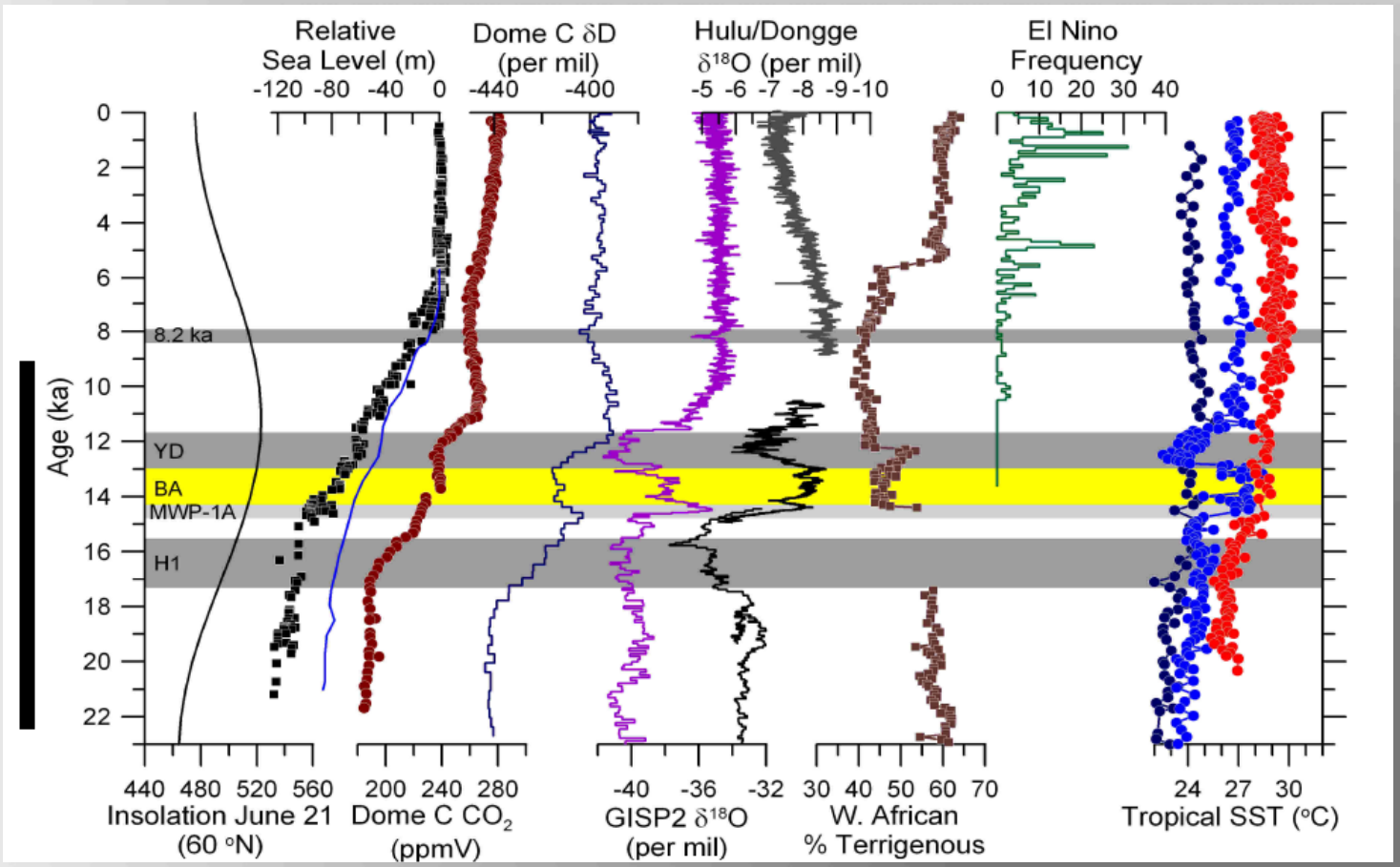
Applications: Paleoclimate Modeling

Deglacial Changes of Climate Variability

Bette Otto-Bliesner, CESM Paleoclimate WG Co-chair

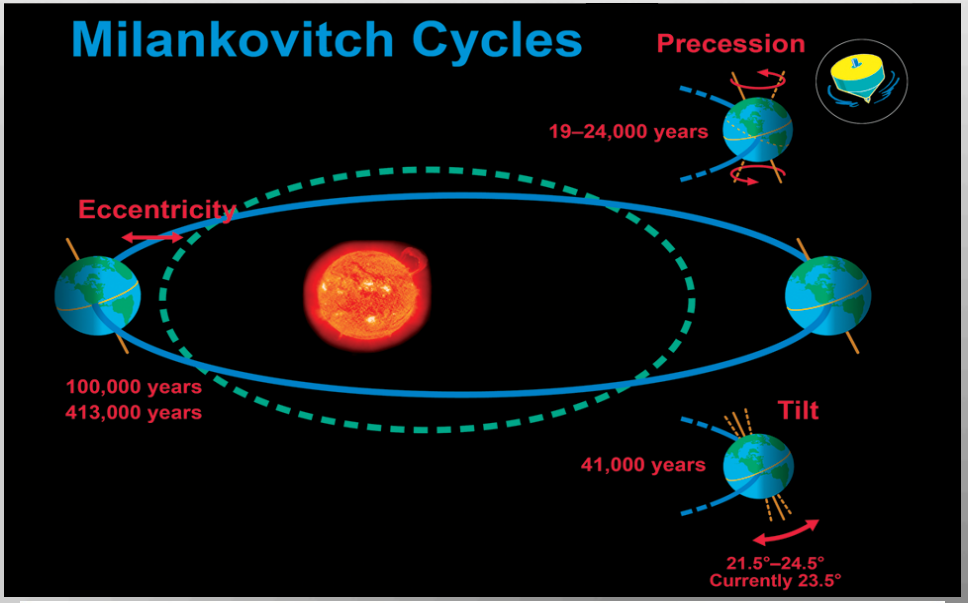


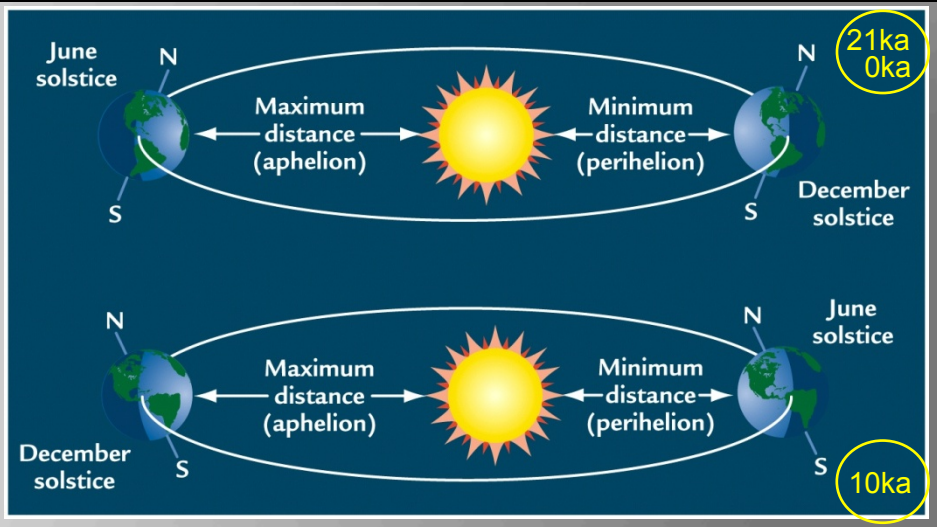
Centennial to millennial variability in the climate system: from 21,000 to 10,000 years ago

- "External" forcings acting on the climate system
- Evidence from data of this variability – focusing primarily on the atmosphere
- Using climate model simulations to interpret what is observed and to understand the mechanisms
- Conclusions and thoughts on future modeling work

“External” forcings acting on the climate system

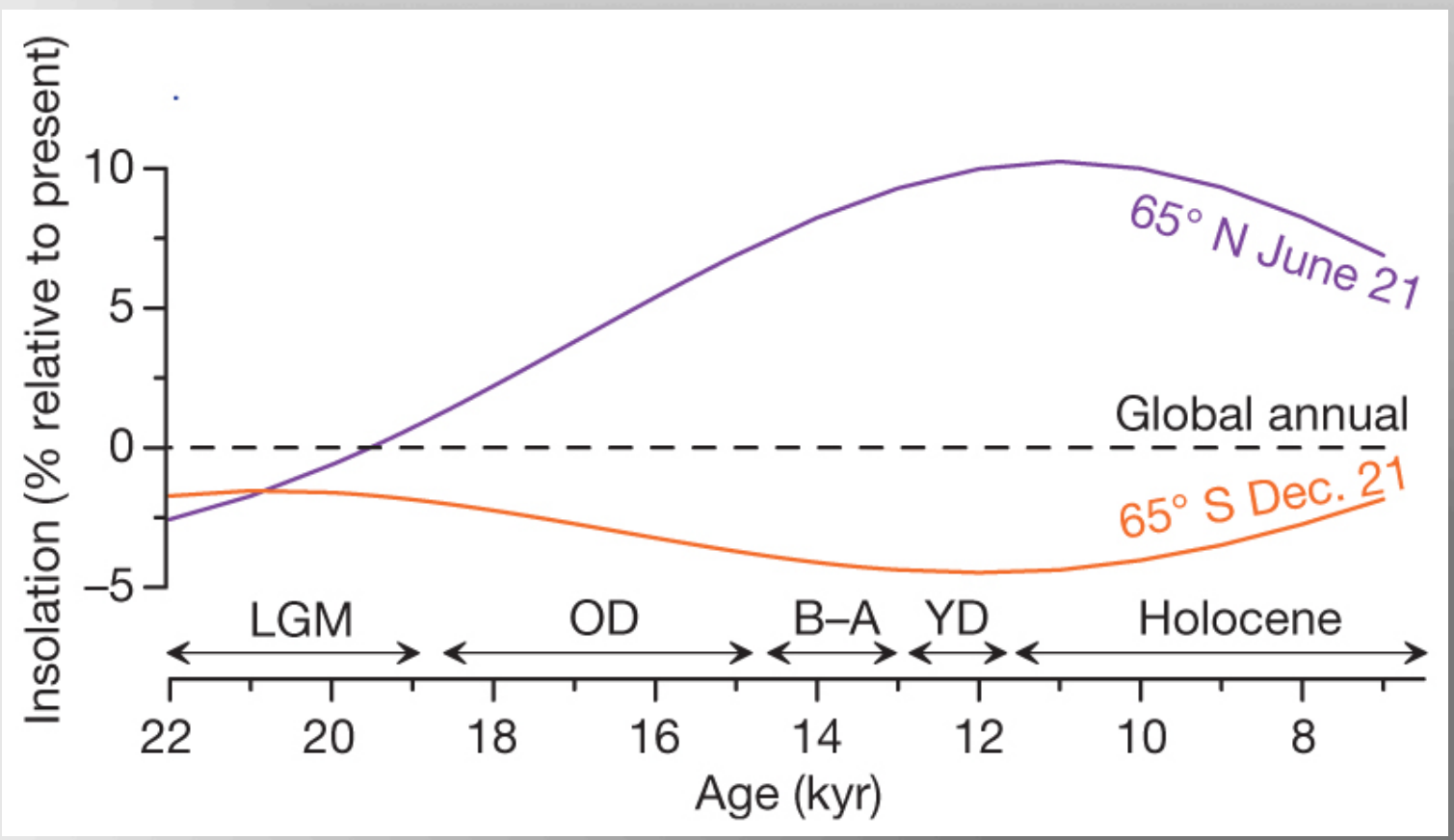
Orbital Forcing





“External” forcings acting on the climate system

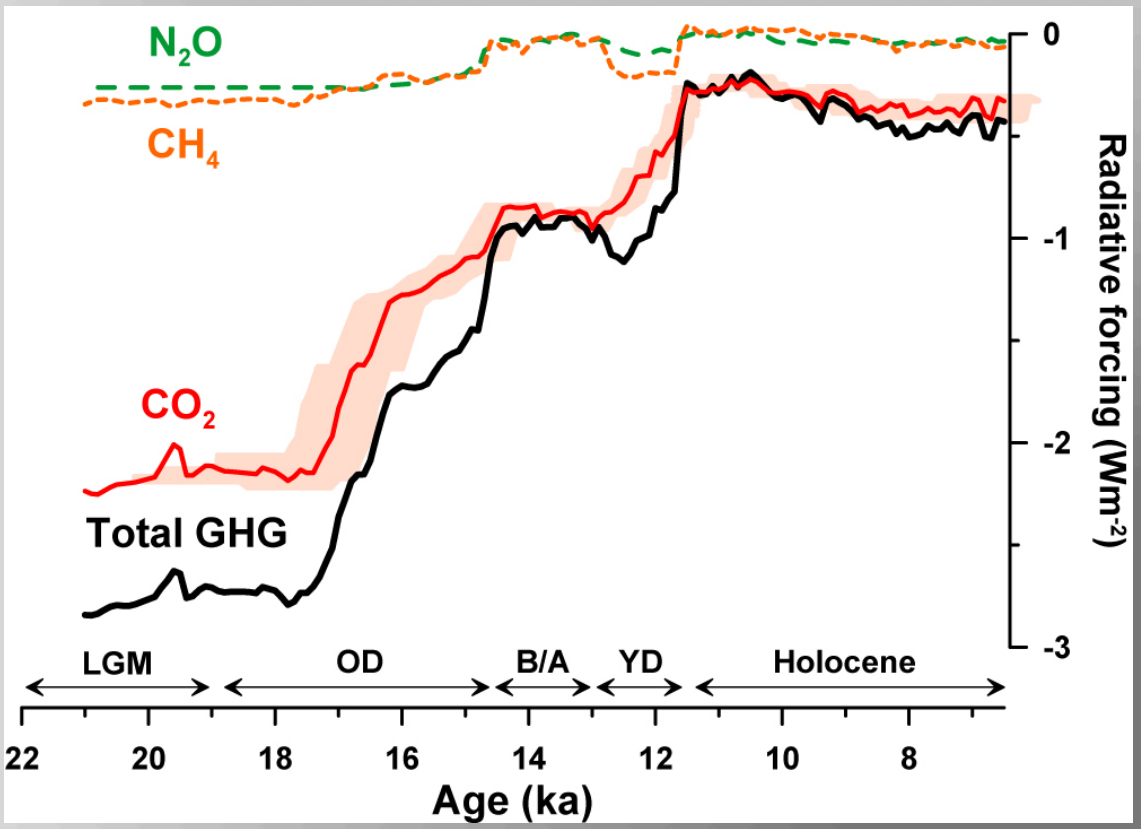
Dominant orbital forcing is 21 kyr precessional cycle



Shakun et al., 2012

“External” forcings acting on the climate system

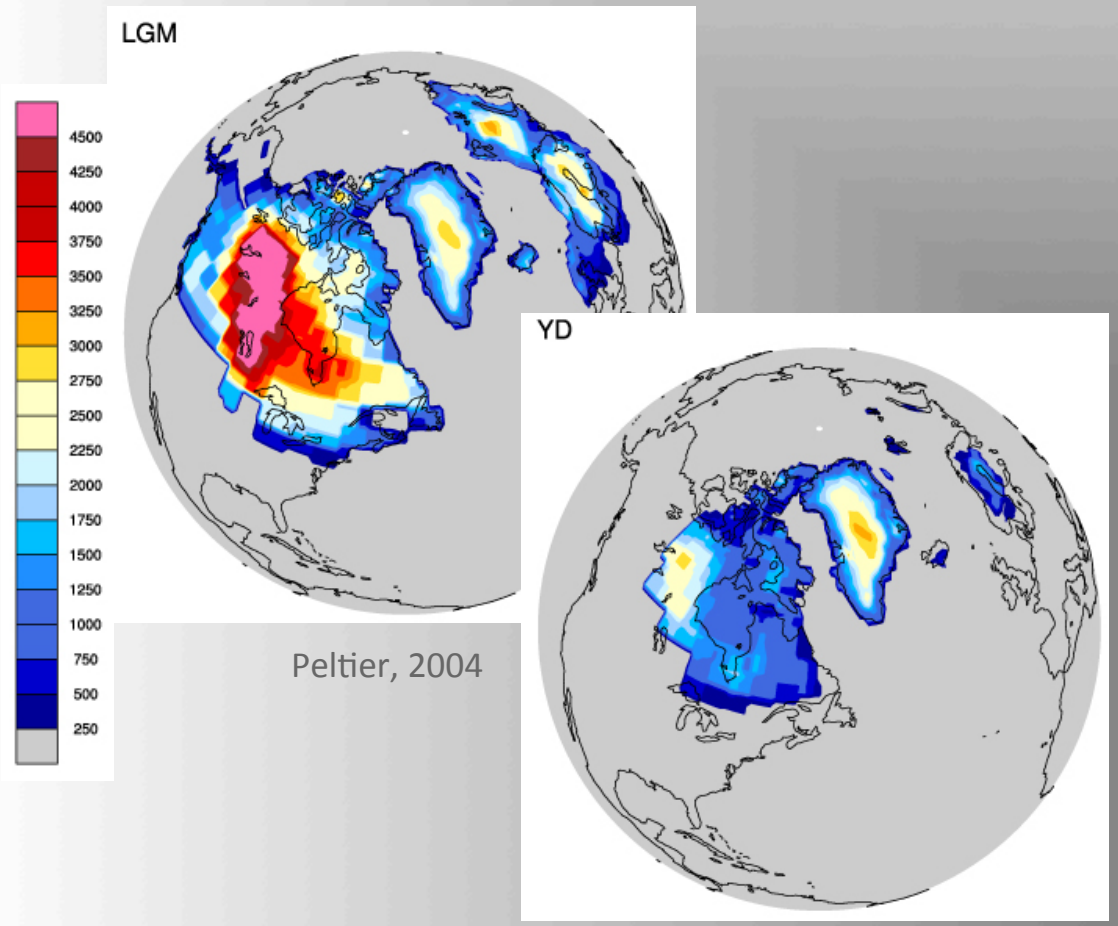
Greenhouse gases increased – exerting positive radiative forcing (heating) on the global climate system



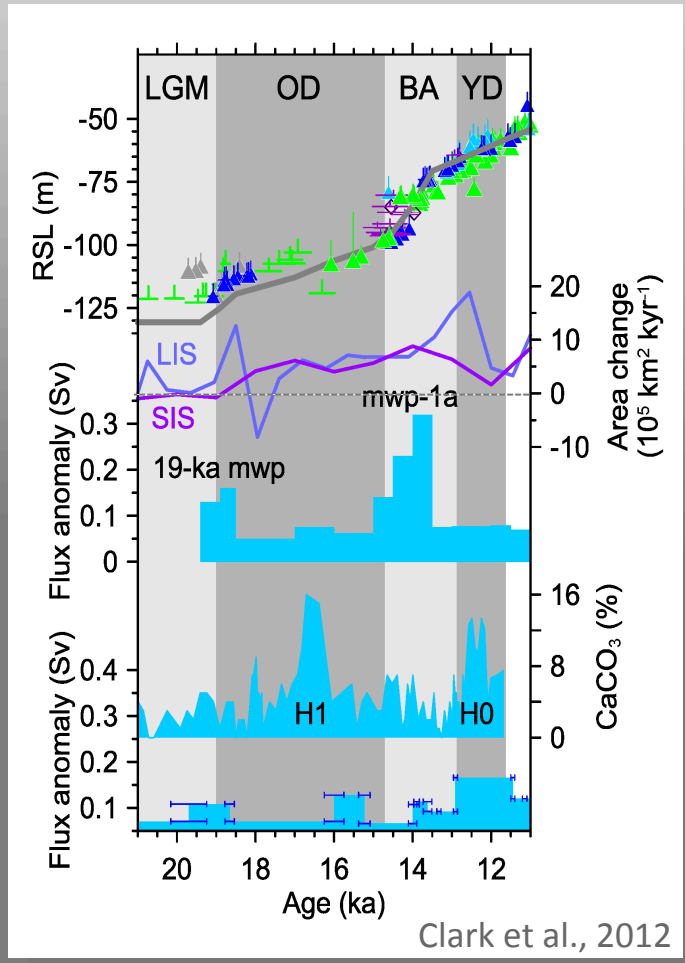
Shakun et al., 2012

“External” forcings acting on the climate system

Ice sheets, particularly over North America and Europe,
influenced atmospheric circulation,
and as melted back added freshwater to oceans



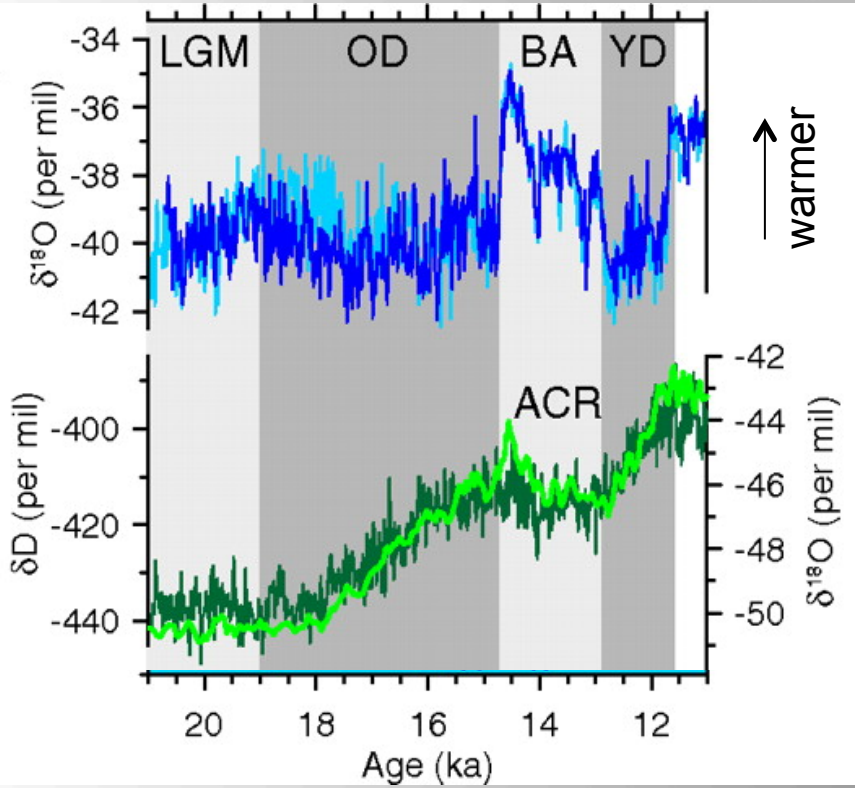
Peltier, 2004



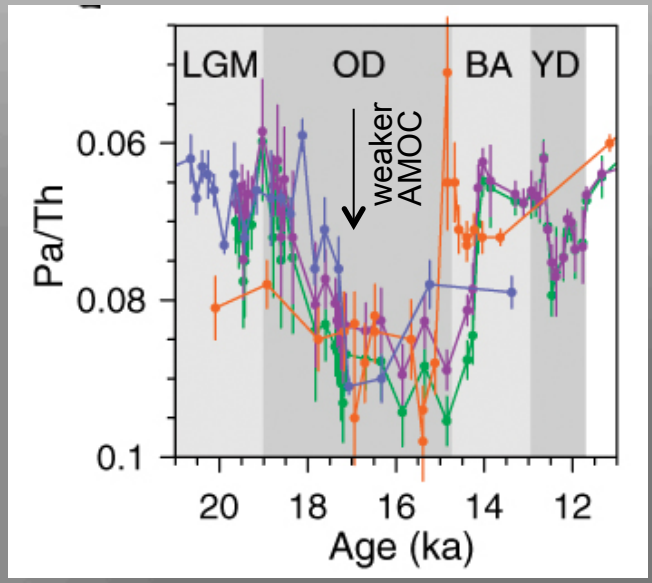
Clark et al., 2012

Centennial to millennial variability in the climate system: Evidence from the data

Greenland and Antarctic ice cores exhibit very different responses



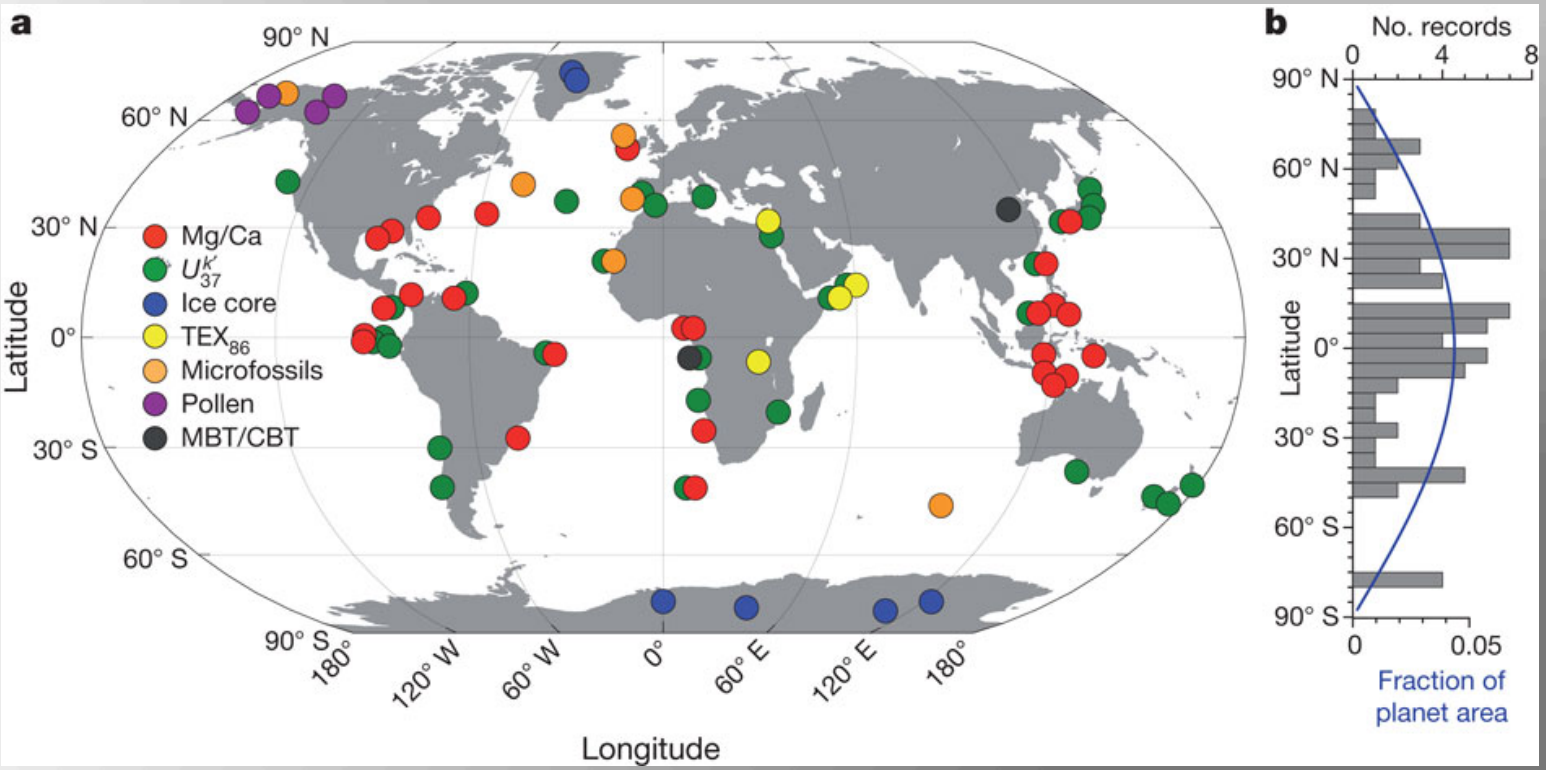
North Atlantic cores indicate variations in the strength of the Atlantic Meridional Overturning Circulation (AMOC)



Clark et al., 2012

Centennial to millennial variability in the climate system: Evidence from the data

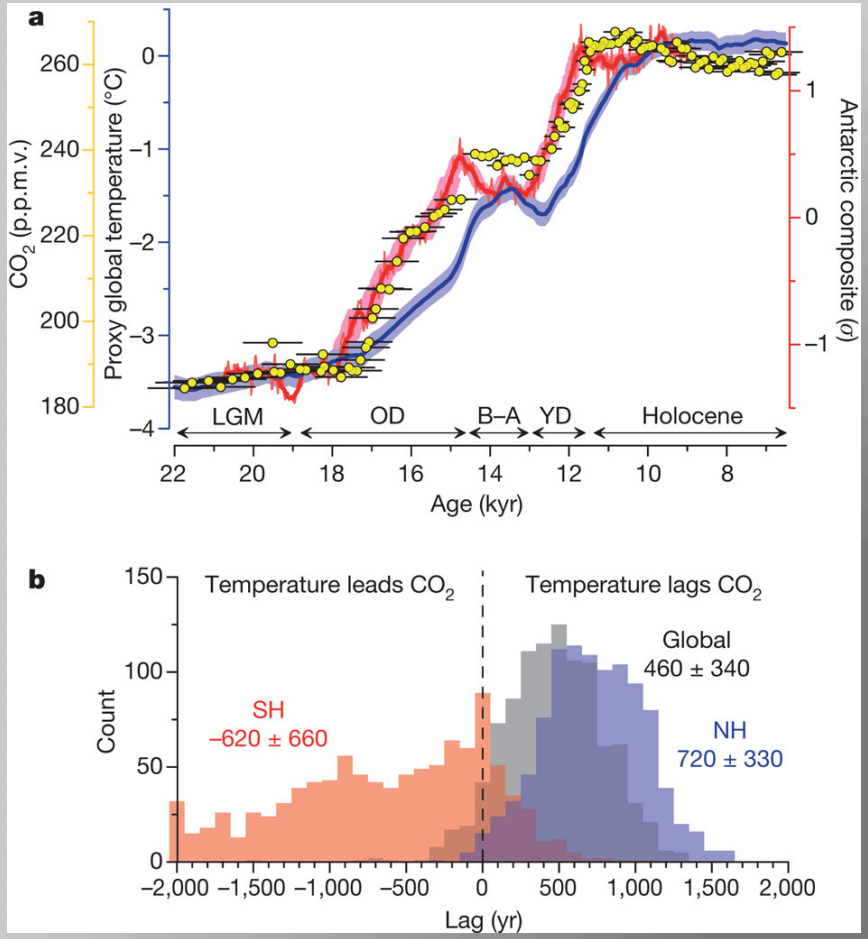
Proxy temperature records



Shakun et al., 2012

Centennial to millennial variability in the climate system: Evidence from the data

CO_2 concentration and temperature



Shakun et al., 2012

Centennial to millennial variability in the climate system: Using climate models to understand mechanisms

Meteorological Primitive Equations

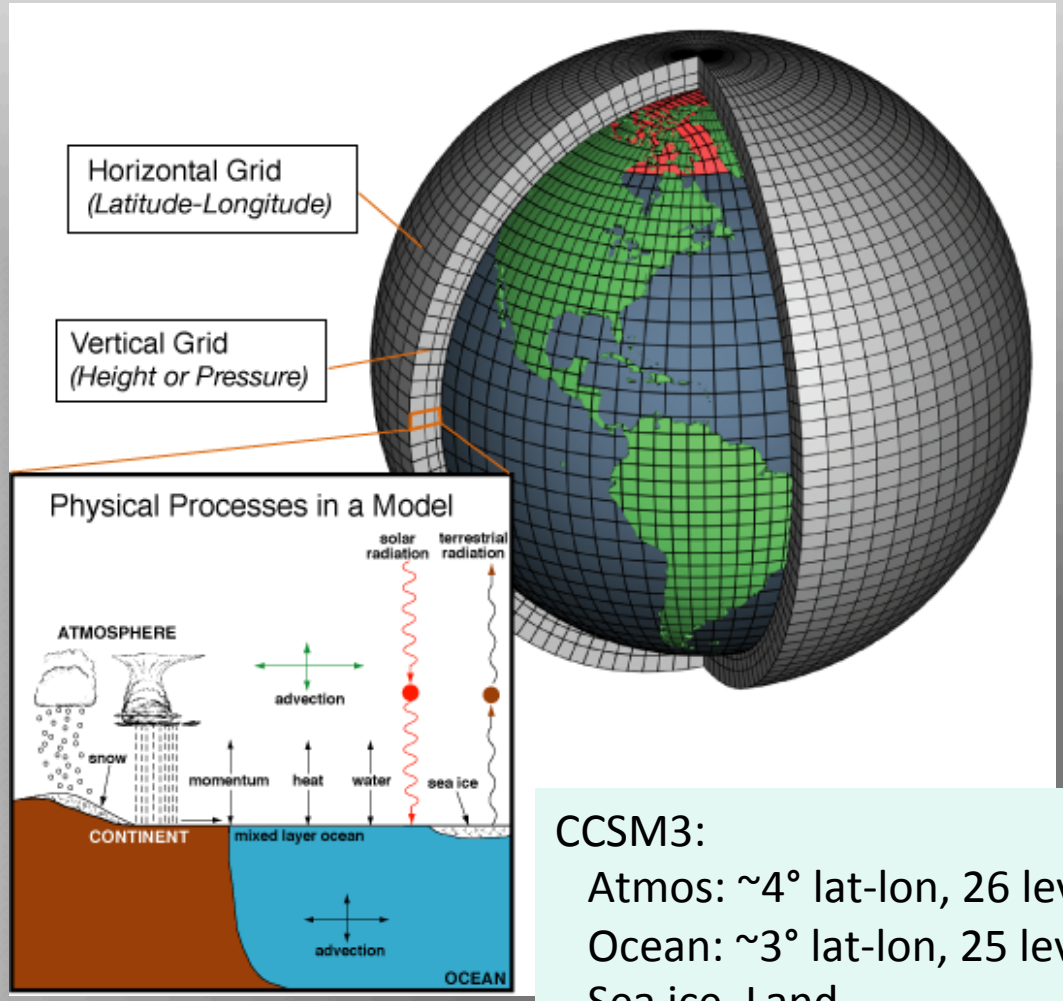
$$d\overline{\mathbf{V}}/dt + fk \times \overline{\mathbf{V}} + \nabla\overline{\phi} = \mathbf{F},$$

$$d\overline{T}/dt - \kappa\overline{T}\omega/p = Q/c_p,$$

$$\nabla \cdot \overline{\mathbf{V}} + \partial\overline{\omega}/\partial p = 0,$$

$$\partial\overline{\phi}/\partial p + R\overline{T}/p = 0,$$

$$d\overline{q}/dt = S_q.$$

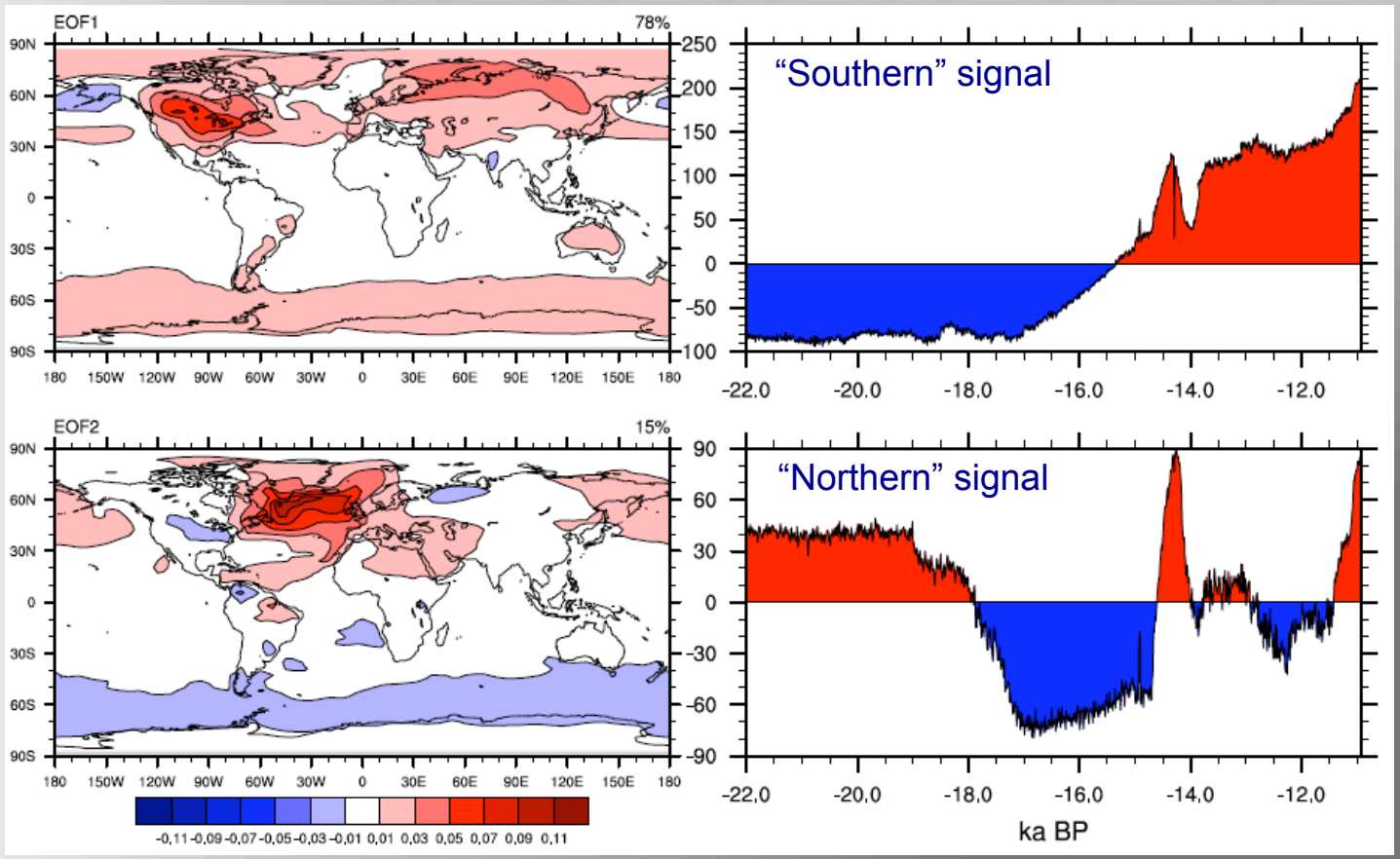


Δ time 30 minutes
~400 million time steps: 22ka to present
Monthly data for atm, ocn, sea-ice, lnd, veg

CCSM3:
- Atmos: ~4° lat-lon, 26 levels
- Ocean: ~3° lat-lon, 25 levels
- Sea ice, Land

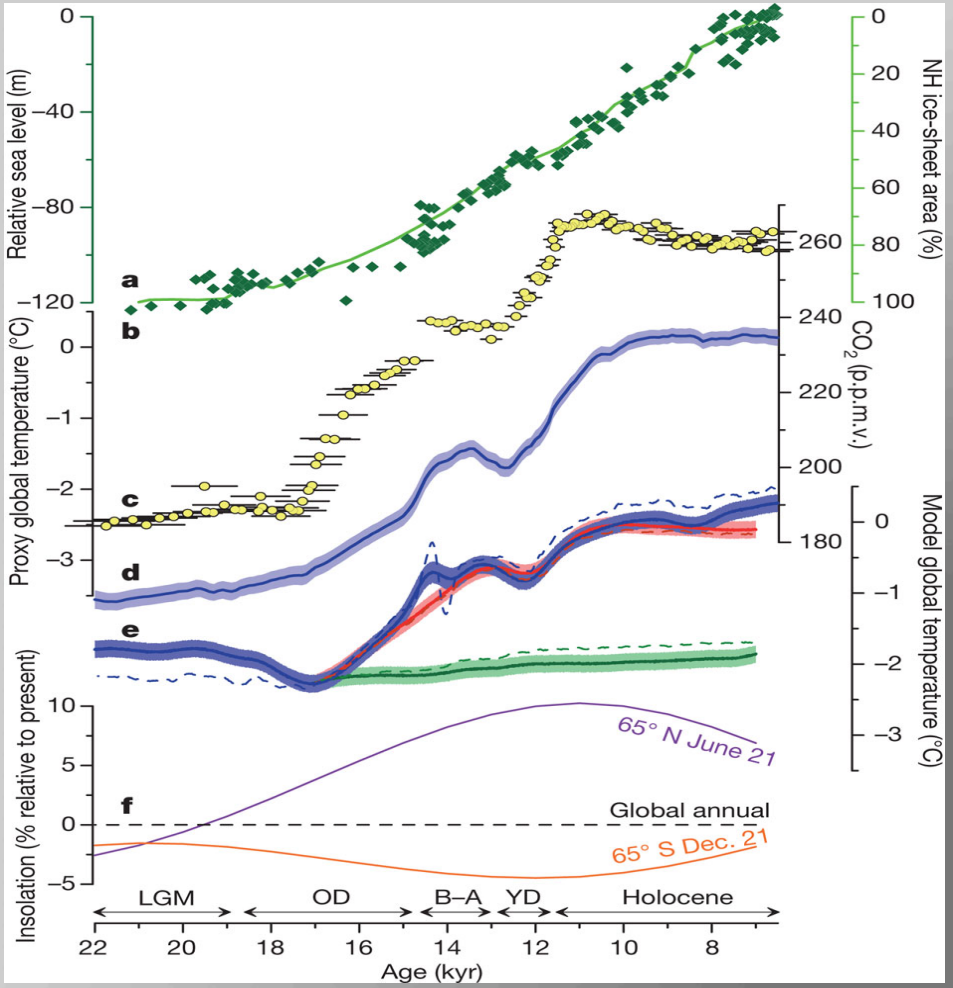
Centennial to millennial variability in the climate system: Using climate models to understand mechanisms

Characterization of model deglacial temperature (decadal mean) variability



Centennial to millennial variability in the climate system: Using climate models to understand mechanisms

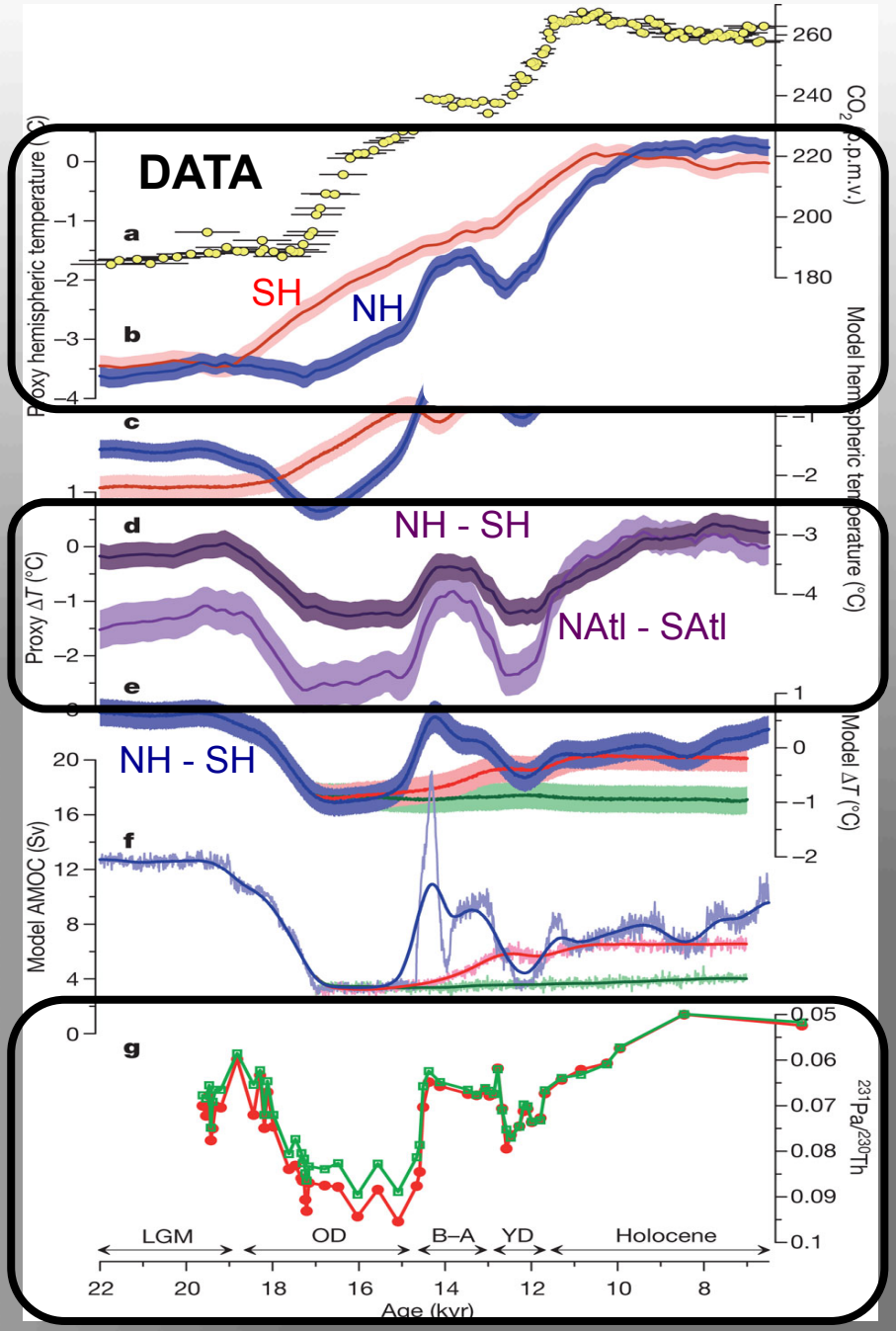
Global temperatures: data and model



Shakun et al., 2012

Centennial to millennial variability in the climate system: Using climate models to understand mechanisms

Hemispheric temperatures: data and model

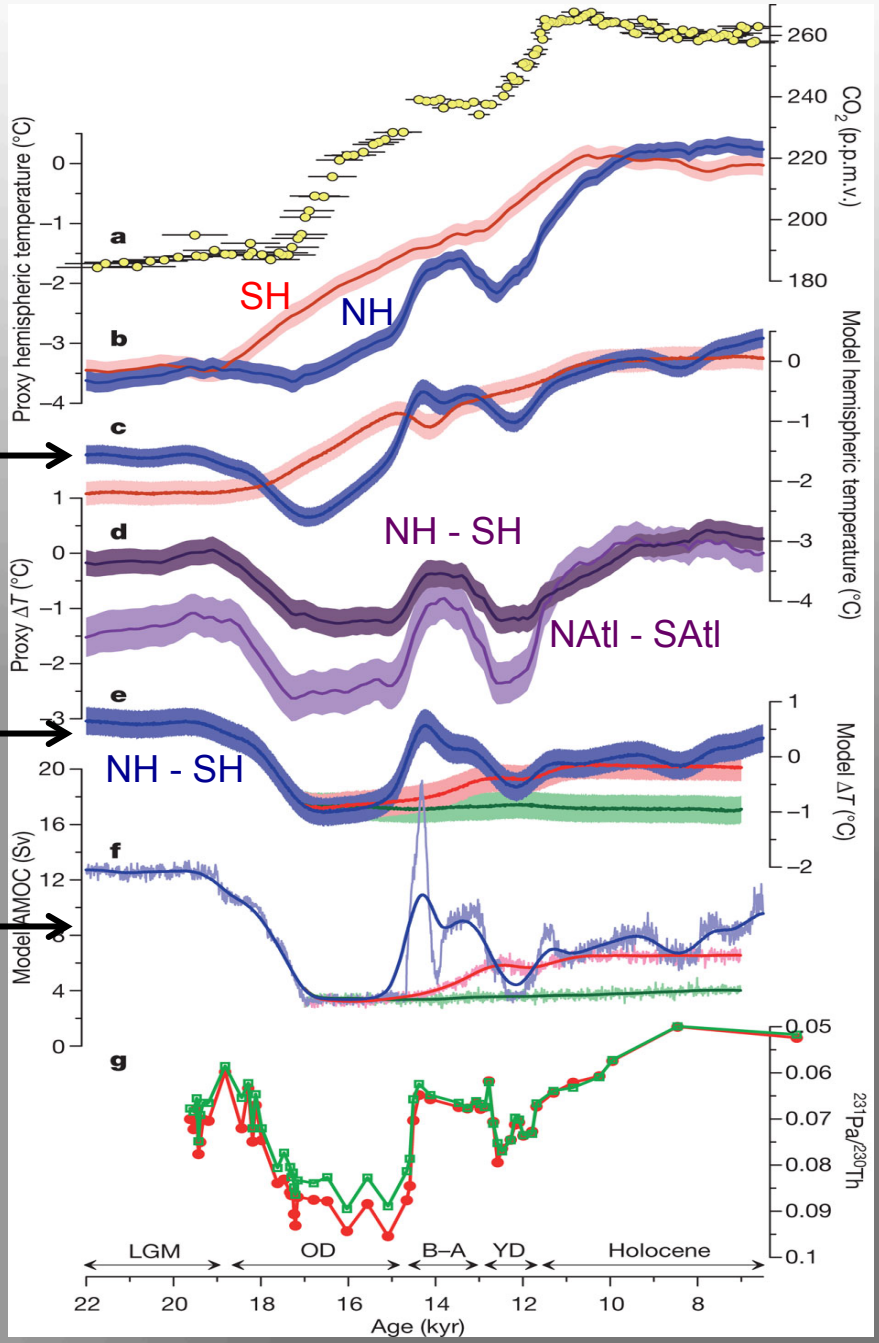


Shakun et al., 2012

Centennial to millennial variability in the climate system: Using climate models to understand mechanisms

MODEL

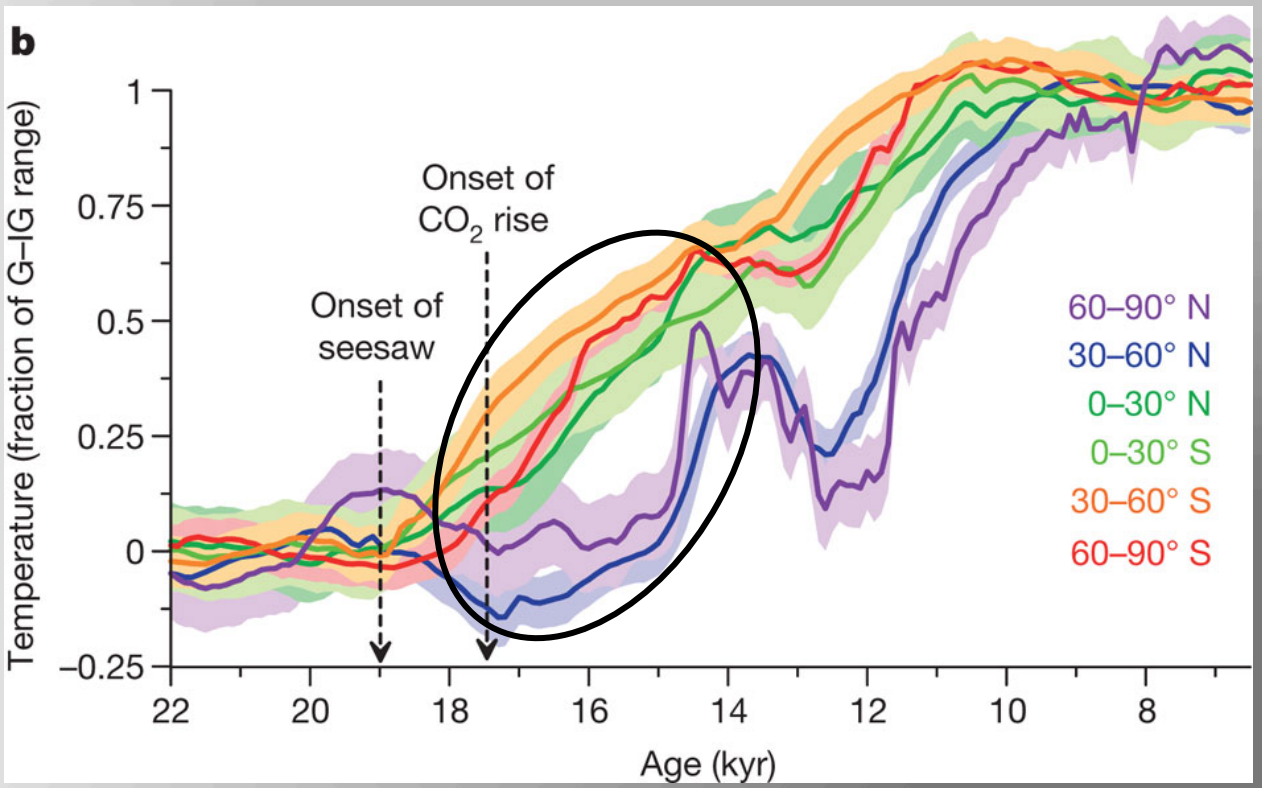
Hemispheric signatures: data and model



Shakun et al., 2012

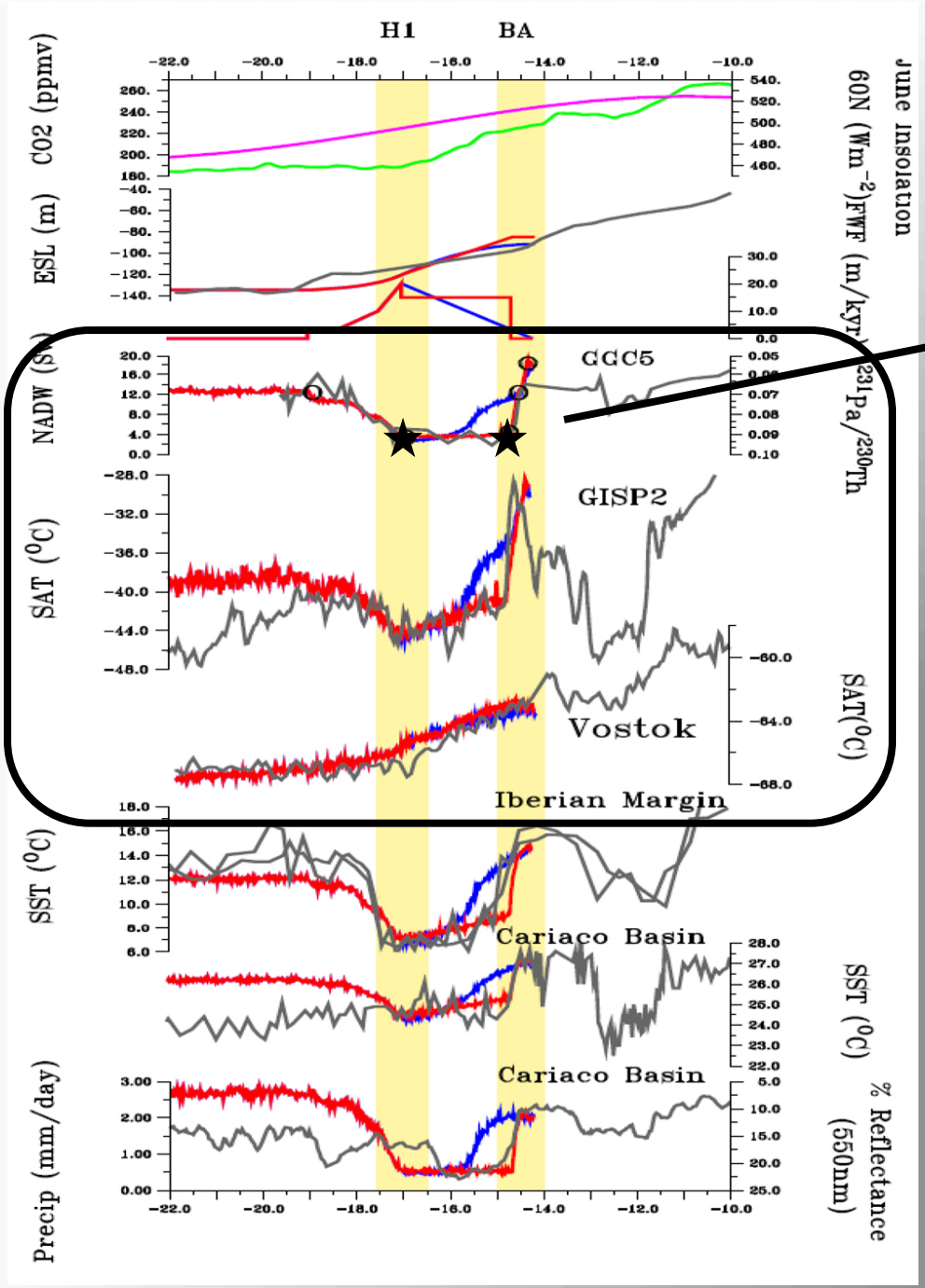
Centennial to millennial variability in the climate system: Evidence from the data

Latitudinal responses of temperature

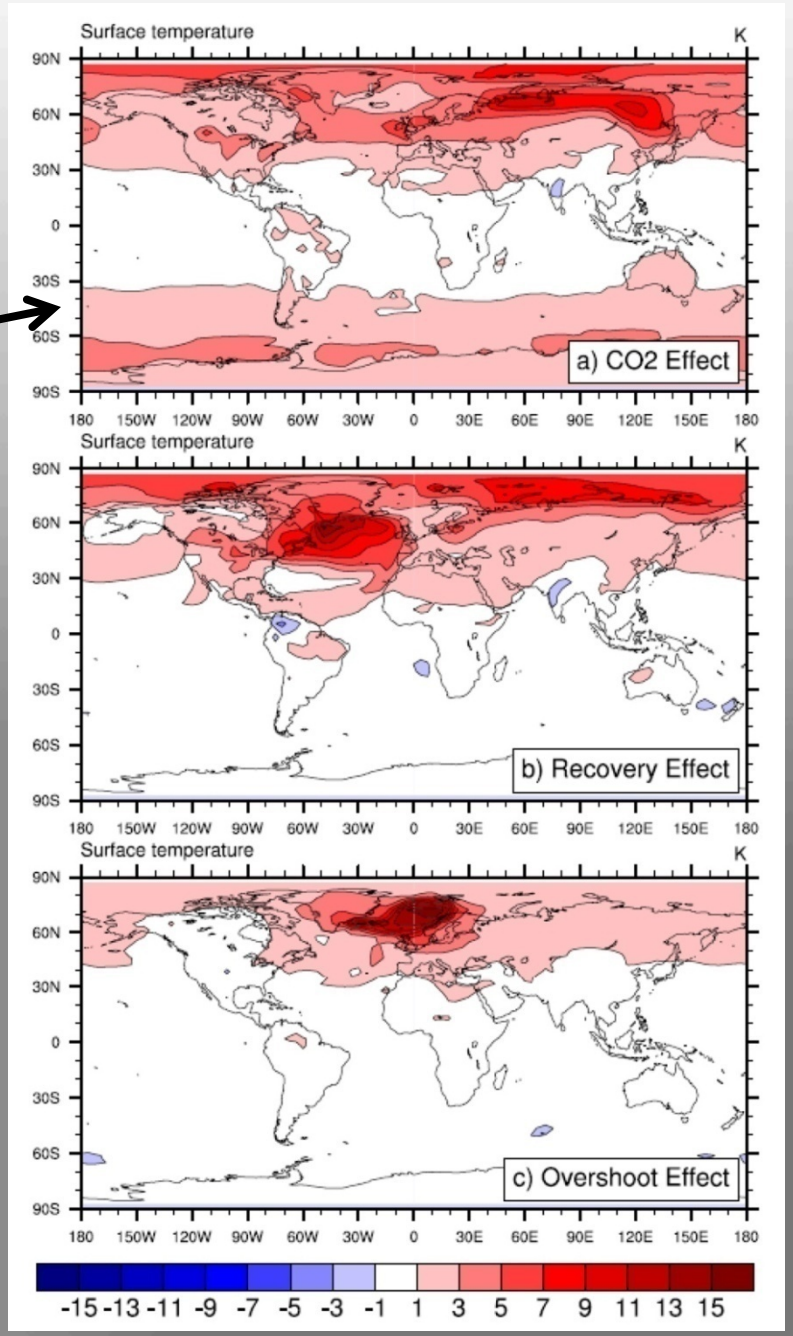


Shakun et al., 2012

Liu, Otto-Bliesner et al., 2009



Surface temperature changes



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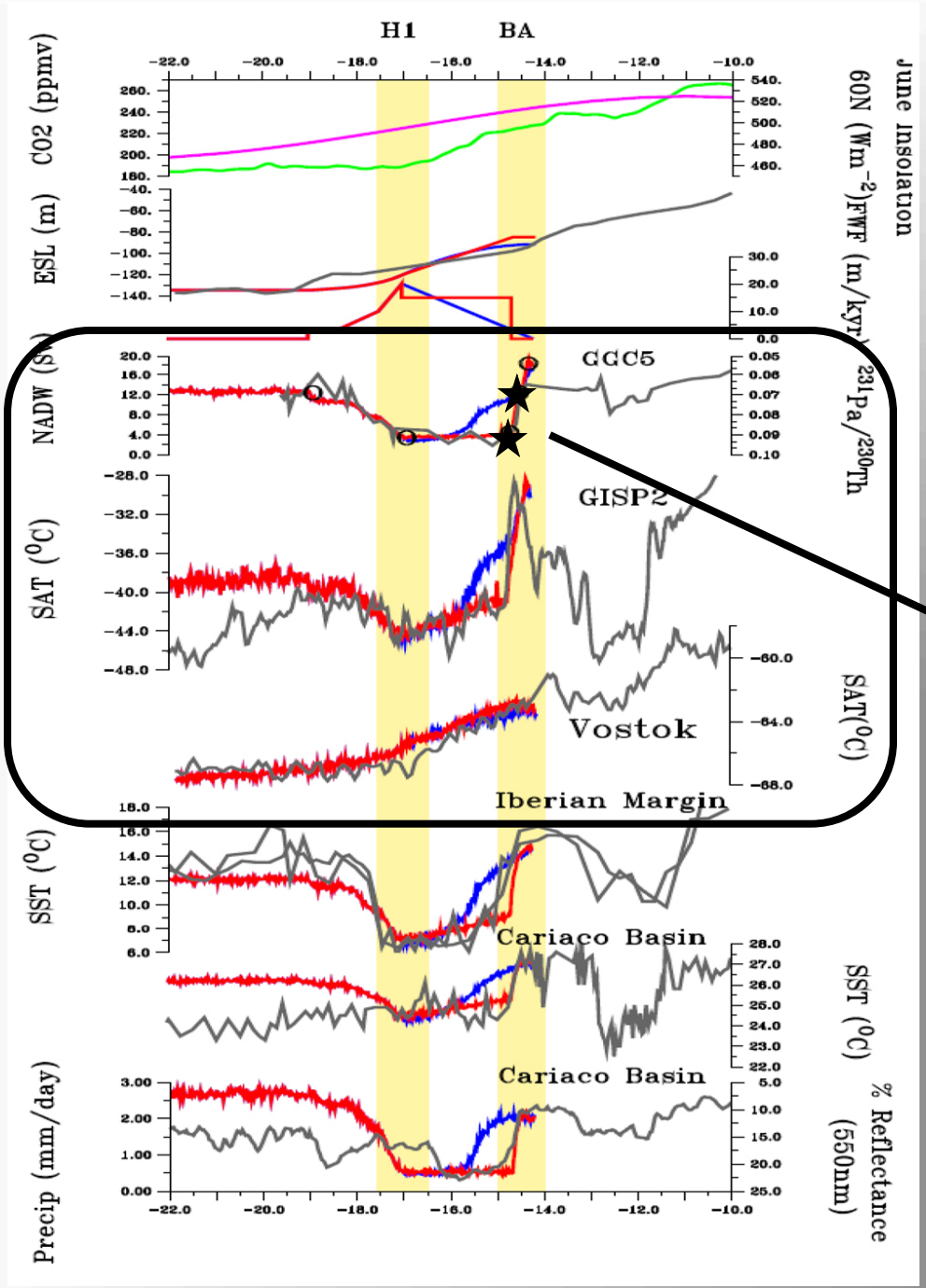

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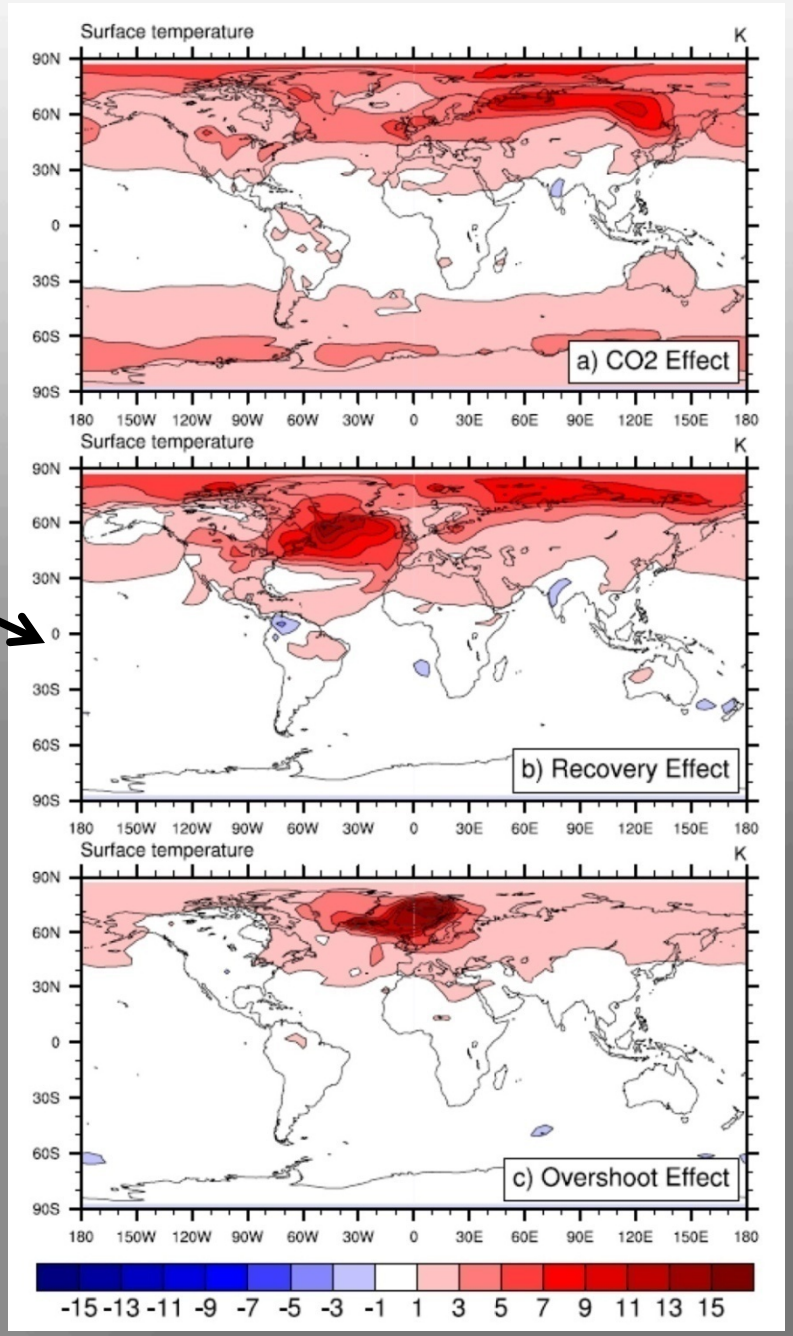

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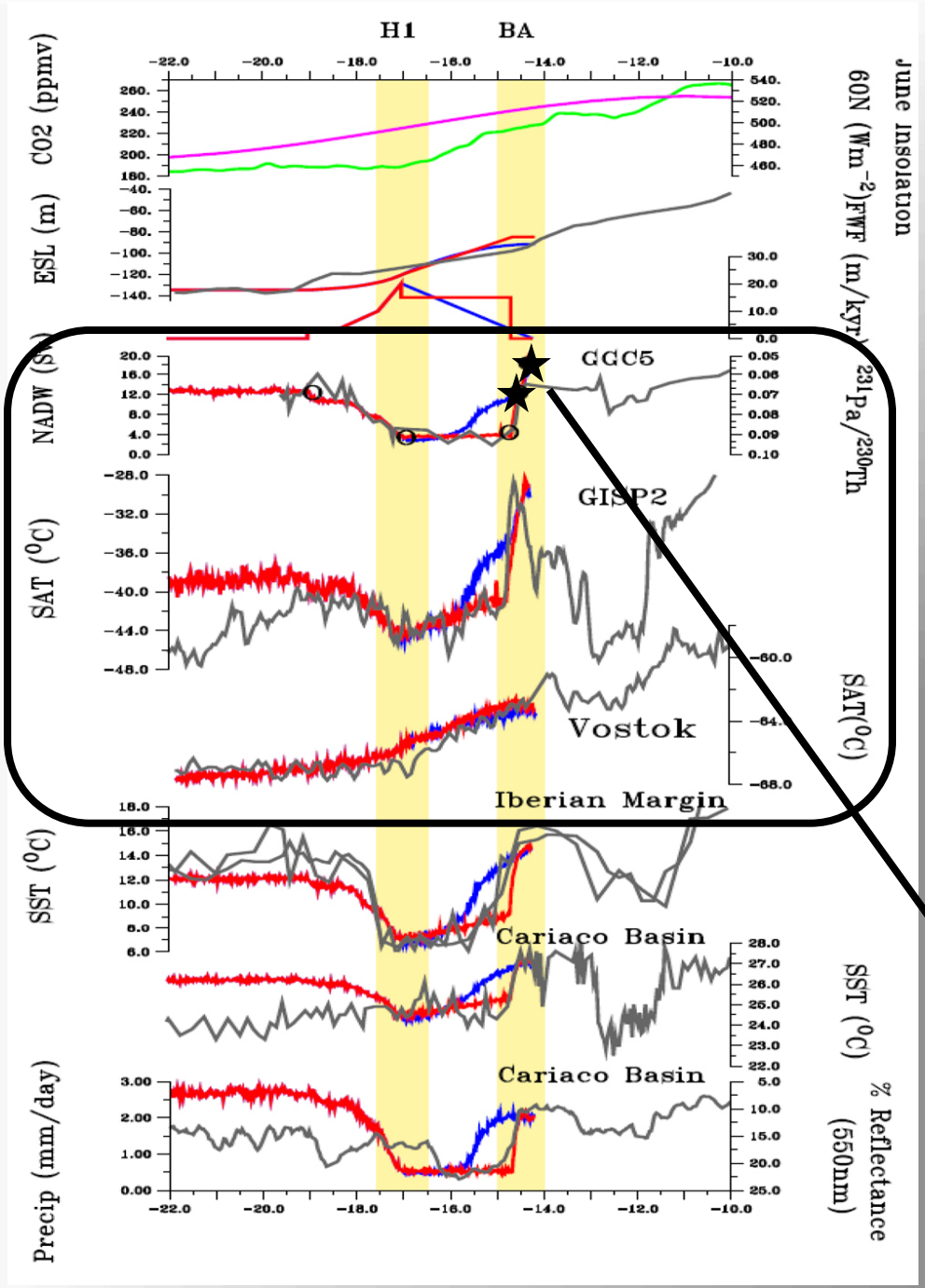

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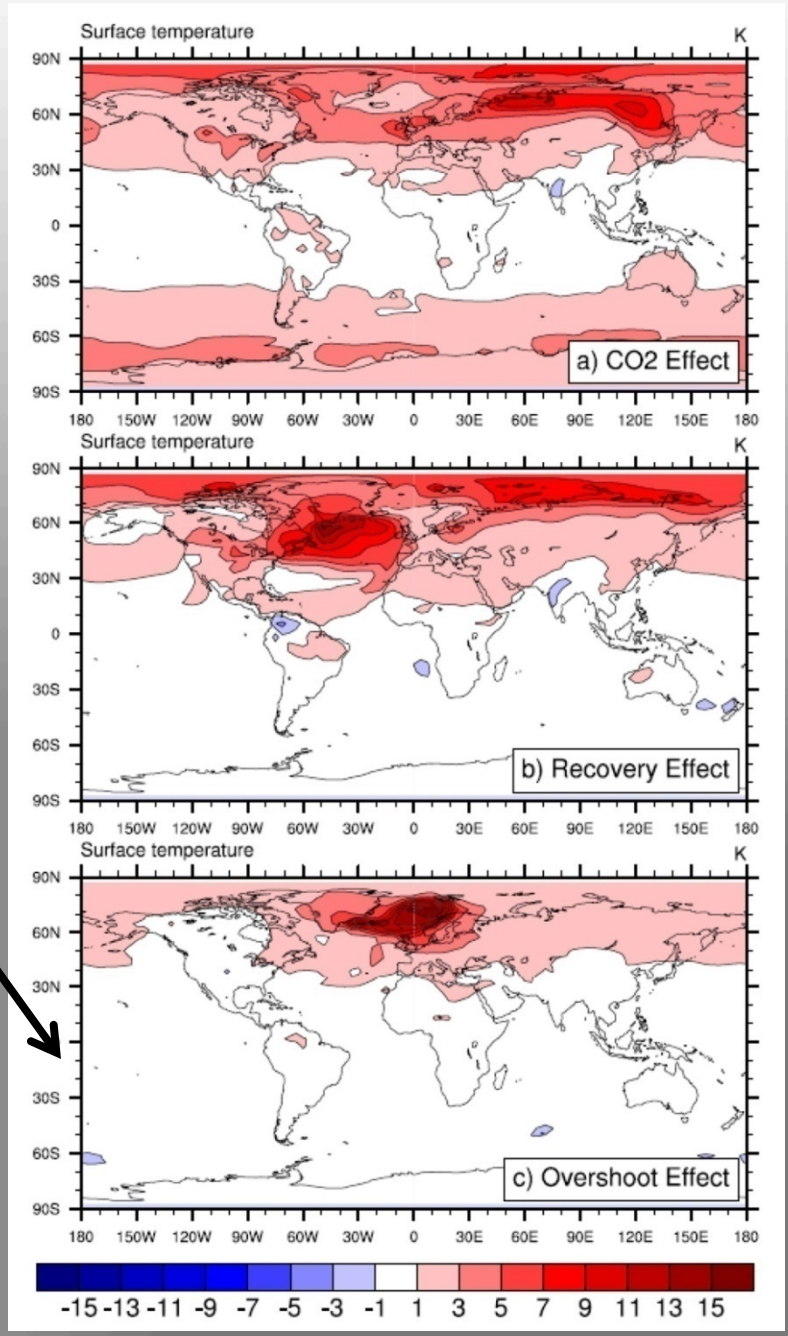
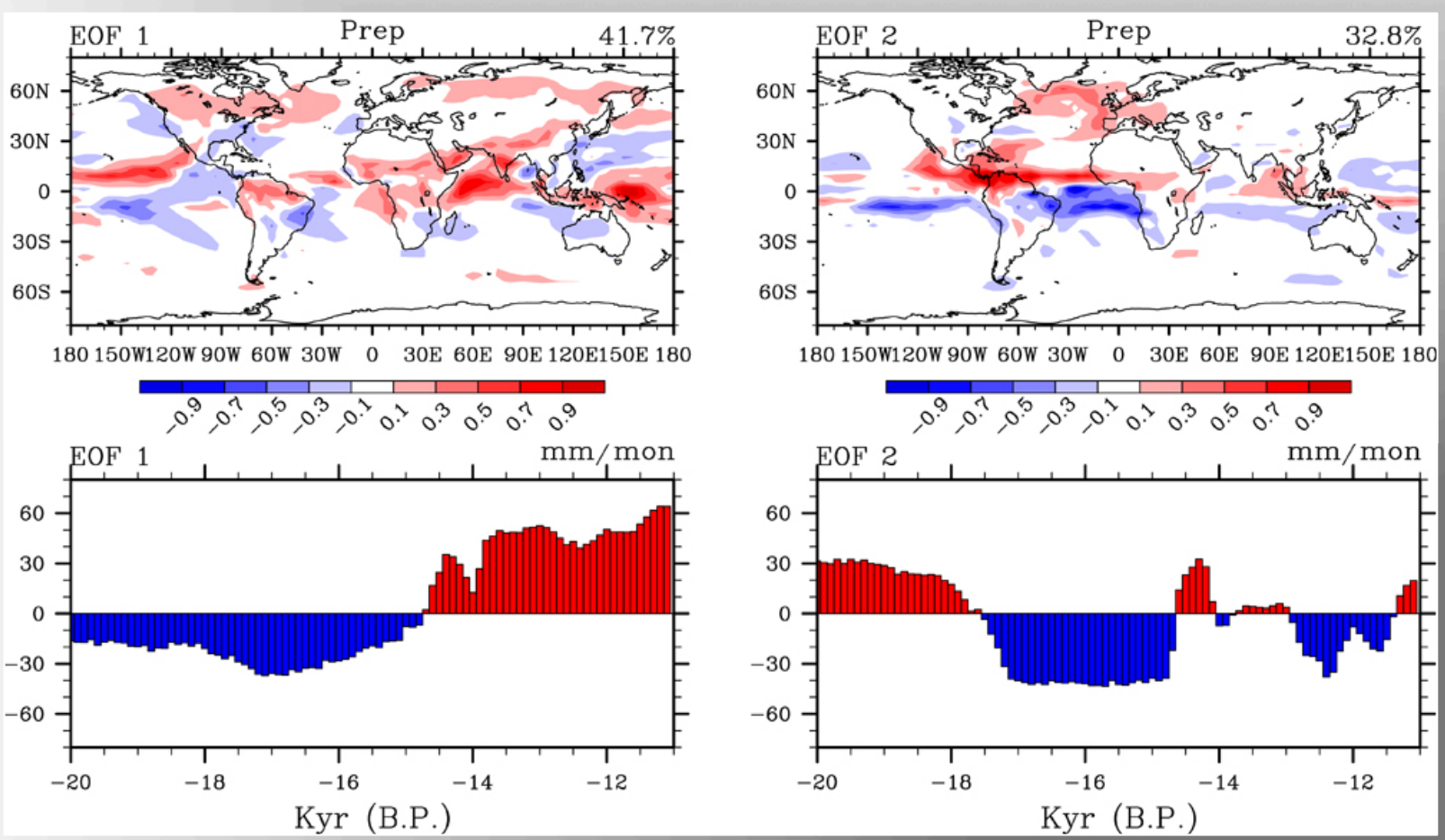


Centennial to millennial variability in the climate system: Using climate models to understand mechanisms

Characterization of model deglacial precipitation variability



Centennial to millennial variability in the climate system: from 21,000 to 10,000 years ago

- "External" forcings acting on the climate system: GHGs, orbital, ice sheets and meltwater are all important depending on region and climatic variable.
- Evidence from data and transient model simulations:
  - GHG changes can explain most of mean deglacial warming of global temperature,
  - Meltwater from ice sheets important for Greenland response and for explaining abruptness seen in some T and precip records.

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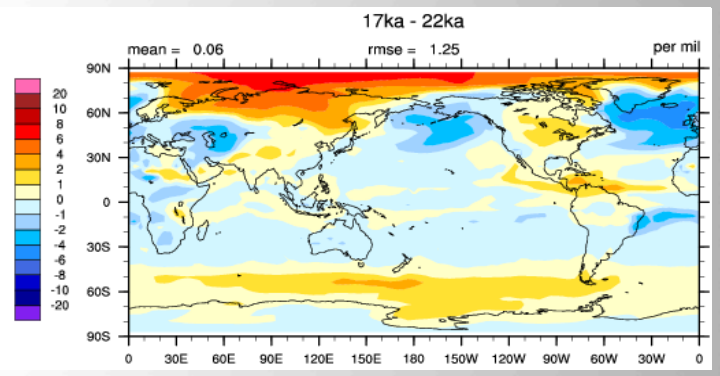
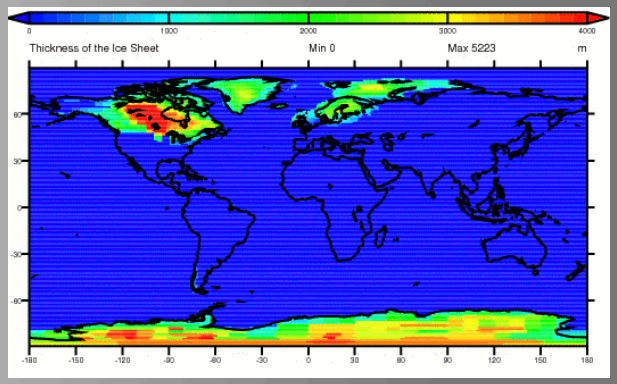
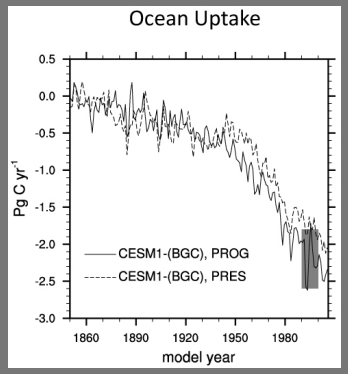
  - Meltwater from ice sheets important for Greenland response and for explaining abruptness seen in some T and precip records.
- Orbital forcing is the external forcing that acts as pacemaker for glacial-interglacial cycles: Earth system model will simulate the feedbacks: carbon cycle, ice sheets; for comparison to proxies: isotopes







Centennial to millennial variability in the climate system: References

JD Shakun *et al*. *Nature* **484**, 49-54 (2012)
"Global warming preceded by increasing carbon dioxide concentrations during the last deglaciation"

PU Clark et al. *PNAS* **109**, E1134-E1142 (2012)
"Global climate evolution during the last deglaciation"

Z Liu, BL Otto-Bliesner et al. *Science* **325**, 310-314 (2009)
"Transient simulation of last deglaciation with a new mechanism for Bølling-Allerød warming"