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Climate of the Past Discussions

Interactive comment on "Evaluating the dominant components of warming in Pliocene climate simulations" *by* D. J. Hill et al.

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Myself and the co-authors would like to thank the anonymous reviewer for his review and the positive set of specific comments that will improve the final manuscript. We are glad the reviewer sees the merit of this work, although the questions raised in the general comments show that a wider context for this work needs to be established in the manuscript. A section will be added to the introduction setting the context for the PlioMIP Experiments within previous Pliocene studies and also the importance of this particular analysis within PlioMIP. PlioMIP is the only internationally recognised multi-model palaeoclimate intercomparison project to explore a warmer than modern climate. Its fixed experimental design and the participation of nine different modelling groups from around the world give it some unique advantages to estimate and understand

the model dependencies in simulations of the Pliocene climate. Haywood et al. 2013 provides a thorough description of the results of PlioMIP Experiments 1 and 2, but this manuscript represents the primary analysis of the causes of warming within the PlioMIP Experiment 2 simulations.

Specific comments:

1. This sentence as written could indeed be misleading. The intention was not to suggest that the albedo feedbacks dominate the global signal, but rather that they are the most important factor in the high latitudes. This sentence will be changed accordingly.

2. All the surface air temperature (and precipitation and sea surface temperature) maps for the individual models are presented in Haywood et al. 2013 (Supplementary Figure 3). As this data is already available within this special issue we felt that it was unnecessary to reproduce it within this paper. As described in Haywood et al. 2013, the Pliocene reconstruction includes the infilling of Hudson Bay, which requires changes to the land-sea mask of the coupled climate models. These changes are not incorporated into a number of the PlioMIP simulations (see Haywood et al. 2013 Table 1) and so the variance between Hudson Bay SATs is large. However, this is a small issue when considering the zonal mean climatology, so we feel that the documentation and discussion of this issue within Haywood et al. 2013 should be sufficient.

3. ΔT_{topo} is a crude correction that is applied to our results, whose inclusion in the calculations does, however, remove some spurious features from the energy balance components (e.g. a cooling in Antarctica apparently due to increased greenhouse gases). It is unable to capture many of the complexities that would contribute to the temperature change due to changing the topography in the models, but it is the best we can do with the limited information available from the PlioMIP simulations. A section of text making this clear and discussing ΔT_{topo} will be added to the manuscript.

4. and 5. We think that there is some merit in considering the various energy bal-

ance components of the individual simulations, rather than just comparing the individual components across the ensemble. As such we believe that Figure 2 is an important figure to the overall manuscript, even if it is not as useful as later figures. However, as there is much agreement in the overall structure of the energy balance components, section 6 could be removed with some of the discussion being moved to the following section, if it would improve the manuscript.

6. The vegetation boundary conditions specify a northward advance of grasslands in both central Asia and continental North America. This is reflected in most of the simulations, where temperature increases due to clear sky albedo in the Northern Hemisphere mid-latitudes are reduced or reversed. The increase in albedo seems to be particularly marked in the MRI simulation, possibly due to the particulars of the vegetation translation scheme used (both albedo and vegetation translation scheme being documented in Kamae and Ueda, 2012). The ensemble mean clear sky albedo increases shown in Figure 5 closely follow the northward expansion of the grasslands and reflect the subsequent albedo changes that should have been imposed on all the simulations following the surface physics translation table in the experimental design protocol (Haywood et al., 2010). A sentence will be added to the figure caption outlining the cause of the increases in albedo.

7. We need to clearly define the climate sensitivity that we are using here, so this will be added to the manuscript.

8. This is not an important point and can easily be omitted.

9. CCSM seems to have a muted response over the Antarctic continent, although the warming is higher than any other latitude, it is the coolest overall maximum. CCSM has the lowest polar warming in the ensemble probably due to the model response to changes in the ice sheets. The energy balance analysis clearly shows that this is due to the clear sky albedo response to changes in the ice sheet. This will be highlighted in the manuscript text.

10. The simulated changes in the ITCZ and the Hadley Cell have been widely discussed in previous mid-Pliocene and PlioMIP papers. Kamae et al., 2011 particularly focuses on patterns of tropical circulation, so we will add that reference to the above sentence.

11. This sentence needs to be reworded to reflect that the energy balance calculations show the increased impact of the reflection of incoming radiation by clouds causes the significant cooling effect seen at high latitudes.

12. We are referring to the negative feedback that heat transport provides to polar amplification (the more polar amplification – the lower the thermal gradient – the less heat is transported – reduced polar amplification). We will rephrase the sentence to make this clear.

13. The different land-sea masks used by the different models, as documented in Haywood et al. 2013, are a major factor in the large variance in the Hudson Bay region. Similarly large variances in the North Atlantic and Kuroshio Current regions probably reflect differences in the way the models simulate ocean circulation. Hence these regions are particularly highlighted in the manuscript.

14. Snow albedo feedbacks could indeed contribute to the strong clear sky albedo impact. The individual components cannot be calculated, but the paper shows that there combined impact is greater than cloud cover changes in the high latitudes. Snow albedo is already present in the same list in the caption for Figure 5, so its omission will be rectified in the above list.

15. A future publication is planned on the sea ice in PlioMIP Experiment 2 simulations. Further breaking down of the clear sky albedo is hampered by the lack of the relevant fields (e.g. snow-free albedo) produced by some of the models, although some of the data can be found in the publications documenting the individual simulations (Table 1).

All the technical corrections with be dealt with as required.

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