Geophysical Research Abstracts
Vol. 18, EGU2016-10854, 2016
EGU General Assembly 2016

Uncertainty in Ice Crystal Orientation Distributions in Ice Sheets

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Crystal-orientation fabrics in polar ice sheets have a strong influence on ice flow due to the plastic anisotropy of ice. Crystal orientations evolve primarily in response to applied strain, but are also affected by temperature, impurities, interactions with neighbors, and other factors. While the evolution of each ice crystal is physically deterministic, in limited samples, such as those from ice-core thin sections, measured samples are stochastic due to sampling error. Even in continuum representations from models, crystal orientation distribution functions (ODFs) can be treated as stochastic due to uncertainties in how they developed. Here, we present results on the statistics of crystal orientation fabrics. We show a first-order estimate of the sampling distribution of fabric eigenvalues and fabric eigenvectors from ice-core thin sections. We also analyze uncertainty in electron backscatter diffraction measurements. In addition to sampling error, the strain histories of fabrics are generally poorly constrained, and may have varied in unknown ways through time. Nearby layers in ice sheets can also experience different strain histories due to inherent variabilities such as transient flow, or differences in impurities. This means that the continuum ODF itself can be treated as stochastic, because it depends on an effectively-stochastic unknown strain-history. To explore this, we analyze the effects of strain and vorticity variability on the evolution of the continuum ice-crystal ODF. We recast Jeffery's equation for the evolution of the ODF as a stochastic differential equation, with vorticity and strain perturbed by Gaussian processes. From this, we run a Monte-Carlo ensemble to determine likely bounds of true continuum ODF variability in response to random perturbations of strain and vorticity.