Dear Editor and Reviewers,

We sincerely thank the reviewers for their careful reading and constructive comments on our manuscript. We greatly appreciate the valuable suggestions, which have helped improve the clarity, rigor, and overall quality of the manuscript.

Page and line numbers cited in the responses below refer to the tracked changes version of the revised manuscript.

Reviewer #2

The manuscript describes a very elegant sensitivity analysis of an often ignored but important issue of the vertical variation of soil hydraulic parameters. The lab work and the numerical experiment design are rather convincing.

My most critical comment is that "Data will be provided upon request" is absolutely not an appropriate data availability statement and violates the data policy of HESS https://www.hydrology-and-earth-system-sciences.net/policies/data_policy.html . I am a bit surprised that the editor let this manuscript proceed to review without disclosing any data, or model codes.

It is absolutely critical that ALL the eddy covariance flux data including LHF and SHF and all other site level meteorology, and soil hydrology observations will be made available. Similarly, all the laboratory measurements. Also needed are the exact variant of the NOAH-MP model code that was used, with the data for forcing, initialization and simulation setup for EACH of the simulation cases, and ALL the simulation output. These should all be published with a DOI in a FAIR repository. Make sure there is sufficient metadata to know what each variable in each data file is, and what are the units of reported values. Make sure a sufficient explanation exist as to how to run the model to recapture the simulation cases that were conducted here.

Response: We sincerely thank the reviewer for the valuable comments regarding data accessibility and reproducibility. We apologize for not carefully reviewing the journal data policy before submission. We fully recognize and support the importance of open science and data sharing in current hydrology and Earth system science research.

We welcome all researchers interested in this study to use our observational and experimental datasets. Following the journal data policy, we have revised and expanded the data availability information. Specifically, all key datasets used in this study have been uploaded to the public repository ***figshare*** *and assigned a unique DOI. The publicly available datasets include:*

Eddy covariance observations, including latent heat flux (LHF) and sensible heat flux (SHF)
Site meteorological observations
Soil moisture observations
Laboratory evaporation experiment data (HYPROP) and dry end measurements (WP4C)
Data used for soil hydraulic parameter estimation

For the modeling component, we have also provided the Noah MP model version, parameter settings, and simulation configuration used in this study. The corresponding model input data and necessary configuration files have also been uploaded to support reproducibility of the simulations.

We appreciate the reviewer for pointing out the limitations of the original data availability statement. This suggestion has significantly improved the transparency and reproducibility of the manuscript.

The revised manuscript now includes the data access link and DOI (https://doi.org/10.6084/m9.figshare.32197428) in the Data Availability Statement section to ensure public accessibility and reproducibility of the datasets. Page 55, Line 1055-1058, Page 59, Line 1129-1130.

Another major comment is that there is no mention of sample sizes and variability throughout the manuscript.

How many cores did you extract? Of these, how many were used for the evaporation experiment, and how many to sample bulk density? What was the variability among cores? How representative were the few cores used for the evaporation experiment of the whole site? How did you scale the parameters you found across the whole region, and across different soil types (as shown in Fig 1a)? I may have missed it (in which case, highlight it more prominently) anywhere in the methods. Also, there is no mention of sample size anywhere throughout the results section.

We sincerely thank the reviewer for the thoughtful comments regarding sample size, spatial variability, and representativeness. These issues are closely related to the sampling design and applicability of this study and are important for clarifying the interpretation boundaries of the results. It should be noted that this study adopts a single point observation and single profile sampling strategy. The primary objective is to investigate the vertical heterogeneity of soil hydraulic properties and their influence on hydrothermal simulations, rather than to conduct spatial statistical analysis or regional extrapolation of soil parameters. In response to the reviewer's comments, we have added further clarification in the revised manuscript. Detailed responses are provided below.

(1) Sample size

In this study, a total of n = 11 undisturbed soil cores were collected from different soil depths (see Fig. 4 and Fig. 5). These samples cover the complete soil profile from the surface to deeper layers and form a systematic vertical sampling framework for characterizing the vertical variability of soil hydraulic properties. The depth intervals and corresponding relationships among the samples are summarized in Table 3. In addition, the layer labels (A–K) defined in Table 3 are fully consistent with the curve labels shown in Fig. 7, establishing a direct correspondence among sampling depth, hydraulic parameters, and fitted hydraulic curves. The sampling number and depth information have been clarified in the revised Methods section. Page 8, Line 166. Page 10, Line 216. Page 27, Line 532.

(2) Use of samples in different experiments

Among the 11 undisturbed soil cores collected in this study, samples from different depths were used for evaporation experiments (HYPROP measurements) and physicochemical property measurements such as bulk density. The evaporation experiment samples were used to derive the water retention curves and hydraulic conductivity functions, while bulk density and other physicochemical measurements were used to interpret soil structure and pore characteristics. We have clarified the number and usage of samples for each experiment type in the revised Methods section. Page 8, Line 166. Page 10, Line 216. Page 27, Line 532.

(3) Variability among cores

It should be noted that this study adopts a single profile sampling design, with the primary focus on vertical structural differences rather than horizontal spatial variability. Therefore, repeated sampling at multiple locations was not conducted for statistical analysis of spatial variability. In other words, the results are intended to characterize contrasts among different soil depths rather than to represent the statistical range of spatial variability. We have added clarification in the revised manuscript to better define the applicability and scope of this study. Page 8, Line 163-166. Page 18, Line 369-371.

(4) Representativeness and scaling

Regarding spatial variability and representativeness, we further clarify the background and scale of this study.

At the regional scale, the Sanjiangyuan region is commonly classified as loamy sand in land surface models such as Noah MP, and this soil type occupies a large proportion of the study region (Fig. 1a). The observation site selected in this study is located in a typical alpine wetland environment and is regionally representative in terms of land cover and vegetation composition (Liu et al., 2019, 2021, 2022).

Therefore, the site reflects the general characteristics of this type of alpine wetland ecosystem. However, this representativeness mainly refers to the ecosystem type and does not imply that soil hydraulic properties are spatially uniform.

Although the study area is generally flat and lacks strong topographic controls, which may reduce spatial heterogeneity caused by runoff redistribution and erosion, flat terrain does not necessarily imply uniform soil hydraulic properties. In wetland environments, local scale variability may still arise from differences in organic matter distribution, root structure, and microtopography. Therefore, this study does not assume complete spatial uniformity of soil hydraulic properties, and the analysis is restricted to a single point observational framework.

Within this framework, the study adopts a single point observation and single profile sampling strategy, which is consistent with the typical application of Noah MP and similar land surface models under a given soil type. The primary objective is not to conduct statistical analysis or spatial extrapolation of regional soil hydraulic parameters, but rather to investigate the vertical heterogeneity of soil hydraulic properties and its influence on land surface hydrothermal processes.

Furthermore, this study evaluates the influence of vertically layered hydraulic parameters by comparing them with conventional homogeneous parameter schemes within a single point simulation framework. The results are intended to provide guidance for the treatment of vertical soil hydraulic structure in land surface models, rather than to draw generalized conclusions regarding model structural complexity. It should also be noted that Fig. 1a is included only to provide regional background information and is not used for spatial extrapolation or scaling of soil hydraulic parameters.

Similarly, in section 3.2, I assume the parameter values are not the result of a single measurements, but either the mean of multiple measurements, in which case provide the std and range of observed parameter values, or are derived from fitting the model curve over multiple observations, in which case, provide some goodness of fit metric (preferably r^2).

Figure 7 – here two, are the lines represent single measurement, or are the mean of something? Provide some range of uncertainty around the lines.

Fig 11 – same, you did not simulate only one day. There should be some variation around the lines.

We sincerely thank the reviewer for the detailed comments regarding parameter sources, curve interpretation, and the representation of uncertainty. We agree that these details are important for evaluating the reliability of both the experimental results and the model simulations. Following the reviewer's suggestions, we have clarified the *source of the hydraulic parameters, the meaning of the curves shown in Fig. 7, and the day to day variability represented in the mean diurnal cycles of Fig. 11. Our detailed responses are provided below.*

First, regarding the parameter values presented in Section 3.2, these parameters are not averages of repeated soil core samples. For each depth specific soil core, the hydraulic parameters are derived from HYPROP based curve fitting rather than from averaging multiple samples, while WP4C measurements are used to validate the dry end behavior of the water retention curves. Therefore, the reported parameter values represent fitted results for individual soil layers rather than statistical averages across replicates. Following the reviewer's suggestion, we have clarified this point in the revised manuscript. Page 25, Line 496-499.

Second, regarding Fig. 7, the WRC, PSD, and HCC curves represent fitted curves for individual soil samples at different depths rather than averages across repeated samples. Because each depth corresponds to one undisturbed soil core, it is not possible to calculate standard deviations or confidence intervals based on repeated sampling, and it is therefore not appropriate to add statistically meaningful uncertainty shading around the curves. To avoid misunderstanding, we have clarified the meaning of the curves in both the figure caption and the main text. Page 30, Line 584-586.

Regarding Fig. 11, we understand the reviewer's concern. The figure shows mean diurnal cycles during June to August 2023 rather than simulations from a single day. The original observational data exhibit clear day to day variability across the study period. It should be noted that the statistical metrics provided in Appendix Tables A1–A4, including RMSE, Bias, and R^2*, are used to evaluate model performance relative to observations and do not represent the variability of the observations themselves. Therefore, following the reviewer's suggestion, we added observational variability ranges in Fig. 11 (mean ±standard deviation) to reflect the variability among different days at the same time of day and to avoid the impression that the curves represent a single day. At the same time, the model results are still shown as mean curves to maintain figure clarity and highlight differences among parameter schemes. Page 39, Line 741-742.*

Minor comments:

We thank the reviewer for these helpful and constructive minor comments. All suggestions have been carefully addressed and the manuscript has been revised accordingly. Detailed responses are provided below.

Please provide the references to Brooks Corey (BC), Clapp–Hornberger (CH), van Genuchten (VG), and Kosugi (L47-48) upon first mention and not later. And please provide a reference to Mualem's model, Savitzky–Golay filtering, and perhaps few other formulations which you mention and use, but not reference at all.

Response：We thank the reviewer for this helpful suggestion. In the revised manuscript, we have added the corresponding references at the first appearance of the Brooks–Corey (BC), Clapp–Hornberger (CH), van Genuchten (VG), and Kosugi models. In addition, we have added references for methods mentioned in the manuscript that were previously not explicitly cited, including the Mualem model and the Savitzky–Golay filtering method, to ensure that all methods and formulations used in this study are properly referenced. Page 2-3, Line 45-52.

I personally do not like texts that divulge to alphabet soups, and find sentences like: "CH describes the WRC and HCC with power laws …" confusing. For the ease of the reader, will it be possible, here and most other places, to use the full terms? I.e., CH describes the water retention and hydraulic conductivity curves with power laws … (it only added 2 words)

We thank the reviewer for the helpful comments regarding the use of abbreviations in the manuscript. We understand that excessive or consecutive use of abbreviations may affect readability and make the text more difficult to follow. Following the reviewer's suggestion, we carefully reviewed the manuscript and replaced abbreviations with full terms in many key statements to reduce "alphabet soup" style expressions. At the same time, necessary abbreviations were retained where they do not reduce readability, in order to balance clarity and conciseness.

L126 "Observation Station (denoted by the red dots in…" - There is only one dot. Is the plural "dots" a typo, or should there be more than one station? Also, a red color in Fig 1a is also used for one of the soil type. Slightly confusing. Consider a different color for the dot station marker.

We thank the reviewer for the careful observation. We have corrected "red dots" to "red dot" to match the fact that only one observation station is shown in Fig. 1a. In addition, we adjusted the color of the station marker in Fig. 1a to better distinguish it from the soil type colors and avoid visual confusion.

For sections 2.4 – 2.7 I am missing a table similar to table 2, clarifying what is measured (direct observation), what is calculated from which equation and what is a fitted parameter.

In table 2, last column, it will make sense to mention which equation the parameter comes from.

We thank the reviewer for the helpful suggestion. After careful consideration, we revised the relevant sections as follows. For the key soil hydraulic parameters discussed in Sections 2.4 and 2.5, including b, ψs, Ks, and θs, which are also the core variables used in the sensitivity experiments summarized in Table 2, we expanded Table 2 to include the parameter source, corresponding governing equation, and physical meaning of each parameter. This revision serves the same purpose as a summary table while *keeping the manuscript structure concise. Page 19, Line 395.*

For Section 2.6, this section mainly involves diagnostic indices such as beff and NSC, which are analysis metrics rather than fundamental hydraulic parameters, and therefore were not included in the summary table. In Section 2.7, the equivalent pore radius and pore size distribution are both derived from the same theoretical relationship, namely the Young–Laplace equation, and the corresponding references have already been provided in the manuscript.

Through these revisions, we improved the clarity and readability of the Methods section without introducing an additional table.

1. Liu R, J Wen, X Wang, Z Wang, Z Li, Y Xie, L Zhu, D Li. 2019. Derivation of vegetation optical depth and water content in the Source Region of the Yellow River using the FY-3B microwave data. Remote Sensing. 11(13), 1536. DOI:10.3390/rs11131536.

2. Liu R, J Wen, X Wang, Z Wang, Y Liu, M Zhang. 2021. Estimates of daily evapotranspiration in the Source Region of the Yellow River combining visible/near-infrared and microwave remote sensing. Remote Sensing. 13(1), 53. DOI:10.3390/rs13010053.

3. Liu R, J Wen, X Wang, Z Wang, Y Liu. 2022. Case studies of atmospheric moisture sources in the source region of the Yellow River from a Lagrangian perspective. International Journal of Climatology. 42(3), 1516-1530. DOI: 10.1002/joc.7317.

4. Wang X, R Liu, M Köhli, J Marach, ZL Wang. 2025. Monitoring soil water content and measurement depth of cosmic-ray neutron sensing in the Tibetan Plateau. Journal of Hydrometeorology. 26(2), 155-167, https://doi.org/10.1175/JHM-D-23-0103.1