Mid to Late Holocene seasonal SST records along coastal Peru and their implications for ENSO behavior and climate change

NORTHERN ILLINOIS UNIVERSITY
Department of Geology and Environmental Geosciences

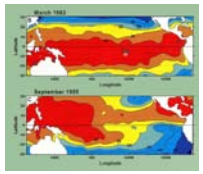
Cumpston, J.L., Loubere, P.

P. A. N. C.

Introduction

The El-Niño Southern Oscillation(ENSO) impacts global climate. Through teleconnection, distant marine biological resources and regional climate dynamics are highly dependent on the variability and feedback within the ENSO system. Key factors in ENSO development are the depth and temperature of the thermocline off the west coast of South America, the trade wind strength, and the seasonal insolation cycle. These variables play key roles in ENSO frequency and serve as a stimulus for ENSO phase switching. The sensitivity of the ENSO phase switching and its relationship to the background state of the Eastern Equatorial Pacific (EEP) can be tested by examining the sea surface temperatures and seasonal cycles off of coastal Peru under different global climate states. Over the Holocene, as recorded in Ecuadorian lake deposits, ENSO frequency has been variable. Sea surface temperatures and seasonal cycles off of Coastal Peru during climate states of the Holocene can be supplied in the form of oxygen isotope records of the surf clam Mesodesma donacium from archeological deposits along coastal Peru. This particular investigation examines Mesodesma donacium remains from the archaeological Late Archaic Period (5000-3800 YBP). During this period lake deposits indicate that ENSO variability was diminished compared to the present. We analyzed shell records to see if these support that interpretation, and to see what imposed greater ENSO stability.

Figures 1 and 2. ENSO warm phase (El Niño) and cool phase (La Niña) and the associate sea surface temperatures along the eastern equatorial Pacific.



Methods

Mesodesma donacium inhabits the sandy beaches along coastal Peru. Within their shells they record their growth history in ridging patterns and growth bands. Reconstruction of the environmental conditions (SST) can be obtained through oxygen isotope records within the growth bands of the clam using a published calibration. Shells from the archaeological Late Archaic period were analyzed with the following procedure to obtain the paleo-records:

- Shells are sectioned to examine the internal growth band pattern
- Shell ridging topography is graphed to show the annual periods of growth
- The internal growth bands of the clam are drilled to powder samples on a mircomill. The carbonate samples are then be analyzed in the mass spectrometer.

This provides for the sea surface temperatures corresponding to sub-annual (monthly to bi-monthly) sampling of the annual cycle. Individual shells contain a record 3 to 8 years long.

Figure 3. An archaeological Mesodesma donacium shell from coastal Peru.

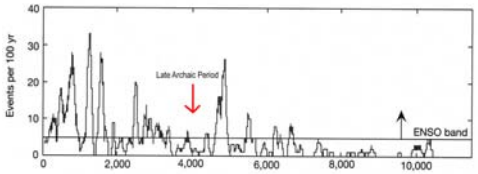
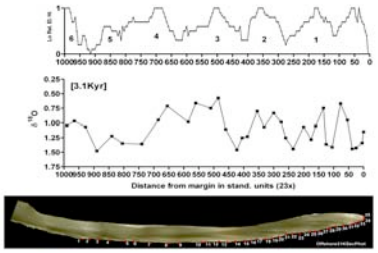


Figure 4. The Lake Pallacocha sediment record of ENSO activity based on flood deposits. The Late Archaic Period is associated with decreased ENSO activity. We aim to understand the background conditions to shed some light on potential relationships between ENSO frequency and the background state of the EEP.

Figures 5, 6, and 7. Our method begins with a careful analysis of the growth pattern of the shell which is associated with seasonal sea surface temperature(SST) and the annual cycle, both previously identified key factors in ENSO frequency.
The diagrams to the left:
A representation of growth ridges representing the annual growth cycle (top).
Oxygen isotope records that indicate annual SST cycles (middle).
The observed growth banding pattern when a shell is sectioned (bottom).



Study Location

Figure 8. Map of coastal Peru indicating the region of study, the Norte Chico. This area lies near the research base in Barranca in the Pativilca and Forteleza River valleys.

Figure 9. Map of the Norte Chico and the associated archeological sites. The occupancy dates of these sites range from 4000 to 500 YBP. Settlements were occupied during periods of significant change in ENSO frequency.

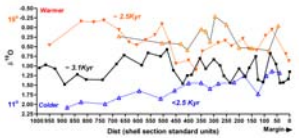
Figures 10 and 11. At the archaeological sites, well preserved remains of Mesodesma donacium clams can be found in shell middens or dated stratigraphic columns.

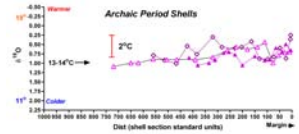
Preliminary Results

Figures 11 and 12.

(Top) Shell isotopic profiles for periods from a more recent time than the Late Archaic. This diagram shows a range of coastal Peru temperatures between 2-3 kyr. Due to upwelling the temperatures of coastal Peru are a representation of the thermocline temperature. These clams recorded distinct seasonal cycles superimposed on the temperature mean. These shells correspond to a lake record that suggests more frequent ENSO activity (2.5 – 3 cal. kyr) and a younger interval of diminished activity.

(Bottom) Oxygen isotope records of Late Archaic records. These records correspond to a period of decreased ENSO activity according to the Laguna Pallacocha record. Notice the reduced annual SST cycling indicated by the oxygen isotope profiles, and the similarity of this to La Niña years in the modern Callao SST record (see below).





Figures 13 and 14. Callao sea surface temperature records from the 1997 El Niño and the 1985 La Niña. The seasonal cycles of the two phases of oscillation are quite different. El Niño bringing warmer SST and La Niña bringing cooler SST with poorly developed seasonal cycles.

Conclusions

The shell oxygen isotope records obtained from the Late Archaic period show poorly developed seasonal cycles at cooler temperatures. This is what would be expected in a period of La Niña dominance which is recorded in the Lake Pallacocha sediment record.

Future Work

- A statistical analysis of sea surface temperatures and clam records will be performed to identify the number of samples needed to provide for a reliable record of the background conditions of the past.
- Additional shells will be analyzed from the other periods of ENSO frequency shift to establish background state conditions of these time intervals.
- Theories on ENSO regulation will be tested with examination of the frequencies observed through the lake records and the background state conditions identified in the clam records.
- Background conditions indicated by the clam records will provide insight in the environment during times of rise and collapse of Andean civilizations.

NSF
PAGES PAST GLOBAL CHANGES
The Field Museum