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Climate of the Past Discussions



# *Interactive comment on* "Modelling large-scale ice-sheet–climate interactions following glacial inception" *by* J. M. Gregory et al.

**Anonymous Referee #2**

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Review of the manuscript ÂńModelling large-scale ice-sheet-climate interactions following the glacial inceptionÂż

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General comment:

In this paper, the authors promotes the coupling between the AOGCM FAMOUS and the Glimmer ice sheet models and the ability of this coupling to reproduce the last glacial inception. Results obtained are not new but are in good agreement with geological evidence since they obtain some ice caps growing over the Canadian Archipelago and over the Scandinavian mountain range. However, this study presents several drawbacks and limits that are in my opinion, not clearly discussed in this work.



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Interactive Discussion

Discussion Paper

the author performed some ÂńsimultaneousÂż and ÂńasynchronousÂż simulations. They conclude that the asynchronous way is also very satisfying in the case of glacial inception. I don't understand then what is the advantage here to interactively couple the ice sheet model to the AOGCM.

- It is not clear to me what is the point of setting the GHGs values for inception experiments to pre-industrial values since precipitations should be affected over the high latitudes by the use of different GHGs. In that context, it is difficult to discuss the amount of ice volume simulated in the various experiments. what is the sensitivity of your simulations to lower GHGs?

- Since the Glimmer grids are restricted to some particular areas, I think it is very difficult to state, as for example in the Abstract, that the Laurentide ice sheet started to grow over the Canadian Archipelago. As you wrote in the discussion, the Rockies, the Cascades and the Alaska are also other possible areas of inception in North America. And as shown by several studies and for example Charbit et al. (2002), it is highly GCM dependent. You should also discuss more the choice of Âńregional ISM gridsÂż with respect to a Northern Hemisphere grid. Since your models combination seems to be only little demanding in terms of computational resources. What will be the costs using a Northern Hemisphere grid? The use of regional grid makes very difficult the discussion of the ability of your coupled models to reproduce the inception. Since Glimmer turns all the precipitation into snow, some ice caps are likely to develop over eastern Siberia, which in reality should not be the case (based on geological evidence).

- In this paper, the ISM is not coupled with ocean. I think that accounting for the sea-level drop and then changing the landsea mask could also help for the development of the grounded ice sheets since in the inception areas, the continental shelves are very shallow and should be in some particular points emerged during the inception.

Finally the main drawback to my sense is the absence of ice shelf dynamics in Glimmer which stops from a realistic simulation of the last glacial inception. Indeed, it has been



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shown that the Eurasian Arctic Islands are also considered as nucleus sites for the last glacial inception together with the Scandinavian mountain range. A simple estimates of the ice volume distribution over the Eurasian Last glacial Maximum component shows that at least 50% is located over the shallow continental shelfs in the Arctic Ocean.

To conclude, the paper is well structured and written but it would benefit from more explanations regarding the initial configuration choices and parameters of the ice-sheet model as well as the main strengths of the coupling between FAMOUS and Glimmer. This paper is well suited for Climate of the Past and I recommend it for publication after some moderate revisions.

Major comments: ————

page 175 - lines 1-3: I think you should refine those statements in something like: Âń...global-mean quantities cannot predict glacial inception without a significant drop in GHGs combined to a decrease in insolation in our model.Âż I think you obtain a slightly warmer climate at 115k because of the perihelion date which is slightly more favourable to pre-industrial climate and because you don't adjust to 115k GHGs values. It is not clear to me why you chose to setup your glacial inception simulations using pre-industrial GHGs. What was your strategy? Because the fact that your model do not develop a perennial snow cover along the Arctic margin at 115k cannot be analysed as a real bug of the model... What about the perennial snow cover under 115k GHGs values?

page 175 - line 13-18: Ok, but is the global mean SAT in the high resolution version of the model still warmer than in the pre-industrial control run? What is the effect of the spatial resolution?

page 175 - line 19-21: is it not inconsistent with the fact that some ice develop in Glimmer although no perennial snow cover is simulated by the GCM? At the end of the coupled Glimmer-FAMOUS experiments, do you get some perennial snow in FAMOUS?



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page 175 - 176 - first paragraph: I think the fact that no ice shelves can spread over the Arctic marine shallow continental shelf is a big drawback for glacial inception, which at least for the last glacial inception, mainly started over the Arctic island of Svalbard etc...

page 176 - lines 9-19: Why did you considered two separate grids? It has been shown that the planetary wave are affected by the changes in topography. Don't you think that it could influence the growth of the ice over the Eurasian part? Then, why did you restricted your grid over western Eurasia? In may ISM, ice sheets also develop over Eastern Siberia which is a proof that the mass balance scheme is not producing some realistic results for the inception. Moreover, it is not because no perennial snow develop in GCM that the ISM will not grow some ice sheets. It depends on the PDD scheme in the ISM. It is also interesting to include the Greenland ice sheet in the paleo-ISM simulations to see how stable is the coupling.

page 176 - line 19: Why did you switch off the isostatic adjustment? If the ice is not very thick, maybe it can be neglected. However, in you case, you develop lost of very thick ice as for e.g. in the 1:100 experiments, twice Greenland ice sheet is accumulated. what is the effect of rebound in your case?

page 177 - line 7: How did you chose the lapse rate value? According to Abe-Ouchi et al. (2007) and Bonelli et al. (2009) for example, the laspe rate for the inception over NA and Eurasia has been found to be around 5C/km. 8°C/km corresponds to an already built-up ice sheet that have a large albedo and temperature influence on the above atmosphere like in central Antarctic and Greenland (Krinner et al. 2003). One question is: what is the effect of the lapse rate on the inception in your coupled simulations?

page 181 - lines 9-11: Well then, what is the real difference with iterating a stand-alone AOGCM with a stand-alone ISM offline each 500 yr? What are the strengths of your coupling approach in that case?

page 181 - lines 13-2: I am not sure to understand the point of your comparison with



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present.day continental Arctic cryosphere. To my point of view, you cannot use that comparison. Radic and Hock (2010) compared glaciers mass balance resulting from the entire last glacial cycle climate evolution including pre-industrial period and present-day anthropogenic period. In your work, you simulated instead pre-industrial using some fixed GHG values. I think you should test your coupling sensitivity to lower GHG values to see how it impact son the high latitudes mass balance.

page 182 - lines 10-13: I am not sure to agree with that statement. The main problems with the actual models are the incapability of simulating transient states from warm to cold or from cold to warm climates. I think on the contrary the fact that a model is not able to simulate a correct glacial cycle inception is not a failure. It just points out that maybe we need to revise some bases of our modelling schemes in the GCMs to make them more flexible to various climate states. That is one of the main challenge for the next decades.

page 183 - lines 4-14: Maybe there is an underestimated ice volume because Glimmer cannot grow ice shelves which greatly limits the overall ice dynamics and the thickening process, especially between the Ellesmere Islands and Greenland.

page 185 - lines 20-22: In any case, it is very difficult to interpret the heat transport precisely since it is model and resolution dependent.

page 191 - lines 1-3: Yes but some EMICs already have the ice shelves dynamics implemented which is really important for the Northern Hemisphere ice sheets growth and they are, in a sense, more evolved than your combination since they do represents the evolution of several glacial cycles accounting also for vegetation feedbacks which is also important for the inception. It depends on what your are looking at. If your goal is to reproduce inceptions, then you only need the elevation and ice-albedo feedbacks as well as the vegetation feedback. If you need to couple with ocean, which is not the case of your coupling here, you need to have a precise representation of the processes at the ice-sheets margins for example which requires in those cases a more refined physical



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model. Besides, you did not account for 115k GHGs values, which are much lower than during pre-industrial and may have also reduced precipitation in FAMOUS by further cooling the climate in the high latitudes and you also consider that precipitation = snow which enhance the PDD scheme in Glimmer.

Minor comments: ————————-

page 171 - line 5: I would add a comma after (SMB)

page 171 - line 18: the start of the ice-sheet growth in the Northern Hemisphere

page 171 - line 21: following the last glacial inception

page 176 - line 22: is a annual positive degree-day scheme (PDD)

page 176 - line 11-13: Have you try to force Glimmer with the snow field instead? Don't you think that you overestimate the quantity of ice that will be formed effectively?

page 182 - lines 1-3: What about the effect of spatial resolution? (see Vavrus et al. 2011)

pages 184 - line 11: Âńtends to reduceÂż remove the s at the end of ÂńreduceÂż

page 185 - line 27: Âńthere is a warmingÂż. is that what you wanted to write?

page 190 - line 26: it should be written this way already in page 176, line 22.

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Interactive comment on Clim. Past Discuss., 8, 169, 2012.