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Climate of the Past Discussions
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Interactive comment on "Sensitivity of atmospheric forcing on Northern Hemisphere ice sheets during the last glacial-interglacial cycle using output from PMIP3" *by* Lu Niu et al.

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Liu et al. present a study that identifies a strong sensitivity of glacial-interglacial ice sheet evolution to applied atmospheric forcing fields, particularly summertime temperature. It highlights uncertainty in climate forcing as a major control on long-term evolution (in this case, past evolution).

GENERAL COMMENTS Recent publications have already highlighted the important/dominant role of climate forcing on long-term ice sheet evolution (e.g. Qing et al., 2014, 10.1007/s00376-013-3002-6; Dolan et al., 2015, 10.5194/cp-11-403-2015; Fyke et al., 2014, 10.1007/s00382-014-2050-7, for example, I know there are others out

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there). In addition, I'm not sure the finding of summertime temperature (or more accurately, summer energy balance) conditions as the major control on ice sheet extents is highly novel (for example, two early studies that discuss this sensitivity: Gallee et al., 1992 10.1029/92JD01256; Oerlemans, 1991; 10.1177/095968369100100106). Generally, a stronger literature review is necessary, both to recognize these earlier efforts and also to place the present effort in context in terms of originality.

It seems odd to have the first part of the paps focus on COSMOS-AWI, then turn somewhat orthogonally to evaluation of the PMIP3 ensemble. As it stands the manuscript is too disjointed, in part validation of COSMOS-AWI, and in part a PMIP3-based sensitivity experiment. The two need to be better linked if they are too be included as one study - for example, by just including the COSMOS-AWI-based simulations as an additional PMIP3 ensemble member and reserving special evaluation of COSMOS-AWI-based PISM simulations as a separate study.

The driving of ice sheet models with transient climate model data, where ice sheet topographies, surface types, etc. are prescribed in the climate models to recreated reconstructed ice sheet topographies, is arguably circular. For example, due to the coupled nature of land-surface/near-surface temperatures (including over-ice temperatures, which are strong functions of ice elevation) and albedo feedbacks, temperatures should be much higher in bare-land regions, which strongly limits simulated ice advance past the reconstructed southern ice margins. This is very likely why the PISM ice extents simulated here very consistently do not go southwards of the reconstruction's southern limits. This circularity needs to be addressed, in terms of how it potentially impacts the main results of this paper.

Recent work has recognized that temperatures alone do not determine the majority of the summertime response - perhaps a dominant aspect comes from direct radiative forcing, at the point where the snow/ice is at the melt point (see van den Berg, 2012, 10.1038/NGEO1245, for the case of Eemian Greenland). Thus, PDD assessments of glacial behavior are missing a major control on summertime ablation conditions. Bet-

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ter justification needs to be given here to why PDD-based assessments of ice sheet sensitivity to glacial climate change are valid, in light of more physically accurate energy balance-based approaches (which is where the broader community is increasingly turning).

SPECIFIC COMMENTS

P2L15: Also, Fyke et al. (2011), 10.5194/gmd-4-117-2011

P2: A focus on the importance of ice-sheet/climate coupling seems a bit out of place, given this study does not include this coupling. More justification is needed (and I think possible) on the value of standalone modeling, forced with previously-generated climatologies.

P3, section 2.1.1: how is PISM internal temperature initialized (not that it perhaps makes a big difference here, since the main areas of interest have no ice at t=0)

P3, section 2.1.1 & 2.1.3: How are ocean interactions accounted for in the simulations presented here? Is ice removed if floating? This has a bearing for which ice sheet dynamics (SIA vs SSA) are dominant in PISM in these simulations and also on the marine margins of the simulated ice sheets.

P5, L3: It is not immediately clear to the reader how the white noise term is added.

P5, section 2.2 and Figure 2: It is not clear how conditions 'outside' of the LGM/PD range are accounted for, given the 0-1 index range defined between present and 21 ka conditions. For example, much of the Holocene, and the late Eemian, and much of the LGM lie outside of the LGM/PD window. Please describe how these conditions at these points are calculated.

P5, section 13 (also, PMIP3 section): The choice to use observed/reanalyzed present-day conditions instead of model conditions for the present-day needs to be better justified. It would seem more consistent to use the GCM's present-day (or more accurately, preindustrial) conditions. This could, for example, limit cases where the LGM is possibly spuriously warmer than the PD due to GCM LGM warm biases. More generally, it seems that for times where the glacial index is closer to 0 (present-day, for example, the frequent glacial interstadials) the signal of GCM forcing is 'diluted' by observations/reanalyses, which adds ambiguity to the main 'sensitivity to GCM forcing' aspect of the study. Can the authors describe in the manuscript how use of GCM PD conditions could increase/decrease the spread of ice sheet conditions in response to different GCM forcing?

Section 2.2: is there a lapse rate correction for temperature, in the case where the ISM elevation differs from the GCM elevation? This would seem to be an important feature to include, and is often included (I think) as part of other standalone ice sheet simulations driven by PDD schemes.

Section 2.2: Does the COSMOS-AWI simulation also use the PMIP3 blended ice sheet LGM reconstruction?

P7L18: . . ."this indicates the abrupt warming in Greenland resulted in negative surface mass balance." It's not clear that this isn't simply a result of the experimental design.

P7L20: "The total ice volume reached it's relative high arount 109kyrBP": it's not clear what this means. Clearly ice volume was much bigger around the LGM.

P7L25: could the authors describe mechanistically why they think neglecting SW/LW radiation would cause less variability relative to the reconstructed sea level?

P7L27: Given that Dansgaard-Oeschger (D-A) cycles recorded in NGRIP were quite possibly driven by ice sheet dynamics, the authors should justify the somewhat circular argument that the PISM response to D-A cycles temperature and precipitation forcing is realistic (since in the real world, D-A cycles were quite possibly a response to ice sheet change, not the reverse).

P8L32/Conclusion #1: The authors shoulds state to what extent similarities between the ice sheet and reconstruction extents at various times (particularly the LGM) relate

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to the strong control the reconstruction has on temperatures, via elevation (as noted earlier in the manuscript) and potentially in lieu of a temperature lapse rate implementation. It seems likely that ice sheet extents are controlled strongly by where temperature increases due to lower elevation, because of reconstructed ice sheet limits.

P10L7: I think the relationship between summer temperature and ice sheet extent should be shown more quantitatively and compared quantitatively against other seasons/precipitation, via regression/correlation methods, to confirm the qualitative conclusions presented thus far. Also, the line contours of temperature could be overlain on ice sheet extent (i.e. figure 9 overlaid on figure 8) to allow readers to see the similarity more clearly.

P11L16: While it is likely that summer SAT is indeed important, the lack of ocean forcing in these experiments is likely a large caveat to the main conclusions. For example, much recent work has highlighted the role of ocean forcing in driving glacial ice sheet variability, yet the simulations presented here do not sample this potential source of climate-driven ice sheet change. This should be clearly noted.

Discussion/Conclusions: an informed discussion on why, exactly, summer temperatures are so different between GCMs would be useful here, to provide more background to the reader (and also to climate modelling groups, as they attempt to calibrate their models for LGM simulations and look for important processes to focus on).

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