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Extending the fabric from the EGRIP ice core in space with geophysical methods and modelling

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Anisotropic crystal fabrics in ice sheets develop as a consequence of deformation and hence record information of past ice flow. Simultaneously, the fabric affects the present-day bulk mechanical properties of glacier ice because the susceptibility of ice crystals to deformation is highly anisotropic. This is particularly relevant in dynamic areas such as fast-flowing glaciers and ice streams, where the formation of strong fabrics might play a critical role in facilitating ice flow. Anisotropy is ignored in most state-of-the-art ice sheet models, and while its importance has long been recognized, accounting for fabric evolution and its impact on the ice viscosity has only recently become feasible. Both the application of such models to ice streams and their verification through in-situ observations are still rare. Ice cores provide direct and detailed information on the crystal fabric, but the logistical cost, technical challenges, particularly in fast-flowing ice and shear margins, difficulty in reconstructing the absolute orientation of the core, and their limitation of being a point measurement, make ice cores impractical for a spatially extensive evaluation of the fabric type. Indirect geophysical methods applied from or above the ice surface create the link between the small scale of laboratory experiments and ice–core observations to the large-scale coverage required for ice flow models and the complete understanding of ice stream dynamics. Here, we present a comprehensive analysis of the distribution of the ice fabric in the upstream part of the North-East Greenland Ice Stream (NEGIS). Our results are based on a combination of methods applied to extensive airborne and ground-based radar surveys, ice- and firn-core observations, and numerical ice-flow modelling. They show that in the onset region of NEGIS and around the EGRIP ice core drilling site, the fabric is horizontally strongly anisotropic, forming a horizontal girdle perpendicular to the ice flow, while the horizontal anisotropy reduces quickly over distances of less than five ice thicknesses outside of the ice stream's shear margins. Downstream of the drill site, the fabric develops into a more vertically symmetric configuration on a time scale of around 2 ka, the first observation of this kind. Our study shows how ice-core based fabric observations, geophysical surveys and ice-flow modelling complement each other to obtain a more comprehensive picture of the spatially strongly varying fabric.

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