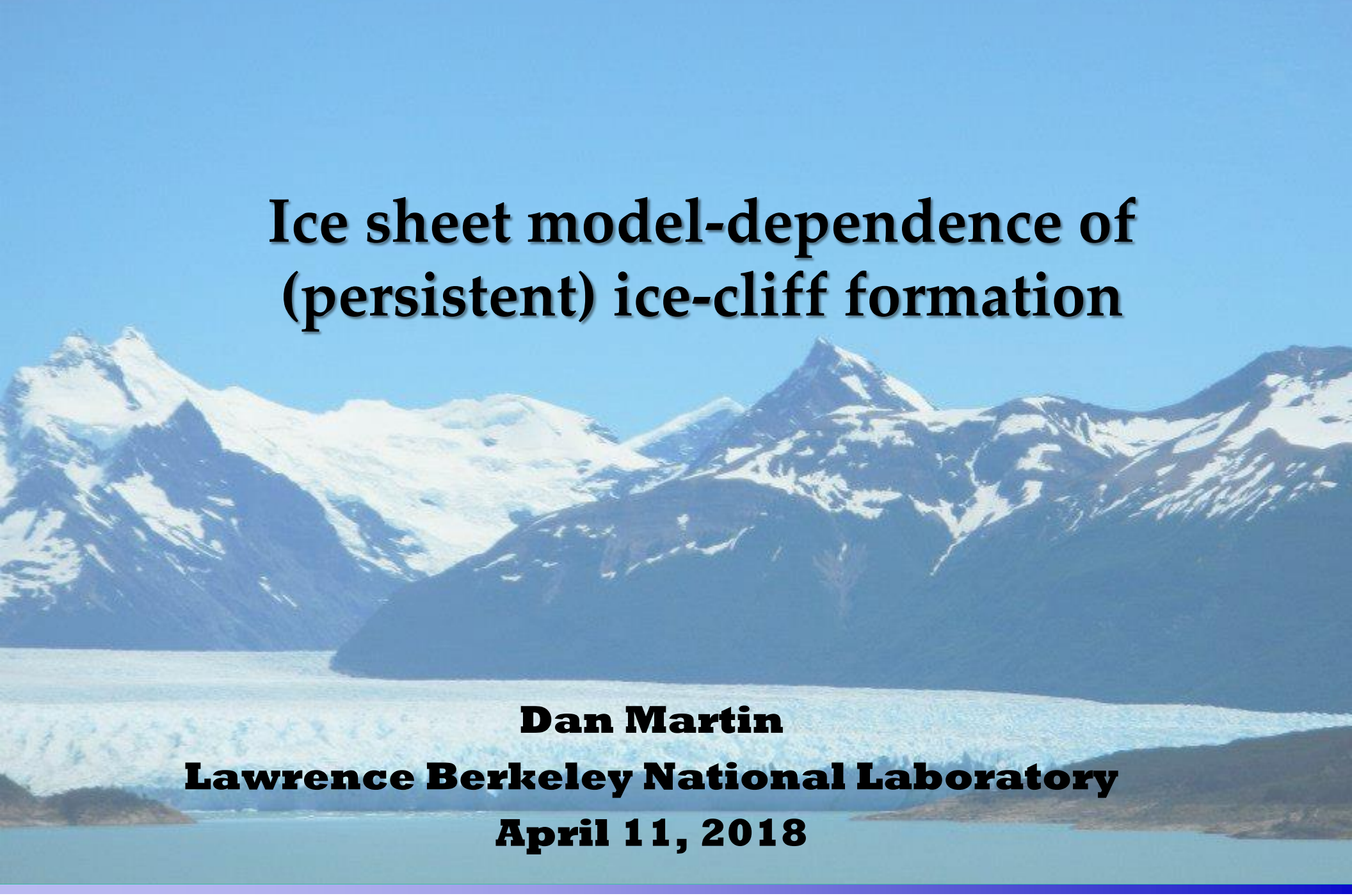


Ice sheet model-dependence of (persistent) ice-cliff formation

Dan Martin

Lawrence Berkeley National Laboratory

April 11, 2018

U.S. DEPARTMENT OF ENERGY | Office of Science

BERKELEY LAB | Los Alamos NATIONAL LABORATORY EST. 1943 | University of BRISTOL

Joint work with:

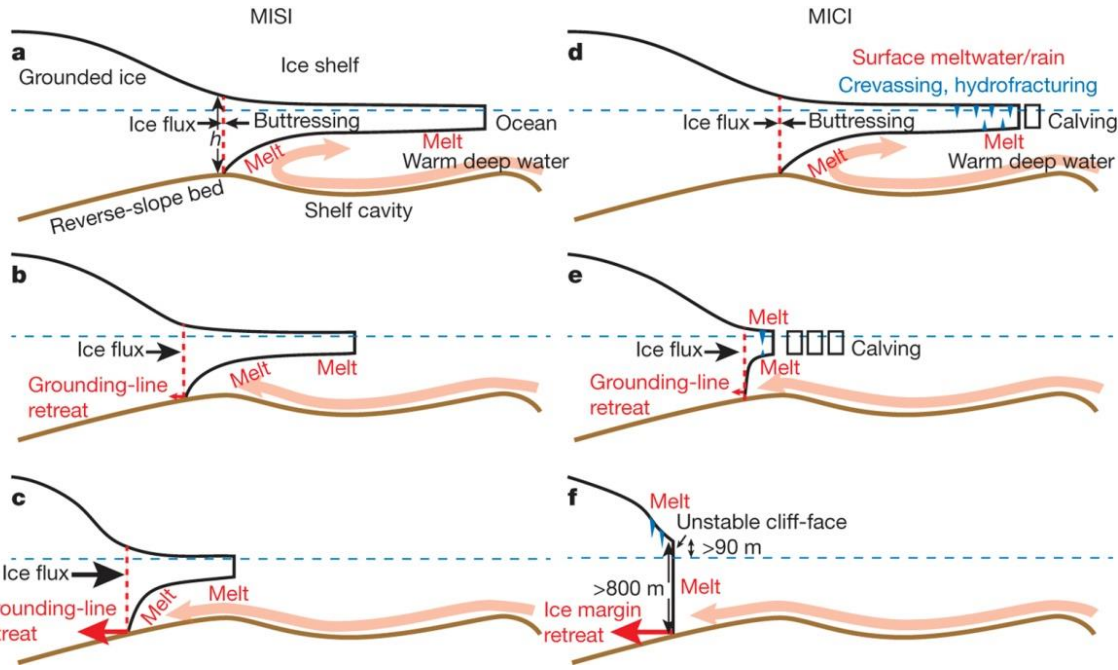
- **Stephen Cornford** (Swansea/Bristol)
- Brent Minchew (MIT)
- Esmond Ng (LBNL)
- Stephen Price (LANL)

- Support provided in part through the Scientific Discovery through Advanced Computing (SciDAC) program funded by the US Department of Energy (DOE), Office of Science, Advanced Scientific Computing Research and Biological and Environmental Research Programs under Contract No. DE-AC02-05CH11231.

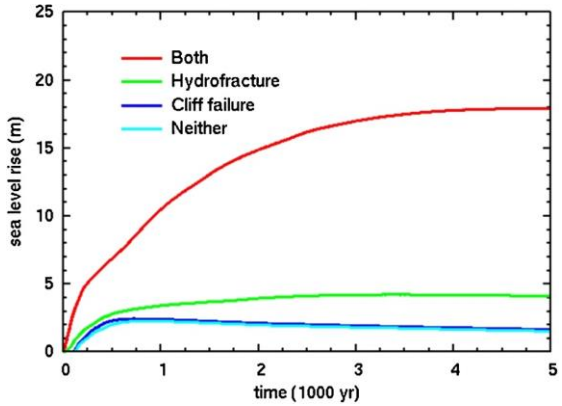
Marine Ice Cliff Instability

- Deconto and Pollard (2015) - wanted to be able to match paleorecord of large SLR

- Surmised mechanism:
  - hydrofacture (eliminate ice shelves)
  - Resulting ice cliffs exceed yield strength of ice.
  - Cliff collapse (drive retreat into EAS basins)
  - Allows for much greater SLR



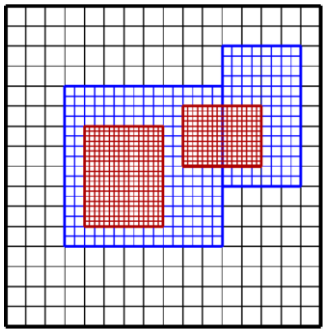
(above) Pollard and Deconto (2016)
(right) Pollard et al, (2015)

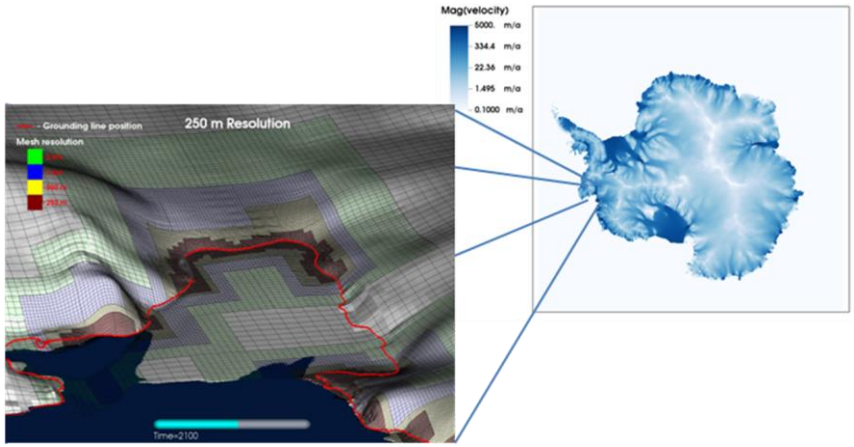


- Matches current observations of hydrofracture and max cliff size…

BISICLES Ice Sheet Model

- Scalable adaptive mesh refinement (AMR) ice sheet model
  - Dynamic local refinement of mesh to improve accuracy
- Chombo AMR framework for block-structured AMR
  - Support for AMR discretizations
  - Scalable solvers
  - Developed at LBNL
  - DOE ASCR supported (FASTMath)
- Collaboration with Bristol (U.K.) and LANL
- Variant of “L1L2” model (Schoof and Hindmarsh, 2009)
- Coupled to Community Ice Sheet Model (CISM).
- Users in Berkeley, Bristol, Beijing, Brussels, and Berlin…

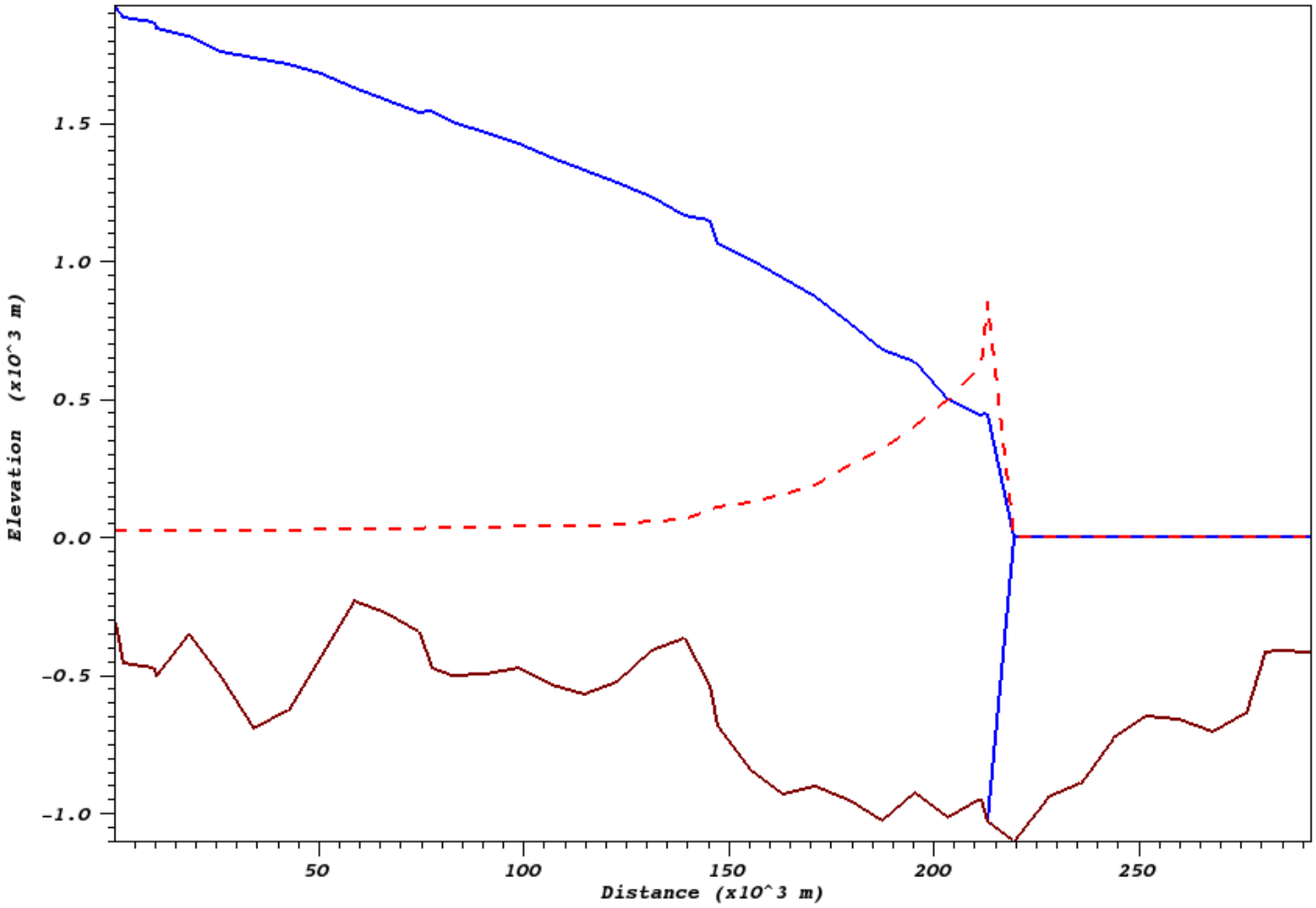




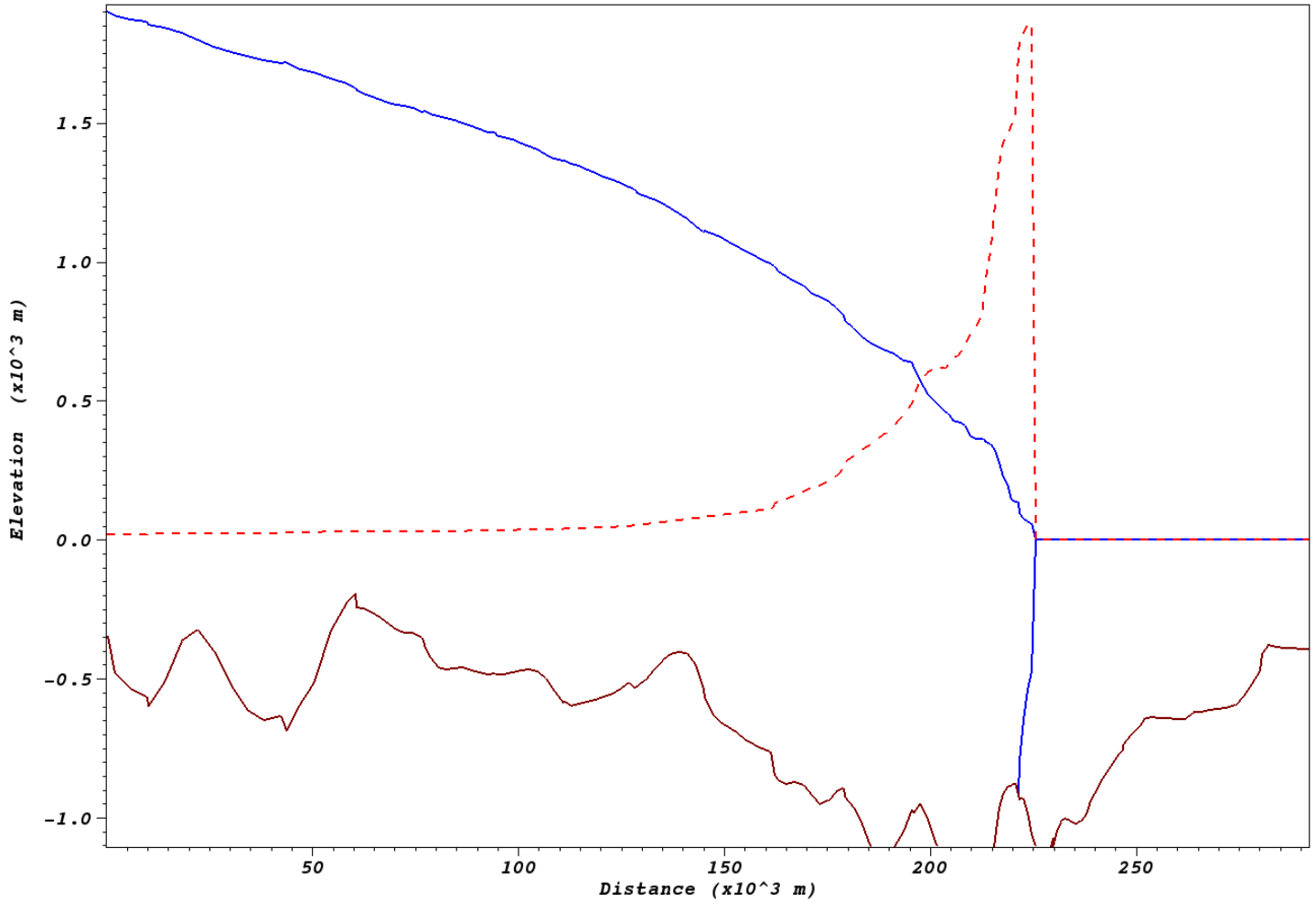
MICI and BISICLES…

- We've been doing Antarctic melt-sensitivity studies.
- High (sufficient) resolution for GL dynamics -- (O(1km) at GLs with a subgrid friction scheme)
- No MICI mechanism, but wanted to evaluate the potential impact.
- Can look at local surface slopes to see if we get "cliffs"
  - Yes, but sporadic and ephemeral

8km resolution - cliffs!



But 1km resolution…



Time= 15.00 years

Is MICI a symptom of under-resolution?

BISICLES cliff-collapse scheme

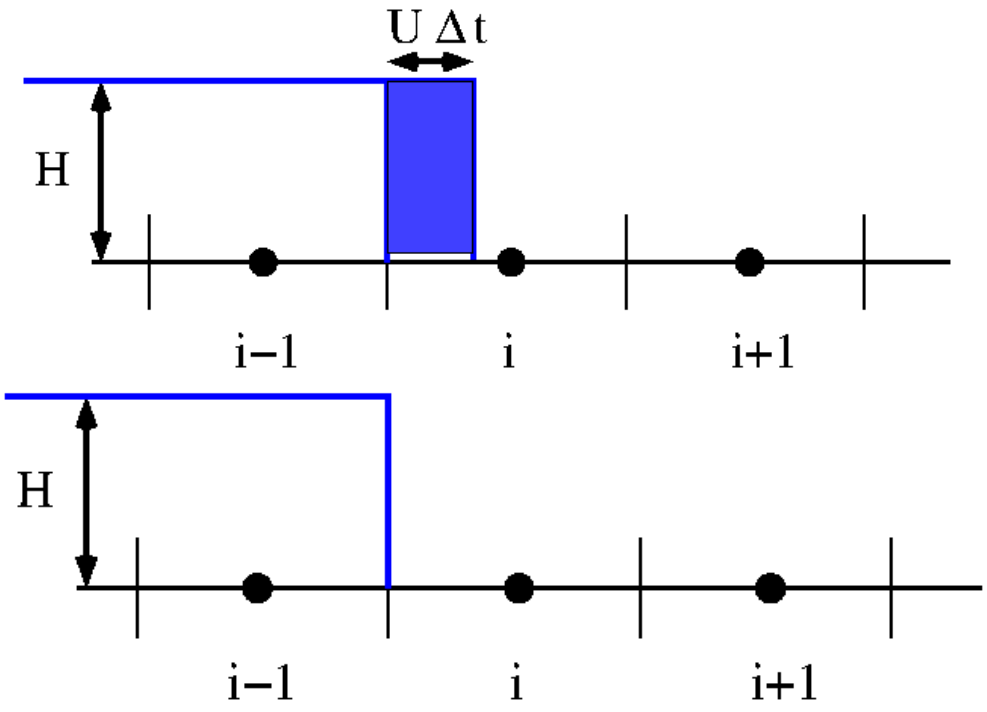
- Extend existing partial-cell scheme (designed for shelf-regrowth in MISOMIP)
- BISICLES is a finite-volume code; compute cell-averaged quantities which are updated by ice thickness fluxes across the cell faces.
- Maintain an area fraction φ, which is the fraction of the cell area (2d) which contains ice
- Wind up with an effective thickness:

$$\tilde{h} = \frac{h}{\varphi}$$

- If there is a cliff,

$$\varphi^{new} = \varphi - r\frac{\Delta t}{\Delta x}$$

$$h^{new} = h\frac{\varphi^{new}}{\varphi}$$

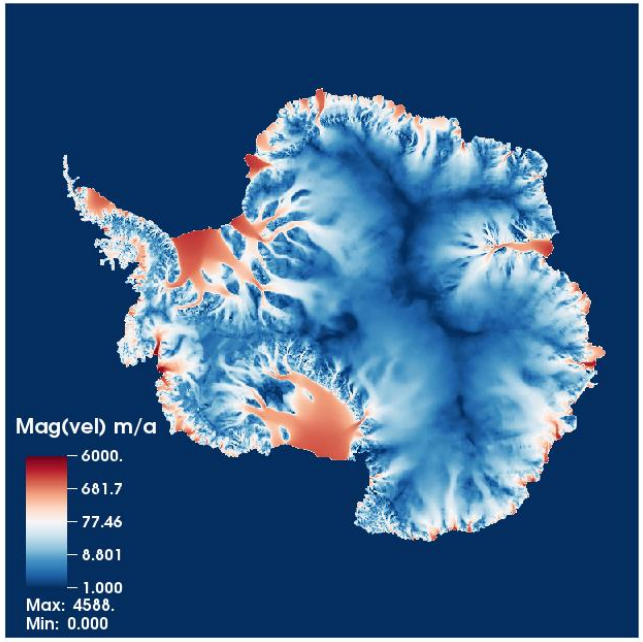


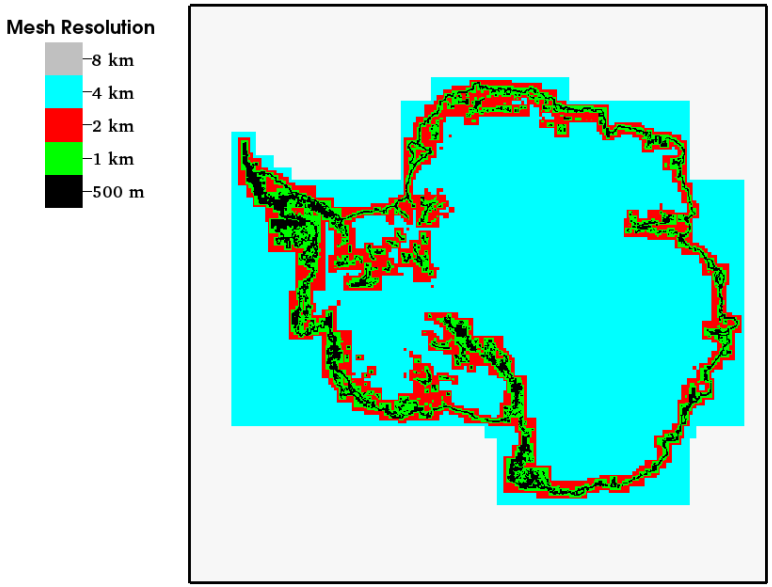
Experiment – 250-year Antarctic simulations

- Designed to trigger MICI wherever possible
- Range of finest resolution from 8 km (no refinement) to 1km (3 levels of factor-2 refinement)
- Shelf-thinning: 10 years of an aggressive shelf-thinning regime – thins most shelves down to O(400m) to weaken enough to be susceptible to hydrofracture.
- Hydrofracture: calve off any floating ice thinner than 500m.
- Run with and without MICI
  - Use Pollard and Deconto MICI parameters:
  - 1km threshold,
  - 3km/year recession rate

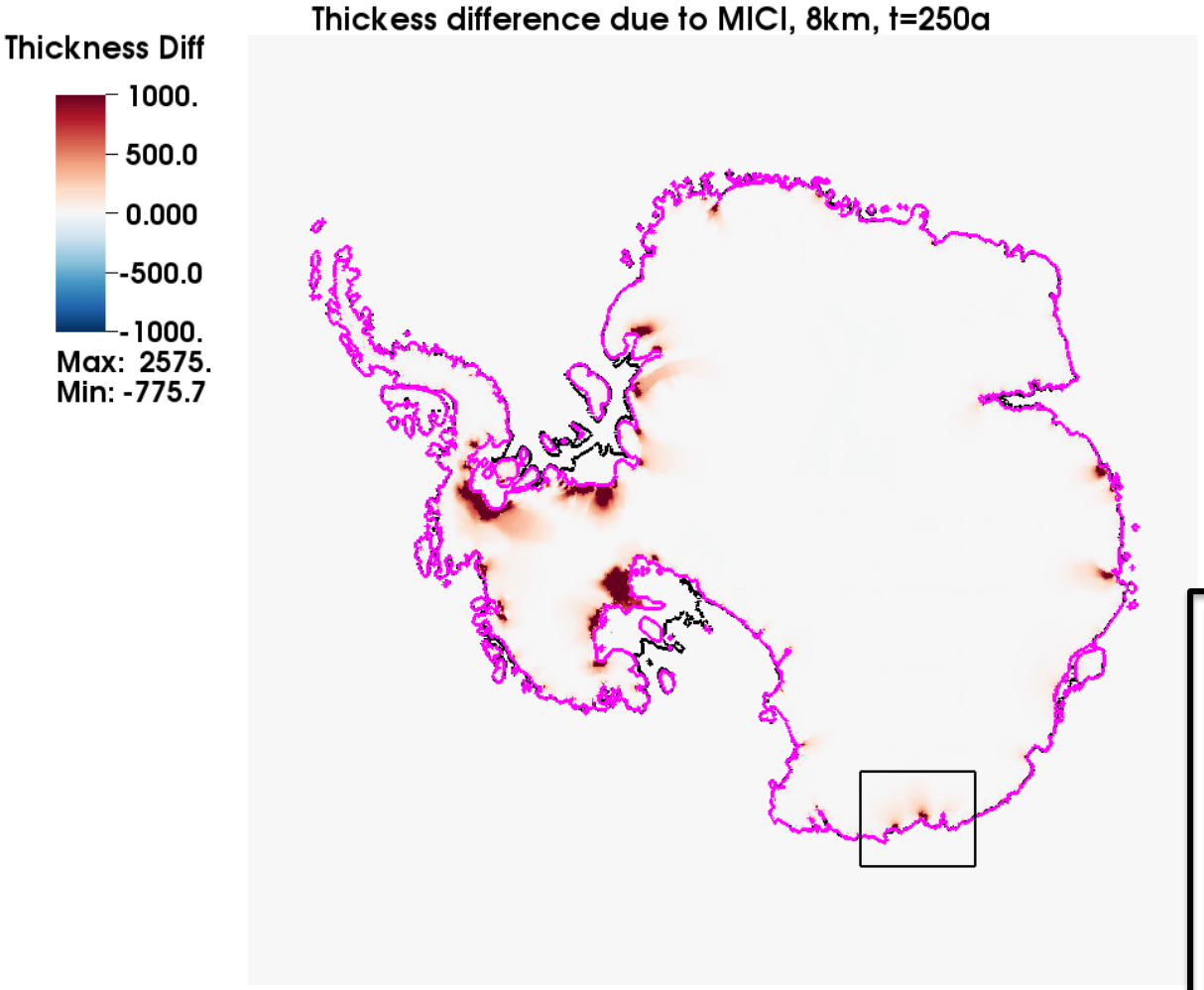
Initial Condition for Antarctic Simulations

- Full-continent Bedmap2 (2013) geometry
- Temperature field from Pattyn (2010)
- Initialize basal friction to match Rignot (2011) velocities
- SMB: Arthern et al (2006)
- AMR meshes: 8 km base mesh, adaptively refine to Δx_f

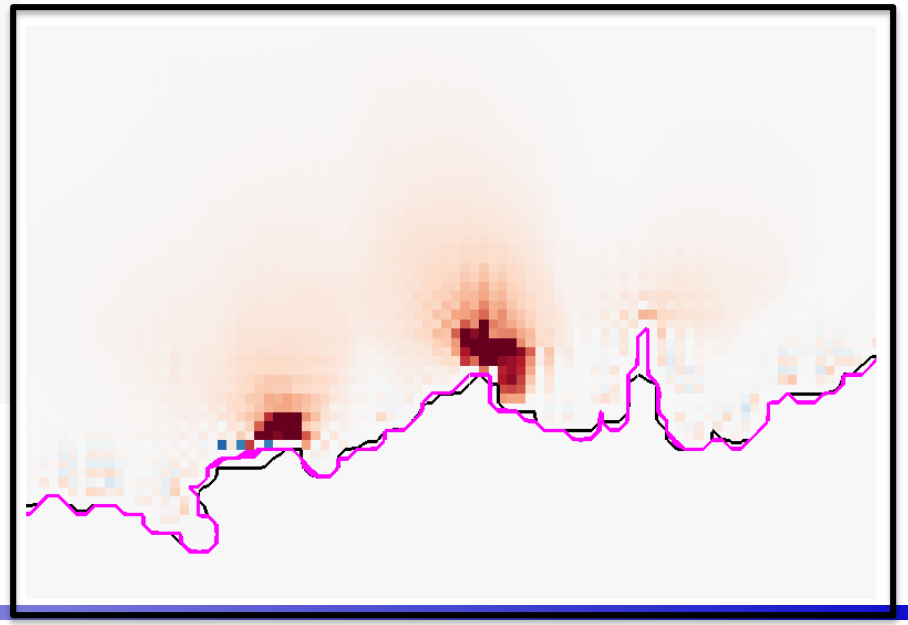




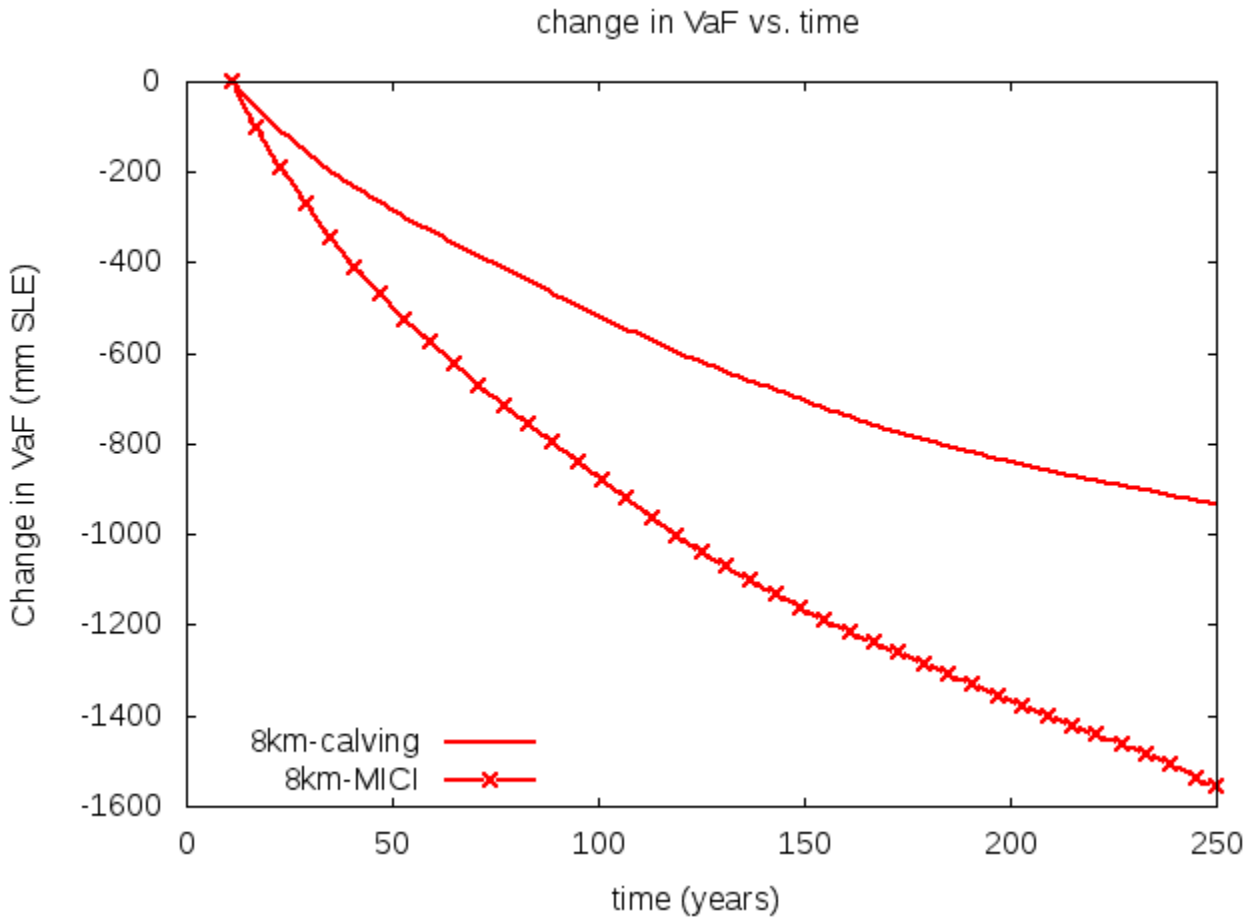
Results - 8km resolution



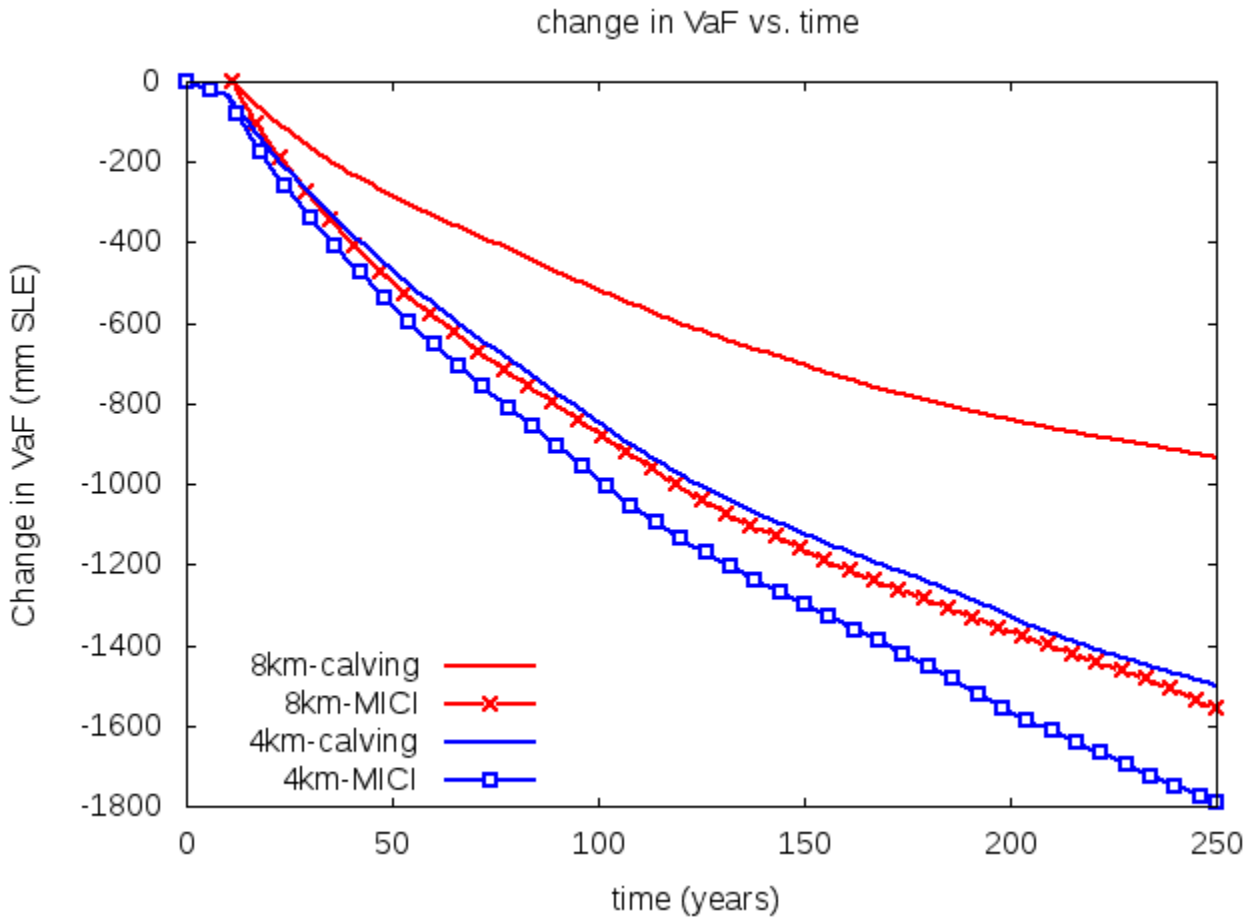
- Ice thickness differences between 8m MICI and no-MICI runs
- Shown at final time (t=250)
- Inset shows Wilkes Basin



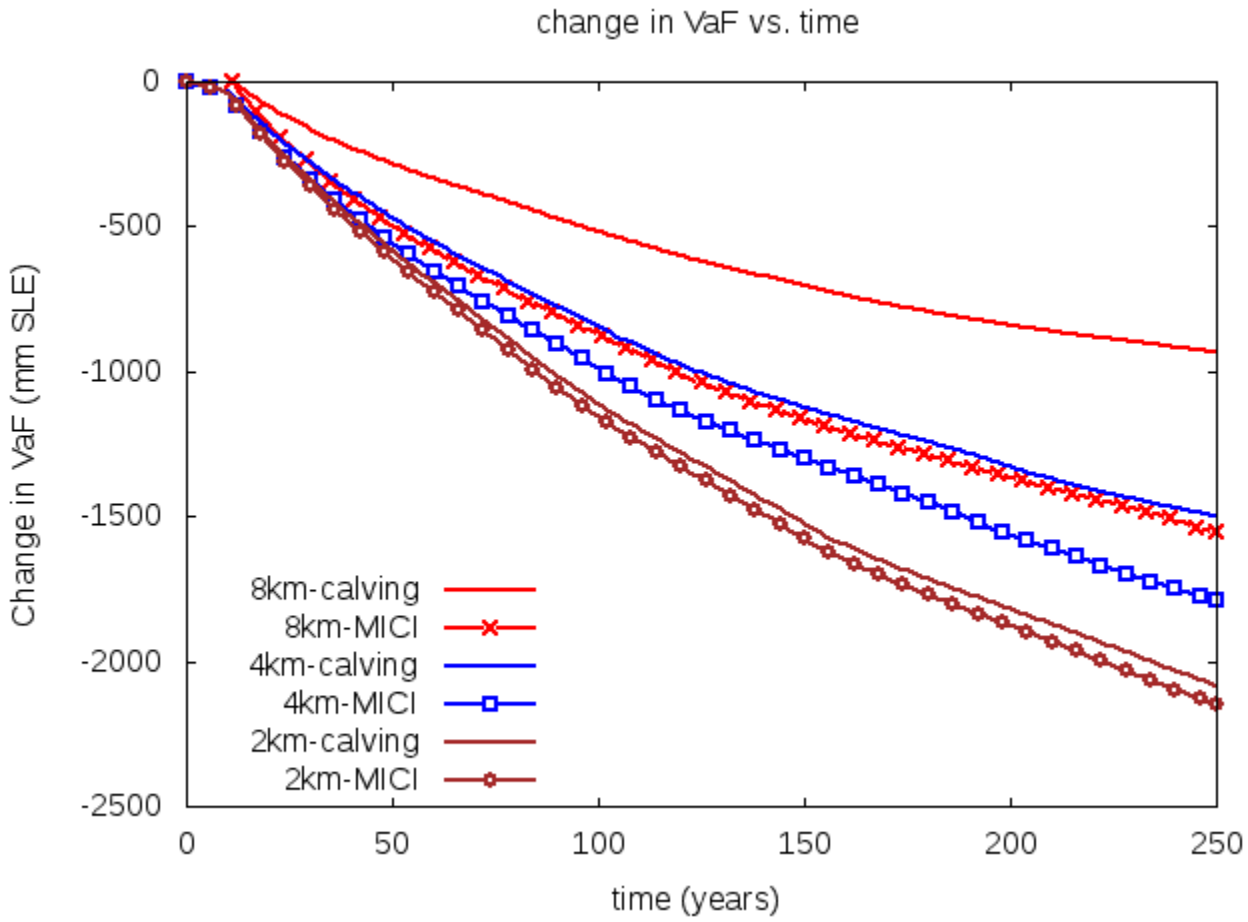
Volume above Flotation…



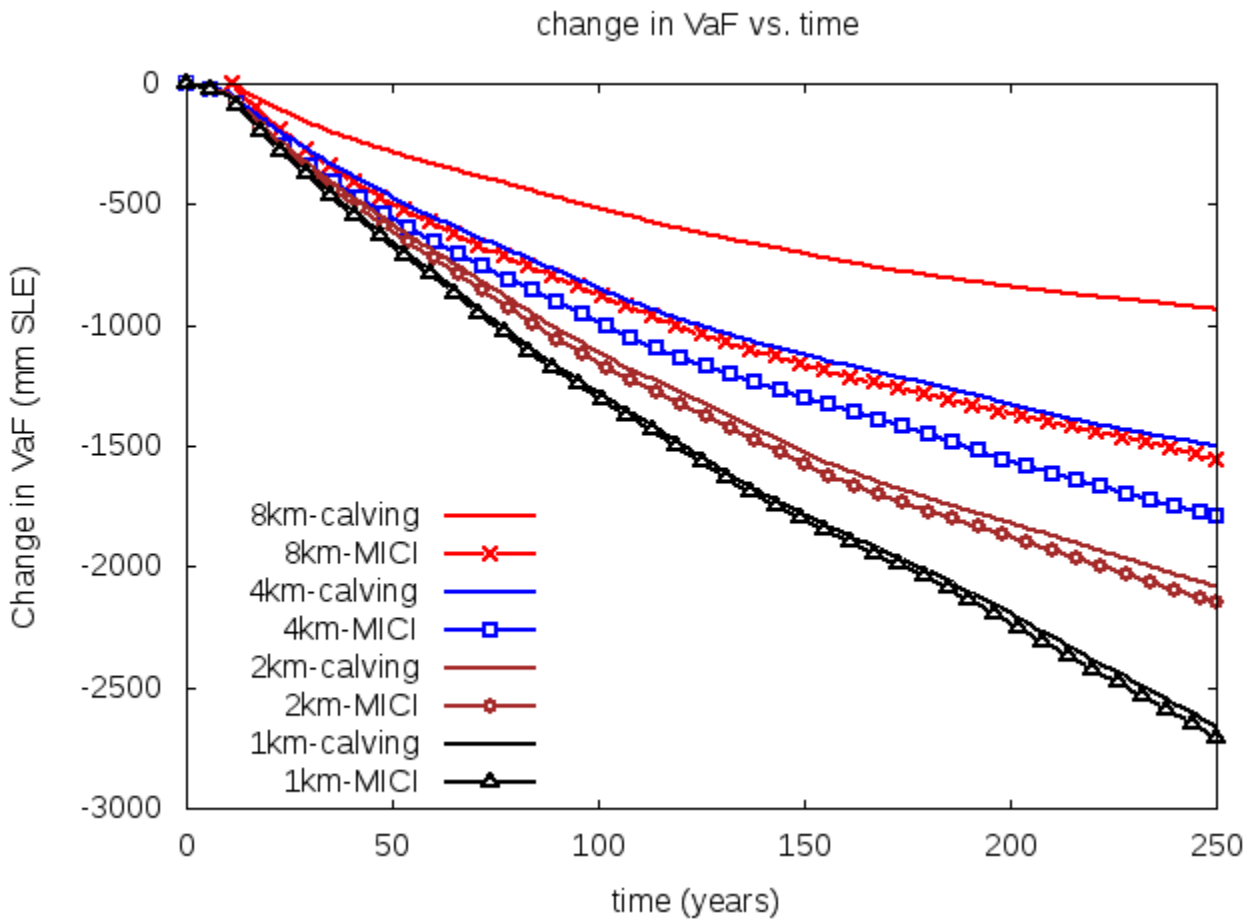
Volume above Flotation…



Volume above Flotation…



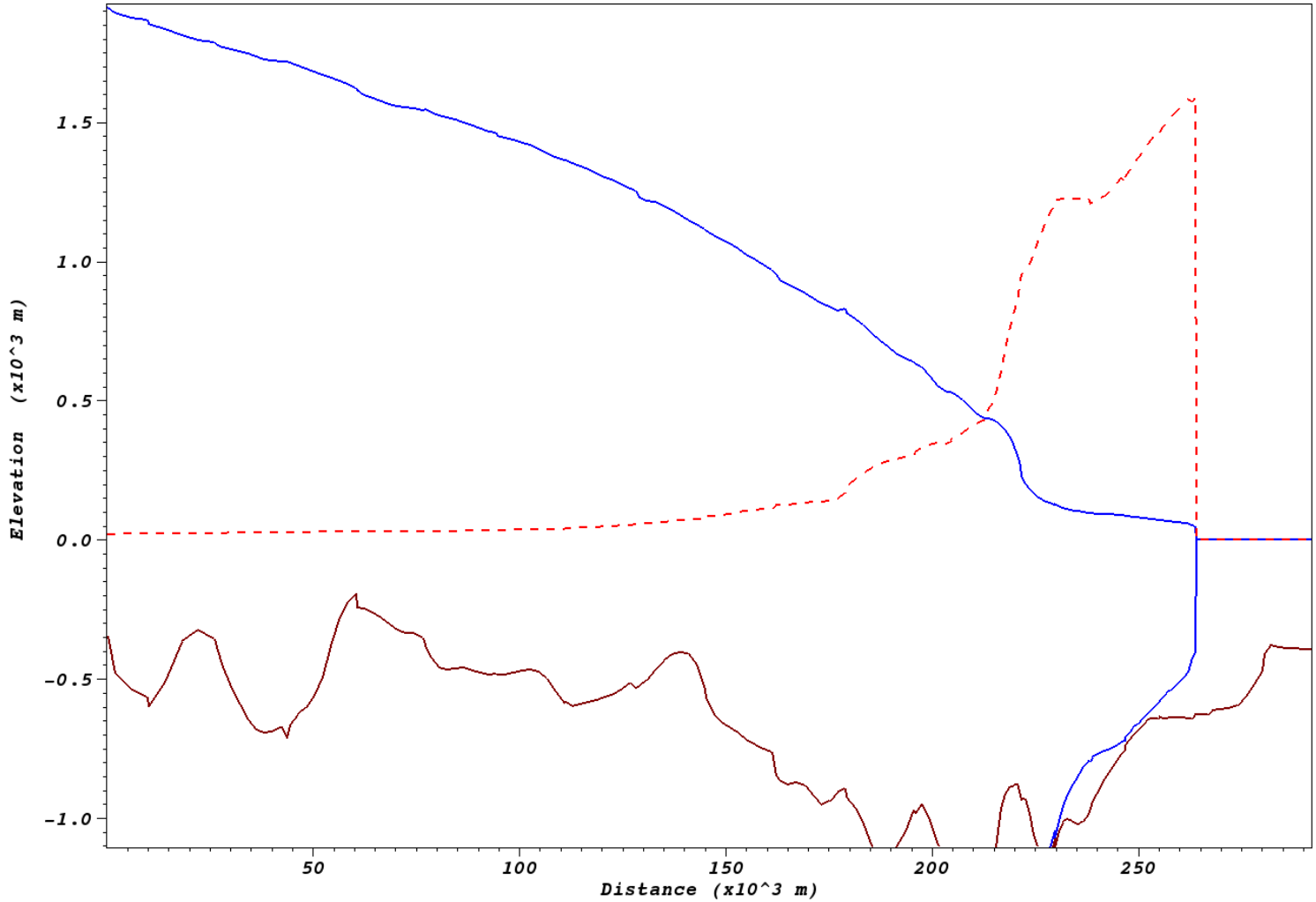
Volume above Flotation…



Alternative hypothesis

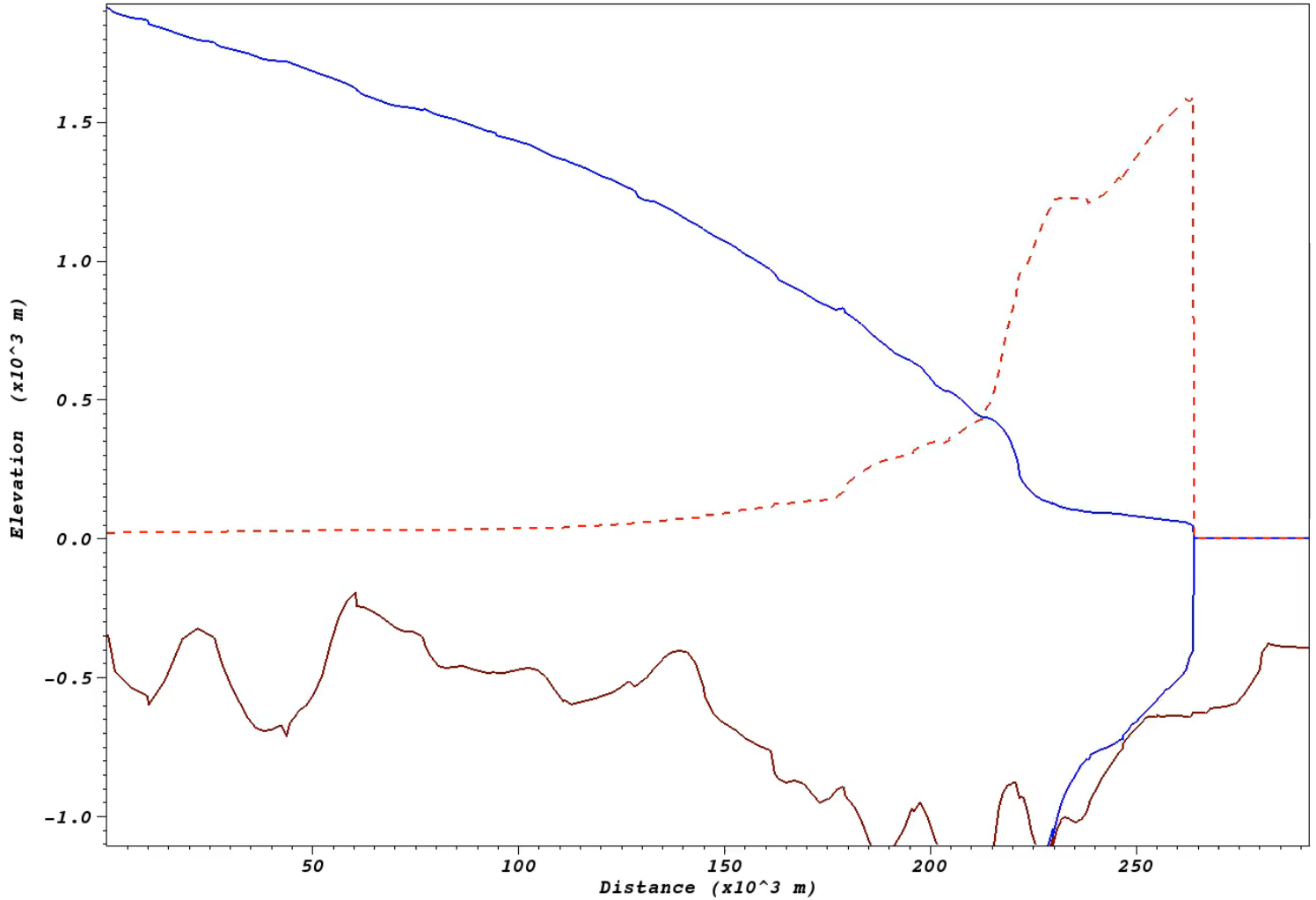
- Ice dynamics works to prevent/remove ice cliffs on macro scales
  - Local acceleration
  - Upstream thinning
- These ice dynamics operate on “fine” scales in the context of continental-scale ice sheet models
  - Likely O(a few GL ice thicknesses)
- Suggest that we need to resolve these scales to get retreat dynamics correct.
- Thinning phase is important – upstream adjusts to reduced buttressing
-

One example – Wilkes Basin: 1km resolution



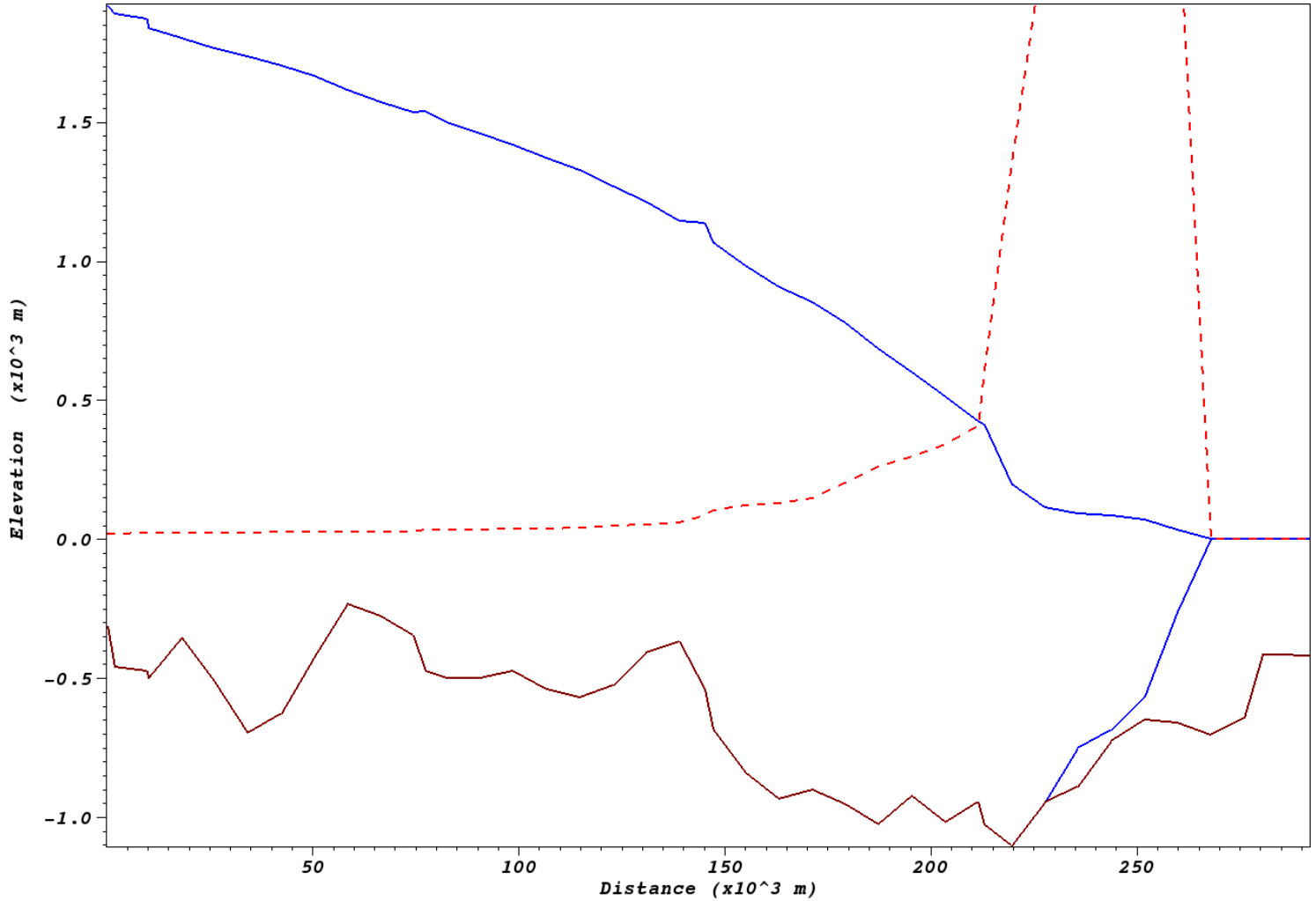
Time= 0.00 years

One example - Wilkes Basin



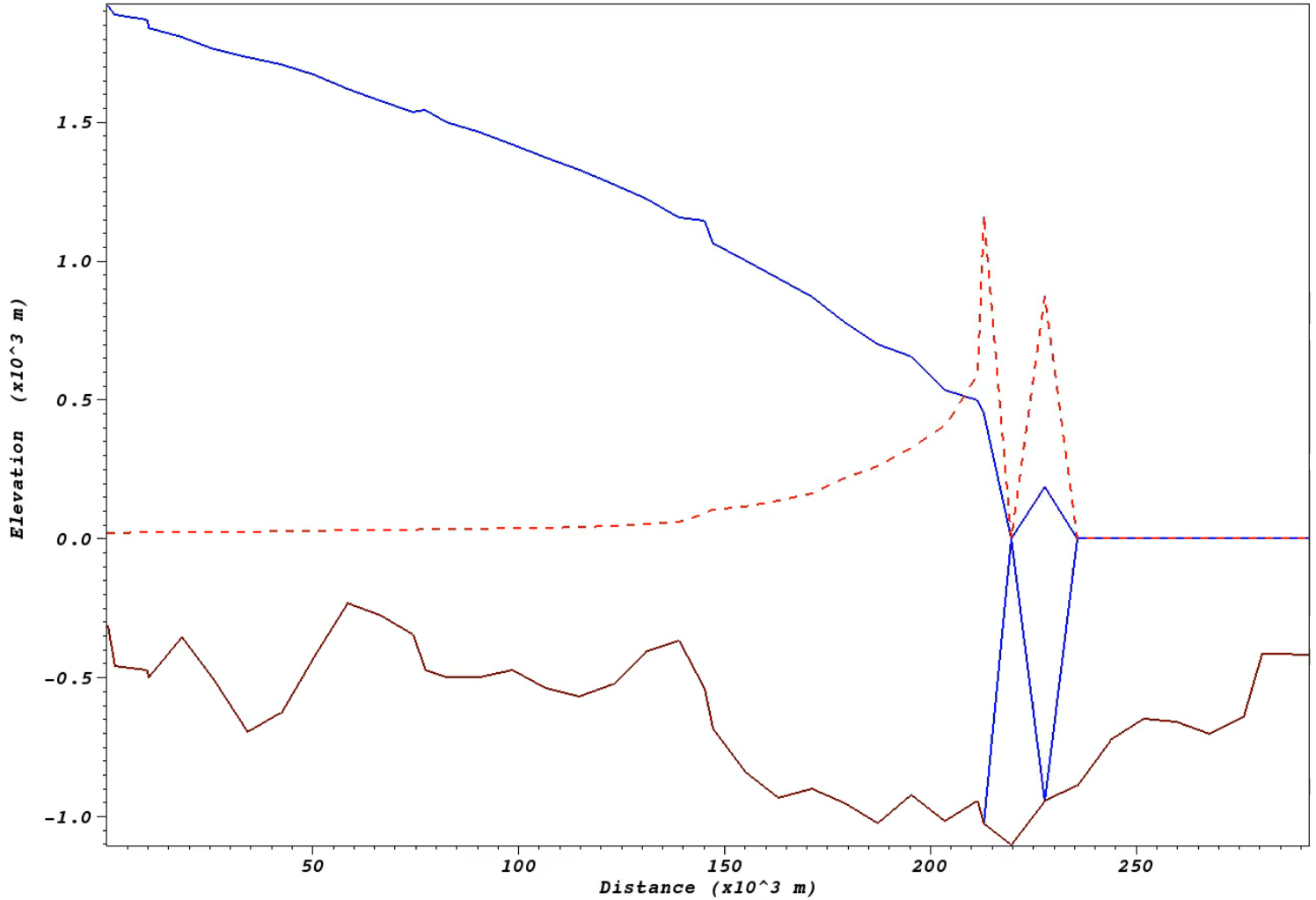
Time= 0.00 years

Wilkes Basin: 8km resolution



Time= 0.00 years

Wilkes Basin: 8km resolution



Time= 11.00 years

Conclusions

- There seems to at least be some indication that some MICI might be a result of some under-resolution.

- Hypothesis: (relatively) fine-scale ice dynamics works to prevent or destroy ice cliffs

Thank you!