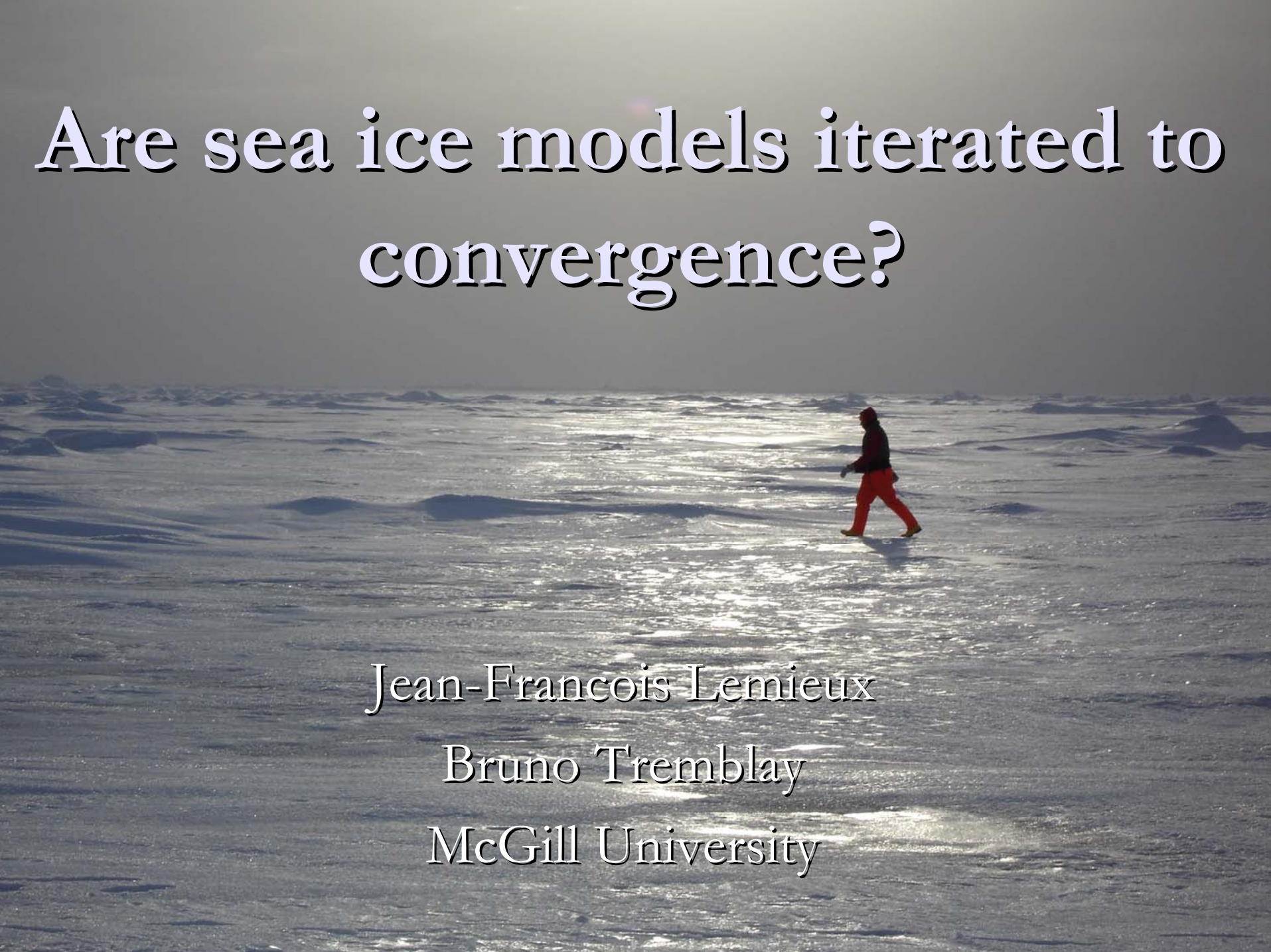
Are sea ice models iterated to convergence?



Jean-Francois Lemieux
Bruno Tremblay
McGill University

Main Messages

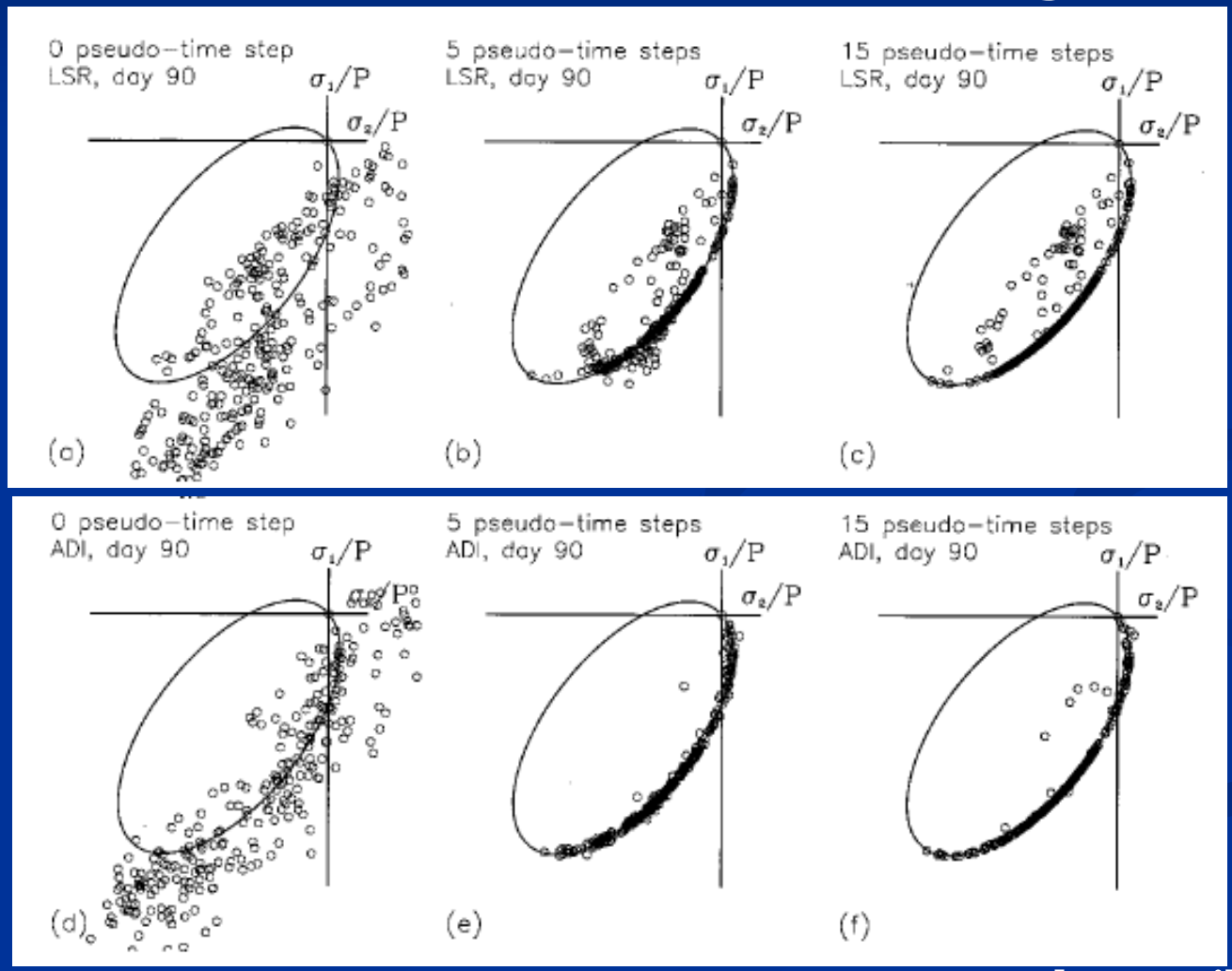
- We do not iterate sea ice models to convergence
- The residual errors are of the same order of magnitude of the mean sea ice drift.
- The mean residual errors are not random and are also of the same order of magnitude as the mean drift.
- Do we have the same problem in the EVP formulation?

Stess State vs Pseudo Time Step

0 5 15

LSR

ADI



Zhang Hibler, 2000

Calibration of ice model against buoy data

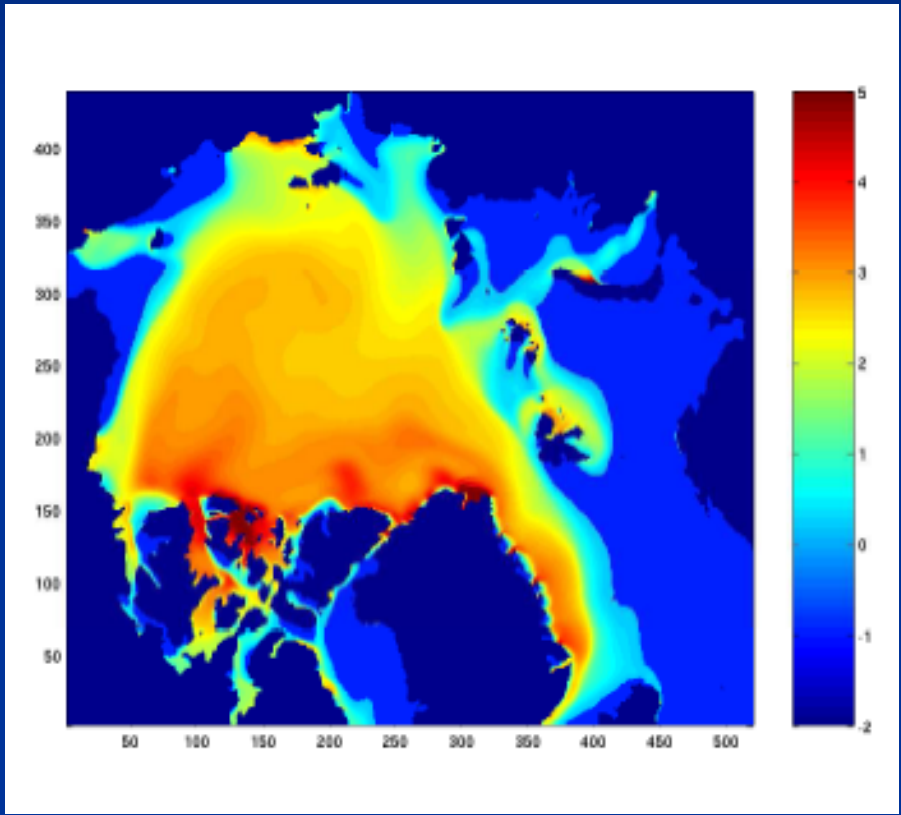
P* = 27.5 KN/m2

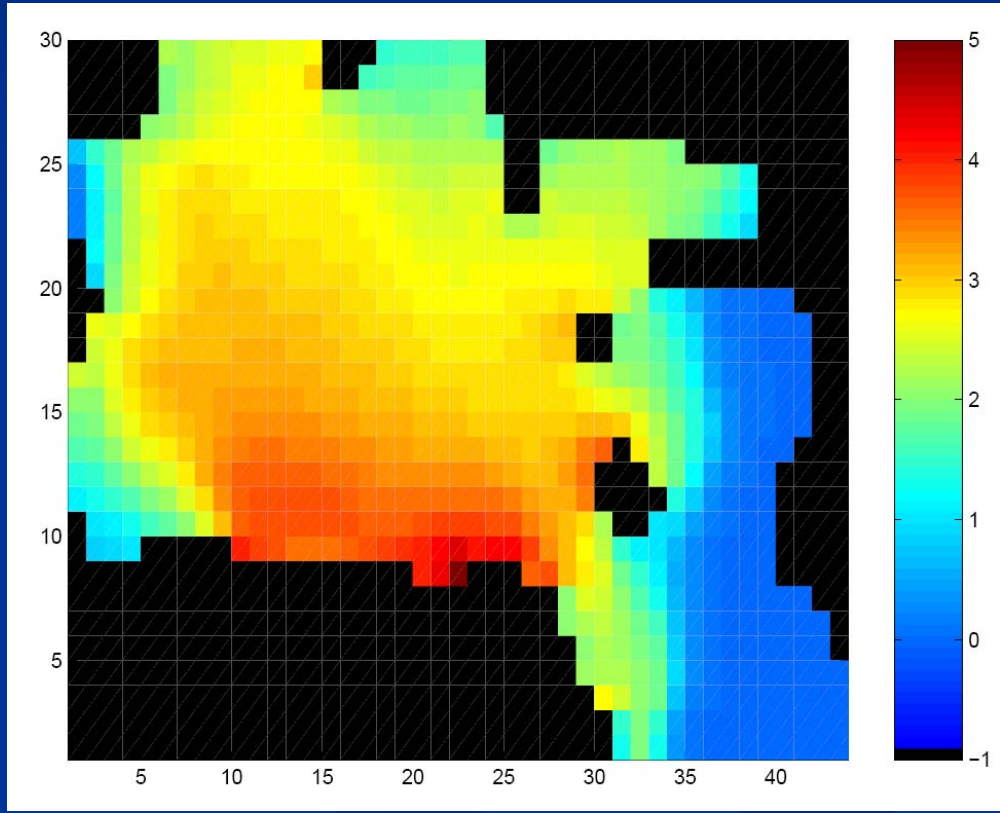
- Hibler Walsh, 1982
  - Cda = 1.2 x 10-3
  - Geostrophic winds

P* = 15 KN/m2

- Kreyscher et al, (2000)
  - Cda = 2.75 x 10-3
  - Surface winds

10 km – 110 km models





Elliptical yield curve and normal flow rule

Numerical Scheme

$$\frac{\partial}{\partial x}\left[(\eta(\mathbf{u}_l^k)+\zeta(\mathbf{u}_l^k))\frac{\partial u^k}{\partial x}\right]+\frac{\partial}{\partial y}\left[\eta(\mathbf{u}_l^k)\frac{\partial u^k}{\partial y}\right]+\frac{\partial}{\partial x}\left[(\zeta(\mathbf{u}_l^k)-\eta(\mathbf{u}_l^k))\frac{\partial v^k}{\partial y}\right]+$$
$$\frac{\partial}{\partial y}\left[\eta(\mathbf{u}_l^k)\frac{\partial v^k}{\partial x}\right]-\frac{1}{2}\frac{\partial P}{\partial x}+\rho_i h f v^k-C_w(\mathbf{u}_l^k)(\cos\theta_w u^k-\sin\theta_w v^k)=b_u$$

$$\mathbf{u}_l^k=\frac{(\mathbf{u}^{k-1}+\mathbf{u}_l^{k-1})}{2}$$

Numerical Scheme

1. Start with an initial guess $\mathbf{u}^0$

do k=1, k_{max}

2. Linearize the momentum equation
3. Solve $\mathbf{A}\mathbf{u}^k = \mathbf{b}$ with the preconditioned GMRES method

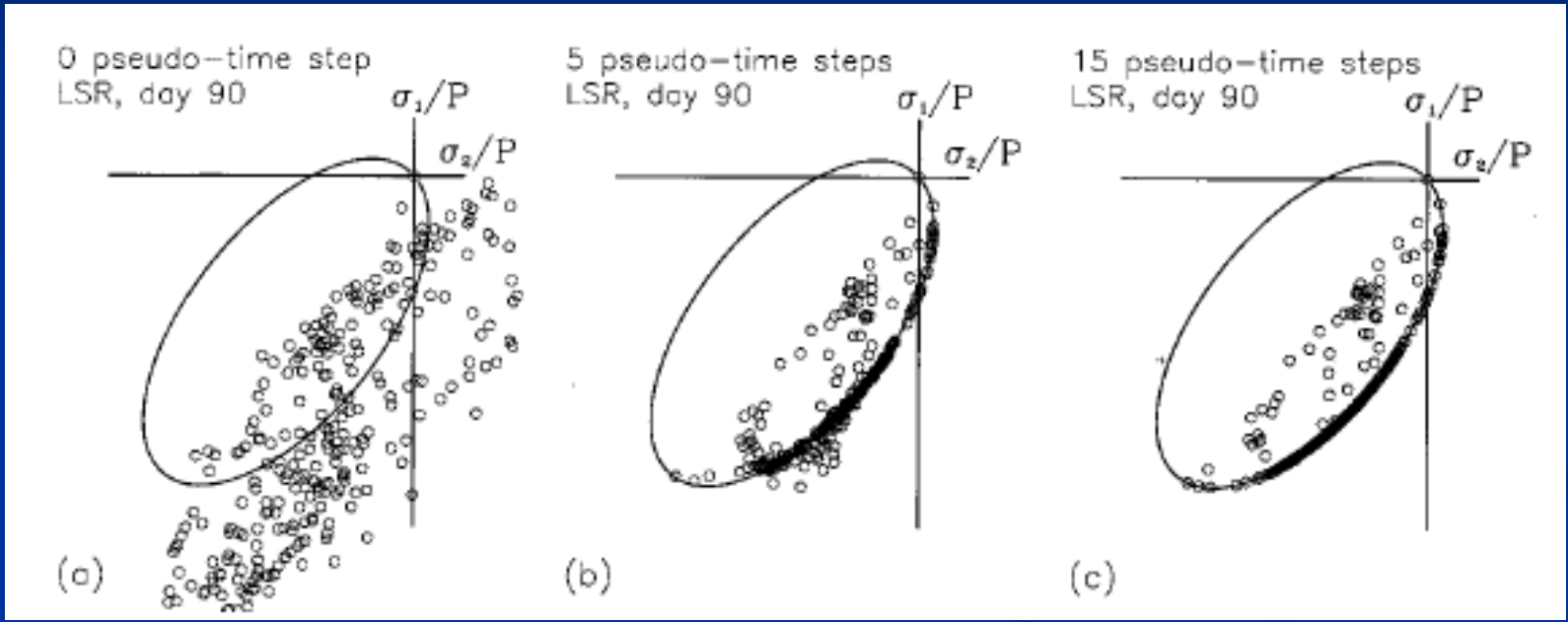
enddo

GMRES as other Krylov methods:

- Low storage requirements
- Good convergence properties when preconditioned
- Allows parallelization

Symmetry is not a prerequisite for GMRES.

Convergence criteria



Convergence Criteria

Criterion: avg KE of the pack is within 1% of the fully converged value

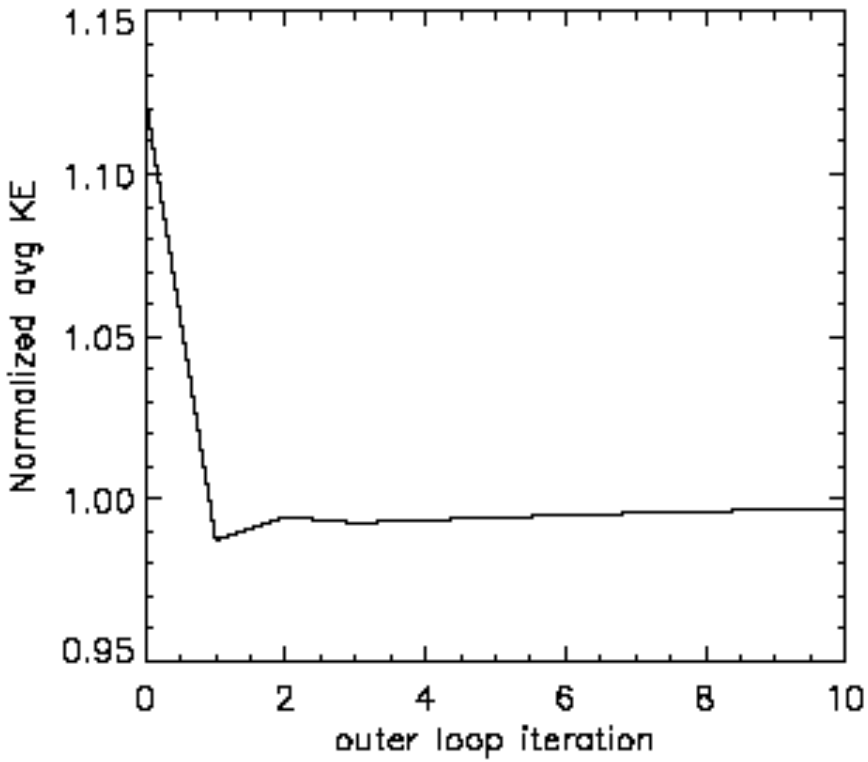
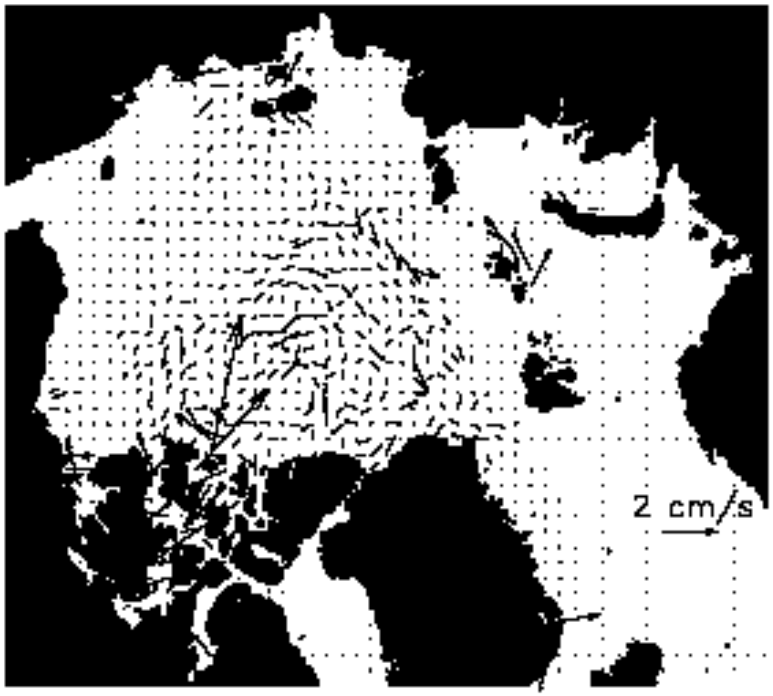


Figure: Normalized average KE of the pack on January 1st 1997 at 00Z as a function of the outer loop iteration

Residual error after 8 outerloops



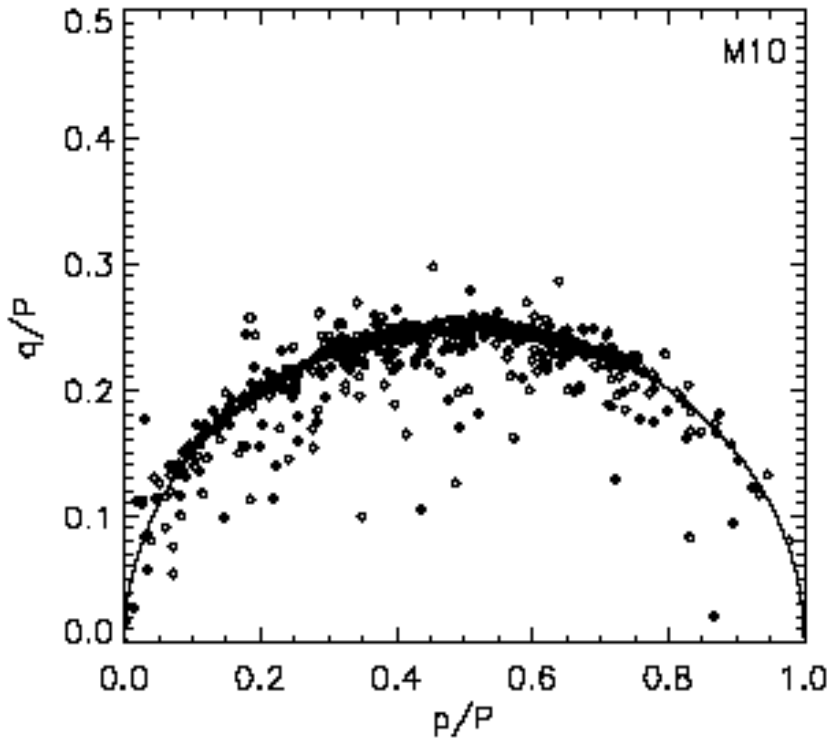
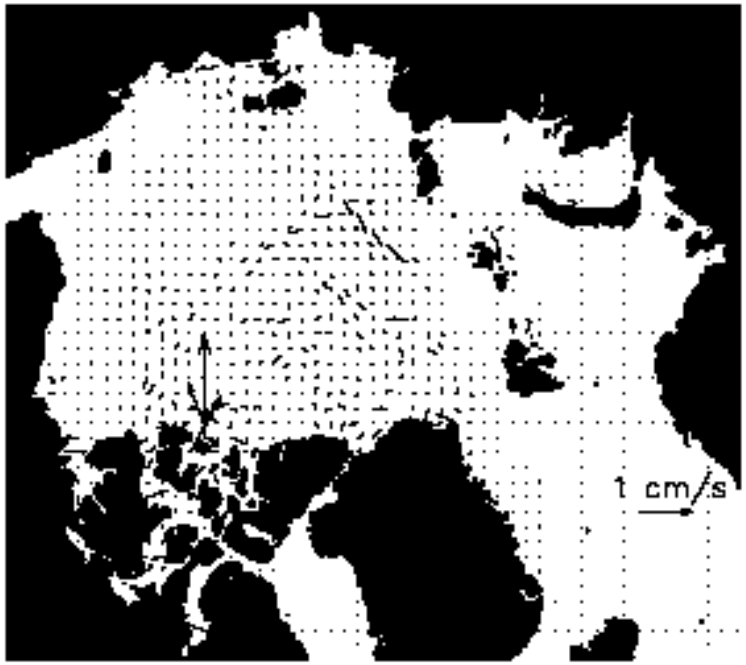


Figure: Left: velocity field difference (8 loops - 250 loops), Right: stress states after 8 outer loop iterations

After 40 outerloops



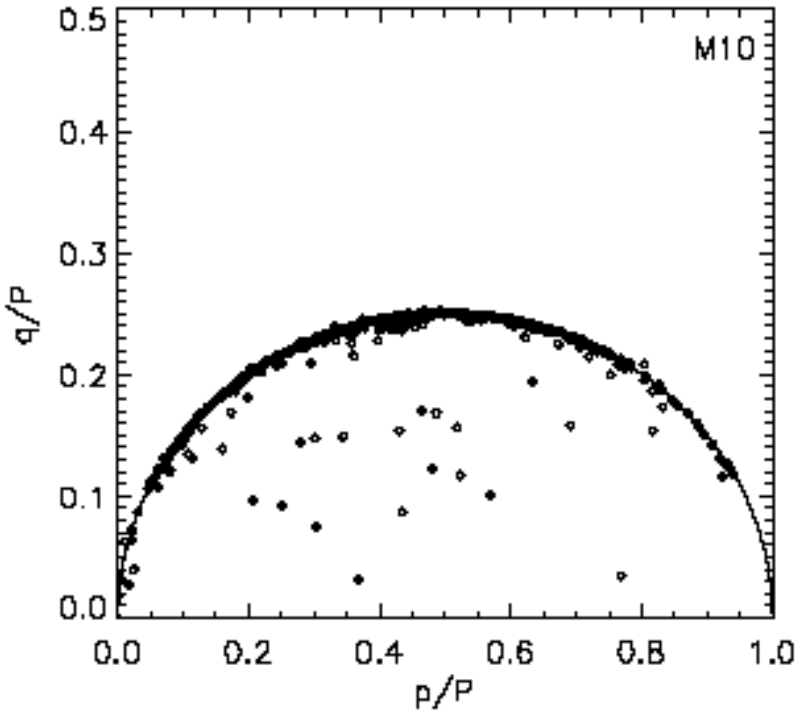


Figure: Left: velocity field difference (40 loops - 250 loops), Right: stress states after 40 outer loop iterations

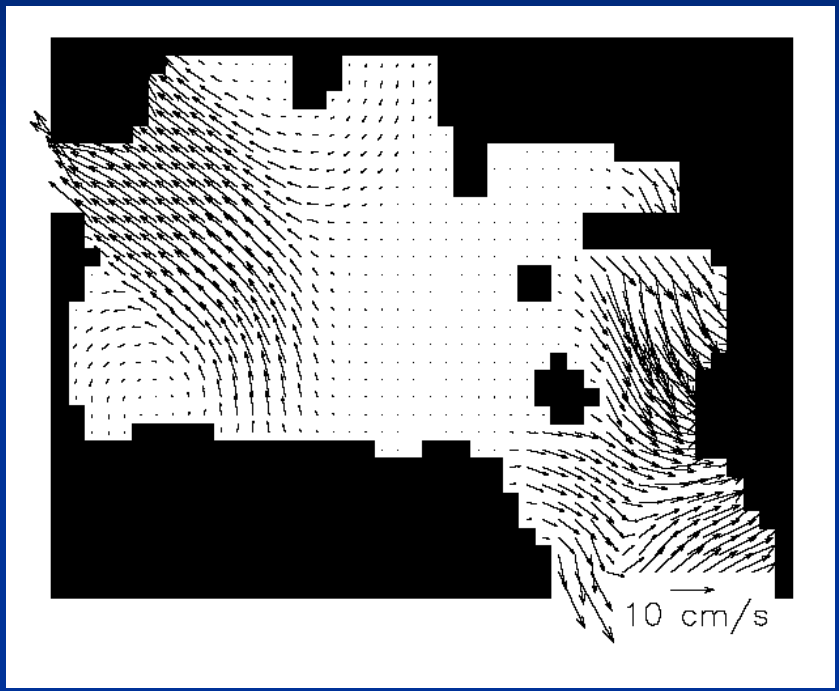
Message

- Stress state can be on the yield curve, there can still be large errors
- Mean kinetic energy of the pack can be within 1% of the converged value, there can still be large errors

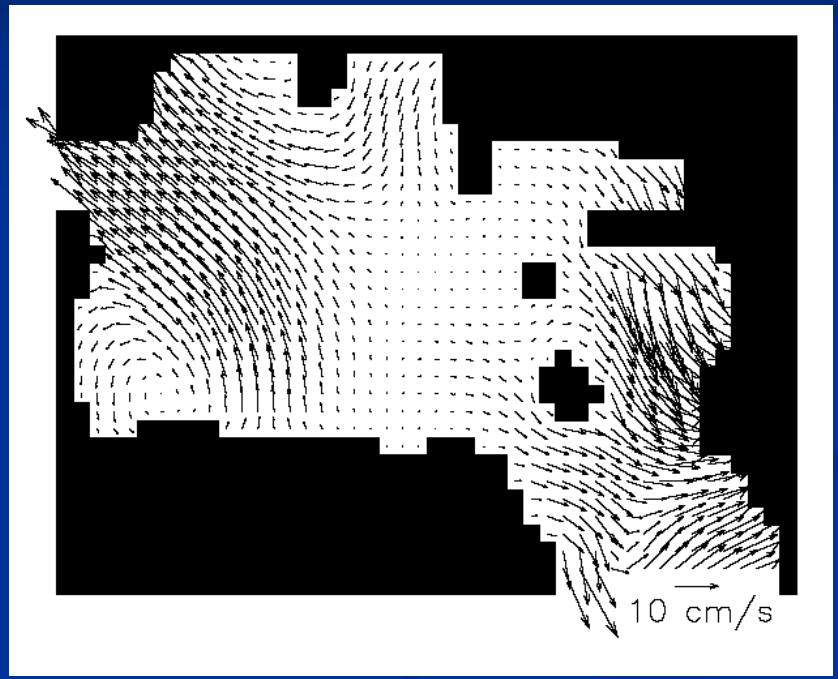
Instantaneous Fields

Instantaneous Fields

Jan 1 - 1997



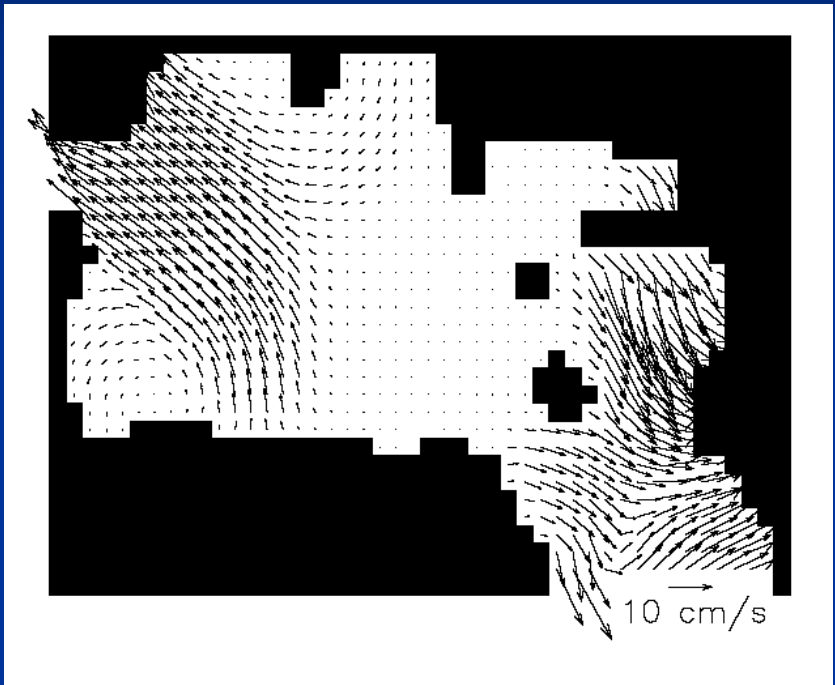
1000 outerloops



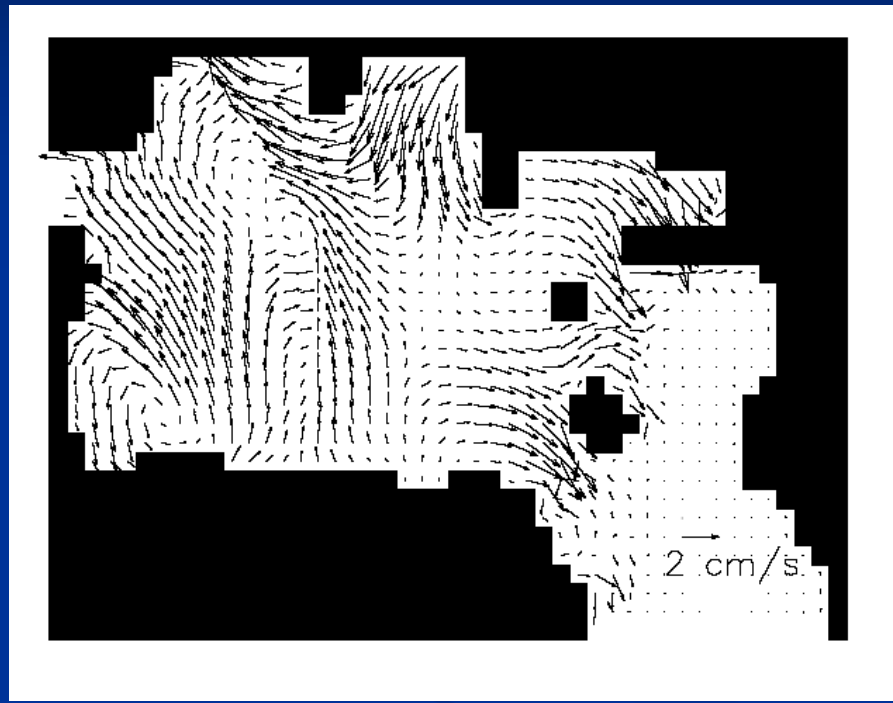
2 outerloops

2 Superloops

Jan 1, 1997



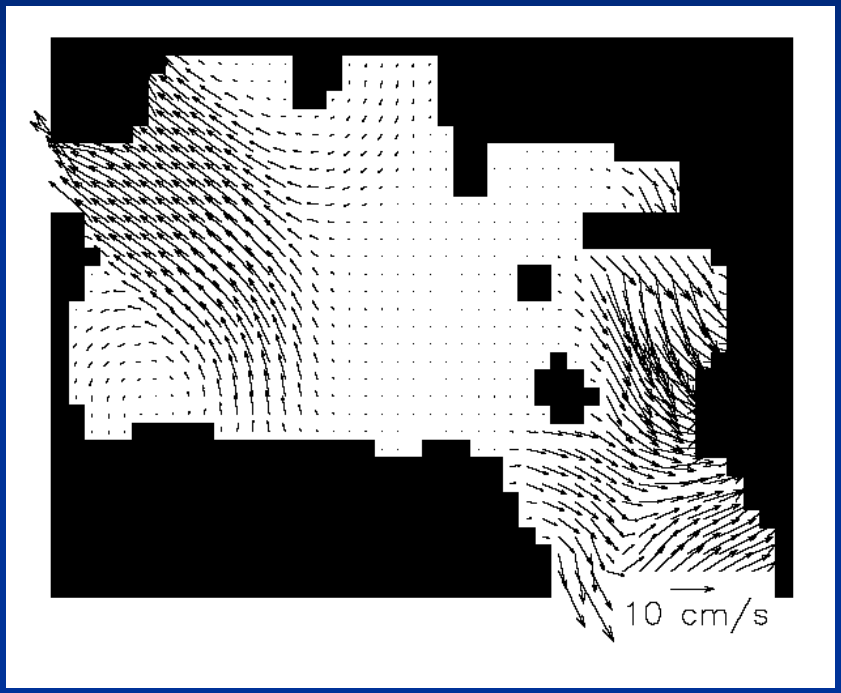
1000 superloops



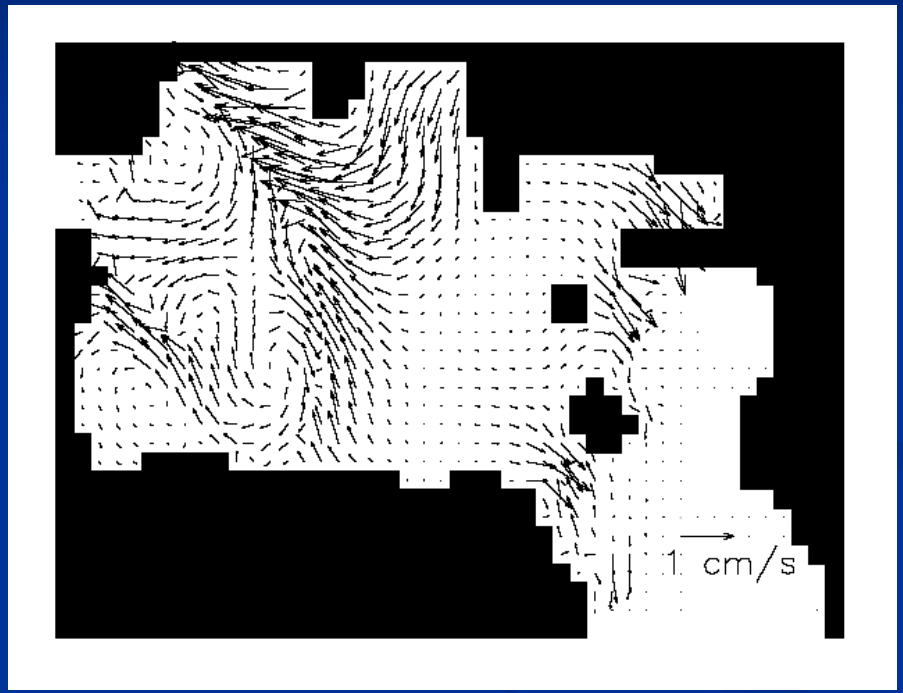
2 superloops - 1000

10 Outerloops

Jan 1, 1997

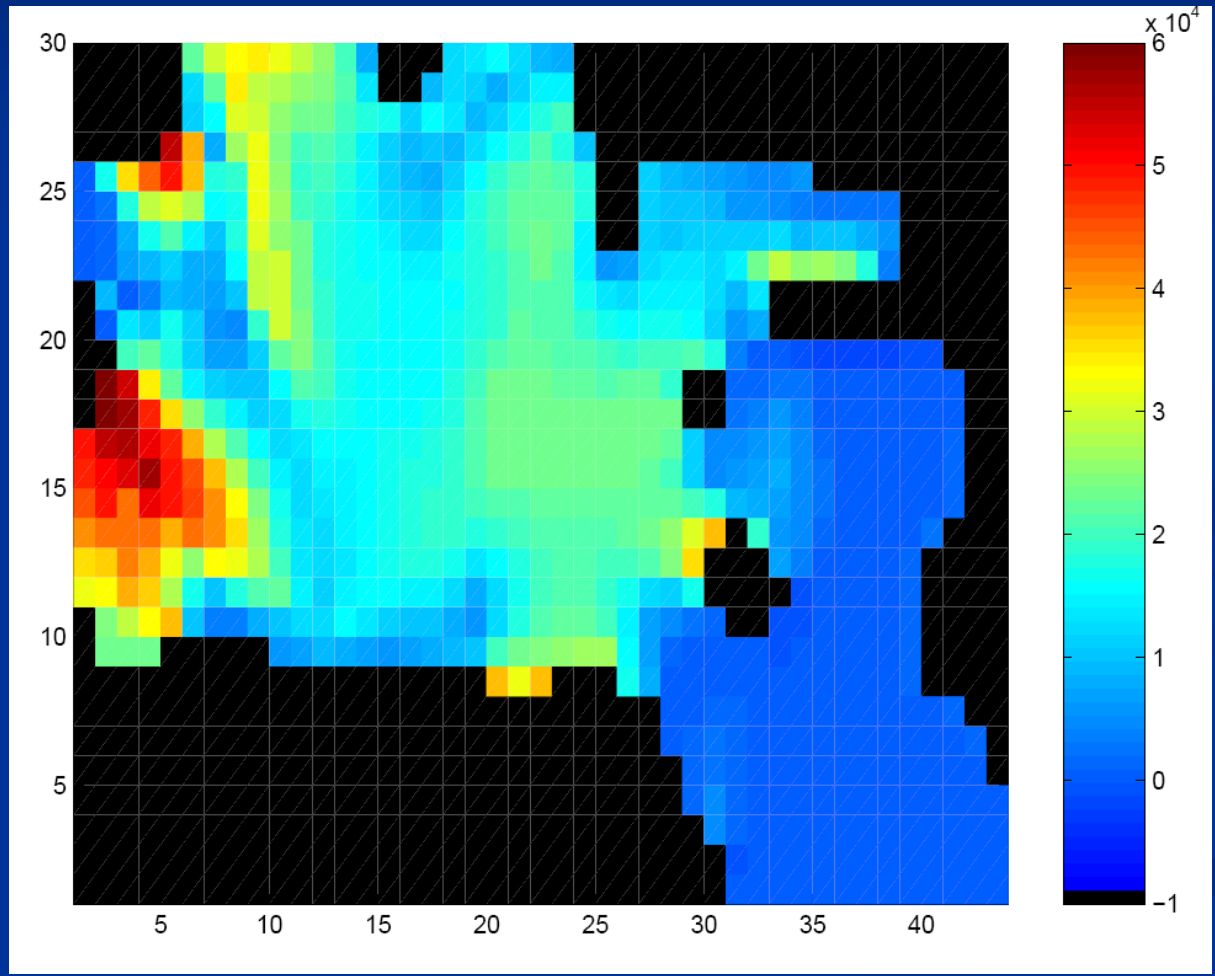


1000 superloops



10 superloops - 1000

Sea Ice Pressure jan 1 1997

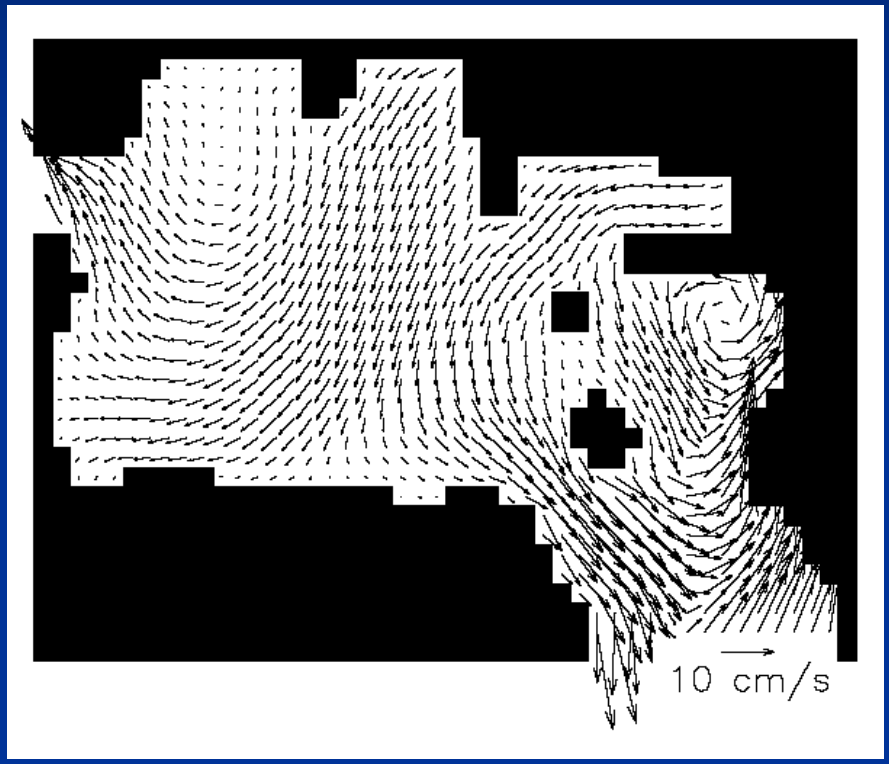


Mean Quantities

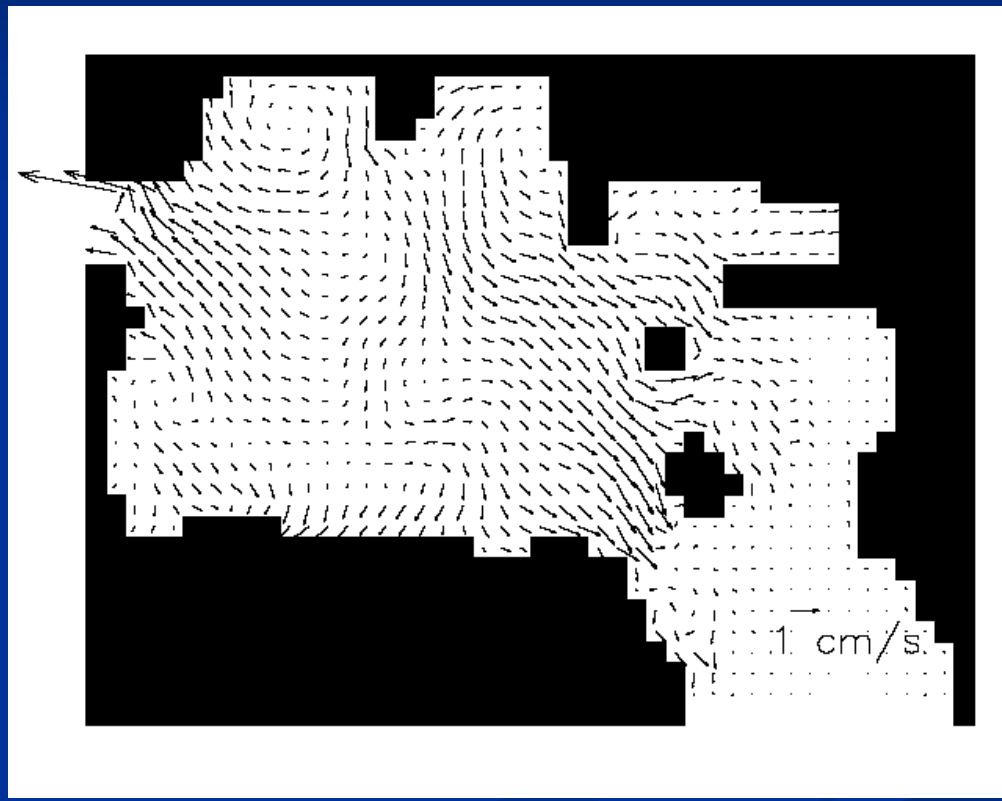
- Are the error random and do they average out with time?

Mean January 1997

2 outerloops



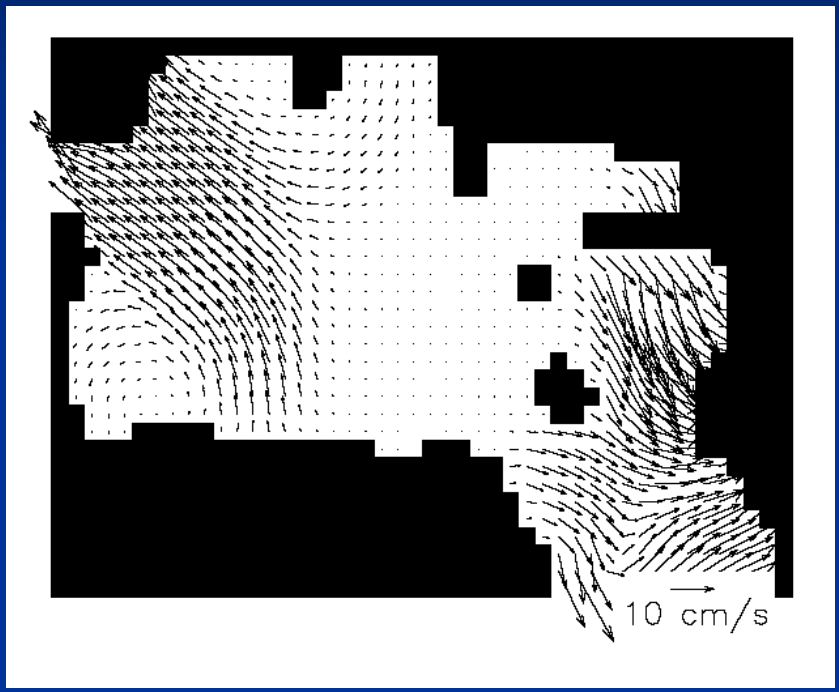
Mean velocity



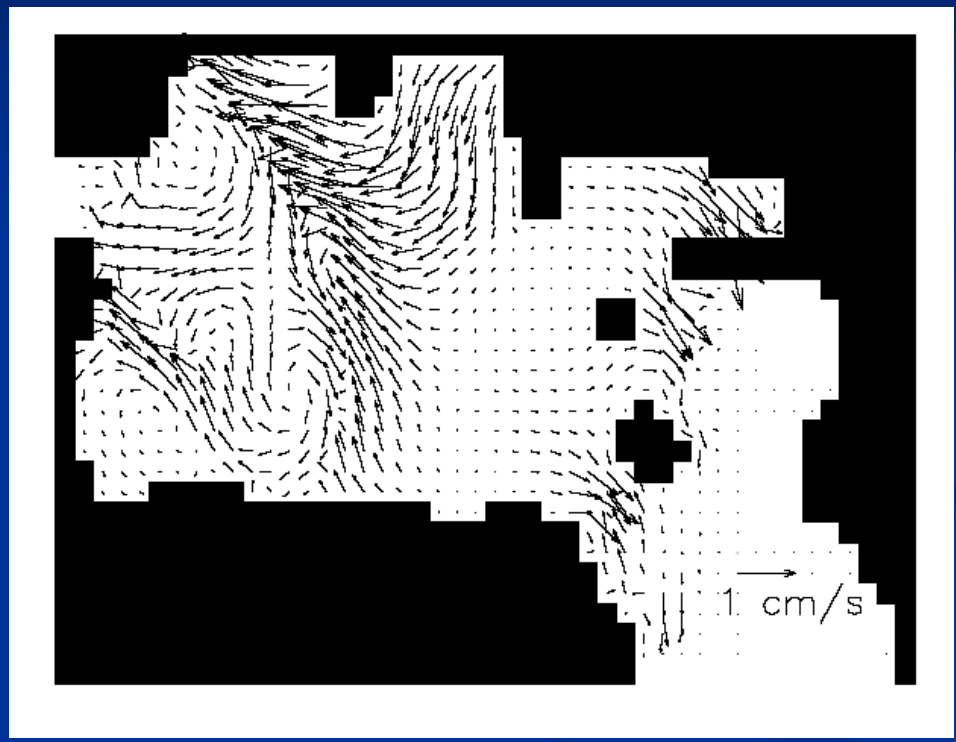
2 superloop - 1000

10 superloops

Jan 1, 1997



1000 superloops

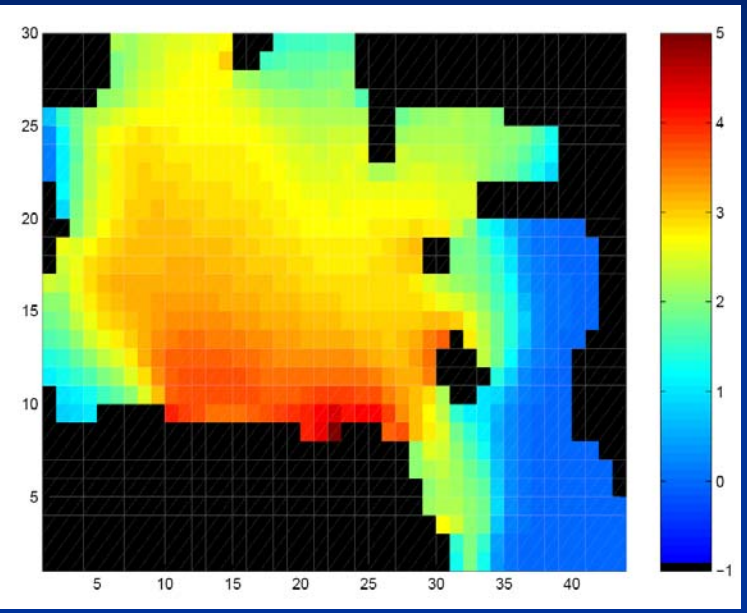


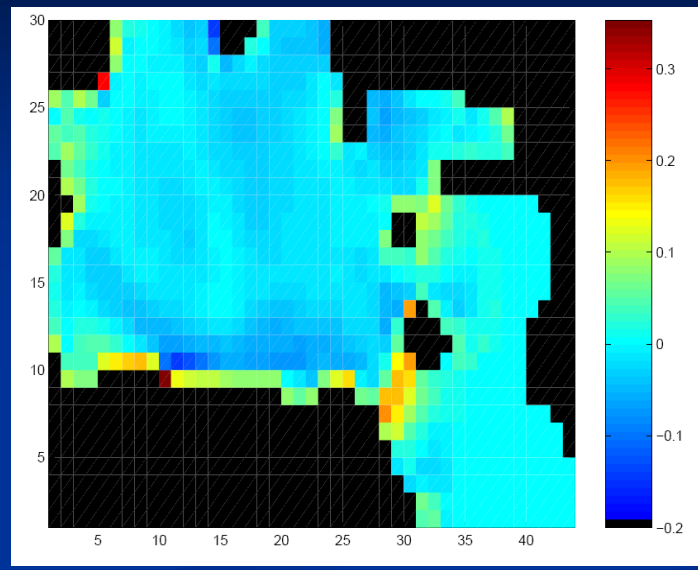
10 superloops - 1000

2 superloop

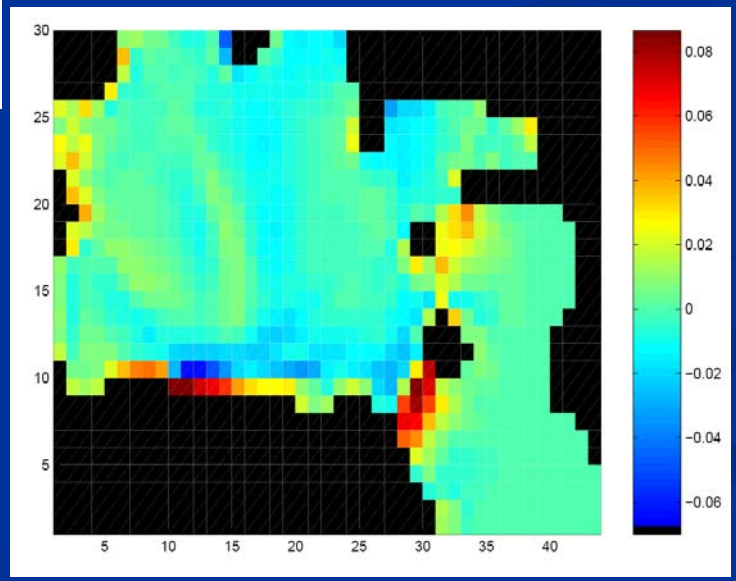
Sea Ice Thickness

January - 1997



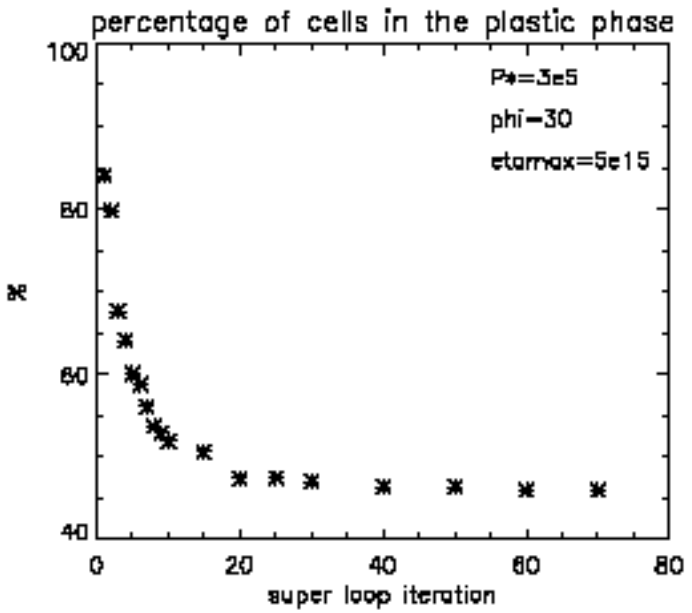


2 outerloops



10 outerloops

Plastic vs Viscous



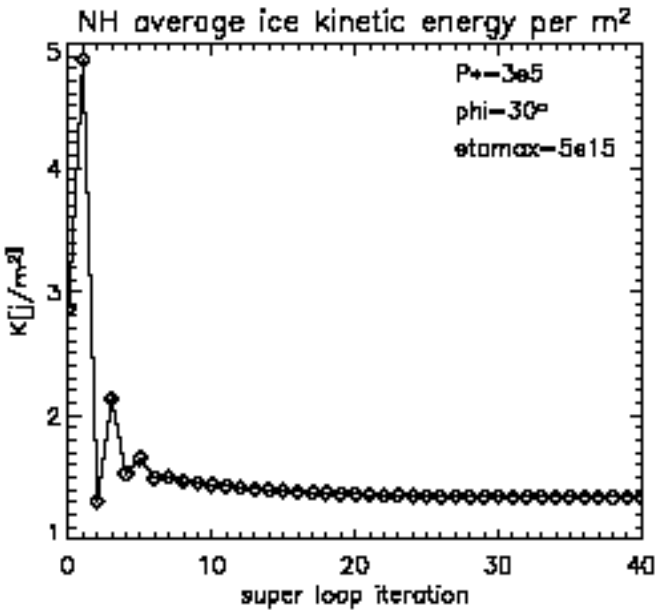


Figure: % of ice-covered grid cells in the plastic phase (left) and Northern Hemisphere average kinetic energy (right) as a function of the number of 'super loop' iterations

Future Work

- Costly to iterate until convergence
- Develop a Jacobian-free Newton Raphson method
- Parralelization of the code