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The Cryosphere
Discussions

Interactive comment on "Monitoring the temperature dependent elastic and anelastic properties in isotropic polycrystalline ice using resonant ultrasound spectroscopy" *by* M. J. Vaughan et al.

R. Cooper (Referee)

reid_cooper@brown.edu

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(Please note: I did my review reading the edited version of the manuscript posted by author Matthew Vaughan on 04 August 2016.)

This is a lovely piece of work; fun, really; and carefully explained. My compliments! There are a few very minor comments below, which the authors might wish to address at their discretion.

The significantly increased attenuation (decreased Q) noted exclusively for extensional (Youngs-modulus)-modes with increasing temperature, and its assignment to premelting at the grain boundaries is curious. I do not here argue against the idea – at least not directly; rather, I'll point-out behavior to which the current data might be compared.

We've done low-frequency ($0.001 \leq f$ (Hz) ≤ 1), high-temperature measurements of attenuation in silicate glass-ceramics and partial melts in both shear and (flexural) Youngs-modulus modes. In these materials, the quasi-equilibrium texture is to have melt (glass) confined to grain triple junctions (as a fully interconnected network, even at low volume fractions of melt/glass) and melt-free (i.e., crystalline) grain boundaries. As a consequence, shear attenuation was only modestly affected by the melt phase but Youngs-modulus attenuation was significant. In the latter, the pressure wave promotes/produces the relative motion of the melt and crystalline phases, following what the geodynamics community describes as compaction theory, as augmented with interfacial energy thermodynamics.

I'm no expert on premelting in ice. But experience with ice, consistent with what's seen in nature, is that water does not wet ice grain boundaries. A similar texture to silicate partial melts, rather, seems likely. Getting back to attenuation, if premelting in ice occurs at grain boundaries (or is uniquely associated with grain boundaries), would it not have two mechanical effects: (a) making degenerate the structures (and energetics) of the boundaries and so (b) affecting (presumably increasing) the shear attenuation more than the Youngs-modulus attenuation? Question is, what would be the thermodynamics and mechanics allowing premelting to be associated primarily with the extensional modes?

Perhaps this question is beyond the scope of the current manuscript. Nevertheless...

The recent work out of the materials community by scholars at Lehigh (Martin Harmer) and MIT (Craig Carter) on grain boundary 'complexions' is perhaps the key. If premelting does not represent a single quasi-liquid state but rather a host of states bridging a crystalline grain boundary at one extreme and a water film at the other, then the transformation(s) amongst states (and their kinetics), nicely described in the Harmer/Carter efforts, could be an (the?) important aspect of extensional-mode attenuation.

Here are the little points (again, based on the 04 Aug 16 version):

Page 1-Line 4: It's Q that decreases with increasing temperature, not "attenuation" (which is 1/Q).

Page 3-Line 22: I do not understand "imperfections" in elasticity. The physics of elasticity do not change: you are measuring the stiffness of the bonds; it is by definition, perfect. Non-infinite Q means that the mechanical stimulus has sampled responses (anelastic +/- plastic) that dissipate, instead of store, strain energy.

Page 3-Line 25: I am not sure exactly what you mean by "intrinsic attenuation". "Intrinsic" usually means that which is solely a function of temperature (+/- pressure), i.e., independent of chemical potentials and texture. There are intrinsic effectsâĂŤadiabatic loss; proton reordering in ice; point defect motion – but RUS can also "see" losses associated with texture, e.g., the presence of nonequilibrium defects like dislocations, grain boundaries, heterophase boundaries, etc. My experience with RUS has been to look at the impact of a finely disbursed second phase in synthetic peridotite, for example.

Respectfully,

Reid F. Cooper, Department of Earth, Environmental and Planetary Sciences, Brown University, Providence, Rhode Island, USA

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