

Reviewer #1

Review Comments: Accepted subject to minor revisions

This manuscript provides a comprehensive overview of the priorities and opportunities pertaining to Land and Land Ice in the CMIP7 Data Request, delivering valuable insights for guiding the development of Earth system models (ESMs) and advancing climate research. To further strengthen its scientific rigor and alignment with emerging technical paradigms (e.g., artificial intelligence [AI] and big data), the following targeted revisions and expansions are recommended—with a specific focus on comparisons with CMIP6 and the enhancements enabled by AI and big data technologies.

Author Response: Thank you for the positive feedback. We have revised the manuscript to address your comments by adding more discussions regarding comparisons with CMIP6 and acknowledge the need for Earth system models' integration with AI and big data. Please see our responses to your specific comments below.

1. Clarify Key Differences Between CMIP7 and CMIP6 in Land and Land Ice Themes, and Their Underlying Drivers

While the manuscript acknowledges advancements from CMIP6, it lacks a systematic comparison of the substantive differences between CMIP7 and CMIP6 in three critical areas: scientific focus, variable design, and technical scope. Equally important, the motivations driving these changes (e.g., new scientific insights, evolving climate research needs, or technical advancements) are not fully elaborated. Strengthening this section will contextualize the innovations of CMIP7, highlight its unique added value, and help readers better understand the rationale for updating the Land and Land Ice themes.

Author Response: We thank the reviewer for highlighting the significance of a systematic comparison between CMIP6 and CMIP7 data requests. A comprehensive, cross-thematic comparison of scientific focus, variable design, and technical scope across CMIP6 and CMIP7 is indeed valuable. However, such an analysis is beyond the scope of the present manuscript, which is intentionally focused on the Land and Land Ice Data Request only.

The objective of this paper is to describe the guiding principles, scientific motivations, and data harmonization process underpinning the CMIP7 Land and Land Ice Data Request, rather than to provide a full, project-wide comparison with CMIP6. A broader and more systematic overview of structural changes between CMIP6 and CMIP7 will be provided in a planned data request overview paper.

Nevertheless, we have revised the manuscript to more clearly articulate key conceptual shifts from CMIP6 to CMIP7 as they pertain specifically to Land and Land Ice, including changes in scientific focus, variable design, and technical advancement, and to explicitly link these shifts to their motivations and lessons learned from past CMIP6 and evolving scientific priorities.

Thus, we have added more texts in the Discussion (Page: 17, Lines: 461-481):

"The CMIP7 Land and Land Ice Data Request differs fundamentally from that of CMIP6 in its scientific focus, variable design, and technical implementation, reflecting both evolving scientific priorities and lessons learned from CMIP6. In CMIP6, the land data request defined a centralized and comprehensive set of variables spanning a wide range of land processes, with increasing process complexity driven by CMIP6-endorsed MIPs (Jukes et al., 2020). While scientifically valuable, this large variable list contributed to the increased burden on modelling centres (O'Rourke, 2023) against the tight timelines of IPCC Assessment Report 6 (Dunne et al., 2025).

By contrast, the CMIP7 Land and Land Ice Data Request adopts a more community-engaged and opportunity-driven approach. Scientifically, the focus has shifted from broad process completeness (Eyring et al., 2016) toward emergent and societally relevant topics, including land-related dangerous weather patterns, carbon-cycle management, tipping points, and coupled land–ice interactions (Dunne et al., 2025). This shift is enabled by the increased maturity of land and land ice process representation, diagnostics, and evaluation, which now supports investigation of full Earth system feedbacks rather than isolated components.

Correspondingly, variable design in CMIP7 moves away from a single centralized definition toward a structure informed by community input, CMIP6 user experience, expert judgement, and variable downloading frequency (see section 2). This innovative approach aims to balance scientific objectives with feasibility and usability, reducing unnecessary burden while targeting variables that best support priority science questions. Technically, while CMIP7 continues to rely on NetCDF CF metadata conventions, it introduces the interactive and cloud-based Airtable platform that enable timely community feedback, clarification, and correction of variables—an innovation not available in CMIP6. Together, these changes reflect a deliberate and systematic evolution in how Land and Land-Ice Data Request moves from CMIP6 to CMIP7."

2. Enhance Alignment of CMIP7 Land and Land Ice Themes with AI and Big Data Requirements

A critical gap in the manuscript is its lack of discussion on how CMIP7 can support AI/big data-driven climate research. This omission is notable given the growing role of machine learning in advancing climate science—including applications in process parameterization, uncertainty quantification, and impact prediction. To address this, the manuscript may explore how CMIP7's variable design, data formatting, or metadata standards can be optimized to facilitate AI/ML workflows.

Author Response: We agree that AI and big-data approaches are increasingly important for land and land-ice research. As this paper focuses on scientific priorities and opportunities in the data request (i.e., land and land ice variables and the associated temporal and/or spatial constraints), rather than wider CMIP7, we have added a brief paragraph acknowledging AI/ML use cases. Detailed data infrastructure considerations (i.e., variable design, data formatting, and metadata standards) should be addressed in the cross-thematic overview paper of CMIP7 Data Request.

To address the reviewer's concerns, we have added a paragraph in the Discussion to reflect the importance of considering AI/ML for Earth system model development.

(Page: 19, Lines: 526-533)

"While this paper focuses on scientific Opportunities and Priorities in Data Request activities for the CMIP7 Land and Land Ice Theme, we recognize the rapidly growing use of data-driven approaches (e.g., artificial intelligence and machine learning) in land surface and cryosphere modeling research. For instance, such approaches have been applied to process emulation (e.g., for parameter optimization; Li et al., 2023a), uncertainty reduction (e.g., Yuan et al., 2022), and impact-relevant analyses (e.g., examples in Ruane et al., 2025). Opportunity-oriented variables in the CMIP7 Data Request would better support these applications by providing more specific targets for data-driven methods. Broader considerations related to data formatting, metadata standards, and computational frameworks for data-driven workflows are addressed at the CMIP7 program level and in cross-cutting infrastructure discussions."

These revisions will strengthen the manuscript's relevance to both traditional climate science and emerging AI/big data paradigms, ultimately ensuring that CMIP7's Land and Land Ice data maximizes its scientific impact and societal value.

Author Response: We thank the reviewer again for providing these helpful suggestions to improve our manuscript.

Reviewer #2

General comments

This manuscript by Li et al. presents the community-led development of the Land and Land Ice Theme component of the CMIP7 Data Request. It effectively outlines the scientific priorities, methodological approach, and final set of variable groups (25 groups, 716 variables) designed to address key knowledge gaps in land-atmosphere coupling, hydrological processes, glaciers, ice sheets, land use, and plant phenology. The paper builds a compelling case for these new "Opportunities," highlighting the need for high-frequency output, sub-grid scale data, and improved process representation compared to CMIP6. The description of the collaborative process is a particular strength. The manuscript is generally well-structured and aligns with the scope of GMD, providing a valuable resource for modeling centers and the broader climate science community.

Author Response: We appreciate the reviewer in identifying our community-engaged approach in the Land and Land Ice Theme Data Request for CMIP7. All your comments have been carefully addressed in the revised manuscript.

Comments

It is surprising that the foundational paper by Juckes et al. (2020) on the CMIP6 Data Request is not cited. This work is seminal in the field and establishes the framework, terminology, and technical challenges of data requests. The authors should cite this work and briefly introduce the concept and evolution of the CMIP Data Request. Furthermore, the discussion in Section 5.2 would be enriched by contextualizing the issues (e.g., variable harmonization) with the challenges previously identified in Juckes et al. (2020).

Author Response: Thanks. Following your valuable suggestion, we have cited Juckes et al. (2020) in Section 5.2 to provide more context regarding the challenges previously identified in CMIP6 Data Request.

(In Section 5.2, Page:17, Lines: 462-466)

"In CMIP6, the land data request defined a centralized and comprehensive set of variables spanning a wide range of land processes, with increasing process complexity driven by CMIP6-endorsed MIPs (Juckes et al., 2020). While scientifically valuable, this large variable list contributed to the increased burden on modelling centres (O'Rourke, 2023) against the tight timelines of IPCC Assessment Report 6 (Dunne et al., 2025)."

(In Section 5.2, Pages: 18-19, Lines: 515-522)

"We understand that a "unified" or "harmonized" data request requires input not only from the CMIP7 Data Request Task Team (for reviewing the opportunities), but also from the MIPs (for updating the variable groups), the modeling centers (regarding which variables can realistically be produced in their models), and the data users (regarding the challenges they face when using the data). Achieving this is different from the CMIP6 Data Request (Juckes et al., 2020) that aimed to provide a comprehensive variable set and will require a detailed Theme-related review of the requested variables and feedback from all these parties.

This represents a considerable amount of work and has, so far, been partially implemented in the current CMIP7 Data Request process."

The term "Data Request" is a central concept of this paper, yet it first appears rather late in the final paragraph of the introduction. I recommend introducing and defining the CMIP Data Request earlier in the introduction, following the example set by Juckes et al. (2020), to better frame the study for readers.

Author Response: We adopt the reviewer's recommendation to introduce and define the CMIP7 Data Request earlier in the introduction by citing Juckes et al. (2020).

(In Introduction, Page: 2, Lines: 48-49)

"Following CMIP6 definition, CMIP7 Data Request includes both output variables and their associated spatiotemporal constraints (Juckes et al., 2020)."

The authors introduce the "Opportunities" first in the text, followed by the "Priorities." For consistency with this internal logic, the authors may consider reversing the order of these words in the title, though this is left to their discretion.

Author Response: We thank the reviewer for this thoughtful consideration. We prefer to keep the current order of these words in the title due to a couple of considerations. First, "Priorities" can be understood as the priority for scientific objectives and the priority for specific variable list within each "Opportunity". The scientific priority guided where opportunities were pursued in the whole process of CMIP7 Land and Land Ice Data Request. The current title order reflects what our paper is primarily about by highlighting both scientific and variable selection priorities. Given these thoughts, we prefer to have "Priorities" first in the title, which aligns with the titles of other Themes (e.g., Atmosphere, Earth System Data Request papers).

L548: ...effective variable management (e.g., e.g., removal of duplicates... – Remove the repeated "e.g.,".

Author Response: Done. Thank you!

L558: The mention of the "ESMValTool" appears somewhat abruptly, and its specific role in variable harmonization is not explained. I suggest the authors provide references to guide readers who may be unfamiliar with it.

Author Response: We have added more explanations for ESMValTool and provided a reference to guide readers in the revised manuscript.

(Page: 21, Lines: 598-600)

"Furthermore, community tools such as ESMValTool (i.e., a community diagnostic and performance metrics tool for ESM evaluation, Righi et al., 2020) should be developed or updated to support the harmonization of variables within the whole Earth system and improve data consistency."

Reference

Righi, M., Andela, B., Eyring, V., Lauer, A., Predoi, V., Schlund, M., Vegas-Regidor, J., Bock, L., Brötz, B., de Mora, L. and Diblen, F.: Earth System model evaluation tool (ESMValTool) v2.0—technical overview. *Geoscientific Model Development*, 13, 1179-1199, <https://doi.org/10.5194/gmd-13-1179-2020>, 2020.

We have also performed minor edits in the Conclusion to ensure that all take-home messages are clear to the readers.

(Page: 20, Lines: 581-583)

"Driven by a transparent and community-engaged approach, the updated request in the Land and Land Ice Theme includes six refined Opportunities addressing distinct scientific questions."

(Page: 21, Lines: 591-592)

"In this context, CMIP7 Data Request in Land and Land Ice reflects community efforts to facilitate maximum consistency between requested variables and model outputs."

(Page: 21, Lines: 594-595)

"Looking ahead, modeling groups—who best understand the capabilities of their models—are expected to weigh in more on basis of the current community-engaged approach for future data requests."

Reference for Comment:

Juckes, M., Taylor, K. E., Durack, P. J., Lawrence, B., Mizielinski, M. S., Pamment, A., Peterschmitt, J. Y., Rixen, M., and Sénési, S.: The CMIP6 Data Request (DREQ, version 01.00.31), *Geosci. Model Dev.*, 13, 201-224, [10.5194/gmd-13-201-2020](https://doi.org/10.5194/gmd-13-201-2020), 2020.

Author Response: We have cited this paper in the revised manuscript. We thank the reviewer again for the thoughtful consideration and useful suggestions.