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Comparison of seismic velocities derived from crystal orientation fabrics and ultrasonic measurements on an ice core

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Understanding the internal structure of glacier ice is of high interest for studying ice flow mechanics and glacier dynamics. The micro-scale deformation mechanisms cause a reorientation and alignment of the ice grains resulting in a polycrystalline structure with a strong anisotropy. By studying the crystal orientation fabric (COF), details about past and ongoing ice deformation processes can be derived. Usually, obtaining COF requires a work-intensive ice core analysis, which is typically carried out only at a few ice core samples. When similar information can be obtained from geophysical, for example, seismic experiments, a more detailed and more continuous image about the ice deformation would be available.

For checking the suitability of seismic data for such purposes, we have analysed the COF of several ice core samples extracted from Rhone Glacier, a temperate glacier located in the Central Swiss Alps. The COF analysis yield a polycrystalline elasticity tensor for a given volume of ice, from which we predicted seismic velocities for acoustic waves originating from any azimuth and inclination. The seismic data predicted were then verified with ultrasonic experiments conducted along the ice core in the vicinity of the analysed COF. Additional X-ray tomographic measurements yield further constraints about the microstructure, especially about the air bubble content in the ice affecting the data of the ultrasonic experiments. Predicted and measured velocities generally show a good match. This is a very encouraging result, because it suggests that in-situ measurements of seismic velocities can be employed for studying ice deformation. A possible option is to perform seismic cross-hole measurements within an array of boreholes drilled into the glacier ice.