

Bound to fail

J.N. Bassis

Department of Atmospheric, Oceanic and Space Sciences

University of Michigan

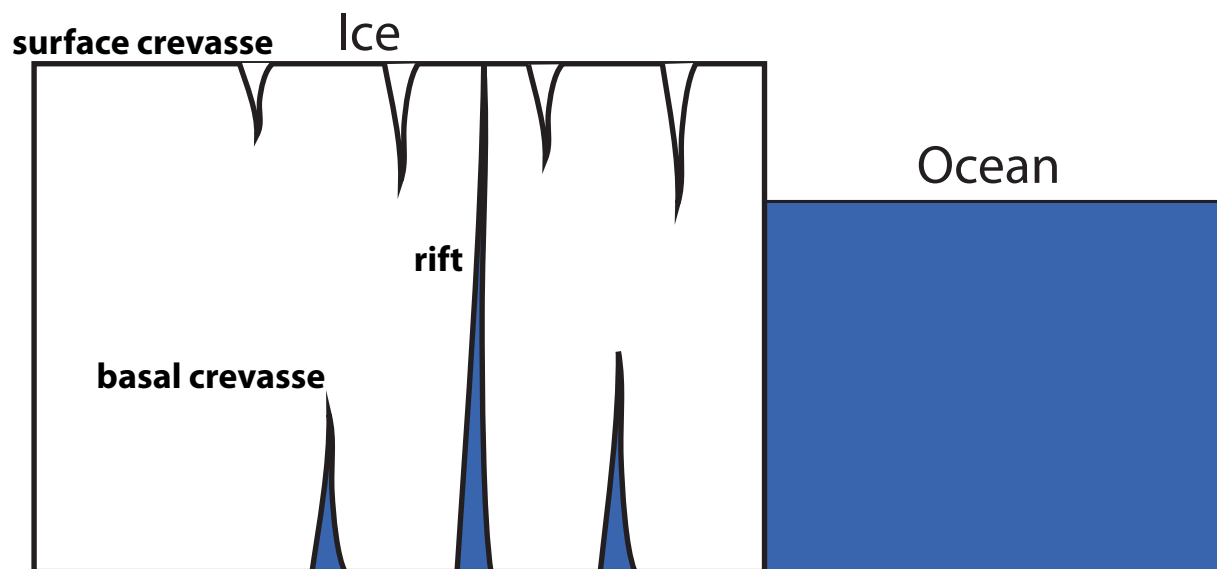
Iceberg Calving

Definition: sudden detachment or breaking away of a block of ice from an ice mass

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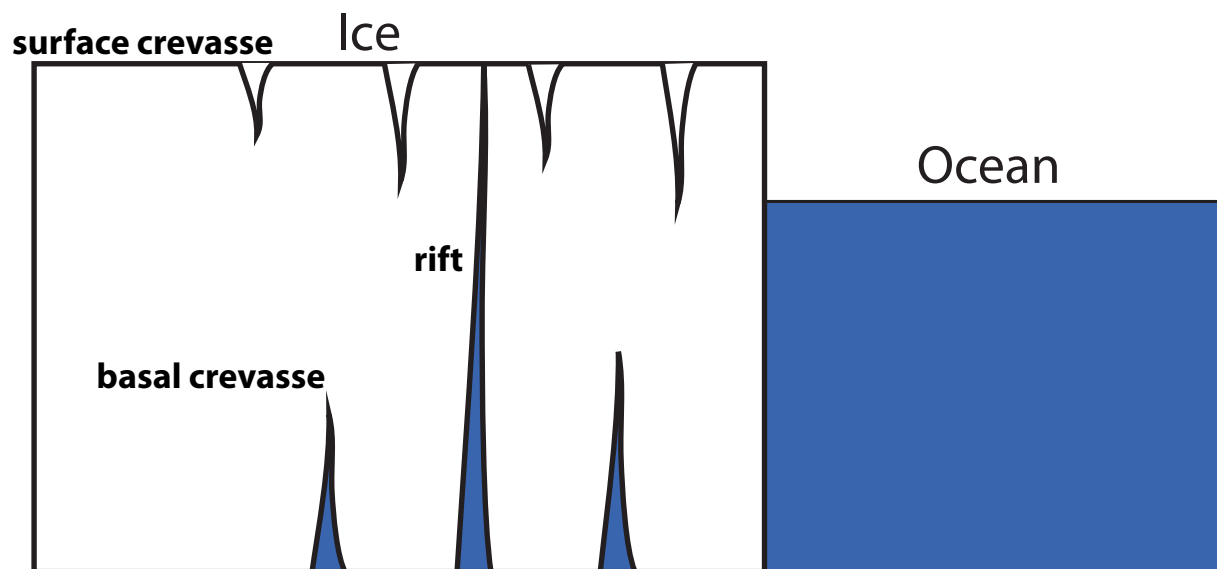
Definition: sudden detachment or breaking away of a block of ice from an ice mass

Iceberg calving requires *fracture* of ice



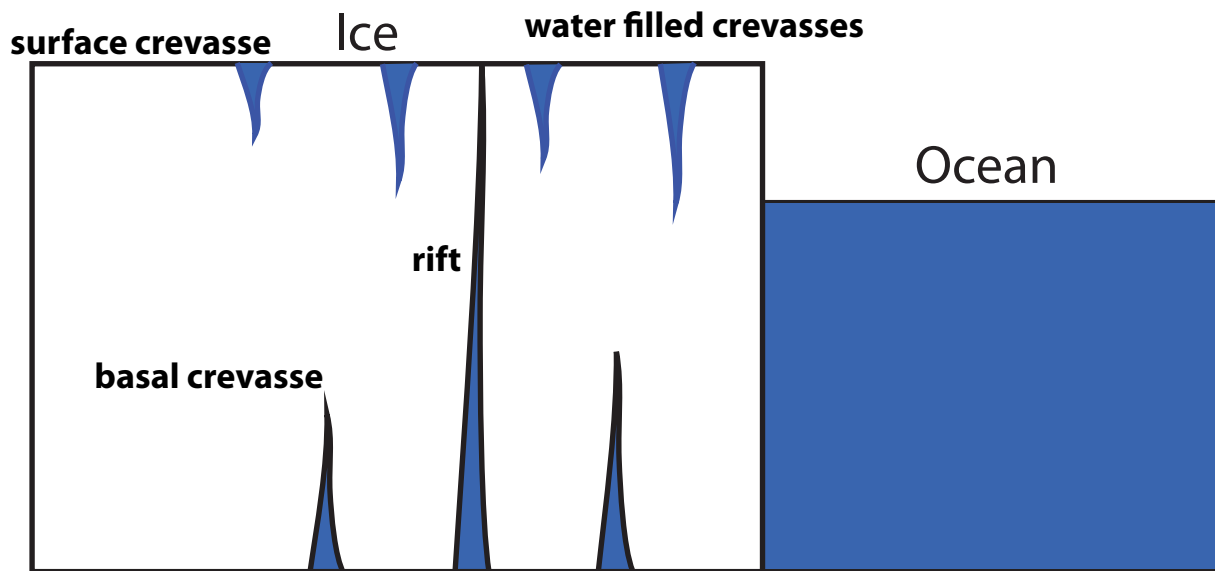
Forcing vs Fracture

Iceberg calving is a fracture mechanics problem but . . . need to know forcing



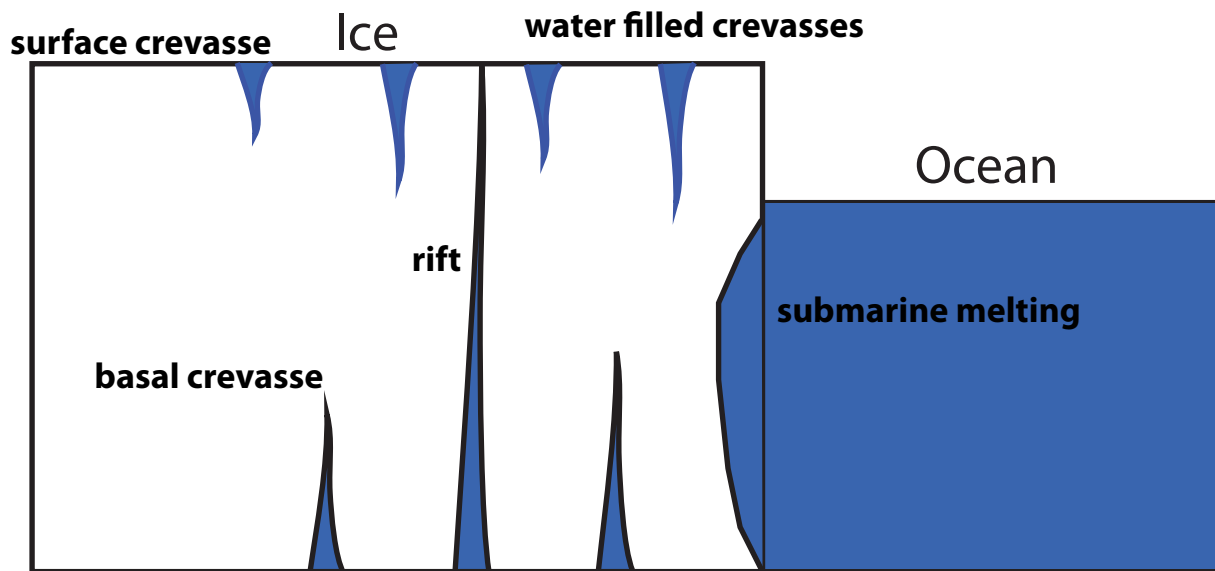
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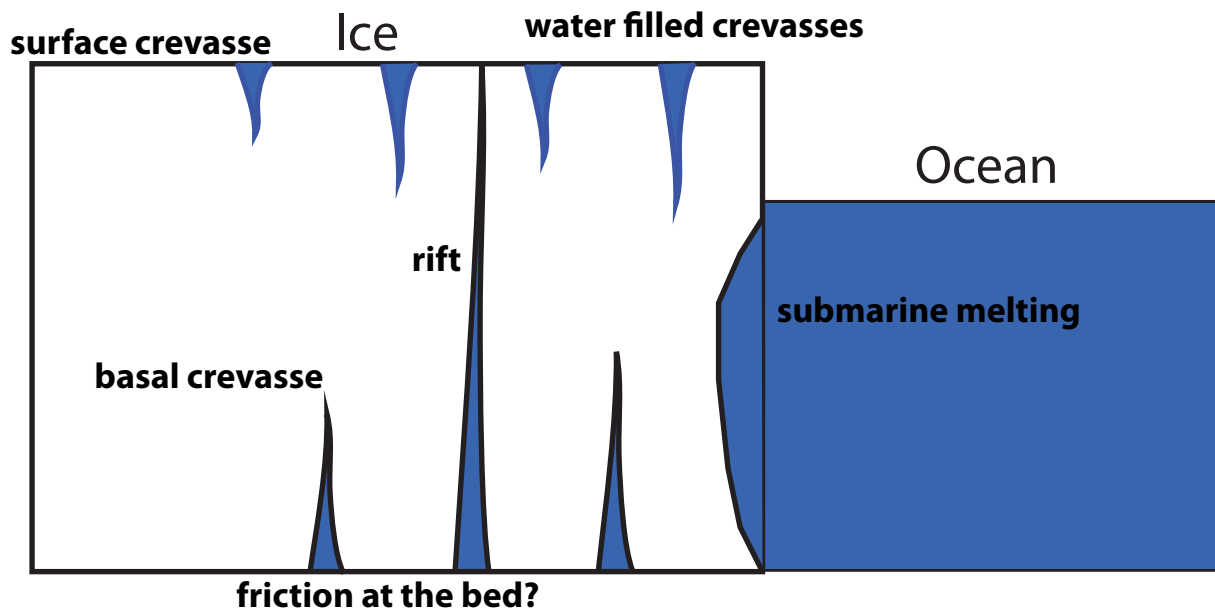
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Evidence for a dynamic control on terminus position

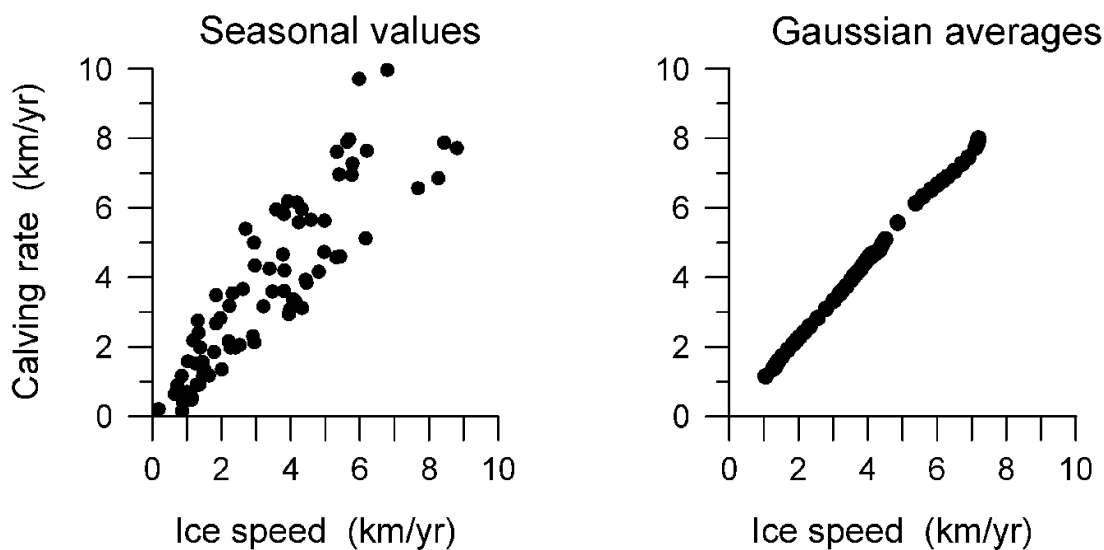


Figure 4 Relation between calving rate and glacier speed on Columbia Glacier, using values determined for each flight interval (left) and Gaussian smoothed values (right)

Source: based on data from Krimmel (2001)

Representation of iceberg calving

Stamp Collecting (focus on details)

Caricature (focus on big picture)

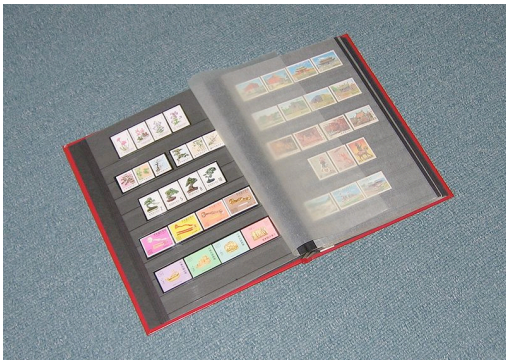


Representation of iceberg calving

Stamp Collecting (focus on details)

Fracture mechanics approach:
Simulate initiation and propagation of fractures within the ice

Examples: LEFM, Nye-zero stress model, damage mechanics



Caricature (focus on big picture)

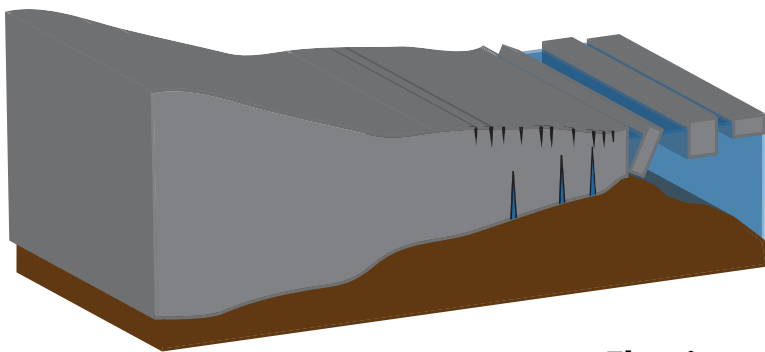
Calving law approach: Represent calving rate as a function of internal and external variables

Examples: Height-above-buoyancy, water depth, strain rate, ice thickness

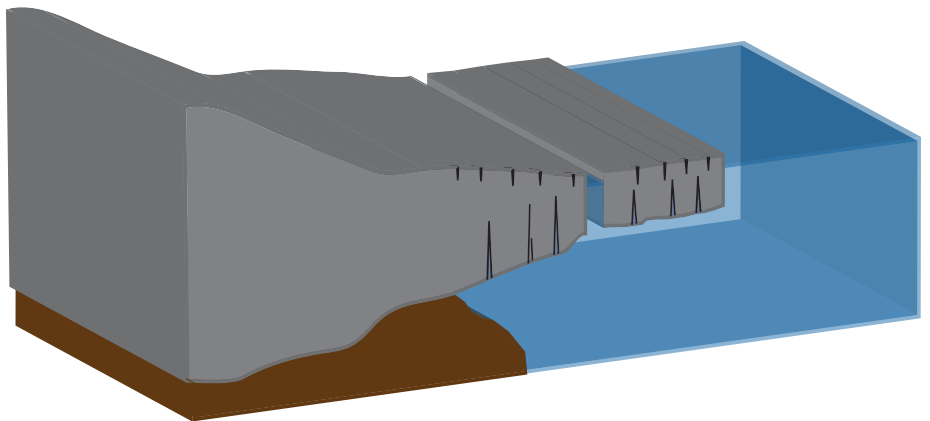


Iceberg Calving Regimes

Grounded termini

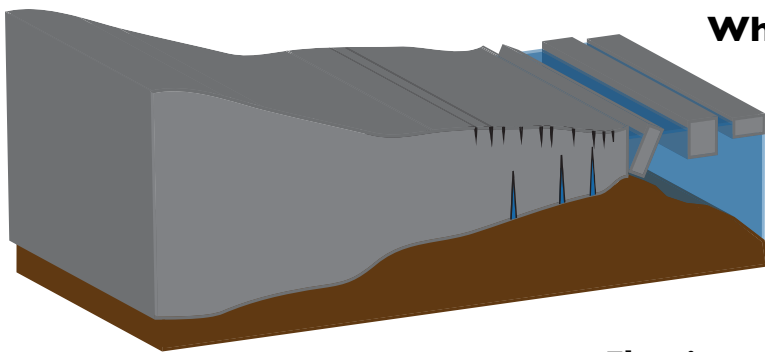


Floating termini



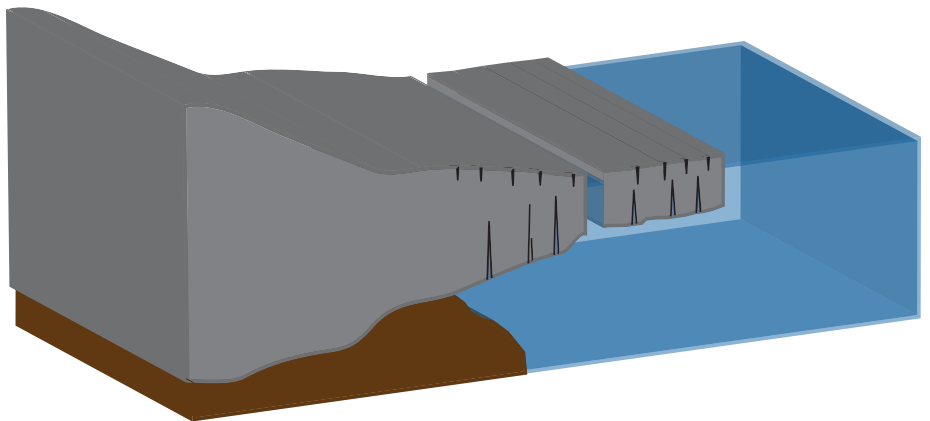
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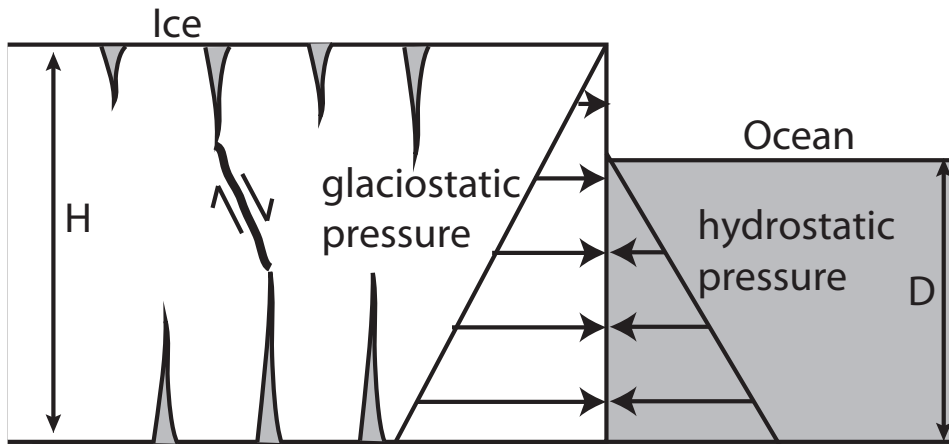
What causes different calving regimes?

Floating termini



Failure of ice

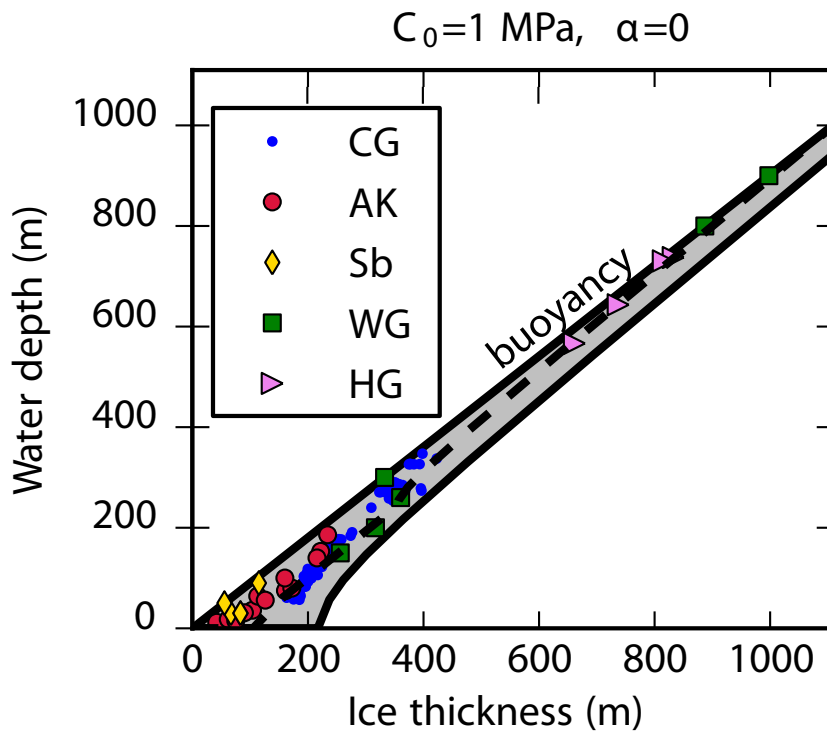
Force balance along the calving cliff



Ice fails when yield stress exceeded

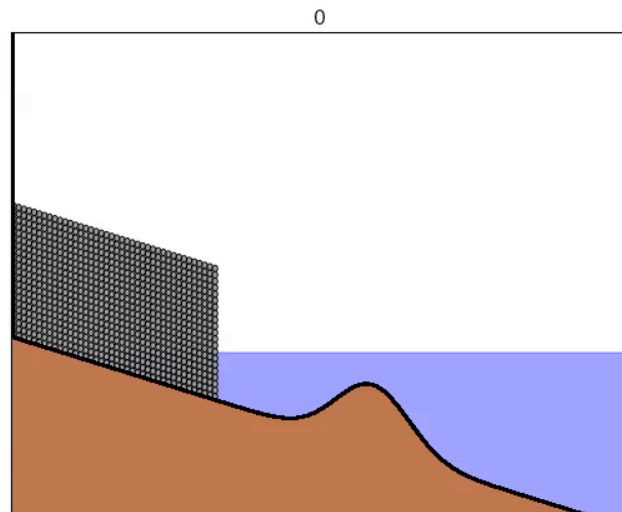
Failure of ice

Maximum height of calving cliff



Ice shelves and ice tongues are most stable configuration for given ice thickness

What about the lower limit?



Literal interpretation of Austin Post "Columbia Glacier is too shattered to support a floating ice tongue"

Conceptual Model of Ice: Molecular Dynamics

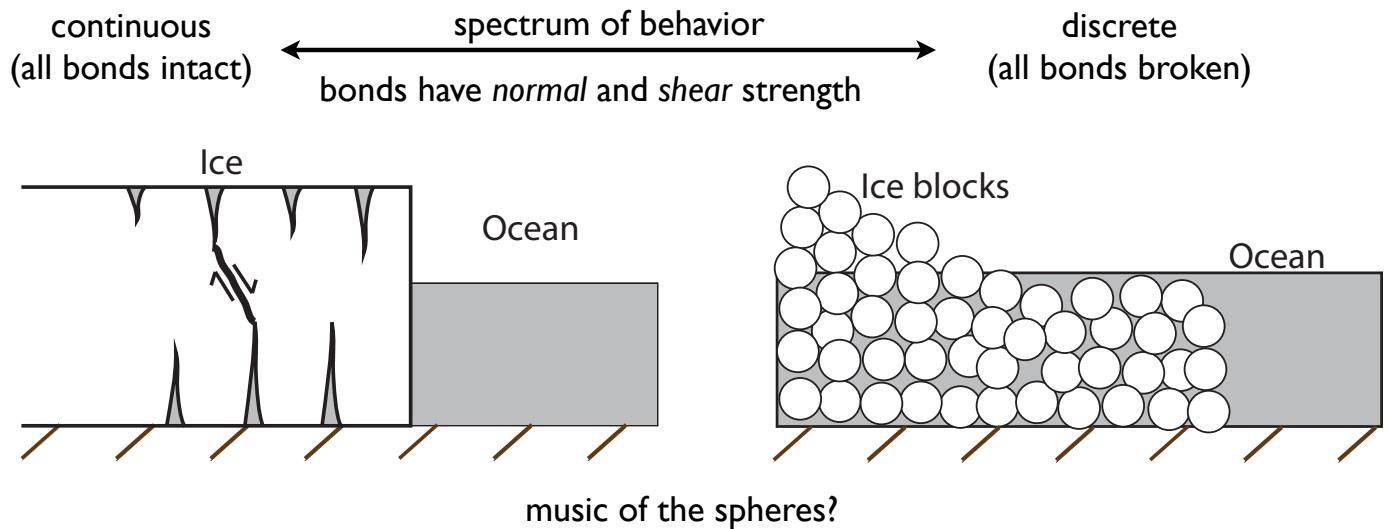
Atom: from Greek meaning uncuttable or indivisible

Molecule: Atoms held together by bonds

“Atoms” of ice are spherical boulders of ice

“Molecules” are boulders of ice glued together by bonds with finite strength

Spheres of ice interact through: (1) elasticity, (2) friction, (3) bond forces



Icebergs capsize after detaching

Time 0.0 s, $\phi=0.0\%$

2005-05

1 km

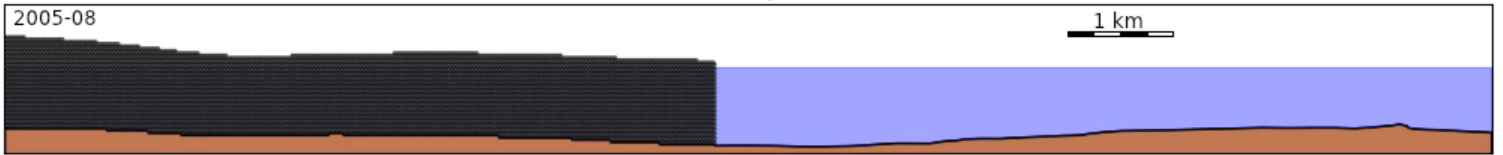


Iceberg detaches and drifts away

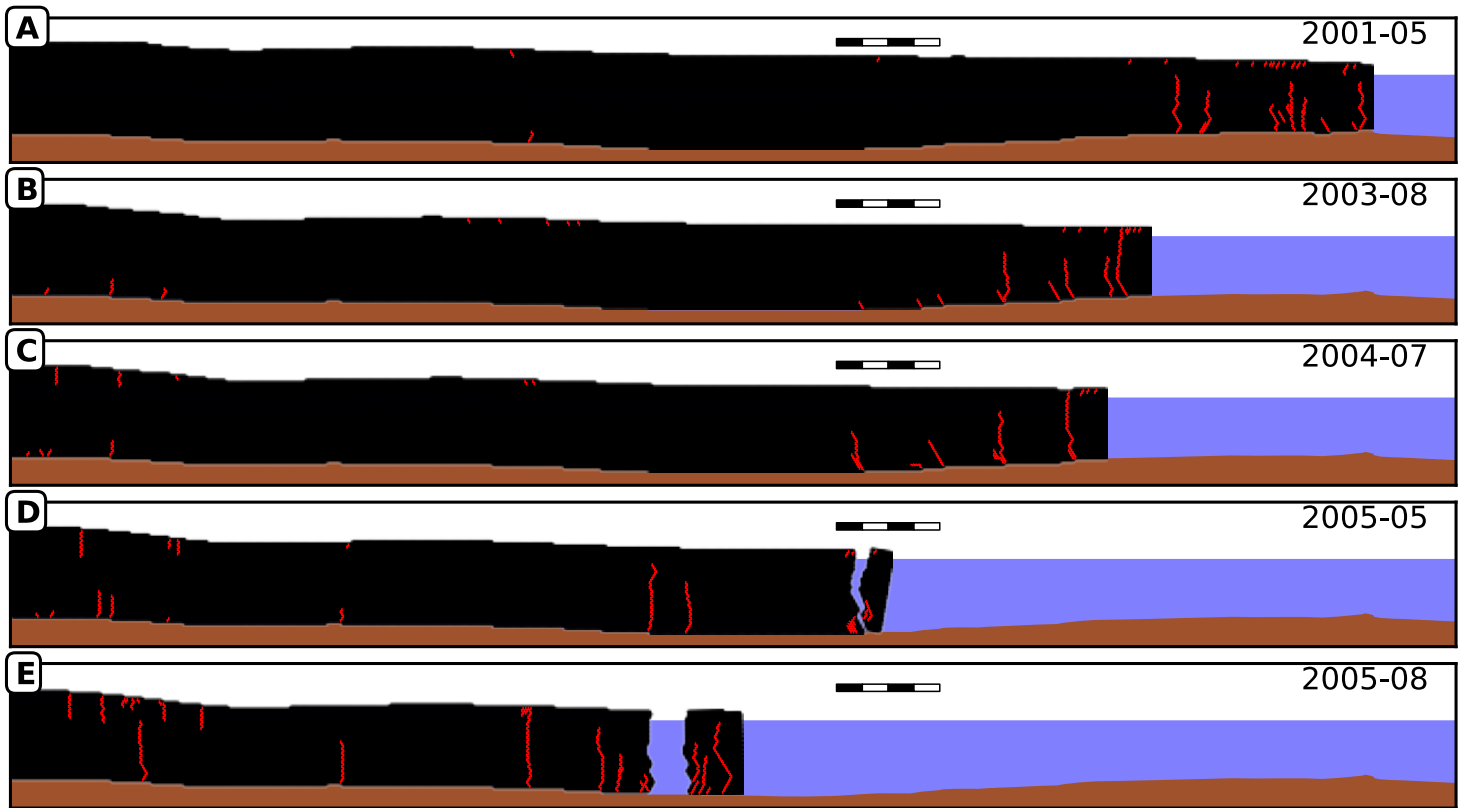
Time 0.0 s, $\phi=0.0\%$

2005-08

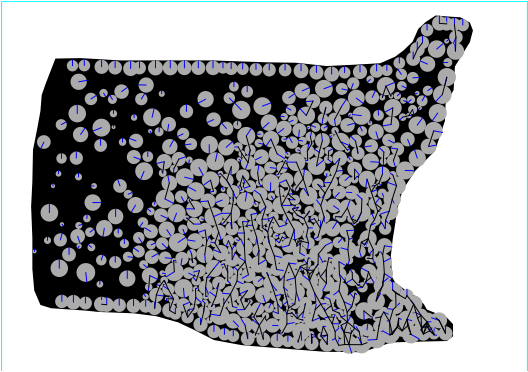
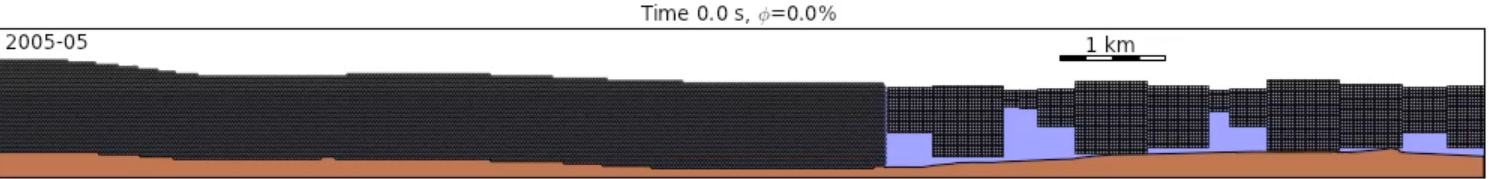
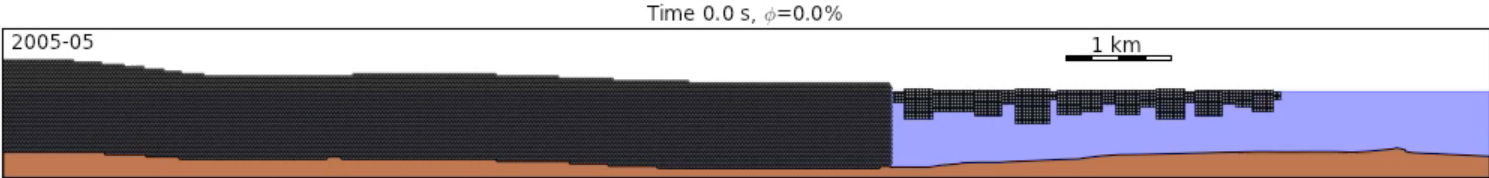
1 km



More realistic geometry: Helheim Glacier ca 2001-2005

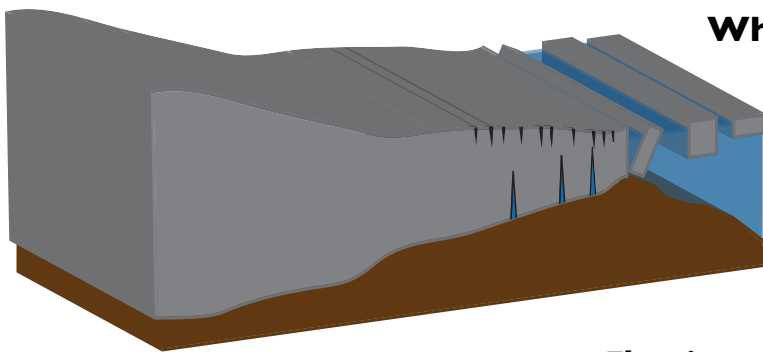


Export of icebergs can limit detachment



Iceberg Calving Regimes

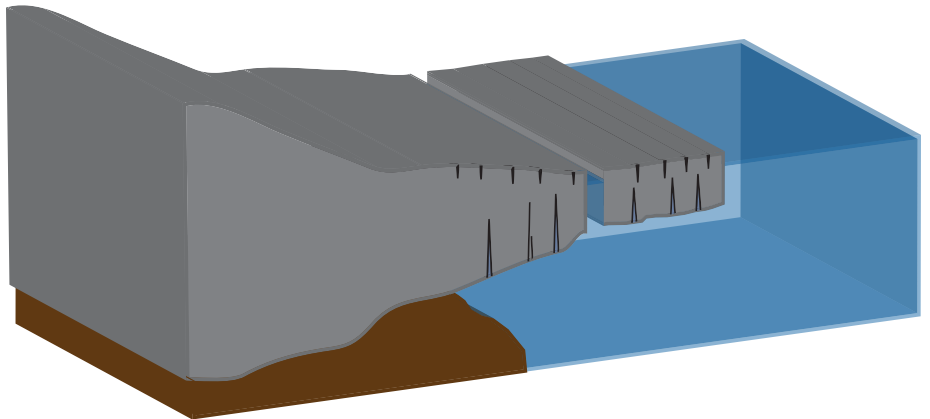
Grounded termini



What causes different calving regimes?

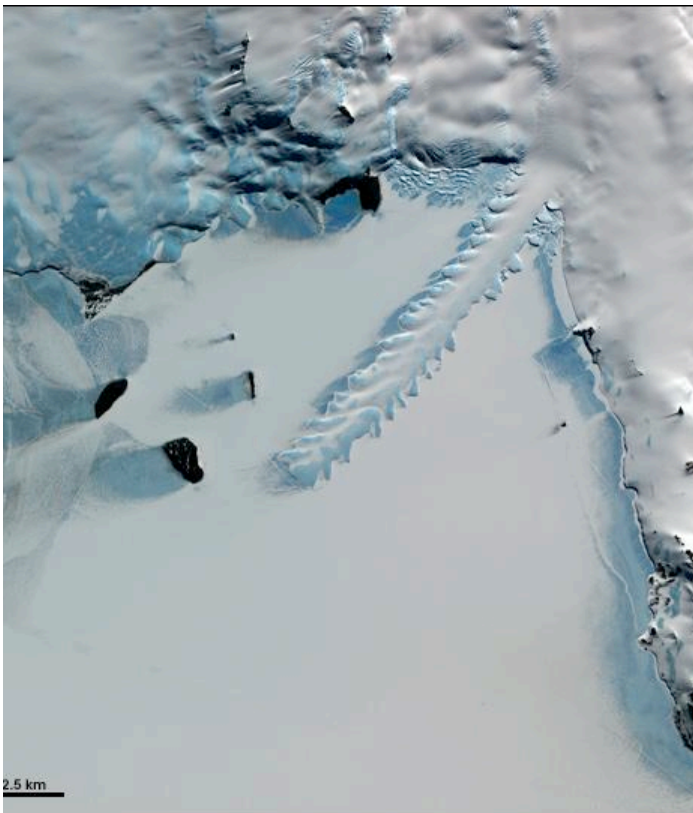
Floating termini

- 1. Fracture propagation**
- 2. Export of icebergs**
- 3. Evolution and advection of fractures after inception**

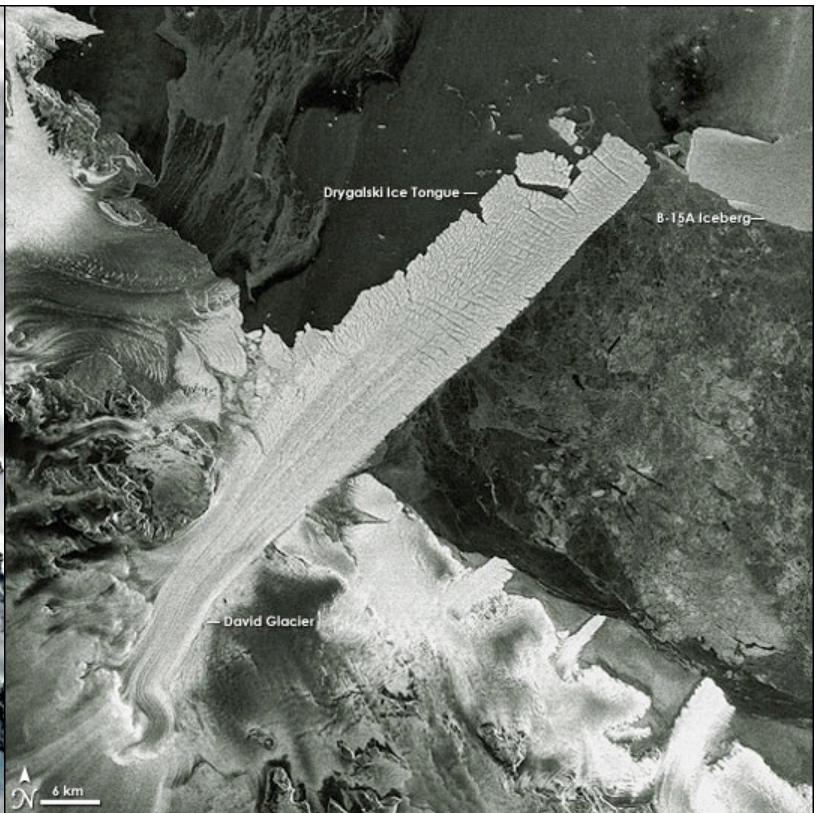


Floating ice tongues

Erebus ~ 10 km long

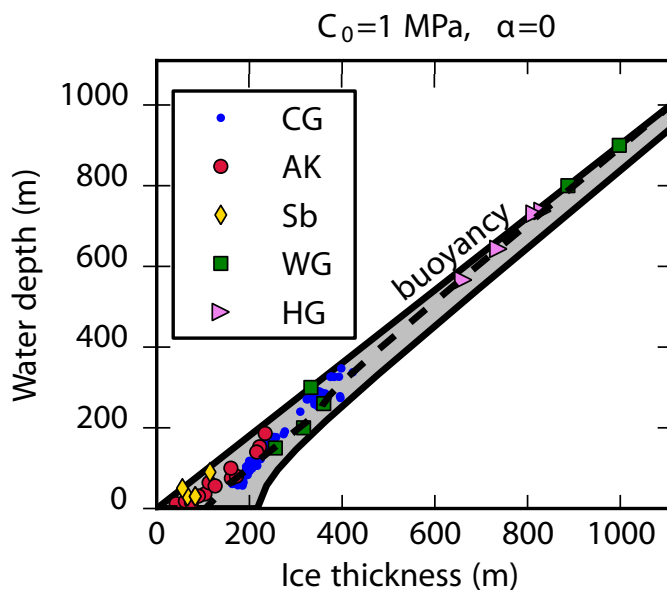


Drygalski ice tongue ~ 90 km long



Glacier geometry controls maximum calving cliff height

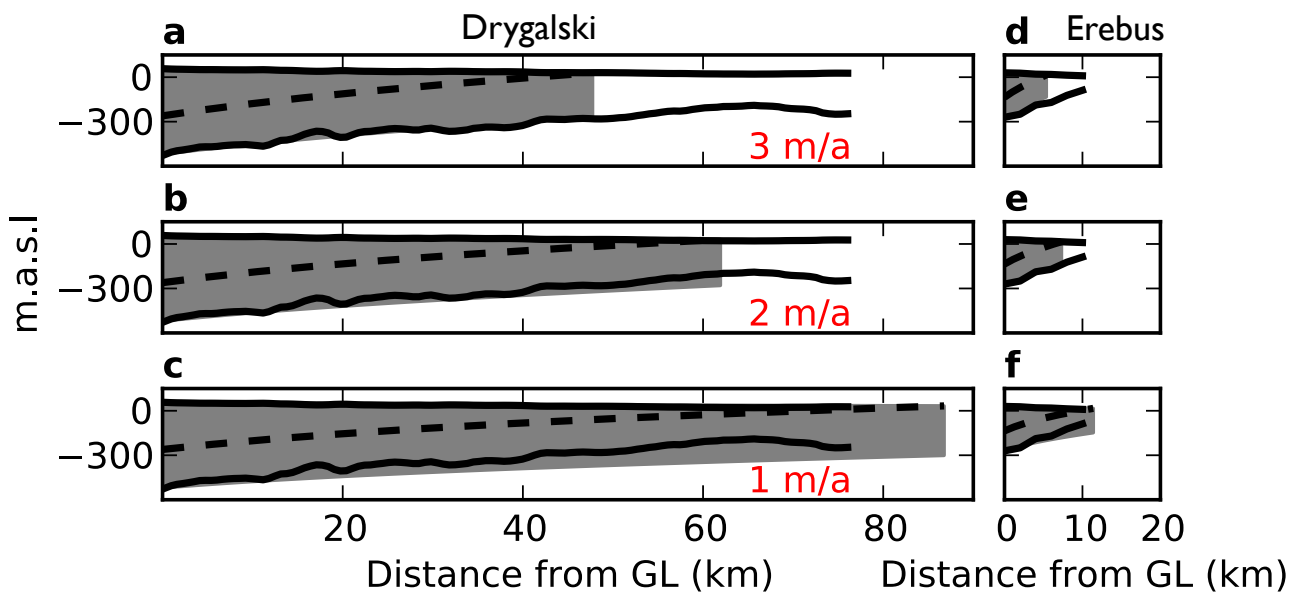
Upper bound on calving cliff height, based on laboratory fracture strength



Need to explain why grounded glaciers don't all form floating ice tongues

- Surface water fills crevasses?
- Pre-existing fracture initiate upstream and advect to calving front?
- Submarine melting?

Revisit: Floating ice tongues



Basal melt rate and ice temperature controls ice tongue length

Instability grows faster in warm ice where thinning rate is highest