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Manuscript tc-2025-5733: Contrasting dynamics of lake- and marine-terminating glaciers under same climatic conditions
March 31, 2026

Dear Referee,

Thank you for reviewing our manuscript and for providing us with constructive and structured feedback, which we believe strengthened our work. We provide our response in the following with your comments coloured blue, our responses black, and manuscript changes brown.

Florian Vacek,

on behalf of all authors

Summary

Reviewer Comment:

Overall, this is a very nice study. It presents a well-designed examination of a glacier system that has both a marine-terminating branch and a lake terminating branch. Overall, lake-terminating glaciers in Greenland are understudied, and also the literature on marine and lacustrine termini are somewhat disconnected. Thus, this paper addresses an important knowledge gap and helps bridge these two fields. In particular, the results highlighting the contrasting front dynamics of the two branches are very interesting, including the different styles of seasonal variability, the episodic large calving events at the lake terminus, and the role of geometry and potential pinning points in modulating stability. The manuscript is clear and very well written.

My comments primarily surround the transition from the results section — which is largely clear, careful, and well supported by the data — to the discussion & conclusions, which at times feel somewhat speculative or more strongly framed than the evidence allows. Some interpretations would be better presented as discussion points or potential implications rather than firm conclusions. In particular, the sections involving ocean conditions inferred from the offshore reanalysis product appear to be a weak point. Nevertheless, I am confident that, with some revision and clarification, this manuscript will make a valuable contribution to the field.

Author Response:

Thank you for your overall positive summary. We have addressed your concerns, specifically about the ocean conditions as well as the effect of lake ice and have changed our manuscript accordingly. See specific answers below.

Major comment 1: Ocean conditions

Reviewer Comment:

This paper uses the ORAS5 ocean reanalysis data, at a grid cell outside the fjord mouth and averaged between 20–100 m depth, to infer the ocean conditions at the marine terminus. I have several concerns about this approach. First, there's no discussion if ORAS5 performs well in this general region of coastal Greenland (I would suspect not). Second, I would be skeptical that the ocean conditions from ORAS5 outside the fjord mouth would be representative of conditions in the upper fjord at the terminus, especially given the shallow moraine/sill of less than 50 m that would restrict the deep inflow. The fjord geometry, combined with the inputs of subglacial discharge at the glacier, means there's a strong possibility that the near-glacier conditions are markedly different from those outside the fjord and follow a different seasonal cycle.

I wonder if there are any CTD casts from the fjord, from OMG or other campaigns, that could be used to validate the reanalysis product and/or to compare inside vs. outside fjord conditions.

Further, one of the central results is that retreat rates correlate more strongly with runoff and air temperature than with ocean temperature. However, the uncertainty in the ocean temperature estimate is likely much larger than that of the atmospheric and runoff variables, because the ocean temperature is derived from a low-resolution reanalysis product outside the fjord, whereas runoff and air temperature are better constrained. A weaker correlation with ocean temperature could reflect higher uncertainty/spatial mismatch, rather than weaker physical influence.

For these reasons, I think the manuscript currently overstates the ability to rule out ocean forcing as a driver of marine terminus variability. Unless the reanalysis product can be validated for this setting or a better data set is available, the results related to the ocean conditions should be framed more cautiously.

Author Response:

We agree with the referee that the ORAS5 data is likely not representative of the ocean conditions close to the glacier front. The issue regarding ORAS5 data was also raised by another reviewer. Therefore, we have removed our analysis and interpretation that relied on ORAS5 data.

In our revised manuscript, we rely on a comparison of the physical properties of the ocean and the lake (see revised Section 5.5 below). This comparison illustrates that even under cold ocean conditions subaqueous melt rates must be much higher at MT compared to LT. Following the suggestion of referee 2, we included a CTD measurement from Hansen et al. (2025) just outside of the moraine. The CTD measurement shows an average temperature in the top 100 m of about 0.6 °C in June 2023. Assuming this temperature and a lake temperature of 0.7 °C (measured), results in a thermal driving which is 3 to 4 times larger in the ocean due to the freezing point depression in salt water.

Therefore, in the revised manuscript we focus on elaborating that melt rates must be much lower in the lacustrine environment, even under cold ocean conditions and that these low melt rates contributed to the formation and stability of the floating ice tongue in the lake. Nonetheless, we have good indication that MT is at least influenced by submarine melting through subglacial plumes (please see response to referee 1, first comment where we also include images showing undercutting and plume formation at MT).

Manuscript Changes:

1. Freezing point depression: In the marine environment, the freezing point of ocean water is lowered due to the salt content. With a salinity of 32 PSU the freezing point drops to about -1.8 °C. A lower freezing point increases the thermal driving (or thermal excess), consequently increasing submarine melt rates. Even in a cold ocean environment this freezing point depression leads to higher melt rates compared to a freshwater environment. For example, assuming an ocean temperature of 0.6 °C (average temperature of the top 100 m measured by Hansen et al. (2025) in Tunulliarfik Fjord, close to Qooroq Fjord) and a lake temperature of 0.7 °C (measured in lake Motzfeldt) results in a thermal driving that is 3 to 4 times higher in the ocean compared to the lake (2.4 °C vs 0.7 °C above the freezing point).
2. No subglacial plume formation: The formation of subglacial plumes can significantly enhance submarine melt rates (Jenkins, 2011), promote undercutting, and consequently calving (Slater et al., 2017). However, lakes generally consist of freshwater and therefore lack vertical circulation at the ice front, driven by the density differences of fresh and salt water (Truffer and Motyka, 2016). Consequently, we observe the formation of subglacial plumes at MT but not at LT, arguably leading to even higher melt rates at MT compared to LT. Furthermore, this implies that additional runoff at MT would enhance melt rates by generating stronger plumes, whereas in the lake, additional runoff would not affect melt rates and could even cause the lake to cool. This could possibly explain why seasonality in front positions is observed at MT but not at LT.
3. Heat transport: A lake is a semi-closed system where no transport of large quantities of warm water masses toward the glacier front from distant sources takes place. The energy input to the lake is limited to long and short wave radiation, heat exchange with the atmosphere, and advected heat (e.g., rainwater, streams, and groundwater) (Wetzel and Likens, 2000). In the fjord, on the other hand, water masses can be transported to and from the glacier front through ocean circulation and exchange with more distant water masses. Even in fjords with a prominent sill, exchange with shelf water is not completely blocked, and cold water can be transported away and exchanged with warmer waters (e.g. Mortensen et al., 2018).

The differences outlined above clearly demonstrate that subaqueous melt rates must be higher at MT than at LT, even with cold ocean conditions. The presence of a meltwater plume, the undercutting of the ice front, and the correlation between surface runoff and glacier front position all suggest that submarine melting affects the dynamics of the marine-terminating glacier. At LT on the other hand, low melt rates create favourable conditions for a floating extension of the glacier through limited thinning and calving rates. This comparison indicates that the difference in subaqueous melt rate contributes to the contrasting dynamics that we observe.

Major comment 2: Lake ice

Reviewer Comment:

The paper attributes reduced winter calving to the buttressing effect of lake ice cover. However, calving also coincides strongly with the runoff season, so couldn't reduced winter calving just reflect the absence of subglacial discharge? Given that lake ice cover and runoff seasonality are closely aligned, it seems difficult to disentangle their relative roles, and the discussion should acknowledge this ambiguity (or provide further reasoning for how you separate their effects).

Author Response:

A similar point was also raised by referee 2. We have removed our interpretation that lake ice acts in a similar way as an ice mélange, as evidence for that is lacking. In the revised manuscript we mention that lake ice possibly prevents icebergs from drifting away and helps to keep the glacier front together in winter, but not that it provides a buttressing effect similar to an ice mélange. We also discuss that during the runoff period, buoyant forces are increased through thinning of the glacier from the surface as well as through a rise in lake level due to increased meltwater input. We are now more careful with our formulation and phrase it as a possibility that runoff and or lake ice has an influence on calving.

Manuscript Changes:

Remarkably, all documented calving events occur between mid May and mid October, coinciding with the runoff period. This could indicate that also buoyant forces play a role in triggering calving events, as it was observed at several other lake terminating glaciers (Howarth and Price, 1969; Holdsworth, 1973; Warren et al., 2001). During the runoff period, buoyant forces are increased through thinning of the glacier from the surface as well as through a rise in lake level due to increased meltwater input (Fig. A1). Furthermore, we observe that all calving events occur outside of the lake ice covered period. Although lake ice could provide some backstress to the glacier, it is unclear as to what magnitude and what effect it would have on calving. However, we believe that lake ice possibly functions as a binder, preventing icebergs from drifting away, helping to keep the glacier front together during winter.

Minor comments:

Reviewer Comment:

1. Figure 4: why is the colorbar not quantitative? It's just labeled as floating vs. grounded but why not show the numeric value of the flotation index, especially since the text mentions specific values (e.g. "on the ridge, the flotation index reaches up to 200 m")

Author Response:

Changed to numerical values.

Reviewer Comment:

2. I would consider putting A1 and A2 figures in the main text (perhaps combined into one figure). It

seems a little arbitrary why those two in the appendix relative to the rest of the figures.

Author Response:

We would prefer to keep the figures in the appendix, as the manuscript already has 8 figures in the main text. We chose to put those two figures in the appendix, as it can easily be described with words what is seen in the plots (e.g. CTDs show a depth averaged temperature of 0.7 at the glacier front).

Reviewer Comment:

3. Section 5.5 feels somewhat misaligned with the results presented for this glacier system. For example, point (1) appears to summarize mechanisms (e.g., the influence of warm Atlantic water reaching the glacier) that might not apply to this fjord due to the shallow sill. In point (2), the discussion draws on studies of plume-driven melting in marine settings when interpreting subaqueous melt in the lake, but the physical processes in lacustrine environments might not be entirely analogous

Author Response:

We have revised the Section 5.5 "Key differences between the lake and marine terminus and potential causes" in order to elaborate in more detail as to why subaqueous melt rates are lower at LT compared to MT. The arguments we provide hold true for our case but also for a comparison of lakes and fjords in general. We think that it is a very valuable comparison for readers working with these environments as it also applies to other regions. See list of arguments provided in reply to comment 1.

Reviewer Comment:

4. It would be helpful to clarify whether there is any information on the relative magnitude of subglacial discharge routed to the marine versus the lake terminus. Even a qualitative estimate or catchment-based comparison could strengthen the interpretation of differences between the two branches.

Author Response:

The catchment is about an order of magnitude larger at MT compared to LT. However, due to the lack of salinity differences, runoff does not lead to the formation of plumes in the lake (second point in the list in the reply to comment 1). Therefore, any additional runoff does not increase subaqueous melt rates and calving through undercutting at LT.

Reviewer Comment:

5. At several places through the text, it refers to the two termini as experiencing the same “climatic conditions” or same “climatic forcing.” I guess this is not wrong, but perhaps a little confusing because one might think that the climate that the glacier experiences is based on water and air temperature - but water temps are not similar in these two places. (As an analogy, two locations that are nearby geographically but at very different elevations would have different air temperatures and not the same climate forcing.) Perhaps a bit subjective, but I would suggest rewording to something about how they exist in the same regional climate but experience different water boundary conditions, or something.

Author Response:

We changed this as suggested on several occasion.

Line by line comments:

Reviewer Comment:

Fig 1 caption: “CTD profiles” instead of “CTD measurements”, especially to make clear between the moored temp-depth sensor

Author Response:

Changed as suggested.

Reviewer Comment:

L146: would mention that CTD profiles were collect from surface to bottom, or surface to XX m depth, or whatnot

Author Response:

Changed as suggested.

Reviewer Comment:

L 178; is there a typo here? Should second “before” be “after” instead?

Author Response:

Changed as suggested.

Reviewer Comment:

L223: says no distinct moraine where the glacier was stagnant until 2012, but isn’t this the location of the front, not the grounding line?

Author Response:

Yes, indeed. We removed the part about the moraine.

Reviewer Comment:

L232, should be “depth average temperature” not just “depth average”

Author Response:

Changed as suggested.

Reviewer Comment:

Figure 6 caption: should this say “full lake ice cover” instead of just “lake ice cover”?

Author Response:

Yes. Changed as suggested.

Reviewer Comment:

L376: “sections” instead of “chapters”

Author Response:

Changed to section.

References

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