Sensitivity of Thwaites Glacier to Ice Shelf Melting

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Finite Element Shallow Shelf (MacAyeal) Model

~300 m resolution above grounding line
• High Resolution Bed DEM created from AGASEA and Operation Ice Bridge Data Sets (CRESIS)
• New Accumulation Map (Medley et al, in prep)
Model Initialization

- No spinup, model initialized by inverting for basal shear stress (n=3 power sliding law) using the 1996 flow speed.
- Reference melt depth-dependent parameterization from PIG simulations where m=1x (melt parameterization) yielded steady state.
- After first year of simulation with reference melt (m=1x) modeled basin-wide loss is 27.6 Gtons/year compared with an estimated 28.8 Gtons/year.
- m=1x loss stays within range of 22 to 43 Gtons/year over a 250 year run.
Grounding Line Retreat with Fixed Velocity

Year of Simulation When Ice First Ungrounds

m=1x Vel. fixed

m=4x Vel. fixed
Grounding Line Retreat for Different Melt Scenarios

- m=0.5x
- m=1x
- m=3x
- m=4x

Year of Simulation When Ice First Ungrounds

0  50  100  150  200  250
Thinning for the m=3x simulation
Snapshots of thinning for m=3x simulation
Ice Loss for Different Melt Scenarios over 250 years
Two Additional Simulations

- Increase surface accumulation linearly by 20% over 100 years and then maintain constant value.

- Start with high melt, then decrease melt back to $m=1x$ after 100 years.
Ice Loss for Variable Accumulation/Melt over 250 years
• Previous simulations assume a shelf forms where the ice ungrounds.
• In actuality, a rifted or weakened shelf might form.
• To examine the sensitivity to a weakened shelf, we cut the flow parameter, B, in half on the existing and developing ice shelf.
Ice Loss for Shelf with 50% B over 250 years

Note factor of 10 change in y-axis scale
Summary

• Only a reduction in melt and increased accumulation produce something approaching steady state.
• All other simulations continue to lose mass at rates similar to or greater than present.
• Even with high melt, ice sheet could sustain moderate losses (<0.25 mm/yr) for at least a century and m=1x at (<~0.1 mm/yr) for the entire 250 year simulation.
• High melt scenarios force grounding line retreat to near the edge of the shallow region, at which point much larger losses expected a 2+ centuries in the future.
• Formation of a strong ice shelf as the grounding line recedes is crucial for maintaining small losses over the next 2.5 centuries.
• A weakened shelf (50%B) could increase losses by more than order of magnitude (5+ mm/yr).
• Complete inability to form an ice shelf (i.e., a grounded terminus) would yield a rapid collapse (10+ mm/yr).