The Cryosphere Discuss., 9, C3114–C3117, 2016
www.the-cryosphere-discuss.net/9/C3114/2016/

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

T. Watts et al.

tom@tpwatts.com

Received and published: 28 February 2016

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

The authors reported on the measurement results of natural and artificial ice layer densities in the snowpack using a new field measurement technique. They also discussed the errors resulting from their technique in detail. Thus, their results should be more certain than the previous studies. Because the number of observations is too small, the work does not present completely innovative results, but rather presents an incremental advance in a technique to measure accurate density of ice layer in the snowpack. From this viewpoint, this paper is worth publishing in TC. However, I think there are

several points to clear before publication. Below I give suggestions on improvements for better understanding the arguments in the manuscript.

We are glad that the reviewer recognises the importance of improvements in this area. In the discussion we refer to future work to further increase the number of measurements of ice layer density and hope that this publication will encourage others to apply this method too.

L94-96: How was the mean squared error in the measurement of the ice sample volume calculated? Please add more detail explanation.

Added ($error = \sqrt{0.125^2 + 0.125^2}$) so the sentence now reads:

"Based on carrying out 10 repeat measurements on 10 centrifuge tube photos the (mean) error was found to be $\pm$0.125 cm^3 in each photo of the ice sample volume equating to a root mean squared error in the measuremnet of the ice sample volume of ± 0.18cm^3 ($error = \sqrt{0.125^2 + 0.125^2}$), as each volume measurement involves reading the volume from two photos.""

L147: How was the random error in the density measurements calculated? Please add more detail explanation.

The random error in density was calculated by applying the random error in the volume measurements (0.18 cm^3) to the bias corrected volume of the sample and calculating the minimum and maximum mean density. When looking at the field measurements in order to clarify this point I noticed that while the mean density had been correctly calculated using the bias corrected values the random error in density had not been calculated using the bias corrected values. As a result overall uncertainty in the density measurements is $\pm$28 kg m^{-3} rather than $\pm$18 kg m^{-3}. This makes no difference to the conclusions or outcomes of this paper and has been changed throughout the manuscript.

In response to the reviewer's comment this section has been updated to read:

"After meansurements were corrected for bias the mean sample volume was 6.4 cm^3, when the random error of $\pm$0.18 cm^3 was applied to the volume measurements an uncertainty of $\pm$28 kg m^{-3} was calculated"

L157 & Table 3: The explanation of Table 3 is insufficient. What is n in the Table 3? If n indicates the measurement number, what does "n<0. 1" mean? Please add more detail explanation.

Updated caption to:

"Measurements of ice layer bubble size and ice layer thickness (all sizes in mm). n is number of samples, $n < 0.1$ is the number of bubbles with diameter of less than 0.1 mm.""

L181 & Fig. 4: Is the simulation results of 800 kg m-3 in Fig. 4 true? The areas replaced by bubbles in the figure seem to be much larger than those supposed from its density. The simulation results should depend on the initial pure ice density, which does not have any bubbles. Thus, please add the explanation of the initial pure ice density in the simulation.

The appearance of having too many bubbles is a function of the viewing angle of the cube - i.e. bubbles in the foreground will shadow ice behind it hence giving the impression there are too many bubbles, despite the fact it's correct. To clarify the issue of the initial pure ice density line 181 was updated to:

"After each sphere was placed, the total volume of all the spheres and the density of the ice sample was calculated. Spheres were added to the sample until the desired density was reached starting from an initial pure ice density of 916 kg m^{-3}."

L202: Do you think the dependence of pure ice density on temperature is enough strong to affect the density difference between artificial and natural ice layer? As shown in Table1, the density difference between the 0^{o}C and -40^o C is less than 7 kg m^{-3}. Please add the detail explanation if you have any idea to support your hypothesis.

We estimate the maximum possible variation in ice layer temperature for our data to be less than 20^{o}C, which represents a density variation of less than 2 kg m^{-3}. While there is potential for this to have a small impact we do not have field data of ice layer temperatures and are therefore unable to constrain the error. We recognise that there is potential that this could have an impact on measurement accuracy and as a result this is mentioned in the discussion.