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δ¹⁸O and salinity variability from the Last Glacial Maximum to Recent in the Bay of Bengal and Andaman Sea

A.V. Sijinkumar [a, b, *], Steven Clemens [a], B. Nagender Nath [b], Warren Prell [a], Rachid Benshila [c], Matthieu Lengaigne [d, e]

[a] Earth, Environmental, and Planetary Sciences, Brown University, Providence, RI, USA
[b] CSIR-National Institute of Oceanography, Dona Paula, Goa, India
[c] CNRS/LEGOS, Toulouse, France
[d] LOCEAN, IPSL, Sorbonne Universités (UPMC, Univ. Paris 06)/CNRS/IRD/MNHN, Paris, France
[e] Indo-French Cell for Water Sciences, IISc-NIO-IITM–IRD Joint International Laboratory, NIO, Goa, India

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ABSTRACT

Oxygen isotopes of surface, thermocline and bottom dwelling foraminifera were analysed from two well-dated Andaman Sea cores and combined with nine previously published records from the Bay of Bengal (BoB) and Andaman Sea to create a transect spanning 20°N to 5°N. Combined with temperature estimates and the observed seawater δ^{18}O-salinity relationship, these data are used to estimate past changes in BoB salinity structure. Compared to modern, mid-Holocene (9–6 cal ka BP) surface waters in the northern BoB were 2.5 psμ (8%) fresher, Andaman Sea were 3.8 psμ (12%) fresher, and southern BoB were 1.2 psμ (3.5%) fresher. Conversely, during the last glacial maximum (LGM), surface waters in the northern BoB were 2.9 psμ (9%) more saline while Andaman Sea were essentially unchanged and southern BoB were 1.7 psμ (4.9%) more saline compared to modern. The relative freshness of the Andaman during the last glacial maximum is likely the result of basin morphology during sea level low stand, resulting in reduced surface water mixing with the open BoB as well as shelf emergence, causing increased proximity of the core locations to river outflow. Sensitivity experiments using a regional ocean model indicate that the increased mid-Holocene north to south (20°N to 5°N) salinity gradient can be achieved with a ~50% increase in precipitation/runoff while the decreased glacial age gradient can be achieved with a ~50% reduction in precipitation/runoff. During the deglaciation, both surface and thermocline-dwelling species in the Andaman and northern BoB exhibit depleted δ^{18}O within the Younger Dryas (YD), indicating colder and/or more saline conditions. None of the records from the southern BoB site have clear YD structure, possibly due to the combined effects of bioturbation and low sedimentation rates.

1. Introduction

The north-eastern Indian Ocean is an important region for reconstructing changes related to monsoon precipitation and river runoff (Fig. 1). The major rivers of India, Bangladesh and Myanmar (Ganges-Brahmaputra, Irrawaddy and Salween) are largely fed by summer monsoon precipitation and glacial meltwater and are responsible for delivering the majority of sediments to the Bengal Fan and Andaman Sea (Colin et al., 1998; 1999). Annual runoff to the Bay of Bengal (BoB) is estimated to be 2950 km^3 (Fekete et al., 2002; Sengupta et al., 2006) and contributes to the freshwater flux into the BoB in equal proportion with rainfall over the ocean north of 15°N (Chaitanya et al., 2014), strongly impacting the BoB salinity budget (Rashid et al., 2007; Akhil et al., 2014).

Direct precipitation (P) plus runoff (R) exceeds evaporation (E) throughout the annual cycle (P + R–E>0) leading to a strong low salinity cap in the northern BoB and Andaman Sea, with saltier waters in the southern BoB (Duplessy, 1982; Kudrass et al., 2001; Rashid et al., 2007). The resulting north to south surface salinity gradient, with lowest salinity values in the north and highest in the south, largely reflects regional changes fresh water input via precipitation and runoff in the northern BoB. The East Indian Coastal Current, a well-defined, seasonally reversing western boundary

* Corresponding author. Department of PG Studies & Research in Geology, Govt. College Kasaragod, Kerala, India.
E-mail address: sijingeo@gmail.com (A.V. Sijinkumar).

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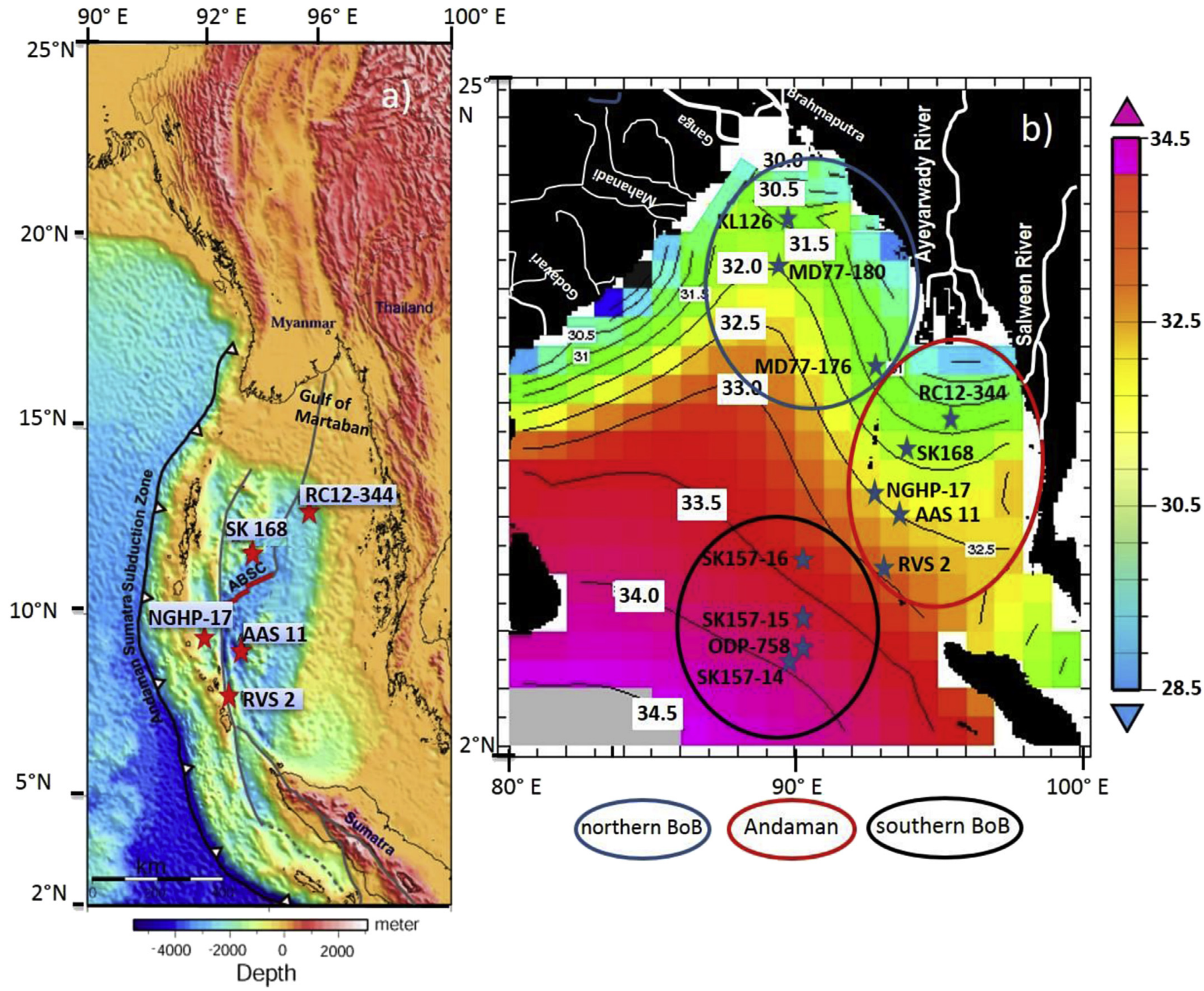

Fig. 1. Location map a) bathymetry of core locations in the Andaman Sea; b) Location of the sediment cores used in the BoB. Colour shading is the present day annual average surface salinity (data from Levitus and Boyer (1994)). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

current in the BoB drives most of the exchange of water masses between the BoB and Arabian Sea (Akhil et al., 2014). Its southward flow right after the summer monsoon transports fresh waters from the northern BoB to the southern tip of India (Chaitanya et al., 2014). Its northward flow during southwest monsoon, which transports high-salinity water into the southernmost BoB from the Arabian Sea, subducts beneath the fresh, low-density surface waters at ~5°N such that the 35 psμ isohaline deepens to ~250 m depth by 15°N (Vinayachandran et al., 2013). Thus, the BoB surface salinity gradient is not impacted by mixing with Arabian Sea surface waters, but rather, by loss of fresh water to depth by vertical mixing (Akhil et al., 2014). The dominant response of the surface salinity gradient to insitu processes make it ideal for reconstructing changes in monsoon-driven precipitation and runoff.

Various workers have utilized deep sea sediments from the BoB and the Andaman Sea to study past monsoon variability (eg. Chen and Farrell, 1991; Cullen, 1981; Govil and Naidu, 2011; Kudrass et al., 2001; Rashid et al., 2007), changes in surface and deep water circulation (eg. Ahmad et al., 2008; Raza et al., 2014) as well as sediment provenance and the tectonic history of source regions (eg. Ali et al., 2015; Awasthi et al., 2014; Colin et al., 1998; 1999; 2006; Kurian et al., 2008). Cullen (1981) first reconstructed BoB north-south salinity gradients using planktonic foraminiferal assemblage data. Cullen found higher glacial age salinity and a reduced north to south salinity gradient but no change in Holocene salinity relative to modern. These results were attributed to local changes in precipitation and runoff, having eliminated the impact of meltwater on the basis of volumetric estimates of modern ice mass and river discharge.

This study utilizes a suite of eleven AMS dated records spanning 20° N to 5°N, including BoB and Andaman Sea sites. We combine the $\delta^{18}O$ of surface-, thermocline- and botton-dwelling foraminifera with paired records of sea surface temperature (SST) to reconstruct changes in the BoB N-S salinity gradients during the LGM, when the summer monsoon is thought to be relatively weak and the early Holocene, when the summer monsoon is thought to be relatively strong (Cullen, 1981, Marzin et al., 2013; Govil and Naidu, 2011; Kudrass et al., 2001; Rashid et al., 2007).