



Melting Consequences of Pine Island Glacier Calving

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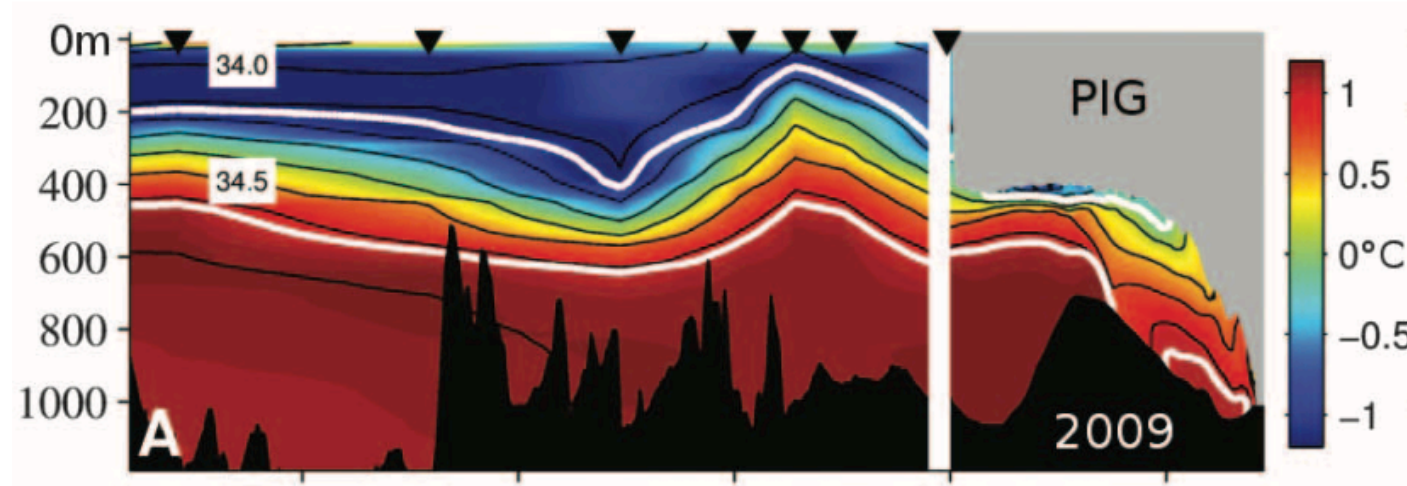


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Melt-calving interactions

Commentary

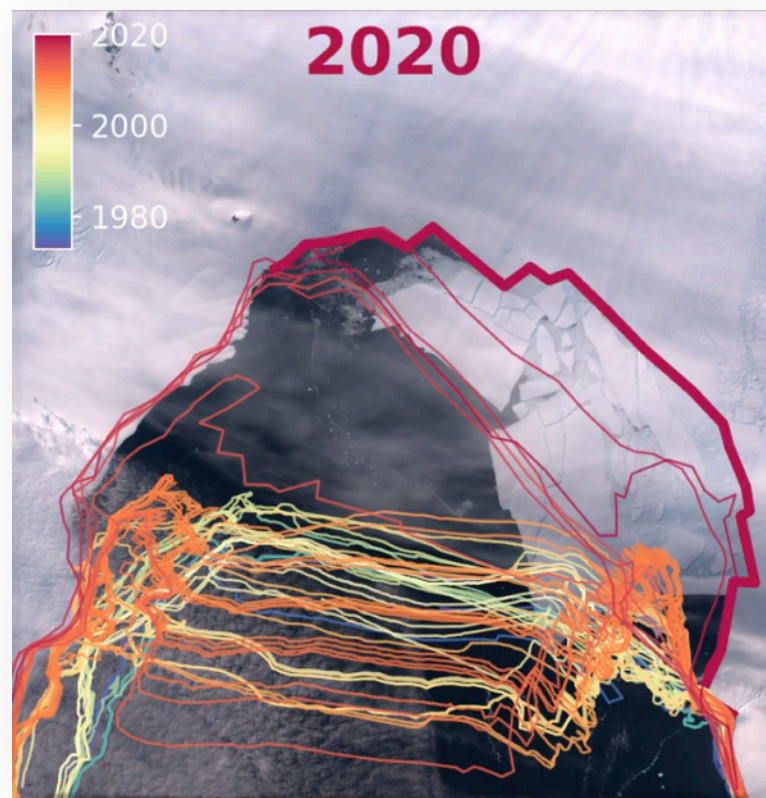
Dutrieux et al. 2014



Pine Island ice shelf and a seabed ridge provide a **strong topographic barrier** to the inflow of warm water...

- In combination with a seabed ridge, the Pine Island ice shelf provides a strong barrier to the inflow of warm water to the inner cavity, and thus strongly controls melting

Lhermitte et al 2020

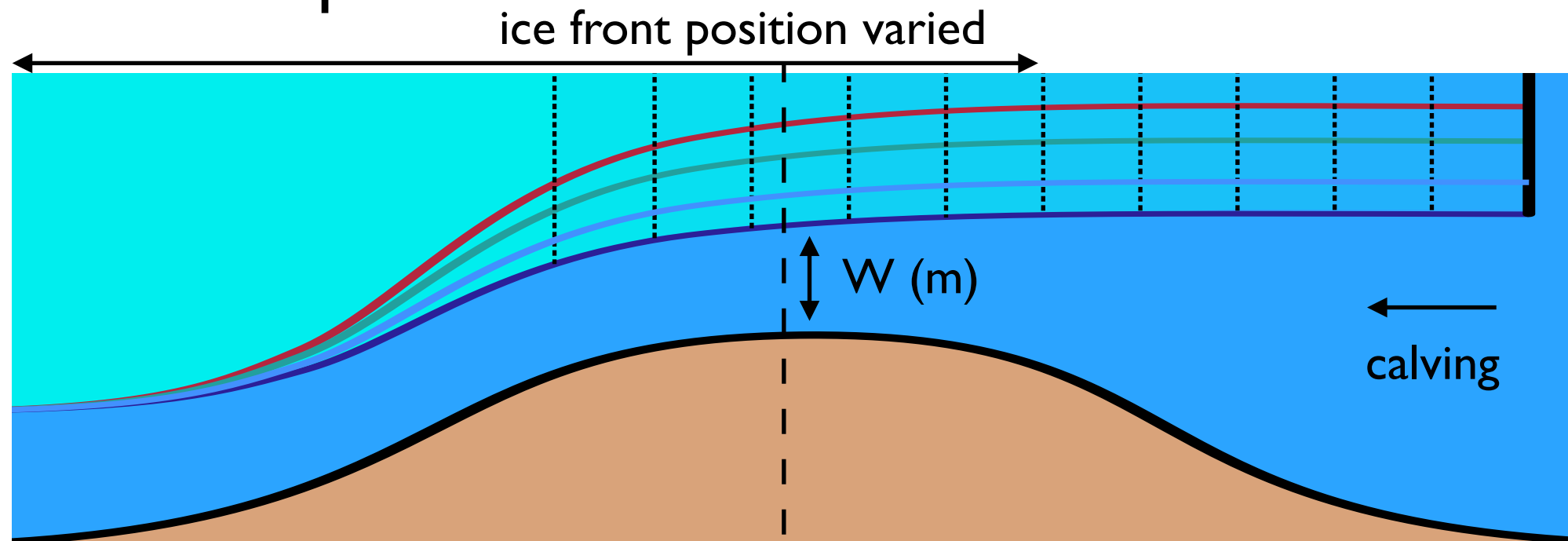


...but Pine Island ice shelf has **calved significantly** in recent years, and has the potential for **further large losses**

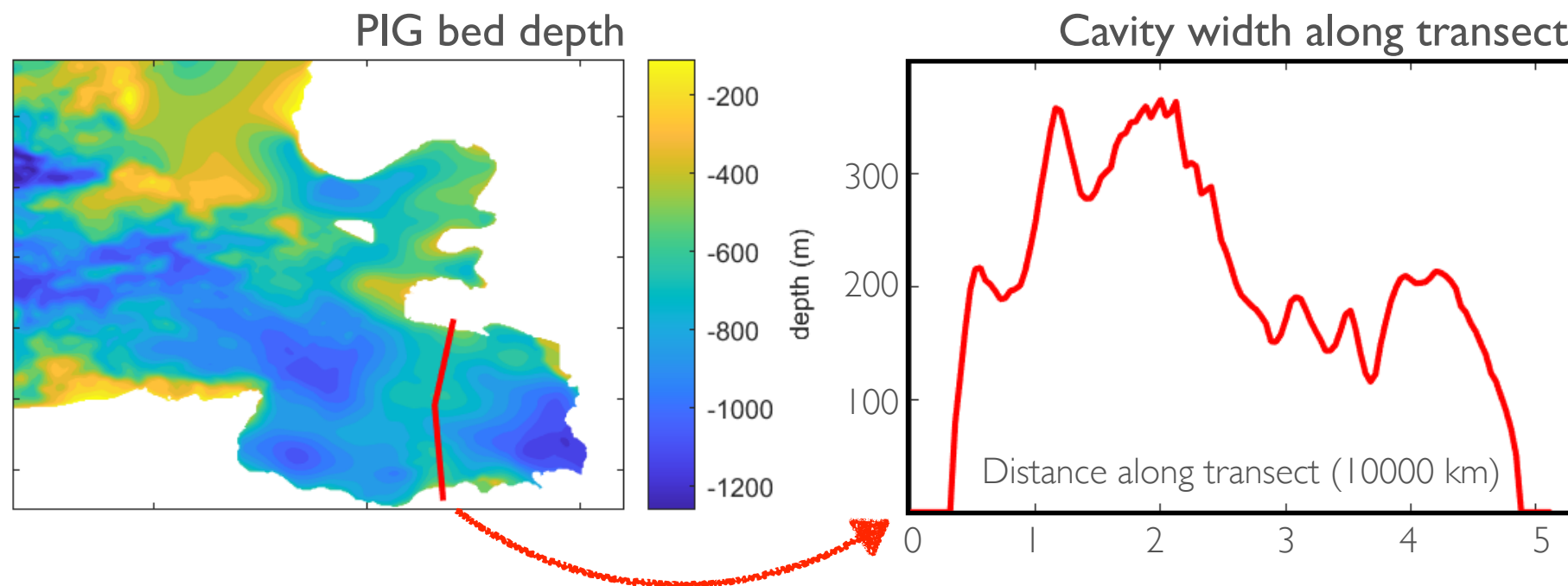
- Pine Island has calved extensively in recent years and further calving is expected
- Have these recent calving events relaxed the topographic barrier that exists in PIG? i.e. will melt rates change significantly as a result of past and future PIG calving?

How does calving change the melt rate in a cavity with such a topographic barrier?

Model Setup



Parameter values motivated by observations:



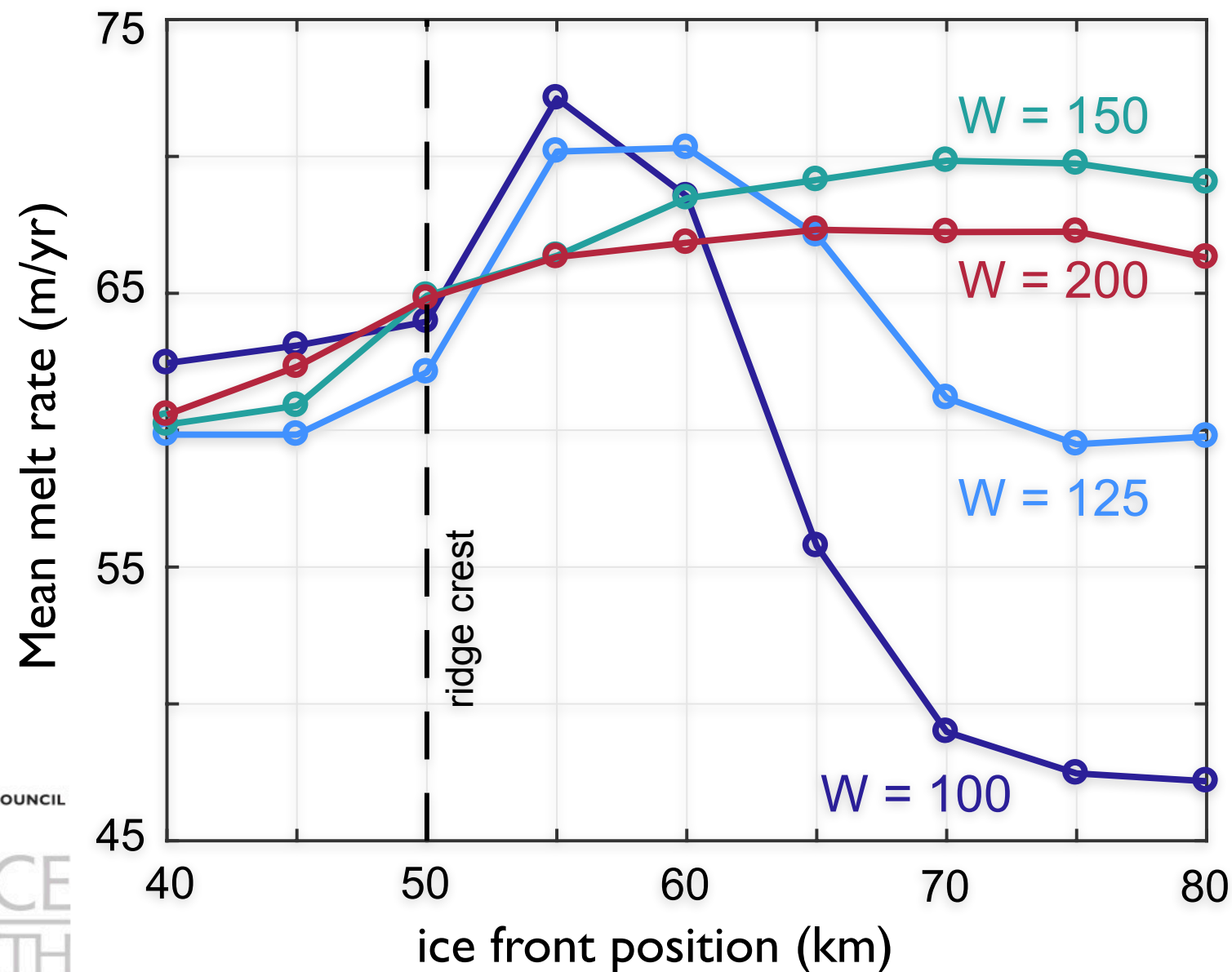
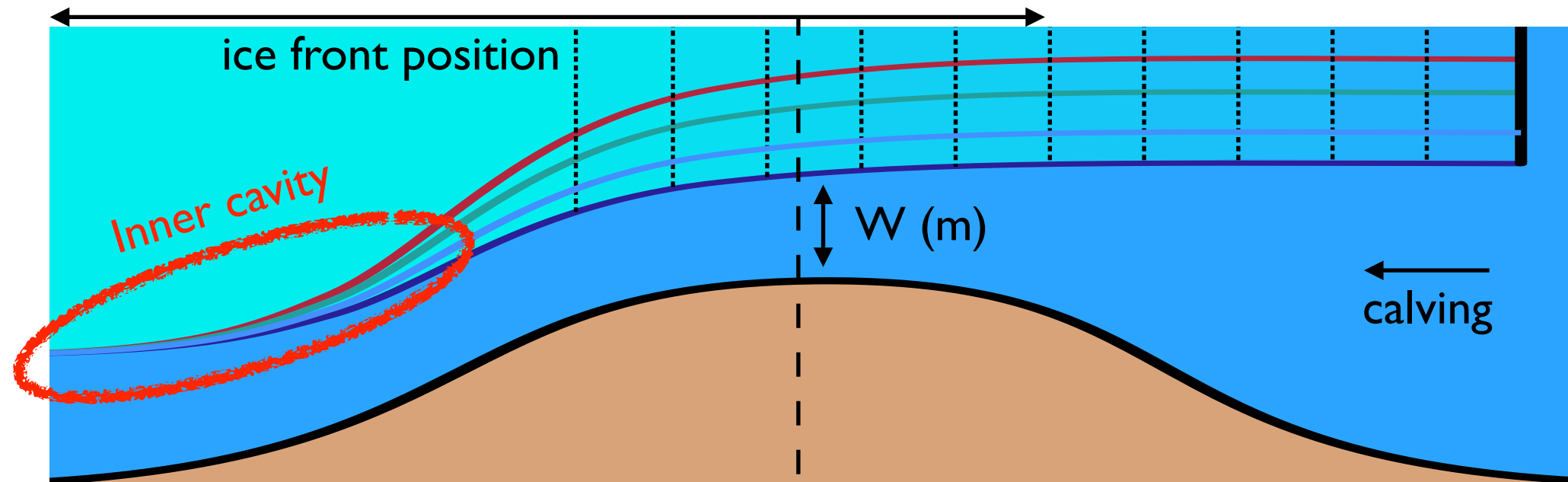
Model info:

MITgcm in hydrostatic mode, 10m/400m vertical/horizontal resolution, 3 equation formulation for melting, boundary restoring to typical Amundsen Sea conditions.... [contact for more info!]

Commentary

- Central question: Will melt rates change significantly as a result of past and future PIG calving?
- Use idealised modelling to assess changes in melt rate and diagnose the mechanisms responsible for these changes
- Simulate calving by changing the position of the ice front, and resolving the cavity circulation explicitly (no ice dynamics!)
- Experiment repeated for different gap widths W : assess the importance of the strength of the topographic barrier in how melt changes with calving

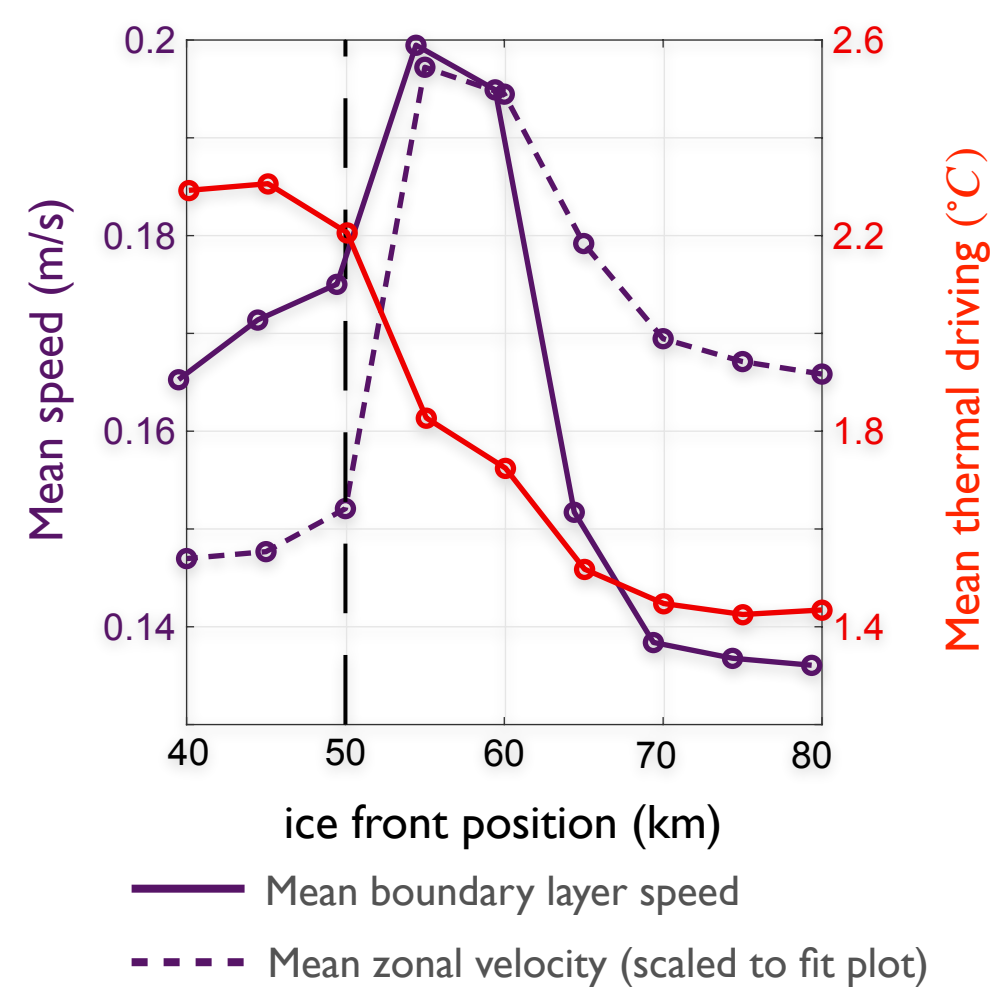
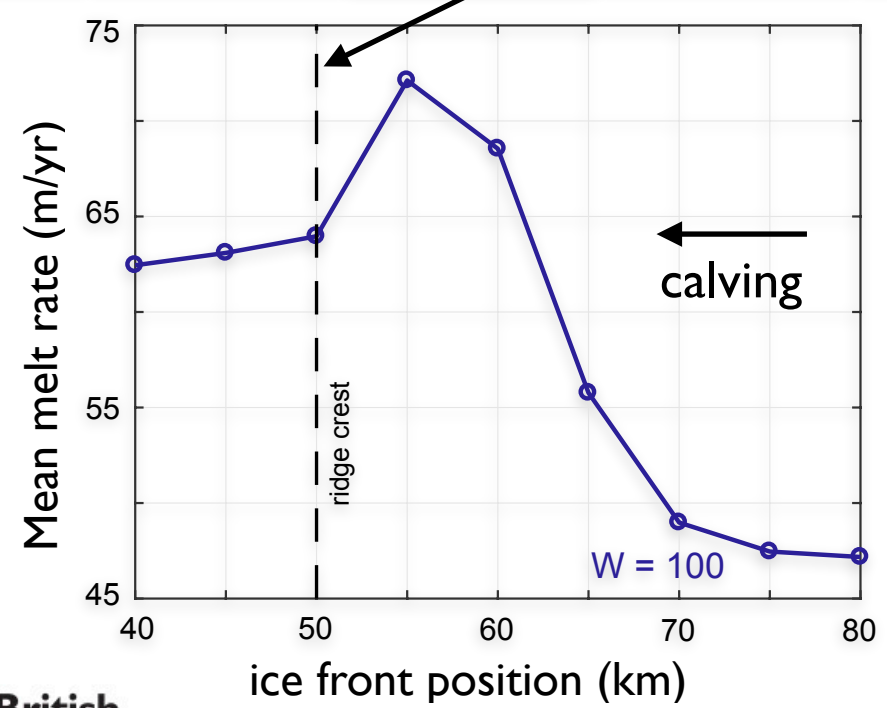
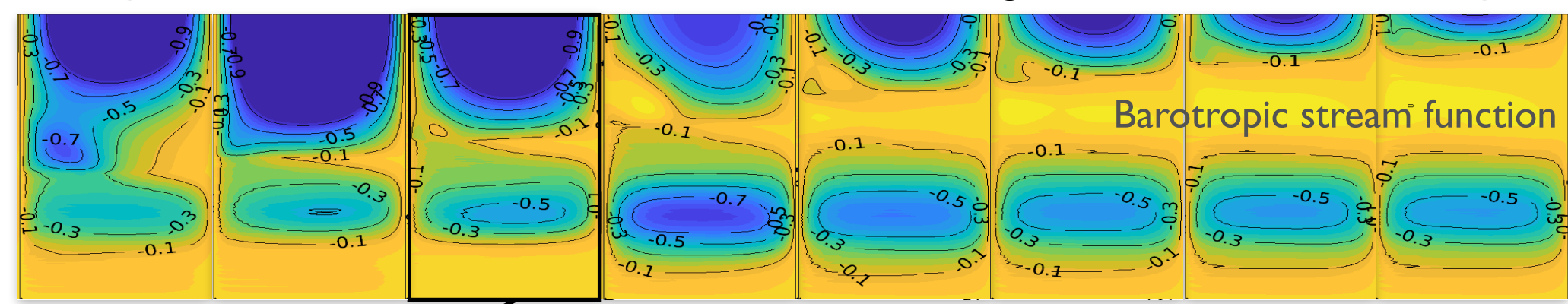
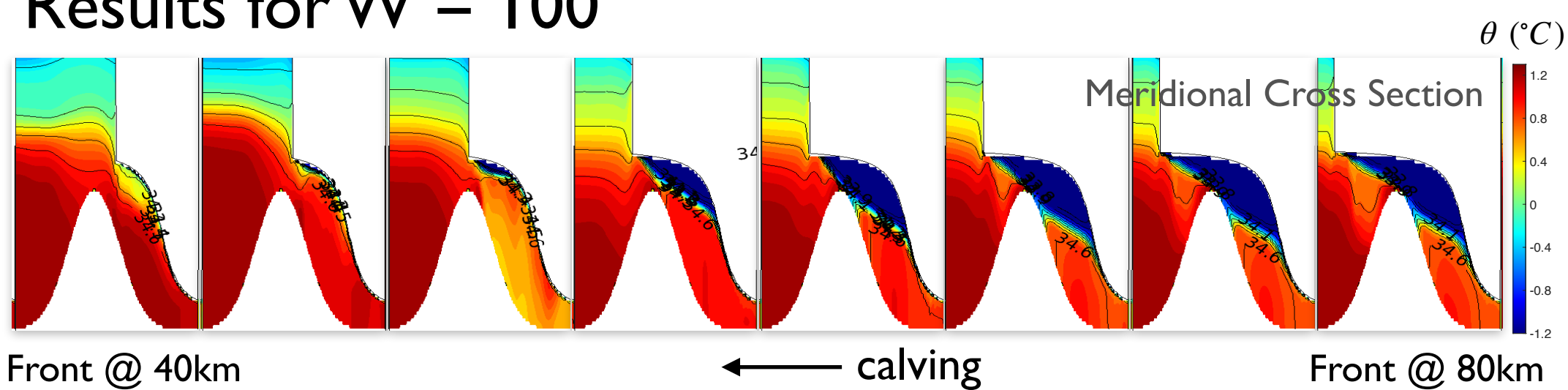
Key results: change in melt rate with calving



Commentary

- Changes in melt rate with calving depend sensitively on the strength of the topographic barrier (via W)
- Melt rates show complex changes and can either increase or decrease strongly with calving
- Narrow gap scenarios ($W = 100, 125$) display a threshold after snapping beyond the ridge that is not seen in the wider gap cases
- In the following slides, we discuss the mechanisms responsible for these changes for each W in turn

Results for $W = 100$



Commentary

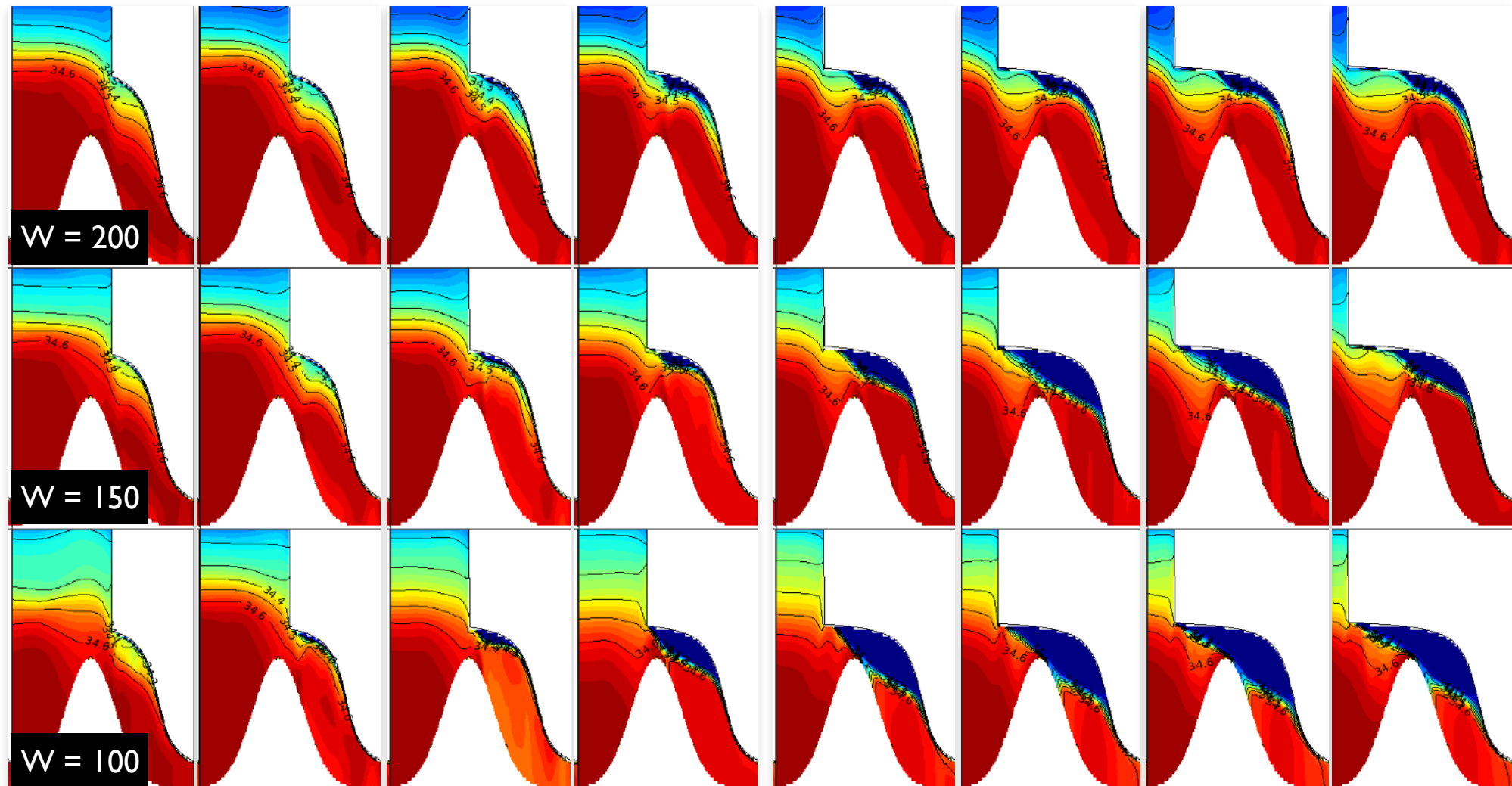
- For narrow gaps ($W = 100, 125$), melt rates increase with calving while the front is outside of the ridge, but decrease sharply when the calving front retreats beyond it.
- When front outside cavity, retreat permits more warm, salty water into cavity. This increases melt rate as the inner cavity is (i) more stratified (more vigorous geostrophic circulation) and (ii) warmer
- When snapping beyond the ridge, the strong potential vorticity barrier is relaxed; inner and outer become dynamically connected and inner cavity circulation shuts down

“Why?” I: Front Outside Ridge

θ (°C)

Commentary

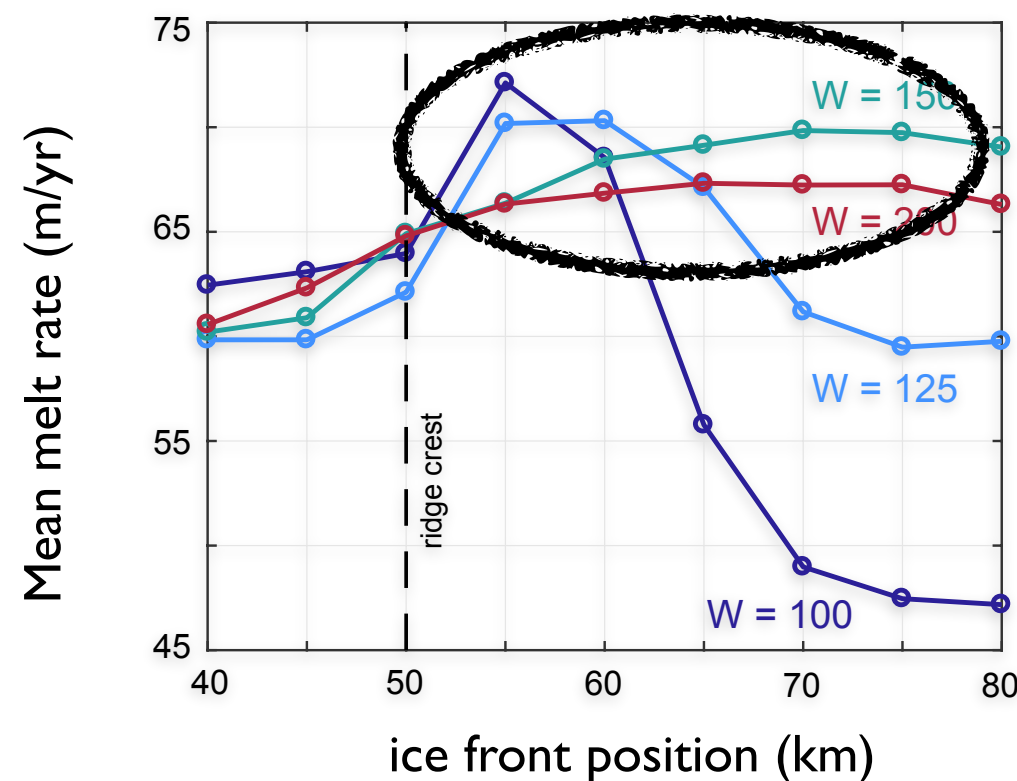
- As the gap width W increases, the peak in melting moves to the right
- As W increases, the cold ‘wedge’ between ridge and ice shelf that blocks warm water access occupies a smaller part of the ridge-ice gap. Warm water is allowed in sooner (with less calving), and associated melt increases peak sooner
- For very wide gaps ($W \gtrsim 200\text{m}$), the melt rate is independent of ice front position



Front @ 40km

← calving

Front @ 80km

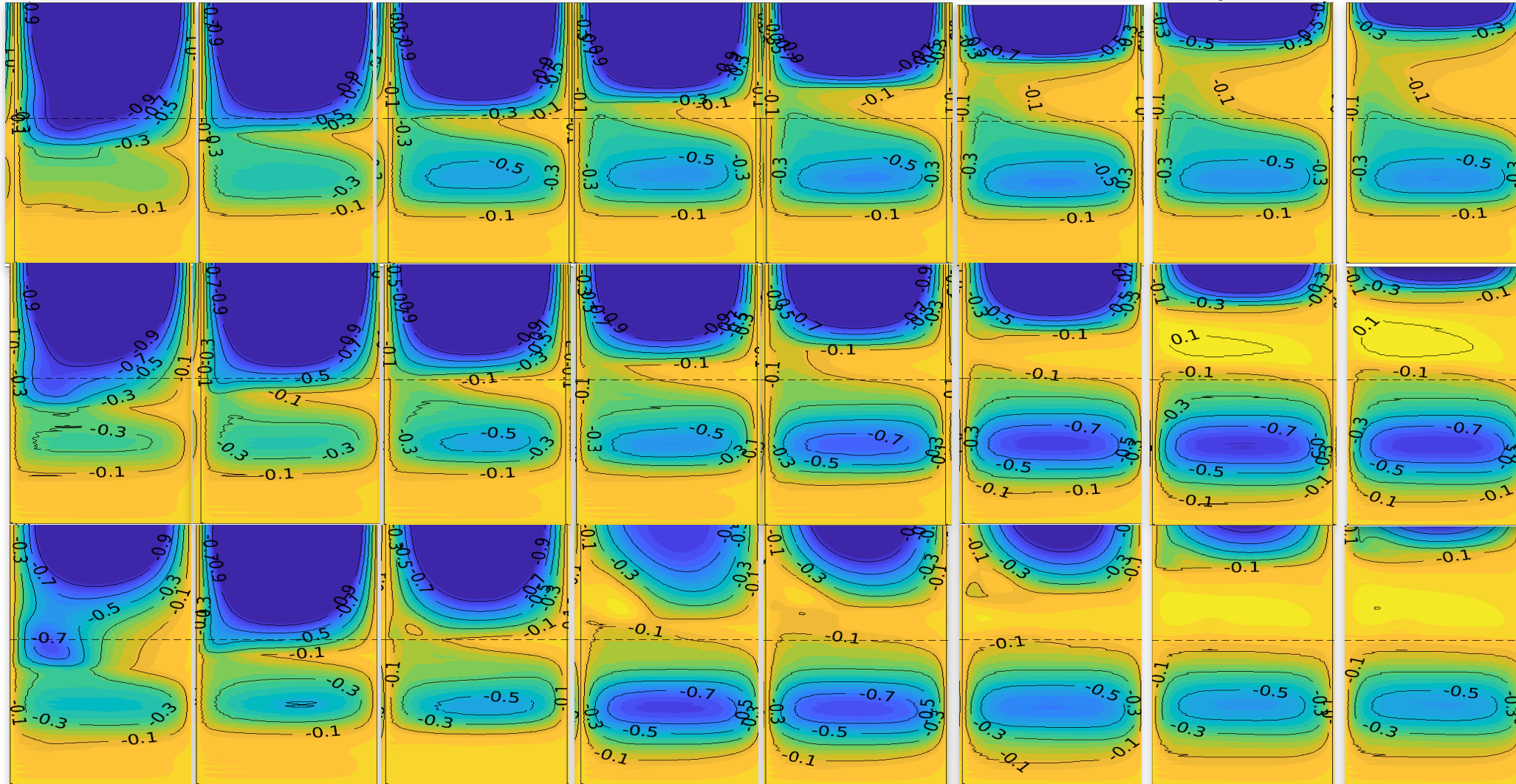


“Why?” II: Front Inside Ridge

Barotropic stream function

Commentary

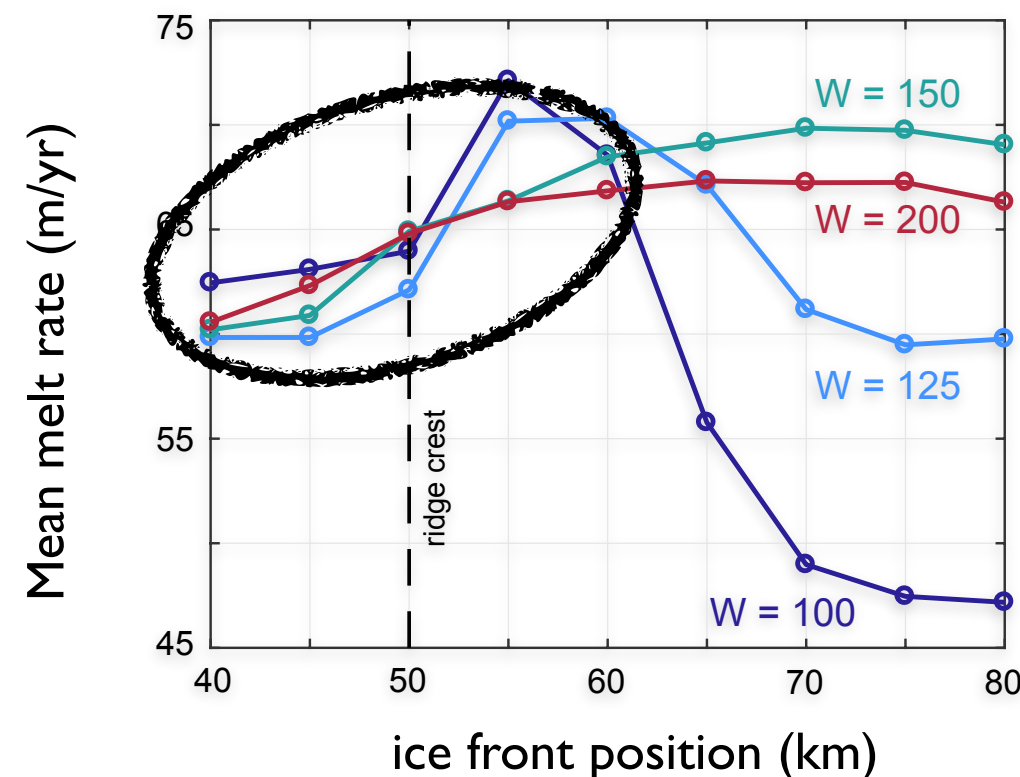
- Circulation in the inner cavity, and thus melt rates, reduce when the inner and outer cavity become dynamically connected
- For narrow gaps ($W = 100$), the potential vorticity barrier is sufficiently strong that this connection only occurs when calving beyond the ridge
- For wider gaps ($W \gtrsim 150$), this barrier is not as strong, the regions become connected before calving front reaches the ridge



Front @ 40km

← calving

Front @ 80km



Conclusions:

- Melt rate changes with calving depend sensitively on the geometry
- Stratification of the inner cavity plays an important role in these changes, suggesting that results may be sensitive to ambient stratification
- We see both increases and decreases in melt rate with calving; suggests complex future changes in melting in PIG

Discussion:

- Experiments have reach beyond PIG; an archetype for calving effects on melting when ice and bed interact (e.g. grounding line retreat)
- Implications for melt rate parametrizations, most of which assume no dependence on ice front position

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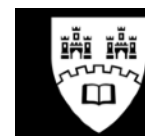
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