# Berkeley ISICLES – *A High Performance Adaptive Ice Sheet Model*

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## Project Outline:

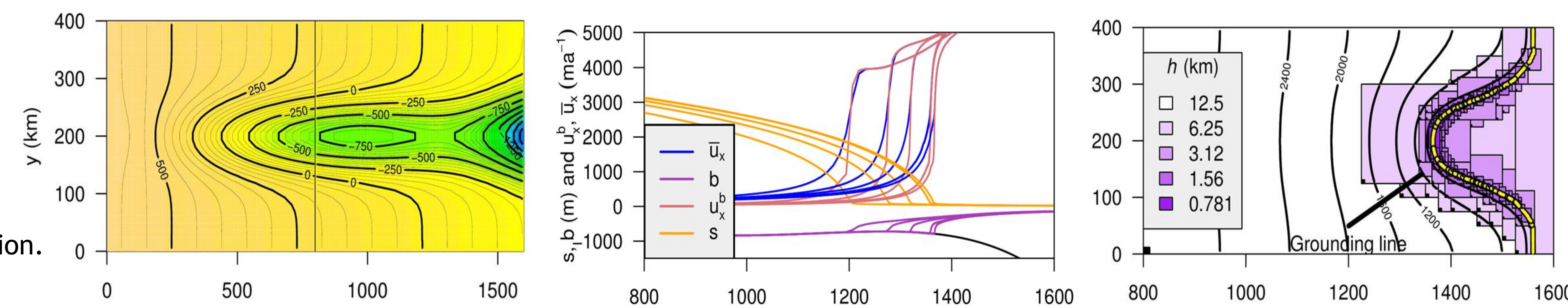
- Understanding ice sheet dynamics is essential for projections of sea level rise
- modeling capabilities at the time of the IPCC AR4 were deemed inadequate.
- Very fine resolution (better than 1 km) is needed to resolve dynamic features like grounding lines, ice streams, calving fronts -- computationally prohibitive for uniform-resolution studies of Antarctica.
- Large regions where finest resolution is unnecessary – ideal for adaptive mesh refinement (AMR).
- Project goal is to build a high-performance, scalable AMR ice sheet model for use in climate modeling.
- The Chombo AMR framework enables rapid code development and provides scalability "out of the box".

## Numerical Model: (Schoof and Hindmarsh, 2010)

- Stokes flow with nonlinear (shear-thinning) constitutive relation
- Perform asymptotic expansion in 2 parameters: $\epsilon = \frac{[h]}{[L]}, \lambda = \frac{\tau_{shear}}{\tau_{normal}}$, retaining terms of $O(\epsilon)$
- Leading order term in stress field has a simple dependence on $z$ which can be vertically integrated, allowing a 2D nonlinear elliptic solve for the horizontal velocity field rather than full 3D Stokes solve
- Can construct ice velocity field to $O(\epsilon)$ using only leading-order terms in velocity and stress fields
- Coupling vertically-integrated velocity solve with horizontal AMR results in computational efficiency

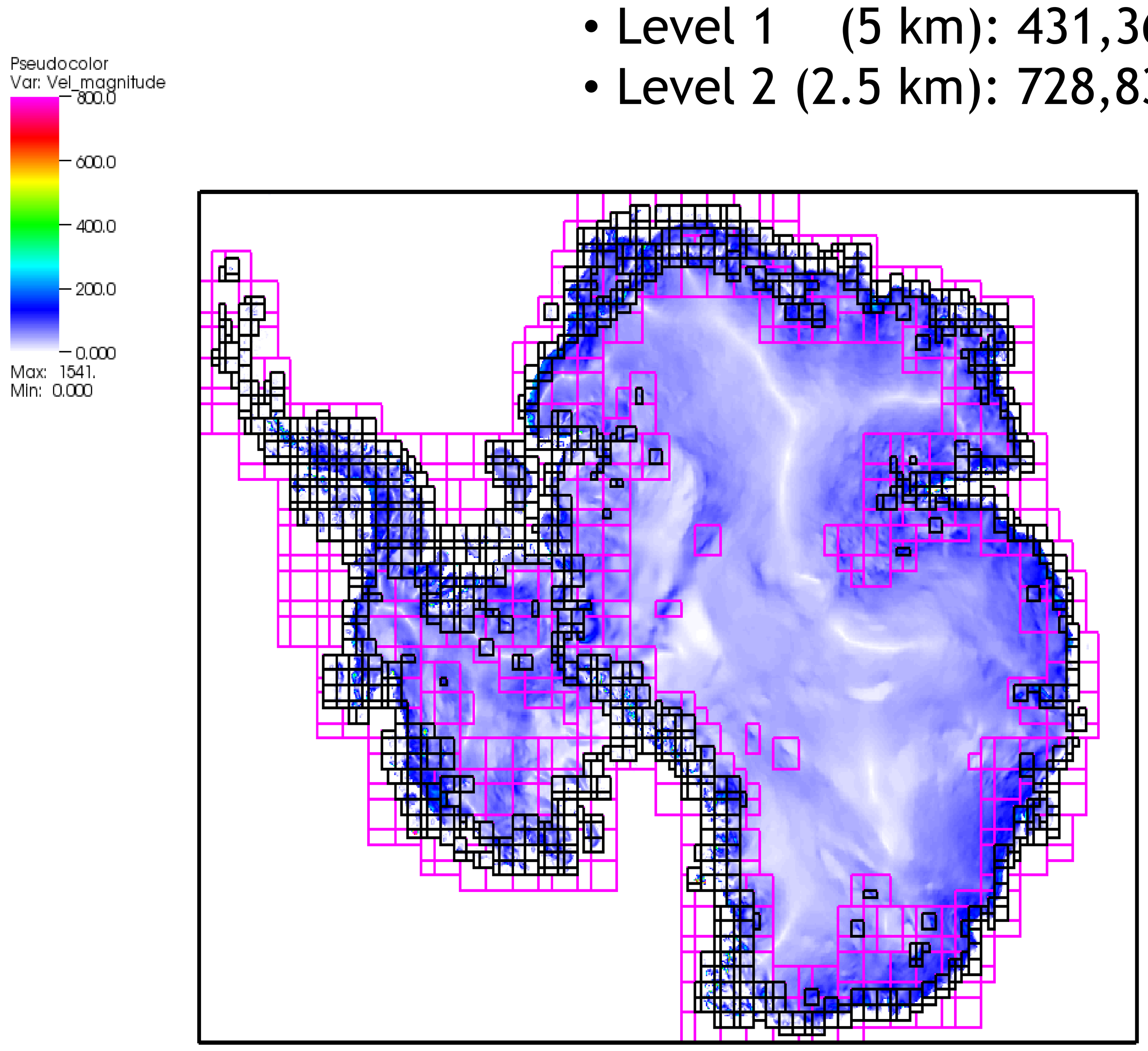
## Grounding Line Study:

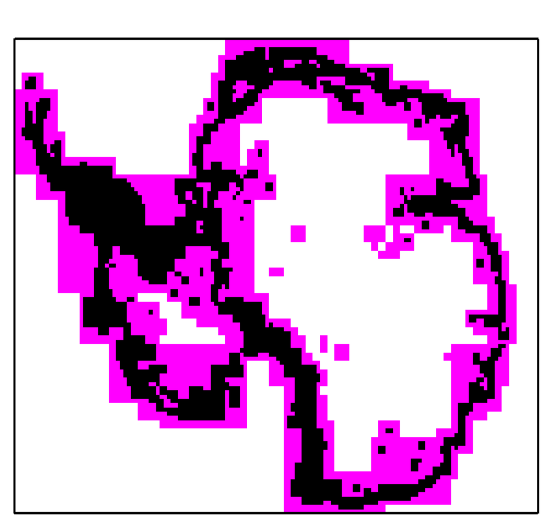
- Bedrock topography based on Katz and Worster (2010)
- Evolve initially uniform-thickness ice to steady state
- Repeatedly add refinement and evolve to steady state again
- G.L. advances with finer resolution
- Appears to require finer than 1km mesh to resolve G.L. location.

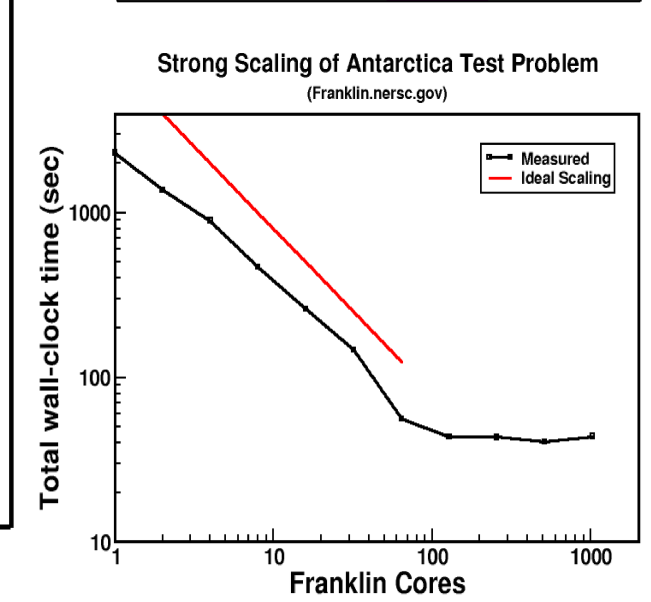



## Antarctica: 10 km base mesh with 2 refinement levels

- Level 0 (10 km): 258,048 cells (100% of domain)
- Level 1 (5 km): 431,360 cells (41.8% of domain)
- Level 2 (2.5 km): 728,832 cells (17.7% of domain)

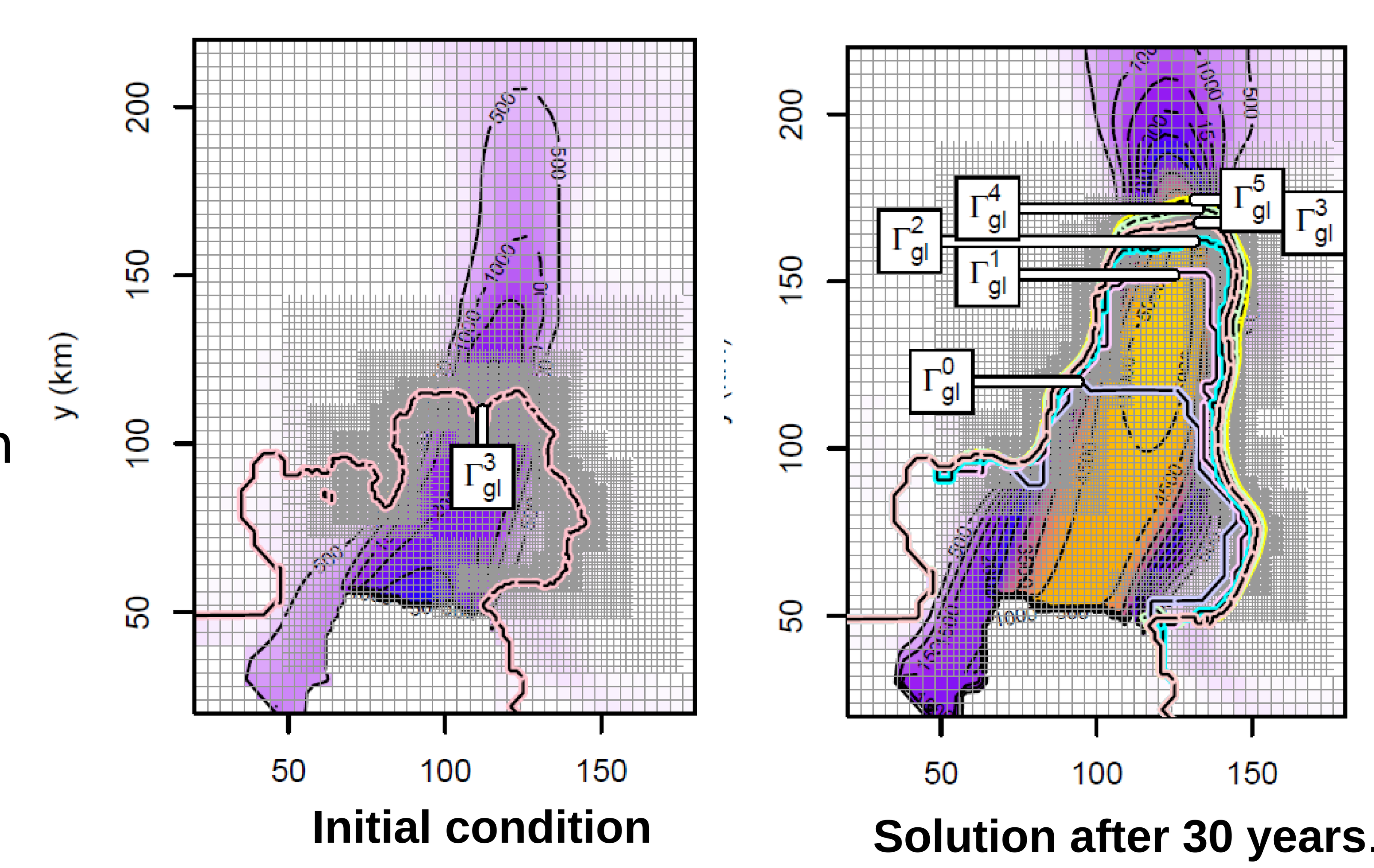





## Pine Island Glacier:

- Cornford, et al, FRISP San Diego (2011)
- PIG configuration from LeBrocq:
- Isothermal ice, A=4.0× $10^{-17}\ Pa^{-\frac{1}{3}}\, m^{-1/3} a$
- Basal friction chosen to roughly agree with Joughin (2010) velocities
- 256 km x 384 km (64 x 96 base mesh - $\Delta x = 4$km), 3 levels of refinement
- Specify melt rate under shelf
- Constant surface flux = 0.3 m/a
- Calving model and marine boundary condition at calving front
- Evolve solution with adaptive meshing
- Grounding-line location exhibits dependence on resolution




*Coloring is ice velocity, $\Gamma_{gl}$ is the grounding line. Superscripts denote number of refinements. Note resolution-dependence of $\Gamma_{gl}$*

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