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Discussions

Interactive comment on "Deriving seismic velocities on the micro-scale from c-axis orientations in ice cores" *by* Johanna Kerch et al.

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Review

"Deriving seismic velocities on the micro-scale from c-axis orientations in ice cores"

by J. Kerch et al. Submitted to The Cryosphere

Overall, the paper is very nicely written and well organised. Descriptions of the different tools, and different steps are very clear, an easy to read. I will therefore have mainly one main comment, about the purpose of the work and the way it is provided through the text.

As mentioned in the summary, the purpose of using seismic or sonic data to explore

ice anisotropy development in ice sheets and glaciers is to be able to (i) avoid using the long and small-scale technique of thin-section + analyser, (ii) to provide data including larger volume of ice and therefore more representative, and (iii) to perform more measurements, over larger areas. (There might exist other interests, but these ones are already strong). To do so, one needs to be able to invert the seismic signal into a texture data. The best would be to have access to the full orientation of every grain (c- and a-axes). In the "real life", we will mainly have access to some "symmetry" of the texture, at a polycrystalline scale, over a given volume. A symmetry that is associated with the tool used (radar...) and the inversion procedure. This is likely why previous works mentioned in the text focused on the eigenvalues of the second orientation tensor, with some symmetry hypotheses, as the likely result of this inversion. But there is no hope that this inversion could give access to the exact c-axis orientation distribution over this volume (as far as I know from the available equipment so far). Therefore it should be made very clear that the work performed in this paper is an exercise aiming at pointing the likely error deriving from the inversion procedure in some specific cases. Otherwise, making use of an existing c-axis distribution data set to obtain seismic velocities has no interest by itself. Therefore how the given algorithm (cx framework) will help to improve the inversion procedure should be made clearer in the text. For instance, could a shear-wave splitting from a seismic dataset could be directly inverted as resulting from a non-symmetric orientation distribution (cf. Abstract), and provide some information about this orientation distribution? From the comparison between the ev and cx framework performed here as an "exercise", could some specific signal be obtained to be able to assess that an experimentally obtained seismic signal is related to a non vertically clustered fabric (as in the case of the bottom of KCC)?

In the discussion part, the authors should make it clear how there work can be used to provide "safeguards" against misinterpretation of the seismic signal by a "simple" inversion toward an eigenvalue data set.

Another important point that the authors should mention is that, contrary to the c-axis orientation angles, the eigenvalues of the second order orientation tensor do not provide a complete and unambiguous description of the texture. Indeed, one would require all the other orders of this orientation tensor to do so. By working with eigenvalues, we already work with an incomplete and bias COF data. Therefore, some variability are strongly smoothed by this procedure. Indeed, a multi-cluster type of texture will appear like a cone-angle type with the eigenvalue data, while the c-axis orientation distribution will give access to the complexity. So this is not such a result to find that the variability is better reproduced by using directly the full c-axis data...

One more point, that seems to me important but that could result from a misunderstanding from my side: The eigenvalues are provided together with the set of eigenvectors. The orientation of these eigenvectors provide the "orientation of the fabric" (if we can call it that way) relative to the thin section referential... Let's assume the thin section was done with a very strict control so that it's orientation relative to the "real" vertical is very well known, and that the core can be assumed to be vertical, then, the orientation of the eigenvector referential should tell us about some "non verticality". By making the assumption that this referential corresponds somehow to the "real" vertical, one introduce a strong assumption. This is hard to do otherwise, because of all the unknown mentioned before. BUT this assumption is not made at all when using the cx framework, since the true orientations are considered, and these orientations could be titled relative to the "real" vertical because of a tilted core, or during the thin section process... We can then expect some bias in the comparison due to this difference of consideration of this "tilt" of the fabric. This is mentioned somewhere within the text, but it does not appear to be considered as a source of differences between the velocity measurements, although is could play a strong role, especially along the KCC core. Shouldn't it be tested? For instance by aligning systematically the incidence angle with the eigenvector relative to the largest eigenvalue?

And the end, about the discussion corresponding to the layering of the core (discussion part). Couldn't this cx framework be perfectly adapted to test the effect of such a

layering on a seismic velocity data set? One could artificially vary the length of the layers, and force the anisotropy and check whether the response stands within the resolution frame of the measurements, etc. Maybe I am not qualified enough to see where the difficulty stands but it would be a nice byproduct of this cx framework?

Detailed comments:

p1. l. 20: Please site previous works done on that, or mention that Faria et al. is a review... For instance Alley 1988, Azuma 1985...

Part 2.4: maybe remind here that you are entering the cx-framework... Not so clear when reading the paper for the first time.

P7. l.1-2: here for instance, the authors refer to the error introduced in the ev framework, as if it was interesting "by itself", while it should be put back in the context of the inverse approach that aims at going from seismic data to eigenvalues (since going to real c-axis measurements will not be possible). What is the amount of signal lost? What kind of mistake could be made?? Is this inversion making sense? This is why the cx framework could be really meaningful.

P7. l. 5: maybe mention here again the fact that you call it cx framework (I was a little lost).

P8. l. 8: do you mean Appendix B (instead of 1A)?

p9. l. 4-5: here I started questioning myself about the effect of a non vertical texture that is translated into "non vertical" eigenvectors (to say it simply, see previous remarks), and that could have some impact by not being considered into the ev framework, but well integrated, per-se, into the cx framework.

P11. l. 3: how many layers do you use for the RMS calculations? How to you choose them? How does this impact the result? Same question for the case of KCC data treatment.

P11. l. 14: maybe put here "change in the estimated variation of seismic velocities", since these velocities are modelled and not measured... By the way, what is the resolution expected in the seismic velocity measurements? Are the differences evidenced here above or below these resolutions?

P13. l. 7: OK theoretically, but in general we don't know where is the exact vertical when analysing thin sections, and it can be tilted more than 10°, either because of inclined drilling, or because of thin section processing, or both...

p15. l. 15: about the likely misinterpretation, maybe give an illustration in the data, for clarity?

P16. l. 6: maybe put the figure in appendix at least, I was quite frustrated not to see it...

p17. l. 2: "The cx framework provides a refined approach for the use of fabric information to obtain seismic velocities in ice"... Once again, what we aim at is to obtain the fabric out of seismic data (unless there exist other purposes that should be mentioned!). So what can we learn out of this "exercise" that could help to solve the inversion problem, and to be more accurate in treating seismic data in terms of fabric information???

p17. l. 24-29: I find this paragraph highly speculative, and not necessary here... to relate stress conditions to grain bounding so quickly is speculative, and to mention the effect of GBS (that is far from being realistic along ice cores with large grain size) on elasticity is also very strong! Maybe it would be better to remain in the core of the subject?? or you would need to justify more...

p18. l. 9: Again, OK with what is said here, but since we have no hope to be able to inverse seismic data into exact c-axis orientations, how helpful is this framework?

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