Response to Referee 2

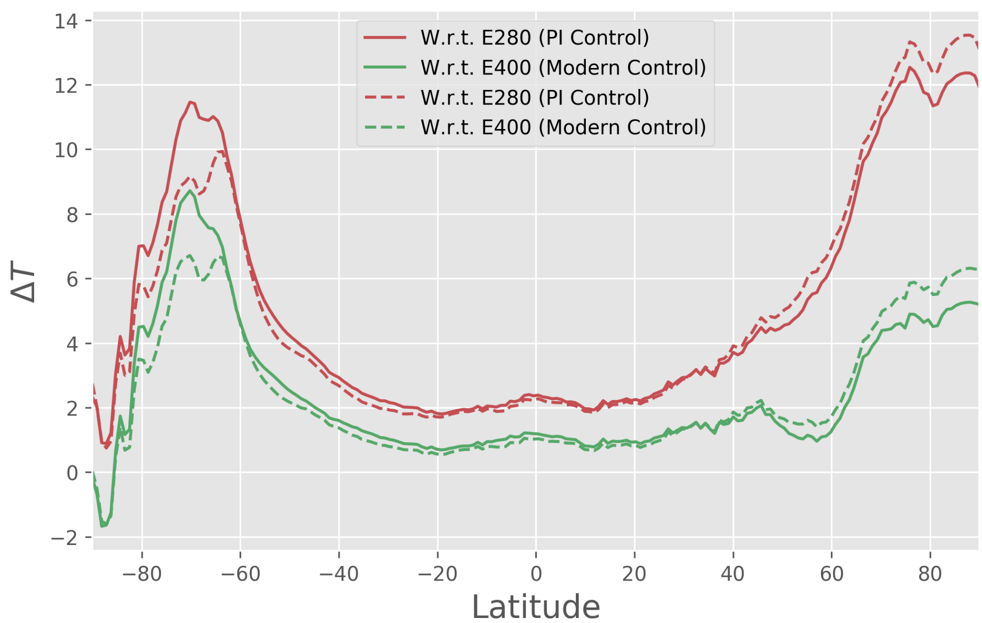
We are very grateful to the referee for the time taken to review our manuscript. The comments and suggestions have enabled us to further improve the clarity of the manuscript in a way that will make the work more accessible to the reader.

> In this paper, based on the PlioMIP2 boundary conditions, the authors use the CCSM4 to simulate the mid-Pliocene warm climate. The experiments are well designed and described in the paper. The paper is well written, and provide very good summaries for the Pliocene studies from aspects of ocean, land-ice reconstructions.
>
> However, in the paper, the authors do not clarify why they choose different diapycnal mixing k to carry out their experiments. In their models outputs, it is clear that the depth-dependent k remarkable changes the simulated ocean climate. Why do the authors only compare the simulated Pliocene and PI climate in the experiments with depth-dependent k? Do these experiments provide even stronger warming in the high- latitudes? In the revised version, I suggest the authors to plot figures similar to Figure 6, but based on the experiments with the constant k.

We thank the reviewer for asking us to clarify our reasons for choosing two types of κ. Although we have discussed in the manuscript our motivation behind the choice for κ profiles that remove modern day constraints (page 6, last paragraph), we were remiss in not providing the same level of clarity regarding the decision to produce simulations based upon two different choices for κ. The primary motivation behind this choice was to study the sensitivity of the AMOC under PlioMIP2 boundary conditions for different choices of κ. This was motivated in part by the comparison of AMOC strengths for different PlioMIP simulations in *Zhang et al.* [2013]. We have added the following clarification in the Results and Discussion section of the revised manuscript:

> We mentioned previously that the simulations based upon the POP1 diapycnal diffusivity variant will constitute our primary PlioMIP2 results. This is simply because this depth dependent mixing profile has a structure that agrees with the diapycnal diffusivity of the deep ocean that is required to support the upwelling of deep abyssal water that is required to close the Antarctic bottom water cell. Therefore, in what follows, only the climatologies of the POP1 variants of the simulations will be discussed, and results from the constant κ variants will only be discussed in very select situations.

The reviewer's comment concerning warming at high-latitudes led us to discover an interesting response of the mid-Pliocene surface atmosphere temperature to the choice of κ. The figure below is a modification of the manuscript Figure 8 such that in addition to the zonal-mean anomalies of $\mathrm{E}oi^{400}\mathrm{P}$ compared to $\mathrm{E}^{280}\mathrm{P}$ and $\mathrm{E}^{400}\mathrm{P}$ (solid lines) it also shows the anomalies of $\mathrm{E}oi^{400}$ compared to E^{280} and E^{400} (dashed lines). This comparison shows an asymmetric response of the anomalies between the two hemispheres. The anomalies obtained with constant κ simulations (dashed lines) are appreciably reduced in the southern hemisphere, compared to the anomalies obtained with POP1 type simulations (solid lines), while the opposite is true for the northern hemisphere. There are no appreciable differences throughout the tropical and extra-tropical latitudes. We believe this analysis provides a useful first estimate to the community regarding the magnitudes of changes that could be expected, and the regions where those changes can be expected with regards to changes in κ. This should assist the community to better understand the differences among results from the various models participating in PlioMIP2.



Furthermore, the differences in surface air temperature at high latitudes (originating from the choice of κ) is certainly going to be an important consideration for any future study that wishes to simulate the response and the stability of high-latitude Pliocene ice-sheets using ice-sheet models forced by simulated temperatures as boundary conditions. This analysis and accompanying discussion has been added to our revised manuscript.

> I also suggest the authors to plot AMOC for both two sets of experiments. It is helpful for other groups to judge which k provides better simulations for AMOC.

Figure 13 in the manuscript does show the AMOC for both two sets of experiments. There are two sets of curves in each sub-figure. The curves that begin mid-way in the sub-figures are for the POP1 type experiments. This is easier to see in the first sub-figure which shows the AMOC for the control experiment; there are two sets of red curves and green curves. In the other sub-figure, a discontinuity is present near year 1,100, but it is less apparent than in the control sub-figure primarily because the Pliocene constant κ simulations were not continued for very long after branching.

> Since this work is taking part in the PlioMIP2, the authors should provide suggestions for other groups which set of experiments should be used in the future intercomparsions, the set with the constant k or the set with the depth-dependent k. Why?

We thank the reviewer for making an important point here. For PlioMIP2 we expect other groups to use the diagnostics computed with our POP1 type experiments. We have made this clearer in the revised manuscript in the section "Design of the Numerical Experiments" where we first introduce the two sets of experiments with the following comment:

> Since one of the defining large-scale characteristic of the global oceans are their vertical variation of the diapycnal diffusivity by an order of magnitude from low values in the thermocline to high values closer to the rough ocean bottom [*Waterhouse et al.*, 2014], our

POP1 variant simulations will constitute our primary PlioMIP2 simulations and it is these simulations that should be used by other groups for inter-comparison purposes.

References

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