

Interactive comment on “3-D image-based numerical computations of snow permeability: links to specific surface area, density, and microstructural anisotropy” by N. Calonne et al.

Anonymous Referee #2

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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

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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.

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?

Technical edits and suggestions. Page 1158, line 20, I suggest changing “grains scale” to “grain scale,” as I believe this is more common usage in the literature.

Page 1158, line 23, The μ in the equation should be italicized as it is italicized in the definition.

Page 1160, line 16, should read “Two other similar experiments. . .” instead of “Two others similar experiments. . .”

Page 1160, line 20, delete the “of” between “draining” and “their”

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Page 1161, line 7, define ε

Page 1161, line 15, The last sentence in this paragraph is a little confusing. I suggest changing it to something like, "Assuming that this condition is fulfilled, the derivation of Darcy's law from the physics at the pore scale using the homogenization method for periodic structures is justified (Ene and Sanchez-Palencia, 1975; Auriault, 1991)." The phrase "the main results concerning" is ambiguous, and so I recommend deleting it, and changing the word "presented" to "valid" or "justified" as in the suggested sentence above.

Page 1162, line 3, I suggest deleting the phrase, "for example" as it's not needed

Page 1162, line 6, x should be defined

Page 1162, line 9, the word "the" or "a" needs to be inserted before the word "solution"

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 the 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.

Page 1162, line 18, I suggest changing the phrase, "through the whole porosity of REV's" to "through the whole porosity of the REV" (or "of the REV's" if you want the sentence to read more generally).

Page 1163, line 13, The sentence should read "the same SSA value as the sample. . ." instead of "the same SSA value than the sample. . ."

Page 1163, line 17, Should the "." be at the end of the abbreviation REV's? I'm not sure if that is intentional.

Page 1163, line 18, I suggest defining K here again, as there are many definitions of

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permeability being used in the paper, to help the reader clarify which value of permeability is being discussed.

Page 1164, line 2, The comma after "computation" is not needed.

Page 1164, line 7, I would suggest rewording this sentence to something along the lines of, "This normalization is equivalent to using r_{es} since these two radii. . ." The phrase, "as good as" seems informal.

Page 1164, line 10, This sentence should be written, ". . .it cannot be estimated experimentally, only numerically, from 3-D images."

Page 1164, line 24, I suggest adding the symbol, K^* to this sentence, "Fig. 1 displays four curves of the dimensionless permeability, K^* . . ."

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^* .

Page 1166, line 1, Delete the "The" in front of Shimuzu's.

Page 1166, line 7, The punctuation should be written as: was counted as $m + 1$ grains." i.e. the period comes before the ending quotation mark.

Page 1167, line 6, The sentence is awkward to read. I would recommend rewriting as follows, "This can be explained by the large number of experimental data as well as the difficulty making reliable and reproducible measurements of permeability." Also, in recent years, the measurement of permeability has improved to reduce these sources of error, but it is true enough that past measurements did not always include recent improvements.

Page 1167, line 7, should read, "A first source of error. . ." instead of "A first source of errors. . ."

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Page 1167, line 23, Again, I'm not sure that the "." after REVs is intentional here, or a typo.

Page 1167, line 24, The phrase should read, "are generally equal to or larger than..."

Page 1168, line 6, This sentence is a little awkward to read. I suggest something along the lines of, "Increasing the volume size (from volume 1 to 4 or 5 in Fig. 3) of the calculated samples produces permeability values approaching one another for the separate samples, which is consistent with the definition of the REV." I'm still not sure if that is what the authors are trying to describe, and the sentence could probably use a little more work.

Page 1168, line 9, I suggest deleting the phrase "Thus, we point out the fact that..." and reword it to: "If K , SSA and/or ρ s are computed on a volume smaller than their REV..."

Page 1168, line 15, The phrase should be worded, "Numerical estimations of the permeability tensor allow computation..."

Page 1168, line 20, suggest changing the phrase, "is clearly more intense" to "is clearly higher"

Page 1168, line 29, suggest changing the phrase, "the microstructure influences similarly both variables" to "the microstructure influences both variables similarly."

Page 1169, line 6, suggest rewording the first sentence to "...by solving numerically a specific boundary value problem arising from the homogenization process on a REV."

Page 1169, line 13, suggest rewording the first sentence to "Values of K^* , the average of the vertical and the horizontal components of K^* ..."

Page 1169, line 16, change the "of" between data and literature to "in"

Page 1169, line 24, change the phrase "allow to differentiate the DH and FC samples..." to "enable the differentiation of the DH and FC samples" or "allow for the

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differentiation of the DH and FC samples..."

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.

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.

Interactive comment on The Cryosphere Discuss., 6, 1157, 2012.

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