

## ***Interactive comment on “Imaging air volume fraction in sea ice using non-destructive X-ray tomography” by O. Crabeck et al.***

### **Anonymous Referee #1**

Received and published: 5 November 2015

#### General Comments

This is an interesting paper and the authors should be commended for applying an existing tool (medical CT) to a new problem. Other strong points of this paper include: good discussions of the processes affecting air inclusions in sea ice; a solid comparison of alternative methods of measuring sea ice air inclusions; thorough analysis; and thought provoking presentations of the data (figures).

I have two primary concerns, assumptions underlying the study that are hinted at, perhaps, but should be addressed explicitly. First, the authors need to discuss the potential ramifications on their work of temperature changes during the coring/storage/analysis process. These cores were  $-4^{\circ}\text{C}$  to  $-8^{\circ}\text{C}$  at the ice-atmosphere interface, and  $-1.6^{\circ}\text{C}$  to  $-2^{\circ}\text{C}$  at the ice-water interface. They were stored at  $-20^{\circ}\text{C}$ , and gas was extracted

C2136

in a cold room at  $-25^{\circ}\text{C}$ . These cold temperatures would have produced changes in the size of brine inclusions and air pockets and the influence of this on the results and interpretation should be discussed fully (perhaps in Section 4.3).

Second, I believe the conclusion is a bit far-reaching. Although I tend to agree that, “air volume fraction should be an important inclusion in parameterizations of sea ice permeability,” I’m not sure that the authors “introduce new perspectives on processes regulating gas exchange at the ice-atmosphere interface”. They show large bubbles and high air volume fraction in the upper (granular) portion of the sea ice. For these bubbles to play a role in gas exchange, they must be connected. The authors did not actually test permeability, or demonstrate it by analyzing pore connectivity in the vertical dimension. Nor did they monitor changes in a single sample over time and changes in temperature. Thus the assertion that these large air pockets are important in gas exchange at the ice-atmosphere is based on the rules governing permeability, rules which are based on columnar sea ice. And yet, the large bubble-high air volume fraction layers are in the granular ice. I would like to see these two points addressed explicitly in the final paper.

#### Specific Comments

Page 5208, line 26 – I’m not sure what is meant by “the evolution of gas concentrations”. This should be reworded for clarity.

Page 5217, lines 17-18 – Here the authors should cite Golden et al. again. But, they should also note here and in their later analysis that the Rule of Fives they allude to is specific to columnar ice.

Page 5219, lines 17-19 – Here the authors state that, “traditional methods can hardly be used to validate the imaged data at the same resolution.” This is true, BUT scanning electron microscopy does provide such an opportunity, and has been used to validate thresholding in microCT analysis (see Lomonoco et al., 2009, citation at end of this review).

C2137

Page 5221, line 12 – Bubbles as small as 0.019 mm are reported. Somewhere, here or on page 5211, the spatial resolution of the instrument should be explicitly stated.

Page 5223, line 24 – If the authors are going to cite their Rayleigh number results, they need to show the data.

Page 5226, lines 14-19 – “We systematically observed an increase of the bubble size and a decrease of the bubble density in the granular ice (Fig 11a), suggesting the presence of coalescence processes.” The word “systematically” here is confusing, and the observation of larger but fewer bubbles doesn’t necessarily mean coalescence, does it? Likewise, it seems a bit of a leap to say that the bubble geometry shown in four lateral slices in Figure 13 derives from coalescence unless the authors have observed their development over time. Larger bubbles could be related to post depositional processes, but could they not also be related to snow density and microstructure and fluid flow during flooding?

Page 5228, lines 15-18 – Note my second concern in the introductory paragraph of this review. It may be reaching to say that the authors “introduce new perspectives on processes regulating gas exchange at the ice-atmosphere interface”. They show large bubbles and high air volume fraction in the upper (granular) portion of the sea ice. For these bubbles to play a role in gas exchange, they must be connected. They did not actually test permeability, or demonstrate it by analyzing pore connectivity. Nor did they monitor changes in a single sample over time and changes in temperature. Thus the assertion that these bubbles are important in gas exchange at the ice-atmosphere is based on the rules governing permeability of columnar sea ice. And yet, the large bubble-high air volume fraction layers are in the granular ice. I think the authors should couch the conclusions in those terms.

#### Technical Corrections

All of the figure captions need editing for typographical errors and clarity. For example: Figure 1: “every black dots represent”, should read “every black dot represents”.

C2138

Figure 2, there is a typo, “withe” for “white”. Captions for figures 3-5 and 11-13 should not begin with “shows”. Figure 6: The caption should explain the discontinuities in the second and third thin sections. Figure 7: “threshold” should be “thresholds” and “extend” should be “extent”. And so on. I found the captions to Figure 10-13 particularly awkward.

Page 5207, line 18 – Add New Hampshire (or NH) after Lebanon.

Page 5207, line 25 – Should “porTable” have an upper case T in it?

Page 5211, line 1 – What is a U-channel? (explain)

Page 5214, line 22 – I think this should read, “In the following section. . .” rather than “paragraph.”

Page 5219, line 22 – I believe M-V should be M/V

Page 5222, lines 16 and 17 – Something is missing in this sentence(s)

Page 5223, lines 5 and 7 – I believe the authors mean “increase” instead of “accumulation”

Page 5225, line 6 – “create” should be “creates”

Page 5225, line 8 – Add a space between “stable” and “bubble”

Page 5225, lines 11-12 – This is not a complete sentence.

Page 5225, lines 15-16 – This is a complete sentence and I think I understand it, but it is awkward as written.

Page 5225, lines 20-22 – This short paragraph seems to float here by itself. It needs to be anchored with references to your figures, at least.

Page 5225, line 28 – “by surface processes due to snow falls” would be more succinctly worded, “as a result of snow fall.”

C2139

Page 5226, lines 1-4 – “on” should probably be “by”. Here the authors say the snow layer “was able” to flood the ice by producing negative freeboard. Did this in fact happen? Through cracks? Explain.

Page 5228, lines 2-3 – This sentence is unclear. What is meant by “At any growth step”?

#### Reference

Lomonaco, R.W., S. Chen and I. Baker (2009) “Characterization of Porous Snow with SEM and Micro CT”, *Microscopy and Microanalysis*, 15(2):1110-1111  
doi:10.1017/S1431927609093313

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Interactive comment on The Cryosphere Discuss., 9, 5203, 2015.