Great Barrier Reef 'Climatic Optimum' at 5,800 y BP


Parts of North America and Europe were warmer during the mid Holocene while a stronger monsoon produced warmer/wetter climates in northern Africa and central Asia (COHMAP, 1988). The nature of the mid Holocene 'climatic optimum' is less clear for the southern hemisphere; although recent work on ice cores from high-altitude tropical glaciers in Peru indicates that air temperatures were warmer from 8,000 to 5,000 Y BP (Thompson et al., 1995). At the same time, sea surface temperatures (SSTs) along the coast of Peru may have been warmer and less variable suggesting that the El Niño - Southern Oscillation (ENSO) may have been weak, or absent (Sandweiss et al., 1996).

The new PAGES-CLIVAR initiative on Annual Records of Tropical Systems (ARTS) promotes the synthesis of palaeoclimatic, instrumental, and modeling data to improve our understanding of tropical climate variability. An important goal of the ARTS initiative is to reconstruct climate systems during ancient periods with different background climates and forcings.

Toward this goal, we have applied a multi-tracer approach to a fossil coral from the windward side of Orpheus Island, central Great Barrier Reef, to reconstruct climatic conditions in northeast Australia during one century of the mid Holocene (Gagan et al., 1995). At Orpheus, well-preserved massive Porites micro-atolls have been cored to reveal 100 years of continuous coral growth. The largest colony, for which preliminary data are presented, has a conventional radiocarbon age of 5,800 Y BP. The fossil coral data presented here have been calibrated via proxy data for modern corals growing adjacent to the fossil coral colony.

Examination of the coral UV fluorescence, indicating the intensity of runoff from mainland rivers (Isdale, 1984), suggests that monsoonal rainfall during this century of the mid Holocene was much less variable than today (see Figure). The intensity of UV fluorescence for modern corals analogues varies from 0 to 700 fluorescence units in response to cycles of drought and flood. In contrast, fluorescence in the mid Holocene coral is restricted to 100 to 300 units. The results indicate that droughts and floods were rare during this century of the mid Holocene.

In order to further verify the UV fluorescence record, we made high resolution measurements of the coral Sr/Ca to examine SSTs (Beck et al., 1992) and δ¹⁸O to document the seasonal dynamics of monsoonal rainfall (Gagan et al., 1994; McCulloch et al., 1994). The calibrated coral Sr/Ca-SSTs for years 80 to 96 indicate that mid Holocene SSTs were 1°C warmer than those of the last two decades. If these elevated SSTs represent regional warming in the western Pacific, higher evaporation rates and persistent summer cloudiness should follow. Note that the summer SSTs are closely confined to a mean temperature of about 29.5°C, and rarely exceed 30°C. This is the situation today further north near New Guinea where high evaporation rates produce persistent summer clouds which block incoming short-wave radiation, resulting in a negative feedback on further increases in SST. Persistent clouds also tend to damp fluctuations in summer SSTs. The warm, consistent summer SSTs indicated by the coral Sr/Ca reinforce the UV fluorescence in suggesting that summers in the Great Barrier Reef were typically cloudy with moderate monsoonal rainfall.

The 16-year Sr/Ca-δ¹⁸O record also provides a rare opportunity to look for evidence of individual ENSO events. Contemporary ENSO-induced droughts in northeastern Australia coincide with cool winter SST anomalies of at least 1-2°C. In addition to providing information about SST, coupled measurements of coral Sr/Ca and δ¹⁸O make it possible to determine seawater δ¹⁸O by removal of the temperature component of the coral δ¹⁸O signal. Seasonal changes in seawater δ¹⁸O, as registered by the coral, provide a good measure of the magnitude of river runoff and precipitation. The coral record spans the three years that we perceived to be the driest in 100 years, based on visual inspection of the coral UV fluorescent bands (years 82-85 in lower panel). Despite this period being fairly dry, the winter cooling associated with this 'drought' is negligible, and certainly not indicative of ENSO. This record is admittedly short, but the Sr/Ca and δ¹⁸O data have now been extended to nearly 30 years with no sign of winter cooling or drought indicative of ENSO.

Taken together, the evidence suggests that this century of the mid Holocene was marked by warmer SSTs, more dependable monsoonal rainfall, and possibly a weaker ENSO. The persistence in time of the apparent weakening of the mid Holocene ENSO is unknown but, if real, the ramifications of a weakened ENSO should be evident in high-resolution palaeoclimate records throughout much of the tropics.

Text submitted by:

Dr. Michael K. Gagan
Environmental Geochemistry Group
Research School of Earth Sciences
Australian National University
Canberra, A.C.T. 0200, Australia
Phone: +61 6 249 5926
E-mail: michael.gagan@anu.edu.au

References:


GREAT BARRIER REEF SSTs AND RUNOFF AT 5,800 y BP

A) 100-year record of annual UV fluorescence for the 5,800 y BP Porites micro-atoll from Orpheus Island, central Great Barrier Reef. Bar labelled 'Sr/Ca - δ18O' indicates 16-year interval chosen for coupled Sr/Ca and δ18O measurements.

B) 16-year record of coral Sr/Ca (black line) and δ18O values (grey line with dots) converted to SST. The difference between the Sr/Ca and δ18O curves represents the intensity of monsoonal runoff. Horizontal lines show the mean winter and summer SSTs for 1970-1994.

C) Coral δ18O residuals converted to show the magnitude of runoff from the palaeo-Burdekin River.