GEOTRACES Activity is continuing in India with sampling in The Indian Ocean and measurement of trace elements and isotopes. Flow injection system to measure dissolved Fe was developed and several deep water profiles were measured in Indian Ocean. Funding for GEOTRACES programme in India is continuing through the Ministry of Earth Sciences, Government of India. We are in process of purchasing two in situ pumps for sampling particulates.

Science Highlights

<u>*Distributions of dissolved iron (DFe) in the Indian Ocean*</u>

Dissolved iron (DFe) concentrations from different meridional sections in Indian Ocean collected during GEOTRACES-INDIA cruises SK-304, 311 and 312 between 18 °N to 28 °S (Fig. 1). The clean sampling and measurement techniques were validated using measurement of DFe at Japanese cross over stations in the Indian Ocean and by analyzing GEOTRACES and SAFe reference samples. The DFe in Surface waters of the Indian Ocean ranges from 0.1 nM to 1.8 nM. The higher surface concentrations are observed in Arabian Sea which shows the high amount of dust deposition from nearby desert sources. The concentrations of DFe in sub-surface waters got elevated and reach a maximum of 1.5 nM.

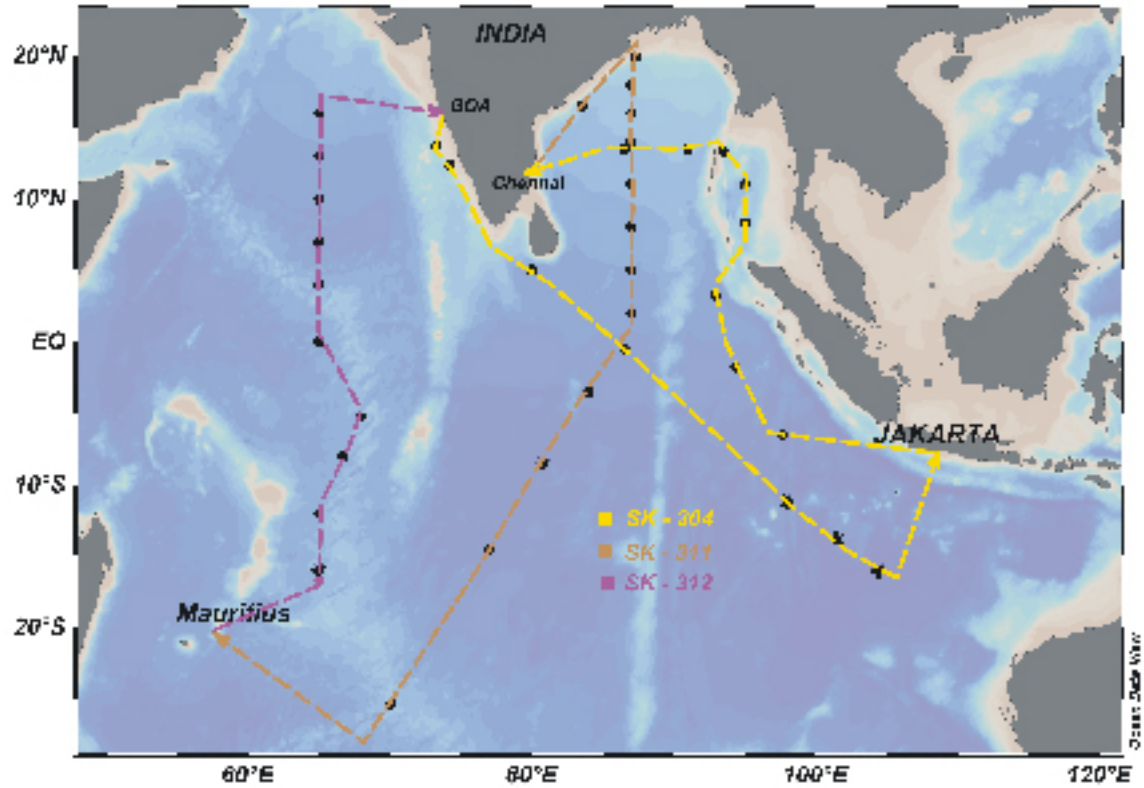

Figure 1: Various sections sampled for SOTRACES studies in the Indian Ocean

Remineralization of sinking organic matter may be the cause for the elevated concentrations of DFe in the sub-surface waters and remains constant throughout the water column. The Bay of Bengal is also characterized by higher DFe concentration owing to higher riverine particulate flux and OMZ. Water sampled around some of the hydrothermal sections along the central Indian ridge display high DFe concentrations, reaching a maximum of 27 nM. In addition to diverging boundaries in the oceans, the converging boundaries are also acting as an important source of dissolved Fe to the oceans.

εNd in the Arabian Sea: Water Mass mixing vs particle – water interaction

Arabian Sea is characterized by intermediate water column oxygen minimum zone resulting from high productivity sustained by upwelling during SW monsoon. It receives significant amount of particulates from the rivers such as the Indus, the Narmada etc and atmospheric dust from adjoining arid landmasses. An extensive study of Nd isotope composition has been carried out in the Arabian Sea to characterize the various water masses present and quantify the Nd sourced from the fluvial and Aeolian particles by their interaction with the seawater. Several water profiles were collected onboard Sagar Sampada during April 2012 in the Arabian Sea along 68 °E meridional section between equator and 21 °N. Nd isotope composition was determined using MC-ICPMS after pre-concentrating and purifying it from ~20 liters of seawater. $\boldsymbol{\varepsilon}_{Nd}$ in the Arabian Sea vary significantly from -14.37 to -5.57 with less radiogenic values in the northern Arabian Sea and more radiogenic Nd in the surface waters between 4 °N and 16 °N. The $\boldsymbol{\varepsilon}_{Nd}$ results demonstrate the significant presence of Antarctic Bottom Water AABW) and North Atlantic Deep Water (NADW) in the bottom and deep Arabian Sea respectively. Persian Gulf water (PGW) and Red Sea Water (RSW) are present at water depth 400 to 1000 m between 4 °N to 16 °N. Important features of this study are the non-radiogenic Nd in the northern Arabian Sea and the radiogenic Nd in the surface water of the Central Arabian Sea, between 4 °N to 16 °N. Northern Arabian Sea is dominated by less radiogenic Nd resulting from its release from the lithogenic particles with $\boldsymbol{\varepsilon}_{Nd}$ ~ -14 brought by the river Indus. Radiogenic Nd of the surface water of the Central Arabian Sea is contributed by dissolution of Aeolian dust having $\boldsymbol{\varepsilon}_{Nd}$ ~ -6. Particle – water interaction seems to have a dominant control on the Nd budget of the Arabian Sea with Nd contribution from fluvial particles increases towards northern Arabian Sea whereas Aeolian contribution decreases towards northern and eastern Arabian Sea.

Upper Ocean cabon export using 210Po/210Pb disequilibrium

Naturally-occurring particle-reactive radionuclides (^{234}Th, ^{210}Po) provide possible means for quantifying export flux of particulate organic carbon (POC) from the surface ocean at various time scales, because of their specific half-lives. The naturally occurring radionuclide ^{210}Po is typically deficient relative to its parent ^{210}Pb in the surface ocean due to preferential removal by biota, while it is in near equilibrium or excess below the surface mixed layer due to rapid regeneration from sinking organic matter.

Seawater profiles for ^{210}Po and ^{210}Pb from surface to 800 m water depth were collected at several locations from the Arabian Sea, Bay of Bengal and the Indian Ocean during March – May, 2014 under GEOTRACES programme. The Arabian sea, being more productive zone, shows more deficit of ^{210}Po relative to ^{210}Pb indicating intense biological removal of ^{210}Po. Generally surface waters of the Indian Ocean have excess ^{210}Pb, which increases sharply north of the equator due to atmospheric input of ^{210}Pb from continental aerosol. Removal flux of ^{210}Po relative to ^{210}Pb from 0-300 m depth from two transects along 87 °E and 65 °E between 18 °N to 14 °S ranged widely from 0.03 to 84.4 dpm m^{-2} d^{-1}. The C/^{210}Po ratio in particulates ranged between 239 and 717 µM dpm^{-1}. The derived export flux of POC using

^{210}Po varied from 0.01 to 33.2 mmol m^{-2} d^{-1} due to the variable source of biogenic particles and spatial changes in the surface biogeochemical and physical conditions.

Submarine groundwater discharge and nutrient addition to the coastal zone of the Godavari estuary

Submarine groundwater discharge (SGD) represents a significant pathway of materials between land and sea, especially as it supplies nutrients, carbon and trace metals to coastal waters. To estimate SGD fluxes to the Godavari estuary, India, we used multiple tracers: salinity, Si, ^{223}Ra, ^{224}Ra, ^{228}Ra and ^{226}Ra. Tracer abundances were elevated in groundwater from the unconfined coastal aquifer and in surface water from the near shore zone; these enrichments decreased to low levels offshore, indicative of groundwater discharge. A model based on the decay of ^{224}Ra relative to ^{228}Ra was used to determine apparent water ages of various bays within the estuary. These ages ranged from 2.6 to 4.8 d during November 2011. Knowing the water age, the distribution of radium in the estuary, and the radium isotopic composition of groundwater enabled us to calculate SGD fluxes to the estuary. These fluxes (in units of 106 m^3 d^{-1}) were on the order of 5 in the Gautami Godavari estuary, 20–43 in the Vasishta Godavari estuary, and about 300 in Kakinada bay, where enhanced ion exchange processes and redox-controlled cycling in the mangrove ecosystem may contribute to higher fluxes. These estimates of water fluxes allowed us to determine the magnitude and seasonal variability in the nutrient fluxes to the estuary associated with SGD. These nutrient fluxes (in units of mmol m^{-2} d^{-1}) ranged from 1–19 (N), 0.6–2.6 (P), and 5–40 (Si) in Gautami Godavari; 19–40 (N), 2.6–5.5 (P), and 200 (Si) in Vasishta Godavari; and 120–140 (N), 10 (P), and 220 (Si) in Kakinada bay. The high SGD fluxes to Kakinada bay contribute significant nutrients to this bay; considerably lower SGD fluxes to Vasishta Godavari still contribute significant nutrients to this estuary. Thus SGD represents a major source of new nutrients to these coastal ecosystems. For the entire Godavari estuarine system, SGD fluxes contribute (48–88) × 10^9 mol DIC y^{-1} and (51–94) × 10^9 mol TA y^{-1}. These fluxes represent ~54 and ~62% of the riverine DIC and TA fluxes to the Godavari estuarine system. This study provides baseline data against which future changes in nutrient and carbon fluxes due to urbanization and economic growth over this region can be compared.

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