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The effect of anisotropy on simulated ice dynamics: an idealised ice shelf example using the Ice Sheet System Model

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An essential component of an ice sheet model is its description of how ice deforms under applied stresses – its material constitutive relation. Current large-scale ice sheet models routinely rely on Glen's flow relation, which is an isotropic material constitutive relation that is not dependent on the character of the stress applied. However, laboratory experiments subjecting ice to simultaneous simple shear and compressive stresses (a typical situation in ice sheets) show that with sustained deformation under constant stresses, steady state viscous creep becomes anisotropic. For various combinations of simple shear and compression, results show that flow enhancement further increases as the stress configuration becomes dominated by simple shear. The empirical, scalar, tertiary, anisotropic rheology (ESTAR) is a computationally-efficient flow relation that incorporates anisotropic effects through a parameterisation for a flow enhancement factor that takes into account the proportion of simple shear in the overall stress regime. Here, we use the Ice Sheet System Model to investigate the impact of anisotropy on the dynamics of an idealized ice shelf by comparing simulated flow fields using ESTAR with those of the standard (isotropic) Glen flow relation. When enhanced to match simple shear flow rates, the Glen flow relation overestimates velocities at the ice-ocean front by up to 36%. Significantly, no single Glen enhancement factor accurately captures the spatial variations in flow over the ice shelf produced by ESTAR. Our results have implications for reconstructions and projections of sea level using ice sheet models that do not account for anisotropy.