

Interactive comment on “Strain heterogeneities at the ductile to brittle transition; a case study on ice” by Thomas Chauve et al.

Anonymous Referee #1

Received and published: 21 April 2017

In the work described in this MS, the authors investigate, using the method of Digital Image Correlation (DIC), the localization of plastic strain and of cracking within one specimen of S2 freshwater ice as it shortened by up to 5.5% under a set of creep conditions just on the ductile side of the ductile-to-brittle transition; specifically, under a compressive stress of 1 MPa at -7 °C (or 0.97 T_m). They present observations which show that strain is concentrated within a few bands, by a factor as high as 10 to 20. In addition—and this is the novelty of the MS—they claim to see evidence of dynamic recrystallization at the tips of short, deformation-induced cracks that formed outside the regions of localized plastic flow. Recrystallization, they state, serves to relax and then to redistribute stresses that develop within the crack-tip plastic zone and thus, presumably, to stabilize cracks against propagation. The work could be seen to support an earlier model of the DB transition (Renshaw and Schulson, 2001), even

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though that model does not specify the need for dynamic recrystallization, and thus to add further detail about a phenomenon that is important to the inelastic behavior of a variety of materials. That said, the MS leaves something to be desired.

The major shortcoming is unambiguous evidence of dynamic recrystallization at crack tips. The claim is made (p.10, lines 18-19; p.14, lines 5-8) that cracks-2 & 3 of Fig 8c-8d appear to be localized within an area where new grains recrystallized. While it is quite reasonable to expect that recrystallization could occur within the plastic zone at the tips of cracks, particularly within material as warm as that examined here, the evidence to support this point—the key point of the MS—is not compelling.

Another shortcoming, perhaps more an oddity than a weakness, is the apparent absence of shear deformation within the near-vicinity of cracks. In Figure 8 strain near the three cracks is shown to be predominantly tensile. Yet the cracks are inclined to the direction of loading and so one would have expected a shear stress to act in their plane. In the ideal case of no end-constraint (point 3, below), the ratio of shear stress to normal stress is given by $R = \tan \theta$ where θ is the angle between the normal to the plane of the crack and the direction of loading; in the real case of end-constraint, $R > \tan \theta$. For crack-3 in Fig 8, for instance, $\theta \sim 15$ degrees so that $R > 0.25$. This is a rather large ratio, begging the question: why is no shear strain detected in the near-vicinity of the three cracks?

Thus, owing to the points noted in the previous two paragraphs, this MS as presently developed should not be published. However, the authors should be encouraged to pursue their work, for the presentation of unambiguous and compelling evidence of the main point they have in mind, assuming it to be correct, would be a positive contribution to the literature. In so doing, they should consider and then address the following points:

1. In calculating strain from relative displacement of points on a speckle pattern using the DIC method, what precaution was taken to ensure that the only movement detected

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from one image to the next was through deformation of the ice? In other words, to what extent did vibration and other extraneous movements of the camera contribute to apparent displacement and hence to inelastic strain?

2. Identify using an arrow “decohesion features” in Fig 3c, and then define them. Are they the kind of feature reported by Picu and Gupta (*Acta Mater.*, 43(10), 3791-3797 ([http://dx.doi.org/10.1016/0956-7151\(95\)90163-90](http://dx.doi.org/10.1016/0956-7151(95)90163-90)) and by Weiss and Schulson (*Phil. Mag. A*, 80(2), 279-300 (dx.doi.org/10.1080/01418610008212053)).

3. Could the deformation bands shown in Fig.4 and elsewhere be a result of end-constraint imposed on the square-shaped (9 cm x 9cm) specimen by boundary conditions external to the ice (i.e.,by the loading platens)? Boundary conditions are mentioned in the Discussion (p.11,12), but more within the context of grain boundaries and their influence on local stress state than within the context of end zones. Given the square shape of the specimen, the entire volume of the ice was effectively confined. To know whether deformation bands are an intrinsic feature of ice creep, experiments need to be run using specimens whose length to width ratio is closer to 3 or more.

4. To Figure 6 and elsewhere where blue (compressive strain) and red (tensile strain) arrows signify the two principal strains, add a scale.

5. In the increment of strain from Fig 8b to 8c, crack-3 appears to close. Closure is claimed (p.10, line 22; p.14, lines 15-20) to be caused by a local compressive stress which is related to the formation of new boundaries formed by nucleation. How exactly would recrystallization develop a compressive stress normal to the plane of crack-3?

6. Typos

The images in Fig.4 should be reversed, in that the one on the left is of the lower spatial resolution.

On p. 7, “if the AITA” should read “of the AITA”

On p.10, lines 29 and 34, “there” should be spelled “their”.

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On p.14, line 26, “beyong” should be “beyond”.

Interactive comment on *Solid Earth Discuss.*, doi:10.5194/se-2017-24, 2017.