Towards better simulations of ice/ocean coupling in the Amundsen Sea Sector, West Antarctica, using a coupled ocean, sea-ice, and ice-sheet model.

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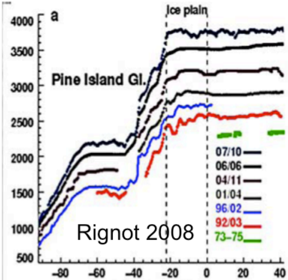
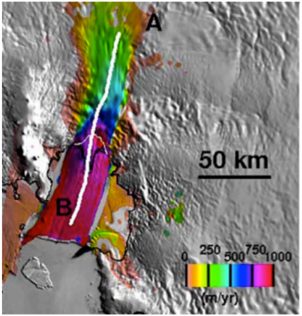
Outline

1. Introduction
2. Model
3. Results
4. Conclusions/Perspectives

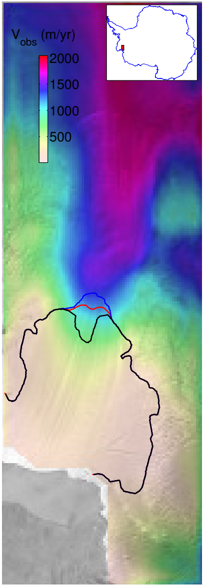
- Acceleration of Pine Island Glacier in the past two decades, synchronous with increased melt rate at the grounding line ?
- How does the cavity shape interact with the ocean circulation?
- How do melt-rates impact grounding line dynamics?
- Could melt-rates and channelization be the controlling factor of migration, and not stress-balance at the grounding line?
- One-way coupled ice/ocean models cannot answer these questions, need for full-coupling, where the cavity shape is updated by an ice sheet model, and the melt rates computed by a circulation model.





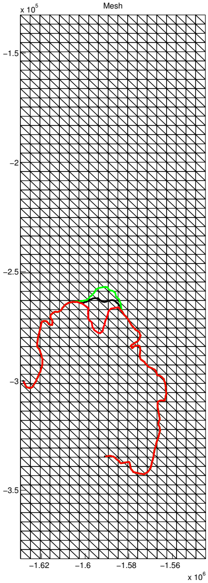
Model setup: domain

- Reduced Pine Island Domain because of extensive computational requirements.
- 1° latitude range, 10° longitude range
- 20 x 60 regular grid for the ocean (5km resolution cells)
- 2242 elements, 1200 vertices for the ice sheet



Model setup: mesh

- Triangular elements for FEM model ISSM
- Square grid for Finite Difference model MITgcm
- 2D model for ISSM (SSA), 3D circulation model for MITgcm



Modeling Strategy

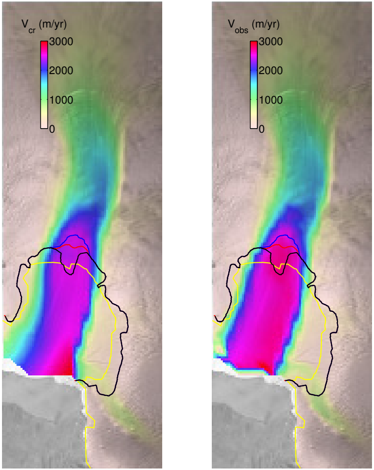
- 2D SSA ice-flow model:
  - Depth-integrated flow, constrained inland with 1996 InSAR surface velocities (Rignot et al, 2008)
  - Inversion of basal friction inland and ice hardness for the ice shelf.
  - Steady-state thermal regime
  - Sub-element grounding line parameterization (Seroussi 2014, TCD)
- 3D GCM circulation model:
  - z-level model
  - Volume conserving
  - 66 levels in vertical thickness
  - Boundary conditions from optimed ECCO cube-sphere.

Modeling Strategy (coupling)

- Coupling sequence
  1. Send draft from ISSM to MITgcm
  2. Update wetting and drying of cells.
  3. Run 2 weeks of MITgcm circulation
  4. Compute two-week averaged melt rates at center grid
  5. Send melt rate from MITgcm to ISSM
  6. Run ISSM stress balance and mass transport
  7. Compute new cavity shape (new draft and new grounding line position)
  8. Start at 1 again.
- Transfer of draft and melt rates is done at center grid, which is coincident with mesh vertices (no loss by interpolation).
- Both frameworks are independent, driven by a matlab loop. Configuration is generic, applicable to any basin.

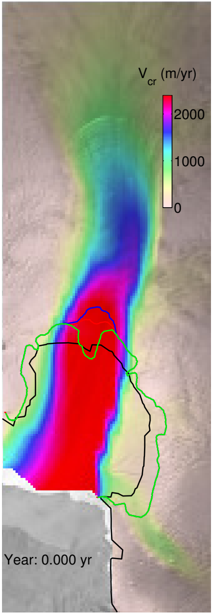
Spin-up

- Bathymetry is from International Bathymetric Chart of the Southern Ocean (IBCSO), which includes BEDMAP2 in ice shelf cavity.
- Bedrock and bathymetry taken identical, to avoid transition issues $->$ bedrock at the grounding line and near the ice plain will not be accurate.
- Inversion of basal friction and ice hardness to match 1996 surface velocities from InSAR (Rignot et al, 2008)
- Initial melt-rate from MITgcm computed with steady-state grounding line.
- 150 year relaxation of ISSM using fixed initial melt rate and grounding line migration for 150 years.
- Modeled grounding line position near 1996 position.
- Transient runs start from this initial configuration.

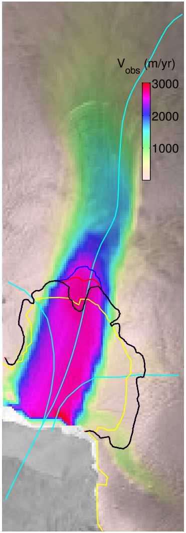


50 year transient

- 50 year fully coupled transient run
- Grounding line position retreats inland, except near the main trunk
- Strong retreat towards Thwaites Glacier and towards Moses Mount in the North.
- Retreat occurs on upward sloping bedrock.

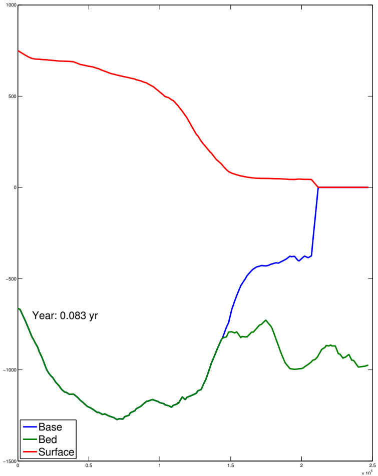


Cross-section profiles



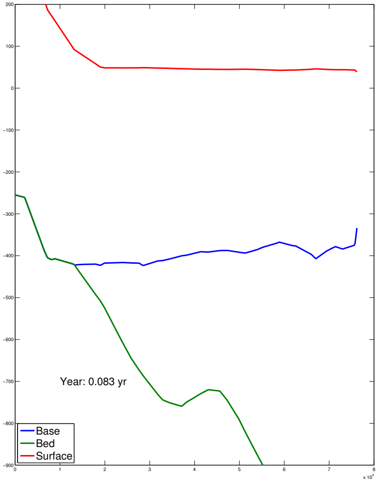
Center flowline

- Stable even through downwards sloping bedrock/ice plain.
- Initial increase of cavity size far downstream, and stabilization after 15 years $->$ decrease in melting rate?
- Mesh resolution at grounding line locks the position in place?



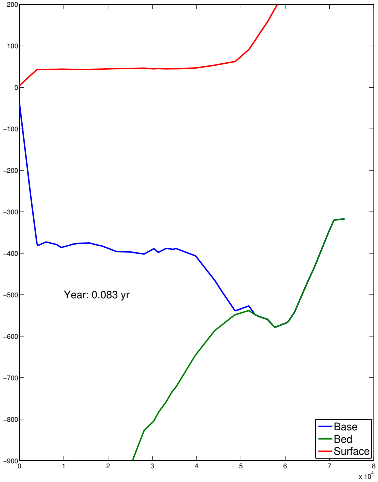
Flowline towards Moses Mount

- Dynamic retreat from the onset
- Develops a sharp cavity (channel) near the grounding line
- Stablization due to proximity of boundary conditions (flux constrained)



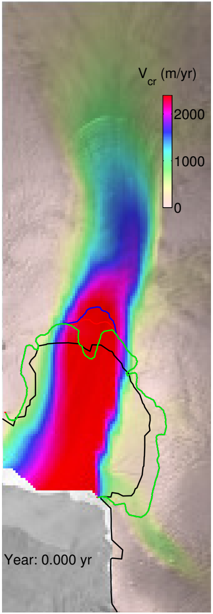
Flowline towards Thwaites Glacier

- Dynamic retreat from the onset, prolonged in time.
- Develops a sharp cavity (channel) near the grounding line, with strong thinning inland.
- Creates new ice stream 30 years on
- Potential merging with Thwaites Glacier?



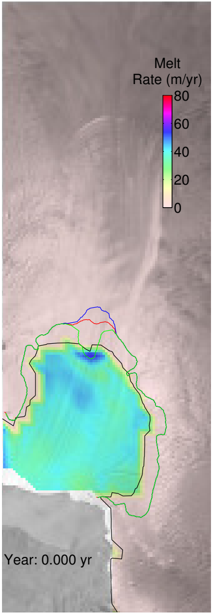
Sensitivity to far field ocean temperature

- $+1^\circ$ at the boundary of the Amundsen Sea Embayment
- 125 year run
- Grounding line locked on main trunk of PIG.
- Develops new Ice Stream between PIG and Thwaites 50 years on.



Melt Rates

- High melt rate near the trunk grounding line, transient stabilizes after initial 1 year.
- Melt rate towards Thwaites Glacier increases, ensuing creation of a new ice stream
- High melt rates near the main trunk not sufficient to further retreat PIG.
- Transient regime responsible for increase in surface velocities
- Retreat to the North not clearly explained.



Conclusions

- Prototype of coupled Ice-sheet/Ice-shelf dynamics and Ocean circulation.
- Exact energy-mass transfer between two very different discretization frameworks.
- Grounding line dynamics, cavity shape and melting rates captured within accuracy of mesh resolution
- Instability not triggered on the main trunk of PIG, but near its tributaries, especially towards Thwaites Glacier.
- Interplay between melt rate channelization and destabilization of flow in upward sloping bedrock areas.
- Need for integrated bathymetry/bedrock maps to understand better what is involved in the migration of the main trunk.

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