An Evaluation of the Present Day Surface Energy and Mass Balance over Greenland Ice Sheet in GEOS-5

Bin Zhao, Richard Cullather, Sophie Nowicki, Max Suarez

Global Modeling and Assimilation Office, NASA Goddard Space Flight Center

CESM Landice Working Group Meeting Feb, 2013

Overall Project Objective

" Investigate the sensitivity and feedbacks of the atmosphere-ocean-cryosphere coupled system, along with its impact on the climate, ice sheet and sea-level evolutions."

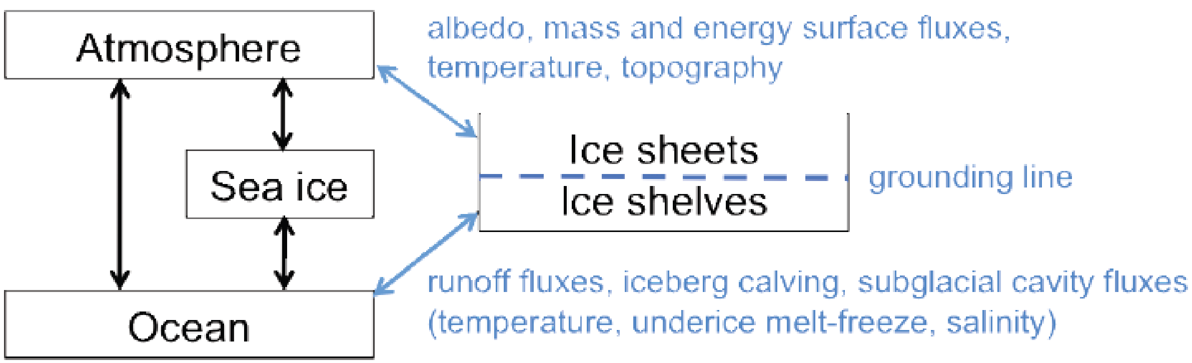


Figure 1: Schematic diagram of a two-way coupling between the atmosphere, ocean, ice sheets and ice shelves. Information flow is indicated by arrows. We propose to address processes in blue.

Ice Sheet Surface Parameterization in GCMs

- RCMs for Greenland and Antarctic feature highly detailed snow/firn physics (RACMO, MAR etc.) and high resolution

- GCMs typically represent snow in a much simplified way: fixed density, fixed depth, fixed albedo, no refreezing …
  and resolution too coarse to resolve the narrow ablation zones

CESM certainly is an exception, other models start to catch up (e.g., LMDZ/IPSL)

- Dynamic ice sheet models need realistic surface temperature and mass balance as forcing

- Ocean and sea ice components need a better constrained freshwater input from parameterized ice sheet surface processes

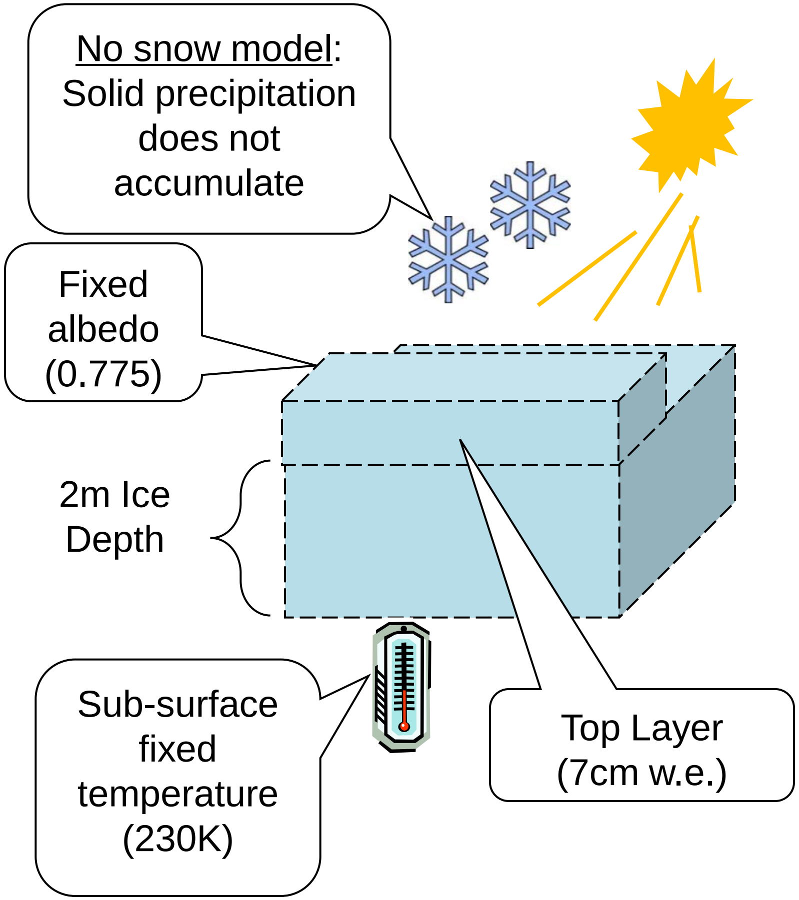
GEOS-5 GCM

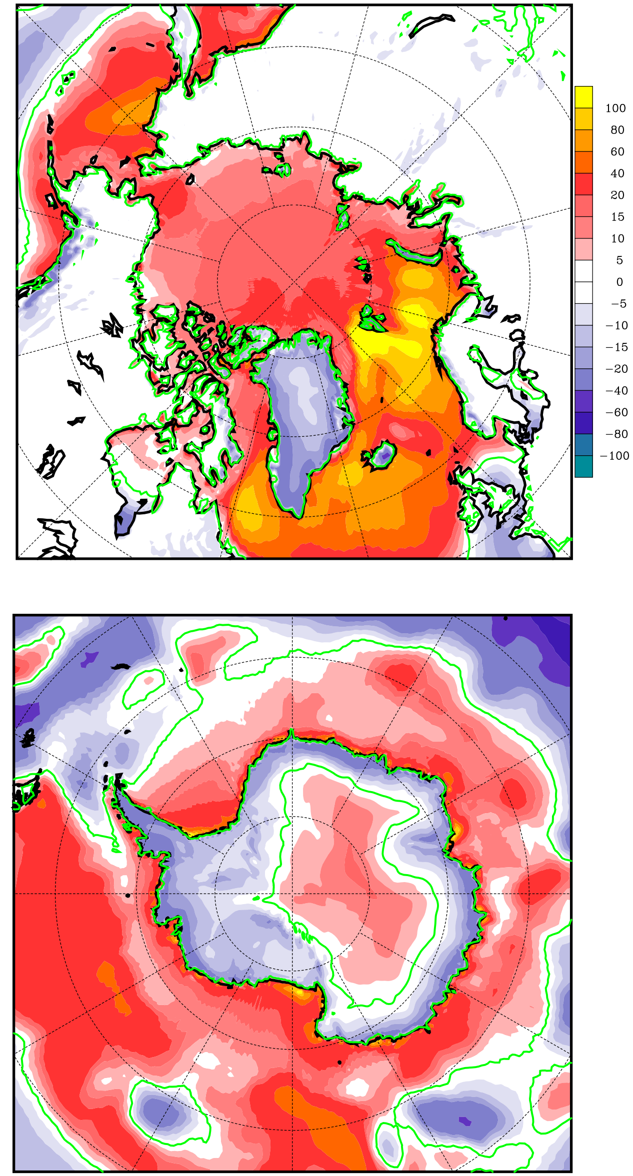
- Finite volume dynamical core on latlon and cubedsphere grid
- Physics parameterization (Molod et al. 2012) includes schemes for atmospheric convection, large scale precipitation and cloud cover, longwave and shortwave radiation, turbulence, gravity wave drag

- Land surface is a catchment-based hydrologic model (Koster et al., 2000) coupled to a sophisticated multi-layer snow scheme (Stieglitz et al., 2001)

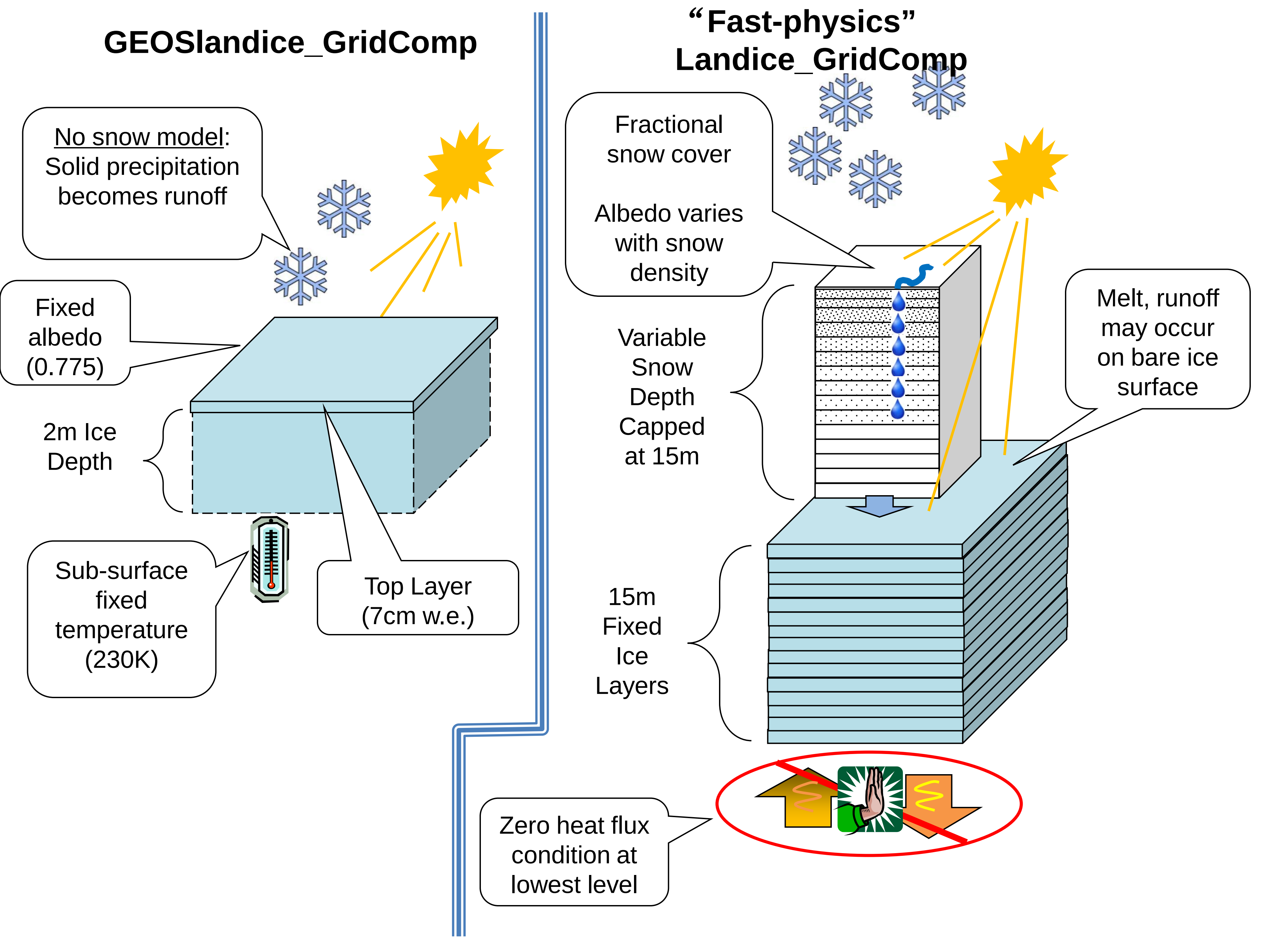
- Previous versions used as part of MERRA (Modern-Era Retrospective Analysis for Research and Applications, Rienecker, et al., 2011)
- Used for both operational forecasts and climate (decadal) runs
- Standard resolutions at 2-, 1-, 0.5- and 0.25-deg and 72 levels
- Coupled to GFDL MOM4/5 and CICE4

GEOS5 Landice GridComp

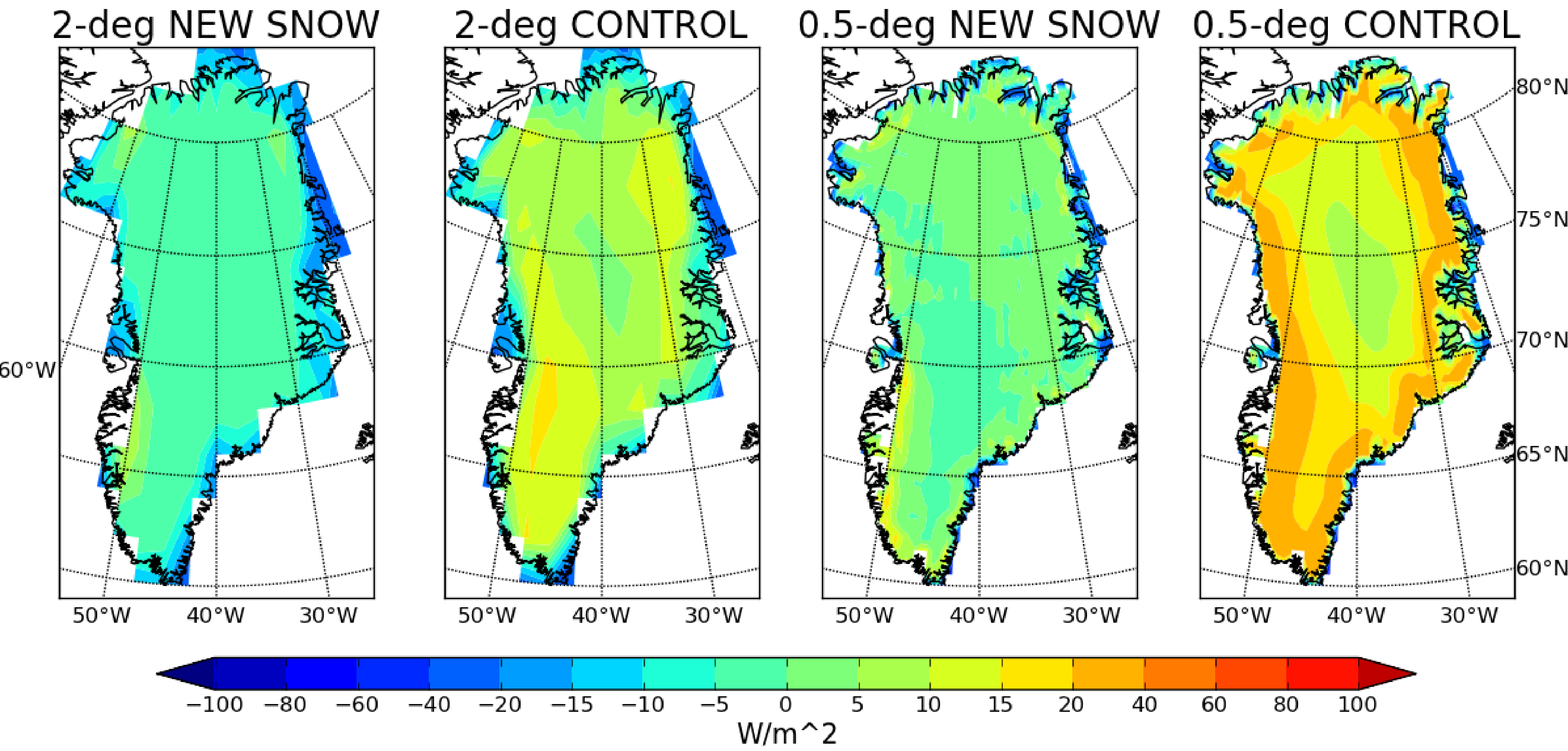




Annual average net surface heat flux from MERRA (Cullather et al. 2011)

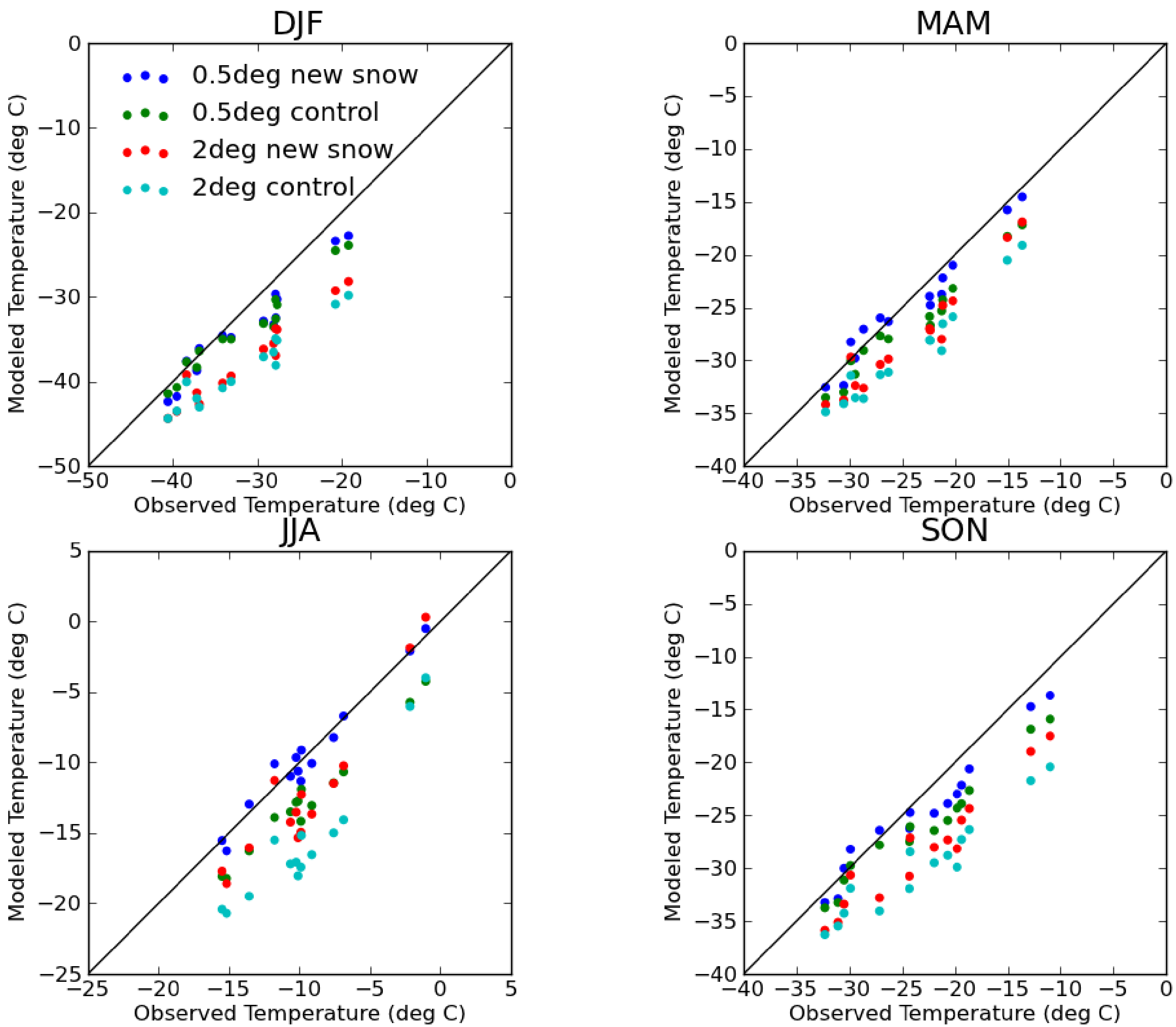

GEOSlandice_GridComp
"Fast-physics" Landice_GridComp
No snow model: Solid precipitation becomes runoff
Fixed albedo (0.775)
2m Ice Depth
Sub-surface fixed temperature (230K)
Top Layer (7cm w.e.)
Fractional snow cover
Albedo varies with snow density
Variable Snow Depth Capped at 15m
Melt, runoff may occur on bare ice surface
15m Fixed Ice Layers
Zero heat flux condition at lowest level

Annual average net surface heat flux

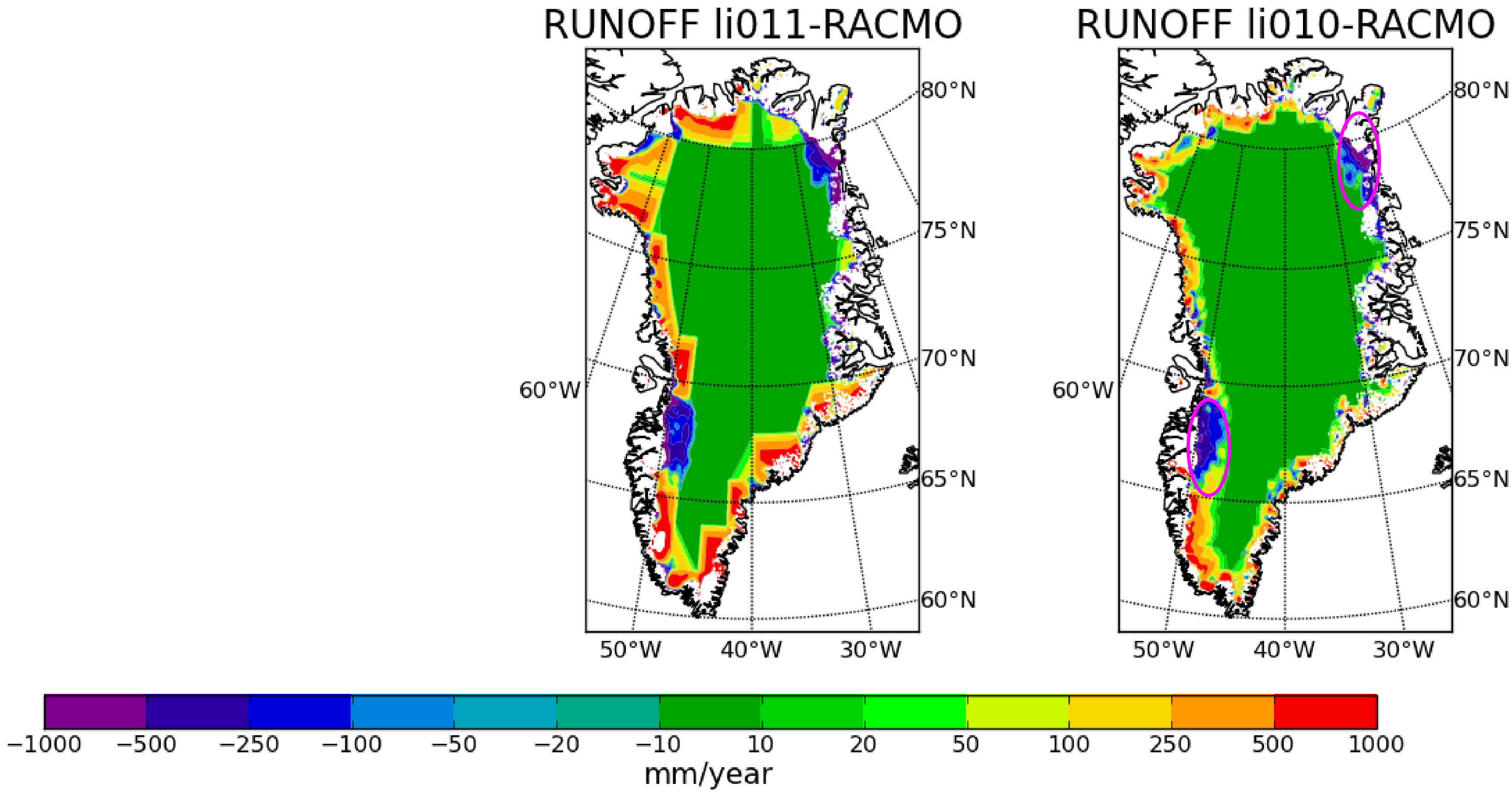


- Surface heat flux bias eliminated

Near-surface air temperature

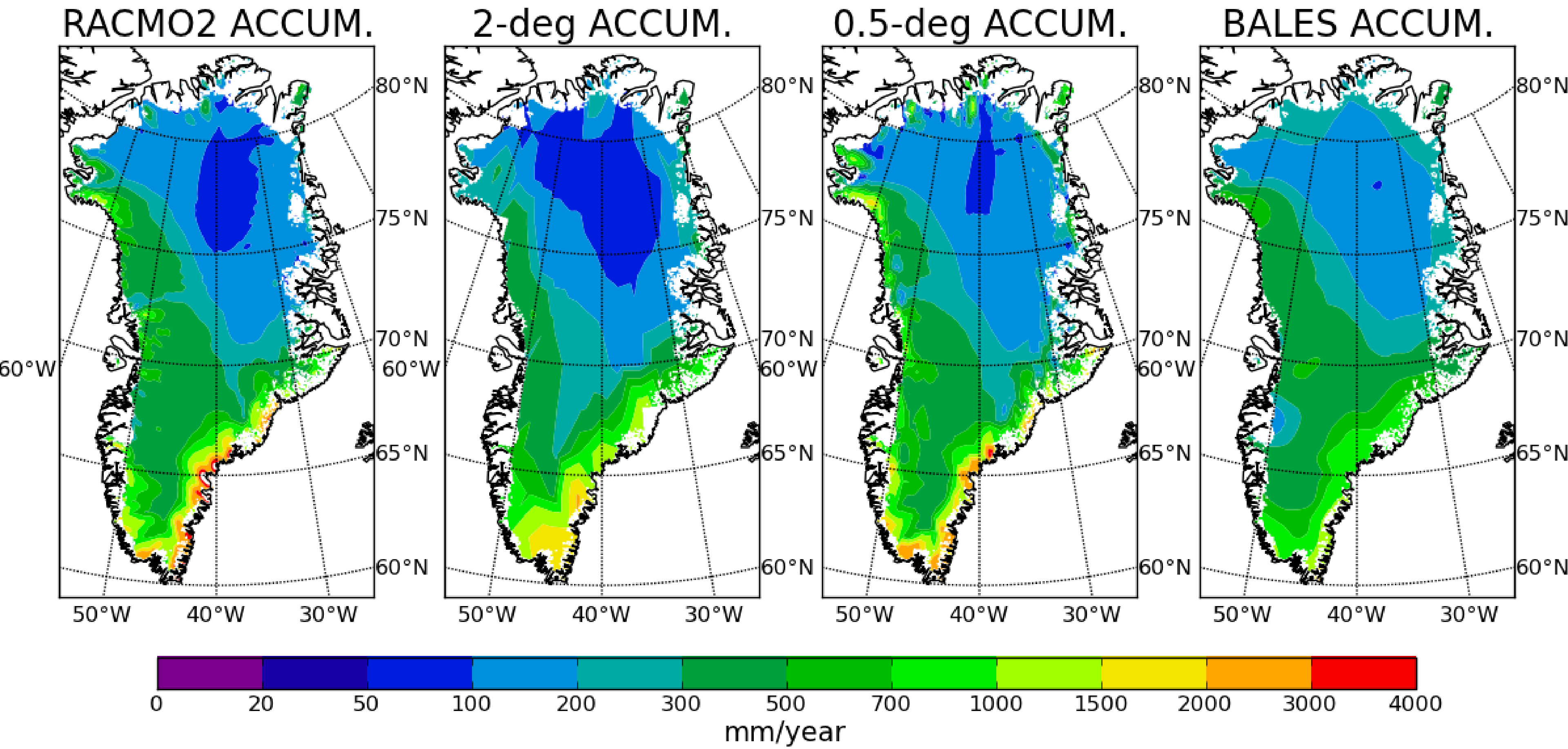


* Observations from GC-Net



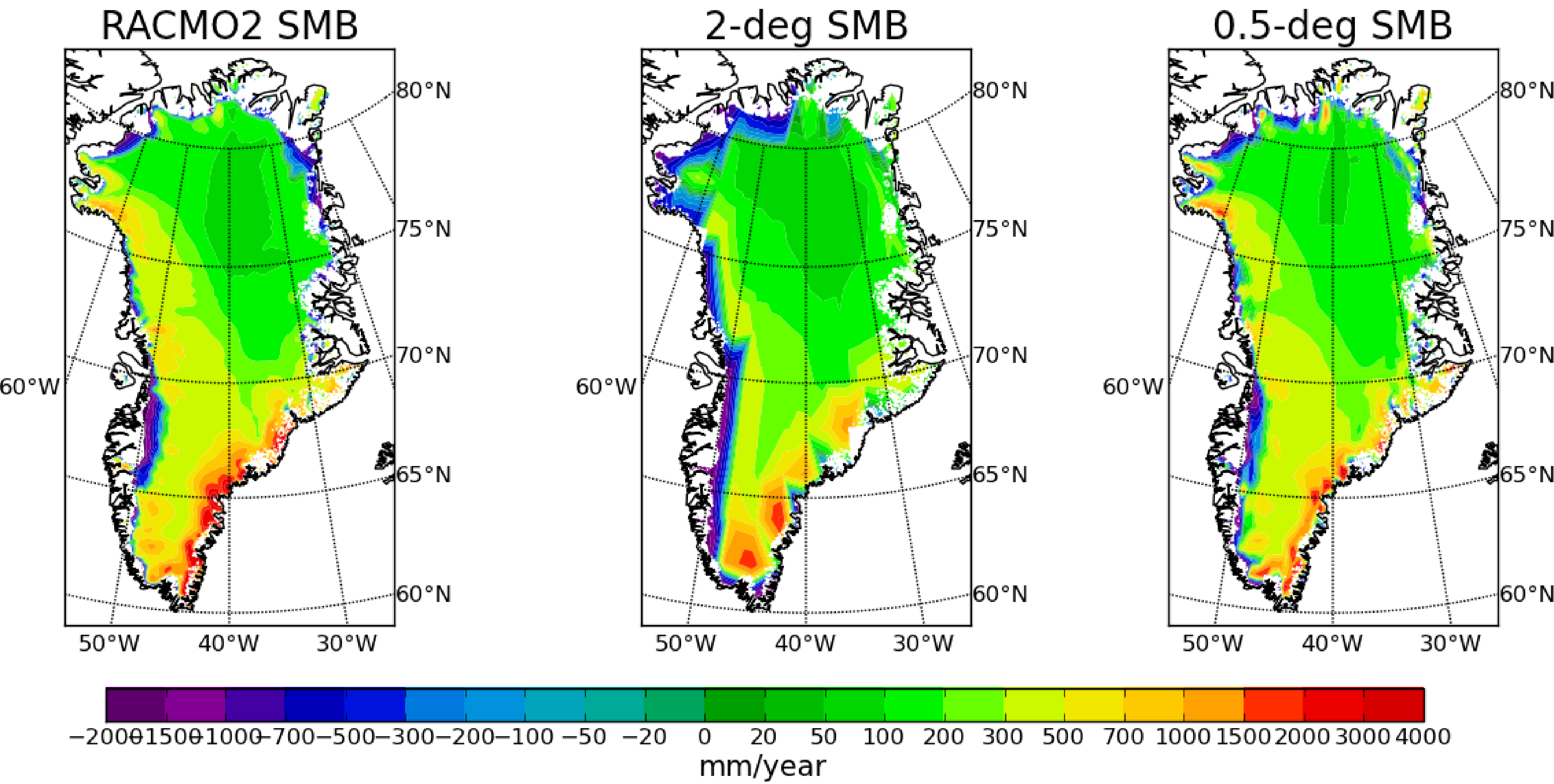
- Runoff over most of the ablation zone overestimated relative to RCM, except portions over the northeast and southwest with enough resolutions
- Overestimation may be related to inadequate liquid water holding/refreezing capability

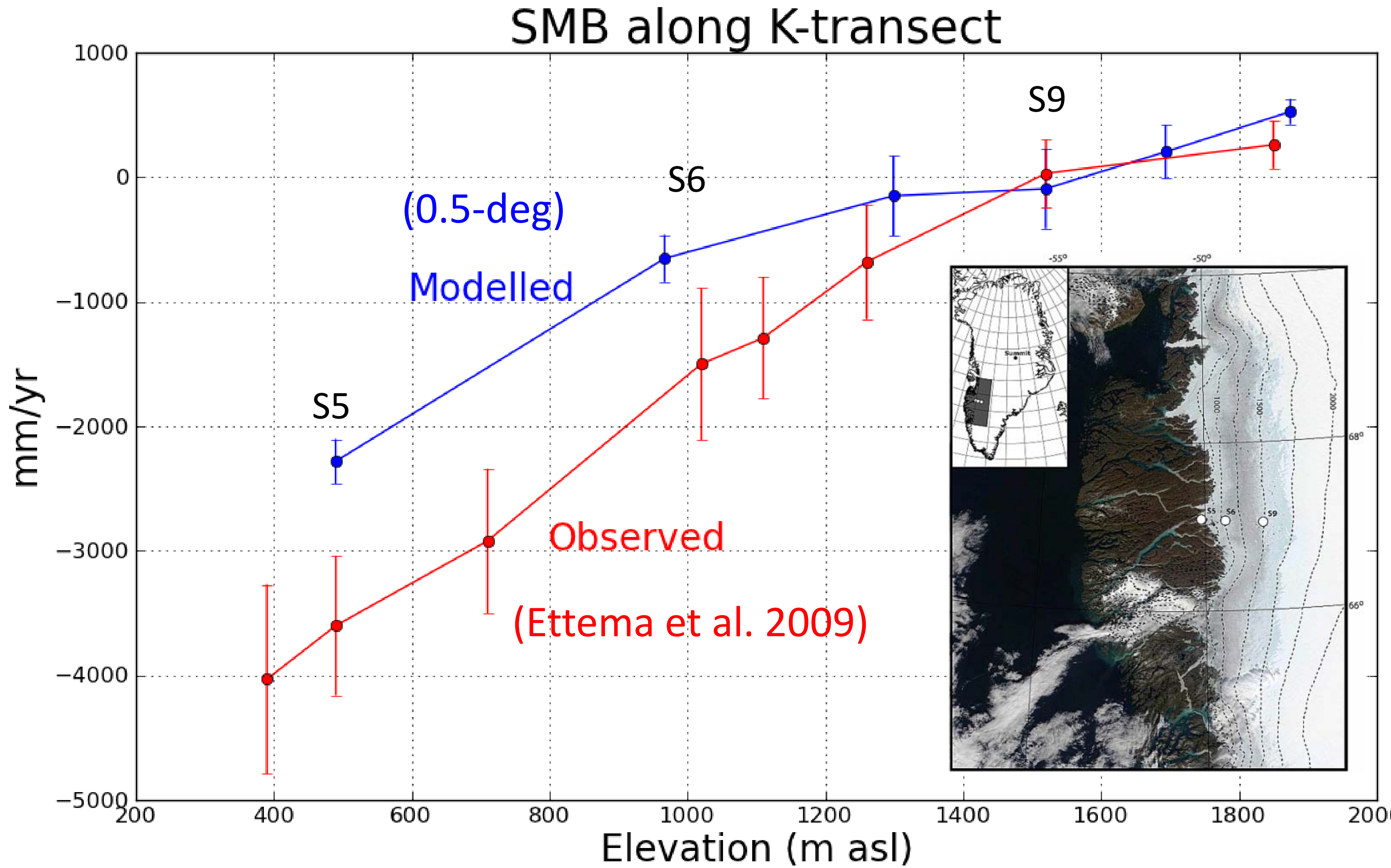
Annual Mean Accumulation



- GEOS5 agrees more with the RCM than ice core data
- Peak accumulation in the southeast/northwest margin is only captured in high-resolution

Annual Mean SMB





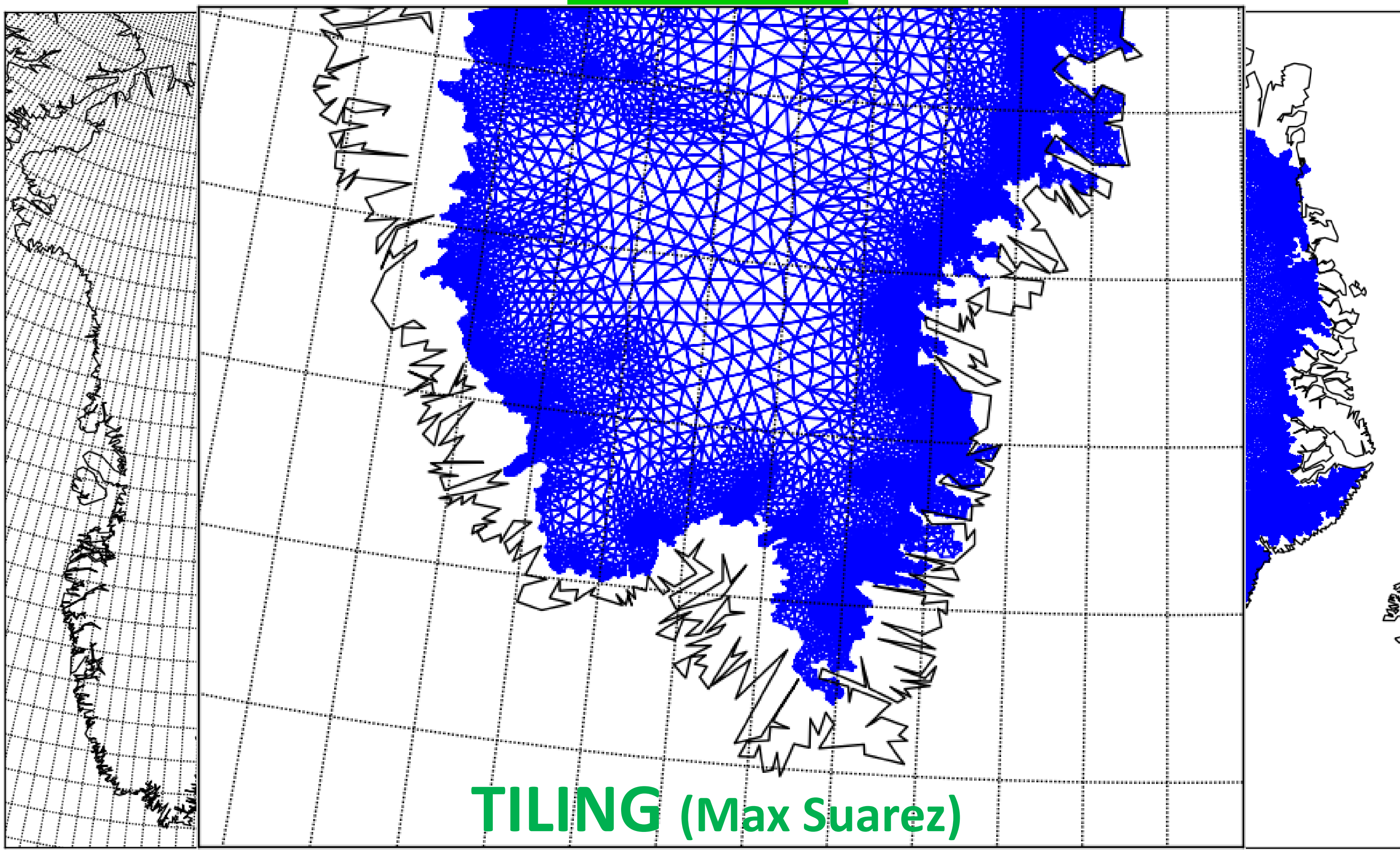
SMB along K-transect
1000
0
−1000
−2000
−3000
−4000
−5000
mm/yr
200
400
600
800
1000
1200
1400
1600
1800
2000
Elevation (m asl)
S5
S6
S9
(0.5-deg)
Modelled
Observed
(Ettema et al. 2009)
Summit

GrIS Area in SeaRise grid (5km)
1.771 x10^6 km^2

	Runoff (GT/yr) Model grid	Runoff (GT/yr) SeaRise Grid(5km)	Accum. (GT/yr) Model grid	Accum. (GT/yr) SeaRise grid (5km)	SMB (GT/yr) SeaRise grid (5km)	GrIS Area (10^6 km^2)
GEOS5 2-deg	460	409	748	629	220	1.993
GEOS5 0.5-deg	500	334	860	728	394	1.996
RACMO 11km	248	241	717	706	465	1.711
MAR 25km	178(248)		636(611)		455(359)	1.701
PMM5 24km	232				170	1.691
ERA40 5km	248				324	1.678

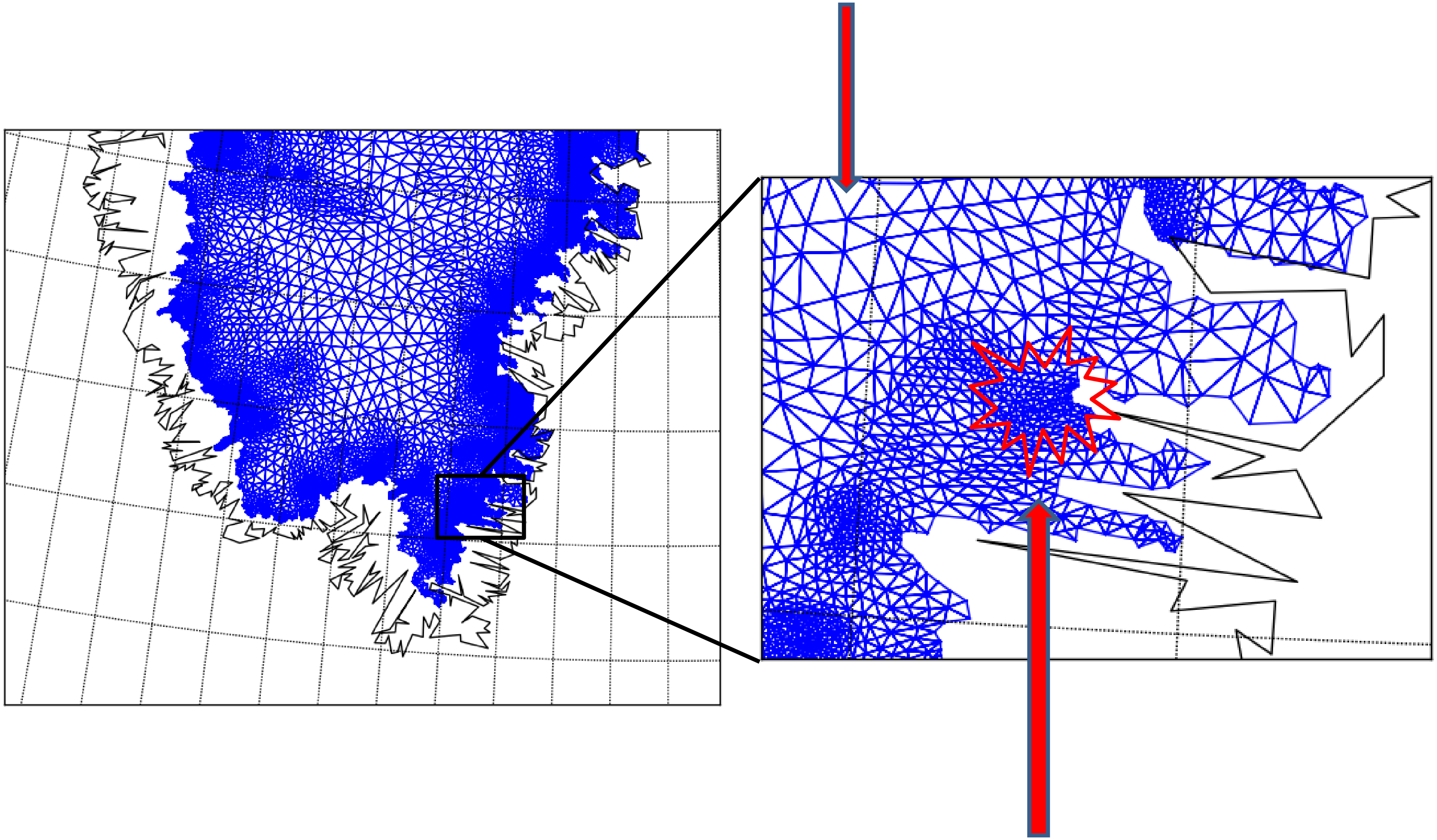
Dynamical Ice Sheet Model (ISM) Coupling With GEOS-5

Strategies



* Courtesy of Eric Larour

“Fast Physics” ESMF Landice Component



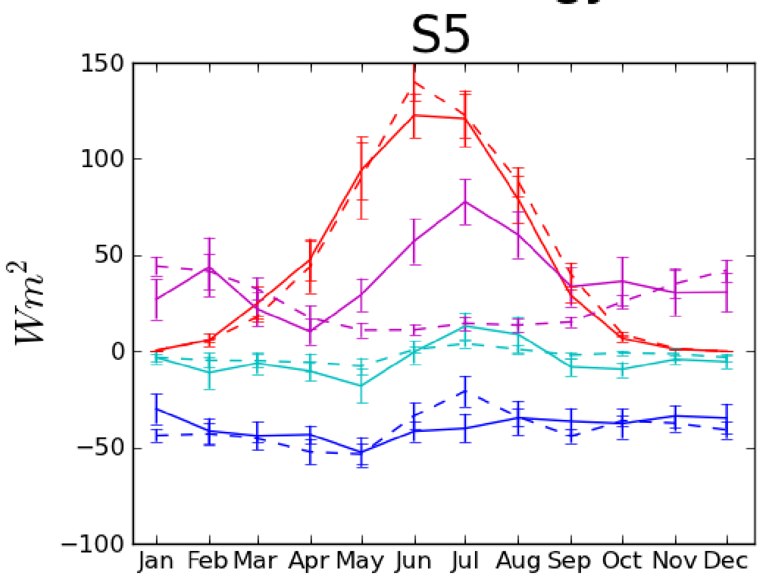
Aggregation!

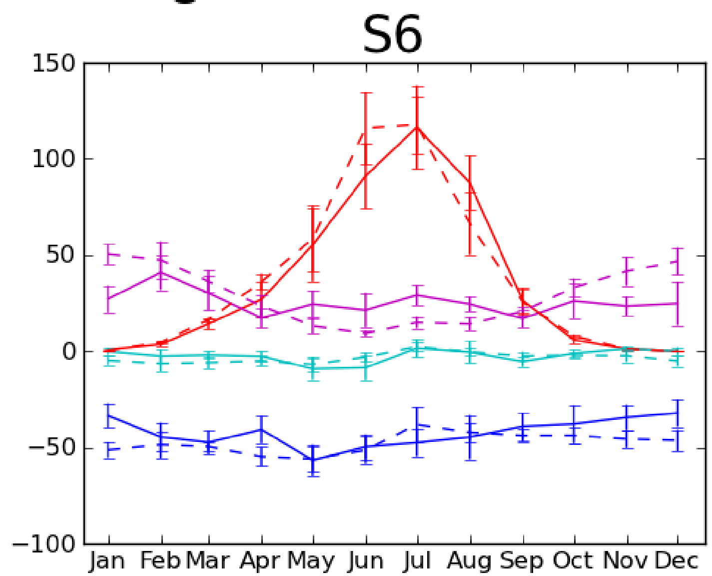
proximity, elevation

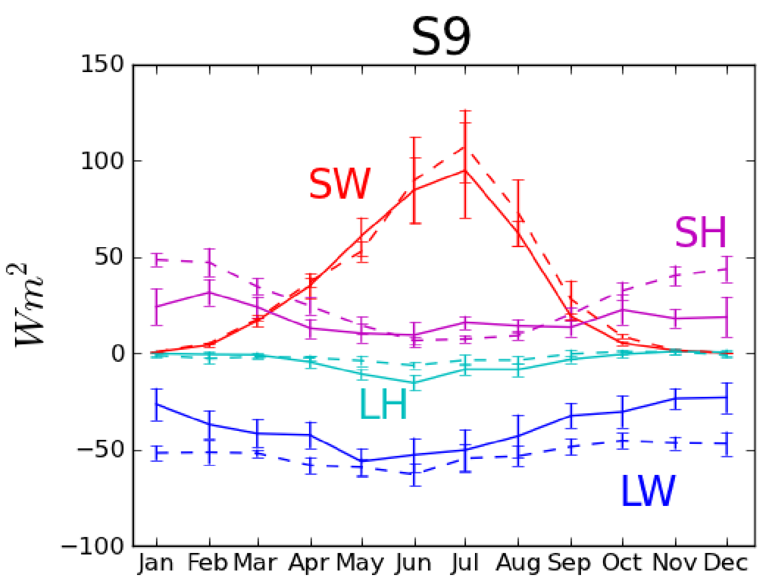
Summary

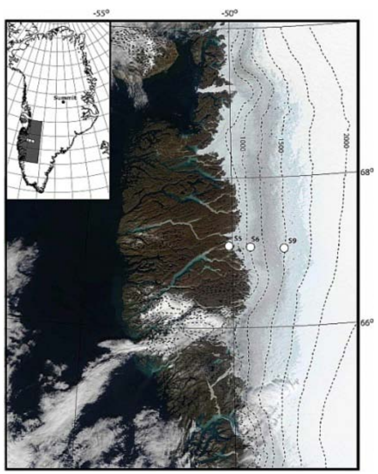
- A multi-layer physically-based snow scheme coupled to the ice sheet surface improves the surface energy balance and temperature
- GEOS-5 produces a lower SMB than RCMs due to higher ablation; getting to higher resolutions tend to increase accumulation
- Where GCM resolutions adequately resolve ablation zones, detailed physical processes (turbulent exchange, albedo, local precip. etc.) are important to the net SMB
- A tiling scheme is planned for coupling to dynamical ice sheet models

Surface Energy Fluxes along K-Transect









* Data from Michiel van den Broeke

Sensible heat flux underestimated at S5 during summer months

Annual Mean Accumulation Difference