Referee comment to McDowell et al. "A cold laboratory hyperspectral imaging system to map grain size and ice layer distributions in firn cores".

General comments

I enjoyed reading this manuscript by McDowell et al. as it is well written and valuable for the cryo, and especially firn, community. The authors describe a new imaging system based on hyperspectral imaging, which advances the possibilities to map stratigraphy and grain size in firn quickly. The manuscript is well-structured and clearly describes the technique, its results, and its possible limitations. The authors also tackle the tricky question of "what is grain size" and present a well-thought-out approach. I only have a few general thoughts, which are more questions than comments.

I am interested in the total duration of a measurement session, and it would be great if the authors could elaborate on this a bit. How long does the entire procedure take, i.e., preparing the device and firn core, conducting the measurements, and processing the files? What´s the longest you used it in the cold? I guess the question is if the scanner could be used in the field running all day long like a visual stratigraphy line scanner. This would be a real advantage in preventing post-depositional effects and the logistical difficulties of transporting firn cores to the cold lab.
You mention the 16 firn cores drilled, but I would like to know if the two broken cores are important for this study. They are not used, and just ignoring them would increase the readability of the plots.

I only raised a few specific comments below. However, I am confident the authors can provide an updated version for those minor revisions, and I would be happy to see the edited manuscript published in the Cryosphere.

Specific comments

L. 1: The phrasing of both ice sheets being "covered in a thick layer of firn" sounds a bit off. The firn thickness of roughly 40-120 m in Greenland and Antarctica is not thick in comparison to the ice sheet thickness. The meaning is clear, but it could be described clearer, e.g. "ice sheets contain a porous layer of firn".
L. 7: "required to test/implement into/check", I am not sure if "to inform" is necessary.
L.8: I see the point that grain size measurements can be subjective, but that depends strongly on the method. Microstructural analyses with e.g. fabric analysers or large area scanning macroscopes of thin and thick sections, respectively, can provide good statistics decreasing the rate of subjectivity. To avoid this issue, you could change it to "time-consuming, and can be subjective depending on the method".
L. 22: I would switch the sentence to "interpreting previous atmospheric compositions via ice cores,…".
L. 27: Matter of definition, but in my opinion, firn belongs to the ice sheets and the firn volume is thus "of" or "within ice sheets".
L. 30: A (half) sentence displaying the processes could help to connect the open porosity of firn fact with the changes in climate and the need for a better understanding, which I totally agree with.
L. 32: Including a new (in review) study could be of interest and would be good to include here to show the state of the art regarding optical methods on firn:

Westhoff, J., Freitag, J., Orsi, A., Martinerie, P., Weikusat, I., Dyonisius, M., Faïn, X., Fourteau, K., and Blunier, T.: Combining traditional and novel techniques to increase our understanding of the lock-in depth of atmospheric gases in polar ice cores - results from the EastGRIP region, EGUsphere [preprint], https://doi.org/10.5194/egusphere-2023-1904, 2023.
L. 39: Again, a question of terminology, but I think "Microstructural properties" would be clearer than "grain-scale properties". Grains could be mistaken for dust grains and thus a different scale.
L. 41: "firn layers" could be confusing here, because it refers to the total firn layer but might also refer to individual layers of firn. "Firn column" is clearer also used in the cited study by Gregory et al. (2014).
L. 68: You include microstructure mapping here, which also works on firn thick sections and is comparably fast and has a very high optical resolution: Kipfstuhl, S., Faria, S. H., Azuma, N., Freitag, J., Hamann, I., Kaufmann, P., Miller, H., Weiler, K., and Wilhelms, F. (2009), Evidence of dynamic recrystallization in polar firn, *J. Geophys. Res.*, 114, B05204, doi:10.1029/2008JB005583.
Recent grain size measurements from ice thin sections via fabric analyser use pixels instead of radii/diameter and are thus able to reproduce a fairly accurate grain area, see e.g. Stoll, N., Eichler, J., Hörhold, M., Erhardt, T., Jensen, C., and Weikusat, I.: Microstructure, micro-inclusions, and mineralogy along the EGRIP ice core – Part 1: Localisation of inclusions and deformation patterns, The Cryosphere, 15, 5717–5737, https://doi.org/10.5194/tc-15-5717-2021, 2021.
Nevertheless, both methods are limited to discrete samples and do not have the advantages of continuous measurements.
L. 72: Baunach et al. 2001 study laboratory grown snow kinetics and measure grain size along the way showing the subjective assessments of six experts. I am not sure if this is a good example to conclude that the described methods above can be subjective. The study is more than two decades old and thus not state-of-the-art any more (as you show with the other cited studies). I am happy to be convinced that this study, and the conclusion you draw, are still as relevant as 2001; some rephrasing might help here. Without a doubt there are enough reasons to develop new methods to measure firn grain size fast and accurately.
L. 74: The topic of the perfect grain size method/tool/parameter has been discussed for decades and there is still no obvious solution due to the 3D shape of grains and the spatial limitation of firn and ice cores. Averaging a large number of grains is thus necessary to obtain "good statistics".
L. 80: You start with "Ice" and then switch to "snow grains". Similar switching occurs in the sentences below. To avoid confusion, it would be good to stick with the same nomenclature of snow/ice grain/particle.
L.. 89: maps of grain size…
L. 90: "in the field" not needed
L. 95-106: This reads more like a summary than the objective paragraph. To be more precise clearly state the objectives of your study here so the reader knows what to expect. It is a good paragraph, just at the wrong location.
L. 109. Maybe directly mention the number of firn cores here. In addition, it would be convenient to state the drilling method (hand-drill, hans-tausen, etc?) without having to read the cited publications.
L. 120: I suspect via commercial companies dealing with frozen goods?
L. 121: …chemical analysis of x using…?

L. 150: Just out of curiosity, what is the maximum time between measurements you left the device in the cold without using it? Could it be insulated to avoid removing after measurements?
L. 179: Nolin Dozier technique (Nolin and Dozier, 2000)
L. 186: Did you play around with the impurity concentration? 0 ppb is very unlikely for natural settings especially in Greenland.
L. 238: Should it be “deep (>10 m)”?
L- 240: number of ice layers
Fig. 3: Do I understand it correctly that you measure effective grain size and then translate those values with a model to radii? So, it is not a direct measurement as one would assume from the figure? If the effective radii are shown please make that clear on the axis label or the caption.
The legend with infiltration ice is slightly confusing, if it refers to the 2012 melt layer, why not mention it here and give it the same black and white line as in the plot.
Fig. 4b: For a more precise comparison, it could be helpful to add the exact mean values for each core next to the dotted line.
L. 284: depth bands could be confusing; I would exchange it to depth regimes.
L. 290: State the three cores here.
L. 312: To demonstrate this point, it would be helpful to see a high-resolution photograph of the characterized infiltration ice. Having a “real” image next to the depth regimes shown in A1 would be great. However, the samples might have been used for other purposes by now so this might not be an option anymore.
Fig. 5 Having a similar plot concept as in Fig. 3 might be more accurate to display the infiltration ice. Now the impression could occur that the percentage/x-axis is the spatial area of infiltrated ice as is the case for visually inspected ice.
L. 319: Is it possible (and maybe even planned) to test the device in the field? Packing, storing and shipping especially of snow and firn is always risky in regards of microstructure so of course it would be great to get these data in the field. The set-up seems to be portable enough to fit into a few Zarges boxes.
Figure 6.a Just to be sure since it is not described, did you mirror the data after measuring the curved site? Some features look mirrored and could explain the visible difference between the left and right side of the core. If it is just a question of lighting, there are probably ways to fix it – how about attaching a strong light source directly to the images as is done for the visual stratigraphy line scanner from e.g. Schäfter+Kirchhoff used by AWI (https://www.sukhamburg.com/products/linescancamera/scannersystems/microstructuremapping/ilcs.html)?
L. 336: Latex format error /sim.
L. 351: It is very reassuring that the focus does not play a major role for grain size analysis. That will make the deployment much easier and less experienced people can easily take over during a measurement campaign. Great that you checked this in advance.
Fig 7b. I see the logic in the arrangement of a, b, and c, but having wider histogram plots in b) would increase the visibility of the two regimes.
L. 402: Since they are labelled Core 1-16, I would write “Core 16”.
Figure 8 caption: b) instead of c); 2012 melt layer (pink); standard deviation of/in grain sizes
L. 407: Here you only refer to the 14 undamaged firn cores. It might make sense to exclude the two damaged ones completely and thus have easier labels (Core 1-14).
Fig. A4: The legend for the mean annual air temperature seems to be missing.