flux at T_s, and H_{T_0} is the heat flux referenced to surrounding environment when $T_s = T_0$. Subsequently, we obtain the following expression:

$$H_{T_s} = H_{T_0} + \varepsilon\sigma(T_s^4 - T_0^4) - G_s ln\left(\frac{T_s}{T_0}\right), \quad \text{(A7)}$$

Coupled with H_{T_0} is the terrestrial ET in the reference state (LE_{T_0}). An optional reference state is local thermal equilibrium (T_s= T_0) for ET. In the original NP method, the conventional equilibrium ET(LE_E) cane be expressed as:

$$LE_E = \frac{\Delta}{\Delta+\gamma}(R_n - G_s), \quad \text{(A8)}$$

where Δ is the slope of the saturated vapour pressure, and γ is the psychometric constant, was introduced. In practice, T_0 refers to the surface air temperature (T_a) measured using a standard meteorological instrument. The definition yields $H_{T_0} = \Delta/(\Delta + \gamma)(R_n - G_s)$ to satisfy the energy conservation correspondingly. Combined with Eq.5, the sensible heat flux can be expressed as:

$$Hs = \frac{\gamma}{\Delta+\gamma}(R_n - G_s) + \varepsilon\sigma(T_s^4 - T_a^4) - G_s ln\left(\frac{T_s}{T_a}\right), \quad \text{(A9)}$$

where *Ts* is the land surface temperature, *Ta* is the surface air temperature, ε is surface emissivity, and σ is the Stephan Boltzmann constant.

Then, the latent heat flux, LE, which is equivalent to the actual ET, can be estimated based on the energy budget, and the LE estimated by the original NP method is:

$$LE = \frac{\Delta}{\Delta+\gamma}(R_n - G_s) - \varepsilon\sigma(T_s^4 - T_a^4) + G_s ln\left(\frac{T_s}{T_a}\right), \quad \text{(A10)}$$

The derived formulas for sensible (Eq.A9) and latent heat fluxes (Eq.A10) contain only observable physical quantities, thus avoiding parameterization of resistance in the non-parametric approaches.