Green light for Greenland?

Progress and challenges in improving CESM's ice sheet climate

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Why care about ice sheets?

- Paleo-thermometers *(Paleo working group)*
- Impact on ocean circulation *(Ocean working group)*
- Impact on large-scale atmosphere circulation *(Atmosphere working groups)*
- Firn and snow, meltwater runoff *(Land working group)*
- It's my daily job *(Land ice working group)*
- Sea ice – ice sheet interactions *(Polar climate Working group)*
- Polar amplified climate change *(all)*
- Sea level rise *(all)*

…

Why care about ice sheets **in CESM2**?

1. Two-way coupled CESM2-CISM2 in place: we can study ice sheet – climate interactions… providing realistic *ice sheet climate forcing*

2. All CESM2 simulations will have ice sheet surface mass balance downscaling active by default.

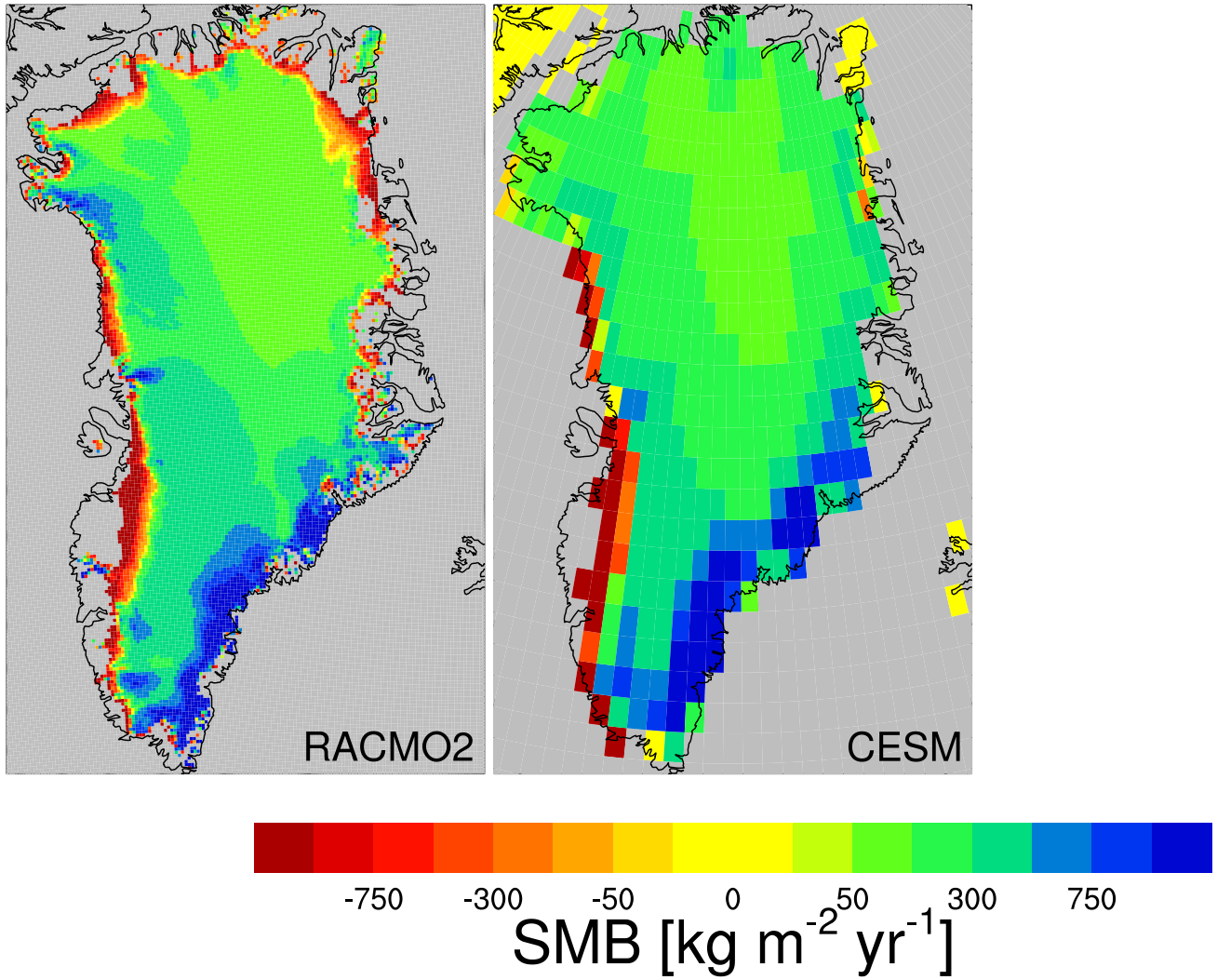
   SMB = precipitation – sublimation – meltwater runoff

   Forcing for ice sheet dynamics (CISM2)

   Dependent on ice sheet climate (atmosphere + snow)

   CAM6 CLM5

Greenland SMB in CESM1



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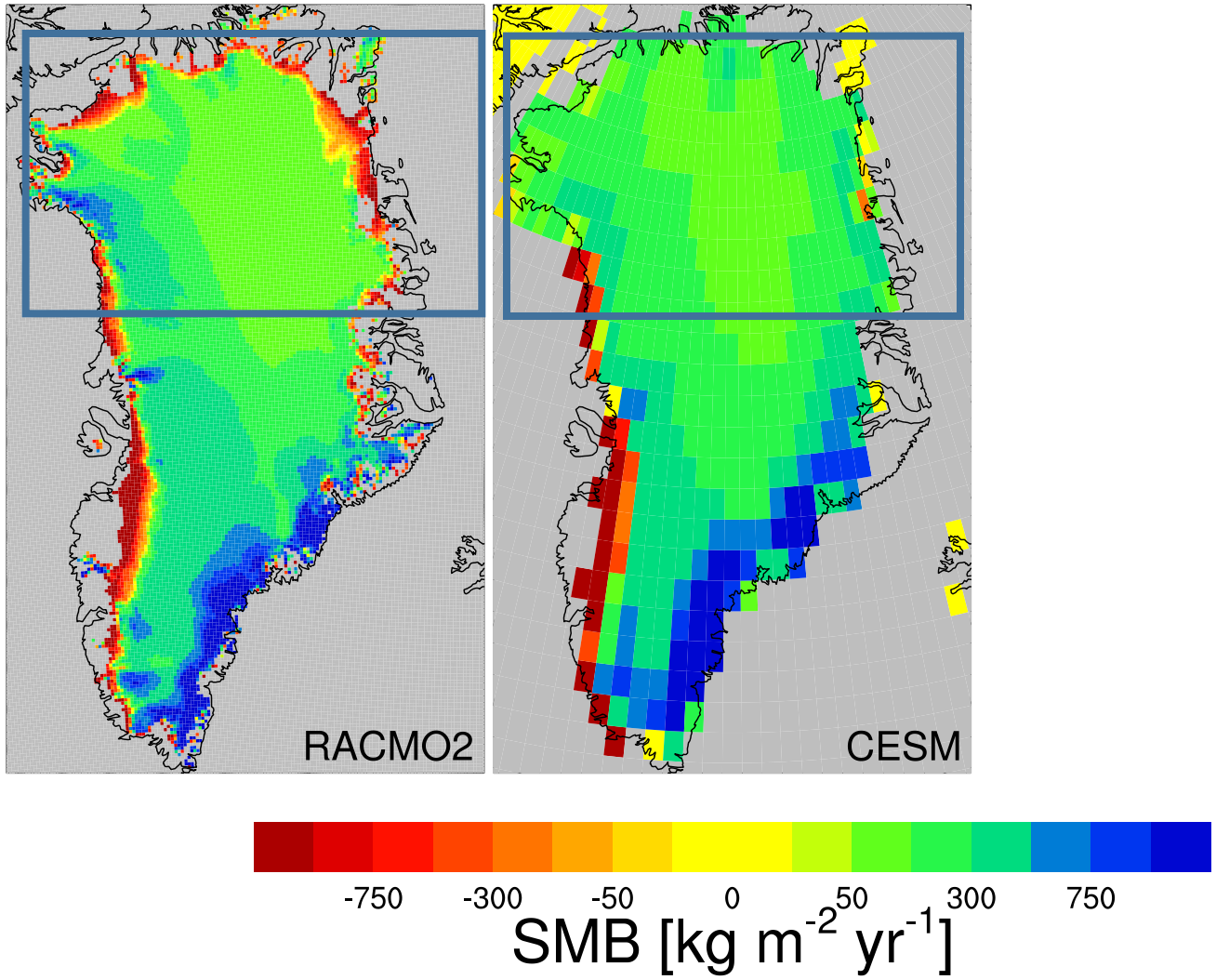
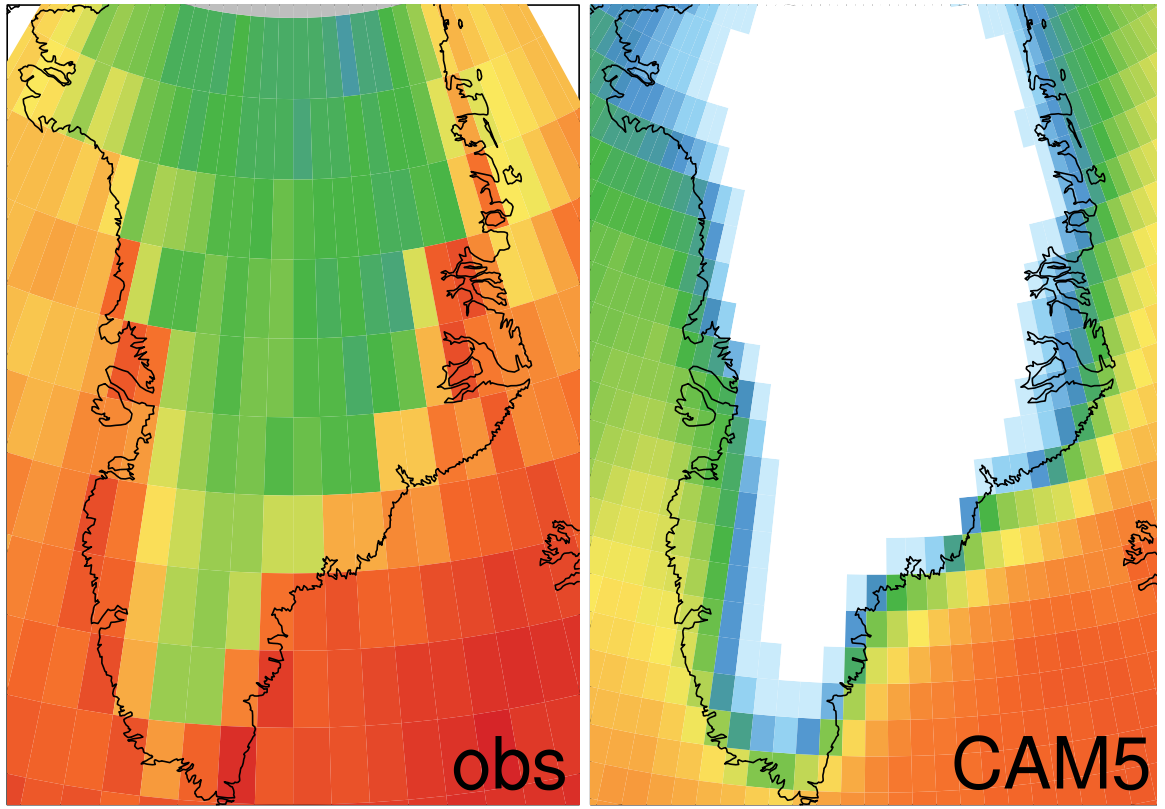


CAM5 too cold!

Clouds over Greenland



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

Cloud LWP

↓

Incoming longwave radiation

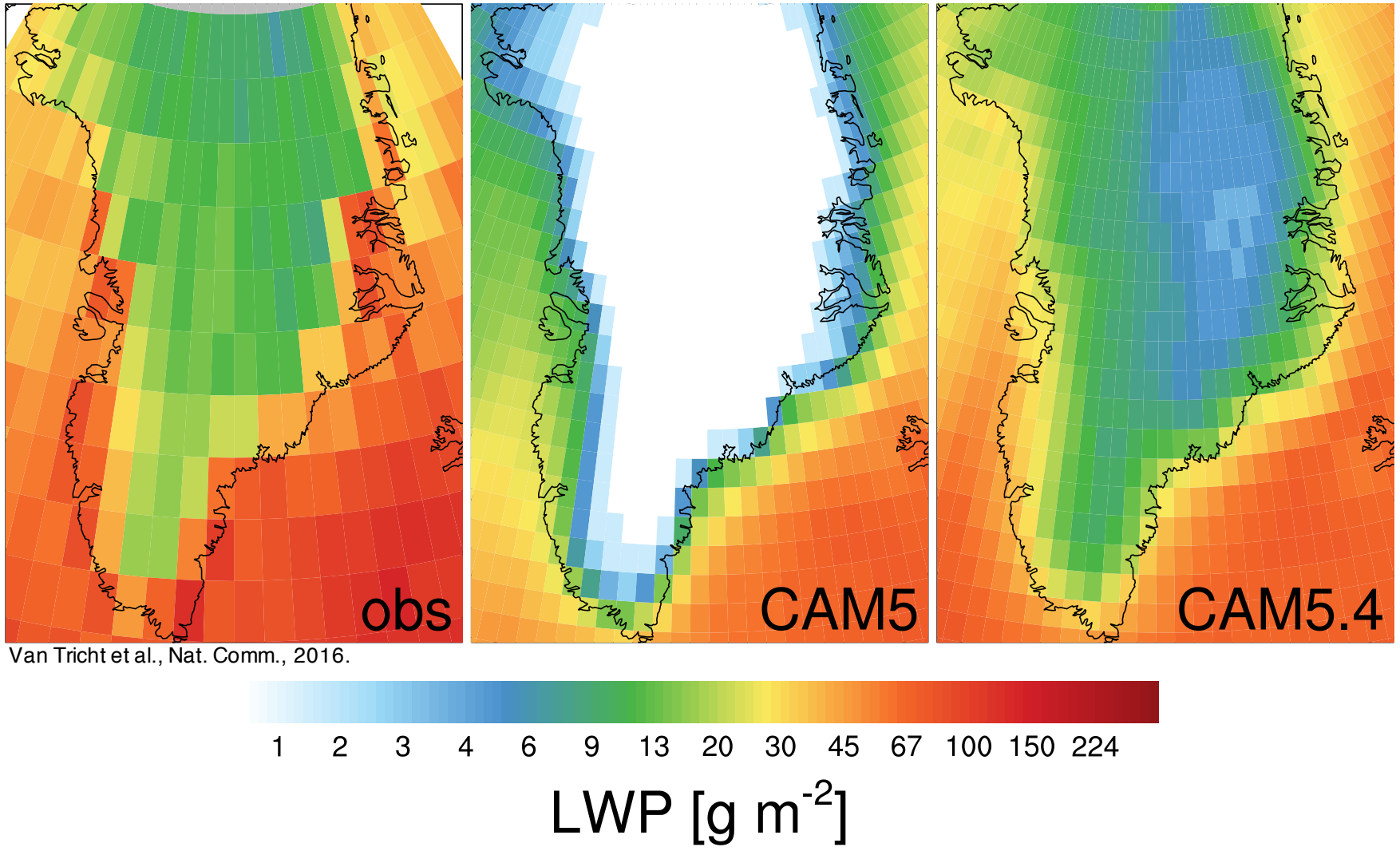
↓

Surface energy balance

1 2 3 4 6 9 13 20 30 45 67 100 150 224

LWP [g m^{-2}]

Clouds over Greenland



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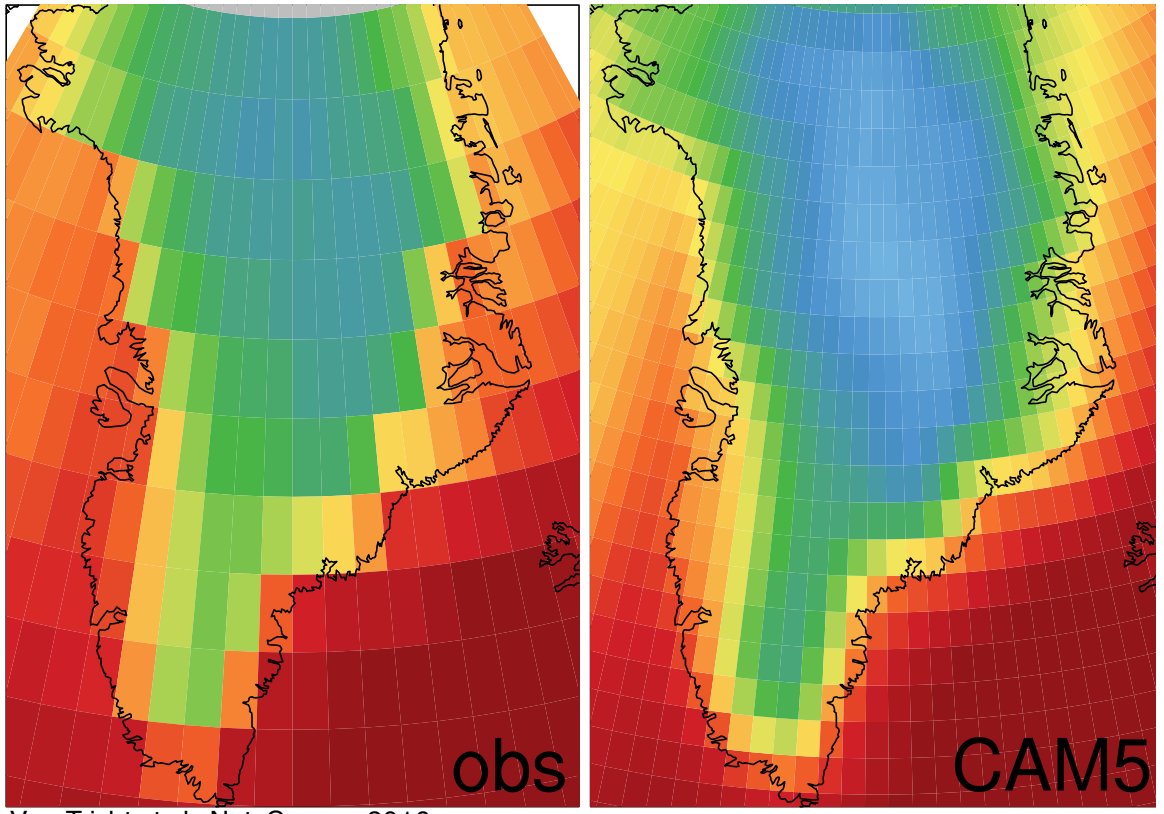

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Cloud LWP

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Incoming longwave radiation

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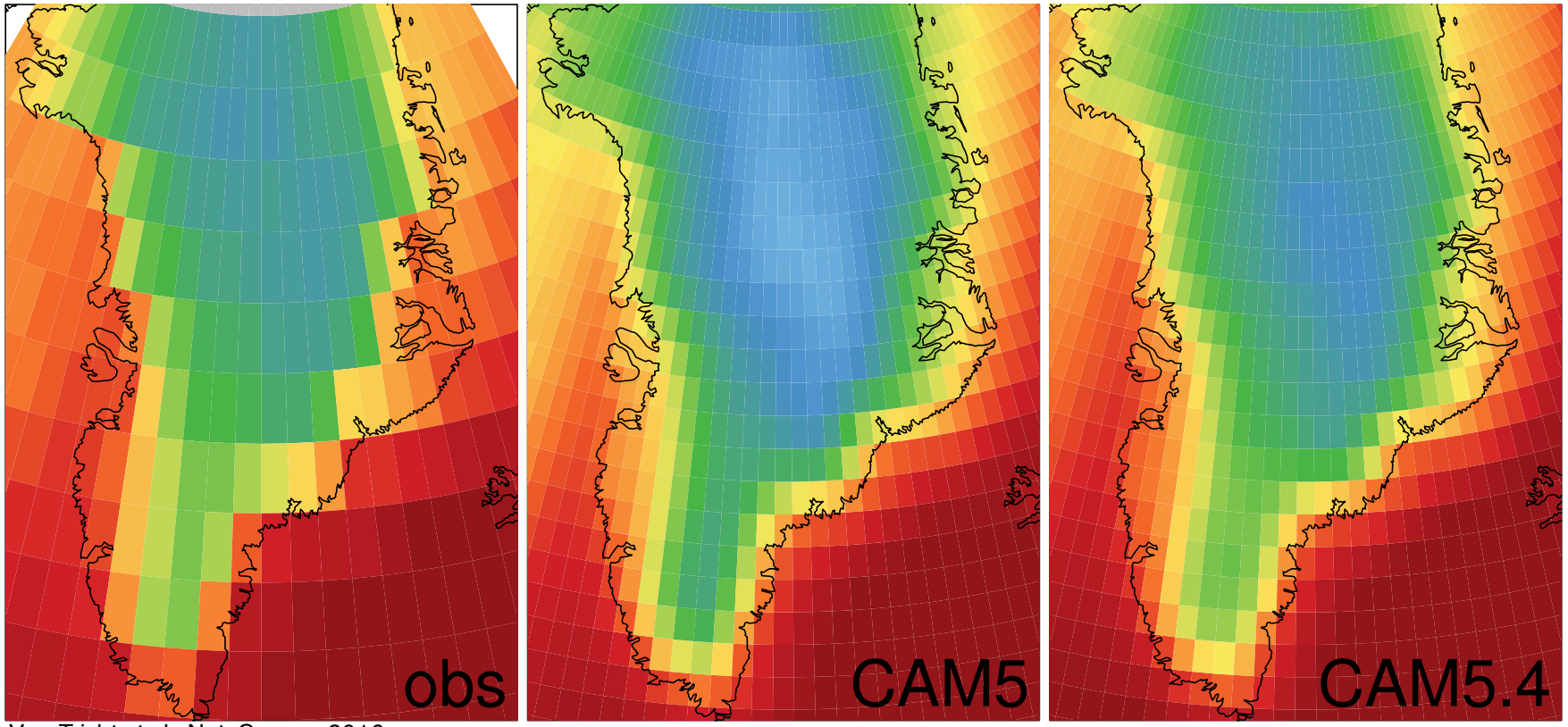
Surface energy balance

100 114 128 142 156 170 184 198 212 226 240 254 268 282 296

Incoming LW [W m^{-2}]

Clouds over Greenland



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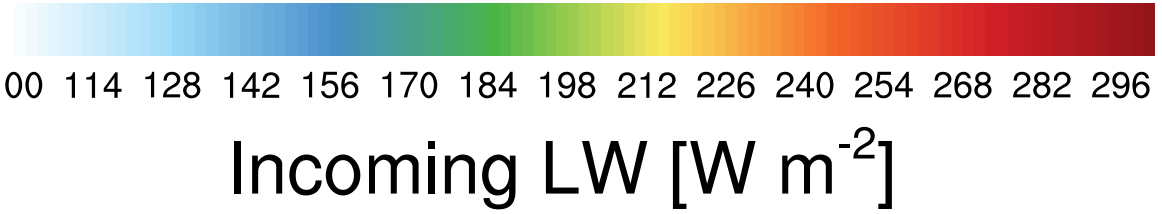
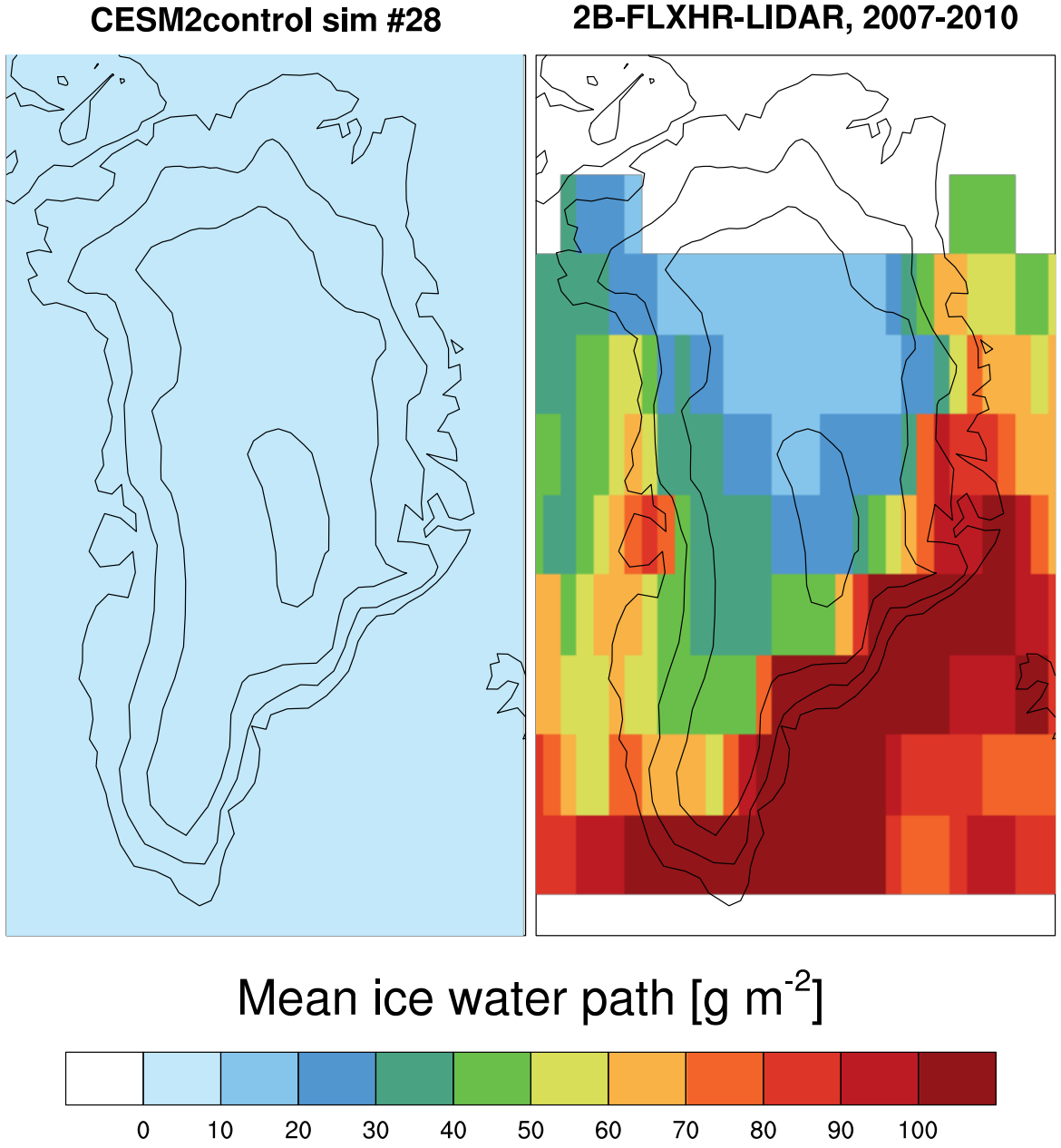


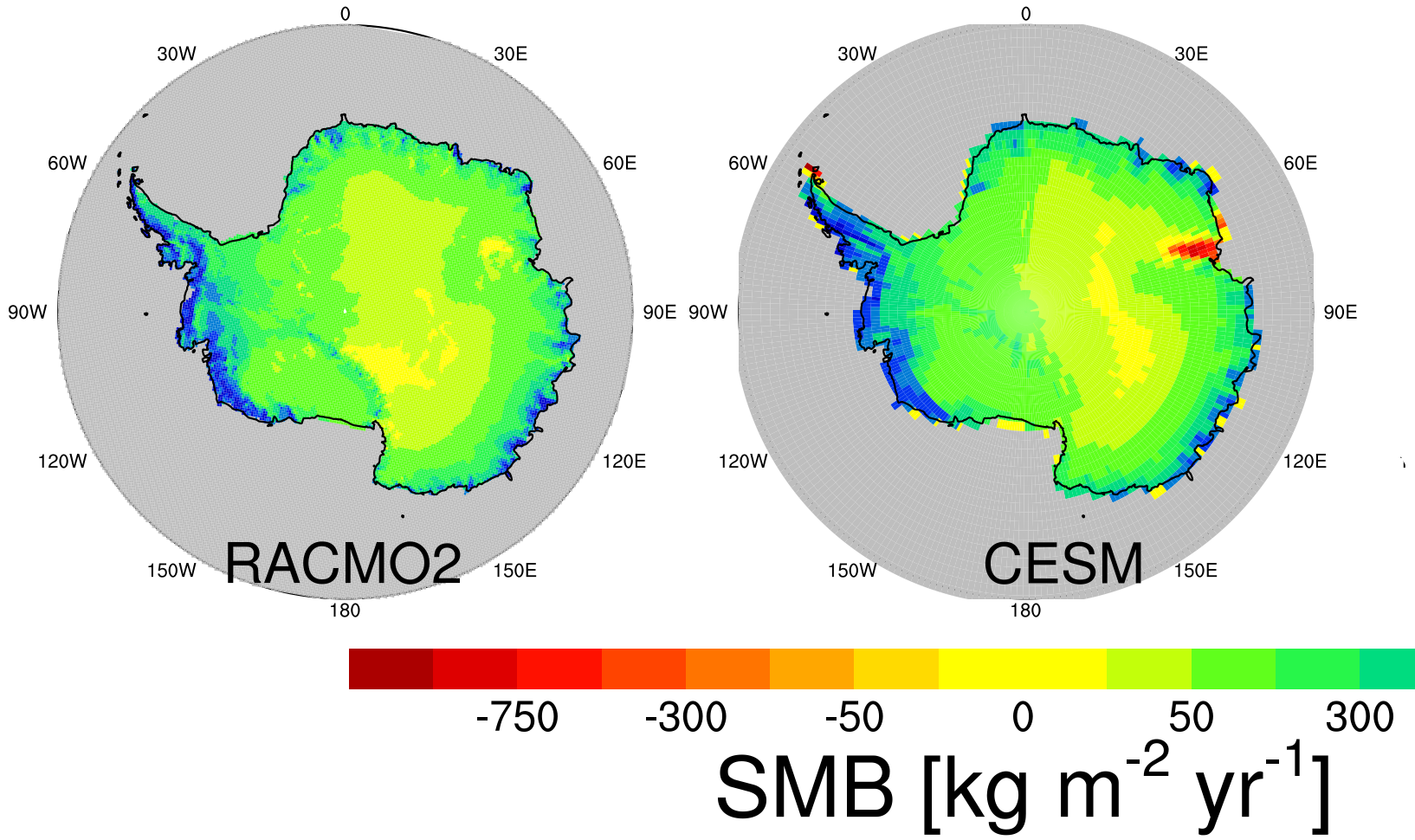
20 - 30 W m^{-2} more downward longwave
Better shortwave cloud forcing
In line with findings over sea ice

Cloud ice gone…

Auto-conversion will help



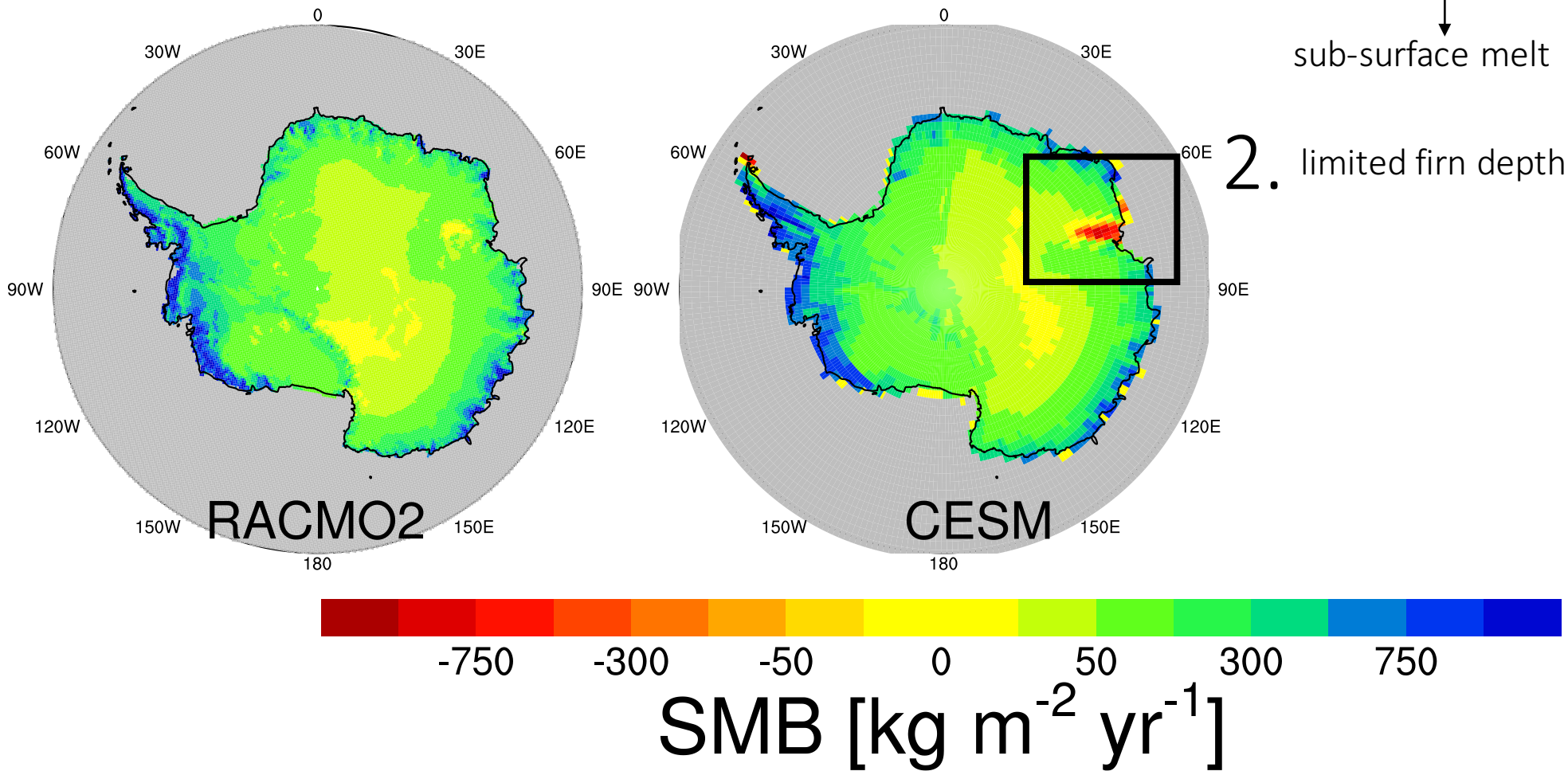
Antarctic SMB in CESM1



Antarctic SMB in CESM1

1. low snow density
   ↓
   heat conduction exaggerated
   ↓
   sub-surface melt

2. limited firn depth (1 m w.e.)



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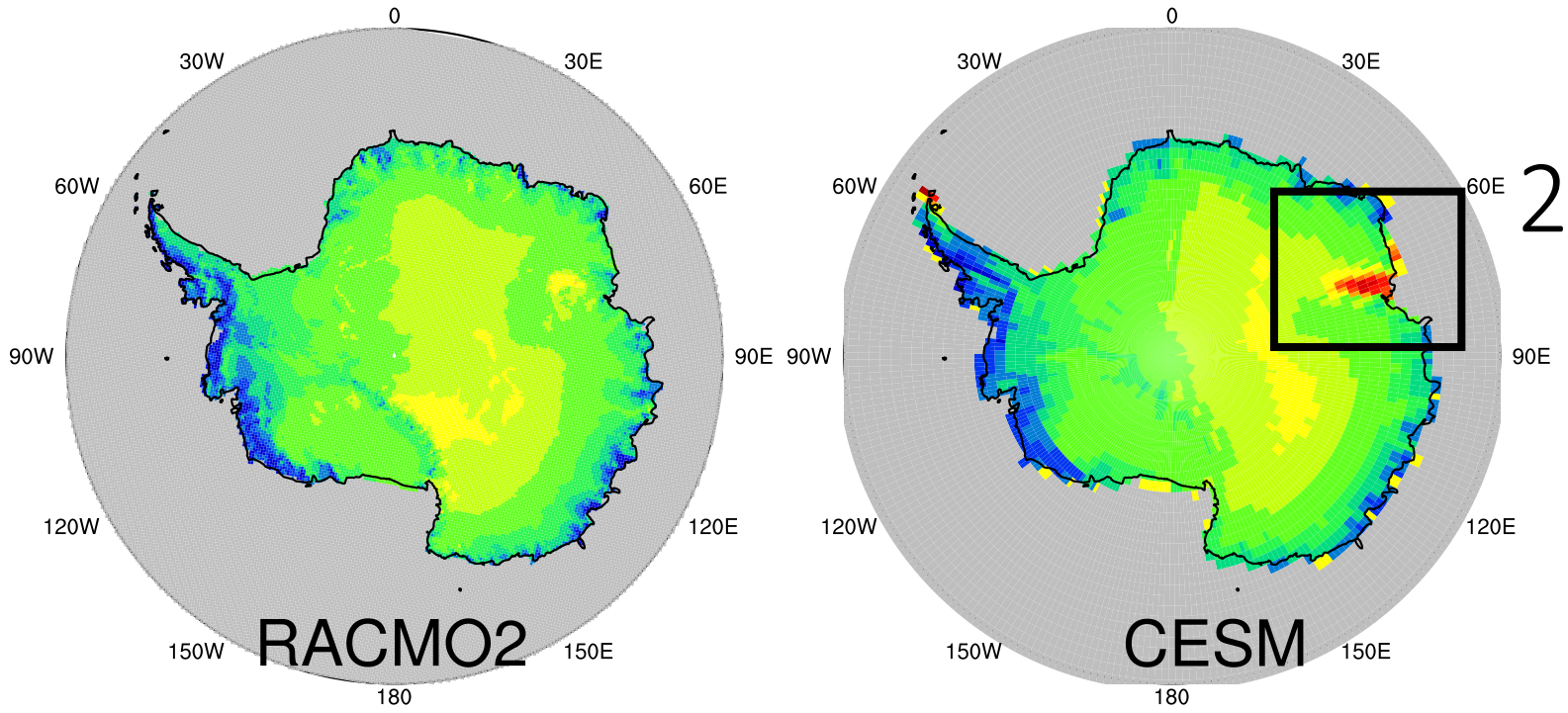


Resolved 1. and 2. in CLM

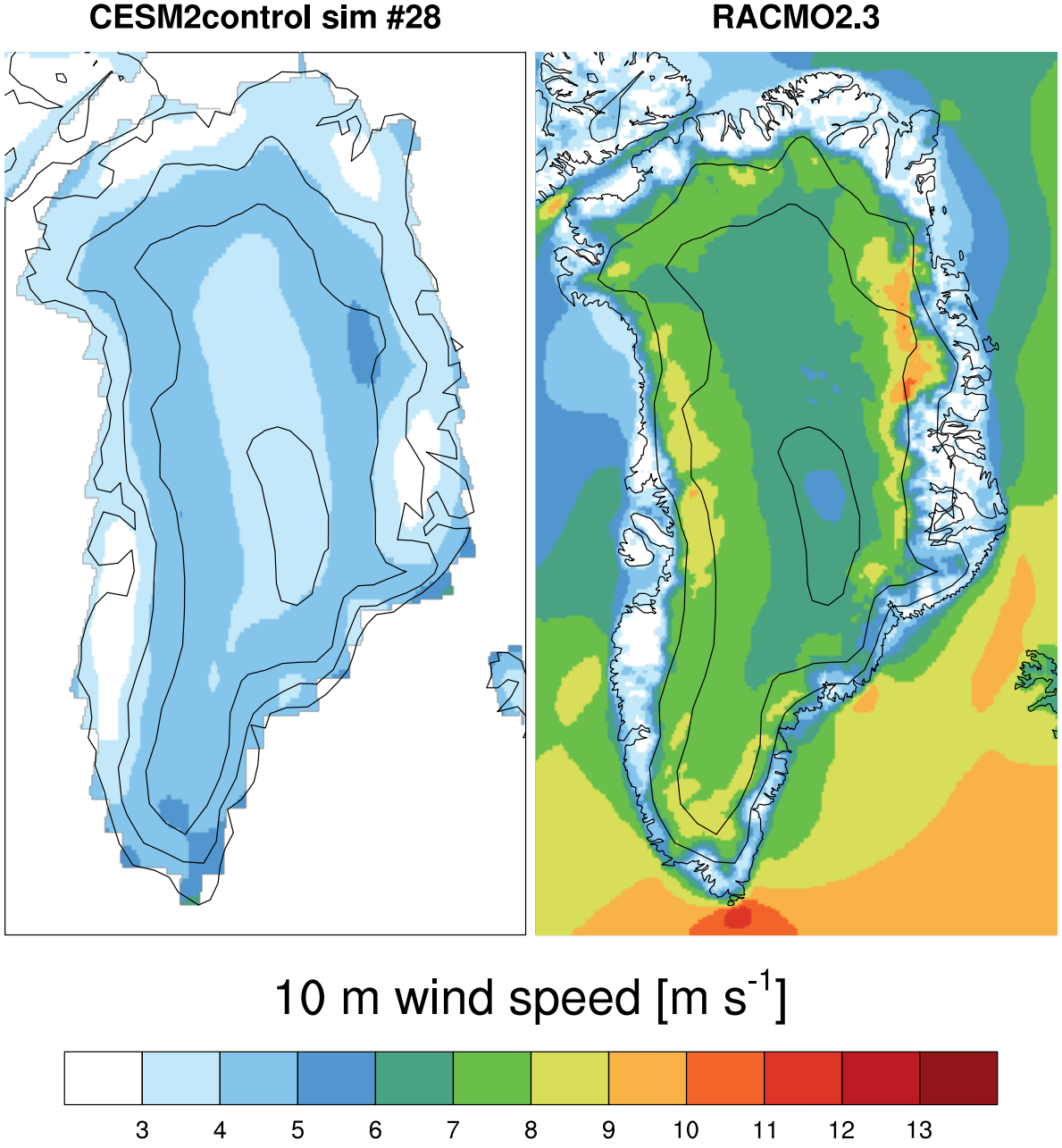
But…

-750 -300 -50 0 50 300 750

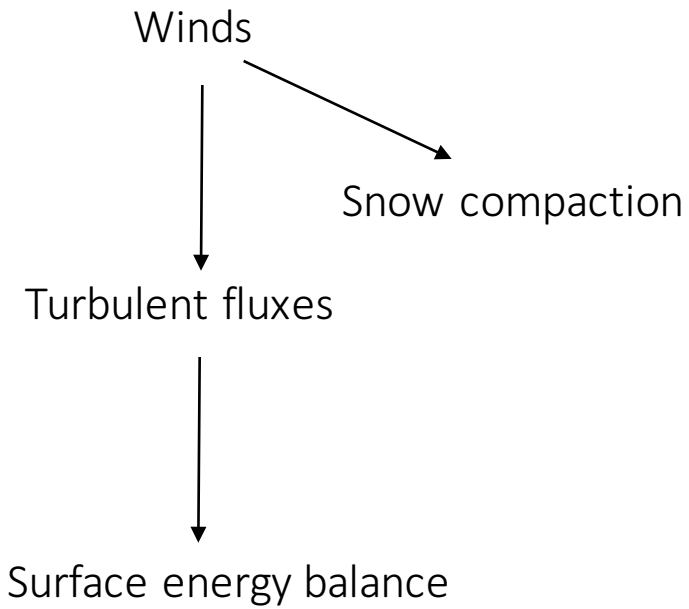
SMB [kg m^{-2} yr^{-1}]

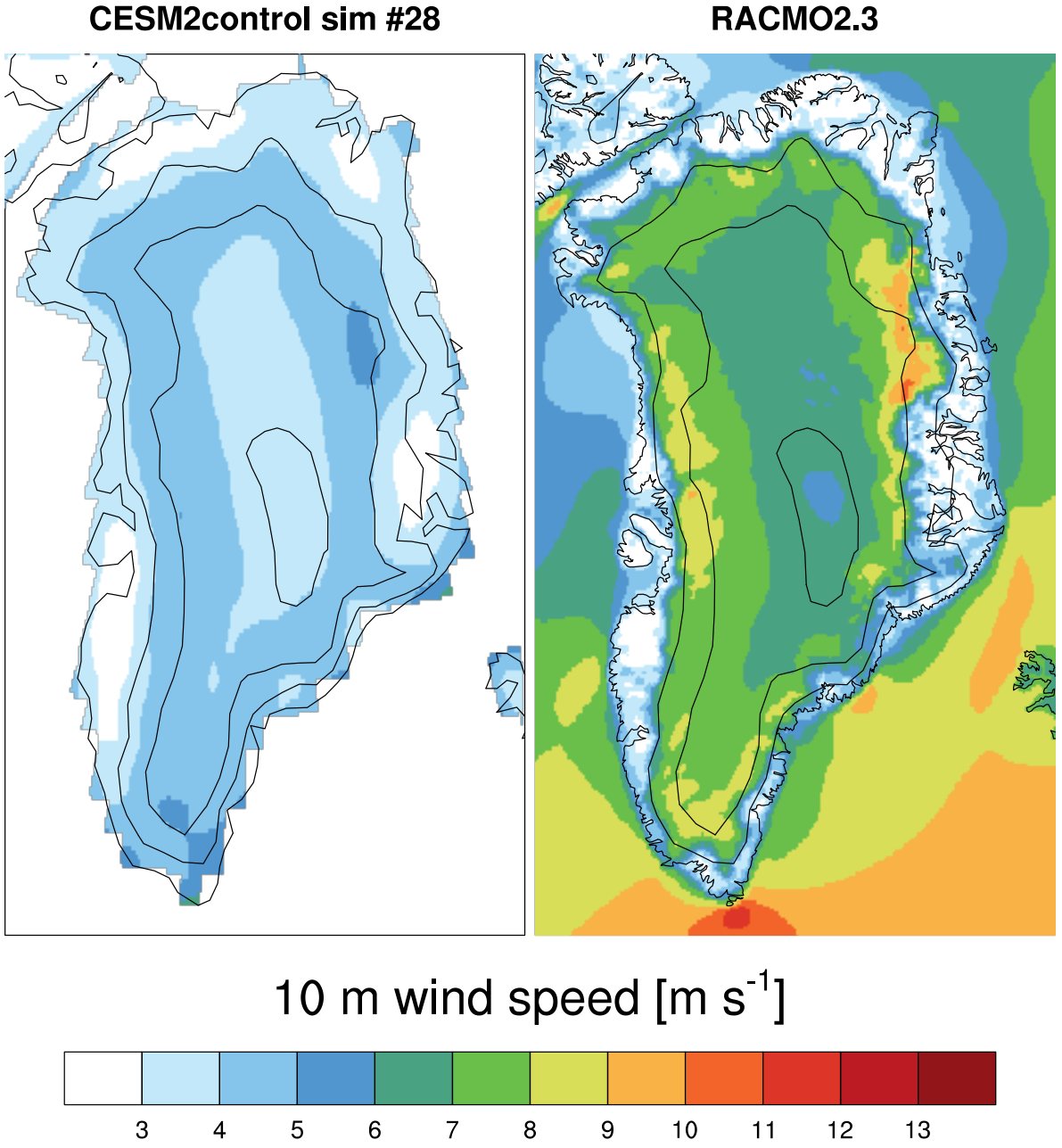
Surface winds

Winds → Snow compaction



Surface winds

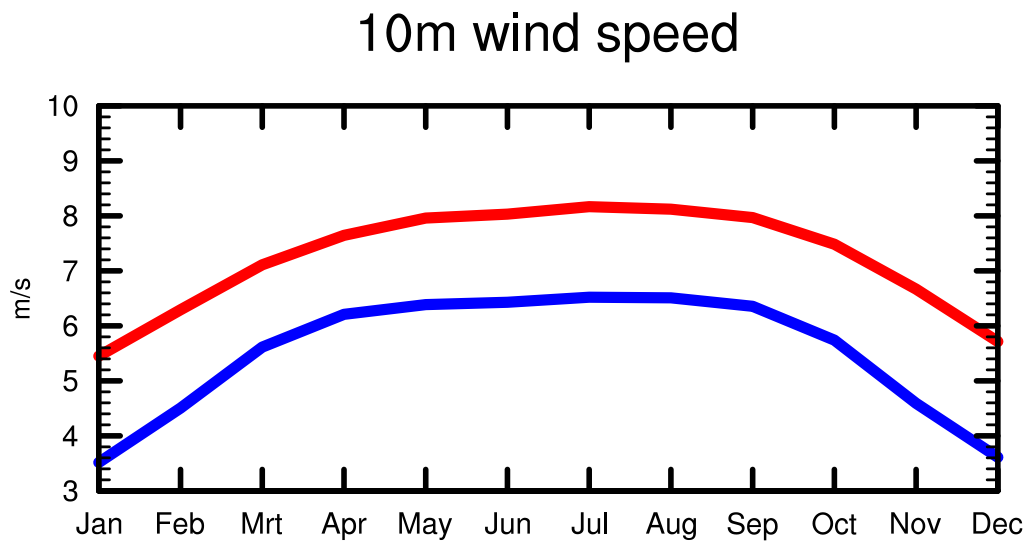


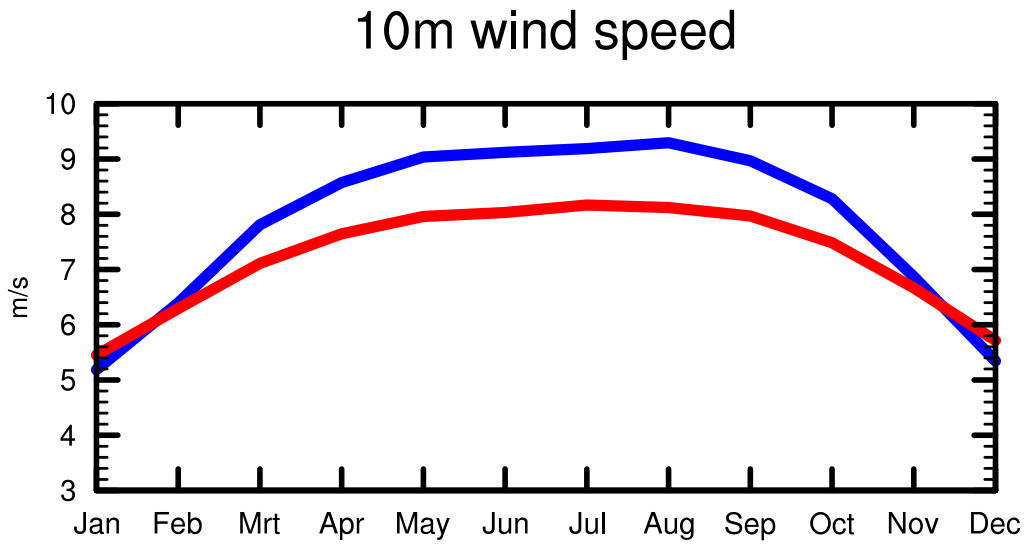


TMS

New wave drag scheme

Julio Bacmeister (NCAR)

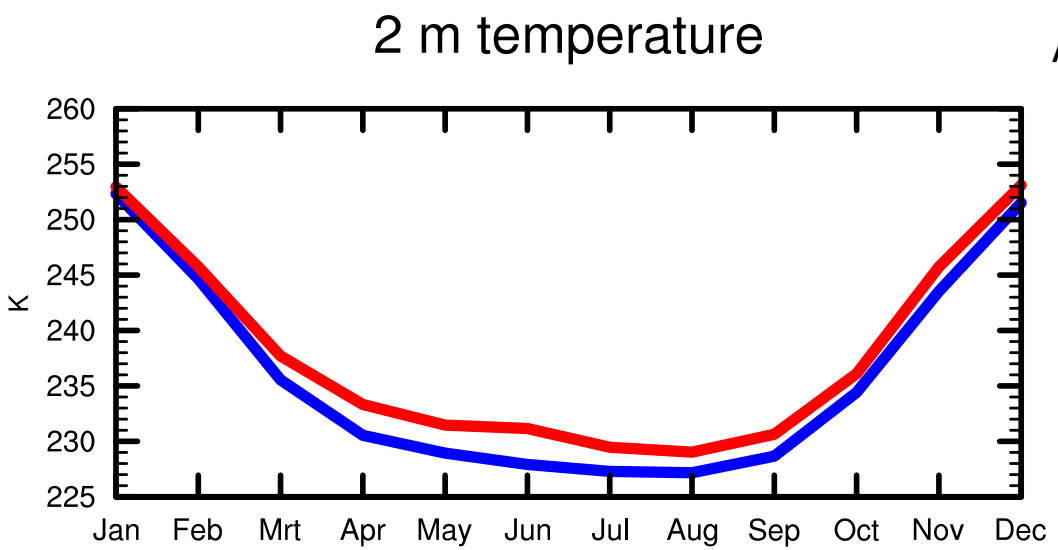


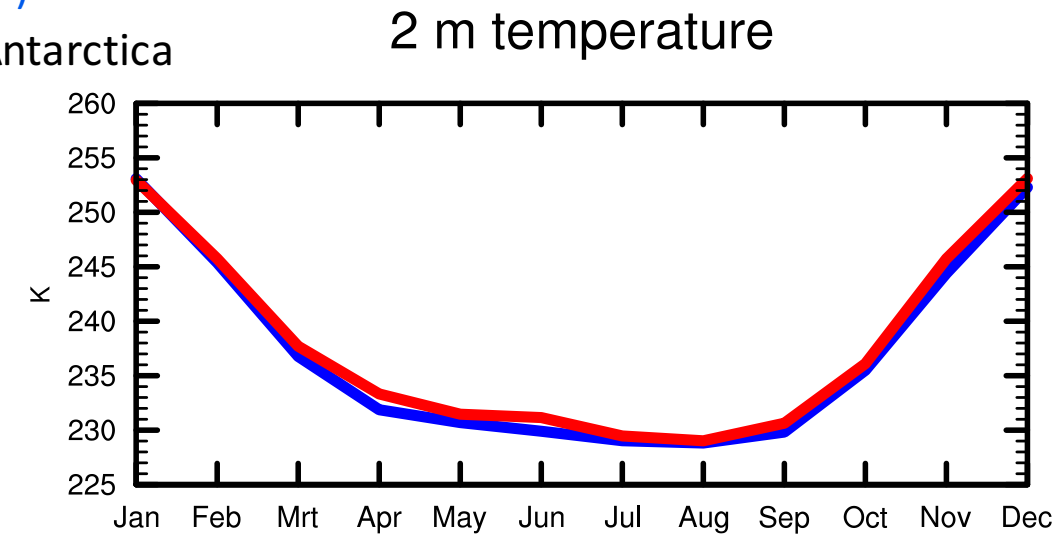


RACMO2 (evaluated with observations)

CAM 5.4 (AMIP)

Averages for Antarctica





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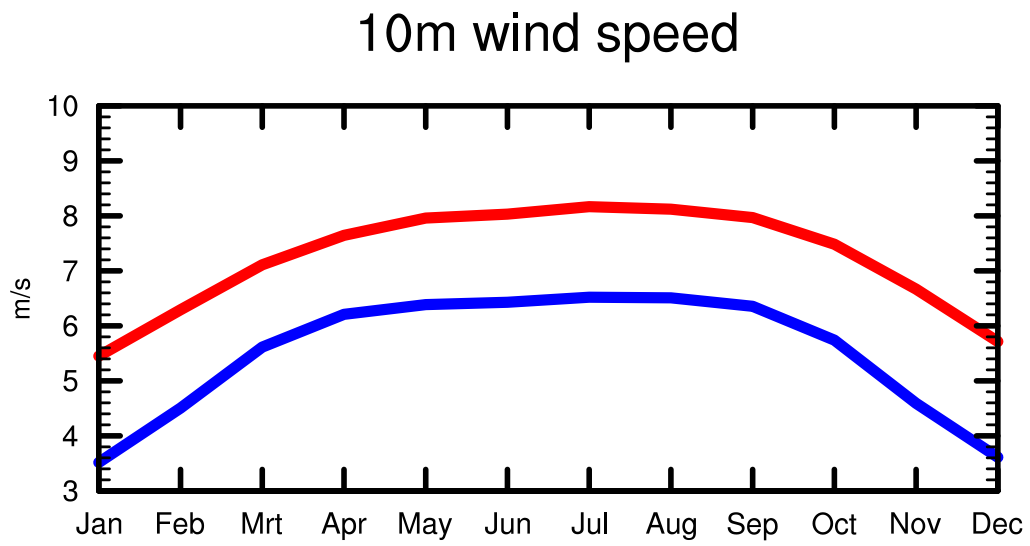

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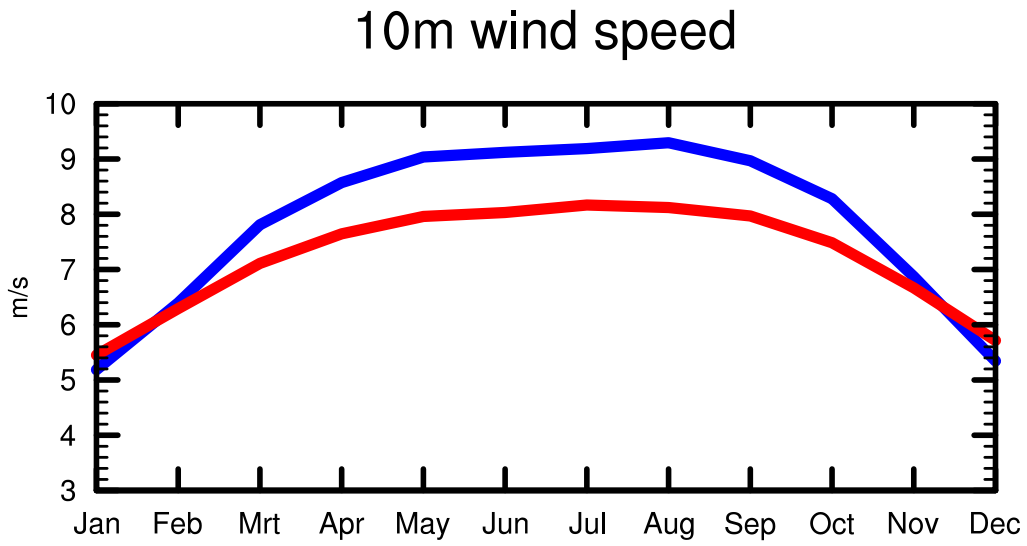
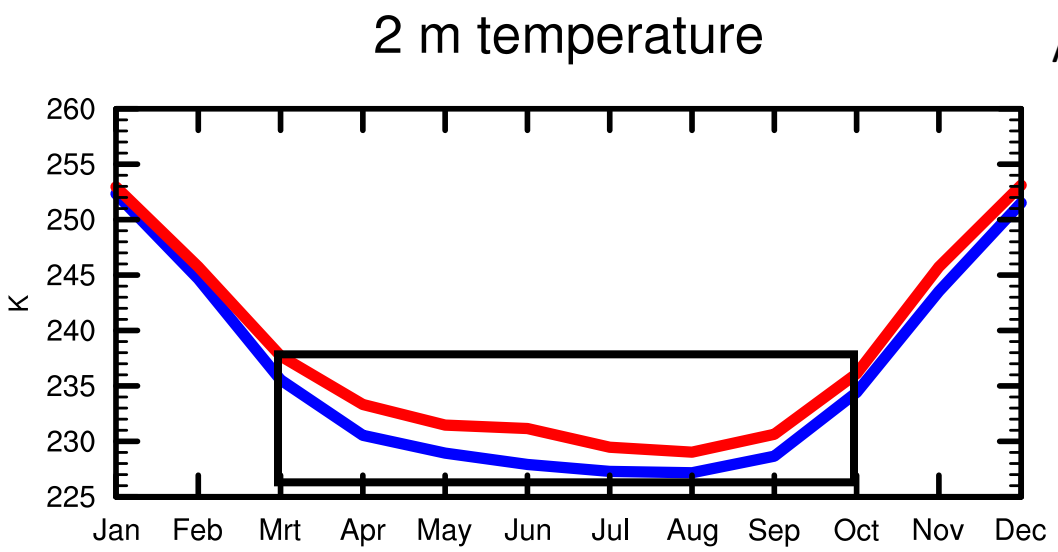
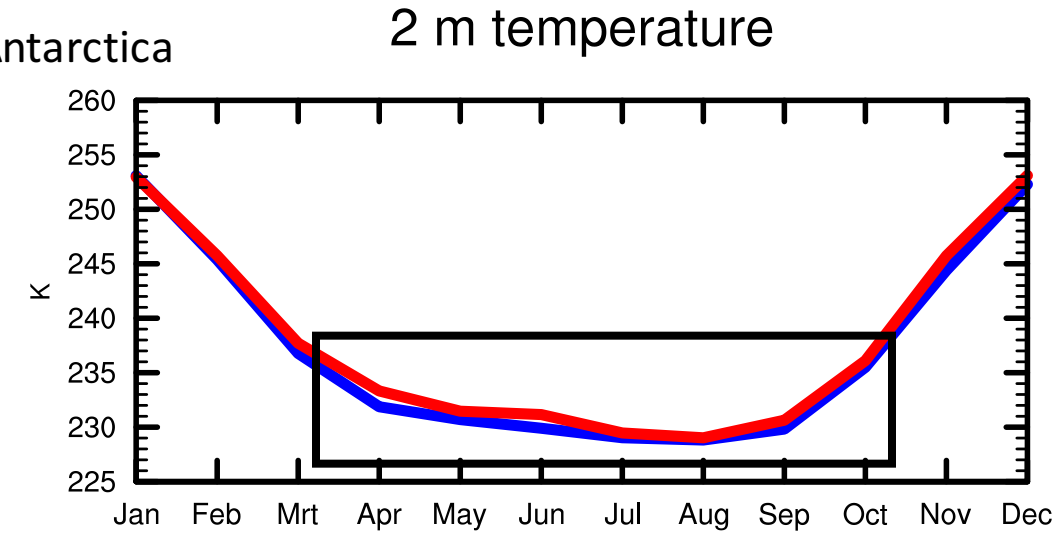


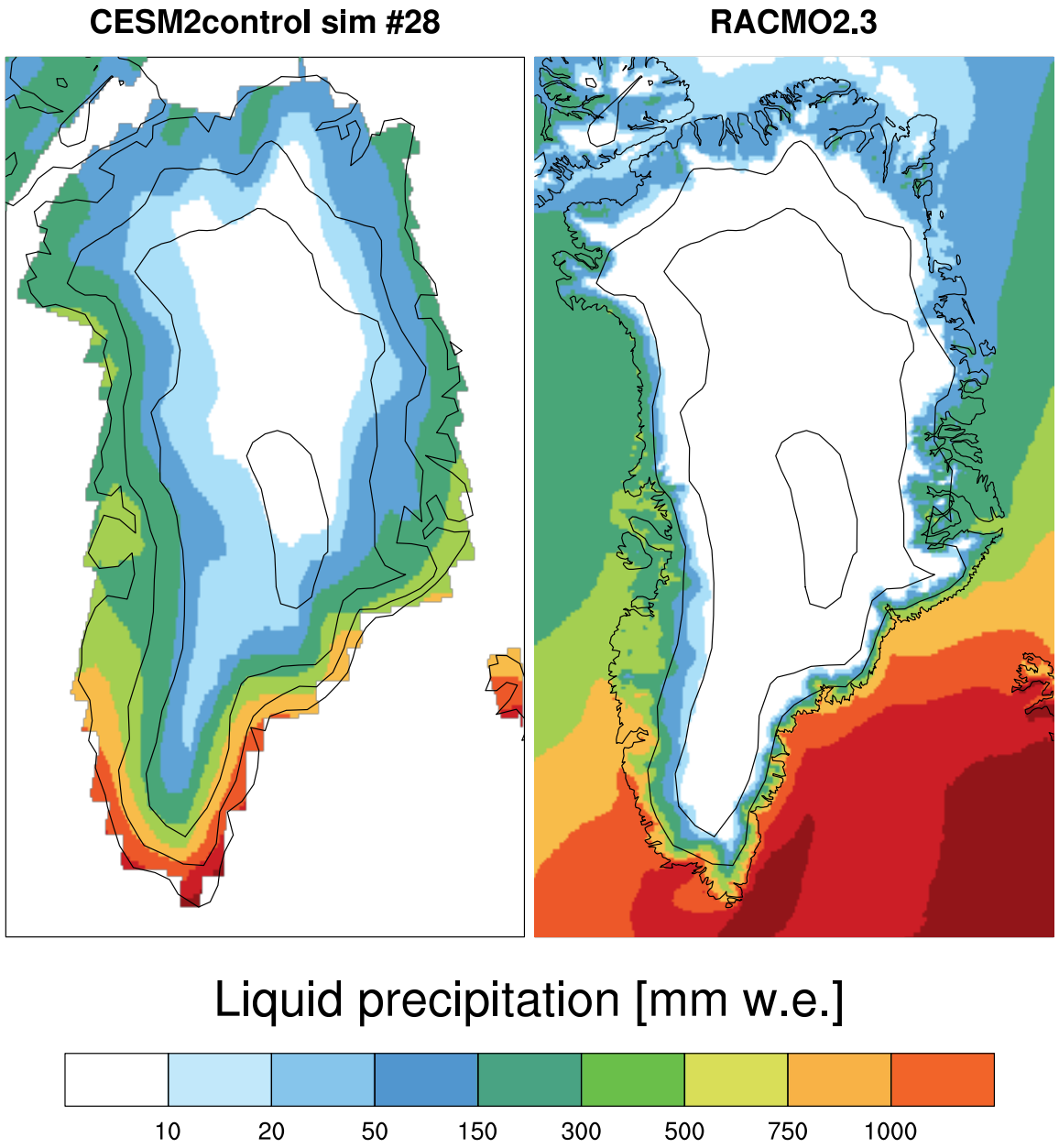




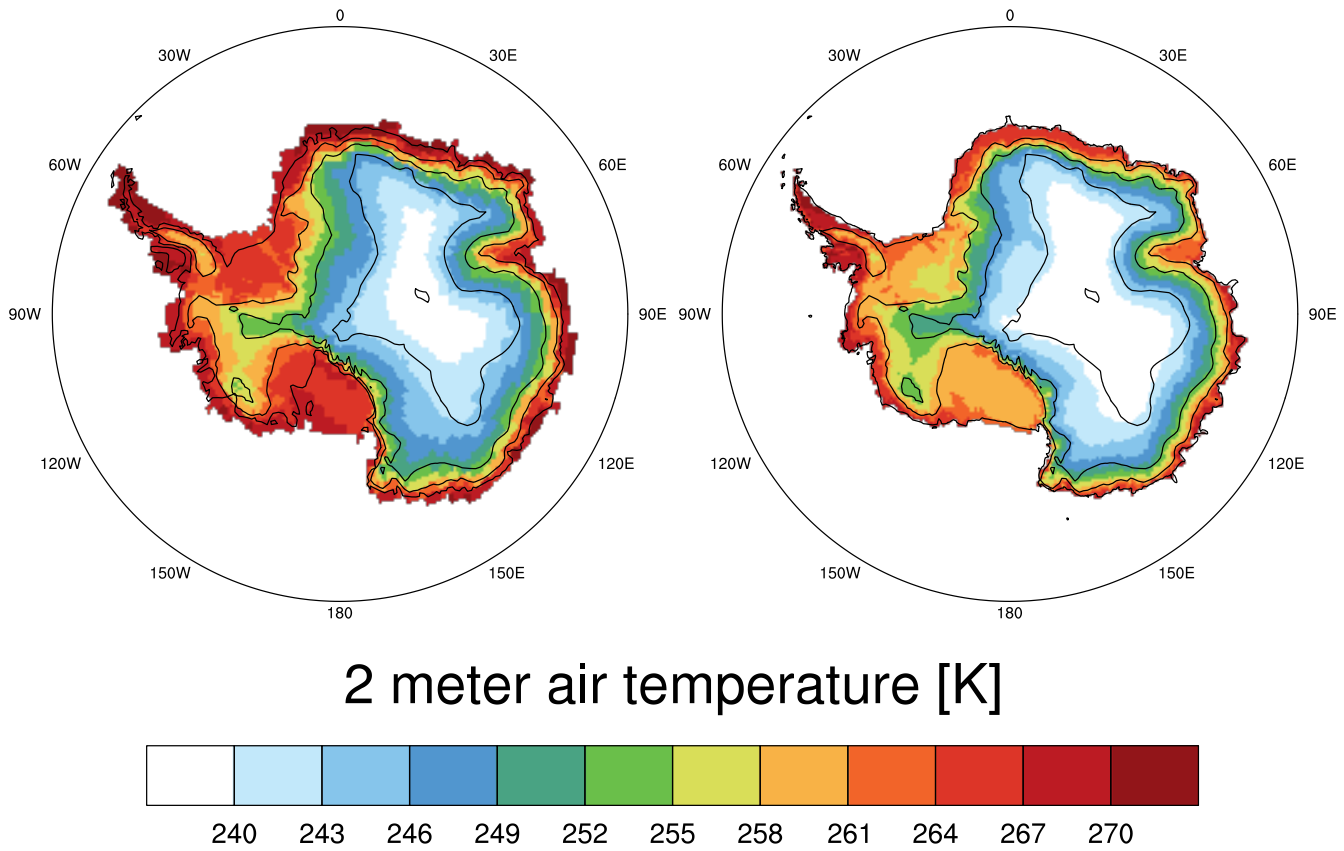
New bias: precipitation

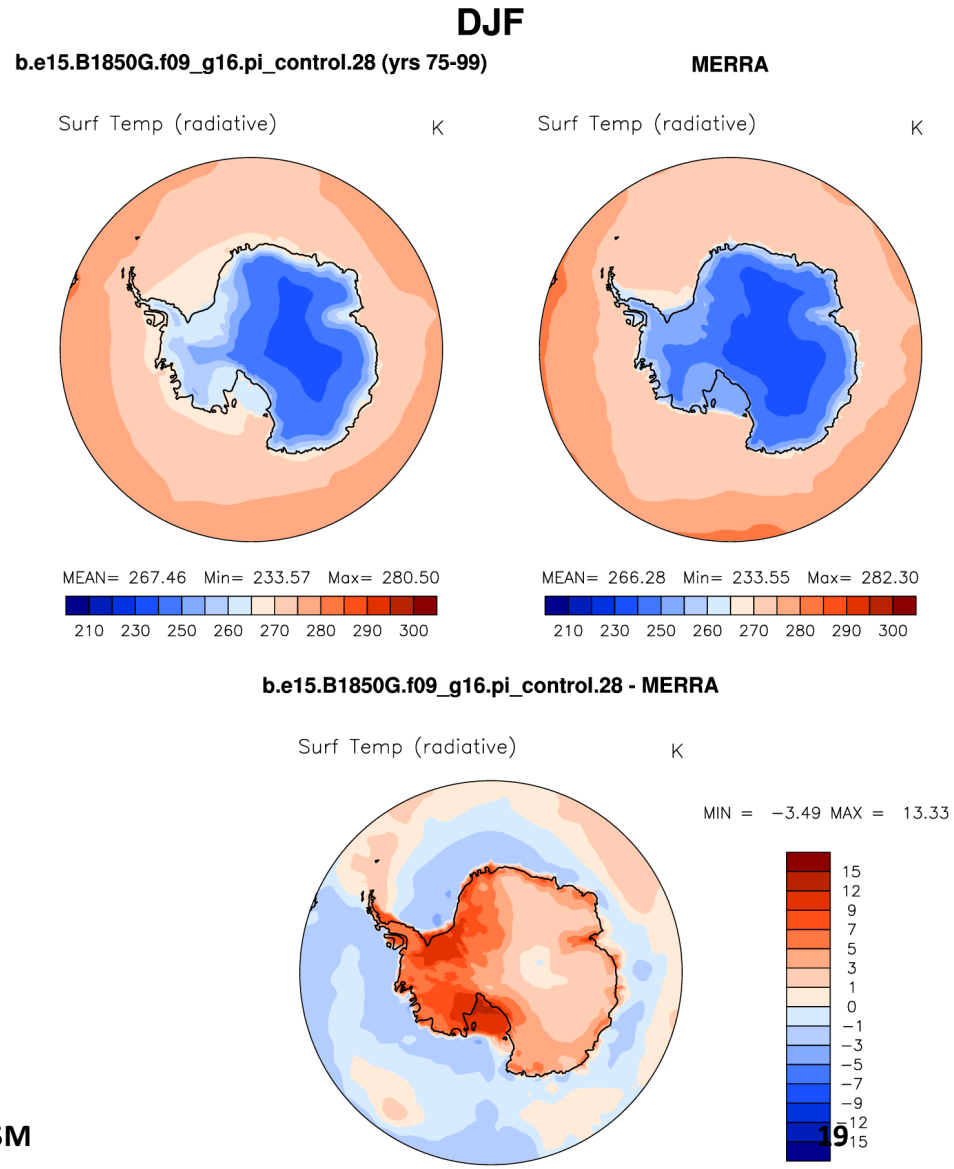
1. Generally overestimated total precipitation (~30%)
(general Arctic problem – ref. Dave L.)

2. High-elevation liquid precipitation is back!

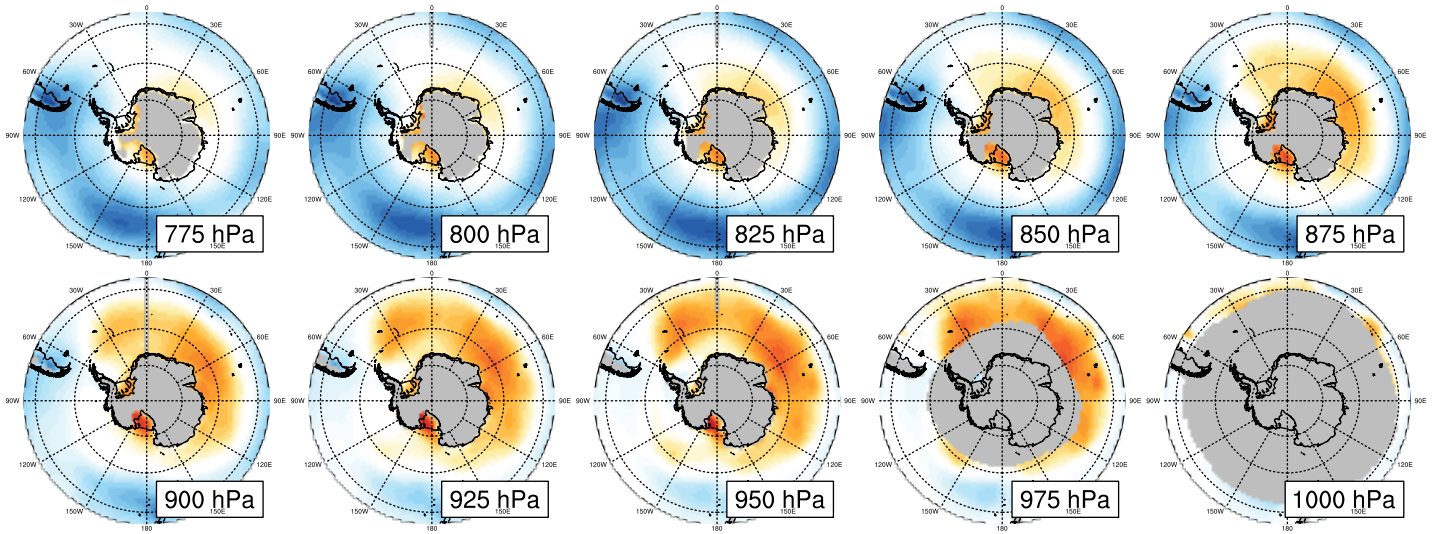


Hot Antarctic summers

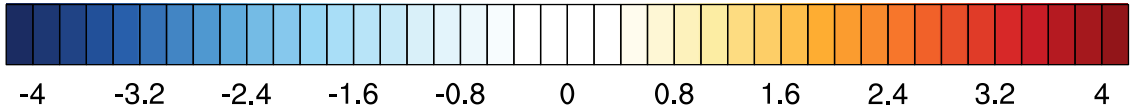




Where does the 'heat' come from?



Temperature CESM - ERA-Interim [K]



Surface energy balance does **not** look too bad.

Summer temperature too high below 800 hPa and bias increasing to the surface.

Promotes snow grain growth, lowering albedo, further increasing bias.

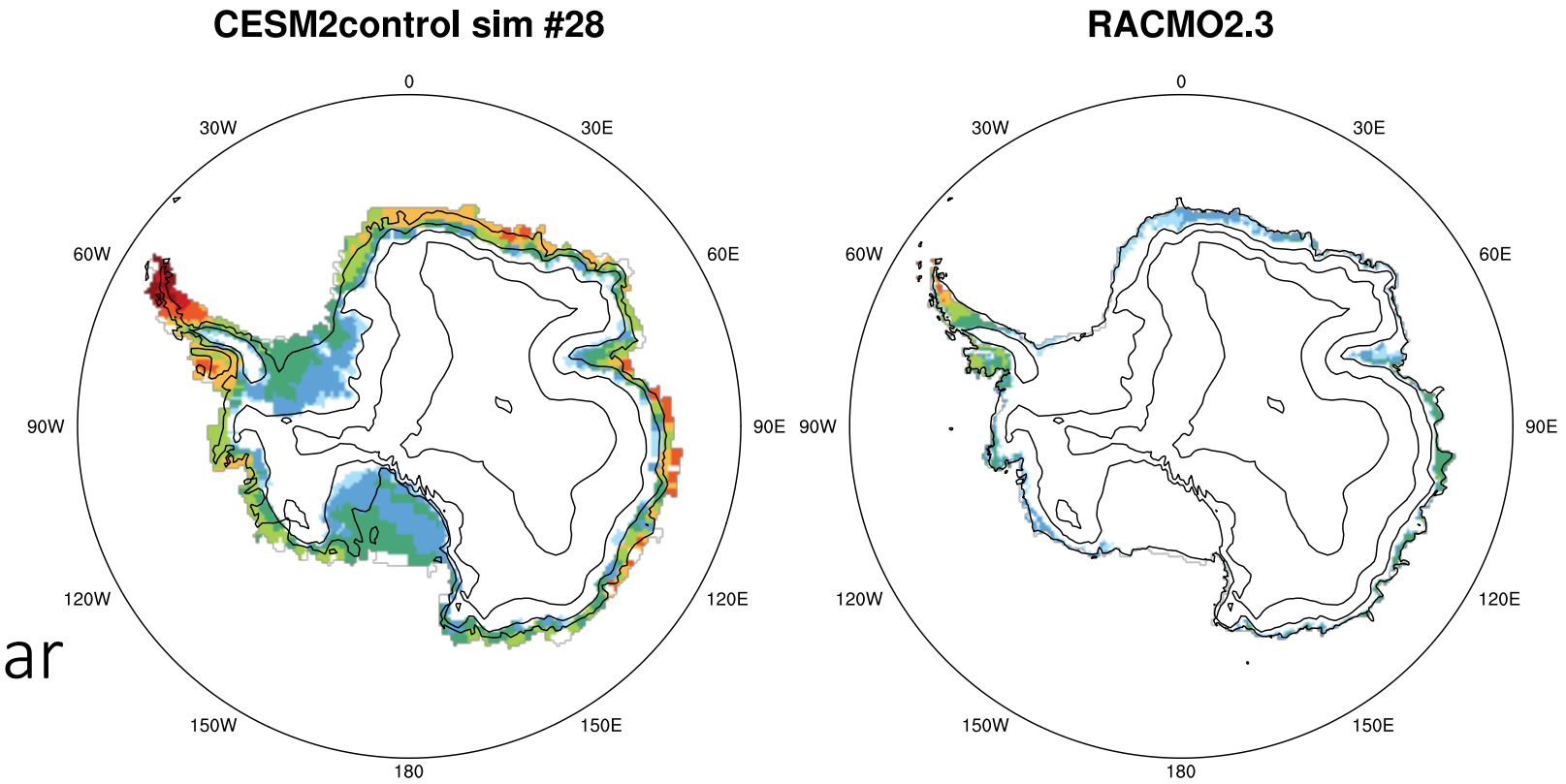
Reason? Solution? Tuning possible (clouds)?

Note: Albedo&melt look OK in forced CLM5 simulations – which means that with colder atmosphere things will probably get much better.

Antarctic melt

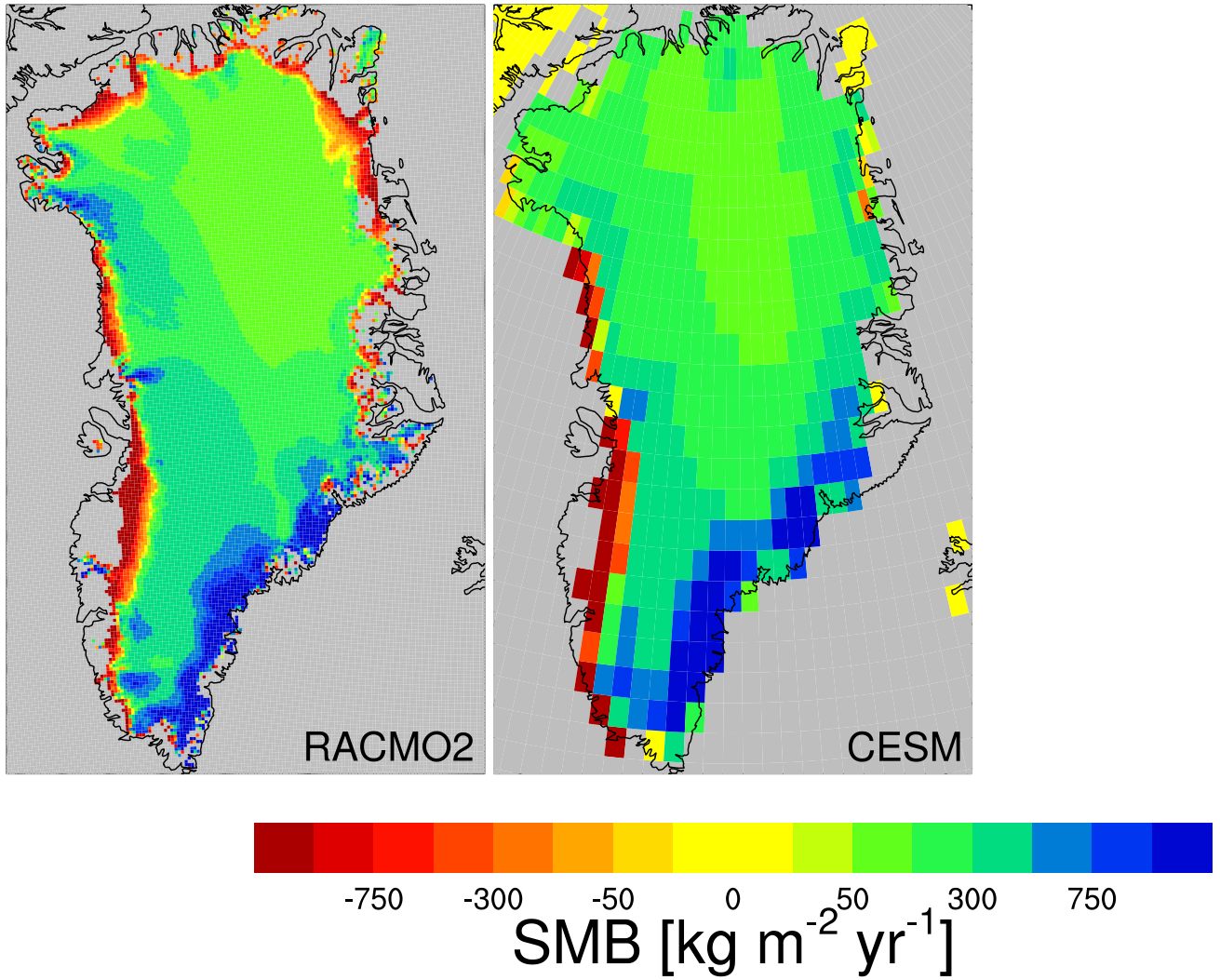
Obs: ~100 Gt per year

CESM1.5: ~700 Gt per year



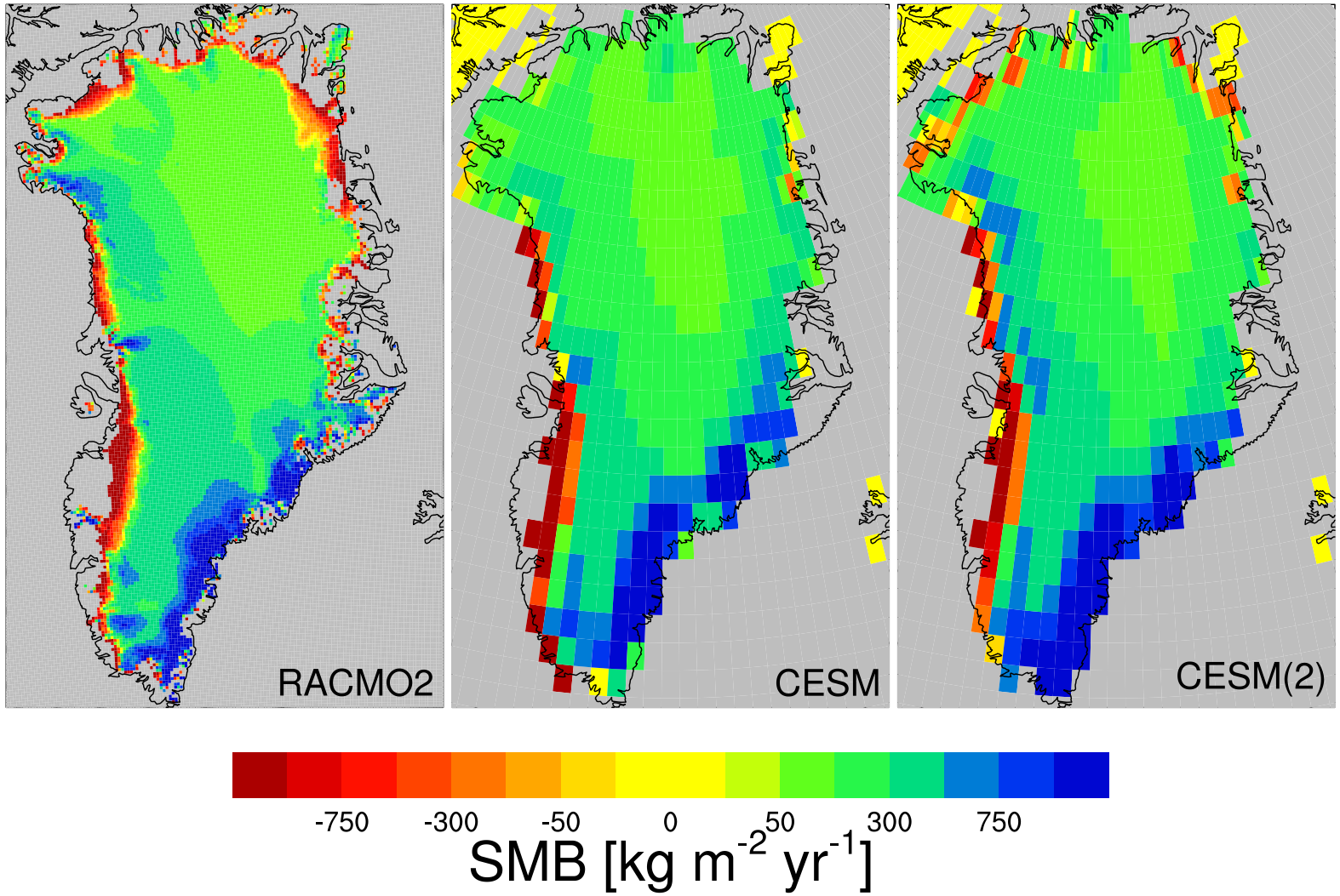
Note: this does not directly impact Antarctic SMB because all meltwater refreezes in the firn.

Greenland SMB

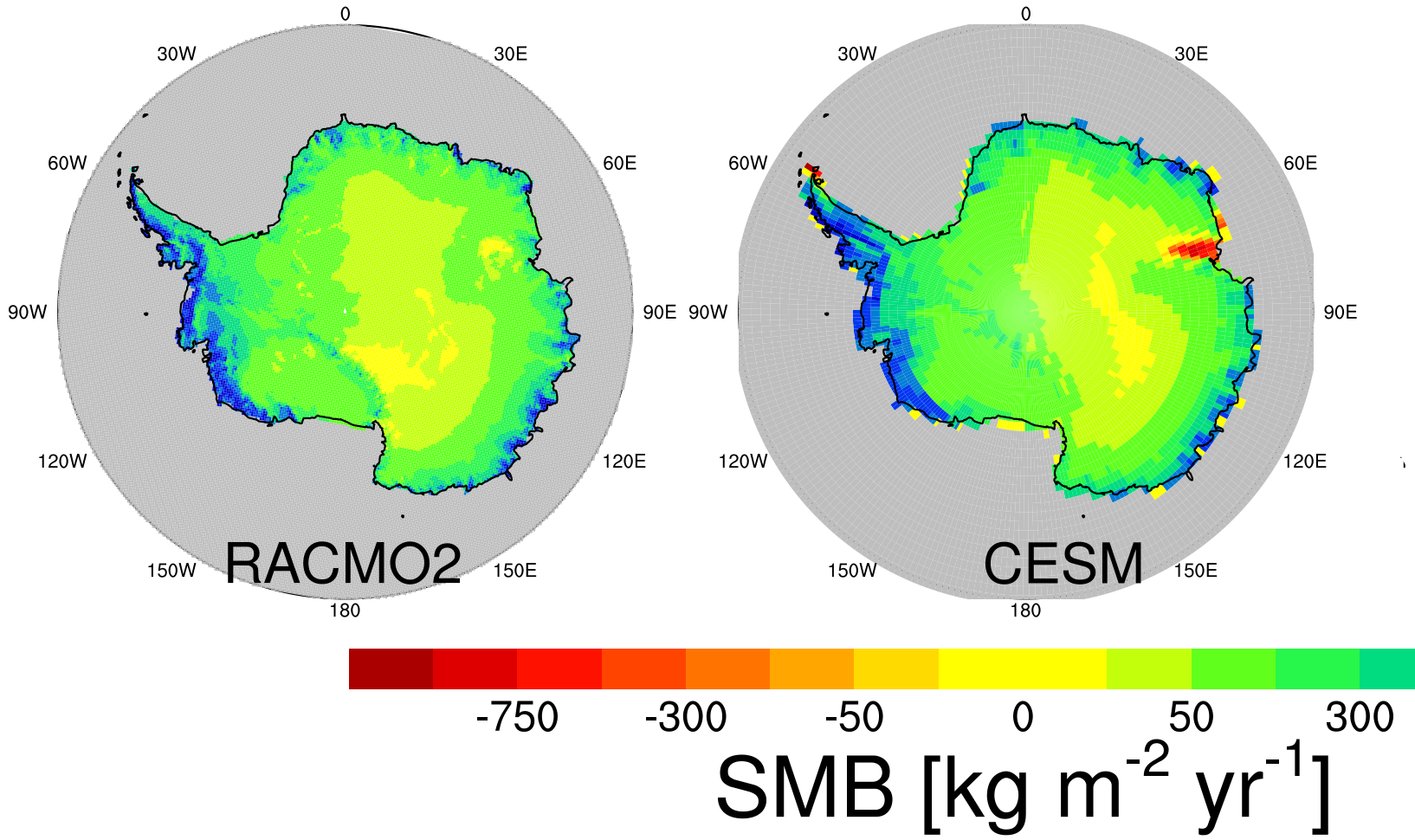


Greenland SMB

CESM1.5 ('simulation 28')
1980-2005



Antarctic SMB



Antarctic SMB

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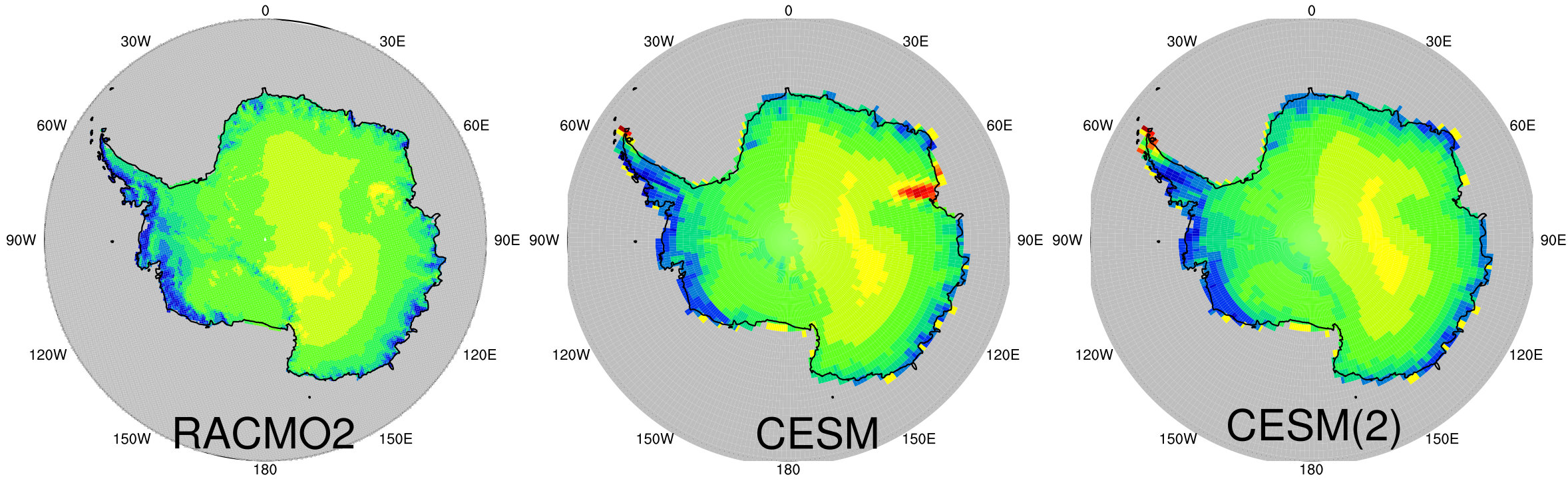
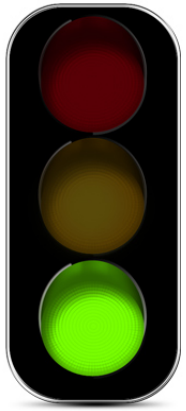
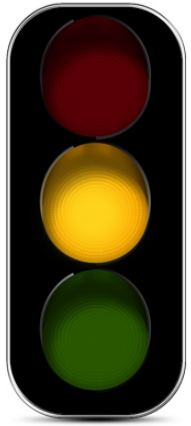


Green light for ice sheets in CESM2?



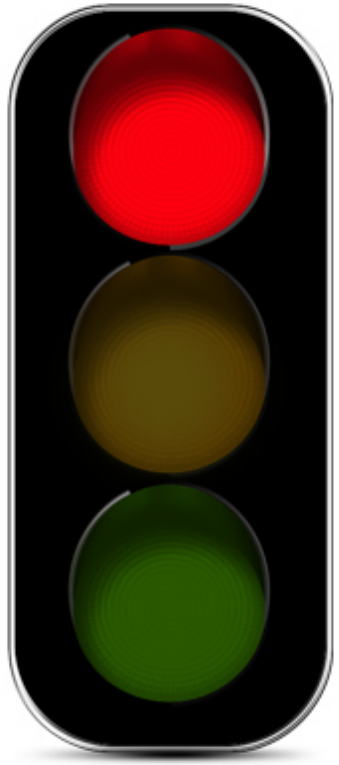
Firn processes

Snow density



Clouds

Surface winds



(Liquid) precip

Antarctic melt