Ancient corals reveal the changeable moods of El Niño-Southern Oscillation

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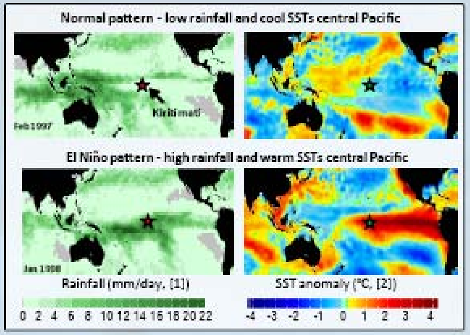
Context

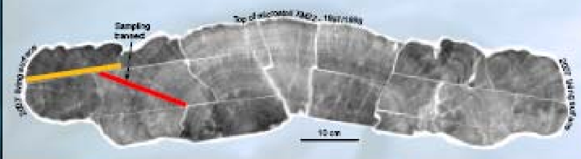
The El Niño-Southern Oscillation (ENSO) system plays a significant role in modulating climate across the globe. Yet it is unclear whether or not El Niños will become more frequent and/or larger amplitude in a future warmer world, and a key challenge identified by the IPCC is to improve predictions of ENSO. A major barrier to better understanding ENSO is the shortness of the instrumental record from which ENSO models are tested. To this end our research uses the oxygen isotope ratios ($\delta^{18}O$) of fossil corals from Kiritimati Island, central Pacific to extend the record of ENSO variability and to provide insights into the processes that may lead to changes in ENSO behaviour.



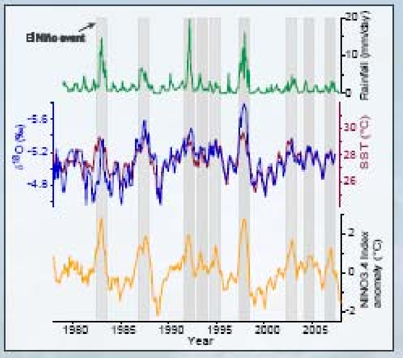
The ENSO system consists of warm El Niños and cool La Niñas recurring every 2-7 years. Kiritimati (Christmas) Island, central Pacific, an ideal location for investigating ENSO - sea surface temperatures (SST) are anomalously warm and rainfall is anomalously high during warm El Niños.

1. *Porites* coral microatolls are a rich source of paleoclimatic information

Individual microatoll colonies grow up to mean spring low tide level (left). Further upward growth is limited due to exposure of the upper coral surface at low tide, and the coral then grows laterally to form large, discoid colonies [3]. X-rays of the microatoll skeleton reveal growth (density) bands and the coral growth history (e.g. microatoll cross-section below).

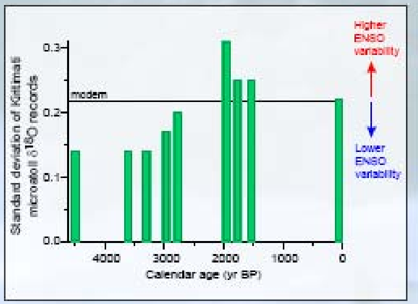


2. Kiritimati microatoll $\delta^{18}O$ clearly records ENSO variability



The Kiritimati microatoll $\delta^{18}O$ (blue, above, [4, 5, 6]) correlates strongly with sea surface temperature and the NINO3.4 index, local rainfall (green, [7]) and SST (red, [8]), and the NINO3.4 index (yellow, [9]), both key parameters for defining ENSO events. The microatoll $\delta^{18}O$ is dominated by SST variability [6].

3. Fossil microatoll $\delta^{18}O$ records show changes in Holocene ENSO



Initial fossil coral $\delta^{18}O$ results suggest that ENSO may have been more variable 2,000 years ago (see above, [4, 5, 10] and large amplitude El Niño events may have been commonplace; several large amplitude anomalies similar in magnitude to, if not larger than, the 1997/1998 El Niño 'event of the century' have been identified (not shown, see [11]). In contrast, corals that lived 3,000-4,500 years ago show a suppressed ENSO signal (above).

4. Integrating coral results with climate models to understand ENSO dynamics

A. ENSO frequency likely increased from the mid-Holocene to present.

Inferred ENSO frequency based on data from Lake Pallcacocha, Ecuador [11].

B. Ages of our fossil Kiritimati microatolls span much of the past 6,000 years.

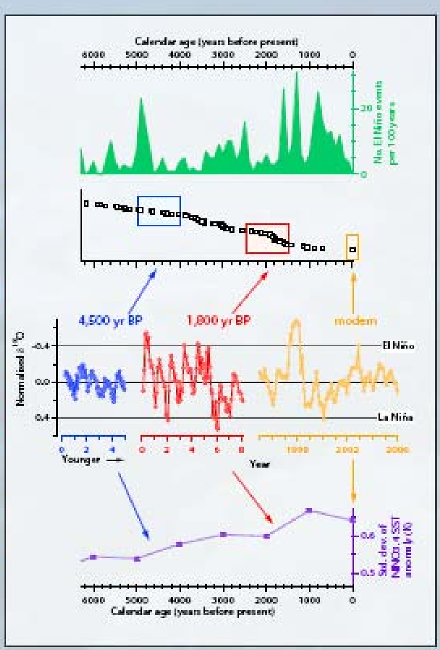
Squares are dates on microatoll samples. Boxes indicate our initial target periods.

C. Holocene ENSO changes could be due to changes in the interaction between ENSO and the seasonal cycle - corals can reveal these changes.

Monthly resolution $\delta^{18}O$ results from two fossil Kiritimati microatolls, 4,500 yr BP and 1,800 yr BP, compared with the modern microatoll record. The 4,500 yr BP coral shows annual cycles similar to the present, and the 1,800 yr BP coral shows asymmetrical annual cycles and large amplitude variations. All records have been normalised by subtracting the mean.

D. Climate model results broadly agree with coral $\delta^{18}O$ trends

Standard deviation of the NINO3.4 SST anomaly, a measure of ENSO variability, derived from snapshot simulations from the CSIRO Mk3L model [12]. The model results show increased ENSO variability towards the present, with a peak in variability ~1 ka.



Future work will focus on integrating the coral results with climate models to further define how climate changes translate into an ENSO response.

References and notes

1. IGOSS SST anomaly, Reynolds et al. (2002) Journal of Climate. 2. CAMS_OPI v0208 rainfall anomalies, Janowiak and Xie (1999) Journal of Climate. 3. Stoddart and Scoffin (1979) Atoll Research Bulletin. 4. Woodroffe and Gagan, (2000) Geophysical Research Letters. 5. Woodroffe et al., (2003) Geophysical Research Letters. 6. McGregor et al., (in review) Geochimica et Cosmochimica Acta. 7. CAMS_OPI v0208 centered on 158°10'W, 1°10'N (including Kiritimati Is.), Janowiak and Xie (1999) Journal of Climate. 8. ERSST v3b centered on 158°W, 2°N (includes Kiritimati Is.), Smith et al. (2008) Journal of Climate. 9. NOAA Climate Prediction Center (http://www.cpc.noaa.gov/data/indices/). 10. Phipps & McGregor, (2010) Frontiers of Science Meeting, Perth, Australia. 11. Moy et al. (2002) Nature. 12. Phipps, (2010) The CSIRO Mk3L climate system model v1.2, Technical Report, ISBN 1-921197-04-8.

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