The Abdus Salam International Centre for Theoretical Physics

United Nations Educational, Scientific and Cultural Organization

IAEA International Atomic Energy Agency

SMR/1884-3

Conference on Milankovitch cycles over the past 5 million years

22 - 24 March 2007

Trends & Cycles in the Equatorial Pacific: Observations

Yair ROSENTHAL

Instit. of Marine & Coastal Services
Rutgers University
71 Dudley Road

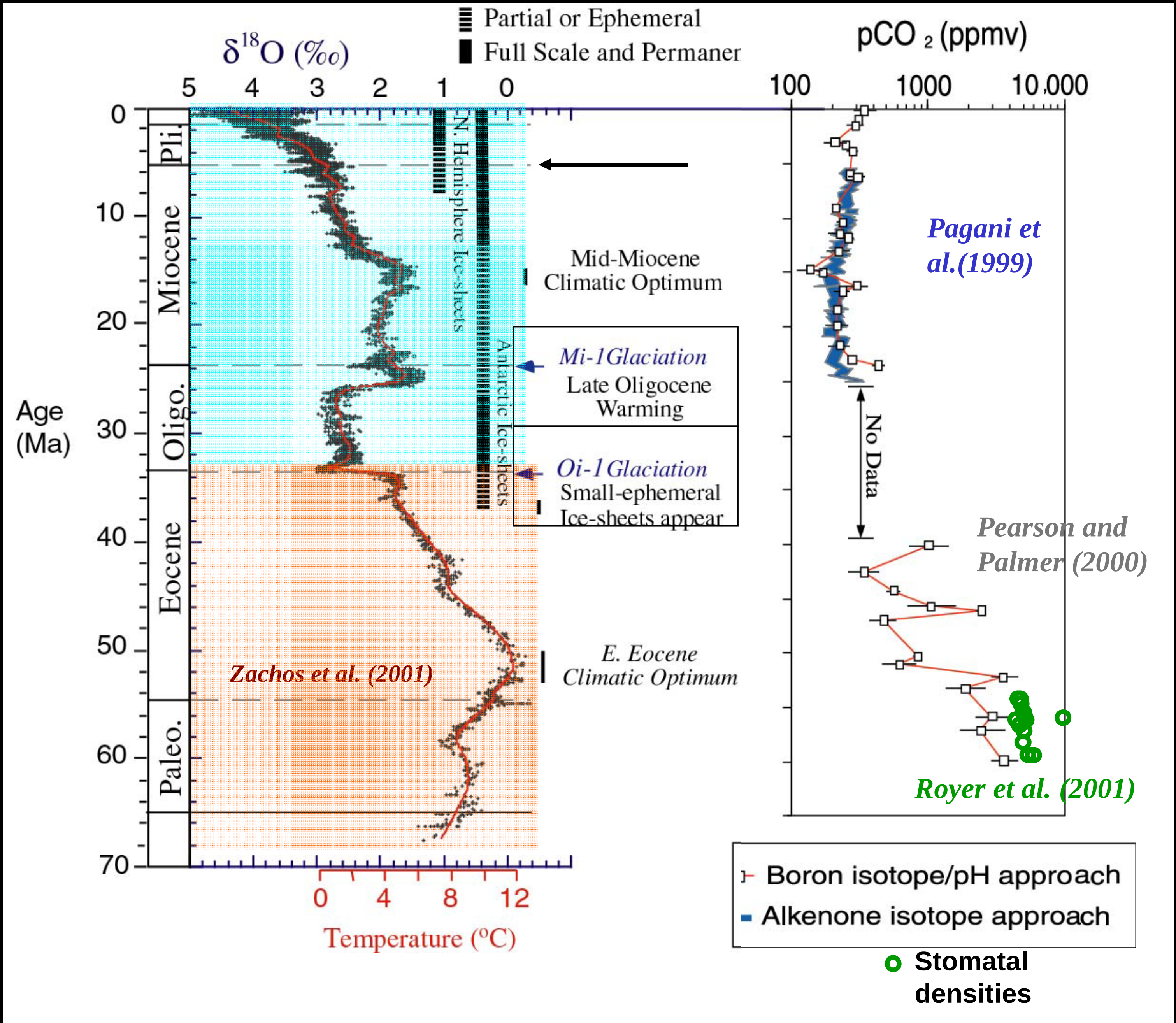
Trends and Cycles in the Equatorial Pacific: Observations

Yair Rosenthal
Rutgers University

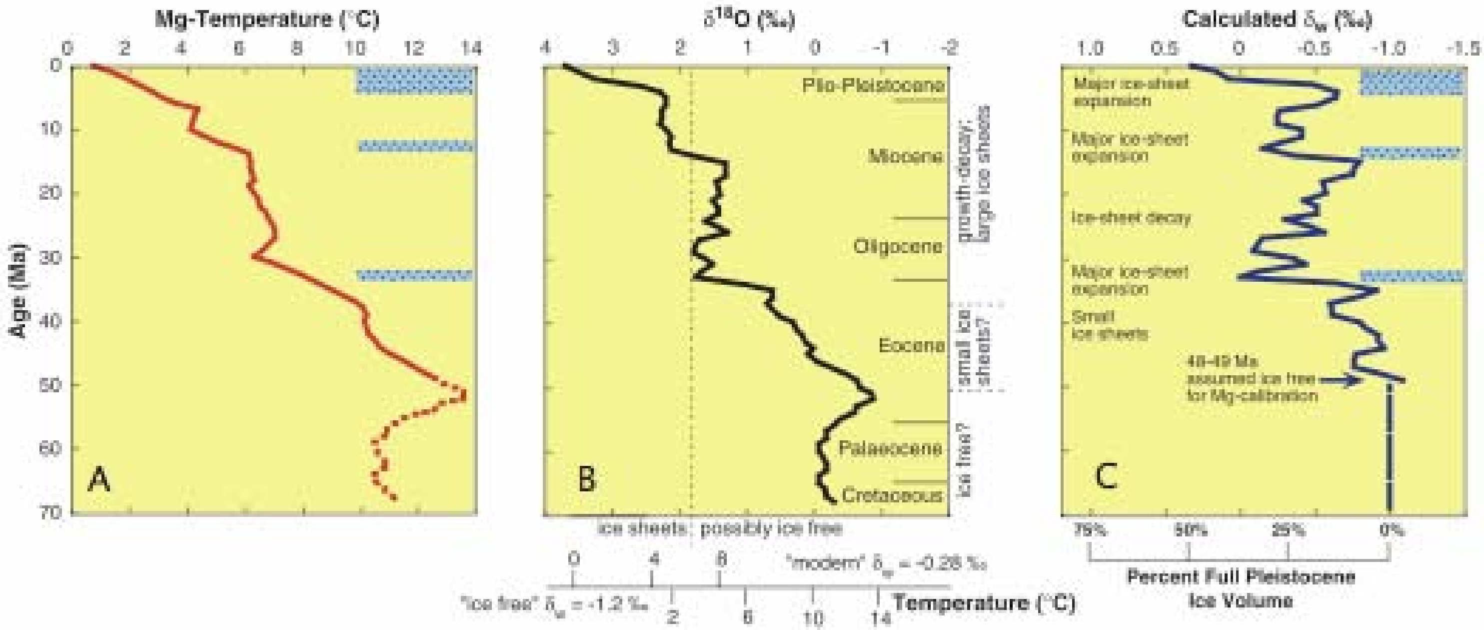
OUTLINE

- Changes in the mean background climate state
- Orbital frequencies
- ENSO modulations
- Temporal relationships

Cenozoic climate history and paleo-pCO_2

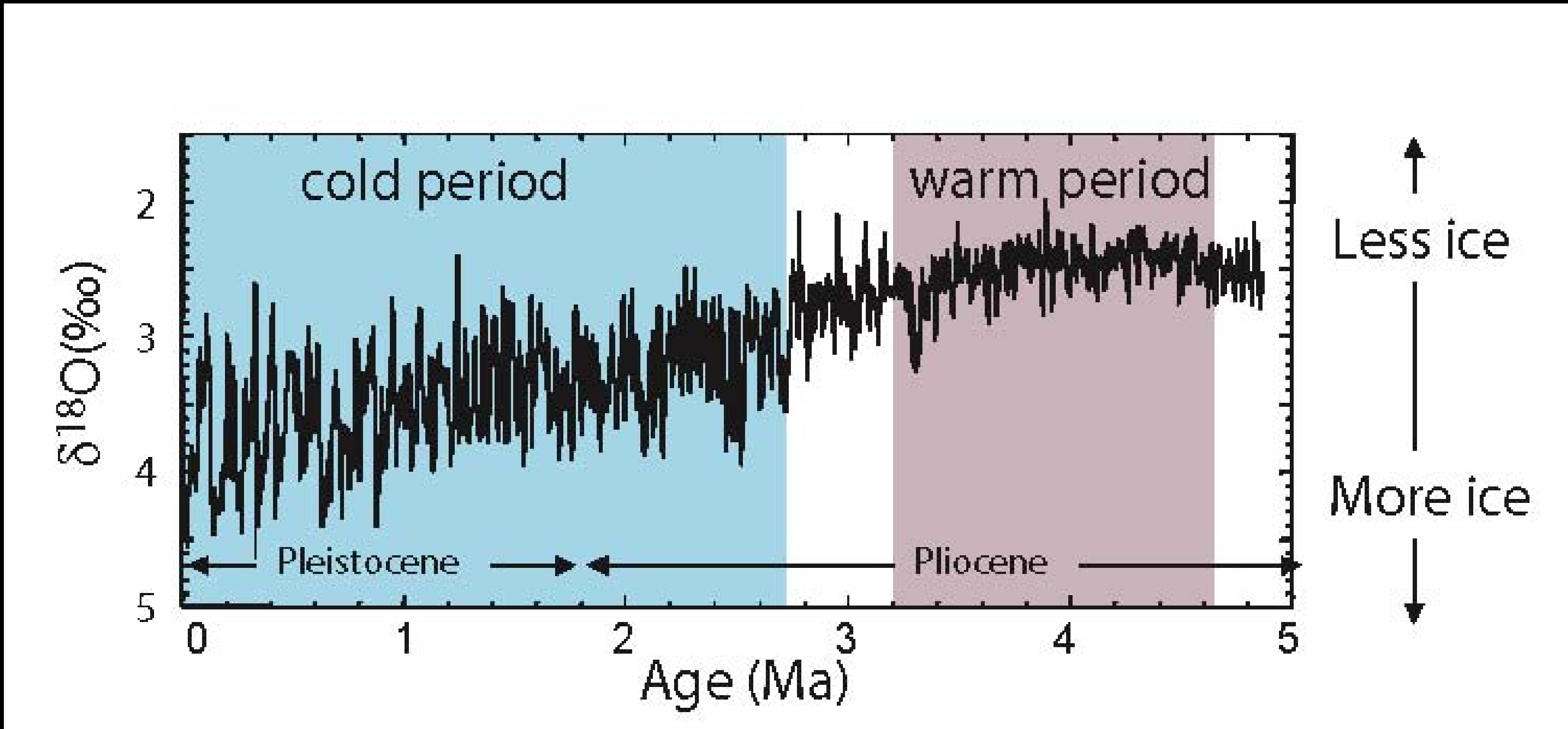


Eustatic sea-level and bottom water temperature: Evidence from δ18O and Mg/Ca measurement of bentic foraminifera

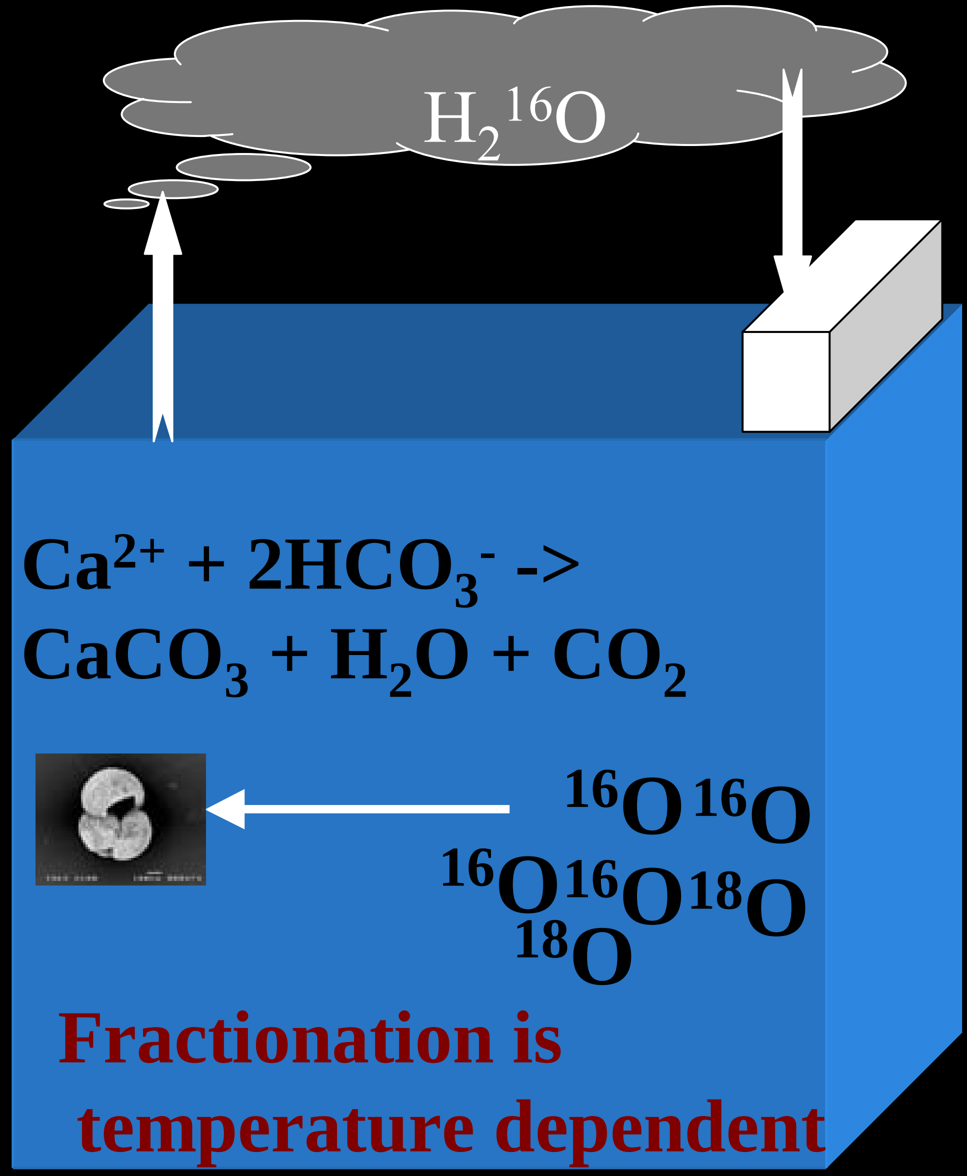


Lear et al., 2000

The last 5 My



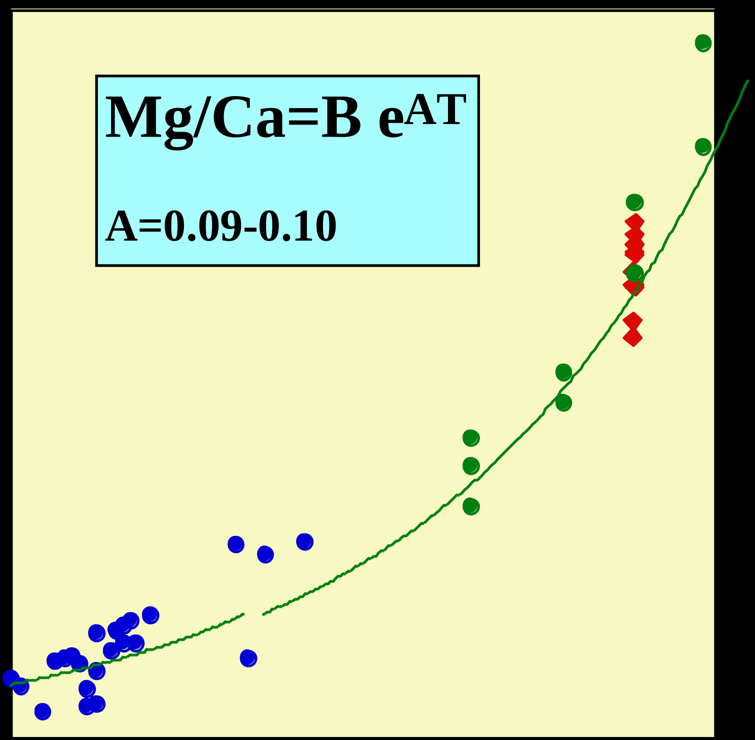
cold period
warm period
Less ice
More ice
Pleistocene
Pliocene
δ18O(‰)
2
3
4
5
0
1
2
3
4
5
Age (Ma)



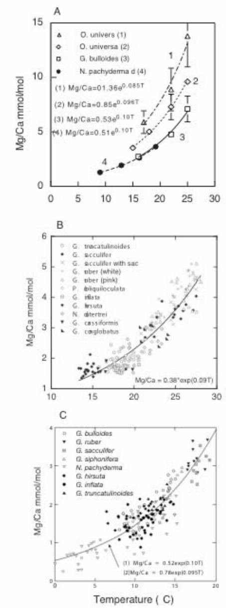
$$\text{Temp} = 16.9 - 4.38\,(\delta c - \delta w) + 0.1\,(\delta c - \delta w)^2$$

Foraminiferal Mg/Ca: A new Paleothermometer

$$CaCO_3 + Mg^{2+} \text{ ---}K_{eq}\text{----> } MgCO_3 + Ca^{2+}$$



- ● *N. pachyderma l.* Core tops (Nürnberg, 1995)
- ● *G. sacculifer* culture (Nürnberg et al., 1996)
- ◆ *G. sacculifer* *Depth transect* Siera Leone Rise (Rosenthal and Boyle, 1993)



Culture studies
A=0.085-0.10
Lea et al, 1999
Russell et al., 2004
Langen et al., 2005

Sediment traps
A=0.065-0.095
Annand et al., 2003

Core tops
A≈ 0.095

Proxies

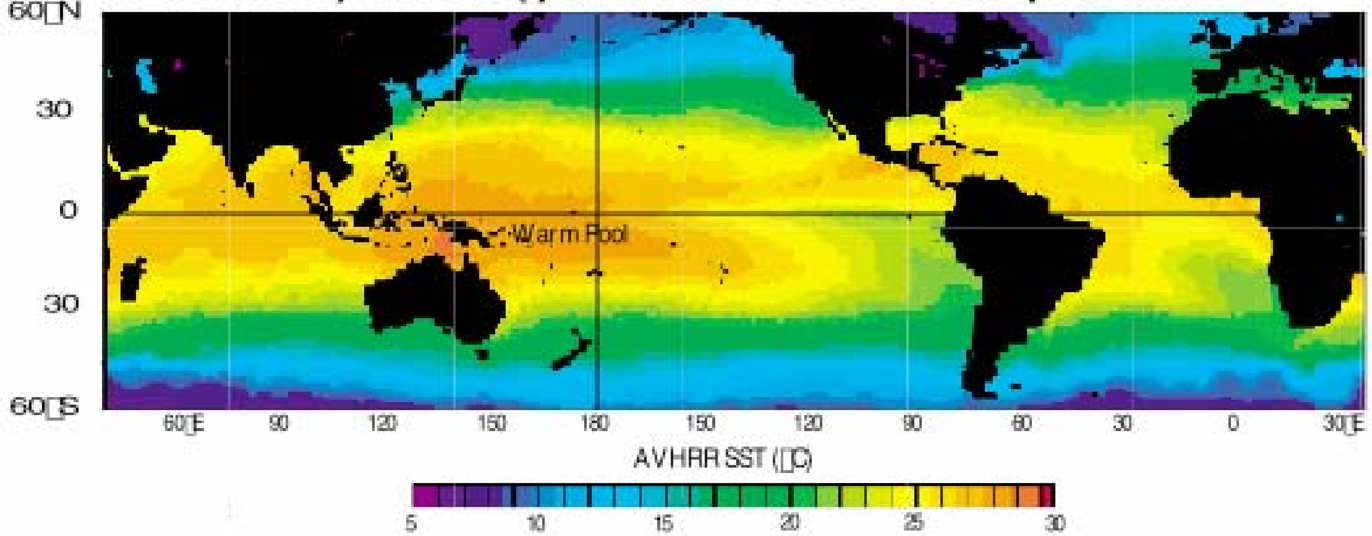
Foraminifera: unicellular animals

Mg/Ca → Temperature

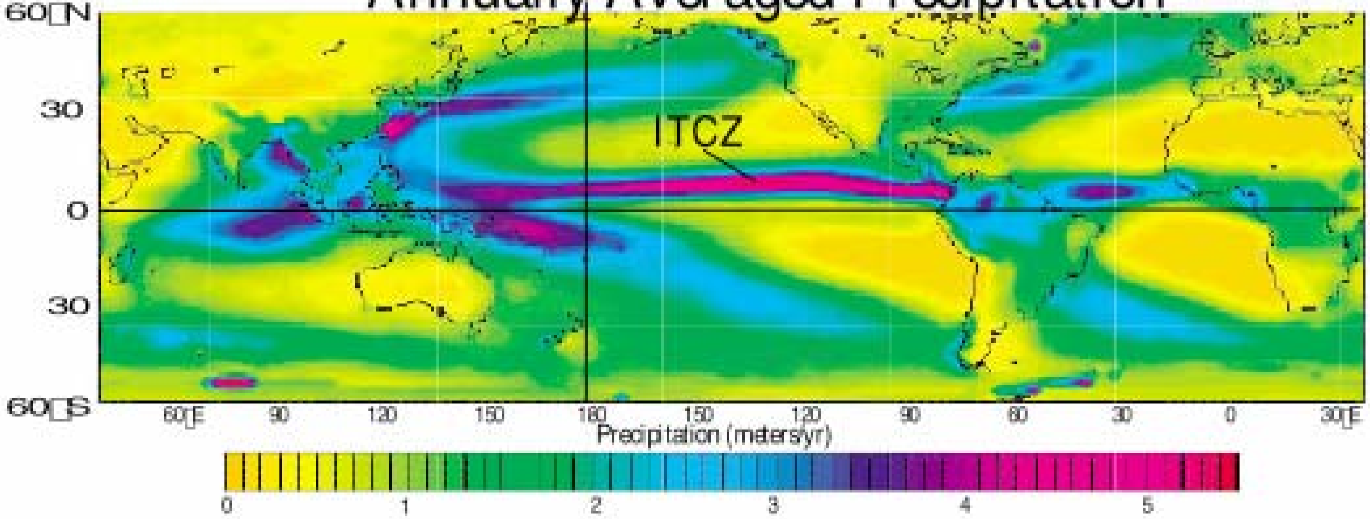
$\delta^{18}O$ → & $\delta^{18}O_{SW}$

$\delta^{18}O_{SW}$ → Salinity

Annually Averaged Sea Surface Temperature

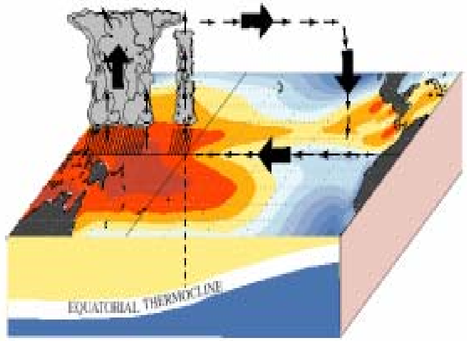


Annually Averaged Precipitation

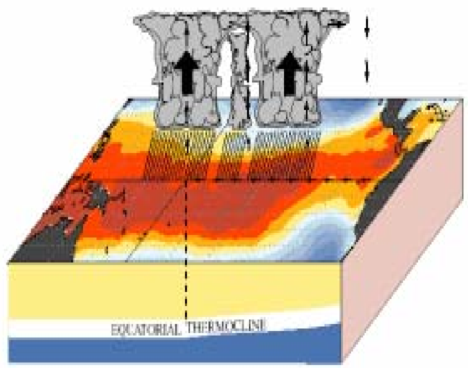


Atmosphere and ocean conditions during ENSO

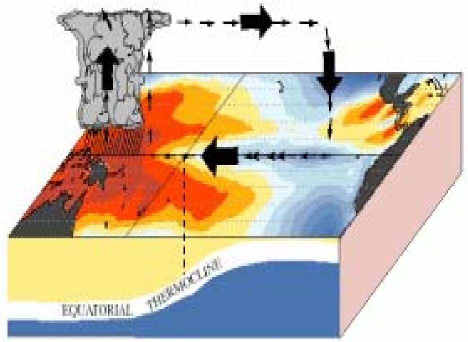
December - February Normal Conditions



December - February El Niño Conditions

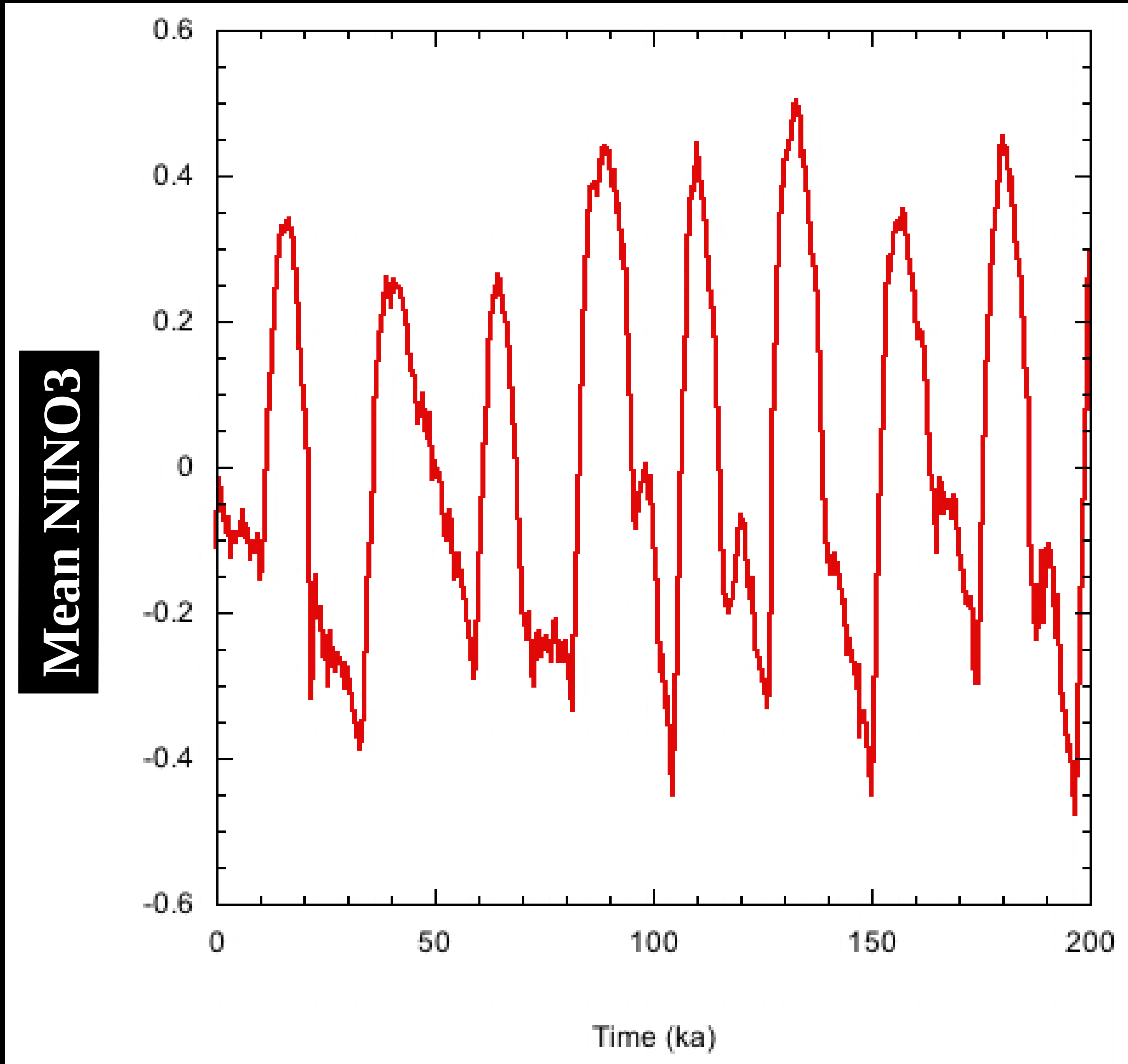


December - February La Niña Conditions

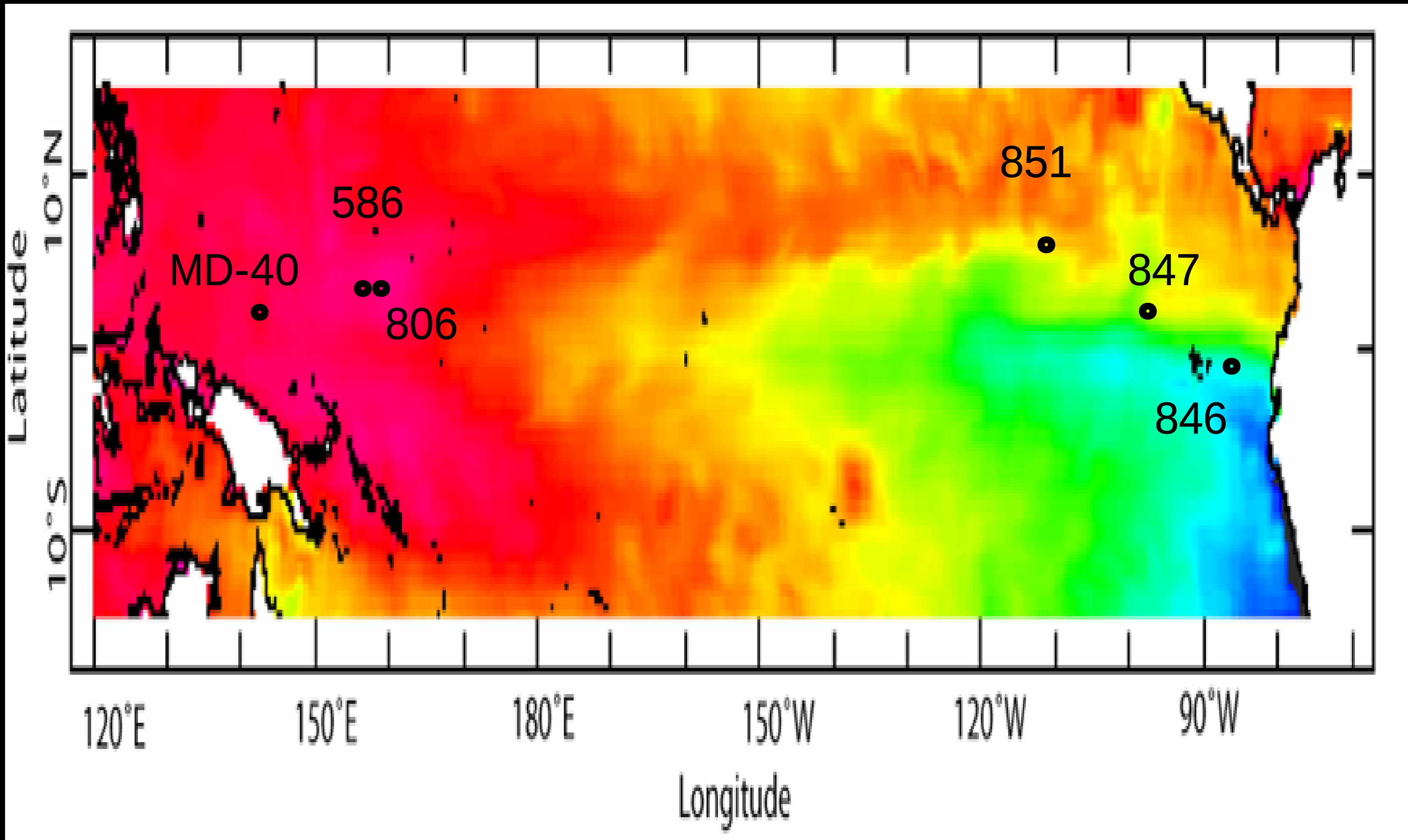


Source: IRI

Clement & Cane model



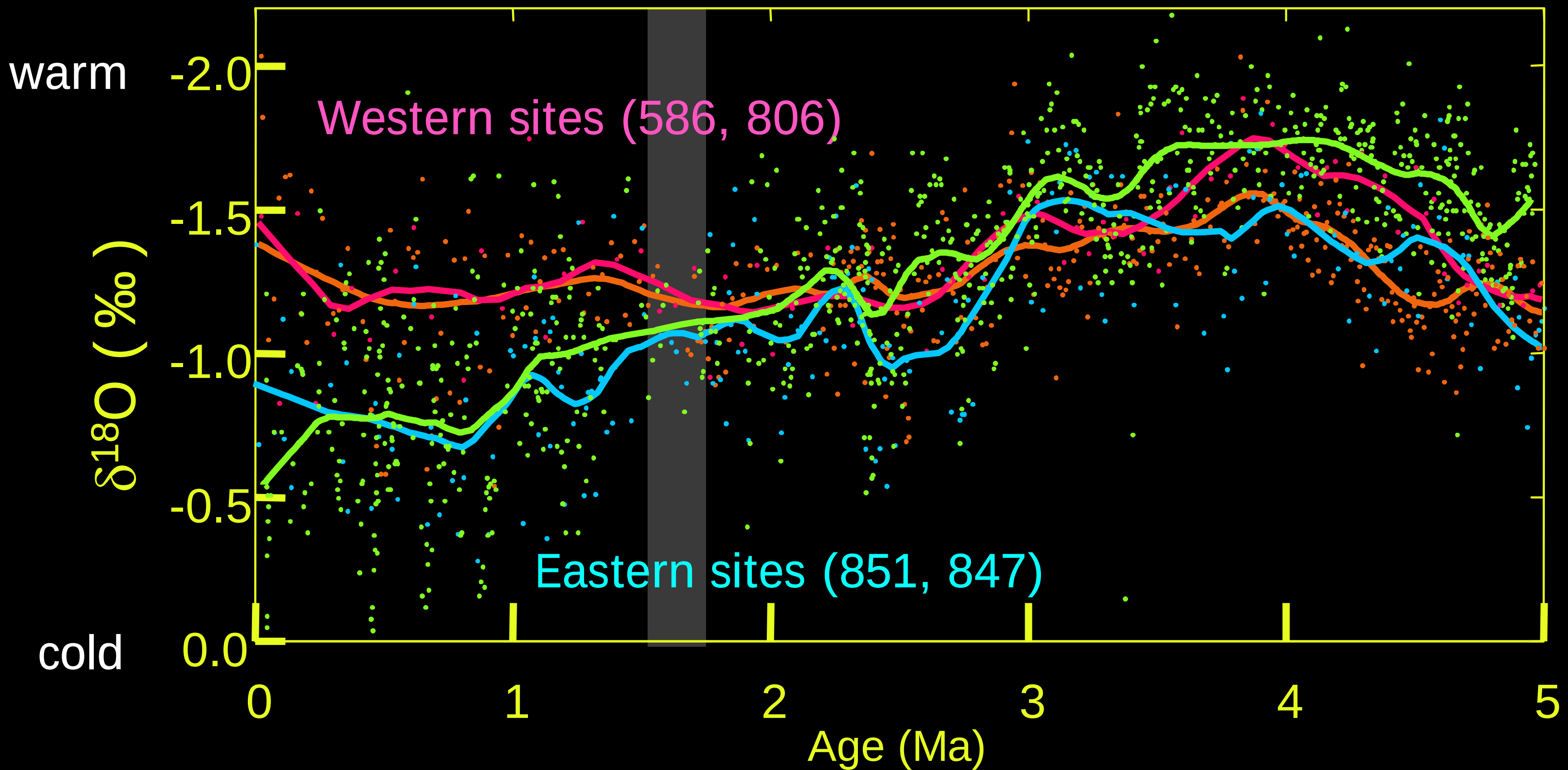
Cores Location

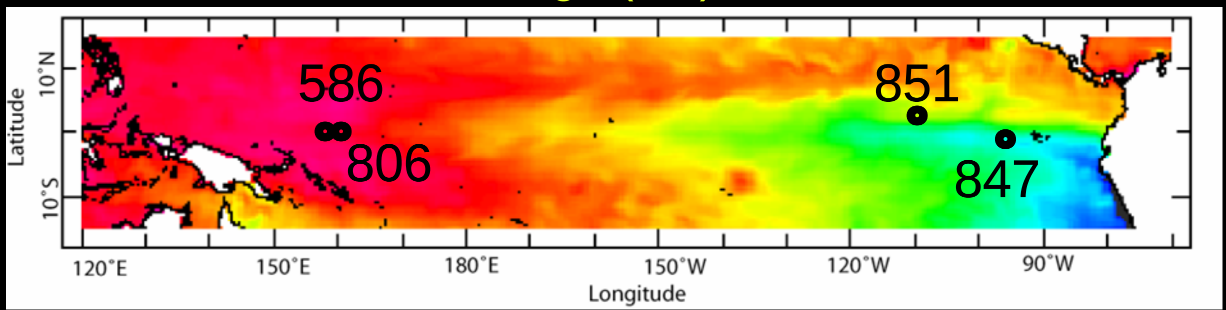


Site 846 3°S 90°W   Site 847 0°N 95°W

Site 806 0°N 159°E   MD-40 2°N 141°E

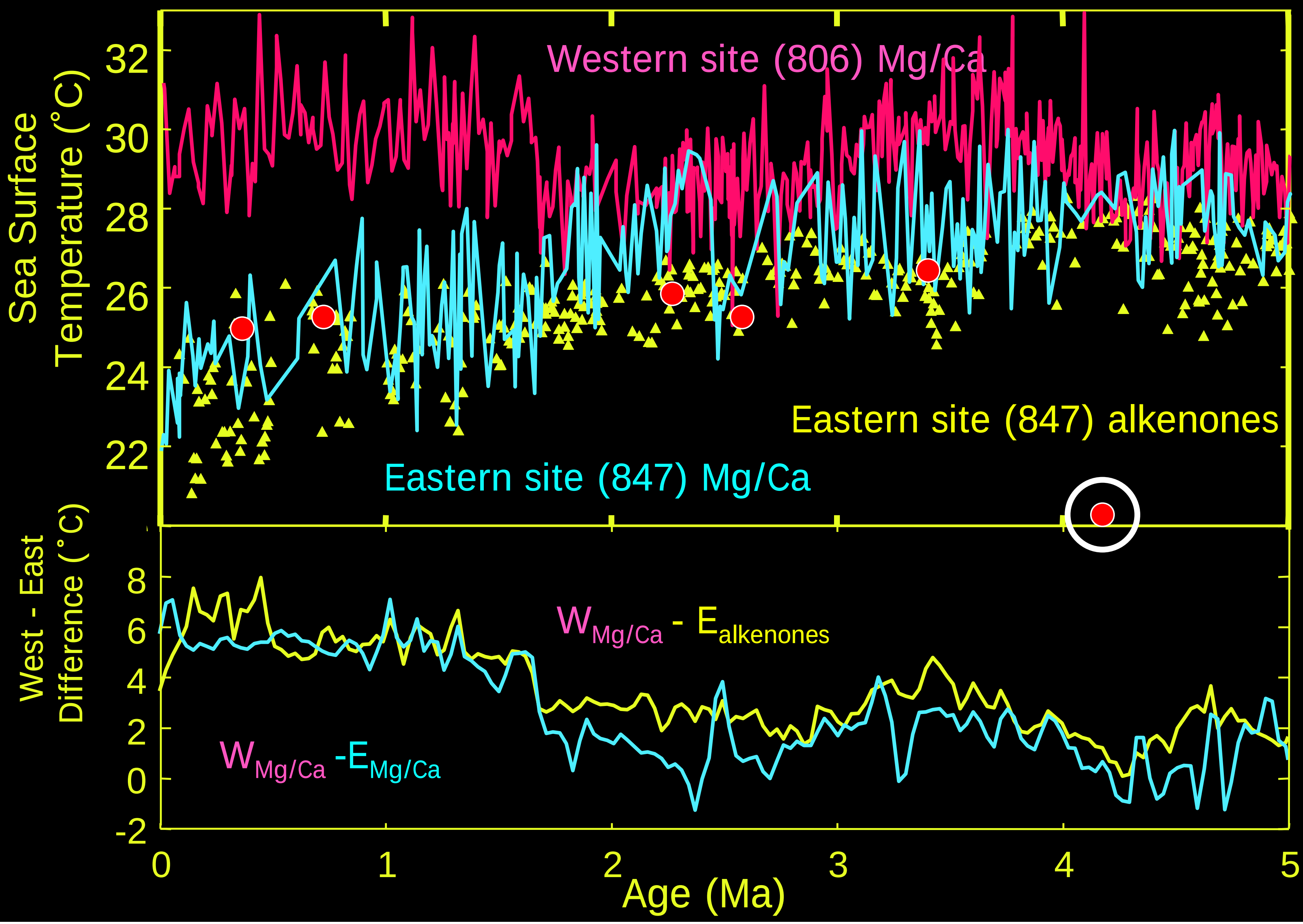
δ¹⁸O asymmetry of tropical Pacific established ~1.6 Ma



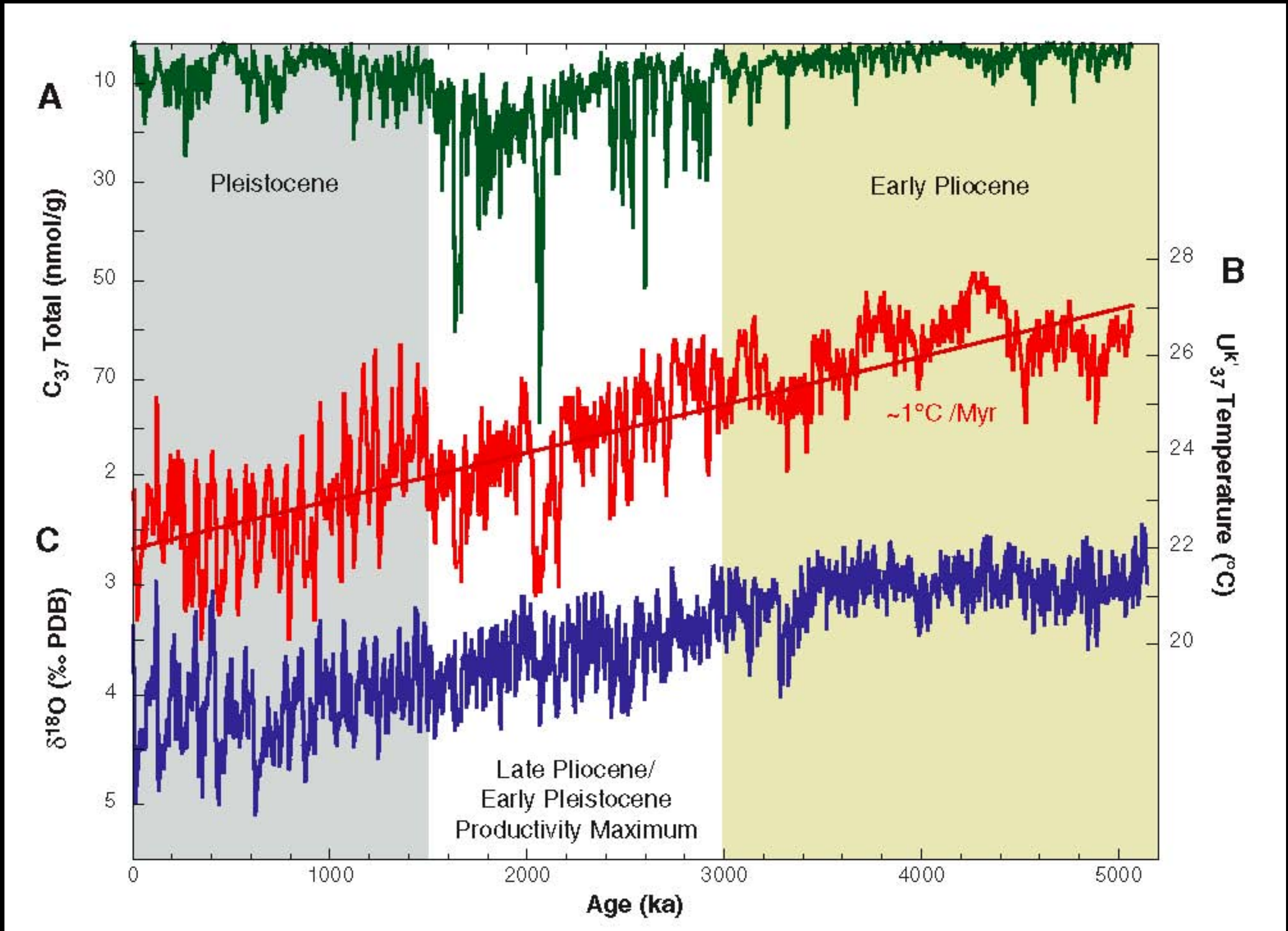


Data from: *Whitman & Berger*, 1992; *Chaisson and Ravelo*, 2000; *Wara et al.*, 2005; *Cannariato and Ravelo*, 1997)

Temperature asymmetry of tropical Pacific established ~1.6 Ma



Eastern Equatorial Pacific SST and productivity records (ODP site 846)



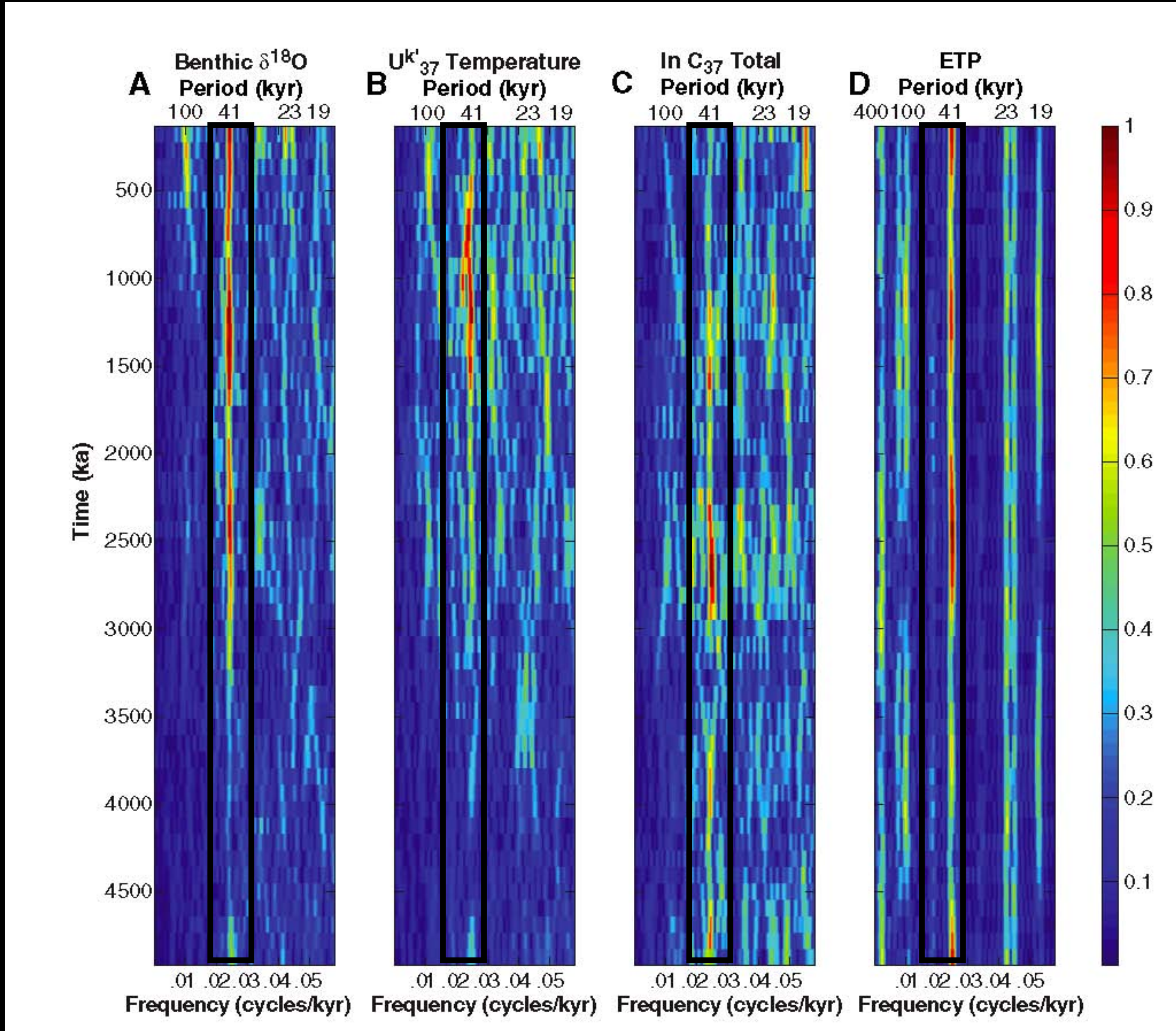
Obliquity modulation occurs throughout the record with increasing amplitude at 3Ma

Long-term cooling trend ~1°C/Myr with no significant change at 3Ma in contrast with the benthic $\delta^{18}O$ record

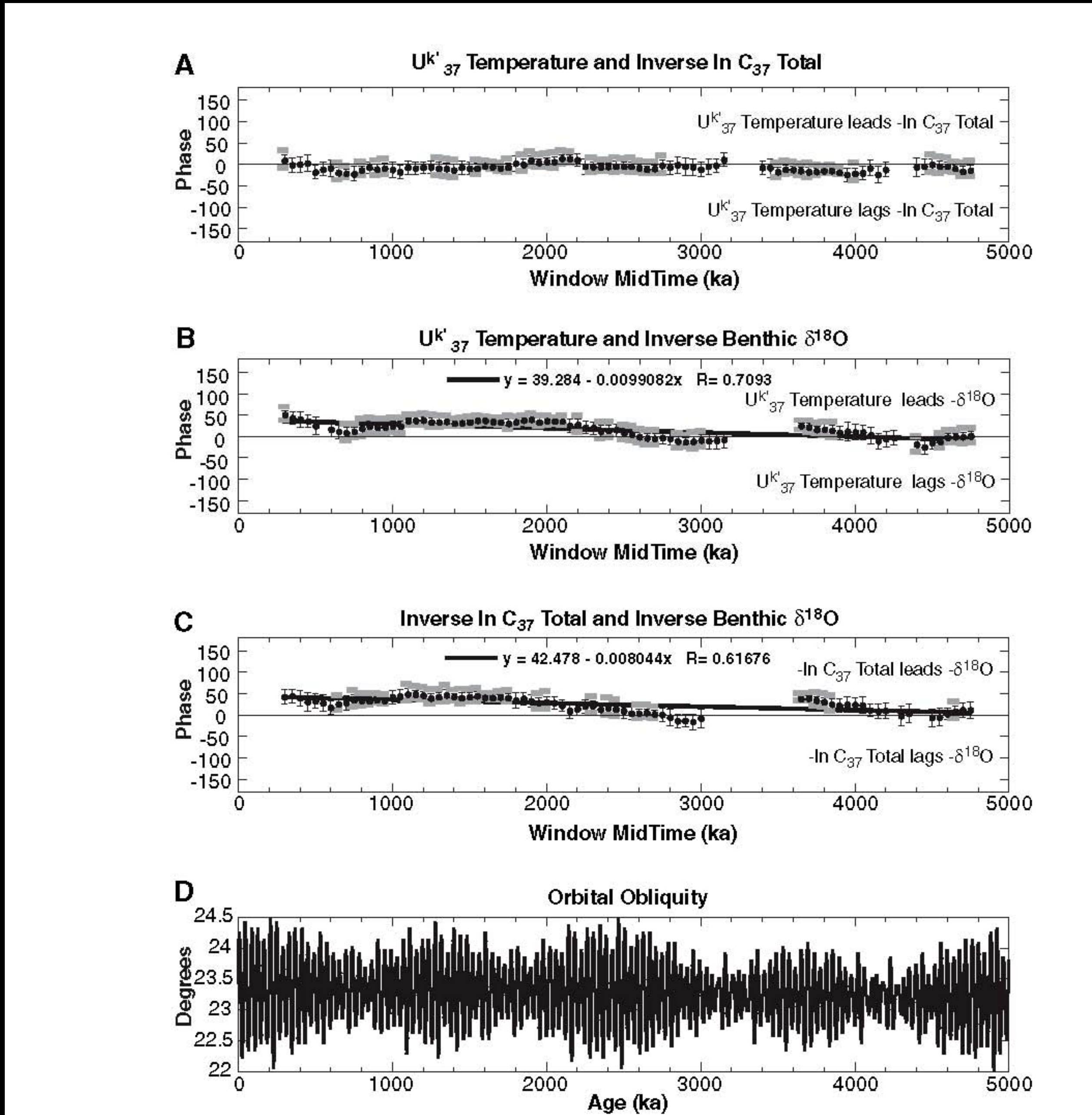
SST and PP are coupled on orbital time scales: cold T=high PP

But only weak link between SST and PP on long time scales

Lawrence et al., 2006

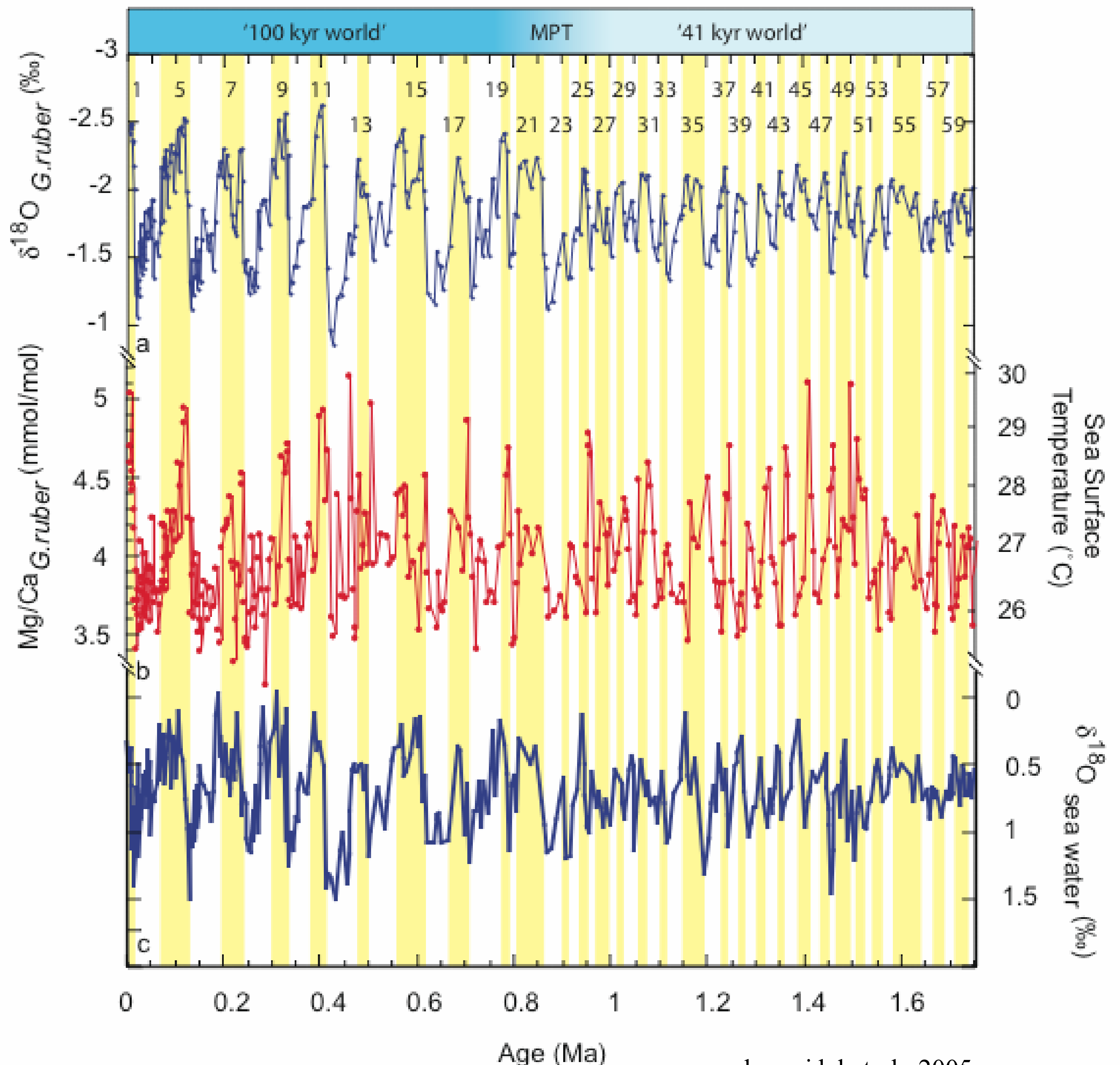


Strong obliquity but only weak precessional powers



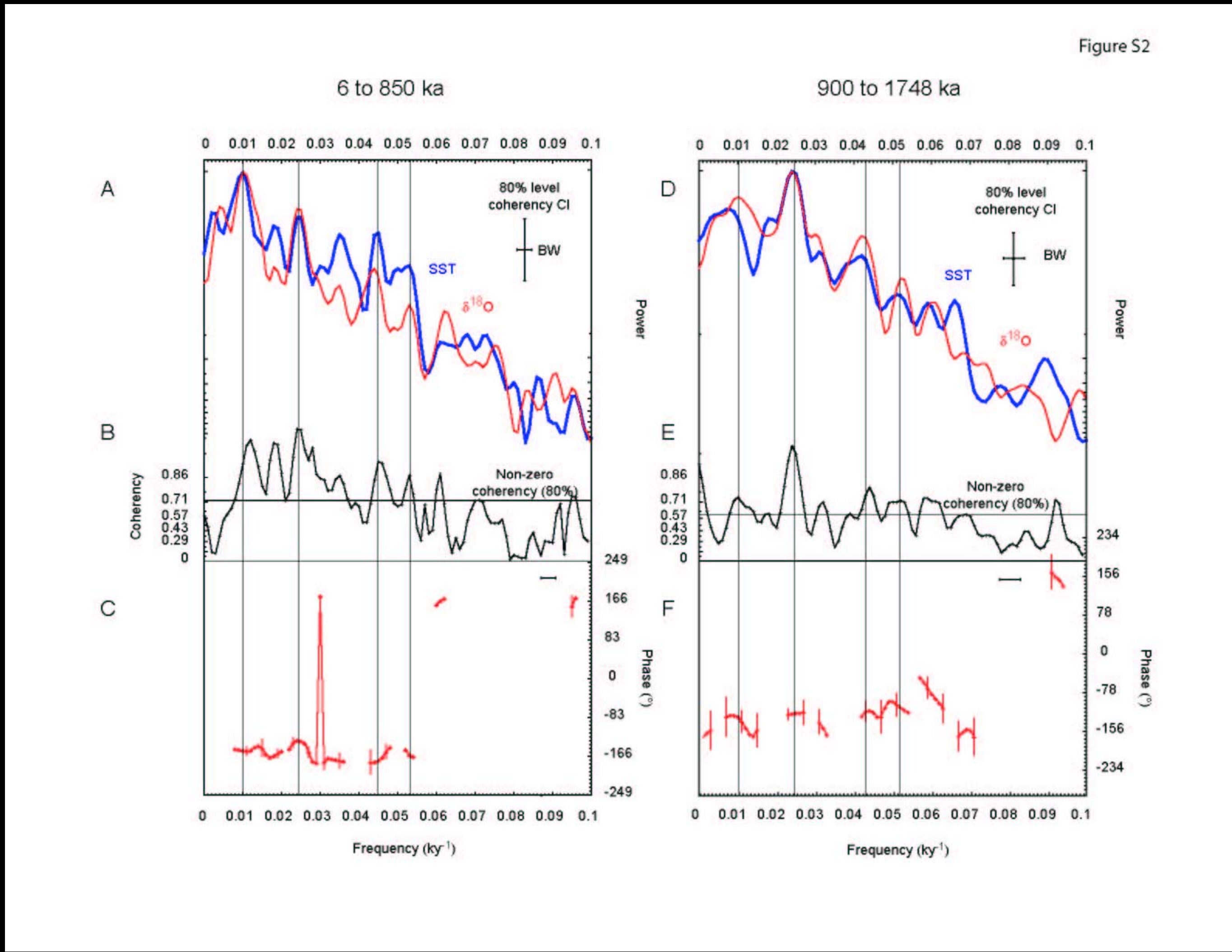
SST&PP are coherent and nearly in phase with the benthic $\delta^{18}O$ record but out of phase with low latitude insolation at the obliquity band i.e., cold SST and high PP correlates with low obliquity and warm SST and low PP correlates with high obliquity.

The Western Equatorial Warm Pool



de garidel et al., 2005

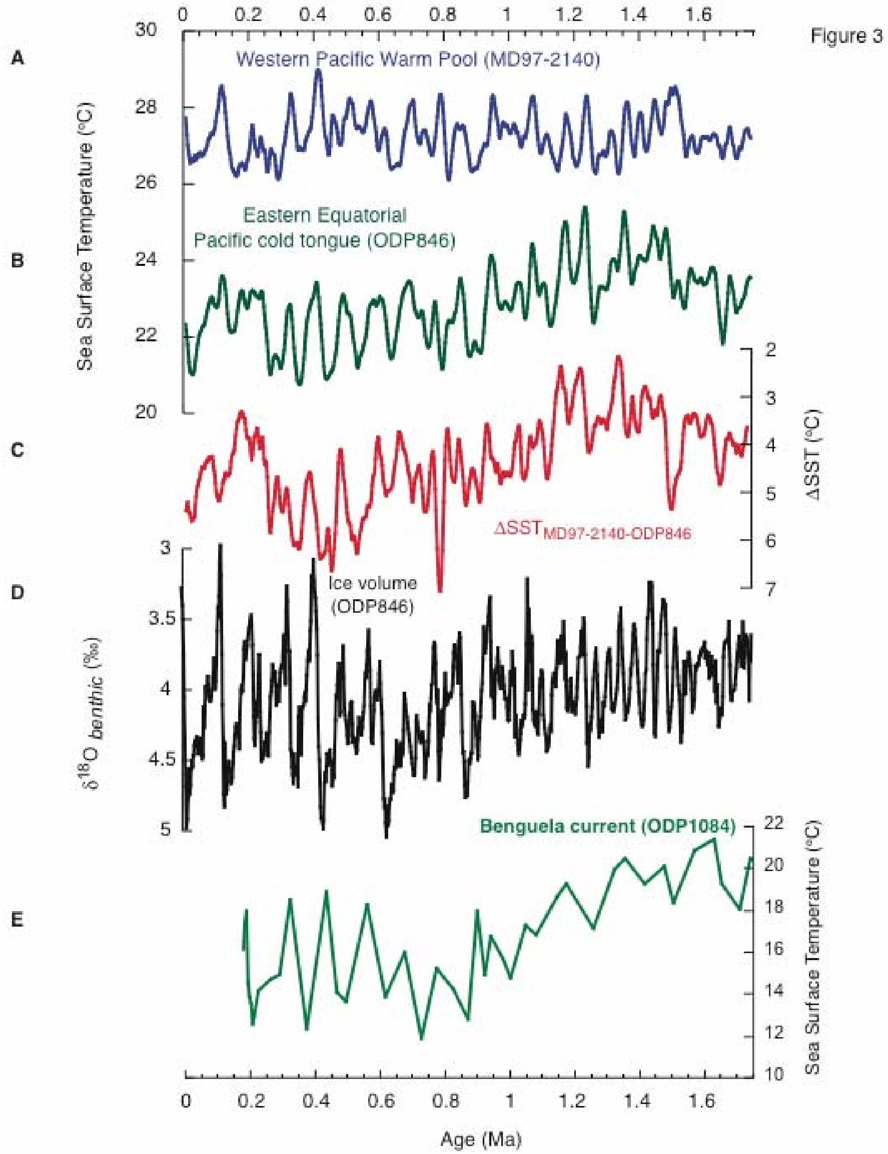
Cross-spectral analysis between SST and *G. ruber* $\delta^{18}O$



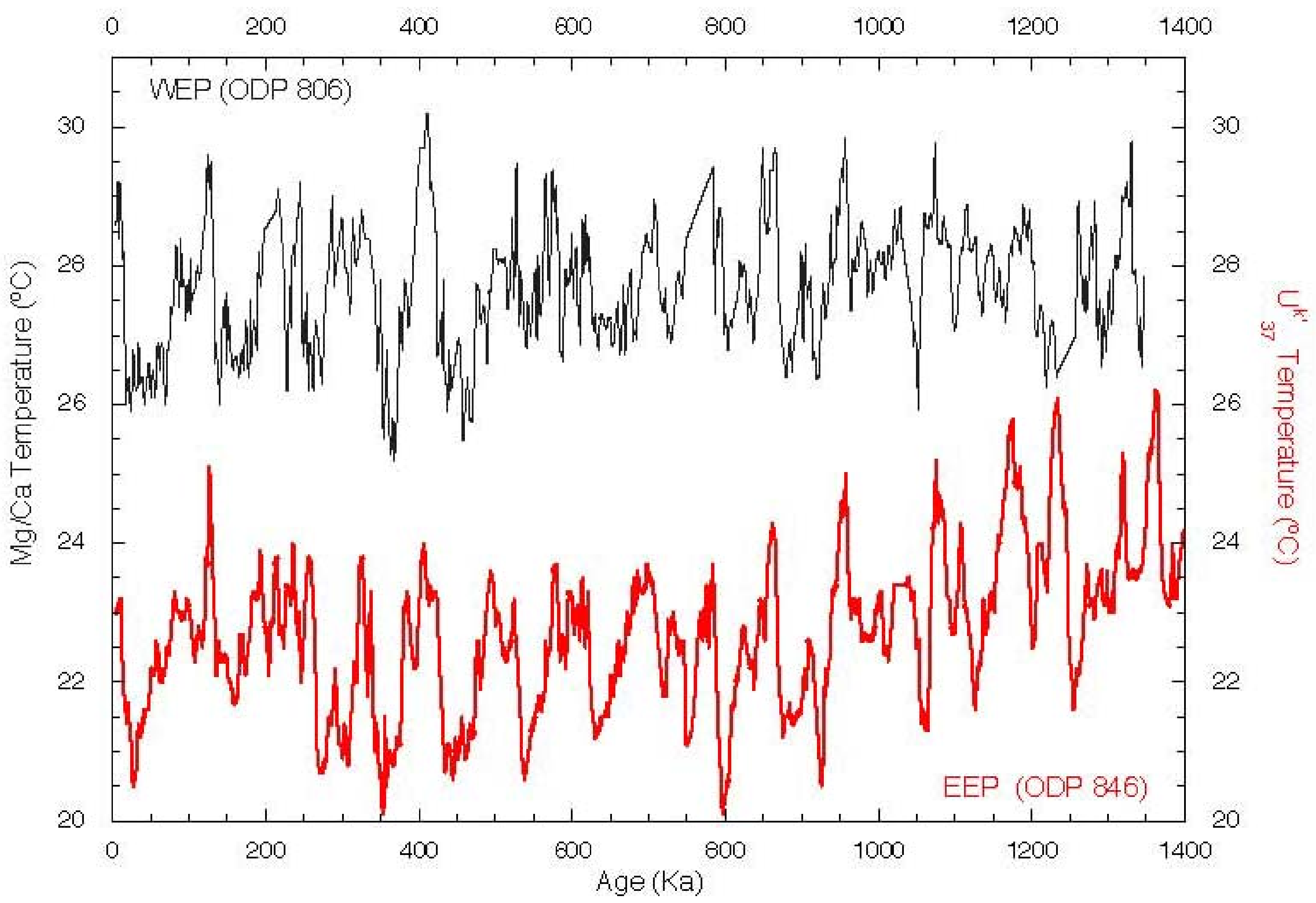
Variance both in the eccentricity and obliquity bands.
SST lead ice volume by ~4ky in the eccentricity band

most of the variance is in the obliquity band;
maximum SST = minimal in equatorial insolation
SST lead ice volume by 10±4 ky

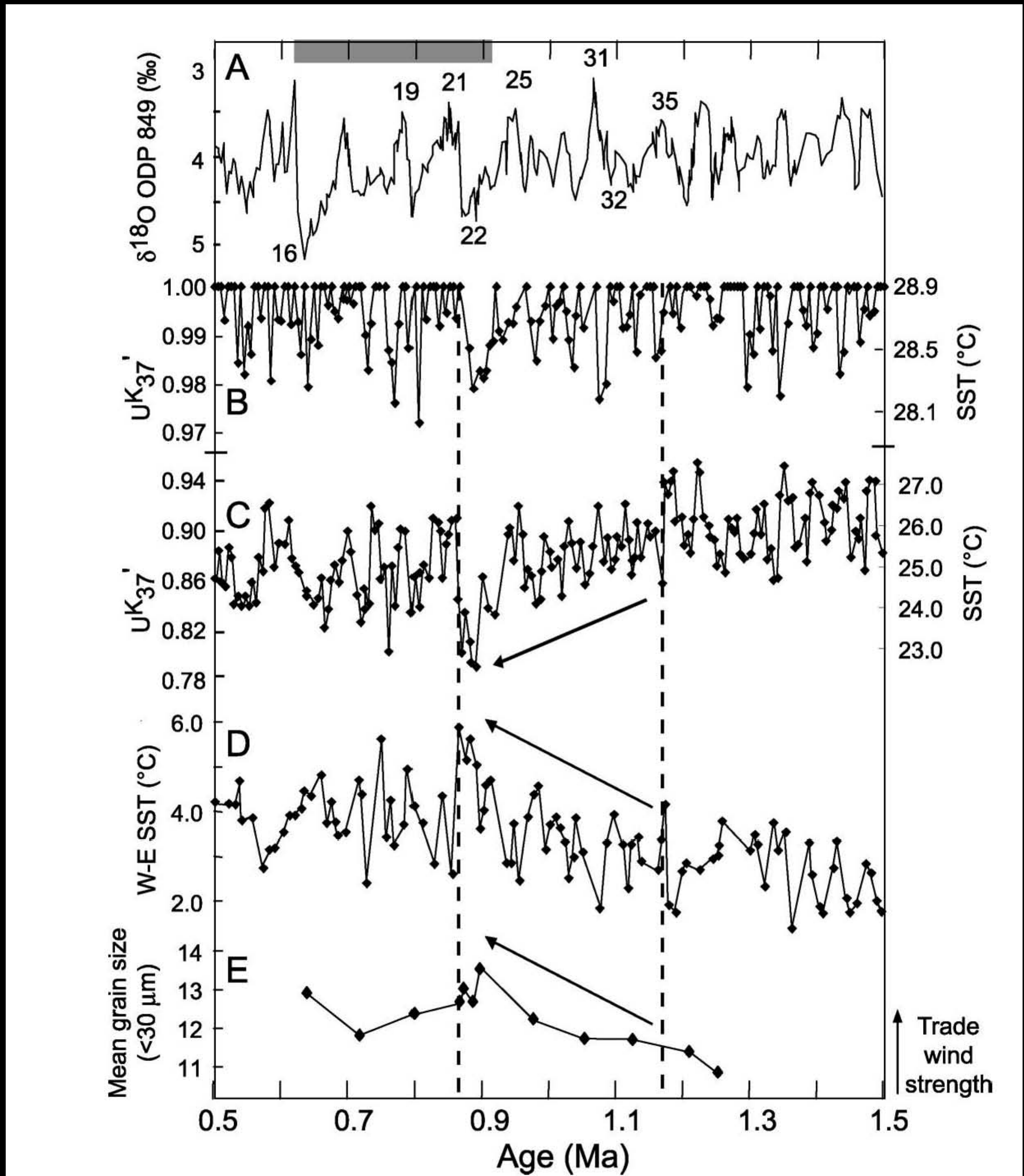
East-West SST Gradient



Tropical and extra-tropical forcings



G-I modulation of tropical Pacific SST and the E-W gradient



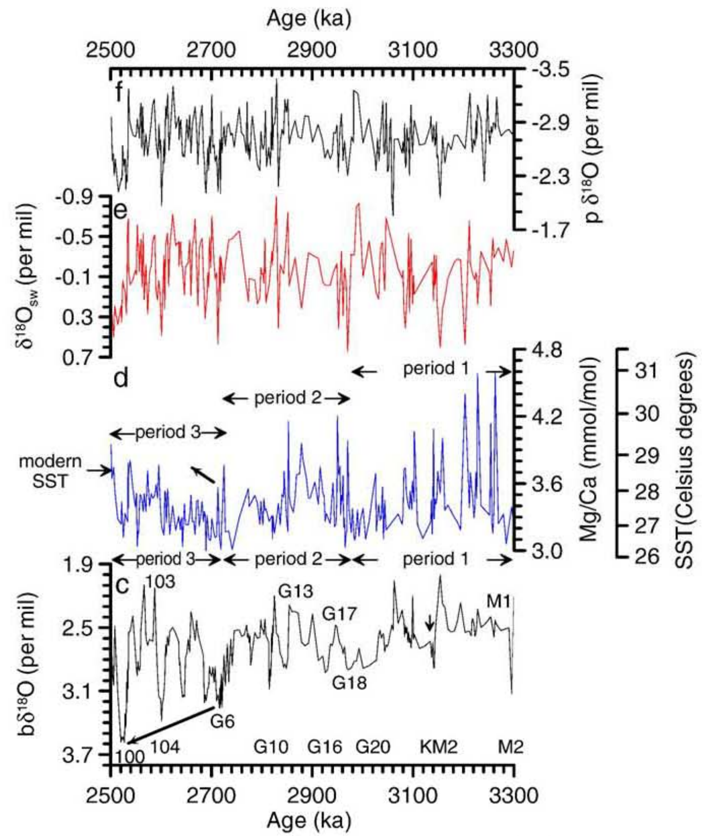
McClymont & Rosell-Melé, 2005

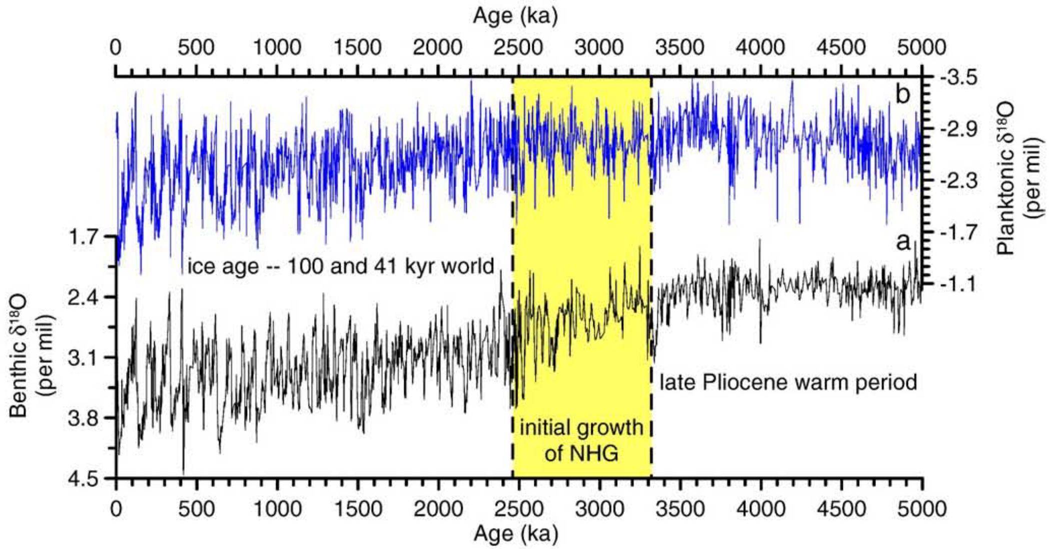
Corollary

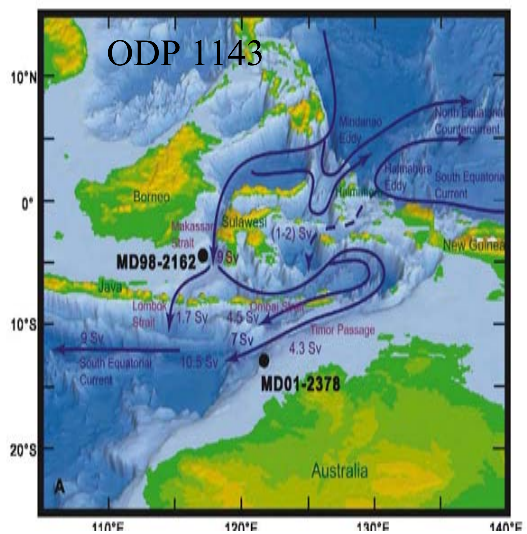
On orbital time scale, the consistency in G-I SST variability between the eastern and western equatorial Pacific suggests a common forcing likely atmospheric CO_2. But, is there also a secondary ENSO signature?

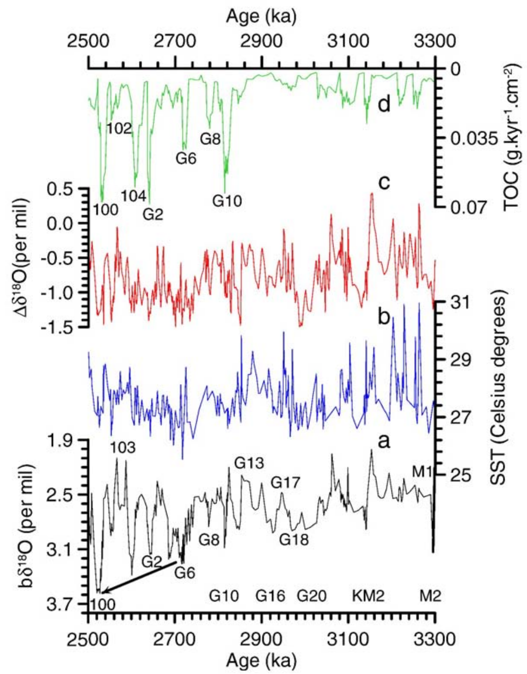
On longer time scales- why there is such a difference between the SST records from the EEP and WEP?

South China Sea ODP site 1143









The Timor Sea records

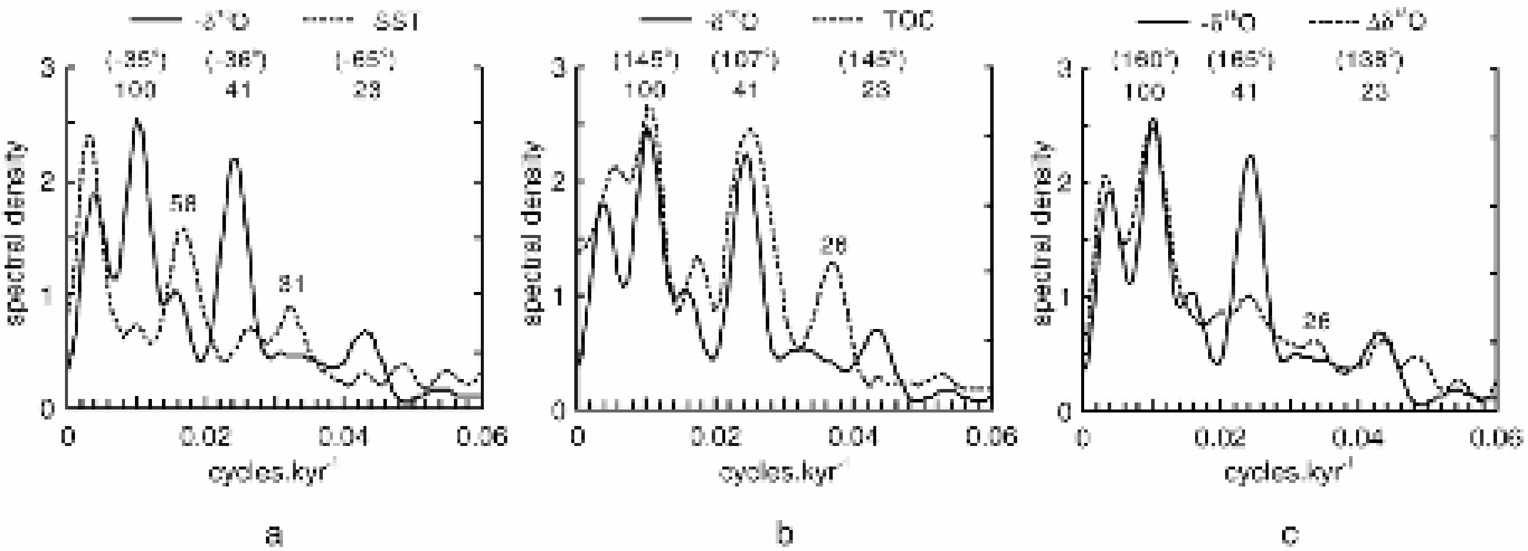
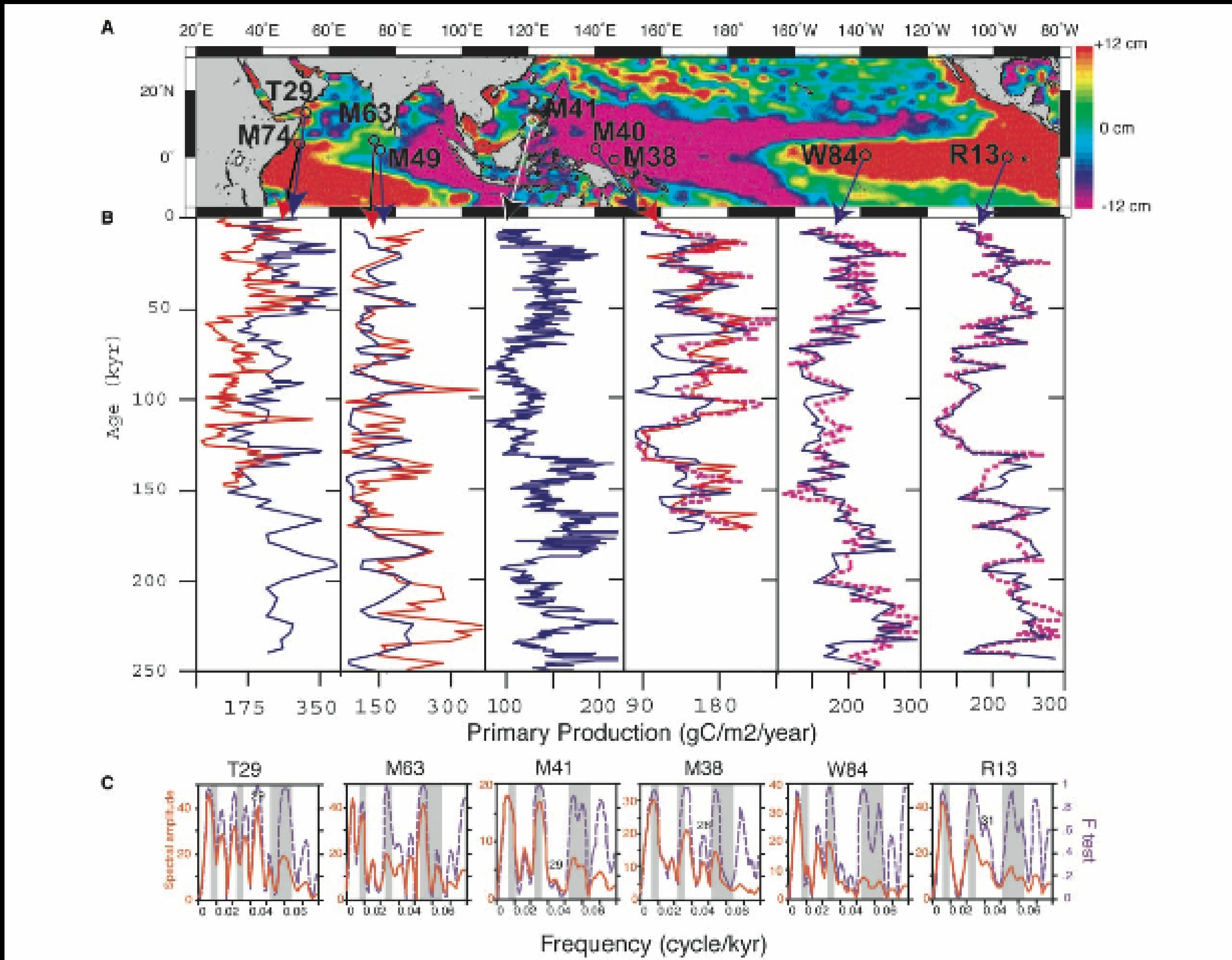
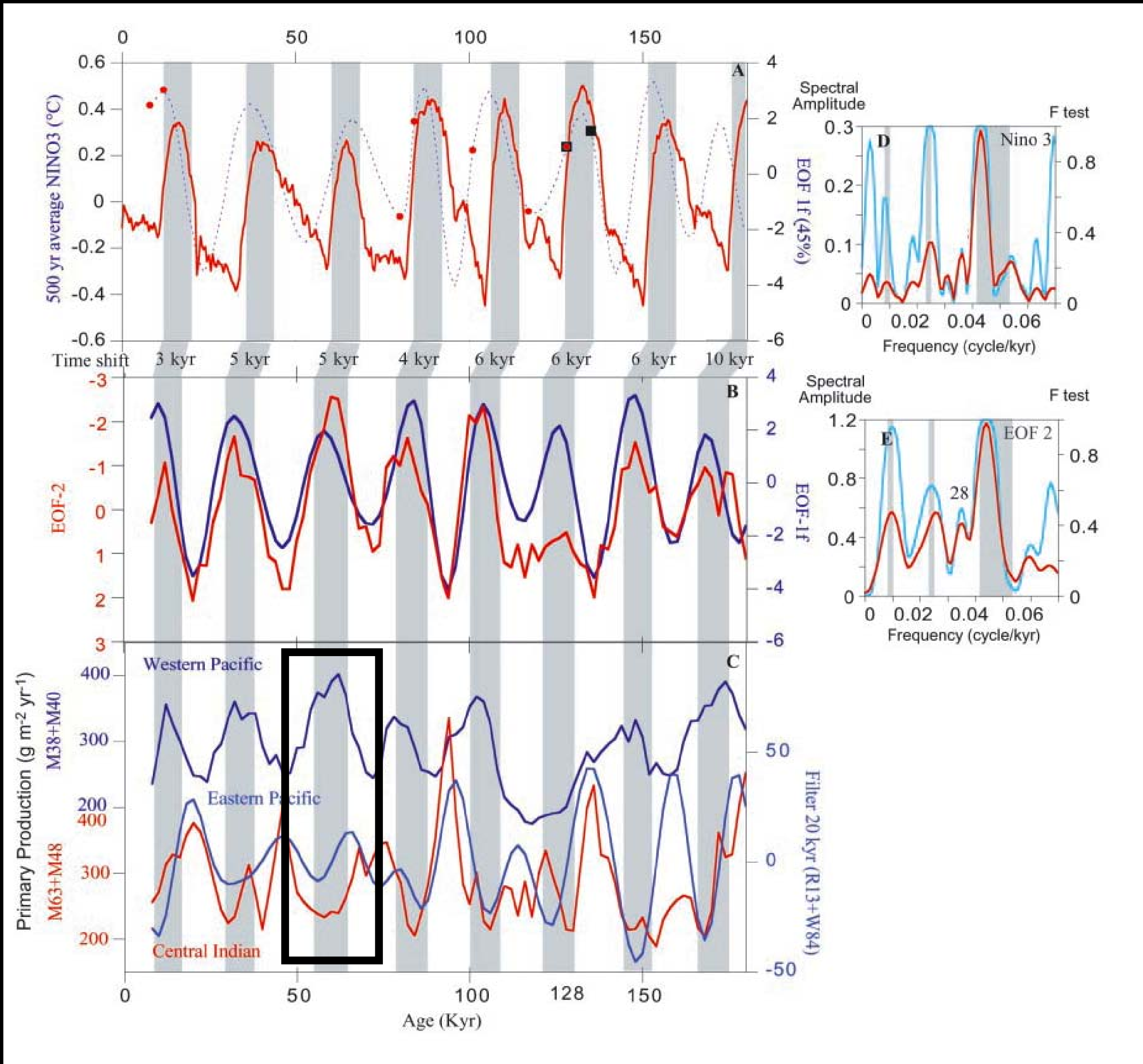


Fig. 4. Comparison among spectral analyses of *Cibicidoides* $-\delta^{18}O$ and Mg/Ca derived SST records, TOC records and $\Delta\delta^{18}O$ records from ODP Site 1143 in the period of 2.5–3.3 Ma. (a), spectrum of $-\delta^{18}O$ (solid line) and SST (dashed line). (b), spectrum of $-\delta^{18}O$ (solid line) and TOC (dashed line). (c), spectrum of $-\delta^{18}O$ (solid line) and $\Delta\delta^{18}O$ (dashed line). Numbers in the brackets of (a), (b) and (c) denote the phases at the 100-kyr, 41-kyr and 23-kyr bands. Negative phases denote SST leads $-\delta^{18}O$, and positive phases denote TOC or $\Delta\delta^{18}O$ lags $-\delta^{18}O$.

ENSO-like forcing on Oceanic Primary Production during the late-Pleistocene



Beaufort et al., 2001 PP estimates based on *Florispharea profunda*



EOF-1(40%): Represents global G-I variability, high during glacials low during interglacials

EOF-2/EOF-1f (19%):

A strong precessional signal with opposing trend between the western and eastern Pacific PP records.

An ENSO modulation?

Paleoproductivity records from the Timor Sea

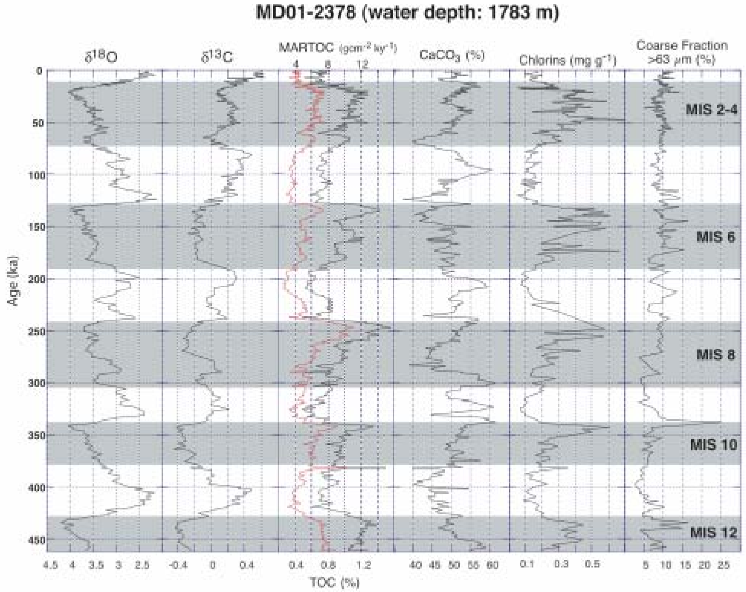


Figure 4. Benthic foraminiferal $\delta^{18}O$ and $\delta^{13}C$, TOC percent and accumulation rates, carbonate percent, chlorins concentrations, and coarse fraction >63 μm % in Core MD01-2378.

6 of 18

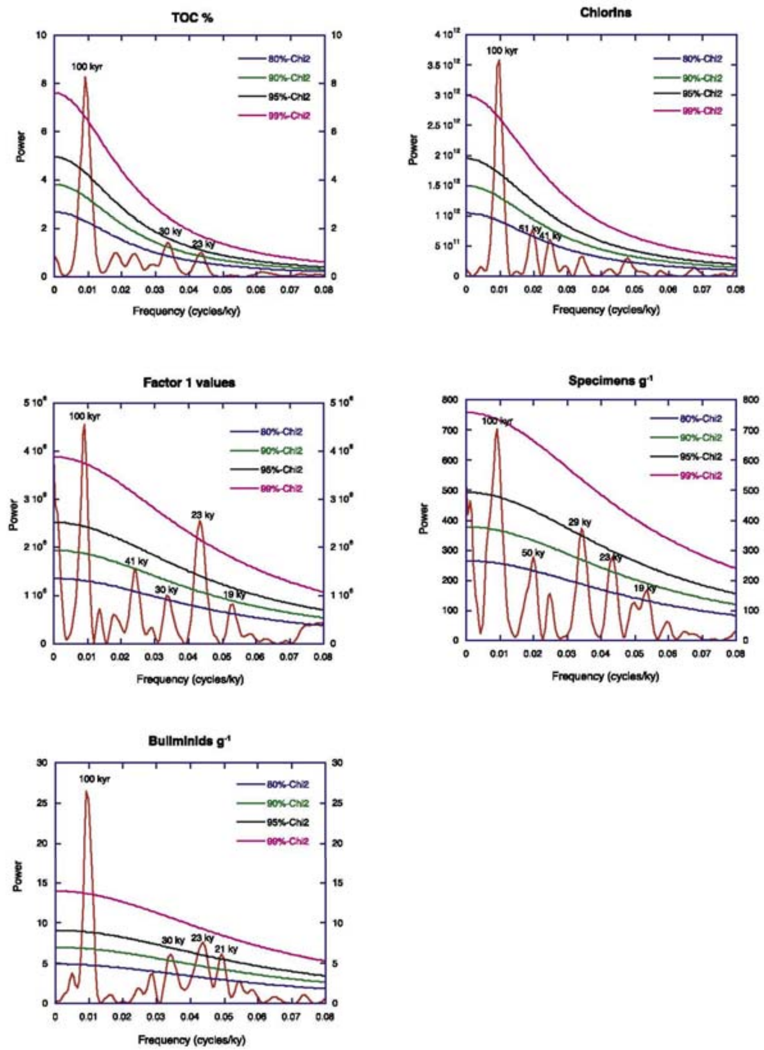
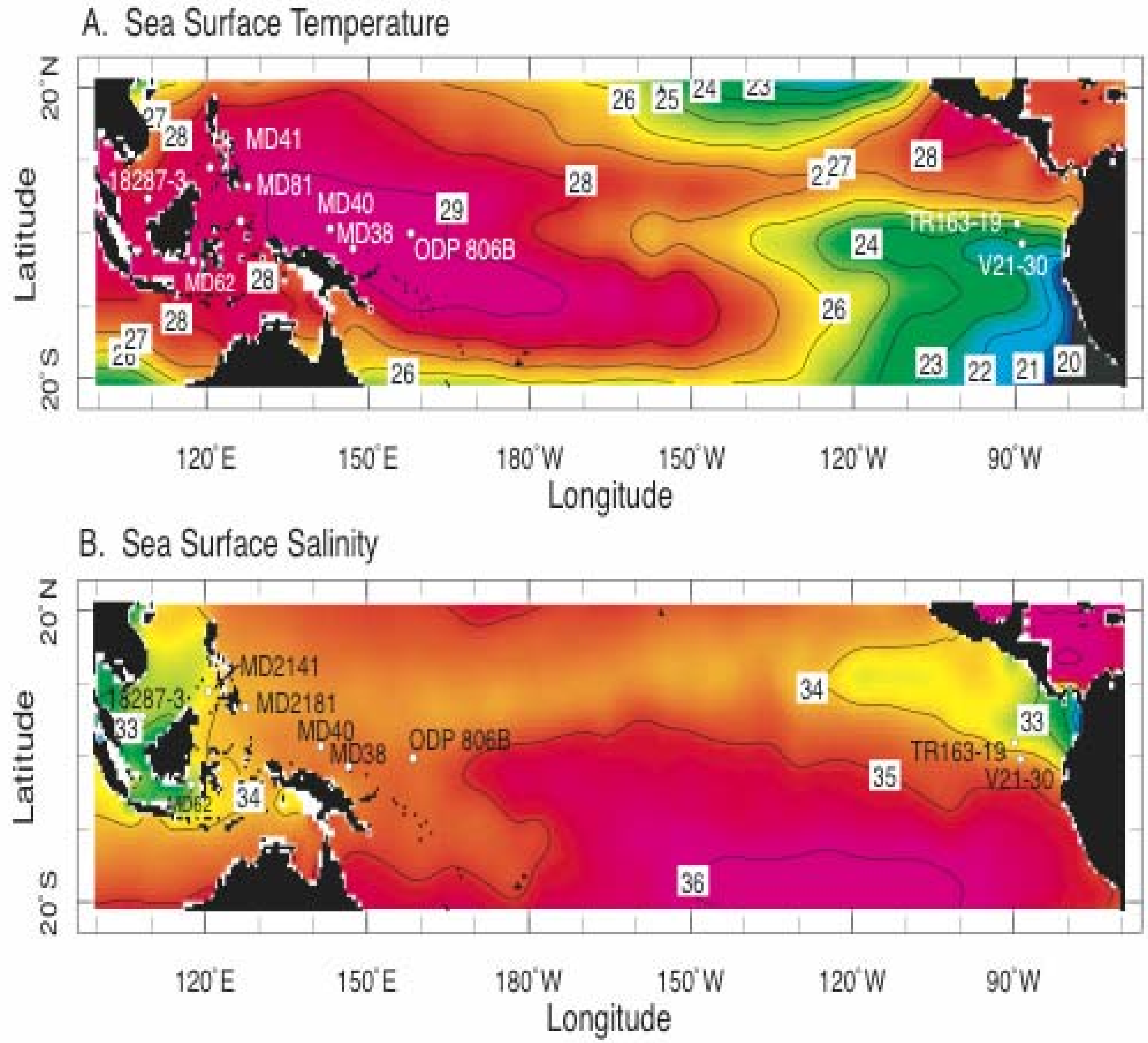


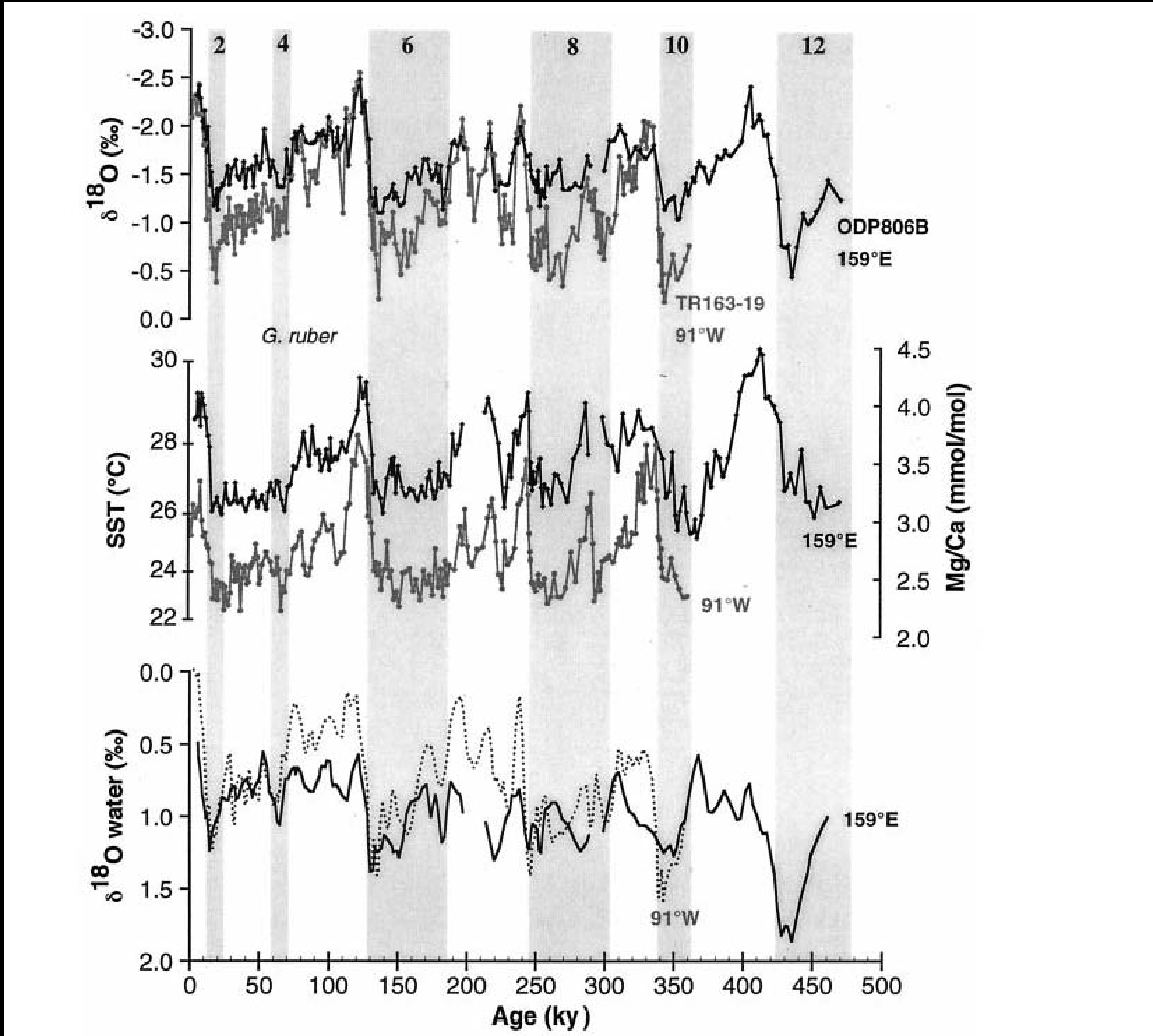
Figure 7

11 of 18

Holbourn et al., 2005

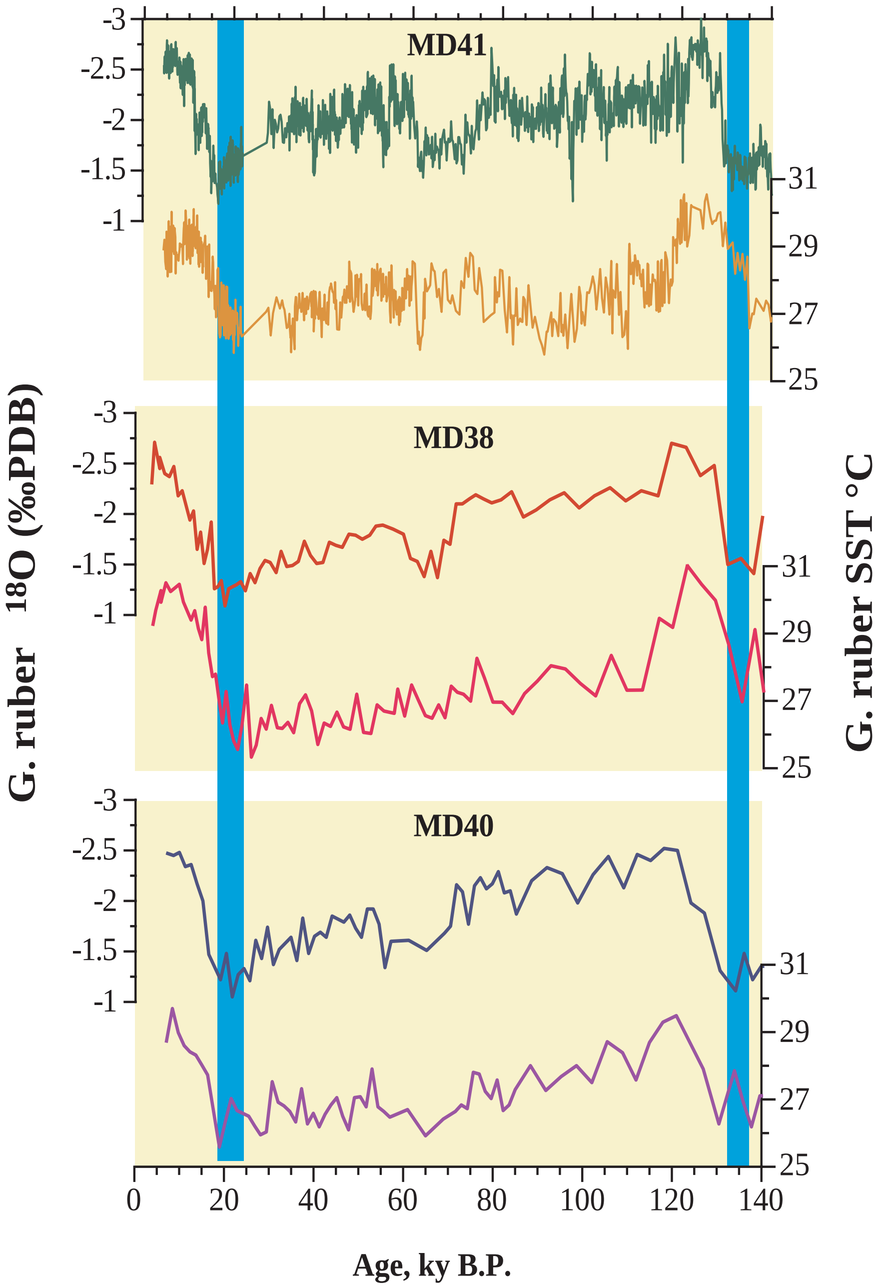
Cores Location





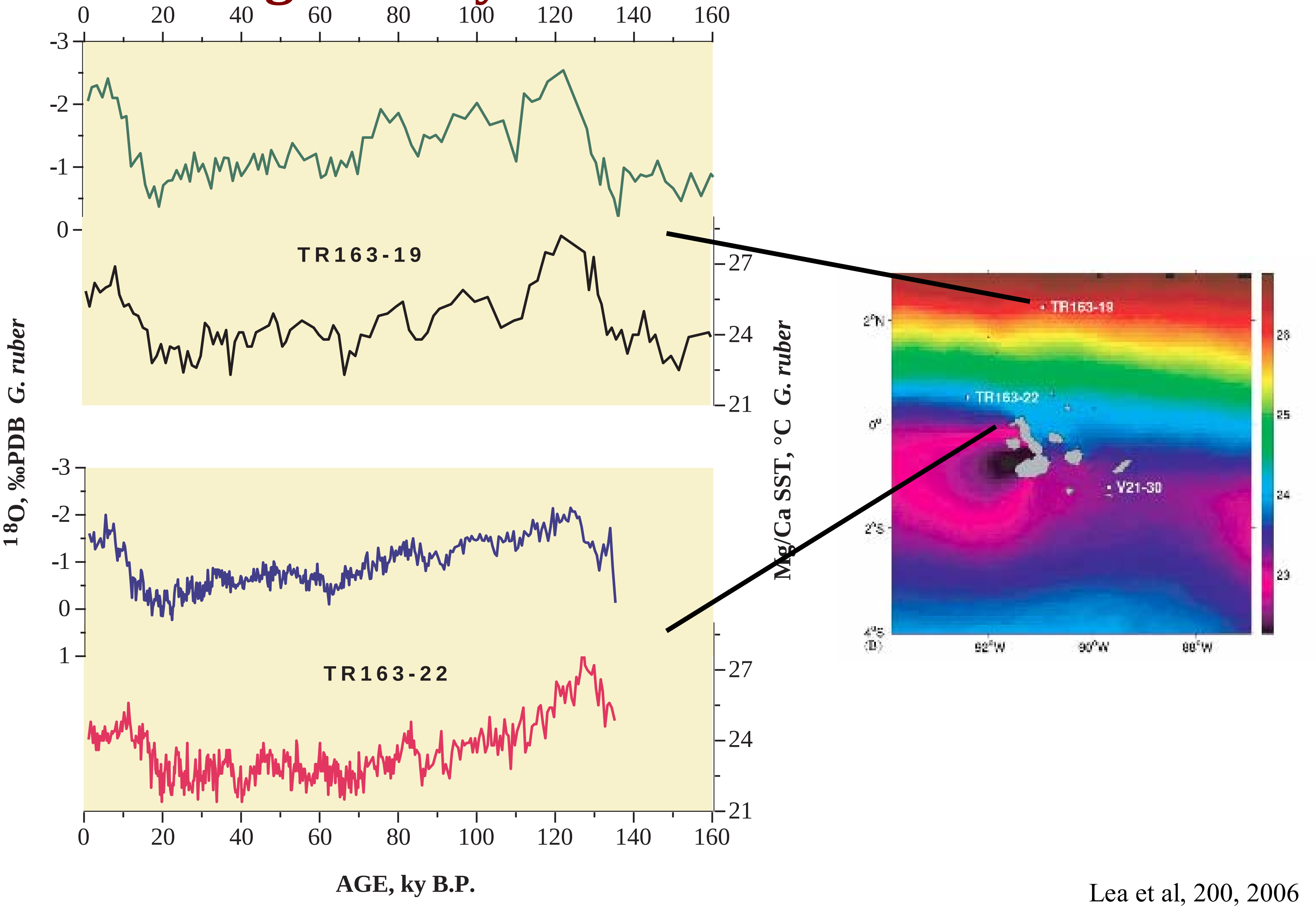
Lea et al., 2000

Last glacial cycle in the WEP

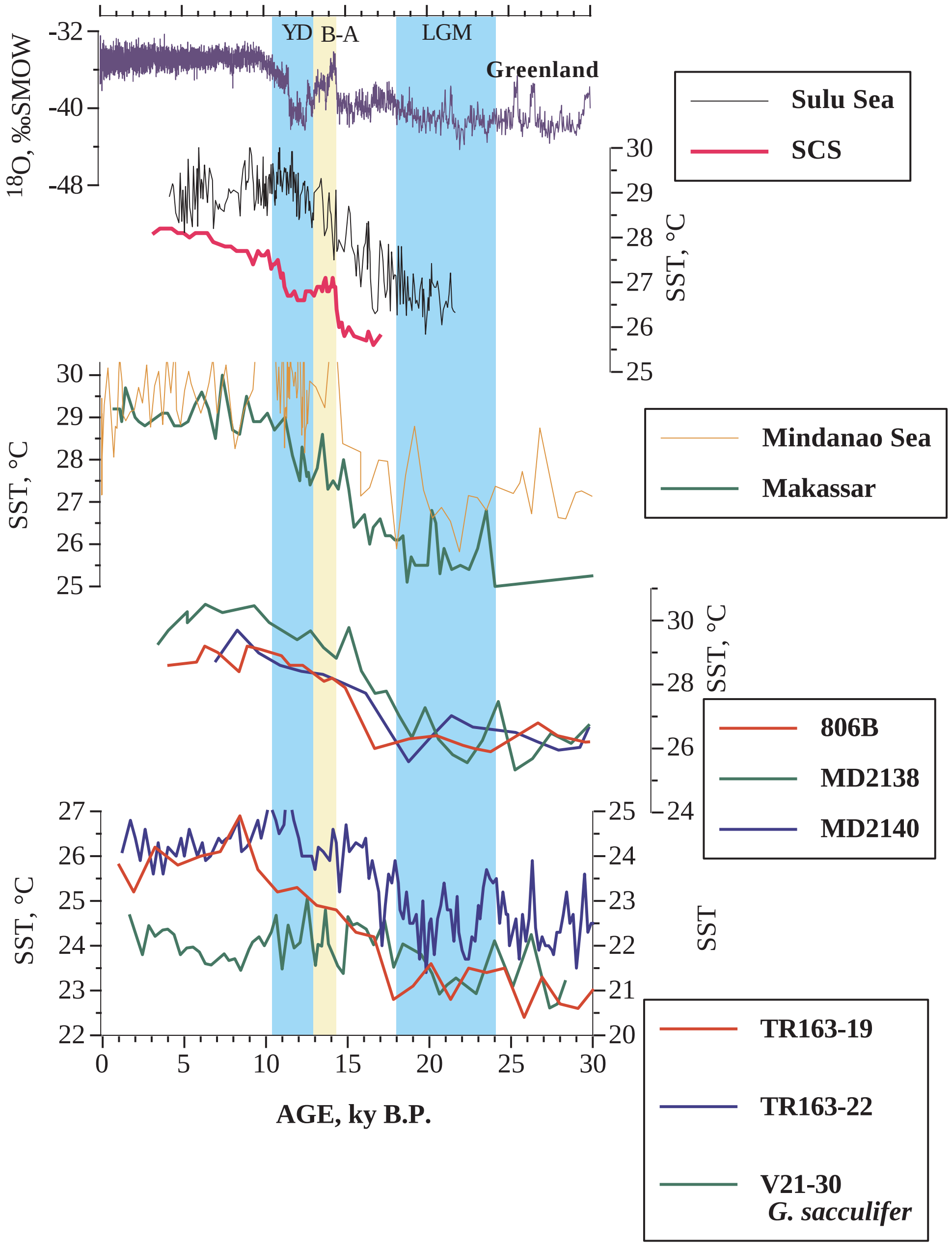


Rosenthal et al., 2003
de Garidel et al., 2005
de Garidel et al., 2007

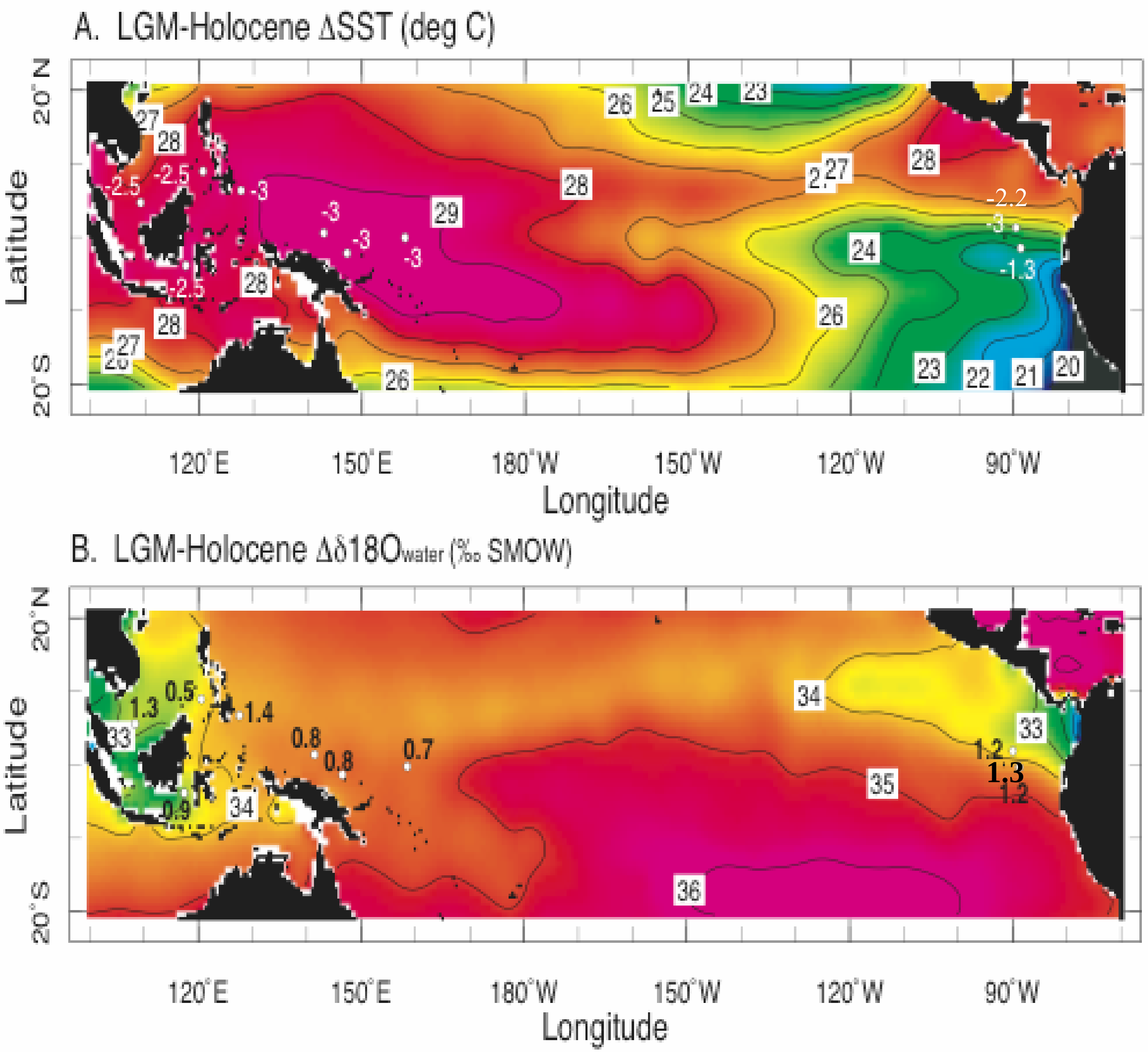
Last glacial cycle in the EEP



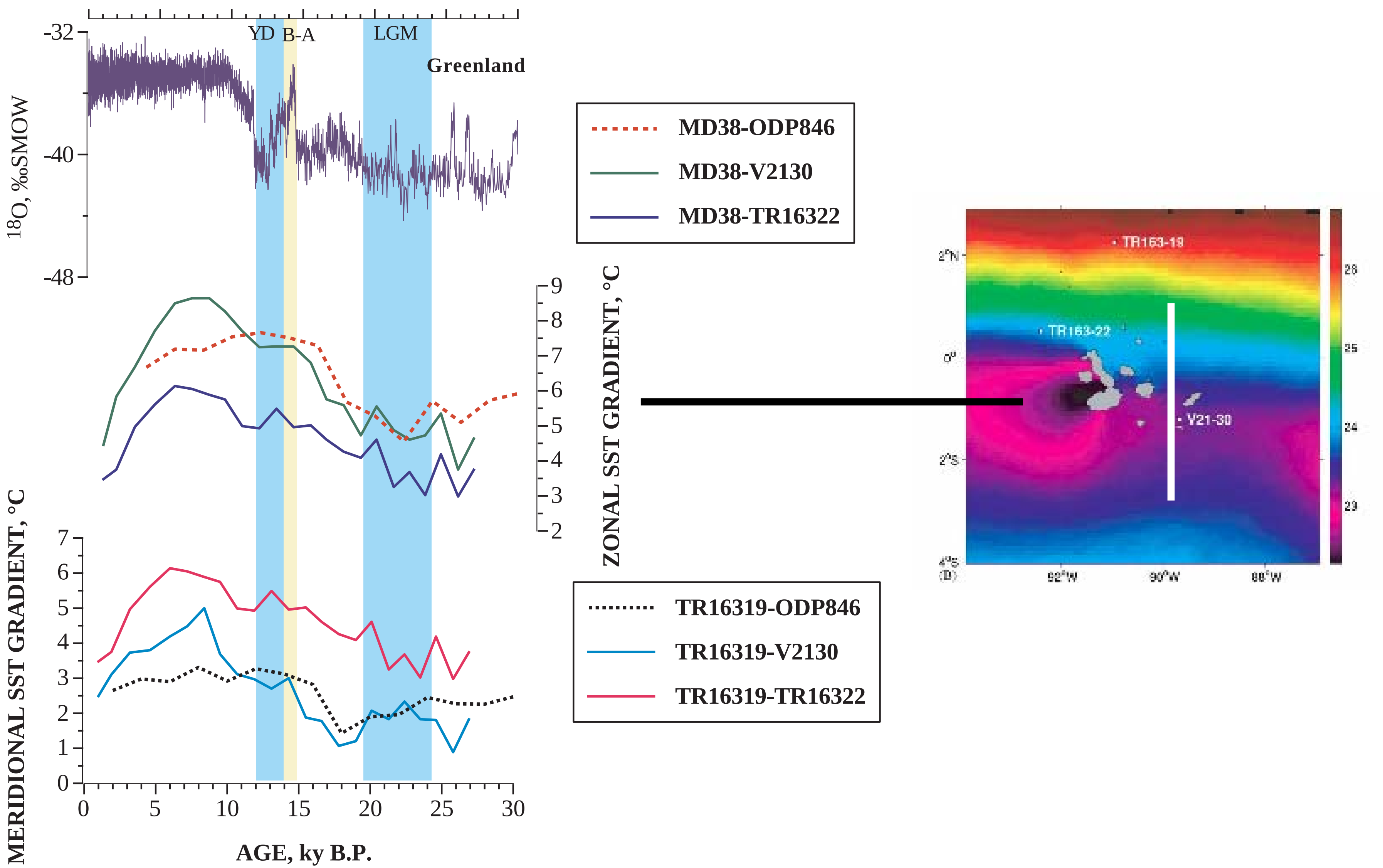
Lea et al, 200, 2006



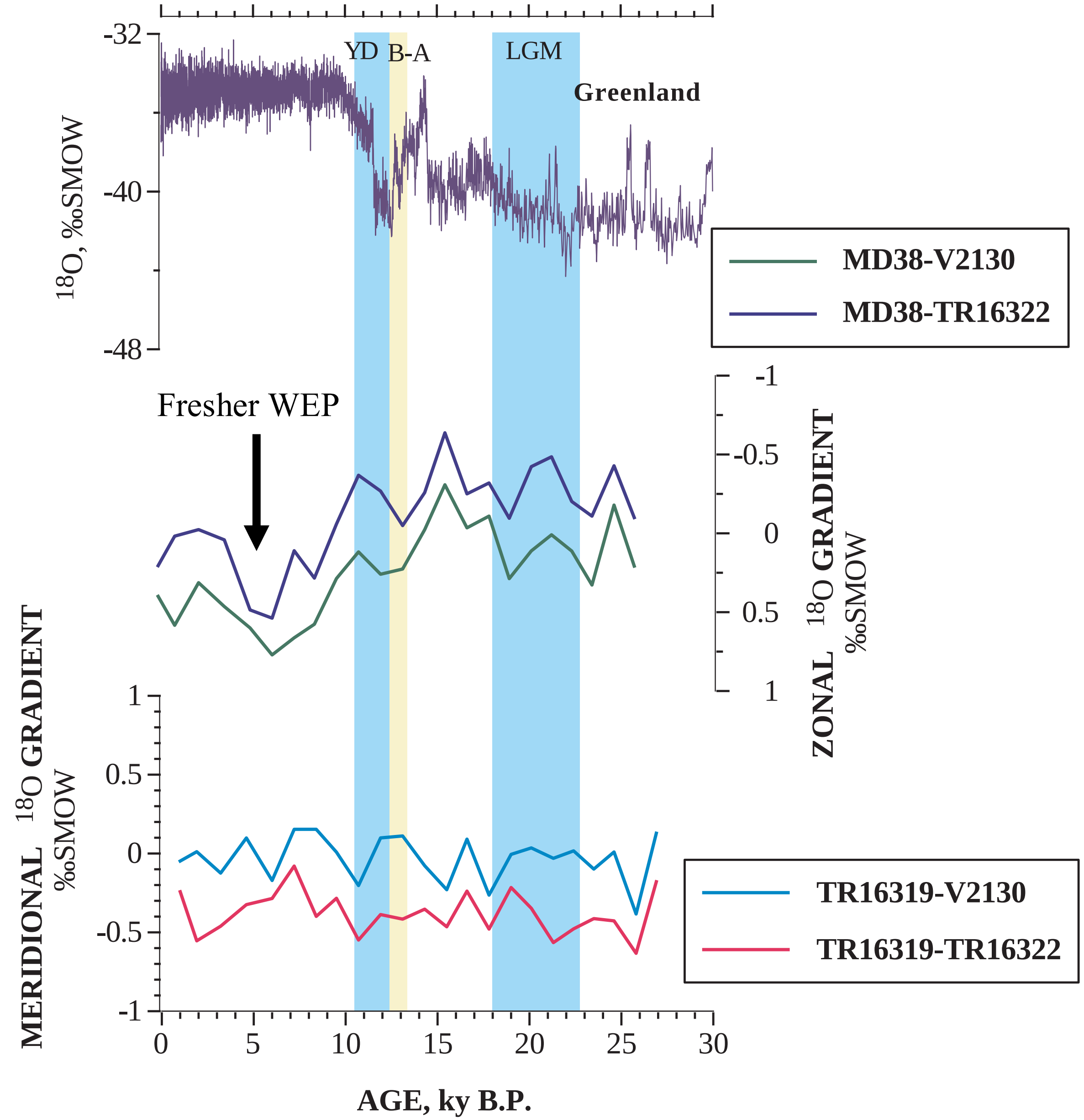
YD
B-A
LGM
Greenland
^{18}O, ‰SMOW
-32
-40
-48
Sulu Sea
SCS
SST, °C
30
29
28
27
26
25
Mindanao Sea
Makassar
806B
MD2138
MD2140
24
TR163-19
TR163-22
V21-30
G. sacculifer
SST
AGE, ky B.P.
0
5
10
15
20

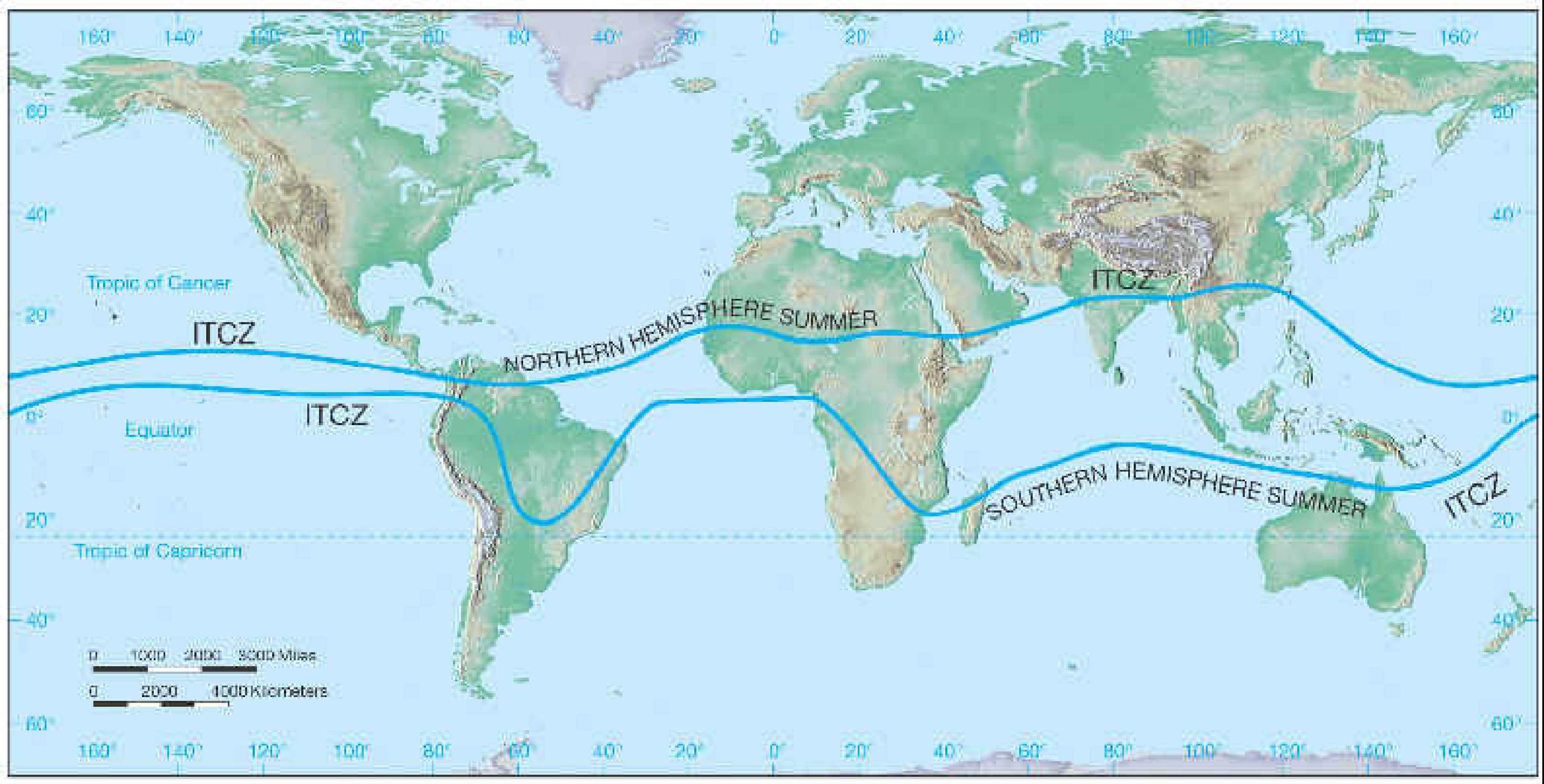

A. LGM-Holocene ΔSST (deg C)
Latitude
20°N
20°S
120°E
150°E
180°W
150°W
120°W
90°W
Longitude
26
25
24
23
27
28
-2.5
-2.5
-3
-3
-3
-3
29
28
-2.2
-3
24
-1.3
28
-2.5
28
27
26
23
22
21
20
B. LGM-Holocene Δδ18Owater (‰ SMOW)
Latitude
20°N
20°S
120°E
150°E
180°W
150°W
120°W
90°W
Longitude
1.3
0.5
1.4
33
0.8
0.8
0.7
0.9
34
34
33
1.2
1.3
1.2
35
36

Equatorial Pacific thermal gradients during the last degalciation



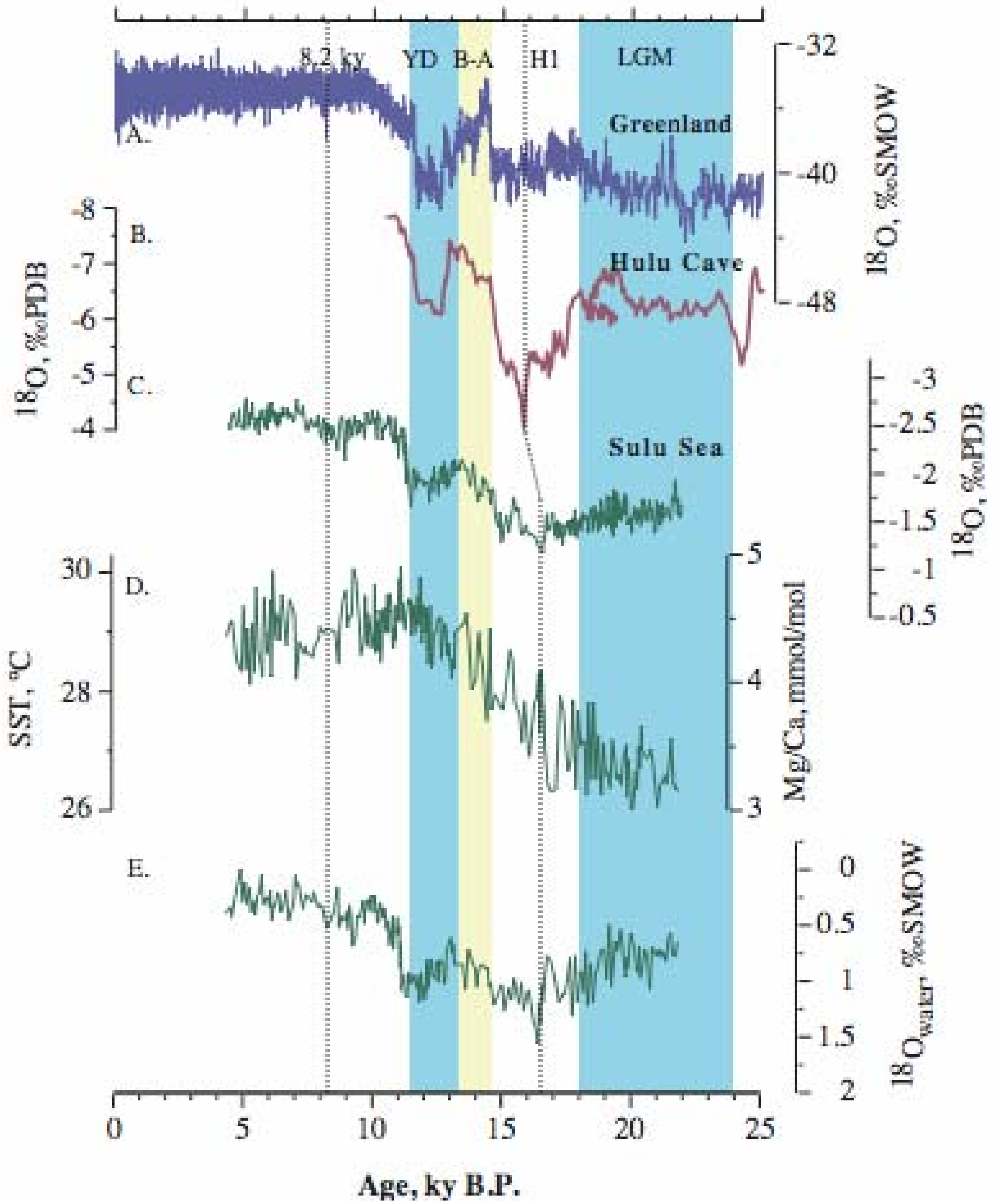
Equatorial Pacific "salinity gradients" gradients during the last degalciation

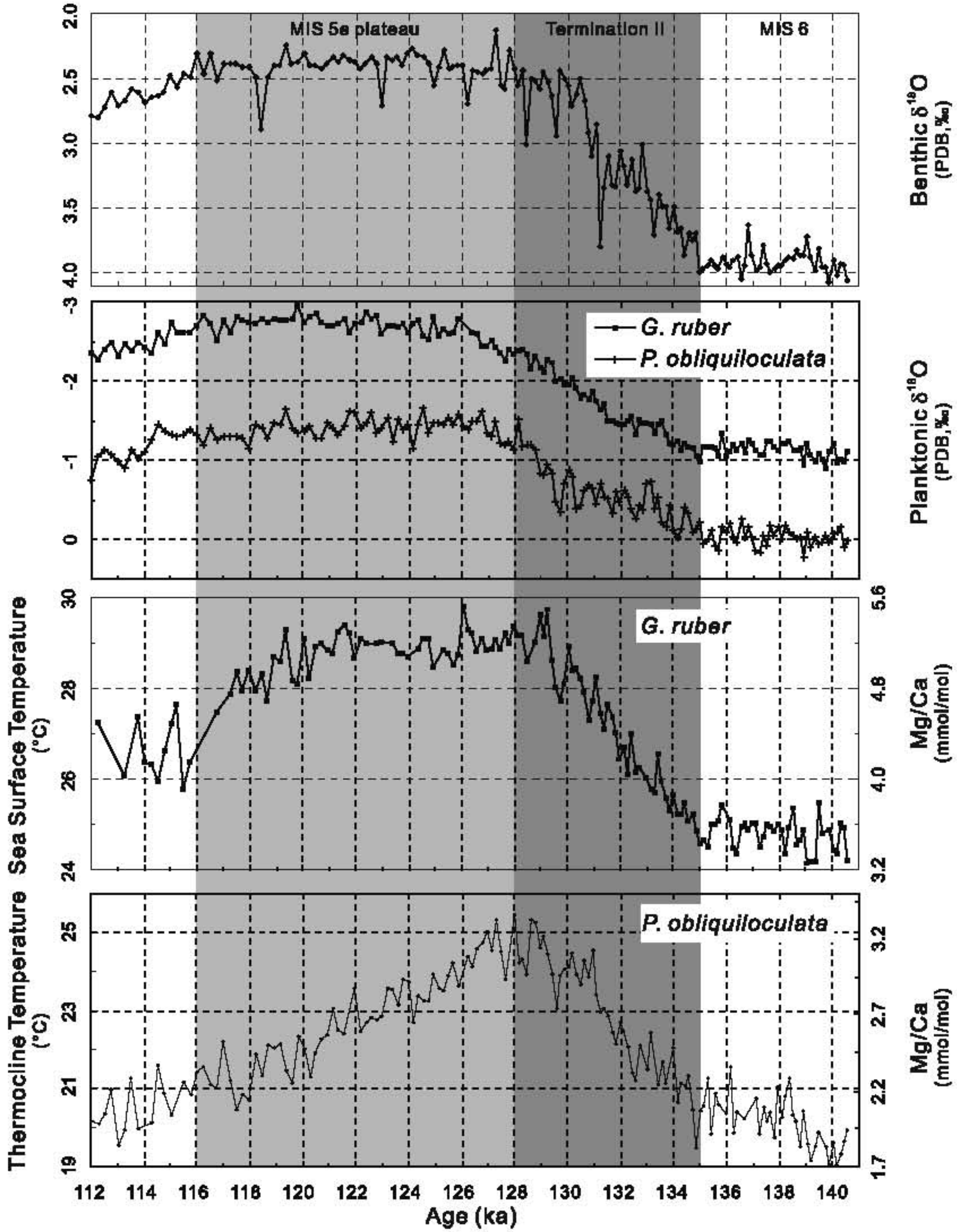




Tropic of Cancer
ITCZ
NORTHERN HEMISPHERE SUMMER
ITCZ
Equator
ITCZ
SOUTHERN HEMISPHERE SUMMER
ITCZ
Tropic of Capricorn
0 1000 2000 3000 Miles
0 2000 4000 Kilometers

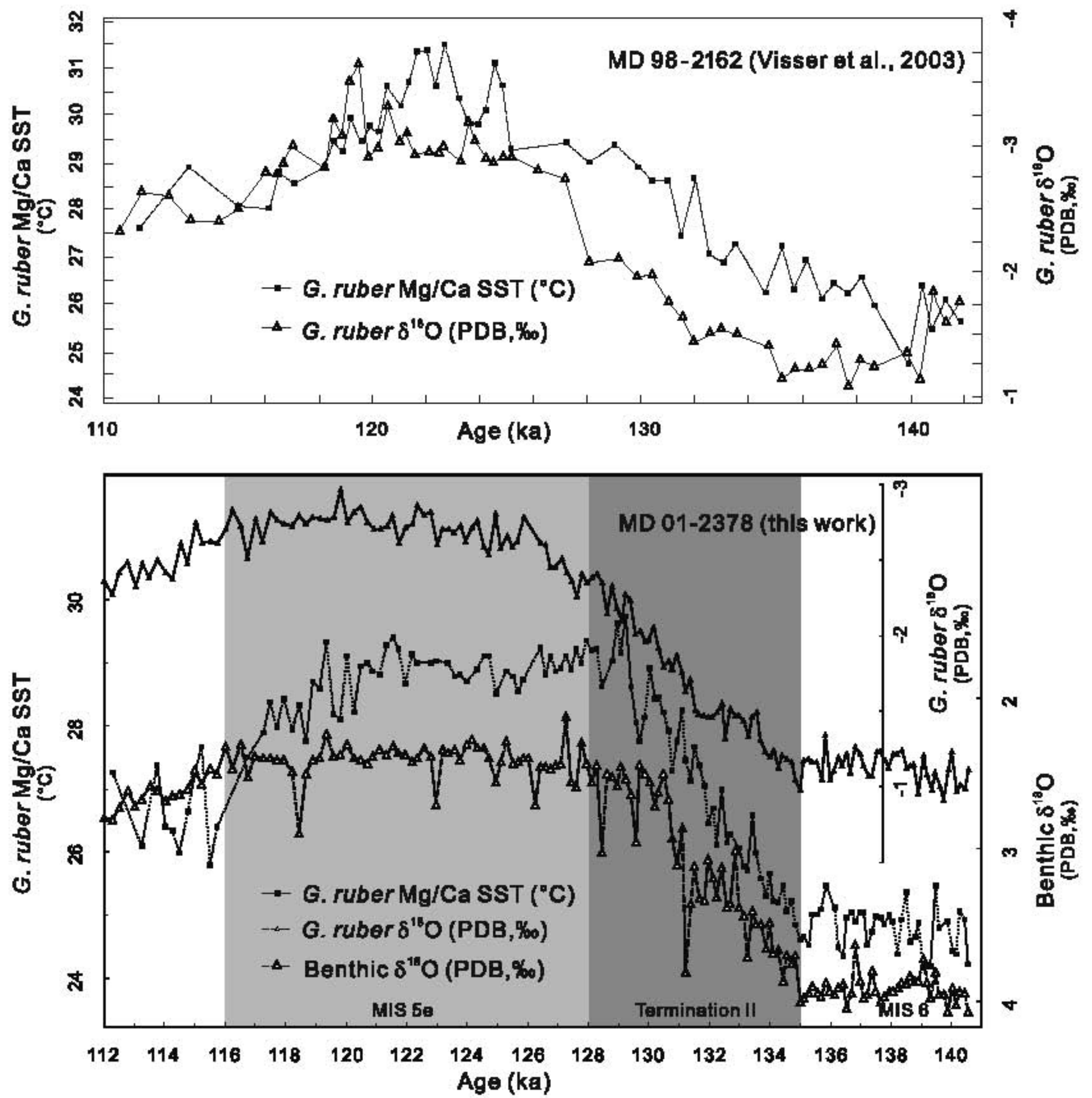
Equatorial Pacific SST lead on ice volume?
The Sulu Sea record





Termination-2
in the Timor Sea

Xu et al. 2006



MD 98-2162 (Visser et al., 2003)
G. ruber Mg/Ca SST (°C)
G. ruber δ18O (PDB,‰)
G. ruber Mg/Ca SST (°C)
G. ruber δ18O (PDB,‰)
Age (ka)
MD 01-2378 (this work)
G. ruber Mg/Ca SST (°C)
G. ruber δ18O (PDB,‰)
Benthic δ18O (PDB,‰)
MIS 5e
Termination II
MIS 6
G. ruber Mg/Ca SST (°C)
G. ruber δ18O (PDB,‰)
Benthic δ18O (PDB,‰)
Age (ka)

SUMMARY

- Changes in the mean background climate state:

  from permanent El Niño to La Niña
- Orbital frequencies:

  Strong obliquity signal likely forced from the high latitude. Precession strong in monsoon dominated region
- ENSO modulations:

  significant tropical dynamics superimposed on globally forced G-I changes. ENSO may not be the best analog
- Temporal relationships

  The Pacific lead is still controversial