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Interactive comment on "Impact of physical properties and accumulation rate on pore close-off in layered firn" *by* S. A. Gregory et al.

Anonymous Referee #2

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Gregory et al. discuss an important topic of firnification, the pore close off at the transition of firn to ice. This is of general interest for glaciology and in particular for ice core scientists who work on gases in ice cores. Our confidence in the gas ages and conclusions drawn about the phasing between temperature and CO2 depends critically on our understanding of the air enclosure process. Gregory et al. present results obtained by x-ray computed tomography (xCT) from WAIS Divide in West Antarctica and a Megadune site on the East-Antarctic plateau, two polar sites with different temperatures and accumulation rates. Focussing on permeability measurements they examine the nature of pore close off processes. They find that the open pore structure plays a more importantant role than density in predicting gas transport properties. In combination with permeability measurements the results are new and interesting, thus important to better chracterize pore close off and the air enclosure process in polar ice.

The presented study is highly relevant, however, we are concerned in several respects about the interpretation and conclusions drawn from the results:

1. The dimensions of the samples investigated are 8 mm by 8 mm by 15 mm. The authors do not discuss how representative a cube of typically 1 cm3 is to draw firm conclusions about the processes controlling pore close off on a much larger scale. For example, firn gas sampling is collecting air over cross sections of 10 cm at least.

2. Gregory et al. discuss pore close off on the micro-scale without taking into consideration its percolation nature.

3. Gregory et al. are obviously not aware of the effect impurities have on densification in deep firn, see Hörhold et al., EPSL 2012, 325–326, p93–99.

4. Grain size an important parameter has not been determined quantitatively. It is only described qualitatively.

5. Both sites are some sort of end member sites because in the Megadunes post-depositional processes are important and at WAIS Divide surface density seems to be exceptionally high (above 400 kg/m3).

All these aspects are not addressed adequately in the present manuscript. For example, Gregory et al. do not show a figure comparing the bulk densities of their large samples the cubes for xCT are taken from and the densities derived later from these little cubes. The scale problem becomes obvious in Figures 5 and Figure 9. See page 2545 lines 6 ff: ... "To understand the increase in closed porosity with no change seen in total porosity" applies only for Figure 5a and the small xCT samples while bulk density presented in Fugure 9a clearly shows that density and thus total porosity increase below the LID (lock in depth). The scale problem is a fundamental problem, the percolation problem as well but which parameter control the percolation threshold? This does not become clearer from the paper in its present version.

It is important to investigate which processes control pore close off: density and/or

microstructure in the widest sense. The results as presented are important, however, as important is a critical discussion of the results and in particular because the xCT samples are so small. This part is missing in the present version of the paper.

Specific comments:

Important aspects have not been discussed. Therefore I do not make many specific comments.

Abstract

Line 14/15: Pore close off can not be defined by open porosity because such a definition is contradicting itself. How about "critical porosity of pore close off"?

Do we understand correctly that you conclude that pore close off depends on grain size in such way that fine grained firn closes off at a higher critical porosity (i.e. lower critical density) than coarse grains firn. Do you imply that fine-grained firn contains more air than coarse-grained firn under the same climatic conditions? Does this conclusion not contradict the "orange model" that the critical close off density/porosity is independent on the "orange/sphere" radius?

Figures:

- Dealing with the low permeabilities at pore close off some results would better be presented on a logarithmic scale, e.g. Fig. 1f, 9b or 10a.

- The results are generally shown versus depth. Are not some results better plotted against density as the more "natural" parameter?

- It would be helpful to see how bulk density and xCT densities of the same sample compare. -ÂăIn some figures units are missing

Fig. 5: A graph showing open versus closed porosity is missing - to compare with the Schwander et al. closed porosity.

Fig. 6 Is this figure needed in particular as the conclusion of Fig. 5 is valid only for the xCT samples but nut the bulk density/porosity?

Fig. 7 "Closed pore fraction" is misleading. It is more interesting to see this parameter versus density or total porosity.

Fig. 9 Where do we see the density cross-over? The three red dots at higher density abetween 50 and 60 m depth?

Fig. 10 Probably better shown on a log-scale. Not clear, how the error is defined. What is it's meaning?

page 2541 l13,14 sentence seems not complete: Where the degree ...

Megadune firn Site conditions and postdepositional processes make the MD firn so special, no so much the climatic conditions in general.

p2547/8 The cross-over in density is not clearly seen in the presented data (Fig. 9a). The WDC06A data were not accessible.

For the discussion which layers first reach pore close off density see Hörhold et al.,2012.

Microstructure is often used synonymously for grain size but often also in a much wider context.This is confusing.

Interactive comment on The Cryosphere Discuss., 7, 2533, 2013.