2024 European Polar Science Week

Challenges in modelling ice shelf processes

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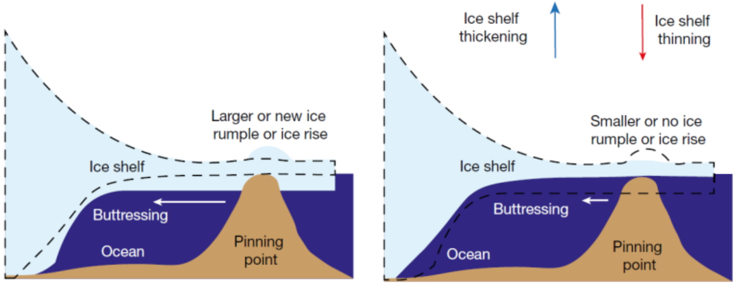
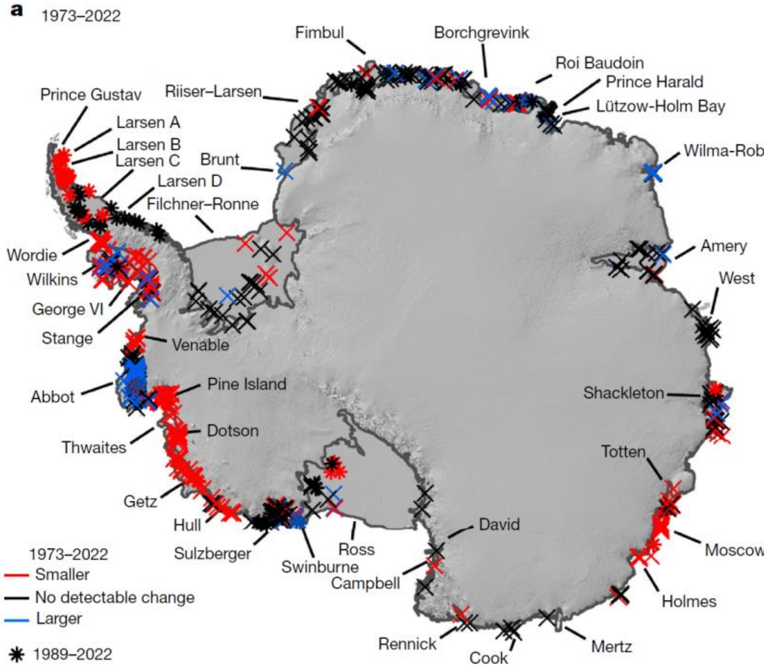
Ice shelves matter

Regularize grounded ice flow through buttressing

Major freshwater source for Southern Ocean

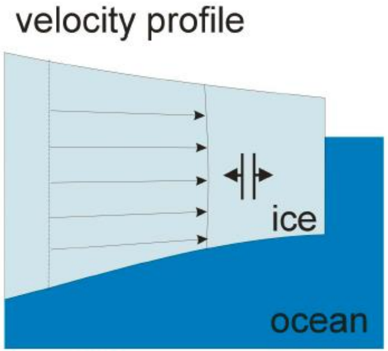
The waterfall at the Nansen ice shelf. (Wong Sang Lee / Korea Polar Research Institute)





Miles and Bingham (2024)

The flow of ice shelves is well understood



Ice shelf: buoyancy-driven flow (longitudinal stretching + lateral shearing)

$$4\frac{\partial}{\partial x}\left(\eta h\frac{\partial u}{\partial x}\right) = \rho_i g h\frac{\partial s}{\partial x}$$

$$\eta = \frac{1}{2}A^{-1/n}\dot{\varepsilon}^{\frac{1-n}{n}}$$

Non-local stress balance

Flow speed controlled by ice viscosity and ice/water pressure at calving front

Ocean boundary condition

$$2\eta h\left(2\frac{\partial u}{\partial x}\right) = \frac{\rho g h^2}{2}\left(1 - \frac{\rho}{\rho_w}\right)$$

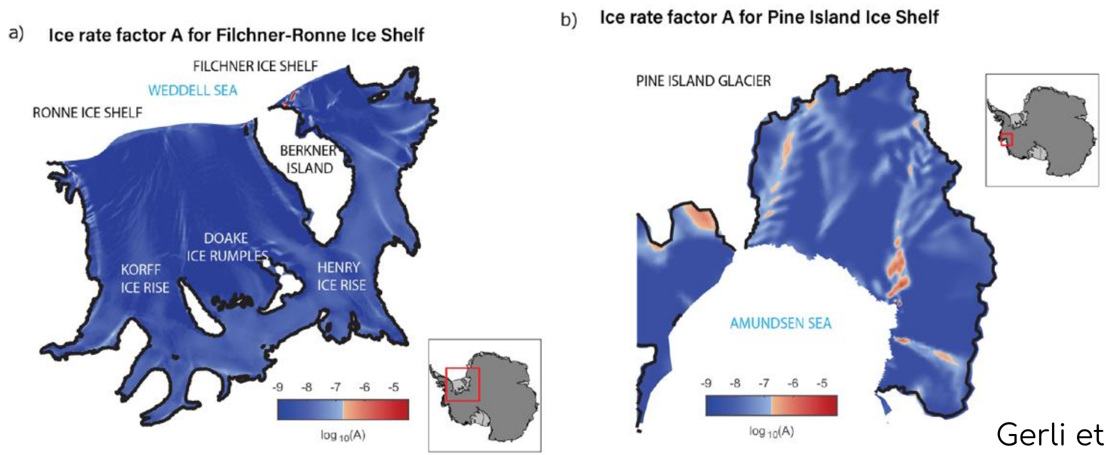
Morland (1987)

Some aspects of ice shelf flow are less well understood

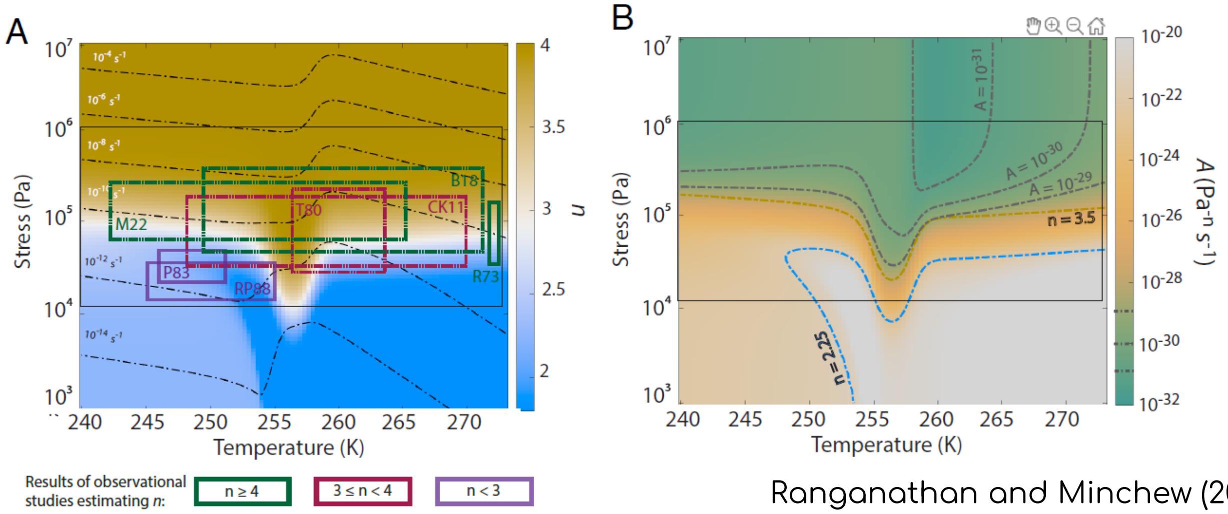
Effective viscosity of ice shelves has a large spatial variability

Glen's flow factor shows large variability

Glen's flow exponent n=4?



Gerli et al (2024)



Ranganathan and Minchew (2024)

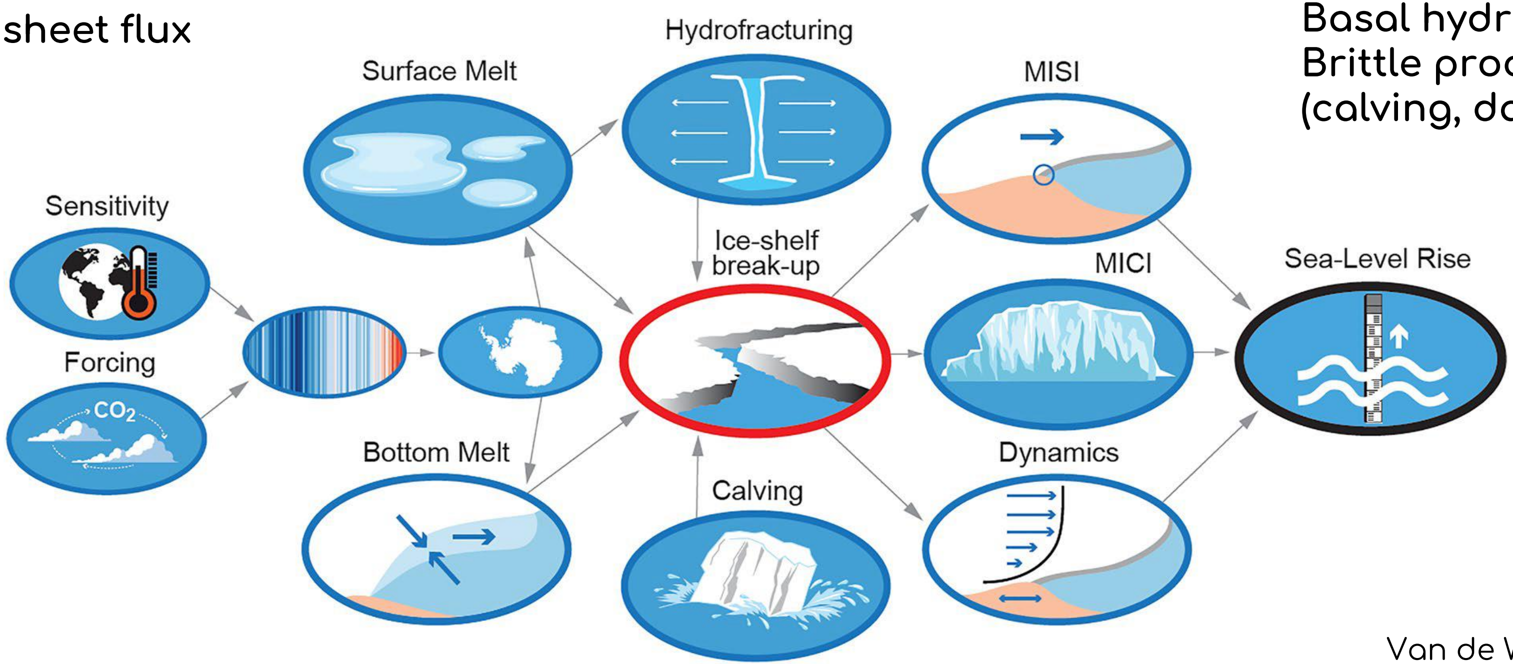
Numerous processes impact ice shelves

BOUNDARY CONDITIONS

Atmosphere
Ocean
Ice sheet flux

PROCESSES

Sub-shelf melting
Surface melt
Basal hydrology
Brittle processes
(calving, damage)



Van de Wal et al (2022)

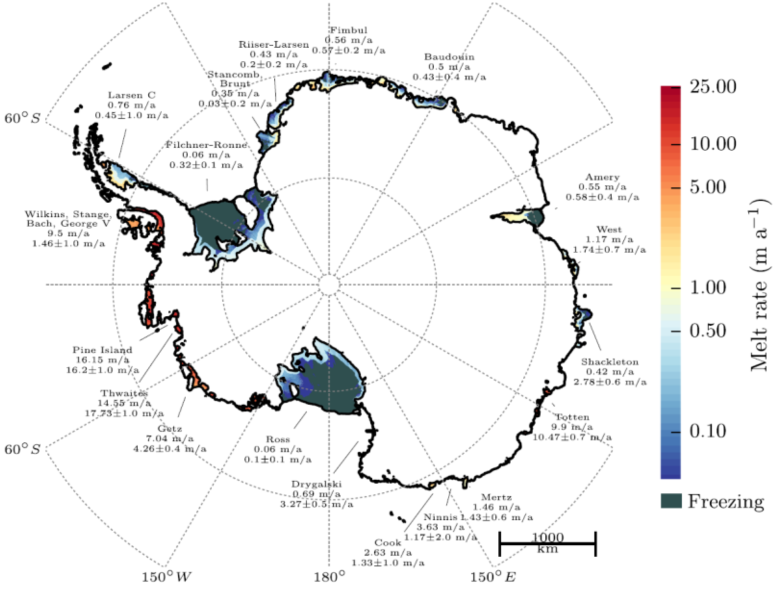
Sub-shelf melt in ice sheet models

Need to resolve ocean circulation in sub-shelf cavities

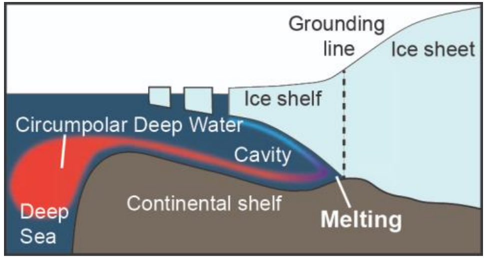
Parameterized models (ocean box and plume models)

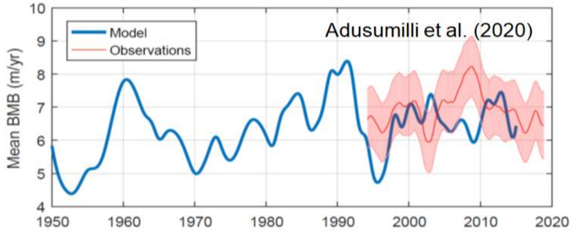
Some validation of sub-shelf melt schemes with observations

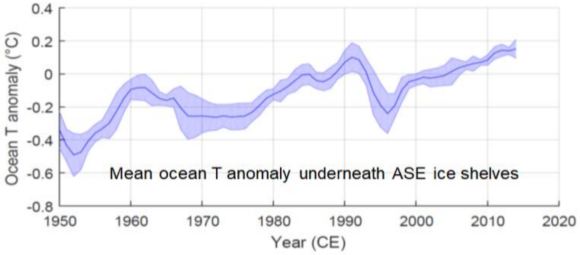
ocean reanalysis?



Reese et al (2018)

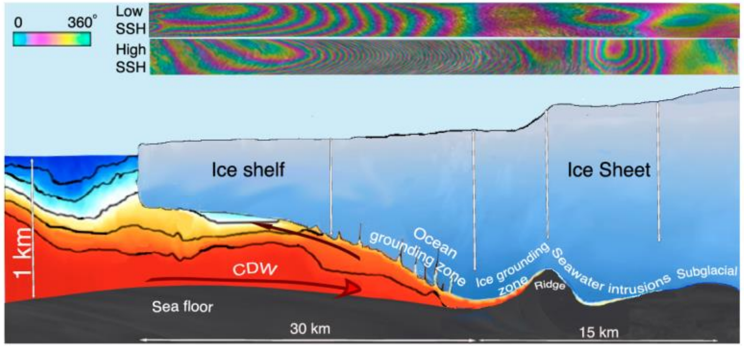




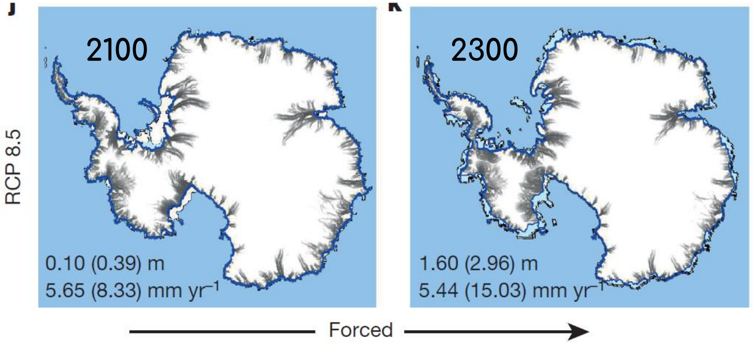


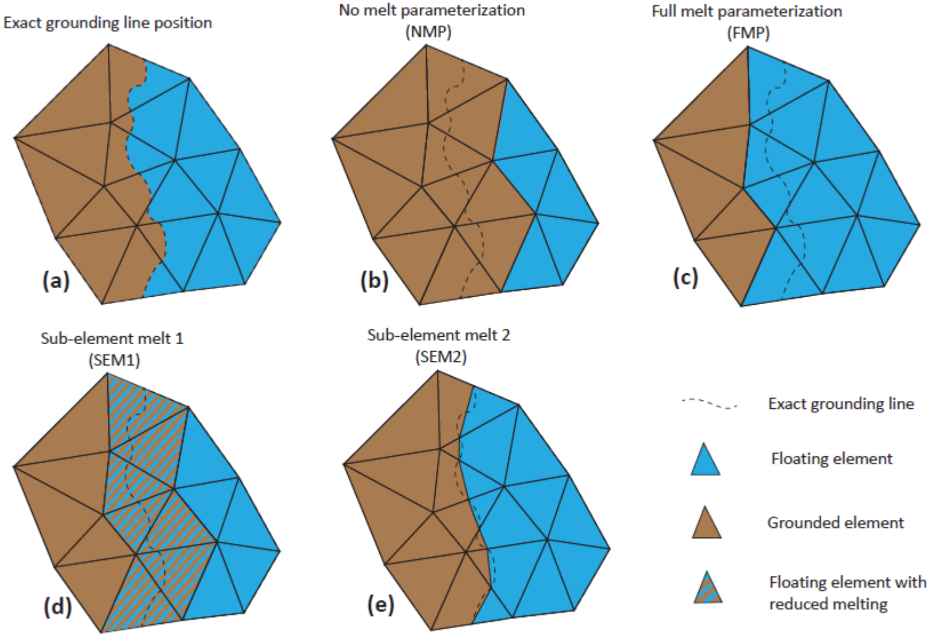
Coulon et al (2024)

Sub-shelf melt intrusion under grounded ice increases the sensitivity of ice sheet response



Rignot et al (2024)

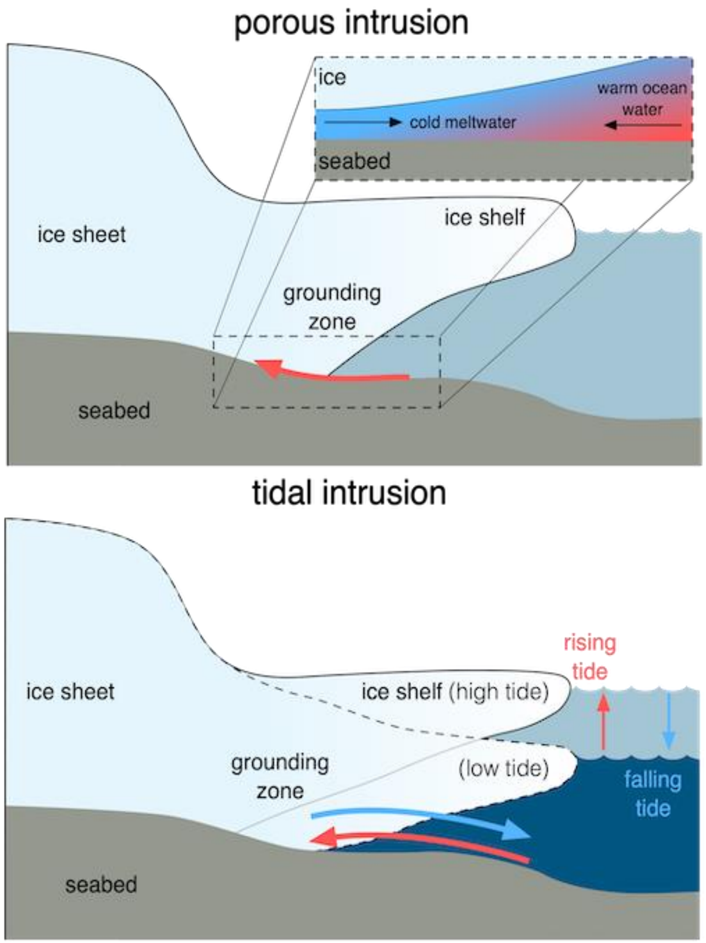




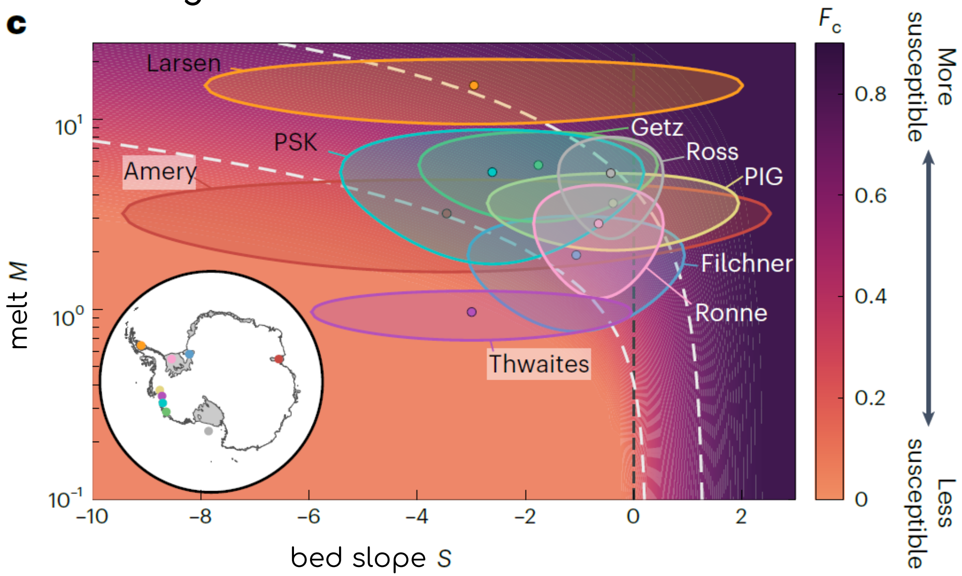
Seroussi and Morlighem (2018)

Golledge et al (2015)

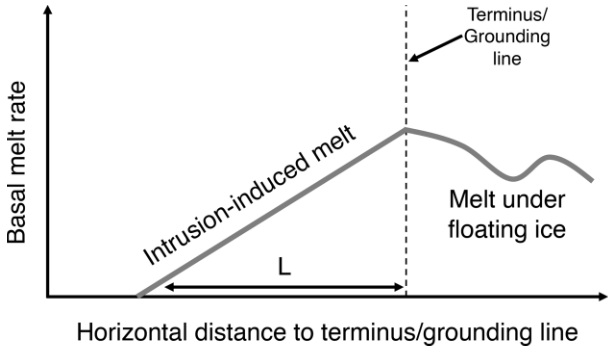
Melting causes enhanced warm water intrusion



Bradley and Freer (2024)

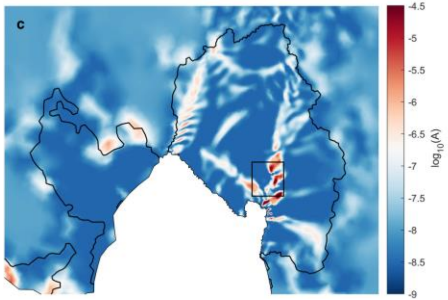


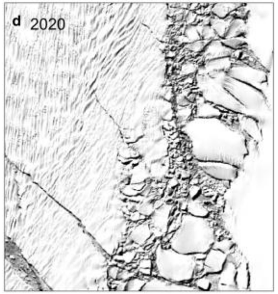
Bradley and Hewitt (2024)



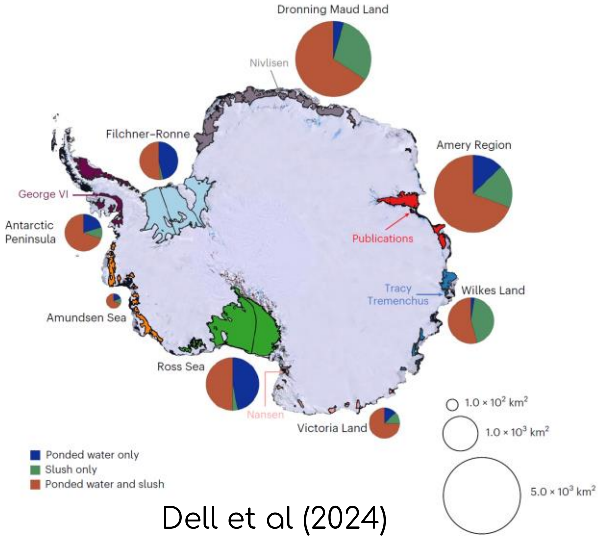
Robel et al (2022)

Brittle processes: hydrofracture and damage

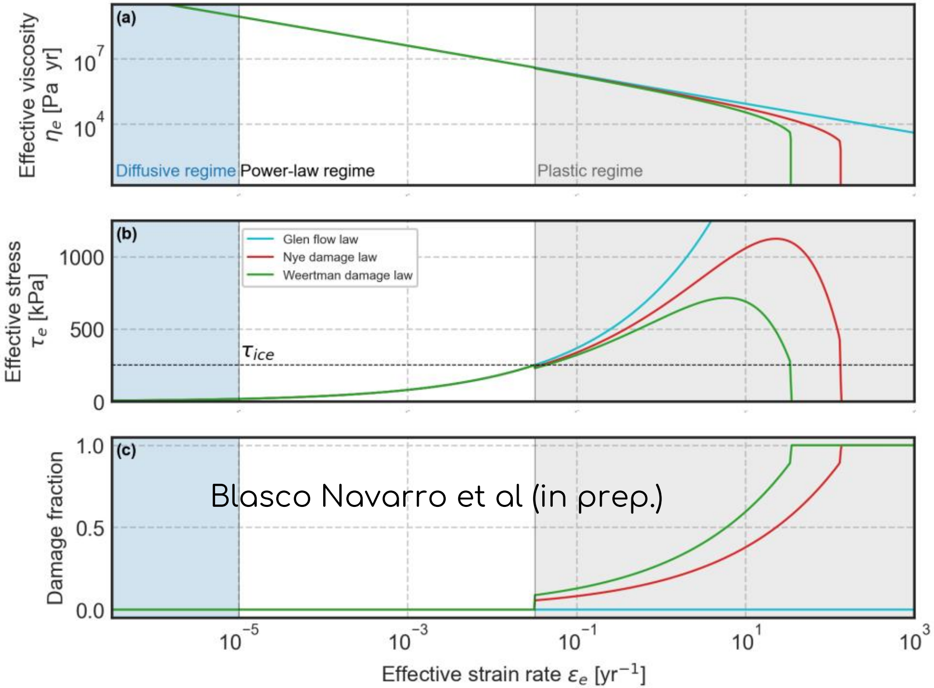




Sun and Gudmundsson (2023)



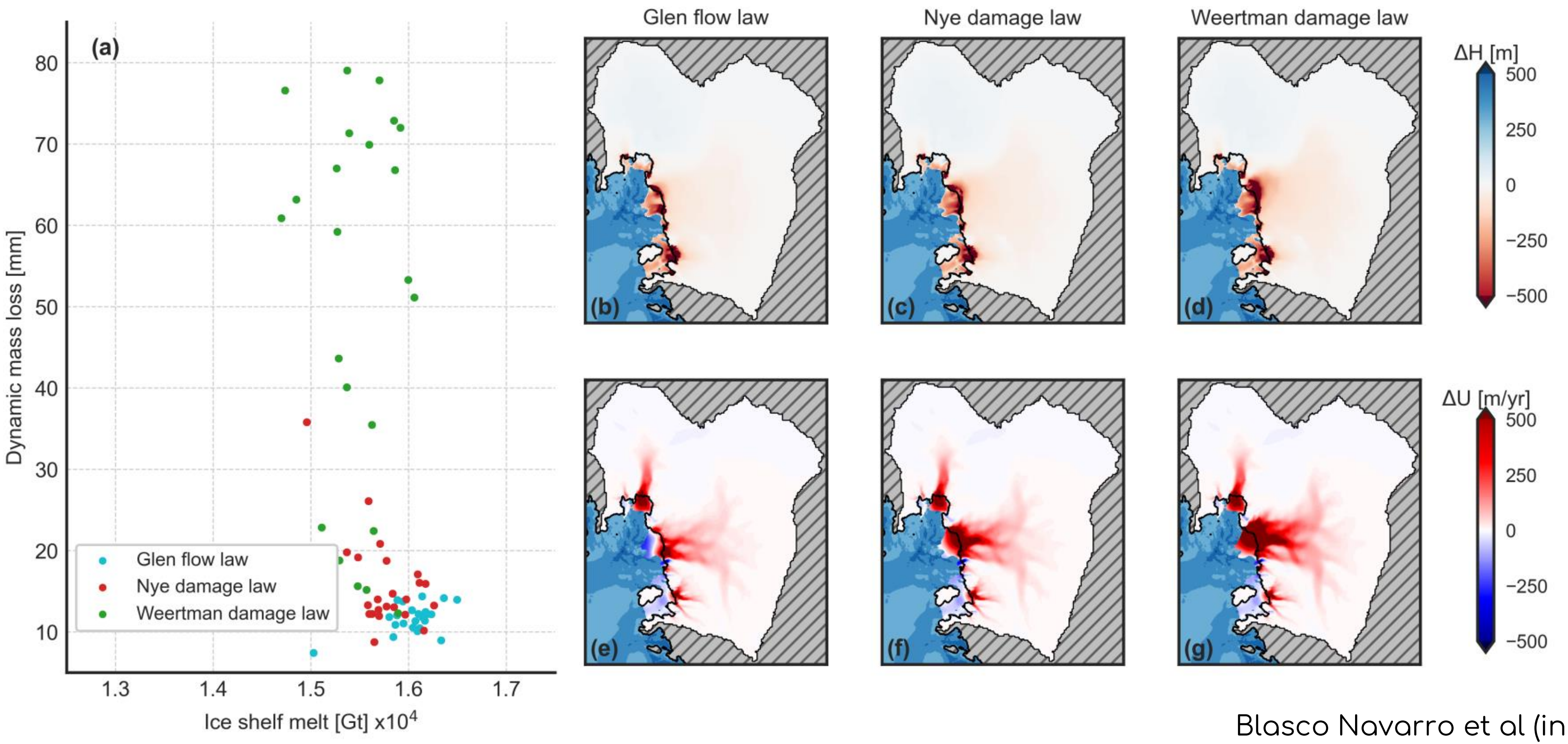
Dell et al (2024)



Blasco Navarro et al (in prep.)

Surface/bottom crevasse formation as a function of principal stress
Surface melt water -> ponding + hydrofracturing

Damage creates more damage (feedback)



Blasco Navarro et al (in prep.)

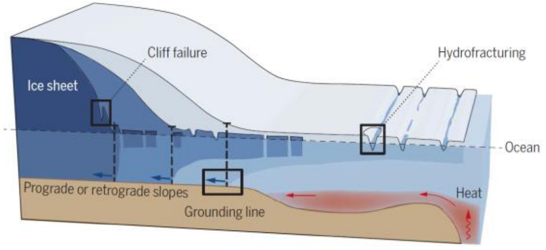
MICI: ice cliff collapse parameterizations

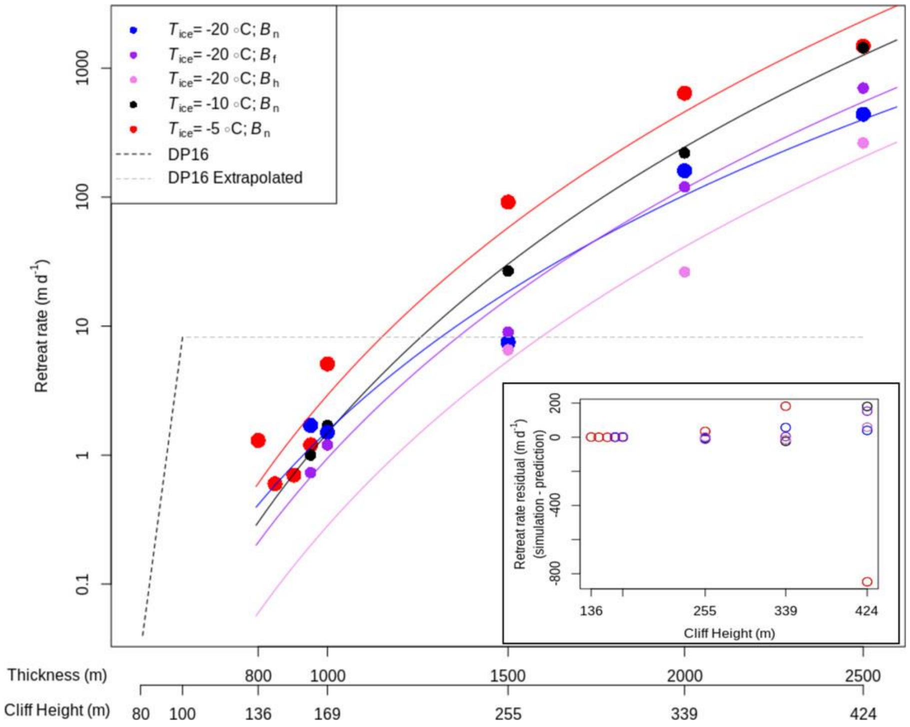
Cliff collapse parameterized in DeConto and Pollard (2016)

Process takes place after ice shelf collapse and through hydrofracturing

Not operating today (therefore cannot be tested/validated using direct observations)

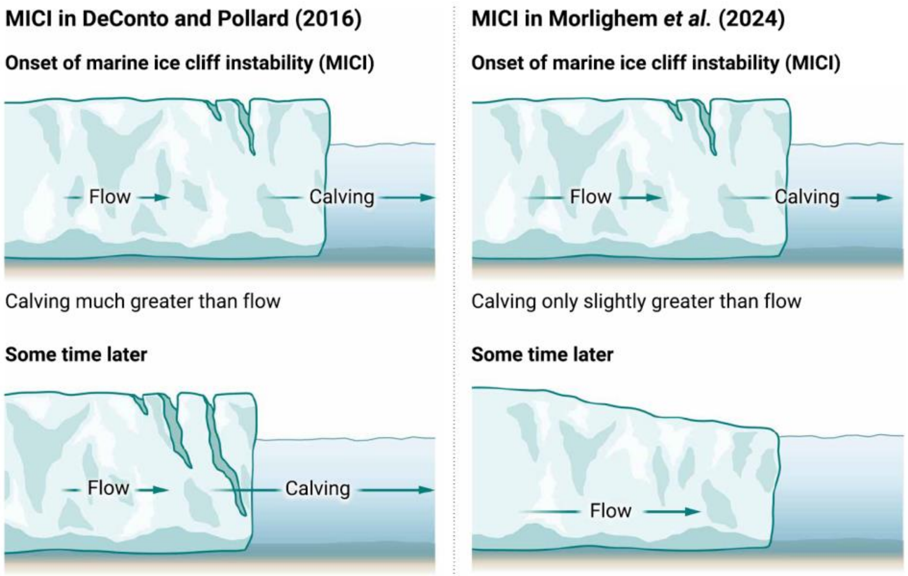
Parameterized as retreat rate and not calving law

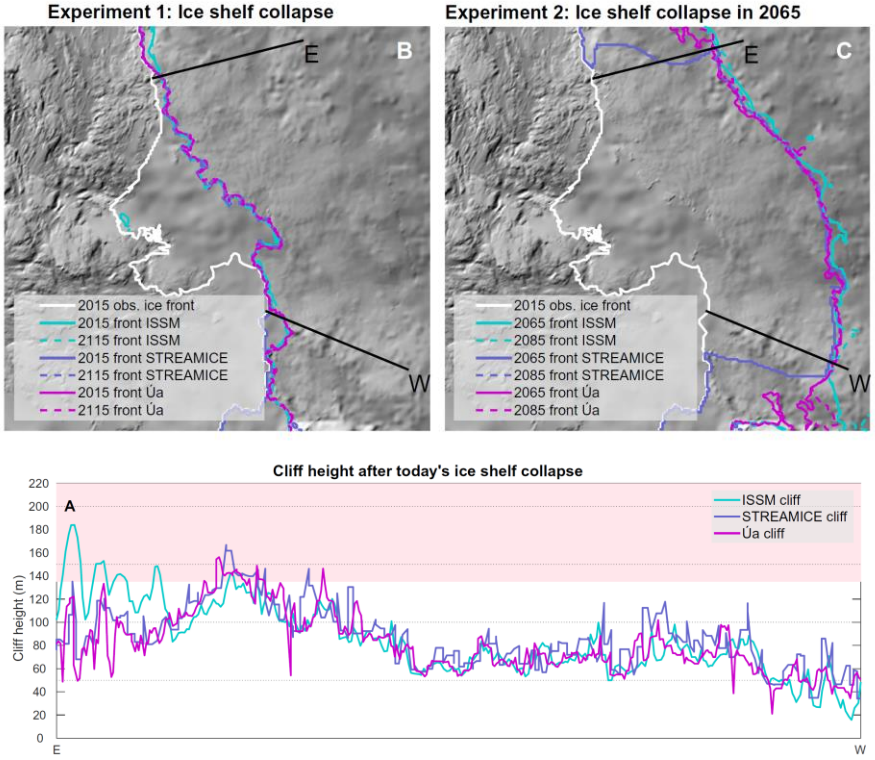




Crawford et al. (2021)

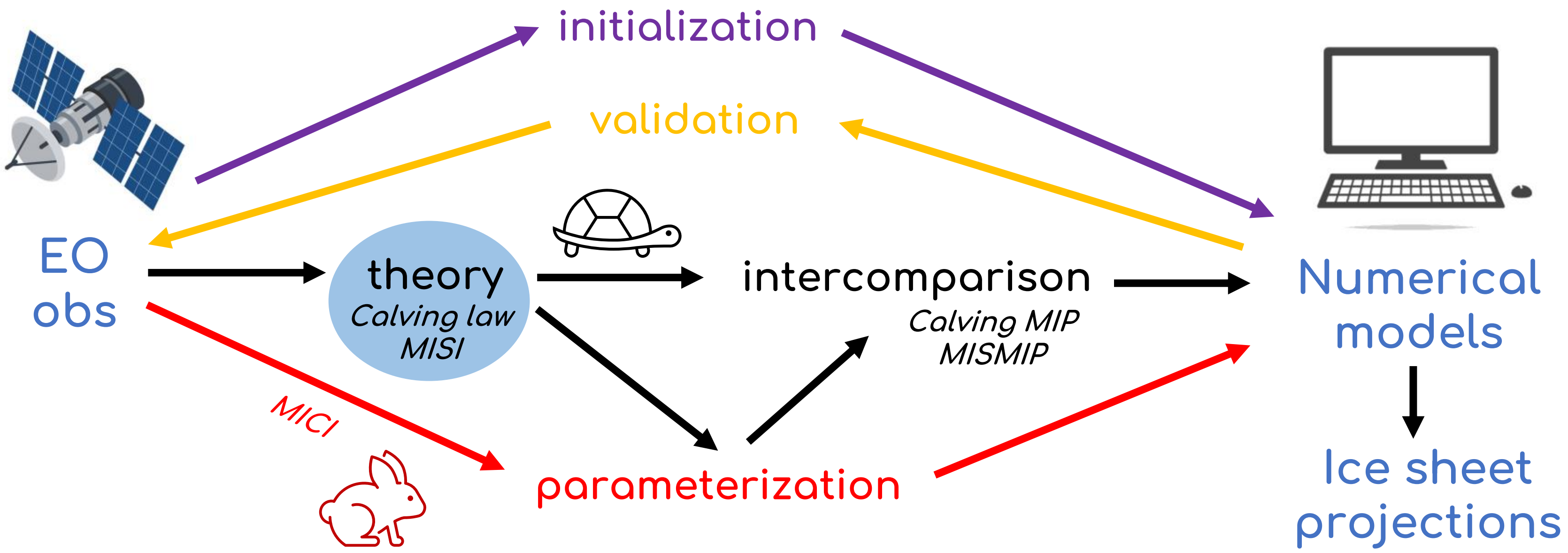
Cliff collapse may lead to stabilization





Robel (2024); Morlighem et al (2024)

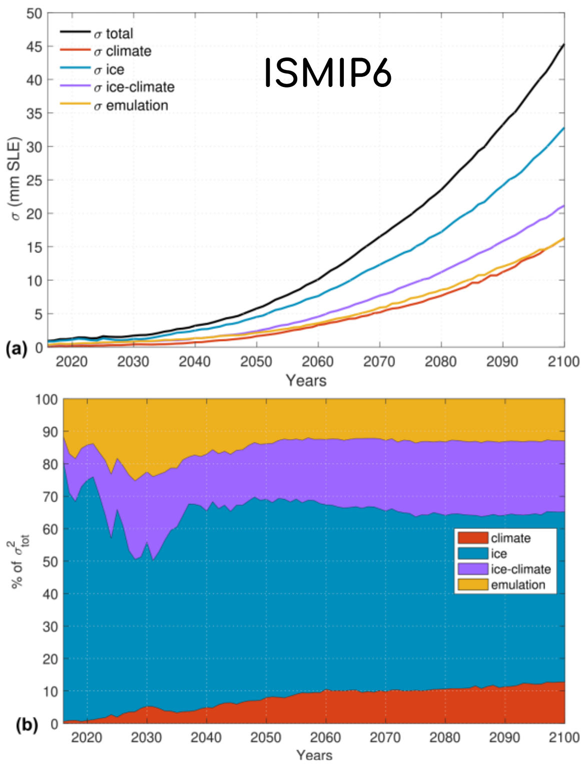
Summary: integrating EO/obs and modelling



Bradley and Hewitt (2024): "*this suggests a mechanism for dramatic changes in grounding-zone behaviour, which are not currently included in ice-sheet models*"

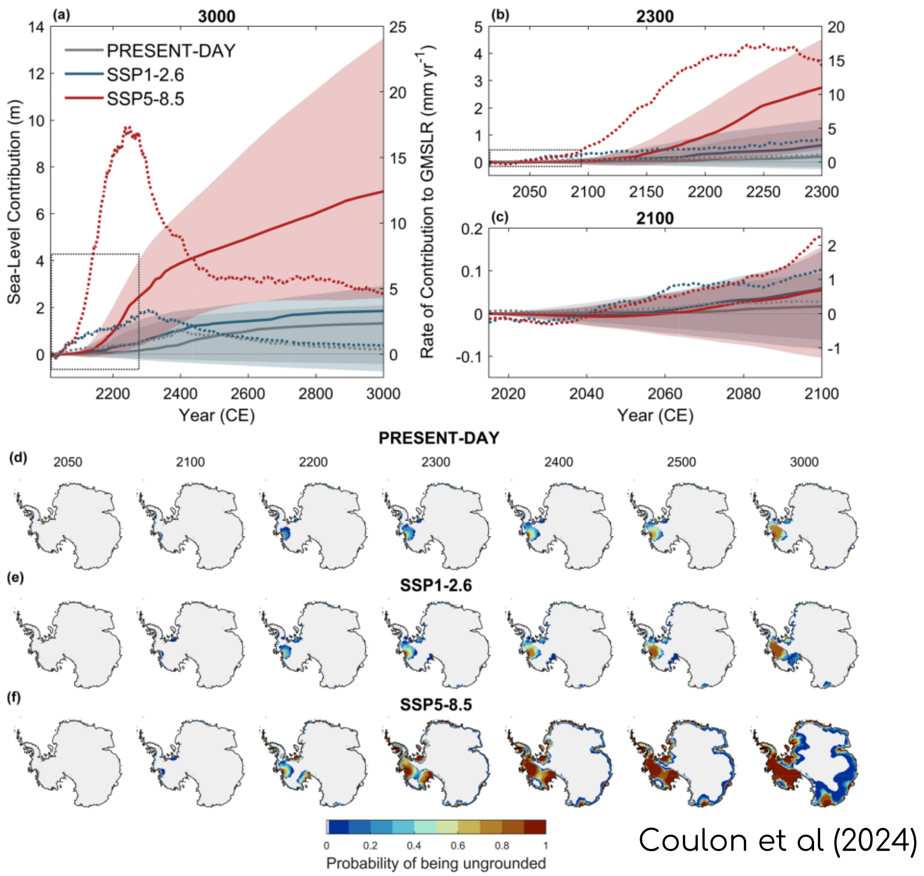
Rignot et al (2024): "*the physical processes driving melt under grounded ice have not been included in ice sheet models*"

Model complexity / processes / interactions / feedbacks determine ice mass change uncertainty



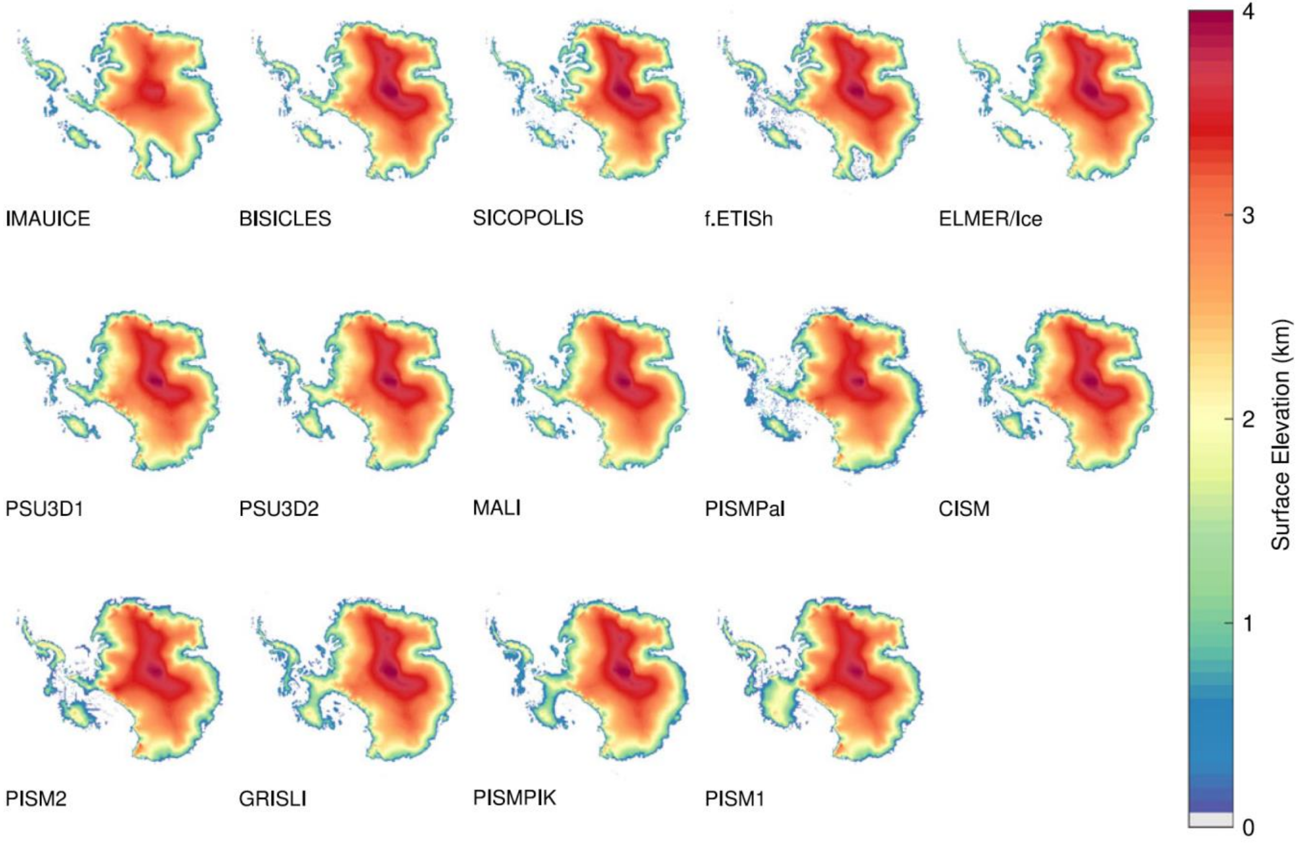
Seroussi et al (2023)

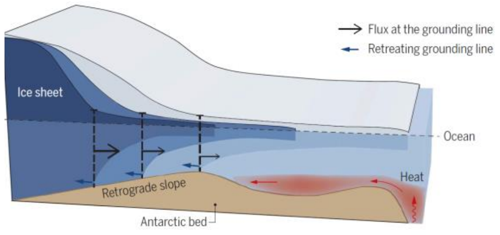
Uncertainty increases with the amount of mass lost



Coulon et al (2024)

Ice shelf collapse leads to (partial) WAIS collapse





Pattyn and Morlighem (2020)

ABUMIP

Sun et al. (2020)