Marine ice sheet experiments with CISM

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NCAR

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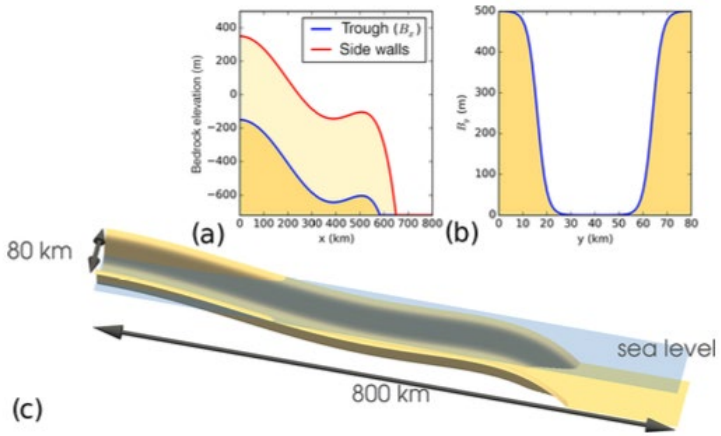
Goals

- 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)



Bed topography

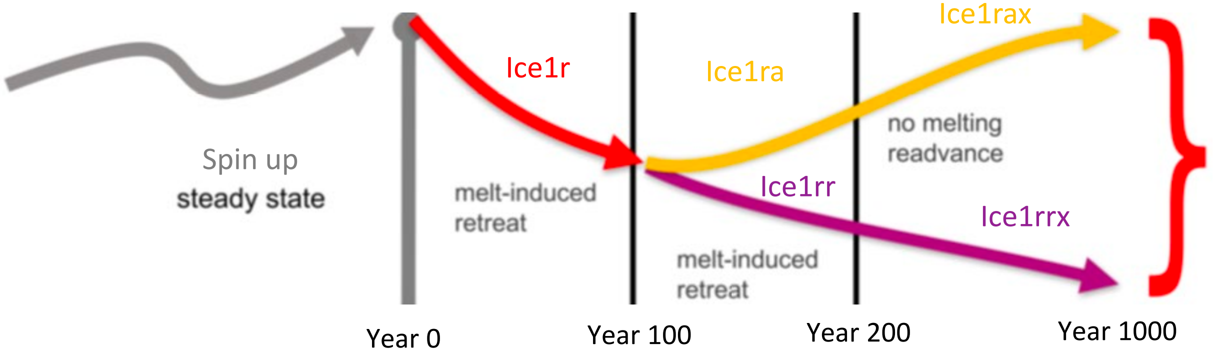
Strong buttressing due to presence of bed topography walls

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

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

Z_d = ice shelf basal elevation

Experimental protocol

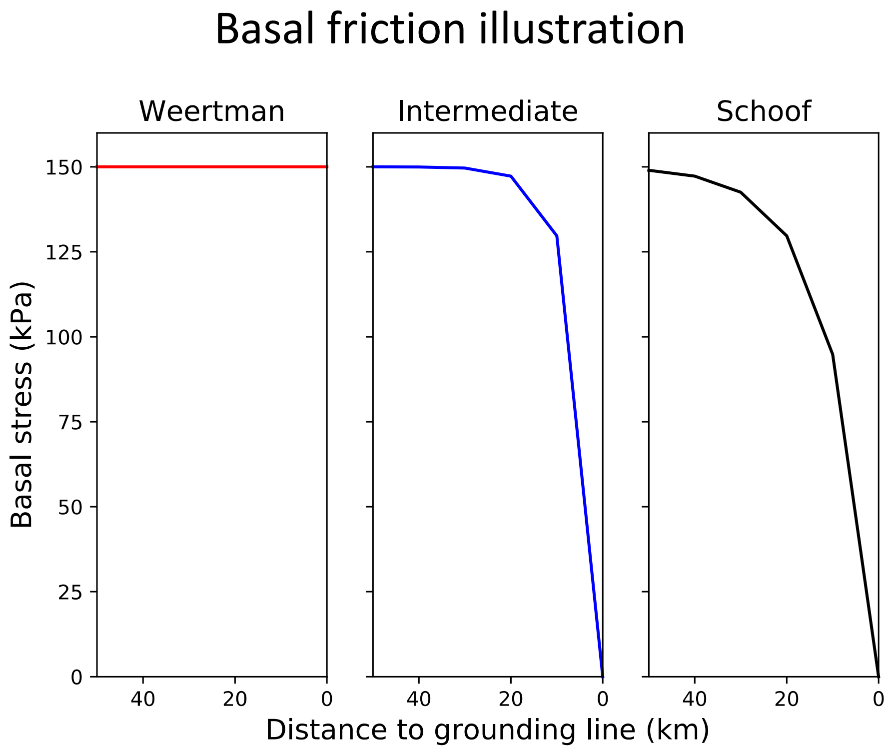


6 experiments total
(figure from Cornford et al. 2020)

Experimental setup: Basal friction laws

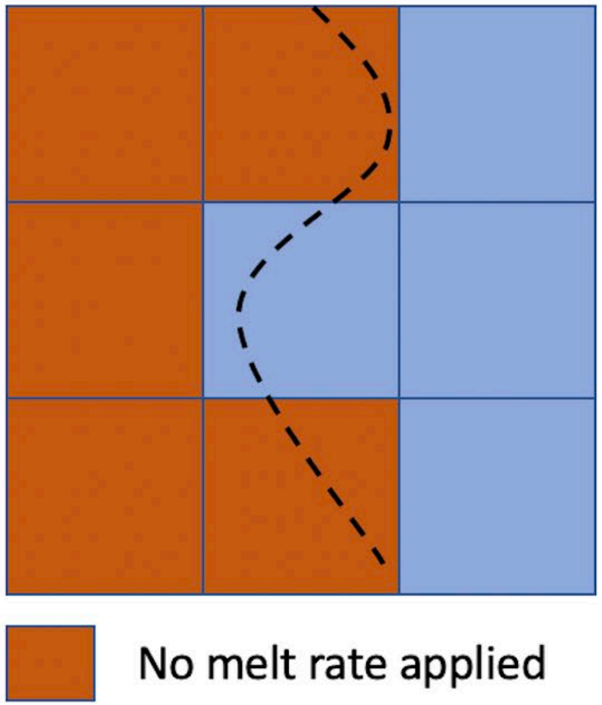
Several **basal friction laws** are common in ice sheet models:

- **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

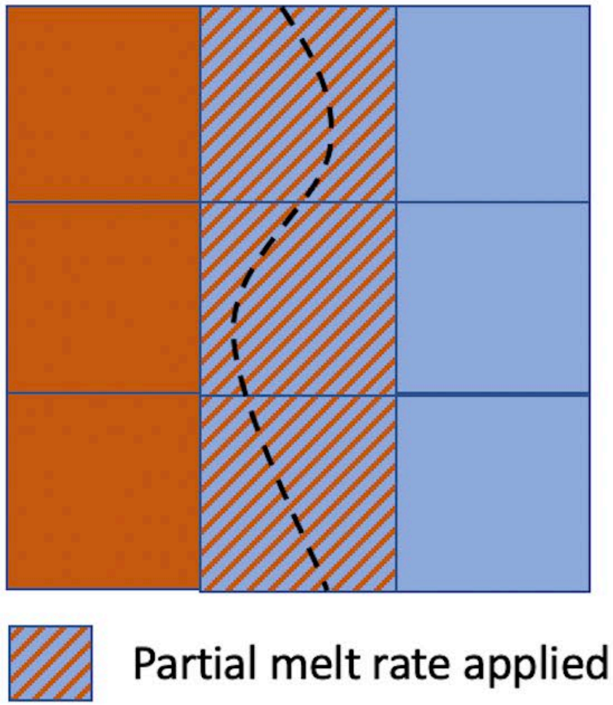


Experimental setup: Basal melt parameterizations

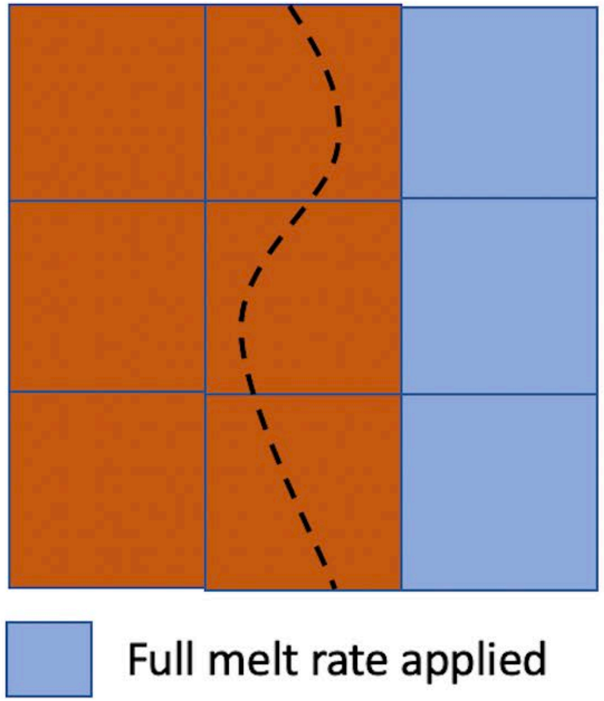
Floatation condition melt parameterization. (FCMP)



Partial melt parameterization. (PMP)



No melt parameterization. (NMP)



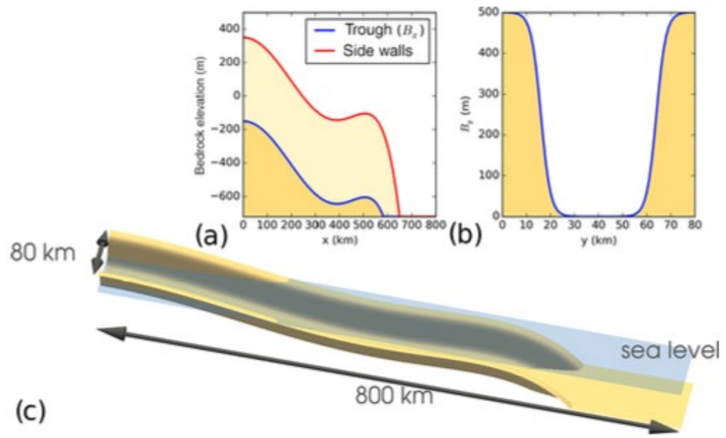
Which option should we use?

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 Pa m^{-1} $a^{1/3}$
- Tuned ice softness so that GL = 455 km +/- 1km
- Ice calves at x = 640 km

3 experiments:

Exp1 (moderate melt)
$a = 0.3$ m a^{-1}
$m_{max} = 30$ m a^{-1}

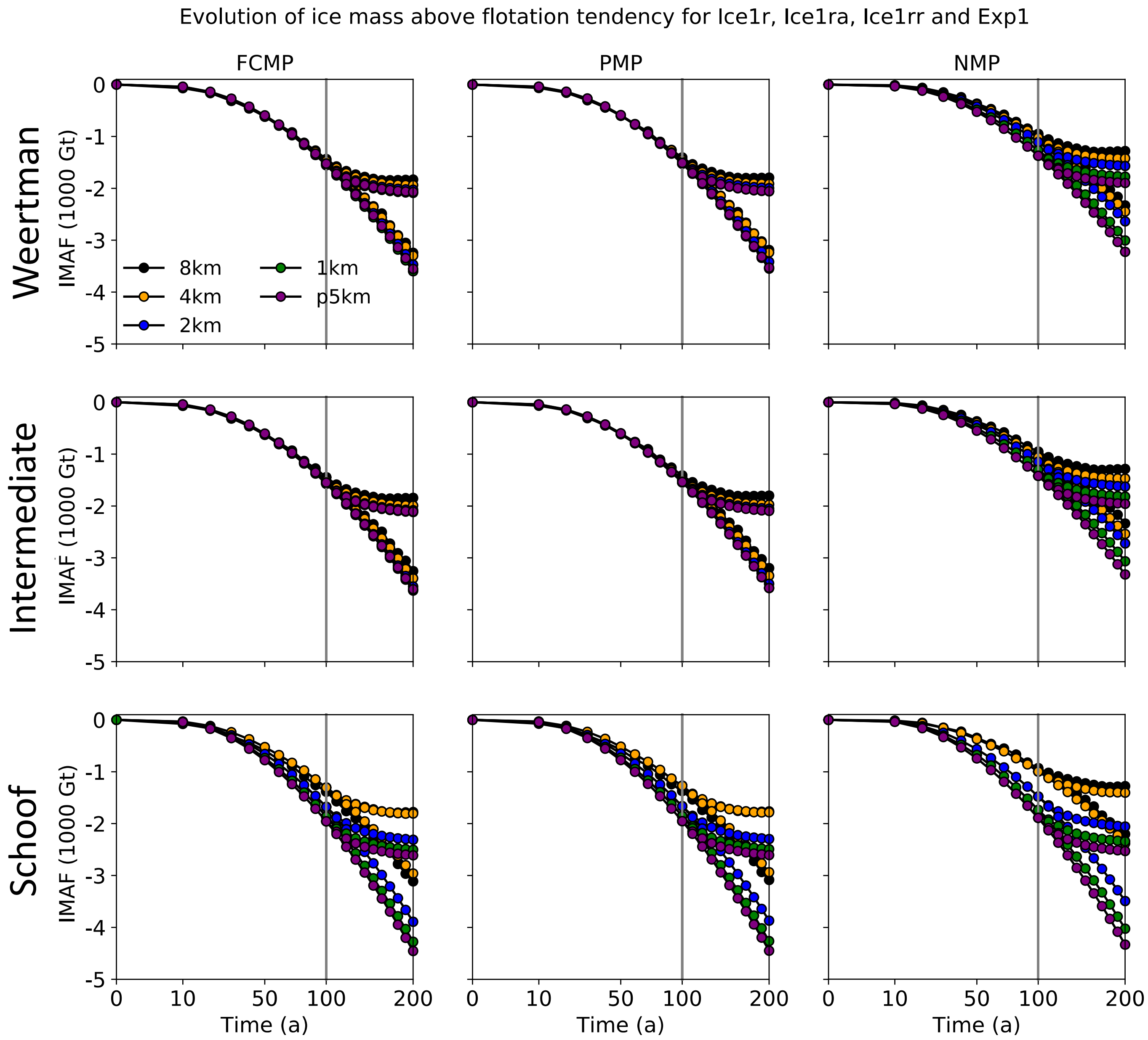
Exp2 (high melt)
$a = 0.3$ m a^{-1}
$m_{max} = 150$ m a^{-1}

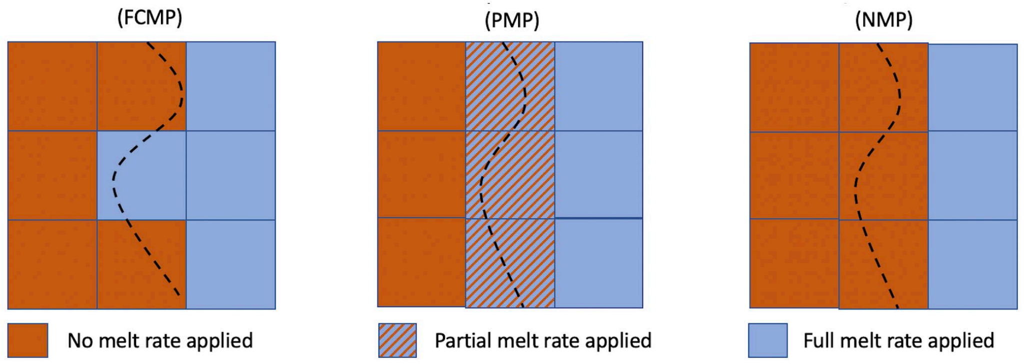
Exp3 (low accumulation, slow-moving ice)
$a = 0.05$ m a^{-1}
$m_{max} = 30$ m a^{-1}

Exp1 (moderate melt)

$a = 0.3\ m\ a^{-1}$

$m_{max} = 30\ m\ a^{-1}$

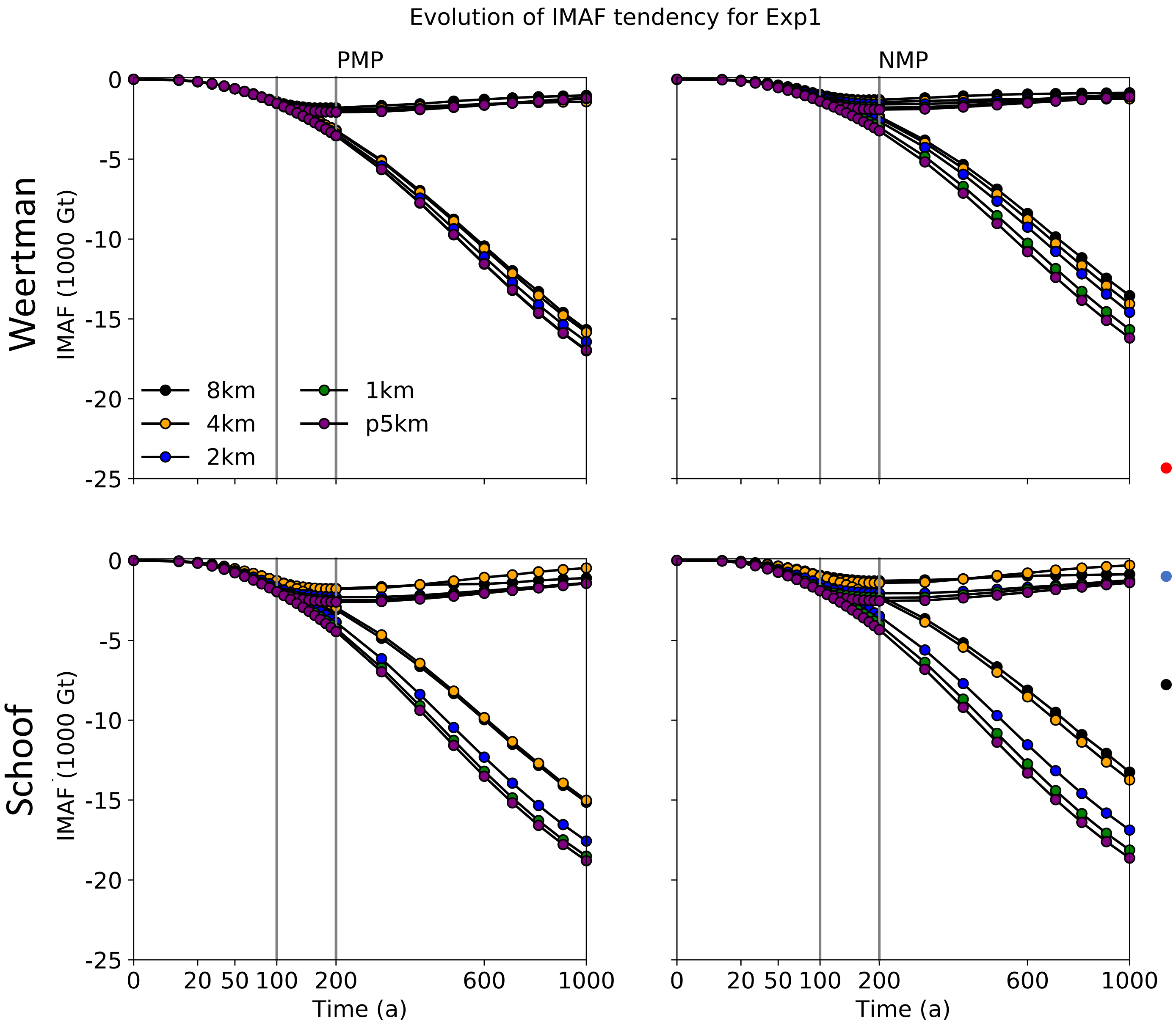


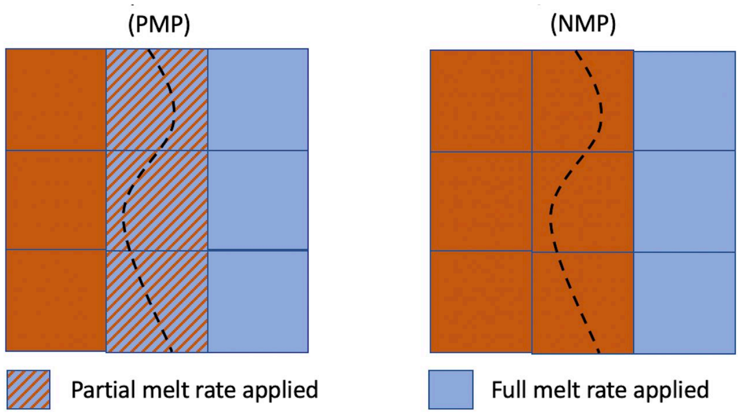


- Faster convergence using FCMP or PMP than NMP.
- FCMP and PMP results always similar.
- Greater loss of grounded ice with higher resolution.
- Smaller ice loss for Weertman and Intermediate; greater ice loss with Schoof.

Exp1 (moderate melt)

$a = 0.3\ m\ a^{-1}$
$m_{max} = 30\ m\ a^{-1}$



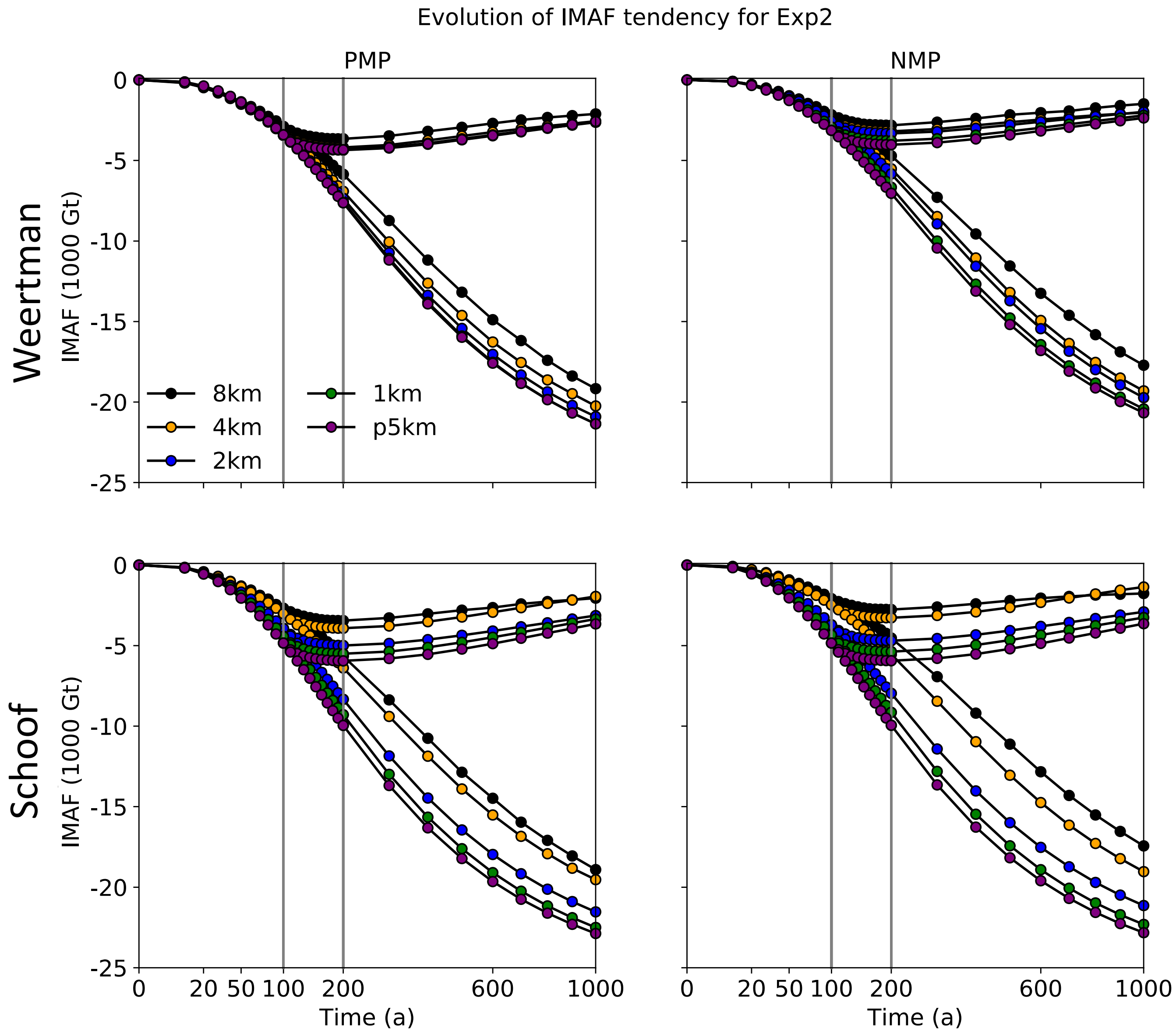


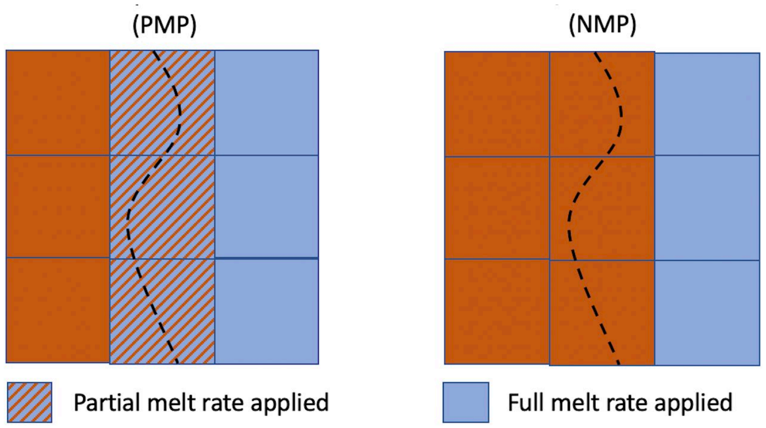
- Beneficial to allow some melt in cell containing the GL for all basal friction laws.
- Greater sensitivity to resolution and greater ice loss with Schoof than Weertman.
- With Schoof law, 1 km resolution is needed. Otherwise, resolution 2-4 km is sufficient.

Exp2 (high melt)

$a = 0.3\ m\ a^{-1}$

$m_{max} = 150\ m\ a^{-1}$

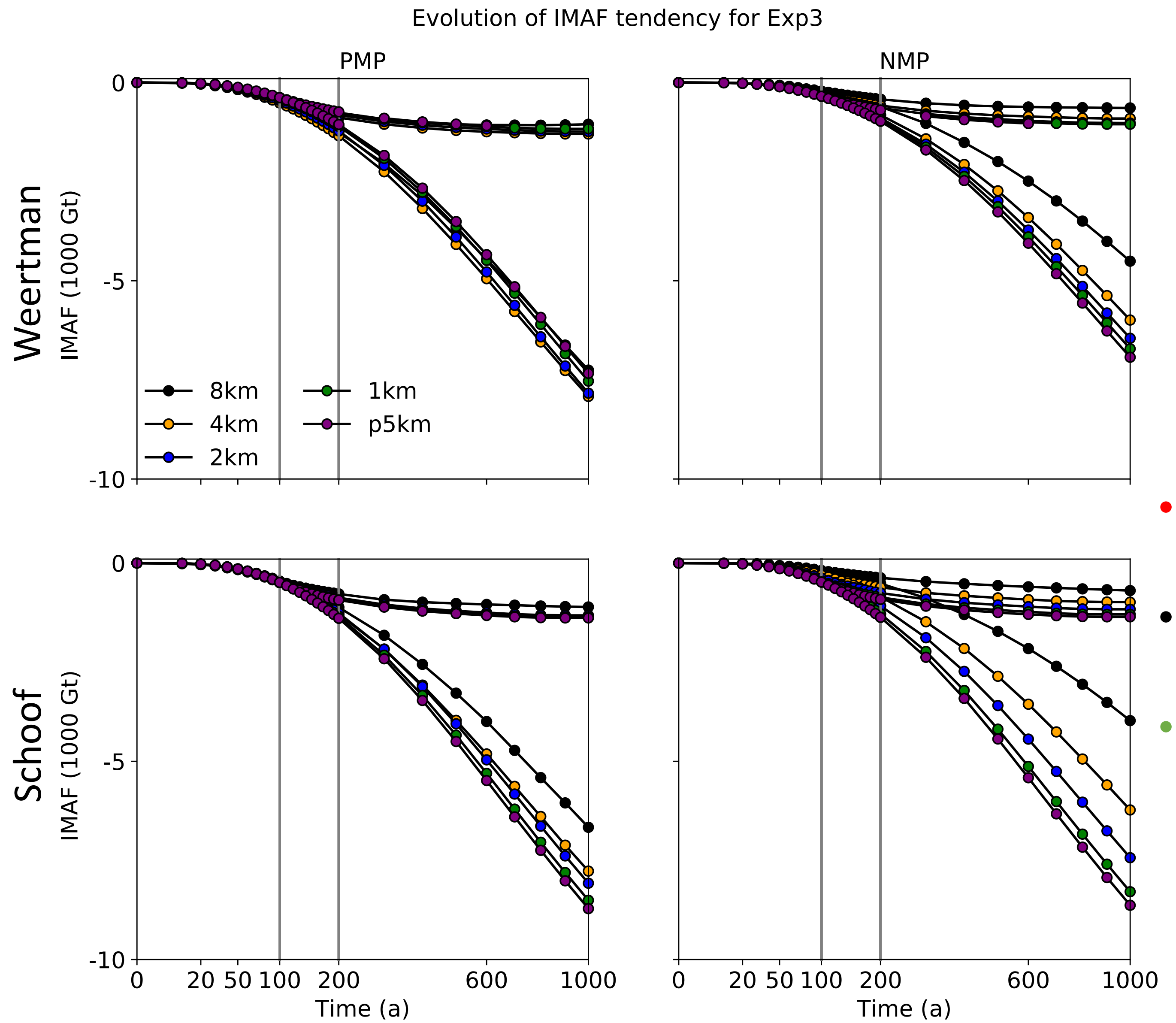


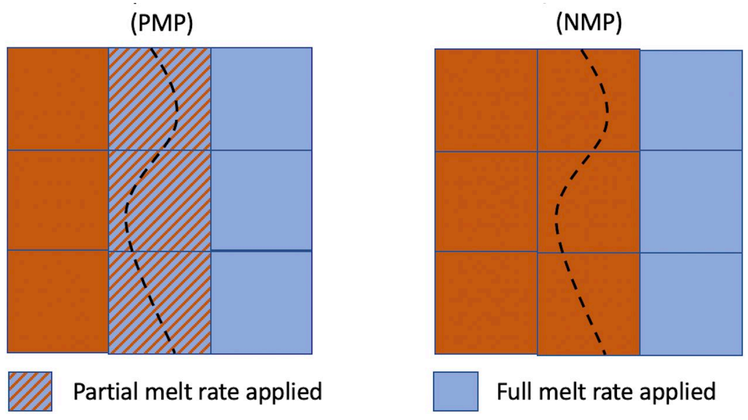


- Better convergence with PMP than NMP for all basal friction laws.
- Slower convergence with Schoof than with Weertman.
- With PMP, results at resolutions 1-4 km are within 10% of those at 0.5 km.

Exp3 (low accumulation, slow-moving ice)

$a = 0.05$ m a^{-1}
$m_{max} = 30$ m a^{-1}





- 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

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."
The Cryosphere Discussions (2020): 1-33.