Update on CISM in CESM2

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Outline

- Update on CISM 2.1, the dynamic ice sheet component of CESM2
- Some standalone model results for the Greenland ice sheet
- Update on the Ice Sheet Model Intercomparison Project for CMIP6 (ISMIP6)

Community Ice Sheet Model, version 2

CISM 2.0 was released in Oct. 2014:

- Replaced CISM1 (shallow-ice model using older Glimmer code) as the ice sheet component of CESM
- Available at **http://oceans11.lanl.gov/cism/**; git repo at **https://github.com/cism**
- Parallel dynamical core (Glissade) with a suite of velocity solvers (including shallow-shelf, L1L2, Blatter-Pattyn)

CISM 2.1 is almost ready for release

- Efficient depth-integrated viscosity approximation (DIVA; Goldberg 2011)
- New options for basal sliding

Model description paper (Lipscomb et al., 2016) in prep for GMD

Goals for Greenland simulations

For CESM2 we plan to run Greenland Ice Sheet simulations

- with higher-order dynamics
- at moderately high resolution (~4 km)
- on century-to-millennial time scales (required to equilibrate the ice sheet and choose optimal parameters)
- under past, present and future forcing
  - SLICE project: (Bette Otto-Bliesner et al.): Simulate Greenland during the Pliocene, Last Interglacial and future to ~3000

CISM must be **robust**, **efficient** and **accurate** for these Greenland simulations.

Greenland initMIP experiments

- Informal first phase of ISMIP6; entry card for later activities
- Goal is to compare and evaluate initialization methods used by the community
  - Initialization can have a large effect on projections
- Useful for flushing out problems that could arise during coupled climate experiments
  - Use parameter settings appropriate for long spin-ups and paleoclimate simulations

initMIP: Experimental setup

- Initialize to present day with method of choice
- Run two forward experiments
  - control run (**ctrl**)
  - prescribed schematic SMB anomaly (**asmb**)
- Paper (led by Heiko Goelzer) by end of 2016

Requirements:

- Model has to be able to prescribe an SMB anomaly
- No adjustment of SMB due to geometric changes in forward experiments
- No bedrock adjustment in forward experiment
- All other forcing constant

initMIP: CISM simulations

Model configuration

- Glissade dycore, Depth-Integrated Velocity Approximation (DIVA)
- Pseudoplastic basal sliding law (from PISM); small number of tunable parameters
- Immediate calving of floating ice

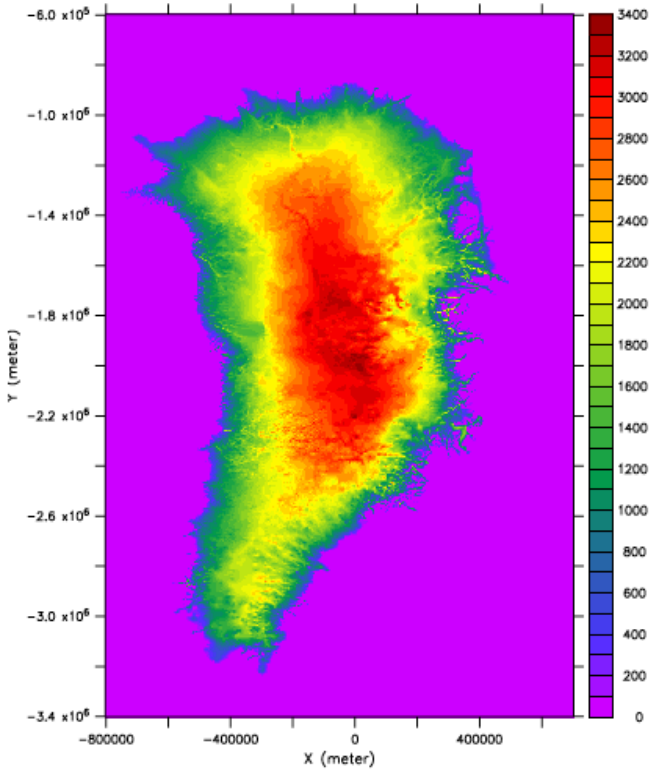
Forcing

- SMB and surface temperature from RACMO2 climatology, 1961-1990
- SMB = -2 m/yr beyond RACMO2 ice sheet mask (working on upgrade)
- Uniform basal heat flux (0.05 W/m^2)

Spin-up

- Start with "observed" bed topography and thickness (Morlighem mass-conserving bed) and idealized temperature profile
- Run for 20,000 years (dt = 0.2 yr) to quasi-equilibrium
  - ~1000 simulation years per wall-clock hour on LANL Wolf (128 cores)

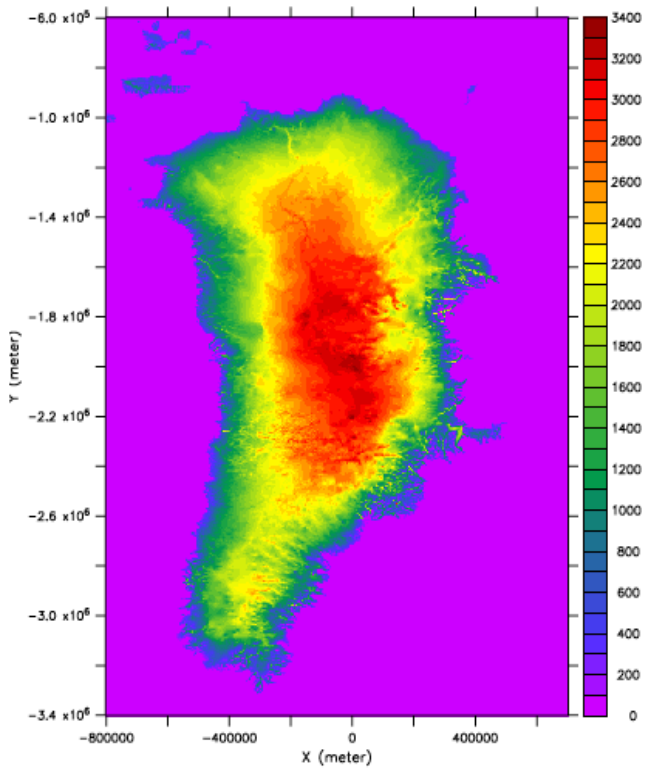
initMIP: CISM spin-up



Observed ice thickness (m)

Area = 1.78 x 10^6 km^2

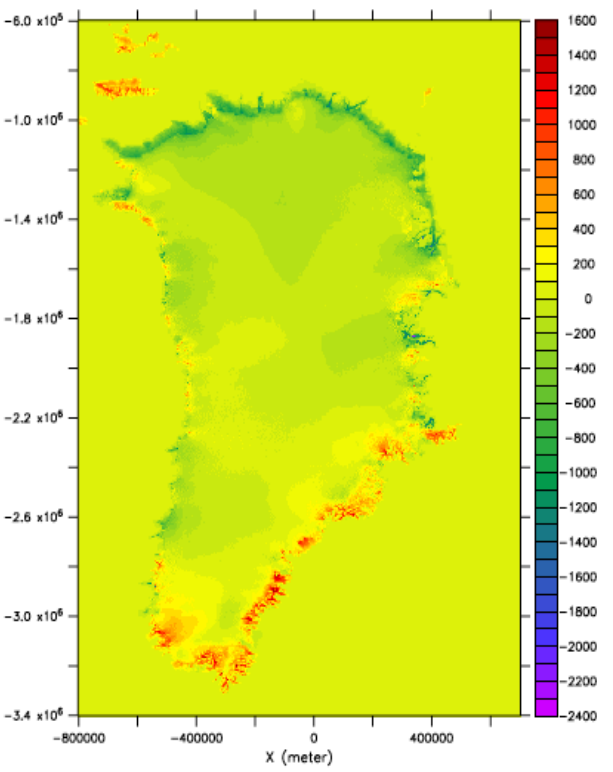
Volume = 2.96 x 10^6 km^3



Model ice thickness (m) after 20 ka CISM spin-up

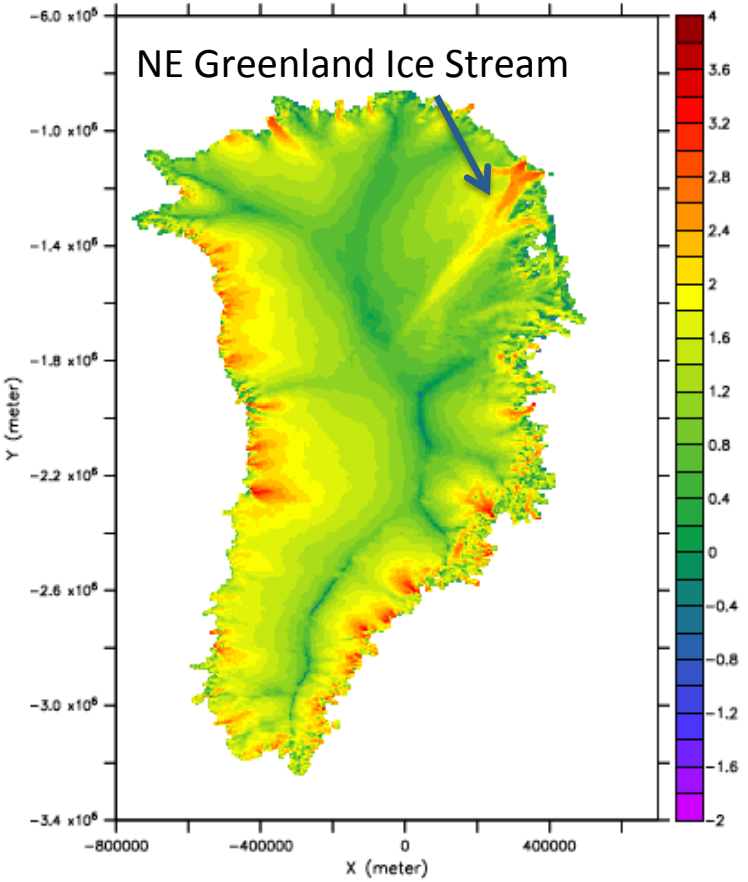
Area = 1.65 x 10^6 km^2

Volume = 2.90 x 10^6 km^3



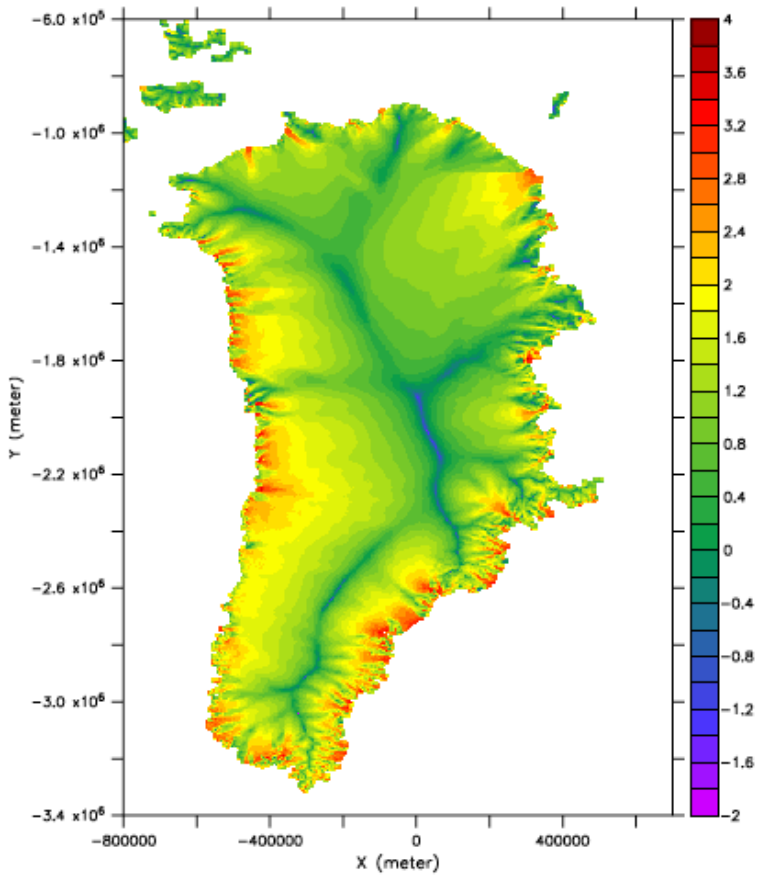
Model minus observed thickness (m)

initMIP: CISM spin-up



$\log(v_{sfc})$ (m/yr)

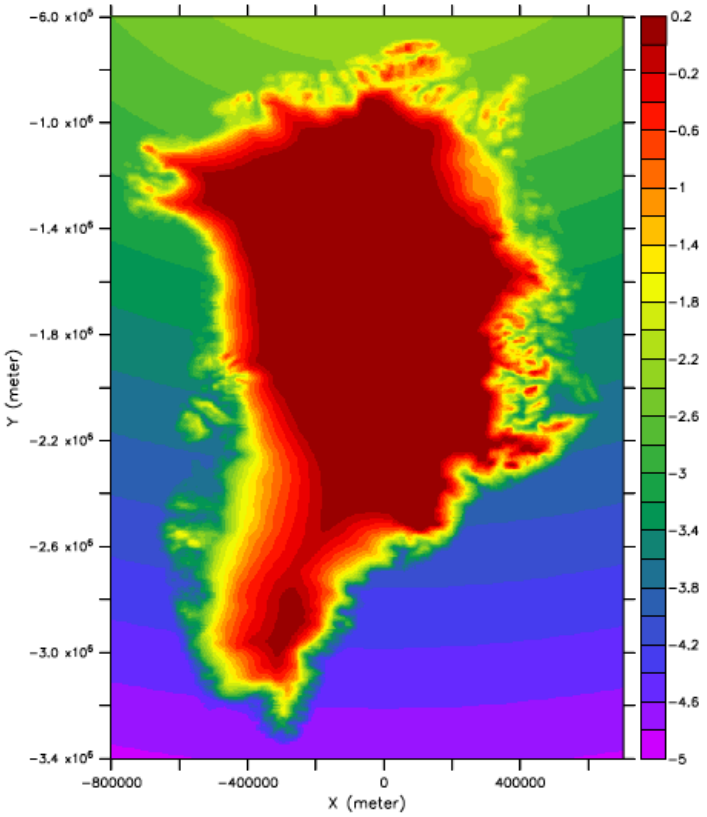
Observed surface ice speed



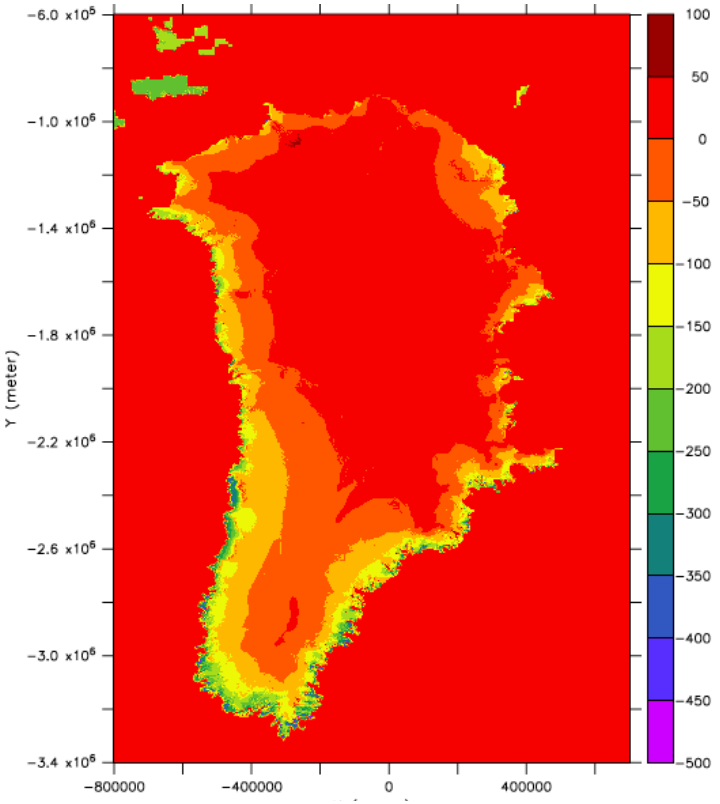
$\log(v_{sfc})$ (m/yr)

CISM ice speed after 20 ka spin-up

initMIP: CISM with SMB anomaly



SMB anomaly (m/yr)

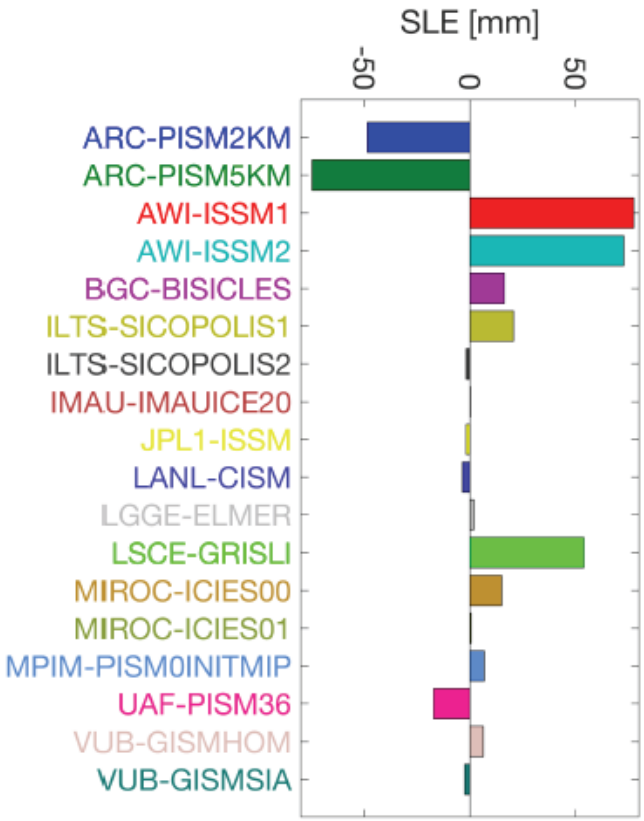


Thickness difference (m) after 100 yr, anomaly minus control

Control ice mass after 100 yr = 2.664 x 10^6 Gt
Anomaly ice mass after 100 yr = 2.616 x 10^6 Gt
Difference = 48 x 10^3 Gt = 13 cm SLR

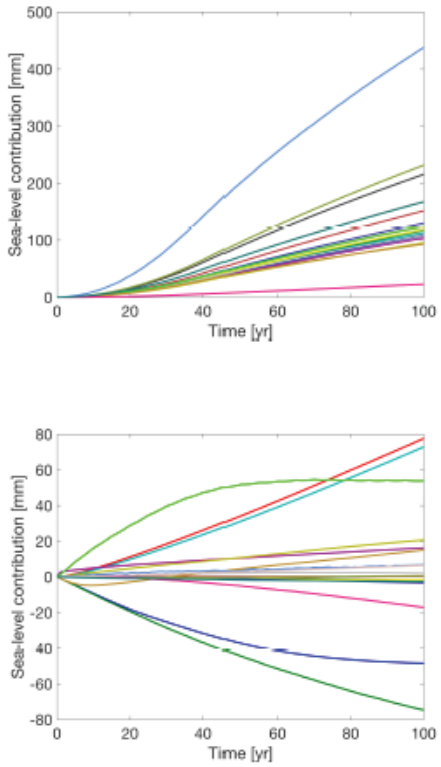
initMIP: Forward experiments

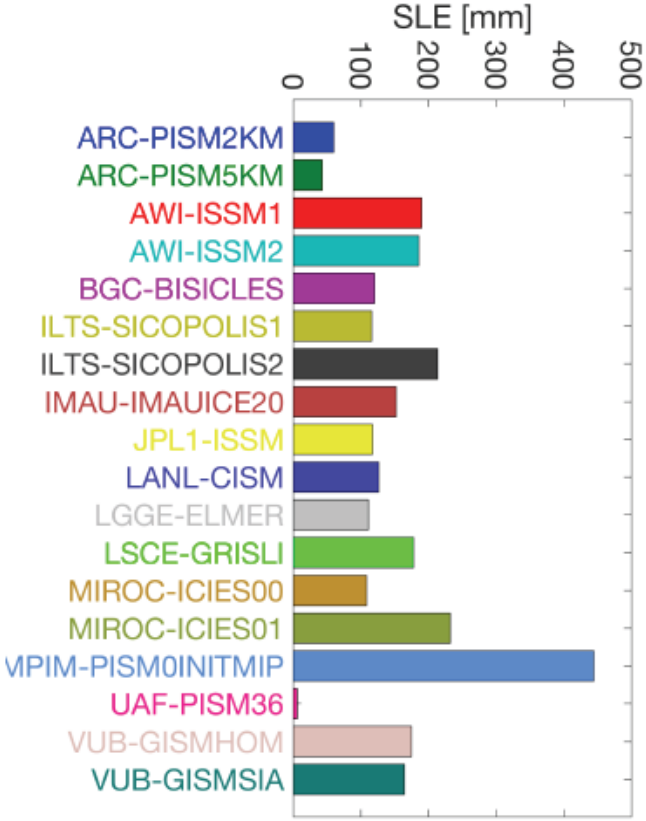
(preliminary results for EGU 2016)



ctrl

Courtesy of H. Goelzer





asmb - ctrl

Left: Centennial background trend in sea-level rise (mm) due to model drift

Right: Simulated sea-level contribution (mm) as the difference between forced and unforced experiments

Ice Sheet Model Intercomparison Project for CMIP6

S. Nowicki (USA), T. Payne (UK), E. Larour (USA)

A. Abe Ouchi (Japan), H. Goelzer (Belgium), J. Gregory (UK)

W. Lipscomb (USA), H. Seroussi (USA), A. Shepherd (UK)

What is ISMIP6?

- ISMIP6 is a targeted activity of the Climate and Cryosphere (CliC) project of the World Climate Research Program (WCRP).
- *Primary goal*: To estimate past and future sea level contributions from the Greenland and Antarctic ice sheets, along with associated uncertainty
- *Secondary goal*: To investigate feedbacks due to dynamic coupling between ice sheet and climate models, and impacts of ice sheets on the Earth system
- The experimental design uses and augments the existing CMIP6 DECK experiments, building on the ice2sea, SeaRISE and COMBINE efforts.
- See Nowicki et al. (2016, GMD) for details.

Experimental design for ISMIP6

1. **Existing CMIP experiments** to be analyzed in terms of ice sheet forcing

2. **Standalone ice sheet experiments** based on CMIP model output to estimate past and future sea level rise, and explore uncertainty due to ice sheets

3. **Coupled AOGCM-ISM experiments** to explore impacts and feedbacks due to ice sheets

CMIP6 exp to be used by ISMIP6 (all AOGCM)

- Pre-industrial control
- AMIP
- 1% per yr CO_2 to 4xCO_2
- Abrupt 4xCO_2
- CMIP6 Historical Simulation
- ScenarioMIP RCP8.5/SSP5x (up to year 2300)
- Last Interglacial PMIP

Standalone ISMIP6 exp (ISM only)

- ISM control
- ISM for last few decades (AMIP)
- ISM for the historical period
- ISM forced by 1% per yr CO_2 to 4xCO_2
- ISM for 21st / 23rd century (RCP8.5/SSP5x)
- ISM for Last Interglacial
- ISM specific experiments to explore uncertainty

New proposed ISMIP6 exp (coupled AOGCM-ISM)

- Pre-industrial control
- 1% per yr CO_2 to 4xCO_2
- Scenario RCP8.5/SSP5x (to year 2300)

ISMIP6 Participants

Climate Modeling Centers:

CESM (USA)
CNRM-CM (FR)
EC-Earth (SWE + 9EU)
GISS (USA)
INM (RU)
IPSL (FR)
MIROC-ESM (JP)
MPI-ESM (DE)
UKESM (UK)

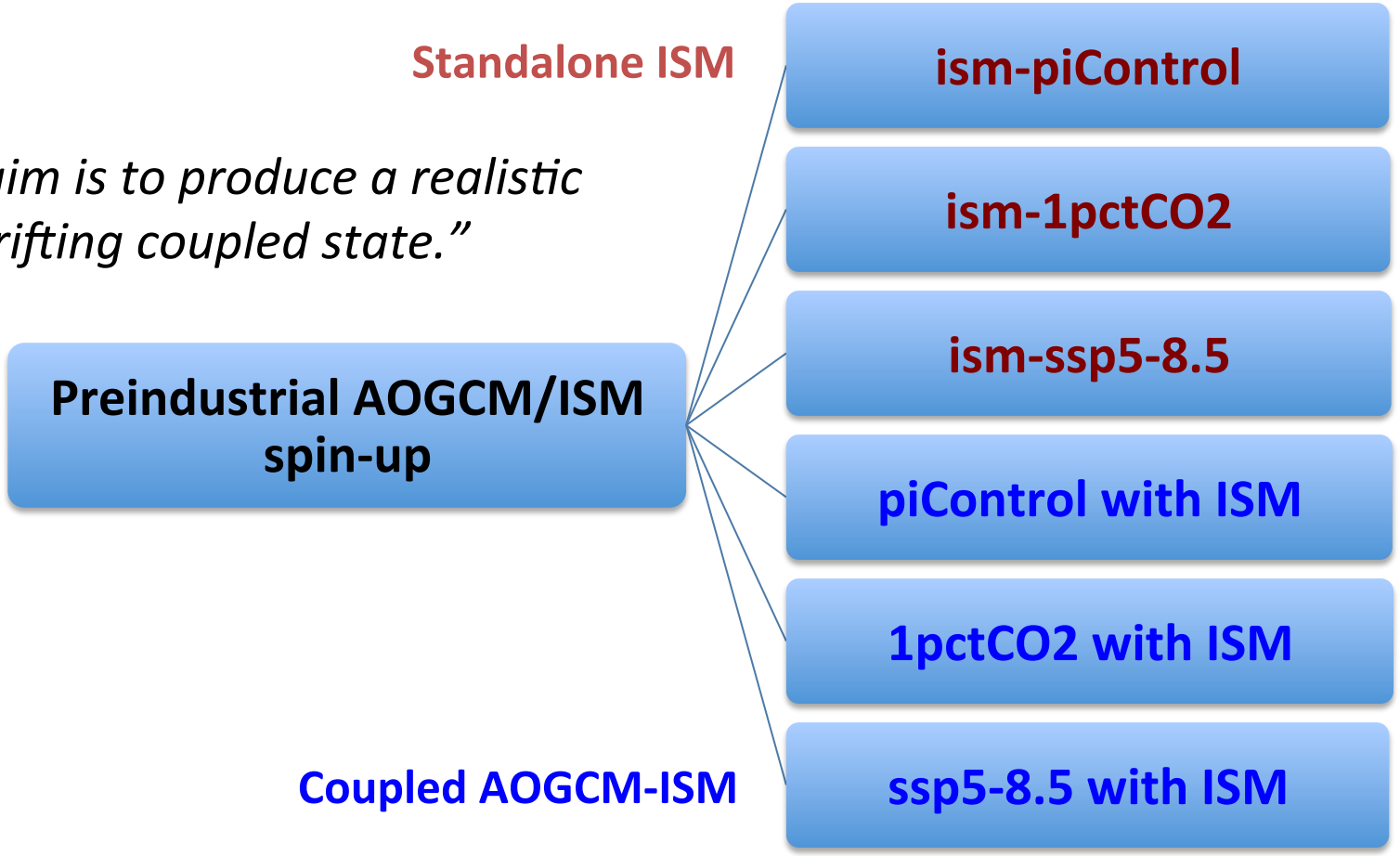
Ice Sheet Models (and hopefully more):

BISICLES (UK + USA)
CISM (USA)
Elmer/ICE (FI + FR + JP)
GISM (BE)
GRISLI (FR)
IcIES (JP)
ISSM (USA + DE)
MPAS-LI (USA)
PennState (USA)
PISM (USA, DE)
PISM-PIK (DE)
SICOPOLIS (JP)
UMISM (USA)

More information:
http://www.climate-cryosphere.org/activities/targeted/ismip6

Simulations with ice sheets

"The aim is to produce a realistic non-drifting coupled state."



Spin-up

Method 1:

- Spin up and tune the ISM as desired.
- Couple the ISM to the AOGCM and run to quasi-equilibrium, applying the SMB from the AOGCM.
  - Will likely require asynchronous coupling
  - Modest SMB biases in the climate model can lead to large deviations of the ice-sheet geometry from present day. This changes the sensitivity to climate change.

Method 2:

- Spin up the ISM using the "observed" SMB (e.g., regional model or paleo reconstruction) to get a good approximation of the present-day geometry.
- Determine the SMB required to maintain this geometry.
- Couple the ISM to the AOGCM, applying SMB *anomalies* from the AOGCM.
  - Analogous to "flux corrections" applied in earlier climate models
  - Issues: Energy non-conservation, sweeping biases under the rug

Ground rules

- The SMB from the climate model is computed using an energy-based method (no PDD schemes).
  - Downscaling methods left to the discretion of each group
- The surface type and the surface elevation of the climate model are dynamic.
  - Dynamic surface type should at least include albedo changes between ice-covered and ice-free surfaces.
- Changes in ice sheet mass should affect the ocean temperature and salinity.
- Ice sheets are free to go where the forcing wants them to go.
  - No prescribed masks to prevent ice sheet advance

Beyond CESM2…

- Finer grid resolution (1 or 2 km)
  - Could improve the simulation of fast outlet glaciers
  - Required for grounding lines
- Evolutionary basal hydrology
  - Would replace simple sliding laws
- Improved isostasy model
  - Still using the serial model from Glimmer
- Antarctic ice sheet modeling
  - New software infrastructure
  - Improved calving models
  - Coupling to ocean model with sub-ice-shelf cavities