The Cryosphere Discussions

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Comment on tc-2021-196

Johannes Freitag (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-RC1, 2021

General comments:

The study of Calonne et al. provides new estimates of effective coefficients of diffusion and permeability of polar firn from two low accumulation sites in Antarctica (DomeC and LockIn) and from various snow types based on pore-scale computations on X-CT-images of cm-sized samples. New regressions are proposed based on a rescaled porosity. The rescaled porosity is an easy-to-measure parameter and substitutes open porosity in former regressions with the implication that the new formula becomes applicable without assumptions/measurements of open porosity.

The study addresses a relevant scientific question within the scope of TC. It contributes to an improved modelling approach of air-transport in firn and relates directly to the interpretation and dating of ice core records. In my opinion the scientific methods are valid but not well outlined: for the modelling part I miss a comprehensible introduction how diffusion and permeability are actually solved on the three-dimensional lattice. For the CT-data part I could not find any discussion about the limited sample size (7x7x7mm3) and its implications on the estimates of diffusivity / permeability. In the text it was mentioned that the CP-estimates are affected by the limited size, the CI-estimates maybe not. Interestingly, the open porosity profile (Schwander 1989) shows a different behaviour than both, CP and CI estimates as well (figure 5). It would be worth to know the portion of pores cutted at the surfaces. I would suspect that the high (100-CP) values for high densities result from the large amount of cutted pores that are not counted as isolated pores but count for the total pore volume. On the other hand the CI (largest pore/total pore volume) tends to be underestimated at the percolation threshold in small samples because large pores become less frequent and might be not adequate presented in the sample. This would underestimate the transport properties at the percolation threshold (= closeoff area) as well. I would really appreciate a discussion of the pore-cut effect as it is not even mentioned at all. In respect to the conclusions I am wondering if the implications that both investigated sites show no significant differences in the transport property-density relationships can give further insides into the general properties of polar firn. However due to missing information (how much is the difference in accumulation between DomeC and LockIn?, what is the reason for the huge difference

in Closeoff-depth of 10m although the sites are less than 150km apart?) /adequate figures I was not able to really assess if the similarity in transport properties between the sites are expected or not.

The abstract provides a concise summary, the presentation is well structured, the language fluent and precise. Number and quality of references are appropriate. A few minor points are listed below.

Minor points/suggestions:

line0: I would prefer a different title like "Effective coefficient of diffusion and permeability of firn at DomeC and LockIn, Antarctica **and various snow types**– estimates over the 100-850kgm-3 density range

The present title is a little bit misleading because at DomeC and LockIn there is no 100 kgm-3 snow, even at surface the snow is already of the order of 300 kgm-3. The authors compiled measurements of DomeC/LockIn firn (550kgm-3 and denser, 23m-133m depth) and alpine/artifical snow (100kgm-3 to 550 kgm-3).

Line 1: *..,the entire ice sheet column…* -> (change to) ...the entire firn column of polar ice sheets…

Line 10: *…with density over the firn density range…snow data.* -> ..with density by extending the data set with data from alpine and artificial snow.

Line 23: *…to thousand of years…* -> …to hundreds of years… (the air in the open pores is not too old, it is the age-difference between air and ice that can be reach thousand of years…)

Lines 72,73: please provide some additional information about the DomeC, LockIn and Vostok site such as mean annual temperature and accumulation rate to better assess the differences in microstructure and transport properties between the cores.

Line 79 : explain the term: "*representative elementary volume*". In what respect is the volume "representative"?

Lines 84,85,86: a few more sentences about how the diffusion coefficients and permeabilities are estimated would be helpful to understand the approach solved by software Geodict.

Line 105: …*CI is 100% when the porosity is fully open and 0% when pores are closed*… Comment: CI defined as the ratio between the largest pore and the total pore volume can not be 0% per definition. It tends to 1/bubble-number if all pores are closed and approximately of equal volume.

Line 133: maybe you can add an additional sentence about the CI and CP behaviour at 85m depth: here CI is 75% whereas CP is close to 0%. -> possible interpretation: pore-cut effect(?): pores cutted at the surface loose (artificially) the connection to the open pore space within the volume.

Lines 146,147: *…,indicating than even after the close-off, open pores are still present, even down to 133 m depth, which …* This is a misleading sentence: I would rather think that the <100% of CP below the close-off depths are caused by the amount of cutting pores that are not counted as isolated pores – again a pore-cut effect.

Figures 2, 3: What is the size of the "T" symbols in Figures 2,3 telling us? Is it the std of a set of measurements? How many measurements/ or estimates are averaged?

Lines 278,283: …*For firn (550-917kgm-3)*… -> For firn (550-850kgm-3)…Samples with density in the range between 850 kgm-3 and 917kgm-3 are referred to as bubbly ice (with isolated bubbles).