DEPARTMENT OF EARTH SCIENCE

The Surface Mass Balance of the Greenland Ice Sheet during the Last Interglacial

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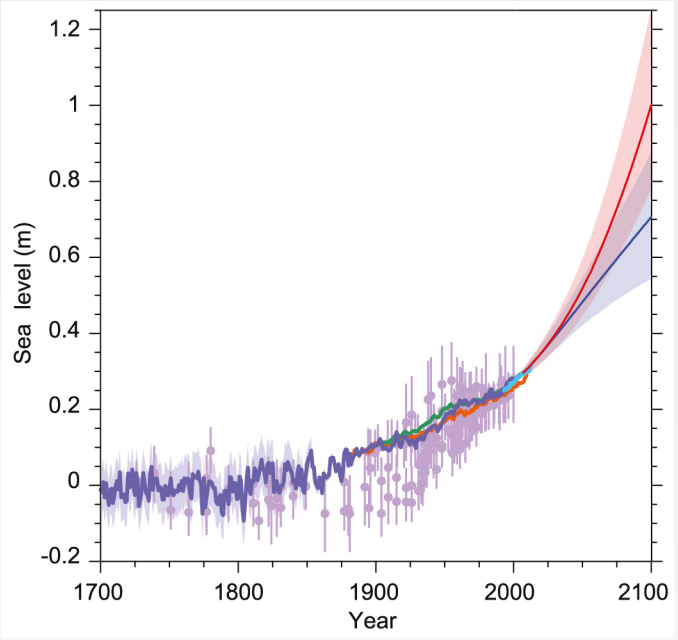
Why is the Greenland Ice Sheet (GrIS) important?

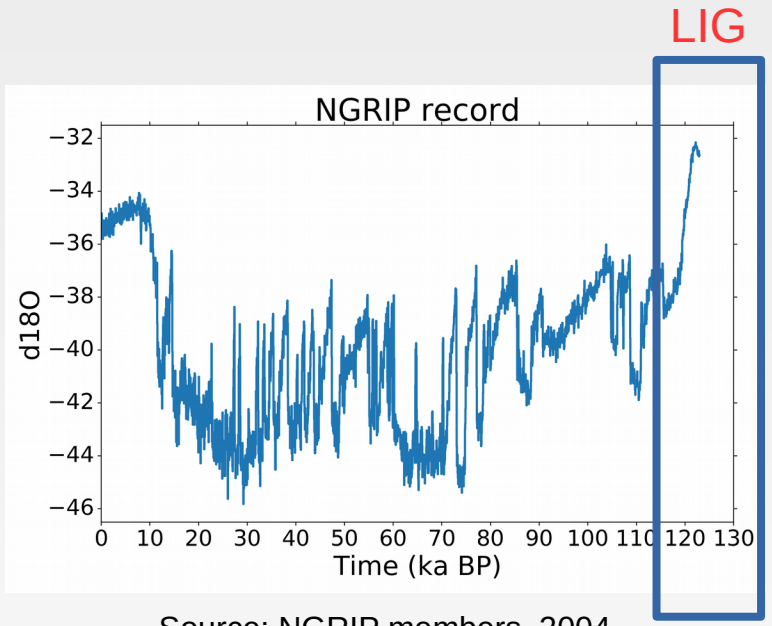
- Melting GrIS contributes to Sea Level Rise
  - Greenland Ice Sheet (**GrIS**) ~7 m
  - Antarctic Ice Sheet (**AIS**) ~10x GrIS
- Most recent IPCC report (AR5; Chp. 13 Sec. 13.8):
  - "...significant uncertainties remain, particularly related to the magnitude and rate of the ice-sheet contribution for the 21st century and beyond..."



Source: IPCC AR5 Fig. 13-27

Why is it important to know the GrIS looked in the past?

- Sensitivity of ice sheets to climate change
- looking at warmer past
- Last Interglacial (**LIG**) peaked around 125 kyrs BP
- Paleo data to constrain model results
  - No constraints on future projections
  - LIG not a perfect analogue for future

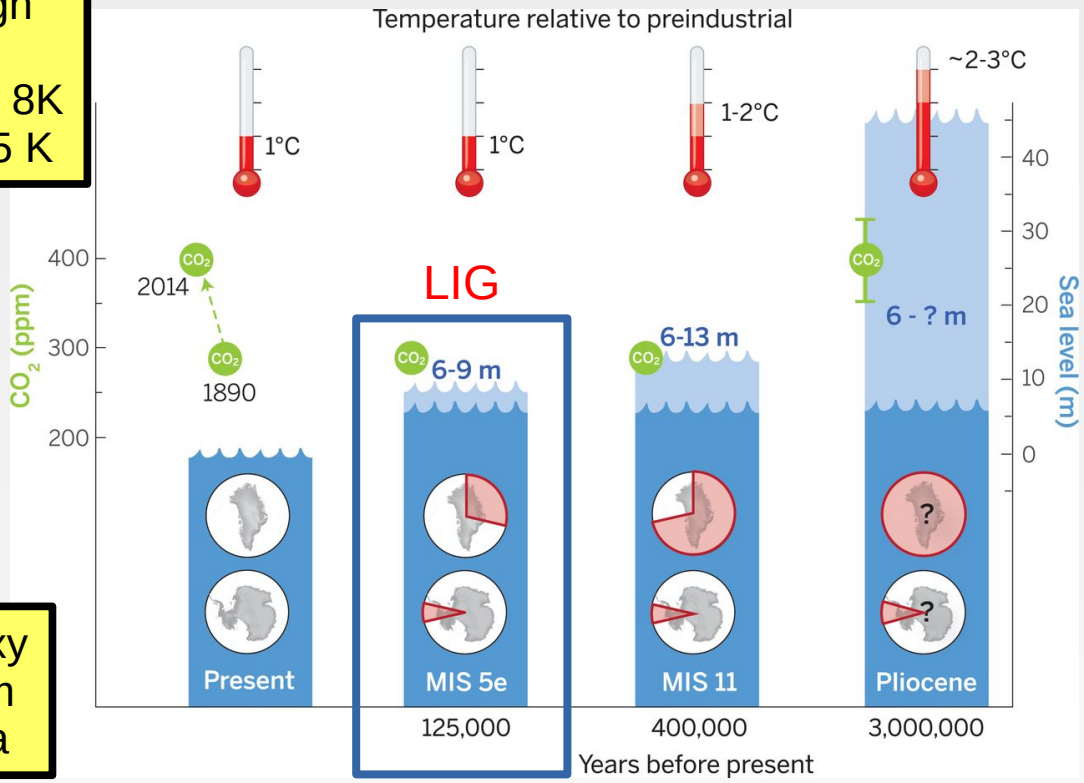


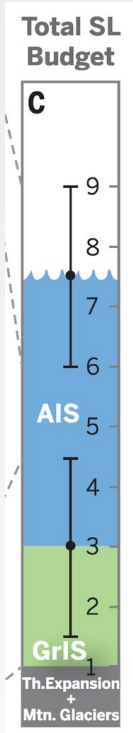
Source: NGRIP members, 2004

Sea level during warmer periods

Warming at high latitudes!
Greenland ~5 to 8K
Antarctic ~3 to 5 K

Contribution from AIS needed

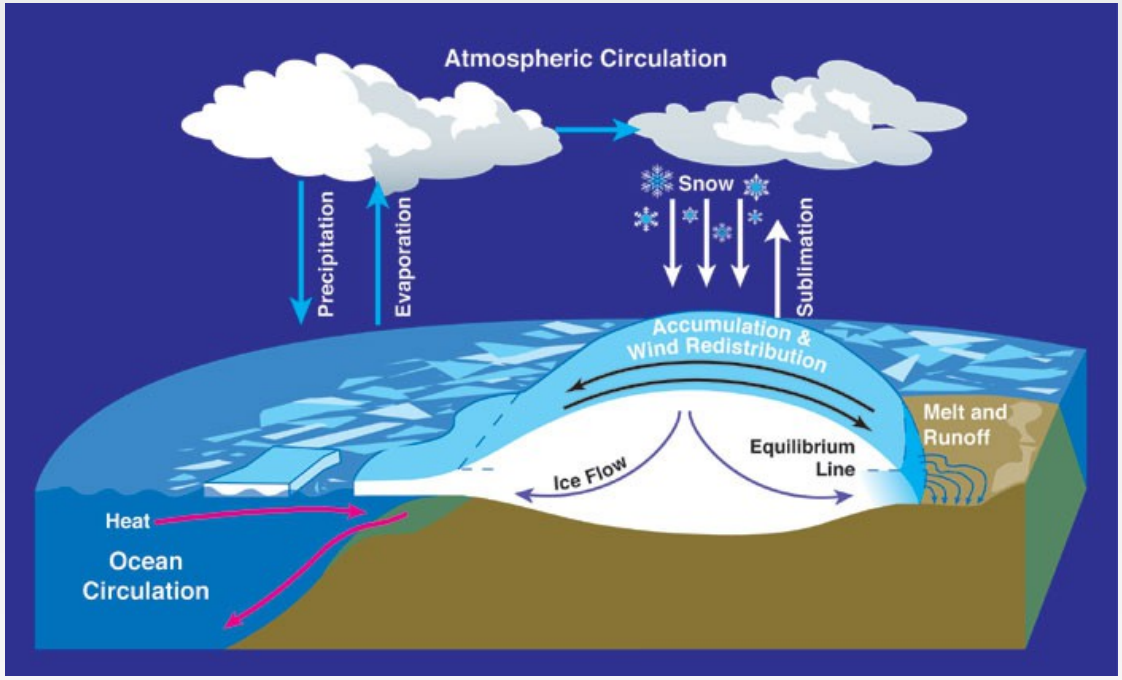




Little proxy data from Antartica

Source: Dutton et al. 2015

Surface mass balance and Ice dynamics



Source: AntarcticGlaciers.org

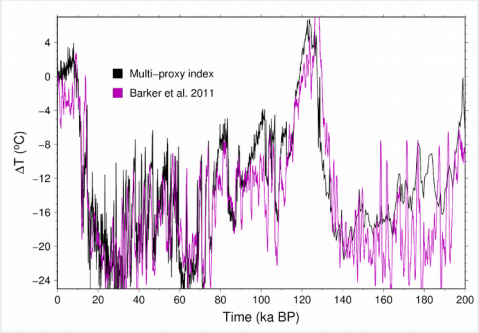
Surface Mass Balance
= precipitation – melt (runoff)

Total Mass Balance
= surface mass balance + ice dynamics

1. Atmospheric forcing – Index / Model

Index method

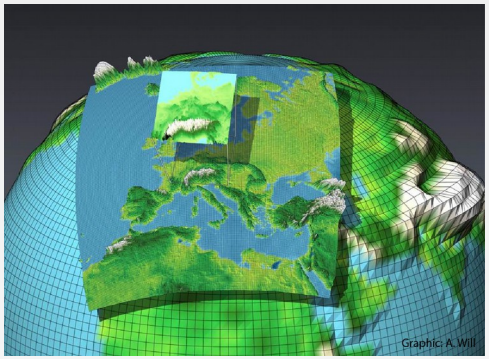
- Ice cores



Source: Quiquet et al. 2013

Climate models

- Global Circulation model (GCM)
- Regional climate model (RCM) or other types of downscaling



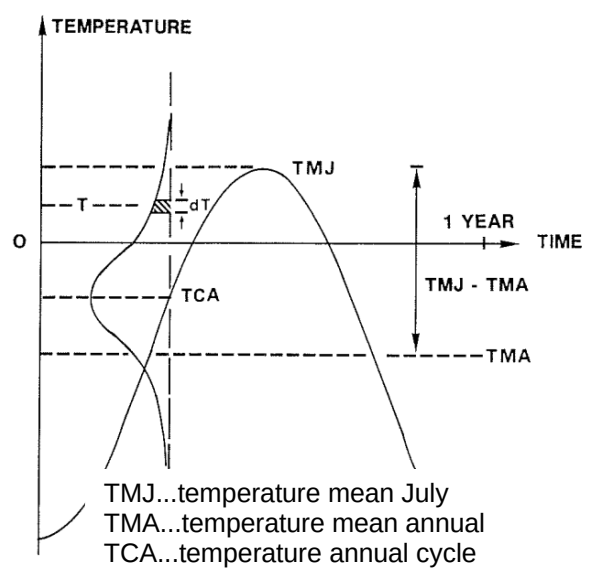
Source: www.clm-community.eu

Offline coupling of ice sheet and climate!

2. Surface Mass Balance - melt scheme

Positive Degree Day (PDD)

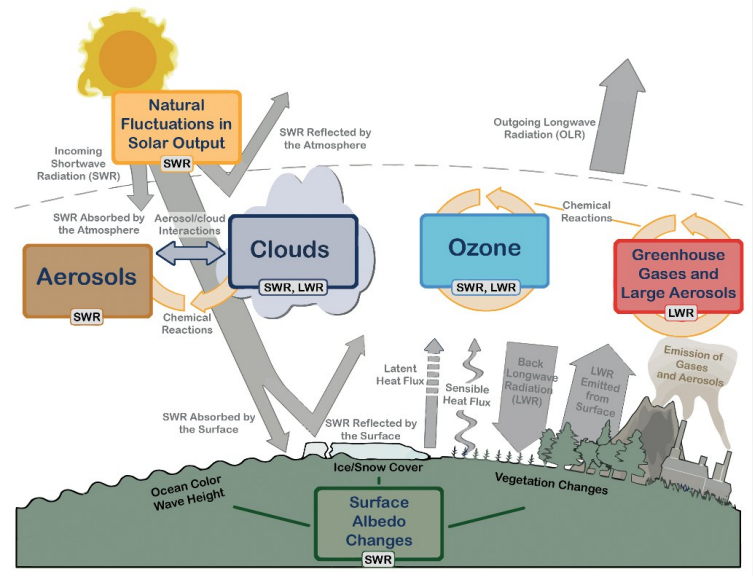
easy and empirical



Source: Reeh 1991

Surface energy balance (SEB)

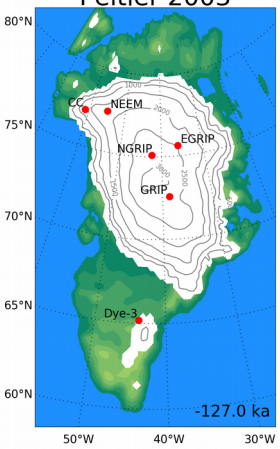
more advanced and physical



Source: IPCC AR5 2013 (Fig. 1-01)

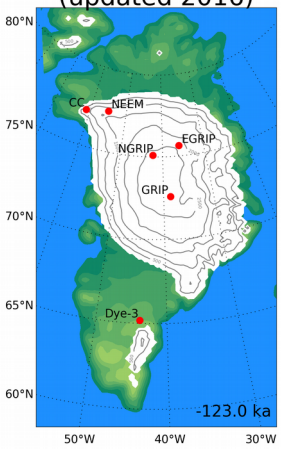
Review of LIG studies

Tarasov and Peltier 2003



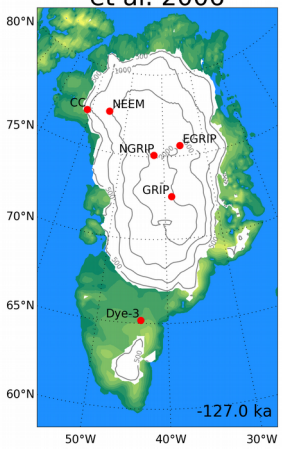
Index; PDD

Greve 2005 (updated 2016)



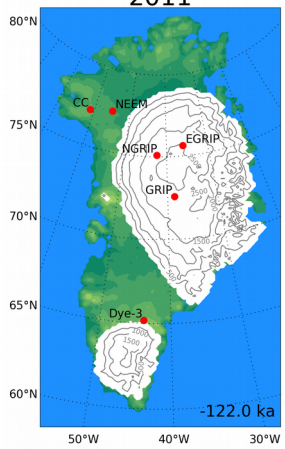
Index; PDD

Otto-Bliesner et al. 2006



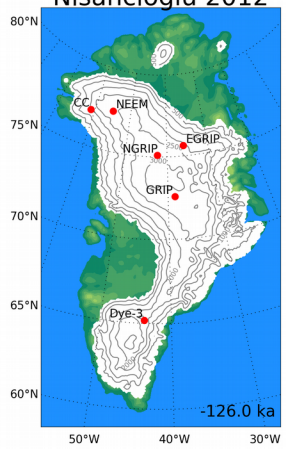
GCM; PDD

Robinson et al. 2011



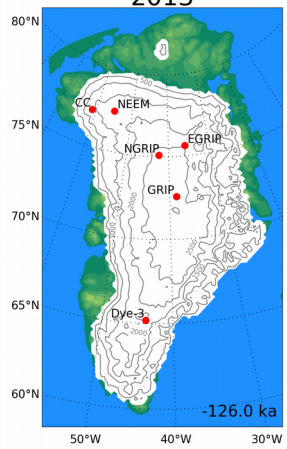
Downscaled; SEB

Born and Nisancioglu 2012



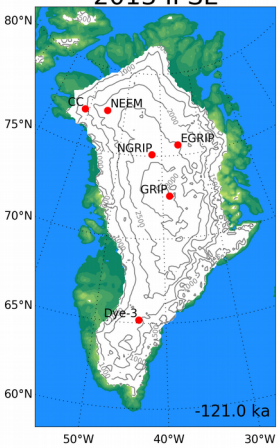
PDD; GCM single snapshot

Stone et al. 2013



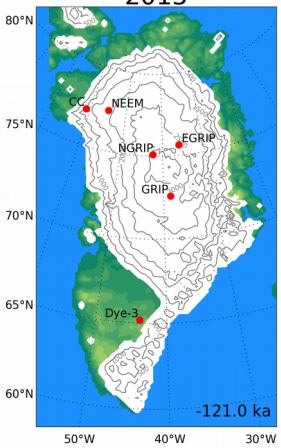
PDD; GCM 3 GrIS topos

Quiquet et al. 2013 IPSL



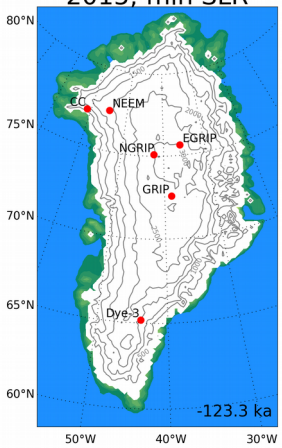
PDD; Index + GCM anomaly

Helsen et al. 2015



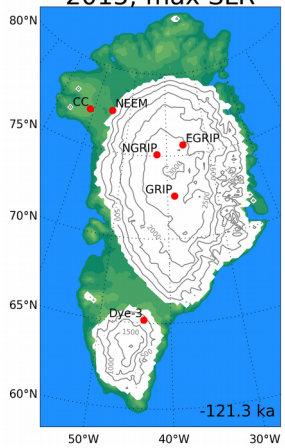
RCM 1.5 kyrs; SEB

Calov et al. 2015; min SLR



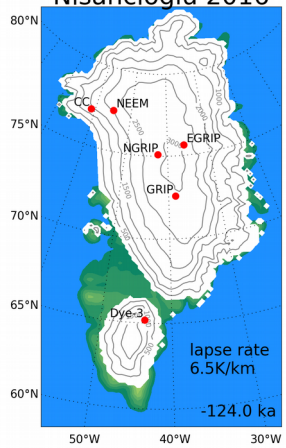
SEB; Downscaled; discharge

Calov et al. 2015; max SLR



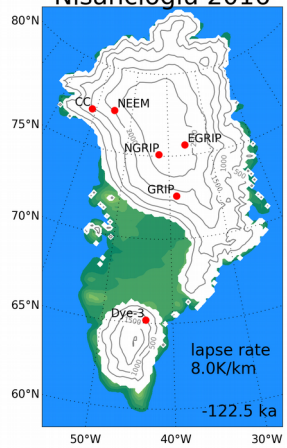
SEB Downscaled; discharge

Langebroek and Nisancioglu 2016



GCM; PDD

Langebroek and Nisancioglu 2016

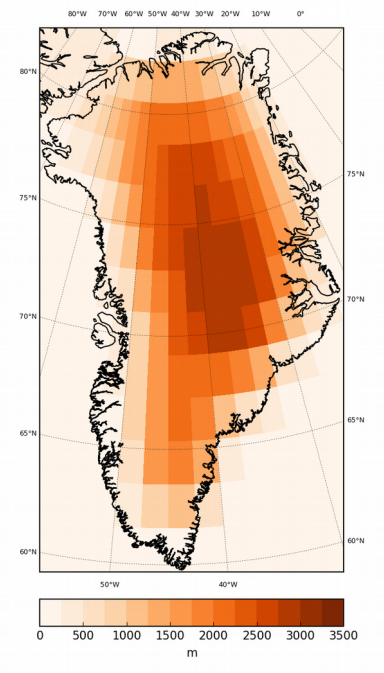


GCM; PDD

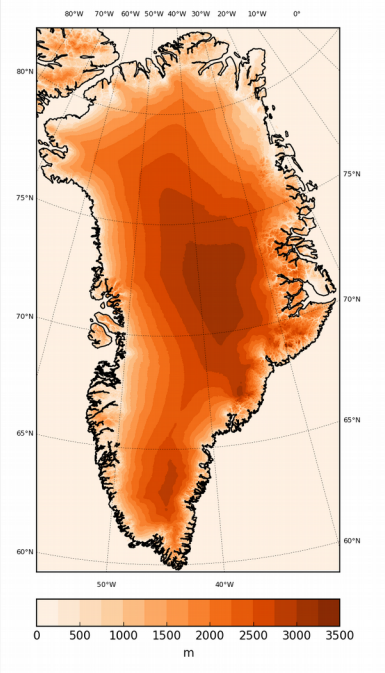
Source: own work

Ice sheet topography (model vs. reality)

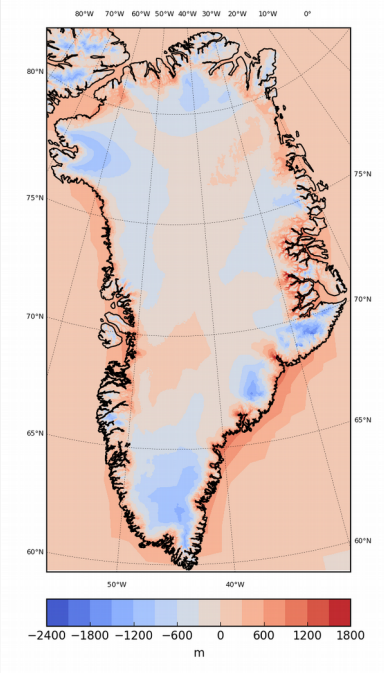
Climate model



Ice sheet model
(present-day observed)



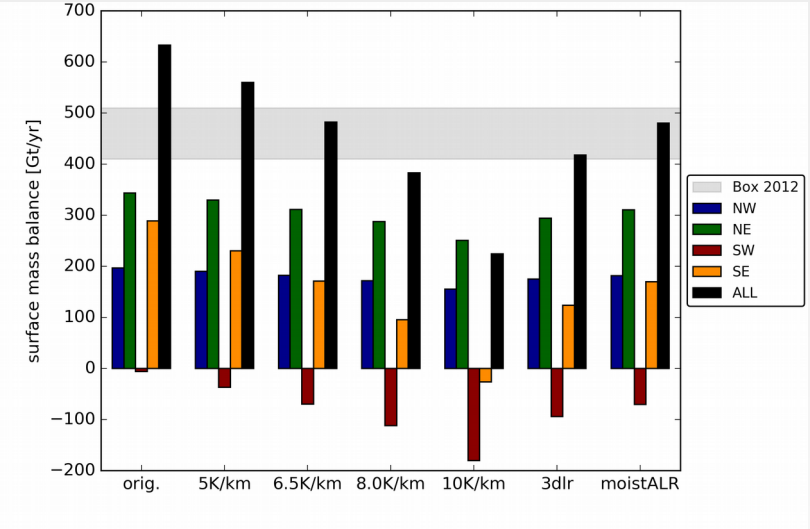
Topography difference



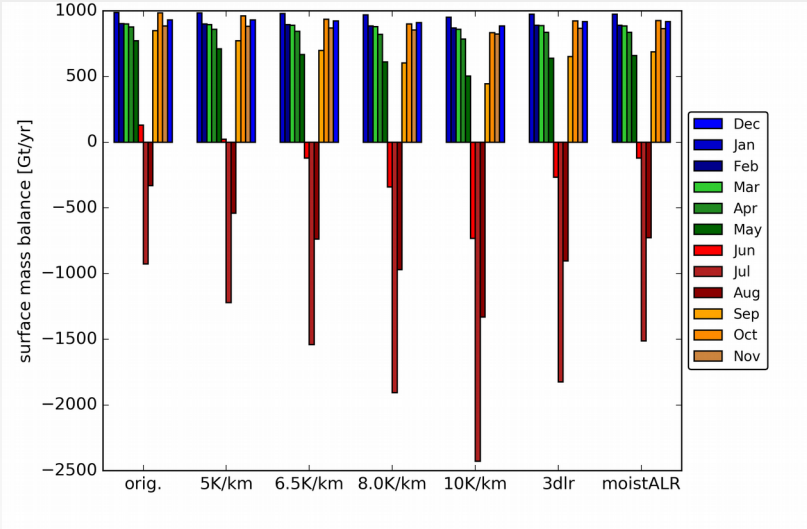
SMB sensitivity to lapse rate correction

Test for pre-industrial

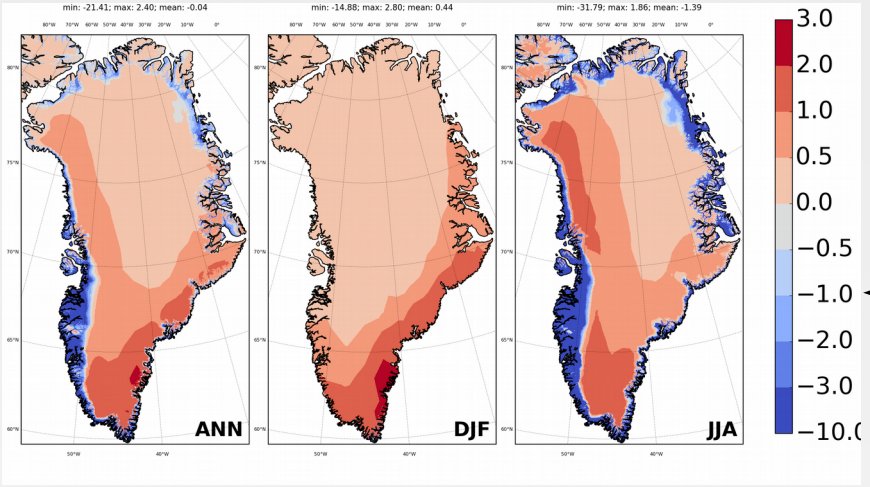
Total SMB [Gt/yr]



Monthly SMB [Gt/yr]



Possible SMB during LIG

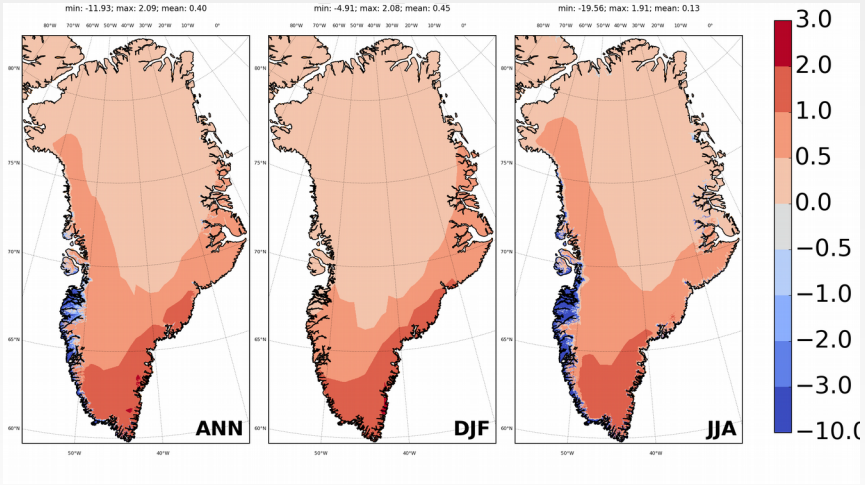


[m/yr]
Blue = negative SMB
Red = positive SMB

125 ka

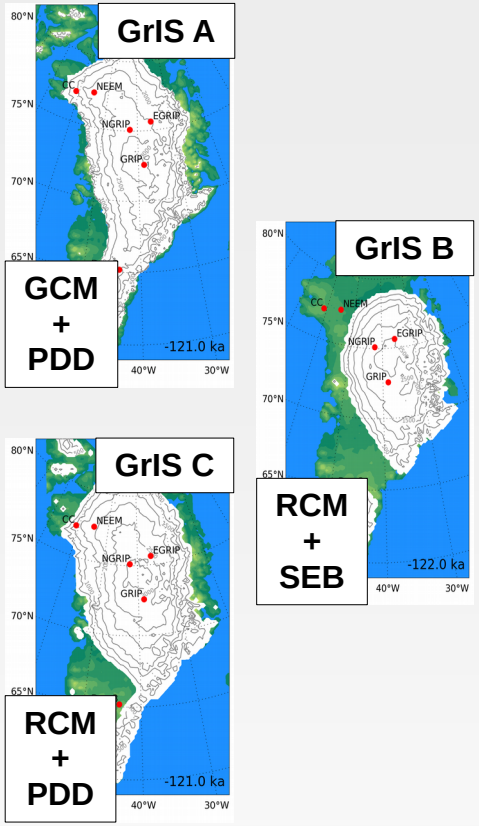
One possible SMB (6.5 K/km)
To show spatial pattern

115 ka



Summary / Future goals

- GrIS melt important for sea level
- Paleo – analogue + proxy data
- sensitivity of ice sheets on atmospheric forcing (in previous studies)
  - Atmosphere: Index vs. GCM vs. RCM
  - Melt: empirical vs. energy balance
- Choose SMBs for ice sheet modeling
  - GCM + PDD, RCM + PDD, RCM + SEB
  - Lapse rate sensitivity
  - PDD parameters sensitivity



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