Author comment to Anonymous Referee #2

We thank Reviewer #2 for his/her positive appreciation of our work. Please find below our responses to the specific points raised.

General Comments. Overall, this manuscript presents new and interesting results in terms of the computation of the permeability of seasonal snow, and the relationship of permeability to snow microstructural parameters. The work represents an important step forward in the determination of permeability computationally and the understanding of the physical processes governing fluid flow in a matrix of snow under a pressure gradient. The examination of the full tensor quantity of permeability, as well as the anisotropic nature of permeability in relation to previous thermal conductivity measurements is of particular interest and will hopefully lead to future work.

The manuscript is well written, and is clear and precise. The figures are especially well done, are easy to understand and contain a lot of information. Below I have few specific comments and mostly minor technical edits and suggestions for the authors to improve the clarity and readability of the manuscript.

Specific Comments. In the Introduction section, the authors are missing a reference to some permeability modeling work that was done by Freitag et al. (2002), who computed 1-D values of permeability using a lattice-Boltzmann model, using a serial section technique to obtain a sequence of 2-D images used as the input geometry for their model should be included. This reference should be included in the summary of previous work done to calculate permeability values for firn.
Ref: Johannes FREITAG, Uwe DOBRINDT, Josef KIPFSTUHL, A new method for predicting transport properties of polar firn with respect to gases on the pore-space scale, Ann. Glaciol., 35, 538-544.

We thank Reviewer #2 for providing this reference, which has been added in the introduction (page 2, line 51) as follows: "Recently, Freitag et al. (2002) and Courville et al. (2010) computed one component of the permeability of firn samples using Lattice-Boltzman modeling and Zermatten et al. (2011) performed direct pore-level simulations on five snow samples."

Page 1160, Have the authors examined the difference between artificial and natural snow samples as part of this work or previous work? Is there any noticeable difference in the results if the natural snow samples are considering as a separate sample set from the artificial samples? I wonder, specifically, if the value of anisotropy for artificially grown depth hoar is the same for natural depth hoar, or if any of the previous work has examined the differences. Would it be of any benefit to designate artificial vs. natural snow samples in the figures using a set of different symbols?

Figure 1 tends to show that there is no distinction between the behavior of the snow samples collected in the field and that of samples coming from cold room experiments. However, the melt forms (density near 500 kg/m3) of our study have not been compared to natural samples, and should be compared in future work. Also notice that our dataset does not include natural depth hoar, precluding a firm conclusion regarding the impact of natural vs. artificial snow on its anisotropy of permeability. Nevertheless, microstructural observations (visual inspection) show no obvious difference in morphology between artificial and natural depth hoar, probably because these structures result from the same physical mechanisms.

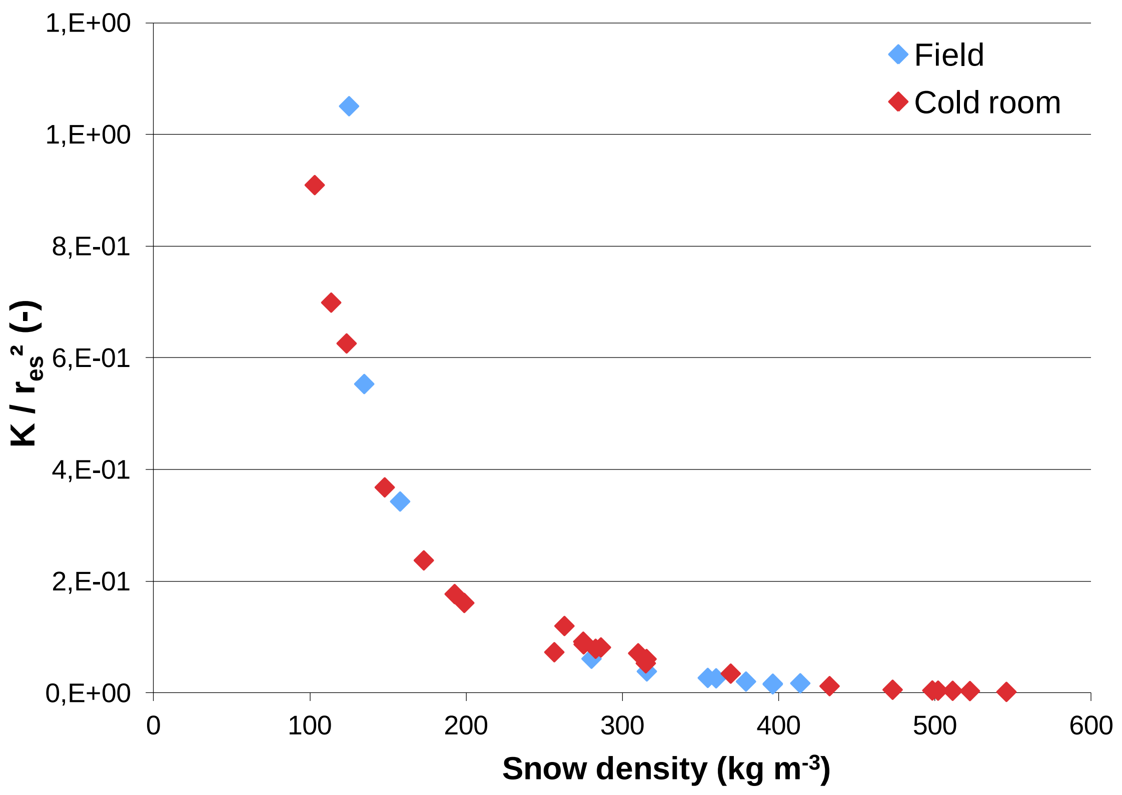

Figure 1 Values of permeability dimensionless (K / r_{es}^2) versus snow density using snow samples collected in the field (red) and from cold room experiment (blue).

Technical edits and suggestions.

We thank Reviewer #2 for her/his proofreading. All the corrections proposed have been taken into account. However, due to the requirements of Reviewer #1, several parts have been completely rewritten. In the following, we answer to some specific points raised by Reviewer #2.

Page 1162, line 16, How was the ratio of closed to open porosity determined? I'm assuming it was through image analysis, but it would probably be good to add a sentence here about the method to determine open porosity from the micro-CT data, or to cite here previous work that computed the open and closed porosity. I would also suggest specifying what the average ratio of closed to open porosity is in order to strengthen the authors' assertion that it is negligible.

We added an explanation in the paper (page 5, line 132): "Before carrying out the computations, voxels that are part of the network of interconnected pores were detected by image analysis, allowing to determine the ratio between closed and open porosity and check that it was very small (less than 0.004 for all the samples). This means that it is correct to consider that air can flow through the whole porosity of the REVs for all of our samples."

Page 1164, This is just a slight thing, but the figures are plotting the dimensionless permeability, and the expressions i-iii, K is defined as opposed to K*. To be consistent, this difference should either be explained in the text, or the expressions should be written to define K*.

We added an explanation in the paper (page 10, line 299): "(note that Fig. 1 and 4 show the corresponding curves in terms of dimensionless permeability: $K^* = K / r_{es}^2$)."

I really like the figures. The one minor suggestion I would make is that in Figure 3, make the label in the figure itself read, "rounded grains", "faceted crystals" and "melt forms" instead of RG, FC, and MF to be consistent with the other figures which spell these terms out, or to put these definitions in the figure caption. It just makes for an easier read of the figure for readers, and again, is more consistent with the other figures.

We thank Reviewer #2 for her/his appreciation and comments. We have modified the figure according to her/his suggestion (Figure 6, page 25).

I think there is a minor mistake in the figure label for Figure 2, and that Courville et al., 2009 should be Courville et al., 2010.

This mistake has been corrected (Figure 4, page 23).