Anonymous referee #2

The manuscript presents research that is highly relevant to the cryospheric community and is of strong scientific quality. The authors propose a new machine-learning-based downscaling method for Earth System Models (ESMs). They have conducted a thorough analysis and present a substantial number of interesting and relevant results. According to the abstract, the study introduces a physics-constrained generative modeling framework based on a consistency model (CM) to downscale surface mass balance (SMB) and surface temperature fields over the Greenland Ice Sheet by up to a factor of 32 (from 160 km to 5 km resolution). The model is trained on MARv3.12 outputs and conditioned on topography and insolation, while enforcing conservation constraints to preserve large-scale totals and ensure robust generalization. The approach outperforms interpolation-based methods, accurately reproduces variability across spatial scales, and demonstrates strong potential for directly downscaling ESM outputs such as NorESM2. Overall, the method provides a computationally efficient and physically consistent way to generate high-resolution climate forcing for ice-sheet modeling and projections of sea-level rise.

Thank you for this positive assessment and accurate summary of our manuscript! We will answer all comments and suggestions below (blue font).

However, I agree with the other reviewer that the current format is not well-suited for The Cryosphere. The manuscript is highly technical and method-focused, with limited analysis of the results and their implications for the cryospheric community.

I suggest that the authors consider submitting the work to a more technically oriented journal, such as Geoscientific Model Development (GMD) or JGR: Machine Learning and Computation. Alternatively, if the authors wish to keep it within The Cryosphere, substantial restructuring will be necessary. Specifically, the manuscript should follow the conventional structure: introduction, methods, results, discussion, and conclusion.

We agree that the manuscript is currently very technical, without showing too many results, and that the manuscript needs restructuring. However, we are convinced that our manuscript will be a good fit for TC after revising the whole manuscript, including additional analysis with emphasis on cryosphere-scientifc applications.

I also find that the results section would benefit from some re-writing to improve readability. As it stands, the text is quite dense, and readers may need to reread several passages to fully grasp the main points. I recommend that the authors break up long sections into shorter paragraphs and present metrics in parentheses to support the narrative, rather than in standalone paragraphs. Including a brief summary at the end of each results subsection would also help guide the reader. Finally, the authors should ensure that no new results are introduced in the figure captions, as this can make the presentation confusing.

Thank you for this comment! We fully agree and will make corresponding changes to the results section.

The discussion section would also benefit from a clearer structure. I suggest that the authors divide it into subsections, each with an informative subtitle, to guide the reader through the different aspects of the discussion. For The Cryosphere, the discussion could be expanded somewhat, with particular emphasis on the broader impacts of the methodology and findings on cryospheric science.

We agree that the structure is not optimal in the current state and that we miss a discussion on the broader impact on cryospheric science and the ice-sheet modelling community. We will revise the section.

In summary, the study presents very interesting and valuable results, and the authors have done excellent work overall. However, the manuscript would benefit from substantial rewriting and restructuring to make it suitable for publication in The Cryosphere.

Thank you! We expect that the revised version will be more suitable for publication in TC.

PS: I've added a supplementary file with line-by-line comments.

Thank you; we will consider all line-by-line comments in the revised version. Below, we answer the technical questions raised in the line-by-line comments:

Page 2 (#1): I don't understand this part because your model is trained on RCM data, so how can it downscale SMB from another source than an RCM?

While our model is trained on RCM data, it does not differentiate between different sources of the input fields during inference. That is, it only requires the temperature and SMB fields (in addition to the auxiliary insolation and topography) as coarse input fields for the downscaling task. Therefore, we can use, for example, coarse ESM fields as input.

Page 3 (#7): I i remember correctly, the same margin artifact problem was observed in van der Meer et al. 2023

We believe that this is simply a consequence of the large variability of the SMB fields at the margins compared to the interior of the ice sheets.

Page 7 (#3): Is there a reason why you took such a small batch size ?

This is purely a limitation of the available GPU memory.