Climate of the Past Discussions

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Comment on cp-2022-70

Anonymous Referee #1

Referee comment on "Modelling feedbacks between the Northern Hemisphere ice sheets and climate during the last glacial cycle" by Meike D. W. Scherrenberg et al., Clim. Past Discuss., https://doi.org/10.5194/cp-2022-70-RC1, 2022

General comments

Scherrenberg et al. Use an ice sheet model to simulate the ice sheet evolution of the Northern Hemisphere ice sheets through the last glacial cycle. To force their ice sheet model they use two climatic snapshots from the PMIP ensemble (LGM and PI). To interpolate temporally the climate fields needed by the ice sheet model they use two methods: a classical glacial index (based on CO2) and a more sophisticated climate forcing (matrix in the text) method which also takes into account insolation and that includes a simple parametrisation of albedo and precipitation change. They show that the uncertainties related to differences amongst GCMs are larger than the ones due to temporal interpolation method. To my knowledge such a comparison of these methods is novel and is of interest for the community. I have a few minor comments listed below.

- Matrix method and snapshots used.
The authors define as a matrix method a climate interpolation between only two snapshots. It is in fact a very minimal version of the matrix. I believe that a proper matrix method should use more snapshots (Pollard, 2010; Abe-Ouchi et al., 2013; Ladant et al., 2014). With only two snapshots your ice sheet evolution can be very much constrained by the extent of the reconstructed ice sheet at the LGM. Perhaps you should replace the term "matrix" here or better list the limitations of the approach followed here.
For example, an interesting feature of the matrix method is to cover a range of possible ice sheet extent, CO2 and insolation. Here you have a very minimal version of the matrix. Ice sheet extent and CO2 are both extremes in the matrix. But much lower insolation (or larger) is not really explored (while it could be of importance). There are only few GCM simulations of MIS3 or MIS4 but perhaps you could have used the PMIP-lig127k experiment to increase the size of your matrix? You should add a discussion on what would be the benefit of having other snapshots covering the last glacial cycle.
Perhaps some of the discrepancy regarding the temporal evolution of the ice sheets through the last glacial cycle?
I think that all this should be better acknowledged somewhere in the manuscript.

- model of intermediate complexity.
There is an wide literature on ice sheet – climate coupling using climate model of intermediate complexity, which is very relevant for the topic addressed here. At present in the manuscript only GCMs (forced or coupled) are discussed. Elements on intermediate complexity model approaches should appear in the introduction as well as in the discussion. Although simpler than GCMs in their physics, the intermediate complexity model can explicitly represent ice sheet climate interactions instead of using parametrisation as in here.

- ice sheet – climate feedbacks.
There is an oversimplification in the manuscript when it is stated that the climate "matrix" is able to take into account the ice sheet – climate feedbacks. From my understanding the climate matrix interpolation method improves the glacial index method on two points: a simple way to account for different albedos / insolation and a more clever way to parametrise the precipitation correction. Ice sheet – climate feedbacks are more complex. For instance the geometry of the ice sheet will affect the precipitation/temperature patterns not only due to height changes but also due to atmospheric circulation changes. Here only two geometries are used (LGM and PI) and intermediate ice sheet sizes or alternative geometries cannot be taken into account. Also, an other major ice sheet – climate feedbacks is the melt freshwater release into the ocean and its impact on oceanic circulation. This is completely ignored by the climate matrix method (also because the PMIP GCMs do not explore this neither).
That being said, I think that the climate matrix as presented is a nice alternative to the index method but the authors might rephrase the manuscript in some places (e.g. l.18, section 3.2, l.284).

- Ice sheet – ocean interactions.
There is very little info to the way ocean forcing is treated here (only a reference to de Boer paper). And the authors do not invoke oceanic circulation changes in shaping the last glacial cycle while they were probably critical. Do you have noticeable differences in terms of sub-shelf melt through the glacial cycle? Does the model is sensitive to these changes? A dedicated section could be welcome.

- Grids.
The different ice sheets are fully disconnected here, while there could be some interactions between the Innuitian ice sheet with the Greenland ice sheet. Also there could be an ice shelf in the Baffin Bay affecting the North American ice dynamics. Have you tried to include such interactions? It might deserve a discussion at some point.
A minor thing: the North American grid seem too small, for example MIROC-ESM is cut in the South. It is not too bad here since, except for MIROC-ESM, all your climate forcing produces smaller ice sheet than the reconstructions.

- Minimal version of albedo.
The background albedos are tunable but close to what we expect but how the two critical parameters (set here to 15 and 0.015) have been selected (Eq. 2, l. 321)? Could you show a map of the albedo from RACMO and from the parametrisation to see how the formulation performs? Such a comparison with a timeseries for a grid point in the ablation area could be also very nice.

- Climate matrix parameters.
Please justify the use of different methodology / weighing factors for the different ice sheets (l. 160-161 and l. 415-420). Explain the choice of the different weighing factors (l. 415-420).

- Ice sheets too thick.
Can you comment on the respective role of climate forcing and basal drag to explain this bias?

Specific comments

l. 30-31 and 35: the ice sheets respond on multi-millenial timescales but they can show abrupt changes as well (marine ice sheet instabilities, saddle-collapse,...). Please rephrase here.

l. 38-39: ice thickness and extent are NOT known over "millions of years"… eventually eustatic sea level is known to a certain degree… Please rephrase.

l. 86: "the LGM"

l. 130: Even though the albedo and topography changes are expected to be smaller for the Antarctic ice sheet with respect to the Northern Hemisphere ice sheets, changes there can strongly affect the Atlantic meridional overturning circulation (deep water formation), hence Northern Hemisphere climate. Add a sentence on this here.

l. 160: Greenland spatial resolution is higher so the model can see some change in topography. Please justify better why you do not follow the same protocol for this ice sheet.

l. 177: problem with the sentence.

l. 215-220: Sub-shelf melt / oceanic biases can be a reason for the Eurasian ice sheet

bias?

l. 225-230: Basal drag vs. precipitation bias?