The Cryosphere

Discussions

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**Interactive
comment**

Interactive comment on "Development of physically based liquid water schemes for Greenland firn-densification models" *by* Vincent Verjans et al.

Anonymous Referee #1

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Development of physically based liquid water schemes for Greenland firn-densification models. Verjans et al.

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Discussion paper

1 General Comments

This paper makes an extremely valuable contribution to our understanding of the performance of models developed to describe the densification of snow in the percolation zone. These models are important not only for the interpretation of elevation change in terms of mass balance change, but also in the calculation of meltwater output from ice sheets. The authors compare 3 methods of modelling the movement of water in firn; a simple bucket model, a one-dimensional Richards Equation model for flow in porous media and a combination of porous flow and faster flow through preferential pathways. These models are combined with 3 different methods of calculating densification; the linear viscous model used in the CROCUS model, the Herron and Langway model for dry snow densification and the Kuipers-Munnecke model. Input data comes from the RACMO2 regional climate model, available at 5.5 km horizontal resolution at 3-hourly intervals.

The authors choose input data from 4 different locations on the Greenland Ice Sheet and compare the model output to measured firn density profiles from single cores collected at these locations. Although it is clear they are aware of the extreme variability of firn density in the percolation zone, they do not comment on the difficulty of up-scaling from a single point measurement to the model scale. It would be very useful to have a discussion, early on in the paper, about what features of the observed data a good model, fed by their input data, could be expected to reproduce. Perhaps the overall densification rate? Perhaps the amount of refrozen meltwater in the profile? Certainly not the position and size of ice layers as this is notoriously variable.

Given this preliminary discussion the authors would be able to concentrate on the differences in model outputs, which are interesting and illuminating, and could avoid putting too much weight on the comparison with observed data. Small changes would

probably be enough; for example, if Figures 4, 5, 8 and 10 had a very pale grey indication of the observed data in the background, the model outputs would be easier to compare with each other and the reader would be led away from the idea that the model output "should" reproduce the point observations in detail.

2 Detailed comments

The descriptions of what each model is doing are very good and show great insight into how these quite complex models work. However, the mass of material in the Results section is rather overwhelming and the authors might consider whether all of it is needed. It may be that all the results are indeed required, in order to justify the points made in the Discussion section. In that case, maybe the answer would be to move some material into a Supplementary Material section.

The statement (p.8 l.26) that water cannot fill the entire pore space because otherwise there would not be enough space for the liquid to freeze is a bit confusing. Is it equivalent to saying that as water in a saturated layer freezes, the part that won't fit is expelled into another layer? What about the possibility that a saturated layer expands on freezing?

3 Technical Comments

The paper is generally well written in very good English. Just occasionally the first author has been deceived by "false friends" . It would be worthwhile looking at each use of "therefore" to ensure that the authors really do mean a strong causal connection; the alternative might be to use the weaker 'so" or even "and".

- p. 1 l.22 "in actuality" should be "in reality"

- p.2 l. 29 "through the porosity" should be "through the pores"

- p.3 l.2 "Snow models have developed" should be "Snow modellers have developed"

- p.4 equation(2) and other equations following. If the numerical value of a parameter is given in an equation it should have its units attached e.g. 273.15K. Otherwise use parameter names and define them eg η_0

- p.5 l.14 lower case rather than upper case for " Where"

- p.5 l.15 If r_0 has units of m then so must b_0. b_1 has units of m K^{-1} and b_2 m yr/m w.e.

- p.5 equation (8) Roman font for "exp"

- p.6 l.26 "the depth from which firn density does not reach"? Not clear what is meant here

- p.8 l.6 and elsewhere. "capillary suction" should be "capillary tension"

- p.9 l.7 "superior to zero" should be "greater than zero"

- p.9 l. 23 "above the impermeability threshold"? Not clear what is meant here.

- p.11 l. 16 "synthetically" should be " artificially"'

- p.25 l.19 maybe say "developed for seasonal snow models"?