Reply on RC2
Michiel L. J. Baatsen et al.

Author comment on "Warm mid-Pliocene conditions without high climate sensitivity: the CCSM4-Utrecht (CESM 1.0.5) contribution to the PlioMIP2" by Michiel L. J. Baatsen et al., Clim. Past Discuss., https://doi.org/10.5194/cp-2021-140-AC2, 2022

General Comments
This manuscript presents new simulations of the Pliocene warm period using the CESM model. The authors present simulations using a range of different CO2 levels, using both modern and Pliocene boundary conditions. They find significant warming due to changing the boundary conditions, mainly because of ice-albedo effects that allow a larger insolation, independently of greenhouse forcing. The model's climate sensitivity to CO2 is roughly the same under both boundary conditions. The model achieves a generally very good fit to Pliocene proxies, and the remaining discrepancies are examined in an appropriate manner. The paper is mostly about describing the model and its main features of variability, and it is generally well written, so I suggest mainly minor revisions to clarify the data presentation.

My biggest recommendation for change is to revise the colormaps in the anomaly plots. I suspect the authors have put significant effort into the color schemes, so I'm sorry to insist upon changes here. However, I find that the color scheme used for most of the manuscript figures does (a) a good job of representing absolute values, and (b) a poor job of representing anomalies. There are several reasons for this:

The banded color regions tend to create “critical values” when changing to different colours. This is ok when there is no particular critical threshold in the data, but with anomaly plots, there is a critical value of zero that must be highlighted. Having 6 different colour bands in the anomaly scale means there seem to be critical values jumping out everywhere, and it’s hard to get an intuitive sense of the positive and negative changes.

The second reason is that some colours have a highly suggestive nature that can be deceptive. For example, most papers use red for a warm anomaly and blue for a cold anomaly, which makes intuitive sense. The authors have in many places used blue shading for warm anomalies, which is very jarring to interpret. (E.g. Fig 4b, 5b, 9c, 10, 11). I suggest for all of the anomaly plots (especially temperature and precipitation) either use:

A) only one colour (with intensity shading) either side of the zero value, so that the critical values are very obvious, e.g. red for warming, blue for cooling;

B) use two colours either side of the zero, but choose them to be carefully matching in tone and intuitive, e.g. purple and blue for cooling, brown and red for warming. Or: green and blue for wetting, brown and red for drying.

AC: The authors would like to thank the reviewer for the detailed feedback and specific comments. A lot of thought has indeed gone into the colour schemes, but we agree that
especially the difference plots can be improved. Having asymmetric (about 0) colour bars in many of the difference plots is motivated by largely one-sided temperature changes. We do agree, that it is best practice to not incorporate blue/green colours on the negative side of the scheme and will adjust the figures accordingly. We will also adjust the remainder of the difference plots by making the diverging colourbars more simple (only using orange/red and blue/purple shades). Some of the suggested changes can be seen in Figures C1-C3 from the supplement.

Apart from this, I have a couple of scientific suggestions:

1. Why is there a large change in direction of the temperature trends at around 1000 years in the Eoi400 run? This is a curious feature of the spinup that deserves a stronger explanation.
   AC: This indeed stands out in the spin-up of our Eoi400 simulation. In the first phase of this spin-up, there is only a shallow and sluggish AMOC. Only after ~1000 years, we see the development of a much deeper and stronger northern overturning cell which then has a significant impact on the global heat distribution and radiative budget. We will clarify this here and refer to sup. Figure 5 showing the full evolution of the AMOC maximum.

2. Since the main result is that Pliocene boundary conditions cause significant warming (independently of CO2), it would be good to examine the radiative forcing changes in more detail. This can be done using a framework such as in Lunt et al (2021, https://doi.org/10.5194/cp-17-203-2021) and Heinemann et al (2009, https://doi.org/10.5194/cp-5-785-2009)
   AC: We agree that using this framework fits well within this study, using the set of model simulations that we present. This analysis will be added, replacing the straight comparisons of radiative fluxes in sup. Table S2, as well as most of the related discussion. The results lead to similar conclusions and can be found in Figure C1.

Line Comments

L29: “foe” typo
AC: We will correct this.

L93: This equation looks a bit ugly in current format. Is it possible to use nicer labels, such as “d” for depth rather than “dpth”, and why do “vdc1” and “vdc2” need so many characters?
Why not “c1” and “c2” for instance, and use subscripts for a nicer appearance?
AC: We chose to follow the exact syntax used in the CESM reference manual and related publications. Although we agree that the equation can be simplified/clarified, we suggest to keep it in the current form for consistency.

L182: TOM has not been defined in the main text. It was defined in a Figure caption but it should be spelled out in the main text as well.
AC: We will add this here.

L210-211: “to not select a mode?” is a strange way of phrasing this. Are the authors trying to say that they (a) calculated EOFs for the North Atlantic, and then (b) disregarded leading EOF modes that correlated highly with ENSO or the PMV? I don’t understand, please clarify.
AC: This can indeed be clarified; the EOF related to the AMO can be somewhat tricky to find as the North Atlantic SSTs are also influenced by several external factors such as PDO/ENSO/AMOC. Rather than just taking the first/dominant EOF, we therefore select the one that correlates best with the 10-70N average North Atlantic SST such that we are comparing similar modes between the different simulations. We will explain this more
clearly here.

L219: “more easy”  □ easier
AC: we will adjust this

L321: “Straight”  □ Strait
AC: we will correct this

Figure 5 caption: I think it’s better to use “variables” rather than “observables”
AC: Although we prefer the term observables, to distinguish physically meaningful variables from others used internally by the model, we agree that a variable such as the barotropic stream function is not something one could easily observe directly. We will change this here as well as in Figure 4, for consistency.

Figure 7a,b: There is too much information stacked in the overturning plots. The contours can’t be seen properly on top of the colours. I suggest expanding this plot to put the Eoi560 overturning on separate panels - there is plenty of space to do so.
AC: The colour scheme will likely change here, which may solve this issue. Otherwise we will indeed expand this into a 6-panel figure.

L357: “clearly reflected atmospheric MHT difference”: there’s a word missing here, please Clarify
AC: we will change this to ‘reflected in the atmospheric MHT difference’

Figure 8a,b: Again please expand the overturning plots to use separate plots for different streamfunctions. The contours are too difficult to read over the colours - it is information overload.
AC: This issue is partly solved by switching towards a more simple colour scheme. Showing the Eoi560 and Eoi280 meridional overturning stream functions as well mostly served to point out that the differences between Pliocene and Pre-industrial are mostly because of the topographic changes and mixing parametrisation. We therefore prefer to just show the Eoi400 and E280 stream functions, and only the Eoi280-Eoi560 and Eoi280-E280 differences in contours (see Figure C3).

Figure 9c: Here the use of blue to signify warming is really jarring, especially the blue proxy circles. Please revise the anomaly colorbars (as in my general comments).
AC: we will revise the colour scheme to make this easier to interpret.

L409-410: Here it might be useful to reference Li et al (2019, https://doi.org/10.1029/2019PA003760) which shows the impact of changes to coastal upwelling on large-scale Pliocene SSTs
AC: this is a great reference to add here, we will do so.

L414: This sentence would be improved by deleting “It is noteworthy that”
AC: This part of the sentence will be removed.

Figure 10: As noted above on colorbars: there are large swathes of blue used to represent warm anomalies. Please revise.
AC: The colour scheme will be revised accordingly.

Figure 12c: The contours overlaid on colours here are very difficult to interpret (as in Figs 7, 8). Please expand the number of panels to separate the clashing information.
AC: We hope that this is solved by revising the colour scheme, otherwise we will expand the figure.
L483: “there is a lot more”: perhaps delete “a lot”, since this a vague descriptor.
AC: this can indeed be left out, we will rephrase to make it clear that there is larger
variability rather than it being more significant (although the latter is also the case).

L523-524: “this differential warming patterns” : fix grammar. Also, instead of saying “dif-
ferent parameter choice”, can you be more specific and say “enhanced diffusivity”?
AC: We will adjust this part and specify

L532: “dryer” □ drier
AC: we will correct this

Please also note the supplement to this comment:
https://cp.copernicus.org/preprints/cp-2021-140/cp-2021-140-AC2-supplement.pdf