ABSTRACT

The high resolution study of foraminiferal assemblage of 445 samples from Ocean Drilling Program (ODP) Hole 723A and box core RC 2730, northwestern Arabian Sea, provides an useful information of the climatic variability in the Indian Ocean area over the past thirteen thousand years. These sites lie below an upwelling zone caused by strong southwest (summer) monsoon winds and are ideal for studying benthic as well as planktic foraminiferal records The intense monsoon driven upwelling causes high surface biological production in the study area, leading to high biogenic sediment record and intense Oxygen Minimum Zone (OMZ). Because of the intense OMZ the effect of bioturbation is either absent or minimal. The seasonal reversal of the wind direction and associated circulation pattern thus has a direct bearing on the biological productivity in the Arabian Sea.

The population abundance of planktic foraminifer, *Globigerina bulloides*, is used to decipher the variations in the monsoon intensity. The time series of the widely used monsoon proxy, *Globigerina bulloides*, is compared with other paleoclimatic proxies to understand a coherency between different paleoclimate records. Spectral analysis was performed to detect and quantify periodic fluctuations in the *G. bulloides* and sunspot number time series during the Holocene.

Quantitative analyses (R-mode factor and Q-mode cluster analyses) of benthic foraminiferal data were performed on relative abundance data of highest ranked benthic species using SAS/STAT package to identify different biofacies dominating the monsoon record of the past 13,000 years. Information on recent benthic foraminifera is used to interpret the environments of each biofacies. Stable isotope analysis of benthic foraminifera, *Uvigerina peregrina,* was carried out at Brown University, USA. The benthic foraminiferal faunal and isotope record helped to study changes in the deep sea waters and to correlate them to variations in the monsoon intensity.

The southwest monsoon intensity was low during the cold interval, Younger Dryas, in the late Pleistocene (13,000-11,000 years) and there was intermediate to high organic carbon flux with very low oxygen concentrations in the deep sea, as indicated by biofacies Bp-Bal. The conditions became warm and humid from 11,000 to 7000 cal yr BP, owing to high southwest monsoon intensity, when biofacies Ri-Na and Hb-Ba dominated and there was sustained flux of organic matter with low or no seasonality and low oxygen conditions in the deep sea. During

the mid-Holocene (7000 to 5000 cal yr BP), there was a gradual transition from high to low southwest monsoon intensity, a sharp decline in the abundance of benthic species characteristic of the OMZ and a notable shift in the stable isotope values of the benthic foraminifer, *Uvigerina peregrina*. The food supply to the sea floor became highly fluctuating ~5,700 cal yr BP onwards as reflected by biofacies Fr-Go. The late Holocene is characterized by a weak summer monsoon circulation, when there was widespread aridity and Indus Valley civilization transformed from an organized urban phase to a post urban phase of smaller settlements with southwards migration of population. The strength of the southwest monsoon significantly increased again during the Medieval Warm Period (750-550 cal yr BP), and organic flux to the sea floor became high (biofacies Rc at RC2730, Gt-Rc at ODP 723A). However intensity of the southwest monsoon was greatly reduced during the Little Ice Age (500-100 cal yr BP), when the organic flux to the seafloor also decreased (biofacies Bs at RC2730).

This study identifies a major shift in stable isotope values during the mid-Holocene related to intense monsoon activity. The stable isotopic record of the benthic foraminifer, *Uvigerina peregrina,* documents a shift in both $\delta^{18}O$ (1.4 ‰) and $\delta^{13}C$ (0.4 ‰), which is equal to or greater than the global glacial to interglacial changes for marine carbonates. This isotopic shift could be related to the proliferation of sulfate reducing bacteria, the intake of which as food by benthic foaminifera such as *U. peregrina* might have driven their calcitic test out of equilibrium with the ocean water in the early Holocene.

Close study of the *G. bulloides* record reveals ten distinct phases of decreased southwest monsoon strength since the Younger Dryas; nine of them closely are aligned to intervals of cold spells in the North Atlantic – the so-called Bond Cycles 0-8. The southwest monsoon shifts are also found to be associated to sub-orbital "1,500-year" cycle as the North Atlantic drift-ice events. Comparison of a recently published record of Holocene sunspot activity with this high resolution record of the Indian summer monsoon winds reveals intervals of weak summer monsoon during the sunspot minima. This suggests multidecadal to centennial scale coherency of the sun-monsoon connection indicating that small changes in solar irradiance can bring significant changes in the tropical monsoon.