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Sea-surface hydrographic variations during the past 165,000 years in the southeastern South China Sea (near Palawan Island)

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Abstract

Using Mg/Ca ratios of planktonic foraminifer *Globigerinoides sacculifer* and alkenone unsaturation index of bulk sediments from the deep-sea core MD972142, we reconstructed sea-surface paleotemeratures of the past 165 thousand years for the southeastern South China Sea near the Palawan Island. The paleo-SSTs fluctuated between ~24°C and 29°C through the past two glacial-interglacial cycles with the coldest SSTs of ~24°C at the last glacial maximum. The SSTs during the late Holocene are comparable to the peak values of the marine oxygen isotope stage 5.

To examine the salinity/hydrographic variation, the effects of temperature and ice-volume were subtracted from the $\delta^{18}O$ values of planktonic foraminifer *Globigerinoides sacculifer*. The resultant residual $\delta^{18}O$ profiles indicate that the surface oceans have been fresher than today's for most of the time during the past 165 thousand years. In general, during the low sea-level periods in glacial stages, the corrected $\delta^{18}O$ values tend to deviate from the current value, signifying various degrees of freshening. Contrarily, when the sea-levels were high, the surface waters tend to be as salty as it is today. Nevertheless, at millennial scale, the surface waters were more stratified during the interstadial than in the stadial intervals due to stronger fresh-water input and higher surface temperature..
Keywords: South China Sea, SSTs, Hydrograph, Paleotemperature.

Introduction

The tropical oceans play an important role in controlling the Earth's climate, as the distribution of warm tropical waters largely affects the amount of heat and moisture contributed to the atmosphere. Therefore, reconstruction of past SSTs of tropical oceans is essential for understanding the past climate changes. Foraminiferal Mg/Ca ratio, faunal transfer functions and unsaturated alkenone ($U^{k'}_{37}$) have been the most widely used proxies. Among them, foraminiferal Mg/Ca ratio offers a major advantage over existing SST proxies because it can be measured from the same sample set or specimens as $\delta^{18}O$ does, and therefore, providing a means of estimating simultaneously temperature and oxygen isotopic composition of the seawater. This allows for a direct comparison between the Mg/Ca-derived SST and the $\delta^{18}O$ of sea water without the potential complication introduced by subtracting temperature effect imprinted during different seasons, at different depths of water column (Mashiotta et al., 1999). This paper reports the Mg/Ca-derived SSTs and $\delta^{18}O$ of seawater (reflecting the balance between precipitation and evaporation) for the past 165,000 years of the southeastern South China Sea. For an additional check, we also derived SSTs using unsaturated alkenone ($U^{k'}_{37}$) from bulk sediments and calculated the $\delta^{18}O$ of seawater. Both methods yielded consistent patterns of hydrological (temperature and salinity) variations through the last 170,000 years.

The South China Sea (SCS; Figure 1) is the largest marginal sea in the tropical western Pacific and overlaps a part of the Western Pacific Warm Pool (WPWP) (Yan et al., 1992; Miao et al., 1994). Its critical location between the East Asian landmass and the western Pacific makes this marginal sea very sensitive to climate changes especially to the monsoon system. The surface water circulation in SCS is mainly driven by the annually reversing monsoon winds that create large volumetric changes in surface water flow (Wyrtki, 1961). One of the most distinctive characteristics of the monsoon climate is the alternating wet and dry seasons. In wet seasons, warm and moist winds blow inland from the oceans, bringing precipitation over vast areas of Asia, Africa and Australia and adjacent marine realm. In contrast, during dry seasons, the wind reverses direction, bringing cold and dry air seaward from the interiors of the winter continents. In each season, there are two principal rainfall maxima: one over Africa, the other, the larger one, over the Southeast Asia and Australia (Webster, 1987). In either case, the southern South China Sea receives large quantity of fresh water from river run-off and precipitation. The salt budget of the southern South China Sea therefore is heavily influenced by the precipitation brought about by monsoons. The other factor that controls the salt budget is the exchange efficiency of the basin water with the open-ocean waters, either from the Indian Ocean or the Pacific. It is expected that during the last glacial maximum at about 20,000 years ago, when sea levels dropped by 120 to 140 m

(Fairbanks, 1989; Lambeck et al., 2002), the southern South China Sea would become a semi-enclosed inner sea because of the shoaling of most of the seawater passages connecting to open oceans, the salinity in this region would reflect more faithfully the influence of precipitation, and hence a good gauge of the strength of monsoons during the glacial periods.

In this study, based upon high-resolution records derived from a deep-sea core adjacent to the Palawan Island, we attempt to examine the hydrological changes of the southeastern South China Sea over the past 165 kyrs, roughly covering the last two glacial-interglacial cycles. During this period, the sea level rose and dropped as polar ice-sheets waxed and waned, sea-surface temperatures (SSTs) fluctuated and monsoon intensity varied concomitantly. The interplay between sea-level, sea-surface temperature and monsoon intensity (which affects precipitation) must have resulted in a dynamic change of salt budget; and hence the sea-surface salinity, which, in turn, may exert also influence on density of seawater and cause variation in circulation and ventilation of the South China Sea.

Materials and Analytical Methods

Materials

Planktonic foraminifera *Globigerinoides sacculifer* from the top 11 m of Core MD972142 (12°41.33'N, 119°27.90'E, 1557m water depth, Fig. 1) was selected for the Mg/Ca and $\delta^{18}O$ analyses. This core was recovered from the southeastern region of SCS during the IMAGES-III-IPHIS-Leg II cruise. Because the water depth of this site is well above the calcite lysocline, the calcareous foraminifera in this core are well preserved. In addition, surface dwelling planktic forminifera *G. ruber* and thermocline dwellers, *Neogloboquadrina dutertrei*, were also analyzed. The longer $\delta^{18}O$ record of *Globigerinoides ruber* of the same core in its whole length has been reported by Wei et al (2000, 2003).

Foraminifera were obtained by washing and sieving (>63 μm) bulk sediments several times in distilled deionized water to remove clays and fines. The dried sediments were then sieved into different size fractions, and specimens of *G. sacculifer* were handpicked from the 300-355 μm size fraction. After the picking process, all operations were performed using trace-metal cleaning techniques in a HEPA laminar flow hood to avoid contamination. The trace-metal cleaning techniques used were modifications of previously developed cleaning methods (Shen, 1996). Briefly, 0.5-1 mg of foraminiferal tests were gently crushed and cleaned. The samples were first subjected to an oxidizing solution followed by a reducing solution, and then rinsed

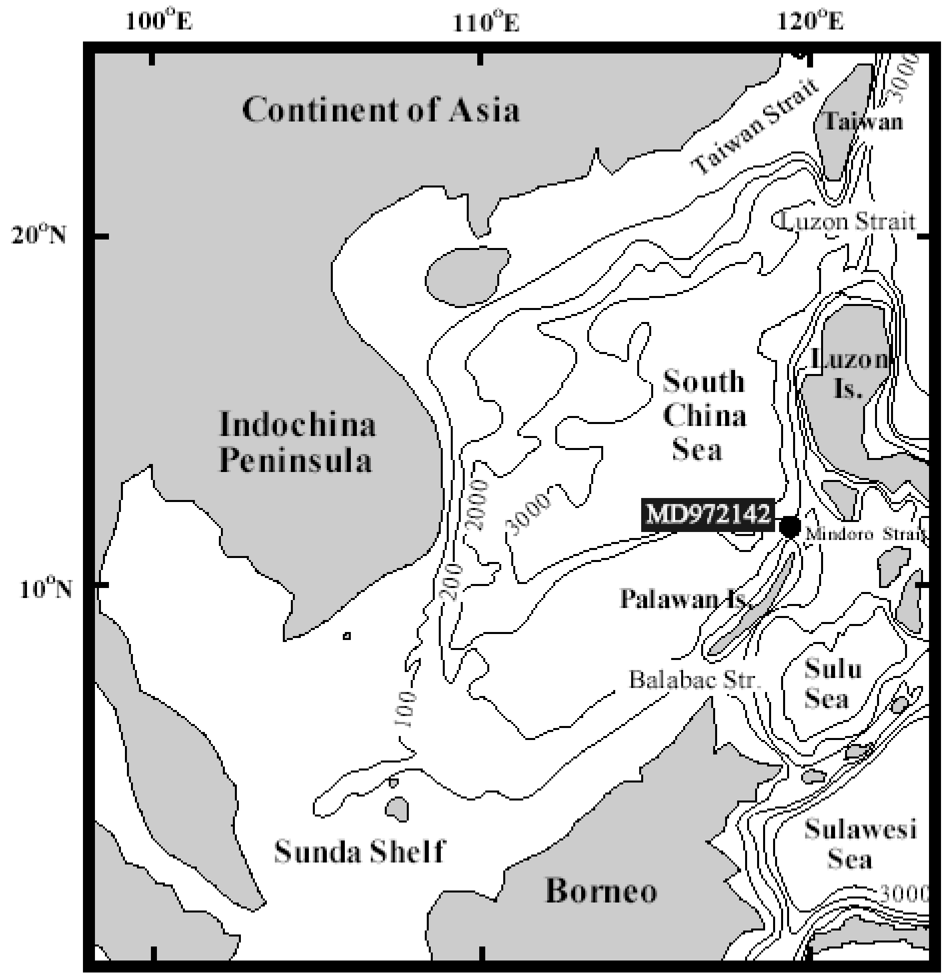


Figure 1. Bathymetric map of the South China Sea showing the location of Core MD972142 and other cores mentioned in this study.

three times with distilled deionized water using ultrasonication at the beginning and between all steps. Subsequently, the cleaned samples were dissolved and diluted in HNO_3 for Mg and Ca analyses. Mg and Ca were measured using a Perkin Elmer flame atomic absorption spectrophotometer. The measurement precision was <± 3%. *G. sacculifer* from the same size fraction was also picked for $\delta^{18}O$ analysis using a Finnigan MAT Delta^{Plus} mass spectrometer with Kiel Device housed in the Institute of Geosciences, National Taiwan University. Also analyzed were specimens of *G. ruber* from the 300-355 μm size fraction and *N. dutertrei* from the 300-355 μm size fraction. All the $\delta^{18}O$ values were converted to Pee Dee Belemnite (PDB) scale using NBS-19, an international standard, the precision of $\delta^{18}O$ measurement was ±0.08$^{o}/_{oo}$. To independently check the validity of the Mg/Ca ratios measured by atomic absorption spectrometer, some left-over *G. sacculifer* specimens in the previously washed samples were also analyzed using a newly installed ICP-MS at the Dept. of Geosciences, National Taiwan University. The results are consistent with each other in the given range of analytical uncertainty and intra-sample variability (Fig.2)

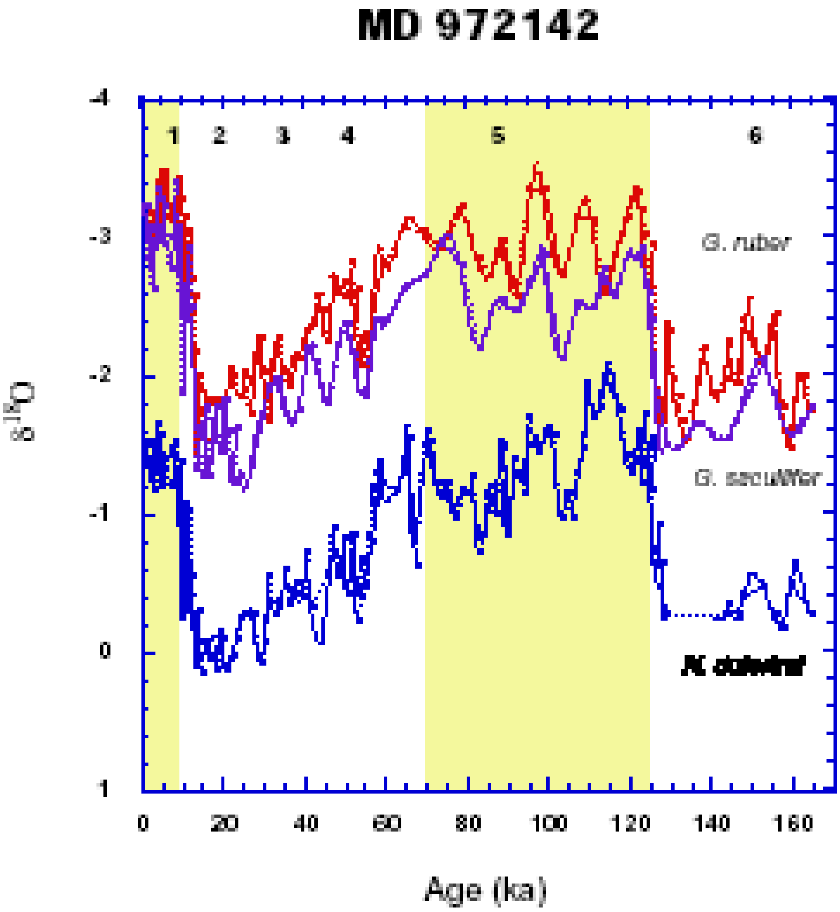


Figure 2 Correlation between the oxygen isotope stratigraphy of *Globigerinoides sacculifer* (this study) and *Globigerinoides ruber* (Wei et al., 2000) in Core MD972142, and the Low-latitude stack (Bassinot et al., 1994).

We also reconstructed the sea-surface temperatures using $U^{k'}_{37}$ measured from the bulk sediments.

Sea-surface Paleo-temperature Reconstruction

For temperature calibration, we used the species-specific Mg/Ca SST calibration curve for *G. sacculifer* (Anand et al., 2003). An exponential fit was adopted:

$T^{o}C = 11.111 * \ln((Mg/Ca)/0.347)$ ……………………..…………….(1)

The reconstruction of paeleotemperatures from $U_{37}^{k'}$ index was based upon Pelejero and Grimalt (1997):

$U_{37}^{k'} = 0.031T + 0.092$ …………………………………………………(2)

Where $U_{37}^{k'} = [C_{37:2}] / ([C_{37:2}] + [C_{37:3}])$ (Prahl and Wakeham, 1987).

The calculation of $\delta\ ^{18}O_{seawater}$ at the PDB scale was based upon the equation proposed by Mulitza et al (2003):

$T^{o}C = 14.91 - 4.35(\delta^{18}O_{C} - \delta^{18}O_{w})$ ………………………………………(3)

A conversion between PDB and SMOW scales was made:

$\delta^{18}O_{w\text{-}SMOW} = \delta^{18}O_{C\text{-}PDB} + 0.27$……………………………………………(4)

Alternatively, the $\delta\ ^{18}O_{seawater}$ was also calculated using the equation suggested by Spero et al (2003):

$T^{o}C = 12.0 - 5.67(\delta^{18}O_{C} - \delta^{18}O_{w})$ ……………………………………………(5)

Calculation of Oxygen Isotopic Compositions of Surface Seawater

The difference in oxygen isotopic composition between two foraminiferal samples ($\Delta^{18}O_{f}$) can be attributed to quite a few factors, including temperature, ice-volume, precipitation, evaporation, differential dissolution of foraminiferal tests and vital effects of living planktic foraminifera (Berger, 1979). Such multiple effects on the $\Delta^{18}O_{f}$ can be expressed in the following equation:

$\Delta^{18}O_{f} = \Delta^{18}O_{temp.} + \Delta^{18}O_{ice} + \Delta^{18}O_{precip.\,-\,evap.} + \Delta^{18}O_{dissol.} + \Delta^{18}O_{vital}$ ….(6)

This study aims to examine the hydrological variation through the past two interglacial-glacial cycles (the past 165 kyrs), particularly the effects of precipitation and evaporation. Therefore, the $\Delta^{18}O_{precip.\,-\,evap}$ term in eq. 6 will be regarded as a surrogate, and all other terms be separated. In calculating the $\delta^{18}O$ w using equation 4 we have removed only the temperature effect ($\Delta^{18}O_{temp.}$). Because we have confined the size fraction of analyzed *G. sacculifer* tests within a relatively narrow range (300-355μm), the vital effects can be ignored. Attributing to the shallow water depth of the studied core, the picked foraminiferal tests were also well-preserved; consequently, the effect caused by differential dissolution can also be ruled out. To extract the $\Delta^{18}O_{precip.\,-\,evap}$, the only term needed to be removed is the global ice-volume effect ($\Delta^{18}O_{ice}$). The ice-volume effect was calculated by converting the sea level variation constructed by Lea et al (2002) into equivalent $\delta^{18}O$ change in sea-water. Each meter change in sea level was assumed to cause a change of 0.01 $^{o}/_{oo}$ in ocean water $\delta^{18}O$ (Lea et al., 2002).

Results and Discussion

<u>Chronological Framework</u>

The age model was constructed mainly by correlating the $\delta^{18}O$ profiles of *G. sacculifer* and *G. dutertrei* (Fig. 3) to the low-latitude oxygen isotopic stack of Bassinot (1994). The last appearance datum of pinked *G. ruber* was used to independently mark the Termination II. The age of the top section of the core is constrained by five carbon-14 dated samples (for detail, see Wei et al., 2003). The studied section spans the last 164.3 kyrs, extending back to the upper part of the marine oxygen isotope stage (MIS) 6. The average sedimentation rate for the studied section (top 1096cm) is about 6.6 cm/kyrs while the temporal resolution of this study is about 2 kyrs in average.

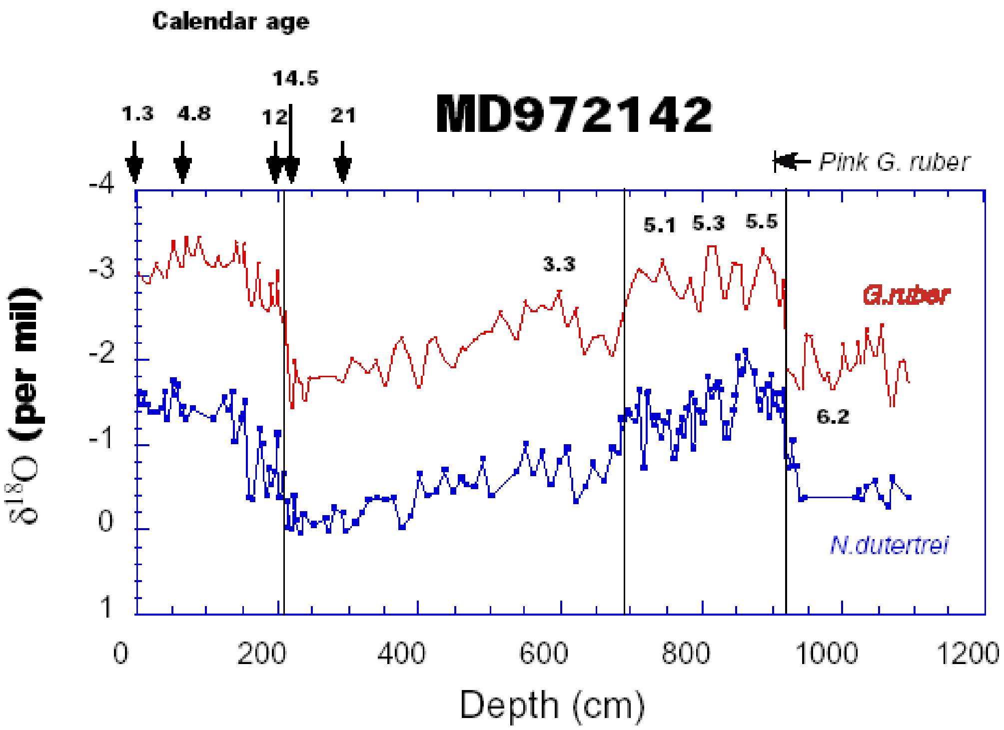
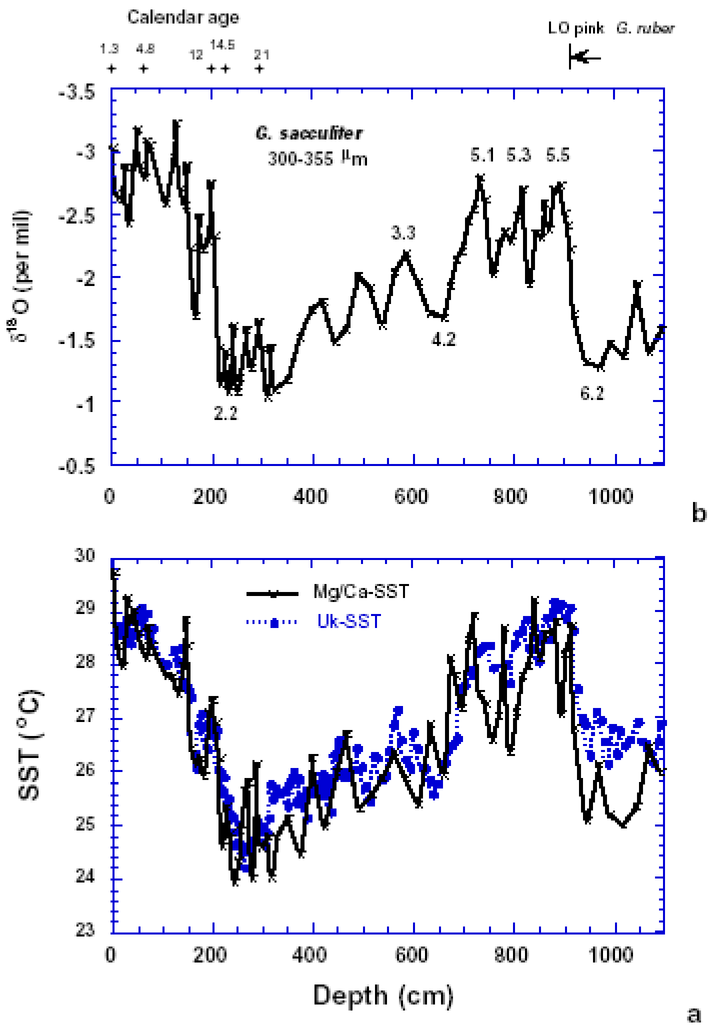


Figure 3 (a) Planktonic $\delta^{18}O$ stratigraphy derived from *G.sacculifer* in Core MD972142; (b) Mg/Ca SST record of Core MD972142, corresponding Mg/Ca ratio was shown on the right axis; (c) Sea-surface salinity (SSS) record calculated from $\delta^{18}O$ of *G.sacculifer* and Mg/Ca SST after subtracting the global ice volume effect. The modern SSS is taken as $33.4^{o}/_{oo}$ (Levitus and Boyer, 1994).

Sea-surface Temperatures of the Southeastern South China Sea

The Mg/Ca ratios fluctuate between ~3.0 and ~5.0 mmol/mol, corresponding to a temperature range of ~23 to 28.4°C (Figure 4a). Clear glacial-interglacial oscillations in Mg/Ca are observed. Comparison of the Mg/Ca record and the $\delta^{18}O$ record of the same core (Figure 4b) indicates that oscillations in both records match fairly well, with a r = -0.83. The Mg/Ca ratios of *G. sacculifer* are considered to record the annual mean SST (Hastings et al., 1998). In Core MD972142, this is supported by the core top Mg/Ca SST of ~28.4°C, which corresponds well to the observed sea surface temperature in this region (summer SST: >29°C, winter SST: ~27°C; Levitus and Boyer, 1994). Further support is found by comparing both the Mg/Ca SST record and the annual mean SST record derived from foraminiferal assemblages (Yu et al., 2000). The reconstructed paleo-SST record of MD972142 reveals an average Holocene SST of ~27.0°C and a LGM SST of ~23°C, showing a ~4°C glacial-interglacial SST warming. Our LGM-Holocene SST difference is in good consistence with the estimations made by Miao et al., (1994) in the near-by sites by planktic foraminiferal fauna canges. The calculated annual mean SSTs in the LGM range from 24.2°C to 25.3°C, and the annual mean SSTs in Holocene range between ~28-29°C, leading to a LGM-Holocene warming of ~3-4.5°C. Similar LGM-Holocene warming amplitude was also reported in the western part of SCS and a core from west of Luzon (Wang et al., 1999). On the other hand, our result is larger than the ~2.8°C SST change estimated for southern SCS using $U^{k'}_{37}$ (Pelejero et al., 1999).

On-site comparison of the Mg/Ca-derived SSTs with the $U^{k'}_{37}$-derived shows that there is a good agreement for the topmost 600 cm, but the two records differ from each other in the lower part of the record (Fig. 4a). A closer examination reveals that the Mg/Ca-derived SSTs tend to yield colder temperatures during the glacial or stadial intervals. The discrepancy in the lower section suggests that the Mg/Ca derived SST tends to underestimate paleo-temperature due to dissolution. It is because Mg-enriched part of the foraminiferal tests is more susceptible to dissolution, any differential dissolution would cause to a lower Mg/Ca ratio preserved in the robust tests and lead to a lower estimation of the SST. It has been reported that the dissolution effect becomes stronger during the glacial period in the South China Sea (Chen et al., 1999, and other Refs.), probably due to stronger disgenesis seen in the glacial sections in which the biogenic calcite was diluted by terrigenous input (Chen et al., 1999). However, the mg/Ca-derived SSTs for the MIS6 are comparable to that for the LGM, suggesting a consistent result, whereas the –derived SSTs show big discrepancy between the



LGM and the MIS6. (Fig. 4a),

On the other hand, this temperature offset between the Mg-SST and $U^{k'}_{37}$ might be explained by the difference in the time of signal generation and the depth habitats of the $U^{k'}_{37}$ signal producing coccolithophorids and foraminifera during the glacial and statdial periods. We envision that during the glacial and stadial periods, the coccolithophorid flora in the South China Sea would be dominated by *Gephyrocapsa oceanica* (because *E. huxleyi* became dominated only after 470 ka, Ref. Y) because of its inner sea setting; and the $U_{37}^{k'}$ values generated by *G. ocenica* tend to be higher (due to its lower abundance of $C_{37:3}$, Ref. Z), therefore the SSTs were over-estimated by eq. 2 for the older sections.

The SSTs during oxygen isotope stage 5 are comparable to those in Holocene, while the SSTs during stage 6 are slightly warmer than those in stage 2. Notably, the SSTs in substages 5.1 and 5.3 were as high as those in substage 5.5, despite the cut off of warm water inflow from Indian Ocean through Sunda Shelf which might be caused by a sea level lowering of ~20-60m (Shackleton, 1987; Chappell et al., 1996; Lea et al., 2002). Furthermore, the consistent high temperatures of the substages 5.1, 5.3 and 5.5 (~27.5-28^{o}C) are consistent with the similar high δ^{18}O values (Fig. 4b). Such a δ^{18}O profile of MIS5 at Site MD972142 differs remarkably from the δ^{18}O profile in the SPECMAP stack which shows cascading steps from substages 5.5 to 5.1. This pattern has also been observed from other cores in southern SCS (Lee et al., 1999; Pelejero et al., 1999). Both the Mg/Ca SST record and fauna assemblages-derived SST record (Yu et al., 2000) show consistent, comparable high SSTs during substages 5.1, 5.3 and 5.5, implying the warm pool of the western Pacific extended persistently to this region during substages 5.1, 5.3 and 5.5.

The Mg/Ca SST in Core MD972142 shows a ~1.4^{o}C cooling at about 10-11ka which is associated with a ~0.7$^{o}/_{oo}$ increase in the oxygen isotope record. This short-lived cooling event corresponds to the Younger-Dryas (YD) event originally documented in the high-latitudes in and around the Atlantic Ocean (e.g. Ruddiman and McIntyre, 1981; Dansgaard et al., 1989). This event was initially thought to occur at the high latitudes, however, it has now been established that the Younger Dryas event is also found in the tropical regions based upon planktic foraminiferal fauna changes (e.g. Linsley and Thunell, 1990). Wei et al. (1998) reported a temperature drop by ~1^{o}C in the northeast SCS based upon foraminifera-derived SST and $U^{k'}_{37}$ SST. Wang et al. (1999) reported also the occurrence of Younger Dryas event in Core 17940 and Core 17927, which showed synchronous cooling signals in SST and δ^{18}O records. As augmented by our Mg/Ca-derived SST profile for site MD972142, the occurrence of the Younger Dryas in SCS confirms that this event is not only characteristic in high-latitude records, but also manifested in the tropical regions as a global cooling event.

Oxygen Isotopic Composition of Surface Sea Water During the past 165,000 Years

The oxygen isotopic compositions of sea water during the past 165,000 years (lower half of Fig. 5a) were calculated by subtracting temperature effect (Fig. 5b) from the δ^{18}O of planktic foraminifera *G. sacculifer* (upper half of Fig. 5a). The global ice-volume effect is shown in Fig. 5c, and the ice-volume corrected δ^{18}Ow is shown in Fig. 5d. As mentioned in the methodology section, such a ice-volume corrected δ^{18}Ow curve can be also alternatively calculated using –derived SST using equation proposed by either Mulitza et al (2003) or Spero et al (2003), we did all the combinations and result in four estimates of $\delta^{18}O_w$ for the past 165,000 years (Fig. 6). Those four curves are basically similar to each other. For the following discussion, we chose the curve as a representative derived from Mg/Ca-SST and Multiza et al (2003) equation.

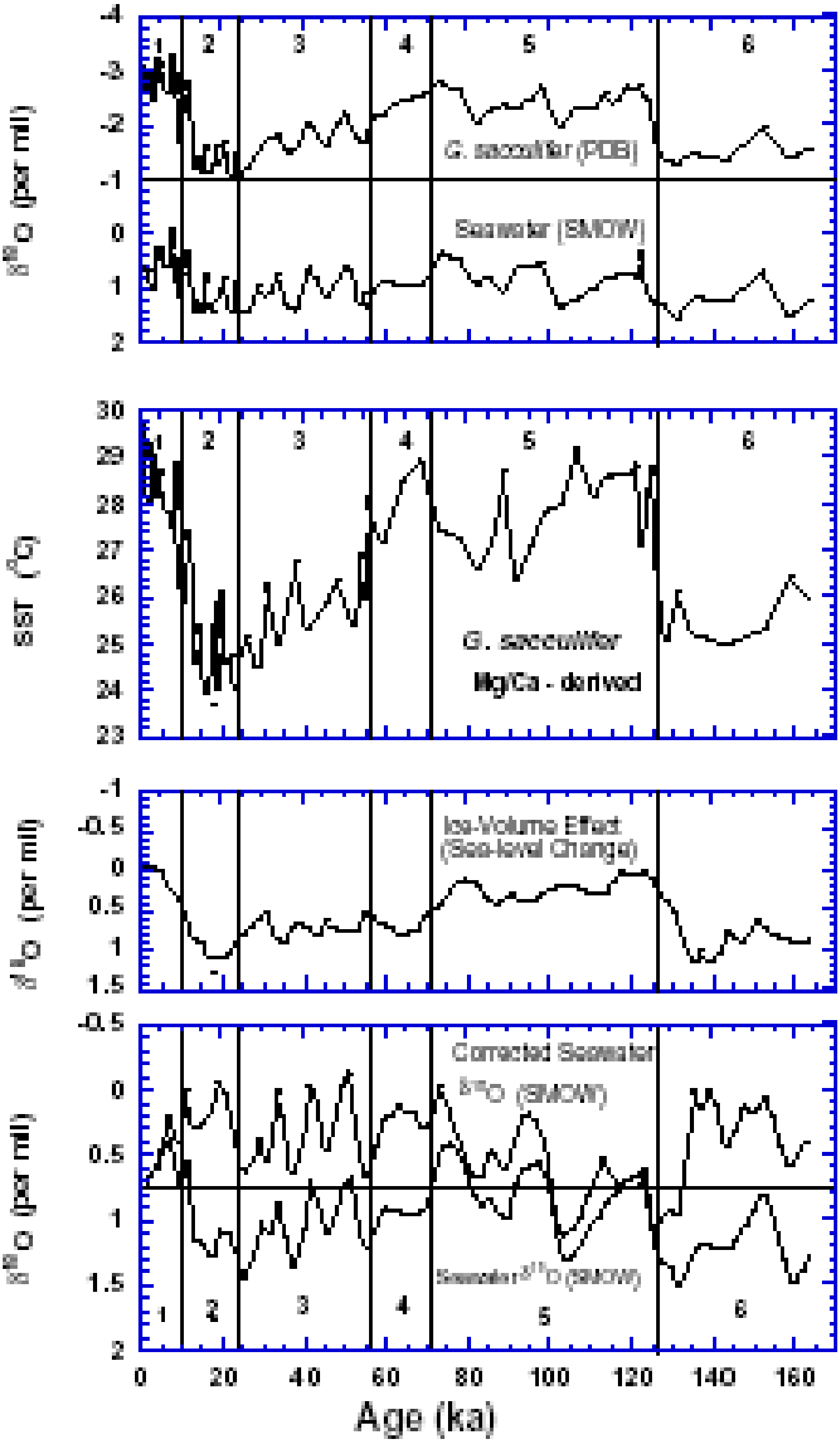


Fig5_142 170k mgca 18O

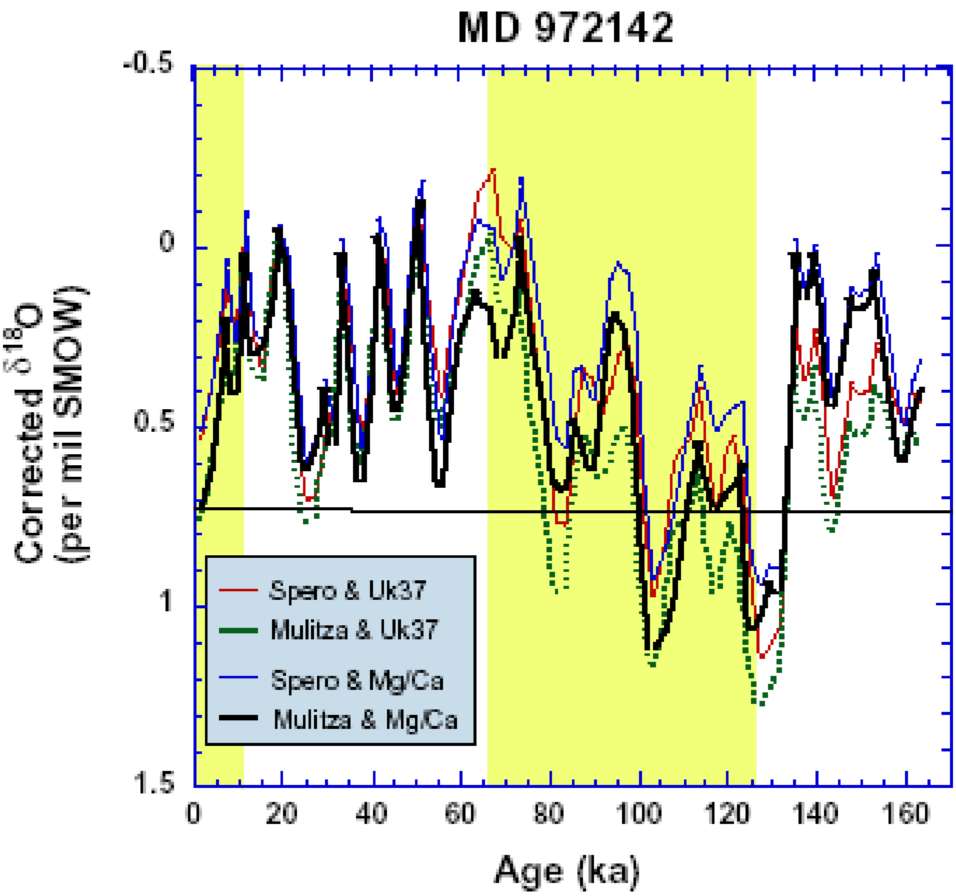


Fig6_142 corrected 18Os age

Several factors have contributed to the variation in this "residual" curve, including fresh-water input from rivers and meteoritic precipitation, salt-water input from open-ocean as well as local evaporation. Generally speaking, this curve can be viewed as a surrogate of salinity variation of the past 165 kyrs. However, the amount effect on precipitation during summer monsoon in this area can be amount to -1.4 $^{o}/_{oo}$ per 100 mm/month increase (Wei et al., 2003), and therefore, part of the $\delta^{18}O_w$ variation should be ascribed to precipitation intensity of summer monsoons (Wei et al., 2003). On the other hand, the changing efficacies of water exchange between the South China Sea and the open ocean (Indian and Pacific) would also play a significant role in regulating the local $\delta^{18}O_w$ values. For the sake of simplicity, the "residual" values of $\delta^{18}O_{w\text{-}smow}$ shown in Fig. 5d is considered as a proxy of salinity in the following discussion.

The ice-corrected δ^{18}Ow-smow values at Site MD972142 range from approximately -0.1 to 1.2$^{o}/_{oo}$ (Figure 5d). Most of such residual values during the past 165 kyrs are lighter than the core-top value (~0.7$^{o}/_{oo}$) except for intervals of 125-130 ka and 100-110 ka, corresponding roughly to Termination II and MIS 5.4 (Fig. 5). Both time intervals are marked by low SSTs. Otherwise, no obvious systematic glacial-interglacial variations are observed. The overall 'sea-surface salinity (SSS)" fluctuation at Site MD972142 is different from those found in the open ocean, which shows systematically high salinity values during glacial periods and lower salinity values during interglacial time (e.g. Rostek et al., 1993). The "SSS" fluctuation in our result is more or less similar to those calculated in Core 17954 (Wang et al., 1999) from northwestern part of SCS, suggesting a different scenario in the record of SCS compared to the open ocean.

The SSSs are particularly low in substage 6.1 and 6.3 with a minimum $\delta^{18}O_w$ value of -0.1$^{o}/_{oo}$. Low SSSs are also found during substages 5.3, 5.1 and during stage 3, stage 2 and the early Holocene. It is interesting to note that the SSSs during substage 5.5 are higher than those during substages 5.3 and 5.1 (Fig. 5d), probably reflecting a better efficacy of water exchange with the open ocean owing to higher sea-level. The higher SSSs during substage 5.5, in fact, represent the signals of saltier water from the open ocean at high sea level stand. In comparison, during substages 5.3 and 5.1, as the sea level dropped and the SCS was semi-isolated, amplification of local environment changes was recorded, resulting in lower SSSs. For termination II and substage 5.4 which show higher SSSs than today, again, the high salinity values during termination II and substage 5.4 may reflect increased evaporation and/or decreased precipitation during a time when water-exchange with the open oceans was restricted.

The salinity variations in Core MD972142 are closely related to the changes in local evaporation and freshwater input in the southeastern SCS. Because the location of Site MD972142 is quite distant from the major rivers of the Indochina Peninsula, the riverine freshwater input is less significant to the salinity variations at this site. We consider that the evaporation-precipitation (E-P) balance and amount effect of precipitation largely controls the $\delta^{18}O_w$ variations at this site, especially during the low sea-level periods. As shown by modern monsoon studies, the precipitation in this area is mainly brought by the southwest monsoon and the highest precipitation rate is obtained in August (from web site of Goddard Space Flight Center, NASA; http://dao.gsfc.nasa.gov/). Hence, the δ^{18}Ow variation during the glacial period is indicative of summer monsoon intensity that strongly controlled the precipitation in this area.

On the other hand, at high sea level stand, when the SCS is connected to the open ocean, the $\delta^{18}O_w$ in SCS has been influenced by saltier water inflow from the Pacific and Indian Oceans. The local precipitation-evaporation changes might be obscured and would not accurately register the salinity variation caused by monsoon precipitation. In contrast, during glacial periods or any sea level drop exceeding 40m, such as from substage 5.4 until the beginning of Holocene (Shackleton, 1987; Chappell et al., 1996; Lea et al., 2002), the Sunda Shelf was exposed and the water inflow to southern SCS was cut off. The only connection to the open ocean is through Luzon Strait in northeastern SCS and resulting in semi-isolated environment for the SCS. The SCS was then under a stronger influence of local hydrological and precipitation conditions. Under such a semi-isolated condition, with the size reduction of sea surface and the SST decline, the evaporation rate was lower and the vapor supply from sea surface was reduced. According to P. Wang (1999), during the LGM when the SSTs in SCS were 2-5^{o}C cooler than today, the evaporation rate was assumed to be reduced by 10-25% due to the SST decrease. This will strongly affects the E-P balance and reflects in the local salinity variation. And this might be the case for the salinity lows seen in the δ^{18}Ow record of Core MD972142, especially during stages 2, 3, and 6. However, those salinity lows may be signals of the increased water discharge from the Mekong River and Molengraaff River in the southern part of SCS. Result from pollen studies revealed that during the last glaciation, the exposed Sunda Shelf experienced a humid climate under the enhanced Winter Monsoon (Sun et al., 2000). The freshwater discharged to the southern SCS might then be driven to the northern part by surface water circulation and affected the $\delta^{18}O_w$ values there. Limited to the few SSS records in SCS, the $\delta^{18}O_w$ variations in this region are not yet fully understood. Other independent proxies for monsoon intensity or monsoon moisture are needed to further interpret the monsoon history in the past.

Conclusions

Foraminiferal Mg/Ca- and $U^{k'}_{37}$ –derived estimations of sea-surface temperatures at Site MD972142 show clear glacial-interglacial variation, which corresponds well with oxygen isotope record. The calculated core-top Mg/Ca SST is close to the modern observed SST in this region and reveals compellingly its utility for paleo-temperature reconstruction. The LGM-Holocene SST difference of ~4^{o}C is quite close to the result from faunal-derived SST records, and also matches fairly well with the $U^{K'}_{37}$, faunal-derived SST results from the same core and other previous results in the SCS. The SST and $\delta^{18}O_f$ values at substages 5.1, 5.3 and 5.5 are comparable to those in Holocene, indicating a warmer condition and/or lower salinity in the southeastern part of SCS, and confirming the western extent of the Western Pacific Warm Pool throughout stage 5. The Younger Dryas event, which is a characteristic feature in high-latitude climate records, is also registered in both the $\delta^{18}O$ and Mg/Ca SST records at ~11ka.

The calculated $\delta^{18}O_w$ of core MD972142 are mostly lower than the modern value for the past 165 kyrs. During glacial periods or any sea level lowering which exceeds 40m, the SCS was more isolated and was very sensitive to the influence of local hydrological and precipitation conditions. The salinity variations have been mainly controlled by the evaporation-precipitation (E-P) balance in this region, and thus serve as a sensitive climate indicator. Consequently, the variations in sea surface $\delta^{18}O_w$ were sensitive to reflect the regional evaporation and precipitation changes related to the East Asian monsoon system. The salinity lows during glacial periods might be caused by low evaporation rate due to SST decrease and/or the mixing of less saline water from the southern SCS. On the other hand, the heavier values of $\delta^{18}O_w$ during the high sea-level stands reflect more or less situations analogous to today, namely, good connection with open-ocean and similar hydrological regime.

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