# Study on the Increase of Sea-surface Temperature in Asian Monsoon Region Based on Coral Skeletal Climatology (Abstract of the Final Report)

**Contact person** Atsushi Suzuki
Senior Research Scientist
Biogeochemical Cycles Research Group
Institute of Geology and Geoinformation
National Institute of Advanced Industrial Science and Technology
AIST Tsukuba Central 7, 1-1-1 Higashi, Tsukuba, 305-8567 Japan
Tel:+81-29-861-3769 Fax:+81-29-861-3765
E-mail:a.suzuki@aist.go.jp

**Total Budget for FY2001-FY2005** 128,412,000Yen (**FY2005**; 21,730,000Yen)

**Key Words** Global warming, Sea-surface temperature, Coral skeleton, Monsoon, Radiocarbon

## 1. Introduction

The ocean and atmosphere in the tropics are major sources of atmospheric water vapor and heat for the high latitude region. The strong ocean-atmosphere coupling results in complex climate systems such as the Asian Monsoon phenomenon from which variability propagates throughout the globe. These phenomena seem to be influenced by the global warming and sea-surface temperature (SST). The tropical monsoon has become a focus for intensive observational and modeling programs. However, these studies lack a long-term temporal perspective, as local instrumental SST data rarely extend beyond the past few decades. We propose a collaborative research program to develop a better understanding of ocean-atmospheric variability in the frequency spectrum of monsoon based on “coral skeletal climatology”. Massive corals can provide high-resolution (monthly and near- weekly) climate and environmental records for the world's shallow-water tropical and subtropical ocean regions. Recent paleoclimatic studies have demonstrated that corals preserve the history of temperature and salinity in the surface ocean for the last several centuries. We examine the ocean-atmospheric variability in the Asian Monsoon region by acquiring a series of coral-based temperature and salinity reconstructions.

## 2. Research Objective and Methods

The purpose of the research is to investigate the relationship between SST increase due to the global warming and Asian Monsoon phenomenon based on coral skeletal climatology. Study area includes the relatively wide area from Ryukyu and Izu-Ogasawara Islands of Japan to Southeast Asia and Indian Peninsula regions. The research will be carried out as a collaborative work between the National Institute of Advanced Industrial Science and Technology (AIST) and the National Institute for Environmental Studies (NIES). Expedition participants will drill *Porites* coral cores containing more than 100-200 year-long records from the Ryukyu Islands, the Philippines, Malaysia, Indonesia, Australia and the adjacent areas (Figure 1). Coral oxygen isotope ratio responds to changes in SST and oxygen isotope ratio of seawater, while skeletal Sr/Ca ratio in corals has been recently shown to record primarily change in SST[1)]. By conducting coupled measurements of coral skeletal oxygen isotope ratio and Sr/Ca ratio, changes in both SST and seawater oxygen isotope ratio can be determined over the period of two to three centuries. Coral $^{14}C$ concentration may provide information of the history of upwelling activities and surface currents in coastal seas as well as the transfer velocity of carbon between the ocean and atmosphere. Coral oxygen isotope ratio and Sr/Ca ratio are analyzed at the AIST, while coral $^{14}C$ contents are measured at the NIES using an AMS facility named NIES-TERRA. We will synthesize the results from all sites by developing a coral multi-proxy approach to improve accuracy for paleotemperature and paleosalinity reconstructions and the data will be used for investigating the relationship between SST increase due to the global warming and Asian Monsoon phenomenon.

During the project, we carried out research on two topics: (1) oxygen isotope measurements on coral cores from the western Pacific and SE Asia regions, (2) high- resolution $^{14}C$ analyses of annually-banded coral skeletons from the Rowley Shoals, Western Australia. We also continued developing the analytical procedures for coral multi-proxy analysis including Sr/Ca, Mg/Ca, U/Ca ratios and $^{14}C$.

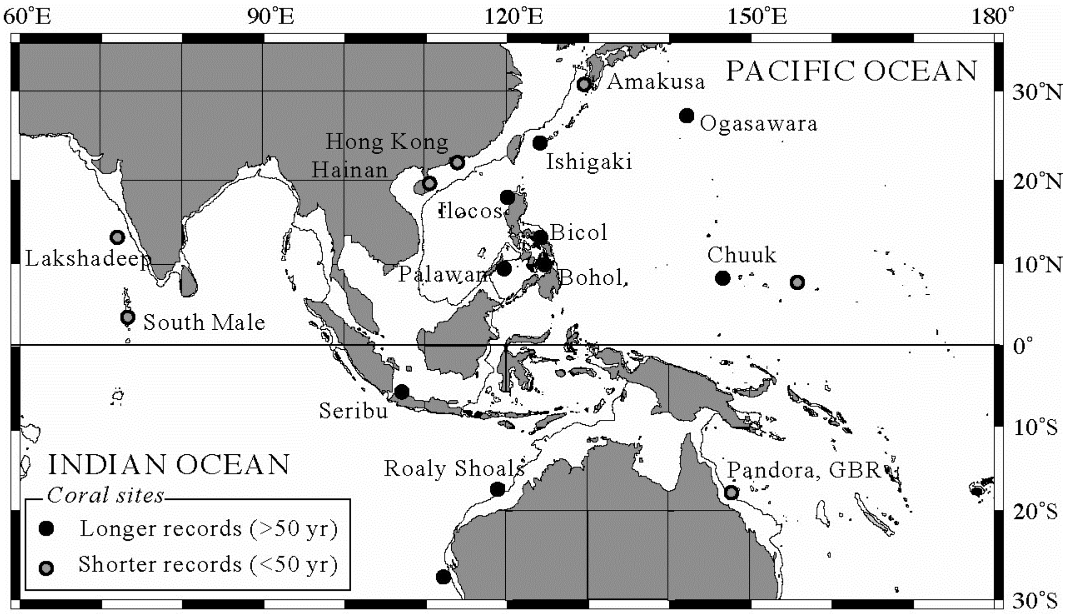

Figure 1 Study sites in the Eastern and Southern Asian Monsoon region.

## 3. Results and Discussion

### (1)Oxygen isotope measurements on coral cores from Western Pacific and SE Asia regions

We conducted isotopic measurements on coral cores collected from Ishigaki Island, Ogasawara (Japan), Bicol (the Philippines), and Chuuk Atoll (Micronesia). Coral cores were sectioned into seven-mm-thick slabs and cleaned with deionized water for X-radiography. The procedure for extracting samples for isotopic microprofiling is described in Gagan et al. (1998)[1)]. A milling machine with a moveable table was used for shaving sequential samples along the growth axis at 400 µm intervals, by using 2-mm diameter drill bit. The powdered sample falls on a weighing paper placed beneath the coral slab mounted on the milling table. Usually, 0.5-1mg of coral powder was collected for the individual increments. Microsampling of coral from Ogasawa was conducted at an interval of 2mm by using a dental drilling machine with a tungsten-carbide bit. Microsamples typically weighing 70-130µg were reacted with 100% $H_3PO_4$ at 90°C in an automated carbonate device (Multiprep, Micromass Co. Ltd.) coupled with a Micromass Optima mass spectrometer at the AIST[1)]. Carbonate samples for other specimens were processed by an automated individual carbonate reaction (Kiel) device attached to a Finnigan-MAT251 mass spectrometer at the Australian National University and University of Bremen. Isotopic data are reported as per mil (‰) deviations relative to V-PDB (Vienna Peedee Belemnite). All mass spectrometers had comparable internal precision. For the Micromass Optima mass spectrometer at the AIST, the internal precision is 0.03‰ and 0.04‰ (1$\sigma$) for $\delta^{13}$C and $\delta^{18}$O, respectively, based on replicate measurements of 23 consecutive samples of the NBS-19 calcite standard.

A century-long coral oxygen isotope record from Ishigaki Island clearly indicates decreasing trend of about 0.2‰, probably corresponding to SST increase observed in the area (Figure 2). Coral record from Bicol, the Philippines, also showed decreasing trend in $\delta^{18}$O and the decreasing rate reached a relative large value of 0.2‰ for recent 30 years. In contrast, Ogasawara coral showed almost stable fluctuation without clear decreasing trend in $\delta^{18}$O in the 20th century.

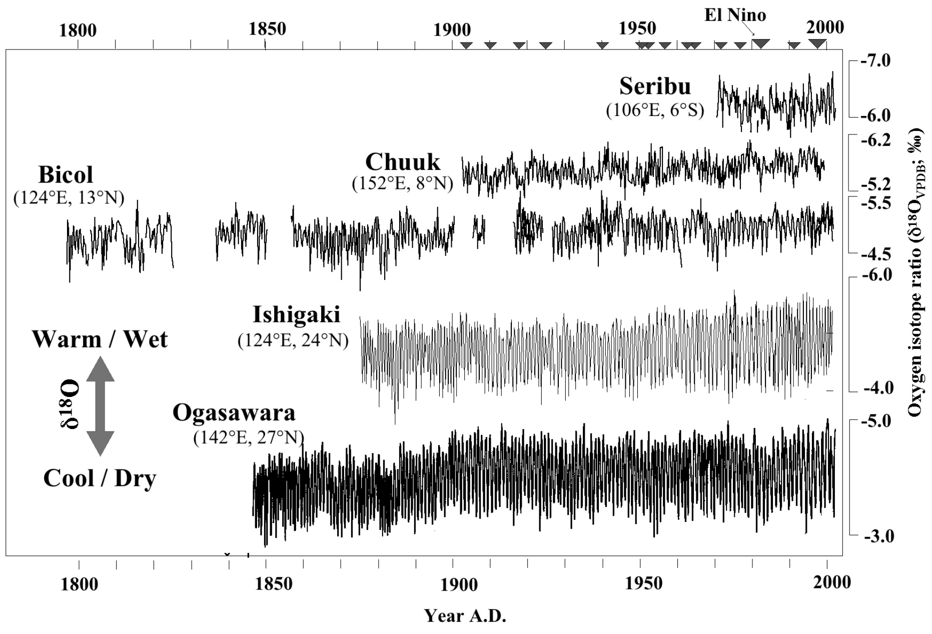


Figure 2 Coral oxygen isotope records from the western Pacific and SE Asia region.

High-resolution $\delta^{18}$O records from annually banded modern *Porites* spp. corals collected in the tropical northwestern Pacific have been used successfully to monitor recent marine climatic events, including the strong El Niño in 1997–98, severe coral bleaching, and a long-term rise in SST (Figure3). In the relatively high-latitude region of the western Pacific (Ishigaki Island, Japan), coral $\delta^{18}$O records are a good proxy for SST because of the limited influence from $\delta^{18}O$-depleted rainfall on the $\delta^{18}O$ of seawater. In contrast, temporal variations in coral $\delta^{18}O$ from the Micronesian islands (Chuuk and Pohnpei) appeared to be affected by both SST and SSS variations. The temporal pattern of a distinct increase in $\delta^{18}O$ followed by compression of the $\delta^{18}O$ curve in Micronesian corals is a useful signal for identifying past El Niño events in long coral records from the region.

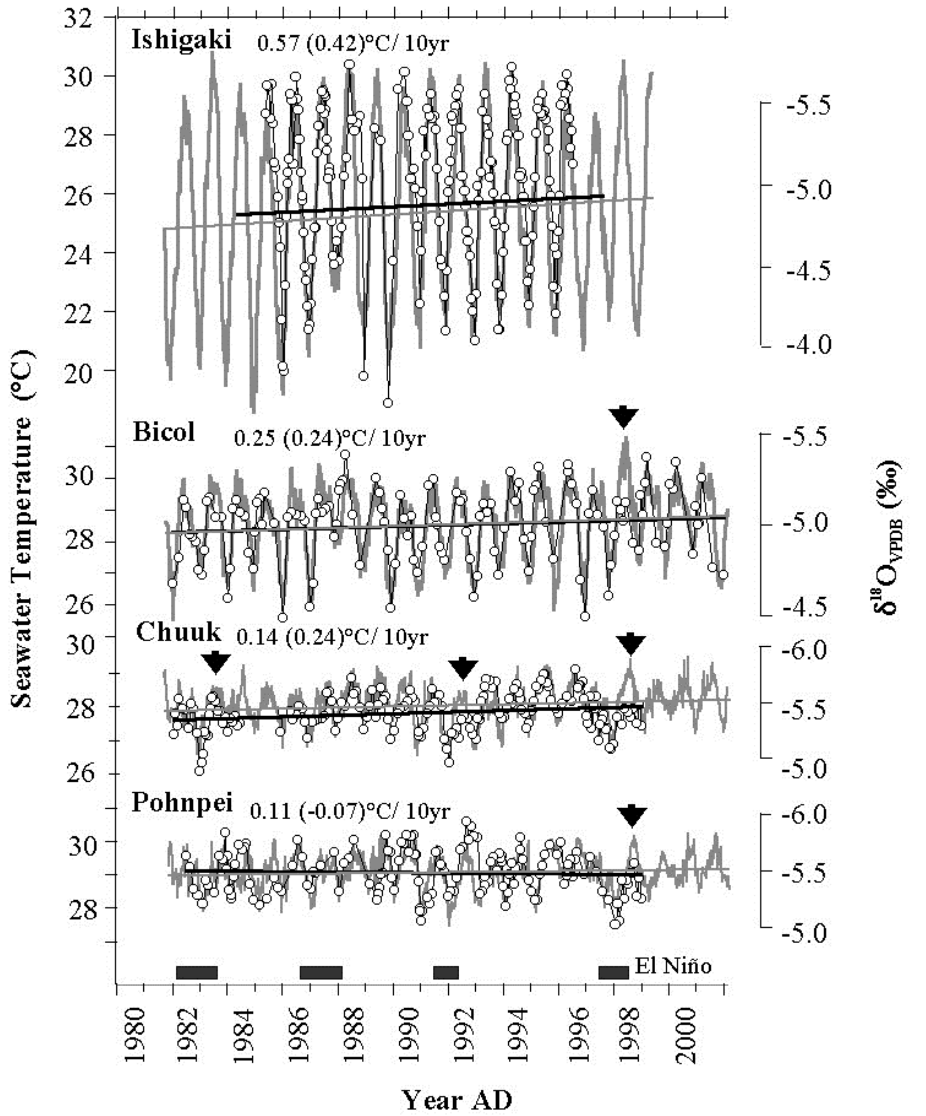


Figure 3 Comparison of instrumental SST (gray curves) and *Porites* coral $\delta^{18}O$ values (curves with circles). Regional weekly SSTs (IGOSS NMC SSTs) are shown. Coral $\delta^{18}O$ curves are related to "apparent" SSTs based on $\delta^{18}O$–SST relations. "Apparent" SSTs derived from the coral $\delta^{18}O$ values include offsets due to changes in seawater $\delta^{18}O$ in each region. The gray and solid lines show simple regressions for instrumental and coral-derived "apparent" SSTs, respectively. Magnitudes of the warming trends between 1981 and 2000 calculated from instrumental SSTs and coral "apparent" SSTs are also shown (the latter in parentheses). Arrows mark times of severe El Niño-related drought in the region. Gray blocks at the bottom represent the periods of El Niño events.

At Ishigaki Island and the Pacific side of the Philippine Islands, a decreasing trend in $\delta^{18}O$ was found even over the relatively short period between 1980 and 2000, which may indicate an SST rise and/or surface-water freshening related to global warming. Any recent global warming/freshening trend recorded by the Micronesian corals may have been masked by the influence of the recent large number of El Niño events, which cause local cooling and drying toward the end of the record. Our results are intriguing enough to warrant further data acquisition and attempts at quantitative time-series analysis. This study also demonstrated that high-resolution coral $\delta^{18}O$ records have potential for studying the climate of the recent and distant past, which may provide partial analogs for the future greenhouse Earth.

(2)High-resolution $^{14}C$ analyses of annually-banded coral skeletons from Asian Monsoon region

In order to prepare hundreds of sample of precise $^{14}C$ analysis from coral cores, we developed a rapid sample preparation system based on an elemental analyzer in FY 2001- 2002. Then, we have also conducted research on the optimization of the system and preparation procedures, and on the evaluation of the performance of the system. Using this system, we have reconstructed the temporal change of radiocarbon contents in coral skeletons (*Porites* sp.) from the Monsoon Pacific region (FY 2003-2004)[2-5]. To investigate the geographical variability of radiocarbon activity in surface water, in FY 2005, we analyzed a series of molluscan shells taken prior to the atomic bomb tests, which disturbed the radiocarbon distribution in not only atmosphere but also DIC in surface water.

The coral samples taken from the Rowley Shoals, Western Australia, indicated that the temporal change of radiocarbon activities in a coral skeleton can be a useful proxy for the regional strength of $CO_2$ exchange rate between ocean and atmosphere, which is valuable indicator to evaluate carbon cycle models. Furthermore, the regional correction value for the apparent radiocarbon age in surface water ($\Delta R$ value) was estimated to be around 400 years in Rowley Shoals' samples prior to atomic bomb tests. This indicated DIC in this region was partially originated from depleted carbon from deep water. To estimate the source of $^{14}C$-deplited water, the radiocarbon contents in surface water was estimated molluscan shells taken from the western Pacific including the Japanese archipelago, Taiwan, SE Asian islands, and Micronesia.

The $\Delta R$ value, the regional correction value for the marine reservoir effect, showed significant variations in this region (Figure 4). The water masses belonging to the subtropical gyre seems to be in equilibrium to atmosphere, while the Micronesian islands showed slightly depleted radiocarbon activities. On the other hand, the water of the subarctic gyre showed significantly lower radiocarbon activity. However, the results from the SE Asia and the Tress Straits do not indicate significant difference from the averaged surface water. The data did not suggest clear influence on radiocarbon depletion at the Rowley Shoals by the water mass in the Pacific. Although the local environment in the shoal could contribute the larger $\Delta R$ value there, the influence by the water masses from the Indian Ocean should be discussed in the future studies. Additional data from the Indian Ocean will suggest the more reliable interpretation.

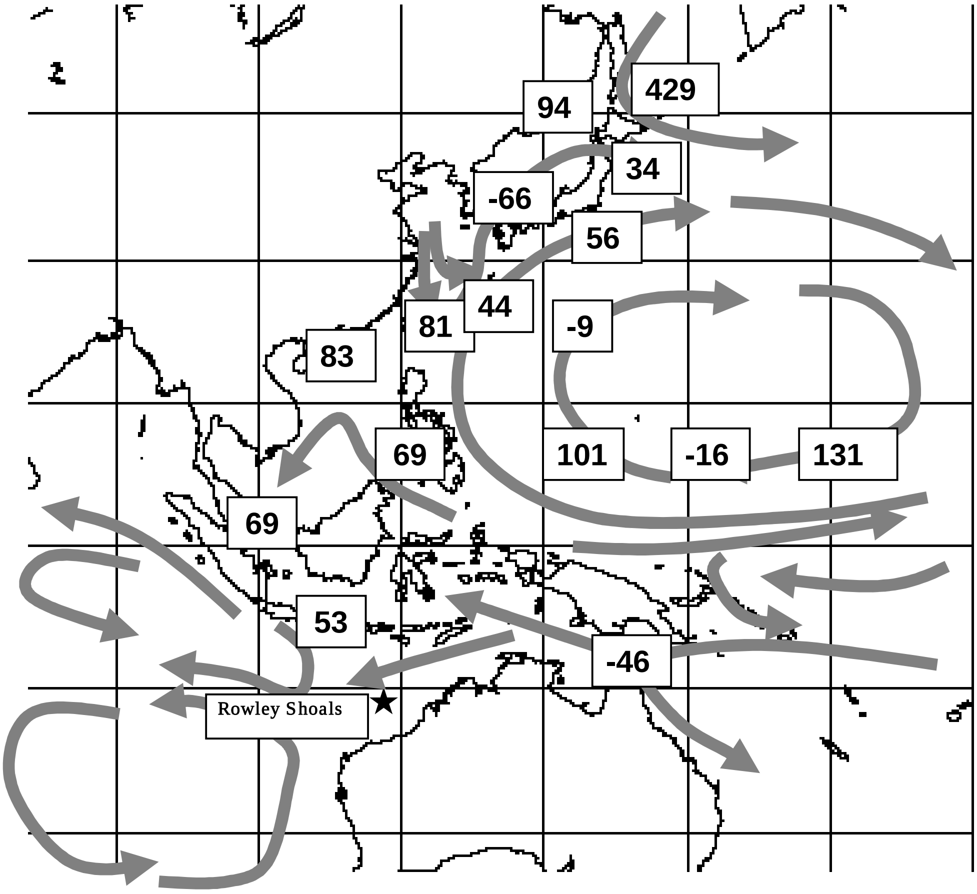


Figure 4 The ΔR values in the Monsoon Pacific estimated by the pre-bomb shells.

References


1) M. K. Gagan, L. K. Ayliffe, D. Hopley, J. A. Cali, G. E. Mortimer, J. Chappell, M. T. McCulloch, and M. J. Head: Temperature and surface-ocean water balance of the mid-Holocene tropical western) Pacific, Science, 279, 1014-1018, (1998)
2) M. Yoneda, Y. Shibata, A. Tanaka, T. Uehiro, M. Morita, M. Uchida, T. Kobayashi, C. Kobayashi, R. Suzuki, K. Miyamoto, B. Hancock, C. Dibden, J. S. Edmonds, AMS 14C measurement and preparative techniques at NIES-TERRA, Nucl. Instr. Meth. B, 223-224, 116-123 (2004)
3) T. Mitsuguchi, H. Kitagawa, E. Matsumoto, Y. Shibata, M. Yoneda, T. Kobayashi: High-resolution 14C analyses of annually-banded coral skeletons from Ishigaki Island, Japan, Nucl. Instr. Meth. B, 223-224, 455-459 (2004)
4) P.X. Dang, T. Mitsuguchi, H. Kitagawa, Y. Shibata, T. Kobayashi, Marine reservoir correction in the south of Vietnam estimated from an annually-banded coral, Radiocarbon 46, 657-660 (2004).
5) M. Morimoto, H. Kitagawa, Y. Shibata, H. Kayanne, Seasonal radiocarbon variation of surface seawater recorded in a coral from Kikai Island, subtropical northwestern Pacific, Radiocarbon, 46, 643-648 (2004).