Responses to comments <essd-2023-242>

Dear Editor and referees,

We appreciate the opportunity to further refine our manuscript. In response to your comments, we have made two main changes in the revised manuscript:

- In response to Editor's comments, we have added comparisons between the ELM simulations and four reference datasets of different variables.
- In response to referee2's comments, we have updated the method section to clarify the purpose of the spatial scaling analysis to avoid misunderstanding.

The point-by-point responses to the specific comments are provided below in blue. All line numbers listed below correspond to those in the clean version of the revised manuscript. We hope that our modifications have addressed all the concerns raised, and we appreciate your consideration of our revised manuscript.

Sincerely,

Lingcheng Li and co-authors

Editor

Given the issues raised by the reviewers, I recommend providing authors an opportunity for additional revisions. The authors should focus on addressing major issues regarding the evaluations against observations, which were raised by previous reviews but not well addressed by the authors. The third reviewer also raised an additional concern related the issues of upscaling. Once these concerns are addressed, the manuscript can be evaluated for potential acceptance.

We acknowledge the reviewers' concerns regarding the evaluations against observations. To address this, we have conducted a comprehensive analysis of the ELM simulations with reference datasets, including SM, LH, ELR, and ASR. It is important to note that no model parameter recalibration was conducted (see discussions for details).

Therefore, we added the following content.

In L26–L28,

"The comparison against four benchmark datasets indicates that ELM generally performs well in simulating soil moisture and surface energy fluxes."

In L345–L356,

"**3.4 Reference datasets for evaluating ELM simulation**

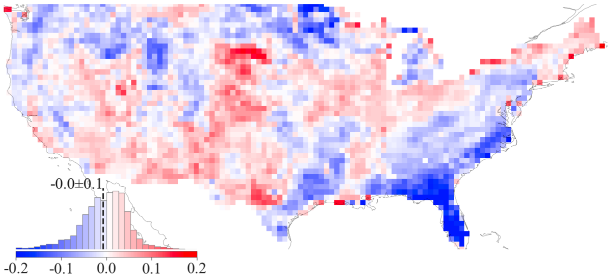
We also performed a comparison of all four ELM-simulated variables against reference datasets. It is important to note that we used the default model parameters and did not perform any calibration (see discussions for details). For reference datasets, soil moisture was obtained from the Global Land Evaporation Amsterdam Model (GLEAM; Martens et al., 2017), latent heat flux data was from the MODIS product (Running et al., 2021), and both ELR and ASR data were processed from the land component of the fifth generation of European ReAnalysis (ERA5_Land; Muñoz-Sabater et al., 2021). For the soil moisture evaluation, we compared the surface layer soil moisture from GLEAM (10 cm depth) with the weighted average of the first four-layer soil moisture from ELM (about 11 cm depth). To ensure comparability, we unified the spatial resolution of both reference datasets and ELM simulations to a 0.5-degree resolution and focused our analysis on the annual mean data for 2014."

In L593–L614.

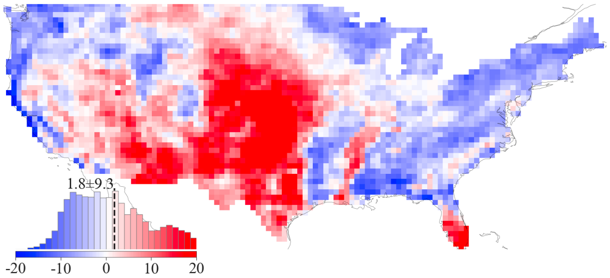
“4.7 Comparison of ELM simulation against reference data

The average spatial biases between ELM and reference datasets across CONUS are relatively small, with SM bias at -0.01 m^3/m^3, LH bias at 1.8 W/m^2, ELR bias at -3.8 W/m^2, and ASR bias at 1.1 W/m^2 (Figure 13 and Figure S27). The correlation coefficient (R^2) between ELM and reference datasets was relatively high at 0.60 (for SM), 0.70 (for LH), 0.96 (for ELR), and 0.90 (for ASR). However, the spatial distribution of these biases exhibits variability, with some areas showing more pronounced biases than others. Specifically, in comparison with GLEAM SM, ELM tends to underestimate SM in the southeastern Texas and across the eastern and southeastern CONUS, while it overestimates SM in the western, central, and southwestern CONUS, including the central eastern US which are primarily agricultural areas. For LH, ELM simulates higher values than the MODIS LH dataset in the western and central US and Florida, but lower values in regions such as the eastern and northeastern CONUS, the western US coastal areas, and the Pacific Northwest. Regarding radiation variables, ELM generally underestimates ELR across nearly all of CONUS and tends to overestimate ASR, particularly in the southwestern, southern, eastern, northeastern, and northern regions of CONUS.

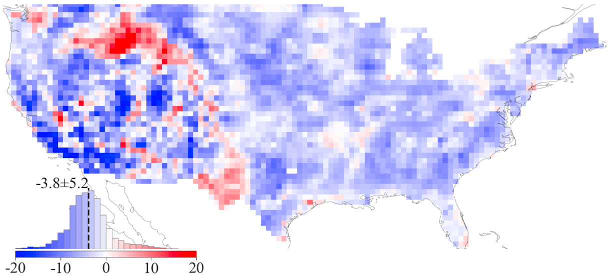
(a) Difference: SM (m^3/m^3); $R^2 = 0.60$



(b) Difference: LH (W/m^2); $R^2 = 0.70$



(c) Difference: ELR (W/m^2); $R^2 = 0.96$



(d) Difference: ASR (W/m^2); $R^2 = 0.90$

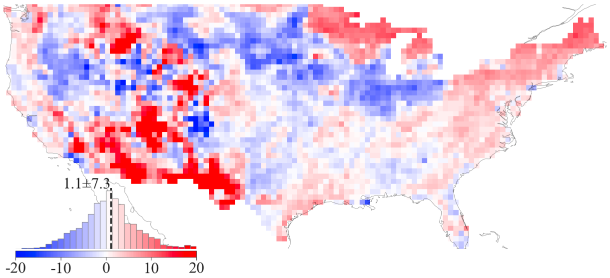


Figure 13. Annual mean bias between ELM-simulated variables and reference datasets over CONUS: (a) SM, (b) LH, (c) ELR, and (d) ASR. The negative values indicate lower ELM values compared to the reference data. The inserted histogram plot illustrates the distribution of grid values. For spatial patterns of the reference datasets, refer to Figure S27. The correlation coefficient (R^2) between the ELM simulation and the reference dataset is calculated and displayed in the title of each subplot."

In L708–L713.

"This is clearly evidenced in our ELM demonstration simulations, where, despite relatively low CONUS averaged biases for water and energy simulations, the spatial variation in these biases cannot be overlooked, with some regions exhibiting notably larger biases. It is important to emphasize that enhancing model performance requires not just updated input data, but also appropriate calibration of model parameters and faithful model structures to represent various processes."

Figure S27 in the supplementary.

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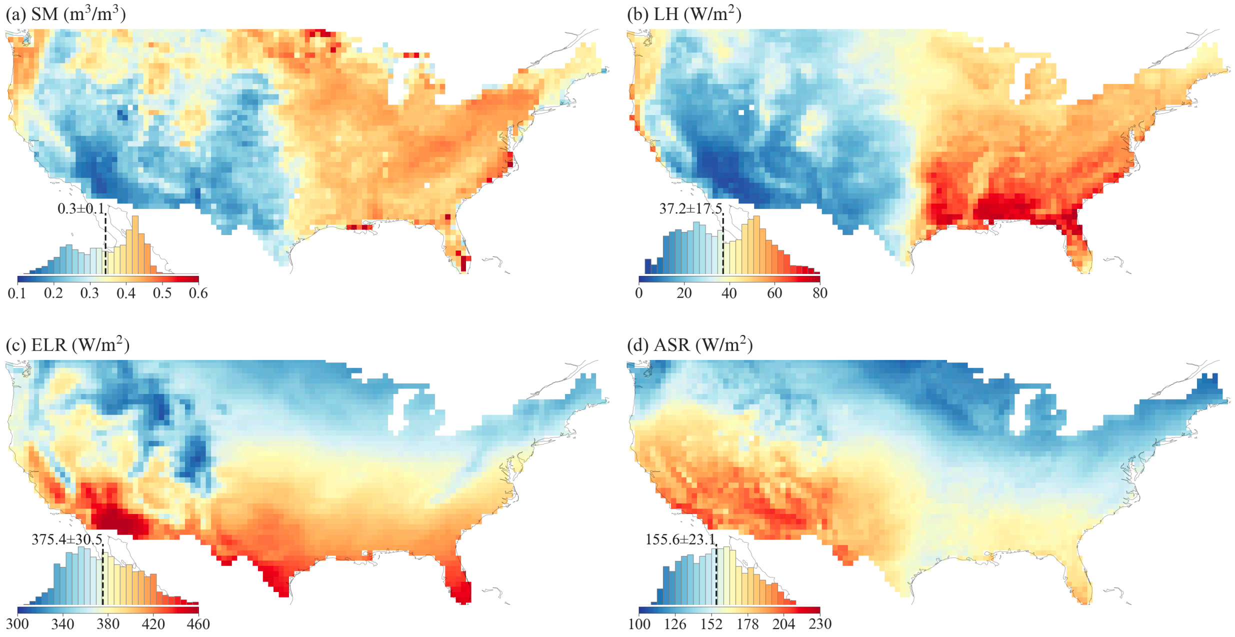

Figure S27. The annual mean for reference data of (a) GLEAM SM, (b) MODIS LH, (c) ERA5_Land ELR, and (d) ERA5_Land ASR over CONUS. The inserted histogram plot illustrates the distribution of grid values. ”

Referee 1

The authors have addressed issues I raised in my previous comments well, though many things can be improved in future edition of data or by further work. I am content with the modifications for publication of this paper.

We greatly appreciate your time and constructive suggestions during the review process, which have substantially improved the manuscript.

Referee 2

Very sorry to be late. I reviewed their revised manuscript. Reading their responses for the previous reviews, their revision looks quite defensive (both previous reviewers asked the authors to compare their results to the observations as major issues, but the authors did not do that).

We have added the comparison between ELM simulations and reference data. Please refer to the above response.

I'd like to add one more concern here. In result section (BTW, it's 4th section instead of 3rd), they showed the information loss (reduction of spatial variability) by upscaling. They upscaled the results of the 1 km simulation as well as the 1 km parameter to examine the reduction in spatial variability. Here, the simulation results with upscaled parameters should be used to investigate the spatial variability reduction for simulated variables (e.g., LH). Otherwise, the "critical role of land surface parameters in contribution to the spatial variability of water and energy in land surface simulations" as stated in L599 can be inappropriate. This is because the low-resolution simulation results with upscaled parameters are different from the upscaled simulation results with high-resolution parameters. This concern affects Figures 8 through 12. Therefore, I would like to request them to show at least a CONUS simulation of 0.1 degrees with upscaled parameters and then confirm the simulation result is as similar to the upscaled from the 1km simulation.

Thank you for your insightful comments and for highlighting concerns regarding our spatial scaling analysis method. Our approach draws on the methodology from the well-established study by Vergopolan et al. (2022), which demonstrated significant information loss—on average 48% and up to 80%—when upscaling 30-m SMAP-HydroBlocks soil moisture (SM) data to 1 km resolution. In their study, no simulations were conducted at 1 km to compare with the 1 km SM upscaled from 30 m resolution, and we followed the same approach.

In our analysis, we aim to quantify the extent of spatial variability information retained at 1 km resolution compared to 12 km resolution within each 0.5° × 0.5° box, thereby highlighting the potential benefits of high-resolution simulations. Our analysis should not be interpreted to suggest that low-resolution simulations with upscaled parameters are equivalent to upscaled low-resolution simulations derived from high-resolution model configurations with high-resolution parameters.

We acknowledge that simulations at low resolution using upscaled parameters can yield different spatial variabilities compared to upscaled simulations from high-resolution simulations. Specifically, within each 0.5° × 0.5° box, the comparison of spatial variability in 12 km upscaled SM simulations versus directly simulated SM at 12 km could be different because of the non-linearity of many processes represented by land surface models.

To clarify our methodology and avoid misunderstanding, we have added the following content in section 3.2, L321–325.

"It is crucial to clarify that the upscaled 1 km simulation results in the spatial scaling analysis are not equivalent to the results obtained from a coarse resolution ELM conducted using upscaled parameters. The spatial scaling analysis is intended to emphasize the value of high-resolution modeling in capturing fine-scale spatial variabilities, and to highlight the contributions of high-resolution land surface parameters on the simulated variables."