Giant clam recorders of ENSO variability

Mary Elliot[1], K. Welsh[2] and R. Driscoll[3]

[1]Laboratoire de Planetologie et Geodynamique, Université de Nantes, France; mary.elliot@univ-nantes.fr
[2]School of Earth Science, University of Queensland, St. Lucia, Australia; [3]School of GeoSciences, University of Edinburgh, UK

Giant clam stable isotope profiles from Papua New Guinea faithfully record all the major El Niño events between 1986 and 2003, thus illustrating the usefulness of this archive to reconstruct past ENSO variability.

Considerable uncertainty remains about the response of the El Niño-Southern Oscillation (ENSO) to future climate scenarios (Merryfield 2006). Reconstructions of past changes in seasonality and ENSO from natural archives have a key role in providing information for understanding both the full range of variability and the sensitivity of ENSO to changes in climate boundary conditions. Geochemical time series extracted from skeletons of annually banded reef-building corals and mollusks constitute powerful records in this regard. A number of exciting recent studies have illustrated how clams (i.e. bivalves) can be used in paleoenvironmental studies (e.g. Sano et al. 2012; Wanamaker et al. 2012).

Here we specifically illustrate the usefulness of one bivalve species, *Tridacna gigas* (Fig. 1) as a natural archive for paleo-ENSO. Massive *Porites* spp. corals and *Tridacna* spp. clams are both reef-dwelling, aragonite secreting organisms. Their annual bands can be subsampled and analyzed to derive profiles of oxygen isotope ratios ($\delta^{18}O$) which have been shown to reflect the combined effects of regional sea surface temperature (SST) and sea water $\delta^{18}O$ from which they precipitate their aragonite structures (Tudhope et al. 1995; Welsh et al. 2011). Time series of $\delta^{18}O$ in modern and fossil corals collected in northern Papua New Guinea in the heart of the Western Pacific Warm Pool have been used to reconstruct ENSO variability for short windows of time over the past 130 ka (Tudhope et al. 2001). These records are however extremely rare because of the tendency for the porous *Porites* skeleton to undergo diagenetic alteration during periods of subaerial exposure. An advantage of *T. gigas* is that they have relatively impervious and finely layered shells that inhibit infiltration of ground waters that would lead to the diagenetic processes of dissolution, recrystallization and precipitation of secondary calcite. Finally, while coral $\delta^{18}O$ show an isotopic disequilibrium, *Tridacna* spp. precipitate their shells in isotopic equilibrium. This provides the possibility to more accurately quantify past changes in absolute SST and see water $\delta^{18}O$.

Figure 1: Photo of a live Tridacna gigas *from Heron Island.* T. gigas *are reef dwelling mollusks which have symbiotic algae living within their mantle. Valves are 50 cm from end to end. Photo K. Welsh.*

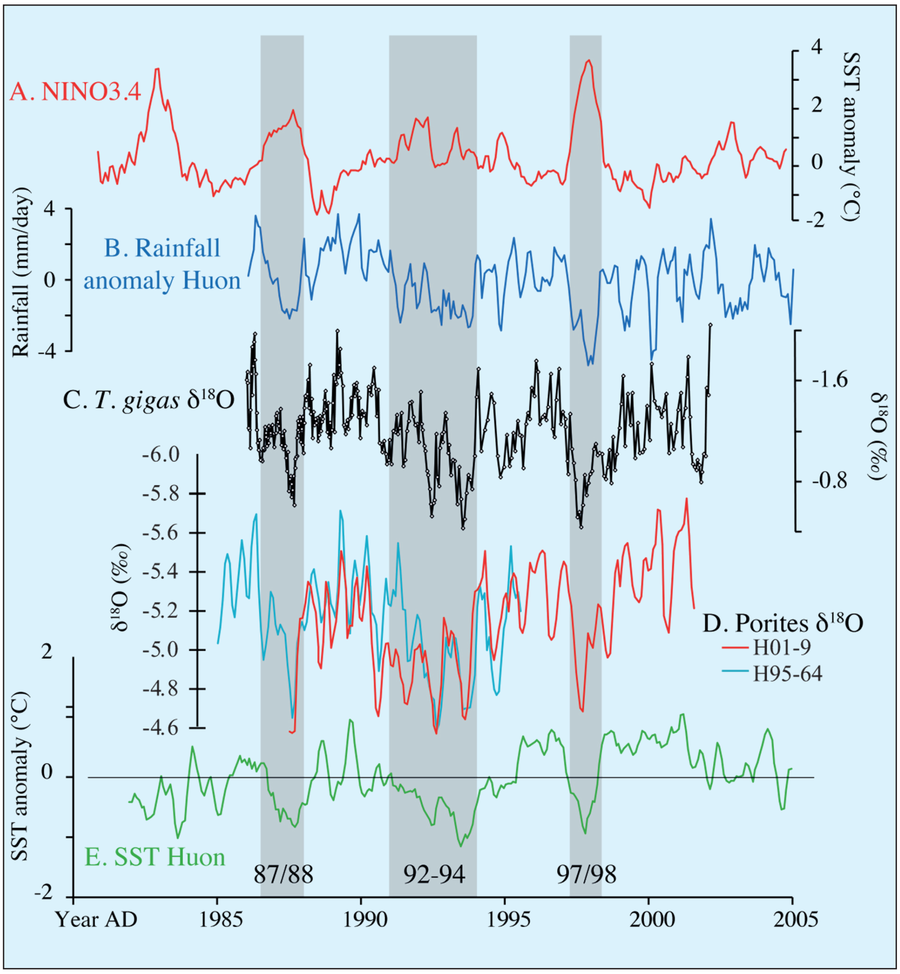

Figure 2: Comparison of T. gigas *$\delta^{18}O$ profile with ENSO index, local temperature and rainfall data.* ***A)*** *NINO3.4 index,* ***(B)*** *3pt smoothed monthly rainfall anomaly (mm day^{-1}, NASA/GPCPV2) for 146.25°E, 6.25°S,* ***(C)*** T. gigas *$\delta^{18}O$ record,* ***(D)*** *Porites $\delta^{18}O$ profiles and* ***(E)*** *3pt smoothed monthly SST anomaly (from IGOSS) for the same grid box as the rainfall data. Y-axes of the $\delta^{18}O$ are inverted. The shaded bands indicate El Niño events.*

Calibration

To illustrate the potential of *T. gigas* as paleo-ENSO recorders, we obtained a high-resolution $\delta^{18}O$ profile from a modern specimen that we compared to modern *Porites* coral $\delta^{18}O$ profiles and an ENSO index. Samples were collected from three localities along the Huon Peninsula in northern Papua New Guinea. Profiles of $\delta^{18}O$ were obtained by subsampling the annual growth bands using high precision microdrilling devices. The age of the coral and bivalve $\delta^{18}O$ profiles were obtained independently (i.e. they were not tuned to one another) by counting the annual growth bands when visible and using the $\delta^{18}O$ maxima and minima to position the warmest and coolest months. The *T. gigas* $\delta^{18}O$ profile covers the period 1986-2002 and the *Porites* $\delta^{18}O$ records cover the period 1987-2001 (Fig. 2). Average SSTs at the Huon Peninsula are around 29°C with an annual range of 0.5-1.5°C in monthly means. The predicted equilibrium skeletal annual average $\delta^{18}O$ is -1.6‰. Therefore, our results confirm that *T. gigas* precipitate their shell close to isotopic equilibrium as has been shown previously (e.g. Aharon et al. 1991).

Comparison of bivalve and coral profiles

A striking feature is the high degree of resemblance between the coral and bivalve records despite their geographic separation of approximately 30 km and their average $\delta^{18}O$ offset of ~4‰ (Fig. 2). Profiles correlate in detail on the seasonal and on the interannual levels. This correlation is particularly interesting given that paleoclimate archives obtained from coastal areas characterized by strong SST and salinity gradients can potentially be significantly influenced by the local micro-environmental hydrography. Our results clearly show that corals and clams record large-scale regional patterns. Furthermore, the good correlation between $\delta^{18}O$ coral and bivalve profiles remains constant although measurements have been obtained from different carbonate secreting organisms with fundamentally different biological controls on carbonate formation and different growth rates.

Giant Clams as recorders of ENSO events

In northern Papua New Guinea precipitation and temperatures are coupled on seasonal and interannual timescales. El Niño periods are associated with lower than average SST and drier conditions, whereas La Niña periods are associated with higher than average SST and wetter conditions. The associated changes in see water $\delta^{18}O$ and SST will thus have cumulative effects on shell $\delta^{18}O$, which will become more positive during El Niño and more negative during La Niña phases. The comparison of the ENSO index with the *T. gigas* and *Porites* $\delta^{18}O$ records shows that each El Niño event is recorded in the shell and coral profile by isotopic shifts of around 1.0 to 1.2‰ toward more positive values (Fig. 2) reflecting the combined influence of lower temperatures and decreased rainfall. During the El Niño phase of the Southern Oscillation, the region experiences relative drought and slightly reduced SSTs (~-0.2 to -0.5°C anomaly, see Fig. 2). These factors combine to drive skeletal $\delta^{18}O$ to heavy values, with SST explaining about 30-50% of the skeletal $\delta^{18}O$ range.

Take away message

We show that shells of *T. gigas* can be used to produce multi-decadal climatic records, hence providing a valuable resource for investigating changes to the frequency and strength of ENSO events in the past. The excellent reproducibility of clam and coral $\delta^{18}O$ profiles illustrates the strength of using these archives to reconstruct large-scale hydrographic changes.

References

Elliot M et al. (2009) *Palaeogeography, Palaeoclimatology, Palaeoecology* 280: 132-142

Sano Y et al. (2012) *Nature Communications* 3: 761, doi:10.1038/ncomms1763

Tudhope AW et al. (2001) *Science* 291: 1511-1517

Welsh K et al. (2011) *Earth and Planetary Science Letters* 307: 266-270