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Getting Inside the Heads of Corals:
The Path to Accurate PaleoTemperature Reconstruction

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Coral skeletons are a treasure trove of climate and environmental information with potential to take us back far beyond the instrumented record, with unparalleled temporal resolution. Coral polyps, however, the builders of skeleton, hold the key to this rich ocean archive. Skeleton-building requires that polyps modify the carbonate chemistry of seawater in a semi-isolated calcifying space, elevating pH and carbonate ion concentration ([CO32-]) so that aragonite crystals can nucleate and grow. This process exerts its own influence on skeletal geochemistry, distorting the climate signal captured by the growing skeleton.
Using abiogenic calcium carbonate precipitation experiments, we found that Rayleigh fractionation, caused by aragonite precipitation from a semi-finite volume of calcifying fluid, exerts the over-riding control on Element/Ca ratios commonly used to reconstruct past ocean temperatures from corals, including Sr/Ca. When aragonite precipitation efficiency is high, skeletal Sr/Ca ratios are low, mimicking high SSTs. Indeed, we induced a wide range of Sr/Ca values in corals reared at constant temperature, by manipulating their precipitation efficiency.
Our abiogenic precipitation experiments reveal that uranium/calcium ratios (U/Ca) in aragonite are controlled primarily by the [CO32-] of the calcifying fluid. Based on this information we developed a multi-element coral paleo-thermometer, using U/Ca to account for variations in [CO32-] that control precipitation efficiency, Rayleigh fractionation and the consequent distortion of coral Sr/Ca. The U/Ca normalized Sr/Ca ratios (Sr-U values) of multiple species of massive long-lived corals sampled in the Atlantic and Indo-Pacific oceans exhibit a significantly stronger correlation with temperature than Sr/Ca alone.
We tested the spatial Sr-U SST relationship in the temporal domain, reconstructing 20th century SSTs from Sr-U values of two Atlantic corals. For their overlapping time period, Sr-U of both corals captured the mean satellite SSTs, whereas Sr/Ca-derived SSTs were consistently too cold. A continuous 96-year long Sr-U SST record captured both the mean SST and the 20th century warming trend. The Sr/Ca SST record did not, indicating instead a long-term cooling of tropical Atlantic SSTs.
Our results indicate that multi-element thermometry holds significant promise for accurate down-core reconstructions of paleoSST from modern and fossil corals. Critically, we show that understanding the fundamental processes that drive geochemical variations in biological archives is critical for the development and application of new and accurate climate proxies.