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Interactive comment on "Temperature and strain controls on ice deformation mechanisms: insights from the microstructures of samples deformed to progressively higher strains at −10, −20 and −30 °C" *by* Sheng Fan et al.

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We thank Reviewer 1 for her thoughtful and helpful review of our paper. The comments have helped us improve the manuscript significantly. Our reply to reviewer comprises two parts: (1) some short general statements and (2) point-by-point reply to comments from reviewer. Please refer to the supplement PDF for point-to-point replies.

Section one: general statements

1. This work contains data which are completely new. We would like to emphasize that

the sequence of microstructures and CPOs developed with increasing strain has not been documented before for ice deformed at cold temperatures (-20, -30 °C). This is highlighted by one of the comments by the reviewer: "The hypothesis that GBM being less active at low temperature, the impact of grain rotation driven by intracrystalline slip prevails is much clearer, especially since it is very coherent with the observations that the cone angle is reduced, and more orientations are found close to the vertical. This assertion is, indeed, justified by the experimental observations. This is, in fact, the main "novelty" of the presented work and should be emphasised more." Earlier work showing the up-strain microstructures and CPOs (e.g. Jacka & Macagnan, 1984; Montagnat 2015) are at warm conditions where the CPO evolves towards an open cone (small circle). Experiments at colder temperatures (-30 °C and colder) to strains of ∼ 20% (Craw et al., 2018; Prior et al 2015) show CPOs have maxima of c-axes parallel to compression. No published work shows the up-strain evolution of microstructures or CPOs at -20 or -30 °C (or colder temperatures). Jacka & Li (2000) show CPOs at ∼10% strain at ∼ -15 and -20 °C and ∼ 3% strain at -45 °C but include no microstructural data and do not explore the up-strain evolution. Recent work by Wilson et al (2019) shows CPOs at -15 and -20 °C at 20% strain, but show no up-strain evolution. In this paper the up-strain sequence at -30°C documents the evolution towards a cluster CPO, the sequence at -10 °C the evolution towards an open cone CPO and the sequence at -20 °C something between these two. Understanding how and why different CPOs develop as a function of temperature should give a better insight into the mechanisms that control CPO development and mechanical behaviour.

2. Different interpretations can be made from the same observation. One of the reviewer's objections relates to our interpretation of the microstructural development as involving grain boundary sliding (GBS). We accept that the factual observations could be interpreted in different ways and in the revision, we include some alternative interpretations (including "spontaneous" nucleation) of the data, with some discussion of the merits and drawbacks of each of these interpretations. We hope that we have kept the observations and interpretations clearly separated and we have reduced

the emphasis on our preferred interpretation of GBS. We have also identified some of the tests that may facilitate distinguishing these different interpretations in the future. Some more details are included in answers to specific points. The reviewer's comments highlight that our original manuscript did not really make clear that we do interpret intracrystalline dislocation glide that causes lattice rotation as one of the key processes controlling CPO development. We hope that we have made this much clearer in the revised manuscript. The operation of a GBS process, if this is correct, would be additional to the role of intracrystalline dislocation glide and associated recovery and recrystallisation processes.

Please also note the supplement to this comment:
https://www.the-cryosphere-discuss.net/tc-2020-2/tc-2020-2-AC1-supplement.pdf

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