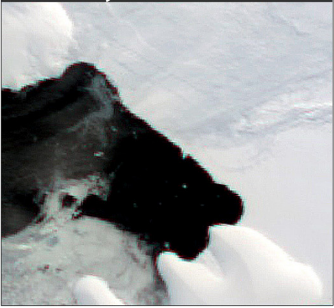
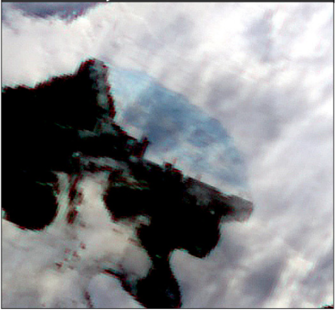
Simulation of Glaciogenic Tsunamis During the Collapse of the Wilkins Ice Shelf in 2008

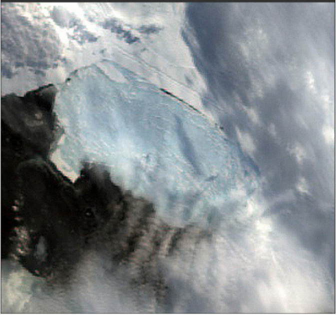
February 28, 2008



February 29, 2008



March 8, 2008



National Snow and Ice Data Center, Boulder, CO

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 3×10^{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

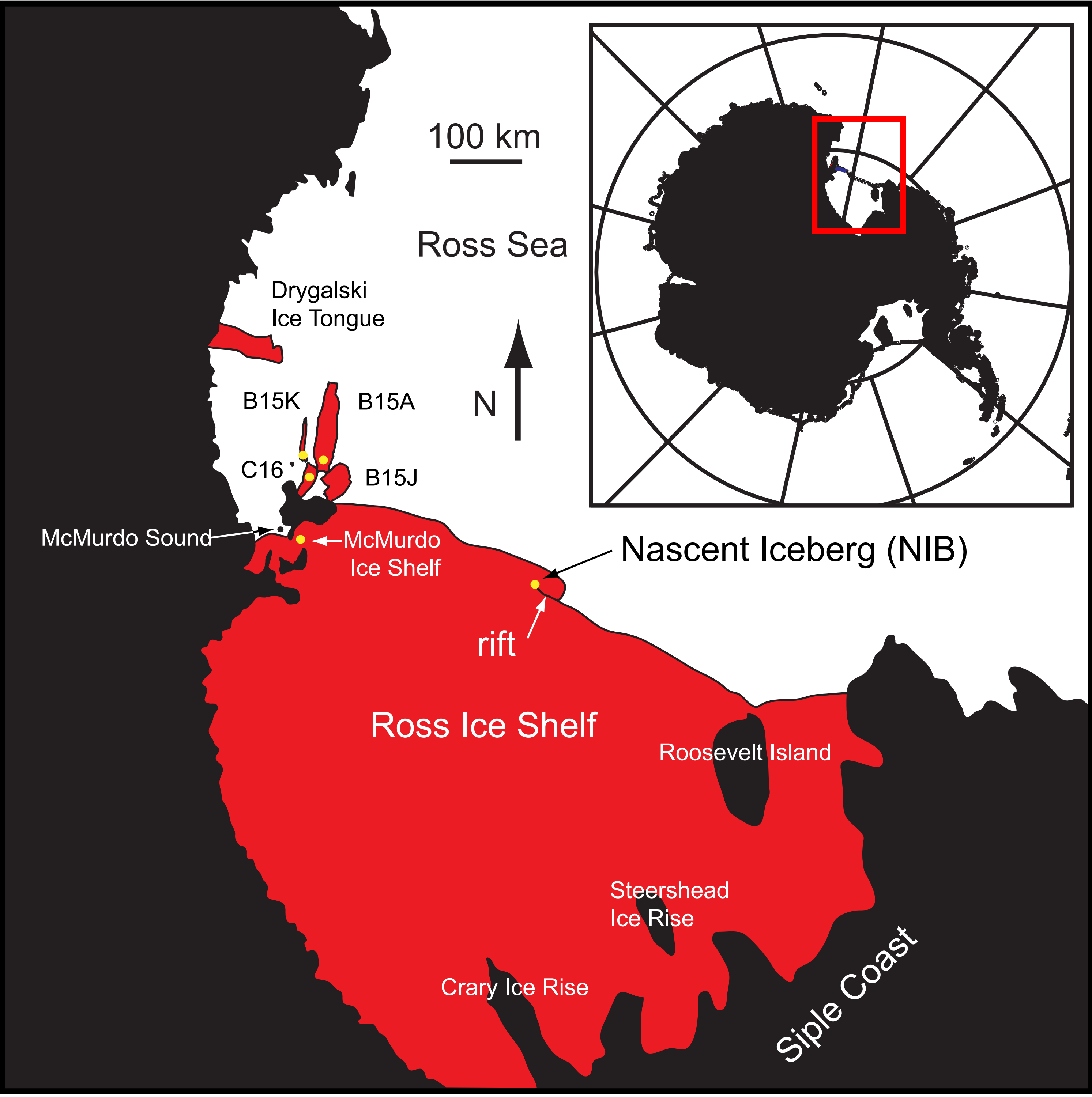
where does this energy go???

- 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"???

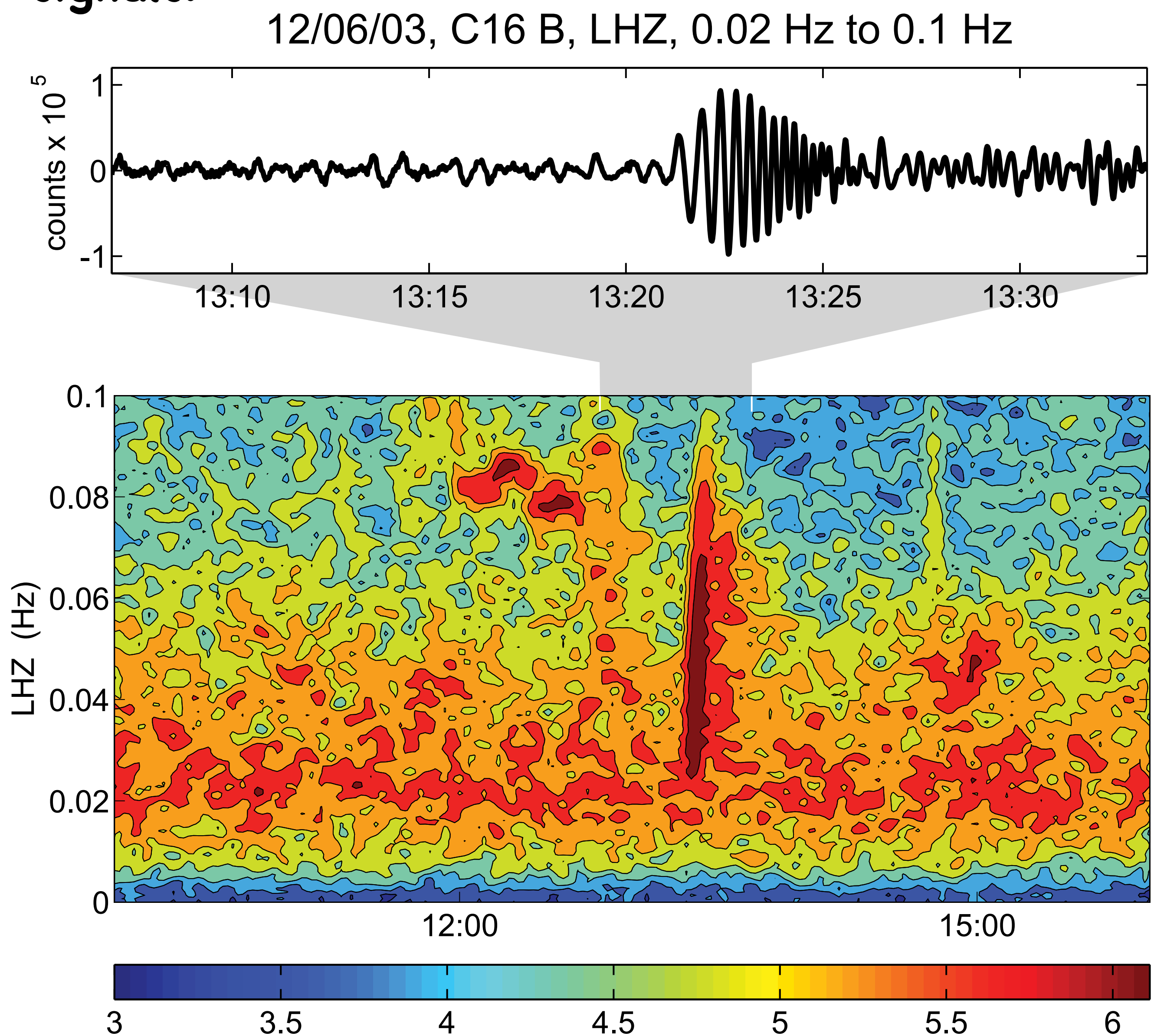
current orthodoxy...

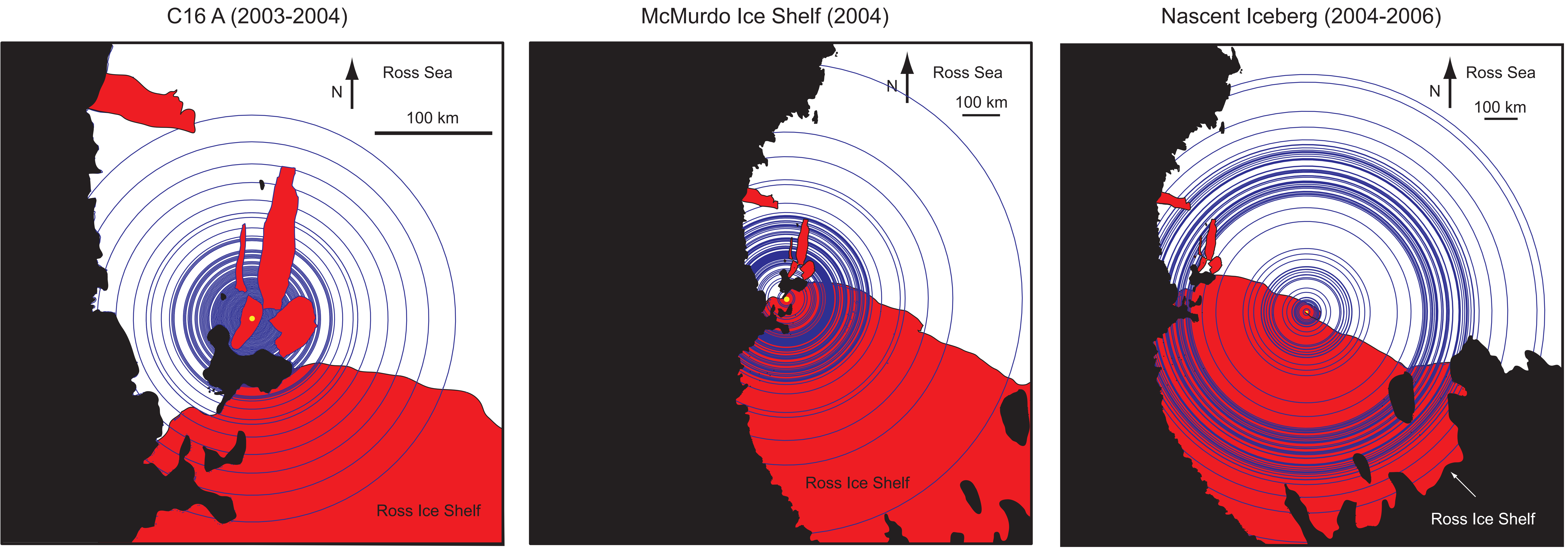
Ocean waves (tsunamis) made by icebergs are at the root of this problem...


100 km
Ross Sea
Drygalski
Ice Tongue
N
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

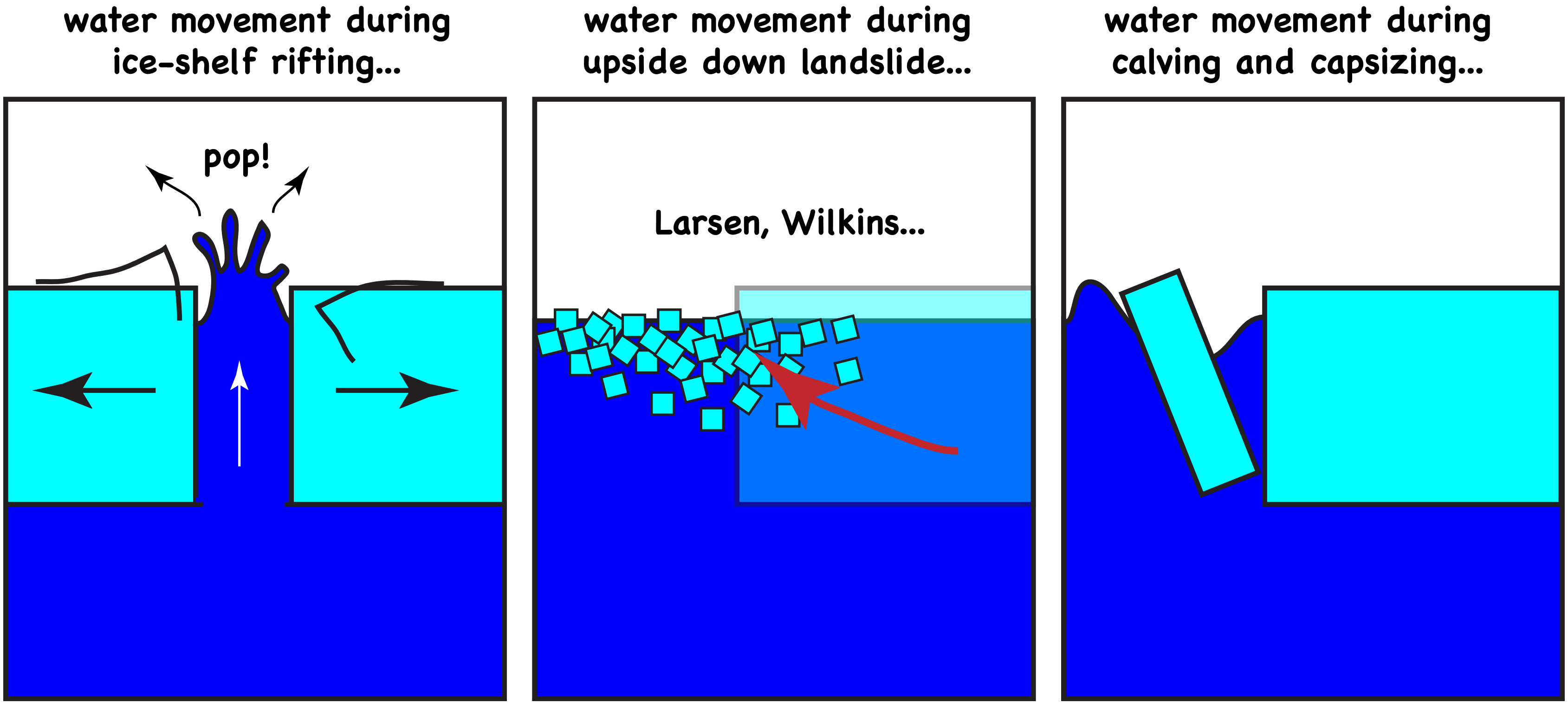
West Anarctica's ice sheet is tsunamigenic…

"Incoming" signals:



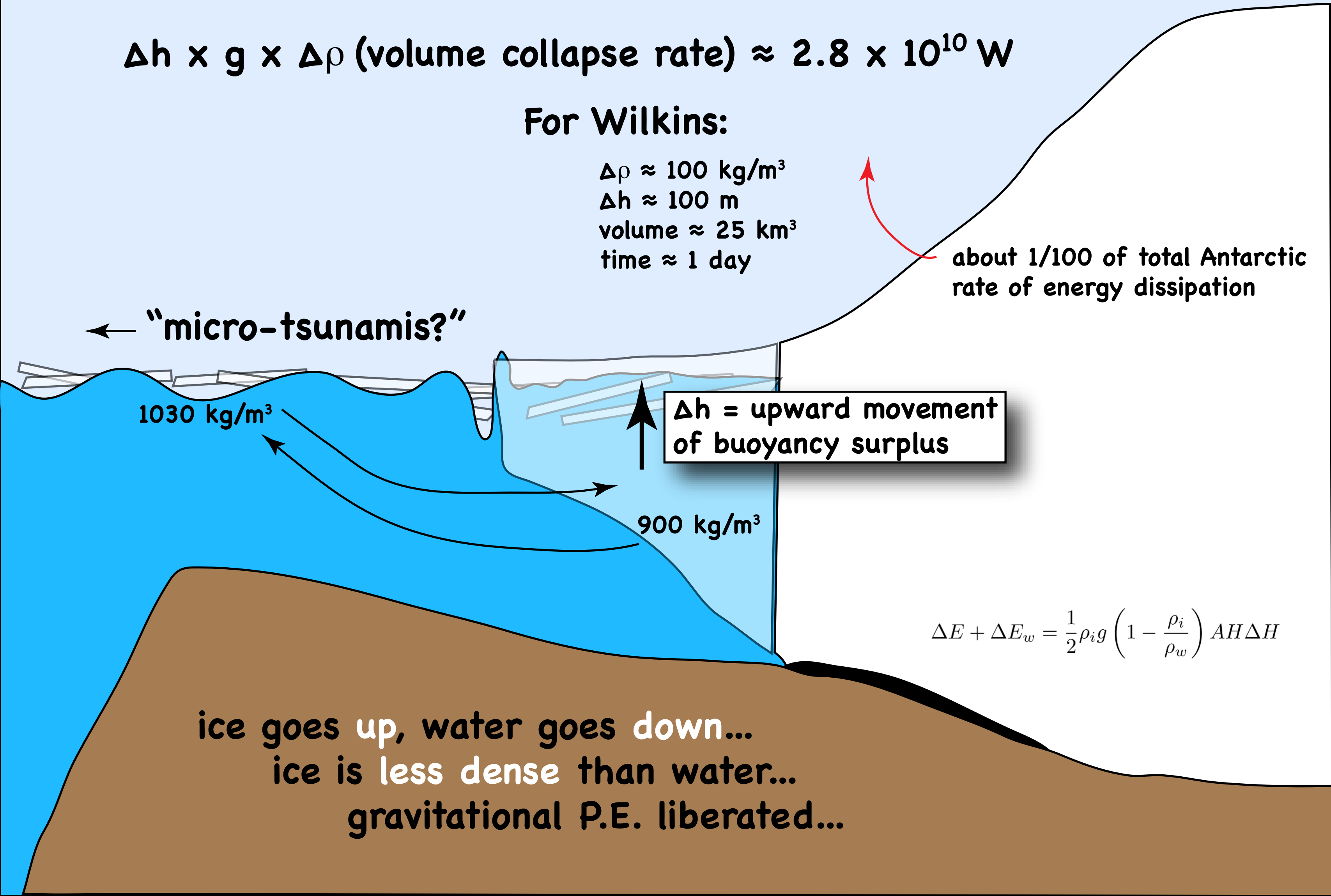

C16 A (2003-2004)
Ross Sea
N
100 km
Ross Ice Shelf
McMurdo Ice Shelf (2004)
Ross Sea
N
100 km
Ross Ice Shelf
Nascent Iceberg (2004-2006)
Ross Sea
N
100 km
Ross Ice Shelf

Glacial tsunamigenesis mechanisms:



Ice-shelf disintegration liberates energy...

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

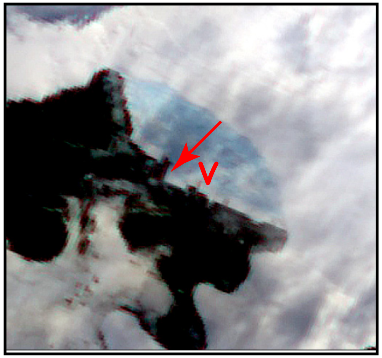


What happens to the energy?

- 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 ≈ 1.5 m/s ≈ 3.0 knots observed ≈ 0.3 m/s

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

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

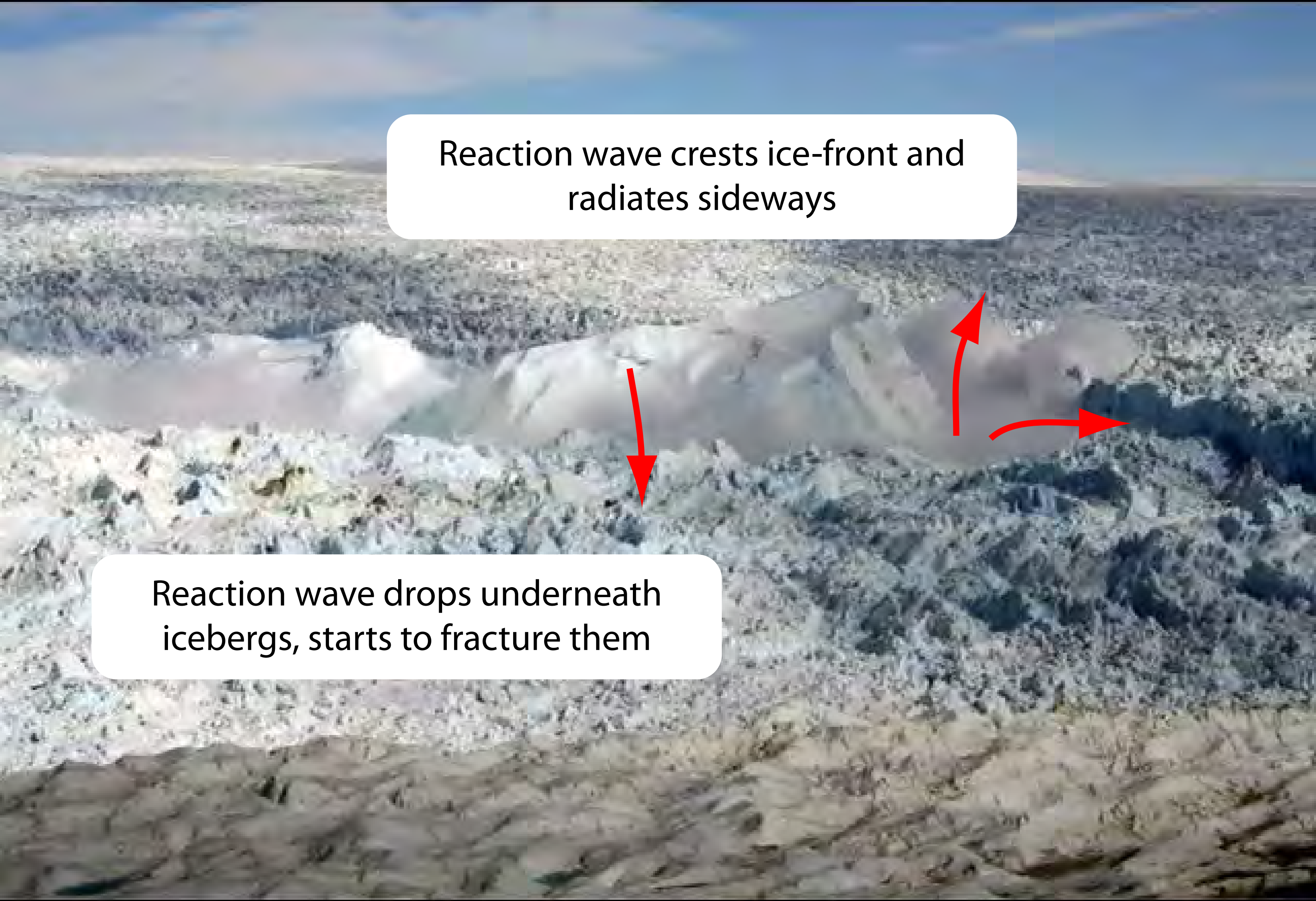
Yes, but ocean waves (tsunamis) can't break ice shelves... so forget about it!

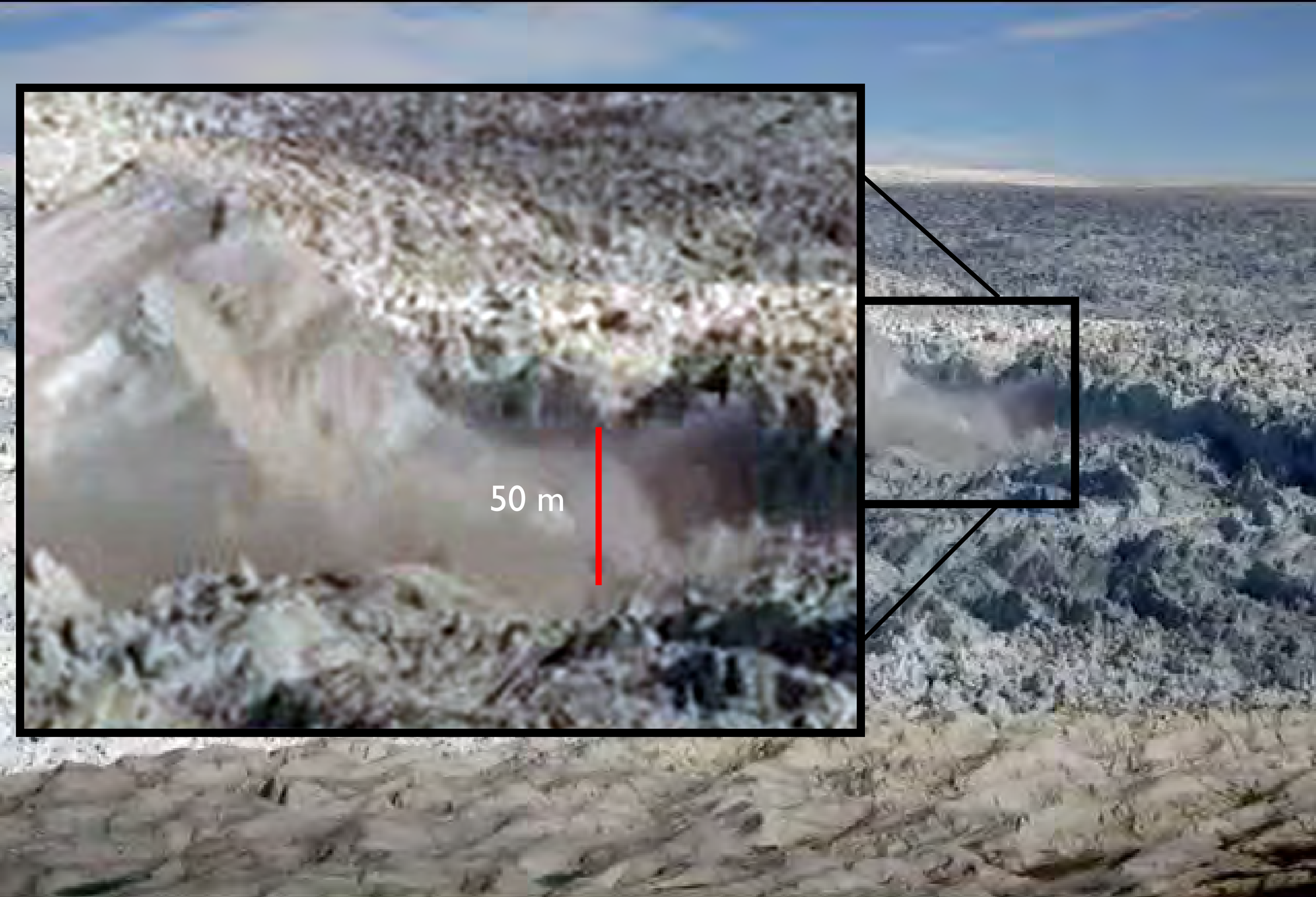
Not so fast, my dear friends !!!

- 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


Reaction wave crests ice-front and radiates sideways
Reaction wave drops underneath icebergs, starts to fracture them


50 m

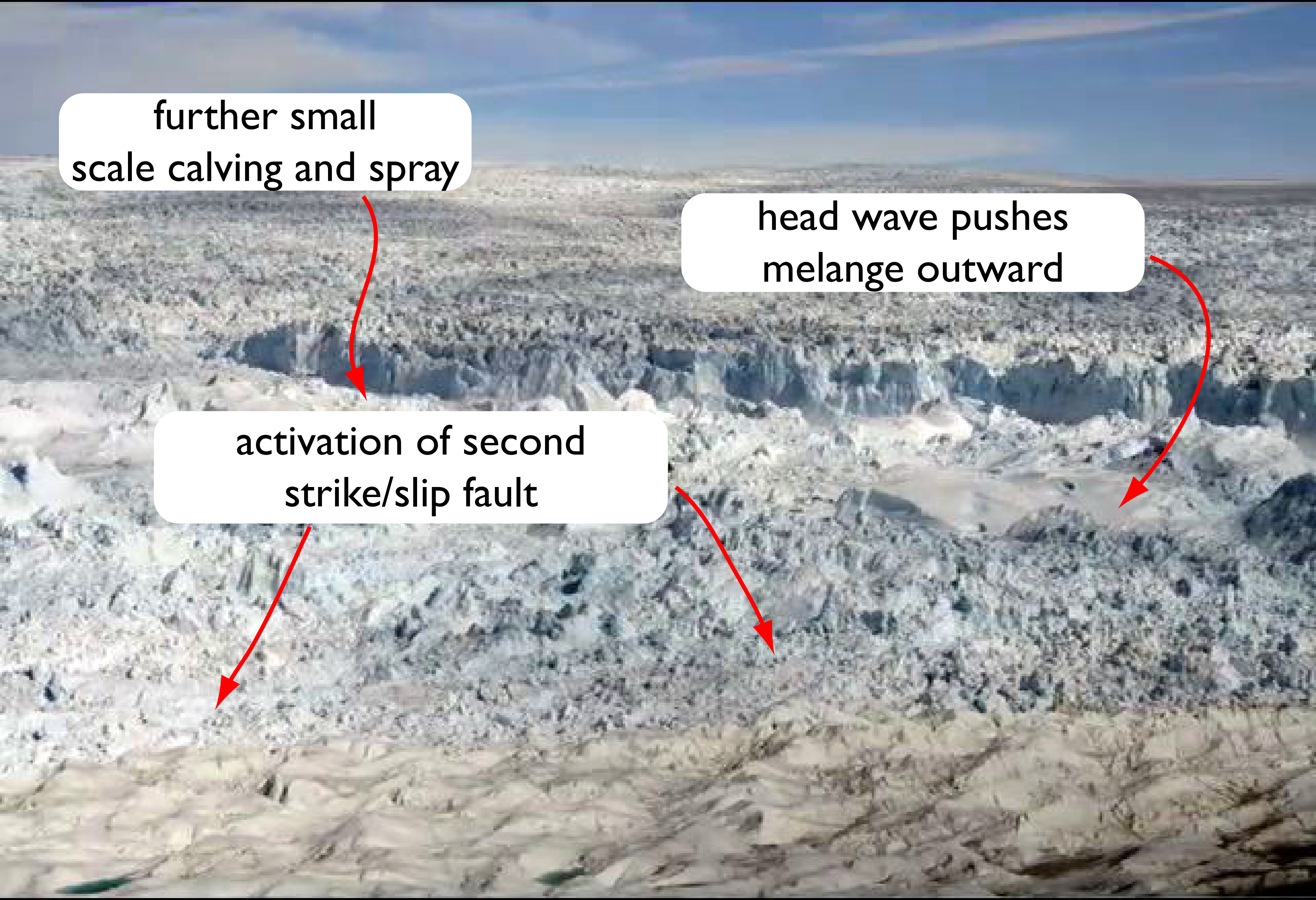

iceberg begins to "break its back"
with first cracks on ice/firn transition...


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...

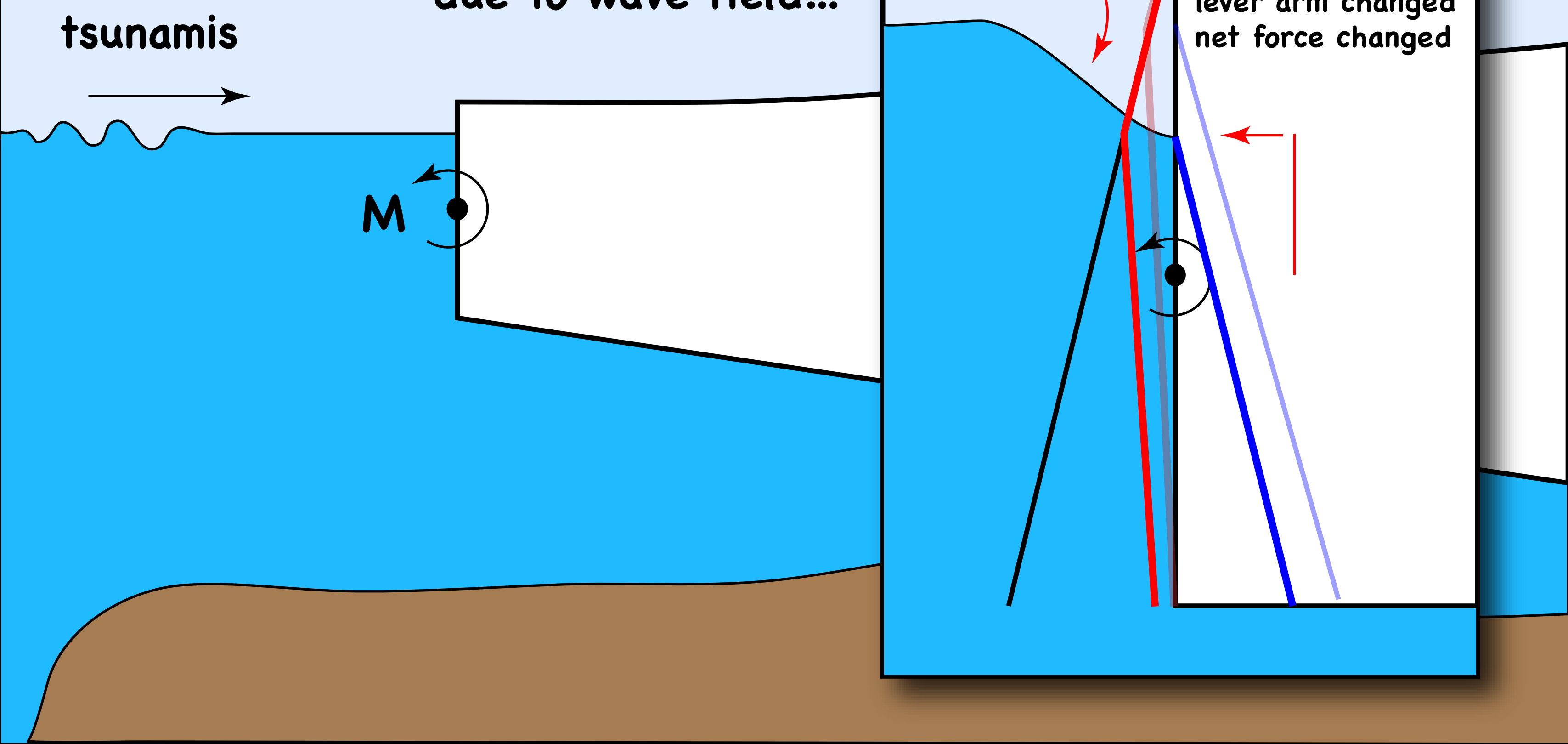

further small
scale calving and spray
head wave pushes
melange outward
activation of second
strike/slip fault

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

… A question of bending moments …

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

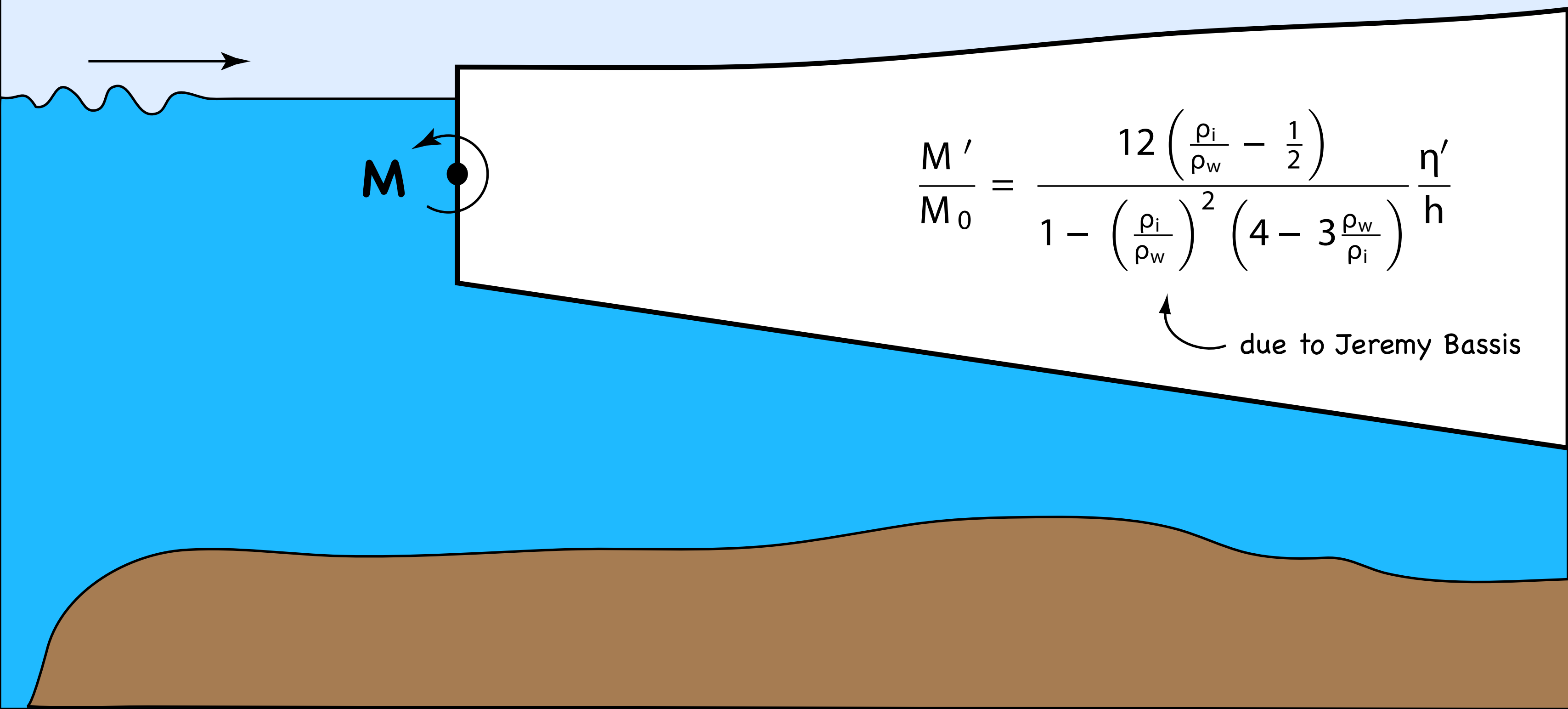
fluctuating moment due to wave field…



... 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...



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

Is ice-shelf collapse an autocatalytic process?

Can tsunami energy be "trapped"?