

Responses to Reviewer 1, 2nd round, for EGU-2025-3035:  
“Simulating the effect of natural convection in a tundra snow cover”

February, 2026

**Answers to general comments, specific comments, and technical comments**

Corresponding changes based on the comments from reviewer 1 and 2 and the additional changes in the revised manuscript are highlighted in green color.

**General Comments:**

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.

Answer:

We thank the reviewer for the thoughtful comments and continued effort in improving our manuscript. We are pleased that the revisions have streamlined and clarified the paper and that the reviewer finds the results valuable. In response to the remaining points, we have implemented the requested minor and technical modifications.

**Minor Comments:**

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

Answer:

These are typical values chosen for the soil part in examples provided in the source code of SNOWPACK since the soil characteristics (apart from temperature) should not influence the convection in snow .

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

Answer:

Yes, the reason is to show the difference in snow density and structure when the wind-compaction is not considered.

**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.

Answer:

Thanks. We agree but it is worth it to show if the model follows well the enforced measured snow height during settling and snow ablation, when adjustment is paused.

**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.

Answer:

Thanks for the insightful comment with which we agree. The line 450 reflects and agrees with the reviewer's comment that the induced space heterogeneity over large time scales is the problem preventing a simple parameterization based on classical dimensionless numbers like the Rayleigh number.

#### **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

Answer:

Thanks. Done.

**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. taiga/boreal forest) snowpacks. For instance, Domine et al. (2016) is based on Bylot, i.e. a (high-)Arctic site.

Answer:

Thanks. Done.

**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).”

Answer:

Thanks. Done.

**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).

Answer:

Thanks. Done.

**L244** Perhaps “discussed” rather than “explained”.

Answer:

Thanks. Done.

**L244** Perhaps “discussed” rather than “explained”.

Answer:

Thanks. Done.

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

Answer:

Thanks. Done.

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

Answer:

Thanks. We removed it.

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

Answer:

Thanks. Done.

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

Answer:

Thanks. Done.

**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.”

Answer:

Thanks. Done.

**L348** Perhaps “about” rather than “roughly”.

Answer:

Thanks. Done.

**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.

Answer:

Thanks. The purpose of these lines is highlighting that convective vapour transport is gradual compared to the wind-compaction events.

**L357** I am not 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.

Answer:

Thanks. Figure 15 is removed.

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

Answer:

Thanks. In all these figures, the scaling factor is applied to the velocity vectors to make it bigger and more obvious.

**Figures 17-24** There is 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

Answer:

Thanks. In all these figures, we keep the cumulative density change as it directly shows the effects of convective vapor transport on snow density.

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

Answer:

Thanks. The panel e is dropped as the snow height is large and adding panel e would exceed one full page limit.

**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.

Answer:

Thanks. As answered in the previous comment, the panel e is dropped as the snow height is large and adding the panel would exceed one full page limit for the related figures.

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

Answer:

Thanks. Yes, exactly.

**L408** "Arctic Bylot site".

Answer:

Thanks. Done.

**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, ..."

Answer:

Thanks. Done.

**L410** Remove "move" or "lead"

Answer:

Thanks. Done.

**L450** The font of Ra is different from that L446.

Answer:

Thanks. Revised.

**L452** How is the "snow element temperature difference" defined?

Answer:

Thanks. The snow temperature is the phase-averaged temperature between the ice phase and gas mixture. It is defined as the snow temperature difference between top and bottom nodes of a snow element in a vertical profile.

**References:**

*Jafari, M. and Lehning, M.: Convection of snow: when and why does it happen?, Frontiers in Earth Science, Volume 11- 2023, <https://doi.org/10.3389/feart.2023.1167760>, 2023b*

*Domine, F., Barrere, M., and Sarrazin, D.: Seasonal evolution of the effective thermal conductivity of the snow and the soil in high Arctic herb tundra at Bylot Island, Canada, The Cryosphere, 10, 2573, 2016.*

Responses to Reviewer 2, 2nd round, for EGU-2025-3035:  
“Simulating the effect of natural convection in a tundra snow cover”

February, 2026

**Answers to general comments and specific comments**

Corresponding changes based on the comments from reviewer 1 and 2 and the additional changes in the revised manuscript are highlighted in green color.

**General Comments:**

This is a re-review of "Simulating the effect of natural convection in a tundra snow cover". Overall I think the authors have well addressed my concerns. The manuscript generally reads better, and I think I more readily follow the results. A few lingering points. I think that the impact of the windslab reducing convection should be clearly noted in the abstract.

Answer:

We thank the reviewer for the thoughtful comments and continued effort in improving our manuscript. We are pleased that the previous concerns have been adequately addressed and that the revised version reads more clearly. In response to the remaining points, we have implemented the requested minor and technical modifications. Regarding the impact of the windslab in reducing convection, this is stated in the abstract in the sentence: “events that are well synchronized with cold events are numerically simulated by the SNOWPACK-OpenFOAM coupler for a herb tundra permafrost at Bylot Island only if we neglect wind slab formation for surface layers.”

**Specific points:**

**L3** Throughout, I don't like the term "real" or "realistic". It's too qualitative and subjective. I think using "observed" is stronger. A realistic snowcover could be a homogenous snowcover of a fixed density and temperature. It fulfills the laws of physics. But almost certainly is not what we would observe. But "this is what we observe" has an objective strength to it.

Answer:

Thanks for the comment. The terms “real” and “realistic” have been removed throughout the revised manuscript.

**L4** "among different snowcover" perhaps add "conditions"?

Answer:

Thanks. We have added the term "conditions".

**L5** "numerically observed" -> numerically simulated

Answer:

Thanks. Done.

**L 17** i.e. fix throughout to be i.e., <- the comma is important. Same with e.g.,

Answer:

Thanks. Done.

**L40** "However, the combined [...]" I think this might be a strong way to end this paragraph. Move to the end?

Answer:

Thanks. Agreed.

**L43** snowpackBuoyantPimpleFoam led me to believe this was directly used in this study, but L185 makes it seem like a Pimple formulation /isn't/ used? Please clarify.

Answer:

Thanks. In this study "*snowpackBuoyantPimpleFoam*" has not been used. We implemented the SNOWPACK-OpenFOAM coupling solver named "*SNOWPACKFoam*".

**L47** "(as shown later in section 3)" suggest w/c/ ->"(as described later in section 3)"

Answer:

Thanks. Done.

**L50** "This model shows [...]" result, remove.

Answer:

Thanks. Done.

**L84** missing, after OpenFOAM (?) Throughout, the choice of punctuation in the listed items is inconsistent. Suggest the authors standardize on one, perhaps ; ? Would help readability

Answer:

Thanks. Done.

**L107** missing space between transport(sublimation)

Answer:

Thanks. Done.

**L152** extra leading period

Answer:

Thanks. Revised.

**L152** this eqn is what is in OpenFoam? just note where in the coupling this goes

Answer:

Thanks. Yes, this equation is implemented in OpenFOAM is required to be presented in the revised manuscript.

**L237** Figure 1, this is nice.

Answer:

Thanks.

**L238** e.g.,

Answer:

Thanks. Done.

**L242** "Forcing data of snow depth [...]" was that in this study? move to methodology

Answer:

Thanks. Yes. The line is moved earlier as a new item in "Materials and Methods".

**L244** "based on the assumptions and limitations" this is probably redundant

Answer:

Thanks. Yes. We removed the line.

**L262** "showed error" -> "had errors"?

Answer:

Thanks. Done.

**Figure 4** Use K to keep consistent with text

Answer:

Thanks. We keep the snow temperature in degrees as it is common for the time series of snow temperatures to be represented in degrees.

**Figure 4** Is black zero value or missing? Isn't deep red 0 (as per legend)?

Answer:

Thanks. Yes. The black color refers to zero value. Even though the deep red is for warmer temperatures, only the black color refers to zero values.

**L283-285** missing  $\cdot$  between units

Answer:

Thanks for the comment. Throughout the paper, we do not use the symbol  $\cdot$  between units, and we have kept this formatting consistently as our standard style.

**Figure 8, 9** need a yaxis unit, and amount. Is xaxis really dimensionless?

Answer:

Thanks for the comment. No, xaxis is not dimensionless and it is revised now.

**L328** Consider have cumulative snow density change as a percent difference to quickly allow the reader to know "is this a lot or not"

Answer:

Thanks for the comment. We agree and have revised the line to end as "(1.3 to 3.6 percentage of the hard slab density).

**L340** "bound of convection with" -> convection intensity?

Answer:

Thanks for the comment. No, at the lower bound of convection, the convection intensity does not increase.

**L347** "The time series [..]" unsure if text and figure required? Or toss it in suppl materials? You have a lot of figures already so reducing would be good in my opinion.

Answer:

Thanks for the comment. We agree and we already removed the snow temperature time series.

**Figure 12** might be a good suppl figure you just make reference to in the text. I like you have this, but a suppl might be best.

Answer:

Thanks for the comment. We made a careful decision to keep Figure 12 in the main manuscript, as moving it to the Supplementary Material reduce the readability of the main text.

**Figure 14** 100h is this described in the methodology?

Answer:

Thanks for the comment. We keep it as it is, since the “100 h” is only figure-specific information and does not need to be included as part of the core methodology.

**L354** "impulsive" w/c, maybe transient?

Answer:

Thanks. Done.

**Figure 15** Suggest also changing this to be K instead of degC

Answer:

Thanks for the suggestion. We have removed this figure to reduce the manuscript size, and therefore this change is no longer required.

Figure 15, the black is unclear, isn't zero red?

Answer:

Thanks for the suggestion. We have removed this figure to reduce the manuscript size, and therefore this change is no longer required.

**Figure 17,18** and all the other Paraview outputs have the xaxis slightly cut off. These have y and x units that are not dimensionless can this be done for the other figures?

Answer:

Thanks for the comment. We agree that the x- and y-axis units are not dimensionless. We have followed the same formatting standard for all our ParaView outputs as much as possible throughout the manuscript.

**References:**