

RC1: 'Comment on egusphere-2025-3517', Anonymous Referee #1, 05 Nov 2025

This manuscript extends the widely-used benchmarking tool ILAMB to include soil moisture and uses it to perform a comprehensive evaluation of soil moisture Earth System Models from CMIP6, both near the surface and to a depth of 1m. It represents a substantial contribution to the field. The evaluation is extensive and reproducible; of particular note is that a variety of different metrics are used, including the relationship between soil moisture and other variables. The presentation quality is high throughout.

- Author Response: We thank the referee for the positive assessment of our manuscript and for the constructive and insightful comments provided below.

Specific comments

Add some sentences mentioning that soil moisture below 1m can be important too (particularly in areas with deep roots), even though evaluating it is beyond the scope of this analysis.

- Author Response: We thank the referee for this suggestion. We added a sentence in the Introduction acknowledging that soil moisture below 1 m can be important for ecosystem functioning, particularly in regions with deep rooting systems, while clarifying that our analysis focuses on surface and rootzone soil moisture. This addition is supported by recent literature (e.g., Stocker et al., 2023; Kühnhammer et al., 2023). This can be found on Lines 107-110 of the revised manuscript.

Line 160: this is an important point you make here – refer back to it in section 3.2

- Author Response: We thank the referee for this suggestion. We added a sentence in Section 3.2 explicitly referring back to the discussion in Section 2.2, noting that some models have first soil layers deeper than 5 cm and that integrating `mr_sol` to 5 cm can introduce additional uncertainty in comparisons with ESA-CCI, which likely contributes to part of the spread in surface soil moisture performance. This can be found on Lines 301-305 of the revised manuscript.

Line 212-3 This statement needs citations. Even better would be to add a brief justification of this statement and mention the limitations of these datasets, so that the reader can bear these in mind when interpreting your results.

- Author Response: We thank the referee for this comment. We revised the paragraph in Section 2.3 to add explicit citations for the WECANN GPP, AVH15C1 LAI, and GLEAM ET datasets, and to briefly justify their use as benchmarks. We also expanded the text to clarify that these products are observationally informed estimates derived from models or statistical algorithms, and to note their key limitations and associated uncertainties, so that readers can better interpret the results. This can be found on Lines 200-232 of the revised manuscript.

Line 249 Add a description of how Overall Score is calculated from Bias Score, RMSE Score, Seasonal Cycle Score, and Spatial Distribution Score. Add few words to clarify the “Seasonal Cycle Score” and “Spatial Distribution Score”.

- Author Response: We thank the referee for this suggestion. We added a brief explanation in Section 3.1 describing how the ILAMB Overall Score is constructed as a composite of the Bias, RMSE, Seasonal Cycle, and Spatial Distribution scores following Collier et al. (2018), and we clarified that the Seasonal Cycle Score reflects agreement in the timing and amplitude of the annual cycle, while the Spatial Distribution Score reflects agreement in the spatial patterns of the fields. This can be found on Lines 250-256 of the revised manuscript.

Line 272: I couldn't see anywhere what time resolution was used to calculate the Taylor plots (e.g. annual, monthly or daily?). Same for fig. 6 and 7.

- Author Response: We thank the referee for pointing this out. Although the monthly temporal resolution is stated in Section 2.1, we added explicit clarification in Sections 3.2 (Line 306) and 3.4 (Line 365) indicating that the Taylor diagrams (Figure 4) and the SM–ecohydrology relationship plots (Figures 6 and 7) are based on monthly mean fields, to make the temporal resolution clear to the reader.

Line 299: what do you mean by “parameters that mask deficiencies in SM representation”? Maybe add a clarifying phrase, or an example.

- Author Response: We thank the referee for this suggestion. We clarified this statement in Section 3.3 by adding a brief explanation and example, noting that compensating errors in parameters such as soil hydraulic properties or effective soil water holding capacity can partially compensate for missing or simplified processes (e.g., groundwater or root water uptake), leading to apparently realistic ET despite underlying deficiencies in soil moisture representation. This can be found on Lines 348-351 of the revised manuscript.

Line 300: I disagree with this statement because I would characterize transpiration as a vegetation-related process. The representation of water flux through the canopy and carbon flux through the canopy typically both rely structurally on very similar parts of the code.

- Author Response: We thank the referee for this comment and agree with the point raised. We revised the text in Section 3.3 to clarify that transpiration, carbon uptake, and phenology are all vegetation-controlled processes and often rely on similar canopy and stomatal formulations in land models. We now emphasize that the differing apparent performance across ET, GPP, and LAI more likely reflects differences in observational constraints and sources of uncertainty, rather than a fundamental separation between vegetation and hydrologic processes. This can be found on Lines 341-346 of the revised manuscript.

Line 319: “However, it is important to note that the ILAMB spatial climatology used in Figures 6 and 7 may be affected by ESA-CCI’s inconsistent spatiotemporal coverage” I don’t understand this sentence – what does the phrase “ILAMB spatial climatology” mean here?

- Author Response: We thank the referee for pointing out this ambiguity. We revised the sentence in Section 3.4 to clarify that the climatologies shown in Figures 6 and 7 are computed from the available gridded data within ILAMB, and that gaps in ESA-CCI’s spatial and temporal coverage can bias the inferred climatological means and relationships, potentially affecting the model–data comparison. This can be found on Lines 380-384 of the revised manuscript.

Technical corrections

Line 43: consider replacing “, most commonly relying” with “. The majority rely” (the existing sentence has an ambiguity about whether “most” refers to “ESMs” or “commonly” which hampers the sentence flow)

- Author Response: We thank the referee for this suggestion. We revised the sentence (Line 40) in the Introduction to remove the ambiguity by splitting it into two sentences and clarifying that the majority of ESMs rely on bucket-type soil moisture schemes.

Line 45: consider replacing “by incorporating” with “using” or “incorporating it into”

- Author Response: We thank the referee for this suggestion. We revised the wording in the Introduction (Line 44) by replacing “by incorporating” with “using” to improve clarity and sentence flow.

Line 121: the minus sign in both units needs to be in the superscript

- Author Response: We thank the referee for noting this. We corrected the unit formatting so that the minus signs in the exponents are properly shown as superscripts (Line 131).

Consider putting `mrsol` and `mrsos` in monospace font, given that it is the name of a variable

- Author Response: We thank the referee for this suggestion. We revised the manuscript to format the variable names `mrsol` and `mrsos` in a monospace font to clearly distinguish them as model variable names. We also did this for `gpp`, `lai`, and `evpsbl` whenever these processes are actually the variables from the model outputs.

Equation 1: It is more standard to not use italics if the variable contains more than one letter i.e. consider making all letters non-italic apart from n , l , z , w , ρ . Consider renaming `mrsol` in equation 1 with something briefer e.g. mSM , θ_m

- Author Response: We thank the referee for this suggestion. We revised Equation 1 to avoid italicizing multi-letter variable names, while retaining italic formatting for single-letter variables

and indices (Line 139). We kept $mrsol(i)$ to avoid confusion that this variable is indeed the same one from the model output.

Line 137: put the numbers in the volumetric SM units into superscript

- Author Response: We thank the referee for noting this. We corrected the formatting of the volumetric soil moisture units so that the exponents are properly shown as superscripts (Line 148).