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Tropical Climate Characteristics of the Last Millennium as Revealed by Splicing Fossil Corals from the Central Pacific

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Our understanding of the response of the El Niño-Southern Oscillation (ENSO) to the last decades of increasing global means temperatures is hampered by the fact that few high-resolution records, either instrumental or geological, extend beyond the pre-industrial era. Specifically, the question of whether El Niño events have become stronger and/or more frequent is hotly debated, and bears consequence for ENSO predictions of the next century (Trenberth and Hoar, 1996; Latif et al, 1997). The importance of the tropics in affecting global climate on longer time-scales is demonstrated in a tropical climate model which proposes that dynamics involved in ENSO play a role in climate phenomena such as glacial-interglacial transitions and even millennial-scale variability (Clement et al, 1999). Fundamental questions remain, in particular those concerning a) the relationship of ENSO variability to decadal, century-scale, and mean global climate changes, and b) the natural range of ENSO frequencies and amplitudes and tropical climate variability in general.

A 1998 expedition to Palmrya Island (6ºN, 162ºW) yielded a long modern coral and numerous fossil coral sequences which are spliced together to provide monthly-resolved, multi-century windows on Pacific climate over the last millennium. The validity and feasibility of splicing fossil corals together depend on the following requirements: 1. the modern coral oxygen isotopic record must faithfully record regional-scale temperature anomalies, 2. the absolute dates on the fossil coral heads must be known to ±10 years, and 3. overlapping coral sequences must contain oxygen isotopic records that are similar enough to justify a splice between them. The 112-yr oxygen isotopic record from the modern coral is strongly correlated (R=0.59) to the regional-scale sea-surface temperature (SST) NIÑO3 index, which tracks ENSO variability. Ages from the fossil corals were obtained by U/Th chemistry, with a total error of ±10-20 years, including the error associated with the contribution of daughter Th by non-radiogenic sources. In order to better quantify this contribution of non-radiogenic Th, a young fossil coral dated to 1920 A.D. ±15 years was absolute-dated to 1937 ±2 years by matching its oxygen isotopic record to that of the modern coral. Applying this estimate to the older fossil corals yielded corrections of 5-30 years, depending on the level of detrital contamination. Moreover, the near-perfect overlap between the modern and fossil oxygen isotopic records demonstrates that head-to-head variability and geochemical differences between the living and fossil corals are seemingly insignificant, fulfilling the third requirement.

Guided by the improved U/Th dates and distinct patterns of the high resolution oxygen isotopic records, three fossil coral sequences were overlapped and spliced together to form one 95-yr long, continuous climate proxy record spanning 1355-1448 A.D.. Reassuringly, the corrected U/Th dates and the dates inferred from the splice of the three corals agree to within two years, further validating the application of the 20th century correction to these 500-yr old materials. The similarity of the oxygen isotopic variabilities in the overlapping intervals of the three heads is striking, and supports the validity of this approach for building long, continuous reconstructions.

In addition to the 95-yr spliced record, we present 30+yr of oxygen isotopic climate proxy records from ~950A.D, ~1290A.D., and ~1650A.D. These records fall in and around such intervals as the "Medieval Warm Period" (900-1200A.D.) and the "Little Ice Age" (1400-1850A.D.), periods of globally warmer and cooler temperatures that are suggested by higher latitude climate proxy records such as tree rings and ice cores. One fundamental observation of note is that large (1-2°C), ENSO-related SST variability occurs in all of the coral sequences analyzed to date, with periods that are statistically indistinguishable from the 3-7yr ENSO periods documented over the 20th century. These preliminary data suggest that the ENSO dynamics were not strongly affected by processes that reportedly changed climatic patterns in extra-tropical regions. Some features, however, are unprecedented in the modern-day tropical climate record, most notably an abrupt, sustained cooling of as much as 2°C for as long as 12 years which is centered at 1380A.D.. The relative contribution of hydrography versus SST to this particularly large anomaly is addressed through alternative geochemical SST proxies using the modern coral as a calibration for interpreting the fossil coral records.

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