

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

M.K. Gagan, L.K. Ayliffe, S. Anker, D. Hopley, M.T. McCulloch, P.J. Isdale, J.M.A. Chappell and J. Head

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 paleoclimatic, 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 $\delta^{18}\text{O}$ 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 Pa-

cific, 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- $\delta^{18}\text{O}$ record also provides a rare opportunity to look for evidence of individual ENSO events. Contemporary ENSO-induced droughts in northeast 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 $\delta^{18}\text{O}$ make it possible to determine seawater $\delta^{18}\text{O}$ by removal of the temperature component of the coral $\delta^{18}\text{O}$ signal. Seasonal changes in seawater $\delta^{18}\text{O}$, 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 $\delta^{18}\text{O}$ 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

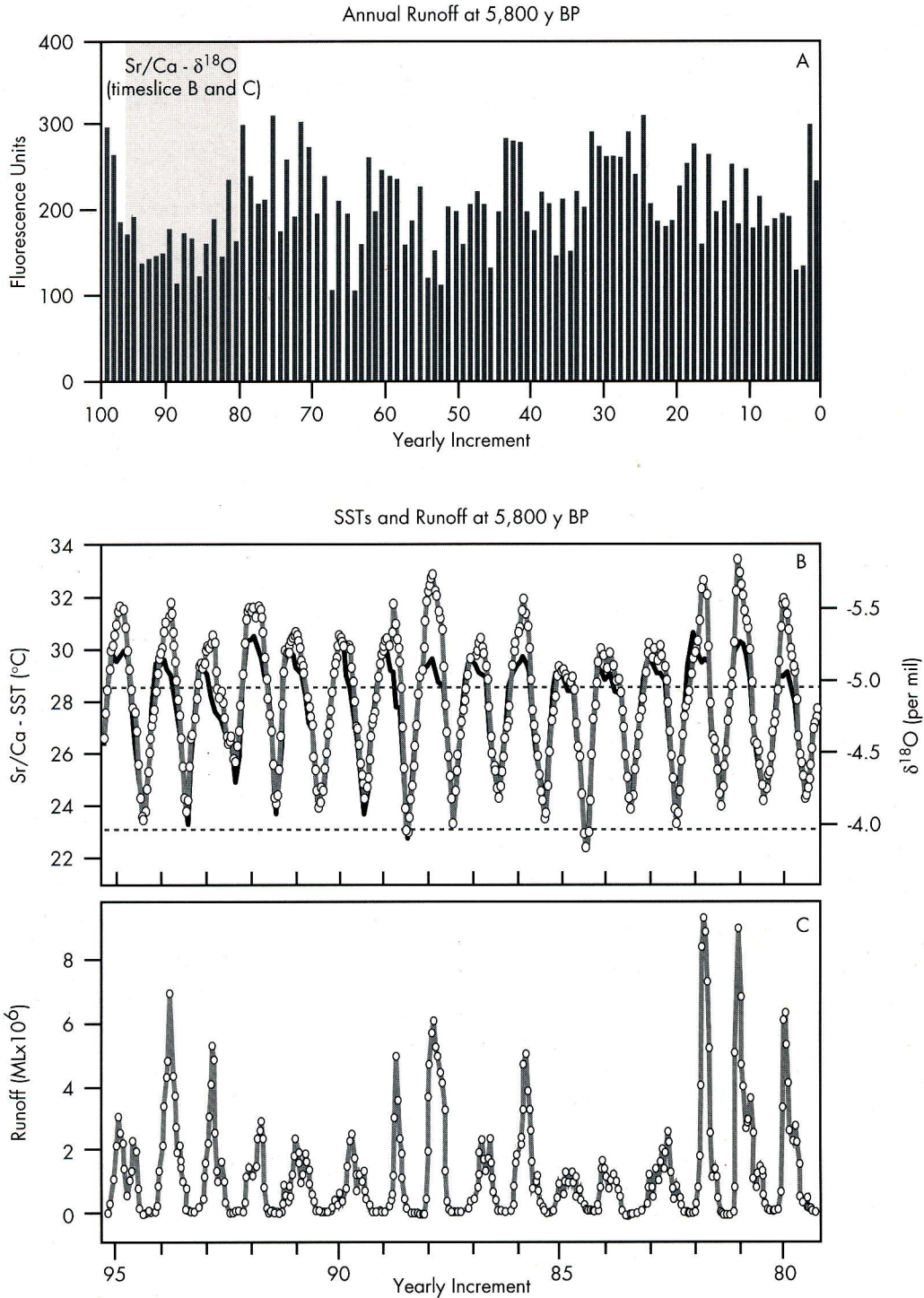
Environmental Geochemistry Group
Research School of Earth Sciences
Australian National University
Canberra, A.C.T. 0200, Australia
Phone: +61 6 249 5926
E-mail: michael.gagan@anu.edu.au

References:

- Beck, J.W., R.L. Edwards, E. Ito, F.W. Taylor, J. Recy, F. Rougerie, P. Joannot and C. Henin 1992. Sea-surface temperature from coral skeletal strontium/calcium ratios. *Science* 257: 644-647.
- COHMAP Members, 1988. Climatic changes of the last 18,000 years: observations and model simulations. *Science* 241: 1043-1052.
- Gagan, M.K., A.R. Chivas and P.J. Isdale 1994. High resolution isotopic records from corals using ocean temperature and mass-spawning chronometers. *Earth Planet. Sci. Lett.* 121: 549-558.
- Gagan, M.K., L.K. Ayliffe, M.T. McCulloch, S. Anker, D. Hopley and P.J. Isdale 1995. Sr/Ca and $\delta^{18}\text{O}$ in Great Barrier Reef corals and ENSO dynamics at 5.8 ka BP. American Geophysical Union Fall Meeting, EOS Supplementary Issue 76: 316.
- Isdale, P. 1984. Fluorescent bands in massive corals record centuries of coastal rainfall. *Nature* 310: 578-579.
- McCulloch, M.T., M.K. Gagan, G.E. Mortimer, A.R. Chivas and P.J. Isdale 1994. A high-resolution Sr/Ca and $\delta^{18}\text{O}$ coral record from the Great Barrier Reef, Australia, and the 1982-1983 El Niño. *Geochim. Cosmochim. Acta* 58: 2747-2754.
- Sandweiss, D.H., J.B. Richardson III, E.J. Reitz, H.B. Rollins and K.A. Maasch, 1996. Geoarchaeological evidence from Peru for a 5,000 years BP onset of El Niño. *Science* 273: 1531-1533.
- Thompson, L.G., E. Mosley-Thompson, M.E. Davis, P.N. Lin, K.A. Henderson, J. Cole-Dai, J.F. Bolzan and K.B. Liu, 1995. Late glacial stage and Holocene tropical ice core records from Huascarán, Peru. *Science* 269: 46-50.



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 - $\delta^{18}O$ ' indicates 16-year interval chosen for coupled Sr/Ca and $\delta^{18}O$ measurements.
 B) 16-year record of coral Sr/Ca (black line) and $\delta^{18}O$ values (grey line with dots) converted to SST. The difference between the Sr/Ca and $\delta^{18}O$ curves represents the intensity of monsoonal runoff. Horizontal lines show the mean winter and summer SSTs for 1970-1994.
 C) Coral $\delta^{18}O$ residuals converted to show the magnitude of runoff from the palaeo-Burdekin River.

