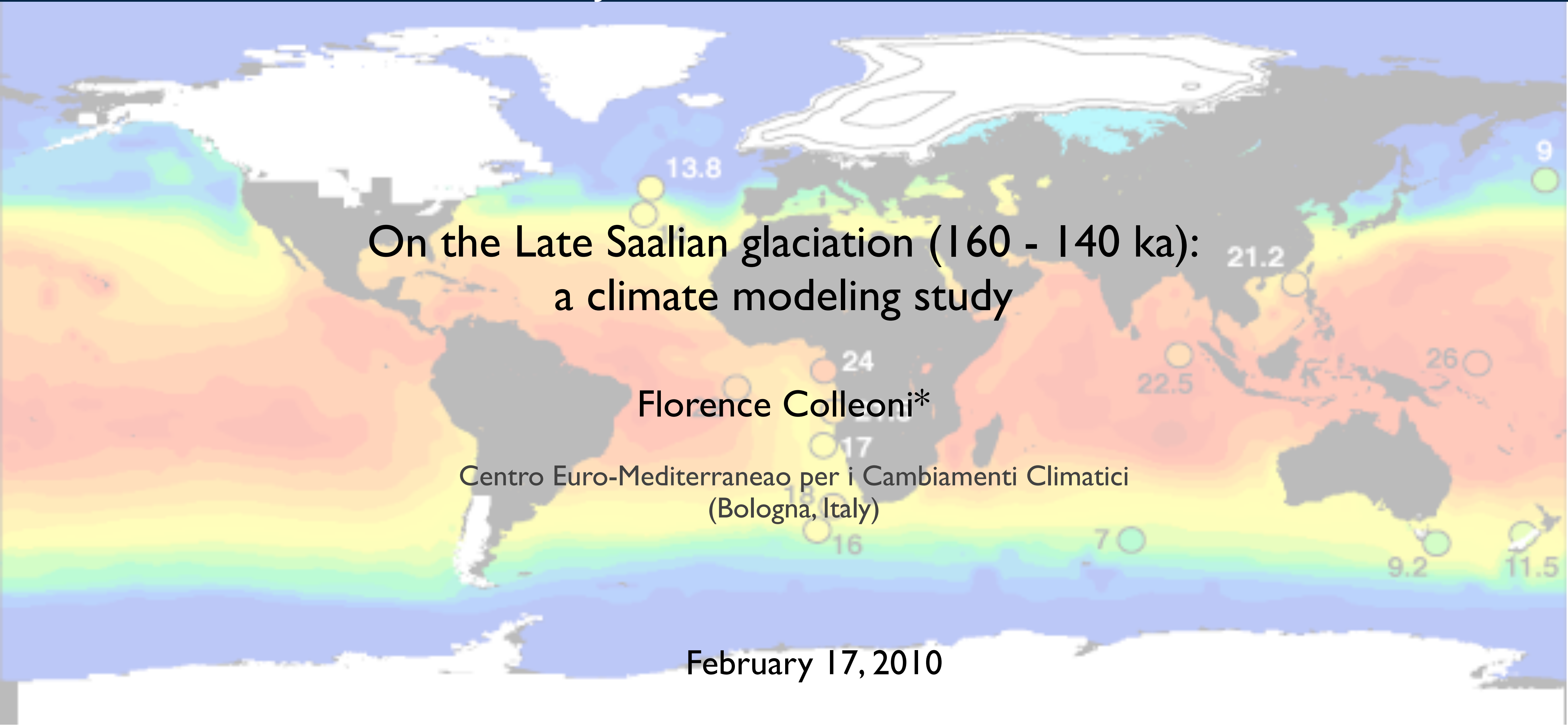

On the Late Saalian glaciation (160 - 140 ka): a climate modeling study

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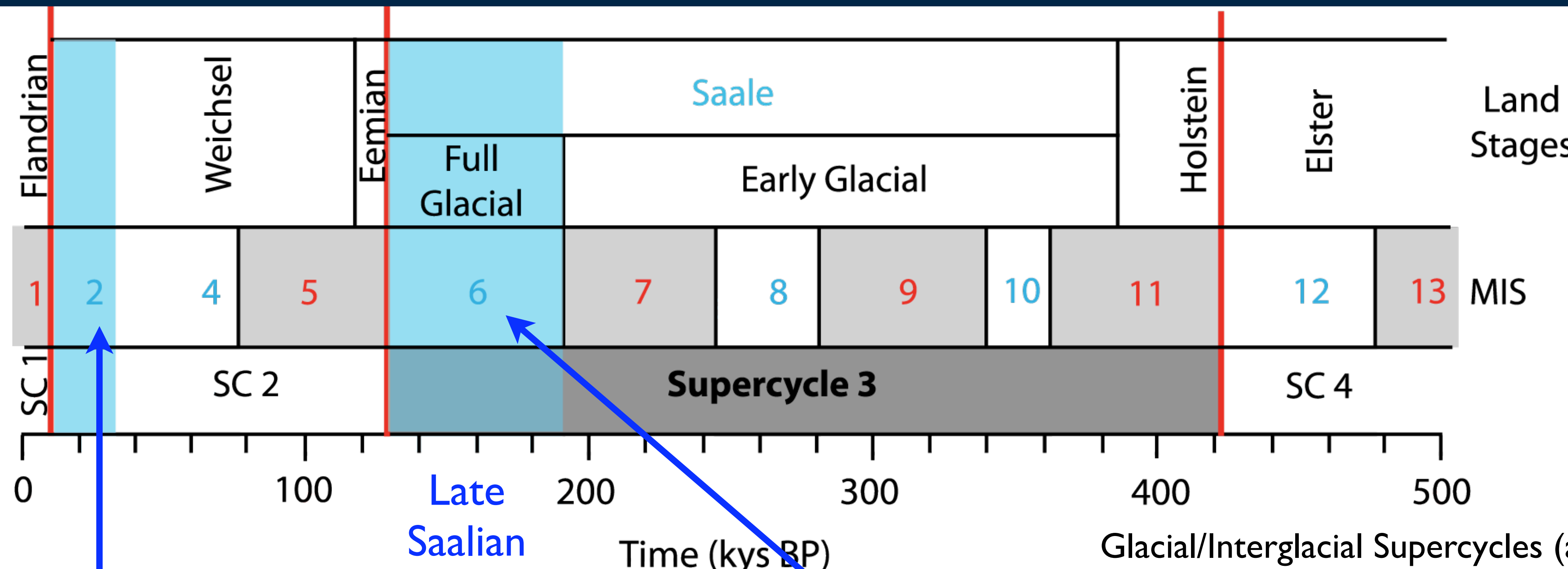
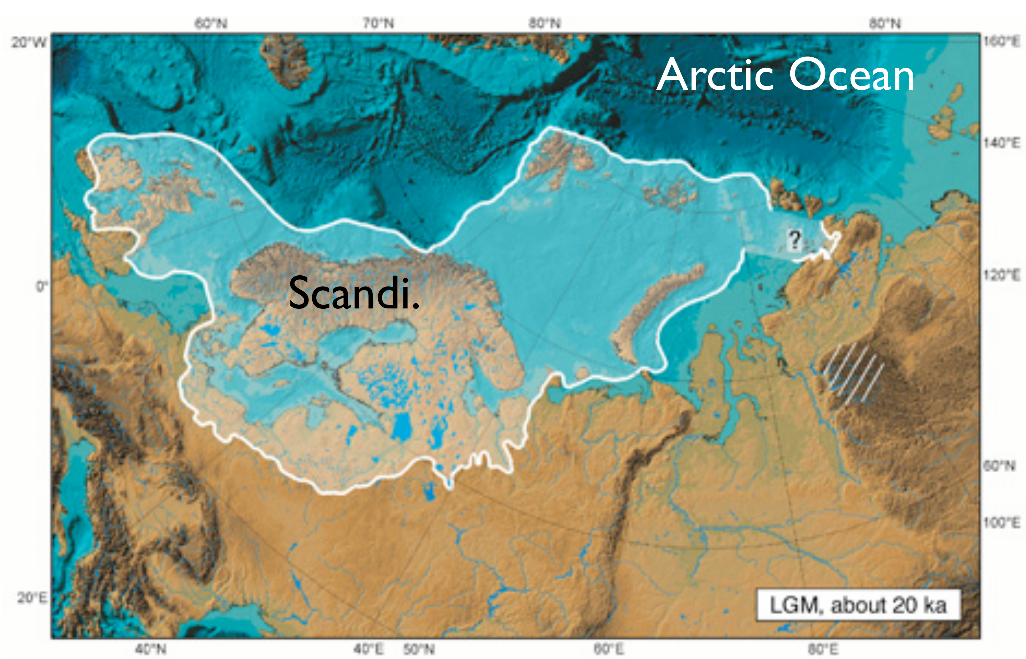


Glacial/Interglacial Supercycles (after Kukla, 2005)

Last Glacial Maximum (~ 21 ka)



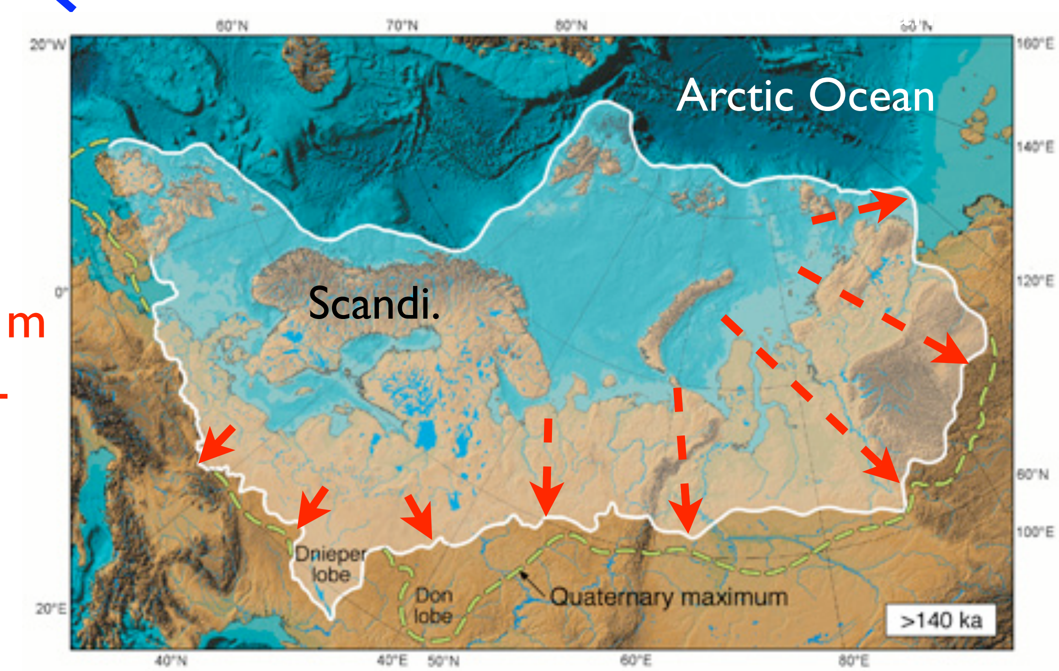
(Svendsen et al., 2004)

> 2 x larger

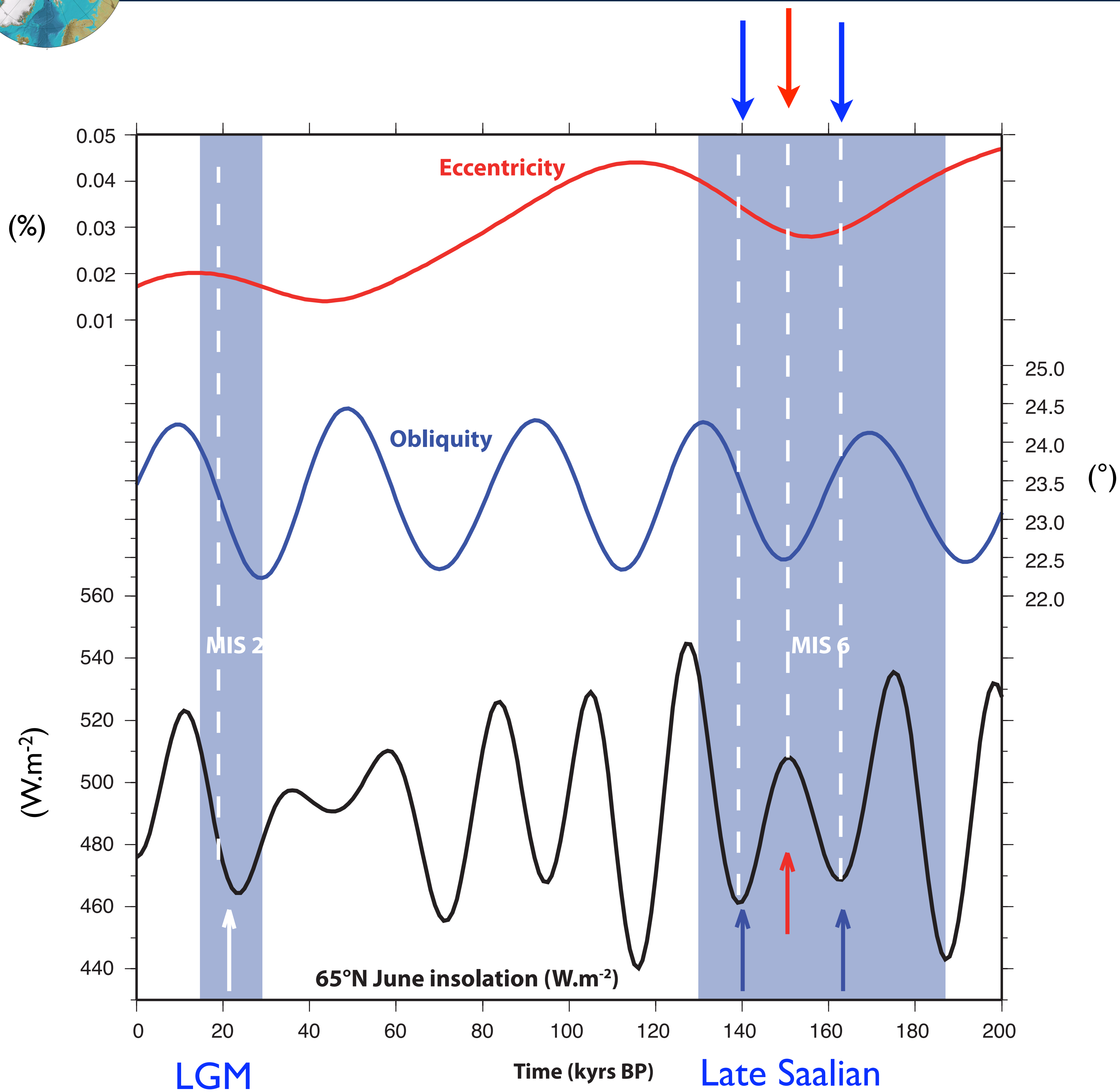
~ 22 m ESL* ← ~ 60 m ESL

*Equivalent Sea Level

Late Saalian (~ 160 -140 ka)



The Late Saalian astronomical forcing



- **140 ka**: highest eccentricity
  Perihelion: December 6*
- **150 ka**: lowest eccentricity
  Perihelion: June 28
- **160 ka**: largest obliquity
  Perihelion January 7

Perihelion = shortest distance to the sun

Late Saalian: larger eccentricity than during the LGM

***LGM**: Perihelion January 17

After Berger and Loutre (1991)

Laboratoire de Glaciologie et Géophysique de l'Environnement

Stockholm University

Centro Euro-Mediterraneo per i Cambiamenti Climatici

Focusing on the Late Saalian (160 - 140 ka)

How could the ice sheet survive the insolation peak at ≈ 150 ka?

→ **Reconstruction of the boundary conditions:**

- Global Late Saalian topography
- Dust deposition distribution
- Vegetation cover in equilibrium
- Sea surface temperatures

↓

simulating 160 ka, 150 ka and 140 ka climate

Numerical models and boundary conditions

Orbital parameters and Greenhouse gas

Continental boundary conditions: dust, lakes, vegetation, ice sheets

Oceanic boundary conditions: sea surface conditions

Atmospheric General Circulation Models

Climate simulations

Little geological evidence for the 160 - 140 ka period

Reconstructed or simulated Late Saalian boundary conditions based on LGM boundary conditions

Simulated Late Saalian boundary conditions:

BIOME4 (Kaplan et al. 2004)

Equilibrium vegetation model

simulated vegetation cover

Initialised using:
LMDZ4 climatology (~21 model yrs)
forced with a LGM vegetation map
(Crowley, 1995)

Iterative scheme until equilibrium

Planet simulator (Fraedrich et al., 2005)

AGCM + oceanic mixed layer

simulated sea surface conditions

Horizontal resolution: T42 (128*64)

Initialized using:
LGM monthly SST from Paul & Schaefer-Net (2003)

Return SST through heat fluxes calculation

Length of simulation: 50 model years

global atmospheric simulations

LMDZ4

(Hourdin et al., 2006)

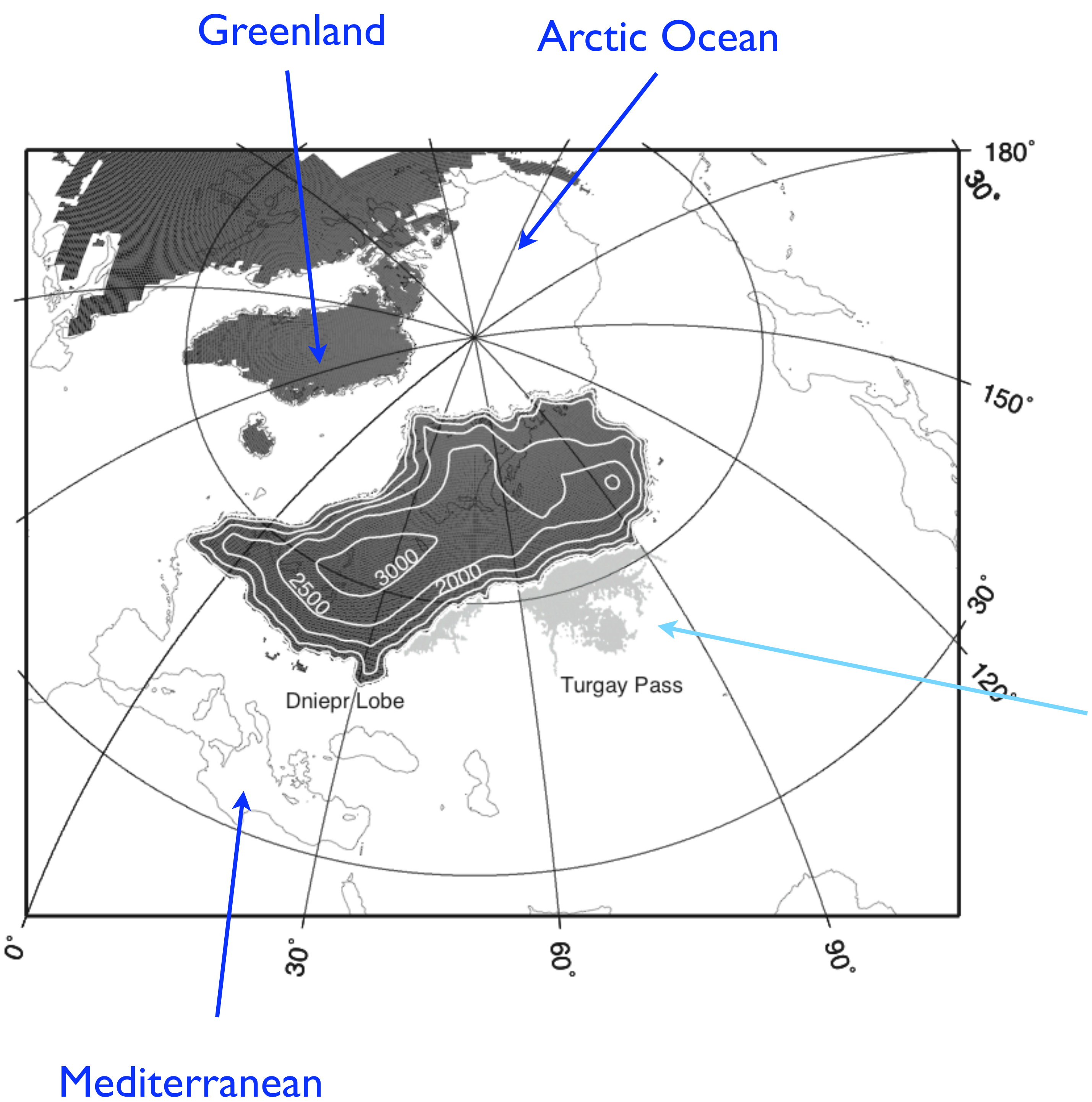
Horizontal resolution: 96 x 72

Vertical resolution: 19 layers

Zoom over Eurasia: (grid space ~ 100 km)

Length of simulations: 21-year snap-shots

The Late Saalian Northern Hemisphere topography



Eurasian ice sheet: 3000 m high reconstruction using GRISLI ice sheet model (Peyaud, 2006; Ritz et al. 1991)

Laurentide and Antarctica ice sheets: LGM ICE-5G (Peltier, 2004)

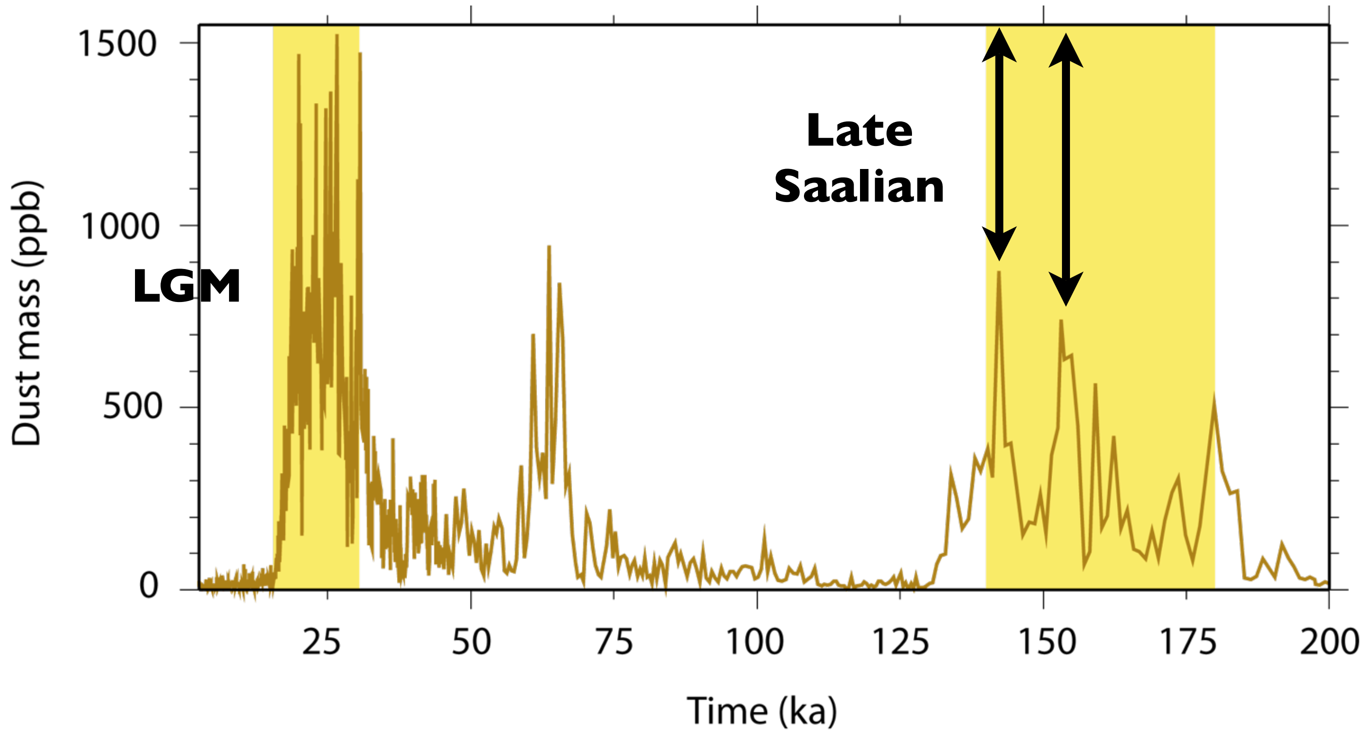
→ problem for the global ESL: excess of mass

Proglacial lakes: after Mangerud et al. (2001)

- developed in the topographic basin in front of the ice sheet
- damming of the rivers network

The Late Saalian dust distribution

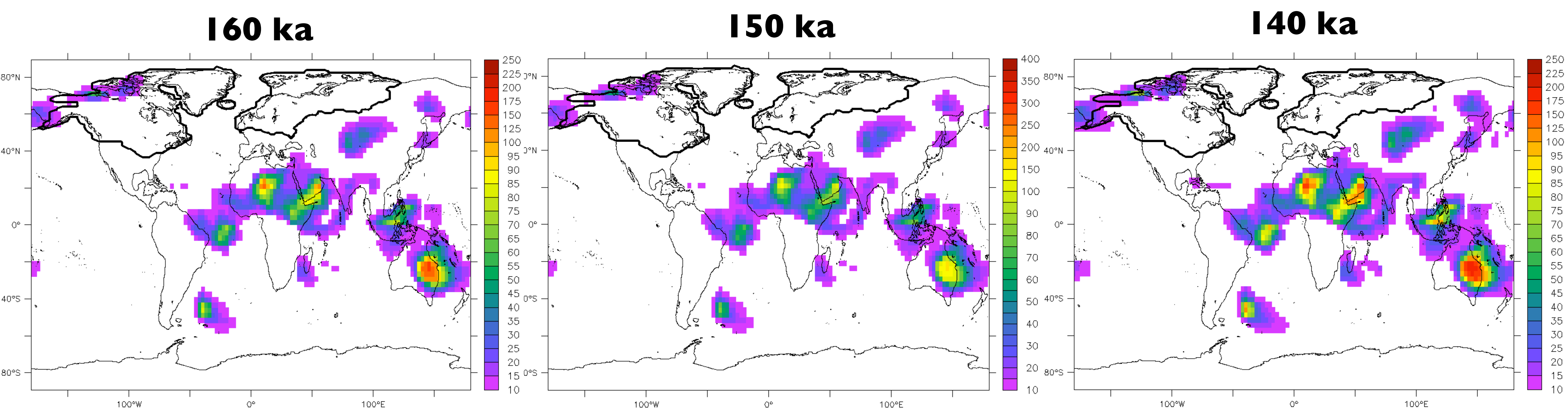
Epica Dome C, East Antarctica (Delmonte et al., 2004)



Dust concentration: comparison with LGM:

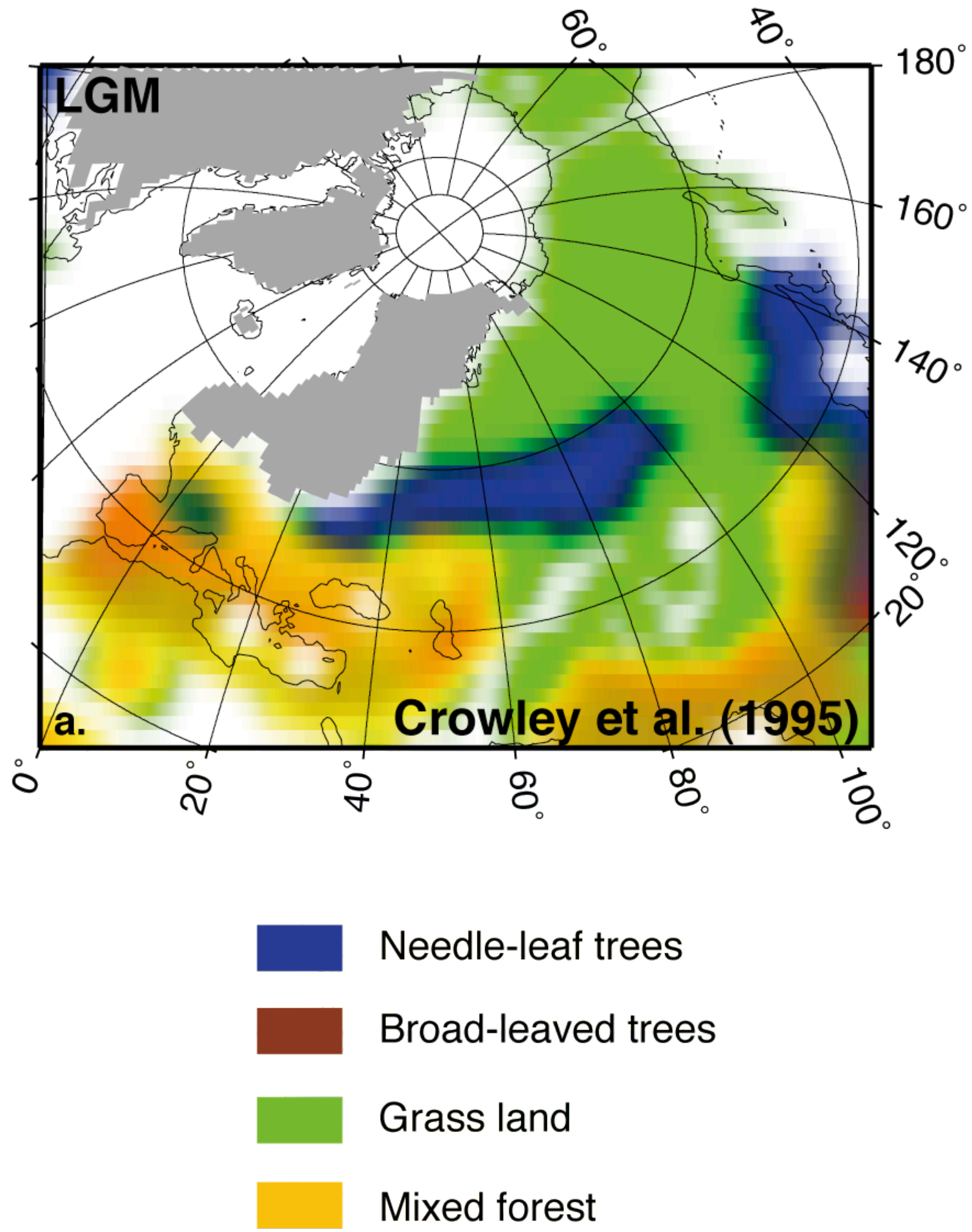
- 140 ka: 40% lower than LGM
- 150 ka: 80% lower than LGM
- 160 ka: 50% lower than LGM

In agreement with the Siberian loess stratigraphy (Chalchula, 2003)



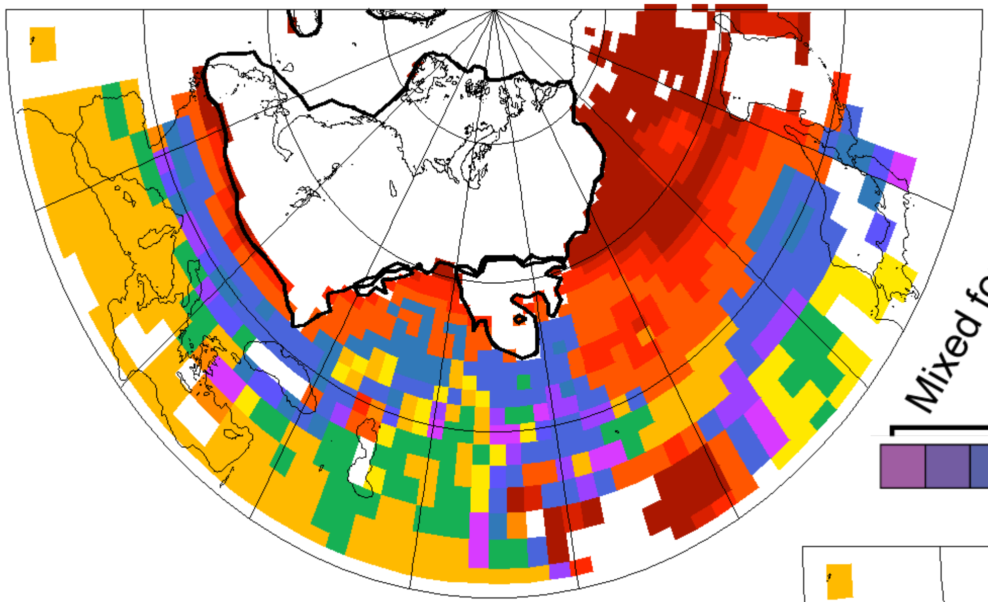
Dust concentration g/m²/yr

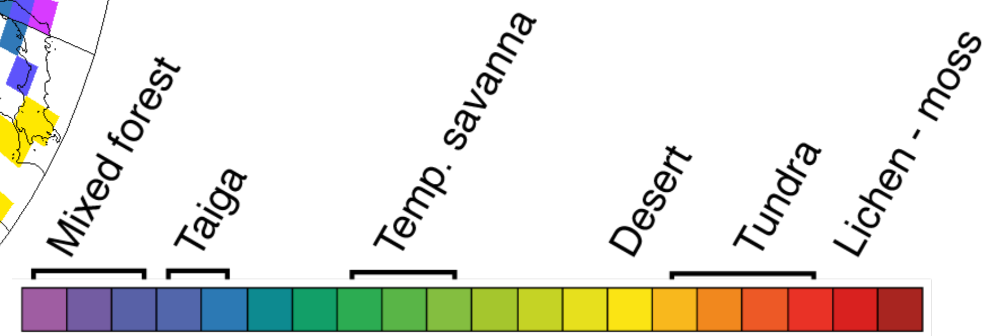
Reference vegetation map used in all the Late Saalian reference simulations



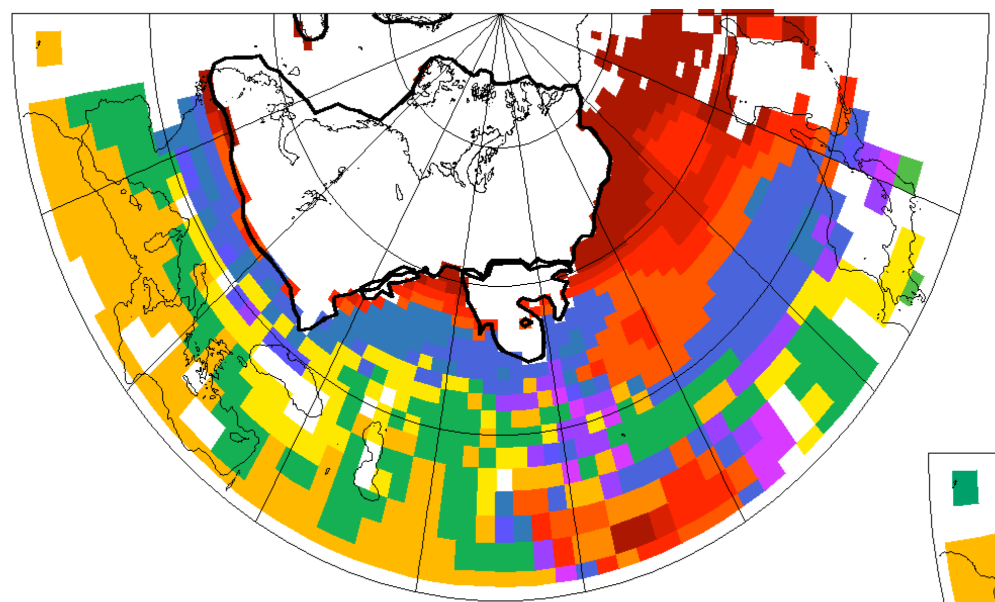
Vegetation cover: using BIOME 4

160 ka





150 ka

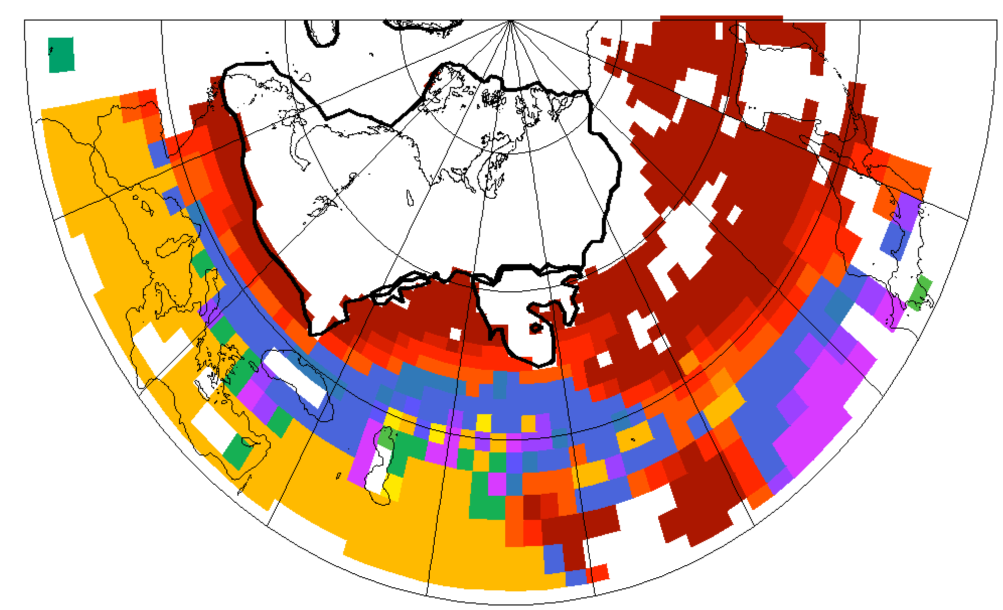


BIOME 4 / LMDZ4 iterations

x 3

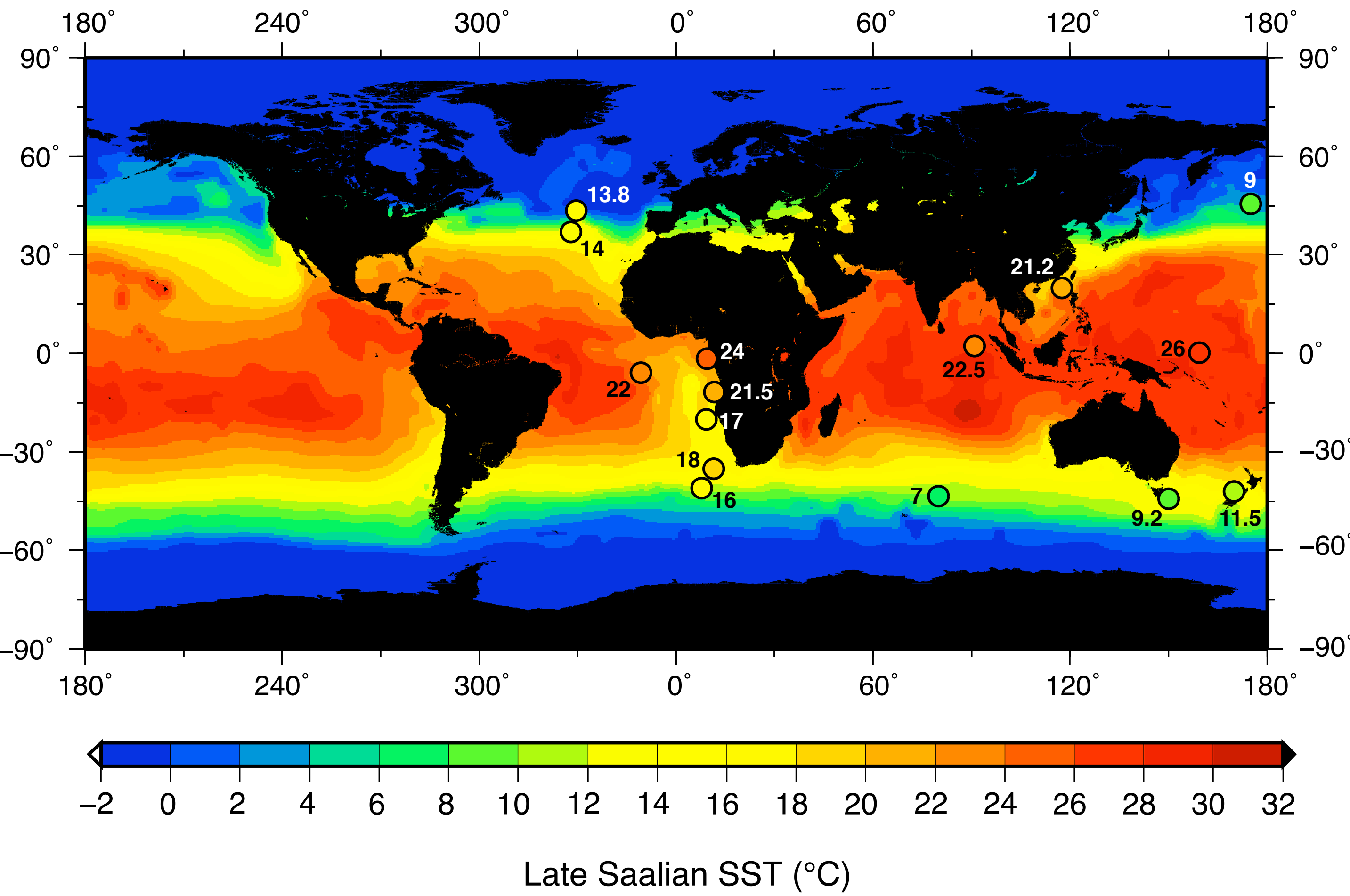
21-year snap-shots

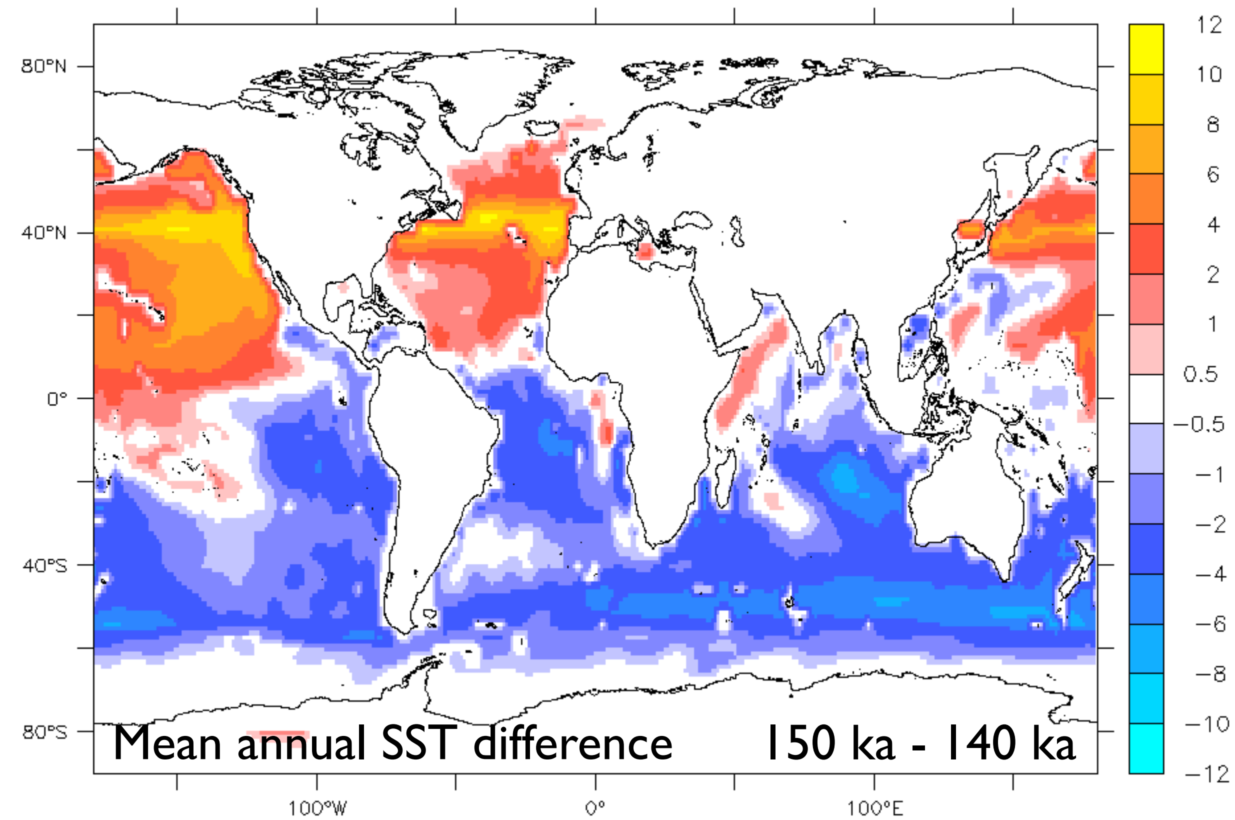
140 ka



- 160 ka: large tundra extent
- 150 ka: tundra replaced by mixed forests
- 140 ka: progression of barren soils: glacial maximum

Late Saalian sea surface conditions

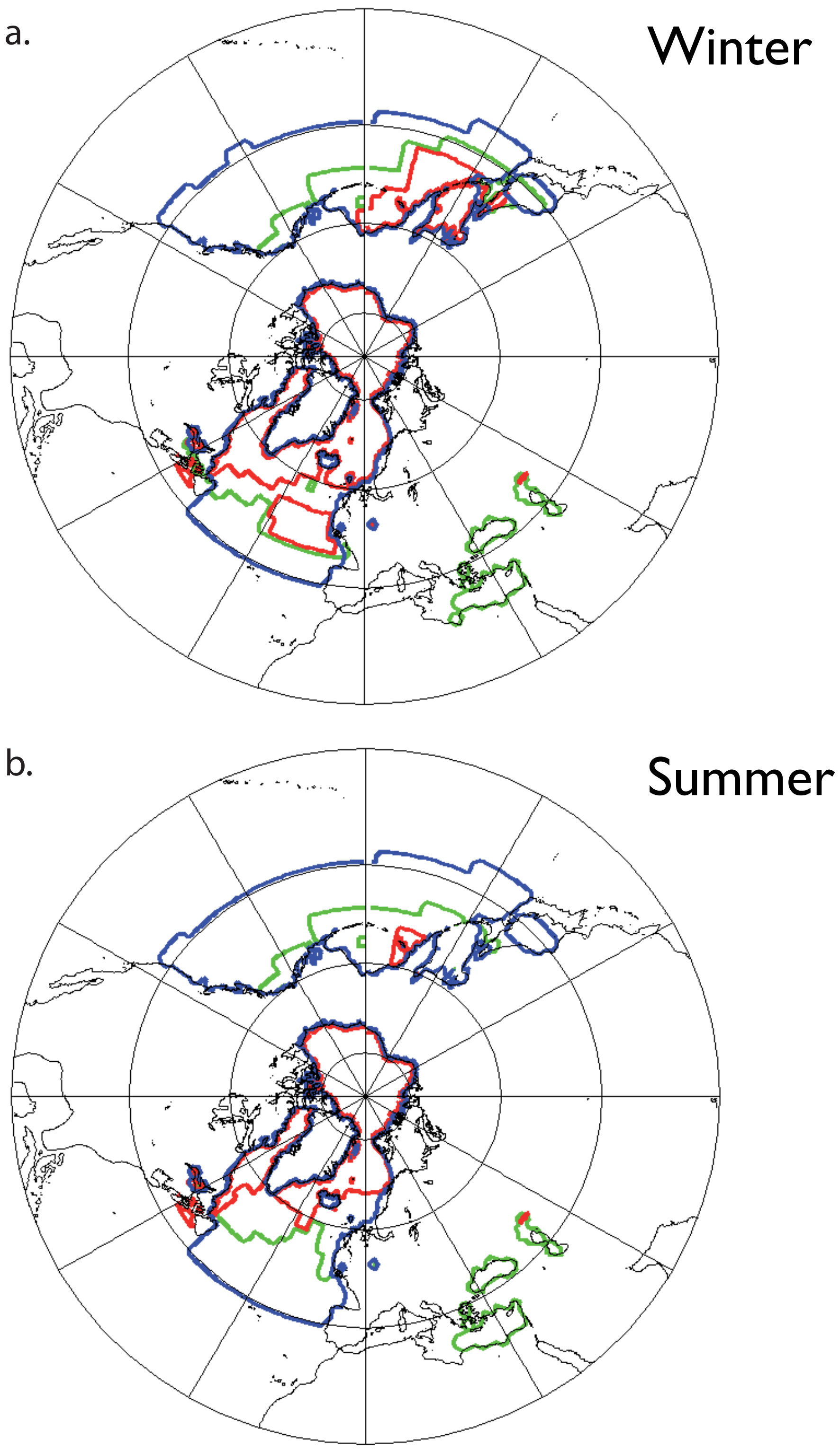




- Equatorial / Tropical SST: good agreement with data
- High latitudes Atlantic SST: underestimate data
- Large SIC extent in NH high latitudes: ~ 40°N

- Asymmetry due to 140 ka SST large sea-ice cover: albedo feedback
- At 160 ka: similar to 150 ka (slightly warmer falls at 150 ka)

(Colleoni et al., sub.)

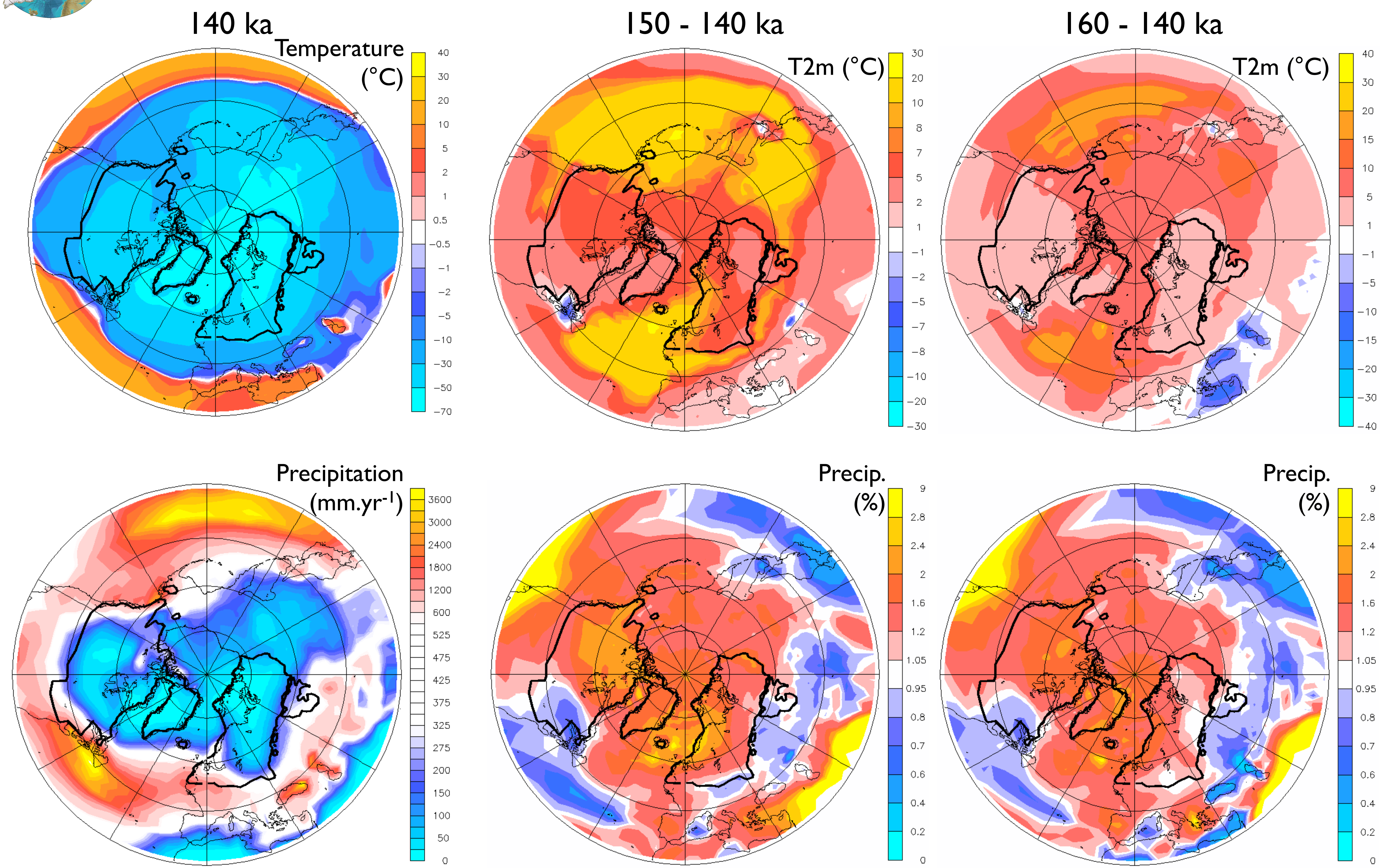


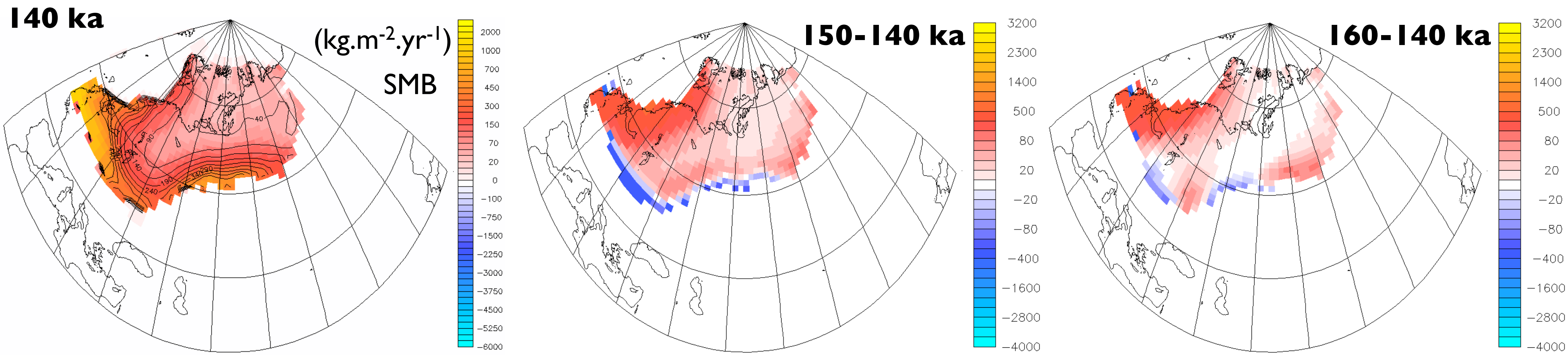
140 ka
150 ka
160 ka

Northern Hemisphere Sea-ice Cover:

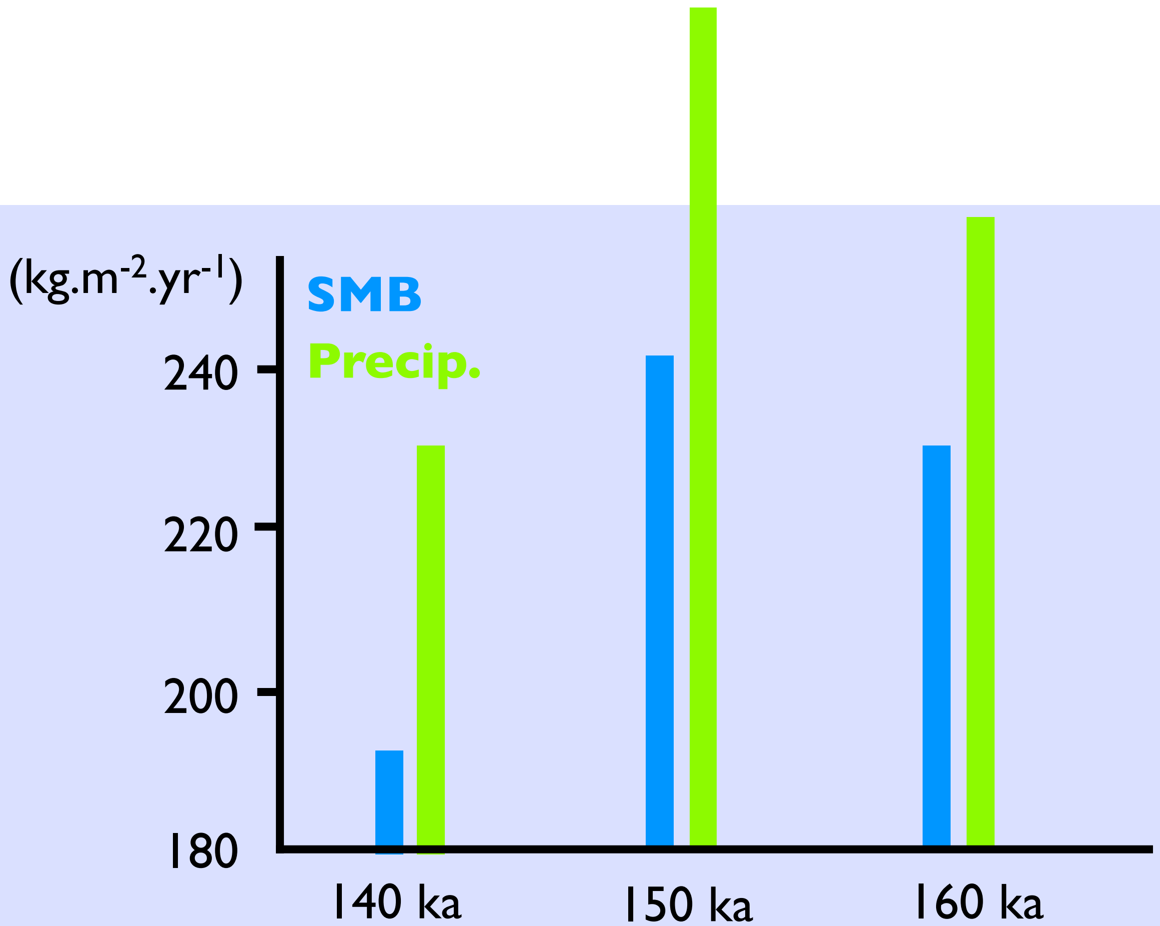
- **Largest extent**: 140 ka
- **Smallest extent**: 150 ka more or less similar to present-day extent
- **Intermediate extent**: 160 ka almost similar to CLIMAP LGM reconstructions

The Late Saalian mean annual climatology (160 ka to 140 ka)





(kg.m^{-2}.yr^{-1})	140 ka	150 ka	160 ka
Tot. precip.	226	329	289
Snow	226	310	282
Evaporation	33	53	44
Ablation	0	15	5
SMB	**193**	**243**	**233**



Conclusions:

How could the ice sheet survive the insolation peak at ≈ 150 ka?

warmer mean annual climate at 150 ka than before:

- More open sea surface conditions: larger moisture advection
- Larger forest extent: warmer regional climate

↓

Larger ablation compensated for by a larger accumulation along the oceanic margins