Mid-Holocene Climate Reconstructions from Kiritimati Coral Records

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Introduction

The geochemistry of coral skeletons are powerful tools for studying past climate changes in the tropical oceans hundreds to thousands of years in the past. Specifically, the oxygen isotope composition ($\delta^{18}O$) of the coral aragonite ($CaCO_3$) can provide records of temperature and salinity variations.

Figure 1: Beach at Kiritimati Island.

This research project focuses on coral reconstructions from a remote island in the central equatorial Pacific Ocean (Kiritimati Island) during the mid-Holocene (~6,000 years ago). This area is important to study because this is where El Niño-Southern Oscillation (ENSO; a major mode of climate variability) events operate and where the ENSO signal is largest. During warm El Niño events, the ocean becomes warmer and fresher at Kiritimati, while the opposite happens during cool La Niña events.

Kiritimati coral records indicate that mean coral $\delta^{18}O$ was more isotopically enriched (i.e., higher $\delta^{18}O$ values) going back in time, indicating that the mean state of the tropical Pacific was cooler and/or drier in the mid-Holocene relative to the present (Fig. 3). Previous studies have demonstrated that ENSO events were weaker and/or less frequent in this region during the mid-Holocene (Grothe et al., 2019). However, there is uncertainty in these mean climate reconstructions due to coral-to-coral variations in mean coral $\delta^{18}O$ values (Fig. 3). These coral-to-coral variations can arise from a range of sources, including changes in coral growth rate, secondary alteration of the coral skeleton after it was formed (diagenetic alteration), and climate variations. Also, there is a difference between the bulk records and the high-resolution records. Namely, the bulk records show there is less coral to coral variability in the mid-Holocene compared to other time periods, while the high-resolution records do not show this.

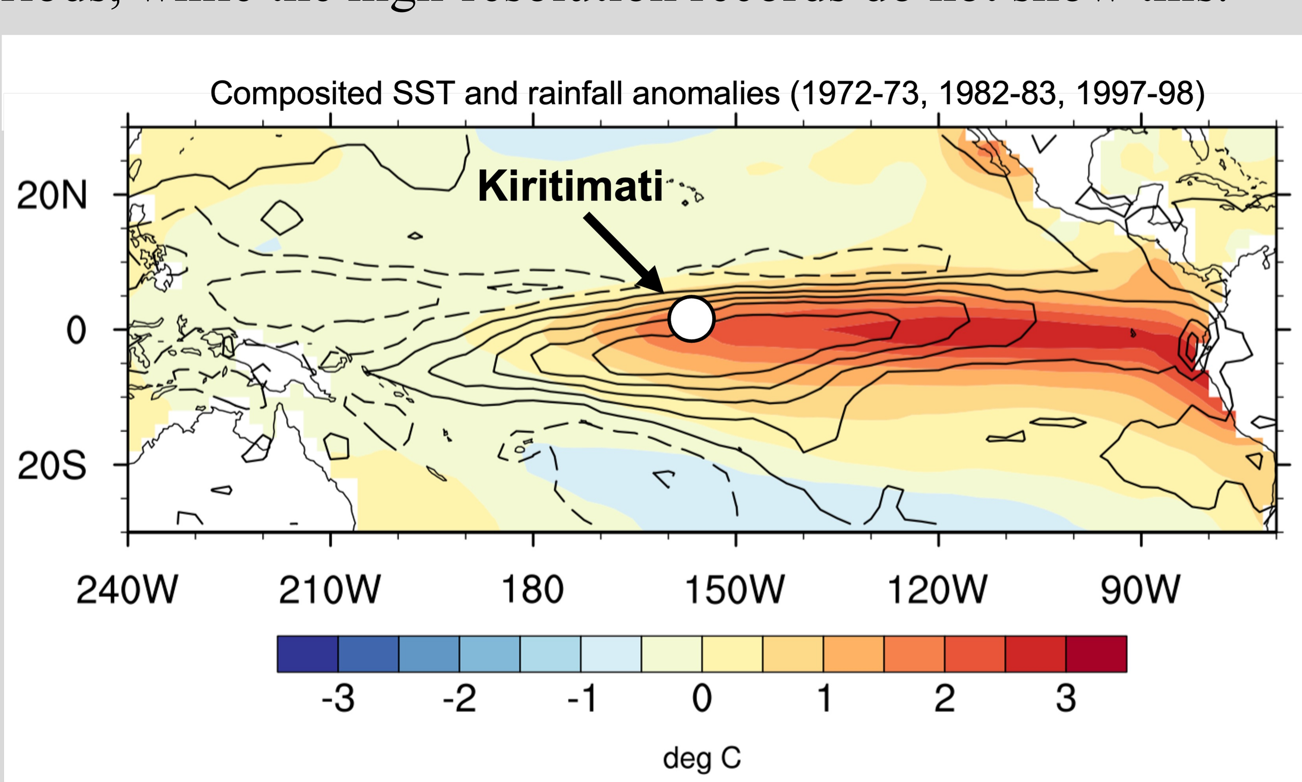

Figure 2: Map of ENSO years. Contours are the anomalies associated with ENSO events (precipitation and sea surface temperature).

For my project, I am trying to identify the source of the low coral-to-coral variability in the bulk records during the mid-Holocene. Are they a true climate signal or are they driven by differences in coral vital effects or diagenetic alteration? To investigate this, I am re-running the bulk coral $\delta^{18}O$ records at high resolution, as this will help me screen for diagenesis.

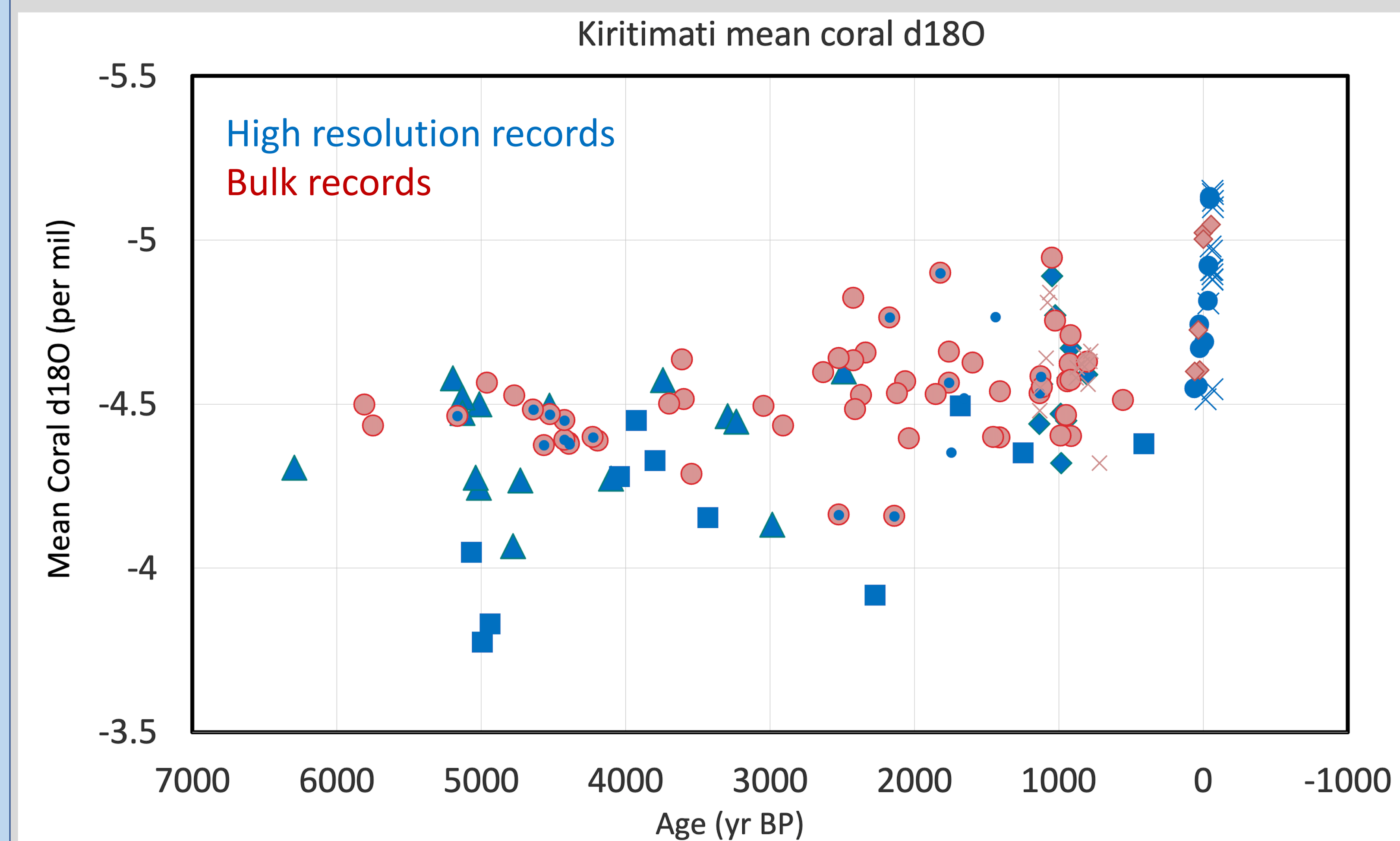

Figure 3: Mean coral $\delta^{18}O$ from Kiritimati over the last 6,500 years.

Methods

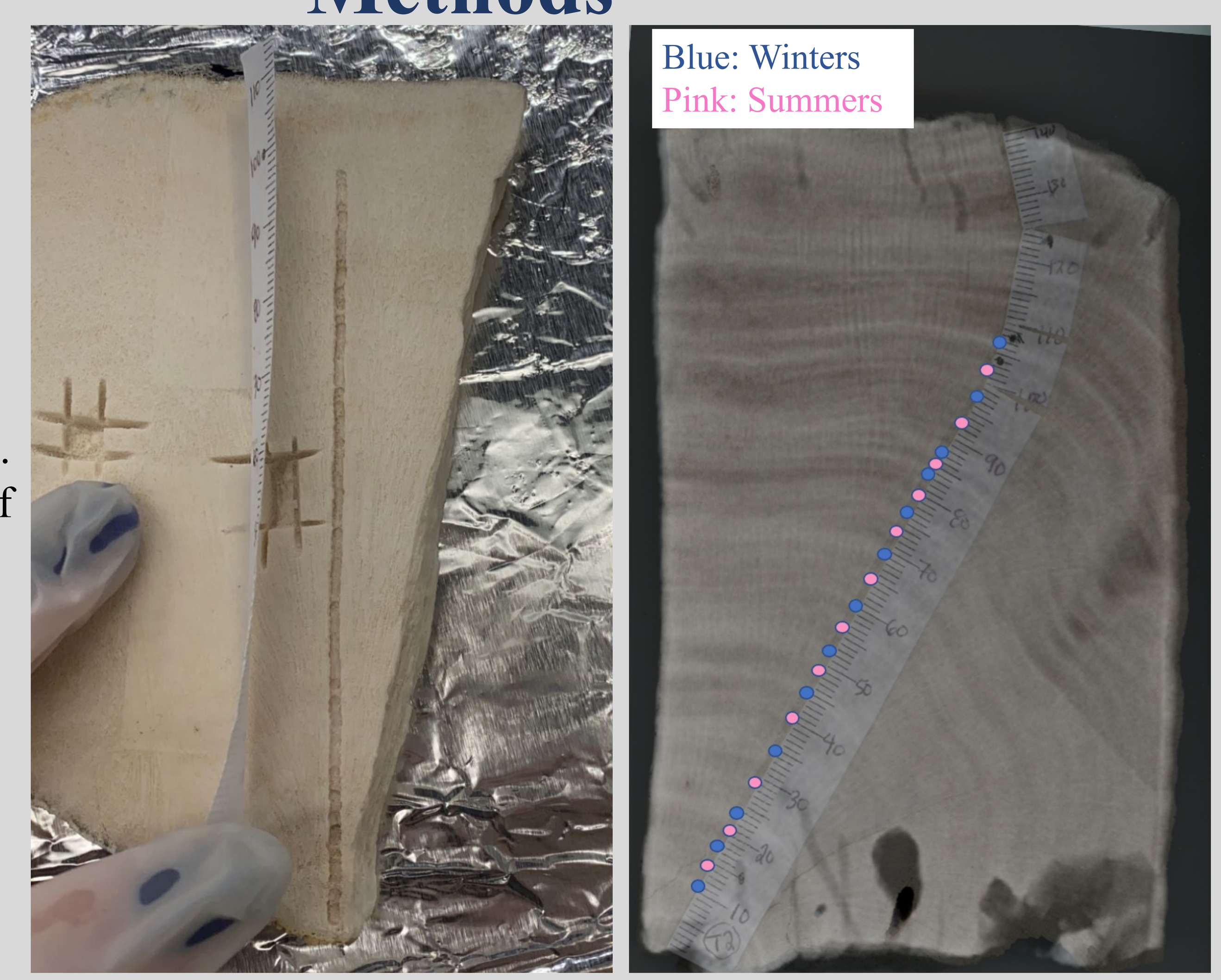

Figure 4 : Left: coral slab with drilling along growth transect. Right: X-Ray of coral with age model.

The bulk sampling technique consists of drilling along the growth axis in one continuous sweep, homogenizing the powder.

Drilling for high resolution data:

- First, the coral is slabbed along the maximum growth axis and the best transect is determined, through looking at growth (banding) patterns.
- High resolution sampling requires using a small drill to collect samples millimeter by millimeter along the growth transect.
- 100-200 micrograms of coral powder are analyzed on an isotope ratio mass spectrometer to determine the ratio of oxygen isotopes.

Screening for diagenesis:

- Observe and analyze oxygen isotope data, look for large changes in data and outlier points.
- Scanning Electron Microscope (SEM) images can show areas where the mineral structure has changed.
- Investigate X-Ray images of coral slabs. (Figure 4)

Results

Figure 5 provides an example of a high-resolution $\delta^{18}O$ record from Kiritimati coral X15c-21-22, a 5,165 year-old coral. The x-axis indicates the millimeter drilled on the growth transect and the y-axis indicates the $\delta^{18}O$ value (the less negative, the cooler and drier the conditions). Analyzing this type of high-resolution data is one important way to screen for diagenesis. Typically, outliers in the data indicate diagenesis, or secondary alteration. Jumps in consistent data could indicate an ENSO event.

The $\delta^{18}O$ data from the coral in figure 5 shows typical seasonal and year-to-year variability, indicating no compelling evidence for diagenetic alteration. However, the coral data will need to be compared with other coral records in the Holocene data set to completely screen for diagenesis.

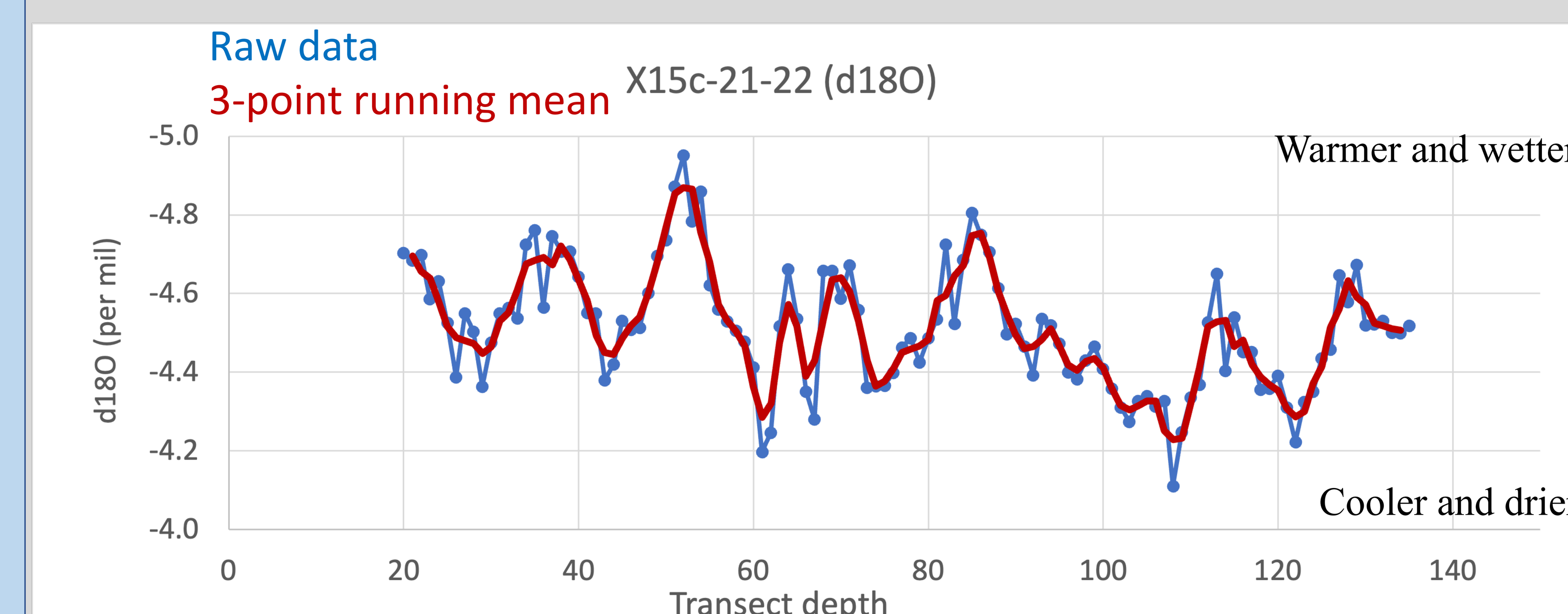

Figure 5: High resolution oxygen isotope data from coral X15c-21-22.

Conclusions and Next Steps

We have now rerun 10 bulk records from the mid-Holocene at high resolution. Based on our initial analyses, we have not observed compelling evidence for diagenesis as the source of the low inter-coral variability in mean coral $\delta^{18}O$ values during the mid-Holocene. However, we will complete other screening tests for diagenesis, including looking for the presence of secondary aragonite needles and calcite in Scanning Electron Microscope images.

In the coming months, I will be analyzing additional corals from the mid-Holocene at high resolution to further this analysis. I am hoping to rerun 3 additional coral records from the mid-Holocene at high resolution. To further evaluate diagenesis as the source of low coral-to-coral variability in the mid-Holocene, I will analyze the effect of coral growth rate on mean $\delta^{18}O$.

References

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