Response to Anonymous Referee #2:

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*.

The manuscript provides a new global ET dataset, which is meaningful for the detection of long-term global ET variation and water resource detection. Then that dataset is validated by FLUXNET sites and water-balance ET data. The subject of the manuscript is within the scope of ESSD. It is worth publishing in the journal provided a major revision following the comments given as below:

The concept of "Nonparametric Approach" which was mentioned in the title, it suggested to briefly explain the core concept of this method in the Abstract.

Response: We sincerely appreciate your valuable suggestion regarding the explanation of the nonparametric approach in the Abstract. To address this problem, we have revised the text accordingly. The updated statement is as follows:

"*The nonparametric (NP) method and Surface Flux Equilibrium-nonparametric (SFE-NP) method are ET estimation approaches that without the parametric of resistance parameters.*" (Line20-21)

L 28: "our dataset offers a continuous and seamless ET dataset suitable for global research." The repeated use of the dataset, and the sentence should be simplified.

Response: We sincerely appreciate your feedback on this statement. As suggested, we have revised the sentence to improve clarity and precision. The revised statement is as follows:

"*Furthermore, RSNP provides continuous and gap-free global ET.*" (Line27)

L 28: "This study contributes to the advancement of global ET estimation and informs future water balance studies." It is too general and lacks specific descriptions of your contributions.

Response: We sincerely appreciate your valuable suggestion regarding the need for a more specific description of our study's contributions. As suggested, we have revised the concluding sentence of the Abstract to better highlight the key advancements of our work. The updated text now clearly states:

"*This study advances global ET estimation by eliminating the need for resistance parameterization, and the RSNP ET dataset directly supports improved water resource management and climate modeling efforts.*" (Line28-30)

L 37: Please extend the description with how and why the distribution of these flux sites across the global land surface influenced the accuracy of estimating global ET.

Response: Thank you for your valuable suggestion, which has helped improve the clarity of our manuscript. According to your comments, we have refined our description to more explicitly highlight the discontinuous temporal coverage and discrete spatial distribution of ground-based observations limit their ability to estimate global ET. And the revised sentence lays the groundwork for subsequently discussing the advantages of using remote sensing to estimate regional ET. The updated text now reads:

"*This discontinuous and uneven sampling makes point-scale observations particularly inadequate for capturing the spatiotemporal dynamics of regional water and energy cycles. Notably, the underlying surface within a region often demonstrates greater homogeneity compared to the localized conditions represented by individual stations, further emphasizing the limitations of relying solely on discrete point measurements.*" (Line39-43)

L 39: The word "conduct" is repeatedly used, please rewrite the sentence.

Response: We sincerely appreciate your valuable suggestion regarding the repeated use of the word "conduct." As per your comment, we have revised the sentence to improve clarity and avoid redundancy, and the revision is as following:

"The ability to perform periodic and repetitive observations over regions, coupled with its cost-effectiveness, enables remote sensing conducting global ET observation (Liu et al., 2022; Zhang et al., 2016). " (Line43-45)

L 64: Although the last paragraph of Introduction mentions the non-parametric method (NP) and the surface flux equilibrium-non-parametric method (SFE-NP), there is no detailed explanation of the principles of these methods and their advantages over the traditional parametric methods. Nor is it explained how these methods avoid the complex parametric process and how they improve the accuracy and applicability of ET estimation.

Response: We sincerely appreciate your valuable comments regarding the need for more detailed explanations of the NP and SFE-NP methods. In response to your suggestions, we have made the following revisions to the manuscript:

(1) In the last paragraph of the Introduction section, we have added a more comprehensive explanation of both methods' principles and advantages:

"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." (Line74-76)

"*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.*" (Line76-80)

(2) As supplementary material, we are providing a detailed derivation of the NP and SFE-NP formulations (Appendix A and B), which includes the mathematical foundations of both methods and step-by-step derivations of key equations.

L72: In the Introduction section, although the RSNP model was mentioned, but there is no detailed explanation of how this model solves the problems of existing models and its unique contribution in global ET estimation. The research goals should be more specific and clearer.

Response: Thank you very much for your comments regarding the gap that this study addresses. As you suggested, a clearer explanation for RSNP's novelty and specific research goal is of vital importance in the Introduction section. After introducing the NP and SFE-NP methods, we pointed out the novelty of developing a global dataset based on the NP approaches, and the crucial role

that RSNP will play in reducing systematic errors in the global land surface ET analysis of multi-dataset integration. The revised statement of research goal is as follows:

"*Consequently, developing a global ET dataset based on NP approaches helps to reduce uncertainty by eliminating the reliance on resistance parameterizations. A globally improved model based on NP approaches (namely RSNP model) is proposed in this paper, from which a global, gap-free ET dataset has been produced. As a novel Hamiltonian principle-based global ET model, RSNP model would especially reduce the systematic errors of the datasets based on the same principle (e.g. the PM method) when integrating different global ET datasets for global change research.*" (Line88-94)

L84: Please explain how the 1 km resolution of MODIS land cover data was reconciled with the 0.1° resolution of other datasets. Was any downscaling or upscaling applied, and if so, what methods were used?

Response: We sincerely thank you for your constructive feedback, which helps to improve the clarity of our manuscript. In this research, the 1km MODIS land cover classification dataset was resampled with the maximum fraction method. According to your comments, we added the following description in Section2.2:

"*The land use type was aggregated to 0.1° by the maximum fraction method before adapted into the RSNP model.*" (Line157-158)

L109: The RSNP model's input data are mainly from ERA5-Land, and ERA5-Land also provides a data set of actual ET. However, the section of cross-validation of RSNP does not reflect the comparison with ERA5-Land.

Response: We sincerely appreciate your insightful comment regarding the comparison between RSNP and ERA5-Land ET datasets. Since the radiation variables and surface temperature in RSNP model are derived from ERA5-Land, we acknowledged that a systematic comparison would better highlight the unique characteristics and advantages of the proposed RSNP. In response to your suggestion, we have added the following analysis in the revised manuscript:

(1) We added the ERA5-Land to the validation and comparison:

The revise scatter plot of model validation shows that RSNP has a more concentrated scatter density distribution than ERA5-Land, especially less underestimations (Fig.4). For different land covers, 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 (Fig.5). At the basin scale, statistical comparisons reveal that RSNP's RMSE, bias and R^2 values fall within similar ranges as other global ET products, suggesting equivalent capability in capturing ET dynamics at the basin scale.

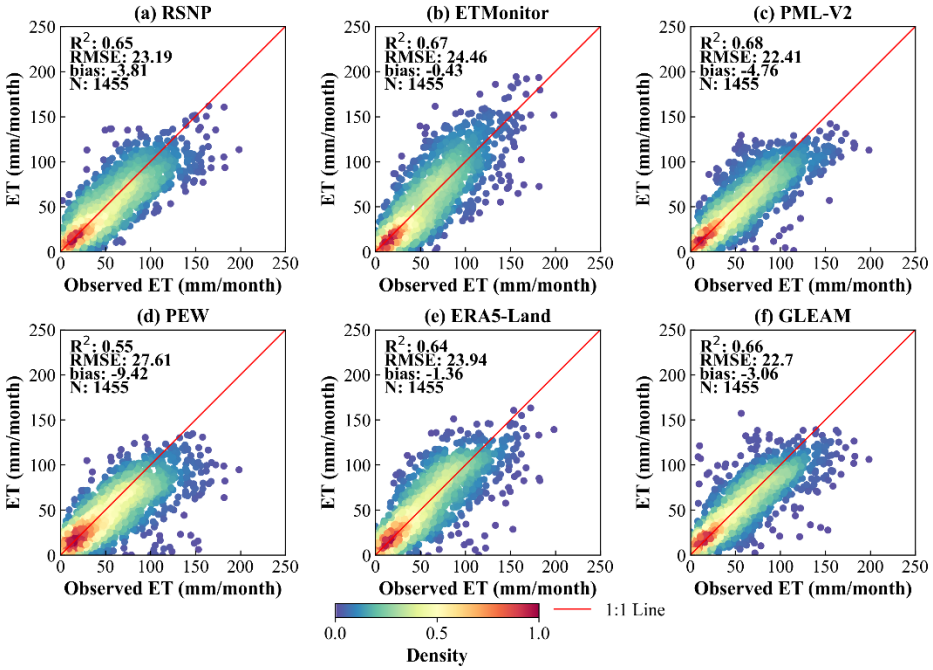

Figure 4: Comparison of estimated ET and observed ET over FLUXNET2015 sites. The relative mean square error (RMSE) and the bias are both in mm/month.

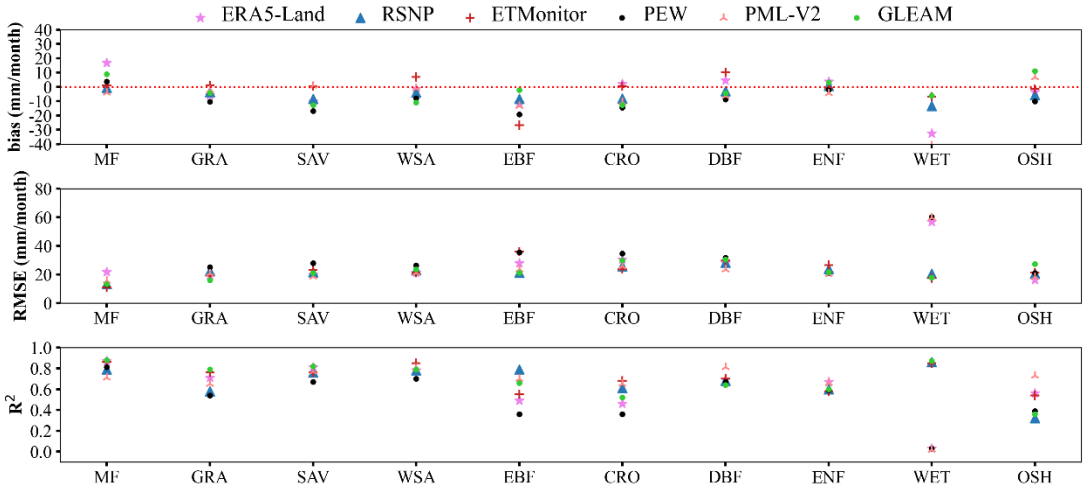

Figure 5: Comparison of estimated ET and observed ET over FLUXNET2015 sites at ten types of land covers, including MF (Mixed Forest), GRA (Grassland), SAV (Savanna), WSA (Woody Savanna), EBF (Evergreen Broadleaf Forest), CRO (Cropland), DBF (Deciduous Broadleaf Forest), ENF (Evergreen Needleleaf Forest), WET (Wetland), OSH (Open Shrublands). The relative mean square error (RMSE) and bias are both in mm/month.

(2) We added the ERA5-Land ET dataset to the spatial distribution analysis:

Although RSNP and ERA5-Land ET sharing identical input parameters, they fundamentally different in algorithmic principles - physical parameterization versus Hamiltonian-based nonparametric formulation, which lead to distinct spatial patterns in estimated terrestrial ET. From the comparison in regional areas, RSNP shows more details than ERA5-Land such as in the South Africa (Fig.12).

"For instance, in South America, ERA5-Land shows minimal spatial differentiation in ET between low and high vegetation areas, whereas RSNP successfully captures the gradual variation of ET, better reflecting the actual surface heterogeneity." (Line383-385)

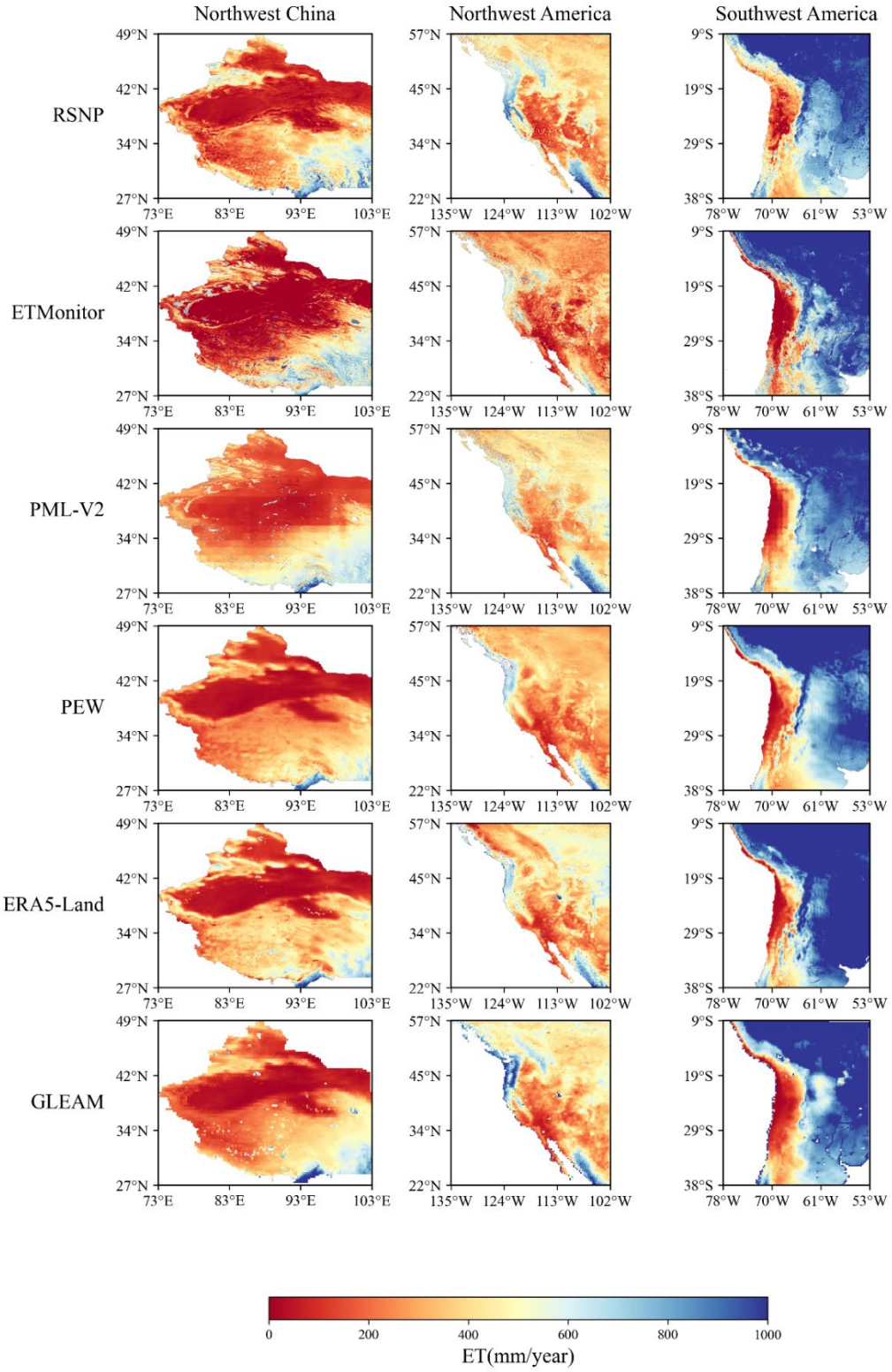

Figure 13: Spatial pattern of global ET datasets in typical regions in 2014. Columns from left to right: (a) Northwest China; (b) Northwest America; (c) Southwest America.

L110: Several acronyms (e.g., PT-JPL) are introduced without full definitions upon first mention, which hinders readability for non-specialist audiences. Ensure all abbreviations are spelled out at first occurrence.

Response: We sincerely appreciate your careful reading and constructive suggestion regarding acronym definitions. In response to this comment, we have spelled out all acronym when they firstly occurred at the Introduction section of the revised manuscript, such as:

"PEW is constructed based on a unified water balance model derived from the generalized proportionality hypothesis and incorporating available water control into the Priestly Taylor-Jet Propulsion Laboratory (PT-JPL) algorithm, …" (Line214-216)

L138: There is an error in Equation2 for calculating net surface radiation, and it should be revised.

Response: We greatly appreciate your careful examination and valuable correction, and we sincerely apologize for the error in Eq.2 regarding the calculation of net surface radiation. We have added the 4th power superscript to the final term of the net surface radiation equation as follows: (Line124)

$$R_n = (1-\alpha)R_{sd} + R_{ld} - \varepsilon_s \sigma {T_s}^4, \quad (3)$$

L180: "Direct validation is composed of validation at the point scale and validation at the basin scale". It is necessary to elaborate on the specific differences and complementarities of these two validation methods, and to verify the validity and reliability of the model from which aspects respectively?

Response: We sincerely appreciate your insightful suggestion regarding the clarification of our validation approaches. We have substantially revised the statement to better explain the differences and complementarities between point-scale and basin-scale validation methods, as well as their respective roles in verifying model performance. The revised statement is located in Section2.3:

"*The performance of RSNP ET was evaluated through a multi-scale framework. At the point scale, RSNP monthly ET were compared against in-situ Eddy Covariance observations to verify their accuracy against ground observations. For the regional scale, RSNP annual ET were evaluated with water-balance based ET at basins to access the model's effectiveness. Additionally, comprehensive cross-validation was conducted with multiple global ET products to examine the consistency and discrepancies in global spatio-temporal patterns.*" (Line161-167)

L196: Figure 4 reflects the scatter density with stretched colors, but a color band indicating whether red or blue represents a high or low density is missing?

Response: We sincerely appreciate the reviewer's careful observation regarding the clarity of Figure 4. In response to this comment, we have revised the figure to include a labeled color bar indicating the density scale, where red represents high-density regions with frequent data points and blue represents low-density regions with sparse data points), and the revised Fig.4 is as follows:

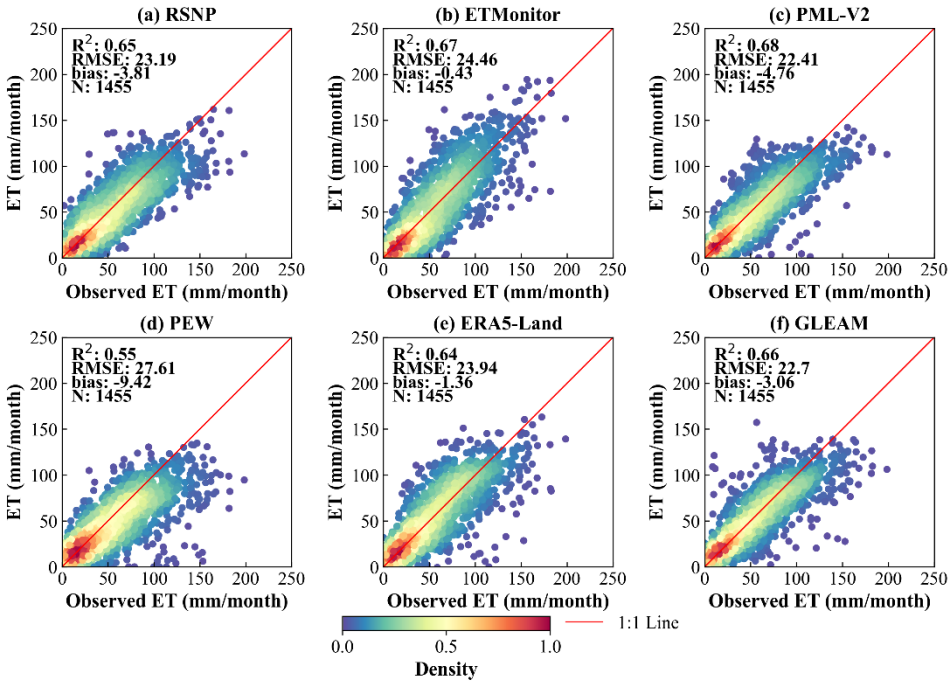

Figure 4: Comparison of estimated ET and observed ET over FLUXNET2015 sites. The relative mean square error (RMSE) and the bias are both in mm/month.

L228: "RSNP has certain advantages in monitoring basin or regional ET on a global scale", but it does not specify what these advantages are. Similar general statements in the article should be thoroughly proven and expanded.

Response: Thank you very much for your feedback regarding the need for more specific and evidence-based statements about RSNP's advantages. In response to this comment, we have thoroughly revised the statements to explicitly highlight RSNP's strengths.

(1) We have added the statement to emphasis RSNP's ability of estimating ET at basin scale: "*Comparative analysis revealed that RSNP consistently outperformed ETMonitor, PEW, and GLEAM at the basin scale, exhibiting both lower RMSE and slightly higher R² across all validation basins. Nevertheless, although most ET datasets exhibited substantial biases in basins with annual ET exceeding 1200 mm/yr, RSNP demonstrated the least overestimation among them.*" (Line265-269)

(2) We have concluded the Hamiltonian principle-based ET dataset is qualified for regional analysis: "*The consistency between RSNP and other global ET datasets in WBET validation confirms the reliability of the Hamiltonian principle-based and resistance parameterization-free model for global land surface ET estimation, providing strong evidence to support its application and adoption.*" (Line272-275)

L330: The expression "unsatisfactory performance" is not specific enough. It is suggested to change it to "limited accuracy".

Response: We sincerely appreciate your constructive suggestion to improve the precision of our manuscript. Following your recommendation, we have carefully revised the expression to better reflect the meaning, and the revised sentence is as follows:

"This highlights that the performance of ET datasets is not solely determined by spatial resolution.

(Stisen et al., 2008; Zheng et al., 2022).” (Line 387)