The uncertainty in Antarctic sea-level rise projections due to ice dynamics

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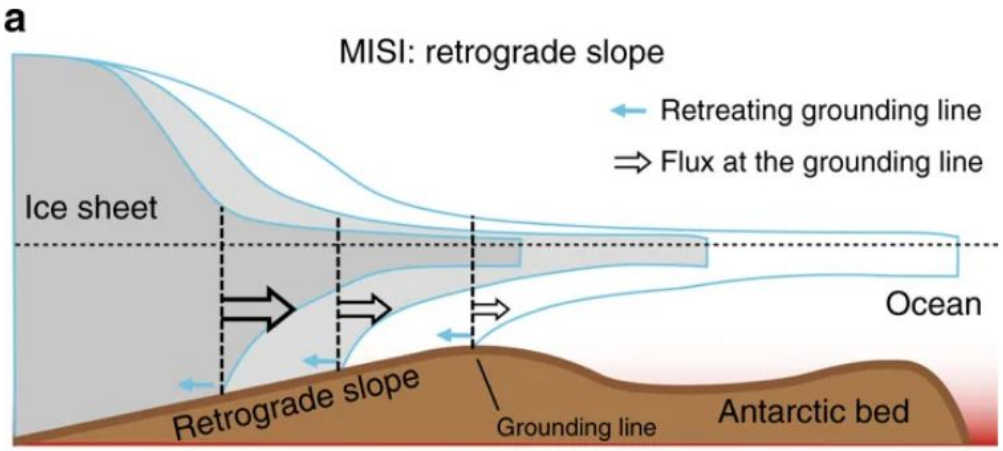
Motivation



Pattyn et al., 2018

WAIS is the largest source of uncertainty in future sea-level projections

IPCC, AR5, 2013

Sources of uncertainty:

- Projections
- Physical processes:
  - Ice-Ocean interaction
  - Grounding-line processes
  - **Ice dynamics**

How do different basal-dragging laws affect sea-level rise projection?

Experimental setup

- The ice-sheet-shelf model Yelmo (Robinson et al., 2019) is forced towards an equilibrated **LGM** state and, through a deglaciation spin-up, driven towards **PD** conditions

- Different friction parameters are investigated for every friction laws (ensemble of >1000 simulations)

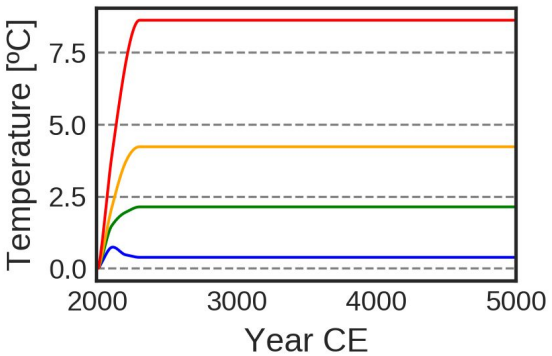
$$\boldsymbol{\tau}_\mathrm{b} = -\beta\ \mathbf{u}_\mathbf{b} = -C_\mathrm{b}\, f(|\mathbf{u}_\mathbf{b}|, u_0)\ \mathbf{u}_\mathbf{b} = \begin{cases} -\frac{C_\mathrm{b}}{u_0}\mathbf{u}_\mathbf{b} & \text{linear law} \\ -C_\mathrm{b}\left(\frac{|\mathbf{u}_\mathbf{b}|}{u_0}\right)^q \frac{\mathbf{u}_\mathbf{b}}{|\mathbf{u}_\mathbf{b}|}, & \text{pseudo-plastic power law} \\ -C_\mathrm{b}\left(\frac{|\mathbf{u}_\mathbf{b}|}{|\mathbf{u}_\mathbf{b}|+u_0}\right)^q \frac{\mathbf{u}_\mathbf{b}}{|\mathbf{u}_\mathbf{b}|} & \text{regularized Coulomb power law} \\ -C_\mathrm{b}\,\frac{\mathbf{u}_\mathbf{b}}{|\mathbf{u}_\mathbf{b}|} & \text{plastic law} \end{cases}$$

where

$$c_b = c_f \lambda_b N_\mathrm{eff} \qquad N_\mathrm{eff} = \rho_i g\,(H - H_f)$$

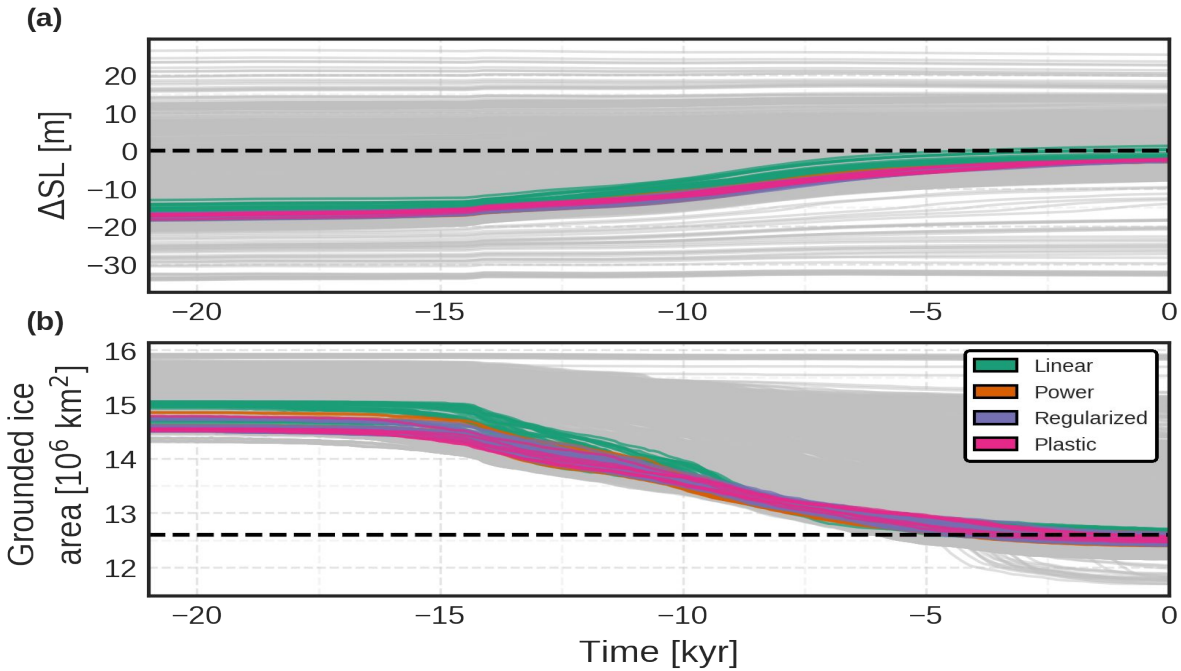
$$\lambda_b = \begin{cases} 1 & \text{if } z_b \geq z_1 \\ \exp\left(\frac{z_b - z_1}{z_1 - z_0}\right) & \text{if } z_b < z_1 \end{cases}$$

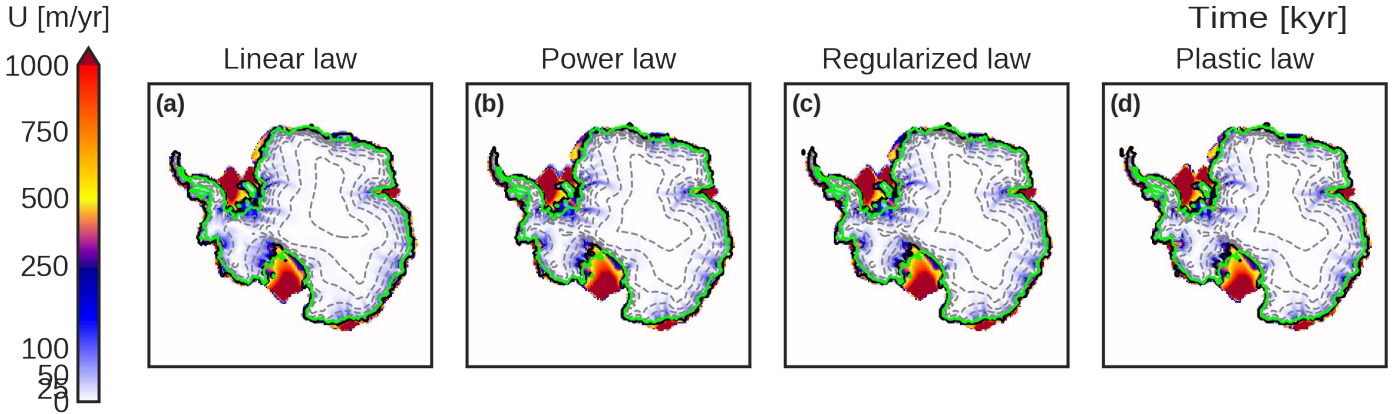
- Simulations that match realistic **LGM** and **PD** states are considered for future RCP scenarios



Deglaciation spinup

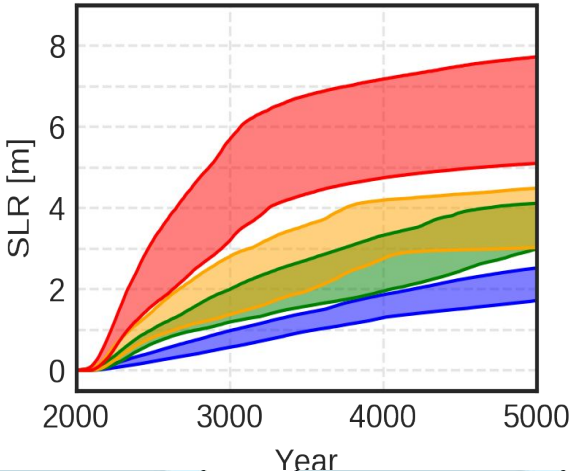
- 105 of 1048 simulations matched a realistic **PD** and **LGM** state
- Without the **LGM** constraints 128 simulations matched a realistic **PD** state

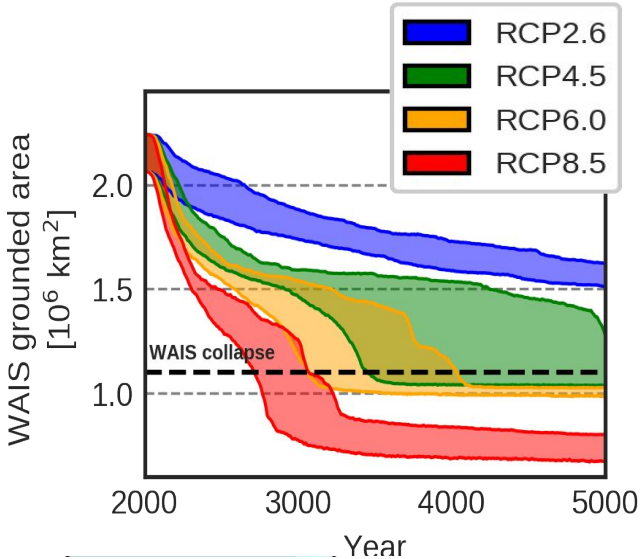




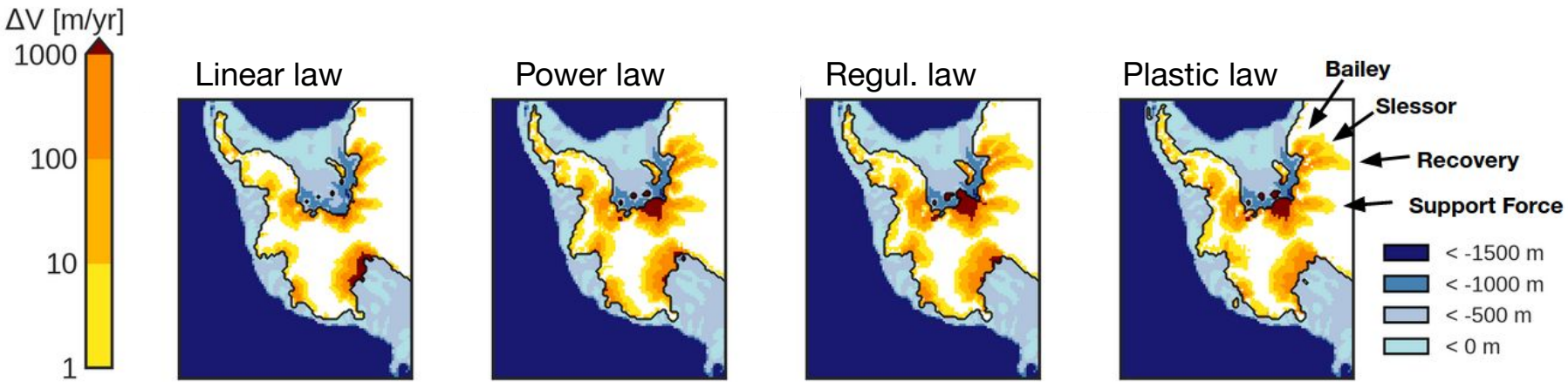
Future projections

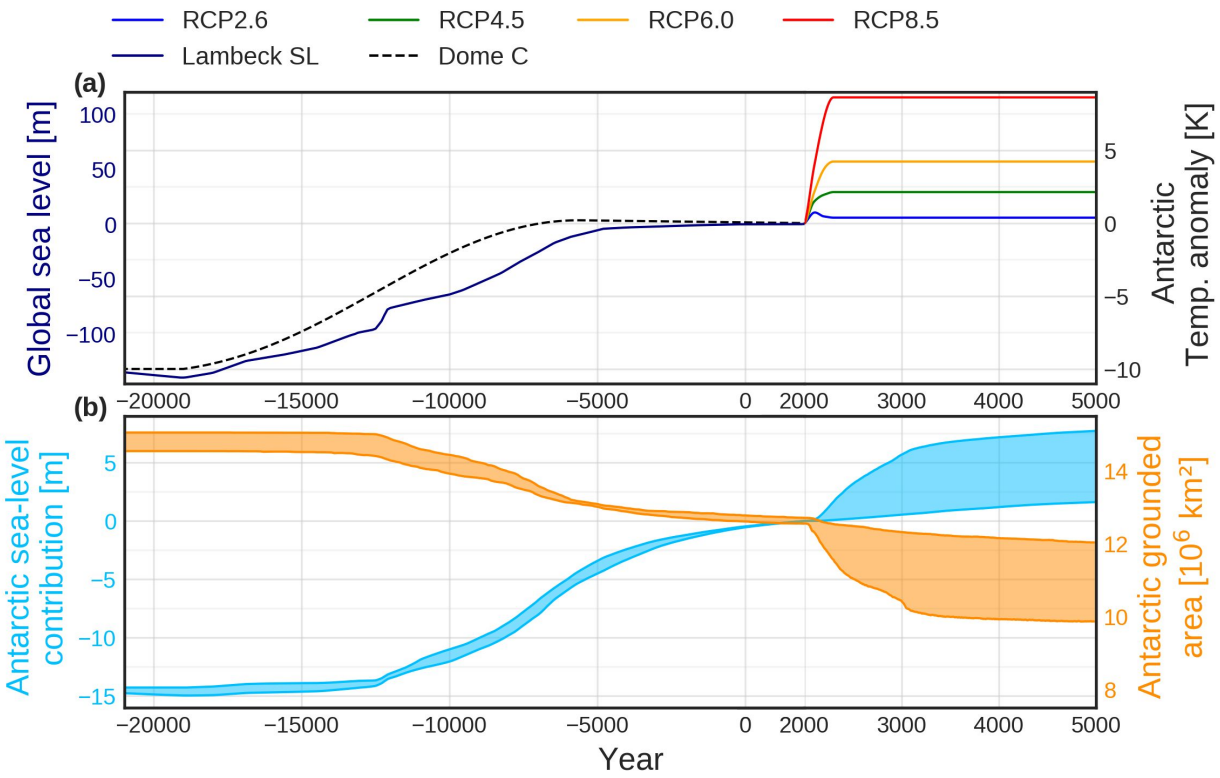
- Lower bounds in SLR correspond to a linear friction law
- Upper bounds to regularized and plastic friction law -> Velocity anomalies penetrate deeper inland





Velocity anomaly year 2300 RCP4.5:





Take-home messages:

- The RCP scenario is the main driver of SLR
- The occurrence of a WAIS collapse increases with RCP scenario
- The velocity anomaly of a linear friction law propagates less inland and discharges less ice