Land Ice Working Group Update

- First Science
- Progress/Upcoming Work
- Future Science & Prospects for Collaboration

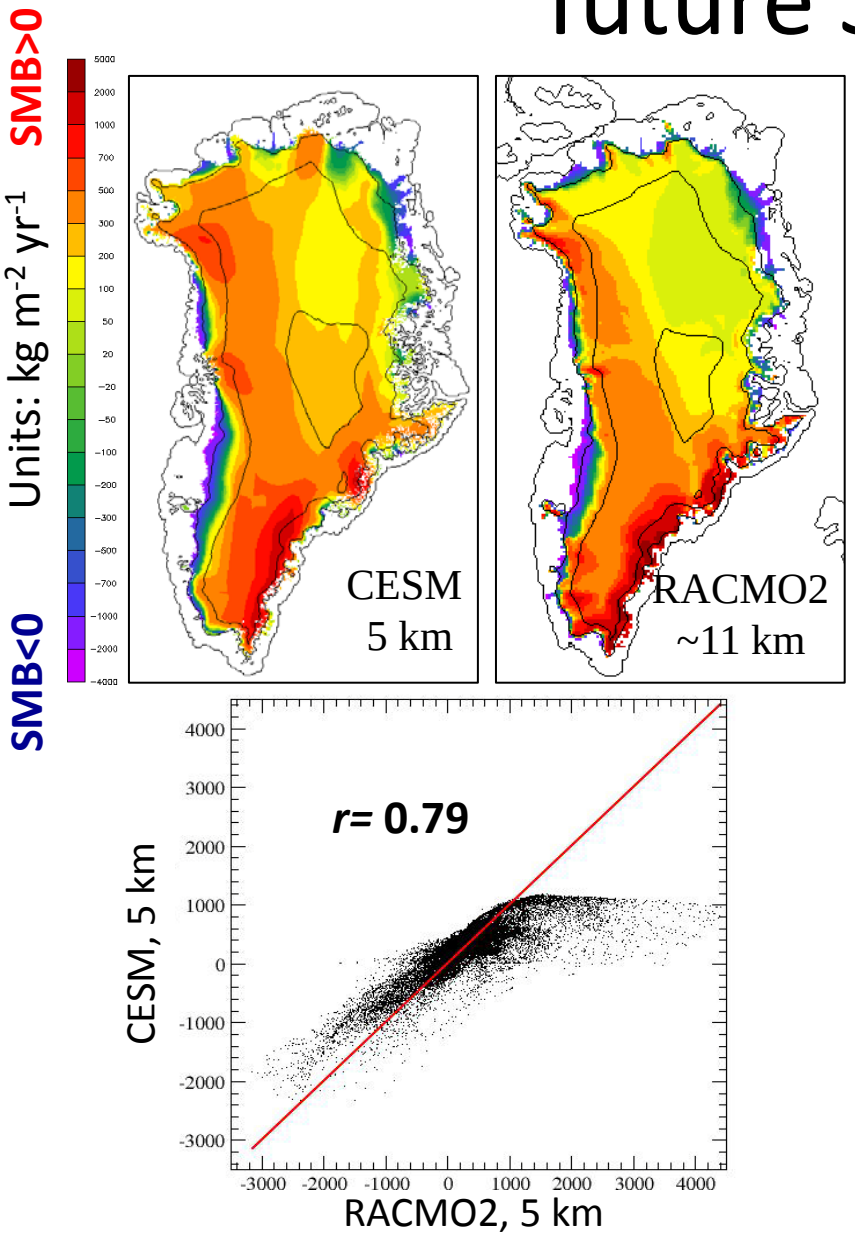
Jeremy Fyke, Miren Vizcaino, William Lipscomb, Bill Sacks and the LIWG

LAUR: LA-UR-13-20903

First Science

- First model surface mass balance evaluations and sea level rise projections for Greenland Ice Sheet under review for *Journal of Climate* Special Issue:
  - Miren Vizcaino et al. (x2)
  - Bill Lipscomb et al. (x1)
- Contributors and contributions from:
  - *NCAR, LANL, IMAU (Netherlands), U of T (Austin), Sandia, Berkeley, Oak Ridge*

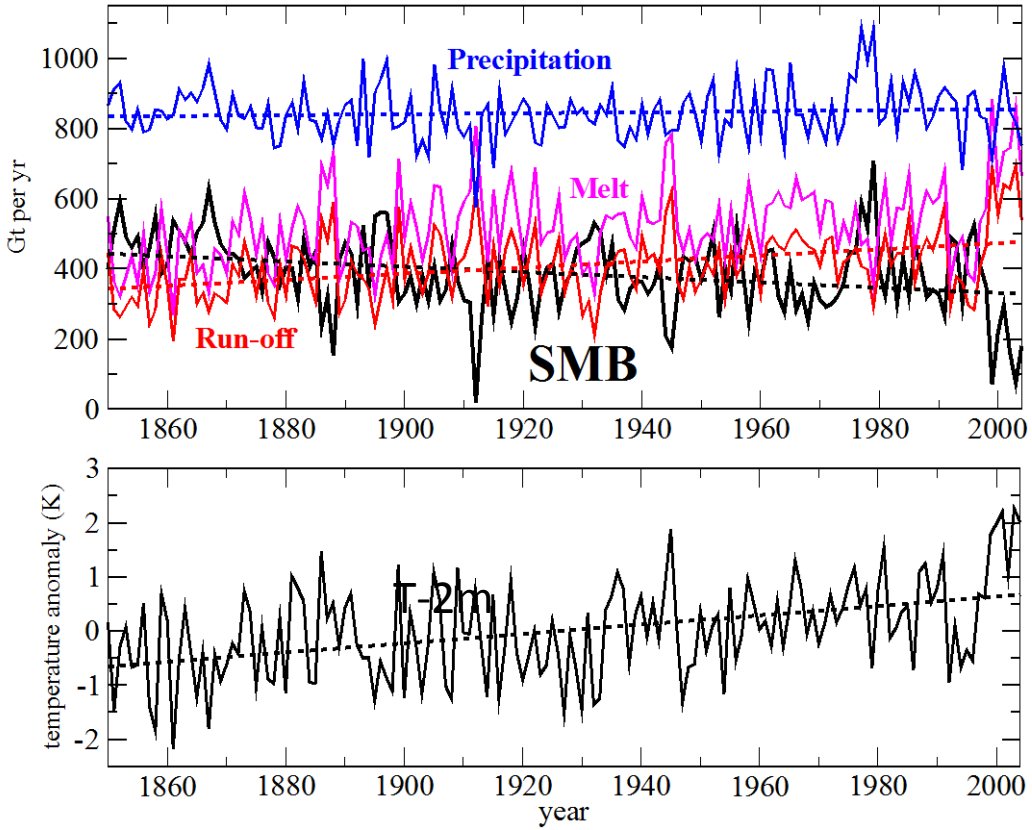
1960-2005 SMB: comparison with RCMs & future SMB trends



	CESM	RACMO2	Other RCMs (MAR/PMM5/ERA40-d)
Net SMB	**359**	**376**	**288/356/287**
PREC	**866**	**723**	600/696/610
Rain/PREC	0.15		0.04/0.03/0.05
MELT	**568**	**504**	
Refreezing	242	245	
RUN-OFF	**457**	**306**	
SU	54	40	5/108/38

Units: Gt yr^{-1}

1850-2005 GIS SMB evolution



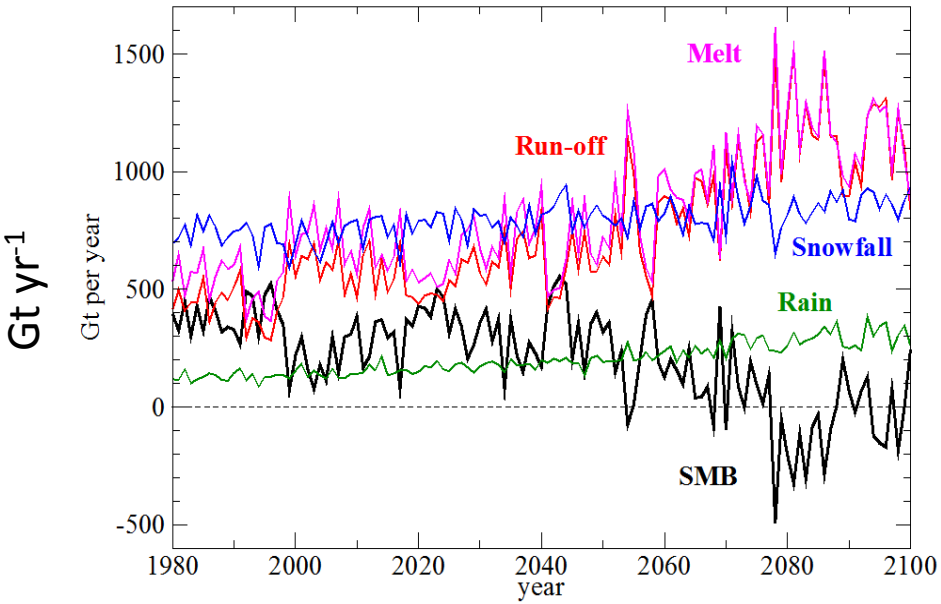
+0.14 Gt yr^{-2}

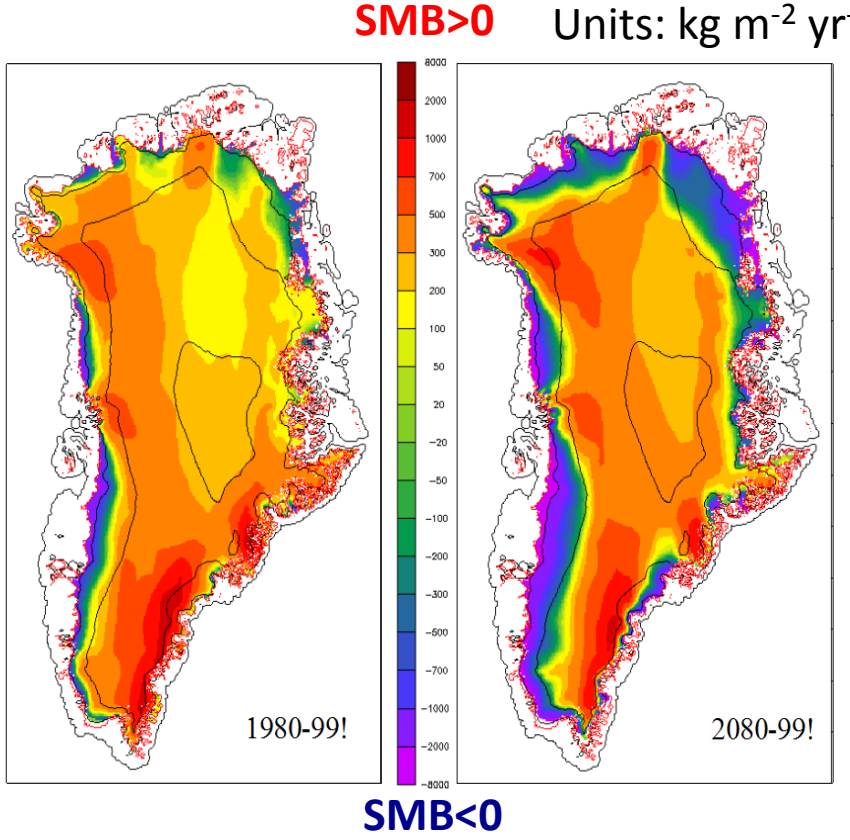
+0.87 Gt yr^{-2}

-0.75 Gt yr^{-2}

+0.0086 K yr^{-2}

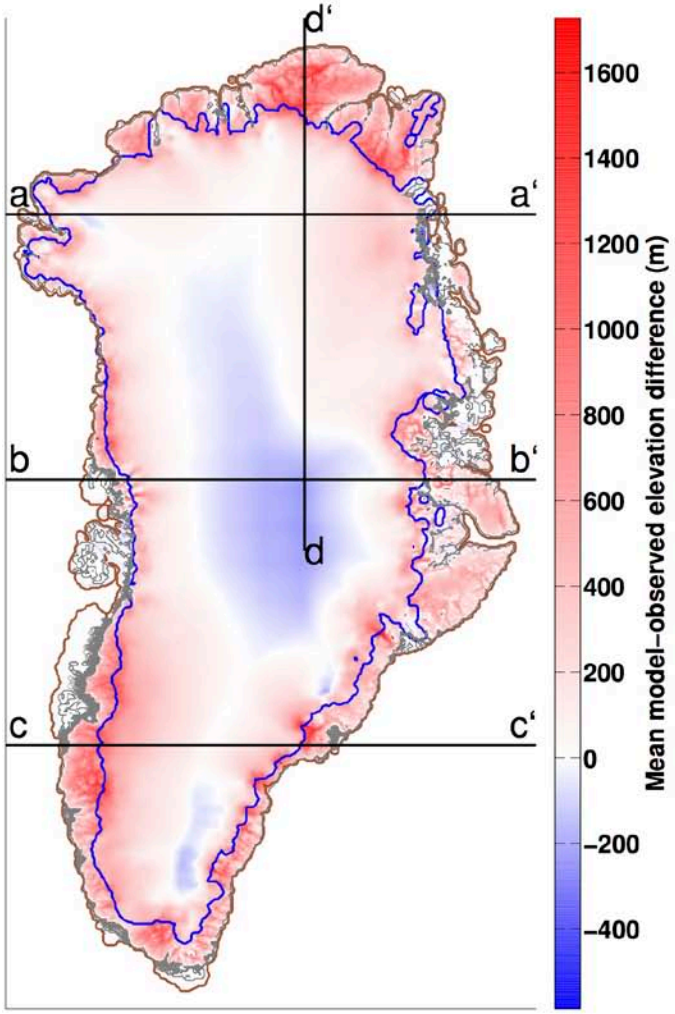
GIS projections (RCP8.5)

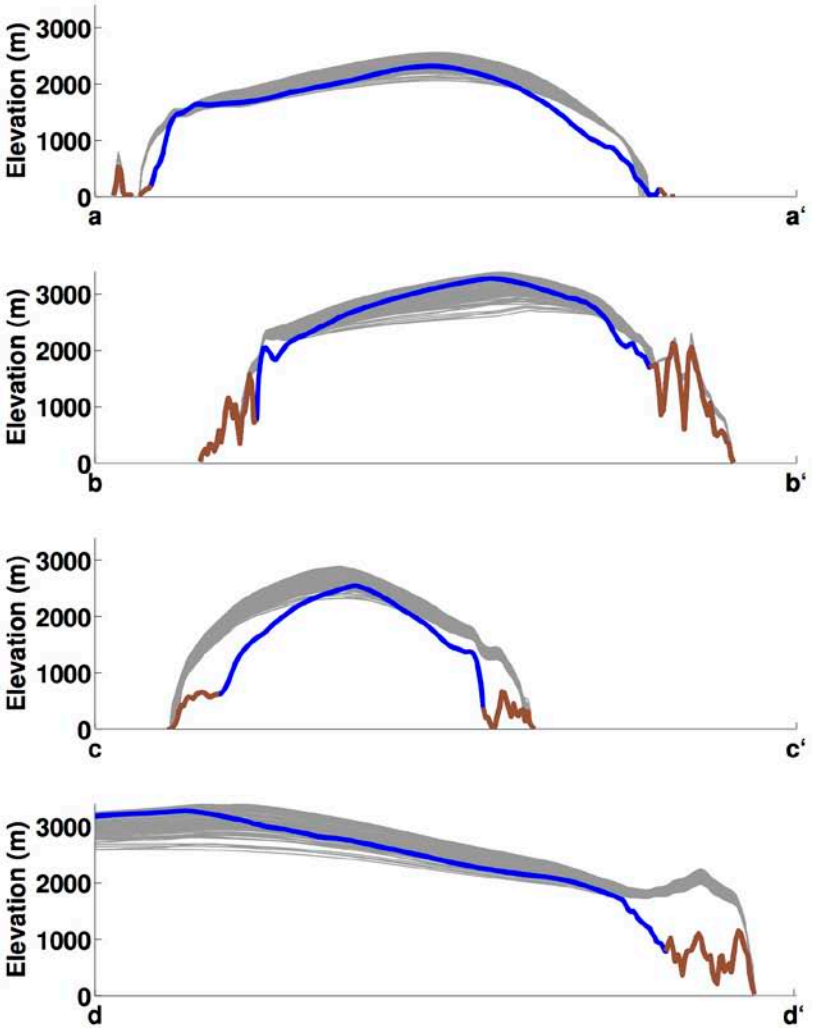




Change in SMB distribution

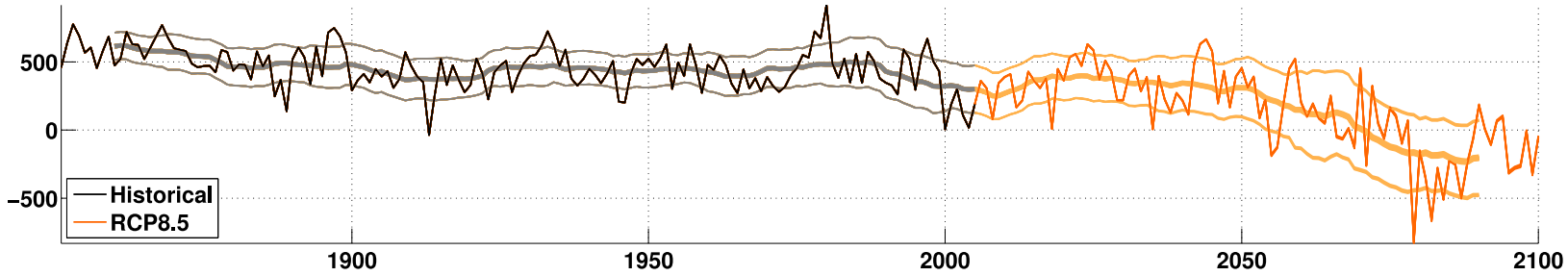
Preindustrial CISM Greenland steady-state perturbed-physics ensemble

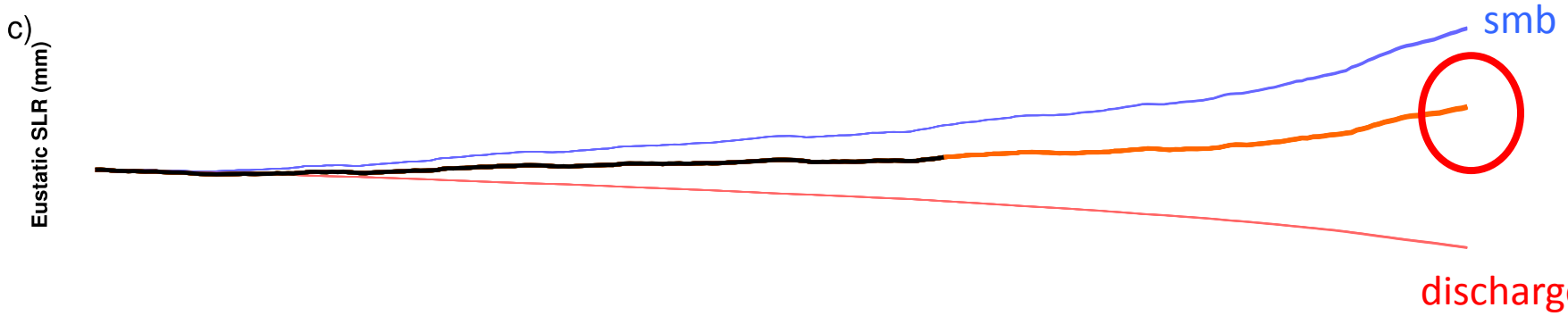




CESM-driven CISM Greenland sea level contribution

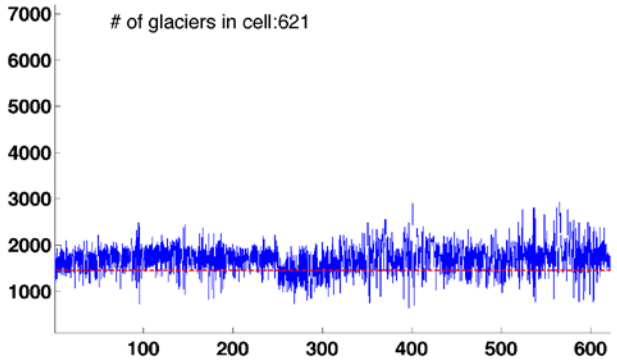
- GIS sealevel prediction (RCP8.5)

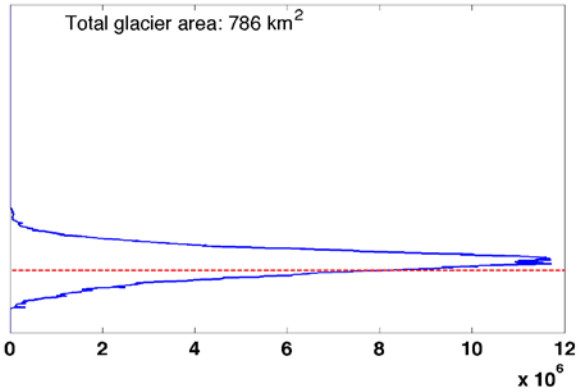


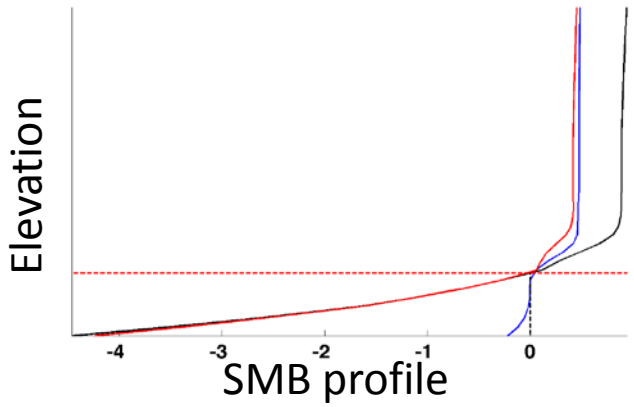


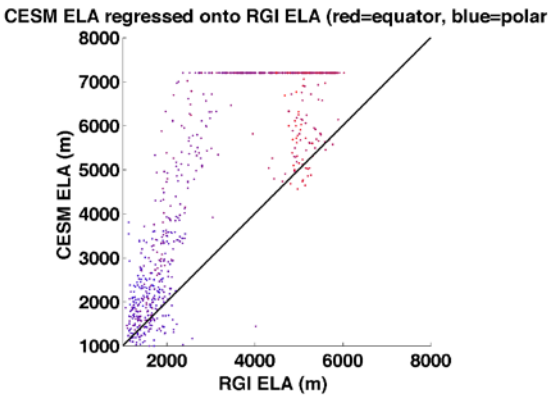
Non-GIS SMB evaluation

- SMB generated anywhere in CESM where mountain glaciers occur in comprehensive Randolph Glacier Inventory



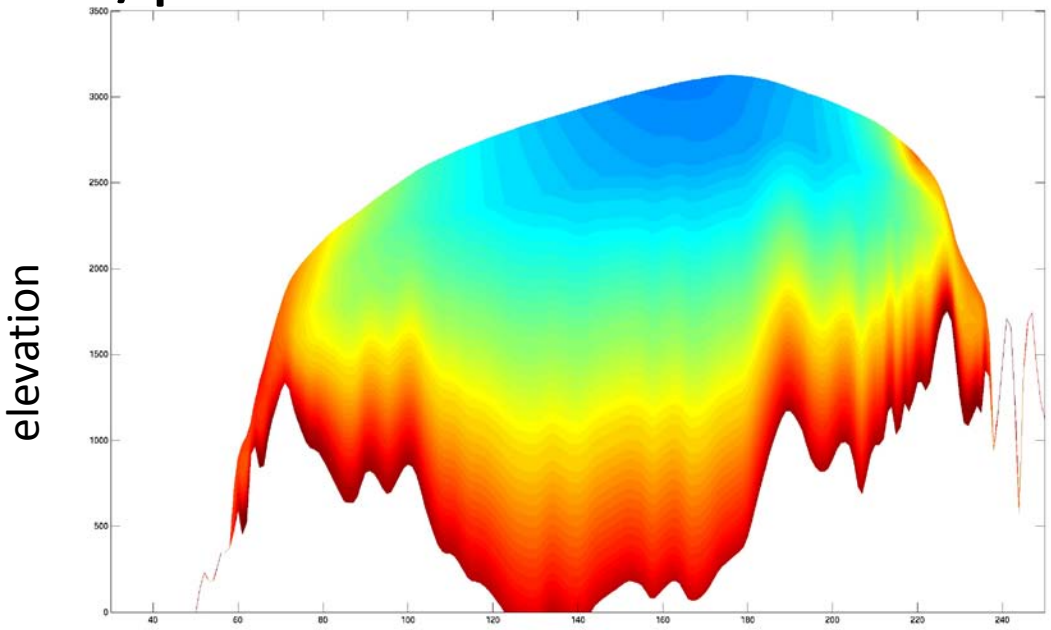




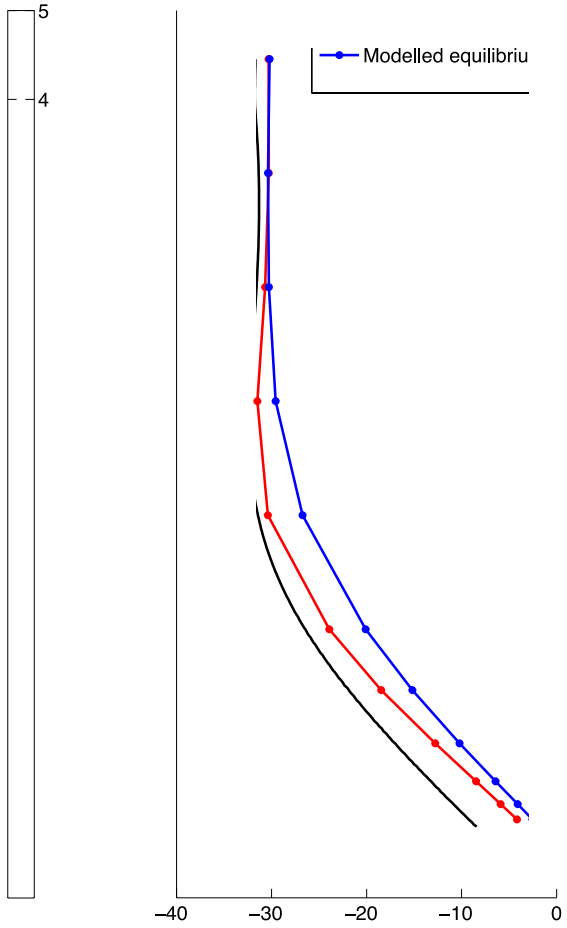


Ice sheet initialization

- CESM-and-climate-consistent 122,000 year spin up completed through last glacial cycle
- Forced with GRIP $\delta^{18}O$-interpolated SMB, end-members from CCSM4 LGM/mid-Holocene/preindustrial IG simulations



Ice sheet initialization



Progress/upcoming work

- Ongoing/upcoming work broadly falls under:
  - Ice sheet-climate coupling development
  - Climate model surface mass balance validation
  - Ice sheet model development
- Collaborators come from:
- NCAR, LANL, NPS, IMAU, U. of British Columbia, SFU, U. of Bristol, U. of Cambridge, U. of S. Carolina, Chinese Academy of Sciences, Ohio State U., NASA GSFC, U. of Washington, CReSIS / U. of Kansas, U. of Colorado, U. of Texas (Austin), Florida State U.

Coupling to-dos:

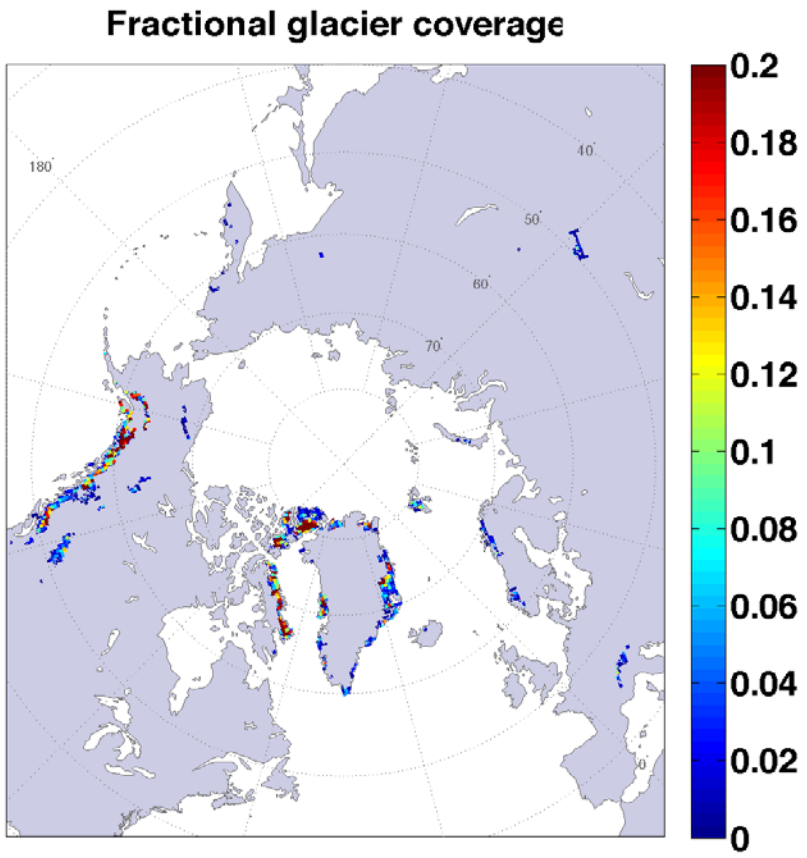
- Dynamic landunits (Bill Sacks, Jon Wolfe):
  - Necessary to grow tundra, etc., as Greenland Ice Sheet retreats
  - Complementary to other CESM requirements for dynamic land units
  - Summer 2013 completion?
- Runoff routing to ocean:
  - Necessary for linking ice volume changes to ocean freshwater forcing, isolating ocean-sea ice/ice sheet feedbacks
  - Summer 2013 completion?

Coupling to-dos, *continued*:

- Dynamic atmosphere coupling (Fyke, Lauritzen):
  - Necessary to allow dynamic atmospheric adjustment to ice sheet geometry changes
  - First coupling to be bash-scripted, based on DART
  - Fall 2013 completion?
- Conservative downscaling to ice grid, multiple ice sheet instances (Wolfe, Sacks, Lipscomb):
  - Current downscaling scheme non-conservative
  - Multiple ice instances needed to support simultaneous Antarctic, Laurentide, Fennoscandian (etc.) ice sheets
  - Fall 2013 completion?
- Ice shelf-ocean coupling: more to follow

CLM-RASM coupling (Fyke)

- Regional Arctic System Model requires a land ice component
- Development of SMB in VIC land model ongoing
- Alternate approach: couple regional SMB-enabled CLM to RASM



Upcoming CESM-side evaluations

- CAM5-forced BG simulation (Fyke, Vizcaino):
  - Can we improve marginal Greenland + SMB bias?
- SMB evaluation Antarctic Ice Sheet (CAM4/5) (Vizcaino):
  - What does CESM AIS SMB look like?
- SMB evaluation in CLM4.5 (Fyke, Vizcaino):
  - How will SMB change with migration to CLM4.5?
- Diagnosis tools for evaluating land ice performance in CESM (Kate Evans, Jenn Kay)

Land ice model development: "tactical"

- CISM1.0:
  - 'software coupled' and tested, current operational, computationally cheap shallow-ice-approximation model
- CISM2.0:
  - 'software coupled', will undergo testing within CESM with higher-order ice dynamics
  - parallel, expensive, untested in CESM: available for 'alpha' CESM use late 2013
- Bicicles*:
  - block-structured AMR model potentially operational within a year over Antarctic domain, but integration into CESM TBD.
- Ice-ocean coupling with POP2*:
  - ability to couple dynamic ice shelves to upper boundary of ocean model, at high resolution, critical for Antarctic simulations
  - Integration into CESM TBD

BISICLES: Antarctic ice sheet velocities using L1L1 with block-struct. AMR

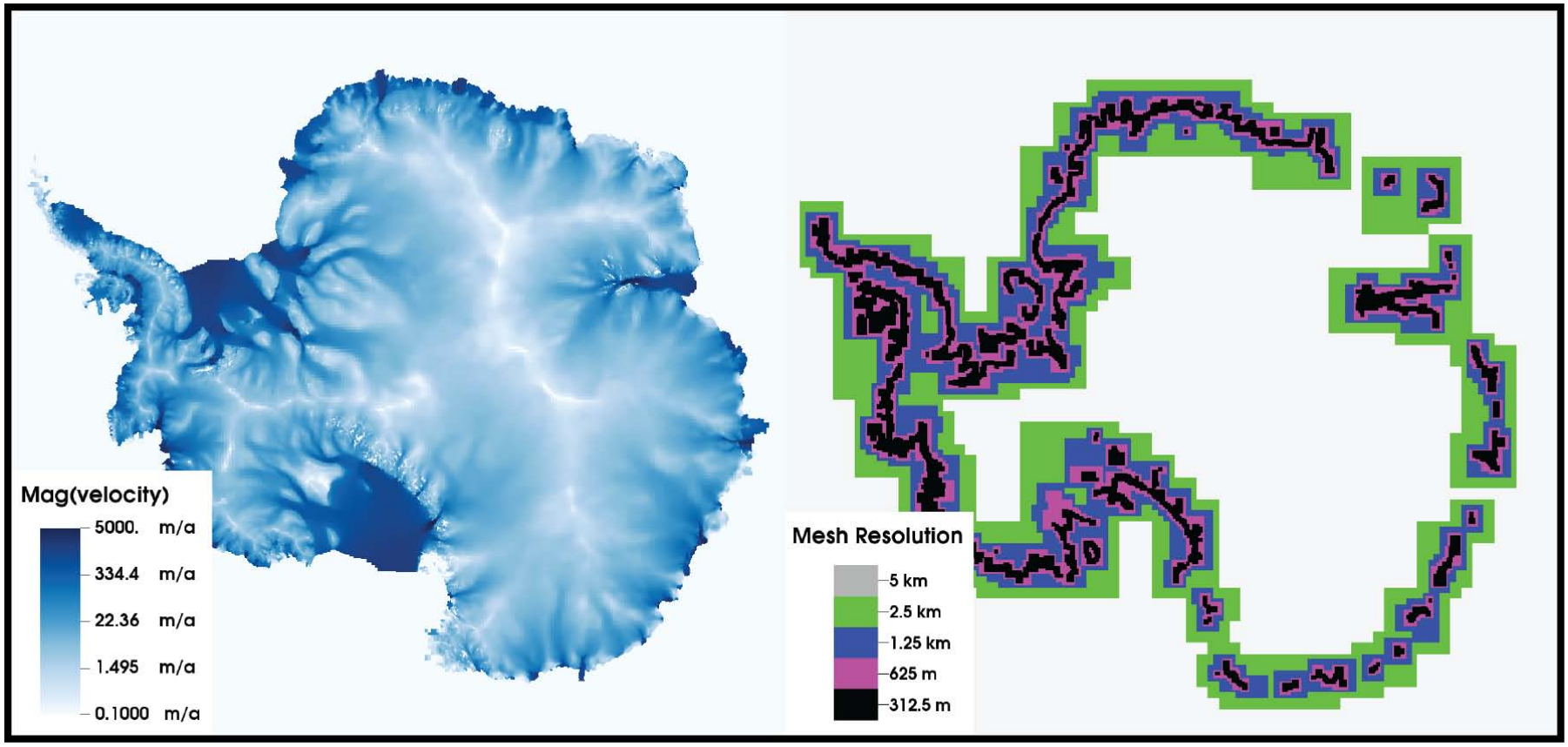
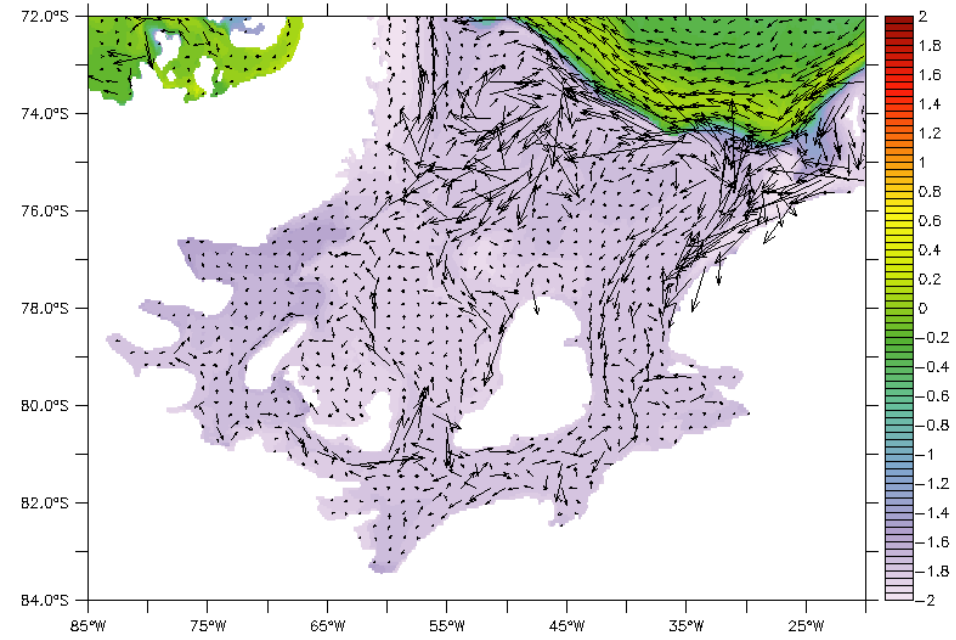


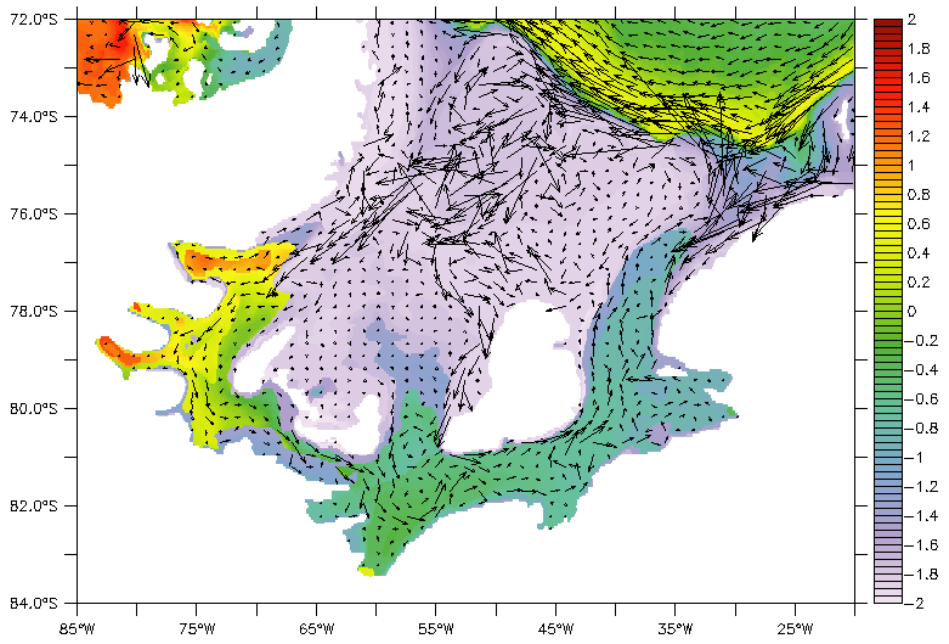
Figure courtesy of D. Martin (LBL) & S. Cornford (UOB)

POP2 sub-ice-shelf circulation: regional Southern Ocean model

Water temperature



No Ice Shelves

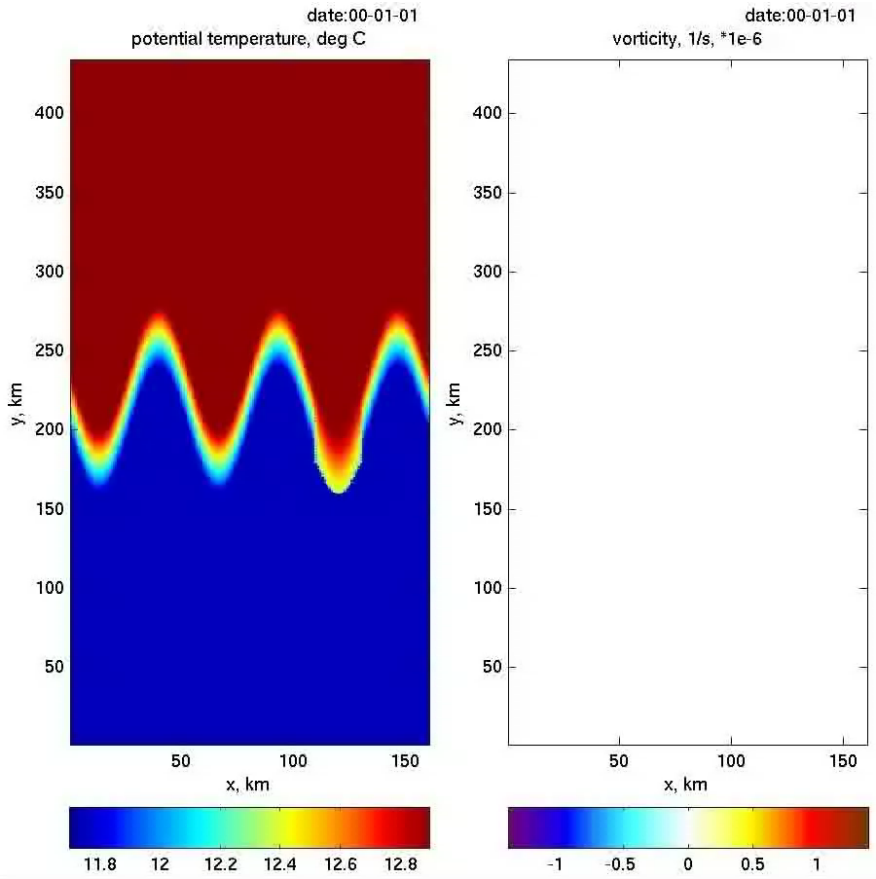


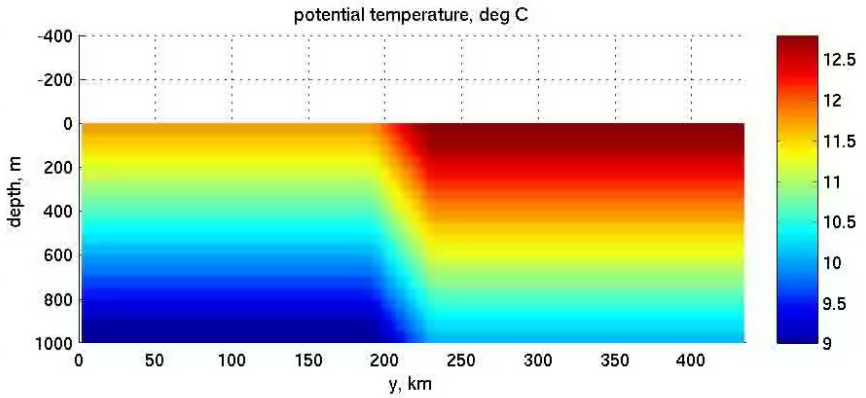
Idealized Ice Shelves

Land ice model development: "strategic"

- MPAS-based dycore development:
  - Variable resolution grids
  - FE-based (more robust, improved treatment of BCs, etc.)
  - Formal optimization capabilities
- MPAS ocean-ice shelf coupling*:
  - Common high-res mesh in ice shelf cavity/grounding line, but decreased elsewhere
  - MPAS-ocean upper boundary depression can handle evolving ice shelf drafts (100s of meters) stably – very difficult with POP

MPAS ice shelf-ocean coupling





Near-term potential science applications

- Long-term stability of Greenland Ice Sheet
- Quantification of albedo and height feedbacks
- Future changes in radiative forcing for GIS and AIS
- 21st century projections of AIS SMB
- Impact of realistic and coupled glacial runoff on ocean circulation
- SMB variability & trends: connection with atmospheric patterns & sea-ice state
- Attribution of SMB changes to anthropogenic forcing
- Explaining recent observed GIS SMB extremes & trends using CESM
- Ideas from the PCWG welcome! Greenland is in the polar climate!
- PCWG wishes and technical criticis ms will be valuable in:
  - guiding remaining coupling
  - figuring out biases
  - informing ice sheet model development priorities