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Assessing microscale anisotropy of a temperate glacier with seismic and radar borehole measurements

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The anisotropy of polycrystalline ice due to a preferred crystal orientation has a significant influence on the glacier's ice flow dynamics. However, the determination of the ice crystal orientation is sophisticated and non-trivial. Usually, an ice core analysis is required, including the preparation of thin sections and the analysis of the ice crystals c-axis orientation in these sections. With this method, only discrete measurements at selected depths can be obtained. The crystal orientation and the connected physical properties have a direct influence on wave propagation of seismic and radar signals. Hence, both geophysical methods are suitable to investigate the ice crystal anisotropy and they provide continuous volumetric information. Furthermore, these two methods complement each other since radar and seismic wave velocities are inversely affected by the crystal orientation distribution. Unfortunately, macroscopic anisotropy effects (e.g. induced by crevasses, pockets, or water and air inclusions) overlay with the microscopic crystal anisotropy. For studying all these effects in detail, we performed a comprehensive experiment on the temperate Rhone Glacier, located in the Central Swiss Alps. We drilled twelve boreholes, arranged in a ring with a diameter of 40 m, into the glacier. This configuration allowed to obtain numerous seismic and radar cross-hole measurements with a large azimuthal coverage. We performed 2D inversions along tomographic planes that were parallel to perpendicular to the glacier flow direction. With these analyses, we attempt to distinguish between anisotropy effects resulting from crystal anisotropy and macroscopic anisotropy effects. To validate our results, we compared these findings with crystal orientation data of an ice core retrieved from an additional borehole in the centre of the investigation area.