The South China Sea mixed layer depth changes in response to the East Asian Monsoon since the Last Glacial Maximum: A planktonic foraminifera based reconstruction

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Introduction

The oceanographic patterns of the South China Sea (SCS) (Figure 1) are substantially affected by the East Asian Monsoon (EAM), an atmospheric feature of global influence[1]. The planktonic foraminifera (PF) faunal assemblages are expected to respond this interaction once its composition is determined by environmental conditions[2]. Here we investigated which environmental variable may have acted as a primary controlling factor of the PF fauna over the last 20 ka in order to investigate the paleoceanographic and paleoclimatological patterns evolution of the SCS and the EAM during the Late Quaternary.

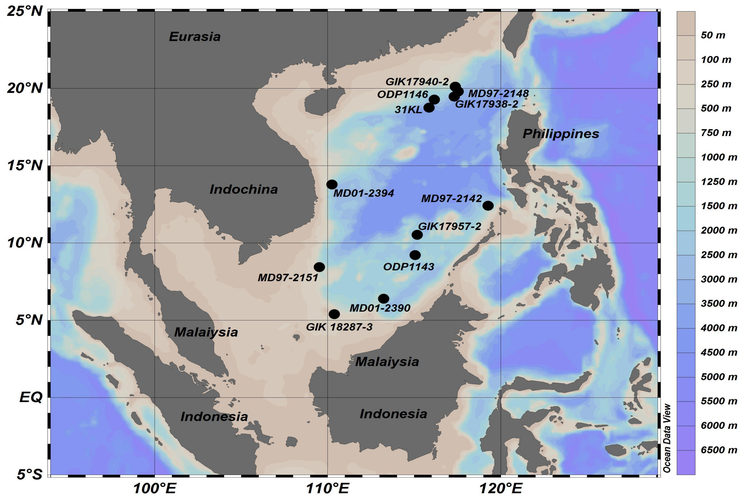

Figure 1. Map of the South China Sea, East Asian, and the locations of the investigated cores in this study

Data and Chronology

We compiled a dataset composed of 12 PF published census records (>150 µm) from cores retrieved from the SCS. The ages were obtained from the published records based on $\delta^{18}O$ stratigraphy or ^{14}C dating (which were calibrated to calendar years with Calib 7.1) (Table 1).

Table 1. Core sites of planktonic foraminifera assemblages records from the SCS. (1) ^{14}C dating; (2) $\delta^{18}O$.

Core ID	Lat (°N)	Long (°W)	Water depth (m)	Time interval (ka BP)	Number of points	References
31-KL	18,75	115,87	3360	14,462 - 15,921[1]	14	Chen et al., 1998[3]
GIK17938-2	19,47	117,32	2840	0,323 – 19,749[1]	36	Chen et al., 1999[4]
GIK17940-2	20,11	117,38	1727	0,146 – 19,472[1]	93	Pflaumann & Jian, 1999[5]
GIK17957-2	10,53	115,18	2195	0,8 – 17[2]	8	Jian et al., 2000[6]
GIK 18287-3	5,39	110,39	598	3,357 – 16,664[1]	51	Steinke et al., 2001[7]
MD01-2390	6,38	113,24	1545	1,011 – 18,865[1]	40	Steinke et al., 2008[8]
MD01-2394	13,78	110,25	2097	1,412 – 1,598[1]	16	Yu, P. et al., 2008[9]
MD97-2142	12,41	119,27	1557	0,083 – 19,661[2]	33	Chen et al., 2003[10]
MD97-2148	19,79	117,54	2830	19,08-22,84[2]	36	Chen et al., 1999[4]
MD97-2151	8,43	109,52	1589	0,135 – 19,809[1]	68	Huang et al., 2002[11]
ODP 1143	9,21	113,17	2097	2,365 – 17,291[1]	3	Li, B. et al., 2004[12]
ODP 1146	19,27	116,16	2092	1,686 – 13,524[2]	3	Li, B. et al., 2004[12]

MLD transfer function based reconstruction

A Canonical Correspondence Analysis (CCA) was performed between modern environmental variables (i.e., nutrients, chlorophyll, oxygen, mixed layer depth) and modern and fossil PF assemblages from SCS and the tropical and subtropical North Pacific. We then applied a PF based transfer function to reconstruct MLD changes in the SCS since the LGM. As a secondary tool we also reconstruct MLD changes using the percentage of deep-dwelling PF species (*i.e.*, *Globorotalia* spp., *Neogloboquadrina* spp.) through a generalized additive model (GAM) in R to calculate the Akaike Information Criterio (AIC). To obtain the MLD stack curves we divided the records into two groups and combined records to generate continuous (from 0 to 20 ka) records representing the North (records retrieved above 13°N) and South (records retrieved below 13°N) SCS.

Results

The CCA reveals that the fossil assemblage is more similar to assemblages found today in the subtropical North Pacific indicating that this region cannot be excluded from the transfer function reconstruction and that the MLD is the primary controlling factor of the PF assemblage composition (Figure 2). The MLD reconstruction present a decrease in the relative abundance of deep-dwelling PF since the LGM in both sectors, indicating the presence of deeper MLD during the glacial followed by a progressive shoaling of the MLD towards the Present (Figure 3).

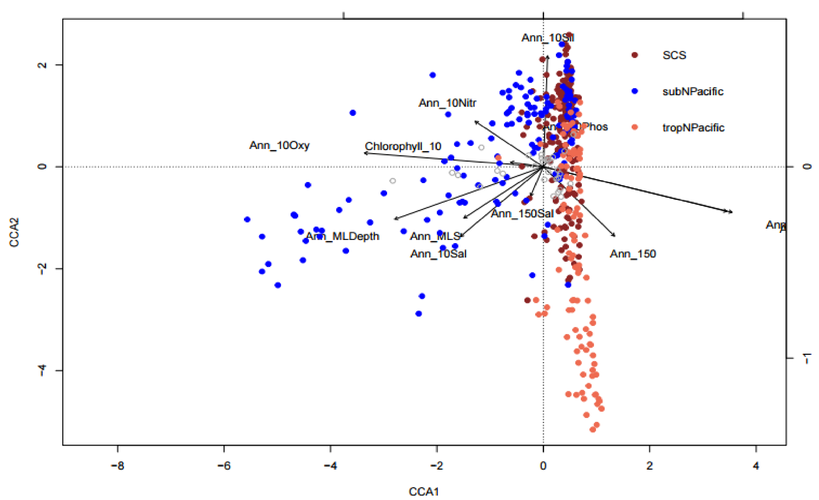

Figure 2. Distribution of the modern planktonic foraminifera species over the South China Sea (SCS), subtropical Northern Pacific (subNPacific) and tropical Northern Pacific (tropNPacific) considering different environmental variables controlling the fauna. White dots correspond to fossil data

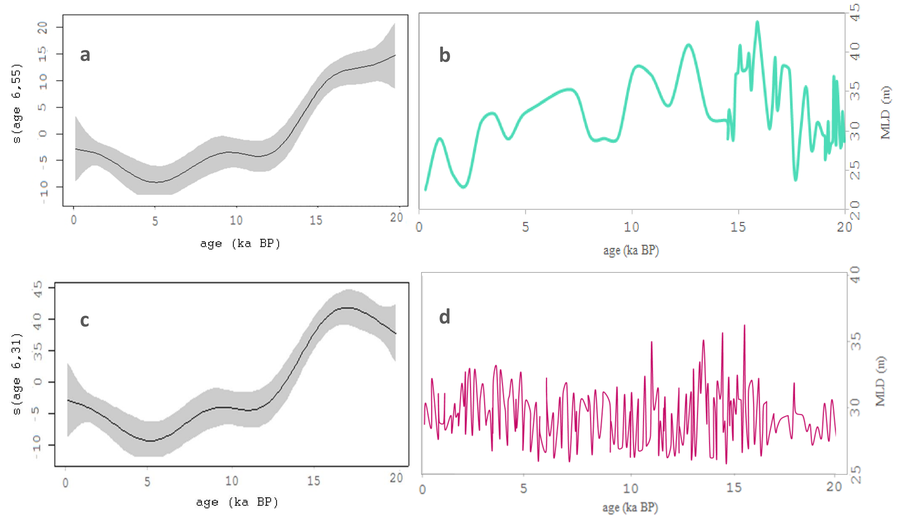

Figure 3. Variability of the planktonic foraminifera deep-dwellers over the last 20 ka in the (a) Northern and (c) Southern SCS and the MLD tranfers function based reconstruction to both Northern (b) and Southern (d) sectors.

Discussion

Our reconstructions indicate the presence of a deeper MLD during the LGM followed by a progressive shoaling of the MLD towards the Present. The stronger EAWM winds are able to increase the MLD throughout the SCS, additionally the loss of surface heat during a glacial is expected to increase the instability of the water column[13], resulting in higher susceptibility of the mixed layer to wind disturbance. In this way a deeper MLD affecting the PF fauna distribution as a primary control factor may reflect the strong winds turbulence over the surface waters promoted by an intensified East Asian Winter Monsoon during the LGM.

Acknowledgments

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