

# 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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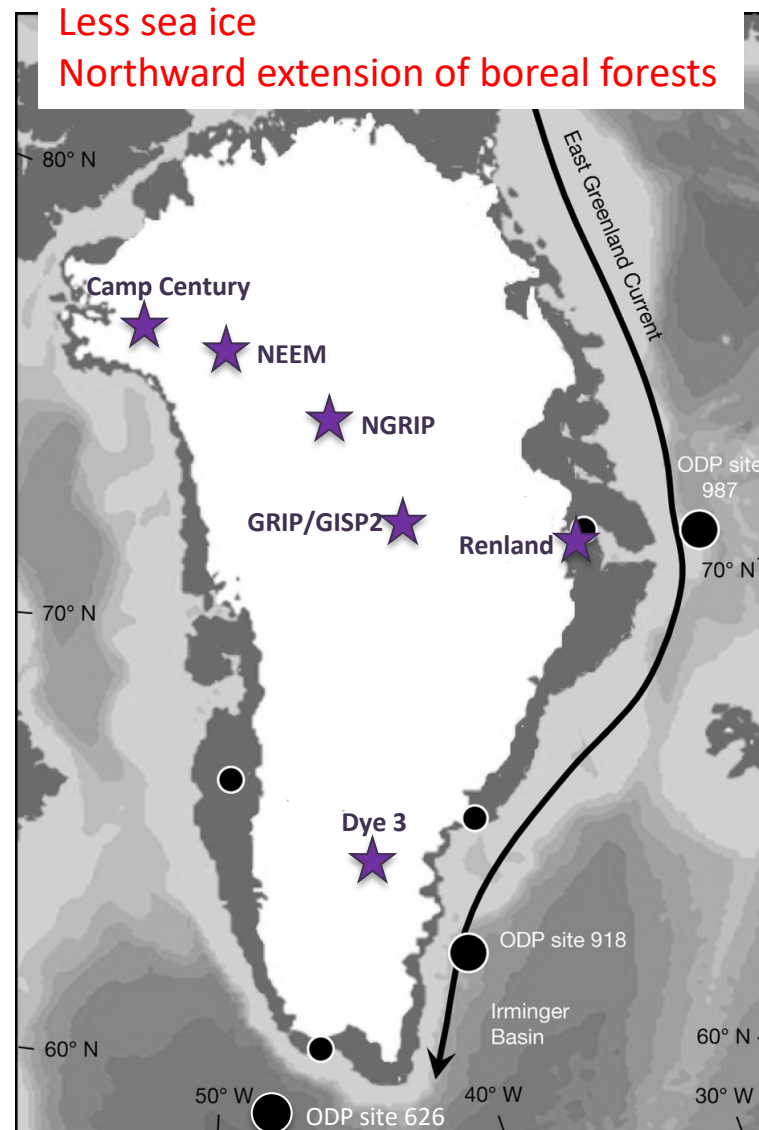


# Last Interglacial [129-116 ka] – Some Evidence from Data

## Ice cores

- 6 deep ice-coring projects have reached ice layers back to LIG
- *NEEM: surface elevation estimated  $130 \pm 300$  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

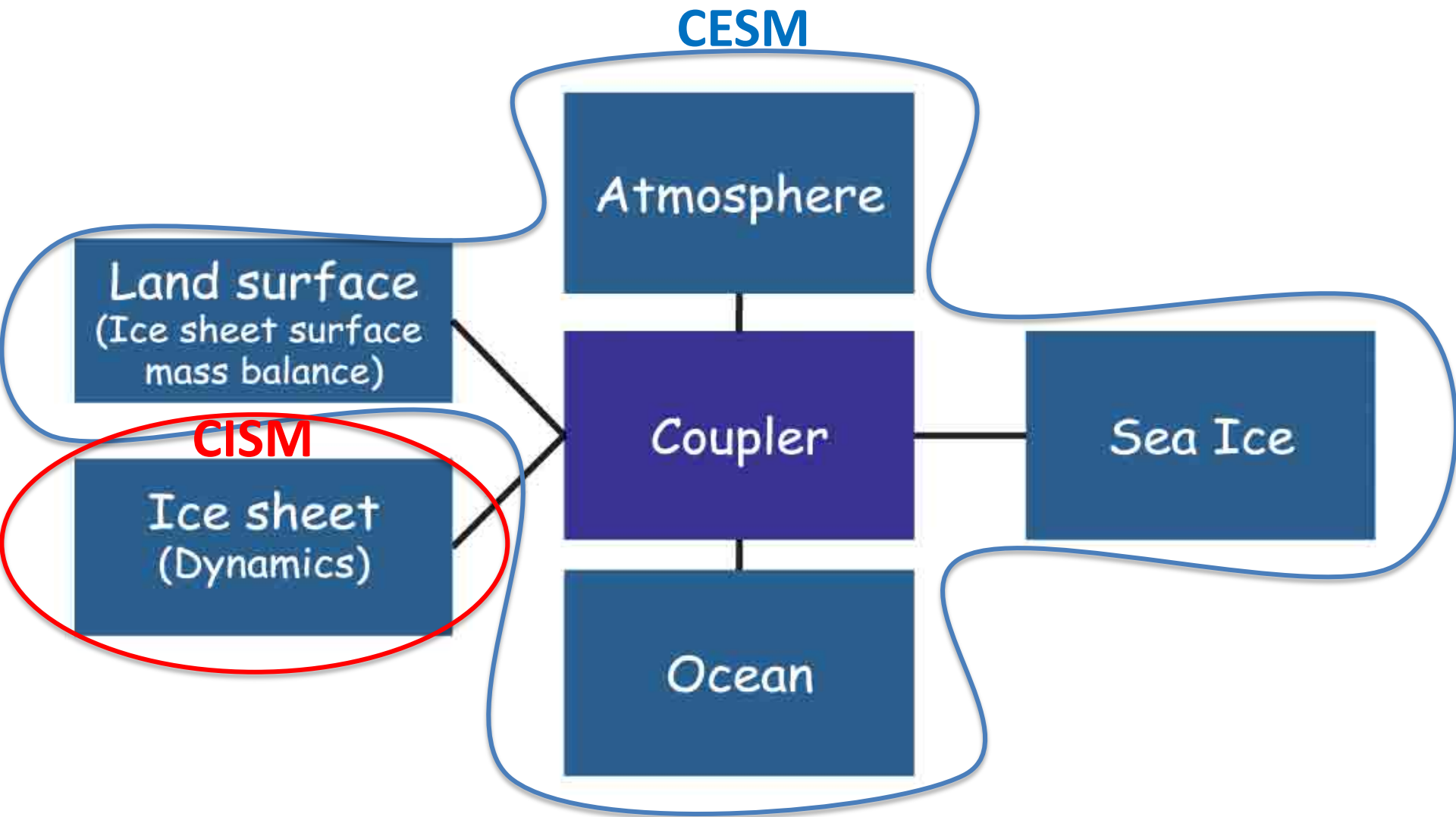
*De Vernal et al., 2008; Colville et al., 2011; Hatfield et al., 2016; Bierman et al., 2016*

# 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
→ Goetzler et al. (2016)	Synch, 2-way coupling global model	1.4

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





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

Land -> Ice Sheet

(10 elevation classes + bare land)

- Surface mass balance
- Surface elevation
- Surface temperature

Land surface  
(Ice sheet surface  
mass balance)

Ice sheet  
(Dynamics)

Ice Sheet -> Land

- Ice extent
- Ice surface elevation
- SMB mask

Atmosphere

Coupler

Ocean

Ice sheet -> Atmosphere  
(offline)

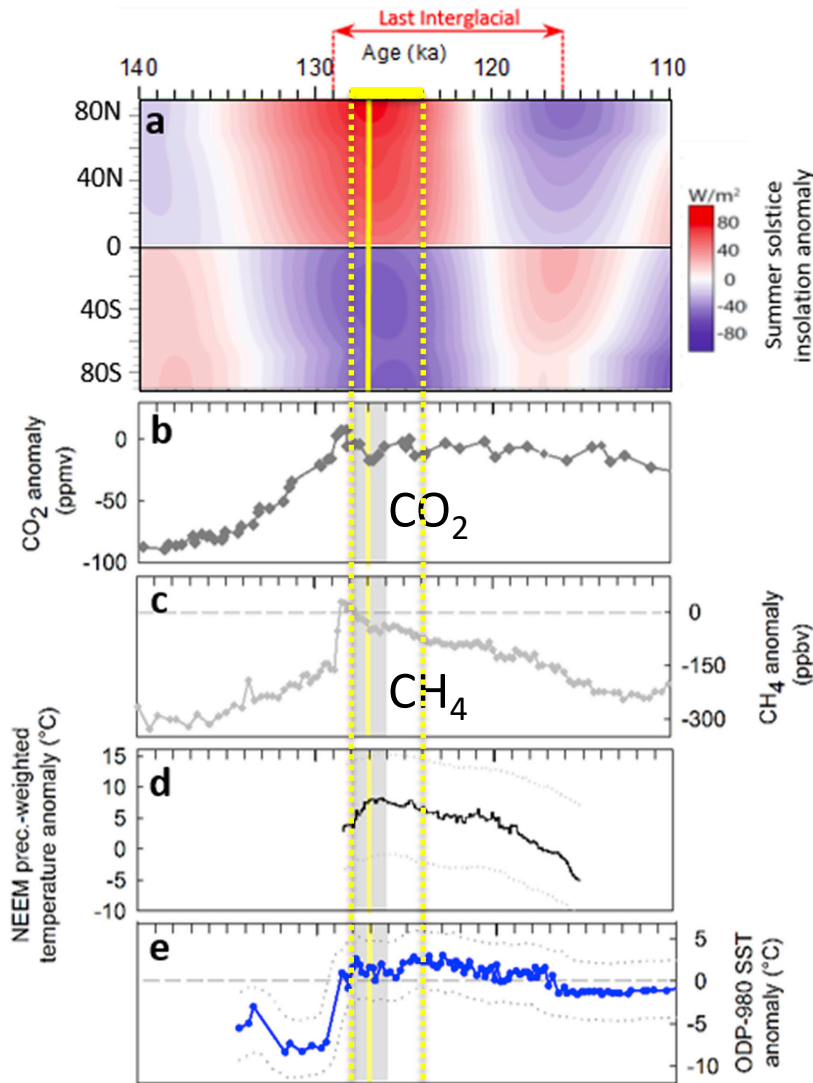
- Surface topography

Sea Ice

Ice sheet -> Ocean

- Solid and liquid fluxes

# 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

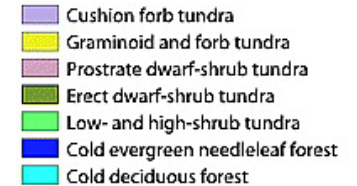
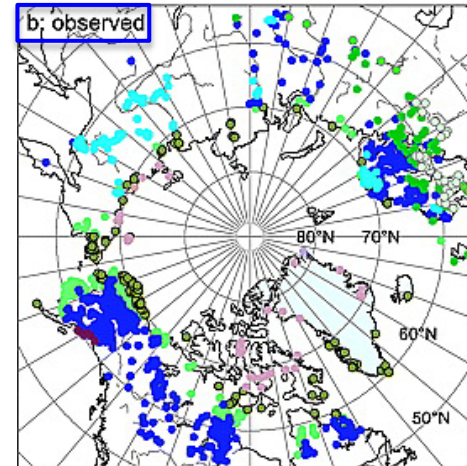
## CESM1.5 (FV1x1) coupled to CISM1 (4km)

- 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

# Two Exploratory Simulations Last Interglacial (128 – 124 ka)

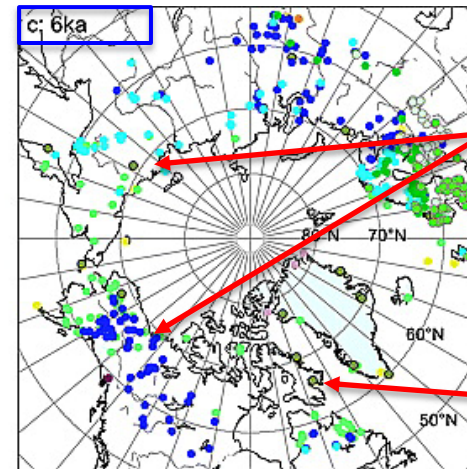
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LIG  
Boreal forest

Low- and high-shrub tundra

# Two Exploratory Simulations Last Interglacial (128 – 124 ka)

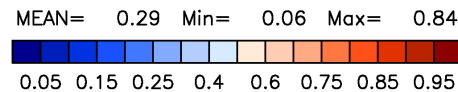
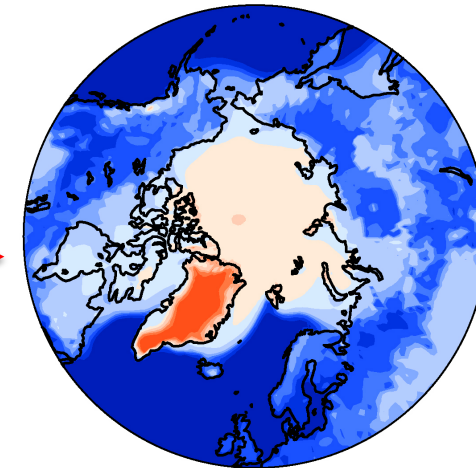
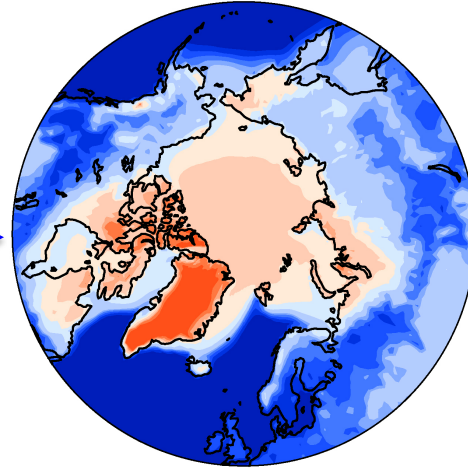
## 1) LIG 127ka orbital forcing

- 2000 CISM yrs, 155 CESM yrs
- Overall SMB > 0
- Ice sheet area: ~96% modern
- SLE: 0.6 meters
- Equiv. SLR: 0.1 m/kyr

## 2) LIG 127ka orbital forcing + boreal forests to Arctic Ocean

- + 2000 CISM yrs, 80 CESM yrs
- Overall SMB < 0
- Ice sheet area: ~85% modern
- SLE: 1.8 meters
- Equiv. SLR: 0.7 m/kyr

Annual Sfc Albedo



Surface albedo  $\searrow$

Solar radiation absorbed at surface  $\nearrow$

Temperature (locally & remotely)  $\nearrow$

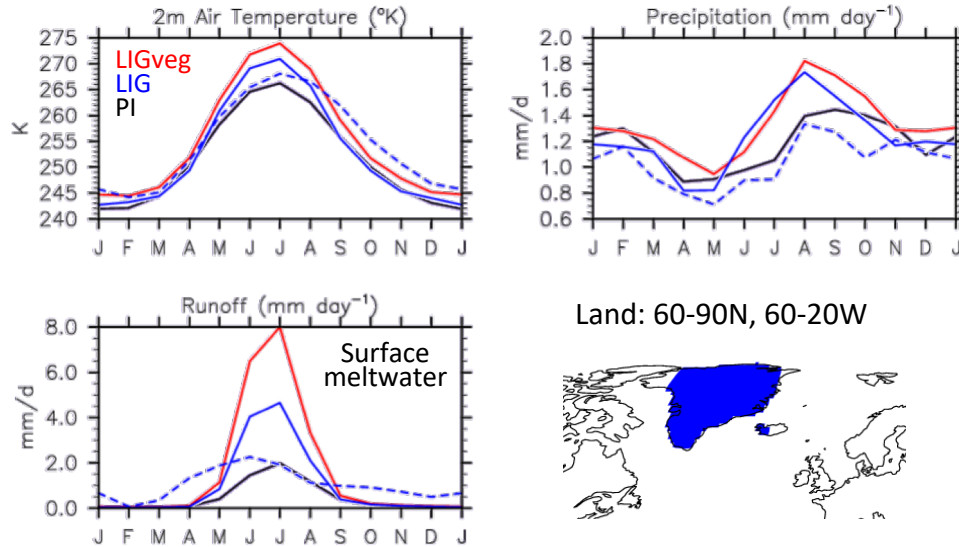
Sea ice (summer)  $\searrow$

Water vapor in atmosphere – GHG  $\nearrow$



# CLIMATE: Greenland & Arctic sea ice

## Seasonal cycle over Greenland

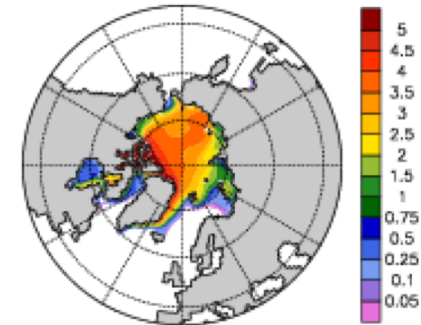


Land: 60-90N, 60-20W



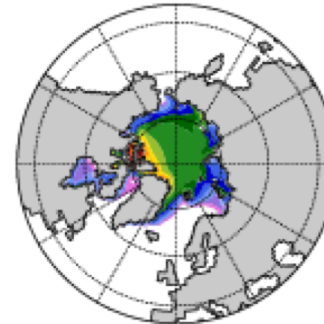
## JAS Sea ice thickness

Preindustrial  
grid cell mean ice thickness m



LIG

grid cell mean ice thickness m



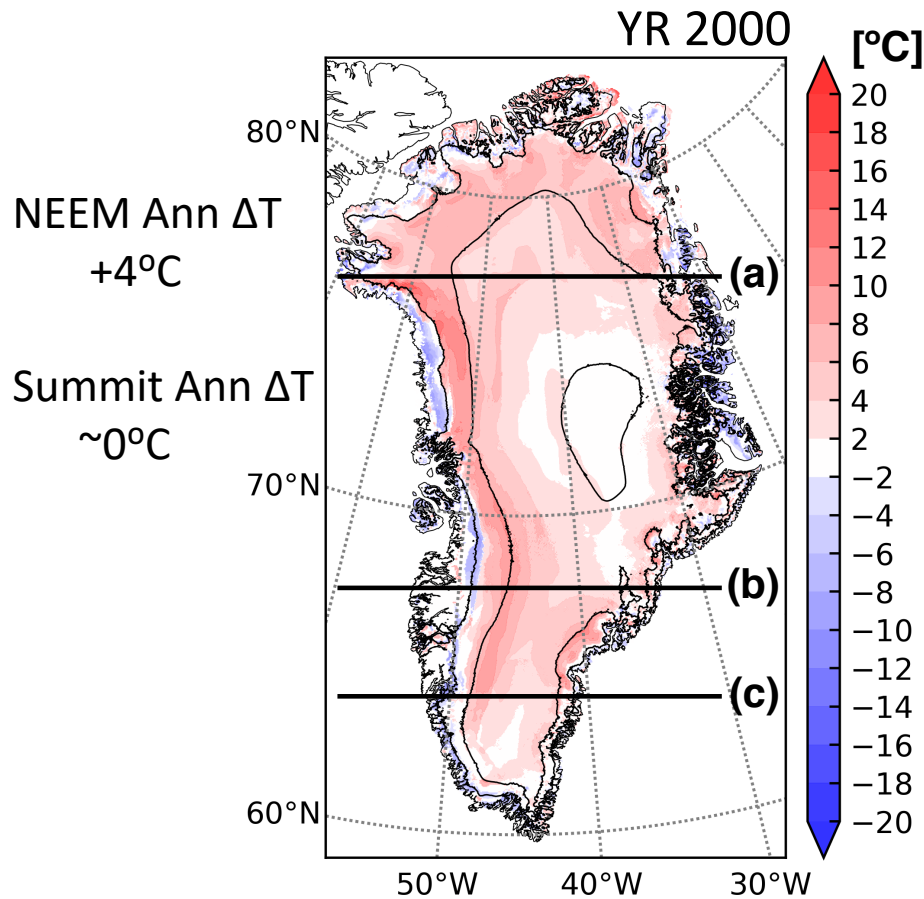
LIGveg

grid cell mean ice thickness m



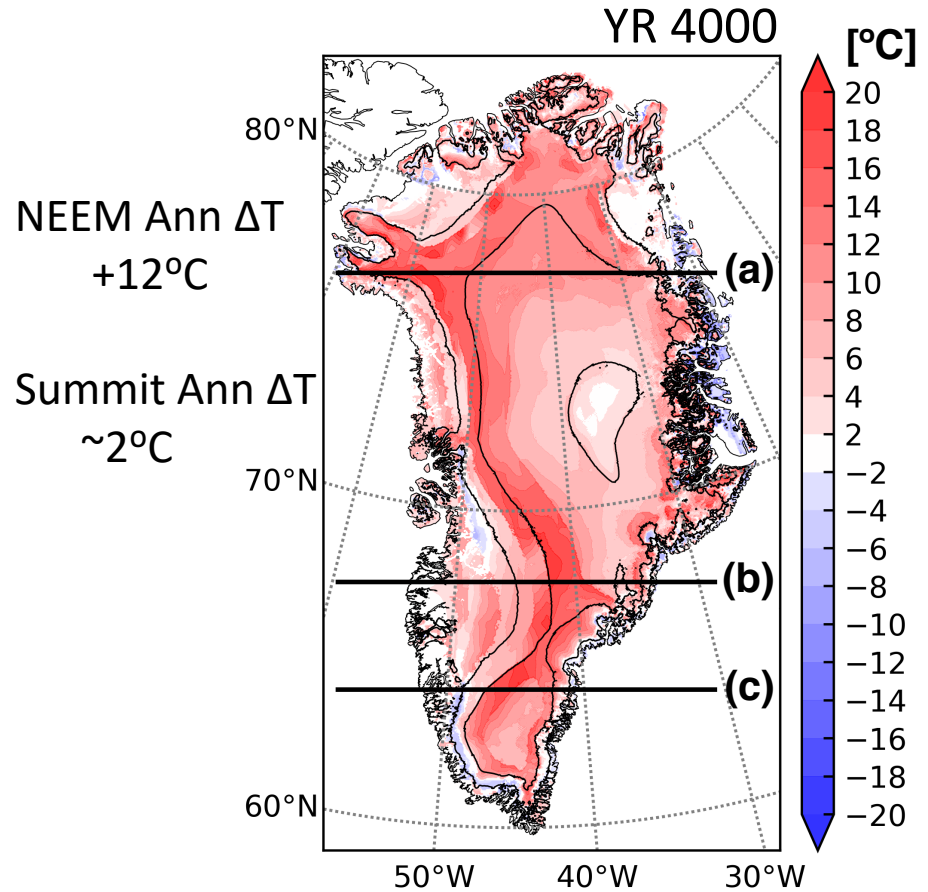
# Evolution of Greenland annual surface temperatures

**LIG simulation**  
(Seasonal insolation anomalies)



**Global Mean Ann  $\Delta T$ :  $0^{\circ}\text{C}$**

**LIGveg simulation**  
(+Boreal forests extended northward)



**Global Mean Ann  $\Delta T$ :  $0.7^{\circ}\text{C}$  !**

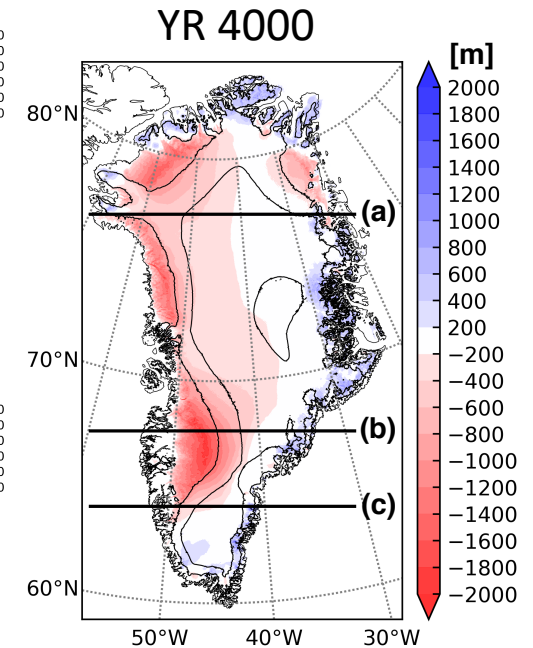
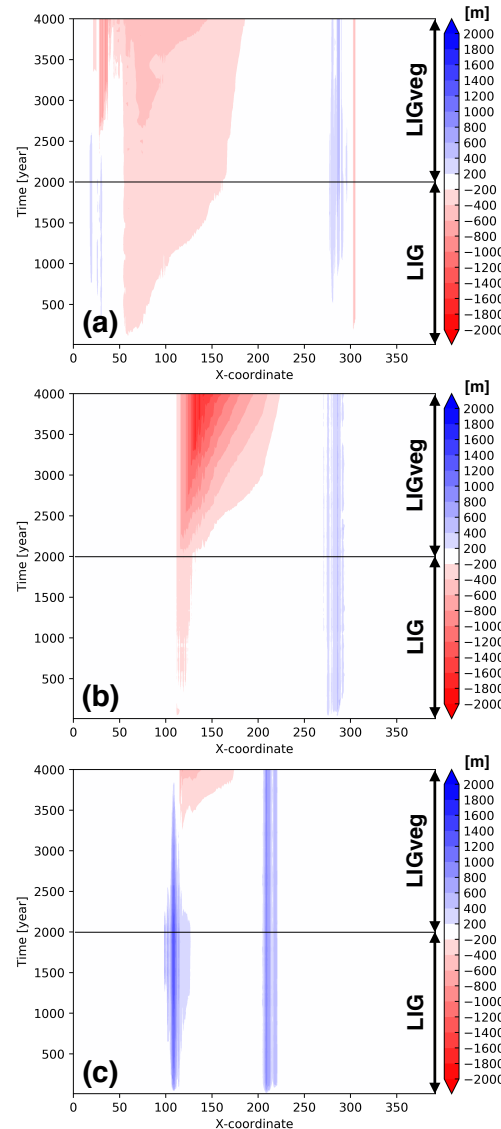
# Evolution of Greenland ice sheet thickness

## 2) LIGveg simulation

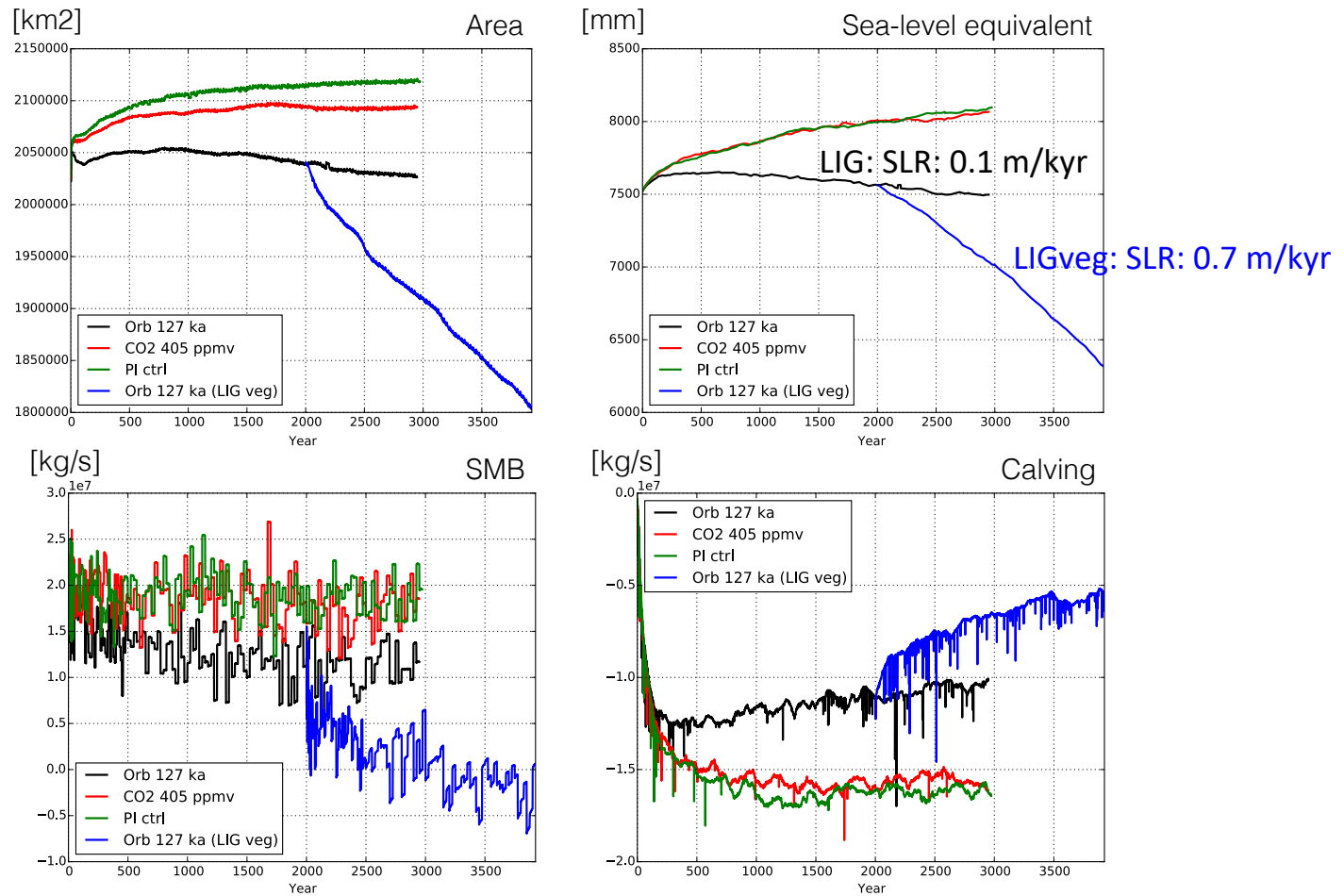
- Overall SMB < 0
- Ice sheet area: ~85% modern
- SLE: 1.8 meters

## 1) LIG simulation

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



# Evolution of Greenland ice sheet

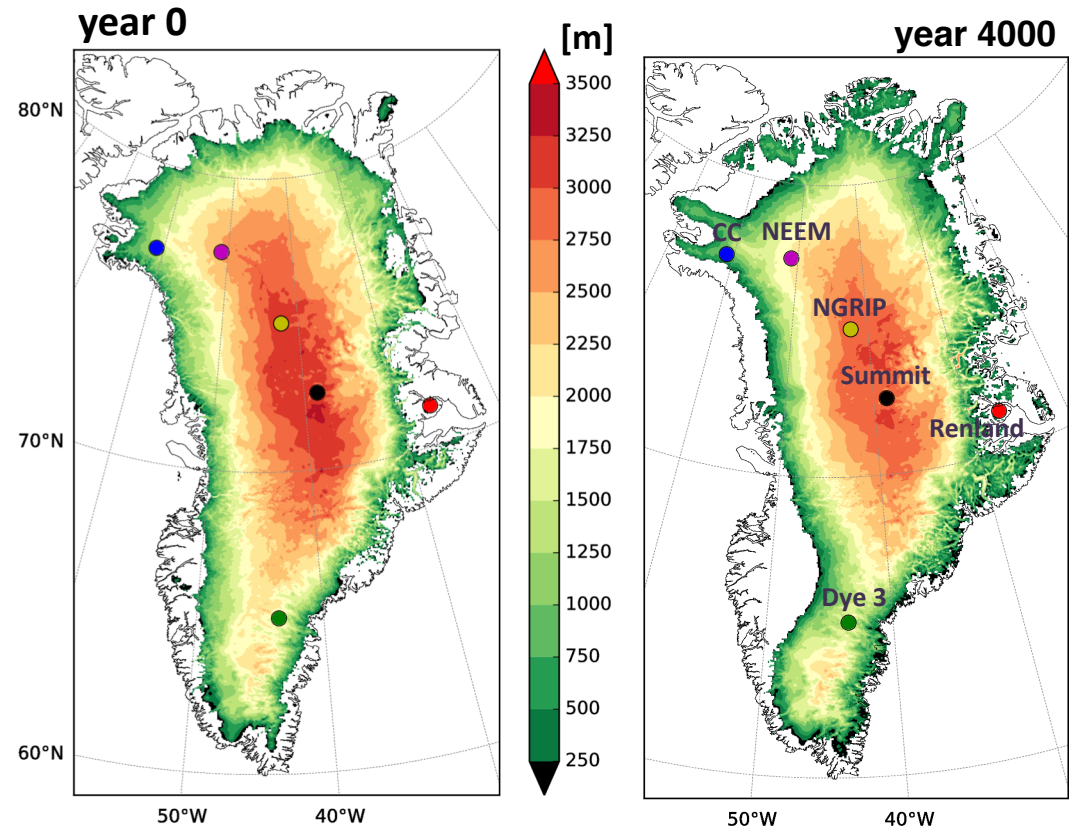




# Summary

- ~ Thickness change at ice cores

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



# Next steps

- Rerun with final CESM2 configurations and spunup  
GrIS initial state
- Refine vegetation map
- New calving/marine basal melt and other new parameterizations ... [maybe]
- ★ Transient simulation ★