Implementing an ice sheet model in CCSM

William Lipscomb

LANL ice sheet modeling workshop

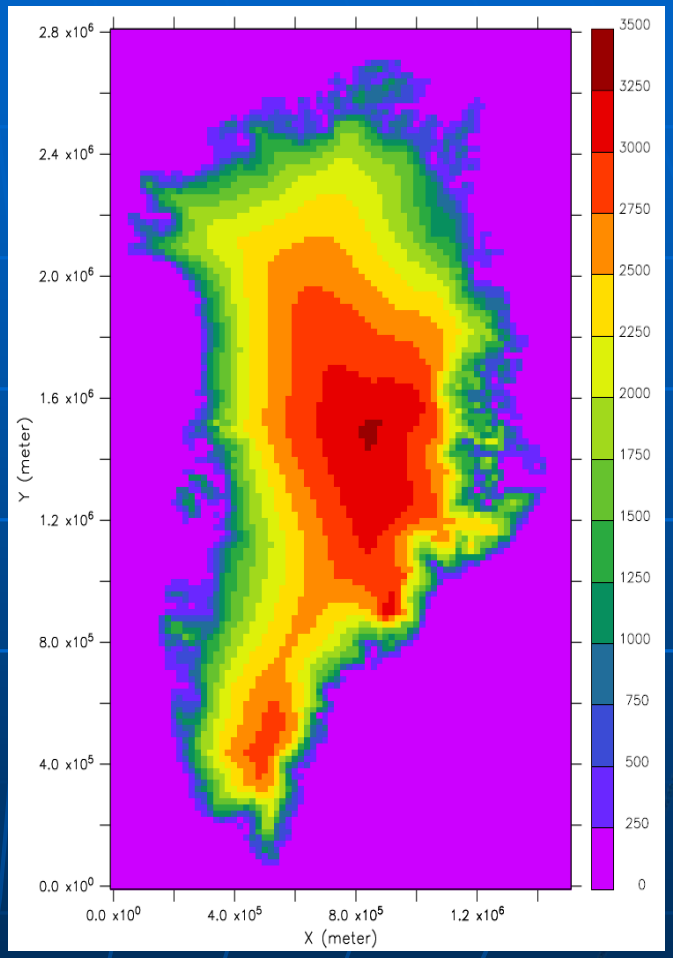
19 August 2008

Outline

- Describe progress to date in implementing an ice sheet model in the Community Climate System Model (CCSM).
- Outline a strategy for developing an IPCC-ready community ice sheet model in 1 to 2 years.

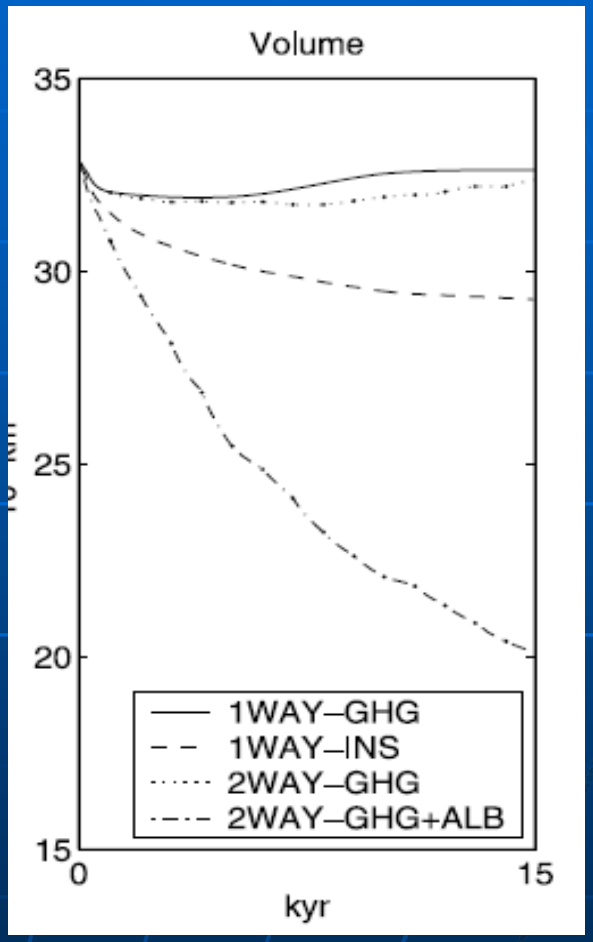
Progress to date

- I have coupled the GLIMMER ice sheet model to CCSM.
- In the CCSM land model I have implemented a surface-mass-balance scheme with multiple elevation classes for land ice.
- This fall we will test and tune the surface-mass-balance scheme in coupled simulations.
- The goal is to get a realistic present-day Greenland ice sheet as a starting point for climate-change experiments.



Surface mass balance for climate change studies

- Many studies (e.g., Ridley et al. 2005) have computed ice-sheet surface ablation using a **positive-degree-day** (PDD) scheme based on present-day empirical parameters.
- For climate projections it is better to use a **surface-energy-balance** scheme.
- A recent study (Pritchard et al. 2008) shows that surface albedo feedbacks from ice sheets warm the atmosphere and increase the rate of melting. These feedbacks should be included at runtime.



Laurentide volume change

Pritchard et al. (2008)

Surface mass balance in CCSM

- Traditional approach: Pass surface radiation and temperature fields to the ice sheet model and compute the mass balance on the fine (~10 km) ice sheet grid.

- We are computing the mass balance in the land model (CLM) on a coarse (~100 km) grid in ~10 elevation classes. Ice thickness changes are then interpolated to the ice sheet grid.
  - Energetic consistency
  - Cost savings (~1/10 as many columns)
  - Avoid code duplication
  - Surface albedo changes feed back on the atmosphere

We have introduced a new landunit type, ***glacier_mec***, i.e., glaciated regions with multiple elevation classes.

Glacier_mec landunits need not be associated with a dynamic ice sheet model.

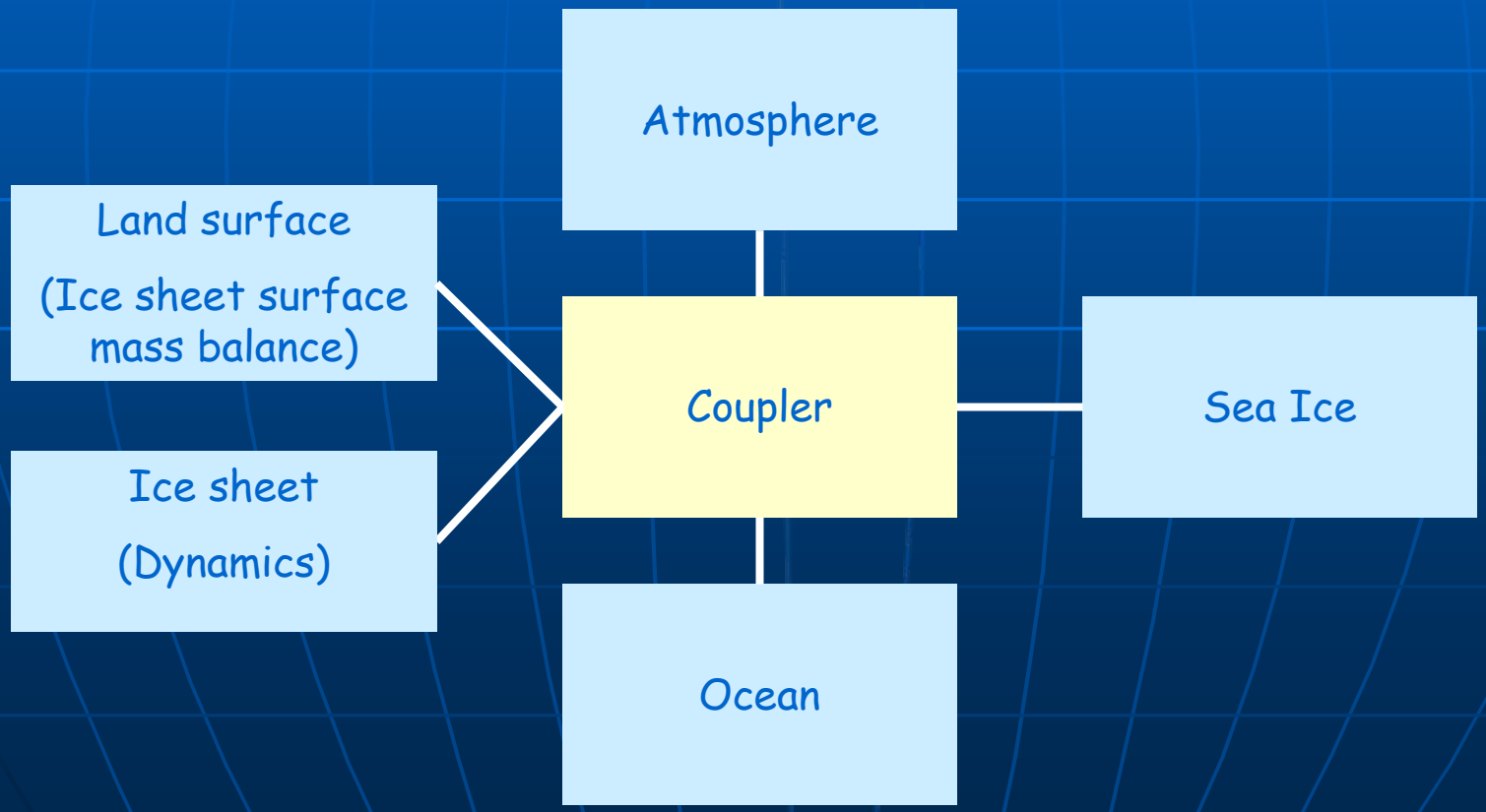
Ice-sheet coupling in CCSM

Land -> Ice sheet (10 classes)

- surface temperature
- surface elevation
- ice accumulation/ablation

Ice sheet -> Land (10 classes)

- ice fraction, elevation, thickness
- runoff/calving flux
- heat flux to surface



Toward an IPCC-ready CISM

- For climate and sea-level projections we need **coupled, high-resolution, whole-ice-sheet** models with **higher-order flow dynamics** and **improved physical processes**.
- Such a model does not exist, although many of the pieces do:
  - GLIMMER: Coupled to CCSM
  - PISM: Parallel, ~5 km resolution, whole ice sheet
  - ISMIP-HOM (Pattyn et al., 2008): 27 participating higher-order models
- How do we get from here to there in 1 to 2 years?

Beg, borrow, and steal

- Use infrastructure from POP and CICE (ocean and sea ice components of CCSM)
  - Built-in MPI communications for logically rectangular grids (ghost-cell updates, global sums, and all that)
  - Block data structure for load balancing and cache optimization
  - Standardized routines for history files, restarts, time management, grid interpolation, and coupling
  - CCSM-compliant
  - Efficient scaling to thousands of processors
  - CICE 4.0 was released last week

Modularity

- Define the essential elements of a dynamical core:
  1. Velocity solver
  2. Mass evolution
  3. Temperature evolution

  Note: Temperature advection could go with either (2) or (3).

- Develop standard calling interfaces

- Plug and play different codes that serve the same function (e.g. Pattyn and Payne HO velocity solvers).

Keep it simple

- Start with higher-order approximations ("Blattyn"); full-Stokes later
- Start on a rectangular grid with ~ 3 to 5 km resolution; adaptive grids later
- Simple basal physics (plastic?) using empirical bed parameters
- Parameterized sub-shelf melting using output from ocean GCM; full coupling later
- Simple, stable calving law
- Grounding lines (?)

Organize

- Identify a group responsible for ongoing CISM development
- Meet on a regular basis
- One possibility: Form a CCSM Land Ice working group (and meet jointly with Polar Climate, Land Model, Ocean Model, or Paleoclimate groups)

5-step process: Ice sheet observations

1) Professor X writes a proposal to acquire data: "These data are essential for validating ice sheet models."
2) The project is funded and the data are acquired.
3) Professor X and postdoc Y analyze the data and write a paper.
4) The raw data sit on a server somewhere.
5) Professor J laments that there are no good data sets for validating ice sheet models.

5-step process: Ice sheet observations

1) Professor X writes a proposal to acquire data: "These data are essential for validating the Community Ice Sheet Model."
2) The project is funded (with high scores for community impacts) and the data are acquired.
3) Professor X and postdoc Y analyze the data and write a paper.
4) Postdoc Y converts the data to a gridded netCDF file in a standardized format.
5) Professor J validates CISM and is happy.

5-step process: Ice sheet modeling

1) Professor X writes a proposal to develop a new physical parameterization: "This parameterization is essential for next-generation ice sheet models."
2) The project is funded and graduate student Z codes up a parameterization.
3) Professor X and graduate student Z validate the parameterization and write a paper.
4) The undocumented code sits on a desktop somewhere.
5) Scientist L laments that CISM is useless for IPCC experiments because it lacks realistic physical parameterizations.

5-step process: Ice sheet modeling

1) Professor X writes a proposal to develop a new physical parameterization: "This parameterization is essential for the Community Ice Sheet Model."
2) The project is funded (naturally, since it supports CISM!) and graduate student Z codes up a parameterization.
3) Professor X and graduate student Z validate the parameterization and write a paper.
4) Graduate student Z visits a national lab and works with Scientist L to put the new parameterization in CISM.
5) Scientist L tells scientist G that CISM is ready for IPCC experiments. Scientists L and G are happy.

Take-home messages

- The perfect is the enemy of the good.
- Stealing code is the sincerest form of flattery.
- We need to organize ourselves and develop community standards.
- Early-career scientists are critical for success.
- This is an opportunity to take the lead on some very high-impact science.