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Anisotropic continuum model of granulated sea ice

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A continuum model describing sea ice as a layer of granulated thick ice, consisting of many floes, intersected by long and narrow regions of thinner ice, known as leads, is developed. We consider the evolution of mesoscale leads, formed under extension, whose lengths span many floes, so that the surrounding ice is treated as a granular plastic. The leads are sufficiently small with respect to basin scales of sea ice deformation that they may be modelled using a continuum approach. The model includes evolution equations for the orientational distribution of leads, their thickness and width expressed through second-rank tensors and terms requiring closures. The closing assumptions are considered for the case of negligibly small lead ice thickness and the canonical flows types of pure and simple shear, pure divergence and pure convergence. We present a continuum-scale sea ice rheology that depends upon the isotropic, material rheology of sea ice, the orientational distribution of lead characteristics and the thick ice thickness. Calculations show that the model produces physically reasonable behaviour and overcomes two significant deficiencies of a previous model of sea ice dynamics, introduced by the authors: (i) It prevents thick ice thinning under extension; (ii) The consideration of the thick ice as a granular material eliminates the problem of indefinite lead opening under pure shear.