Review of EGU-2025-3035: “Simulating the effect of natural convection in a tundra snow cover”

This is my second review of egu-2025-3035. I thank the authors for their work revising the manuscript and responding to the two reviews. The manuscript has been streamlined and clarified. It was also extended to better show that the obtained results can provide some good ideas on the extent to which convective vapor transport can impact snowpack density and how this mechanism can be inhibited by the presence of a low-permeability wind-slab.

I think the results are valuable for our understanding of vapor transport in Arctic snowpacks and the role it plays in their structure. For me the article is suited for publication in the Cryosphere after some quick minor/technical modifications.

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Minor Comments

L93 Why were these specific initial conditions chosen for the soil?

L255 Is there a reason to run the SNOWPACK-only simulations without wind-compaction in the comparison?

L258-261 I’m not sure if it is pertinent to use snow height as a metric to discuss the precision of the models. As they are both driven by snow height, it seems normal that they both tend to reproduce the imposed snow height whenever they can.

L459 Is the fact that properties change over large time scales (at least larger than the typical time involved in convection) really a problem when defining a Rayleigh number? I have the impression that is really the space heterogeneity that is the problem.

Technical Comments

L24 I would remove the word “statistically” and just say “significant”. For me “statistically significant” has a specific meaning (with p-value, null hypothesis and such), and I’m not sure that is what the authors mean.

L30 High density layer on top and low density at the bottom is a trait of Arctic (i.e. what is sometimes called tundra) rather than subarctic (i.e. taïga/boreal forest) snowpacks. For instance, Domine et al. (2016) is based on Bylot, i.e. a (high-)Arctic site.

L135 This sentence feels a bit off, as the info was already given L99. Perhaps rephrase to something like: “Numerically, this challenge can be addressed by using separate, disconnected meshes for each SNOWPACK domain, though careful attention would be required for defining boundary conditions and information exchange across these discontinuities. This includes taking into account the different soil columns modeled by the different SNOWPACK domains. It will be possible to represent the lateral thermal variations at the bottom of snowpack for the OpenFOAM solution as suggested by (Jafari and Lehning, 2023a).”

L238 I would rather say some “Alpine and some subarctic”, since, as mentioned after in the text, convection has been reported in shallow 30/40cm subarctic snowpacks (Sturm and Johnson, 1991).

L244 Perhaps “discussed” rather than “explained”.

L255 Perhaps change “diffusive” to “with vapor diffusion”.

L275 The definition of cumulative density change has already been given.

L334 I would move the paragraph to the start of Section 3.2

L343 The word “basal” might be confusing here (as it also means the snow near the ground elsewhere in the article). Perhaps rephrase to “and redeposits it into a denser layer with a lighter, newly deposited layer on top.”

L348 Perhaps “about” rather than “roughly”.

L354-356 This sentence feels like a redo of the L348-349, where it is already stated that wind compaction produce abrupt density increases during wind peaks.

L357 I am tot sure why temperature helps seeing that convective vapor transport and phase changes have a lower impact on density than wind compaction. Perhaps consider removing Figure 15 to lighten the manuscript, as it is not further really analyzed in the article.

Figures 17-24 Why apply a factor on the velocity? Shouldn’t it be applied to the colorscale instead?

Figures 17-24 There is are a lot of information on these, and I’m wondering if they could be simplified for clarity. Perhaps remove the cumulative density change panel, which if I understand well, integrate phase change all over the season and it thus not directly related to the events depicted in the figures.

Figures 19-24 The caption for panel e) is missing.

Figure 22 and 24 Panel e) is missing compared to the rest of the similar figures. I guess it has to do with integrating the figure on a single page, but I think that this panel is important to show.

L400 What does it mean to be diffusion dominated? That the vapor fluxes/phase changes are mainly controlled by diffusion?

L408 “Arctic Bylot site”

L409 The formulation could be taken meaning that SNOWPACK does not include wind compaction. Perhaps rephrase to “a SNOWPACK version where surface wind compaction has been turned-off, …”

L410 Remove “move” or “lead”

L450 The font of Ra is different from that L446.

L452 How is the “snow element temperature difference” defined?