Manuscript Number: EGUSPHERE-2026-3119

Manuscript Title: Understanding ecosystem gross primary productivity, evapotranspiration, and water use efficiency of maize using ISBA-A-g_s land surface model over temperate and tropical semi-arid climates.

AUTHORS' RESPONSES TO REFEREE-2 COMMENTS

This manuscript evaluates the performance of the ISBA-A-gs land surface model in simulating gross primary productivity (GPP), evapotranspiration (ET), and water use efficiency (WUE) of maize across two contrasting agroecosystems: a temperate site in France and a tropical semi-arid site in India. The study is based on a rich observational dataset, including eddy covariance measurements, meteorological observations, vegetation variables, and irrigation information. The modelling results are generally encouraging, particularly for GPP, and the comparison between conventional and alternate furrow irrigation is potentially useful for understanding carbon-water trade-offs in irrigated maize systems.

- We sincerely thank the reviewer for the positive feedback on our manuscript and for recognizing the significance of this study. We are pleased that the reviewer acknowledged the comprehensive observational dataset, the encouraging performance of the ISBA-A-g_s model, particularly in simulating GPP, and the relevance of comparing conventional and alternate furrow irrigations for improving our understanding of ecosystem carbon-water trade-offs in irrigated maize systems. The reviewer's constructive comments have helped us further improve the clarity, organization, and scientific quality of the manuscript. We have carefully addressed all of the reviewer's comments and detailed point-by-point responses are provided.

However, I find that the manuscript in its current form does not yet clearly articulate its main scientific contribution. The dataset is valuable and the simulations appear promising, but the manuscript reads largely as an extensive model calibration and evaluation exercise rather than a tightly framed contribution to understanding ecosystem carbon-water coupling. I therefore recommend major revision.

- We sincerely thank the reviewer for this constructive and insightful comment. We have thoroughly revised the manuscript to better highlight its scientific novelty and contribution

to understanding ecosystem carbon-water coupling. All these modifications can be found in the revised manuscript.

- Specifically, we have restructured the introduction to clearly establish the research gap and objectives, reorganized the results and discussion to focus on the underlying eco-physiological mechanisms rather than model performance alone, and strengthened the conclusions to emphasize the broader scientific implications of the findings. In particular, the revised manuscript highlights how the ISBA-A-g_s model reproduces ecosystem carbon-water coupling across contrasting hydro-climatic conditions and captures the effects of irrigation management through process-based diagnostics, including underlying WUE (uWUE) and the EF-VPD relationship.
- We believe these revisions have significantly improved the scientific focus and clearly articulate the main contribution of the study.

Major comments:

1. The novelty and central contribution need to be clarified.

The manuscript currently presents its novelty in several different ways: (i) the first application of ISBA-A-gs in its MEB configuration to a semi-arid Indian maize system, (ii) an ecosystem-scale WUE assessment using a locally calibrated LSM under contrasting climates, partly motivated by a keyword-based literature gap, and (iii) the effect of irrigation management (CFI vs AFI) on carbon-water coupling. In my view, the third aspect is the most scientifically compelling contribution, but it is not developed as the main thread of the paper. A first application of an existing model to a new site is useful, but it is mainly incremental and may not provide sufficient novelty on its own. I strongly encourage the authors to define a single central research question, for example: can a process-based LSM reproduce and mechanistically explain irrigation-driven divergence in ecosystem WUE, and does this behavior differ between temperate and semi-arid maize systems? The manuscript should then be restructured around this question, with the CFI/AFI analysis and its mechanistic interpretation placed at the center.

- We sincerely thank the reviewer for this insightful and constructive comment. We agree that the scientific novelty of the original manuscript was not sufficiently articulated and

that the central contribution needed to be more precisely framed. In response, we have thoroughly revised the manuscript to better highlight this central scientific contribution. The Introduction has been rewritten to clearly establish the research gap and to define the study objectives around evaluating whether the ISBA-A-g_s model can realistically represent irrigation-driven variations in ecosystem GPP, ET, and WUE under contrasting hydro-climatic conditions. Accordingly, the introduction has been revised to clearly define this research gap and to position irrigation-driven carbon-water coupling as the central scientific theme of the study.

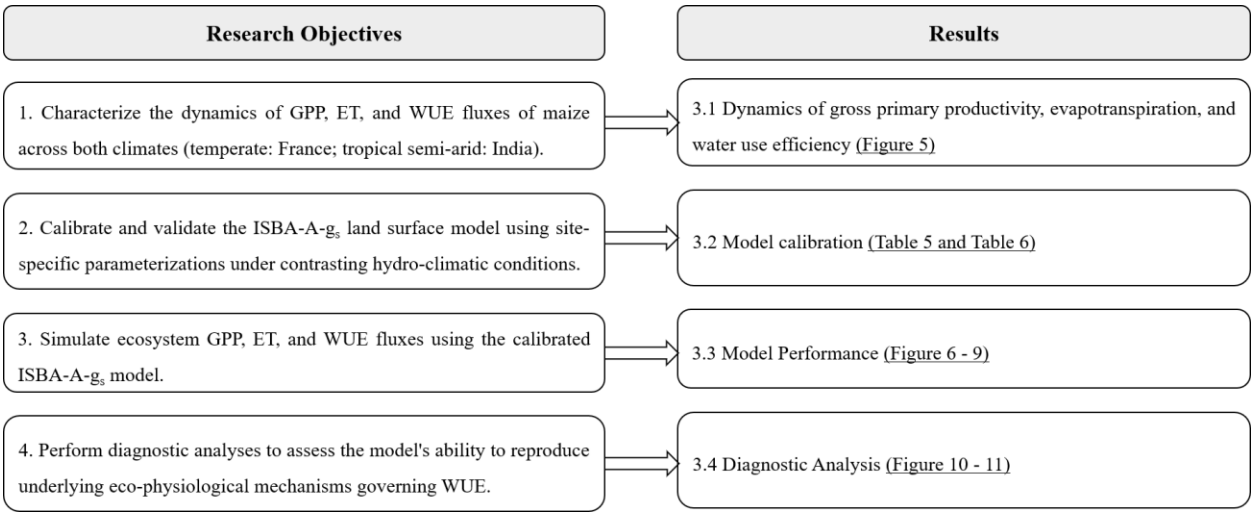
- To better support this objective, we have reorganized the results section into four complementary subsections.
- First, the dynamics of GPP, ET, and WUE under varying irrigation and climatic conditions now emphasizes site-specific responses and explicitly compares the divergence of ecosystem carbon and water fluxes between the CFI and AFI treatments (Section 3.1), thereby directly addressing the central research question.
- Second, the model calibration section has been revised to provide a mechanistic interpretation of the optimized site-specific parameters, explaining how differences between the CFI and AFI treatments, as well as between the tropical semi-arid (Ind-IITH) and temperate (FR-Lam) sites, influence carbon-water flux simulations (Section 3.2).
- Third, the model evaluation section now emphasizes not only the overall predictive performance of ISBA-A-g_s but also its ability to distinguish contrasting irrigation regimes and climatic conditions (Section 3.3).
- Finally, the diagnostic analyses based on underlying water use efficiency (uWUE) and the evaporative fraction-vapour pressure deficit (EF-VPD) relationship have been expanded to demonstrate how the model reproduces ecosystem carbon-water coupling and irrigation-induced differences across the two study sites (Section 3.4).
- Further, the discussion section has also been substantially revised to synthesize these findings and highlight their broader scientific implications. Rather than presenting the work primarily as a model calibration exercise or the first application of ISBA-A-g_s to a new region, the revised manuscript now emphasizes its principal contribution: demonstrating the capability of ISBA-A-g_s to mechanistically represent irrigation-driven ecosystem carbon-water interactions and WUE dynamics across contrasting temperate and tropical

semi-arid maize agroecosystems. We believe these revisions have significantly strengthened the scientific focus and clearly articulated the main novelty and contribution of the study.

2. The manuscript is too long and repetitive.

The manuscript would benefit from substantial streamlining. The Introduction alone is very long (over 150 lines) and currently reads more like a broad survey than a targeted motivation for the study; it should be shortened and focused on the specific knowledge gap that this paper addresses. Similar redundancy occurs throughout the manuscript. Much of the Results section restates, in prose, values that are already shown in the figures and tables, including year-by-year and treatment-by-treatment GPP, ET, WUE, and performance metrics. The Discussion also frequently repeats the Results before developing broader interpretation. In addition, the site and instrument descriptions are highly detailed and partly overlap with information available in previous publications. I recommend that the authors condense the Introduction, move routine methodological or site details to tables, figures, appendices, or the Supplement, and focus the main text on the patterns, anomalies, and mechanistic interpretation that directly support the central research question. The two diagnostic analyses should either be more clearly differentiated in terms of their scientific purpose or streamlined if they lead to similar conclusions. A substantial reduction in length would greatly improve the clarity and readability of the manuscript.

- Agreed, and thanks for the great recommendations. We have substantially streamlined the manuscript and reorganized its structure to better emphasize the scientific findings and their mechanistic interpretation.
- In the revised manuscript, we revised the introduction, which is substantially shortened to highlight the specific research gap, scientific motivation, and objectives of the study, while removing background information that was not directly relevant.
- The results section has been reorganized into four subsections aligned with the study objectives as shown in below flowchart.



An illustrative diagram showing the sequence of results corresponding to the research objectives and the respective figure numbers associated with the description of results falling under individual research objectives.

- Descriptive text that merely repeated values presented in the figures and tables has been removed or substantially reduced, with greater emphasis placed on interpreting the major patterns, treatment differences, and site-specific responses.
- The discussion section has also been substantially revised to avoid repetition of the results and is now organized into three focused sections addressing (i) the implications of the model calibration, (ii) the model's capability to simulate ecosystem carbon and water fluxes under contrasting climates and irrigation treatments, and (iii) the underlying physiological and land-atmosphere mechanisms revealed by the diagnostic analyses. This restructuring places greater emphasis on the broader scientific implications of the findings rather than reiterating the results.
- The redundant descriptions of the study sites and meteorological conditions, which were previously presented in section 3.1, have been merged into Section 2.1 to establish a clearer connection between the study objectives and the subsequent results. Similarly, unnecessary details regarding the instrumentation and methodology have been condensed, and overlapping descriptions have been removed where appropriate.
- Finally, the scientific purposes of the two diagnostic analyses have been clearly distinguished before presenting them as results (Section 3.4). The uWUE analysis is now presented as a diagnostic of ecosystem carbon-water coupling, whereas the EF-VPD

relationship is used to evaluate land-atmosphere coupling and surface energy partitioning under contrasting irrigation and climatic conditions. Together, these complementary analyses provide independent process-based evidence of the model's ability to represent ecosystem carbon-water interactions.

- Overall, these revisions have substantially reduced redundancy, improved the organization and readability of the manuscript, and strengthened its scientific focus.

3. The calibration/validation strategy at Ind-IITH is unclear, and the dataset is insufficient for strong transferability claims.

The two sites are strongly imbalanced in data volume. FR-Lam includes six growing seasons, whereas Ind-IITH, which is presented as a key novel component of the study, includes only one year, with monsoon and winter seasons under CFI and AFI (Table 2). This limits the assessment of interannual variability at the Indian site and makes strong claims about model transferability across contrasting hydro-climatic regimes difficult to support. These claims should be tempered unless additional years are included or the associated uncertainty is discussed more explicitly.

More importantly, the calibration and validation design for Ind-IITH is unclear. Sect. 2.4 states that simulations were conducted for "four treatments (2 seasons)" at Ind-IITH during calibration, but also states that the optimized parameter set was validated using "Ind-IITH: two seasons" not included in the calibration phase. In addition, Table 6 reports separate optimized parameter values for CFI-Monsoon, AFI-Monsoon, CFI-Winter, and AFI-Winter. The authors should specify exactly which observations were used for calibration and which were used for validation, explain how independence between calibration and validation was ensured, and adjust the wording of the conclusions accordingly.

- We agree that the limited duration of observations at the Ind-IITH site (one agricultural year comprising monsoon and winter seasons under CFI and AFI) does not facilitate an assessment of interannual variability comparable to the six growing seasons available for the FR-Lam site. Consequently, we have revised the manuscript to temper statements regarding the transferability of the ISBA-A-g_s model across contrasting hydroclimatic conditions and explicitly acknowledge this limitation in section 5.0 of revised manuscript.

- Nevertheless, we emphasize that the Ind-IITH dataset was specifically designed to evaluate model performance under contrasting irrigation management (CFI and AFI) and seasonal climatic conditions within the same agricultural year. The inclusion of both monsoon and winter growing seasons provides a broad range of hydrometeorological conditions and enables a robust assessment of the model capability to represent irrigation-driven variations in ecosystem GPP, ET, and WUE.
- Furthermore, Figure 5, which presents the distribution of GPP, ET, and WUE using box plots, provides valuable insight into the intra-annual variability, treatment-specific differences, and associated uncertainties in the observed and simulated fluxes. Rather than supporting claims of long-term transferability, these analyses help identify site-specific patterns, quantify variability within the available observations, and evaluate the model's ability to reproduce contrasting ecosystem responses under different irrigation treatments.
- Accordingly, we have revised the manuscript to clarify that the conclusions for the Ind-IITH site are restricted to the available observation period and should be interpreted as evidence of the model's capability under contrasting irrigation and seasonal conditions, rather than as a comprehensive assessment of long-term transferability across years.
- We agree that the calibration and validation strategy for the Ind-IITH site required further clarification. Accordingly, we have revised section 2.4 to describe the calibration procedure adopted for both study sites. For the FR-Lam site, the ISBA-A-g_s model was calibrated using multiple growing seasons and independently validated using the remaining seasons that were not included in the calibration, thereby ensuring independence between the calibration and validation datasets. In contrast, only one agricultural year of observations was available for the Ind-IITH site. Consequently, separate parameter sets were calibrated for each of the four irrigation-season combinations (CFI-Monsoon, AFI-Monsoon, CFI-Winter, and AFI-Winter) to investigate the effects of contrasting irrigation treatments and seasonal climatic conditions on ecosystem carbon and water fluxes. Because no additional independent observational dataset was available, an independent validation was not performed for the Ind-IITH site. We have now explicitly clarified this in the revised manuscript and corrected the previous wording, which may have incorrectly implied that an independent validation dataset was available. The purpose of deriving separate parameter sets for the four irrigation-season combinations was not to demonstrate

temporal transferability, but rather to quantify how model parameters and ecosystem processes respond to contrasting irrigation management and seasonal environmental conditions within the available experimental period.

4. The quantitative reporting needs to be made consistent.

Some key numbers are reported inconsistently across the manuscript. First, the sign convention for GPP is confusing. In the Abstract, GPP is reported as a positive cumulative value, for example 1039 gC m^{-2} at FR-Lam and 766 gC m^{-2} at Ind-IITH (p. 2, lines 33-38). However, in the Results, FR-Lam GPP is reported as negative, for example −8 to −11 gC m^{-2} day^{-1} in Sect. 3.2 and −900 to −1500 gC m^{-2} in Sect. 3.4 (p. 28-37, lines 614-617 and 778-780). At the same time, WUE is defined as GPP/ET and is always reported as positive. The authors should use one sign convention for GPP throughout the text, figures, and equations.

- In the original manuscript, GPP was reported as a negative flux following the conventional ecosystem carbon flux sign convention, where carbon uptake by the ecosystem is represented as a negative flux to indicate its direction. However, we agree that this sign convention has to be inconsistent with the quantitative definition of WUE, otherwise may cause unnecessary confusion for readers.
- In response, we have revised the manuscript to adopt a consistent sign convention, whereby GPP is reported as a positive throughout the manuscript, including the abstract, results, discussion, figures, tables, and equations. This sign convention is consistent with the definition of WUE presented in Equation 3. Accordingly, all daily (gC m^{-2} day^{-1}) and cumulative GPP (gC m^{-2}) values have been revised to positive values, and the associated figures have been updated to maintain consistency throughout the manuscript.

Second, some cumulative ET values do not match across sections. For example, FR-Lam ET is reported as about 610 kg H_2O m^{-2} in the Abstract, 500-800 kg H_2O m^{-2} in Sect. 3.4, and 800-1150 kg H_2O m^{-2} in the Discussion (p. 2, lines 33-35; p. 37, lines 788-789; p. 45, lines 1014-1015). If these numbers refer to different time periods or calculation methods, this should be clearly explained. Otherwise, the values should be corrected. Overall, the authors should check all key GPP, ET, and WUE values in the Abstract, Results, and Discussion for consistency.

- Thank the reviewer for carefully identifying these discrepancies. The values reported in the abstract (610 kg H_2O m^{-2}) represent the mean cumulative ET across all six growing seasons at the FR-Lam site, whereas the values presented in Section 3.4 (500-800 kg H_2O m^{-2}) correspond to the minimum-to-maximum range of cumulative ET observed across the six individual growing seasons. We also agree that the ET values reported in the discussion (800-1150 kg H_2O m^{-2}) were inconsistent with those presented in the abstract and results. These values were inadvertently misreported and have therefore been removed from the revised manuscript to maintain consistency.
- In addition, we have thoroughly reviewed and cross-checked all key GPP, ET, and WUE values reported throughout the manuscript to ensure complete consistency.

Minor comments:

1. Please check the use of "correspondingly" in the Abstract. "respectively" would be more appropriate in most cases.
    - Agreed. The abstract has been revised accordingly.

2. Line 138: the citation "(Boone et al., 2017)" should be Boone et al., (2017).
    - Agreed. This has been corrected, and all narrative citations have been checked throughout the manuscript.

3. Please check whether "leaf are index" in the caption of Figure 4 should be "leaf area index".
    - This is a typo and is corrected in the captions of Figures 4 and 5.

4. The initial value of mesophyll conductance (gm) is given as 7.53×10^{-2} m s^{-1} in the text (Sect. 3.3) but as 7.53×10^{-3} m s^{-1} in Table 5. Please reconcile.
    - Agreed. The incorrect text has been corrected to match the values reported in Table 5.

5. The unit for WUE is written inconsistently, e.g., "g C kg H_2O^{-1}" in Eq. (3) versus "gC kg^{-1} H_2O" elsewhere. Please standardize unit and symbol notation throughout the text, equations, tables, and figures (including spacing, e.g., "gC" vs "g C").

- The WUE unit and notation have been standardized throughout the manuscript as gC kg H_2O^{-1}.

6. The manuscript would benefit from a thorough English-language edit; there are recurrent issues with articles, tense, and phrasing that occasionally impede readability.
    - The manuscript has been thoroughly proofread and professionally edited to improve grammar, clarity, and readability.