The Cryosphere Discuss.,
https://doi.org/10.5194/tc-2019-244-RC1, 2019
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The Cryosphere Discussions

Interactive comment on "Impact of West Antarctic Ice Shelf melting on the Southern Ocean Hydrography" *by* Yoshihiro Nakayama et al.

Anonymous Referee #1

Received and published: 30 December 2019

General comments

In this study the authors use the finite element ocean/sea ice/ice shelf FESOM model to study the impact of increased basal melting of the ice shelves in the Amundsen (AS) and Bellingshausen (BS) Seas on the hydrography of the entire Antarctic continental shelf and the condition of Antarctic Bottom Water (AABW) just off the continental shelf. This is done through examining four 32 year long simulations where the ice shelf basal melt rates are increased between simulations by modifying the transfer coefficients between the ice and the water underneath. The freshening signal not only propagates onto the Ross Sea continental shelf, but within the time frame of these simulations also makes its way around almost the entire continent onto the Weddell Sea continental shelf. The increased melt scenarios also impact the AABW off the Ross Sea and have

slight impacts on AABW elsewhere.

I thought the paper was generally clear and well written. The impacts of increasing ice shelf basal melt in the AS and BS on Antarctic continental shelf waters and AABW are an important problem and, in my opinion, well worth the attention of the Cryosphere. FESOM, with its high resolution on the Antarctic continental shelf (including under the ice shelf cavities) and slope, explicit ice shelves, and global domain (so no worries about lateral boundary conditions) is a fantastic tool to study this question.

My only negative general comment is relatively minor, but I do think there are some warnings about the applicability of these results that should be included. The LMELT results are using what the authors think the heat and salt transfer coefficients should be, but this results in low basal melting compared to observations. No mention is made of why they think the melting is low compared to current day conditions: Is this because of unknown ice/ocean interaction physics or is there a problem with the representation of water masses on the continental shelf? If it's an issue with the water masses, does this influence the rate at which meltwater advects (due to lateral density gradients) in the coastal current over the continental shelf? Also, the HMELT increased melting is not due to changes in the AS/BS shelf conditions, as they presumably are in the real world since the mid-20th century, but rather numerical manipulation of the ice/ocean transfer coefficients. Does this have an impact on the results?

I have some other specific comments and suggestions below, but most of these are very minor and should be easily dealt with by the authors.

Specific comments

Abstract, line 3: The abstract states that the long term impact of enhanced melting of the Amundsen Sea ice shelves "on the Southern Ocean hydrography has not been well investigated". However, there have been several studies of this (e.g. Fogwill et al., 2015; Golledge et al., 2019; Lago and England, 2019), just not with models setup as nicely as the FESOM model used here (i.e. explicit ice shelves and high resolution

around Antarctica). I think it would be helpful to mention some of the other studies in the Introduction, but also include mention of why the model used here is better suited for examining this question.

Abstract, line 7 and line 155: See comments below about the propagation of the meltwater, but suggest changing "propagates further" to "can propagate further".

First paragraph of model section: Even though the authors mention the ice/ocean heat/salt transfer coefficients in the next paragraph, I think it would be helpful to readers not familiar with FESOM to explicitly mention in this paragraph that FESOM does simulate the melting/freezing of the base of the floating ice shelves. Should also explicitly mention that FESOM does have a dynamic sea ice model.

Lines 71-73: I think it would be helpful if the authors added a figure about the simulated sea ice extent to the Supplement.

Lines 124-126: The HMELT case shows the propagation of the freshening signal as described here, but it's often hard to see if there has been a propagation of the signal in the other cases. For example, the red and orange lines in Figure 6c do not stay below zero until $\sim$ year 15 and then go back above zero for a good portion of the time past year 20. In 6d, one could argue that the red and orange lines do not stay below zero until almost the end of the period. This is why I suggested the change in line 7 of the Abstract/line 155.

Line 151: I think it's a bit much to say this paper is investigating the impact of the meltwater on "the Southern Ocean hydrography". It is looking at some aspects of the hydrography (Antarctic continental shelf conditions and changes in AABW), but not at all the broad scale water masses that are involved in the Southern Ocean. Suggest changing "Southern Ocean hydrography" to something a little more focused.

Technical corrections

Line 15: To avoid confusion from some readers about ice shelf vs. grounded ice con-

tributions to sea level rise, suggest changing "ongoing sea level rise and ocean freshening" to "ongoing ocean freshening as well as to sea level rise".

Line 21: Suggest changing "There exist a few other evidences" to "There is some evidence".

Line 35: Suggest changing "focuses" to "of a focus".

Lines 60 and 61: Are the transfer coefficients set to constants as in Hellmer and Olbers or functions of the friction velocity as in Holland and Jenkins? From other FESOM ice shelf papers, I assume they are functions of the friction velocity, but I can't tell from how it is written here.

Line 82: From Rignot et al. (2013), I get 664 Gt/yr (not 459) for their estimate of the basal melt of the combined AS and BS (numbers 5-18 in Table S3) ice shelves.

Line 83: Change "at that the time in the middle" to "in the middle".

Lines 87-88 and Figure 3: If the Figure 3 plots are mean bottom salinity, then how does this show that the salinity at 200-m depth is stable? Is "bottom" over the continental shelf in the figure defined at 200-m?

Line 89: Suggest changing "the RS continental shelf further along the east Antarctic coast and towards" to "the RS continental shelf and then further along the east Antarctic coast as well as towards".

Line 92: Typo, "Fig .3" should be "Fig. 3".

Line 101: Suggest changing "Despite underestimated" to "Despite being underestimated".

Line 143: Typo, "0.030" should be "0.0030" and "0.048" should be "0.0048" (assuming Table S4 is correct).

Line 167: Add "on" after "commented".

Figure 2: Why does the temperature scale top out at 1.0C? The Schmidtko et al. observations have the mean BS temperature > 1.0, and thus it's hard to make comparisons between the model and the observations in the AS and BS continental shelves.

Table S1: What are the units for the sea ice salt concentration and is the value here correct? Timmermann et al. (2009) has it as 5 (psu or g/kg).

Table S3: I don't understand what "16" and "17" are in the references. I assume one is Depoorter et al. and one is Rignot et al., but can't tell which is which.

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