List of changes according to the reviewer's comments:

<u>Substantial changes according to Ms. Maupins review comments:</u>

1. *about potential off-plane reflections that may affect the comparison between ultrasonic and COF-derived velocities – We revised the respective part of the Discussion section (lines 298-318) and further discussed the influence of off-plane reflections and of the grains size:*

"Furthermore, we also observed a clustering of grains with similar orientation. In particular, small grains surround a larger grain, usually called parent grain, as a result of strain-induced grain bounday migration with nucleation of new grains (called SIBM-N, see Faria et al. (2014)). The irregular shape of the grains and the clustering of grains with similar orientation may lead to differences between the two velocity profiles. The Fresnel zone is actually a volume (third dimension not shown in Fig. 5) with a size of a few cm3. The individual measurements are therefore capturing the full three-dimensional shape of the grains. Furthermore, the Fresnel Volume concentrates on a small volume within the sample. The clustering effect due to SIBM-N leads to an over-representation of some clusters within these limited volumes. Thus, these clusters around a few large grains are dominating the measured velocity profile. We have qualitatively analysed this effect and were able to find a combination of two or three clusters that reasonably fits to the actually measured ultrasonic velocity profile. However, several combinations of these four clusters led to similar results and we assume that the fit might also be a statistical effect. We could not find a profound physical explanation. Ultrasonic measurements followed by a COF analysis on the same piece of ice are required to analyse this further. In contrast to the ultrasonic measurements, the thin sections for the COF-derived velocity profiles only provide limited information in the third dimension. This is even more important for an estimated guess of the size of such branched and large grains. Grains close to the thin section but out of plane are invisible for the COF-derived velocity profiles. Furthermore, a cut through a branched large grain may let this grain appear as several small grains, usually called island grains (see Monz et al. (2021), their Fig. 3). A large grain is then underrepresented in the COF-derived profiles, but is more prominent in the Fresnel Volume and therefore more prominent in the velocities measured by the ultrasonic method. This can be regarded as an out–of–plane effect when comparing ultrasonic and COF-derived profiles. To reduce this off-plane effect, we have always combined sets of three thin sections perpendicular to each other (see Hellmann et al. (2021), their Fig. 4) to obtain the COF-derived profiles. As a consequence, the actual number of grains included in the calculations for the COF-derived profiles differs significantly from the number of grains included in the individual ultrasonic measurements, where a few branched large grains may be quite prominent in the actually measured ice volume (see Fig. 5)."

2. *Figure 4 is a very central figure. The data are actually duplicated from a 0-180 to a 0-360 degrees range. I think this might increase artificially the impression of fit and should be avoided. It would be interesting to have the vertical velocity in the same figure, as an extra small column to the right for example, in order to exploit more the vertical direction velocity in the interpretation.*

We adjusted the Figure (0-180° range) and added the vertical measurements to Fig. 4 (and Fig. 6). For clarifying that these measurements contain a periodicity, we have added the first/last measurement to the end/beginning of the profile.

3. *lines 129-130: I do not understand what you are saying here. Your step 4 is a Voigt average (linear average of elastic tensors); when you say here "seismic velocities", do you mean you take the Voigt average (and Reuss and Hill) to calculate the isotropic mean velocities?*

We rephrased this sentence as follows:
The seismic velocities can be calculated from the elasticity tensor or the inverse compliance tensor. Both approaches provide velocity profiles oscillating around an upper (Voigt bound) and lower (Reuss bound) mean velocity (Hill, 1952). We calculated the seismic velocities from both tensors to obtain these upper and lower bounds of the potential velocity range and further derived the velocity profile from the Hill tensor (the mean of elasticity and compliance tensor).

4. *line 163: unclear sentence. The small wavelength does not favour that the individual measurements are a good integrated representation of the whole sample. Do you want to point out here that the wavelength is smaller than the grain size? Anyway, it is only the Fresnel zone dimension that matters to see if the wave field sees one grain at a time along its propagation, not the wavelength.*

We rephrased the sentence for clarification: "Thus, the wavelength is small enough to measure an integrated seismic velocity. This velocity can be regarded as the integrated velocity of the individual grain velocities. Much larger wavelengths may introduce geometric issues such as stationary waves, which are not representative for acoustic waves travelling through the glacier and thus would later inhibit a comparison with in-situ data."

5. *line 186: it seems there are many dark points within the clusters. It is not clear to me why they have been removed.*

Indeed, we excluded all grains below 0.5 mm^2 (< 1250 pixels). Those grains usually occur in fissures and as patches within the ice core. However, we reviewed the effect of these small grains and realised that they only minimally affect the calculated velocities (because the grain size is used as weighting factor for the sum over the velocities of the individual grains), visible changes only appear at 22 m and 45 m depth. Therefore, we also include these grains to avoid confusion. We changed Fig 2, 3, 4 and 6 respectively.
During this review, we realised that we used a wrong input file for the velocity calculations in 33 m and corrected this issue (minor changes visible in this figure).

6. *line 228: The coincidence is not as good as stated by this sentence. The maxima for the COF and measured coincide only at depths 2 and 22m. For the three other depths, they do not coincide at all. At 45m, the maximum for the measured coincides with a minimum in COF.*

Together with the new Fig. 4, this discrepancy becomes more obvious and we extended this sentence as follows (to correct for this imprecision):
"All 5 samples show a set of 2 maxima surrounded by 4 minima and 2 local side-maxima. For the samples at 2, 22 and 65 m the positions of the maxima for measured and COF-derived profiles coincide within a range of a few degrees of azimuth (≤15°, Figs. 4a, b, e). At 33 m, there exist a significantly larger azimuthal shift (30°, Fig. 4c) and for the sample at 45 m maxima of one profile coincide with a minimum of the other (Fig. 4d)."

<u>Changes according to Mr. Priors recommendations (Community Comment) and Ms. Maupins review comment to line 218*:*</u>

about the influence of the core diameter on the anisotropy:

"Due to the thermal drilling method, thin water layers refroze along the ice core surface, which led to a rough and partially concave surface. This uneven surface and the limited height of the transducer's tip resulted in a poor coupling and we removed the outermost 3 mm thin ice layer (i.e. this meltwater "skin") by lathing the sample. The ice core diameter was then determined manually for each individual measurement.”

<u>Smaller changes according to Ms. Maupins line by line comments:</u>

line 14: "concise": should be "consistent"?

Indeed, this should be consistent, changed.

Figure 2 is cited before Figure 1, as far I can see, and you should normally exchange the figure numbers. As Figure 1 is a good overall summary of your set-up, find a way to cite it before?

We added a reference to Fig 1c before referencing this Fig 2a-g here.

line 44-45: rephrase. "since..." does not really make sense with beginning of sentence.

We rephrased this sentence as follows:
These methods investigate the elastic parameters of the ice. Since elastic parameters and COF are directly related, the methods can also be employed for COF analyses.

line 59: benchmark to what?

We replaced this term by “relevant measurement parameter”.

line 101: move sentence to line 128, as this gives the impression you won't give any details, but you give them afterwards, and they are necessary.

We agree that this sentence may confuse the reader. Therefore, we combined parts of this sentence with text from line 128 and formulated a new sentence in line 129: “The calculations for the polycrystalline tensor and acoustic velocities are described in more detail in Maurel et al. (2015) and Kerch et al. (2018).”

line 133: at this point you have not said you measure at -5deg. You have said you have frozen the core to -30deg.

This is true. We rephrased the sentence and added in parentheses that the measured temperature is -5°C as described below. However, at this stage the exact temperatures are not necessary and in addition, they vary between ultrasonic and in-situ experiments.

line 199: would be good here to have the pure ice value for comparison.

The given values in this section (incl. Table 1, Fig. 2) are the pure ice values. We clarified this in the captions of Fig 2 and Table 1. We applied the air correction for the first time, when comparing the data with the ultrasonic measurements (Fig. 3).

line 230: One curve does not look like a smooth version of the other; I do not think you can blame the smoothness for the difference in amplitude.

We rephrased the respective sentence: “The COF-derived profiles are in general rather levelled with smaller differences between the minima and maxima.”

line 230: This section is about the horizontal velocities, that do not increase with depth. You might remove this sentence.

We have removed this sentence.

line 247: you say that the air bubbles not associated with grain boundaries are spherical, but what about the grain boundary bubbles?

We have added a sub-sentence in parentheses to clarify that bubbles on grain boundaries are influenced by the grain boundary processes and that other processes complicate an interpretation: “(and therefore not pinned to and affected by the boundary pathways)”.

We also corrected some typing errors and replaced the reference to Hellmann et al. (2020, preprint in TCD) and Monz et al. (2020, preprint in TCD) with the published versions Hellmann et al. (2021) and Monz et al. (2021).