Ocean and Climate Change Institute
Final Report

Reconstructing Tropical Atlantic Variability

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What were the primary questions you were trying to address with this research? (Or, if more appropriate, was there a hypothesis or theory that you were trying to prove or disprove?)

Our goal was to reconstruct tropical Atlantic sea surface temperature (SST) for intervals of the last few centuries using the geochemistry of long-lived corals. Direct measurements of SST are only available back to 1856. Extending this record will provide important information about natural climate variability. First, we needed to confirm that the geochemistry of the coral skeleton recorded SST accurately. Second, we planned to target specific intervals of the last few centuries, like the Little Ice Age, a cold period in the North Atlantic.

What have you discovered or learned that you didn't know before you started this work?

We have shown that coral extension rates (or, inversely, the distance between annual bands) for a common Caribbean coral genus (Montastrea), needs to be considered when converting geochemical data to SST. If we do this, our results on Caribbean (St. Croix) corals suggests that SST were not very different from today during at least a 5-year interval of the Little Ice Age (Saenger et al., in resubmitted).

We have also shown that the extension rates of another coral genus (Siderastrea) are correlated to SST. We have applied this technique to a long-lived coral collected in 1991, providing the first, annually resolved, accurately dated, continuous SST record spanning over 4 centuries from the low-latitude Atlantic (Bahamas). The new SST record, developed by JP Student Casey Saenger, reveals multidecdal to century scale SST variability at Bahamas. Coldest SSTs were at ~1725AD, at the end of a long cooling period that began at ~1600AD. A second cold period occurred at ~1850 and marked the end of the Little Ice Age.

What is the significance of your findings for others working in this field of inquiry and for the broader scientific community?
First, we suggest ways that SST can be reconstructed more accurately. Second, our continuous record should lead to a better understanding of spatial and temporal modes of variability in the Atlantic, and of the role the ocean plays in propagating decadal climate anomalies.

What is the significance of this research for society?

Our data can be included as part of a larger effort to test numerical models that are used to predict changes in climate (e.g. precipitation) under global warming scenarios. Annually resolved, accurately dated records of past cool and warm intervals can be used to assess whether the sensitivity of the model climate to past changes (and hence future changes) in SST are correct.

What were the most unusual or unexpected results and opportunities in this investigation?

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The exciting opportunity that the new work suggests is the ability to use coral extension rate as a proxy for SST.

What were the greatest challenges and difficulties?
An ongoing challenge is to understand the mechanisms controlling the geochemistry and extension rate of coral skeletons, and how these processes relate to temperature. This continues to be a focus of co-PI Anne Cohen's work.

When and where was this investigation conducted? (For instance, did you conduct new field research, or was this a new analysis of existing data?)
Most of the work was conducted at WHOI on corals that had been collected previously. However, work at St. Croix helped with our modern calibration and paved the way for future work.
-Surveys of area reefs: ~15 large Montastrea spp. coral colonies were identified that are estimated to be in excess of 150 years. These colonies may be suitable for long paleoclimate reconstructions and may be cored on subsequent excursions.
-Temperature data collection: 3 data loggers, which monitor sea-surface temperature (SST) at bi-hourly intervals, were deployed in May, 2006. The SST data from these loggers was downloaded and used to determine negligible SST differences between the three sites used for our modern calibration.
- Coral staining: A suite of ~5 corals were stained at the Gentle Winds site in May, 2006 to deposit a horizon of known age within the coral skeleton. These corals were re-stained in February, 2007 to deposit an additional horizon, and will be cored during subsequent field work to better understand intra-annual coral growth.
- Meeting with National Park officials: Recent bleaching conditions and past SST trends were discussed with Zandy Hillis-Starr, chief park ranger at Buck Island National Park, St. Croix

What were the key tools or instruments you used to conduct this research?'
ICP-MS, CAT-scan, stable isotope mass spectrometer, x-ray machine.

Is this research part of a larger project or program? *Yes, our goal is to continue to use these kinds of proxies to reconstruct SST for the last 500 years or so. We have also initiated a collaboration with Ping Chang to incorporate a modeling component to our research.*

What are your next steps?
We are hoping to carry our similar analyses on similar material from Bermuda, the south Atlantic and Indian Ocean. See above.

Have you published findings or web pages related to this research? Please provide a citation, reprint, and web link (when available).

We have one paper resubmitted to Paleoceanography with responses to minor comments from the reviewers:

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A manuscript incorporating this work, entitled " Interpreting sea surface temperature from strontium/calcium ratios in *Montastrea* corals: The link with growth rate and implications for proxy reconstructions , by Saenger, C., A L. Cohen, D. W. Oppo, and D. Hubbard
In this paper, Sr/Ca is calibrated to SST, and finds Sr/Ca to be a function of both SST and coral growth rate. Applying the calibration to a coral from the Little Ice Age (LIA) estimates that SST in the eastern Caribbean at the time was not significantly different from today. Parallel measurements of coral d18O suggest the Caribbean was also more arid during the LIA. This is the first growth-dependent Sr/Ca-SST calibration for Montastrea, the dominant reef-building Caribbean coral, and the first reconstruction of LIA Caribbean SST from coral Sr/Ca. Our findings are significant because they suggest existing differences between foraminiferal estimates of LIA SST and those from coral Mg/Ca or d18O may be reconciled by using our growth-dependent Sr/Ca-SST calibration.

We have a second manuscript in preparation for Nature, which discusses the continuous SST record from Bahamas (Saenger et al., in prep.).

Please provide photographs, illustrations, tables/charts, and web links that can help illustrate your research.