



INDIA

Cruise Report

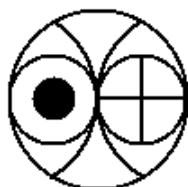
ORV Sagar Kanya

Cruise # 311

From: Chennai, March 24, 2014

To: Mauritius, April 24, 2014

GEOTRACES & Hydrothermal Programme



Chief Scientist: Dr. R. Rengarajan

Geosciences Division

Physical Research Laboratory, Ahmedabad

Itinerary of the SK-311 cruise program

Name of vessel	ORV SAGAR KANYA
Cruise No.	311
Port of Embarkation	Chennai
Date & time of Embarkation	March 24, 2014; 2000 Hrs.
Port of Disembarkation	Port Luis, Mauritius
Date & time of Disembarkation	April 24, 2014; 0800 Hrs
No. of Scientists participated	20
Region	Bay of Bengal & Indian Ocean
Operations performed	Clean CTD, ship CTD (Rosette system), Peterson Grab, MPN, Zooplankton net, Gravity coring
Sample type	Seawater and sediment
Parameters studied	Trace Elements and their Isotopes, C-14, DO, pH, Alkalinity, pCO ₂ , Carbohydrates, Amino acids and Proteins (CAP), Nutrients, N ₂ O, CH ₄ , DIC, DMS, ¹³ C _{DIC} , ¹⁵ N, Particulate Organic Carbon (POC), Total Chlorophyll, HPLC pigments, Primary Productivity, Phyto-plankton, Zooplankton, Total Bacterial Count (TBC), Total Viable Count (TVC), Macro and Meio Benthos, Aerosol and rain water composition, chemical parameters & trace metals in Hydrothermal plumes in water column
Name of Chief Scientist	Dr. R. Rengarajan

Participating Institutes:

- 1) National Centre for Antarctica & Ocean Research (NCAOR), Goa
- 2) National Institute of Oceanography (NIO), Goa
- 3) National Institute of Oceanography (NIO), Regional Centre,
Vishakhapatnam
- 4) Mangalore University, Mangalore
- 5) Pondicherry University, Port Blair
- 6) Physical Research Laboratory (PRL), Ahmedabad

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ORV Sagar Kanya
CRUISE REPORT
Cruise No. 311
GEOTRACES & Hydrothermal Programme

INTRODUCTION

Trace elements and their isotopes (TEIs) can function as micronutrients, contaminants, and tracers or proxies of various oceanographic processes. Results from the Geochemical Ocean Sections Study (GEOSECS) of the 1970s led to much of this recognition; however, only a few TEIs were determined during this early program. The development of clean sampling protocols and new, highly sensitive analytical methods, combined with advances in modelling tools that can link and synthesize large data sets, have revolutionized our ability to now study the marine biogeochemical cycling of trace elements and isotopes on a global scale.

INDIAN OCEAN

The Indian Ocean is the only ocean that is bounded by land at the tropical latitudes around 26°N. The northern Indian Ocean comprises two major basins, the Arabian Sea in the northwest and the Bay of Bengal in the northeast. These basins experience very different hydrographic and climatic conditions. The Arabian Sea is a region, evaporation far exceeds precipitation and runoff while the reverse holds true for the Bay of Bengal. Moreover, the Southwest Monsoon winds are also stronger over the Arabian Sea, forcing upwelling along both the western (off Somalia, Yemen and Oman) and eastern (off India) boundaries. The monsoon circulation is predominately wind-driven, although in some locations it is modified by heat and fresh-water fluxes. Both the Arabian Sea and the Bay of Bengal experience severe oxygen depletion at mid-depths.

Despite the enormous river runoff into the Bay of Bengal/Andaman Sea and huge consumption of synthetic fertilizers in South Asia, the total flux of dissolved inorganic nitrogen by rivers to the Bay of Bengal is relatively modest ($<0.5 \text{ Tg N y}^{-1}$). This is one reason why hypoxic conditions are not known to develop over the inner shelf off the mouths/deltas of major rivers (e.g. Ganges/Brahmaputra and Irrawaddy).

Oceanographically, the Bay of Bengal is a very important region wherein seven large rivers (six from India and Irrawaddy River from Myanmar) annually discharge $\sim 10^{15} \text{ g}$ sediment and $\sim 10^{15} \text{ L}$ of water, a major fraction of which is contributed by the Ganga-Brahmaputra River estuarine system itself. The river outflow during the SW monsoon is so large that the Bay of Bengal can effectively be considered an estuary of this giant river system. The Ganga and Brahmaputra Rivers influence ocean chemistry through their unique river water chemistry and large flux of immature sediment. The flux and isotopic ratio of strontium from the Ganga-Brahmaputra Rivers to the ocean has become a matter of controversy in terms of its lithologic source (silicate vs. carbonate) and its corresponding isotopic ratio. Special attention has been focused on fluxes of Sr because the highly radiogenic composition of $^{87}\text{Sr}/^{86}\text{Sr}$ from this system plays a significant role in determining the present day oceanic ratio. Changes with time in Sr flux and isotopic ratio certainly affect the marine paleo record.

In addition to the huge fluxes of water and sediment from the rivers, additional fluxes from submarine groundwater discharge (SGD) have been recognized at the river mouth. These fluxes augment the already high river fluxes of alkaline elements Sr, Ba, and Ra. The source of these elements appears to be weathering of aquifer protolith as well as adsorption-desorption reactions with aquifer solids. It is likely that other elements are also affected by SGD. Thus, SGD may serve as source and sink with respect to TEIs.

Atmospheric deposition is one of the most dominant and effective means of delivering trace element and their isotopes (TEIs) to surface waters of interest to GEOTRACES. This is particularly the case in the Indian Ocean, where enclosed sub-basins to the north are located in close proximity to large arid areas of dust and large human populations with related industrial emissions located on the Indo-Asian sub-continent. This includes the Bay of Bengal, which is impacted by dust and other aerosol emissions from

both the Indian subcontinent to the west and East Asian regions to the east. The mineral aerosol is particularly prevalent during the inter-monsoon winter period.

HYDROTHERMAL STUDIES

Hydrothermal circulation occurs when seawater percolates downward through the fractured ocean crust along the volcanic mid-ocean ridge (MOR) system. Seafloor hydrothermal circulation plays a significant role in the cycling of energy and mass between the solid earth and the ocean. Hydrothermal systems play a key role in the fostering of high global biodiversity in the deep-sea. The rising buoyant parcels of hydrothermal effluents mix with the background seawater and eventually reach a level where the plume water density is in equilibrium with the background seawater density and the non-buoyant plume then starts dispersing along equal potential density surfaces.

The physical properties used to locate the hydrothermal plumes are water temperature and light transmission anomalies (either light attenuation or light scattering). The temperature and salinity anomalies depend on the ambient deep water salinity and temperature gradient. Light transmission anomalies arise from the precipitation of particles within the plumes.

OBJECTIVES

The present GEOTRACES Section Cruise is an attempt to understand various biogeochemical processes controlling the distribution of various Trace Elements and their Isotopes (TEIs) in the Bay of Bengal and the Indian Ocean (Fig. 1). Broadly, the objectives of this study can be classified under the following themes:

Sources, sinks and internal cycling

- 1) To understand and quantify how the water masses are modified after the contact with the margins and the river mouths within the energetic continent/ocean interface surrounding the Bay of Bengal and in the Indian Ocean basin.
- 2) To trace the Himalayan weathering and its impact on the chemical composition of the neighbouring ocean,
- 3) To contribute to tracer studies of ocean circulation in association with physical oceanographers.

- 4) To understand the role of TEIs in primary productivity and their distribution within the water column.
- 5) Atmospheric deposition of TEIs, their fluxes and processes.
- 6) To calibrate the behaviour of paleo-circulation and paleo-weathering proxies.

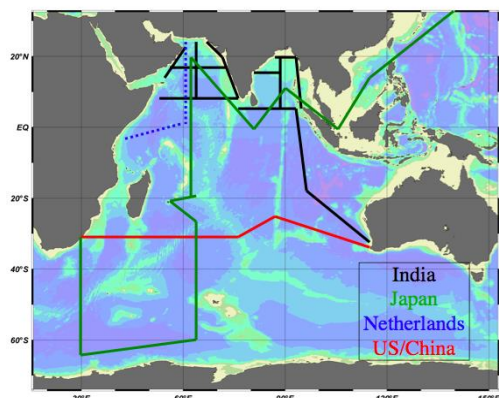


Fig. 1: Summary of tracks proposed for GEOTRACES cruises in the Indian Ocean during the GEOTRACES Indian Ocean Workshop, Oct 2007.

To understand the various physical processes governing ocean circulation, productivity being controlled by micronutrients, ecosystem and ocean anoxia, a coordinated global research programme named GEOTRACES has been initiated. This cruise is an attempt to address some of these issues in context of the Indian Ocean and would try to cover the GEOTRACES Section Cruise -02 as decided during the working group meeting during the GEOTRACES Indian Ocean Workshop (Fig. 1).

We have planned to collect chemical and trace metal data along the hydrothermal vent plume layer in the water column over Central Indian Ridge in the Indian Ocean.

MATERIAL AND METHODS

This cruise was allocated to GEOTRACES for studies of water and sediments for the GEOTRACES Section - 02 for measurement of several trace elements and their isotopes (TEIs) to understand various biogeochemical processes responsible for their distribution in the Indian Ocean region. One of the major requirements for the GEOTRACES cruise was

requirement of clean sampling system which was procured for this programme. The clean sampling system was successfully operated during the cruise for seawater sampling.

a) Trace metal clean sampling systems

Rapid and non-contaminating sampling system for trace elements with a complete facility for trace-metal clean seawater sampling at sea (e.g., non-contaminating rosette with GO-Flo or equivalent bottles; non-contaminating Kevlar wire; clean lab with HEPA filtered air for processing samples) was acquired for the first time in the Indian Ocean region for the GEOTRACES India project by Physical Research Laboratory, Ahmedabad with generous support of Ministry of Earth Sciences, New Delhi (MoES). This trace metal clean sampling system is a valuable asset to GEOTRACES. Clean sampling systems of somewhat different design have been constructed by scientists in Japan, the Netherlands and the U.S.A.

b) Sediment sampling:

For paleoclimatic studies, long cores from various area were collected with gravity corer.

c) Grab sampling:

For surface sediment, grab sampling was operated at various locations.

d) Zooplankton Net:

To identify the distribution of zooplankton for studying the grazing behaviour in the surface ocean.

Additionally, various scientific equipments used for onboard analysis are:

- 1) CTD with rosette with 10 L Niskin sampler
- 2) Autosol for salinity measurements
- 3) Thermosalinograph
- 4) Water purification system (Milli-Q)
- 5) Deep freezers
- 6) Ovens
- 7) Refrigerators
- 8) Refrigerated storage room
- 9) Multibeam sounder
- 10) Laminar flow bench
- 11) Fumehoods
- 12) Deep sea Echosounder

13) UV Oxidation unit

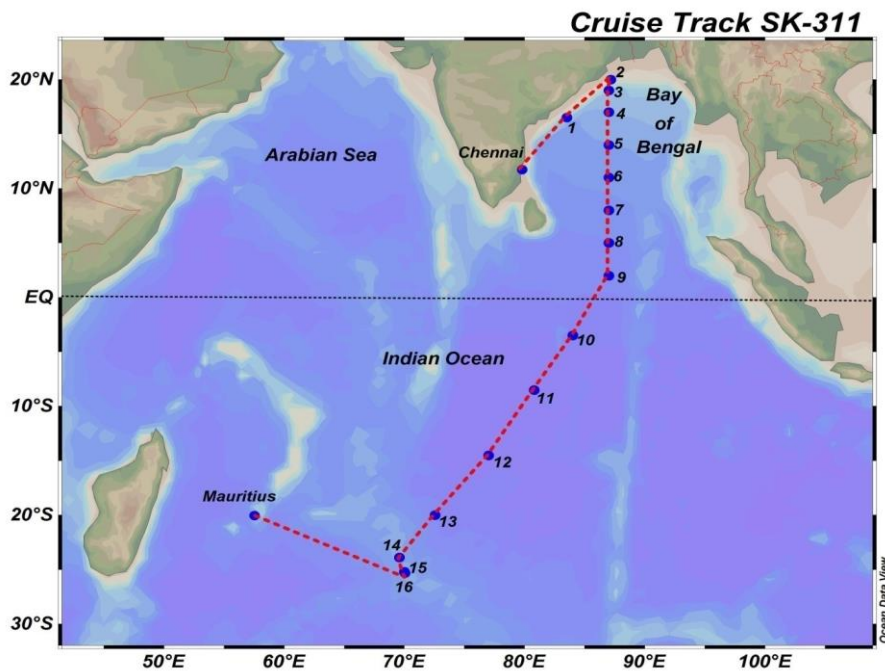


Fig. 2: Cruise track of the GEOTRACES/Hydrothermal Front cruise SK-311 from Chennai to Port Luis, Mauritius. The sampling stations from 14 to 16 are for the study of Hydrothermal fronts.

SAMPLING DETAILS

The scientific operations carried out at the stations across a range of contrasting regions in the Bay of Bengal and the Indian Ocean during the cruise SK-311 (Fig. 2) are described below:

Cast Details

24.3.2014 20:00	Departure from Chennai port
25.3.2014 10:00	Stopped for testing Clean CTD, Regular CTD and Deep-sea winch

14° 38.708'N 81° 46.421'E; water depth 3086 m
All bottles are closed properly. Winch and Deck units are working
alright

SK311/Station 1

26.3.2014 06:15 Station started. 16° 31.912'N 83° 33.898'E; Water depth 2983 m
Cast 1 Clean CTD Deep up to 2850 m. Trace metals and isotopes
Cast lowered at 07:08; cast on deck at 10:17
Cast 2 Regular CTD Deep up to 2850 m. Oxygen probe; Ra isotopes at 400 m
Cast lowered at 10:30; cast on deck at 13:15
Cast 3 Clean CTD Shallow up to 100 m. Trace metals and isotopes
Cast lowered at 13:40; cast on deck at 14:03
Cast 4 Regular CTD Deep up to 200 m. Radium isotopes at 200 m
Cast lowered at 14:15; cast on deck at 14:34
Cast 5 Regular CTD up to 100 m. Radium isotopes at 100 m
Cast lowered at 15:00; cast on deck at 15:15
Cast 6 Regular CTD up to 50 m. POC for NIO, Vizag
Cast lowered at 15:30; cast on deck at 15:40
Cast 7 Regular CTD up to 2 m. Radium isotopes at 2 m
Cast lowered at 16:07; cast on deck at 16:11
Cast 8 Deepsea Gravity corer. Water depth 2972 m
Started at 16:25; ended at 19:15
5.8 m core obtained
26.3.2014 19:30 Station completed

SK311/Station 2

28.3.2014 00:20 Station started. 19° 56.670'N 87° 17.731'E; Water depth 1079 m
Cast 1 Clean CTD Deep up to 1000 m. Trace metals and isotopes
Cast lowered at 00:50; cast on deck at 01:43
Cast 2 Regular CTD Deep up to 1000 m. Oxygen probe; Ra isotopes at 400 m
Cast lowered at 02:02; cast on deck at 03:20
Cast 3 Regular CTD Shallow up to 200 m. Radium isotopes at 200m.
Cast lowered at 03:32; cast on deck at 03:52
Cast 4 Regular CTD Deep up to 100 m. Radium isotopes at 100 m
Cast lowered at 04:10; cast on deck at 04:20
Cast 5 Regular CTD up to 2 m. Radium isotopes at 2 m
Cast lowered at 04:35; cast on deck at 04:39
Cast 6 Regular CTD up to 100 m. POC at 100 m and 75 m for NIO Vizag
Cast lowered at 04:52; cast on deck at 05:02
Cast 7 Regular CTD up to 50 m. POC for NIO, Vizag
Cast lowered at 05:17; cast on deck at 05:23
Cast 8 Regular CTD up to 10 m. POC for NIO, Vizag
Cast lowered at 05:38; cast on deck at 05:41
Cast 9 Deepsea Gravity corer. Water depth 1079 m
Started at 06:00; ended at 07:20

3.5 m core obtained; clayey
 Cast 10 Grab sample
 Started at 07:30; cast on deck at 08:40
 26.3.2014 08:50 Station completed

SK311/Station 3

29.3.2014 00:30 Station started. 18° 0.896'N 87° 0.029'E; Water depth 2502 m
 Cast 1 Clean CTD Deep up to 2400 m. Trace metals and isotopes
 Cast lowered at 00:38; cast on deck at 02:45
 Cast 2 Regular CTD Deep up to 2400 m. Oxygen probe; Ra isotopes at 400 m
 Cast lowered at 02:55; cast on deck at 04:55
 Cast 3 Clean CTD Shallow up to 150 m. Trace metals and isotopes
 Cast lowered at 05:01; cast on deck at 05:17
 Cast 4 Regular CTD Deep up to 200 m. Radium isotopes at 200 m
 Cast lowered at 05:30; cast on deck at 05:42
 Cast 5 Regular CTD up to 100 m. Radium isotopes at 100 m
 Cast lowered at 05:55; cast on deck at 06:05
 Cast 6 Regular CTD up to 2 m. Radium isotopes at 2 m
 Cast lowered at 06:25; cast on deck at 06:28
 Cast 7 Regular CTD up to 75 m. POC for NIO, Vizag
 Cast lowered at 06:45; cast on deck at 06:56
 Cast 8 Regular CTD up to 25 m. POC for NIO, Vizag
 Cast lowered at 07:12; cast on deck at 07:17
 29.3.2014 07:30 Station completed

SK311/Station 4

29.3.2014 21:40 Station started. 16° 0.185'N 87° 0.014'E; Water depth 2816 m
 Cast 1 Clean CTD Deep up to 2700 m. Trace metals and isotopes
 Cast lowered at 21:55; cast on deck at 30.3.2014 00:54
 Cast 2 Regular CTD Deep up to 200 m. Radium isotopes at 200 m
 Cast lowered at 01:10; cast on deck at 02:00
 Cast 3 Regular CTD up to 100 m. Radium isotopes at 100 m
 Cast lowered at 02:22; cast on deck at 02:42
 Cast 4 Regular CTD up to 2 m. Radium isotopes at 2 m
 Cast lowered at 03:00; cast on deck at 03:03
 Cast 5 Clean CTD Shallow up to 100 m. Trace metals and isotopes
 Cast lowered at 03:15; cast on deck at 03:37
 Cast 6 Regular CTD up to 10 m. POC for NIO, Vizag
 Cast lowered at 03:50; cast on deck at 03:57
 Cast 7 Regular CTD Deep up to 2700 m. Oxygen probe; Ra isotopes at 400 m
 Cast lowered at 04:45; cast on deck at 08:08
 Cast 8 Deepsea Gravity corer. Water depth 2805 m
 Started at 08:10; ended at 12:20
 2.75 m core obtained

30.3.2014 12:30 Station completed after Bongo net

SK311/Station 5

31.3.2014 02:00 Station started. 14° 0.210'N 87° 0.061'E; Water depth 3094.8 m
Cast 1 Clean CTD Deep up to 3000 m. Trace metals and isotopes
Cast lowered at 02:35; cast on deck at 05:30
Each one of 300m and 200m bottles did not close (Position 3 & 4 magnets are rusted and not getting triggered)
Cast 2 Regular CTD Deep up to 3000 m. Oxygen probe; Ra isotopes at 400 m
Cast lowered at 05:47; cast on deck at 09:00
Cast 3 Clean CTD Shallow up to 150 m. Trace metals and isotopes
Cast lowered at 09:10; cast on deck at 09:30
Cast 4 Regular CTD Deep up to 200 m. Radium isotopes at 200 m
Cast lowered at 09:40; cast on deck at 09:58
Cast 5 Regular CTD up to 100 m. Radium isotopes at 100 m
Cast lowered at 10:18; cast on deck at 10:26
Cast 6 Regular CTD up to 2 m. Radium isotopes at 2 m
Cast lowered at 10:37; cast on deck at 10:42
Cast 7 Regular CTD up to 75 m. POC for NIO, Vizag
Cast lowered at 10:53; cast on deck at 10:59
Cast 8 Regular CTD up to 25 m. POC for NIO, Vizag
Cast lowered at 11:13; cast on deck at 11:18
31.3.2014 11:30 Station completed after Bongo net

SK311/Station 6

01.4.2014 07:30 Station started. 11° 0.780'N 87° 0.024'E; Water depth 3450.3 m
Cast 1 Clean CTD Deep up to 3350 m. Trace metals and isotopes
Cast lowered at 07:54; cast on deck at 10:39
Cast 2 Regular CTD Deep up to 3350 m. Oxygen probe; Ra isotopes at 400 m
Cast lowered at 10:47; cast on deck at 14:20
Oil leakage in the winch tank; while this was getting repaired, clean CTD was used for bulk sampling.
Cast 3 Clean CTD Deep up to 200 m. Radium isotopes at 200 m, 100 m and 2 m
Cast lowered at 14:34; cast on deck at 14:53
Cast 4 Clean CTD Deep up to 200 m. POC (NIO, Vizag) at 100, 75, 50, 25, 10, 2 m
Cast lowered at 15:25; cast on deck at 15:38
Cast 5 Clean CTD Shallow up to 350 m. Trace metals and isotopes
Cast lowered at 16:20; cast on deck at 16:48
Cast 6 Deepsea Gravity corer. Water depth 3447.9 m
Started at 17:00; ended at 20:00
No core obtained; siliceous ooze on core catcher, which was spoiled due to rocky terrain.
1.4.2014 20:10 Station completed after Bongo net

SK311/Station 7

2.4.2014 16:30 Station started. 8° 1.022'N 86° 59.928'E; Water depth 3768.7 m
Cast 1 Clean CTD Deep up to 3650 m. Trace metals and isotopes
Cast lowered at 17:10; cast on deck at 21:15
AT is having problem. After 1 hour this was rectified.
Cast 2 Regular CTD Deep up to 3600 m. Oxygen probe; Ra isotopes at 400 m
Cast lowered at 21:34; cast on deck at 3.4.2014 01:57
Cast 3 Clean CTD Deep up to 100 m. POC (NIO, Vizag) 100, 75, 50, 25, 10, 2 m
Cast lowered at 02:00; cast on deck at 02:16
Cast 4 Regular CTD Deep up to 200 m. Radium isotopes at 200 m
Cast lowered at 02:24; cast on deck at 02:37
Cast 5 Regular CTD up to 100 m. Radium isotopes at 100 m
Cast lowered at 02:49; cast on deck at 02:57
Cast 6 Regular CTD up to 2 m. Radium isotopes at 2 m
Cast lowered at 03:10; cast on deck at 03:17
Cast 7 Clean CTD Shallow up to 300 m. Trace metals and isotopes
Cast lowered at 03:23; cast on deck at 03:55
Cast 8 Deepsea Gravity corer. Water depth 3765 m
Started at 04:10; ended at 07:50
1.5 m core obtained
3.4.2014 08:00 Station completed

SK311/Station 8

4.4.2014 05:30 Station started. 5° 0.563'N 86° 59.754'E; Water depth 4106.8 m; chartered depth 3850 m; Swell 2 m
Cast 1 Clean CTD Deep up to 4000 m. Trace metals and isotopes
Cast lowered at 06:25; cast on deck at 10:18
While taking CTD on deck, cable sheath got crunched in the pulley. 10 m wire is cut and reconnected (Though there was no problem with electrical connection).
Cast 2 Regular CTD Deep up to 4000 m. Oxygen probe; Ra isotopes at 400 m
Cast lowered at 10:30; cast on deck at 14:05
Ball bearing of the winch is making noise and heat was produced due to faulty ball bearing. This requires replacement at shore.
Cast 3 Regular CTD Deep up to 100 m. Radium isotopes at 100 m
Cast lowered at 14:18; cast on deck at 14:33
Cast 4 Regular CTD up to 200 m. Radium isotopes at 200 m
Cast lowered at 14:55; cast on deck at 15:09
Cast 5 Regular CTD up to 2 m. Radium isotopes at 2 m
Cast lowered at 15:15; cast on deck at 15:21
Cast 6 Regular CTD up to 50 m. POC for NIO, Vizag
Cast lowered at 15:29; cast on deck at 15:36
Cast 7 Regular CTD up to 10 m. POC for NIO, Vizag

Cast 8 Cast lowered at 15:56; cast on deck at 16:00
 Clean CTD Shallow up to 200 m. Trace metals and isotopes
 Cast lowered at 16:18; cast on deck at 16:42
 4.4.2014 17:00 Station completed with Bongo net

SK311/Station 9

05.04.2014 13:30 Station started. 2° 04.10'N 87° 0.031'E; Water depth 4449 m
 Cast 1 Clean CTD Deep up to 4300 m. Trace metals and isotopes
 Cast lowered at 13:50; cast on deck at 17:30. CTD tension meter stopped
 at 4340 m. Last sample collected at 4300 m depth.
 Cast 2 Regular CTD Deep up to 4340 m. Oxygen probe; Ra isotopes at 400 m
 Cast lowered at 18:30; cast on deck at 21:19
 Cast 3 Clean CTD Shallow up to 1200 m. Trace metals and isotopes
 Cast lowered at 21:26; cast on deck at 23:00
 Cast 4 Regular CTD Deep up to 200 m. Radium isotopes at 200 m
 Cast lowered at 23:10; cast on deck at 23:23
 Cast 5 Regular CTD up to 100 m. Radium isotopes at 100 m
 Cast lowered at 23:36; cast on deck at 23:46
 Cast 6 Regular CTD up to 2 m. Radium isotopes at 2 m
 Cast lowered at 23:55; cast on deck at 06.04.2014 00:00
 Cast 7 Regular CTD up to 100 m. POC for NIO, Vizag
 Cast lowered at 00:10; cast on deck at 00:30
 Cast 8 Regular CTD up to 50 m. POC for NIO, Vizag
 Cast lowered at 00:36; cast on deck at 00:41
 Cast 9 Regular CTD up to 10 m. POC for NIO, Vizag
 Cast lowered at 01:00; cast on deck at 01:07
 Cast 10 Clean CTD Shallow up to 150 m. Trace metals and isotopes
 Cast lowered at 01:24; cast on deck at 01:45
 Cast 11 Deep-sea Gravity corer with pinger. Water depth 4449 m
 Started at 02:30; ended at 06:20
 Corer penetrated fully. Due to CaCO₃, the core sediment got washed
 away. No core obtained. Pinger did not work.
 06.04.2014 06:30 Station completed

SK311/Station 10

08.04.2014 02:30 Station started. 3° 30.040'S 84° 0.028'E; Water depth 5005.2 m
 Cast 1 Clean CTD Deep up to 4800 m. Trace metals and isotopes
 Cast lowered at 02:50; cast on deck at 07:00. Bottle #4 did not close
 though rust is cleaned in the rosette.
 Cast 2 Regular CTD Deep up to 4800 m. Oxygen probe; Ra isotopes at 400 m
 Cast lowered at 07:25; cast on deck at 11:13
 Cast 3 Clean CTD Shallow up to 1200 m. Trace metals and isotopes
 Cast lowered at 11:25; cast on deck at 12:25
 Cast 4 Regular CTD Deep up to 200 m. Radium isotopes at 200 m

Cast 5 Cast lowered at 12:33; cast on deck at 12:50
Regular CTD up to 100 m. Radium isotopes at 100 m
Cast lowered at 13:11; cast on deck at 13:21

Cast 6 Regular CTD up to 2 m. Radium isotopes at 2 m
Cast lowered at 13:41; cast on deck at 13:44

Cast 7 Regular CTD up to 100 m. POC for NIO, Vizag
Cast lowered at 14:00; cast on deck at 14:10

Cast 8 Regular CTD up to 50 m. POC for NIO, Vizag
Cast lowered at 14:25; cast on deck at 14:35

Cast 9 Regular CTD up to 10 m. POC for NIO, Vizag
Cast lowered at 14:48; cast on deck at 14:52

Cast 10 Clean CTD Shallow up to 150 m. Trace metals and isotopes
Cast lowered at 15:03; cast on deck at 15:25

Cast 11 MPN up to 500m depth; Lowered for foram collection.
Cast lowered at 15:58; cast on deck at 16:49

600-300m	Net1	16:21
300-200m	Net2	16:34
200-100m	Net3	16:38
100-50m	Net4	16:43
50-surface	Net5	16:46

Flow meters in and out are found to be faulty.

Cast 12 Deepsea Gravity corer. Water depth 5000 m
Started at 17:05; ended at 21:50
30 cm core obtained. The bottom is hard soil/rock. The corer got bent.

08.4.2014 22:00 Station completed

SK311/Station 11

10.4.2014 14:50 Station started. 8° 29.9'S 80° 48.122'E; Water depth 5281 m

Cast 1 Clean CTD Deep up to 5100 m. Trace metals and isotopes
Cast lowered at 15:41; cast on deck at 19:46

Cast 2 Regular CTD Deep up to 5100 m. Oxygen probe; Ra isotopes at 400 m
Cast lowered at 20:02; cast on deck at 02:48

Cast 3 Clean CTD Shallow up to 1500 m. Trace metals and isotopes
Cast lowered at 02:52; cast on deck at 04:32

Cast 4 Regular CTD Deep up to 200 m. Radium isotopes at 200 m
Cast lowered at 04:40; cast on deck at 05:07

Cast 5 Regular CTD up to 100 m. Radium isotopes at 100 m
Cast lowered at 05:25; cast on deck at 05:39

Cast 6 Regular CTD up to 2 m. Radium isotopes at 2 m
Cast lowered at 06:00; cast on deck at 06:03

Cast 7 Regular CTD up to 100 m. POC for NIO, Vizag
Cast lowered at 06:20; cast on deck at 06:33

Cast 8 Regular CTD up to 50 m. POC for NIO, Vizag
Cast lowered at 06:50; cast on deck at 06:57

Cast 9 Regular CTD up to 10 m. POC for NIO, Vizag

Cast 10	Cast lowered at 07:12; cast on deck at 07:15 Clean CTD Shallow up to 200 m. Trace metals and isotopes
Cast 11	Cast lowered at 07:43; cast on deck at 08:06 MPN connection problems. Not used.
11.4.2014 08:30	Station completed with bongo net

SK311/Station 12

13.4.2014 08:00	Station started. 14° 29.456'S 76° 59.688'E; Water depth 5281 m
Cast 1	Clean CTD Deep up to 5100 m. Trace metals and isotopes Cast lowered at 08:17; cast on deck at 14:23 Gusty winds, swells make difficult to position ship with DP winch wire speed was very slow. Bottles #3, 4 did not close. Magnetic trigger did not work.
Cast 2	Regular CTD Deep up to 5100 m. Oxygen probe; Radium isotopes at 400 m, 150m for ²¹⁰ Po. Cast lowered at 14:26; cast on deck at 19:32. Altimeter attached.
Cast 3	Clean CTD Shallow up to 800 m. Trace metals and isotopes Cast lowered at 19:30; cast on deck at 21:41. Bottles #3, 4 again did not close. 2m sample is taken from regular CTD
Cast 4	Regular CTD Deep up to 200 m. Radium isotopes at 200 m Cast lowered at 21:47; cast on deck at 22:03
Cast 5	Regular CTD up to 100 m. Radium isotopes at 100 m Cast lowered at 22:15; cast on deck at 22:25
Cast 6	Regular CTD up to 2 m. Radium isotopes at 2 m Cast lowered at 22:39; cast on deck at 22:45
Cast 7	Regular CTD up to 100 m. POC for NIO, Vizag Cast lowered at 23:08; cast on deck at 23:20
Cast 8	Regular CTD up to 50 m. POC for NIO, Vizag Cast lowered at 23:38; cast on deck at 23:46
Cast 9	Regular CTD up to 10 m. POC for NIO, Vizag Cast lowered at 23:59; cast on deck at 00:04
Cast 10	MPN-1 Cast lowered at 14.04.2014 00:14; cast on deck at 00:53 300-200 m 0032 200-150 m 0040 150-100 m 0043 100-50 m 0047 50-0 m 0050
Cast 11	MPN-2 Cast lowered at 01:12; cast on deck at 01:40 200-100 m 0124 100-50 m 0134 50-0 m 0135
14.04.2014 02:00	Station completed

SK311/Station 13

16.04.2014 04:30 Station started. 17° 59.977'S 72° 32.355'E; Water depth 4423 m
 Cast 1 Regular CTD Deep up to 200 m. Radium isotopes at 200 m
 Cast lowered at 05:28; cast on deck at 05:52. Sea is choppy, sea state 5.
 Due to swells, CTD was going along ship hull. Position of the ship corrected
 Cast 2 Regular CTD Deep up to 100 m. Radium isotopes at 100 m
 Cast lowered at 06:09; cast on deck at 06:22.
 Cast 3 Regular CTD Deep up to 10 m. Radium isotopes at 10 m
 Cast lowered at 06:36; cast on deck at 06:39.
 Cast 4 Regular CTD up to 100 m. POC for NIO, Vizag
 Cast lowered at 06:52; cast on deck at 07:02
 Cast 5 Regular CTD up to 50 m. POC for NIO, Vizag
 Cast lowered at 07:14; cast on deck at 07:22
 Cast 6 Regular CTD up to 10 m. POC for NIO, Vizag
 Cast lowered at 07:34; cast on deck at 07:36
 Cast 7 Clean CTD
 Cast lowered at 07:48; cast on deck at 07:56
Due to rough sea and huge swells, wire slackened while lowering CTD. As per captain's advice station cancelled. Due to ship movement, slackening wire and chances of jumping out of pulley were seen several times.
 16.4.2014 08:00 Station completed

SK311/Station 14

17.04.2014 17:30 Station started. 23°53.360'S 69°86.091'E; Multi beam Echosounder started at 17:30 and stopped at 21:00. Water depth 3375 m – 3442m.
 Cast 1 Depth 3578 m (Multibeam Echosounder)
 Regular CTD
 Cast lowered at 21:10 and ended at 02:15
 Plume layer is not found (Turbidity layer).
 Cast 2 Regular CTD
 Cast lowered at 04:12; cast on deck at 07:10
 Plume is located between 2700-3100
 Samples collected for Nutrients, DO, Methane, pH, Alkalinity and TM from depths 3150, 3060, 3000, 2950, 2900, 2850, 2800, 2750, 2600, 2500, 2000 and 1800 m. Samples were collected in cubitainers and filtered in the clean van for TM.
 Cast 3 Regular CTD shallow up to 1500 m. Nutrients and trace elements
 Cast lowered at 09:00 and cast on deck at 10:20.
 Depths: 1500, 1200, 1000, 800, 500, 300, 200, 100, 75, 50, 25 and 10 m.
 Cast 4 Deep sea Grab. Water depth 3300 m
 23°52.560'S 69°35.88'E
 Started at 11:04; ended at 12:55
 Grab did not close and sent again at 13:00 ended at 15:30
 Sediment obtained
 18.4.2014 15:30 Station completed with bongo net

SK311/Station 15

19.4.2014 05:10 Multibeam Echosounder on at 05:25 to 10:00 hrs.
25°11.116'S 69°59.809'E
Depth – 3229 (Echo sounder)
Cast 1 Regular CTD Deep up to 3300 m.
Cast lowered at 05:44; cast on deck at 08:12
Cast 2 Deepsea Grab. Water depth 3400 m
25°9.937'N 69°59.735'E
Started at 9:00; ended at 11:50
Volcanic crust. No sediment.
19.4.2014 12:00 Station completed

SK311/Station 16

19.4.2014 13:06 25°19.204'S 70°2.431'E. Water depth 2442 m (MBES). Kairie system
Cast 1 Regular CTD Deep up to 2400 m. Trace metals
Cast lowered at 13:49; cast on deck at 16:29
Depth: 2400, 2350, 2320, 2300, 2260, 2230, 2200, 2150, 2100, 2000, 1800 m.
Turbidity layer at 2300 – 1900 m.
Cast 2 Clean CTD Deep up to 2260 m. Nutrients, Trace metals, Nd isotopes, pH, Alkalinity and ²³⁴Th.
Cast lowered at 17:40; cast on deck at 19:25
Depths: 2260, 2000, 1500, 1200, 1000, 800, 500, 300, 200, 150, 100, 75, 50, 25, 12 and 5 m.
Cast 3 Regular CTD Deep up to 400 m. Radium isotopes at 400 m
Cast lowered at 20:05; cast on deck at 20:25
Cast 4 Regular CTD Deep up to 200 m. Radium isotopes at 200 m
Cast lowered at 20:41; cast on deck at 20:52
Cast 5 Regular CTD up to 100 m. Radium isotopes at 100 m
Cast lowered at 21:15; cast on deck at 21:22
Cast 6 Regular CTD up to 5 m. Radium isotopes at 5 m
Cast lowered at 21:35; cast on deck at 21:37
Cast 7 Regular CTD up to 100 m. POC for NIO, Vizag
Cast lowered at 21:48; cast on deck at 21:57
Cast 8 Regular CTD up to 50 m. POC for NIO, Vizag
Cast lowered at 22:12; cast on deck at 22:18
As sea was windy and swells were 3-4 m waited for morning to do grab sampling.
Cast 9 Deepsea Grab. Water depth 2500 m
25°18.484'S 70°1.728'E
Started at 06:00; ended at 09:00
No sediment came. Moved a bit and attempted again.
Cast 10 Deepsea Grab.
Started at 09:25; ended at 11:45

	Sediment with forams obtained.
Cast 11	MPN Cast lowered at 11:45; cast on deck at 12:05
	300-200 m 1155
	200-150 m 1158
	150-100 m 1159
	100-50 m 1200
	50-0 m 1201
20.4.2014 12:15	Station was completed with bongo net and started proceeding to Port Luis, Mauritius.

Analytical Procedures

Samples collected during the cruise SK-311 cruise are given below:-

- 1) Trace Metal: Two L of seawater samples collected after pressurized filtration of seawater filtered through 0.2 μm Acropak filters. A total of 285 numbers of trace metal samples were collected from different depths of 14 stations. Onboard analysis of Fe and Al were carried out using Flow Injection Analysis System (FIAS).
- 2) Neodymium isotopes: About 15-18 L of seawater samples were collected after pressurized filtration of seawater filtered through 0.2 μm Acropak filters. A total of 63 samples of different depths from 5 different stations.
- 3) ΣCO_2 : About 200 mL unfiltered seawater samples were collected for ΣCO_2 measurements. A total of 80 samples of different depths were collected from 8 different sampling stations.
- 4) TOC: About 300 mL seawater were collected for TOC (Total Organic Carbon) Measurements. A total of 159 samples of different depths were collected from 14 different sampling stations.
- 5) $\delta^{18}\text{O}$: 60 mL unfiltered seawater were collected for stable oxygen isotope measurements. A total of 82 samples of different depths were collected from 9 different sampling stations.
- 6) ^{14}C : 500 mL unfiltered seawater were collected for ^{14}C measurements. A total of 89 samples of different depths were collected from 8 different sampling stations.
- 7) Salinity: About 300 mL unfiltered seawater samples were collected for salinity measurements onboard. Several samples of different depths were collected from different sampling stations to compare with CTD measurements.

- 8) ^{234}Th : 4 L of seawater samples were collected measurements of ^{234}Th isotopes. Th was co-precipitated with MnO_2 and counted onboard for beta activity using Beta counting system set up on board to determine the ^{234}Th content. A total of 135 samples of different depths were collected from 13 different sampling stations.
- 9) $^{210}\text{Po}/^{210}\text{Pb}$: 12 L of seawater samples were collected for $^{210}\text{Po}/^{210}\text{Pb}$ measurements. These isotopes were pre-concentrated using $\text{Fe}(\text{OH})_3$ precipitation after adding ^{209}Po spike and Pb carrier. The precipitate is taken to the laboratory for radiochemical separation and counting by Alpha Spectrometer. A total of 77 samples of different depths were collected from 7 different sampling stations.
- 10) ^{228}Ra , ^{226}Ra : About 100 L of seawater sample were collected were collected and pre-concentrated on board using Mn fibre column for ^{228}Ra , ^{226}Ra isotope measurements. A total of 56 samples of different depths were collected from 14 different sampling stations.
- 11) Aerosol: PM_{10} air samples were collected from High Volume Air Sampler in Quartz filter papers. Filters were collected in 24 hours interval only in sailing conditions. A total 12 numbers of samples were collected from 24/03/2014 to 23/04/2014.
- Air samples were also collected in Teflon filters through Staplex sampler for trace metal and Sr and Nd isotopic analyses. A total of 12 samples were collected from 24/03/2014 to 23/04/2014.
- 12) AIMS: AIMS is a continuous monitoring system for few water soluble major cations and anions. It collects and measures samples with a resolution time of one hour. It has been operating onboard since 24/03/2014 to 24/04/2014.
- 13) Rain Water: Rain water samples were collected whenever available using a funnel system for stable isotope and other miscellaneous measurements. A total of 3 samples were collected during the period 24/03/2014 to 24/04/2014 in different raining events.
- 14) Sediment Core: Gravity Corer was used to get sediment cores from different locations. A total 4 numbers of sediment cores were taken from different places in the SK 311 cruise.

Samples collected by NIO, RC, Visakhapatnam in the SK 311 cruise. Details are given below:-

- 1) Nutrients: 150 mL of unfiltered seawater samples were collected for nutrients (Ammonia, Nitrite, Phosphate, Silicate and Nitrate) measurements onboard. A total of 286 samples of different depths were collected and measured onboard from 14 different sampling locations.
- 2) Dissolved Oxygen: 60 mL of unfiltered seawater samples were collected for dissolved Oxygen measurements. A total of 286 samples of different depths were collected and measured onboard from 14 different sampling locations.
- 3) pH & Alkalinity: 60 mL of unfiltered seawater samples were collected for pH and Alkalinity measurements onboard. A total of 286 samples of different depths were collected and measured onboard from 14 different sampling location.

RESULTS

The following figures show results of the onboard measurements made on the various water profiles at each station.

SCIENTIFIC OBSERVATIONS

River fluxes: Fresh water influx is the most important external component in the Bay of Bengal. In addition to the considerable buoyancy introduced to surface waters and to the dissolved load, the suspended sediments react with seawater to initiate desorption-adsorption reactions. Alkaline earths and REEs are also supply a source-specific signature. In this region, nutrients and their cycling, and the influence of metal-organic interactions on them, are important.

Atmospheric input: Perhaps the most important atmospheric input is rainfall that carries particles and aerosols and contributes buoyancy to surface waters. The region does not receive significant Saharan dust flux. However input of continental dust and of rainfall during the monsoon and under the influence of episodic events (cyclones, fires) requires further investigation. Anthropogenic inputs in the form of acid rain are significant.



Fig. 3: Clean CTD getting lowered into the sea to obtain Physical Parameters, samples for trace elements, isotopes and Nutrients in the vertical profile of seawater column.

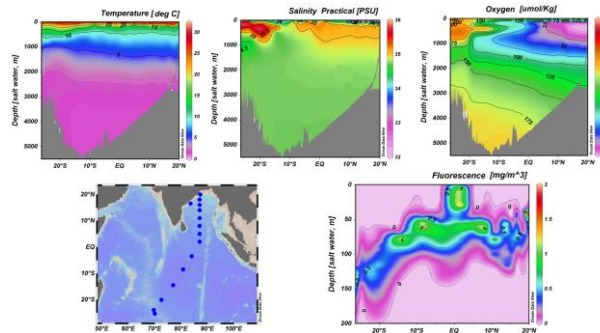


Fig. 4 A section of Physical Parameters in the vertical profiles of seawater column along the ship transect of SK-311.

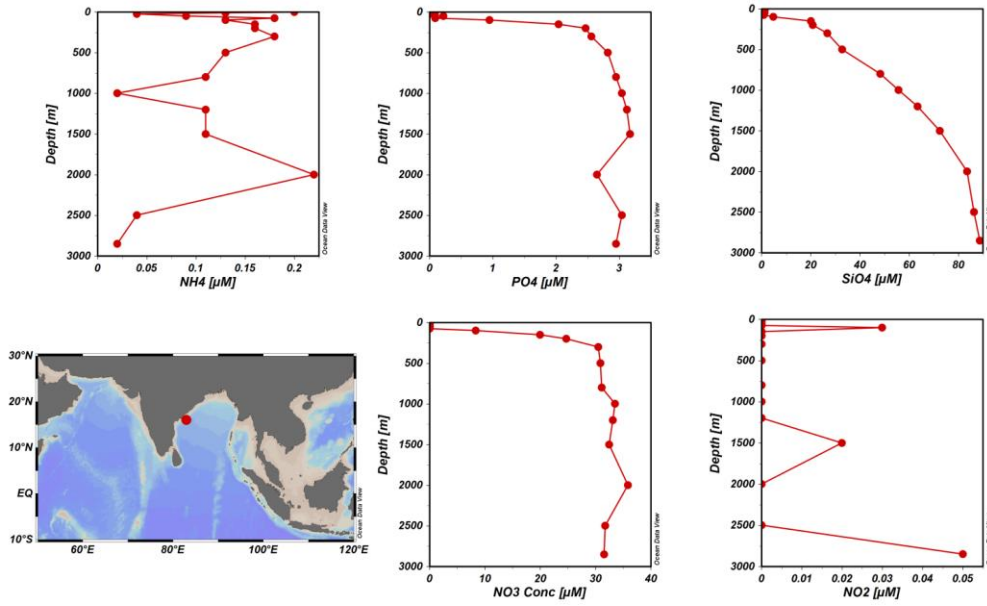


Fig. 5: Variation of Nutrients in the vertical profile of seawater column at the station SK-311-01.

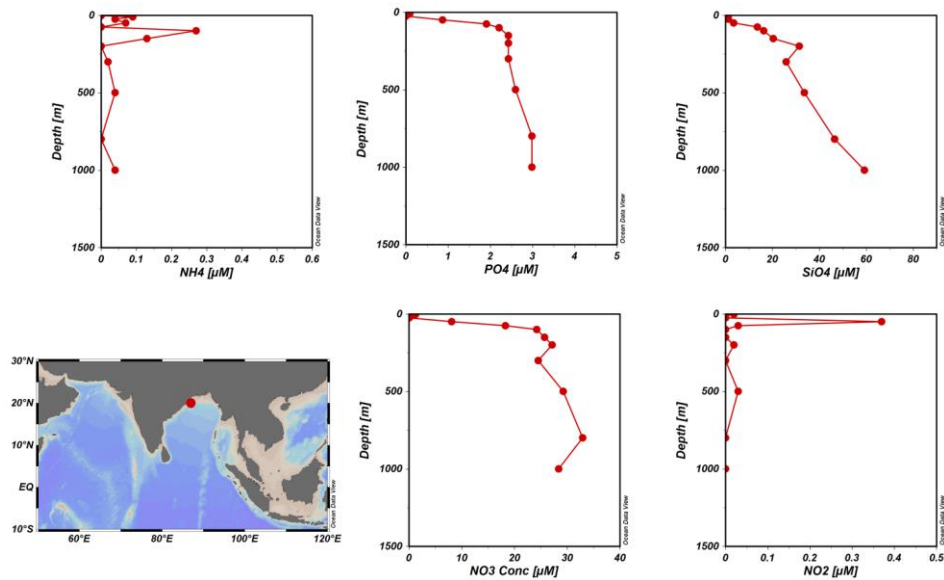


Fig. 6: Variation of Nutrients in the vertical profile of seawater column at the station SK-311-02.

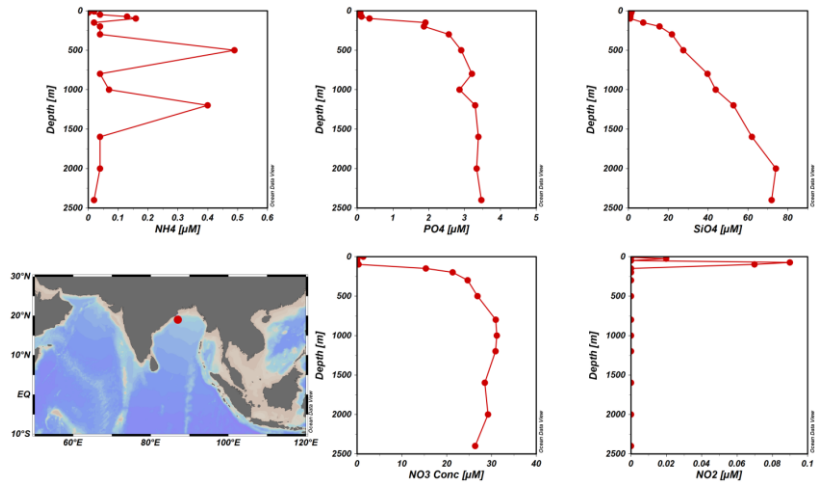
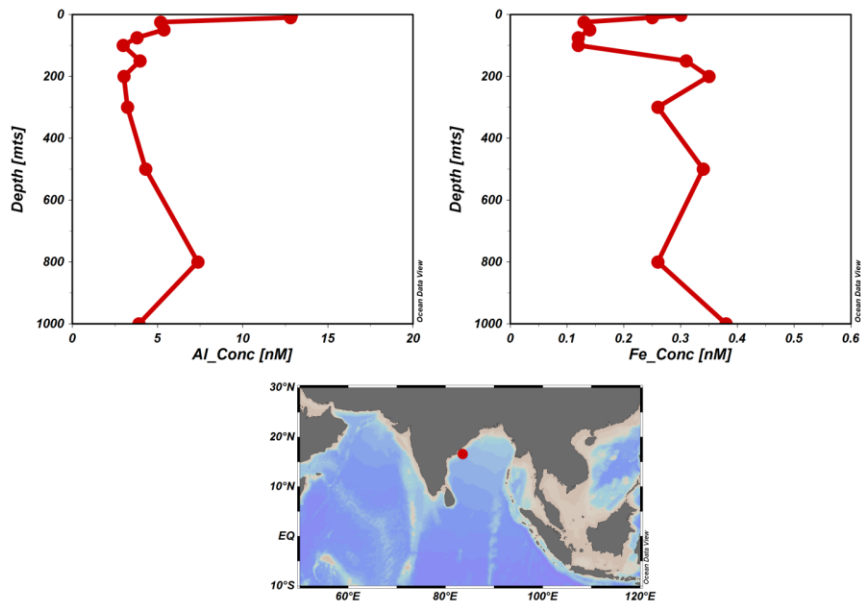


Fig. 7: Variation of Nutrients in the vertical profile of seawater column at the station SK-311-03.



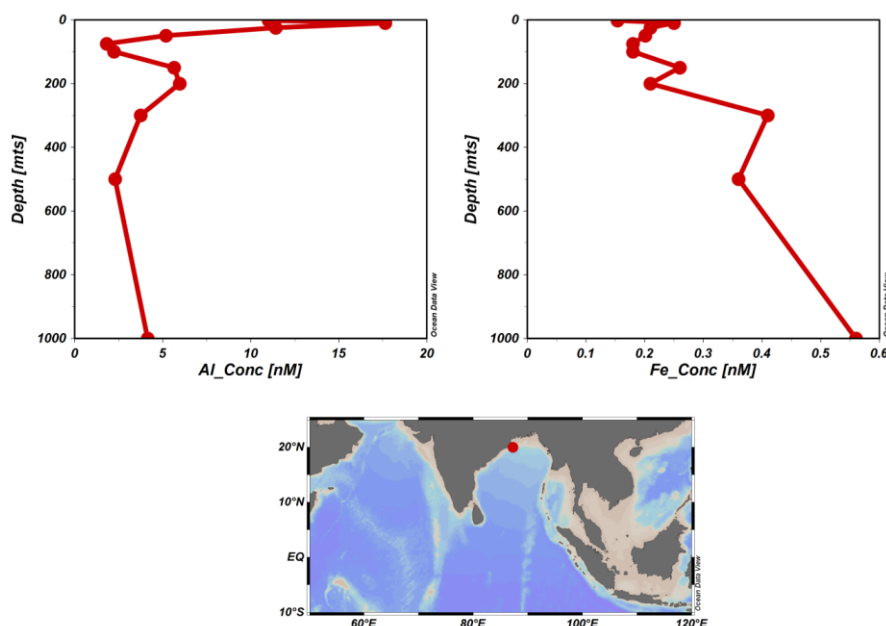


Fig. 8: Variation of Al and Fe in the vertical profile of seawater column at the station SK-311-02 (top) and SK-311-03 (bottom).

Productivity controls: Productivity is limited in this region by nutrient supply from river water, SGD and vertical mixing, N_2 fixing and the ballast effect that removes live biomass to the aphotic zone. In spite of the fact of low biological production and a less intense OMZ compared to the Arabian Sea, intense N_2O production occurs in the Bay of Bengal shelf waters.

Indonesian throughflow: The Indonesian Through Flow (ITF) represents a major element of global meridional overturning circulation, as warm surface water from the Pacific moves into the Indian Ocean. Part of the ITF water is influenced by sediment-water exchange reactions as it passes over the shallow shelf regions surrounding Indonesia and Southeast Asia. Sources and sinks of TEIs associated with these exchange processes should be quantified. Exchange of water across the Indonesian archipelago between the old Pacific waters and younger Indian Ocean water of different biogeochemical signatures can be constrained by stable isotopes (C, N, O) and radioactive isotopes (^{14}C , ^{226}Ra)



Fig. 9. Sample collection for on board processing of seawater for ^{234}Th measurement to get carbon export flux from Surface Ocean

Residence time of surface water: The Bay of Bengal is an integrating basin where concentrations are affected by external fluxes and internal recycling. A key parameter in evaluating these effects is the residence time of the surface water.

Deep sediment sources: The Bengal submarine fan extends to 12°S . The deposition of its sediments is modulated by the glacial-interglacial changes over the geological time scale. Paleo-depositional and diagenetic proxies of productivity, climate, continental weathering, hydrothermal and geothermal inputs are traceable by the analysis of different inorganic and organic proxies. Sediment cores collected from this region will help in understanding these processes.

HYDROTHERMAL STUDIES OVER CENTRAL INDIAN RIDGE IN THE INDIAN OCEAN

Under the Hydrothermal Program in SK311 cruise, we conducted four CTD (14, 14-1, 15 and 16) and three grab operations. They were done at two locations (Sta. #14 and 16) near known vents fields and a potential geological location at Rodriguez triple junction on central Indian ridge in Indian Ocean (Sta. #15).

The Edmond vent field (23°52.7'S, 69°35.8'E) is about 160 km NNW from the Kairei vent field. The Edmond vent field also occurs on the eastern rift valley wall and at water depth of 3290–3320 m. The main area of the high-temperature vent field is about 40 m.

In this vent field we carried out two CTD stations; the first CTD cast is drifted away from the vent field due to bad weather along with huge swells of 3 to 4 m. Subsequently, we did a second cast on vent location and this time the plume was observed as 200 m thick turbidity layer at depths between 2850 and 3050 m with maximum intensity anomalous layer about 0.07 NTU (Fig. 1).

Water samples were collected for the chemical, methane and biological measurements in the plume depths by PRL and NIO (Visakhapatnam) scientists. About one nautical mile distance from north side of the vent location we collected sediments with grab sampler. The sediments appeared brownish in color and are preserved for offshore laboratory analysis. Initially the sediments were observed under microscope which are mostly planktonic foraminiferal shells and tropical and subtropical common species of planktonic foraminiferal species *Orbulina universa* was abundant. The sediment samples are stored in ship cold room.

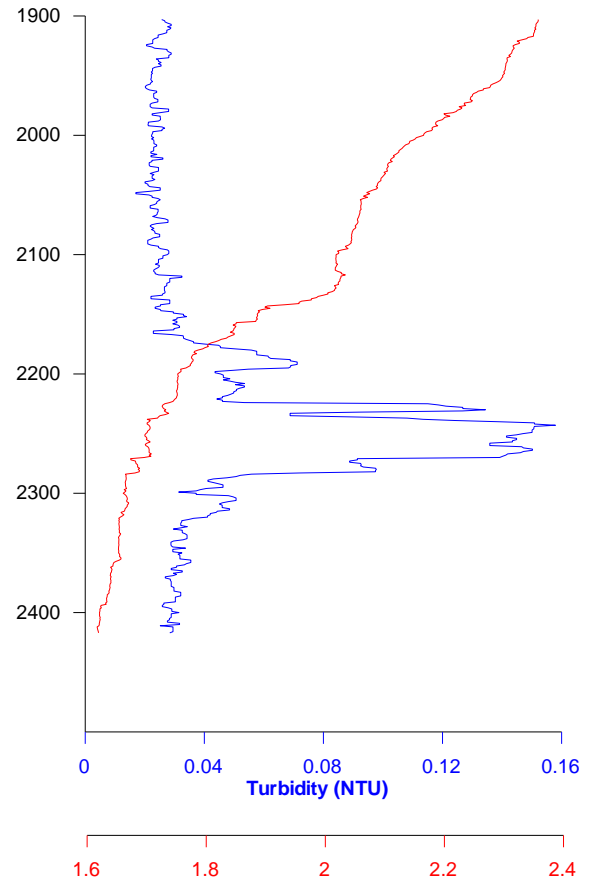
Second cast was made on small hill structure near the transform fault area in which we identified ultramafics and sulphide in the previous dredge station (SK299). But we did not see any anomalous turbidity layer in water column. After this, grab was taken on the hill and it contained about 1 kg single piece of volcanic crust. The rock is basaltic with surface covered with the ferromanganese deposits.

The Kairei vent field (25°19.2'S, 70°02.4'E) was first discovered by scientists from Japan using the ROV Kaiko on board R/V Kairei in August 2000. The hydrothermal venting occurs high on the eastern rift valley wall, where the seafloor is 2420–2460 m, and is about 1800 m shallower than the maximum rift valley depth.

We lowered CTD exactly on the vent field. Very vigorous turbid layer was observed from 2180 to 2320 m depths (Fig. 2). Water samples were collected for the full cast including the turbidity layer. We did grab sampling which brought the white calcareous shell type of sediment and small fossil gastropod shells and foraminifera shells along with some unknown fossil calcareous shells.

**SK311-CTD16 - Downcast
Kaiei vent field**

**Lat - 25°19.002'S
Long - 70°2.6'E**



SK311-CTD14 cast2 - Downcast
Edmond vent field

Long - 69°37.75'E
Lat - 23°52.82'S

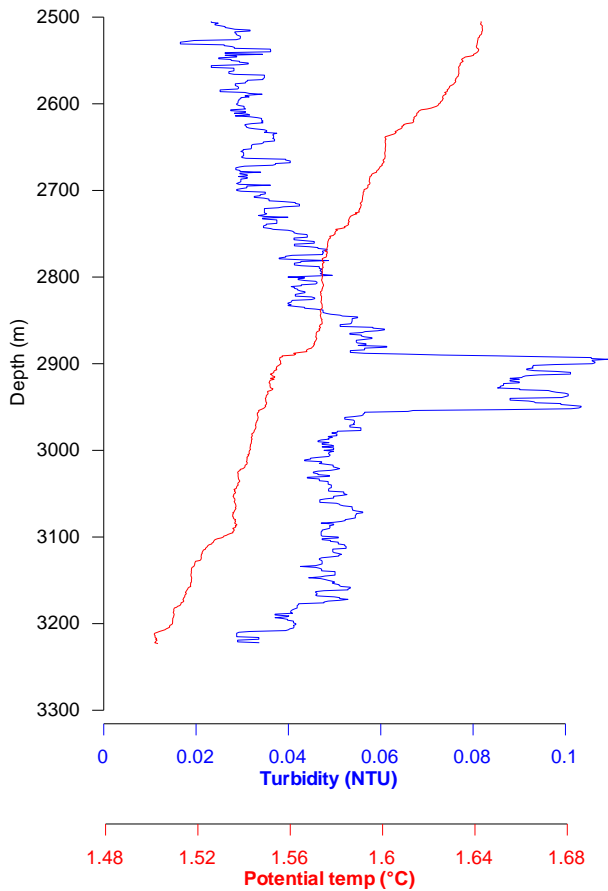


Figure 10. Temperature and Turbidity profile of station 14

ACKNOWLEDGEMENTS

I am highly grateful and thankful to Dr. Shailesh Nayak, Secretary, MoES for his generous support and encouragement to the GEOTRACES

scientific programme. On behalf of all scientific participants, I thank Master Captain M. S. Pangtey and the ship staff of ORV Sagar Kanya for their help, hospitality and excellent support during the SK-311 cruise. They made our stay on Sagar Kanya a very pleasant time, despite rough weather during the last part of the cruise. I am grateful to Dr. S Rajan, Director NCAOR for his support and encouragement in providing ship time for this cruise. The Norinco engineers onboard were very kind and helpful in our various deck operations, onboard measurements and scientific requirements. I would like to thank Mr. M. M. Subramaniam, NCAOR and its ship cell, who took special interest in our scientific requirements for this cruise and were very supportive with respect to our requirements for this GEOTRACES cruise and made appropriate logistics arrangements. And finally, I would like to thank all scientific participants of this cruise from various institutions, who with their dedicated hard work and cooperation made this cruise a grand success.

Dr. R. Rengarajan

Chief Scientist

Physical Research Laboratory
Navrangpura, Ahmedabad 380 009

Annexure - I

Technical Observation and Suggestions

ORV Sagar Kanya Cruise # 311

Observations & suggestions:

- 1) The new ship CTD winch wire had kinks at about 2000 m due to which we have to operate the old winch as we require deeper CTD casts. The ball bearings were found to be damaged in this winch, thus making noise and getting heated and we could not operate at optimal speed. This requires replacement/repairs.
- 2) Sagar Kanya being an oceanographic research vessel, scientific instruments and labs onboard should be in the best of the working condition with proper and routine maintenance. The ship has also provided efficient cooling system of the scientists cabins and port side and starboard side dry labs all through the cruise. Proliferation of bed bugs and cockroaches were put under effective control throughout the cruise.
- 3) Auto Analyser is major tool for any chemical oceanography cruise. In its absence, we could perform nutrient measurement onboard manually with our spectrometer. We should go for a latest new digital Auto Analyser.
- 4) MilliQ RO system tank developed leaks and requires replacement with a new one.
- 5) For onboard chemical processing of samples to measure short-lived radionuclides and acid-cleaning of bottles for trace metal collection, fume cupboard with good suction is required to remove acidic vapours. The present ones in both starboard and port side wet labs are not having sufficient suction due to the low capacity of the impeller motor assembly (500 cfm). A motor and blower assembly giving 1500 cfm of air replacement is required separately for each fume cupboard in the port and starboard labs for suitable use.

Annexure – II

SK-311 Participants

Physical Research Laboratory, Ahmedabad

- | | |
|------------------------|-------------------|
| 1. Dr. R. Rengarjan | Chief Scientist |
| 2. Ms. R. Chandana | JRF |
| 3. Mr. Venkatesh Cinni | JRF |
| 4. Mr. Shubha Anand | Project Associate |
| 5. Mr. Chinmay Shah | Project Associate |
| 6. Mr. Utsav Gandhi | Project Associate |

National Centre for Antarctica and Ocean Research, Goa

- | | | |
|-------------------------------|------------------|---------------------|
| 7. Ms. Lathika N. | Scientist-B | Dy. Chief Scientist |
| 8. Ms. Racheal Chacko | Res. Scientist-B | |
| 9. Mr. Arvapalli Srinivas Rao | Res. Scientist-B | |
| 10. Mr. Rupesh Sawant | Shipboard Asst. | |

National Institute of Oceanography, Goa

- | | |
|-----------------------------|-------|
| 11. Mr. Ralph Mevil D'Souza | PA-II |
|-----------------------------|-------|

National Institute of Oceanography, Regional Centre, Vishakapatnam

- | | |
|-------------------------|--------|
| 12. Mr. D.H. Bardhan | PA-II |
| 13. Mr. M. H. K. Prasad | PA-III |

Pondicherry University, Port Blair

- | | |
|--------------------------|------------------|
| 14. Mr. Muruganantham M. | Research Student |
|--------------------------|------------------|

Mangalore University, Mangalore

- | | |
|----------------------|----------------|
| 15. Mr. Naveen Kumar | Project Fellow |
|----------------------|----------------|

Engineers - M/s Norinco Pvt. Ltd

- | | |
|--------------------------------|------------------|
| 16. Mr. J. Viswanathan | Service Engineer |
| 17. Mr. G. K. Tharaneetharan | Service Engineer |
| 18. Mr. Narayanan Dhanasekaran | Service Engineer |
| 19. Mr. Vinu Jose | Service Engineer |
| 20. Mr. Manuel Michell Mathew | Service Engineer |

Annexure – III

Cruise Report – SK 311

Submitted by National Institute of Oceanography – Goa

Ralph D'Souza

The surface Velocity profiler (SVP) is a drifting buoy specifically designed to track ocean currents at a depth of 15 meters, which can be varied according to the length of the drogue.

The Key elements of the surface velocity profiler includes : the surface float which contains the telemetry system , sensor necessary to retrieve and transmit the required data, and the drogue that it is designed to hold the SVP in place on the ocean surface.

The following drifters which have been deployed also have a barometric pressure sensor which provides the atmospheric pressure along with SST (Sea surface temperature) and GPS position along with date and time.



Fig. 12. NIO – Goa (Met Ocean) drifters being deployed.

Also 96 SSS (sea surface salinity) Samples in 100 ml narrow neck plastic bottles were collected, which will be analyzed in NIO – Goa.

13 NIO – Goa (Met Ocean) drifters have been deployed and 5 NOAA – USA (Pacific Gyre) drifters have been deployed.

Drifter Deployment Details

Met Ocean (NIO)

Argo ID	Latitude	Longitude	Date	Time
133640	17 00N	86 59E	29/03/14	14:31
133641	14 59N	87 01E	30/03/14	19:21

133642	11 00N	87 00E	01/04/14	16:05
133643	09 00N	86 59.9E	02/04/14	09:40
133644	04 58N	86 59E	04/04/14	17:20
133645	02 54N	86 59E	05/04/14	07:27
133646	00 00N	85 49E	06/04/14	22:57
133647	04 01S	83 40E	09/04/14	02:31
133648	06 00S	82 23E	09/04/14	19:01
133649	10 00S	79 50E	11/04/14	20:51
133650	12 00S	78 35E	12/04/14	12:29
133651	18 30S	73 46E	15/04/14	13:59
133652	20 30S	72 07E	16/04/14	12:39

Pacific Gyre (NOAA)

Argo ID	Latitude	Longitude	Date	Time
126942	12 59N	86 59E	31/03/14	18:43
126943	06 59N	87 00E	03/04/14	14:42
126944	02 00S	84 49E	07/04/14	14:58
126945	08 05S	81 04E	10/04/14	11:35
126946	14 30S	76 54E	14/04/14	02:21

I would like to thank chief Scientist Dr. R. Rengarajan (PRL), Captain and his team, SK311 for providing me the chance to learn Filtration & Acidification, CTD operations. Also I would like to thank them for their advice, support and making the cruise enjoyable.

Annexure IV



**NATIONAL INSTITUTE OF
OCEANOGRAPHY
REGIONAL CENTRE, VISAKHAPATNAM**



CRUISE REPORT

ORV SAGAR KANYA - 311
(24th March to 24rd April, 2014)

Biogeochemical observations in the Bay of Bengal and Indian Ocean

Chief Scientist
Dr. R. Rengarajan (PRL)

Participants:

Name	Designation & Place of working
Mr. M. Harikrishna Prasad	PA III; NIO-RC, Waltair
Mr. Harsabardhan Dalabehera	PA II; NIO-RC, Waltair

Objective:

The main objective of this study is to identify and understand the process and quantify the fluxes those control the distribution of trace elements and their isotopic ratios in the ocean and understand biogeochemical processes in the ocean. In order to study biogeochemistry of this region, in this cruise we collected:

1. Water samples at different depths for analyses of biogeochemical parameters such as Dissolved Oxygen (DO), Total Chlorophyll (Chl a), HPLC pigments, Carbohydrates, Amino acids and Proteins (CAP compounds), pH, Alkalinity, Particulate Organic Carbon (POC), Nutrients, trace gases Nitrous Oxide (N₂O) and Methane (CH₄), Carbon isotopic composition of DIC (¹³C_{DIC}), Total Bacterial Count (TBC) and Phytoplankton
2. Zooplankton samples using Plankton Towing Net,
3. Surface sediment (grab) samples for Macro Benthic community structure, texture analyses.
4. To understand variability in trace gases like Methane, Nitrous Oxide and Carbon dioxide concentrations and possible mechanisms controlling them in the ocean and to estimate fluxes of these gases to atmosphere and microbial production and decomposition of organic matter on cycling of these trace gases.

Equipment brought from the NIO, Regional Centre, Visakhapatnam:

Name (No.)	Make
Potentiometer (1)	Metrohm
Spectrophotometer (1)	Shimadzu
Aspirators (2)	Cole Parmer

Sampling:

Samples for study were collected on board ORV Sagar Kanya (SK 311) from March 24 to April 23, 2014 in the Bay Of Bengal and Indian Ocean. The cruise covered up to date 15 transects, nine in the Bay Of Bengal and six in the Indian Ocean. Most of the stations covered comparatively deep water (~5000 m). Temperature and salinity data were collected using a clean CTD system. Water samples (All Basic parameters) were collected from ~ 25 isolated depths (near surface, 10 m, 25 m, 50 m, 75 m, 100 m, 150 m, 200 m and thereafter 100 m intervals up to 1000 m and 500 m intervals' up to 5000m depth). Bulk water samples (For all filtrations) were collected using general CTD.

Parameters measured on board:

Basic chemical Parameters:

1. DO - Metrohm Titrator (Grasshoff et al., 1983)
2. Dissolved Inorganic Nutrients (Nitrate, Nitrite, Ammonia, Phosphate, Silicate) - Manual (Spectrophotometric) (Grasshoff et al., 1983).

Biological Parameters (By filtration process):

1. Chlorophyll
2. Phaeopigments - HPLC

3. Particulate Organic Carbon
4. Primary Productivity: a) ^{13}C primary productivity b) Light and Dark Bottle.

Geological Parameters:

1. Sedimentary

Parameters to be measured off board:

Chemical Parameters:

1. Nitrous oxide (surface)
2. Methane (surface)
3. ^{13}C DIC
4. Carbohydrates, Amino acids, Proteins (CAP)

Biological Parameters:

1. Phytoplankton
2. Zooplankton
3. Total Viable Count (TVC)
4. Total Bacterial Count (TBC)
5. Benthos.

Expected Outcome:

- ✓ Processes involved in the formation of trace gases that is resistant to microbial degradation could be revealed, this could
- ✓ be help for understanding how much quantity of these gases contribution to the atmosphere.
- ✓ Organic carbon is a chief component of the Carbon cycle, the percentage of contribution of various sources to organic carbon in the ocean can be revealed from the study.
- ✓ This would provide a better idea in understanding how organic carbon reacts with other components of the ocean. In other words, how other components control the variability of carbon in the marine ecosystem.
- ✓ The part of the organic carbon-the carbohydrates or amino acids or proteins that provides this resistance could provide more details. Effect on light penetration.

Annexure V

GEOTRACES CRUISE PROGRAMME ON INDIAN OCEAN - 2014

SK311 Cruise REPORT

Chief Scientist: Dr. R. Rengarajan

March-24 - April-24, 2014

M. MURUGANANTHAM

PONDICHERRY UNIVERSITY

ANDAMAN 744 112

INTRODUCTION:

GEOTRACES is an international programme to study and understand the global distribution, sources and concentration of bio-geochemical trace elements and isotopes and using new proxies for the climate change in World Ocean. India is one among the leading nations of this research, our aim is mainly concentrated on the distribution and concentration of Trace Elements in water column and sediment, Radioisotope studies for different water mass detection, carbon export flux, surface water mixing, stable isotopes for surface water temperature and productivity etc., Part of the Indian ocean cruise track was successfully done in the earlier cruise of GEOTRACES, Now the second cruise is covering the vertical sampling of Bay of Bengal towards mid-western Indian Ocean and Arabian Sea.

OBJECTIVE:

In this cruise my objective is to collect the Sea floor surface sediment, surface and bottom water, and their Physico-Chemical factors, vertical collection of zooplankton samples for Planktonic foraminifera. Benthic and planktonic foraminiferal shells are used to study the bio- mineralization status of ambient water.

SUMMARY:

As a participant of this cruise I have involved the water sample collections for radio isotope study such as ^{234}Th , ^{210}Po and ^{226}Ra , also sediment core and grab samples collection

for foraminifera and their geochemical studies. The vertical haul zooplankton collected using through Multi Plankton Net (MPN) Mesh size 200 μm , from different depths (0-300 m) according to chlorophyll distribution for planktonic foraminiferal studies.

OBSERVATION:

In the Bay of Bengal trichodesmium bloom has noticed along with that the planktonic foraminifera spinose species *Globigerina bulloides* were identified. In the mid Indian Ocean low latitudes the surface sediment samples analyzed and observed that the abundance status of *Orbulina universa*.

SCIENTIFIC TECHNIQUES LEARNT ON BOARD:

I have learnt the beta counting technique for ^{234}Th study. I also concentrated on the study of ^{210}Po and ^{226}Ra . Here the Radium isotopes are used to measure the mixing rate of the surface water. The water samples collected different depths in mixed layer were passed through the MnO_2 coated fiber column to pre-concentrated radium isotope. ^{210}Po often is used as a tracer for estimation of carbon transport in the water column. Due to its high affinity with Biological particles it is used as a powerful tracer for particulate matter sinking out of Surface Ocean. For this purpose 10 to 20 l of water was collected and ^{210}Po and ^{210}Pb were scavenged with $\text{Fe}(\text{OH})_3$ precipitation. The precipitate collected and stored in 60 ml polyethylene bottle for further analysis.

ACKNOWLEDGEMENT:

I am grateful to my research guide Prof. Dr. P. M. Mohan, head of the Department of Ocean Studies and Marine Biology, Pondicherry University, Port Blair, Andaman. I am thankful to chief scientist, Dr. R. Rengarajan, for his valuable teaching and support. I am happy to share my thanks to all participants, Norinco and crew members.

Annexure VI

GEOTRACES CRUISE REPORT- SK311

Submitted by Mangalore University

Principle investigator: Dr. B .R. Manjunatha, Associate Professor.

Participant: Naveen Kumar A, Junior Research Fellow.

OBJECTIVE:

In this program our aim is to do mineralogical studies in atmospheric aerosol samples from the Arabian Sea, Indian Ocean, Andaman sea and the Bay of Bengal.

As part of GEOTRACES cruise program, I collected 5 mineral dust samples from the Arabian Sea and the Indian Ocean along the cruise track for the mineralogical studies, which will compliment scientific studies of the GEOTRACES mission.

SCIENTIFIC TECHNIQUES LEARNT ONBOARD:

- I have learnt the sampling techniques employed with the clean lab facility onboard.
- To collect samples from the clean CTD system for their different chemical and biological studies onboard.
- Learnt sample collection technique and onboard processing for various radioisotope studies in sea water.

As a researcher in the field of oceanography, this cruise program will help me to improve my knowledge and skills in my future research.

ACKNOWLEDGEMENTS:

I would like to thank my guide Dr. B. R. Manjunatha, Department of marine geology, Mangalore University. I thank chief scientist Dr. R. Rengarajan (PRL), for providing me the chance to learn collecting seawater samples for trace element and isotope s. I would also like to thank him for his guidance to learn. I acknowledge Ministry of Earth Science (MOES) for providing funds under this programme.

Annexure-VII

List of Seminars presented in SK-311

Speaker	Institute	Date	Topic
Dr. R. Rengarajan	PRL	17/04/2014	Introduction to GEOTRACES and Particulate carbon export
Mr.Arwapalli Srinivas Rao	NCAOR	17/04/2014	Hydrothermal Plumes