EGU21-7556
https://doi.org/10.5194/egusphere-egu21-7556
EGU General Assembly 2021

Seismic quality factor measured for compressional and shear waves in the firn column of Korff Ice Rise, West Antarctica

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Comprehensive descriptions of the seismic properties of glaciers and ice masses require that both compressional (P-) and shear (S-) wave components are considered. Among these properties is the seismic attenuation, expressed by the Quality Factor (Q). Q is valuable for two reasons: first, to correct measurements of seismic amplitude for wavelet propagation effects, as in reflection amplitude-versus-angle (AVA) studies. Second, Q is an indicator of ice properties such as temperature and impurity content, and laboratory/field studies of soils and geological materials suggests that the ratio of the compressional- and shear-wave quality factors, Qp/Qs, may indicate fluid saturation (particularly when considered jointly with the velocity ratio Vp/Vs). Thus, a measurement of Qp/Qs could usefully inform the hydrological structure of the firn and indicate variations in the density of the firn column.

Despite its importance, few studies appear to have measured Qp in firn columns and none appear to have measured Qs in firn. Doing so for either compressional- or shear-wave arrivals is challenging, due to the ray paths followed by the diving wave first arrivals and their accurate representation in attenuation measurement methods. In preparation for an AVA study of bed properties at Korff Ice Rise, West Antarctica, we have used spectra of diving wave first arrivals and a modified spectral-ratio method to measure Qp and Qs as a function of depth in the firn column. Shot gathers with vertically oriented geophones at offsets of 2.5 - 1000m were used to measure Qp. For detecting the shear component, the geophones were oriented horizontally; in this configuration, diving and reflected shear phases were recorded with high signal-to-noise ratios. The variation of Q with depth is represented as discrete constant-Q layers with thicknesses between 6 and 27 m. Qp shows progressive increases in depth from 21 ± 3 in the uppermost 20 m (where Vp < 3000 m/s), to 246 ± 30 between 74 and 80 m depth (3750 m/s < Vp < 3770 m/s). Qs increases from 14 ± 4 in the uppermost 20m, to 80 ± 6 between 80 and 90m depth. The ratio Qp/Qs varies throughout the depths measured, from Qp/Qs ~ 1.5 at the surface, to Qp/Qs ~ 3 at 80 m. This is broadly consistent with previously quoted values, but the variation may imply that Qp/Qs is influenced by firn structure.

Similar measurements at a variety of sites could help to inform a relationship between Qp, Qs and

firn properties. In the immediate future, the measurement of Q in the firn will aid measurements of bed reflectivity, and help to determine the material properties of the ice-bed interface.