PROGRESS REPORT FOR AINGRA09021

**PROJECT TITLE**
Ocean temperatures from the Sr/Ca ratio of coral microatolls: a tool to investigate past mega-El Nino events

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**SCIENTIFIC OBJECTIVES**

This project sets out to:

1) Demonstrate that the Sr/Ca measured in coral microatolls is a proxy for sea surface temperature (SST).

2) Use the microatoll Sr/Ca-SST relationship developed in 1) to track SST variability during the mega-El Nino events that appear to be common approximately 2000 years ago.

The results will allow us to better characterise how mega-El Nino events initiate, progress and terminate. We will be able to document, in terms of SST, the transition from El Nino to La Nina, and test hypotheses as to the climatic factors that govern El Nino-Southern Oscillation (ENSO) variability.

**PROGRESS REPORT and RESEARCH OUTCOMES**

Modelling the behaviour of tropical climate systems is an important pursuit for climatologists and scientists studying the effects of a warming climate. The data available for these models from instrumental records, however, is limited to the past 150 years, which is likely to be an insufficient representation of tropical climate systems through time. One way to extend climate datasets is to use records stored in natural climate archives, such as coral skeleton, which contains characteristic chemical signatures that can be related to environmental conditions such as SST. Of particular interest and promise to obtaining SST specific information is the ratio of strontium to calcium (mmol/mol) in aragonite (Correge, 2006). In this project the suitability of microatolls from Kritimati Island, Kiribati (1570 30’ W, 2000’ N), as a sea surface temperature (SST) climate archive was examined. Coral microatolls are an unusual growth form of *Porites* that can be up to several meters in diameter, containing hundreds of years of climatic data.

The Sr/Ca ratio from a modern microatoll was measured using the inductively coupled plasma atomic emission spectrometry (ICP-AES) facilities at the Australian Nuclear Science and Technology Organisation (ANSTO). Corals have skeletal Sr/Ca variability of ~10% requiring high analytical precision to measure these variations and as such, a series of experiments were conducted to optimise the ANSTO ICP-AES for analysing coral samples. Analytical precisions of 0.27 %RSD were achieved using a power setting of 1.3 kW, a nebuliser flow rate of 0.75 L/min, and a matrix matched coral reference solution.

The Sr/Ca measurements from the modern microatoll were then compared to the IGOSS satellite SST record and a calibration equation relating Sr/Ca to SST was developed. Sr/Ca (mmol/mol) was found to decrease predictably with SST (°C) (Sr/Ca = 10.744 - 0.0581 * SST; r² = 0.7363) suggesting that coral microatolls are...
capable of recording SST specific information. In addition, a strong Sr/Ca response related to the 1997/98 El Niño demonstrates that coral microatolls are good recorders ENSO related SST variability.

Application of the Sr/Ca relationship developed in this study to the abundant fossil microatolls on Kiritimati Island has the potential to reveal ENSO related SST variations well beyond the instrumental record and provide valuable information on ENSO dynamics and tropical climate processes.

DATA

Samples were taken along three tracks from coral XM22 (Fig. 1). Seasonally-resolved samples were taken from track XM22-3i and used in the preliminary development of the ICP-AES methods (Fig. 2). Samples from track XM22-1 were further used to refine the ICP-AES technique (Fig. 3), and after further refinement of the methods, high-precision, monthly-resolved Sr/Ca measurements were made and samples from track XM22-3ii (Fig. 4). Results from track XM22-3ii were used to calibrate the coral Sr/Ca against instrumental sea surface temperature (Fig. 5--7).

Figure 1 X-Ray of of skeletal material from coral XM22 with sampling tacks: Green line marking sampling track XM22-1, pink XM22-3i, and purple, XM22-3ii. Note all sampling tracks are along maximum growth axis where growth rate effects are minimised. Colony growth radiates from bottom right hand side vertically and horizontally, till it is terminated by the water surface, and lateral growth becomes dominant. Dark bands represent higher density material and lighter bands of lower density material. Differences in shading between sections comprising this image are a result of a slight variation in thickness of the coral slices.

Figure 2 Comparison of Sr/Ca measurements from three batches seasonally sampled track XM22-3i. The maximum growth axis of the coral was sampled in increments of 4mm, which is representative of roughly a season’s growth. Note a substantial displacement between batches with no predictable offsets. The variability probably relates to reduced measurement precision.
Figure 3 Monthly resolution Sr/Ca measurements from sample track XM22-1 with an overall measurement precision of 0.41 % RSD. A clear annual oscillation is not evident whilst some larger scale trends are retained. Frequent large variations from point to point, larger than expected from monthly SST variations alone, suggest that precision needs to be improved.

Figure 4 Monthly Sr/Ca measurements taken from sample track XM22-3ii. Samples taken every 0.4 mm, representing a fortnight’s growth, with every second sample analysed. Measurements were made using an ICP-AES with a plasma power of 1.3 kW and nebuliser flow rate of 0.75 L/min. Calibration standards and reference solutions closely matching Sr/Ca content of the coral were used and values represent the average of two batch runs carried out on separate days. Precision was measured at 0.26 %RSD. Note the good agreement between the two batches in regards to both sample to sample variability and the entire batch overlap.
Figure 5 Monthly Sr/Ca measurements from coral slice XM22-3ii compared to instrumental IGOSS SST. Measurements made using ICP-AES with precision of 0.26% RSD. Chronology developed by McGregor et al. (in prep) by overlapping maxima and minima of oxygen isotope measurements with IGOSS SST. IGOSS SST is satellite-based and represents the averaged water temperature over a 1° grid that includes the coral’s locality (Reynolds et al., 2002). Note the easily identifiable maxima and minima in the Sr/Ca data, and similarity between Sr/Ca and SST amplitude. Transparent circles denote maxima and minima used in the SST calibration. Red circle denotes 97/98 El Niño maximum temperature, whilst blue represents an anomalously low measurement during the winter of 2000.

Figure 6 Regression of XM22-3ii Sr/Ca against IGOSS instrumental SST. Sr/Ca measurements were overlain with IGOSS data with at least one sample from every maxima and minima selected. Red circle denotes the maxima Sr/Ca value during the 1997/1998 El Niño event whilst the blue circle denotes the minima Sr/Ca value of the 2000 winter.

Figure 7 Calibration of coral Sr/Ca against instrumental SST. c. Sr/Ca SST estimates from coral microatoll XM22-3ii compared to IGOSS instrumental SST. The overall regression was constructed using Sr/Ca values from maxima and minima, ‘summer’ used only maxima values, whilst ‘winter’ used only minima values. Note that the SSTs predicted by the three regressions are almost perfect matches to each other.
AINGRA09021 Zeko, D. 2009 Ocean temperatures from the Sr/Ca ratio of coral microatolls: A tool to investigate past El Niño events, Bachelor of Environmental Sciences Honours Thesis, University of Wollongong, pp. 80. (s) A manuscript for publication in *Chemical Geology* is currently in preparation.

**PhD STUDENTS**

David Zeko - Bachelor of Environmental Sciences Honours, Class 1, completed November 2009.