

Antarctic Surface Mass Balance from 1980 to 2017

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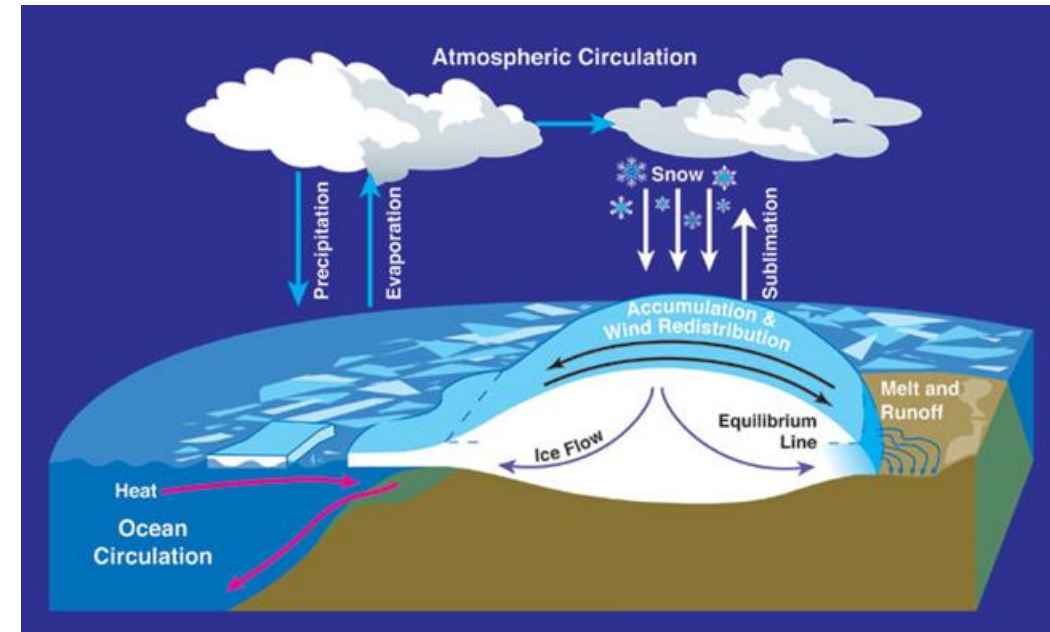
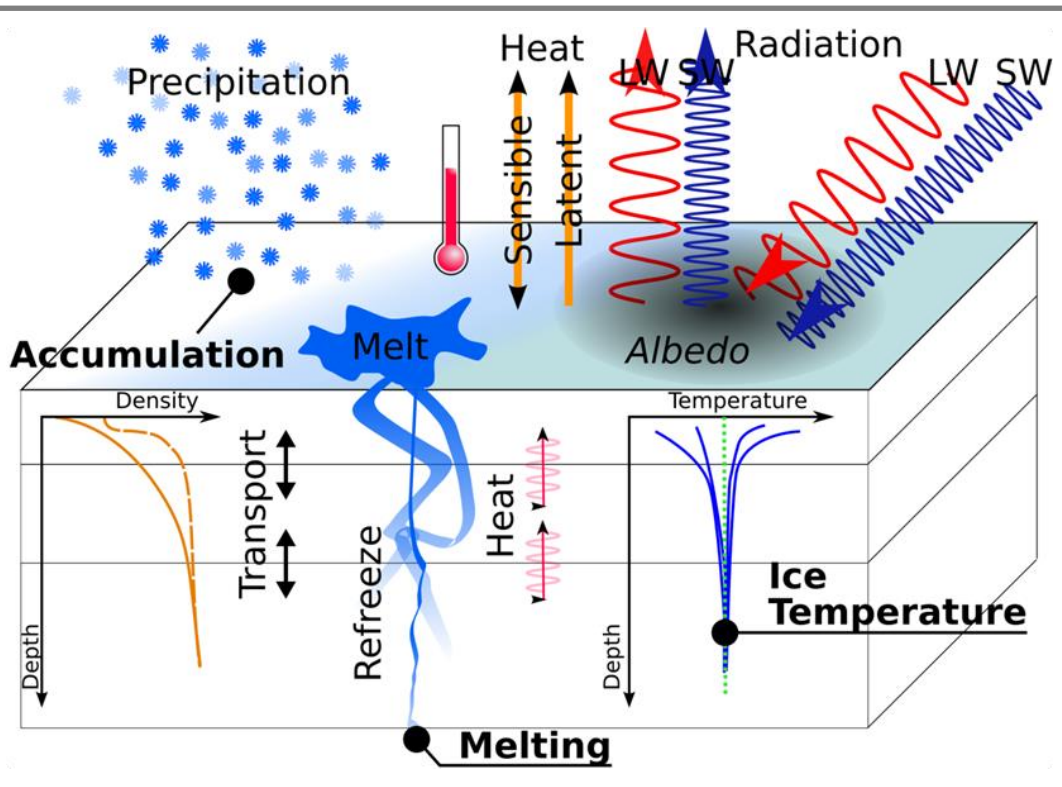
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What is the mass balance?

$$MB = SMB - D$$

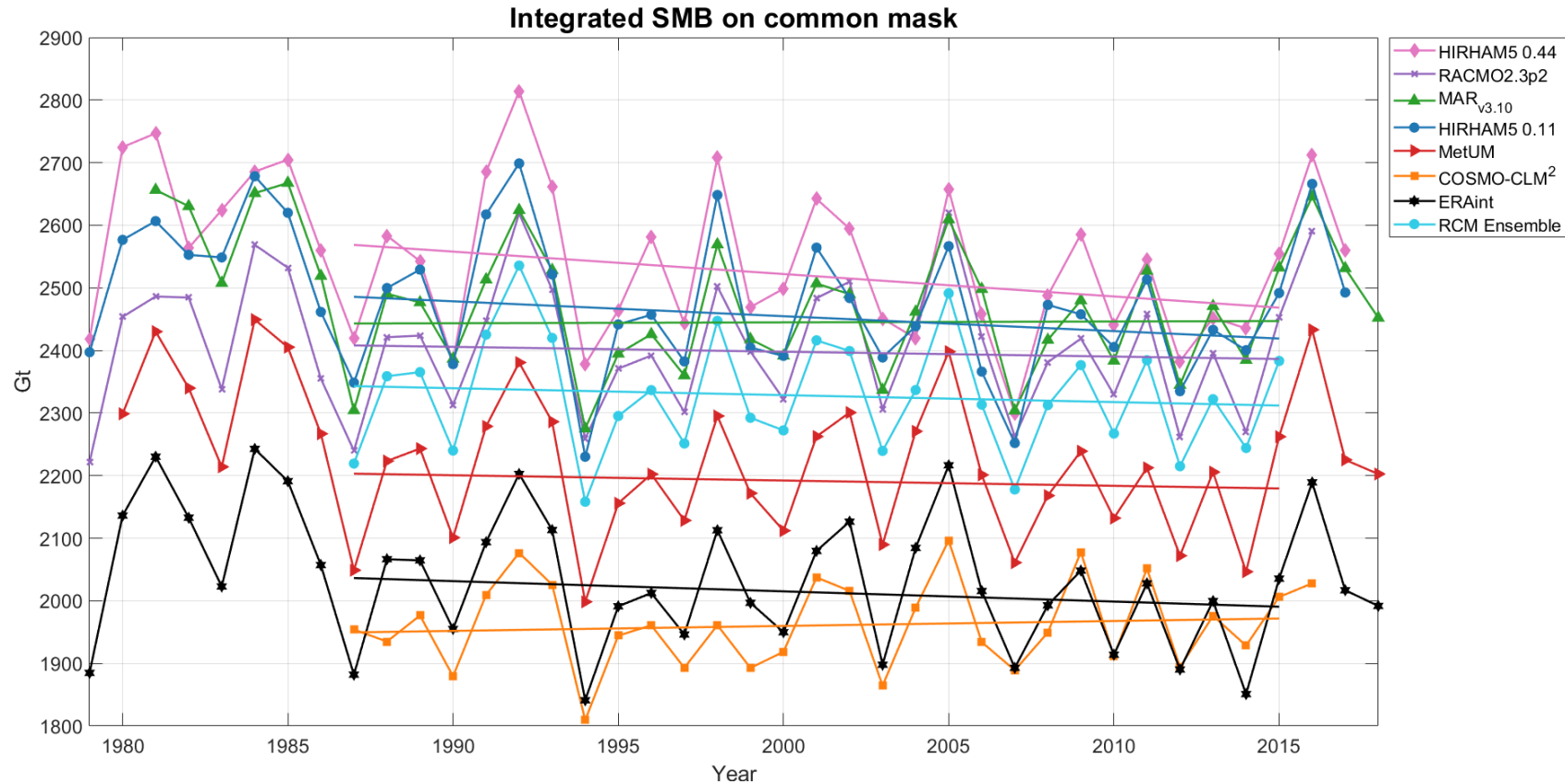
$$SMB = \text{precipitation} - \text{runoff} - \text{evaporation} - \text{sublimation}$$

$$D = \text{discharge}$$



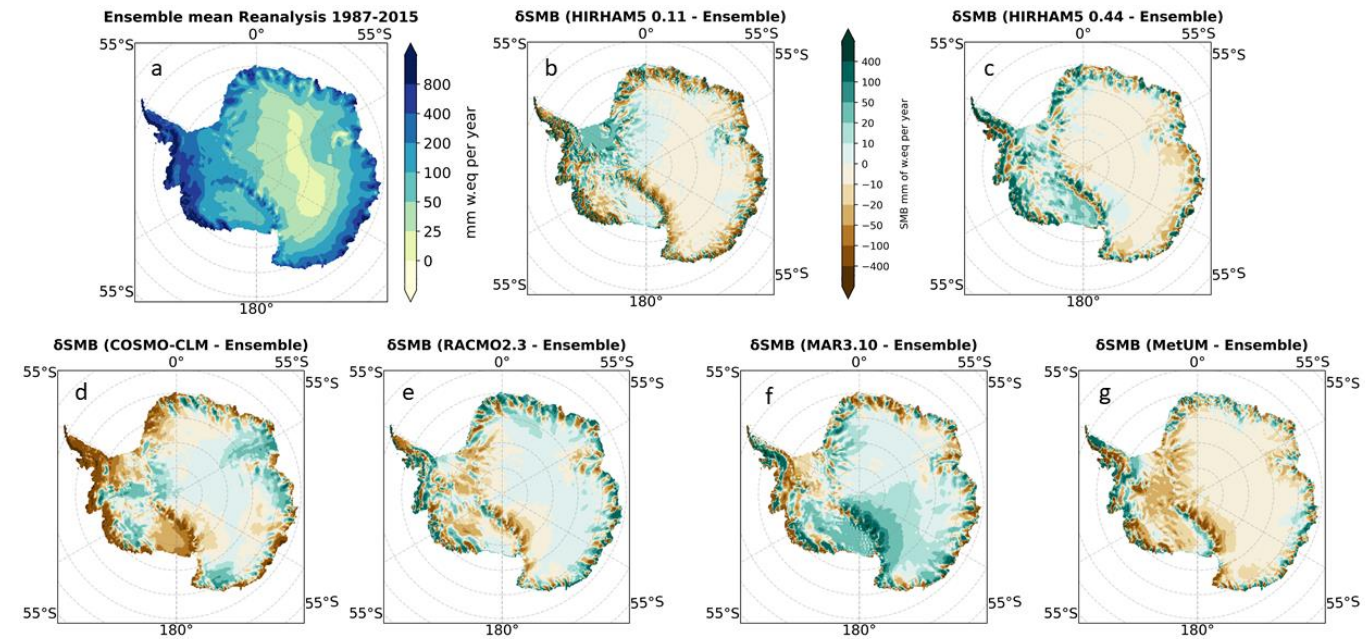
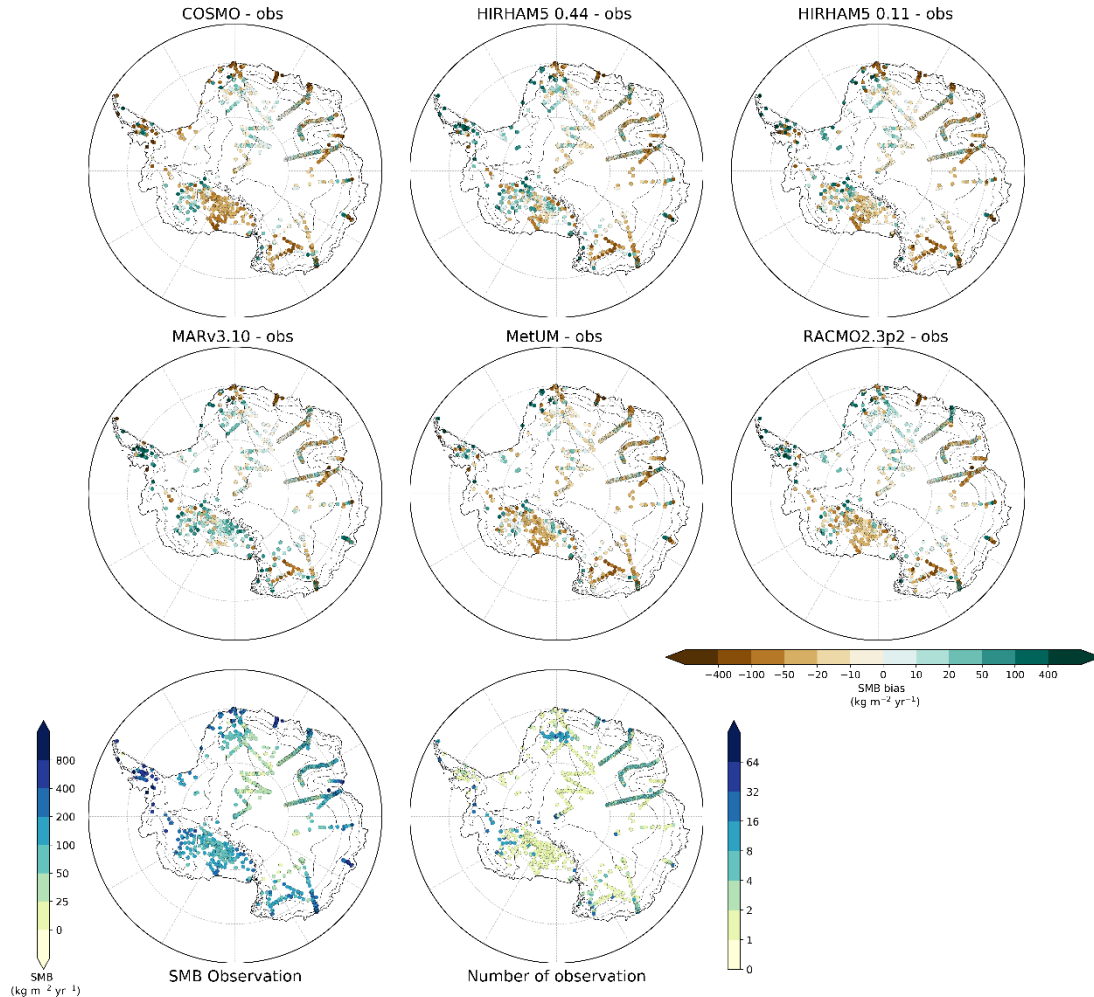
Spread in Regional Climate Models

- SMB model spread of 550 Gt per year
 - Equivalent to nearly 2 mm sea level change per year



Plot from Mottram et al. 2020

- Large spatial differences
 - Inter-model disagreement on where the precipitation is dropped



Plots from Mottram et al. 2020

Model: three subsurface simulations

Running and evaluating the results

Fixed layer model

- 32 layers
 - Fixed layer height
 - Spun up 1980-1989, 25 times
 - Called Fixed from now on
- (Langen et al. 2017)

Dynamical layer model

- 64 layers
- Dynamical layer merging/splitting, based on: temp, density, grain size, water/ice/snow content and shallowness

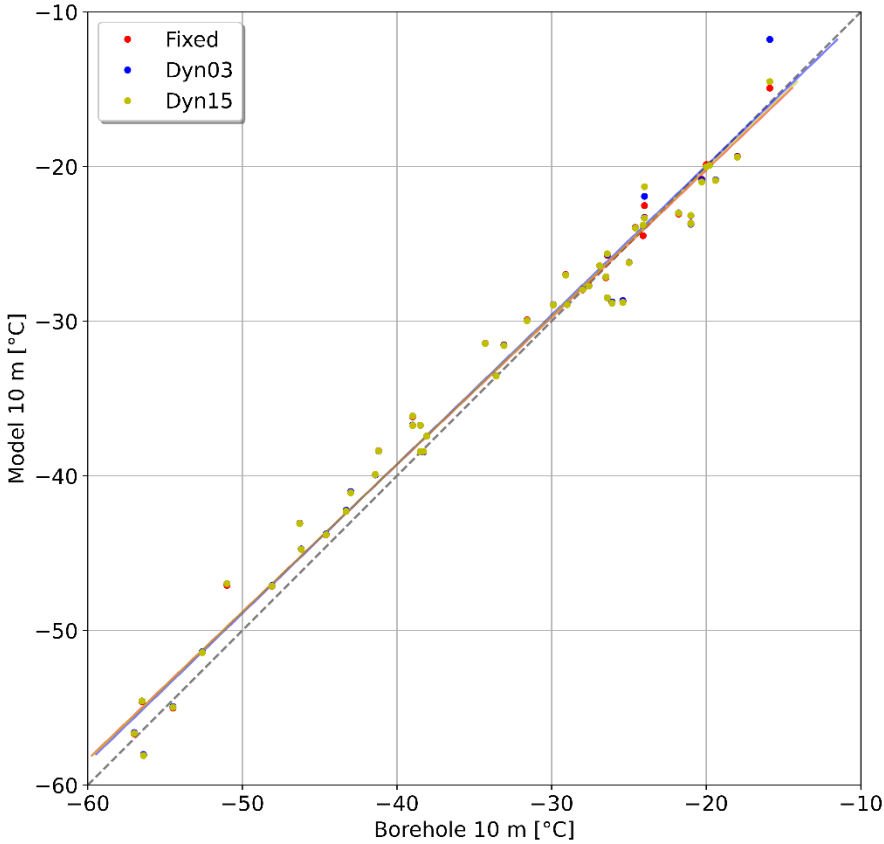
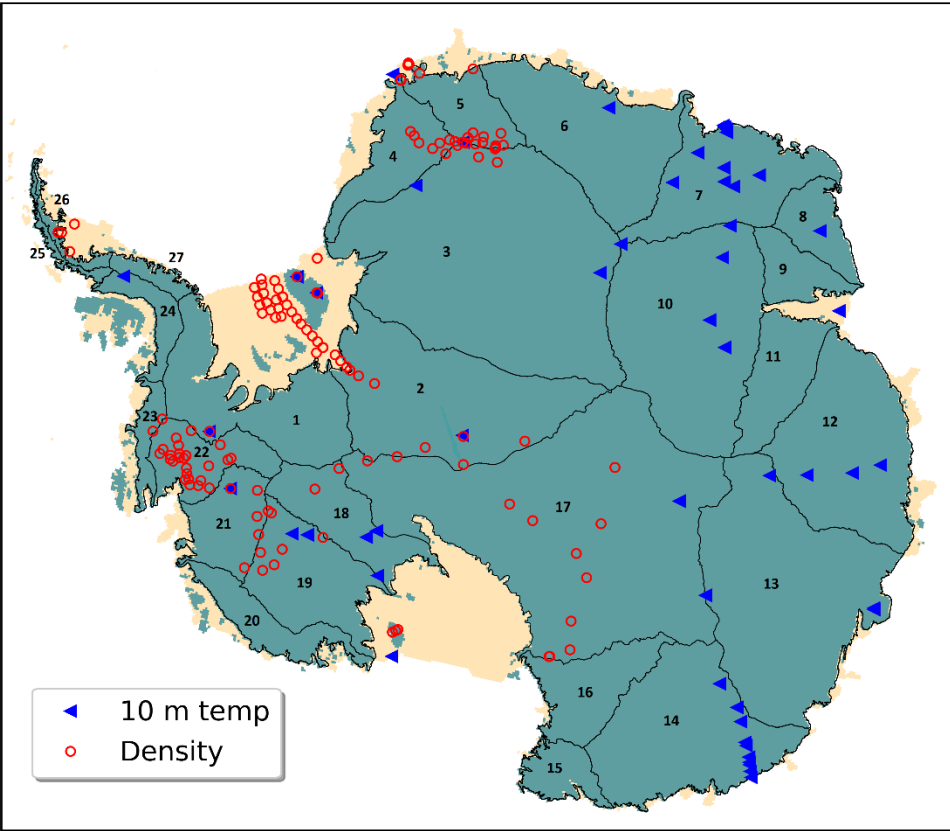
Two model runs, both spun up from the Fixed model

- Dyn03 spin up length Fixed+3 decades
- Dyn15 spin up length Fixed+15 decades

(Vandecrux et al. 2018)

	Fixed	Dyn03	Dyn15
Thickness	Constant over time and space	Varies over time and space	Varies over time and space
#Layers	32	64	64
Spin-up [yr]	250	280	400
Melt	First snow then ice	Snow and ice simultaneously	Snow and ice simultaneously

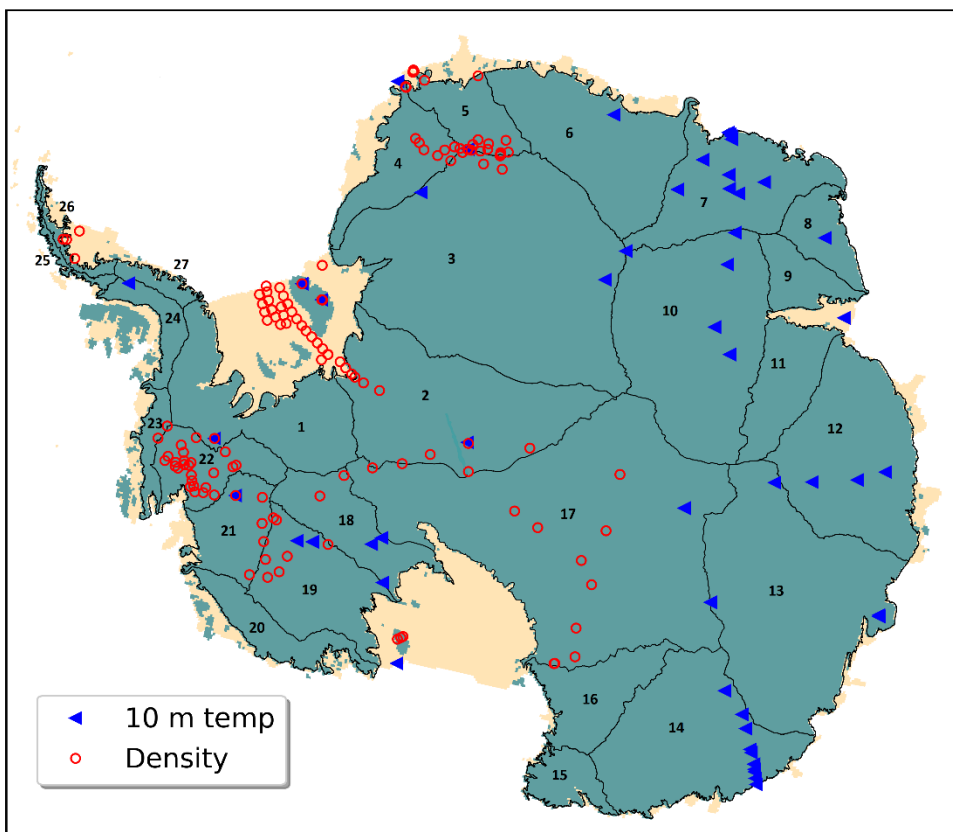
Main reason to use the dynamical version is so the variables do not get smeared out within one layer



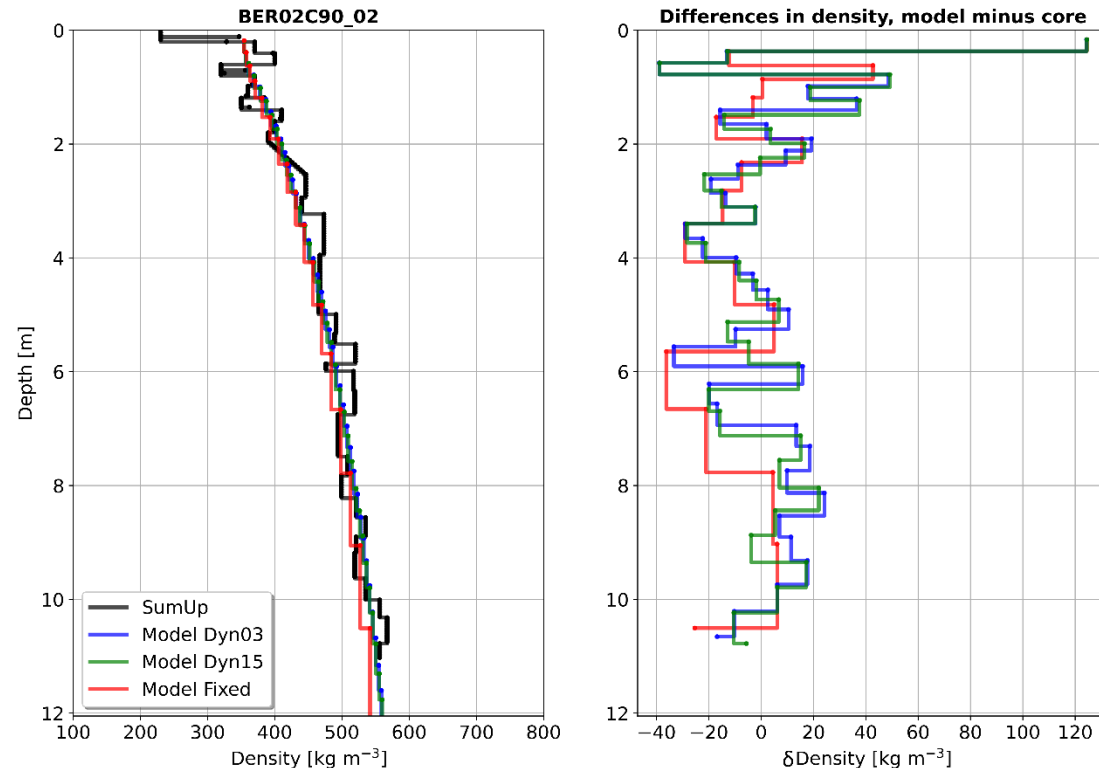
	Fixed	Dyn03	Dyn15
Mean difference [°C]	0.42	0.52	0.46
RMSE [°C]	1.66	1.77	1.71
R ²	0.98	0.97	0.98

Data from Van Wessem et al. 2014

Evaluating the model with firn density



Data from:
<https://arcticdata.io/catalog/view/doi:10.18739/A26D5PB2S>



For 139 cores

Fixed

Dyn03

Dyn15

Mean bias($\rho < 550 \text{ kg m}^{-3}$)

-24.0

-8.2

-10.0

std($\rho < 550 \text{ kg m}^{-3}$)

18.4

15.3

16.4

Mean bias($\rho > 550 \text{ kg m}^{-3}$)

-31.7

-32.5

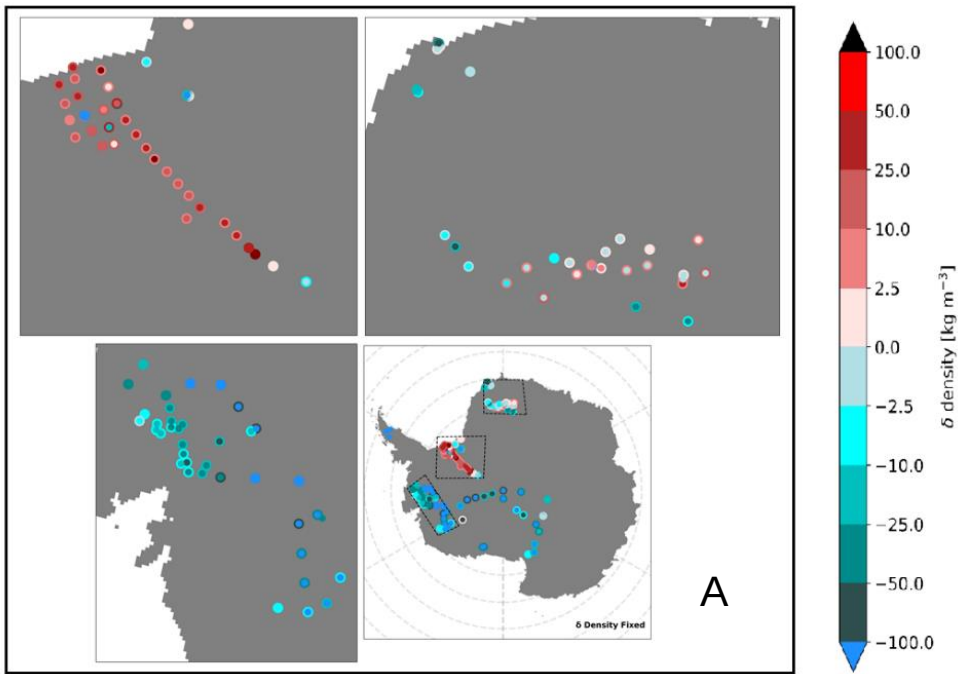
-35.0

std($\rho > 550 \text{ kg m}^{-3}$)

23.4

23.1

23.7



Density bias (model minus core)
the outer ring represent densities
less than 550 kg m^{-3} and the inner
circle represents densities greater
than 550 kg m^{-3} .

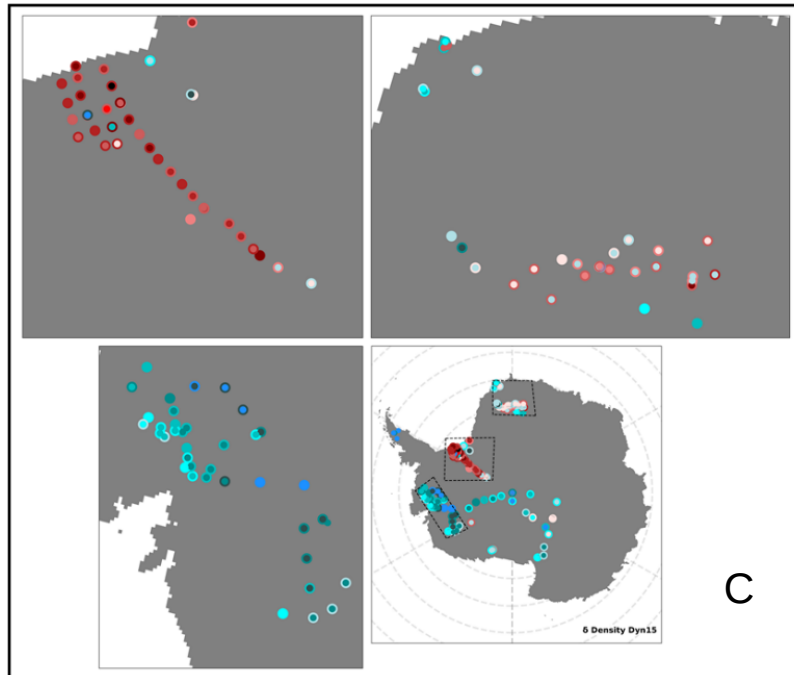
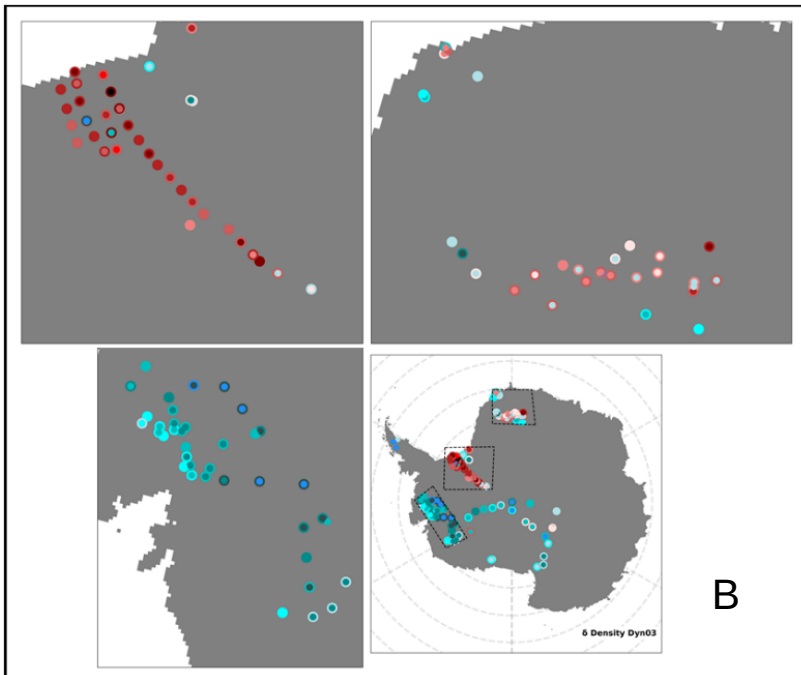
(A) is the Fixed model,

(B) is the Dyn03,

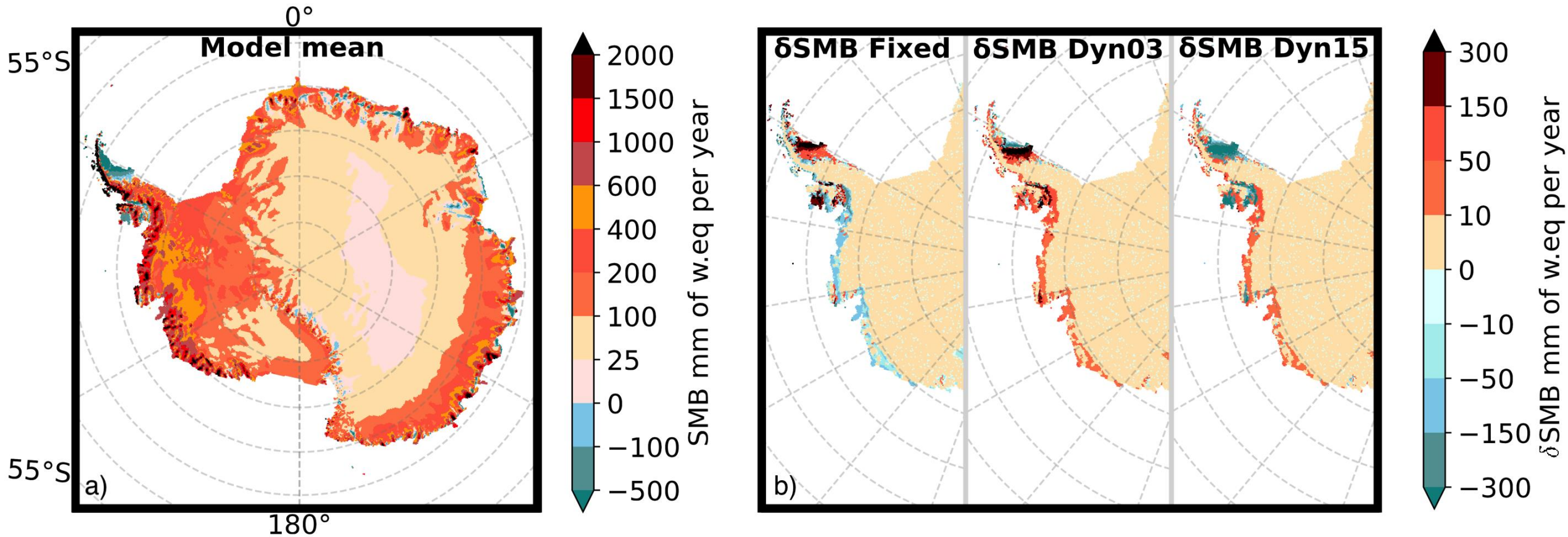
(C) is the Dyn15.

Each panel show the entire AIS
with three dashed black boxes,
each box outlines a zoom-in area,
from east to west the Dronning
Maud Land, Filchner–Ronne ice
shelf and Marie Byrd Land.

These panels show that that there
is a spatial density bias.

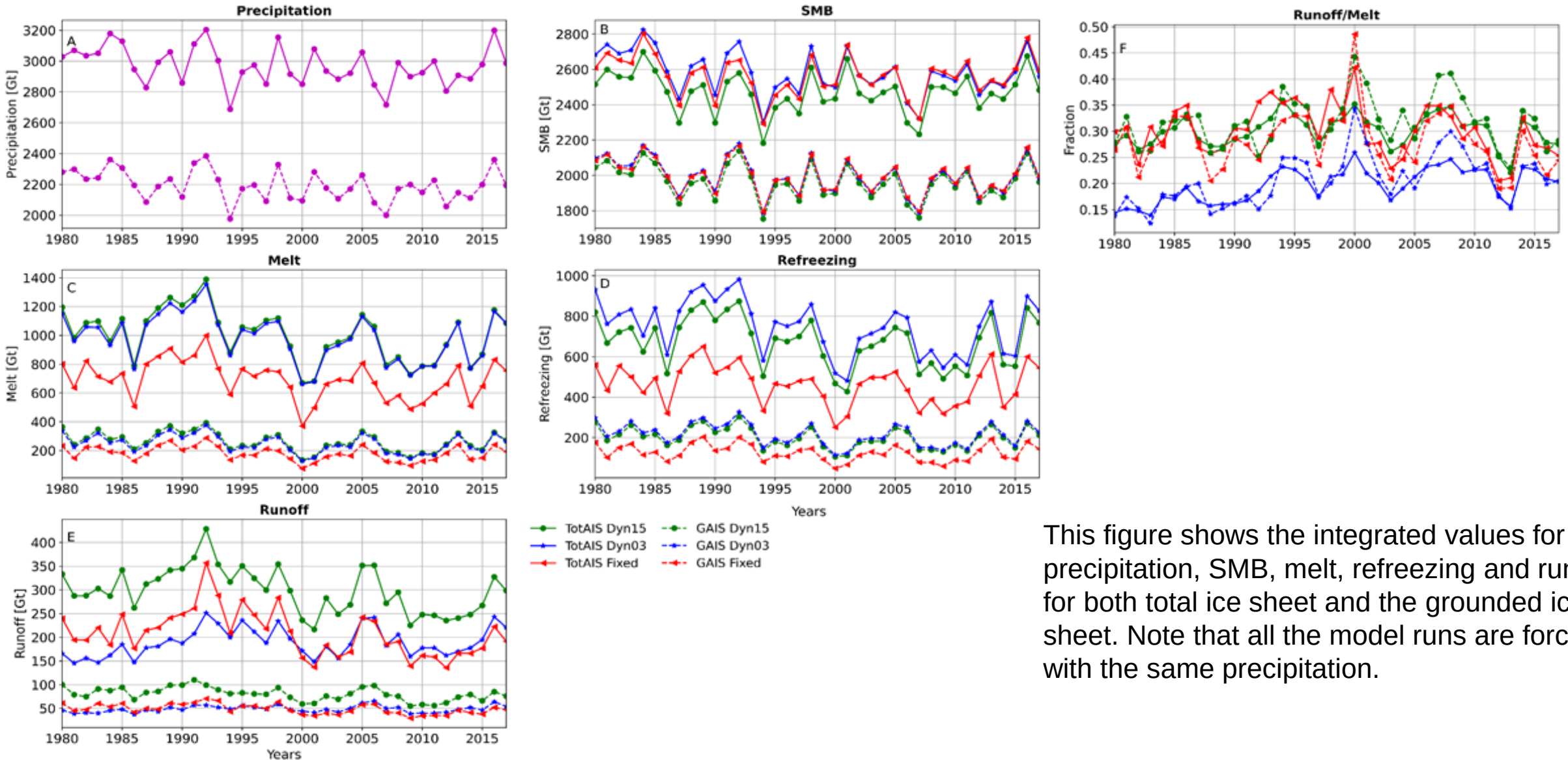


Mean SMB with the largest differences between model versions in West Antarctica



Mean SMB from 1980 to 2017 in mm per year of water equivalent. a) the mean of the model mean, note nonlinear colour bar. b) West AIS where the SMB has the largest differences between model versions, (model minus ensemble mean).

Integrated components of the SMB over total and grounded AIS

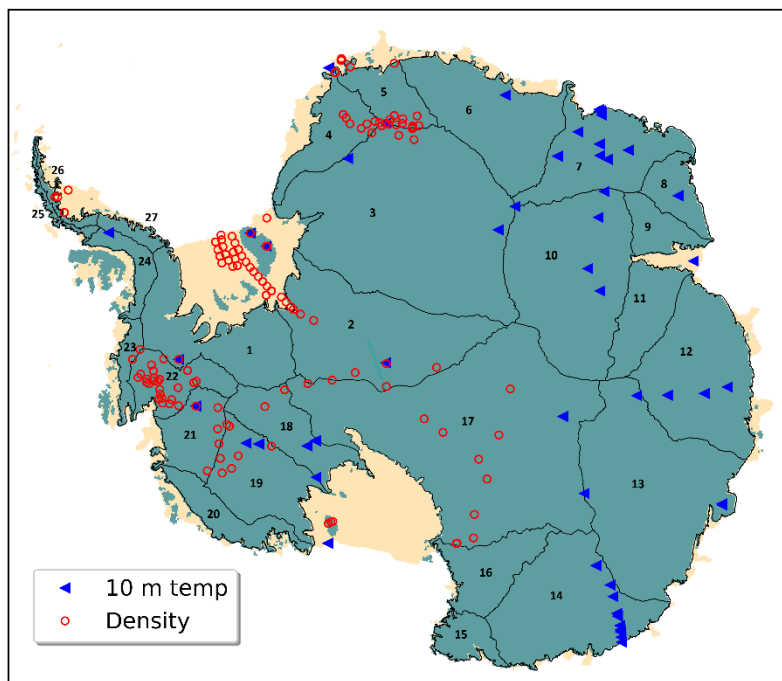


This figure shows the integrated values for precipitation, SMB, melt, refreezing and runoff, for both total ice sheet and the grounded ice sheet. Note that all the model runs are forced with the same precipitation.

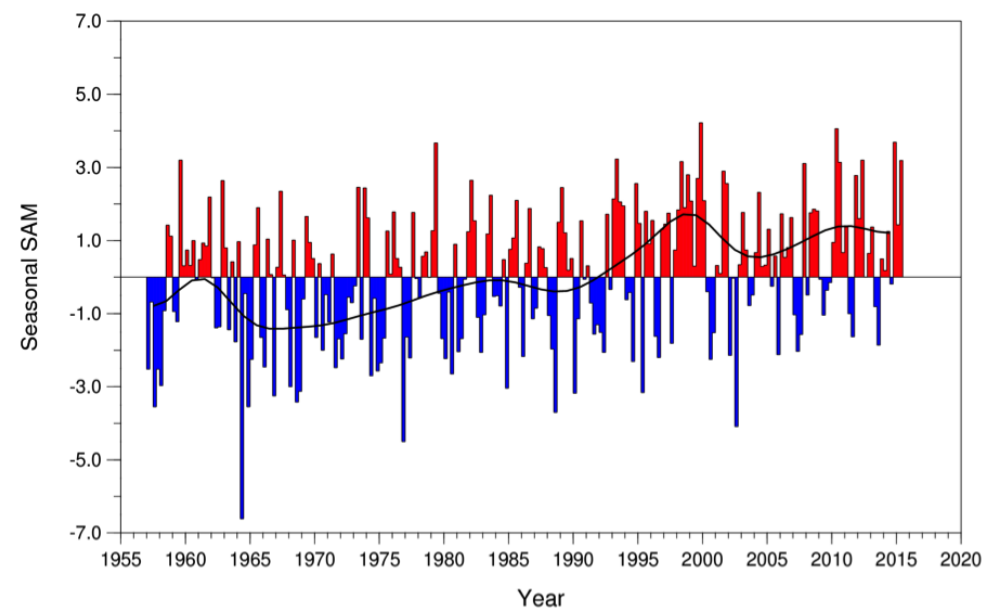
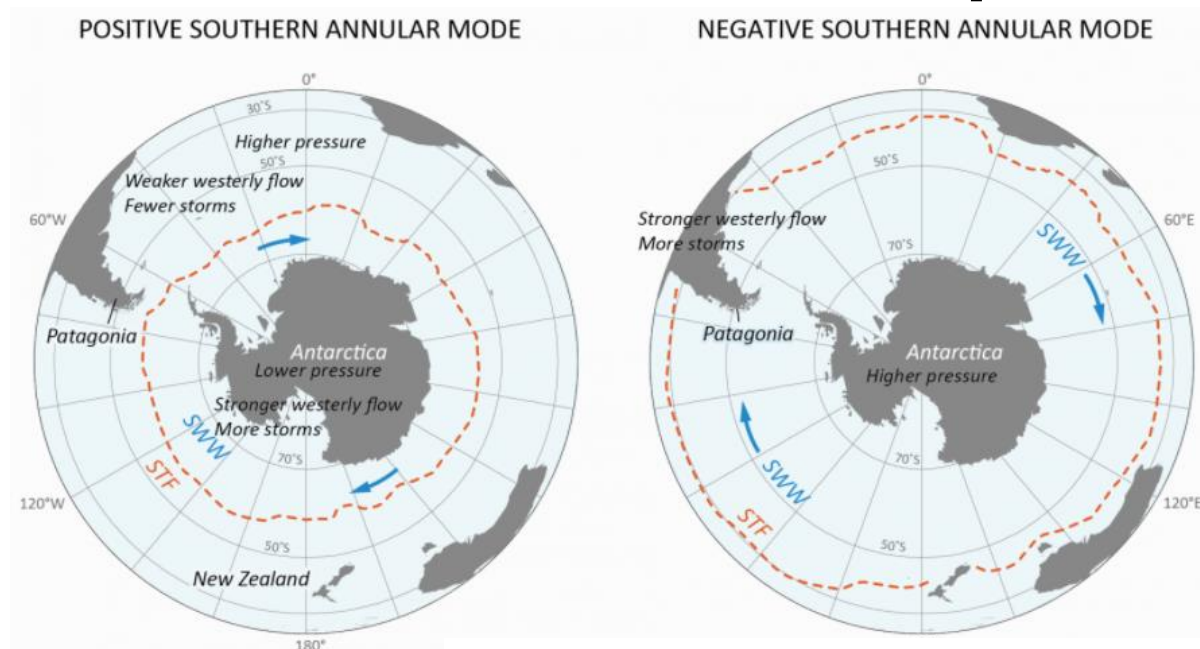
Mean values in Gt per year

Model		SMB	Melt	Refreeze	Runoff	Precipitation
Fixed	ToAIS GAIS	2564±114 1995±96	695±132 180±50	464±97 125±40	208±48 49±10	2971±122 2194±98
Dyn03	ToAIS GAIS	2583±122 1995±99	984±166 248±62	749±133 215±54	190±30 49±7	-----
Dyn15	ToAIS GAIS	2474±114 1963±96	1005±174 262±66	675±122 201±51	300±47 81±14	-----

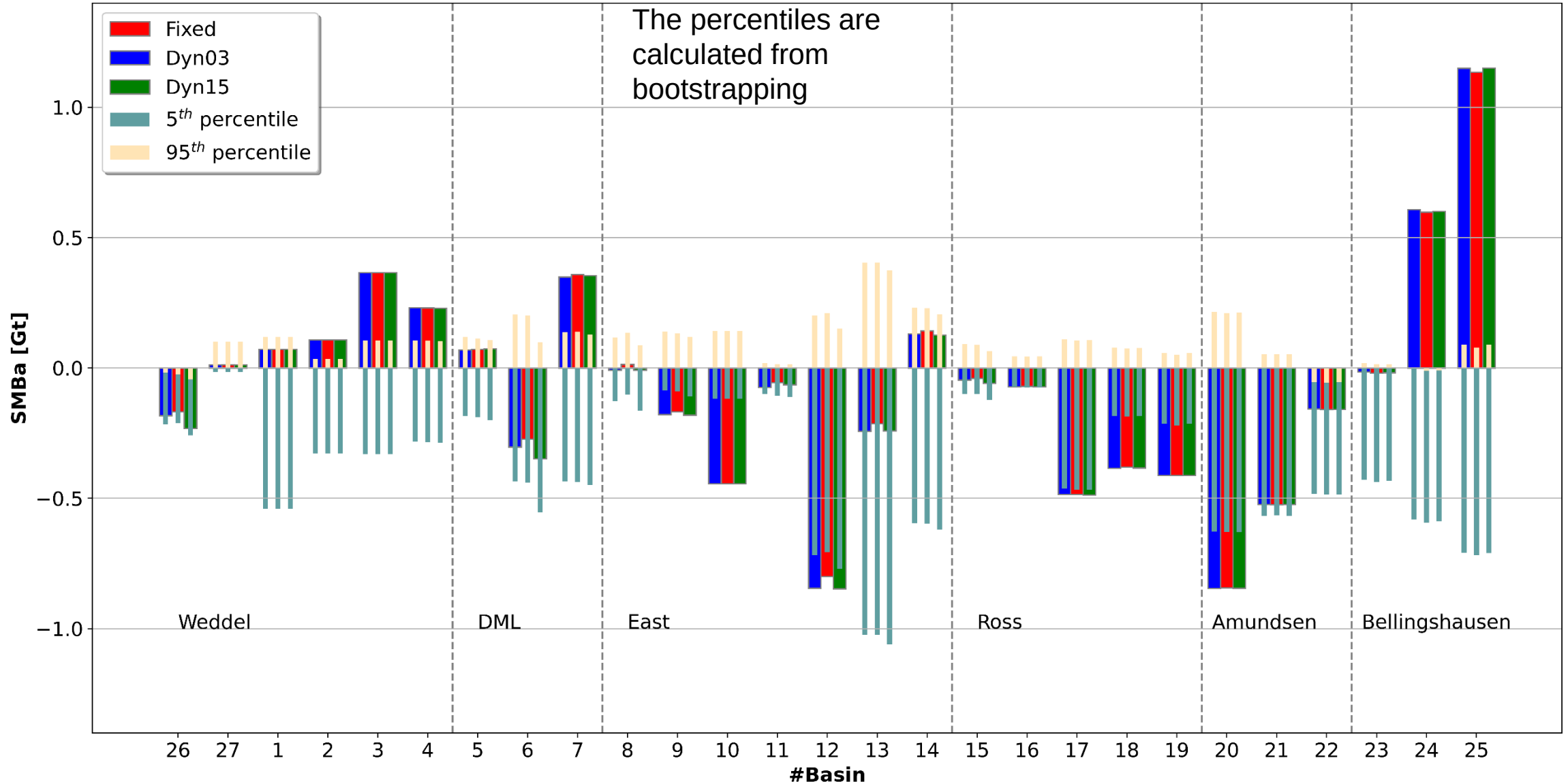
How does the Southern annular mode impact the SMB?



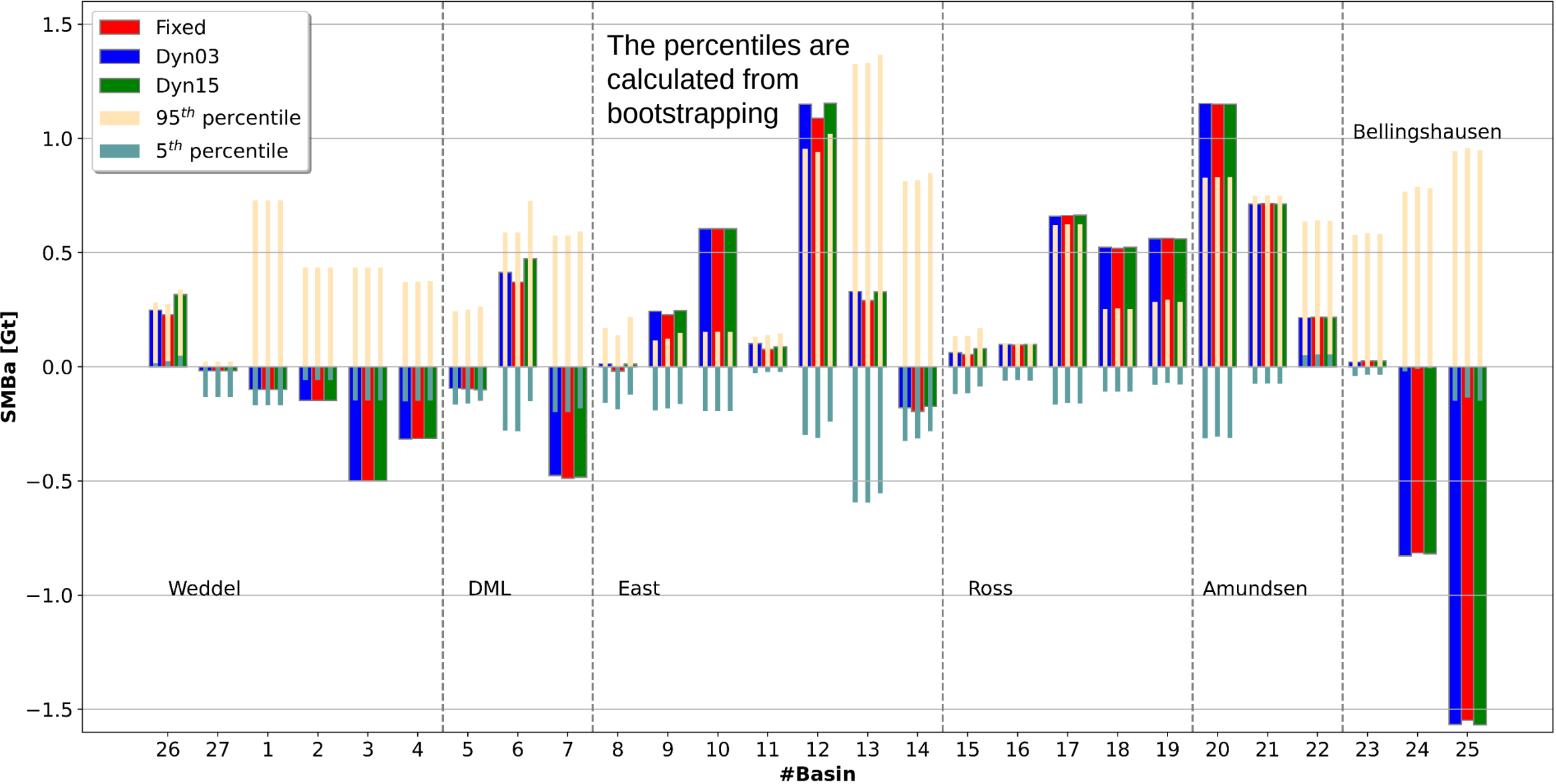
Southern annular mode (SAM) impact on basin scale, monthly data, when SAM positive the westerlies are closer to Antarctica, when negative SAM westerlies are further away from Antarctica



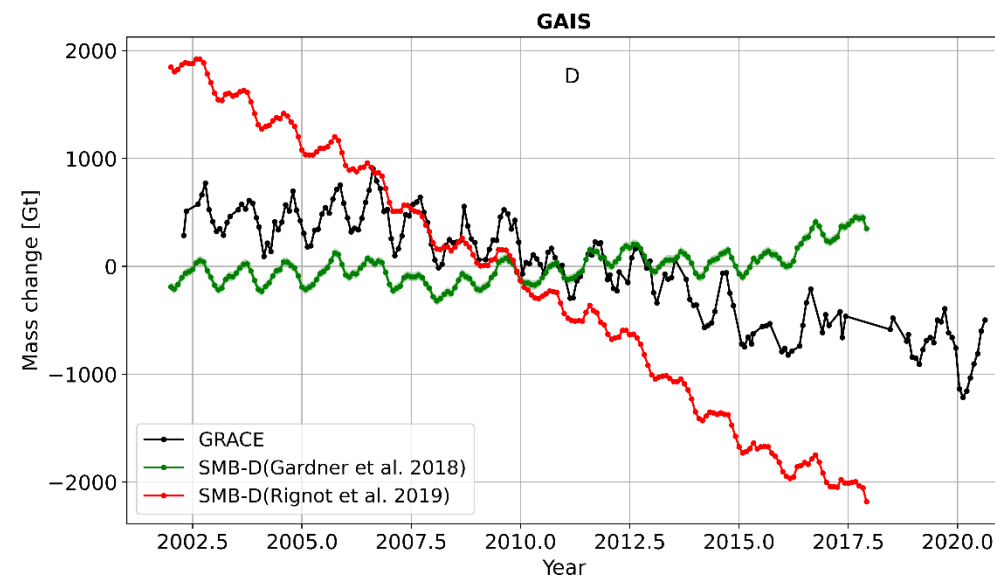
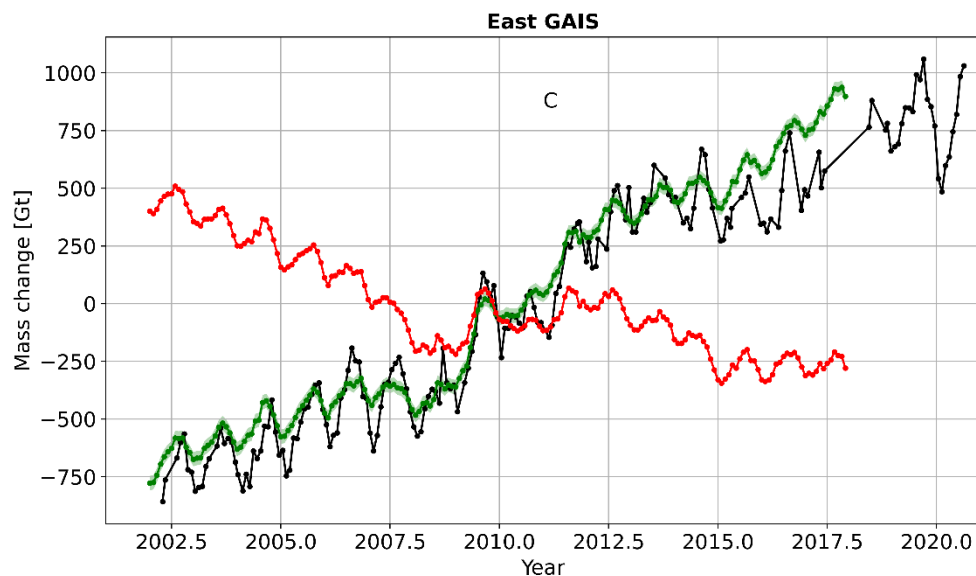
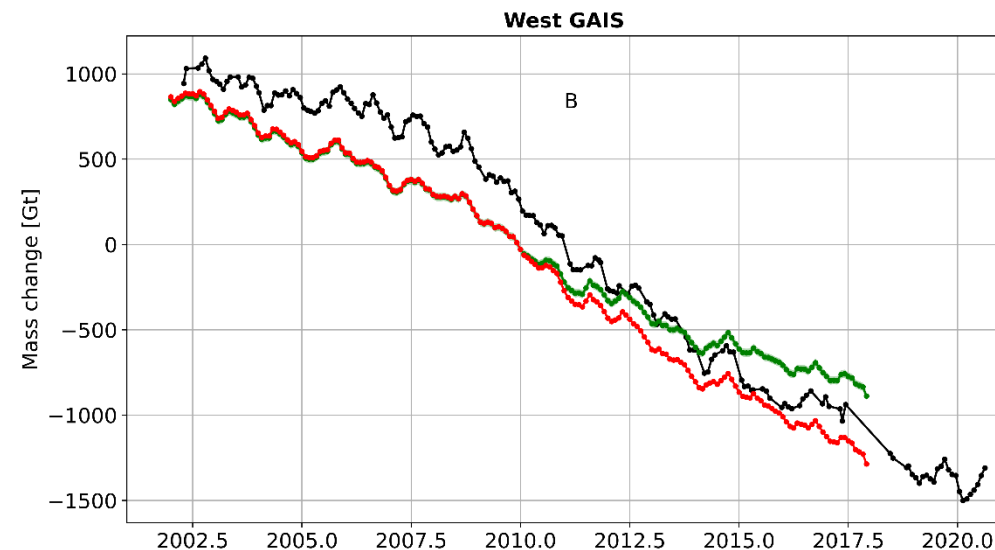
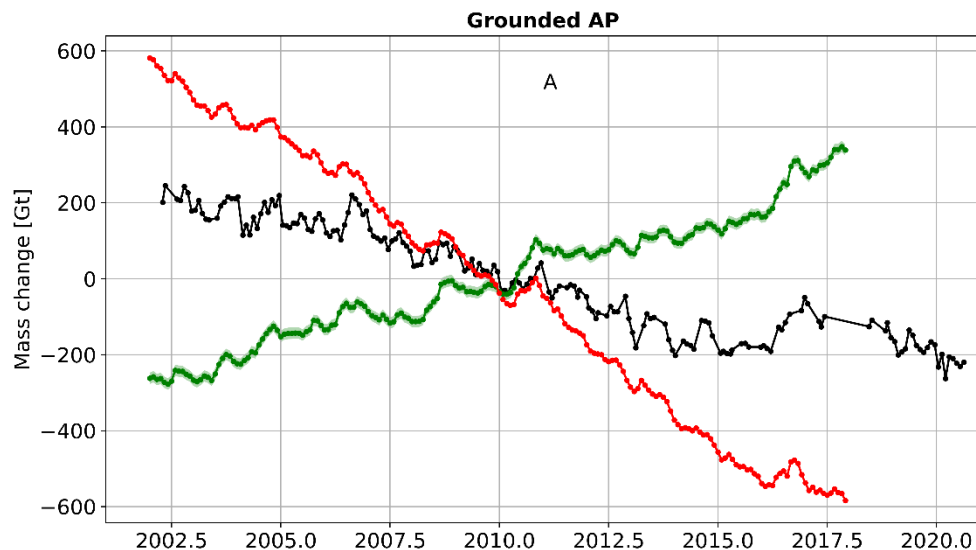
Robust relationship between SAM+ and delta SMB on basin scale



Robust relationship between SAM- and delta SMB on basin scale



SMB-D(Gardner) and SMB-D(Rignot) compared to GRACE mass loss



Summary

- Main difference between simulations are over the ice shelves
- There are spatial varying density biases (important for e.g altimetry use)
- The phase of the SAM affects the spatial distribution of SMB
- Regional estimations of SMB-D, can vary a lot depending on the discharge data set

Read the full study:

<https://doi.org/10.5194/tc-2021-69>

Downscaled surface mass balance in Antarctica - impacts of subsurface processes and large-scale atmospheric circulation

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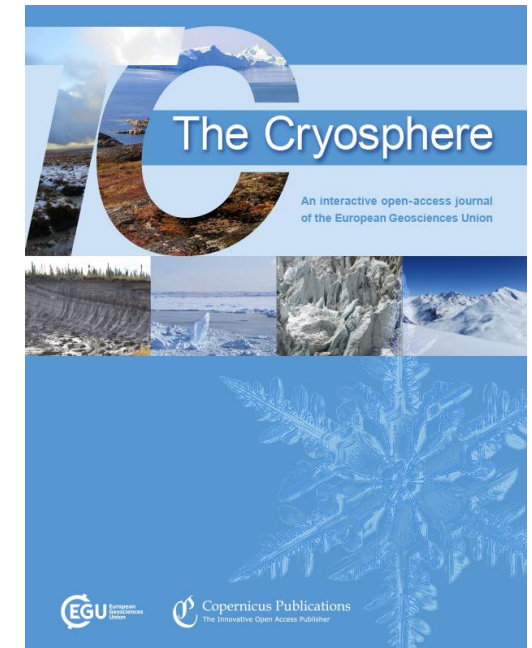
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