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Seismic Anisotropy Tomography from Glacial Microseismicity: an Antarctic Example

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Much of the uncertainty in current prognosis on sea level rise originate from different predictions for the contribution of the West Antarctic Ice Sheet. This contribution is mostly constrained from large-scale ice sheet models, which are designed to understand the ice sheet behaviour in response to external forces. An essential part of such models are flow relations, which relate applied stress and the deformation in the ice. Stress modifies the internal structure of glacial ice through the alignment of individual anisotropic ice crystals. The internal structure of ice, hereafter referred to as ice fabric, then influences the mechanical properties, and therefore the flow pattern of ice streams. Fabric is therefore an important element when modelling ice flow.

Here, we show that shear wave splitting (SWS) of glacial microseismicity can be used to invert for seismic anisotropy and ice fabric at Rutford Ice Stream (RIS). RIS is a fast-flowing Antarctic ice stream, a setting crucial for informing flow models but for which few direct observations of fabric exist.

We present 202,651 SWS measurements from RIS, using three months of data from a 38-station passive seismic network, deployed in 2018/19. Results indicate seismic anisotropy of up to 6.6% in the glacial ice, which has a thickness of ~2.2. km at our study side. However, anisotropy strongly varies depending on azimuth and incidence angle of the seismic rays. We invert the data for depth-dependent ice fabric, making use of the fact that different types of ice fabric can be discriminated against each other based on their anisotropic pattern. The layout of the input models for inversion is designed based on prior knowledge from radar. We find that the following three-layer model fits the data best: a broad vertical cone near the base of RIS (500 m thick), a thick vertical girdle, orientated perpendicular to flow, in the middle (1200 m thick) and a tilted cone fabric in the uppermost 400 m. Such a fabric would cause a depth-dependent strength profile of the ice with the middle layer being harder to deform along flow than across flow. If such a configuration is representative for fast-flowing ice streams, it would call for a more complex integration of viscosity in ice sheet models.

Category

Geophysics

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