Reply to the reviewer 1

We thank the reviewer for careful review of our manuscript and thoughtful comments to improve it. In the following, we describe our responses (in blue) point-by-point to each of reviewer's comment (in black).

Dear editor,

This paper investigates the crystal orientation fabric of the Dome Fuji Station ice core using a novel methodology as the dielectric anisotropy (from the dielectric permittivity tensor). Dielectric anisotropy is revealed as a good indicator of the vertical clustering of the crystal orientation fabric, also exhibiting a correlation with the concentration of chloride ions and with the amount of dust particles in the ice core. From the results, the authors conclude that the COF clustering is therefore affected by the presence of chloride irons, which increase the dislocation density, promote dislocation creep and enhance the COF clustering, while the presence of dust impedes it. The results show a COF layering in the upper 80% of the ice sheet, where the COF contrast amplitude increases at deeper layers. The conclusion is sound regarding the lowest 20% of the ice sheet, as layers will behave differently under stress depending on the COF cluster strength.

This well-written and well-organised manuscript presents a very useful methodology to be further evaluated in the future. We could obtain the COF contrast from the permittivity contrast obtained in VHF/UHF radar sounding. This will allow comparing deep COF layers avoiding areas with layers with heterogeneous thickness. This heterogeneity can lead to layer disturbances and folding due simple shear close to the bedrock.

The detailed description of the presence of soluble impurities and particles and its correlation with the COF is very useful for the understanding on the effect of them on ice rheology, which is currently unknown.

The manuscript is relevant for The Cryosphere and thus can be a valuable contribution once some important issues are addressed. Thus, I recommend that the paper is accepted after minor revisions.

We thank the reviewer a lot for the summary above.

Suggestions for improvement:

Line 50: this statement "It has been suggested that the finer grain size in glacial ice results from high concentrations of impurities such as dust particles or soluble substances that restrict grain growth via pinning and drag at the grain boundaries" requires a reference.

We will add references, for example,

Alley, R.B., and Woods, G.A.: Impurity influence on normal grain growth in the GISP2 ice core, Greenland, J. Glaciol., 42(141), 255-260, https://doi.org/10.3189/S0022143000004111, 1996.

Gow, A.J., Meese, D.A., Alley, R.B., Fitzpatrick, J.J., Anandakrishnan, S., Woods, G.A., and Elder, B.C.: Physical and structural properties of the Greenland Ice Sheet Project 2 ice core: A review, J. Geophys. Res., 102(C12): 26559-26575, https://doi.org/10.1029/97JC00165, 1997.

Line 80: I would give details of the physicochemical properties obtained.

We did not fully understand what the reviewer intended to comment. If it was meant so that the authors should give details of the physicochemical properties obtained, at this stage of the introduction, our idea to revise this part as follows.

Present sentence:

The resulting data were compared with various physicochemical properties obtained from analyses of the DF ice core to better understand the factors influencing COF development.

Idea of revision:

The resulting data were compared with various chemical and physical properties of ice, such as major ions, amount of dusts, salt inclusions, grain size and so on, obtained from analyses of the DF ice core to better understand the factors influencing COF development.

Table 1: Could you explain in the text why the thickness at the EDC samples (Durand) are not indicated?

In two papers by Durand et al., we did not find information on the thickness at the EDC samples. However, because they used thin-section-based method, we guess it was approximately 0.5 mm or slightly less. We will explain it in the main text too.

Line 110: the authors do not explain why this study focuses on the upper 80% and not in the whole ice core. What are the difficulties to apply it in the bottom 20%? A discussion on this aspect will be useful.

To make readers better understanding, we will add following sentences:

It is noted that we expect that the interpretation of the COF from dielectric measurements will be *challenging below 2400 m due to the inclined layers and extremely coarse crystal grains. The layered structures began to be inclined relative to the horizontal layer; the inclination is less than 5^{o} above 2400 m, however, it reaches 20^{o} at 2800 m, and 50^{o} at 3000 m (Dome Fuji Ice Core Project Members, 2017). Additionally, the extremely huge coarse grains (with grain size of > 50 cm) are observed at the deepest part from visual inspection. The influences of these factors should be confirmed by experiments in the future. Therefore, we conducted the measurements to a depth of 2400 m in present paper.*

Figure 2. Colouring in red and blue the lines is not necessary as they do not provide extra information.

We will modify it as suggested.

Line 150: the detrended Ae value is a key parameter used in this work. It is mathematically defined in the text, but it would be very useful for readers to be able to see an explanation of what it value means, in practical terms.

We will add a following sentence at around Line 154:
The detrended $\Delta\varepsilon$ represents the relative degree of c-axis clustering and the extent of deformation relative to the surrounding depth.

Line 186. has the value of 0.0334 for the single ice crystal been determined in this study or does it come from the literature? In this case, a citation would be needed.

Thank you for pointing it out. Indeed, it comes from Appendix in Saruya et al., (2022). We will add "Appendix in Saruya et al., (2022)". (This paper was finally published in 2022.)

Line 213. Would it be possible to briefly explain the relationship between the permittivity value and the normalized eigenvalues? (here or in the caption of figure 6). I find the reference to Saruya et al. 2021 not enough, as this data is relevant for the conclusions.

We will add following sentences in the main text.
In Saruya et al., (2022), it was explained as,

$$\varepsilon_x = \varepsilon_{\perp} + \Delta\varepsilon\, a_1^{(2)}$$

in equation 5 (where ε_x is the relative permittivity along the principal axis x, $\varepsilon_{\perp}$ is the permittivity perpendicular to the c-axis). That is, if ε_x and ε_y (the relative permittivity along the principal axis y)

are approximately equal, these permittivity components have variable range as $\Delta\varepsilon\, a_1^{(2)}$.
Eigenvalues $a_1^{(2)}$ change from 0 to 1, while $\Delta\varepsilon$ =0.0334. $\varepsilon_\perp$ is also given in appendix in Saruya et al., (2022), as 3.1367. Using this relation, we can compare the values of eigenvalues and permittivity.
We will add explanation about it in the revised manuscript.

Figures 4 and 5: I suggest including the references at the legend, as in figure 7.

We will add a reference at the legend. Reference for the DF1 core is Azuma et al., (2000).

In general: please, check the graphics in all figures. Box and axis markers do not match (as in figure 7).

In figure 7, we slightly separated the bottommost tick from lower axis for the visibility. (Standoff function in Igor Pro). It was made in purpose.

Line 384: the reason why the presence of HCl has a stronger effect on dislocation migration than NaCl is explained later, in line 387. I suggest moving line 384 there to make the paragraph more understandable.

We will move the sentence.

Line 444: In general: It should be explained with a bit more detail, what the positive or negative feedback mechanism referred to Azuma (1994) does mean (Relationship between CPO and deformation conditions).

We will add sentences meaning following contents:
At very shallow depth where COF is close to random, the c-axes start to rotate toward compressional axis as the deformation progress. At this beginning stage, c-axes' rotation toward compressional axis cause temporally increase population (density) of slip planes close to the plane of maximum shear stress (45 degrees from the compressional axis). Then, deformation enhancement is temporally higher than that of the initial random fabric. This means, initial deformation made the ice softer; it is positive feedback. In contrast, as the development of fabric progresses more, ice becomes harder since these c-axes rotate further closer to the compressional axis; for majority population of the crystal grains, slip planes tend to rotate away from the plane of maximum shear stress. Then ice will be harder progressively; it is negative

feedback.

Line 499: Regarding the alteration of layers in the deep parts in ice sheets, here I miss some discussion with observations already done in ice cores (as in Faria et al., 2010; Jansen et al., 2016, etc…).

Thank you for your suggestion. We will add discussion about layer disturbance at the bottom part as follows:

Actually, layering disturbances and folding at the bottom part of ice cores have been observed in various ice cores (e.g., Svensson et al., 2005; Faria et al., 2010; Jansen et al., 2016). For example, Jansen et al. (2016) investigated the small-scale disturbances at bottom parts in the NEEM ice core from numerical modeling and concluded that the folding structures were initiated by the formation of tilted-lattice bands relative to the bulk COF. This conclusion seems to agree with the suggestions by Azuma and Goto-Azuma (1996).

In the EDC ice core, although the layering disturbances are not reported from visual inspections, highly fluctuated development of eigenvalues has been observed in Durand et al. (2009). Moreover, they reported there were no clear correlation between the fabric fluctuations and climate or chemical compositions. Below a depth of 2846 m, very small grains less than 1 mm were appeared between the large grains, which means the starts of crystal nucleation. Although the evidences of migration recrystallization such as interlocking grain boundaries were not observed, they suggest the possibility of migration recrystallization as the temperature is high enough. Thus, further and detailed investigations are required for a better understanding of the COF development and deformation regime at deeper part.

Conclusion and chapter 4.5 Implications for the deformation regime in ice sheets: both texts are very similar. I would modify the conclusion part in bullet points or in a more synthetised way, because as it is now it reads as a repetition of the explanation given in the previous section 4.5.

We agree with your suggestion. We will modify and simplify the “Conclusion” section with bullet.