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Influence of anisotropy on seismic data, Colle Gnifetti, Switzerland

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A possibility to detect anisotropy in ice sheets and glaciers is by analyzing seismic data. Two effects are impotant: (i) sudden changes in crystal orientation fabric (COF) lead to englacial reflections and (ii) the anisotropic fabric induces an angle dependency on the seismic velocities and thus also traveltimes.

In 2010 a seismic survey using a micro-vibrator source (ElViS) was carried out in compression (P)- and shear (SH)-wave mode at Colle Gniefetti, Switzerland. In both cases reflections could be observed in the firn and ice column. We use eigenvalue COF data from a nearby ice-core to derive elasticity tensors and thus have the possibility to model traveltimes and reflection coefficients of seismic P- and SH-wave data. By comparison of the modeled with the measured data we are able to connect some of the observed reflections to changes in crystal orientation fabric. Further a discrepancy occurred for the depth of the bed reflection between the P-, SH-wave and ice-core data. While the depth of the SH-wave bed reflection fitted quite well to the ice-core depth, the P-wave bed reflection was to shallow after depth conversion. We are able to explain these differences with the conceptual errors introduced by assuming isotropic media and thus using velocities traditionally derived from stacking (normal moveout (NMO)-velocity), with an offset-to-depth ratio of one, for the depth conversion. The NMO-velocity includes the lateral velocity variations and can differ from the vertical root-mean-square (RMS) velocity for P-waves by up to 20%, for SH-waves only by up to 7% in case of single maximum fabric. Modeling velocities at Colle Gnifetti based on the ice-core COF can quite well explain the largest part of the introduced depth difference for the P-wave, while it also shows that the existing anisotropies only introduce a difference between NMO- and vertical RMS-velocity of 1% for the SH-wave.

Our data show that it is highly important to include anisotropy into the depth conversion of seismic data on glaciers and ice sheets, especially the error in depth conversion of the P-waves becomes considerable otherwise. This implies that we are able to derive information about anisotropies from the depth difference of seismic P-wave data when the correct depth is known from other data sources like boreholes or radar data.