Documentation of review 'The terrestrial ice margin morphology in Kalaallit Nunaat (Greenland)'

Below we document the changes made to the manuscript as well as the dataset following the reviews. We indicate the reviewer who raised the issue in brackets, as well as the lines where changes were made (line numbers referring to the document without track changes). All changes to the manuscript can be traced through the track changed document. Individual changes to the dataset can be derived from the version control in the github repository (https://github.com/fidelsteiner/tIM).

1) A minor technicality for now, but for some reason my Latex (or the Overleaf setup) produces a bug on the fixed headings of the template (Introduction, Conclusion, Author contributions etc). When I use the coded heading it replaces the headings with a full stop and I was not able to find a solution after searching extensively. For the time being I have 'hard coded' those headings, I will revert to the original formatting once I found a so the bug. The final PDF should be the same however.
2) We have made the suggested Editorial changes in manuscript (add country) and Supplementary file (edit titles).
3) Following a number of recommendations, additional data is now provided in the repository (primarily to describe uncertainties and differences to statistics from previous publications) and further documented in the associated readme. We propose to update the Zenodo after further review.
4) We have rewritten the abstract to remove the strong focus on the margin statistics (in response to RC1, CC). While introducing the general statistics of margin lengths is of course important to appreciate the role of the land-terminating margin and subsequently our interest, we have also considerably reduced the text pertaining to these general statistics in the first paragraphs of the Results as well as in the first paragraph of the Discussion, where we provide more context in comparison to (Ryan et al., 2024) – likely the best study where margin lengths can be compared 1:1 – but remove the discussion of the significance of lake/marine margins, not at the center of this study.
   We now address the importance of the ice masks used for this work, and how the choice of different ice masks leads to vastly different estimates in total ice margin length (ranging from ca 30 to 80 000 km, L299f). The point raised by the reviewers that the margin statistics aren't the central aspect here is well taken and discussion around it has been reduced throughout, but how this margin is used naturally also has an impact on how the statistics of the land-terminating part are to be interpreted.
5) We apologize for the erroneous data stored in the gpkgs in the repository (noted by CC). Due to some regions being stored multiple times in the same file, the overall statistics were inflated and did not correspond anymore to the actual lengths. The data files have now been updated and stored under the same file names and correspond to the numbers reported in the manuscript. We have also brought them to the same projection, where previously we had separate datasets stored in WGS84 ('4326') and others in '3413'.
6) In response to RC2 we now clarify our error in describing the ice sheet mask used as well as the reason for that choice (L92ff), making reference to other products including those published in peer-review (Citterio & Ahlstrøm, 2013; Luetzenburg et al., 2026; Rastner et al., 2012). While we acknowledge the existence of an additional product by the Danish government (published through https://www.klimadatastyrelsen.dk/ under https://dataforsyningen.dk/data/4771), we do not refer to it in the manuscript as it has no stable DOI/URL and would not be useful in our study due to its scattered coverage of the margin, without clear documentation of methods.

We also provide corrected masks we used for the analysis as part of the repository, and have added a separate folder including the separately mapped marine-termini that have an ice-water interface to explain the discrepancies with statistics from previous publications. In response to RC1 we have now removed large parts of the focus on the actual margin statistics. However, to ensure the validity of the margin mask as such it is of course important that the general statistics match align with previous assessments. We previously failed to note an important study analyzing the ice-water interface in Greenland (Ryan et al., 2024), which we now do in the Results with respect to both marine- as well as lake-terminating ice. To answer the three specific concerns by CC, we address (a) the mismatch in total margin, (b) the mismatch in lake termini and (c) the mismatch in ice-ocean interfaces.

a. (Ryan et al., 2024) refer to the perimeter of the GrIS with ca 29 000 km, while we note it to be ca 76 000 km. First, due to the error explained, we did not use the PROMICE margin from the 1980s, but relied on the CCI margin produced for the ice sheet as part of the RGI contribution (Rastner et al., 2012), which is time stamped around the year 2000. The quality of the PROMICE and the CCI mask are similar, with the earlier 94758 km in perimeter for the ice mask and the latter 81385 km. Our number comes from the corrected mask after removing duplicates that are also included in the PGIC. The much larger length for these masks compared to (Ryan et al., 2024) can likely be explained with the higher resolution of the mask, introducing many edges and – as noted – nunataks that increase the margin length. It can not be answered here, which is the 'true' margin but for the purpose of our study, referring to masks that can then be reused as is crucial. We now provide a short note on these discrepancies at the end of the first paragraph of the Discussion (L285ff).
b. The mismatch in lake termini can again be explained by this difference in the mask quality. We use any margin ending in a lake, which may in fact be much shorter if remapped from imagery (as done in (Ryan et al., 2024)) but would require a reworking of the mask itself. We also would like to point out that other studies already mentioned in the manuscript have similarly diverging margin length numbers for lakes, highlighting the issue of mask choice. We emphasize again that our margin lengths should not be directly used as flux gates. We discuss this in the first paragraph of the Discussion (L293f).
c. To evaluate how much of the mapped marine margin was actually marine terminating in the mask used here, vs what part was simply a shear margin, we investigated the margins individually for all basins with a marine terminus (n=197), that had more than 10 km of marine terminating margin and where part of the GrIS rather than the PGIC (n=84). The calving margins in direct contact with the ocean, were 33% shorter than what we define as marine termini in the manuscript (every margin below 10 m a.s.l.). On average individual basins had 35% shorter actual marine terminating margins, with a 21% standard deviation. This brings our estimate of the marine terminating margin for the ice sheet (2741 km) down to just 1838 km of termini that have an actual ice-water interface, and hence much closer to the estimates of 1400 to 1600 km in (Ryan et al., 2024), who very clearly mapped those interfaces. We now describe a description explaining this mismatch in the first paragraph of the Discussion (L289f).

7) The concerns of RC2 regarding the ability of the mask to capture ice morphologies are crucial. The first aspect addressing the issue is explained above, namely our erroneous

identification of used ice mask. In L92ff we now discuss the issue of existing masks (incl. the most recent one, which only became available during review, (Luetzenburg et al., 2026)) and present the arguments for our choice. As explained above, we refrain from discussing the dataset by the Danish government (https://dataforsyningen.dk/data/4771) as it is not complete for the whole ice sheet, there is no accessible documentation on how it was produced and we are unsure if the data will be accessible in future under that domain. From L390f we now also highlight the issue relating to larger retreat rates at glacier snouts, relying on most recent data from (Larocca et al., 2023). We also refer to this again in the Discussion of the reliability of the morphology data (L380f). Additionally, we have now expanded the sampling with transects. The 43 (not 41 as erroneously stated before) transects previously chosen remain and as described in the Supplementary, were chosen from locations authors were familiar with or where the margin was especially clear. Here the erroneous sections were just 5%. We now placed an additional 109 transects (Figure 1) across all of Greenland (simply choosing every second subcatchment and randomly placing a transect in each along the land-terminating margin) and find 17 (16%) to be erroneous. This number is likely a better error estimate for any location across the margin, as it is not biased towards known locations and many transects were placed where the ice mask was off or the DEM does not allow for a good capture of the actual margin. We use his number of 16% as the error associated to the method in identifying the margin (also in Abstract and Conclusion) and explain this process in the Supplementary material (text expanded), but also bring the Results into the main manuscript from L220ff. We still want to emphasize that – as stated earlier – margins at glacier termini are more prone to being inadequately placed and hence were already excluded (hence the 8.4% of total land-terminating margin we don't even evaluate since it is likely not suitable, see Table 1). It was not feasible to include 109 extra maps into the Supplementary, and we just show the overview map and have now provided all transects (including their result with respect to error analysis) as a separate folder in the Data Repository (folder 'Validation_transects'), including the Code that allows to extract the actual topography data from the individual ArcticDEM tiles. We refer to this in the respective text as well (L222). In the process we realized that one figure showing transect examples was misplaced in the supplementary, this is now corrected.

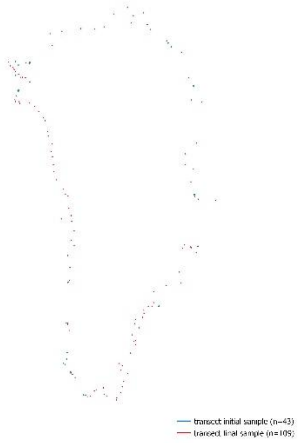

Figure 1: Validation transects placed around Greenland for the initial (43) and final (109) sample, to estimate our ability to capture the actual margin with the buffered ice mask. Now an additional figure in the Supplementary Material.

8) In L127f we now explicitly describe the weakness with respect to differentiating between marine- and land-terminating margins in the transition zone (RC1). We additionally include a brief section at the end of the Discussion that outlines these weaknesses and suggests potential future improvements (L380ff, Section 5.2).
9) Following the suggestion by RC1, we have now investigated morphology sections further, that is how long cliffs/shallow/steep ramps can be and whether there is a clear difference between those lengths for the different morphologies. The discussion of this aspect is now placed in L341ff, including one figure (Figure 10, see Figure 2 below) to illustrate the learnings. We understand that further in depth analysis of the individual morphologies would be great to understand their role, but believe that even with shortening the manuscript as we did with respect to the general length statistics, isn't warranted within this study (also considering the additional methodology that would be required).

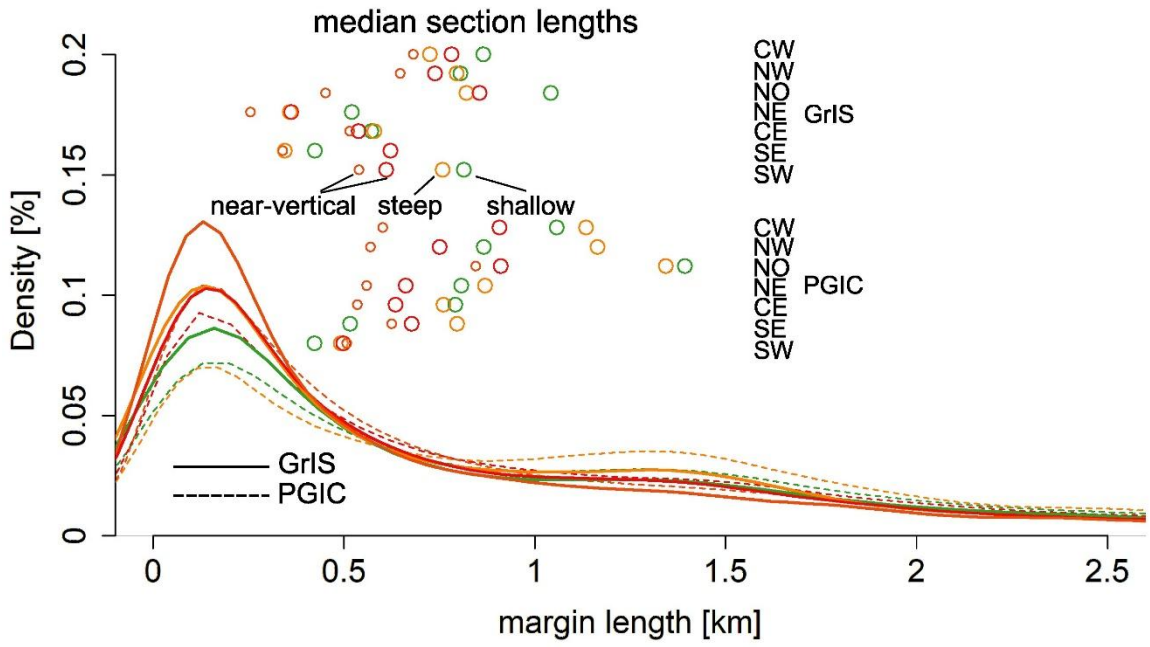

Figure 2: Additionally produced Figure, now Figure 10 in manuscript.

10) Following the suggestion of RC1, we now expand on the discussion what is possible with the margin product. This comes now as a separate section 5.1 to bring together these aspects, before we move to Limitations and how to address them (L363ff).

References

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