The Cryosphere Discuss.,
https://doi.org/10.5194/tc-2020-217-RC3, 2020

The Cryosphere Discussions

Interactive comment on "Pervasive diffusion of climate signals recorded in ice-vein ionic impurities" *by* Felix S. L. Ng

Alan Rempel (Referee)

rempel@uoregon.edu

Received and published: 29 October 2020

I agree that it would be helpful to signpost a later discussion on the importance of grain-size variations for determining how vein constituents behave. I would also welcome having the ideas surrounding the specific assumption regarding uniformity of vein radii in the Rempel et al. (2001) model attributed to a personal communication. However, I do not think that such a reference is necessary. While it is true that the matter was not discussed at length in that work, the reasoning was explicitly provided by the statement that "as the surface energy of curved interfaces acts to make vein radii uniform, variations in cB must correlate with changes in the total length of veins per unit sample volume", with the following sentence going on to note the qualitative support provided by observed anti-correlations between bulk impurity content (cB) and

grain size.

The twenty years since we completed that work have seen tremendous advances in the community's ability to characterize the physical and chemical characteristics of ice cores at increasingly fine scales. Despite these advances, it is noteworthy that we still lack a quantitative mechanistic understanding for precisely how the anti-correlation that is commonly observed between cB and grain size develops. Your new model brings welcome attention to the consequences of that important issue. In your comment you: 1. highlight the importance of the detailed form of the anticorrelation for determining the fate of vein constituents, 2. champion the generality of your formulation in being readily adaptable to examine the affects of different grain size evolution laws, 3. assert the need for a mechanistic understanding of the role of impurity loading on grain size, and 4. emphasize the inability of existing theories of grain growth to address this problem. I think we have broad agreement on each of these points, which offer a clear motivation for filling these knowledge gaps and bolstering confidence in the integrity and resolution of these important paleoclimate records.

Beyond the observed fine-scale grain-size variations themselves, an argument in favor of the uniform vein radius assumption employed in the Rempel et al. (2001) treatment is the long-term preservation and apparent fidelity of fine-scale cB signals recovered from ancient ice. If, as in your model treatment, vein radius evolves to force diffusive impurity redistribution, then your analysis implies that either those deep signals are distorted from their original form, thereby compromising detailed paleoclimate interpretations, or instead their preservation might be attributed to one or both of the mechanisms that you suggest, namely: residence outside of the vein network under much warmer conditions than the eutectic temperatures of their solutions, or blockages that manage somehow to severely restrict vein diffusivity. The observed anti-correlation between impurity content and grain size would in any case remain unexplained. However, should this problem be addressed, the precise manner in which grain sizes respond to impurity content or perhaps some coincident variable (e.g. impurities on two-grain boundaries)

could be accounted for in a refined treatment that extends beyond the locally uniform grain size case that is the focus of the example calculations in your paper. While we're each free to argue over the set of assumptions we feel to be most reasonable, whichever situation actually dominates is not currently known.

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