Response to Reviewer #2:

We thank the reviewer for their comments. Our responses are shown in blue, and the updated lines are in green. In addition, we have made minor grammatical corrections and fixed some typographical errors.

Review of Sensitivity of grounding zone melting to subglacial discharge configuration and sediment dynamics across contrasting ice shelf cavity regimes

The paper by Papapetros et al examines various aspects of subglacial drainage into an idealized ice shelf cavity based on the ISOMIP+ experiments. Different thermal regimes, set by far field ocean conditions, are examined, as is the position of the drainage (and distributed vs channelized). The ROMS model is also utilized to look at the impacts of sediment inflow and mobilization using a multi-grain size sediment model and parameterization for density effects of sediment load.

Introducing subglacial drainage into an ice-shelf cavity model is not a new development at this point; the study does investigate position of inflow which is somewhat novel for ice-shelf cavities, but what I think is new is the investigation of sediment load and transport in the water, and the effects of input from subglacial sources. As such I do think that the paper could be suitable for TC, but there are a number of somewhat major issues relating to presentation and clarity, which will certainly need addressing.

General comments:

1. I did not find this an easy paper to get through, unfortunately, and I think to some extent this can be addressed by better presentation of results. Each new results section presents a rather LARGE array of figures to look at. The reader is then invited to visually pick apart differences e.g. in figures of circulation cells, some of which are not side by side (eg when we are asked to compare 2cd, and 6cd). In figures where an array of raster plots are shown i would prefer to see comparison of some sort of metric -- for instance, the strength (and maybe position) of circulation cells in fig 2a and similar. I would ask the authors to really think about how to do this, as it is difficult to take much away from e.g. most rows of Fig 3. Alternatively or additionally readers should not need to visually compare such images, but should instead be shown anomalies where appropriate. The text in turn is quite a dense description of the figures and I wonder if Sections 3.1 and 3.2 can be shortened by taking some of these suggestions on board, and instead trying to give an overarching message.

We understand that the large number of results makes the paper visually dense. This reflects the systematic design of the study, which examines multiple discharge locations and configurations across contrasting ice shelf cavity regimes. The purpose of Figures 2-4 and 6, is therefore to show how the spatial structure of the response changes across different scenarios, rather than to reduce the response to a single summary metric.

Comparisons between configurations are presented throughout the manuscript where relevant. Figure 2 establishes the baseline response, Figures 3 and 4 explore the response to different discharge locations in the warm and cold regimes, respectively, and Figure 6 examines the distributed discharge configuration. Although the control cases are already presented in Figure 2,

we have included them again in Figure 6 to facilitate direct comparison with the distributed discharge experiments.

Alongside the spatial structures of the streamfunctions, which provide information on the location and geometry of the circulation cells, we also provided a quantitative measure of circulation strength (maximum values shown in mSv). Subglacial discharge locations are also explicitly indicated in the figures by red arrows. We therefore do not consider that an additional metric of circulation-cell strength or position would provide substantially different information without losing some of the spatial structure that is central to this analysis.

We also considered presenting anomaly fields. However, we found that this made the interpretation of the absolute spatial structures less straightforward, particularly for the barotropic streamfunction and temperature fields, where the sign of the values is important for interpreting the circulation direction and thermal structure. We therefore decided to retain the absolute fields.

Nevertheless, we have reviewed Sections 3.1 and 3.2 and streamlined the text where possible, while retaining the sequential description needed to interpret the multi-panel results. We have also revised several qualitative statements and added quantitative ranges where these provide useful context for the spatial patterns.

2. There are numerous instances with figures not being suitably described in the text or in the caption -- please look out for these in specific comments below.

NOTE ABOUT ABOVE COMMENTS: due to limited time I was not able to look over the Appendix in detail -- but I maintain that a reader should not need to do so. And so even if it turns out that some of my concerns are addressed in appendix, my comments stand.

We have carefully revisited the text and captions throughout the manuscript and addressed the specific comments below. In particular, we have revised the relevant descriptions to make clearer what the reader should look for in the figures and to ensure that the main text and captions provide the information necessary to interpret the results without requiring reference to the Appendix.

In a few cases, the Appendix provides additional detail or a more resolved view of features discussed in the main text. Where relevant, we now explicitly refer to these supplementary figures as supporting material. However, these figures are not intended to provide information necessary for the interpretation of the main-text results; rather, they corroborate and further illustrate features that are already described and supported by the main-text figures.

3. As I said, I believe the sediment load aspect is the unique aspect of this paper. In the final results section we see how it affects melt, but I would like to know whether this is due to density changes or bathymetry changes, neither is really addressed; and I would like in general to better understand how sediment load impacts circulation.

The effects of suspended sediment and bathymetric changes on circulation and basal melt are discussed in detail in Papapetros et al. (2025). In the present study, however, these effects are not separated in the experiments, and we therefore cannot quantitatively attribute the simulated melt rate response to changes in water column density versus changes in bathymetry.

Our results nevertheless provide some indication that bathymetric changes may play an important role. In particular, melt rate anomalies in the cold regime (Figure 7e) are substantially reduced in experiments where erosion occurs and modifies the bathymetry (e.g. locations 40-44 and 50). This is consistent with the findings of Papapetros et al. (2025), which indicate that bathymetric changes can have a stronger influence on the melt response than buoyancy driven density changes. We therefore discuss this as a possible mechanism in the revised manuscript, while noting that dedicated experiments isolating the effects of evolving bathymetry would be required to establish the relative contribution of the two mechanisms, as follows (previous lines 389-391):

"These bathymetric adjustments alter circulation pathways (Zhou et al.,2020) and modulate melt rates (Papapetros et al.,2025). In particular, reductions in melt rates in the cold regime at locations where erosion substantially modifies the seabed (locations 40, 42, 44 and 50; Figures 4g and 7e) suggest that bathymetric feedbacks may contribute more strongly to the sediment-induced response than changes in water-column density associated with suspended sediment, consistent with Papapetros et al. (2025). However, because our experiments do not isolate these mechanisms, we interpret the sediment-induced response as arising from coupled effects of suspended sediment and morphodynamic adjustment, rather than attributing it quantitatively to either component alone."

Regarding the impact of subglacial sediment on the grounding zone circulation, suspended sediment modifies the density of the water column and can therefore influence the buoyancy-driven circulation associated with the subglacial discharge. This circulation response, together with sediment transport and evolving bathymetry, can subsequently modify the distribution of heat and melt. We have clarified this connection in the revised manuscript and refer to Papapetros et al. (2025) for a more detailed investigation of these mechanisms, as follows (previous lines 56-59):

"Suspended sediments may influence buoyancy-driven circulation through changes in water-column density (Salcedo et al., 2013; Papapetros et al., 2025), while deposition and erosion near the grounding zone can modify local bathymetry (Alley et al., 1989; Horgan et al., 2013). These processes can in turn alter circulation pathways and basal melt, creating coupled feedbacks between sediment transport, cavity circulation, and ice shelf basal melt (Papapetros et al., 2025)."

4. The method of introducing subglacial drainage, a momentum flux at the boundary of cells, is a somewhat standard approach at this point, as shown by the sources cited. The flux of 73 cumbers is actually not unheard of, Gourmelen et al (2025) infer that for brief periods, runoff into thwaites cavity may have reached 10x this value. Subglacial channels, however, are not likely to be substantially less than 2km wide (and likely not as tall as the grounding line water column, which is not stated..) meaning that the input momentum is quite diffuse and current effects are due to salinity gradients. As I expect sediment mobilization is nonlinear in current speed, this may not have the same effect as current speeds associated with a 20-50m wide opening. I invite the authors to discuss this in the manuscript.

Addressing subglacial water flux first - the prescribed discharge rate of 72 m^3 s^{-1} used in our experiments was selected based on Vaňková et al. (2025), allowing direct comparison with their experiments, and is in line with steady-state channel fluxes simulated by Ehrenfeucht et al.

(2025). We note that such substantially larger discharge rates can occur over short periods, for example during subglacial lake outbursts, but episodic extreme events are outside the scope of the present study.

The reviewer is correct that the spatial scale over which subglacial discharge is introduced can affect the resulting current speeds and, consequently, may affect the magnitude of sediment mobilization. Given the 2 km horizontal resolution of the model, the prescribed volume flux is applied over a larger horizontal and vertical range than would be expected for a real subglacial channel. Concentrating the same discharge through a much narrower channel opening would produce higher local velocities, which would generally be expected to produce a narrower and faster meltwater plume and carry sediments further from the grounding line before deposition. In addition, the sediment deposited in the model is averaged over a 2 km grid cell, and therefore smoothes out bathymetry changes which in reality might be larger locally.

The choice of model resolution is a balance between the ability to model changes in basal melt rate over the full ice shelf, and resolving fine scale processes in the grounding zone. Although the 2 km horizontal resolution may smooth fine scale details at the grounding line, we followed Vaňkova et al. (2025), who conducted sensitivity tests with 1 km and 4 km resolutions and reported qualitatively similar results. We have added additional text to the Discussion to address this point and reflect its impact on results (see below).

Despite the smoothing of fine-scale processes at the grounding line, we believe the chosen resolution is appropriate for the experiments presented. Our objective is not to provide a quantitative prediction of sediment transport associated with an individual subglacial channel, but rather to investigate the relative response of the grounding zone environment to different discharge configurations and cavity regimes. The differences between channelised and distributed discharge, and between the warm and cold regimes, should therefore be interpreted primarily within this comparative framework, rather than as predictions of sediment transport at the scale of an individual subglacial channel.

We have revised the manuscript as follows (Section 4):

“In addition to uncertainty in sediment concentration, the spatial representation of subglacial discharge introduces important limitations. The vertical distribution of subglacial discharge modelling choice may influence the magnitude of basal melt: Vaňková et al. (2025) tested discharge confined to the uppermost or bottommost layer, as well as discharge distributed throughout the water column. Although the resulting melt rates differed by up to 20% depending on the discharge configuration, the scaling relationship between melt and discharge remained unchanged. The horizontal model resolution introduces an additional limitation: The 2 km model resolution is wider than a typical subglacial channel, which means that the prescribed subglacial discharge is spread over a wider area, reducing the inflow velocity. This could impact local sediment deposition rates, and more generally the model will smooth fine-scale processes at the grounding line which are important for local bathymetry changes. While the purpose of this paper is to examine the relative response of the grounding zone to different discharge configurations and cavity regimes, future studies might look in detail at the fine-scale local processes affecting sediment deposition and ocean dynamics close to the grounding line.”

Line by line Comments

Line 119-120 - can you justify the load assumption from literature

We have clarified the basis for our sediment concentration assumption in the revised manuscript, as follows (previous lines 118-120):

"The subglacial discharge acts as a source of sediment discharge, and its prescribed flux is relatively high compared with values considered by Nakayama et al. (2021), Gwyther et al. (2023) and Papapetros et al. (2025). We therefore prescribe a sediment concentration of 1 kg m^{-3}, corresponding to the upper end of the 500-1000 mg L^{-1} range estimated for high-flux conditions by Aitken et al. (2024), with a grain density of 2650 kg m^{-3} (Aitken et al., 2024; Papapetros et al., 2025)."

Line 165 - I did not follow, can you reword

We have reworded the text as follows (previous lines 165-166):

"As the eastern circulation cell expands westward, the boundary between the two cells becomes increasingly important in influencing the thermohaline dynamics at the grounding zone (Figure 2a-d)."

FIg 2f: I think change from initial baths would be better to show here

We considered this suggestion, but prefer to retain the absolute bathymetric elevation in Figure 2f. Figure 2 is intended to provide the absolute values for the grounding zone context and to show the resulting bathymetric configuration of the simulations. We therefore consider the absolute values to be more appropriate for this figure and also allow the bathymetry to be presented consistently with the other panels.

Fig 2g: caption says "grounding line geometry" which I don't think is true. Im guessing this is the bed initially (black line) and after X years simulation (blue/red line) in the southernmost cells? Please define more carefully.

Panel (g) shows a vertical cross-section of the bathymetry along the grounding line, with the grey line representing the reference bed and the coloured lines representing the final bed geometry for each experiment. We have clarified this description in the caption and applied the same clarification to the corresponding panels in Figures 3, 4 and 6 for consistency.

Line 173: Do you mean SGW has a stronger impact in the cold regime?

Yes, we refer specifically to the stronger and more spatially extensive salinity response to subglacial discharge in the cold regime. We have reworded the sentence to make this explicit.

Line 194: "relative to the warm regime.." They look the same to me.

The difference between the warm and cold regimes is indeed subtle at the scale shown in Figure 2g (order of meters). However, the cold regime exhibits slightly greater local deposition, with a mean bathymetric difference of approximately 15 cm relative to the warm regime. This difference is more clearly resolved in the anomaly panels presented in Figure A2, Appendix A. We have clarified this in the text and now explicitly refer to Figure A2, Appendix A when describing the difference.

Fig 3: this is far too much. I would prefer to see where possible for each row some metric comparing with the relevant figure in 2a (1st or 2nd column?) or a difference with this column. Similar with Fig 4.

We acknowledge that Figures 3 and 4 contain a large number of spatial fields, which make the direct comparison between discharge configurations less straightforward. We have therefore retained the absolute fields, which are important for illustrating the spatial structure and magnitude of the circulation, hydrographic, and melt rate responses, but now explicitly report selected quantitative values in the text where they facilitate comparison between experiments.

Line 225, "This generates" it is hard to see any pattern or signal from the figures

We understand that the temperature patterns may not be sufficiently clear in the original figure. We have therefore adjusted the colour scale to improve the visualization of the spatial temperature patterns. Upon revising the manuscript, we also concluded that the sentence did not add substantial information to the interpretation of the results and have therefore removed it to improve the clarity and focus of the text.

Line 240-241: how can we see this from 3g and 4g? Tell us what to look for (and I don't think we should need to refer to the appendix, per the definition of "appendix")

We believe that the erosion events are directly identifiable in Figures 3g and 4g: as stated in the text, they correspond to episodes of local bathymetric lowering, and panels (g) show the resulting bathymetric elevation for different discharge locations. The subsequent sentence further specifies where these events occur (primarily at discharge locations 40, 42, 44 and 50) and relates them to the circulation and grounding line geometry. Figure 5 further shows in detail the temporal evolution of one of these erosion events. We have nevertheless revised the wording to make this connection more explicit for the reader, as follows (previous lines 240-241):

"The depositional environments formed in the cold regime are additionally characterised by episodic erosion events. The effect of these events can be seen at discharge locations 40, 42, 44 and 50 in the cold regime (Figure 4g), where the bathymetry peak formed through sediment deposition adjacent to the discharge location is substantially smaller than in the warm simulations (Figure 3g). This implies an additional erosion process has occurred in the cold cavity, and an example of the episodic erosion process involved is shown in Figure 5. An illustration of the temporal evolution of these events is further provided in Figure A3a (Appendix A)."

We would also like to clarify the role of Appendix A. The appendix is not required to identify or interpret the erosion events presented in the main text. The main text paragraph describes where the events occur, how they manifest in the figures, and the physical mechanisms responsible for them. Appendix A provides an illustrative example of the temporal evolution of two experiments and further details of the erosion process, and is therefore intended as supporting material rather than as necessary evidence for the interpretation presented in the main text.

Fig 5f: please do not truncate the erosional stress plot.

We have revised Figure 5f to show the full range of erosional stress values, avoiding truncation of the y-axis. To ensure that the minimum erosional stress associated with the erosion event remains discernible, we have added Figure A3b in the Appendix A, which provides a close-up of Figure 5f over the relevant time interval.

Line 254, "thereby": it would be nice to see more clearly how the bed depth and suspended sediment influences heat transport.

As discussed in our response to Major Comment 3 above, we have expanded the discussion to clarify how suspended sediment and bathymetric adjustment can modify circulation pathways and, consequently, the redistribution of heat and basal melt.

Fig 270: you should be showing an anomaly figure, not asking us to compare.

As discussed in our response to the major comment above, we considered presenting anomaly fields but chose to retain the absolute fields because they provide the clearest representation of the spatial structures and their physical interpretation. To enable direct comparison with the control experiment, we have now included the control cases within Figure 6.

Section 3.4: There are numerous issues with the presentation of these results -- which are interesting -- and so I don't think I will be able to list them all.

*** My principal concern is that the lines in Fig 7 are not sufficiently explained (***which needs addressing***) so I needed to infer them. In figs. 6a and 6e, I believe this shows the melt rate in the ocean grid cell where SGW is entering, so that e.g. at point 34, we see the melt rate in x=34 *when the SGW enters x=34*, and not otherwise. This of course explains why the mean melt rate in 6c,g is so much smaller. (I also infer that the "grounding zone mean" is the average over all these cells (which is not quite the definition of a "grounding zone"). One issue I have is that this is taken later as evidence that channelized runoff at a given location greatly increases melt.. where really, we need to take the mean into account. As such, I do not like the comparison here, and I also feel isolated melt and distributed melt should not be compared. I *think* it is, but to be honest I found the text in this section confusing. I suggest the authors take a clean approach at writing this section (which is thankfully not very long) as it communicates useful messages.**

Also in fig 6: all axes where there are values shown should be labeled. Say that the dashed lines correspond to right hand axes. And (if it is true) say that rows 2 and 4 show GZ average.

We believe there may be a figure-numbering discrepancy in the comment, as the melt rate results discussed in Section 3.4 are presented in Figure 7 rather than Figure 6. Nevertheless, we understand that the meaning of the different lines in Figure 7 could be made more explicit. The grounding line and grounding zone metrics are defined in the Methods section, and we have now reiterated their definitions when introducing Figure 7 and clarified their interpretation in the caption.

Specifically, for channelised discharge, the grounding line values correspond to the first ocean grid cell adjacent to the prescribed discharge location, whereas the grounding zone values are spatially averaged over the region extending up to 8 km downstream of the grounding line, as defined in the Methods. The larger local response at the grounding line therefore does not imply a comparable enhancement in the grounding zone mean. Rather, the contrast between these two metrics reflects the spatially localised nature of the channelised response.

We retain the comparison between channelised and distributed discharge because it is central to our analysis, while explicitly distinguishing the responses at the two spatial scales. Channelised discharge produces stronger local melt enhancement near the discharge location, whereas distributed discharge produces a weaker but more spatially extensive response, resulting in a greater influence on grounding zone averaged melt rates.

We have also revised the Figure 7 caption to make the plotted quantities and spatial metrics explicit, as follows:

"Figure 7. Melt rates and associated anomalies at the grounding line and across the grounding zone for the warm (top two rows) and cold (bottom two rows) regimes. The panels on the left (a, c, e, g) correspond to the channelised subglacial discharge experiments, and the panels on the right (b, d, f, h) represent distributed discharge experiments. Rows 1 and 3 show melt rates at the grounding line, evaluated at the first ocean grid cell adjacent to each discharge location. Rows 2 and 4 show melt rates averaged over the grounding zone, defined as the region extending 8 km downstream of the grounding line. Each subplot includes three experiments: $Control_0$ (blue), Sgw_x or Sgw_D (orange), and $Sgw+Sed_x$ or $Sgw+Sed_D$ (red). For channelised experiments, markers indicate the individual discharge locations, whereas continuous lines represent distributed discharge experiments. The purple dashed lines represent the difference between sediment-laden and freshwater-only experiments [($Sgw+Sed_x$ – Sgw_x] or [$Sgw+Sed_D$ – Sgw_D]), shown as percentage anomalies on the right-hand axes. Absolute melt rates are plotted on the left-hand axes."

Line 298, 173%. this is only where the melt is released no? do we even see what happens to melt elsewhere? or are you now actually talking about 7c, not 7a?

The 173% increase refers to the melt rate at the grounding line in the warm regime, adjacent to the discharge locations. This metric is described in the Methodology, and Figure 7a is the appropriate panel for this comparison. We have clarified the wording to make this explicit, as follows (previous lines 298-299):

"When freshwater-only forcing is added (Sgw_x_warm), melt rates at the grid cell immediately adjacent to the discharge location increase by an average of 173%, reaching around 90-110 m yr^{-1} (Figure 7a)."

Line 306-7: indicating that changes outwith the location of runoff are VERY different, which you don't make clear.

We understand that the original wording could be confusing. Our intention was to refer to the qualitative response between experiments, rather than to the magnitude of the response. We have therefore revised the sentence to make this distinction explicit. The text now reads (previous lines 306-307):

"When averaged over the broader grounding zone, melt rates under channelised discharge show the same qualitative response between experiments as at the grounding line, with subglacial discharge enhancing melt rates and sediment-laden discharge reducing this enhancement, but with substantially lower magnitudes (Figure 7c,g)."

Line 320, 37% increase: in the mean, or locally?

The 37% increase refers to the mean melt rate. We have clarified this in the main text (previous line 320):

"...representing an approximately 37% increase in the mean melt rate relative to the control scenario..."

Line 326: please cite slater 2015 here and elsewhere where this result is discussed, as it is relevant even if it applies to a tidewater glacier (both have a theoretical scaling from Jenkins 2011 which basically makes this argument). and this is not quite true for COLD, x=54

We have revised the manuscript to acknowledge the findings of Slater et al. (2015) and discuss them alongside the more recent results of Vaňková et al. (2025), highlighting how the relationship between discharge configuration and basal melting may differ between experiments and scenarios. We have also clarified the exception observed in the cold regime experiment at discharge location 54, which produces a similar grounding zone-averaged melt rate as the distributed discharge case. This exception is now explicitly acknowledged in both Results and Discussion sections.

Lines 332-333: .. if you only consider where the SGW is released. please make this clear.

We have revised the sentence to clarify that the stronger melt response from channelised discharges occurs near the discharge location.

Line 339, Lebrocq et al 2013. If you cite this, then you should also cite Gourmelen et al, 2025.

We have added Gourmelen et al. (2025) alongside Le Brocq et al. (2013) in this statement. We also note that our intention was not to imply that all studies cited here focus on warm cavities. Rather, we refer to the broader conceptual framework for discharge-driven melt enhancement, which has been developed predominantly from studies of warm cavities. We have therefore slightly revised the wording to make this distinction clearer, as follows (previous lines 398-341):

"This fresh and buoyant outflow increases entrainment towards the ice base, driving stronger turbulent exchange to the ice-ocean interface (Le Brocq et al., 2013; Nakayama et al., 2021; Gwyther et al., 2023; Pelle et al., 2023; Vaňková et al., 2025; Papapetros et al., 2025; Gourmelen et al., 2025). However, the conceptual framework for discharge-driven melt enhancement has been developed predominantly from studies of warm ice shelf cavities, where relatively strong background circulation reinforces buoyancy-driven melt intensification."

Line 340: "However..." LeBrocq focused primarily on cold cavities.

See our response to the previous comment.

Line 353-355: you should comment on what position is most likely from a glacial perspective.

We have added the following text (Section 4):

"From a glaciological perspective, the configuration and location of subglacial discharge emerge from the underlying subglacial hydrological system, which is influenced by basal topography and hydraulic potential (Dow et al., 2022; Simkins et al., 2021). Channelised discharge is likely to emerge preferentially where subglacial flow pathways converge at the grounding line, whereas distributed discharge represents a more diffuse drainage configuration in which freshwater is supplied over a broader portion of the grounding line (Ehrenfeucht et al., 2025). In this context, our experiments provide a sensitivity framework for assessing how the oceanographic response varies across idealised discharge configurations and outlet positions, rather than predicting the spatial distribution of subglacial discharge itself."

Lines 373-4: i would argue that one must look at GZ-averaged results here. while it can have a large effect on mean melt, it does not raise melt by 2 orders of magnitude.

We agree that the distinction between local melt rates at the grounding line and averaged over the grounding zone is important here. The strongest melt rate enhancements occur locally near the grounding line, whereas the grounding zone averaged response is considerably smaller. Thus, the large local response should not be interpreted as a two-orders-of-magnitude increase in the grounding zone averaged melt rate. We have revised the text as follows (previous lines 372-374):

"Within this framework, a predominantly cold cavity can still exhibit substantial melt rate enhancements in response to strong subglacial discharge forcing. The enhancement reaches approximately 955% at the grounding line, but averages approximately 165% across the grounding zone, highlighting the strong spatial variability of the melt response."

Line 389: the current paper does not distinguish between the influence due to density change and that due to bathymetry change.

As discussed in our response to Major Comment 3 above, the present experiments do not allow us to quantitatively distinguish between the effects of suspended sediment on water column density and those associated with evolving bathymetry. While our results suggest that

bathymetric feedbacks may have a dominant influence on the melt rate, this remains a hypothesis because the two effects are combined in our simulations. We have clarified this point in the revised manuscript and now explicitly state this limitation (see our response to the third major comment).

Line 392: i thought the wedges were constructed similarly to moraines (sediment being pushed by ice) -- if you are going to bring this point up perhaps you should include this as a source? or compare source magnitudes?

We note that our discussion focuses on grounding zone wedges (GZWs) in marine settings, which form through progressive accumulation and aggradation of sediment at the grounding zone, rather than moraines, which are associated with grounding line migration (Dowdeswell et al., 2016). We therefore do not compare sediment source magnitudes with those involved in moraine formation, as these represent distinct sedimentary processes and are not resolved by our experiments. Our results instead indicate how contrasting patterns of sediment deposition and remobilisation may influence the conditions for GZW development and persistence. To further clarify the scope of our interpretation, we have revised the text to explicitly acknowledge that our simulations do not resolve grounding line migration or the millennial timescales over which GZWs develop, as follows (previous lines 400-403):

"Furthermore, recurring seabed reworking could also inhibit the progressive accumulation and consolidation of sediment required for persistent GZW development. While our simulations do not resolve grounding line migration or the millennial timescales over which GZWs develop, the contrasting patterns of sediment deposition and remobilisation suggest that the cavity thermal regime may influence the conditions under which grounding zone wedges can develop and persist, with potential implications for their effectiveness as stabilising pinning points."

References

Aitken, A. R. A., Delaney, I., Pirot, G., and Werder, M. A.: **Modelling subglacial fluvial sediment transport with a graph-based model, Graphical Subglacial Sediment Transport (GraphSSeT)**, The Cryosphere, 18, 4111–4136, https://doi.org/10.5194/tc-18-4111-2024, 2024.

Alley, R. B., Blankenship, D. D., Rooney, S. T., and Bentley, C. R.: **Sedimentation beneath ice shelves — the view from Ice Stream B**, Marine Geology, 85, 101–120, https://doi.org/10.1016/0025-3227(89)90053-4, 1989.

Dow, C. F., Ross, N., Jeofry, H., et al.: **Antarctic Basal Environment Shaped by High-Pressure Flow Through a Subglacial River System**, Nature Geoscience, 15, 447–452, https://doi.org/10.1038/s41561-022-00994-z, 2022.

Dowdeswell, J. A., Hogan, K. A., Arnold, N. S., Mugford, R. I., Wells, M., Hirst, J. P. P., and Decalf, C.: **Sediment-rich meltwater plumes and ice-proximal fans at the margins of modern and ancient tidewater glaciers: Observations and modelling**, Sedimentology, 62, 1665–1692, https://doi.org/https://doi.org/10.1111/sed.12198, 2015.

Ehrenfeucht, S., Dow, C., McArthur, K., Morlighem, M., and McCormack, F. S.: **Antarctic Wide Subglacial Hydrology Modeling**, Geophysical Research Letters, 52, e2024GL111 386, https://doi.org/10.1029/2024GL111386, 2025.

Gourmelen, N., Jakob, L., Holland, P. R., and ...: **The influence of subglacial lake discharge on Thwaites Glacier ice-shelf melting and grounding-line retreat**, 16, 2272, https://doi.org/10.1038/s41467-025-57417-1, 2025.

Gwyther, D. E., Dow, C. F., Jendersie, S., Gourmelen, N., and Galton-Fenzi, B. K.: **Subglacial Freshwater Drainage Increases Simulated Basal Melt of the Totten Ice Shelf**, Geophysical Research Letters, 50, e2023GL103, https://doi.org/https://doi.org/10.1029/2023GL103765, 2023.

Horgan, H. J., Christianson, K., Jacobel, R. W., Anandakrishnan, S., and Alley, R. B.: **Sediment deposition at the modern grounding zone of Whillans Ice Stream, West Antarctica**, Geophysical Research Letters, 40, 3934–3939, https://doi.org/https://doi.org/10.1002/grl.50712, 2013.

Le Brocq, Anne M., R. N., Griggs, J. A., Bingham, R. G., Corr, H. F. J., Ferraccioli, F., Jenkins, A., Jordan, T. A., Payne, A. J., Rippin, D. M., and Siegert, M. J.: **Evidence from ice shelves for channelized meltwater flow beneath the Antarctic Ice Sheet**, Nature Geoscience, 6, https://doi.org/10.1038/ngeo1977, 2013.

Nakayama, Y., Cai, C., and Seroussi, H.: **Impact of Subglacial Freshwater Discharge on Pine Island Ice Shelf**, Geophysical Research Letters, 48, e2021GL093 923, https://doi.org/https://doi.org/10.1029/2021GL093923, e2021GL093923 2021GL093923, 2021.

Papapetros, P., Galton-Fenzi, B. K., Gwyther, D. E., Boeira Dias, F., and Zhao, C.: **Effects of Sediment-Laden Subglacial Discharge on Ice Shelf Basal Melting and Seabed Evolution**, Journal of Geophysical Research: Oceans, 130, e2025JC023, https://doi.org/10.1029/2025JC023422, 2025.

Pelle, T., Greenbaum, J. S., Dow, C. F., Jenkins, A., and Morlighem, M.: **Subglacial discharge accelerates future retreat of Denman and Scott Glaciers, East Antarctica**, Science Advances, 9, eadi9014, https://doi.org/10.1126/sciadv.adi9014, 2023.

Salcedo-Castro, J., Bourgault, D., Bentley, S. J., and deYoung, B.: **Non-hydrostatic modeling of cohesive sediment transport associated with a subglacial buoyant jet in glacial fjords: A process-oriented approach**, Ocean Modelling, 63, 30–39, https://doi.org/https://doi.org/10.1016/j.ocemod.2012.12.005, 2013.

Simkins, L. M., Greenwood, S. L., Munevar Garcia, S., Eareckson, E. A., Anderson, J. B., and Prothro, L. O.: **Topographic Controls on Channelized Meltwater in the Subglacial Environment**, Geophysical Research Letters, 48, e2021GL094, https://doi.org/10.1029/2021GL094678, 2021.

Slater, D. A., Nienow, P. W., Cowton, T. R., Goldberg, D. N., and Sole, A. J.: **Effect of near-terminus subglacial hydrology on tidewater glacier submarine melt rates**, Geophysical Research Letters, 42, 2861–2868, https://doi.org/10.1002/2014GL062494, 2015.

Vaňková, I., Asay-Davis, X., Branecky Begeman, C., Comeau, D., Hager, A., Hoffman, M., Price, S. F., and Wolfe, J.: **Subglacial discharge effects on basal melting of a rotating, idealized ice shelf**, The Cryosphere, 19, 507–523, https://doi.org/10.5194/tc-19-507-2025, 2025.

Zhou, Q. and Hattermann, T.: **Modeling ice shelf cavities in the unstructured-grid, Finite Volume Community Ocean Model: Implementation and effects of resolving small-scale topography**, Ocean Modelling, 146, 101, https://doi.org/https://doi.org/10.1016/j.ocemod.2019.101536, 2020.