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Interactive comment on "How do icebergs affect the Greenland ice sheet under pre-industrial conditions? – A model study with a fully coupled ice sheet–climate model" *by* M. Bügelmayer et al.

Anonymous Referee #2

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The authors present a study describing the impact of various different treatments of iceberg water and latent heat release on the climate and the Greenland Ice Sheet. They show that, under a preindustrial climate, the details of how freshwater from icebergs enters the ocean has less impact on the climate/ice sheet than the treatment of latent heat.

They present interesting results that are not only interesting for those interested in modelling icebergs but also interesting to climate modellers concerned with correctly treating ice sheet – ocean coupling.

There are many details in the analysis of the model results that need clarification, and the model run descriptions are lacking. The figures are far from clear and many need a new colour scheme to make them understandable. The manuscript also needs some serious copy editing, much of the discussion/explanation of results is extremely hard to follow. However, the underlying science appears sound, it could just be better presented.

Major Concerns.

The details of the various model set ups are not sufficiently well described. In particular I do not understand the details of the CTRL experiment at all. A reference to Roche et al. 2013 is insufficient here as understanding the model set up is crucial to the whole of this manuscript. In particular how are freshwater and latent heat treated in CTRL. The description of the model seems to suggest that no water flux is used yet the text repeatedly hints that there is some water flux.

How does the model compute the surface mass balance?

How well do the various ice sheets compare to the observations?

Figures – The blue-green-red colour scheme is, for numerous reasons, an appalling choice and should always be avoided. It is especially useless in most of the figures in this manuscript because there are large areas where the anomalies are near zero, of no interest, yet their colours dominate the figures. The divergent Brewer colour schemes, which go through white, are a far better choice (http://colorbrewer2.org/) and versions of these are available for most plotting software. The figure captions should indicate where the colour schemes are non linear.

The order of the figures in the text appears to be almost random. For example why are the figures for section 3.3.3 (CALV-FWFc) numbered 5 and 12? Having them on adjacent pages would make it far easier to follow the text and figures without excessive scrolling.

Specifics

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195-19 – Runoff, does this mean calving? Runoff to me means liquid water flowing off the icesheet, it does not refer to solid ice.

197-25 – Describe this simluation better. How is water treated in this experiment?

199-24 – I do not have a fig 4(c).

200-3(on) – please refer to the relevant figures

I do not understand the chain of causality in the description of this experiment. As I see it, Fig 10(a) shows a small change in the albedo in the regions where the sea ice expands, but the largest change >5% is located over the land, indeed the 5% contour seems to trace the model's coast line. The largest SAT cooling is located to the east of this albedo change, almost in the middle of the Denmark Strait, to the north of the largest SST cooling. Over the region of expanded sea ice there is an increase in the snow fall, which peaks nearest the coast, and over the ice sheet itself there is an increase in snow fall that is up stream of the peak cooling. This description does not fit with the explanation of cool SST → cool SAT → reduced snowfall. Please can you explain?

200-17 – what is "excess snow"?

200-14 – The logic in these statements would be clearer if it read something like:

"But in the Barents Sea and along the coast of North America, CTRL displays lower SST than CALV despite the large iceberg melting rates (Fig. 7a). These differences arise from the parameterisation of the take up of latent heat used in CTRL. In CTRL the latent heat is released uniformly across the Atlantic Basin. In CALV, by contrast, the pattern of the latent heat released depends on the melt pattern of the icebergs which is largest near the coasts. CTRL therefore overestimates the latent heat released west of the GIS as well as further away from shore, but underestimates it along the east coast and south of Greenland (Fig. 7a). This leads to the observed cooler SST away from the GIS that are seen in CTRL. "

200-22 – Again what is “excess snow”? The description CTRL to me says that there is no liquid water flux to the ocean in CTRL, therefore how can CALV have less of a water flux than CTRL in Baffin Bay?

201-5 – See previous comments on the interpretation of the snow fall and temperature – why does a temperature drop give a snow fall decrease.

202- 6 – thereby should be therefore.

202 – 10, I don’t understand this. What does latter refer to? This sentence appears unrelated to the previous one, therefore latter is not a suitable term. This whole paragraph is very confusing.

Perhaps rewrite this paragraph to be structured filling in the ...:

“The location of the freshwater fluxes has quite distinct impacts. To the west of Greenland the freshwater promotes an increase in sea ice thickness (Fig. 5b) because ... . In the GIN Seas, however, there is a decrease in the sea ice thickness (Fig. 8c) because . . .. . Furthermore, the SST and SSS in the GIN Seas are further increased by more extensive convective activity (Fig. 8a, b and d), resulting in an enhanced inflow of relatively warm and saline Atlantic waters and a stronger ocean- to-atmosphere heat flux. South of Greenland the input of the freshwater fluxes lead to a shift of the convection site eastward, with the effect of . . . . To the north east of Greenland the sea ice thickens because...”

However you choose to structure it you need to explain why there is a huge SST and salinity increase in the GIN seas which are counter to what you would expect when you introduce cooling and freshening.

202-17 on – This parpagraph does not make sense. The train of logic is very difficult to follow. Perhaps structure it:

“In Baffin Bay the release of the calving flux and the take up of heat needed to melt it causes lower SST and SSS (Fig. 8a and b). This facilitates the formation of sea ice, thus enhancing the albedo in this region (Fig. 11a). This increase in the sea ice is linked with a decrease in the sensible heat flux between the ocean and the atmosphere (Fig. 11d). Over central and east Greenland we see an increase in the snowfall that is due to . . . . This different accumulation pattern, with more snow over the eastern and less over the western GIS, is shown in the mass balance field (fig 13). This results in ice sheet thickness over eastern (western) Greenland that is up to 300 m higher (lower) compared to CTRL (Fig. 6f) "

202-21 – If you plot the sensible heat flux for each grid box rather than as a contour plot do you see an increase in the flux over the continent? It looks to me as though the large SHF sits only over the warm SST. It appears to extend over the land areas due to the interpolations that are made when you plot things as contours. For low resolution models, such as loveclim, contour plots can give the appearance of far higher resolution than there actually is. At a T21 resolution much of the structure that you see in the atmospheric fields is most likely the result of the plotting.

202 – 19 – What does "former" refer to? This statement is somewhat redundant or needs explanation, why is there a reduction in the sensible heat flux?

202- 22 – How do large sensible heat fluxes lead to increased snow fall?

202 – 25 – the logic is weird here. Snowfall changes the mass balance, which in turn changes the ice sheet thickness. The sentence, as structured, implies that the mass balance change is a result of the ice sheet thickness change when it is in fact the other way around.

I'm not even sure that the sensible heat flux is a very useful diagnostic to use. I don't know what we learn from it. Take for example Figure 11. Looking at the SHF field we see large anomalies over Baffin Bay and in the GIN seas. The large GIN seas flux is a manifestation of the warmed SST; it just reflects the warm ocean warming the overlying air. In Baffin Bay, although there is reduced SHF due to the presence of sea ice, the SAT is essentially unchanged, therefore the SHF's effect on the climate is negligible.

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Thus the effect of the SHF is either obvious or irrelevant. Or am I missing something?

203 – 6 figs (5) and (12), why aren't the figures next to each other for the reader's ease?

204 **Discussion**. Is the purpose of this section to set the presented results in the wider context of previous literature? If so you need to do this. For each of the previous studies, how are they different to this one? Why are they different? What is the implication?

205 – 3 – present study, not prevailing study. This paragraph is very hard to follow. I have taken the liberty of rewriting it as I understand it. Please note the question in *italics* in the latter part.

"In the present study the climate conditions and ice sheet geometries do not differ much between the experiments. This is because they were done under pre-industrial conditions where the calving rates are relatively constant and small. However, the impact of icebergs on the ice sheet's geometry is thought to be stronger during colder climate conditions when the calving rates are higher. Moreover, icebergs can also influence the timing of the climate's response during rapid climate changes such as Heinrich Events. Heinrich events are large surges of icebergs released from the Laurentide ice sheet during the last glacial (Hemming et al., 2004), for which widespread evidence has been found in marine sediment cores. Using the same iceberg module coupled to LOVECLIM (Goosse et al., 2010)., Jongma et al. (2013) mimicked the impact of these Heinrich event by introducing large surges of dynamical icebergs in the model under glacial boundary conditions. They compared this experiment with a run in which an equivalent volume of water was released as liquid freshwater fluxes. They revealed that icebergs that freshen and cool the ocean can cause a faster. climatic response as well as a faster recovery of the system. In a similar experiment Green et al. (2011) investigated the impact of deep-draft icebergs released due to the break-up of the Barents ice sheet collapse during MIS 6 (140 kyr B.P.). Using the global climate model

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FRUGAL coupled to the iceberg module based on Bigg et al. (1997) they found that the effect of icebergs on the ocean circulation was weaker in the beginning *of what*?, but lasts over a longer time period *than what? When compared to what?.* Both studies show that not only the size of the calving fluxes, but also their form – either icebergs or freshwater fluxes – is important. "

205 – 3. If I recall Jongma introduced their freshwater over the area of the Atlantic ocean not just at a few grid points near the edge of Greenland. This point must be emphasised since it could well explain the different conclusions.

Figures

The red-green-blue colour scheme must be changed.

Please note in the figure captions where the scale is non-linear.

The maps show too great a geographical area, so it is hard to make out the details that are important. You should focus in on the Greenland area – no reference is made to the area outside this so it need not be shown.

Figure 13 – what are the units of accumulation?

I appreciate how hard it is to write in a non-native tongue. However, the train of logic in much of the analysis is very hard to follow. Words such as, hence, former, latter, therefore, have very specific meanings which if misused render the text very unclear.

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