

Response to reviewer comments

Reviewer 1

This paper describes the protocols and reasoning for the experiments requested as part of CFMIP4, which is in turn part of CMIP7. Given the importance of cloud feedbacks in climate system and their role in the structural diversity across models, this is an important initiative to get right. This paper is timely, given that CMIP7 simulations are now beginning and is publishable with only a few minor revisions.

We thank the reviewer for their positive and thoughtful comments on our paper.

L.85-90 The variation in ECS between 2xCO₂ and 4xCO₂ is not that large (except for a few models, like CESM2, which already have too high an ECS), and so I am unsure how important this will turn out to be in the real world. It is worth looking into more (as suggested here). I note that some papers referenced use 8xCO₂ runs as well, and I start to get a little nervous since most models are starting to push their basic assumptions at such high forcing levels (high water vapor effects on the equation of state or radiative transfer, mis-match of the ozone layer location and the rising troposphere etc.)

Thanks. We changed “remarkable inter-model spread” to “substantial inter-model spread”. We agree with the reviewer regarding the interpretation of 8xCO₂ results.

L. 141. The amip-piForcing experiment seems to be basically the same as the amip-sst experiment in CERESMIP in CMIP6Plus. Probably better to have the same name.

Yes, agreed. Given that amip-piForcing predates amip-sst, and that CMIP naming conventions require us to avoid changing experiment names unless necessary, we will stick to amip-piForcing here, but will encourage the CERESMIP community to adopt the amip-piForcing name.

L. 141. The choice of SST/SIC driving file is problematic (for reasons acknowledged in the text). It's possible that there will be an update to HadISST2.x relatively soon which would be better - and so maybe leave this ambiguous for now? Or allow for an update?

Our understanding is that there is no timeline yet for the publication of HadISST2.x; only HadISST1.1 is operational. We therefore stick with the choice of HadISST1.1 for the alternative amip-piForcing variant.

Table 1. Can the authors ask for simulations up to Dec 2025 for all historical runs? CMIP is endeavoring to update forcing fields by the fall of the following year. So Dec 2025 forcing (not just for SST) should be available by the end of this calendar year. (Hewitt et al, 2025; <https://doi.org/10.1371/journal.pclm.0000708>). Data to the end of 2024 should already be available (though it probably isn't). We should at least be aspiring to keep things as up-to-date as possible.

While we agree this would be desirable from a science standpoint, it is outside the scope of CFMIP to request extensions to the historical coupled runs (or even amip, which isn't a CFMIP experiment). We support community initiatives such as CERESMIP to extend model simulations closer to present-day. Our extended amip-piForcing variant with HadISST boundary conditions was also proposed in this spirit.

l. 168. The "true" value of ECS? I think this is a little optimistic. The longer-term model-specific ECS is more achievable!

By "true" we meant in model world rather than in reality, but we acknowledge this was a poor choice of words. We have removed "true" from this sentence.

Reviewer 2 (A. Gettelman)

This manuscript describes simulations for the Cloud Feedback Model Intercomparison Project (CFMIP) with the motivation for the different simulations. The simulations are generally well described. Some of the text is a bit hard to follow, so this should be publishable with minor revisions. I like the description of why the experiments are requested. Also, the forcing data needs to have a DOI, and the data request should be attached in some way (supplement likely) to the manuscript.

We thank the reviewer for their positive and thoughtful comments on the manuscript.

Specific comments:

Page 3, L75: I think this imbalance has since turned around....

It depends on the timescale considered. There has indeed been a slight decline in EEI post-2023, but we don't want to overinterpret short-term EEI variations, and our focus is on the longer-term trend since 2000.

Page 4, L81: What about cloud processes themselves and how they contribute to cloud feedbacks and the spread of cloud feedbacks? There is lots of interesting recent work on this (disclaimer: some of it this reviewer has done): e.g. Gettelman et al 2024, Duffy et al 2023. Relevant for aerosols as well (L80).

Gettelman, A., T. Eidhammer, M. L. Duffy, D. T. McCoy, C. Song, and D. Watson-Parris. 2024. "The Interaction Between Climate Forcing and Feedbacks." *Journal of Geophysical Research: Atmospheres* 129 (18): e2024JD040857. <https://doi.org/10.1029/2024JD040857>.

Duffy, Margaret L., Brian Medeiros, Andrew Gettelman, and Trude Eidhammer. 2023. "Perturbing Parameters to Understand Cloud Contributions to Climate Change." *Journal of Climate*. *Journal of Climate* 37 (1): 213–27. <https://doi.org/10.1175/JCLI-D-23-0250.1>.

Thanks for pointing us to these papers. We certainly agree that cloud process studies are fully within the scope of Q1 of the CFMIP4 proposal, and we already cite several studies on this topic (first paragraph of section Q1). We have added some brief extra discussion of process studies, including the papers referenced here.

Page 4, L104: maybe a phrase or sentence on what the AMIP-piForcing experiment is?

We have added a brief description of the experiment, with a reference to Table 1 for a more detailed description.

Page 5, L120: Circulation shift research predates 2020....maybe need to cite some earlier work?

Agreed – we have added a couple of earlier references.

Page 5, L124: again, please describe what these experiments are in a few words: or supply a table.

We have expanded the text here to briefly describe these experiments.

Page 7, Table 1: piSST-pxK simulation: do you need to specify where in the 4xCO₂ run you want the Δ SST measured from? And how is this different from a4SSTice?

Thanks for catching this – it should be years 111–140 of 4xCO₂ (now added to the table; this was already mentioned in the text). piSST-pxK uses a spatially and temporally uniform x-K SST increase, whereas a4SSTice uses actual time-varying SST and sea-ice from 4xCO₂.

Page 10, L235: Has anyone ever done AMIP-p4k-turb? Not a big fan of speculative MIP experiments. Especially if someone tried it and it had little impact, why ask everyone to do it? Seems a bit disingenuous to ask model groups to do it.

In any event, how this experiment could be done needs to be noted if no one has published it before? Or is there detailed documentation somewhere already?

Yes, these experiments have been performed in two studies with two different models – MIROC6 (Ogura et al. 2023, 10.1029/2023GL104786) and Webb et al. (in revision). Although it is already cited elsewhere, we will add a reference to Ogura et al. 2023 where we introduce the new experiments.

As for the second point: we hope that the description of the protocol in the present paper is sufficient for other modelling groups to reproduce the experiment. If the reviewer feels that details are missing, we would welcome his feedback.

Page 10, L236: please state the purpose of the piClim-deltaSST experiment. It's implied (pattern effect?) but could be better stated here. Again, has anyone done this before with a single GCM? If not, I question whether it is useful (especially considering the last attempt doesn't seem like it was useful).

We now specify that the aim of the experiment is “to represent the climate response to *model-specific* CO₂-forced SST change”. This experiment has been performed by Jonathan Gregory, with a paper in preparation, and also by Wang et al. (10.1175/JCLI-D-23-0528.1).

Page 11, L259: what is a ‘forcing index’?

We mean the “f” indices in the variant labels (e.g. r1i1p1f1, f2, etc.). This has been clarified.

Page 12, L288: when you say monthly and daily I assume you mean monthly and daily averages right?

Correct. The wording has been clarified to avoid ambiguity.

Page 12, L307: The data request as it stands at time of paper publication probably needs to be put in a static archive. Is this a web page or a document?

Suggest you make a supplement with the data request and attach it to this manuscript.

The CMIP7 data request (including CFMIP as well as other MIPs) is a live webpage, available from <https://wcrp-cmip.org/tag/data-request/>. Successive versions of the data request are also archived on Zenodo (<https://doi.org/10.5281/zenodo.17986580>). We have provided a hyperlink, rather than attaching this to the manuscript.

Page 13, L325: probably needs a DOI. Also, the variables need to be attached in some way to this manuscript record (see comment above).

We now provide DOI links to the SST and sea-ice datasets needed to perform CFMIP4 simulations. Note also that, per the executive editor's comment, any links to data are now provided in the main text, rather than in the "code and data availability statement".

Reviewer 3 (C. Zhou)

This paper is very well written, which provides an important framework for understanding the cloud feedback processes. Its contribution to the CMIP7 ensures it will be important for future research and the next generation of climate projections.

Nevertheless, I have a suggestion to address a potentially inaccurate statement in the paper: According to Figure 1, the pattern effect analyzed using amip-piForcing is induced by the evolving spatial patterns of both SST and SIC. Although the SST pattern effect dominates, a relatively smaller SIC pattern effect also exists when analyzing the amip-piForcing experiment according to our previous study. In contrast, the piClim-deltaSST experiment appears to include the SST pattern effect only, excluding the SIC pattern effect. Therefore, I suggest adding a discussion on whether the SIC pattern effect is accounted for in the pattern effect analyses across these different experiments.

We thank the reviewer for the positive comments. We agree that sea-ice changes will likely also contribute to the time evolution of climate feedback in abrupt-4xCO₂, which will not be included in the piClim-deltaSST experiment. We have added a mention of this at the end of section 3.3, with a reference to the reviewer's work on the sea-ice pattern effect (doi: 10.1126/sciadv.adr4248).

Executive editor comment

In the Data Availability section of your manuscript, you have included a misleading statement regarding the availability of data for two experiments. The Data Availability section must contain information regarding the data used to produce the work presented. Your manuscript describes an experiment; however, it does not present the results of data or have made use of datasets. Also, you have not included a Code Availability section in the manuscript. Therefore, you should rename the Data Availability section as "Code and Data Availability" and it should read "No code or data has been used or is necessary to replicate the work here presented."

Thanks for pointing this out. We have made the changes as requested, and moved any data links to the main text.