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Downhole distributed acoustic seismic profiling at Skytrain Ice Rise, West Antarctica

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Antarctic ice sheet history is imprinted in the structure and fabric of the ice column. At ice rises, the signature of ice flow history is preserved due to the low strain rates inherent at these independent ice flow centres. We present results from a distributed acoustic sensing (DAS) experiment at Skytrain Ice Rise in the Weddell Sea Sector of West Antarctica, aimed at delineating the englacial fabric to improve our understanding of ice sheet history in the region. This pilot experiment demonstrates the feasibility of an innovative technique to delineate ice rise structure. Both direct and reflected P- and S-wave energy, as well as surface wave energy, are observed using a range of source offsets, i.e., a walkaway vertical seismic profile (VSP), recorded using fibre optic cable. Significant noise, which results from the cable hanging untethered in the borehole, is modelled and suppressed at the processing stage. At greater depth, where the cable is suspended in drilling fluid, seismic interval velocities and attenuation are measured. Vertical P-wave velocities are high (V_{INT} = 4029 ± 244 m s^{-1}) and consistent with a strong vertical cluster fabric. Seismic attenuation is high (Q_{INT} = 75 ± 12) and contrary to observations in ice sheets over this temperature range. The signal level is too low, and the noise level too high, to undertake analysis of englacial fabric variability. However, modelling of P- and S-wave traveltimes and amplitudes with a range of fabric geometries, combined with these measurements, demonstrates the capacity of the DAS method to discriminate englacial fabric distribution. From this pilot study we make a number of recommendations for future experiments aimed at quantifying englacial fabric to improve our understanding of recent ice sheet history.