Firn modelling in CESM

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Motivation

1. Meltwater can refreeze in snow/firn, thus limiting the amount of freshwater ocean runoff and increasing SMB

2. Glacial inception: firn is thought to turn to ice when it reaches a density of 850 kg/m3. The depth at which this happens varies.

3. Ice sheet instability is linked to firn air depletion:

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Firn air depletion as a precursor of Antarctic ice-shelf collapse

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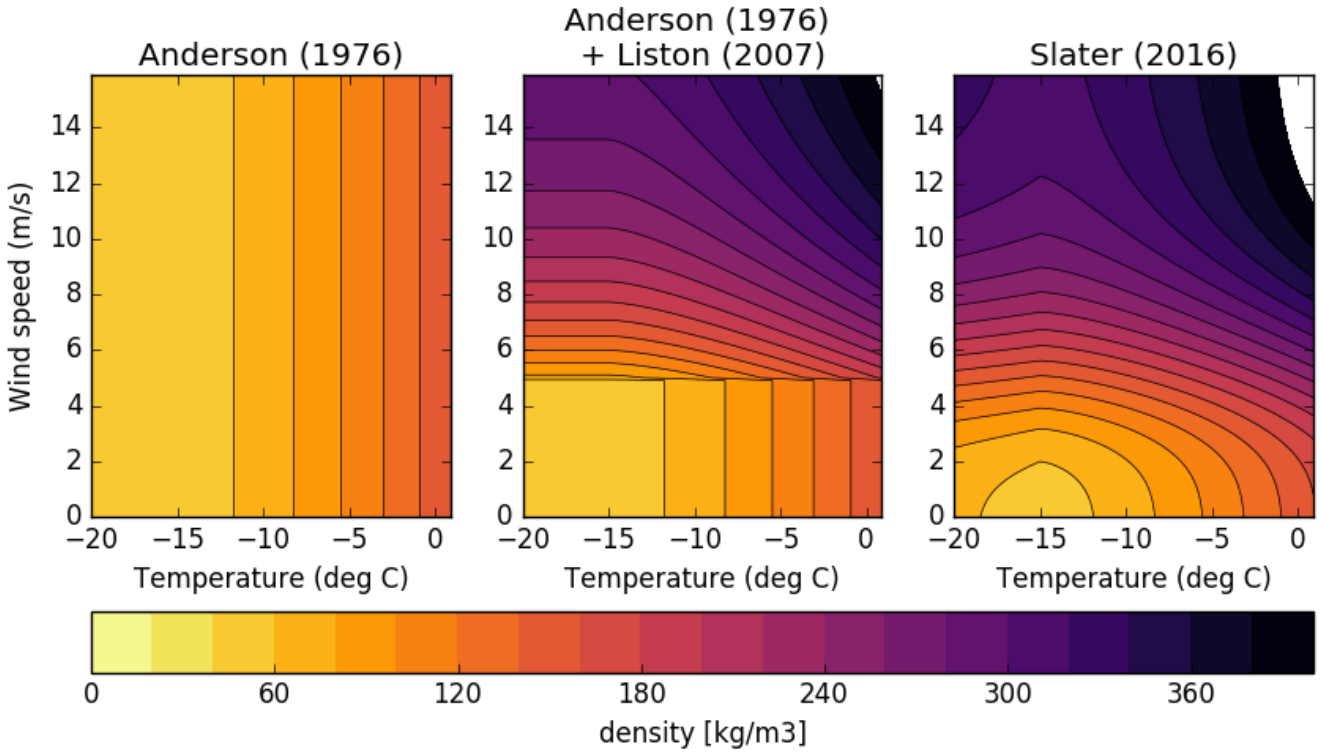
Code changes past year

- Introduced a deeper snowpack, by default 10-metre depth W.E. ~ 25 m actual depth
- Wind-driven fresh snow density
- Tuning of destructive metamorphism, overburden pressure and fresh snow density [Drew Slater & Dave

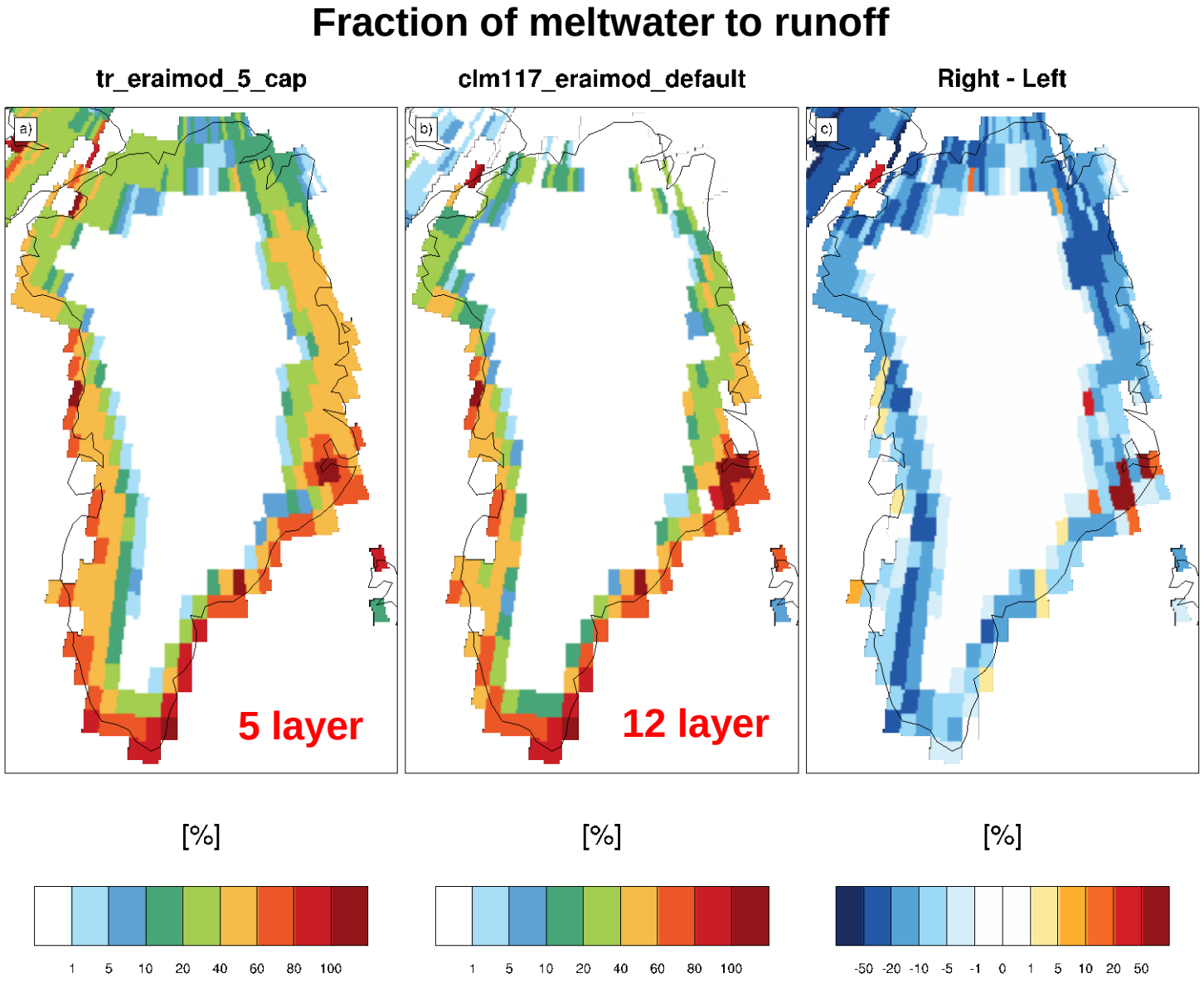


10 meter snowpack

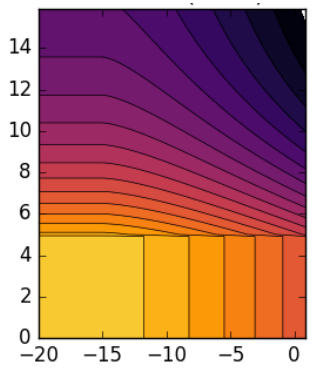
Offline CLM

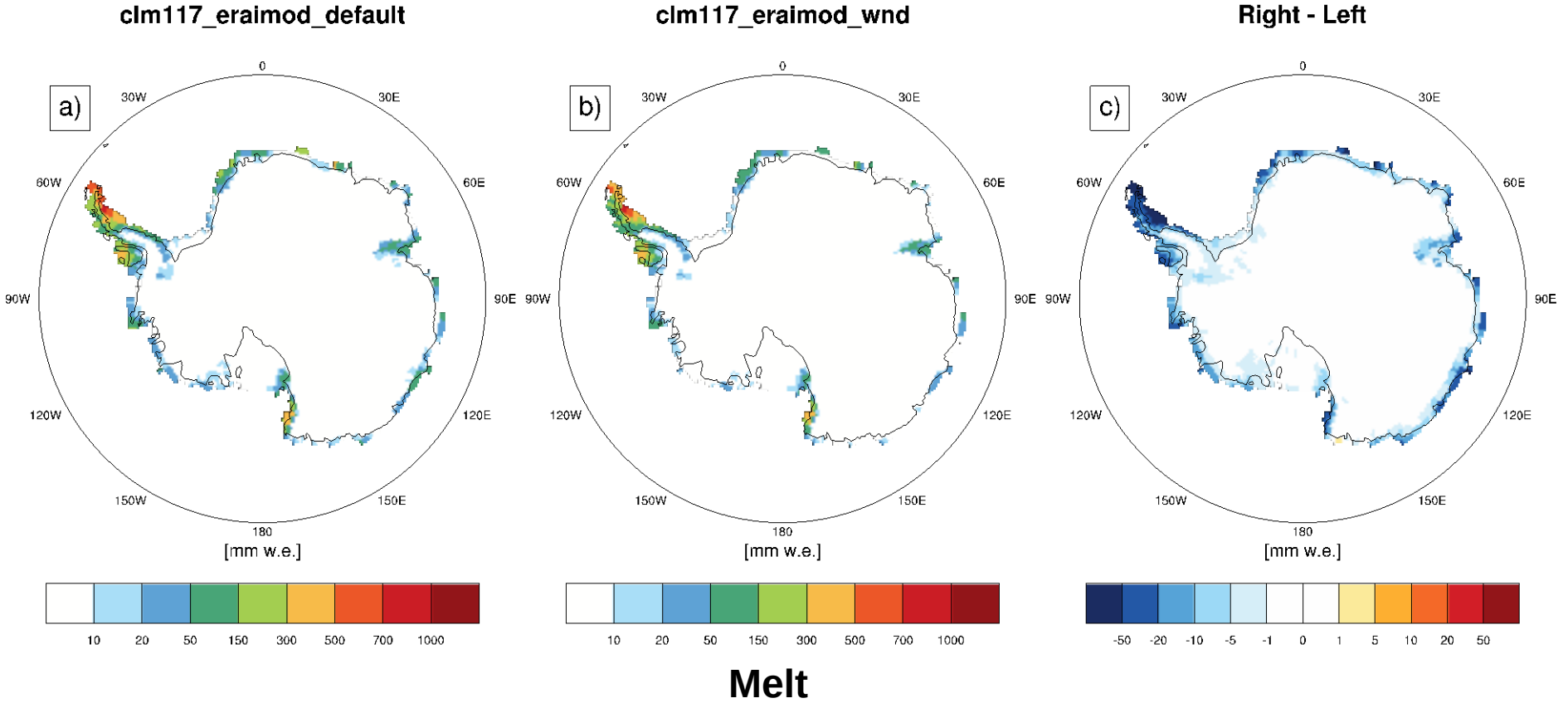
ERA-Interim forcing 1979-2014

Spinup: 96 years

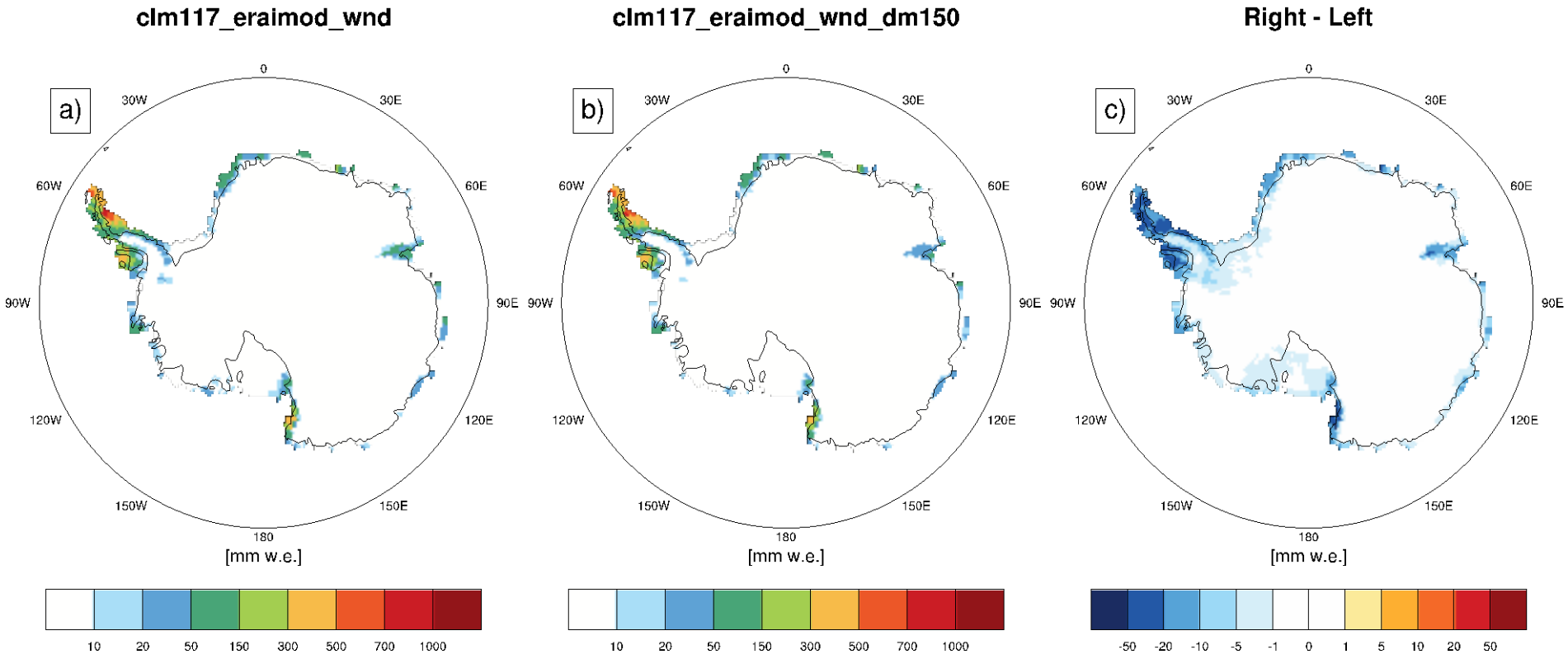


Wind-driven compaction



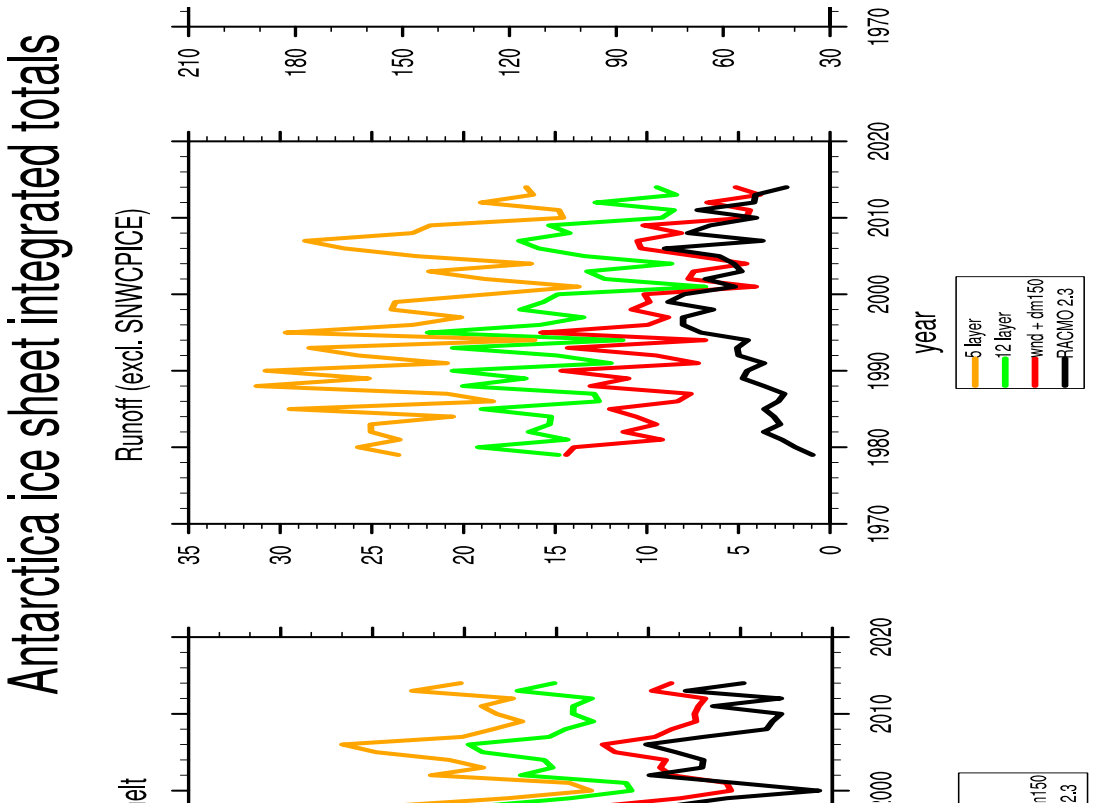


Destructive metamorphism



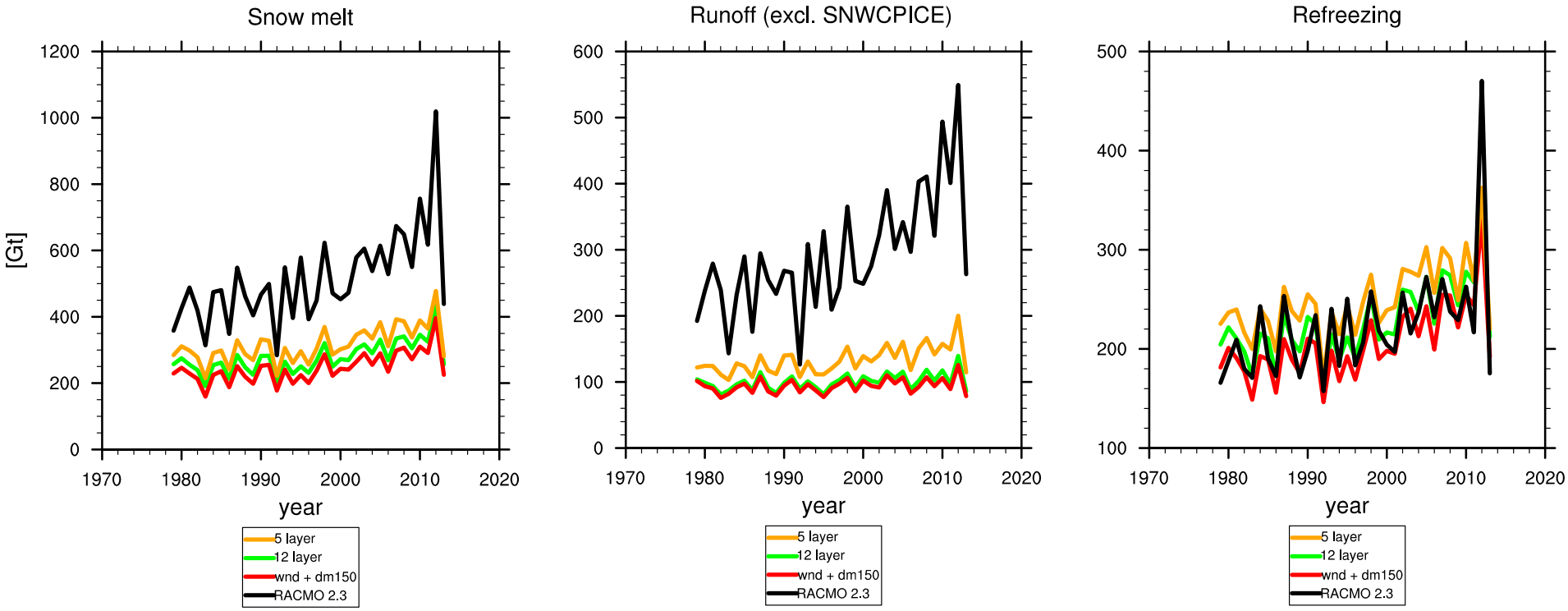
Melt

AIS integrated totals



- Increases in density help resolve the Antarctic (subsurface) melt bias

GIS integrated totals



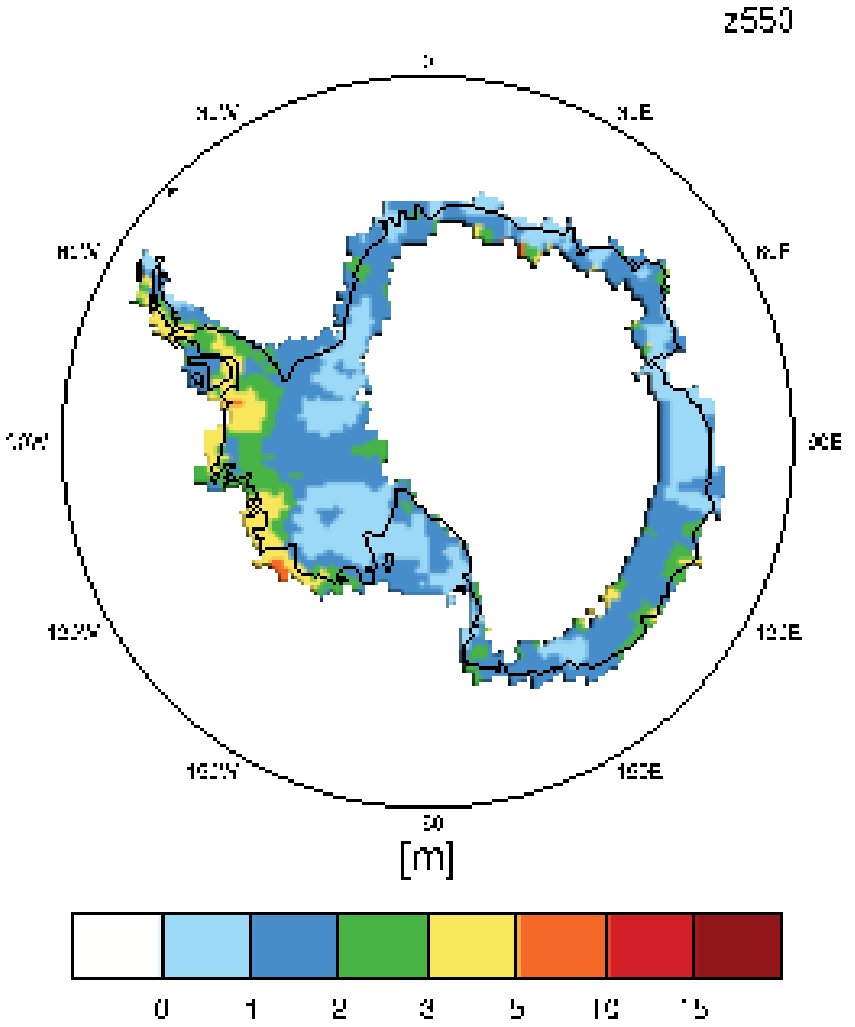
- Melt on Greenland is underestimated, but arguably not made worse by the changes

Something is not right…

z550: depth at which density of 550 kg/m3 is reached

On Antarctica, typically between 7-25 meters, with highest values in cold interior and high precip areas

Culprit: overburden compaction scheme



Compaction by overburden

$$\frac{d\rho}{dt} = \frac{-\sigma}{\eta}$$

CLM:

$$\eta = \eta_0 * \exp(a(T_{freeze} - T) + b\rho)$$

CLM 4.5 Tech Note

Crocus:

$$\eta = f_1 f_2 \eta_0 \frac{\rho}{c} * \exp(a(T_{freeze} - T) + b\rho)$$

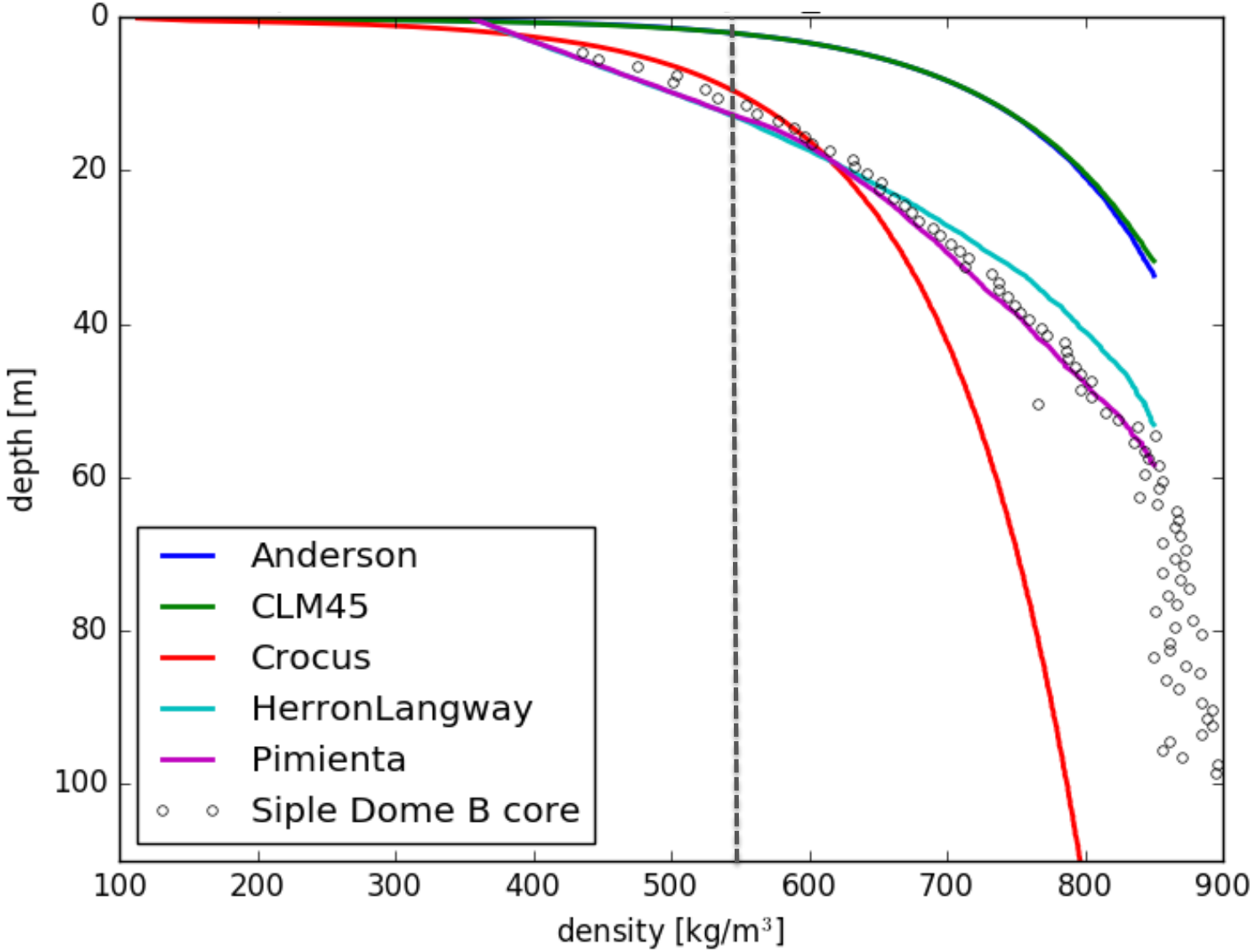
Vionnet et al, 2012

Testing in a dry firn model (DFM)

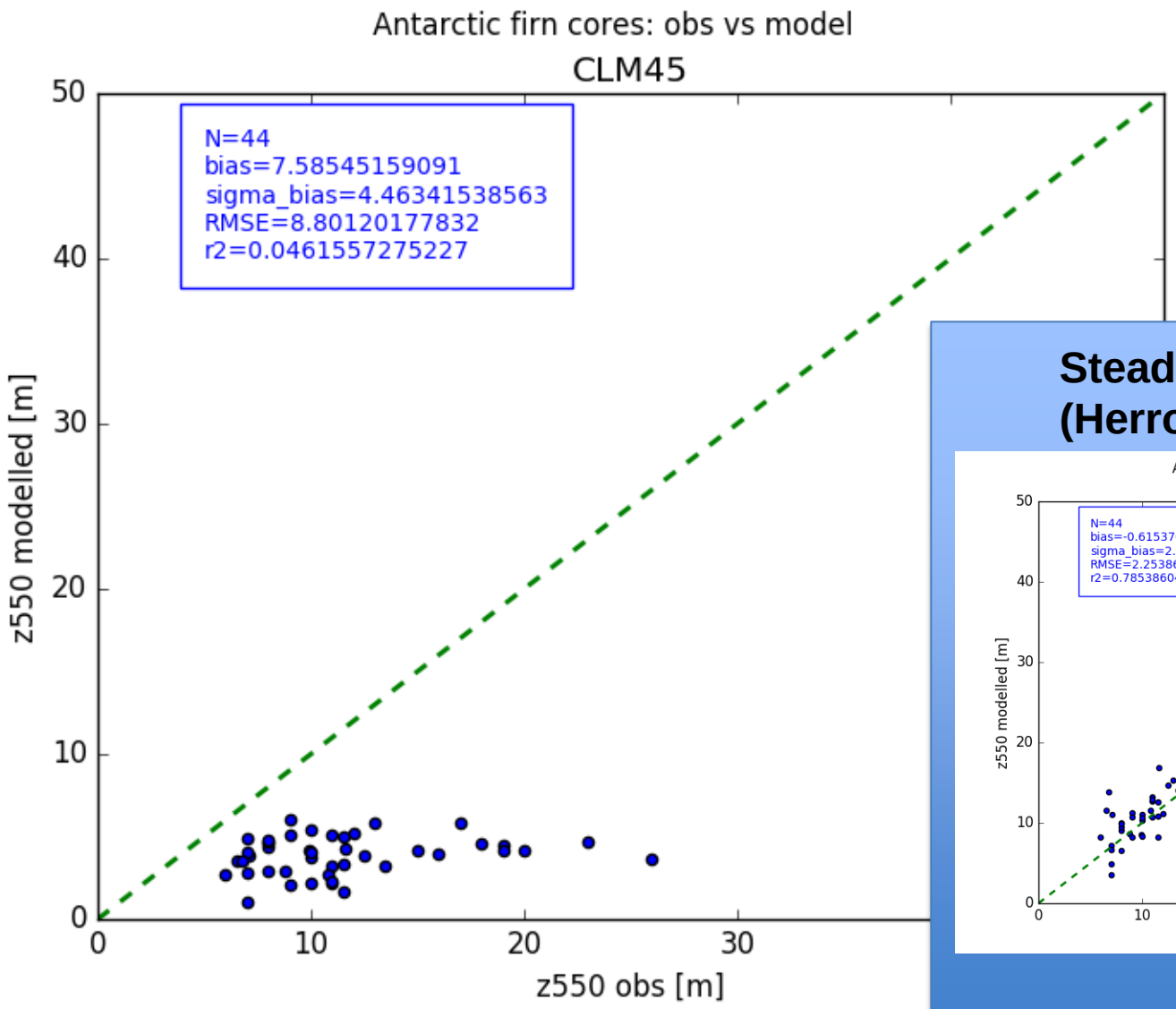
- Single column model, 10cm vertical resolution
- Explicit / implicit heat equation solver
- Different compaction formulations (steady-state, overburden)
- Forced by 6-hourly RACMO2.3 meteorology (T, acc, U)

https://github.com/kampe004/compaction

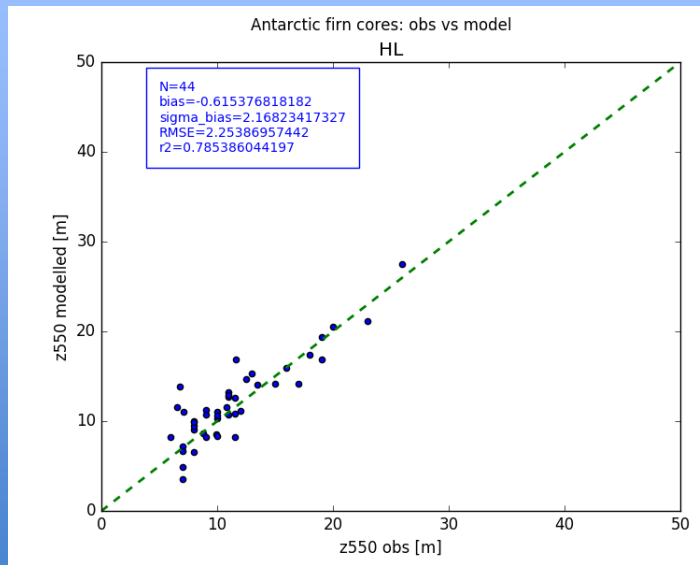
Siple Dome, Antarctica



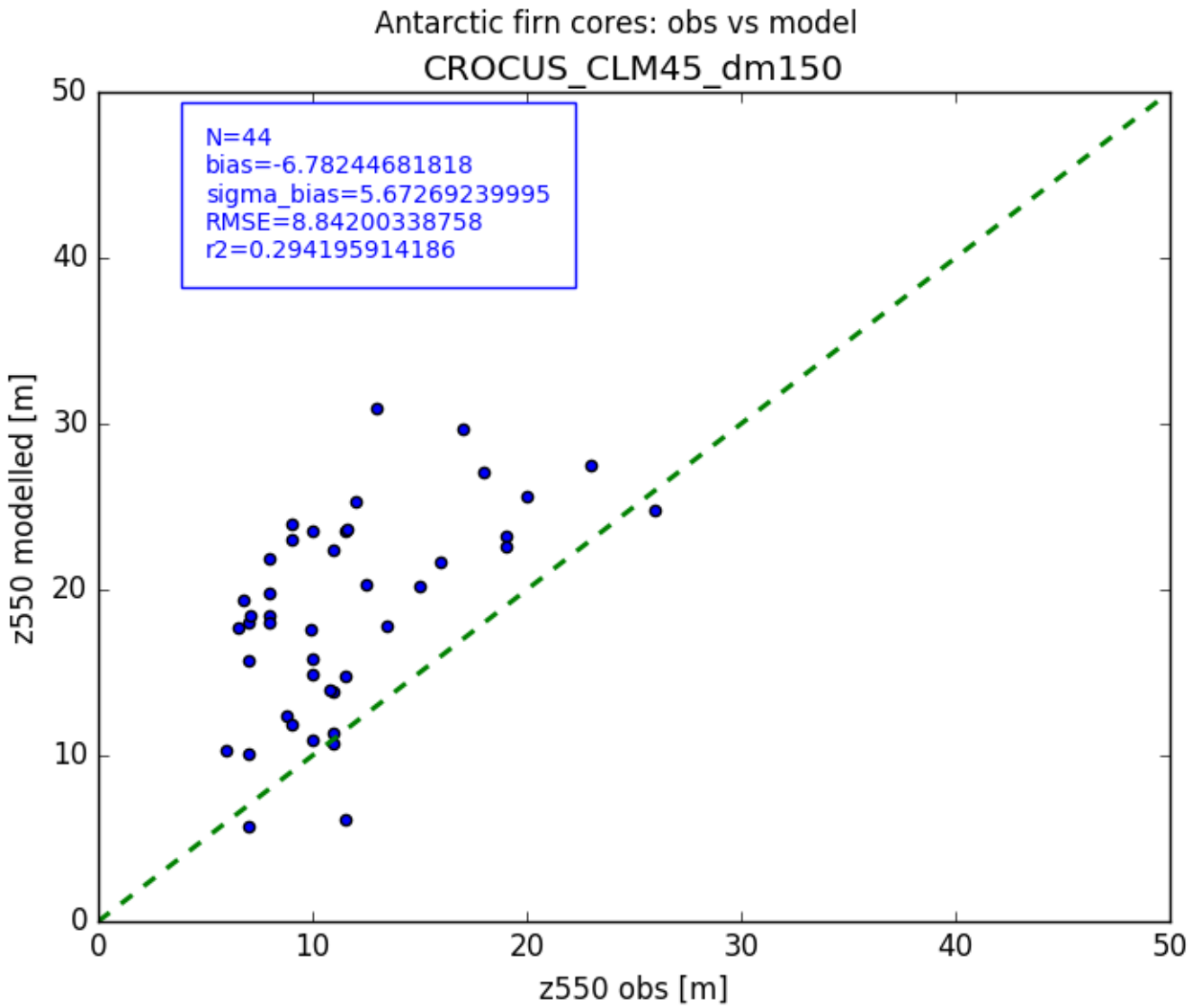
Modelling z550



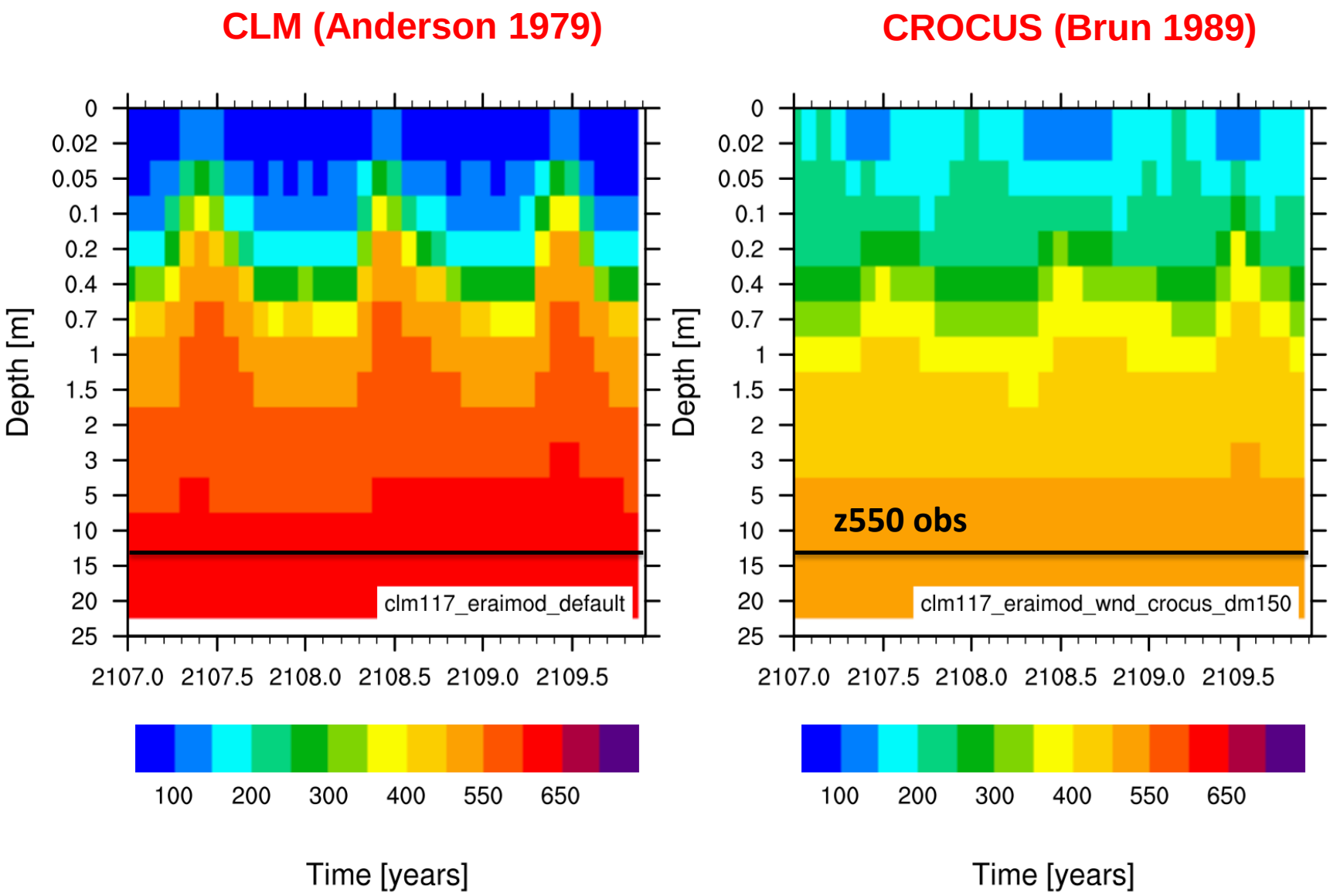
Steady state model (Herron & Langway)



Modelling z550 (2)



Summit, Greenland



Future plans

- Introduce new overburden compaction parameters + wind drift parametrization
- Water on ice → effect on energy fluxes
- Increase vertical resolution and layering based on physical properties (creates potential for impermeable layers and isotope tracking)

THANK YOU