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GCM sea ice rheology determined from sub-continuum mechanics

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Sea ice rheologies that are used in Global Climate Models (GCMs) are defined for a continuum scale that is large enough so that averaging over the sub-continuum yields isotropic behaviour. The minimum resolution of GCMs is therefore limited so that this assumption is still valid. A model to determine large-scale stress from imposed large-scale strain-rate, small-scale material rheology, and small-scale geometry is developed. The model is based on a simple kinematic model to describe the motion of the floes in the domain of interest. The individual cracks between the floes are assumed to be plasticly deforming, and the stress in each crack is estimated from a Reduced Reiner-Rivlin constitutive relationship. Existing material rheologies that have been applied to sea ice such as the viscous-plastic rheology [e.g. Hibler and Schulson, 2000] are taken as the small-scale rheology. The estimates of large-scale stress are estimated by area averaging the stresses in the individual cracks. Analytical results for a simple geometry consisting of square sea ice floes are presented. This reveals the yield curve sensitivity of the large-scale stress to the relative orientation of floes. Considering ensemble averages over all orientations of the square geometry yields alignment of the principal axes of stress and strain-rate. The methodology allows for the estimation of large-scale compressive strength from the small-scale compressive strength of sea ice. Future work will incorporate a laboratory determined material rheology.