Ice-Sheet Model Calibration and Parametric Uncertainty Analysis for 2000-2024

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Antarctica's freshwater outflows contribute significantly to sea level rise, responsible for around 10% of the global average increase.

OCEAN:ICE WP4 AIMS

- To project the freshwater fluxes of the AIS in ice sheet and coupled ice sheet-ocean models from 2020-2300 and its contribution to SLR.
- To apply surrogate modelling techniques to quantify modelled freshwa flux uncertainties and sensitivities to a range of climate forcing scenari identify tipping points.

Circum-Antarctic Simulations With Úa (2000-2300) - 4 Steps

2000

Snapshot inversions

↓

Ice-sheet initial states

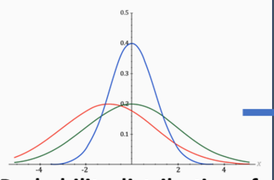
Ensemble: *n*, *m*, sliding law, regularization parameters

2020

Diagnostic Perturbations

Impose measured changes in ice thickness and ice front between 2000 and 2020

Compare diagnostic response to observed changes in velocity



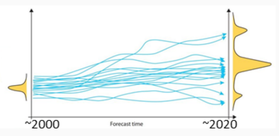
Probability distribution of initial states

2000 - 2020

Transient hindcast

Transient simulations between 2000 and 2020 starting from initial states, for a range of forcing parameters (focus on basal melt)

Comparison to observed changes in velocity, ice thickness, GL location



Updated ('calibrated') distribution of model parameters

2020 - 2300

Transient forecast

Transient simulations between 2020 and 2300 starting from calibrated set.

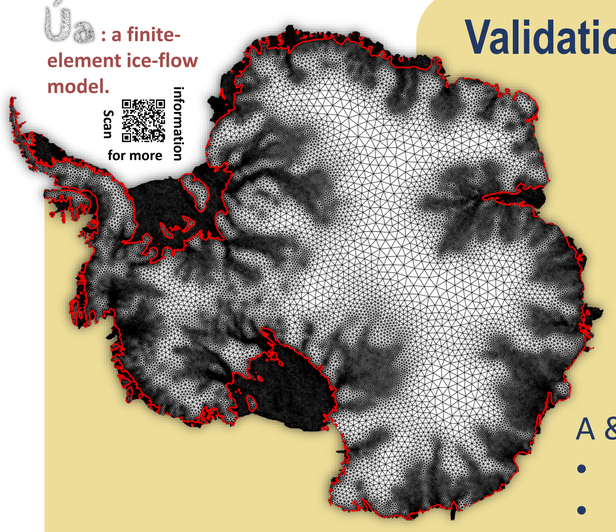
Sensitivity of FWF to

- Climate forcing
- Physical parameters

(focus on ocean and SMB first, need to think about calving and damage)

Úa : a finite-element ice-flow model.

Scan for more information



Validation of Circum-Antarctic Ice-Sheet Model

Inversion: An ensemble of initial states for 2000 generated with inversions for different sliding laws and rate factors.

Geometry for 2000: Bedmachine s+ds, with ds based on CPOM and ITSLive data.

Velocities from MeaSUREs, ITSLive.

A & C estimates generated from **one of the inversions.**

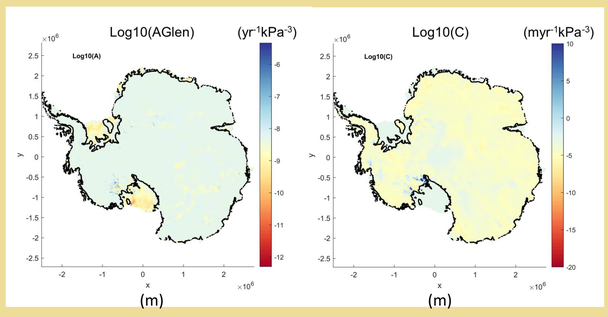
- Creep exponent (Glen's law) n = 3.
- Sliding law exponent (Weertman sliding law) m = 3.

Mesh & GL

——: grounding line (GL).

Median area of elements: 35 km^2 .

Reservation around GL: 3 km.



Basal mass balance:

- Local quadratic melting parameterization (Jourdain et al., 2020)

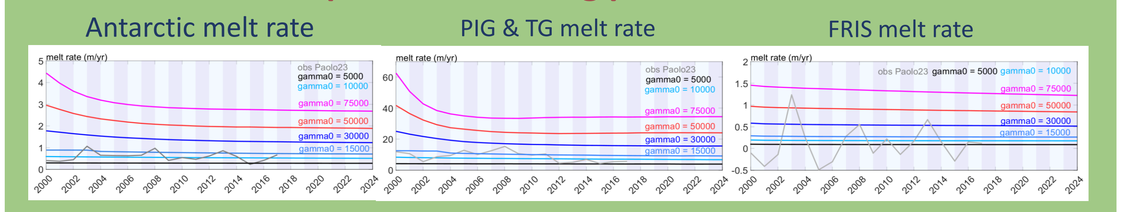
$$m(x,y) = \gamma_0 \times \left(\frac{\rho_{sw} c_{pw}}{\rho_i L_f}\right)^2 \times \left\{\max\left[\mathrm{TF}(x,y,z_{draft}) + \delta T_{sector}, 0\right]\right\}^2$$

- PICO model (Reese et al., 2018a)

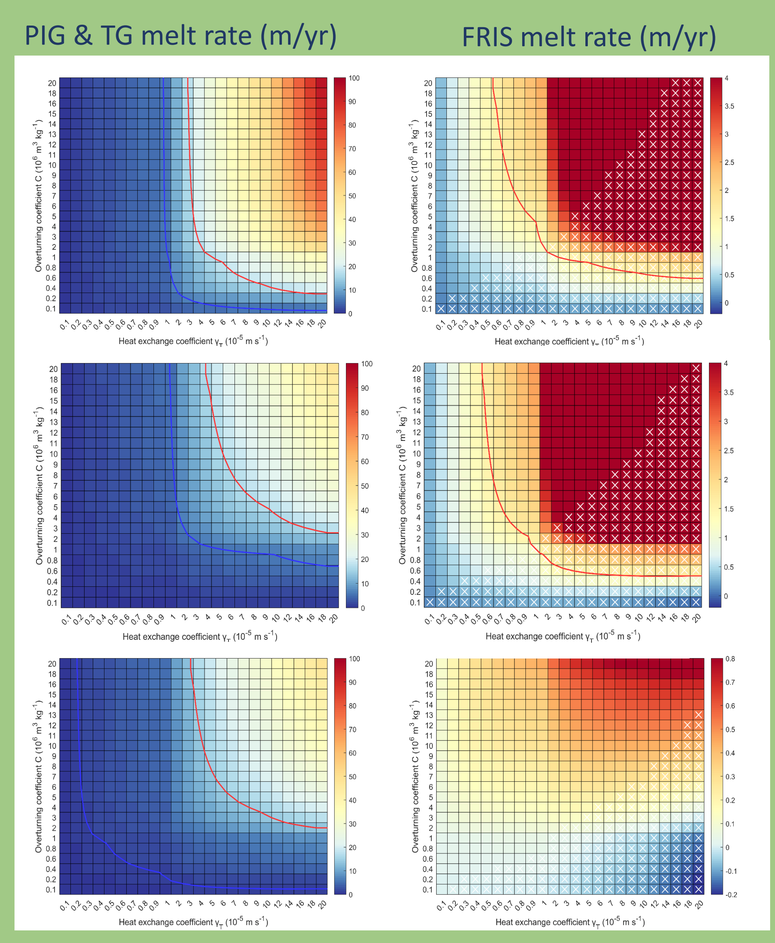
Surface mass balance: MAR SMB

Initial Sensitivity Study of Basal Melting to Key Parameters and Geometry

Local quadratic melting parameterization



PICO



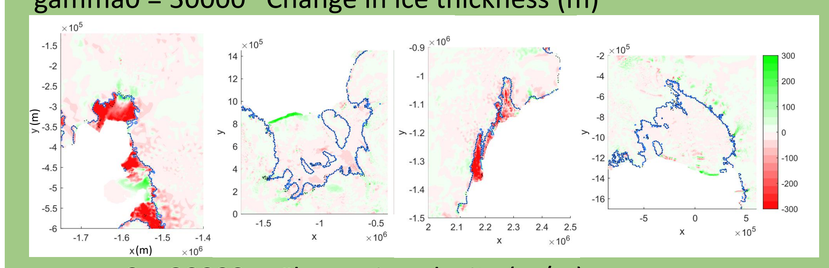
—— Highest and —— lowest observed melt rate in the record, based on quarterly observational data (Paolo et al. 2023).

╳ White crosses indicate refreezing in first box.

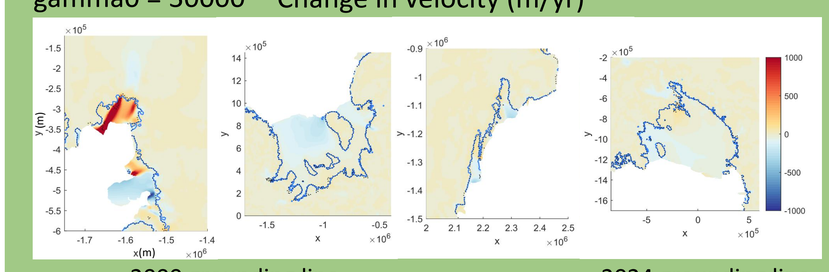
Preliminary Results (2000-2024)

Local quadratic melting parameterization

gamma0 = 30000 Change in ice thickness (m)



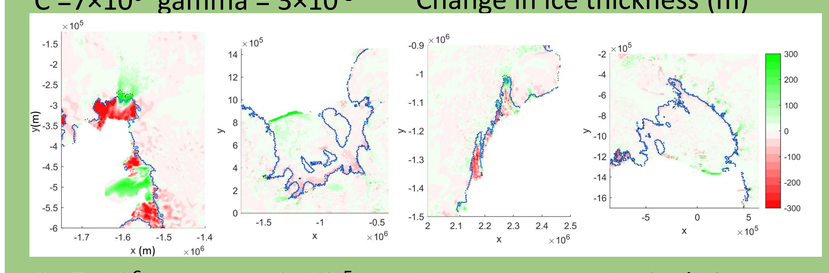
gamma0 = 30000 Change in velocity (m/yr)



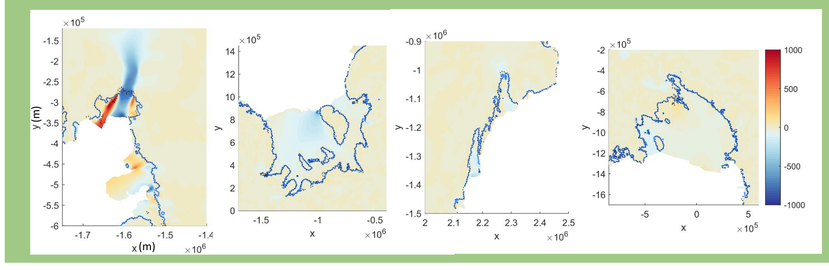
┈┈2000 grounding line ——2024 grounding line

PICO

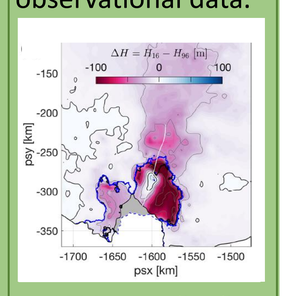
C =7×10^6 gamma = 3×10^{-5} Change in ice thickness (m)



C =7×10^6 gamma = 3×10^{-5} Change in velocity (m/yr)



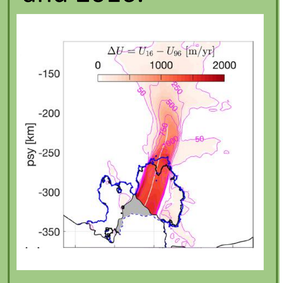
Change in ice thickness between 1996 and 2016 based on observational data.



—— 1996 grounding line

—— 2011 grounding line

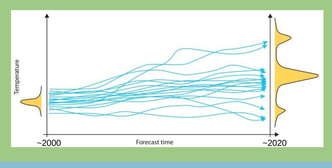
Observed increase in surface speed between 1996 and 2016.



Next Steps

By using **a range of** ice-sheet initial conditions, along with different **basal melting parameterizations**, **key physical parameters**, and external forcing, an ensemble of hindcast simulation results will be produced.

These results will then serve as the starting points for the next phase of forecast transient simulations.



Transient Forecast

Run transient simulations between 2020 and 2300 starting from calibrated set for projected future scenarios.

- Coulon, V., De Rydt, J., Gregov, T., Qin, Q., & Pattyn, F. (2024). Future freshwater fluxes from the Antarctic ice sheet. Future, 13, 1.
- Jourdain, N. C., Asay-Davis, X., Hattermann, T., Straneo, F., Seroussi, H., Little, C. M., & Nowicki, S. (2020). A protocol for calculating basal melt rates in the ISMIP6 Antarctic ice sheet projections. The Cryosphere, 14(9), 3111-3134.
- Paolo, F. S., Gardner, A. S., Greene, C. A., Nilsson, J., Schodlok, M. P., Schlegel, N. J., & Fricker, H. A. (2023). Widespread slowdown in thinning rates of West Antarctic ice shelves. The Cryosphere, 17(8), 3409-3433.
- Reese, R., Albrecht, T., Mengel, M., Asay-Davis, X., & Winkelmann, R. (2018). Antarctic sub-shelf melt rates via PICO. The Cryosphere, 12(6), 1969-1985.