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Climate of the Past Discussions

Interactive comment on "The impact of early Holocene Arctic Shelf flooding on climate in an atmosphere–ocean–sea–ice model" *by* M. Blaschek and H. Renssen

Anonymous Referee #2

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In their manuscript *The impact of early Holocene Arctic Shelf flooding on climate in an atmosphere–ocean–sea–ice model*, M. Blaschek and H. Renssen address the influence of the shelf flooding during the early Holocene on the ocean circulation and climate. They use the EMIC LOVECLIM in experiments with different shelf geometries and with and without the influence of melting ice sheets. They come to the result that the flooding of the shelves results in an increase in sea ice production in the Arctic Ocean and to a Nordic seas cooling although the sea-ice export through Fram Strait is reduced. They find a change in the strength of the polar vortex and in the wind systems as responsible for the cooling of the Nordic seas.

The topic clearly fits the scope of this journal and is of relevance to understanding the

processes during the last deglaciation. I am not aware of previously published studies explicitly addressing the shelf flooding effect. There are studies with more advanced models (e. g. Singarayer and Valdes (2010); Smith and Gregory (2012)) that include this period, but do not focus on the explicit effect of the shelf flooding. Thus, there is a clear gap in pre-existing knowledge that is addressed by this study.

LOVECLIM contains a coarse resolution ocean general circulation model with a sea ice model, 3-layer coarse resolution atmospheric model with prescribed cloud cover, and a land surface component. The model seems suitable to study the ocean response to these changes. I would be very careful with interpreting the atmospheric effects. I am not an expert on atmospheric circulation, but the large-scale features and changes seem to be plausible.

The setups isolate the effect of the flooding of the arctic shelves. They do seem to ignore the effects of the rising sea level on the worldwide ocean bathymetry, including the Greenland-Scotland ridge, that is crucial for the Nordic Seas overflows. This limits the scope of the study to the explicit effect of the shelf flooding, and reduces the comparability with geological evidence.

The paper is well-structured and generally well-written. The discussion is very difficult to follow and should be extended by a discussion of the capabilities of the model relevant to the analysis performed. All in all, I consider the study **clearly worth publishing** after addressing some issues in the text. I therefore recommend **major revisions**.

Specific comments:
Section 3.1.1:
Please also mention the sea ice export in the comparison of the model with observations. It is one of the key quantities analyzed in the publication, and seems to be off substantially.

Please compare the spatial distribution of the sea ice production with the present day

values given in the introduction. The influence of the shelves on the sea ice production is of key importance in this publication so a comparison of the modeled present-day values with the presented observations would help putting the results into perspective.

Section 3.1.2:
How much does which shelf contribute to the sea ice production in 9kOG? Do these contributions match with the changes in Arctic ocean sea ice production obtained in the experiments with (individual) dry shelves?

Section 3.2:
p. 4202 lines 17ff. *The shift in convection results in cooler and fresher surface waters near the Denmark Strait (Fig. 5d-f) and along the EGC as far north as Fram Strait (Fig. 5a-c), because of more sea-ice cover and increased sea-ice melting.* Please split this more clearly into effects in the north and in the south. From the current wording, it seems as if a southward shift in deep convection areas would lead to increased sea ice melting in the EGC near Fram Strait.

Section 3.3.1:
As stated above, I have limited trust in the capabilities of a 3-layer atmosphere model. Therefore a few words on how well the present-day simulations represent the features analyzed at 9ka would be helpful for putting the results into perspective.

Is there a substantial difference in cloud cover over the ocean areas in the Arctic and over the adjacent land? How do the prescribed clouds affect the modeled climate in the dry-shelf experiments? (might be part of the discussion)

A mention of the differences (or similarities) between the experiments with and without ice sheet melt (presented in figure 7) would be interesting.

Section 3.3.3:
On page 4205 lines 9ff. you state *However, it should be noted that our model has a low spatial resolution leading to a biased atmospheric circulation over the Arctic (Goosse*

et al., 2003; Goosse and Renssen, 2001). Please mention this in section 3.1.1 where you discuss the atmospheric changes and explain in which way you expect this bias to affect your results (the effect might also be part of the discussion, the problem should be mentioned in 3.3.1).

Section 4:
In the comparison of modeled effects and proxies a few words on the effects of the general trends in background climate and deeper ocean bathymetry on the climatic features compared would be helpful.

On page 4207 lines 19ff. the modeled changes in sea-ice cover in the East Greenland Current are compared with proxy data from the northern Fram Strait. A comparison of data from the same location/region would probably be more enlightening.

On page 4207 lines 26ff. the almost complete summer-melt of the sea-ice cover in the 9kaOG scenario is commented on. While this plausible because of the summer warming, it should be considered that the present-day simulations substantially underestimate the summer sea ice volume.

Section 5:
On page 4209 lines 1f it is stated that the decrease in Fram Strait Sea ice export (9kOG vs. 9kOGSIB) is not statistically significant. Is this referring to page 4202 lines 1f? Is this really not significant when comparing 100-year averages? If it is not significant, the abstract should be adopted to reflect this.

minor issues and technical comments:
p. 4199 lines 9f. please use the same units for the LIS and the GIS melt.
p. 4200 line 8 please state explicitly by how much the sea ice volume is underestimated in PRE2005
page 4202 lines 9f seem to largely contain a repetition of lines 5–7.
table 2: please include the PRE2005 experiment

figures in general: Please make sure a) b) c) ... are easy to find in all of the figures.
figure 1: The stars (especially green and purple) are very hard to find on the map. Please make this easier.
figure 7: This figure contains a lot of information, but is extremely hard to read. It is difficult to distinguish the different strengths of color and shading. Would contour lines instead of gray shades work for the absolute values? I did use a decent printer but the streamlines in (c) are almost completely lost in the printout and need substantial magnification on the screen.

References

Joy S Singarayer and Paul J Valdes. High-latitude climate sensitivity to ice-sheet forcing over the last 120 kyr. *Quaternary Science Reviews*, 29(1-2):43–55, 2010. ISSN 0277-3791. doi: 10.1016/j.quascirev.2009.10.011.

R S Smith and J Gregory. The last glacial cycle: Transient simulations with an AOGCM. *Climate Dynamics*, 38(7-8):1545–1559, 2012. ISSN 09307575 (ISSN). doi: 10.1007/s00382-011-1283-y.

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