

# Modeling sea ice fracture at very high resolution with VP rheologies

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**What is sea ice? And why do we care?**

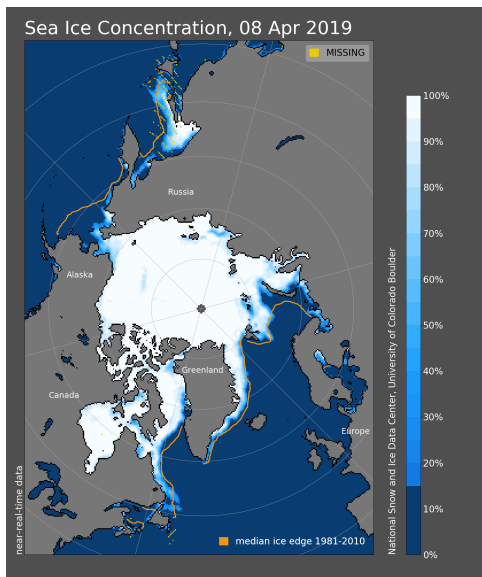


# What is sea ice? And why do we care?



Credit: Damien Ringeisen

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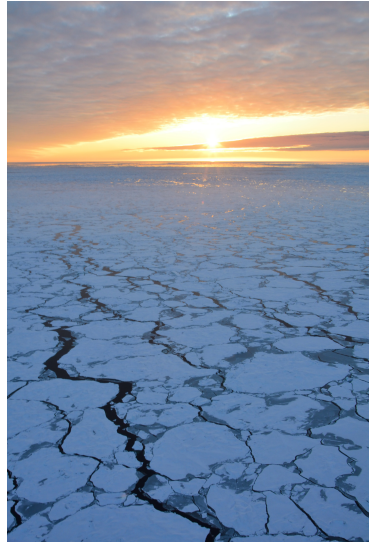
Credit: National Snow and Ice Data Center

# What is sea ice? And why do we care?

Large scale fracture event

# What is sea ice? And why do we care?

- Fractures influence:
  - Heat exchanges
  - Mass balance
  - Dynamics
- Important to model accurately

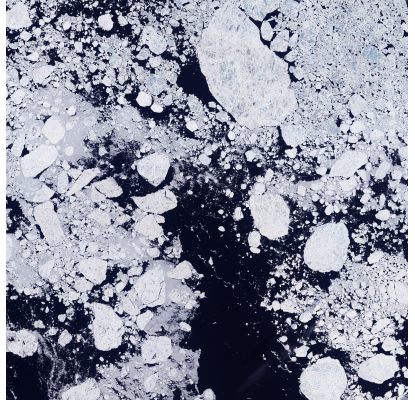


Credit: Nils Fuchs

# Sea ice: Physical properties

## Sea Ice ...

- is 2D granular medium

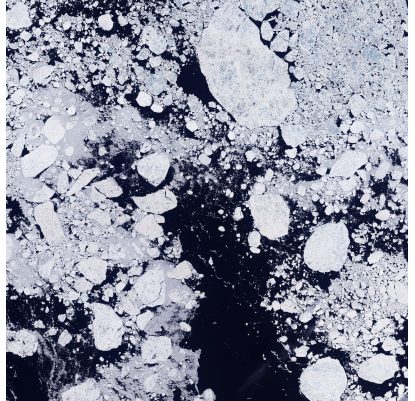


Credit: NASA

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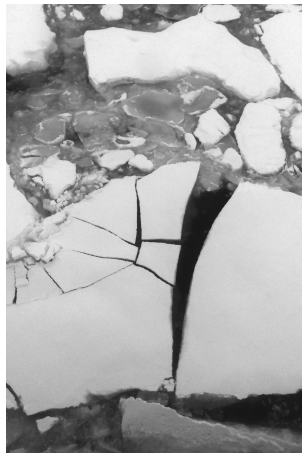


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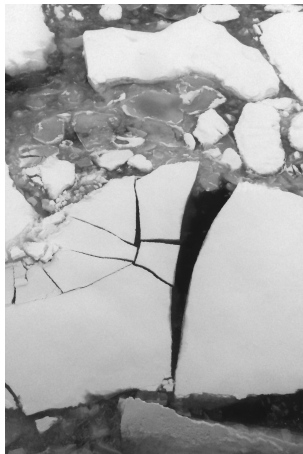


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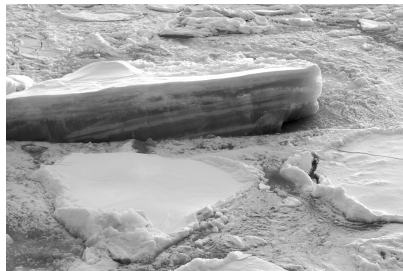
Credit: Damien Ringeisen



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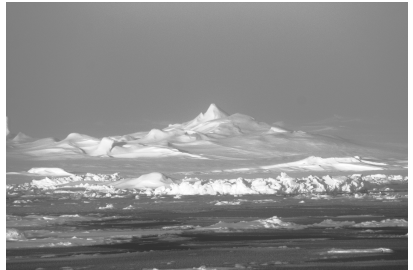


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Credit: Damien Ringeisen

# Sea Ice models

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- Bases in Elastic-Plastic (Coon et al., 1974)
- Viscous-Plastic Material (Hibler, 1979)
- Used in 30 of 33 models (Stroeve et al., 2014)
- 100 km  $\rightarrow$   $<$  1 km
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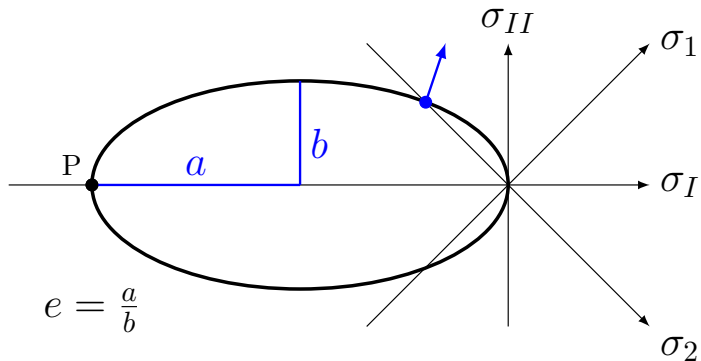
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$$\sigma_{ij} = 2\eta \dot{\epsilon}_{ij} + (\zeta - \eta) \dot{\epsilon}_{kk} \delta_{ij} - \frac{P}{2} \delta_{ij}$$



# Sea ice model : Yield Curve

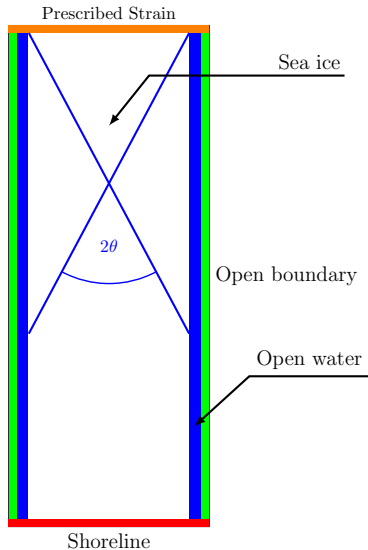


Standard:  $P = 2.75 \cdot 10^3 \text{ N m}^{-1}$  and  $e = 2$

# High resolution simulation

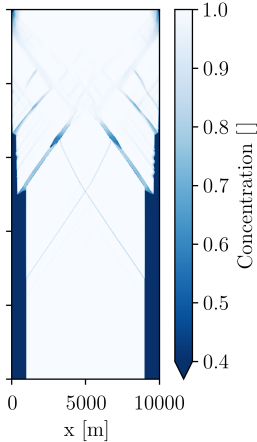
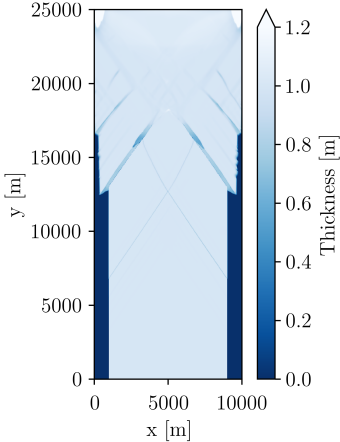
High resolution simulation

# Idealized Experiment

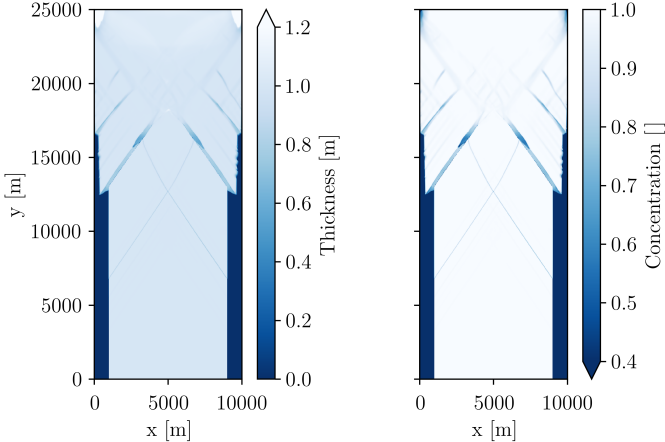


- In MITgcm (Marshall et al., 1997; Losch et al., 2010)
- Uniform thickness  $h = 1\text{ m}$
- Uniform concentration  $C = 100\%$

# Results: 45 min

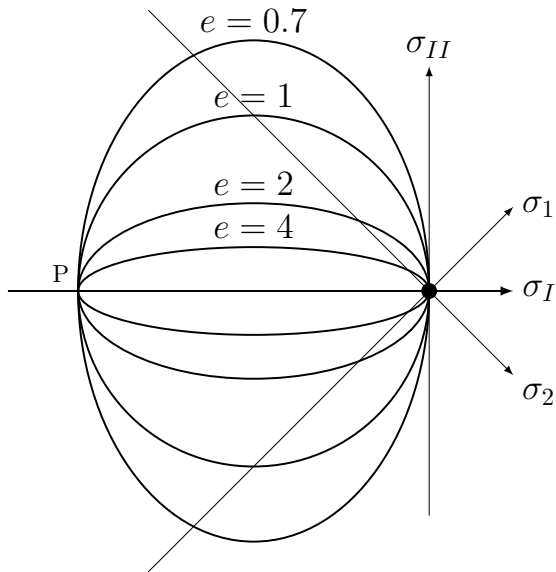


# Results: 45 min

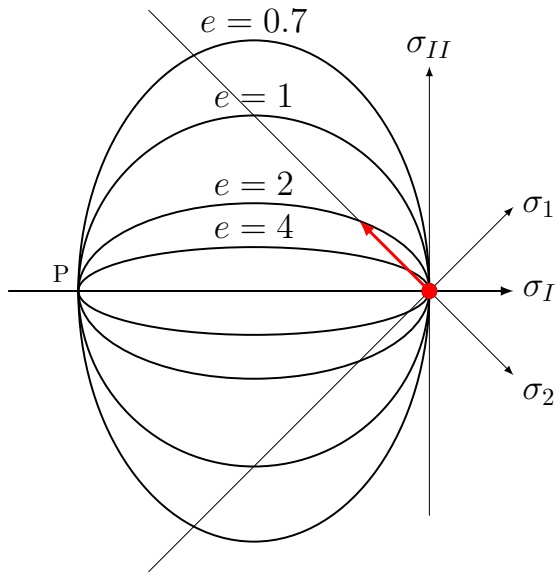


Initial fracture : after 5 seconds

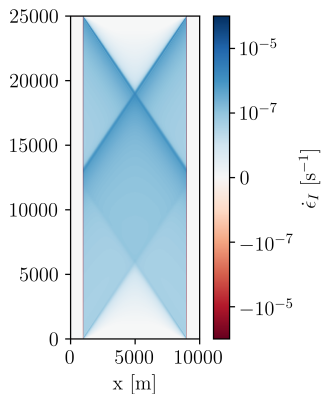
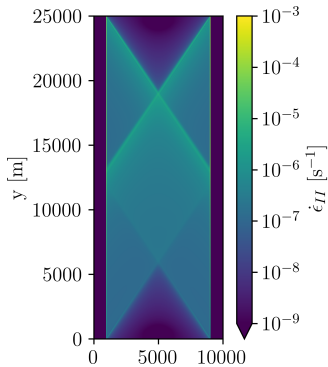
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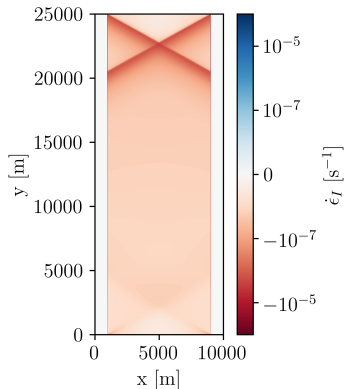
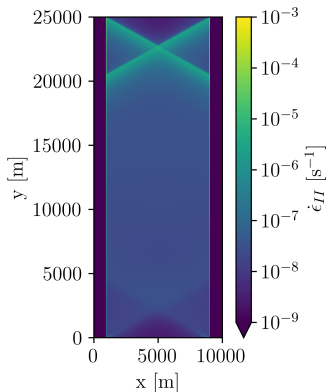
# Results: Elliptical yield curve



$$\theta|_{e=2} = 34^\circ$$

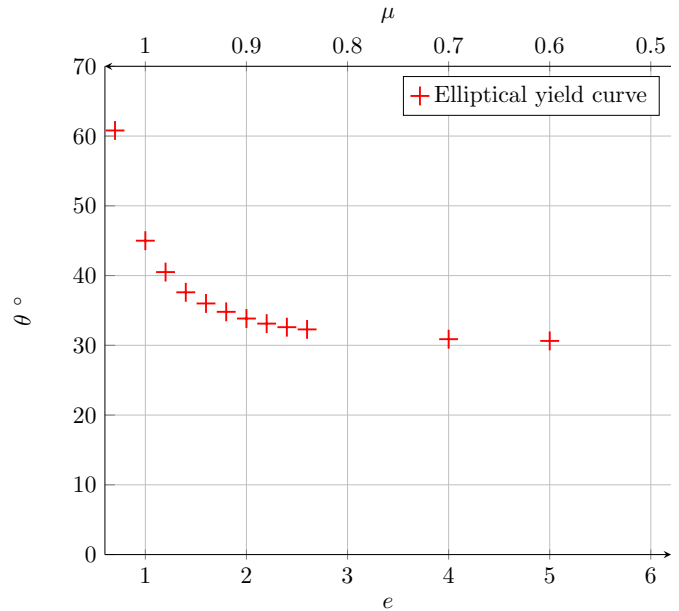


# Results: Elliptical yield curve

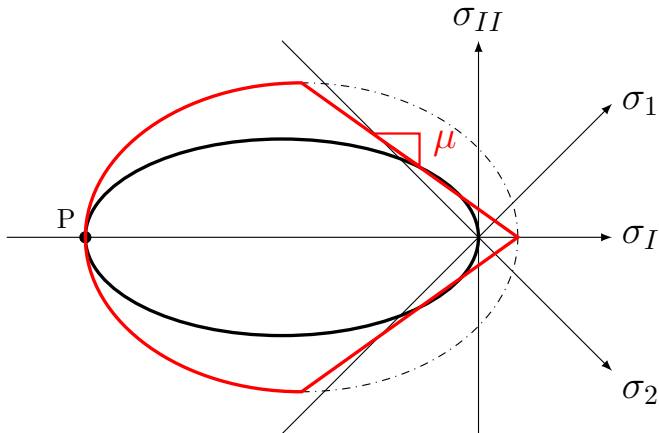


$$\theta|_{e=0.7} = 61^\circ$$

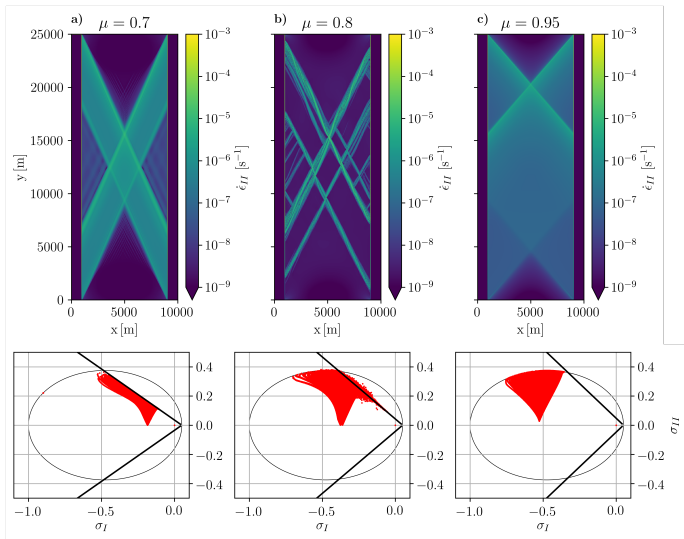
# Results: Elliptical yield curve



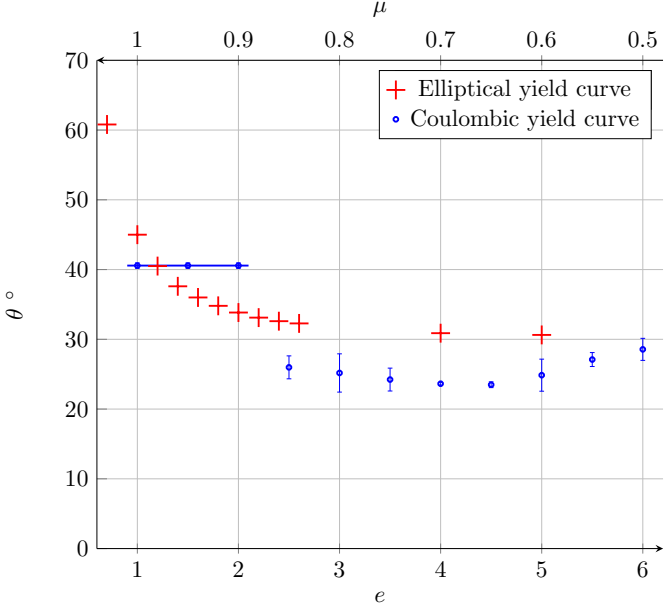
# Results: Coulombic yield curve



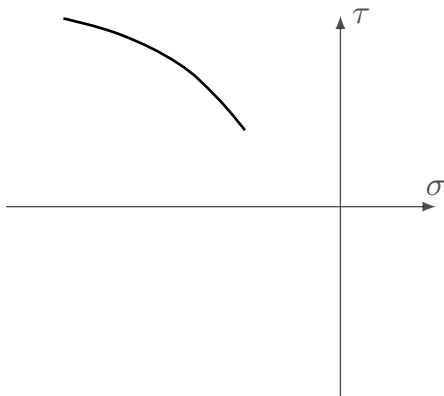
# Results: Coulombic yield curve



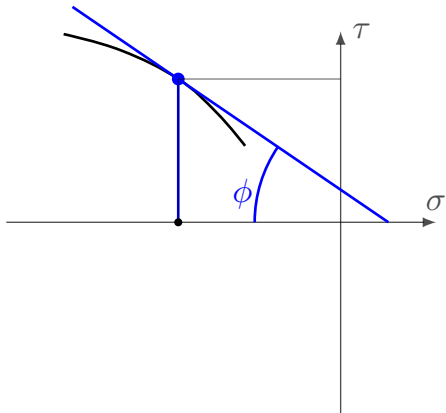
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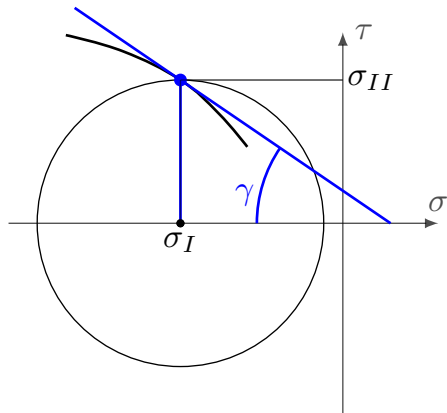
# Mohr's circle



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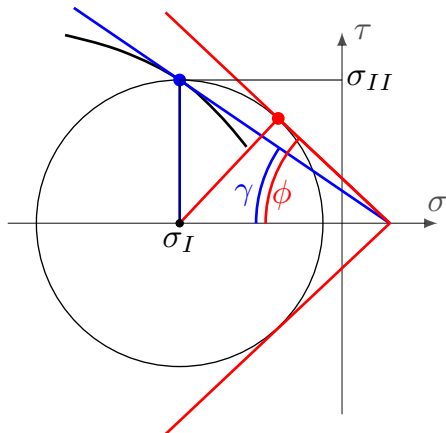


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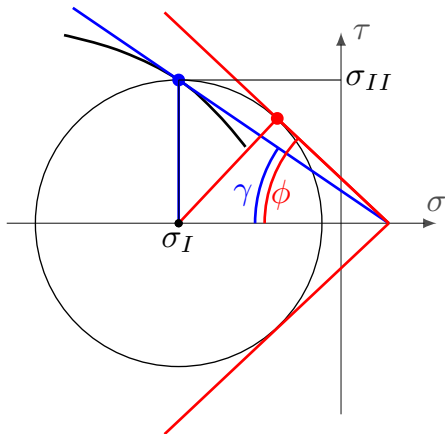




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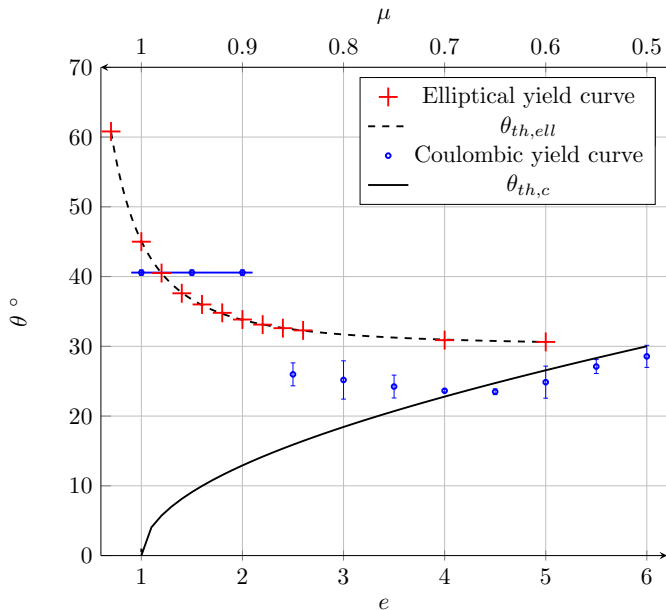


# Mohr's circle



$$\theta_{th,ell}(e) = \frac{1}{2} \arccos \left[ \frac{1}{2} \left( 1 - \frac{1}{e^2} \right) \right] ; \theta_{th,c}(\mu) = \frac{1}{2} \arccos(\mu)$$

# Fitting modelled angles



# Summary

- Elliptical yield curve :
  - No Fracture angles below  $30^\circ$
  - More shear strength  $\rightarrow$  increase angle
- Coulombic yield curve
  - Possibility of smaller angle
  - No kink in the yield curve!
- Linked fracture angle/yield curve

We need a **new yield curve** and **flow rule** to model sea ice at high resolution as a **granular** material with fracture angles that **compare** to observations.

**More details in**

Ringeisen et al. 2019



# And now what?!

## Surface forcing and

- Material properties test
- Sea ice models are different
- **Surface forcing tests:**
  - The fracture angle is different than before
  - Because of gradients of stress in the ice

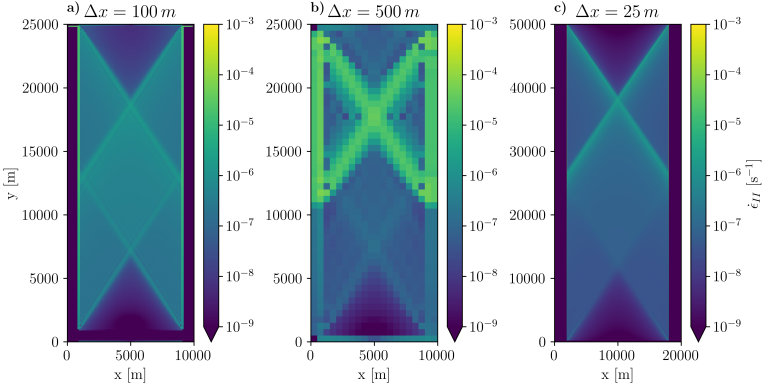
## New Yield curve

- Teardrop yield curve (Zhang and Rothrock, 2005)
- Implementation pending:
  - Problems with the mathematical formulation

# Surface forcing

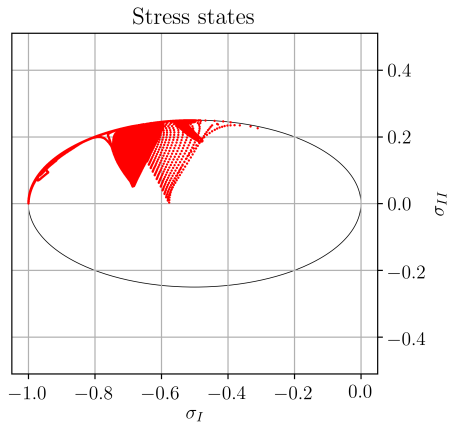
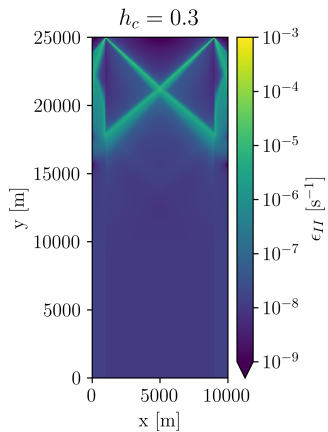
Fracture with surface forcing

# Resolution and scale

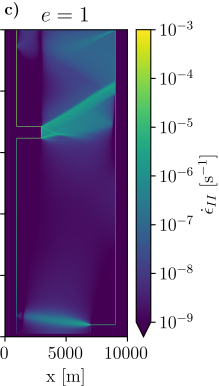
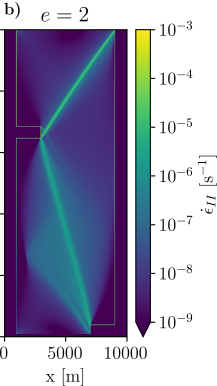
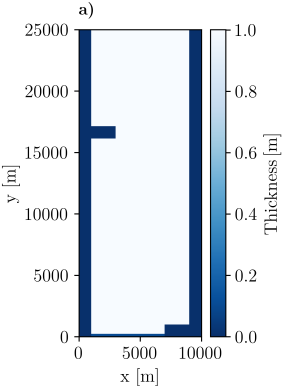




# Confinement



# Initial conditions



# References I

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