Response of Early Eocene Climate to Greenhouse Gas Forcing - A Model Study with CCSM3

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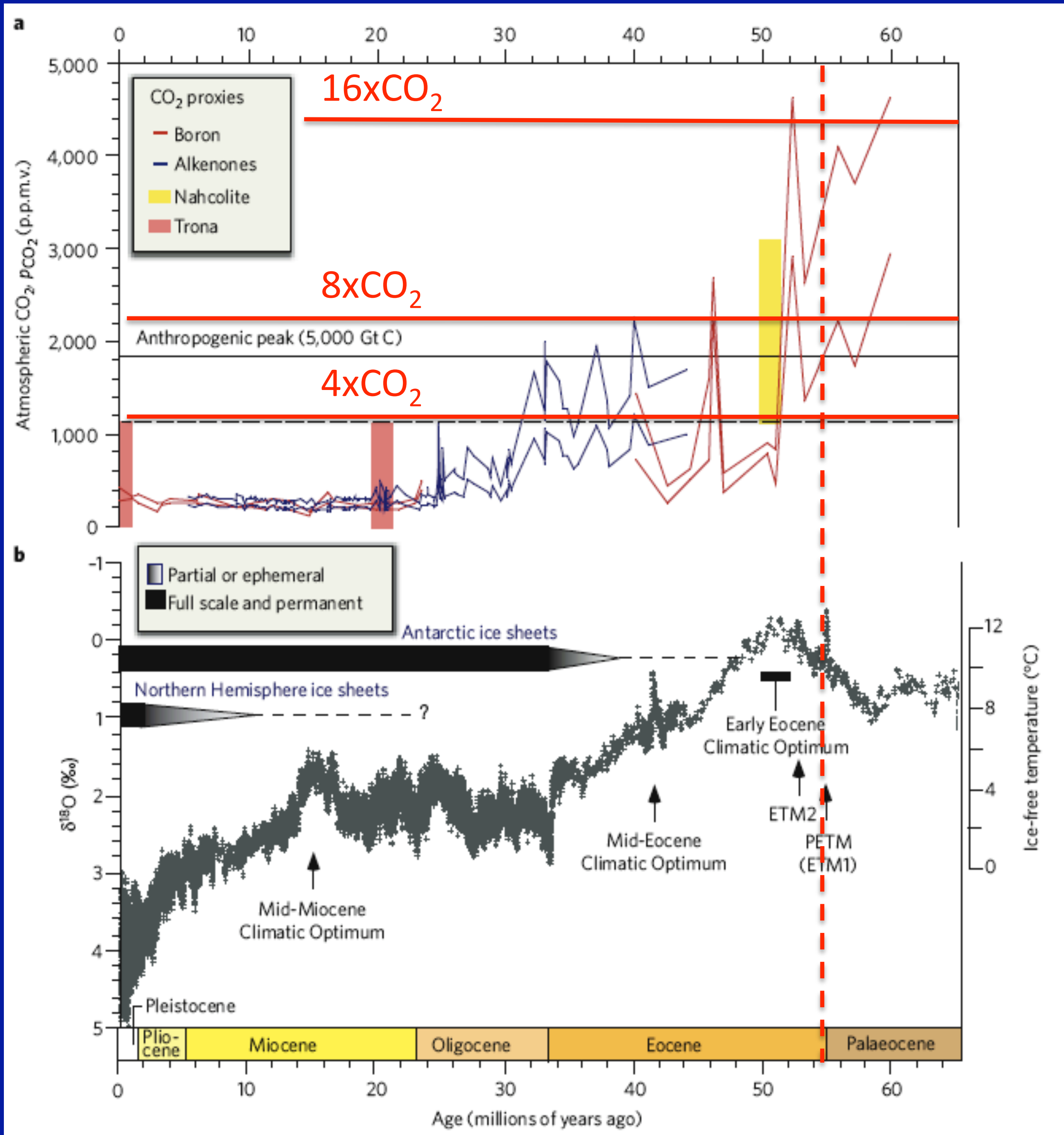
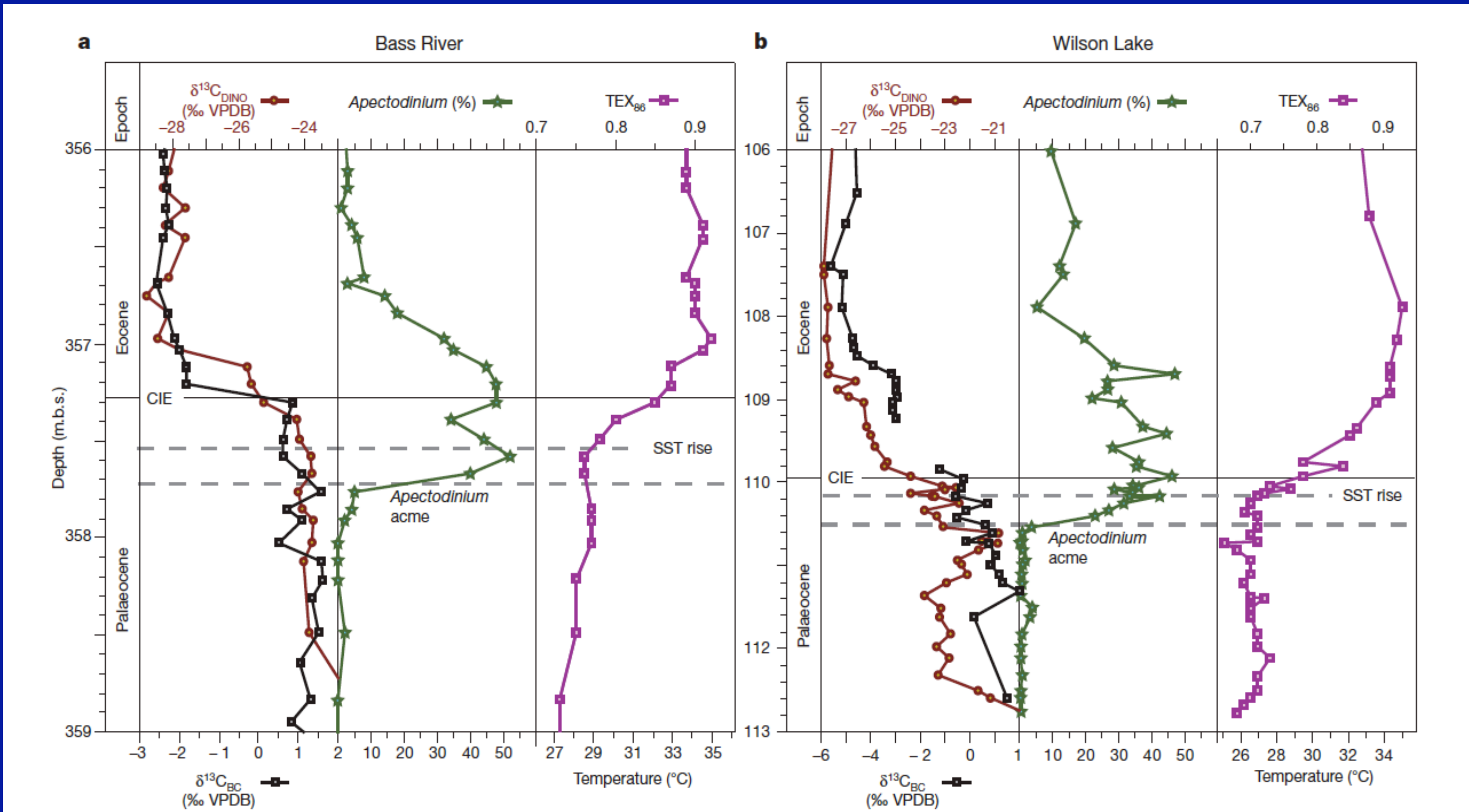
Graphical Support: Chandirka Nagaraj, Vinit Asher



Zachos et al., Nature, 2008

High-Resolution Records Across the Onset of the PETM at the New Jersey Shelf Sites

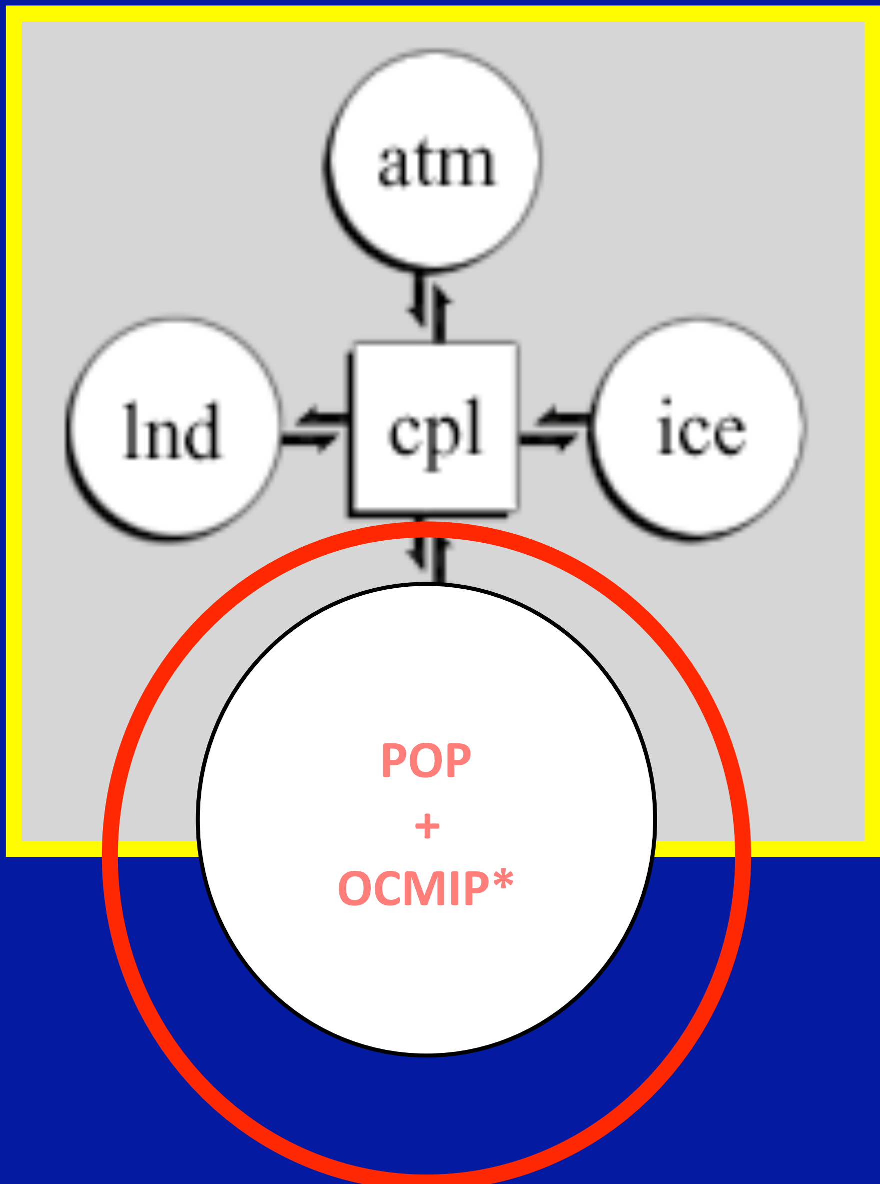


Sluijs et al., Nature, 2007

Objectives

- Could changes in the ocean-atmosphere system have contributed to a warming that could have triggered the PETM?
- How much CO_2 radiative forcing is required to simulate a climate consistent with the sedimentary record?
- Could anoxia have contributed to the extinction of benthic organisms?

CCSM3.0



OCMIP* (Doney et al., 2006)

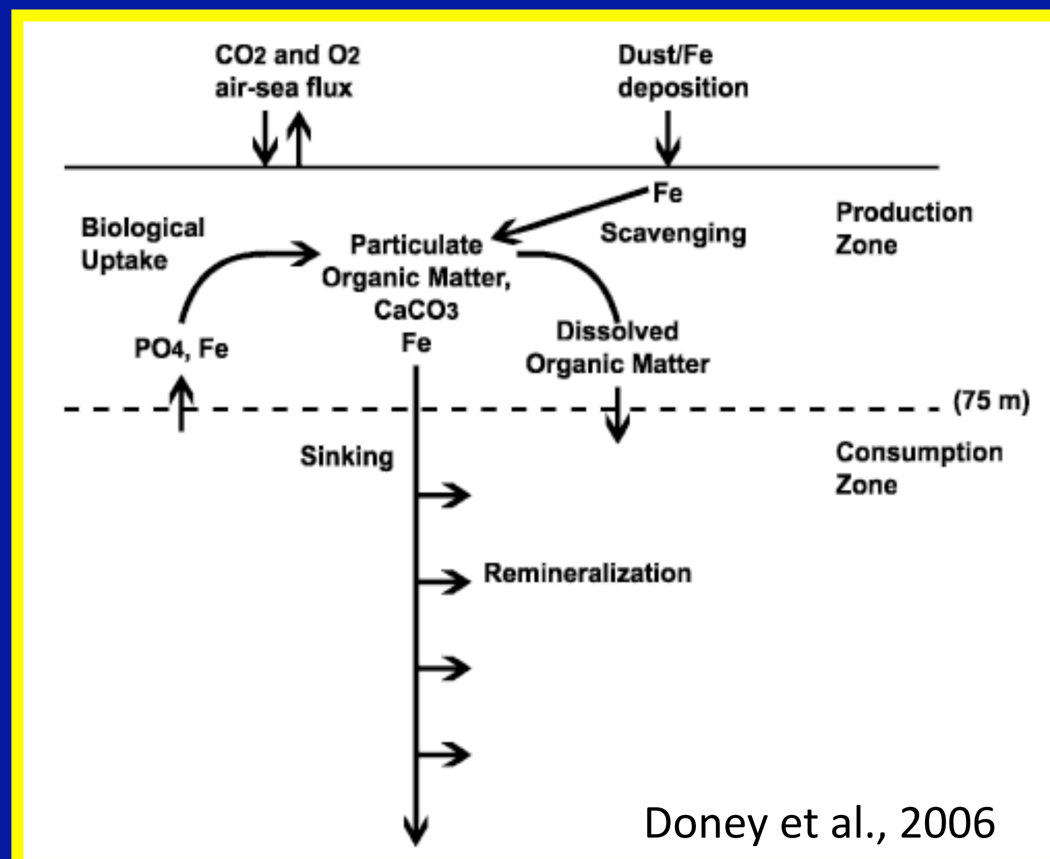
- OCMIP-2 Redfield Ocean Model
- $J_{prod} = F_T * F_N * F_I * B * \max(1, z_{ml}/z_c)$

  $F_T = (T+2)/(T+10)$

  $F_N = \min(PO_4/(PO_4+K_{PO4}), Fe/(Fe+K_{fe}))$

  $FI = I/(I+\kappa_I)$

  $B_{min} = (PO_4, Fe/r_{Fe:PO4})$
- Martin et al. parameterization
- Surface deposit of Fe from atmosphere



Doney et al., 2006

Important Model Parameters for PETM

- Solar Constant:

  1362 W m^{-2} (0.44% reduced from modern Value; Caldeira & Kasting, 1992)

- Orbital Parameters:

  Eccentricity: 0°; Obliquity: 23.5°; Vernal Equinox: 0°

- Greenhouse Gas Concentration:

  CO_2 : 4 x, 8 x, 16 x CO_2 ; CH_4: 0.7 ppmv ;
  N_2O: 0.285 ppmv

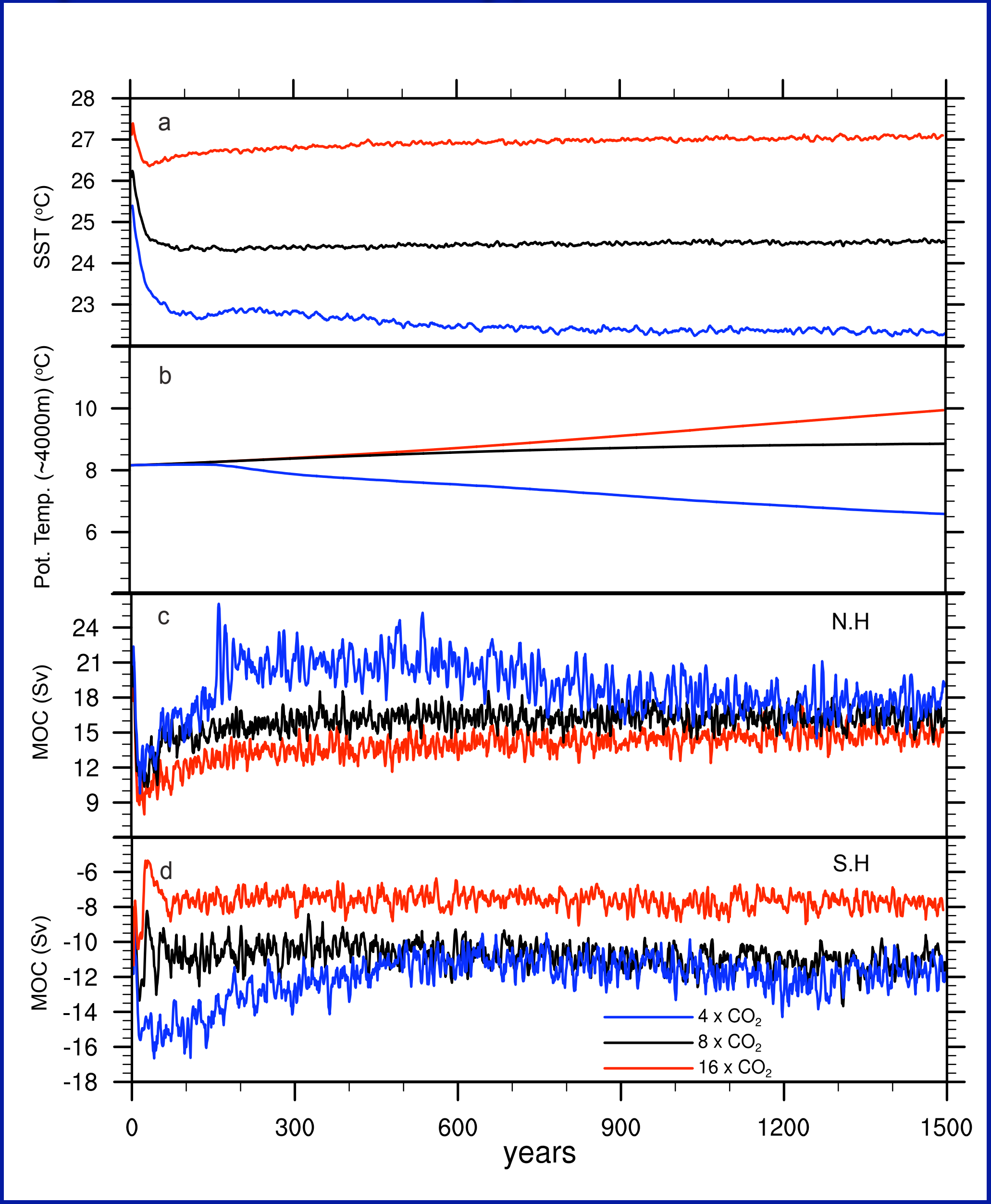
- Vegetation:

  Sewall et al., 2000; Shellito and Sloan, 2006

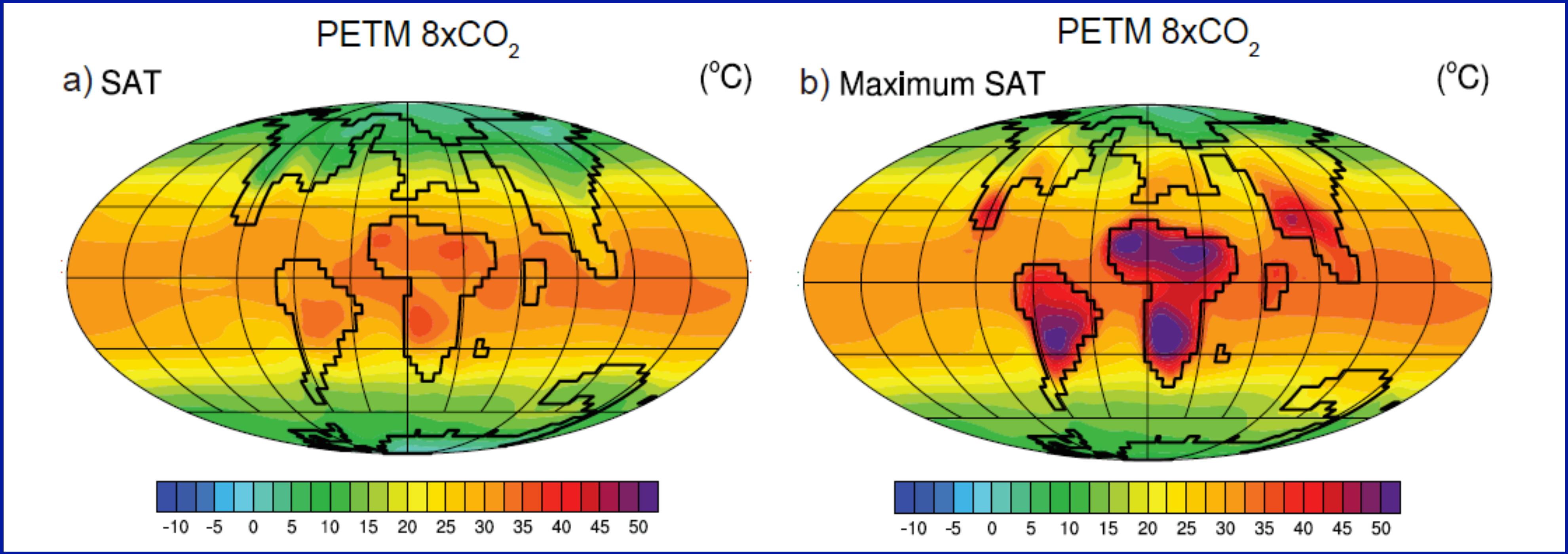
- Topography:

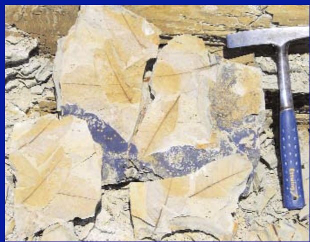
  Sewall et al., 2000; Shellito et al. 2003; Winguth et al., submitted.

Timeseries of SST, Pot. Temperature (~4000 m), and MOC

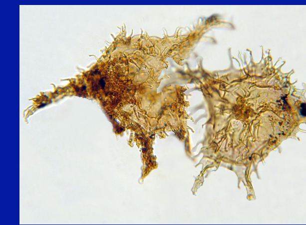


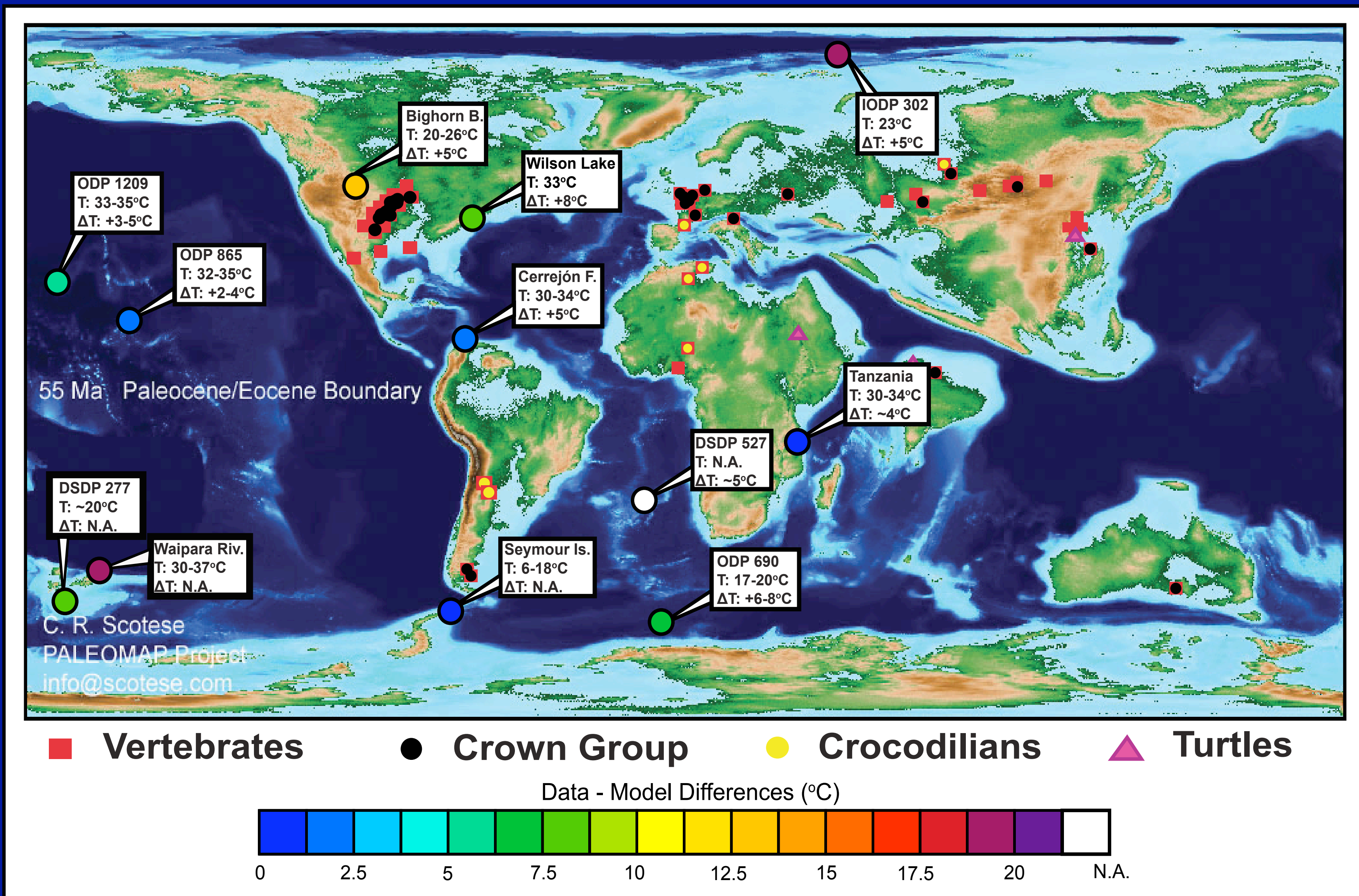
PETM Surface Air Temperature





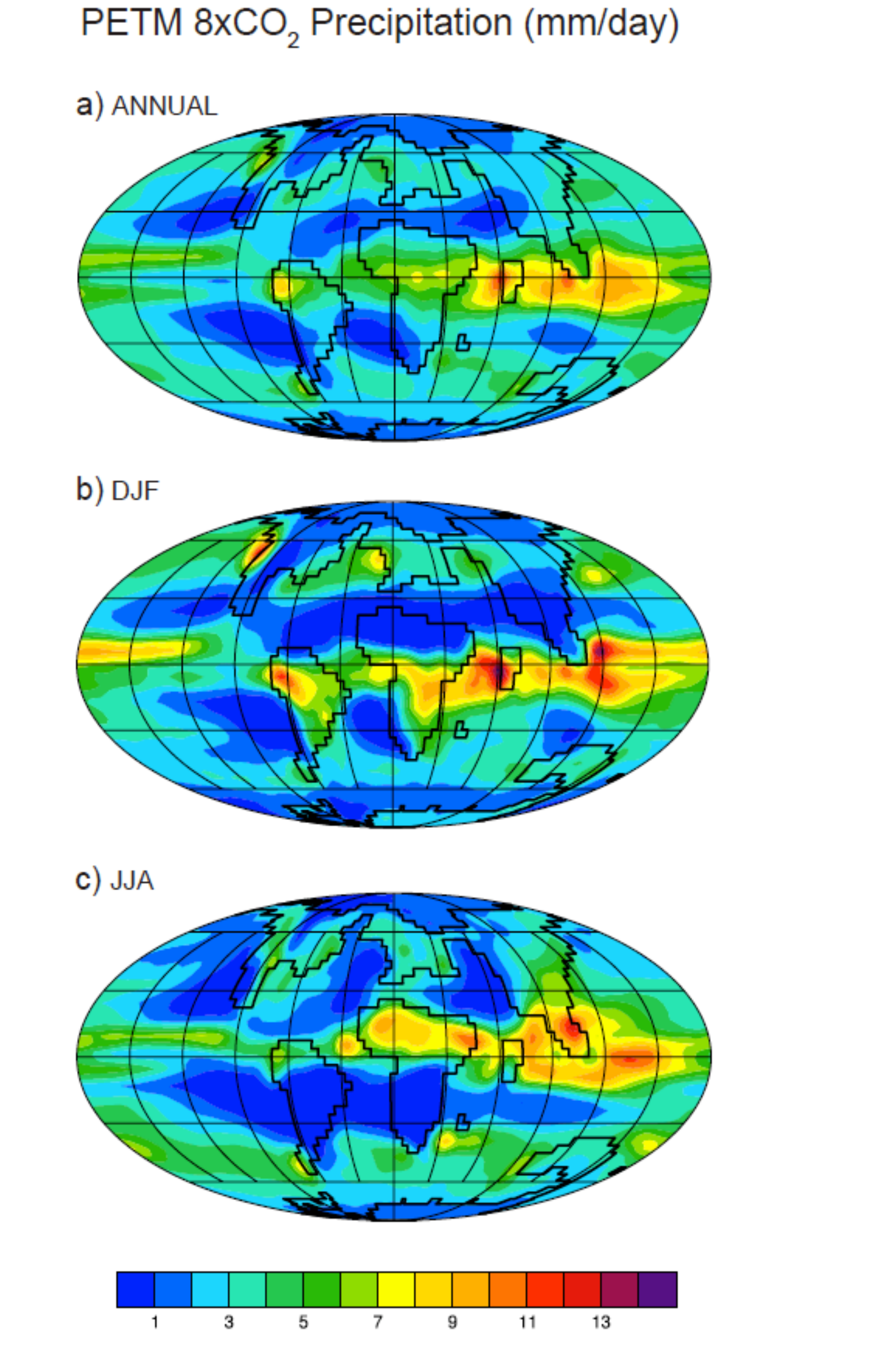
The Paleocene-Eocene Thermal Maximum (55 Ma)



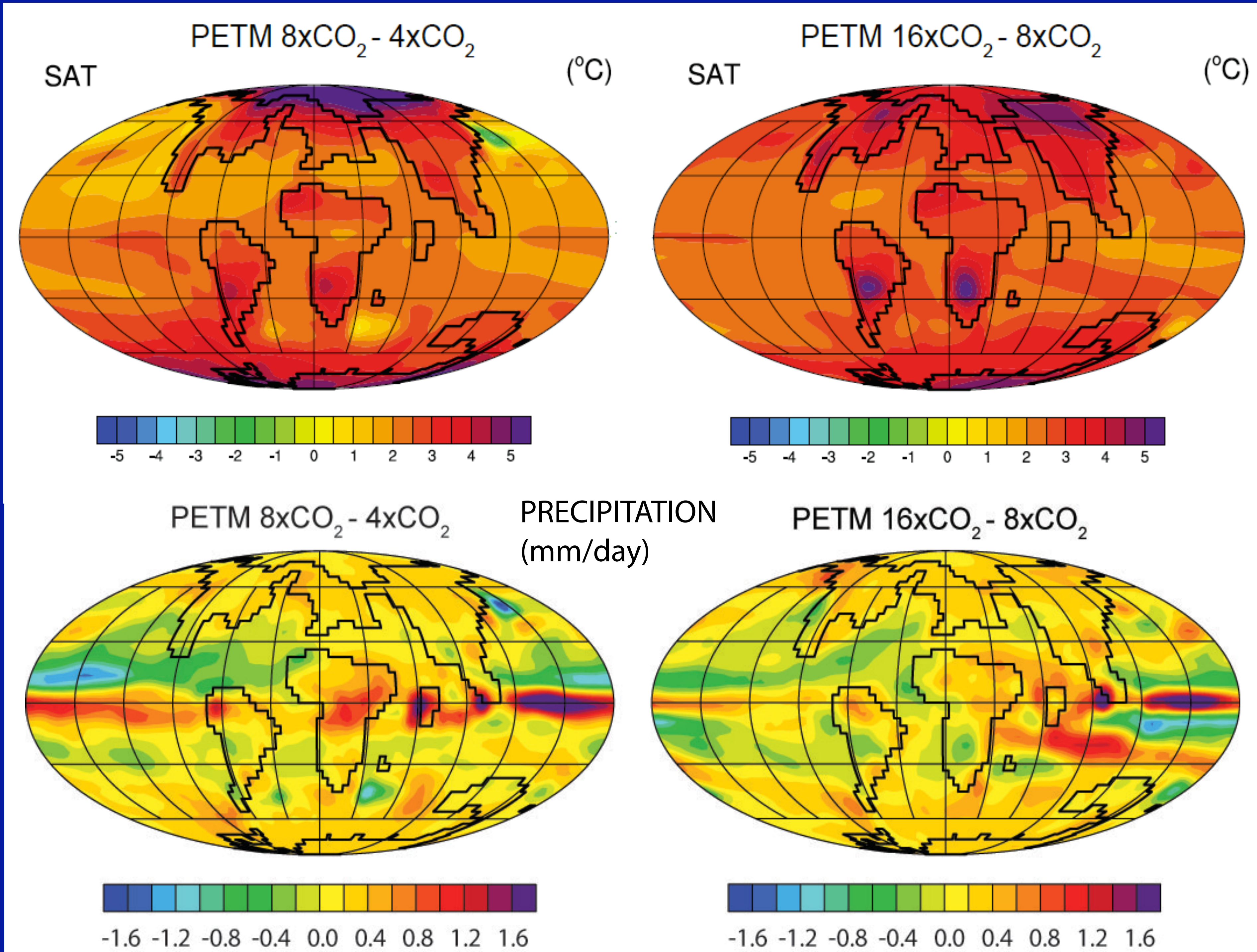


PETM Precipitation

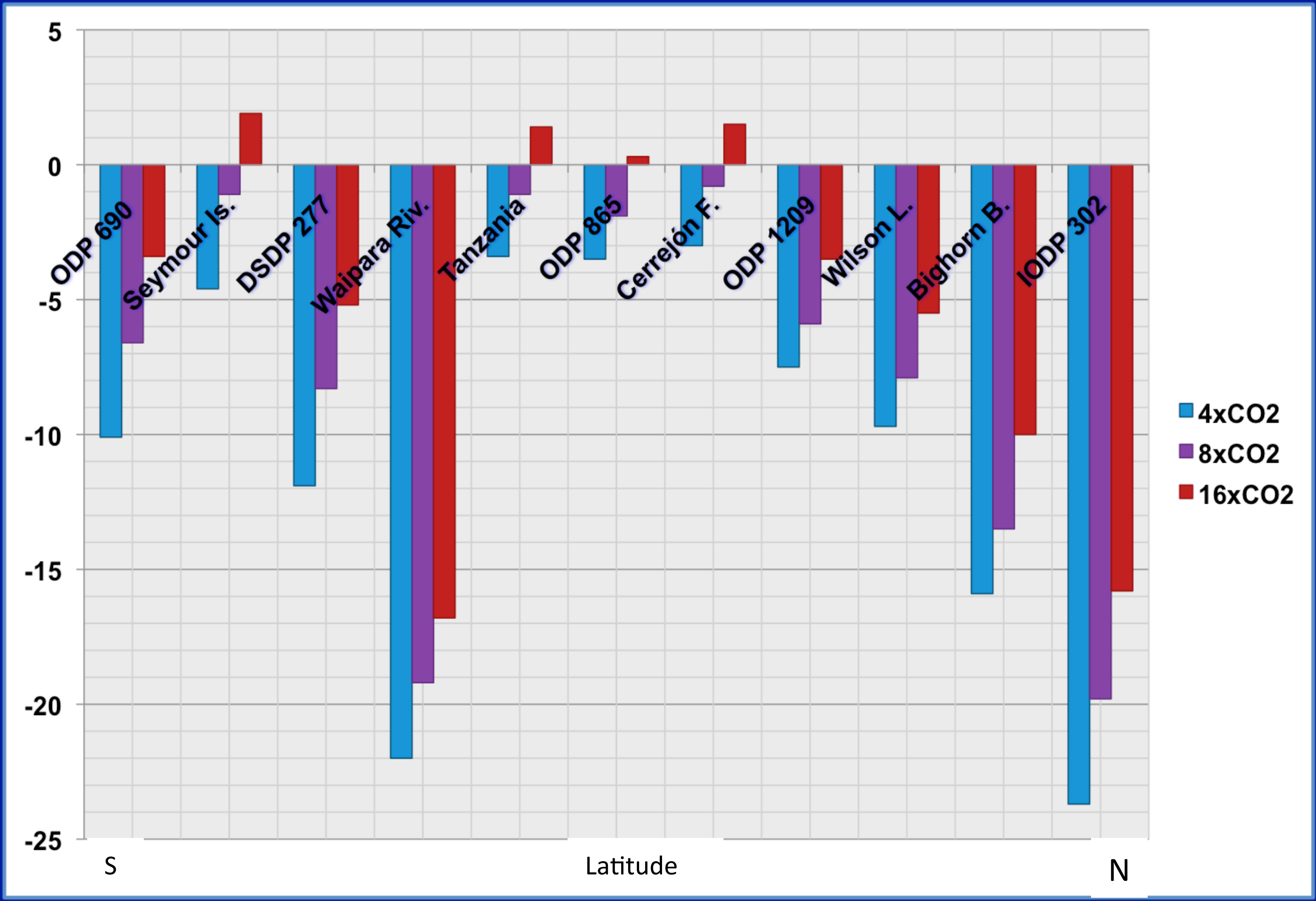
- Northward shift of ITCZ
- Higher then present-day land-to-ocean ratio favor less tropical precipitation
- Higher then present-day greenhouse gases favor higher precipitation
- Strong Seasonal Variability in subtropical Africa and S. America

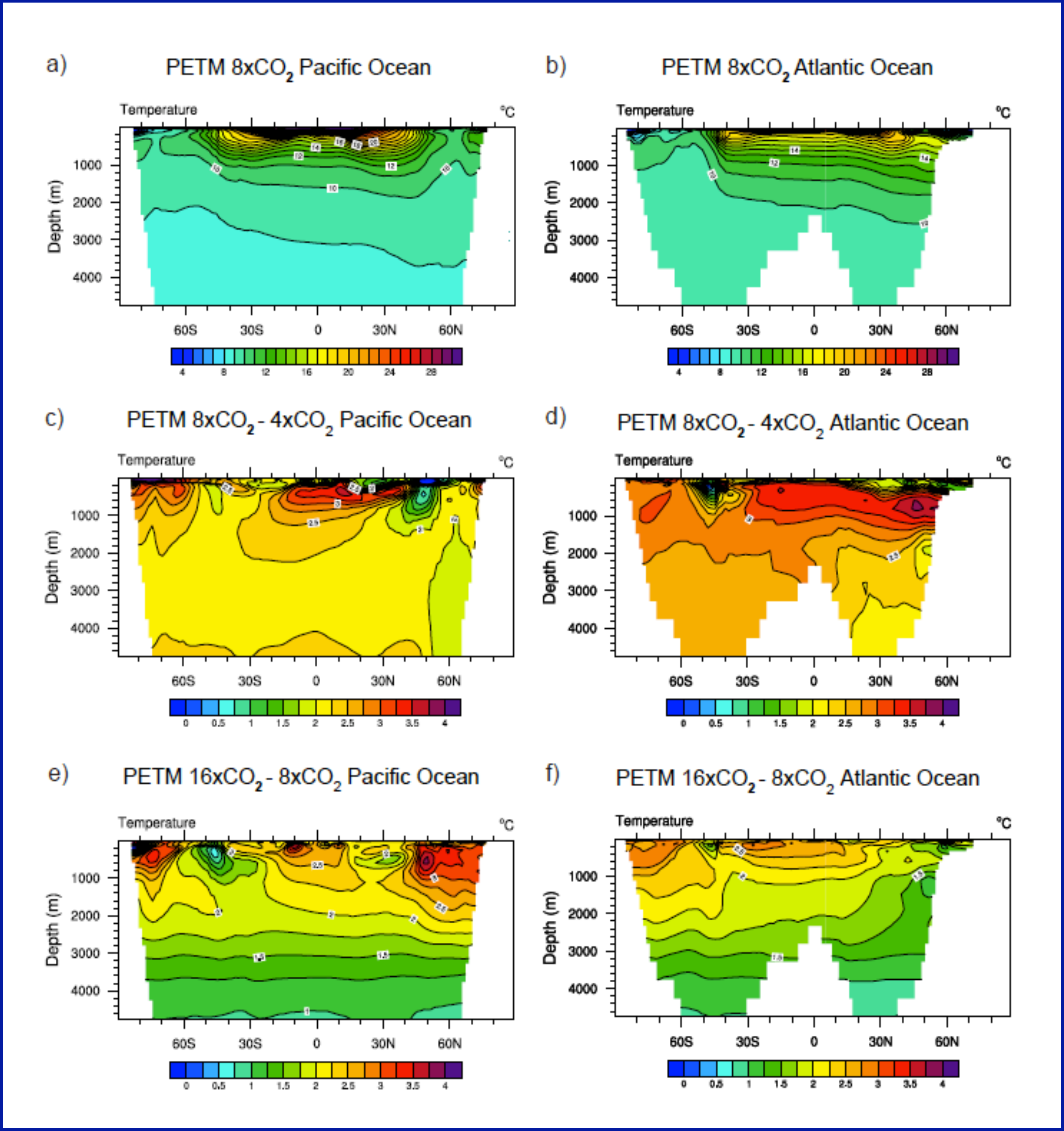


PETM Temperature and Precipitation



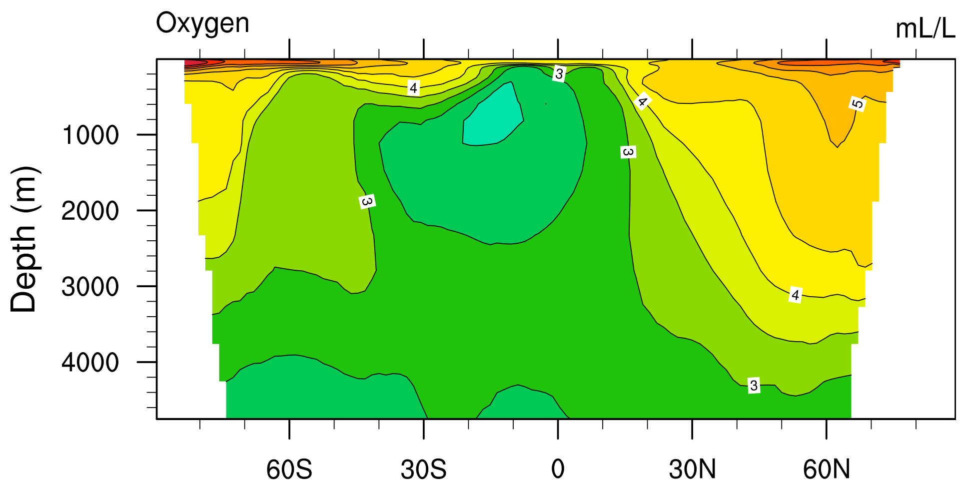
Model-Data Temperature Differences [°C]



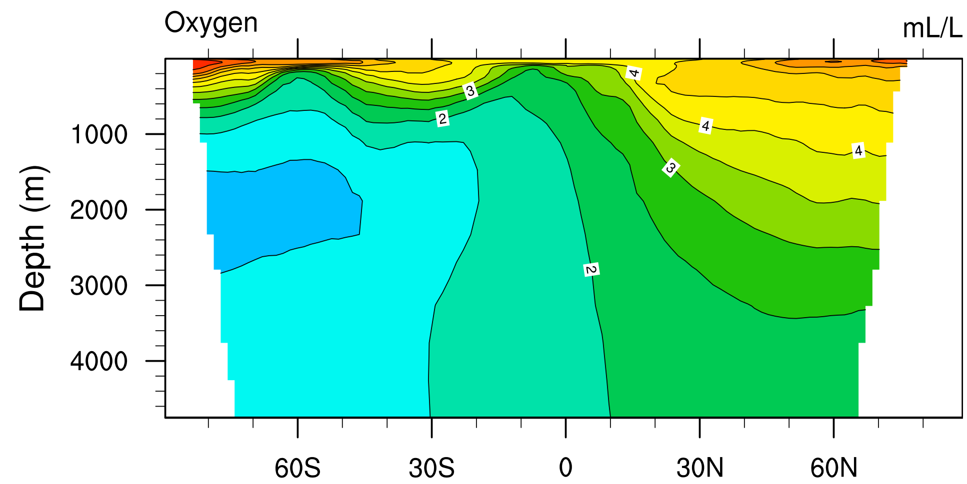

a)
PETM 8xCO_2 Pacific Ocean
b)
PETM 8xCO_2 Atlantic Ocean
c)
PETM 8xCO_2 - 4xCO_2 Pacific Ocean
d)
PETM 8xCO_2 - 4xCO_2 Atlantic Ocean
e)
PETM 16xCO_2 - 8xCO_2 Pacific Ocean
f)
PETM 16xCO_2 - 8xCO_2 Atlantic Ocean
Temperature
°C
Depth (m)
1000
2000
3000
4000
60S
30S
0
30N
60N
4
8
12
16
20
24
28
0
0.5
1
1.5
2
2.5
3
3.5
4

PETM Oxygen Concentration

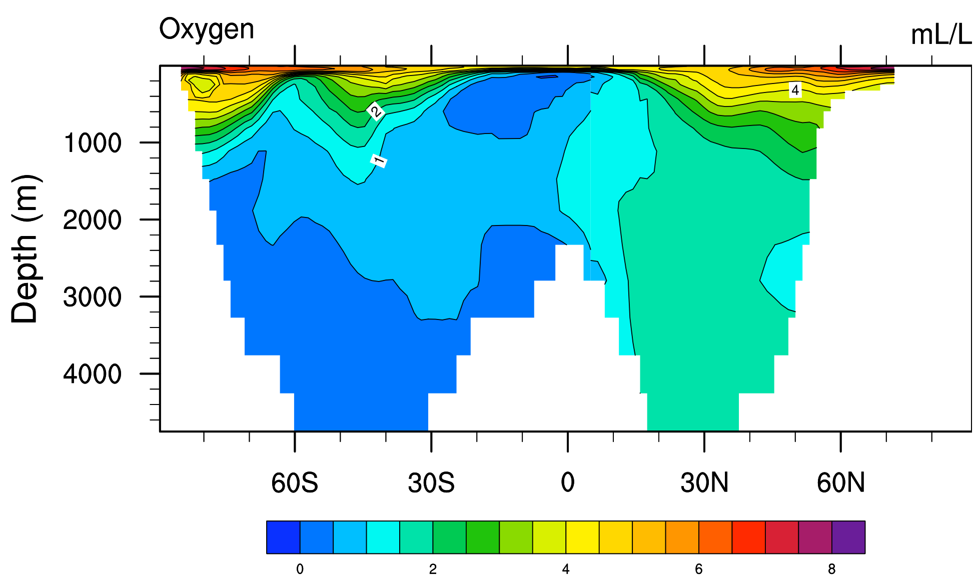
Eocene 8xCO_2 Pacific Ocean



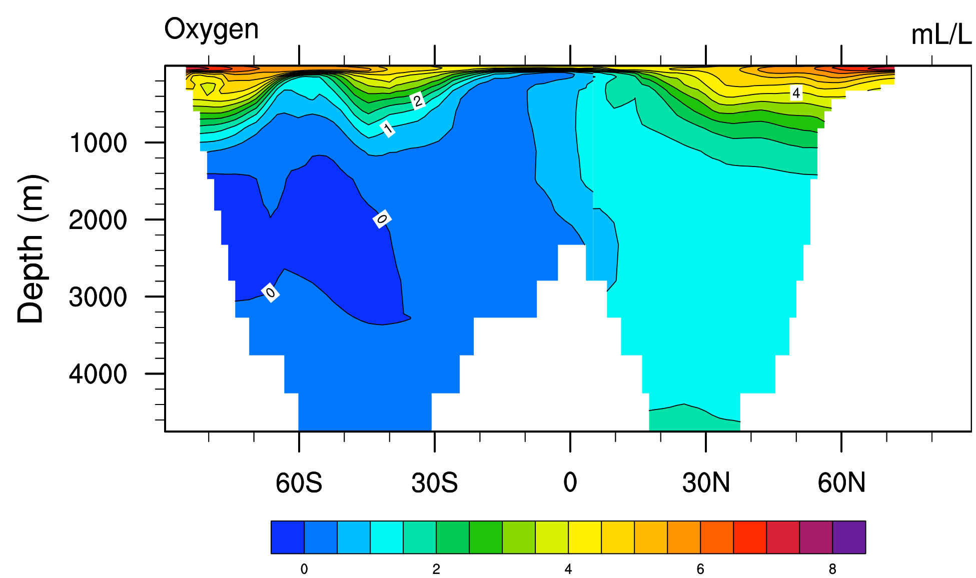
Eocene 16xCO_2 Pacific Ocean



Eocene 8xCO_2 Atlantic Ocean



Eocene 16xCO_2 Atlantic Ocean



Conclusions and Outlook

Conclusions:

1. The warming of the intermediate water masses in response to an initial CO_2 increase could have acted as a trigger for the PETM.
2. The 16xCO_2 PETM simulation provides the best fit to temperature reconstructions.
3. Anoxia in the deep-sea could have contributed to the extinction of benthic organisms.

Future Outlook:

A higher resolution simulation would provide a more realistic description of the exchange between climatically relevant seaways (Drake Passage, Arctic, Tethys, Panama Passage).