Responses to Reviewers

Purple is quoted comment; Orange is a response, and Blue is quoted text from manuscript.

Reviewer 1

- In the introduction, Global Hydrological Models (GHMs) are described in several separate paragraphs, which makes the information somewhat fragmented. I recommend consolidating this into a more concise summary, perhaps in two or three paragraphs. This will help to present the key aspects of the model more clearly and cohesively, improving the overall readability of the section.

  We thank the reviewer for the constructive feedback regarding the description of Global Hydrological Models (GHMs) in the introduction. We agree that consolidating the information will improve clarity and cohesion. We have revised the section detailing specific examples of global models (GHMs, LSMs, and DGVMs) used within ISIMIP into a more concise summary paragraph (Lines 56 – 70 in the new manuscript). The Paragraph is presented here for quick reference

  Line 56:

  Within the ISIMIP ensemble (Table 1), various models exemplify different categories. For instance, GHMs like (Burek et al., 2020) focus on water quantity assessment across sectors (Becher et al., 2024; Palazzo et al., 2024), H08 (Hanasaki et al., 2018) maps water abstractions and availability, PCR-GLOBWB (Sutanudjaja et al., 2018) simulates the terrestrial water cycle including human influences (Becher et al., 2024; Burek et al., 2020; Palazzo et al., 2024), The Variable Infiltration Capacity (VIC) assesses human impacts on water resources (Liang et al., 1994), and WaterGAP (Müller Schmied et al., 2021) simulates runoff, recharge, and streamflow considering various storages. LSMs such as CLM, CLASSIC, JULES, and MATSIRO (Best et al., 2011; Lawrence et al., 2019; Melton et al., 2020; Takata et al., 2003) simulate broader land surface processes including energy, water, carbon fluxes, and vegetation dynamics, often incorporating hydrological components. DGVMs like LPJmL (Sitch et al., 2003) simulate vegetation dynamics and surface water balance, including human influences like irrigation. Despite differing primary objectives, these models are often used collectively in ensemble studies to assess CC impacts on various hydrological aspects like groundwater recharge (Reinecke et al., 2021), river flow (Gudmundsson et al., 2021) and soil moisture (Porkka et al., 2024), river ecological functioning (Thompson et al., 2021), droughts (Kew et al., 2021; Pokhrel et al., 2021), and floods (Dottori et al., 2018; Tabari et al., 2021; Zhou et al., 2023), both globally and regionally.

- The comparison of SWAT+ ET with the GLEAM dataset lacks a clear description of the time range. It is essential to specify the exact time period and resolution used for the comparison

  Thanks for pointing out the need for clarification regarding the time range and resolution used in the evapotranspiration (ET) comparison. Upon a closer look, we have updated the reference for GLEAM 4 (Line 173) as the final paper has since been published in Nature. We have also included dataset resolution here so that the user does not have to read the referenced manuscript to know this.

  We have also made a correction in Section 2.3) specifying that evaluation was done with GLEAM v4. We have revised Section 3.1 to explicitly state that the comparison between SWAT+ simulated ET and the GLEAM dataset covers the effective simulation period of 1982-1990 (after the 5-year warm-up)

Line 173:

GLEAM v4 dataset available at 0.1° resolution was used for evaluating ET (Miralles et al., 2025). The datasets require pre-processing to be used by the SWAT+ model.

Line 263:

A comparison of ET for the effective simulation period (1982 – 1990) shows that the spatial pattern between SWAT+ ET and GLEAM ET is comparable overall.

- The manuscript lacks a comparison analysis for the performance of monthly river discharge with other ISIMIP global hydrological models. The comparison is essential to provide a comprehensive understanding of the performance and limitations of the global SWAT+ model.

Thank you for your suggestion regarding a comparative analysis of monthly river discharge performance against other ISIMIP global hydrological models. We acknowledge the value of model intercomparison exercises like ISIMIP for contextualizing model performance. However, a direct, quantitative performance comparison with the existing ISIMIP model ensemble was not a primary objective of this particular study. Our main goals were to: (1) Develop the high-resolution (2km) global SWAT+ model setup, which is novel for SWAT+ at this scale, (2) establish the reproducible CoSWAT framework to manage the associated data and computational challenges, and (3) provide an initial, uncalibrated baseline evaluation of this high-resolution model's performance using standard metrics and datasets.

Furthermore, conducting a direct, station-by-station performance comparison between our 2km model and the standard ISIMIP model outputs (typically available at 0.5-degree resolution) presents significant conceptual and technical challenges. The fundamental difference in spatial scale means that our model explicitly represents fine-scale landscape heterogeneity, hydrological processes, and potentially smaller river systems that are inherently averaged or entirely unresolved within a 0.5-degree grid cell (~55km at the equator). Evaluating both model types against the same point-based gauge data, therefore, does not constitute a like-for-like comparison. For instance, the hydrological response at a gauge used for evaluation might be dominated by processes within a catchment much smaller than a 0.5-degree cell, processes which only the high-resolution model attempts to capture. Directly comparing KGE values, for example, could be misleading as the models are simulating fundamentally different spatial representations of the hydrological system.

While the CoSWAT framework developed here could potentially facilitate such comparisons in the future (e.g., by aggregating SWAT+ outputs or comparing against upscaled observations), our focus in this initial paper was on demonstrating the feasibility and presenting the baseline characteristics of the high-resolution global SWAT+ simulation itself. We have added a note in the Discussion section acknowledging this limitation and suggesting detailed inter-model comparison, accounting for scale differences, as an avenue for future research.

Line 356:

Finally, while placing model performance in the context of established global models like those within the ISIMIP ensemble is valuable, a direct quantitative comparison of river discharge statistics (e.g., KGE) was considered beyond the scope of this initial study and potentially misleading due to fundamental differences in model resolution. Comparing our high-resolution outputs, which capture finer-scale heterogeneity, against typical ISIMIP model outputs (0.5-degree) at specific gauge locations requires careful consideration of scale mismatches. Future work could explore methodologies for robust inter-comparison that account for these scale differences, potentially leveraging the aggregation capabilities of the CoSWAT framework.

- In Table 1, Nr 1 “CWatM” should maintain consistent capitalization with "CWATM" in line 57.

  We thank the reviewer for catching this, we have made the suggested correction in the revised manuscript for all references of CWatM.

- In line 66, the abbreviation “CC” is introduced without its full form. This should be corrected to enhance the clarity of the manuscript.

  Good catch! In the revised manuscript, we have now fully introduced the abbreviation upon mentioning it for the first time in main text (Line 33).

- In line 101, the abbreviation “ORCHIDEE” and “SWBM” is introduced without its full form.

  Due to the need to shorten the model description paragraphs, we have removed direct reference to these two models within main text.

- In line 109, the phrase “with between” in the sentence “Despite the differences in general purposes and focus for model development with between LSMs, GHMs and DGVMs” is grammatically incorrect, please remove “with”.

  This has been reviewed as suggested.

- In line 144, in the sentence “increased uncertainty (Sood & Smakhtin, 2015) in model outputs (Sood & Smakhtin, 2015)”, the same reference is cited twice in close proximity, which is unnecessary and can be confusing for readers.

  Thanks for pointing this out, we have made the correction.

- In line 211, The sentence “Gleam4 dataset was used for evaluating ET (Miralles et al., 2011, 2024) The datasets require preprocessing to be used by the SWAT+ model.” contains a grammatical error. It appears to be a comma splice, where two independent clauses are joined without proper punctuation.

  This sentence has now been updated and reads as follows:

  Line 173:

  GLEAM v4 dataset available at 0.1° resolution was used for evaluating ET (Miralles et al., 2025). The datasets require pre-processing to be used by the SWAT+ model.

- In line 211, “Gleam4 dataset was used for evaluating ET”, In line 274, “We also evaluated the ET output against GLEAM v3 dataset”. It is unclear whether these refer to the same dataset or different versions of the dataset. For clarity and consistency, the authors should ensure that the dataset names are used accurately and consistently throughout the manuscript. The word “Gleam”, the authors should maintain consistency when referring to GLEAM. Please revise the terminology throughout the entire paper accordingly.

  We thank the reviewer for this feedback. We have made correction regarding the inconsistency as clarified under the second comment. We have also revised all references in the manuscript for consistency including proper capitalisation.

- In line 259, mentions “HRUs”, a detailed introduction to HRU is needed.

We agree that introducing this SWAT+ concept earlier is needed. We have added a brief explanation of Hydrologic Response Units (HRUs) within the paragraph that introduces the SWAT+ model in the Introduction section, clarifying that HRUs are the basic computational units representing unique land use, soil, and slope characteristics.

Line 90:

SWAT+ (Soil and Water Assessment Tool) is a completely revised version of the original SWAT model (Arnold et al., 2018; Bieger et al., 2017). It performs hydrological simulations at the Hydrologic Response Units (HRU) scale. HRUs represent unique combinations of land use, soil, and slope characteristics within each landscape unit or subbasin. The SWAT+ model can simulate a wide range of processes including surface runoff and infiltration, evapotranspiration...

- In line 274, The sentence "We also evaluated the ET output against GLEAM v3 dataset using maps and sample point difference distribution." is somewhat ambiguous. It is unclear how exactly the evaluation was conducted using "maps and sample point difference distribution." For clarity, the authors should provide more specific details about the methods used for this evaluation.

Thank you for highlighting the ambiguity in our description of the evapotranspiration (ET) evaluation method. We agree that more specific details were needed. We have revised the relevant sentence in the Methodology section (originally line 140) to explicitly describe how the maps and sample point difference distribution were used. Specifically, we now state that the maps were visually compared to assess spatial pattern agreement and that the sample point difference distribution was generated by calculating the difference between SWAT+ and GLEAM ET at quasi-randomly selected global points (shown in Figure 6) and plotting the frequency of these differences to evaluate overall bias and distribution around zero.

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