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Session03: Interpretation of Observed Seismic and Acoustic Signals from the Solid Earth and the Cryosphere

Modelling the crystallographic preferred orientation (CPO) of a fast-shearing Antarctic ice glacier from seismic anisotropy

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The flow behaviour of natural ice is fundamentally influenced by the ice crystallography because dislocation glide on the ice basal-plane is much easier than on other planes. Consequently, an anisotropic crystallographic preferred orientation (CPO) will develop as the c-axes of polycrystalline ice keep rotating and lining up under stress. The CPO records the ice deformation history and has been associated with accelerating rate of ice flow. Understanding CPO and measuring CPO across large ice masses is important in assessing the ice flow response to global warming. Measurements of seismic anisotropy have been proven practical in constraining the large scale CPO of ice flow because the sound wave travels up to 5% faster along the c-axes of ice crystals.

Here we present active-source seismic observations on a fast-flowing shear margin in the lower-stream of the Priestley Glacier, Antarctica. Four strings of single-component or three-component geophones were deployed parallel or perpendicular to the ice flow direction. The geophones recorded the seismic waves from seventeen separated explosive sources, where each source was buried at the depths of ~2 m. Source and receivers were all placed in hard ice leading to very high data quality with no noise from scattering events. We extracted the direct ray-path P-wave and S-wave arrival times and shear wave splitting (SWS) parameters from the raw geophone measurements. The regional seismic anisotropy was quantified from the P-wave and S-wave velocities and the SWS parameters relative to the ray path azimuth and inclination. These data were compared with the velocities and splitting parameters expected for different ray paths, as generated from forward models of the polycrystalline elastic stiffness tensor based on experimentally deformed ice samples. The result shows that the fast-flowing ice shear margin in the Priestley Glacier is dominated by a CPO with the c-axis clustered perpendicular to the shear plane. This CPO is likely to be critical in controlling the rate of marginal deformation associated with further glacier flow and with ice shelf break-up. The result suggests that it is essential to consider the anisotropic ice CPO in ice-sheet modelling to predict the future sea level.