

Evaluation of present-day surface energy and mass balances of the Greenland ice sheet with CESM (CAM5)

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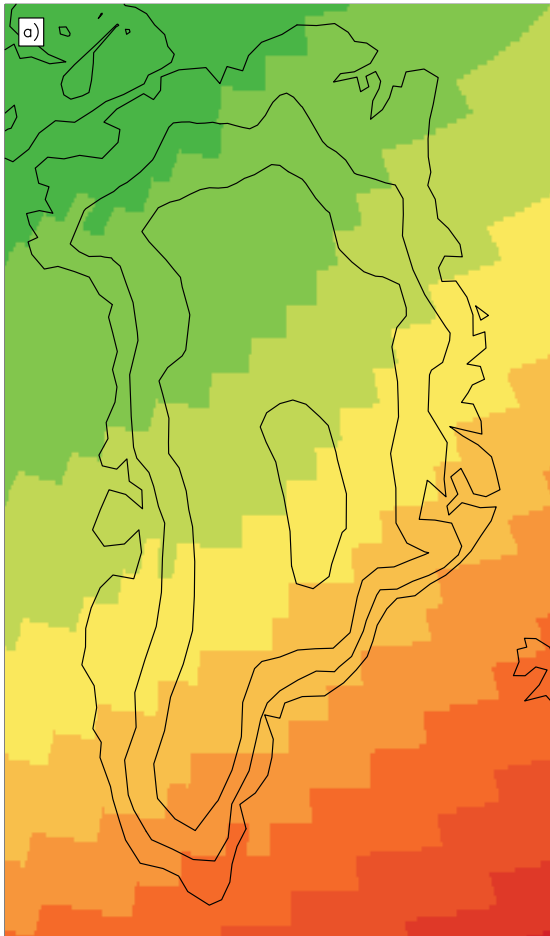
Outline

Comparison of 3 products

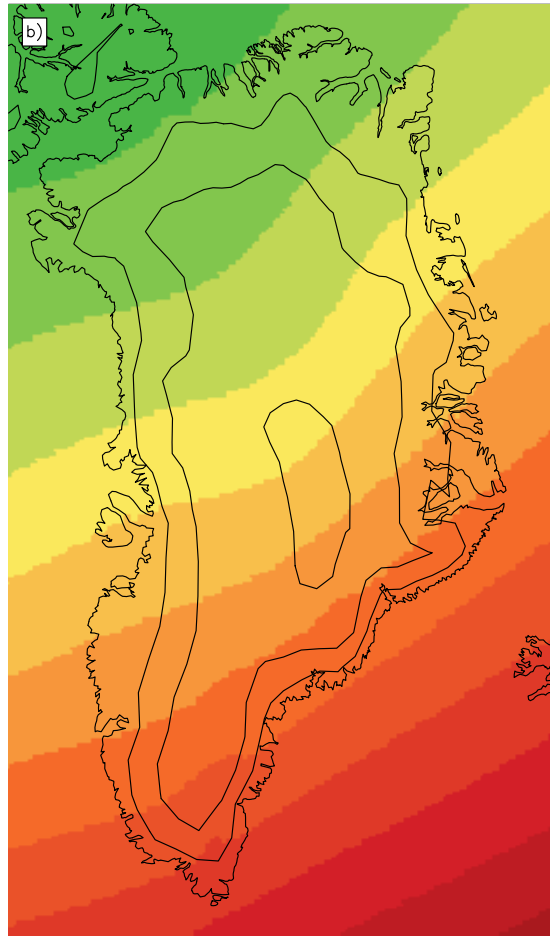
| | CESM (CAM5) | RACMO2.3 | 2B-FLXHR-LIDAR (R05) |
|-------------------|-------------|----------|---|
| <i>type</i> | ESM | RCM | satellite data (CloudSat, CALIPSO, MODIS) |
| <i>resolution</i> | 100km | 11km | 200 km (resampled) |

- RACMO does state-of-the-art modeling of ice sheet climate [Van Angelen 2012, Lenaerts 2012]
- 2B-FLXHR-LIDAR Rev05 has improved detection of supercooled liquid clouds

CESM, period 1960-2005

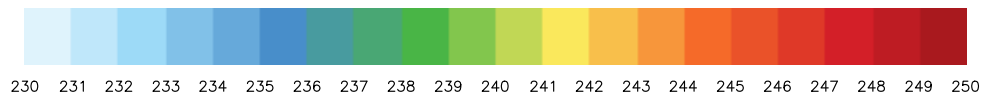


RACMO, period 1960-2005



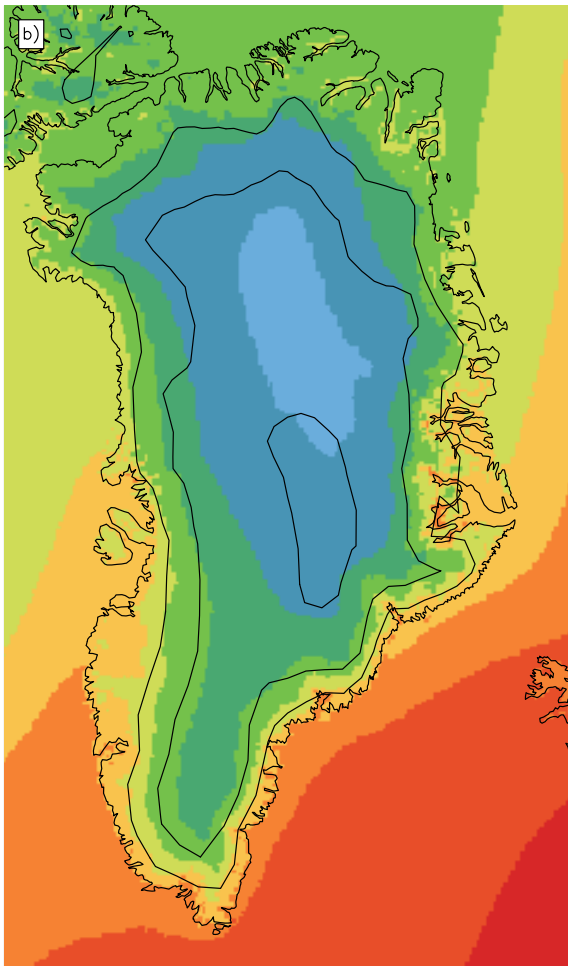
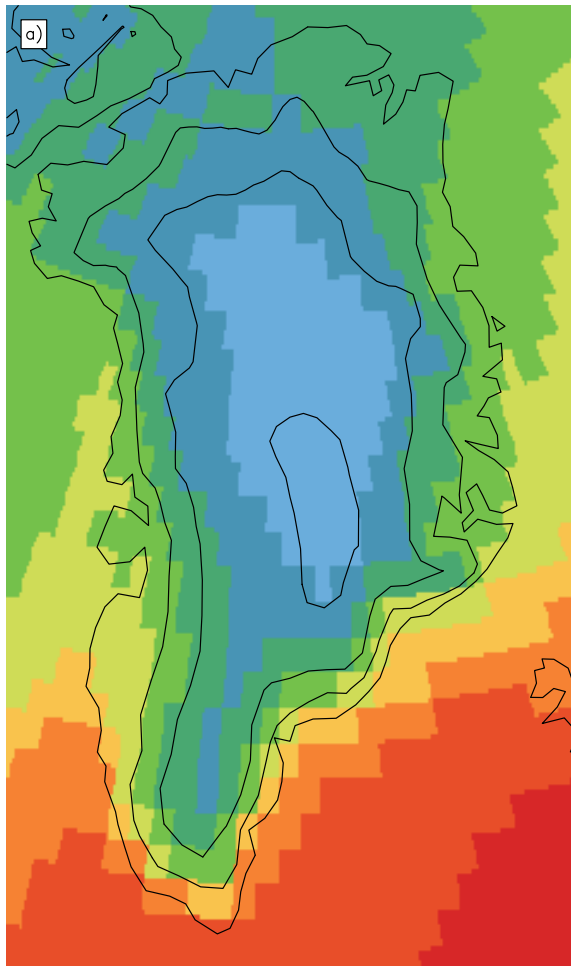
Large-scale
atmospheric
circulation is captured
well

500 hPa temperature [K]



CESM, period 1960-2005

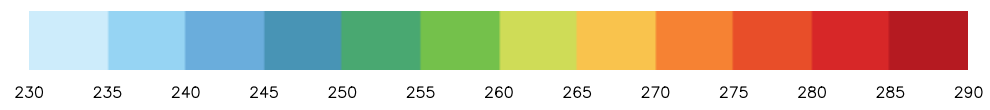
RACMO, period 1960-2005



General pattern is well resolved

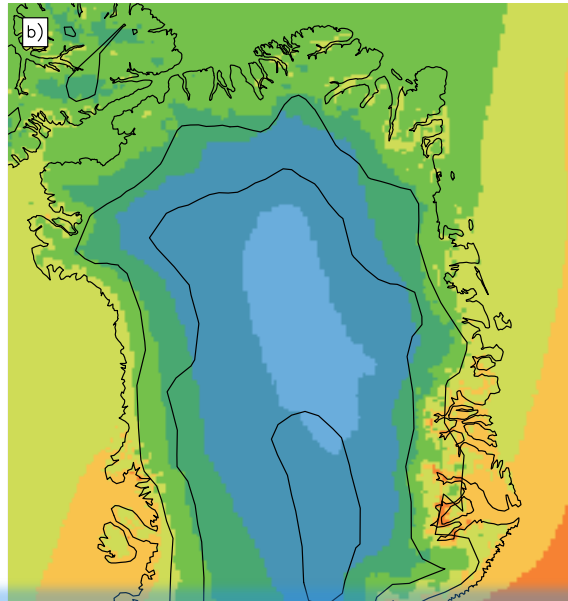
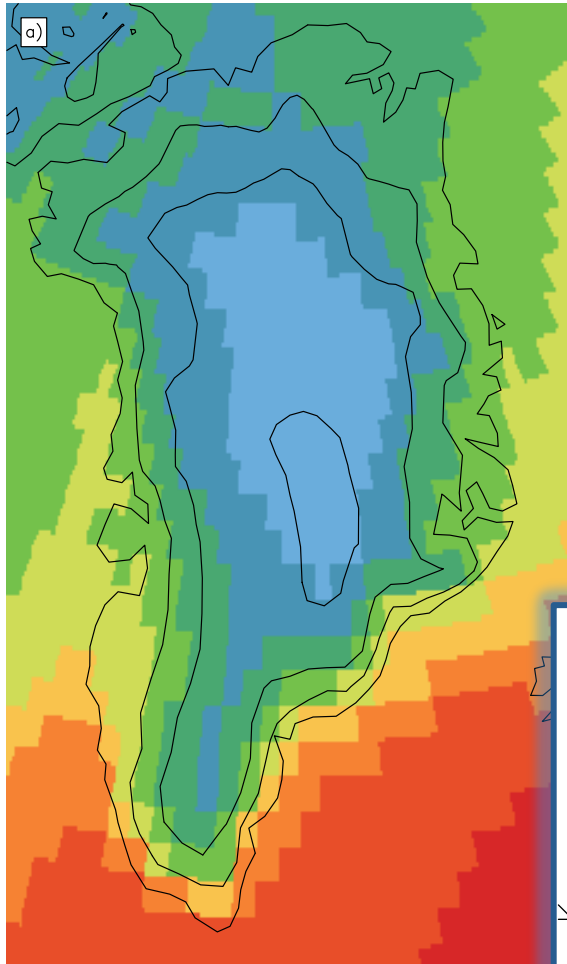
But CESM has cold bias of ~ 2K

2 meter air temperature [K]



CESM, period 1960-2005

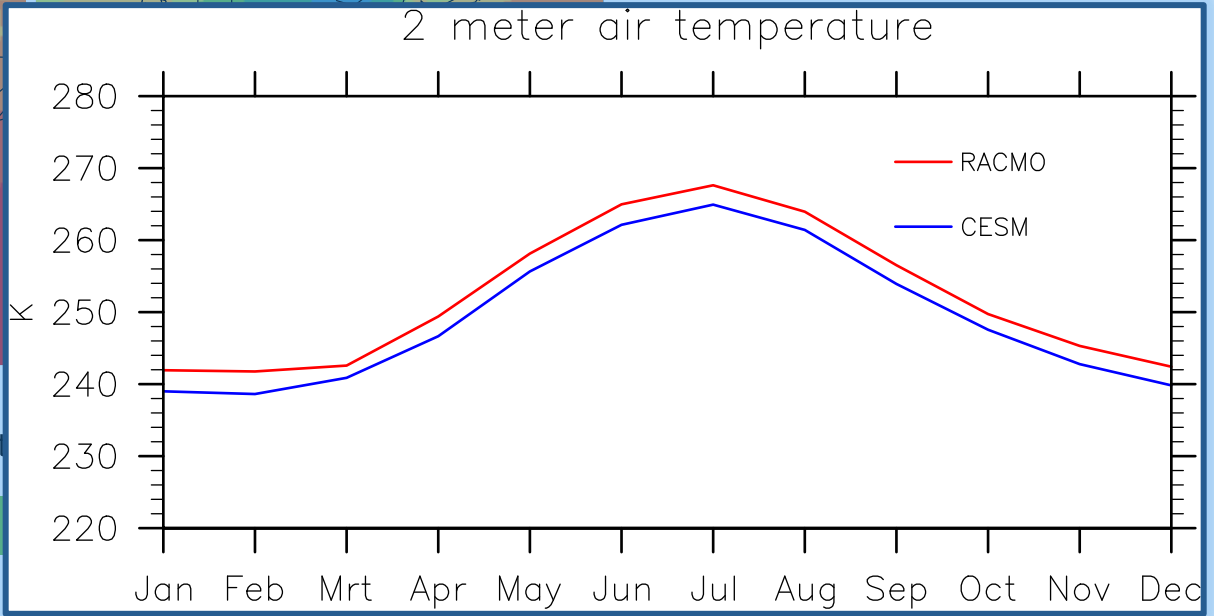
RACMO, period 1960-2005



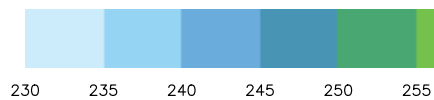
General pattern is well resolved

But CESM has cold bias of ~ 2K

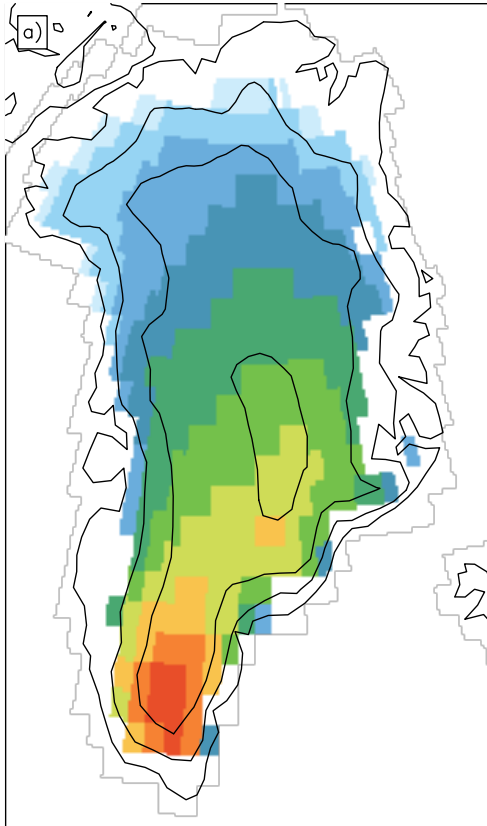
2 meter air temperature



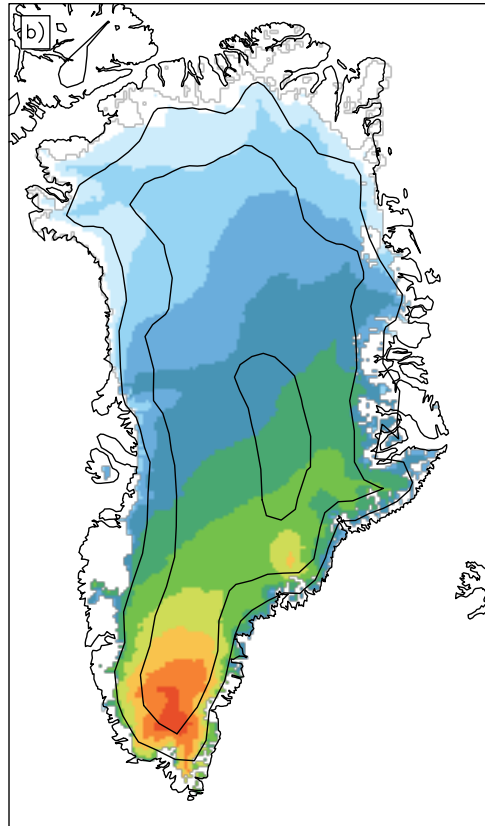
2 meter air t



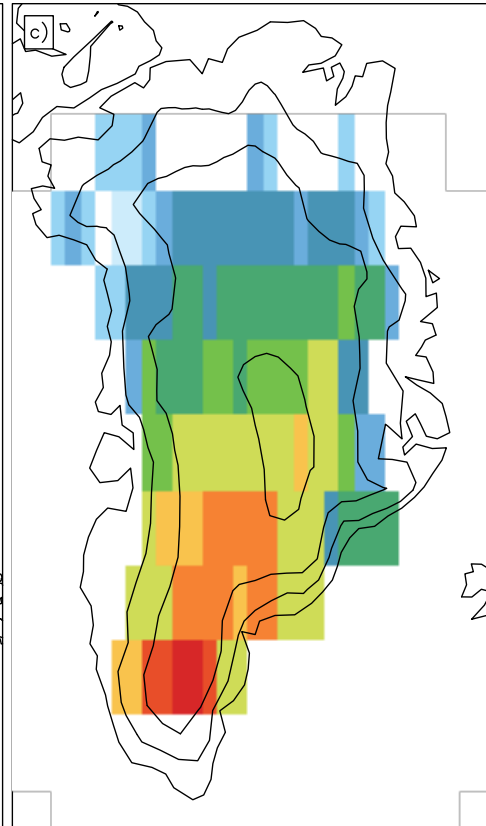
CESM, period 1960-2005



RACMO, period 1960-2005



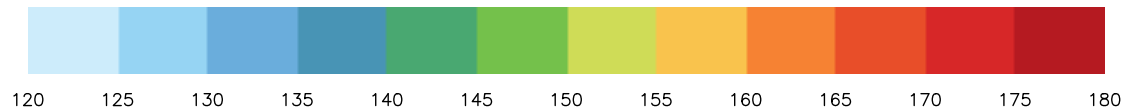
2B-FLXHR-LIDAR, 2007-2010



Better match with observations than RACMO

Does NOT explain missing energy

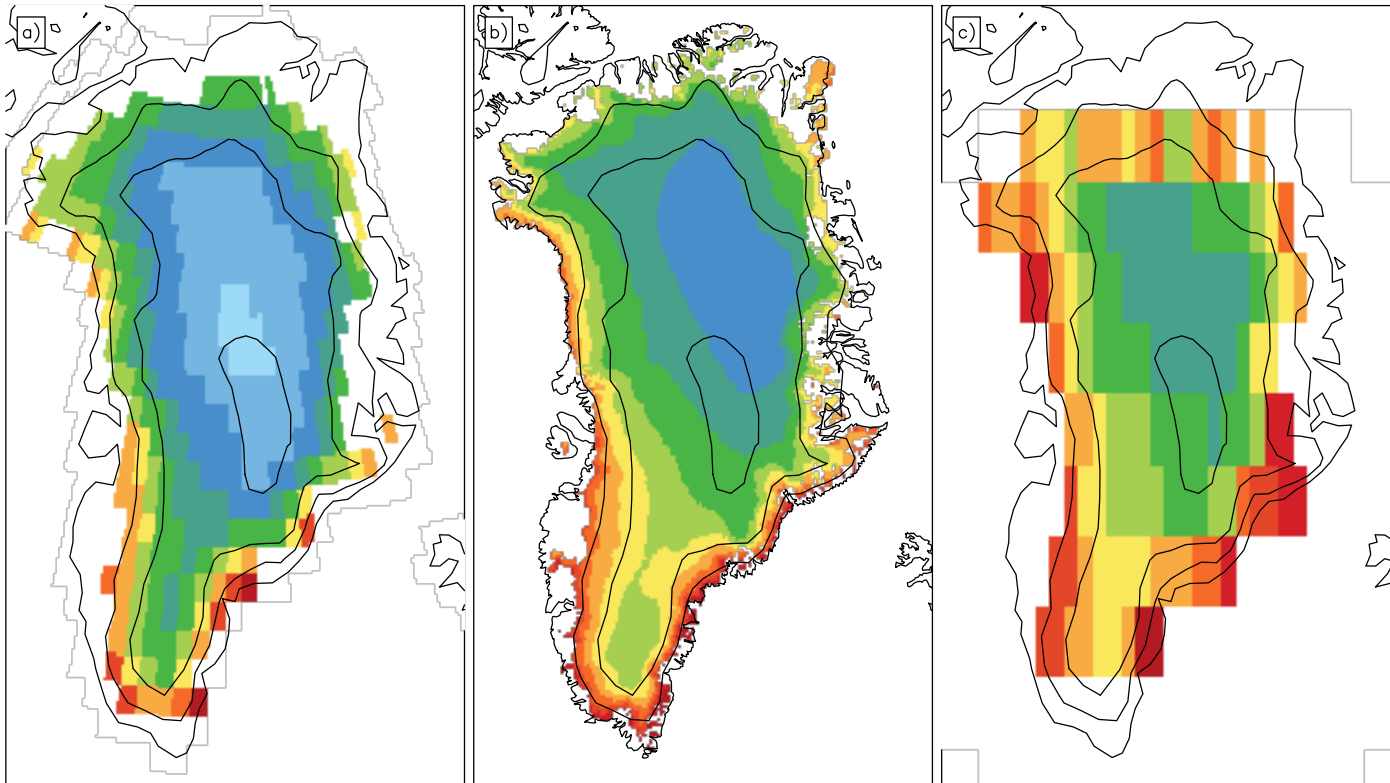
Incoming shortwave at the surface [W/m^2]



CESM, period 1960-2005

RACMO, period 1960-2005

2B-FLXHR-LIDAR, 2007-2010

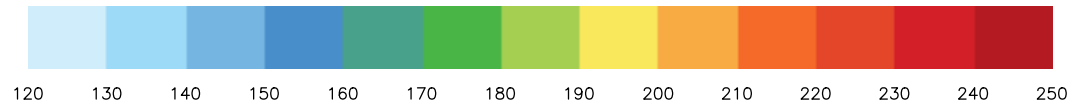


LW deficit

- CESM ~ 15 Wm⁻²
- RACMO ~ 5 Wm⁻²

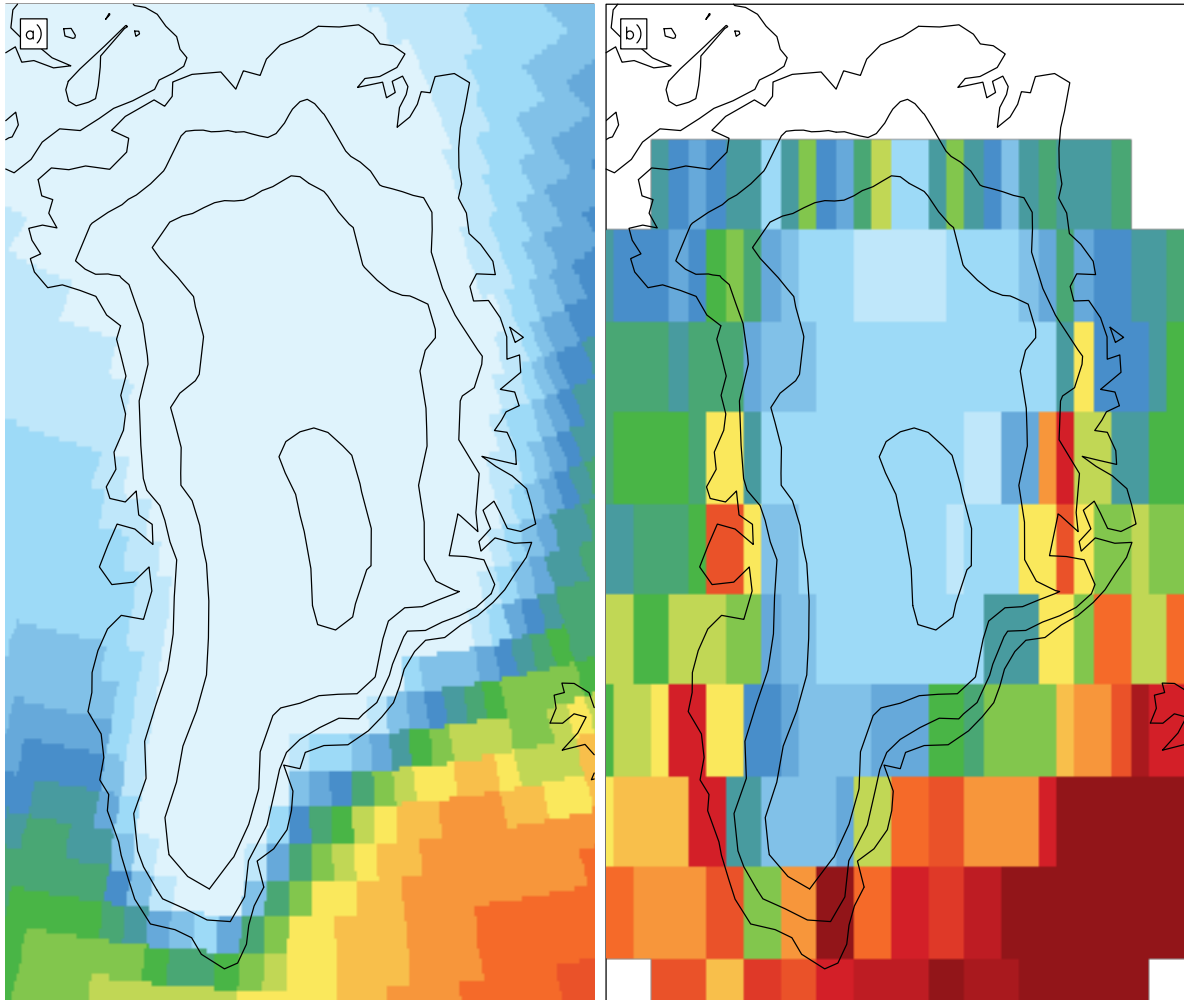
→ could explain missing energy!

Incoming longwave [W/m²]



CESM, period 1960-2005

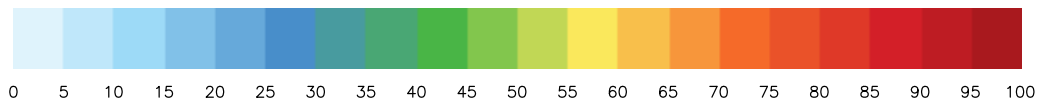
2B-FLXHR-LIDAR, 2007-2010



Underestimation of LWP
reduces capacity of
clouds to absorb and re-
emit LW radiation

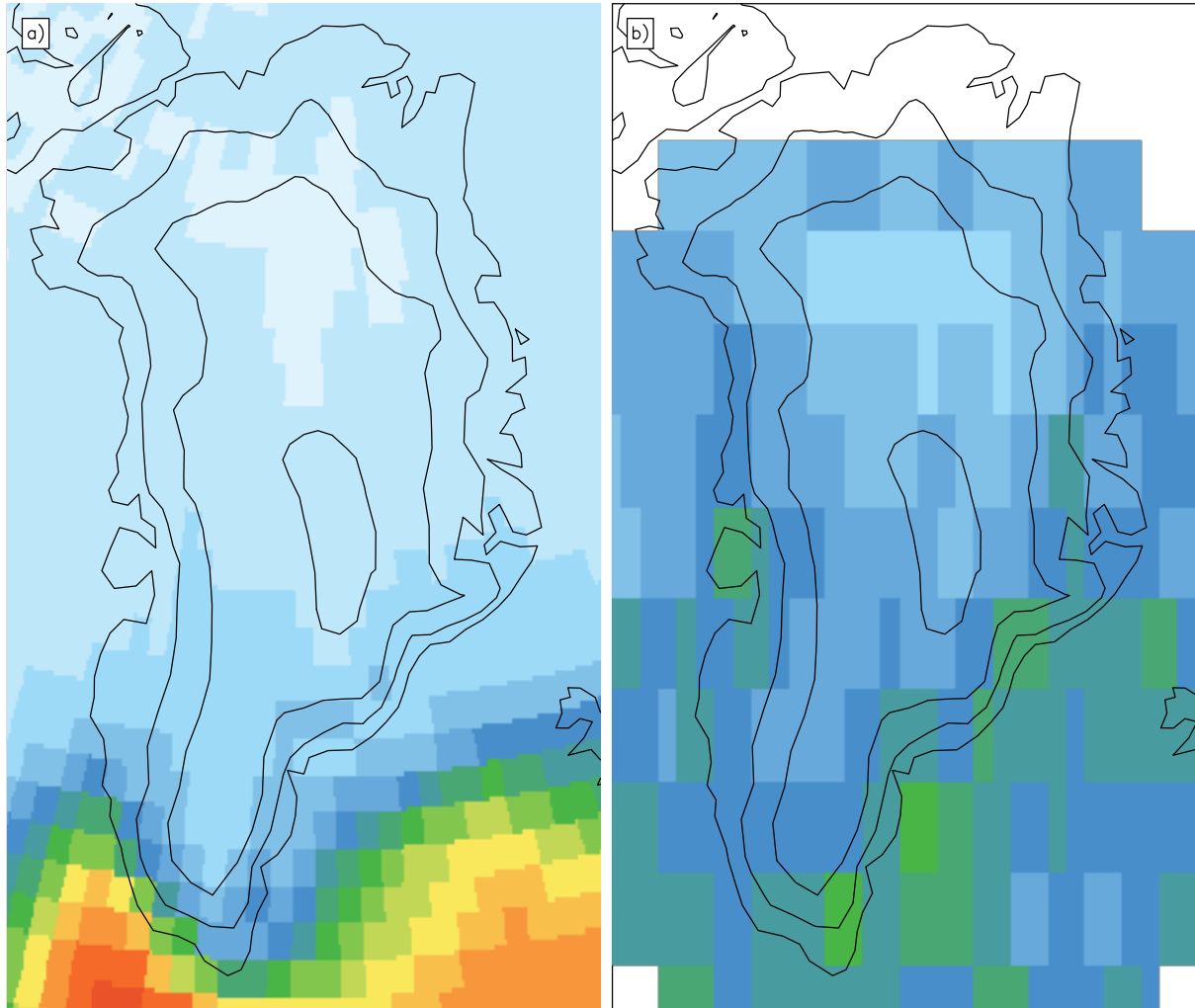
→ Explains negative LW
bias

Mean liquid water path [g m⁻²]



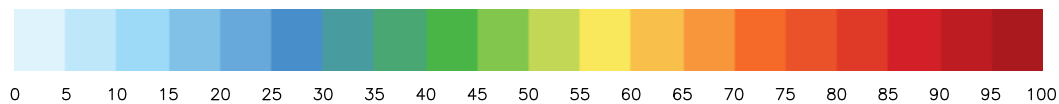
CESM, period 1960-2005

2B-FLXHR-LIDAR, 2007-2010

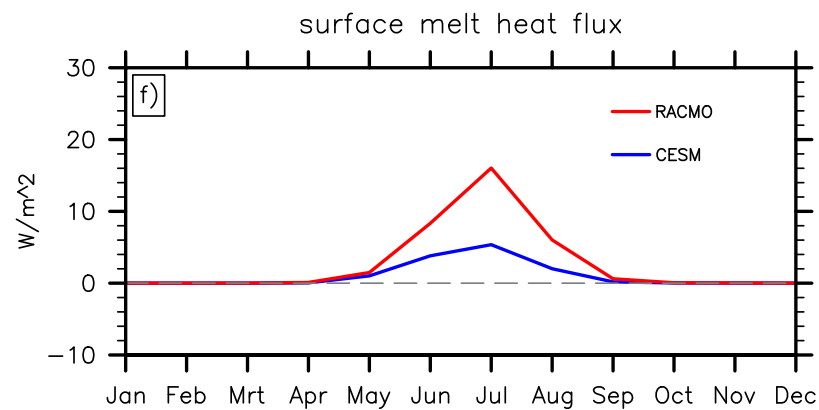
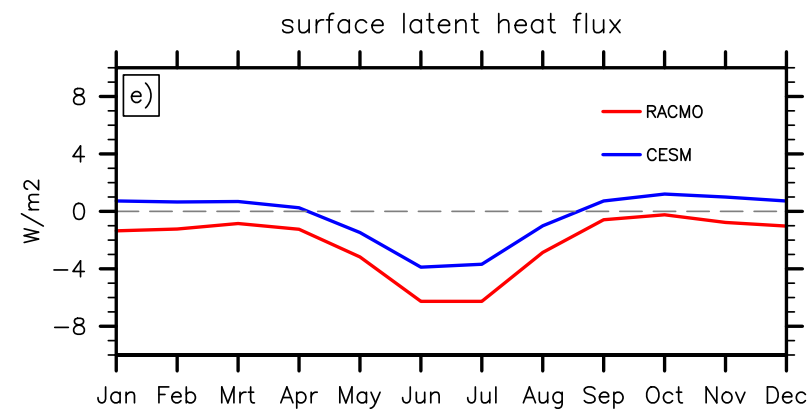
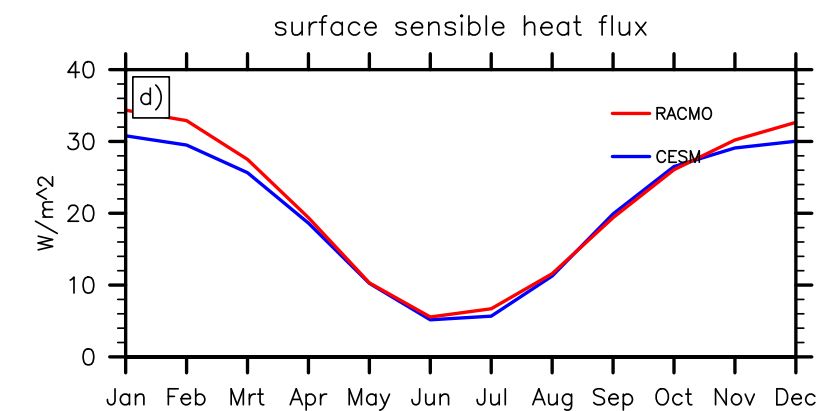
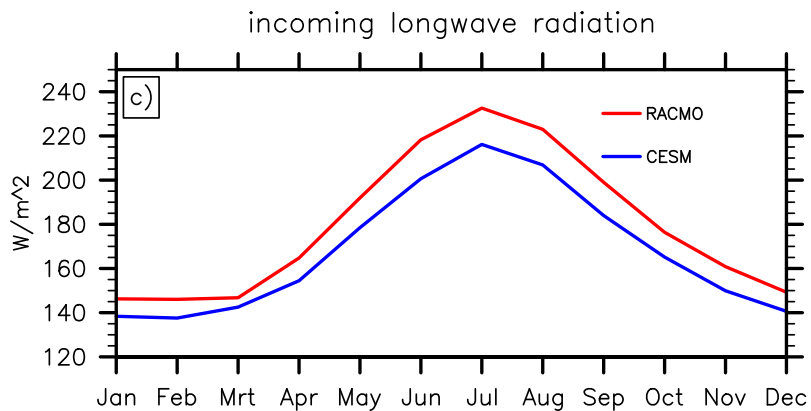
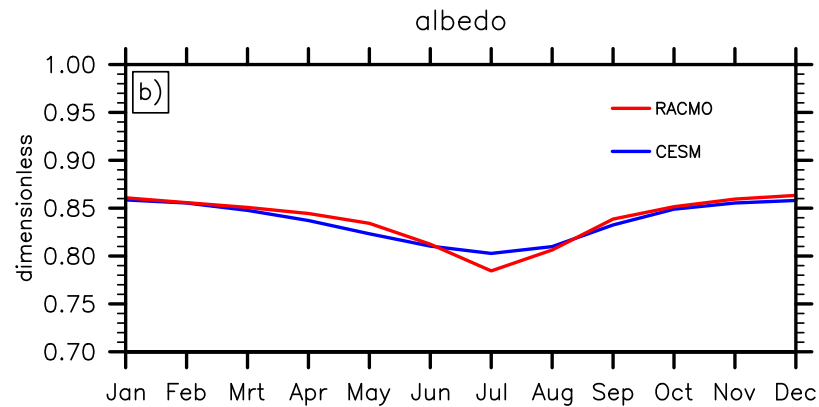
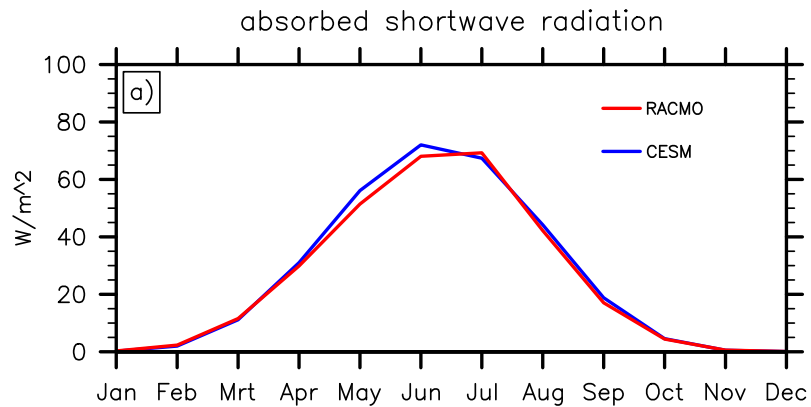


Total water path also too low: too few / thin clouds?

Mean ice water path [g m⁻²]



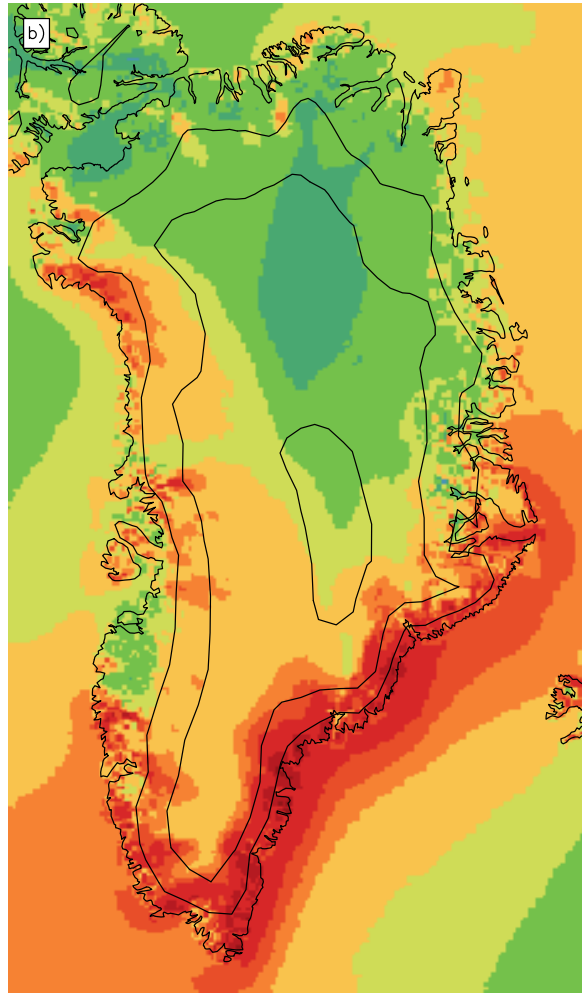
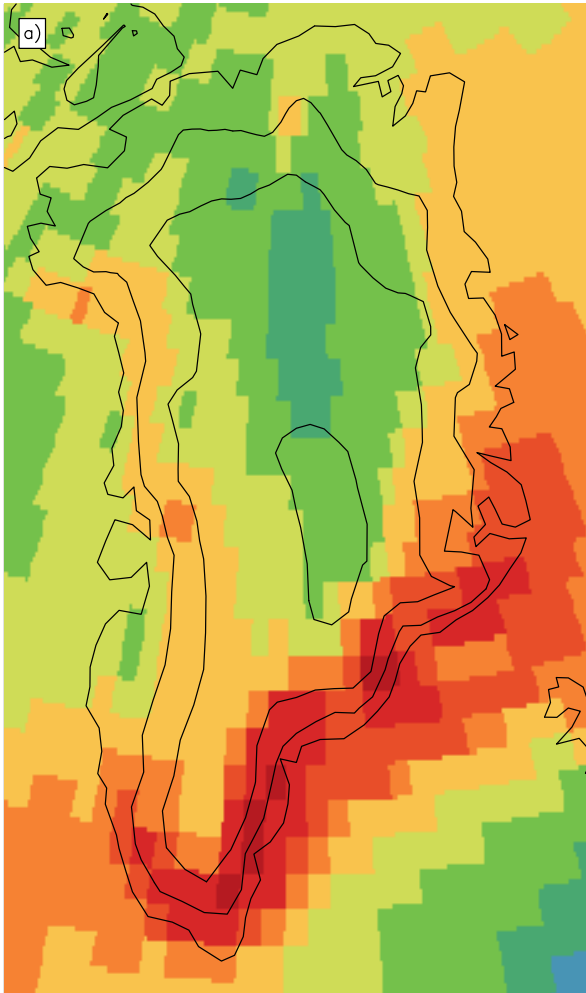
Mean surface energy fluxes in period 1960-2005



Effects on the surface mass balance (SMB)

CESM, period 1960-2005

RACMO, period 1960-2005



Snowfall is near perfect

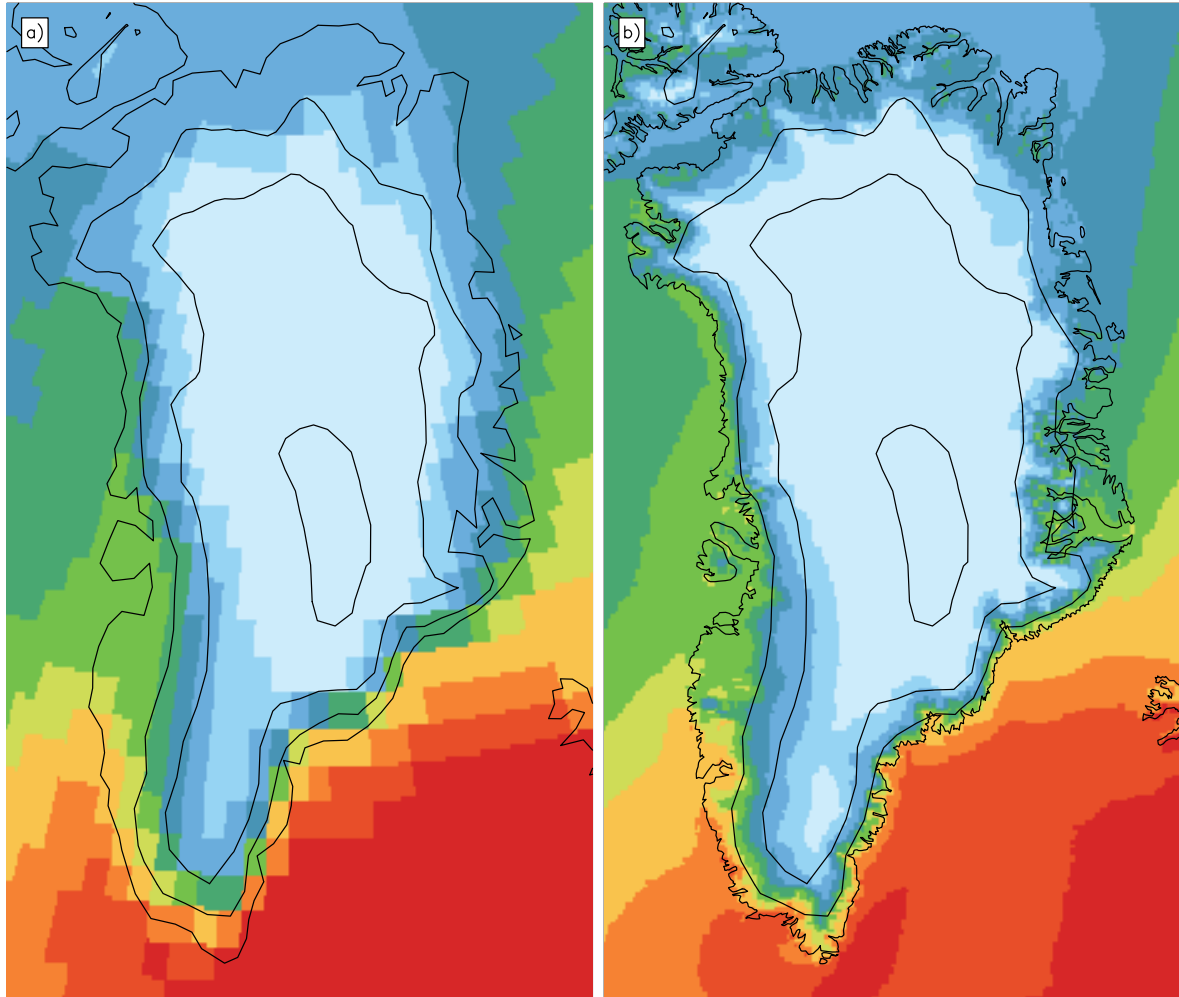
Only NW has slight underestimation

Solid precipitation (snow) [mmWE]



CESM, period 1960-2005

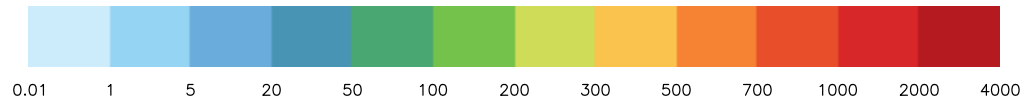
RACMO, period 1960-2005



Rainfall pattern looks also great

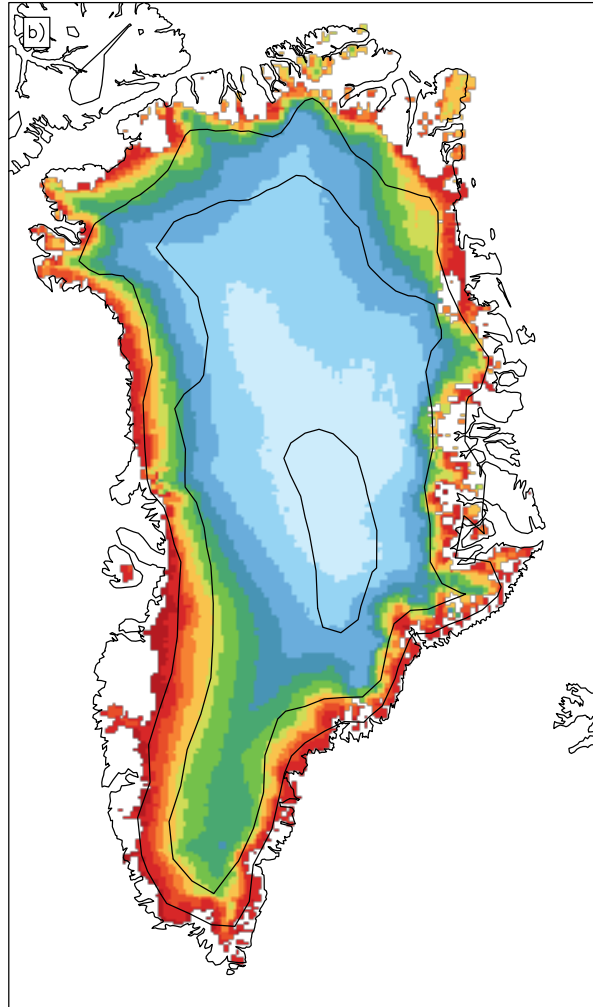
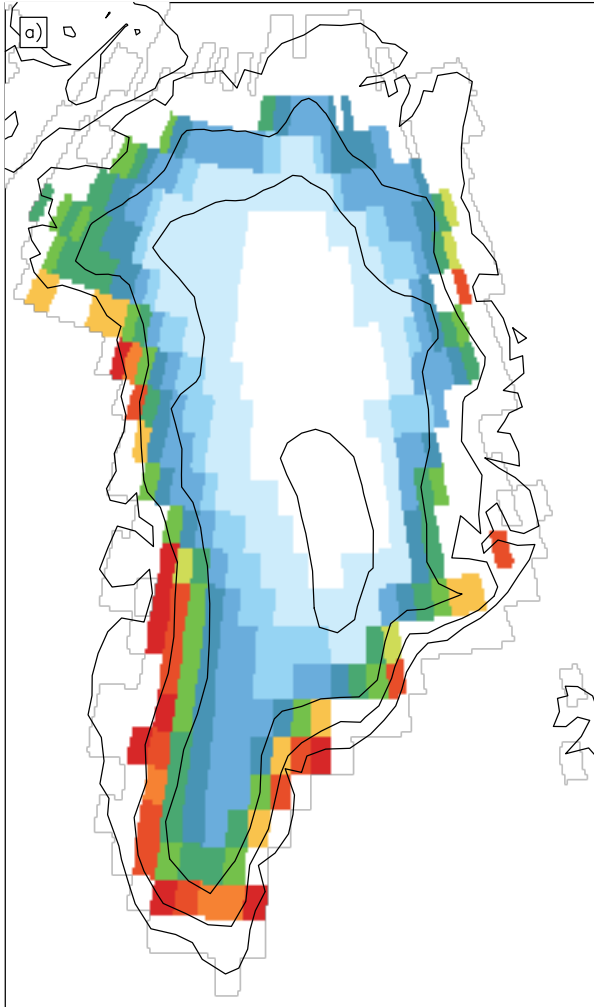
CAM4 rainfall problem at low temperatures has been solved!

Liquid precipitation (rain) [mmWE]



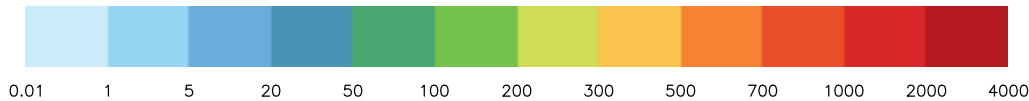
CESM, period 1960-2005

RACMO, period 1960-2005



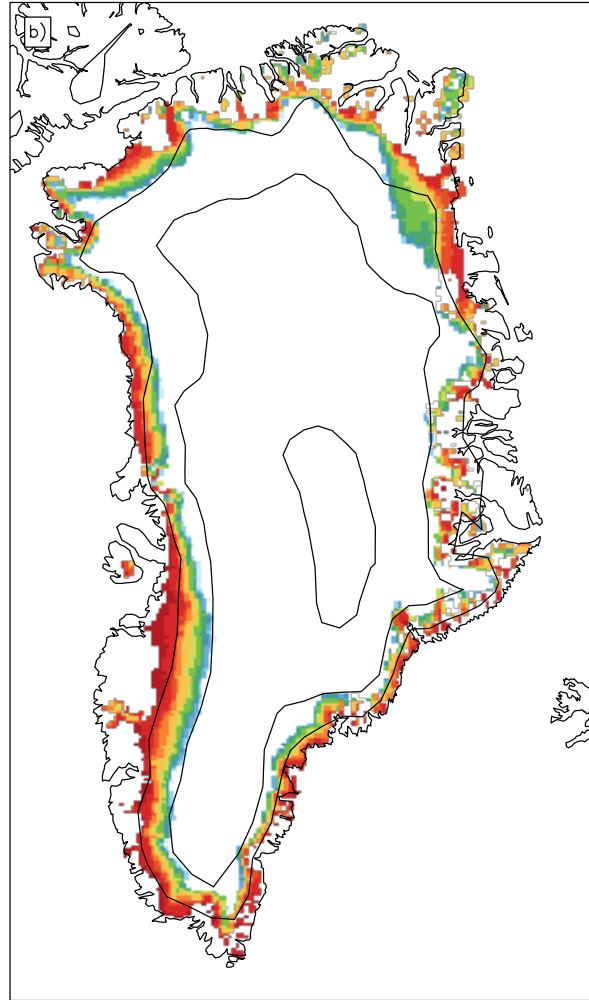
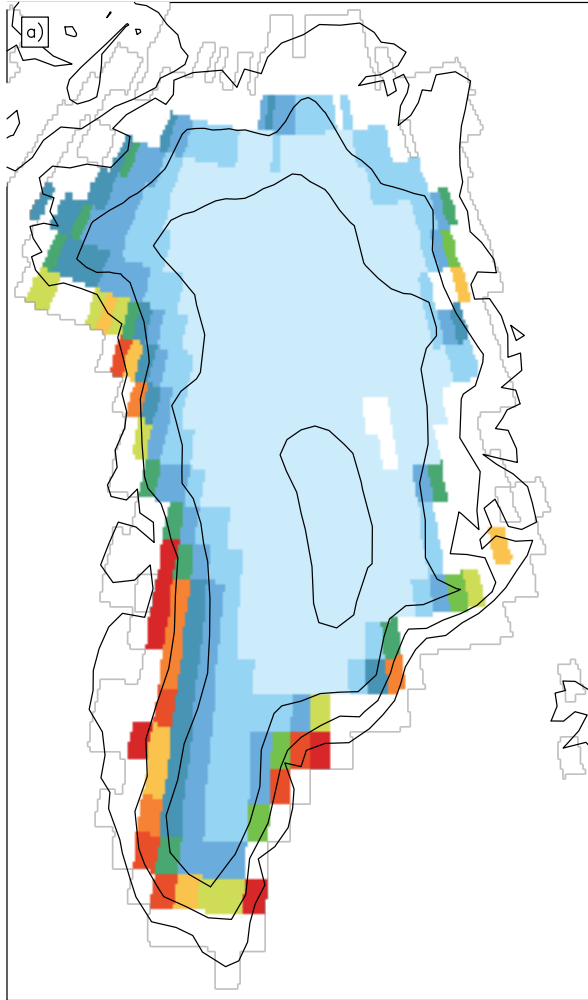
Melt is underestimated
due to bias in the energy
budget

Snow melt [mmWE]



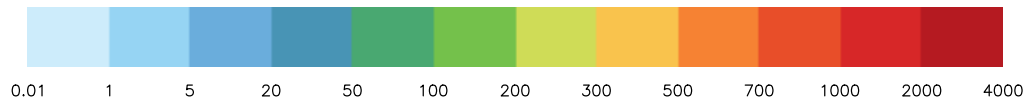
CESM, period 1960-2005

RACMO, period 1960-2005



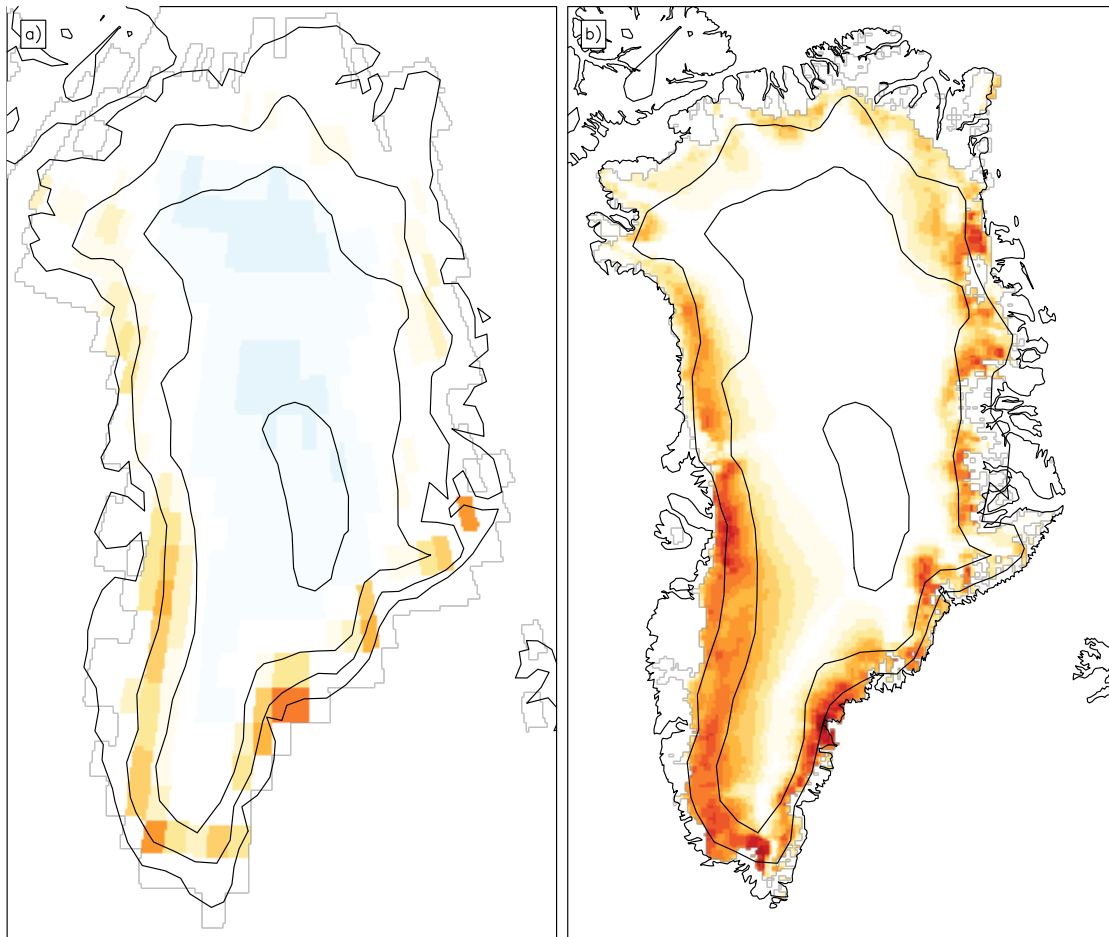
Runoff is underestimated directly through the melt bias

Runoff [mmWE]



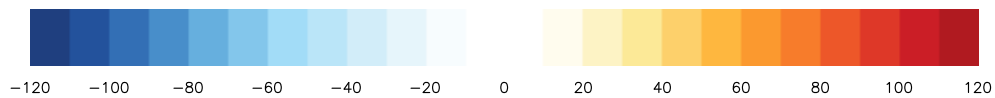
CESM, period 1960-2005

RACMO, period 1960-2005

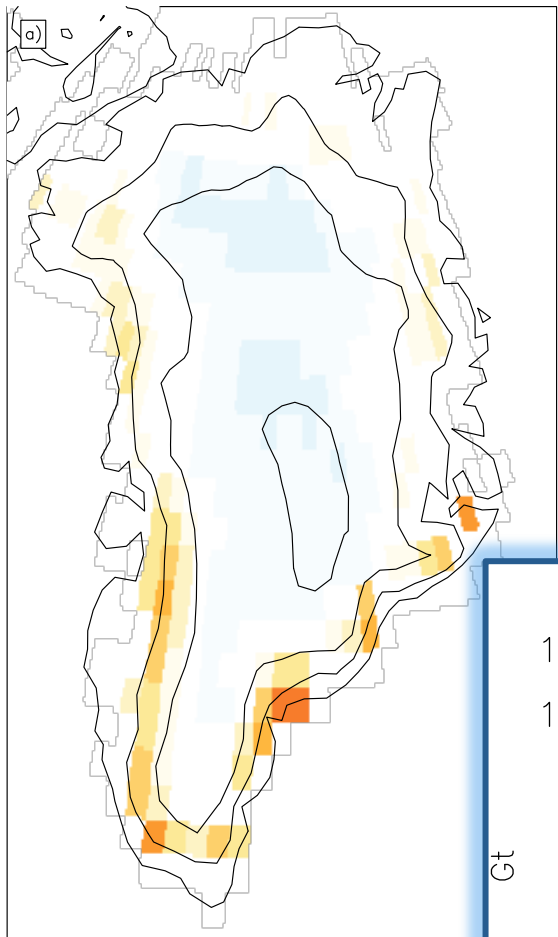


RACMO has increased sublimation rates due to drifting snow scheme

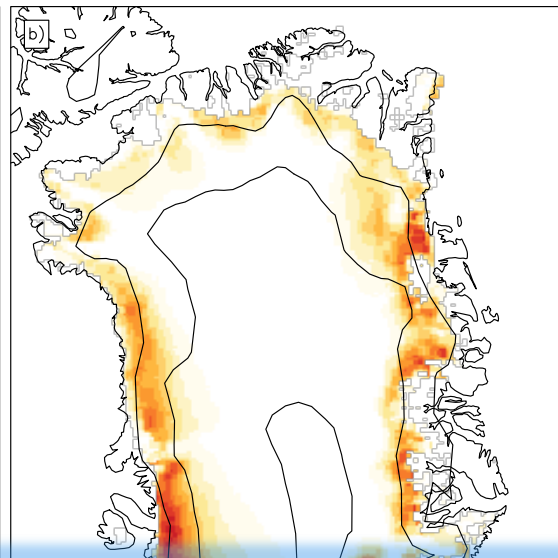
Sublimation [mmWE]



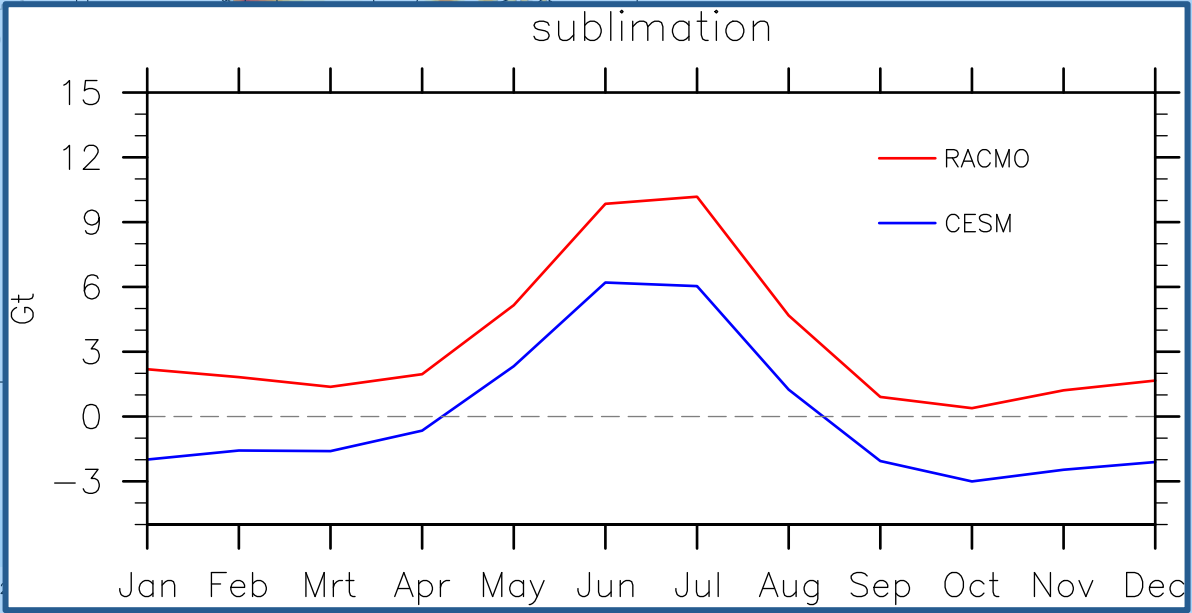
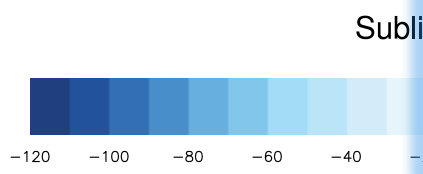
CESM, period 1960-2005



RACMO, period 1960-2005



RACMO has increased sublimation rates due to drifting snow scheme

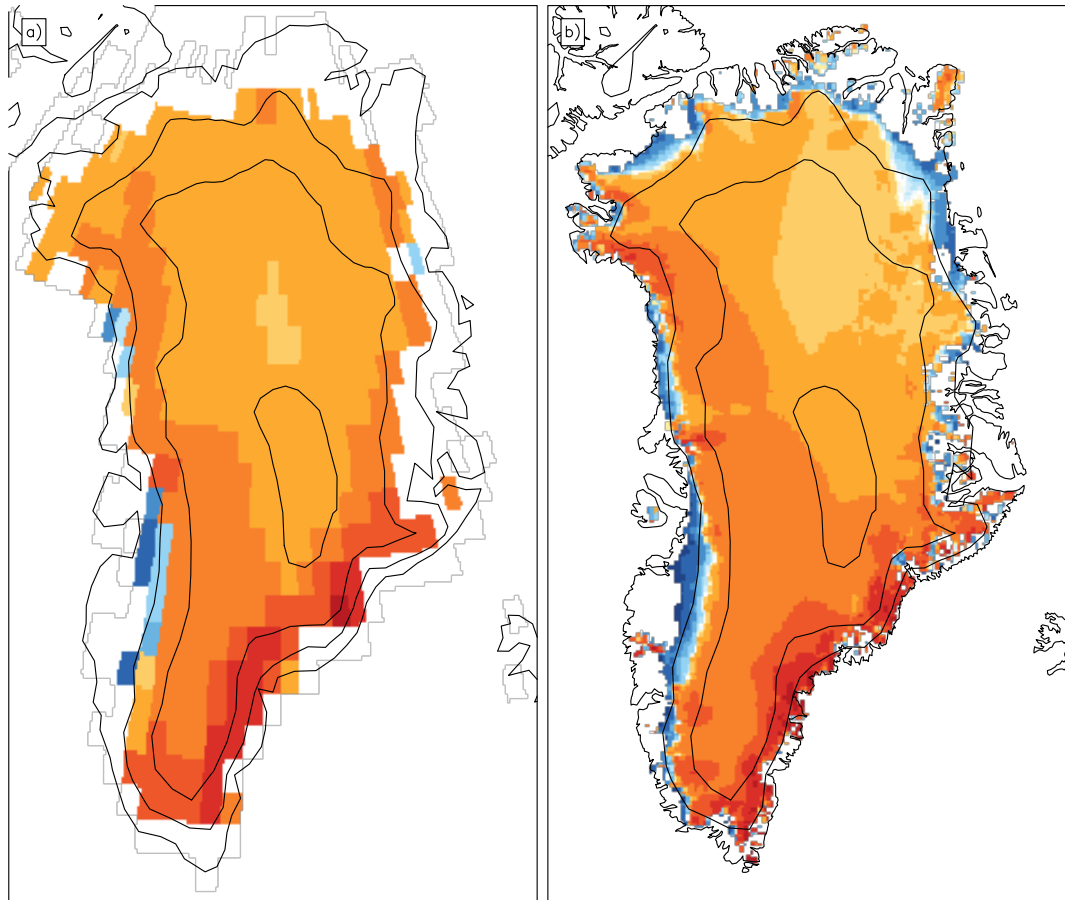


CESM, period 1960-2005

RACMO, period 1960-2005

Surface mass balance

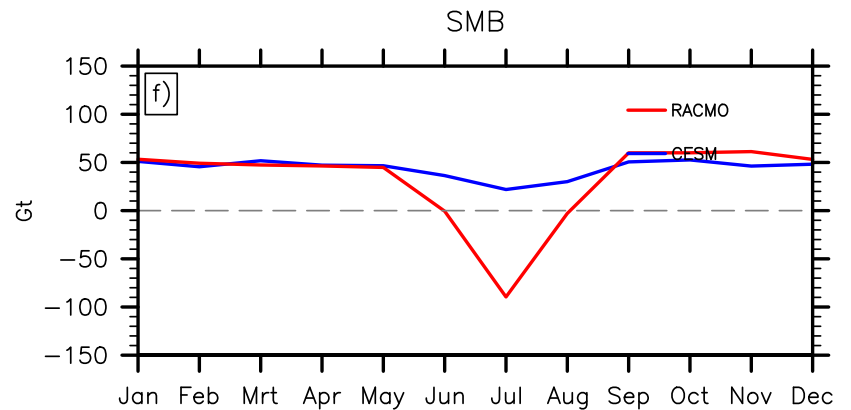
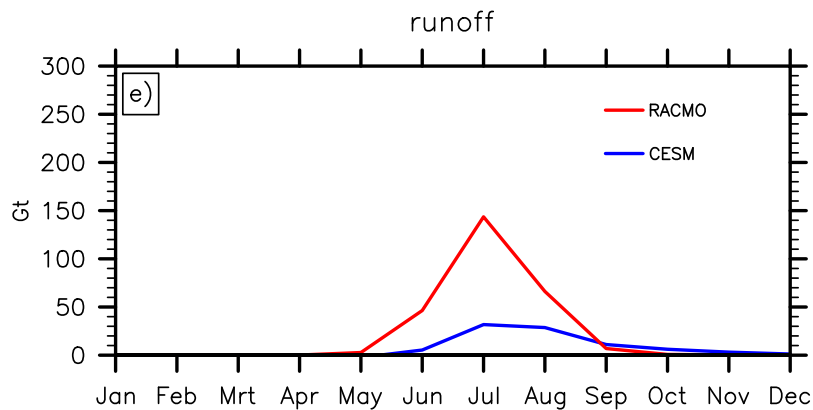
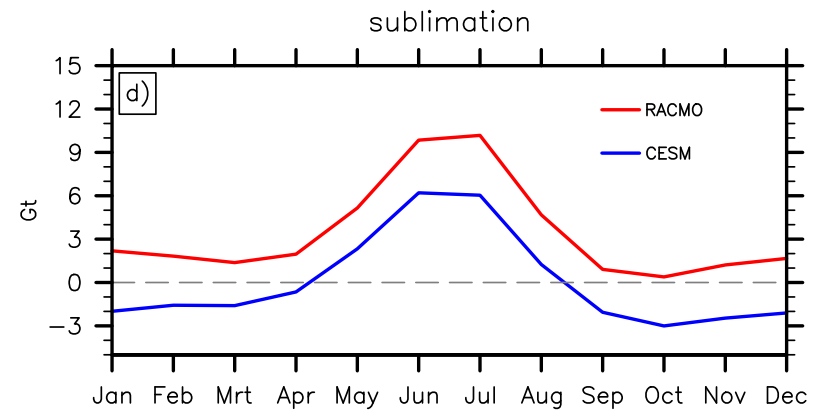
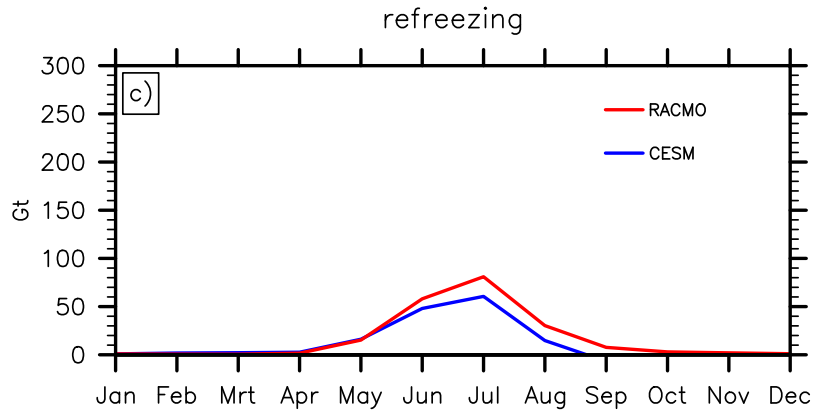
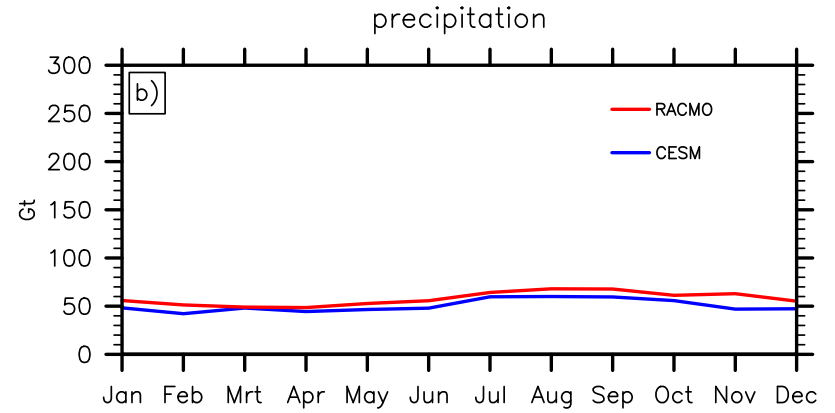
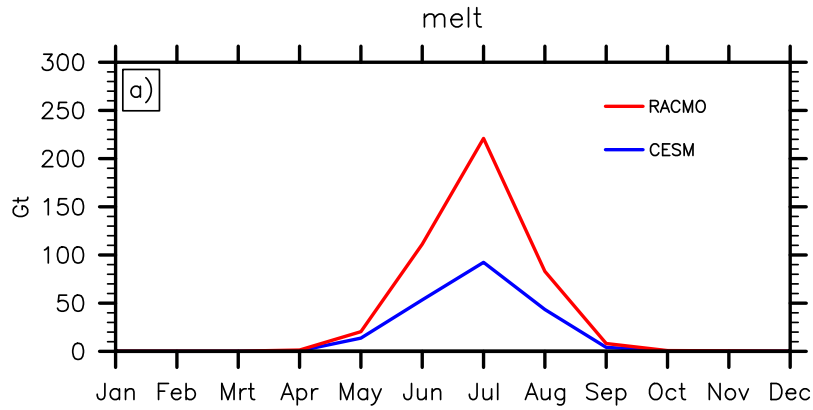
Ablation areas in CESM are much smaller and fewer in CESM due to negative melt bias



SMB [mmWE]



Mean surface mass fluxes in period 1960-2005



Conclusions

the Good:

- ✓ Many improvements over CAM4 (shortwave, albedo)
- ✓ Rainfall problem in the interior is resolved
- ✓ Spatial patterns are all good

the Bad:

- ✗ Cold bias due to insufficient downwelling LW
 - ✗ Unrealistically low melt and
 - ✗ subsequently high SMB
- ✗ Clouds are too thin?

Outlook

- We are *very* interested in evaluating new cloud schemes as they are continually improved
- **How we can help?**
 - IMAU has been operating automatic weather stations (AWS's) at Greenland for over 20 years;
 - Long history in regional climate modeling, ice core data
 - Remote sensing data made suitable for ice sheets (Kristof van Tricht, paper in preparation)

Thanks

- Brice Noël for providing his RACMO2 data
- Kristof van Tricht for providing the 2B-FLXHR-LIDAR data
- Michiel van den Broeke
Miren Vizcaíno
Jan Lenaerts for their advice



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