

Response to comments on “The terrestrial ice margin morphology in Kalaallit Nunaat (Greenland)” (essd-2025-2424) by Steiner et al.

Response to RC1 (Erin Pettit):

Review of Steiner et al

The terrestrial ice margin morphology in Kalaallit Nunaat (Greenland)

The authors state two goals. First, to provide the lengths of margins of the three main categories (marine, land, and lake terminating). And a second goal to show the variable morphology of the land-terminating glaciers, which range of shallow ramps to steep cliffs.

First - I really like that this paper is tackling the question of land-terminating glacier terminus morphologies. There is lots to be learned from the terminus behavior. So I really appreciate the authors efforts!

This paper overall describes the data set, and does not provide any scientific analysis alongside that data set. I admit that I expected - based on the title - to see some interpretation of the data. The last sentence of the abstract informs reader that this paper describes the data set and they leave the interpretation to others.

What I see as unique about this paper is the focus on the varying morphologies of the land-terminating ice margin. This goal, however, seems to take lesser importance in the abstract to the overall lengths of the margins. I would suggest that the authors emphasize this more novel data set and less on the cumulative distance that is marine/lake/land.

We appreciate the constructive reading of the manuscript. We agree that a large part of the study is circling around the production of a dataset. Considering that this hasn't been done before for the margin morphology and the nature of the land termini has previously not been described at this scale, we still consider this an analysis of data. However, what you characterize as the first goal has indeed taken too much center stage in our presentation of the results. While it consumed quite some work to accurately identify where the land terminating margin is located, it was simply a means to an end. Considering that compared to marine and even lake termini the land terminating margin has so far received relatively little attention in the literature on Greenland cryosphere, we felt it was important to state its relative magnitude. We also do not want the calculation of margin length (which, as we note, is purely based on the already existing margin products made by others) to be seen as the main take away, which has also confused others. While the numbers are still important, we now considerably reduce this part of the study and instead emphasize the aspect of morphology and how it was obtained further.

First the general categorization goal: While the categorizing of termini and determining total lengths of each can be important for some projects, without context for the numbers provided in the abstract, this is not so useful. Are those numbers bigger or smaller than expected? Are they changing? What year do they represent? I appreciate that they include all the margins, not just those with significant ice discharge - as the lateral margins of glaciers can play an important role. I looked to one tidewater glacier as an example in the data set - one where I have an upcoming project (69.79521923, -50.23659187) and saw 3.5km section of the northwest lateral margin (presumably against a fjord wall) flipping between land and tidewater, of a tidewater glacier as a mix of land and tidewater termini. Similarly the southeast margin has a section identified as tidewater that is not. This makes me question the overall quality control and the value of

publishing these numbers. The authors state in line 123 that they did visual quality control, so I am surprised that one random glacier picked seems to have errors - as does the glacier to the north. The data set is useful! - although specific use might require fixing the errors. For example, ice flux could be more accurately determined for different regions by the dot product of the normal to the margin and the ice flow direction across the margin - if both data sets are of sufficient resolution.

Thank you for checking the margin product itself – we share the same frustration when finding inaccurate margin classifications when identifying individual areas but believe that this is an outcome of a pragmatic choice that also has advantages. We have considered whether we should manually classify the margin between marine, lake and land termini. While this would have likely reduced the number of misclassifications, it would also have resulted in a much more subjective dataset from region to region, without the chance to eventually reproduce the same approach as datasets like the ice mask are updated. Making the distinction purely based on elevation allowed us to assure a consistent quality across Greenland. As you note, the problem is especially accentuated along outlet/tidewater glaciers, where we are in transition from below to above sea level at the DEM. Also in response to the CC, we now account for this shortcoming by mapping a subset of such locations, manually determining which parts are termini and which sections are at the sides of outlet glaciers, with a DEM < 10 m a.s.l. but obviously no direct ice-water interface. We suggest that this provides a possibility to interpret the absolute number of what we call ‘marine-terminating’ margin with respect to their useability. We also would like to emphasize again, and have done so now more clearly in the Methods as well as the Results, that our marine margins should not be seen as termini with actual ice discharge. For that – like you suggest – a point location of the actual terminus location would be useful (and ideally placed by the user, depending on what application is attempted) or datasets from other studies (Kochtitzky et al., 2022; Kochtitzky & Copland, 2022; Ryan et al., 2024) is more appropriate.

My suggestion is that this primary margin categorization be less of the end goal, and less emphasized in the abstract - unless the authors want to interpret their results in context of the Ryan et al 2023 and other papers that have done similar work using a slightly different approach and goals. And please be more clear that quality control is weak (i.e. line 123) - so the data should be used with caution.

We agree that the margin characterization is not the primary goal here, especially with respect to the non land-terminating sections. We have now also made the description of quality control clearer and note that it should be used with caution, which we believe is reasonable with a product at this scale. With the discussion of other potential ice masks (see response to RC2), this section has now also considerably expanded.

Towards their goal of the shape of the land terminus - this I find is a unique and useful contribution, as the shape of the terminus reflects the interaction of physical processes (ice flow with fracturing and details of surface mass balance). And I believe we can learn about evolving ice dynamics from these margins.

We agree that it would be great to have a much more in depth analysis with a number of other – ice dynamic and possibly also climatic – variables and their potential role in explaining variables. The work we do here we would hope is a segway to be able to eventually do that. Since, however, at this resolution getting such data isn’t trivial without having to explain also their intrinsic challenges we felt that with the space we already needed to reasonably explain how we derived the margin morphologies, this would have gone well beyond a manuscript where we can do these

aspects justice. For ice flow for example we would need to determine the direction at the respective – not always very straight – margin sections, climate data is often not available in appropriate resolution and linkages to morphology that has evolved over decades, centuries or longer are not trivial. We have now made substantial changes to the analysis focusing specifically much more in the morphology and less on the margin outline itself and hope that this allows for a solid basis to do this kind of analysis (as well as the analysis of how this morphology is changing in time) in subsequent steps. We now also emphasize these potential future steps more clearly in the Discussion.

The paper describes the methods for delineating steep versus shallow ramps in a clear way - I am not an expert in remote sensing analysis of this kind, so I don't feel like I can speak to those details, but it generally seems robust except for the issue of it being clear what dates are attached to the results, so they can be used to look at changes.

We agree that this hasn't been clarified clearly (also in metadata) and we have now amended this. Following changes from the response to RC2 there have been substantial changes regarding dealing with timing of the products, which resulted in substantial changes in this general description, but also now includes a clear communication of time frame the product is valid for.

If the authors choose not to do any analysis with their data set, I would suggest one additional statistical result might be helpful for understanding the data - perhaps for quality control, perhaps for science. That is to look at the distribution of lengths of margin segments of each type (separately doing the land/lake/marine versus the steep/shallow). For the general margin categories, this kind of statistical analysis might point to errors - short sections of marine terminating margin <500m that are separated from a longer section of marine terminating might point to places where the categorization is in error (such as the location I identified above).

Thank you for the suggestion. We agree this is a worthwhile undertaking and now provide this analysis before the discussion of the morphology and replacing some of the earlier text that only presented raw numbers on margin lengths.

For the steep/shallow categorization on the other hand, the distribution of many short segments versus fewer longer segments might offer some insight into the dynamics.

Thanks for the suggestion. Considering we have now reduced the discussion of results from simple margin statistics, we now include a more in depth discussion of such patterns (in the Discussion section), as far as that is possible with additional discussion of variables like ice dynamics, an analysis that is definitely of interest but we think goes beyond the scope of a manuscript like this one invested in the establishment of the morphology dataset.

General comments about the structure:

The introduction spends a lot of time motivating why we want to know the margins - especially the land terminating margins. That approach seems good, but the discussion and conclusions don't really come back to these ideas - instead the discussion focuses on lengths of different categories and the value of Arctic DEM. The discussion/conclusions that relate back to the introductory material is very general - mostly saying this is future work. My suggestion is better balancing the physical explanations introduced early in the paper with the discussion/conclusions so that there feels like some closure for the reader. If the authors want to emphasize that the biggest gap in answering physical questions is the lack of good data set - then

emphasize that more in the introduction, why has there been a lack of sufficiently good data sets to tackle the question of steep versus shallow? Is it just the morphology data set? What other data sets do we need to answer some of these questions? While they suggest this data set is the primary one lacking in line 80, they could expand on this more - and clearly lay out the gap in knowledge they are trying to fill. To summarize my thinking here - the introduction suggests that the authors are going to assess the physical processes more than they do. The discussion/conclusion don't really say much except that their data set might be helpful for future work (without many details).

We are very grateful for the close reading on the general scope. We actually thought that our main aim always was the morphology and the retrieval from the DEM products but agree that in the course of writing it this hasn't come through well enough the way things were structured and emphasized. We have now significantly reduced the aspects of margin outline analysis (adding a few suggestions that have been made to also further sharpen this and revised the product following comments from all reviewers), provide a clearer discussion on the reasoning why this data is important and where there was a gap as well as providing clearer framing on what future analysis, beyond what is reasonable in the space here, is feasible, including what data is needed, where this is at all useful and realistic and where the focus of such analysis can lie (also considering the quality and shortcomings of the present dataset).

I felt like the paper was overall well written and explained their method clearly, I do not have many suggestions details of wording in these areas.

We are very grateful for the close reading on methods and comments.

I am happy to chat more with the authors if they wish.

References:

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