The authors present a model study on the impact of a reduced East Antarctic Ice Sheet in context of the mid-Pliocene Warm Period, using the HadCM3 model which took part in the PlioMIP2. They present the results of a number of sensitivity studies in which the height of the EAIS is gradually reduced. This study is relevant and the results are interesting, but I am missing a thorough scientific basis beneath many of the results presented. The study is also missing a good discussion regarding how these results can be interpreted in light of the present/future climate, as they are based on Pliocene simulations. The latter were shown several times to be highly dependent on the mid-Pliocene boundary conditions, stressing on the importance of a good assessment of the state-dependency of the system. I believe a considerable improvement can be made in order to better explain the results and provide more context on how they can be interpreted in light of present-day climate.

General comments:

1) Terminology regarding EAIS is a bit confusing; '0% EAIS' for the largest anomaly is not very intuitive. Consider adjusting to e.g. -25/-50/-75/-100%, and 0% or 'original' for the default configuration.

We have changed the names of the sensitivity experiments following the suggestion (lines 117-118), except for the "0% or original" for the default configuration. This is because the "0% or original" is a control experiment. Thus we prefer to name it as "MPControl", following conventional use.

2) Does the inclusion of dynamic vegetation have any significant impact compared to the original configuration?

In this study, all the boundary conditions (including the vegetation) are the same except for the height of the East Antarctic Ice Sheet. Therefore, it is difficult to discuss the effect of the dynamic vegetation just based on our sensitivity experiments.

3) Overall, figures of different experiments are rather repetitive. It could be more informative to show e.g. anomalies normalized by the 0% EAIS anomaly, to check

whether the other experiments result mostly in a linear response of the strongest signal.

Our study has already analyzed the anomalies normalized by the MPControl experiment (100%EAIS instead of 0%EAIS). The results show a linear response of temperature and precipitation to the EAIS height changes, i.e. a warming of 5 °C per kilometer of EAIS height lost and a precipitation enhancement of ~5% per °C (lines 140-143, 166-168). We believe that the two approaches (100%EAIS and 0%EAIS) answer the same question.

4) The paper is quite descriptive, I am missing a more mechanical insight into the responses shown. Many of the claims or explanations are not supported by what figures show, or not shown at all, making it hard to follow the discussion of the results.

We have improved the Figures 6 and 10 following the suggestions of reviewer #2 (see Figures 6, 10 in the manuscript). In addition, a new Figure (Figure 1 in the manuscript) has been added in our paper and some sentences have been added to make the claims or explanations more clear (lines 163-164, 196-200).

5) Subsections 4.1 and 4.2 seem to be mostly results and should therefore at least partly move to section 3?

Thanks for the suggestions. Subsections 4.1 and 4.2 aim to explain the changes in Antarctic precipitation and global temperature, respectively. Therefore, we would rather keep them in the Discussion section. To make the expression more clear, we have replaced the titles of Subsection 4.1 and Subsection 4.2 with "Cause of Antarctic precipitation changes" (lines 188-189) and "Cause of global temperature changes" (line 219), respectively.

6) Structure can be improved; many of the analyses implemented are presented 'on the go', rather than in the methods section up front along with their motivation. This would make the overall storyline clearer.

Done. We have added some sentences in the methods section to make it clearer (lines 119-124).

Specific remarks:

1) L19: surely there are studies? e.g. work of DeConto et al, Gasson et al.

DeConto et al. (2016) investigated the contribution of Antarctic ice sheets to past and future sea-level rise, and Gasson et al. (2016a, b) evaluated the climate effect of Antarctic ice sheet changes in the Miocene. Our sensitivity experiments are hypothetical scenarios, which focus on the EAIS height changes and their climate effect during the mid-Pliocene. We have added some words to make the expression more clear (line 20).

2) L25: temperature changes as a result of pressure changes: how are these linked?

As shown in Figure 8 in the manuscript, the surface air pressure increases over Antarctica and decreases elsewhere, which is similar to the spatial pattern of the air temperature changes (Figure 3 in the manuscript). With the reduction of the EAIS height, the air mass increases over Antarctica at the expense of those over the rest of the globe, leading to higher air pressure over Antarctica and lower air pressure over extra-Antarctic regions (Figure 8 in the manuscript). According to the ideal gas law (Clapeyron, 1834), lower air pressures correspond with lower air temperatures, which well explains the temperature contrast between Antarctica and extra-Antarctic regions.

3) L136: 5C/km is much lower compared to free tropospheric lapse rate (usually ~7K/km, often ~8C/km over ice sheets), is there an explanation for this?

A previous study has shown that the lapse rate over the Greenland ice sheet depends strongly on background climate (Erokhina et al., 2017). Specifically, the lapse rates for the early Holocene, preindustrial and observational periods are within the range of ~5.5 and 9.5°C km^{-1}, while the LGM lapse rates are up to 4°C km^{-1} higher than the interglacial values. Therefore, we believe that the low lapse rate obtained in our study (5°C/km) may result from the warm conditions in the mid-Pliocene, which is consistent with the finding of Erokhina et al. (2017).

4) L167: Some decrease in precipitation can indeed be expected at lower temperatures, but can you also estimate how much? Does that explain the changes seen? Apart from the global precipitation reduction outside of Antarctica, I hardly see any correlation between the temperature and precipitation anomaly patterns, so clearly other processes are at play to explain the regional responses.

Our results show that annual precipitation decreases consistently over most areas on the globe in all the sensitivity experiments compared to the MPControl experiments. This is consistent with the decreased air temperatures, which reduce moisture carrying capacity of the air and lead to less precipitation (lines 173-176). However, precipitation varies from region to region, it is hard to estimate how much it has been decreased.

It's true that, except the global pattern, the correlation between the temperature and precipitation anomaly patterns is hard to see. Our results show that he largest precipitation anomaly is found in the tropics that are dominated by the intertropical convergence zone (ITCZ). In general, for most areas except the Southern Ocean, the simulations that display the largest SAT sensitivity to the prescription of EAIS height changes also exhibit the largest precipitation anomaly (lines 183-185). The temperature changes may lead to the southward shift of the ITCZ, which contribute to the regional precipitation changes.

5) L175: The precipitation response seems to occur mostly in the South Pacific ITCZ and SPCZ, can you explain why?

The ITCZ is a zone of convergence at the thermal equator where the trade winds meet. It is a narrow band of intense precipitation and migrates with the changing position of the thermal equator. Based on our results, the temperature increases over Antarctica with the successive reduction of the EAIS height, which may lead to the southward shift of the ITCZ. This reasonably explains why the precipitation response occurs mostly in the South Pacific ITCZ and SPCZ.

6) L188: It would be very helpful here to make a simple budget analysis of the zonally averaged southward moisture transport at different atmospheric levels. The strongest precipitation responses extend quite far over the ocean, suggesting that reduced baroclinicity may play an important role as well.

Thanks for the suggestion. As shown in Figure 7 in the manuscript, the weakened katabatic flow, due to the successive topographic reduction, leads to an elevated moisture transport into the continent, which well explains the increased precipitation over EAIS (Figure 5 in the manuscript; lines 196-200). Anyway, it is worthy of further study on the moisture transport at different atmospheric levels, as well as on the changes in baroclinicity, which will definitely be included in our future work.

7) L198: again, it would be nice to know whether the responses of the different experiments are linearly related to the EAIS reduction factor and if not how they can be explained.

Yes, the responses of the different experiments are linearly related to the EAIS reduction factor (see answers to the general question 3).

8) L220: I doubt whether this seemingly very simple reasoning explains what is going on; besides the global pattern the temperature and pressure responses do not seem to be that well correlated either. What about circulation changes, heat transports, radiative effects?

In our study, we focus on the temperature and pressure contrast between Antarctica and extra-Antarctic regions. The results show that the temperature and pressure both increase over Antarctica and decrease over extra-Antarctic regions. We analyzed the energy balance (Figure 10 in the munascript) which represents a combined result of heat transport, topography, GHG, cloud, and albedo. We found that heat transport is the primary factor influencing temperature, and the topography (which represents the ideal gas law) and GHG play a secondary role (turquoise line in Figure 10). As for the discrepancies in temperature and pressure responses over relatively small scales, the internal feedback should be important, which requires further study.

9) If it is purely the effect of pressure, you should use the ideal gas law and estimate the temperature response from the pressure response and compare it to the actual temperature change found.

Based on the analysis of the energy balance (Figure 10 in the manuscript), we found that the primary factor is actually heat transport. However, the topography is also important (turquoise line in Figure 10). We did not say that the temperature changes are purely the effect of pressure changes. We are sorry for the misleading sentence, which have been rewritten (lines 220-221). Moreover, we add some words to make the expression more clear (line 234).

10) L234: Your abstract suggests that such studies do not yet exist?

Sorry for the misleading expression. Tewari et al., (2021; L234) addressed future climate changes, while we focus on the studies of Pliocene warm period.

11) L238: Can you support this statement?

I think this statement is a reasonable inference. To support this statement, we performed a new experiment in which the EAIS height has been reduced 100% but the land topography (away from Antarctica) is reduced by 60m, to artificially raise the sea level (lines 255-258). The results show that the cooling away from Antarctica is robust, and would occur even if sea level changes were accounted for.

12) L260: This EBM approach was also used for the Eocene by Lunt et al 2021 and for the Pliocene by Baatsen et al 2022.

The references have been added (line 275).

13) L262: The heat transport component indeed seems to be quite important over Antarctica. I do not follow how a cooler Southern Ocean is linked to higher Antarctic temperatures here? Also, it would be very useful to separate the temperature gradient and circulation components of the meridional heat transport.

Based on the energy balance analysis (Figure 10 in the manuscript), the heat transport component is the primary factor influencing the temperature changes over Southern Ocean. The heat transport increases significantly over Antarctica, while it decreases over the rest of the globe. We think the heat transport from the rest of the globe, especially from the Southern Ocean, to Antarctica is the primary factor influencing the temperature changes over Antarctica (Figures 10). This may result from the proximity of the Southern Ocean to Antarctica. We have rewritten the sentence to make the expression more clear (lines 276-279).

Thanks for the suggestion on separating the temperature gradient and circulation components of the meridional heat transport. We would conduct such analysis in our future work.

14) L281: I do not find this number anywhere in the results, how was it determined? Same for the 5% precipitation increase per degree C.

Both the temperature and precipitation numbers are shown in the results section (lines 140-143, 166-168).

15) L286: Yet, you show that the heat transport is more important in the EBM analysis?

Yes, based on the analysis of the energy balance (Figure 10 in the manuscript), we found that the heat transport is the primary factor influencing the temperature changes, which ultimately result from the topography changes of Antarctica. To make the expression more clear, we have rewritten this sentence (lines 300-301).

16) L287: This seems to be more of a motivation, rather than a conclusion from the results.

Thanks. We have deleted the sentence (lines 302-303).

Figures:

1) Missing a figure showing the heights and/or height anomalies applied in the experiments.

Done. The figure has been added (Figure 1 in the manuscript).

2) Figure 2: it would be helpful to remove the idealised lapse rate effect due to elevation changes, to distinguish with other dynamical/feedback effects.

The lapse rate is actually obtained from Figure 1 rather than Figure 2. We would like to keep it just for reference.

3) Figure 3: SST responses are almost identical to SAT responses, so I'm not sure what this figure adds besides using a more practical colour scale. Maybe showing the full-depth or upper x meter average temperature response would reveal some more fundamental circulation-related impacts. In fact, I am missing any ocean circulation responses in the figures shown.

Yes, the SST responses are almost identical to SAT responses. I think this means that the height reduction of the EAIS has similar effect on SAT and SST. We have tried our best to adjust the colour scales of Figure 2 and 3. As the SST is an efficient indicator for ocean temperature and is widely used for analyzing patterns of climate variability. We think that the SAT parameter is sufficient to address the effect of EAIS height changes, and would keep the suggestion in mind in our future investigations.

4) Figure 4: again this figure is rather repetitive between the experiments. While this is useful to know, it does not give any explanation of the patterns seen. Are these the direct result of elevation changes, or rather e.g. the related temperature/circulation changes? What are the seasonal responses?

Figure 4 in the manuscript shows the spatial distribution of the annual mean precipitation anomalies over Southern Hemisphere between each sensitivity experiment and MPControl experiment. The explanation of the patterns is given in Subsection 4.1

(lines 190-217), because it is not appropriate to discuss it in the results section. Our experiments were deigned to investigate the effect of EAIS height changes, and we believe the precipitation patterns are the result of elevation-induced changes. As all figures show annual results, we thus present the precipitation annually instead of seasonally to be consistent and facilitate comparison.

5) Figure 5: precipitation anomaly plots are always challenging to interpret, as there is already substantial variability in the reference, without which it is tough to see what is relevant.

   Done. We have added the reference plot into Figure 5 (Figure 6e in the manuscript).

6) Figure 6: This is a very useful figure, but hard to read. Why show the entire Southern Hemisphere, rather than e.g. 30S-90S? The projection used seems to be cylindrical, which contracts Antarctica at the expense of lower latitudes. Using a polar stereographic projection seems to be a more logical and practical choice here. Interpreting anomaly quiver plots is pretty challenging. I think it would help to add colour shading showing whether the anomaly induces a weakening (e.g. blue) or strengthening (e.g.) red of the flow in the MPcontrol.

The temperature and precipitation changes both show the entire Southern Hemisphere and use the cylindrical projection. To be consistent, here we also show the entire Southern Hemisphere rather than 30S-90S and keep the cylindrical projection.

7) Figure 8: global sea level is adjusted by lowering the land by 60m, but coastlines seem unaffected? This figure also shows that besides the EAIS, temperature and pressure anomaly patterns do not correlate well.

This experiment was designed to remove the unrealistic surface air pressure anomaly over the land (Figure 8a in the manuscript), and see how this affected the surface air temperature anomalies. Therefore, locations where the land was below 60 m are set to 0 m to maintain the mid-Pliocene land sea mask. We have added some sentences to make the experiment design more clear (lines 258-262).

8) Figure 9; it is hard to see what is going on besides Antarctica and for the largest terms. Consider changing the scaling or separating some of the components. The different components do not show actual warming/cooling, but their estimated (linear) temperature contribution from the EBM.

Done (see Figure 10 in the munascript).

Typos/small errors:

1) L134: increases?

Yes, it should be "increases" (line 139). We have corrected this mistake.

2) L194: MPcomtrol

Done. We are sorry for this mistake and have revised it (line 207).

3) L195: the Antarctic continent?

Our MPControl experiment uses the PRISM4 boundary conditions without any changes. As the West Antarctic Ice Sheet has been melted in the PRISM4 boundary conditions, here we use the East Antarctic continent.

4) L209: explained by lapse rate: something is missing here

To make the expression more clear, we have rewritten this sentence (lines 220-221).

5) L268: height sheet

Done. We have revised it (line 286).

6) L284: decrease

Done. We have replaced "decreases" with "decrease" (line 302).

References

Clapeyron, É.: Mémoire sur la puissance motrice de la chaleur. Journal de l'École polytechnique, 14, 153–190, 1834.

DeConto, R. M., and Pollard, D.: Contribution of Antarctica to past and future sea-level rise. Nature, 531(7596), 591–597, 2016.

Erokhina, O., Rogozhina, I., Prange, M., Bakker, P., Bernales, J., Paul, A., and Schulz, M.: Dependence of slope lapse rate over the Greenland ice sheet on background climate, J. Glaciol., 63(239), 568–572, 2017.

Gasson, E., DeConto, R. M., Pollard, D., and Levy, R. H.: Dynamic Antarctic ice sheet during the early to mid-Miocene, P. Natl. Acad. Sci. USA, 113(13), 3459–3464, 2016a.

Gasson, E., DeConto, R. M., and Pollard, D.: Modeling the oxygen isotope composition of the Antarctic ice sheet and its significance to Pliocene sea level, Geology, 44(10), 827–830, 2016b.

Tewari, K., Mishra, S. K., Dewan, A., Dogra, G., and Ozawa, H.: Influence of the height of Antarctic ice sheet on its climate, Polar Sci., 28, 100642, doi:10.1016/j.polar.2021.100642, 2021.