

The Cryosphere Discuss., referee comment RC1
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Comment on tc-2021-188

Zoe Courville (Referee)

Referee comment on "Microstructure, micro-inclusions, and mineralogy along the EGRIP ice core – Part 1: Localisation of inclusions and deformation patterns" by Nicolas Stoll et al., The Cryosphere Discuss., <https://doi.org/10.5194/tc-2021-188-RC1>, 2021

The authors present a very methodical, comprehensive examination of solid micro-inclusions in polar ice at a range of depths that shows the potential for such a systematic approach to answer many outstanding questions about the role of impurities in ice structure and evolution. The work represents the first investigation of solid micro-inclusions in fast moving polar ice, and uses the methods outlined by Eichler et al. (2017) to construct impurity maps of over 5000 micro-inclusions and allows a robust statistical analysis of the frequency of location of micro-inclusions within the ice microstructure at a level that has not been obtained to date, and helps shed light on several long-speculated processes.

Future implications are particularly tantalizing...e.g., the examination of the impacts of mineralogy, grain boundary sliding, and precipitation and recrystallization on ice properties from the microscale to the mesoscale, which has been suggested in past literature, but with no prior methodology for proving definitively, is a very interesting consequence of this work.

The methods, results and conclusions are well articulated and presented, I have only a few minor specific comments and a small amount of very minor, technical corrections.

Specific comments:

Figures: I found the figures particularly compelling and interesting, especially Figures 1 and 2 (but all of the figures showing the variability of the micro-inclusions both within and

outside of grain boundaries is very interesting).

Abstract, line 10:

"Analysing the area occupied by grain boundaries in the respective samples shows that micro-inclusions are slightly more often located at or close to grain boundaries in half of all samples. Throughout all samples we find strong indications of dynamic recrystallisation, such as grain islands, bulging grains and different types of subgrain boundaries."

I think understand this sentence, but it is slightly confusing to read it. (Took me a couple of times for it to make sense). I think just rewriting it as, "In half of all samples, micro-inclusions are more often located at or close to the grain boundaries by a slight margin (in the areas occupied by grain boundaries). Not sure that last bit is needed.

Pg 5, Figure 2 caption (and throughout): on the last line here, and in other areas throughout the text, you state that something is "rarely close" to the micro-inclusions. Is it possible to define what you mean by "close" and is it just the 300 micron buffer surrounding the grain boundaries that defines what "close" is?

Pg 6, Line 114 what were the criteria for choosing samples, ie., what CFA values, grain sizes and orientation? For example, it seems like the Bolling Allerod period was targeted for sampling, and samples in the Younger Dryas and before and after the Holocene, but what other criteria were used to choose depths of interest?

Pg 8, Line 194, Is it worth discussing how it is determined if microinclusions are plates or clathrate hydrates here? It is mentioned in the figure caption for Figure 4, but seems like there is some more details that could be added about that in the text.

Pg 13, Line 240, Not sure if this is planned for the future work, or what exactly it would look like, but is it possible to plot grain size evolution of NEEM vs. EGRIP? That would be interesting to see. I understand there are likely limits that can be made in the intercomparison due to depth/age mismatches and differences in sample sizes and resolution, but the location of EGRIP over the ice stream vs. NEEM would be very interesting to see.

Technical corrections:

Pg 2, line 26, "depend" should be "depends"

Pg 3, line 62, I think you should add the word "microstructure" to describe localization, to differentiate it from the broader, cm to m scale localization...since that is a key point of this work, that you can actually identify the microstructural context of the solid impurities within the matrix vs. a CFA approach where you lose that information. In my opinion, it's good to point that out just to make clear.

Pg 3, Line 83, "question" should be "questions"

Pg 6, Line 108, "was obtained" should be "were obtained"

Pg 6, Line 113, "interests" should be "interest"

Pg 8, Line 189, Does 1 refer to Table 1 in "see 1 column nmi"

Pg 10, Figure 4 caption, 2nd line, "micro-inclusion" should be "micro-inclusions." Also, I mentioned this in the specific comments, but in this caption it is mentioned that there are plate-like inclusions and clathrate hydrates, but there is no mention in the text about the difference and how the two types are determined. Guessing it's just a visual determination?

Pg 10, Line 201, I think that this should be "an upper-limit assumption"

Pg 11, Table 1, Does "Size" refer to sample size? Or a region of interest?

Pg 16, line 299, "inclusion" should be "inclusions"

Pg 16, Line 325, Does "1" refer to Table 1?

Pg 17, Line 330, think that both instances of "effected" should be "affected" unless you mean that the reduced grain growth is causing the grain evolution.

Pg 17, Line 339, This sentence is confusing as it's written: "Our results (Fig. 3) indicate that solid micro-inclusions are not a main driver of e.g., grain size change via localised deformation along grain boundaries." Is it that micro-inclusions are not a main driver of grain boundary sliding (and the grain size change is an example of what grain boundary sliding would be that is not present)? or a main driver of grain size change? I think there is something missing after "of" or that the sentence should be rewritten to make clearer.

Pg 18, Line 366: I don't understand what the phrase "thus exist at grain boundaries" means. I think it is referring to amorphous water veins existing at the grain boundaries, but then the phrase in the parentheses is confusing.

I think this sentence is saying, "amorphous water veins, which can be either liquid-like, e.g., Mader, 1992, or solid-like, thus exist at grain boundaries"

Pg 18, Line 367, "changed temperature" should probably be "changes in temperature" as a more common phrase.

Pg 18, Line 368, "Comparably" should be "Comparable"

Pg 18, Line 382, missing parenthesis after Fig. 1.

Pg 19, Line 414, "indicates" should be "indicate"

Pg 20, Line 438, "in" should be "with"

