Influence of albedo parameterization on surface mass balance in the perspective of Greenland ice sheet modelling in EC-Earth

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Summary:
The authors implement and test the impact of a new, relatively simple ice sheet albedo scheme for the EC-Earth earth system model with respect to Greenland ice sheet surface mass balance. The impact of varying parameters in the scheme on SMB is assessed. SMB is then used to force the IMAU-ICE ice sheet model to understand the impact of the range of SMB simulations on overall ice sheet mass balance.

General Comments:
The study is an interesting exploration of the impact of the albedo parameterization on both the surface mass balance in a GCM and the subsequent state of the ice sheet. It shows that small changes in the proposed parameters for a simple albedo parameterization can have a large effect on the state of the ice sheet, as well as the importance of including a dynamic albedo scheme in future projections of ice sheet change in GCMs. Some issues need to be addressed before the paper can be published. In particular:

(1) I agree with Dr. Fettweis that there should be some comparison between simulated and observed albedo values. Despite the authors' statement that the focus of the analysis is not necessarily to achieve an accurate simulation of albedo, it is still useful to know how well the different simulations agree with observed albedo, which would reveal strengths and limitations of the current scheme. This would not necessarily need to be a very detailed evaluation, given the relative simplicity of the scheme employed. As Dr. Fettweis mentioned, RACMO albedo estimates might be sufficient. In particular, it would be useful to see a comparison with observed albedo at specific sites (Fig. 1), to better reveal which scheme best captures the typical evolution of albedo in each region. An ice-sheet wide comparison, such as the comparison shown in Fig. 3 for SMB would also be useful.

(2) The authors only mention the influence of bare ice towards the end of the paper. Since it is an important factor it should be discussed more often and earlier in the paper. The model's apparent inability to simulate bare ice exposure is also a limitation that should be mentioned.

(3) It should be emphasized a bit further that the "best" scheme at present may be partially compensating for biases associated other processes that are not simulated, such as refreezing of meltwater and bare ice exposure. Including these processes would necessitate a simultaneous revision and improvement of the albedo scheme. Also the "best" scheme, if not consistent with observed albedo can produce feedbacks that lead to magnified errors in future simulations.

Specific Comments:

1. **Title:** The phrase "in the perspective of Greenland ice sheet modelling" doesn't seem grammatically correct.
2. **P. 1, Lines 1-2:** Bare ice exposure should be mentioned as a factor as well.
3. **P. 1, Line 5:** There are not really "eight snow albedo schemes"; there are is really one scheme that is employed, with varying parameters, and some small adjustments. Please revise.
4. **P. 1, Lines 4-8:** More details need to be provided here; the writing style is rather vague. The main purpose of the study is unclear. The source of ice sheet topography should be mentioned, along with the model used for the future projections. Some specific results should be provided.
5. **P. 1, Line 16:** Explain briefly what features of the ISM could lead to different methods for computing SMB inputs.
6. **P. 2, Lines 26-28:** The role of bare ice exposure in variations in albedo should be mentioned here, along with the influence of impurities, especially over bare ice.
7. **P. 3, Line 15:** Mention sublimation here as well.
8. **P. 3, Line 30:** A brief description of the EC Earth model should be given here, including its use of spherical harmonics.
9. **P. 3, Lines 31-32:** Please provide a few more details about the snow scheme. e.g. it appears that only one layer of snow is simulated. Are heat fluxes through the snowpack calculated? What about snow density? Can any liquid water be stored in the snow?
10. **P. 4, Line 1:** Suggest "linearly decreasing" and "exponentially decreasing" in place of "linear" and exponential, for clarity.
11. **P. 4, Line 8:** This sentence is confusing. How can snow accumulate above the maximum thickness?
12. **P. 4, Line 24:** Note that the description here is of the "base" or "control" scheme that is then modified by each group.
13. **P. 4, Line 25:** What is the threshold for resetting the snow albedo? 1 cm?
14. **P. 4, Lines 28-29:** Please specify the units for Δt and F. Does 10 represent 10 millimeters?
15. **P. 4, Lines 32-33:** What is meant by the "flux of meltwater"? Is this the flux of meltwater out of the snowpack? Does it include rainfall events? What is the difference between "internal melting" and "flux of meltwater"…does this mean meltwater is stored in the snowpack?
16. **P. 5, Equations (3) and (4):** In this case I believe Δt refers to the total elapsed time, rather than the length of the timestep. Please clarify.
17. **P. 6, Lines 5-9:** The 0.45 value is consistent with bare ice… perhaps mention that here.
18. **P. 6, Line 18:** Change "Shown in this figure" to "Shown in Figure 1" for clarity.
19. **P. 6, Line 26:** Change 'The Copenhagen code' to 'The "Cph" scheme'
20. **P. 6, Line 30:** Which figure or set of figures is being referred to here? Perhaps the results for the other simulations could be briefly discussed and included as supplemental figures?
21. **P. 6, Line 31:** It would be helpful to compare with a figure showing this observed pattern.
22. **P. 7, Lines 11-12:** Again, it would be helpful to see the observed albedo.

23. **P. 8, Lines 4-8:** Provide some more details about RACMO, e.g. reanalysis forcing, spatial resolution. If comparison with RACMO albedo is included, some details of the albedo scheme should be provided.

24. **P. 8, Lines 31-34:** The influence of bare ice and bare ice albedo should be discussed.

25. **P. 9, Line 29:** Clarify "each climatology".

26. **P. 10, Line 1:** Does regridding of RACMO2 qualify as downscaling? Isn't the model simulation at a higher resolution?

27. **P. 10, Lines 4-5:** Perhaps change "GrIS model" to "GrIS ISM".

28. **P. 10, Lines 16-20:** Some more details are needed here. How is the forcing applied? Is a monthly climatological SMB forcing applied to the ice sheet model until it reaches steady state? The "height-mass balance effect" needs to be explained further. What is the effect of generating runoff beyond 10 m of accumulation on topography changes?

29. **P. 11, Line 31:** The presence of impurities also likely has an impact on the bias here.

30. **P. 12, Lines 1-3:** Although this is the best scheme for agreement with RACMO, it may not be the most accurate scheme, given that it may be compensating for errors in other schemes. If this is so, then feedbacks may not be accurately captured, leading to errors in future projections. Please discuss these potential errors.

31. **P. 12, Lines 4-14:** Note that adjusting the scheme for refreezing may require adjustment of the albedo scheme… i.e. they have to be changed together. Also perhaps simulating exposure of bare ice should also be a subject for future study.

32. **P. 13, Line 5:** Note caveats associated with this being the optimal scheme.

Technical Corrections:

1. **P. 1, Line 20:** Change "generally regarded superior" to "generally regarded as superior"

2. **P. 2, Line 12:** Change "ISM component" to "ISM components"

3. **P. 3, Line 1:** Change "To better understand the ice sheet changes and its interaction…" to "To better understand changes in the mass of the ice sheet and in its interaction…"

4. **P. 5, Line 1:** Suggest changing "can be" to "is".

5. **P. 6, Lines 2-3:** The sentence is repetitive. Perhaps change to read simply 'For dry conditions, the "Utr" scheme adopts the same choices as the "Cph" scheme.'

6. **P. 7, Line 24:** Change "next to that" to "in addition".

7. **P. 8, Line 21:** Change "(and wide)" to "(and extensive)"

8. **P. 9, Line 28:** Change "tje" to "the".