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The Cryosphere Discussions

Interactive comment on "Effects of snow grain shape on climate simulations: Sensitivity tests with the Norwegian Earth System Model" *by* Petri Räisänen et al.

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We thank Anonymous Referee #2 for his/her constructive comments on the manuscript. Point-by-point responses to the comments are provided below. The referee comments are written in *italic* font, and our responses in normal font.

Comment: *The study investigates the impacts of including the effects of non-sphericity of snow grains in the NorESM model in slab ocean mode. They find that due to a smaller asymmetry parameter, snow broadband albedo is generally higher. Despite a global mean radiative forcing associated with this change of only -0.22 W/m2, this*

leads to considerable differences in the simulated equilibrium climate — particularly at high latitudes.
The paper is very well written, structured, illustrated and argued. It is, quite frankly, a pleasure to read and I have only extremely minor suggestions for improvement. It fits within the journal and I suggest to accept with only minor changes.

L109: Would it be relevant to mention (just briefly) if and how the sea ice model is dynamic and how this works on top of the slab ocean?

Response and change in the manuscript: Yes, CICE4 is a dynamic sea ice model. We will add the following explanation: "Like fully coupled configurations, the slab ocean setup uses the full prognostic thermodynamic and dynamic configuration of the sea ice model. Ice velocities are prognostic and calculated based on winds from the atmosphere model and ocean currents specified from an earlier fully coupled run with NorESM (the same preindustrial control simulation as used for calculating the Q-fluxes for the slab ocean component). In addition to the thermodynamic response, this allows for transport and deformation of sea ice in response to changes in the atmospheric circulation."

Comment: *Eqs (3) and (4): Perhaps note that the time step DeltaT is multiplied onto these rates to get the dr's used in Eqn (2).*

Response and change: In the revised manuscript, we will include Δt on the rhs of Eqs. (3) and (4), so they directly give the $dr_{e,\mathrm{dry}}$ and $dr_{e,\mathrm{wet}}$ needed in Eq. (2).

Comment: *L226: at the end of the sentence, do you mean "SPH and ERA-Interim reach -7 K"?*

Response: No, the sentence is correct as it is. Its purpose is to stress that NONSPH also differs a lot from SPH, not only ERA-Interim. (The maximum difference between SPH and ERA-Interim in Antarctica in summer is close to -6 K). Thus, no change in the manuscript.

Comment: *L246: Perhaps note that these diagnostic calculations were the same used to calculate the TOM RF.*

Response and change: This will be noted in the revised manuscript.

Comment: *L264: "smaller contribution". It is not completely clear to me how you see that this contribution is smaller. Please explain better.*

Response: Quantifying precisely how much the change in snow grain size r_e contributes to the albedo difference between NONSPH and SPH would require extensive and laborious off-line radiation calculations. However, even without performing such calculations, it is safe to say that the contribution from changed r_e to the overall albedo diffence seen in Fig. 5b is (much) smaller than the contribution from increased snow and sea ice cover. The impact of the change in r_e can best be discerned from other factors in regions with permanent snow cover (i.e., Greenland and Antarctica); it is also these regions which show the most consistent decrease in r_e in the NONSPH experiment in Fig. 7b. By taking the difference between the actual albedo difference between NONSPH and SPH (Fig. 5b) and the corresponding albedo difference from diagnostic radiation calculations (Fig. 5a), we estimate that the reduced r_e in NONSPH increases the snow albedo in these regions on average by 0.007, although the difference reaches 0.02 for some grid points. Albedo differences of this size are

quite small compared to the differences between NONSPH and SPH in those regions where NONSPH features increased snow and sea ice cover (which can be well above 0.1; Fig. 5b). Therefore, beyond reasonable doubt, the dominant contribution to the albedo differences in Fig. 5b comes from changed snow and sea ice cover rather than changed r_e.

Change in the manuscript: In the revised manuscript, we will include a shorter version of the above explanation at the end of Sect. 4.3.: "The impact of this is most easily discernible in the permanently snow-covered regions of Antarctica and Greenland. In these regions, the actual albedo difference between NONSPH and SPH (Fig. 5b) is slightly larger than that derived from diagnostic radiation calculations (Fig. 5a); on average by 0.007 and by up to 0.02 for some grid points. These albedo changes are, however, much smaller than the albedo differences between NONSPH and SPH in regions of changed snow and sea ice cover."

Comment: *L322-330+Table 2: Is this part really necessary? If you want to shorten, this could be a place.*

Response and change: True enough, it is not strictly necessary. This part will be eliminated in the revised manuscript.

Comment: *L337: yes, because the default parameterization was used when other parts of the model were tuned originally.*

Response and change: The following sentence will be added to the revised manuscript: "In particular, the spherical snow grain shape assumption was used in NorESM when other parts of the model were tuned originally."

Comment: *L357: NONSPH → SPH*

Response and change: Thanks for spotting this! It will be corrected.

Comment: *L516: reports*

Response and change: This will be corrected.

Comment: *L529: Perhaps: "at high latitudes up to XX K."*

Response and change: We will add: '"(up to -4 K in the extreme northeastern parts of Russia and locally -7 K in the Southern Ocean near Antarctica)".

Comment: *L531: Perhaps add to end of sentence something like "and therefore leads to large efficacy of the RF". This would better justify including the efficacy section in Section 7.*

Response and change: We will formulate this as "The climatic response is amplified by strong snow and sea ice feedbacks, which leads to a very high efficacy of the RF associated with changed snow grain shape."

Comment: *L552: Delete "to".*

Response and change: This will be corrected.

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