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Geoscientific Model Development Discussions

Interactive comment on "NEMO-ICB (v1.0): interactive icebergs in the NEMO ocean model globally configured at coarse and eddy-permitting resolution" *by* R. Marsh et al.

Anonymous Referee #2

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In "NEMO-ICB (v1.0): interactive icebergs in the NEMO ocean model globally configured at coarse and eddy-permitting resolution" Marsh, Ivchenko, Skliris, Alderson, Bigg, Madec, Blaker, and Aksenov present an interactive dynamic-thermodynamic iceberg model component coupled to the well established NEMO-LIM ocean sea-ice model. As duly noted in the study, neither the iceberg model nor its coupling to an ocean model are new developments. Obviously, the study closely follows an earlier work by Martin and Adcroft (2010), in which the same iceberg model is applied to the GFDL's climate model CM2G. Nevertheless, interactive icebergs in NEMO are a novelty and as NEMO is used by many groups all over Europe this is an important step forward in both accepting icebergs as an important component of the climate system

and testing the sensitivity of modeled oceans to realistic icebergs. The authors study the sensitivity of NEMO to icebergs by means of two control simulations with grid resolutions of 2 deg and 0.25 deg, respectively, where the former run features 105 years and the latter only 14. The very short spin up of the high-resolution run is unfortunate and the one major concern I have with this work. It would be desirable to have the ORCA025 simulation extended for at least another 16 years, or even better 36 years. This suggestion is based on my assumption that the authors have access to high performance computers. My experience is that 10 years of ORCA025 take 5 days or even less depending on the HPC system used. Otherwise the study is carried out thoughtfully and the well-structured manuscript is nicely written. The focus of the paper is entirely on the presentation of this new model set up and thus matches well the journal topic. I thus recommend this paper for publication in GMD after major revisions.

Detailed comments:

As mentioned above I have trouble believing your statement that the ORCA025 simulation is in equilibrium after only 14 model years. In Table 3 it is shown that calving and melt fluxes are not balanced in ORCA2 averaged over model years 10-14 and the difference is big compared to the (im-)balance in years 101-105. The greater imbalance compared to the CM2G may partly be due to the short averaging period of just 5 years for the ORCA results (100 years for CM2G). Moreover, the average iceberg mass for ORCA2 after 10 years is similar to that in ORCA025 after 10 years but from the upper panel in Figure 1 one can see that the iceberg mass further increases in ORCA2 after year 10 and levels off around years 40 to 50. This suggests that the iceberg mass in ORCA025 is not in equilibrium, yet. By the way, a spin up for iceberg mass of about 50 years agrees nicely with the 60 years noted by Martin and Adcroft (2010). However, the results of Martin and Adcroft support the notion that calving and total iceberg melt fluxes (not iceberg mass!) are in balance after about a decade. Nevertheless, 14 years of spin up are too short to draw conclusions for the deep ocean as you do later in the paper (Section 3.3).

By page/line:

5662/5 Here, it is briefly noted what the forcing in the control simulation without icebergs looks like, i.e. the freshwater forcing that compares to iceberg calving in the sensitivity run. This bit of information is unfortunately missing in Section 2 and I strongly recommend to more clearly state in Section 2 whether there is a freshwater flux comparable to calving in the control simulation and how it is distributed in the absence of an iceberg model component.

5662/14 I believe that this conclusion has to do with above issue. Again, please explain clearly what kind(s) of runoff are accounted for in the control and the iceberg experiments and how they are handled. This is instrumental to understand the simulation results and to compare to earlier studies such as Jongma et al. (2009) and Martin and Adcroft (2010), which both are referred to in the text.

5662/20 The last sentence of the abstract is not clear to me without further knowledge of the main text. What is "eastward transport tendency" referring to? Please rephrase.

5663/23 Please add here, how Jongma et al. (2009) handled runoff in their control experiment. I believe their runoff from Antarctica was distributed globally in the control experiment, which is in stark contrast to the control run with CM2G and could explain the opposing sea ice trends caused by introducing icebergs to these different models.

5665/13 There is only a single 14 year experiment presented here; remove "s" from "experiments".

5665/15 Please describe here the runoff distribution scheme in CONTROL. Is there a flux in CONTROL that is redirected to iceberg calving in ICEBERG or does NEMO-ICB feature an additional flux of energy and mass due to calving?

5666/13 Is such a simple drag law implemented in NEMO-ICB? Please make this more clear in this sentence.

5667/3-6 You correctly state that "icebergs [. . .] are largely submerged into the ocean"

(5666/27) and thus implement the iceberg model as part of the ocean model (and not as part of the sea ice model as Martin and Adcroft did). However, I am surprised that you do not take advantage of this and force the icebergs by the surface instead of the available 3-D fields of ocean temperature and currents and you also seem not to feed 3-D fields of iceberg melt back into the ocean. Why?

5667/12 Please explain why you are using a seemingly small calving rate of 1140Gt/yr. As you elaborate in the remainder of this section this is a rather conservative number. How did you derive this number?

5668/23 Since you only show 10-year averages of the iceberg mass in ORCA2 in Figure 1 I cannot follow your conclusion that the calving and melting rates are in balance by year 10. Please revise Figure 1 as outlined below. You may also want to refer to Table 3 to support this statement (although I don't believe the numbers based on years 10-14 are fully convincing).

5669/1 In continuing this argument: By stating that SH iceberg mass in ORCA025 is in equilibrium after just 10 years you also state that ORCA025 has about 100 GT ($\sim$15%) less SH iceberg mass than ORCA2. Why? I think the iceberg mass is not in equilibrium in year 10 of either simulation. Figure 1 shows that these years belong to a transient period although the iceberg mass of the first 10 years is astonishingly similar to the later equilibrium state. Further, you state that semi-enclosed basins and embayments prolong the lifetime of icebergs in the NH. Why would the enhanced resolution of coastlines in ORCA025 (compared to ORCA2) not lead to more "grounded" icebregs and enhance lifetime in the SH as well? (also see line 5669/8).

5669/8-11 I would expect most NH icebergs to drift into the North Atlantic and hence melt about as quickly as SH icebergs moving out to the ACC. Is such a comparatively large storage of icebergs in embayments in the NH realistic or a model characteristic? Out of curiosity: Are more icebergs "grounded" in ORCA025 than in ORCA2?

5669/25 I am wondering if the short averaging period of just 5 years may cause some

of the greater imbalance in NEMO-ICB compared to the number form CM2G.

5670/9 The different partitioning between iceberg erosion and basal melt may also be due to different SST and wind speeds in the forced ORCA runs compared to the fully coupled CM2G.

5671/15 please add "... associated with local imbalances of precipitation and evaporation (P-E), and sea ice growth and melt." as I assume the net freshwater flux (see caption of Figure 4) includes (virtual) sea ice freshwater fluxes.

5671/28 I suggest to rephrase: "In the Greenland Sea of ORCA2, negative values indicate areas where sea ice formation acts to increase salinity (not shown), i.e. causing a negative net freshwater flux, although both terms are locally small."

5672/24 Do you show maps of actual ice thickness (m) or mean ice thickness (mˆ3/mˆ2), i.e. sea ice volume per grid cell area? The latter would be affected by changes in ice concentration. A greater (smaller) ice concentration in a grid cell with an unchanged actual ice thickness would yield a greater (smaller) mean ice thickness. The fields in Figures 5 and 6 look pretty similar, which hints at mean ice thickness.

5672/28 Considering that the model does not account for iceberg sea-ice mechanical interaction (Section 2.2) I am not convinced that changes in sea ice thickness are due to dynamical effects. On the contrary, the spatial distribution of iceberg melt water in Fig. 3 (and its ratio to local freshwater sources, Fig. 4) show that areas of great iceberg melt also have great increases in sea ice thickness, which would indicate a thermodynamic effect: freshening by iceberg melt supports sea ice formation).

5673/18 This sentence needs an explanation in Section 2.4 Calving. How is runoff redirected in the iceberg runs? (see related comments above)

5674/10-21 I think these conclusions are not well supported by the results presented here for the following reasons: First, the calving rate is considerably lower in the NEMO-ICB runs than observed as stated in Section 2.4. Second, the model runs are based

on a climatological cycle (Section 2.1) and comparisons are done for the "unrealistic" case of no icebergs versus one with icebergs. Hence, it is unclear what the impact of a transient climate on iceberg mass and melt distribution would be — let alone that we don't know well, how the calving forcing should evolve in such a scenario. And third, as noted above, the spin up and averaging periods are short for investigations of the deep ocean. For instance, 14 years of ORCA025 run is even shorter than the period 1982-2000, which didn't indicate changes in iceberg mass from observations.

5675/12 Here is another thought you may want to add to the discussion of Figures 11 & 12: While freshening dominates above 500m in both seas, there is warming between 500 and 2000m in the iceberg run. This warming indicates that there is likely a decreased upwelling/mixing of these deep, warm waters with the cooler but fresher upper ocean due to the stabilizing effect of the upper ocean freshening. Hence, the distribution of melt water by icebergs helps to stabilize the Weddell and Ross seas making open ocean deep convection more unlikely.

5676/15 These negative differences only indicate an intensification of the MOC by icebergs in case of a negative MOC streamfunction. Is this statement referring to enhanced northward transport of bottom water in ICEBERG? Please add information on sign convention and the sign of MOC in CONTROL for clarification.

Table 1: This table is the same as Table 1 in Martin and Adcroft (2010), except that the length of the icebergs is not given here. Please add "(reproduced from Martin and Adcroft (2010))" to the caption.

Table 3: add "(100yr mean)" below CM2G to indicate the averaging period.

Figure 1: I strongly recommend to plot bars with yearly resolution instead of 10-year means for years 1-20 in the upper panel (results of ORCA2) in order to make this comparable with the lower panel (ORCA025 results). Alternatively, since I do not favor bar plots, I suggest to simply plot individual lines for SH, NH, and global iceberg mass; thin lines for annual mean and bold lines for 10-year running-mean; for both the upper

and lower panels even though there will be only 5 data points of running-mean for the ORCA025 case. You may even consider not to stretch the x-axis of the lower panel and use the same 100 year axis for the ORCA025 run as for ORCA2. This way, the graphs will be comparable despite the very different extent of the simulations and the reader will hopefully be more easily convinced that the simulations have reached equilibrium with respect to iceberg mass. Moreover, you could add time series of calving and iceberg melt fluxes to show that these reach equilibrium much earlier than iceberg mass as you state in the main text (Section 3.1).

Figure 2: This snap shot of spatial iceberg distribution is somewhat confusing if compared to the 5yr mean of iceberg melt flux in Figure 2. For example, there are no icebergs north east of the Antarctic Peninsula in ORCA025 in Figure 2 despite a melt flux (Figure 3) of comparable magnitude to ORCA2. Is it possible to show a 5year mean of iceberg "density" or, say, likelihood of iceberg presence?

Figure 6: Please indicate unit: "Sea ice thickness (in metres) . . ."

Figures 11 & 12: Please add longitudes used to define Ross and Weddell Sea sectors to captions.

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