Review of: Climate and ice sheet evolutions from the last glacial maximum to the pre-industrial period with an ice sheet – climate coupled model by Quiquet *et al*

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1 Overview

Quiquet *et al.* present the results of a fully coupled ice sheet-climate model applied to the deglaciation of the Northern Hemisphere ice sheets from the Last Glacial Maximum. They use a climate model of intermediate complexity to couple in a bi-directional manner. Impressively, this is done at a very high frequency, with 5 years of ice sheet model for ever one year of simulated climate. The coupled model run produces a satisfactory representation of the deglaciation. One of the major findings is that the gradual input of freshwater in the ocean causes a shutdown of the AMOC. In some of their additional tests, they find that the AMOC does not shut down without this freshwater input. Other experiments showed only weak dependence on parameters related to surface and subglacial processes.

Overall, I enjoyed reading this paper, and found that it was well written. The experimental setup was well described (though note some of my comments below), and the implications for the ice sheet collapse on the overall climate was thorough. My comments below are mainly related to some parts of the modelling that should be elaborated a bit, and I do not think additional experiments are necessary. Therefore, I recommend relatively minor corrections.

2 Comments

2.1 Computational overhead

I am particularly impressed by 5/1 ratio of ice sheet to climate model years in this coupled setup. My question, though, is what is the computational costs of this model setup? If there is relatively low cost, then perhaps it could easily be adopted by other groups to investigate other problems, so this would be a good way to sell it.

2.2 Ice sheet model resolution

Perhaps as part of the last point, I am curious as to why an ice sheet model resolution of 40 km is used. Is this a computational limitation? In experiments done by our group here at the Alfred Wegener Institute, we found that the trajectory of the ice sheet evolution can be radically different just by going from 40 km to 20 km resolution. In general, the computational expense of ice sheet models tends to be pretty low compared to climate models, so I think some discussion on this choice needs to be made.

2.3 Glacial isostatic adjustment

The GIA model used for the experiments is not described, so I would ask that this be added. Looking at Figure 9, the topography is depressed far more than in reality, which causes broad glacial lakes to form along the southern margin that are much bigger than during the actual deglaciation. This is one of the possible reasons (or even the main reason) that deglaciation was faster than expected.

2.4 Sediment thickness for basal sliding

I don't understand why the Laske and Masters (1997) dataset was used to parameterize sediment distribution. That dataset is a map of Phanerozoic, undeformed sedimentary rock thickness for use in global seismology problems, and is vastly different to the distribution of unconsolidated sediments that would be important for ice sheet sliding. There are places with sedimentary bedrock where there are no unconsolidated sediments (for instance in Ontario and central Manitoba), and there are places on the Precambrian Shield where there are thick unconsolidated sediments (for instance the Thelon Basin in Kivalliq). As a first order approximation, I guess you could assume that areas where the bedrock is Phanerozoic sedimentary rocks are more likely to be covered by unconsolidated sediment, so I don't think it would radically alter the results. However, I suggest in the future that a different dataset be used. Full disclosure, I have created such a dataset for North America (Gowan et al., 2019).

2.5 Spinup time

A 200 kyr spinup is used to initialize the ice sheet to the LGM state. I'm wondering why such a long spinup was necessary, considering that during the last interglacial (about 100 kyr before the LGM), there were essentially no ice sheets in the Northern Hemisphere except for perhaps part of the Greenland Ice Sheet. Even the Eurasian Ice Sheets were probably almost non-existent just 15 kyr before the LGM (Hughes et al., 2016). Would such a long spinup affect the results?

2.6 Comparison with geological data

There is a section that compares the modeled results with some ice sheet reconstructions. I think this is fine, but don't feel too bad that you don't match things exactly, since the margin chronology in North America is in the process of being revised (Dalton et al., 2020). In some places the timing of advance and retreat is being revised by thousands of years. In particular, I would say that the 20.5 ka timing of your maximum ice extent is actually closer to observations than what is presented in these reconstructions (for instance, the maximum of the western half of the Laurentide ice sheet was achieved around that time Jackson et al. (2011); Lacelle et al. (2013)).

One thing that might be interesting to look at more is the causes of more major discrepancies in the model from geological observations. There are three main things that I would like to see comments on. I am guessing that these discrepancies are likely the result of biases in the climate model, but it would be interesting to know more.

1) The Northwestern part of the Laurentide Ice Sheet, which covered Banks and Victoria islands, was one of the first places to deglaciate, but in your model it remains ice covered until after 8 ka.

2) An ice cap persists on the outer parts of the Grand Banks at the end of your simulation, a place that probably wasn't even glaciated during the MIS 2 glaciation. This seems like an odd place for an ice cap, considering it is below sea level and surrounded at all sides by the ocean.

3) Iceland remains ice covered through to the end of the simulation.

Best Regards,
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