Pinning points influence on ice sheet/shelf stability

A local study in Dronning Maud Land, East Antarctica

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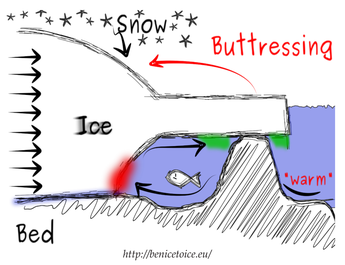
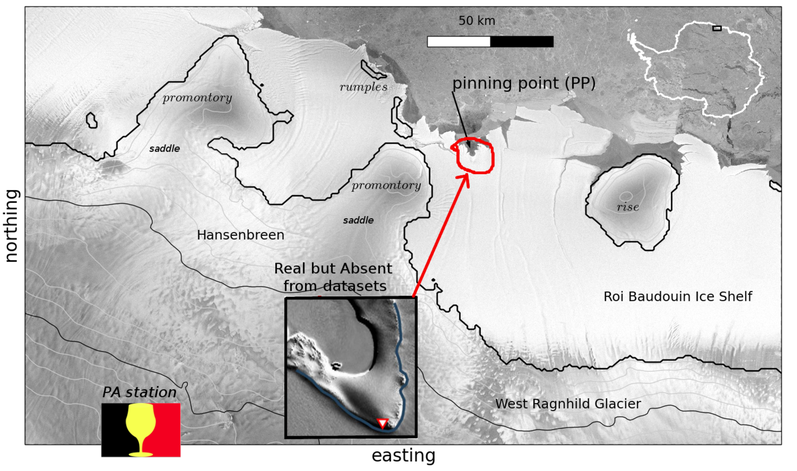
Pinning points

- **Pinning points** are ice hills protruding through **ice shelves**. They stem from the **contact** between submarine **topographic highs** and the bottom surface of floating ice. They **buttress** the ice sheet, induce strong **velocity gradients** and modify the **ice rheology** (e.g., by crevasse-weakening).
- Still **overridden** by the ice shelf, they are called **ice rumples**
- Exhibiting a **radial-flow** center among a much faster ice shelf, they are called **ice rises** or **ice promontories**, the latter being still connected to the main grounded ice sheet with a **saddle**.
- Most of them are smaller than 10 km^2, which makes them potentially **unresolved in global datasets** used by modellers.



http://benicetoice.eu/

Domain studied



Radarsat mosaic, 2002, Hansenbreen and Roi Baudouin ice shelves, Dronning Maud Land

Scientific questions of main interest

Q1-Are there potential topography-driven (due to bed overdeepening) instabilities ?

Q2-What is the effect of omitting PP in initialisation on future ice-sheet dynamics ?

Q3-How does PP unpinning affect the stability of these outlet glaciers ?

Numerical modelling

- Ice-sheet model BISICLES [2]
- Schoof-Hindmarsh approximation of the full-Stokes equations
- Model vertically integrated
- Adaptive gridding (1 km grid at the grounding line, 4 km away)
- Ice-sheet initialisation with inverse method to infer:
  - C the basal friction coefficient: $\tau_b = C|U|^{m-1}U$
  - ϕ the stiffening factor: $S = \phi\,\dot{\varepsilon}_e^{\frac{1-n}{n}}\,\dot{\varepsilon}$

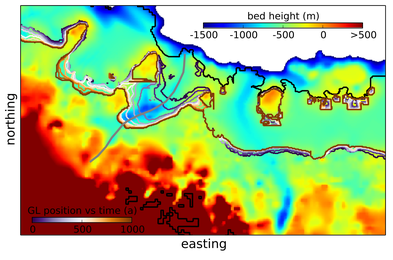
Initialisation and future scenarios

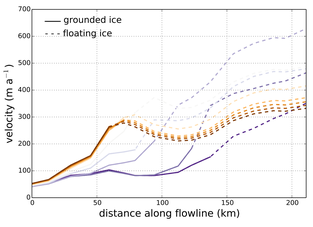
	Inverted dataset		Initial geometry
	Velocity	Geometry	
Reference	[1]	[1]	[1]
Unpinning	[1]	[1]	[5]
NoPP	[4]	[5]	[5]

[1] : Velocities and ice/bed geometry with pinning point
[4] : Velocities without pinning point
[5] : Ice/bed geometry without pinning point

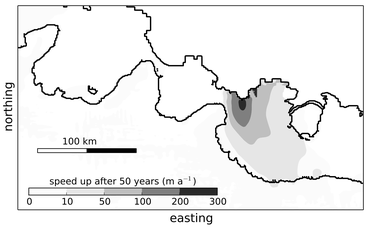
Other parameters: linear sliding (m=1), high sub ice-shelf melt rates at the GL, low elsewhere, in total half, similar to and twice current melt rates [3]

Topography as the main driver of the retreat

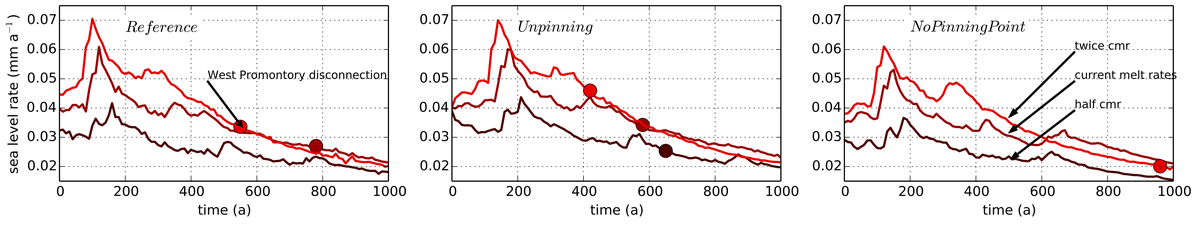


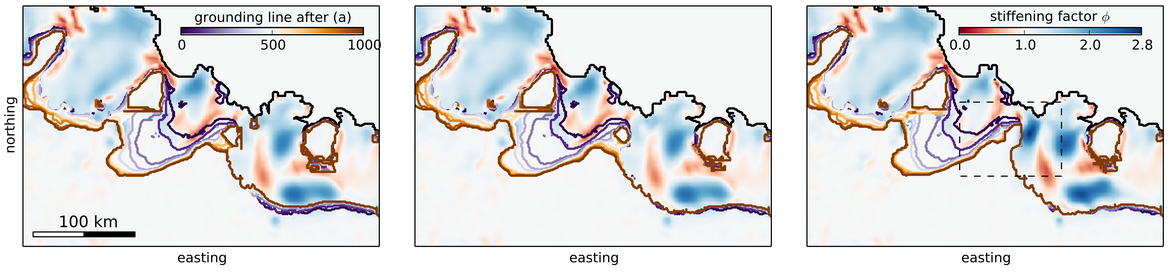


Unpinning 1 and speed up



Unpinning 2 & Uncharted pinning point, effects on transient simulations





Take home messages

Q1 Hansenbreen is unstable and will retreat very soon

Q3 Unpinning has not much effect on SLR but slightly affect the timing of retreat (for these specific glaciers...)

Q2 Initialisation without PP decrease SLR by 10% and delays significantly the timing of the grounding line retreat

-> Accounting for these local, subtle processes will help to improve sea level predictions

-> The Antarctic margins provided in publicly available datasets need to be resolved with as much accuracy as possible

References

[1] Berger et al., 2016, *Journal of Glaciology*
[2] Cornford et al., 2015, *The cryosphere*
[3] Depoorter et al., 2013, *Nature*
[4] Rignot et al., 2011, *Science*
[5] Fretwell et al., 2013, *The cryosphere*