CESM Tutorial 2011
Application: Paleoclimate Modeling

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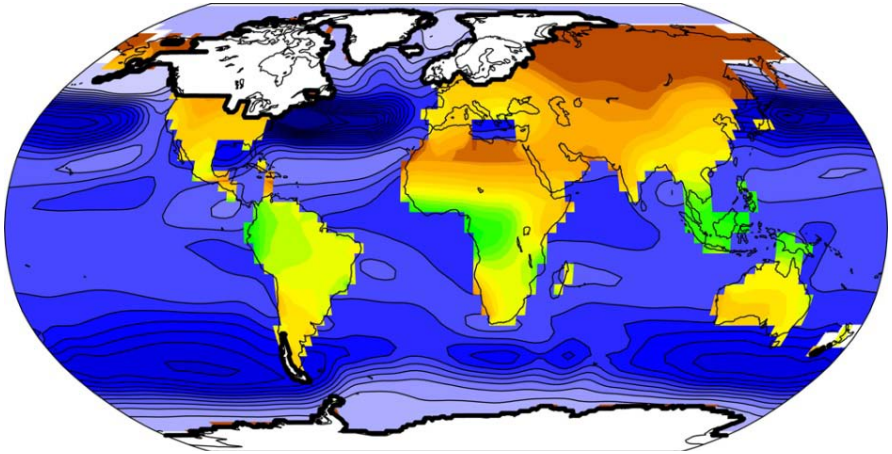
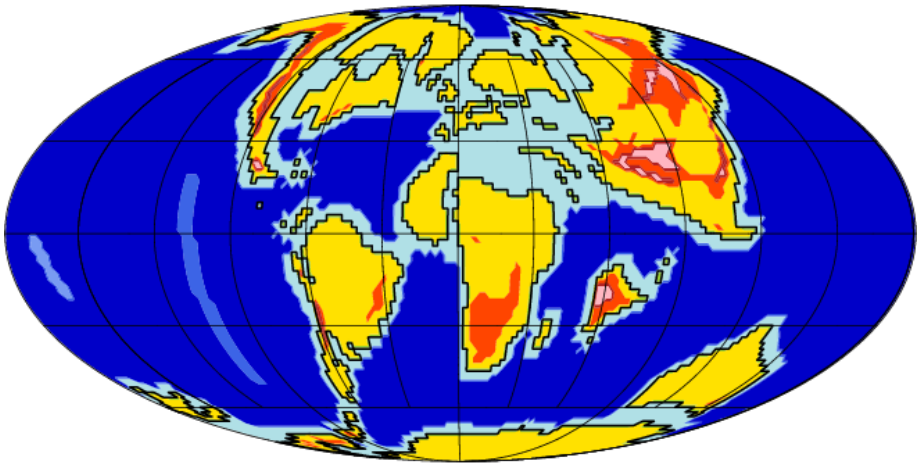
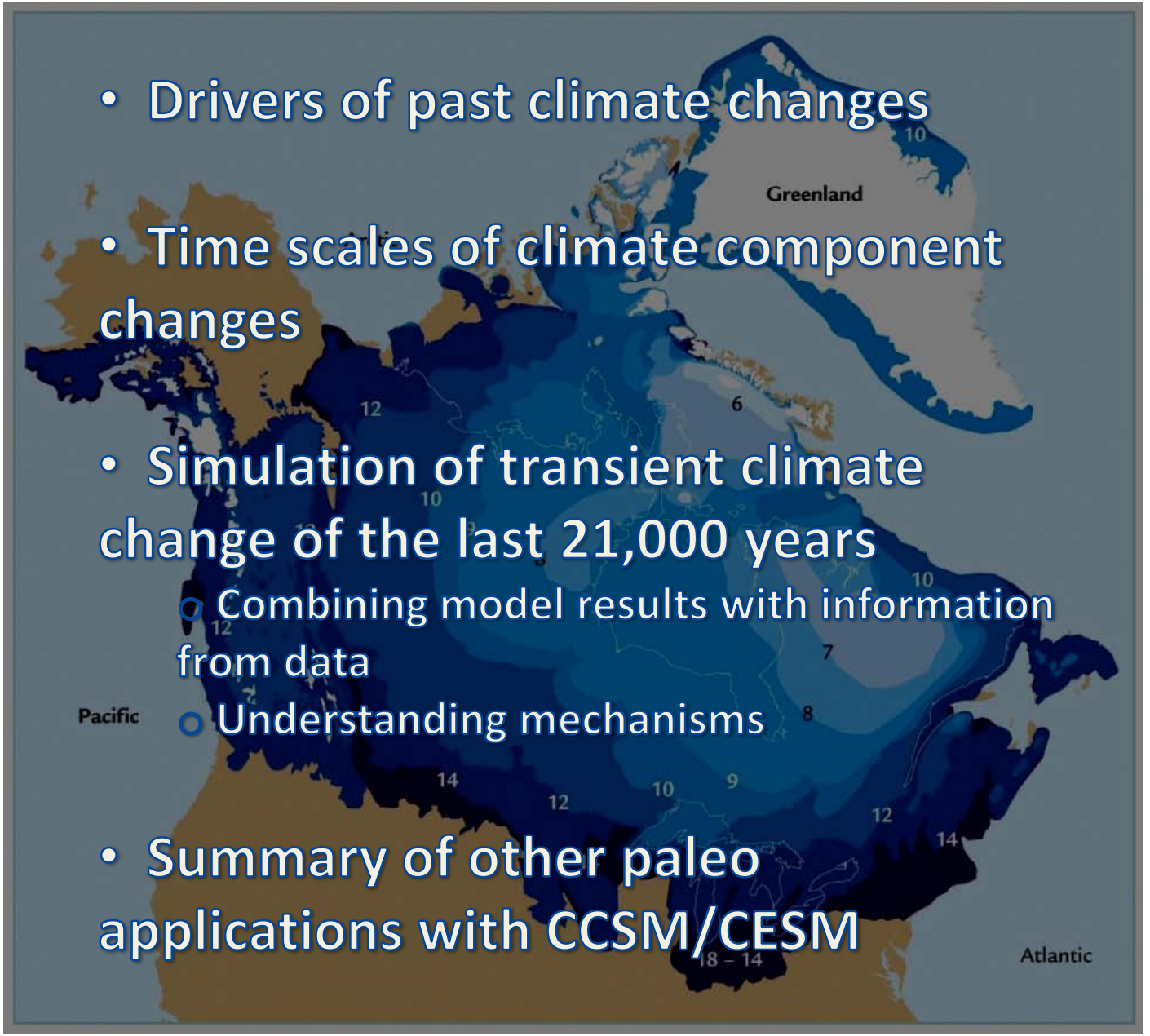


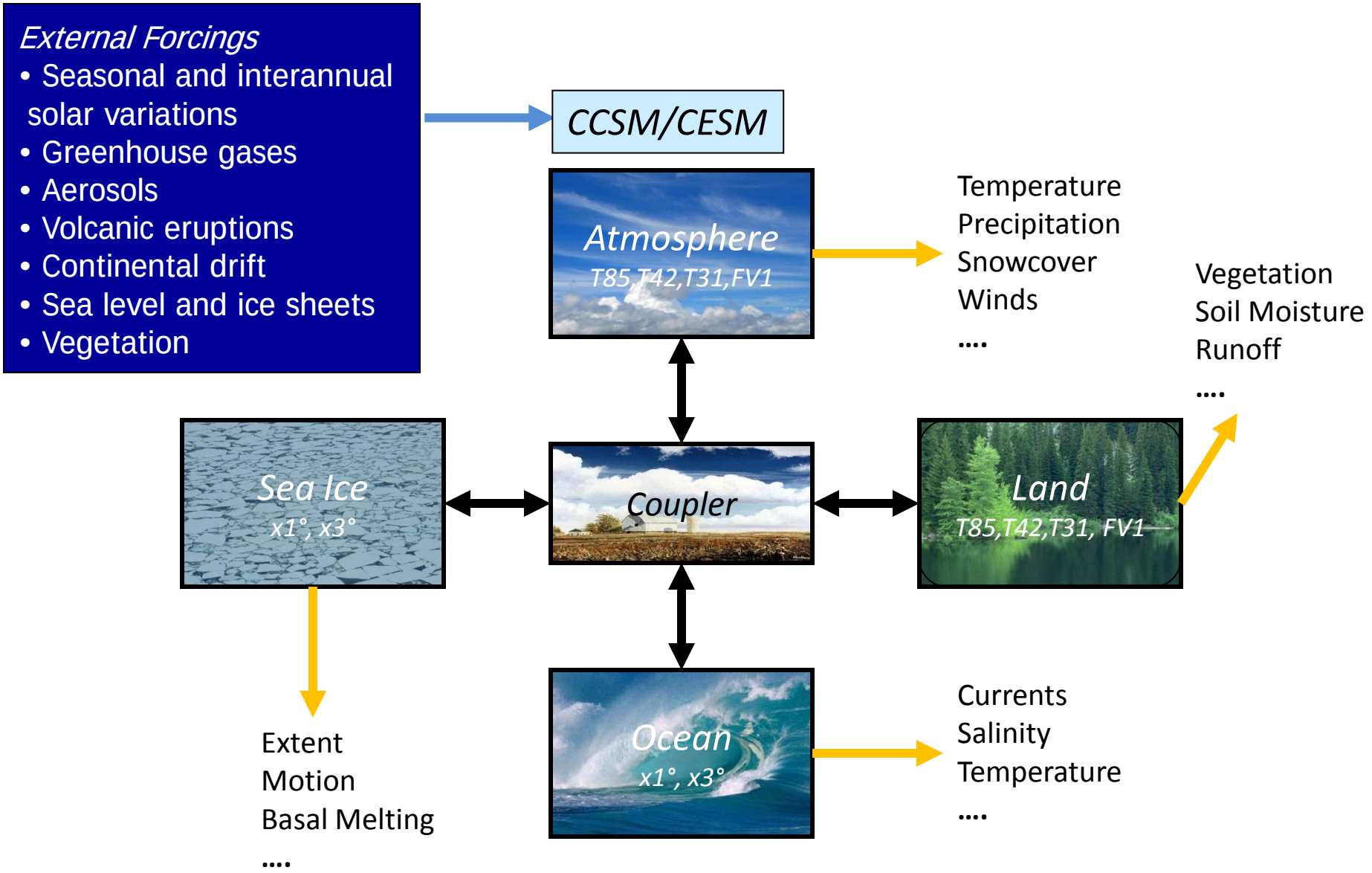


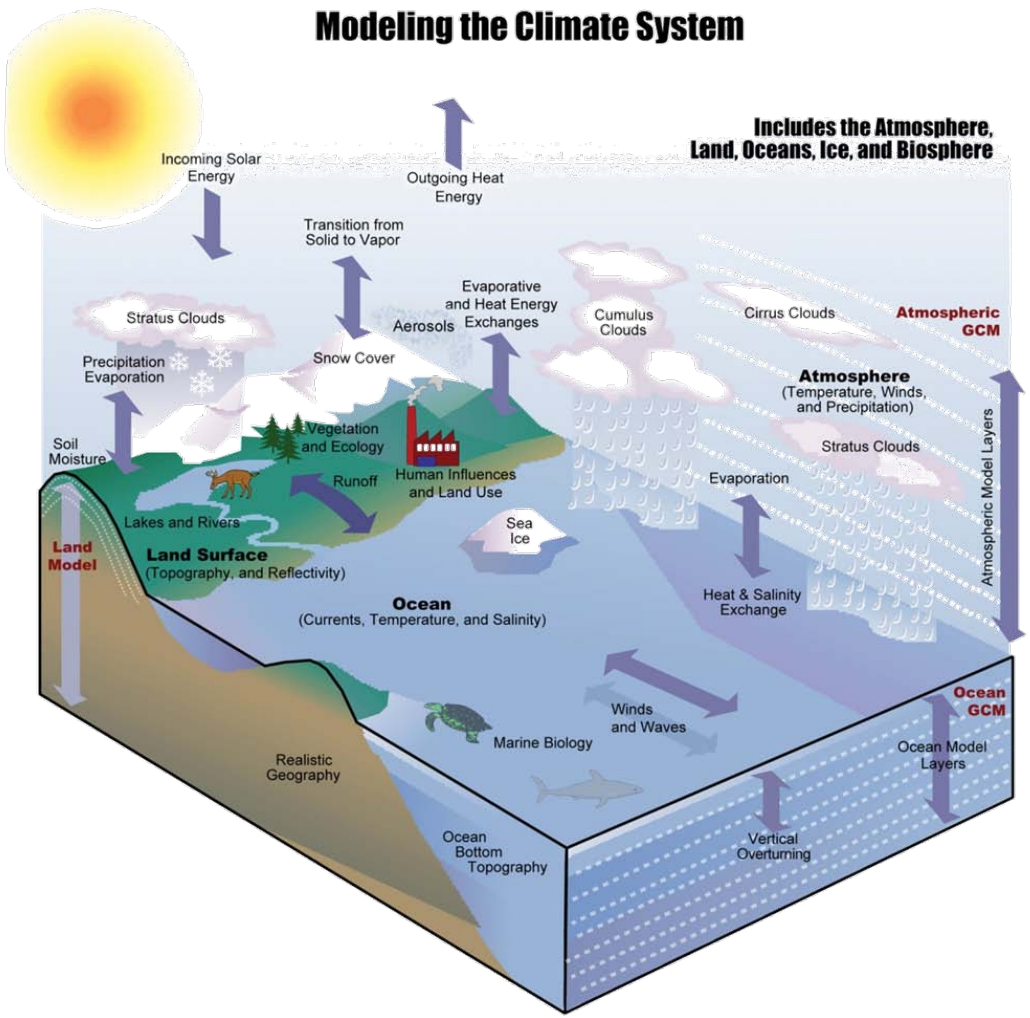
TOPICS



- Drivers of past climate changes
- Time scales of climate component changes
- Simulation of transient climate change of the last 21,000 years
  - Combining model results with information from data
  - Understanding mechanisms
- Summary of other paleo applications with CCSM/CESM

Paleo Climate Model Simulations





Karl and Trenberth, 2003; Bamber and Payne, 2004

The Earth's climate system

Time scales:

Atmosphere - days

Sea ice – days to centuries

Vegetation – days to centuries

Oceans – months to centuries

Ice sheets – centuries to millennia

Need to consider these time scales when designing a simulation

Modeling the Climate Evolution and Abrupt Changes over the Last 21,000 Years

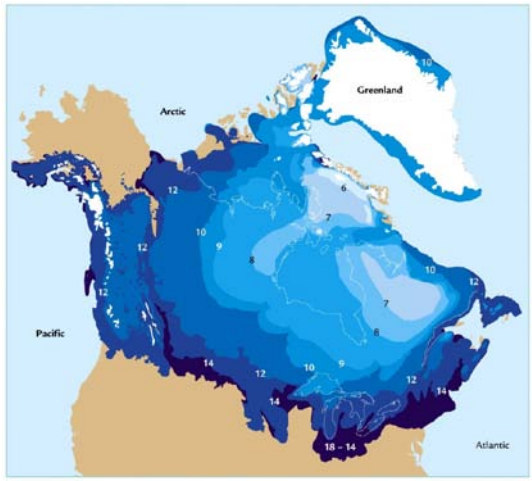
Inputs:

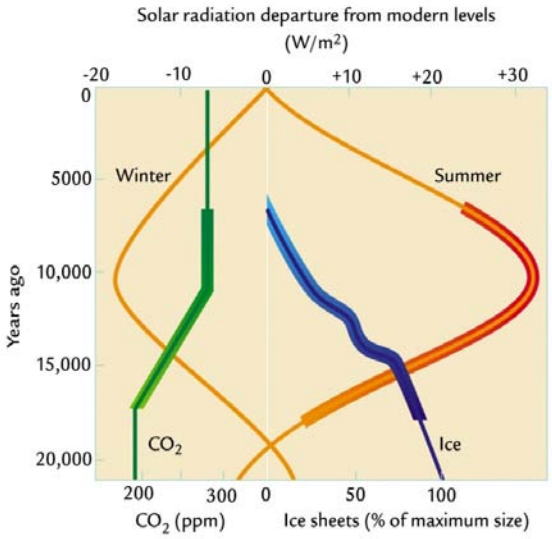
Earth's orbital configuration
Atmospheric composition of GHGs
Amount of water tied up in ice sheets:
- Ice sheet extent: albedo
- Ice sheet height
- Sea level / geography

Meltwater from ice sheets freshening oceans

Model:

CCSM3 T31x3 with predictive vegetation
~100 simulation years / calendar day

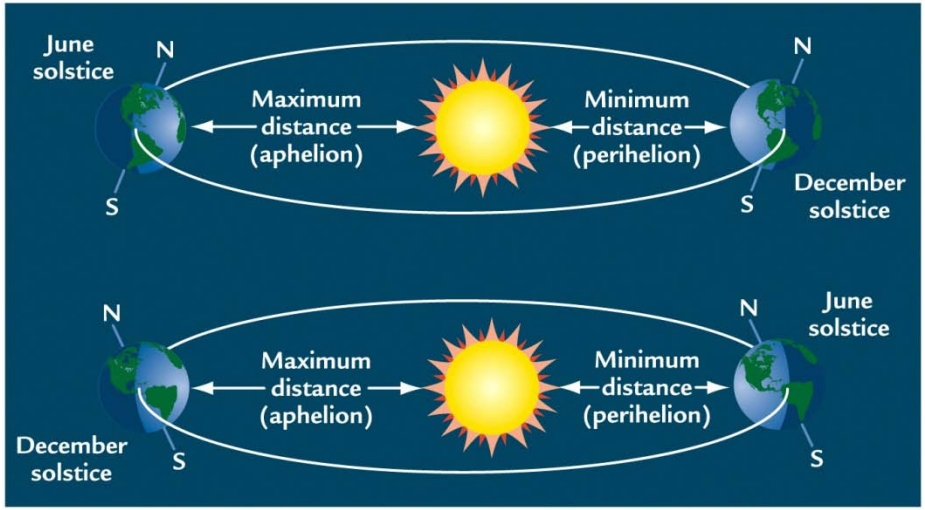




Ruddiman, 2000

NSF Office of Science U.S. Department of Energy NCAR THE NELSON INSTITUTE FOR ENVIRONMENTAL STUDIES University of Wisconsin-Madison
Where Environmental Leadership Beg

Orbital Variations of Incoming Solar Radiation



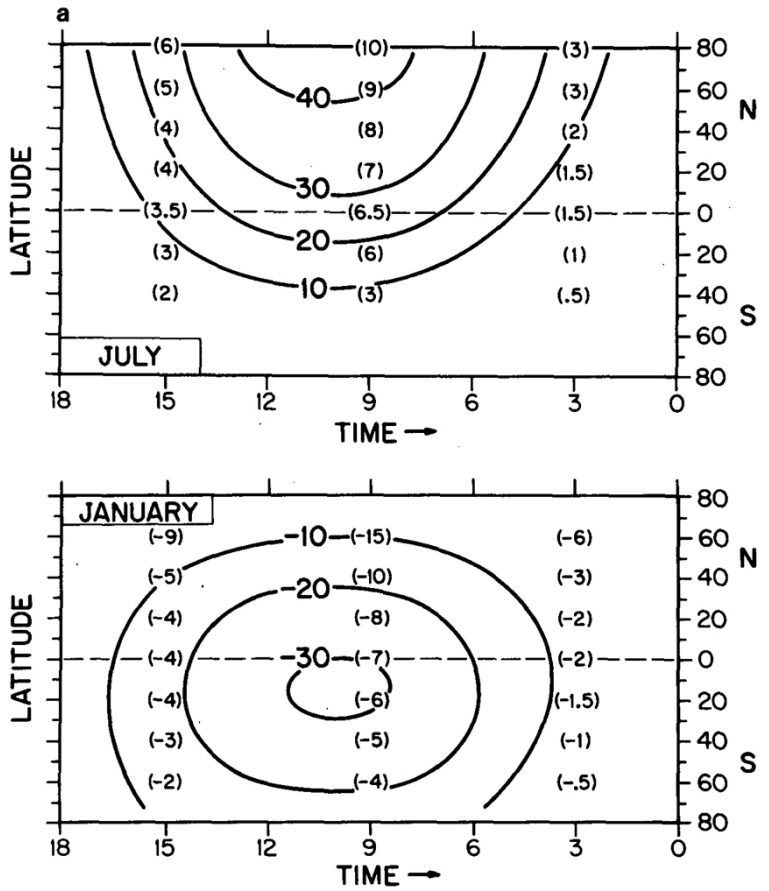
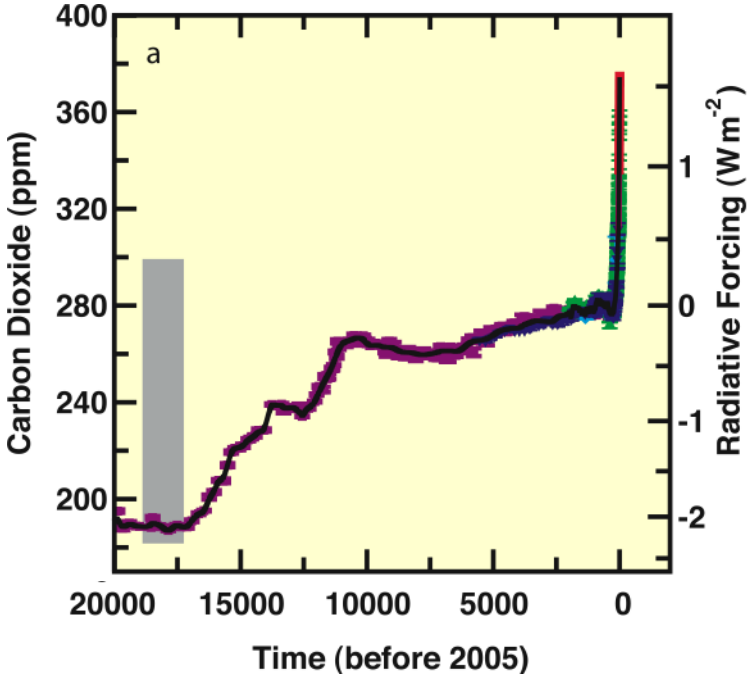
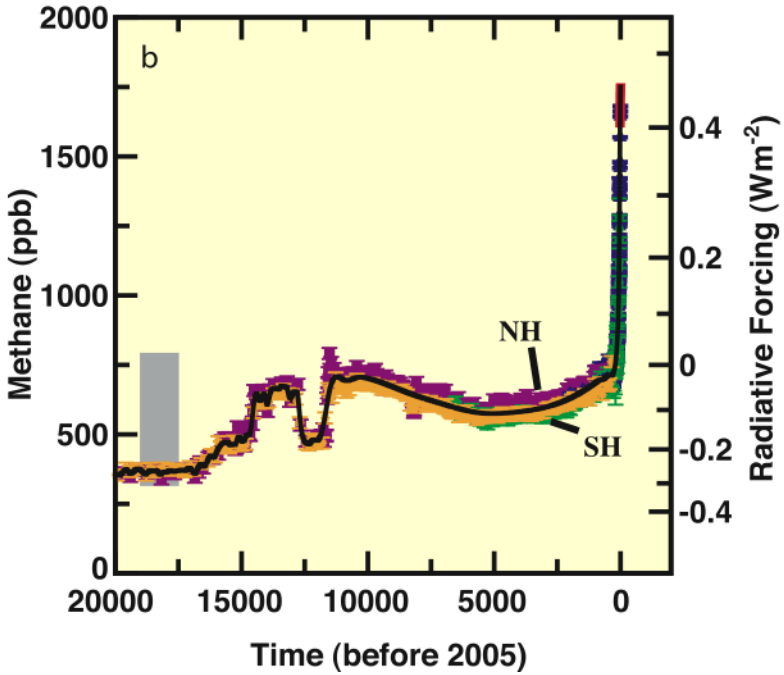


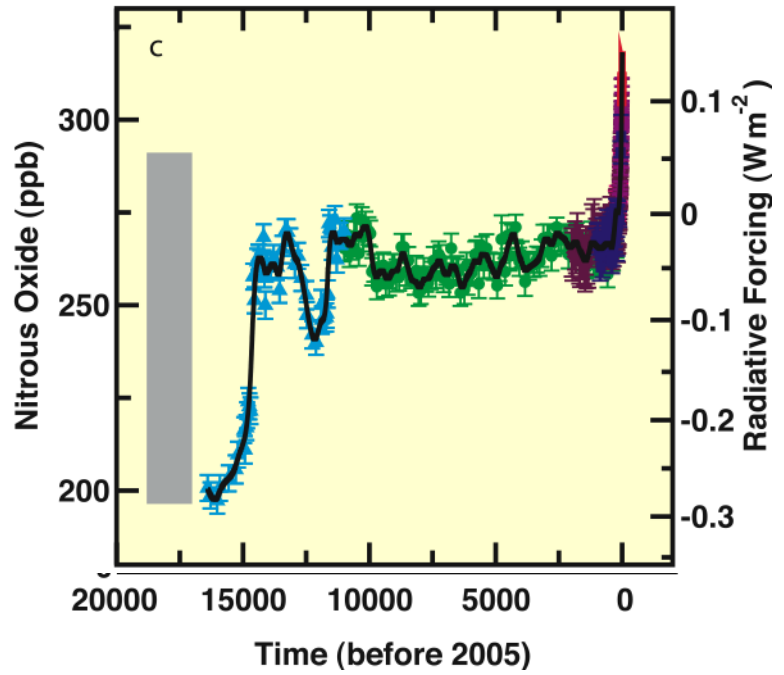
FIG. 4a. Solar radiation departures (past-minus-present, in W m^{-2}) for July and January as a function of latitude and time (18 kyr BP to 0 kyr BP). The numbers in parentheses are the departures from present expressed in percent.

Kutzbach and Guetter, 1986; Ruddiman, 2000

Greenhouse Gases: CO_2, CH_4, N_2O

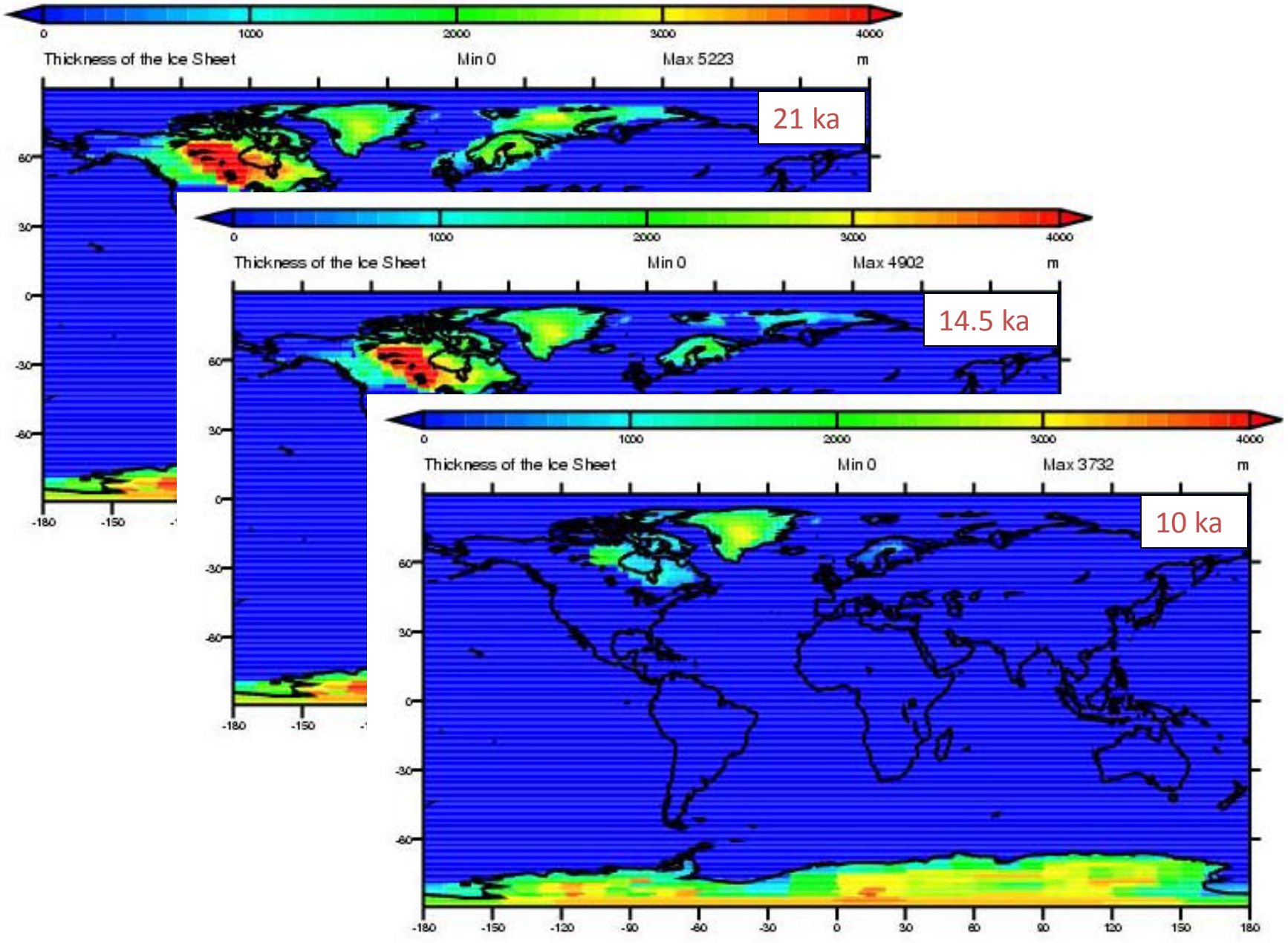






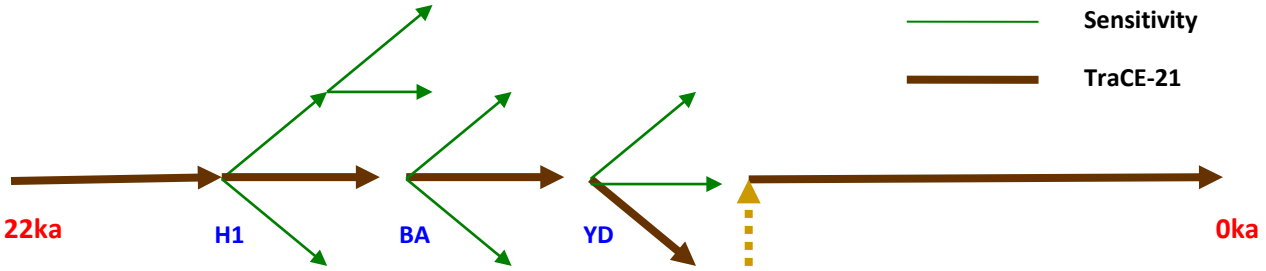
IPCC AR4 WG1, 2007

Ice Sheet Extents and Heights

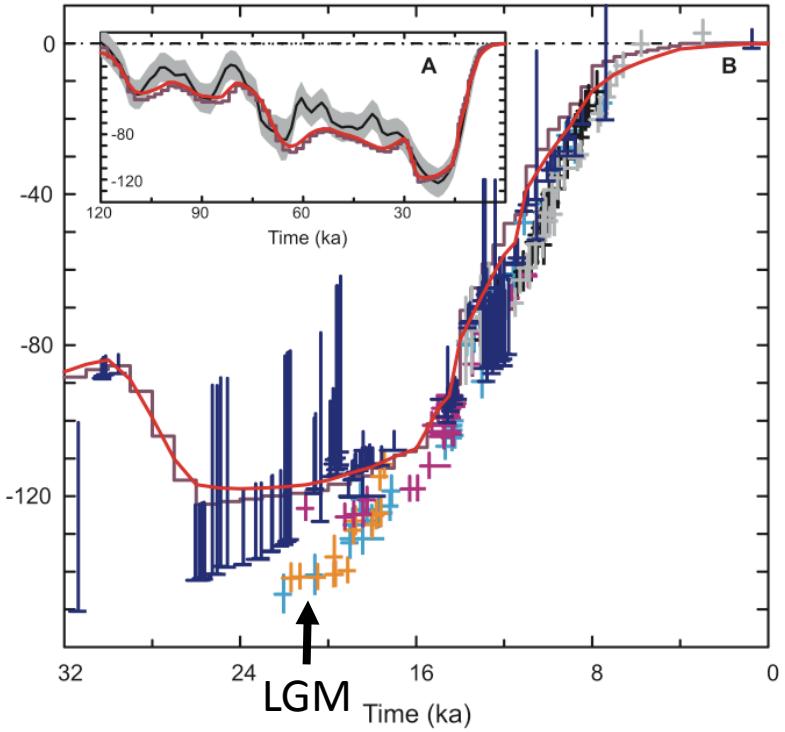


Peltier, 2004

Meltwater History During the Deglaciation ?

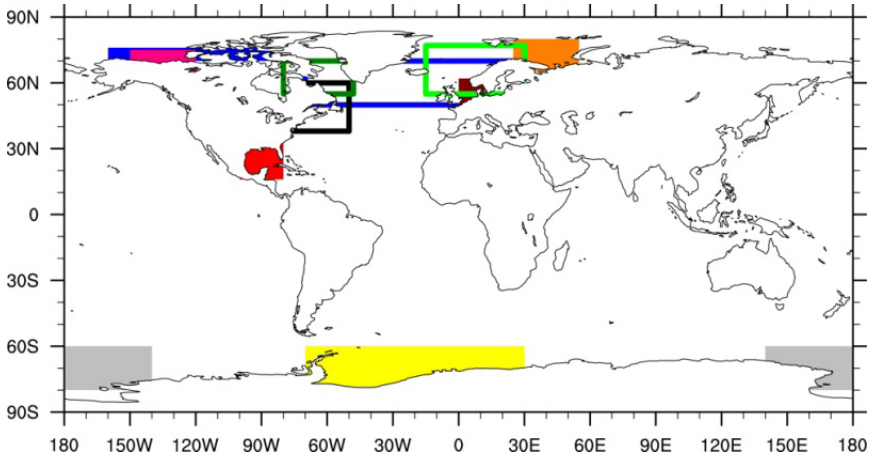


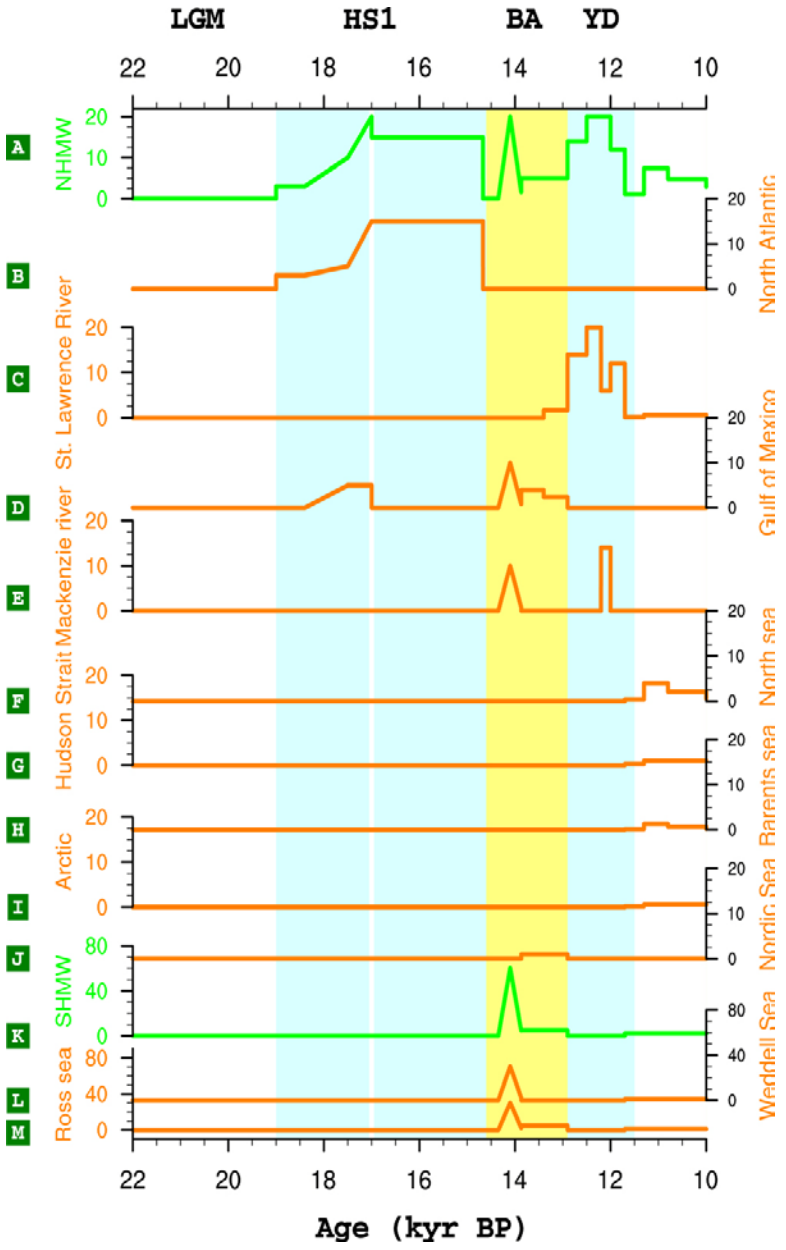
- Sea level records
- Marine cores: concentrations of lithic grains, detrital carbonate, geochemical proxies
- Stratigraphic evidence of ice margin retreat and drainage outlets



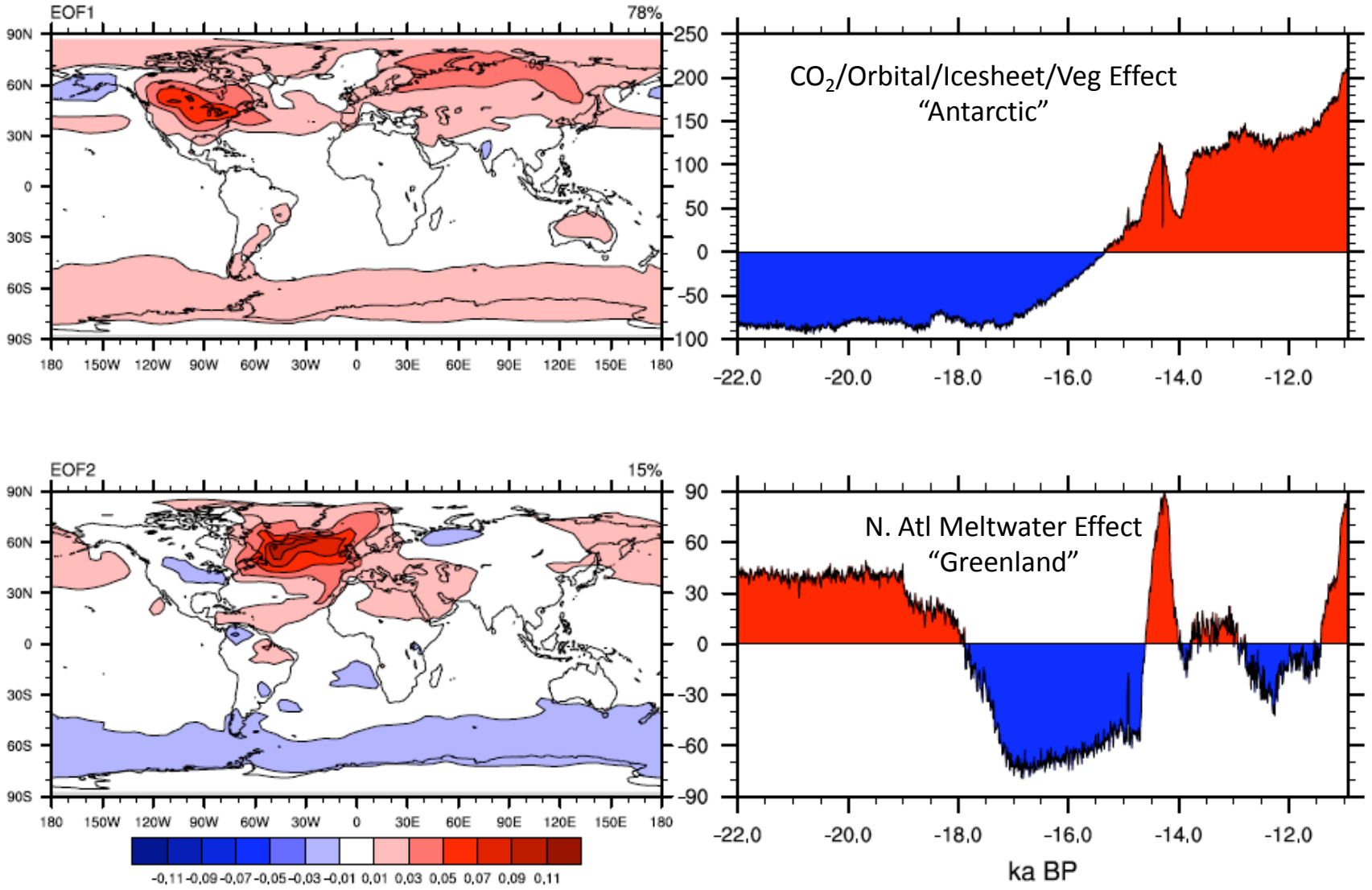
IPCC AR4 WG1, 2007

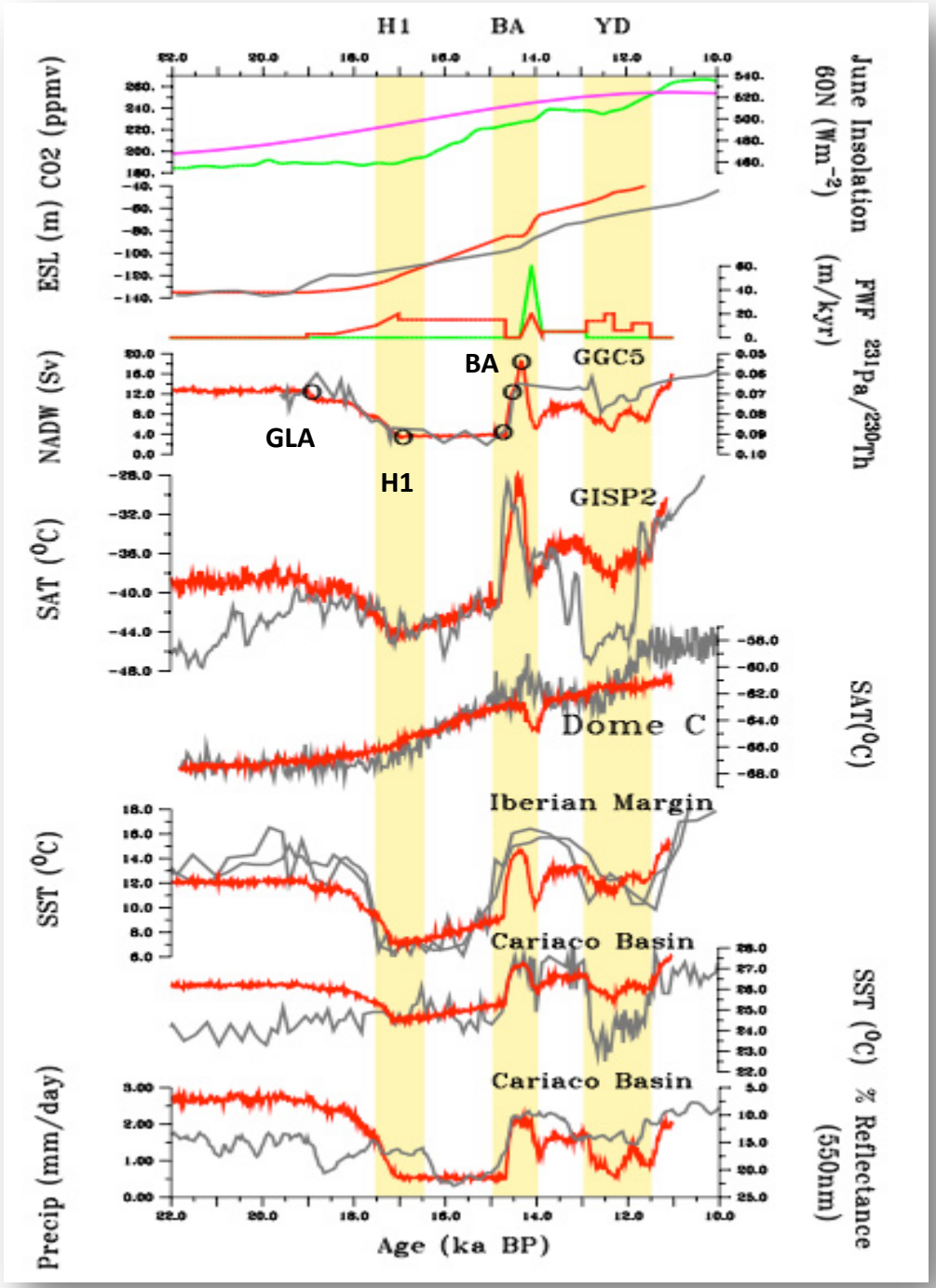
Freshwater Forcing:





Leading EOFs of Surface Temperature (Decadal)





Transient "forcings"

Orbital Insolation
Greenhouse Gases: CO_2, CH_4, N_2O
Ice Sheet Extents and Heights
Meltwater Fluxes ***

Transient responses

Atlantic Ocean Overturning

Greenland Temperature
(model offset by -3°C)

Antarctic Temperature

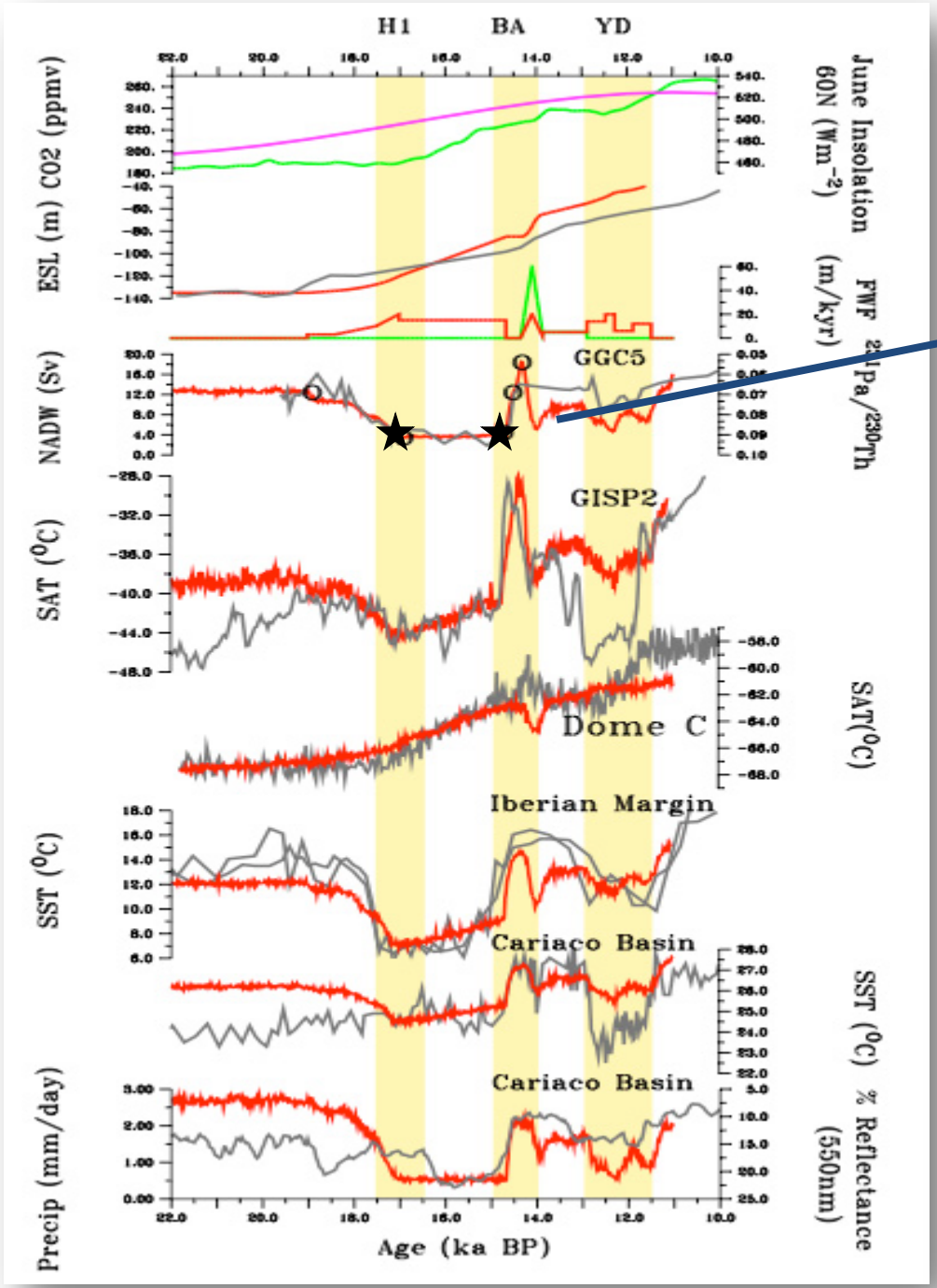
Iberian Margin SST

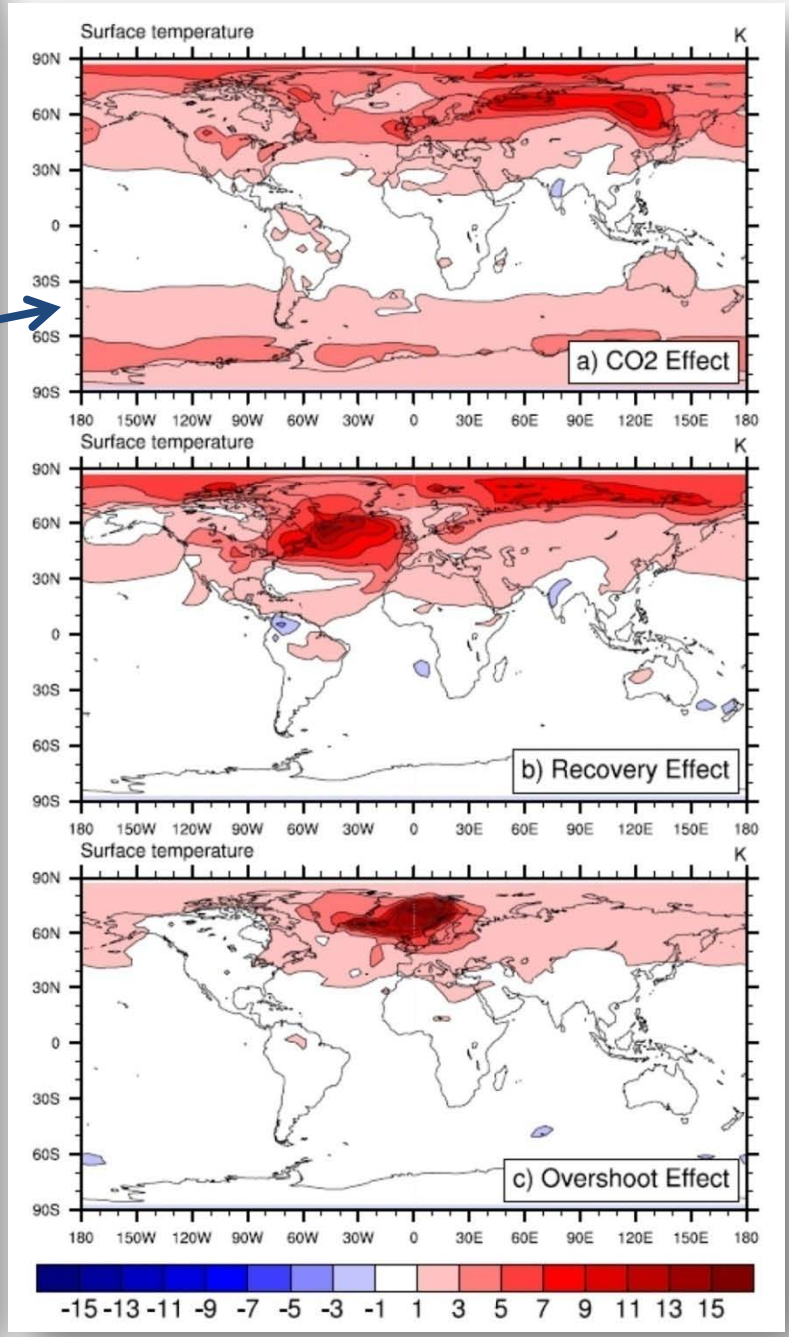
Cariaco Basin SST
(model offset by 4°C)

Cariaco Basin Precipitation

*** Gray: Proxy data estimates

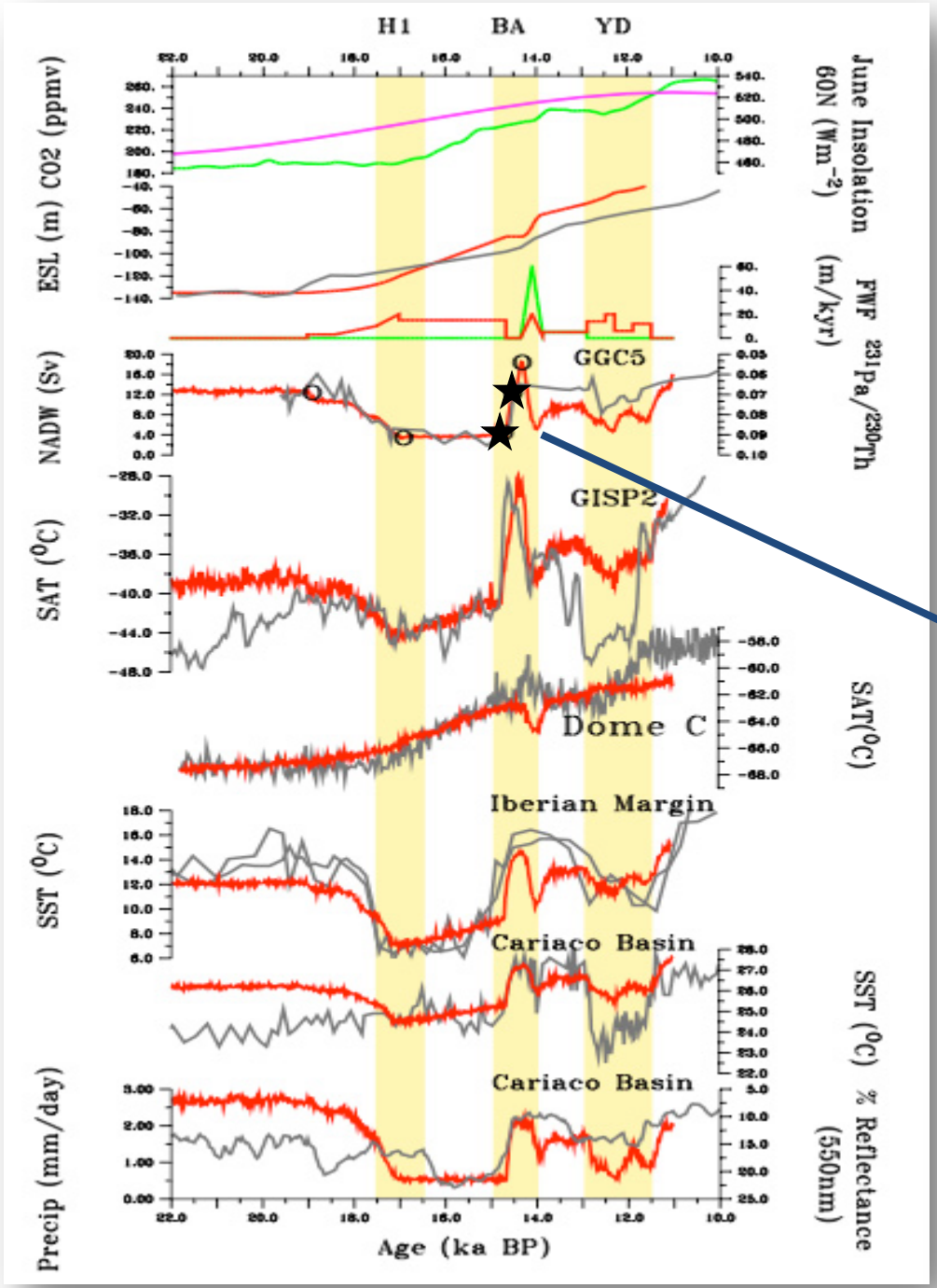
Attribution

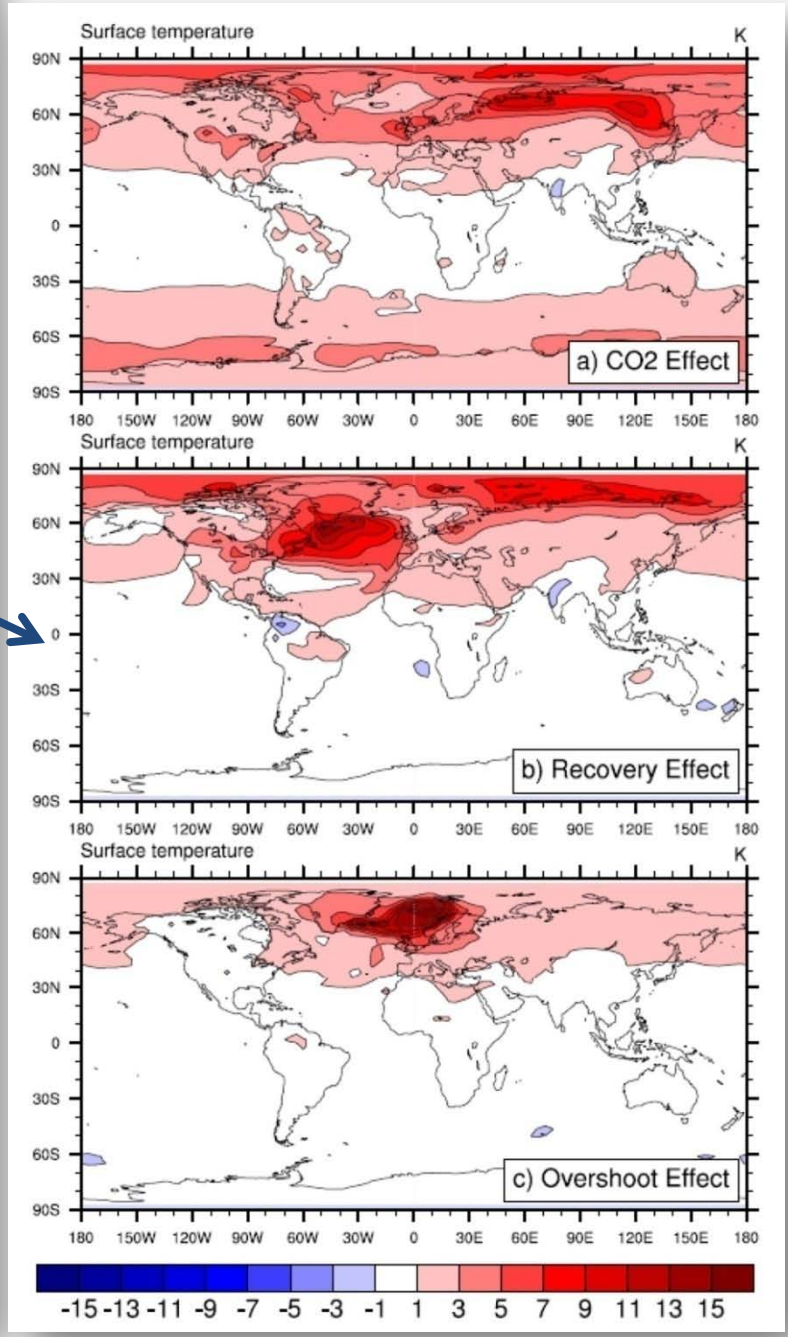




Liu, Otto-Bliesner et al., 2009

Attribution





Liu, Otto-Bliesner et al., 2009

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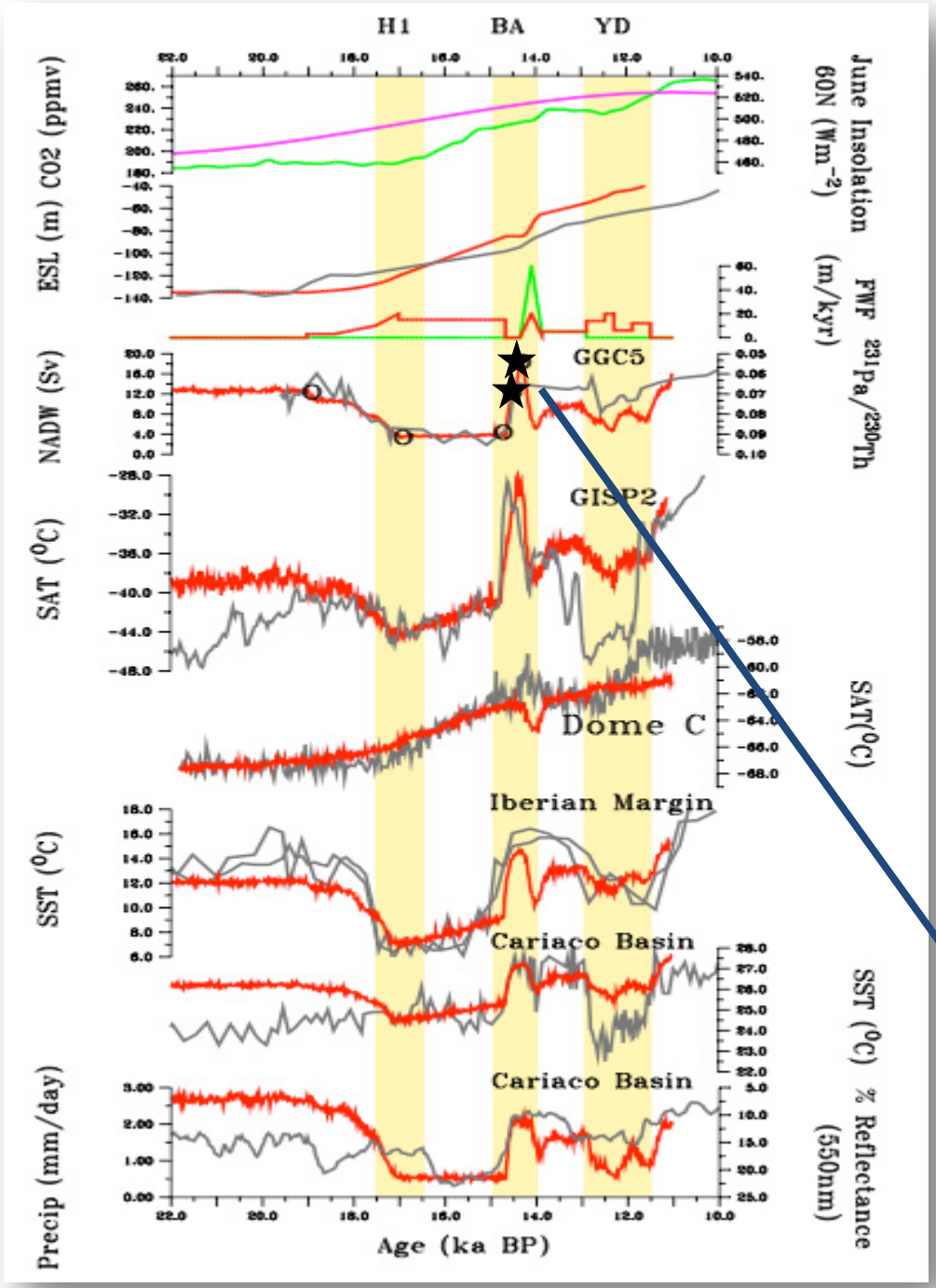
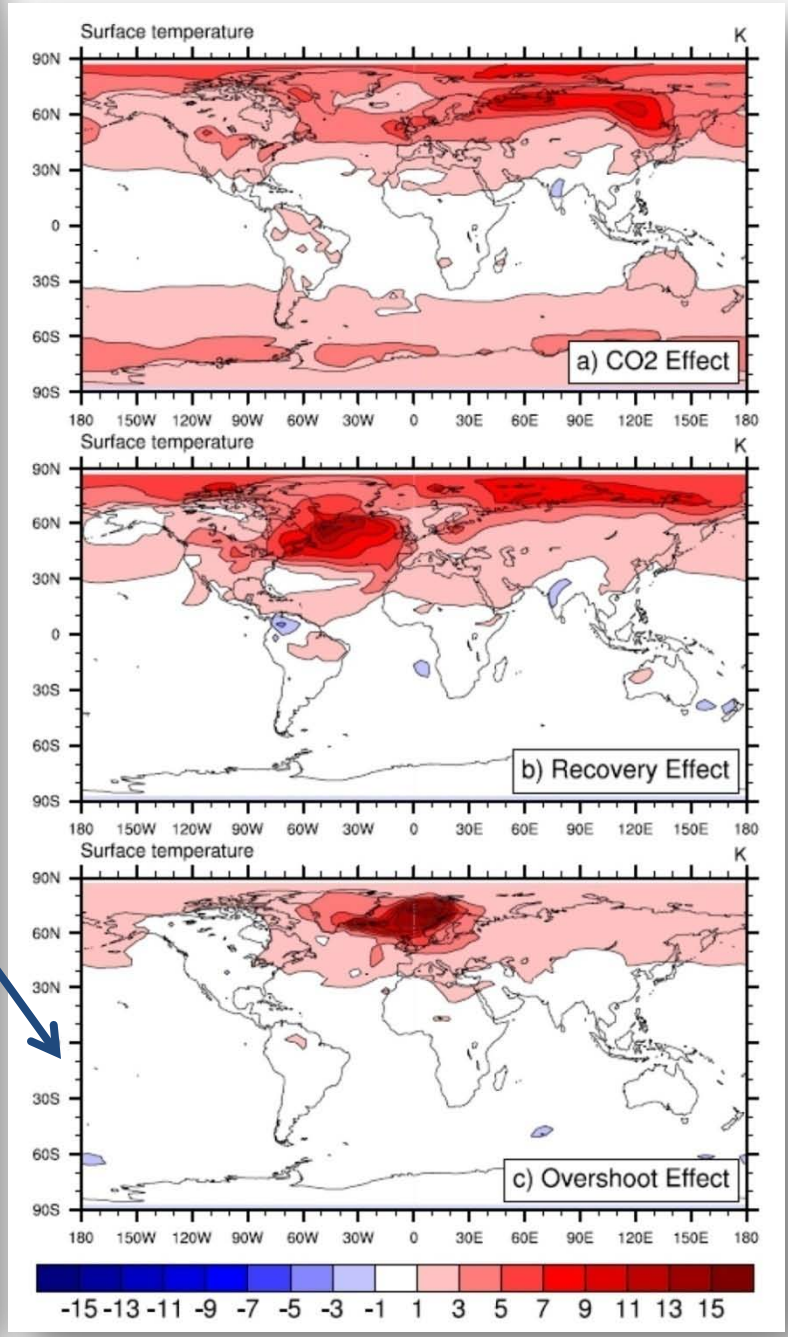
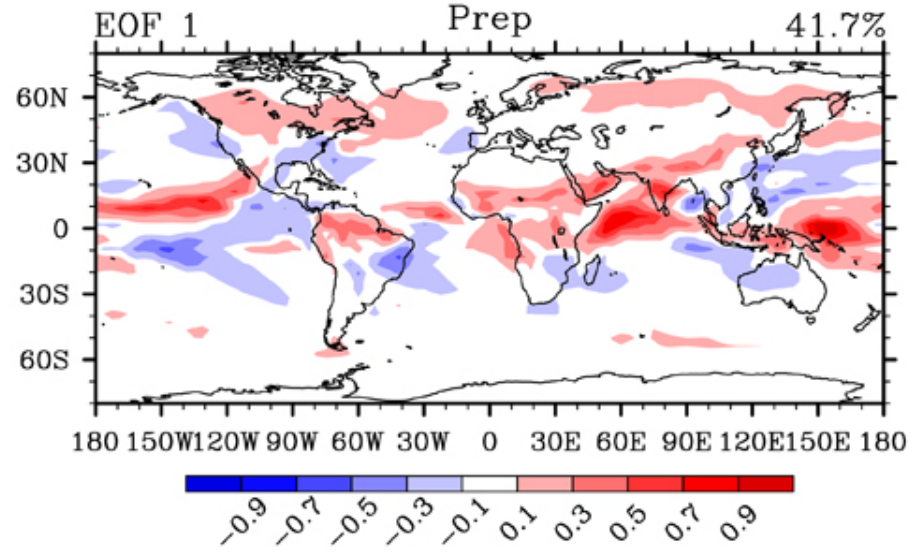
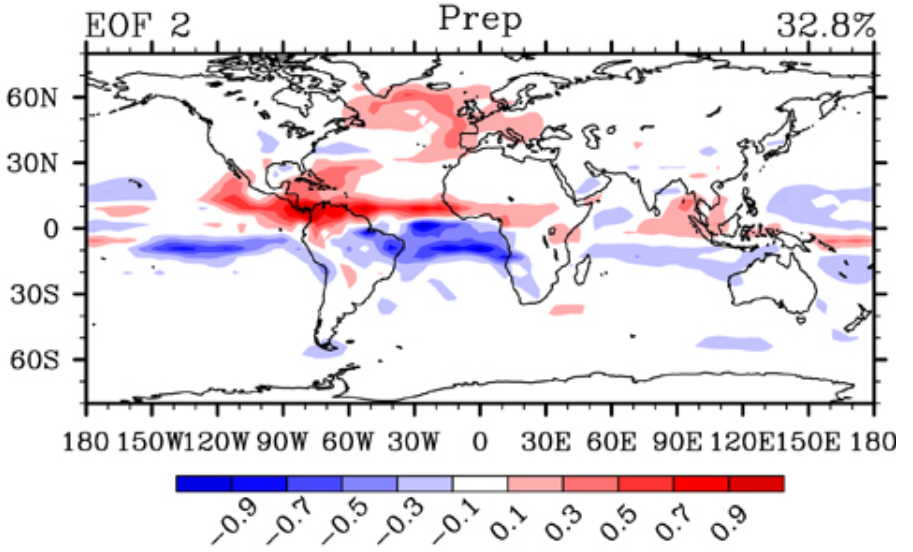


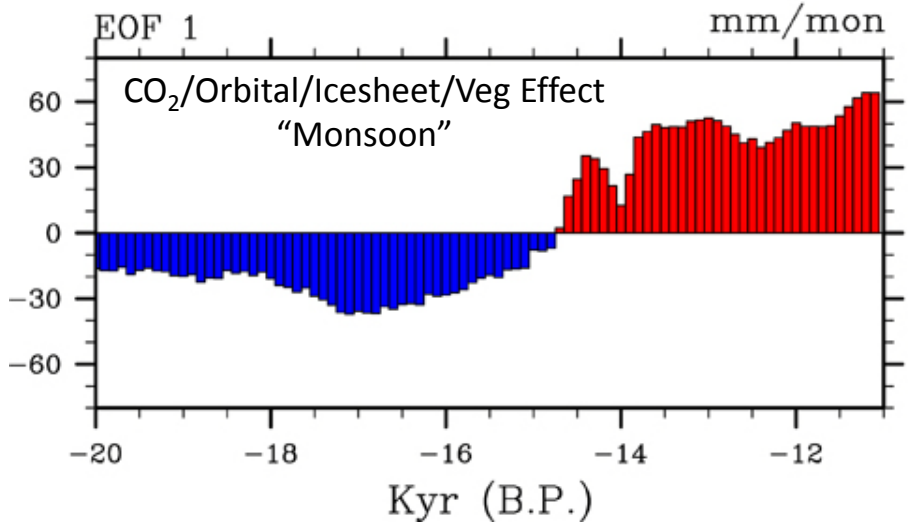


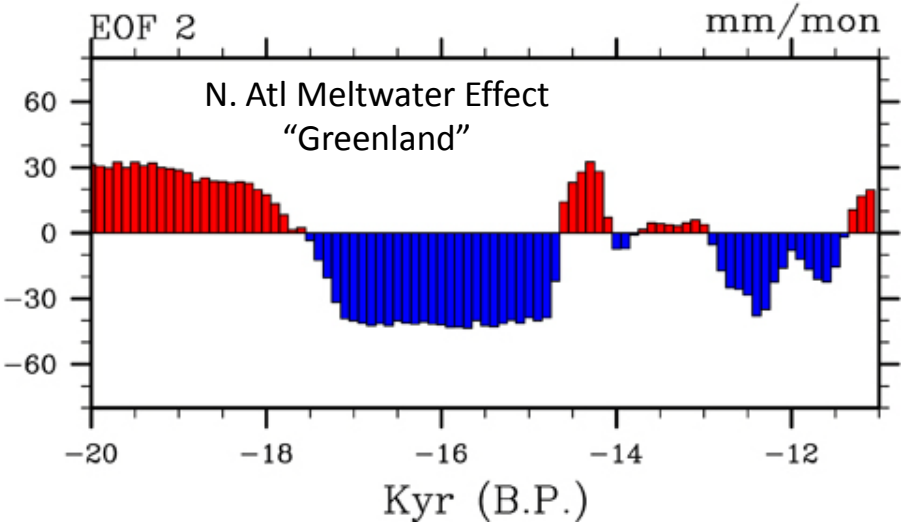
Liu, Otto-Bliesner et al., 2009

Leading EOFs of Precipitation (Decadal)

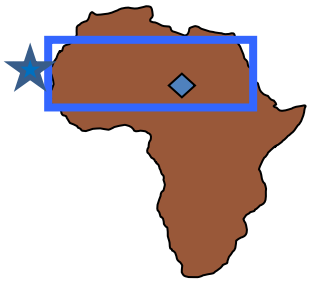




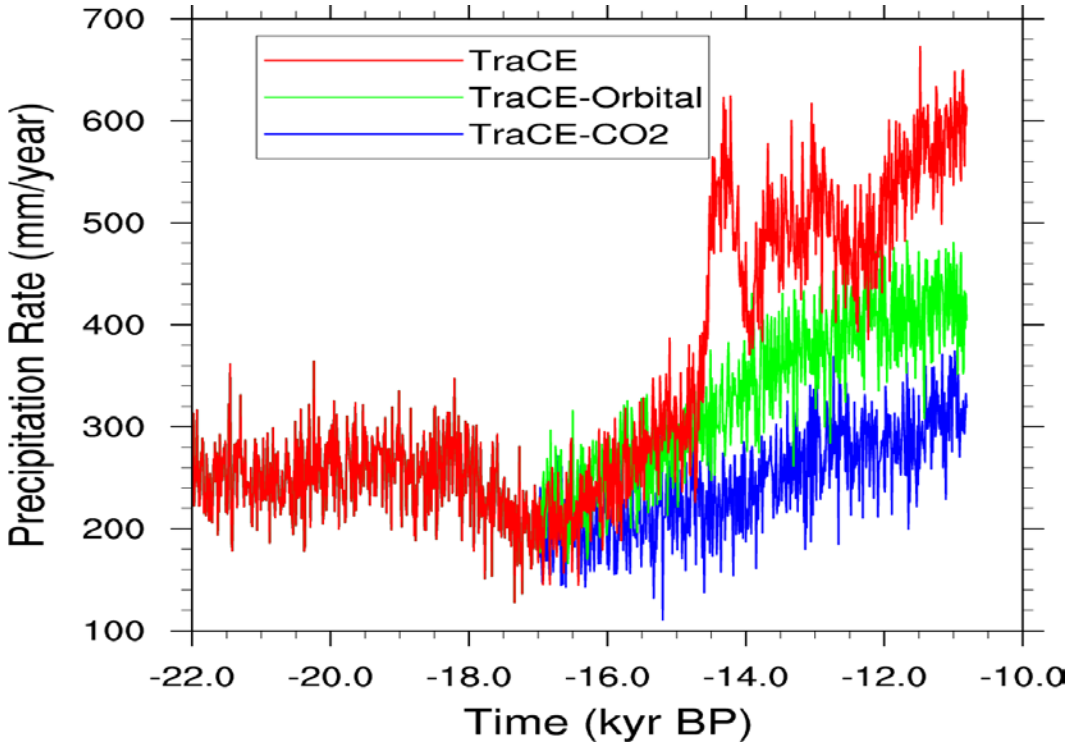




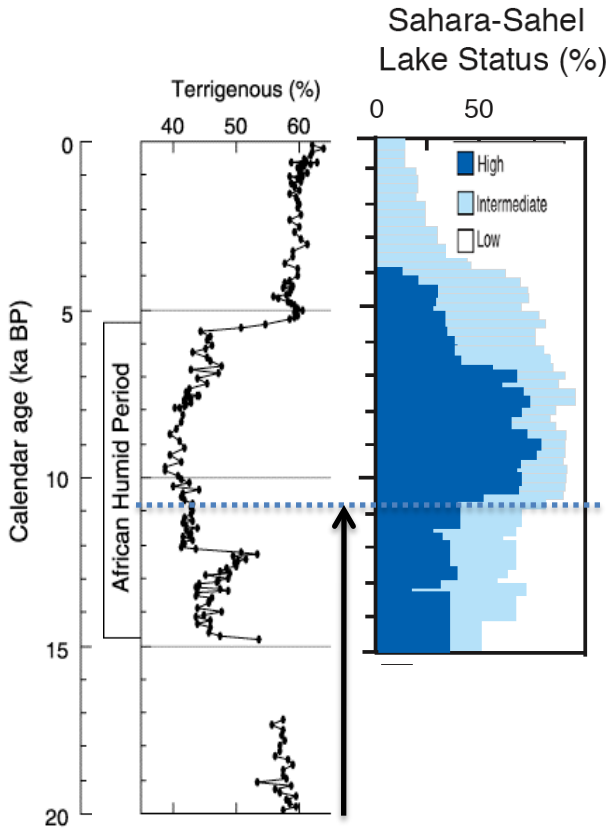
Northern Africa Hydrologic Cycle



CCSM3 transient simulation
Sahel (12.9-16.7°N, 11.25-22.5°E)



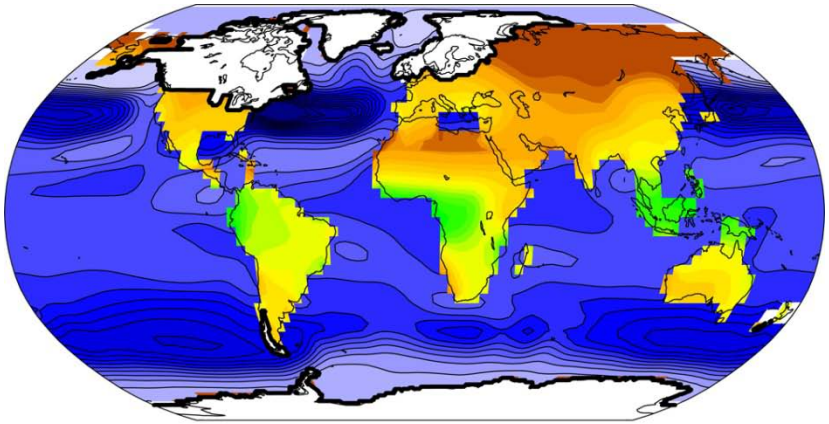
Otto-Bliesner et al., in prep.

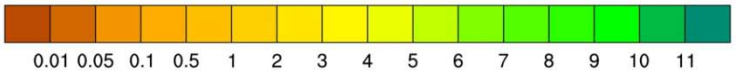


deMenocal et al., 2000; Hoelzmann et al., 2004; Liu et al., 2007

CCSM can also predict vegetation changes

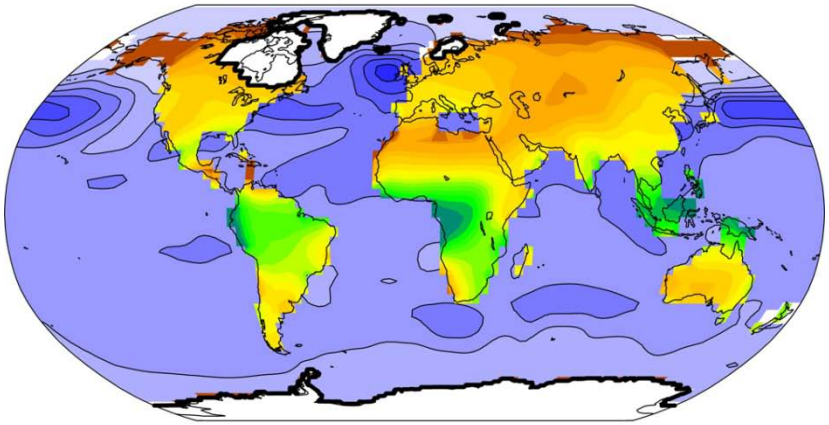
21 ka

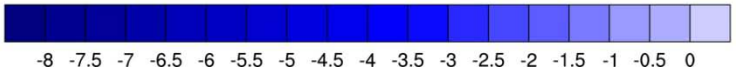




TLAI

10 ka

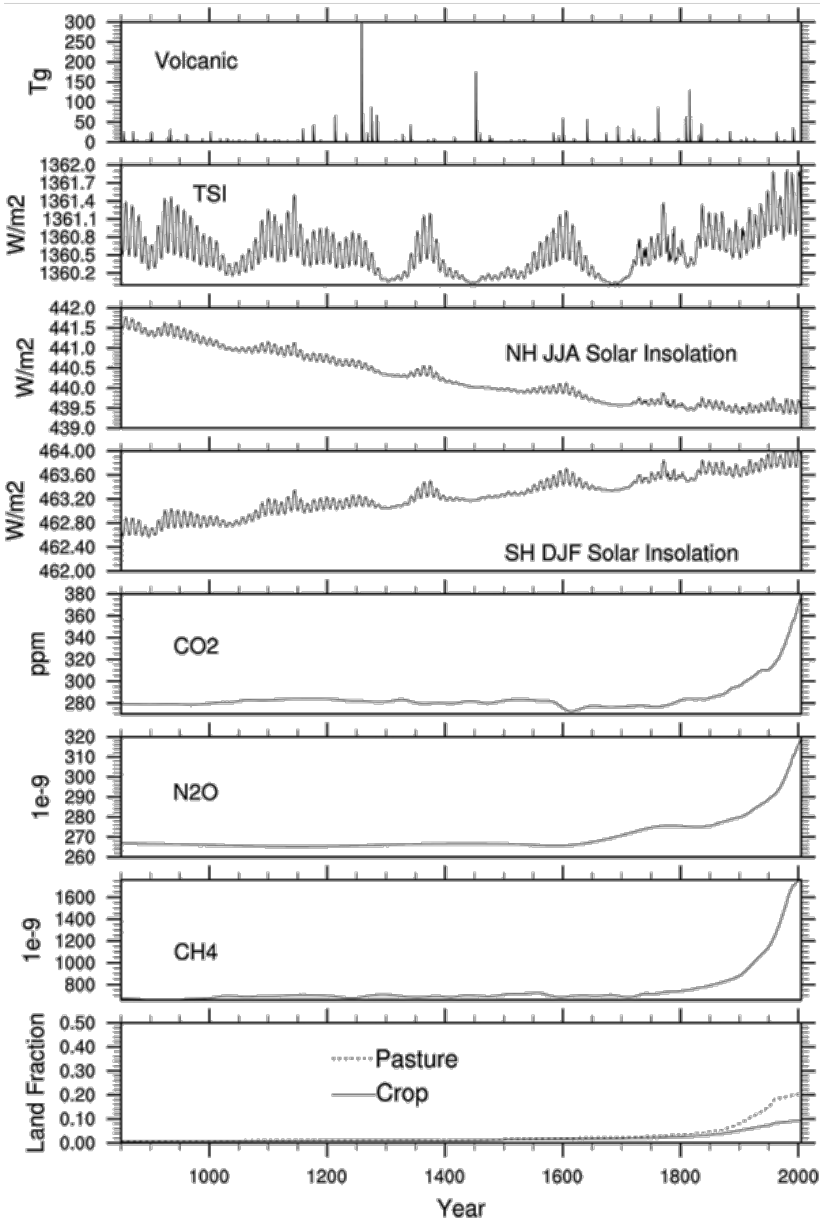


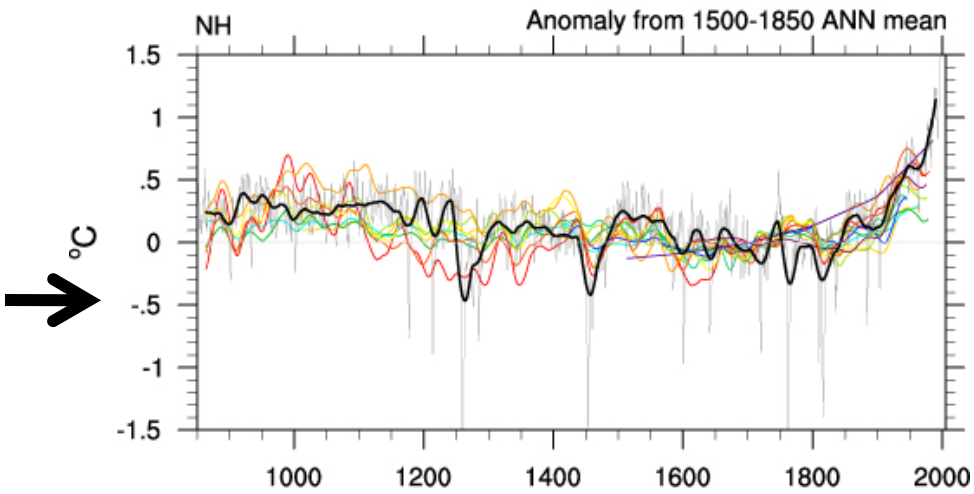


Δ SST

Transient Simulations: Last Millennium

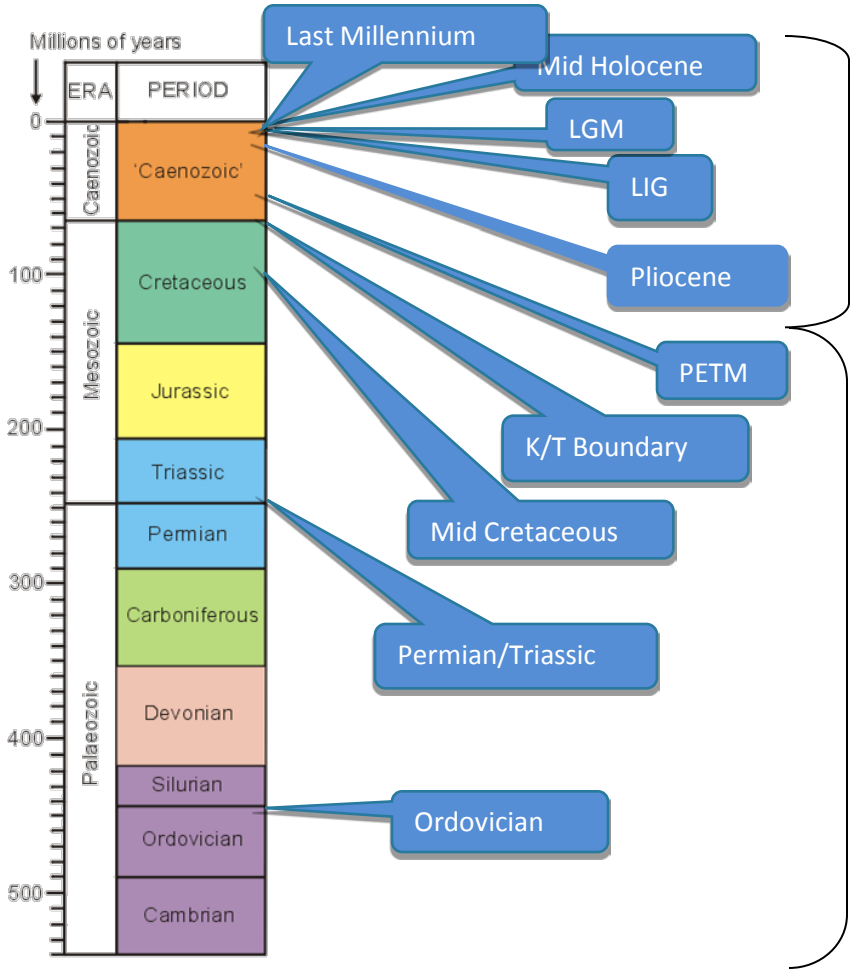
CCSM4 1° x 1°





Black line: Smoothed CCSM4 simulation
Colored lines: Reconstructions from data

Many more CCSM/CESM Paleoclimate Snapshot Simulations



CESM1
High Resolution (FV1)
Atm/land: ~1°
Ocn/ice: ~1°

CCSM3
Low Resolution (T31)
Atm/land: 3.75°
Ocn/ice: ~3°

More Information

Applying CESM to Paleoclimate is a science problem

- CCSM3 Users Guide: www.cgd.ucar.edu/ccr/paleo/UsersGuide/TECH-NOTE-000-000-000-851.pdf
- Quaternary simulations: Nan Rosenbloom (nanr@ucar.edu)
- Pre-Quaternary simulations: Christine Shields (shields@ucar.edu)