On behalf of the author team, I would like to thank the Editor, Nanna Bjørnholt Karlsson, for handling this manuscript. We thank the reviewers for their valuable suggestions and comments, which have certainly helped to improve the manuscript. We have applied the changes in the manuscript and replied to the questions raised by the reviewers below. Our replies to each reviewer question with the action taken on the manuscript are provided in green font.

Best regards,

Maria-Gema Llorens

REFEREE#1
I am fully satisfied with the extent of revisions that authors have undertaken for this revised version. The revised manuscript and figures are really nice and this will be a good contribution to the field. I especially commend authors for professionally and calmly addressing the constructive aspects of Reviewer #2's review while ignoring the pompous bluster that was wholly inappropriate and unprofessional.
One tiny edit to look out for (in the proof only, I do not require a revision) is at line 552, I would change "a most of" to "at most". No other comments.

Many thanks! This sentence is in line 452. We have corrected it.

REFEREE#2
I maintain that ELLE/VPFFT is an outlier on the importance of recrystallization—and while I do not think it mitigates the importance of the work I find that section 6 needs expansion. In my view, it is simply not good enough to disregard recrystallization affecting CPO based on modeling, which is more-or-less what was done in the review response. The authors also disregard experimental evidence saying that Fan et al. show that “strain weakening in ice is dominated by CPO development, where grain size reduction plays only a minor role” but the question is not about strain weakening. This statement does does not mean that DRX is unimportant for CPO development, and I think Fan et al. demonstrate that (I am aware that there is author overlap with this paper, but I feel the need to point this out nonetheless). For example, the first two rows of their Figure 9 are classic migration recrystallization cones. Qi et al, 2019, show additional fabrics that almost certainly require DRX, as they argue in section 4.6. Indeed, in that paper modeling with ELLE/VPFFT (again, done by/with authors on the present work) does show notable differences with and without DRX in their Figure 9. Given that experimental evidence, as well as ice-core evidence from shear margins that shows fabrics clearly caused by DRX (e.g., Jackson and Kamb, 1997; Gerbi et al., 2021), and the simple fact that even relatively cold ice is over 95% its melting point, I think it is clear that DRX would matter for CPO in some of the cases considered here—if the authors disagree, at a minimum I hope they would concede that it is not well known, and put a little bit more into Section 6. In particular, some citations to acknowledge that there is in fact evidence of recrystallization in natural ice (e.g. citations above, in addition to others that can be found in the Faria reviews), would help the last sentence. Additionally, there should be some consideration of how inaccurately modeled DRX could affect the results (by which I

mean at least nucleation and GBS, processes that even the authors concede could affect the fabric); I appreciate the supplementary figure showing us how the model does with DRX, but want a little more humility on the possibility that the model is imperfect. Again, I am not suggesting more modeling, just a little more consideration of the possibility that DRX may, contrary to what ELLE/VPFFT says, control CPO development in some of the cases considered here. Particularly, this seems likely in shear margins, where there is direct evidence of recrystallization-controlled fabrics. It also seems like the authors should acknowledge that the very slow rates of fabric development by lattice rotation in series C could cause DRX to be of relatively greater importance.

We agree that the role of *DRX* on CPO is a matter of debate, and maybe that of GBS even more. We have extended accordingly the section 6, where different key questions about the effect of DRX in nature are specified and discussed. Moreover, we discuss the effect of these processes in our approach, as shown in in suppl. figure 4, where adding GBM, recovery and polygonisation in our modelling scheme has virtually no effect on the CPO. However, these processes do result in a significantly different microstructure (grain shape, size, etc.), as was shown in previous papers by Llorens et al. and Steinbach et al. Therefore, there is no need to add these processes to the current simulations, as we are only concerned with the CPOs. As discussed in the revised section 6, we do realise that this does not necessarily mean that in nature DRX has no effect on CPO. At the moment, we unfortunately cannot include GBS in our simulation code. This is a limitation that we now also clearly acknowledge. We have included the following text and changed the title of the section including "*further processes*":

6. Model limitations and further processes

The models presented consider only deformation and exclude recrystallisation processes. This needs some discussion as recrystallisation is inferred to be an important process in both laboratory experiments (Fan et al., 2020; Journaux et al., 2019; Kamb, 1972; Montagnat et al., 2015; Qi et al., 2017; Qi et al., 2019) and in nature (Duval and Castelnau, 1995; Gerbi et al., 2021; Jackson and Kamb, 1997; Monz et al., 2021; Thomas et al., 2021). There are three aspects to assess when considering the limitations of excluding recrystallisation processes from model outcomes:

1. *Do dynamic recrystallisation processes, that we can model, significantly change the modelled CPO patterns (symmetry, orientation, strength)?*
2. *Are there key processes that may affect CPOs and that cannot yet be modelled?*
3. *Are model representations of recrystallisation kinetics robust?: do recrystallisation processes change the rate (as a function of strain or time) at which CPOs develop?*

A number of studies that use the VPFFT-ELLE modelling approach (e.g., in Llorens et al., 2016a, 2016b and 2017; Steinbach et al., 2017 and Gomez-Rivas et al., 2017) indicate that model representations of dynamic recrystallisation processes, including grain boundary migration, subgrain rotation, intracrystalline recovery and polygonization, have a minor effect on the CPO pattern development (symmetry, orientation, strength). For the current series of simulations, we tested this (suppl. Fig. 4) and again found this to be the case. Including recrystallisation processes that we are able to model will make little difference to model outcomes while making the simulations more complex.

Some elements of the effect of recrystallisation on CPOs are not well captured in detail when these processes are modelled. These include small circle girdles in compression and double maxima in shear. Experiments conducted at conditions where dynamic recrystallisation dominates (relatively high temperatures and low strain rates) give small circle girdle CPOs under uniaxial compression (Jacka and Maccagnan, 1984), with the small circle closing and becoming a weak maximum parallel to compression at conditions where dynamic recrystallisation is reduced relative to deformation (Fan et al., 2020; Qi et al., 2017). Double maxima tend to be developed in shear where dynamic recrystallisation dominates (Qi et al., 2019). Although developing ways that better capture these recrystallisation effects is important (e.g., Richards et al., 2021), the effect on CPO patterns are details that are unlikely to significantly affect the analysis carried out in the present study.

Grain boundary sliding (GBS) is a process that is not included in our simulations, although some studies suggest it may play a role in natural ice flow (Fan et al., 2020; Behn et al., 2021). Its effect on microstructure and CPO is, however, not well established. It is suggested that it would reduce the strength of a CPO (Richards et al., 2021) and experiments tentatively support this (Craw et al., 2021; Fan et al., 2020), but we are not aware of any study showing that the CPO would be significantly altered otherwise. From this we deduce that, if GBS would operate, our results would probably still largely apply, except for the strength of the CPOs that were modelled without GBS.

The effect that recrystallisation has on rates of CPO change is largely unconstrained. Duval and Castelnau (1995) estimate that microstructures of polar ice can be entirely recycled with little strain (by 1% strain at -10ºC and natural strain rates). It is not clear how the microstructural re-organisation corresponds to CPO modification. There are very few attempts in experiments to change one CPO to another (Craw et al., 2019 is the only one we know of). And there are no field studies where ice is collected on transects where the deformation kinematics change along the transport pathway so that CPO change rates can be documented. Thomas et al (2021) show CPOs that relate kinematically to a marginal shear zone, in ice where they infer that the grain microstructure (size and shape) has been overprinted by the effects of tidal flexure deformation. If this is right, this is an example of recrystallisation changing grains but not CPOs. Understanding the kinetic effects of recrystallisation is an important area of research for the future.

Specific comments:
L50: A fabric reference is inappropriate for such a basic claim about ice dynamics. Perhaps Cuffey and Paterson is most fitting, or Aggasiz, Forbes, or Tyndall from the 1800s?
We have modified the reference to Cuffey and Paterson.
Fig 5. A label on the green, downward arrow would be helpful
We have included "single regime" on the green arrow.
L451: Typo muddles the meaning; unclear if "a most of" means an upper limit or a best approximation.
According to reviewer #1 we have modify it to "at most".
L481: What does effectivity mean here? Effectiveness at what? Perhaps this is jargon which which I am not familiar, but I suggest a different word choice for clarity.
We have changed effectivity to "The influence of the second flow regime on the reorientation of the inherited CPO".
L494: It would seem that this is contradicted by series C.

Included “with the exception of series C, when a strong point maximum CPO developed during the first deformation regime”.
L497: Where along the margins—they vary substantially.
We consider that the paragraph is clear enough now and it already includes this information.
L566: I think conclusion 4 should be deleted, since the two sentences essentially contradict each other. If it were a reliable indicator, then we would not need caution (we know present-day deformation better than past, so trying to infer flow from CPO would happen most often in areas with multi-stage history).
We agree. We have modified the conclusion 4 to “According to our results, CPOs are reliable indicators of the current flow conditions, as they usually adapt to them in a relatively short time. However, caution is warranted when a volume of ice may have experienced consecutive flow events with the extension direction in the same direction.

References:
Gerbi, C., Mills, S., Clavette, R., Campbell, S., Bernsen, S., Clemens-Sewall, D., Lee, I., Hawley, R., Kreutz, K., and Hruby, K.: Microstructures in a shear margin: Jarvis Glacier, Alaska, J. Glaciol., 1–14, https://doi.org/10.1017/jog.2021.62, 2021.
Jackson, M. and Kamb, B.: The marginal shear stress of Ice Stream B, West Antarctica, J. Glaciol., 43, 415–426, https://doi.org/10.3189/S0022143000035000, 1997.

EDITOR
Fig. 1: For consistency and readability, please move "I" and "II" outside of the ice so they are placed above the ice sheet in the same way as "III" and "IV"
Done.
Line 152: The sentence "At depth, observations from ice cores indicate a vertical single maximum" is unclear. Does this refer to ice at a ridge? Or away from a ridge? Also, which observations? There should be a reference here.
Modified to “At depth, microstructural descriptions from ice cores performed in domes and ridges indicate a vertical single maximum (Thorteinsson et al., 1997; Azuma et al., 1999; Durand et al., 2007; Faria et al., 2014; Weikusat et al., 2017)”
Line 158: What is "zone IVa"? I don't see a IVa in the figure.
Corrected to zone IV
Line 217: "coherent" -> "consistent"?
“coherent” is in line 192. We have modified it to “consistent”
p. 10 (and elsewhere): "Table 1 and 2" should be "Tables 1 and 2"
Corrected.
Line 400: Figs. 3 and 4 do not show the final CPO after simple shear only. Do you mean Fig. 5a?
We have modified the text to “Although the final CPO symmetry is coherent with simple shear deformation, its shape after a strain of $\varepsilon 2=4$ still differs from that of the previous case (series A) (see the last step for the second regime in Figs. 3a and 4a) or that of simple shear only (see figure 5 in Llorens et al., 2017).
Line 440: "... the final CPO continues being dominated..." -> "... the final CPO continues to be dominated..."
Corrected.
Line 552: "2,8 kyr" -> "2.8 kyr"

Corrected.
Line 565: "2,5 kyr" -> "2.5 kyr"
Corrected.
Line 603: Flow is not necessarily considerably faster in the NEGIS margins. I suggest rephrasing to clarify that strain is considerably higher in the margins which is really the point.
Modified to "where strain is considerably higher (i.e. strain rate of ~ 4x10-10 s-1)
Fig. 9: The new and the old version are identical?
Yes, according to referee's comments we didn't change this figure.

References:

Richards, D.H., Pegler, S.S., Piazolo, S. and Harlen, O.G., 2021. The evolution of ice fabrics: A continuum modelling approach validated against laboratory experiments. Earth and Planetary Science Letters, 556, p.116718.

Behn, M.D., Goldsby, D.L. and Hirth, G., 2021. The role of grain size evolution in the rheology of ice: implications for reconciling laboratory creep data and the Glen flow law. The Cryosphere, 15(9), pp.4589-4605.

Craw, L., Treverrow, A., Fan, S., Peternell, M., Cook, S., McCormack, F., and Roberts, J., 2021, The temperature change shortcut: effects of mid-experiment temperature changes on the deformation of polycrystalline ice: Cryosphere, v. 15, no. 5, p. 2235-2250.

Duval, P., and Castelnau, O., 1995, Dynamic recrystallization of ice in polar ice sheets: Journal De Physique Iv, v. 5, no. C3, p. 197-205.

Fan, S., Hager, T. F., Prior, D. J., Cross, A. J., Goldsby, D. L., Qi, C., Negrini, M., and Wheeler, J., 2020, 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: The Cryosphere, v. 14, no. 11, p. 3875-3905.

Gerbi, C., Mills, S., Clavette, R., Campbell, S., Bernsen, S., Clemens-Sewall, D., Lee, I., Hawley, R., Kreutz, K., and Hruby, K., 2021, Microstructures in a shear margin: Jarvis Glacier, Alaska: Journal of Glaciology, v. 67, no. 266, p. 1163-1176.

Jacka, T. H., and Maccagnan, M., 1984, Ice crystallographic and strain rate changes with strain in compression and extension: Cold Regions Science and Technology, v. 8, no. 3, p. 269-286.

Jackson, M., and Kamb, B., 1997, The marginal shear stress of Ice Stream B, West Antarctica: Journal of Glaciology, v. 43, no. 145, p. 415-426.

Journaux, B., Chauve, T., Montagnat, M., Tommasi, A., Barou, F., Mainprice, D., and Gest, L., 2019, Recrystallization processes, microstructure and crystallographic preferred orientation evolution in polycrystalline ice during high-temperature simple shear: The Cryosphere, v. 13, no. 5, p. 1495-1511.

Kamb, W. B., 1972, Experimental recrystallization of ice under stress, *in* Heard, H. C., Borg, I. Y., Carter, N. L., and Rayleigh, C. B., eds., Flow and Fracture of Rocks, American Geophysical Union, p. 211-242.

Montagnat, M., Chauve, T., Barou, F., Tommasi, A., Beausir, B., and Frassengeas, C., 2015, Analysis of dynamic recrystallisation of ice from EBSD orientation mapping: Frontiers of Earth Science, v. 3, p. 13.

Monz, M. E., Hudleston, P. J., Prior, D. J., Michels, Z., Fan, S., Negrini, M., Langhorne, P. J., and Qi, C., 2021, Full crystallographic orientation (c and a axes) of warm, coarse-grained ice in a shear-dominated setting: a case study, Storglaciären, Sweden: The Cryosphere, v. 15, no. 1, p. 303-324.

Qi, C., Goldsby, D. L., and Prior, D. J., 2017, The down-stress transition from cluster to cone fabrics in experimentally deformed ice: Earth and Planetary Science Letters, v. 471, p. 136-147.

Qi, C., Prior, D. J., Craw, L., Fan, S., Llorens, M. G., Griera, A., Negrini, M., Bons, P. D., and Goldsby, D. L., 2019, Crystallographic preferred orientations of ice deformed in direct-shear experiments at low temperatures: The Cryosphere, v. 13, no. 1, p. 351-371.

Richards, D. H. M., Pegler, S. S., Piazolo, S., and Harlen, O. G., 2021, The evolution of ice fabrics: A continuum modelling approach validated against laboratory experiments: Earth and Planetary Science Letters, v. 556.

Thomas, R. E., Negrini, M., Prior, D. J., Mulvaney, R., Still, H., Bowman, M. H., Craw, L., Fan, S., Hubbard, B., Hulbe, C., Kim, D., and Lutz, F., 2021, Microstructure and Crystallographic Preferred Orientations of an Azimuthally Oriented Ice Core from a Lateral Shear Margin: Priestley Glacier, Antarctica: Frontiers in Earth Science, v. 9, no. 1084.