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Towards a seismic anisotropy strategy for the rheological characterisation of temperate ice masses.

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Cross Borehole seismic surveys were carried out at Glacier de Tsanfleuron, Switzerland, in order to characterise the internal structure and gross ice crystal orientation in its upper ablation zone. Seismic velocities were found to be in the region of 3550 ms^{-1} to 3700 ms^{-1}, with a mean velocity of approximately 3650ms^{-1}. This is in agreement with velocities suggested in other temperate ice masses. Field data suggests that anisotropy increases with depth. Sources of anisotropy, such as crystal orientation or anisotropic water inclusions can also be identified. We estimate crystal orientation by determining the relationship between the velocity of waves travelling between boreholes and direction of travel. Minimum wave velocity occurs perpendicular to the c-axis orientation of the ice crystal. Therefore we are able to calculate gross c-axis trends through an ice mass. Estimations of crystal orientation are in agreement with crystal fabric analysis carried out on ice cores previously extracted from the glacier. We identified buried crevasses through changes in the signal amplitude and frequency. Buried crevasses can also contribute to velocity anisotropy. The field data will allow validation of a seismic anisotropy strategy currently being developed to determine patterns of c-axis orientation within temperate ice. Such patterns are difficult to map using existing field techniques, but are important for the calibration of flow models of temperate and polythermal ice masses.