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Ultrasonic velocity experiments on ice cores to complement fabric measurements

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The ice crystal structure and in particular the crystal orientation fabrics (COF) provide valuable information about the deformation history of ice sheets and glaciers. Therefore, COF analysis has been among the standard measurement techniques for most deep ice core drilling projects in the last three decades. The analysis depends on carefully prepared thin sections of ice that are measured with cross-polarised light microscopy or electron backscattering and diffraction (EBSD). The preparation of thin sections is labour-intensive and therefore only a discrete number of samples along the ice core is usually analysed. Geophysical methods such as ultrasonic sounding along the ice core could be employed to complement the discrete fabric data by providing data to fill the gaps. A suitable method needs to be reasonably fast, ideally non-invasive and provides unambiguous information in combination with the established methods.

In our study, we demonstrate the feasibility of such ultrasonic experiments applied to an ice core to support the approved cross-polarised light microscopy method. Point-contact transducers transmitted ultrasonic waves into ice core samples from a temperate glacier. X-ray computer tomography measurements provide the required information to consider the effect of a two-phase medium (ice and air bubbles) in a porosity correction of the velocity. We determined the azimuthal variation of the seismic velocity. This variation is a result of seismic anisotropy due to the crystal orientation within the ice core volume. The measurements can be acquired within minutes and do not require an extensive preparation of ice samples.

In addition, the COF of adjacent ice core samples was measured with cross-polarised light spectroscopy. From this, we derived the elasticity tensor and finally calculated the associated seismic velocities for the same azimuth and inclination angle as for the ultrasonic experiments. We compare these two velocity profiles and discover a significant discrepancy in presence of large ice grains. However, with an increasing number of ice grains both methods provide similar results. Although the ultrasonic measurements reveal some ambiguities, these can be resolved when considering the information derived from the standard analysis.

We conclude that ultrasonic measurements along the ice core are suitable to support the established COF analysis for sufficiently small grains as found in polar cores. We recommend further exploration of the potential of the presented technique as it provides both the chance to obtain a continuous fabric profile and a direct link to large-scale seismic measurements in the vicinity of ice core drilling sites.

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