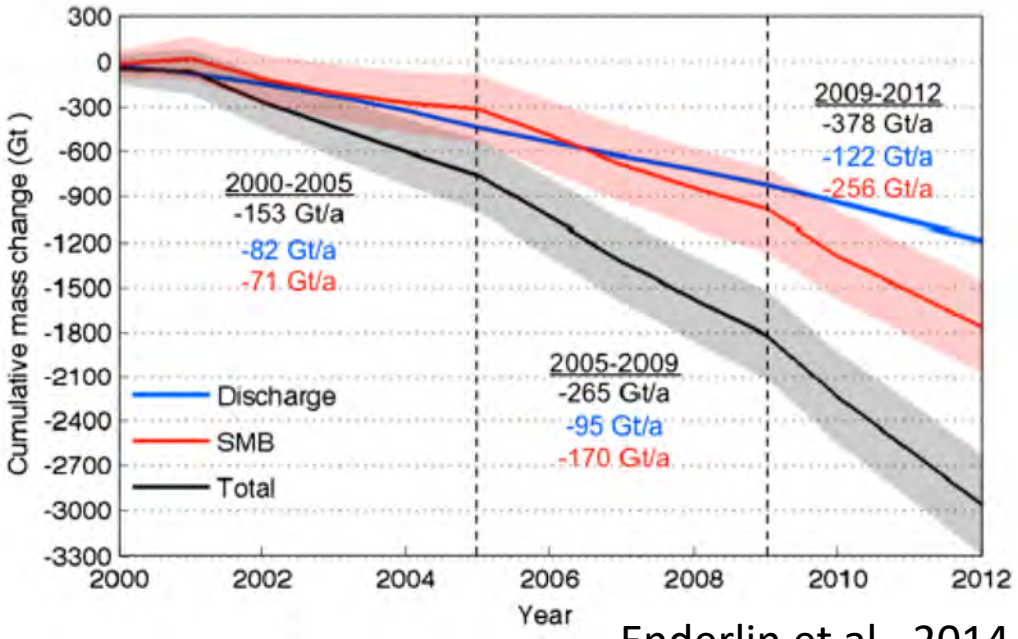
Lessons learned from coupling ice sheet models to Earth system models

Greenland mass loss



Enderlin et al., 2014

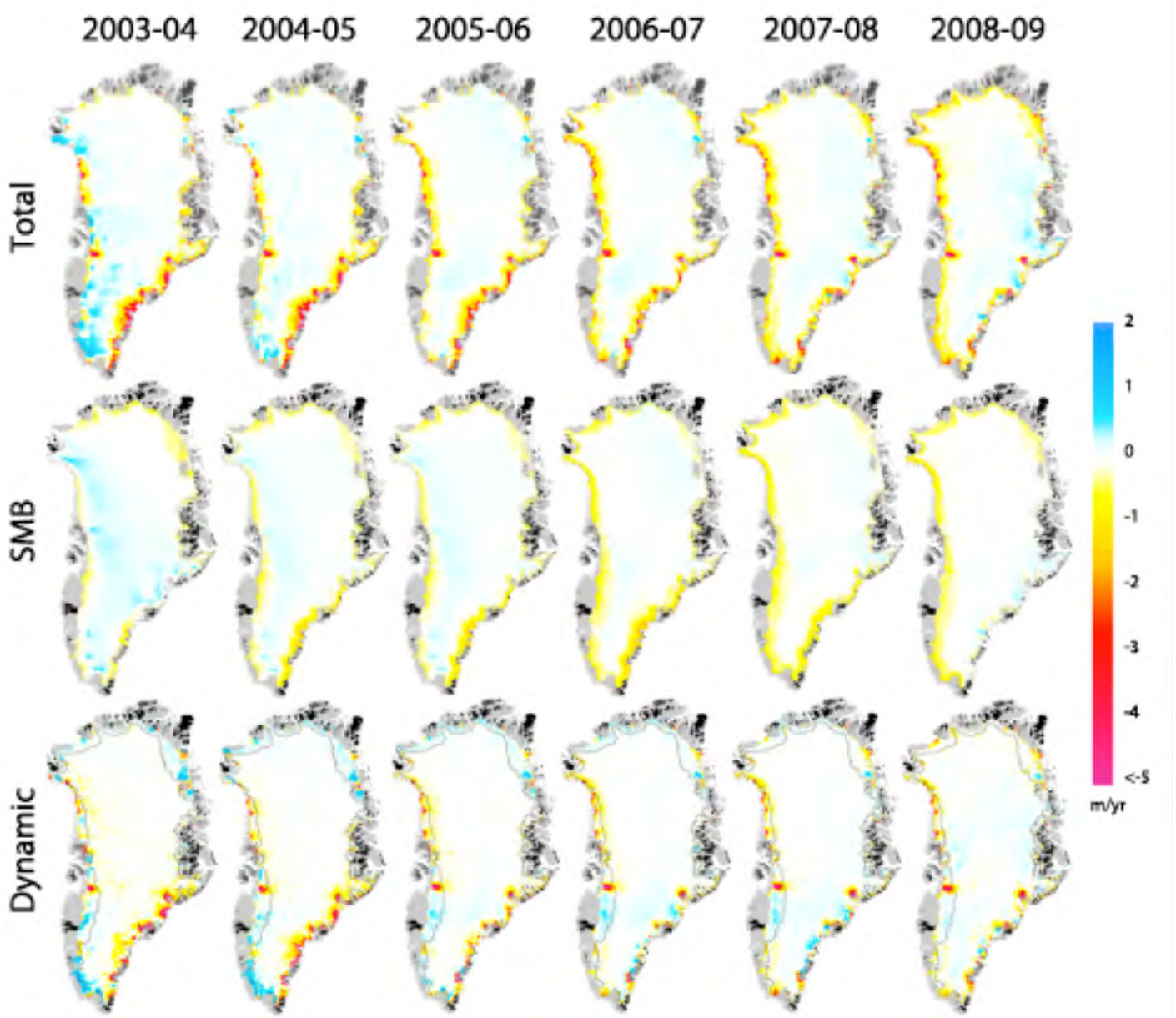
Sophie Nowicki, NASA GSFC

and many conversations with

R. Cullather, B. Zhao, E. Fischer and ISMIP6 participants

The Future of Earth System Modeling: Polar Climates, 11/28/2018

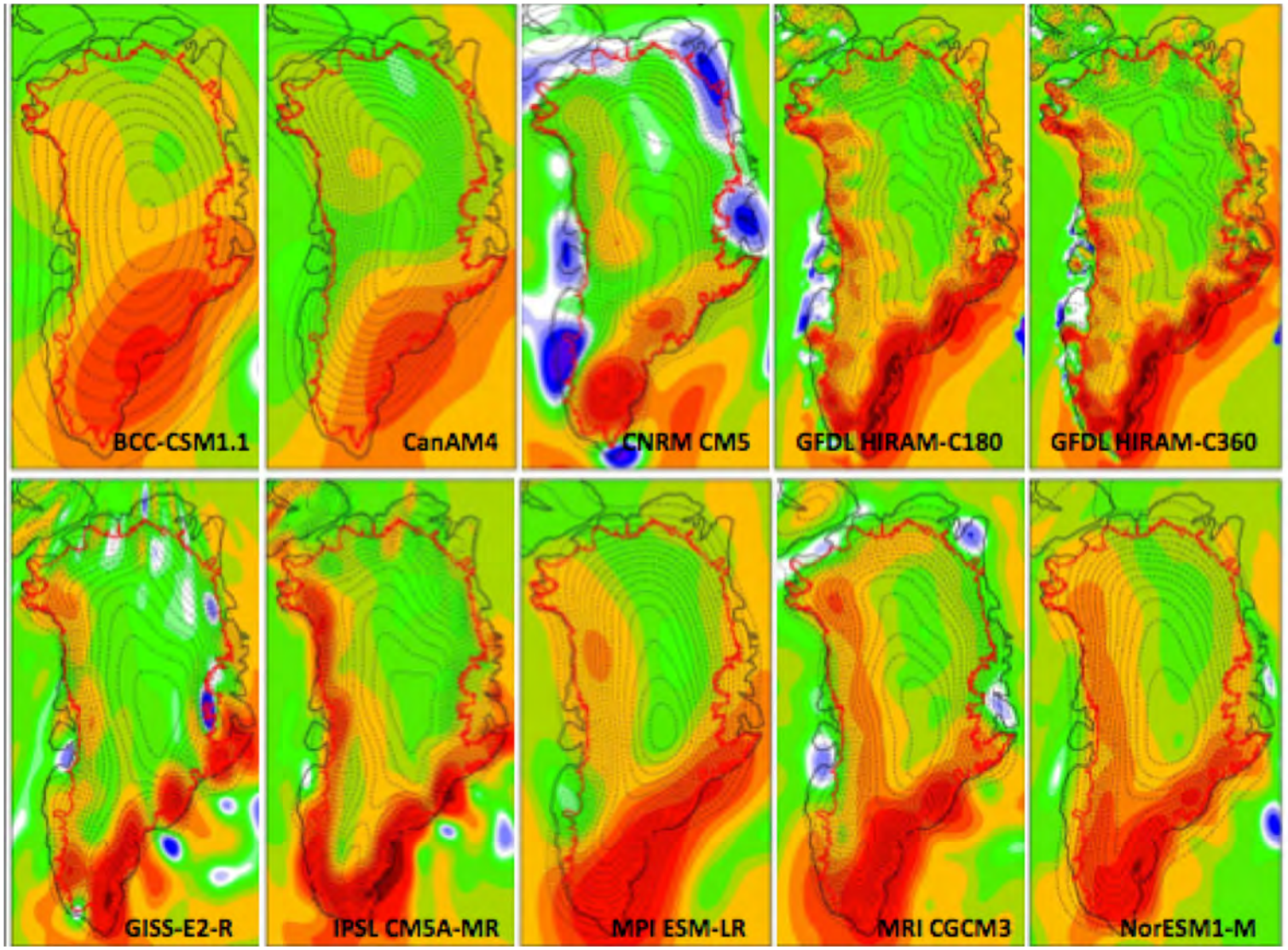
A lot of the action occurs at the margins of the ice sheets…

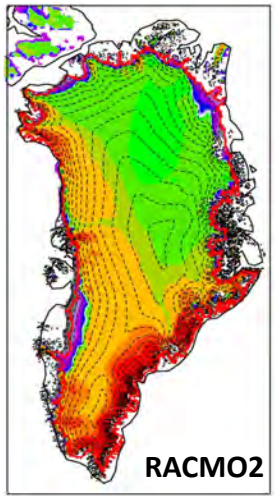


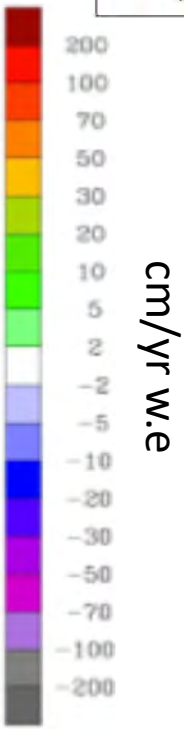
Csatho et al., 2014

What would a typical CMIP5 model give you...

Surface Mass Balance from CMIP5 AMIP (1980-2008)

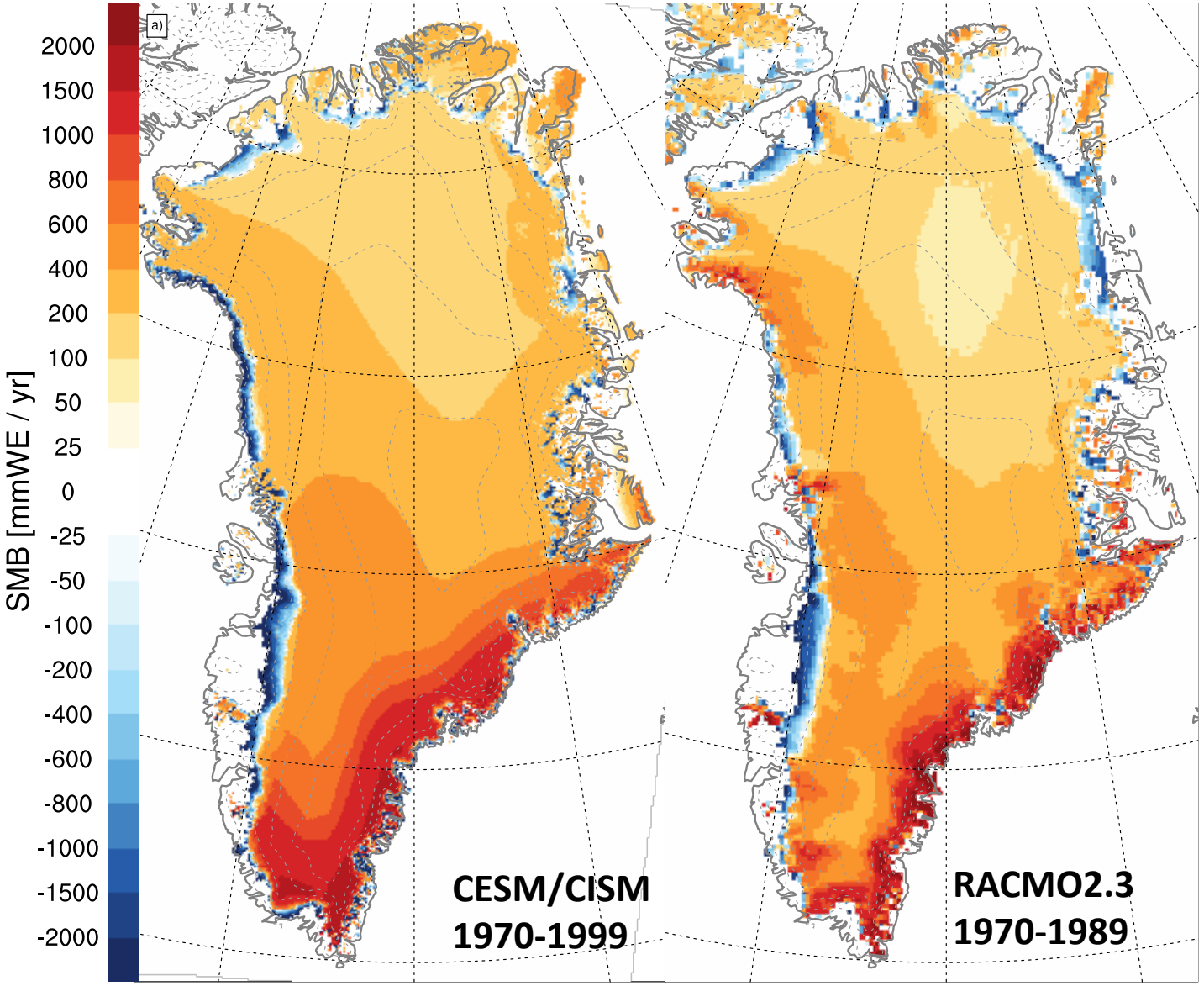






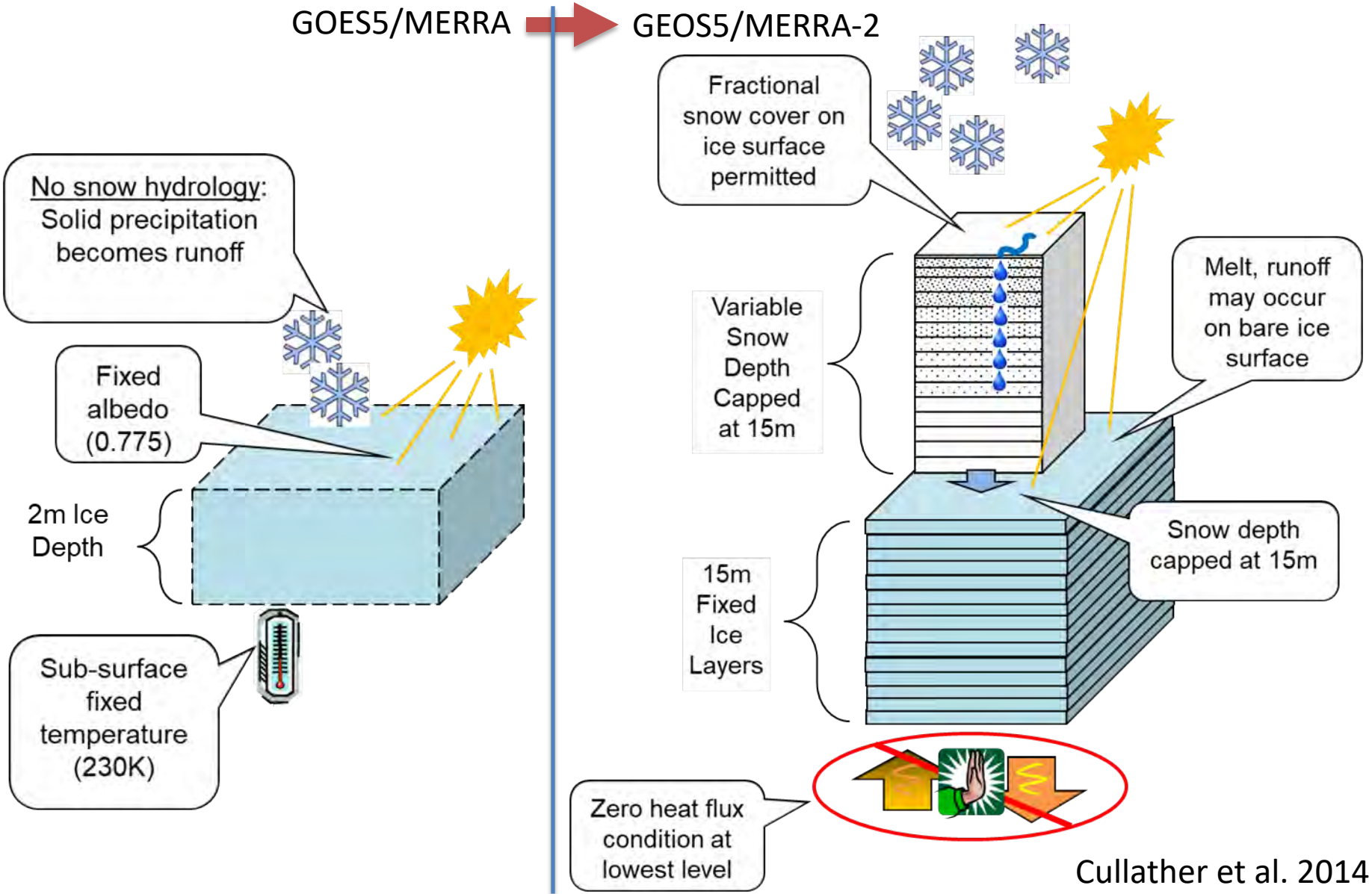
Slide courtesy of R. Cullather

Climate models are improving over the polar regions: SMB as simulated by the Community Earth System Model…



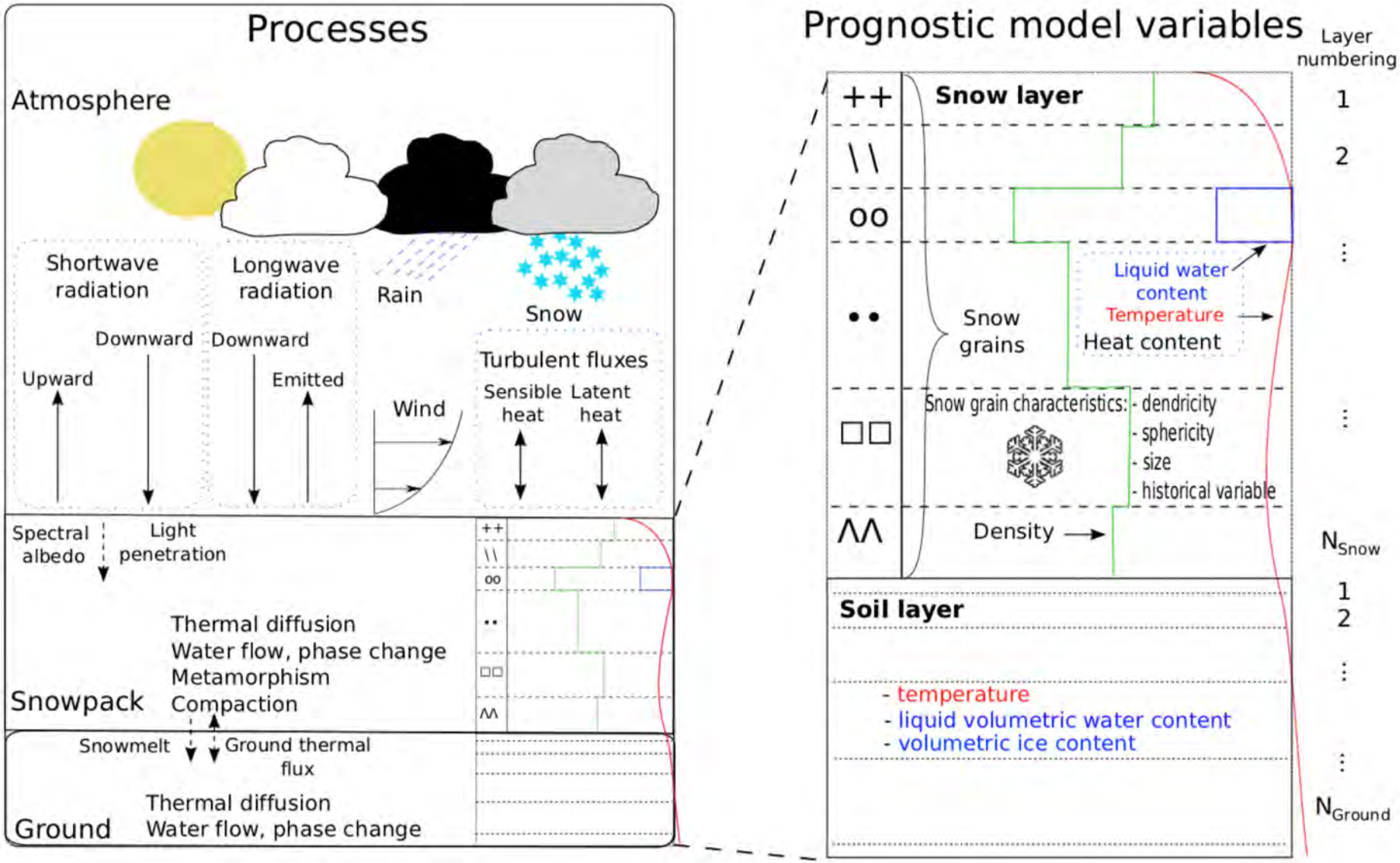
Slide courtesy of L. van Kampenhout

As ice sheets are being coupled to climate models, one of the first step is to improve the SMB models…



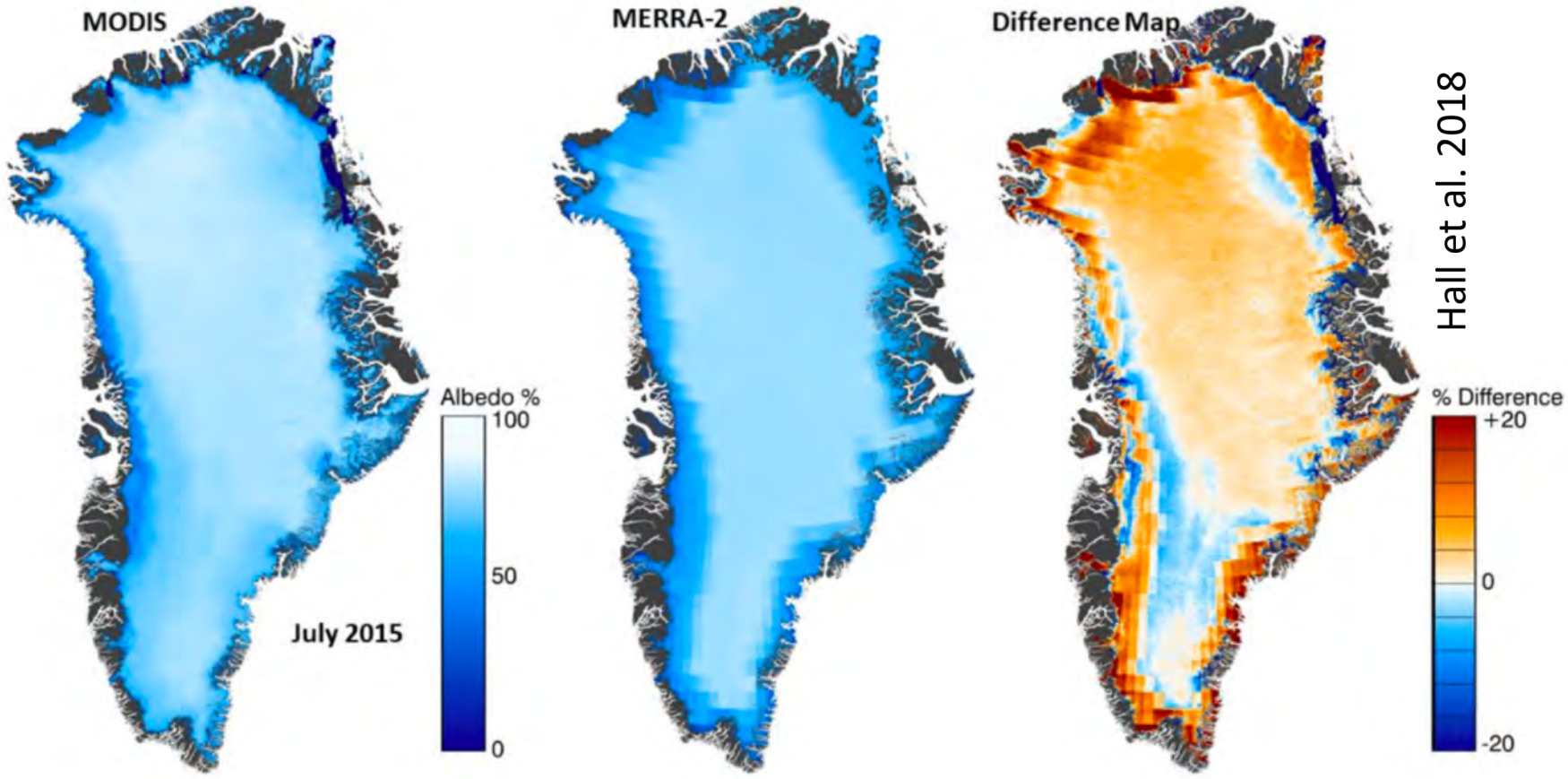
Cullather et al. 2014

More fancy snowpack models include the Crocus snowpack model…



Vionnet et al. 2012

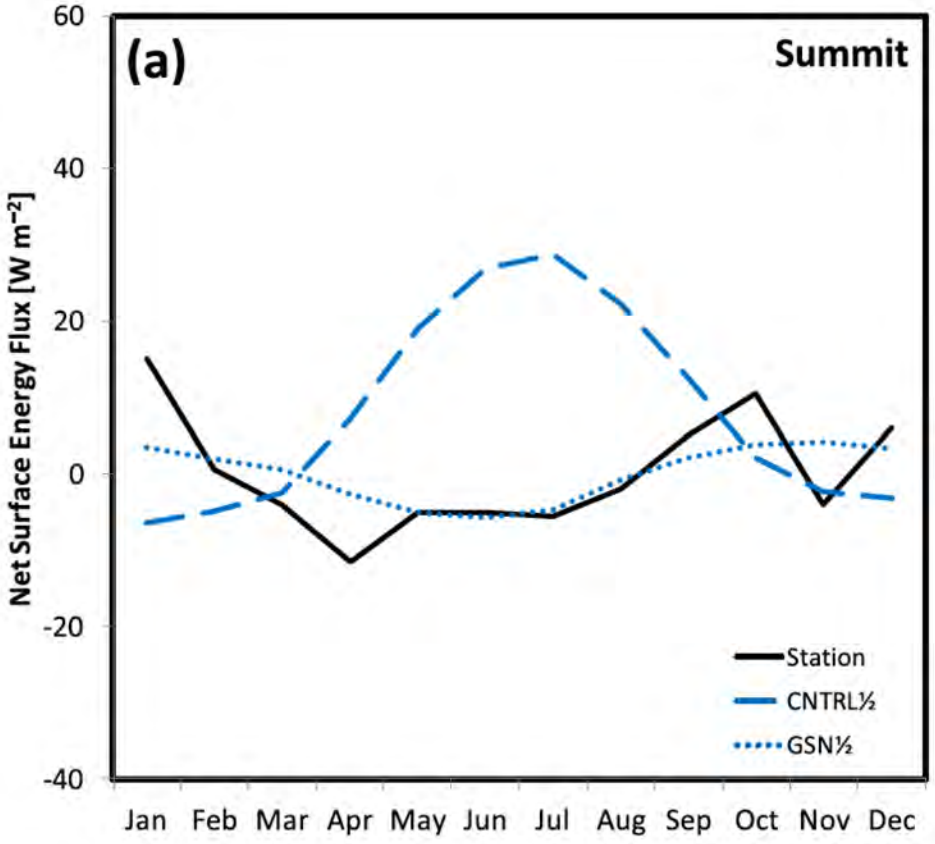
In GEOS-5 albedo is now a function of snow density (it used to be fixed)…



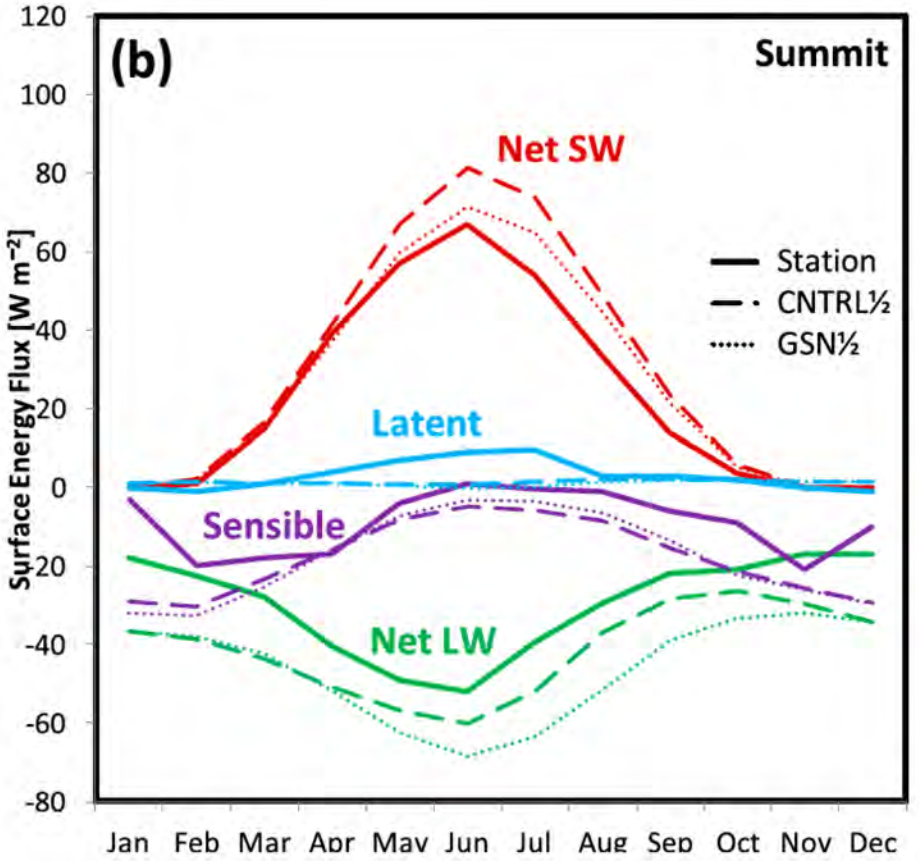
Other models also consider albedo change due to: snow age, grain size, aerosol deposition, etc

In GEOS-5, improvements in the SMB model (and albedo) results in a better treatment of the shortwave flux…

Net Surface Energy Flux

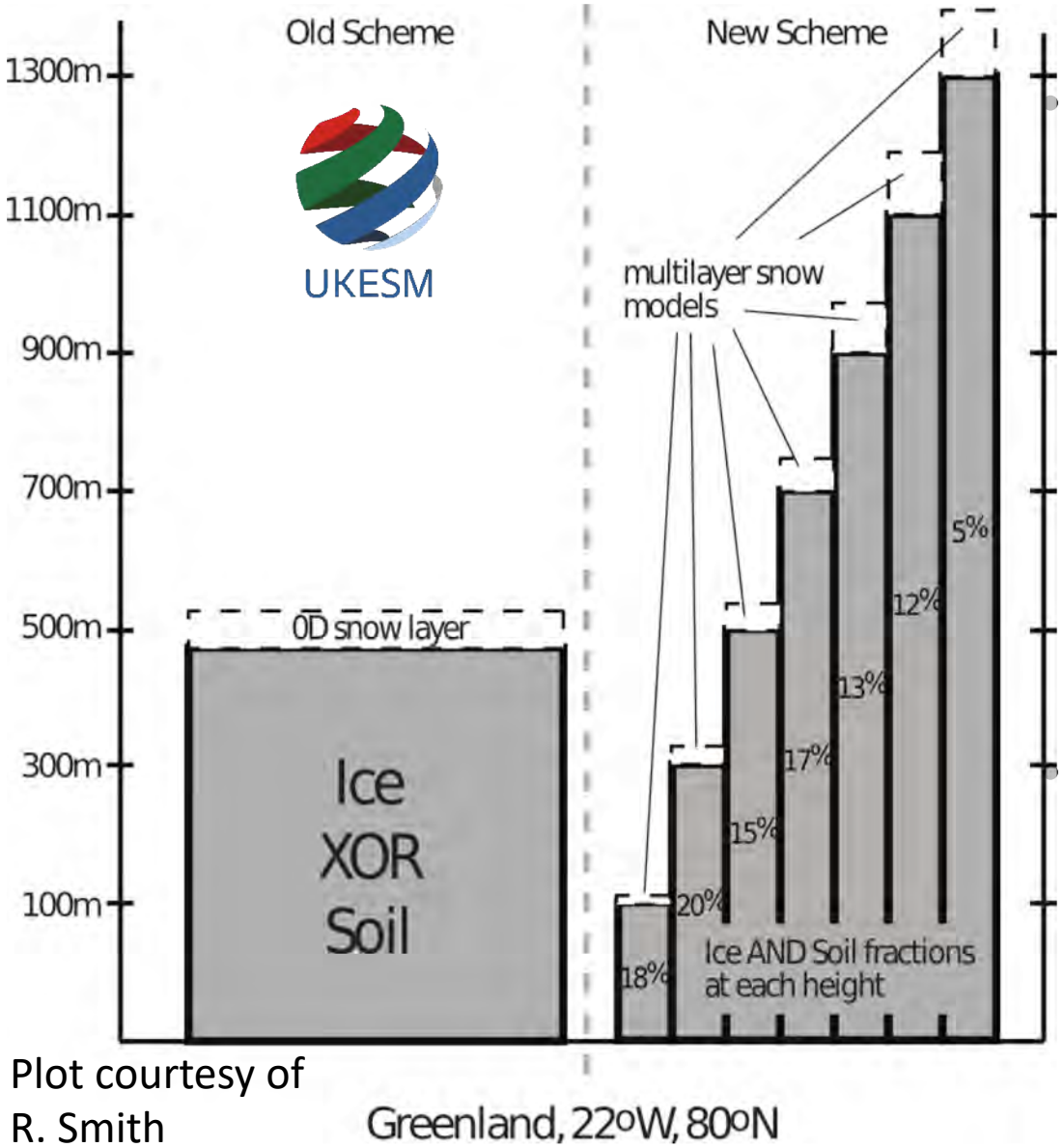


Surface Energy Flux



Cullather et al. 2014

Elevation classes are being implemented in ESM to allow for more refined SMB at ice sheet margins…

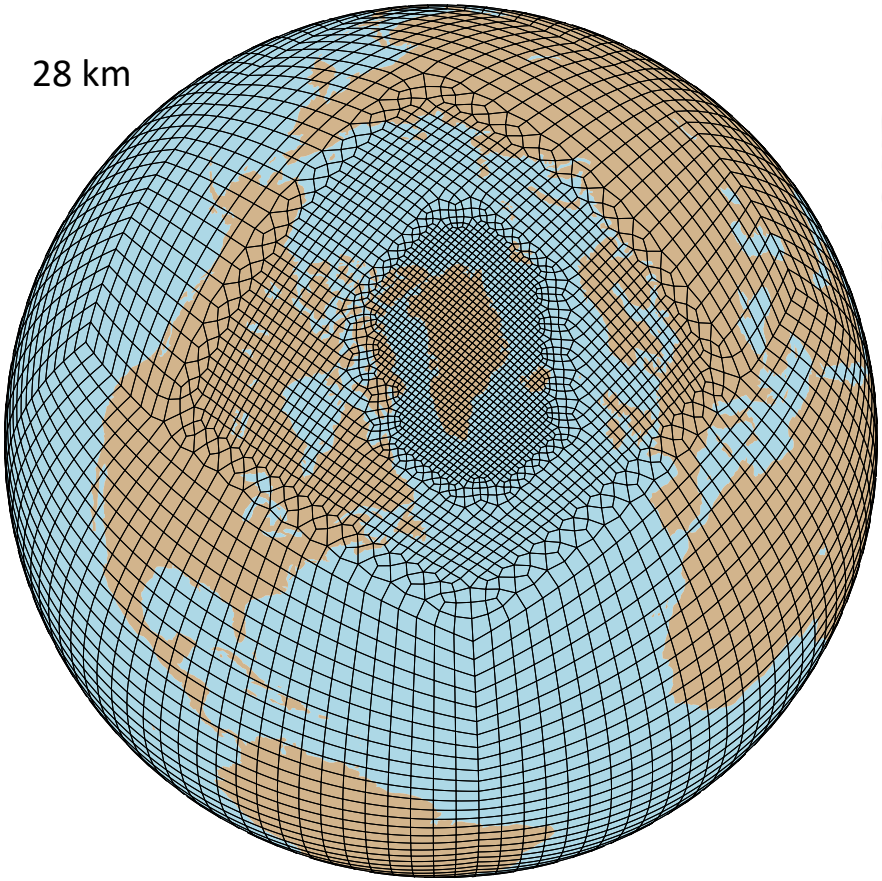


Plot courtesy of R. Smith

Elevation classes also used in CESM, MPI, ModelE…

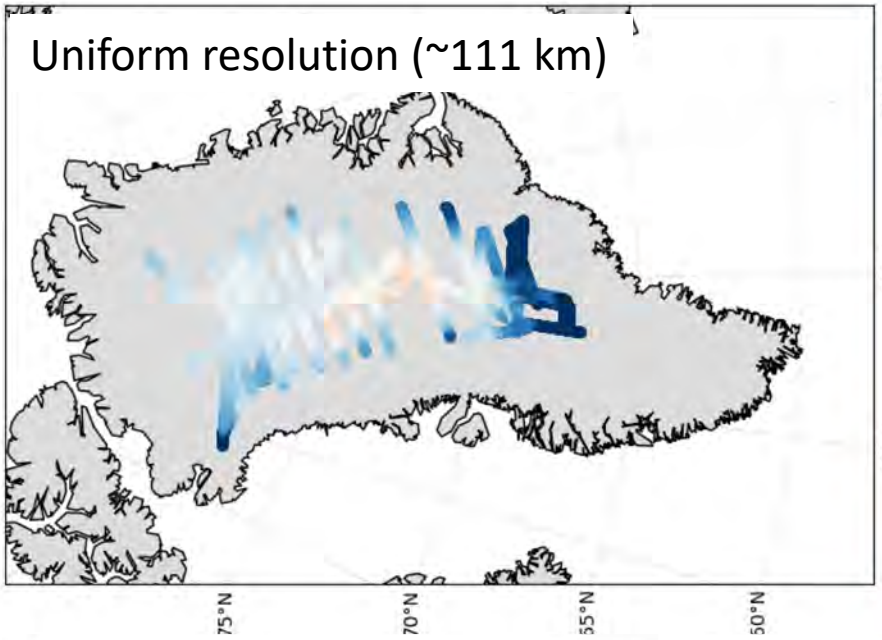
In GEOS5, we compute SMB on surface tiles that correspond to the ISSM mesh

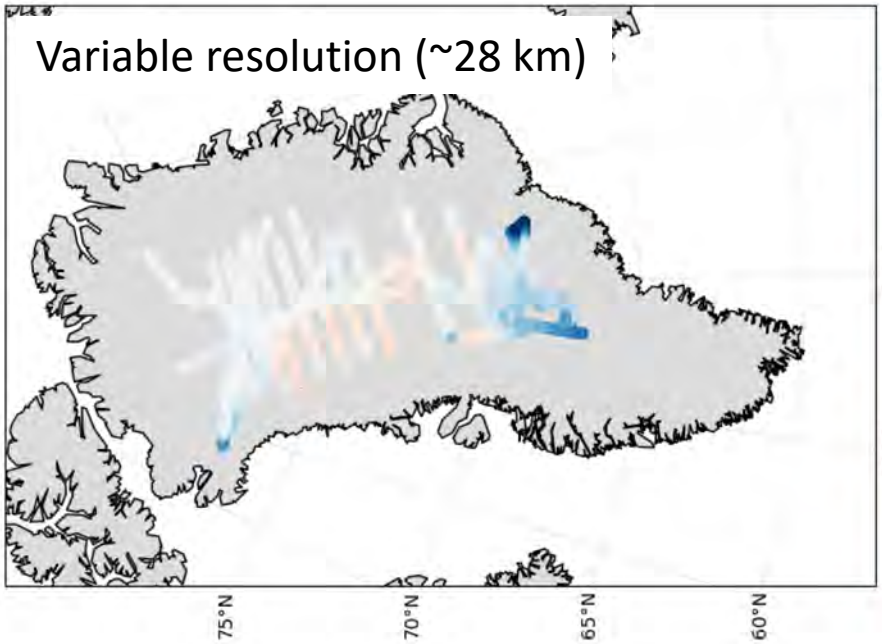
Other tricks implemented in CESM that improve the SMB: variable resolution…



van Kampenhout et al., in preparation

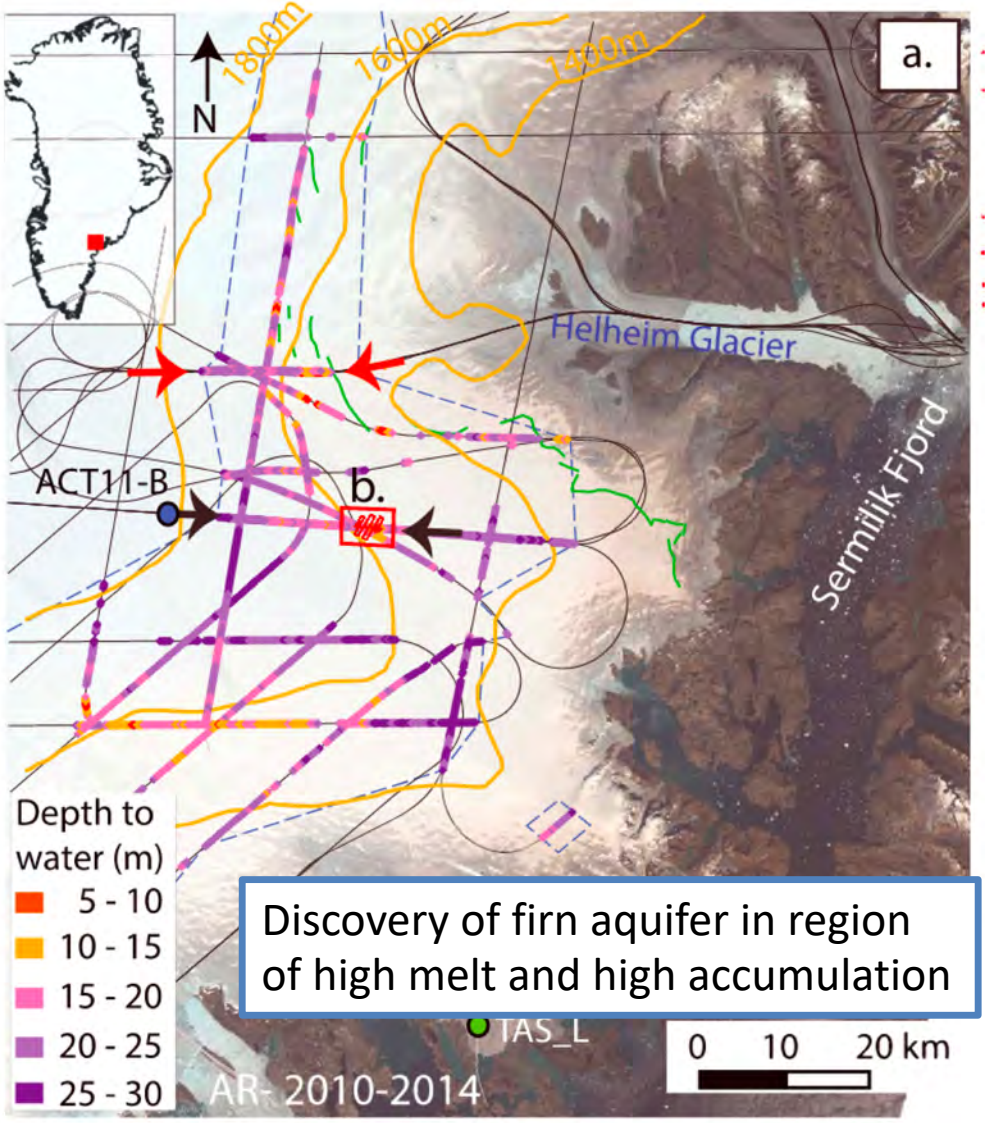
Simulated accumulation – IceBridge





Most models simply ”dump” surface runoff to the closest ocean cell, but there are development in…

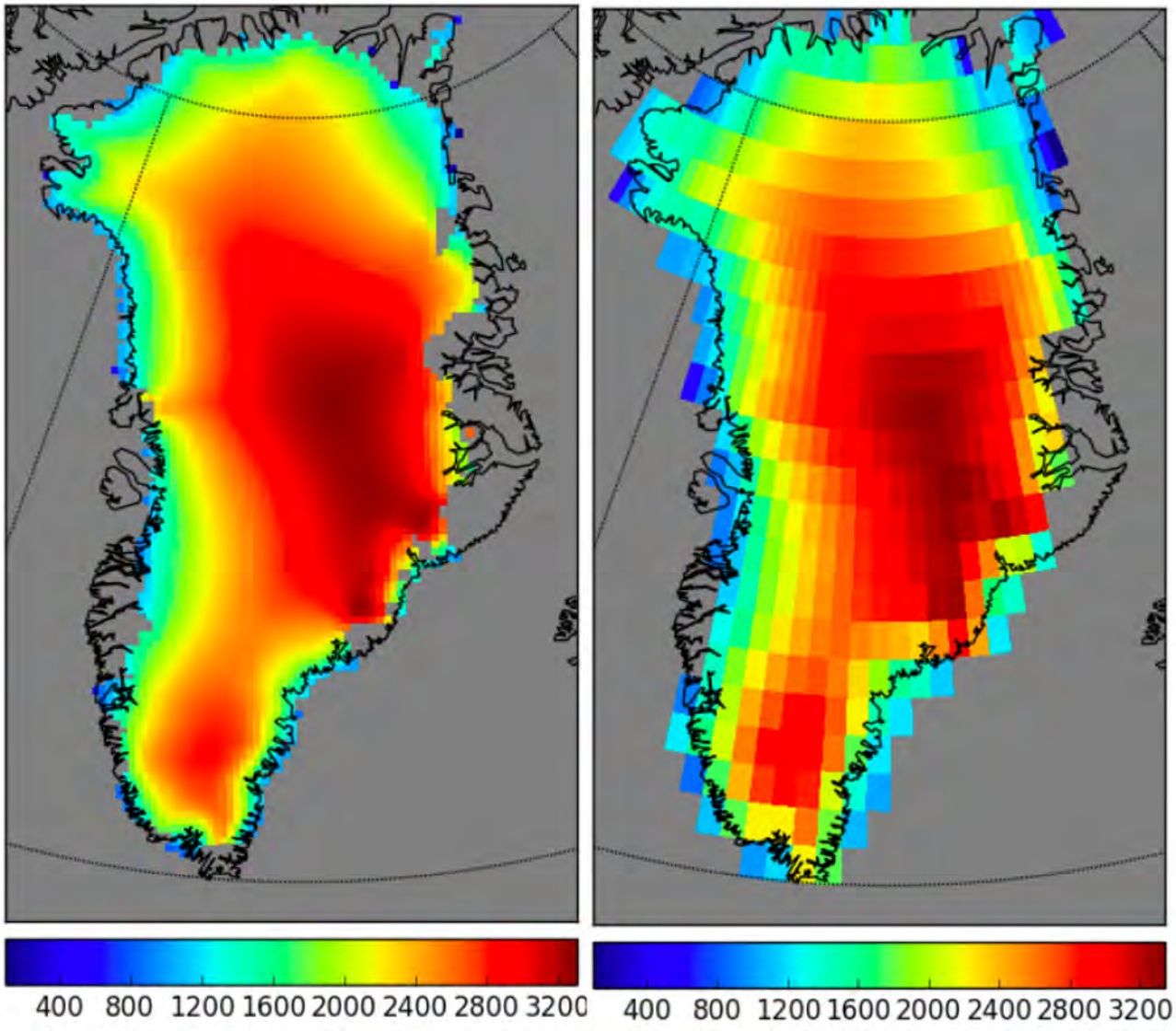
- Routing of surface water (aka river flow)
- Firn models and firn aquifers (following development in RCMs)



Discovery of firn aquifer in region of high melt and high accumulation

An issue is that ESM and ISM see different ice sheets, and that many ocean models cannot do partial grid cells…

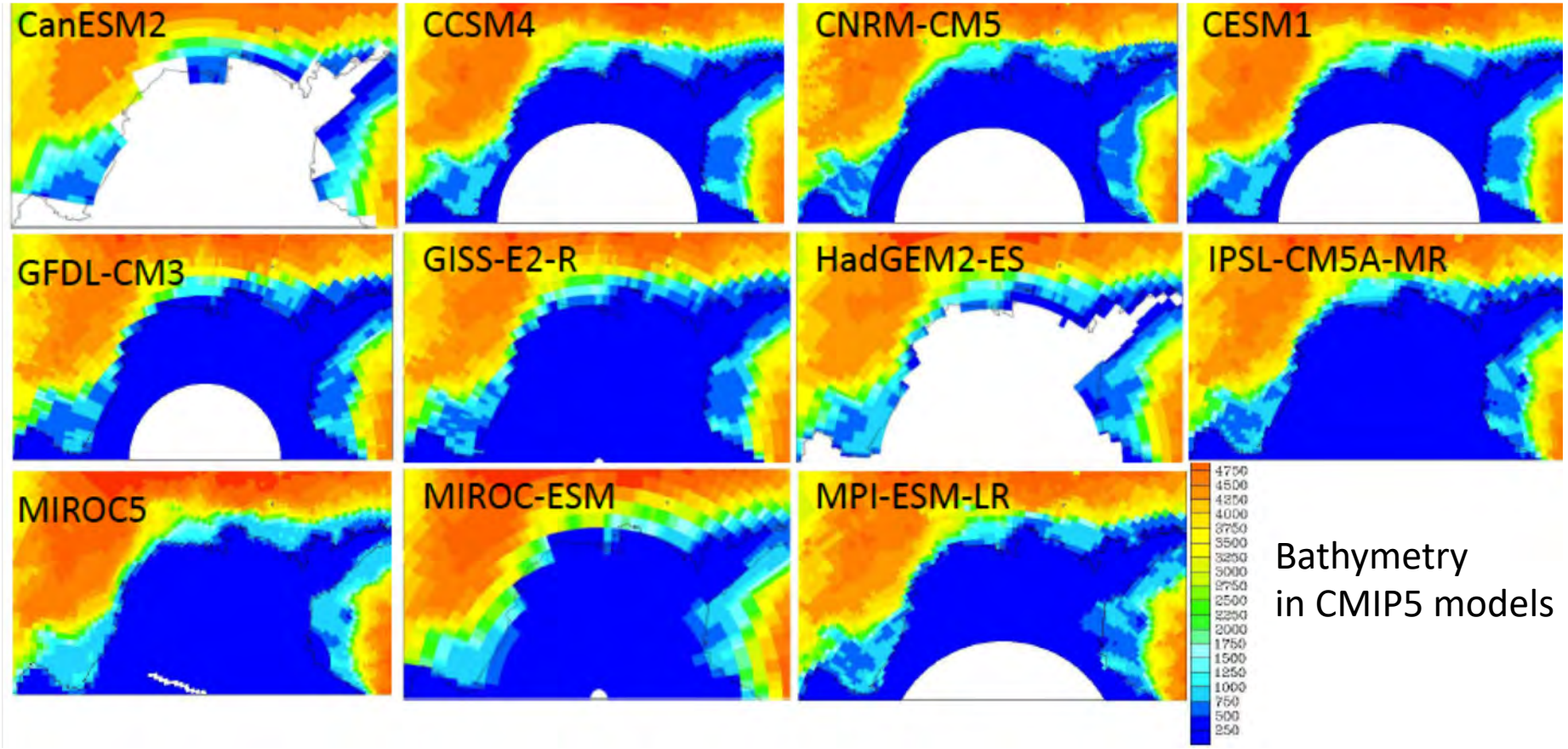
PISM



ModelE

Plot courtesy of E. Fischer

Ice sheet-ocean interaction remains super tricky, as most ESM do not allow for ocean to flow within the ice shelf cavities…



… but this is changing with MITgcm, MOM6…

However capturing ”moving boundaries” also remains non trivial…

As ice sheets are being coupled to climate models, we see that albedo and ice-elevation feedback matters for SMB…

On the importance of the albedo parameterization for the mass balance of the Greenland ice sheet in EC-Earth

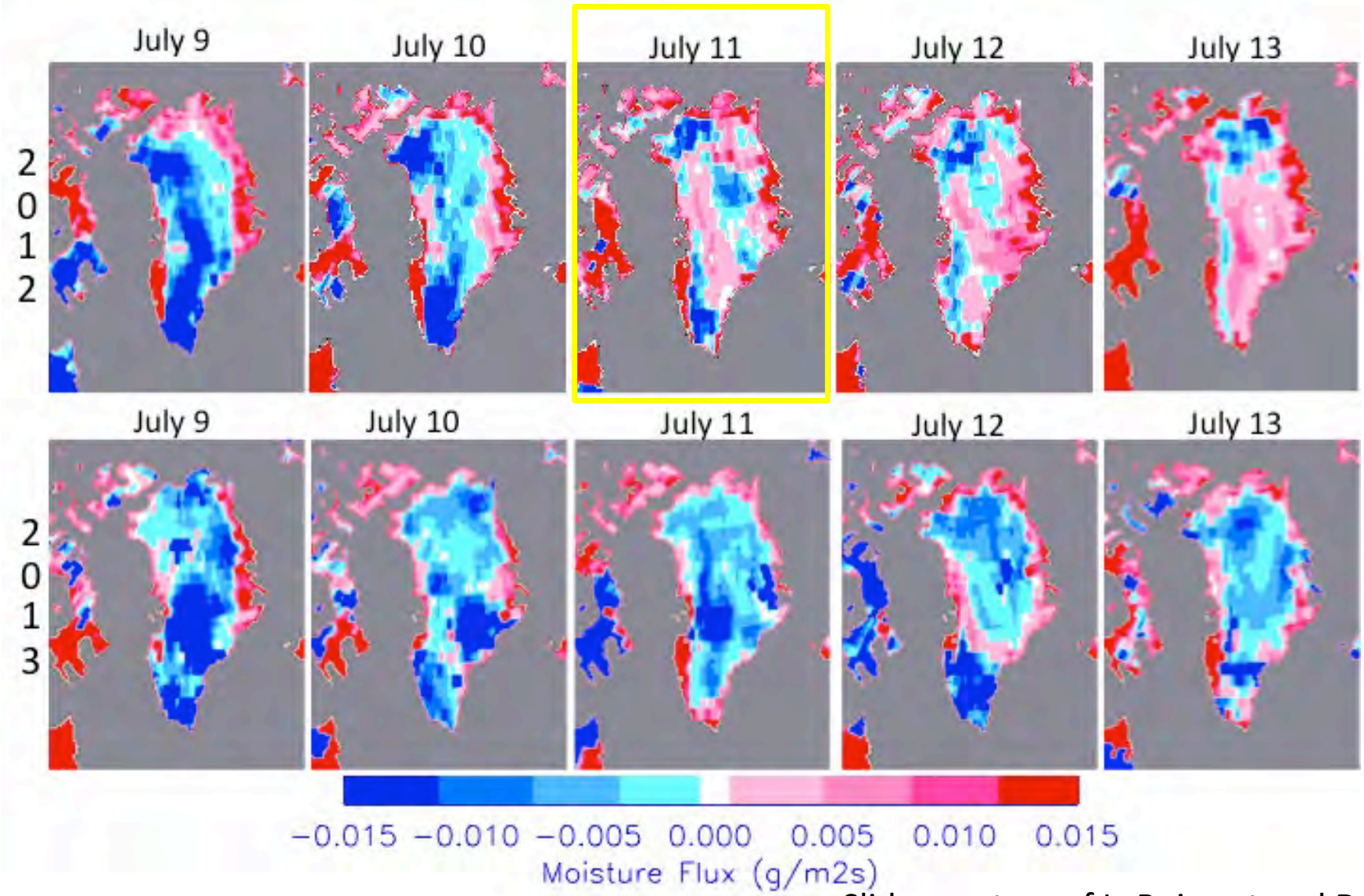
Michiel M. Helsen[1], Roderik S. W. van de Wal[1], Thomas J. Reerink[1], Richard Shuting Yang[3], Qiang Li[4], and Qiong Zhang[4]

The Cryosphere, 11, 1949–1965, 2017
https://doi.org/10.5194/tc-11-1949-2017

As ice sheets are being coupled to climate models, we see that dynamic ice sheets matter…

"Both UKESM and CESM have seen significant impacts on North Atlantic when interactive ice sheet runoff/calving (changing freshwater balance) and snow/ice building up in the north of Greenland"
ISMIP6 participants, AOGCM-ISM break out group, Sassenheim workshop (September 2018)

Could ice sheets influence climate and Earth energy budget in ways that we have not yet thought of?



Slide courtesy of L. Boisvert and D. Wu

Ice sheets and their coupling to Earth system models: a little improvement goes a long way…

- Ice sheet, SMB & ESM models are rapidly becoming more fancy, and feedbacks are important
- However many processes are still poorly known, and being discovered

Thank you!

ISMIP6

Climate model	Ice-sheet model	Institute/country
CanESM	None	CCCma/CA
CESM2	CISM	NCAR-LANL/USA
CNRM-CM	GRISLI	CNRM/FR
EC-Earth	GrIS	DMI/DK
GISS	PISM	NASA-GISS/USA
INMCM	VUB	INM/RU
IPSL-CM6	GRISLI	IPSL/FR
MIROC-ESM	IcIES	AORI-UT-JAMSTEC-NIES/JP
MPI-ESM	PISM	MPI/DE
UKESM	BISICLES	MetOffice/UK