EGU21-2129, updated on 20 Oct 2021
https://doi.org/10.5194/egusphere-egu21-2129
EGU General Assembly 2021

A microstructure-based parameterization of the effectivetransverse isotropic elasticity tensor of snow, firn, and porous ice

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Effective elastic properties of snow, firn, and porous ice are key for various applications and influenced by ice volume fraction and different types of anisotropy. The geometrical anisotropy of the ice-matrix created by temperature gradient metamorphism in low-density snow and firn and the crystallographic anisotropy commonly created upon deformation in high-density, porous ice. Towards a quantitative-distinction of the impact of the different anisotropies on elasticity, we derived a parametrization for the effective elasticity tensor over the entire range of volume fractions as a function of density and geometrical anisotropy. We employed FEM simulations on 395 X-ray tomography microstructures of Lab, Alpine, Arctic, and Antarctic samples. We employed an empirical two-parameter modification of the anisotropic Hashin Shtrikman bounds to obtain a closed-form parametrization accounting for density, anisotropy, and the correct limiting behavior for bubbly ice. We compare our prediction to previous parametrizations derived in limited density regimes and we utilize the Thomson parameter to compare the geometrical-elastic anisotropy to the crystallographic-elastic anisotropy of monocrystalline ice. Our results suggest that a coupled treatment of geometrical and crystallographic effects would be beneficial for a careful interpretation of acoustic measurements in deep firn.