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Constraining ice anisotropy and temperature from active source borehole seismology in the Ross Ice Shelf

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During the 2017/18 season of the Aotearoa Ross Ice Shelf Drilling Program two climate and oceanographically motivated hot water drill boreholes were drilled through ~370 m of ice in the central Ross Ice Shelf. These boreholes were spaced at a distance of ~560 m along the ice flow direction. This provided an unique opportunity to use cryoseismology to study ice shelf fabrics and temperature, which both are crucial parameters for ice deformation behavior.
One borehole was instrumented with eight frozen in 3-component, 15 Hz seismometers at 35 m spacing between depths of 80 m and 325 m inside the ice column. These recorded seismic waves excited from a sparker borehole seismic source that was fired in 10 m spacing between depths of 70 m and 270 m inside the second borehole. This is, to our knowledge, a world-first seismic cross-hole experiment in ice. Shooting seismic waves along nearly isothermal raypaths through the ice shelf allows an multi-depth investigation of englacial temperatures from measurements of seismic attenuation and velocity. Thermistors that are collocated with the borehole seismometers provide temperature measurements at depth to calibrate the seismic observations.

A multi-azimuth and multi-offset experiment using surface hammer-and-plate and shear-wave seismic sources was also recorded on the eight-level borehole sensors to study seismic anisotropy of the ice shelf. The observation of variable seismic shear wave splitting along different raypaths informs the ice shelf mechanical anisotropy at this location that formed from flow deformation and will influence future flow dynamics. A potential explanation of the observed seismic anisotropy from a synthetic crystallographic preferred orientation forward model in the ice with its implications for ice shelf deformation history is discussed.