Surface mass balance of the Greenland Ice Sheet simulated with CESM

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overview

1. CLM simulations with MOAR forcing
   a) 20th century SMB
   b) 21st century projections (RCP8.5)
2. Sensitivity tests with the fully coupled model (“year 2000” climate)
   a) Ice albedo
   b) Resolution
3. Conclusions and future plans

Model and set-up: IG-MOAR runs

Set-up: land model is run at 1° with data atmosphere from a previous 20th century run (MOAR). SMB is calculated at 10 elevation classes and downscaled to finer grid (10 km). Ice dynamics off.

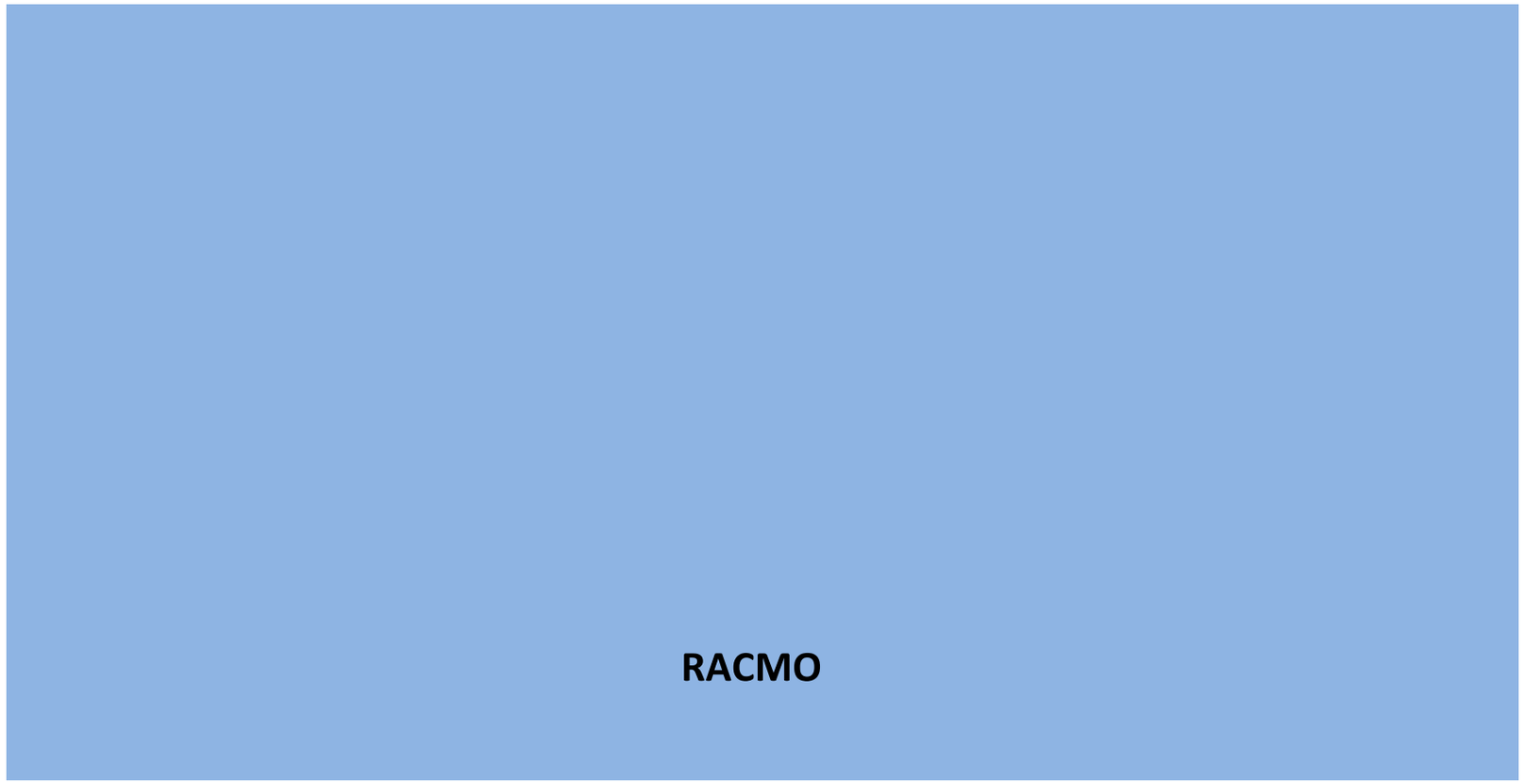
Validation: regional model RACMO (forced by ERA-40/ECMWF operational 1958-2008; *Ettema et al. GRL, 2008*). 11 km resolution.

1. CLM with MOAR forcing ➔ set-up

Simulated climate1958-2005

1. CLM with MOAR forcing ➔ a) 20th century SMB

Simulated climate 1958-2005



- Two bands of max. precip along SW and E margins are well captured
- Precipitation is overestimated in N interior and underestimated in SE
- Near surface climate agrees well with RACMO, with some discrepancies
  - July albedo is too low in W margin and N tundra regions. The second is probably due to overestimation of prescribed glacier extent
  - Incoming LW is higher in winter (RACMO underestimates it), possibly improving LW forcing

Simulated surface mass balance

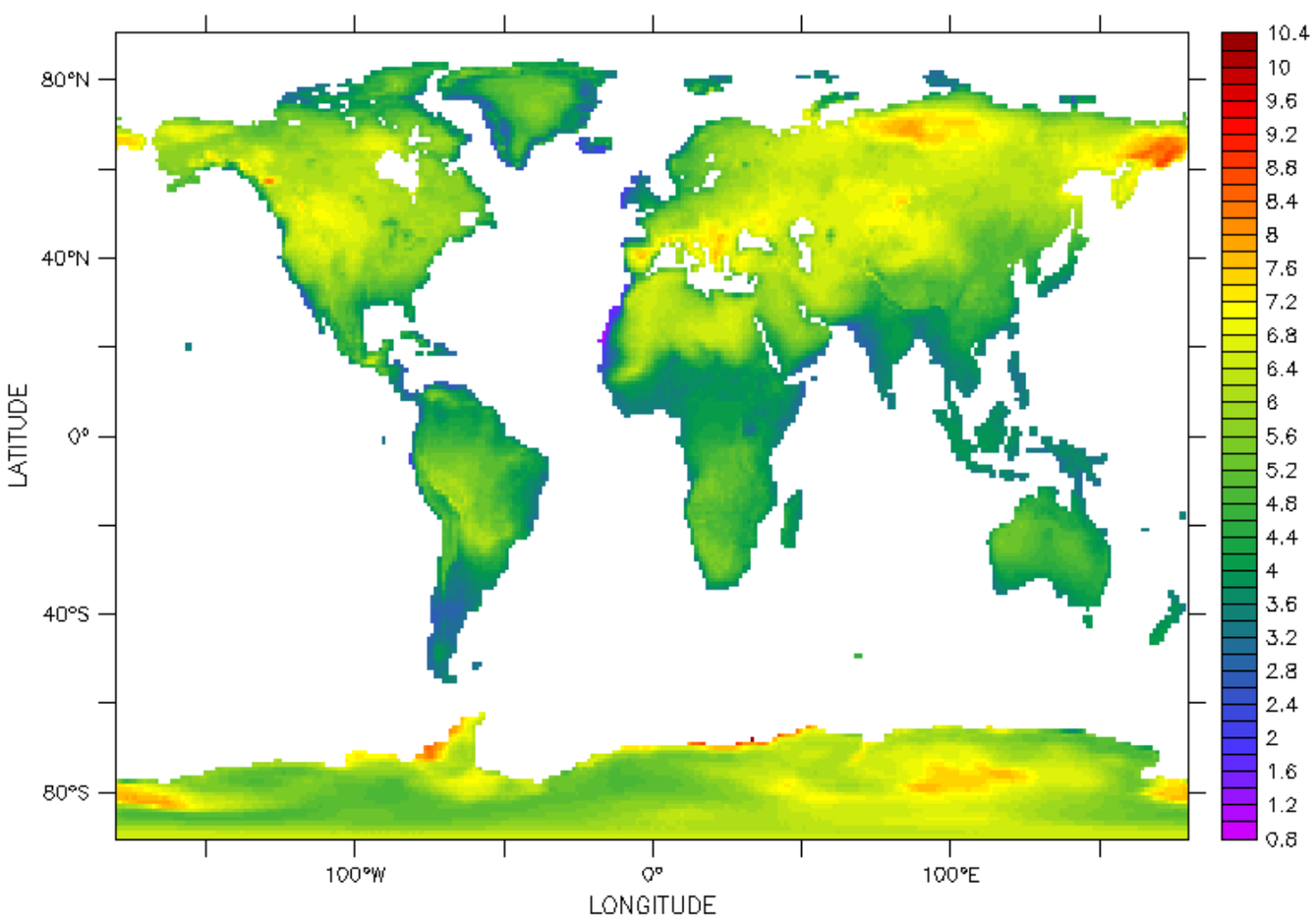
1. CLM with MOAR forcing ➔ a) 20th century SMB

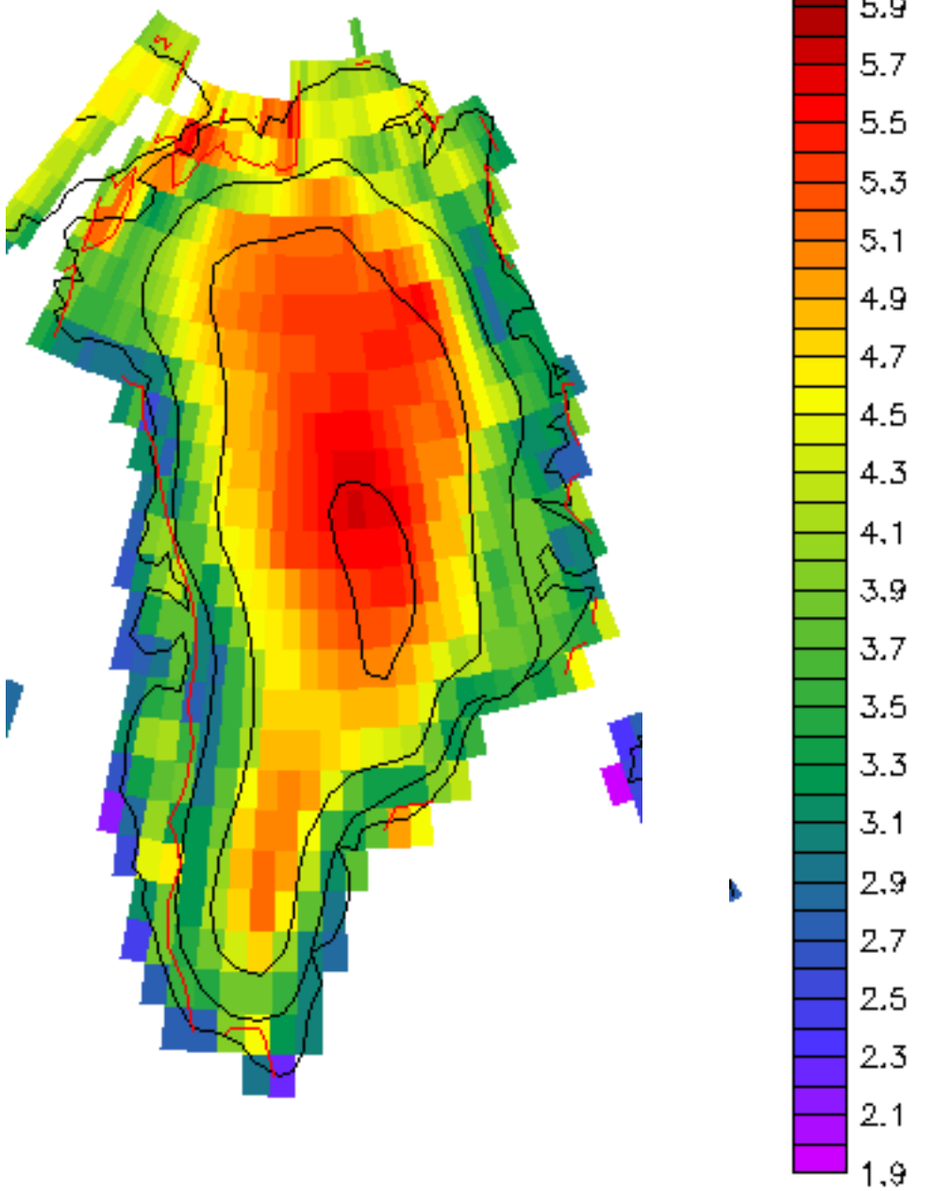
Simulated surface mass balance

1. CLM with MOAR forcing ➔ a) 20th century SMB

21st century projections (RCP8.5)

Summer near-surface temperature increase 2081-2100 wrt 1958-2005 [K], global and zoom



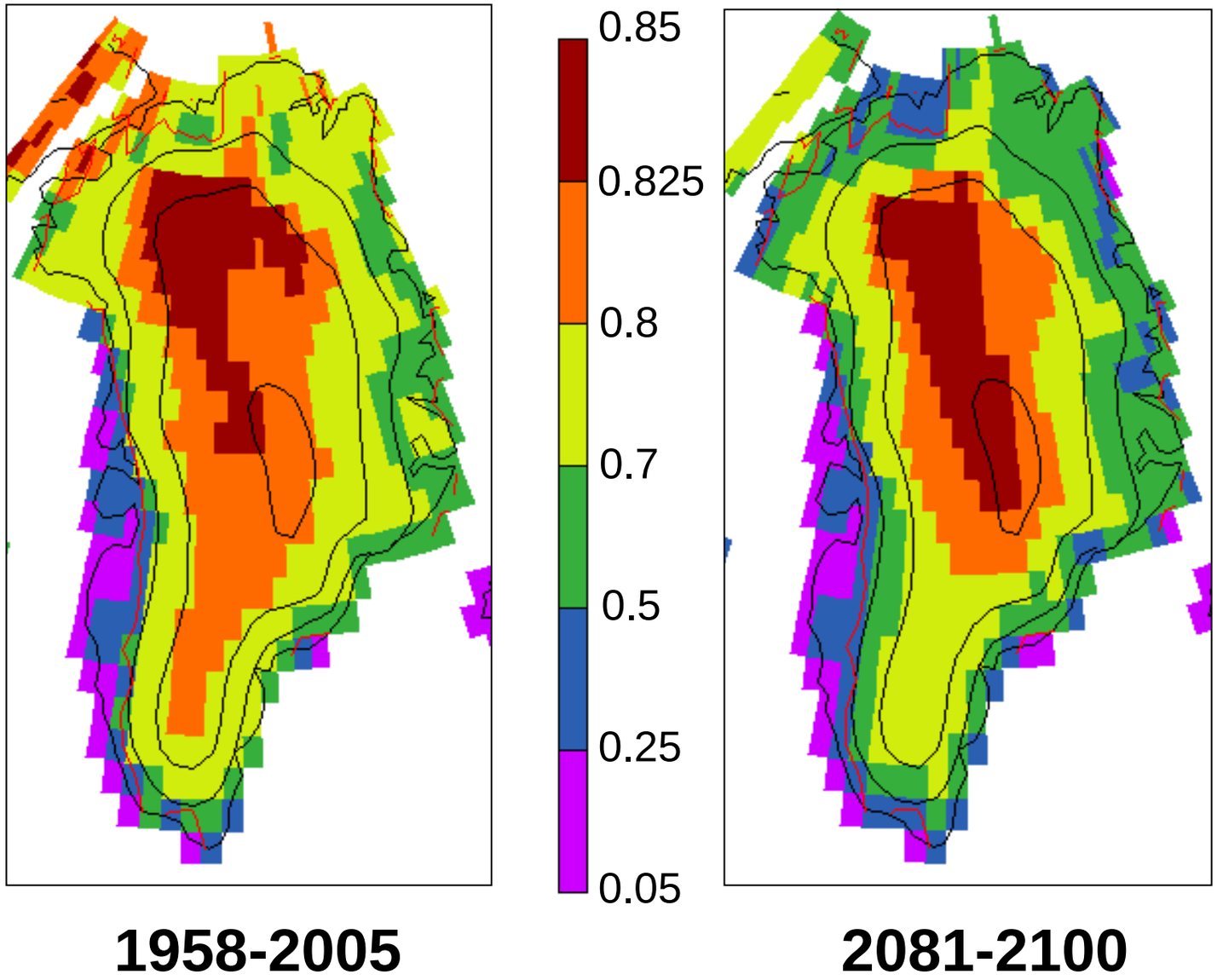


1. CLM with MOAR forcing ➔ b) 21st century SMB

21st century runs: note of caution

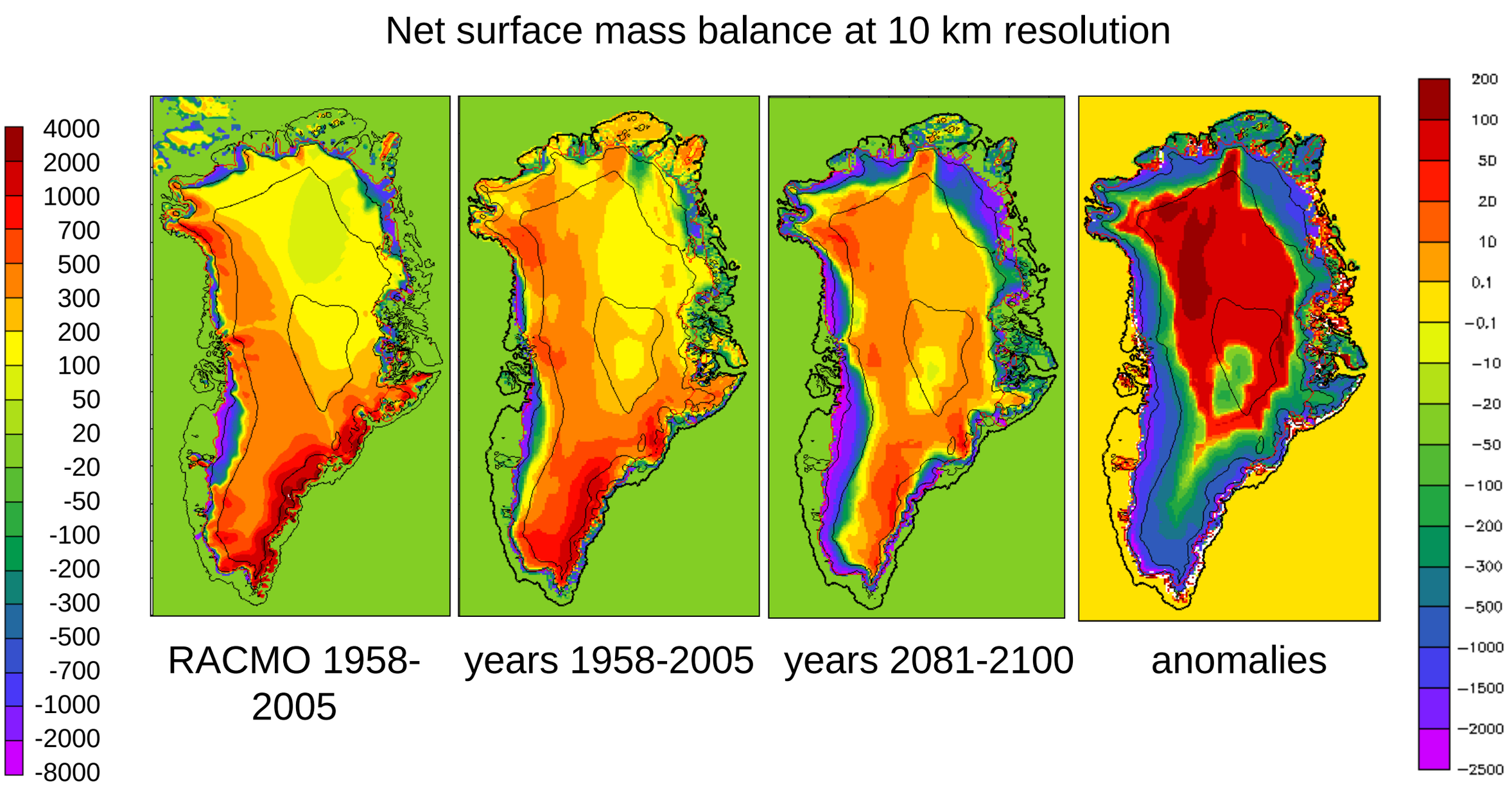
- Ice dynamics are off.
- Here we focus only on surface mass balance change (currently half of mass loss is due to glacier calving)
- **no SMB-height feedback** (increase of melt with decreasing elevation)!

July albedo (RCP8.5)



1. CLM with MOAR forcing ➔ b) 21st century SMB

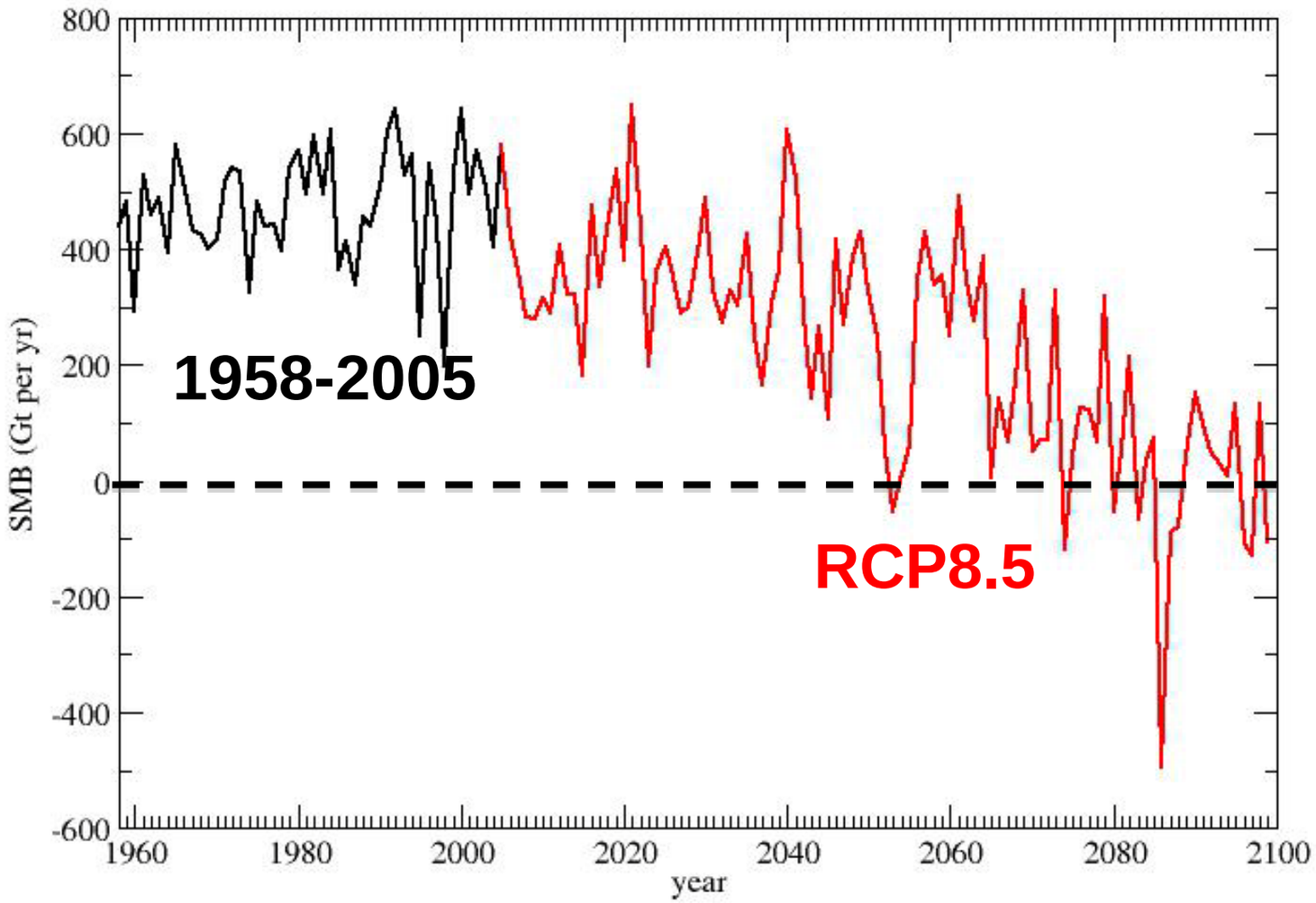
Surface mass balance RCP8.5 (kg m^{-2})



1. CLM with MOAR forcing ➔ b) 21st century SMB

SMB time evolution

Time series of downscaled (10 km) net surface mass balance [Gt yr^{-1}] integrated over Greenland ice sheet



1. CLM with MOAR forcing ➔ b) 21st century SMB

Total SMB, FV1 grid (ice sheet + glaciers)

Surface mass balance terms integrated over ice sheet and ice caps [Gt yr^{-1}]. Total area is 2.019 x 10^6 km^2. RACMO values (*Ettema et al., GRL, 2009*) are listed for the sake of validation. Stds are given in parenthesis

Variable	**RACMO 1958-2005**	**1958-2005**	**2081-2100**
Precip	743 (78)	974 (105)	**1275 (81)**
Rain & rain frac	46 0.06	136 (26) 0.14	**321 (41)** **0.25**
Sublim	26 (3)	66 (4)	**81 (4)**
SMB	469 (107)	380 (125)	**-424 (225)**

1. CLM with MOAR forcing ➔ b) 21st century SMB

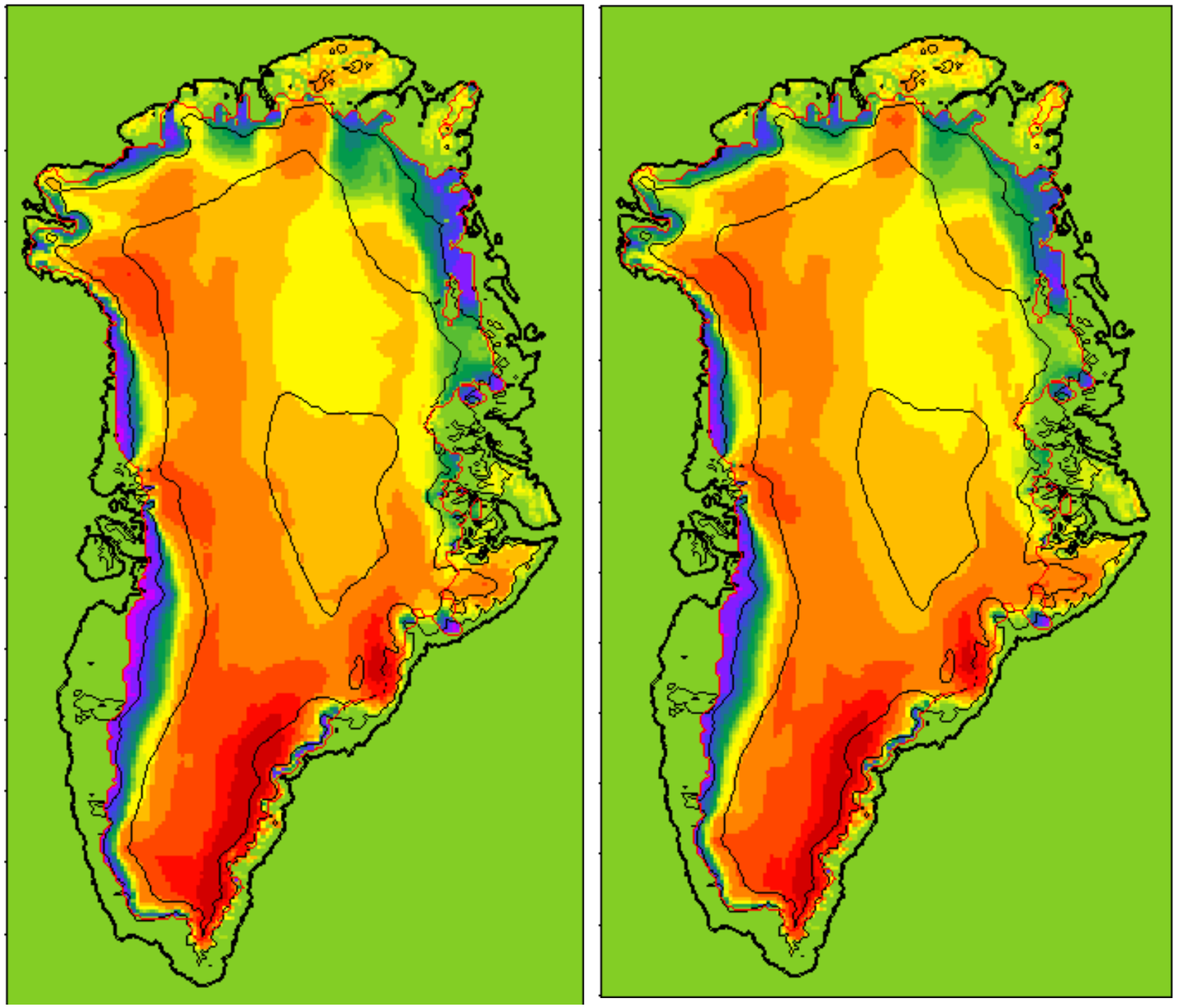
Summary

- We present results from simulations with the land model of the Community Earth System Modelled forced with a data atmosphere from a previous CESM run for the 21st century (2005-2100, RCP8.5). The Greenland surface mass balance is downscaled to 10 km resolution at the heights given by *Bamber et al. (2001)*. A simulation with the same setup but forced with 20th century data from CESM is used as reference for 21st century climate change.
- By the end of the 21st century, ablation has increased with similar magnitude **at all margins**. The equilibrium line has moved **to 2000 m** at all margins except the NW, where its height is close to 1500 m.
- Precipitation rates over glaciated areas of Greenland increase **by 31%** from 1958-2005 to 2081-2100. The annual rain fraction increases from 14% to 25%.
- The increase in near-surface temperatures is highest in the interior of the ice sheet (~6 K above 2000 m). Areas at elevations between 1000 and 2000 m are warmer by ~4.5 K, and below 1000 m, by ~3 K.
- Outlook: Simulations will be repeated with the coupled atmosphere-ocean-land model

Ice albedo sensitivity

- Increasing ice albedo does not change much the width of ablation areas, because it depends on whether the snowpack is melted (depends primarily on snow albedo)
- It reduces melting at the highest melting areas, because they have long ablation season

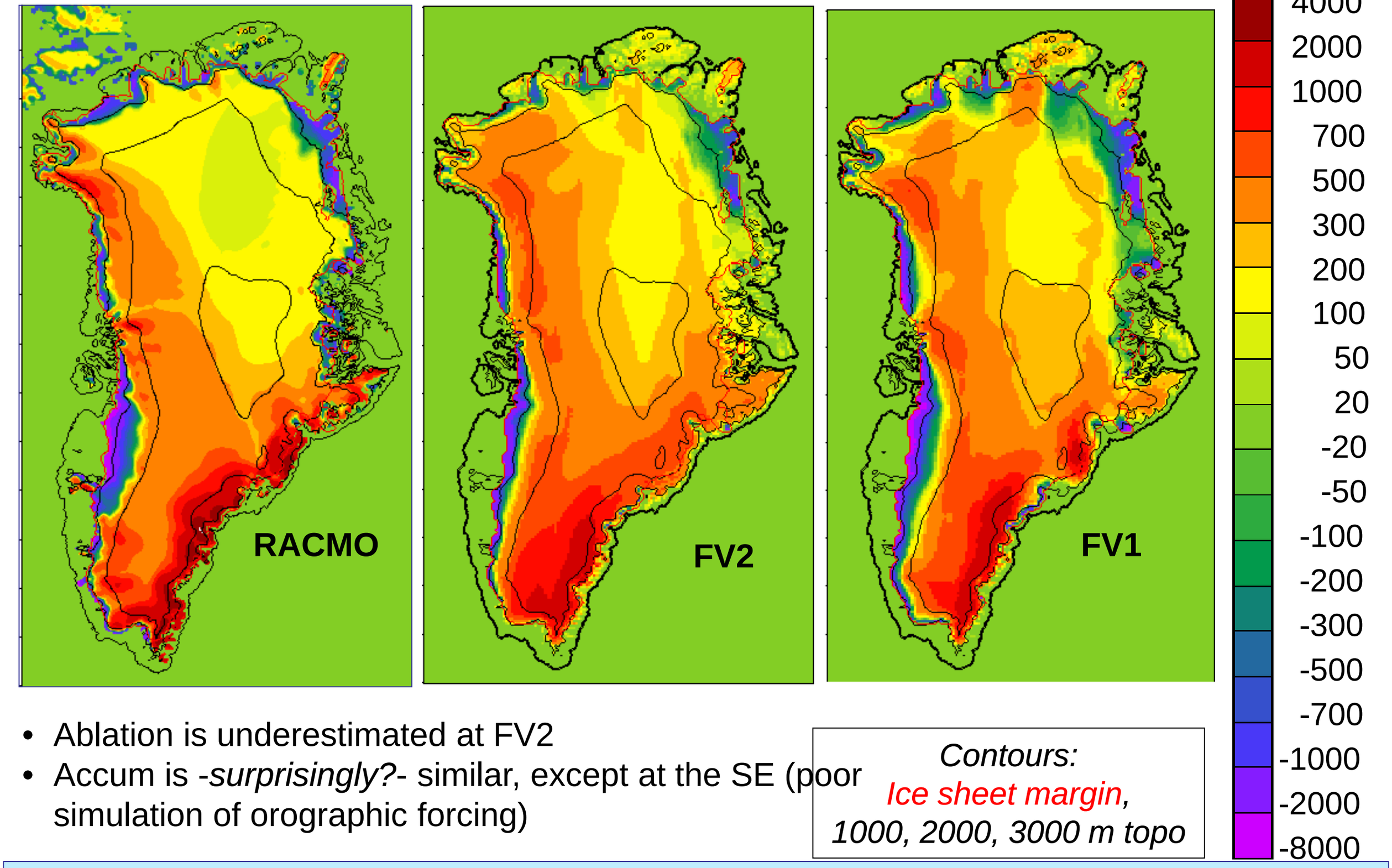
Contours:
Ice sheet margin,
1000, 2000, 3000 m topo



alb_{vis}=0.60
alb_{nearIR}= 0.40

alb_{vis}=0.75
alb_{nearIR}= 0.50

Sensitivity to resolution: BG2000 FV1 vs FV2



- Ablation is underestimated at FV2
- Accum is -*surprisingly?*- similar, except at the SE (poor simulation of orographic forcing)

Contours:
Ice sheet margin,
1000, 2000, 3000 m topo

Net SMB at 10 km resolution (kg m^{-2})

	2000-climate
FV1	**361 (79)**
FV2	**509 (67)**
FV1 high albedo (0.75/0.50)	**386 (98)**

For comparison, these numbers for pre-industrial SMB

Variable	10 km grid	Pre-ind CCSM4 FV1/FV1	Pre-ind CCSM4 FV1/FV2	RACMO	Other reg models (*)
SMB	**380 (97)**	429 (121)	315 (132)	469 (107)	288/356/287
Area (10^6 km^2)	**1.685**	2.131/2.019			

2. Sensitivity tests (year 2000 climate, full model) ➔ Summary

Conclusions

- Climate and SMB compares well to state-of-the-art regional model RACMO
- Main biases possibly due to biased glacier mask
- First 21st century runs (only SMB) show increase of ELA height to 2000 m & SMB < 0 by end of century
- Relatively high sensitivity to model resolution
- Relatively low sensitivity to choice of ice albedo

Ongoing work

- Improved glacier mask from Bamber et al.
- Spin-up of BG1850CN run (reference CMIP run)
- Next: CMIP runs (whole model with glacier elevation classes and carbon cycle)
  - 20th century
  - 21st century

3. Conclusions