Announced title:
Elevation classes for SMB calculations

Miren Vizcaino, TU Delft

NEW TITLE

Coupled climate and Greenland ice sheet evolution up to A.D. 2300 simulated with the MPI model

Miren Vizcaino (1), Uwe Mikolajewicz (2),

Florian Ziemen (2), Christian Rodehacke (2,3),

Ralf Greve (4), and Michiel R. van den Broeke (5)

(1) Department of Geoscience and Remote Sensing, Delft University of Technology, The Netherlands

(2) Max Planck Institute for Meteorology, Hamburg, Germany

(3) Department of Arctic and Climate Research, Danish Meteorological Institute, Denmark

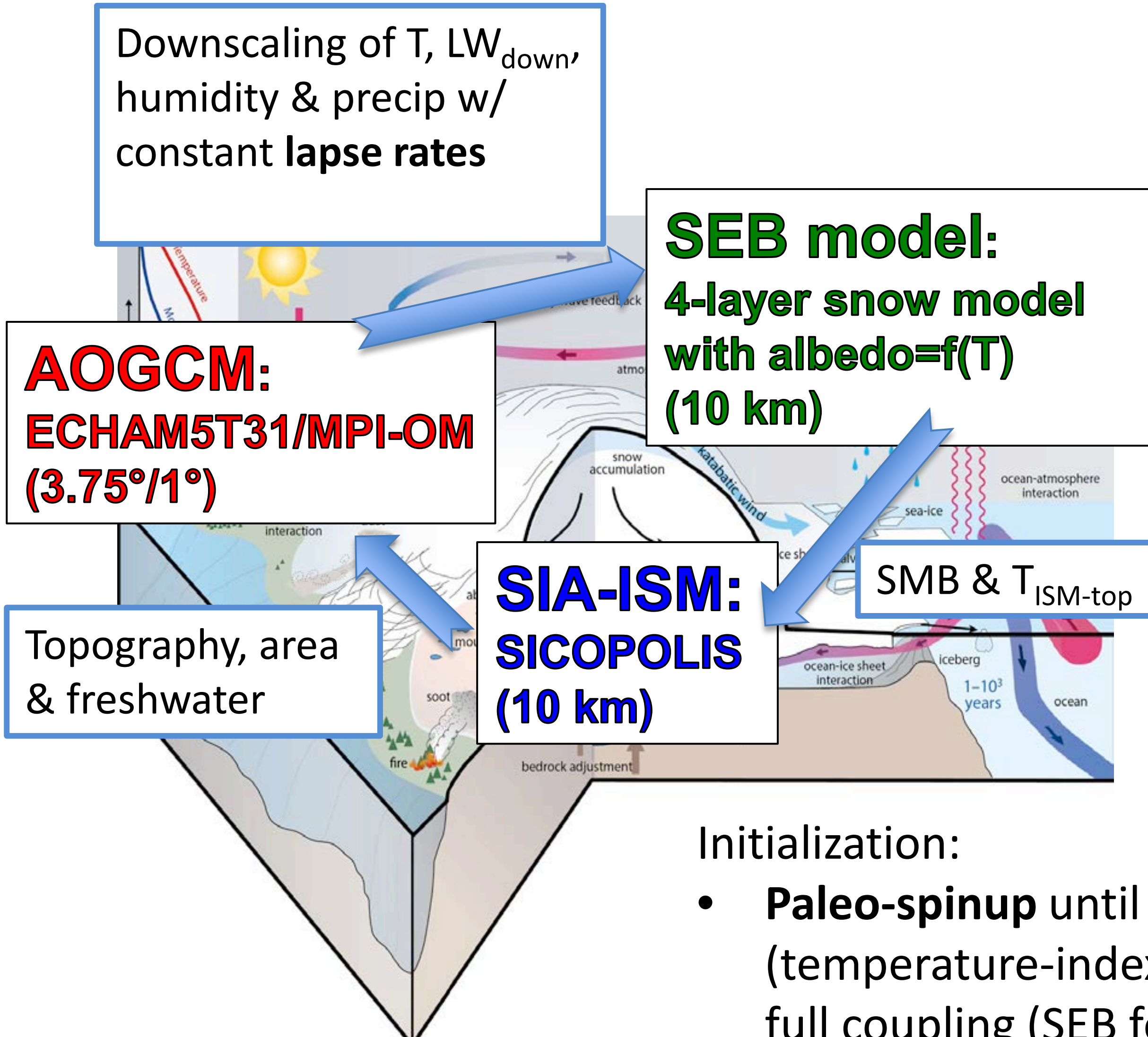
(4) Institute of Low Temperature Science, Hokkaido University, Japan

(5) Institute for Marine and Atmospheric Research, Utrecht University, The Netherlands

Motivation

- ISMIP6
- Ice sheet sensitivity to climate variability
- Propagation of SMB biases in a coupled model
- Processes that can be investigated with a coupled model

Model



Initialization:

- **Paleo-spinup** until 9,000 yr BP (temperature-index for SMB), then full coupling (SEB for SMB)
- Corrections are **not** applied

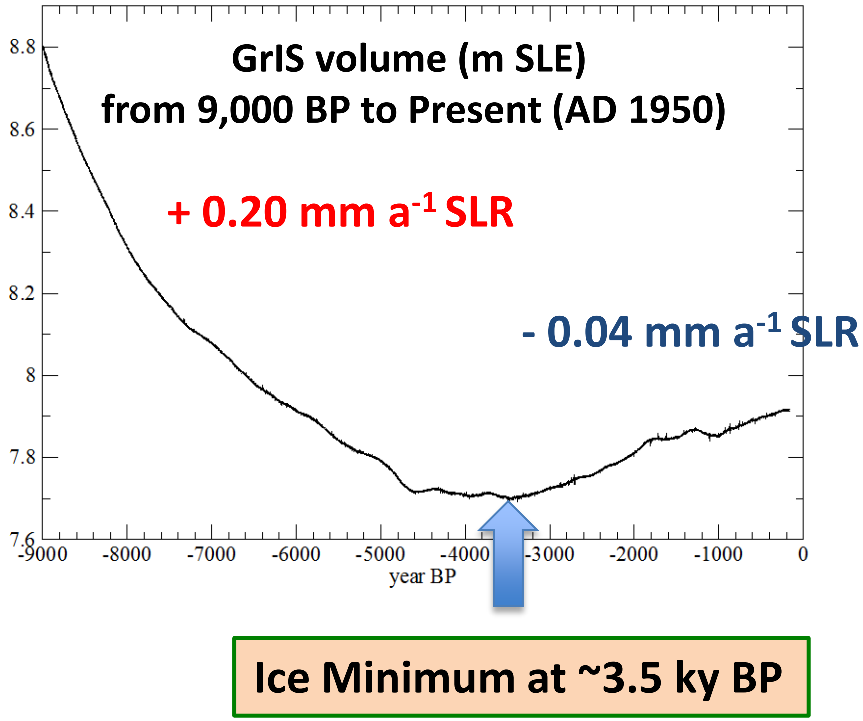
ISMIP6 coupled experiments

Table 1: Summary of the ISMIP6 experiments.

Experiment Title	CMIP6 Label (experiment_id)	Experiment Description	Start Year	End Year	Minimum # Years Per Simulation	Major Purposes
DECK Experiments						
AMIP	*amip* *ism-amip-std*	observed SSTs and SICs prescribed	1979	2014	36	evaluation, variability
pre-industrial or present day control	*piControl* *piControl-withism* *ism-piControl-self* *ism-pdControl-std*	pre-industrial (pi) conditions imposed with CO_2 concentration fixed, or present day (pd) condition imposed	n/a	n/a	500	evaluation, unforced variability
abrupt quadrupling of CO2	*abrupt-4xCO2*	atmospheric CO_2 concentration abruptly quadrupled and then held constant	n/a	n/a	150	climate sensitivity, feedbacks, fast responses
1% per year CO_2 increase	*1pctCO2* *1pctCO2-withism* *ism-1pctCO2-self* *ism-1pctCO2-std*	atmospheric CO_2 concentration prescribed to increase at 1% yr^{-1} and then held constant to quadruple levels	n/a	n/a	150	climate sensitivity, feedbacks, idealized benchmark
CMIP6 *historical* Simulations						
CMIP6 historical	*historical* *historical-withism* *ism-historical-self* *ism-historical-std*	simulation of the recent past with CO2 concentration prescribed	1850	2014	165	evaluation
CMIP6 ScenarioMIP Simulations						
ScenarioMIP	*ssp5-8.5* *ssp5-8.5-withism* *ism-ssp5-8.5-self* *ism-ssp5-8.5-std*	future scenario with high radiative forcing by the end of the century	2015	2300	286	climate sensitivity
CMIP6 PMIP Simulations						
PMIP last interglacial	*lig127k* *ism- lig127k -std*	simulation of the last interglacial	n/a	n/a	3000	climate sensitivity, feedbacks, long responses

Nowicki et al., GMDD

Holocene results

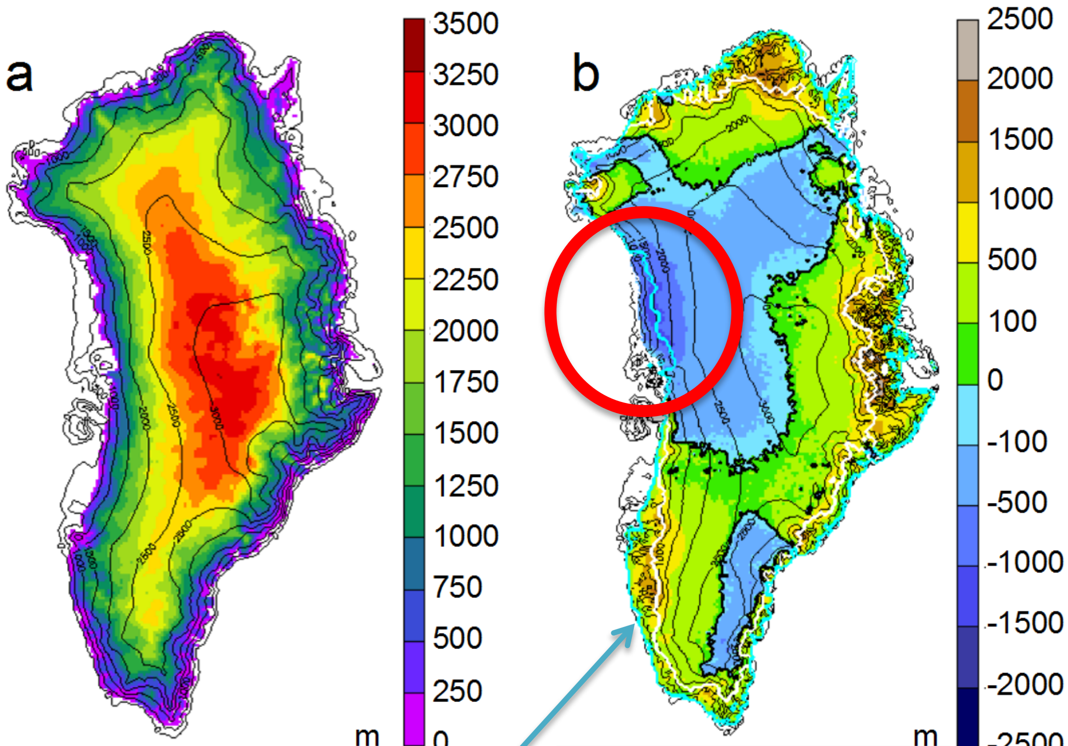


- **From 9 to 3.5 ky BP**, volume **decreases** in response to high insolation
- **Without human GHGs**, the modeled present-day GrIS **gains mass**

Vizcaino et al., GRL, 2015

Present-day topography

Simulated 1960-2005 thickness and bias w.r.t. observations (Bamber et al. 2001)

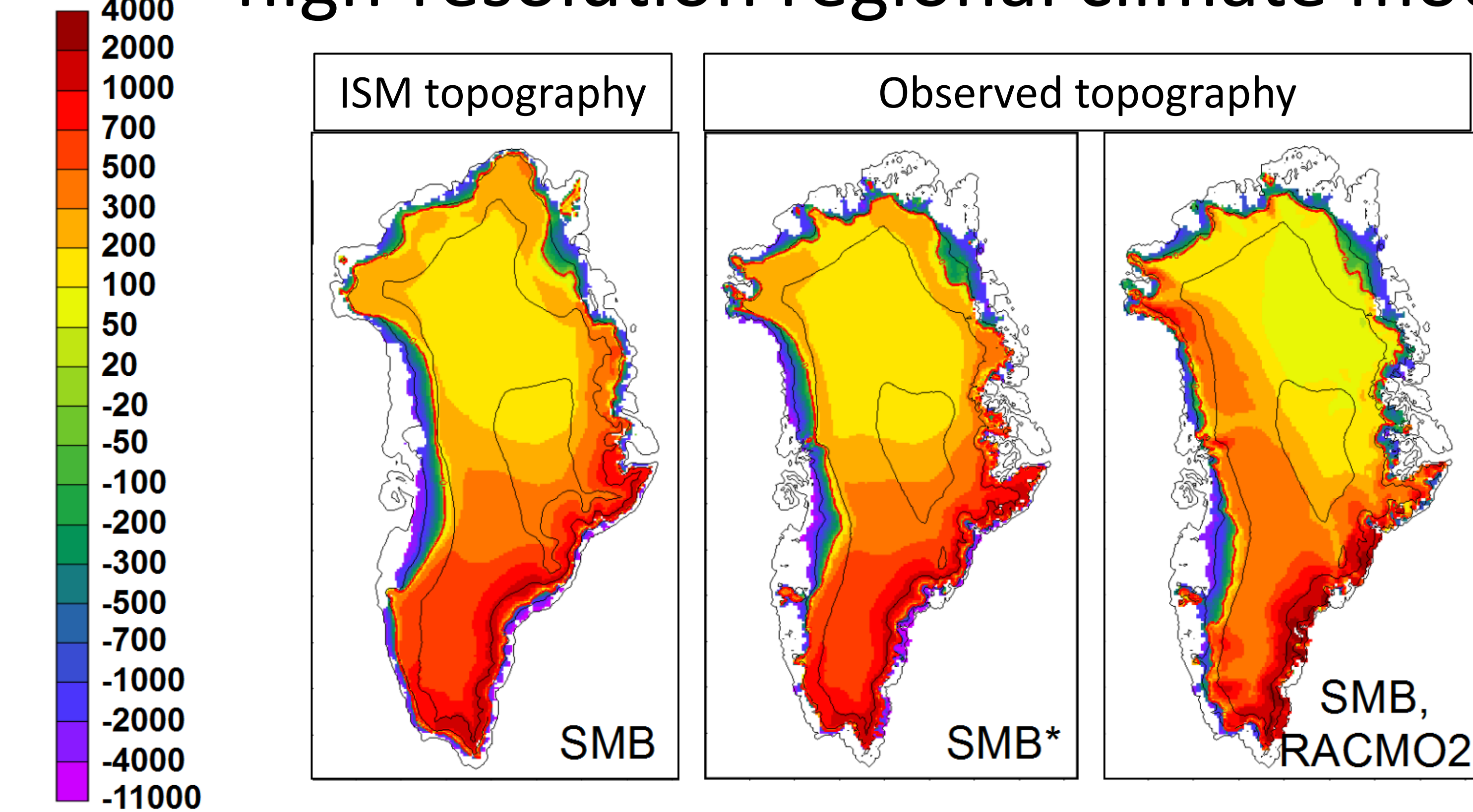


- Total **area** and **volume** are **overestimated**
- **NW margin too far** from coast

Contours:

- Simulated and observed topography
- Modeled and observed (white) margins

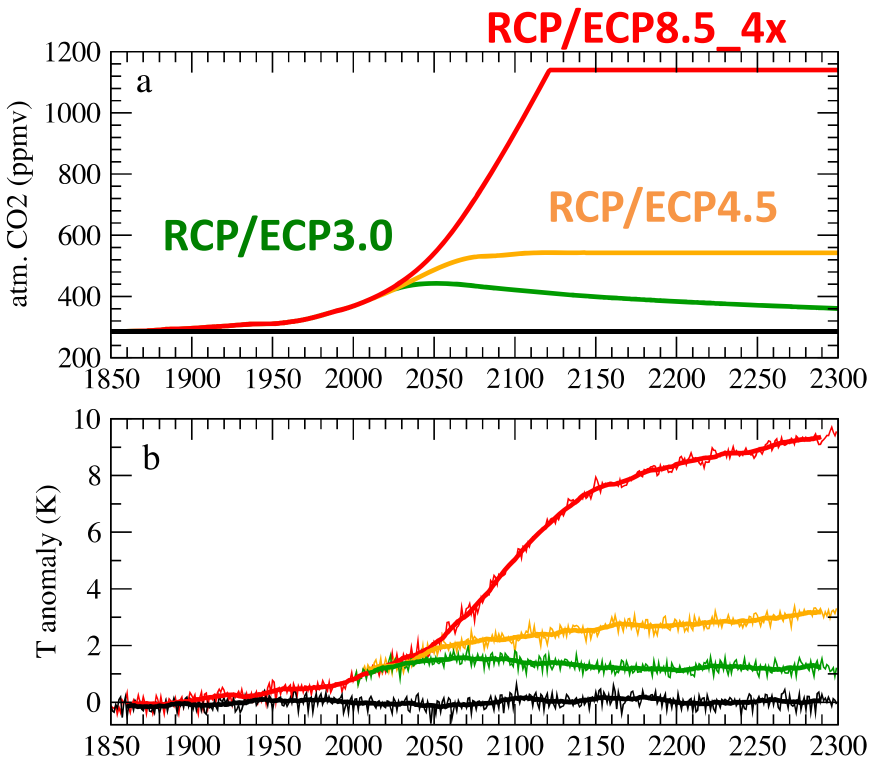
SMB compares relatively well with high-resolution regional climate model



1960-2005 mean

- Differences with RCM are due to atmospheric and topographic biases (* isolates atmospheric bias)
- **NW** thickness biases are caused by **insufficient accumulation**

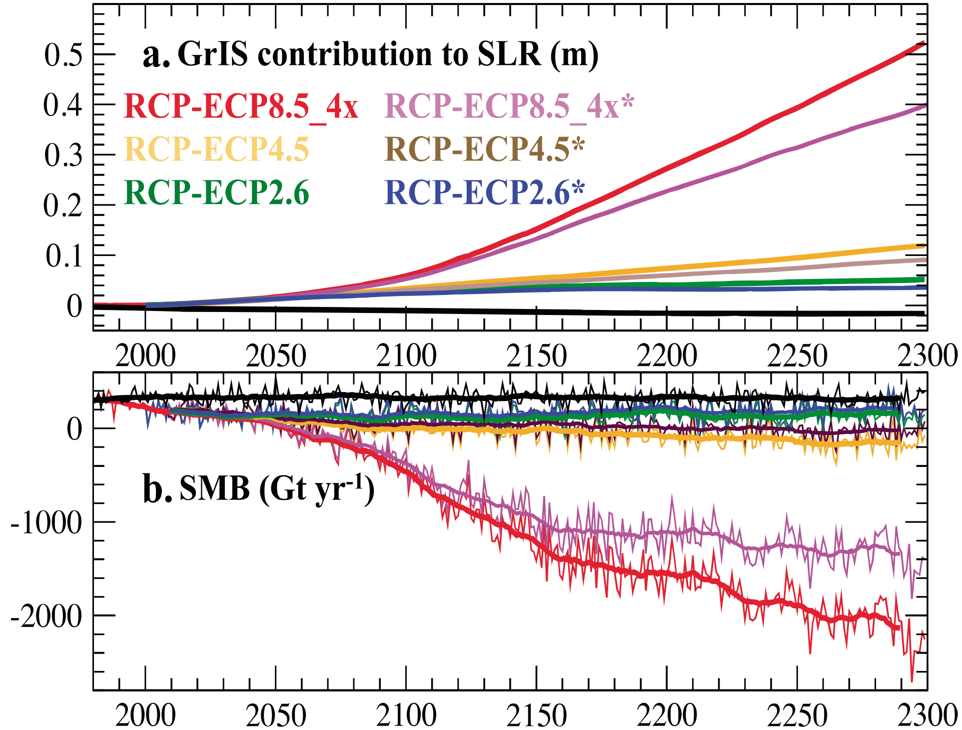
Three scenarios



Vizcaino et al., GRL, 2015

- 3 scenarios: **RCP3.0**, **RCP4.5**, **RCP8.5** and their extensions (ECP's)
- In **RCP2.6**, T peaks in 21st century, then declines
- **1**, **3** and **9** K warming by 2300

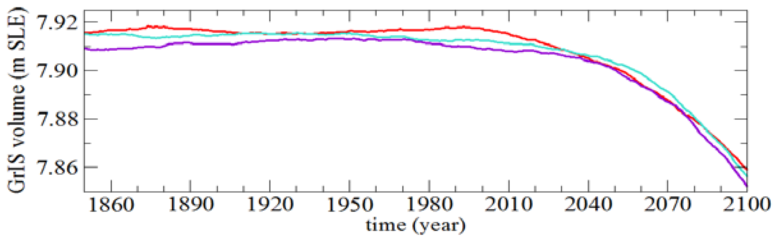
Volume and SMB evolution

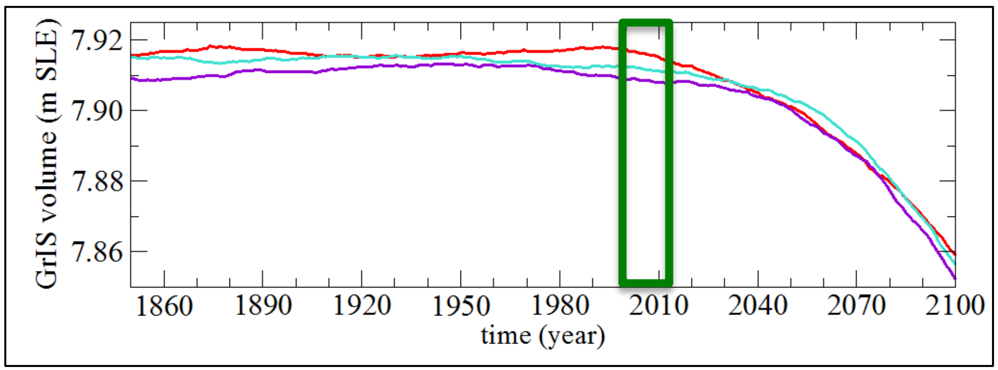


Gt a^{-1}		RCP/ECP 2.6		RCP/ECP4.5		RCP/ECP8.5_4x	
	1980-1999	2080-2099	2280-2299	2080-2099	2280-2299	2080-2099	2280-2290
SMB	**288**	**88**	**149**	**-5**	**-145**	**-313**	**-2132**
Accu	**707**	**+7%**		**+9%**		**+18%**	
RU	**419**	**+60%**		**+84%**		**+273%**	

- 37, 44 and 68 (2100) and 68, 135 and 539 (2300) mm global-mean **SLR**
- **10-30%** less mass loss if **SMB-elevation feedback** is not included (*)
- SMB becomes **negative by 2100** in RCP4.5 and RCP8.5

Variability in the simulated 1990-2013 GrIS mass trend

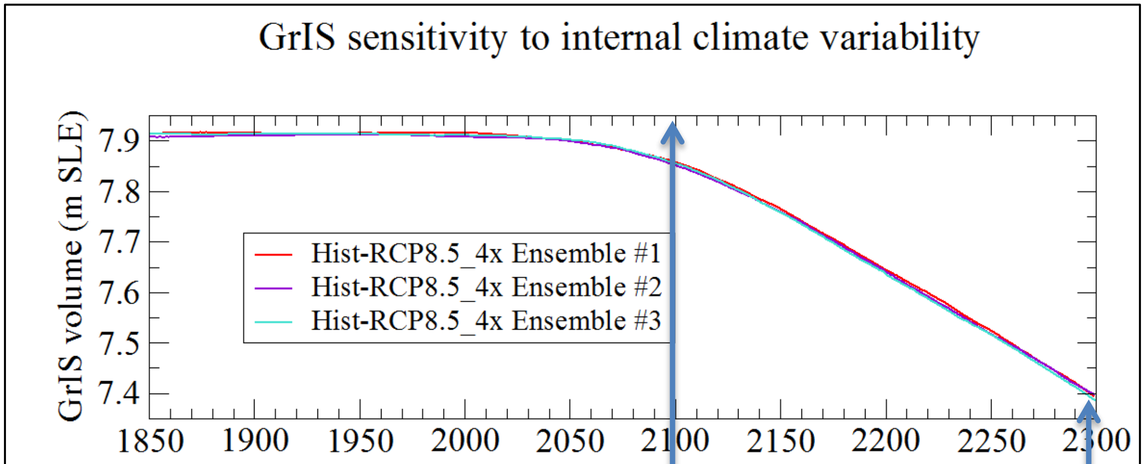




- Net **mass loss** in the three ensemble members
- **Large spread**: 0.06, 0.08 & 0.15 mm a^{-1} SLR
- Mass loss is **underestimated** (Shepherd et al. 2012: 0.39±0.13 mm a^{-1} SLR) due to lack of ocean forcing

Vizcaino et al., GRL, 2015

Small sensitivity of future volume loss to internal climate variability



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By 2100:

- Mean: **67** mm a^{-1} SLR
- σ: **1** mm a^{-1} SLR

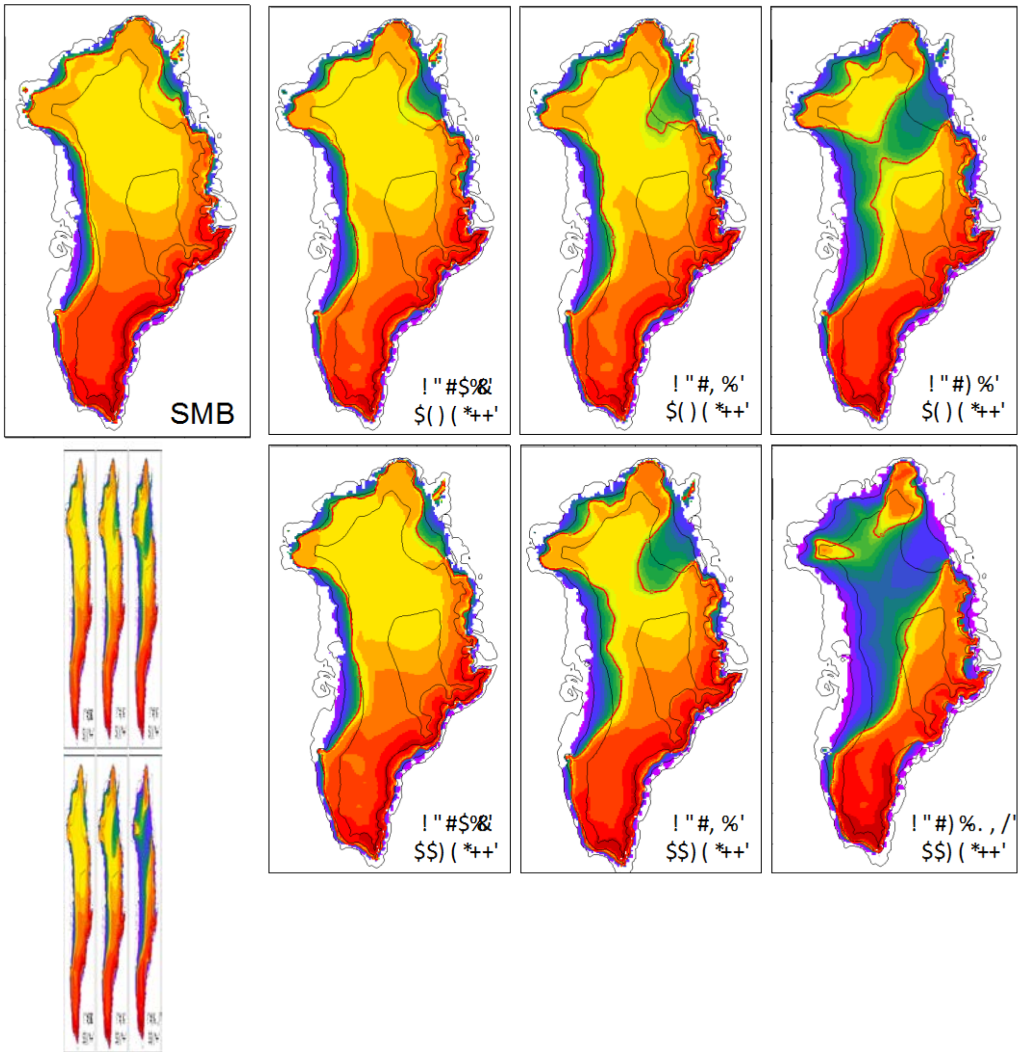
By 2300:

- Mean: **536** mm a^{-1} SLR
- σ: **7** mm a^{-1} SLR

- Approx. linear increase of sigma with the mean
- Much less variation within ensemble than for different scenarios

Future SMB

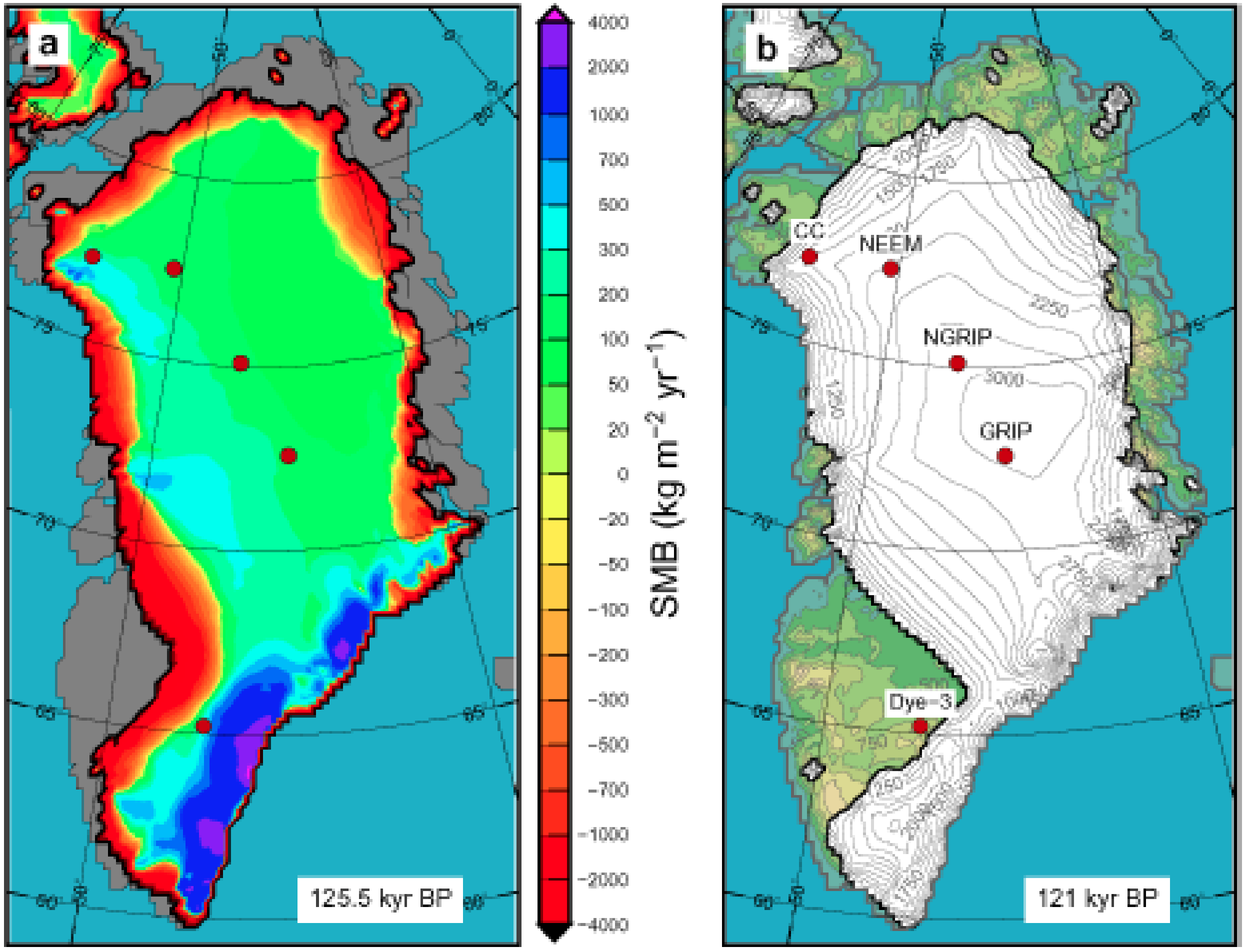
1960-2005



- ELA increases in all simulations, particularly in the **northern half**
- SMB increases over N & SE accumulation areas due to increased snowfall

Vizcaino et al., GRL, 2015

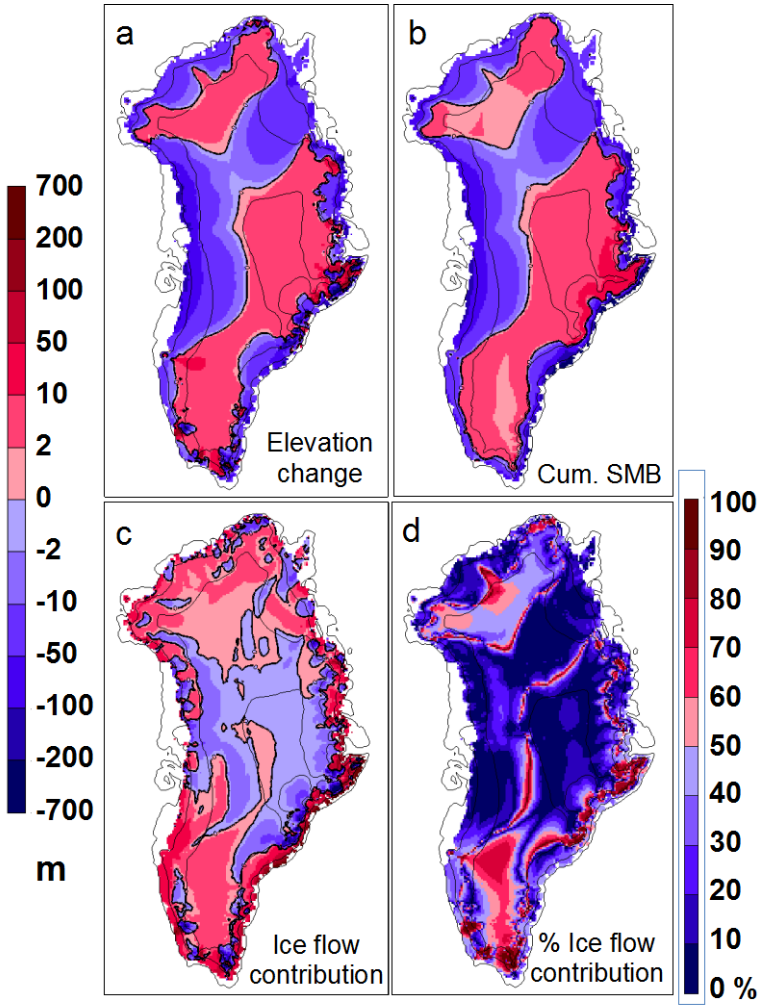
No “pinning-point”



Eemian GrIS as simulated with RACMO-ANICE (Helsen et al., 2013)

Sources of elevation change

2080-99 minus 1980-99, under **RCP8.5**:



- Gross pattern largely given by cumulative SMB
- Increased surface slope from cumulative SMB enhances ice flow
  - This partially counterbalances elevation reduction from enhanced melt

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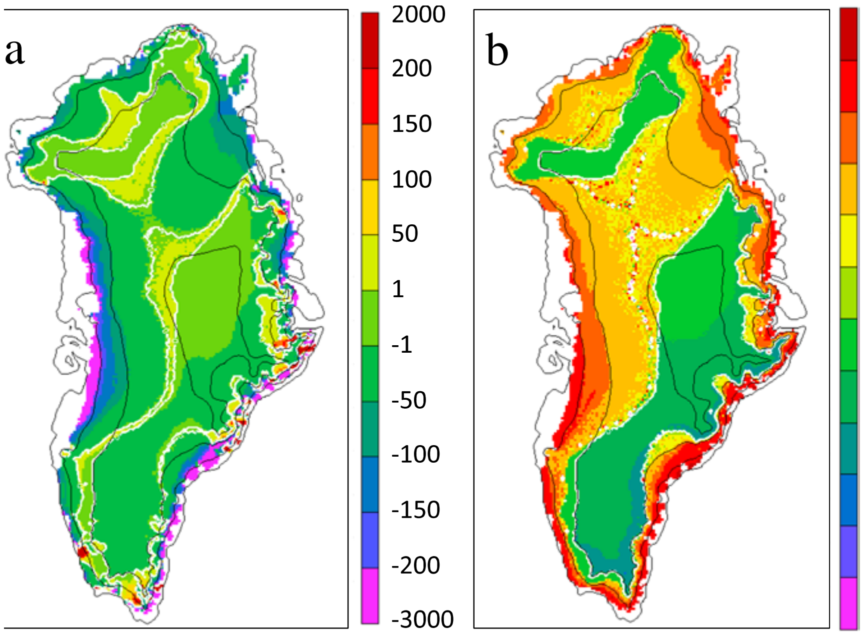
Elevation-SMB feedback

SMB anomaly associated with elevation change 2080-99 minus 1980-99 under **RCP8.5**



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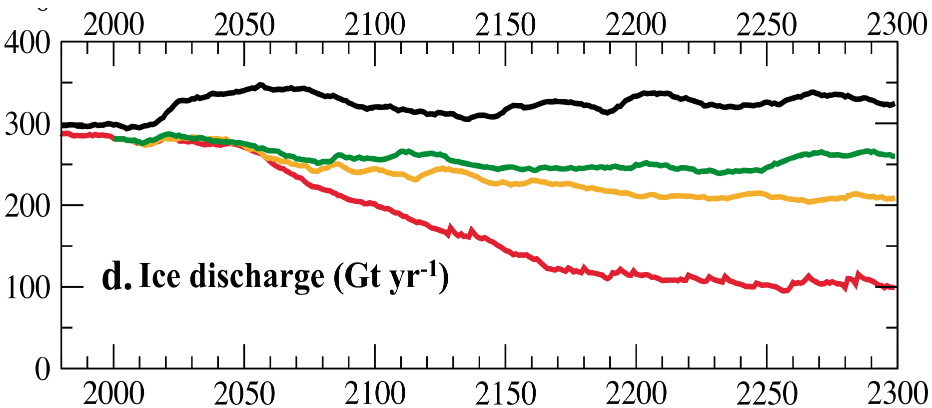
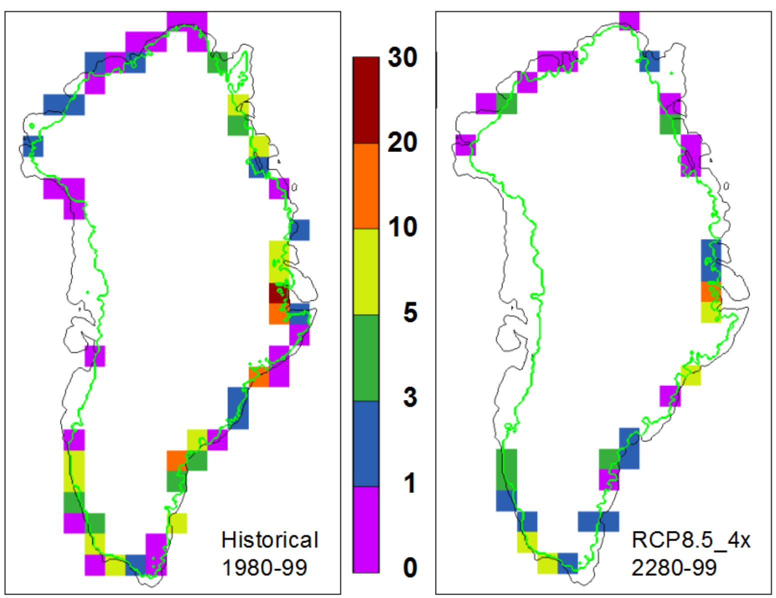
- Elevation change affects **melt, precipitation, and rain fraction**
- Feedback estimated from simulations where SMB is calculated at fixed 1980-1999 ISM topography
- Feedback reduces SMB over most of the ice sheet
  - **Melt increases** at reduced elevations
  - **Accumulation is reduced** at increased elevations
- **Large spatial gradients**, as in *Helsen et al., [2012]*

Ice discharge evolution



Simulated ice discharge in Gt a^{-1} per 10^4 km^2 and GrIS margin (green contour) :



- Decreases in all simulations due to **marginal retreat and thinning** caused by increased runoff (as in Lipscomb et al., J. Clim., 2013)
- However, ice discharge distribution is **not realistically simulated** (e.g., NW) & model **does not reproduce current glacier acceleration**

Vizcaino et al., GRL, 2015

Conclusions

- **First** coupled simulation from GrIS model and AOGCM under RCP/ECP forcing
- Results suggest that GrIS would be **growing in absence of anthropogenic climate change**
- Surface mass balance, elevation and ice flow are **coupled**
- **SMB-elevation feedback** enhances mass loss by **10% (2100)** and **30% (2300)**
  - ➢ Limited validity of fixed-topo SMB projections beyond 2100
- Ensemble reveals
  - – **wide spread** in simulated **present-day** mass trends
    - ➢ Caution in evaluation of models with observations
  - – **small** sensitivity to **future climate variability** compared with sensitivity to GHG scenario

Vizcaino et al., GRL, 2015