The Cryosphere Discussions

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Comment on tc-2021-196

Zoe Courville (Referee)

Referee comment on "Effective coefficient of diffusion and permeability of firn at Dome C and Lock In, Antarctica, and of various snow types – estimates over the 100–850 kg m^{-3} density range" by Neige Calonne et al., The Cryosphere Discuss., https://doi.org/10.5194/tc-2021-196-RC2, 2021

The manuscript presents an improved method for defining transport properties in snow and firn through the examination of microstructural parameters derived from micro CT results and numerically derived values of permeability and diffusivity. The authors propose a simple yet elegant concept of rescaled porosity which accounts for the effects of pore closure on transport values in denser/deeper firn. This approach has promise to improve prediction in firn over previous methods using open porosity of the firn. The fact that the approach improves regression models over a wide range of density values at different polar locations with different conditions also suggests the method is a promising step in developing a generalized snow permeability and diffusivity model.

There are some mostly minor technical edits that should be addressed that are listed by line number below. In addition, I have included suggestions to clarify some of the labeling and description of the figures,

Abstract: As written, it is not clear what was done as part of this research and what was past work (need to make the tense of the sentences consistent throughout).

I.e., on line 1, "To this end, different regressions were proposed to estimate the effective coefficient of diffusion and permeability of firn." When I read this, I get the sense that this is part of the work that is being presented. I think it could be written as (just a suggestion), "To this end, different regressions have been proposed in the past to estimate the effective coefficient of diffusion and permeability of firn,"

Line 3 (and example of shifting tense): "were little evaluated as data of these properties

are scarce”

could be written, “have not been evaluated very often as data of these properties are scarce”

Line 10: “by including snow data.” What snow data does this refer to? The micro-CT data? Or are you referring to surface snow vs. firn at depth?

Line 11: “Classical analytical models and regressions from literature are evaluated.” Evaluated compared to what?

Line 15 “with φoff the close-off porosity.” Should be “with φoff equal to the close-off porosity.” Or something similar since with “φoff the close-off porosity” is not a complete phrase.

Line 20: Air entrapped in the closed pores of ice preserved past atmospheric air, from couple of thousands to few millions of years old, providing invaluable data on past Earth’s environment.

Couple of suggestions: “preserved” should be “is preserved” or “preserves”

“from couple of thousands to few millions of years” should be “on the order of a few thousand years to a few million years old” or “thousands to millions of years old”

Line 23: “Among others challenges” should be “Among other challenges”

Line 29: “til” should be “until”

Line 48: “Only few parameterizations are based on measurements or modeling over the entire firn column (Adolph and Albert, 2014), limiting their range of validity (Tab. 1).” is slightly confusing, suggest rewriting as “Few parameterizations are based on measurements or modeling…”

Line 49: “Especially, it is crucial to describe well air transport properties in the lock-in zone

from the beginning of the pore closure to the close-off." should be:

It is especially crucial to describe air transport properties well in the lock-in zone

Line 59: "plus few data of Vostok" should be "in addition to a few data from Vostok" It would be helpful to explain here what those data are, since it starts to get confusing in the results section and in Figure 1 about what data from Vostok were used. I.e., it seems like it was density, SSA, diffusivity and permeability from 80 m depth. Maybe it makes sense to say that, i.e., "in addition, density, SSA and diffusivity and permeability from 80 m depth from Vostok were used."

Line 62: "allowing to assess the anisotropy of properties and compare lateral to vertical gas transport"

Line 63: "A variety of parameter to characterize firn microstructure was also estimated from images" should be "A variety of parameters to characterize…"

Line 75: til should be until

Line 76: "controlled conditions in cold-laboratory" should be "controlled conditions in a cold-laboratory" or r controlled conditions in the cold-laboratory

Line 106: "This index allows to describe more accurately the pore closure in firn and bubbly ice than the classical closedto-total porosity ratio, the latter being sensitive to the sample size (Burr et al., 2018)." Should be "This index allows the pore closure in firn and bubbly ice to be more accurately described than…"

Figure 1: The circles are hard to see in the figure for diffusivity and permeability because they show up as half circles in the figures and resemble the diamonds. Is there another symbol that can be used to make it clearer? Also, the square symbols are very hard to see. Could they be black instead of grey so that they show up better? I also cannot see the black diamond indicated the Vostok values for CP and CI, but again, this is unclear if this was calculated for the Vostok core. It's also hard, but not impossible, to see the Vostok value indicated by the black diamond on the Density graph. Not sure if there is a way to make the black diamond more visible? Can it be layered on top of the other sites' data points?

Last thing, it would be helpful if the two dashed lines that indicate the close-off depths

were either listed in the legend (i.e., if the difference between the two shades of grey were designated), or if there was a label on the figure that indicated which dashed line designated the Dome C close-off depth and which line designates the Lock In close-off depth. If that makes the figure too cluttered, perhaps that can at least be specified in the figure legend.

Line 124: evolves should be evolve

Line 129: value should be values

Line 152: "Both figures show dimensionless permeability values, i.e. permeability values K divided by the equivalent sphere radius r = 3/(SSA × ρi) to the square." I'm not sure what "to the square" refers to. Is it that the squares in the figure denote the dimensionless permeability? That could be written as "as designated by the squares in Figure 2."

Figure 2: What do the T symbols pointing up or down indicate? Are the in different directions just so that they show up differentiated from one another when they overlap, or is there a physical significance? Also, should the rescaled porosity be defined earlier in the paper so that the inset in the figure is better defined? As it is, the definition doesn't come for another couple pages.

Line 173: "Those extremes values" should be "extreme values"

Line 196: "a assemblage" should be "an assemblage"

Figure 4 caption: What do the dotted lines represent in the right-hand figures?

Table 1: This table is a very nice summary of the available relationships for permeability and diffusivity.

Line 225: "To provide a satisfactory estimates of diffusion coefficient" should be "To provide satisfactory estimates of diffusion coefficient"

Line 232: "Figure 5 allows comparing the computed data" should be "Figure 5 compares the computed data"

Line 245: “Permeability predicted by the regressions of Freitag 2002 and Adolph 2014 match overall well our data.” should be “Overall, permeability predicted by the regressions of Freitag 2002 and Adolph 2014 match our data well.”

Line 279: ” although their dataset originate” should be “although their datasets originate”