A Case for Synchronous Two-Way GCM/Ice Model Coupling with GLINT2

Robert Fischer, Sophie Nowicki, Max Kelley, Gavin Schmidt

NASA Goddard Institute of Space Studies
New York City

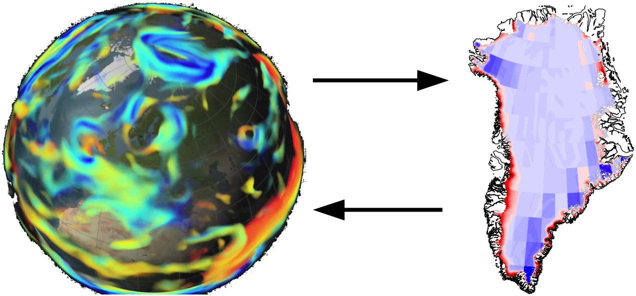
January 30, 2014

What's Up in the World?

- Pine Island Glacier, Jakobshaven: Acceleration.
- Collapse of Larsen B Ice Shelf.
- Increased Runoff into North Atlantic.
- Heinrich Events.
- Rapidly Changing Arctic Climate.
- Potential Changes in North Atlantic Overturning Circulation.
- Sea level rise: how much, and when?
- Greenland Tipping Points and Equlibrium States?

How can we understand and model these phenomena?

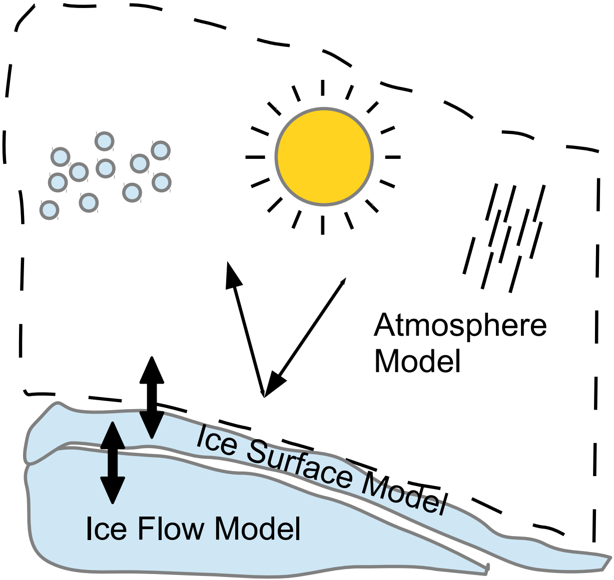
Coupled GCM – Ice Model



- One-way Coupling
- Asynchronous Two-Way Coupling
- Synchronous Two-Way Coupling

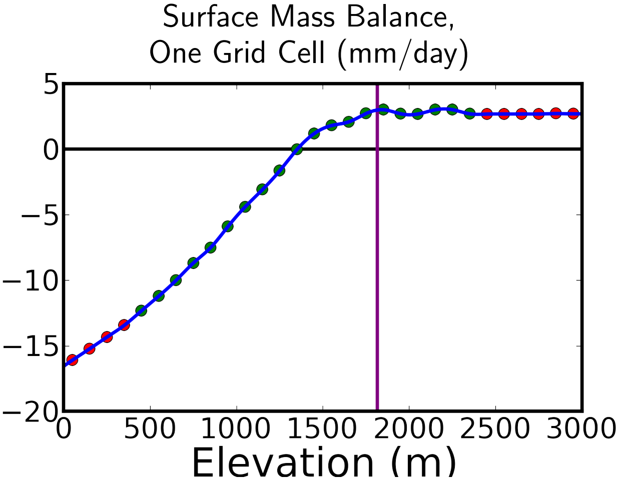
How far must we go to model phenomena of interest?

Three Models, Three Grids



Elevation Points

- Assumption: in grid cell, same elevation ⇒ same SMB.
- Required for good SMB from a GCM!



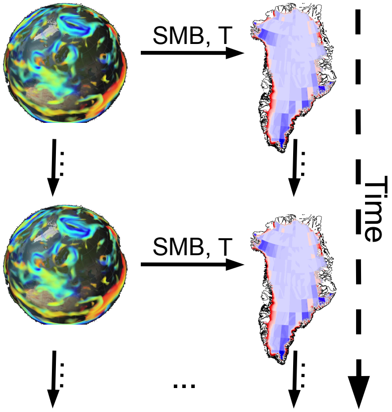
One-Way Coupling

SMB Scheme:

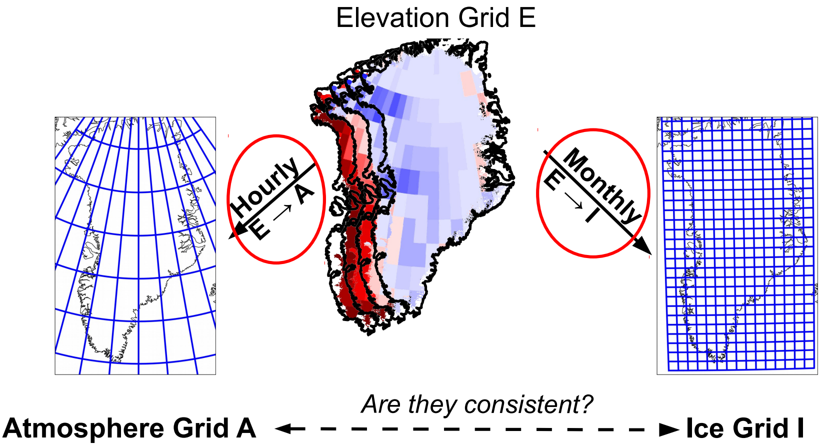
- Full Energy Balance (no PDD today)
- Runs on elevation grid.

Top T Boundary:

- Average T over coupling timestep



Conservation



NOTE: Grids not to scale.

Asynchronous Two-Way Coupling

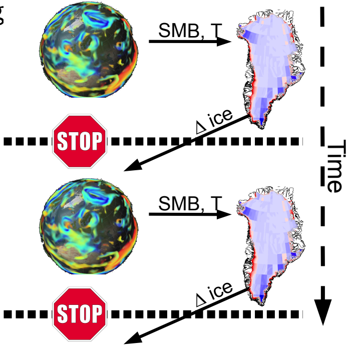
Procedure:

- Evolve ice model w/ one-way coupling
- Stop GCM, adjust ice configuration. **(Now a miracle occurs)**
- Rinse, repeat

OK for:

- Investigation of equilibrium states
- Effects of Ice Loss on Climate

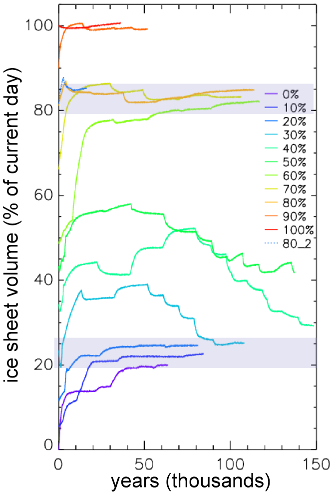
Are $E \rightarrow A$ and $E \rightarrow I$ consistent?



Asynchronous Two-Way Coupling

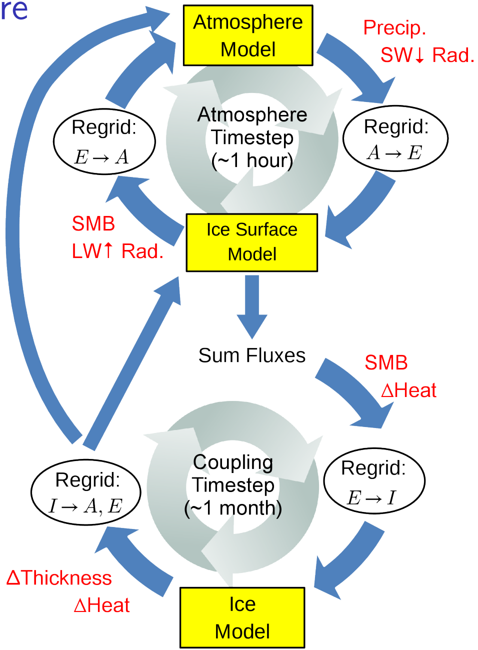
Problems:

- Unknown forcing at coupling time.
- Transients not realistic.
- Time to reach equilibrium wrong.
- Equilibrium states possibly wrong.

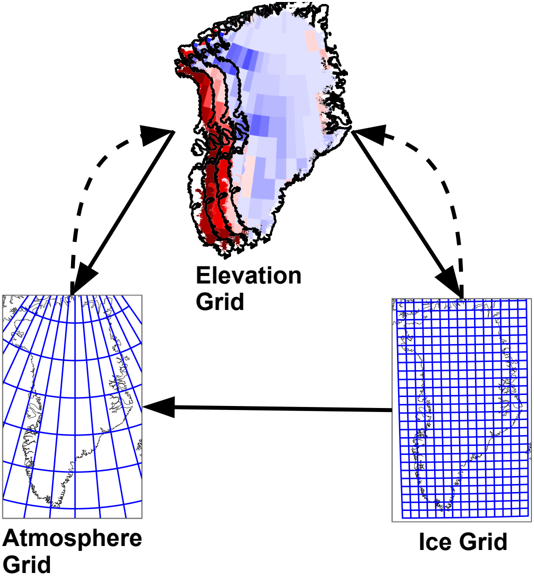


(Jeff Ridley, 2013)

The Big Picture



Five Conservative Transformations

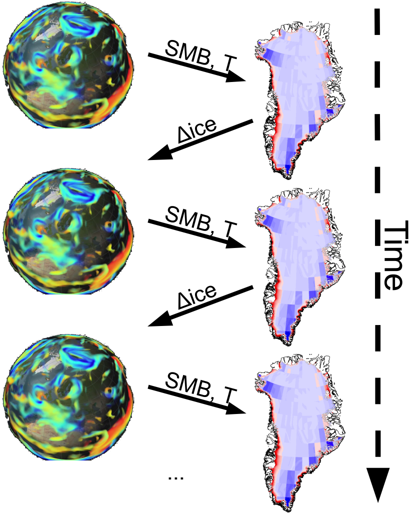


Synchronous Two-Way Coupling

Requirements/Challenges:

- All regridding must be conservative.
- Careful of $A \rightarrow E$ transformation!
- Top T bouncary condition chosen to produce desired heat flux.

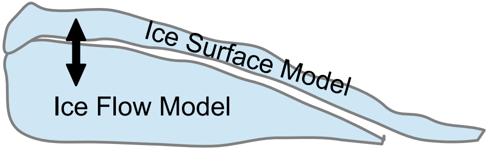
No Miracles!



Challenge: Top T Boundary Condition

Model Mismatch:

- Ice models: Top T Boundary Condition
- GCM: Energy Flux



Approach:

- Minimize energy flux: ice surface model 10 − −15m thick.
- Derive "effective surface T" from energy flux (Schmidt et al, 2004)
- Track and correct for actual vs. desired flux of effective T.

Schmidt, G. A., Bitz, C. M., Mikolajewicz, U., and Tremblay, L. B.: Iceocean boundary conditions for coupled models, Ocean Model., 7, 5974, doi:10.1016/S1463-5003(03)00030-1, 2004.

GLINT2: Coupling Library

http://citibob.github.io/glint2

Lat/Lon
Cubed Sphere
Geodesic

Cartesian
Adaptive (Chombo)
F.E. Mesh

Problems Addressed:

- Many GCMs, many Ice Models.
- No "standardized" transfer grid.
- Conservation: Mass & Energy

Features:

- Direct transfer from GCM to Ice Grid.
- Works for all grids.
- Conserves mass and energy.

Challenge: Can we Accelerate?

- No obvious way to accelerate synchronously coupled GCM and Ice Model.
- Significant ice changes require long runs.
- Much computer time required.

Conclusions

- Many interesting problems need syncronous coupling.
- Additional challenges:
  - Ice Surface Model
  - Full surface energy balance
  - Elevation Classes
  - Conservation of Mass and Energy
  - Top T boundary condition
  - Long runs
- GLINT2 coupling library does the "heavy lifting"
  http://citibob.github.io/glint2
- GMD Discussions Paper:
  R. Fischer et al, A system of conservative regridding for ice/atmosphere coupling in a GCM, gmdd-6-6493-2013