Evolution Of Basal Crevasses Links Ice Shelf Stability To Ocean Forcing

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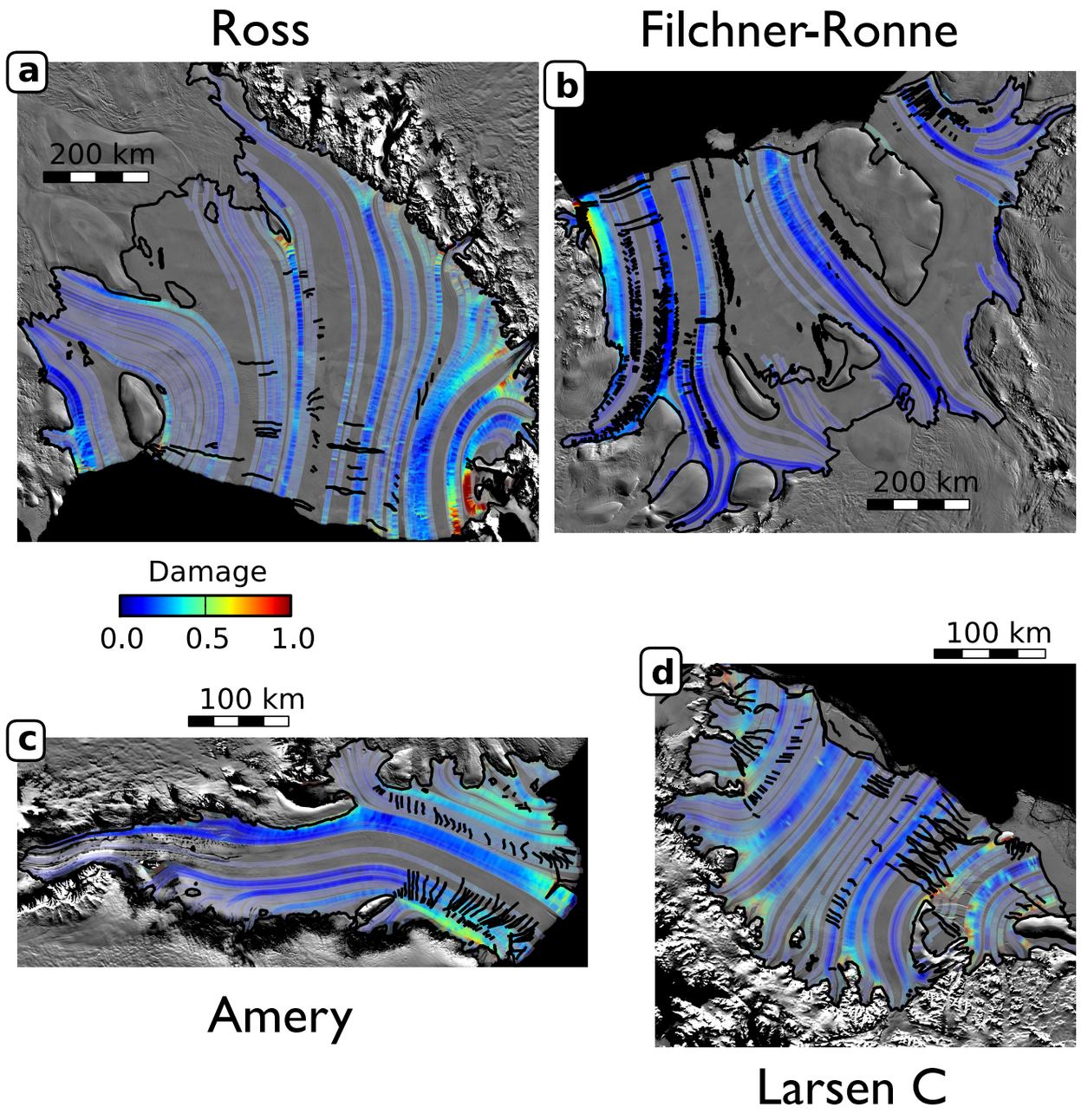
Mass balance of ice shelves

- Mass lost from ice shelves
  - 1/2 basal melting (controlled by ocean forcing)
  - 1/2 calving (controlled by ?)

Iceberg calving is linked to ocean forcing

Don't need crevasses to explain calving

Where do ice shelves break?

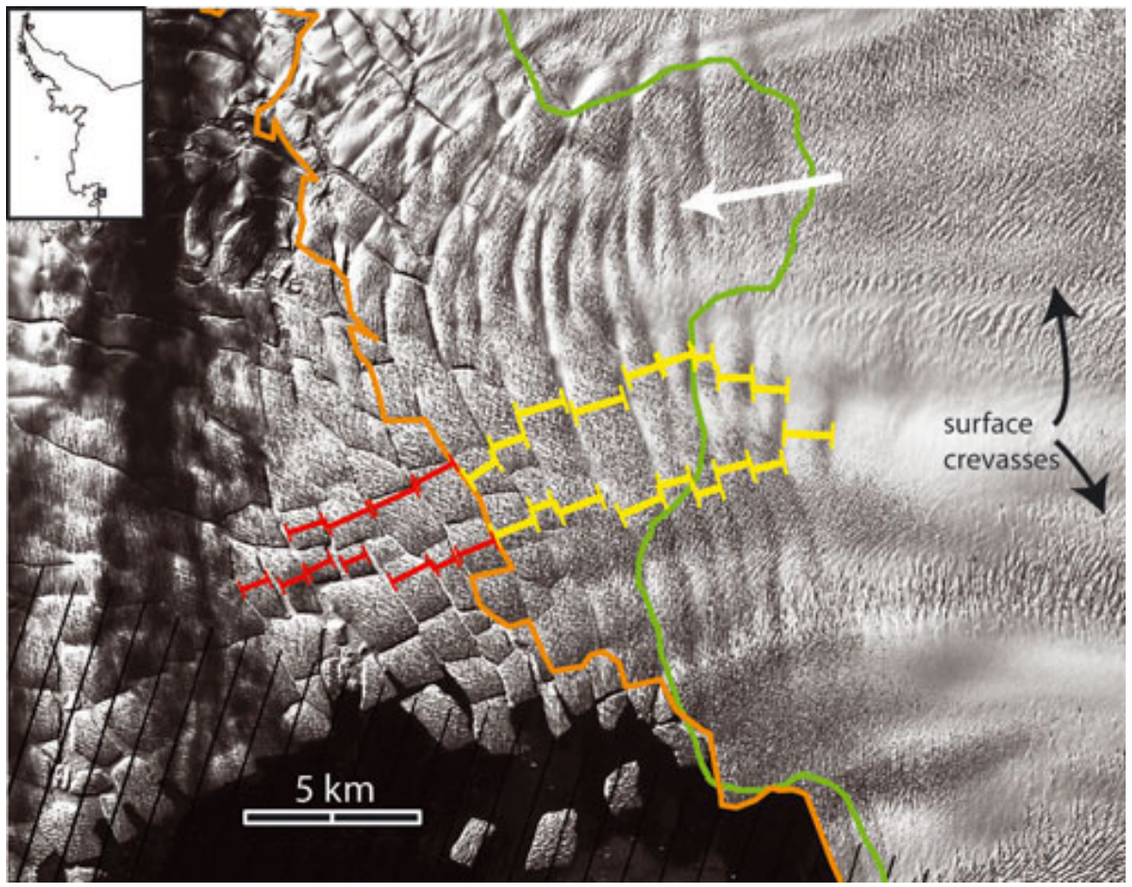


1. Fracture mechanics predict crevasses do not penetrate entire ice thickness

2. Crevasse penetration ratio greatest near grounding zones and smallest near the calving front

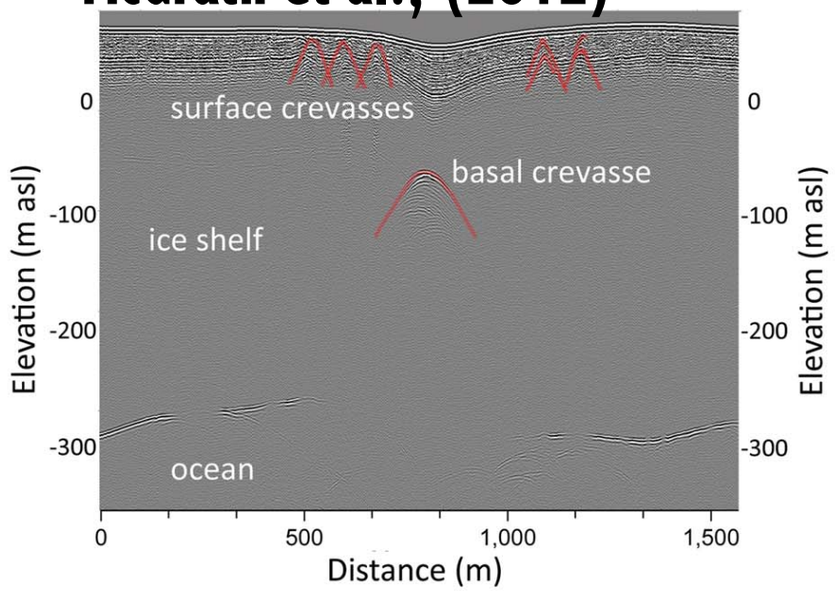
What happens to crevasses after they initiate?

Logan et al., (2013)

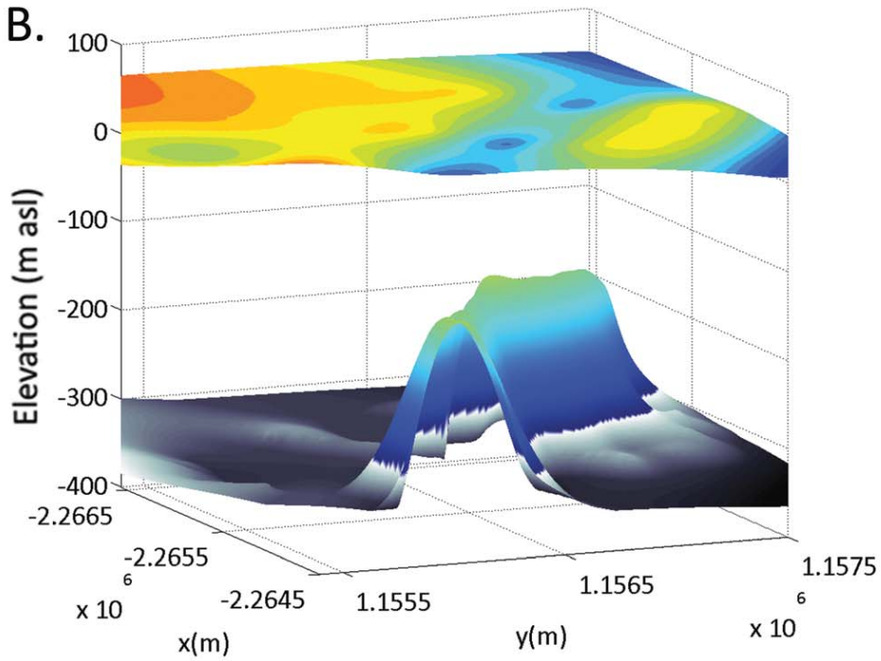


can get deeper as they advect downstream

A. **McGrath et al., (2012)**



B.



can be > 400 m wide

What happens to crevasses after they initiate?

Aspect ratio of brittle fractures is small

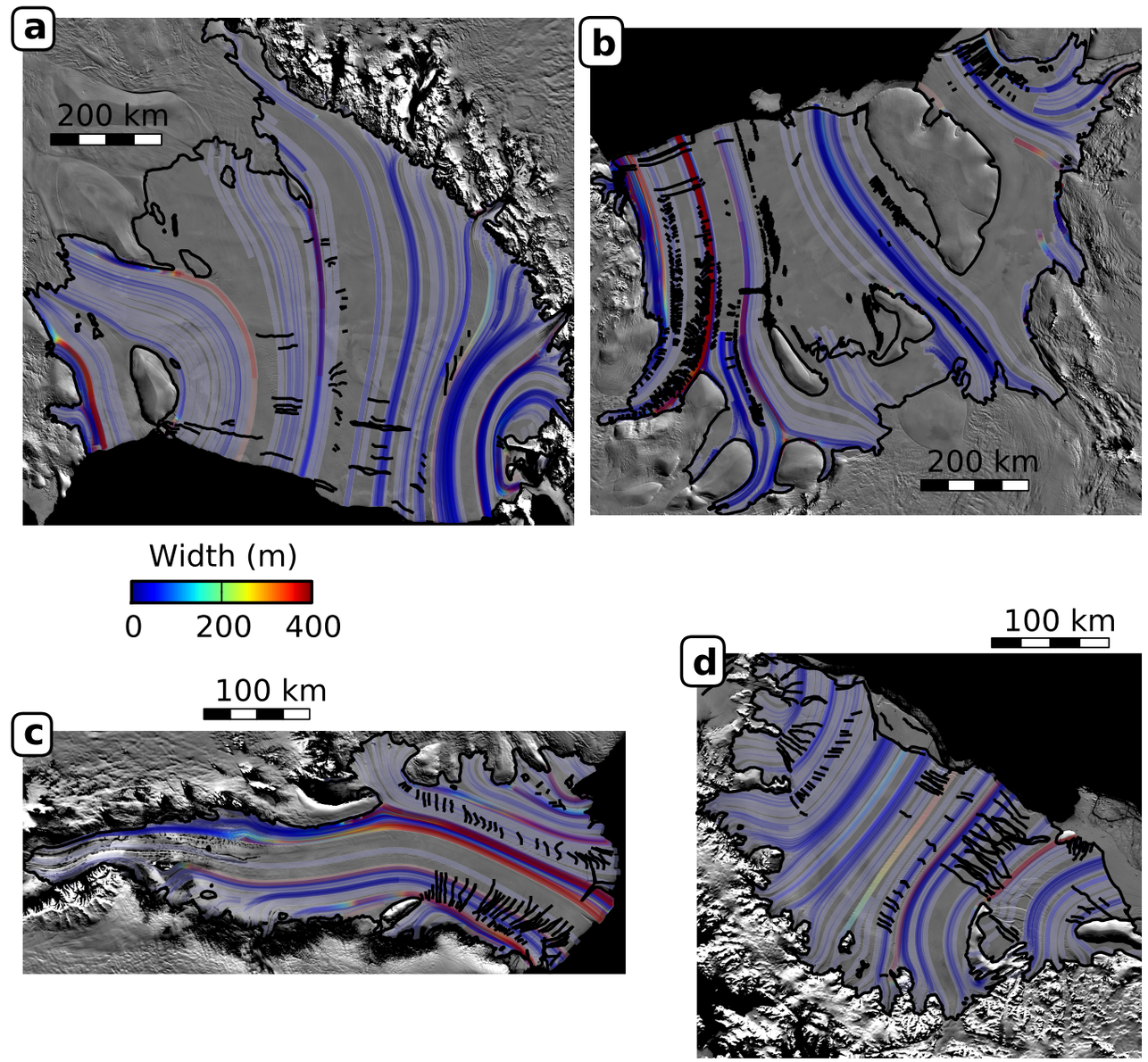
$$\frac{w}{\lambda} \approx \frac{\sigma}{G} \approx \frac{100\ \text{kPa}}{1\ \text{GPa}} = 10^{-4}$$

Advection and widening

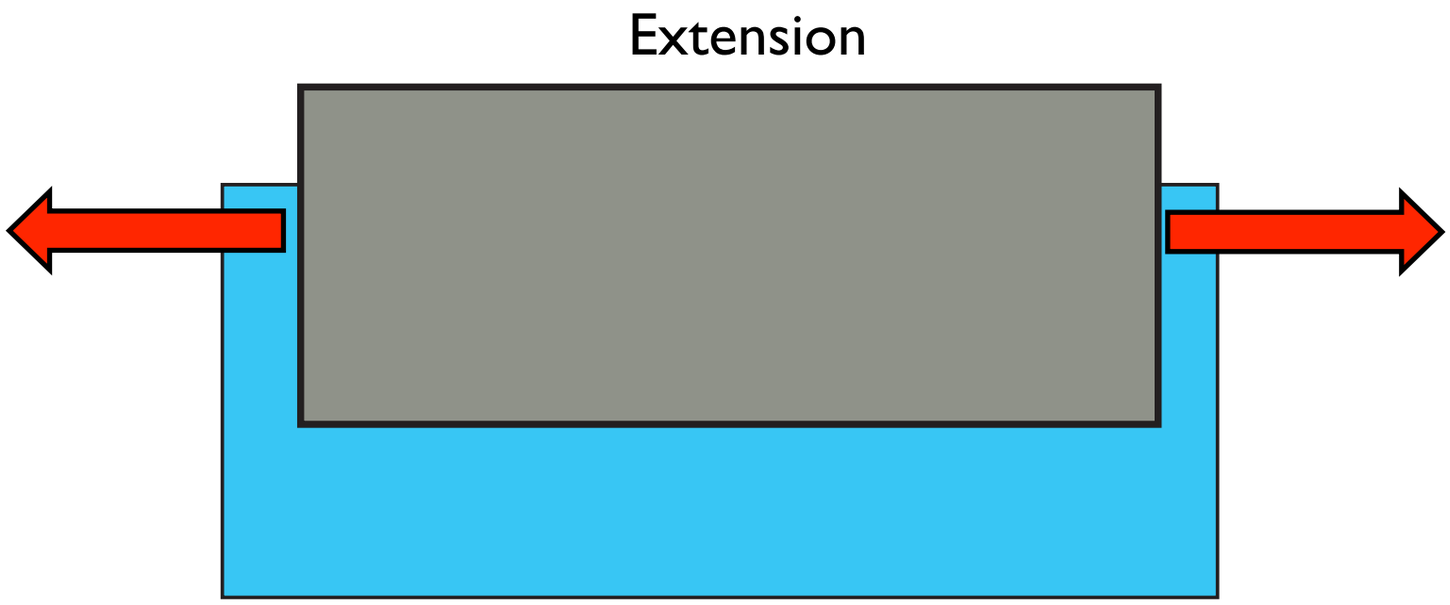
$$\tau = \frac{1}{\dot{\varepsilon}} = 100\text{-}1000\ \text{years}$$

Crevasse depths <u>decrease</u> as they advect

$$\frac{d\lambda}{dt} = -\dot{\varepsilon}\lambda$$



Plastic Necking



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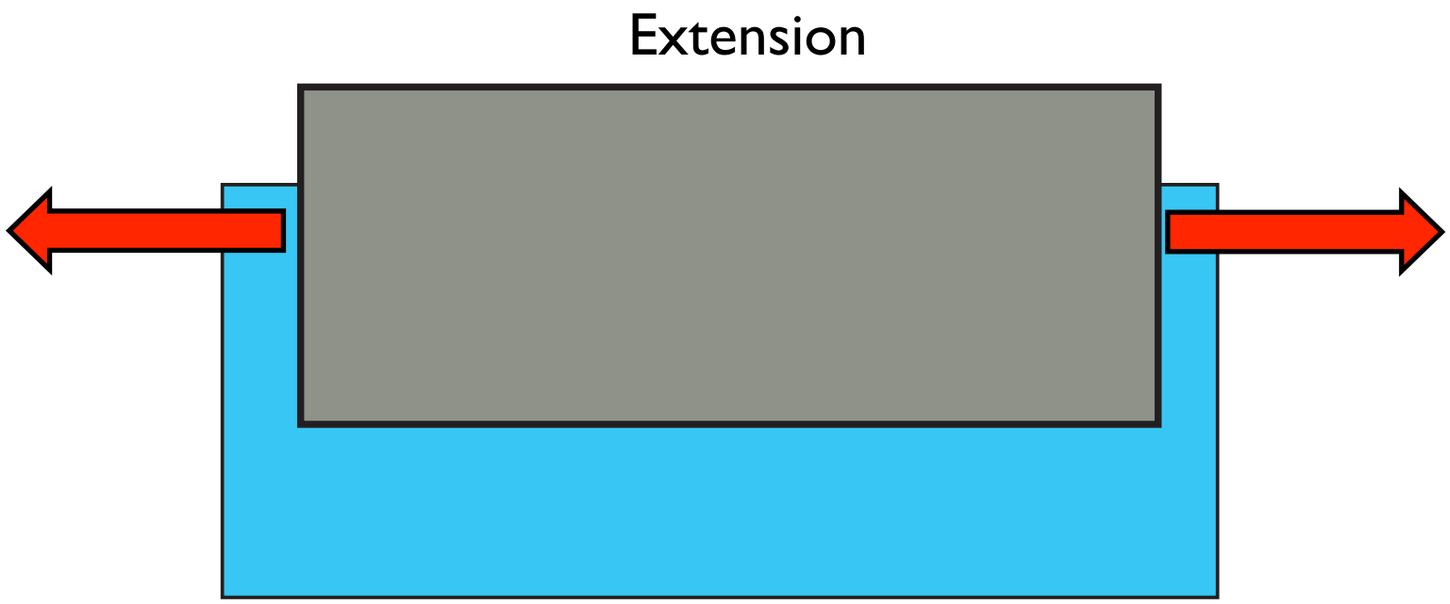
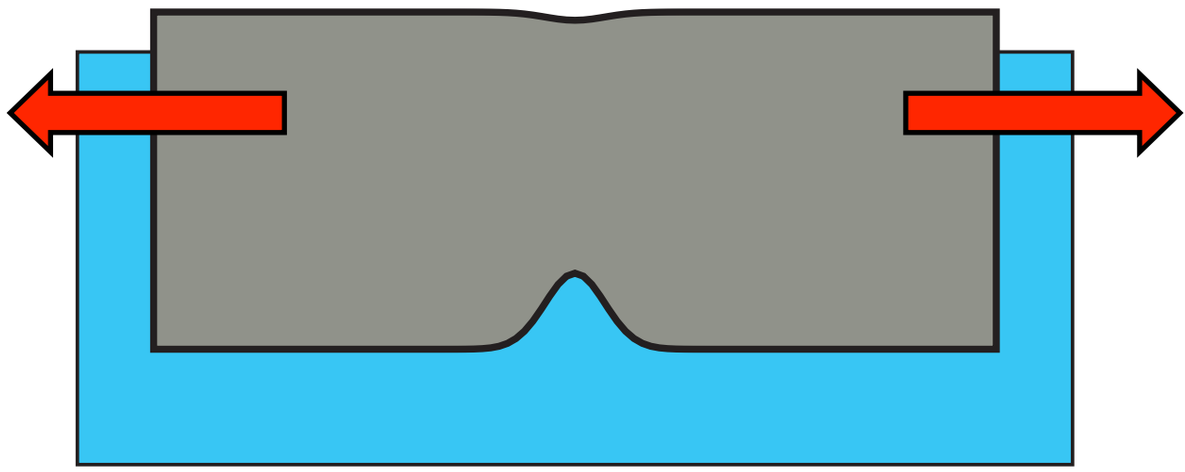
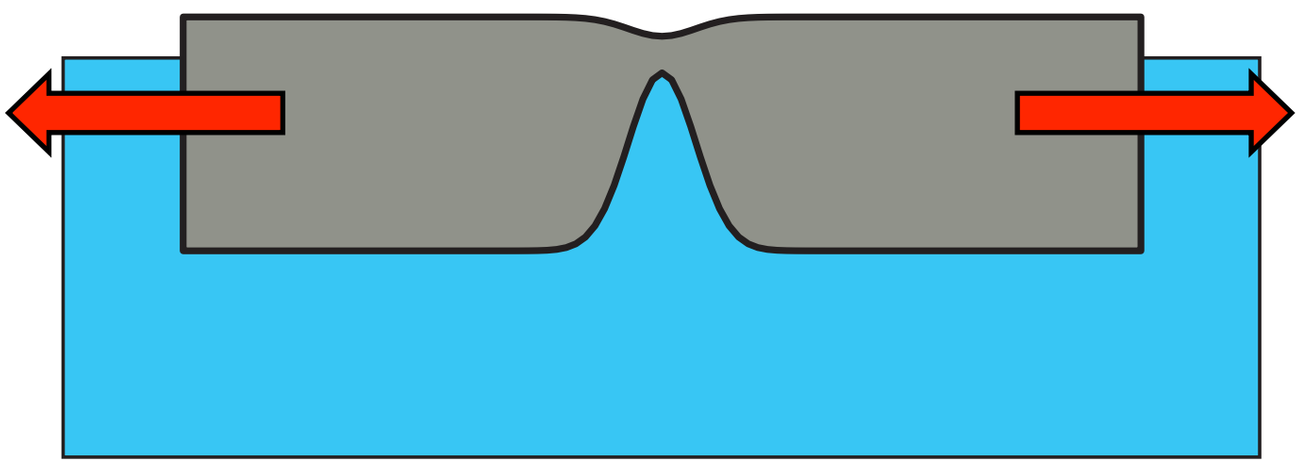


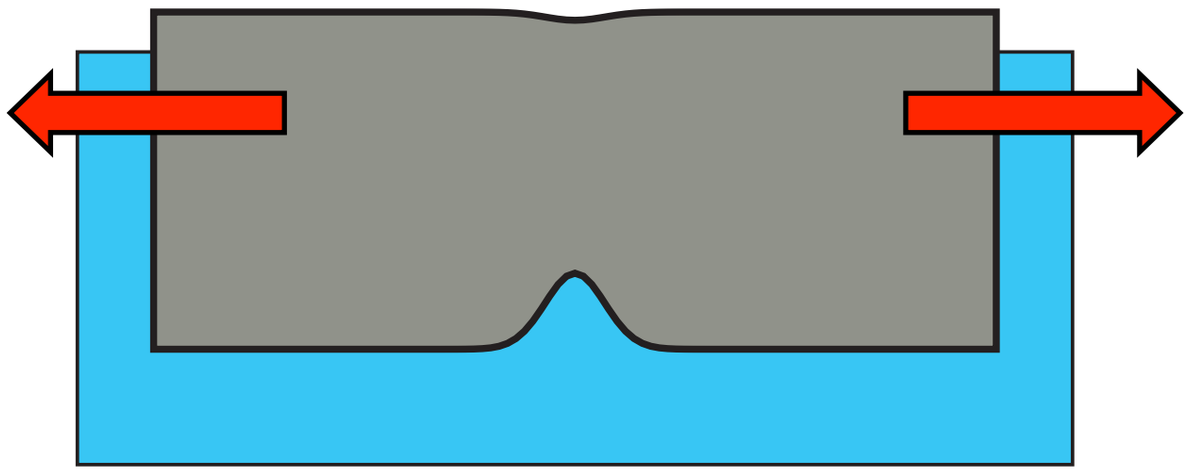


Plastic Necking

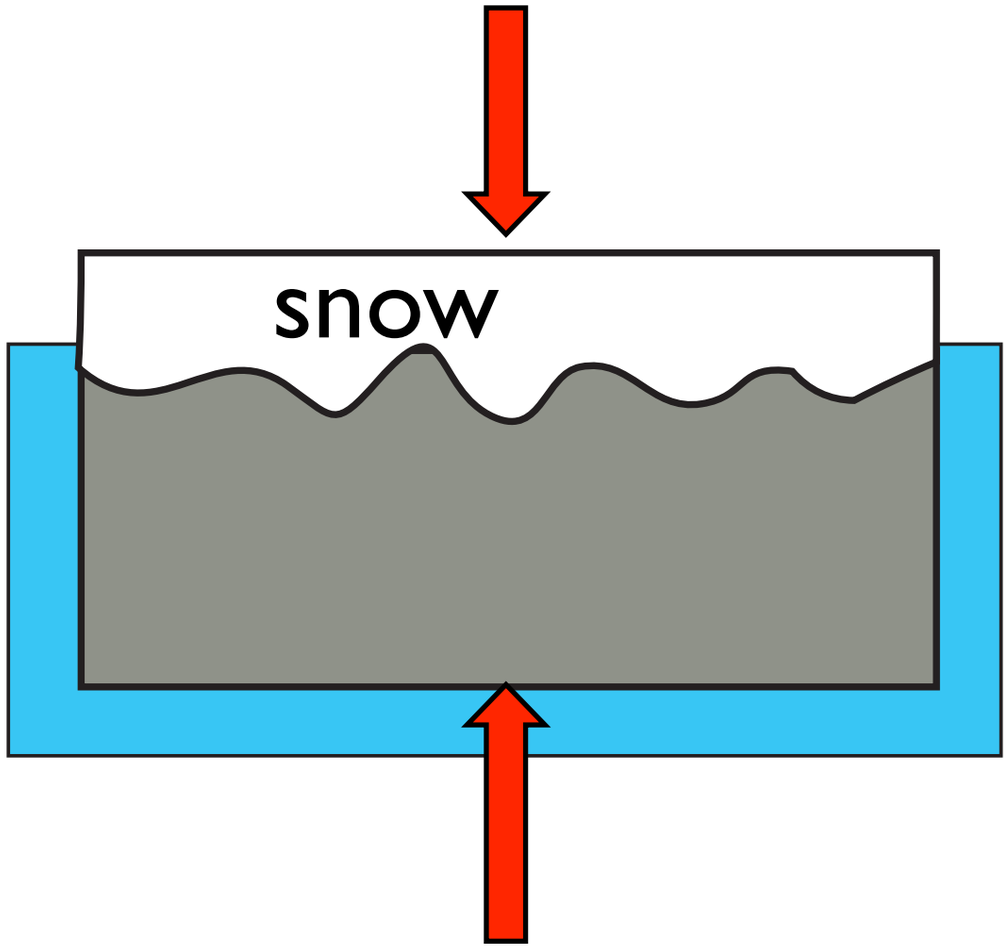
Extension

Strain weakening





. . . But Gravity Resists



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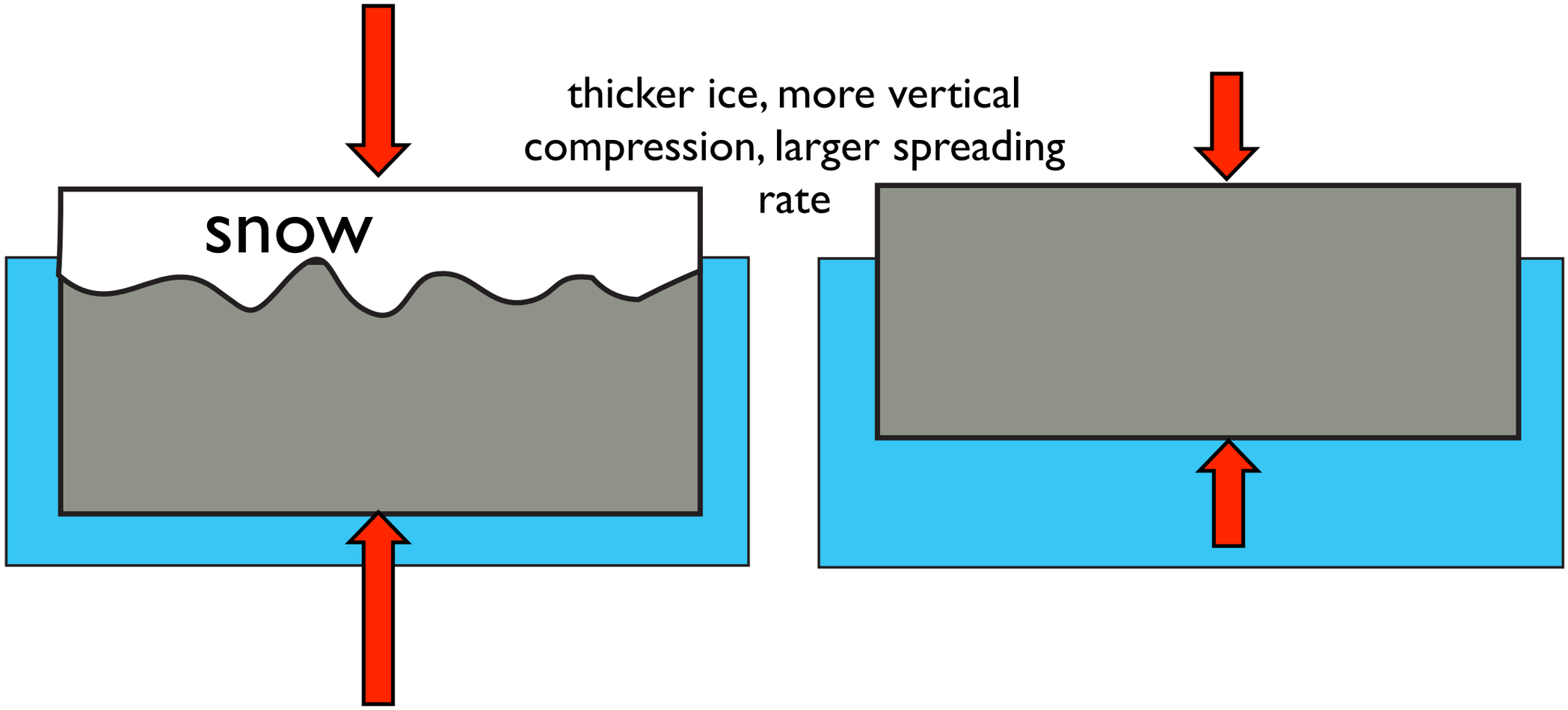

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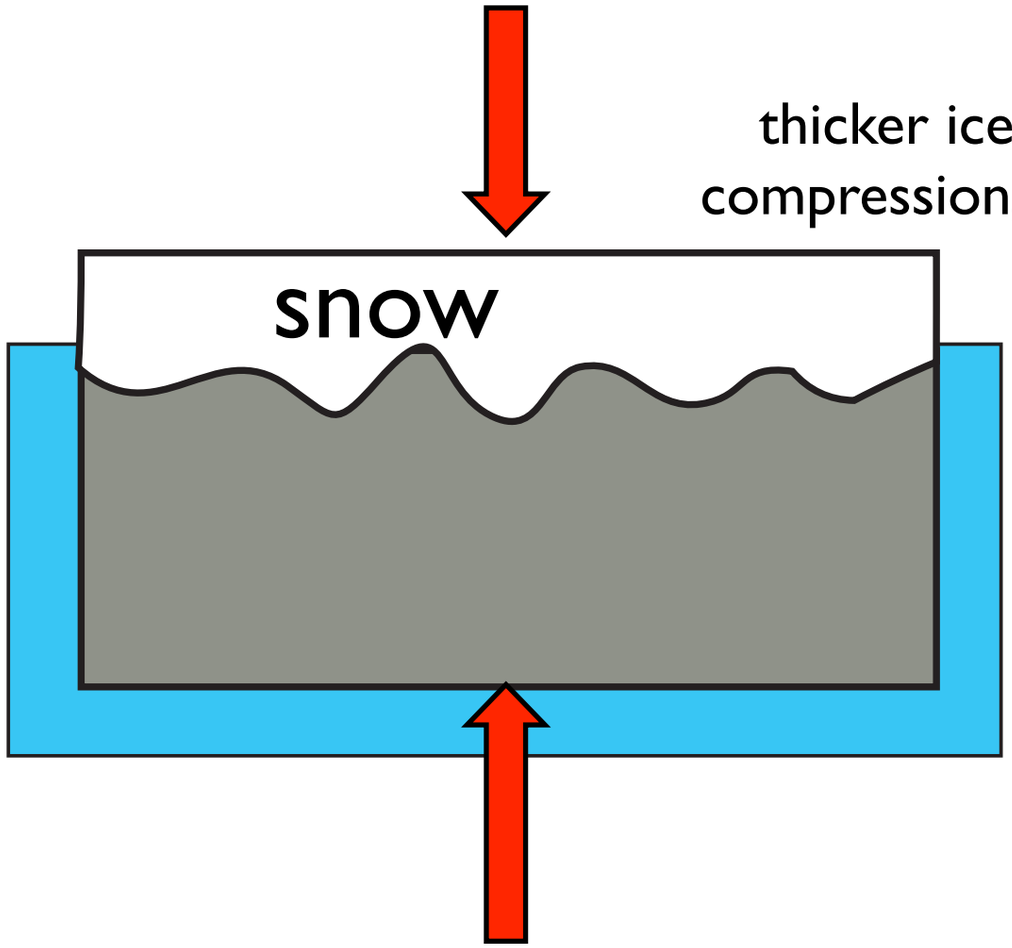
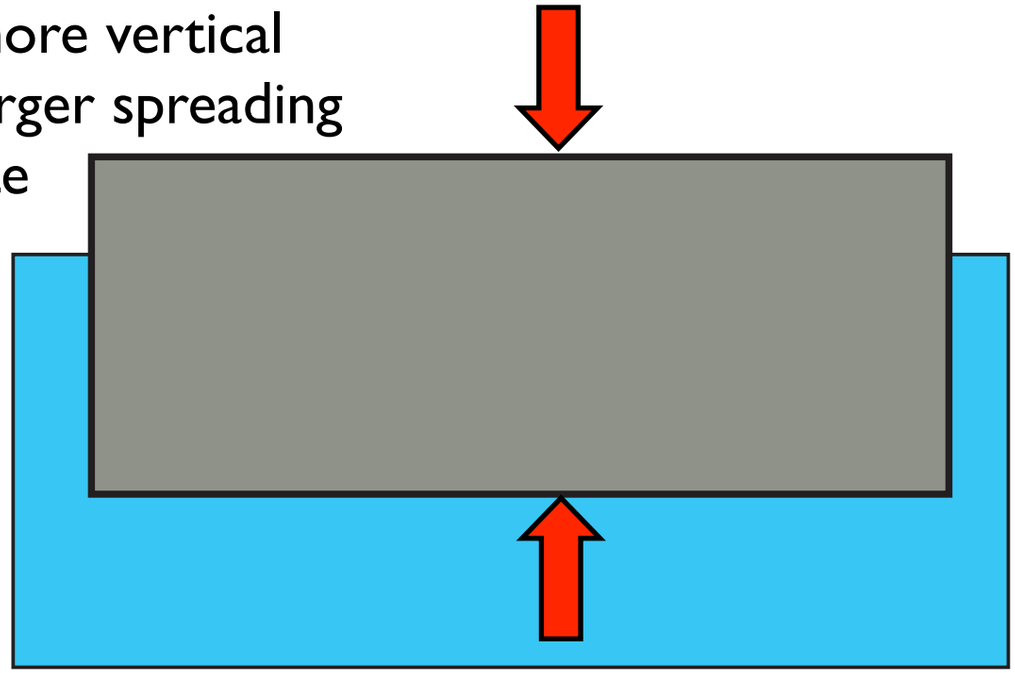
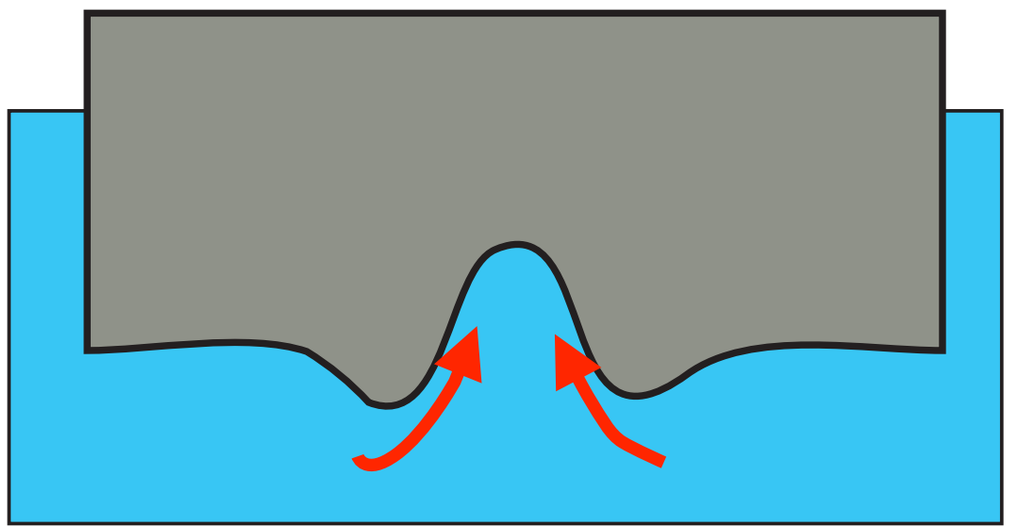
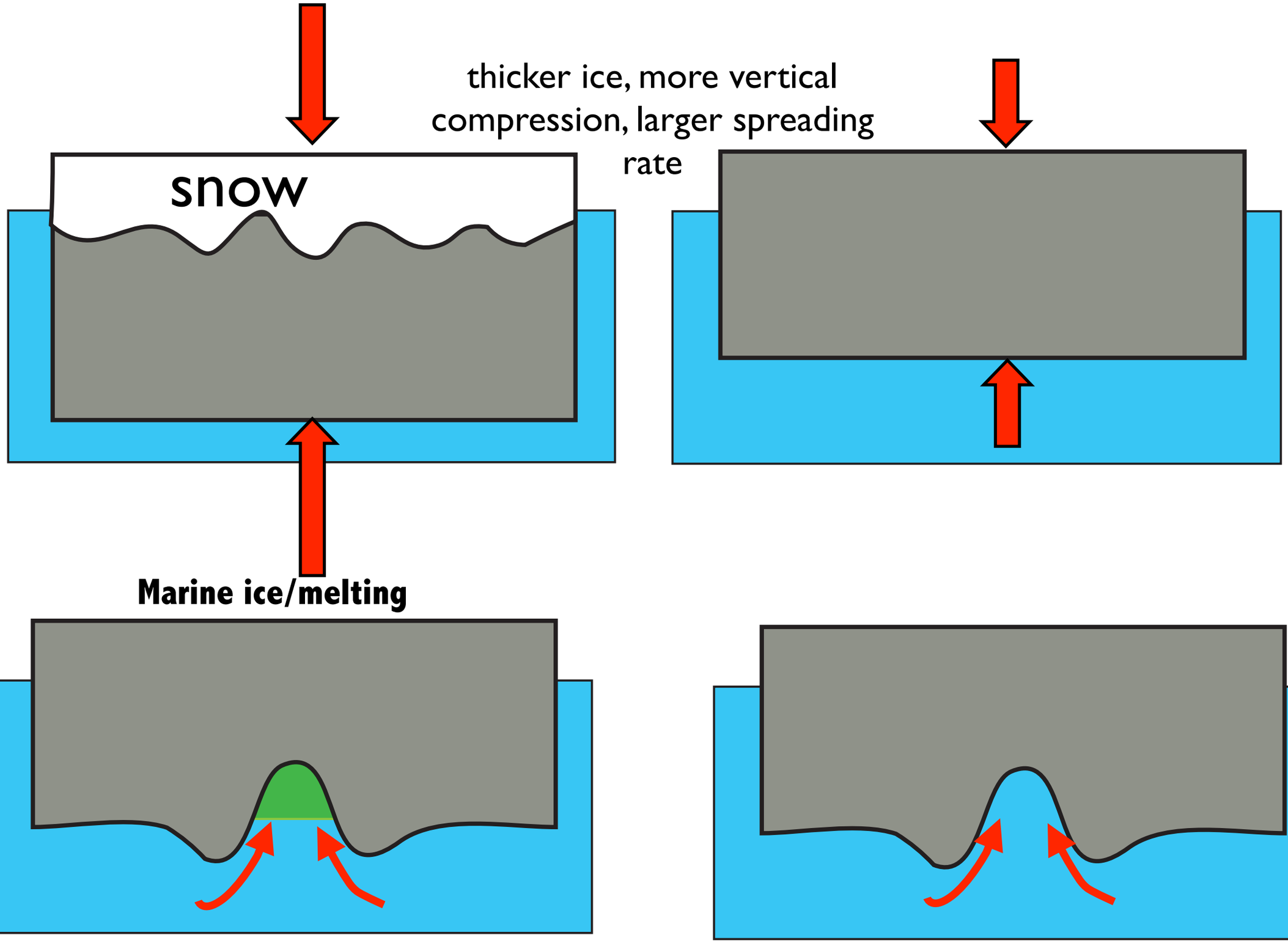


thicker ice, more vertical compression, larger spreading rate





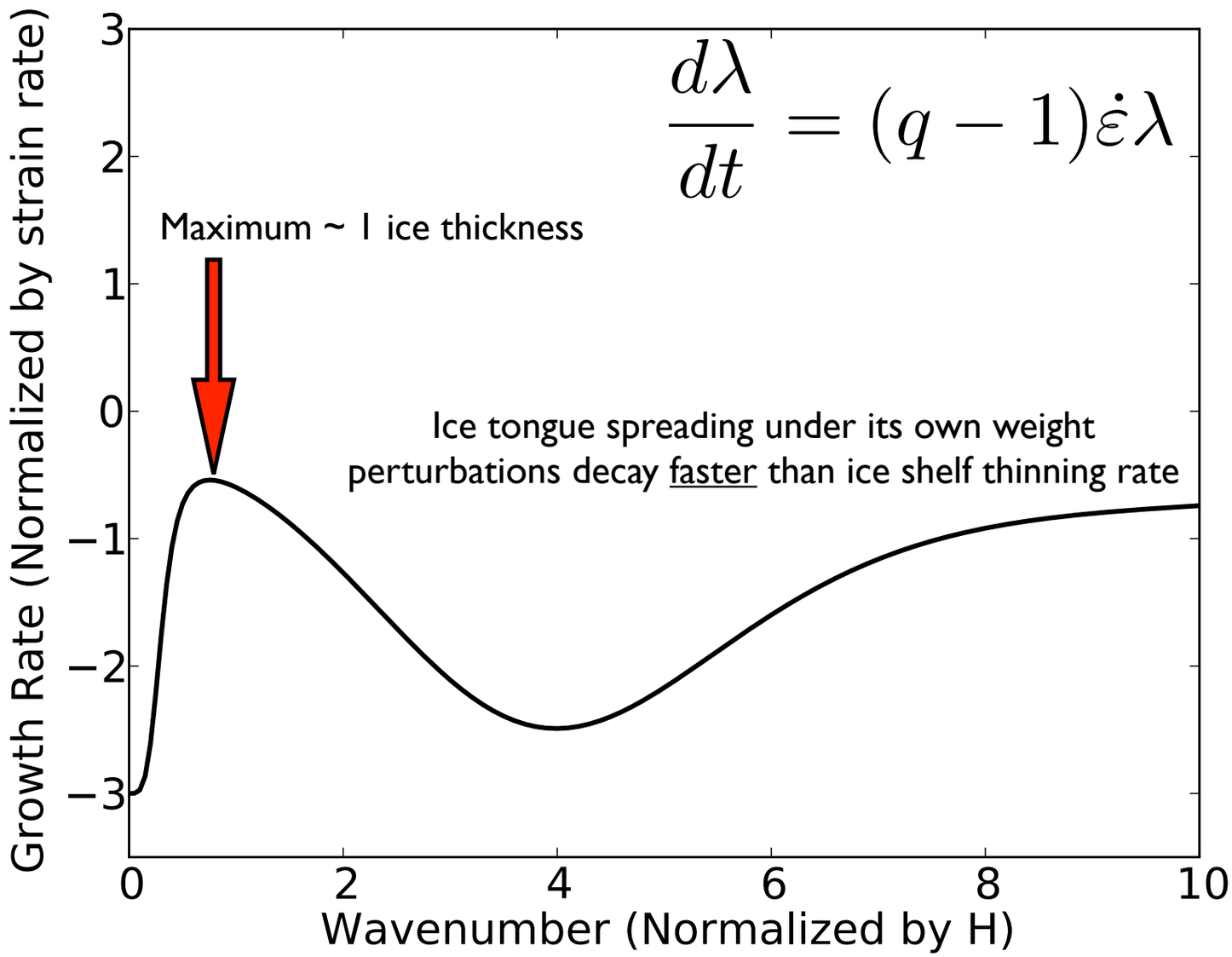
. . . And Melting/Freezing?



(un)Stable Extension Of Ice Shelves

Stability controlled by:

$$S = \frac{(\rho_w - \rho_i) g H_0}{\mu_0 \dot{\varepsilon}}$$



Solve for growth rate of perturbations of different wavenumber

Perturbations at some wavelengths grow faster than others

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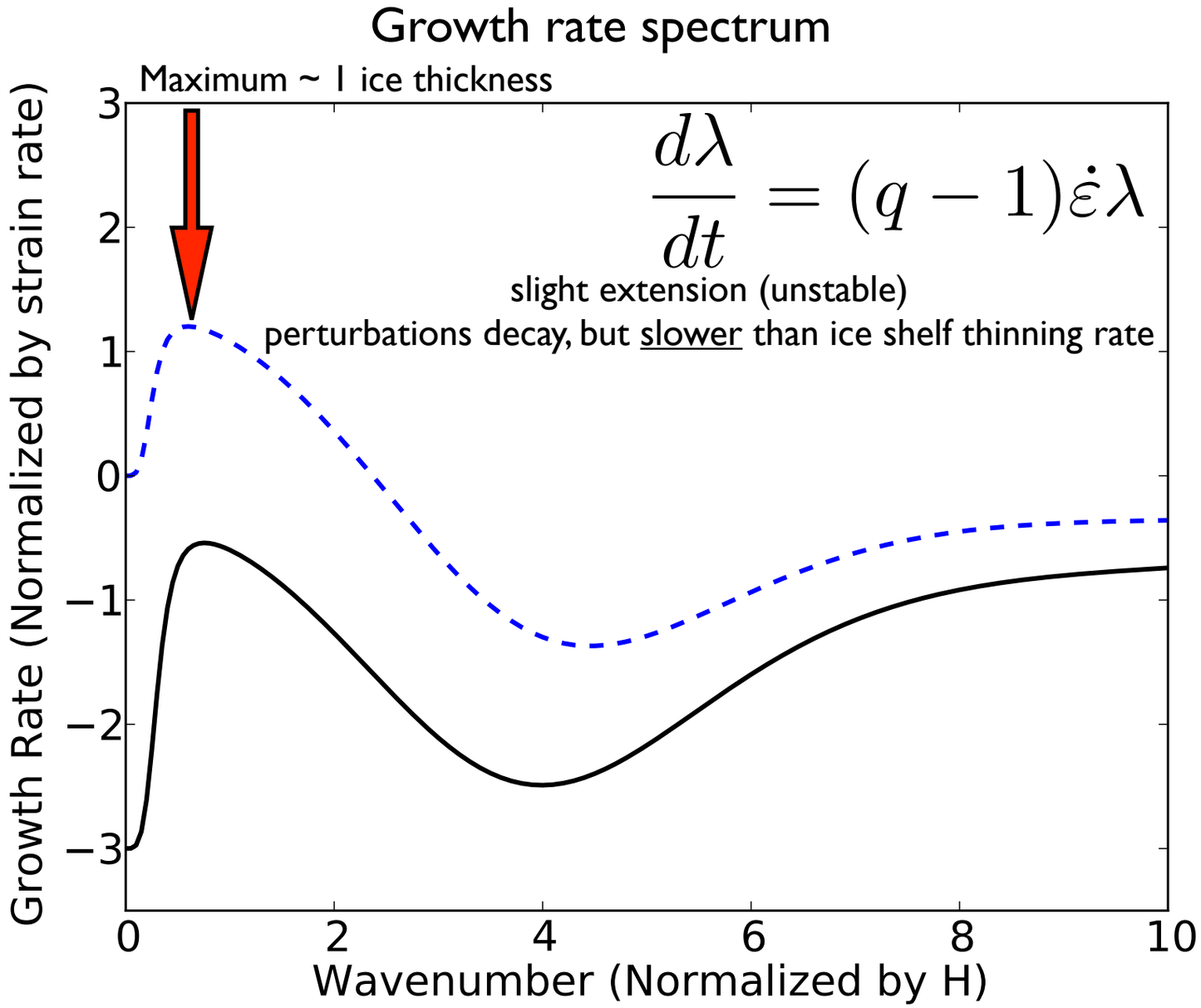

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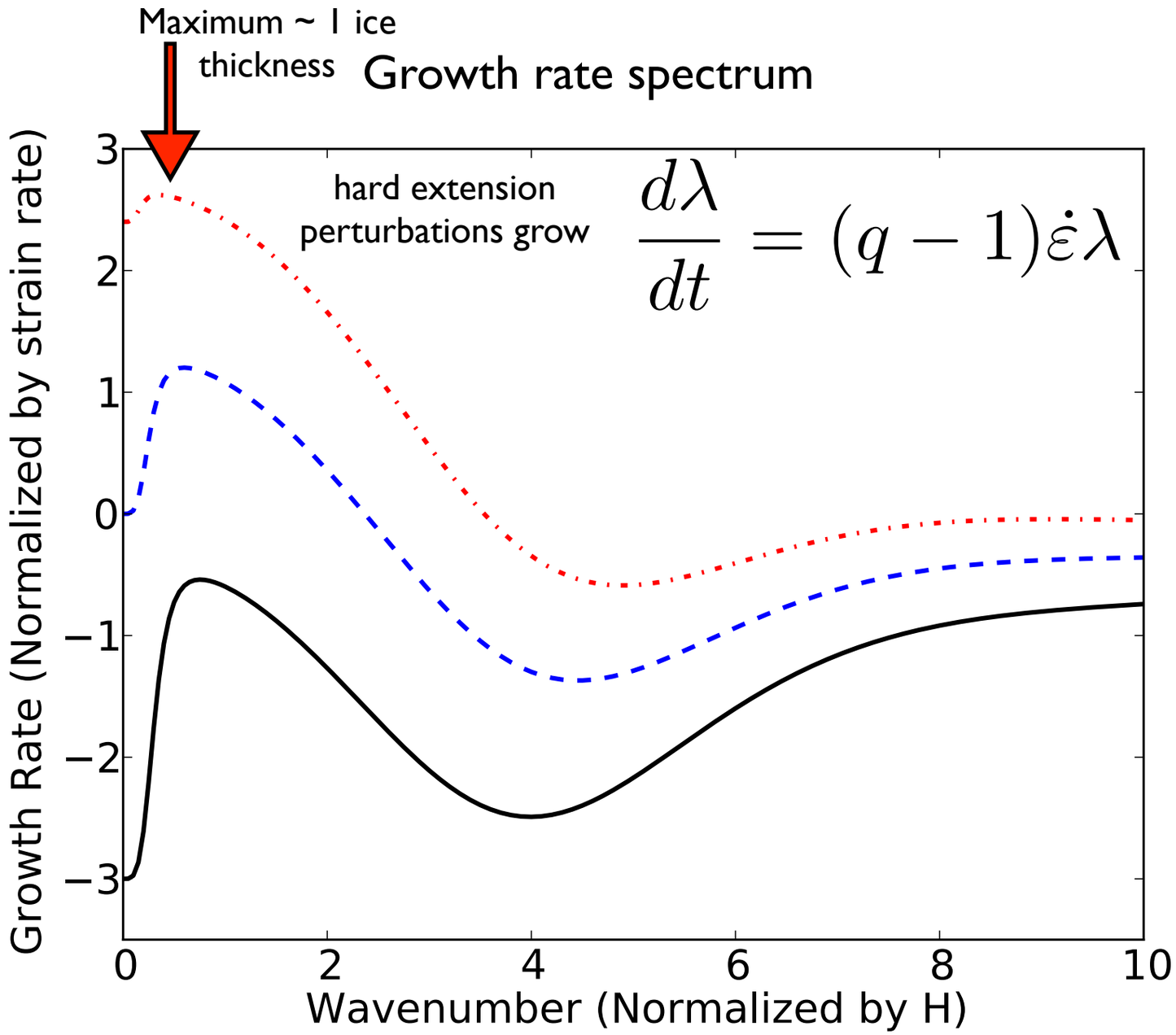

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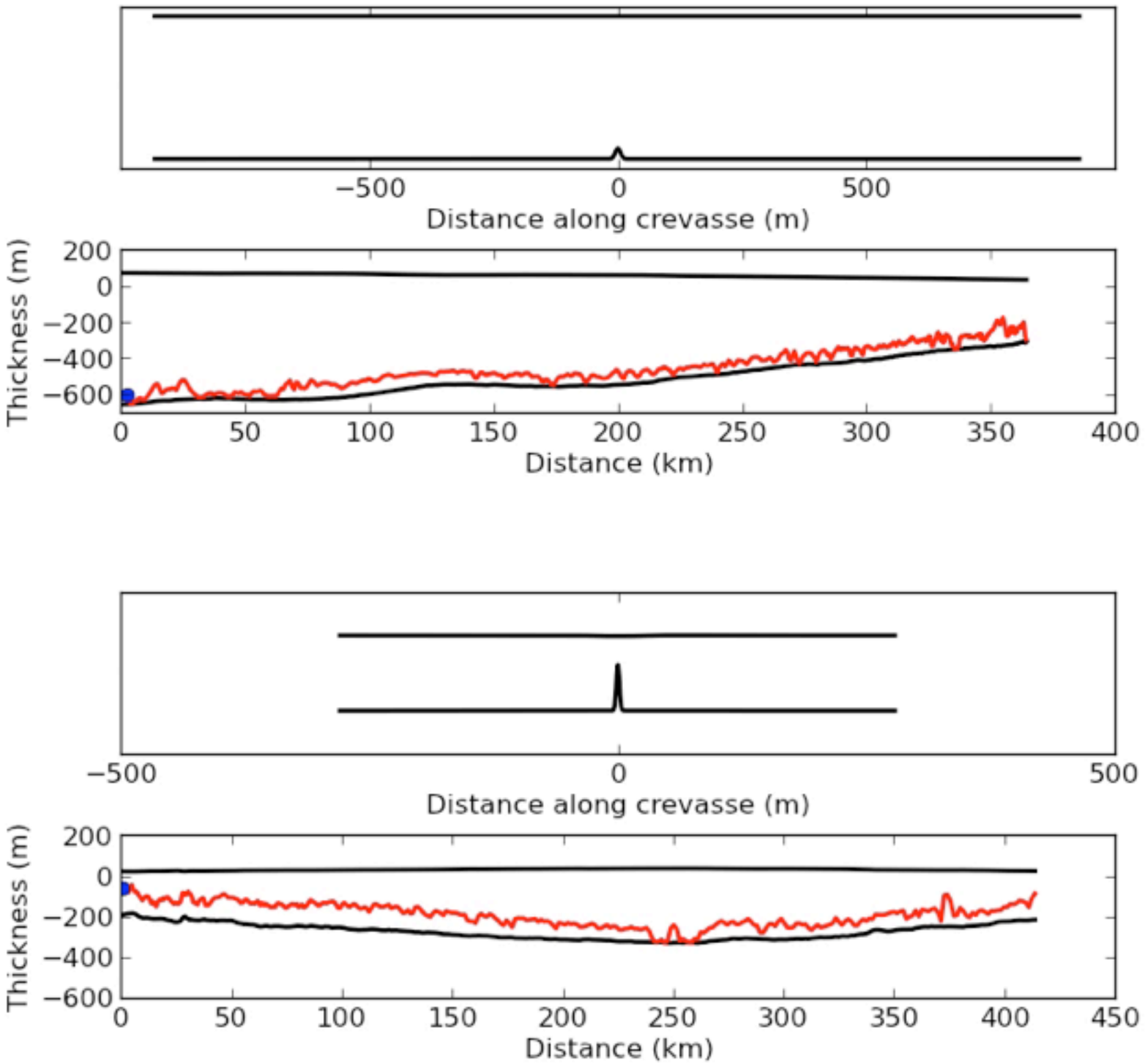
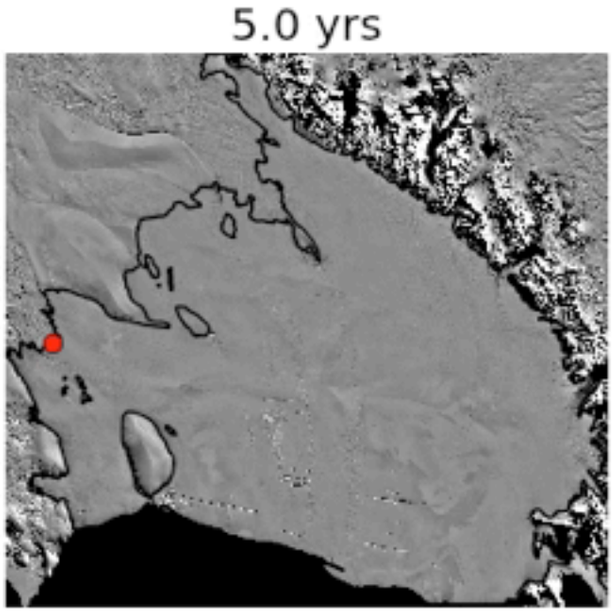
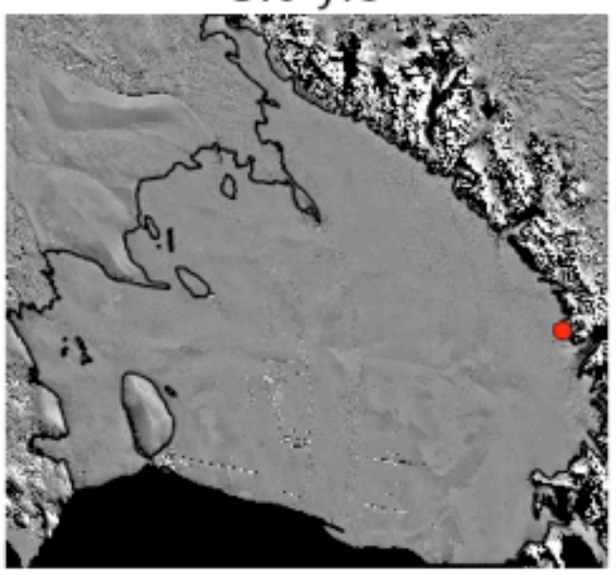
Evolution Of Basal Crevasses



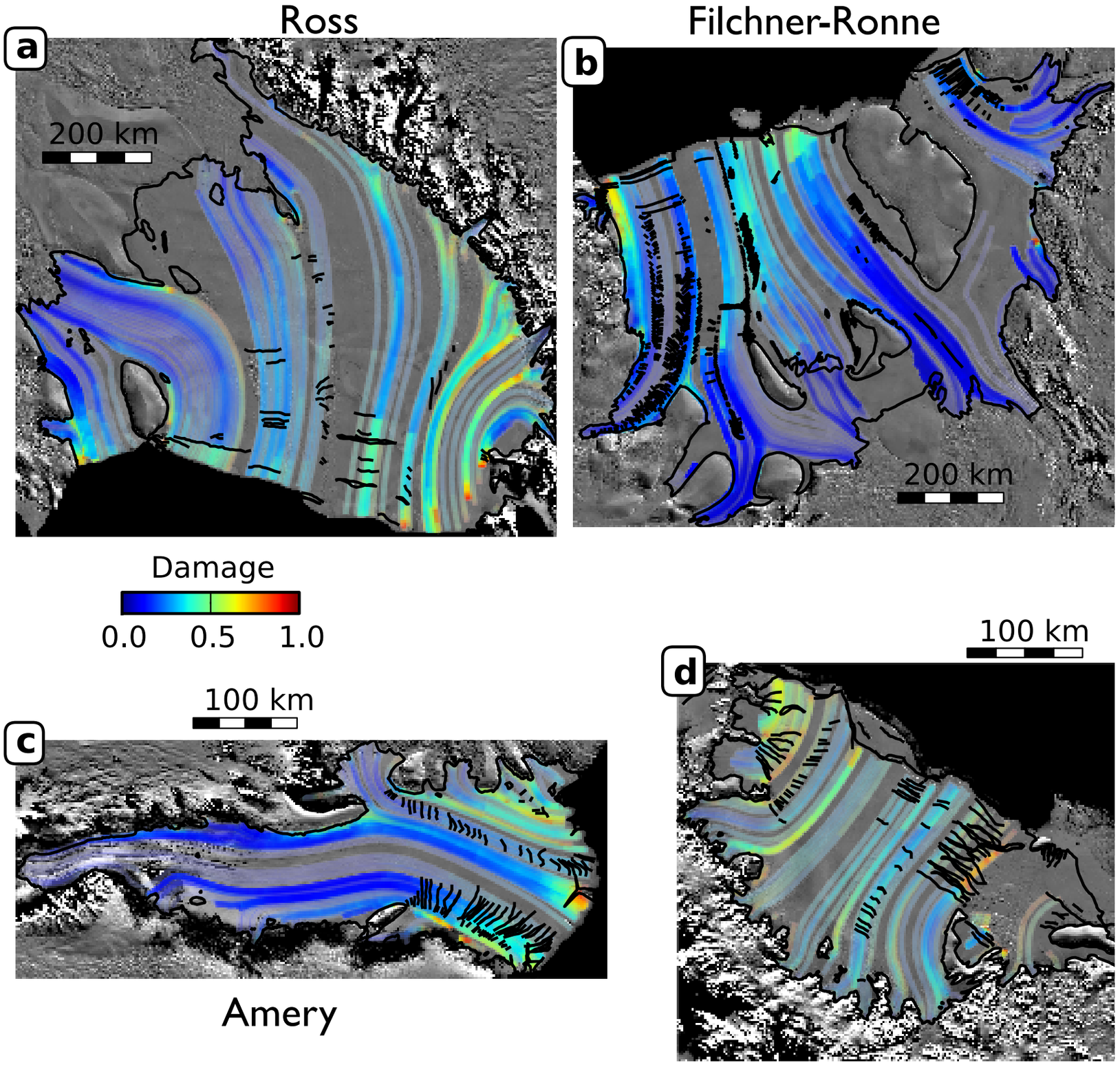




Dynamic response superimposed on background thickness

Plastic Necking: The Big 4

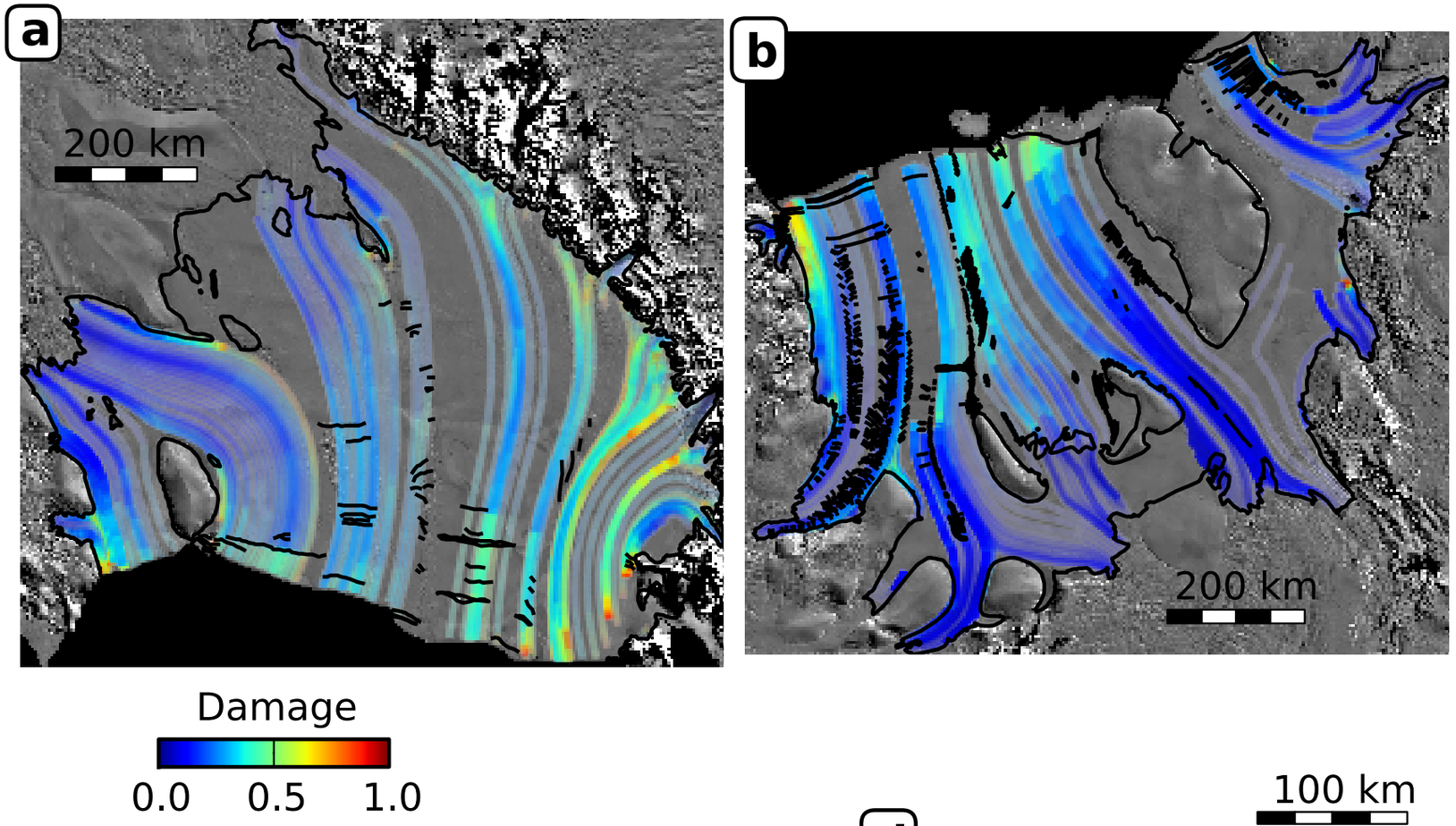
Growth of perturbations superimposed on ice thickness



Plastic Necking: The Big 4

Growth of perturbations superimposed on ice thickness

Growth rate comparable to **basal melting** and **refreezing** rates



Plastic Necking: The Big 4

Growth of perturbations superimposed on ice thickness

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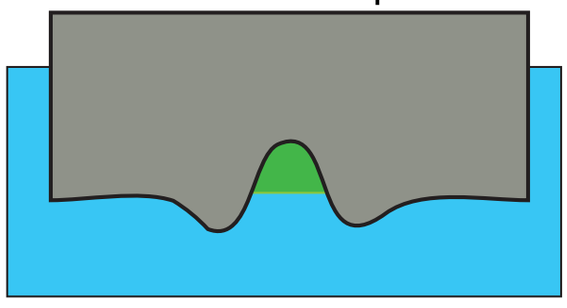
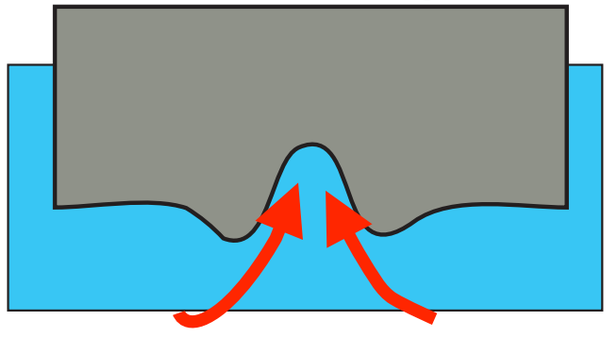
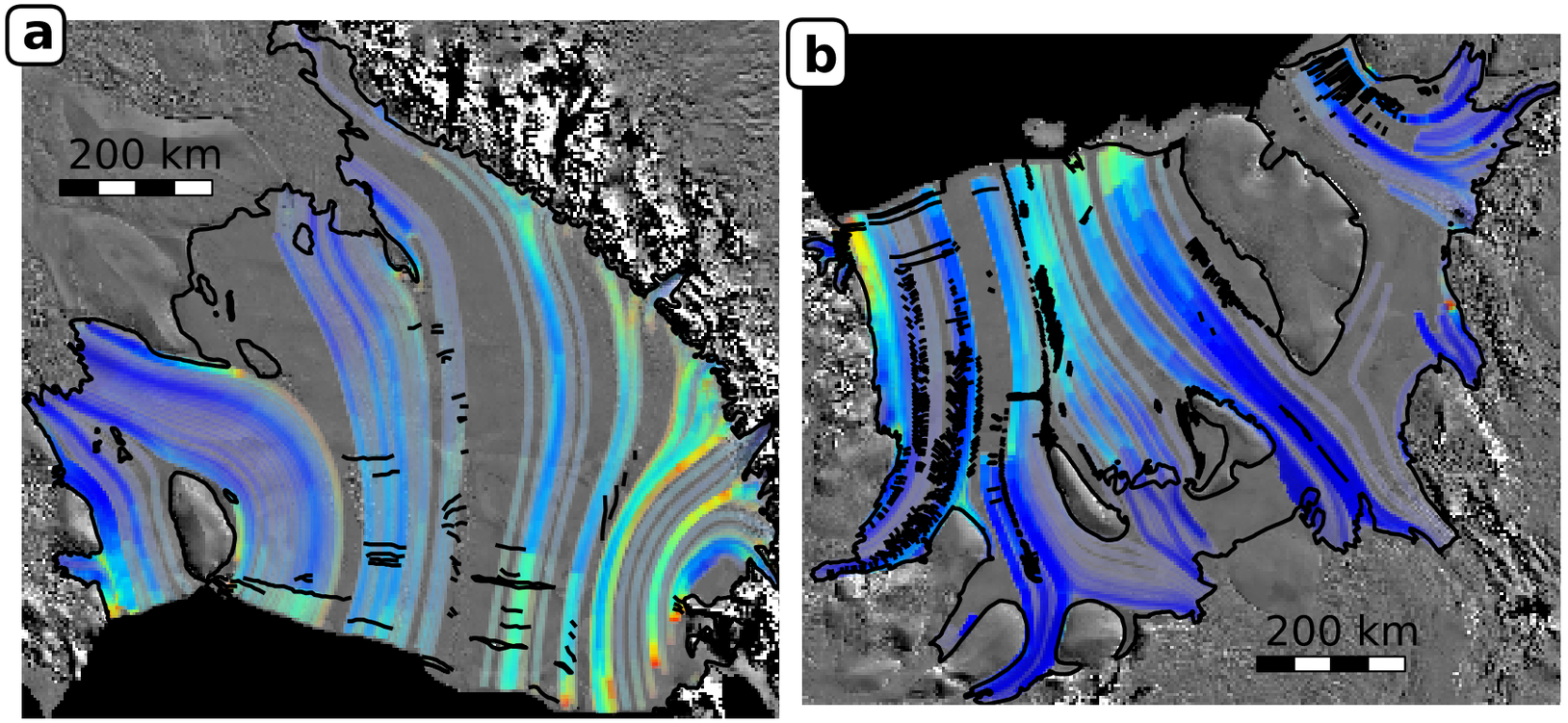
Marine ice fills depression



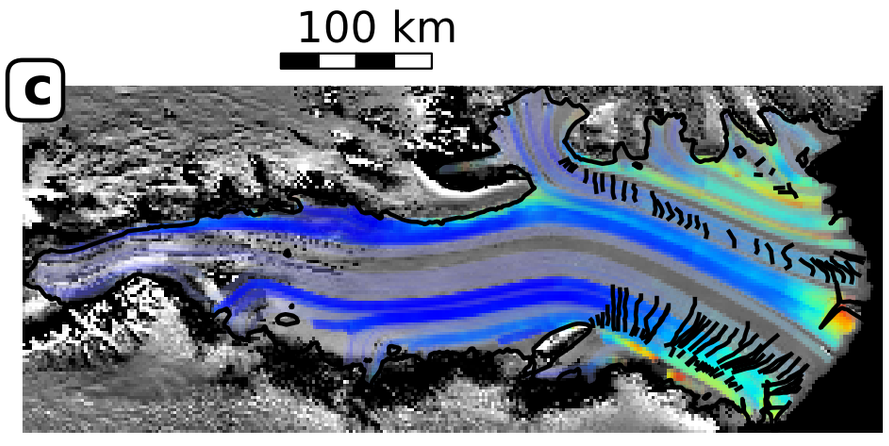
"Burn" through

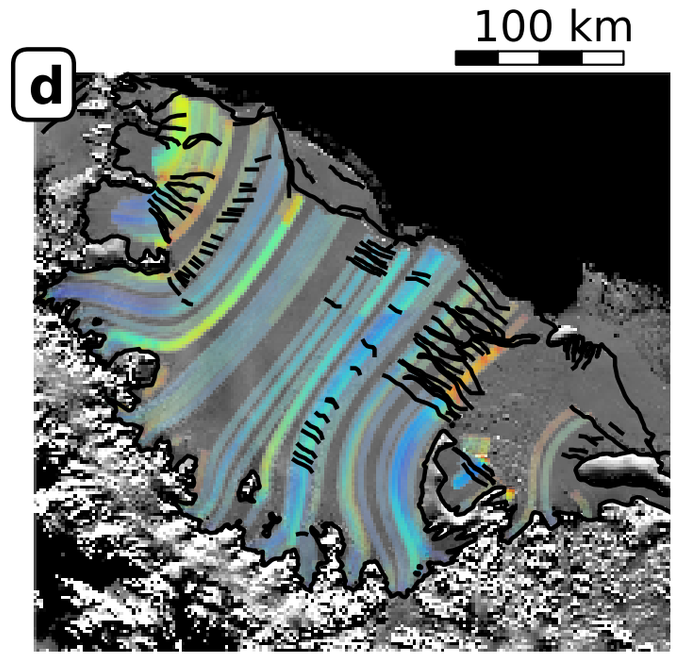




Damage

0.0 0.5 1.0

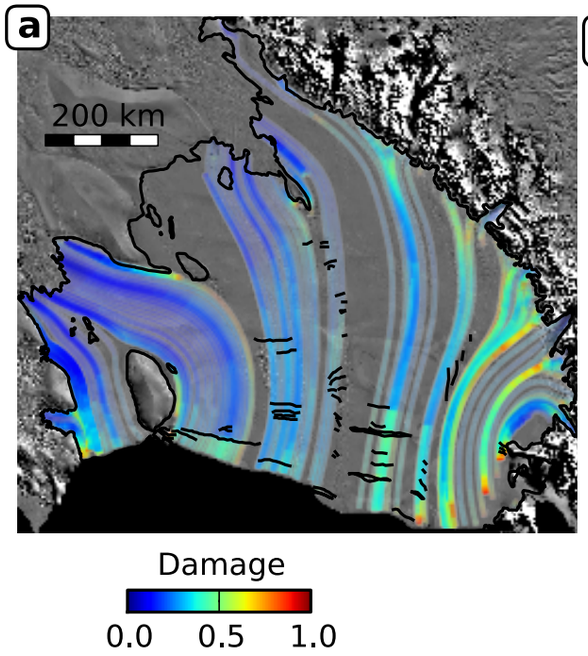


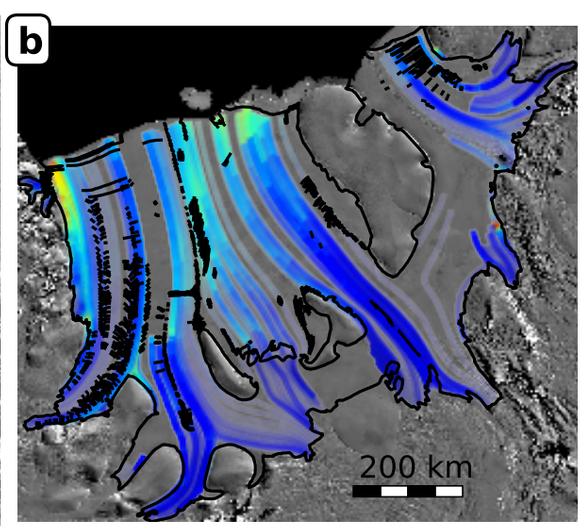


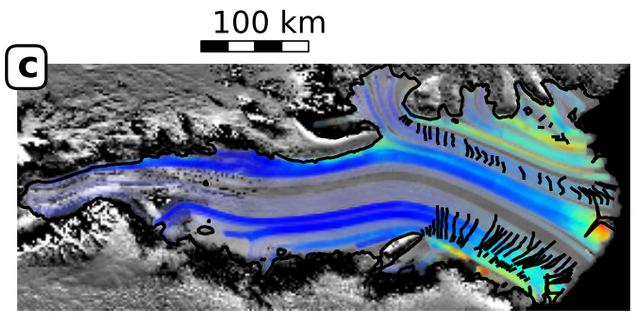
Implications

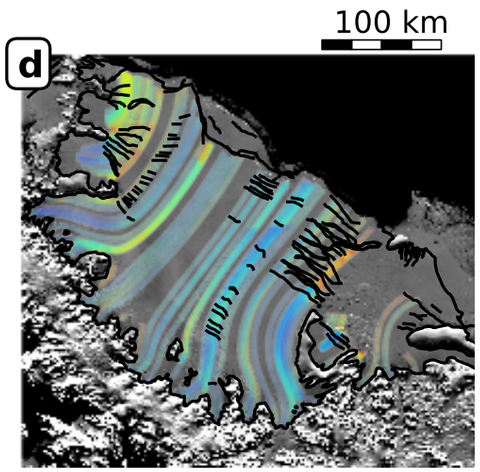
- Ductile failure explains **wide** crevasses that **deepen** as they advect
- Long time scale of instability forces crevasses to interact with the ocean
- **Any** long wavelength perturbation (e.g., **melt channels**) can seed the instability

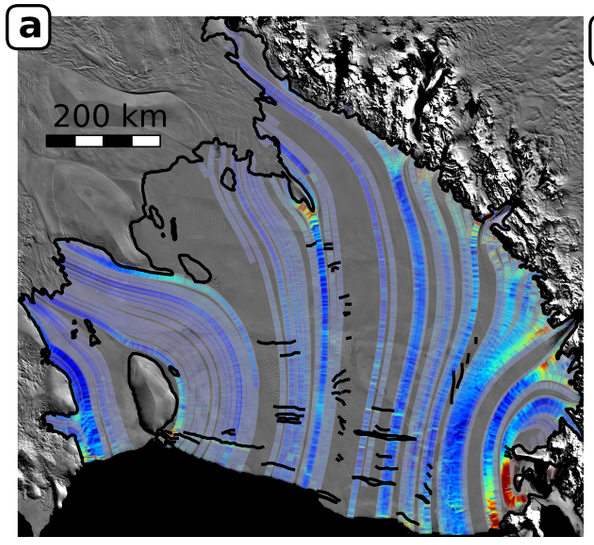
Process that controls the width of crevasses also controls the depth

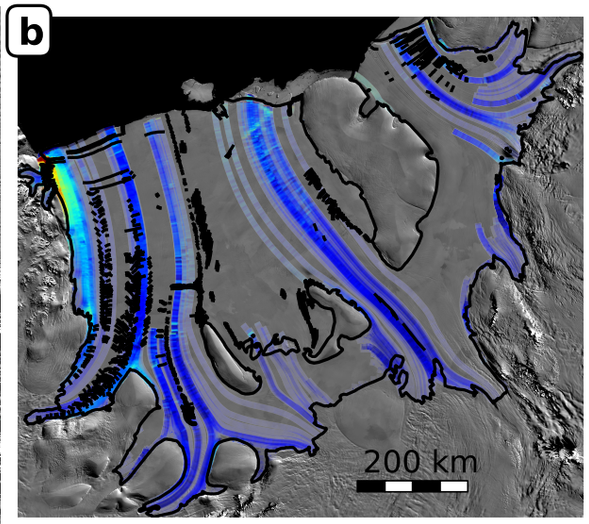

a
200 km
Damage
0.0
0.5
1.0

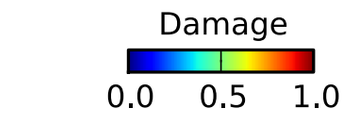

b
200 km

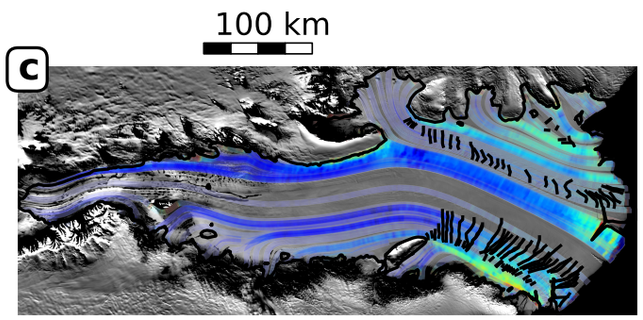

c
100 km

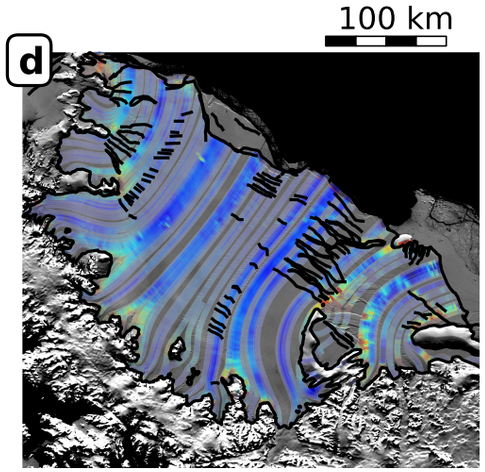

d
100 km


a
200 km


b
200 km


Damage
0.0
0.5
1.0


c
100 km


d
100 km