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Interactive comment on "Impacts of Antarctic runoff changes on the Southern Ocean sea ice in an eddy-permitting sea ice-ocean model" *by* V. Haid et al.

Anonymous Referee #2

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This paper examines the model response of sea ice to the supply of additional freshwater at the surface of the ocean around Antarctica. The model used is NEMO, forced by global atmospheric reanalysis data with LIM2 sea ice model. Five scenarios are examined and compared with a control run. The scenarios include cases where the fresh water "runoff" is distributed uniformly around the coast of Antarctica, and others with regional maxima that approximately coincide with major ice shelves. In a third category the runoff is applied offshore, to mimic iceberg drift. The total magnitude of the runoff also differs between most of the simulations. The authors conclude that fresh water input increases sea ice extent and volume, up to a "turning point" value whereupon the sea ice trend is inverted. They also find that their experiments are sensitive to the

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Discussion paper

distribution of fresh water runoff at the ocean surface.

The paper is well written and readable and makes a useful contribution. One of the more interesting aspects of this paper is that the authors segregate the response of the sea ice into a thermodynamic and a dynamic components. I congratulate the authors on this part of their discussion.

MAIN COMMENTS

1. This is a topic of current interest, as evidenced by the fact that at least two highly relevant papers have appeared in the literature in the time that this article has been in process. Some details of the present paper need to acknowledge the publication of these two studies. They are

Merino, N. J. Le Sommer, G. Durand, N. Jourdain, G. Madec, P. Matthiot and J. Tournadre, (2016) Antarctic icebergs melt over the Southern Ocean: climatology and impact on sea-ice. Ocean Modelling, 104, 99-110, doi:10.1016/j.ocemod.2016.05.001

Pauling, A.G., C. M. Bitz, I. J. Smith, and P. J. Langhorne, (2016) The response of the Southern Ocean and Antarctic sea ice to fresh water from ice shelves in an Earth System Model. J. Climate, 29, 1655–1672. doi: http://dx.doi.org/10.1175/JCLI-D-15-0501.1

2. An interesting aspect is the hypothesis that a large amount of freshwater will reduce the sea ice. I am not sure I understand why this is the case. In addition, as the conclusion is based on one experiment, and as I could not see a clear pattern in the qualitative behaviour of the system with increasing freshwater flux, my opinion is that the authors need to work a little harder to be convincing.

3. In relation to this, please can you explain why the simulations of sea ice are considered to represent sea ice behaviour, while the simulation period of 10 years is too short for the water characteristics to reach equilibrium (see e.g. p. 2, line 28-33). Are you saying that you are investigating sea ice response processes and therefore do not

need to reach equilibrium? If this is the case, I am not sure I understand how you may conclude that there is a reversal of behaviour when more than a certain amount of fresh water (undetermined from these experiments) is added to the system. How can you tell that this is not due to variability between runs? This may require more explanation of the known behaviour of the model. The existence of a turning point based on evidence of a single simulation requires additional argument for its existence.

4. How was the seasonal variation in ice shelf "runoff" decided (see Fig 1e)?

5. Development in time and variability on p. 9: How much is know about variability between model runs when there has not been a repeat of an experiment? Perhaps this is well known for the model and could be briefly explained to the reader.

6. Comments 2-5 lead me to be unconvinced by the authors' conclusion that (the small) freshwater input they apply causes the sea ice to expand, while a larger input inverts the trend. This needs to be very carefully re-evaluated.

TECHNICAL COMMENTS

p. 2, line 9-10: Merino et al and Pauling et al (2016) need to be added to the previous studies.

p. 2, line 24-25: Note that Pauling et al (2016) have added fresh water spatially-distributed according to ice shelves, and at the depth of the ice shelf. However their simulations did not vary in magnitude through the year.

p. 2, line 28-33: (as main comment) Please can you explain why the simulations of sea ice are considered to represent sea ice behaviour, while the simulation period of 10 years is too short for the water characteristics to reach equilibrium. Are you saying that you are investigating sea ice response processes and therefore do not need to reach equilibrium? If this is the case, I am not sure I understand how you may conclude that there is a reversal of behaviour when more than a certain amount of fresh water (undetermined from these experiments) is added to the system. How can you tell that this is not due to variability between runs? This may require more explanation of the known behaviour of the model. The existence of a turning point based on evidence of a single simulation requires additional argument for its existence.

p. 4, line 5-6: Was Dai and Trenberth (2002) applied in all other parts of the globe, apart from Antarctica? Was the seasonal variation used (see Fig 1a – actually I think it is 1e) from Dai and Trenberth (2002)? If so how do you justify using the seasonal behaviour for river runoff to represent melting ice shelves?

p. 4: Table 1 is very useful but has not been referred to in the text. It would be useful to refer to it in section 2.2.

p. 4, lines 12-33: I think that the subfigures of Fig. 1 have been mislabeled.

p. 4-5: Experiment design – please note that Merino et al (2016) and Pauling et al (2016) both conduct experiments with fresh water distributed to mimic iceberg melt.

p. 5, line 20 onwards: This is a very interesting discussion regarding the influence of additional fresh water at the surface on the SSH, the velocity and thus on sea ice thickness. I was confused about how changes in the direction of the velocity were taken into account? Does the right hand column of Fig 2 show speed not velocity?

p. 5: Spatial Response Patterns: How can you have a high confidence interval in the difference when, at each time step, there are only two quantities? Is it time-averaged?

Fig 2 is for the “winter” months. Which months are “winter”?

p. 6: line 9-10: Is a salinity-dependent freezing point coded in the model?

p. 6, line 23 + p.7, lines 14, 27, 28, + p. 8, line 12, + p. 13 line 23: use of the word “acceleration” when I think you mean “faster speed”.

p. 7, line 26: please mark Princess Martha Coast on a map.

p. 8, line 10: please mark Filchner/Ronne Ice Shelf on a map.

p. 9, line 10-12: Why are the larger amplitude anomalies in 2009-2011? Why are the anomalies smaller in 2012-2013?

p. 10, line 9-15: We are not shown the surface salinity or the SST so it is difficult to follow this discussion. Could the essential elements be presented in a figure?

p. 11, line 13 & line 16: I believe it is more appropriate to state as estimates 6 – 24% and 5 – 23% . p. 13, line 23: Stammerjohn et al (2012) have shown that there is strong correspondence between anomalies in the timings of sea ice retreat and subsequent advance, and you may wish to refer to this paper. Stammerjohn, S., R. Massom, D. Rind, and D. Martinson (2012), Regions of rapid sea ice change: An inter-hemispheric seasonal comparison, Geophys. Res. Lett., 39, L06501, doi:10.1029/2012GL050874. p. 13, line 23: Why would there be sea ice melt in winter? Is there evidence for this in the model runs? p. 14, line 2: replace "lose density" with "density reduces" p. 14, line 12-13: Some experiments have been done by Pauling et al (2016).

Fig 1: I did not understand the caption at all. I also think that the sub-figures are mislabeled. Please give a key for regions 1-10 in a).

Fig 2: Do you mean speed rather than velocity? What months are represented? How is the t-test performed when it is the difference between only 2 quantities?

Fig 3 b, d, f.: Are the large jumps in values between month 1 and month 12 expected?

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