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North Atlantic climatic changes reflected in the Late Quaternary foraminiferal abundance record of the Andaman Sea, north-eastern Indian Ocean

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ABSTRACT

Here, we present planktonic foraminiferal, benthic foraminiferal and other proxy profiles from well-dated sediment cores in the Andaman Sea showing changes in climate and oceanography at Dansgaard-Oeschger (D/O) and Heinrich scales. The large temporal variations in the abundances of total benthic foraminifera, *Globigerina rubescens* and *Neogloboquadrina dutertrei* suggest substantial changes in the surface to bottom hydrography of the Andaman Sea. *G. rubescens* abundance minima during the last glacial cycle correspond to warm interstadials (D/O events 1 to 14) while maxima correspond to Heinrich events (H1 to H4), the last glacial maximum (LGM) and the Younger Dryas. D/O events are marked by very low *G. rubescens* and high *N. dutertrei* abundances which indicate freshened surface water related to increased direct precipitation (over evaporation) and strengthened Irrawaddy outflow. Lower abundance of *N. dutertrei* (and higher abundance of *G. rubescens*) during North Atlantic Heinrich events, the deglacial, the YD and the mid- to late-Holocene reflect reduced influx of fresh water as a result of weakened summer monsoon freshwater input. The timing of these Andaman Sea monsoonal changes indicate a strong teleconnection to North Atlantic climate change.

1. Introduction

Dansgaard-Oeschger (D/O), Bond and Heinrich events associated with Northern Hemisphere glacial climates during the late Quaternary were first identified in marine records of the Atlantic Ocean (Bender et al., 1994; Bond et al., 1992, 1997; Heinrich, 1988) and later in the distant regions such as China (Wang et al., 2001), Santa Barbara Basin (Behl and Kennett, 1996; Hendy and Kennett, 2000), Arabian Sea (Burns et al., 2003), Bay of Bengal (BoB) (Kudrass et al., 2001; Marzin et al., 2013) and Andaman Sea magnetic records (Colin et al., 1998). The records from the BoB, Santa Barbara basin and China demonstrate a strong link between the East Asian monsoon and the North Atlantic climate for the last glacial period (Dykoski et al., 2005). These rapid changes also correlate to high-amplitude climatic changes inferred from $\delta^{18}O$ records of Greenland ice cores and are believed to be driven via atmospheric and or oceanic teleconnection (Zonneveld et al., 1997). The study by Bond et al. (2001) also shows that these glacial climatic fluctuations extend in to the Holocene.

The impact of the North Atlantic climate changes on larger Asian monsoon systems has gained wide attention. Studies show that enhanced summer monsoons were coincident with interstadial D/O events whereas weak monsoons were coincident with Heinrich events of the North Atlantic (Sirocko et al., 1996; Schulz et al., 1998). Thus, recent focus has been on understanding the relationship between North Atlantic rapid climate change and the Indian monsoon and to infer the mechanisms responsible for the linkages.

An atmospheric teleconnection with the eastern and central North Pacific and an atmosphere–ocean interaction in the tropical North Pacific are also thought to play a key role in modulating the strength of the Indian monsoon (Lu and Dong, 2008). At the same time, Zhang and Delworth (2005) analysed the tropical response to a weakened Atlantic Meridional Overturning circulation (AMOC) and suggested that the Indian monsoon is weakened due to a weakening of the Walker circulation in the southern tropical Pacific. Modelling studies suggest that the Asian monsoon circulation is weakened during the Heinrich events of the last glacial cycle (Jin et al., 2007). Goswami et al. (2006); Feng and Hu (2008) demonstrate a link between North Atlantic surface temperature and Indian monsoon intensity through a physical mechanism affecting the meridional gradient of upper tropospheric temperature between the Tibetan Plateau and the tropical Indian Ocean. Marzin et al. (2013) shows that the events of high salinity are associated with weak Indian monsoon circulation during cold events in the North Atlantic and Arctic. The mechanism involves increased freshwater flux in the North Atlantic, which results in a reduction of the AMOC intensity. With

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the weakening of AMOC, there is a simultaneous cooling of the Indian subcontinent (northern part) which is believed to be the causative factor for the weakening of the Indian Monsoon (Marzin et al., 2013).

In the last decade, substantial research has been carried out to better understand the impact of North Atlantic rapid climate changes on the climate of distant basins (Jin et al., 2007; Wang et al., 2001; Hendy and Kennett, 2000). There are number of isotopic and magnetic proxy records indicating rapid changes during last glacial cycle in response to the North Atlantic climate events, but there is limited data based on faunal changes from the north-eastern Indian Ocean. A large hydrological perturbation at a millennial timescale comparable to the North Atlantic was inferred from the isotopic record from the northern BoB (Kudrass et al., 2001; Marzin et al., 2013). But their inferences are mainly based on oxygen isotope records.

Our intention is to study the response of planktonic and benthic foraminifera of Andaman Sea to rapid climatic events of the North Atlantic. We employed the abundance variations of *Globigerina rubescens*, *Neogloboquadrina dutertrei* and total benthic foraminifera to evaluate potential links between the North Atlantic surface temperature and monsoon climate during the last glacial period. We used temporal changes in the abundances of *G. rubescens* (indicator of cold climate) and *N. dutertrei* (freshwater runoff and resultant low salinity) as a proxy for understanding the variability of the Indian Ocean monsoon and found large salinity variations recorded in a sediment core raised from the Alcock Seamount Complex (close proximity to Irrawaddy) and two cores from the central and southern Andaman Sea. At present, the northern core location is influenced by freshwater discharge from the Irrawaddy and Salween rivers (Fig. 1).

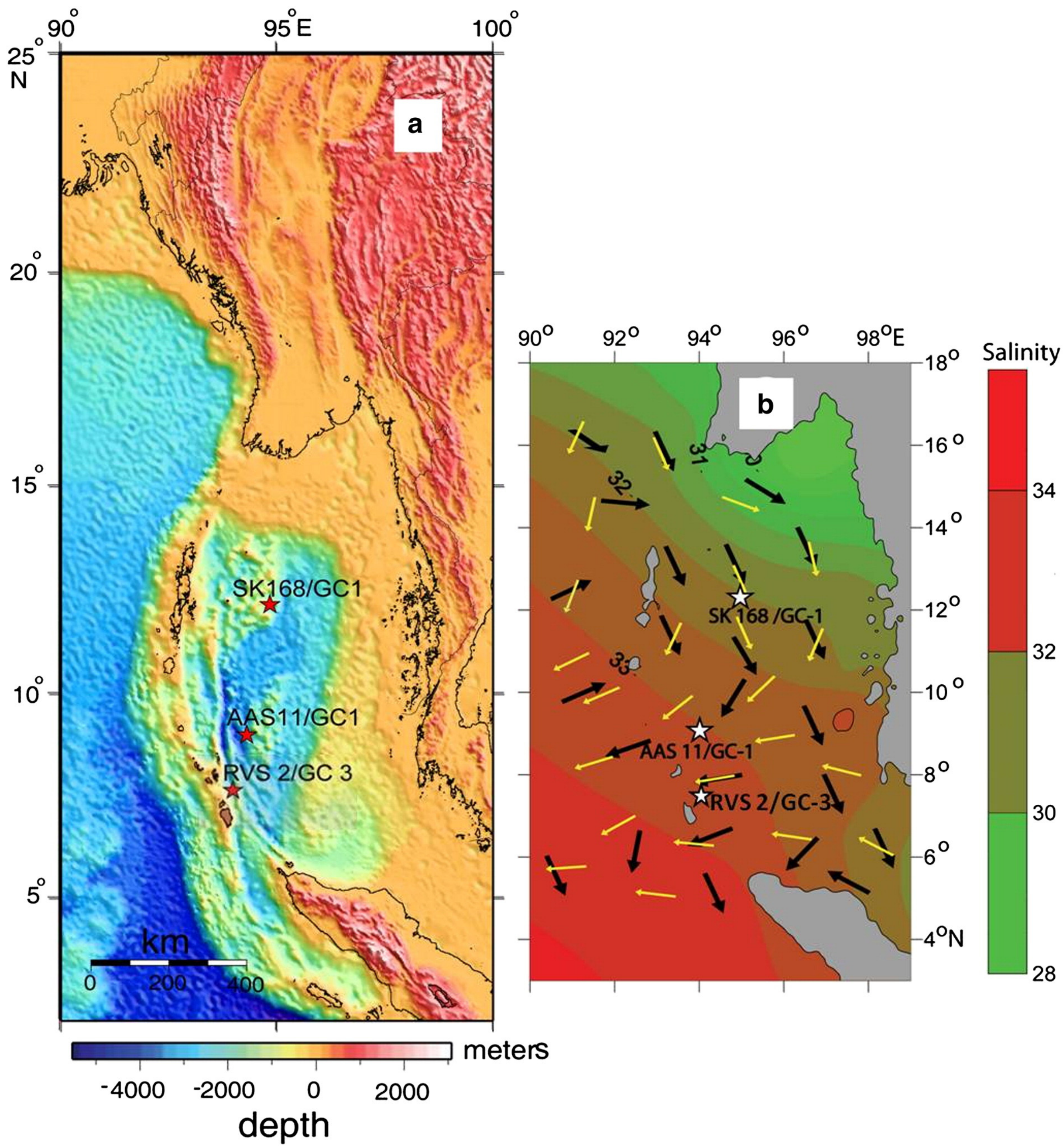

Fig. 1. Map showing core locations in the Andaman Sea in the eastern Indian Ocean: (a) bathymetry of the Andaman Sea along with core locations; (b) salinity (annual salinity at the surface, www.nodc.noaa.gov) and monsoon currents in the Andaman Sea. Black arrow, summer monsoon; yellow arrow, winter monsoon (modified from Brown, 2007 and references therein).