Review of Revised Submission (gmd-2014-117)

Anonymous Referee #2 (report 18 May 2015)

In "Representing Icebergs in the iLOVECLIM Model (version 1.0) – A Sensitivity Study" Bügelmayer, Roche and Renssen assess the sensitivity of the North Atlantic and Arctic climate system to the effects of interactive icebergs under various greenhouse gas forcing scenarios. While the paper is well structured and easy to follow it lacks some scientific novelty. The iceberg model and its implementation to iLOVECLIM, an earth system model including coupled ice sheets, has been described in a paper by the same authors in The Cryosphere, 2015, 9, pp. 821-835. Nevertheless, a more detailed analysis of the effect of wind and ocean current forcing as well as initially prescribed iceberg size classes is a useful addition giving more insight to the behavior of the coupled iceberg model, which is well received by the scientific ice-ocean modeling community.

I recommend publication of this manuscript in GMD after minor though extensive revisions. My comments and suggestions all aim at sharpening the arguments in the manuscript. In general, I would like to ask the authors to more precisely formulate the goal of this study considering the limitations of using a coarse resolution model of intermediate complexity.

General comments:

My main concern is the obvious misbalance between the sensitivity experiments of initial iceberg size distribution and CO2 forcing (clime scenarios) considering the variations in iceberg sizes and radiative forcing chosen. The change in radiative forcing seems overwhelming. As the authors state in line 100 the "chosen size distribution may not be a valid representation of calving events in past or future climate conditions", i.e. iceberg sizes are always close to the present state of the climate. In contrast they apply relatively extreme CO2 forcing of 70 and 1120 ppm (compared to the 280 ppm off the preindustrial control run, see lines 229ff). It can be expected without much reasoning that such changes to the GHG concentrations have significant impact on the climate state of the model, including the Greenland ice sheet, whereas the iceberg size distribution seems tailored to relatively small icebergs in general (max. iceberg length is 1 km, far below the 8 km lower size limit set for present day "giant icebergs" by Silva et al, 2006). With an intermediate complexity model such as iLOVECLIM one would have the right tool to quickly test a much larger range of iceberg sizes than done in the present study. Although "giant icebergs" are not seen around Greenland these days, they might have been more common during glacial times matching the "cold" state simulated here. Given the presented simulations, I am not surprised that differences between runs BIG, CTRL and SMALL are not significant (see Fig. 4, bar diagram). Although this is an unfortunate and unnecessary weakness of the paper I am not insisting on additional model experiments considering the advanced state of the publication process. I recommend revising the associated discussion, however, and turning Fig. 4 into an addition to Table 3.

Silva, T.A.M., Bigg, G.R., Nicholls, K.W., 2006. Contribution of giant icebergs to the

Southern Ocean freshwater flux. J. Geophys. Res., 111.

Further, please test results in Table 3 and Figure 4 for statistical significance and indicate this in a revised Table 3. It seems that when calculating spatial integrals the differences between the CTRL, SMALL, and BIG experiments are not statistically significant. Iceberg size still impacts spatial distribution, I think (Fig. 1).

Unfortunately, effects on the ocean sate are only discussed in terms of SST. What about the large-scale circulation, e.g. the North Atlantic Current, and deep convection sites with links to the Atlantic Meridional Overturning Circulation (AMOC)? Do they change in position or strength?

For an improved structure I suggest to rename sections 2.4.1 and 2.4.2 to "Iceberg Dynamical Forcing" and "Initial Iceberg Size Distribution, respectively, and add a section 2.4.3 called "CO2 Forcing" or "Radiative Forcing". Results are already presented according to this order in Section 3.

Detailed comments (lead by line number):

15 delete "as well as on the icebergs' size" (iceberg size changes are implied)

21 "… oceanic forces on iceberg mass and melt flux distribution, and …"

22 remove "used" and replace "as well as on" by "including"

25 please always use "icebergs" and not "bergs"

27-29 shorten "These different characteristics … North Atlantic waters." to, for instance, "Icebergs remaining close to Greenland last up to two years longer as they reside in generally cooler waters"

35 replace "used initial size distribution of the icebergs" by "initial iceberg size distribution."

41 remove "1*": "1 Sv = 10^6 m^3s^{-1}"

41/42 "… affect the upper ocean by freshening and cooling due to melting and uptake of latent heat."

43/44 remove "the": "that freshening", "as cooling" and "whereas freshening"

48 delete "Therefore,"

50 suggest to replace ", consequently," with "thus"

53 remove "the": "on air temperature and precipitation"

57 “episodic massive discharges of icebergs” to emphasize unusual amount of calved mass

59 “These periods have been proposed …”, reference is clear.

64 remove “and affected the global climate.” or add reference.

67 replace “fed” with “forced”

67/68 “… and oceanic input fields from uncoupled model simulations.”

75 change “based on” to “from”

135 replace “consisting of” with “including”

138 “consists of” -> “uses”

143 remove comma

146-148 I do not understand how this parameterization works. Please revise this sentence adding some more detailed information. Does it really only affect the heat budget (“uptake of latent heat”) but the freshwater/salt budget? Which region is affected, what kind of geographic mask is applied? What are the prevailing ocean conditions: temperature, waves, … ?

156 “do not consider” -> “exclude”

158 “… thickness at the ice shelf front is less …”

181 remove “Therefore,”

183/184 it appears there is an additional empty space in “air- ,” and “water- ,” because comma appears in next line.

188 “bergs” -> “icebergs”

197-200 “This initial ice sheet thickness … the observed one. We consider this bias negligible for the present study because we focus on differences between our sensitivity runs using the same initial state for all experiments. The individual simulations are long enough to yield results that are independent of the initial conditions and only functions of the different forcing applied. ”

203 suggest to change title to “Iceberg Dynamical Forcing” (see also general comments) in order to separate these experiments from those of changed radiative forcing (cf. your section titles 3.3.1 and 3.3.2 and my comment on title of 3.1 and 3.2 below)

204/205 “… ocean and the atmosphere on iceberg dynamics, we separate the individual forcing terms of the iceberg momentum balance:

208 “the air drag (Fa) and the wave radiation force …”, parenthesis missing, add “the” before “wave”

212 move reference to Table 1 to end of paragraph

217-219 “… was only applied to the momentum balance of the icebergs. The mass balance of icebergs, … (AUTHOR et al., YEAR, Eq. ???), is the same in all experiments. ” Please add reference for mass balance of iceberg model; I didn’t find it in Bugelmayer et al., 2014, TC; I think Jongma et al., 2009, Ocn. Mod., which is referenced already, describes it for ECBilt-CLIO.

220 suggest to change title to “Initial Iceberg Size Distribution” (see general comments)

221 “By altering the initial size distribution of the icebergs we are able to investigate the potential sensitivity of the atmosphere, ocean and ice sheet to iceberg sizes.”

225 remove sentence: “The differences in the resulting … and the ice sheet.”

227 I strongly recommend introducing a new subsection “2.4.3 Radiative Forcing” here, which then begins with:
227 “We conducted three sets of experiments, of which the first set was done under … for 200 years. This set includes experiments with the CTRL, SMALL, and BIG iceberg size distributions as well as the experiments ATM and OCN with individually turned off dynamical forcing. In the second set, a ‘warm climate’ experiment, …”

231/232 “The ‘warm’ and ‘cold’ experiments were conducted to analyse the effect of the iceberg size distributions during periods …

235 suggest to change title as follows to distinguish between dynamical (ATM, OCN) and radiative (CO2) forcing: “Impact of Dynamical Forcing and Initial Size on the Transport and Lifetime of Icebergs Under Pre-Industrial Conditions”.

237 shorten sub-title “The CTRL Experiments”

246 “bergs” -> “icebergs”

248 remove reference “(Fig. 1d,f)” because Fig. 1d is linked in the previous sentence already and SMALL (Fig. 1f) is not yet discussed.

249 “… of the same magnitude and distributed over the same area as in CTRL-COM (Fig. 2a).”

252 “… and into warmer waters.”

265 shorten title “The BIG Experiments” (drop experiment names)

277-279 shorten: remove “The BIG-ATM icebergs … (Fig. 2c).” and rewrite “The strong southward component of the wind keeps the icebergs from drifting farther into the GIN Seas.”

294 shorten title “The SMALL Experiments” (drop experiment names)

298 “… melted within two years. This difference is much smaller than the difference to the lifetime of BIG icebergs (see Fig. 3).”

312 “Impact of Iceberg Dynamical Forcing and Initial Size on Pre-Industrial Climate”

315 I think that Fig. 4 should be turned into a table, probably added to Table 3 (see comments on Figures below). If this suggestion is followed, then the beginning of section 3.2 must be revised accordingly.

320 Good point to mention the deep convection sites in the North Atlantic: I think it is not enough to look at SST and surface air temperature, which are closely related anyway (except there is sea ice). How is the strength of the AMOC affected? Please check the streamfunction maximum at about 30°N in the all simulations. This would be interesting to show here in case iceberg size makes an impact in any of the three climate states.

345/346 “…, the calving flux from the GrIS is declining (…) especially in South Greenland. This has a direct impact on the iceberg melt flux .”

357 “… bigger than 200 m in diameter (size category 3, Table 2), such as in SMALL, allows …”

379 either “releasing the most melt water” or “ having the biggest IMF”

382 “bergs” -> “icebergs”

386-388 “These results show that the initial iceberg size distribution used do not … applied forcing. They clearly indicate that the extreme differences in boundary conditions of past and future climates have greater influence than any variability in present-day iceberg size distribution. ”

390 “… on the lifetime and motion of icebergs, we find …”

402 “… small bergs of up to 200 m in diameter (size classes 1 to 3, Table 2) …

409 Why do not compare the results (iceberg mass and melt distribution) with Jongma et al., 2009, Fig. 1 or Martin and Adcroft, 2010, Fig. 2?

425 I am not convinced that icebergs from Greenland do not have a potential impact on the southern hemisphere, for instance by affecting deep convection in the North Atlantic and subsequently the AMOC. I agree that the iceberg size,

varied within the range considered here, has likely no impact. It is probably rather due to significant changes in calving rates or calving of much larger icebergs that last longer and carry farther onto the ocean. These lines should be carefully revised.

434 What about much bigger icebergs of up to 10 km in diameter? Are they realistic in the North Atlantic under a much colder climate?

444 "The spread of iceberg mass on the ocean depends …"

445 "… by big icebergs of more than 500 m in diameter." Conclusions should be understandable without checking tables and figures.

454 "… (1120 ppm or 70 ppm CO2 over 1000 model years),…"

457 "… (all size classes, less than 200 m and more than 500 m in diameter only), … does not differ significantly." If significance tests are successful, then say "not digger strongly but significantly."

464 I am not entirely sure of that. What if iceberg size did vary beyond the current size distribution in past 'cold' climates? If one would test for, say nearly unrealistically giant icebergs and the response is still small compared to changes in radiative forcing, this would be much easier to believe.
By the way, just a thought, is there a stability limit to iceberg size based on first principles? This could limit the iceberg size distribution for all climate states.

TABLES:

Table 1 provides a good overview of the various experiments; this is really useful.

Table 2: please change notation "5.16E05" to "5.15 * 10^5"; alternatively add "10^5" to column label and express numbers as factors of 10^5. Also, I think numbers in column 5 represent "fraction" and not "percentage".

Table 3: The differences listed in column 4 appear to be puny. In most cases they are not significant at, say a 95% level (2 times the standard deviation) compared to the interannual variability given in column 3. I recommend listing the differences not only in percent but also in absolute numbers (10^12 m^3) for comparison with the STDEV. Further, I suggest to move the order of magnitude to the label, i.e. remove "E+15 " and "E+12" from all numbers but add 10^15 and 10^12 to Mean and STDEV respectively.

FIGURES

Figure 1: The nine panels provide a nice overview of iceberg size and atmosphere and ocean forcing. Why not presenting mean iceberg mass or

meltwater influx per m^2, i.e. quantities that are physically more meaningful than number of bergs? Apart from that, differences between rows, i.e. the impact of the forcing, is easy to see, differences between columns, i.e. impact of iceberg size, are much harder to detect. I thus recommend to plot panels b) and c) as difference to panel a), and similarly e,f) as difference of d) and panels h,i) as difference of g). In other words, present absolute values for the CTRL run but differences to CTRL otherwise.
Caption: "… icebergs passing through a grid cell …"

Figure 2: I think it would be nice if one of these panels would represent the entire Northern Hemisphere. I also recommend adding a map on which the various regions are outlined. Maybe one could add these two displays to the present figure, which would then have a 2 by 3 arrangement instead of 2 by 2 panels.
Caption: "… all the grid cells that have at least 10 icebergs passing through per year on average (note area is given in 10^12 m^2) … Arctic Ocean: all area north of 80˚N, IMF is … "

Figure 3: Caption: "Cumulative iceberg melt distribution normalized to 100% as a function of time (months)."

Figure 4: I might not get the hang of this figure but in my view it does not show anything that I can conclude from the other figures or the text:
1) the differences between the CTRL, SMALL and BIG experiments are tiny, maybe even not significant as indicated by the black error bars in this plot, which always overlap and are bigger than the differences between the red, blue and green bars in each panel.
2) COM, ATM, and OCN results are extremely similar as well. It is not that obvious but they might also not be significant.
3) The only visible difference is between the runs of different CO2 content.
Please don't misunderstand me, this is a meaningful result, but it does not necessitate this Figure. A table might be more suitable, in fact differences in SST and Tair could be added nicely to Table 3. This would still suite the discussion now linked to Figure 4.

Figure 5: As with Figure 1 I strongly recommend to plot absolute values only for panel a), COM and then show differences to COM in panels b) and c).