Responses to Reviewer #1

Second review of 'A numerical study on melt water feedback in the coupled Arctic Sea ice-ocean system' by Zhang, Bai, and Wang. I appreciate the detailed responses to my comments from the first round of reviews. The authors did a very nice job of addressing my concerns and improving the manuscript.

Thank you for your comments, which have greatly improved the quality of this MS. In the following, we provide point to point responses (blue text) to the suggestions and revised the MS ***(black bold italic)*** accordingly.

1. One area that I still think needs improvement is the way that negative and positive feedbacks is explained. For example, lines 11-12 state '2) Melt water release has negative feedback on ice melting' and I was left struggling to understand what negative feedback means in this scenario. Does it mean that less ice is melting? Or that more ice is melting. I wonder if the authors could remove wording relating to feedback and just simply talk about the processes. For the example given, lines 11-12 could simply state '2) Melt water reduced ice melting by 16.6% by strengthening ocean stratification'.

Sorry for any confusion caused by wording. In this study, the negative feedback means less ice melting. To explain it more directly, we eliminated the wording related to feedback from the MS. We changed the **Title** of this paper.

Lines 1-2: ***Response of the Arctic Sea ice-ocean system to melt water perturbations based on a one-dimensional model study***

Abstract, lines 7-8***: A one-dimensional coupled sea ice-ocean model is used to investigate how the Arctic Ocean stratification and sea ice respond to changes in melt water.***

lines 12-13: ***2) Melt water reduced ice melting by 17% by strengthening ocean stratification.***

Introduction: line 54: ***… the role of melt water in the ice-ocean coupled system of …***

Section 2.1: line 82: ***… to investigate the influence of melt water in a coupled ice-ocean system …***

Section 3.2.2 (a): lines 324-325: ***This implies that the presence of melt water inhibits sea ice melting during the melting season.***

Section 3.2.2 (c): line 394: ***In summary, the above results indicate that melt water always has an inhibitory effect on ice melting during the melting season.***

Line 397: ***… which is the main reason for the inhibitory effect of melt water on sea ice melting …***

Conclusions: line 487: ***… that the presence of melt water exerts an inhibitory effect on the process of sea ice melt.***

2. Lines 37 to 46 are confusing. I suggest i) the authors clearly define the sources of external and internal freshwater and ii) the authors state their definitions of melt water and river input.

Thanks for the suggestion. We revised some sentences in the **Introduction**.

Lines 38-44: ***The external freshwater sources of the Arctic Ocean mainly include Pacific inflow, precipitation minus evaporation and river runoff, with a total annual inflow of approximately 9400±490 km^3. The annual outflow volume through oceanic gateways, primarily comprising the Fram Strait, Davis Strait, Fury and Hecla Strait, is approximately 8250±550 km^3. Thus, the annual net freshwater flux from the external sources into the Arctic Ocean is about 1200±730 km^3 (Haine et al., 2015). The internal sources of liquid freshwater mainly originate from the melting and freezing processes. Approximately 13,400 km^3 of freshwater freezes during winter, and 11,300 km^3 of freshwater enters the ocean through ice melting (Haine et al., 2015).***

3. Lines 47 to 57 – Again, I find the wording around feedbacks still very confusing. It is particularly confusing that the authors introduced a new term called melt water feedback (without a proper definition). I think the authors should carefully look at the manuscript to see if the terminology around feedbacks adds to the paper or if it is an unnecessary complication.

We removed some sentences from the fourth paragraph in the **Introduction** and eliminated the wording related to feedback from the MS.

…~~***and we call it melt water feedback in this paper……. and the Cloud-Albedo feedbacks (Zelinka et al., 2012; Bodas-Salcedo et al., 2016).***~~

4. Lines 152 to 157 – How did the addition of this extra freshwater forcing impact the results? Is it possible to quantify this change? Perhaps this can be addressed as a supplemental figure or a sentence in this section.

We quantified this change at stations A1, A6, E2, and E7. In strongly stratified regions, additional freshwater forcing led to a slight shoaling of the ML (Fig. S1a-r), with the impacts on sea ice simulation results being less than 1% (Fig. S2a-c and Fig.S3a-c). However, at the weakly stratified E7 station, the maximum difference in winter MLD reaches several tens of meters (Figures S1v-x), and the additional freshwater forcing in the MWP-0% run resulted in 3% increase in ice melting and 8% decrease in ice formation. (Fig. S2d and Fig. S3d). We added some sentences in **Section 2.3.**

Lines 157-160: ***We compared the differences between experiments with and without external freshwater forcing at stations A1, A6, E2, and E7. In regions with strong stratification, the presence or absence of external freshwater has little impact on the results. However, in weakly stratified regions, like station E7, the differences are more pronounced (refer to the supplementary file for further details).***

5. Lines 184 to 185 – I found this statement confusing. Do you meant that you changed the ML definition based on stratification?

We did not change the ML definition based on stratification. This paragraph explains why we chose $\Delta\sigma = 0.03$ kg m^{-3} as the threshold for calculating the MLD. In order to avoid reader misunderstanding, we removed excessive explanations and directly referenced relevant literature.

~~***Peralta-Ferriz and Woodgate (2015) used a threshold criterion of …….. Therefore, we chose the criterion of $\Delta\sigma$ = 0.03 kg m-3 to determine the MLD in this study.***~~

We revised a sentence in **Section 2.4**.

Lines 187-188: ***In this study, the mixed layer depths (MLDs) are calculated as the depth at which the potential density relative to 0 dbar initially surpasses the shallowest sampled density by the threshold criterion of $\Delta\sigma$=0.03 kg m^{-3}, according to previous studies (Toole et al., 2010; Jackson et al., 2012; Peralta-Ferriz and Woodgate 2015).***

6. Figure 3a – Please confirm the title of the y axis – is this what was calculated in equation (8)?

The y-axis in Figure 3a is not calculated based on equation (8). The values of the y-axis represent the net value of the ocean surface freshwater flux. We revised some sentences in **Section 2.4** to provide a clearer explanation of Figure 3a.

Lines 179-183: ***Figure 3a shows the time series of the net ocean freshwater flux, the sum of freshwater fluxes caused by ice melting/freezing and surface freshwater forcing, for the six experiments at station A1, in which the negative value represents freshwater entering the ocean. In this model, the surface freshwater flux caused by ice melting/freezing is on average several tens of times larger than the external freshwater forcing. Therefore, Figure 3a can be regarded as the ocean***

freshwater flux caused by ice melting/freezing.

We revised sentences in the **caption of Figure 3** to clarify the meaning of the y-axis.

Lines 190-191: ***Figure 3: Simulated net ocean freshwater flux and time series of upper 50 m salinity at station A1. (a): Time series of net freshwater flux at sea surface (the sum of freshwater fluxes caused by ice melting/freezing and surface freshwater forcing). ….***

7. Figure 7a to f – It is difficult to see what is happening in the upper 20 m. Does it make sense to only show the upper 50 m, as was done for salinity?

Due to the use of inappropriate x-axis scales, Figure 7a-f does not clearly display the temperature in the upper 20m. Since the temperature variations at stations E6 and E7 occur in the upper 120 m, it is incomplete to only show the upper 50 m. Therefore, we modified the x-axis scales for a clearer view of the temperature in the upper 20 m.

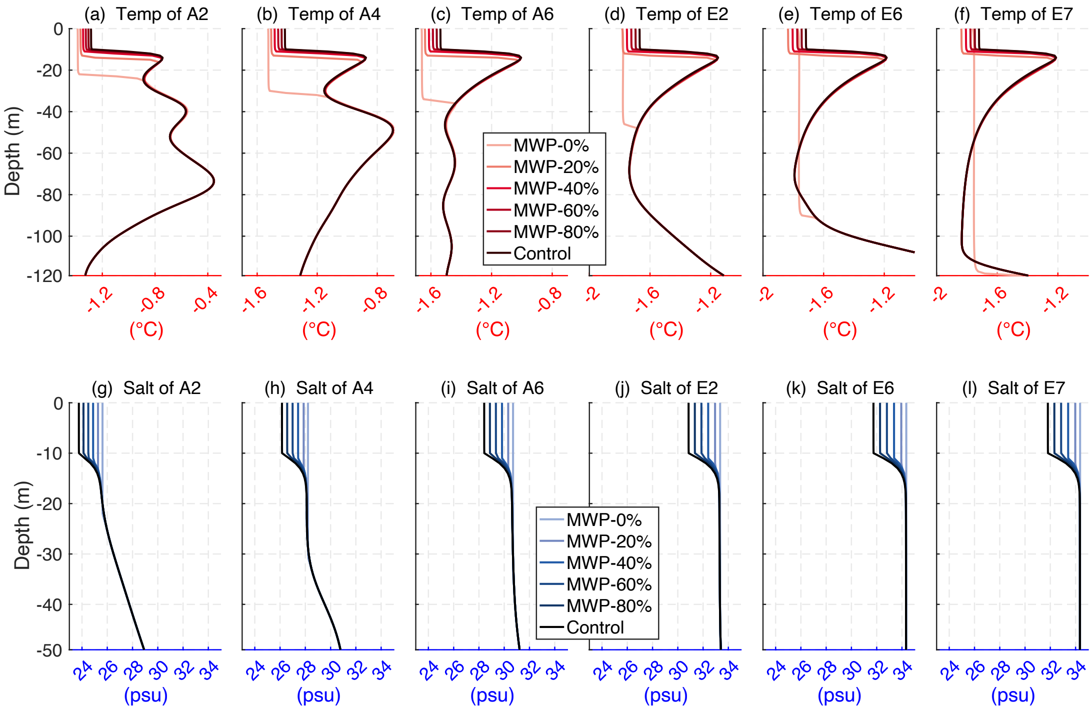

Figure 7: Simulated temperature (top row) and salinity (bottom row) profiles of control runs and MWP runs in mid-August for stations A2, A4, A6, E2, E6 and E7.

8. Lines 350 to 353 – Do the authors have evidence of heat from the NSTM mixing upwards or downwards or is this speculative? Please be clear.

This is a valuable question. We added sentences in the **Section 3.2.2 (a).**

Lines 357-361: ***As shown in Figure 7a-d, the temperature below 10 m in the MWP-0% run is lower than that in the control run, indicating limited heat transfer to the underlying layers at strongly stratified stations. Conversely, Figure 7f illustrates a well-mixed pattern of water temperature between 0-120m in the MWP-0% run in the station E7. Moreover, the temperature between 60-120m exceeds that of the control run, suggesting a downward mixing of heat that warms the underlying water layers.***

Responses to Reviewer #2

This is my second review of a manuscript by Zhang et al. titled "A numerical study on melt water feedback in the coupled Arctic Sea ice-ocean system" in which the authors perform 1D numerical systems of the Arctic Sea ice – ocean system to study the negative feedback related to sea ice melt. In particular, they find that the freshwater from melting sea ice reduced ice melt by ~17% and reduced ice growth by up to 40% depending on stratification.

I thank the authors for thoroughly answering my previous questions and comments and I think the manuscript is now in a much better shape and close to publishable form. I only have very minor comments and consider this a minor revision.

Thank you for your comments, which have greatly improved the quality of this MS. In the following, we provide point to point responses (blue text) to the suggestions and revised the MS ***(black bold italic)*** accordingly.

Main comment:

1. The fact that the simulations are only 1-year long and are not in equilibrium should be clearly discussed somewhere (maybe in the discussion section). For example, figure 6 shows that in all cases, sea ice is growing beyond the initial conditions. Since for most of the manuscript the authors are looking at anomalies from the control run, this should be okay, but the simulations are still likely sensitive to the initial conditions. As mentioned in the last round, I would have personally preferred control simulations that are in equilibrium, but in any case, it needs to be clearly stated that the simulations are not in equilibrium and therefore you focus on anomalies from the control state.

Thanks for the suggestion. We added some sentences in **Section 3.1.2.**

Lines 241-243: ***Figure 6a shows that in all control runs, ice is growing beyond the initial conditions, as the model ran for only one year and did not reach an equilibrium state. Nevertheless, it is still reasonable for this study because this paper focuses on the anomalies from the control run by perturbing the melt water.***

Style & typos

2. Abstract and elsewhere: I think it would be cleanest to use the same number of significant digits. For example, in the abstract I would suggest rounding all the numbers to the full percentages i.e., 17%, 12% and 40%.

Thanks for the suggestion. We rounded all the numbers in the MS to the full percentage.

Abstract, lines 12-14: ***2) … by 17% by strengthening ocean stratification. 3) … by 12% during the winter, while it decreased 43% in …***

Section 3.2.2 (a), lines 323-324: ***… by 21.6 cm (~17%), 6.4 cm (~5%), 3.8 cm (~3%), 2.4 cm (~2%) and 1.2 cm (~1%) (averages of all stations) for the ...***

Section 3.2.2 (b), line 368: ***… of 21 cm (approximately 12%) was …***

Conclusions, line 487: ***… approximately 17% greater than …***

line 493: ***… approximately 12% smaller than …***

3. Methods: I think the lower boundary condition (and the depth of the lower boundary) are not stated anywhere – please add.

Thanks for the suggestion. we added a sentence in **Section 2.1**.

lines 84-85: ***The bottom boundary condition is zero flux, meaning that there is no exchange between the upper water column and the water below 300 m.***

4. Figure 11 and 17. state the months used for melting and freezing seasons in the caption.

Sorry for missing this information in the MS. In fact, the duration of the melting and freezing seasons varies among experiments, depending on the dates when ice melting starts/ends in each experiment. We added some sentences in the **caption of Figure 11** to clarify it.

Lines 331-333: ***Figure 11: … (a) Effective ice thickness change during the melting season. The melting season for each experiment is defined as the period from maximum thickness in May to minimum thickness in September. (b) Effective ice thickness change during the freezing season. The freezing season for each experiment is defined as the period from minimum thickness in September until the end of the simulation.***

Line 432: ***Figure 17: Same as figure 11 but for stations A3, A6, E2 and E7 of the thinner initial ice experiments.***