Marine ice sheet experiments with CISM

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Goals

- Investigate CISM numerical properties in marine ice sheet simulations subject to ocean forcing (basal melt).

- Infer default configurations for Antarctic simulations in standalone and CESM Antarctic-enabled simulations.
MISMIP+ framework experiments (Asay-Davis et al. 2016)

Melt function applied under ice shelves (Seroussi et al. 2018)

\[
m = \begin{cases} 
0 \text{ m a}^{-1}, & z_d > -50 \text{ m}, \\
1/15(z_d + 50) \text{ m a}^{-1}, & -500 < z_d < -50 \text{ m}, \\
30 \text{ m a}^{-1}, & z_d < -500 \text{ m}, 
\end{cases}
\]

\[Z_d = \text{ice shelf basal elevation}\]

Bed topography

Strong buttressing due to presence of bed topography walls

Experimental protocol

6 experiments total (figure from Cornford et al. 2020)
Several *basal friction laws* are common in ice sheet models:

- **Weertman** *(aka power law):*
  - $> 0$ at grounding line (GL).
  - Discontinuous at GL.

- **Schoof**:
  - Asymptotes to a Coulomb law at GL.
  - Transitions smoothly from $> 0$ to zero at GL.

- **Intermediate**:
  - Between Weertman and Schoof.
  - Transitions smoothly from $> 0$ to zero at GL.
  - $0 <$ transition length scale Intermediate $<$ transition length scale Schoof
Experimental setup: Basal melt parameterizations

Which option should we use?
Many modelers argue that NMP should be the default.
Experimental setup

Parameters:
- Resolution: 8km, 4km, 2km, 1km, 0.5km
- Basal friction laws: Weertman, Intermediate, Schoof
- Melt parameterization: FCMP, PMP, NMP

Constants:
- Shear stress factor = $10^4 \text{ Pa m}^{-1} \text{ a}^{1/3}$
- Tuned ice softness so that GL = 455 km +/- 1km
- Ice calves at $x = 640 \text{ km}$

3 experiments:

**Exp1** (moderate melt)
\[ a = 0.3 \text{ m a}^{-1} \]
\[ m_{\text{max}} = 30 \text{ m a}^{-1} \]

**Exp2** (high melt)
\[ a = 0.3 \text{ m a}^{-1} \]
\[ m_{\text{max}} = 150 \text{ m a}^{-1} \]

**Exp3** (low accumulation, slow-moving ice)
\[ a = 0.05 \text{ m a}^{-1} \]
\[ m_{\text{max}} = 30 \text{ m a}^{-1} \]
Exp1 (moderate melt)

- Faster convergence using FCMP or PMP than NMP.
- FCMP and PMP results always similar.
- Greater loss of grounded ice with higher resolution.
- Smaller ice loss for Weertman and Intermediate; greater ice loss with Schoof.

\[ a = 0.3 \text{ m a}^{-1} \]
\[ m_{\text{max}} = 30 \text{ m a}^{-1} \]
Exp1 (moderate melt)

- Beneficial to allow some melt in cell containing the GL for all basal friction laws.
- Greater sensitivity to resolution and greater ice loss with Schoof than Weertman.
- With Schoof law, 1 km resolution is needed. Otherwise, resolution 2-4 km is sufficient.
Exp2 (high melt)

• Better convergence with PMP than NMP for all basal friction laws.
• Slower convergence with Schoof than with Weertman.
• With PMP, results at resolutions 1-4 km are within 10% of those at 0.5 km.
Exp3 (low accumulation, slow-moving ice)

- Better convergence with PMP than NMP for all basal friction laws.
- Requirement of resolution is relaxed compared to other experiments.
- Accumulation rather than buttressing sets re-advance time scale.

\[ a = 0.05 \text{ m a}^{-1} \]
\[ m_{\text{max}} = 30 \text{ m a}^{-1} \]
Conclusion

- Allowing some melt in the cell containing the grounding line is beneficial for CISM (default configuration).
- With a Weertman law, a resolution of 2 km (arguably 4 km) is adequate to accurately diagnose grounded ice loss.
- With a Schoof law, the resolution requirement becomes 1 km (arguably 2 km).
- Re-advance of the ice sheet is controlled by the accumulation time scale.

Lesson learned
- Test your model!

Future work
- Redo experiments in more realistic setting (no smooth bed)
Thank you

Paper under review in TCD
Leguy, Gunter R., William H. Lipscomb, and Xylar S. Asay-Davis.
"Marine ice-sheet experiments with the Community Ice Sheet Model."