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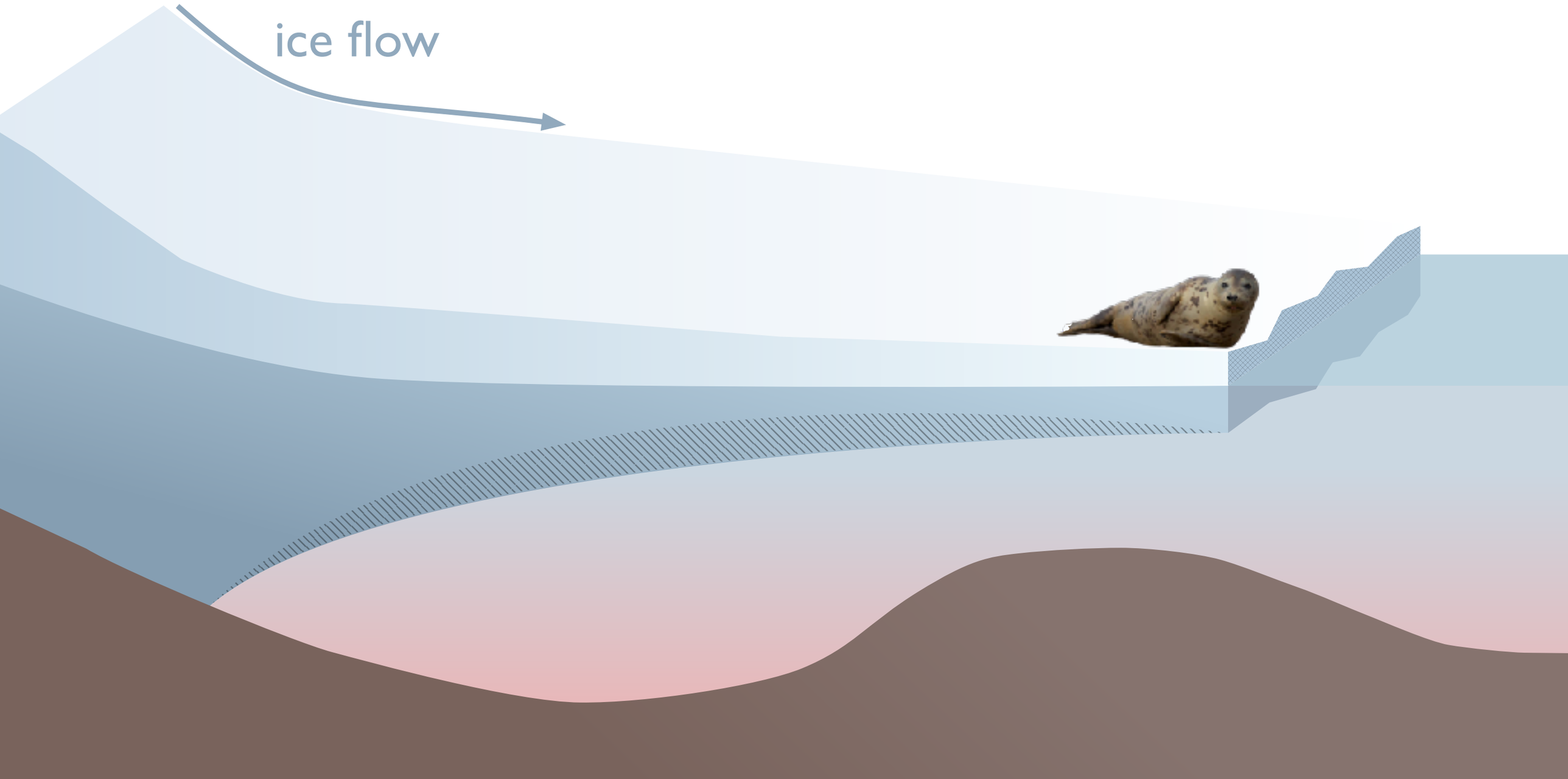
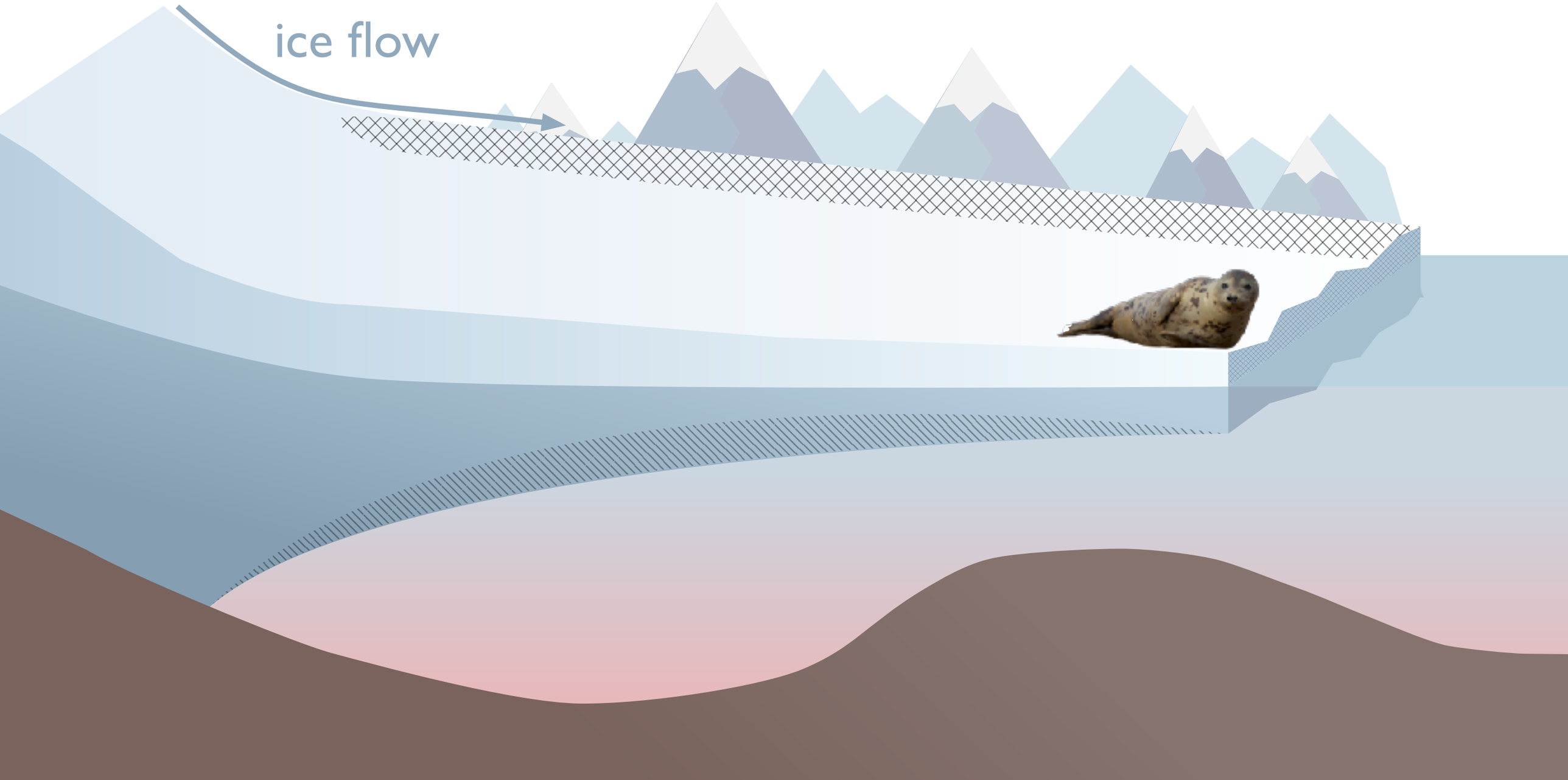
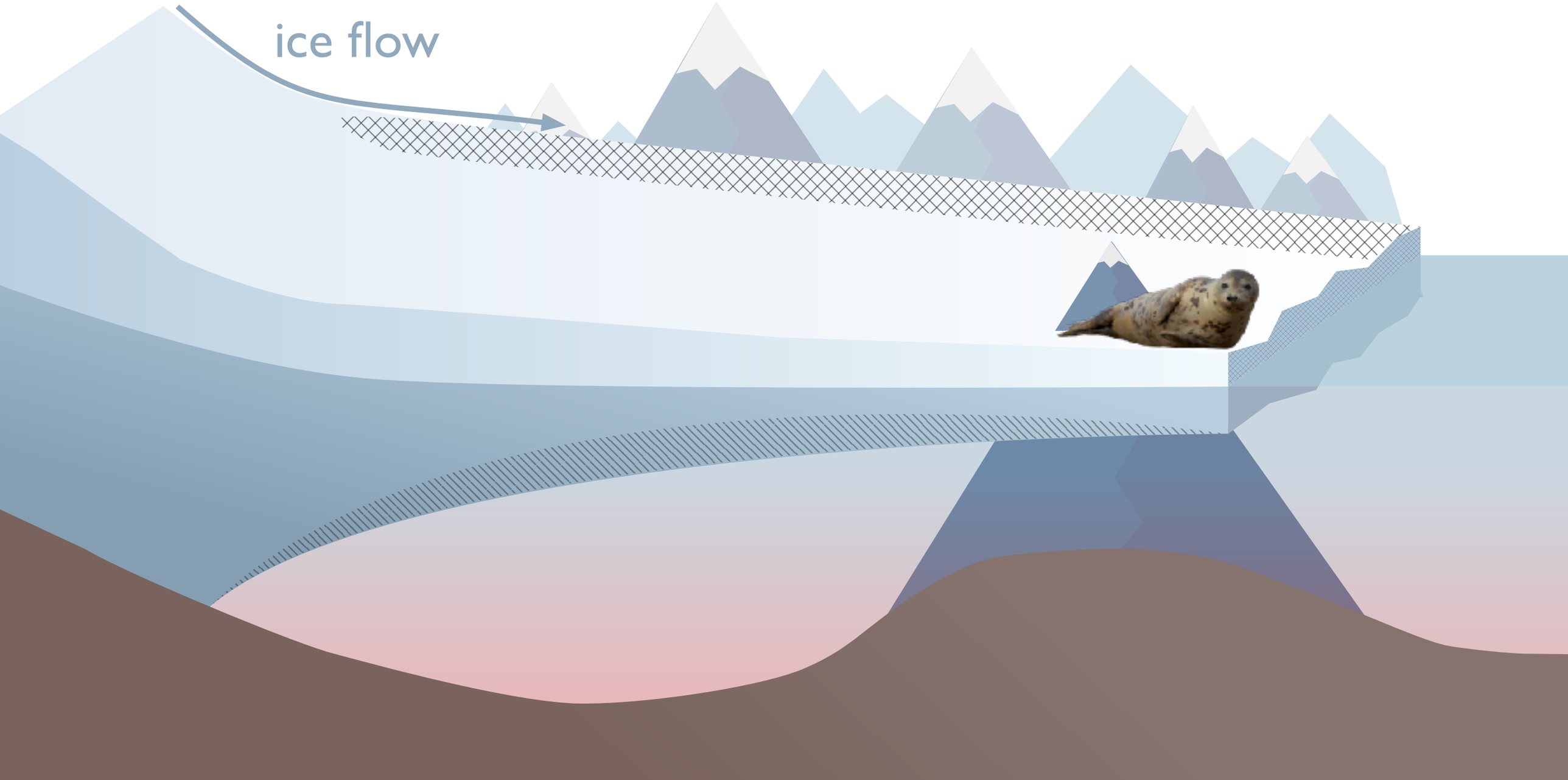
The influence of Pine Island Ice Shelf calving on basal melting

Alex Bradley, David Bett, Pierre Dutrieux, Jan De Rydt, Paul Holland @abraleey


ice flow


ice flow


ice flow

ice flow

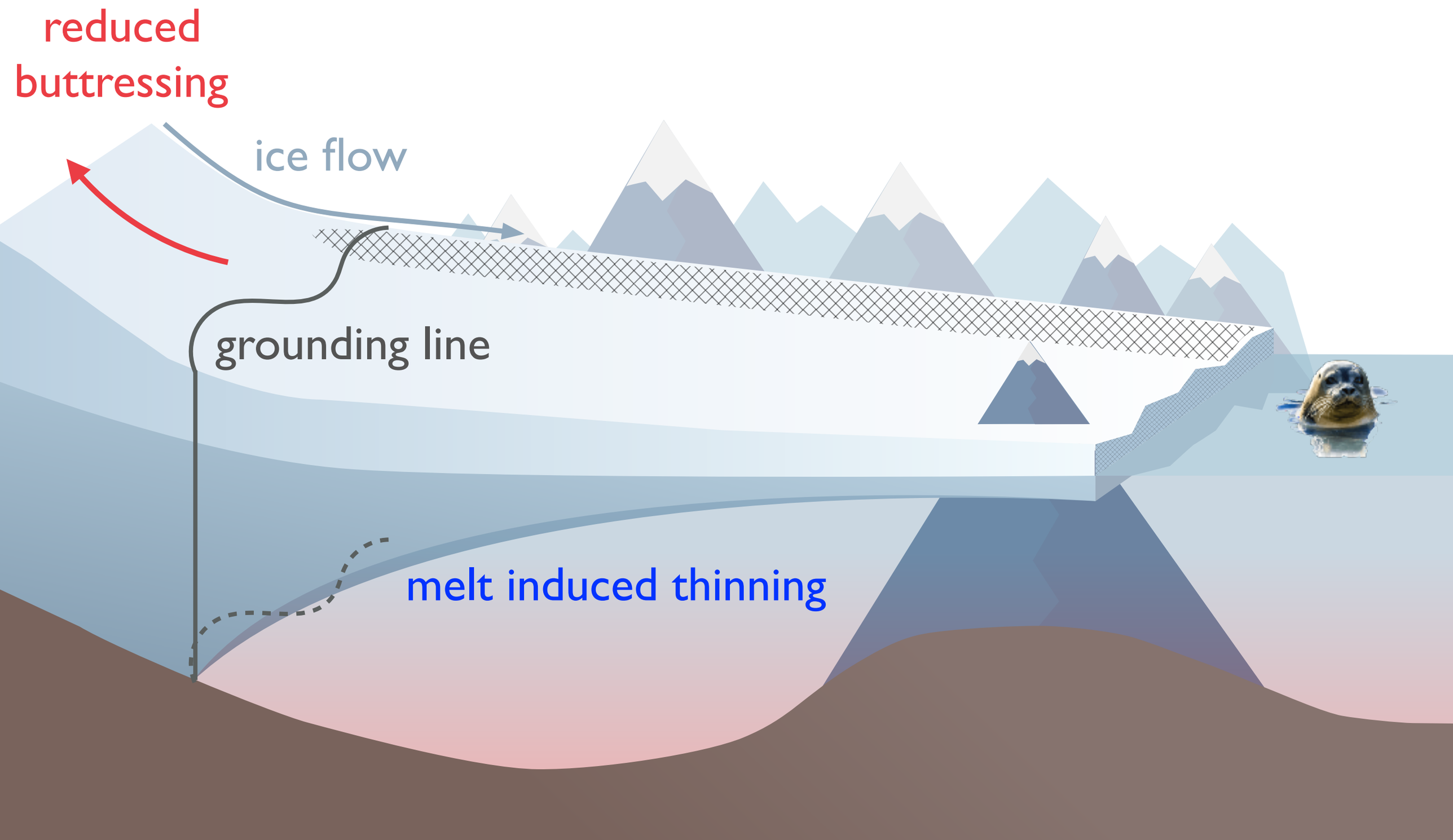
grounding line

buttressing

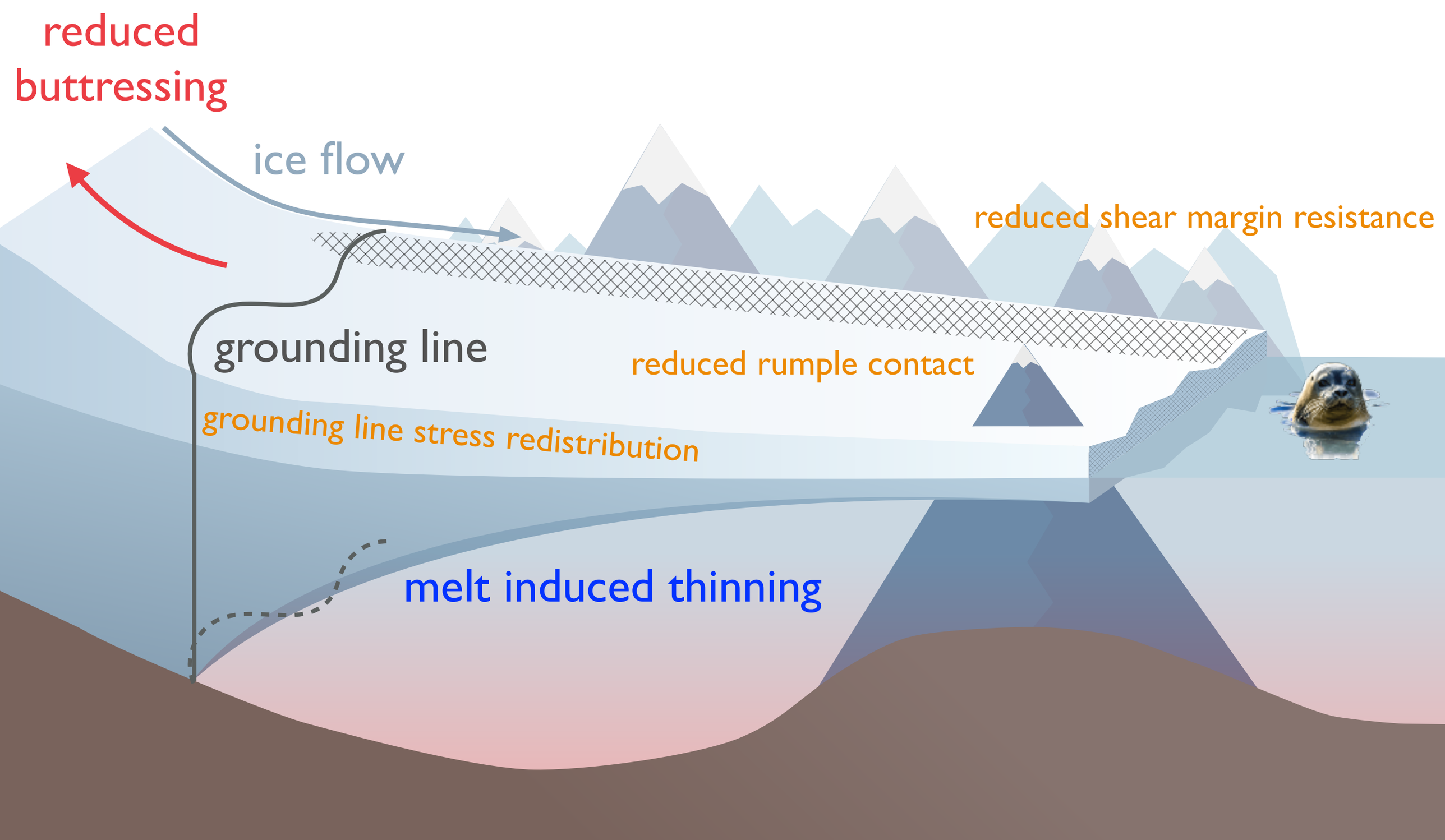
ice flow

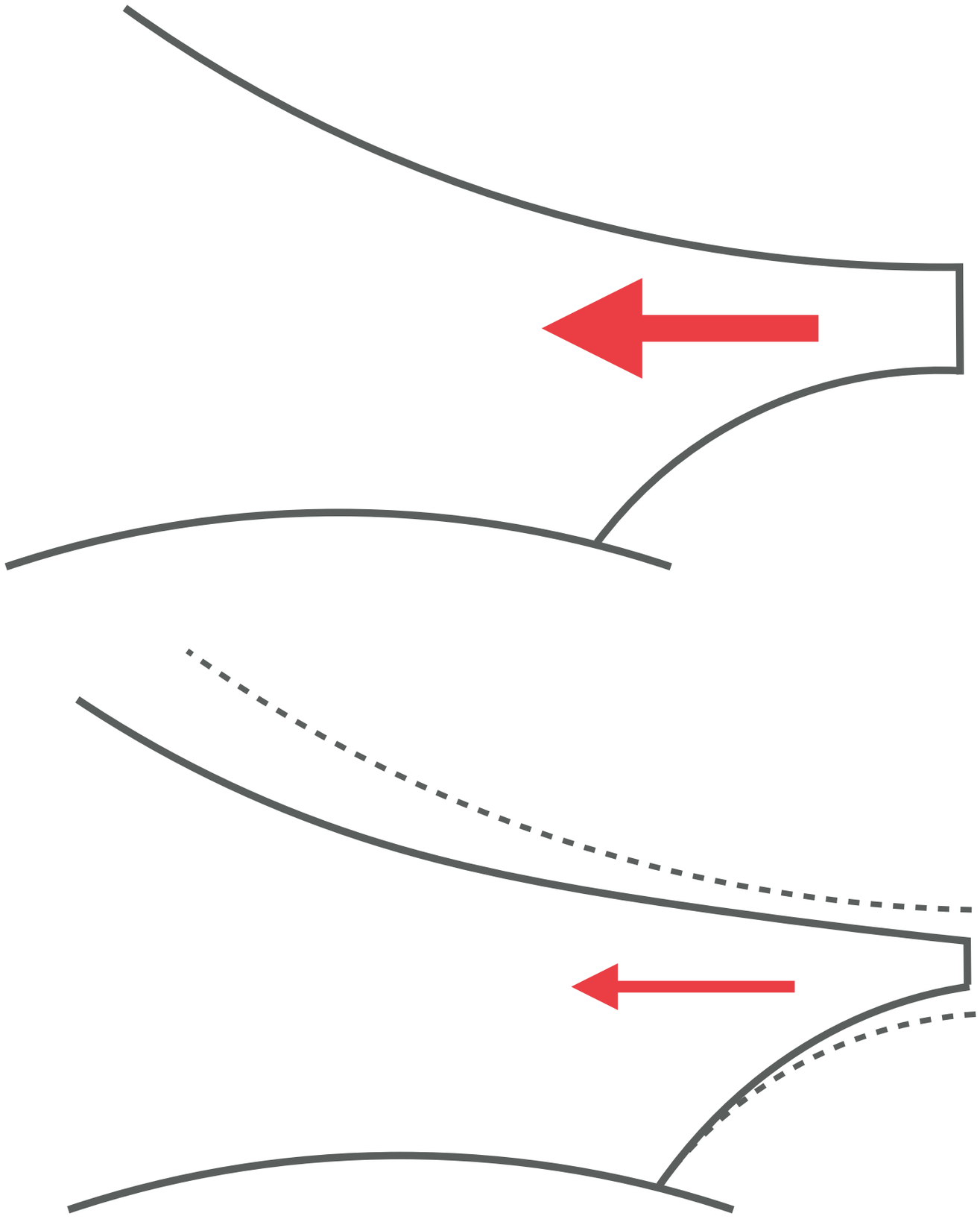
grounding line

Ice shelf thinning reduces resistive buttressing stresses



Ice shelf thinning reduces resistive buttressing stresses





smaller ice shelf

↓

less buttressing
(smaller restraining)

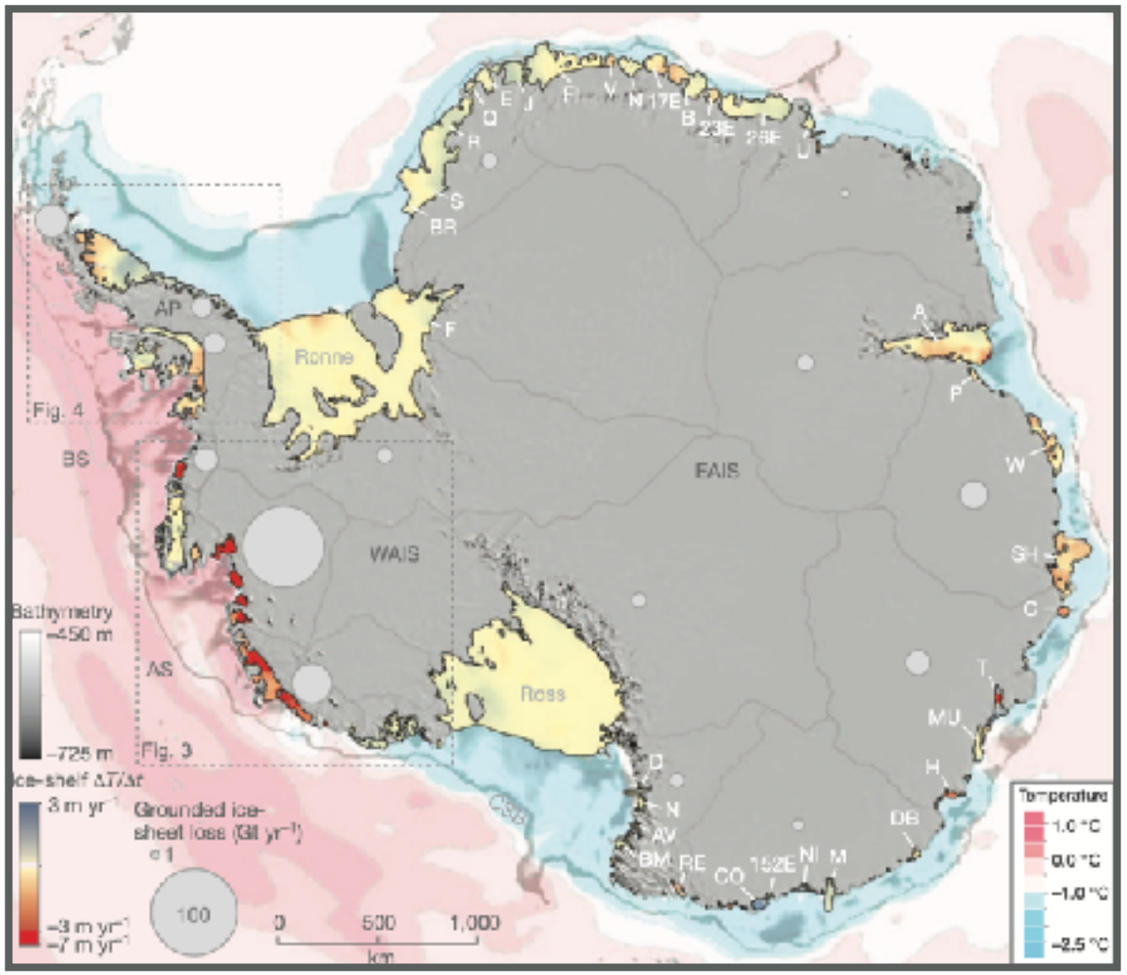
↓

less ice in sheet

↓

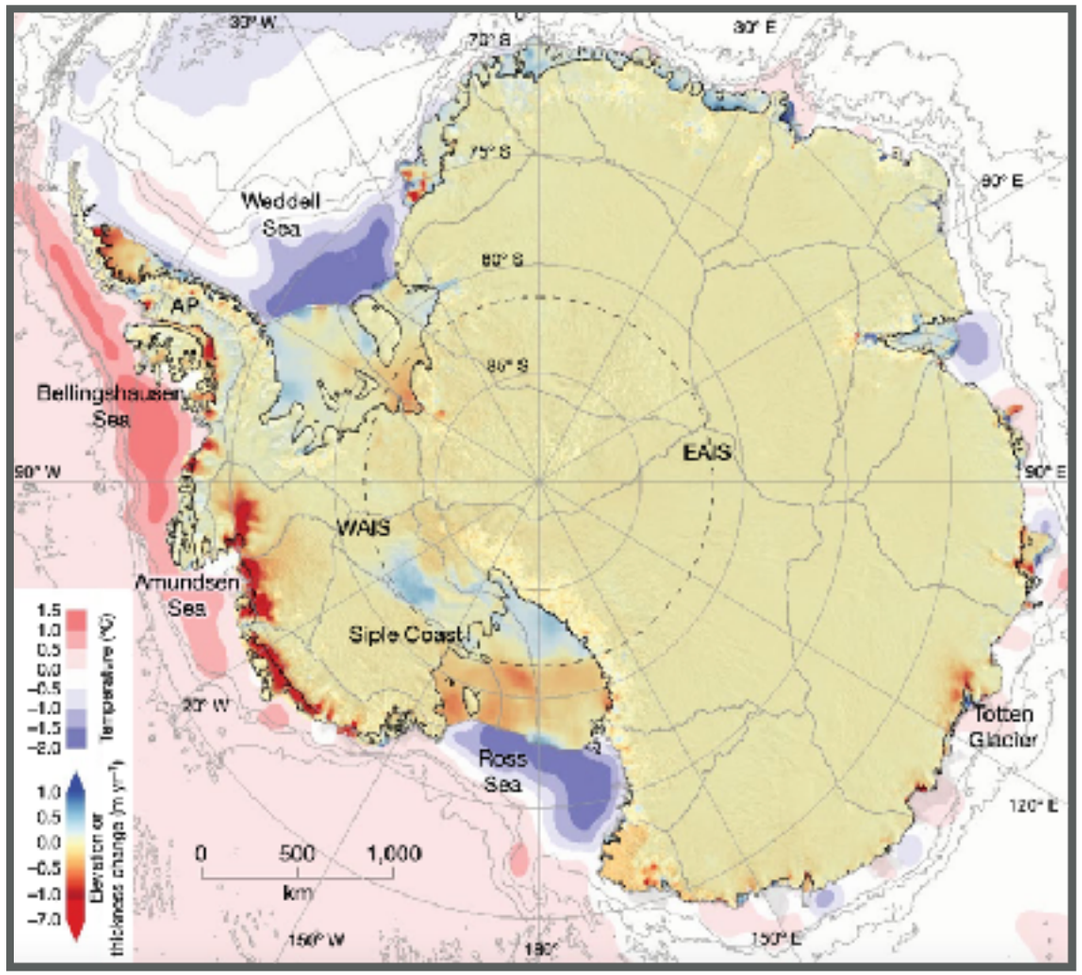
higher sea level

Melting implicated in long term changes to WAIS



Pritchard et al. 2012

2003-2008 average

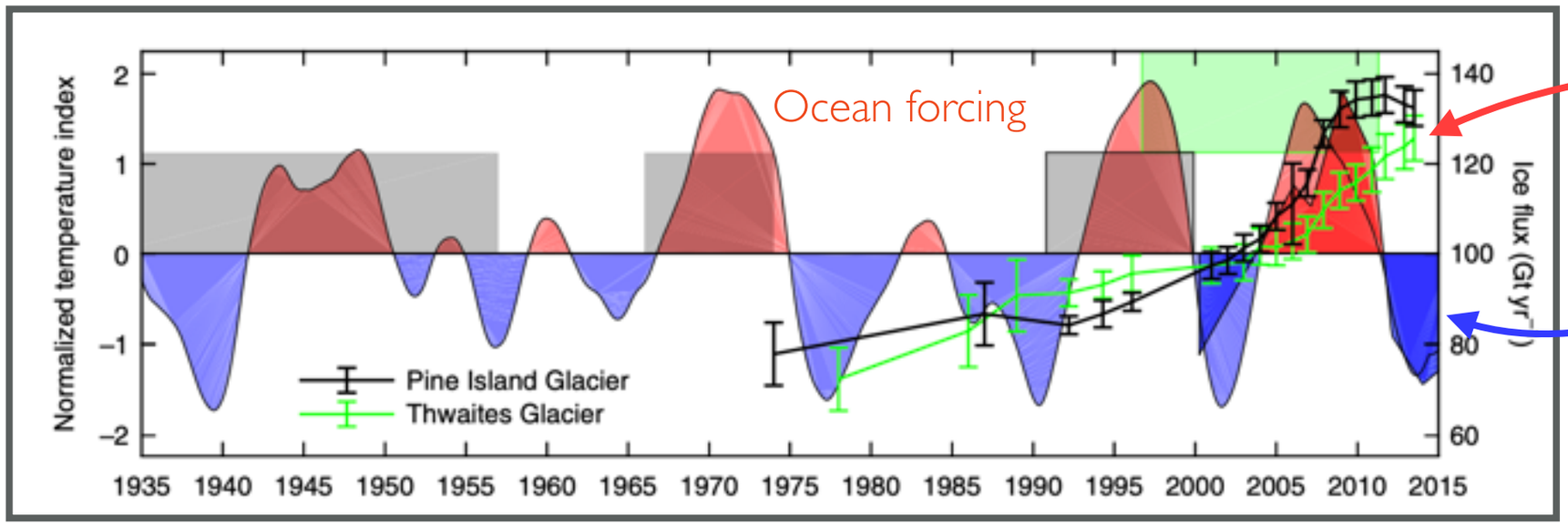


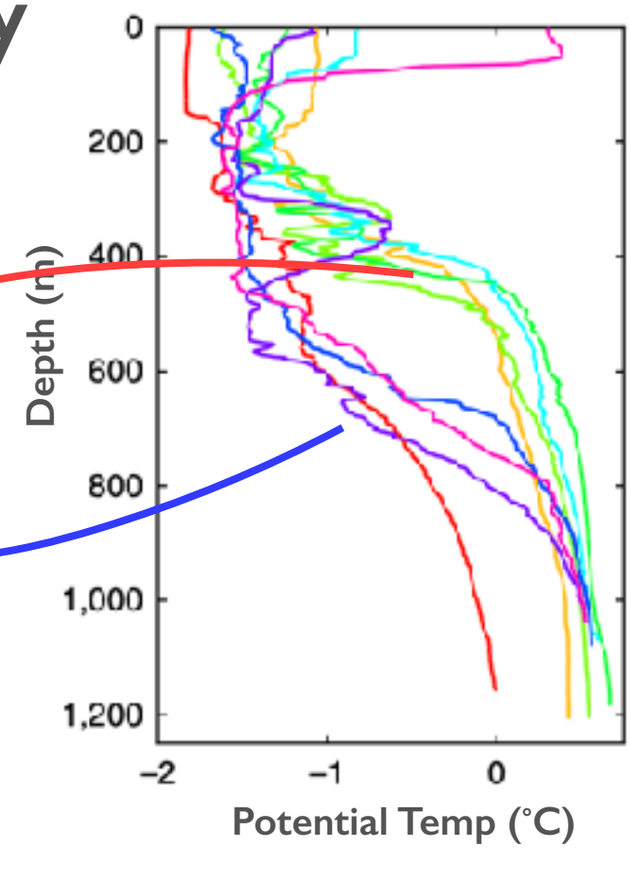
Shepherd et al. 2018

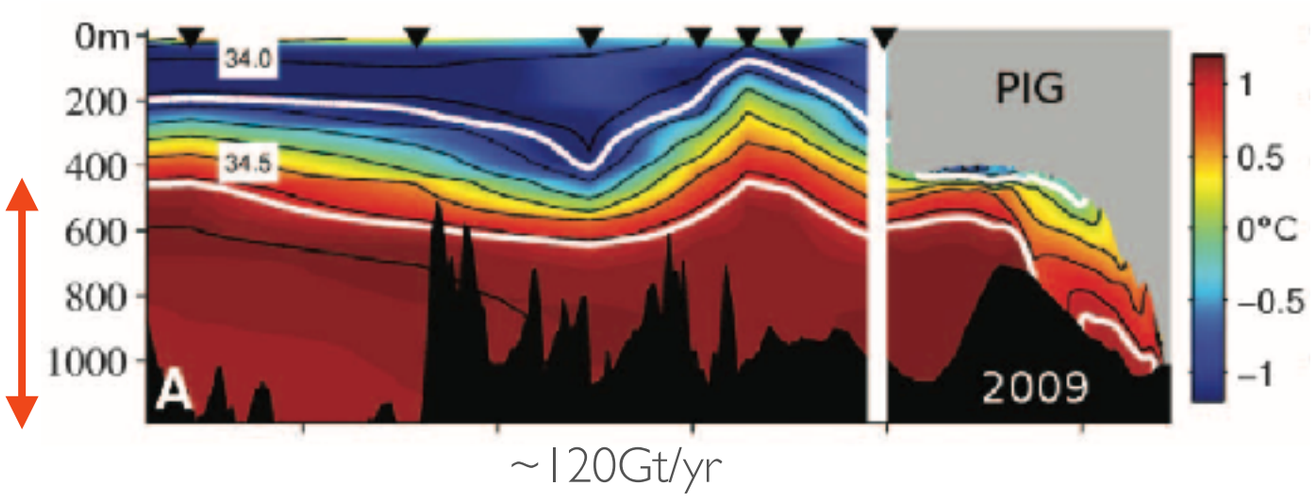
1992-2017 average

WAIS also shows significant decadal variability

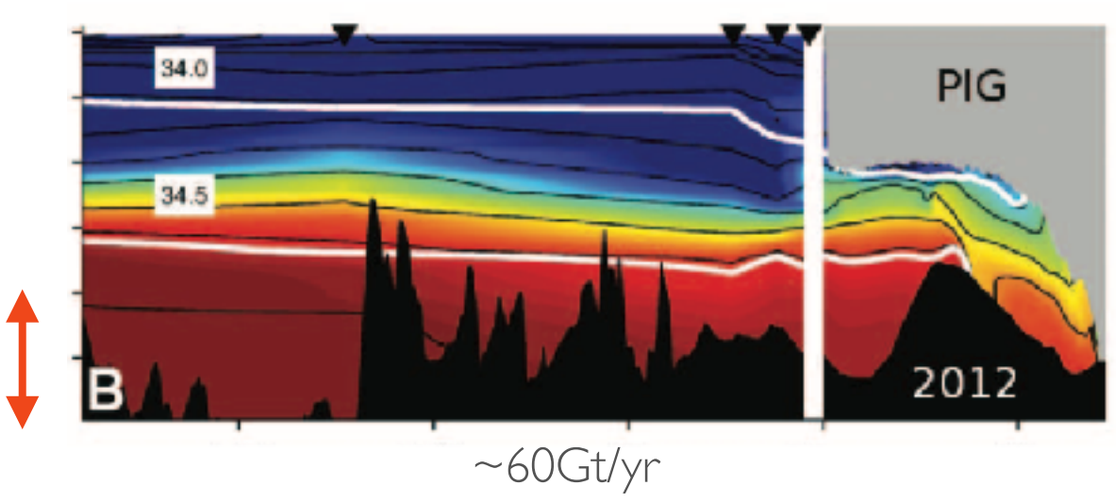
Jenkins et al. 2018







~120Gt/yr

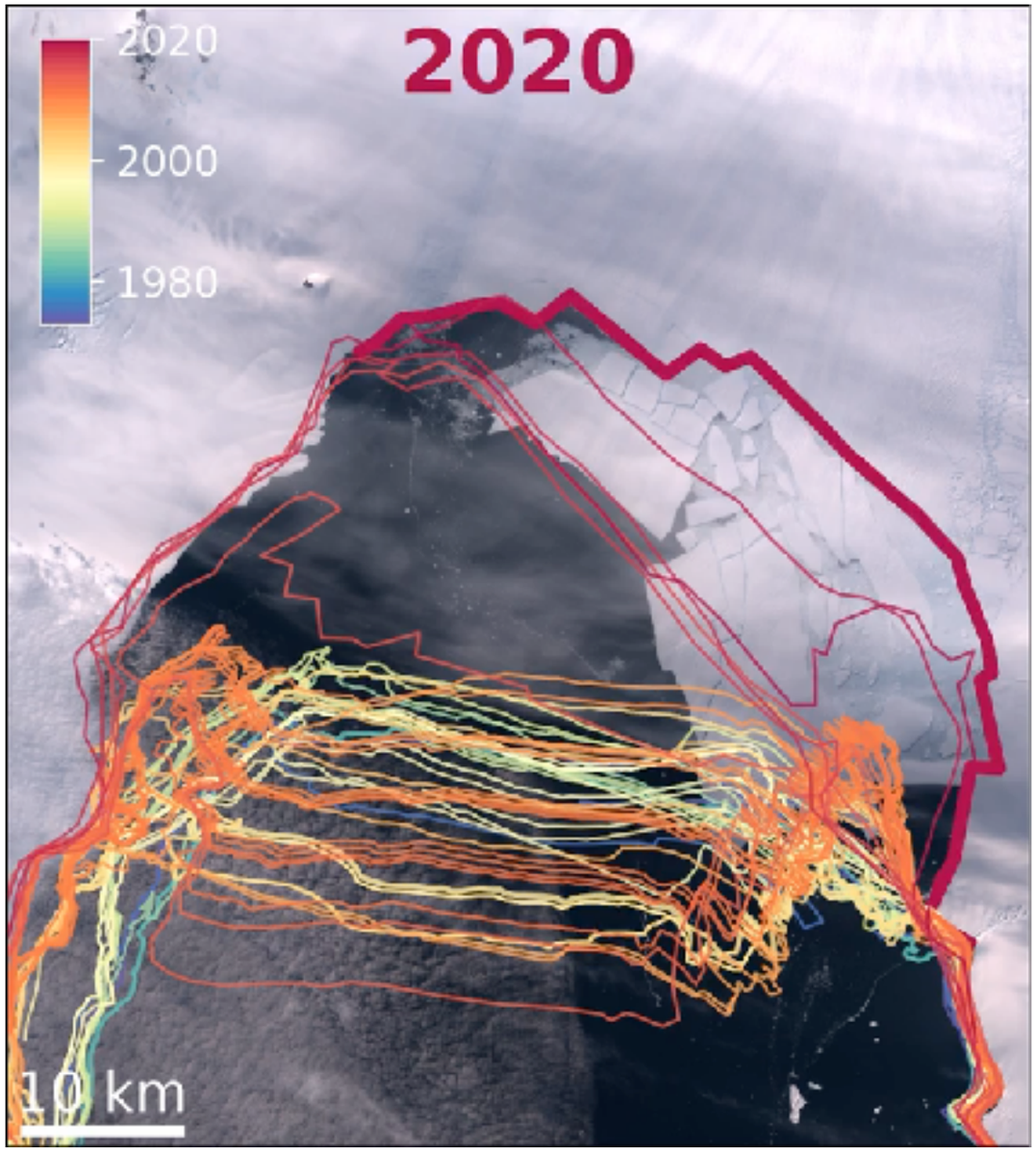


~60Gt/yr

Dutrieux et al. 2014

Seabed **ridge in combination with shelf** acts as a **topographic barrier** to the inflow of **warm water**

Pine Island has undergone significant calving recently



Lhermitte et al. 2020

Presence of **ice shelf** in combination with **seabed ridge restricts warm water access**

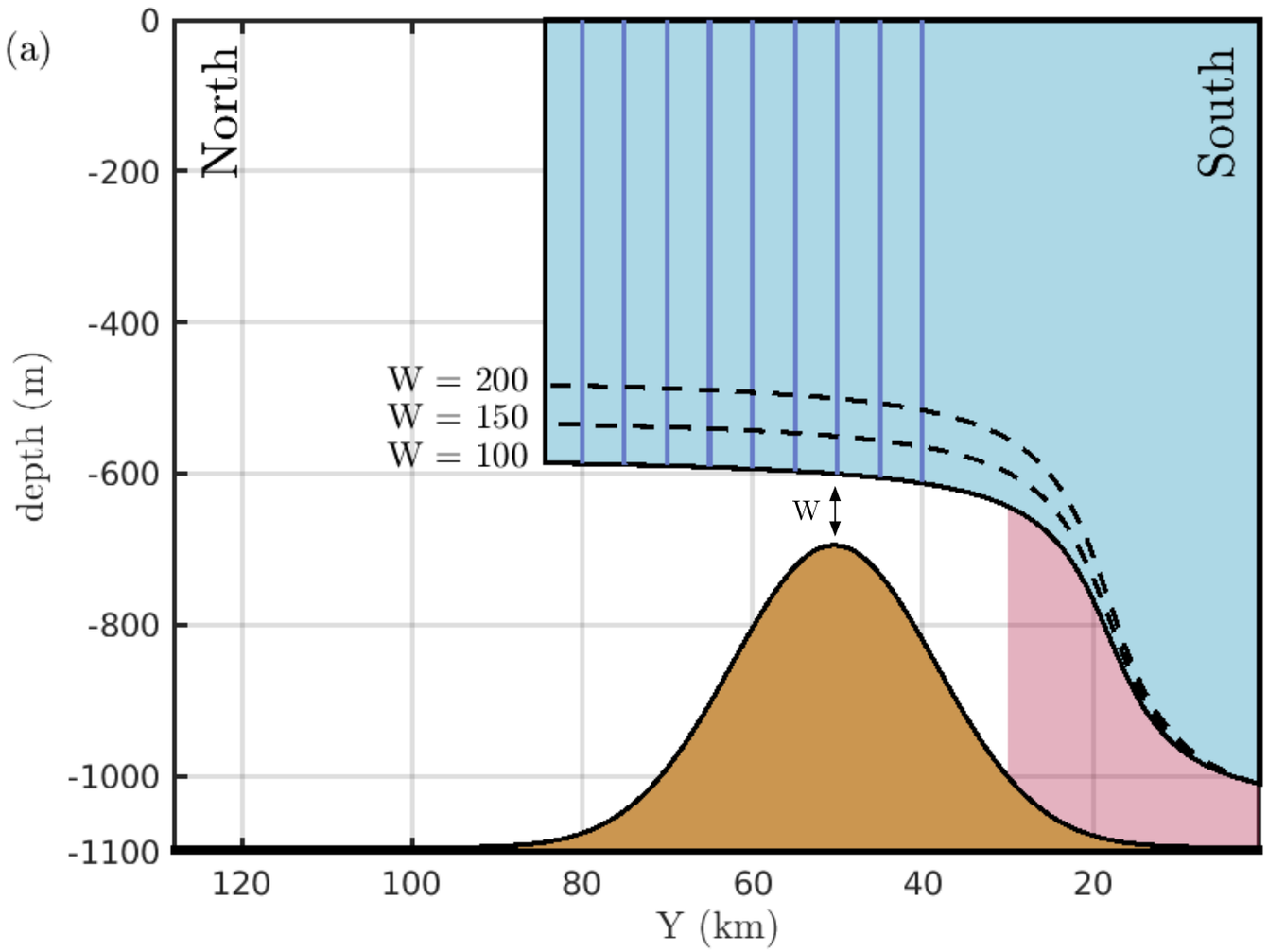
Ice shelf front has **retreated** significantly by calving

?

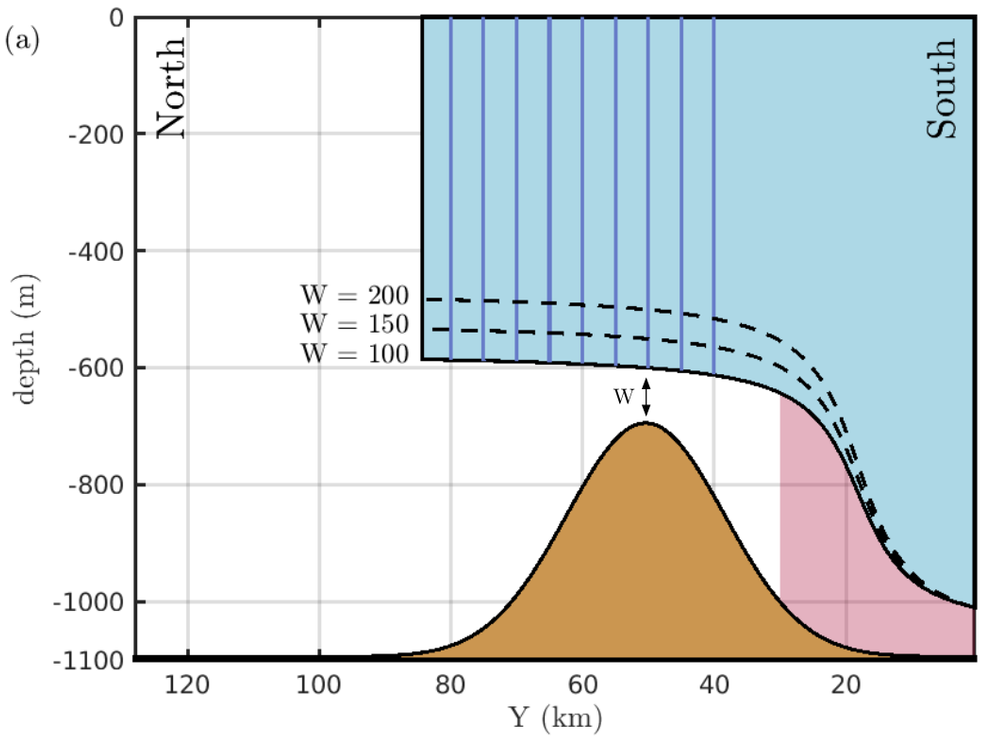
Key question: have **past** and how might **future calving change melt rates? And,** what are the **implications** of those **changes?**

Numerical simulations in both **realistic** and **idealised geometries**

Numerical simulations in both **realistic** and **idealised geometries**



Numerical simulations in both **realistic** and **idealised geometries**



topographic barriers

&

potential vorticity

velocity vs thermal driving

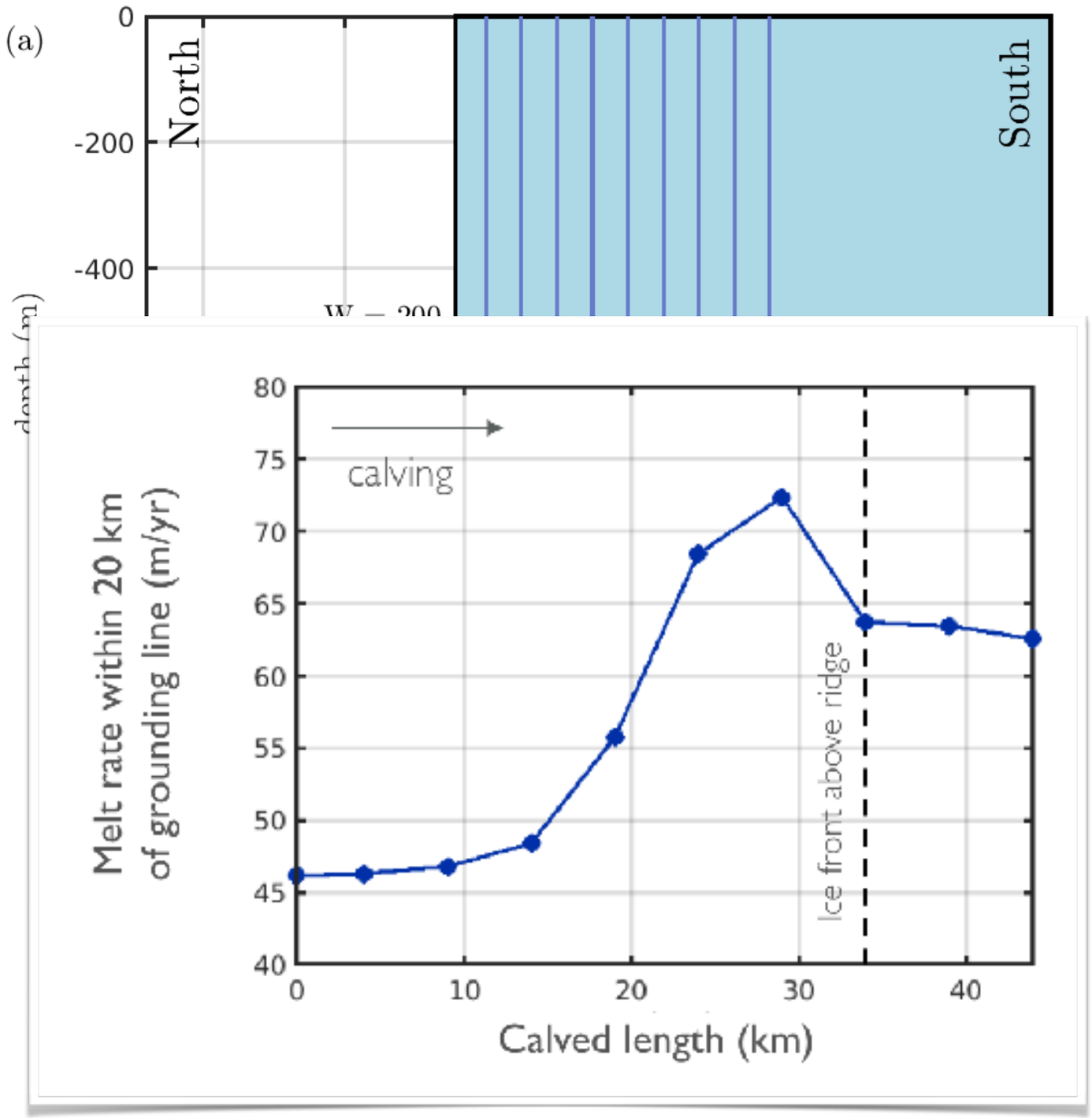
so many goodies!

sensitivity to:

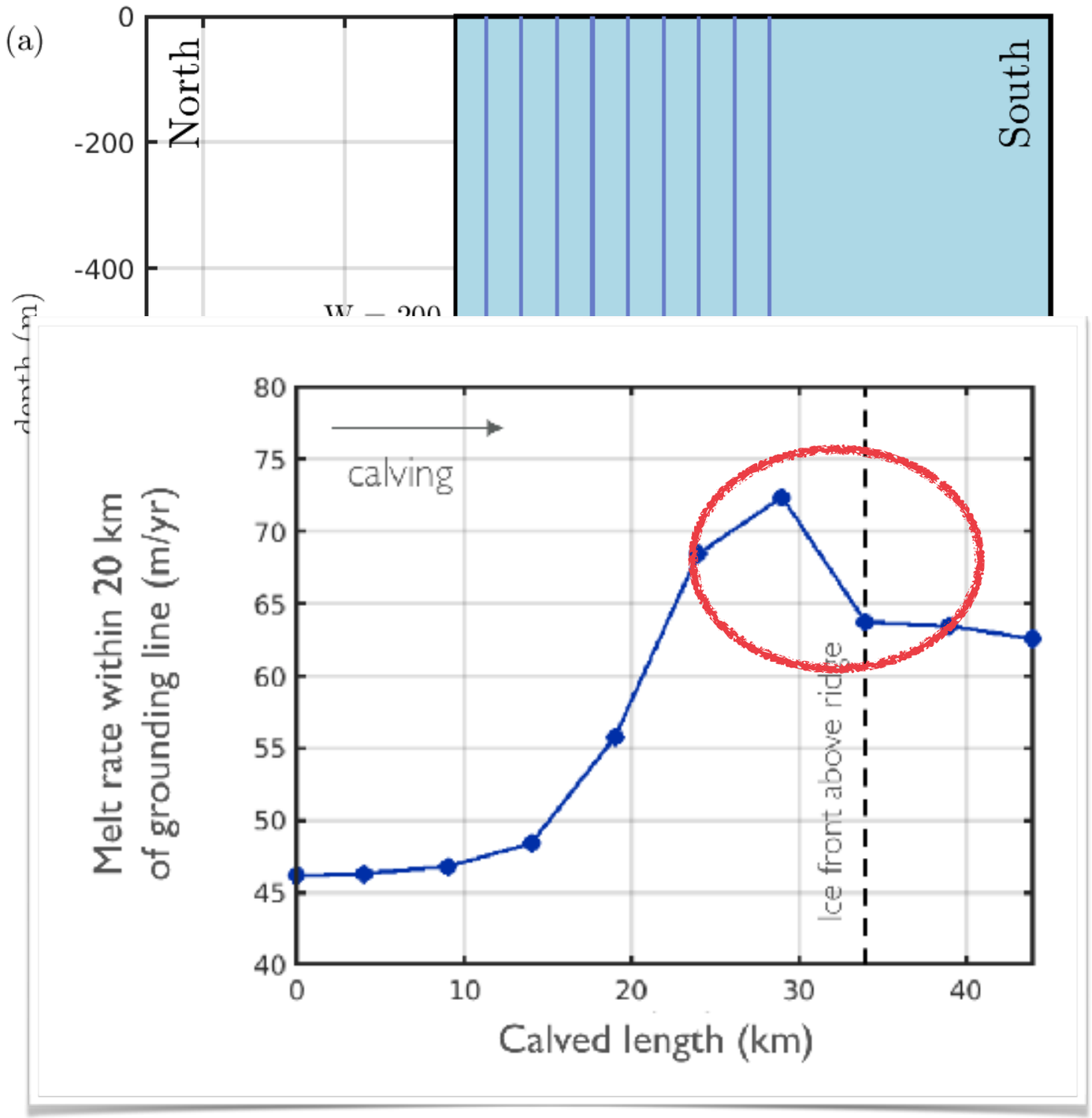
hydrographic forcing

gap width

Numerical simulations in both **realistic** and **idealised geometries**

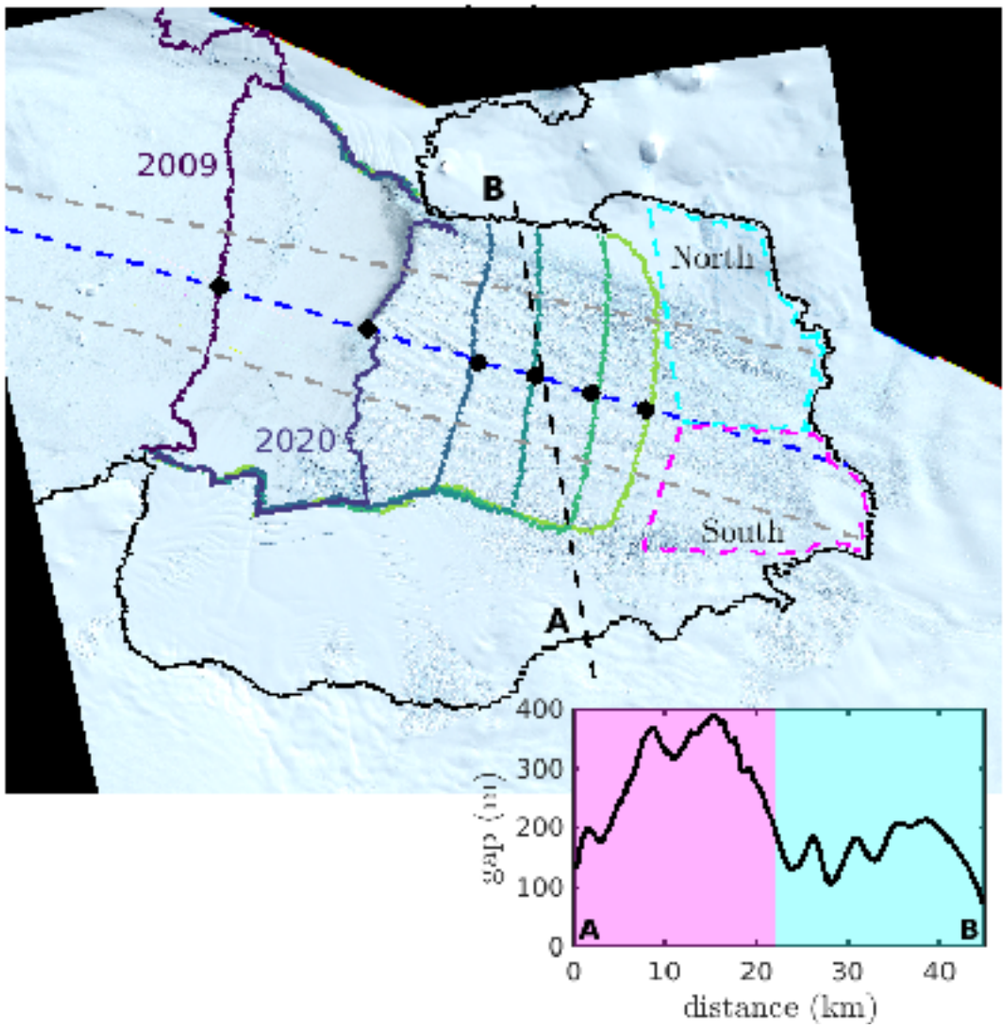


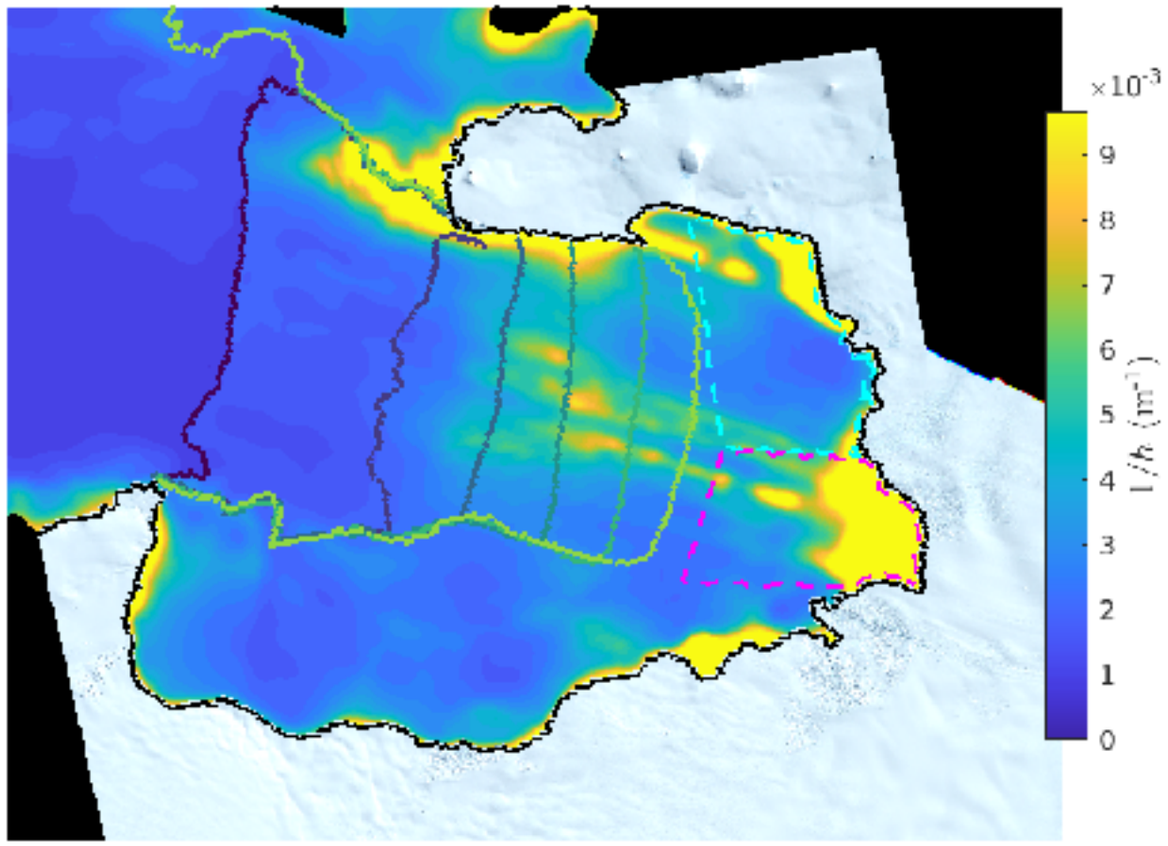
Numerical simulations in both **realistic** and **idealised geometries**



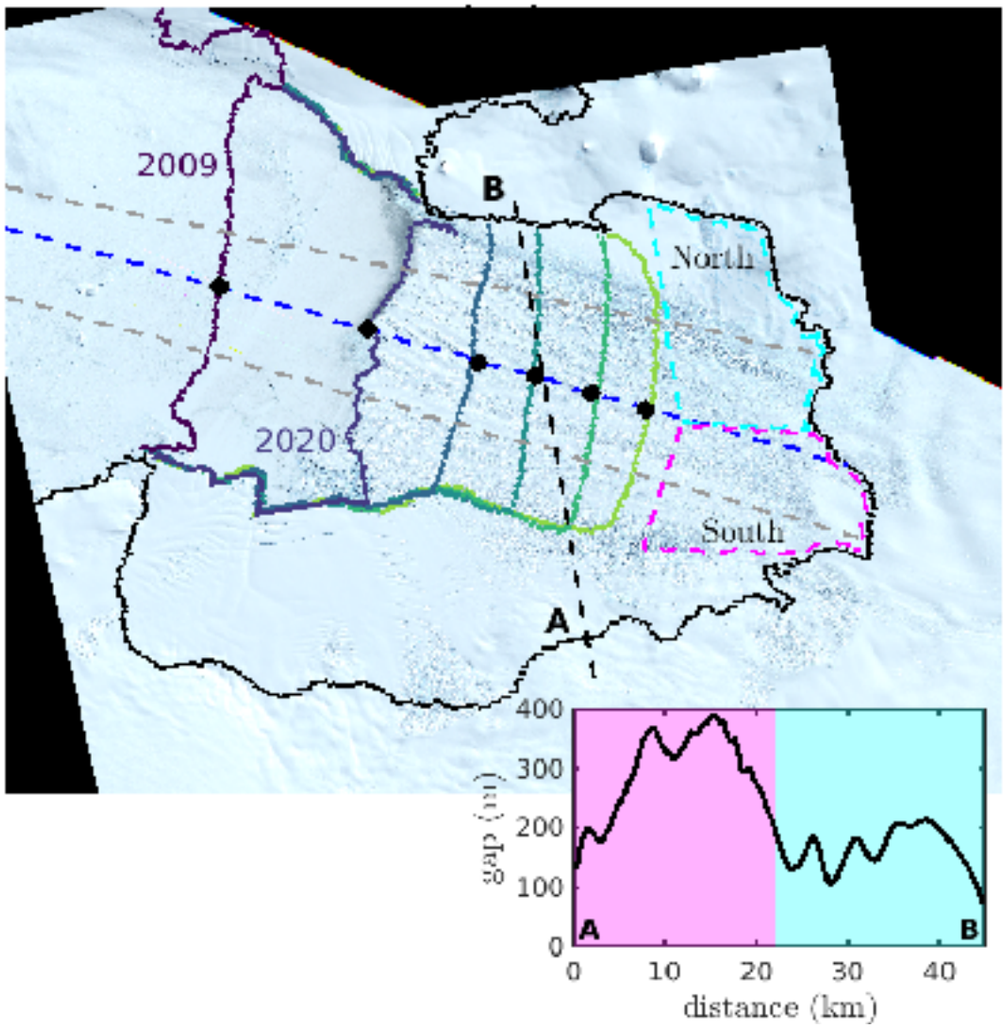
circulation slow down reduces melt rate

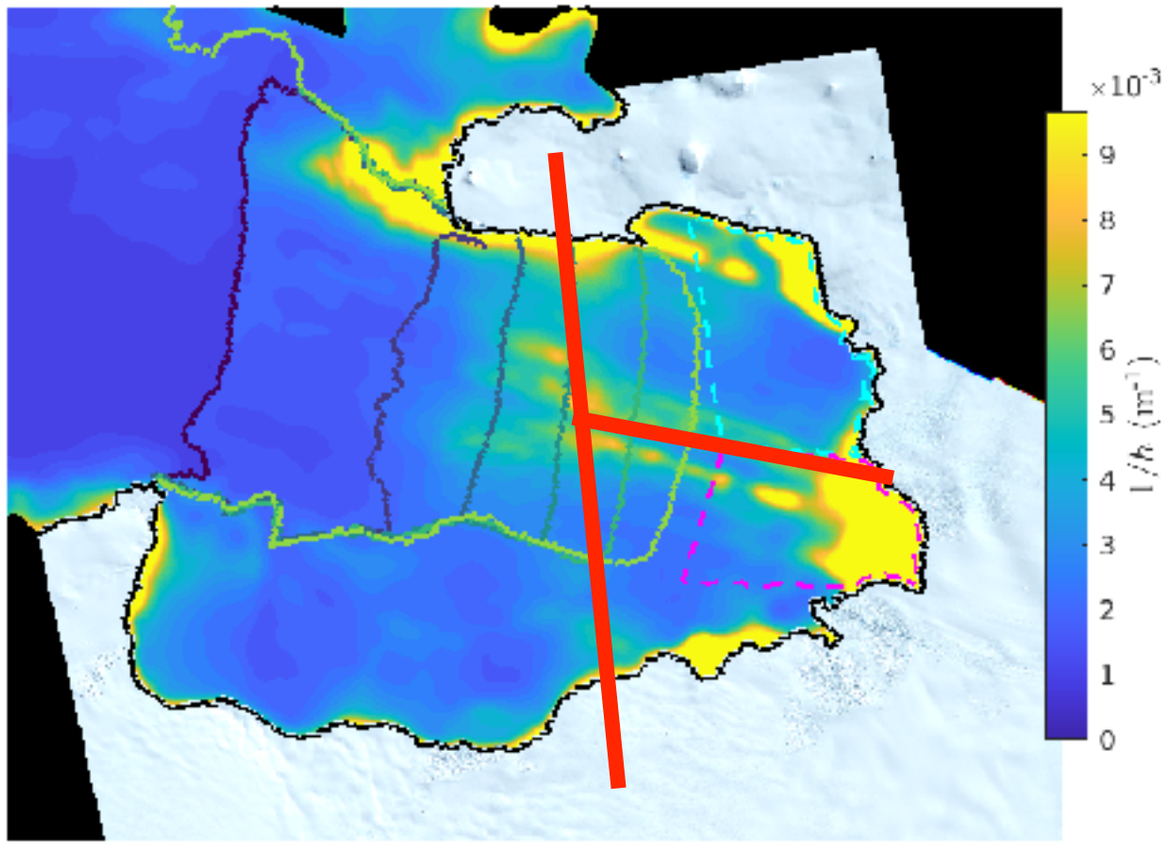
Numerical simulations in both **realistic** and **idealised** **geometries**

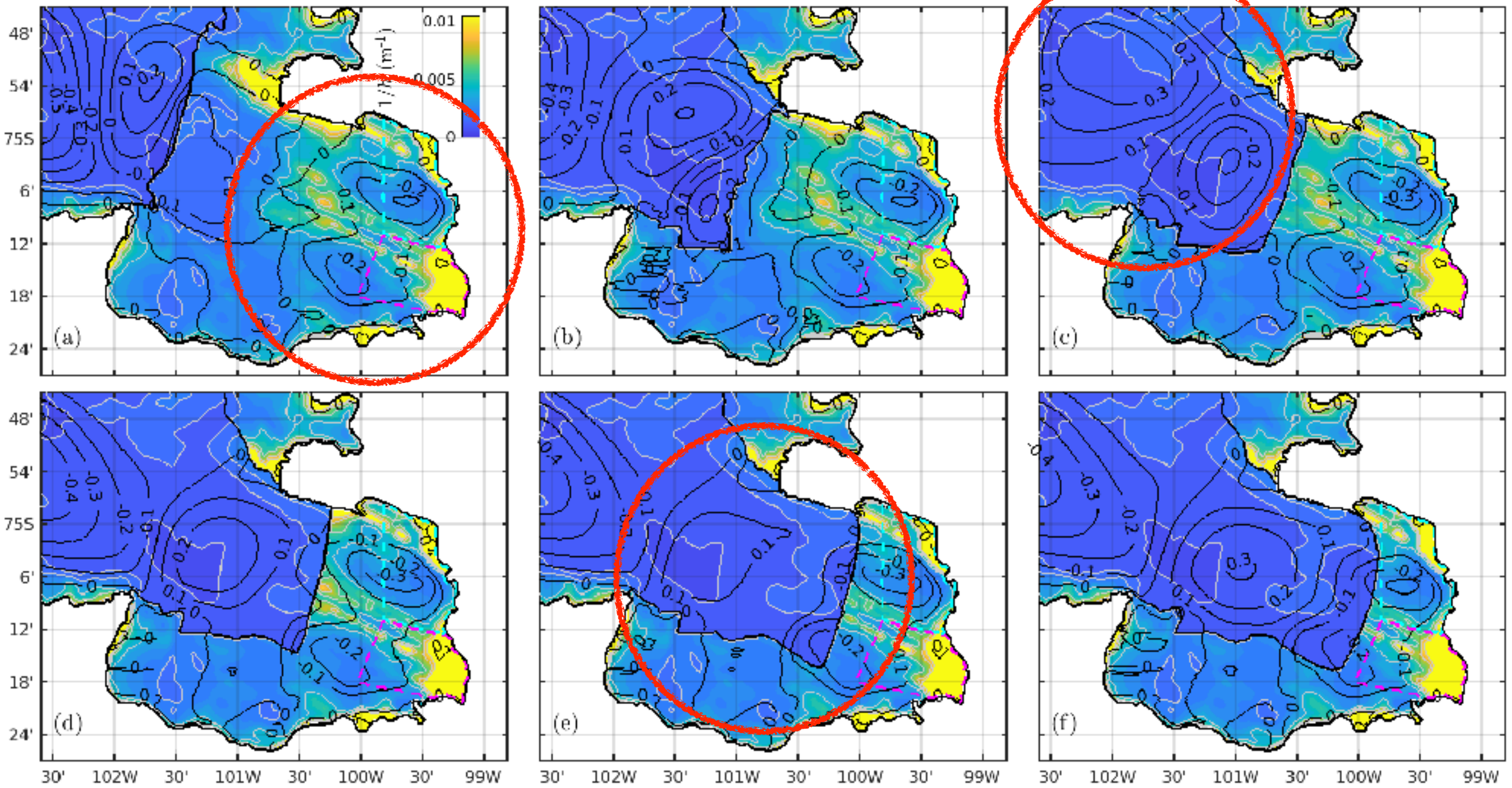


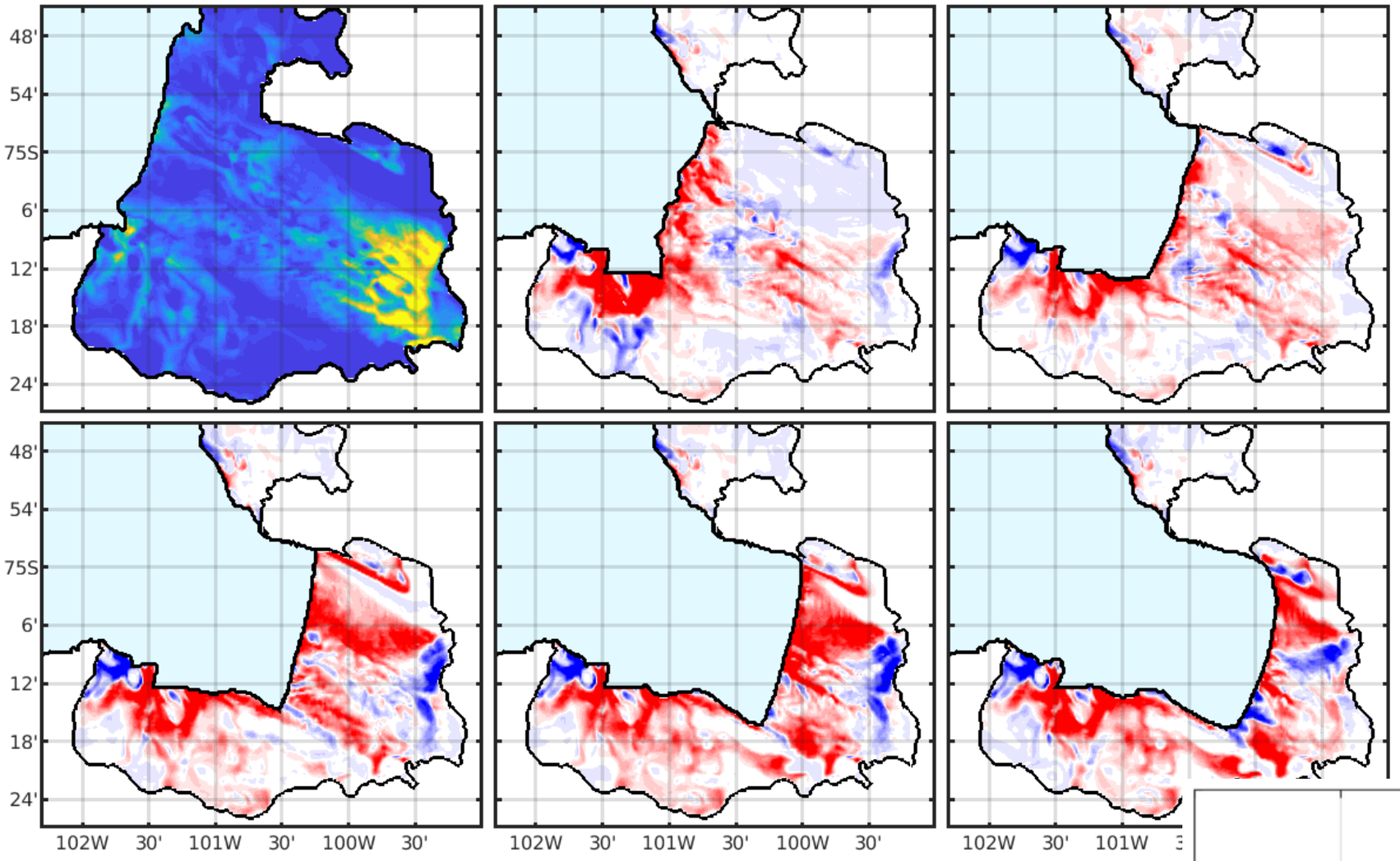


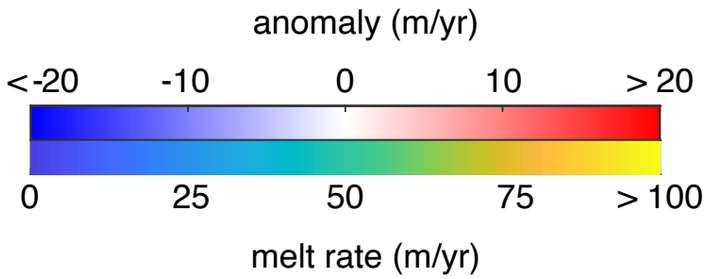
Numerical simulations in both **realistic** and **idealised** **geometries**





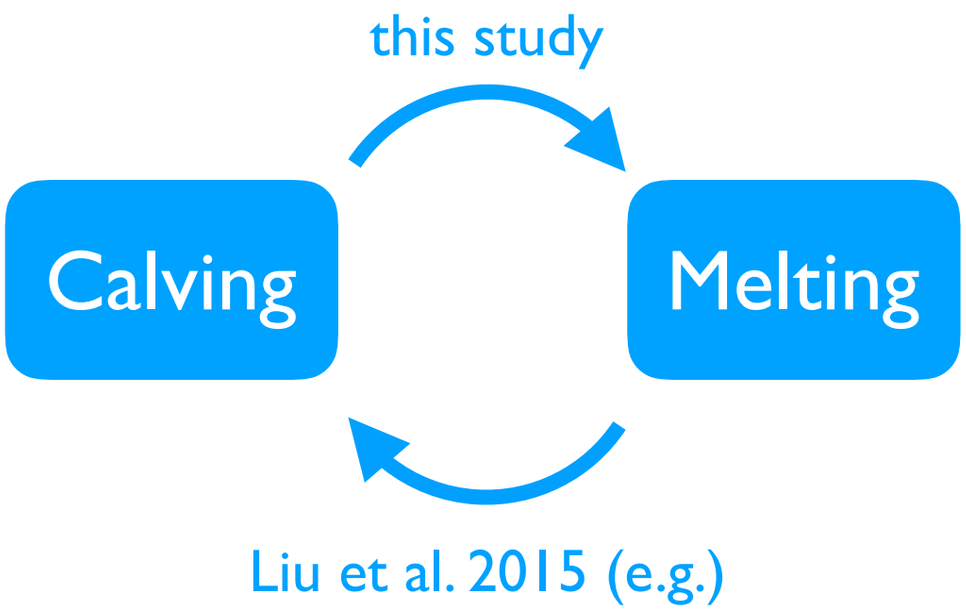

0.01
0.005
0
1/λ (m⁻¹)
(a)
(b)
(c)
(d)
(e)
(f)
48'
54'
75S
6'
12'
18'
24'
30'
102W
101W
100W
99W

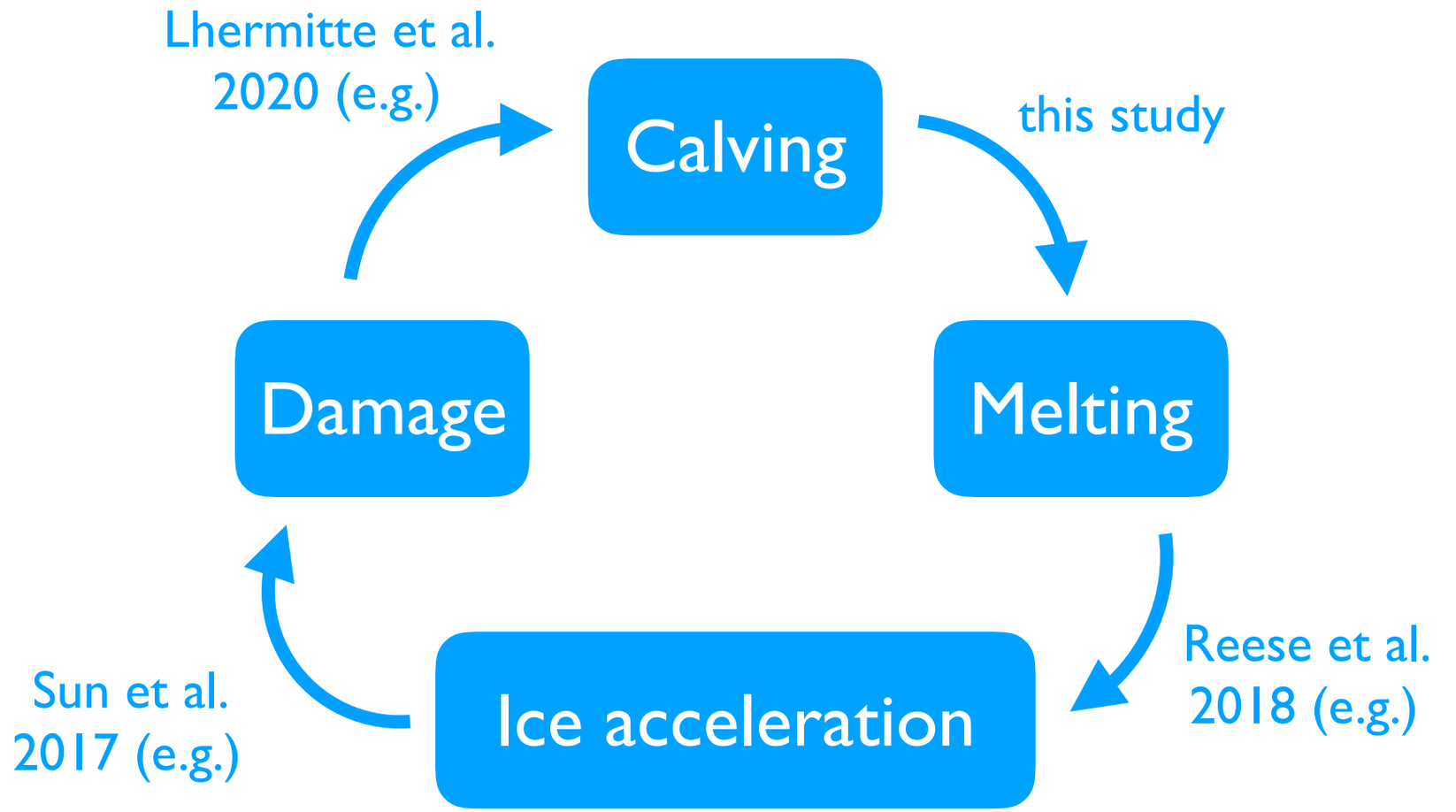

48'
54'
75S
6'
12'
18'
24'
102W
30'
101W
30'
100W
30'


anomaly (m/yr)
< -20
-10
0
10
> 20
0
25
50
75
> 100
melt rate (m/yr)

% change in melt rate
calved length (km)
2009
2020
F1
F2
F3
F4
0
2
4
6
8
0
10
20
30
40

If calving always enhances melting…

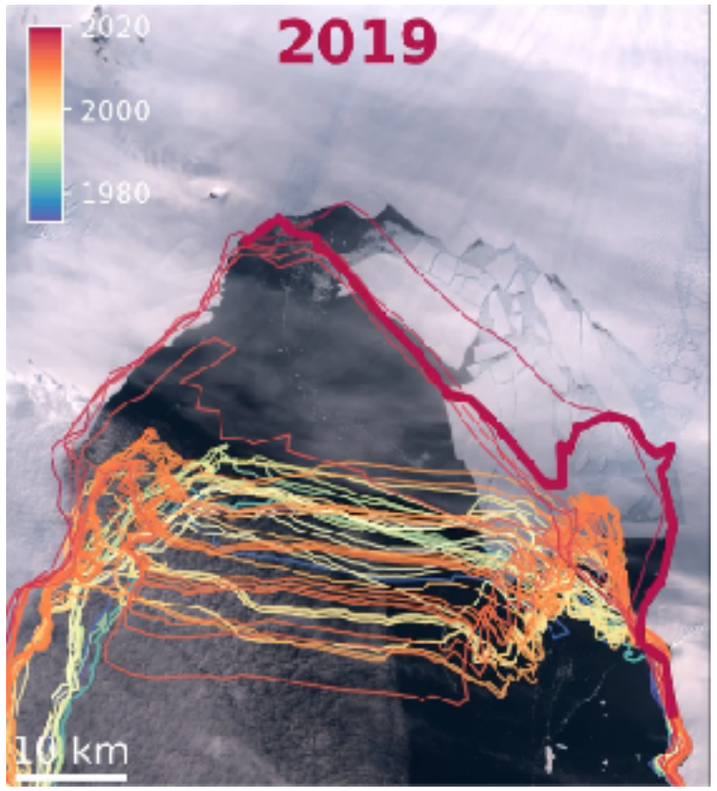


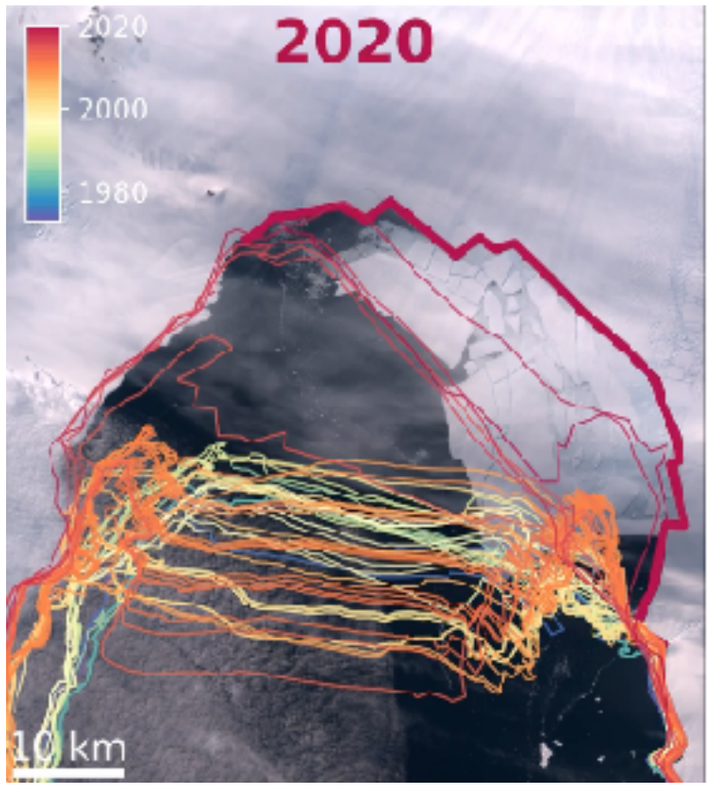


Even without any ice dynamic changes in buttressing!

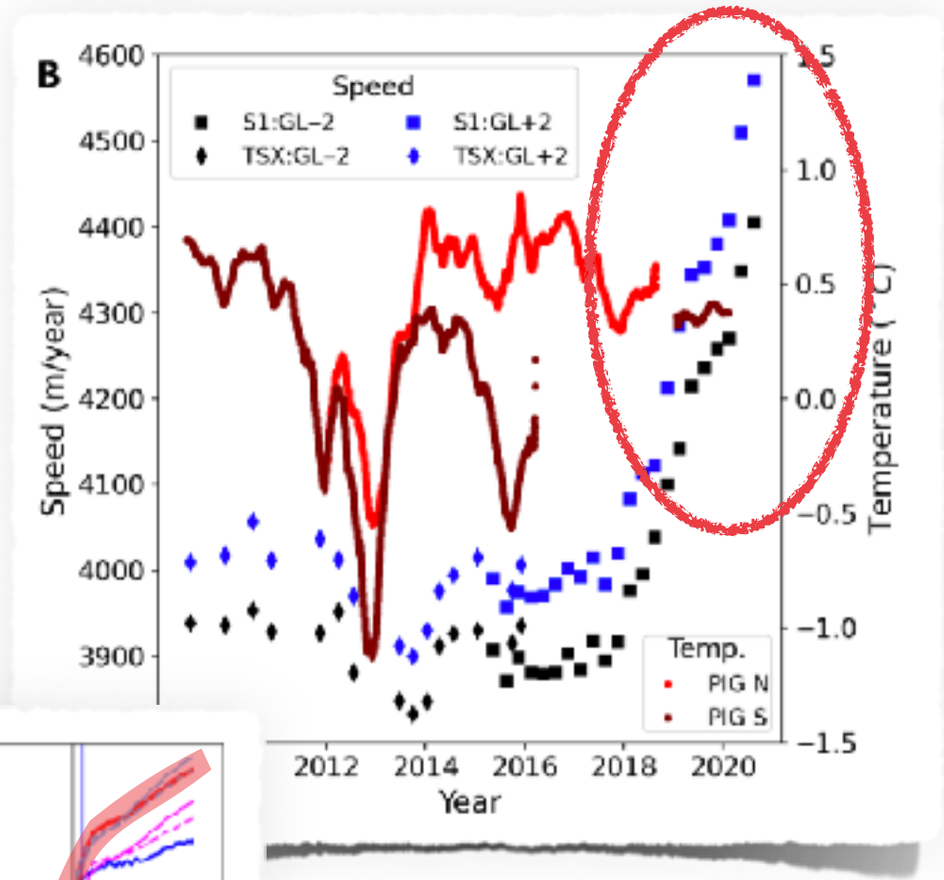
Do melting changes matter for ice shelf buttressing?

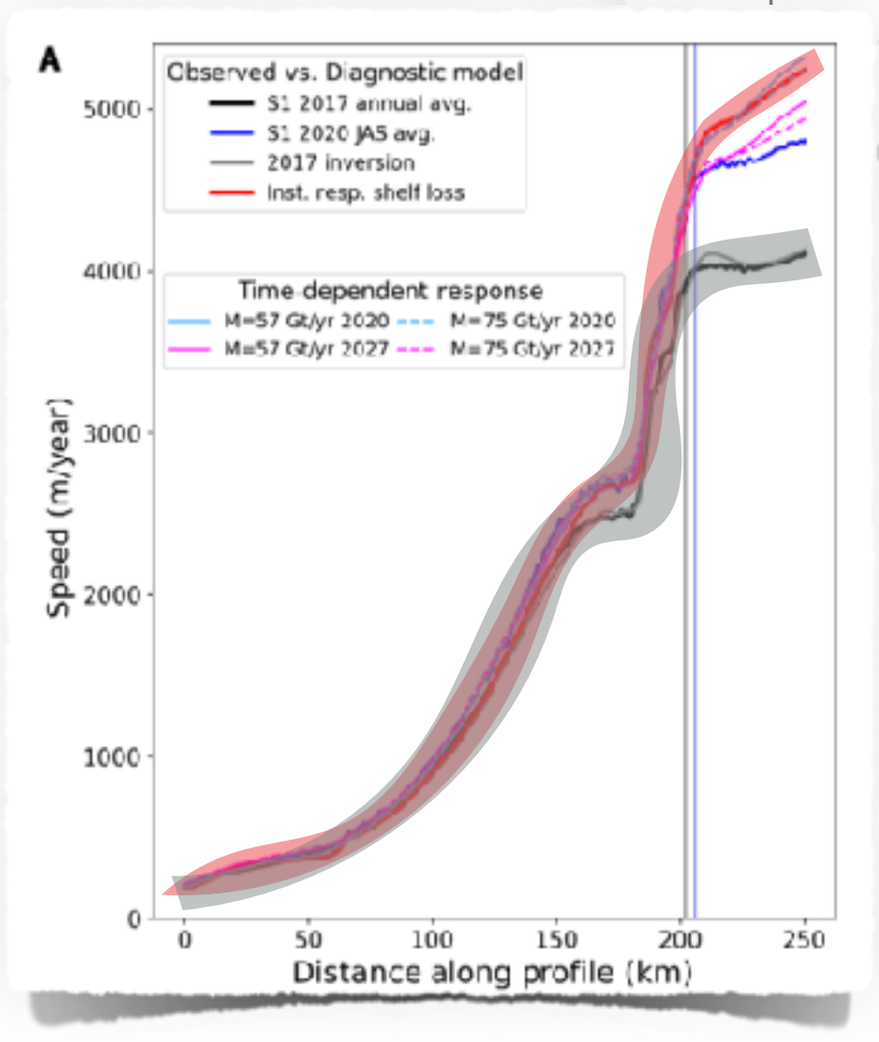
‘Direct losses’ can explain PIG speed up following 2020 calving





Joughin et al., 2021

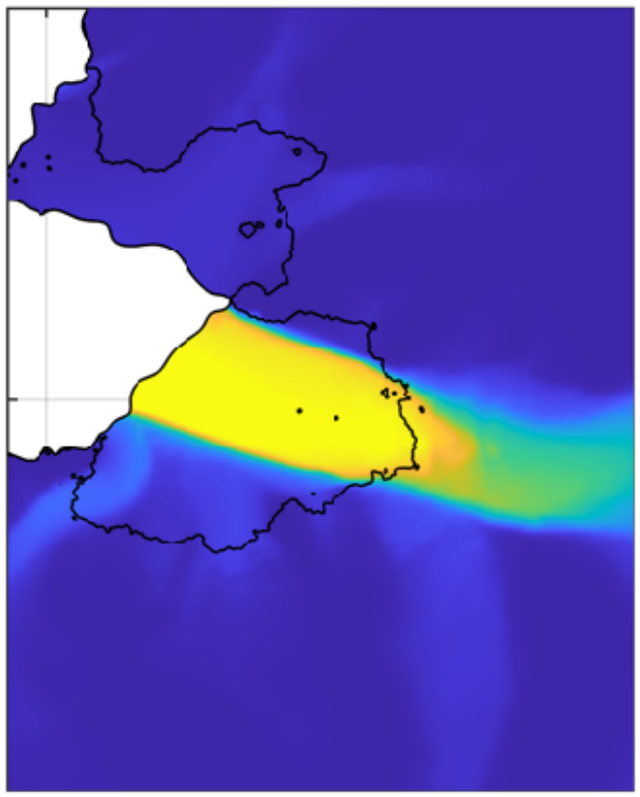


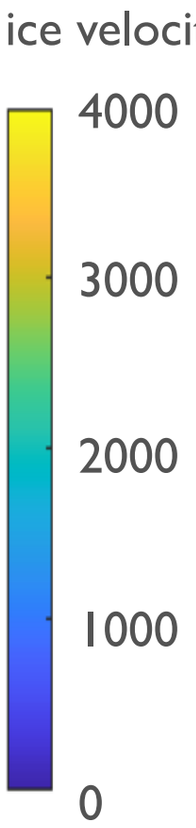


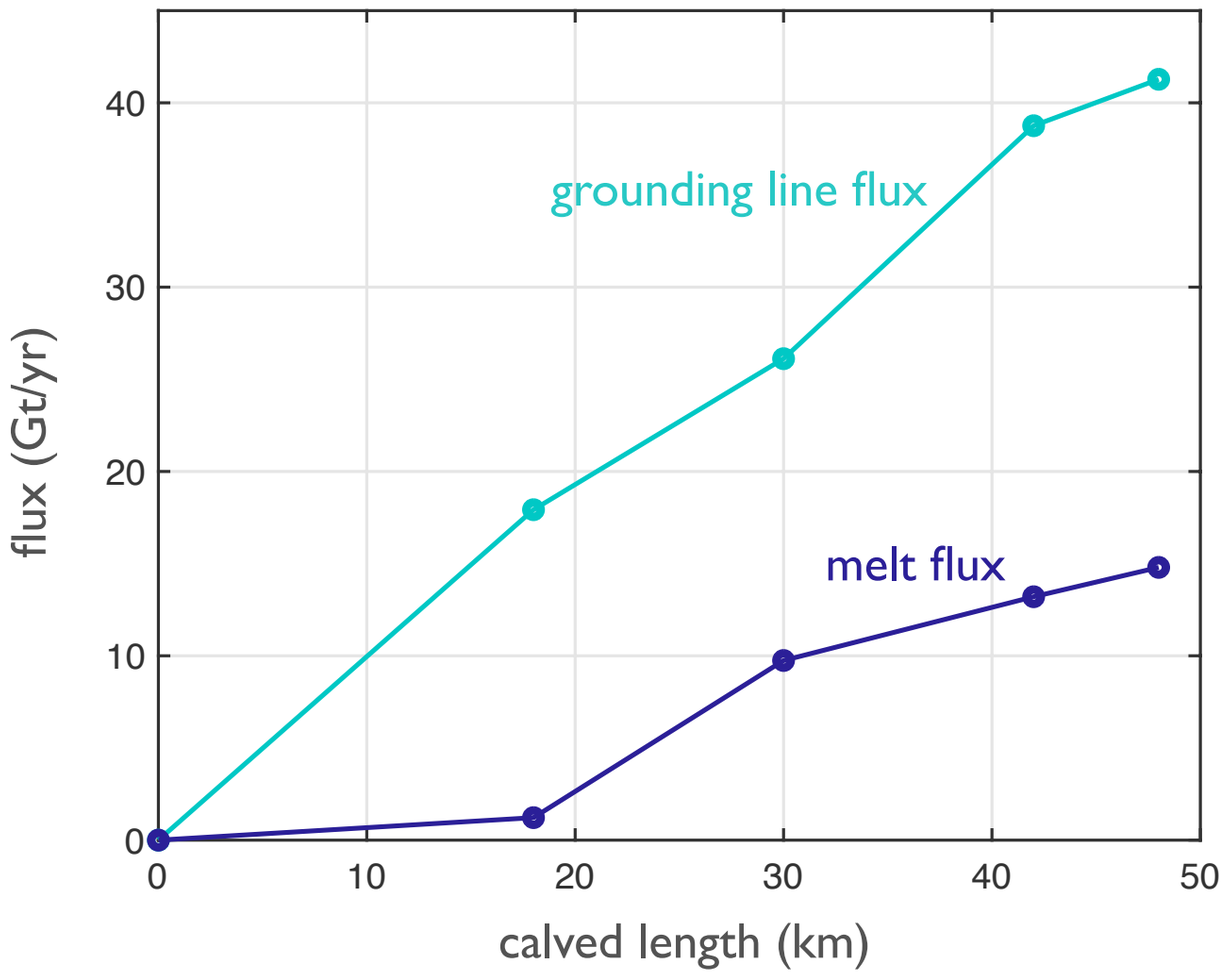
2020 modelled and observed

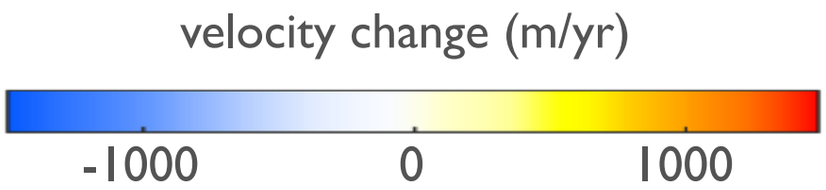
2017 modelled and observed

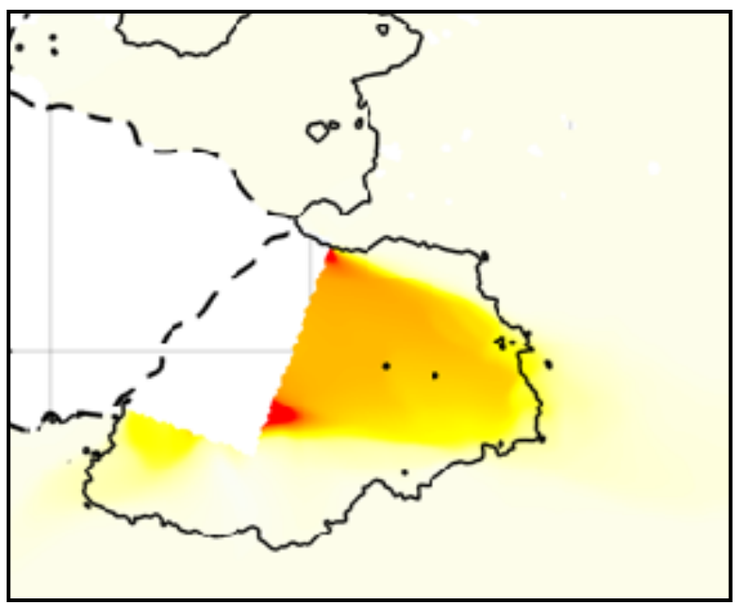
Calving perturbation experiments

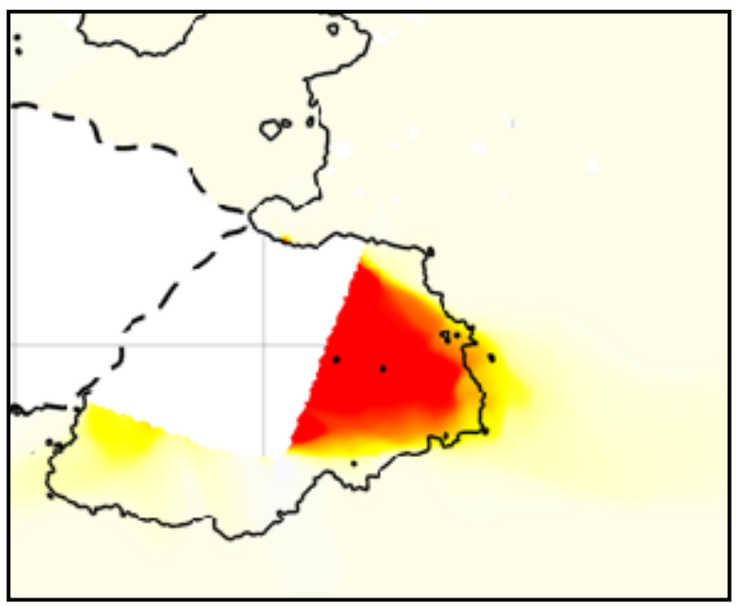


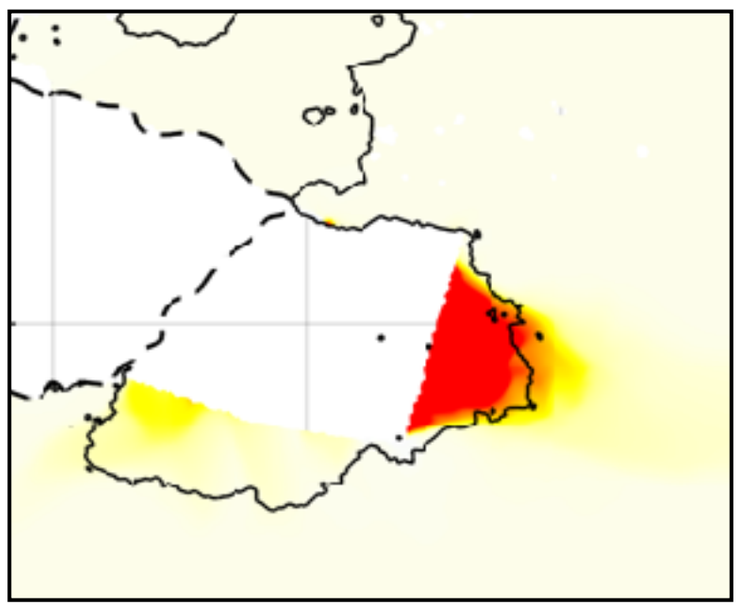




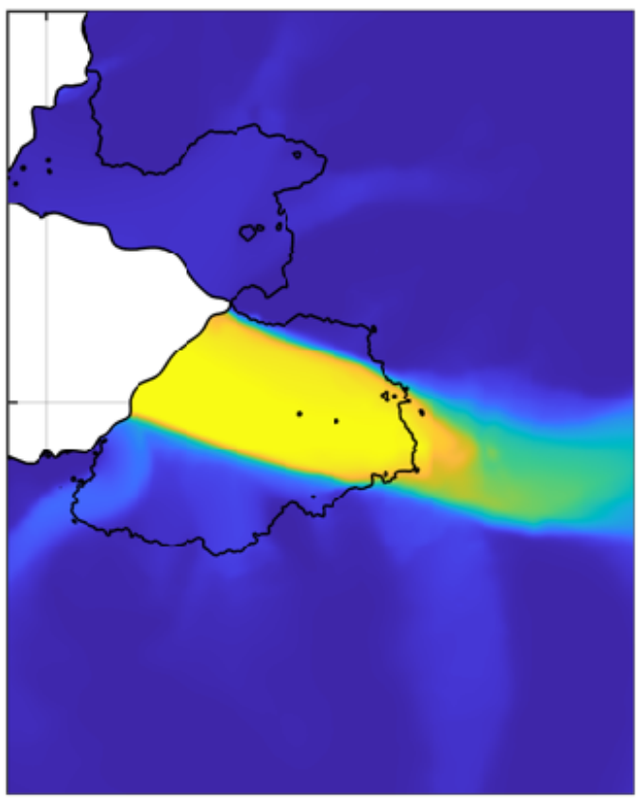


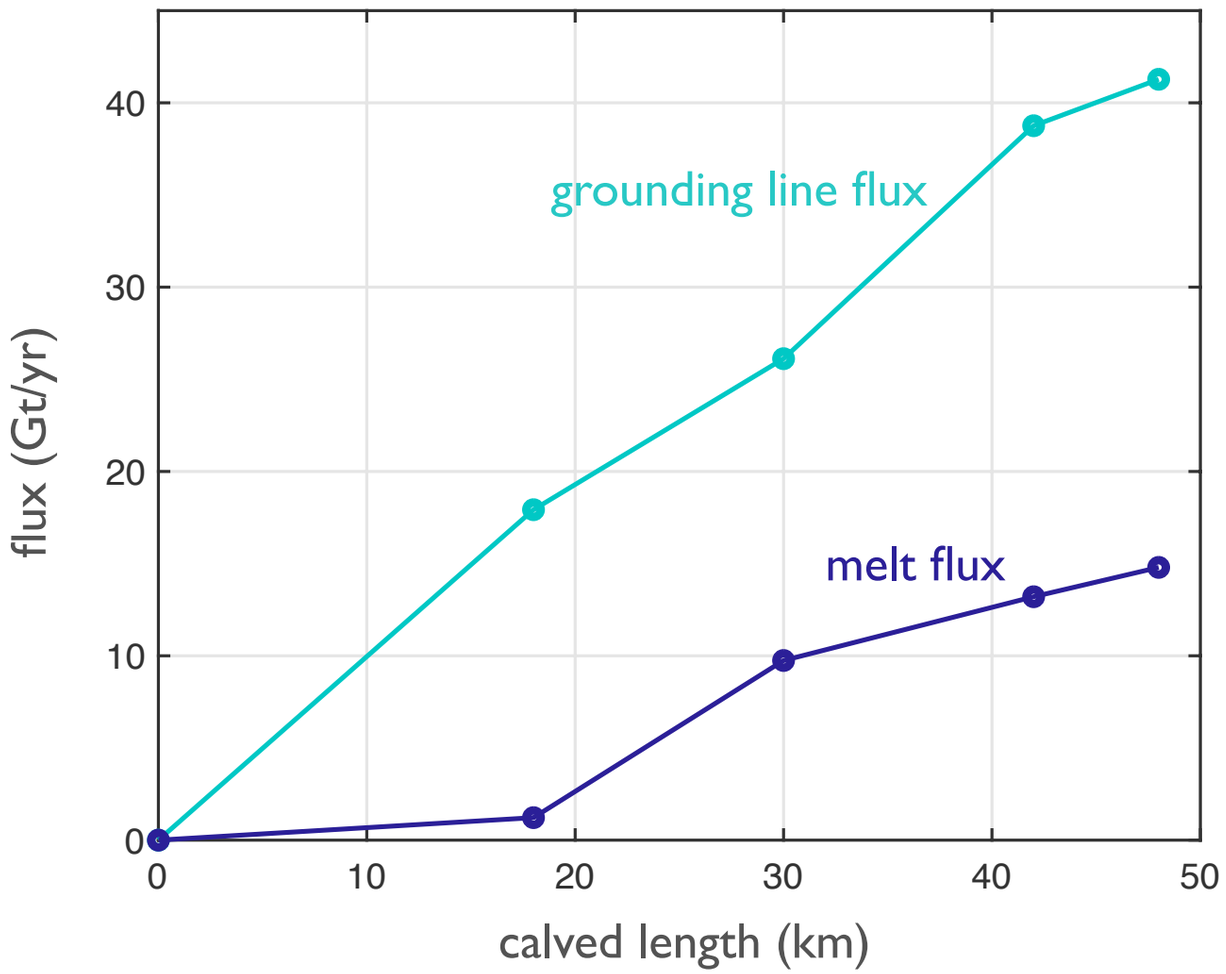






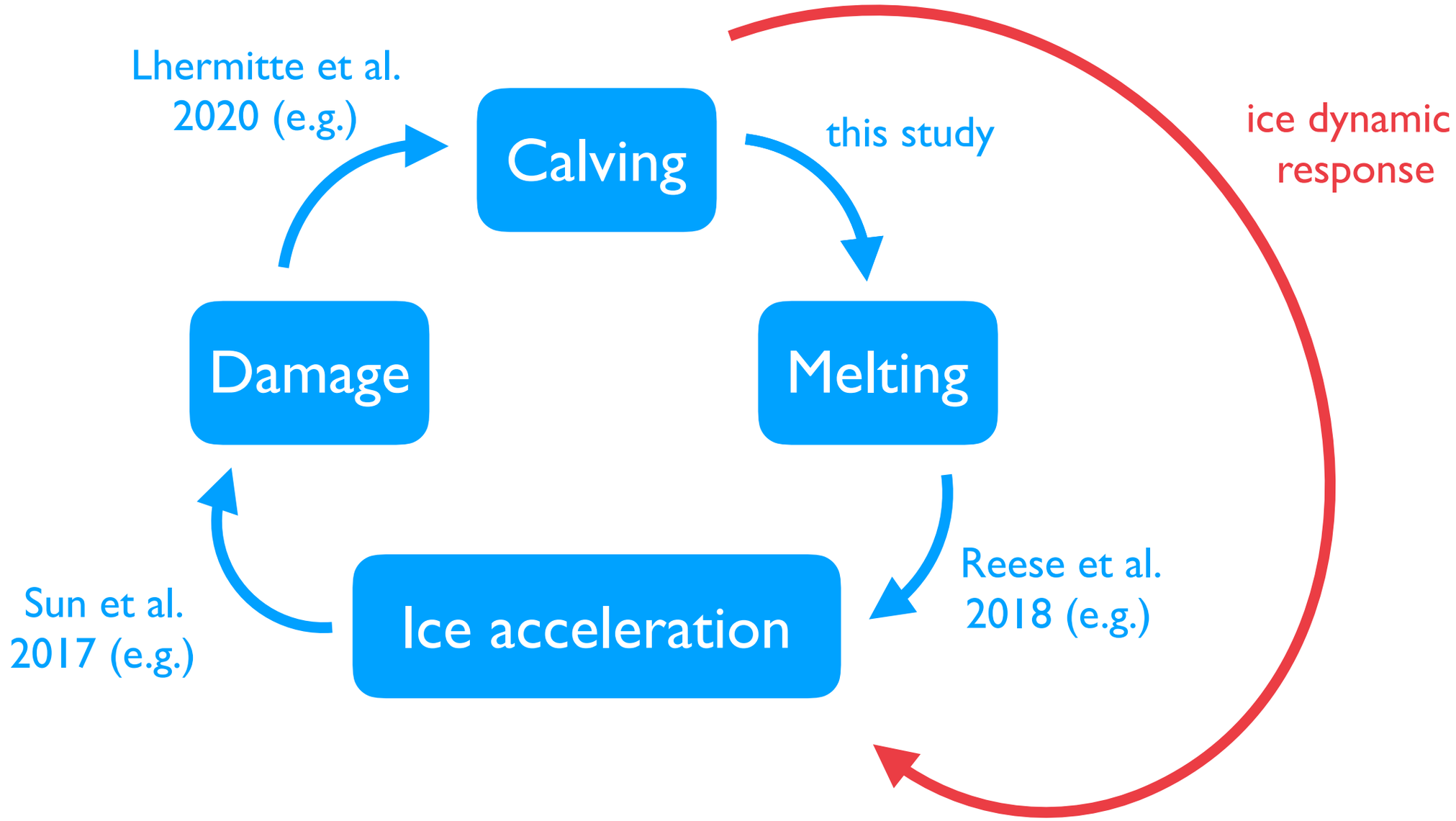
Calving perturbation experiments





Implications?

- Melt response to calving does matter (although smaller than ice dynamic response)
- Ice front position does matter in models
- Modelling PIG (and WAIS?) requires coupled ice-ocean-damage model 😱


Lhermitte et al.
2020 (e.g.)
Calving
this study
ice dynamic
response
Damage
Melting
Sun et al.
2017 (e.g.)
Ice acceleration
Reese et al.
2018 (e.g.)

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A glaciological context to melt perturbations?

$$\frac{\partial h}{\partial t} + \nabla.(h\mathbf{u}) = \dot{m} + \cancel{\dot{a}}$$

thickness changes

ice divergence

melting

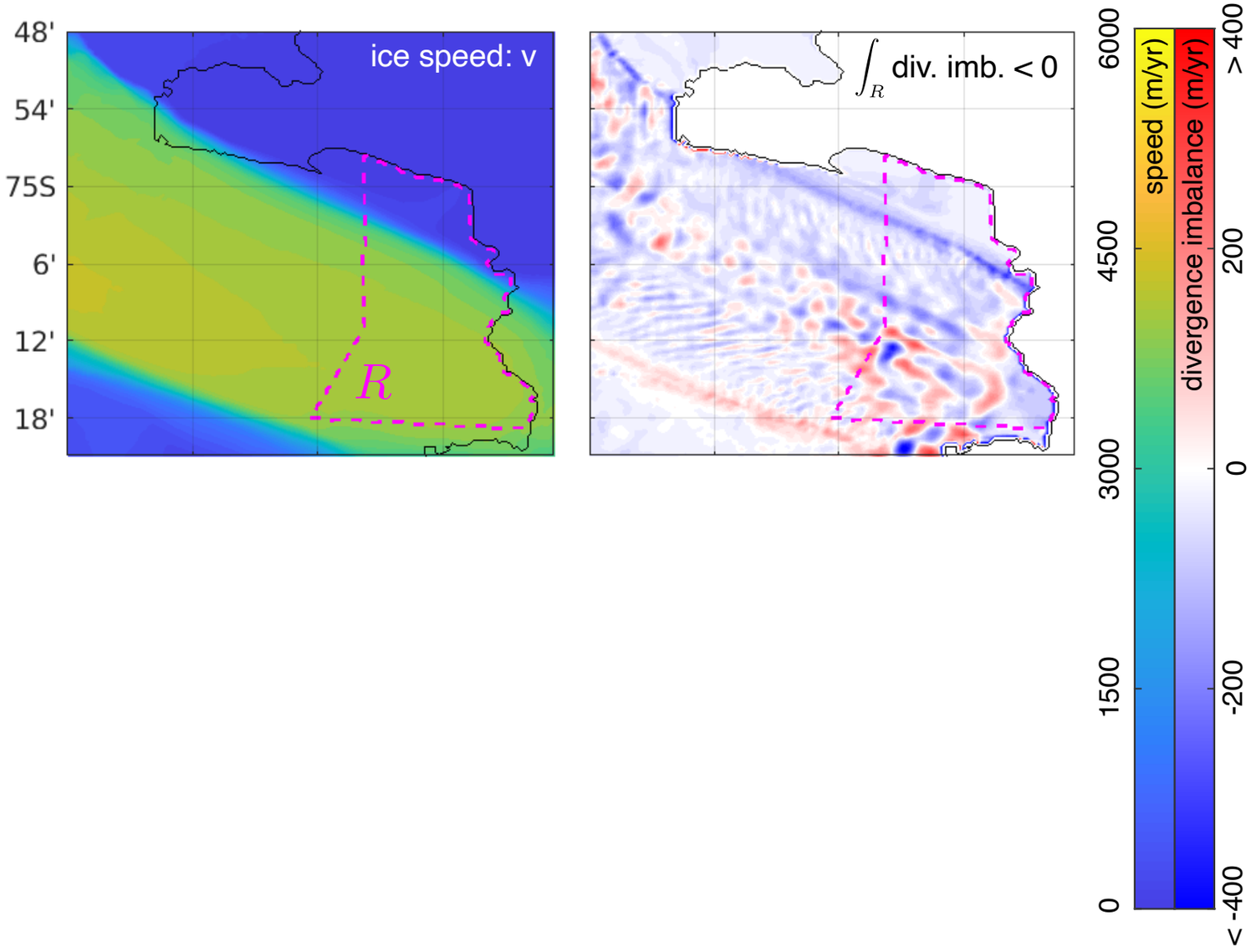
accumulation

$$\dot{m} - \nabla.(h\mathbf{u}) < 0$$ thinning

A glaciological context to melt perturbations?

$$\dot{m} - \nabla.(h\mathbf{u}) < 0$$ thinning

observed ice velocity

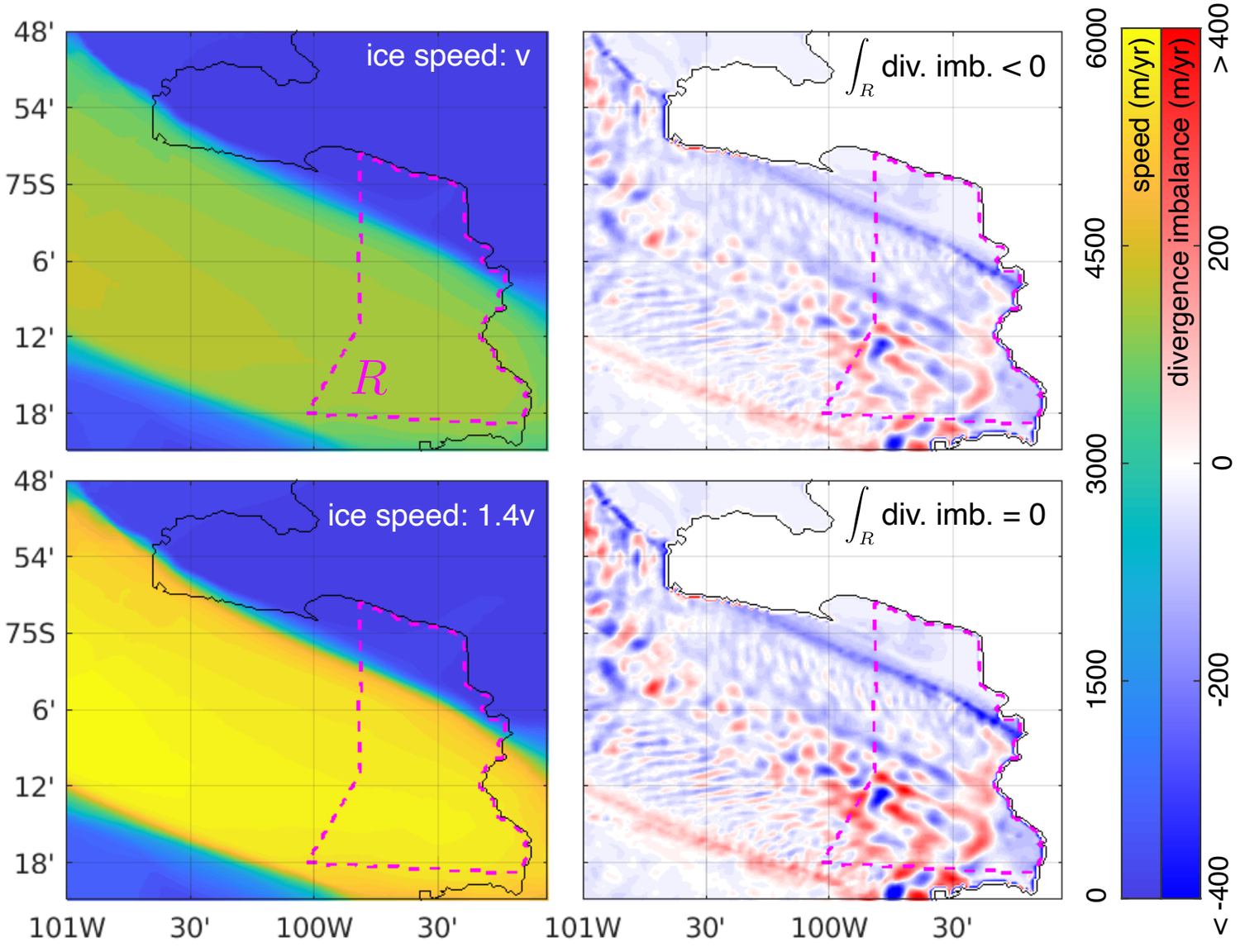


A glaciological context to melt perturbations?

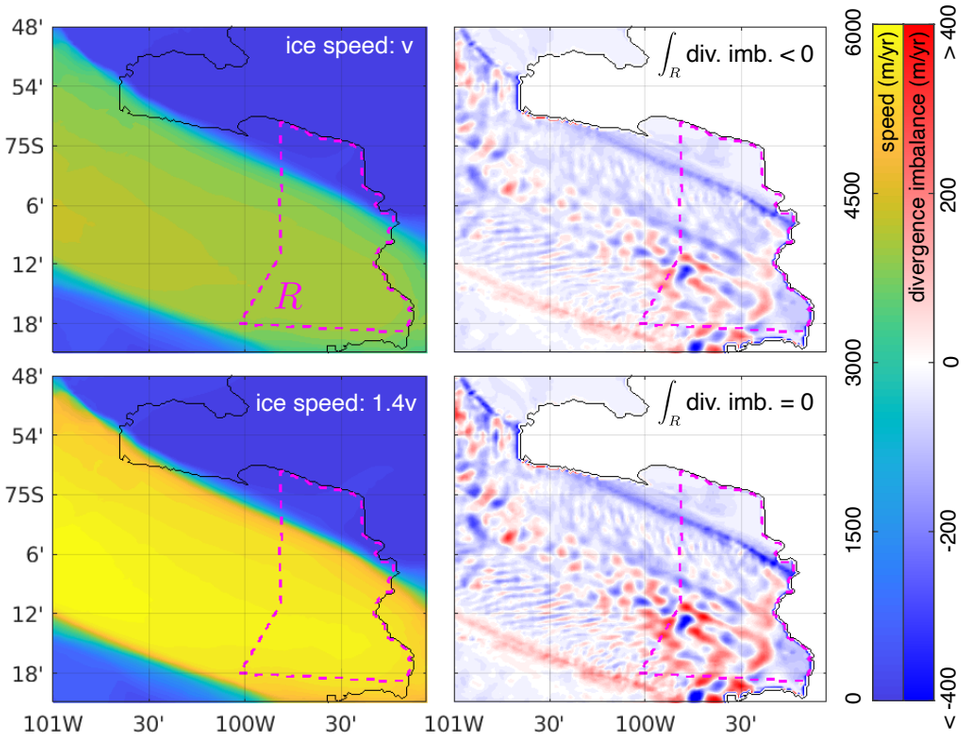
$$\dot{m} - \nabla.(h\mathbf{u}) < 0$$ thinning

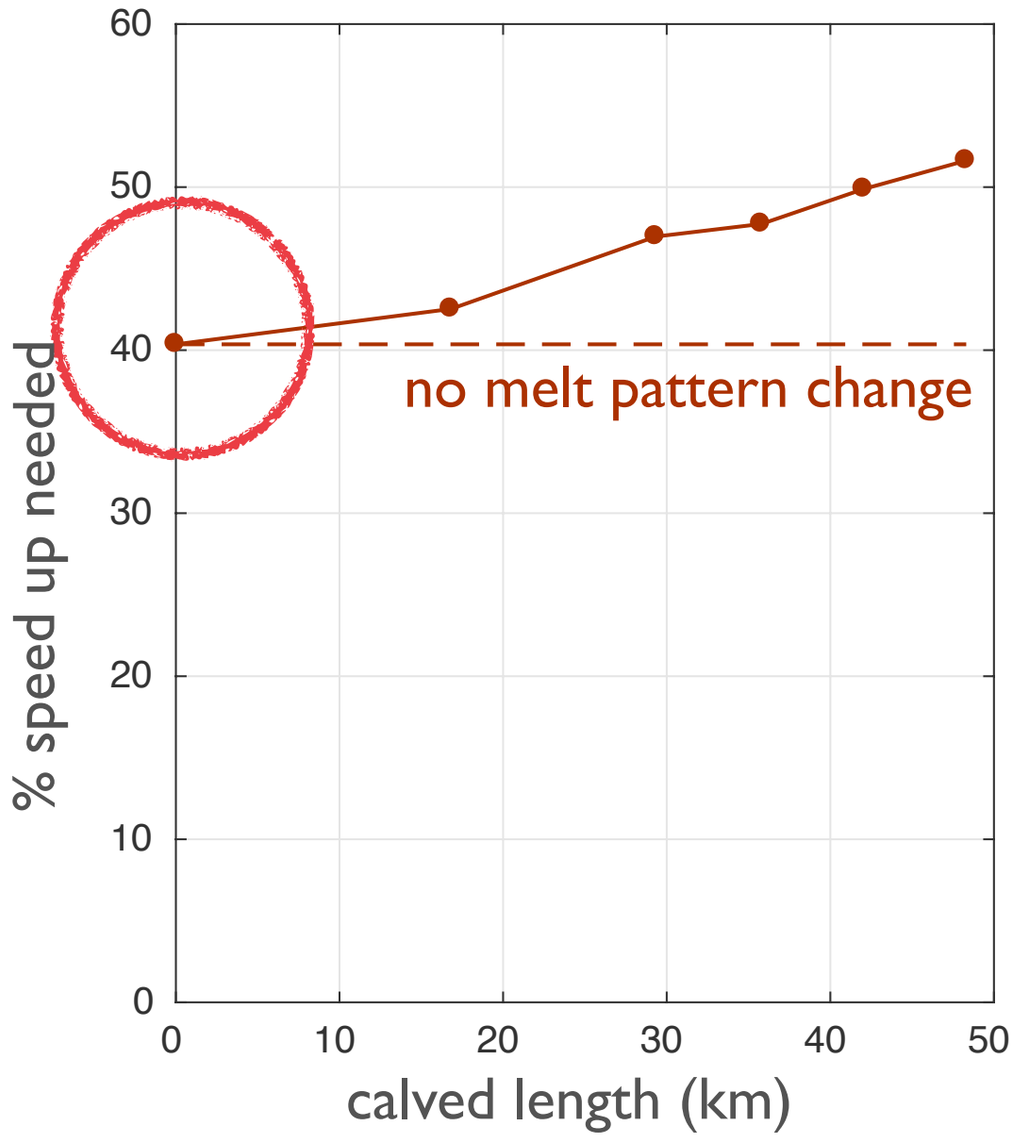
observed ice velocity

observed ice velocity
scaled 1.4x

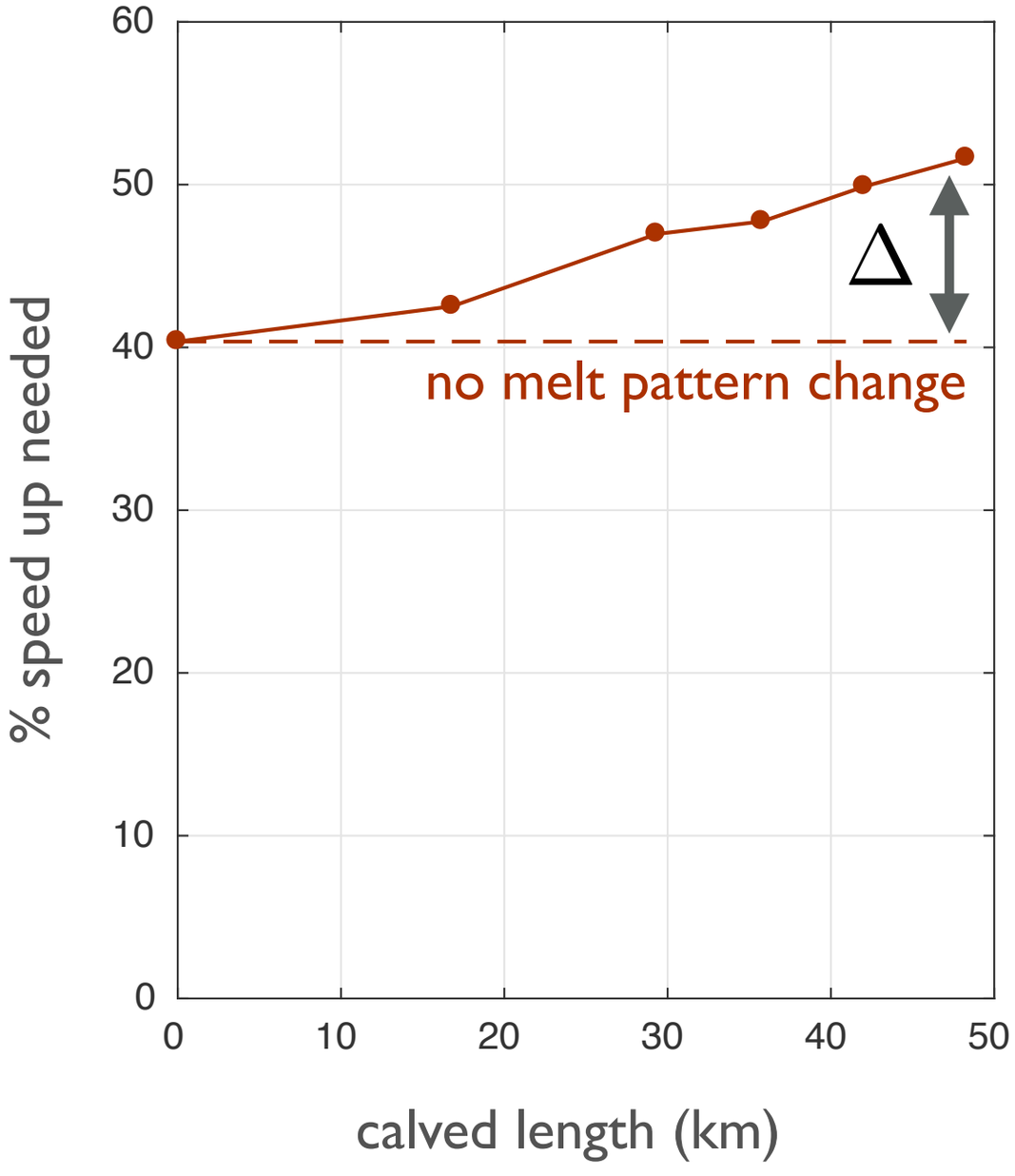


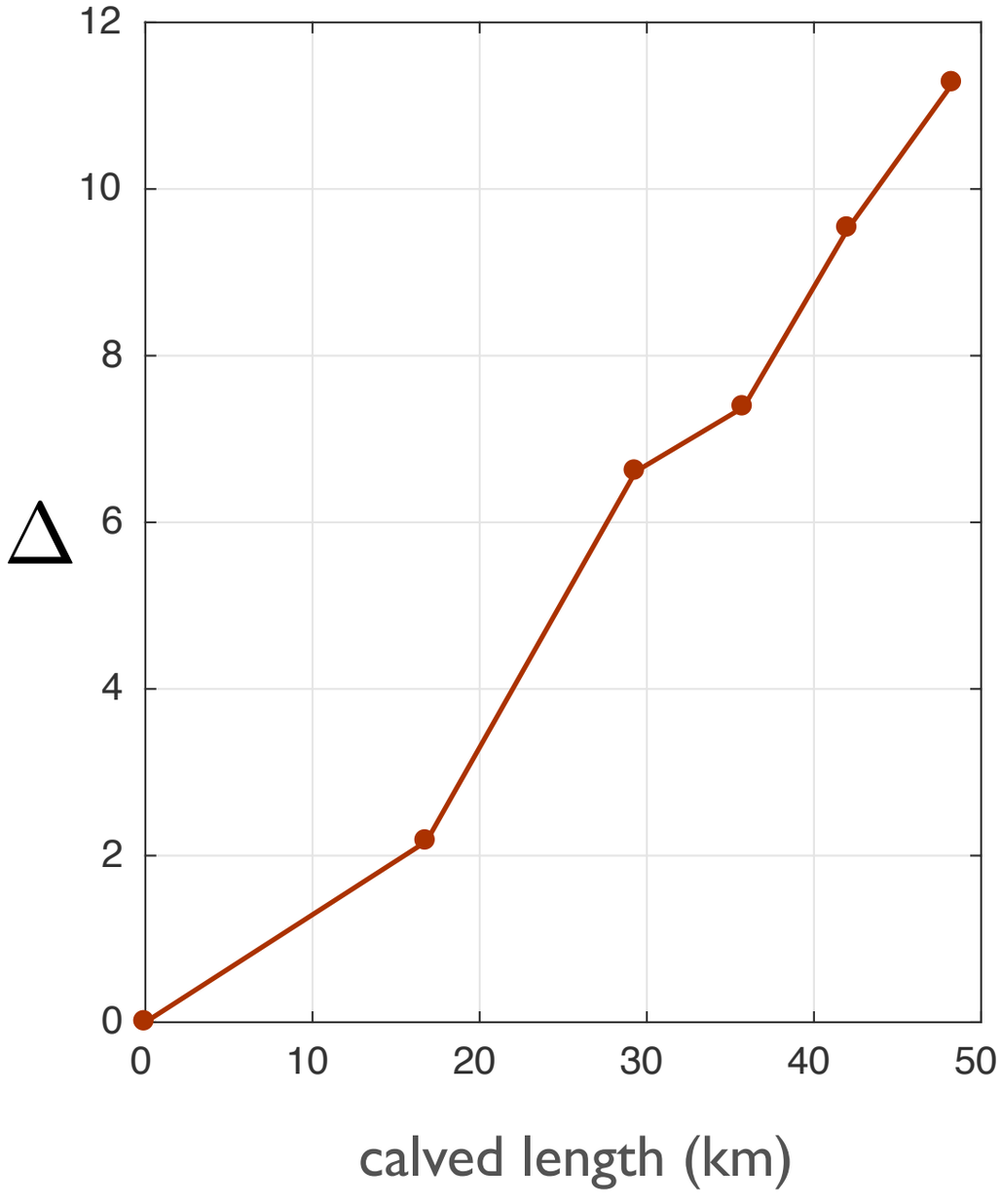
A glaciological context to melt perturbations?



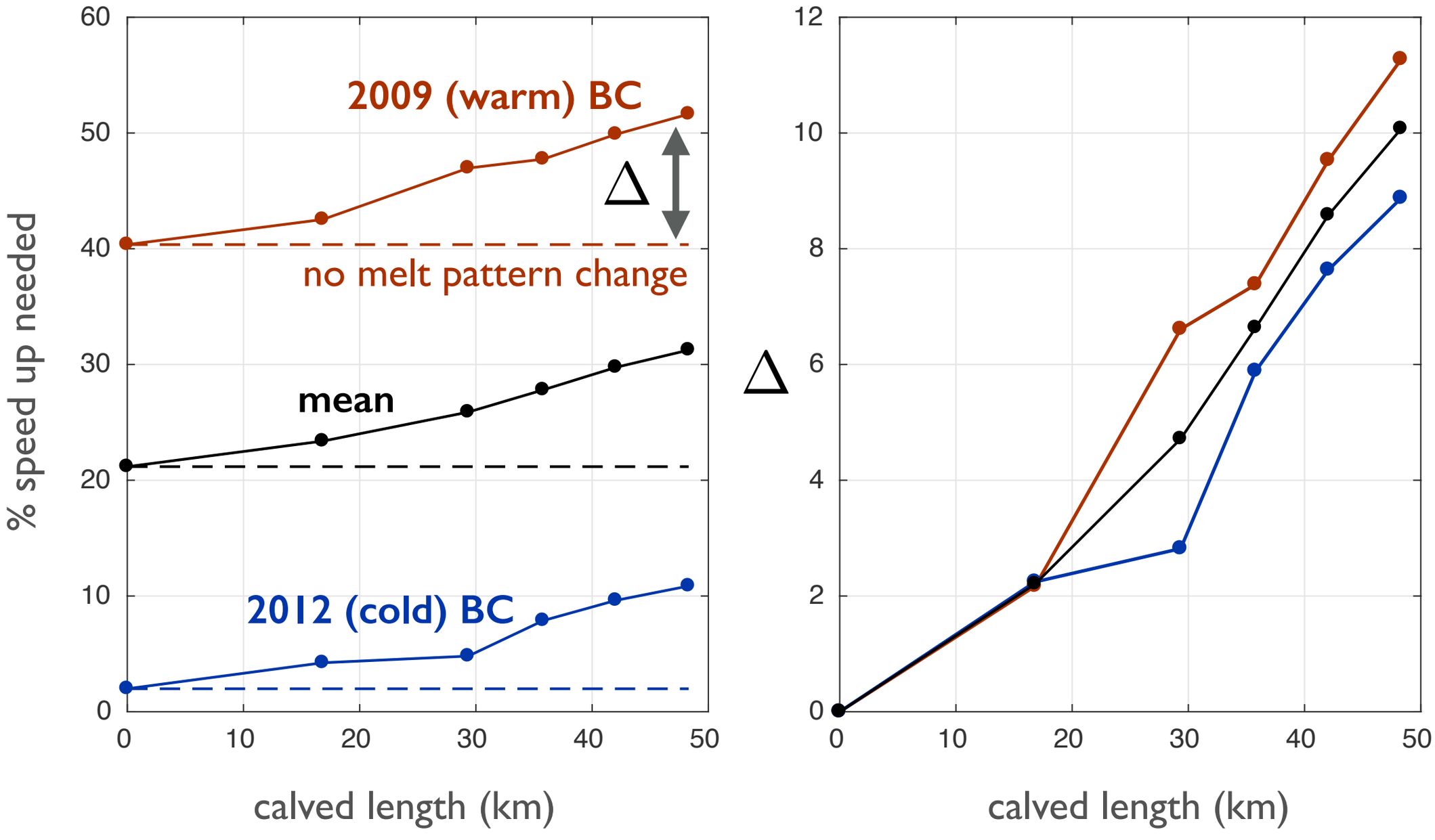


A glaciological context to melt perturbations?





A glaciological context to melt perturbations?



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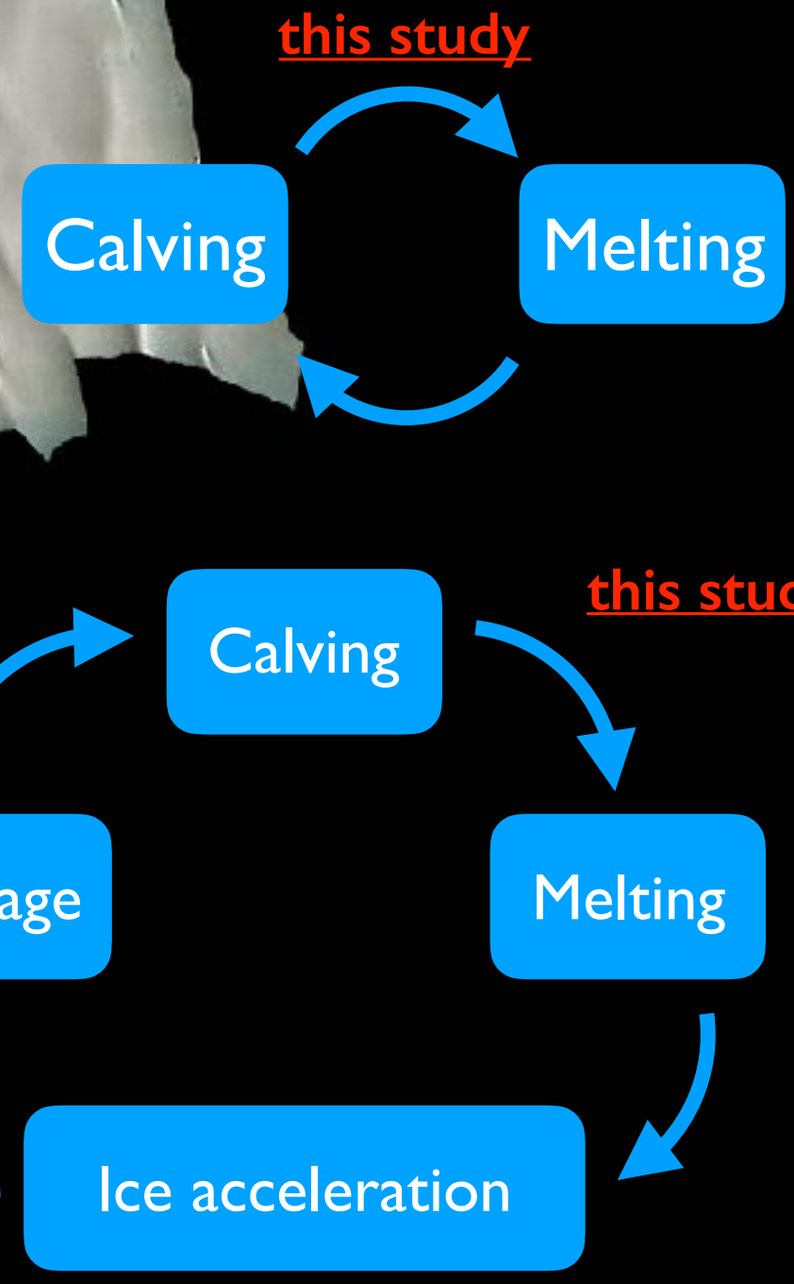
New JGR paper



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