Through the ^{14}Coral Looking Glass: What Can We See?

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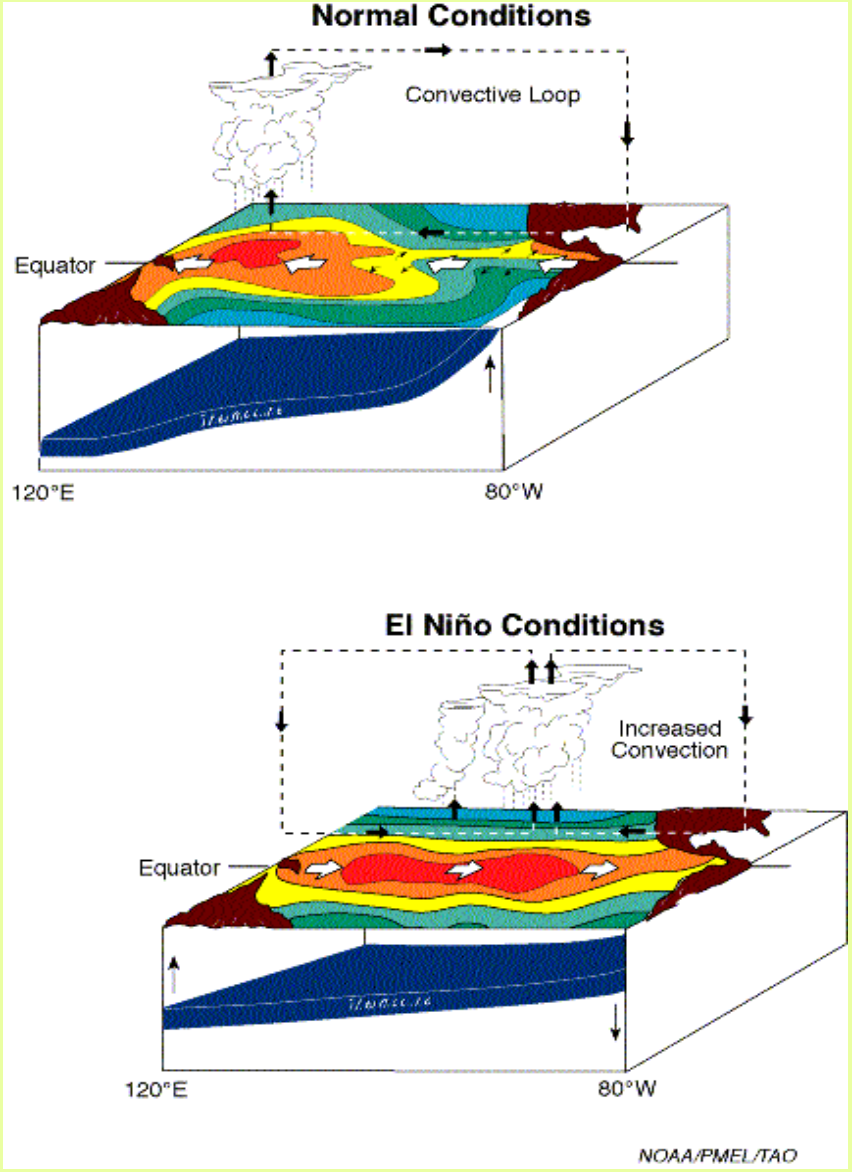
Questions Posed

- What do ^{14}C records in surface corals tell us about changes in circulation and climate?
- Do climate changes during 18th century resemble those during 20th century?

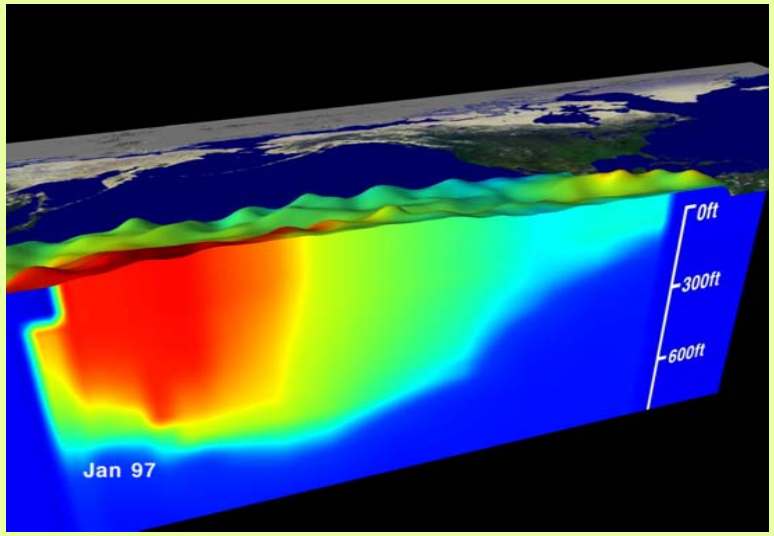
Time Scales of Climate Change

- Seasonal
- Interannual - e.g. El Niño
- Decadal - Pacific, Atlantic, Arctic
- Centennial - Tropical Pacific?

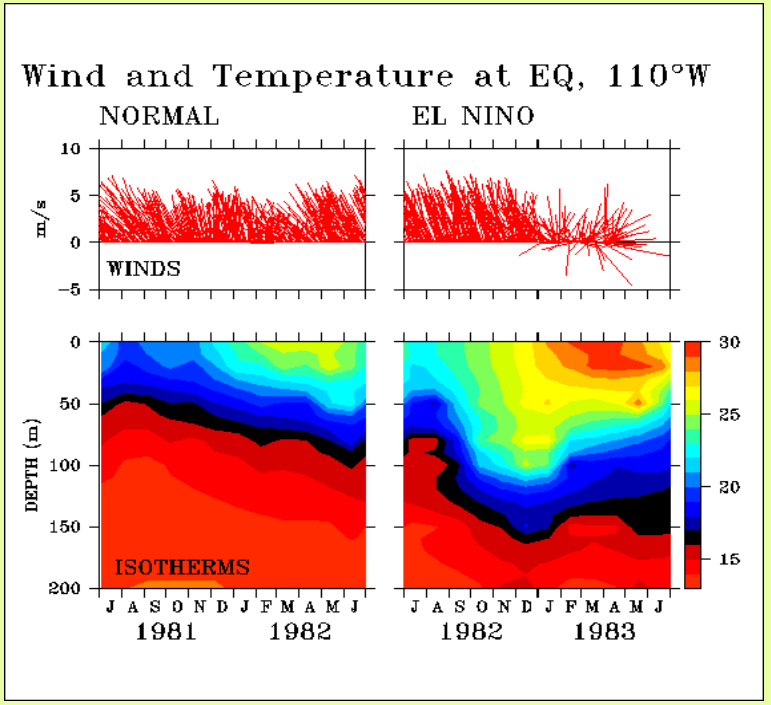
Normal vs. El Niño - Pacific



Normal

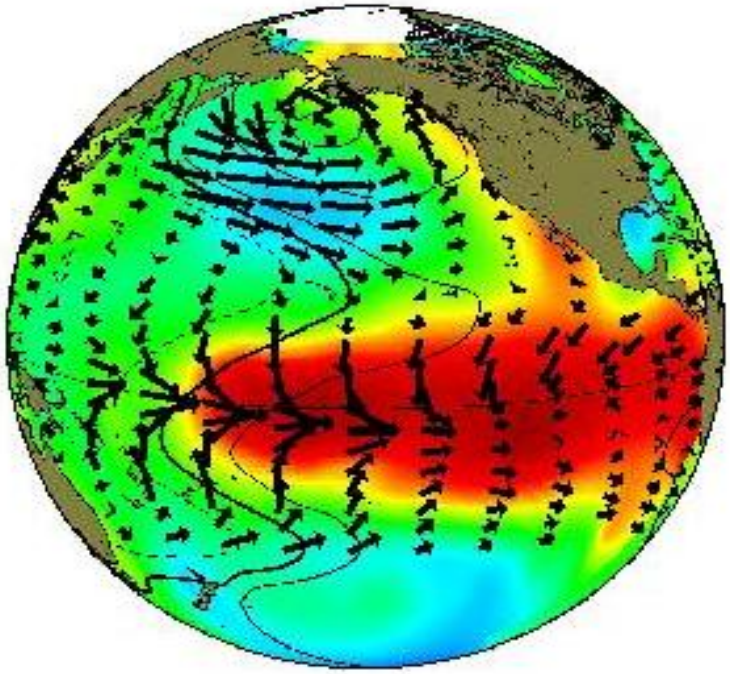


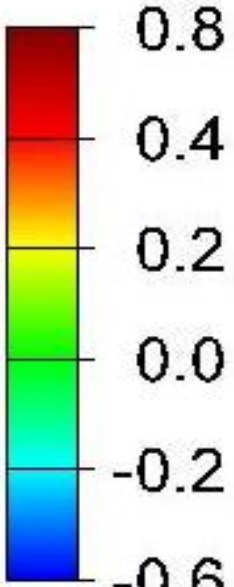
El Niño



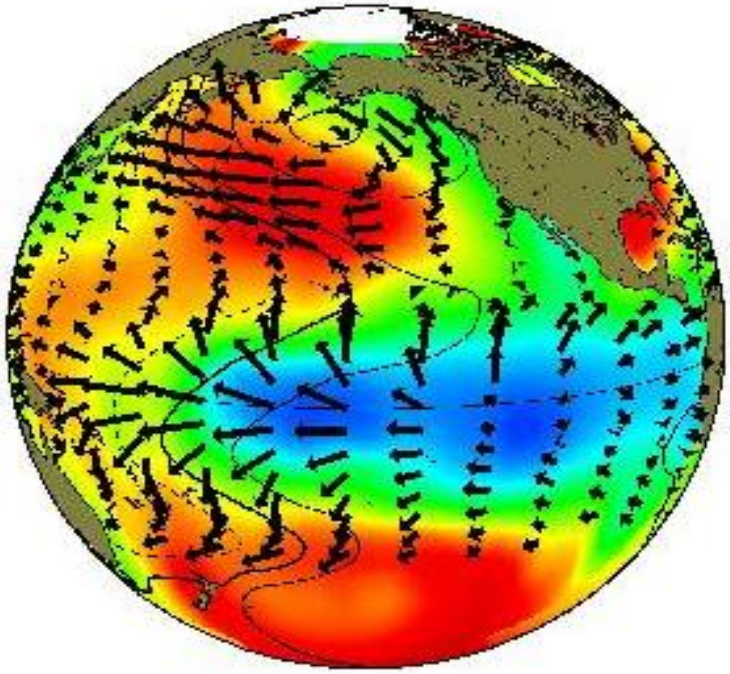
El Nino Southern Oscillation

El Nino





La Nina

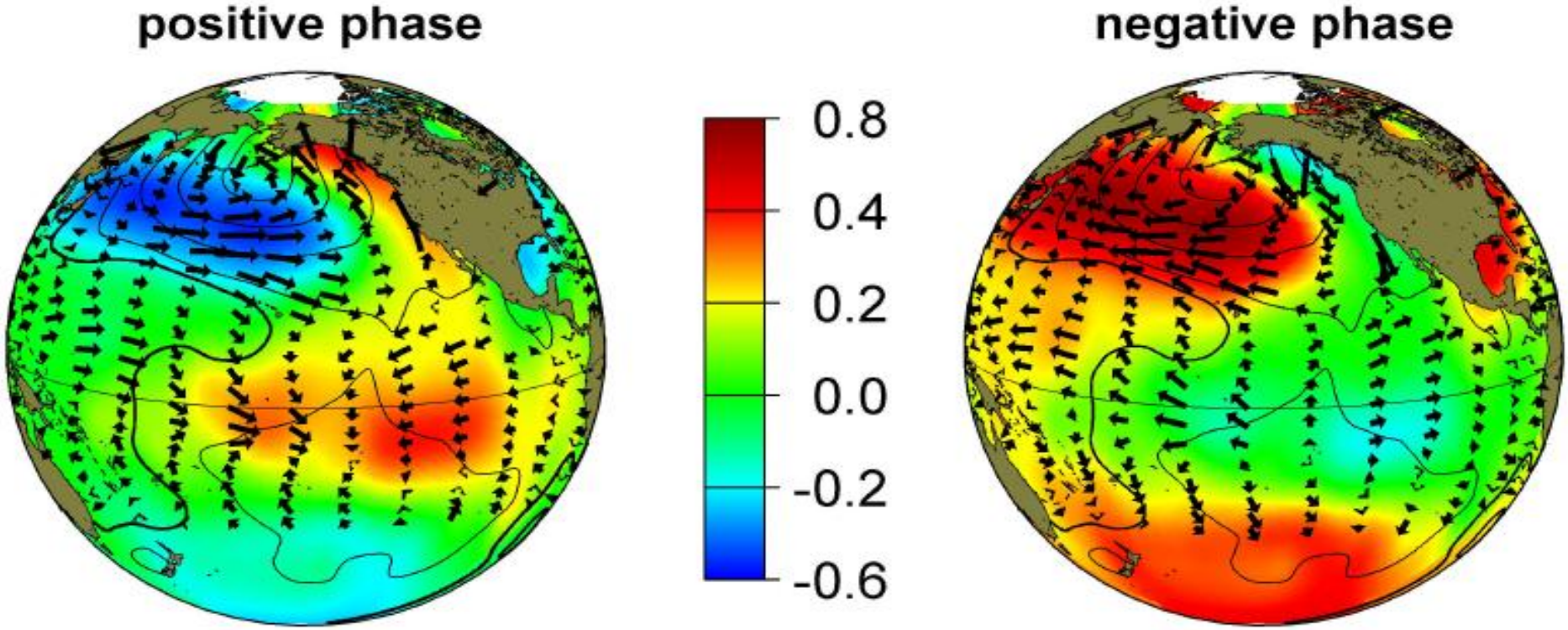


Reversal of Tradewinds

Strong SE Tradewinds

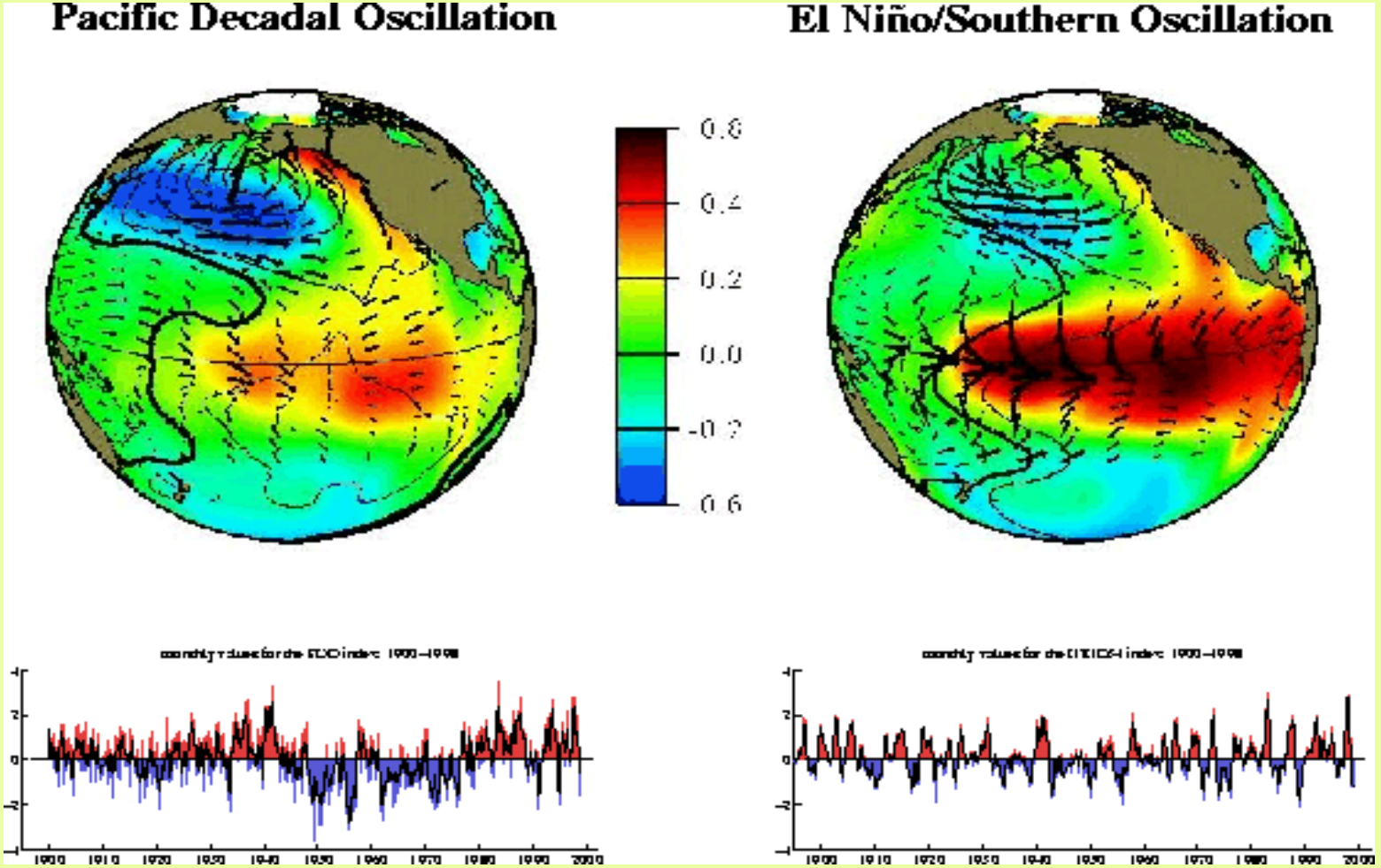
Mantua, 2000

Pacific Decadal Oscillation

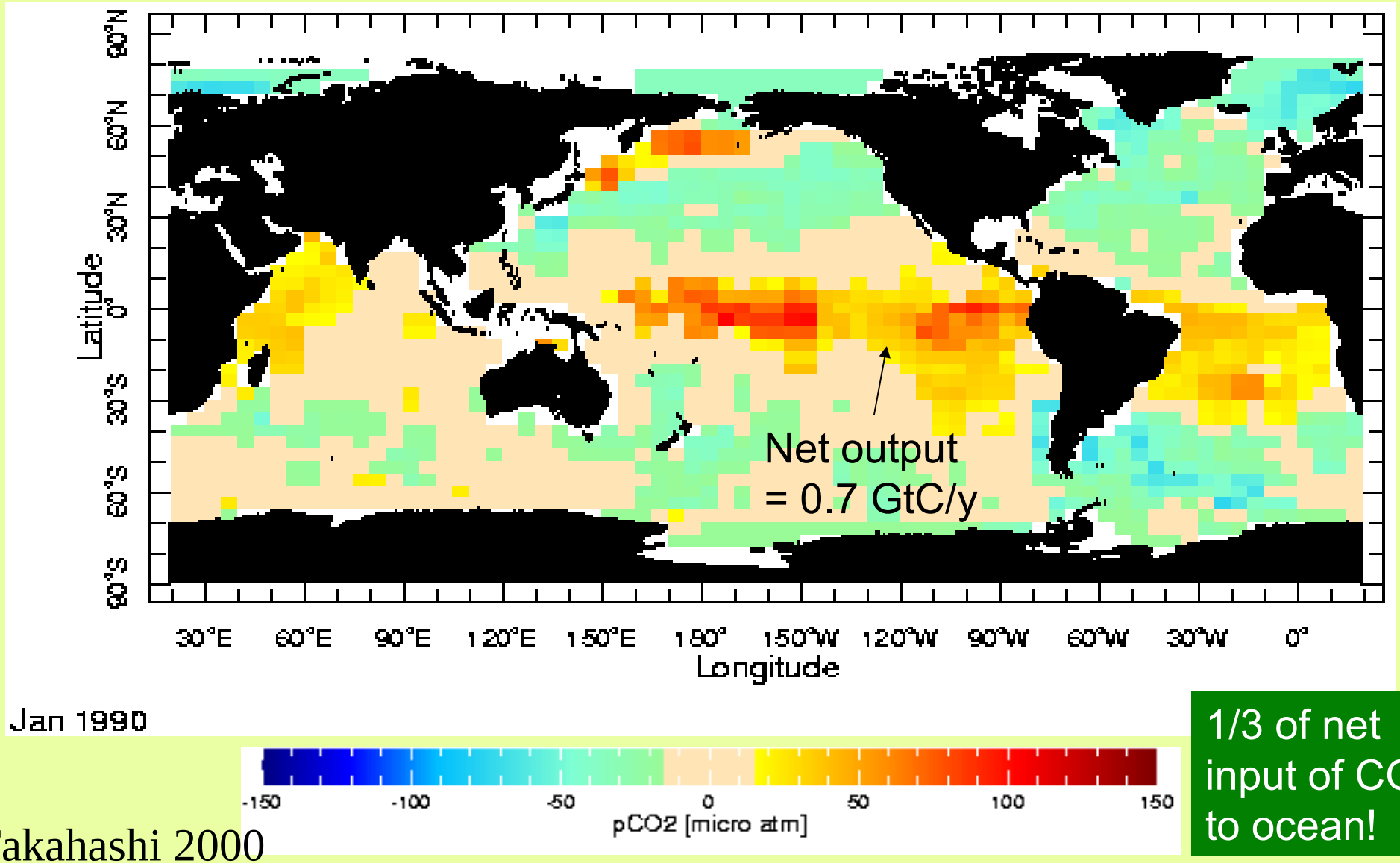


Mantua, 2000

Climate Changes on Decadal and Interannual Timescales



Upwelling of High pCO_2 Waters in the Equatorial Pacific



1/3 of net input of CO_2 to ocean!

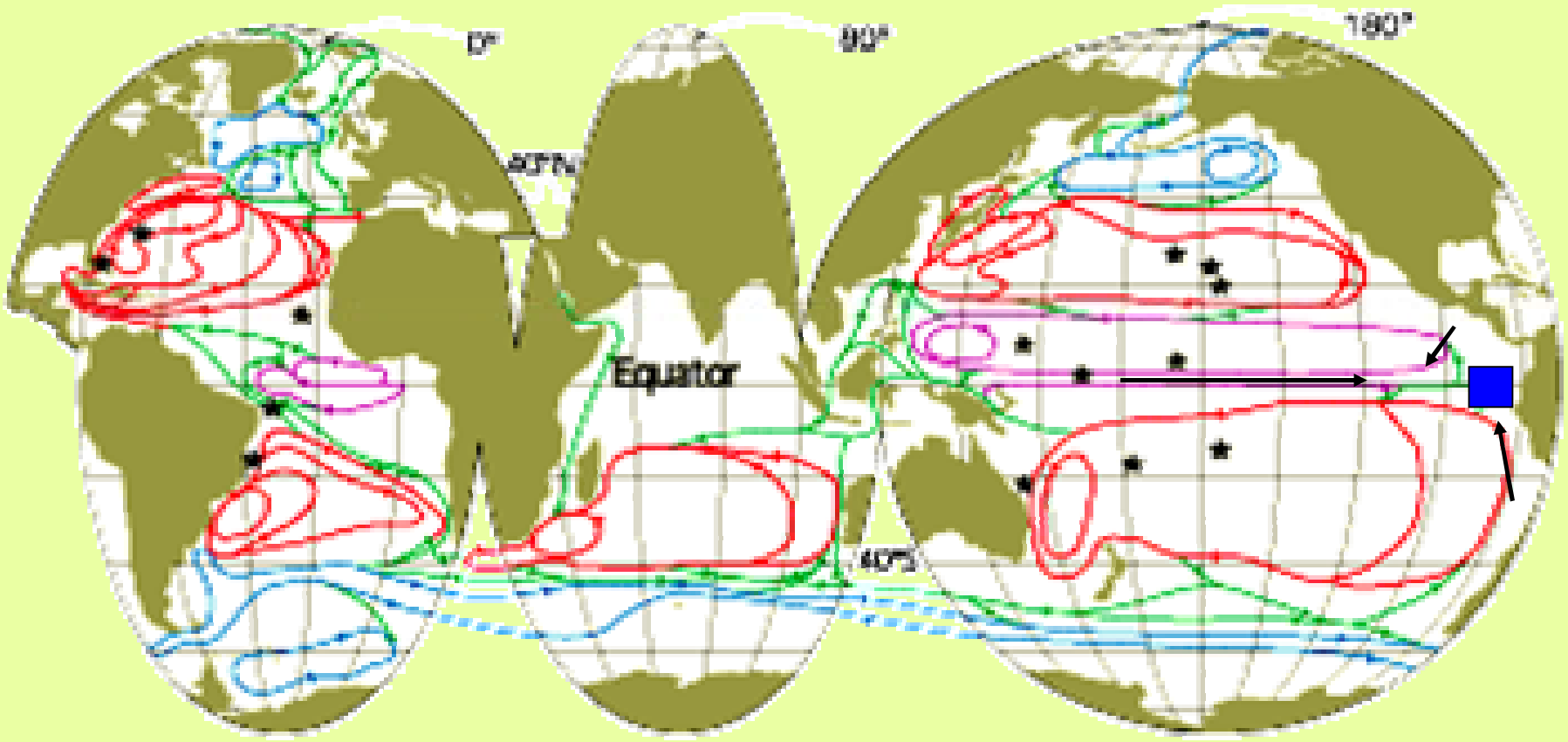
Takahashi 2000

Atmospheric pCO_2 Decreased

- 10 ppm during Little Ice Age
- 80 ppm during Last Glacial Maximum

- Role of the oceans?

Surface Currents and Galapagos coral site



Pavona clavus
from Isabella Is., Galapagos

- Grows ~ 1 cm/year
- Lived 3 m depth
- Uplifted in 1954

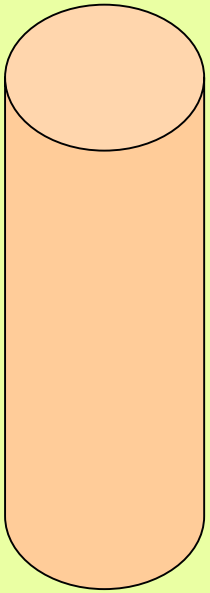
We assume:

$\Delta^{14}C_{coral} = \Delta^{14}C_{DIC}$

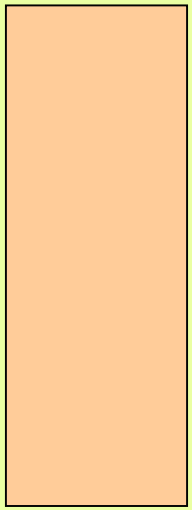
$\delta^{18}O_{coral} = f(SST)$

Sectioning of Coral Core

core

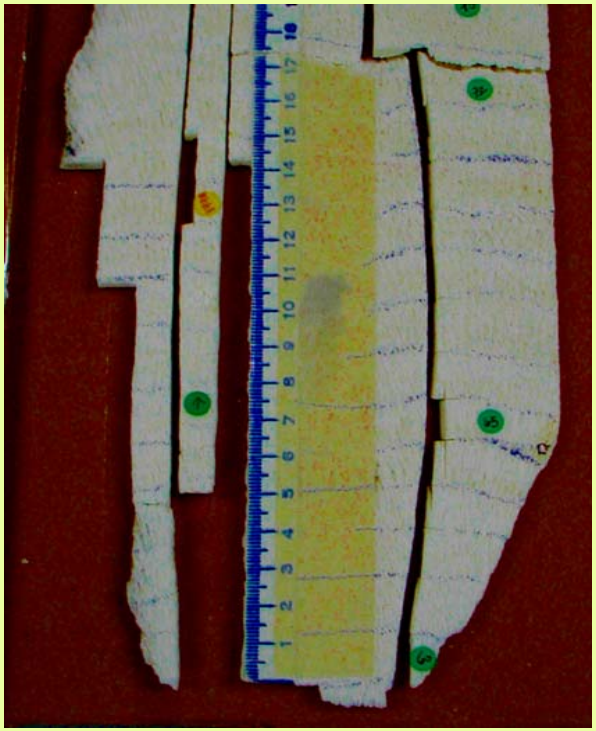


slab



X-ray

Mapped Slab



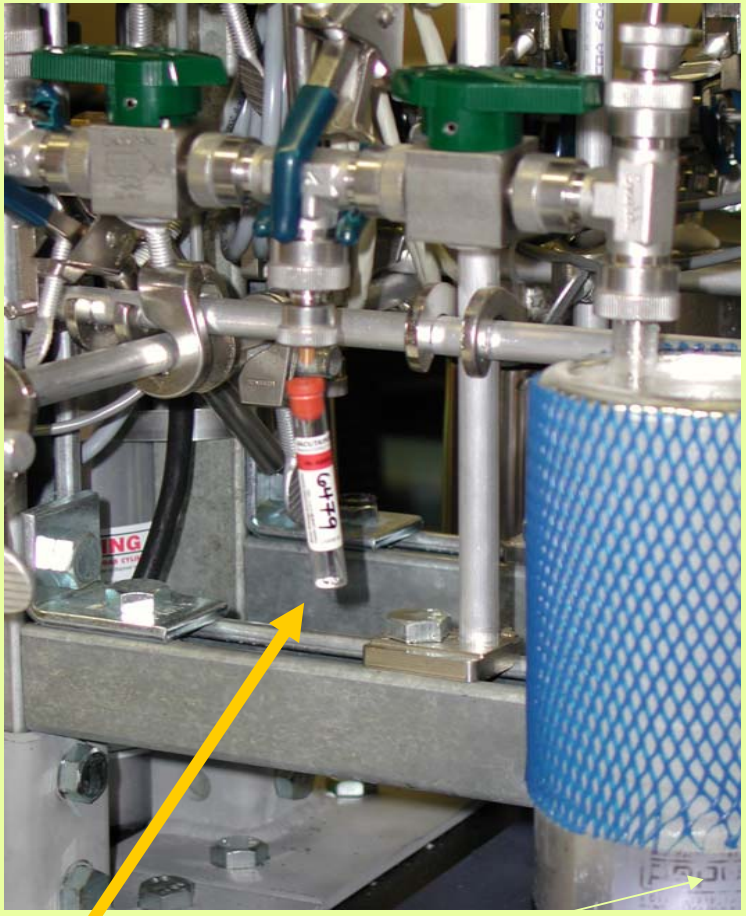
Slab sampled by sanding with Dremel tool

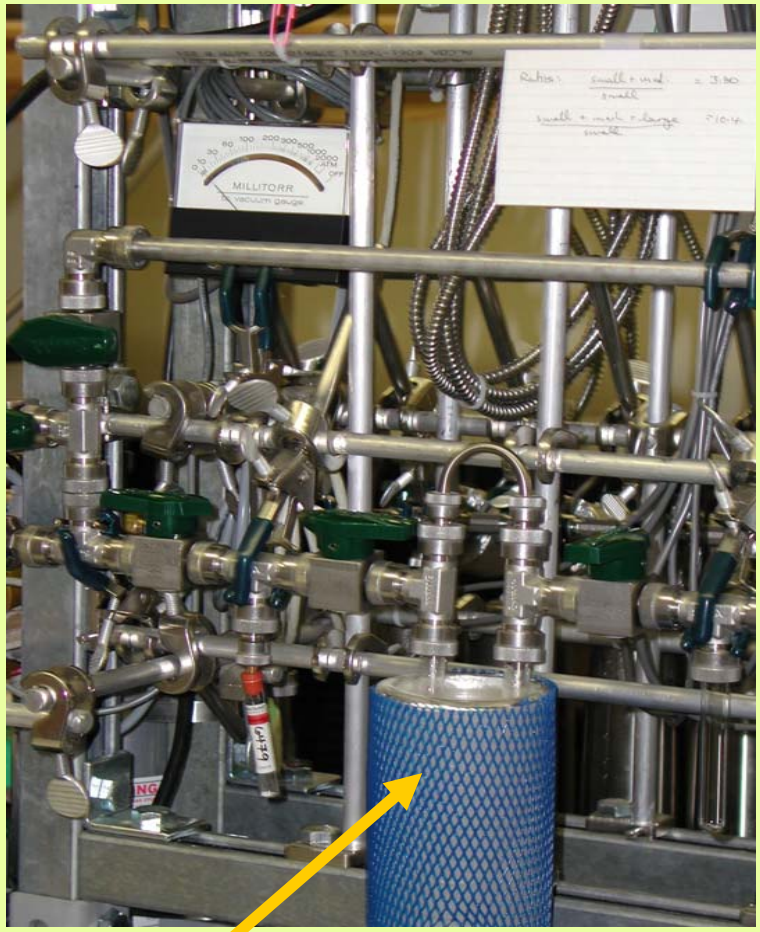
^{14}C (Radiocarbon)

- Produced in the stratosphere
- Reservoir age of surface eastern equatorial Pacific is ~630 ^{14}C years (-72‰ = $\Delta^{14}C$)
- Suess Effect - $\Delta^{14}C$ decrease 1880-1955
- Bomb ^{14}C - > 1957

UCI Keck Carbon Cycle AMS Lab

Preparation of Graphite





$CaCO_3$
Coral

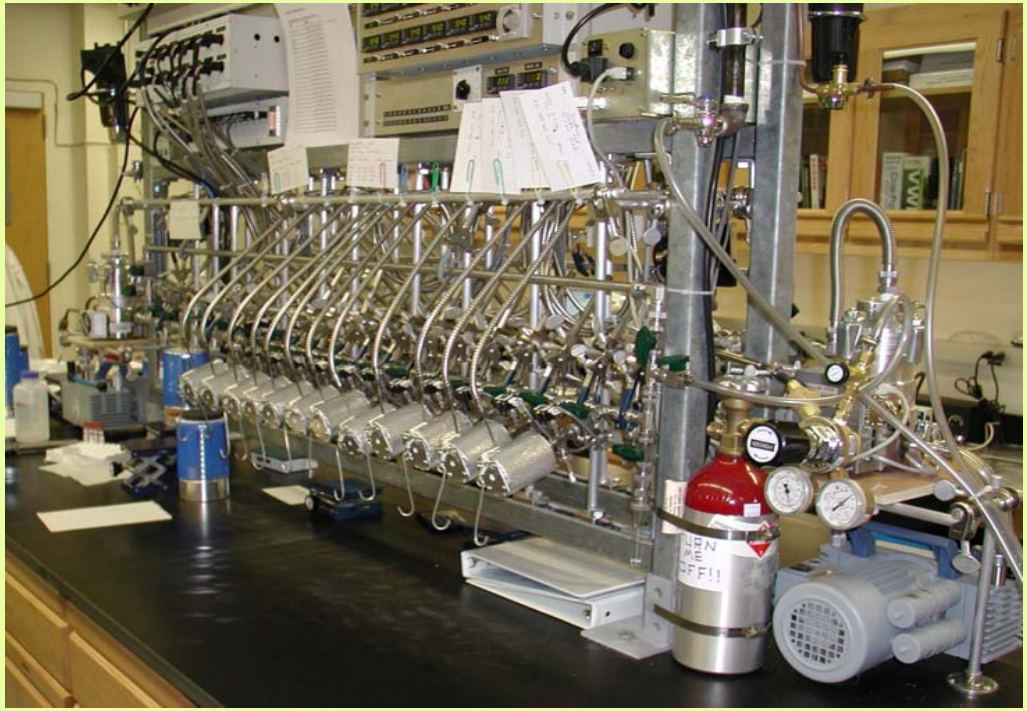
+ Phosphoric Acid

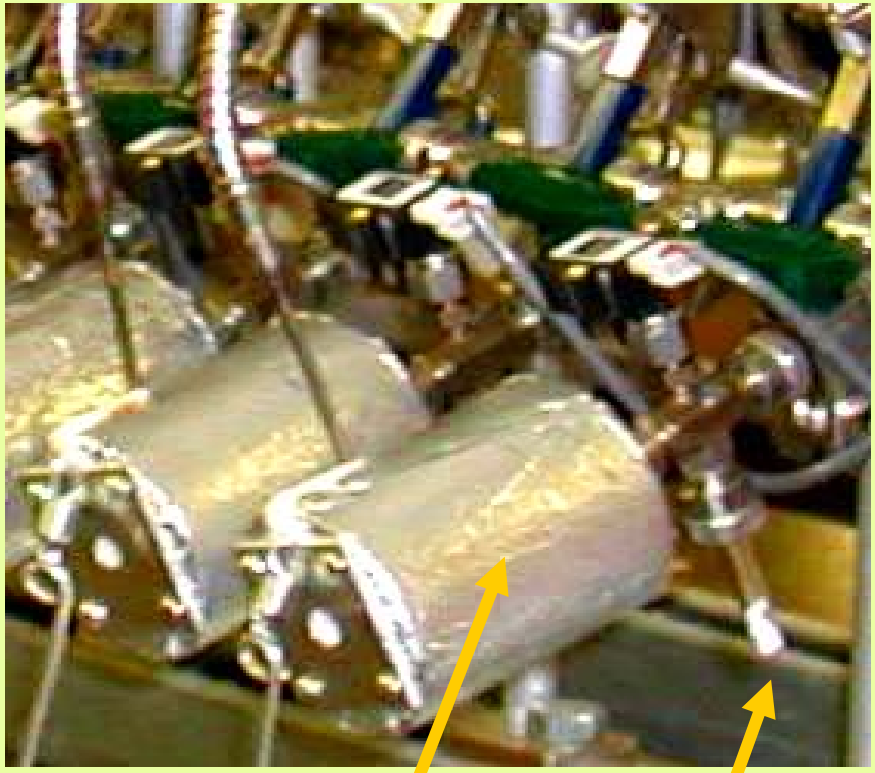
in vacutainer

CO_2 frozen in liquid nitrogen

UCI Keck Carbon Cycle AMS Lab

Preparation of Graphite



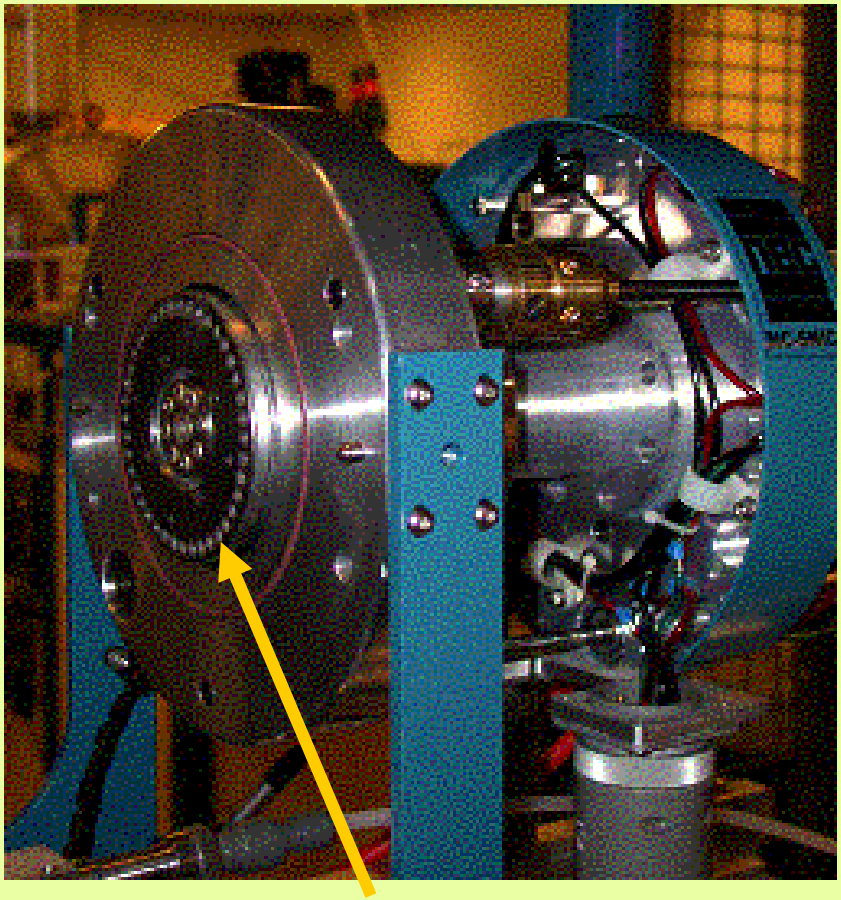


CO_2 → **Reduction with H_2 on Co @ 560 °C** → **graphite + H_2O**

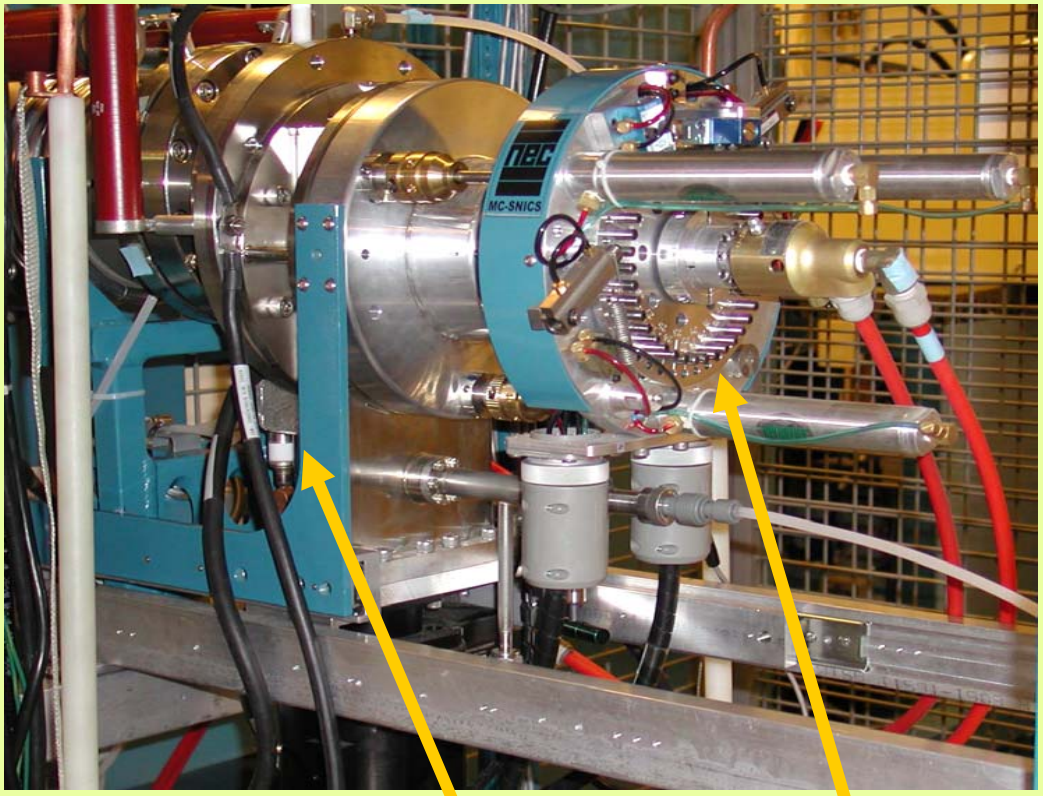
on $MgClO_4$

UCI Keck Carbon Cycle AMS Lab

Graphite Targets Pressed --> AMS Wheel



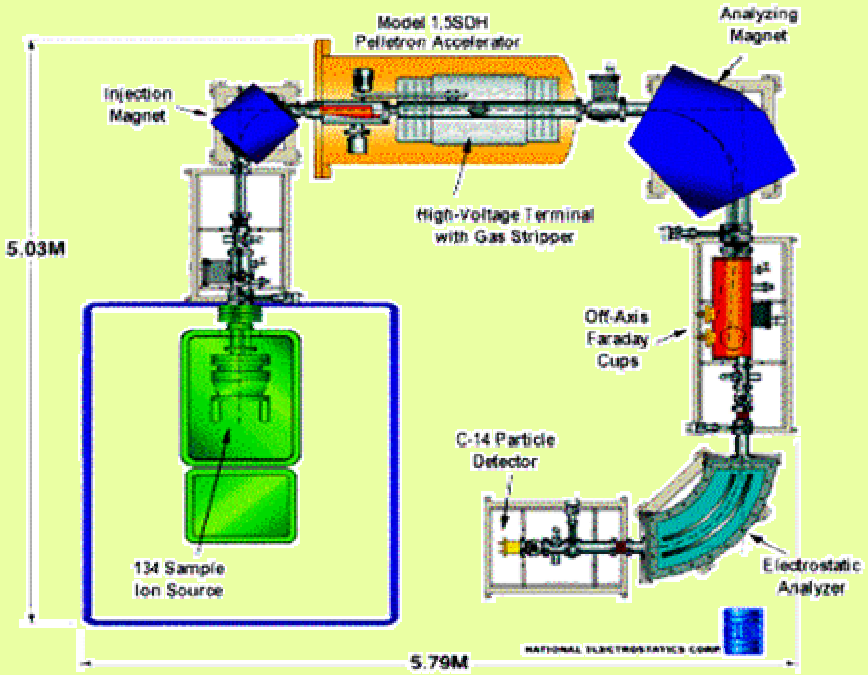
AMS wheel with 40 graphite targets



Ion source

Sample changer

UCI Keck Carbon Cycle Accelerator Mass Spectrometry Lab



Set up July 2002

UCI Keck AMS Lab moved a year later to our new building - Croul Hall

The move

$\Delta^{14}C$

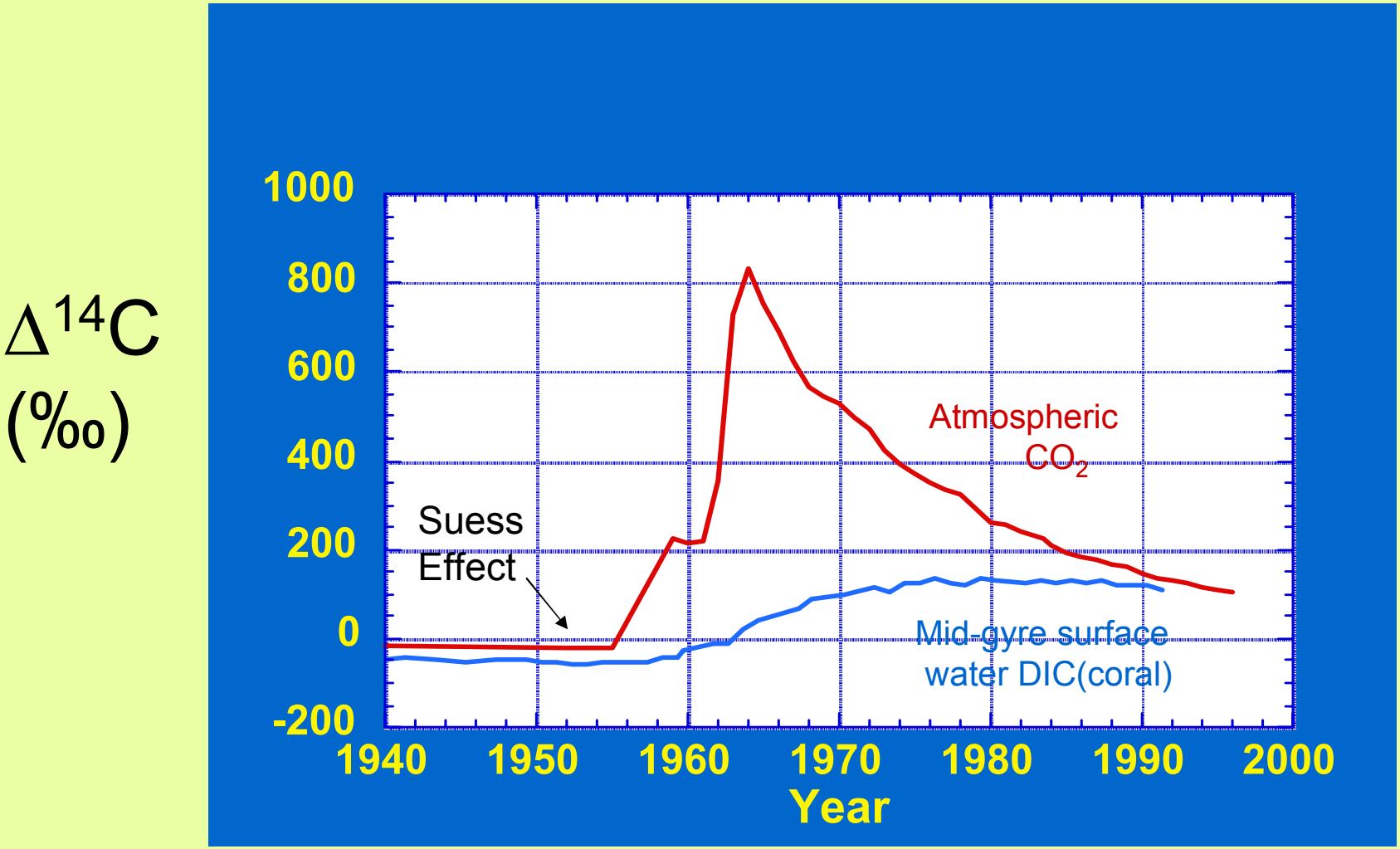
where 0‰ = modern C

and surface Galapagos Pacific = -72‰ (1950)

$$\Delta^{14}C = \left[\frac{(^{14}C/^{12}C)\text{sample}}{(^{14}C/^{12}C)\text{standard}} - 1 \right] \times 1000\ (‰)$$

Isotopic fractionation normalized to a $\delta^{13}C$ = -25‰

Bomb ^{14}C entered the ocean > 1955



Sea Surface Temperatures

- $\delta^{18}O$ varies mainly with SST at the Galapagos

Equilibration Time Scales

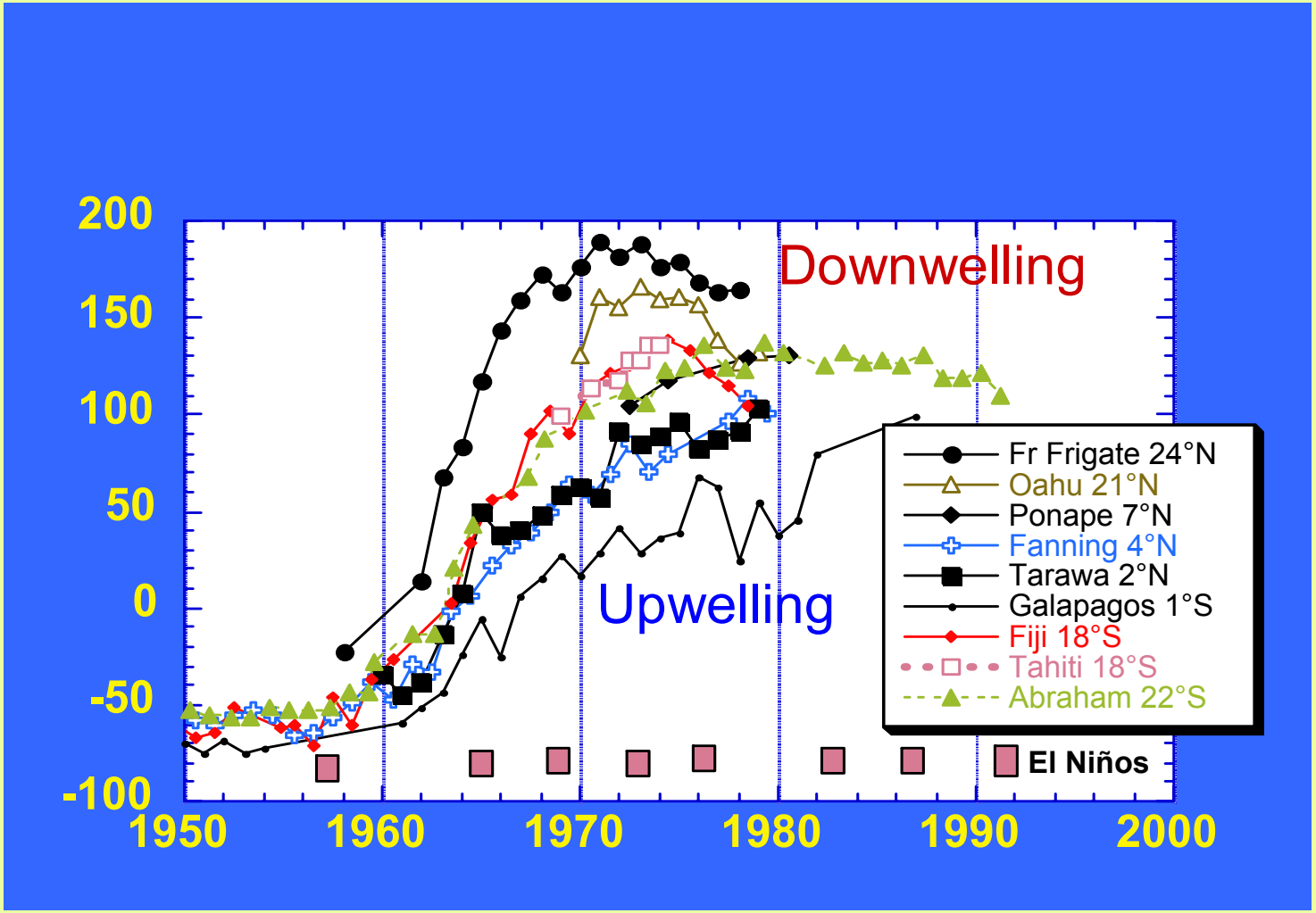
SST by solar warming, evaporation…

1-2 months

Dissolved Inorganic ^{14}C (DIC) by air/sea exchange of CO_2:

10 years

Post-bomb ^{14}C in Pacific Corals



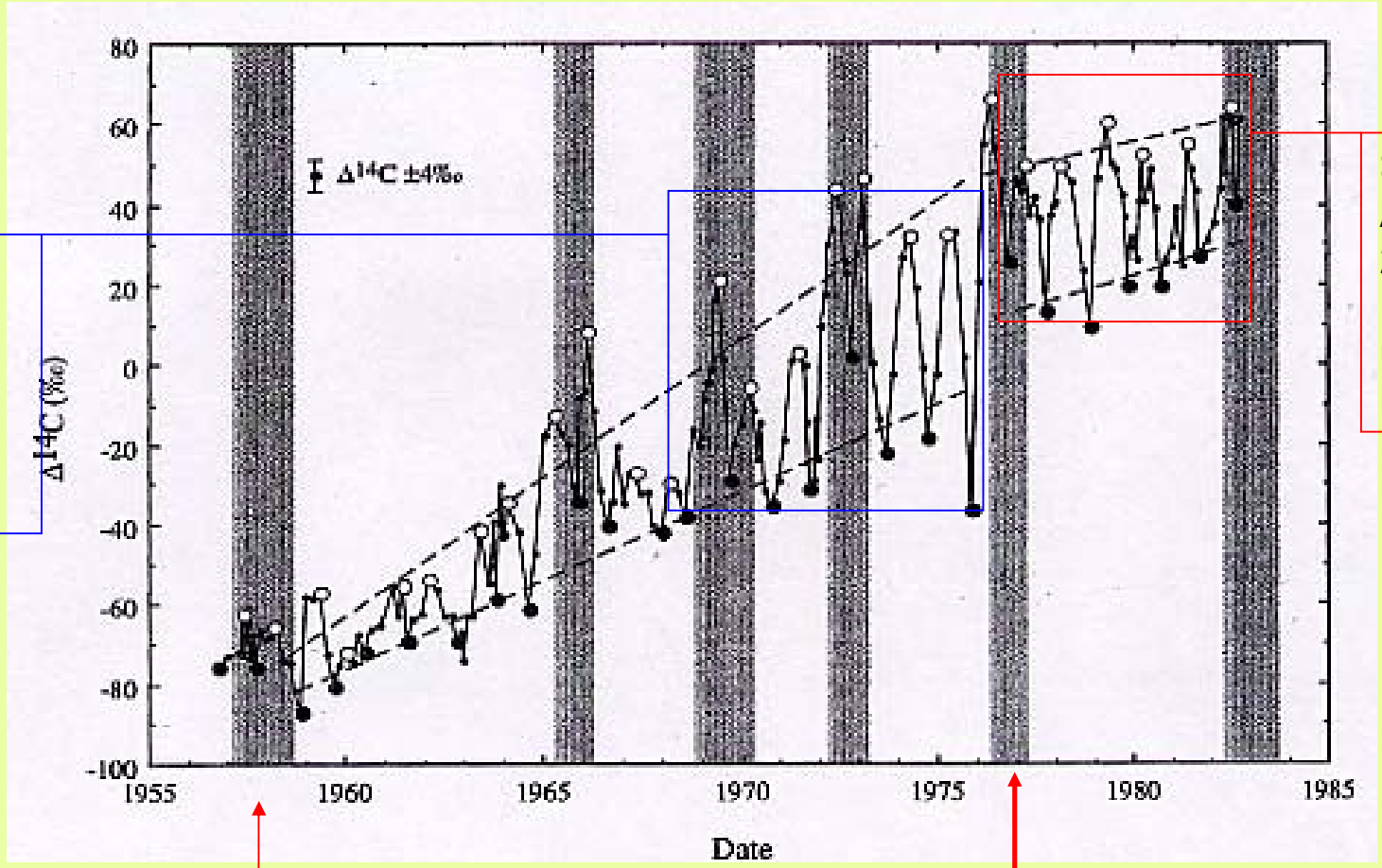
Data sets of
Druffel, Toggweiler, Konishi

Post-bomb ^{14}C Records

- El Niños cause high $\Delta^{14}C$ in tropics, low ^{14}C in SW Pacific
- ^{14}C is a recorder of the physics of climate change - e.g., mixing, upwelling, wind speed/direction, thermocline depth.

Monthly Coral $\Delta^{14}C$ - Guilderson and Schrag (1998)

< 1976 Amplitude = 40-90‰ Strong upwelling in winters.

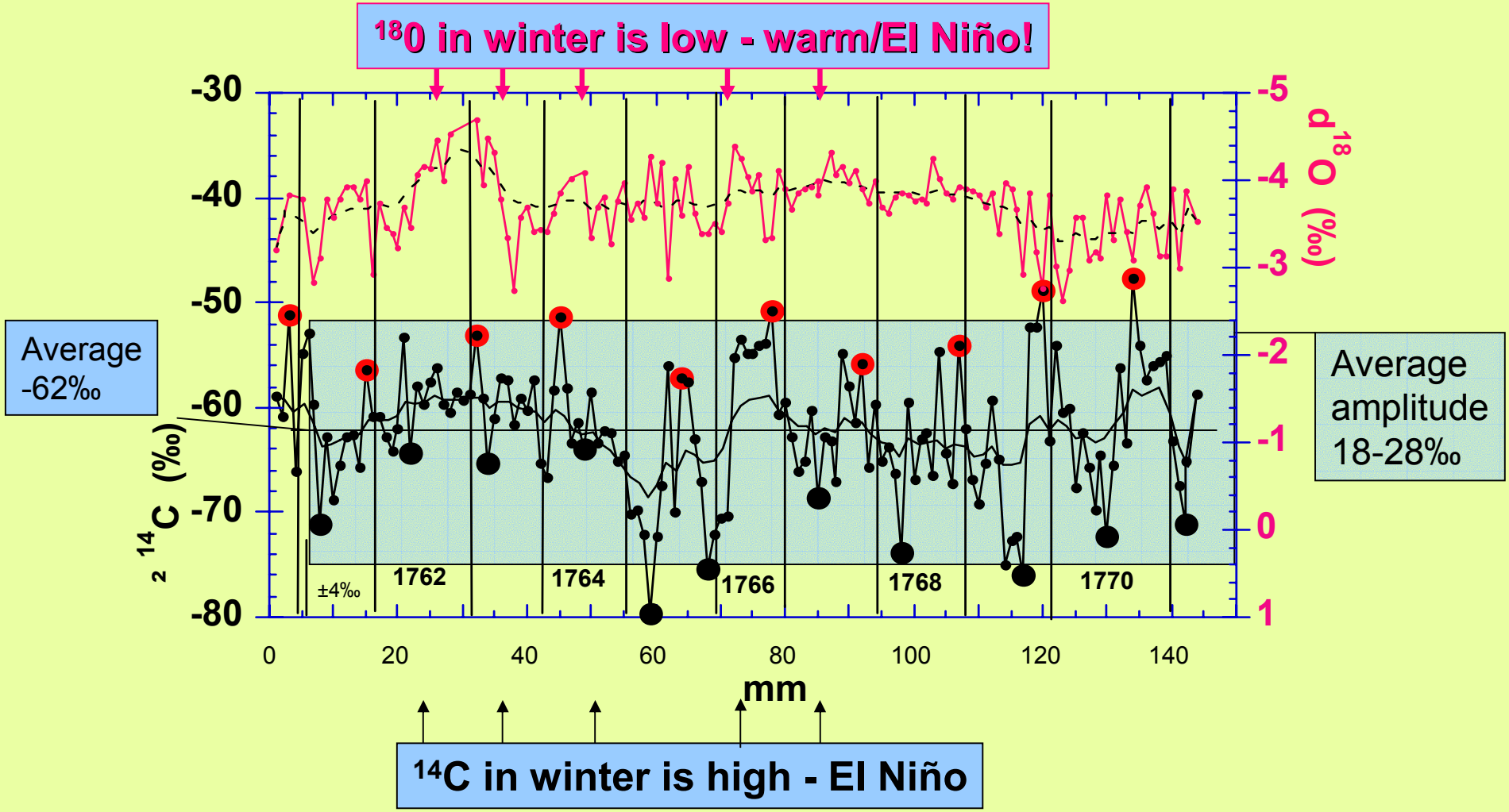


> 1976 Amplitude 20-40‰. Less upwelling in winters

1957 Bomb ^{14}C input to ocean

1976 Climatic Shift

Galapagos Coral
Monthly Coral $\Delta^{14}C$ in 1760s



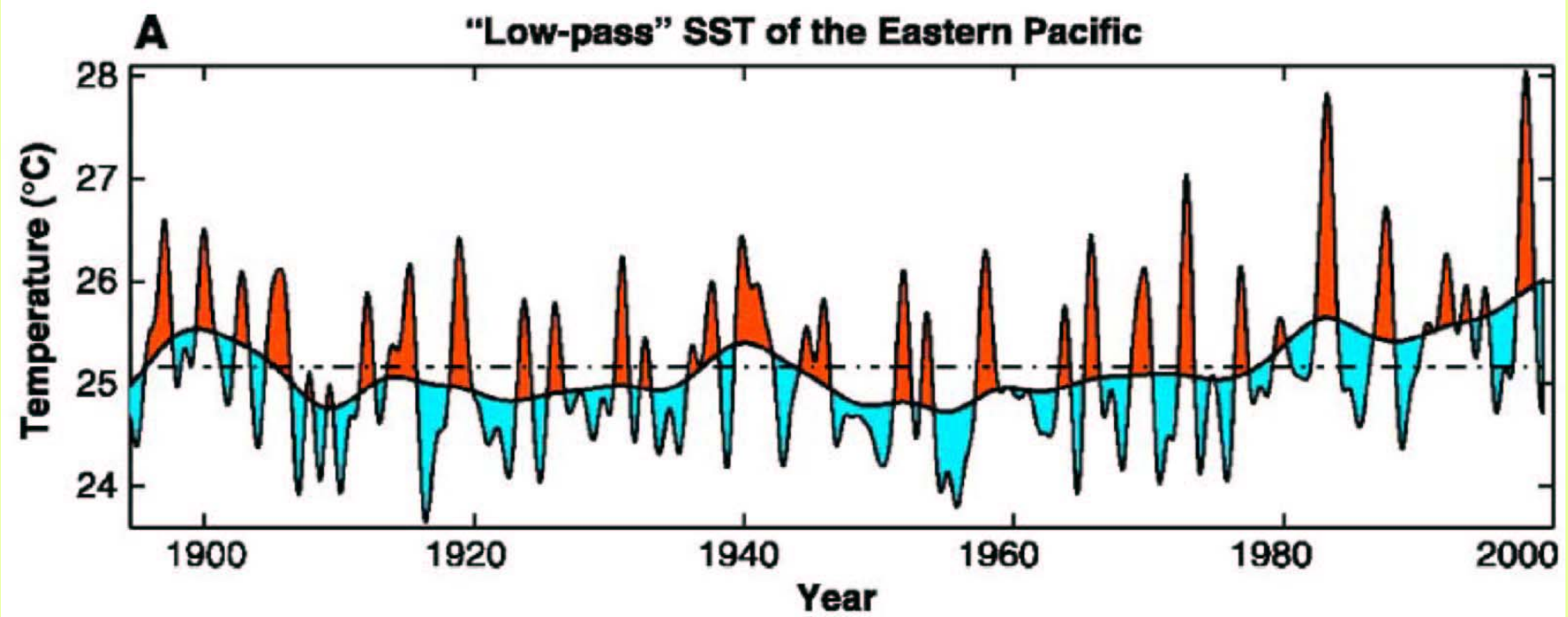
Spectral Analysis

- Spectral densities for both $\delta^{18}O$ and $\Delta^{14}C$ display significant variance at 1 and 4 year periods.

- 4 year period is similar to El Nino period > 1976

- Need to measure other decades to determine if the same periodicity is present.

PDO Removed from SST



(Figure from Fedorov and Philander 2000)

What does the Galapagos ^{14}Coral Reveal About Past Climate?

- $\Delta^{14}C$ during 1760s is 10‰ higher, so the thermocline was deeper than in mid-1900s

- Records of past SST (Dunbar $\delta^{18}O$) and thermocline depth (Δ14C) are not always correlated, indicating complex changes in circulation and water mass