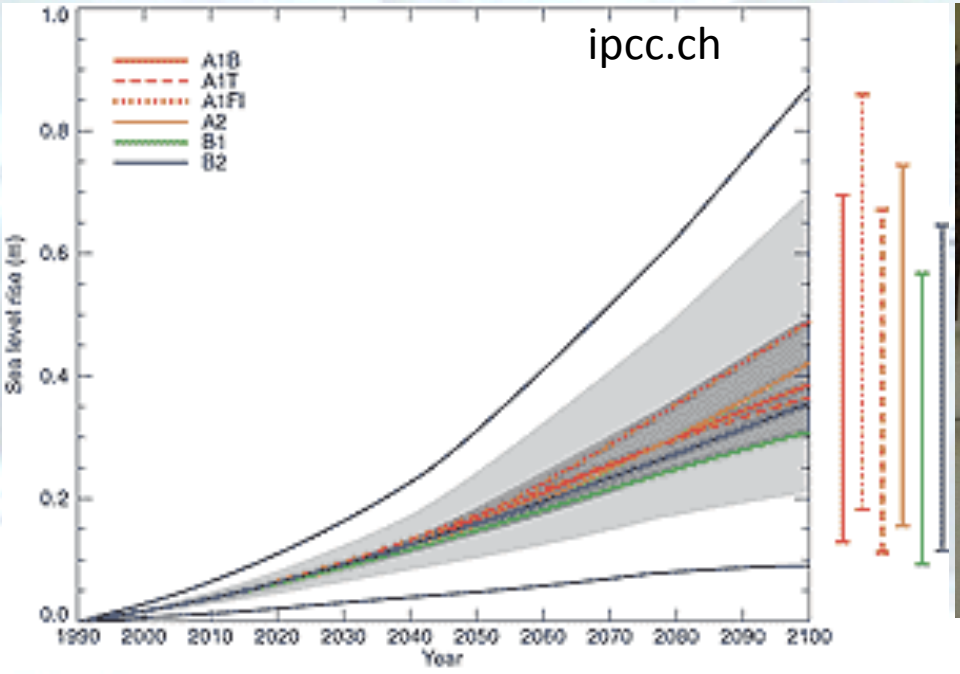
Progresses and challenges in modeling land ice change



Sophie Nowicki, NASA GSFC

Arctic System Workshop, April 9, 2018

Ice sheet and sea level within IPCC cycle…

- No major dynamic response of the ice sheets was expected during the 21st century.
- Main contributor to sea level rise: thermal expansion and melting of glacier.

We know everything…

Ice sheet and sea level within IPCC cycle…

"understanding of these effects (rapid dynamical changes in ice flow) is too limited to assess their likelihood or provide a best estimate or an upper bound for sea level rise."

IPCC, 4th Assessment Report (2007)

We know nothing…

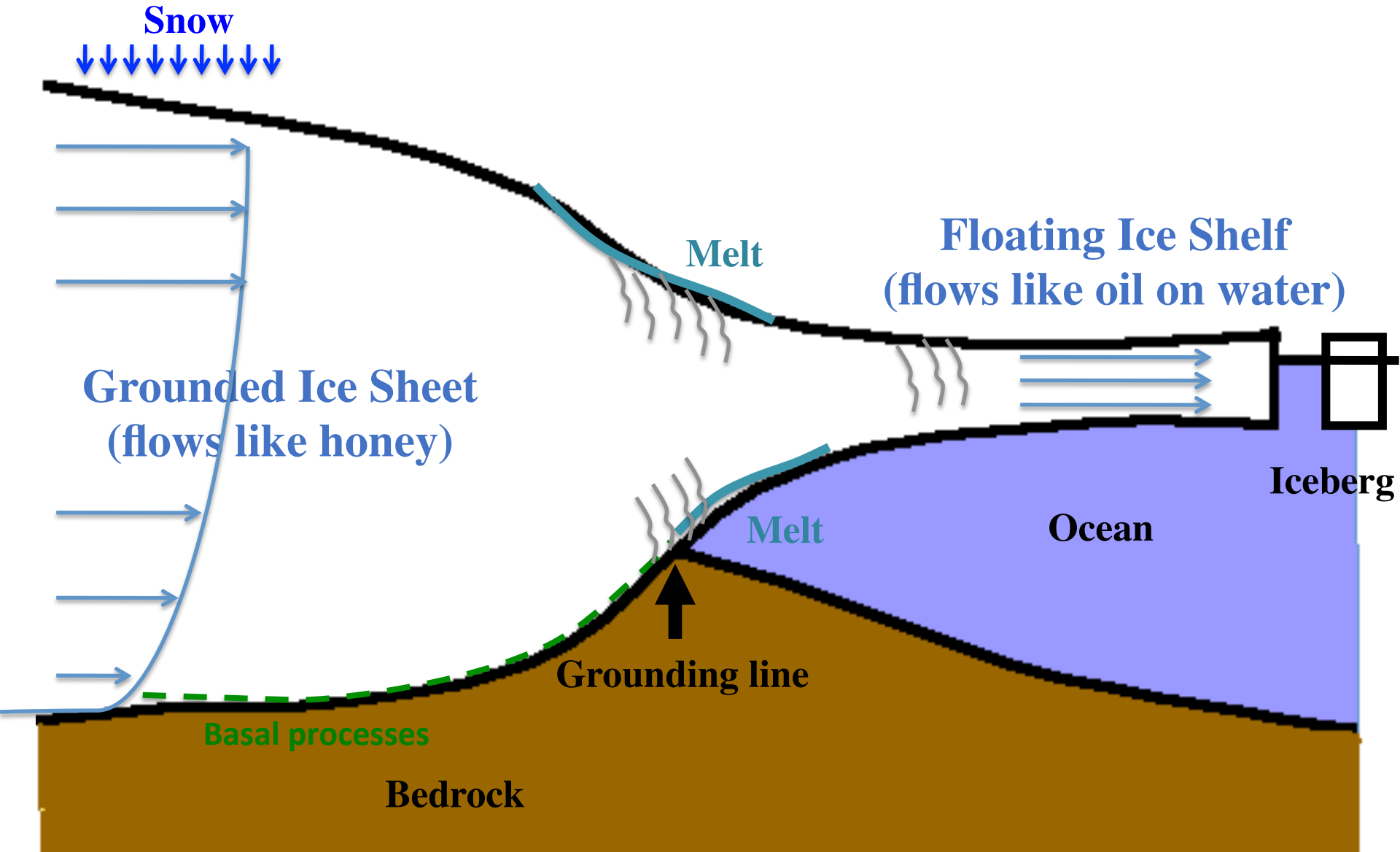
Ice sheet and sea level within IPCC cycle…

"Projection of sea level rise are larger than in the AR4, primarily because of improved modeling of land-ice contribution."

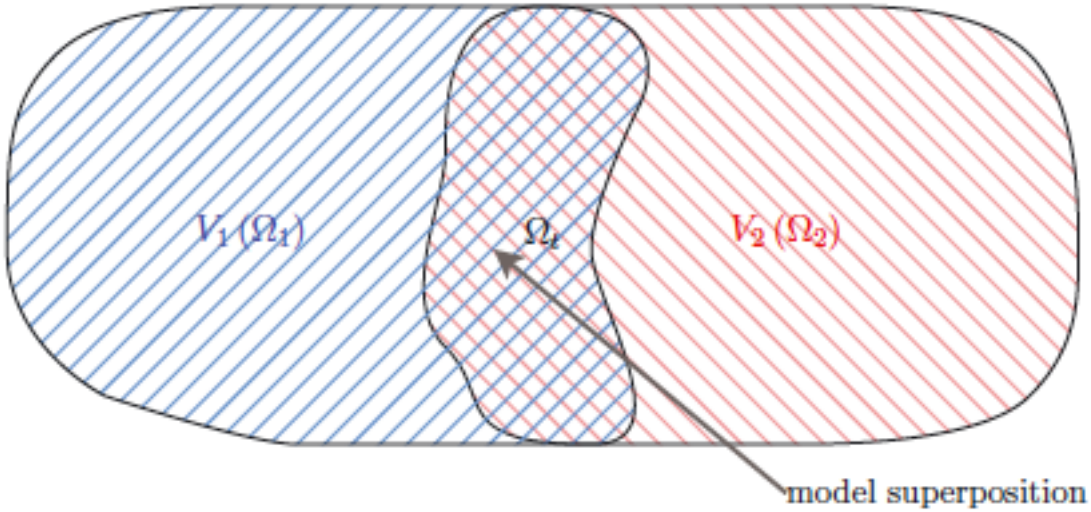
IPCC, 5th Assessment Report, 2013

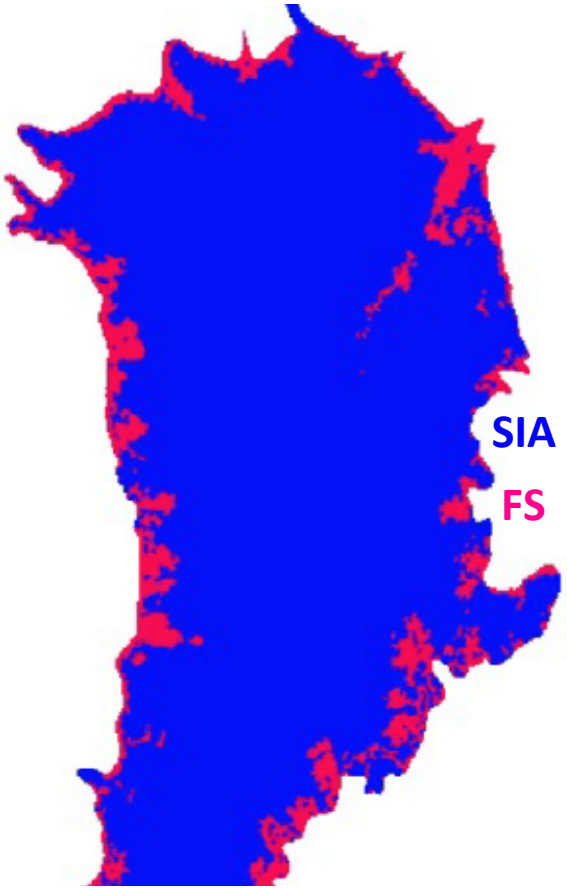
We know something, but not enough…

Ice sheet models are becoming more fancy, but many processes are still poorly known…



Ice sheet models are finding ways to speed up computations, via coupling of different flow models…





Coupling ice flow models of varying orders of complexity with the Tiling method

Helene SEROUSSI,[1,2] Hachmi BEN DHIA,[2] Mathieu MO
Eric RIGNOT,[1,3] Denis AUBR

Dynamically coupling the non-linear Stokes equations with the shallow ice approximation in glaciology: Description and first applications of the ISCAL method

Josefin Ahlkrona[a,*], Per Lötstedt[a], Nina Kirchner[b,c], Thomas Zwinger[d]

Ice sheets are being coupled to climate models…

CMIP6 DECK
(any AOGCM)

Forcings
Requires analysis of climate over and surrounding ice sheets

Feedbacks
How do dynamic ice sheets affect climate?

ISMIP6

Standalone ice sheets models

Coupled AOGCM-ISM

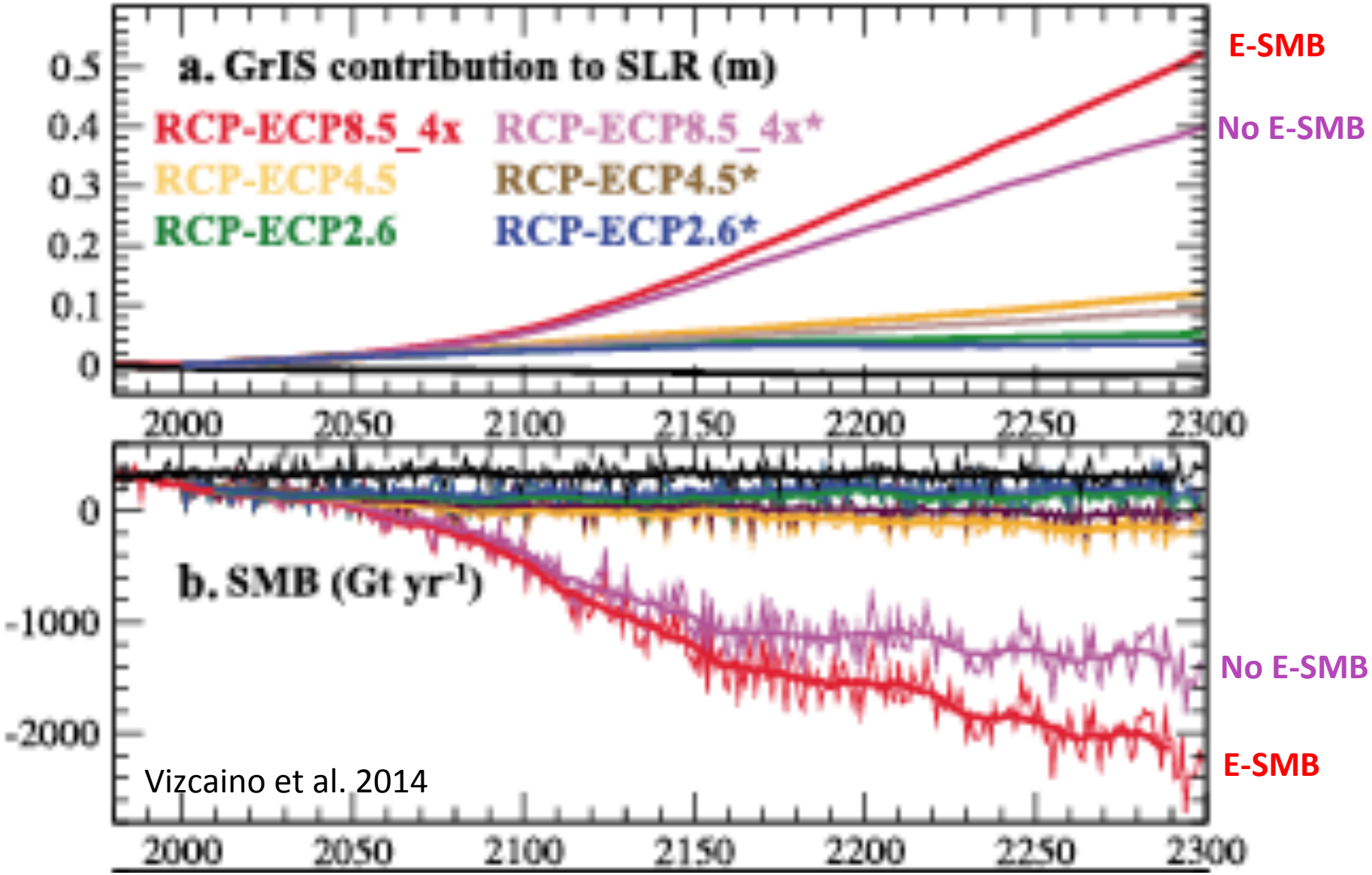
Projections
Historical and future sea level due to ice sheets, and associated uncertainty due to ice sheets.

ISMIP6 is a targeted activity of CliC that addresses the *Cryosphere in a Changing Climate* and the *Future Sea Level* Grand Challenges of the WCRP.

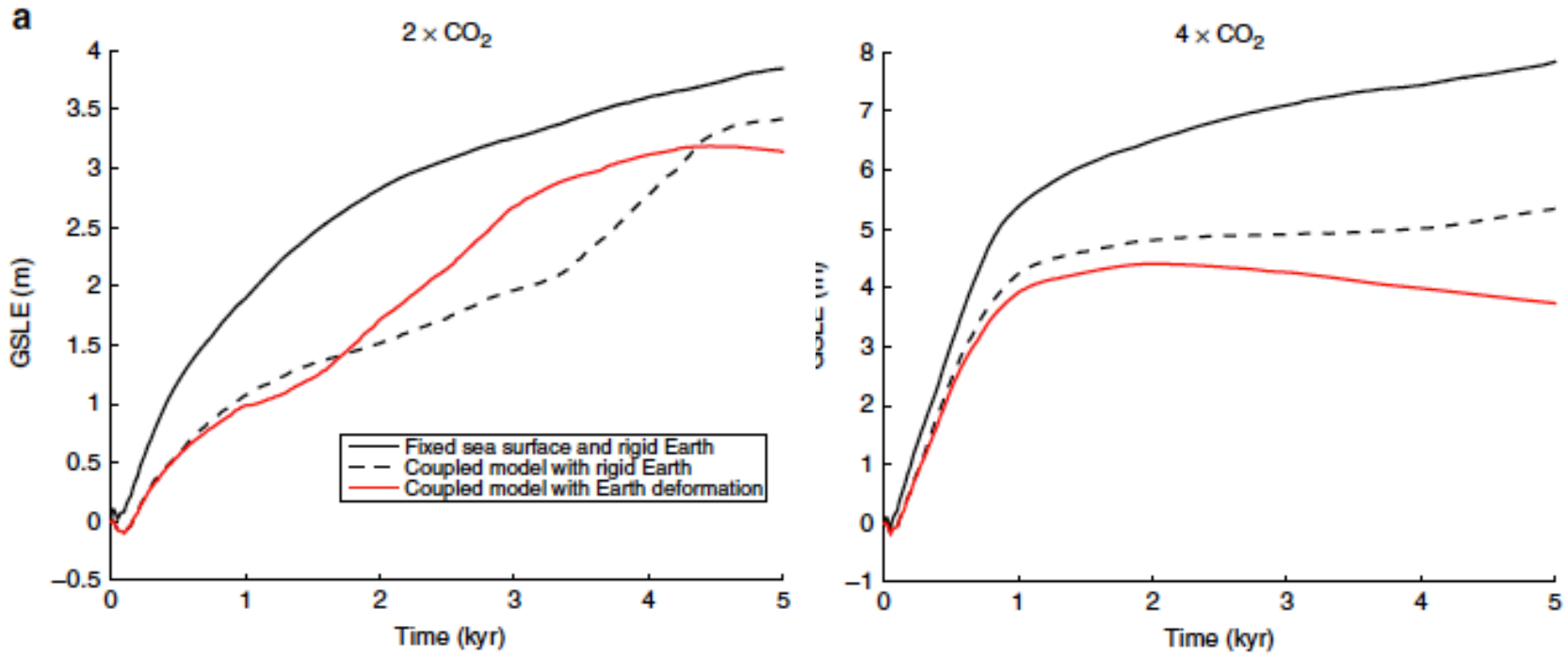
ISMIP6
Ice Sheet Model Intercomparison Project for CMIP6

CliC
Climate and Cryosphere

Ice sheets are being coupled to climate models, and elevation-SMB feedback matters…



Ice sheet models are incorporating more and more processes, such as self-gravity and earth deformation…



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DOI: 10.1038/ncomms9798 OPEN

Sea-level feedback lowers projections of future Antarctic Ice-Sheet mass loss

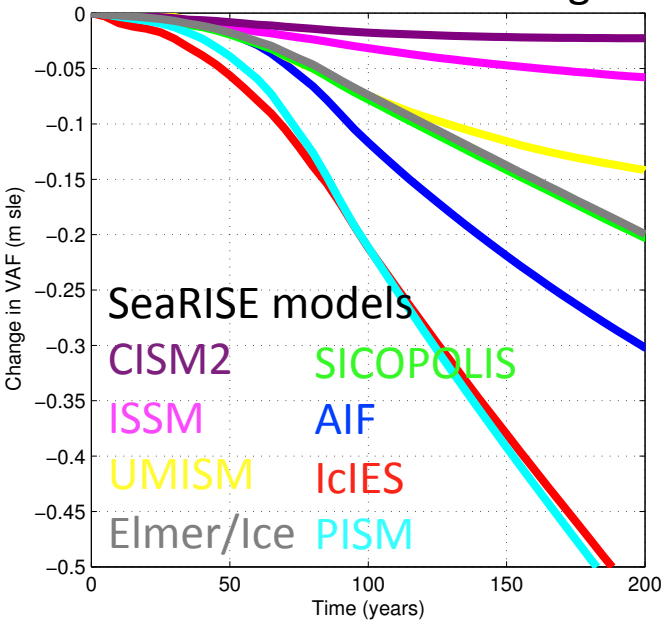
Natalya Gomez[1,2], David Pollard[3] & David Holland[1]

What makes a good model for projection is not easy to define…

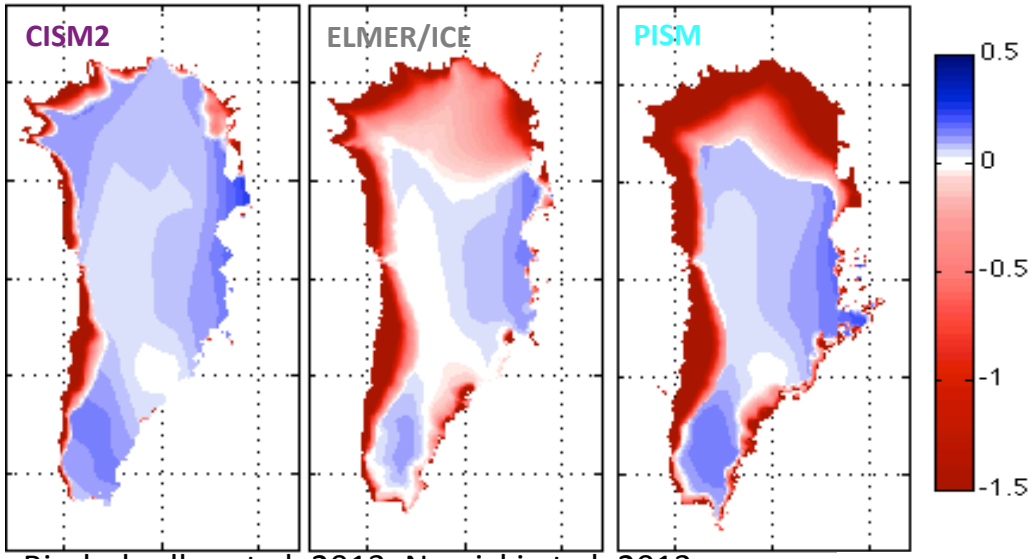
The spread in SeaRISE ice sheet response is due to different:

- Ice sheet model physics, margin migration, sliding laws etc
- Initialization: Spin-up / data assimilation methods (observations play a role)
- Surface forcings and feedbacks, poorly known basal conditions

Ice sheet volume change



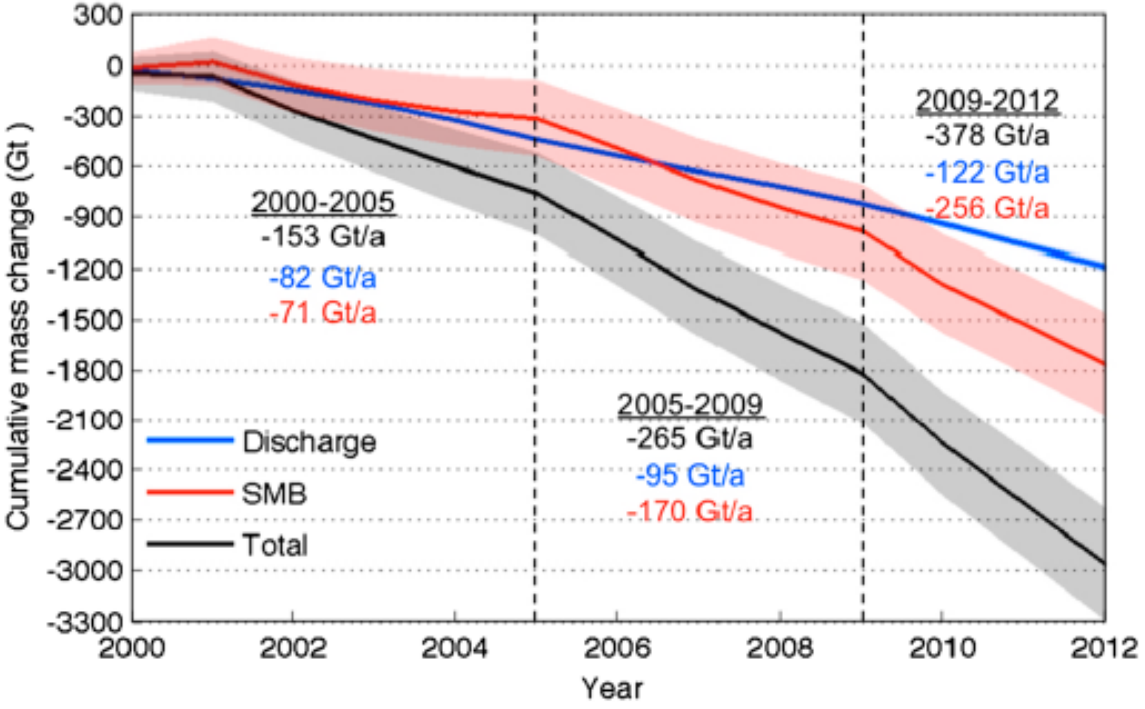
SMB anomaly (m/yr) @ t = 100 yr

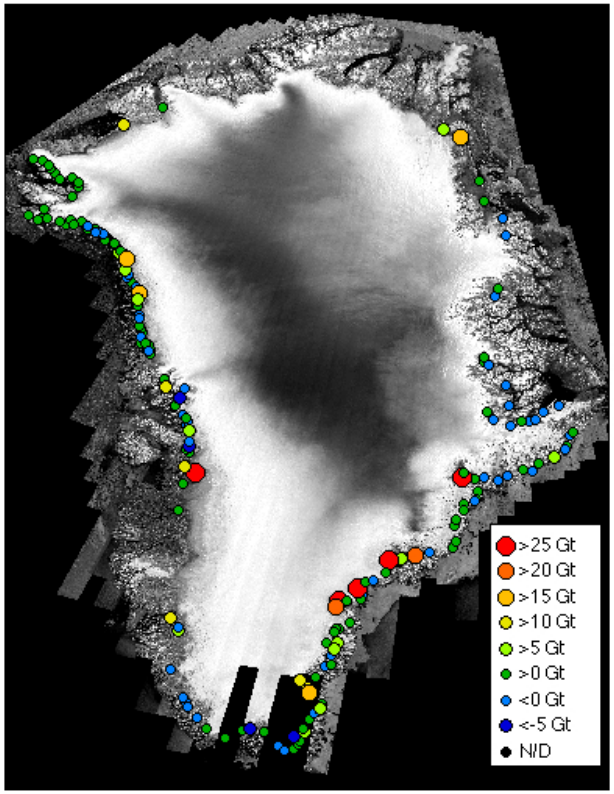


Bindschadler et al. 2013, Nowicki et al. 2013

ISMIP6
Ice Sheet Model Intercomparison Project for CMIP6

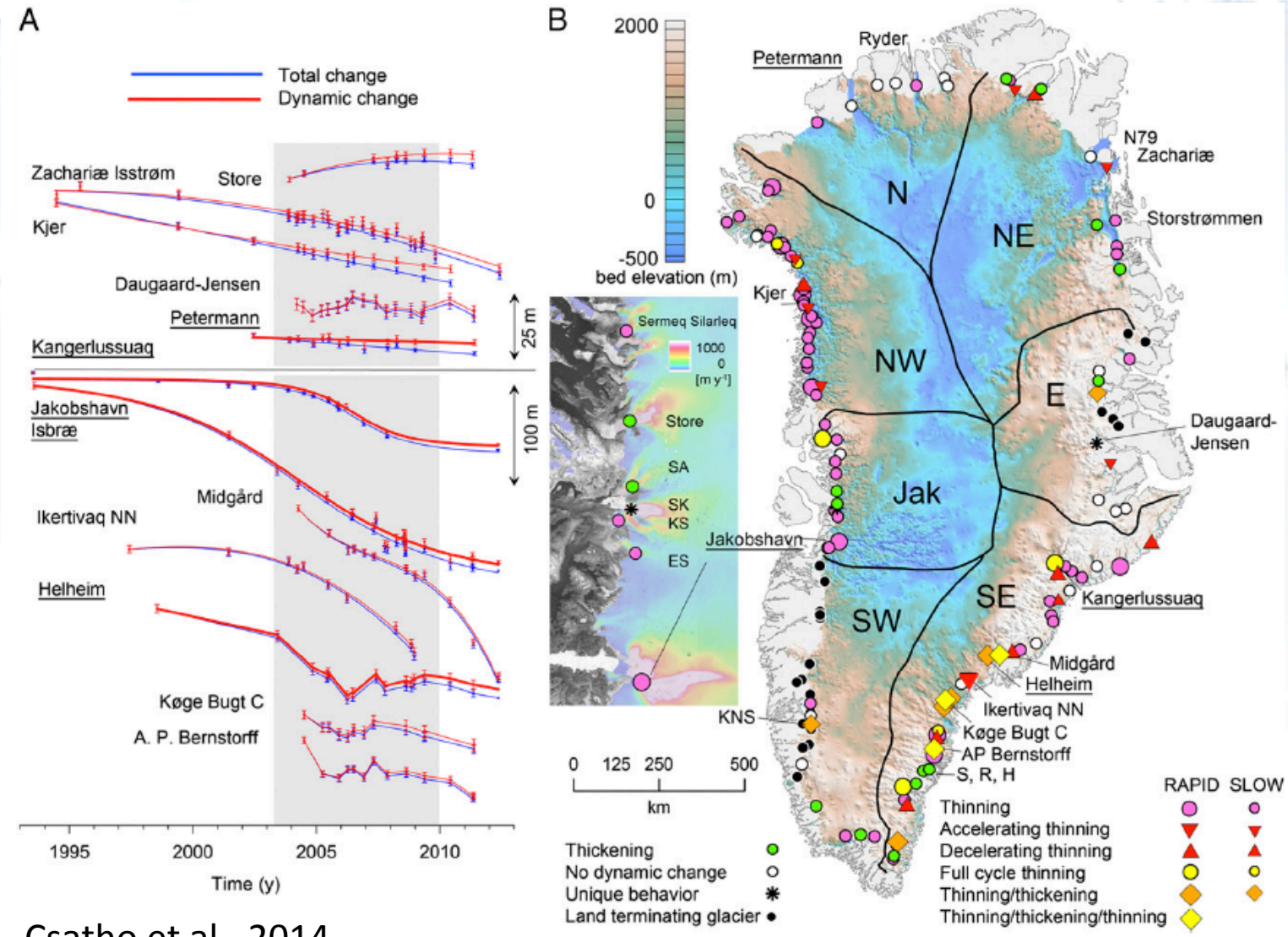
Observational support to recent model projections that SMB, not discharge, is primary driver of GrIS mass loss on decadal and greater timescale…





Enderlin et al., 2014

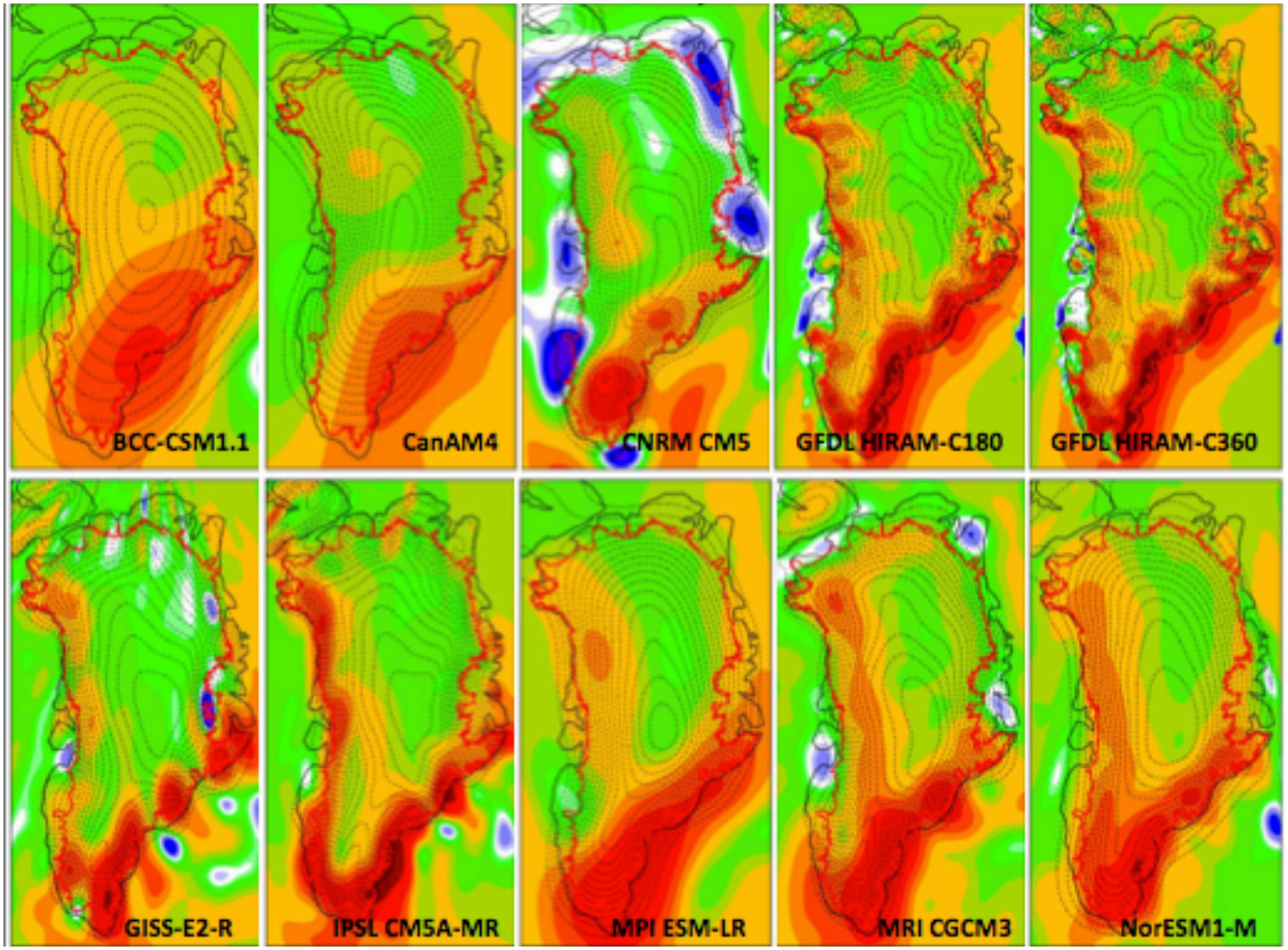
The change in ice flow is very localized and ice sheets “see” regional climate change…

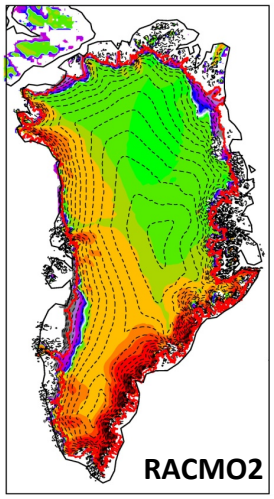


Csatho et al., 2014

Ice sheets see “regional” climate change...

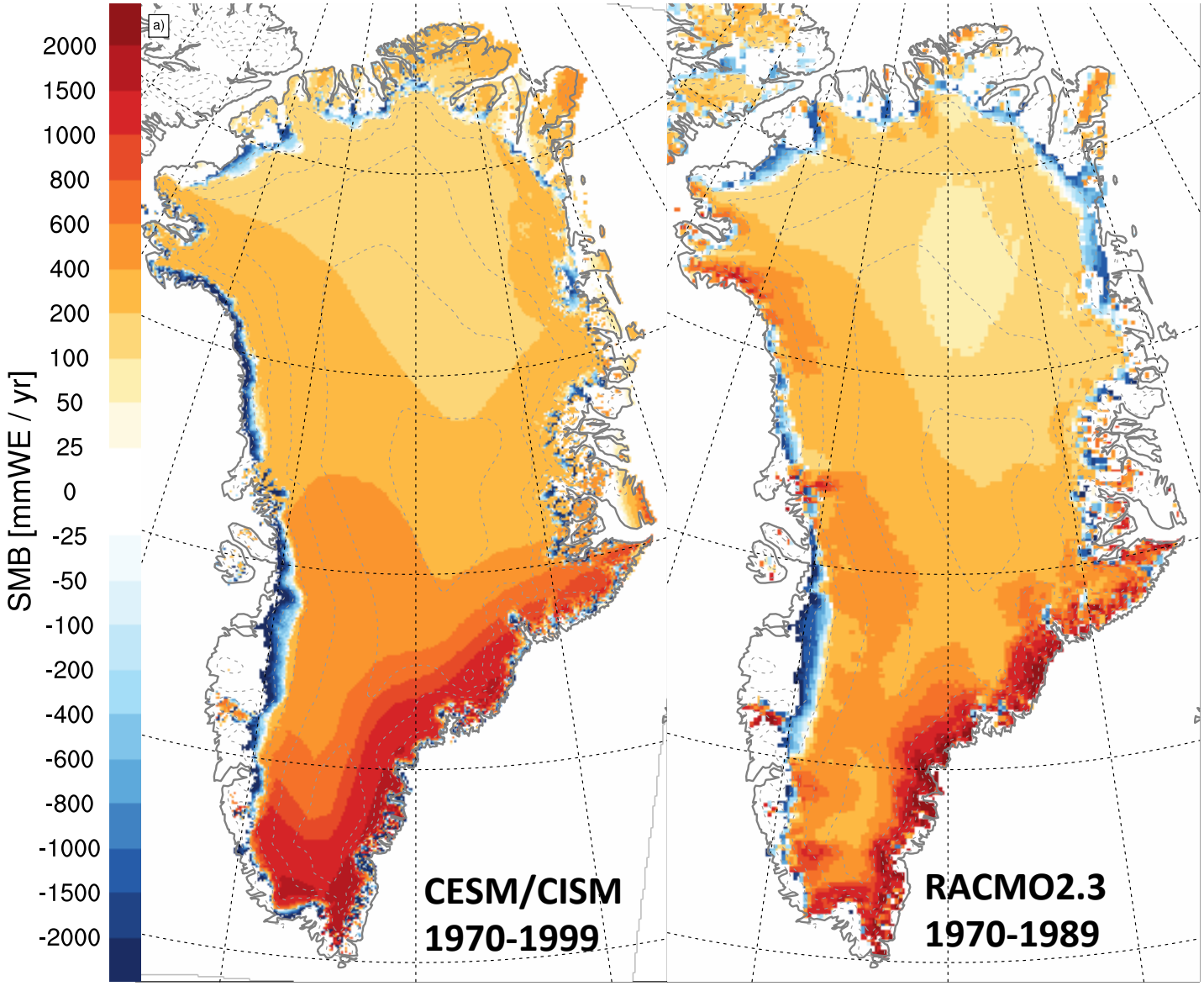
Surface Mass Balance from CMIP5 AMIP (1980-2008)



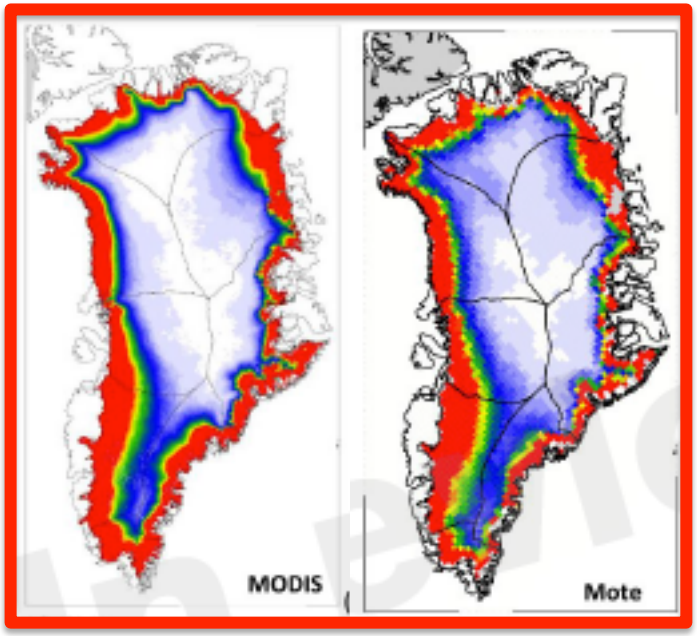


Slide courtesy of R. Cullather

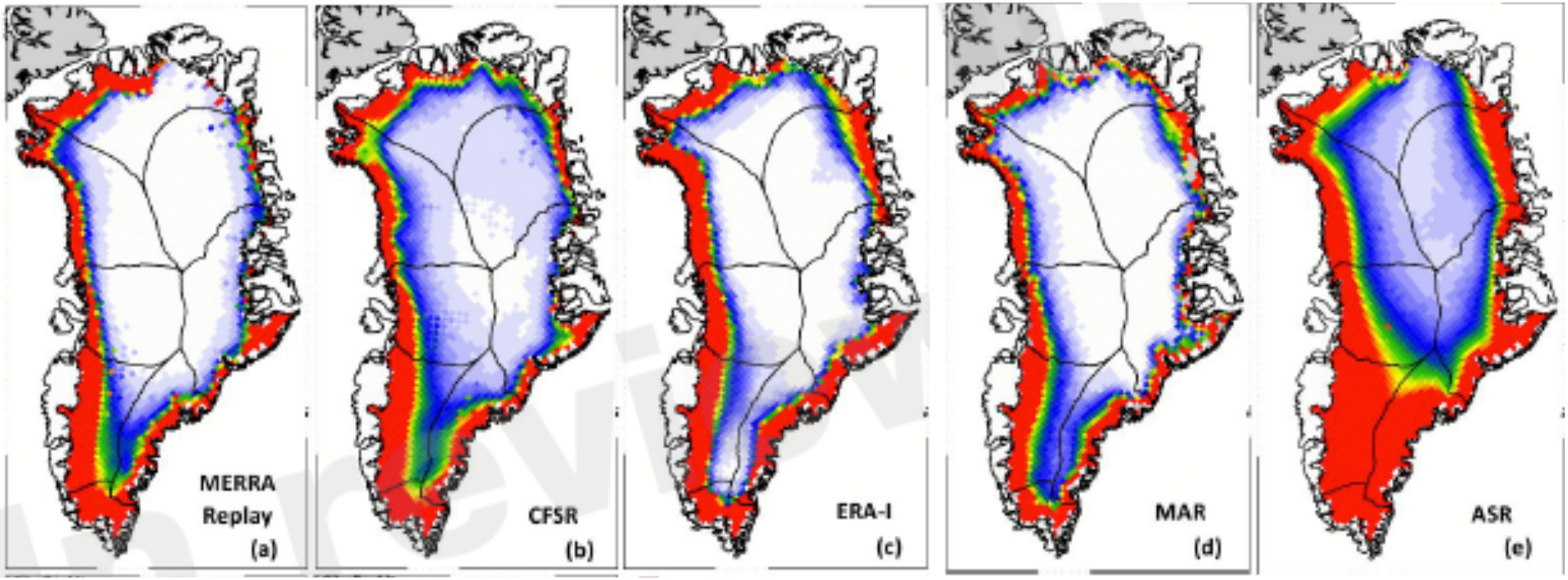
Climate models are improving over the polar regions: SMB as simulated by the Community Earth System Model…



As ice sheets become coupled to climate models: new key metrics will need to be determined. Melt area can be compared to "observations", but ….

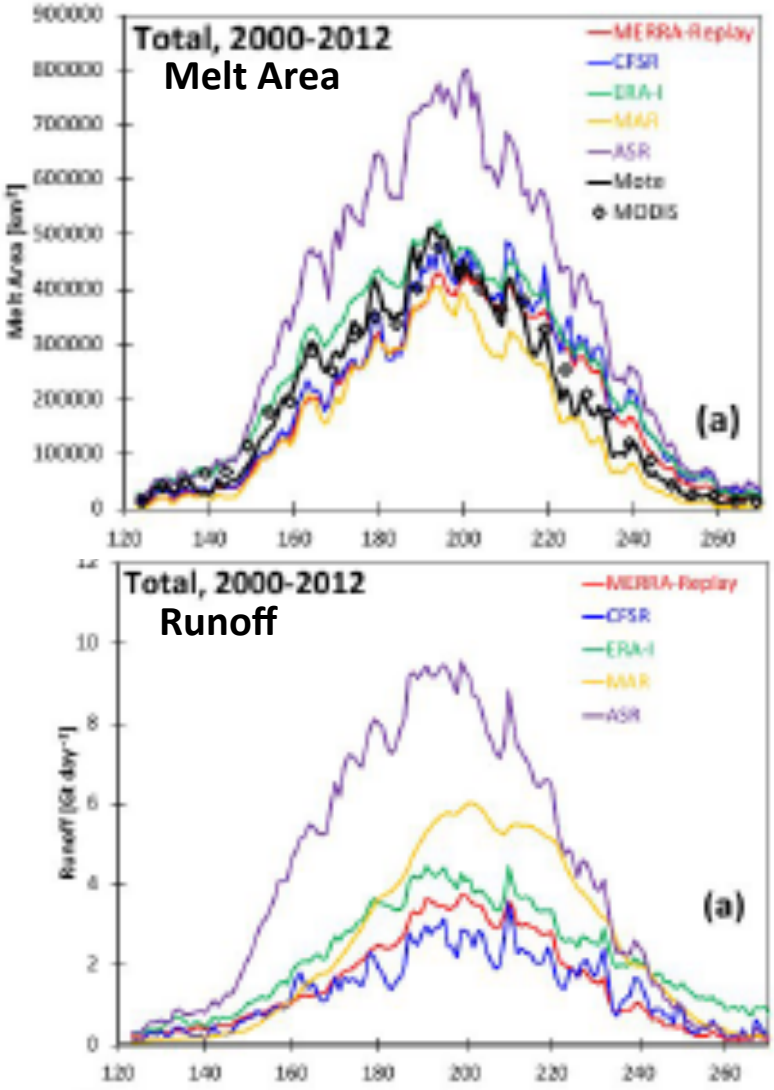


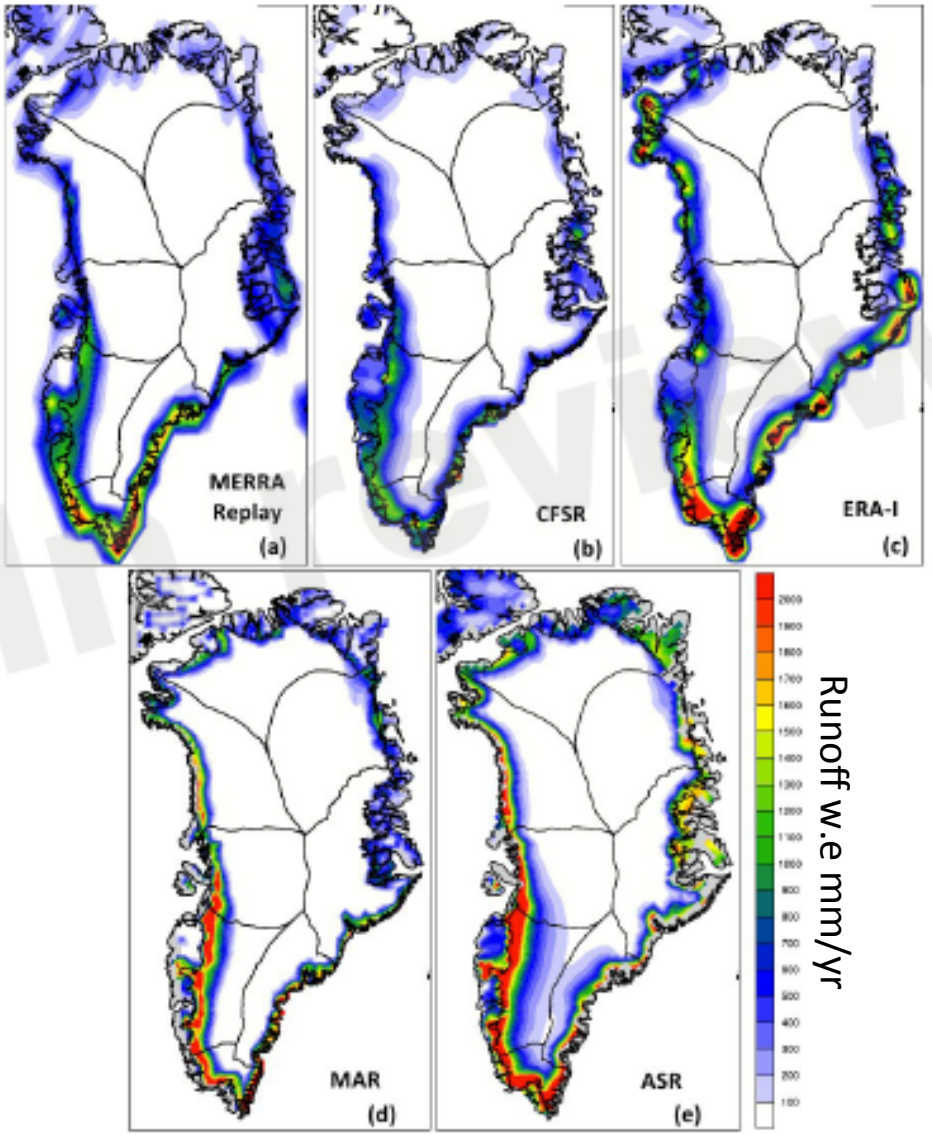
Average number of melt days per year



Cullather et al., 2016

Melt area can be compared to “observations” but runoff cannot…

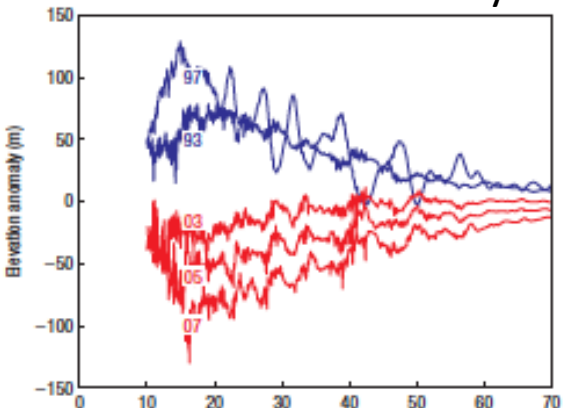




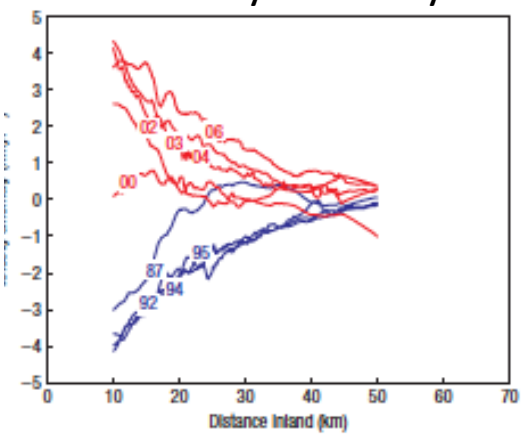
Cullather et al., 2016

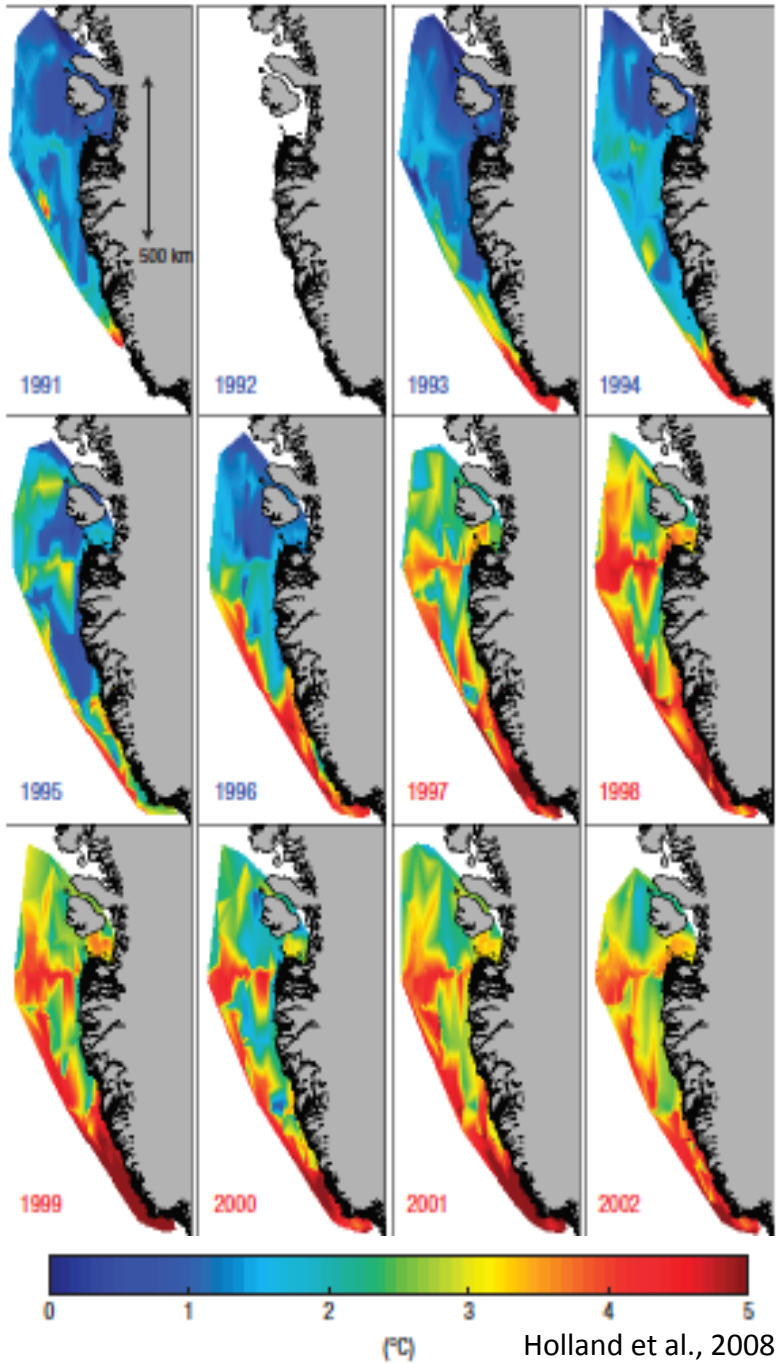
Acceleration of Jakobshavn Isbrae triggered by …
warm subsurface oceanic water attributed to …
changes in atmospheric circulation

Elevation anomaly



Velocity anomaly

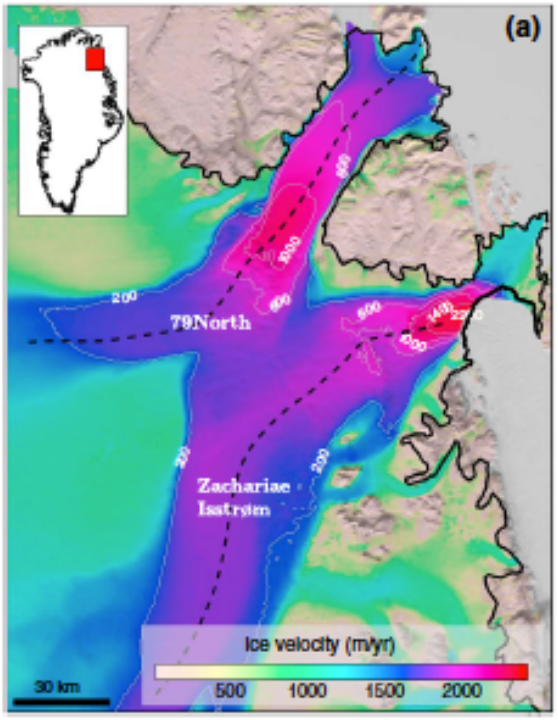




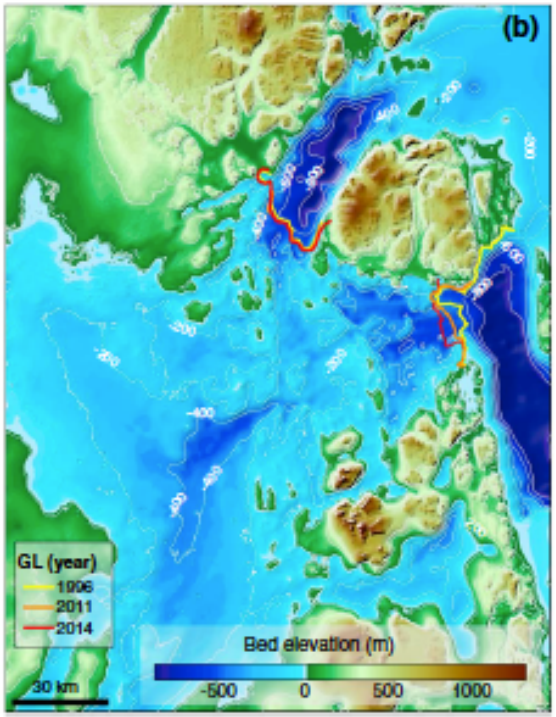
Holland et al., 2008

The basal conditions can stop a grounding line retreat…

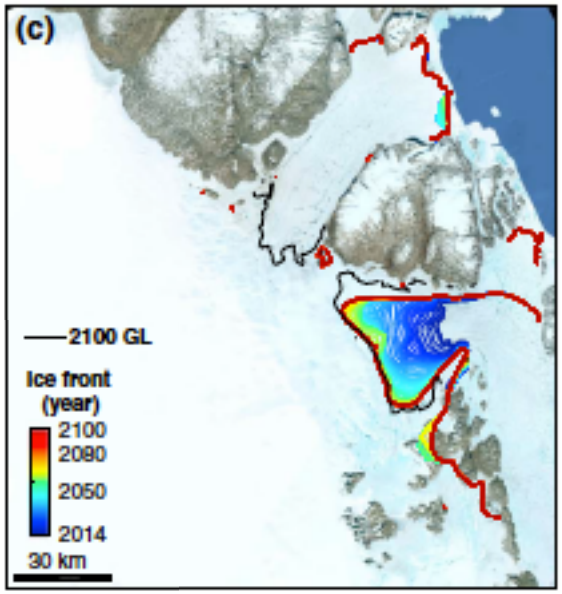
Ice Velocity



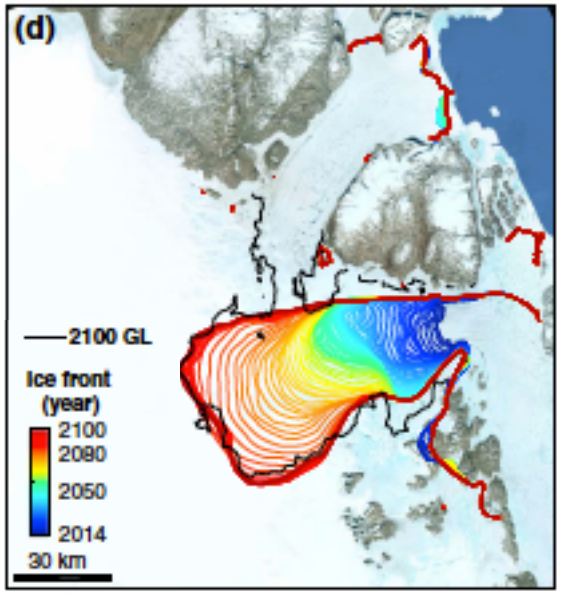
Bed elevation



Maximum frontal summer melt of 3m/d

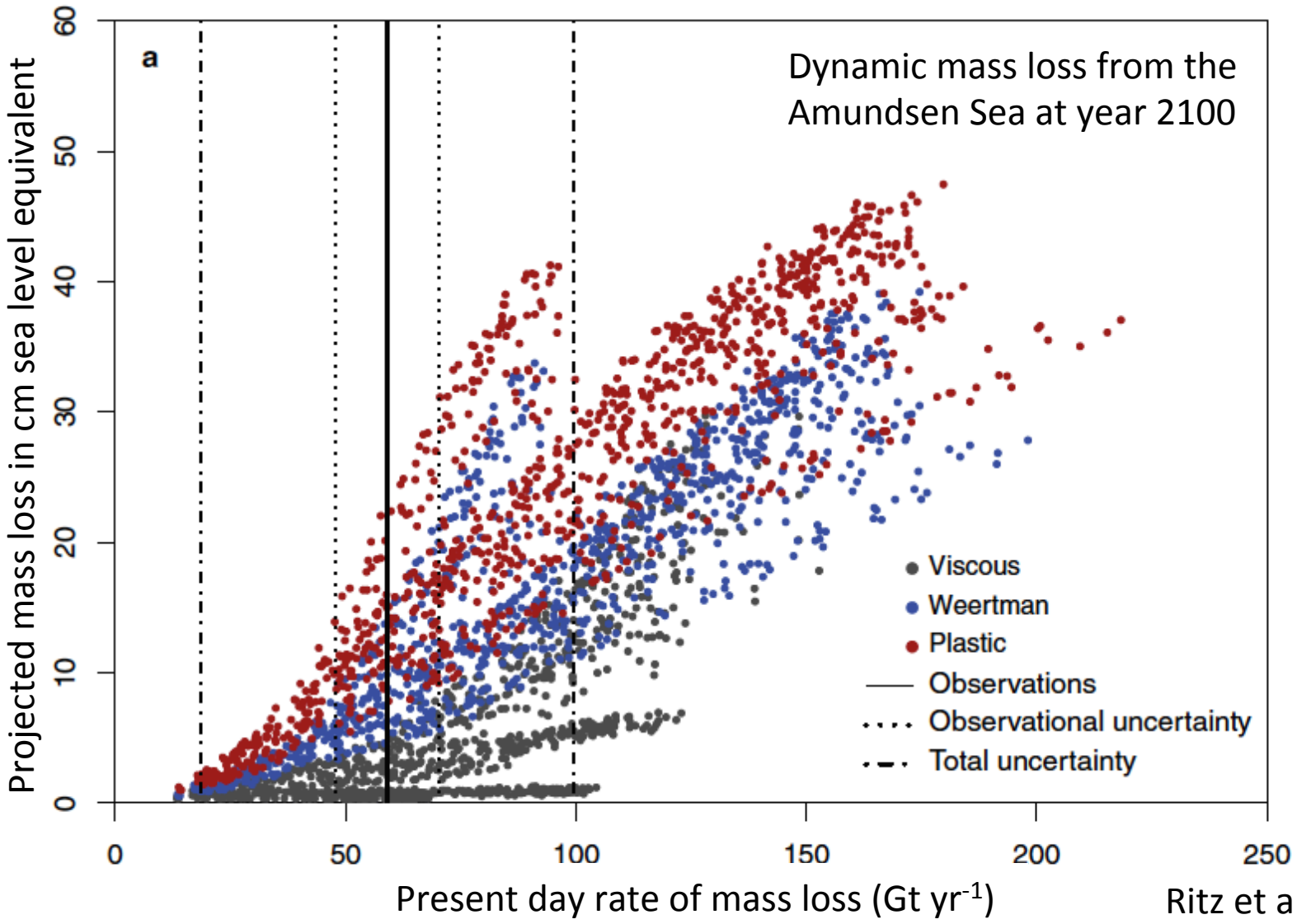


Maximum frontal summer melt of 6m/d



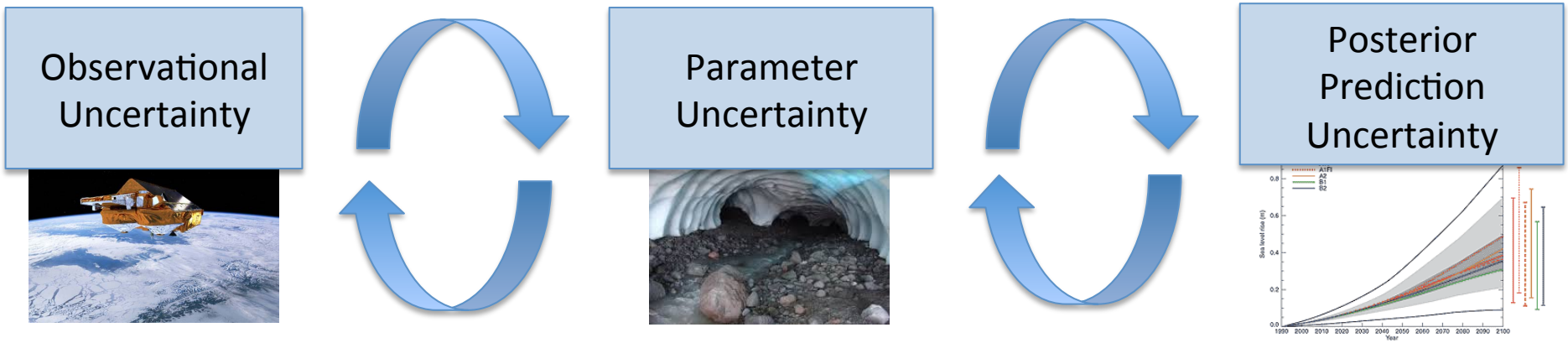
Choi et al. 2017

Uncertainty in properties of the bedrock affect simulated ice sheet response…



Ritz et al. 2015

Given many uncertain processes,
the way forward seems for large member ensembles,
clever constraints and uncertainty quantification…



In this way, the *impact* of new observations on predictions could be assessed

What would we need to achieve this?

- A few postdocs *and the support of the National Labs*
- Calibration methods depend on finding linear sensitivities to large sets of parameters -- **UQ requires sensitivities of sensitivities** *(Thacker, JGR, 1989)* So some software development necessary

Why are simulations from ice sheets so tricky?

- Ice sheets see regional climate change, response is fairly localized but highly complex
- Ice sheet models are becoming more fancy, but many processes are still poorly known
- The projections are becoming limited by key inputs, such as bedrock conditions, or climatic forcing
- What makes “a good model for projection” is not easy to define

Thank you!