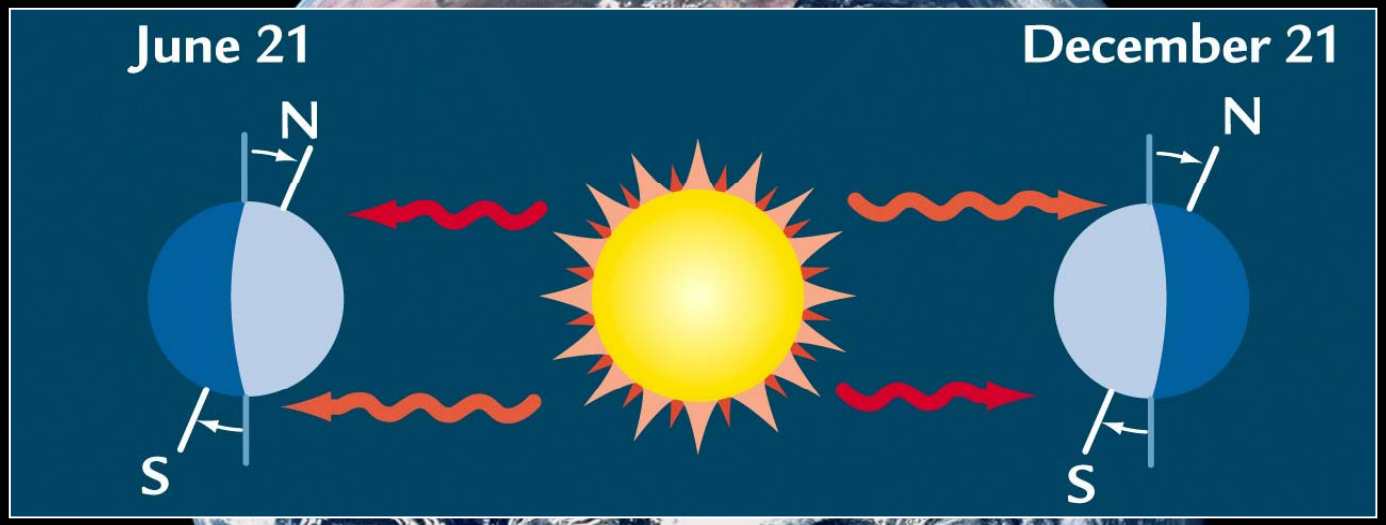
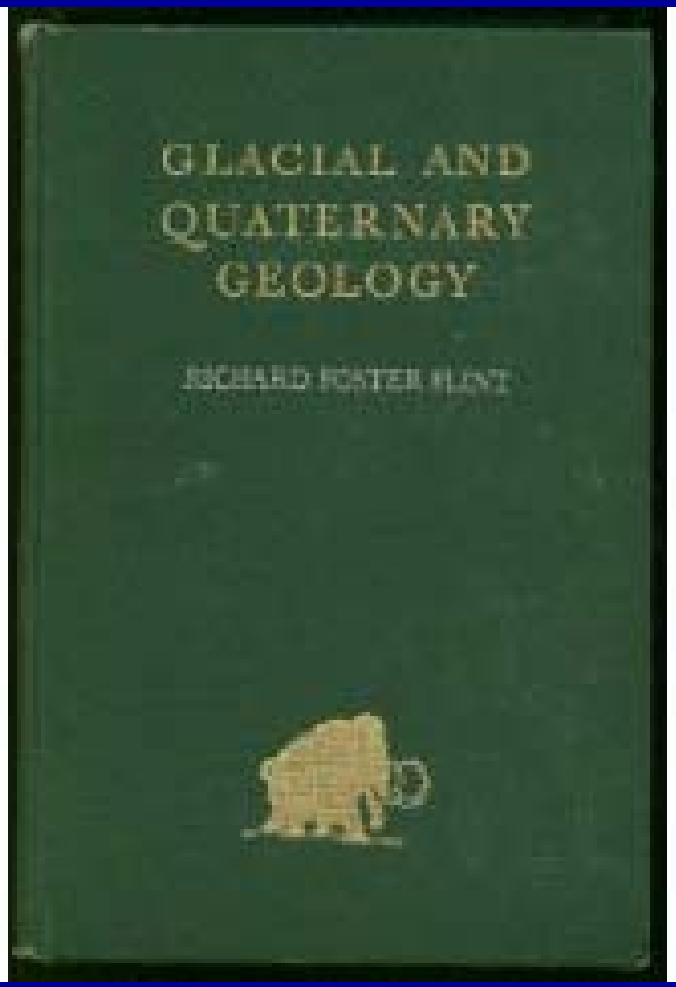
THE ICE AGE CLIMATE EXPERIMENT

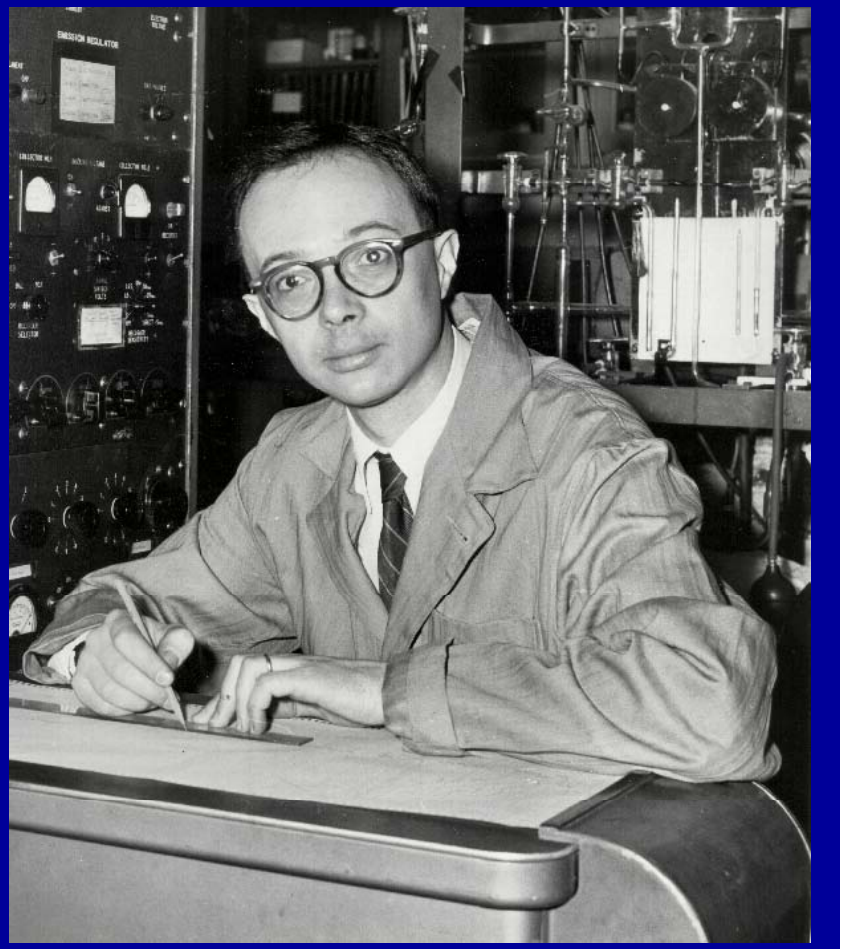


T. Herbert Brown Univ.
L. Cleaveland Luther College
K. Lawrence Lafayette College
Z. Liu U. Hong Kong

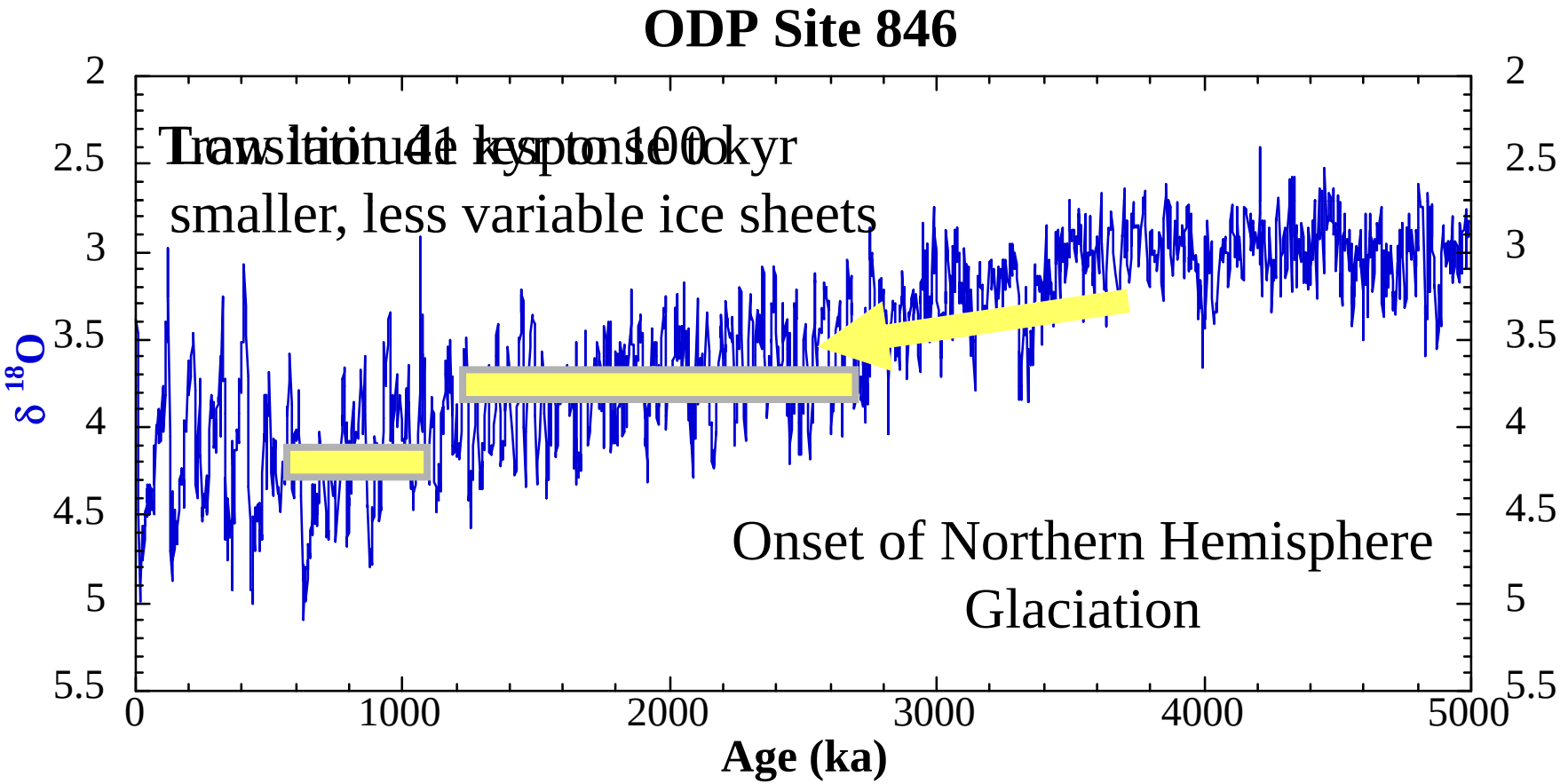


FLINT: ON LAND

EMILIANI: TO THE SEA

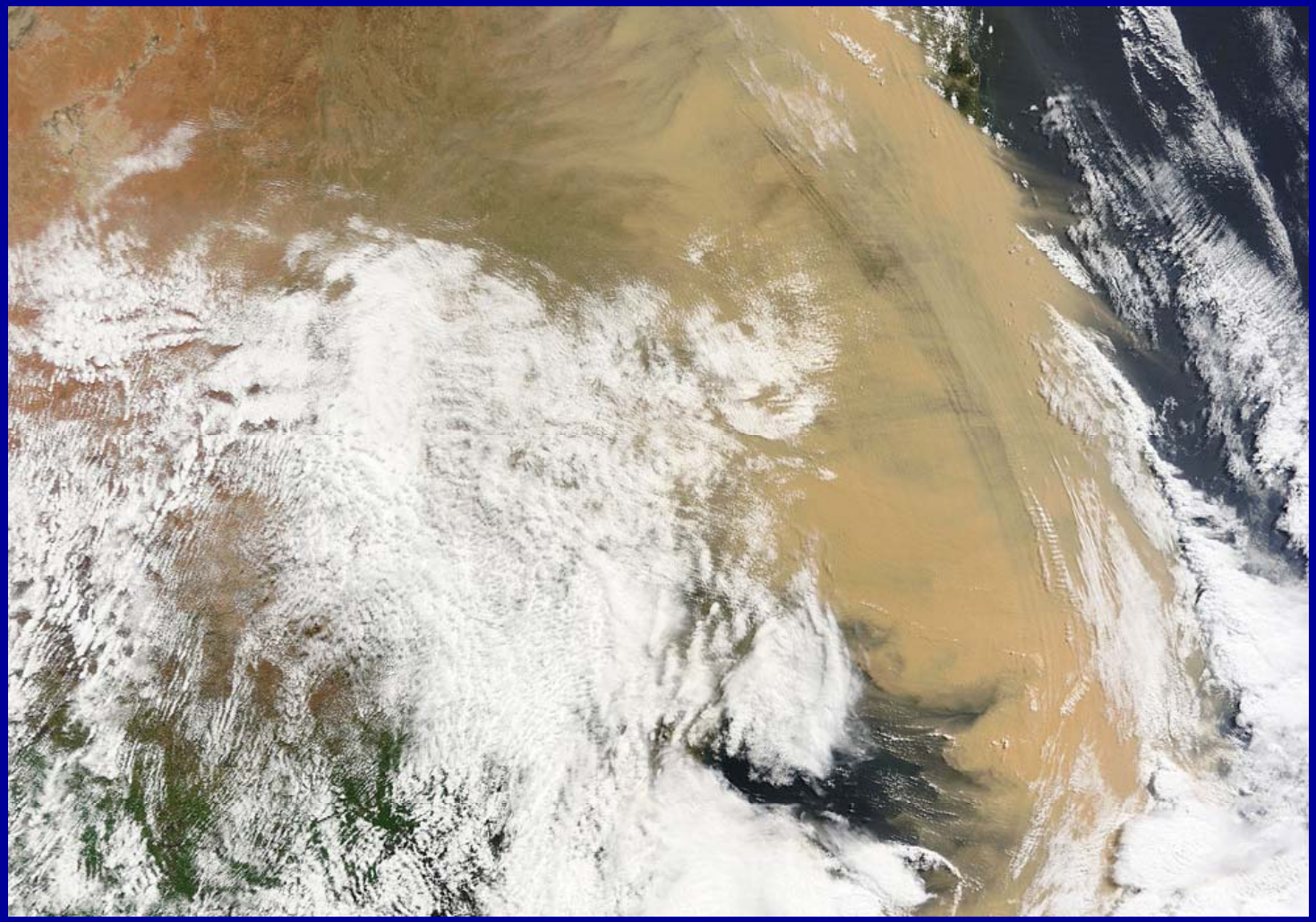


The Plio-Pleistocene Climate Transition

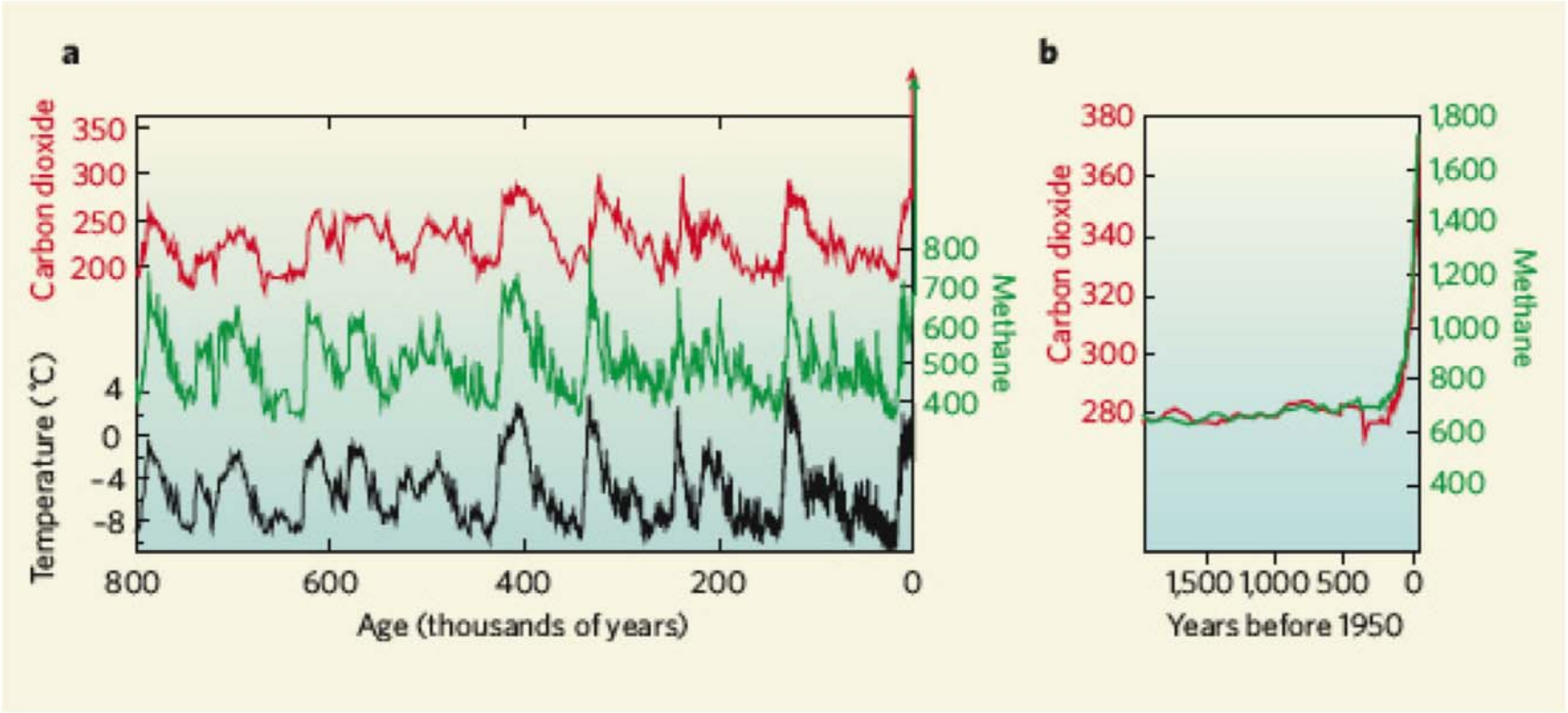


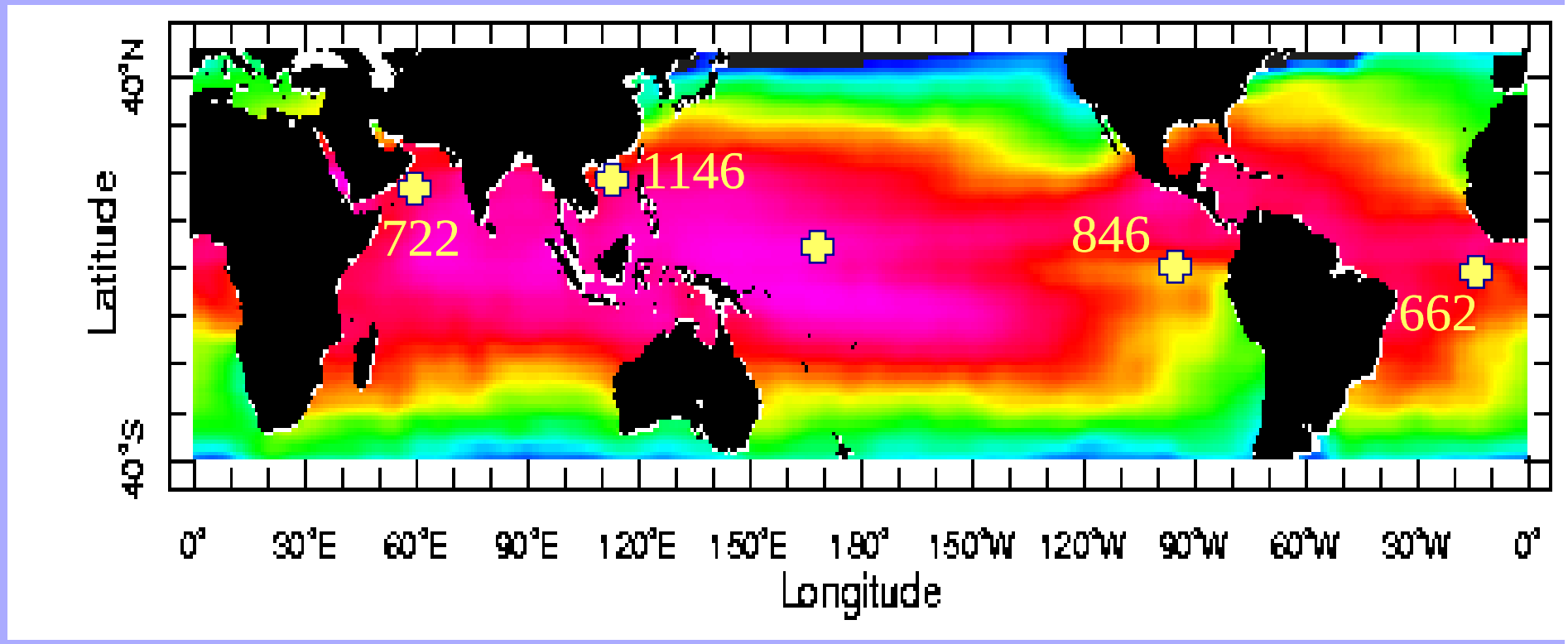
IT'S ALL ABOUT FEEDBACKS: Albedo

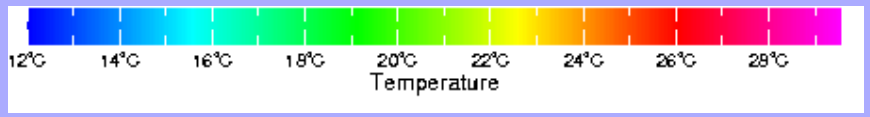
IT'S ALL ABOUT FEEDBACKS: Dust



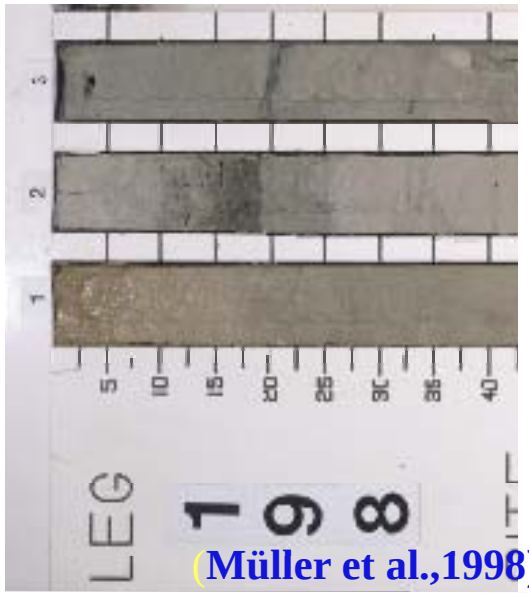
IT'S ALL ABOUT FEEDBACKS: CO_2 & G.G.



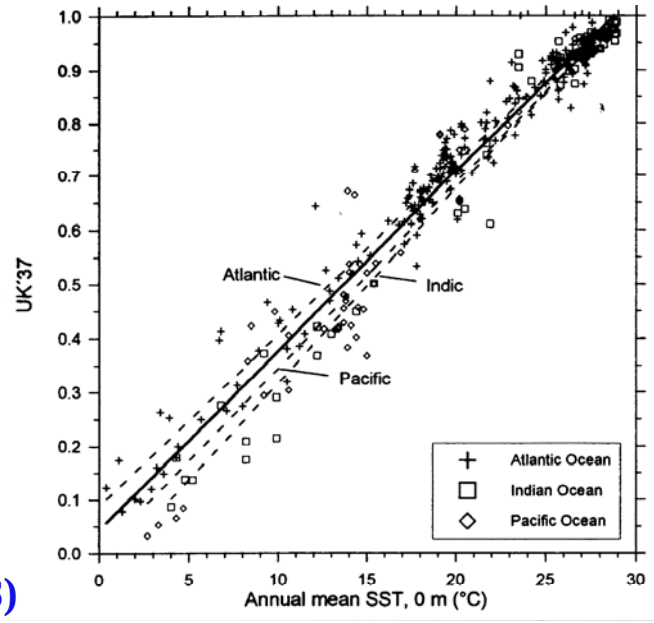


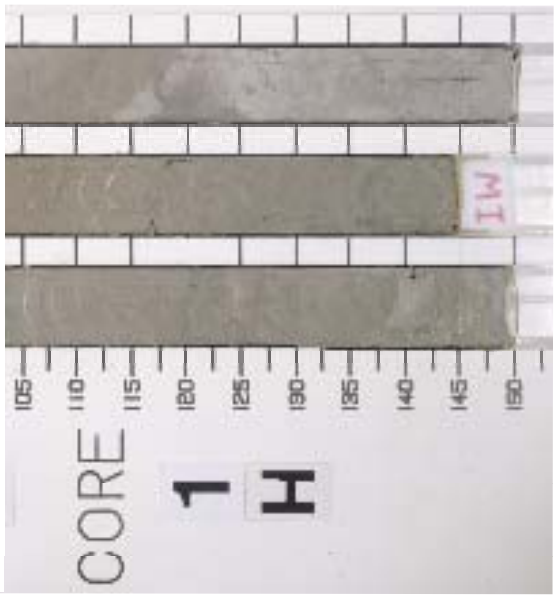


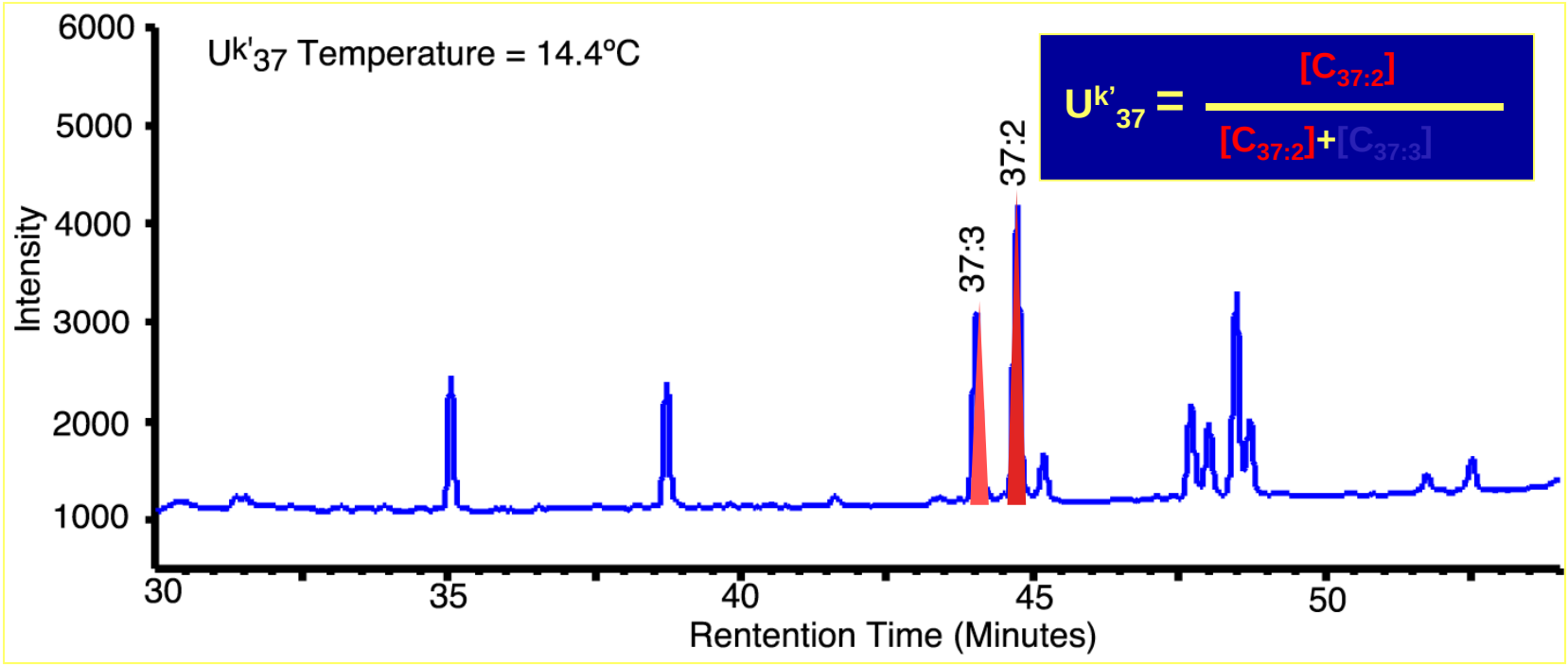
From Levitus Ocean Atlas (1994)



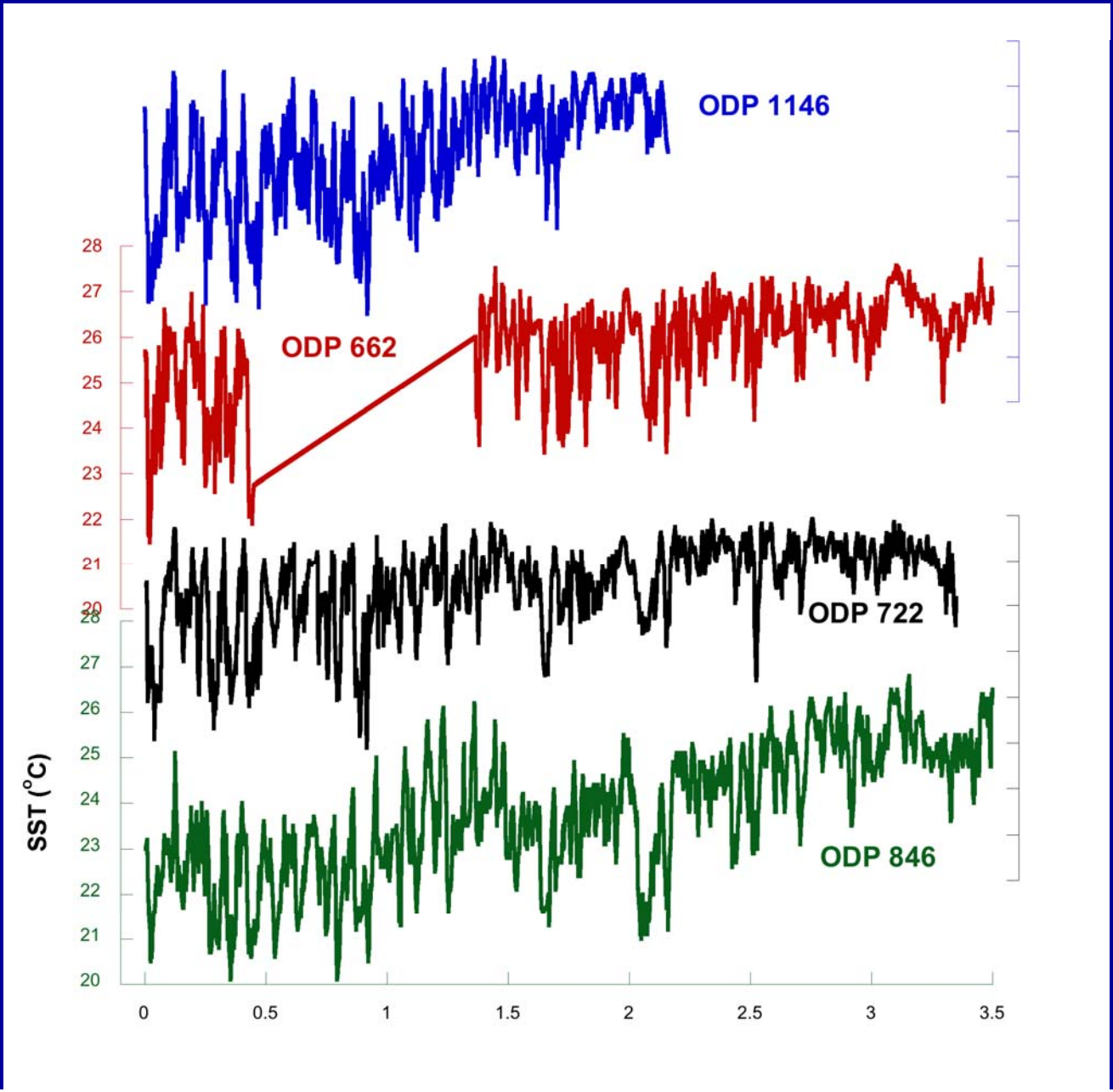
(Müller et al.,1998)



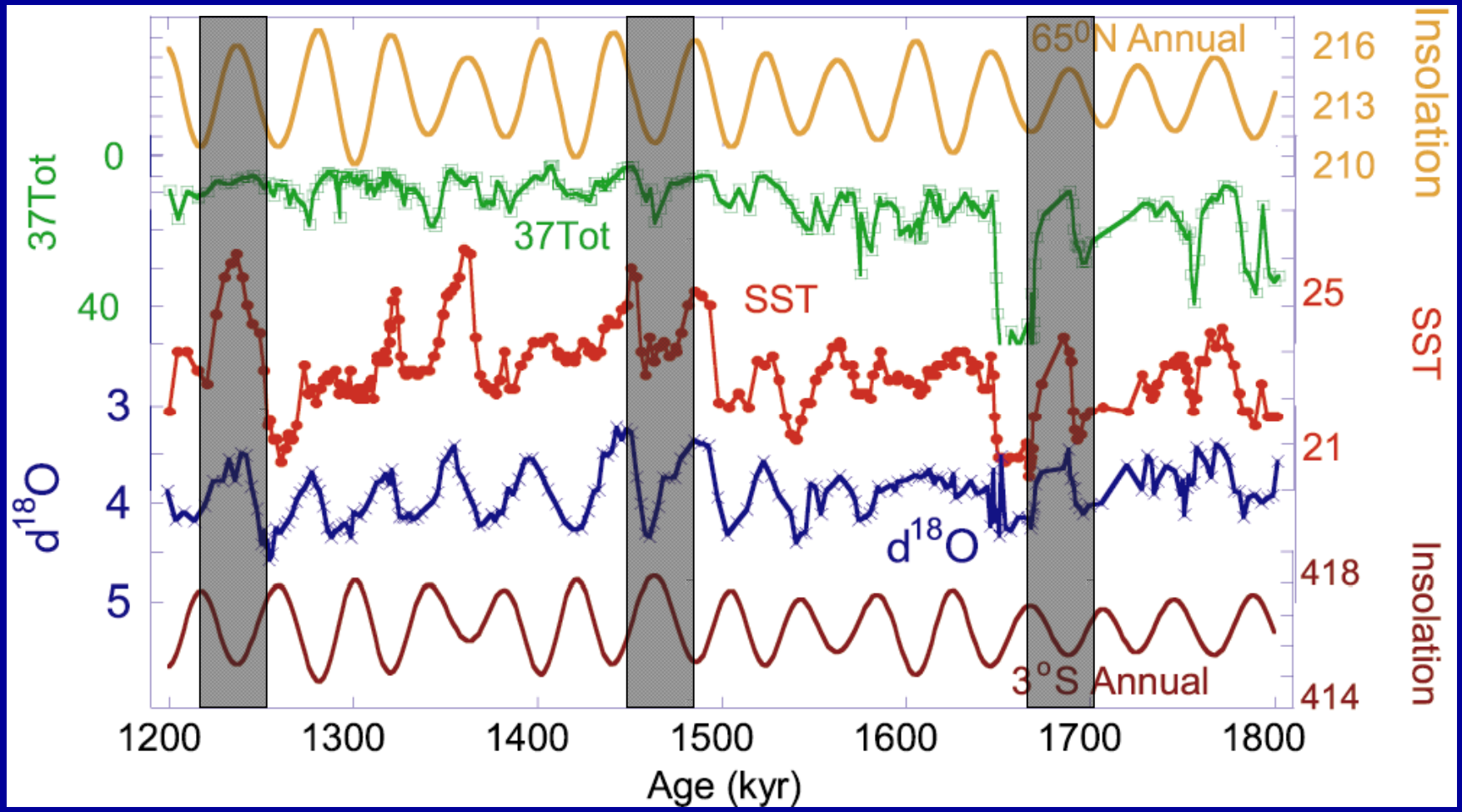




SST CHANGE REALLY SIMILAR!

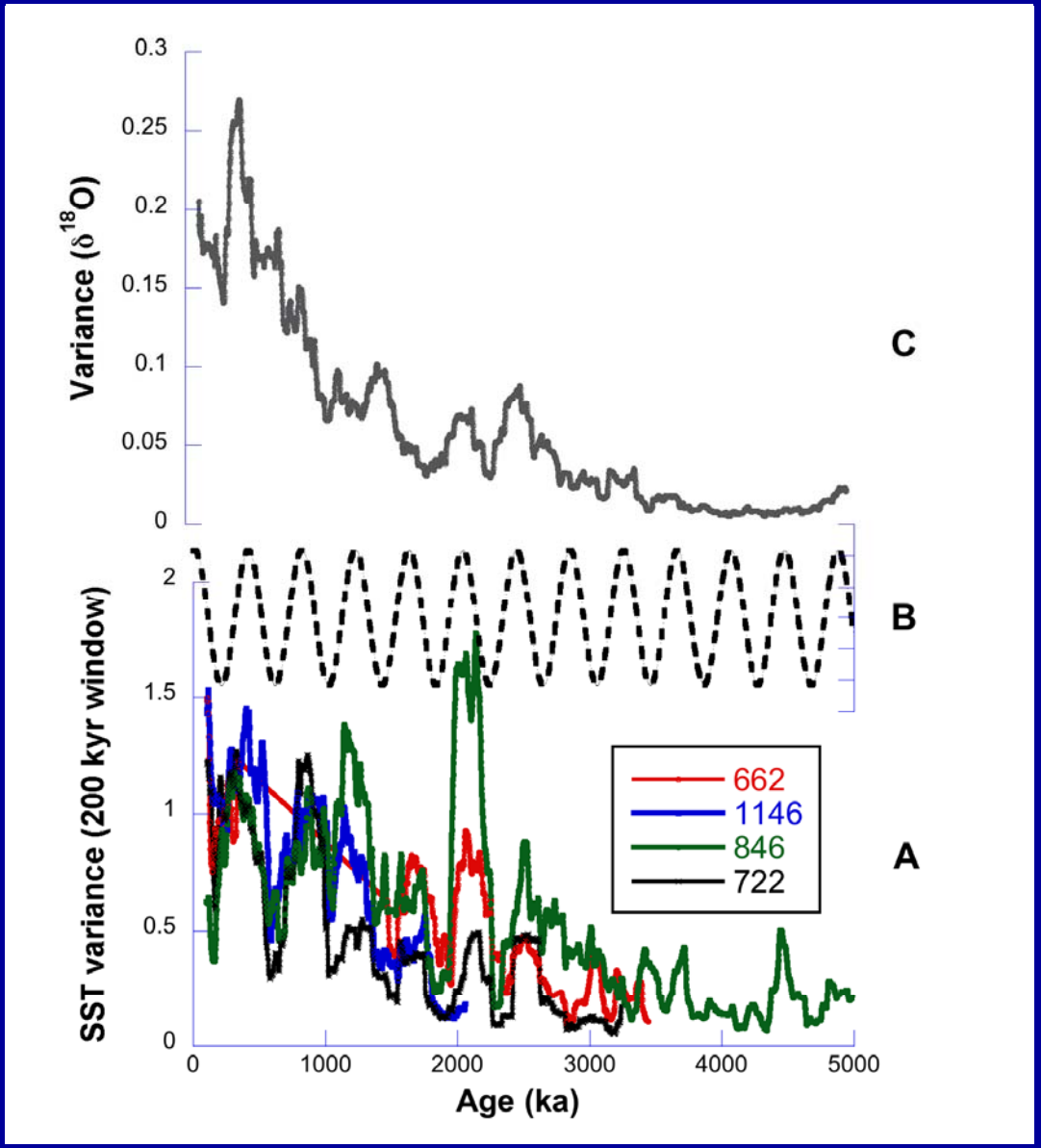


SST VARIATIONS OUT OF PHASE W/ TROPICAL FORCING!

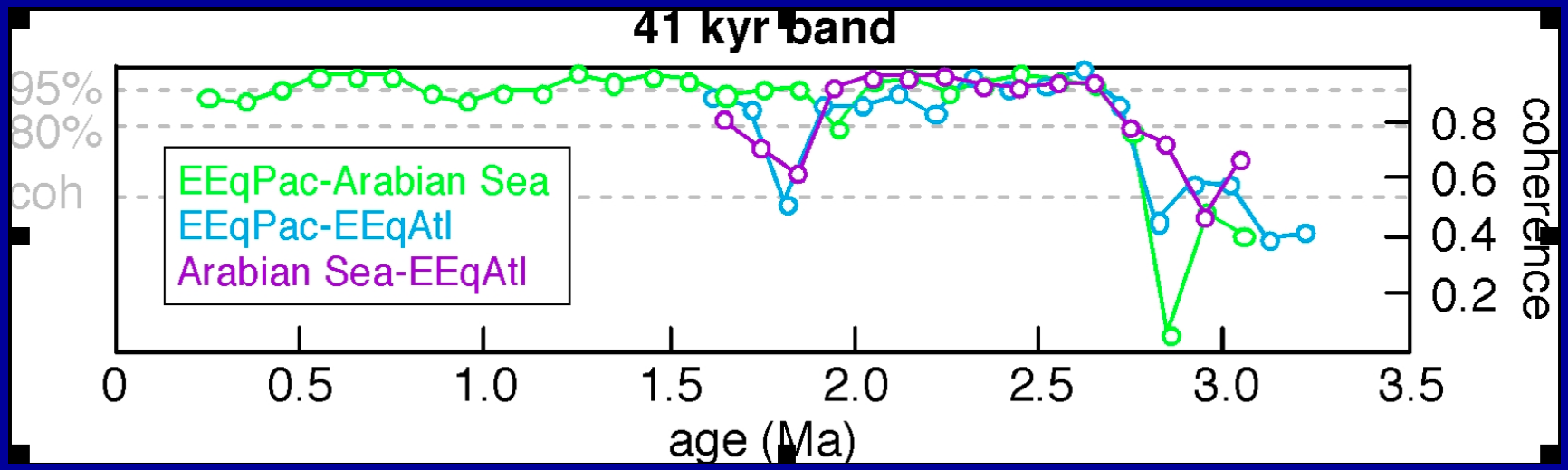


(Liu and Herbert, 2004)

SST VARIANCE INCREASES EXPONENTIALLY



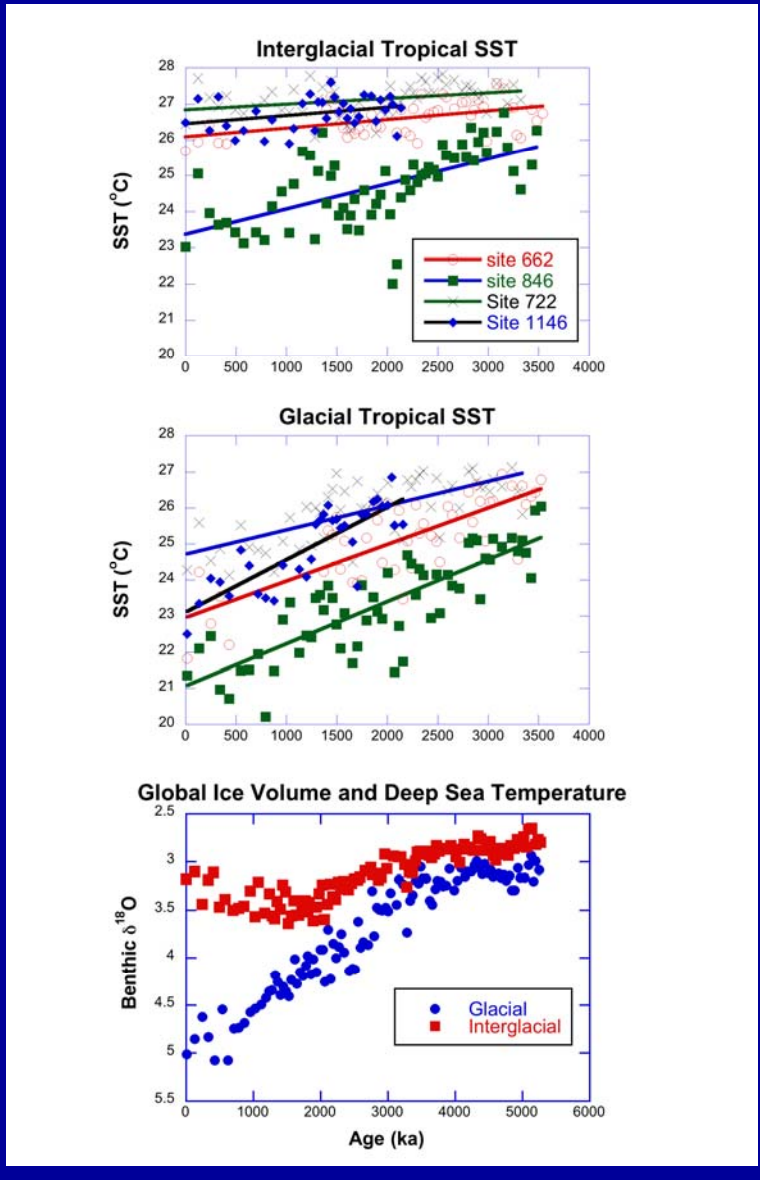
SST VARIATIONS BECOME COHERENT AT ~2.7 Ma!



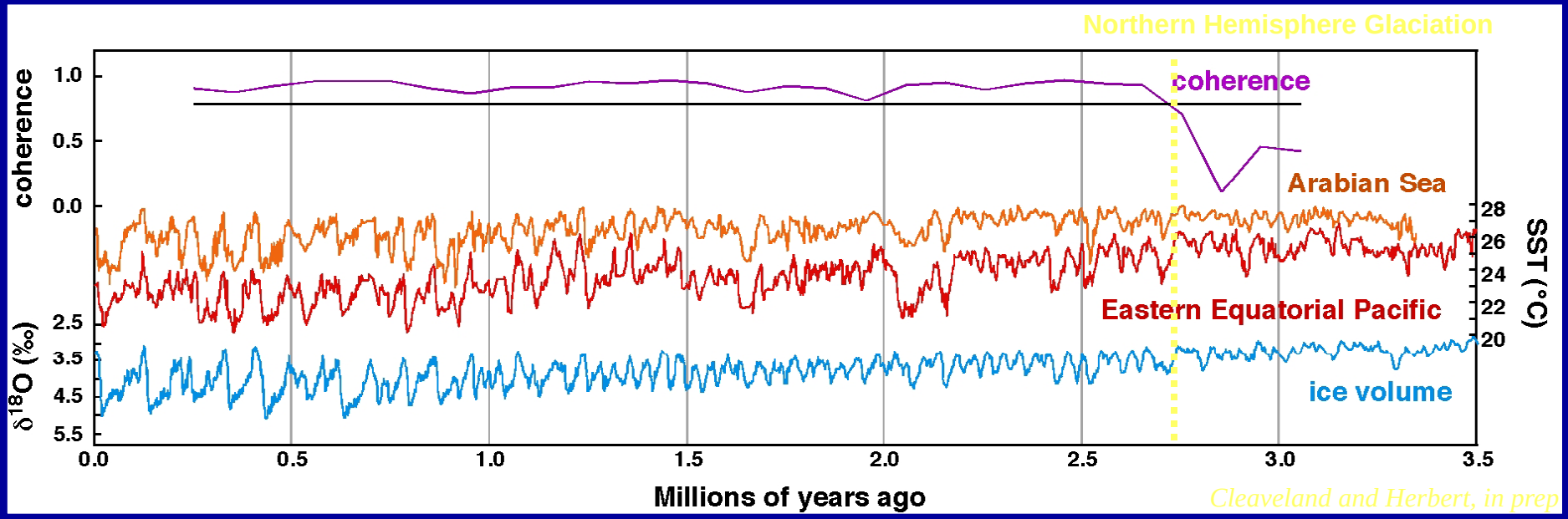
The CO_2-Ice Age Connection

- Tropical SST strongly linked to "high latitude" $\delta^{18}O$ signal, last 2.7 Ma
- 41 kyr response can't originate in tropics
- 41 kyr response not likely driven by thermocline processes -> atmosphere
- "Memory" component stronger than for $\delta^{18}O$, suggests biogeochemical cycle control
- Key "innovation" involved coupling of N. Hemisphere ice sheet growth to CO_2, other G.G. for last ~2.7 Ma on orbital to ~400 kyr time scales
- Did CO_2, G.G. drive the long-term trend, past 3.5 Ma?

ICE AGE/SST EVOLUTION HIGHLY ASYMMETRICAL

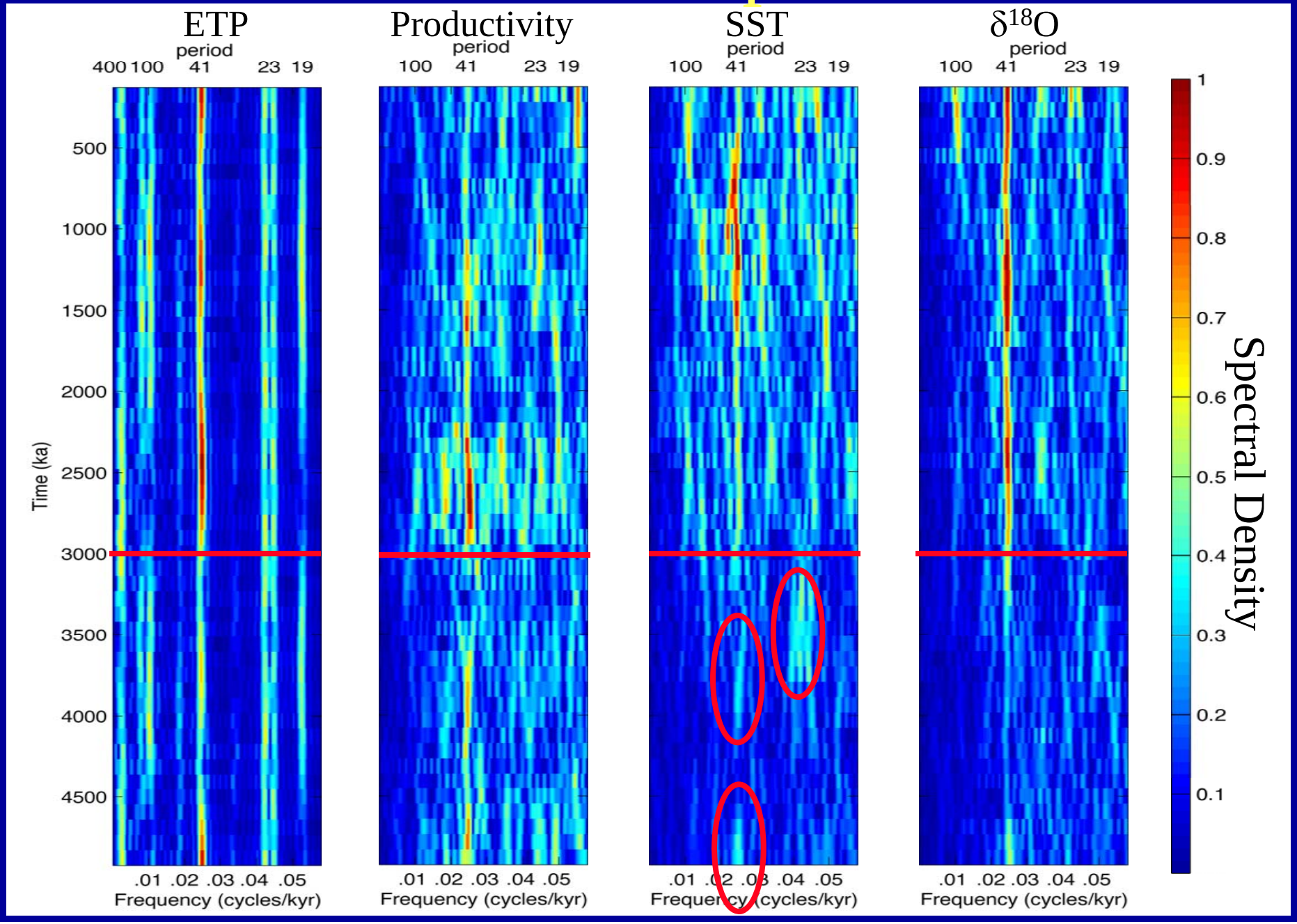


Future work

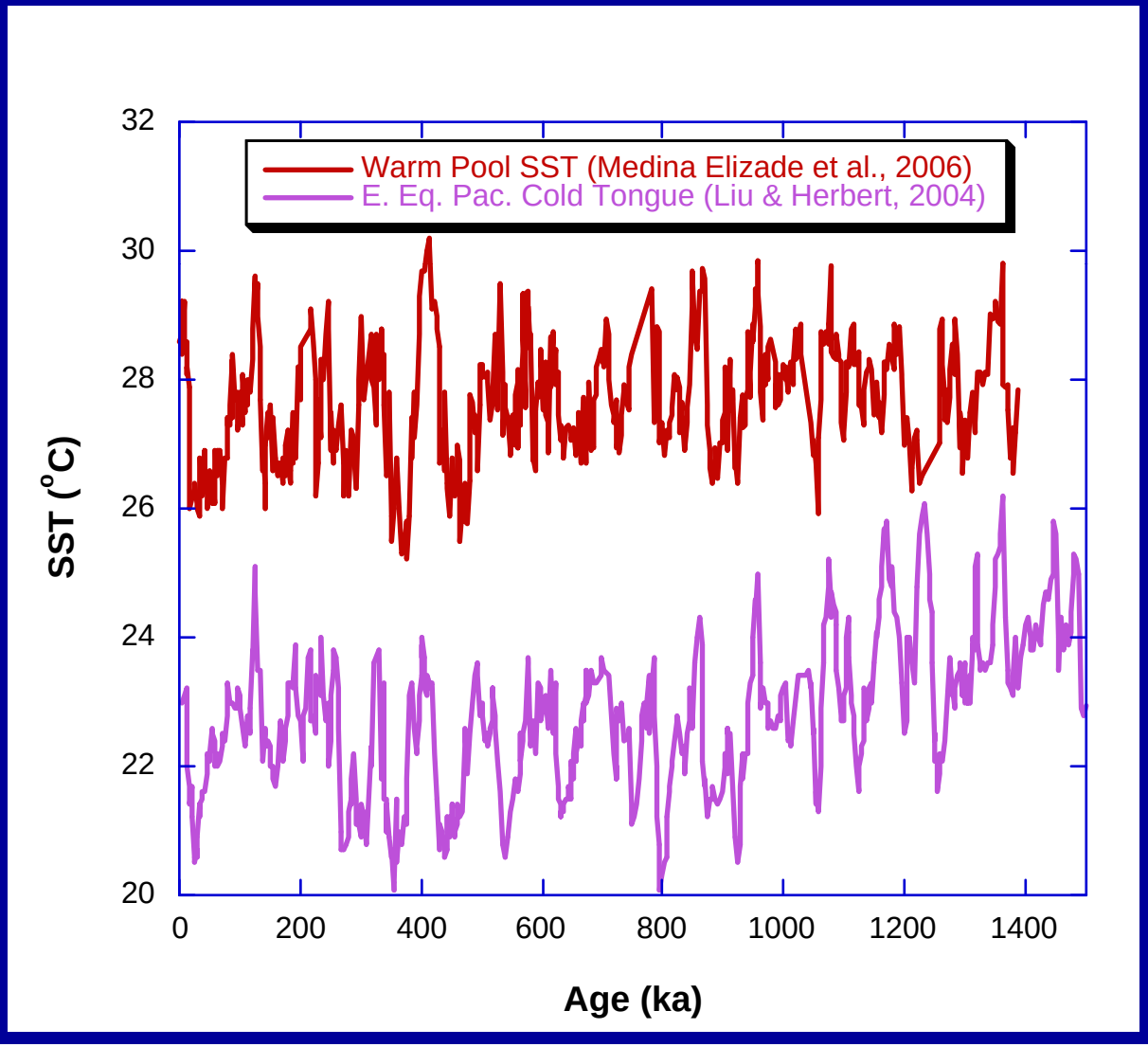


- ocean temperature evolution of the last ~5 million years
  - how do temperature changes propagate throughout the climate system?
  - how closely are different regions of the ocean linked?
- what's happening in the southern hemisphere?

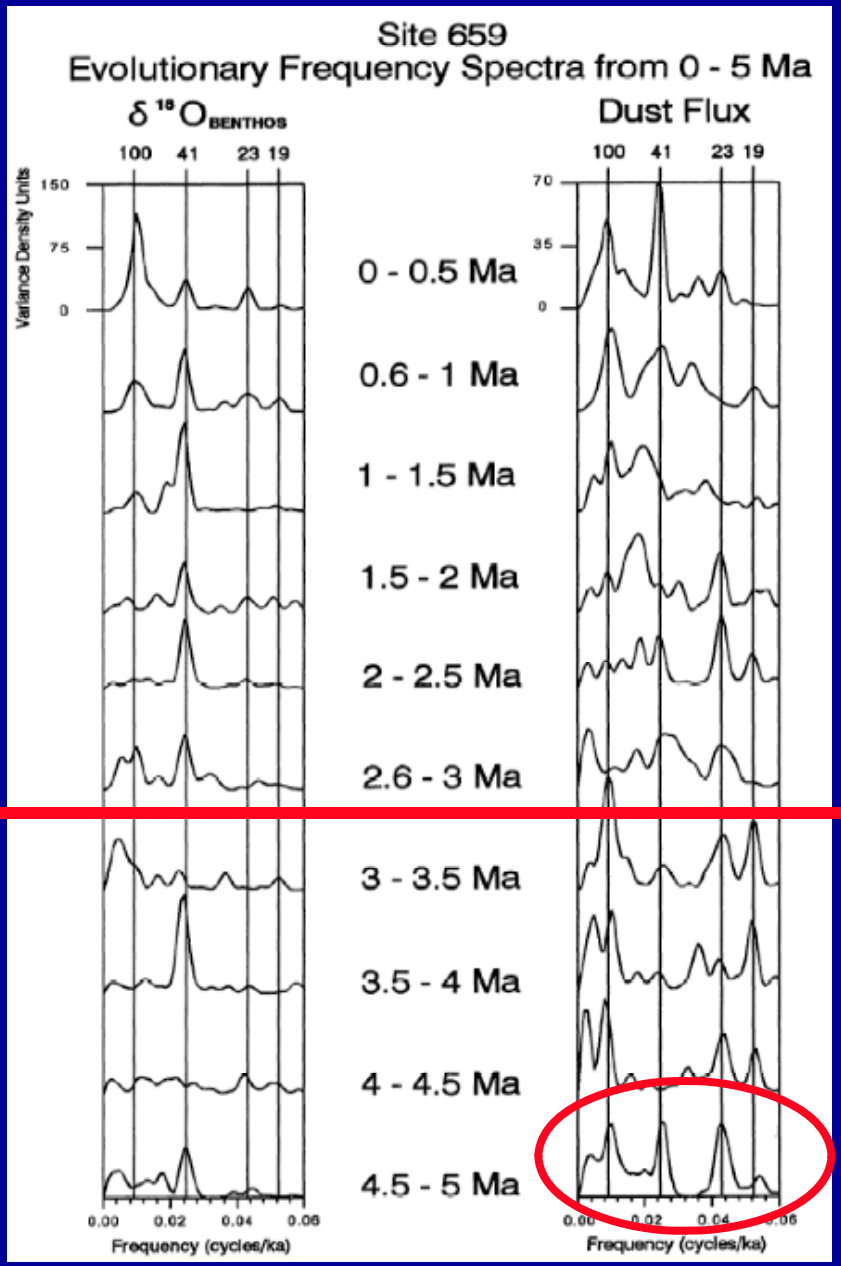
Evolutive Spectra



E-W SST comparison: Not the thermocline, through the atmosphere?



3 Ma Frequency Shift?



41 K

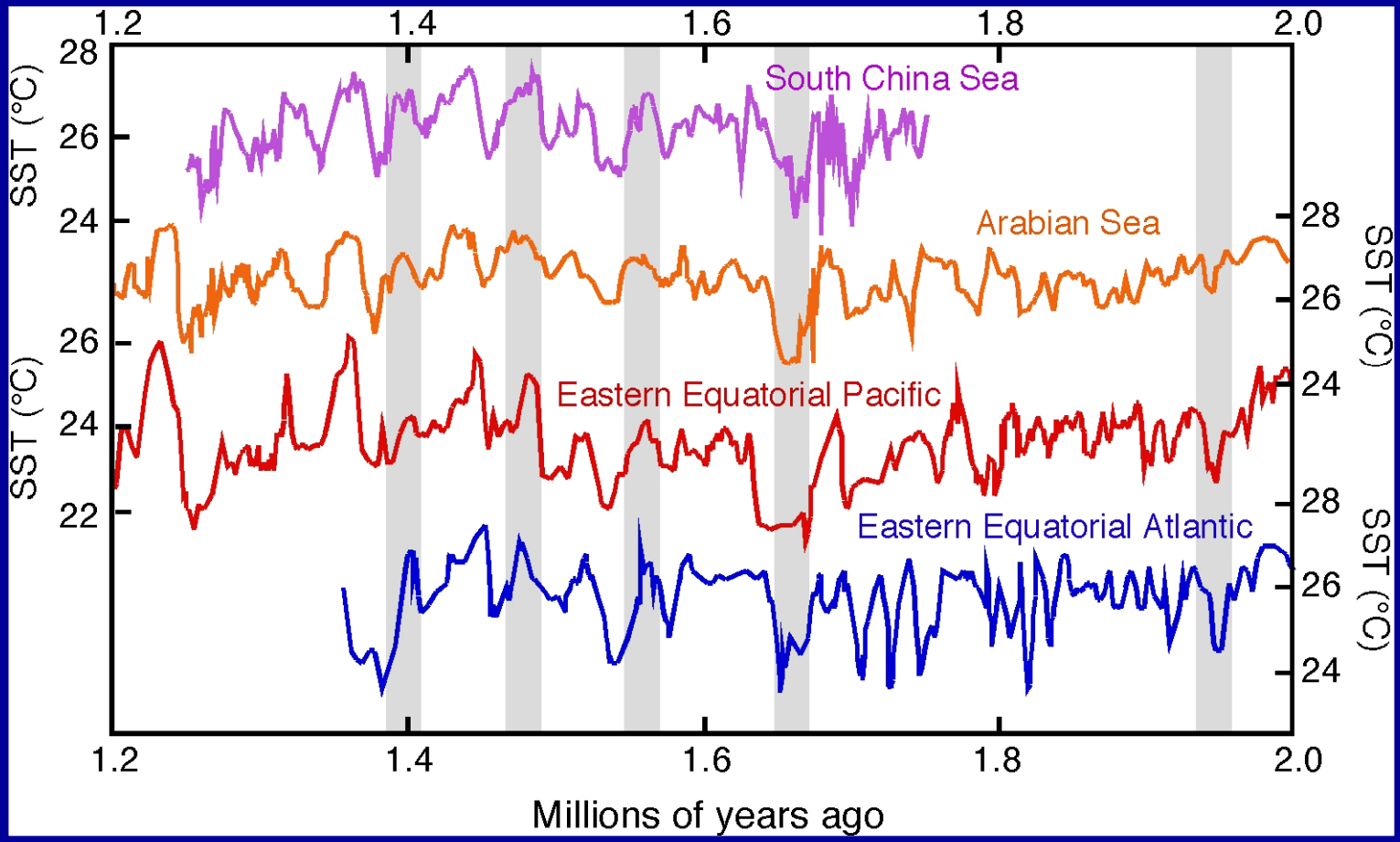
~3Ma

23 K

23 &
41 K

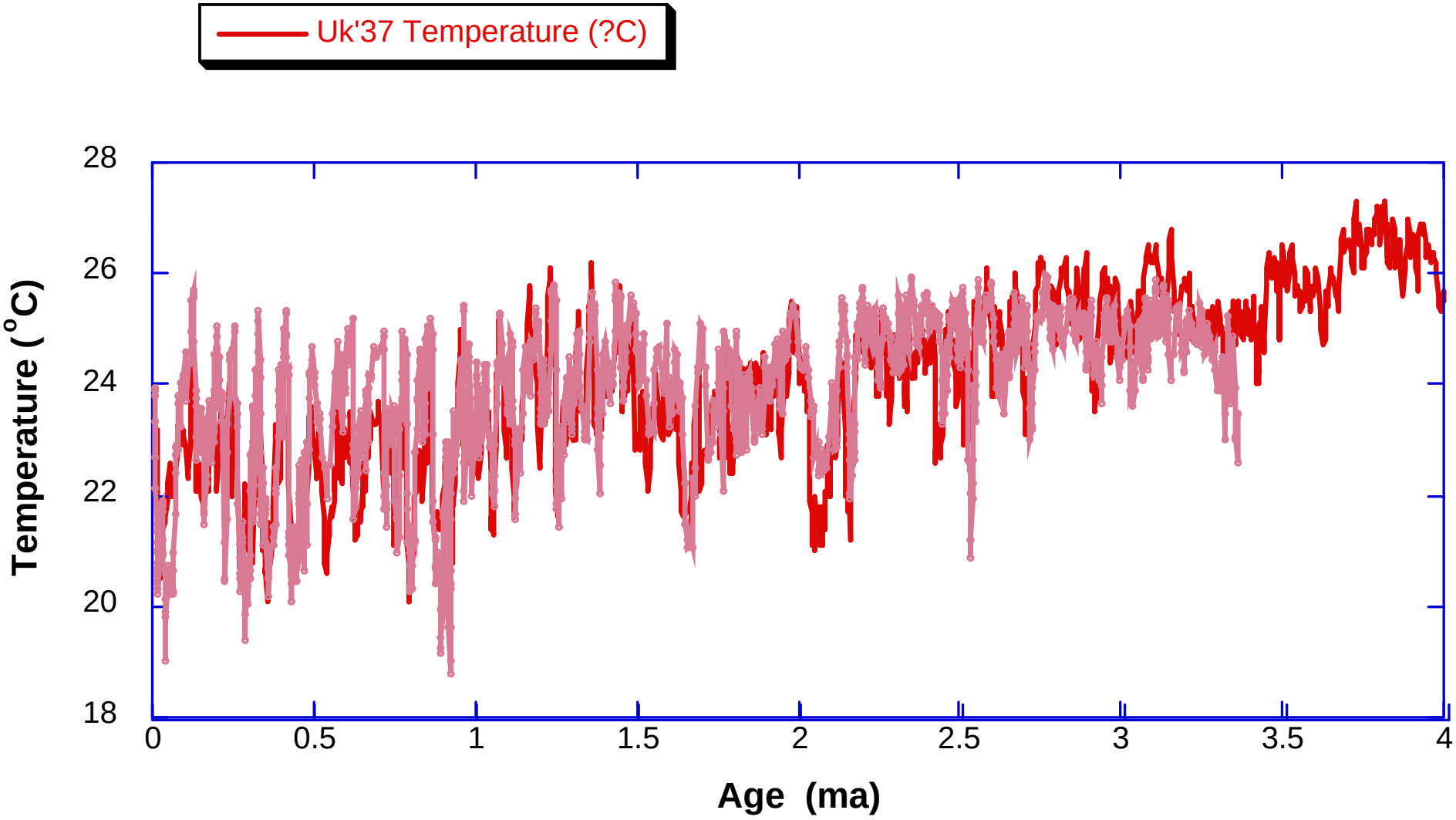
5
Ma

Tropical SST response

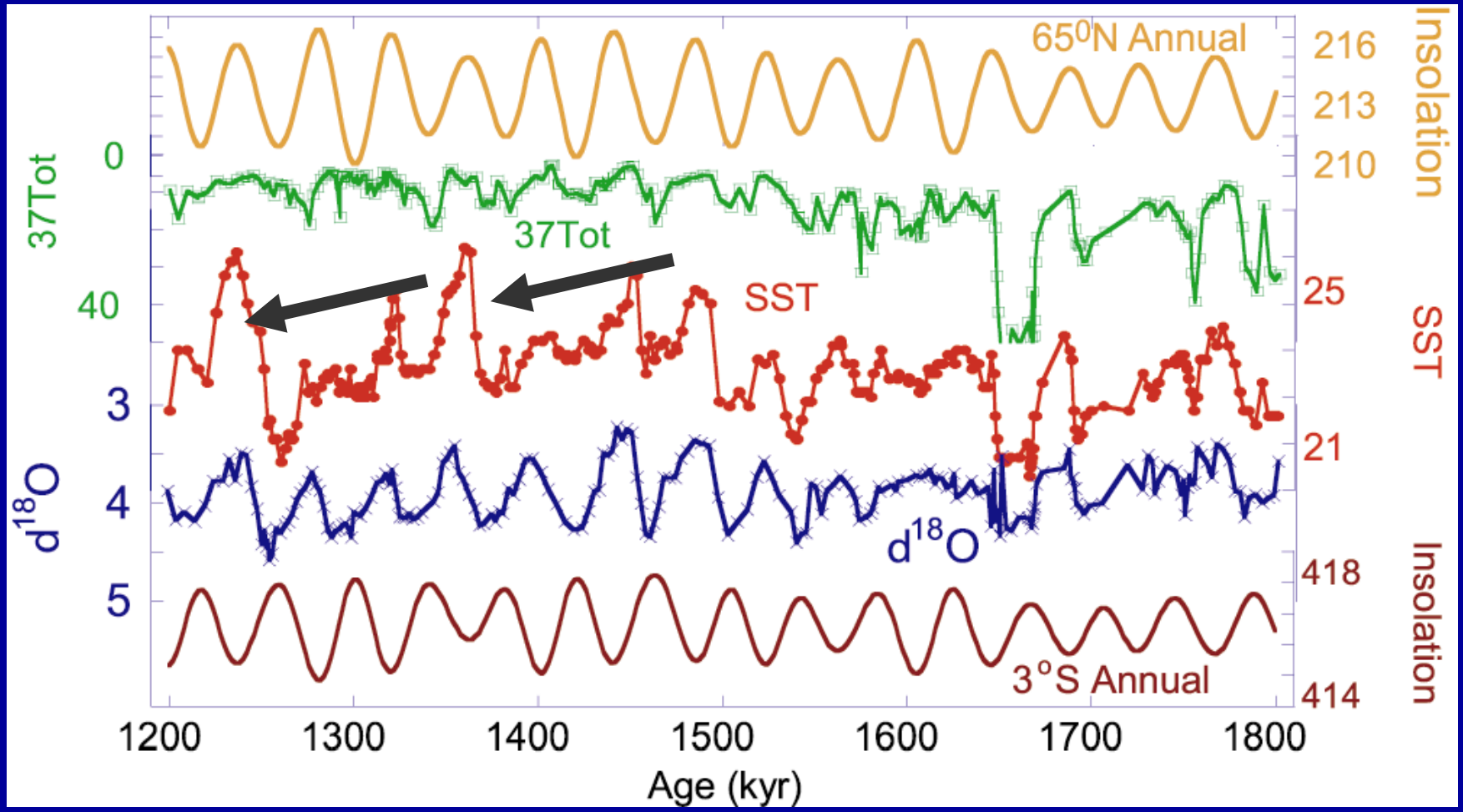


- highly similar SST response across multiple tropical locations, despite differences in local dynamics

Cleaveland and Herbert, 2007

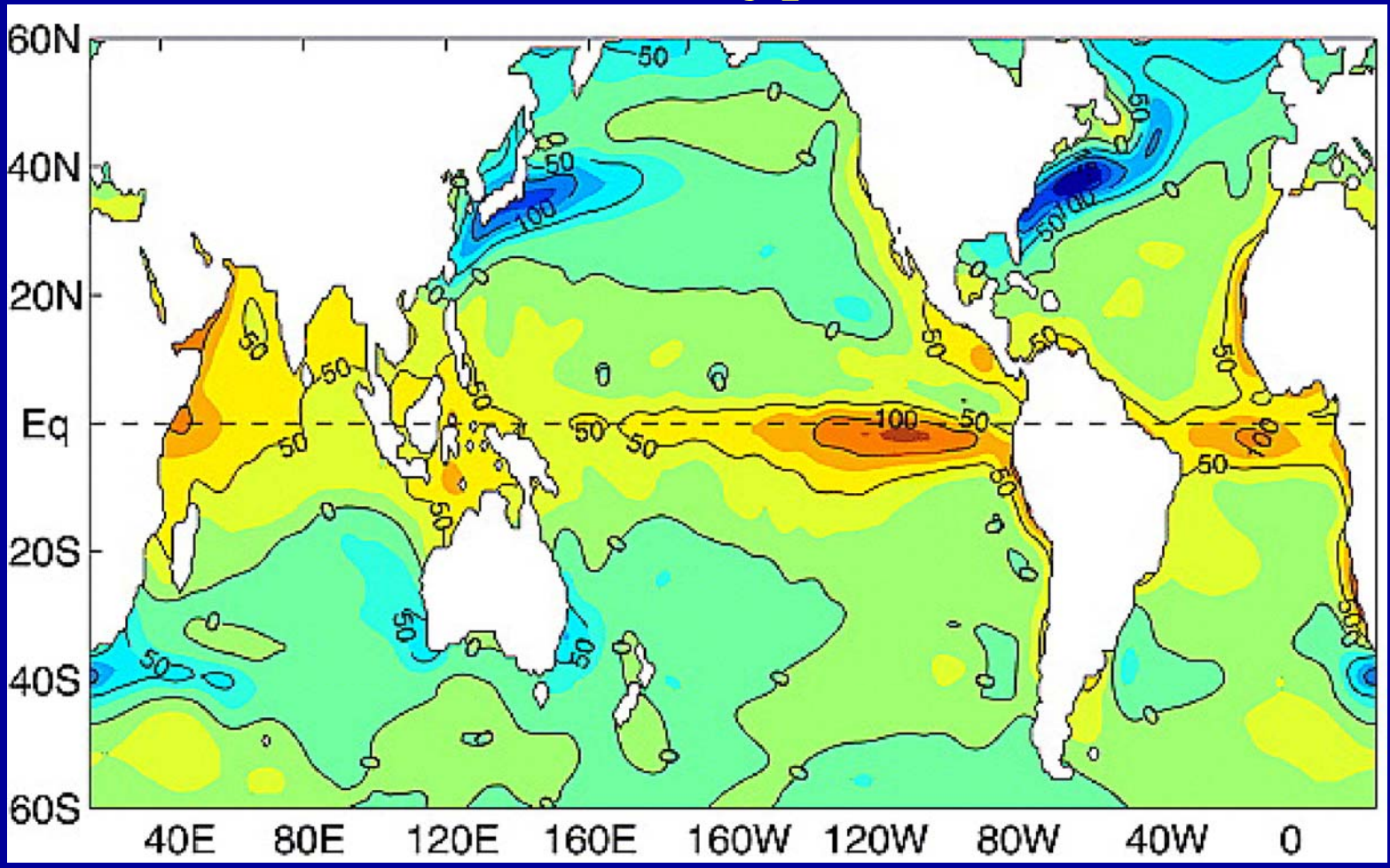

Uk'37 Temperature (?C)
Temperature (°C)
28
26
24
22
20
18
0
0.5
1
1.5
2
2.5
3
3.5
4
Age (ma)

PUZZLE #2: where is the memory?



High/Low Latitude Connections

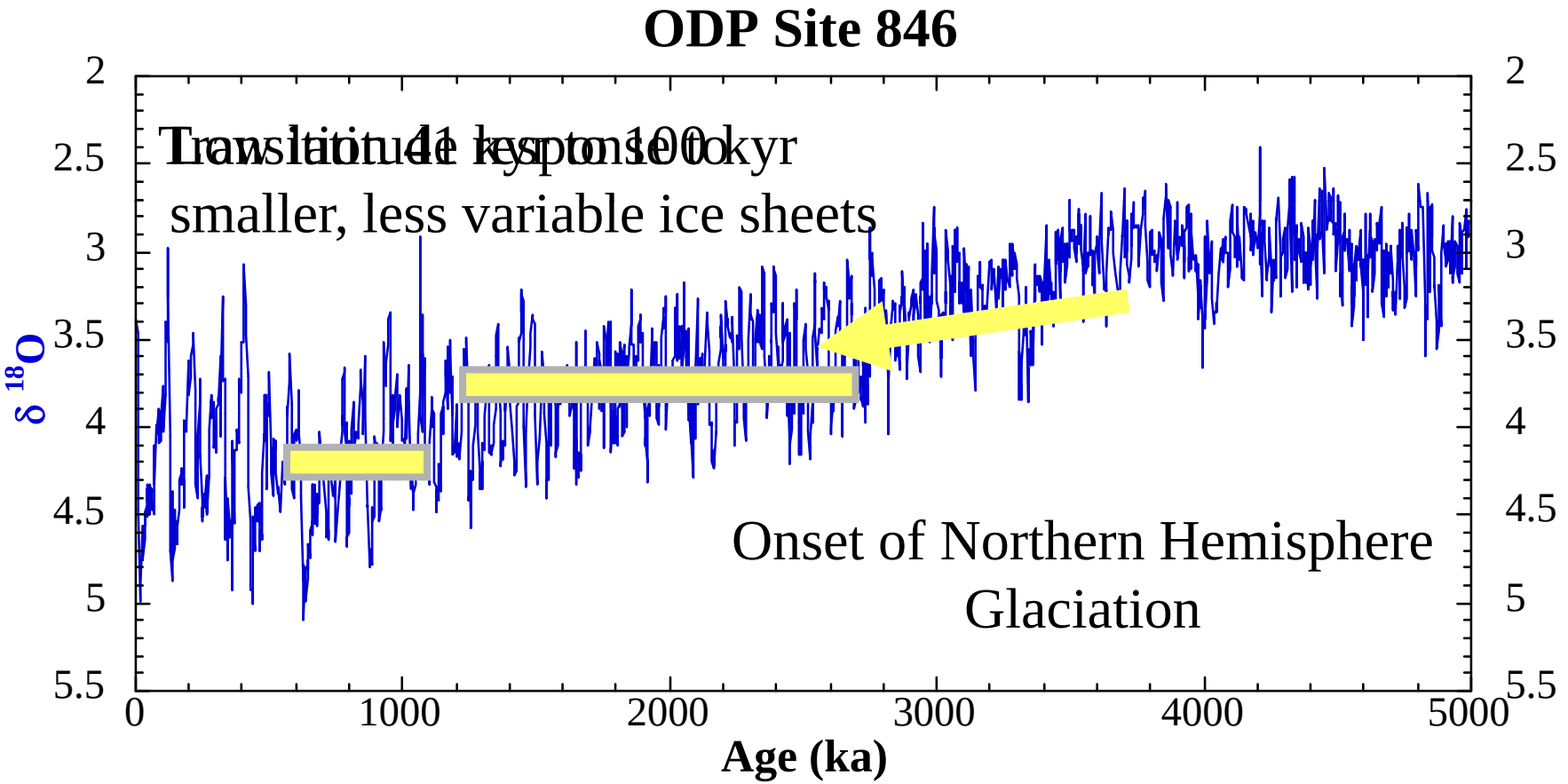
Heat Flux Hypothesis



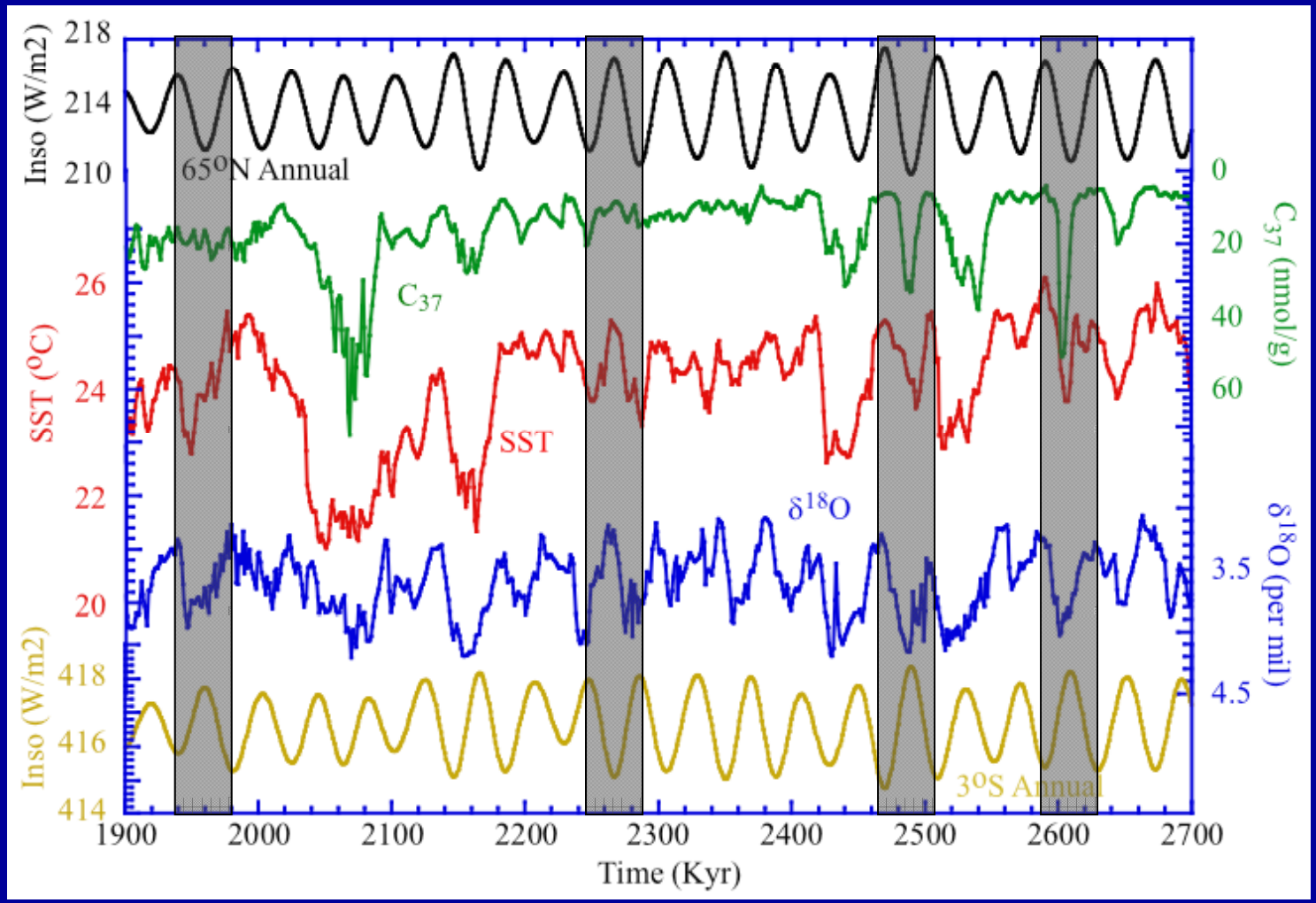
~3Ma Change from a Locally to Non-Locally Balanced Heat Budget

(From Philander and Fedorov 2003)
(After Da Silva et al, 1994)

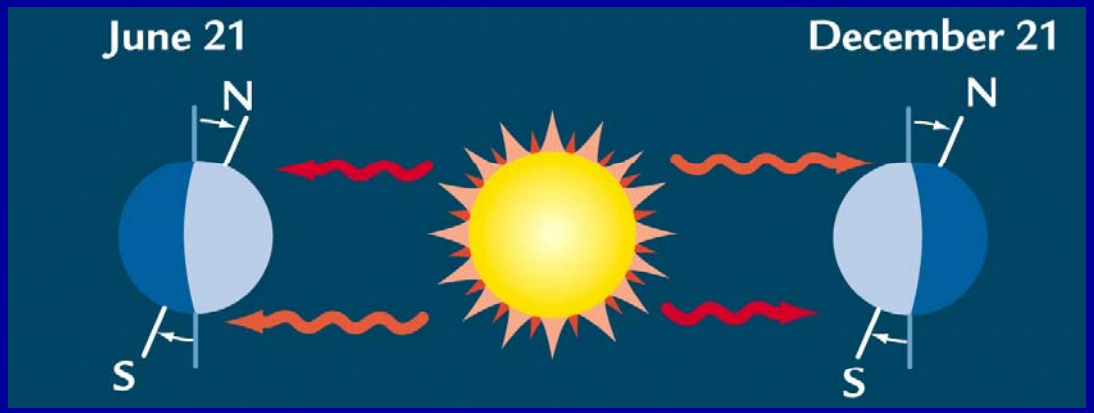
The Plio-Pleistocene Climate Transition



Late Pliocene



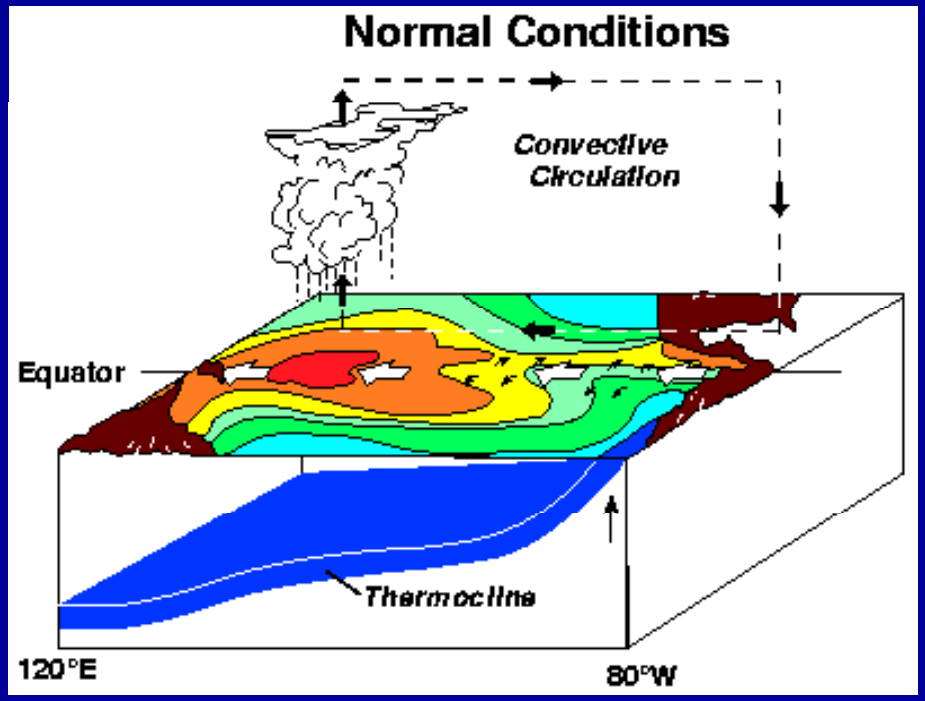
- Same Finding: In the 41 K band, High Ice Volume corresponds to low SST, high Productivity and Weak High Latitude Solar Forcing (Low Tilt)

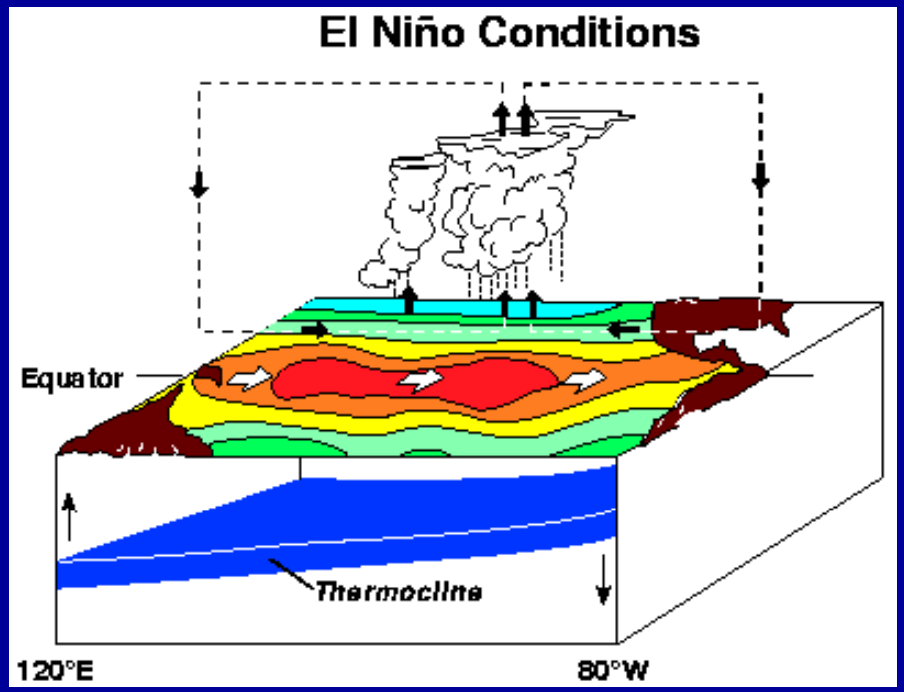


Since ~3Ma Obliquity Controls Tropical Thermocline Depth (Philander and Fedorov 2003)

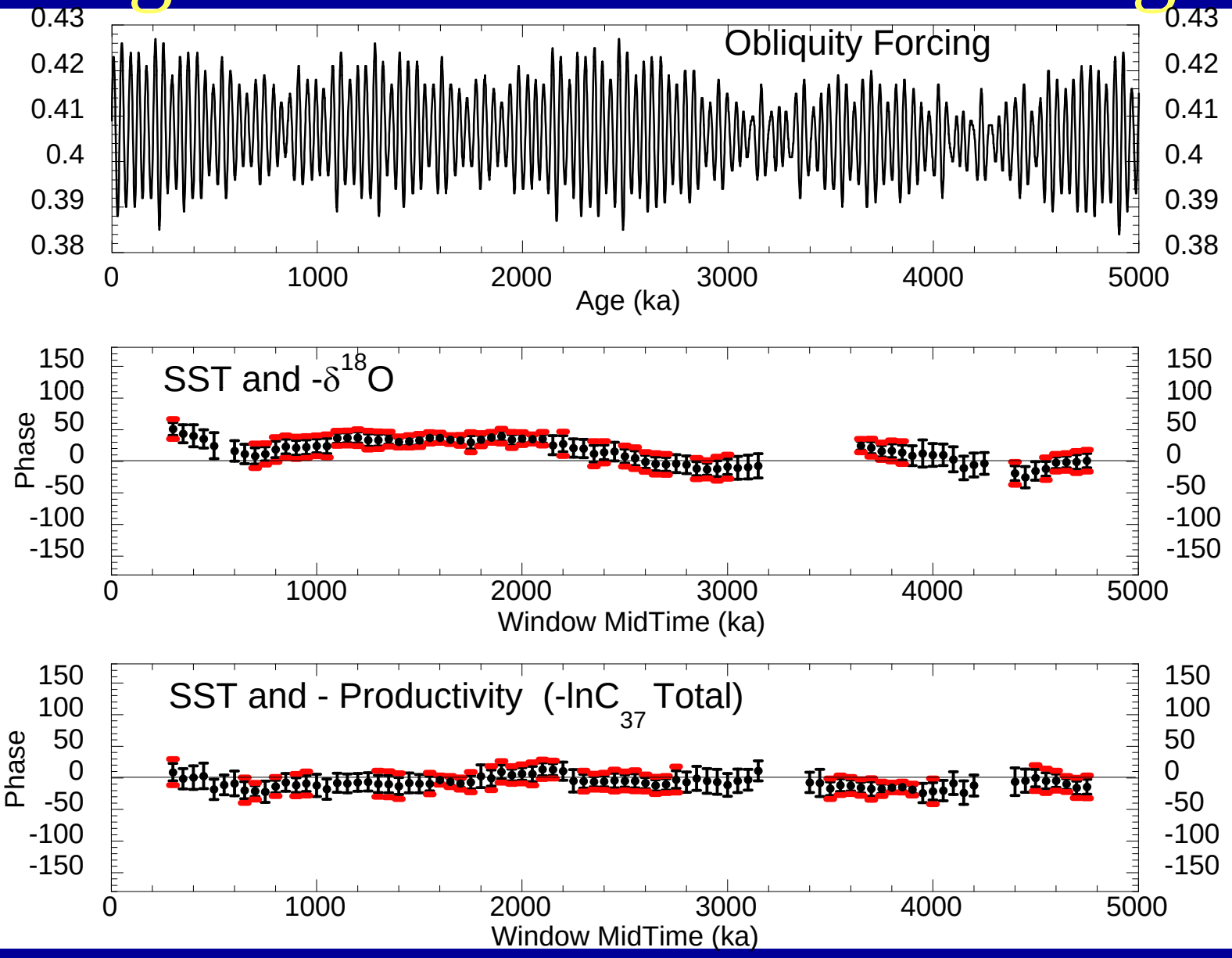
Low Tilt ⇒ La Niña

High Tilt ⇒ El Niño



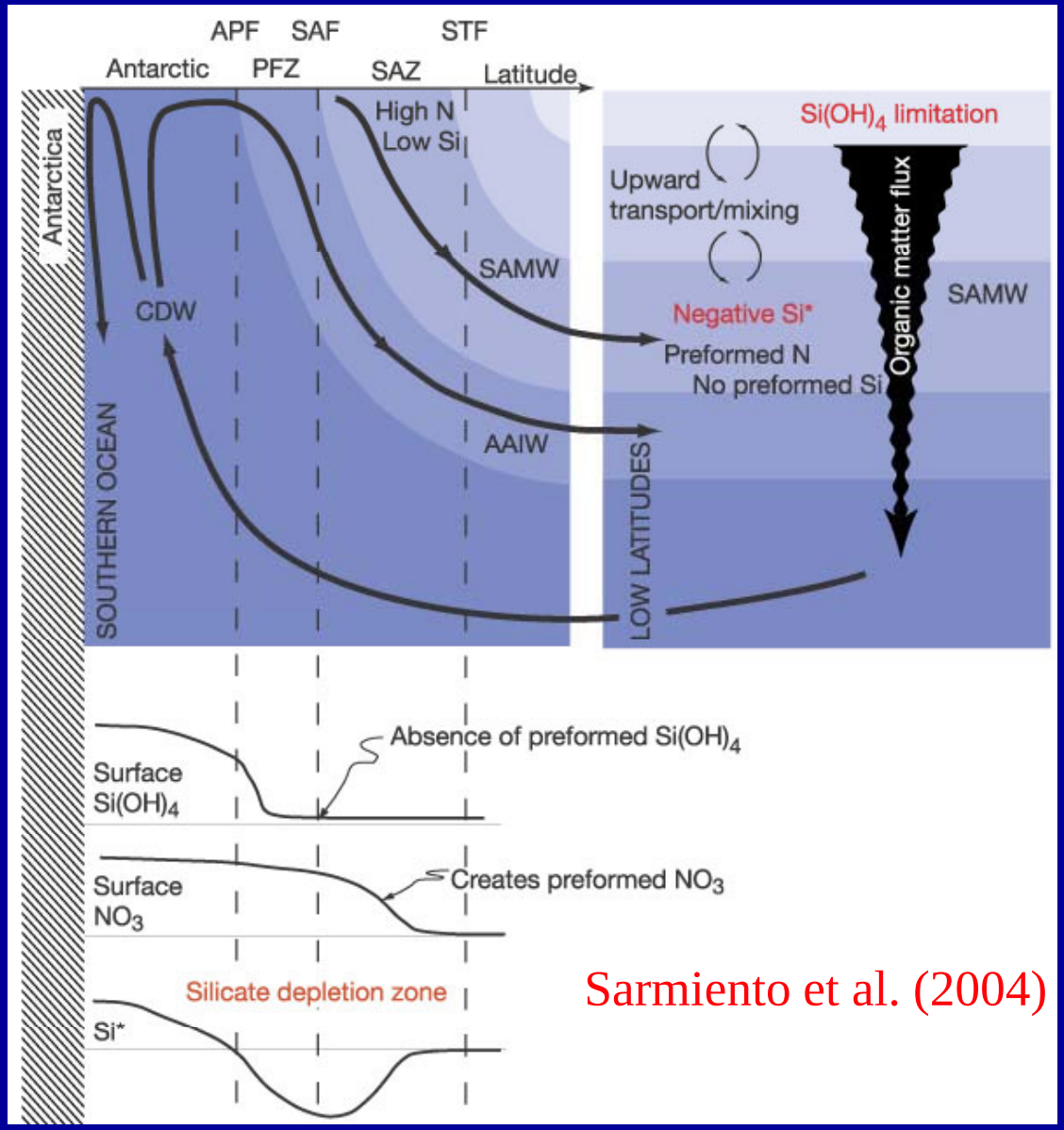


High and Low Latitude Linkage



Phase relationships vary little over the past 5 Myrs

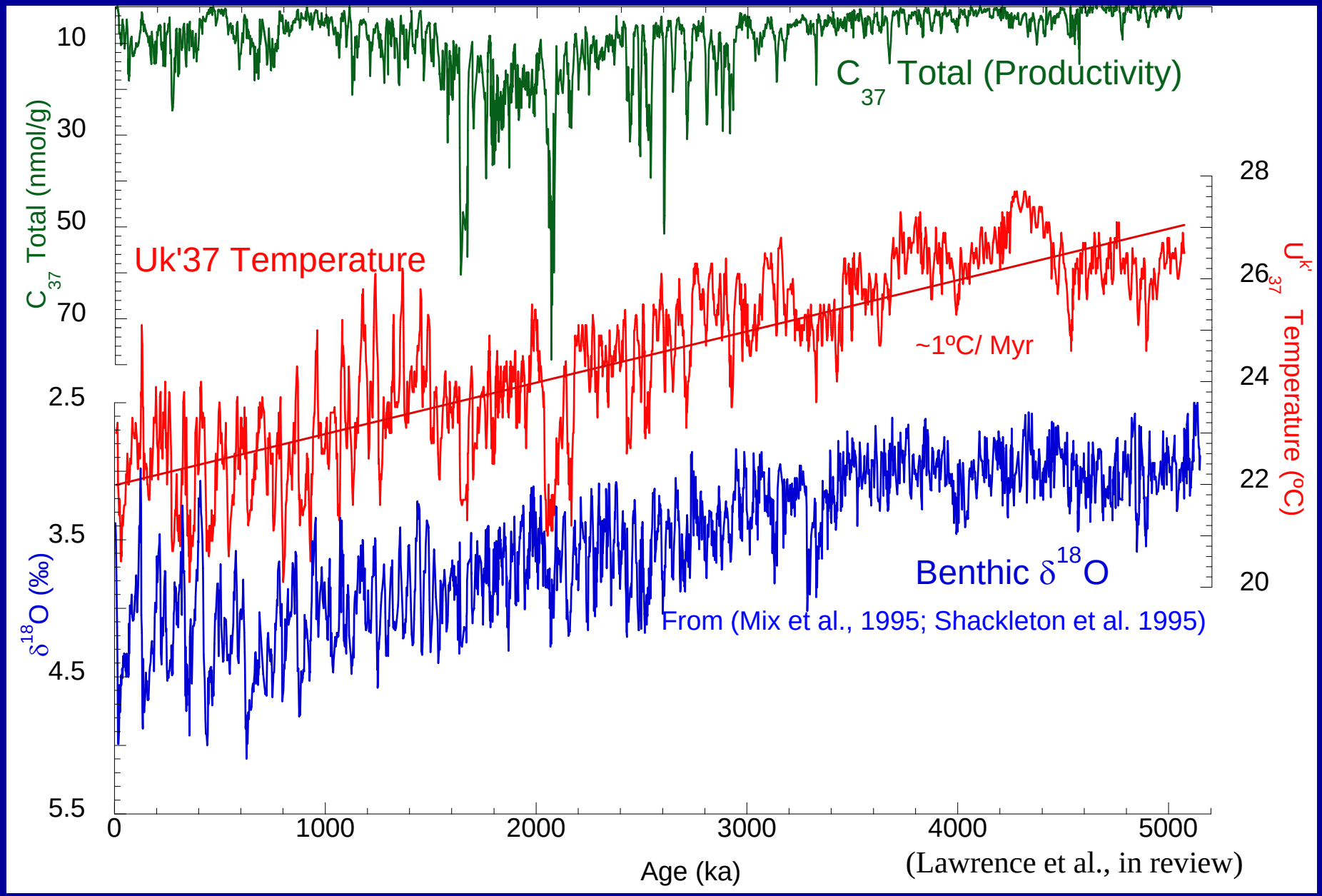
High/Low Latitude Connections



Sarmiento et al. (2004)

Time Transgressive High Latitude Productivity Crash

Low Latitude Alkenone Records



(Lawrence et al., in review)