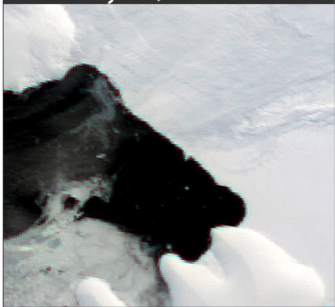
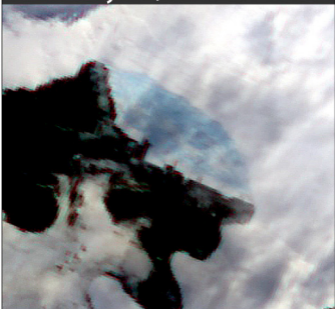


Simulation of Glaciogenic  
Tsunamis During the Collapse  
of the Wilkins Ice Shelf in  
2008

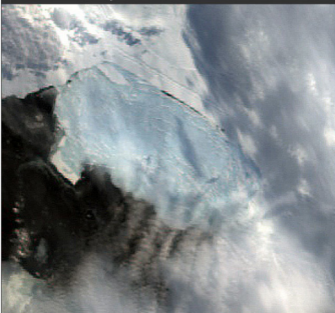
February 28, 2008



February 29, 2008



March 8, 2008



# Explosive pattern of ice shelf disintegration: (what we'd like to know)

- The abrupt, near simultaneous onset of iceberg calving across a large-scale stretch of ice front... (all this happens in **one day!**) ...
- High outward drift velocity (about 0.3 m/s) of a leading "phalanx" of tabular icebergs ...
- Efficient "surface coverage" of the ocean surface in "glaciological mosh pit" ...
- Extremely large gravitational potential energy conversion rates, e.g., up to  **$3 \times 10^{10}$  W**, by the "inverted submarine landslide" process over short periods of time (e.g., hours to days) in the absence of significant ice deformation  
**—where does this energy go???**
- The apparent lack of proximal iceberg-calving triggers (e.g., strong atmospheric storms in the local environment) at the time ...
- What really is the role of "climatic enabling conditions"???

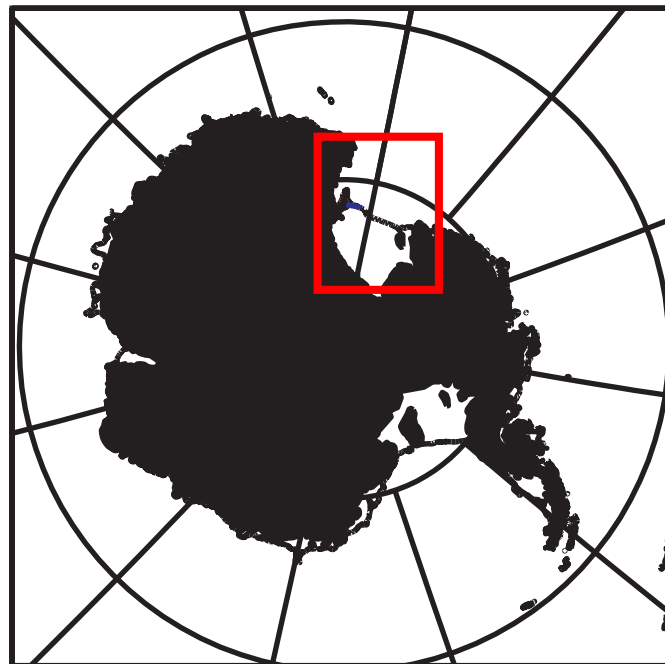
current orthodoxy...

**Ocean waves (tsunamis) made by icebergs  
are at the root of this problem...**

100 km

Ross Sea

N



Drygalski  
Ice Tongue

B15K

B15A

C16

B15J

McMurdo Sound

McMurdo  
Ice Shelf

Nascent Iceberg (NIB)

rift

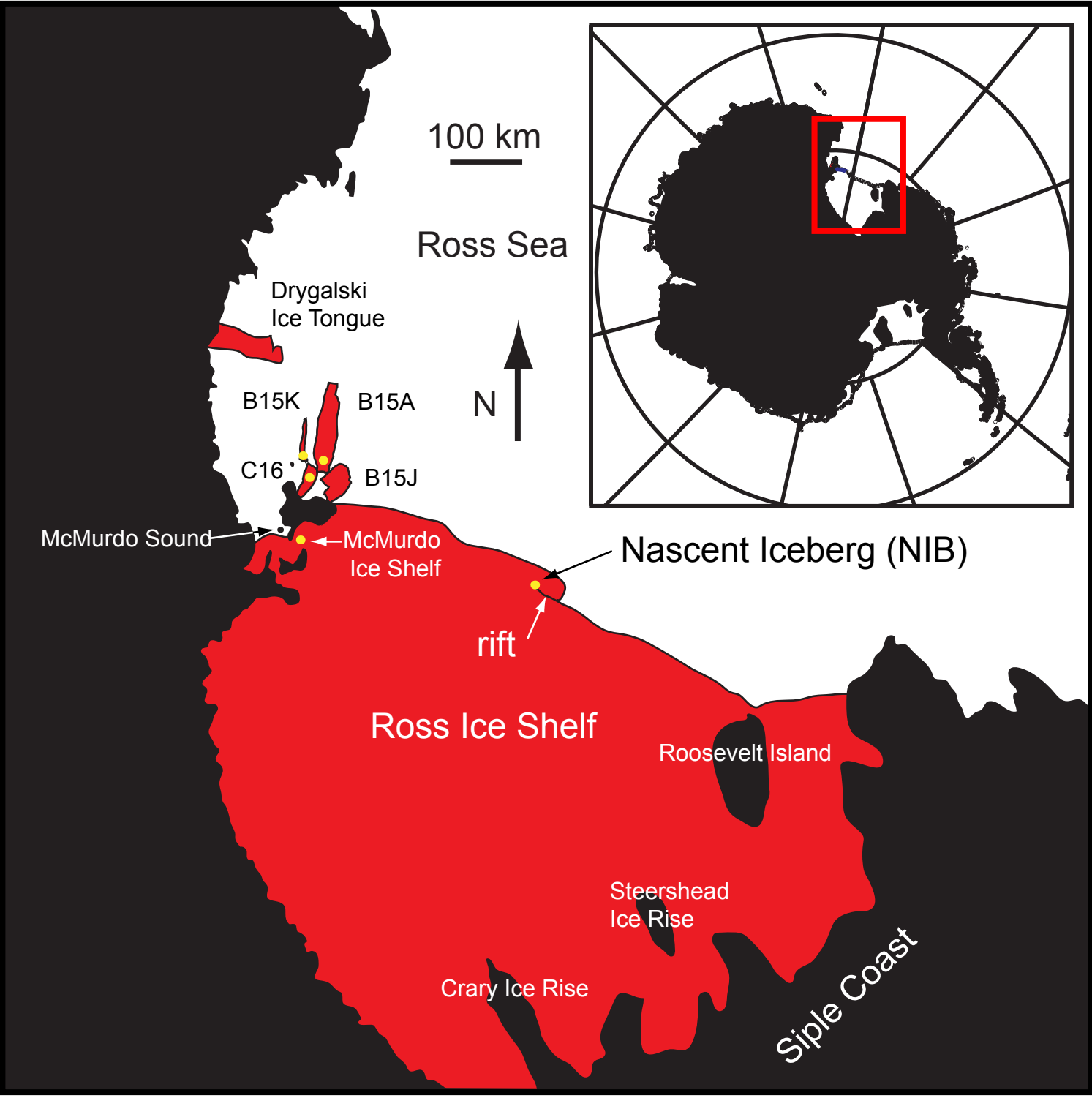
Ross Ice Shelf

Roosevelt Island

Steershead  
Ice Rise

Crary Ice Rise

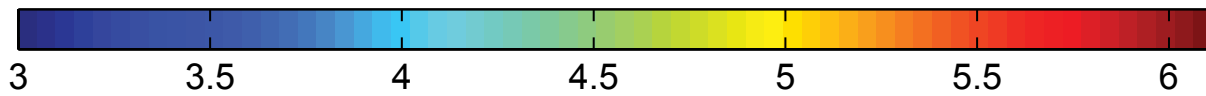
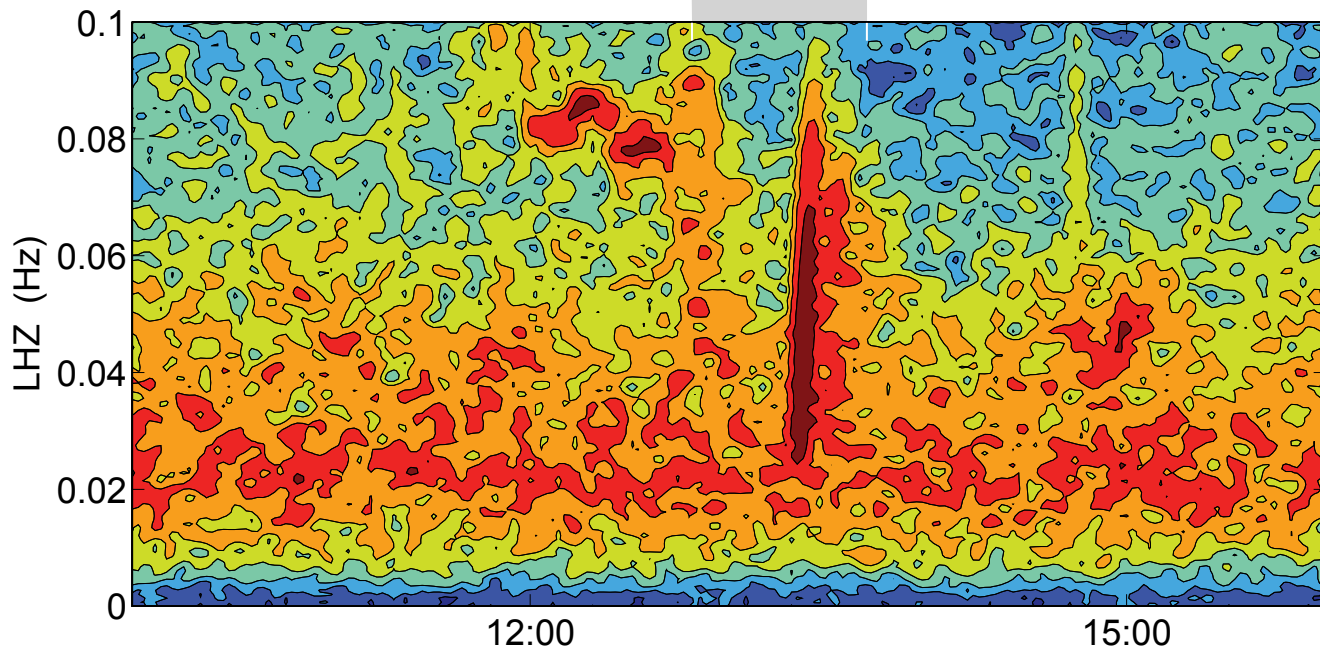
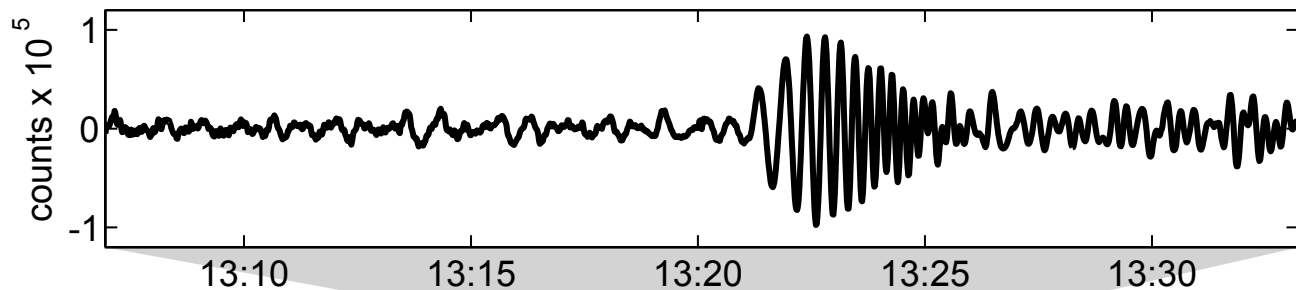
Siple Coast



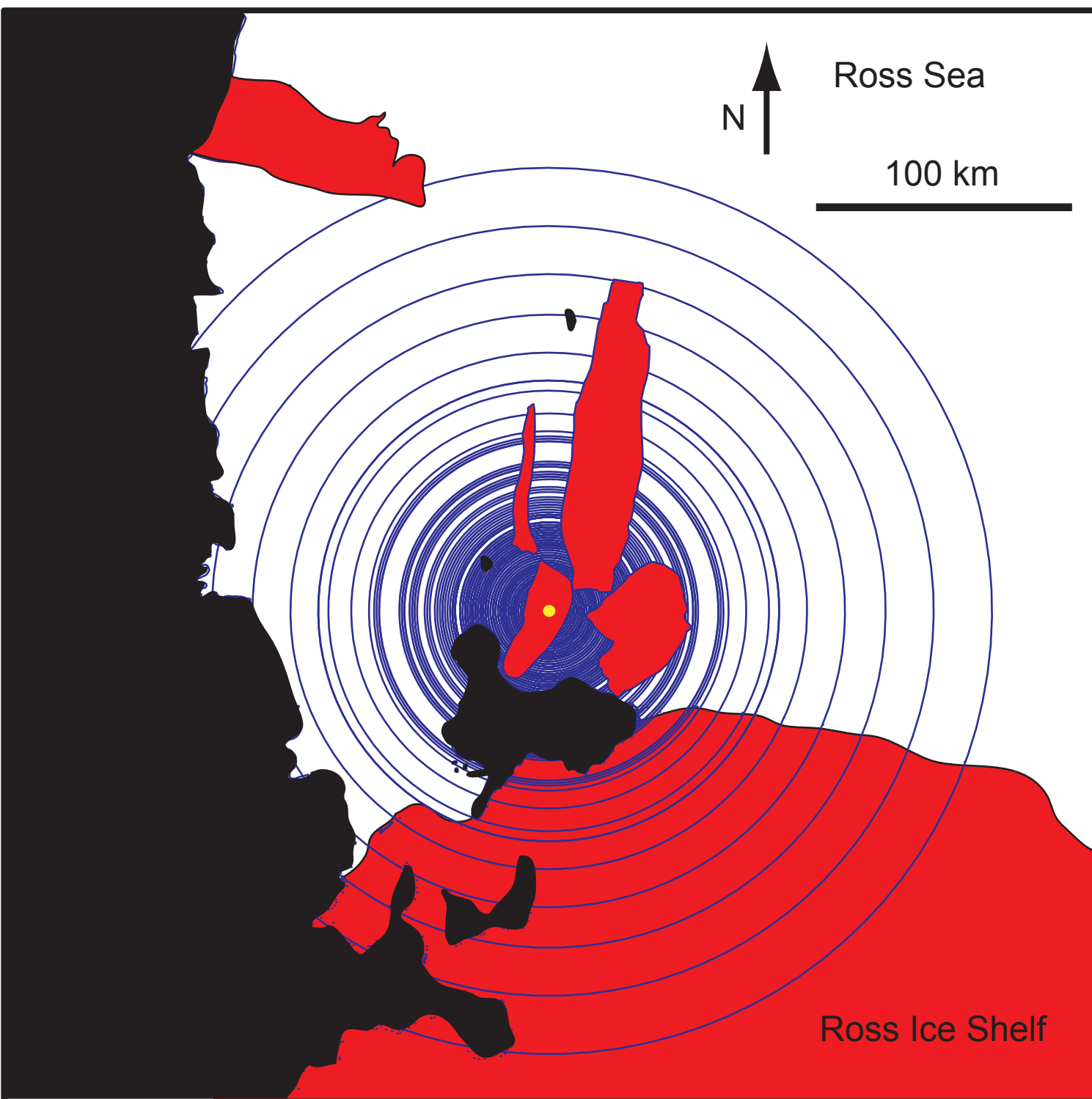
**West Antarctica's ice sheet is tsunamigenic...**

# “Incoming” signals:

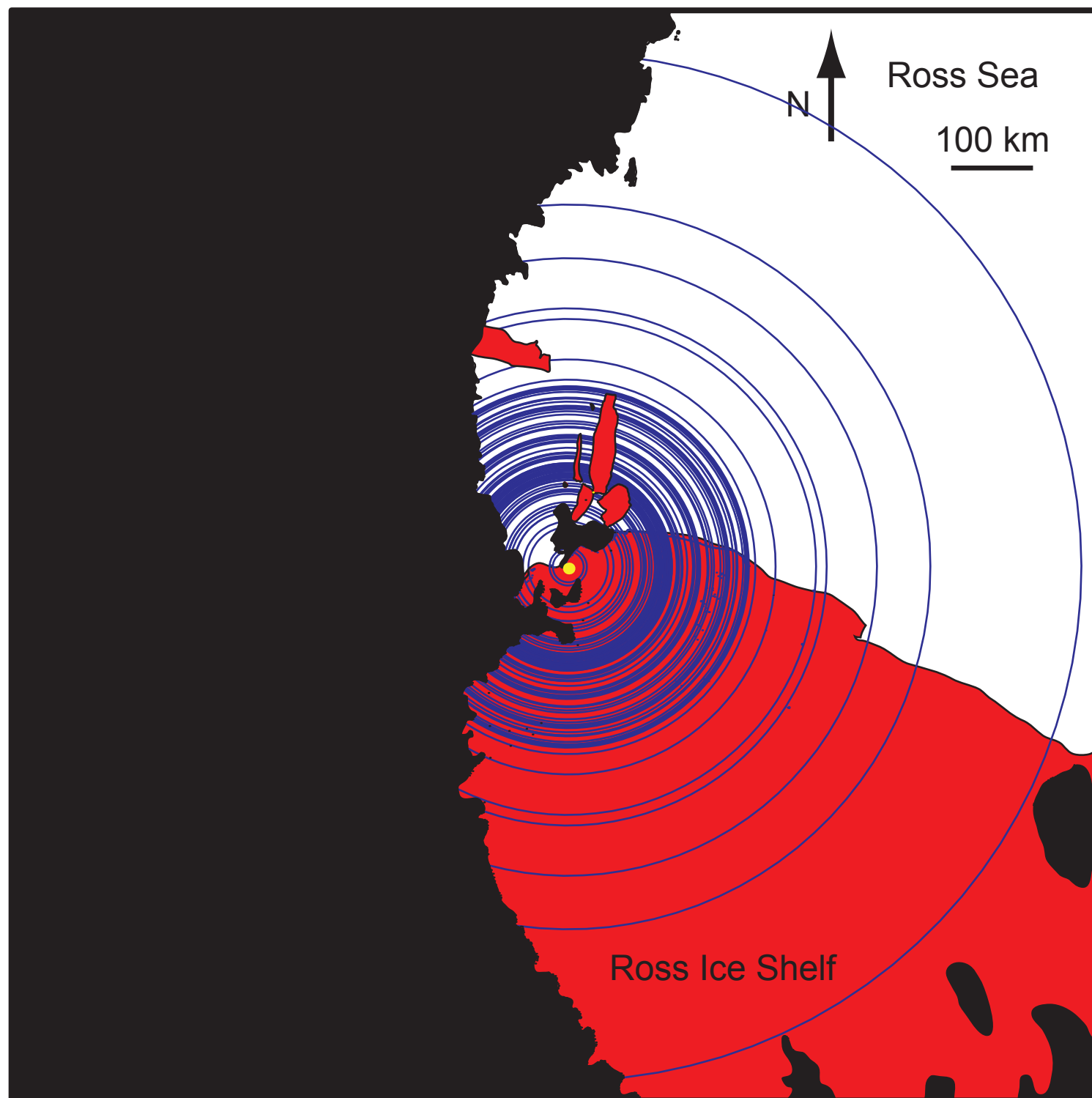
12/06/03, C16 B, LHZ, 0.02 Hz to 0.1 Hz



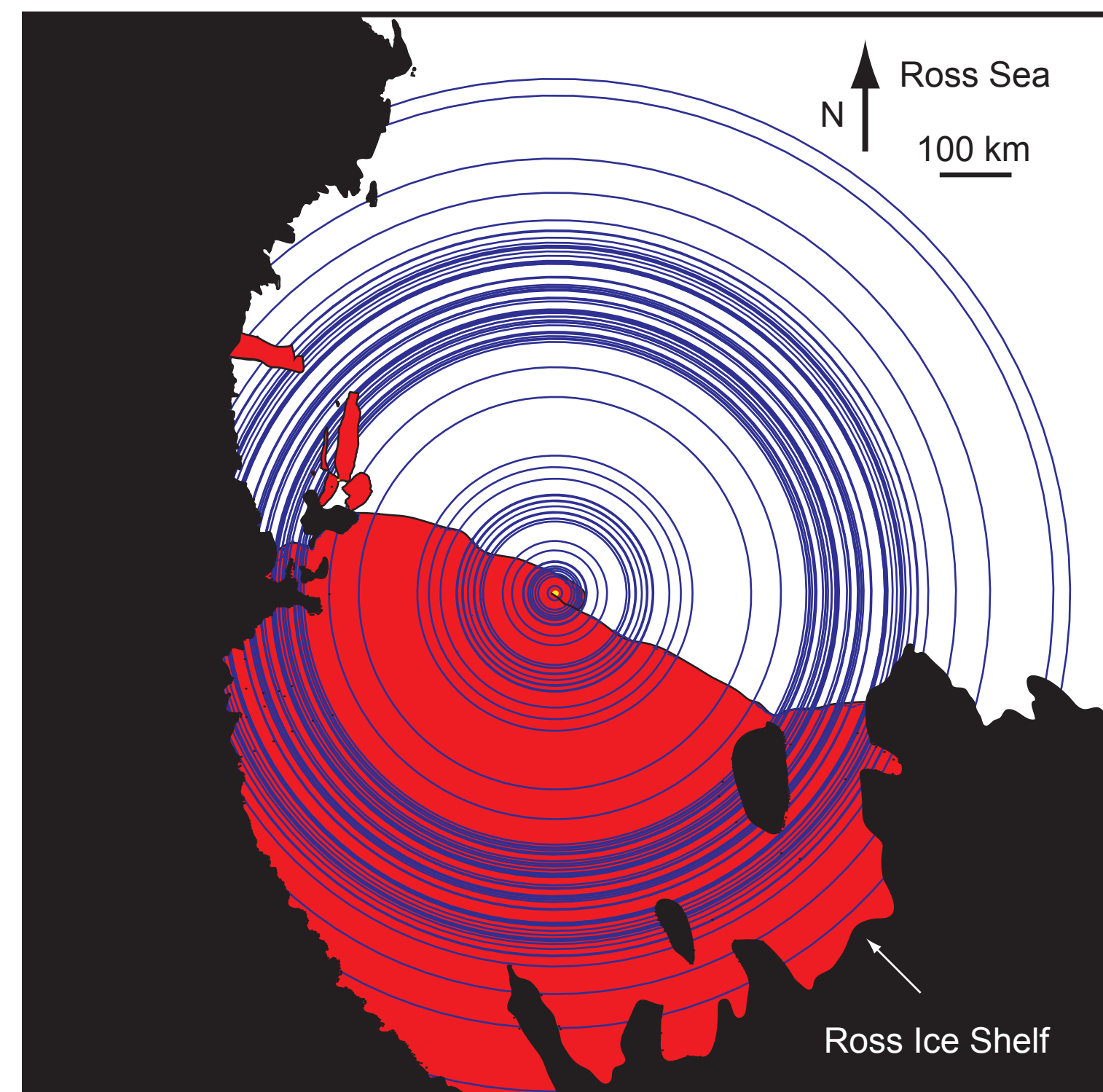
C16 A (2003-2004)



McMurdo Ice Shelf (2004)



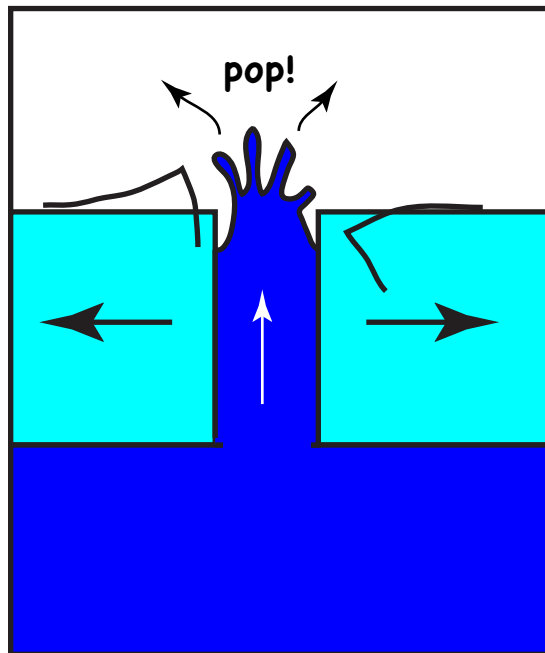
Nascent Iceberg (2004-2006)



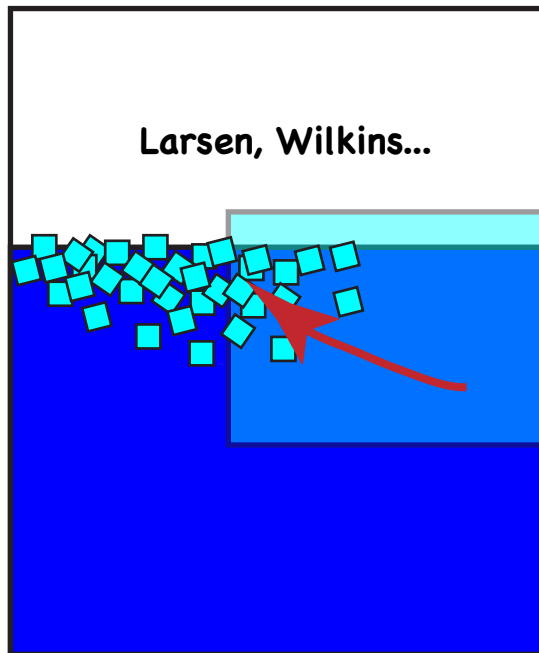


# Glacial tsunamigenesis mechanisms:

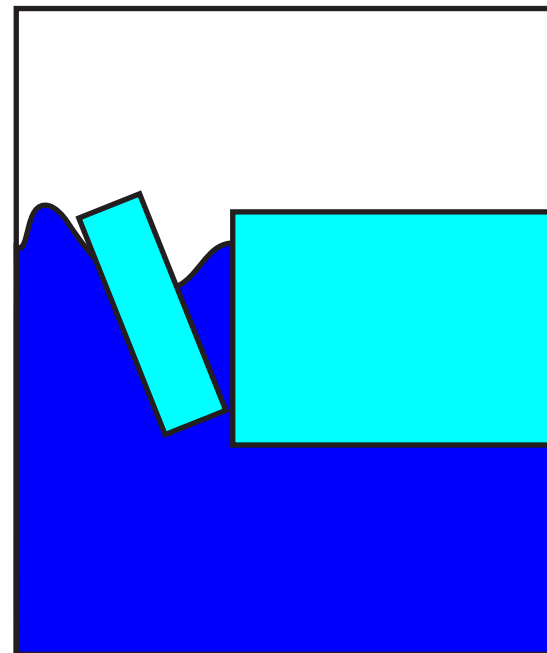
water movement during  
ice-shelf rifting...



water movement during  
upside down landslide...



water movement during  
calving and capsizing...



# Ice-shelf disintegration liberates energy...

$$\Delta h \times g \times \Delta \rho \text{ (volume collapse rate)} \approx 2.8 \times 10^{10} \text{ W}$$

For Wilkins:

- $\Delta \rho \approx 100 \text{ kg/m}^3$
- $\Delta h \approx 100 \text{ m}$
- volume  $\approx 25 \text{ km}^3$
- time  $\approx 1 \text{ day}$

about 1/100 of total Antarctic rate of energy dissipation

← "micro-tsunamis?"

1030 kg/m<sup>3</sup>

900 kg/m<sup>3</sup>

$\Delta h$  = upward movement of buoyancy surplus

$$\Delta E + \Delta E_w = \frac{1}{2} \rho_i g \left( 1 - \frac{\rho_i}{\rho_w} \right) A H \Delta H$$

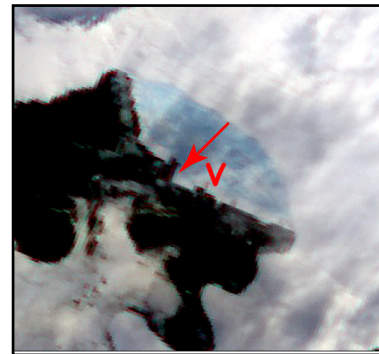
ice goes up, water goes down...  
ice is less dense than water...  
gravitational P.E. liberated...

# What happens to the energy?

- What if all goes into kinetic energy?

$$V = \sqrt{g \left( \frac{\Delta\rho}{\rho_w} \right) \Delta H}$$

- About 1/2 of energy must be radiated as wave energy, because blue slurpee advances too slowly...



**"blue slurpee" advance  
rate of  $\approx 1.5$  m/s  
 $\approx 3.0$  knots  
observed  $\approx 0.3$  m/s**

Wilkins Ice Shelf Collapse of Feb. 2008 =  $2.6 \times 10^{15}$  J

1946 Aleutian landslide of about 8 times the mass produced a tsunami carrying  $1.5 \times 10^{14}$  J, rose 46 m in area, killed 159 people in Hawaii, caused destruction of Graham Land Hut operated by British in Antarctica (cited by Sir V. Fuchs)....

Yes, but ocean waves (tsunamis) can't break ice shelves... so forget about it!

Not so fast, my dear friends !!!

- waves **do** break ice in Greenland, on everyday basis
- also, main mechanism proposed by recent papers for Wilkins cite the role of calving-face bending ...

Jacobshaven Isbrae

Jason Amundson, U. Ak.

Two large icebergs roll backward...











high-amplitude “crest” moves forward, “trough” moves backward



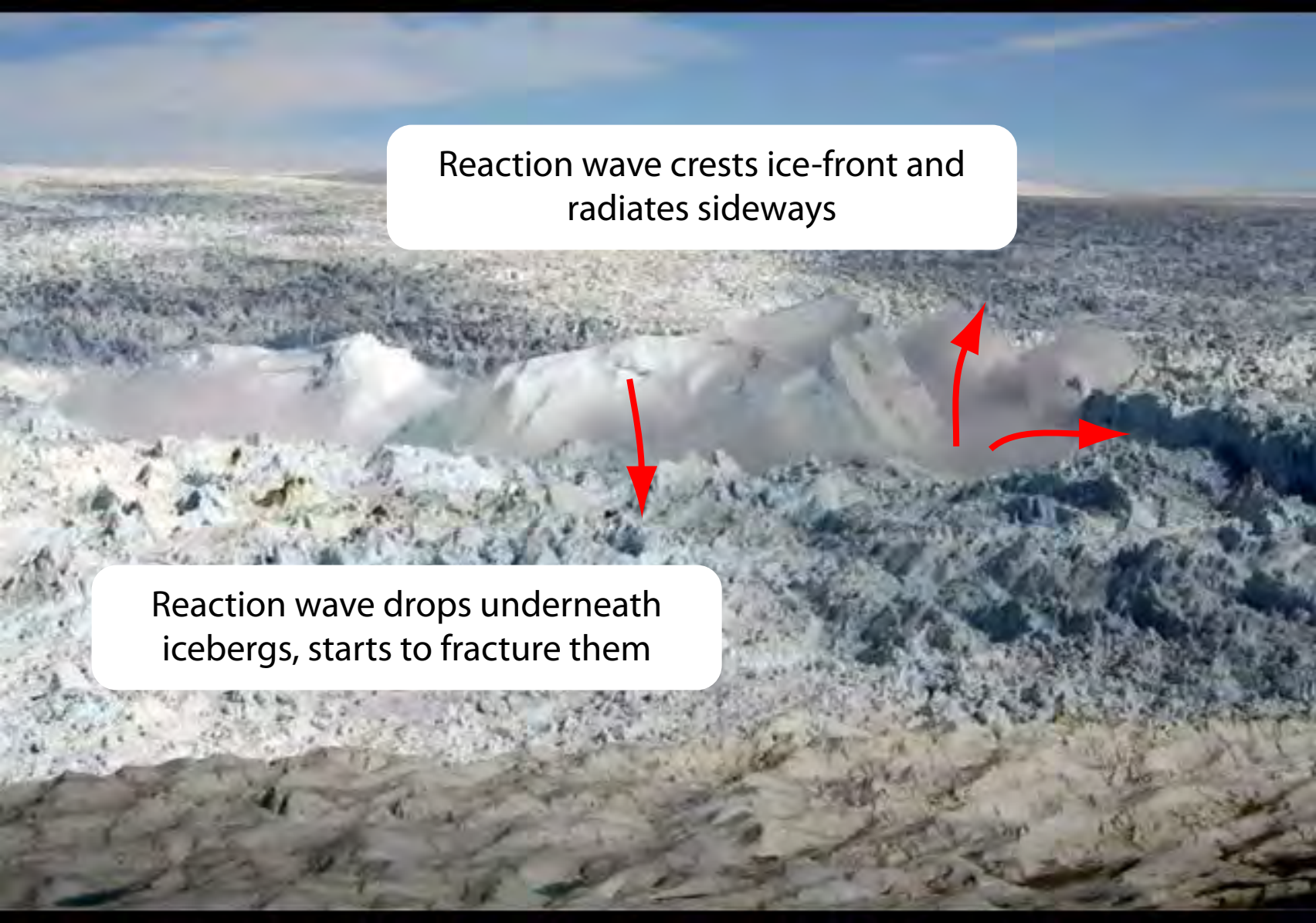










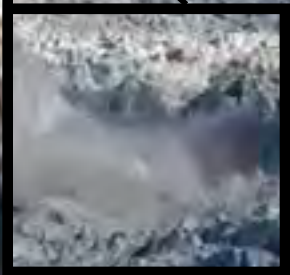
An aerial photograph of a glacier system. A prominent, light-colored, irregularly shaped feature, likely a reaction wave, runs horizontally across the middle of the frame. The glacier surface is highly textured with numerous cracks and ridges. In the foreground, there is a large, dark, rocky area. The sky is clear and blue. Three red arrows are overlaid on the image: one points down from the reaction wave, and two others point away from it in different directions, illustrating the sideways radiation of the wave.

Reaction wave crests ice-front and radiates sideways

Reaction wave drops underneath icebergs, starts to fracture them

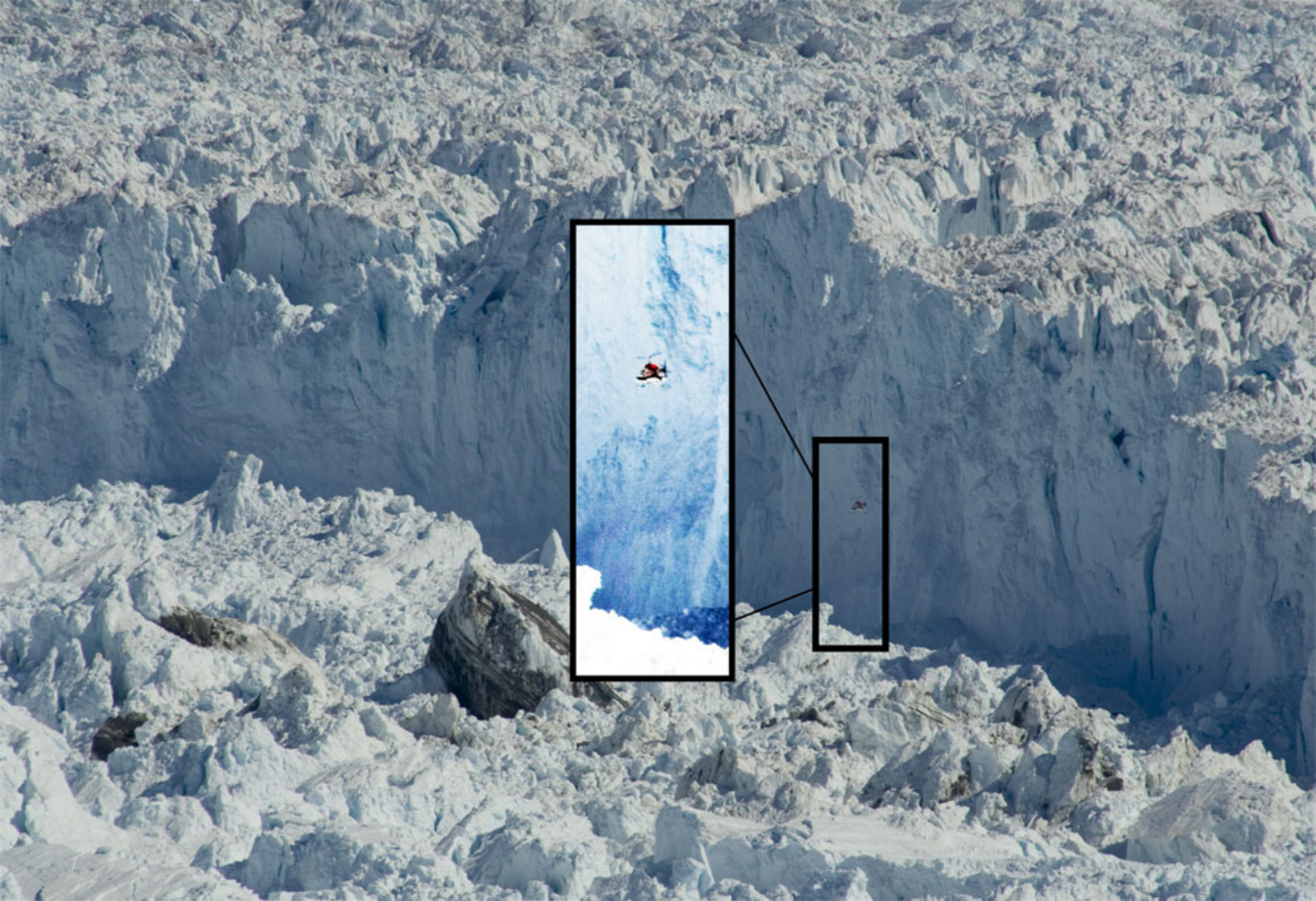


50 m









iceberg begins to “break its back”  
with first cracks on ice/firn transition...



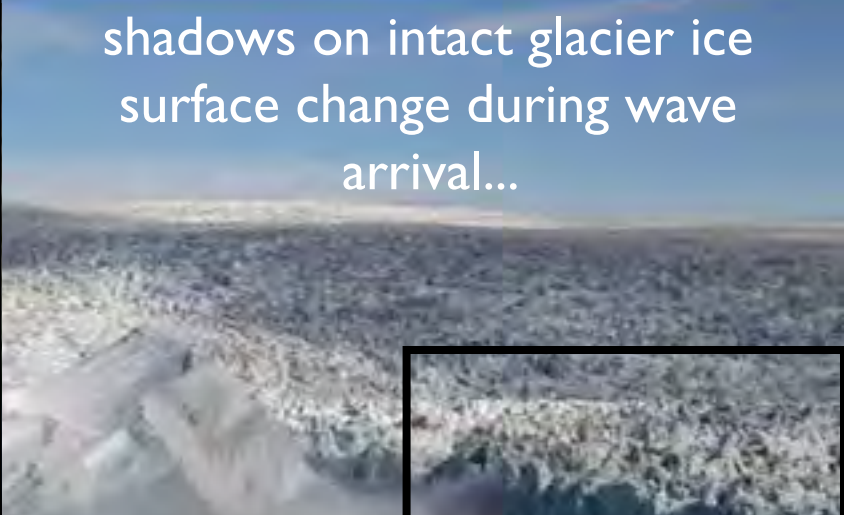


edge wasting as wave impacts cliff

ice mélange “flung” against cliff



shadows on intact glacier ice  
surface change during wave  
arrival...





ice-mélange platform begins  
to "trampoline" from wave radiation









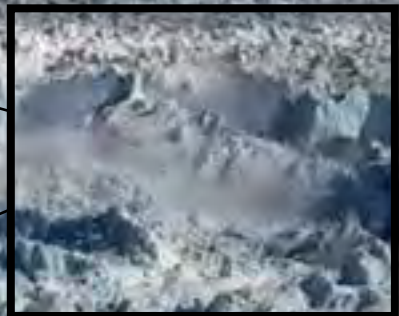








additional calving caused by intact  
ice pieces “slumping” into hole  
created by wave trough...































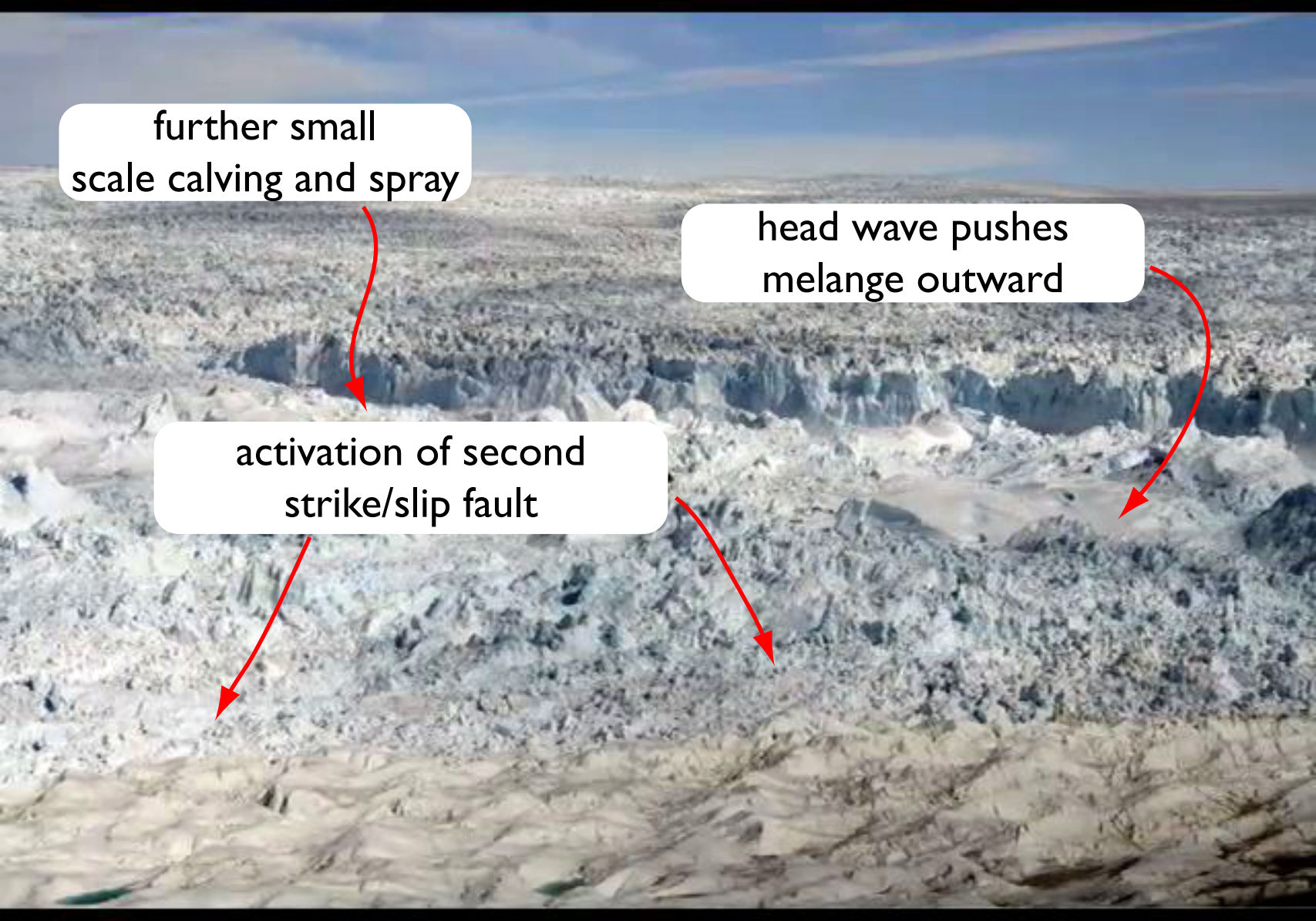





further small  
scale calving and spray

head wave pushes  
melange outward

activation of second  
strike/slip fault





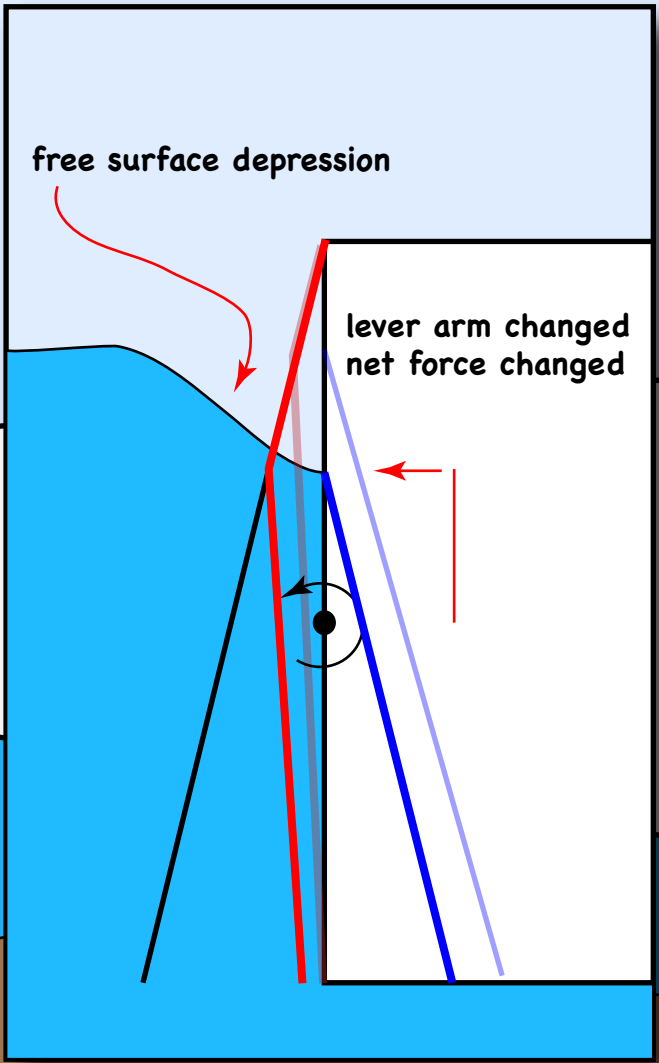
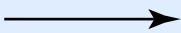
Thank you to  
Jason Amundsen, Martin Truffer  
and Mark Fahnestock!

# ... A question of bending moments ...

$$M = M_0 + M'(t)$$

fluctuating moment due to wave field...

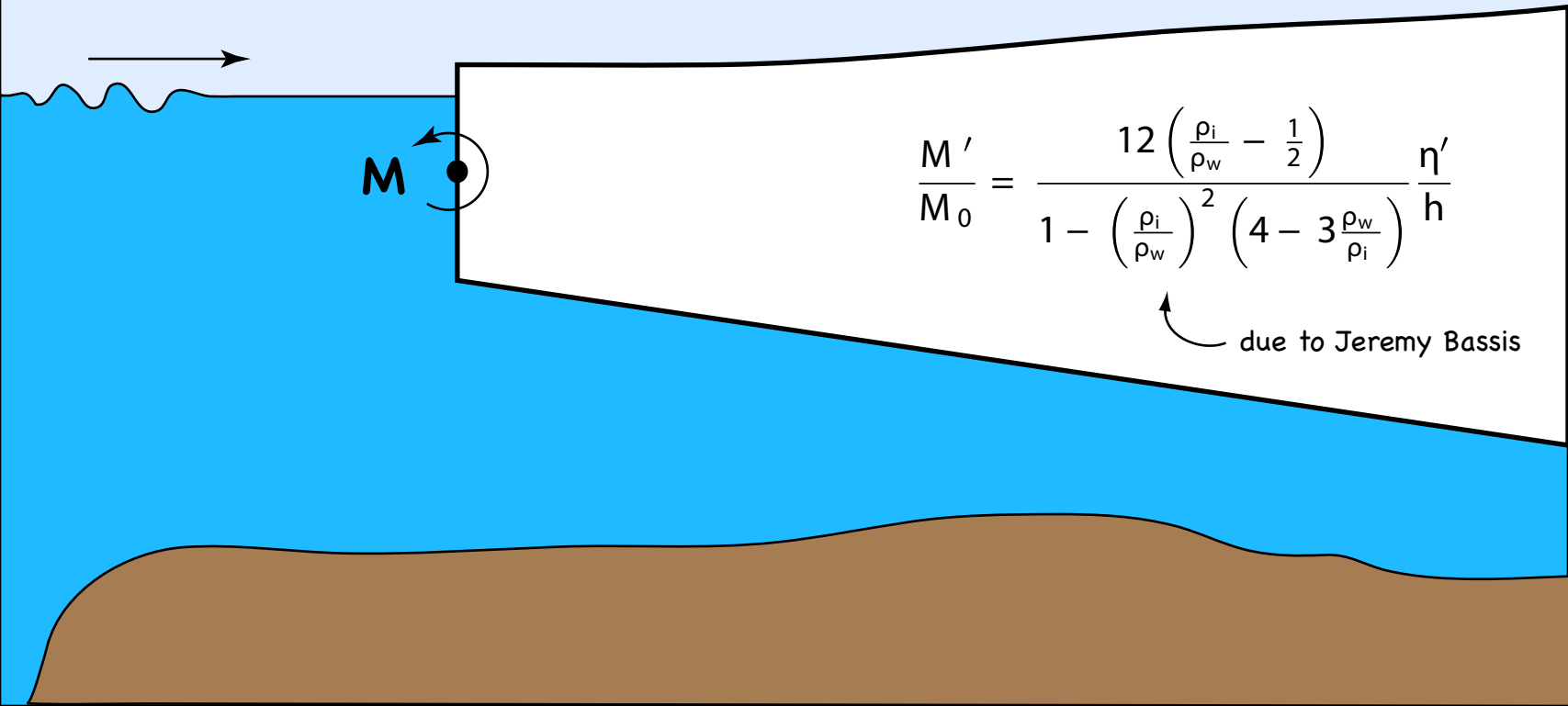
tsunamis



... A question of bending moments ...

$$M'/M \approx 1000 \Delta h/h$$

a 2 meter wave produces a 20% fluctuation  
of bending moment at ice front...



$$\frac{M'}{M_0} = \frac{12 \left( \frac{\rho_i}{\rho_w} - \frac{1}{2} \right)}{1 - \left( \frac{\rho_i}{\rho_w} \right)^2 \left( 4 - 3 \frac{\rho_w}{\rho_i} \right)} \frac{\eta'}{h}$$

due to Jeremy Bassis

**Is ice-shelf collapse an autocatalytic process?**



# Can tsunami energy be "trapped"?

