**Geoscientific
Model Development
Discussions**

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Interactive comment on "Pliocene Ice Sheet Modelling Intercomparison Project (PLISMIP) – experimental design" *by* A. M. Dolan et al.

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We would like to thank the reviewer for their constructive comments. Our response is detailed below.

1. Question about the focus of the project - ice sheet model (ISM) structural uncertainty or uncertainty between reconstructions derived from available ISMs.

The reviewer is correct in highlighting the following sentence: "However, it is first necessary to understand the inherent differences that are caused by structural uncertainty in ice sheet models", pp. 2666, 23-24. The aim of this project is to quantify the uncertainty in Pliocene ice sheet model reconstructions based on the different ISMs available, and therefore this sentence will be removed. Additionally a statement will be included at

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this point highlighting the fact that this project falls short of capturing the entire structural uncertainty of currently available ice sheet modelling systems, which the reviewer themselves stated was beyond the scope of the study.

2. The choice of period. Why not carry out simple experiments with results from CMIP experiments for future warming? Or to carry out an Eemian experiments which with much closer temporal proximity should provide much stronger constraints?

We agree that it is necessary to better clarify our choice of the Pliocene over other relevant periods. We are carrying out this project as part of the wider PlioMIP initiative (Pliocene Model Intercomparison Project). The Pliocene is widely recognised as an accessible epoch of Earth history which displays certain parallels to model predictions of late 21st Century climate (IPCC, 2007). The rationale for choosing the Pliocene is detailed in Haywood et al. in (2010; 2011) and Dowsett et al. (2010) and has already been fully detailed in other parts of this special issue on modelling Pliocene climate. Additionally, we will add to our rationale that although we are undertaking this project because it will enhance our understanding of ice sheets in a warmer-than-modern climate, it is also of scientific interest to reconstruct the Pliocene as accurately as possible. Much work is currently being undertaken to investigate many aspects of Pliocene climate and this project will provide a useful contribution.

3. The current literature indicates that processes at the marine-ice sheet/shelf interface are critical with respect to ice stability. These strongly depend on local scale seasonal SSTs and on vertical marine temperature profiles. It's not clear from the submitted description whether the spatial resolution of the SSTs will be small enough to be relevant to accounting for such interface processes in the models

This is a useful comment. The marine inputs forcing the ice sheet models will be taken from the climate model. The resolution of this is $2.5°$ by $3.75°$ and thus may not fully capture realistic local scale variability. This will always be a problem when combining climate and ice sheet models or at least until we can model the ice-ocean interface on

a scale of metres. Where appropriate the techniques used to overcome these issues will be documented by the relevant modelling groups. However, this short fall will be made explicitly clear when detailing the results from this section of the project (in the subsequent results paper) and will be highlighted as a potential problem in this paper.

4. How will the "most likely geometry and volume of ice masses" actually be reconstructed/ determined? Raw averages? Results conditioned on available proxy data?

The sentence highlighted by the reviewer does need further clarification and this will be added to the text along with any potential caveats. Differences in the model-predicted ice sheet thicknesses will be analysed using root mean square (RMS) measurements. In areas where RMS values are high, there are large differences in model predictions and these areas will need to be explored further. We also intend to measure areal extent of the ice sheets based on presence/absence of ice in each grid-cell throughout the models. This will build up a picture of where the models agree (and therefore were we can have greater confidence in their predictions) and where the models tend to disagree (lower confidence). Based on our range of scenarios and model outputs we intend to identify the most likely size (areal extent) and volume of the ice sheets. These results will be solely based on model output and thus the caveats associated with this will be highlighted. Additionally where available, proxy evidence will be used to evaluate the results. We will also again reiterate here that we are not taking into account all types of structural uncertainty as noted earlier.

5. The uncertainties in climate far outweigh the impact of structural uncertainties in ice sheet models for such modelling. As such, doesn't it make sense to first document the largest sources of uncertainties?

This is correct and we have seen this in pilot studies done using three climate models (HadAM3, CCSM3 and GCMAM3) and one ice sheet model, which formed part of the precursory experiments for PlioMIP. In the future we plan to continue this work incorporating all of the results from PlioMIP (published in this special issue) in order

to document the climate uncertainties. However, at the time of writing and even now, not all of the results are available from PlioMIP in order to undertake such as study. Therefore we decided to start with this project, but also add in an aspect whereby the climate forcings were altered (i.e. Phase 2) to begin to address the effect of climate uncertainties.

6. Rationale for the use of HadAM3 modelled preindustrial climatology as a control alongside an observed climatology for comparison: "...any large differences incurred in the equilibrium ice sheet response as a result of using a HadAM3 modelled climatology (rather than observed) may point to potential weaknesses in the ice sheet reconstructions using the same climate model – I'm not clear on the intended meaning here. Large differences between modelled and observed, or between various models?

The sentence will be rephrased to: "...any large differences incurred in the equilibrium ice sheet response as a result of using a HadAM3 modelled climatology (rather than observed) may point to potential weaknesses in the Pliocene ice sheet reconstructions when forced with Pliocene HadAM3 climatologies." Additionally, we will add in a statement clarifying that we are using HadAM3 derived pre-industrial climate forcing for the ice sheet models as a check that all participating ice sheet models reproduce a good reconstruction of the modern ice sheets. This would give us confidence in the use of the same modelling framework to predict Pliocene ice sheets.

7. Question over use of BEDMAP v.s ALBMAP bed topography data.

ALBMAP is a patch to BEDMAP, adding in new AGASEA/BBAS data in West Antarctica and some data inversion techniques to Coates Land and coastal regions. ALBMAP does not represent the state-of-the-art knowledge in Antarctic subglacial topography and does not apply consistent techniques to the whole of Antarctica. The community still awaits the production of BEDMAP version 2 and therefore it was decided not to update to ALBMAP.

8. What does "standard mode" mean? Best tuned version for modelling present day

Greenland and Antarctica?

This is a useful point. By standard mode we mean the ice sheet model configuration used by each individual modelling group as standard over Greenland and Antarctica. This is normally set up to best simulate the present day ice sheets and will be detailed further in the results papers. A sentence explicitly stating this will be included.

9. Isn't it about time we move beyond this simplistic uniform lapse rate correction? Given that the climate forcing is coming from a single GCM, how about extracting vertical temperature gradients at the appropriate elevations and for each month or season?

We have given this interesting suggestion considerable thought. Geographically and time varying lapse rates are obtainable from HadAM3. Analysis of variations in lapse rate around Greenland and Antarctica show a maximum geographical/time variation of 1K/Km. There are also subtle but discernable differences in lapse rate between a modern and Pliocene HadAM3 experiment (of similar magnitude). This underlines the sensitivity of lapse rate to the configuration of the ice sheets. Given our experimental design does not provide for the experiments to be run in a dynamically coupled ice sheet/climate model set up (our ice sheet simulations are all completed offline with no further interaction with the climate model), we do not see that application of such a rigorous lapse rate correction will be particularly beneficial. The imposed lapse rate field will not remain valid if the ice sheet models then predict Pliocene ice sheet configurations which are different from those given to HadAM3 in the first place.

10. Is not transient response of more relevance with respect to concerns about the future evolution of present-day ice sheets? Why the focus on equilibrium response?

Any palaeoclimate transient forcing will be considerably different to present-day evolution of the ice sheets, as there are as yet no known periods in Earth history when present rates of increase in atmospheric CO2 concentration are seen. However, it is agreed that looking at the transient response of the ice sheets through the Pliocene would be very interesting indeed. Nevertheless, given the modelling framework at

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present (i.e. GCM as climate forcing coupled to an offline ice sheet model), and our lack of knowledge about time varying forcings such as CO_2, we think this approach is impractical at present and is beyond the scope of this intercomparison.

11. I would also like to see some specification of data formats and initial intercomparison of analyses planned in an appendix. This technical issue can cause many headaches in such model intercomparisons.

The specification of data formats is currently available on the PLISMIP website and can be easily put into an appendix. We will also include a description of planned analyses in an appendix.

12. Incorrect figure reference in text will be altered (fig. 3a and 3c).

13. I applaud the inclusion of the phase 2 experiments, given the strong temperature imprint from the ice sheet boundary conditions used by the GCM but I don't understand why one would use present-day Antarctica combined with ice-free Greenland as this is outside the stated estimated bounds for higher sea level during the mPWP ("10 to 30+ m"). Would it not make more sense to have phase 1 and 2 roughly match the bounds on mPWP sea level?

There are a number of sea-level estimates for the Pliocene which would suggest that a modern Antarctic ice sheet is implausible at least for the warmest periods of the epoch. However, the prevailing paradigm is that there has been little change in Antarctica since the Miocene, especially in East Antarctica. This has been strongly advocated in a number of recent high profile papers (Pollard and DeConto, 2009; Raymo et al., 2011) and therefore it seemed appropriate to test this as an end member of the ensemble. We know from previous work that the Greenland Ice Sheet is likely to reduce in a warmer climate, although its relatively small size means this could never be shown from eustatic sea-level estimates, so an ice-free Greenland seemed an appropriate extreme to test.

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14. Detailed descriptions of all model numerics and parameterizations needs to be tabulated.

We agree entirely that this is essential for any good comparison paper and it is intended that such a description table be included in the subsequent results papers. We will add is a statement to this effect.

15. Where possible, consider taking into account participating model results from previous intercomparisons.

Again, it is intended that this be addressed in the results paper. Where possible we will use previous conclusions drawn in the literature of other MIPs to inform our interpretation of the PLISMIP results.

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