ABSTRACT

Arabian Sea is one of the higher biological productive zones in the world's oceans, marked by seasonally reversing of wind system known as Indian summer monsoon (ISM) or southwest (SW) monsoon and winter monsoon or northeast (NE) monsoon. The ISM is a principal constituent of the Earth's climate system, which plays an important role in the socio-economic life of billions of people of the Indian subcontinent as well as the south Asian region. The aim of the present study is to understand centennial to millennial-scale changes in the paleoceanography, ISM variability, upwelling records, and paleoproductivity during the late Quaternary–Holocene. In this study, 500 sediment samples from cores SK291/GC15, SK291/GC13, and SK291/GC11, off the coast of Goa, eastern Arabian Sea, have been analyzed for benthic and planktic foraminifera census data, Total Organic Carbon (TOC wt.%) and stable isotopes ($\delta^{13}C$ and $\delta^{18}O$).

The results of multi-proxy data from eastern Arabian Sea (SK291/GC15) suggest that the SW monsoon strengthened during 5,500-5,000 and 3,000-2,700 calibrated years before present (cal yrs BP). The SW monsoon weakened and the NE monsoon intensified during 4,200 – 1,500 cal yr BP, and the Arabian Sea OMZ attained present day shape during the late Holocene. The $\delta^{18}O$ data shows negative values with an average of -0.95‰ during ~5,000 cal yr BP indicating a relatively short warm and freshwater incursion in this region. Factor and cluster analysis of highest ranked benthic foraminiferal species of this site enabled to identify seven assemblages (ie. Qs-Ec, La-Rs, Ta-Ag, Up-Db, Cc-Np, Ea-Gn, and Cp-Ag), that indicates the mid to late Holocene was characterized by the oxygen-deficient environment with high organic productivity induced by monsoonal upwelling.

The results of site SK291/GC13 suggest that the coastal water off Goa was relatively warmer and/or less saline and low to moderate in organic content during 6,100 to 4,600 or perhaps up to 4,200 cal yrs BP. The foraminiferal abundances combined with TOC (wt. %), and $\delta^{13}C$ and $\delta^{18}O$ values of *Ammonia gaimardii* show distinct variability, indicating changes in the paleoproductivity, oxygenation, and salinity of shallow waters. The $\delta^{18}O$ record suggests that shallow eastern Arabian Sea was relatively colder and more saline during ~4,200 – 2,600 cal yrs BP, and it is coinciding with lower SST in the northeastern Arabian Sea and arid phase in the Indian subcontinent. During 2,900-2,600 cal yrs BP there are frequent short-term cold excursions which have earlier been observed in the northeastern Arabian Sea, off Pakistan. The changes are mainly driven by the monsoonal activity, except for the past ~400 yrs, which is being influenced by the anthropogenic activity.

Factor and cluster analysis of highest ranked benthic foraminiferal species enabled to identify seven assemblages from site SK291/GC11 (Ba-Rs, Tc-Na, La-Up, Ea-Gn, Bm-Up, Cp-Ag, and Cc-Np) characterizing high organic productivity and low oxygen conditions during the studied interval. The present study suggests that prominent cold period occurred during ~29,000-22,000 and 19,000-16,000 cal yr BP. The ISM was weaker during these cold intervals, leading to weak upwelling and low surface productivity. These proxy records suggest that the most likely cause for these cold periods is a combination of changes in hydrography and global ice volume.

Keywords: Indian summer monsoon (ISM); late Quaternary; eastern Arabian Sea; Benthic foraminifera; biofacies; Total Organic Carbon (TOC); Heinrich event; Younger Dryas; Carbon and Oxygen isotope.