Response to Reviewer #1's comments

(NB *italicized text in box* is comments from the reviewer. Some numbers with bold fonts were inserted for our convenience in addressing the comments.)

(General comments) *Kusahara and co-authors use an ocean-sea ice-ice shelf model to describe oceanographic and cryospheric processes in Lützow-Holm Bay, East Antarctica. Consistent with observations, the model shows warm intrusions onto the continental shelf and consequent rapid melting of the Shirase Glacier Tongue. The model also describes the impact of winds and fast ice on warm water delivery to the ice shelf. This study is an important advance to our understanding of the Antarctic system and therefore appropriate for The Cryosphere. However, I believe that some further explanation/analyses are required before the manuscript can be published, as described below.*

Major Comments

(1) *A recent study by Hirano et al (2020) shows new observations from Lützow-Holm Bay. This new study by Kusahara et al represents an important advance compared to that previous study. However, in the text it is not fully clear what is new here. I would try to strengthen what is new here (e.g. cross shelf exchange) and put less emphasis on what both model and observations show.*

General comment and (1): Thank you very much for your careful reading, instructive suggestions, and understanding of this paper's importance. Following your advice, we have added detailed analyses and explanations for water exchange across the shelf breaks (Figs. 16 and 17). In this revision, we have changed the presentation of the model-observation comparison, taking account of both the reviewers' comments. With these modifications, we consider that manuscript's readability is much improved.

We have highlighted the modifications with red color in the manuscript and quoted them in this response letter. In our response, we use new figure numbers in the revised manuscript to point out the corresponding figures. Since we have largely modified the manuscript, the figure numbers are different from the original manuscript.

In the revision process, we found a mistake in the calculation of the eastward transport of the undercurrent (Fig. 19 in the revised manuscript). We have corrected the figure and correlation coefficients in Section 5, but these corrections don't change our conclusions.

(2) *The simulation with fast ice shows warm water (CDW?) all over the water column in the trough. This is not observed anywhere around Antarctica. It seems to me that the no-fast-ice simulation produces more realistic results. A discussion about this is required, including whether the authors think the fast-ice simulation is realistic.*

(3) *Figure 18: I like the schematic. However, how the water intrudes into the canyon is not analysed here. In particular, an eastward undercurrent requires cross-isobath flow (and potentially upwelling) to access the canyon on the eastern side. There is a wide literature describing this. The way this is depicted in the schematic is a bit misleading. I would closely look at the circulation pattern at the mouth of the canyon to see what happens.*

(2) In the revised manuscript, we have displayed vertical profiles of both ocean temperature and salinity along the TROUGH section in the FI and NOFI cases (Fig. 9) to see the CDW signals (characterized by warm and high salinity). The intrusion of warm CDW along the ocean bottom was less modified when fast ice is present in the bay (FI case). In contrast, the ocean temperature at the surface-subsurface layer in the absence of the fast ice is substantially decreased due to atmosphere-ocean interaction in the bay (NOFI case). As you pointed out, we used the results from the NOFI case for several figures (Figs. 11, 15, and 18). We have added sentences to explain why we used the NOFI case for the analyses.

L336–339

In the end of this subsection, we compare the ocean temperature profile along the A-line between the observation and NOFI case (Fig. 11). As shown above, the observations seem to capture the transient conditions. Since the observed temperature profile along the TROUGH section is more similar to that in the NOFI case (Fig. 9), here we use the results from the NOFI case for the comparison along the A-line.

L456–458

In order to examine the detailed characteristics of the undercurrent on the upper continental slope, vertical profiles of ocean temperature, density, and east-westward flow along a section at 35.75°E (see the black line in Fig. 17) are plotted in Figure 18 for the NOFI case, which shows a clear seasonality in the undercurrent.

(3) Thank you for your comment. We have added the detailed ocean flow around the sill region (Fig. 17 for the FI and NOFI cases) and seasonal variation of the inflow transport to the bay across the sill section (Fig.16 for the FI and NOFI cases). These figures clearly illustrate the seasonality in the warm inflow into the bay. In the revision, we removed the schematic figure to reduce the number of figures. The detailed ocean flows in both cases (Fig. 17) seem to be better for this paper than the simplistic schematic figure.

Minor Comments

(4) *Line 17: It is not well known if there is a gyre in East Antarctica, and specifically close to the Totten region. I would be more cautious with this inference. I would rather say that the ACC is closer to the coast in Amundsen/Bellingshausen seas and Totten region than elsewhere.*

(5) *Line 49-54: see above.*

(6) *Line 58: fastest melting?*

(7) *Line 109: Concentration? What do you mean?*

(8) *Line 186: "trough".*

(9) *Line 189- 190: change the wording to be more clear.*

(10) *Figure 10: specify in the caption what the black lines are.*

(4)(5) We have rephrased them.

L23–24

Both regions have a common oceanographic feature: southward deflection of the Antarctic Circumpolar Current brings CDW onto the continental shelves.

L54–63 ### (adding several references)

Ice shelves in the Amundsen and Bellingshausen Seas and the Totten ice shelves have a common feature: the Antarctic Circumpolar Current (ACC) is proximal to the Antarctic continental shelf regions, and thus the CDW can affect regional coastal water masses. The Southern Ocean has three large-scale cyclonic (subpolar) gyres: Ross, Kerguelen, and Weddell Gyres (Gordon, 2008). Amundsen and Bellingshausen Seas and the offshore region of Wilkes Land correspond to south-eastern sides of the Ross and Kerguelen Gyres, respectively, where the southward deflection of the large-scale ocean circulations brings warm water poleward to the Antarctic continental shelves (Armitage et al., 2018; Dotto et al., 2018; Gille et al., 2016; McCartney and Donohue, 2007; Mizobata et al., 2020). By analogy to the relationship between the southward deflection of the ocean circulations and the active ice shelf melting areas, one can naturally speculate active ocean-ice shelf interaction around the south-eastern side of the Weddell Gyre (Ryan et al., 2016).

(6) We have rephrased the sentence.

###L64–65 ###

This glacier, Shirase Glacier in Lützow-Holm Bay (LHB), Enderby Land, East Antarctica, is one of the fastest laterally-flowing glaciers around Antarctica (Nakamura et al., 2010; Rignot, 2002).

(7) We have rephrased the sentence.

###L115–117 ###

Prognostic equations for the sea-ice momentum, mass, and concentration (ice-covered area) were taken from Mellor and Kantha (1989). Internal ice stress was formulated by the elastic-viscous-plastic rheology (Hunke and Dukowicz, 1997), and sea ice salinity was fixed at 5 psu.

(8) We have corrected it (L208).

(9) We have rephrased the sentence.

###L209–212 ###

In the southern part of the trough, there is a north-southward elongated depression at the latitudes from 69.5°S to 70°S with a maximum depth of approximately 1600 m. The feature is confirmed in the observational data. We consider that our dataset is the best estimate of bottom topography in the LHB region at this moment in which available bathymetric observations were taken into account.

(10) We have corrected the caption (Fig. 14).

(11) *Line 290-291: "The observed estimate from the single location includes the entire SGT variability and regional variability." What do you mean? Please clarify. I would put in a map the location of the ApRES. I would also compare model basal melt in a grid point located near the ApRES location.*

(12) *Line 330: "attached to the bottom".*

(13) *Line 371: explained ->balanced.*

(14) *Figure 17: specify in the caption the location of these data.*

(11) Thank you for your suggestions. We have rephrased the sentences and added a comparison of local basal melt rate at around the ApRES location (thin lines in Fig. 7).

L405–412

These general agreements provide some confidence for the model results in this study, especially for the seasonality of the SGT basal melt rate. It should be noted that the ApRES located on the high-gradient zone of the basal melt rate in the model (Fig. 8) and the observation period was less than one year. When comparing the local basal melt rate between the model and observation, the model underestimates the seasonal amplitude of the basal melt rate. This indicates the model underestimates the seasonal cycle of the warm water inflow to the cavity under the ApRES position. The bottom topography under the SGT is outside of our compiled topography data, and thus it was not well constrained by the observed topography. The uncertainty of the bottom topography probably leads to the discrepancy in the seasonal amplitude of the local basal melt rate.

(12) (13) We have corrected them (L462 and L257).

(14) We have corrected the caption for Fig. 20. ("Time series of ocean temperature anomaly and potential density averaged over the box area in Fig. 8 …")