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Interactive comment on "Improved measurement of ice layer density in seasonal snowpacks" *by* T. Watts et al.

T. Watts et al.

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Reviewer's comments are in blue, our responses are in black

The need to account accurately for the density of ice layers is evident from the introductory review of this paper. As no reliable method is available at present, the authors present a novel, simple, and promising method to measure the density of thin ice layers. They also took care to present a thorough error analysis, which is an asset. In addition, the paper reads nicely except for the section on 'effective porosity' that would benefit from some re-visiting by the authors. However, the method was so far applied to 4 ice layers only, two of which were artificial. It is thus questionable whether it can

already be seen as a 'standard' and can be part of the special issue "Intercomparison of methods to characterise snow microstructure" without prior proper comparison with another method, as proposed by the authors themselves. I recommend accepting the paper after the authors addressed the porosity issue and do some minor revisions as suggested below. Whether it is included in the special issue is left to the appreciation of the editor

Thank you for your comments.

p. 5983, line 12: why volume "range"?

We agree with the reviewer that it not a range, it is a single value with uncertainty. The term "range" has been deleted.

p. 5984, line 16: "Consequently . . ." I'm not sure this is the correct statement. You found your method to be accurate to 4 %. Whether this is "low enough" will depend on the application.

We agree. This statement has been removed.

p. 5984, line 18: Field measurements: how were the samples taken and cleared from surrounding snow?

I have added the sentence:

"Ice layers were removed from the surrounding snow and broken to size using a scraper."

p. 5984, line 28: "To create the . . ." unclear! Was the melt-freeze crust in the end part of the ice layer?

The following was added to the paragraph:

"After the removal of recent snow, water was sprayed onto the snowpack to create a surface ice layer. The ice layer was distinct to the melt-freeze crust and was removed when the layer was extracted."

p. 5985, line 21: “thickness gradient” Could you indicate the range in numbers?

Changed to:

"Water was sprayed over an area of 1 m^2, concentrating the spraying towards one edge, creating ice thicknesses between 1 and 6 mm which allowed 28 measurements of ice layer density across a range of ice layer thicknesses."

p. 5986, line 3: “Natural ice layers . . .” Are the two distributions not significantly different? Of course, the statement would still rely on 2 ice layers each!

Added:

"analysis using the Kolmogorov-Smirnov test showed all ice layers to be significantly different."

p. 5986, line 8: “physically reasonable” From Table 2, the mean of 915 kg m^{-3} does not seem less reasonable than from the artificial layer at North Bay!

Changed to:

"The measurements in Inuvik were made outside, and whilst care was taken to ensure the balance was level and condensation was cleaned from the balance as it formed, these cannot be ruled out as sources of error and could be a reason why some of the high outlying measured densities (Figure 3) are physically unreasonable at the Inuvik site."

p. 5987, line 1ff: “effective porosity” Is this the proper term?

In this section both effective porosity and volume error from porosity have been used interchangably. We have corrected this by adding:

(p5988 l9) "As the density of the sample decreased volume error from porosity in the sample ranged from 6.5×10^{-5} to 1 $\times 10^{-3}$ cm^3."

Why in cm^3 (porosity has no dimension).

When effectivity porosity is being referred to the units have been removed, the following changes have also been made:

1. (p5987 l6) "However, due to the presence of bubbles in the ice layers some increase in porosity would occur as more bubbles are exposed when the ice layer was broken and placed in the centrifuge tube. The exposure of the bubbles causes effective porosity and is represented by a dimensionless decimal fraction which represents the proportion of a volume which is available for liquid to flow through."
2. Figure 6 axis updated

Are you not rather decreasing the porosity by breaking the sample in pieces?

Breaking the ice layer will expose more bubbles at the edge of the sample, the following sentace has been updated:

(p5987 l6) "However, due to the presence of bubbles in the ice layers some increase in porosity would occur as more bubbles are exposed when the ice layer was broken and placed in the centrifuge tube. The exposure of the bubbles causes effective porosity and is represented by a dimensionless decimal fraction which represents the proportion of a volume which is available for liquid to flow through."

p. 5987, lines 5-10: Some repetition here!

This has been updated to:

"Air bubbles within the ice layer were represented using spheres, scattered randomly without any overlap, within an ice sample of size x, y, z and density d. The sizes of the spheres were determined by taking a random sample from a normal distribution of bubble sizes based on the mean and standard deviation of bubble diameter measurements. A sphere size was chosen randomly from the distribution and located randomly within the x, y, z axes. If the sphere overlapped another sphere then the location was changed until no overlap occured."

Figure 6: “effect” Can we really speak of an ‘effect’ here?

Changed to: Sample density vs mean simulated sample porosity (Blue line).