High-resolution palaeoclimate reconstruction of Holocene and modern corals in the Philippines, northern western Pacific warm pool

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The Philippines is a key site for studying past climate variability. Located between 5°N and 21°N, and bounding the northern edge of the western Pacific warm pool, the archipelago's present climate is greatly influenced by the monsoons, tropical cyclones and ENSO. Modern and Holocene coral reefs that fringe most of the islands provide a wealth of material for studying changes in tropical climate during particularly interesting time periods in the Holocene.

Modern and Holocene *Porites* corals, sampled along the eastern coast of Samar, Philippines (11.5°N/125.5°E), were analyzed for $\delta^{18}O$ and $\delta^{13}C$. Almost 11 years of record (1994-2004), at fortnightly resolution, has been obtained from the modern coral (SM04-01). Oxygen and carbon isotope ratios range from -5.2 to -6.2‰ (mean -5.7‰) and -1.2 to -5.5‰ (mean -3.1‰), respectively. Annual $\delta^{18}O$ profiles are generally defined by a double peak in summer, typically a sharp peak followed by a smaller but broader peak (Figure 1A). These features are very similar to the $\delta^{18}O$ profile obtained from another modern coral (not shown), signifying the reproducibility of the $\delta^{18}O$ data. In the absence of Sr/Ca values, the weekly IGOSS SST data (centered at 11.5°N/ 125.5°E) were used to approximate the SST signal from the coral $\delta^{18}O$ record. Sea-surface temperature in the vicinity of the study site has an annual oscillation of approximately 3°C with well-defined seasonal fluctuations (Figure 1B). Comparison between the SST data and the $\delta^{18}O$ profile indicate a strong salinity component to the coral $\delta^{18}O$ values.

ENSO events, as indicated by the SOI (Figure 1C), are clearly manifested in the coral record. The strong 1997/98 El Niño produced relatively high $\delta^{18}O$ values (up to -5.2‰) towards the end of 1997, that coincide with higher $\delta^{13}C$ values. The relatively weaker El Niños in 1994/95 and 2002/03 also exhibit the same signature in $\delta^{18}O$ but with smaller amplitude; however, no change in $\delta^{13}C$ values is discernible. On the other hand, the 1998-2000 cold ENSO phase registered relatively low $\delta^{18}O$ values in the coral record. Rainfall data close to the study site recorded very low precipitation during these El Niño years and relatively high precipitation during the 1999-2001 La Niña. The corals appear to be excellent recorders of ENSO variability.

The Holocene coral (MDL-1), radiocarbon dated at 2560+60y BP, has so far yielded approximately 12 years of stable isotope record at monthly resolution (Fig. 1D). Oxygen isotope ratios vary from -4.9 to -5.8‰ whereas the $\delta^{13}C$ values range from 0.0 to -3.6 ‰. These values are offset from those of the modern coral: the $\delta^{18}O$ mean of -5.3‰ is 0.4‰ higher than the modern value, and $\delta^{13}C$ is also 1.6‰ higher. Furthermore, the late Holocene coral record exhibits clear seasonal oscillations in the $\delta^{18}O$ profile; the cyclical peaks and troughs in MDL-1 appear to reflect seasonal SST variability, similar to that observed in the Philippines today. This, together with the higher $\delta^{18}O$ values, indicates higher salinity and a drier climate at 2.5 ka.

Also discernible in the late Holocene coral record is the inter-annual variability in $\delta^{18}O$ values at frequency similar to the present-day ENSO tempo (2 to 7 years). At least three annual profiles display depressed $\delta^{18}O$ peaks that mimick the El Niño signature (cooler SST and lower rainfall) of the modern coral record (Fig. 1D). These

years have anomalously high $\delta^{18}O$ values, approximately 0.2‰ higher than the average peak $\delta^{18}O$ value of -5.6‰ for the entire 12 years. A La Niña-like condition, marked by relatively low $\delta^{18}O$ values, can also be seen in the Holocene coral. Results from the work of McGregor and Gagan (2004) indicate that the late Holocene period is characterized by large and protracted El Niño events. The 12-year long Samar coral $\delta^{18}O$ record already indicates a 2-year long El Niño (Figure 1D), although not as large and protracted as the El Niño events recorded in the corals of Papua New Guinea (Tudhope et al., 2001; McGregor and Gagan, 2004) and Christmas Island (Woodroffe et al., 2003). A longer record from Samar Island, Philippines, is needed for a more rigorous comparison.

References

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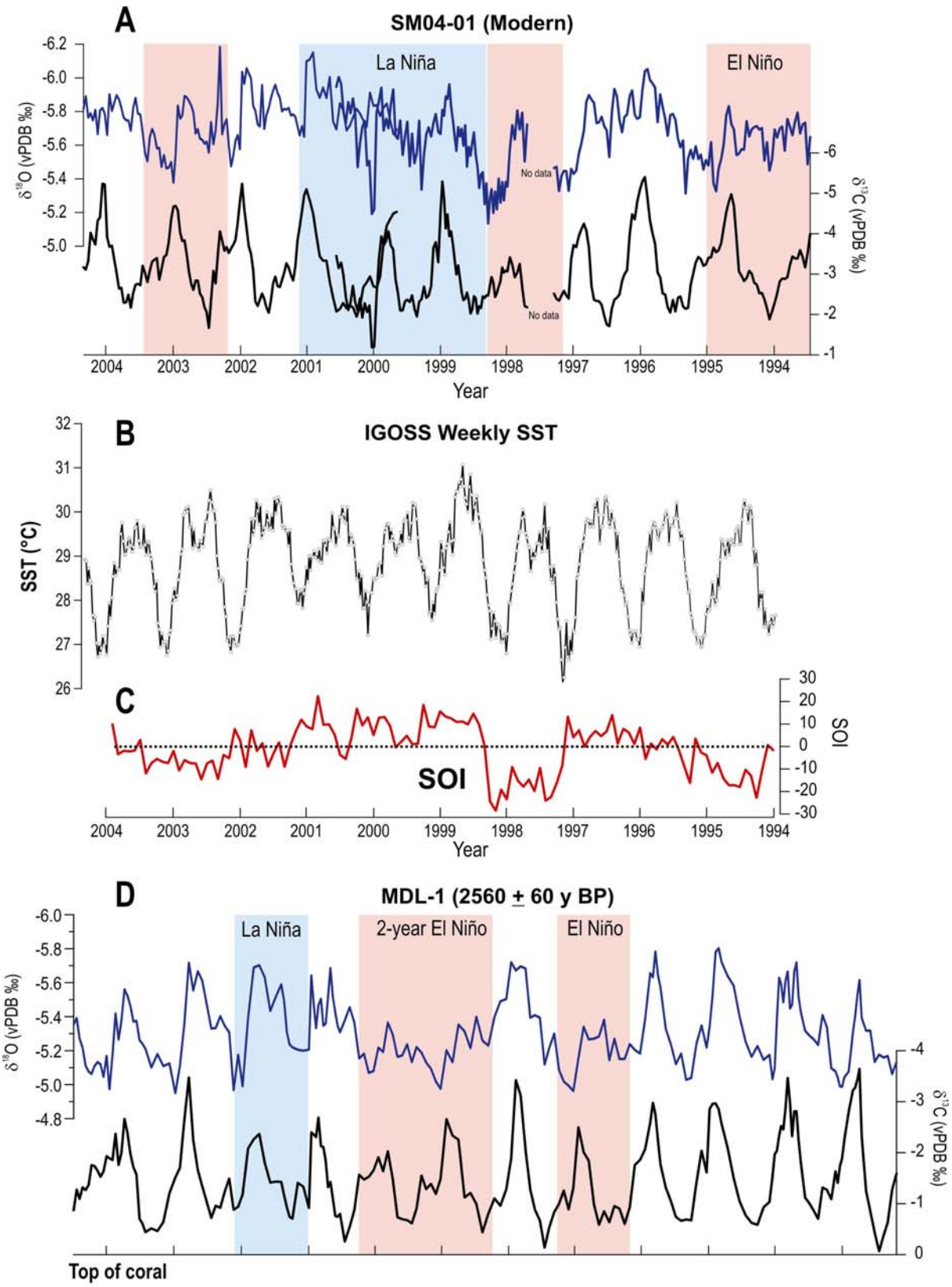

Figure 1. ENSO events are faithfully recorded in the stable isotope records, spanning the period from 1994 to 2004, of a modern coral from eastern Samar, Philippines (11.5°N/125.5°E) (A). Pink and blue bars mark years of El Niño and La Niña, respectively. IGOSS weekly SST data for the area showing an annual range of approximately 3°C and well-defined seasonal oscillation in SST (B). Southern Oscillation Index (SOI) from1994 to 2004 (C). Stable isotope record of a late Holocene coral from the same site exhibits ENSO events at frequency similar to the modern ENSO (D). Also evident in the coral record is a 2-year long El Niño.