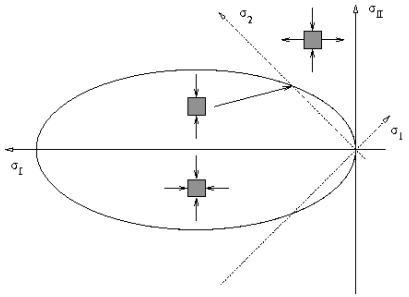
Modelling land fast ice in a viscous plastic model

Einar Örn Ólason

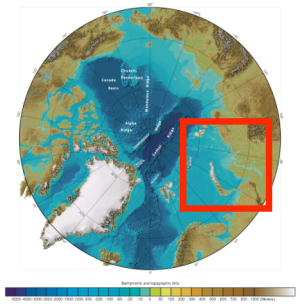
Institut für Mereskunde
University of Hamburg

June 18, 10

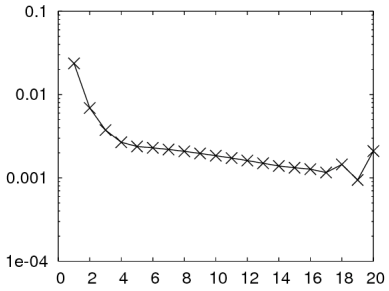
This talk outlines our attempts to model fast ice using a “Hibler-type” VP model



Modeling assumptions



Application in the Kara Sea



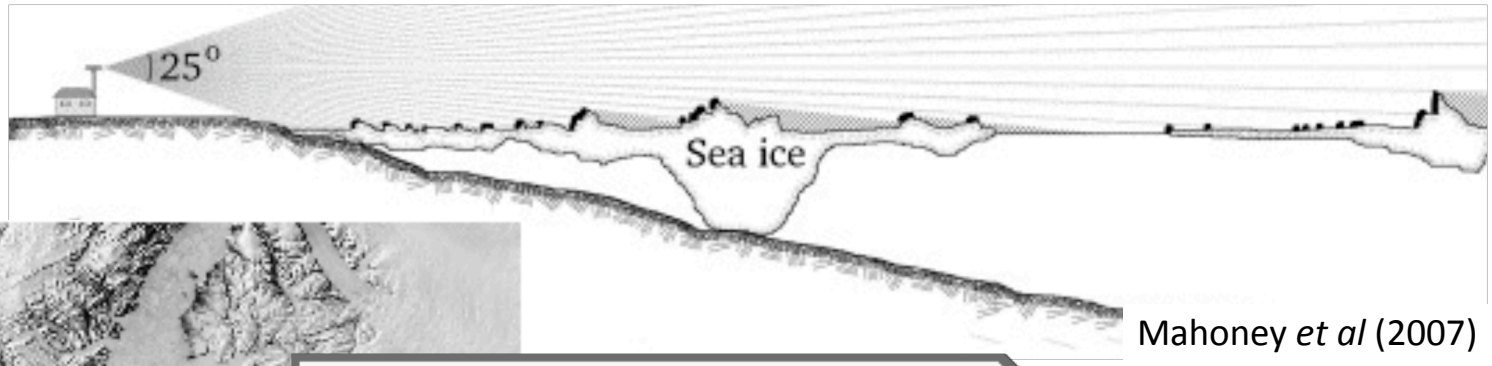
Problems

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

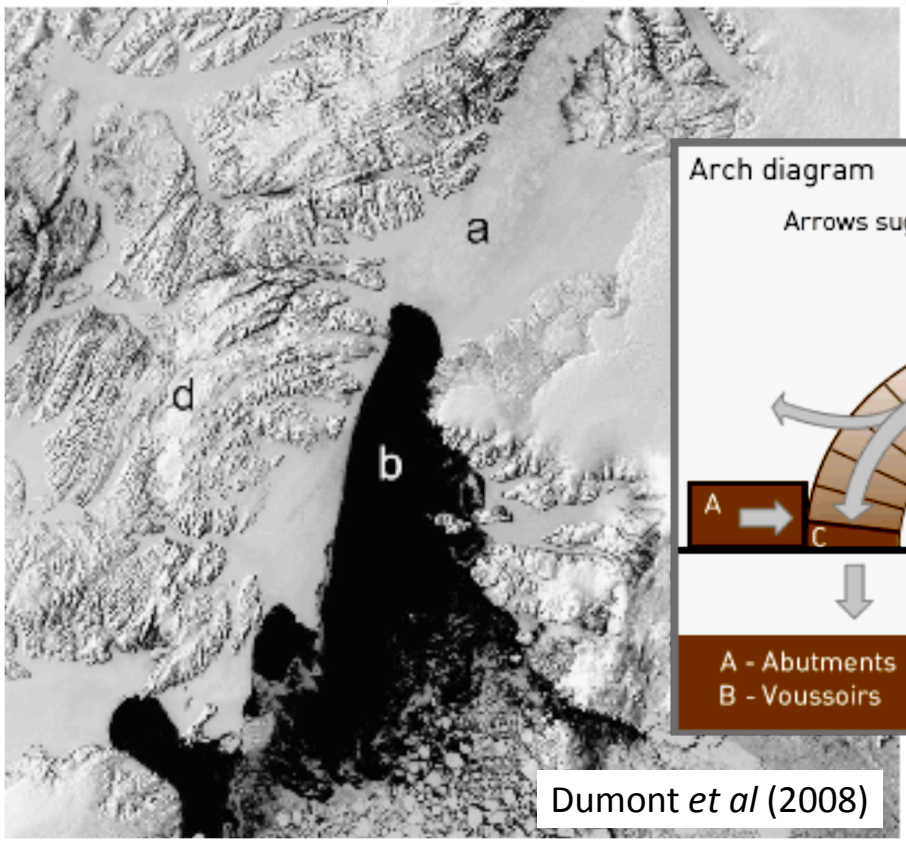
There's no cohesion on the geophysical scale because each grid cell is assumed to contain a large number of ice floes

How does land fast ice become land fast?

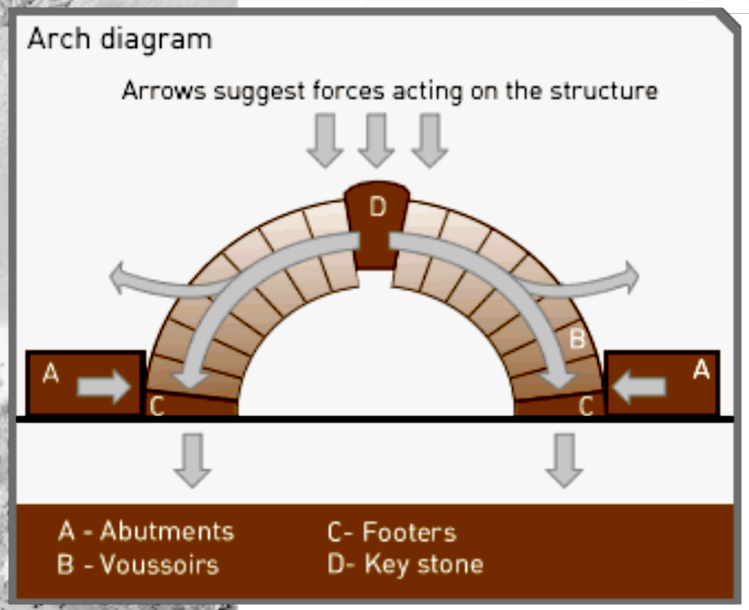
Attached to pressure ridges?



Mahoney *et al* (2007)

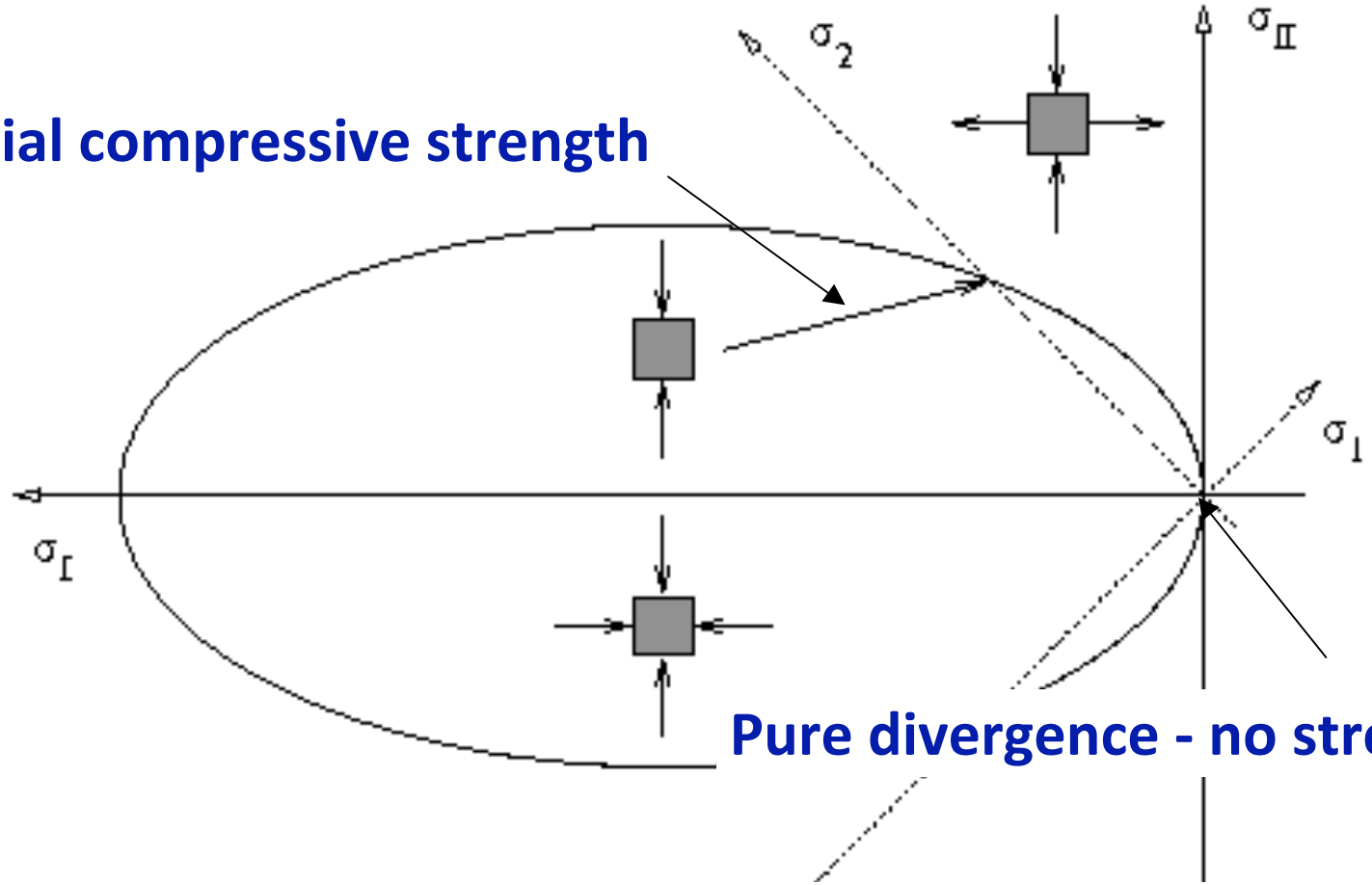


Dumont *et al* (2008)



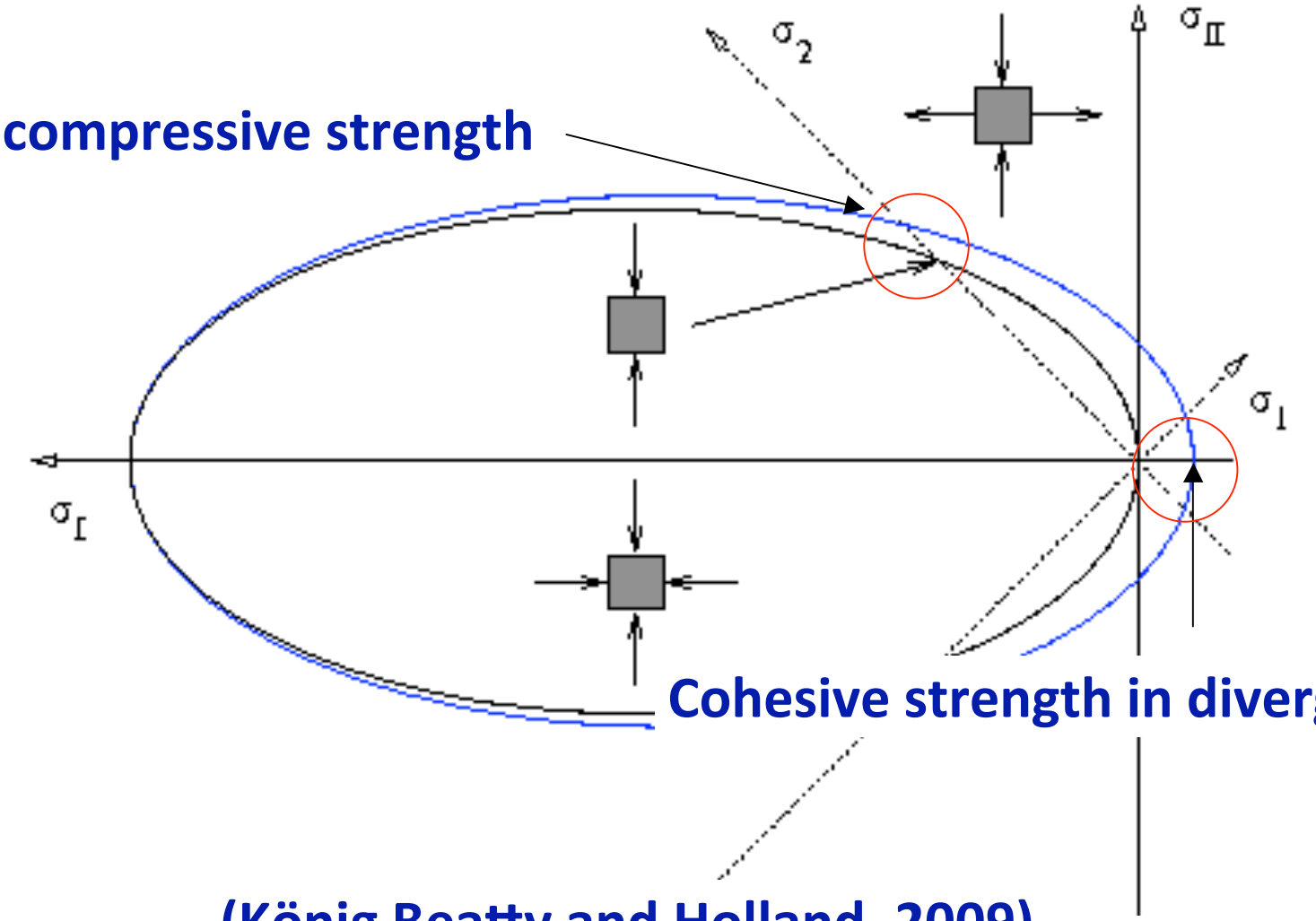
Or arched like a stone bridge?

Consider Hibler's model - can we use it?



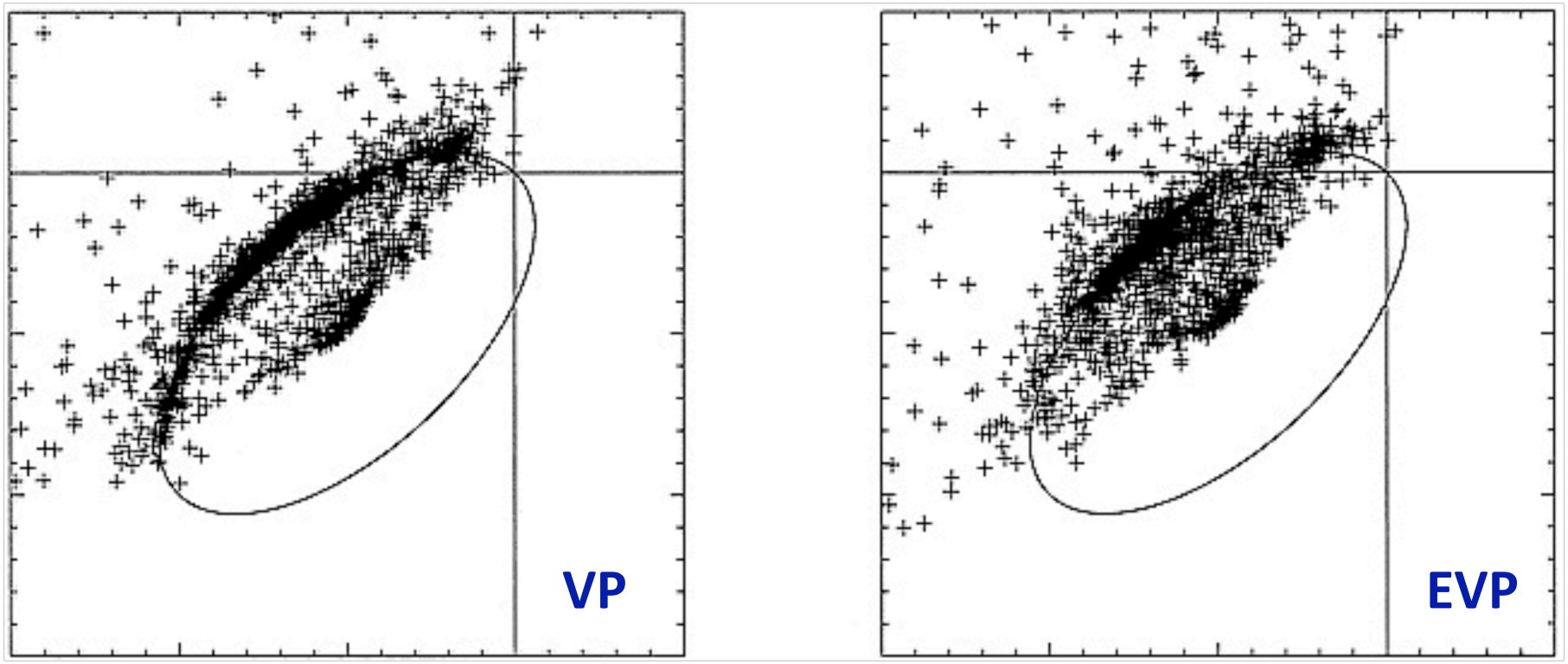
Cohesion exists using an elliptic yield curve and may be controlled by changing the eccentricity (e.g. Dumont *et al* 2008)

Cohesion under divergence can be achieved by shifting the ellipse



(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!

σ depends on ζ,η,*u* and *v* with ζ and η non-linearly dependent on *u* and *v*

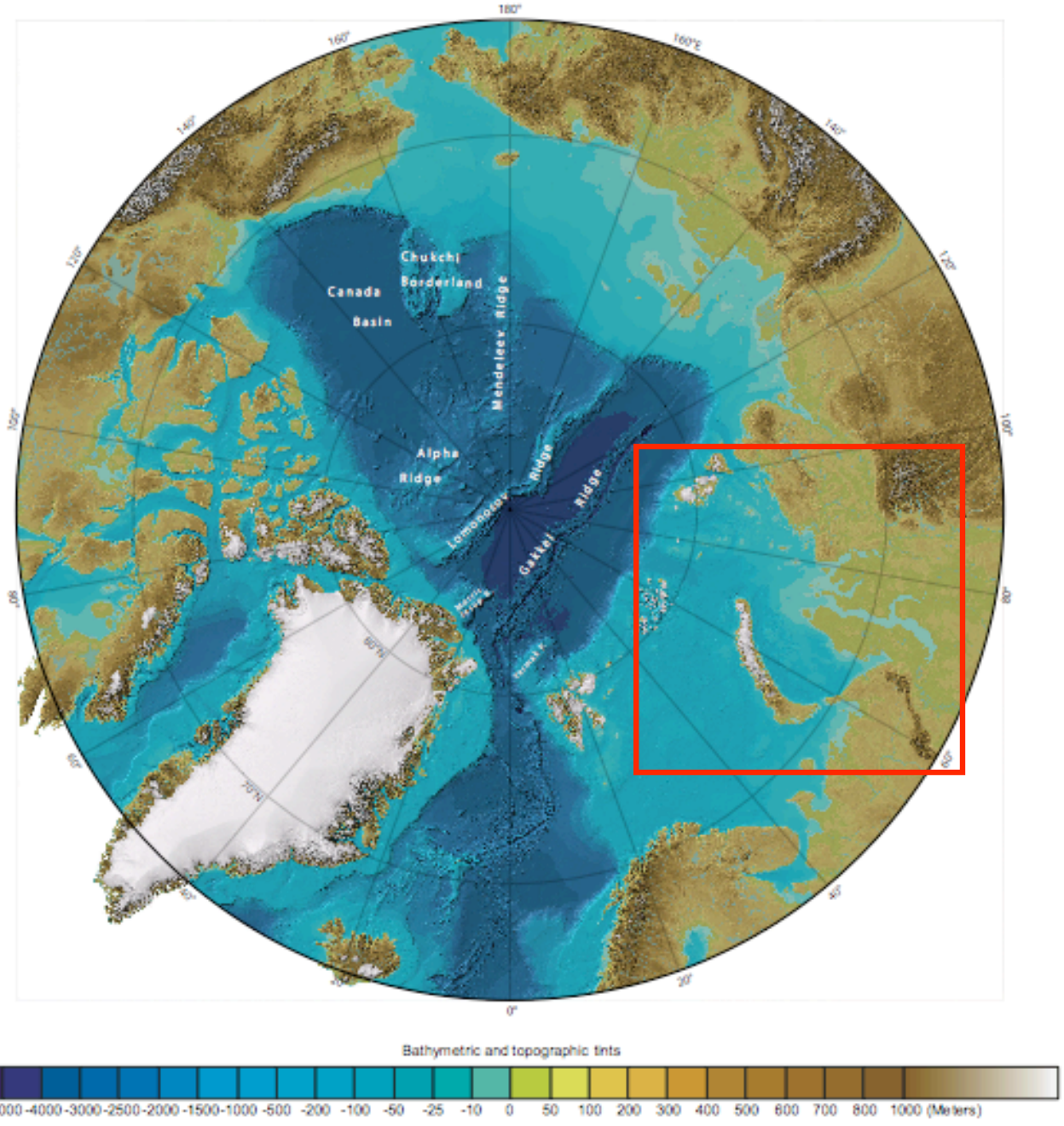
$$\frac{\mathrm{d}\vec{v}}{\mathrm{d}t} = \vec{\tau}_{\mathrm{a}} + \vec{\tau}_{\mathrm{w}} - mf\vec{k} \times \vec{v} - mg\nabla H - \nabla \cdot \sigma$$

A very small time step is needed for plastic convergence

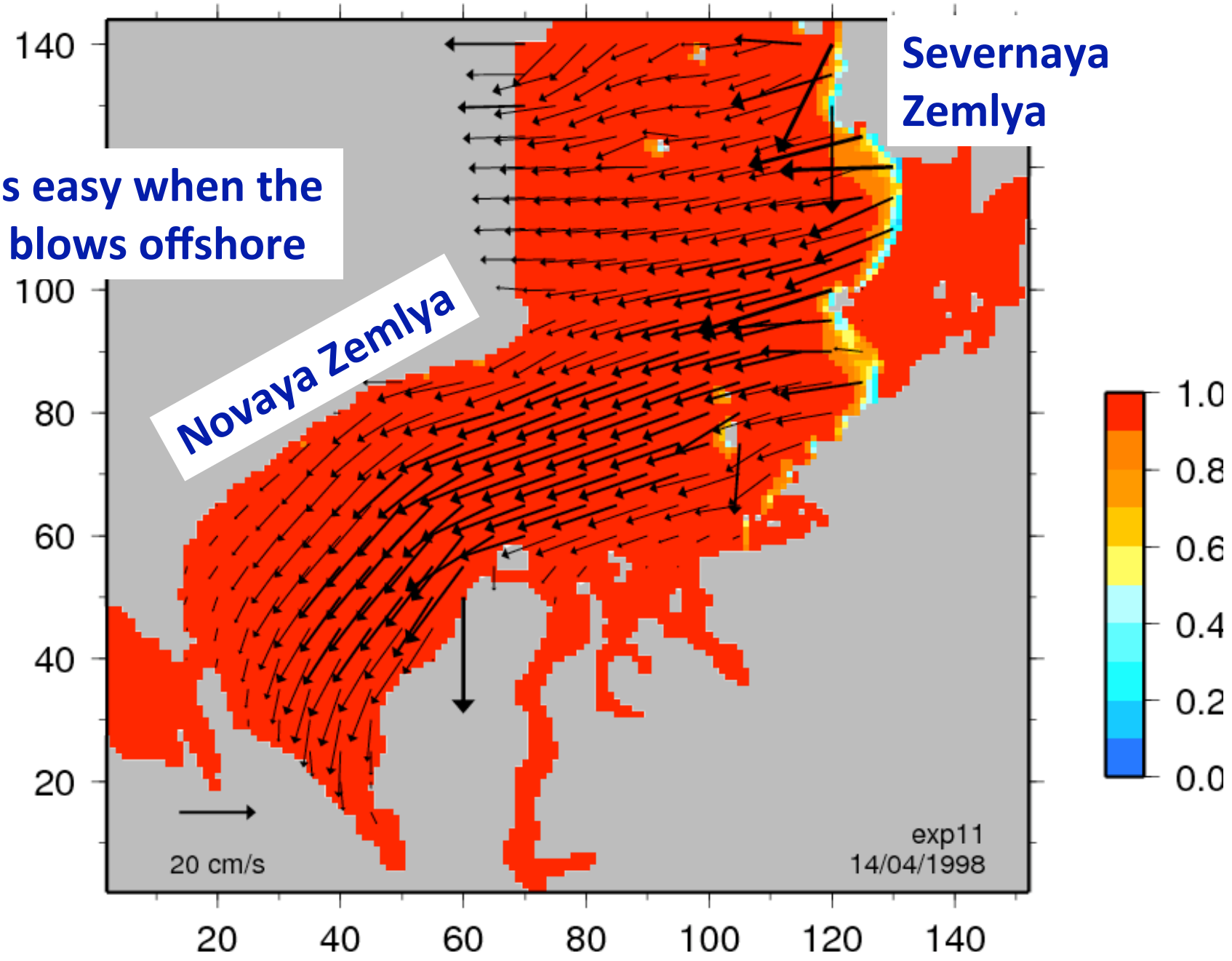
VP: A large number of pseudo-time steps

EVP: A very small elastic time step

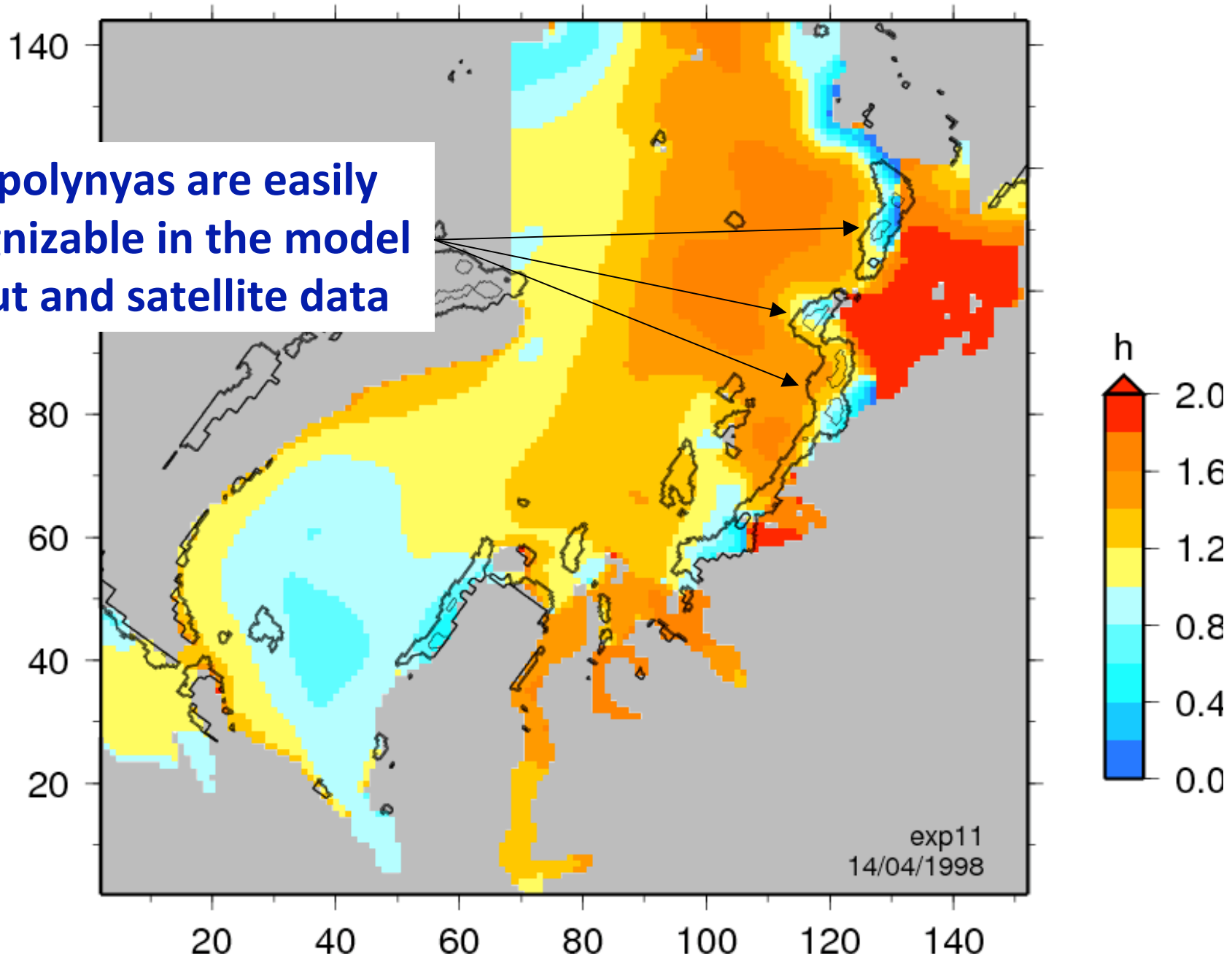
Application in the Kara Sea



Ice velocity should be used to recognize fast ice

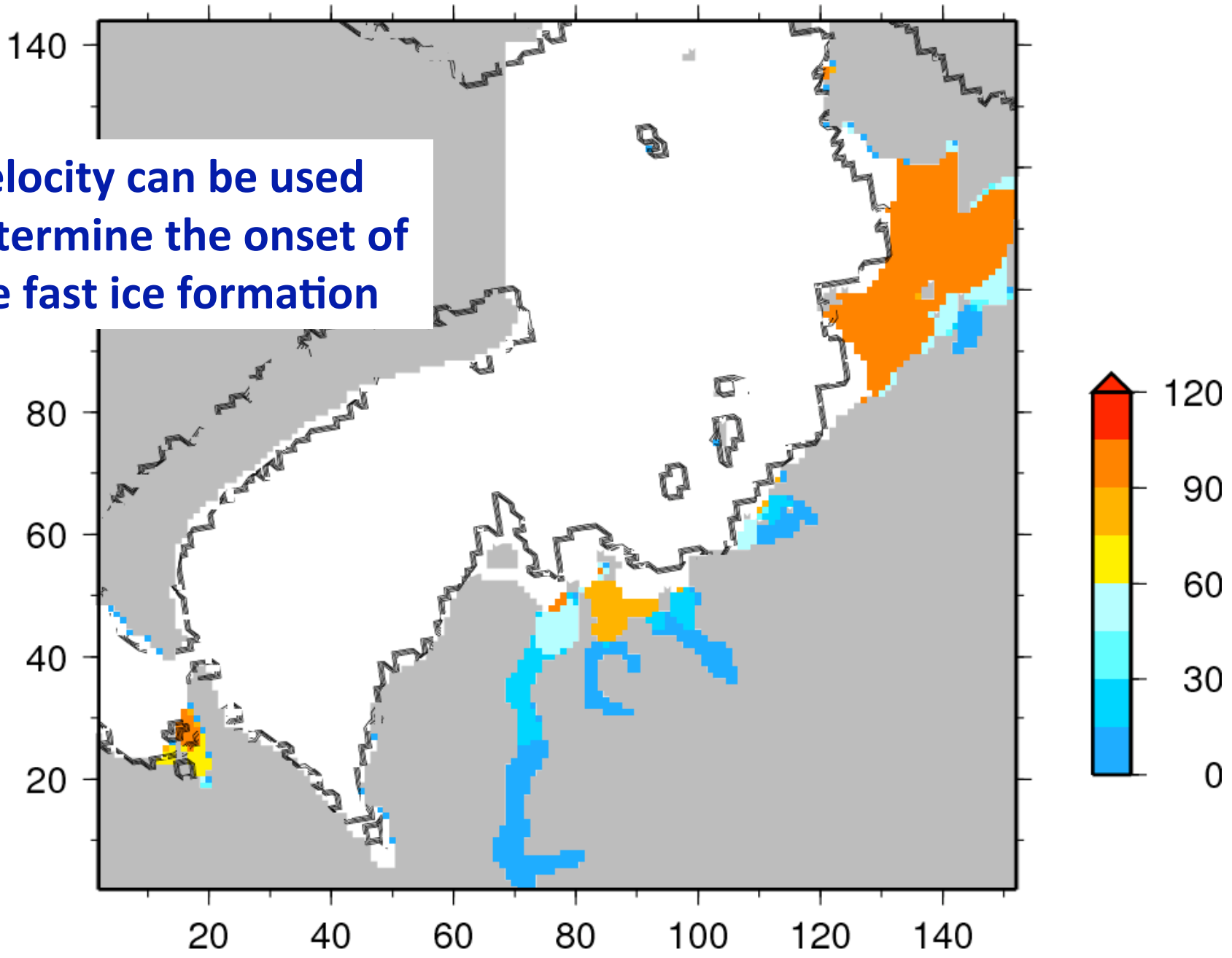


Flaw polynyas and new ice are also useful



Onset of stable fast ice formation

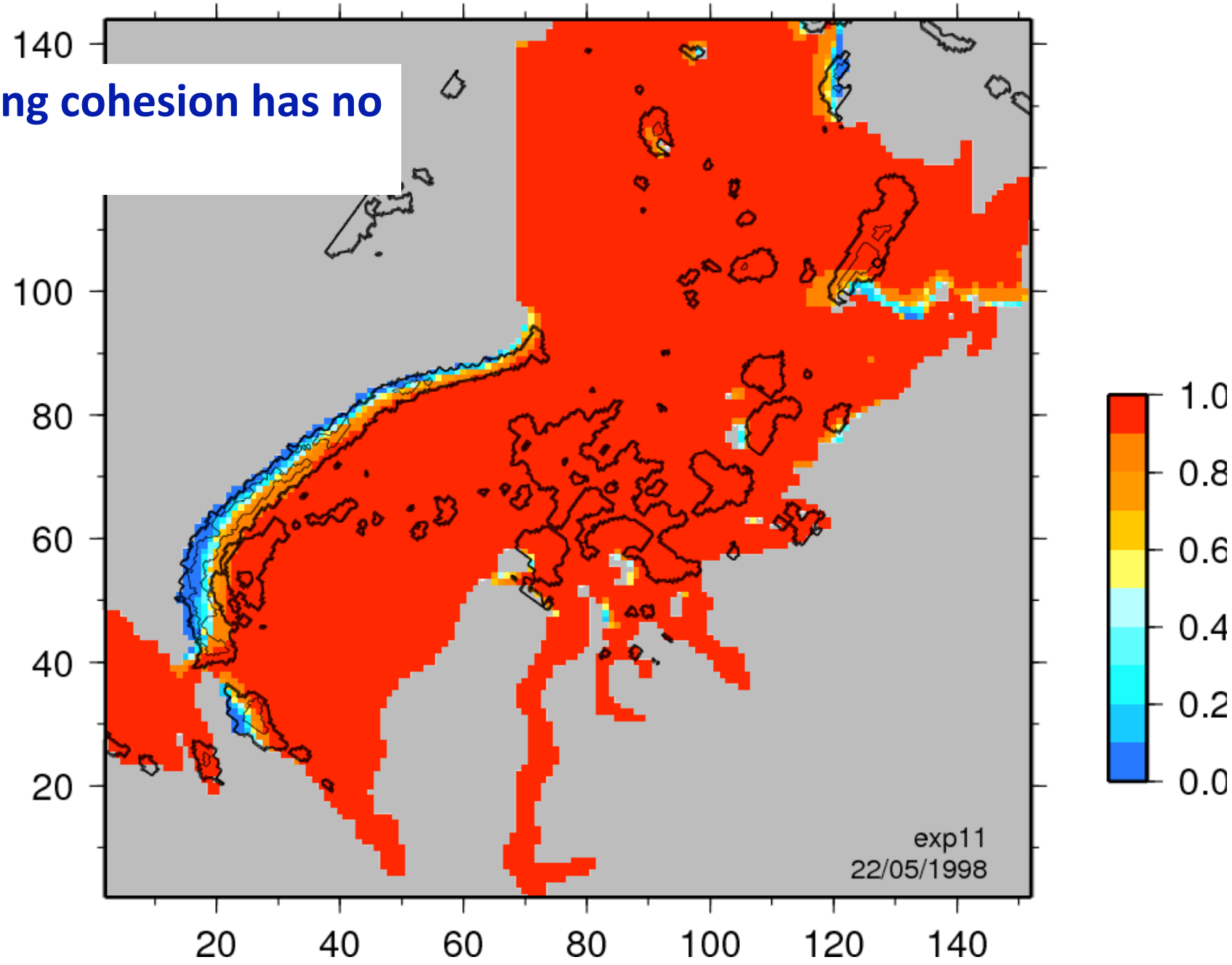
Ice velocity can be used to determine the onset of stable fast ice formation



Problems!

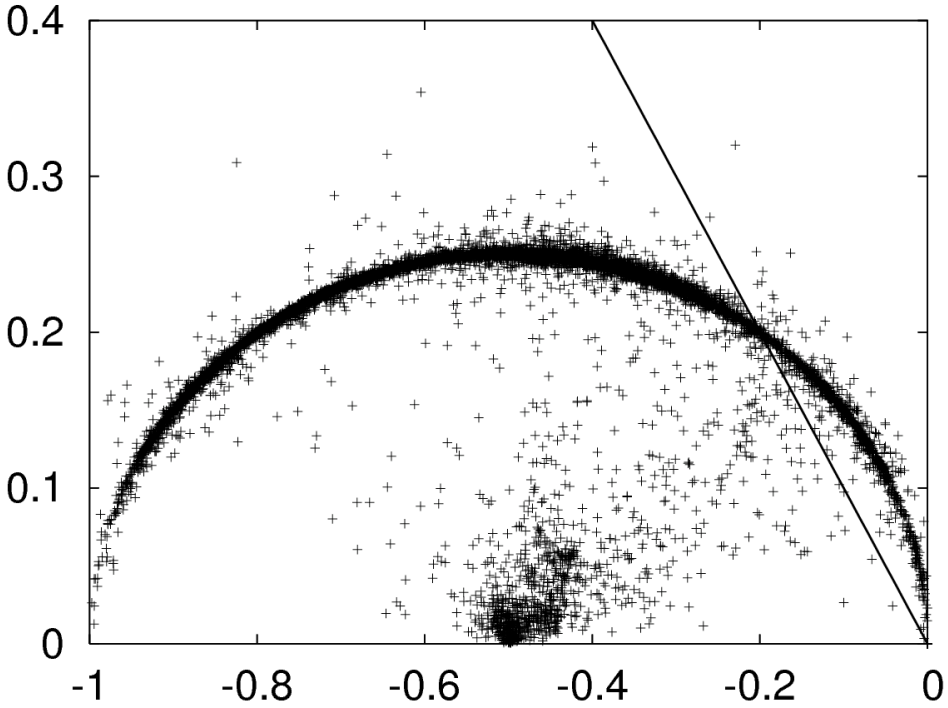
Fast ice breaks up too early in spring

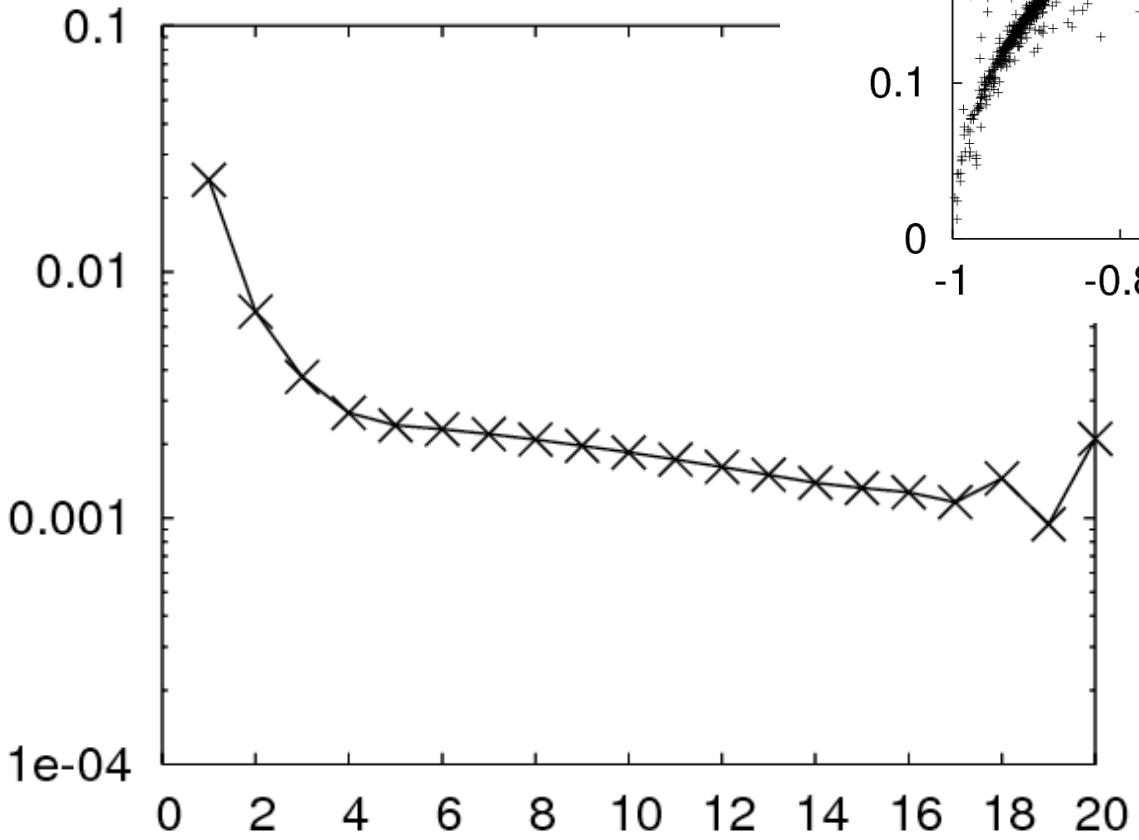
Adjusting cohesion has no effect



20 pseudo-time steps give better convergence, but not perfect

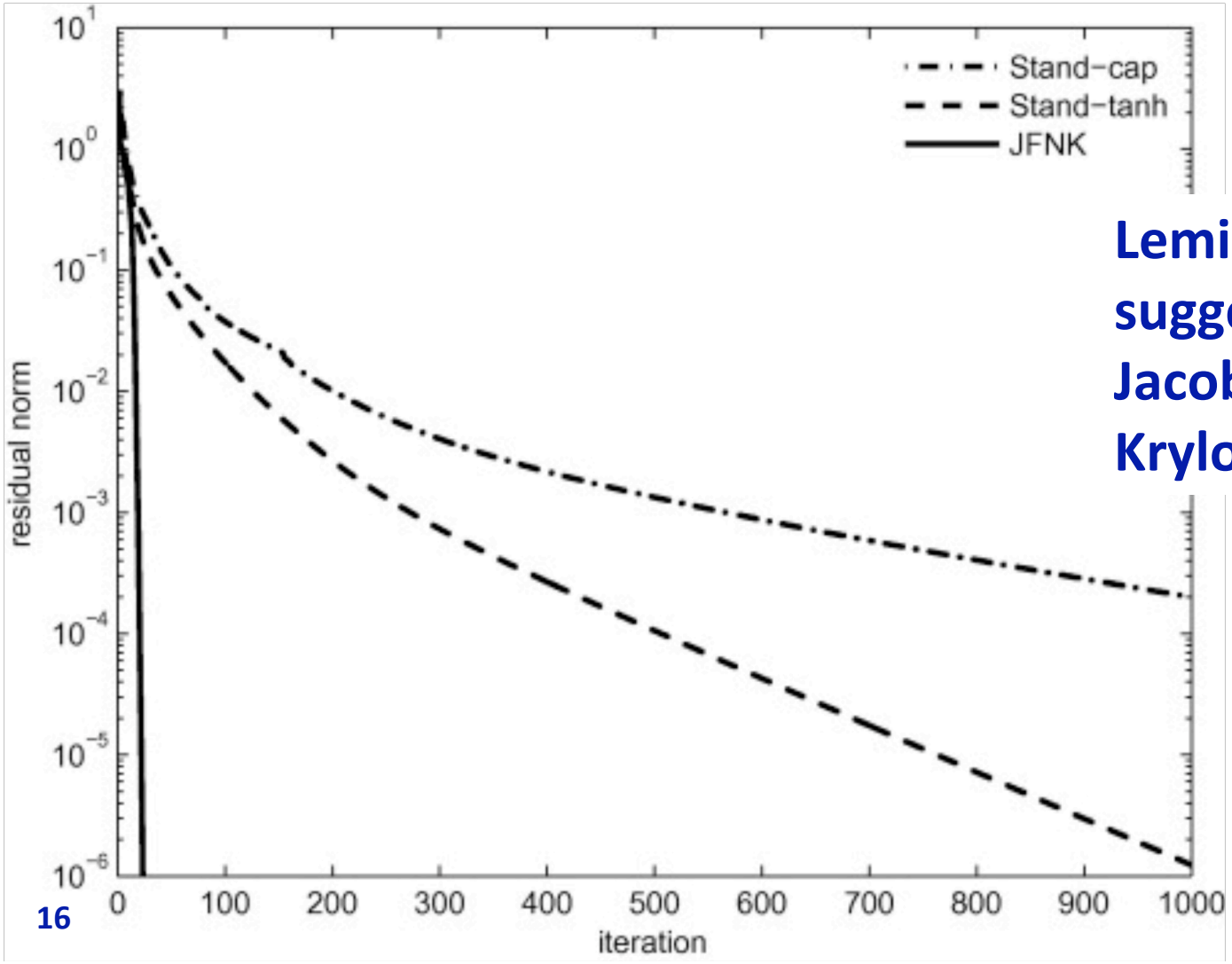
The ice velocity converges slowly or not at all





More pseudo-time steps may give worse results

This may be addressed using an improved solver for the pseudo-time steping



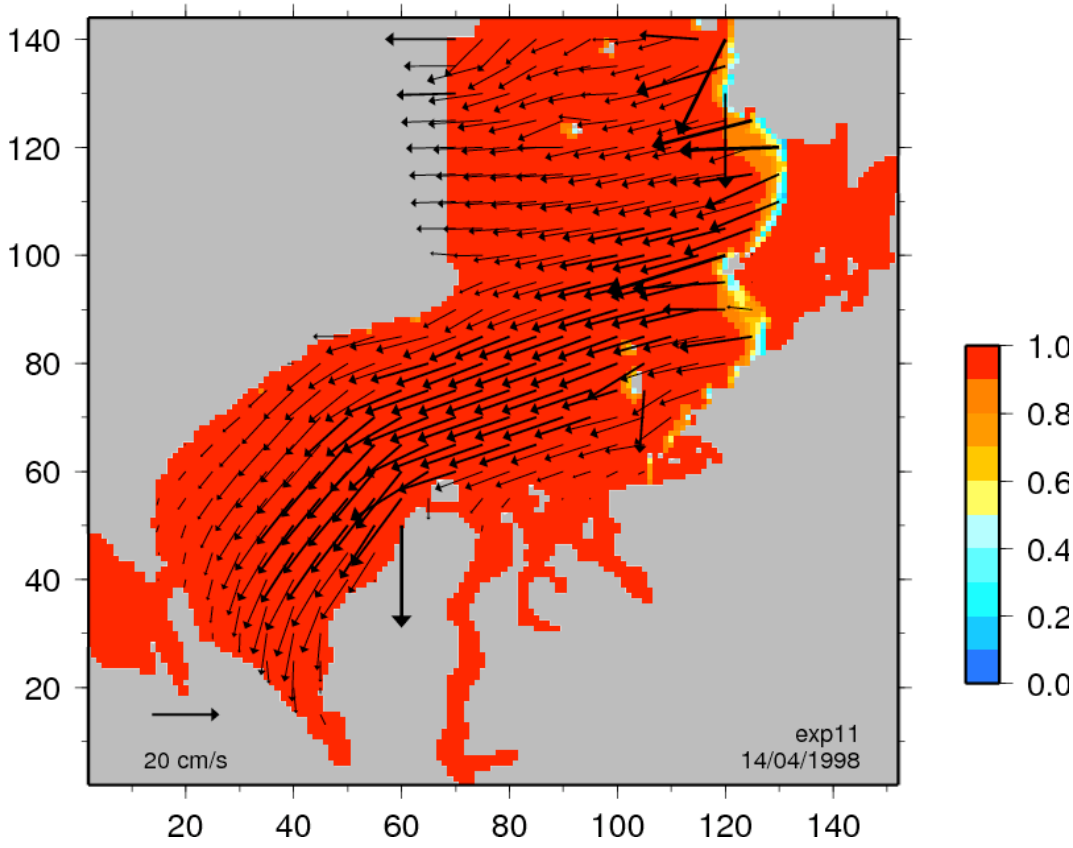
Lemieux *et al* (2010) suggested using a Jacobian free Newton-Krylov method

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?