Constraint on the penultimate glaciation ice sheet topography:

the last two glaciations as simulated by CCSM4

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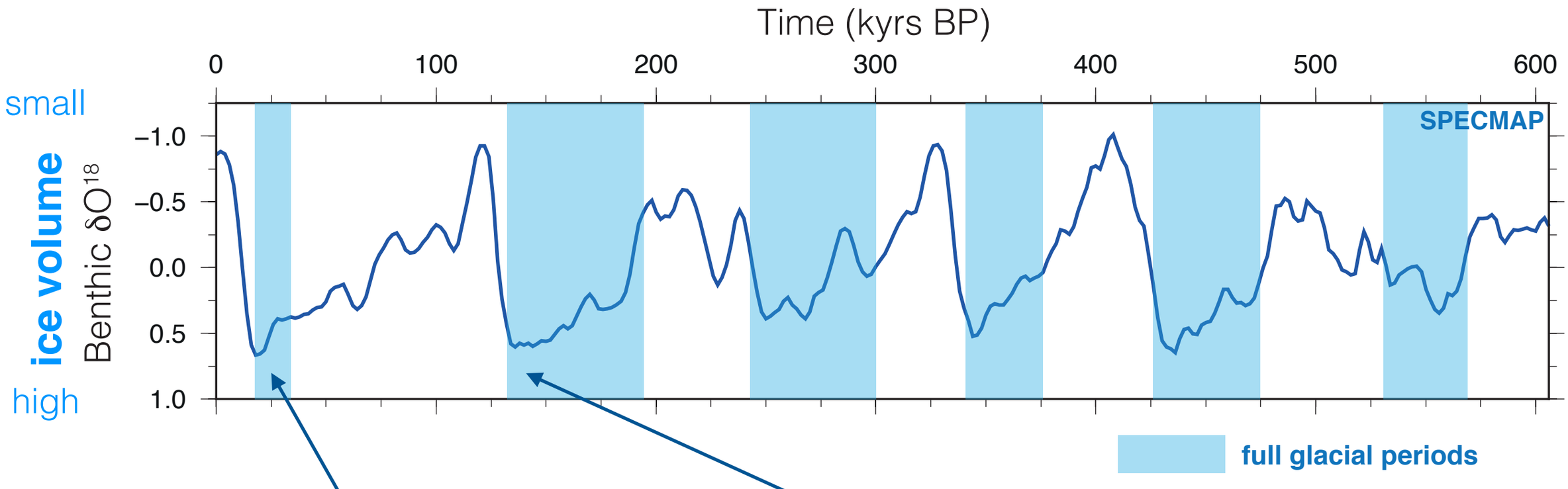
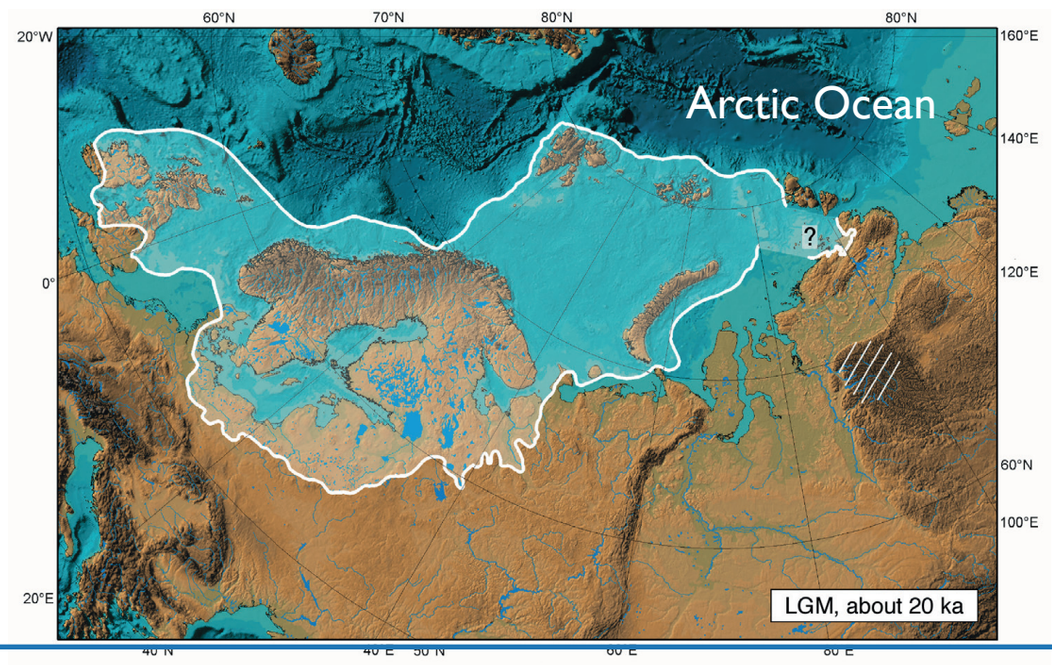
[4]Swedish nuclear waster management Company (SKB, Sweden)

NCAR winter meeting 2016 - PaleoWG

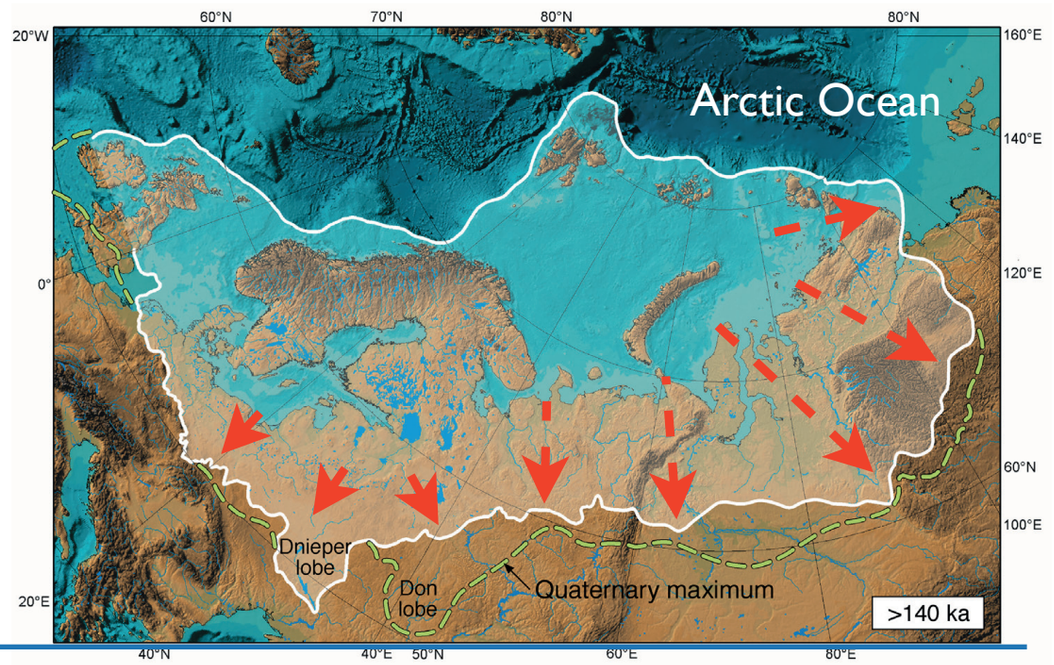
The penultimate glaciation (MIS6, 140 kyrs BP)



Last Glacial Maximum (~ 21 ka)

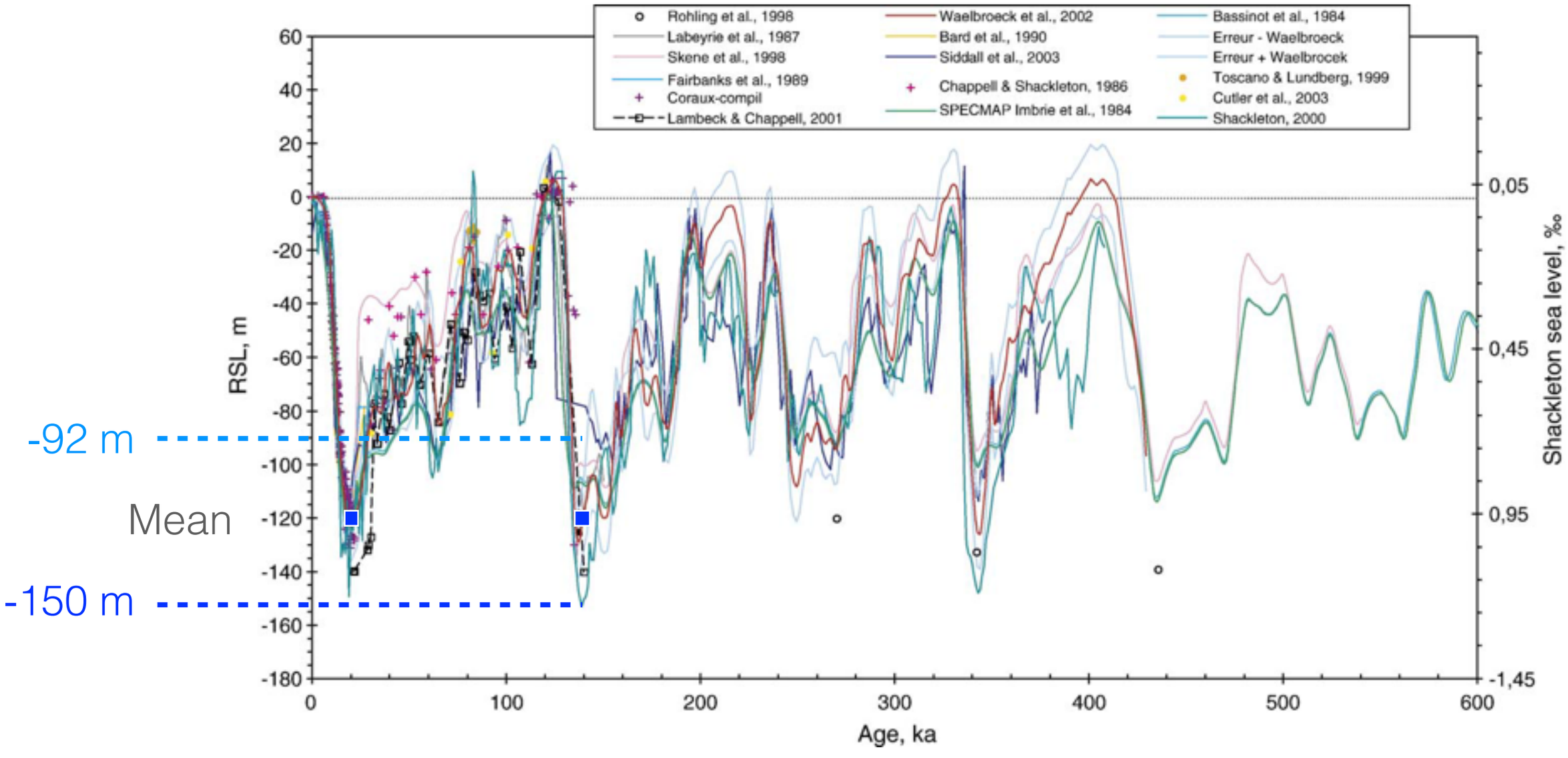


Late Saalian (140 ka)



The penultimate glaciation (MIS6, 140 kyrs BP)

How was sea level compared with the LGM?



Large uncertainty on sea level

Rabineau et al (2006)

The penultimate glaciation (MIS6, 140 kyrs BP)

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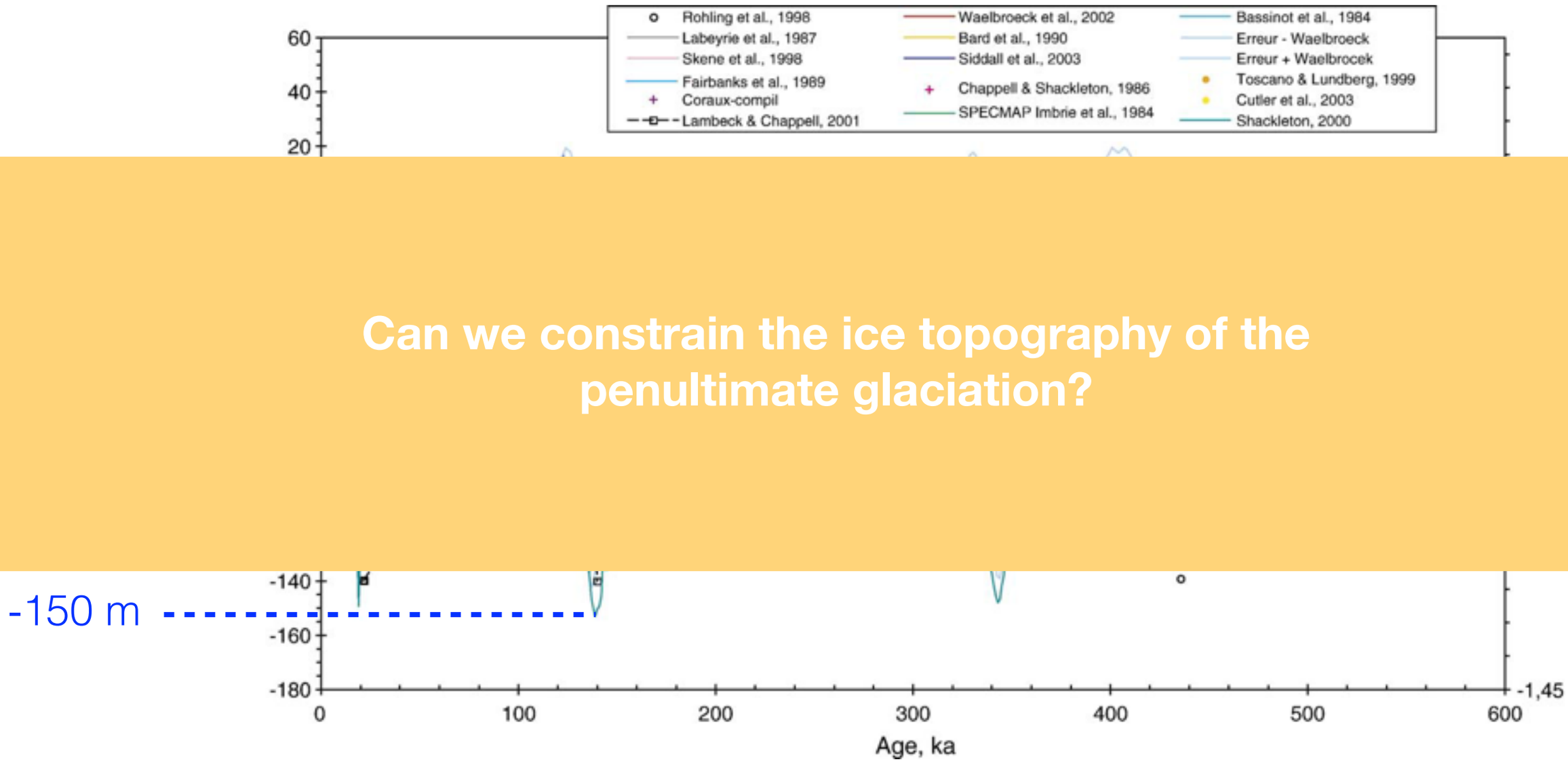
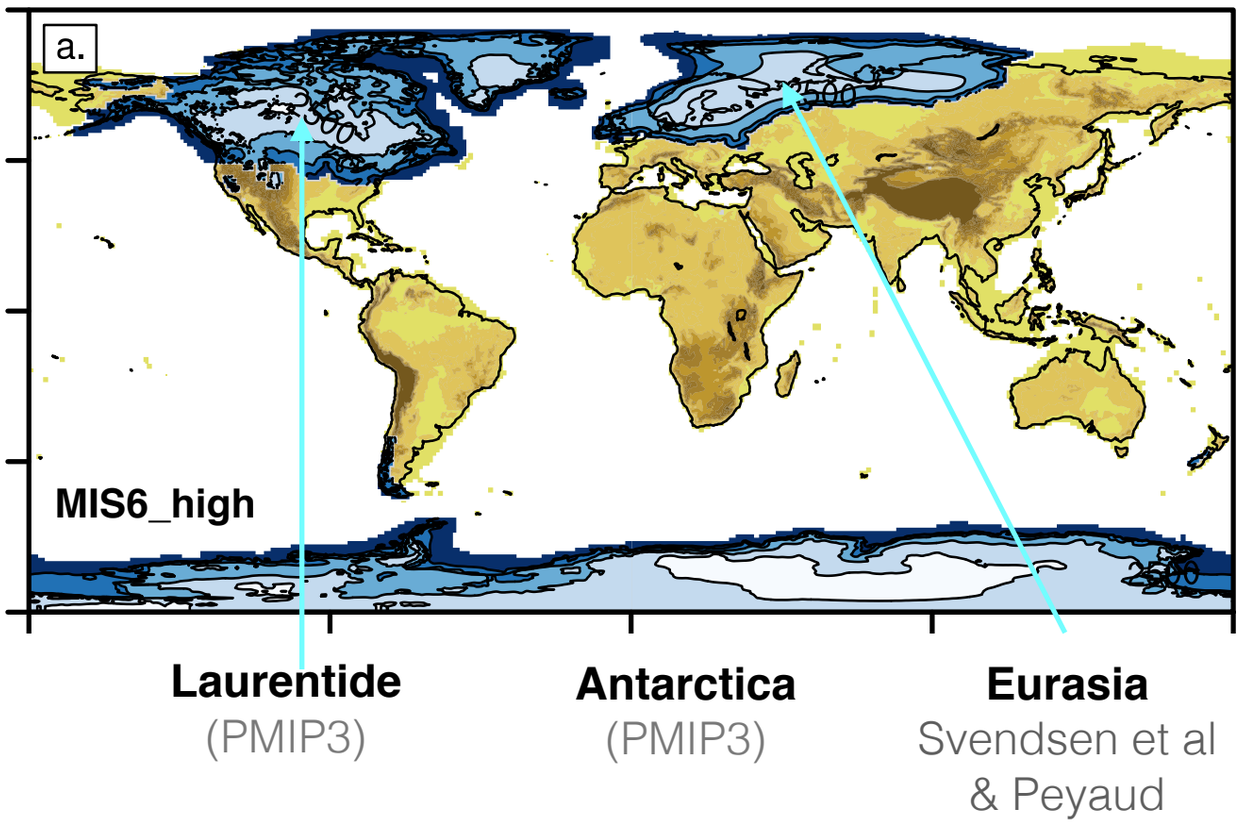


Can we constrain the ice topography of the penultimate glaciation?

Large uncertainty on sea level

Rabineau et al (2006)

The penultimate glaciation (MIS6, 140 kyrs BP)



Late Saalian ice volume (m SLE)

Eurasia	70		
Laurentide (LGM)	74	**TOTAL**	**Observed**
		165	92-150
Others (LGM)	21		

No geological evidence for the Laurentide ice volume

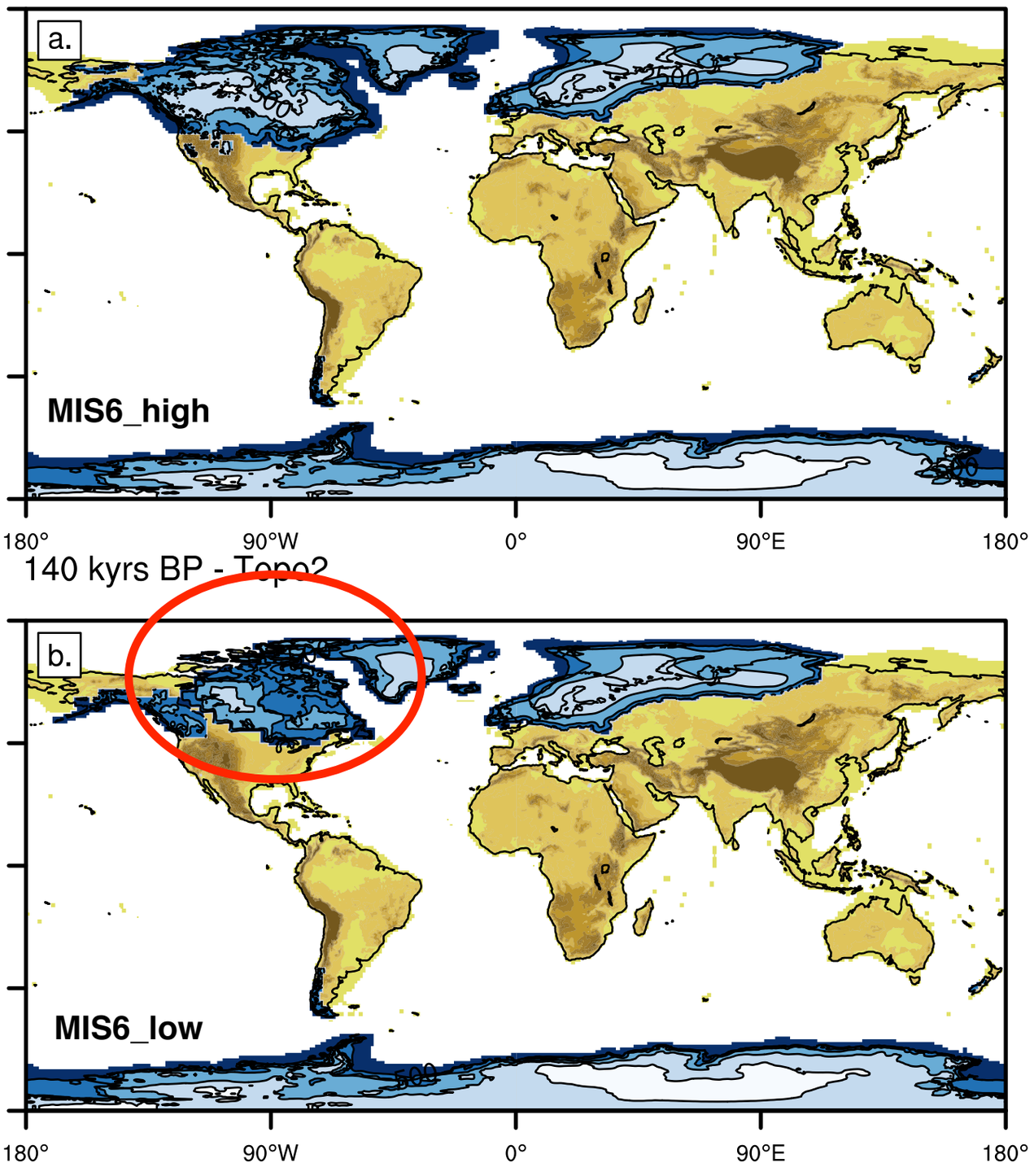
↓

Use a smaller Laurentide to equilibrate eustatic sea level

Colleoni et al. (2016b)

m SLE = meters Sea Level Equivalent

The penultimate glaciation (MIS6, 140 kyrs BP)



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CESM 1.0.5: B compset - CCSM4 configuration

Length of simulations: 900 years

Type of simulations: steady states

Atmosphere: CAM 4

Finite Volume grid

26 vertical levels

0.9°x1.25° horiz. res.

Land: CLM 4

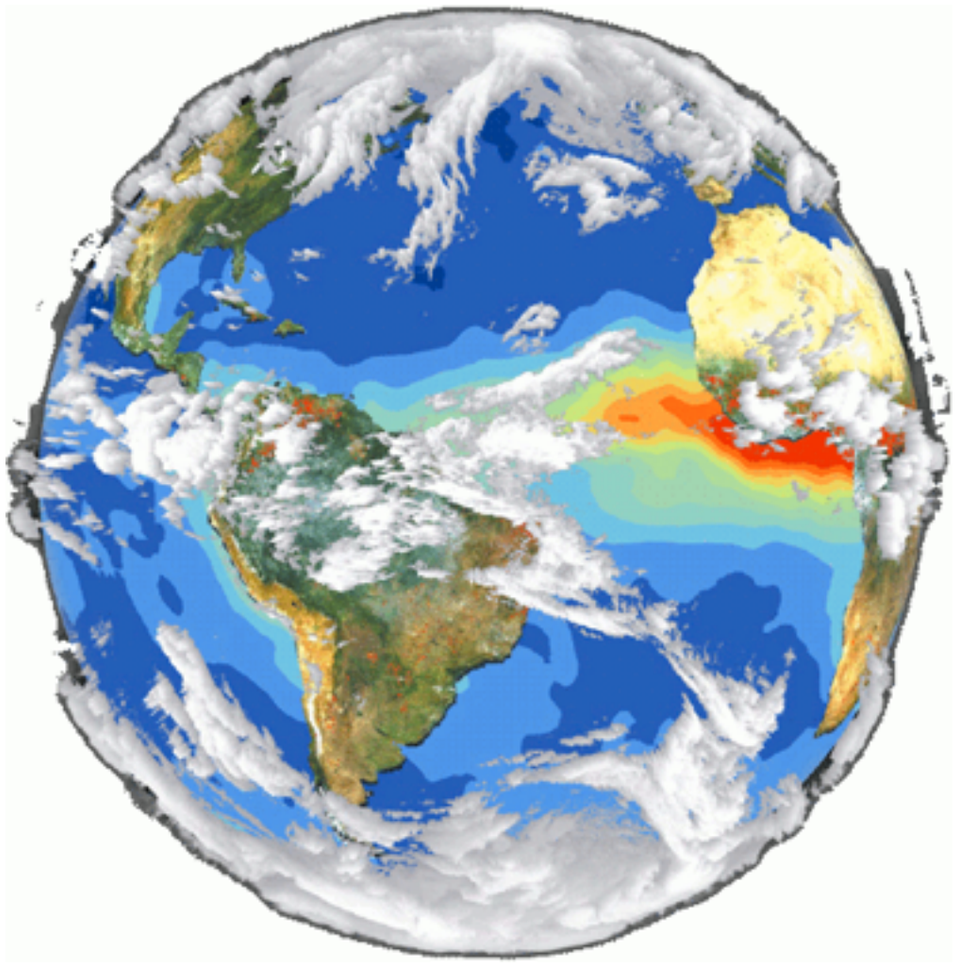
Finite Volume grid

0.9°x1.25° horiz. res.

Vegetation: prescribed

Carbon cycle: diag.

Runoff: RTM module



Sea ice: CICE 4

Displaced pole (Greenland)

~1°x1° grid horiz. res.

Thermodynamics

Ocean: POP 2

Displaced pole (Greenland)

~1°x1° grid horiz. res.

60 vertical layers

External forcing: 140 kyrs BP (21 kyrs BP)

CO_2 = 192 ppmv (185)

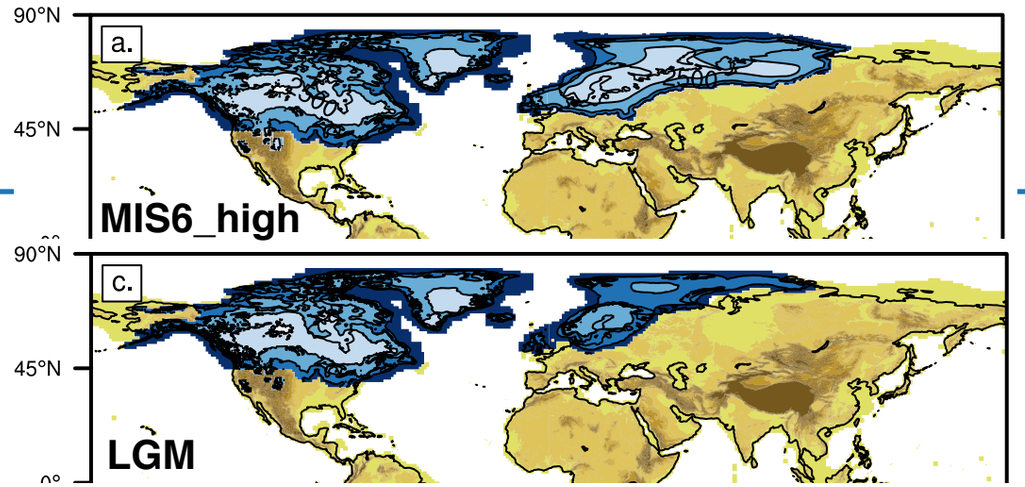
CH_4 = 400 ppmb (350)

Perihelion: Dec. 3 (Jan.17)

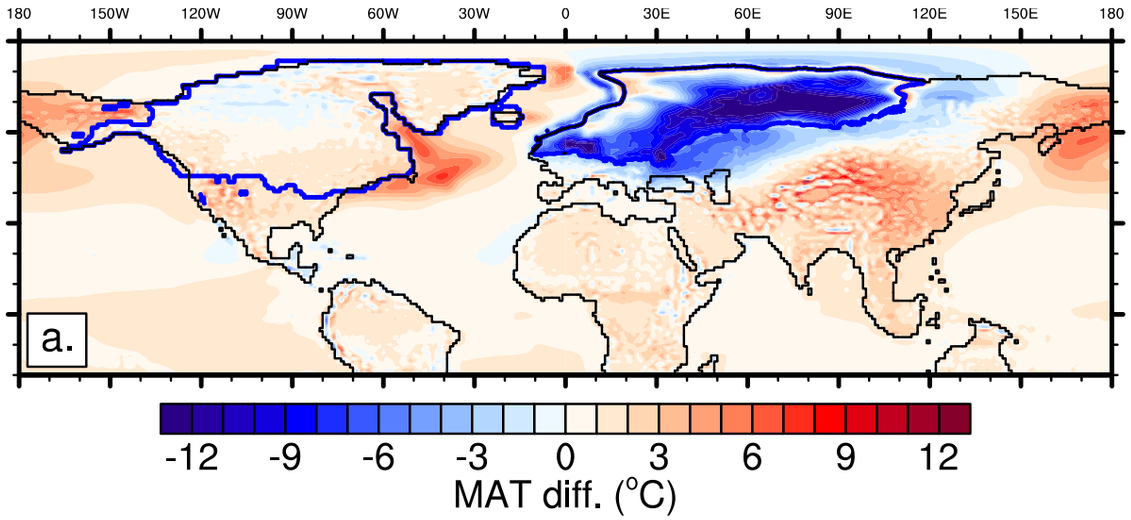
Eccentricity: 0.033 (0.019)

Gent et al. (2011)

MIS6_high versus LGM

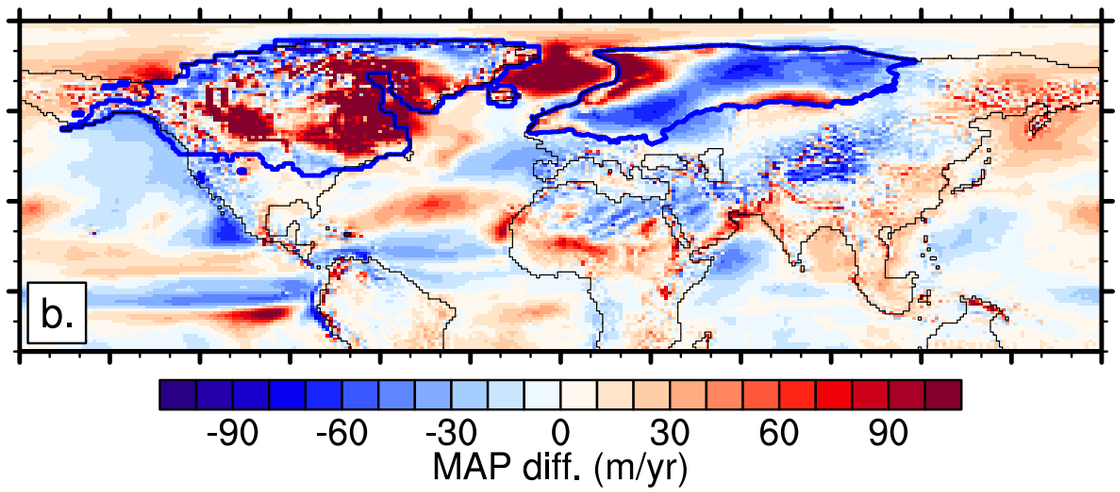


MIS6_high - LGM



Global mean annual cooling paleo-PI	
MIS6_high	-3.7°C
LGM	-4.9°C

(MIS6_high - LGM)/MIS6_high

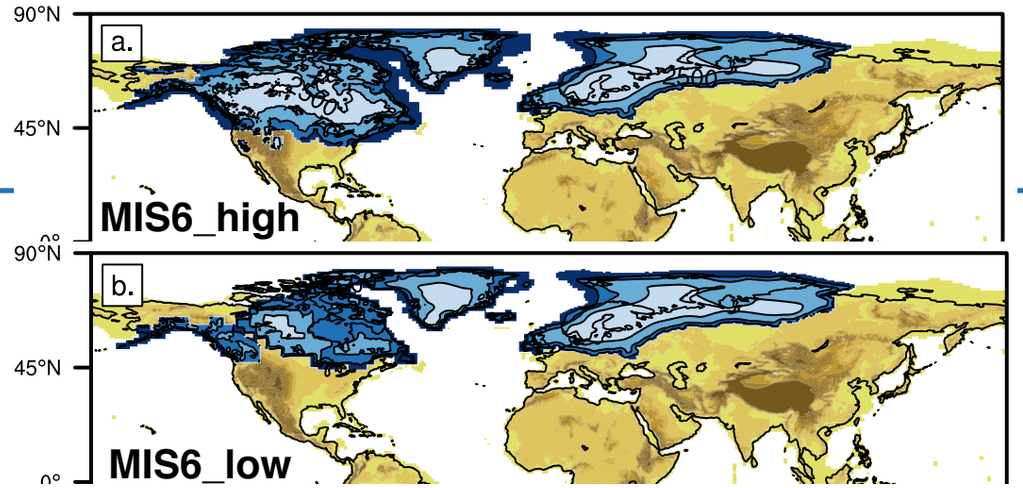


Global mean annual precip	
MIS6_high	2.70 mm/day
LGM	2.61 mm/day

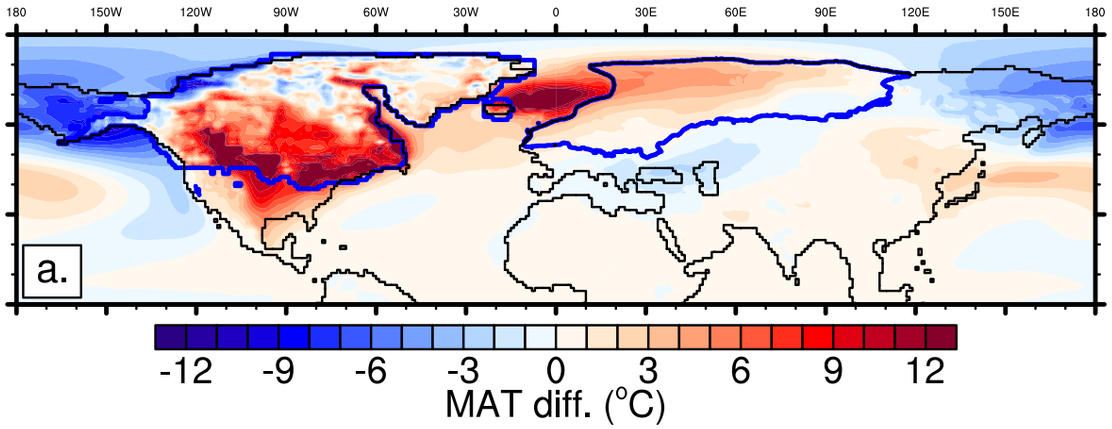
LGM simulation from Brady et al. (2013)

MIS6_high versus MIS6_low

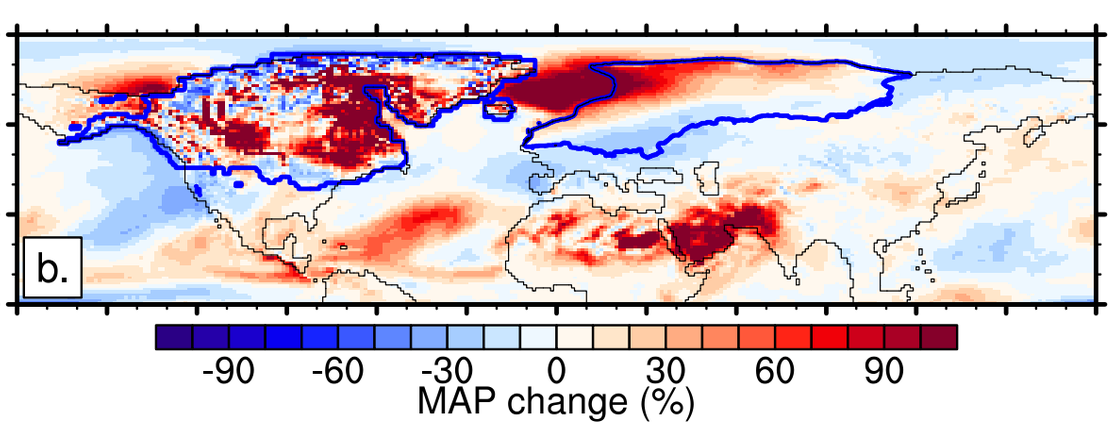
Effect of topography only



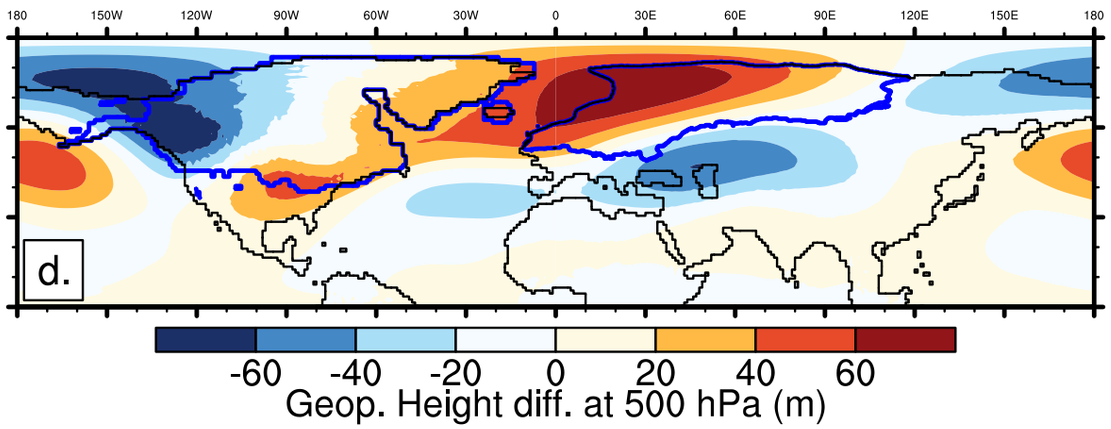
MIS6_low - MIS6_high



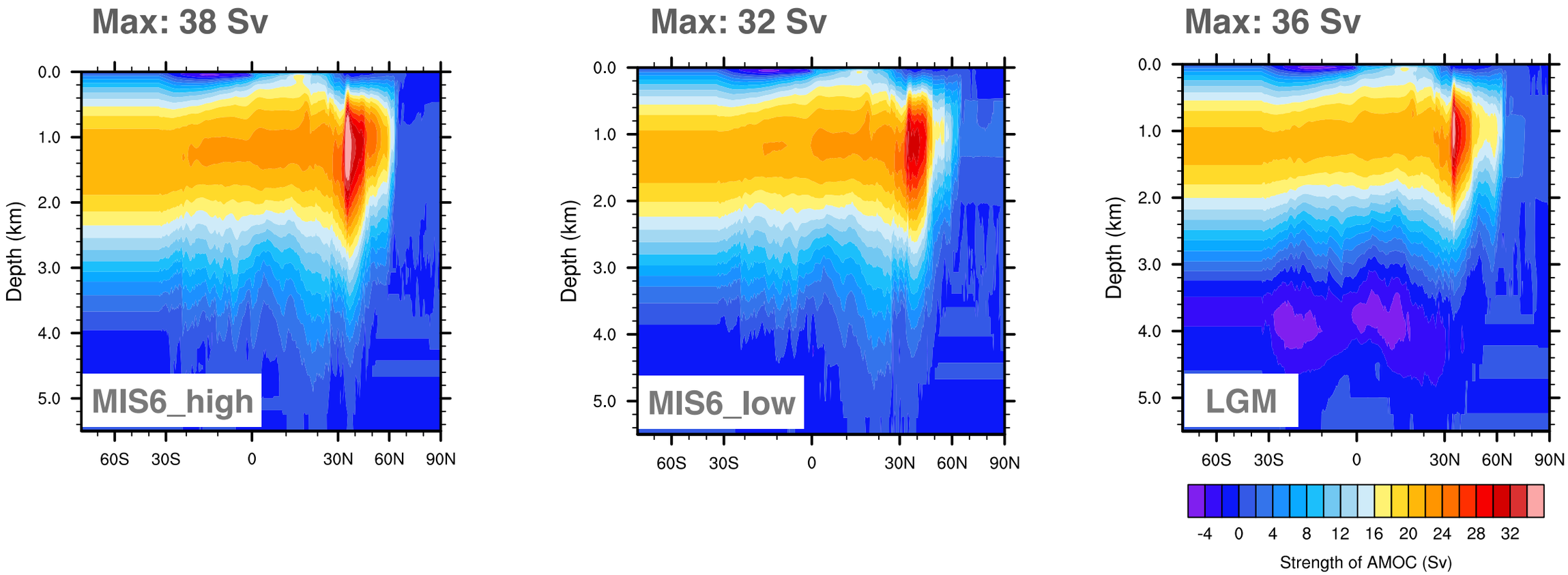
(MIS6_low - MIS6_high)/MIS6_high



MIS6_low - MIS6_high



Atlantic Meridional stream function



- deeper than LGM
- No Antarctic bottom water
- More vigorous than LGM

(shorter spin-up)

- shallower than MIS6_high
- No Antarctic bottom water
- Less vigorous than MIS6_high

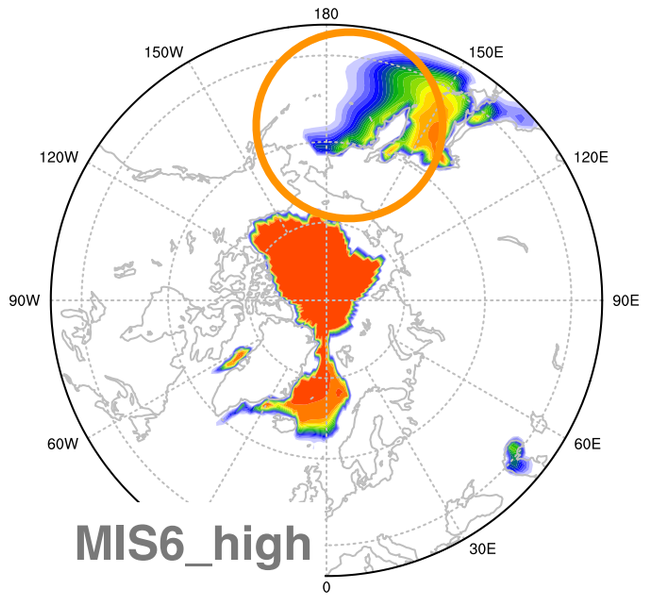
Reduction of equator to pole gradient

- Antarctic bottom water

(longer spin-up)

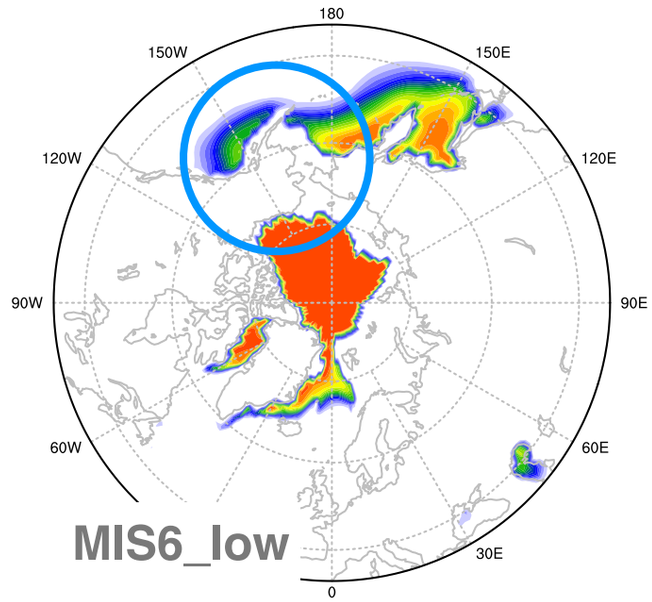
Boreal sea ice cover: spring

Smaller extent than LGM

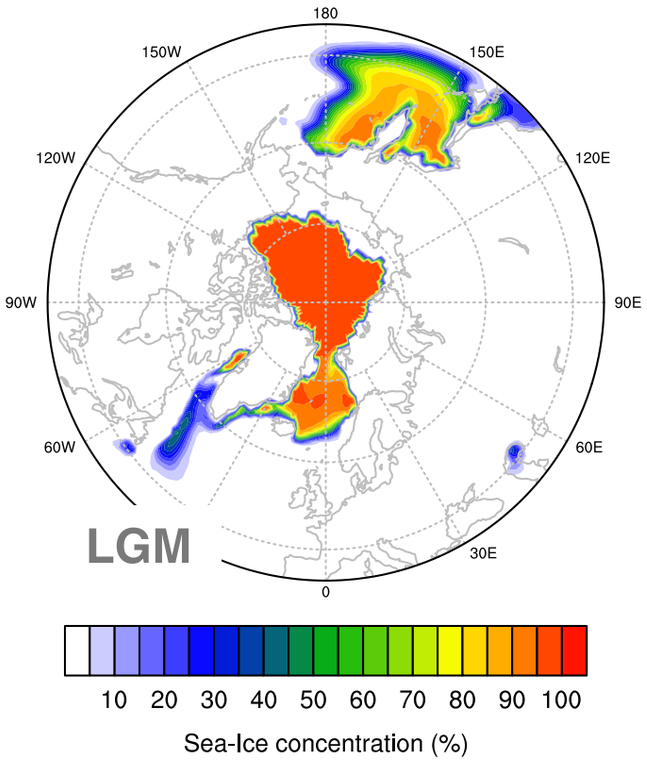


warm T° anomaly caused by the shift in planetary wave compared to LGM

Larger extent than MIS6_high and LGM

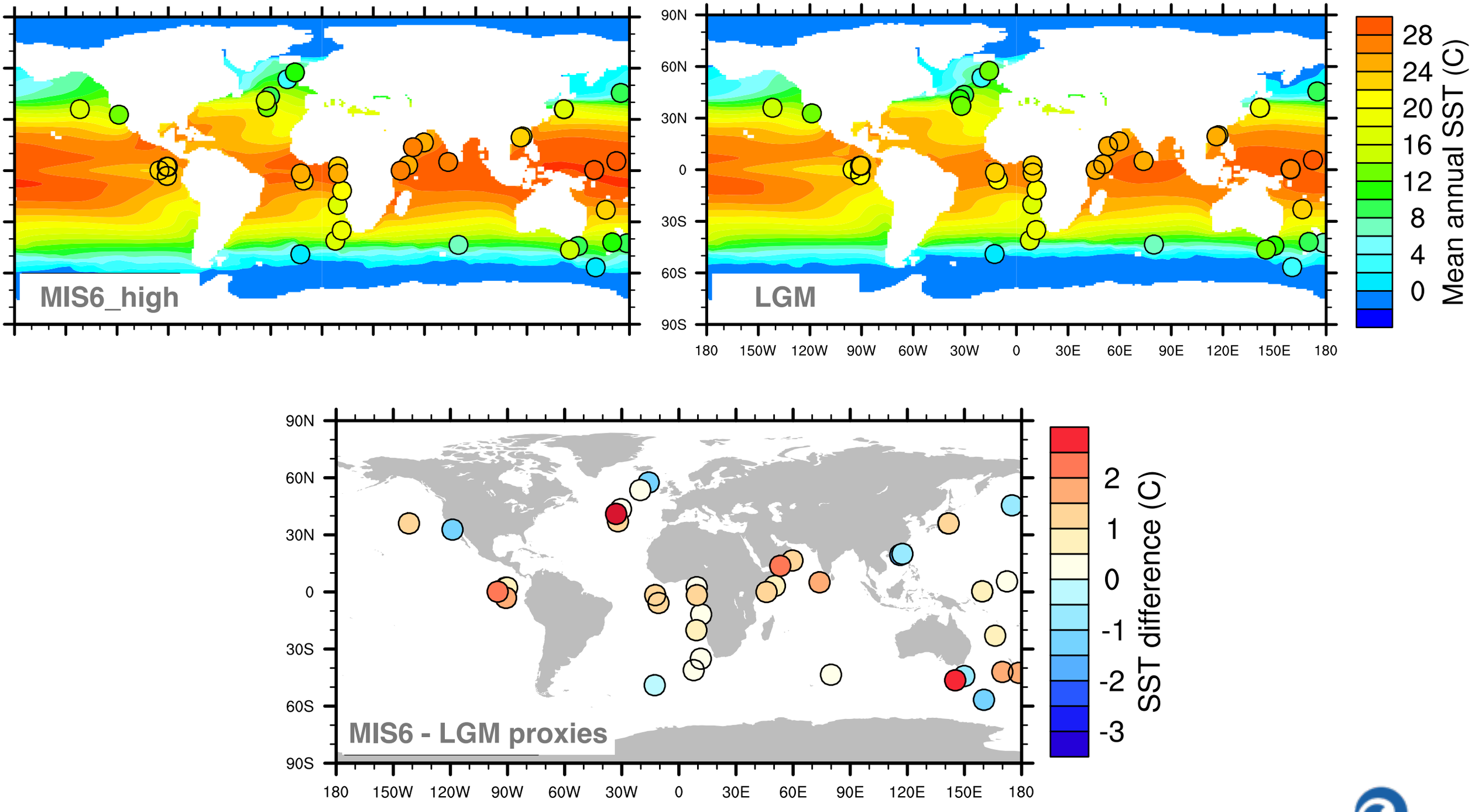


negative T° anomaly caused by the shift in planetary wave compared with MIS6_high and LGM



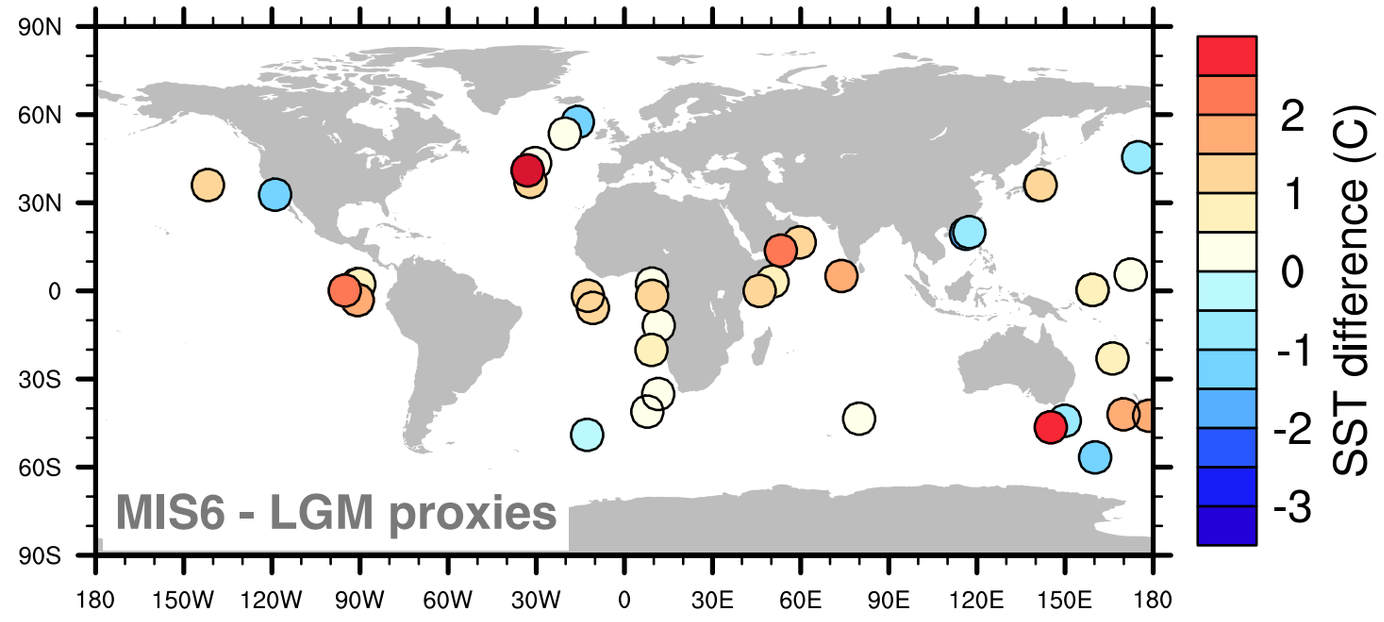
Can we constrain the Northern Hemisphere ice sheet topography?

Sea surface temperature: model vs. proxies



Colleoni et al. (2016b)

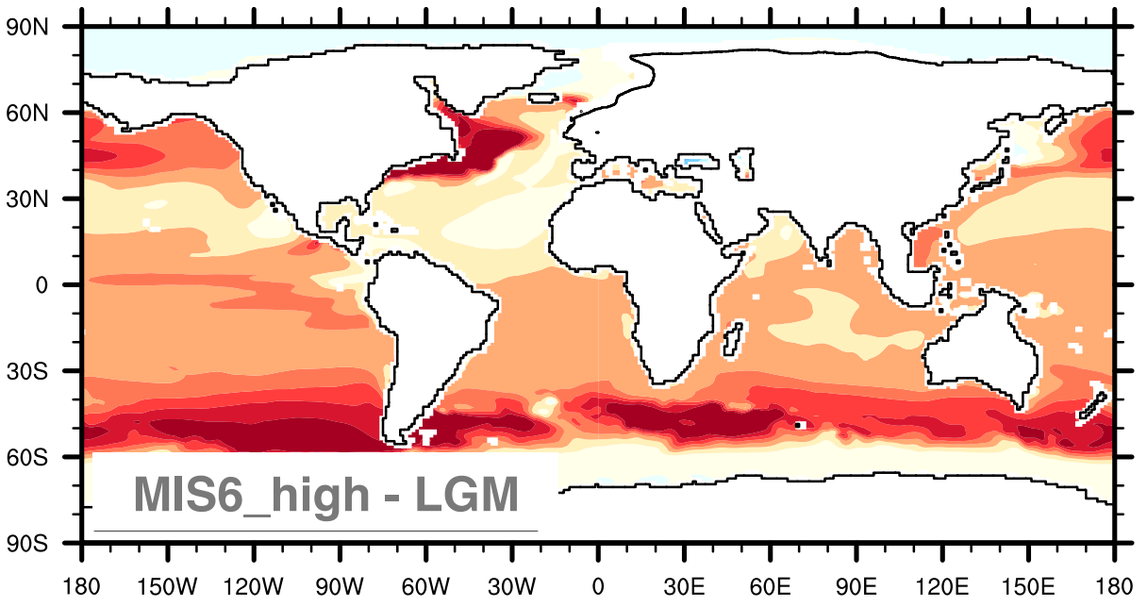
Sea surface temperature: model vs. proxies



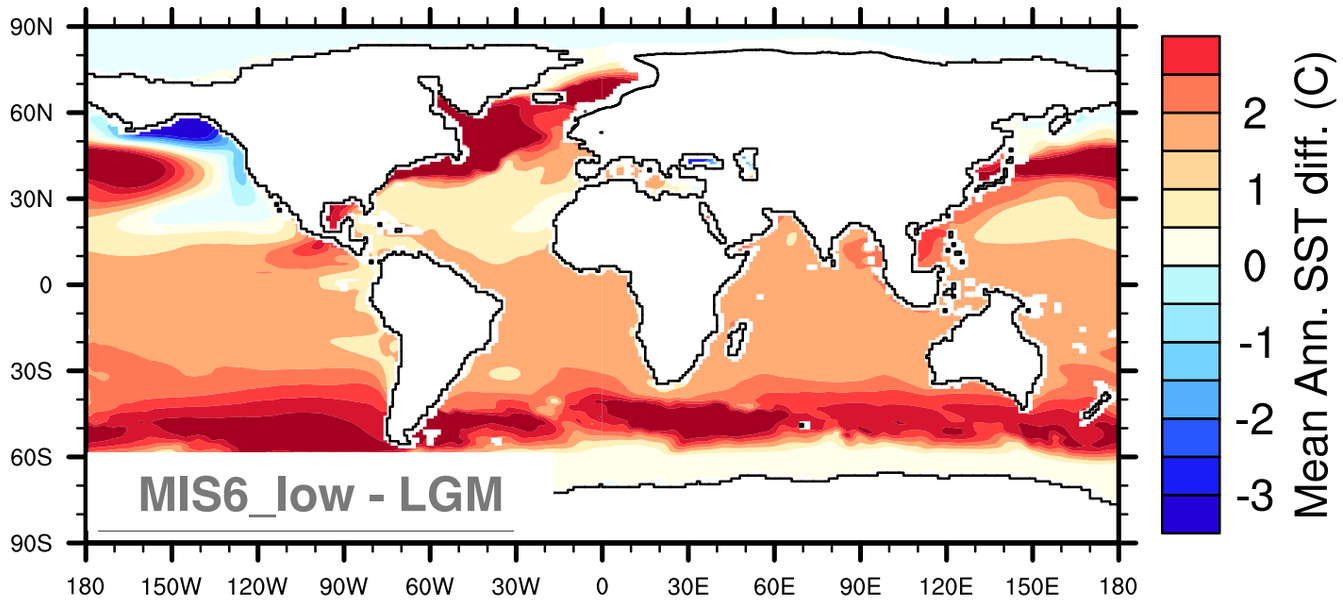
Proxies show that MIS 6 SST were:

- **warmer** then during LGM in the tropics
- **colder** in mid- to high latitudes

Big Laurentide



Small Laurentide

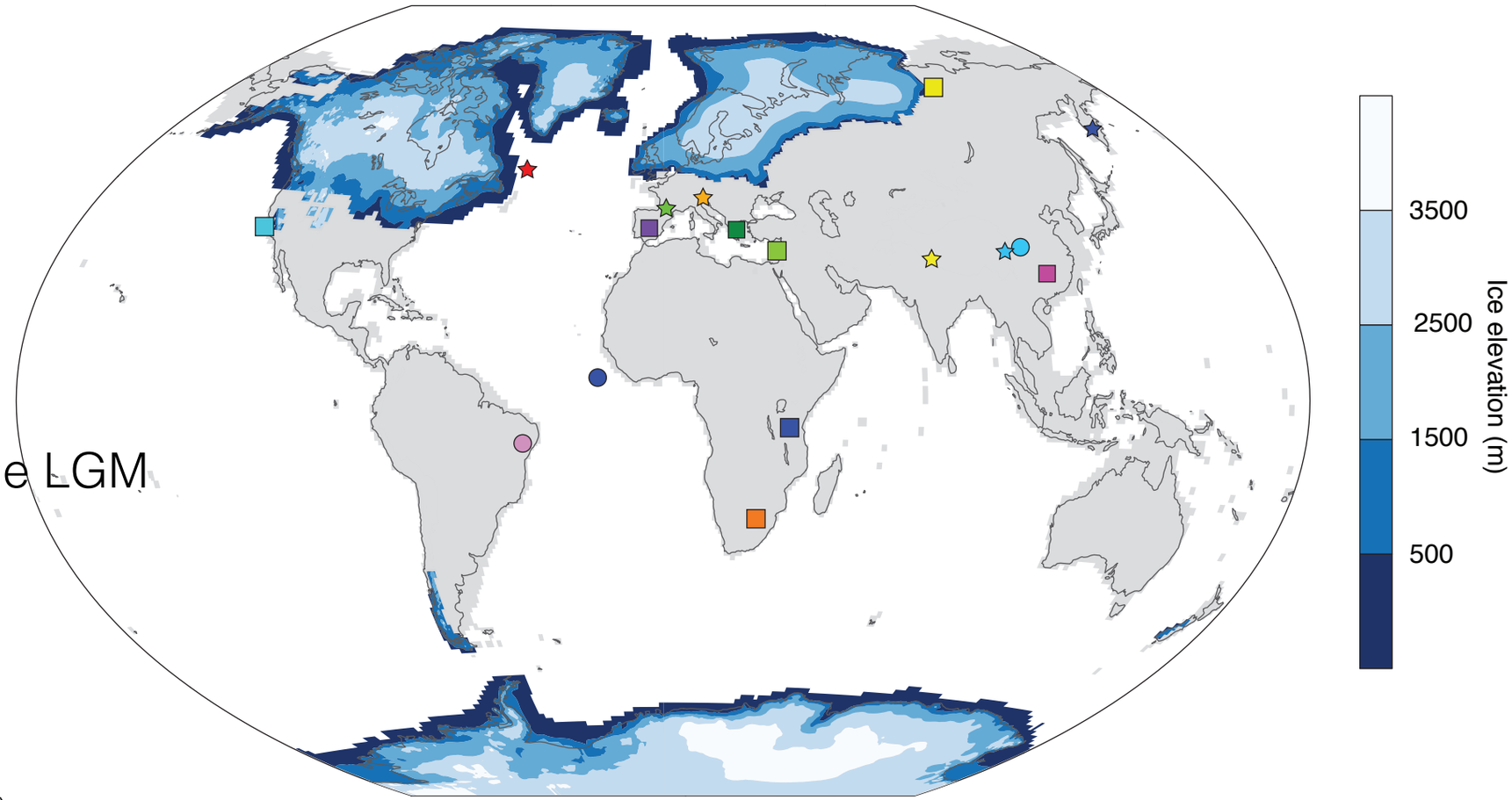


Precipitation and glaciated areas: model vs. proxies

Proxies suggest:

- **larger** European glaciers
- **smaller** Himalayan glaciers

during the MIS6 than during the LGM



Extent of continental glaciated areas

- Kamchatka glaciated (Barr et al., 2014)
- Smaller glaciated area compared with LGM (Owen et al., 2006)
- Most extensive glaciation (Dehert et al., 2010; Preusser et al., 2011)
- Most extensive glaciation (Garcia-Ruiz et al., 2013)
- Smaller Laurentide than at LGM (Obrotcha et al., 2014)
- Large Eurasian ice sheet due to Southward Shift of the Siberian high (Railsback et al., 2014)

Changes in atmospheric circulation

- Southward shift of ITCZ (Wang et al., 2008)
- North East trades dominant + large seasonal contrast (Flores et al., 2000)
- Westerlies as a source for Asian monsoon (Railsback et al., 2014)

Precipitation changes

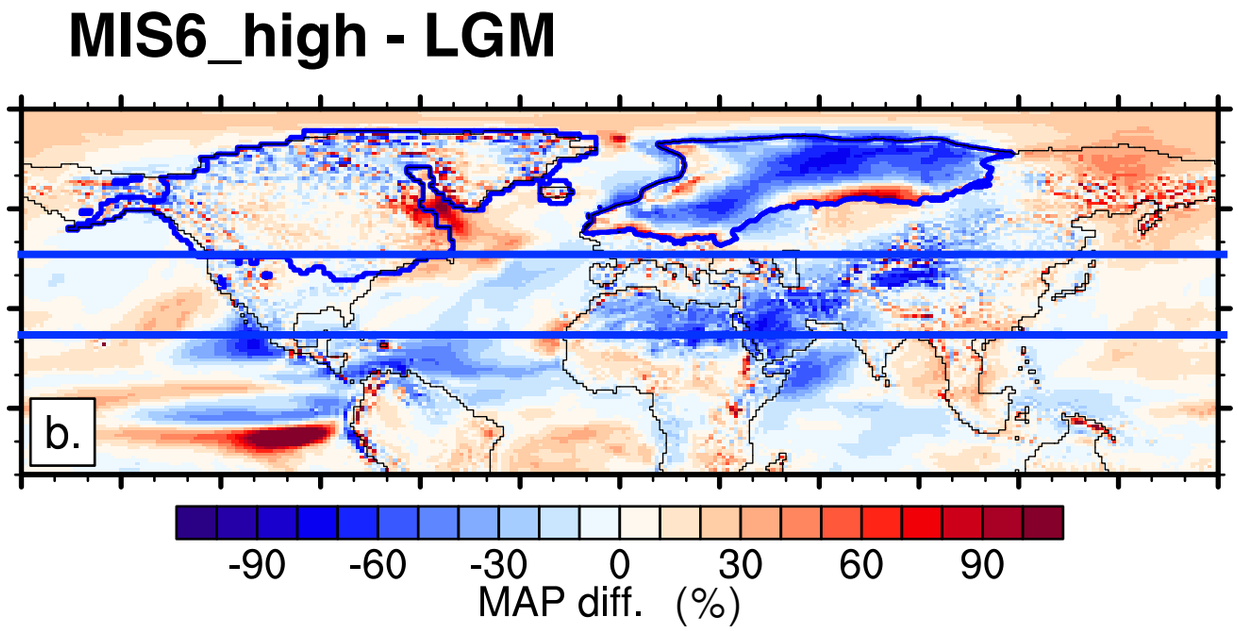
- Drier climate than at LGM (Hodge et al., 2008)
- Drier climate than at LGM (Roucoux et al., 2011)
- Weaker Asia monsoon (Wang et al., 2004)
- Wetter than at LGM (Partridge et al., 1997)
- Wetter than at LGM (Ayalon et al., 2002)
- Drier climate than at LGM (Moernaut et al., 2010)
- Wetter than at LGM (Lachniet et al., 2014)
- Wetter than at LGM (Zech et al., 2013)

Proxies suggest:

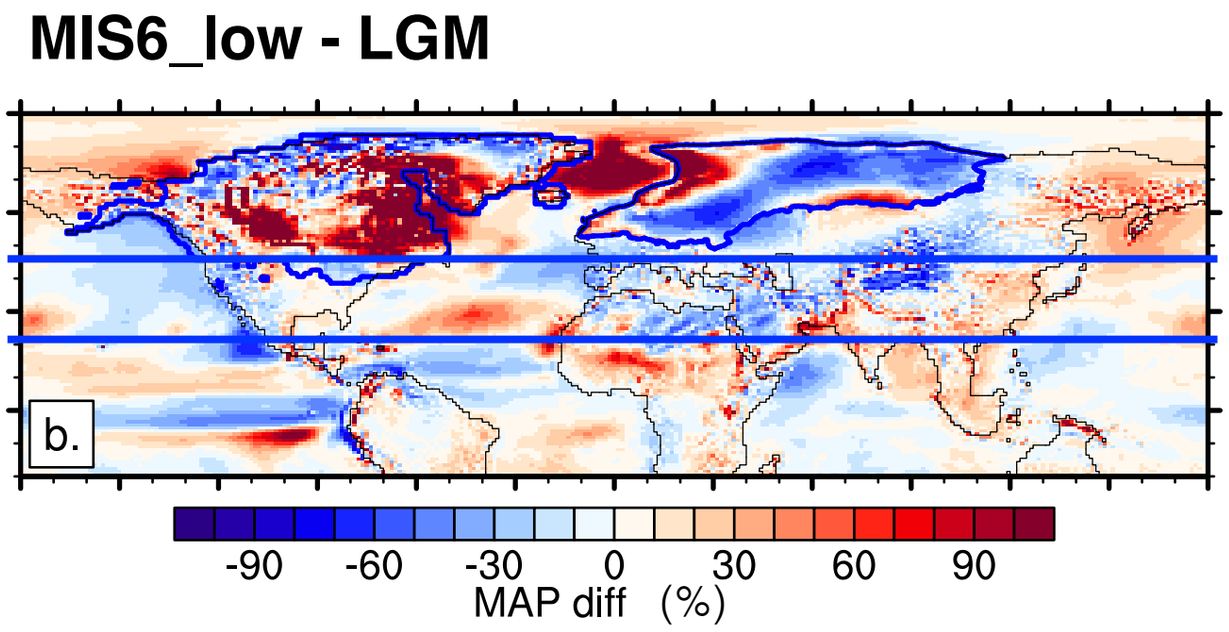
- a **drier** sub-tropical and tropical climate

during MIS 6 than during the LGM

Precipitation: model vs. proxies



Both MIS6 simulations are **drier** in the tropical area than in the LGM one

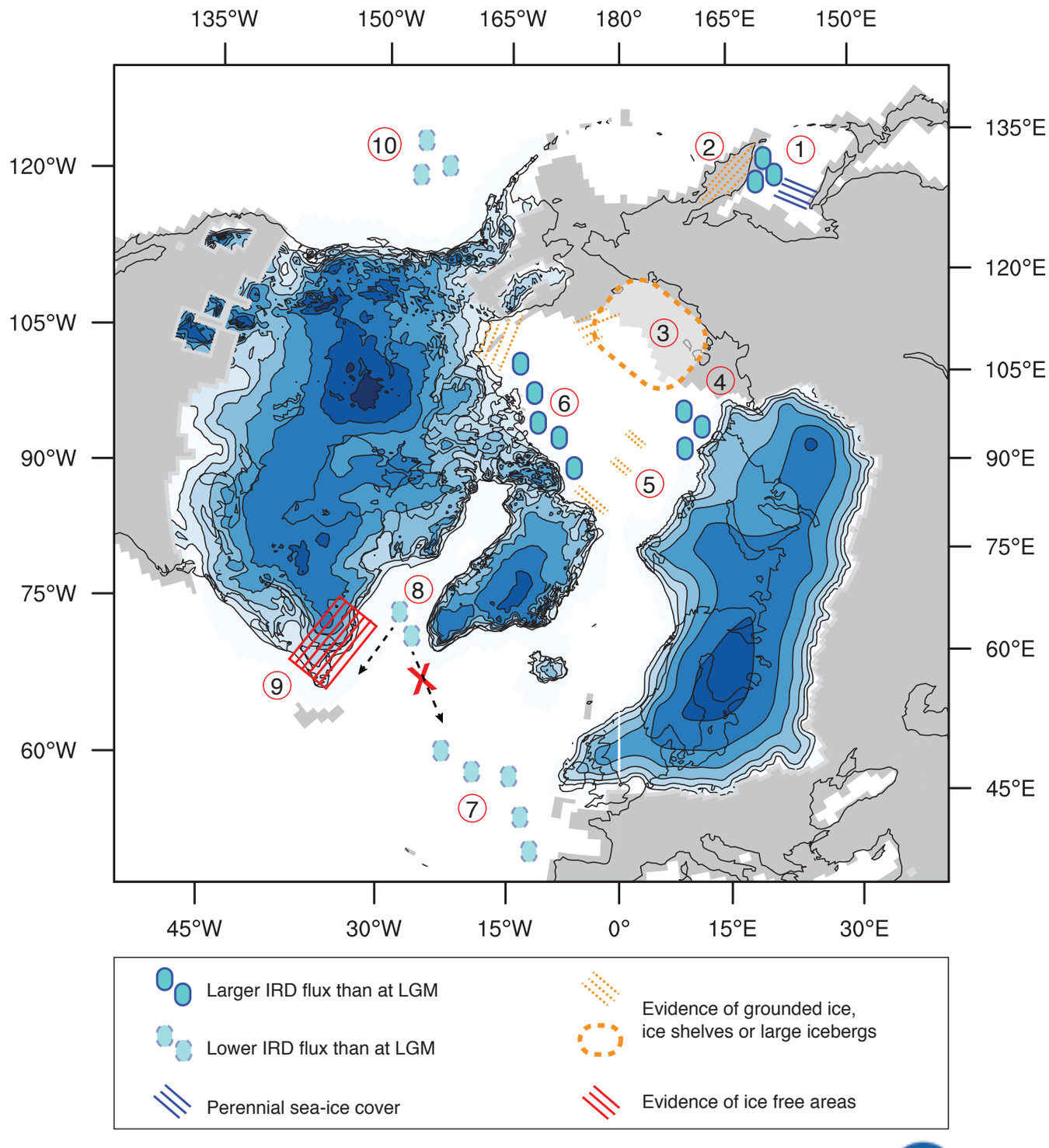


Not in agreement with the proxies

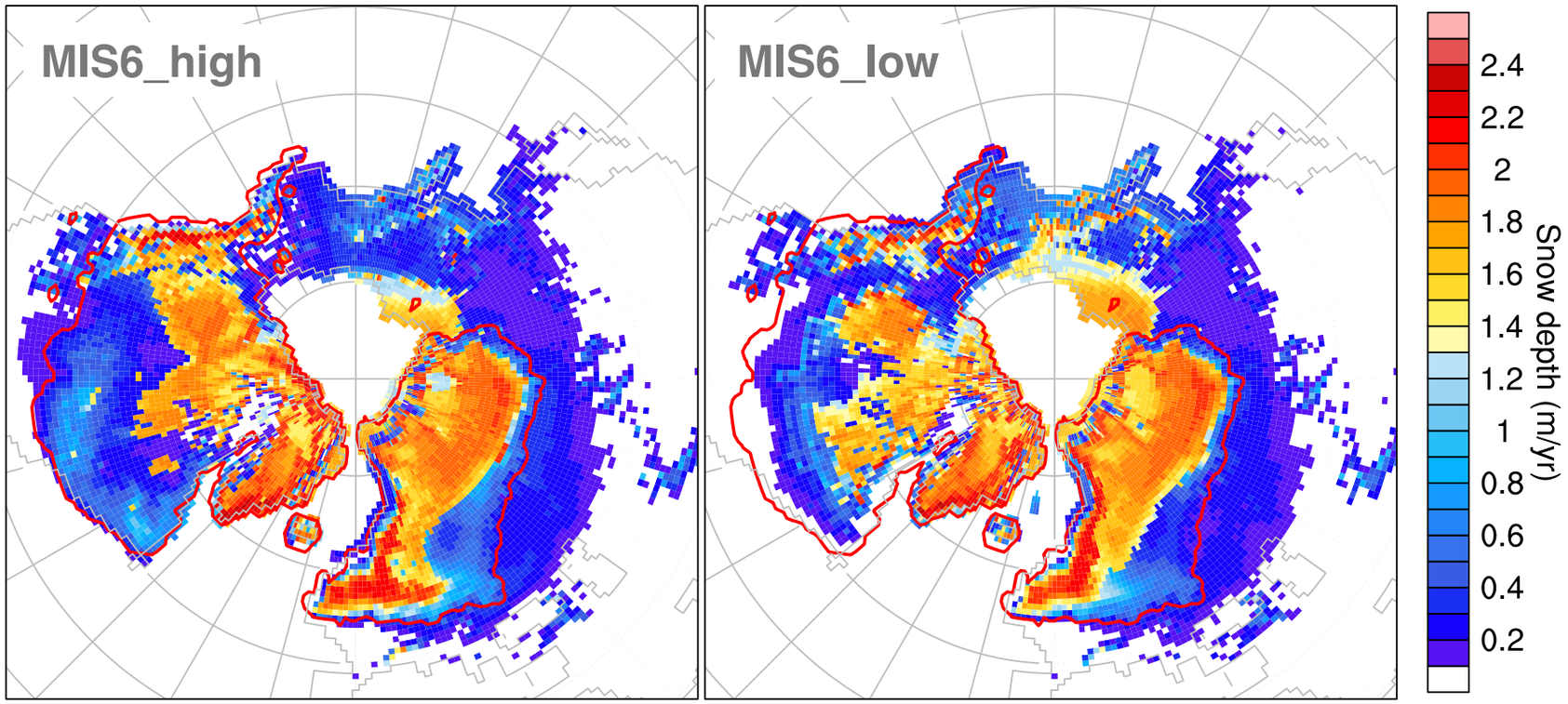
Polar regions cryosphere: model vs. proxies

Compared with LGM, proxies suggest:

- a **smaller** Laurentide
- a **larger** Eurasian ice sheet extent
- **large** ice shelves in the Arctic
- Siberian highs **ice covered**
- East Siberia is **glaciated**
- **Smaller** ice sheet along the Pacific margin

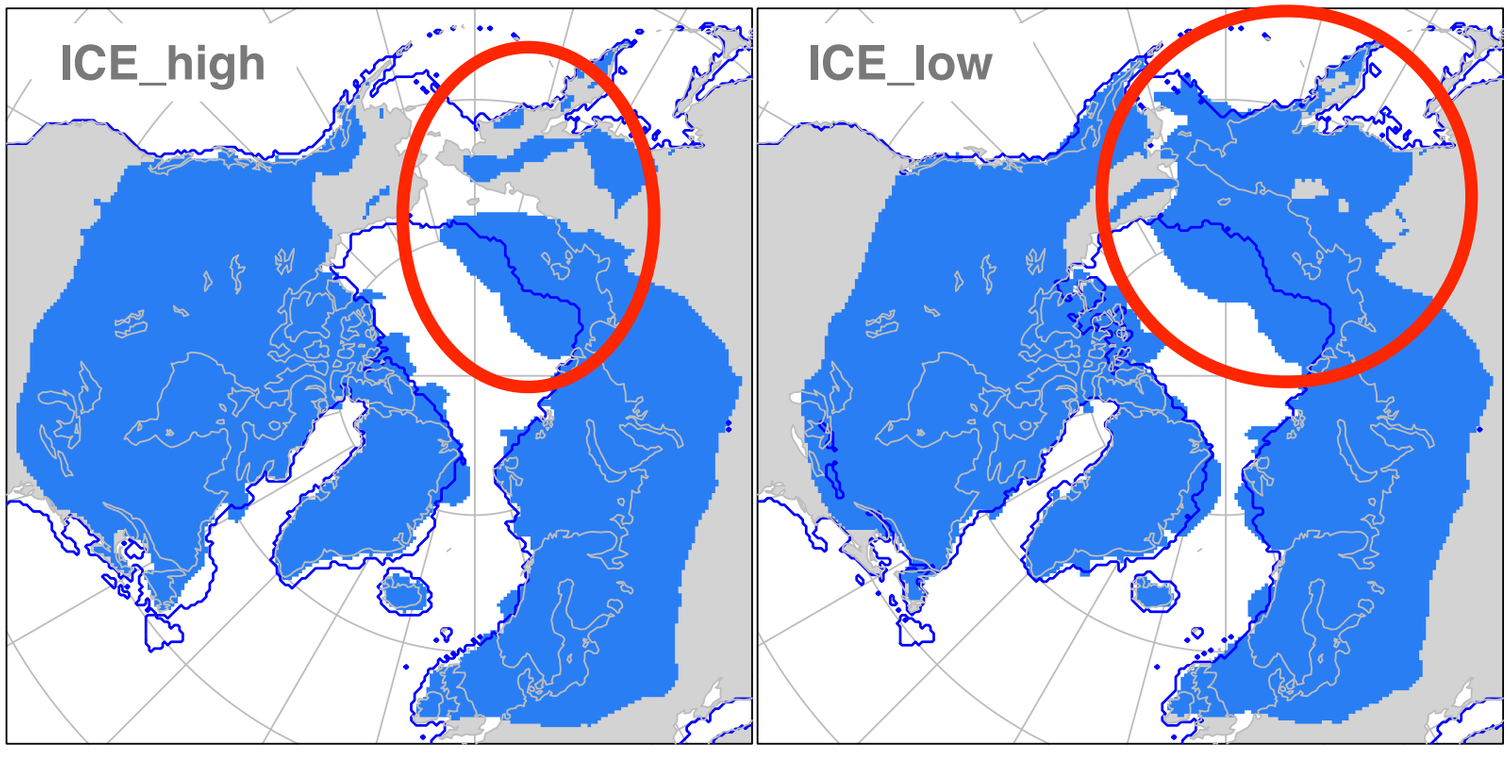


Glaciated areas: model vs. proxies



Proxies suggest that an ice cap develop over East Siberia during MIS 6

Favorable to a small Laurentide:



- MIS6_low yields an extensive snow cover over East Siberia
- The ice sheet model develop an ice cap over East Siberia and covers the Siberian highs until Kamchatka

Ice sheet simulations performed with the GRISLI ice sheet model (Ritz et al., 2001)

Conclusions

- The simulated MIS 6 glaciations exhibit a climate **comparable** to the simulations of LGM

- The use of a small Laurentide causes a **shift in the planetary waves**:
  explains most of temperature and precipitation anomalies between the two MIS 6 simulations

- The comparison between the proxies and the MIS 6 simulations:
  supports a **Laurentide ice sheet smaller than during the LGM**

BUT

- The two MIS 6 topographies tested here are perhaps **too extreme**:
  the solution might be in between.