CESM winter meeting

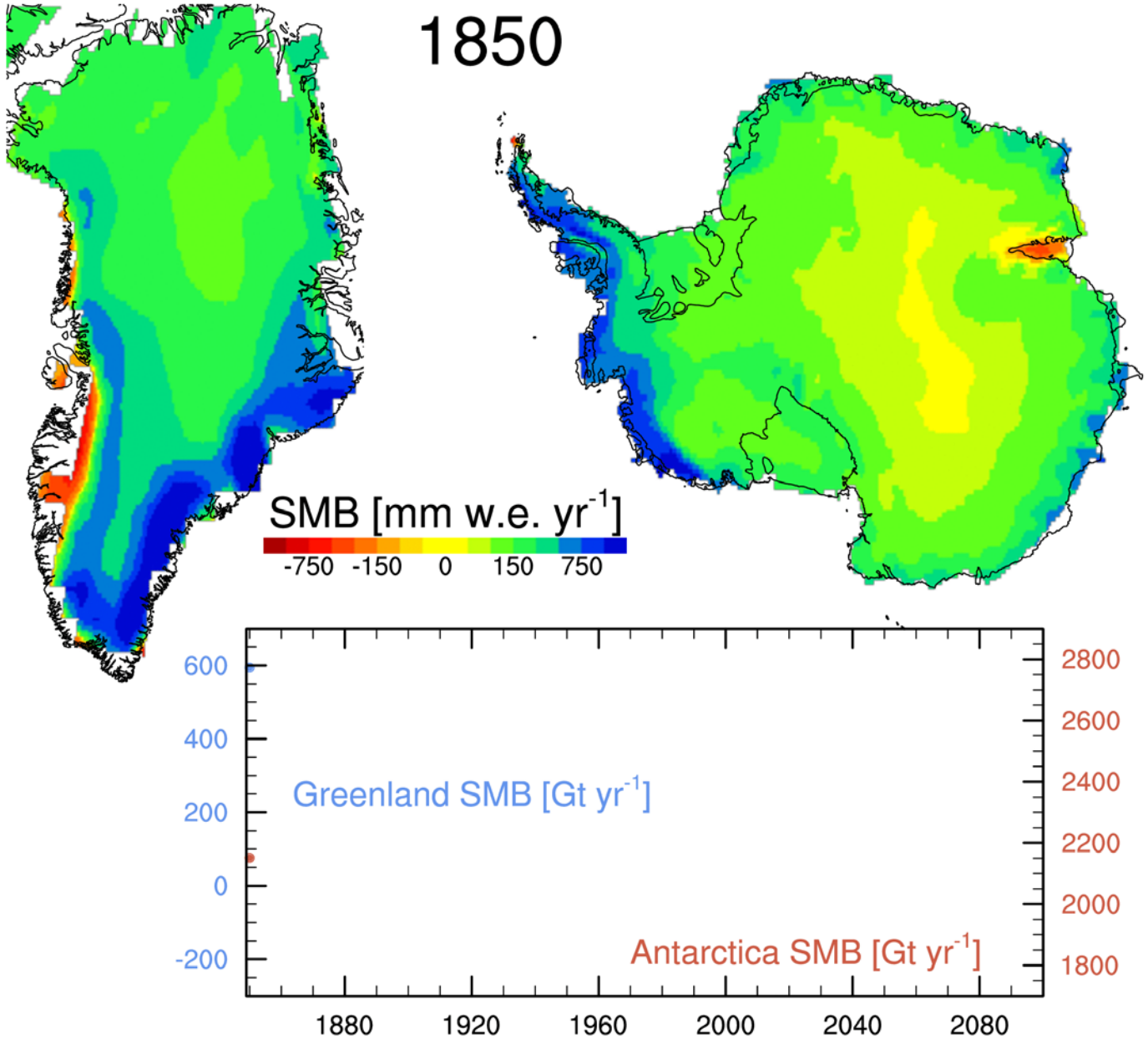
Boulder, February 9, 2016

Ice sheet climate in CESM

Jan Lenaerts

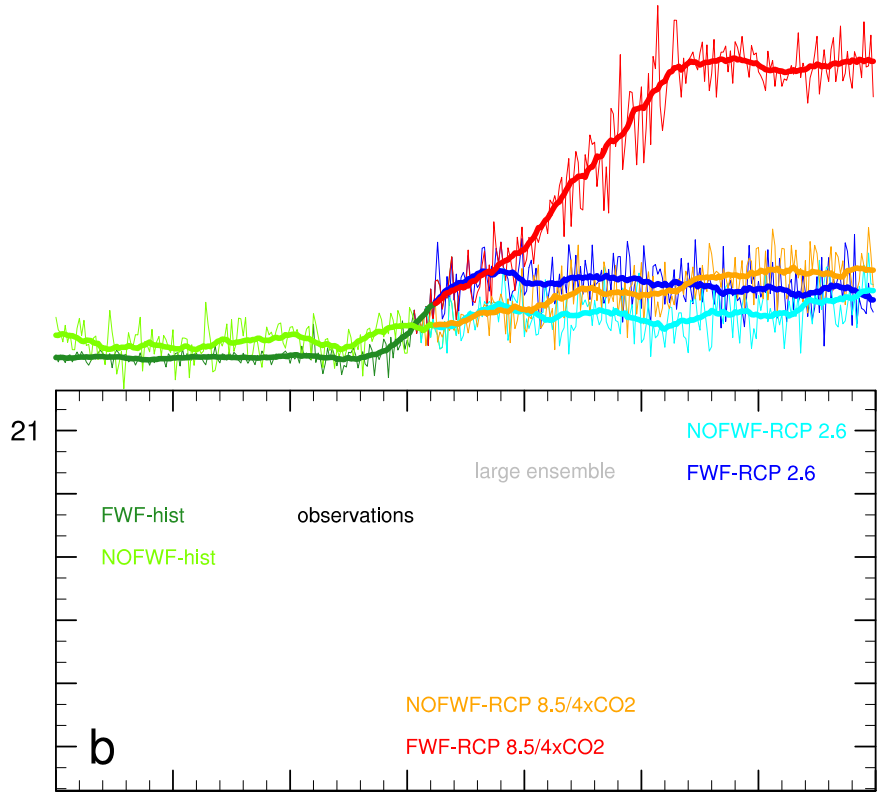
& many CESM community members!

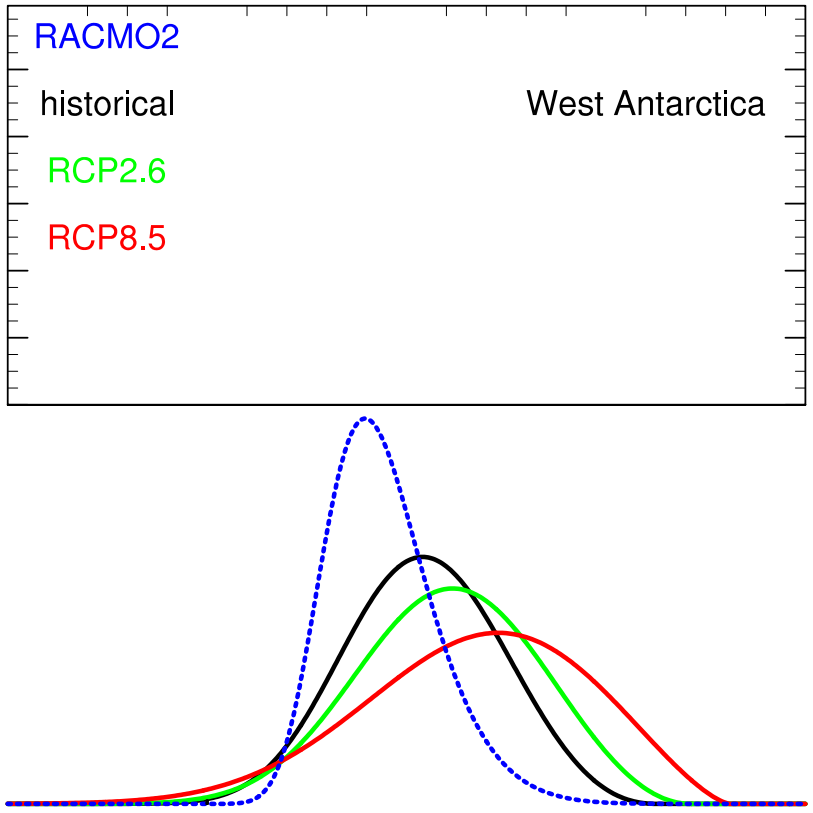
Universiteit Utrecht


1850
SMB [mm w.e. yr-1]
-750 -150 0 150 750
600
400
200
0
-200
Greenland SMB [Gt yr-1]
2800
2600
2400
2200
2000
1800
Antarctica SMB [Gt yr-1]
1880
1920
1960
2000
2040
2080

Exciting CESM land ice science in 2015

Impact of ‘realistic’ GrIS mass loss on AMOC (Lenaerts et al., 2015 (GRL))





Historical and future Antarctic SMB (Lenaerts et al., 2016 (Clim. Dyn.))

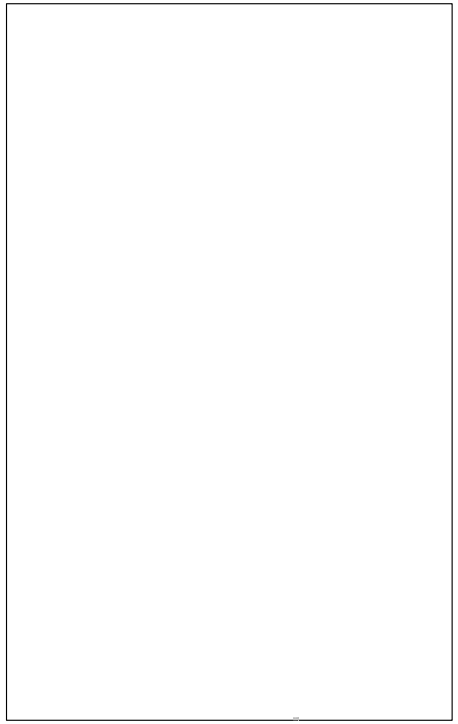
CESM1 ice sheet biases

I. Meltwater refreezing

II. Snow density

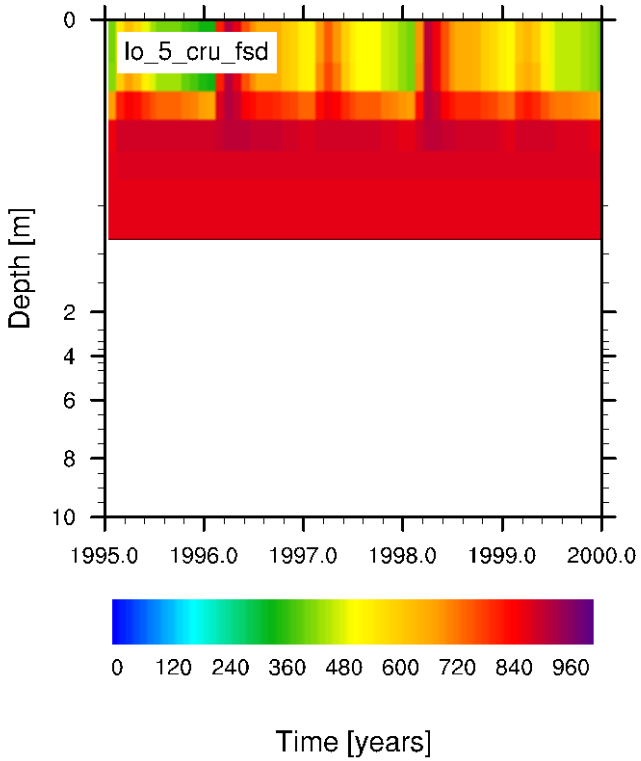
III. Clouds

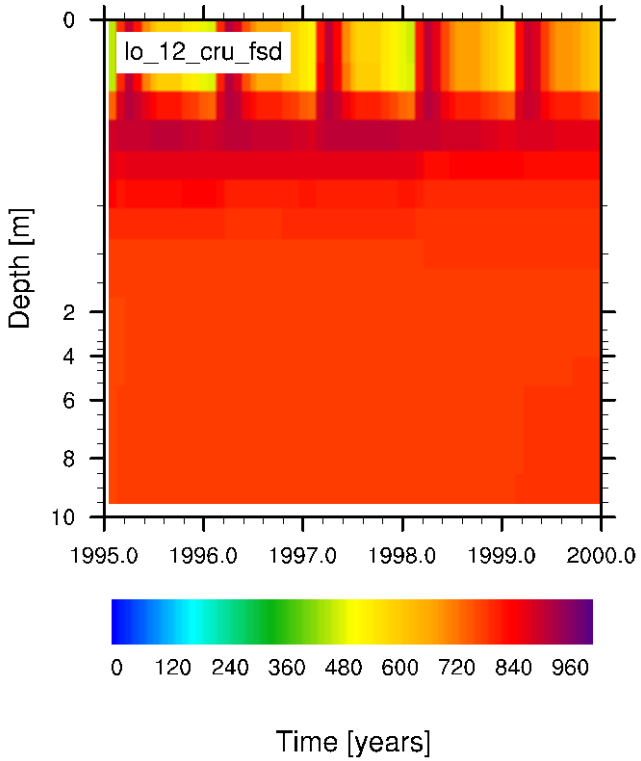
IV. Winds

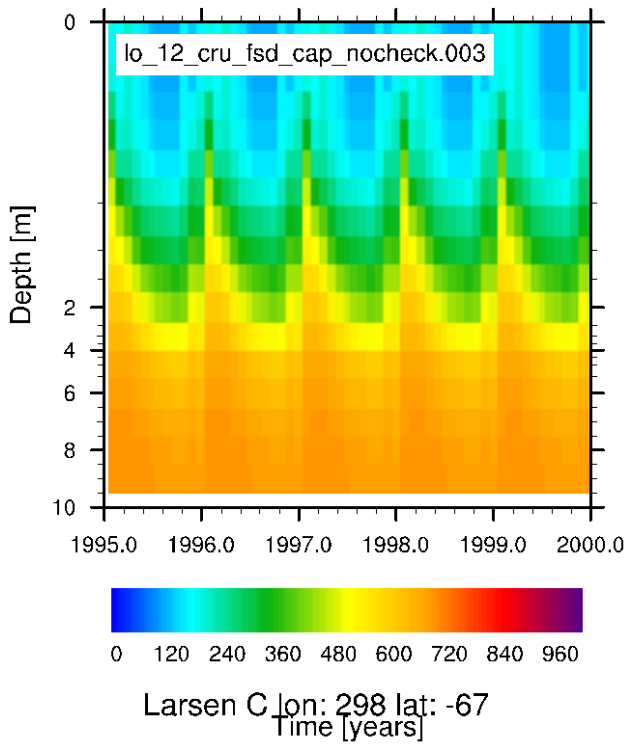


I. Improved snow model resolution

(and repaired a major bug)





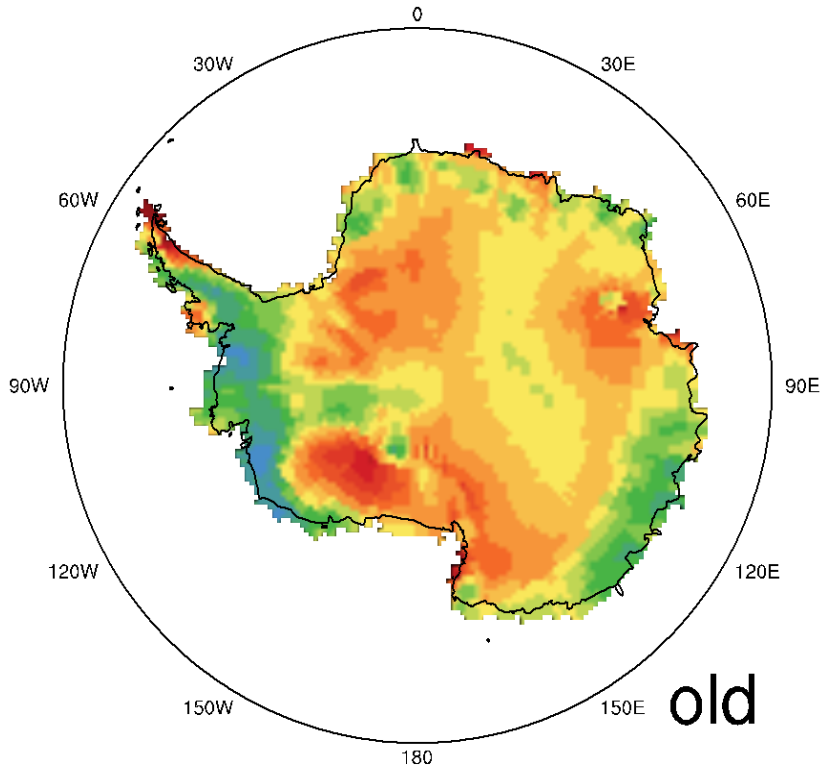


5 layers

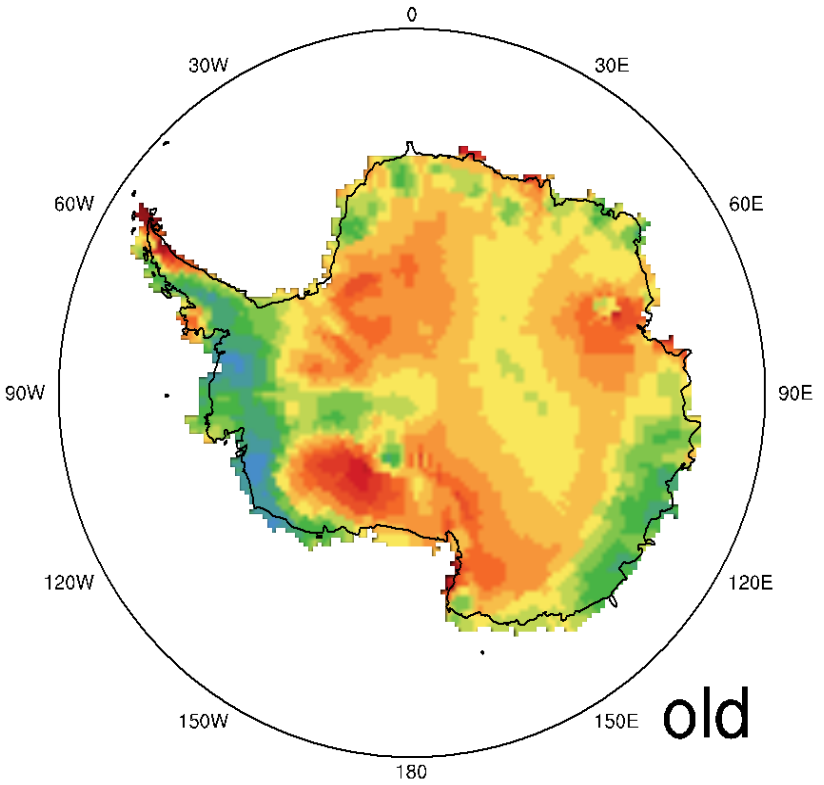
12 layers

12 layers+ cap

II. Wind-enhanced snow compaction



old



old

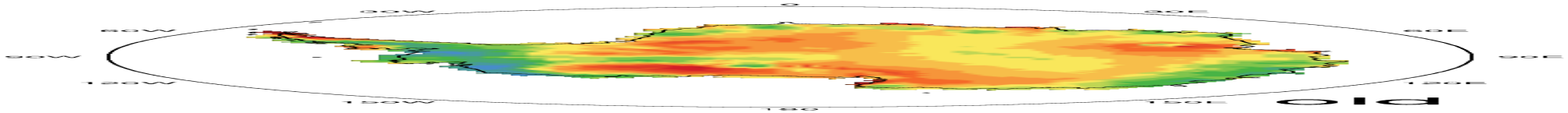
snow density

↓

heat conduction

↓

sub-surface melt



Van Kampenhout et al., in prep.

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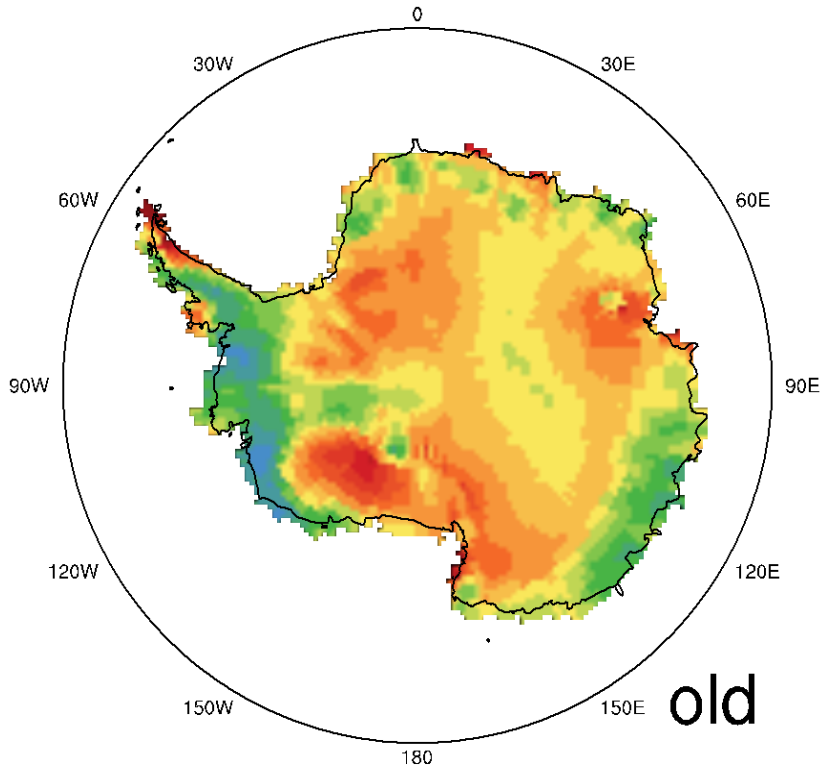
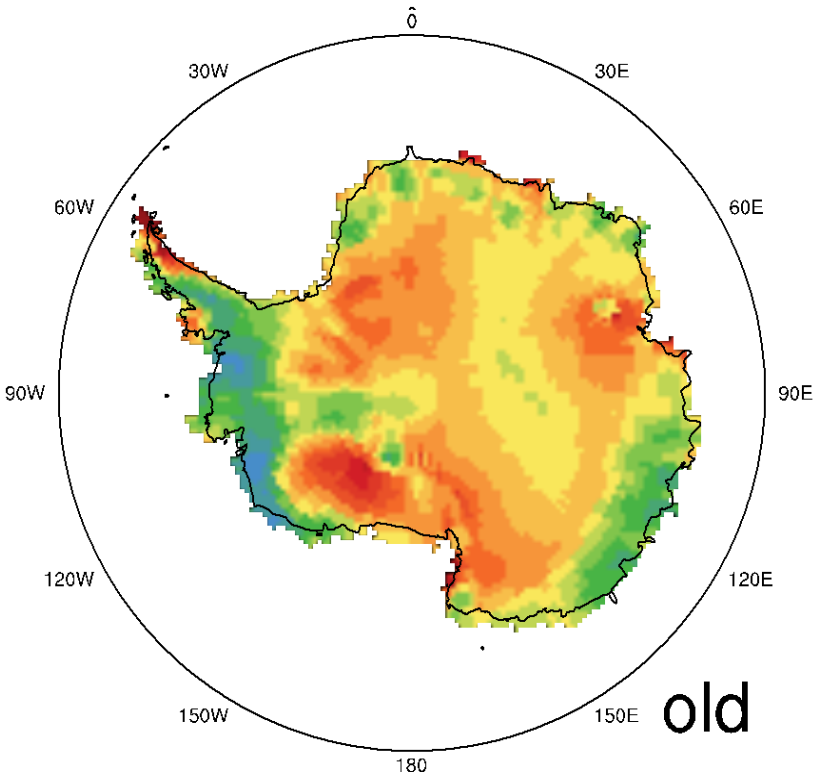


old



old

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heat conduction

↓

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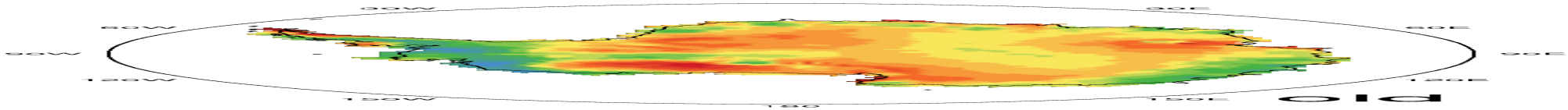
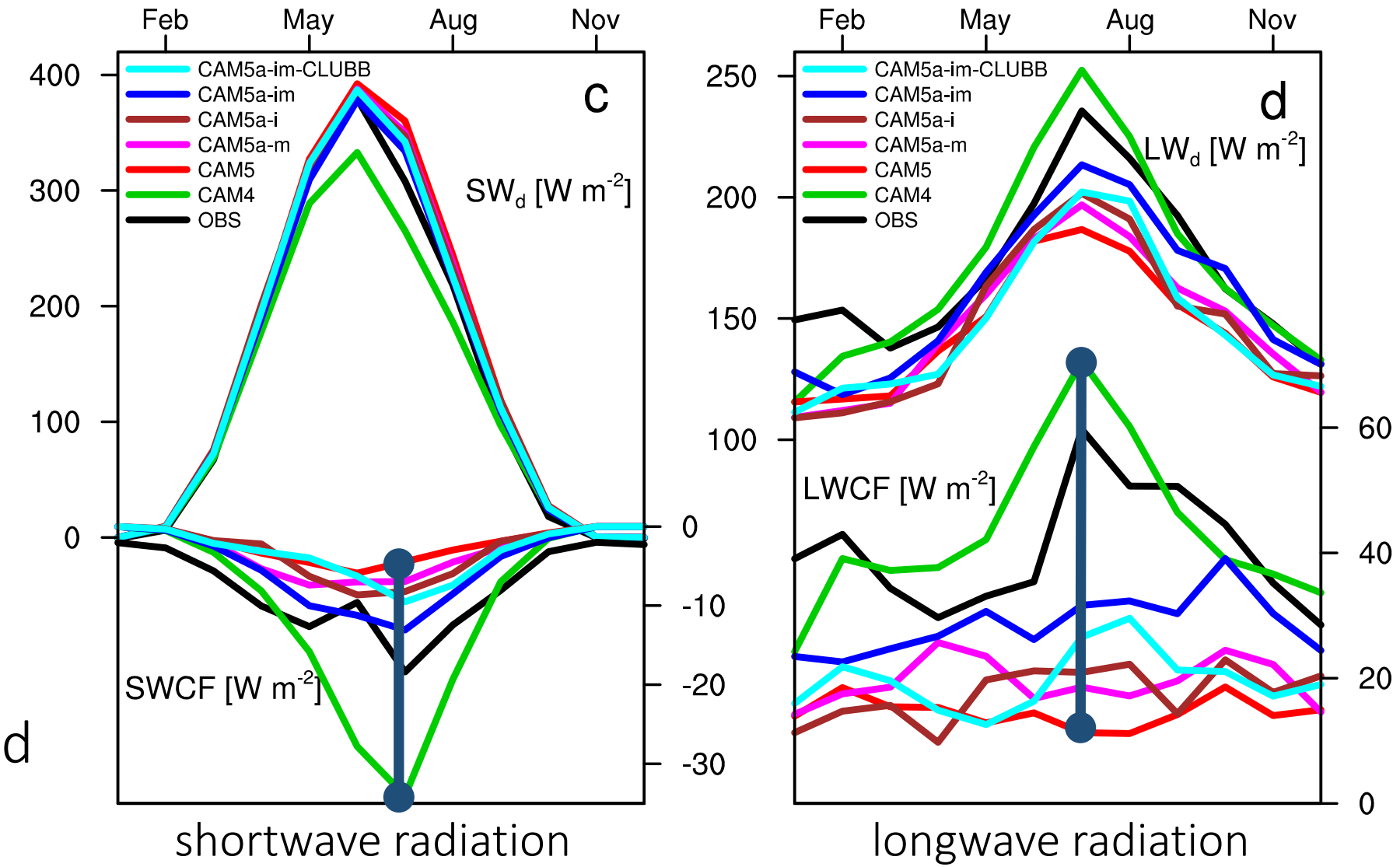


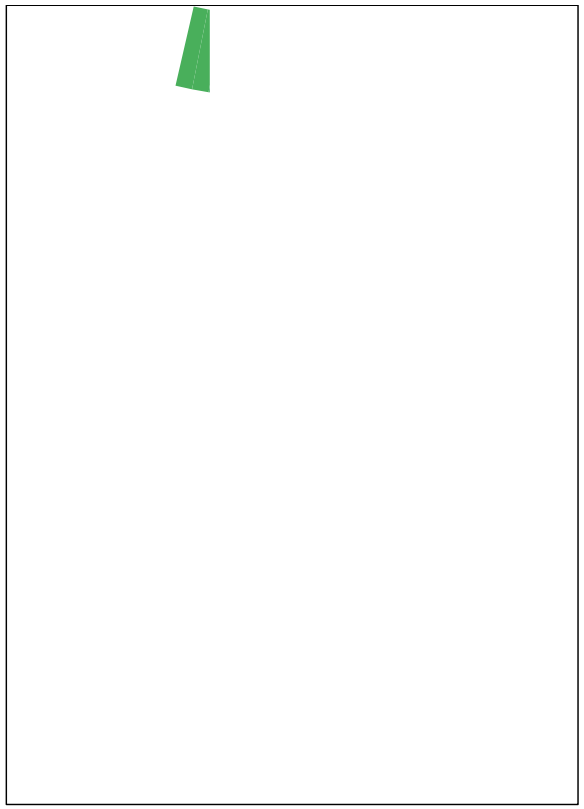
Van Kampenhout et al., in prep.

III. Clouds

Summit, Greenland



III. Clouds

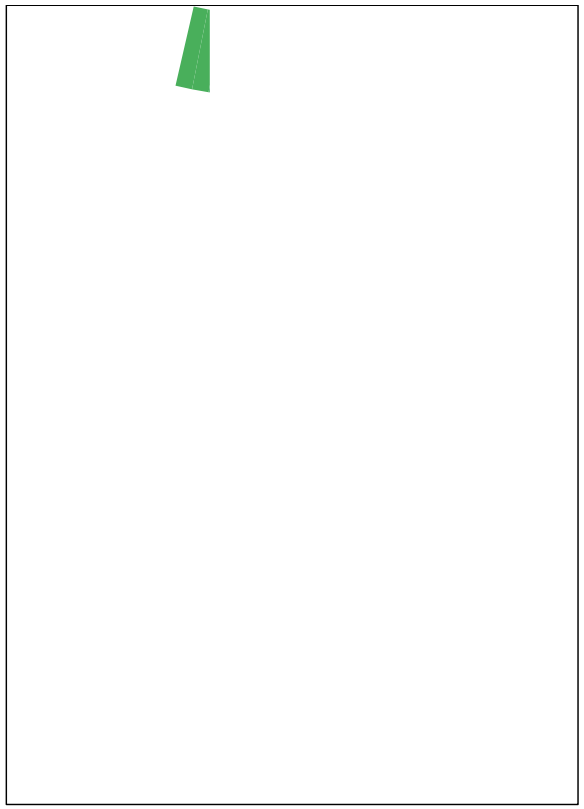


Van Tricht et al., Nat. Comm., 2016.

0 150 224

LWP [g m^{-2}]

III. Clouds

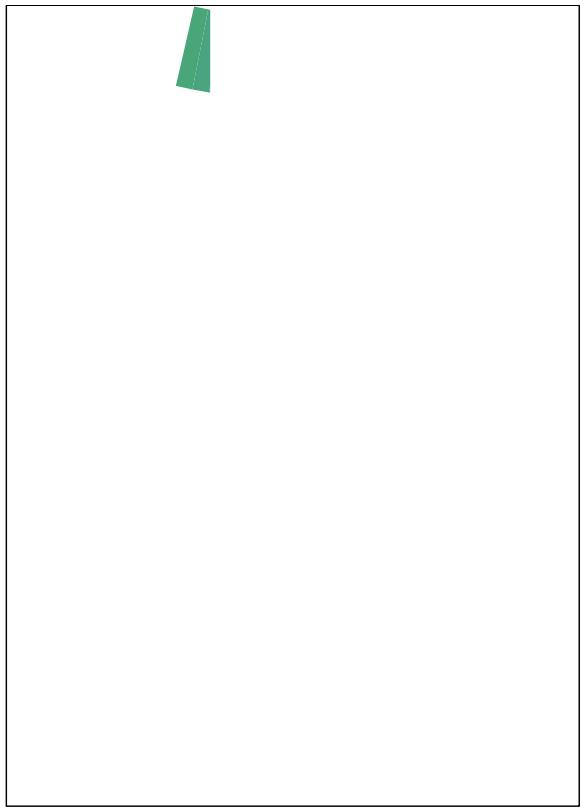


Van Tricht et al., Nat. Comm., 2016.

0 150 224

LWP [g m^{-2}]

III. Clouds



Van Tricht et al., Nat. Comm., 2016.

Cloud LWP

↓

Incoming longwave radiation

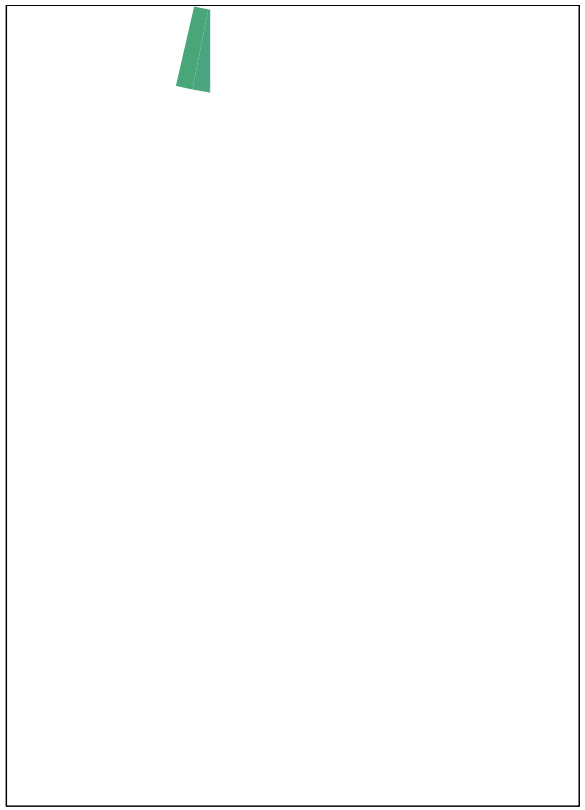
↓

Surface energy balance

0 184 198 212 226 240 254 268 282 296

Incoming LW [W m^{-2}]

III. Clouds

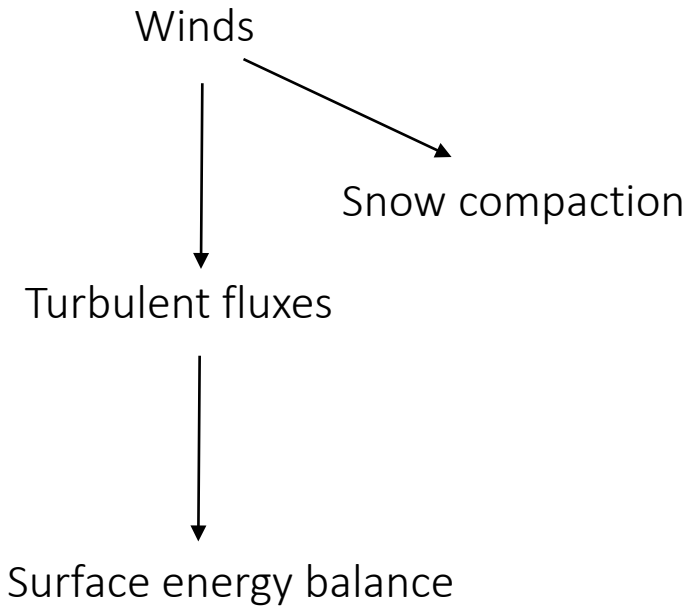


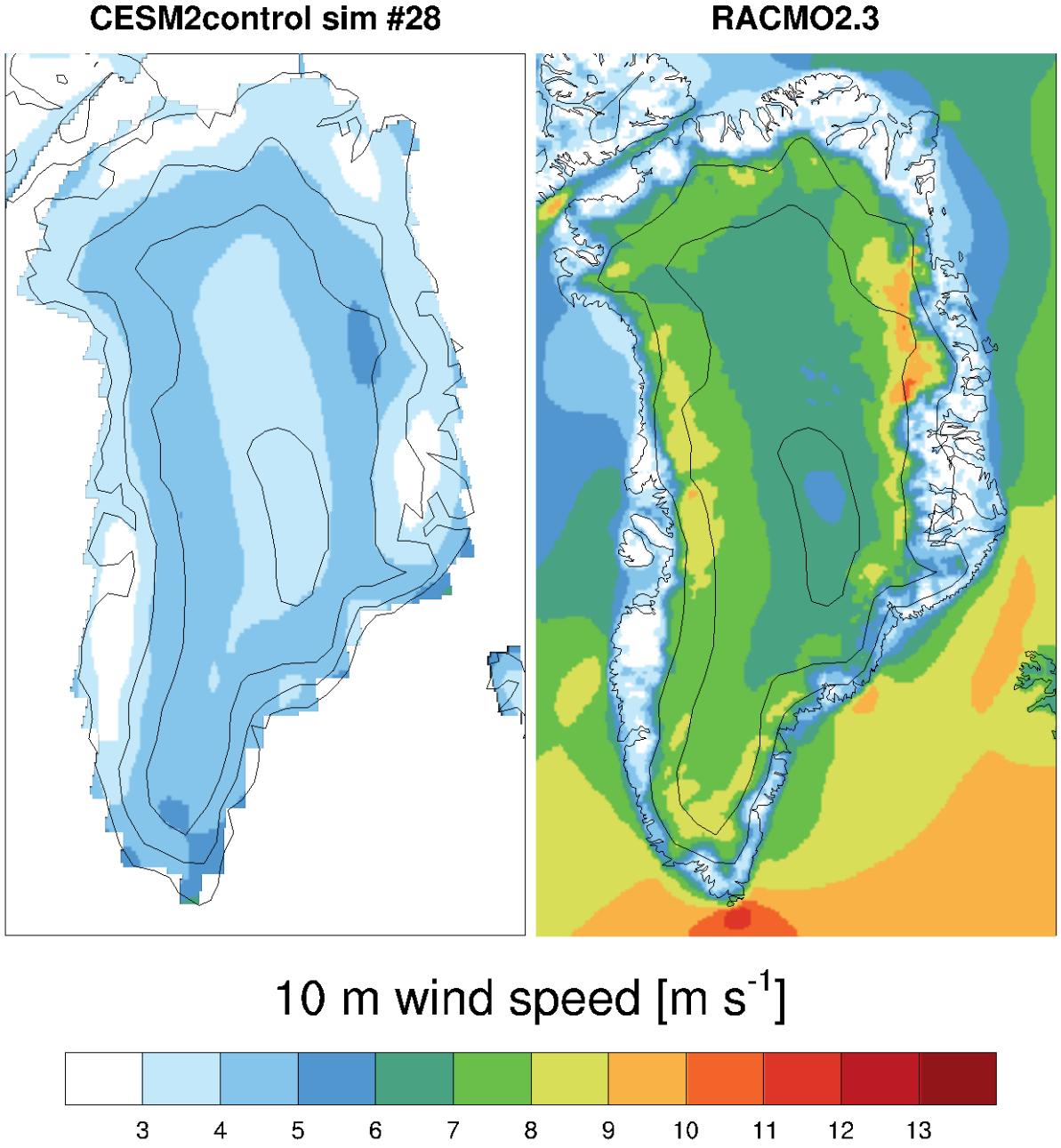
Van Tricht et al., Nat. Comm., 2016.

0 184 198 212 226 240 254 268 282 296

Incoming LW [W m^{-2}]

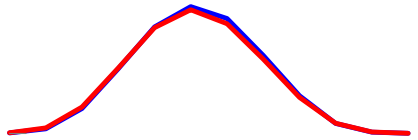
IV. Surface winds





TMS

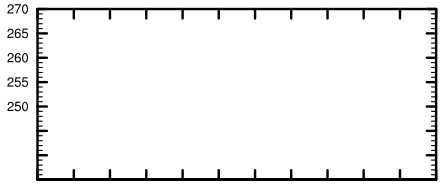
- Turbulent mountain stress
- Added to improve general circulation
- Enhances surface drag of subgrid terrain by increasing roughness length



New wave drag scheme

- Julio Bacmeister (NCAR)
- In latest stages of development
- Can ‘replace’ TMS, only if general circulation is not degraded

Improves ice sheet wind climate
& eliminates winter temperature bias



Antarctic melt

Warm atmosphere

↓

Snow grain growth

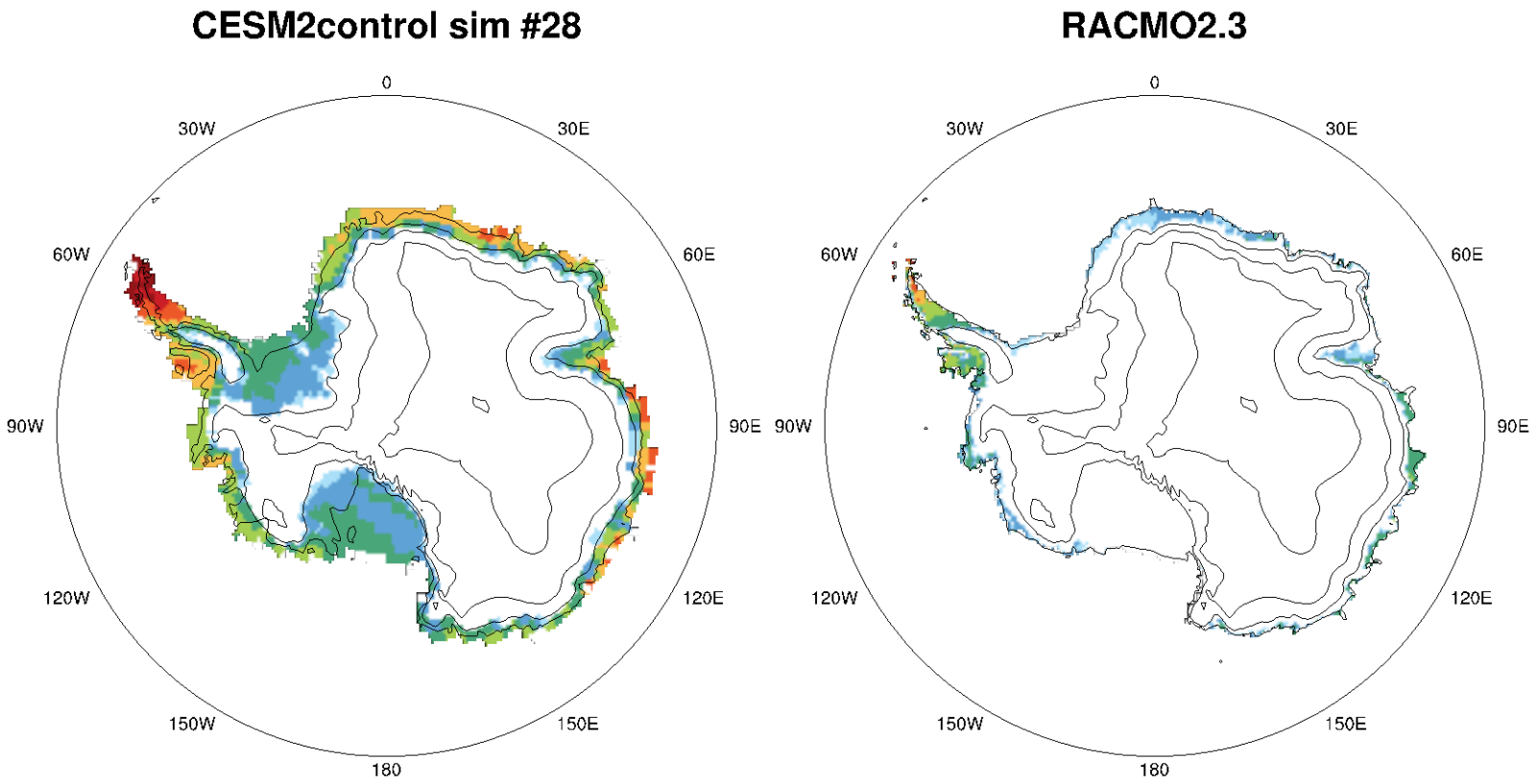
↓

Albedo lowering

↓

Melt

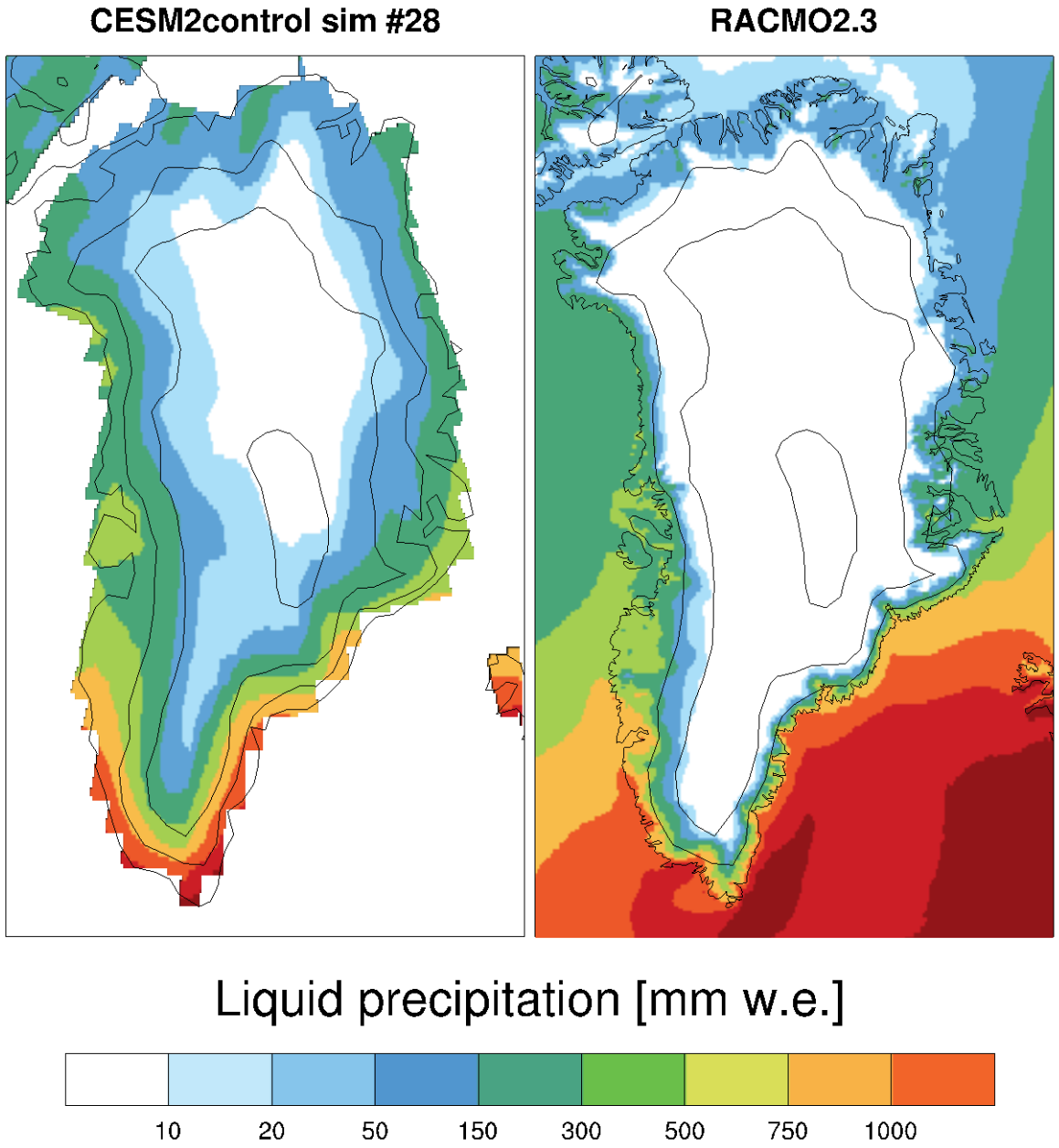
1980-2005



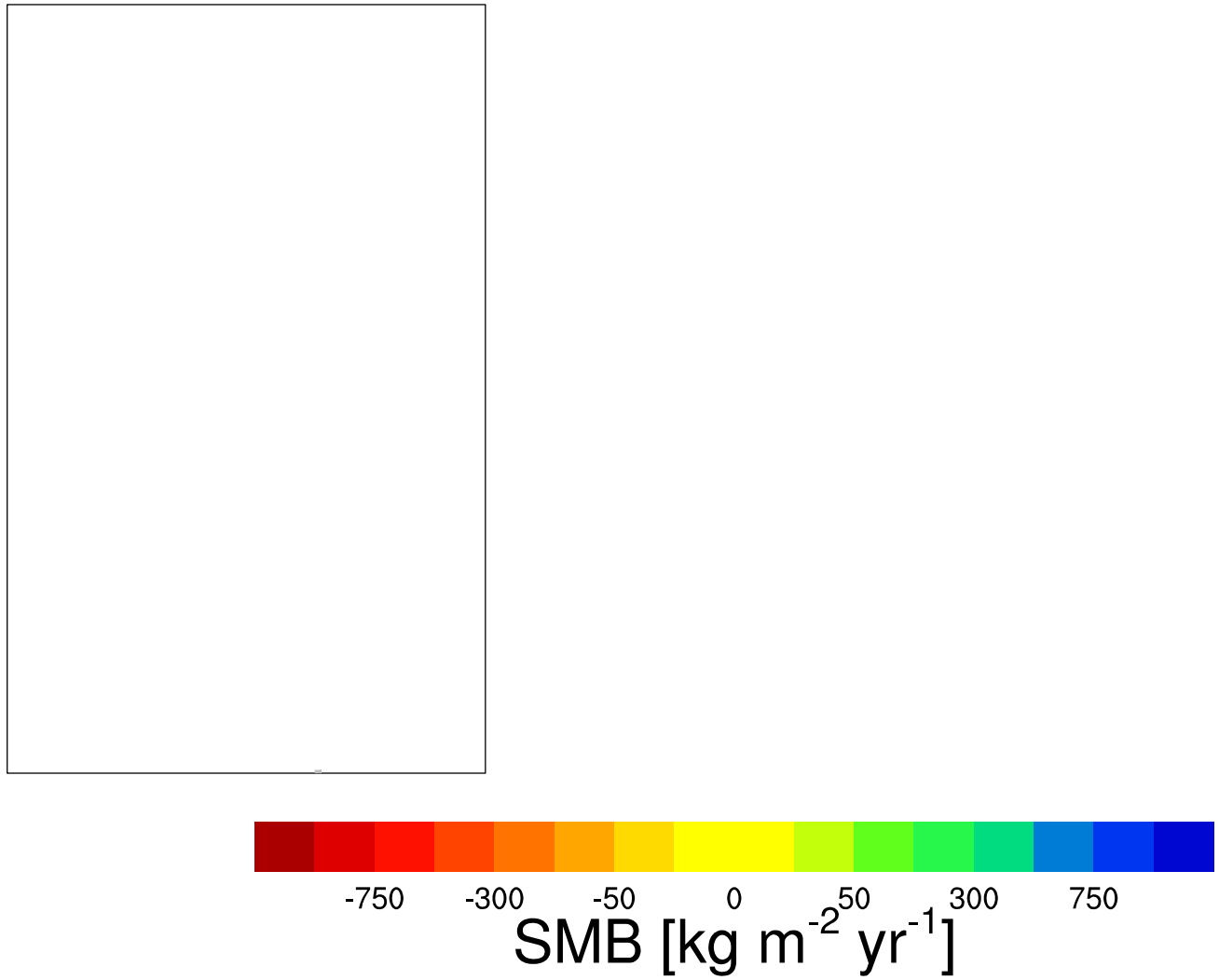
New bias: precipitation

High-elevation liquid precipitation is back!

Hands-on solution: liquid converted to solid in CLM with surface flux correction.

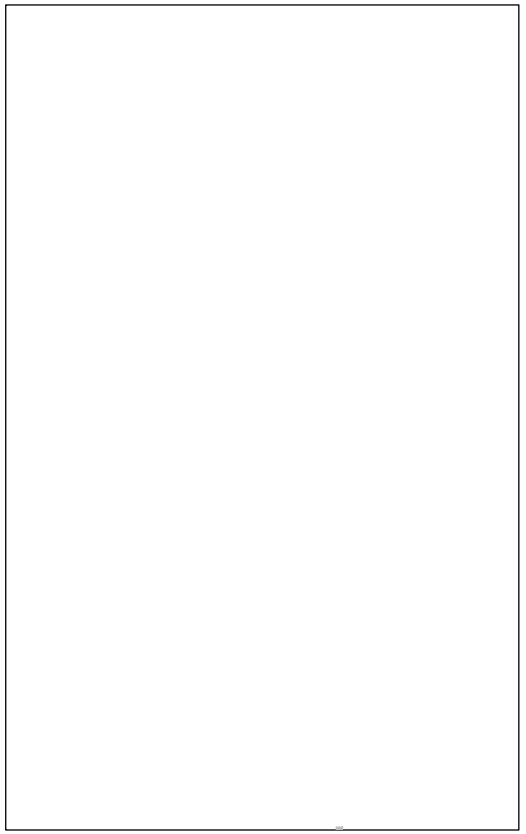


Greenland SMB



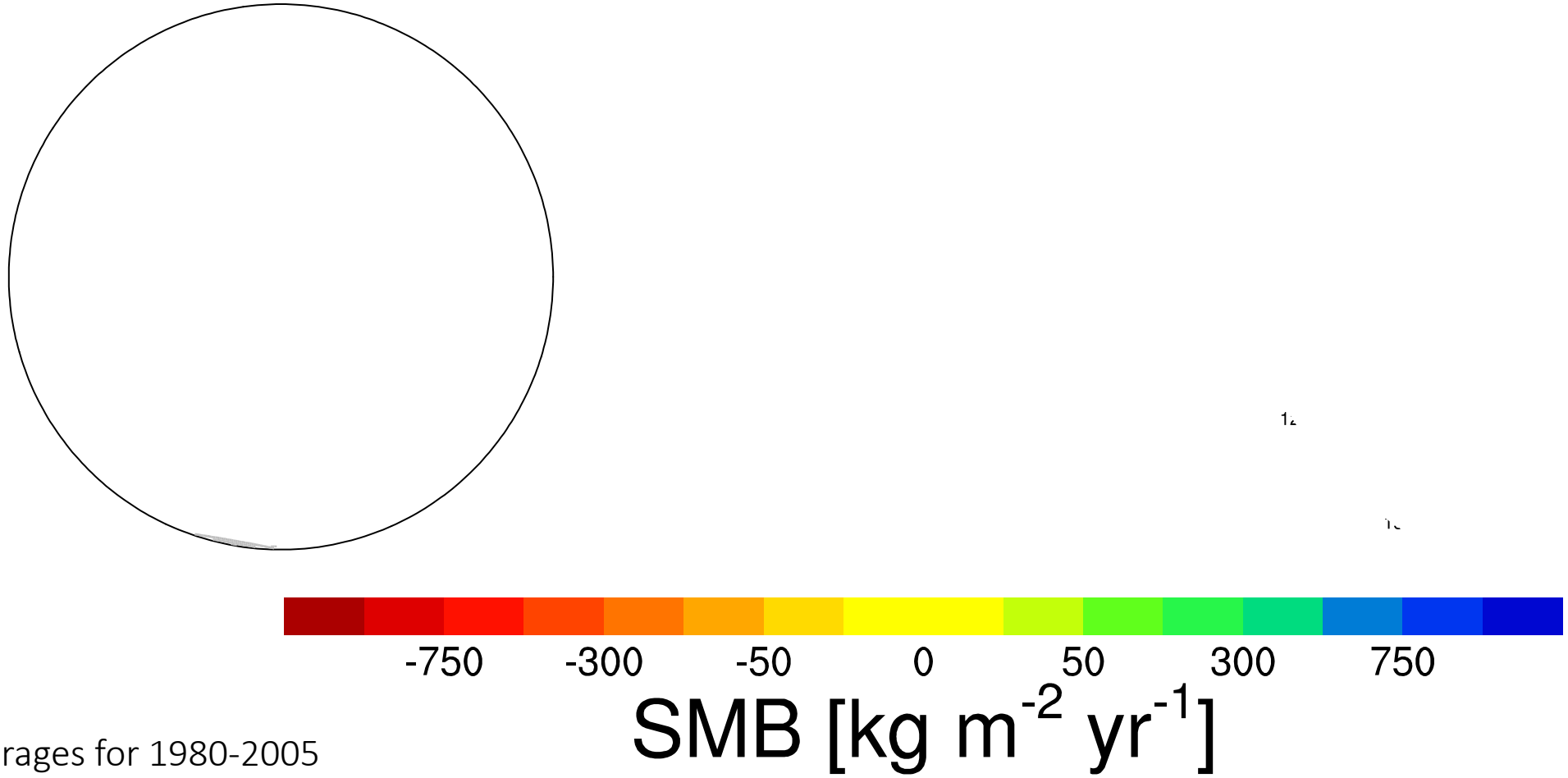
Averages for 1980-2005

Greenland SMB



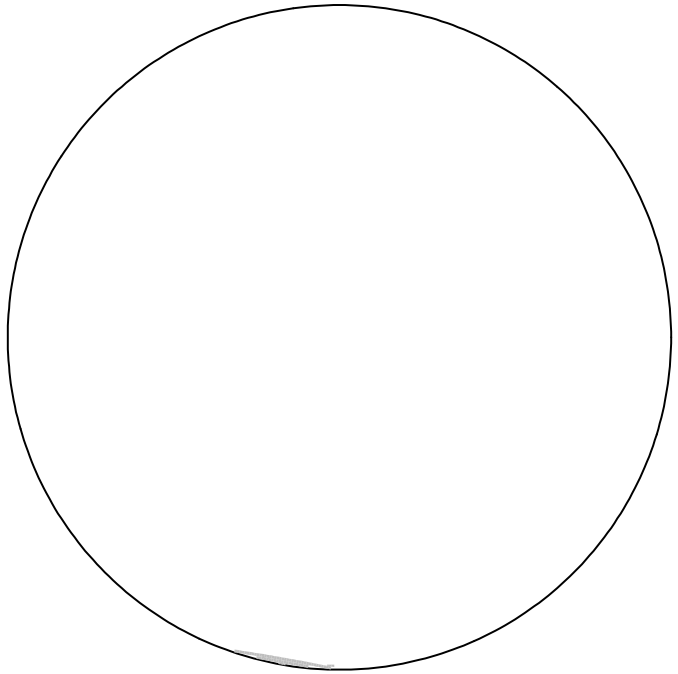
Averages for 1980-2005

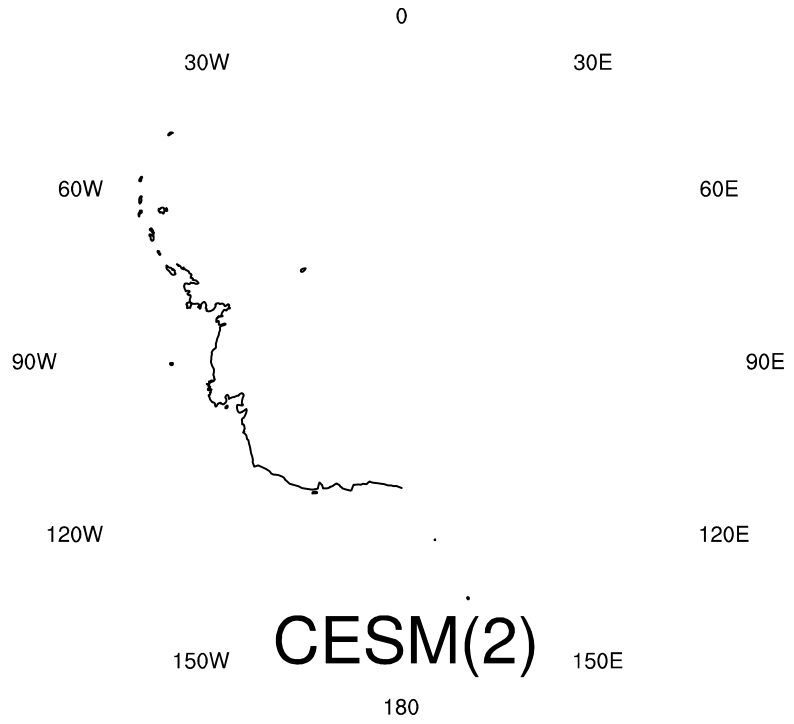
Antarctic SMB



Averages for 1980-2005

Antarctic SMB

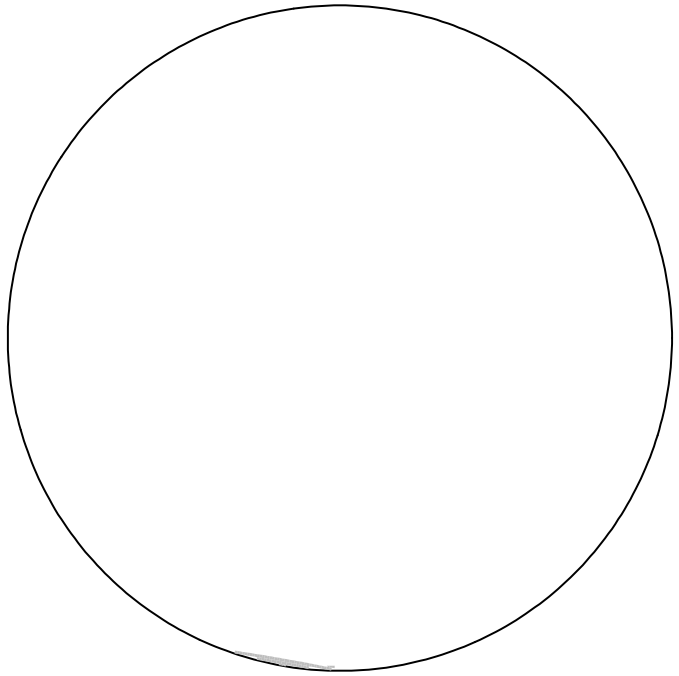


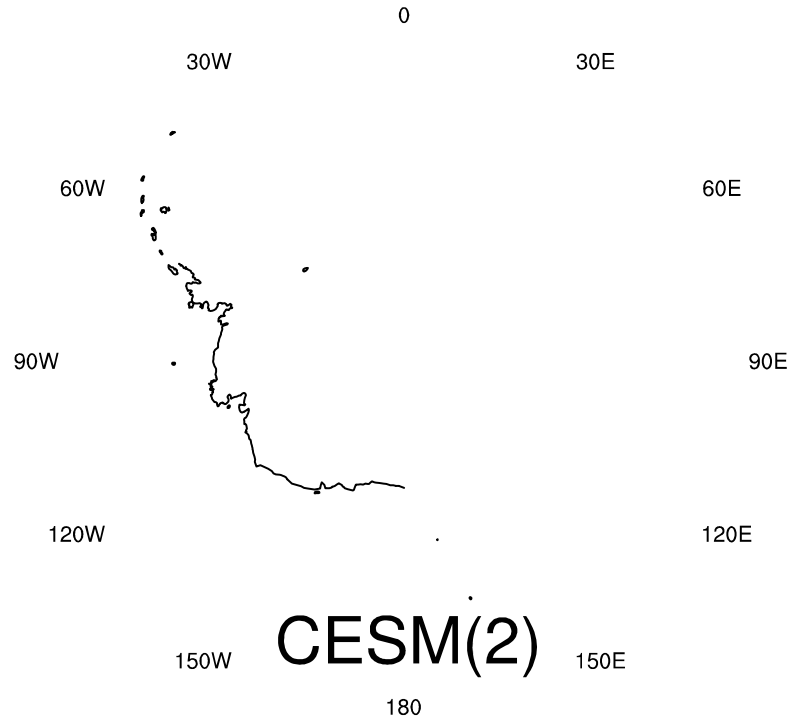


SMB [kg m^{-2} yr^{-1}]

Averages for 1980-2005

Antarctic SMB





SMB [kg m^{-2} yr^{-1}]

Averages for 1980-2005

Some numbers

Greenland

	CESM2 #28	CESM2 #31	*best estimate*
Snowfall	760	740	660
Rain	160	130	40
Melt (snow)	560	440	500
Melt (ice)	170	120	
Refreezing	380	310	250
Sublimation	<10	<10	40
SMB	540	590	400

Antarctica

	CESM2 #28	CESM2 #31	*best estimate*
Snowfall	2840	2760	2600
Rain	180	160	<10
Melt (snow)	730	720	100
Melt (ice)	20	20	
Refreezing	690	670	100
Sublimation	60	60	200
SMB	3000	2900	2400

Averages for 1980-2005

Ongoing/Future work of ‘Dutch CESM group’

Drifting snow (Jan + Leo)

Snow compaction (Leo + Jan)

SMB downscaling (Vincent + Miren + Jan + Leo)

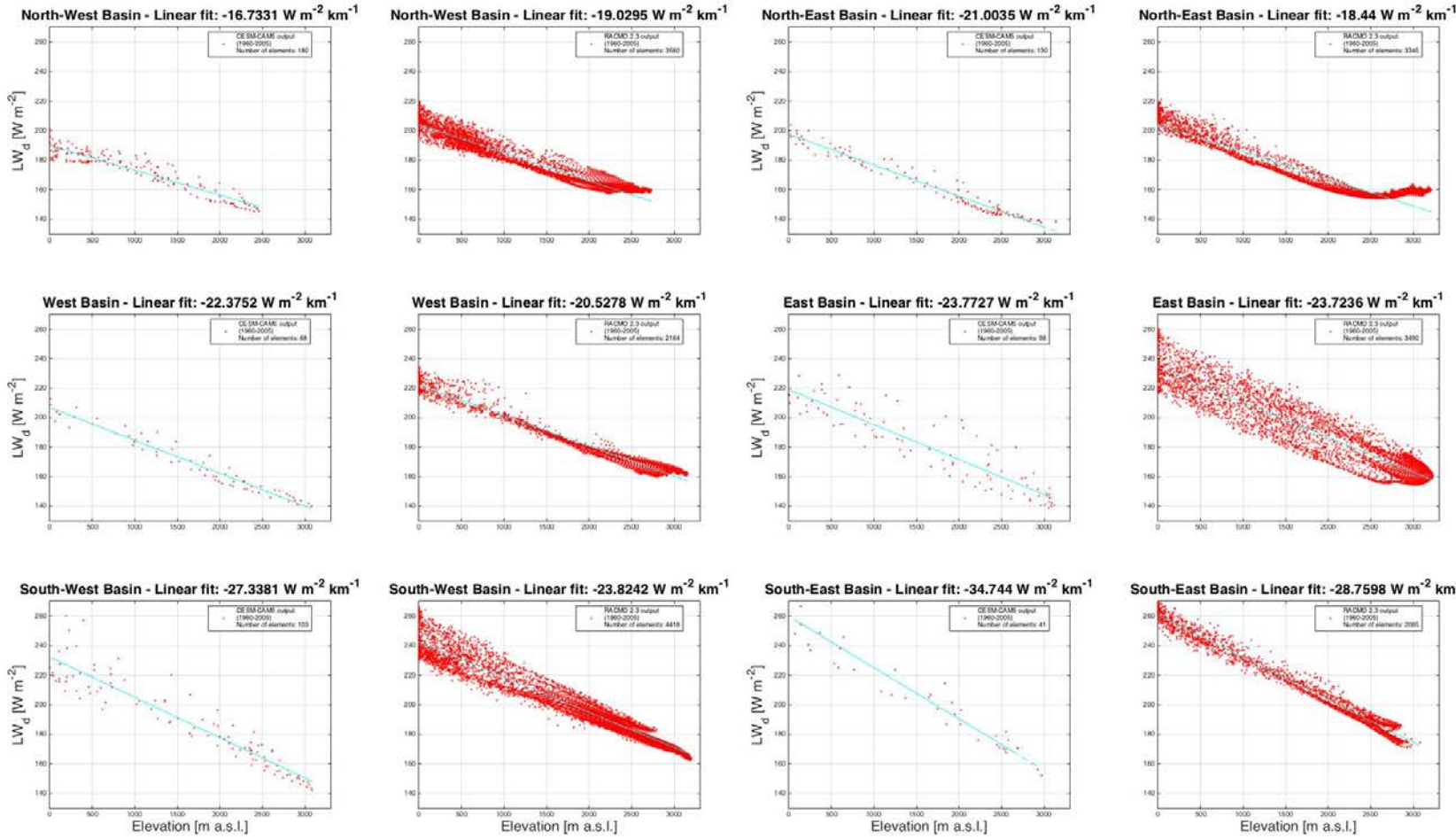
Offline CISM – Greenland ‘threshold’ (IMAU PhD)

Coupled CESM-CISM (Miren ERC + IMAU)

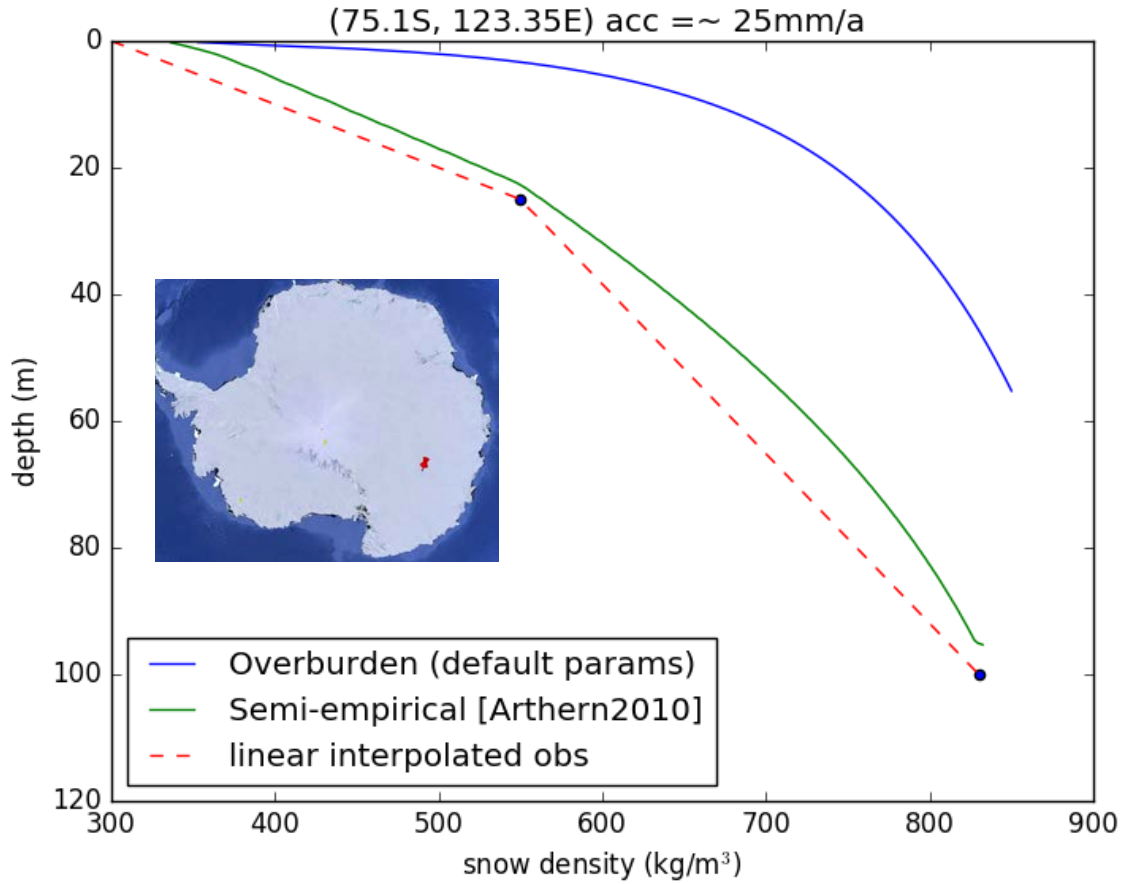
SMB downscaling

elevation

Incoming longwave



Firn compaction



Goal:
improve meltwater refreezing properties of polar firn

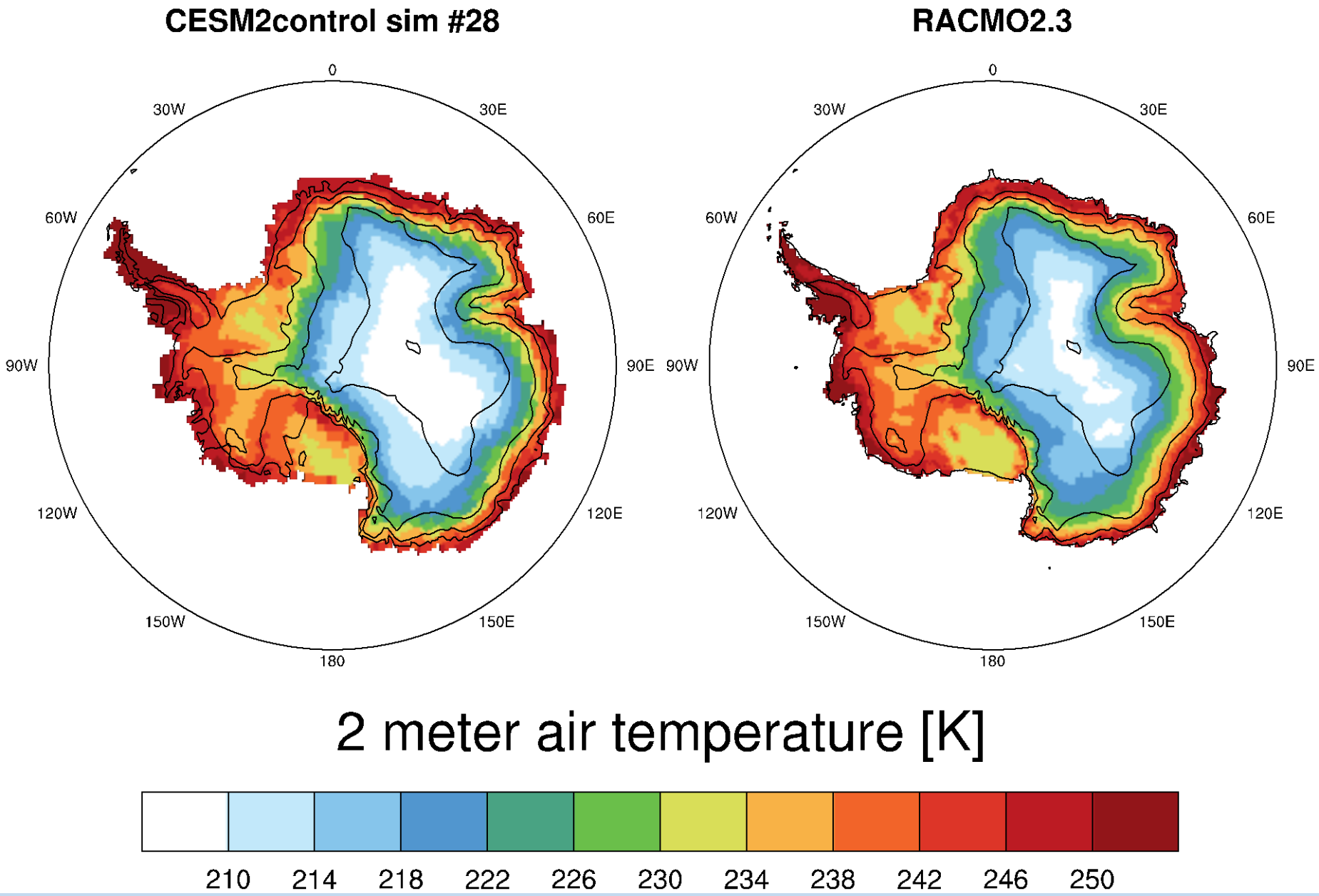
Firn air content	
Semi-empirical model (Arthern 2010)	27.8 m^3
Overburden (Anderson 1976)	10.3 m^3

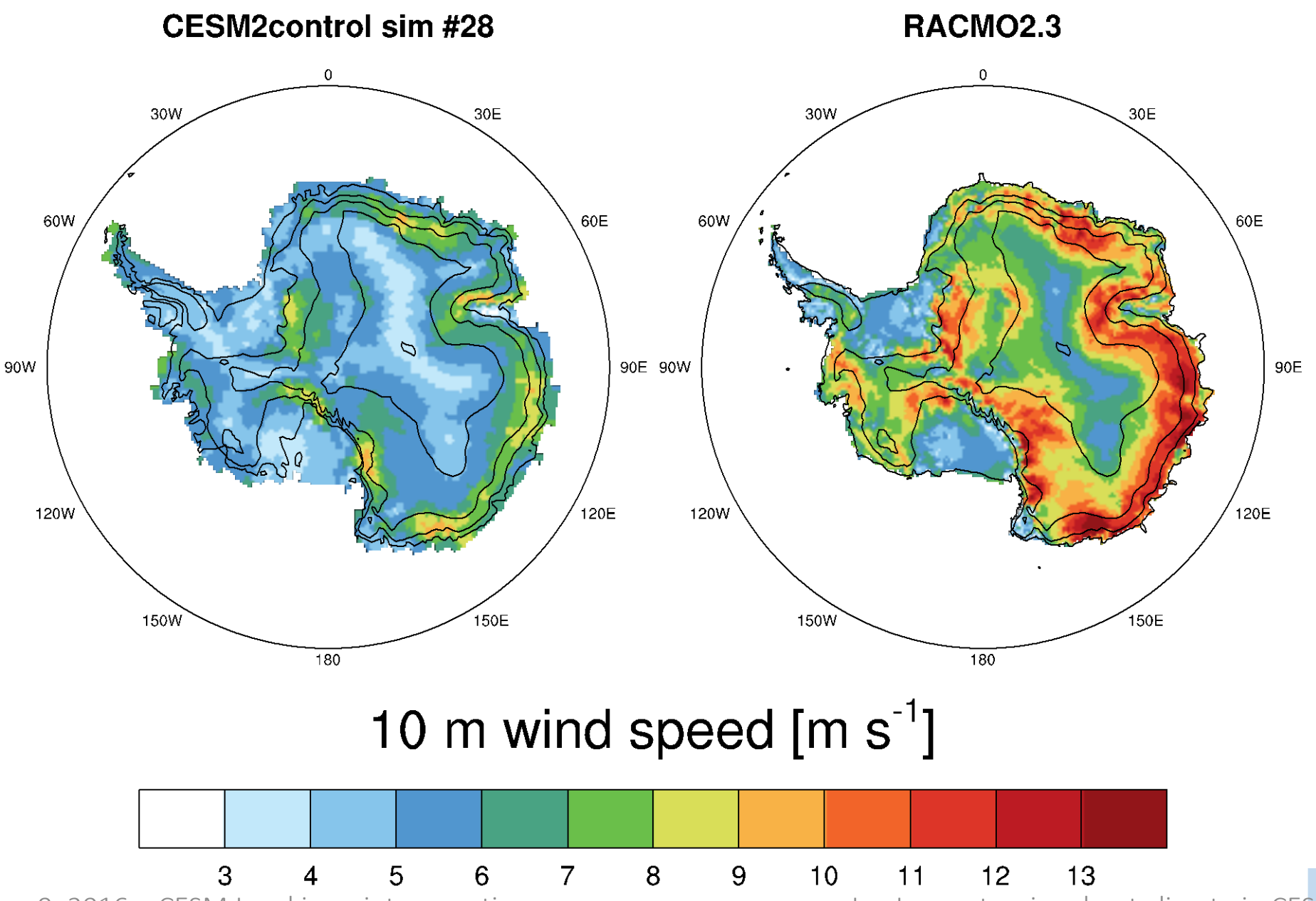
- underestimation of firn air content in large parts of Antarctica (low acc. areas)
- can we tune overburden parameters to work in low temperature, low accumulation regimes?
- non-linear optimization problem with 58 firn core measurements

Conclusions

- CESM2 (control) improves certain aspects of CESM1 over ice sheets
  - Clouds and longwave radiation
  - Firn processes
  - Snow density
  - Winds (hopefully…)
- CESM2 has more realistic ice sheet SMB than CESM1
  - Subject of concern: too much precipitation & high Antarctic melt
- CESM2 will be be run with SMB downscaling on by default
  - Natural SMB variability
  - Ensemble solutions for ice sheet contribution to SLR
  - Detection/attribution

Additional slides


CESM2control sim #28
RACMO2.3
0
30W
30E
60W
60E
90W
90E
120W
120E
150W
150E
180
2 meter air temperature [K]
210
214
218
222
226
230
234
238
242
246
250


CESM2control sim #28
RACMO2.3
0
30W
30E
60W
60E
90W
90E
120W
120E
150W
150E
180
10 m wind speed [m s-1]
3
4
5
6
7
8
9
10
11
12
13