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

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Introduction
The El Niño Southern Oscillation (ENSO) impacts global climate. Through teleconnection, distant marine regions experience changes in sea surface temperatures, rainfall, and winds. The ENSO variability and feedback mechanisms can be tested by examining the sea surface temperatures and seasonal cycles at coastal Peru during climate states of the Holocene. This particular investigation examines Mesodesma donacium remains from the Eastern Equatorial Pacific (EEP) off the west coast of South America. The study period encompasses the Late Archaic period (5000-3800 YBP) and the Holocene, including climate states of the ENSO system. Key factors in ENSO development are the depth and temperature of the thermocline and associated sea surface temperatures along the eastern equatorial Pacific.

Methods
Mesodesma donacium inhabits the sandy beaches along coastal Peru. Within their shells, 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-temperature(SST) and the annual cycle, both sub-annual (monthly to bi-monthly) sampling of the annual cycle. Individual shells contain a record 3 to 8 years long. The internal growth bands of the clam are drilled to powder samples on a micro-mill. The Shell ridging topography is graphed to show the annual periods of growth. Shells are sectioned to examine the internal growth band pattern. 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.

Study Location
Figure 8. Map of coastal Peru indicating the region of study, the Norte Chico. The Norte Chico is a region near the research base in the Palpa River valleys. The shell records from the Late Archaic Period were analyzed with the following procedure to obtain the paleo-temperature(SST) and the annual cycle, both sub-annual (monthly to bi-monthly) sampling of the annual cycle. Individual shells contain a record 3 to 8 years long. The internal growth bands of the clam are drilled to powder samples on a micro-mill. The Shell ridging topography is graphed to show the annual periods of growth. Shells are sectioned to examine the internal growth band pattern. 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 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.

Future Work
A statistical analysis of sea surface temperatures and clam records will be performed to identify the number of samples needed to provide a reliable record of the background conditions of the past. Additional shells will be analyzed from the periods of ENSO frequency shift to establish background state conditions of these time intervals.

Figure 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).

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

Figure 9. 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).

Figure 12. 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.

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.

Preliminary Results
(Top) Shell isotopic profiles for periods from a near record low than the Late Archaic. This diagram shows a range of coastal Peru temperatures between 0°C and 3°C. Due to upwelling, shell records from coastal Peru during climate states of the Holocene can be expected to be in the form of ENSO variability. The Late Archaic Period is associated with 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).

Figure 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.

Figure 11 and 12. (Top) Shell isotopic profiles for periods from a near record low than the Late Archaic. This diagram shows a range of coastal Peru temperatures between 0°C and 3°C. Due to upwelling, shell records from coastal Peru during climate states of the Holocene can be expected to be in the form of ENSO variability. The Late Archaic Period is associated with 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).