

Thank you for your review – please see below for our responses (blue text).

Summary:

In this study, the authors modeled Ryder Glacier in northern Greenland under different climate scenarios to assess the risk and consequences of ice tongue loss. The model results suggested that ice discharge is the primary contributor to mass loss until 2100 under both low and high emission scenarios assumed in the study. After 2100, the results show that surface mass balance becomes the dominant factor driving mass loss under the high emission scenario until 2300, while ice discharge remains the largest contributor under the low emission scenario. The authors compared their results with observations and other modeling studies for neighboring glaciers, Petermann and C.H. Ostenfeld, and highlighted the importance of topographical controls on heterogeneous behaviour in neighbouring glaciers.

Overall, this study raises several interesting discussion points and provides valuable insights for Ryder glacier, which, as noted in the manuscript, has not been studied as extensively as other glaciers in northern Greenland. These findings could also provide valuable insights for other glaciers in northern Greenland and highlight the importance of high-resolution modeling of individual glaciers to better assess the future change in individual glaciers.

However, the manuscript needs revisions, including improvements to the modeling framework part and the overall structure of the writing. Below are the major and minor comments that I believe should be addressed before publication.

Thank you for your constructive review of the manuscript. Our responses to all of your comments are detailed below.

Major comments:

1. Model relaxation.

The model relaxation part (L146-156) is somewhat confusing as it lacks details about the calving parameterization which is only introduced later in section 3.2.2. In addition, I would appreciate more results and clarity regarding this model relaxation. For example, is the purpose of the relaxation to match current observations? How closely does the modeled melt rate match to published present-day melt rate (L149-151)? Is it spatial pattern or the maximum melt rate that you try to compare? How does the mass loss change during this relaxation period compared to the observation? How do the changes in ice front positions compare to observations during the relaxation period? Providing these details would improve the modeling part.

Thank you for this comment, something which was also brought up by the other Reviewer. The entire methods section has been reshuffled with the aim of more clearly describing the model set-up and relaxation. We have created a new subsection ‘Model relaxation’ where we have more clearly stated the aims of the relaxation and explicitly compared our relaxed model with several metrics. Some of these comparisons were also in the previous version of the manuscript (e.g. mass loss during the relaxation was compared with observations in lines L151-153), but hopefully this is presented with more clarity in the new structure. The basal melt parameterisation is described in more detail, alongside additional references to the observational data, in the new subsection ‘Model set-up’.

2. Manuscript structure

Consider revising the structure of 1. Introduction and 2. Petermann, Ryder, and C.H. Ostenfeld Glaciers section. It seems that the primary research questions the authors aim to address in this study are outlined in Section 2 (L107-L109), rather than at the end of the introduction (L44-47). These different questions may confuse readers about the main objectives of the study. Additionally, the comparison between three neighboring glaciers is too detailed in section 2, which may mislead/confuse the readers on the focus of this study. Consider summarizing this comparison part and rephrasing it to emphasize Ryder glacier's unique characteristics and the study's goals. In addition, I think section 3.1. is unnecessary and could be merged with other modeling descriptions. Consider rewriting the modeling part as well, particularly the model relaxation part and related forcings.

Thanks for this comment and related suggestions – similar issues were also raised by the other Reviewer. We have removed section 2 ('Petermann, Ryder and C.H. Ostenfeld glaciers'), and replaced the study area figure with one focusing on Ryder glacier. Some material from this now-removed section has been incorporated into the introduction or the discussion section 'Comparison with other Glacier-Fjord systems'.

The section 'Topographic data' (prev. 3.1) has been removed, with the content merged into the broader 'Methods' section. The 'Methods' section detailing the model inputs and experimental design has been reworked into a new structure which now includes a specific 'Model Relaxation' subsection.

Specific comments:

L18: ... are already higher than at any time during ... -> ... are already higher than at any time during...

Changed.

L27: ...that this this sector contains... -> that this sector contains...

Changed.

L33: "Observational records from recent decades have shown a large degree of spatial...surrounding the future behaviour of glaciers". Add references to support this statement.

References have been added in (Porter et al., 2014; 2018; Cooper et al., 2022)

L53-55: The mean SMB per area is compared between the three glaciers, but what about the spatial pattern of SMB? For instance, are there more negative SMB values near the front of Ryder Glacier compared to the other glaciers? Highlighting such patterns could strengthen the argument.

This data is from the supplementary material of Mouginot et al (2019), where the SMB is given as an integrated value for each drainage basin. However, as part of the re-structuring, this sentence no longer exists.

L61-62: This sentence is unclear. Are you comparing the highest melt rates at Ryder Glacier to the overall melt rates at Petermann Glacier? Clarify the comparison.

This sentence has been changed to: *‘Previous observational records of basal melt show higher overall melt fluxes at Petermann Glacier than Ryder Glacier, but with the Eastern side of Ryder Glacier’s grounding line experiencing melt rates comparable to or even higher than Petermann Glacier at around 60 m yr⁻¹ (Wilson et al., 2017).’*

L64: “higher grounding line melt rates than what?” Clarify the reference point for comparison.

It has been clarified that the comparison is between Ryder and Petermann Glaciers

L85: “The lack of lateral friction at C. H. Ostenfeld’s ice tongue...survived to the present day” Add references.

References added

L120: Is the model domain the same as the green basin shown in Fig.1? If so, clarify this in the text.

This has been clarified, and the domain is more clearly seen in the new Fig.1 which focuses solely on Ryder Glacier.

L125: “performing considerably better” Does this mean more accurate? Better in terms of what specific metric or criteria?

We had clarified that the misfit between HO and FS simulations is smaller than between SSA and FS simulations

L128: “...satisfy the Courant-Friedrichs-Lewy condition”. Add references.

Reference added.

L174: “...increase by around 1oC by 2100 and around 2oC by 2200”. What climate scenario are these values based on? Why not using the same future climate scenarios (SSPs) as the SMB forcing? This needs to be justified.

We have added the following into the text:

1. L173: ‘Subsurface ocean temperatures around North Greenland are projected to increase by around 1°C by 2100 and around 2°C by 2200 (Yin et al., 2011) under a mid-range increase in greenhouse gas emissions. These numbers were chosen as they are based on an ensemble of model runs, are specific to North Greenland, and target increases in the subsurface water temperatures thought to be of importance for Ryder Glacier (Jakobsson et al., 2020).’
2. L189: ‘Although the magnitude of ocean warming as well as the magnitude of subglacial discharge is likely to vary depending on future emissions scenario, by running the same suite of ocean scenarios for both our low and high emissions simulations, we can compare the sensitivity of Ryder Glacier to ocean forcing under different SMB-scenarios.’

L191: Add some transition sentences before explaining calving parametrization to improve the flow.

The following has been added: ‘Calving is another important mass loss process at Ryder Glacier's marine margin, with the choice of calving law being identified as a key source of uncertainty in models of Greenland's future (Goelzer et al., 2020)’

L196: “...best match observations of front position...”: Specify the year or period of the observations you are referring to.

We have specified that we match the front position to the overall trend of ‘no movement’ since 2000.

L199: “Finally, the stress threshold for grounded ice...during the relaxation”: consider rewriting this sentence. Isn’t the calving front floating during the relaxation? Please clarify it.

Ryder Glacier presently has two termini; the (main and much larger) floating terminus, and a second grounded terminus. We have specified this more clearly in the text where Ryder Glacier is first described as well as changing the wording in this section.

Introduction: *‘Petermann and Ryder glaciers are two of the few Greenlandic glaciers which still have a floating ice tongue, although Ryder Glacier also has a smaller, grounded terminus’*

Methods: *‘... this led to the best match with Ryder Glacier’s second, smaller grounded calving front...’*

L205: reducing the value linearly in time?

Yes, it was a linear reduction – something we have now specified

L228: “In all simulations, the melt rate applied across the ... below the floating tongue” : Was this frontal melt rate also applied during the relaxation simulation?

Yes, and we have clarified this into the text

L287: “In a high emission scenario...” Do you mean all high emission scenarios? or is this the mean value from multiple high emission scenarios?

This statement is true for all high emissions scenarios, and we have edited the text to clarify this (‘In a high emissions scenario’ to ‘In all high emissions scenarios’)

L360: “show acceleration occurring” -> “show acceleration of retreat?”

We have changed this sentence as it was badly worded. It now reads: *‘Instead, both the simulations shown in Fig. 6 show acceleration between 2080 and 2150 as the ice tongue shrinks, with a deceleration then being seen post ice tongue loss - something that coincides with an acceleration of SMB-driven thinning.’*