INDIA

Cruise Report

ORV Sagar Kanya

Cruise # 312

From: Mauritius, April 27, 2014
To:, Goa, May 30, 2014

GEOTRACES & Hydrothermal Programme

Chief Scientist: Mr. Subha Anand S
Geosciences Division
Physical Research Laboratory, Ahmedabad

Itinerary of the SK-312 cruise program

Name of vessel	ORV SAGAR KANYA
Cruise No.	312
Port of Embarkation	Mauritius
Date & time of Embarkation	April 27, 2014; 1900 Hrs.
Port of Disembarkation	Mormugao, Goa, India
Date & time of Disembarkation	May 30, 2014; 1500 Hrs
No. of Scientists participated	19
Region	Indian Ocean & Arabian Sea
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_2O, 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 Mieo Benthos, Aerosol and rain water composition, chemical parameters & trace metals in Hydrothermal plumes in water column
Name of Chief Scientist	Mr. Subha Anand S

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

Contents

ORV Sagar Kanya
CRUISE REPORT

Cruise No. 312

GEOTRACES & Hydrothermal Programme

In continuation of the previous cruise SK 311 conducted in Bay of Bengal and the Indian Ocean further sampling for planned Hydrothermal and GEOTRACES stations were conducted. In addition to all the operations conducted during the cruise SK 311, XBT operation were also conducted by NIO, Goa. Both deck operations and onboard measurements conducted were similar to the cruise SK 311.

This cruise was undertaken 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. Additionally we 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.

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 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).

Arabian Sea is a region experiencing seasonally reversing monsoon which affects circulation and biological productivity causing subsurface oxygen deficient conditions. Due to strong winds associated with Southwest monsoon, several areas of the Arabian Sea experience upwelling which leads to surfacing of the nutrient rich waters to the euphotic zone and thereby leading to enhance productivity. This high primary productivity is one of the major factors responsible for prevelance of suboxic conditions in the Arabian Sea. Denitrification process which is a perennial feature of the water column of the Arabian Sea is expected to have control on the distribution of redox sensitive elements. We planned to measure various trace elements and their isotopes to understand their biogeochemical behaviour and the processes governing their distribution.

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 Arabian Sea 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 Arabian Sea and in the Indian Ocean basin.
2) To contribute to tracer studies of ocean circulation in association with physical oceanographers.
3) To understand the role of TEIs in primary productivity and their distribution within the water column.
4) Atmospheric deposition of TEIs, their fluxes and processes.
5) To calibrate the behaviour of paleo-circulation and paleo-weathering proxies

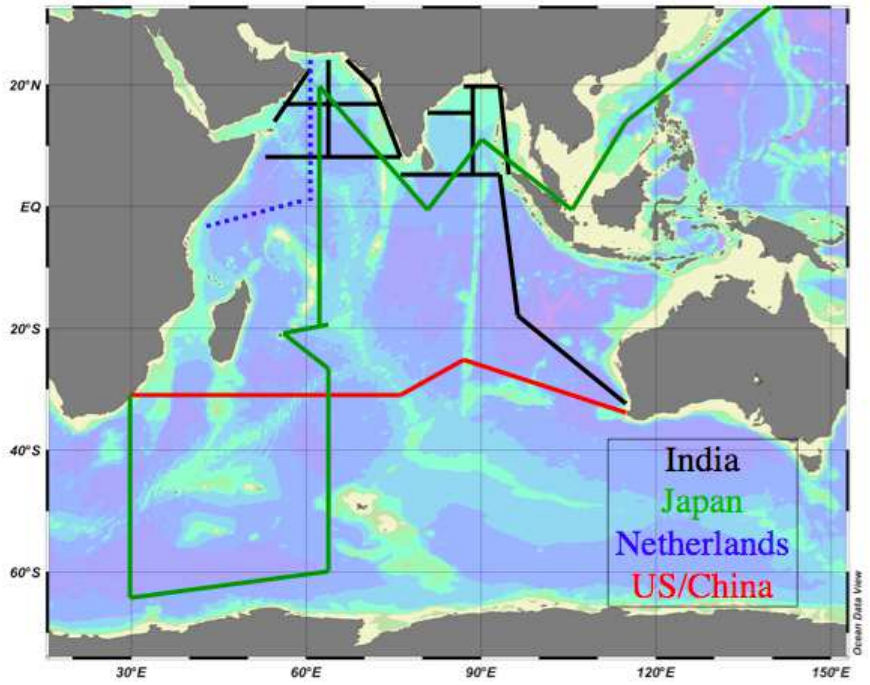

Fig. 1: Summary of tracks proposed for GEOTRACES cruises in the Indian Ocean during the GEOTRACES Indian Ocean Workshop, Oct 2007.

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.

e) XBT and Drifters:

To understand the circulation and physical processes, XBT and Drifters have been deployed during the cruise.

Additionally, various scientific equipments used for onboard analysis are:

1) CTD with rosette with 10 L Niskin sampler
2) Autosal 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

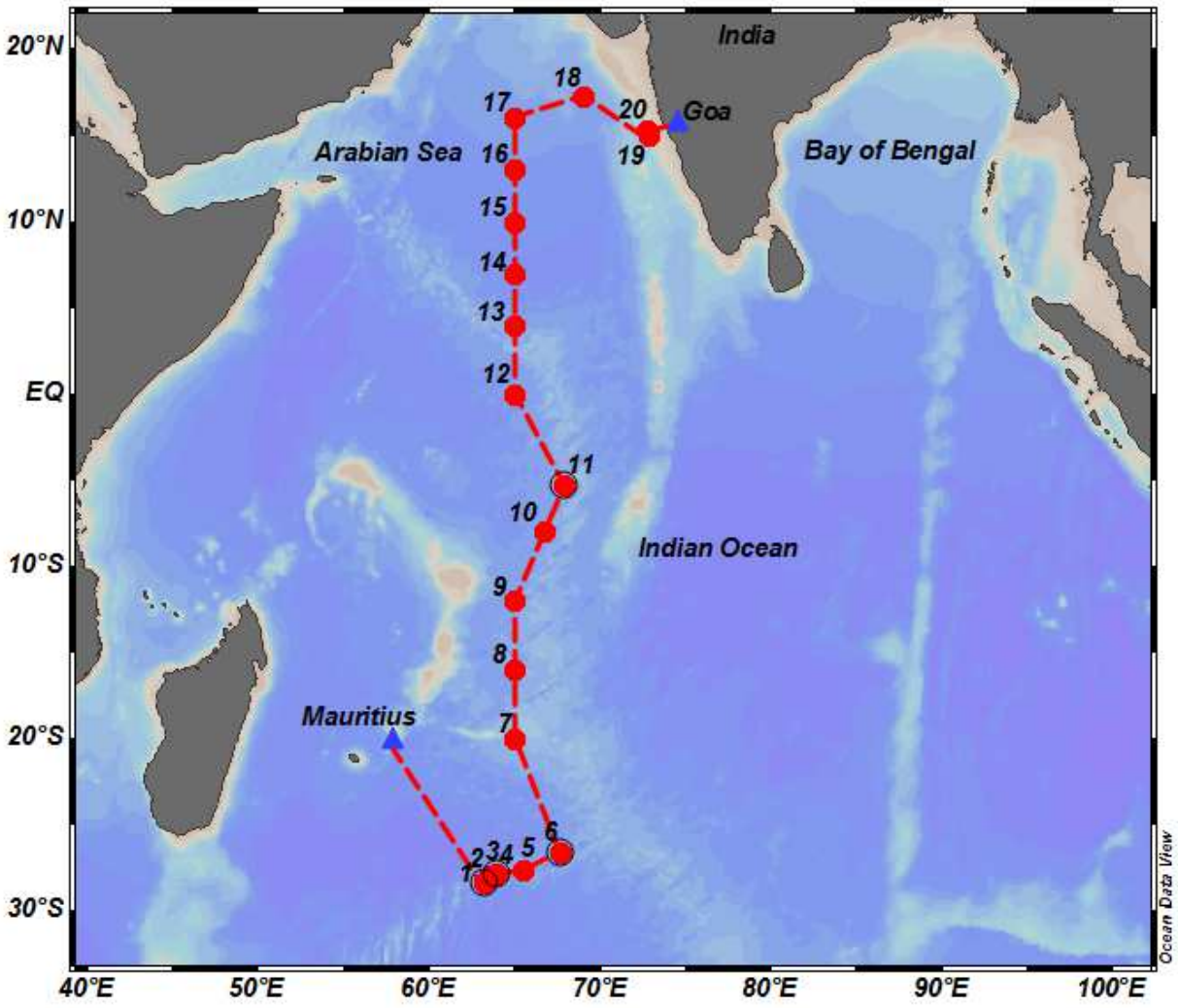

Fig. 2: Cruise track of the GEOTRACES/Hydrothermal Front cruise SK-312 from Port Louis, Mauritius to Mormugao, Goa, India. The sampling stations from 1 to 6 are for the study of Hydrothermal vents.

SAMPLING DETAILS

The scientific operations carried out at the stations across a range of contrasting regions in the Arabian Sea and the Indian Ocean during the cruise SK-312 (Fig. 2) are described below:

Daily Report:
SK 312/ 1

30-04-14 18:00

Lat: 28º18.992' S; Long: 63º14.005' E; Total water column depth: 3605m (MBES)
Bongo net was operated before stopping at the station for 14 mins for Pondicherry University.

Cast 1 Regular SK CTD

Started lowering at 18:43; Brought back to deck at 22.00; Total depth - 3539m
No plume signal is obtained.

Cast 2 Grab

Lat 28º19.975' S; Long: 63º11.054' E; Total water column depth : 2947m
Started lowering at 23:00; Brought back to deck at; 1:13 (01-05-14). As per captain's suggestion, the original location was on slope and grab was not operated there as the wire will get entangled with the grab. New location was selected on top of seamount and grab was operated. A little sandy white sediment was obtained.
Station completed at 01:15 am.

SK 312/ 2

01-05-2014 07:55

Reached station at 05:00 hrs. As ship was not maintained in DP returned came back to position at 07:30 hrs.
Lat: 27° 57.064´ S; Long: 63° 32. 443´ E; Total water column depth: 3705 m (MBES)

Cast 1 Regular SK CTD

Started lowering at 07:55; Brought back to deck at 11:40
No plume signal was found.

Cast 2 Grab

Started lowering at 11:56; Brought back to deck at 14:30; Total water column depth: 3700 m. Volcanic crust sediments were obtained. As no plume signal was obtained one more CTD location was fixed.

Cast 3 Regular SK CTD

Lat: 27° 57.598´ S; Long: 63° 33. 622´ E; Total water column depth: 4000 m (chartered) Started lowering at 15:08; Brought back to deck at 18:33
No plume signal was found.

Cast 4 Grab

Started lowering at 18:45; Brought back to deck at 21:45; Total water column depth: 3700 m. Few small stones (rock samples) were obtained. One more location was fixed for CTD. This location is considered as station- 3. This was fixed between stations 1 and 2. Station finished at 22:00.

SK 312/ 3

01-05-2014 22:30

Cast1 Regular SK CTD

Lat: 27° 57.460´ S; Long: 63° 33. 307´ E; Total water column depth: 4050 m (MBES)
Started lowering at 22:33; Brought back to deck at 01:46 (02-05-2014).
Up cast and downcast files saved separately. Station completed at 01:46 (02-05-2014).

SK 312/ 4

02-05-2014 07:00

Reached station at 07:00 hrs; Lat: 27° 51.068´ S; Long: 63° 55. 376´ E; Total water column depth: 2738 m (MBES)

Cast 1 Regular SK CTD

Started lowering at 07:56; Brought back to deck at 10:36
Up cast and downcast saved separately. No plume signal was obtained. New location was selected for next CTD cast.

Cast 2 Regular SK CTD

Lat: 27° 51.000´ S; Long: 63° 55. 808´ E; Total water column depth: 3050 m (MBES)
CTD lowered upto depth 2960 m. Started lowering at 11:30; Brought back to deck at 13:55

Cast 3 Grab

Total depth lowered: 3100 m ; Started lowering at 14:00; Brought back to deck at 16:20. No sediment obtained. Grab was again tried in a different location.

Cast 4 Grab

Lat: 27° 49.008´ S; Long: 63° 56. 500´ E; Total depth lowered 3600 m; Started lowering at 17:17. Brought back to deck at 19:45. Again no sediment obtained. Station finished at 20:00.

SK 312/ 5

03-05-2014

08:00 Reached station at 08:00 hrs; Lat: 27° 36.002´ S; Long: 65° 29. 980´ E; Total water column depth 4028 m (MBES)

Cast 1 Regular SK CTD

Started lowering at 08:06; Brought back to deck 11:22 am; Total water column depth: 3885m No plume signal obtained.

Cast 2 Grab

Lat: 27° 36.796´ S; Long: 65° 33. 997´ E; Total water column depth: 3653m (MBES)
Started lowering at 11:30 am; Brought back to deck at 13:30.
No sediment obtained. Grab was again tried in a different location.

Cast 3 Grab

Lat: 27° 36.494´ S; Long: 65° 35. 813´ E; Total water column depth: 4000m
Started lowering at 14:35; Brought back to deck at 17:10; No sediment obtained.

Cast 4 Regular SK CTD

New CTD location has been selected between stations 5&6 and named as 5b.
This location is about 9hrs from previous location. Reached the location on 04-05-2014 at 02:00 hrs. Lat: 27° 20.2´ S; Long: 66° 37. 001´ E; MBES was operated. As bottom

water depth was around 4000m. Mr. Srinivas (Research Scientist, NCAOR) wanted to move to another location and CTD was operated there. Lat: 27° 20.982´ S; Long: 66° 37. 001´ E; Depth: 4050m. CTD lowered till 3988m. Started lowering at 04:30; Brought back to deck at 08:25. No plume signal. Water samples have been collected in 4000m, 3500m, 3000m, 2500m, 2000m, 1500m, 1000m, 800m, 500m, 200m, 100m, 50m for conductivity and salinity measurements.
Station completed at 08:25.

SK 312/ 6

04-05-2014

Cast 1 Regular SK CTD

Lat: 26° 37.993´ S; Long: 67° 39. 996´ E; Started lowering at 18:17; Brought back to deck at 21:27. Total water column depth (MBES): 4052m; CTD lowered depth : 3900 m; No plume signal obtained.

Cast 2 Regular SK CTD

Lat: 26° 33.031´ S; Long: 67° 28. 721´ E; Total water column depth 3700m (MBES). Started lowering at 23:45; Brought back to deck at 02:27 (05.05.14). No plume signal obtained.

Cast 3 Grab

Lat: 26° 28.389´ S; Long: 67° 27.373´ E; Total water column depth: 2040m; Started lowering at 01:05. End time 03:37. No sediment obtained. But a few small rock pieces obtained.

Cast 4 Grab

Lat: 26° 30.268´ S; Long: 67° 24.334´ E; Total water column depth: 2000m. Started lowering at 05:45; Brought back to deck at 08:00. No sediment sample obtained. But one big rock sample came in the grab.

SK 312/ 7

Station skipped due to bad weather.

SK 312/ 8

08-05-2014 20:30

Lat: 16° 01.079´ S; Long: 65° 0. 041´ E; Total water column depth 3182 m (MBES)

Cast 1 Bongo net

Bongo net was operated 15 mins before stopping at the station (Pondicherry University). Start Lat: 16° 01.661´ S; Long: 65° 00. 77´ E; Start time 20:19; End Lat: 16° 01.079´ S; Long: 65° 00. 041´ E End Time: 20:35.

Cast 2 Gravity Corer

Due to bad weather, instead of CTD gravity corer was operated first. Started lowering at 21:50; brought back to deck at 00:29 (09-05-2014) Total water column depth: 3200m. Core obtained (length 5.78m). White color sediment. Cut into 1m each. As weather was rough, ship was placed in drifting mode and planned to operate CTD in the morning. Weather was expected to improve in the morning.

09-05-2014 06:45

Reached back station next day morning 06:45 am; Lat: 15° 59.93´ S; Long: 64° 59. 6´ E Total water column depth 3207 m (MBES)

Cast 3 Regular SK CTD

Samples were collected for Radium measurement at 400m depth. Started lowering at 07:20; Brought back to deck at 10:47. Total water column depth: 3200m (CTD lowered till 3100m).

Cast 4 Regular SK CTD

Samples were collected for Radium measurement at 200m depth. Started lowering at 11:03; Brought back to deck at 11:16

Cast 5 Regular SK CTD

Samples were collected for Radium measurement at 100m depth. Started lowering at 11:26; Brought back to deck at 11:34.

Cast 6 Regular SK CTD

5m Ra Samples were collected for Radium measurement at 5m depth. Started lowering at 11:47 Brought back to deck at 11:52.

Cast 7 Regular SK CTD

Sample collected for measurement of POC, Chlorophyll and Productivity at 10m, 5m by NIO (vizag).Started lowering at 12:02; Brought back to deck at 12:06.

Cast 8 Clean CTD

Started lowering at 12:20; Brought back to deck at 15:20; Total water column depth: 3100m; CTD lowered upto 3000m. Samples collected at depth 300m, 2500m, 2000m, 1800m, 1500m, 1000m, 800m, 500m 300m, 200m, 130m, 100m, 75m, 50m, 25m, 12m, 5m for Nd , Trace metals, Th and other basic parameters.

Cast 9 Regular SK CTD.

Started lowering at 15:32; Brought back to deck at 15:45. Total lowered depth 200m. Samples collected at three depths (200m, 100m, 75m). 200m for 'Th' measurement. 50m and 75m for POC, Chlorophyll and Productivity by NIO RCW.

Cast 10 Regular SK CTD.

Started lowering at 16:03; Brought back to deck at 16:19. Lowered upto 50m. Samples collected by NIO RCW at 50m and 25m for measuring POC, Chlorophyll and Productivity.

Cast 11 Bongo net

Bongo net was operated by NIO RCW for 7 mins when started moving from this station.

Station completed and started sailing by 17:30.

SK 312/ 9

10-05-2014 21:30

Lat: 12° 0.059´ S; Long: 64° 59. 984´ E; Total water column depth 3449 m (MBES)

Cast 1 Bongo net

Bongo net was operated 15 mins before stopping at the station (for Pondicherry University).

Cast 2 Clean CTD

Started lowering at 21:45; Brought back to deck at 22:40; Total depth lowered 3300m Samples collected at depths 3300, 3000, 2500, 2000, 1800, 1500, 1200, 1000, 800 for Nd, Archive, Polonium, Trace metals, Thorium and basic parameters.

Cast 3 Regular SK CTD

Lowered upto depth 3300m. Samples were collected for Radium measurement at 400m depth. Started lowering at 22:48; Brought back to deck at 01:41

Cast 4 Clean CTD

Started lowering at 01:53; Brought back to deck at 02:09. Lowered upto 100m depth. Surface cast was lowered before shallow cast. Samples collected at depths 100, 75, 50, 25, 10, 5m for Nd, TE, Thorium, Archive, Polonium and basic parameters. At 100, 75, 50m samples were collected by NIO (Vizag)for POC, Chlorophyll and Productivity.

Cast 5 Regular SK CTD

Lowered upto 200m. Samples were collected for Radium measurement at 200m depth. Started lowering at 02:11; Brought back to deck at 02:23; 200m particulate samples for Th measurement were also collected from this cast.

Cast 6 Regular SK CTD

Lowered upto 100m depth. Samples were collected for Radium measurement at 100m depth. Started lowering at 02:39; Brought back to deck at 02:46.

Cast 7 Regular SK CTD

Lowered upto 5m depth. Samples were collected for Radium measurement at 5m depth. Started lowering at 03:00 Brought back to deck at 03:03.

Cast 8 Regular SK CTD

Samples collected at 25m, 10m, 2m for measuring POC, Chlorophyll and Productivity by NIO (vizag).Started lowering at 03:13; Brought back to deck at 03:19

Cast 9 Clean CTD

Started lowering at 03:28; Brought back to deck at 04:40. Lowered upto depth: 800m. Samples were collected from 800m-75m. Samples were collected for Nd, TE, Archive, Thorium, Polonium and basic parameters. 200 m no 'Nd' sample was collected as bottle handle broke and fell down. At 75 m depth, fired bottle (bottle no. 3) did not close. So archive sample was not collected at this depth.

Cast 10 MPN-1

MPN was collected by Pondichery University. Lowered upto 500m depth. Started lowering at 04:46; Brought back to deck at 5:52. MPN was collected at 5 depths - 500-300m; 300-200m; 200-100m; 100-50m and 50-0m.

Cast 11 MPN-2

MPN was collected by NIO RCW. Lowered upto 200m depth. Started lowering at 05:48 and brought back to deck at 06:10. Samples were collected at 3 depths - 200-100m, 100-50m and 50-0m.

Cast 12 Gravity corer

Started lowering t 06:2; Brought back to deck at 08:35. Lowered upto depth 3850m.

Cast 13 Bongo Net

Bongo net was operated by NIO RCW for 7 mins.

Station completed

SK 312/ 10

12-05-2014 20:15

Lat: 08° 1.087´ S; Long: 66° 41. 434´ E; Total water column depth 4161 m (MBES)

Cast 1 Bongo net

Bongo net was operated 15 mins before stopping at the station (Pondicherry University).

Cast 2 Clean CTD

Started lowering at 20:41; Brought back to deck at 01:20; Lowered up to depth: 4000m. Samples were collected at depths 4000m, 3500m, 3000m, 2500m, 2000m, 1800m, 1500m, 1200m, 1000m for Neodymium, Archive, Trace metals, Thorium and basic parameters.

Cast 3 Regular SK CTD

Lowered upto depth 4000m. Samples were collected for Radium measurement at 400m depth. Started lowering at 01:26; (13-05-14) and brought back to deck at 05:24;

Cast 4 Clean CTD

Started lowering at 05:35; Brought back to deck at 05:53. Lowered upto depth 100m. Surface cast was lowered before shallow cast. Samples collected at depths 25-4m for Neodymium, Trace Elements, Thorium, Archive and basic parameters. Samples were also collected for NIO RCW for POC, Chlorophyll and productivity measurements from depths 100m, 75m, 50m, 25m, 10m and 4m.

Cast 5 Regular SK CTD

Samples were collected for Radium measurement at 200m. Started lowering at 06:03; Brought back to deck at 06:15. 200m particulate samples for Thorium measurement were also collected from this cast.

Cast 6 Regular SK CTD

Samples were collected for Radium measurement at 100m. Started lowering at 06:30; Brought back to deck at 06:39.

Cast 7 Regular SK CTD

Samples were collected for Radium measurement at 2m. Started lowering at 06:49; Brought back to deck at 06:51.

Cast 8 Clean CTD

Started lowering at 07:00; Brought back to deck at 08:06. Lowered upto depth: 1000m. Samples were collected at standard depths from 1000m-50m for Neodymium, Trace Elements, Archive, Thorium, and basic parameters.

Cast 9 Gravity corer

Lowered upto depth 4161m. Started lowering at 08:13; Brought back to deck at 11:30.

Cast 10 Bongo Net

Bongo net operated by NIO RCW for 7 mins.

Station completed.

SK 312/ 11 (Japanese Cross over)

14-05-2014 08:30 Lat: 05° 16.045´ S; Long: 67° 54. 005´ E; Depth 3000 m (MBES)

Cast 1 Bongo net

Bongo net was operated 15 mins before stopping at the station (Pondicherry University).

Cast 2 Clean CTD

Started lowering at 09:00; Brought back to deck at 10:50; Total depth lowered: 2900m; Samples Were collected from standard depths 2900-500m for Nd, Archive, Polonium, Trace metals, Thorium and basic parameters.

Cast 3 Regular SK CTD

Lowered upto 2900m depth. Samples were collected for Radium measurement at 400m depth. Started lowering at 10:55; Brought back to deck at 13:17;

Cast 4 Clean CTD

Started lowering at 13:40; Brought back to deck at 13:52; Total depth lowered: 100m; Surface cast was lowered before shallow cast. Samples collected at standard depths from 100-10m for NIO (Vizag)for POC, Chlorophyll and Productivity measurements. 10m and 4m samples were collected for Nd, TE, Thorium, Archive, Polonium and basic parameters.

Cast 5 Regular SK CTD

Lowered upto 200m depth. Samples were collected for Radium measurement at 200m depth. Started lowering at 13:58 and brought back to deck at 14:09. 200m particulate samples for Th were also collected from this cast.

Cast 6 Regular SK CTD

Lowered upto 100m depth. Samples were collected for Radium measurement at 100m depth. Started lowering at 14:27 and brought back to deck at 14:34.

Cast 7 Regular SK CTD

Lowered upto 2m depth. Samples were collected for Radium measurement at 2m depth. Started lowering at 14:45; Brought back to deck at 14:47.

Cast 8 Regular SK CTD

Lowered upto 10m depth. Samples were collected at 10m, 2m, for POC, Chlorophyll and productivity measurements by NIO RC, Vizag.

Cast 9 Clean CTD.

Clean CTD lowered upto depth 500m. Samples were collected at standard depths from 500m-10m for Neodymium, Trace Elements, Archive, Thorium and basic parameters. Started lowering at 15:07 and brought back to deck at 15:34.

Cast 10 Gravity corer

Started lowering at 15:47; Brought back to deck at 18:05. Total depth lowered: 3100m. Core obtained of length: 5.64m.

Cast 11 Bongo net

Station completed with Bongo Net (NIO Vizag).

SK 312/ 12

16-05-2014 12:45 Lat: 00° 0.408´ S; Long: 65° 0.290´ E; Depth 3900 m (MBES)

Cast 1 Bongo net

Bongo net was operated 15 mins before stopping at the station (Pondicherry University).

Cast 2 Clean CTD

Started lowering at 12:51; Brought back to deck at 15:08'; Total depth: 3800m; Lowered upto depth; 3700m. Samples collected from depths 3800-800m for Neodymium, Archive, Polonium, Trace metals and basic parameters.

Cast 3 Regular SK CTD

Lowered upto depth:3500m. Samples were collected for Radium measurement at 400m depth. Started lowering at 15:18; Brought back to deck at 18:18. Due to high under water current , maintaining the ship in DP takes the CTD below the AT. So captain told that he will remove the DP and keep in drift mode. (Lat: 00° 0.3412´ S;

Long: 65° 1.013´ E). Every time before sampling ship was brought back to position.

Cast 4 **Clean CTD**

Brought back to position. Lat: 00° 0.080´ N, Long: 65° 0.244´ E; Started lowering at 19:28; Brought back to deck at 19:41. Lowered upto depth: 100m. Surface cast was lowered before shallow cast. Samples collected at depths 100-75m for NIO (Vizag)for POC, Chlorophyll and Productivity measurements for POC. 50m-2m samples were collecgted for Neodymium, Trace Elements,Thorium, Archive, Polonium and basic parameters.

Cast 5 **Regular SK CTD**

Samples were collected for Radium measurement at 200m depth. Started lowering at 19:47; Brought back to deck at 20:00.

Cast 6 **Regular SK CTD**

Samples were collected for Radium measurement at 100m depth. Started lowering at 20:14; Brought back to deck at 20:26

Cast 7 **Regular SK CTD**

Samples were collected for Radium measurement at 2m depth. Started lowrering at 20:38; Brought back to deck at 20:41.

Cast 8 Regular SK CTD

Samples were collected by NIO (Vizag) for POC, Chlorophyll and Productivity measurements for POC at 25m, 10m and 2m. Started lowering at 20:53; Brought back to deck at 21:02.

Cast 9 MPN-1

Multi Plankton Net collected by Pondicherry University. Started lowering at 21:10; Brought back to deck at 22:05. Samples were collected at depths 500-300m; 300-200m; 200-100m; 100-50m; 50-0m.

Cast 10 MPN-2

Multi Plankton Net collected by NIO RCW, Vizag. Started lowering at 22:20; Brought back to deck at 23:00. Samples were collected at depths 200-100m, 100-50m, 50-0. Net did not closed properly. Cast repeated again.

Cast 11 Clean CTD

Clean CTD lowered upto depth 800m. Samples were collected from 800-50m for Neodymium, Trace Elements, Archive, Thorium and basic parameters. Lat: 00° 0.260´ N; Long: 65° 1.202´ E; Started lowering at 23:00; Brought back to deck at 23:56.

Cast 12 MPN-3

Multi Plankton Net collected by NIO RCW, Vizag. Started lowering at 00:07; Brought back to deck at 00:33. Samples were collected at depths 200-100m, 100-50m, 50-0.

Cast 13 Gravity corer

Gravity corer lowered at 00:40; Brought back to deck at 05:15. Total depth lowered: 3750m. Core length 5.5m.

Cast 14 Bongo Net

Bongo net operated for NIO Vizag.

Station completed.

SK 312/ 13

18-05-2014 10:30

Lat: 03° 59.848´ N; Long: 64°59.986´ E; Total water column depth 3800 m.

Cast 1 Bongo net

Bongo net (Pondicherry University) was operated 15 mins before stopping at the station.

Cast 2 Clean CTD

Started lowering at 10:46; Brought back to deck at 13:42. Lowered upto depth: 3700m. Samples collected from depths 3700-1000m for Neodymium, Archive, polonium, Trace metals, Thorium and basic parameters. At 2500 m depth no Neodymium sample collected as bottle No. 16 (corresponding to 2500m depth) did not close.

Cast 3 Regular SK CTD

Samples were collected for Radium measurement at 400m depth. Lowered upto depth 3700m. Started lowering at 13:57. Brought back to deck at 17:20.

Cast 4 Clean CTD

Lowered upto 100 m depth. Started lowering at 17:25; Brought back to deck at 17:37. Surface cast was lowered before shallow cast. Samples collected at depths from 100-50m for NIO (Vizag) for POC, pigments and productivity measurements. Depth 75m to 4m for Neodymium, Trace Elements, Thorium, Archive, Polonium and basic parameters.

Cast 5 Regular CTD

Samples were collected for Radium measurement at 200m depth. Started lowering at 17:45. Brought back to deck at 17:56.

Cast 6 Regular SK CTD

Samples were collected for Radium measurement at 100m depth. Started lowering at 18:07. Brought back to deck at 18:15.

Cast 7 Regular SK CTD

Samples were collected for Radium measurement at 4m depth. Started lowering at 18:27; Brought back to deck at 18:29.

Cast 8 Regular SK CTD 3m

Samples collected from 3m depth for POC, pigments and productivity measurements (for NIO, RC Vizag) for POC. Started lowering at 18:40. Brought back to deck at 18:43

Cast 9 Regular SK CTD

Samples collected from 50 - 10m depth (for NIO RC, Vizag) for POC, pigments and productivity measurements. Started lowering at 18:50; Brought back to deck at 19:00.

Cast 10 Clean CTD

Lowered upto 1000 m depth. Started lowering at 19:24; Brought back to deck at 20:16. Samples were collected from 1000m-75m for Neodymium, Trace Elements, Archive, Thorium and basic parameters. 300 m Archive was not collected as niskin bottle did not close.

SK 312/ 14

19-05-2014 20:15;

Lat: 06° 59.869´ N; Long: 64°59.911´ E; Total water column depth:4858 m (MBES)

Cast 1 Bongo net

Bongo net was operated 15 mins before stopping at the station (Pondicherry University).

Cast 2 Bongo net

Bongo net for NIO Vizag.

Cast 3 Clean CTD

Lowered upto depth 4700m. Started lowering at 20:55; Brought back to deck at 01:23. Samples collected from depths 4700, 4300m, standard depths 4000-1500m for Neodymium, Archive, Polonium,Trace metals, Thorium and basic parameters.

Cast 4 Regular SK CTD

Lowered upto depth 4700m. Samples collected for Radium measurement at 400m depth. Started lowering at 01:35; Brought back to deck at 06:15.

Cast 5 Clean CTD

Lowered up to depth 150m. Surface cast was lowered before shallow cast. Started lowering at 06:21; Brought back to deck at 06:38. Samples were collected from 150m-2m for Neodymium, Trace Elements, Thorium, Archive, Polonium and basic parameters. At 50 m 'Nd' sample was not collected as Niskin bottle (no. 17) did not closed.

Cast 6 Regular SK CTD

Lowered upto depth 200m. Samples collected for Radium measurement at 200m depth Started lowering at 06:46; Brought back to deck at 06:58.

Cast 7 Regular SK CTD

Lowered up to 100m depth. Samples collected for Radium measurement at 100m depth. Started lowering at 07:13; Brought back to deck at 07:20.

Cast 8 Regular SK CTD

Lowered upto depth 2m. Samples collected for Radium measurement at 2m depth. Started lowering at 07:32; Brought back to deck at 07:34.

Cast 9 Regular SK CTD

Lowered upto depth 100m. Samples collected from 100m, 75m, 50m for HPLC, chlorophyll, POC and productivity measurements for NIO Vizag. Started lowering at 07:45; Brought back to deck at 07:58

Cast 10 Regular SK CTD

Lowered upto depth 50m. Samples collected from 50m, 25m and 10m (for NIO Vizag) for HPLC, chlorophyll, POC and productivity measurements. Started lowering at 08:12; Brought back to deck at 08:18.

Cast 11 Regular SK CTD

Lowered upto depth 10m. Samples collected from depths 10m and 2m (for NIO Vizag) for HPLC, chlorophyll, POC and productivity measurements. Started lowering at 08:30; Brought back to deck at 08:33.

Cast 12 Clean CTD

Lowered upto depth 1500 m. Started lowering at 08:40; Brought back to deck at 09:48. Samples were collected from 1500m-150m for Neodymium, Trace Elements, Archive, Thorium and basic parameters. Station completed.

SK 312/ 15

21-05-2014 09:45

Lat: 09° 59.924´ N; Long: 65°00.023´ E; Total water column depth 4543m (MBES)

Cast 1 Bongo net

Bongo net was operated 15 mins before stopping at the station (Pondicherry University).

Cast 2 Bongo net

Bongo net for NIO Vizag.

Cast 3 Clean CTD

Lowered upto depth 4400m. Samples collected from depths 4400-1200m for Neodymium, Archive, Polonium, Trace metals, Thorium and basic parameters. Started lowering at 10:15; Brought back to deck at 13:00.

Cast 4 Regular SK CTD

Lowered upto depth 4400m. Samples collected for Radium measurement at 400m. Started lowering at 13:19; Brought back to deck at 16:40.

Cast 5 Clean CTD

Lowered upto depth 100m. Surface cast was lowered before shallow cast. Samples were collected from 100m-4m for Neodymium, Trace Elements, Thorium, Archive, Polonium and basic parameters. Samples at 100m and 75m collected for NIO Vizag for POC, Chlorophyll and productivity measurements. Started lowering at 16:46; Brought back to deck at 17:00.

Cast 6 Regular SK CTD

Lowered upto depth 200m. Samples collected for Radium measurement at 200m. Started lowering at 17:04; Brought back to deck at 17:14.

Cast 7 Regular SK CTD

Lowered upto depth 100m. Samples collected for Radium measurement at 100m. Started lowering at 17: 28; Brought back to deck at 17:36.

Cast 8 Regular SK CTD

Lowered upto depth 4m. Samples collected for Radium measurement at 4m. Started lowering at 17:48; Brought back to deck at 17:50

Cast 9 Regular SK CTD

Lowered upto depth 75m. Samples were collected from 75m, 50m, 25m for HPLC, chlorophyll, POC and productivity measurements for NIO Vizag. Started lowering at 18:00; Brought back to deck at 18:08

Cast 10 Regular SK CTD

Lowered upto depth 10m. Samples were collected from 10m, 2m for HPLC, chlorophyll, POC and productivity measurements for NIO Vizag. Started lowering 18:21; Brought back to deck at 18:24.

Cast 11 MPN-1

MPN samples collected by Pondichery University. Lowered up to depth 500m. Started lowering at 18:29; Brought back to deck at 19:06. Samples were collected between depths 500-300m, 300-200m, 200-100m, 100-50m, 50-0m.

Cast 12 MPN-2

MPN samples collected by NIO RC, Vizag. Started lowering at 19:14; Brought back to deck at 19:33:lowered up to 200m. Sample collected between depths 200-100m; 100-50m; 50-0m.

Cast 13 Clean CTD

Lowered upto depth 1200 m. Samples were collected from 1200m-100m for Neodymium, Trace Elements, Archive, Thorium, and basic parameters. Only one bottle fired at 10m to collect Thorium. From cast 5 Thorium sample was not collected. Started lowering at 19:38; Brought back to deck at 20:45.

Cast 14 Gravity core

Gravity corer lowered. Core obtained of length: 3.1m
Station Completed

SK 312/ 16

22-05-2014 23:00

Lat: 12° 59.935´ N; Long: 65°00.004´ E; Total water column depth 4203m (MBES)

Cast 1 Bongo net

Bongo net sample was collected by Pondicherry university. It was operated 15 mins before stopping at the station.

Cast 2 Bongo net

Bongo net sample was collected by NIO RC, Vizag.

Cast 3 Clean CTD

Started lowering at 23:30; Brought back to deck at 02:08. While lowering down , at 3589m depth clean CTD showed error message on deck monitor. "RS 232 communication time out-unsupported modem message from carousel". CTD was heaved back to deck. The problem was thought to be communication cable damage. It was checked immediately after bringing back to deck. In the mean time gravity corer was operated.

Cast 4 Gravity corer

Gravity corer lowered upto depth 4350m. Started lowering at 02:32; Brought back to deck at 06:03. Core obtained of length: 55cm

Cast 5 Regular SK CTD

Lowered upto depth 4100m. Samples were collected for Radium measurement at 400m depth. Started lowering at 06:08; Brought back to deck at 09:50.

Cast 6 Regular SK CTD

Lowered upto 200m depth. Samples were collected for Radium measurement at 200m depth. Started at 10:05; Brought back to deck at 10:15

Cast 7 Regular SK CTD

Lowered upto 100m depth. Samples were collected for Radium measurement at 100m depth. Started at 10:29; Brought back to deck at 10:40

Cast 8 Regular SK CTD

Lowered upto 2m depth. Samples were collected for Radium measurement at 2m depth. Started at 10:54; Brought back to deck at 10:56

Cast 9 Regular SK CTD

Lowered upto depth 50m. Samples were collected from 50m, 25m, 10m for HPLC, Chlorophyll, POC and productivity measurements (for NIO Vizag). Started lowering at 11:13; Brought back to deck at 11:18.

Cast 10 Regular SK CTD

Clean CTD was not ready yet. So sampling for other parameters started with sagar kanya CTD. Lowered till 4100m. Samples were collected at 4090m, 3500m (for

Neodymium, Archive and Trace Elements), 3000 (only Neodymium).In the mean time , clean CTD got ready and remaining sampling was done using Clean CTD.

Cast 11 Clean CTD

Lowered upto depth 3000m. Samples collected from 3000-500m. Started lowering at 19:06; Brought back to deck at 21:19. Samples were collected for Neodymium, Trace Elements, Thorium, Archive, Polonium and basic parameters at standard depths.

Cast 12 Clean CTD

Lowered upto depth 100m. Started lowering at 23:32; Brought back to deck at 23:46. Samples collected from 100m-3m for Neodymium, Trace Elements, Thorium, Archive, Polonium and basic parameters. 100m-25m samples were collected for NIO Vizag for POC, productivity measurements and HPLC.

Cast 13 Clean CTD

Lowered up to 300m depth. Started lowering at 00:32; Brought back to deck at 00:53; Samples were collected from 300m-25m for Nd, TE,Thorium, Archive, Polonium and basic parameters.

Station completed.

SK 312/ 17

24-05-2014 23:30

Lat: 16° 00.010´ N; Long: 65°00.005´ E; Total water column depth 3797m (MBES)

Cast 1 Bongo net

Bongo net was operated 15 mins before stopping at the station (Pondicherry University).

Cast 2 Bongo net

Bongo net was operated 7 mins before reaching the station (NIO Vizag).

Cast 3 Clean CTD

Started lowering at 00:06; Brought back to deck at 03:10; Total lowered depth: 3600m. Samples were collected in 3 niskin bottles (6,7,8)from depth 3600m. After that when triggering bottles at next depth, error message came, "unsupported modem message from carousel". Bottles were not getting fired. Both system and manual firing did not work. The deck unit was restarted and tried again. But it did not work . Bottles didnot get fired. The salinity , temperature and other profiles were coming. But bottles did not close. The CTD was heaved back to deck for repair. In the mean time, other operations were carried out.

Cast 4 Regular SK CTD

CTD lowered upto depth 3600m. Samples were collected at 400m depth for Radium measurement. Started lowering at 3:20; Brought back to deck at 06:28.

Cast 5 Gravity corer

Lowered upto depth 4000m. Started lowering at 6:40; Brought back to deck at 10:10.Core obtained of length 2.5m.

Cast 6 Regular SK CTD

Samples were collected at 200m depth for Radium measurement. Started lowering at 10:23; Brought back to deck at 10:33.

Cast 7 Regular SK CTD

Samples were collected at 100m depth for Radium measurement. Started lowering at

10:48; Brought back to deck at 11:05.

Cast 8 Regular SK CTD

Samples were collected at 100m depth for Radium measurement. Started lowering at 11:20; Brought back to deck at 11:23.

Cast 9 Regular SK CTD

Lowered upto 100m depth. Started lowering at 11:28 and brought back to deck at 11:32. Samples were collected at 100m and 75m for HPLC, POC, Chlorophyll and productivity by for NIO, Vizag.

Cast 10 Regular SK CTD

Lowered upto 50m depth. Started lowering at 12:00 and brought back to deck at 12:07. Samples were collected at 50m and 25m for HPLC, POC, Chlorophyll and productivity by for NIO, Vizag.

Cast 11Regular SK CTD

Lowered upto 10m depth. Started lowering at 12:25 and brought back to deck at 12:30. Samples were collected at 10m and 2m for HPLC, POC, Chlorophyll and productivity by for NIO, Vizag.

Clean CTD was found to be not working. So sampling continued by Regular CTD.

Cast 12 Regular SK CTD

Lowered upto depth 3000m. Started lowering at 12:50; Brought back to deck at 15:28. Samples collected from 3000m-1500m for Neodymium, Trace Elements,Thorium, Polonium and basic parameters . No Archive samples.

Cast 13 Regular SK CTD

Lowered upto depth 1500m. Started lowering at 15:32; Brought back to deck at 16:32. Samples collected at standard depths from 1500m-300m for Neodymium, Trace Elements, Thorium, Polonium and basic parameters . No Archive samples.

Cast 14 Regular SK CTD

Lowered upto depth 300m. Started lowering at 17:09; Brought back to deck at 17:25. Samples collected at standard depths from 300m-150m for Neodymium, Trace Element, Thorium, Polonium and basic parameters . No Archive samples.

Cast 15 Regular SK CTD

Lowered upto depth 100m. Started lowering at 17:58; Brought back to deck at 18:10. Samples collected at standard depths from 100m-50m for Neodymium, Trace Element, Thorium, Polonium and basic parameters . No Archive samples.

Cast 16 Regular SK CTD

Lowered upto depth 50m. Started lowering at 18:16; Brought back to deck at 18:30. Samples collected at standard depths from 50m-2m for Neodymium, Trace Element, Thorium, Polonium and basic parameters . No Archive samples.

Station completed. Moving to next station (Japanese cross over).

SK 312/ 18

27-05-2014 21:00

Lat: 17° 18.008´ N; Long: 69°03.590´ E; Total water column depth 3600m (MBES)

Cast 1 Bongo net

Bongo net was operated 15 mins before stopping at the station (Pondicherry University).

Cast 2 Bongo net

Bongo net was operated for 7 mins by NIO RCW.

Cast 3 Regular SK CTD

Started lowering at 21:35; Brought back to deck at 01:10. Total depth lowered: 3500m. Samples were collected at standard depths from 3500m- 500m for Trace Elements, basic parameters, Thorium and Polonium. No Neodymium and archive samples were collected.

Cast 4 Regular SK CTD

Started lowering at 02:01; Brought back to deck at 02:21. Lowered upto depth: 300m. Samples were collected at standard depths from 300m- 100m for Trace Elements, basic parameters, Thorium and Polonium. No Neodymium and archive samples were collected.

Cast 5 Regular SK CTD

Started lowering at 03:00; Brought back to deck at 03:10; Lowered upto depth 100m. Samples were collected at standard depths from 100m-10m for Trace Elements, basic parameters, Thorium and Polonium. No Neodymium and archive samples were collected.

Cast 6 Regular SK CTD

Started lowering at 03:41; Brought back to deck at 03:51; Lowered upto depth: 100m. Samples were collected from 2m depth for Trace Elements, basic parameters, Thorium and Polonium. No Neodymium and archive samples were collected. Samples collected from 100m-75m for POC, Chlorophyll and producitivity by NIO RC Vizag.

Cast 7 Regular SK CTD

Started lowering at 04:22; Brought back to deck at 04:30: Total depth lowered: 75m. Samples collected at standard depths from 75m – 10m for measuring POC, chlorophyll and productivity by NIO RC, Vizag.

Cast 8 Regular SK CTD

Started lowering at 04:51; Brought back to deck at 04:56. Lowered upto depth: 25m. Samples collected at standard depths from 25m – 2m for measuring POC, chlorophyll and productivity by NIO RC, Vizag.

Cast 9 Regular SK CTD

CTD lowered upto 400m depth. Samples were collected for Radium measurement. Started lowering at 05:15; Brought back to deck at 05:30.

Cast 10 Regular SK CTD

CTD lowered upto 200m depth. Samples were collected for Radium measurement. Started lowering at 05:45; Brought back to deck at 05:57.

Cast 11Regular SK CTD

CTD lowered upto 100m depth. Samples were collected for Radium measurement. Started lowering at 06:10; Brought back to deck at 06:17.

Cast 12 Gravity corer

Lowered upto depth 3650m. Started lowering at 06:45; Brought back to deck at 09:40. Core obtained of length: 5.52 m.

SK 312/ 19

29-05-2014 19:20

Lat:15°00.72 N; Long: 072°51.15 E; Total water column depth: 690 m.

Cast 1 Gravity Corer

Started lowering at 19:30; Brought back to deck at 20:00. Core obtained of length: 4.65m. This core was given to Mangalore University.
Station Completed.

SK 312/ 20

30-05-2014 00:45

Lat:15°20.39 N; Long: 072°44.00 E; Total water column depth: 600 m.

Cast 1 Gravity Corer

Started lowering at: 01:00; Brought back to deck at 01:30. Core obtained of length: 4.16m. Station completed.
Started sailing to Mormugao port, Goa, India.
Reached Goa on 30/05/2014 at 1500 hrs.

Analytical Procedures

Samples collected during the cruise SK-312 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 213 numbers of trace metal samples were collected from different depths of 11 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 80 samples of different depths were collected from 10 different stations.

3) ΣCO_2: About 200 mL unfiltered seawater samples were collected for ΣCO_2 measurements. A total of 92 samples of different depths were collected from 10 different sampling stations.

4) TOC: About 300 mL seawater were collected for TOC (Total Organic Carbon) Measurements. A total of 34 samples of different depths were collected from 6 different sampling stations.

5) $\delta^{18}O$: 60 mL unfiltered seawater were collected for stable oxygen isotope measurements. A total of 101 samples of different depths were collected from 10 different sampling stations.

6) ^{14}C: 500 mL unfiltered seawater were collected for ^{14}C measurements. A total of 92 samples of different depths were collected from 10 different sampling stations.

7) ^{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 115 samples of different depths were collected from 11 different sampling stations.

8) $^{210}Po/^{210}Pb$: 12 L of seawater samples were collected for $^{210}Po/^{210}Pb$ measurements. These isotopes were pre-concentrated using $Fe(OH)_3$ 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 99 samples of different depths were collected from 9 different sampling stations.

9) ^{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 44 samples of different depths were collected from 11 different sampling stations.

10) 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 13 numbers of samples were collected from 27/04/2014 to 29/05/2014.

Air samples were also collected in Teflon filters through Staplex sampler for trace metal and Sr and Nd isotopic analyses. A total of 13 samples were collected from 27/04/2014 to 29/05/2014.

11) Rain Water: Rain water samples were collected whenever available using a funnel system for stable isotope and other miscellaneous measurements. A total of 6 samples were collected during the period 27/04/2014 to 29/05/2014 in different raining events.

12) Sediment Core: Gravity Corer was used to get sediment cores from different locations. A total of 11 numbers of sediment cores were taken from different places in the SK 312 cruise.

Samples collected by NIO, RC, Visakhapatnam in the SK 312 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

nearly 213 samples of different depths were collected and measured onboard from 11 different sampling locations.

2) Dissolved Oxygen: 60 mL of unfiltered seawater samples were collected for dissolved Oxygen measurements. A total of nearly 213 samples of different depths were collected and measured onboard from 11 different sampling locations.

3) pH & Alkalinity: 60 mL of unfiltered seawater samples were collected for pH and Alkalinity measurements onboard. A total of nearly 213 samples of different depths were collected and measured onboard from 11 different sampling location.

RESULTS

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

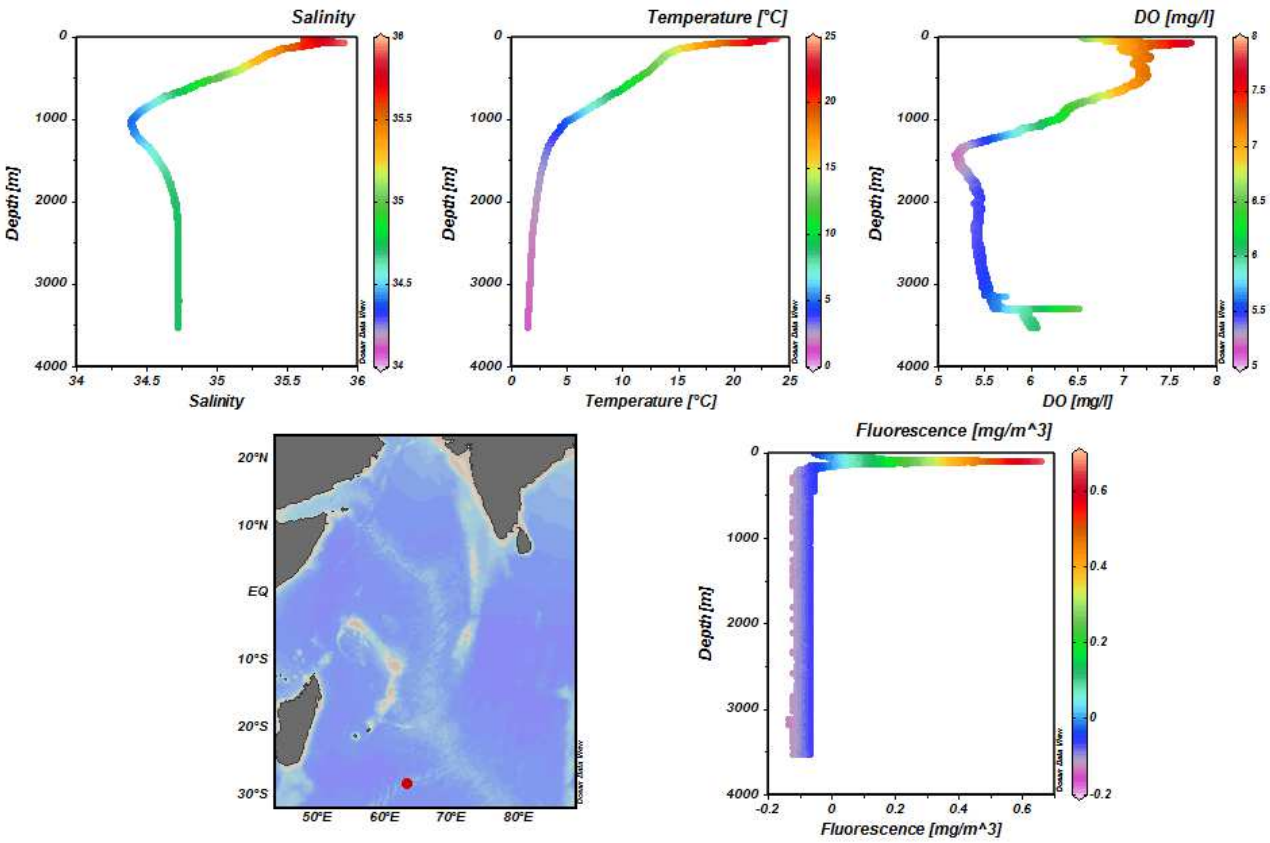

Figure-3. Vertical profiles of biogeochemical parameters at Hydrothermal station (Station-1).

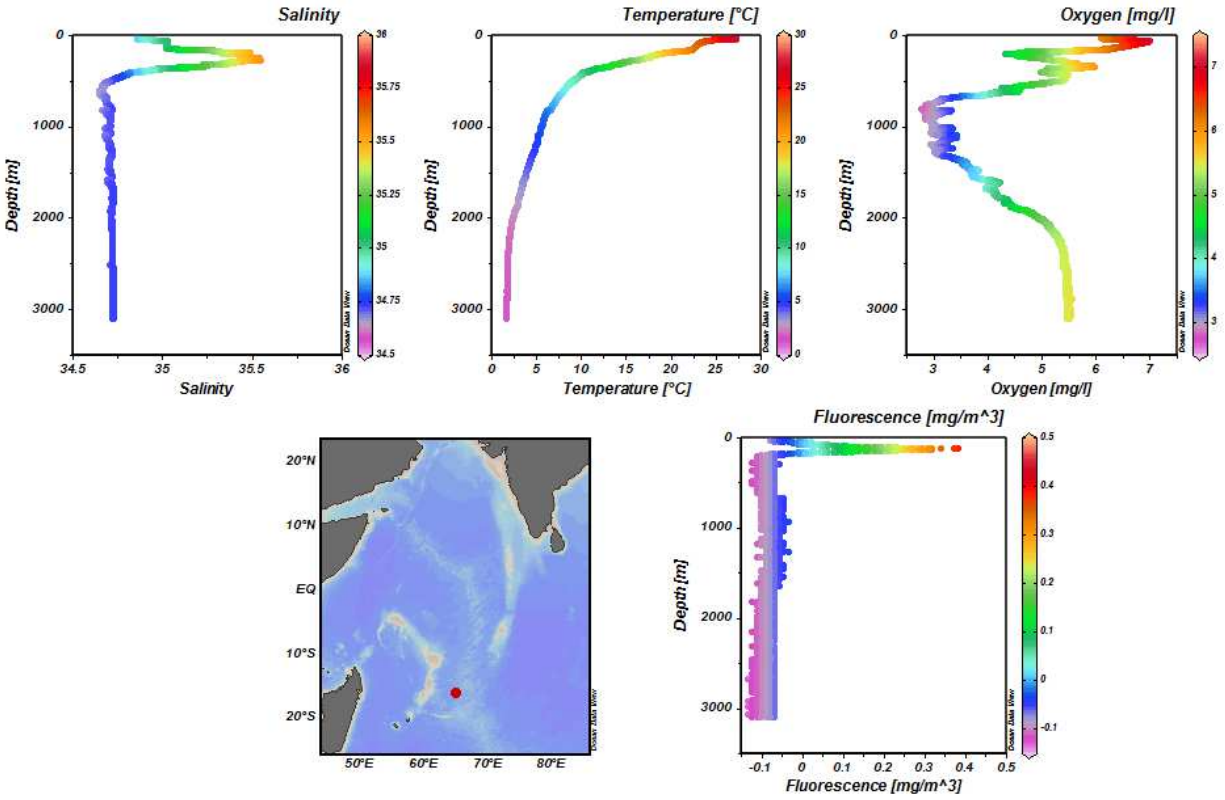

Figure-4. Vertical profiles of biogeochemical parameters in Indian Ocean (Station-8).

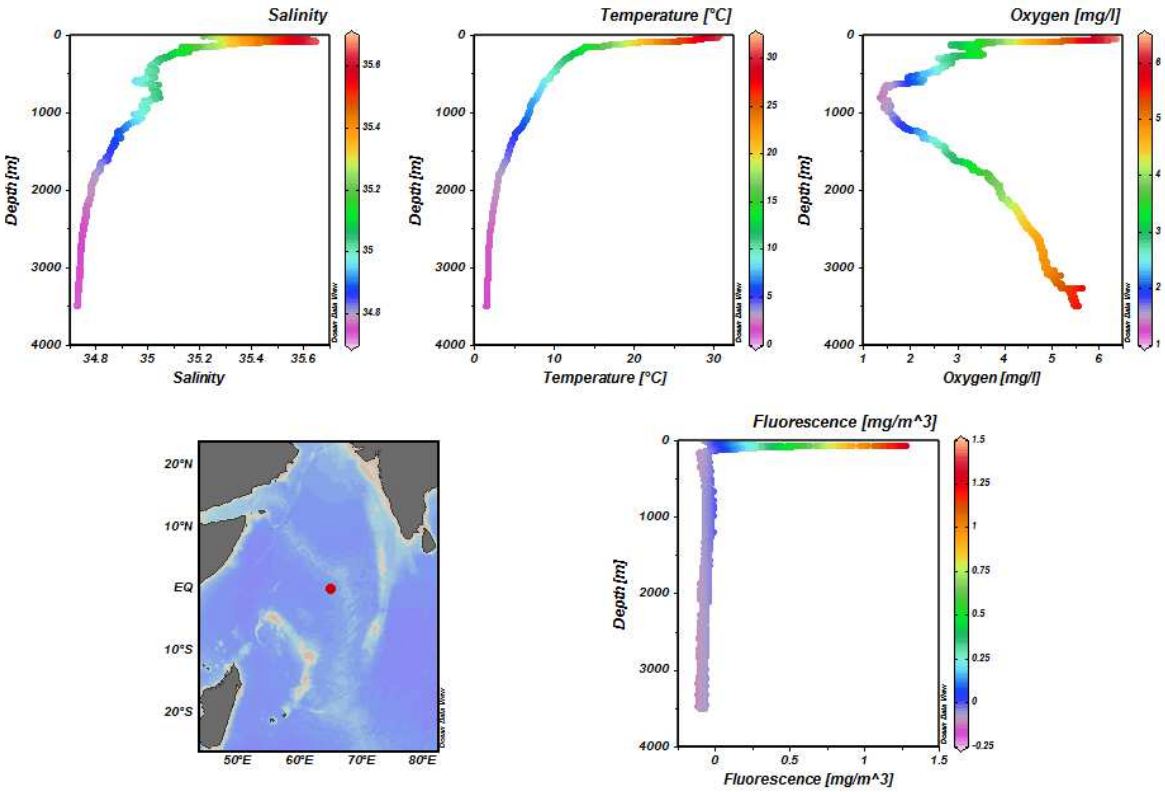

Figure-5. Vertical profiles of some biogeochemical parameters at Equator station (Station-12).

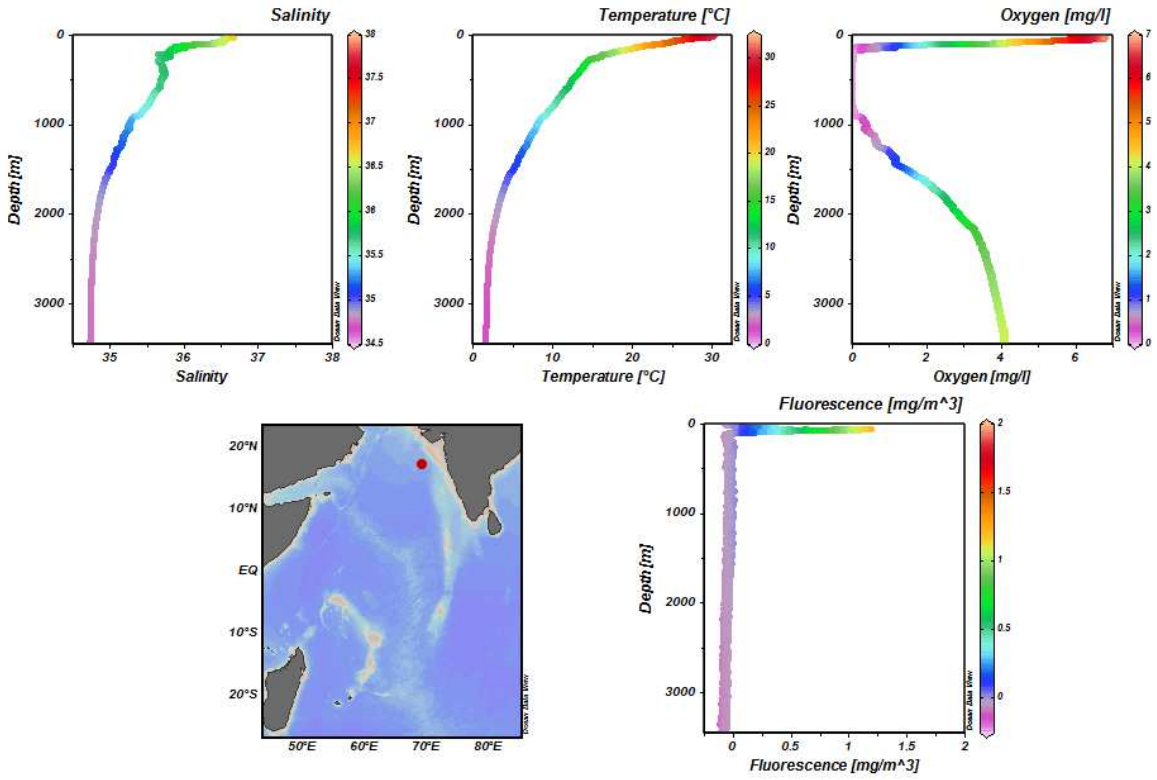

Figure-6. Vertical profiles of biogeochemical parameters in Arabian Sea (Station-18).

SCIENTIFIC OBSERVATIONS

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.

Productivity controls: Productivity in the Arabian Sea is controlled by upwelling associated with Southwest monsoon conditions. Extent of productivity is reflected in the sub-seasurface anoxic conditions. Thus it is very important to understand the biogeochemical behaviour of trace elements as a function of productivity.

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)

Residence time of surface water: The Arabian Sea is north eastern basin of the Indian Ocean 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: 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 the Arabian Sea and the Indian Ocean region will help in understanding these processes.

HYDROTHERMAL STUDIES OVER CENTRAL INDIAN RIDGE IN THE INDIAN OCEAN

Under the Hydrothermal Program in SK312 cruise, we conducted ten CTD (1-6) and nine (1-6) grab operations. These stations were located near known vents fields and a potential geological location on central Indian ridge in Indian Ocean.

SK CTD has been lowered totally nine times at six different stations to identify plume signals and grab samples have been collected nine times at six stations. Plume signal was not found in any of the stations except one (Station-2). The weak signal, temperature anomaly indicates the presence of active vent plume near to this region. The same is also confirmed from Grab samples.

As plume signals were not found in any of the CTD stations, water samples were not collected for chemical, methane and biological measurements in the hydrothermal stations by PRL and NIO (Visakhapatnam) scientists. To identify vents, CTD casts were also made in the locations near to stations (1-6) but again no plume signal was found.

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-312 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.

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Annexure - I

Technical Observation and Suggestions
ORV Sagar Kanya Cruise # 312

Observations & suggestions:

1) The clean CTD operations using the PRL winch system was smooth till the cruise reached Central Arabian Sea. At station 16 during deep water operation at nearly 3000m depth communication of CTD with the unit stopped. CTD was immediately retrived back to deck and it was noticed that Carousel unit has developed water leak. This resulted in damage of the communication PCB card and the triggering PCB card. Norinco team tried to repair it with old spares of CTD but were unsuccessful. Thus station 16 onwards till the end of the cruise clean CTD operations were suspended. The clean CTD carousel unit needs repair of these cards.
2) In absence of oxygen sensor in the clean CTD, the DO data from the regular CTD need to be used. Deck unit from old CTD was used for clean CTD.
3) There was an attempt by someone who hamper the deep sea winch operation by cutting the wires of the deep sea winch control panel. This attempt for sabotage was reported to Captain. However, ship engineers and Norinco people with their expertise rectified the problem at the earliest and deep sea coring could be resumed.
4) The clean flow system in the clean CTD van was malfunctioning during the last few stations of the cruise. Needs replacement of HEPA filters.
5) 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.
6) 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.

7) 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.
8) MilliQ RO system tank developed leaks and requires replacement with a new one.
9) 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-312 Participants

Physical Research Laboratory, Ahmedabad

1. Mr. Subha Anand S — Chief Scientist
2. Ms. R. Chandana — JRF
3. Mr. Venkatesh Cinni — JRF
4. Mr. Chinmay Shah — Project Associate
5. Mr. Utsav Gandhi — Project Associate

National Centre for Antarctica and Ocean Research, Goa

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

National Institute of Oceanography, Goa

10. Mr. Larsen D'Cruz — PA-II

National Institute of Oceanography, Regional Centre, Vishakapatnam

11. Mr. D.H. Bardhan — PA-II
12. Mr. M. H. K. Prasad — PA-III

Pondicherry University, Port Blair

13. Mr. Muruganantham M. — Research Student

Mangalore University, Mangalore

14. Mr. Naveen Kumar — Project Fellow

Engineers - M/s Norinco Pvt. Ltd

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

ANNEXURE-III

Cruise Report- SK 312
Submitted by National Institute Of Oceanography – Goa
Larsen Jose D'cruz

Expendable Bathy Thermograph (XBT):

Expendable Bathy Thermograph (XBT) is a very specialized instrument, which can be operated under any weather conditions and even onboard fast moving ships. The XBT is a system (probe) used to measure vertical temperature profile in real time. Depth is determined by the well drop rate of the probe. When the probe is launched into sea it free falls and measures temperature and transmit digital signal to the data acquisition system (Devil System) through a thin copper wire. The XBT probe is a part of expendable profiling system capable of the highly accurate measurement of oceanographic phenomena and conditions. The XBT probe contains a temperature sensor, a battery, electronics and communication wire. Temperature is measured by sensing resistance changes in a Thermistor. Depth is calculated from the well-known drop rate. Collecting Vertical temperature profiles by deploying XBT's is the most inexpensive approach compared to other oceanographic instruments.

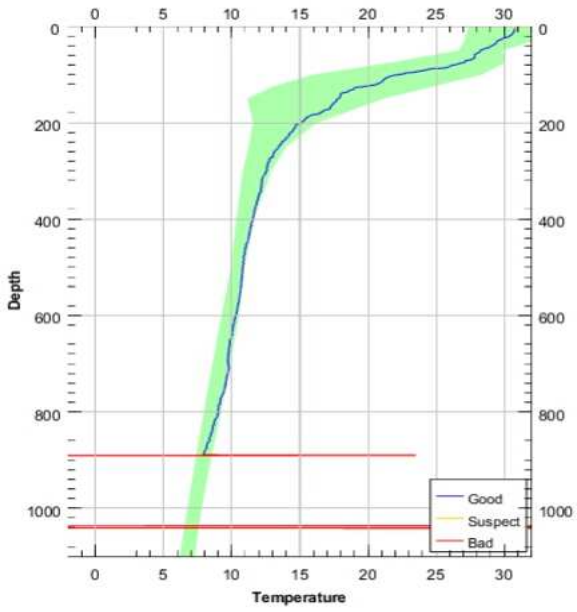


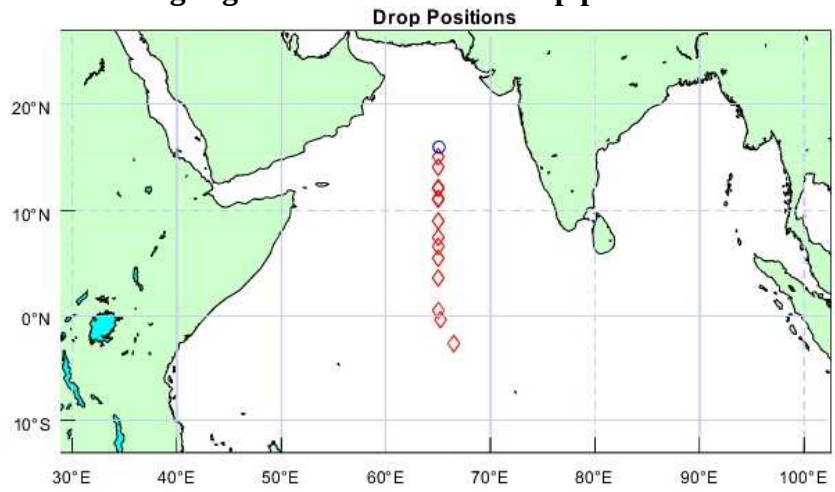
Fig: Hand Held Launcher with XBT T-7 Probe

XBT DEPLOYMENT DETAILS:

Sr.No	Latitude	Longitude	Date	Time	Probe Manufacturing Date	Probe Number
1	02□41'S	66□28'E	15/05/2014	13:53	26/03/2001	992437
2	00□23'S	65□12'E	16/05/2014	08:25	26/03/2001	992441
3	00□29'S	65□01'E	17/05/2014	09:30	26/03/2001	992444
4	03□36'N	65□00'E	18/05/2014	07:10	26/03/2001	992438
5	05□30'N	65□00'E	19/05/2014	08:23	26/03/2001	992445
6	06□38'N	64□59'E	19/05/2014	16:42	26/03/2001	992443

7	07□29'N	64□59'E	20/05/2014	14:19	26/03/2001	992442
8	09□04'N	64□59'E	21/05/2014	01:36	13/03/1998	937326
9	11□09'N	64□59'E	22/05/2014	08:49	13/03/1998	937325
10	12□11'N	65□00'E	22/05/2014	16:48	13/03/1998	937321
11	14□07'N	64□59'E	24/05/2014	09:22	13/03/1998	937318
12	15□05'N	65□00'E	24/05/2014	16:30	13/03/1998	937317
13	15□59'N	65□04'E	25/05/2014	19:58	13/03/1998	937316

The following Figure shows the XBT drop positions



Surface Velocity Profiler (SVP):

The Surface Velocity Profiler or the SVP's are basically the drifting buoy's which are designed to track ocean currents at a fixed depth of around 15 meters. The SVP consists of the Surface float which contains the telemetry system, sensors which are useful in transmitting and receiving the required data and the drogue which is designed to the SVP in place on the ocean surface. The SVP drifter is designed for a maximum free fall deployment height of 10 meters and a travelling ship speed of 2-10 knots.

6 NIO - Goa (Met Ocean) drifters have been deployed and 3 NOAA - USA (Pacific Gyre) Drifters have been deployed.

Drifter Deployment Details:

Met Ocean (NIO)

Argo ID	Latitude	Longitude	Date	Time
133655	20□ 03'S	67□ 04'E	07/05/2014	13:05
133656	15□ 40'S	64□ 57'E	09/05/2014	19:15
133657	08□ 40'S	66□ 22'E	12/05/2014	13:30
133658	03□ 16'S	66□ 48'E	15/05/2014	09:15
133654	07□ 00'N	64□ 59'E	20/05/2014	09:45
133659	12□ 06'N	65□ 00'E	22/05/2014	16:05

Pacific Gyre(NOAA)

Argo ID	Latitude	Longitude	Date	Time
126952	12□ 00'S	64□ 59'E	10/05/2014	19:36
126953	02□ 01'N	65□ 00'E	17/05/2014	19:50
126950	15□ 59'N	65□ 04'E	25/05/2014	19:30

The following drifters which have been deployed also have barometric pressure sensor which provides the atmospheric pressure along with SST (Sea Surface Temperatures) and GPS positions along with date and time.
Also around 100 SSS (Sea Surface Salinity) Samples in 100 ml plastic bottles were collected, which will be analyzed in NIO- Goa

Annexure IV

National Institute of Oceanography, RC
Visakhapatnam

CRUISE REPORT

ORV SAGAR KANYA – 312

(27th April to 30th May, 2014)

Biogeochemical observations in the Indian Ocean and Arabian S

Chief Scientist

Mr. Subha Anand (PRL)

Participants:

S.No.	Name	Designation & Place of working
1.	Mr. M. Harikrishna Prasad	PA III; NIO-RC, Waltair
2.	Mr. Harsabardhan Dalabehera	PA II; NIO-RC, Waltair

Itenary of the vessel:

Name of vessel	ORV SAGAR KANYA
Cruise No.	312;
Port of Embarkation	Mauritius
Date & time of Embarkation	27th April, 2014; 19.00 Hrs.
No. of Scientists participated	19
Region	Indian Ocean and Arabian sea
Operations performed	CTD (Rosette), Grab sampler, Zoo Plankton net

Types sample collected	Water and sediment (grab),plankton
Parameters studied	DO, Total Chlorophyl, HPLC pigments, pH, alkalinity, Carbohydrates, Amino acids and Proteins (CAP), POC, Nutrients, N_2O, CH_4, Phytoplankton, Zooplankton, TBC, TVC, Benthos
No. of Stations	11
Name of Chief Scientist	Mr. Subha Anand S
Name of Dy. Chief Scientist	Ms. N. Latika

Equipment brought from the NIO, Regional Centre, Visakhapatnam

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

Objective: To identify and understand the process and quantify the fluxes those control the distribution of trace elements and their isotopic ratios in the ocean.

The main objective of this study is to 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 Chlorophyl (Chl a), HPLC pigments, Carbohydrates, Amino acids and Proteins (CAP compounds), pH, Alkalinity, Particulate Organic Carbon (POC), Nutrients, trace gases Nitrous Oxide (N_2O) and Methane (CH_4)], 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.

Sampling:

Samples for study were collected on board ORV Sagar Kanya (SK 312) from March 24 to May, 2014 in the Arabian Sea and Indian Ocean. The cruise covered up to date 20stations, twelve in the Arabian Sea and eight in the Arabian Sea. 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) 13C 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. pH & Alkalinity
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 Outcomes:

- ✓ 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 ON INDIAN OCEAN
Chief Scientist: Mr. SubhaAnand
Cruise No: 312
April-27 – May 30, 2014
Submitted By: M.Muruganantham
Pondicherry University, Port Blair, Andaman.

Introduction:

The foraminifera are single cell protozoa which are living benthic and pelagic ocean environments. These organisms secreting their shells from the ambient environment by using the calcium carbonate. The biogenic calcium carbonates of the foraminiferan mainly used to study and understanding about the Paleo-biology, Geochemistry and Paleo-oceanography of ocean environments. GEOTRACES project cruise gave me an opportunity to collect the live foraminiferans in the Indian Ocean.

OBJECTIVE:

In this cruise my objective is collect the Sea floor surface sediment,vertical collection of zooplankton in different depth using through the Multi Plankton Net and surface zooplankton used by the Bongo Net, mesh size 200 µm for Planktonic foraminifera.These samples would be useful for study of spatial variation of planktonic foraminifera from the 28□S to 17□ N and the multiplankton samples will be useful for the vertical distributions. Also the live forominiferal tests are going to study of bio mineralization status in latitude wise of Indian Ocean.

SAMPLE DETAILS

This cruise started from the Port LuiseMoritius to Goa. Here I have collected 15 surface zooplankton and 4 multiplankton samples, vertically from different depth intervals like surface to 500 m, also 4 core top samples and 1 Grab sample from south western Indian Ocean to Arabian Sea.

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. Polonium- 210 often used as a tracer for estimation of carbon transport in the water column. Due to it's 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}Poand 210Pb were scavenged with $Fe(OH)_3$precipitation. The precipitate collected and stored in 60 ml poly ethylene bottle for further analysis.

Annexure VI

GEOTRACES CRUISE REPORT- SK312

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 Indian Ocean and the Arabian Sea.

As part of GEOTRACES cruise program, I collected 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.

AKNOWLEDGEMENTS:

I would like to thank my guide Dr. B. R. Manjunatha, Department of marine geology, Mangalore University. I acknowledge Ministry of Earth Science (MOES) for providing funds under this programme.

Annexure VII

SK312 Cruise report on Hydrothermal studies over South West Indian Ridge (SWIR) in Indian Ocean.

A. Srinivas Rao

NCAOR, Goa

Introduction: Hydrothermal vents are cracks in the ocean floor that emit jets of hot water loaded with minerals. These vents range in diameter from less than an inch to more than six feet. A vent forms when the jet of water shoots through the sea floor and its dissolved minerals begin to precipitate out. Hydrothermal plumes form above sites of venting because of the buoyancy of the hot hydrothermal fluids that rise, entraining ambient sea water with a consequent continuous increase in plume volume, until neutral buoyancy is achieved and the plume disperses laterally.

The first hydrothermal vent was discovered in 1977 in the Galapagos Rift off the coast of South America. Since then, hydrothermal vents have been found along mid-ocean ridges on the seafloor of the Pacific, Atlantic, and Indian Oceans. These natural, deep-sea plumbing systems ventilate heat and minerals from the interior of the Earth, while supporting complex ecosystems of exotic organisms.

In SK312 under hydrothermal program we identified six locations which are near to known hydrothermal vent/plume areas and geologically interested regions. Similar to previous cruise (SK-311), in this also we used CTD and Grab instruments for collection of physical oceanography data and geological samples over SWIR.

Total six CTD locations (10 CTD casts) are occupied between the 67°28′ E, 26°28.38′S to 67°27′E, 26° 28.38′S positions over SWIR. Except 2nd CTD station we did not identified any hydrothermal plume observations in the CTD physical data. Three CTD casts are occupied in second location to identify the exact hydrothermal plume/vent site and its direction because in first cast temperature anomaly observed in the CTD data profile between the depths of 3350m to 3575m in the water column but turbidity sensor not observed any anomalous layer. Further to identify the turbidity signatures another two more CTD casts are done with in one mile from the first CTD cast position. In their casts the turbidity layer is showed the small anomaly range values in the similar potential temperature anomaly depth.

After each CTD cast, immediately grab sampler (six stations-09 casts) also occupied in and surrounding area of CTD location. Out of nine casts only three grabs came with the samples. First grab sampler came with the white loose sediment and contained the planktonic foraminiferal. Second station grab (cast1-63° 32.45E 27°57.06'S) came with full of different color (black, red and brown) material (freshly formed volcanic rock layer surface coated with sulphide and ferromanganese deposit) of the hydrothermal material. Third grab sample (station 6. Second cast 67° 24.33'E 26° 30.26'S) contained only two pieces of thick ferromanganese crusts. On this crust surface we have observed some tubes it is resemblance of the polychate tubes.

Highlight of the hydrothermal sampling is the second stations of CTD and Grab (Fig 1 & 2) sample results of temperature anomalies and grab sample shown the indication of active hydrothermal occurring in this area.

No water samples are collected in this CTD casts.

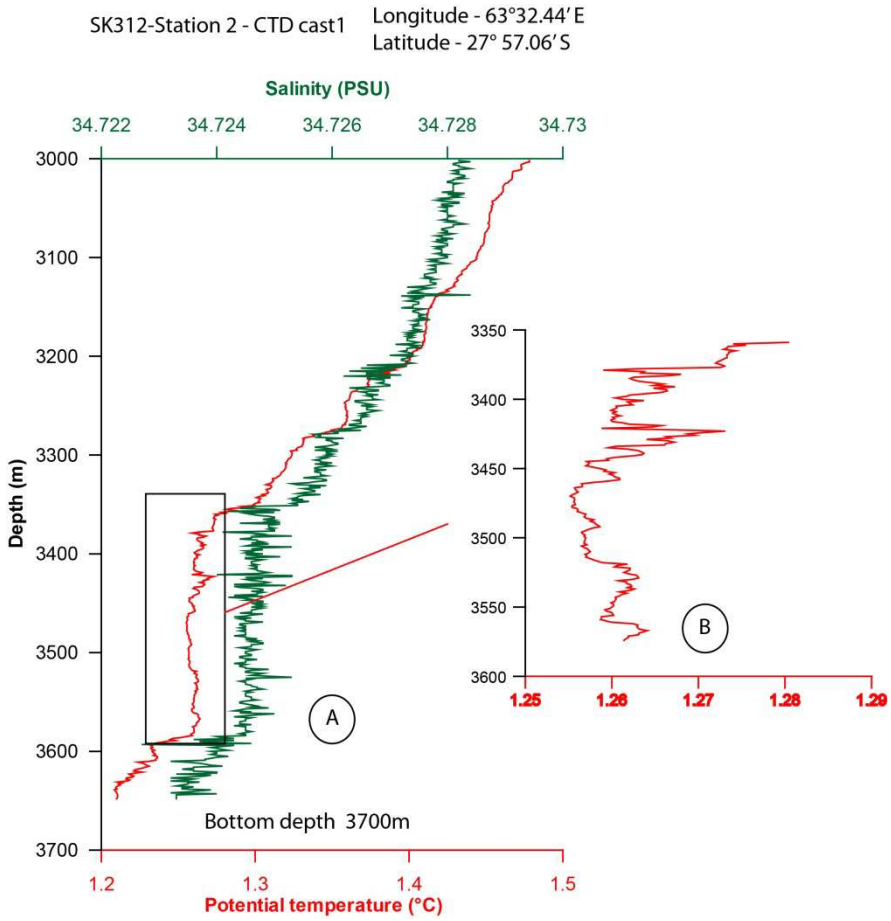


Fig1. A) Vertical profiles of the potential temperature and salinity data.

B) Zoomed area of the temperature profile. The profile is clear that the CTD-rosette intercepted a plume rising above the sea floor at this site.

Fig2. The rock sample is collected the same CTD area.

Annexure-VIII

Seminar presented in SK-312

Speaker	Institute	Topic
Mr. Muruganantham	Pondicherry University	Foraminifera – An Introduction