Authors' reply to referee comments RC2 of the paper tc-2023-148 entitled "Multiscale modeling of heat and mass transfer in dry snow: influence of the condensation coefficient and comparison with experiments" by Bouvet et al.

We thank very much Reviewer 2 for the comments. Please find below our point-by-point replies in blue color.

In the wake of a previous study of Calonne et al. (2014b), this paper aims presents a multiscale approach to follow heat and mass transfers in dry snow focusing on the peculiar role of the condensation coefficient α in order to mimic natural snow evolution during changes in the snow microstructure called temperature gradient metamorphism (TGM). Using a two-fold homogenization of a model coupling the heat conduction through ice and air, the water vapor diffusion in air and the sublimation of ice and deposition of vapor at the ice grain interface, this study's interest mainly consists in the fact that the effect of the condensation coefficient α is poorly described in the literature. Thus, considering a large range for this parameter (from 10-10 to 1), different effective behaviors are obtained through the upscaling process according to a transition value αT $\approx$ 3×10-4. Moreover, the homogenized modelling results were compared with three experimental tests of TGM of snow, providing a solid discussion.

In general, the manuscript is well-written and constructed, and the mathematical statement, the upscaling procedure and the experimental comparisons are well presented. The quality of this paper is indubitable, and I only have minor concerns.

i/ The main articulation between this study and the previous results of the group on the same topic should be highlighted. Indeed, even if many new results are presented here, some interesting links can be made.

The present work follows previous work of Calonne et al. (2014) and Calonne et al. (2015) from our group, as well as other papers from the literature, but explores the full range of condensation coefficient values, broadening the understanding of heat and mass transport modeling in dry snow. This is outlined in the introduction of the paper. The Model A presented in the manuscript corresponds to the model proposed in Calonne et al. (2014), while the Model D (in the revised version) corresponds to the models of Moyne et al. (1988) and Hansen and Foslien (2015). The description of each model and their comparison with existing models are provided in Section 4.2 and recalled in the paper's conclusion.

ii/ The consequences of the model's assumptions (isotropic materials properties, no convective effect, no curvature effects, no natural convection at the pore scale, etc.) could be outlined. In particular, the use of the Hertz-Knudsen at the fluid-solid interphase is one of the key point of this model and requires to be justified in this context.

At the microscopic scale, we have assumed in first approximation that all the material properties are isotropic. This is true for all the properties related to the air, and it seems also reasonable for the properties related to the ice skeleton, such as its thermal properties, as the ice skeleton is constituted of an assemblage of single crystals with isotropic thermal properties. The condensation coefficient α arising in the Hertz-Knudsen is taken as isotropic, although it has been shown that it depends on the ice crystalline orientation. However, since the values of α remain of the same order of magnitude (see experimental dataset from e.g. Libbrecht and Rickerby (2013)), this hypothesis has no consequence on the present analysis.

Concerning the convection, in the present work for the sake of simplicity, we assumed that there is no forced convection induced by wind pumping for example. In the future, such convection could be included in the modeling as it has been done in Calonne et al. (2015) in order to have a more comprehensive model. The natural convection is also neglected in the present analysis. Even if such convection can be present in some particular situations, as it has been simulated recently by Jafari et al. (2022), the model predictions are here compared to experimental data for which natural convection is negligible, as discussed in the manuscript in section 5.2. Consequently, our concluding remarks are not affected by such hypothesis.

Finally, we have considered that the condensation-sublimation processes arising at the ice-air interface are driven by the Hertz-Knudsen equation. This latter equation, initially derived to describe the condensation-evaporation processes at a liquid-gas interface, is widely used in snow physics and is supported by several experimental evidences (e.g., Libbrecht, 2005; Kaempfer and Plapp, 2009; Libbrecht and Rickerby, 2013; Furukawa, 2015; Krol and Löwe, 2016). Moreover, to the best of our knowledge, we are not aware of any another model to describe such processes. The use of classical models encountered in solidification does not seem suitable. The above considerations about the choice of the Hertz-Knudsen equation were more clearly stated in the revised version of the manuscript (line 118).

iii/ The evaluation of the dimensionless numbers defined by Eq. (19) is a key point of the upscaling procedure. Thus if the sensitivity to the coefficient α is well introduced, one may wonder if other similar dependencies of some dimensionless numbers (according to the temperature for instance) may not be discussed.

Most of the physical parameters involved in the problem at the pore scale are temperature dependent, but only to a small extent. Variations in the physical parameters due to temperature dependence cannot change the order of magnitude of the dimensionless numbers in terms of ε, and thus the derived macroscopic models.

Notwithstanding these general remarks, this is a complete work coupling models, numerical simulation and experimental comparisons. It is rigorously presented and detailed in the appendix. That is why, if these minor suggestions are addressed, I suggest to accept the publication of this work.

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