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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 #1

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The authors present a study of the evolution of the Greenland Ice Sheet (GIS) during the Last Interglacial (LIG), using time slices from the GCM NorESM and ice model SICOPOLIS and select the most suitable model outcome using extend and local elevation constraints from ice core data.

I firstly make my apologies for the long time I've needed to complete this review, and secondly make my apologies that I'm not very positive concerning the research presented. The authors use the PDD (positive degree day) method, which is not applicable here, and the results present never look that realistic that it earns some reliability. The latter (an ice sheet glued to the Arctic Ocean) could be bad luck, but using the PDD is a method flaw that could have been avoided. To my opinion the results presented in this manuscript does not provide any new information on the LIG climate, LIG GIS extend or the GIS sensitivity to climate change, nor in how we could tackle this problem.

In the cryospheric community, we are generally kind, but by using a method (PDD) that is unsuitable, it leaves me with no other option that to advise the editor to reject this manuscript unless the authors redo the ice model simulations using an ITM method to derive melt rates from the GCM output.

Primary concerns

Experiment setup: PDD

As the authors know, the PDD is the traditional “way out” if someone has no surface energy balance (SEB) data to estimate melt and runoff. It does work after careful tuning – yes I know - if cloud and insolation characteristics remain similar. Hence, it works for each glacier individually for time scales up to a few centuries. For multi-millennia simulations over the entire GIS the assumption of two constant PDD factors for snow and ice does not hold, neither spatially nor in time. Bluntly said, as PDD is not valid here, it should not have been used. Period. And as melt is the key process that drives the evolution of the GIS during the LIG, it’s lethal for this manuscript.

The (for me obvious) method to use is the an Insolation-Temperature Method (ITM, e.q. Robison et al, 2011, Climate of the Past) which explicitly includes insolation into the derivation of melt/runoff. And also an ITM allows tuning until the model results start to resemble past and current GIS states. Honestly, I can’t understand why the authors did not take the effort to implement this. It is not complicated, neither state of the art. A state of the art approach would be a method like presented in Vizcaino and others, J.Clim., 2013. There is no longer an excuse for using PDD.

Model performance of PI & LIG climate

Figure 6a and b does not give a very affirming feeling that the NorESM & SICOPOLIS combination can realistically model the GIS. The figures show that the model let the pre-industrial (PI) ice sheet grow until it meets the shore. (As SICOPOLIS does not model ice shelves, it can't grow into the sea but if it could, it even might have grown on the continental shelf). Figure 6ab says me that melt and runoff are largely underestimated for the default settings.

As thus calving is determining current shape, it unclear how much additional warming is needed before the ablation becomes strong enough to push the ice sheet from the shore. As the authors show in figure 9, this happens first and only along the south-western margin, but never in the North. One may doubt if the results of Fyke 2011 are the most realistic LIG retreat evolution presented so far, but a GIS that firmly stick to the northern shore of Greenland throughout the whole LIG is a clear indication that the presented model isn't providing a realistic evolution estimate.

I know, the authors discuss this on p12, but that makes the results not trustworthier.

Other (major) comments

Section 3.1

- As also commented at figure 2 (see below), the authors are complaining about something that can be resolved. Correct NorESM temperatures for the topographic differences and now one can discuss whether SICOPOLUS get correct temperatures or not. My feeling: NorESM is too cold, but how much colder was

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Discussion paper

PI compared to now. By the way, why using ERA40 if we have ERA-Interim? And which period of ERA40 is used?

- What actually done for downscaled (=20 km) land points outside the NorESM land domain?
- The authors entirely neglect to evaluate runoff – in this study modeled melt – and hence the SMB. Add the modeled downscaled SMB for the present day topography (using default PDD/ITM settings) in Figure 2 and compare this with an estimate from MAR, RACMO or another state-of-the-art model/observational estimate and discuss, including an estimation of the PI-to-now difference of the GIS SMB.
- Also for the LIG slides, add downscaled modeled SMB using the present day topography. It is maybe better to show for each time slice the downscaled SMB instead of the difference compared to the downscaled SMB for PI. After this improvement the reader has a clue what to expect from the LIG forcing on the GIS (P9 L27-28).

Other sections

P4 L2: Which specific CESM version was branched for NorESM?

P10 L15: As the GIS reaches the coast where it shouldn't it is not (only) due to insufficient calving, but also due to insufficient melting. And for the latter the authors can't excuse by saying "it's SIA".

S3.3: State that this will be discussed in S4.3. The section raises comments which are partly addressed there.

S3.4: See above

S4.1.1 Comparing surface temperatures is senseless if topographies are very different. It is not stated in the manuscript if such a correction is applied; therefore, it is hard to compare various methods.

Besides, the section does not – at least for me – provide a clear conclusion what the analysis say about the results presented in this manuscript.

S4.1.3: The authors suggest that the only method to feed back the shrinking ice sheet into the GCM is through fully coupled simulations. There is, of course, a middle road, namely GCM time slice runs using update topography (e.g. Helsen et al, 2013 did using a RCM).

S4.3: Besides that the GIS extended well up to continental shelf, it also connected with the Laurentide Ice Sheet across Nares Strait. LIG ice sheet presented here is thus likely too small.

What remains unclear: how does this affect the results presented?

P16 L15: As we are quite certain that the preLIG GIS extended on the continental shelf and the LIG GIS extend is also quite bound by sea-level rise proxies and ice core data, the logical conclusion is that it melted thus faster during LIG than the melt rates now required to get to a logical LIG minimum from a too small preLIG GIS. The authors should doubt what they tune (melt rate) not to what they tune to (GIS extent).

F2: This figure must be improved substantially. In the current version it is not clear how the land/sea distribution in NorESM was and the comparison to ERA40 is obstructed by the elevation difference. Furthermore, which temperature is shown? Is it 2m temperature or surface temperature? My suggestion: Left row: use NorESM land/sea mask and remove interpolation (ncl: @cnFillMode = "RasterFill"). Right row: difference with ERA40 after correction for elevation difference using the default lapse rate. The authors now can use a higher-resolution land-sea mask as is done now.

F3: Again, a figure that should have been much clearer. I think, however, that this plot is not needed after all. The authors should add elevation contours to figure 2 (NorESM elevation in the left row, true elevation in the right row) and remove this figure. Furthermore, include the ice sheet outline in NorESM if different from the land/sea mask.

F4: again, use the NorESM land/sea mask and include the NorESM topography and ice sheet extend.

F5: In the case that this figure stays, it should be improved. The figure is unclear on the result for varying PDD factor combinations. Solved this by using (exclusively) red, blue and green for the three PDD snow factors and a horizontal displacement (as in the legend) to distinguish the different PDD ice factors.

F12, F13: Temperature differences are meaningless unless it is clear what the elevation difference is.

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