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Linear kinematic features as mathematical characteristics of brittle coulombic failure

W. Hibler (1), E. Schulson (2), and R. Kwok (3)

(1) International Arctic Research Center, University of Alaska Fairbanks, USA, (2) Thayer School of Engineering, Dartmouth College, USA, (3) Jet Propulsion Laboratory, Pasadena, California, USA

In recent work Hibler and Schulson (2000) have argued that brittle coulombic failure as observed in the laboratory should also apply to the description of sea ice mechanics on the geophysical scale. A characteristic of failure with this type of rheology is the formation of intersecting faults. Using a minimum energy principle together with a non normal flow rule coulombic rheology the equations of motion for a series of rigid plates undergoing coulombic failure at the plate junctions is derived for the general geophysical case of sea ice subjected to wind and water body forces. In this general case the faults at the plate junctions are shown to be mathematical characteristics of the equations of motion with intersection angles dependent both on the internal angle of friction of the failure curve and the flow rule. This angle is found to differ considerably from the fault angle predicted from classical static arguments only from the internal angle of friction. Verification for this theory is carried out via numerical simulations with fixed wind forcing fields and also with a more complex spatial forcing field derived from instantaneous M2 tidal forcing on the Arctic ice cover. In the simulations, by initializing the model with random strengths and then letting the system weaken and/or strengthen under the fixed forcing intersecting linear kinematic features naturally develop with intersection angles in good agreement with the mathematical characteristic theory. The theory also supplies an effective spacing between dynamic linear kinematic features dependent on spatial gradients of the wind and water body forces and the average ice strength. An additional ramification of this minimun energy theory is that variations of the energy of an arbitrary arrangement of intersecting faults can not be used to derive an aggregate rheology for sea ice as has been proposed by a number of authors in the literature. This is because only the minimum energy arrange-

ment of faults obeys Newtons laws for a given set of body forces, boundary conditions and ice rheology.