PISM, a Parallel Ice Sheet Model
ARSC ID “icesheet”

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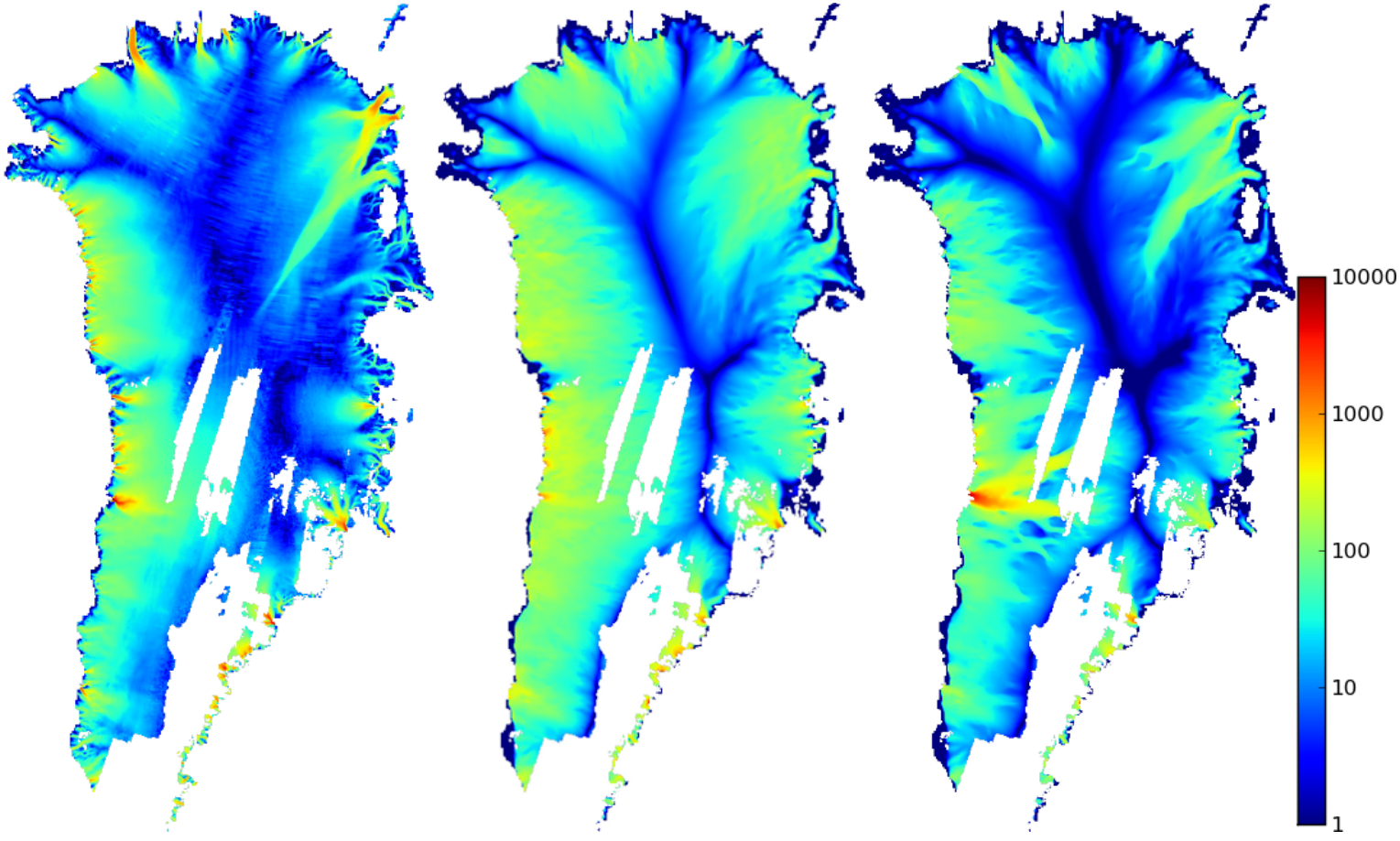
PISM = Parallel Ice Sheet Model

- `www.pism-docs.org`
- simulates the flow of the Greenland, Antarctic, and other ice sheets over time scales from a few centuries to complete ice-age cycles (100,000+ years)
- . . . and especially ice sheet dynamical response to changing climate and effect on sea level
- ice sheet = *shearing & sliding shallow layer of non-Newtonian viscous fluid*
- PISM developed from scratch at UAF, since 2003
- PISM people not on title page:
  - Craig Lingle, GI, retired
  - Jed Brown (now at ETH Switzerland)
  - Nathan Shemonski (summer 2007 ARSC intern)
  - Ben Sperisen (summer 2008 ARSC intern)

surface velocity: observed and modeled



observed

RADARSAT inSAR and speckle-tracking; average of four maps from 2000–2008; 86% area coverage

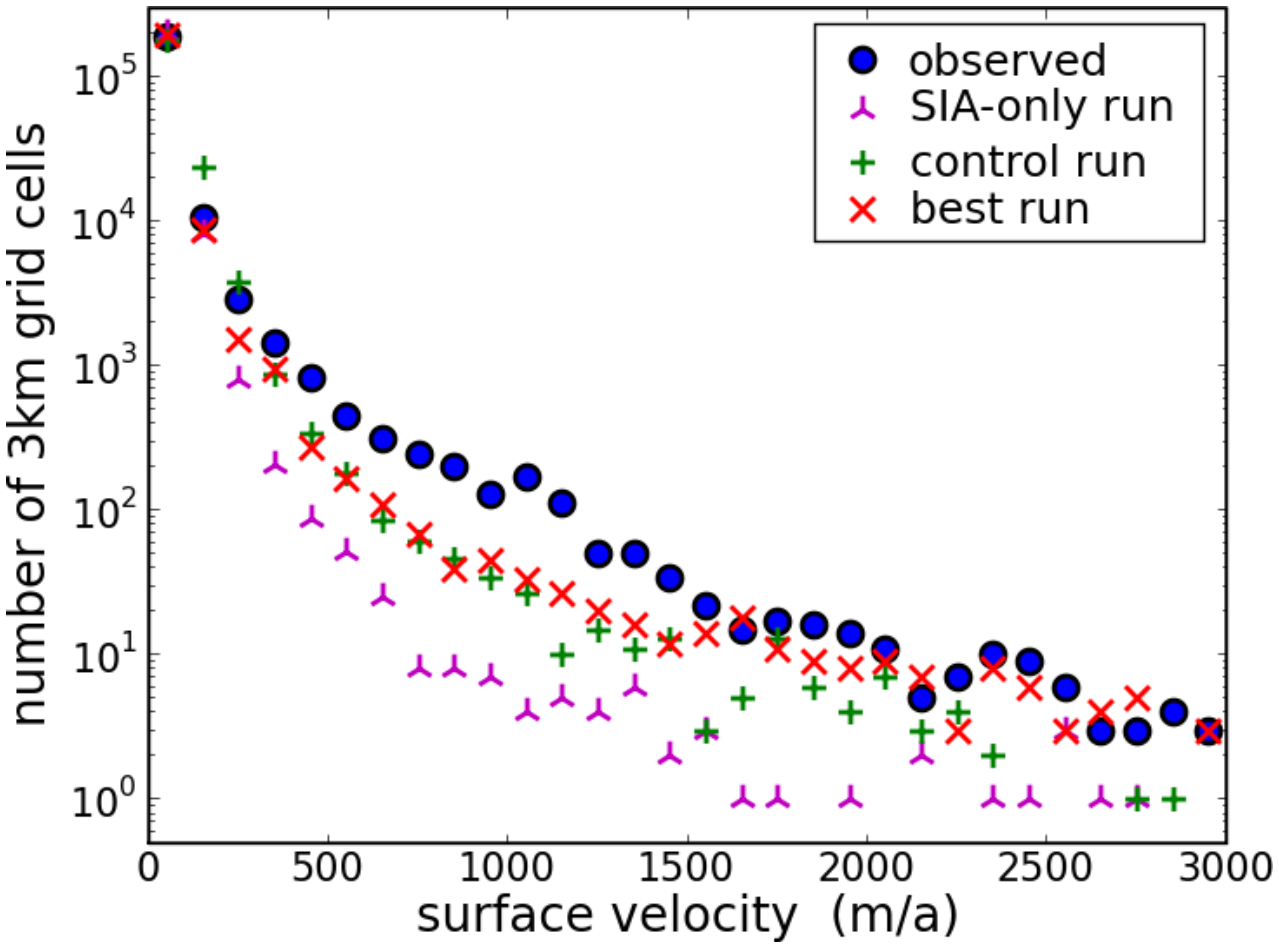
PISM model

$e = 3$ and power law sliding ($u_b \sim \tau_b^4$) and modest allowed basal water pressure

PISM model

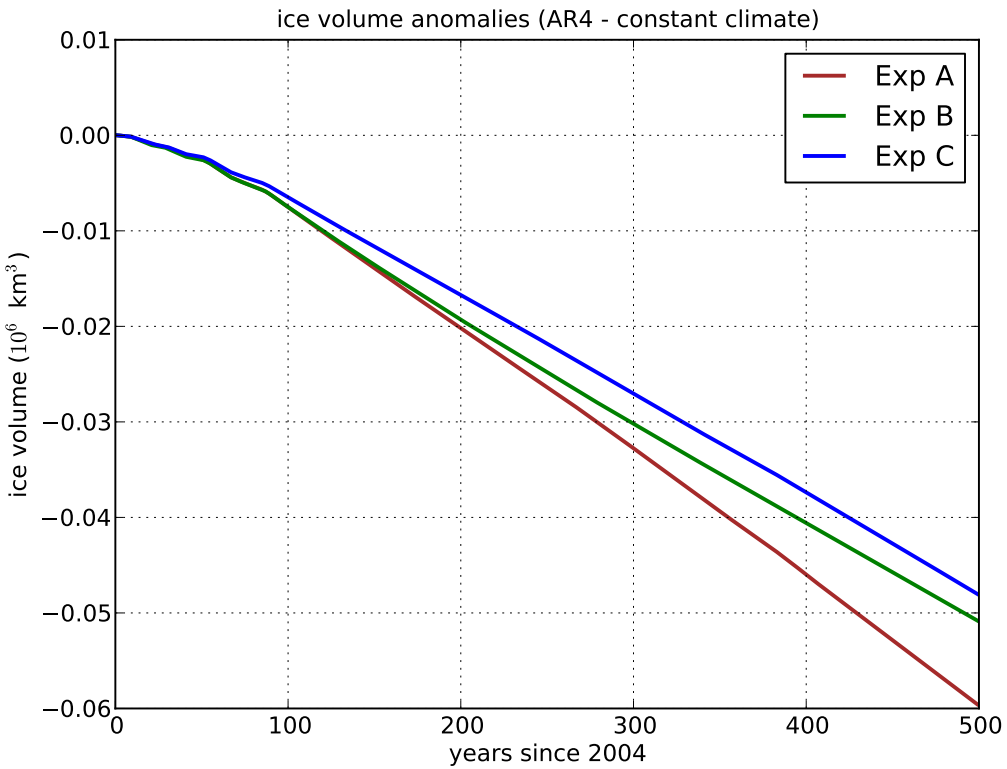
$e = 1$ and nearly-plastic sliding and high allowed basal water pressure

surface velocity: observed and modeled, cont.



- prev slide had
  - and $+$ and $\times$
- note log scale on y-axis

sea level contribution in warmer climate

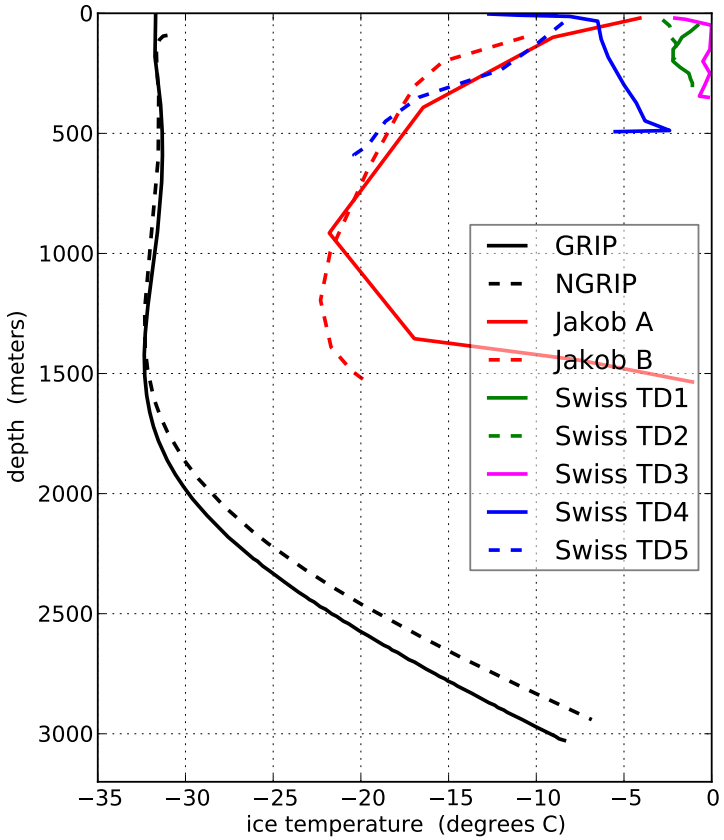


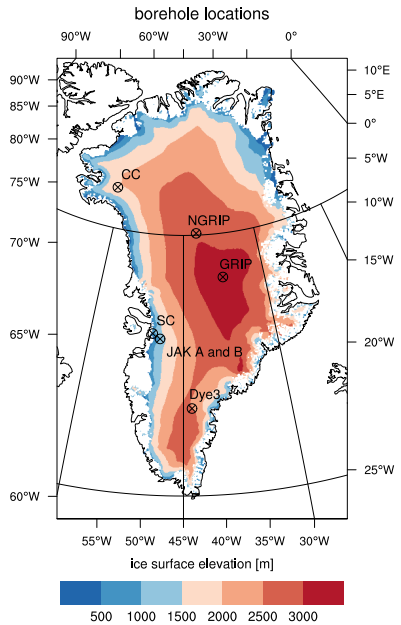
- PISM group is participating in SeaRISE assessment process,

  a community organized effort to estimate the upper bound of ice sheet contributions to sea level in the next 100–200 years

- ← modeling of Greenland in warming climates
- and also Antarctica

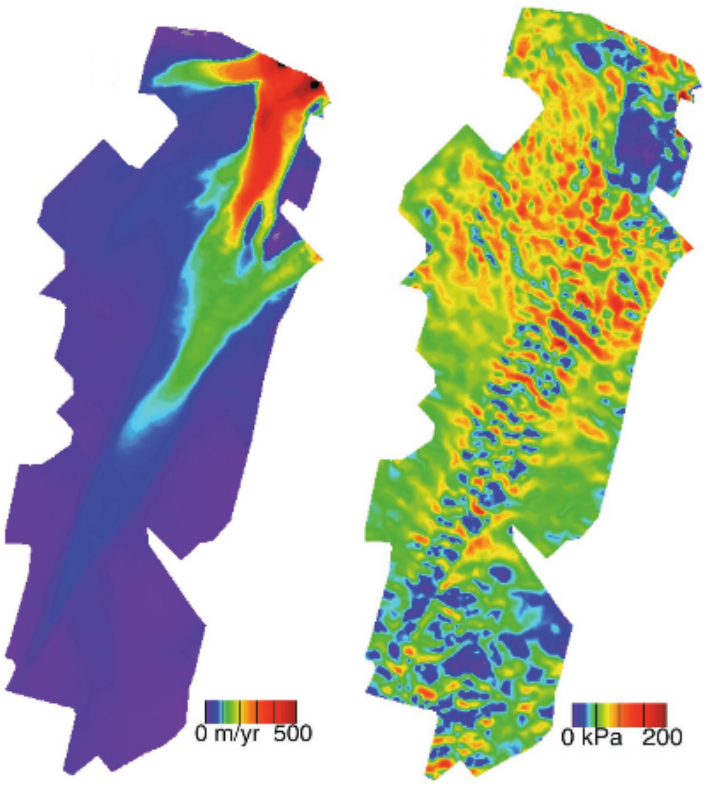
plan: evaluate PISM spin-up using measured temperatures at depth in Greenland holes/cores





- ice sheets have long memory of paleo-climate, esp. temperature which controls ice softness
- . . . so model must "spin-up" for ∼ 100,000 model years
- direct temperature measurements are: *sparse*, *biased*, and *expensive*

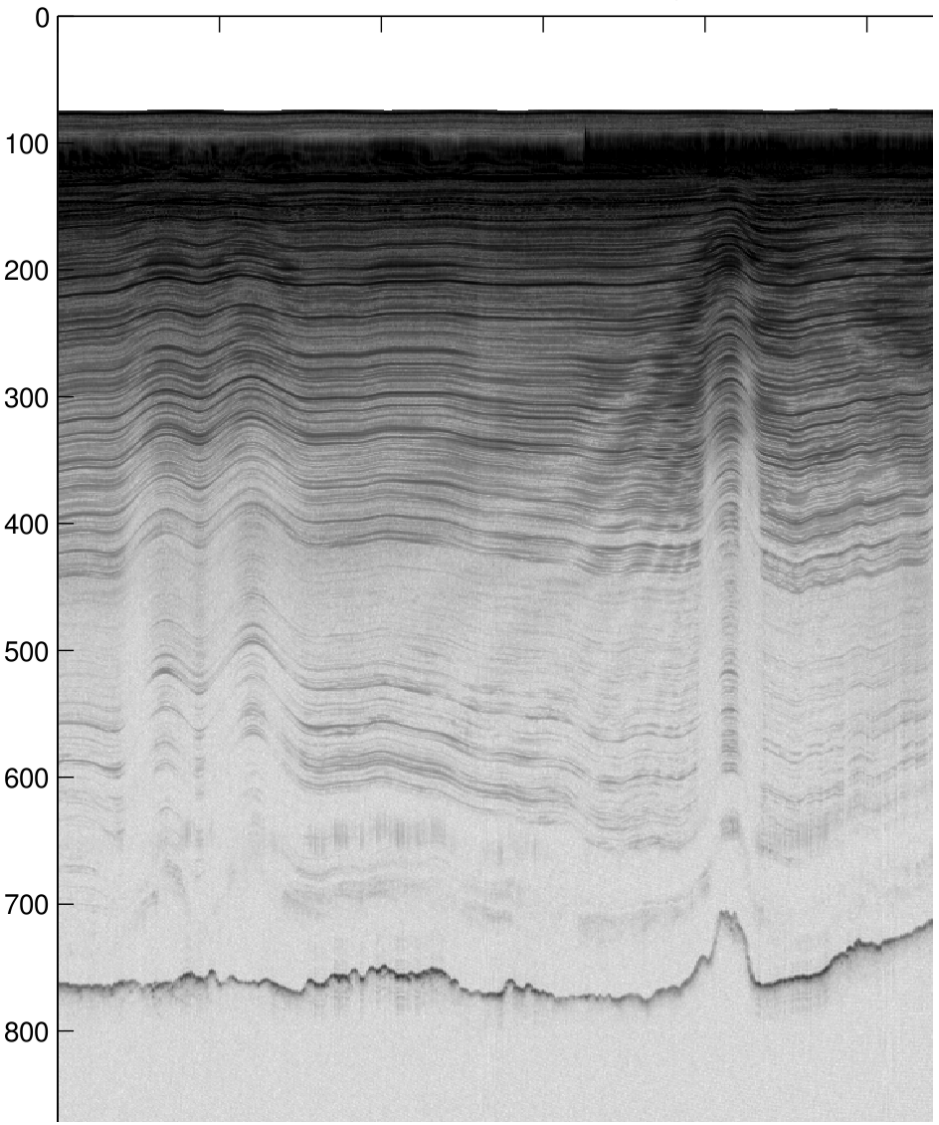
plan: use PISM to invert observed surface velocities for basal stress



Joughin et al. 2001, NE Greenland ice stream

- ice base is hard to observe
- . . . but it is critical for century-scale response to changing climate
- same equations used in PISM as "forward" model [*determine ice flow velocity from stress boundary conditions*] can be used as an "inverse" model [*determine basal shear stress from observed surface velocity*]
- already done by other groups at small spatial scale

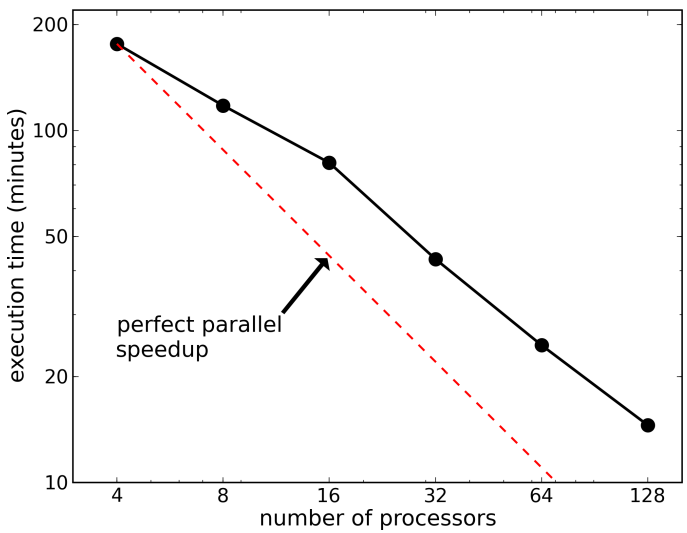
plan: use radar isochrones to evaluate PISM spin-up (and perhaps invert for prior climate)



- ice-penetrating radar can see surfaces of constant age
- e.g.: ← CReSIS 2002 flightline, NE Greenland
- isochrone = level surface of age field
- PISM is already modeling age advection problem

PISM architecture

- grid rectangular in horizontal, but unequal in vertical
- parallel computation model:
  - fields are PETSc Vecs with DA grid/topology
  - = MPI communication, *but not by-hand*
  - solving stress balance including "membrane" stresses requires PETSc KSP
  - need to use more of PETSc functionality
- parallel performance:



- runs have used up to 500 cores on pingo and midnight

libraries & languages in PISM

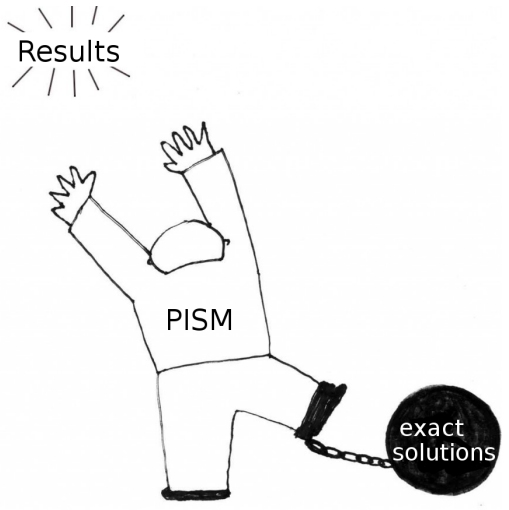
- MPI
- PETSc
- FFTW (for bed deformation component only)
- NetCDF
- subversion[1]
- doxygen
- C++ (lots of uses of derived classes)
- python & scipy (scripts for runs, pre-, and post-processing)

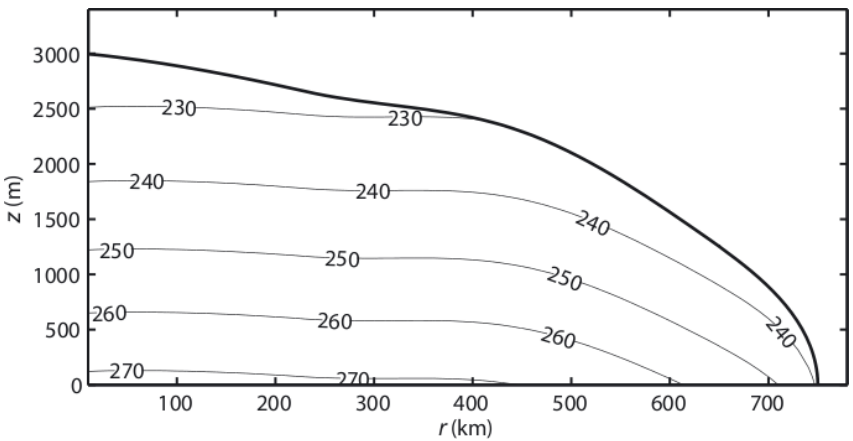
[1] get your PISM by

```
svn co http://svn.gna.org/svn/pism/trunk pism-dev
```

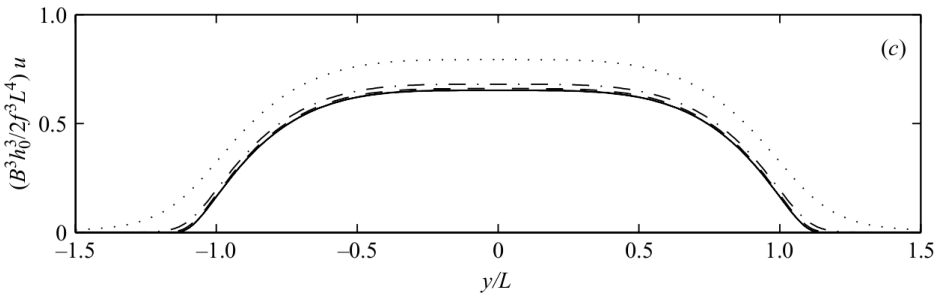
role of verification in PISM

- PISM has software unit tests
- . . . *and* a suite of exact solutions which we run as verification before every commit
- ongoing need for exact solutions to *significant coupled subsystems*,
- . . . because the numerical error on those solutions is the most sensitive and comprehensive “unit test” for that subsystem





thermocoupled, non-sliding SIA; test G in PISM



SSA with pre-determined yield stress; test I in PISM

PISM users

- Potsdam Institute for Climate Impact Research: PISM derived class is model called PISM-PIK →
- Danish Met Institute
- Max Planck Institute for Meteorology
- Inst for Marine and Atmospheric Research, Utrecht, Netherlands
- Antarctic Research Centre, Victoria University of Wellington

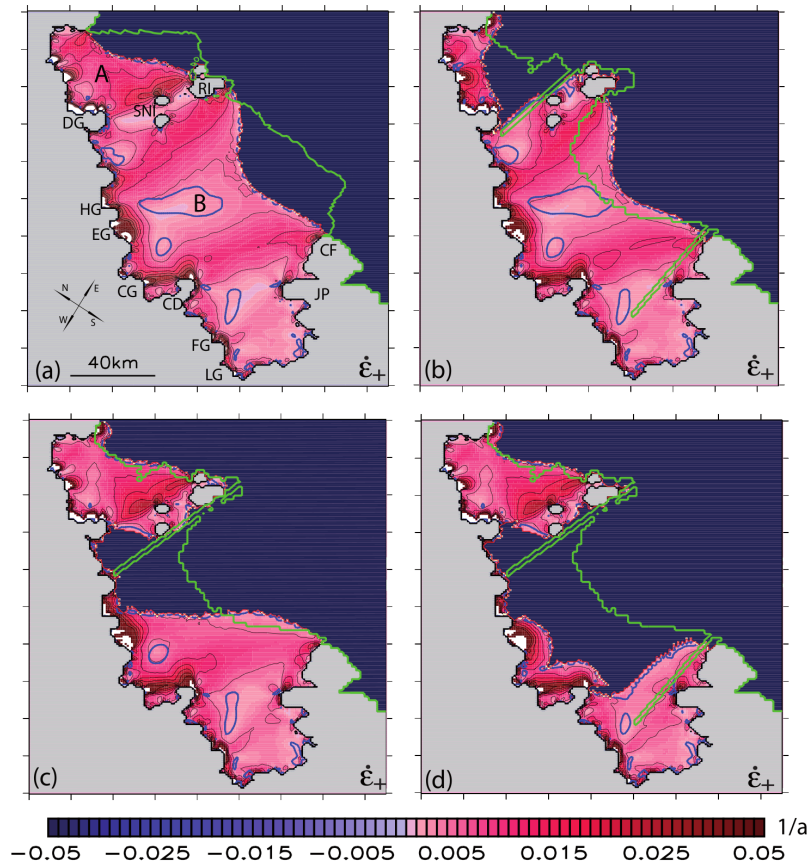
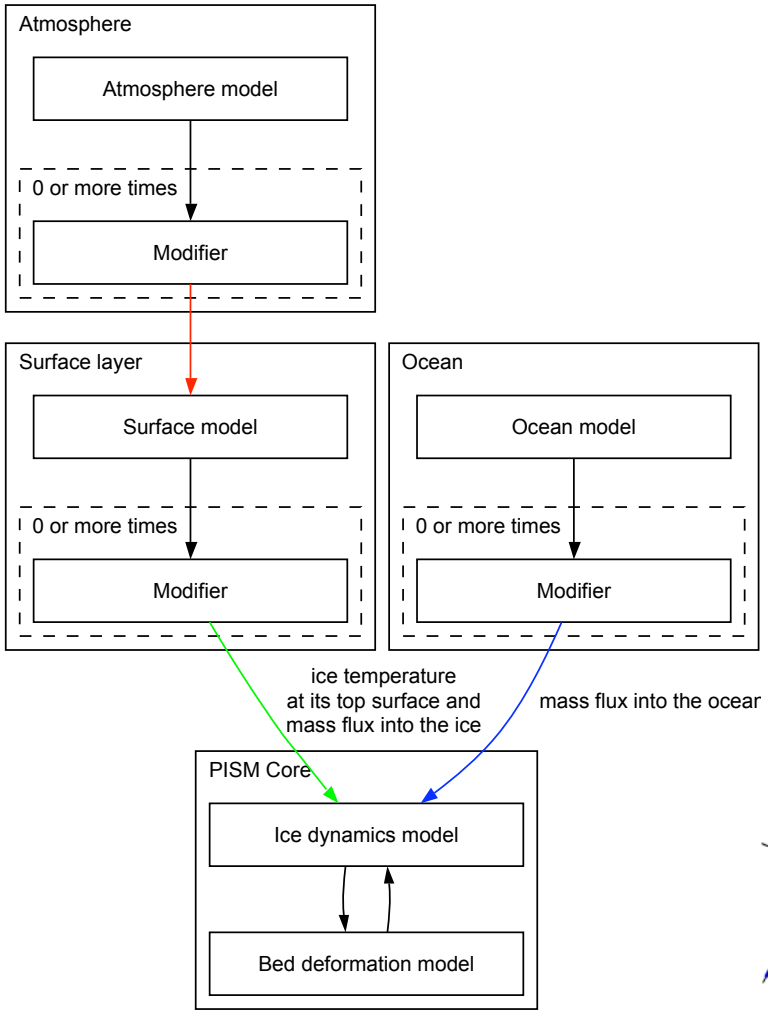


Figure 4: Simulation of multiple stable calving front position of ice shelves Larsen A and B. Each of the ice front positions are stable under the full dynamics. Different positions are

(December submission to *Science* on ice shelf calving)

PISM architecture for model coupling



- nontrivial amount of project time is spent worrying about how to couple other people's models to our ice dynamics
- . . . nonetheless we are just getting started on this