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The Cryosphere Discussions

Interactive comment on "Moderate Greenland ice sheet melt during the last interglacial constrained by present-day observations and paleo ice core reconstructions" *by* P. M. Langebroek and K. H. Nisancioglu

Anonymous Referee #2

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Understanding the stability of the Greenland Ice Sheet (GrIS) during higher than present temperatures is essential, in particular for deriving better projections of future ice sheet mass loss. The reconstruction of the extent and volume of the GrIS during the Last Interglacial period (LIG) has remained a challenge. Significant differences in published results are attributed to differences in applied climate forcing and the methods for coupling the ice sheet and the climate models.

This study adds to the growing literature of ice sheet melt and sea-level contribution reconstructions from Greenland Ice Sheet melt during the LIG. However, it does not

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offer an improvement over previous estimates because of the limitations of the applied methodology. The approach employs SICOPOLIS, a thermomechanically coupled ice sheet model using the Shallow Ice Approximation (SIA) and the Norwegian Earth System Model (NorESM) without fully coupling the two components. Ice sheet melt is estimated using PDD modeling with temperatures adjusted to elevation changes by using spatially and temporarily constant lapse rates.

Although widely used for investigating ice sheet evolution in millennial to multi-million year time scales, the approach has several caveats. Most importantly, PDD factors of snow and ice are not constant in space and time and therefore the PDD method has a poor performance for reconstructing of melt-rate histories. Instead of the PDD method, the authors should have used one of the more realistic and accurate approaches. Such methods do exist, including the insolation-temperature-melt model from Robinson et al., (2011) or the SMB gradient method, introduced by Helsen et al. (Helsen et al., 2012, Coupling of climate models and ice sheet models by surface mass balance gradients: application to the Greenland Ice Sheet. The Cryosphere, 6(2), 255–272. http://doi.org/10.5194/tc-6-255-2012).

Another main limitation of the study is that rather than evolving the ice sheet surface with the changing climate, the present-day ice sheet topography is used for the climate simulation. Relatively high elevations during the LIG likely cause an underestimation of the warming in the LIG, which could result in low estimates of ice loss. The authors dismiss the potential for performing a fully coupled model experiment as computationally too expensive at the present. However, this challenge is no longer prohibitive, as demonstrated by the first coupled ice sheet/climate model, which is currently in discussion in Past Climate (Goelzer, H., Huybrechts, P., Loutre, M. F., & Fichefet, T. (2016). Last Interglacial climate and sea-level evolution from a coupled ice sheet-climate model. Climate of the Past Discussions, 0, 1–34. http://doi.org/10.5194/cp-2015-175).

The authors argue that by using present-day observations and paleo ice core reconstructions to evaluate a range of model results corresponding to different parameter selection (basal sliding, PDD factors and lapse rate) they could obtain a robust estimate of LIG GrIS lost, despite the significant model simplifications. However, this appears to be contradicted by the fact that using the same methodology with similar parameterization but a different climate model that features warmer sea and air temperatures in N Greenland, Born and Nisancioglu (2012) have obtained a completely different pattern of LIG mass loss during the LIG with a strong ice sheet retreat in NE Greenland.

Detailed remarks: Page 2, lines 15-19: the ice penetrating radar mapping only detect the ice that is still present. However, Eemian ice could have thinned and melted in southern Greenland and therefore no longer present.

Page 5, lines 3-9: The modification of the global heatflux estimate from Pollack et al., 1993 by Greve (2005) results in an improved match of basal temperatures measured in the boreholes, but still provides an unrealistic distribution of geothermal heatflow. Rogozhina et al. (Rogozhina, I., Hagedoorn, J. M., Martinec, Z., Fleming, K., Soucek, O., Greve, R., & Thomas, M. (2012). Effects of uncertainties in the geothermal heat flux distribution on the Greenland Ice Sheet: An assessment of existing heat flow models. Journal of Geophysical Research, 117(F2), F02025. http://doi.org/10.1029/2011JF002098) have shown a spatially uniform geothermal heatflow distribution provides the best fit to the borehole temperature observations.

Page 5, lines 12-22: using the techniques mentioned above (ITM or SMB gradient) instead of PDD would eliminate the need of relying on the traditional lapse rate assumptions, thus improve the estimate of surface melt

Page 5, lines 22-25: what is the source of this particular parameterization – please include reference

Page 7, lines 7-12: the motivation of varying the basal sliding parameter is not clear. I assume that the defaults SICOPOLIS value was selected to provide a good match

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for the PI GrIS. The basal sliding parameter, which is usually inferred by parameter assimilation, varies spatially and temporarily. It is not clear what improvement is offered by employing different, constant basal sliding parameters.

MacGregor et al., 2015 reference is missing

Figure 2: why not using ERA-interim or an observation-based reconstruction (e.g., Bales, R. C., McConnell, J. R., Mosley-Thompson, E., & Csatho, B. (2001). Accumulation over the Greenland ice sheet from historical and recent records. Journal of Geophysical Research: Atmospheres (1984–2012), 106(D24), 33813–33825. http://doi.org/10.1029/2001JD900153)

Figure 3: why is the surface elevation in NorESM-L compared to ETOPO1? ETOPO is not used in the study – should it be Bamber et al., 2013?

Figure 5: Units of PDD factors should be added

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