

Answers to Anonymous Referee #1 comments on the paper “Assessing the seasonal compartmentalization of water fluxes in the soil-plant-atmosphere continuum of a high-elevation mountain grassland”

5 Alessio Gentile¹, Davide Gisolo¹, Stefano Brighenti^{2,3}, Giulia Zuecco^{4,5}, Chiara Marchina⁴, Davide Canone¹, Tanzeel Hamza¹, Stefano Ferrari¹, Stefano Bechis¹ and Stefano Ferraris¹

¹ Interuniversity Department of Regional and Urban Studies and Planning (DIST), University of Torino and Polytechnic University of Torino, 10125, Torino, Italy

² Faculty of Science and Technology, Free University of Bozen-Bolzano, 39100, Bozen-Bolzano, Italy

10 ³ Eco Research, 39100, Bozen-Bolzano, Italy

⁴ Department of Land, Environment, Agriculture and Forestry (TESAF), University of Padova, 35020, Legnaro (PD), Italy

⁵ Department of Chemical Sciences (DiSC), University of Padova, 35131, Padova, Italy

Correspondence to: Alessio Gentile (alessio.gentile@unito.it)

15

The study titled “Assessing the seasonal compartmentalization of water fluxes in the soil-plant-atmosphere continuum of a high-elevation mountain grassland” is interesting and investigated seasonal partitioning of water sources supporting plant transpiration and deep drainage using isotopic data and HYDRUS-1D modelling. While the topic is of relevance, the manuscript requires substantial improvements. Below, please find the main and the specific comments regarding the manuscript:

20

We thank the Anonymous Referee #1 for the overall assessment of our manuscript and for recognizing both the relevance of the topic and the interest of the investigated theme. All the comments and feedback received are constructive and will help to improve the manuscript. Accordingly, we will thoroughly revise the paper to address all main and specific comments. Below, we provide our responses to the comments of Anonymous Referee #1, together with our proposed revisions, which we will be pleased to implement, pending a positive decision from the editor. At this stage, proposed revisions referring to specific portions of the manuscript are indicated using the notation “LXX–YY”, where XX and YY represent provisional line numbers that will become definitive if the editor invites us to proceed with the revision and submit the revised manuscript.

25

30

1 Main Comments

1.1 Abstract

35 The abstract clearly motivates the topic and outlines the modelling framework and objectives, but it reads more like an extended introduction and does not provide enough quantitative evidence to support its main claims. In particular, statements that the framework “accurately” simulates VWC/AET/isotope dynamics should be accompanied by performance metrics, and the key ecohydrological-separation findings should be reported quantitatively (e.g., representative SOI ranges or an effect size) rather than described only in qualitative terms such as a “higher degree of separation” or a “greater proportion of winter water” in 2022.

40 **We thank the Anonymous Referee #1 for this comment. We will revise the Abstract by including quantitative performance metrics to support the evaluation of the model performance. In addition, qualitative expressions such as “a higher degree of separation” and “a greater proportion of winter water” will be replaced or complemented with quantitative information. Below, we report the original sentences from the manuscript, followed by our proposed revised versions.**

45 **L28-29: “The results reveal the effectiveness of the proposed modelling framework in accurately simulating volumetric water content, actual evapotranspiration, and isotope dynamics at the study site.”**

Will be replaced with:

50 **LXX-YY: “*The results demonstrate the effectiveness of the proposed modelling framework in accurately simulating volumetric water content (mean absolute error, MAE $\approx 0.03 \text{ cm}^3 \text{ cm}^{-3}$ at 10, 20, and 40 cm), actual evapotranspiration (MAE = 0.62 mm d^{-1}), soil (MAE = 1.6, 3.6, 3.7 ‰ at 10, 20, and 40 cm) and xylem (MAE = 1.85 ‰) isotope content at the study site.*”**

55 **L29-34: “Based on the model outputs, a higher degree of separation between the water used by plants and the water contributing to deep drainage is observed during intense snowmelt periods. Under these conditions, meltwater (winter water) rapidly drains through the lower soil layers, whereas rainfall (summer water), which predominantly occurs after the snowmelt period, remains in the soil longer, sustaining plant transpiration. However, in 2022, we observed a**
60 **shift in hydrological functioning: a greater proportion of winter water contributed to transpiration fluxes under drought conditions.”**

Will be replaced with:

LXX-YY: *“Based on the model outputs, a separation between the water used by plants and the water contributing to deep drainage is evident during the 2018–2020 growing seasons, when median Seasonal Origin Index (SOI) values of transpiration and deep drainage are positive and negative, respectively. Here, positive and negative SOI values indicate an overrepresentation of summer- and winter-derived water in the considered flux. This separation weakens in 2021, when drainage water exhibits a slightly positive median SOI value. Over intense snowmelt periods, meltwater (winter water) rapidly drains through the lower soil layers, whereas rainfall (summer water), which predominantly occurs after the snowmelt period, remains in the soil longer and sustains plant transpiration. The median SOI of transpiration remains consistently positive during the 2018–2021 growing seasons (SOI = 0.19–0.69) but shifts to a negative value in 2022 (SOI = -0.07), highlighting that winter-derived water becomes overrepresented in transpiration fluxes under drought conditions.”*

1.2 Introduction

The Introduction section is well written; however, it needs the following improvements:

1. It consists of paragraphs that do not have a concluding sentence at the end of each paragraph. Therefore, some of the paragraphs need to be revised as mentioned in the specific comments.

We thank Anonymous Referee #1 for this comment. As also addressed in the specific comments, we will revise the Introduction by adding clear concluding sentences to the paragraphs summarizing previous studies. These closing sentences will synthesize the key insights from the reviewed literature and explicitly highlight the main message that each paragraph is intended to convey in the context of the present study. Please refer to our responses to the specific comments, where we report the proposed concluding sentences we will add at the end of the relevant paragraphs. These concluding sentences are also intended to provide a clear transition to the subsequent paragraphs, thereby improving the overall flow and clarity of the text.

2. The introduction lacks a proper objective paragraph. The introduction section needs an objective paragraph in which the authors should mention the following points (in one single concise paragraph as the last paragraph of the introduction section):
 - a. A sentence summarizing the research need
 - b. Stating the main objective of the research
 - c. Stating the specific objectives of the research
 - d. A sentence regarding the value of the study

Therefore, the last two paragraphs of the introduction section should be revised.

We thank Anonymous Referee #1 for this comment. In response, we will thoroughly revise the last two paragraphs of the Introduction and merge them into a single, concise objective paragraph. The revised paragraph will (i) summarize the research need, (ii) state the main objective of the study, (iii) outline the specific objectives, and (iv) highlight the value of the work by emphasizing its contribution to provide new insights into alpine grassland ecohydrology. Please refer to the corresponding specific comment for further details regarding our revised version of the last two paragraphs of the introduction section.

1.3 Methodology

The methodology section is clearly written in detail, however, a performance evaluation section with corresponding metrics to evaluate the modelling is missing and needs to be added. Moreover, the authors should use past tense and passive sentences throughout the manuscript which needs revision. Further minor comments are available in specific comments.

We thank Anonymous Referee #1 for this comment. In response, we will add a dedicated model performance evaluation section to the Results and Discussion section, including appropriate quantitative performance metrics to assess the modelling results. In addition, we will revise the manuscript to ensure consistent use of past tense and passive sentences. Further minor issues raised by the reviewer are addressed individually in our responses to the specific comments.

1.4 Results & Discussion

The Results & Discussion section is informative; however, it needs addressing the following points:

1. The authors calibrated the model using one set of variables and validated it using a different set of variables, but both steps were conducted over the same time period. This raises two concerns: (a) the calibration and validation periods are not independent, so the exercise does not represent out-of-sample validation in the usual sense; and (b) because the validation targets differ from the calibration targets, it is unclear whether the model continues to reproduce the calibrated variables correctly during the validation window, or whether good agreement for the validation variables is achieved through compensating errors/equifinality. Please justify the rationale for this approach!

We thank Anonymous Referee #1 for this thoughtful and important comment. We appreciate the opportunity to clarify the rationale behind our calibration and validation strategy.

The choice to calibrate and validate the model over the same time period was driven by the primary objective of this study. Our goal is not to use the model for predictive purposes, which would indeed require a temporally independent out-of-sample validation, but rather to achieve a process-based reconstruction of the ecohydrological dynamics that occurred during the 2017–2023 period. Given the complexity of high-elevation

environments and the temporal resolution of the isotope sampling, the available data alone allow only preliminary insights into system behavior. For example, the seasonal compartmentalization of water fluxes was already suggested by the dual-isotope plot, as discussed in the manuscript. However, a quantitative assessment of the processes leading to this compartmentalization requires a model capable of consistently reproducing the occurring dynamics both temporally (at daily resolution) and spatially (along the soil profile) throughout the entire study period.

For this reason, we adopted a compartment-based validation approach. The model was calibrated using observations from the soil compartment and subsequently validated against observations from the soil-plant compartment related to outgoing fluxes toward the atmosphere, leveraging actual evapotranspiration measurements, derived from the eddy-covariance technique, and the xylem water isotopic composition. As shown in the Results, the model reproduces actual evapotranspiration and the xylem water isotopic composition satisfactorily, despite not being calibrated directly against variables related to outgoing fluxes toward the atmosphere. This consistency reduces the likelihood that good performance is achieved for the wrong reasons and supports a good description of the processes occurring in the soil-plant-atmosphere continuum under study. Furthermore, the calibrated parameters were evaluated against ranges reported in the scientific literature to ensure their physical plausibility. Where possible (e.g., for θ_r and θ_s), the estimated values were also directly compared with field measurements, providing additional validation and strengthening confidence in the robustness of the parameterization.

Moreover, the analyzed hydrological years exhibit substantial interannual variability (e.g., reduced snowmelt from 2017-2018 to 2021-2022 hydrologic years, see Fig. 1 of the submitted manuscript). Calibrating the model on a limited temporal subset (e.g., 2017–2019) and validating it on a subsequent period would likely bias parameter estimation toward the calibration years and could reduce robustness under contrasting hydroclimatic conditions. In this sense, adopting a traditional split-sample approach might have strengthened the performance during calibration years while weakening the performance during validation years, thus potentially resulting in lower confidence in process-based interpretations during the validation period compared to the calibration period. By calibrating the model across multiple years with highly variable conditions, we aimed to obtain a parameterization representative of a very broad range of system behavior.

We agree that this modeling strategy differs from a predictive validation framework and needs further justifications along the manuscript. In the revised manuscript, we will clarify this rationale more explicitly within the new section on model performance, as suggested by the reviewer.

2. Report on model performance consistently for all evaluated variables in one or more standalone tables. See specific comments.

165 **We thank Anonymous Referee #1 for this comment. In line with the reviewer’s suggestion, model performance will be reported consistently for all evaluated variables in a dedicated standalone table within the new section on model performance.**

3. Enhance visualization. See specific comments.

170 **We thank Anonymous Referee #1 for this comment. Further details of the changes we plan to implement are provided in our responses to the specific comments.**

4. Make tables and figures standalone. See specific comments.

175 **We thank Anonymous Referee #1 for this comment. In accordance with the reviewer’s suggestion, all tables and figures will be revised to ensure that they are fully standalone. This includes providing complete definitions of symbols and abbreviations and expanding captions where necessary. Further details on the specific modifications are provided in our responses to the corresponding specific comments.**

180 **1.5 Conclusion**

The conclusion is concise and can be improved with the following revisions:

1. Add sentences on limitations and uncertainty and how these may influence inference on seasonal partitioning.

185 **We thank Anonymous Referee #1 for this valuable suggestion. In response, the Conclusions section will be revised to explicitly acknowledge the main sources of uncertainty and their potential influence on the interpretation of seasonal partitioning. We propose to add the following paragraph:**

190 *“While the adopted modelling framework enabled a process-based interpretation of seasonal compartmentalization of water fluxes, some limitations should be acknowledged. The degree-day model used in this work provides a simplified representation of snowmelt processes: compaction, refreezing, stratification, and snow sublimation are not explicitly included. These simplifying assumptions propagate into the estimation of both the timing and magnitude of meltwater infiltration. In addition, the adopted snow isotope model does not account for the effects of refreezing or sublimation processes on the isotopic composition of meltwater. Addressing these processes would require dedicated efforts in model development. Further sources of uncertainty arise from the relatively low temporal resolution of isotope sampling, which is largely constrained by the intrinsic challenges of*

195 *complex high-elevation mountain environments, as well as from potential biases associated with the cryogenic vacuum distillation, both of which may affect the estimation of longitudinal dispersivity and the representation of subsurface transport processes.”*

200 2. End with a brief statement on implications under changing snow regimes and one concrete recommendation for future work (or improvements).

We thank Anonymous Referee #1 for this comment. The Conclusions will be expanded to include a brief discussion of the implications of our findings under projected changes in snow regimes. We propose to modify the last two paragraphs as follows:

205 *“Given projected changes in snow regimes under climate warming, including an increasing frequency of snow droughts, the variability in the degree of ecohydrological separation observed in this study has important implications for anticipating future shifts in ecohydrological functioning within similar mountain ecosystems worldwide.*

210 *In this regard, incorporating climate change projections into the modelling framework of this high-elevation grassland would be crucial to provide new insights into future shifts in the relative contribution of winter- versus summer-derived water to transpiration and groundwater recharge.”*

2 Specific comments

L39: “in the subsurface” is vague and generic, use more specific term.

215 **We thank Anonymous Referee #1 for this comment. We agree that the term “subsurface” can be vague. We have clarified its meaning in the text by explicitly stating that it refers to both the vadose zone and the phreatic zone that should be consistent with the framework discussed by Kirchner et al. (2023) where the term “subsurface” has been used.**

L29-40: “Ecohydrological processes occurring in the subsurface have been often conceptualized relying on physical intuition (Kirchner et al., 2023)”

Will be replaced with:

220 **LXX-YY: “Ecohydrological processes occurring in the subsurface, encompassing both the vadose zone and the phreatic zone, have been often conceptualized relying on physical intuition (Kirchner et al., 2023)”**

L46: “available to roots”

225 **We thank Anonymous Referee #1 for this suggestion. Accordingly, we will replace the expression L46: “accessed by roots” with LXX-YY: “available to roots”.**

L70 – 84 & 85 – 96: These paragraphs are presenting previous studies, individually. However, the paragraphs need to have a concluding sentence at the end. Please revise the paragraphs.

230 **At the end of the paragraph L70-84 we propose to insert the following sentence:**

LXX-YY: “Overall, these studies highlight that plant water sources and the degree of ecohydrological separation can vary substantially across sites under different climatic and biological conditions. Nevertheless, additional unmodelled factors, including seasonality, may play a key role in modulating ecohydrological separation.”

235 **At the end of the paragraph L85 – 96 we propose to insert the following sentence:**

LXX-YY: “Overall, these findings highlight that also the seasonal origin of plant water is highly variable across ecosystems and remains strongly dependent on site-specific climatic, hydrological, and biological conditions.”

L97: Use the accurate word for evapotranspiration. The use of evapotranspiration can be misleading for the readers without specifying the type. The authors abbreviated evapotranspiration as AET which can be considered actual evapotranspiration by the readers. If this is true, revise the text as follows: “actual evapotranspiration (AET)”.

240 **We thank Anonymous Referee #1 for this comment and agree that the term “evapotranspiration” should be specified more clearly. Accordingly, we have defined the term as “actual evapotranspiration (AET)” at its first occurrence in the manuscript. Thereafter, the abbreviation AET has been used consistently throughout the text whenever specifically referring to actual evapotranspiration.**

L105 – 131: revise these two paragraphs and make an objective paragraph based on what is proposed in the main comments. Also, these two paragraphs include sentences that belong to methodology and need to be removed from the introduction.

250

Following the guidance provided by Anonymous Referee #1 in the main comments on the Introduction, below we report the original sentences from the manuscript, followed by our proposed revised versions, in order to facilitate the review process.

255 **L105-131: “In this paper, we aim to determine whether, in regions with pronounced seasonality of water inputs (e.g., mountain regions), the nature of ecohydrological separation may be influenced by the interaction between the timing and magnitude of snowmelt and rainfall events, as well as by the temporal dynamics of root water uptake. Water inputs such as snowmelt and rainfall differ in intensity and frequency, which directly affect soil hydraulic conductivity and, consequently, soil water dynamics. These variations can influence the spatial and temporal availability of water to plants, potentially shaping the degree of separation between mobile and bound water pools. With the aim of pursuing**

260

this objective, multidisciplinary approaches, such as the use of conservative tracers and integrated numerical models, have proven valuable, although data scarcity and the inherent complexity of high-elevation sites remain substantial challenges (Gisolo et al., 2025; van Tiel et al., 2024). Among the available models, HYDRUS-1D (Šimůnek et al., 2018) is a widely used and robust software package for simulating water flow and solute transport in variably saturated soils. 265 It incorporates key physical processes (including infiltration, evapotranspiration, root water uptake, and advection–dispersion) offering a comprehensive representation of water and solute dynamics within the soil–plant–atmosphere continuum. Furthermore, HYDRUS-1D enables the simulation of stable water isotope transport in the vadose zone (Nasta et al., 2023; Stumpp et al., 2012).

We follow an approach that integrates meteorological data with field measurements of stable isotopes in precipitation, 270 soil water, plant water, and spring water of a high-elevation mountain grassland. Starting from these data, we employ a modelling framework that integrates a recently introduced snow isotope model and the modified version of HYDRUS-1D (Stumpp et al., 2012) to simulate isotope transport within the soil–plant–atmosphere continuum of this high-elevation ecosystem. Through isotopic composition modeling, we derive the SOI which enables a robust quantification of the seasonal origin of water fluxes (focusing on transpiration and deep drainage fluxes) across 275 multiple years. The study period encompasses years with contrasting hydrological conditions, ranging from very wet to extremely dry. Through the model output, we gain new insights into the hydrological processes shaping the degree of separation between tightly bound soil water and mobile water draining through the soil profile. The integration of isotope measurements with numerical modeling to investigate alpine grassland ecohydrology remains limited, and, according to our knowledge, no study to date has explicitly tested how seasonal variations in water input, typical of 280 high-elevation environments, interact with root water uptake to assess the degree to which the TWW hypothesis holds. Accordingly, we test the following null dichotomous hypothesis (H_0): “Winter precipitation (i.e., snowmelt) rapidly transits the soil profile recharging groundwater and streams, while summer precipitation (i.e., rainfall) remains available to sustain transpiration fluxes”.

285 Will be replaced with:

LXX-YY: *“Thus, understanding how seasonal water inputs and temporal dynamics of root water uptake shape the degree of ecohydrological separation between mobile and bound water pools remains a key challenge in ecohydrology, particularly in high-elevation environments where data scarcity and inherent complexity remain substantial challenges 290 (Gisolo et al., 2025; van Tiel et al., 2024). Accordingly, the main aims of this paper are to:*

- i) investigate the seasonal origin of transpiration and deep drainage fluxes across multiple years with contrasting hydrological conditions ranging from very wet to extremely dry*
- ii) clarify how contrasting seasonal water inputs, typical of high-elevation environments, interact with root water uptake to assess the degree to which the TWW hypothesis holds. Accordingly, we test the following null*

295 *hypothesis: (H₀): “Winter precipitation (i.e., snowmelt) rapidly transits the soil profile recharging groundwater and streams, while summer precipitation (i.e., rainfall) remains available to sustain transpiration fluxes”.*

To this end, meteorological data, soil-related data and field measurements of stable isotopes in precipitation, soil water, plant water, and spring water of a high-elevation mountain grassland have been used. Starting from these data, a modelling
300 *framework that integrates a recently introduced snow isotope model and the modified version of HYDRUS-1D (Nasta et al., 2023; Stumpp et al., 2012) has been employed, thus enabling a process-based assessment of seasonal water flux partitioning and providing new insights into alpine grassland ecohydrology by partially disentangling the processes underlying ecohydrological separation.”*

305 L144: define hydrological year in the body of the manuscript instead of figure 1 caption.

We thank Anonymous Referee #1 for this comment. The definition of the hydrological year has now been included in the main body of the manuscript and, accordingly, removed from the caption and x-axis-label of Figure 1. See LXX-YY of the revised manuscript

310

L156: AET is already defined in the introduction section. No need to redefine it.

Thank you. As indicated in a previous comment, we have defined the term as “actual evapotranspiration (AET)” at its first occurrence in the manuscript. Thereafter, the abbreviation AET has been used consistently throughout the
315 **text whenever specifically referring to actual evapotranspiration.**

L168: refer to the corresponding figure.

We thank Anonymous Referee #1 for this comment. A reference to the corresponding figure will be added at LXX-YY
320 **in the revised manuscript.**

Table 1: Soil sand, silt, and clay content (%) Is not 100% in aggregate!

We thank Anonymous Referee #1 for pointing out the inconsistency in Table 1. In the first version of the manuscript,
325 **soil texture was reported to provide a general pedological characterization of the study site.**

The values were derived from the Regional Soil Map of the Aosta Valley 1:100000
[10](https://geoportale.regione.vda.it/ricerche-nuove/scheda-nuova/?id_tipo=3&uuid=r_vda:04296-</p></div><div data-bbox=)

[META:20220121:091600](#)), from which we report an excerpt corresponding to the area of interest (Figure 1 of this document).

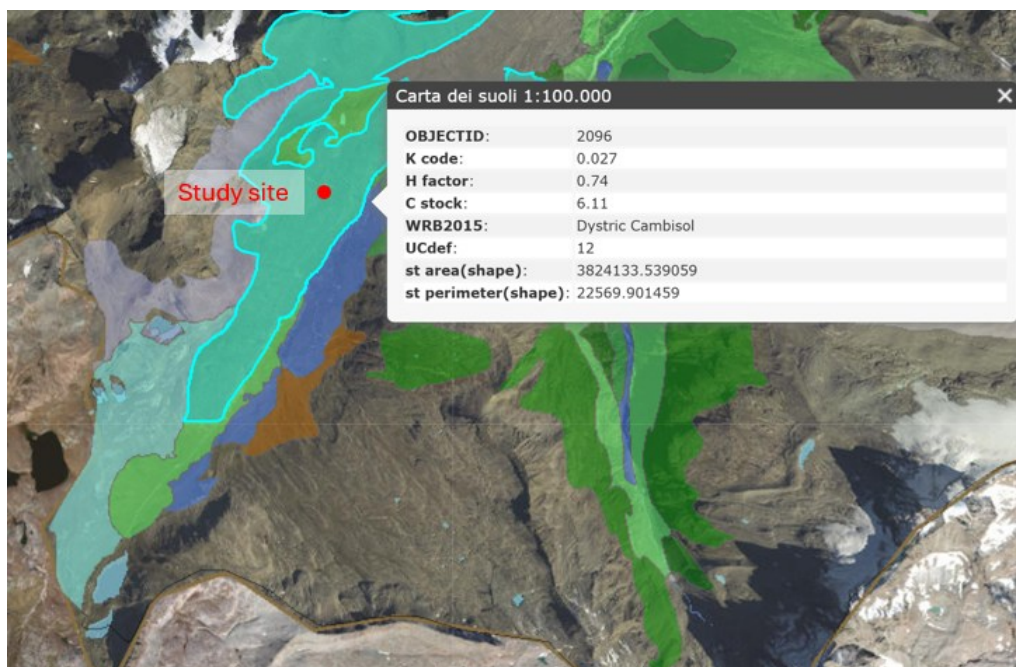


Figure 1 Excerpt of the Regional Soil Map of the Aosta Valley 1:100000 corresponding to the area of interest

Details on soil texture associated with this map are reported in “Carta dei Suoli della Valle d’Aosta – Note illustrative” (https://mappe.regione.vda.it/INVA/Condizioni/CartaDeiSuoli/Note%20Illustrative%20Carta%20dei%20suoli%20020_02_13.pdf).

The reported texture corresponds to the average percentages of sand, silt, and clay calculated across all soil profiles attributed to that specific soil type at the regional scale (i.e., over the Aosta Valley Region). We acknowledge that we have not noticed that the reported percentages of sand, silt, and clay do not sum to 100%. Accordingly, it emerged that the regional dataset appears to contain inconsistencies in the reported soil texture values. We therefore conducted additional and time-consuming checks, which required direct contact with colleagues from the Department of Agricultural, Forest and Food Sciences (DISAFA), Agricultural Chemistry and Soil Science Unit, University of Turin, in order to retrieve and verify site-specific soil data. The time needed to identify and confirm these measurements contributed to the delay in our response. We considered it important to clarify this point, particularly in light of the short time frame within which the reviewer completed the manuscript evaluation.

Notably, one of these soil profiles was described on 20 September 2017 in close proximity to the Eddy-Covariance monitoring station within the study area.

Given that this point-based measurement provides a more representative characterization of the local soil texture than the regional averaged values reported in the Geoportal of the Aosta Valley Region, we have revised the manuscript accordingly and now report the site-specific soil texture data (see LXX–YY of the revised manuscript).

350 It is important to emphasize that soil type and soil texture data were included solely to provide a general description of the study site. Therefore, replacing the regional averaged values with site-specific measurements does not affect the results or their interpretation and discussion.

L185: mention the accuracy of soil moisture and matric potential sensors.

355 We thank Anonymous Referee #1 for this comment. In response, we will include the accuracy specifications of the sensors. Specifically, the soil moisture sensors have an accuracy of $\pm 0.05 \text{ cm}^3 \text{ cm}^{-3}$, while the matric potential sensors have an accuracy of $\pm 10\%$ of the reading + 2 kPa. See LXX-YY in the revised manuscript.

L210 – 215: Use passive sentences.

360 We thank Anonymous Referee #1 for this comment. In accordance with the reviewer's suggestion, the text will be revised to consistently adopt passive constructions in the indicated paragraph. The revised version is provided below for clarity.

365 LXX-YY: *“Using monthly mean air temperature, vapor pressure, and precipitation $\delta^{18}\text{O}$ as inputs, the monthly evaporation line slopes are computed. These slopes are then used to reproject the isotopic composition of fractionated soil and plant water samples back to the Local Meteoric Water Line (LMWL). Technical details of the Craig and Gordon (1965) model are provided in Benettin et al. (2018), together with the MATLAB implementation adopted in this study. To determine whether a water sample is affected by fractionation, the line-conditioned excess* (lc-excess*) is calculated, accounting for uncertainty in the isotopic analysis (Landwehr and Coplen, 2006)”*:

370

Table 2: tables should be standalone, I suggest revising the table and defining each parameter within the table. Also, clearly mention that they are optimized or not in the caption.

375 We thank Anonymous Referee #1 for this comment. In accordance with the reviewer's suggestion, Table 2 will be revised to ensure that it is fully standalone. Each parameter will be explicitly defined within the table (including a brief description), and the caption will be expanded to clearly indicate whether the listed parameters were optimized or not.

380

L295: the authors defined ET_0 as potential evapotranspiration while they defined it as ET_P in Figure 3d. Please revise the text to ET_P or PET.

385 **We thank Anonymous Referee #1 for pointing this out and apologize for the inconsistency. The term ET_0 will be replaced with ET_P throughout the manuscript to ensure consistency with Figure 3d and to avoid any potential confusion.**

L320-321: move to methodology.

L358-362: move to methodology.

390

We thank Anonymous Referee #1 for these comments. In accordance with the reviewer's suggestion, the indicated lines (L320–321 and L358–362) will be moved to Section 2.7, "HYDRUS-1D: main equations and model set up," to ensure that all methodological details are presented consistently within the body of the manuscript instead of in Figures caption.

395

L374: use passive sentences.

We thank Anonymous Referee #1 for this comment. In accordance with the reviewer's suggestion, the indicated sentences will be revised to adopt passive constructions. The revised version is provided below for clarity.

400

L374-377: "In this study, we calculate the SOI by using the isotopic compositions (δ_x) of water fluxes simulated with HYDRUS-1D. We adopt the SOI because, as noted by Allen et al. (2019a), it is specifically designed to assess whether winter or summer precipitation is overrepresented in the considered flux."

Will be replaced with:

405 ***LXX-YY: "In this study, the SOI is calculated using the isotopic compositions (δ_x) of water fluxes simulated with HYDRUS-1D. The SOI is adopted because, as noted by Allen et al. (2019), it is specifically designed to assess whether winter or summer precipitation is overrepresented in the considered flux."***

410 L429: 3. Ensure consistent terminology for correlation metrics throughout the manuscript (e.g., avoid mixing Spearman's rank correlation with Pearson notation).

We thank Anonymous Referee #1 for this comment and apologize for the inconsistency in the symbolic notation used for the correlation coefficient. The correlation analysis was performed using Pearson's Linear Correlation Coefficient,

and the manuscript will be revised to ensure consistent terminology and notation throughout, with Pearson's Linear
415 **Correlation Coefficient correctly denoted as r .**

Table 3: Add the 95% confidence intervals since the results are achieved through inverse solution approach. Also, I suggest defining parameters in the caption or table to have a standalone table.

420 **We thank Anonymous Referee #1 for this comment. In accordance with the reviewer's suggestion, the 95% confidence intervals will be added to Table 3, as the parameter estimates were obtained through an inverse solution approach. In addition, to ensure that the table is fully standalone, we propose to include an additional column entitled "Description," in which each parameter will be clearly defined.**

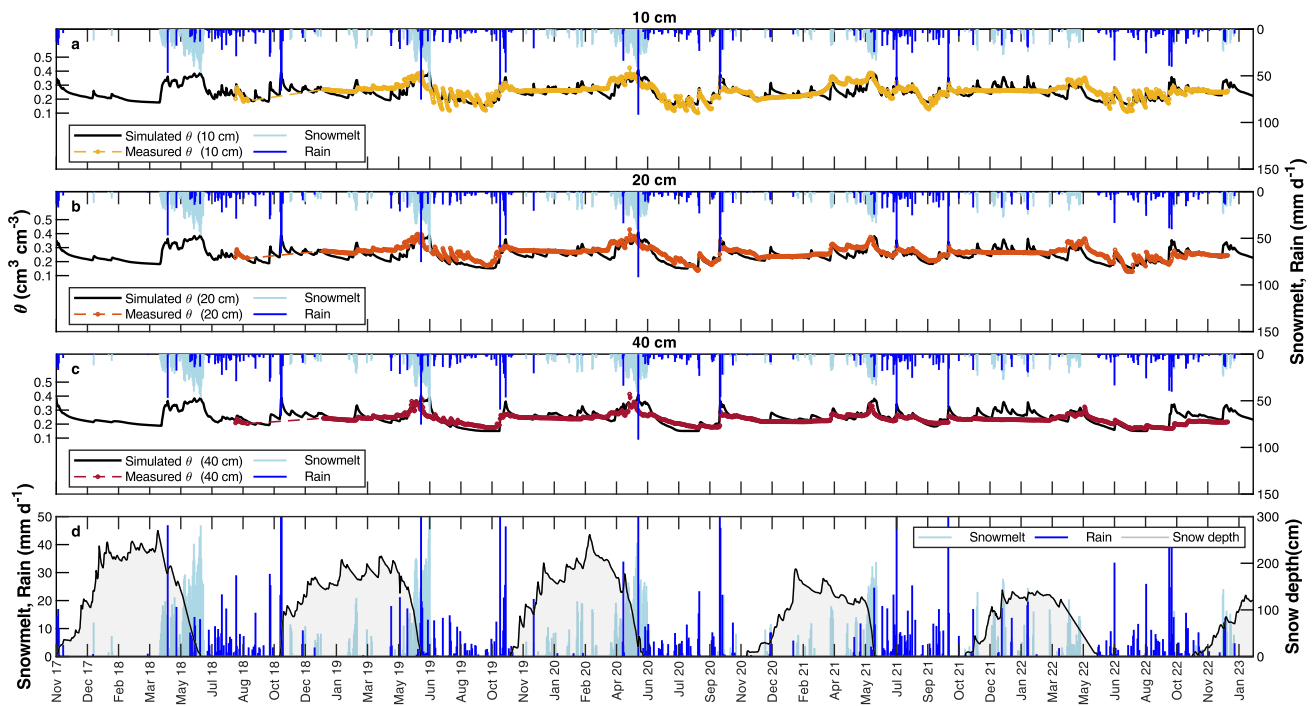
425 Figure 5: showing a fitted VG model based on measurements without any performance metric does not have any value. So, either add performance metric(s) in the figure 5 or table 3. Also, define θ and h in the figure axes or caption.

**We thank Anonymous Referee #1 for this comment. In accordance with the reviewer's suggestion, performance metrics will be included directly in Figure 5 to quantitatively assess the agreement between measured and fitted van
430 Genuchten curves. In addition, the definitions of θ and h will be clarified in the figure caption.**

Figure 7: I suggest using "Sim" than "Mod" since it is widely used in the literature. Also, define the abbreviations in the caption. Moreover, the measurement lines interfere with the simulated lines and they are too congested, please try to use contrasting colors, and size adjustments in order to distinctly visualize the simulation and observation. I suggest using the full
435 words for "Sim" and "Meas" as there is enough space in the graphs.

**We thank Anonymous Referee #1 for these suggestions. In accordance with the reviewer's comments, the term "Mod" will be replaced with "Sim" in Figure 7, and all abbreviations will be clearly defined in the revised figure caption. In addition, the labels "Sim" and "Meas" will be replaced with their full terms ("Simulated" and "Measured") to improve
440 clarity.**

Furthermore, the visualization will be revised to enhance readability by adopting contrasting colors and adjusting line styles and widths to clearly distinguish simulated and measured data. Below we provide the proposed revised version of Figure 7:



445

Figure 2 Proposed revised version of Figure 7

L428-431 & 466-469: It is better to report the simulation performance in table(s) rather than within the body of the manuscript which makes it harder to find for the readers.

450 **We thank Anonymous Referee #1 for this comment. In accordance with the reviewer's suggestion, the simulation performance metrics reported in L428-431 and L466-469 will be moved from the main text to dedicated table in the new Model performance section.**