Reviewer #3

General comments

The Authors seek to provide a solution to a current problem limiting the use of coupled ice-ocean models, namely the increased computational expense of the ocean part of the model when compared to the ice side. I find this a very worthwhile and relevant topic suitable for the journal. The justification, methodology and results are well presented. I feel that at present the authors are slightly over selling the potential use of their method without some further additions and clarifications within the discussion section.

We appreciate the reviewer's positive feedback and recognition of the relevance of our study. In response to your and other reviewers' concerns regarding the potential application of the accelerated forcing approach, we have expanded substantially our discussion in the revised manuscript. This includes a more detailed examination of key limitations such as freshwater inconsistency when using the acceleration approach and the approach's challenges in capturing sub-decadal and decadal ocean forcing variability.

1) In the current model framework, ice calving and the resultant freshwater input to the ocean is ignored. Similarly for any models that use real freshwater fluxes on the ocean time step. Do the authors envisage any potential problems with their accelerated forcing scheme if such processes were to be included?

This was also pointed out by Reviewers #1 and #2. We have included a paragraph in the discussion section of the revised manuscript to address the inconsistencies in freshwater and energy that arise when using the accelerated forcing approach, as

"*It is important to acknowledge the limitations of our idealized study. When investigating the sensitivity of melting responses to changes in the timescale of the boundary conditions, we have only considered the lateral ocean conditions and changes in the ice draft, assuming these factors predominantly control the cavity circulation and, thus, the basal melting. This simplification presents challenges when applied to real-world scenarios where other boundary conditions affecting the cavity properties, as well as the open ocean, can not be ignored. One of them is the total glacial meltwater input to the ocean, comprising melt due to iceberg calving, basal melting, and subglacial discharge (from the subglacial hydrologic system). Numerous studies have highlighted the significant impact of glacial meltwater on ocean stratification, with important consequences for the evolution of sea ice(Bintanja et al., 2013; Merino et al., 2018; Goldberg et al., 2023), Antarctic bottom water formation (Li et al., 2023), ocean currents around Antarctica (Nakayama et al., 2021; Gwyther et al., 2023; Moorman et al., 2020), (Bronselaer et al., 2018; Purich and England, 2023; Li et al., 2024). The current study, which focuses on fine-resolution ice sheet-ocean interactions at the*

Antarctic margins, specifically the ice shelf cavity, includes only the ocean-driven melt component of glacial meltwater. This is because basal meltwater has the largest impact on cavity circulation, mainly through buoyancy forcing. Larger-scale studies would also need to quantify the impact of other components of glacial meltwater, especially the calving flux, under accelerated forcing. "

"*Furthermore, adjustments in glacial meltwater input are necessary to realistically represent its impacts on ocean and climate under the accelerated forcing. Without such adjustments, the total freshwater flux into the Southern Ocean would not be consistent with that under the regular forcing, potentially distorting climate simulations. However, accelerating the meltwater flux introduces its own challenges. A significant increase in local freshwater input over a short period can drastically alter local salinity gradients and stratification. This disruption can affect everything from mixing processes to ocean currents, potentially leading to unrealistic model behavior. Following Lofverstrom et al. (2020), we propose not accelerating the meltwater flux in order to maintain realistic local ocean dynamics. Instead, to mitigate the inconsistent freshwater input in the accelerated simulations, we suggest applying periodic restoration techniques to adjust the ocean's salinity and temperature fields using observed or targeted values (Griffies et al., 2009, 2016; Lofverstrom et al., 2020). Moreover, we expect similar inconsistencies in atmospheric boundary conditions—such as precipitation (freshwater input), and wind and radiation fluxes (energy input)-under the accelerated forcing. The aforementioned periodic restoration techniques can also help reduce the effects of these inconsistencies, thereby ensuring more representative freshwater and energy inputs in the ocean model.*"

2) Likewise, the calving front is currently fixed in time. if it were to move in time would the approach still hold? My inclination would be that 1) and 2) are not deal breakers, but I would appreciate some discussion about them.

This is a valid concern. The applicability of the accelerated forcing approach in the case of dynamic calving has not been tested in our study due to the model complexity when calving parameterisations are added. Implementation of dynamic calving in coupled ice sheet - ocean models is cutting edge, with very few research teams having stably implemented this capability (Asay-Davis et al., 2016), which may introduce additional uncertainties in evaluating the accelerated forcing approach. Our approach specifically presents ice draft change to the ocean model in the form of a rate over time, so the natural way to implement ice front movement would also be through very rapid thinning (corresponding to retreat) or thickening (advance), which brings its own challenges that need to be understood before assessing the coupled system in the context of an evolving calving front. Furthermore, given that the total calving flux is likely on the same order of magnitude as the sub ice shelf melt flux, but likely injected to the ocean over a larger area (as icebergs decay gradually during their drift), we do not anticipate that incorporating a calving flux into the coupled system would have a greater impact than the already included sub ice shelf melting. However, we acknowledge the importance of investigating this aspect. The IceOcean2 experiment in the MISOMIP1 framework, which includes a dynamic calving front, provides an ideal framework for such an evaluation. Thus, we recommend future studies to evaluate the accelerated forcing approach when dynamic calving is activated, focusing on the response of the ocean to the additional calving freshwater input. The following discussion has been included in the discussion section of the revised manuscript:

"*Our study demonstrates that the accelerated forcing approach can directly contribute to the MISOMIP1 project by reducing the required simulation time of 100 years, depending on the acceleration factors. Applying the accelerated approach with a factor of 3 for the IceOcean1 experiment has reduced the spun-up simulation duration by a factor of 3 and reproduced most of the melting diagnostics within 10% of those with the regular forcing approach across two participating coupled models. Recommending the accelerated forcing approach to other participating models within the MISOMIP framework would provide a more comprehensive understanding of the robustness and applicability of the approach in idealized model setups. Furthermore, our current evaluation of the approach has been conducted using the IceOcean1 setup, where the calving front is fixed. It would be worthwhile to explore the applicability of the accelerated forcing approach using the IceOcean2 setup, which is similar to the IceOcean1 setup but includes dynamic calving. This extension could enhance our understanding of the ocean's response to calving fluxes under accelerated forcing, which will be discussed in detail in the following paragraph.* "

3) In regards to ice dynamics melting near or at the grounding line is of crucial importance to represent accurately. As such it is a potential concern that the differences when using the acceleration factor are located in such areas. It would be good to see further discussion on this topic included.

We agree with the reviewer that melting near or at the grounding line is of crucial importance to represent accurately. This is why we have chosen to also examine integrated ice draft changes and grounding line position at the end of the simulation. Specifically, we have added a plot of grounding line evolution to demonstrate that this metric is relatively robust to accelerated forcing (Figure 1). Our slowly evolving simulations based on the spun-up cavity in the Constant experiment class show identical grounding line retreat after 100 years for different acceleration factors (Figure 1a), with only minor variations in the timing of ungrounding of individual model grid elements.

We have included additional statements in the revised manuscript to justify our choice of diagnostics in the subsection on evaluating the accelerated forcing approach: " *In addition, since the absolute differences in ocean-driven melting from the accelerated forcing concentrate close to the grounding line across all experiment classes—a detail that will be elaborated on below—and considering that marine ice sheets are sensitive to melt patterns near the grounding line, we*

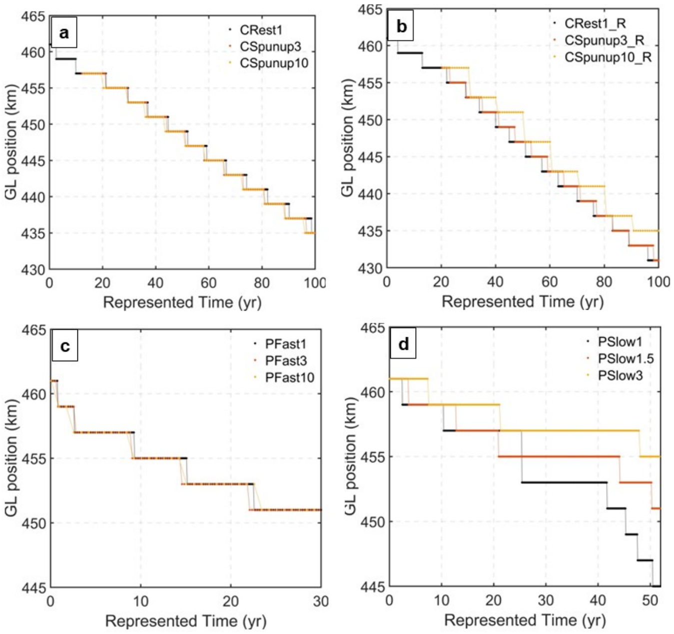

Figure 1: Time series of grounding line positions along the central domain (y = 40 km) across all simulations in (a) FVCOM-based Constant class, (b)ROMS-based Constant class, (c) Periodic-fast class, and (d) Periodic-slow class.

also evaluate integrated ice draft changes and grounding line positions throughout the simulation. These metrics allow us to assess the net effect of melting differences near the grouding line on ice dynamics under accelerated forcing. "

4) At present domain wide volume changes are shown from the ocean side only. It would be good to see some plots of ice Volume Above Floatation to get an idea of the relative impacts of the acceleration method upon sea level predictions. It would also be good to see some measure of the rate of grounding line retreat over time. Perhaps along a central profile, or a measure of domain grounded area?

We appreciate the reviewer's suggestion to enrich our analysis with plots of ice Volume Above Floatation (VAF) and some measures on the grounding line retreat. These additions would indeed provide valuable insights into the broader impacts of the accelerated forcing approach on sea-level predictions and ice dynamics.

In the revised manuscript, we have added plots of time series of grounding line positions along the central line of the domain (y = 40 km) across all experiment classes, as shown in Figure 1.

Unfortunately, we need to rerun the simulations to calculate the VAF. Given that our study primarily focuses on the oceanic response under accelerated forcing, not direct ice sheet behavior, we did not include VAF calculations in our simulations. If necessary, we can rerun some of the key simulations to include the VAF calculations. However, for the current study, we believe that the provided results sufficiently address the intended scope.

We hope that the additional grounding line measures will suffice for the aims of this study, and we appreciate your understanding of the practical limitations related to calculating the VAF.

If the above points are addressed, as well as those of the other reviewers (with who I find myself in agreement) I am in agreement with), I would be happy to recommend publication.

We are grateful for your support of our manuscript. We have addressed the points you highlighted, as well as the concerns raised by the other reviewers, in our revised submission. We hope that these revisions meet your expectations and look forward to your final recommendations.

Minor comments typos:

L 79 "circulation to flush"

Corrected.

L 85 I think a brief mention of the model domain to be used should be included here to help orientate the reader, as it is a little ambiguous what is meant by the MISOMIP1 framework.

The following explanations have been added to the end of the introduction section in the revised manuscript:

"*Section 4 assesses the accelerated forcing approach across three scenarios, employing an idealized coupled model setup consistent with the MISOMIP1 project. This setup features a single, idealized ice shelf and excludes interactions with the atmosphere and sea ice (Asay-Davis et al., 2016).*"

L 175 Is there a reason that different oscillation periods are being used for each set up?

Yes, our selection of varied periods was intentional. We aimed to explore periods that are significantly shorter than, comparable to, and much longer than the mean cavity residence time. Ideally, incorporating a broader range of periods would provide a more comprehensive quantification of the melting response to transient ocean forcing. However, due to limitations in computational resources, we restricted our experiments to the periods presented in the manuscript.

L 216 'Notably, although..'

Corrected.

L 401 'with the exception of the relative...changes exceeding 10%.....'

We have rephrased this sentence for clarity in the revised version of the manuscript, as
" In summary, our analyses show that the accelerated forcing simulations generally reproduce the time-averaged melting response, overall ocean volume changes, spatial distributions of melt rates, and integrated ice draft changes. The relative changes in these variables are kept under 10% across most locations. However, at a few locations near the grounding line, relative differences in melt rates and integrated ice draft changes exceed 10% when a higher acceleration factor of 10 is used. Thus, we consider the accelerated forcing approach to be suitable when the forcing timescale is significantly shorter than the cavity residence time, as suggested by our findings from the stand-alone experiments."

Figure 2 Caption - 'curry colored' could be confusing for non native english speakers.

Modified.

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