The paleo-record of ENSO events

• The Tools: Tracers
  – Geochemical tracers.....

• the application
  – How we really do it
  – what are the issues
The paleo-record of ENSO events (or of anything)

- Go from the Tools (Tracers).
  - to the application…..

- Geochemical tracers of? Climate

- The substrates:
  - Microfossils
  - Chemical “fossils”

- The controls on substrates
  - Biologically mediated
  - Long term recorders
  - “permanent” records

- Controls and issues on the record
  - chronology
The *paleo-record* of climate events: Controls and Issues

- **Chronology** – time control
  - Without time control any record is meaningless
- **Corals** (tree rings are similar)
  - Excellent continuous, in-place records
  - Problem: corals die.....
- **Sediments** (good permanent long-term record)
  - Plus: many microfossils and other recorders
  - Problem – bioturbation
    - Solution: laminated sediments
  - Problem – degradation, hiatuses, erosion
    - Deep sea sediments often have a complete record
The tools

Geochemical tracers! *Ones we know:*

$\delta^{18}O$ – temperature

**TOC** – productivity

**Biomarkers** – temperature (relative productivity)

**Trace metals** - Trace metal ratios in calcite ($\text{CaCO}_3$)

$\text{Cd/Ca}$ (phosphate), $\text{Ba/Ca}$ (nutrients),

$\text{Mg/Ca}$ and $\text{Sr/Ca}$ – temperature
oxygen isotopes in the climate record

Emerson and Hedges 2008
oxygen isotopes of the water

controlled by temperature and records salinity
The temperature effect on $\delta^{18}O$

at 10°C

$0 \, \%\text{o} \rightarrow \_\_\_ \%\text{o}$

at 20°C

$0 \, \%\text{o} \rightarrow \_\_\_ \%\text{o}$
The precipitation effect on $\delta^{18}\text{O}$
$\delta^{18}O$ as a tracer of ENSO: the short term isotope record

Oxygen $\delta^{18}O$ in carbonates is controlled both by:

The $\delta^{18}O$ of the water precipitation (salinity)

and

By the temperature of the water it is precipitated from

It traces both temperature and precipitation (not ice volume)
We can get high resolution records that can resolve ENSO events

- We look to an undisturbed substrate.... CORALS.
Dating is done on coral heads

Not branching corals!
The coral is slabbed and sliced
The slabs are sectioned along growth planes
You can see the “annual” growth bands by x-ray
Galapagos Corals

A 5 point moving average of annual $\delta^{18}$O for Galapagos corals

There are long term trends that extend beyond the instrument record...that only proxy records can show us
The Eastern Pacific ENSO signal

- Temperature is a major component of the signal

- Knowing this we can interpret records that go back farther than the instrument records.

- We can use tracers to tell us more.
Paleo records of climate

• Choose your substrate and your record source well for the task:
• Coral gives us
  – short,
  – Well constrained
• you can get a record but you have to know how to read it
What is el niño?

• Physically?

• Biologically?

• Geochemically?
The el niño record

• What is el niño geochemically?
  – Biologically = Changes in productivity….
  – Should produce changes in what markers?

  – Physically = changes in temperature (and rainfall)
  – Should produce changes in what markers?
The el niño record

- What is el niño geochemically?
  - Biologically = Changes in productivity….
  - Should produce changes in what markers?
    - TOC
    - Biomarkers
  - Physically = changes in temperature and salinity
  - Should produce changes in what markers?
    - $\delta^{18}O$
    - Trace metals
    - Biomarkers
ENSO has a cross Pacific see-saw signal

(The chemists view)

Rain and warm in Peru is dry in Australia (el niño)
Dry and cold in Peru it’s wetter in Australia (la niña)

But it’s not a fully symmetrical signal
The signal in the east is temperature
The signal in the west is precipitation
The El Niño temperature signal varies across the Pacific.
Trace metal inclusions in CaCO$_3$

Trace metals that are of similar size and charge as Ca substitute into the matrix…..

interpretation is based on the simple principle that if there is more in the water there is more in the calcite

Empirically, we have found their chemistry is controlled by:

Cd/Ca (phosphate),

Ba/Ca (nutrients),

Mg/Ca and Sr/Ca – temperature

Mn/Ca oxic versus anoxia
Combining records for better control on interpretations is Multiproxy estimation proof the Tarawa record is precipitation.

Arbitrarily chosen reference lines for δ¹⁸O and accompanying tracers highlight five ENSO events known to have occurred over this time interval: 1963 (very weak), 1965 (moderate), 1969 (weak), 1972-1973 (strong), and 1976 (moderate) [Quinn et al., 1978 and 1987]. (b) Time series Mn/Ca measurements for the period 1960-1977. Samples were cut in approximate trimonthly increments according to band structure as seen on the X radiograph of Figure 2. Ages are based on locations of cut increments relative to δ¹³C samples and the associated age model. (c) Monthly mean rainfall recorded at Tarawa [Taylor, 1973; New Zealand Meteorological Service, unpublished data, 1987; Monthly Climatic Data for the World]. (d) Monthly zonal surface wind measurements.
Combining records for better control

A multi-proxy record can tell us more about the causes of phenomena we observe in one record or another
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Paleo records of climate

• Choose your substrate and your record source well for the task

• Sediments give us
  – Long
  – broad control

• you can get a record but you have to know how to read it
How do we get a time series record from the sediments?
It starts with a core...
Once you have sediment you have to process it

How do you get the mud out of the pipe?
Pull the core out of the coring pipe
Processing the core onboard ship

Label the sections
cut the core liner....
Split the sections
Measure, describe, sample ...
Sample processing
Sample analysis
Stratigraphy – converting length to time

Emerson and Hedges 2008
El Niño in the organic record

TOC – productivity….but you get increased runoff with rain and TOC is ambiguous

Biomarkers – temperature (relative productivity)

but what is the archive that has an organic record?

lets look at this….
Alkenones as a tracer for sea surface temperature

Alkenones are made only by Prymnesiophytes...

Alkenones record SST... in their saturation levels
Alkenones can record information about climate.

The ratio of alkenones in a sample records past temperature similar to $\delta^{18}O$.

Subtropical Atlantic ~250,000 yr record.
Alkenones as a recorder of ENSO events

Proxy records of past (a) SST and (b) haptophyte productivity in Santa Barbara Basin derived from alkenone analyses of varved sediment core (SBBX: 34°13′N, 120°03′W, 590 m wd). Shaded bars indicate ENSO events.
Using temperature records to get a long record of ENSO events

- Long records can only come from cores – which means lower resolution
- Focus on SST variation across the Pacific
  - Temperature change is greatest in the east
  - The western warm pool has smaller changes
  - Over long time frames this gradient can trace changes in El Niño strength
Mg/Ca record of temperature in the equatorial Pacific

The gradient of temperature changes with time….

Present Rosenthal et al (2005) 2 Ma