PISM, a Parallel Ice Sheet Model (stable0.3 release)

Ed Bueler[1], Andy Aschwanden[2], Daniella Della Guistina[3], Regine Hock[3,4], Constantine Khroulev[3], David Maxwell[1], and Martin Truffer[3,5]

[1]Dept of Mathematics and Statistics, University of Alaska Fairbanks, USA [2]Arctic Region Supercomputing Center, UAF
[3]Geophysical Institute, UAF [4]Dept of Geology and Geophysics, UAF [5]Dept of Physics, UAF

Model description

The Parallel Ice Sheet Model project provides an open source, fully-parallel, high-resolution ice sheet model. It has these features:

- a hierarchy of available stress balances, including shallow ice and shelf approximations, a hybrid of these [Bueler and Brown, 2009]
- verification and validation tools
- a polythermal, enthalpy-based conservation of energy scheme
- extensible coupling to atmospheric and ocean models
- complete documentation for users and developers

From the software point of view, PISM is a C++ program which

- uses PETSc for parallel numerics and MPI for interprocess communication
- reads and writes NetCDF files
- automatically converts units by using UDUNITS
- generates CF 1.4-compliant NetCDF files

Changes (compared to stable0.2)

Compared to stable0.2, the new version

- uses a polythermal, enthalpy-based energy conservation scheme [Aschwanden and Blatter, 2009]
- includes improved atmosphere, surface processes and ocean model structure
- puts all model parameters and physical constants in a configuration file which can be changed without re-compiling PISM
- has a better User's Manual
- comes with a command-line option Cheat-Sheet
- has a better PISM Source Code Browser
- supports saving scalar, 2D and 3D diagnostics at given times during the run
- allows climate forcing using spatially-varying "anomalies" (near-surface air temperature and precipitation)
- includes better meta-data handling
- can be stopped and restarted without affecting results of a run
- has more software tests (including regression tests)
- has an automatic vertical grid extension mechanism
- performs area and volume calculations using WGS84 datum to correct projection error
- makes the computation of the age of the ice optional, for efficiency
- has easier-to-extend source code

Supported systems

PISM is known to work on a variety of systems:

- workstations running different flavors of Unix, GNU/Linux and Mac OS X,
- supercomputers such as Cray XT5, Blue Gene and Sun Opteron clusters.

PISM is ready to use existing data

- PISM uses NetCDF as the input and output format, making it easy to set up modeling runs.
- For instance, only a few meta-data adjustments are necessary to use data provided by the SeaRISE project.
- Three online "worked examples" at right, plus several more examples in the *User's Manual*, show these techniques.

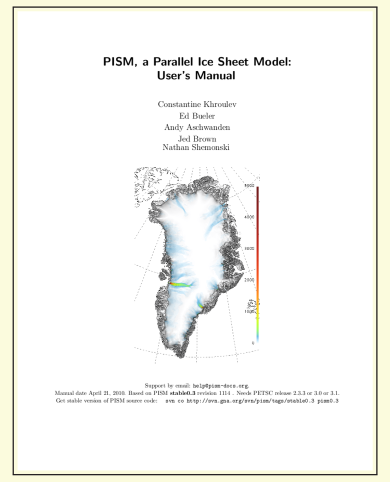
PISM works with a range of pre- and post-processing tools

Using NetCDF and following CF Conventions means that PISM users have many data analysis, pre- and post-processing and visualization tools to choose from:
NetCDF Operators (NCO), *Climate Data Operators (CDO)*, *Unidata IDV*, plotting libraries such as *PyNGL* and *Matplotlib Basemap Toolkit*, *Panoply* and others.

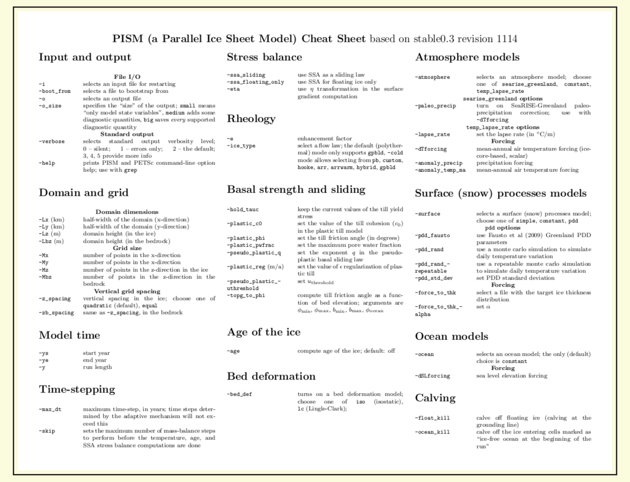
Documentation

PISM stable0.3 documentation includes

a new website



a complete User's Manual



and a Cheat Sheet

SeaRISE-Greenland "worked example": Getting started in the User's Manual

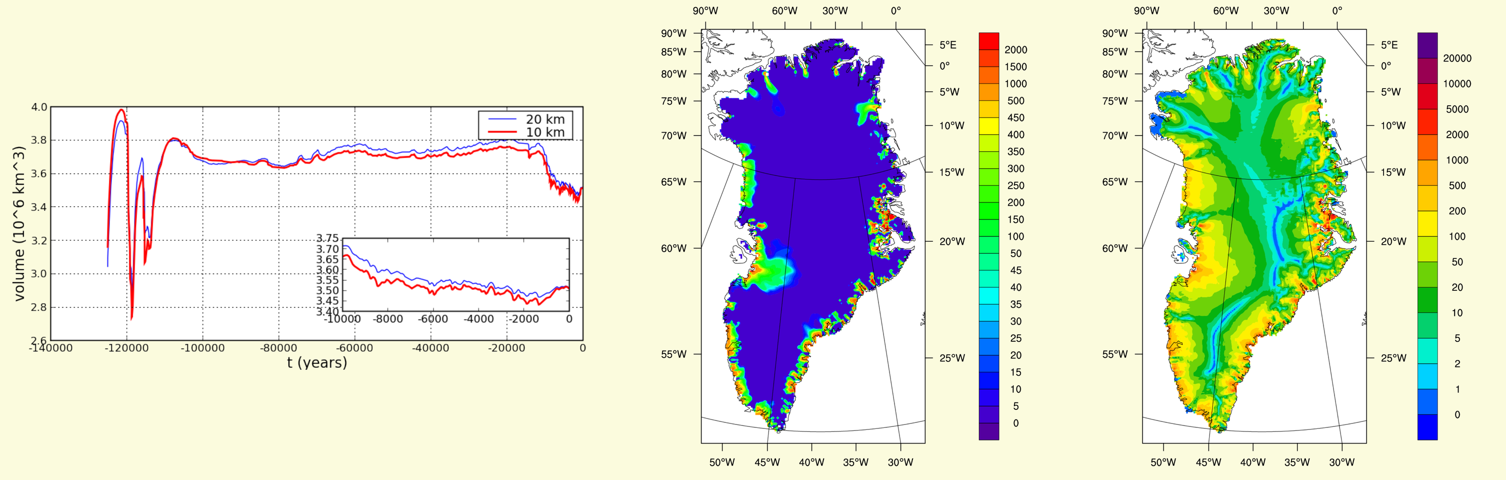
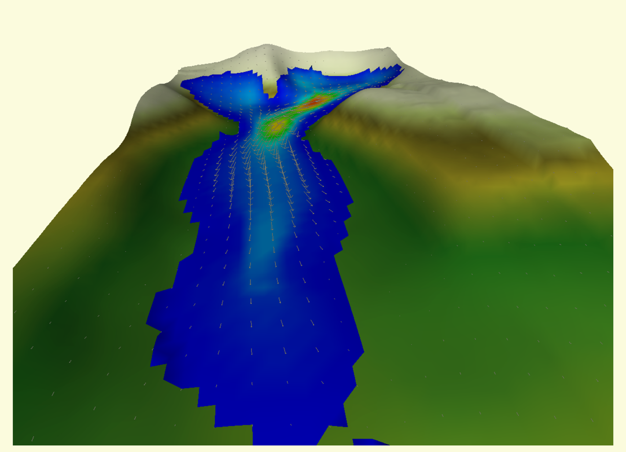


Figure: Ice volume time-series from 20km and 10km runs (left), basal sliding velocity (m/year, center) and ice velocity at the ice surface (m/year, right)

Störglaciaren "worked example"



We have applied PISM to model Störglaciaren, Sweden, a small valley glacier with a rich observational record [e.g. Jansson and Pettersson, 2007]. The model uses the hybrid SIA+SSA stress balance with polythermal thermodynamics and a 40 m grid. A version of this model is available as a "worked example", with online materials.

The figure on the left shows the modeled ice surface velocity, from 0 to 55 m/a, at the ice surface draped over topography.

SeaRISE-Antarctica demo version, a "worked example"

One worked example, available as a demonstration for users, is based on SeaRISE-Antarctica data (dev1.0 version; [Le Brocq et al., 2010]). (This is not a SeaRISE contribution at this time.) The figures below show results from a preliminary spin-up with no basal sliding, and allowing the grounding line to advance to the location of the present calving front. PISM-PIK would allow full marine ice sheet behavior.

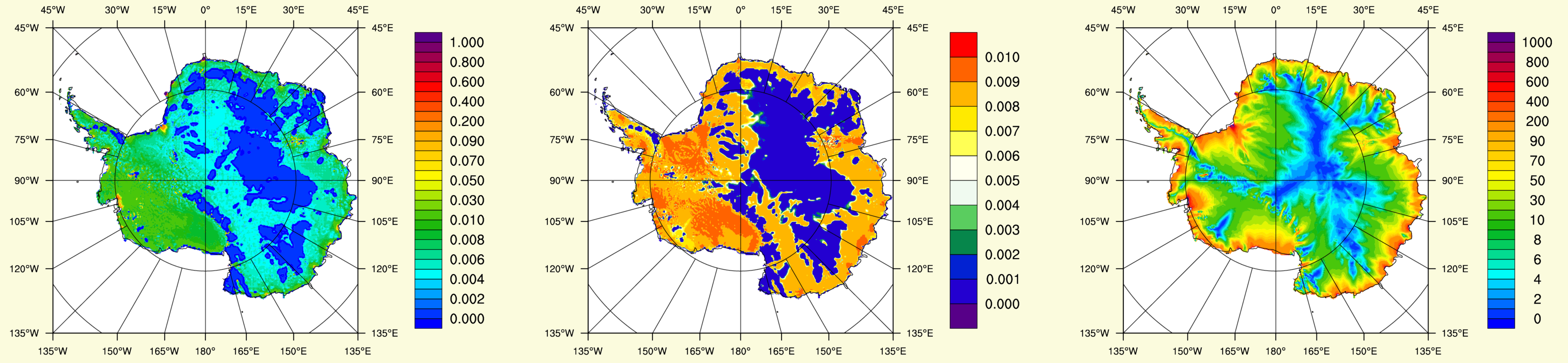


Figure: Basal melt rate (left; m/a), liquid fraction at 13 m above the base (center) and ice velocity at the ice surface (right) in a polythermal, enthalpy-based model for the Antarctic ice sheet at 10km resolution.

Ongoing Work and Future Plans

- integrate inversion techniques [e.g. Maxwell et al., 2008] with current forward SIA+SSA hybrid model to initialize basal strength maps
- couple PISM to regional and global climate models
- merge with marine ice sheet modeling improvements in PISM-PIK (see poster XY352)
- implement new stress balances including Blatter-Pattyn [Blatter, 1995] and alternative SIA+SSA hybridization schemes
- ongoing attention to PISM performance, including improvements to two current PISM strengths:
  - parallel scalability
  - robustness over real-world input data

References

A. Aschwanden and H. Blatter. Mathematical modeling and numerical simulation of polythermal glaciers. *J. Geophys. Res.*, 114, 2009. F01027, doi:10.1029/2008JF001028.

H. Blatter. Velocity and stress fields in grounded glaciers: a simple algorithm for including deviatoric stress gradients. *J. Glaciol.*, 41(138):333–344, 1995.

E. Bueler and J. Brown. Shallow shelf approximation as a "sliding law" in a thermodynamically coupled ice sheet model. *J. Geophys. Res.*, 114, 2009. F03008, doi:10.1029/2008JF001179.

P. Jansson and R. Pettersson. Spatial and temporal characteristics of a long mass balance record, Störglaciaren, Sweden. *Arctic, Antarctic and Alpine Research*, 39(3):432–437, 2007.

Anne M Le Brocq, Antony J Payne, and Andreas Vieli. Antarctic dataset in netcdf format. 2010. URL `http://doi.pangaea.de/10.1594/PANGAEA.734145`.

D. Maxwell, M. Truffer, S. Avdonin, and M. Stuefer. An iterative scheme for determining glacier velocities and stresses. *J. Glaciol.*, 54(188):888–898, 2008.

Acknowledgements

E. B., R. H., C. K., D. M and M. T. are supported by NASA grant NNX09AJ38G.

PISM Support

Visit `www.pism-docs.org` and e-mail `help@pism-docs.org` if you have questions about PISM.

This work was supported by a grant of resources from the Arctic Region Supercomputing Center at the University of Alaska Fairbanks as part of the Department of Defense High Performance Computing Modernization Program.