Author response for egusphere-2024-4061

Katherine Power, Fernanda Matos, Qiong Zhang

April 21, 2025

Dear Editors and Reviewers,

We are extremely grateful to the editor for collating the reviews and the reviewers for thorough evaluations and constructive feedback. We have taken on board every one of their concerns and used them to, hopefully, improve the manuscript to publication level. The lengthy and in depth comments have been invaluable in guiding us as to how to properly address this important subject, going deeper into analysis and exploring more variables to provide a more coherent and investigative picture.

We have undertaken a large rewritting of the paper. In its new form we have included:

- Introduction is now improved with a concise literature review.
- A coherent description of the aims of our study which recognises the importance and necessity of this work.
- Methodology - comprehensive experiment outlines detailing the full procedure undertaken to run these sensitivity experiments.
- Results section now includes proper SAM analysis and investigation in the westerly jet. We provide evidence for all claims.
- Thorough discussion section linking the processes we found, supported by appropriate references.
- Pliocene as analogue section now compares our results with relevant work, plus concise limitations section.
- Conclusion section sets out future work that would add to this study.

We hope we have truly addressed all the concerns and produced a more complex paper that advances our knowledge of this important subject matter. Below follows a reply to each reviewer comment.

Sincerely,
Authors

Reviewer 1

1. It should be made clearer in the title and first part of the abstract that only albedo changes and not orographic changes are taken into account.

#Response#: We have revised the manuscript to ensure the emphasis is in isolating the surface reflectivity (albedo) effect of reduced ice sheet extent, excluding orographic and freshwater feedbacks. This includes changing the title to "Late Pliocene Ice Sheets as an Analogue for Future Climate: A Sensitivity Study of the Polar Southern Hemisphere" and modifying the abstract and other sections of the manuscript.

2. Improved methods: It might be helpful to include a table of the experiments performed with the forcing included. I am actually surprised to see changes in albedo over the East Antarctic ice-sheet in fig. 2d. It is my understanding the ice-sheet is a forcing in this simulation, and thus the albedo over the ice-sheet imposed. Can the authors explain why albedo is changing over land areas where the ice-sheet forcing should not have changed?

#Response#: A table has now been included to section 2.2 that gives full details of the experiments and the forcings. We also give a full description of the pre-industrial experiment design:

"The protocol for our pre-industrial (PI) simulation follows Eyring et al. (2016). Ice sheets, land geography, topography and vegetation are all unmodified from the model. GHG concentrations for CO_2, CH_4 and N_2O are 284.3 ppmv, 808.2 ppbv, and 273.0 ppbv, respectively. For orbital parameters; eccentricity set at 0.016764, obliquity 23.549 and perihelion - 180 is 100.33."

Table 1: The four Core and Tier 2 Pliocene for Future protocol experiments conducted. PI refers to pre-industrial conditions, LP for Late Pliocene. Name terminology is from Haywood et al. (2016).

Experiment ID	Ice sheet Configuration	Land Geography	Topography	Vegetation	CO_2 (ppm)	Orbit
E280	PI	PI	PI	PI	280	PI
E400	PI	PI	PI	PI	400	PI
Ei280	LP	PI	PI	PI	280	PI
Ei400	LP	PI	PI	PI	400	PI

#Response#: Although the ice-sheet extent is prescribed in our experiments, climate feedbacks - such as changes in cloud cover, atmospheric temperature, and moisture transport - alter the surface radiation balance and can reduce albedo in regions like East Antarctica, where the ice-sheet mask remains unchanged. This has been clarified in the results section.

3. Improved analysis
106: the authors state that "when ice-sheet reductions are included there is a persistent positive phase of the SAM, which intensify the westerly winds" On Figure 4, timeseries of SAM indices are shown for all the experiments (note that the x axis is missing), and in all cases the SAM index is much lower in the Ei than E case. So the SAM index is less positive when the ice-sheet reductions are taken into account contrarily to the statement above. I note that even in the PI case (E280), the SAM index is centered on 0.2, which seems odd. The authors should double check their results and include a description of their SAM index calculation.

#Response#: Following this very helpful point, we have rewritten the section in which we detail the polar Southern Hemisphere climatic response to the modified boundary conditions. We have recalculated the Southern Annular Mode (SAM) index using EOF analysis of sea level pressure (SLP) over the Southern Hemisphere. The SAM index (PC1) is standardized for comparability across experiments and is now filtered using a Savitzky-Golay filter. We included the following paragraph on the method, as well as new SAM figures (Figures 1 and 2):

"The Southern Annular Mode (SAM) was calculated using EOF analysis to identify the dominant mode of SLP variability in the Southern Hemisphere. This produced the spatial pattern of the first EOF (the SAM pattern). To calculate the time evolution of SAM, a principal component (PC) analysis is used. This (PC1) is obtained by projecting the SLP anomalies onto the EOF pattern. It is then is standardized to have zero mean and unit variance by removing the mean and dividing by the standard deviation. This allows for a direct comparison of SAM variability across different climate experiments."

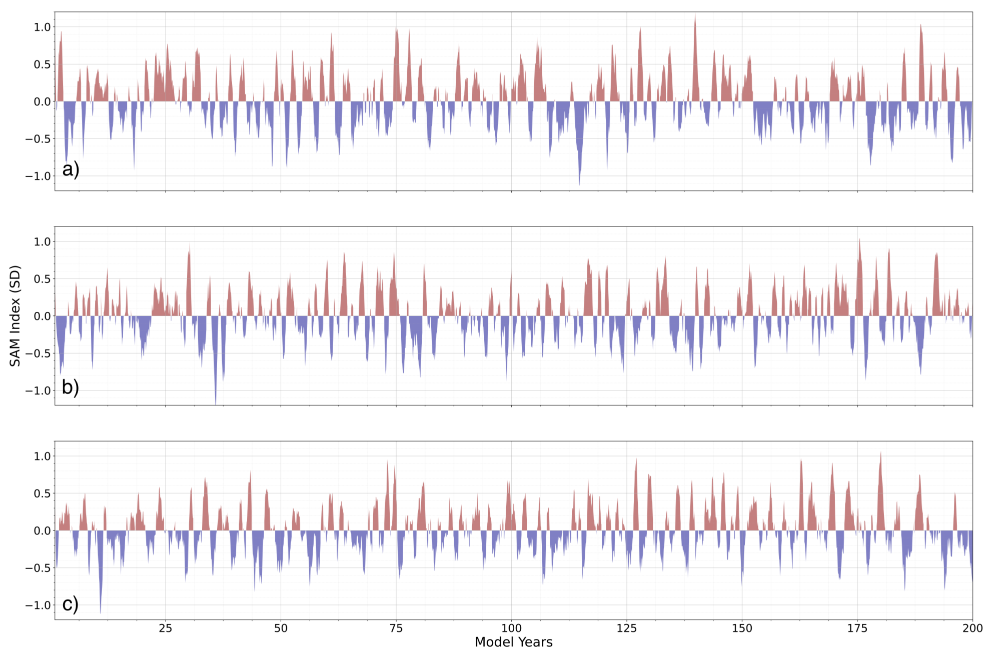

Figure 1: Southern Annular Mode (SAM) index timeseries for the E280, E400 and Ei400 experiments, for a 200 year equilibrium state period. SAM index is filtered using a Savitzky-Golay filter.

Figure 4 now clearly shows:

- A shift towards a positive SAM phase under increased CO_2 atmospheric concentration (E400)
- Amplified SAM variability under combined CO_2 and LP ice sheet extent (Ei400) that indicates a dipole pattern compatible with a negative SAM.

#Response#: We also included anomaly of the zonal wind component to explain the how changes in SAM affect the climate around the polar Southern Hemisphere. The section is now fully rewritten, and we constrain the new SAM analyses with other climatic processes.

114-115: the authors state that there is a "deepening of the Amundsen sea low with stronger winds and stormier conditions", but this is not shown and it sounds to me more like a simple

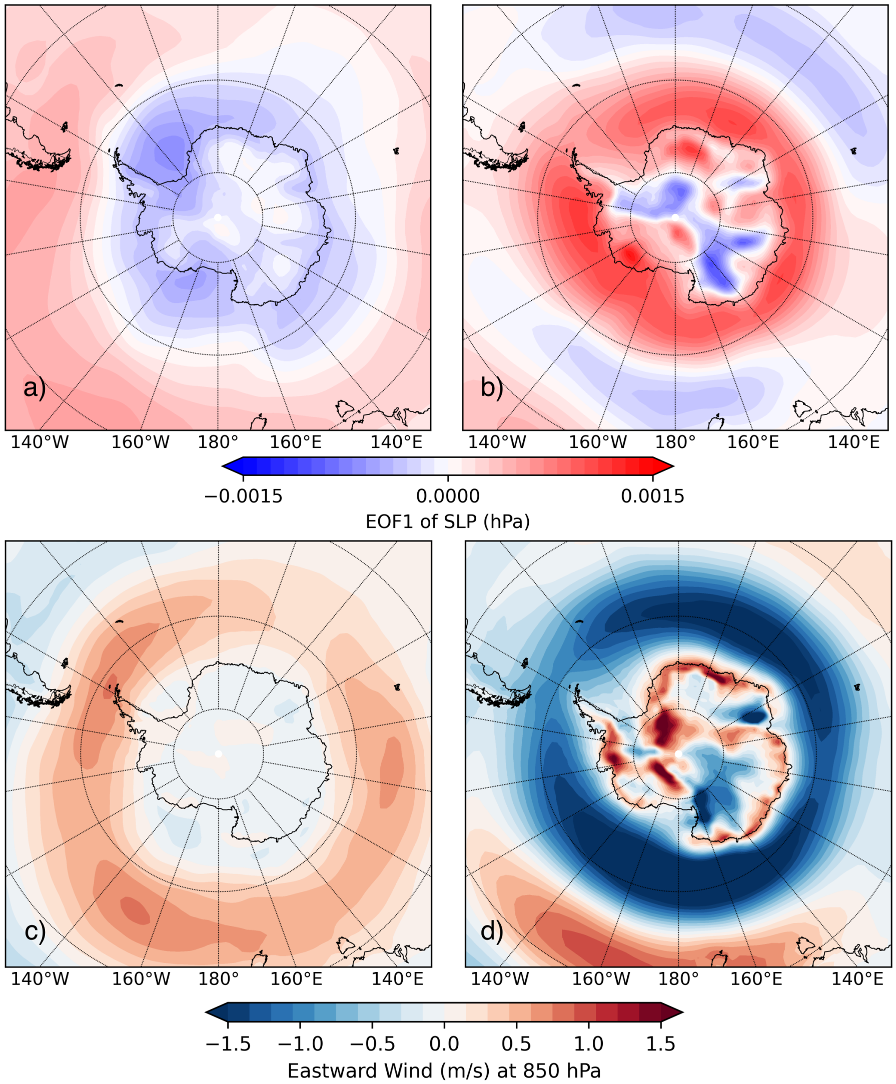

Figure 2: Difference in EOF first mode of sea level pressure. a) E400-E280, b) Ei400-E280. U component of wind anomalies c)E400-E280, d) Ei400-E280.

description of what is expected under positive SAM than in the simulations presented. If you want to keep that statement, then please show the changes in SLP or geopg in a more convincing way as this is really not evident from Fig. 3 c,d. In addition, the two statement above are contrary to the statement L.163-164: "our simulations do not indicate significant changes in the wind regime over Antarctic and the Southern Ocean." These contradictory statements and figures suggest that the authors need to carefully look at their results and assess whether there are significant changes in the winds or not. Please show the wind changes.

118: The authors suggest that the poleward contraction of the westerlies amplifies the upwelling, which accelerates sea-ice melting from below. Related to the comment above, are there significant changes in the westerlies in your simulations? Please show the wind and upwelling changes.

#Response#: The highlighted statements have been revised for consistency and clarity. We removed the figures describing the SLP anomalies, as our analysis was arbitrary and confusing. In the rewritten section, we now do not make claims without having a careful analysis to support it. By including figures that show changes in the SAM spatial and temporal pattern and in the eastward wind at 850, we confirm substantial differences between E400 and Ei400. Our comments on upwelling are now tied to the compound analysis of zonal wind regime that influences ocean divergence, the spatial patterns of temperature and salinity, and the identification of changes in the clockwise meridional overturning circulation that represents the upwelling of the Circumpolar Deep Water (CDW). We also add strong literature evidence to our discussion.

Figure 5 does not seem appropriate to discuss AABW changes. I) the AABW in E280 should be shown. Ii) the AABW taken through this calculation seems really low and does not seem to reflect the lower limb of the MOC as seen on Figure 7. Is your value of the global stream function south of 60S and below 500m even negative (ie anticlockwise circulation)? In fact, on your figure 7, the lower limb of the MOC does seem weaker in Ei400 than E400. Coarse resolution models do have issues representing AABW formation, and on Figure 7, there does not seem to be any downwelling branch south of 60S (ie anti-clockwise circulation south of 60S). Please re-assess your statements L. 153-156.

#Response#: We appreciate the comments drawn towards figure 5. Specifically:

I. We included a timeseries of the AABW in experiment E280 to highlight the changes in E400 and Ei400 in relation to the control simulation variability (Figure 3).

II. The values shown, as explained in Figure 5, represent the absolute values of the streamfunction. They are, as expected, negative. However, we chose to represent the circulation in terms of absolute values as the representation in a streamfunction of AABW in negative (anticlockwise), can be misleading in a timeseries. They are also quite low as they reflect the E400 and Ei400 experiments, where the AABW is weaker.

III. In the statements of given of how the AABW is computed, we mention that it is computed as the absolute value of the minimum at south of 60°S and below 500m depth. Therefore, it does reflect the strength of the AABW in this latitudinal band. The strength seen in the latitudes further north are more related to the export of the AABW to the AMOC, rather than an integration through the polar Southern Hemisphere.

IV. The discussion has been revised to clarify that Ei400 exhibits a partial recovery of AABW after 700 years, while E400 continues to decline.

170-174: I am confused about this paragraph. Is this a statement based on what has been shown in previous studies or based on the authors' results? If the former, then references are critically needed. If the latter, then this should be shown as it does not seem to be what is obtained here (ie SAM is less positive when the albedo decreases over Antarctica), and references to the figures where it is shown should be included.

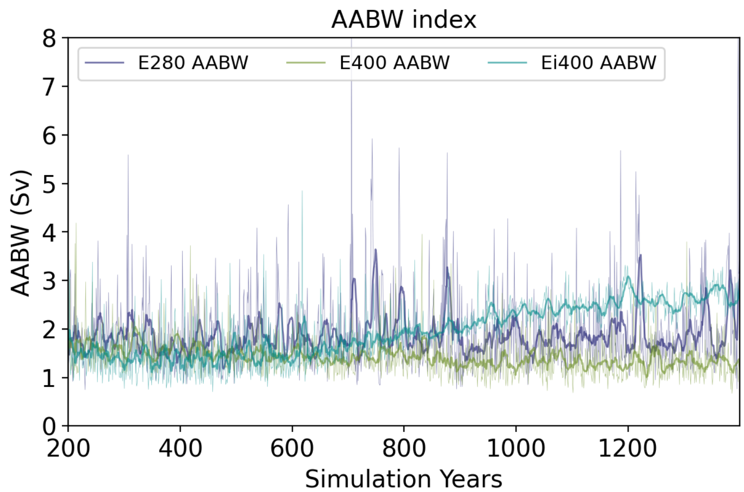

Figure 3: Time series of the Antarctic Bottom Water formation index for experiments E280, E400 and Ei400, calculated as the absolute value of the minimum global streamfunction south of 60°S and below 500 m depth (adapted from Zhang et al. (2019)).

#Response#: This paragraph has been revised to clearly distinguish between our results and previous literature. The discussion now refers to the recalculated SAM index and uses references such as Thompson and Wallace (2000) and Gerber and Vallis (2007) to contextualize the SAM's behavior. We have also been careful towards including all references to figures that represent the patterns we depict and hypotheses we propose.

4. An improved discussion of the results in comparison to previous studies is needed. For example, previous studies looking into the mid-Pliocene (Weiffenbach et al., 2023, Climate Past, https://cp.copernicus.org/articles/20/1067/2024) and Last Interglacial (Yeung et al., 2024, Com. Earth Env., https://www.nature.com/articles/s43247-024-01383-x) highlighted the impact of Southern Ocean warming and reduced sea-ice on stratification and AABW formation, with potential feedbacks on the AIS. The impact of AIS loss on climate was also studied in Hutchinson et al., 2024 (Nat. Com., https://www.nature.com/articles/s41467-024-45501-x). While in that study, changes in orography were also taken into account, it seems relevant to include this study in the discussion as the climatic impact seems much smaller in Hutchinson et al than in your study.

#Response#: Following your suggestions we have included a literature review in the introduction, focusing on paleoclimate insights from the Late Pliocene (LP) as an analogue for future warm climates. This highlights the niche of our study. We have then contrasted our results in the section LP ice sheets as analogues for future climate with other relevant studies. This includes those suggested by yourself for a paleo climate perspective, plus literature examining modern polar Southern Hemisphere climatic change including Goerte et al 2023. We highlight that our larger climate response likely stems from isolating the albedo effect without compensatory feedbacks (e.g., sea-level rise-induced circulation changes). We also highlight the importance of conducting our experiments as to disentangle the contributions of albedo feedbacks from the contributions of change in ice sheet orography that other studies include.

Line by line comments:

60, 61: Please include the references to the mid-holocene, Last interglacial and mid-Pliocene simulations.

#Response#: Thank you for reminding us of it. We have now included Zhang et al 2021 (10.5194/gmd-14-1147-2021), Chen et al 2022 (10.1029/2022GL098816), Han et al 2024 (10.1029/2023GL106145) and de Nooijer et al 2020 (10.5194/cp-16-2325-2020) as the relevant references for this section.

124: If I understand correctly, there is no ice-sheet model. Marine ice sheet instabilities parametrization is only relevant for ice-sheet models.

#Response#: We agree this sentence is misleading. We have removed this statement.

Legend of figure 5: Please include the area or latitudinal band of the Southern Ocean that was used for this graph.

#Response#: We acknowledge that this information is necessary and we have included the latitudinal band of 60-90°S as the region of calculation of AABW index. We have also named this latitudinal band as polar Southern Hemisphere, to properly identify our study region.

131: the reason for the interannual to decadal variability is not shown here, so this seems like a speculation and it does not seem relevant to the study.

#Response#: We agree and have removed this sentence as it was not necessary.

163-164: Please re-assess if this correct after looking into the wind changes (see comment 3 above).

#Response#: After analysis of the eastward wind anomalies, as per recommended, we have corrected our statements.

203-208: this paragraph might need to be a bit modified. Even though there are some uncertainties associated with Antarctic topography after the loss of WAIS, it seems that it would be more consistent to do so. I have no problem with the study only looking at the impact of changes in albedo, but the authors have to acknowledge that assessing the impact changes in orography is also important.

#Response#: We have understood your concern and modified the paragraph to:

"There is a notable gap in existing research on the isolated impact of the abrupt removal of large portions of AIS and GrIS on climate and ocean circulation. The Late Pliocene serves as an important analogue of future climate scenarios due to its modern-like atmospheric CO_2 concentrations, significantly reduced ice sheets and ecosystem shifts. This paleogeographic framework offers a valuable opportunity to assess climate sensitivity to regional albedo changes. In this study, we specifically isolate the albedo effect of ice sheet reduction to examine its role in driving Antarctic climate dynamics and Southern Ocean circulation. A PlioMIP-conform idealised sensitivity experiment would incorporate the orography changes that would accompany the reduction in ice sheet. Under future ice sheet loss, the changes in orography that will result are likely to have significant impacts on the surrounding climate and Southern Ocean. Here, we choose to not include orographical change however. The additional uncertainties from both deriving the parameters needed to modify orography in the model (including adjusting mean orography in the atmospheric component and sub-grid scale parameters such as standard deviation, slope, and angle) and from whether future orographical changes will closely align with those reconstructed for the Late Pliocene, may outweigh the benefits of an idealised sensitivity experiment. Our simulations with isolated PRISM4D ice sheet conditions demonstrate that ice sheets play a critical role in modulating climate feedbacks in response to warming."

We fully acknowledge, however, that assessing the impact changes in orography is important. We have not yet encountered a sensitivity experiment that looks into this effect in an isolated form. The usual analysis of the Late Pliocene ice sheets in climate simulations includes both altering the ice sheet extent and the orography to match the reconstructed LP conditions. Therefore, our approach introduces novelty by disentangling the effects of albedo from orography and facilitates comparison with the PlioMIP/PMIP ensemble for their Ei experiments.

Review 2

In this paper, the authors use the EC-Earth climate model to test the impacts of reduced albedo under Late Pliocene ice sheet configurations to the climate system. Experiments also include the impacts of elevated greenhouse gas levels. While the topic is of great interest, I have several big-picture concerns, specifically about the internal consistency of the experiments presented here.

First, it is unclear what boundary conditions the authors are using for these experiments. In Section 2.2 (Experiment setup), the authors state they are using the PlioMIP 4F Tier 2 experiments (Line 78). PlioMIP uses Pliocene boundary conditions of the ice sheets, including modified ice sheet extent and orography and other changes associated with a reduced ice sheet and warm period, such as changes to vegetation and GHGs etc. However, the previous paragraph (L75) the authors state that they exclude orographic changes and freshwater input associated with the ice sheet extent. If indeed orographic and freshwater changes are not included in these experiments, it remains unclear to me how these changes were implemented in the model. What albedo was chosen in places where West Antarctica or Greenland are longer "ice"? How are these grid cells treated, presumably as land? What albedo is used in these locations? More clarification and explanation is required. Thereafter throughout the manuscript, the authors often refer to using a Pliocene ice sheet configuration, and that such a configuration serves as an analogue of future configurations. The term 'configuration' implies that all relevant elements of that configuration have changed, including orography (e.g. L196). Better explanation and justification is needed on experiment design, and care must be taken when using terms like 'configuration' and 'reduced ice sheet extent' throughout, especially if this is not what the experiment is actually doing.

#Response#: We appreciate the questions raised by the reviewer and understand that we needed to provide a more concise and accurate description of our experiment design and motivation for our study. Firstly, we have included in the methodology section, more detailed information of how the model boundary conditions were changed in order to perform our sensitivity experiments:

"The aim of these sensitivity experiments is to unveil the isolated impact of shrinking of the AIS and GrIS to the climate of the polar Southern Hemisphere. Therefore, Ei simulations involve changing only ice sheet extent for the Greenland and Antarctic Ice Sheets (Haywood et al., 2016; Chandan and Peltier, 2018). LP AIS was originally developed using the high-resolution British Antarctic Survey Ice Sheet Model, integrated with climatologies from the Hadley Centre Global Climate Model (Hill et al., 2007; Hill, 2009), utilising PRISM2 boundary conditions (Dowsett et al., 1999). Figure 1 provides a visual comparison of the modern and LP ice sheet extent. LP GrIS reconstruction is provided for PlioMIP2 Haywood et al. (2016) and based on 30 modelling results from the PLISMIP project Dolan et al. (2012).

The PRISM2 ice sheet mask was interpolated onto the grid of EC-Earth's atmospheric component, IFS, and substituted into the snow depth variable of the initial condition file. IFS does not have a specific variable for ice sheets, therefore, altering the snow depth provides only a change in the ice sheet extent, being ice sheets the regions where snow depth exceeds 10 metres. To solely focus on climatic feedbacks resulting from change of AIS and GrIS; albedo values were not modified, modification of ice sheet orography was excluded and accompanying freshwater hosing experiments to account for meltwater from ice sheet change were not performed. With these exclusions, we aim to create idealised sensitivity experiments."

#Response#: Following your suggestion, we have replaced the term "configuration" with "extent", as this is the specific variable we modify in our experiments.

#Response#: Regarding the potential for analogy that we have drawn in several sections of our manuscript, we have included sentences that highlight the fact that our findings reveal that the albedo change resulted from reducing AIS and GrIS has an opposite impact as what is found in literature for the LP orography and freshwater input from ice sheet melting. With our experiment design, we were able to disentangle the contribution of this aspect of ice sheet dynamic from other climatic feedbacks. Further research under the umbrella of the PlioMIP project phases has only been performing experiments where the orography and ice sheet extent were modified in parallel. Therefore, with our experiment, we are able to acknowledge the amplified importance of reduced ice sheet height and increased meltwater input to the Southern Ocean in the context of current and future climate change. Our findings reveal that the albedo change as a result of our Ei400 experiment, isolated, acts in the opposite direction as freshwater forcing from ice sheet melting and orography change that are analogous to the Late Pliocene conditions. We derive such conclusions with literature from studies that target the Late Pliocene, current and future climate change. Without performing such an experiment, we would not be able to disentangle these forcings and understand their contributions to climate change.

#Response#: We also acknowledge in our conclusions that future research could aid in directly attributing the role of CO_2 forcing, LP ice sheet orography, meltwater forcing and boundary condition modifications onto not only LP but also future climate change:

"This study underscores the critical sensitivity of the Southern Ocean to increased atmospheric warming. Current conditions do not yet reflect the full extent of AIS reduction or collapse, as projected in future climate experiments Roach et al. (2023); Armstrong McKay et al. (2022); Naughten et al. (2023); Steig et al. (2015). However, our results suggest that even under present trends, the ability of the Southern Ocean to ventilate the deep ocean is at significant risk. Furthermore, while we isolate the albedo effect in this study to reduce uncertainties, the exclusion of other climate feedbacks may underestimate the potential catastrophic outcomes of AIS collapse.

This raises potential research questions for future investigation. We believe that an extended set of sensitivity experiments would provide valuable insights into future climate change and even reduce model biases. Experiments would include:"

1. Freshwater hosing equivalent to the ice sheet volume that is reduced in LP relative to PI;
2. Application of reconstructed LP paleogeography (topography and bathymetry);
3. Increased greenhouse gas forcing;
4. Interactive ice sheets.

If I understand correctly, only albedo is being modified in these experiments. I am struggling with the rationale and relevance for such an experiment. Keeping a modern AIS/GrIS topography, but reducing albedo to match Pliocene ice extent results in inconsistent boundary conditions. You cannot collapse WAIS as in Figure 1 but maintain modern topography. If WAIS is ice-free this implies it is collapsed. Therefore, not only is the orography fundamentally different, but also ocean pathways between the Ross, Amundsen and Weddell Seas open up, leading to different ocean circulation, sea ice regimes and atmospheric circulation (e.g. Steig et al (2015), Pauling et al (2023)). Therefore, much of the analyses presented here (changes in sea ice regime, SAM index, albedo, surface air temperatures and precipitation) is limited by the presence of land above sea level in West Antarctica, and drawing conclusions about those elements of the climate system would be inaccurate.

#Response#: We acknowledge this limitation and address it directly throughout the paper. We now emphasize that:

- This is a highly idealized experiment designed to isolate the effect of albedo change;
- Other PlioMIP studies change both orography and extent in parallel, making it hard to separate individual effects;
- Our design provides novel insights by disentangling these often conflicting forcings

#Response#: Future work is proposed to explore experiments that combine albedo, orography, and freshwater forcing in a systematic sensitivity framework.

#Response#: We have also clarified in the text manuscript that we do not change the underlying land/sea mask or surface albedo values in the model. Therefore, although the snow depth is reduced below 10 m (removing the ice sheet), the model retains the pre-industrial albedo values in those grid cells. This simplification helps us isolate the indirect feedbacks (e.g., cloud, temperature) from the direct albedo effect. This has been explained in detail in the methodology section.

If the goal of the study is to ask how the Southern Ocean and AIS climate responds to reduced ice sheets (as in the manuscript title), this experimental design cannot answer that question. Instead, it seems to me that the authors are asking what the impact would be if WAIS was suddenly painted black (or whatever low ocean/land albedo is being used here). If that is the question, please justify. To isolate the effect of albedo a better tool might be a simple global energy balance model. This would also resolve the authors' technical issues with modifying the atmospheric component of the model when modifying orography (though I will note this is technically possible and not uncommon (see PlioMIP experiments)). Another option would be to use the current experiments, but rather than comparing to a PI control run, also compare this simulation to a run where the full configuration of the ice sheets is changed (including orography). This would allow the authors to better detangle the role of albedo-only changes, by comparing to cases with and without orography change.

#Response#: We appreciate the reviewers suggestions and ideas. We considered an energy balance model as they can help isolate radiative effects, but they lack interactive ocean-atmosphere dynamics. Using an Earth System Model enables us therefore to trace feedbacks affecting winds, SAM, stratification and deep-water formation, which are critical aspects of polar climate. We have strengthened our justification for using EC-Earth3 in this context, and drawn more light to the uniqueness of our study as a fully PlioMIP-conform study with the same model has been published in de Nooijer et al. 2020.

Once these big picture issues are taken care of, there are a number of other issues throughout the paper that I recommend addressing. For example: As mentioned above, the title does not accurately represent this work – you are not actually reducing ice sheet extents in these experiments

#Response#: The title has now been changed to more accurately represent our main objectives: " Late Pliocene Ice Sheets as an Analogue for Future Climate: A Sensitivity Study of the Polar Southern Hemisphere".

The abstract needs work to make connections clearer and providing appropriate motivation for the experiment.

#Response#: We have re-written the abstract considering your recommendation. The abstract has been revised to better articulate the motivation and clarify that this is an idealised sensitivity experiment focusing on surface reflectivity change, not full PlioMIP-like boundary forcing.

As mentioned above, the experiment design (Section 2) should include a more comprehensive description of the experiments and implementation.

#Response#: We have now included a table with full experiment design (see below) and an in-depth methodology of the changed boundary conditions, as clarified in early comments.

"To investigate the impacts of varying ice sheet extent and CO_2 concentrations in the polar Southern Hemisphere, we performed a series of sensitivity experiments, displayed in the below table. These experiments employed modern ice-sheet extent (labeled E) and Late Pliocene ice-sheets (labeled Ei) under two atmospheric CO_2 levels: pre-industrial (280 ppmv) and intermediate (400 ppmv)."

Table 2: The four Core and Tier 2 Pliocene for Future protocol experiments conducted. PI refers to pre-industrial conditions, LP for Late Pliocene. Name terminology is from Haywood et al., 2016.

Experiment ID	Ice sheet extent	LSM	Topography	Vegetation	CO_2 (ppm)	Orbit
E280	PI	PI	PI	PI	280	PI
E400	PI	PI	PI	PI	400	PI
Ei280	LP	PI	PI	PI	280	PI
Ei400	LP	PI	PI	PI	400	PI

The protocol for our pre-industrial (PI) simulation follows Eyring et al., 2016. Ice sheets, land geography, topography and vegetation are all unmodified from the model. GHG concentrations for CO_2, CH_4 and N_2O are 284.3 ppmv, 808.2 ppbv, and 273.0 ppbv, respectively. For orbital parameters; eccentricity set at 0.016764, obliquity 23.549 and perihelion - 180 is 100.33.

Figures need to be better labeled. For example, Figure 1 should have labels, and the caption should explain more. Consider also including a cross section of the orography for the two ice sheets.

#Response#: We have worked carefully in labelling our figures in a clearer manner. We have chosen, however, to not include a cross-section of the orography of the two ice sheets as orography is not modified in this study.

Figure 2 it is unclear why albedo is spatially variable in the Ei experiment. This is confusing.

#Response#: While the prescribed snow depth change is fixed, model feedbacks (e.g., clouds, moisture) alter the effective albedo. This is now clarified in the text accompanying the figure:

"In Ei400, albedo changes are not confined to regions affected by ice sheet change and there is an overall albedo decline of 20% across the Antarctic interior, with decreasing severity toward the eastern coastline. There is a small hotspot showing pronounced loss of 30-40% on the east coast (60°–70°E, 75°S). Additionally, albedo decreases of up to 30% are observed along the coastline at 0°–10°E and 140°–160°E. These widespread albedo reductions are a result of the interplay of climate feedbacks, with changes in cloud cover, atmospheric temperature and moisture transport influencing the radiation balance and surface reflectivity."

There are some claims throughout, such as the stability of ice sheets being increasingly at risk, please provide appropriate citations for these.

#Response#: Appropriate references have been added to support such statements, including recent work on AIS vulnerability and Pliocene analogues.

Usually Greenland Ice Sheet is abbreviated as GrIS rather than GIS.

#Response#: This has been corrected throughout.

Include references when discussing EC-Earth's proven capabilities.

#Response#: We have now included, per your recommendation, the references: Hang et al 2021, Chen et al 2022, Han et al 2024 and de Nooijer et al 2020, to prove EC-Earths capabilities over different paleo time periods.

The discussion requires more work, more context, and some of the concluding claims are not well-supported. For example, it is not clear how this experiment will help identify early signals of ice sheet retreat and possibly ice sheet instabilities because this study does not include a dynamical ice sheet.

#Response#: Following the new analysis, improved understanding of atmospheric and ocean processes and properly highlighting the uniqueness of our study, the discussion section has now been rewritten. It now links together our results, the interplay between them and compares the results and mechanisms with other studies, including paleo Antarctic work (Weiffenbach et al., 2024, Hutchinson et al., 2024, Yeung et al., 2024), and literature focusing on current and future polar southern hemisphere change (Silvano et al., 2023, Sidorenko et al., 2021, Kidston et al., 2011, Kusahara et al., 2017). We have fully delved into the limitations of the experimental setup and avoid unsupported conclusions. We now clarify that this experiment isolates the albedo effect, and future studies should include meltwater and orography to understand ice sheet instabilities. This is reflected in the proposed set of follow-up experiments.