

Using CESM and CISM to simulate the long-term evolution of climate and the Greenland Ice Sheet during the Last Interglacial (~129,000 to 116,000 yrs ago)

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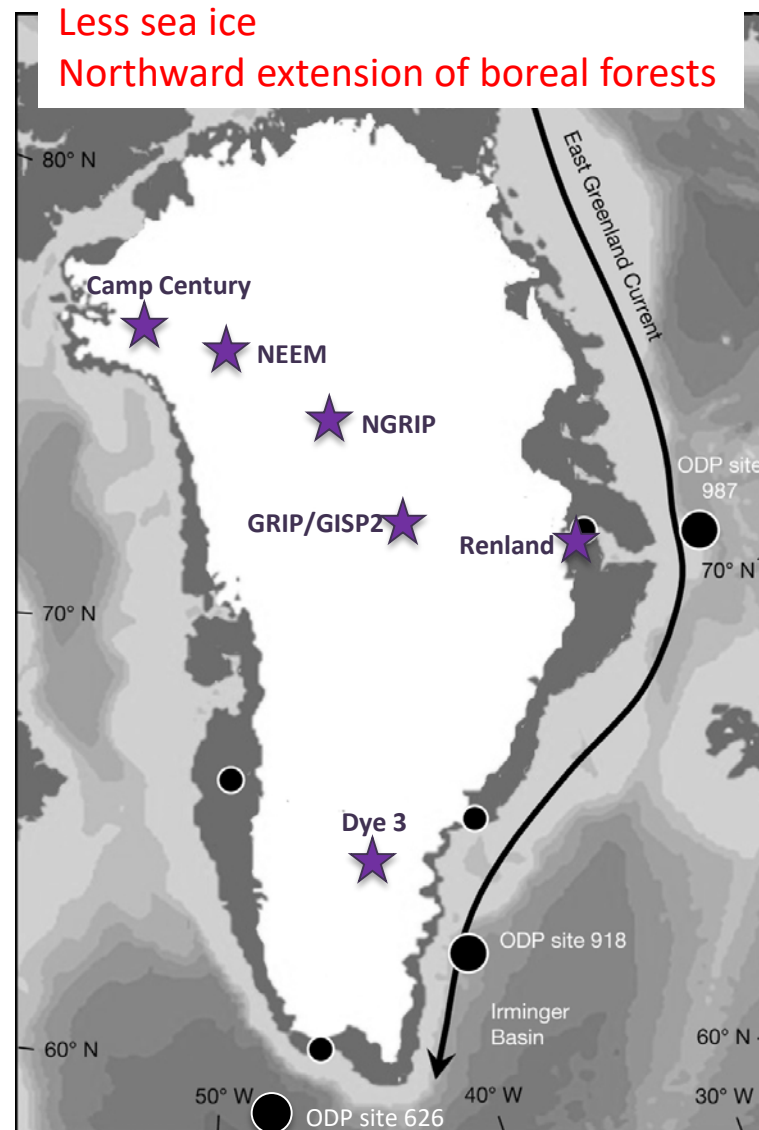


Last Interglacial [129-116 ka] – Some Evidence from Data

Ice cores

- 6 deep ice-coring projects have reached ice layers back to LIG
- *NEEM: surface elevation estimated 130 ± 300 m below present*
- *Annual temperatures NEEM: +7 to +11°C GISP2: +4 to +8°C*
- *Dye 3: new analysis suggests basal ice predates LIG*

Raynaud et al., 1997; Johnsen et al., 2001; NorthGRIP, 2004; NEEM, 2013; Yau et al., 2016



Marine cores

- ODP sites offshore contain sediment sourced from Greenland
- *ODP 626: silt provenance suggests SGRIS present, smaller than in Holocene*
- *ODP 626: shrub tundra and dense fern vegetation over S. Greenland*
- ODP 918 & 987: stable ice sheet in E. Greenland for most of past million years

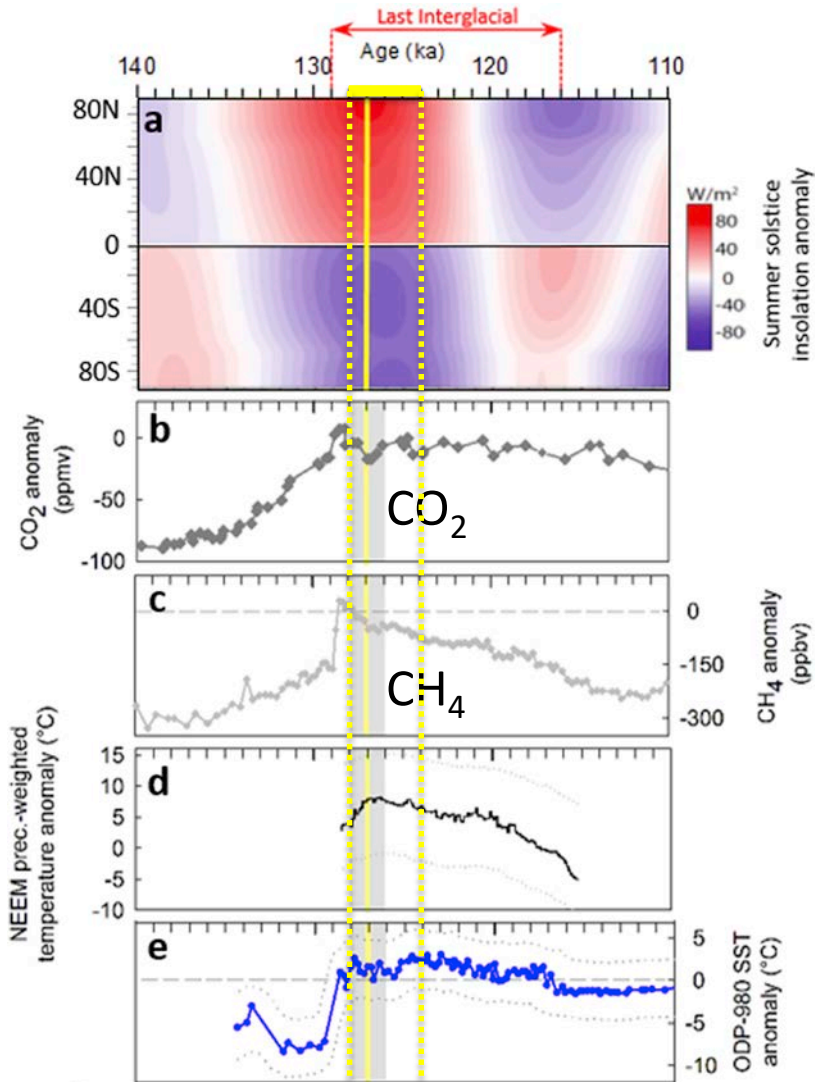
De Vernal et al., 2008; Colville et al., 2011; Hatfield et al., 2016; Bierman et al., 2016

Past Modeling of Greenland Ice Sheet during the Last Interglacial

Global sea level highstand 6-9 meters

Study	SMB method	GIS melting (m of sea level equivalent)
Cuffey and Marshall (2000)	Index	4–5.5
Huybrechts (2002)	Index	5.5
Tarasov and Peltier (2003)	Index	2.7–4.5
Lhomme et al. (2005)	Index	3.5–4.5
Born and Nisancioglu (2012)	GCM snapshots	4.2–5.9
→ Otto-Bliesner et al. (2006)	One-way GCM coupling	2.2–3.4
Stone et al. (2012)	One-way GCM coupling	0.6–3.5
Robinson et al. (2011)	Energy-moisture coupling	0.4–4.4
Quiquet et al. (2013)	Index method	0.7–1.5
Helsen et al. (2013)	Asynch, 2-way coupling reg model	1.2-3.5
Calov et al. (2015)	Asynch, 2-way coupling reg model	0.6-2.5
Yau et al. (2017)	Asynch, 2-way coupling reg model	4.1-6.2
Goezler et al. (2016)	Synch, 2-way coupling global model	1.4

Early Last Interglacial (128 – 124 ka)



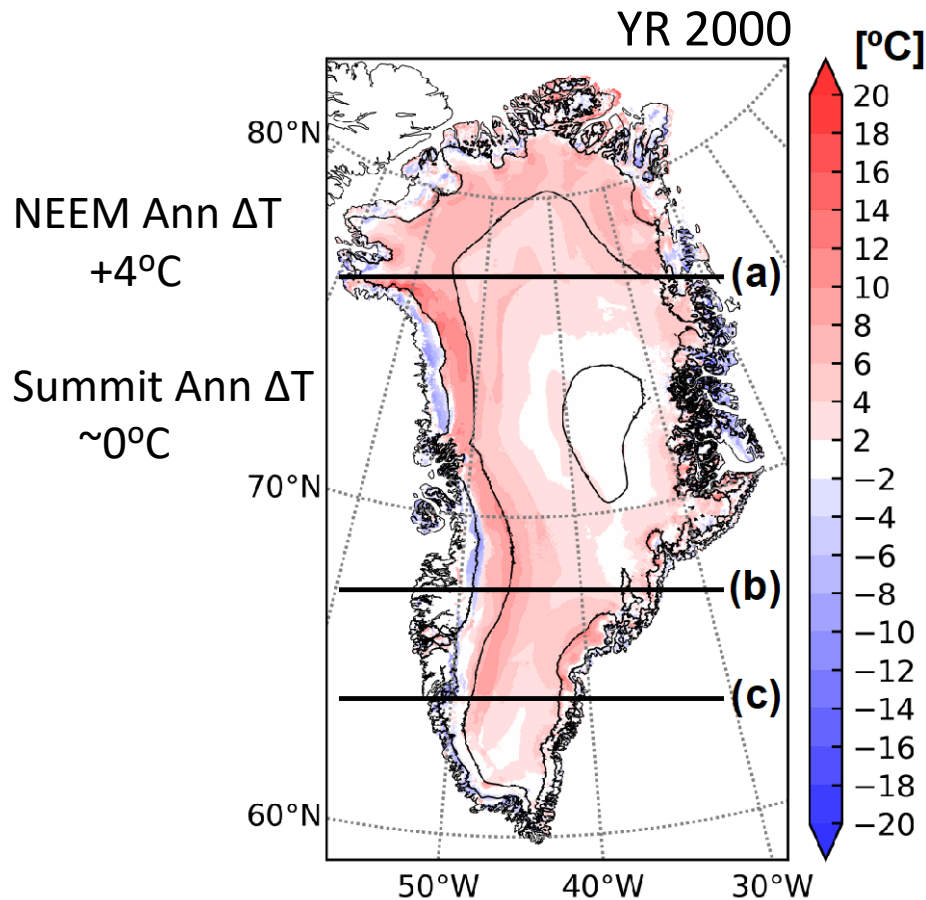
- Large boreal summer insolation anomalies (128-124ka) resulting from orbital forcing → assume 127ka insolation anomalies representative.
- Stable GHG concentrations similar to late Holocene
- Continental and oceanic configurations almost identical to modern

CESM1.5 (FV1x1) coupled to CISM1 (4km)

- 1) LIG 127ka orbital forcing [LIG]
 - 2000 CISM yrs, 155 CESM yrs
- 2) LIG 127ka orbital forcing + (idealized) boreal forests to Arctic Ocean in North America and Eurasia [LIGveg]
 - + 2000 CISM yrs, 80 CESM yrs

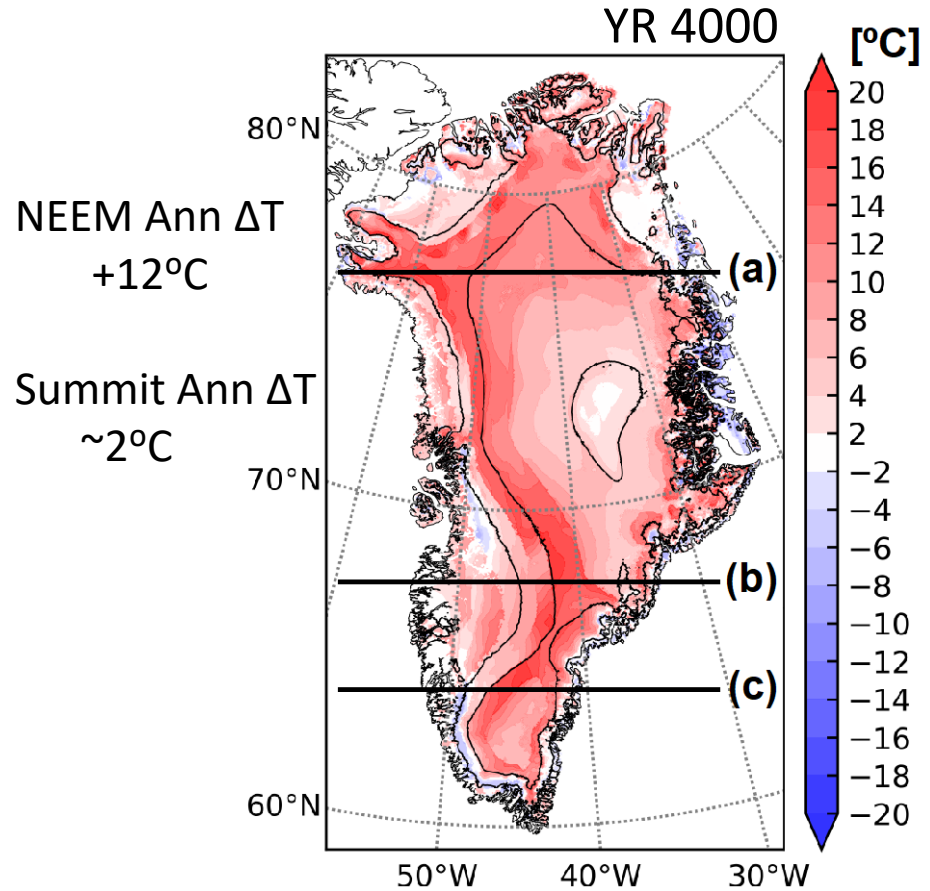
Evolution of Greenland annual surface temperatures

LIG simulation
(Seasonal insolation anomalies)



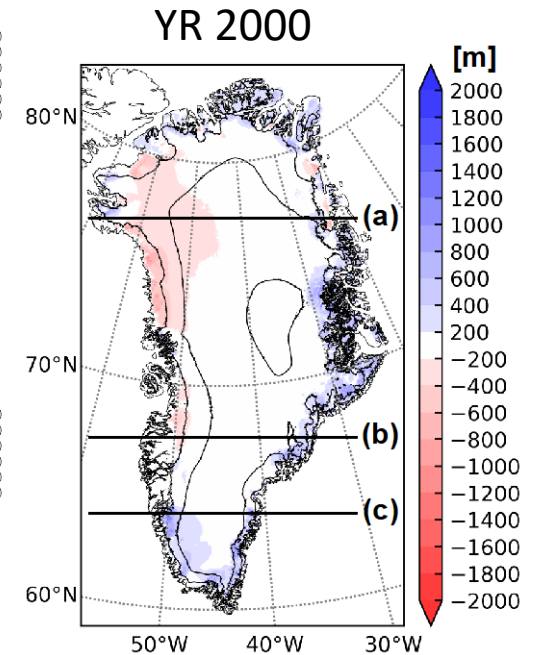
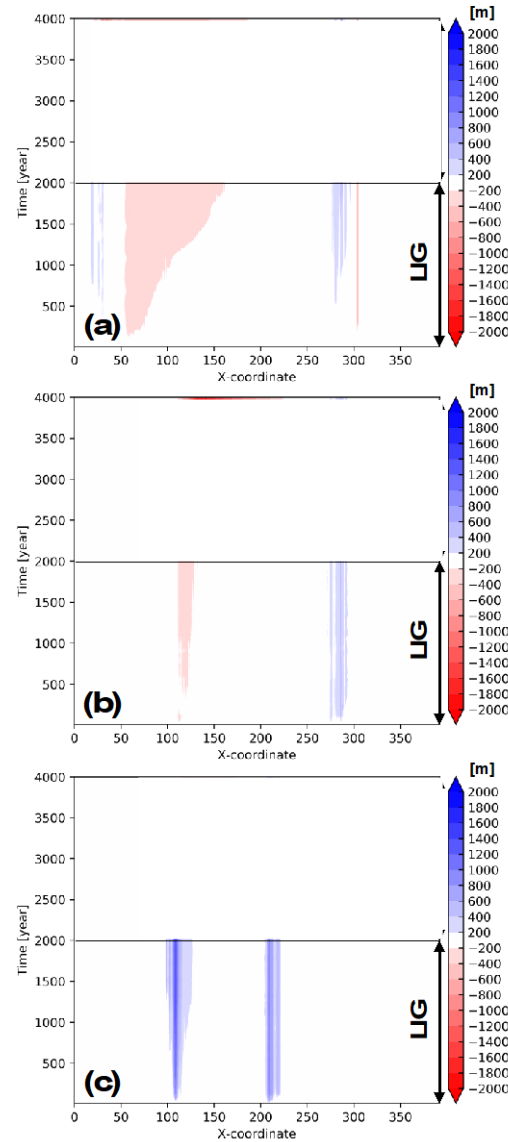
Global Mean Ann ΔT : 0°C

LIGveg simulation
(+Boreal forests extended northward)



Global Mean Ann ΔT : 0.7°C !

Evolution of Greenland ice sheet thickness



1) LIG simulation

- Overall SMB > 0
- Ice sheet area: ~96% modern
- SLE: 0.6 meters

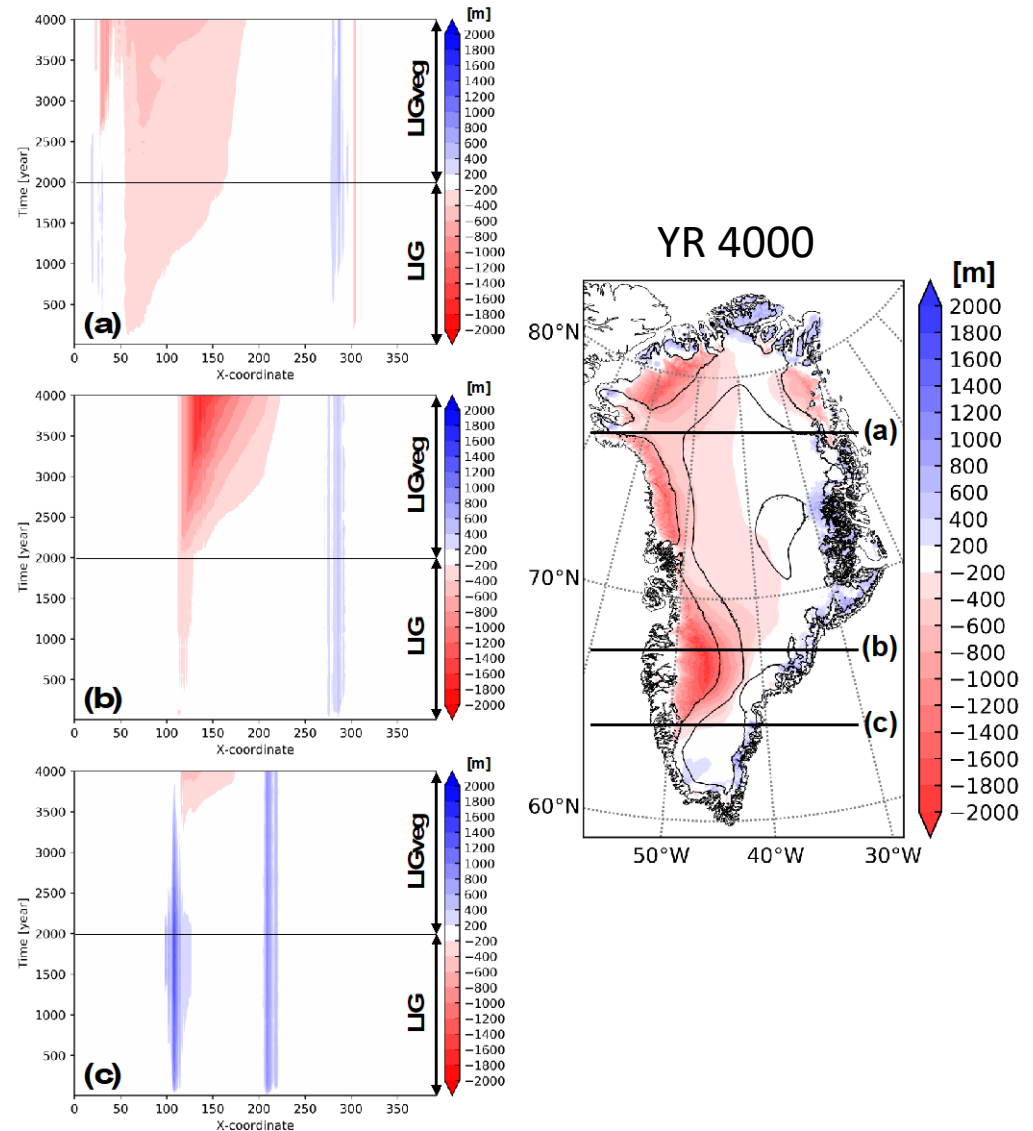
Evolution of Greenland ice sheet thickness

2) LIGveg simulation

- Overall SMB < 0
- Ice sheet area: ~85% modern
- SLE: 1.8 meters

1) LIG simulation

- Overall SMB > 0
- Ice sheet area: ~96% modern
- SLE: 0.6 meters



Evolution of Greenland ice sheet

rea

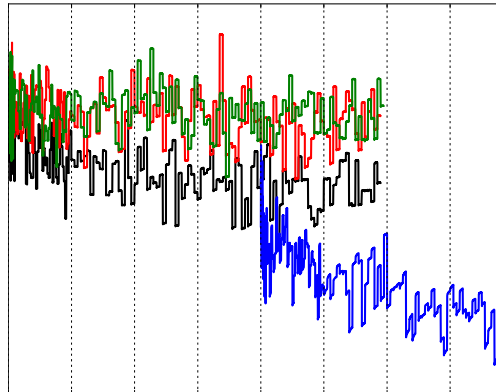
Sea-level equivalent

LIG: SLR: 0.1 m/kyr

LIGveg: SLR: 0.7 m/kyr

SMB

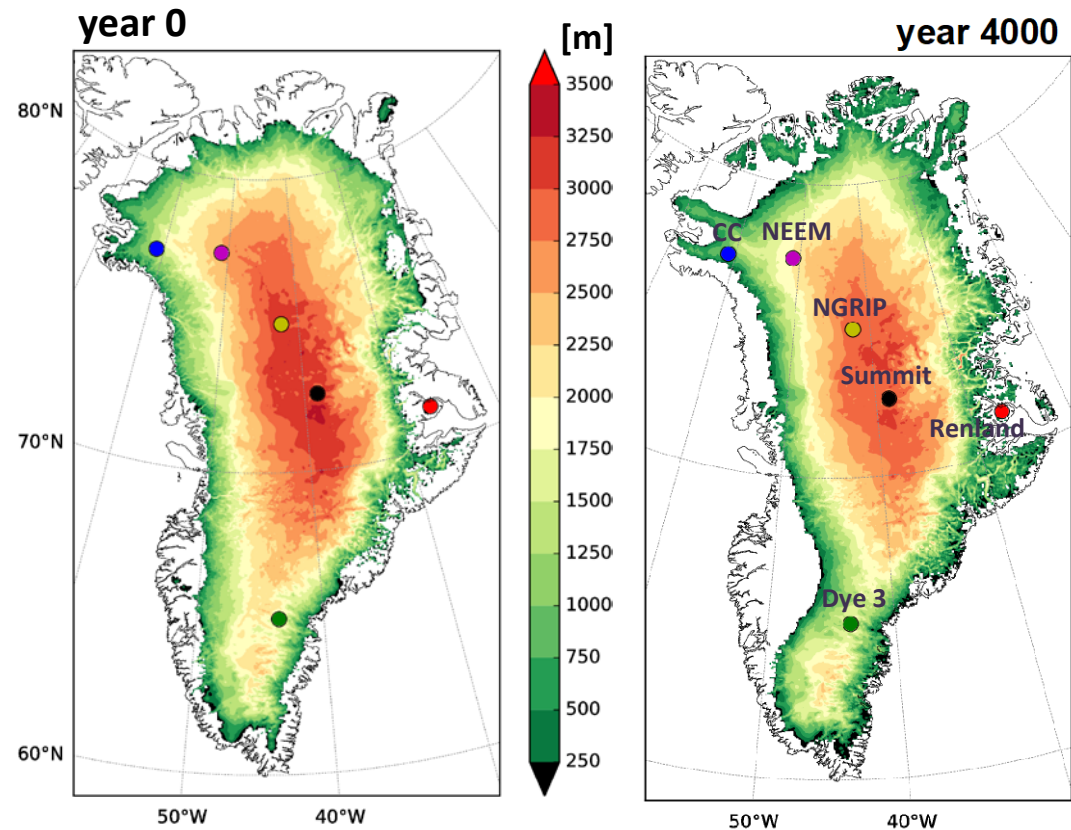
Calving



Summary

- ~ Thickness change at ice cores

- CampCentury -450m
- NEEM -400m
- NGRIP -200m
- Summit -40m
- Renland +20m
- Dye 3 -200m



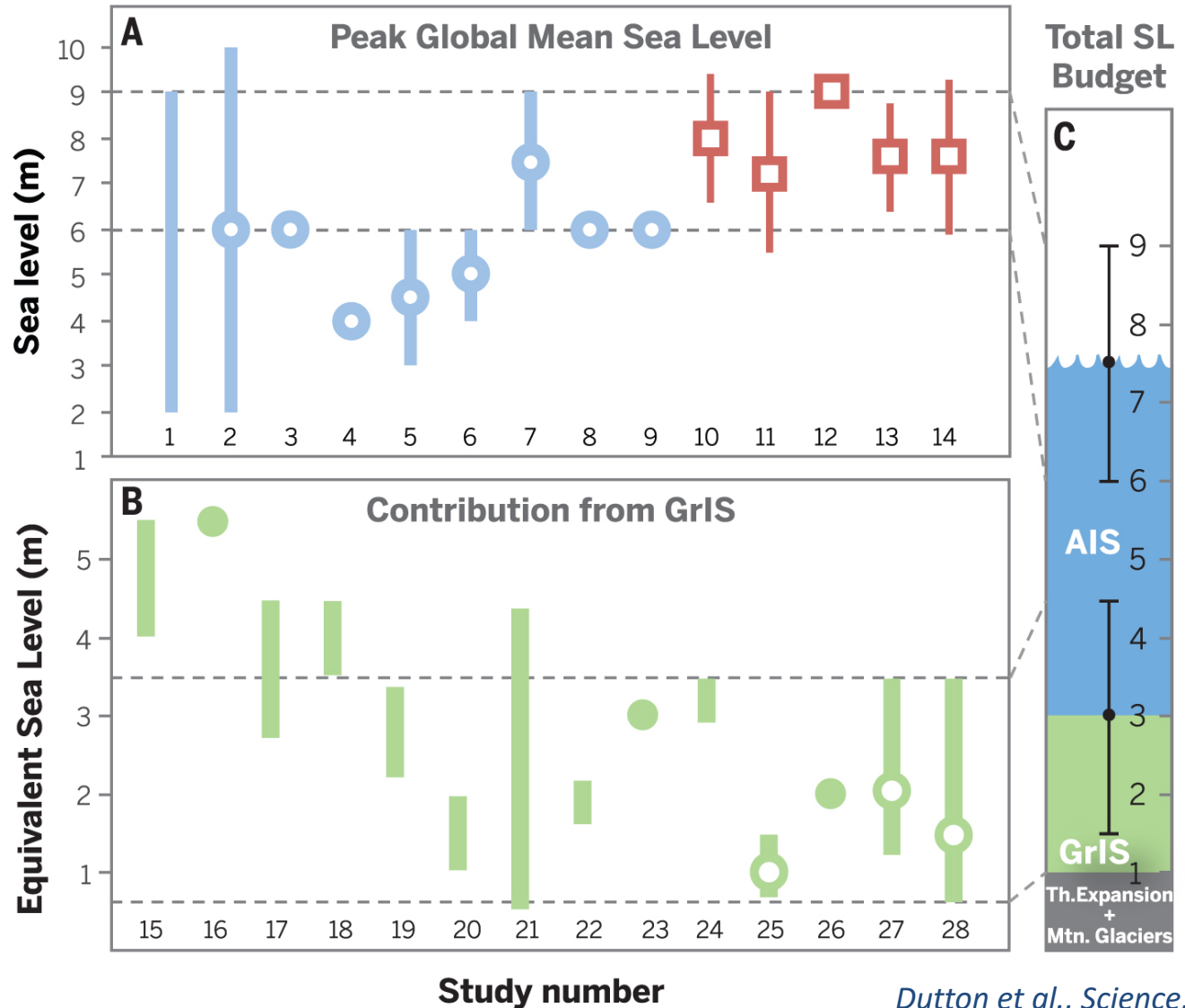
Next steps

★ Transient simulation ★

- Rerun with final CESM2 configurations and spunup GrIS initial state
- Refine vegetation map
- New calving/marine basal melt parameterizations, possibly

Peak Global Mean Sea Level during the Last Interglacial

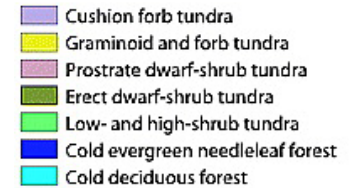
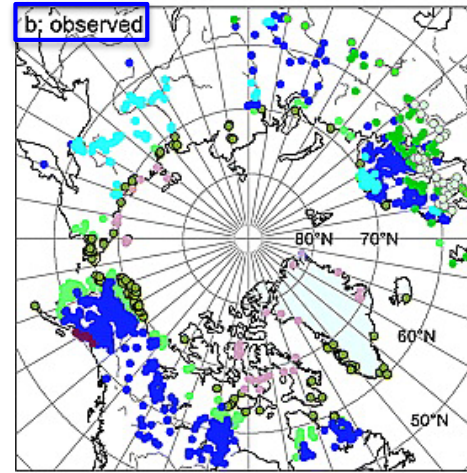
Last Interglacial
[129 – 116 ka]



Two Exploratory Simulations Last Interglacial (128 – 124 ka)

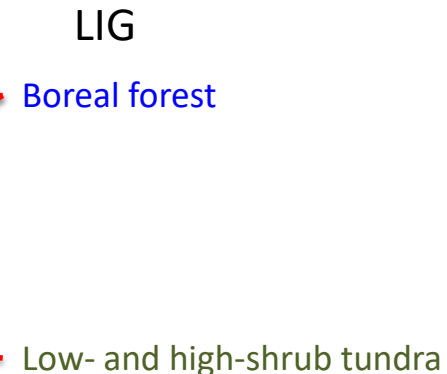
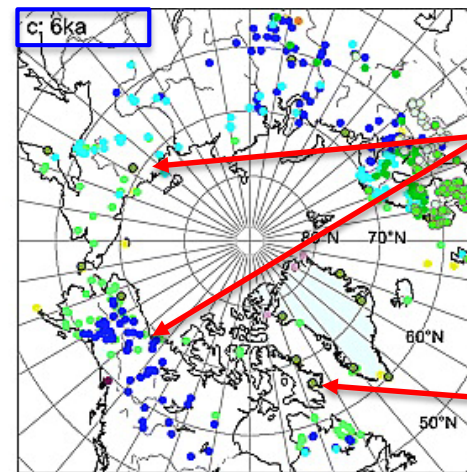
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- 2000 CISM yrs, 155 CESM yrs



2) LIG 127ka orbital forcing + (idealized) boreal forests to Arctic Ocean [LIGveg]

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Surface mass balance - Comparison to RACMO2.3

$$\text{SMB} = \text{Snow} + \text{Rain} - \text{Runoff} - \text{Sublimation}$$

Snow

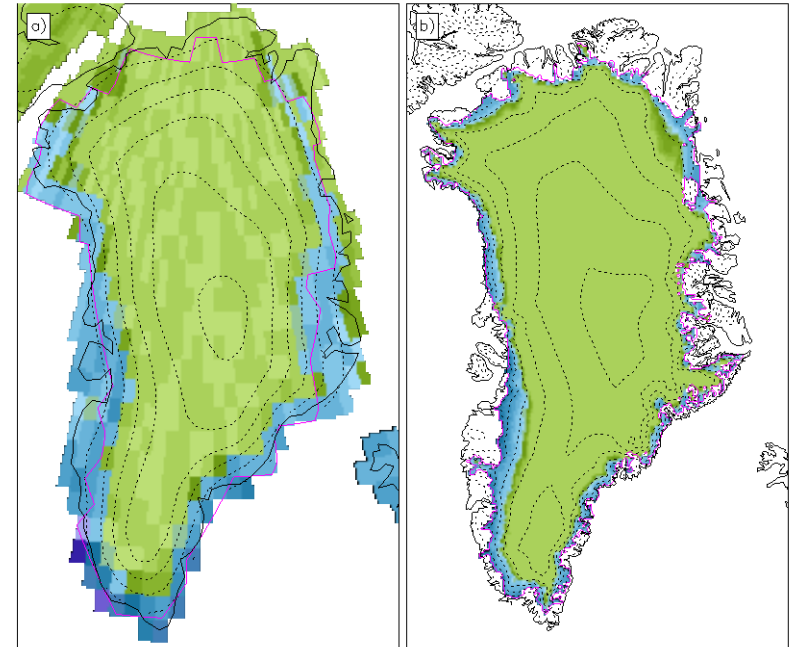
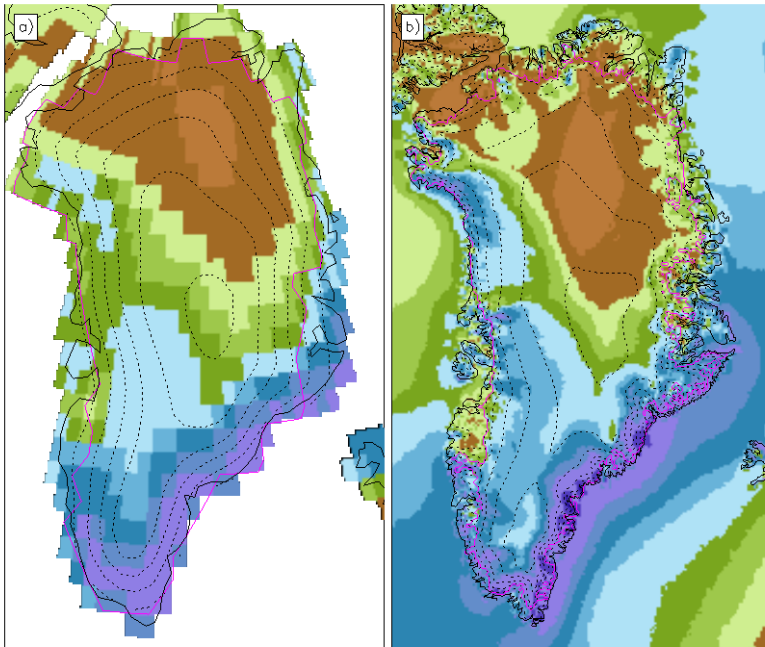
Runoff

PI ctrl ANN

RACMO2.3 ANN 1970-1989

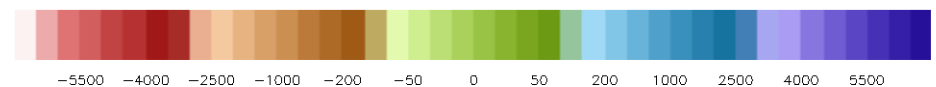
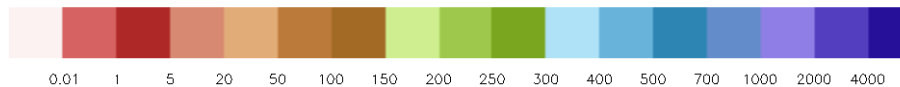
PI ctrl ANN

RACMO2.3 ANN 1970-1989

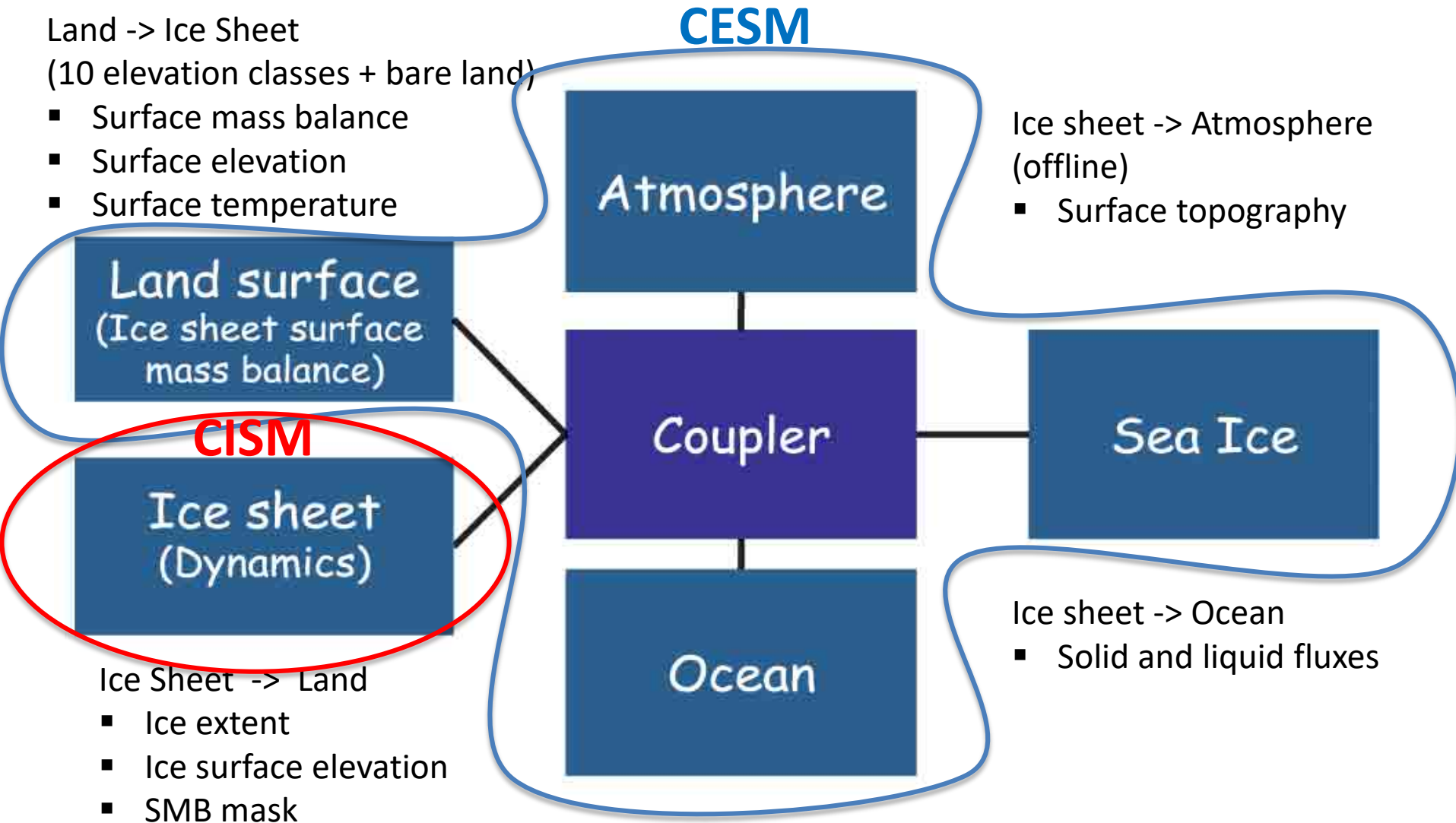


Solid precipitation (snow) [mmWE / yr]

Runoff [mmWE / yr]

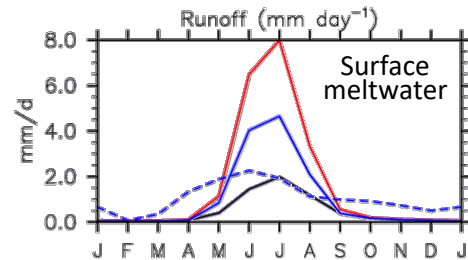
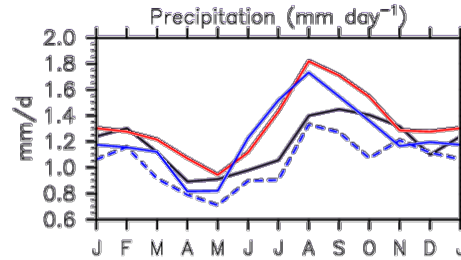
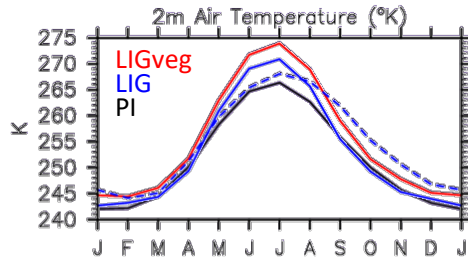


CESM (FV1x1) – CISM (4 km) – two-way coupling



CLIMATE: Greenland & Arctic sea ice

Seasonal cycle over Greenland

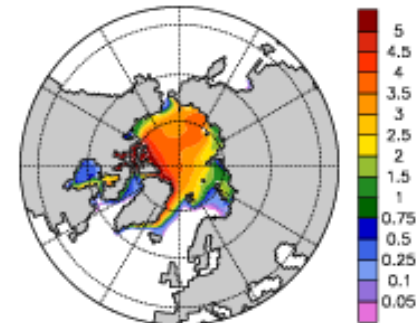


Land: 60-90N, 60-20W



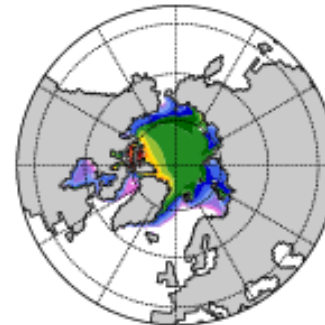
JAS Sea ice thickness

Preindustrial
grid cell mean ice thickness m



LIG

grid cell mean ice thickness m



LIGveg

grid cell mean ice thickness m

