Review of Obase et al manuscript "Multi-model assessment of the deglacial climatic evolution at southern high latitudes" submitted to Climate of the Past

This manuscript analyses transient simulations of the last deglaciation Paleoclimate Modelling Intercomparison Project PMIP4 from six different climate models. The paper focuses on the evolution of Southern Ocean sea surface temperature (SST) and Antarctic air temperatures in response to increasing atmospheric greenhouse gas concentration (GHG) and millennial scale Atlantic Meridional Overturning Circulation variations. The set of simulations are of great interest to assess model dependent representation of a fundamental climate transition during a period of dramatic global warming.

The six analyzed experiments don't follow a strict unified experiment protocol and in particular differ in their freshwater forcing scenario. In consequence AMOC chronologies which are known to be highly model dependent are additionally reflecting differences in the forcing, which hampers a simple intercomparison. The authors deconstruct simulated climate change into AMOC and CO_2 driven changes using a multilinear regression model and a thermal bipolar see-saw model. This approach might allow to compare the predominantly CO_2 driven response independent of differences in freshwater forcing and AMOC response. The applied approach is original and interesting but I found the discussion to be too superficial in some places.

Technically, the paper is mostly well structured and the provided figures are of good quality, but I recommend to condense especially the descriptive parts to improve the readability and to also possibly sharpen some statements where the authors quite generally state the need for better system understanding and more modeling.

In summary I recommend major revisions before publication.

General comments:

Abstract: The findings of the analyses need to be spelled out more explicitly. The sensitivity to freshwater forcing and AMOC is not really new or unexpected. Consider mentioning the sea-saw model and being specific about the results.

3-1 – 3-2-4: This is a bit tiresome to read and should be summarized in some way.

MLR analysis and see-saw model: it would be desirable to have a reference from reconstructed SSTs in Fig. 9 or to also apply these methods to SAT at the two core locations. I It even might be interesting to use the see-saw model with the parameter combinations of table 5 but applying it to the same inputs for all models, e.g. the CO2 and AMOC reconstructions from Figs 1b and 2bd.

While northern hemisphere temperatures are also influenced by the retreat of ice sheets, it is a fundamental assumption in this study that Southern Ocean SST and Antarctic SAT are (primarily) driven by CO_2 change and AMOC variations- this should be spelled out explicitly (maybe in the introduction), substantiated with references and discussed with respect to its limitations. Using CO_2 and AMOC as input in the MLR analysis and see-saw model may

provide a good fit but this does not exclude that for instance the retreating ice sheets also influence southern hemisphere temperatures. So I am reluctant to interpret the CO_2 coefficients in table 4 and 5 as sensitivity to CO_2.

Specific comments:

l. 29-31: maybe use "in phase/concurrent with" instead of "in response to", also this is mixing observations with modeling results which makes the sentence ambiguous.

l.36: model's -> models'

l.99: to avoid misunderstanding: austral spring

l.103ff: include the conclusion of Menviel et al. (2011)

l.128-139: distinguish findings from models and reconstructions

l. 159: please consider to include the Paleomist ice sheet reconstruction (Gowan et al. 2021) in Fig. 1 for ice mass change.

l. 191: what is respectively referring to? What is here the northern boundary of the arealy averaged Southern Ocean SST?

l. 200: SST is here mean Southern Ocean SST?

2-2-2: What are arguments against using normalized AMOC?

l. 333-334: „which is able to explain about half of the total deglacial changes during HS1"- is this statement referring to a specific figure, to observed SST or SAT or simulated SST?

l. 386: delete or replace "although"

l.396: specify: smaller is here in relation to the other models?

l.402-404: in the models, the early warming seems to be not related to AMOC, as there is no weakening of the AMOC and also the see-saw model does not explain the early warming.

l. 420: typo: reache

l. 425-440: This is hard to follow and seems a bit unstructured, as it goes from warming in general to local SAT to SST to ECS and global SAT.

l. 435: "SAT anomalies" maybe better "local SAT change"

l. 435: the fact that CO2 coefficients differ for models with similar ECS values could also be a result of different climate response to the (roughly at the same time) retreating ice sheets, please discuss.

l. 438: can you specify which forcings may be poorly constrained or which feedbacks might be misrepresented

l. 465-467: "gap between climate response and ice sheet reconstructions": awkward, maybe rephrase.

l. 467ff: Maybe also discuss here literature regarding the sensitivity to the specific design of the freshwater scenarios on the northern hemisphere (location and depth of input, as freshwater or as icebergs).

4-3: The models used in this study are of relative coarse resolution. Maybe discuss if resolution (or unresolved processes) may explain discrepancies between models and observations.

Conclusion: The conclusion reads like a summary. Maybe shorten.

Table 4: maybe *averaged* Southern Ocean SST, also please list γ.

Table 5: unit of AMOC coefficient: I understood from the text that the AMOC is not normalized but binary. Also it would be good to evaluate the goodness of fit between original and reconstructed see-saw SST and to compare it to a respective metric (coefficient of determination) in table 4.

References:

Gowan, E.J., Zhang, X., Khosravi, S. *et al.* A new global ice sheet reconstruction for the past 80 000 years. *Nat Commun* **12**, 1199 (2021). https://doi.org/10.1038/s41467-021-21469-w