Weiffenbach et al. assess the state of the Southern Ocean in 15 simulations of the mid-Pliocene performed as part of the Pliocene Model Intercomparison Project (PlioMIP2). 7 simulations with the full mid-Pliocene forcing (Eoi400) are also compared with experiments in which only the mid-Pliocene CO2 gas concentration was implemented (E400). This allows to separate the effects of the higher greenhouse gas concentration from the mid-Pliocene changes in orography. It is found that both the greenhouse gases and Pliocene orography contribute to the high southern latitudes climate change: i.e. warming, higher precipitation, stratification… The manuscript is well written, and the results are interesting. As such I recommend publication in Climate of the Past after the comments below are taken into account.

AR: We thank the reviewer for their positive evaluation and constructive comments and suggestions. Please find our point-specific responses below.

1. **Experimental design:** At the moment the manuscript is targeted for readers who are familiar with the PlioMIP2 experiments. There is no detail in the methods regarding the experimental design used in these experiments. Readers are simply referred to Haywood et al. 2016. Please add some information in the methods regarding the experimental design used in the PlioMIP2 experiments so that a reader of this manuscript does not have to read Haywood et al., to fully understand the study.

AR: The introduction (L39-L51) describes the mid-Pliocene boundary conditions and the experiments, but we agree that a brief description of the PlioMIP2 experimental design explanation could be added in the methods section for those unfamiliar with the ensemble. We will add a subsection “PlioMIP2 experimental design” to the methods section in which we give this overview and refer the reader to Haywood et al. (2016) for the full details.

2. **Discussion:** The discussion needs to be expanded and restructured.

While the discussion focuses on the relevance for future climate, there is a real paucity of references to other studies in the Discussion. There is no discussion of previous multi-model studies of the mid-Pliocene, previous multi-model studies focusing on high southern latitude climate, or previous studies discussing changes in SO stratification and the relation with the abyssal cell. For example, the paragraph starting L. 301 could be expanded to compare the results of the study with previous results.

AR: We agree that it would be good to have more multi-model studies to compare our results to, however, for the mid-Pliocene there are no previous multi-model studies focusing on the Southern Ocean or Southern high-latitude climate other than those we already refer to. We discuss CMIP5 and CMIP6 studies in L302-L304 as well as in section 2.4.3. As suggested by the other reviewer, we will add a reference to Purich et al. (2020) at L304 to consider the effect of (future) SO conditions on AABW formation in CMIP6. We will add the following sentence at L304: “CMIP6 models also show future Southern Ocean surface warming and sea ice decrease, as well as mixed layer shoaling that suggests slowdown of AABW formation (Purich et al. 2020).”

Regarding the relation between the SO and abyssal cell, we discuss this issue in section 2.4.3 in relation to biases in multi-model present day studies (CMIP5/6). We will also expand the paragraph starting at L301 further to include de Lavergne et al. (2014) who found reduced deep convection in the Southern Ocean due to surface freshening in CMIP5, as well Chen et al. (2023) who show that Antarctic meltwater can reduce deep convection and the volume of bottom water in CMIP6.

The model-data comparison is limited and only shown in the SI. I understand there is limited data availability for this time period, but have the authors performed a literature search on the topic? Even though the overlap is small, the authors could look at Grant et al., 2023 (https://egusphere.copernicus.org/preprints/2023/egusphere-2023-108/) for marine sediment cores in the SW Pacific.

AR: McClymont et al. 2020 is currently the only SST dataset of the KM5c time slice (3.205 Ma, 20 kyr time slice), which is the time slice that PlioMIP2 is centered around. This time slice was chosen to avoid any effects by orbital forcing (Haywood et al., 2016), which can impact seasonal and regional distribution of incoming solar radiation. The effect of orbital forcing is especially important in the high latitudes, and therefore we do not want to consider data that falls outside of this time slice. As the dataset from Grant et al. (2023) averages over several interglacials between ~3-3.3 Ma, we have not included it in our model-data comparison.

Finally, the order of the sub-sections in the Discussion should be thought through so that there is a better flow: i.e. The model-data comparison could come first, then discussion of results in the context of previous studies, relevance for future studies and caveats associated with SO biases.

AR: We agree with this suggestion and will change the order of the discussion tot he suggested order.

3. Minor points:

- L. 200: high-latitude North Atlantic?

  AR: This will be corrected.

- L. 219: Relationship between changes in abyssal cell strength and OHT is interesting and consistent with previous studies (e.g. Menviel et al., 2015, EPSL).

  AR: Thank you for pointing this out. We will add this comment and reference to the manuscript.

- L. 301-302 There is not enough information to understand the relevance of the sentence (i.e. which scenarios? When?).

  AR: We will add the missing information to this sentence and rephrase it to: "CMIP5 studies investigating RCP4.5 and RCP8.5 scenarios show a decline in Antarctic Bottom Water formation due to fresher and warmer Southern Ocean surface conditions, and consequentially a slowdown of deep ocean circulation by the end of the 21st century (Meijers et al., 2014; Ito et al., 2015)."

- L. 310-311: I don't understand this sentence

AR: To clarify, we will rephrase L310-311 to: "Since these geographical changes are not relevant for the future, it is uncertain whether the decline in abyssal cell circulation, or the lack of decline exhibited in some models, resembles a plausible future scenario."

- L. 319: "sea-ice cover"

  AR: This will be corrected.

- Figure 7: Is the cooling within the annual sea-ice zone due to the increased stratification?It does correspond to the area of large negative SSS anomalies. Is there reduced deep ocean convection in the Ross Sea sector in most models?

  AR: Figure 7 does not show cooling within the annual sea-ice zone as it shows the SST anomalies minus the global mean SST anomaly. This means that any areas in blue indicate areas that warm less than average, but do not necessarily cool. The below-average warming is most likely related to the persisting sea ice cover reducing air-sea fluxes and thus inhibiting warming of the surface.

  The area that warms less than average indeed corresponds to the area with large negative SSS anomalies, as well the area with a large stratification increase. It is not possible to make any strong claims about the causal relationship between the sea ice cover and the stratification because they influence each other. We think it is most likely that the increased stratification is caused by the large negative SSS anomalies, but it is not completely clear where these large negative SSS anomalies come from. This last point is further addressed in our response to the next comment.

- Figure 8; The fit between precipitation and SSS anomalies is not particularly obvious. I am not sure P-E is a better fit. Should you look into changes in sea-ice melt/freezing, Antarctic runoff and eventually changes in ocean currents to understand the changes in SSS?

  AR: Indeed, the spatial fit is not always obvious because there are many other factors at play that could influence the SSS other than precipitation/P-E. It is likely that changes in sea-ice melt/freezing, Antarctic runoff and ocean currents also significantly influence the SSS and are possibly even more important than the surface freshwater flux in areas where the fit between the SSS and precipitation is not obvious. Unfortunately, the data for these variables is not available for most models. We think an in-depth analysis of the freshwater balance would be very interesting, but this would require a detailed investigation into one or a few models. Such an analysis would be beyond the scope of this study in our opinion.

- Figure S11: Historical and not pre-industrial simulations should be compared with present-day observations.

  AR: It is true that the present-day (1979-1999) sea ice observations used in Figure S11 would preferably be compared with historical rather than pre-industrial simulations. Unfortunately, these simulations are not part of the PlioMIP2 protocol and were thus not performed. As there are only sparse observations of the pre-industrial sea-ice extent, we use the present-day observations to show that the MMM sea-ice extent of the pre-industrial is spatially comparable to the historical observations, and that the model ensemble therefore likely shows a realistic sea-ice extent for the pre-industrial. To emphasize this point, we will change L357-L361 to:

"Supplementary Figure S11 shows that the MMM sea-ice cover and extent in the PI E^{280} simulations is spatially similar to historical observations (1979-1999 NOAA/NSIDC Climate Data Record of Passive Microwave Sea Ice Concentration, Meier, W.N. et al. (2021)), with a MMM E^{280} sea-ice area of 10.4 million km^2 and historical observed sea-ice area of 9.5 million km^2. While the historical observed sea-ice area should ideally be compared to historical simulations, Figure S11 gives some confidence that the simulated MMM E^{280} sea ice cover is realistic for the PI. However, the sea-ice area variation among models is 5.2-15.6 million km^2, which is substantially larger than the discrepancy between the MMM ^{E280} and historical observations."

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