Responses to Referee #2's Comments for Manuscript egusphere-2025-6159

Effectively Assimilate Satellite Land Surface Temperature into Offline Land Surface Models within Ensemble-based Assimilation Frameworks

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Please note that in this response, blue color text indicates the figures and tables in the revised manuscript submitted in the previous round and red color text indicates the corresponding ones in the original manuscript.

Referee Comment

General Comments.

Reviewing comments for "A Systematic Atmospheric Parameter Optimization method to Improve ENSO Simulation in the ICO XPP Earth System Model" (egusphere-2025-5736).

Response:

We thank the reviewer for reviewing our manuscript. After carefully comparing the comments with our revised manuscript and previous response, we found that there are several comments that appear to be based on an earlier version of the manuscript since the concern issues that have been addressed in the revised manuscript or explained in our response. Specifically:

1. The manuscript title and number: "A Systematic Atmospheric Parameter Optimization method to Improve ENSO Simulation in the ICO XPP Earth System Model" (egusphere-2025-5736), do not correspond to our manuscript: "Effectively Assimilate Satellite Land Surface Temperature into Offline Land Surface Models within Ensemble-based Assimilation Frameworks" (egusphere-2025-6159).
2. We have conducted the additional comparison experiments suggested in Referee #3's first-round Comment 1, comparing the joint-update (ST+SM) and temperature-only (ST) schemes; the results are presented and discussed in the Introduction Figure 1 of the revised version.
3. The experimental-configuration Table 2 of the original manuscript has been removed. To maintain consecutive numbering of the tables, the original Table 3 is now renumbered as Table 2 in the revised manuscript. And the schematic workflow (Figure 2) has been added as suggested by the reviewer.

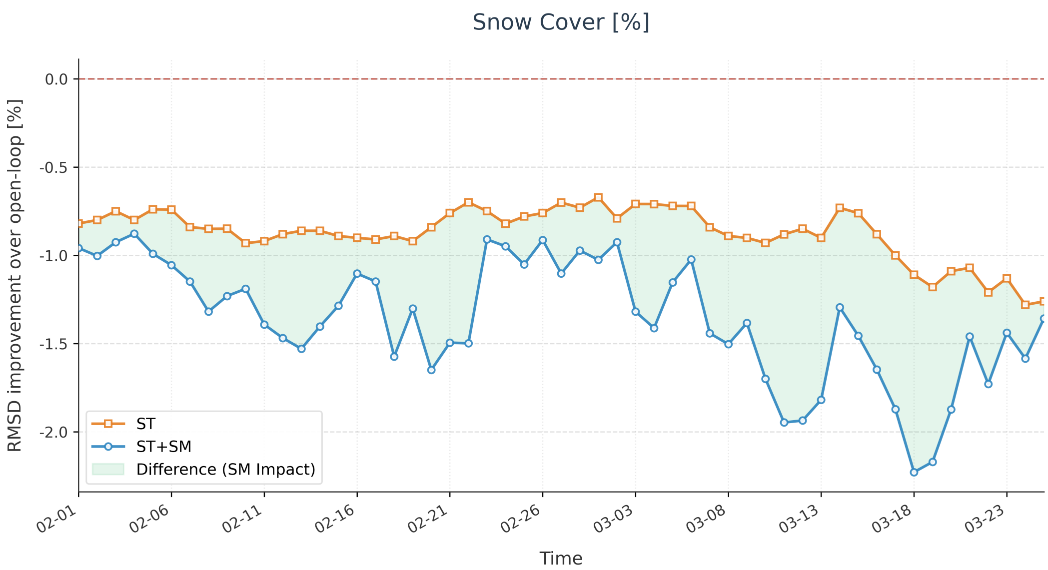
Nevertheless, we have carefully considered all the comments to improve the manuscript accordingly. Detailed responses to each comment are provided below.

Comment 1

The novelty of this manuscript in the revised version is still not clear. How is the model improved from assimilating the land surface temperature by jointly updating the soil moister and soil temperature? This conclusion or its related statistics are not strong and concise either in the Abstract or Conclusion Sections. Additionally, more numerical experiments could be designed for checking the improvements by only updating the soil moister or soil temperature.

Response:

Because of the rapid variability of LST, atmospheric forcing, especially solar radiation, exerts a dominant control over surface temperature and can restore it to equilibrium within a brief period. Consequently, if only the first-layer soil temperature is updated, the assimilation effect is substantially weakened. The revised manuscript highlights the advantage of updating soil temperature and moisture simultaneously over single-variable updates (L69 – L71). A comparison experiment was performed, comprising a joint-update (ST+SM) run and a temperature-only (ST) run. As shown in Figure 1, the joint-update approach consistently yields improvements in both soil moisture (Figure 1a) and soil temperature (Figure 1b) across the AmeriFlux sites. Moreover, the advantage of the joint update over the temperature-only approach extends beyond soil variables. As shown in the following figure, the joint-update scheme substantially outperforms its temperature-only (ST) counterpart in simulating snow cover (evaluated against global ERA5-Land data). This result further demonstrates that the proposed scheme improves not only soil temperature and moisture but also other land surface variables.



Snow cover [%] $\mathrm{RMSD_d}$ of the joint-update (ST+SM) and temperature-only (ST) schemes, defined as the RMSD difference between each scheme and the open loop, $\mathrm{RMSD_d} = \mathrm{RMSD_{scheme}} - \mathrm{RMSD_{OEXP}}$, evaluated against ERA5-Land. Negative values indicate improvement.

Having demonstrated the advantage of the joint-update approach, the manuscript then focuses on its performance relative to the open-loop run. Clear improvements are also observed in water-related variables that are not directly linked to LST, including soil moisture (Figures 11 and 12), snow depth (Figures 9 and 10), and snow cover (Figures 7 and 8).

Finally, the Abstract, the Introduction, and the Conclusion have been updated correspondingly.

Changes: Abstract (L6 – L9), Introduction (L70 – L71) and Conclusion (L581 – L583).

Comment 2

the skill metrics used is confusing, what is the definition of RMSD difference and why is the unit %? Both Figure 8 and Figure 14 are not meaningful;

Response:

The RMSD difference is defined in Section 3.3 of the revised manuscript: $\mathrm{RMSD_d} = \mathrm{RMSD_{AEXP}} - \mathrm{RMSD_{OEXP}}$, with negative (positive) values indicating improvement (degradation) of the assimilation relative to the open loop, evaluated against the same dataset.

Figure 8 shows the snow cover fraction, a dimensionless quantity conventionally expressed in %; its $\mathrm{RMSD_d}$ therefore carries the same unit. For the sake of clarity and to prevent confusion, the unit of the snow cover fraction, (in %), is now explicitly indicated in the corresponding text and captions.

Based on three independent satellite products (ATSR-2, AVHRR, MODIS), Figure 8 illustrates the yearly snow cover $\mathrm{RMSD_d}$, with approximately 10% reductions found across most mid-to-high latitudes of North America and Eurasia. And based on in-situ observations (FLUXNET2015, AmeriFlux), Figure 14 displays the site-specific $\mathrm{RMSD_d}$ of sensible and latent heat fluxes, revealing improvements at most sites. Taken together, these independent observational datasets—both satellite and in-situ—provide robust evidence that the assimilation yields broad improvements in land surface variables beyond those directly updated.

Changes: Section 3.3 (L316 – L317); Section 4.2.2 (L424, colorbar labels and caption of Figure 8).

Comment 3

the reviewer has pointed out some critical issues, but without being addressed properly. For example, the authors state that the Table 2 is removed while it is still kept in the updated manuscript; the subtitle for Figure 13 is not self-explainable for the readers; the overly simple for the subsection title is still there, e.g., the subsection title for 3.2 is 'Experiment'. The improvement from the authors proposed algorithm (e.g., AEXP) and the default one (e.g., OEXP) is not consistently advantageous and even deteriorated.

Response:

(1) The experimental-configuration Table 2 of the original manuscript has been removed. To maintain consecutive numbering of the tables, the original Table 3 is now renumbered as Table 2 in the revised manuscript. And the schematic workflow (Figure 2) has been added as suggested by the reviewer.

(2) We appreciate the reviewer's observation that the caption of Figure 13 did not correspond to the figure layout. This has been rectified in the current revision and the caption now correctly describes

that the difference panels are based on ERA5-Land, GLDAS, and MERRA2. Since MERRA2 does not provide bare-soil evaporation, no related panel is presented in Figure 13. Furthermore, we have added a label below the colorbar of each difference panel to indicate the RMSD difference between the two experiments, thereby enhancing the figure's clarity and self-sufficiency.

(3) The subsection title of Section 3.2, which was overlooked in the previous revision, has been revised from "Experiments" to "Design and Configuration of the Data Assimilation and Open-Loop Experiments". The subsection title of Section 3.1 has also been changed from "Datasets" to "Forcing, Observation, and Evaluation Datasets".

(4) We acknowledge that the assimilation does not yield uniform improvements over the open loop. The degradations are identified and discussed in the revised manuscript (Section 4.2.1, L357 — L362; Section 4.2.2, L469 – L475; Section 4.2.3, L513 – L519). Nonetheless, the proposed scheme outperforms the open loop in the majority of regions and for most variables: soil temperature RMSD is reduced throughout the assimilation period (Figure 5); snow temperature, snow depth, and snow cover are improved across much of the Northern Hemisphere (Figures 6, 8, and 10); and surface fluxes show broad improvements in most regions and at most sites, as summarized in Figures 13 and 14.

Changes: Section 3.1 (subsection title, L211); Section 3.2 (subsection title, L281); Section 3.3 (Table 2, the former Table 3); Section 4.2.3 (Figure 13, colorbar labels and caption).