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The effect of shear rupture on aggregate scale formation in sea ice

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A discrete element model is used to study shear rupture of sea ice under convergent wind stresses. The model includes compressive, tensile and shear rupture of viscous-elastic joints connecting floes that move under the action of the wind stresses. The adopted shear rupture is governed by Coulomb's criterion. The ice pack is a 400 km long square domain consisting of 4 km size floes. In the standard case with tensile strength ten times smaller than the compressive strength, under uniaxial compression the failure regime is mainly shear rupture with the most probable scenario corresponding to that with the minimum failure work. The orientation of cracks delineating formed aggregates are bi-modal with the peaks around the angles given by the wing crack theory determining diamond-shaped blocks. The ice block (floe aggregate) size decreases as the wind stress gradient increases since the elastic strain energy grows faster leading to a higher speed of crack propagation. As the tensile strength grows, shear rupture becomes harder to attain and compressive failure becomes equally important leading to elongation of blocks across the compression direction and the blocks grow larger. In the standard case, as the wind stress confinement ratio increases the failure mode changes at a confinement ratio of around 0.2-0.4, which corresponds to the analytical critical confinement ratio of 0.32. Below this value the cracks are bi-modal delineating diamond shape aggregates, while above this value failure becomes isotropic and is determined by small scale stress anomalies due to irregularities in floe shape.