The response of the Antarctic firn layer to future warming

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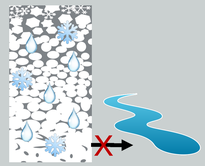
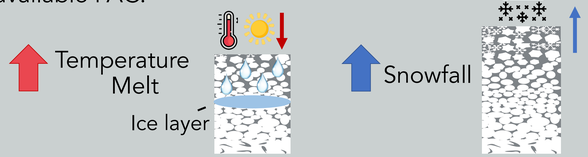
MOTIVATION

- Firn contains pore space, i.e. **the firn air content** (FAC), in which meltwater can be **retained** and **refrozen**
- This currently **prevents** most melt on the Antarctic ice sheet to **run off**
- However, future **warming** could impact the available FAC:





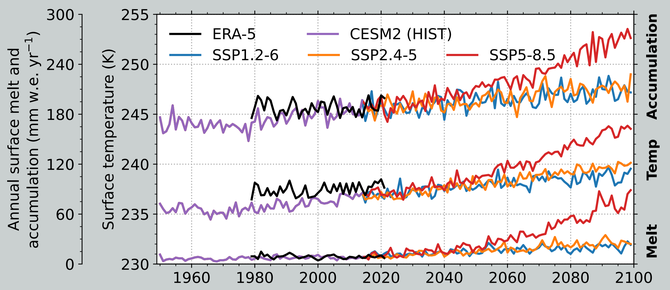
How will the Antarctic firn air content (FAC) evolve in response to future warming?

APPROACH

- Implementation of a complete transient **dynamical** firn **densification** expression[1] in IMAU-FDM
- The densification depends on firn temperature (T), **grain size** (r) and **overburden pressure** (σ) instead of T and **40 yr running averages** of accumulation and temperature:

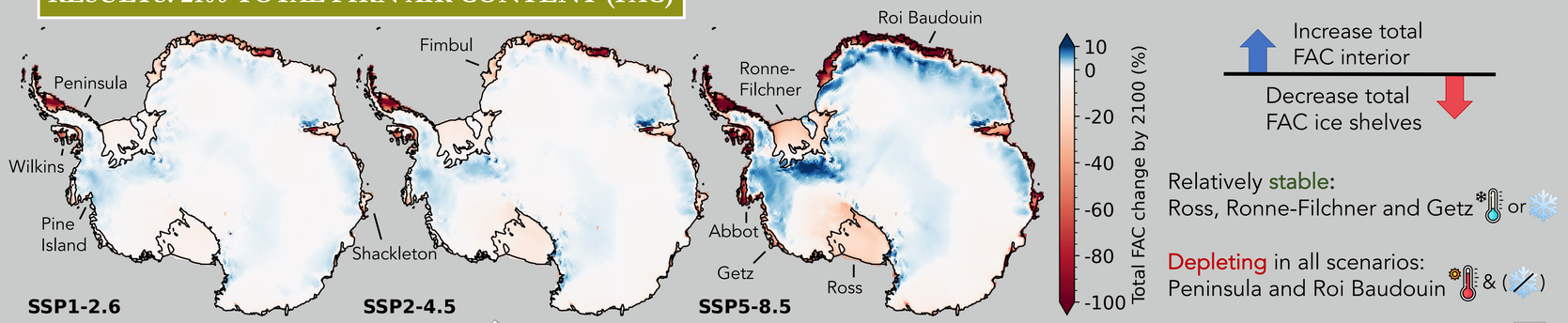
$$\frac{d\rho}{dt} = MO\ k_c\ (\rho_i - \rho) e^{\left(\frac{E_c}{RT}\right)} \frac{\sigma}{r^2} \qquad r_t^2 = r_{t-1}^2 + k_g e^{\left(-\frac{E_g}{RT}\right)}$$

- Forcing: **CESM2** downscaled by RACMO2.3p2 (27 km)
  - Period **1950-2100**
  - **Scenarios** SSP1-2.6, SSP2-4.5 and SSP5-8.5



1 Arthern et al. 2010 In situ measurements of Antarctic snow compaction compared with predictions models
2 Samimi et al. 2021 Time-domain reflectometry measurements and modelling of firn meltwater infiltration at DYE-2 Greenland
3 Clerx et al. 2022 In situ measurements of meltwater flow through snow and firn in the accumulation zone in SW Greenland
4 Culberg et al. 2021 Extreme melt season ice layeres reduce firn permeability across Greenland
5 Gascon et al. 2013 Changes in accumulation-area firn stratigraphy and meltwater flow during a period of climate warming: Devon Ice Cap, Nunavat, Cananda

RESULTS: 2100 TOTAL FIRN AIR CONTENT (FAC)



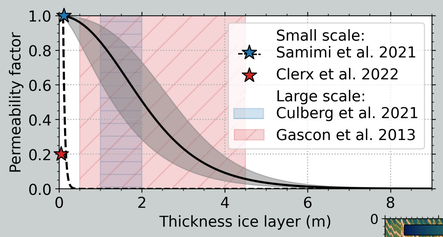
Increase total FAC interior

Decrease total FAC ice shelves

Relatively stable: Ross, Ronne-Filchner and Getz or

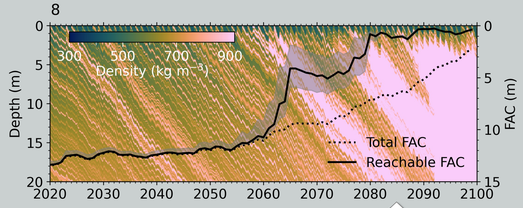
Depleting in all scenarios: Peninsula and Roi Baudouin & (/)

PERMEABILITY ICE LAYERS



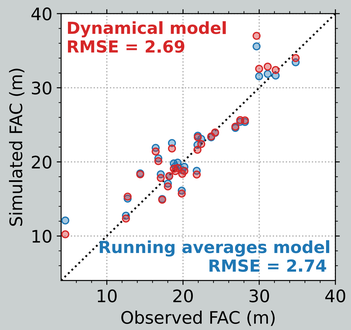
We use ice layer **thickness** to estimate the **permeability** of ice slabs to calculate the **'reachable' firn air content (FAC).** This method is informed by observational studies.

Example Shackleton SSP5-8.5: **Reachable** FAC decreases **faster** than total FAC due to ice layers

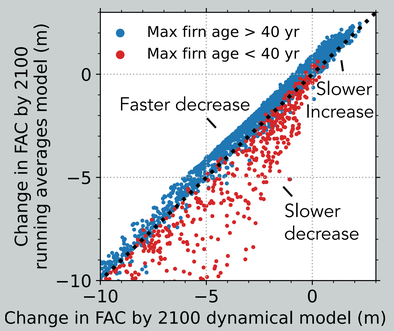


DYNAMICAL vs RUNNING AVERAGES MODEL

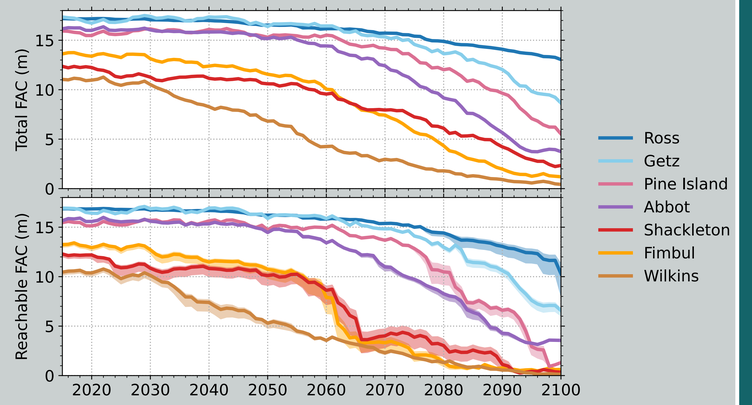
Historical period: **similar** performance to observed FAC



Future period: **impact** on the FAC evolution



RESULTS: REACHABLE FAC ICE SHELVES



- Reduction in total FAC vs reachable FAC for SSP5-8.5
- **Ice layers** accelerate depletion on **intermediate warm & relatively dry** ice shelves: Pine Island, Shackleton and Fimbul
- Limited **sensitivity** to ice thickness-permeability relation

TAKE HOME

- Updated densification expression including **grain size** and **overburden pressure**
- Relatively stable: Ross, Ronne-Filchner and Getz ice shelves
- Depleting all scenarios: Peninsula and Roi Baudouin ice shelves
- **Ice layers** accelerate FAC depletion on **intermediate warm & relatively dry** ice shelves