Reconstructing Central Tropical Pacific Climate of the last Millennium

Andrea Doggett, Taylor Conklin, and Alyssa Atwood, PhD

Motivation

- Reconstructing mean climate and El Niño-Southern Oscillation (ENSO) variability throughout the last millennium within the central tropical Pacific (CTP) is key to understanding ENSO cycles under "normal" climate trends, so we can use our understanding of past climate to better address modern-day climate (Grothe et al., 2020).
- Building upon this climate record is crucial to understanding future climate variability, and should be done before climate change degrades the proxy data within the coral fossils.

Background

ENSO is an interannual climate anomaly that forms in the tropical pacific and impacts global temperature and precipitation patterns. Recent decades have seen an unprecedented rise in ENSO intensity, which has had devastating global impacts. As we don't have a good understanding of preindustrial ENSO events, this project aims to develop a reconstruction of ENSO activity, as well as mean climate, throughout the last millennium.

We are concerned with two climate anomalies that occurred within the last millennium: the Medieval Climate Anomaly (MCA) and the Little Ice Age (LIA), occurring around 1150 - 750 BP and 550 - 150 BP, respectively. Compared to last millennium mean climate, the MCA was a relatively warm period and the LIA was a relatively cold period.

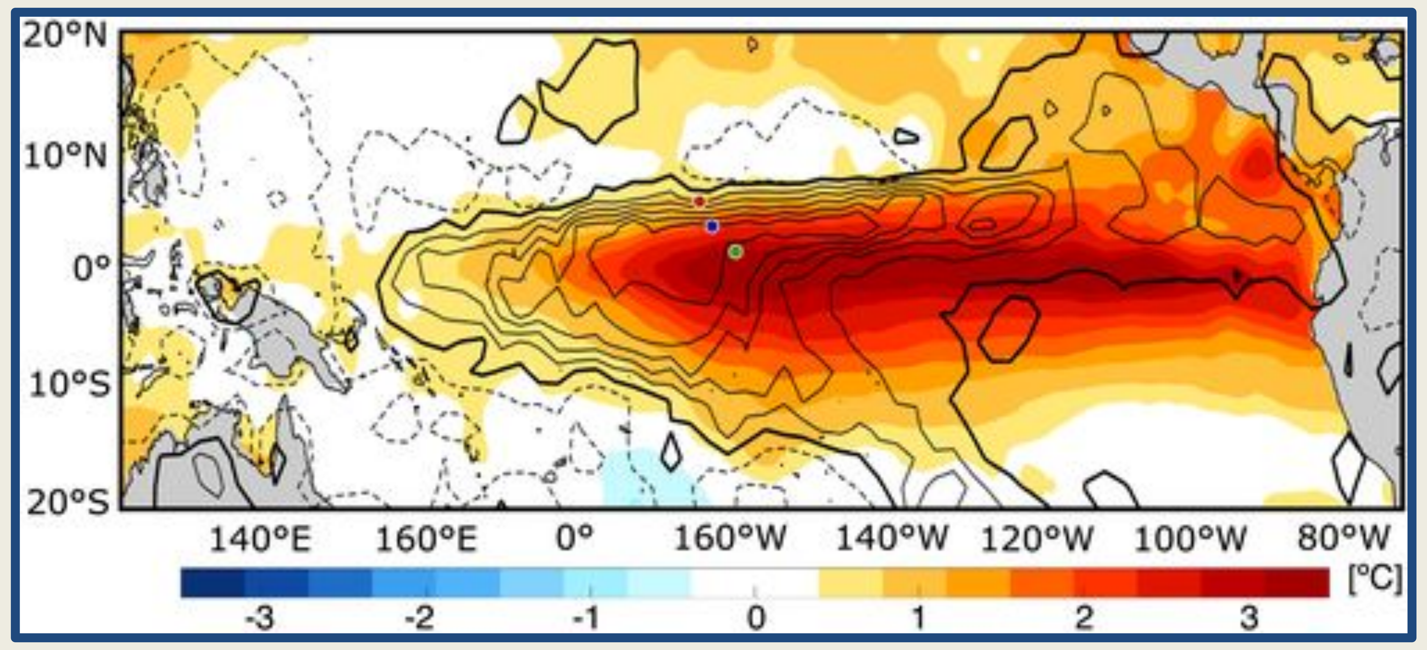

Figure 1: Map of 2015/2016 ENSO event. Contours represent sea surface temperature and precipitation anomalies. Green dot denotes Kiritimati Island (Grothe et al., 2020).

In order to reconstruct climate in this time period, we use coral fossils as a proxy for sea surface temperature (SST) and hydroclimate. The *Porites spp.* coral fossils we are using come from Kiritimati Atoll (2°N, 157°W), located in the CTP. This island is exciting from a scientific standpoint as it's located in the center of ENSO activity (Dee et al., 2023).

We are able to use the geochemistry within the corals to reconstruct past climate. However, the longer a coral is exposed to the sun, rain, and seawater, the more likely it is that the geochemistry of the coral is altered in a process known as diagenesis.

Diagenesis is a source of error in which the coral aragonite is replaced with calcite. This alteration occurs after the formation of the coral, which alters the data (Sayani et al., 2011).

Methods

- We are measuring the age of the corals using two dating methods:
  - radiocarbon dating (+/- 200 years)
  - U/Th dating (+/- 2-20 years)
- Once corals are dated, we measure δ18O to reconstruct past SST and SSS
- In total, 50 corals that were collected from Kiritimati island are:
  - Slabbed, cleaned, and milled for coral powder
- Diagenesis is screened for using SEM imaging and XRD scans, which determines whether the corals are preserved enough to rely on δ18O data
- Each mm of coral is assigned a decimal year based on each coral's growth rate and we are left with a reconstruction of SST and hydroclimate

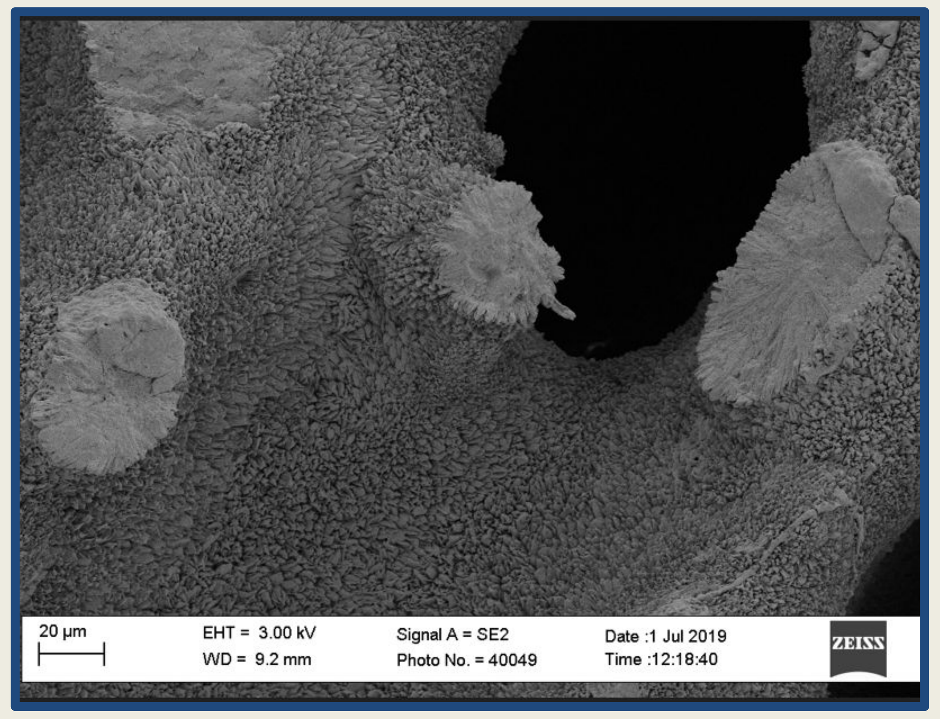

Figure 2: (left) SEM image of a coral contaminated by diagenesis.

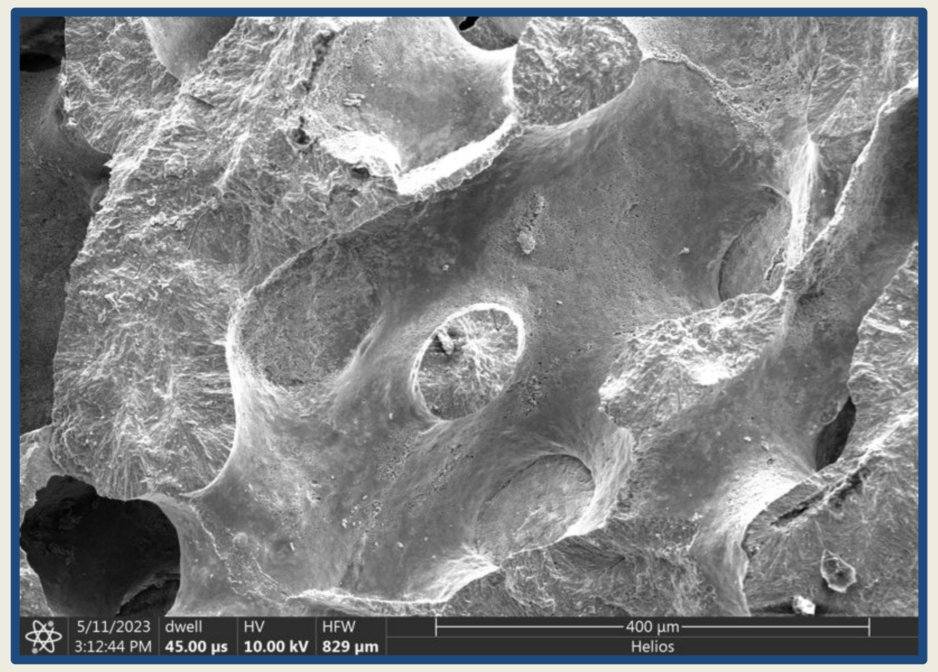

Figure 3: (right) SEM image of a coral uncontaminated by diagenesis.

Acknowledgements

This research is supported by NSF grant OCE-2103035 and NSF OCE-1903640. Thank you to my amazing research mentors, Taylor Conklin and Dr. Alyssa Atwood, who have provided unforgettable kindness and guidance! Finally, none of this would be possible without UROP for giving me this opportunity to participate in incredible research.

Stable Oxygen Isotopes

We measure stable oxygen isotope measurements of coral fossils, which provide us with the proxy data to reconstruct the variability of past sea surface temperature and hydroclimate in this tropical region. We can do this because as the coral grows, it uses the surrounding seawater to build its calcium carbonate skeleton; the resulting chemical composition of the coral is a reflection of the climate conditions at that moment, making the coral a living record of climate (Sayani et al., 2019).

Stable oxygen isotope ratios (18O:16O), which are abundant in seawater, can be used as a proxy for sea surface temperature (SST). This is because the ratio between 18O and 16O is a reflection of evaporation and freshwater input: 16O is preferentially evaporated since it is lighter than 18O, so the ratio of the two can determine if the temperature was warmer or colder as a higher evaporation rate indicates warmer temperatures.

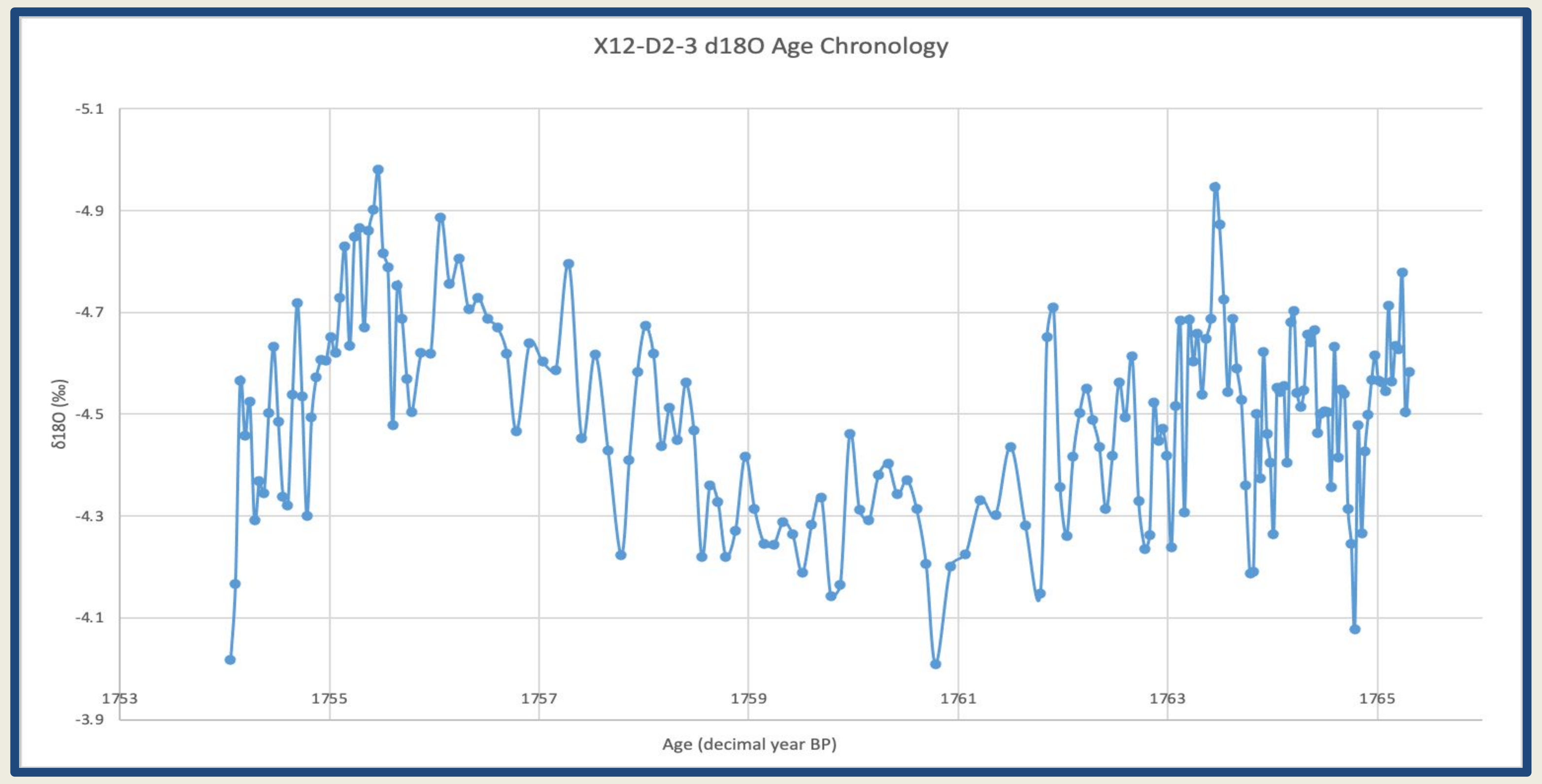

Figure 4: High resolution δ18O data from coral X12-D2-3

Conclusions and Next Steps

- As the data is still being processed, there are no results to present just yet, however, this data will continue to build the archive of climate variability in the CTP, which will aid in our understanding of current climate variability.
- As this current climate change is forced anthropogenically, and the climate change of our data is forced naturally, we will be able to compare the two and further understand the potential impacts of future climate change.
- Once the data is processed, it can also be used to compare the ENSO intensity of anthropogenically forced ENSO events and naturally forced ENSO events, and be used to understand the variability of future ENSO patterns.

References: