Modelling land fast ice in a viscous plastic model

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This talk outlines our attempts to model fast ice using a “Hibler-type” VP model

Modeling assumptions

Application in the Kara Sea

Problems
Small-scale sea-ice exhibits cohesion while geophysical sea-ice does not.

There’s no cohesion on the geophysical scale because each grid cell is assumed to contain a large number of ice floes.
How does land fast ice become land fast?

Attached to pressure ridges?

Or arched like a stone bridge?

Mahoney et al (2007)

Consider Hibler’s model - can we use it?

Uniaxial compressive strength

Pure divergence - no strength

Cohesion exists using an elliptic yield curve and may be controlled by changing the eccentricity (e.g. Dumont et al 2008)
Cohesion under divergence can be achieved by shifting the ellipse

Uniaxial compressive strength

Cohesive strength in divergence

(König Beatty and Holland, 2009)
Plasticity can only be achieved if the modelled stresses lie on the yield curve

This is often not the case resulting in “mostly viscous slightly plastic” models (figure from Hunkie and Zhang, 1999)
Plastic convergence is hard to reach!

$\sigma$ depends on $\zeta, \eta, u$ and $v$ with $\zeta$ and $\eta$ non-linearly dependent on $u$ and $v$

$$\frac{d\vec{v}}{dt} = \vec{r}_a + \vec{r}_w - mf\vec{k} \times \vec{v} - mg\nabla H - \nabla \cdot \sigma$$

A very small time step is needed for plastic convergence

VP: A large number of pseudo-time steps

EVP: A very small elastic time step
Application in the Kara Sea
Ice velocity should be used to recognize fast ice

This is easy when the wind blows offshore
Flaw polynyas and new ice are also useful

Flaw polynyas are easily recognizable in the model output and satellite data.
Onset of stable fast ice formation

Ice velocity can be used to determine the onset of stable fast ice formation
Problems!
Fast ice breaks up too early in spring

Adjusting cohesion has no effect
20 pseudo-time steps give better convergence, but not perfect

The ice velocity converges slowly or not at all

More pseudo-time steps may give worse results
This may be addressed using an improved solver for the pseudo-time stepping

The conclusion is that modelling fast ice using a VP model is possible, but more work is needed.

Good reproduction of fast ice location and onset time

Break-up comes too early

Inaccuracies in velocity prediction

Questions?