CMIP7 DATA REQUEST: ATMOSPHERE PRIORITIES AND OPPORTUNITIES

Response to reviewers

Key: Red Text=Reviewer . Black Text=Author Response. Green Text=Alterations to the manuscript.

All line numbers in the response below refer to the Tracked Changes version of our manuscript.

Anonymous reviewer #1

This paper documents the priorities and opportunities in the CMIP7 Atmosphere theme as a result of the CMIP7 data request process. Eleven opportunities are identified and summarized in individual subsections in section 4 (actually section 3). Overall, the paper is informative and concise. I believe that it is a well-designed, well-executed, and well-documented study that is suitable for publication. I have a few general suggestions (mostly on writing) that are listed below for the authors to consider.

Thank you for carefully reviewing our manuscript. We have addressed your comments as outlined below each comment.

General Suggestions

Among all eleven opportunities, I think the first subsection "Atmospheric dynamics and variability" is very well-written. The first paragraph conducts a brief literature review to identify the *specific* frontiers and gaps in this topic with supporting papers (more than merely mention that large uncertainty still persists in observations, parameterization, etc.). The second paragraph identifies the overarching questions that need to be addressed in the CMIP7 requested experiments. Next, the variables that are grouped and matched to the specific gaps identified in the first paragraph, and example use of these variables are also supported again by sufficient literatures.

I suggest that all opportunities to be revised to the extent similar to the writing of the first subsection. An ideal writing structure could be: (1) the current, *specific* gaps in this topic; (2) questions to be addressed; (3) traditional methods in analyzing the variables; and (4) recent success in novel methodology that prompts related variables to be included in CMIP7 (e.g., a good example at L327-329); (5) other technical details to add on. These elements can be as short as one sentence, but evidence (literatures) should be presented to support them. I am not asking for the review to touch every single detail, as this is not a hundred-page review paper to summarize all frontiers in atmospheric sciences, but I do believe that they are necessary to justify the opportunities and associated variables.

Thank you for highlighting which Opportunity is most clearly presented. We have edited the descriptions of each of the other ten Opportunities to ensure consistency in the format of their descriptions. We have not included all changes in this response (as so many differences in structure and wording are difficult to show clearly), but they are all clearly marked up in our tracked changes document.

The concern about the data volume bloat is stated multiple times throughout the paper. I agree that it is an important consideration when determining the output variables as well as their temporal and spatial resolution. However, I believe that some quantitative analysis could be provided to justify the rigorness of this process. For example, in Table 1 and/or Table A1, the authors could provide an estimate of data volume the variables requested by each opportunity is expected to take. Or, in the methodology, the

authors can include some rough estimate of the data volume each 2D/3D monthly/daily/subdaily variables can take. They could be valuable and practical for modeling centers to take into account.

We would like to thank the reviewer for this comment, and agree that more information will be useful for readers/users of the Data Request. As suggested, we have added a column to Table 1 indicating the estimated data volume for each Opportunity, given in Terabytes per model per ensemble member. We have also provided some context for this value in the Table caption (L139-148):

ID	Opportunity Title	Variable Groups	Total number of variables	Experiment Groups	Total number of experiments	Data volume estimate (Tb per model per ensemble member)
9	Atmospheric Dynamics and Variability	2	82	1	25	28.775
78	Clouds, Circulation and Climate Sensitivity: Baseline	5	268	3	17	43.812
79	Clouds, Circulation and Climate Sensitivity: Extension for Process-Level Studies	9	400	2	5	17.205
71	Clouds, Radiation & Precipitation	3	86	2	14	463.414
26	Detection and Attribution	4	109	1	18	20.595
72	Diagnosing Radiative Forcing	1	56	4	52	14.498
64	Diagnosing Temperature Variability and Extremes	2	33	3	36	24.623
55	Rapid Evaluation Framework	5	99	2	52	7.414
61	Southern Ocean Biogeochemistry to Clouds	5	165	5	52	34.666

63	Synoptic Systems	2	32	2	24	30.291
5	Understanding the Role of Atmospheric Composition for Air Quality and Climate Change	10	439	5	52	245.234

Table 1 Data Request Opportunities primarily accounted within the Atmospheric theme scientific objectives, including the total numbers of Variable Groups, variables, Experiment Groups, experiments requested, and an estimate of the data volume for each Opportunity. Note, 52 experiments requested corresponds to requesting all DECK, Assessment Fast Track, and scenario experiments (excluding scenario extensions). The data volume estimate is a crude estimation of the volume which would be produced by one ensemble member producing all experiments and variables for that Opportunity, given in Terabytes per model per ensemble member, and assuming 2 bytes per floating point after compression. The volume estimate cannot be added to calculate an overall estimation of the Atmosphere Data Request, as variables and experiments are not exclusive to Opportunities. Opportunities are listed alphabetically. The Opportunity IDs were assigned to all Opportunities across the five themes of the CMIP7 Data Request to help the ease the consolation process and as a method for Data Request users to refer to Opportunities quickly.

Some of the citations and references are missing. I detail some of the missing items I found below. Even though the editorial team will check and link all the references in the finalization process, the authors should still carefully check the manuscript to ensure that references are properly added and they are assessed by the reviewers.

Thank you for detailing the citations we have missed from the bibliography or are incorrectly referenced. We have addressed all points raised below, and done a thorough review of the manuscript's bibliography to ensure consistency with GMD's editorial style.

Specific Points

L65: "Eyring et al., 2016" missing reference in the reference list

Added

Figure 1: This is only a question. Somehow I don't see elements about polar climate processes in this schematic diagram. Are they not the focus in the Atmosphere theme?

Thank you for highlighting that the figure does not clearly address all geographic regions covered by the Atmospheric Data Request. Polar climate elements are also included in Atmosphere theme, and so their exclusion from the original figure was oversight when figure was created. We have edited the figure to make clear that processes from the tropics through to the poles are covered by the Atmosphere Data Request. We have also make the link between processes and the Opportunities which address them more clear.

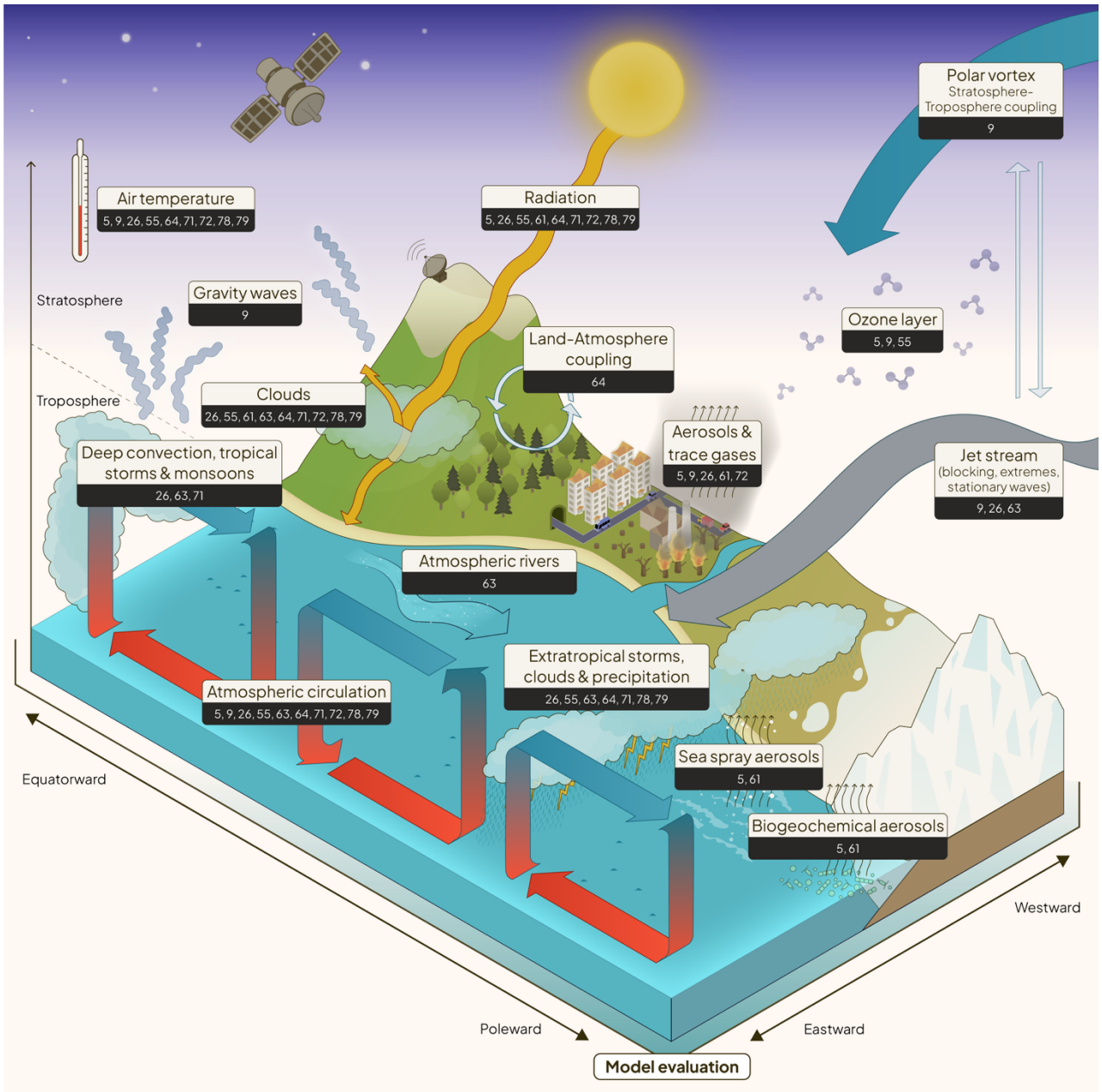

Table 1: "ID" probably a sentence in the table caption to explain what this ID means and why it is not consecutive.

Thank you for highlighting that this is confusing. We have added this clarifying sentence to the caption of Table 1 (L146-148):

The Opportunity IDs were assigned to all Opportunities across the five themes of the CMIP7 Data Request to help the ease the consolation process and as a method for Data Request users to refer to Opportunities quickly.

L159-160: "Error! Reference source not found"

Fixed to correctly reference Figure 2 (L171-172).

L177: “Annex 2” The actual title of the section is “Appendix B”. I think it is better to keep the term consistent (and note that annex and appendix are slightly different). This applies to all occurrences throughout the manuscript.

Thank you for highlighting this. All references to Annex 2 have been corrected to Appendix B (L189, 247, 609).

L184: ID number is missing in subsection title, given that all other subsections have IDs included in the title.

Done (L196):

4.1 Atmospheric dynamics and variability (ID 9)

L194: “Baldwin et al. 2021” missing reference in the reference list

This has been added to the bibliography.

L220: “Abalos et al. 2021” missing reference in the reference list

This has been added to the bibliography.

L221: “Ding et al. 2023” missing reference in the reference list

This has been added to the bibliography.

L306: “attributed” => “attributed to”

Thank you. We have updated this (L357):

‘observed climate changes can be attributed to ‘

L361: “Soden et al. 2008” and “Smith et al. 2020” missing references in the reference list

These have been added to the bibliography.

L388: “Zhang and Boos 2023” missing reference in the reference list

This has been added to the bibliography.

L397: Citation to a website should be formalized as a bibliography entry in the list.

We have fixed this (and any other occurrences of URLs in the main text):

L69-70: (ESGF Data Statistics: https://esgf-ui.cmcc.it/esgf-dashboard-ui/cmip6.html; last accessed 6 December 2025).

L90-91: (CMIP7 Data Request: Call for Atmosphere theme paper co-authors: https://wcrp-cmip.org/cmip7-atmosphere-call/; last accessed 6 December 2025)

L93-94: (Airtable: https://www.airtable.com/platform; last accessed 6 December 2025;

L467-468: (Climate Model Benchmarking Task Team: https://wcrp-cmip.org/cmip7-task-teams/model-benchmarking/; last accessed 6 December 2025)

L479-481: (obs4MIPs - Observations for Model Intercomparison Projects: https://pcmdi.github.io/obs4MIPs/; last accessed 6 December 2025)

L501: "proess representation and understanding" => "proess representation and understanding of SLCFs"

We have added this text (L594):

How do advances in process representation and understanding of SLCFs

L518: "Dunne et al., 2025" => "Dunne et al., 2024"

Thank you. The final version of Dunne et al., has now been published this year (2025), so we have updated the citation and all references to it in the text to Dunne et al., 2025 (Lines 72, 368, 601, and 611).

L658: "2022a". "a" is not necessary as there is only one paper with the same first author and the same year.

Thank you for spotting this, we have fixed this in the newly formatted bibliography.

L666: "Boucher et al. 2013" there is no corresponding citation in the main text.

Removed

L679: "Ceppi et al. 2017" there is no corresponding citation in the main text.

Removed

L762: "Griffies et al. 2016" there is no corresponding citation in the main text.

Removed

L835: "Mackallah et al. in prep" this reference is in prep and does not have a year. In the main text, however, it is cited as "Mackallah et al. 2025". In addition, I don't know whether this publication accepts such reference that has not been peer-reviewed. I just raise this issue here.

We had initially hoped this would be submitted at the same time as our paper (hence the in-text citation being mistakenly listed as Mackallah et al., 2025). We have reverted this to 'in preparation' and are working on submitting the manuscript as soon as possible, before the end of 2025 so that the preprint can be cited before our paper is finalised.

L926: "Zelinka et al. 2020" there is no corresponding citation in the main text.

This was mistakenly omitted from the text. The paper has now been cited twice: Line 260 and Line 502.

Anonymous reviewer #2

This paper presents a comprehensive summary of Opportunities and the targeted scientific questions in the CMIP7 atmosphere theme. The prioritization of variables within each Opportunity and harmonization of pressure levels in the request are well documented. I also agree with the other reviewer that the manuscript is generally well written in terms of both organization and clarity. I recommend that it should be published after some minor revision, which is listed as below.

We would like to thank Reviewer #2 for the helpful suggestions to improve our manuscript. We have addressed these comments below.

Figure 1 is well plotted but not very informative. The 11 Opportunities can be labeled in this figure rather than simply presenting the atmospheric processes involved.

Thank you for this improvement suggestion. We have added Opportunity ID references to each process in the figure as to which Opportunities address which process. This will make the figure much more clear and useful for readers. (See the new figure in the response above).

The authors may do some statistics on model availability for each Opportunity and give some description on the diversity of these models (one or two statements are sufficient).

While we agree such information would be very useful for the community, unfortunately this paper addresses only the request of data. Modelling centres have the freedom to choose what to output, and so statistics on model availability for each Opportunity are not possible to compile until later in the CMIP7 process, once data has been published.

For each Opportunity, the importance or implication of each scientific question could be stated, including model development, policy making, etc.

Thank you for this suggestion. We agree that it should be very clear what the benefits are for a centres producing each Opportunity. Therefore, the text for each Opportunity has been reviewed to ensure its importance is clearly justified. The text additions are outlined below:

In section 4.1 (L252-254):

Including data from this opportunity in a sufficiently large set of models is needed to advance understanding of large-scale stratospheric and tropospheric circulation features, their variability, their connections to surface climate extremes, and the underlying dynamical processes in future climate projections.

Section 4.2 (L299-302):

Producing data from this opportunity across a large collection of climate models will allow major progress across the topics of interest to the CFMIP community, including rigorous evaluation of modelled clouds against observations, detailed and careful diagnosis of cloud-radiative feedbacks, improved understanding of physical processes governing feedbacks and adjustments, and identification of sources of model bias.

Section 4.3 (L321-323):

Producing data from this opportunity across a large collection of climate models will facilitate advanced diagnosis and understanding of cloud processes, feedbacks, adjustments, and biases beyond what is possible with the baseline variables.

Section 4.4 (L352-354):

Contributing to this opportunity will ensure a comprehensive evaluation of the representation of clouds, radiation and precipitation in comparison to observations and other climate models. Additionally, it enables a valid analysis of the sensitivities of cloud properties and the dominant physical processes to climate change.

Section 4.5 (L403-407):

There is a substantial overlap between the fields requested by this opportunity and those proposed as the CMIP7 baseline variables and ensuring that they are provided for the experiments that can be used to understand the role of forcings in the climate system will maximize the utility of these simulations for understanding the historical evolution of the climate system and the role of external forcings in that evolution as well as the representation of forced responses within models and how that may have evolved in this model generation compared to previous generations.

Section 4.7 (L460-461):

This opportunity will maximize the utility of the CMIP7 simulations for diagnosing changing temperature extremes and the processes involved and for assessing their representation in Earth System Models.

Section 4.9 (L519-529):

The Southern Ocean biogeochemistry to clouds opportunity aims to address the following key questions:

- How well are aerosol-cloud interaction processes modelled over the Southern Ocean in this new generation of models, and how does this impact the energy balance?
- How do natural marine aerosol influence cloud properties in the Southern Ocean in current and future climates?
- How can observations guide us in understanding what biogeochemical, chemical, physical and microphysical processes are missing in our models?

Having a concentrated effort on understanding this system will be of great benefit to both understanding the past, present and future of our planet, as well as for future model development. Historically, the Southern Ocean radiative bias has been tackled with a disciplinary approach. With the complexity of models increasing, the need to understand this problem from an interdisciplinary perspective is essential. To aid this endeavour, this opportunity will reduce barriers to end users who are investigating this system, who often work in interdisciplinary teams and are not necessarily modellers themselves.

Section 4.10 (L533-536):

Given their role in temperature and precipitation extremes, it is important to assess how weather systems and their impacts are expected to evolve in the future and to understand how they have changed in the past. It is also important to ensure accurate representation of these weather systems in Earth System Model's, including how they influence other atmospheric processes such as cloud radiative effects.

Section 4.11 (L623-626):

This opportunity will enhance the utility of the CMIP7 simulations for diagnosing present-day effective radiative forcing from changes in anthropogenic speciated emissions, for quantifying the role of

SLCFs in atmospheric composition, air quality, and climate, and for advancing our understanding of the interactions between natural and anthropogenic emission changes with climate and air quality responses.

Sections 4.6 and 4.8 were determined to already contain sufficient information on the importance of producing the Opportunities, though minor tweaks have been made to ensure this is clearly stated.

Text already included in Section 4.6 (L410-414), with additions in green:

Therefore, the systematic diagnosis of radiative forcing in climate models is crucial for interpreting projections of climate change and attributing past changes, evaluating the climate impacts of proposed emission reduction strategies, and for understanding and ultimately reducing climate model uncertainty. This opportunity is dedicated to quantifying the total or "effective" radiative forcing in CMIP simulations, along with its components: the instantaneous radiative forcing and radiative adjustments.

Text already included in Section 4.8 (L491-494), with additions in green:

The impact of the publicly available evaluation and benchmarking results and therefore the interest in participating in this opportunity by the modelling groups is expected to be substantial since the community will be able to get a quick overview of available simulations and their characteristics that might be interesting for many different applications and analyses. This could be in particular interest for studies feeding into the next IPCC assessment report.