On behalf of the author team, I would like to thank the Editor, Nanna Bjørnholt Karlsson, for handling the review process of our manuscript. We thank the reviewers for their 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. Replies to the reviewer are provided in green font and the new or modified text in the manuscript appears in green italic font.

Best regards,

Maria-Gema Llorens

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**Reviewer #3**

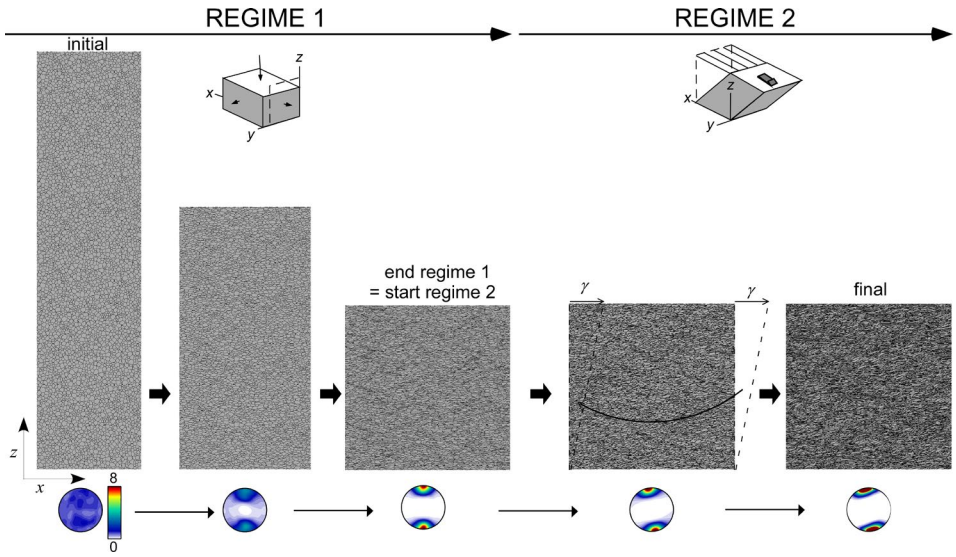
The paper provides a systematic modeling study to examine the effect of pre-existing CPO on final CPO in scenarios where stress state changes in the deformation history. The 4 simplified scenarios are well described and the results are interesting and can help inform interpretation of past flow inferred from core sample microstructures. I recommend publication after some modification.

We greatly appreciate the reviewer's support for publication, and their suggestions for improvement.

My main issue is that it feels a little like a black box. I don't understand how you go from the physics of deformation described in section 2 to the results in, say figure 3c. I don't think you need to provide post-processing and exhaustive details, but it seems like it would help readers like myself who do not model if there was a very simple description of how you get figure 3c, so that a person doesn't have to go to Llorens et al. 2016 for the background needed.

We have extended the postprocessing explanation for the PGR diagram (figure 3c) in the manuscript with to this comment: *"Crystal symmetry shows the relative proportion of point (P), girdle (G) and random (R) components of the (0001) crystallographic axis, or c-axis distribution in a ternary diagram (Vollmer, 1990). The P, G and R proportion is calculated from the three eigenvalues ($a_1$, $a_2$, $a_3$) as $P=a_1 - a_2$, $G=2a_2 - a_3$ and $R=3a_3$."*

*In order to explain how figures are obtained, we include an additional figure where the workflow can be visualised (supplementary figure 5)*




*supplementary figure 5*

Additionally, I provide line by line comments that may help improve readability.

Minor comments:

Line 36: Recommend deleting the word “on”. Deleted.

Line 49: consider reordering this sentence to be clearer. Maybe more like: “Polycrystalline ice (ice Ih) in glaciers, ice sheets, and ice shelvesflows in response to gravitational forces.” Point taken. Changed to: “*Polycrystalline ice (ice 1h) in glaciers, ice sheets and ice shelves flows in response to gravitational forces (e.g., Hudleston, 2015*)”.

Line 73: The Durham et al., 1983 paper doesn’t have anything to do with CPO development or evolution so isn’t appropriate there. Perhaps something by Montagnat?

According to this comment, and also a similar comment by reviewer #2, we have removed the Durham reference and now include the following references: *“Experimental studies have utilised ice to understand how CPOs develop and evolve under deformation (see Kamb et al., 1972; Wilson, 1982; Jacka and Macagnan, 1984, Wilson and Peternell, 2012; Budd et al., 2013; Montagnat et al., 2015; Vaughan et al., 2017, Fan et al., 2020)”.*

Line 80: I would add Fan et al. 2020 to this list. I do see you mention it later in the paper, but would be good here as well.

This sentence refers to experiments starting with a pre-existing CPO, not the case of Fan et al. (2020). However, we have added this reference in the previous paragraph, where we find it fits better (see reply above).

Line 92: consider providing additional refs here to put this work into context with previous modeling efforts

According to this comment, and a similar comment by reviewer #2, we have modified the whole paragraph including references to recent numerical studies: *“Moreover, numerical*

*simulations of polycrystalline ice and their comparison with experimental and natural data provide useful insights into CPO development, as they allow visualizing and quantifying the microstructural evolution up to high strain (Montagnat et al., 2014b; Piazolo et al., 2019).). However, as in the case of laboratory experiments, most numerical studies to date have focused on systems that start with an initially random CPO to which a single deformation event is applied (Montagnat et al., 2011; Llorens et al., 2017,2020).”*

Line 98: sorry, I don't know what a cloudy band is in this context…perhaps define? Are they layers containing dust particles? Perhaps explain why this is or isn't relevant to the effort here

For sake of simplicity, we have modified the paragraph for simplification: *“Jansen et al. (2016), where the viscoplastic response of ice polycrystals with a starting CPO is studied”*

Line 100: perhaps another half sentence for the non-glaciologists: "…experiences multiple changes in deformation regime during ice-sheet flow as it _____" (I don't know, changes course and rounds topographical features?…just a flavor of the type of changes made for those who don't know)

The sentence has been changed to: *“Considering that polar ice typically experiences multiple changes in the deformation regime during ice-sheet flow, such as the transition from the co-axial strain in the centre of the ice mass to non-coaxial strain at depth and away from the centre (Jennings and Hambrey, 2021), systematic studies providing a comprehensive understanding of CPO development during multi-stage deformation histories are essential.”*

Line 107, 369: in intro you didn't use an apostrophe in CPOs for plural. I don't know which it should be, but just be consistent

Point taken. Corrected to CPOs in the whole manuscript.

Line 110: perhaps a sentence here to say something along the lines of flow in nature is complicated, but for ease of understanding you provide the simplified diagram in Figure 1, which divides the flow patterns into four distinct zones. If you are ignoring some aspects of flow (T?) then describe here.

We have included the following sentence at the beginning of chapter 2: *“We analyse different examples of flow changes that represent relevant and/or common deformation regimes in ice sheets, assuming a constant strain rate and temperature.”*

Line 163: I recommend deleting "an"

Corrected.

Line 169: here you define n as the rate sensitivity exponent, but all other occurrences you call it the stress exponent. If you mean the same thing, I recommend calling it the stress exponent here.

Modified now to stress exponent.

Line 205 to 260: I recommend more clearly stating how you came up with the velocity gradient tensors for each zone. It is not clear if this should be a result or an assumption. If it is

an assumption, I recommend more clearly stating that and have this section just be stating that you will run 4 series that represent different transitions from one V to another V, basically introducing Table 2. I would save the qualitative descriptions currently in 3.2.1 – 3.2.4 to instead appear at the beginning of results for each of those series.

We have more clearly stated that the gradient tensors for each zone are assumptions, and we have introduced table 2 in the text: "*We considered four different model series (from series A to D) to simulate flow transitions between pairs of deformation regimes (**V** that dominate in different zones of the ice mass through which a volume of ice may travel (Figure 1).*

*Series A represents ice flowing from the centre of the dome to deep lateral zones (from zone I to zone II in Fig. 1). To simulate this transition, we carried out a series of simulations with first vertical uniaxial compression parallel to y (**V**$_1$), followed by dextral simple shear in the vertical plane (xz) (**V**$_2$) (Table 1 and 2). Similar to A, Series B shows the transition of ice flowing centre parts of the ice sheet, but in this case from the centre of the ridge to deep lateral zones (from zone I to zone II in Fig. 1). For series B, we considered that the ice aggregate is first deformed by **V**$_3$, horizontal uniaxial extension parallel to x, followed by **V**$_2$, dextral simple shear in the vertical plane (xz) (Table 1 and 2). Series C simulates ice flowing from an ice dome to an ice flank or stream (from zone I to zone III in Figure 1). Series C was carried out assuming first vertical uniaxial compression parallel to z (**V**$_1$) followed by uniaxial extension parallel to x (**V**$_3$) (Table 1 and 2). Finally, series C represents ice flowing from an ice-stream or glacier to an ice shelf or shear margin (from zone III to zone IV in Figure 1). For this series, we considered first uniaxial extension in the x direction (**V**$_3$), and subsequently dextral simple shear in the horizontal plane (xy) (**V**$_4$) (Table 1 and 2). For comparison, simulations of microstructures deformed under single-deformation event (**V**$_2$, **V**$_3$ and **V**$_4$) are shown together will all series results."*

According to a similar suggestion from reviewer #2, we have merged sections 3 and 4. The descriptions in 3.2.1 – 3.2.4 now appear at the beginning of the corresponding parts of the results section.

Line 209: recommend changing "examples" to "example"

Corrected.

Line 223: recommend making "simulation" plural

Corrected.

Line 256: recommend deleting "of" and "before" from this sentence.

Corrected.

Line 374 (but really 366 – 381): It is unclear where in this paragraph you are referring to historically, as in past studies, and where you mean the results from this study. Try to make it very clear and emphasize how your results confirm or deny previous works by including some words at the beginning of sentences like: "Indeed, our experiments confirm that…." In case the reader does not have prior knowledge of CPO evolution, drag us along very explicitly. [ah, it is much clearer in the 2$^{nd}$paragraph]

Point taken. We have merged the first and second paragraph in order to avoid confusion about what are results and what are past studies.

Line 429: change “loose” to “lose”

Corrected.

Line 431: recommend changing “effectivity” to “effectiveness”

Corrected.

Line 454: the double negative makes this sentence hard to follow. Consider changing “not destroyed” to “retained”

Addressing this commen,t and those by reviewer #1, the sentence is now modified to: *“Our results suggest that, under natural conditions, as for example those at the onset of the NEGIS onset where the velocity increases by 40 m/yr over a distance of 120 km (i.e. strain rate of ~1x10$^{-11}$ s$^{-1}$; Joughin et al., 2018), an inherited fabric would be preserved for at most for ~ 7 kyr”.*

Line 459: if these results are also in agreement (or even if they are not in agreement) with other polycrystalline materials, here would be a good place to mention that. One study that comes to mind is Boneh and Skemer, EPSL 406, 2014, which experimentally looked at this very thing in olivine. Putting your ice modeling results into broader context might be a good idea.

We have included a new paragraph discussing this work and comparing it with similar studies in olivine: “*The entire change of a previous CPO also takes place in other rocks, such as olivine-rich rocks in the upper mantle, where a new CPO quickly develops according to the new imposed boundary conditions. The observed CPO will thus not record the full history of changes in the kinematics of deformation (Kaminski,2004). However, as our results reveal, the re-orientation of an inherited CPO depends both on its intensity and on the orientation with respect to the new stress field. These results are in agreement with observations from olivine experiments, where the pre-existing texture orientation determines the way the texture evolves (Boneh and Skemer, 2014). Accordingly, the deformation history could have an impact on the CPO in areas with complex flow, as in subduction zones (Di Leo et al., 2014; Li et al., 2014).”*

Line 492: italicize c in c-axis.

Corrected in the whole manuscript.

Line 493: perhaps reword number 4 to exactly answer the title of the paper? (even if with a caveat)

Point #4 has been reworded as: *“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 complex (multi-stage) deformation histories.”*

*References:*


Boneh, Y. and Skemer, P., The effect of deformation history on the evolution of olivine CPO. *Earth and Planetary Science Letters*, *406*, pp.213-222. 2014

Di Leo, J.F., Walker, A.M., Li, Z.H., Wookey, J., Ribe, N.M., Kendall, J.M. and Tommasi, A., Development of texture and seismic anisotropy during the onset of subduction. *Geochemistry, Geophysics, Geosystems*, *15*(1), pp.192-212. 2014

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Kaminski, E., Ribe, N.M. and Browaeys, J.T., D-Rex, a program for calculation of seismic anisotropy due to crystal lattice preferred orientation in the convective upper mantle. *Geophysical Journal International*, *158*(2), pp.744-752. 2004

Li, Z.H., Di Leo, J.F. and Ribe, N.M., Subduction-induced mantle flow, finite strain, and seismic anisotropy: Numerical modeling. *Journal of Geophysical Research: Solid Earth*, *119*(6), pp.5052-5076. 2014