An improved glacier parameterisation for the ecLand land-surface model: local, regional and global impact

The authors updated the parameterizations for glacier ice and snowpack within the land surface model and carried out validation over the Greenland Ice Sheet. The updated model demonstrated comparatively strong performance on the Greenland Ice Sheet and yielded valuable outcomes for the future development of ecLand. However, there remain several unclear aspects and areas lacking sufficient validation. I hope that the following comments will help improve the manuscript.

Major comments:

1. The differences between the existing model (CTL) and the updated model (GLA) are not clearly explained. For example, it is not clear what parameterizations the CTL used. Since this is a key part of the manuscript, I suggest showing the differences between the two models in a table to enhance clarity.

2. The transition from validating against the Greenland Ice Sheet to evaluating river discharge in the Northern Hemisphere feels somewhat sudden. Validation using in-situ albedo may be challenging, but would it be possible to compare the land surface albedo in CTL or GLA with MODIS albedo across the Northern Hemisphere? At least, the authors should discuss whether the GLA experiment also shows a decrease in albedo outside of Greenland.

Specific comments:

Title: In my impression after reading this manuscript, the use of the term “global” feels somewhat excessive. Since the river discharge validation is conducted only for the Northern Hemisphere, it might be better to change the title to “local and regional impact,” or remove the phrase “: local, regional and global impact.”

L35 (Surface processes…): Add melting and refreezing processes.

L67: What do you mean by “physical capping”? Please add a clearer explanation.

2 Methodology: It is better to briefly describe the difference between the GLA parameterization and the other LSM parameterization. Lee et al. (2024) might help you to compare GLA with LSMs (land surface models).

L87: Does “fully coupled” mean “Atmosphere, land and Ocean coupling”?

2.2 New glacier parameterisation: Although the GLA parameterizations are described, it is not clear what has changed compared to the CTL parameterizations. I would like to understand the differences between the two models before seeing results, so I suggest summarizing the characteristics of both models in a table.

L157-158: Previous studies have suggested that new snow density in the polar region exceeds 300 kg m-3 (Greuell and Konzelmann, 1994; Lenaerts et al., 2012; Niwano et al., 2018), so I have no objection to your assumption for the Greenland simulation. However, you should be careful if you apply the assumption to midlatitude areas. New snow density in midlatitudes is typically around 100 kg m-3 as indicated by previous studies (e.g., Niwano et al., 2012). Regarding this point, it should be stated whether changes in snow density parameterization affect snow albedo.

L169-170: Please add the references for the values you used for Eq. (3). If the values are not based on previous studies, please add the rationale why you set the values.

L192: If there is no alternative to the spatial SMB data other than RCM, it should be mentioned.

L205 (different periods for each site): This is vague explanation. Please describe clearly. It would be helpful if you could make a table summarizing the experimental setting, including other experimental settings. A supplemental material might be good.

L220: Did you apply elevation correction to ERA5?

2.4.2 2F global simulations: Please add an explanation regarding spinup simulations.

Figure2 (skin temperature): “Skin temperature” and “surface temperature” are mixed up in the main text. If they mean the same thing, please unify either.

Figure2: What period does the analysis in this figure cover? Please add the period and season for the analysis.

Results: The Results section should be nominally limited to new results from the current observation or calculation and not include a literature review (L264, 281. 334…). I found that the authors' interpretations are included within this section (e.g. L280-284, L332-340). I suggest that you change “Results” section to “Results and Discussion” section.

Line 242: Could you tell me about the specific scheme you improved?

Figure 3 (c): In the OBS experiment, temperature from PROMICE is used as an atmospheric forcing, yet panel (c) shows a bias of nearly 3°C during winter. The result looks strange. Please verify that there are no errors in the simulations or analyses. If no errors are found, the bias may be due to ERA5 precipitation used in the OBS experiment. Additionally, I could not locate the CLIM experiment lines in the figure.

Figure 4 caption: Add the specific season you analyzed.

Line 270: Add the specific months.

Line 280: This paragraph is clearly a discussion.

Figure 5: Please modify the legend. It looks like an old version. It is better to make the texts about the bias values larger.

Figure 6: I could not find the red dashed line at first. Please add that the red dashed line can be seen at 0 kg m-2.

Line 310: It is better to add the explanation regarding snow layers in the models to the method section.

Figure 8: As the color bar in the upper panels and the map in the bottom panels are close to each other, the labels on the color bar were misunderstood for the titles of the lower panels. In addition, please describe the difference between CTL and the validation dataset you analyzed to the labels of Figure 8a and c (for example, difference between Glacier minus CTL, like Figure 8b and d).

Figure 11(a): The text for CTL and GLA is cluttered, so why not red and blue text for CTL and GLA, respectively?

Figure 11(b-e): It is hard to see each line. How about changing the line style to a dashed line for CTL and GLA?

Line 393: Could the cause of this overestimation be the decrease in albedo in the GLA experiment? In the validation over the Greenland Ice Sheet, the GLA experiment showed a significant reduction in

albedo. It is necessary to compare the land surface albedo from MODIS, CTL, and GLA across the Northern Hemisphere and discuss whether the new parameterization leads to a decrease in albedo over the Northern Hemisphere.

References:

Greuell, W. and Konzelmann, T.: Numerical modelling of the energy balance and the englacial temperature of the Greenland Ice Sheet. Calculations for the ETH-Camp location (West Greenland, 1155ma.s.l.), Global Planet. Change, 9, 91–114, https://doi.org/10.1016/0921-8181(94)90010-8, 1994.

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