Sensitivity of the ISMIP6-2300-based Antarctic ice sheet projections to model configurations

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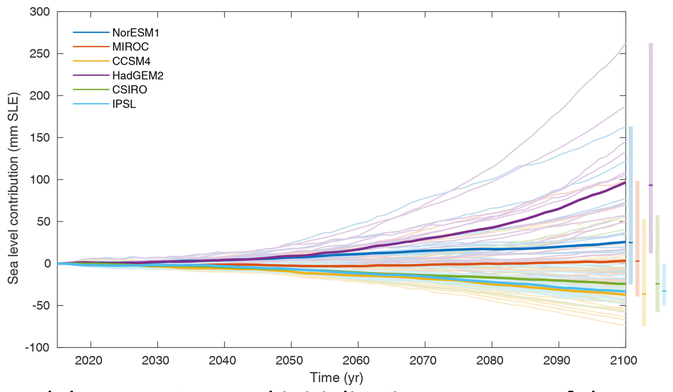
Background and Aims

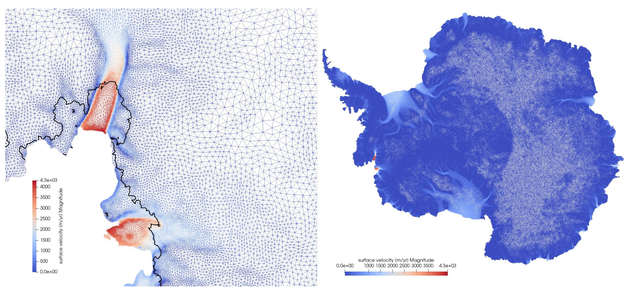
- Large uncertainties in current sea level projections from Antarctic Ice sheet



- Glacier model parameters and initialisations are one of the uncertainty sources
- How sensitive are ice sheet projections to model configurations

Model setup

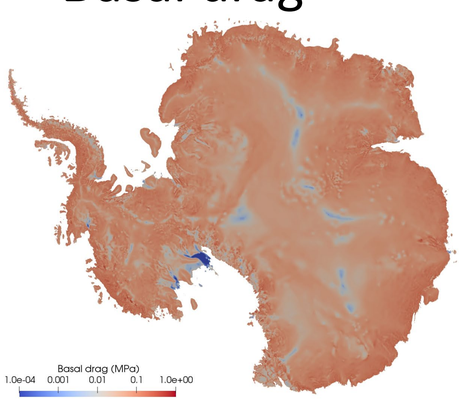
- Elmer/ice (finite-element ice sheet model)
- Shallow Shelf Approximation
- High resolution (1 km near the grounding line)



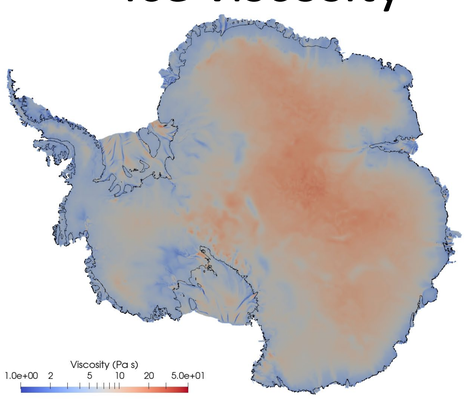
- Basal melt parameterization (ISMIP6 standard approach)
- Climate forcing from UKESM-ssp5-85

Initial State

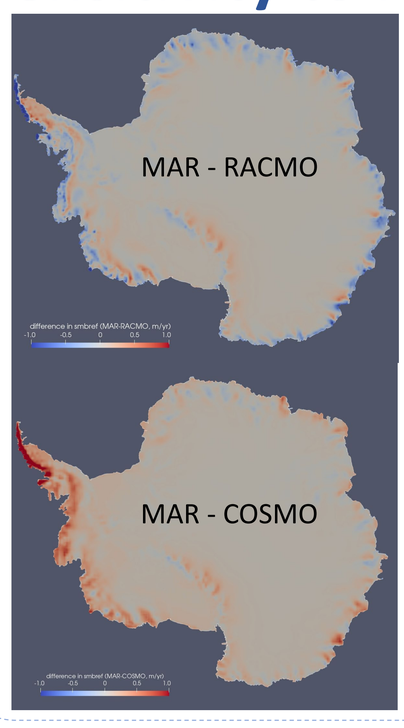
Basal drag

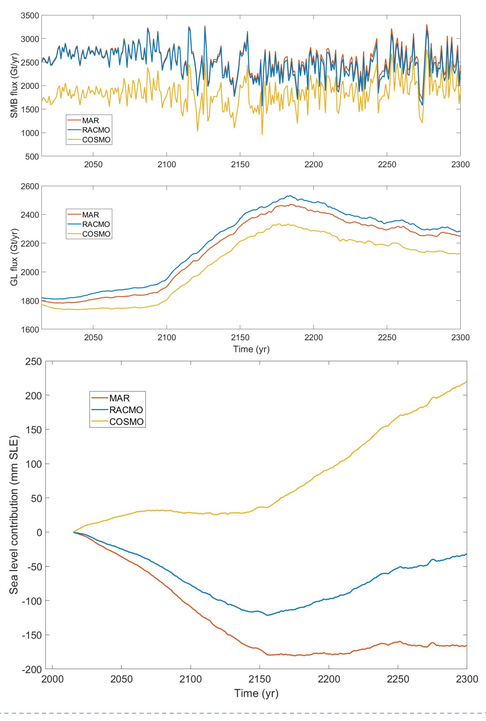


Ice viscosity



Sensitivity to reference SMB





Difference from SMB models may not cause significant changes in ice mass loss but may largely affect the changes in volume above floatation.

Sensitivity to basal sliding law

Linear Weertman (m = 1)

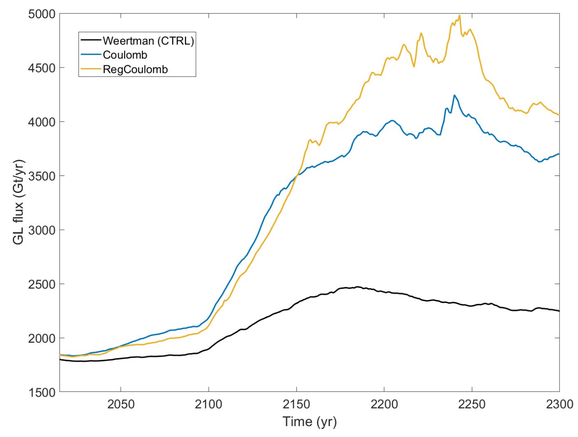
$$\tau_b = C_w \cdot u_b = 10^{\beta} u_b$$

Coulomb Sliding law

$$\begin{aligned} \tau_b &= C_c \cdot N \left(\frac{\chi \cdot u_b^{-m}}{1 + a \cdot \chi^q} \right)^{\frac{1}{m}} \cdot u_b \\ a &= \frac{(q-1)^{q-1}}{q^q} \\ \chi &= \frac{u_b}{C_c^m N^m A_s} \\ N &= \rho_i g H - \rho_o g z_s \end{aligned}$$

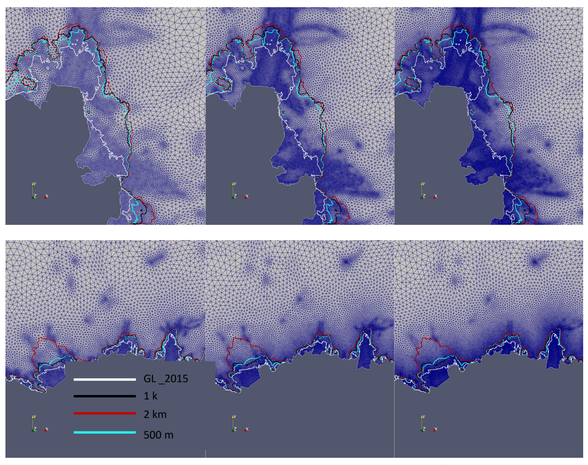
Regularised Coulomb Sliding law

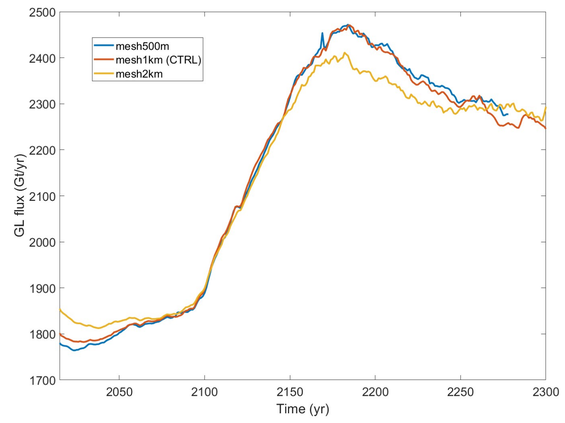
$$\tau_b = \begin{cases} C_c \cdot \left(\frac{u_b}{u_b + u_0} \right)^{\frac{1}{m}} & \text{if } h_{af} \geq h_T \\ C_c \cdot \left(\frac{u_b}{u_b + u_0} \right)^{\frac{1}{m}} \frac{h_{af}}{h_T} & \text{if } h_{af} < h_T \end{cases}$$



Linear Weertman sliding law will largely underestimate ice mass loss compared with pressure-dependent sliding law

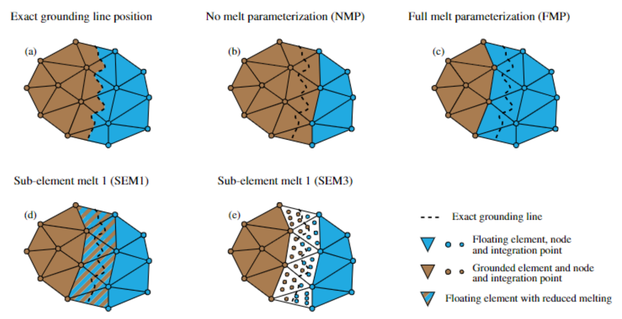
Sensitivity to mesh resolution

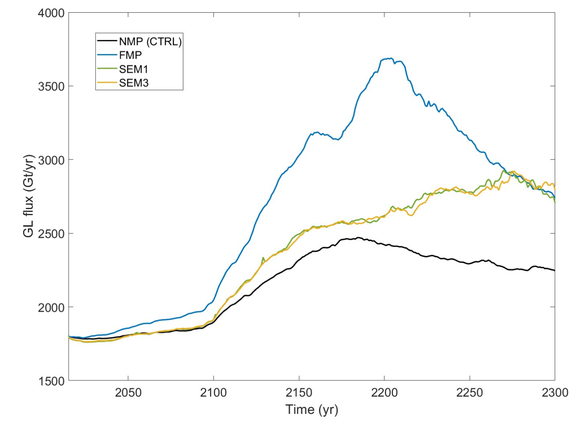




Coarser mesh resolution near the grounding line (GL) will overestimate the GL retreat but underestimate the GL flux

Sensitivity to basal melt applied at partially-floating cells





Coarser mesh resolution near the grounding line (GL) will overestimate the GL retreat but underestimate the GL flux

Conclusion

- Sliding laws considered the effective pressure should be used in future ice sheet projections → effective pressure from a coupled subglacial hydrology-ice sheet model
- A mesh resolution of 1 km near the GL is fine enough to capture the dynamics changes for most regions in Antarctica, while an adaptive mesh refinement is necessary to guarantee a fine resolution for new grounding line position.
- Uncertainty from SMB can largely affect the sea level rise projections.
- Projected ice mass loss is very sensitive to how we apply melt for partially floating cells and sub-element method is recommended.

Acknowledgements: Chen Zhao and Yu Wang received grant funding from the Australian Government as part of the Antarctic Science Collaboration Initiative program (ASCI000002). Rupert Gladstone, Thomas Zwinger and Leopekka Saraste are supported by Academy of Finland grant nos. 322430 and 286587 and wish to acknowledge CSC – IT Center for Science, Finland, for computational resources. We thank the support from Grenoble research communities.

The Australian Antarctic Program Partnership is funded by the Australian Government Department of Industry, Science, Energy and Resources through the Antarctic Science Collaboration Initiative.

The Australian Antarctic Program Partnership is led by the University of Tasmania, and includes the following partner agencies