

SK 248 Tropical Indian Ocean Studies during southwest monsoon



Cruise report

15th July to 19th August, 2008

ACKNOWLEDGEMENT

We the scientific team of SK 248 onboard Sagar Kanya thankfully acknowledge the Secretary, Ministry of Earth Sciences for all the helps provided by him for the successful implementation of the Tropical Indian Ocean Programme. We are grateful to Director NCAOR and Dr. Sudhakar, GD OSSG for their constant encouragement in the planning and execution of this expedition and for providing us the invaluable ship time of Sagar Kanya. We thank the Captain, all SCI Officers and crew members onboard Sagar Kanya for their efficiency in navigating the vessel and the support provided by them in collection of oceanographic data successfully along the predefined cruised track. We acknowledge the catering officer and all his supporting staff for serving us delicious and homely food. We thank NORINCO Engineers regarding the service provided by them for operating all the required scientific equipments onboard for the successful completion of this cruise.



[N. ANILKUMAR]
CHIEF SCIENTIST

1. Embarkation

Sagar Kanya sailed from Chennai port at 22:00 hrs after the embarkation of all scientists and crew members onboard. The vessel headed to 18°S 65°00'E, the first location for all the scientific operations of this cruise programme. A pre cruise meeting was held onboard including all Scientists, Ship Officers and Norinco engineers for discussing the operations to be carried out in the predefined cruise track.

2. Objectives and expected results

1. A comprehensive understanding of the physical, chemical, geological and biological aspects of the tropical Indian Ocean. Studies related to the Equatorial Current system, Water masses and Zonal transport are the key importance of this investigation.
2. Microscopic studies using diatoms and coccolithophores obtained from water sample collected.
3. To understand the nutrient chemistry of the study region from the water samples collected from different depths.
4. The meteorological archive will be useful for a comprehensive understanding of the climatic variabilities.
5. To determine the total quantity of chlorophyll by spectrophotometric method.
6. To study the abundance of zooplankton.
7. To determine total bacterial biomass
8. Microbial studies.

The results obtained from the hydrographic data (XBT, CTD) collected in the tropical Indian Ocean during July-August, 2008 when compared to the previous studies will be attributed to the significant annual changes occurring in the upper ocean thermal structure and variation in the boundary of the equatorial current system and its east west transport in the equatorial region.

For understanding the biogeochemistry of the tropical Indian Ocean a detailed data collection was planned at every one degree latitude from 10°S including water sample collection from different depths.

Diatoms are unicellular, sometimes colony forming eukaryotic microscopic algae, which live free floating or attached to surfaces in fresh-waters and in the oceans. Diatoms are extremely abundant in both fresh-water and marine environments and comprising approximately 23% primary productivity of the world. In sea waters, phosphates and nitrate are usually limited compared to fresh-water conditions and that is why, mostly, open oceans are oligotrophic (poor in nutrients), reflecting on the species composition of diatoms. In order to assess the amount of chlorophyll present in the water column we are planning to collect water samples at different depths from various station locations and will be kept it under preserved conditions for further analysis.

These all data archive will be useful for detailed approach to understand the climatic variabilities

3. Participating Organizations

- 1. NATIONAL CENTRE FOR ANTARCTIC & OCEAN RESEARCH
(NCAOR)**
- 2. PHYSICAL RESEARCH LABORATORY**
- 3. NORINCO**

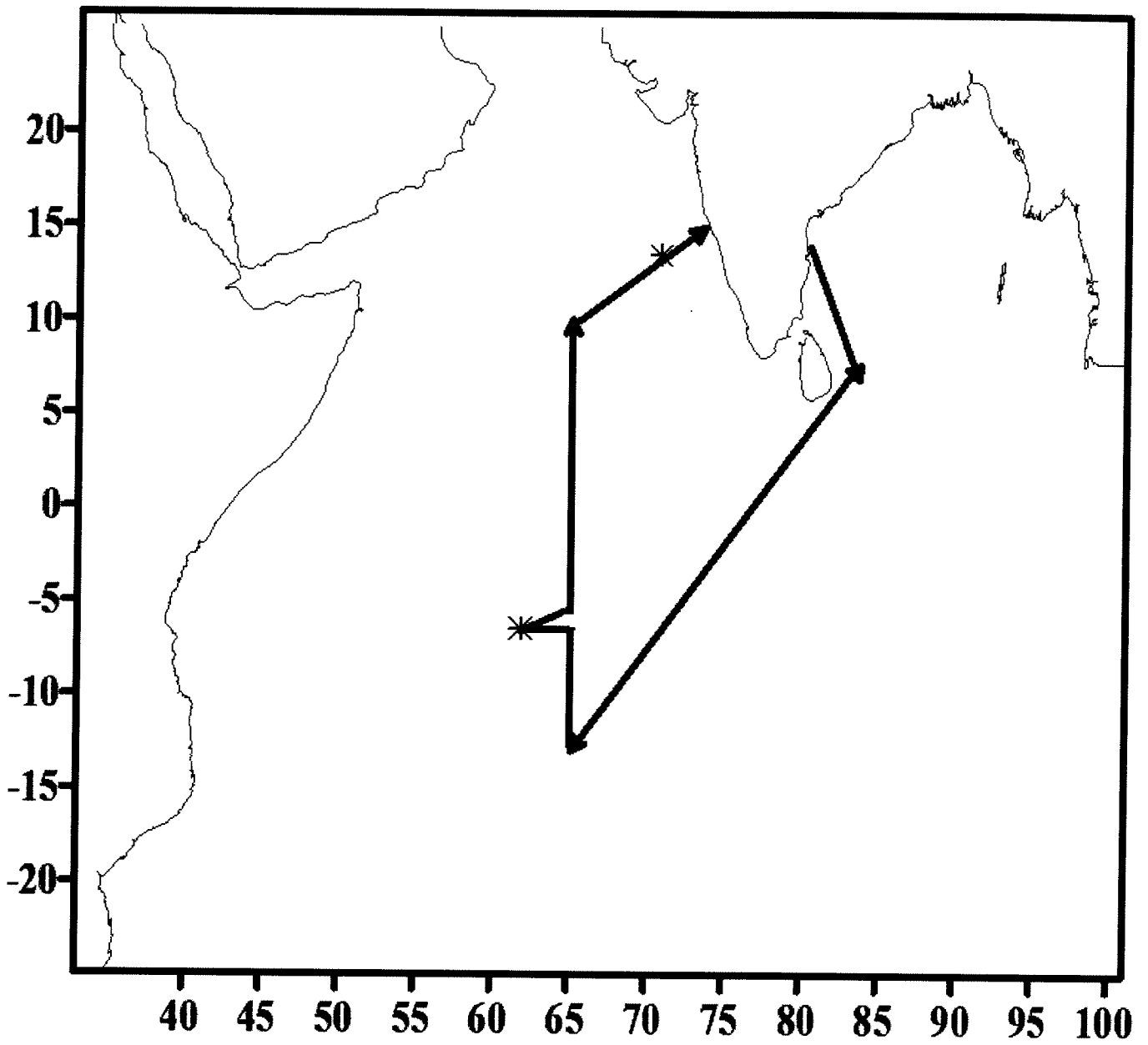


Fig. 1 Cruise track along which CTD, XBT, MPN and Bongo net operations were carried out.

*** Coring Location**

4. List of participants

Sl. No	NAME	Organization
1	Dr. N. Anilkumar (Chief Scientist)	NCAOR
2	Dr. Satya Prakash (Dept. Chief Sci.)	PRL
3	Dr. Zeena Jayan	NCAOR
4	Mr. Rohit Shrivastava	PRL
5	Ms. Racheal Chacko	NCAOR
6	Mr. Naveen Gandhi	PRL
7	Ms. Celsa Margaret Almeida	NCAOR
8	Ms. Sharon Bibiana Noronha	NCAOR
9	Mr. Shramik Maruti Patil	NCAOR
10	Mr. Ghanashyam Kankonkar	NCAOR
11	Mr. Tindel Dipeshkumar (Ship Asst)	NCAOR [Ship trainee]
12	Mr. Bamaniamanish V. (Ship Asst)	NCAOR [Ship trainee]
13	Mr. Biju Vikraman Nair	NORINCO
14	Mr. Avertino Callistus Luis	NORINCO
15	Mr. Mathew Mebish	NORINCO
16	Mr. Hafizur Rahman	NORINCO
17	Mr. Vithu Naik	NORINCO
18	Mr. Thangaraj Ramesh	NORINCO

5. Equipments operated

- 1) Single beam Echo sounder
- 2) Conductivity Temperature Depth [CTD] with rosette samplers
- 3) Expendable Bathythermograph (XBT)
- 4) Gravity corer
- 5) Automatic Weather Station
- 6) Meteorological observations

- 7) Wet Bulb-Dry Bulb and atmospheric pressure
- 8) Acoustic Doppler Current Profiler
- 9) Sub-bottom Profiler

6. Observations (Day to day basis)

Table-1 Observation details

STN. No	DATE	START TIME [IST]	END TIME	LAT	LONG [E]	STN. DEPTH [m]	INSTRUMENTS OPERATED
1	28-07-2008	00:05	06:25	10° S	64° 57'	3360	pCTD, Idronaut CTD
2	28-07-2008	20:25	10:54 (29-07-08)	9° S	64° 59'	3354	pCTD, Idronaut CTD
3	01-08-2008	08:28	21:36	9° S	64° 59'	3500	pCTD, Idronaut CTD, MPN
4	02-08-2008	09:30	18:15	8° S	64° 04'	4100	pCTD, Idronaut CTD, MPN
5	03-08-2008	11:00	15:25	7° S	65° 00'	3540	pCTD, Idronaut CTD, MPN
6	04-08-2008	00:05	11:40	6° S	65° 04'	4321	pCTD, Idronaut CTD, MPN
7	04-08-2008	18:20	22:30	5° S	65° 05'	3919	pCTD, MPN
8	05-08-2008	05:23	14:20	4° S	65° 04'	4400	pCTD, Idronaut CTD, MPN, Bongo Net
9	05-08-2008	20:30	23:43	4° S	66° 00'	3577	pCTD
10	06-08-2008	06:00	09:30	4° S	67° 00'	3439	pCTD
11	06-08-2008	16:00	18:43	4° S	68° 00'	2800	pCTD
12	07-08-2008	04:30	07:05	3° S	68° 00'	2396	pCTD
13	07-08-2008	23:50	01:50 (08-08-08)	3° S	67° 00'	2383	pCTD
14	08-08-2008	08:15	11:50	3° S	66° 00'	3200	pCTD, Idronaut CTD
15	08-08-2008	18:00	03:15 (09-08-08)	3° S	65° 00'	4246	pCTD, Idronaut CTD, MPN
16	09-08-2008	09:15	18:15	2° S	65° 00'	3064	pCTD, Idronaut CTD, MPN
17	10-08-2008	00:20	10:00	1° S	65° 00'	3240	pCTD, Idronaut CTD, MPN

STN. No	DATE	START TIME [IST]	END TIME	LAT	LONG [E]	STN. DEPTH [m]	INSTRUMENTS OPERATED
18	10-08-2008	13:00	17:45	0° 30' S	65° 00'	4816	pCTD, Idronaut CTD
19	10-08-2008	20:15	01:30 (11-08-08)	0	65° 00'	3519	pCTD, Idronaut CTD, MPN
20	11-08-2008	04:15	07:30	0° 30' N	65° 00'	2800	pCTD
21	11-08-2008	09:40	20:15	1° N	65° 00'	3725	pCTD, Idronaut CTD, MPN, Bongo Net
22	12-08-2008	00:45	09:50	2° N	65° 00'	3700	pCTD, Idronaut CTD, MPN, Bongo Net
23	12-08-2008	19:00	23:30	3° N	65° 00'	2608	pCTD, Idronaut CTD, MPN, Bongo Net
24	13-08-2008	08:15	12:07	4° N	65° 00'	3335	pCTD, MPN, Bongo Net
25	13-08-2008	18:00	20:55	5° N	65° 00'	2171	pCTD, MPN, Bongo Net
26	14-08-2008	03:00	07:41	6° N	65° 00'	3880	pCTD, MPN, Bongo Net
27	14-08-2008	13:47	17:25	7° N	65° 00'	3842	pCTD, MPN, Bongo Net
28	15-08-2008	00:00	04:45	8° N	65° 00'	4645	pCTD, MPN, Bongo Net
29	15-08-2008	11:23	15:56	9° N	65° 00'	4000	pCTD, MPN, Bongo Net
30	15-08-2008	23:20	03:54 (16-08-08)	10° N	65° 00'	4520	pCTD, MPN, Bongo Net
31	18-08-2008	02:00		13° N	71° 00'	2379	MPN, Bongo Net

Cruise track of this expedition is given in Fig. 1. The station locations are given in Table 1. It was planned in the pre cruise meeting to carry out XBT observations at 1° interval in the entire cruise track. Sea surface temperature (SST) Sea surface Salinity (SSS) and meteorological parameters was measured at three hourly intervals every day.

16/07/2008

Sea surface temperature (SST), Sea surface salinity (SSS) and Meteorological observations were made 3 hourly intervals. XBT observations were carried out at 1°Latitude interval. AWS, ADCP and SBP were switched ON. Samples for water vapour, oxygen isotope, nitrogen isotope and PON were collected at 12 hours interval.

17/07/2008

Met observations and sea surface data collection were made at regular interval. XBT probes were launched at 1°latitude interval. Samples for isotope, water vapour and PON studies were collected.

18/07/2008

Multibeam was switched ON. Synoptic and all other daily sample collections were made at required regular interval.

19/07/2008

Sea was choppy, sea state was near 5 to 6. Maximum speed obtained by the vessel was nearly 7 knots. All regular observations were made.

20/07/2008

Sea was calm, sea state reduced to nearly force 2. Vessel obtained a speed of around 9 knots. Synoptic observations and all other daily sample collections were carried out at regular interval.

21/07/2008 and 22/07/2008

Samples for isotope, water vapour and PON were collected at 12 hourly intervals. Met observations, SST and SSS data collections were made at regular interval.

23/07/2008

Vessel arrived at 11°09'S 70°32'E. Coring operation was carried out however no core was collected due to bottom topography. Synoptic observations and other data collections were made at regular interval.

24/07/2008

Sea was rough with a sea state of force 6-7. Vessel was getting only 6 knots speed. Regular sample collections were made systematically.

25/07/2008

Sea was very rough with big swells. At 17.30 hrs all regular sample collections were abandoned. A heavy rolling occurred at 19.45 hrs at 15° 1.4'S 67°24'E. This heavy rolling caused damage to some of the items onboard even though those items were intact. After the above incident further southward operations were cancelled considering Captains suggestion regarding the forecasts of rough sea and very bad weather conditions south of 10°S. Considering all the above aspects it was decided to turn the vessel towards north. The vessel started heading northwest considering the most favourable course for sailing.

26/07/2008

The vessel was heading northwest. No observations were carried out due to the prevailing bad weather conditions. Finally it was decided to start the synoptic observations on 27th July 2008.

28/07/2008 and 29/07/2008

No operations were carried out (except the synoptic observations) due to the bad weather conditions up to 10° S, 65° E. CTD operation was carried out at 10°S 65°E during 22.45 hrs. Two casts were made, one up to 1000 meters and the other one up to 200 meters as per the requirement of water samples for biological and chemical analysis. Portable and Idronaut CTD were operated up to 3000 meters for profiles of hydro graphic parameters. The vessel arrived at 9°S 65°E at 2000 hrs on 28/07/2008. Both portable and Idronaut CTDs were operated up to 3000 meters. During this deeper cast the communication of the underwater unit with deck unit was got disconnected at around 3000 meters depth. Operators attempted to rectify the communication problem however could not succeed. Finally the underwater unit was taken on deck and found that the cable was defective. To remove the damaged portion, the cable was cut up to 200 meters and tested however the result was not positive.

30/07/2008 and 31/07/2008

Further the next 500 meter cable was cut part by part for testing the reliability. However the results were not satisfactory. It was decided to remove the cable from the forward winch and test it by cutting from the other end. The cable was removed from the winch and the same procedure of testing was carried out from the other end of the cable also. The cable was cut up to 1000 meters and not found useful. Further two kinks were observed at the middle portion of cable at around 1000 meters apart. These kinks were removed and the cable was tested again. Finally it was found that only 1500 meters of the cable is useful. It was decided to load this cable on the aft winch and remove the present cable of aft winch and load it on the forward winch for further smooth operation of the CTD. The aft winch cable was tested and found OK. Vessel arrived at 9° 23'S 62°14'E at 1835 hrs on 30/07/2008 for coring operation. Gravity corer was operated and core sample was collected. Core length 3.6 meters, core type carbonate. Core was sub sampled at 2 cm length and kept in the laboratory for further analysis/studies. Synoptic observations were being carried out at regular intervals. Aft winch wire has been transferred in to the forward winch. The cable was properly loaded using a dummy weight after reaching the station location 9°S 65°E.

01/08/08

Water sample has been collected for C¹³ studies. Further water could not be collected from 9°S 65°E due some problem with triggering unit of the Idronaut CTD system. Synoptic observations and daily sample collection were made at regular interval.

02/08/2008

Portable CTD has been operated along with Idronaut CTD upto 3000m depth at 8°S 65°E. Carousal unit has been removed for repair work. Hence water sample collection was not carried out. MPN was operated.

03/08/2008

Synoptic observations and the daily sample collection were being carried out at regular interval. Vessel arrived at 7°S 65°E. Portable CTD operation was made upto 3000m depth. MPN was operated.

04/08/2008

The problem with the Idronaut CTD carousal unit was rectified and water sample collection was carried out upto 1000m depth at 6°S 65°E. MPN was operated. At 5°S 65°E portable CTD upto 3000m depth and MPN were operated.

05/08/2008

Vessel arrived at 4°S 65°E. Portable CTD was operated upto 3000m depth. The carousal unit was functioning hence water sample collection was carried out upto 1000m depth for chemical and biological analysis. MPN was operated. Synoptic observations were carried out at regular interval. The vessel started heading towards coring location at 3°S 65°12'E. It was decided to take portable CTD operation at every longitude upto 68°E. First portable CTD along this tract was carried out at 4°S 66°E.

06/08/2008

Portable CTD was operated at 3°59'S 66°58'E and 4°S 68°E. Synoptic observations were being carried at regular interval.

07/08/2008

Coring operation were carried out at 3°04'S 68°12.3'E during 0105 hrs. No core sample was collected due bottom topography (rocky). The next coring operation was carried out 2°S 67°46'E. No core was collected at this location also due to bottom topography. Further the vessel sailed toward 3°S 67°E and the portable CTD was operated at this location.

08/08/2008

Portable CTD operation were carried out 3°S 66°E and 3°S 65°E. Water samples for chemical and biological analysis were collected upto 1000m depth. MPN was operated.

09/08/2008

The vessel arrived at 2°S 65°E during 0900 hrs. Portable CTD was operated upto 2800m depth. Water sample collection [upto 1000m] and MPN operation were carried out.

10/08/2008

Portable CTD and MPN were operated at 1°S 65°E. Vessel headed towards north and portable CTD operation was carried at 0°30'S 65°E. Further portable CTD and MPN were operated at 0° 65°E (equator).

11/08/2008

Portable CTD was lowered at 0°30'N 65°E. Further at 1°N 65°E MPN and portable CTD operations were carried out. Water sample collection was made for biological and chemical analysis since the carousel unit was made operational.

12/08/2008

Vessel arrived at 2°N 65°E at 0045 hrs. Water samples were collected upto 1000m depth. MPN and portable CTD were operated. Further coring operation was carried out at 2°39'N 65°18'E, coring depth 2250m. No core was collected due to bottom topography. Arrived at 3°1.45'N 65°05'E at 1900 hrs. Portable CTD was operated. Plankton collection were made using MPN and Bongo Net.

13/08/2008

Vessel arrived at 4°0.11'N 64° 59.01'E at 08.15 hrs. Portable CTD, MPN and Bongo Net were operated. Further these operations were carried out at 5°N 65°E also.

14/08/2008

Vessel arrived at 6°N 65°E at 0300 hrs. Portable CTD, MPN and Bongo net operations were carried out. All these operations were made at 7°N 65°E also.

15/08/2008

Vessel arrived at 8°N 65°E at 00.00 hrs. MPN was operated upto 400m depth. Bongo Net operation was carried out upto 100m depth. Portable CTD was lowered upto 4000m depth. Vessel arrived at 9°N 65°E at 11.23 hrs. Bongo Net and MPN were operated. Portable CTD was lowered upto 3700m depth.

Vessel arrived at 10°N 65°E at 2320hrs.

16/08/2008

MPN was operated upto 400m. Bongo net was operated upto 100m. Further Portable CTD was operated upto 4200m depth. After completing all these operations the vessel was heading towards the next coring location at 13° 23'N 71°E.

17/08/2008

The vessel was heading towards the aforesaid coring location. All synoptic observations and water sample collection are being made at regular interval.

18/08/2008

Arrived coring station 13° 23'N 71°E at 0145 hrs. Coring operation was carried out, core length: 4.03m. MPN and Bongo net were operated.

Further the vessel is heading to Goa

7. Geological Sampling for Palaeoclimatic Studies

Water samples:

The water samples from 10°S to 2°N were collected at 0, 50, 100, 150 and 200 of water depth to assess the snap shot variation in coccolithophores (calcareous) and

diatoms (siliceous). These two groups of micro fauna are important because they transfer a huge amount of carbon to the ocean bottom. The water samples collected were filtered onto weighed nucleopore filters of 0.4 micron. Dried on board, for analysis on shore using a Scanning Electron Microscope. The data generated would be correlated with the in situ data of the physical parameters at these locations. Further, it would be interesting to understand the variation down the southern latitudes as different water masses are encountered.

Sediment core sample: Collection of suitable cores shall be used for a comparative study of Southwest Indian Ocean paleoclimatology.

Details of core sample collected:

Sample type: *Core (Gravity Core -1)*

Details:

Date: 30/07/08

Time: 1835hrs

Location: 9° 22.9510'S 62° 13.8271'E

Depth: 2410 m

Type: Carbonate

Subsampled Resolution: 2cm

Date: 18/08/08

Time: 0200hrs

Location: 13deg 24'N 71deg E

Depth: 2379 m

Type: Clay

Subsampled Resolution: 1cm

Sediment cores (gravity core) were taken at 9°23'S 62°14'E and 13°24'N 71°E at a water depth of nearly 2500 m. Core lengths were nearly 3.6 meter (360 cm) and 4.03m (403cm). The core was sub sampled into 1cm and 2cm from 300 – 403cm length. The sub sampled core samples were stored in AC cooled Stbd wet lab till offloading.

Sites were selected to obtain samples that may give reliable paleoclimatological records in Northern and Southern hemisphere.

8. Physical Observations

Table-2 XBT operations

Date	Time	Latitude	Longitude	Depth	SST
16/07/2008	06:20	12 N	80 40 E	3359	29.5
	14:00	11 N	81 07 E	3451	29.5
	20:15	10 N	81 32 E	3625	29
17/07/2008	03:00	9 N	81 54 E	3725	29
	09:20	8 N	82 13 E	3780	29
	15:25	7 N	82 15 E	3500	28
18/07/2008	00:50	6 N	82 03 E	4250	28
	10:00	5 N	81 21 E	4248	28
	19:45	4 N	80 48 E	4235	28
19/07/2008	07:00	3 N	80 04 E	3850	28
	13:50	2 N	79 32 E	4338	28.5
	21:45	1 N	78 54 E	4846	28
20/07/2008	06:16	0	78 15 E	4735	29
	16:40	1 S	77 39 E	4700	29
21/07/2008	00:30	2 S	77 00 E	4898	29
	08:10	3 S	76 21 E	5139	29
	15:45	4 S	75 48 E	4755	29
	23:00	5 S	75 07 E	5000	
22/07/2008	06:00	6 S	74 29 E	5130	27.5
	13:00	7 S	73 50 E	5304	28
	22:00	8 S	73 10 E	4091	27.5
23/07/2008	06:20	9 S	72 22 E	2540	26.5
	02:45	10 S	71 33 E	1148	26
24/07/2008	00:00	11 S	70 42 E	2387	26
	11:30	12 S	69 56 E	3416	26
	20:50	13 S	69 07 E	3656	25
25/07/2008	07:30	14 S	68 18 E	3045	25.5
27/07/2008	16:50	10 31S	65 03E	4362	
28/07/2008	17:16	9 20 S	64 57 E	3712	

Date	Time	Latitude	Longitude	Depth	SST
30/07/2008	06:10	9 05 S	64 E	3615	26
	12:25	9 11 S	63 E	3638	26.5
03/08/2008	20:20	06 30 S	65 E	3706	27
04/08/2008	15:00	05 30 S	65 E	3628	27.5
05/08/2008	02:00	04 30 S	65 E	3155	27.5
09/08/2008	06:00	02 30 S	65 E	3734	28
	21:15	1 30 S	65 E	3240	28
10/08/2008	18:00	00 30 S	65 E	4618	28
11/08/2008	07:20	00 30 N	65 E	2800	28
	22:00	01 30 N	65 E	3657	28.5
12/08/2008	14:00	02 30 N	65 E	2610	28.5
13/08/2008	05:15	03 30 N	65 E	2608	28.5
	15:00	04 30 N	65 E	2608	28.5
	23:50	05 30 N	65 E	4801	28.5
14/08/2008	10:40	06 30 N	65 E	4552	28
	20:30	07 30 N	65 E	4627	28
15/08/2008	08:00	08 30 N	65 E	4583	27.5
	20:00	09 30 N	65 E	4526	27.5
16/08/2008	13:15	11 00 N	65 E	4362	27.5
17/08/2008	05:20	12 00 N	68 25 E	4303	27
	20:05	13 00 N	65 E	3200	26

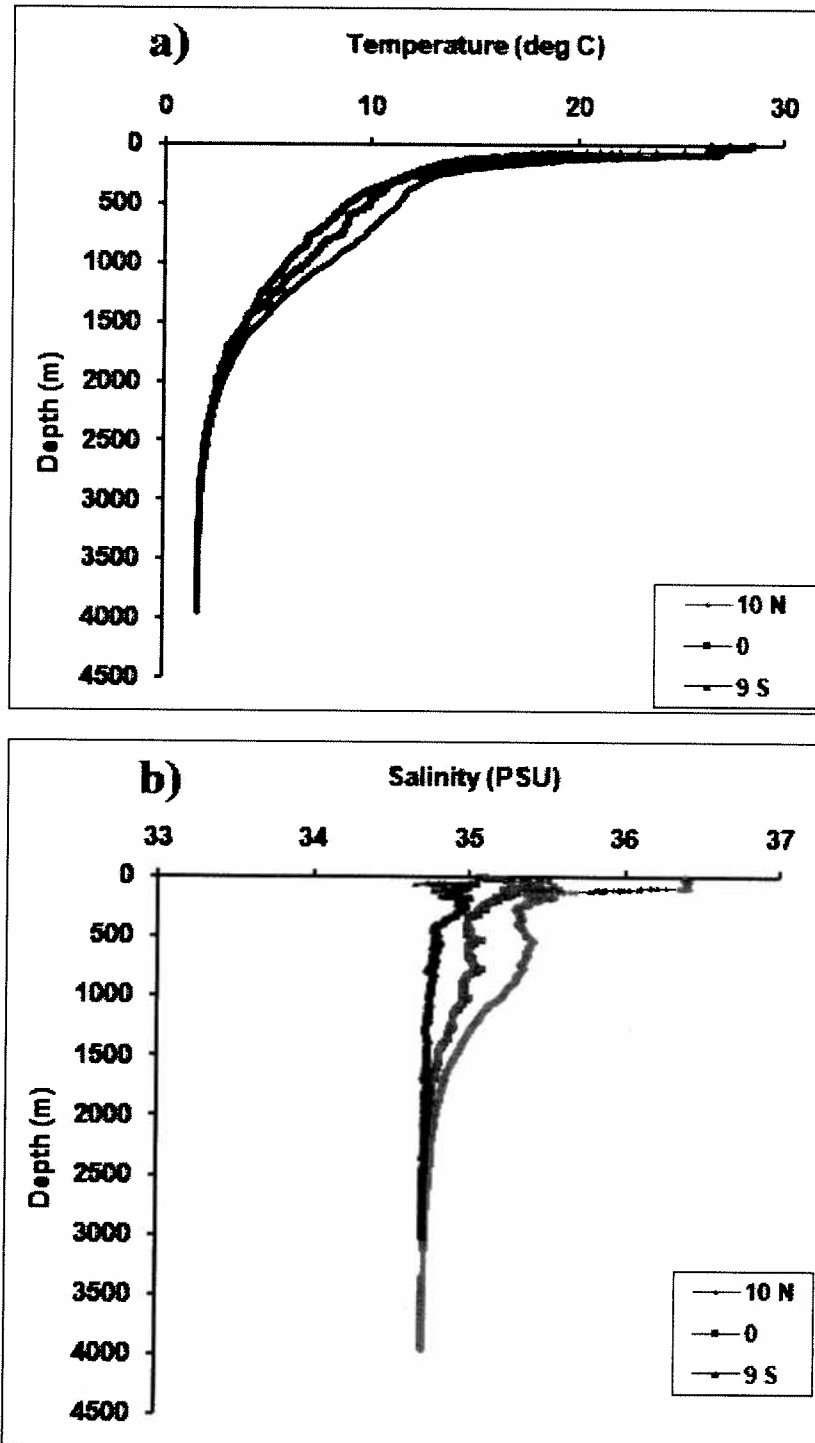


Fig. 2 North south variability of hydrographic parameters

The station locations of CTD and XBT observations are given in Table -1 and Table-2. The north-south variation of the hydrographic parameters is depicted in Fig. 2. The vertical temperature profile based on the Portable CTD data collected at 10°N equator and 9°S are given in Fig. 2a. The Mixed Layer Depth (MLD) is found to be reducing towards south (Fig. 2a and 2b). The salinity profiles at 10°N, Equator and 10°S are

portrayed in Fig. 2b. High saline water observed at 10°N could be an indication of the influence of Arabian Sea High Saline Water.

9. Atmospheric Water vapour, Rain and Ocean surface water sampling for Stable Isotopic studies

The stable isotopes, deuterium (D) and oxygen (^{18}O) are important tracers of the natural hydrological processes. Isotopic fractionation during phase change and slower diffusion rates for the heavy isotopes are the two physical processes that produce the isotope variations observed in precipitation. In most situations, isotopic fractionation is the primary process: the heavy isotopomers (HDO or H_2^{18}O) have lower vapour pressure than the lighter one (i.e., H_2^{16}O) and, as a result, are enriched in liquid or solid phase and correspondingly depleted in the vapour phase. Using these isotopes it is possible to study various processes in the Hydrological Cycle. Only a few theoretical model studies are available which tells the change in the isotopic composition of the vapour over the Ocean as it mixes with the atmospheric free air. This is very important to know the height of diffusion layer as well as mixing of the vapour with free air for the cloud formation and raining processes because Oceans are the origin of our raining system. One important vapour transport isotopic model from Oceans is depicted in figure (1) [Dansgaard, 1964]. It is the first time when we are simultaneously collecting the Sea Surface Water and atmospheric vapour over Southern Tropical Indian Ocean for the stable isotopic studies in the monsoon season. This study will provide better understanding of spatial and temporal variation of evaporation efficiency of the Ocean waters which will give input to understand the cloud formation process and monsoon system. We have already done this experiment over Bay of Bengal. So a comparative study between Bay of Bengal and Southern Tropical Indian Ocean will help us to understand the differences in the evaporation process as it is highly dependent on the physical processes over the oceans. **For this study atmospheric vapour was collected twice in a day (i.e. from 1100 hrs to 1200 hrs and from 2100 hrs to 2200 hrs for most of the cases) with the help of liquid nitrogen traps, from 17th July to 16th August 2008. For a few cases sample collection was at different timing as per to maintain same Universal timing. An ocean surface water sample was also collected during each vapour experiment.**

Apart from this 10 rain water samples were also collected for stable isotopic study. This will also help to validate above described model.

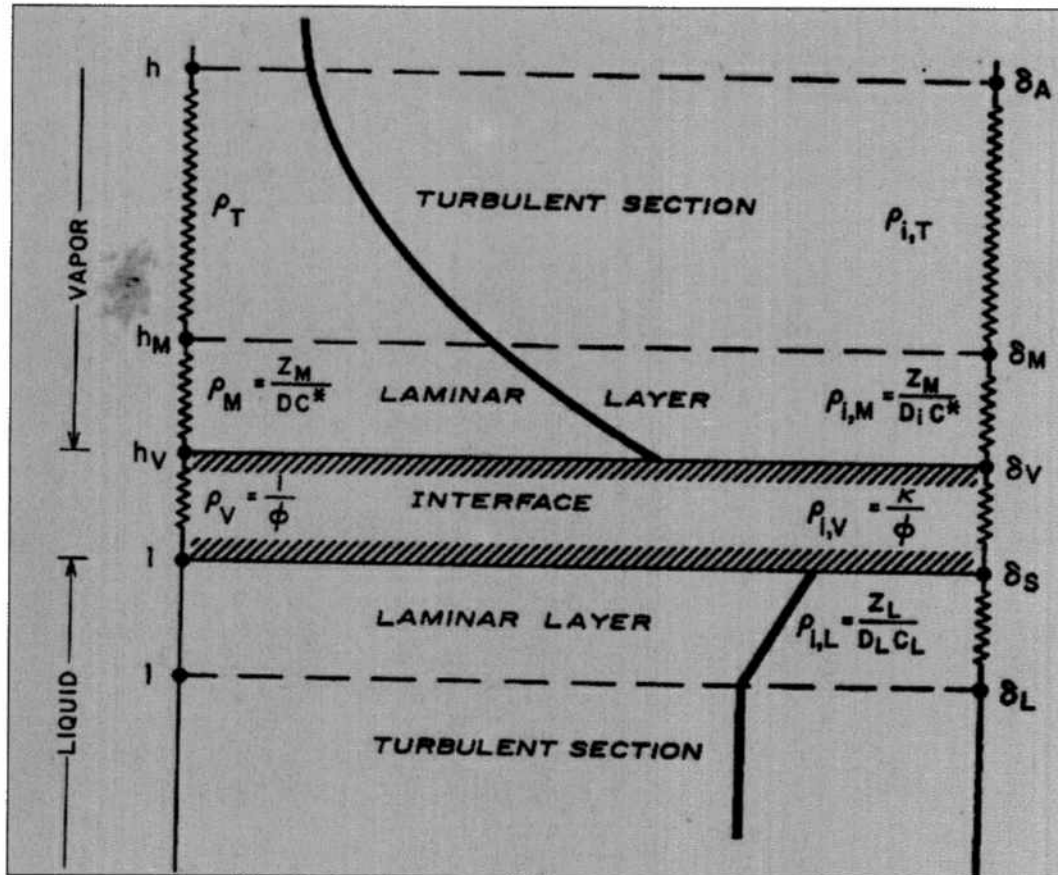


Fig. 3: A laminar layer model for an isolated liquid. The heavy curve in the vapour phase and liquid represents isotopic delta values for the vapour. The various ρ and ρ_i expressions are the transport resistance for the $H_2^{16}O$ and $H_2^{18}O$.

Table 3. Time, date and location of stations at which samples were collected for $\delta^{18}\text{O}$ and δD analysis.

Station number	Date	Latitude (°)	Longitude (°E)
1	17/07/08	7.90	82.23
2	17/07/08	6.50	82.26
3	18/07/08	5.07	81.45
4	19/07/08	2.55	79.88
5	20/07/08	0.54	77.92
6	20/07/08	-1.46	77.33
7	21/07/08	-3.39	76.14
8	21/07/08	-4.14	75.14
9	21/07/08	-4.68	75.33
10	22/07/08	-6.70	74.04
11	22/07/08	-7.82	73.29
12	23/07/08	-9.50	71.96
13	23/07/08	-10.70	70.97
14	24/07/08	-11.91	69.91
15	24/07/08	-13.01	69.11
16	25/07/08	-14.27	68.09
17	27/07/08	-10.97	65.11
18	27/07/08	-10.13	65.01
19	28/07/08	-9.99	64.88
20	28/07/08	-8.99	64.97
21	29/07/08	-8.92	64.64
22	29/07/08	-9.00	65.10
23	30/07/08	-9.18	63.15
24	30/07/08	-9.37	62.35
25	31/07/08	-9.17	63.89
26	31/07/08	-9.02	64.92
27	01/08/08	-9.06	64.92
28	01/08/08	-9.12	64.73
29	02/08/08	-8.01	65.04
30	02/08/08	-7.86	65.12
31	03/08/08	-7.00	65.13
32	03/08/08	-6.36	65.11

Station number	Date	Latitude (°)	Longitude (°E)
33	04/08/08	-6.01	64.94
34	04/08/08	-5.00	65.07
35	05/08/08	-3.96	65.03
36	05/08/08	-3.99	66.00
37	06/08/08	-4.02	67.40
38	06/08/08	-3.67	69.08
39	07/08/08	-2.31	67.85
40	07/08/08	-2.64	67.25
41	08/08/08	-2.97	65.96
42	08/08/08	-2.99	64.97
43	09/08/08	-1.98	64.96
44	09/08/08	-1.56	64.92
45	10/08/08	-0.74	64.89
46	10/08/08	0.02	64.97
47	11/08/08	1.02	64.98
48	11/08/08	1.29	64.98
49	12/08/08	2.31	65.10
50	12/08/08	3.03	65.01
51	13/08/08	4.03	65.02
52	13/08/08	5.06	65.01
53	14/08/08	6.70	65.02
54	14/08/08	7.63	65.00
55	15/08/08	8.96	65.01
56	15/08/08	9.70	65.01

10. Productivity measurements using ¹³C and ¹⁵N tracer technique

Ocean takes up considerable amount of CO₂ through physico-chemical and biological processes and acts as a “sink” of atmospheric CO₂; oceanic biota plays a major role in this process. In Oceanic system the biota mainly consists of micro-

organism called phytoplankton. They are present in the upper sunlit layer of the ocean called as photic zone i.e., the depth at which light becomes 1% of the surface. In the presence of sunlight they convert inorganic CO₂ into organic carbon through photosynthesis. The amount of carbon, thus, fixed by these phytoplankton through synthesis of organic carbon, measured in unit of 'amount of carbon per volume of water per unit time (mgC l⁻¹ hr⁻¹ or mgC m⁻² d⁻¹)' is called primary production. A major part of this primary production is recycled in the photic zone itself, through microbial decay or is eaten by zooplankton, and thus enter the food web but still some part of newly synthesized organic matter is also transported to the deep via sinking. They escape from the upper ocean to the thermocline and below and so they are getting removed from the atmosphere for a longer timescale. This is called as the export production and process is known as the "biological pump".

Nitrogen isotopes can be used as an important tool to estimate the export of carbon out of the surface ocean. On the basis of the source of nitrogen into the euphotic zone, the primary production can be subdivided into new production and regenerated production; new production, where nitrate is a limiting nutrient, is a fraction of primary production supported by the newly borne nitrate into the euphotic zone and regenerated production is that supported by the recycled nutrients such as ammonium and urea. The ratio of new to total production is called the *f*-ratio. Integrated over an annual time scale, new production serves as a measure of the fraction of the photosynthetically fixed carbon that can be exported to the deep. During the present cruise (SK-248) primary productivity (PP) measurements were carried out at five different stations (Table 2): at two stations PP was measured using C¹³ tracer technique whereas at other three stations it was measured using ¹³C-¹⁵N coupled tracer technique. Water samples were collected at 6 different depths, corresponding to 100, 80, 64, 20, 5 and 1% light levels, to cover the entire euphotic zone. Light levels at different depths were measured using a Biospherical PAR sensor attached to portable CTD. Samples were collected using Niskin bottles attached to a CTD rosette sampler. Individual samples were taken, in duplicates, in polycarbonate Nalgene bottles: for ¹³C uptake rate measurements samples were collected in 1L bottles and for ¹³C-¹⁵N coupled tracer method different samples were taken for measurement of nitrate (2L volume), ammonium (2L) and urea (1L) uptakes rates. This was followed by addition of ¹³C and ¹⁵N enriched (99 atom %) bicarbonate, nitrate, ammonium and urea tracers to individual samples taken for measurement of

carbon, nitrate, ammonium and urea uptake rates. Samples were then incubated on the deck after putting on neutral density filter to simulate the light levels from which the samples were collected. Sea water was continuously circulated during the incubation to maintain the temperature. Samples were incubated for 4 hrs symmetrical to the local noon. All samples were filtered subsequently through pre-combusted (4 hrs at 400°C) 47mm diameter and 0.7µm pore size Whatman GF/F filter, dried in oven at 60°C overnight and preserved for mass-spectrometric analysis on shore.

Table 4 Date of experiment, locations and types of methods used to collect samples for estimation of primary productivity during the present cruise.

S. No	Date	Lat/Long	Experiments performed
1	01-08-2008	9°S, 65°E	Primary productivity using ¹³ C tracer technique
2	04-08-2008	6°S, 65°E	Primary productivity using ¹³ C- ¹⁵ N coupled tracer technique
3	08-08-2008	3°S, 66°E	Primary productivity using ¹³ C tracer technique
4	09-08-2008	3°S, 65°E	Primary productivity using ¹³ C- ¹⁵ N coupled tracer technique
5	12-08-2008	2°N, 65°E	Primary productivity using ¹³ C- ¹⁵ N coupled tracer technique

Samples were also collected at different stations (Table 3) in two liter bottles and filtered through GF/F filter, dried in oven overnight at 50°C and preserved for δ¹⁵N analysis. This will help understanding nitrogen biogeochemistry of the equatorial Indian Ocean. 100ml waters samples were also collected simultaneously for nutrient measurements. Nutrients were measured on-board using SKALAR auto-analyzer.

Table 5. Time, date and location of stations at which samples were collected for natural Planktonic $\delta^{15}\text{N}$

S.No.	Time(hrs)/Date	Lat-Lon	Experiments performed
1	09:00/ 18-07-08	5..25°N, 81.27°E	2L sea surface water samples were filtered on 0.7 μm GF/F filter for $\delta^{15}\text{N}$ and PON measurements.
2	09:00/ 19-07-08	2.5°N, 79.9°E	-do-
3	09:00/ 20-07-08	0.5°N, 78°E	-do-
4	21:00/ 20-07-08	1.5°S, 70.3°E	-do-
5	09:00/ 21-07-08	3.2°S, 76.1°E	-do-
6	21:00/ 21-07-08	4.6°S, 75.3°E	-do-
7	09:00/ 22-07-08	6.3°S, 74.2°E	-do-
8	21:00/ 22-07-08	7.8°S, 73.3°E	-do-
9	09:00/ 23-07-08	9.3°S, 72°E	-do-
10	21:00/ 23-07-08	10.7°S, 71°E	-do-
11	09:00/ 24-07-08	11.8°S, 70°E	-do-
12	21:00/ 24-07-08	13°S, 69°E	-do-
13	09:00/ 25-07-08	14.15°S, 68.15°E	-do-
14	09:00/ 27-07-08	11.1°S, 65°E	-do-
15	21:00/ 27-07-08	10.1°S, 65°E	-do-
16	21:00/ 28-07-08	9°S, 65°E	-do-
17	09:00/ 29-07-08	8.9°S, 64.6°E	-do-
18	21:00/ 29-07-08	9°S, 65°E	-do-
19	09:00/ 30-07-08	9.15°S, 63.3°E	-do-
20	09:00/ 31-07-08	9.17°S, 63.35°E	-do-
21	09:00/ 01-08-08	9°S, 65°E	-do-
22	10:30/ 02-08-08	8°S, 65°E	-do-
23	10:30/ 03-08-08	7°S, 65°E	-do-
24	23:30/ 03-08-08	6°S, 65°E	-do-
25	12:00/ 05-08-08	4°S, 65°E	-do-
26	00:00/ 09-08-08	3°S, 65°E	-do-
27	10:00/ 10-08-08	1°S, 65°E	-do-

S.No.	Time(hrs)/Date	Lat-Lon	Experiments performed
28	16:00/ 10-08-08	0°, 65°E	-do-
29	11:00/ 11-08-08	1°N, 65°E	-do-
30	21:00/ 12-08-08	3°N, 65°E	-do-
31	09:00/ 13-08-08	4°N, 65°E	-do-
32	15:00/ 13-08-08	5°N, 65°E	-do-
33	03:00/ 14-08-08	6°N, 65°E	-do-
34	15:00/ 14-08-08	7°N, 65°E	-do-
35	23:30/ 14-08-08	8°N, 65°E	-do-
36	11:30/ 15-08-08	9°N, 65°E	-do-
37	23:30/ 15-08-08	10°N, 65°E	-do-

Note: On missing dates samples couldn't be collected due to very rough weather.

11. Chemical oceanographic studies

The data collected during this expedition will be used to understand the nutrient chemistry of the study region from the water sample collected from different depths.

Procedure:

Collected water samples from 10° S, 5° S, 4° S, 3° S, 2° S, 1° N and 2° N along 65° E longitude from surface, 10m, 20m, 30m, 50m, 75m, 100m, 150m, 200m, 300m, 500m, 750m and 1000 m depths and pH (pH meter), Dissolved Oxygen and nutrients such as nitrite, nitrate, silicate and phosphate were analysed using Autoanalyser (SKALAR).

Preliminary Observations:

Dissolved Oxygen was found to vary from 5 ml/l in the surface to 1 ml/l at 1000m depth. The upper 50m was found to be almost saturated with oxygen (~ 4.5 ml/l).

The nutrients were observed in the following range, no upwelling signatures are present.

Nitrite 0.01-0.06 μ M

Nitrate 0.06-31 μ M

Phosphate 0.01-2.15 μM
Silicate 0.03- 58 μM

Expected Outcome:

The results obtained from the data could be helpful to understand the variation in nutrients, dissolved oxygen and the chemical characteristics of water masses in the Tropical Indian Ocean.

The trend observed for DO (ml/l), Nitrite, Nitrate, Phosphate and Silicate (micromoles) are given below.

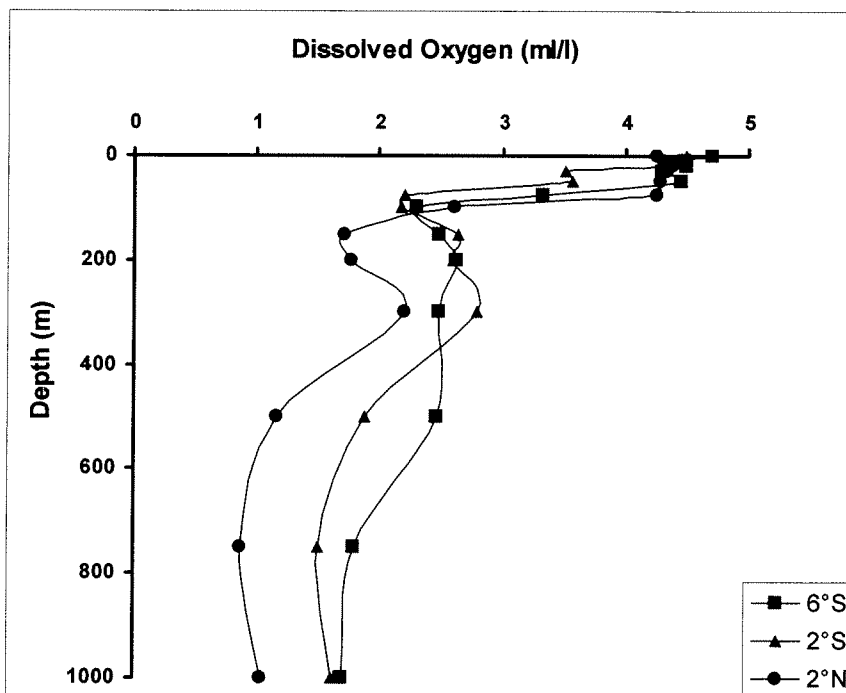


Fig. 4: Vertical Variation of DO (ml/l) at 6°S, 2°S and 2°N

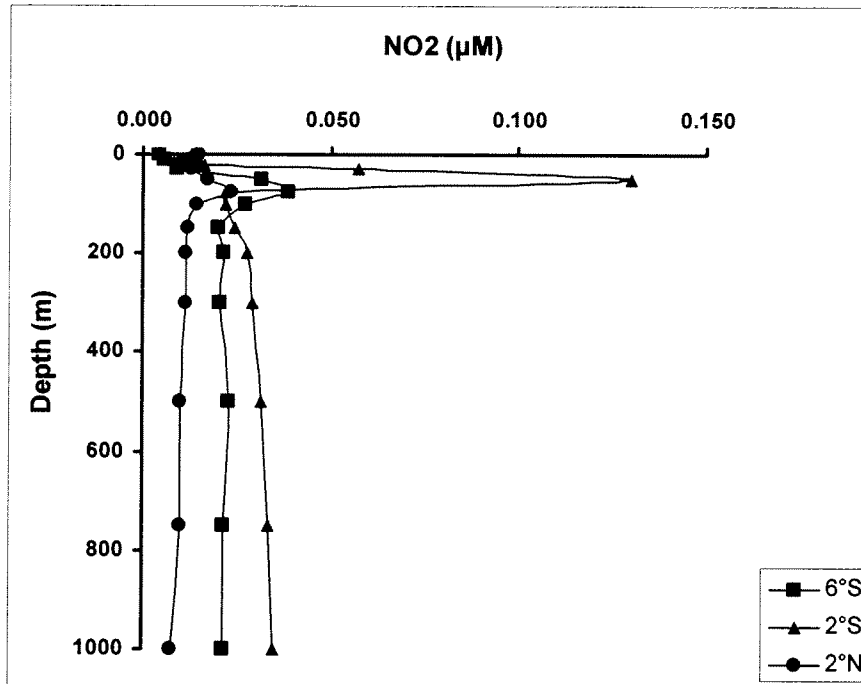


Fig. 5: Vertical Variation of NO₂ (µM) at 6°S, 2°S and 2°N

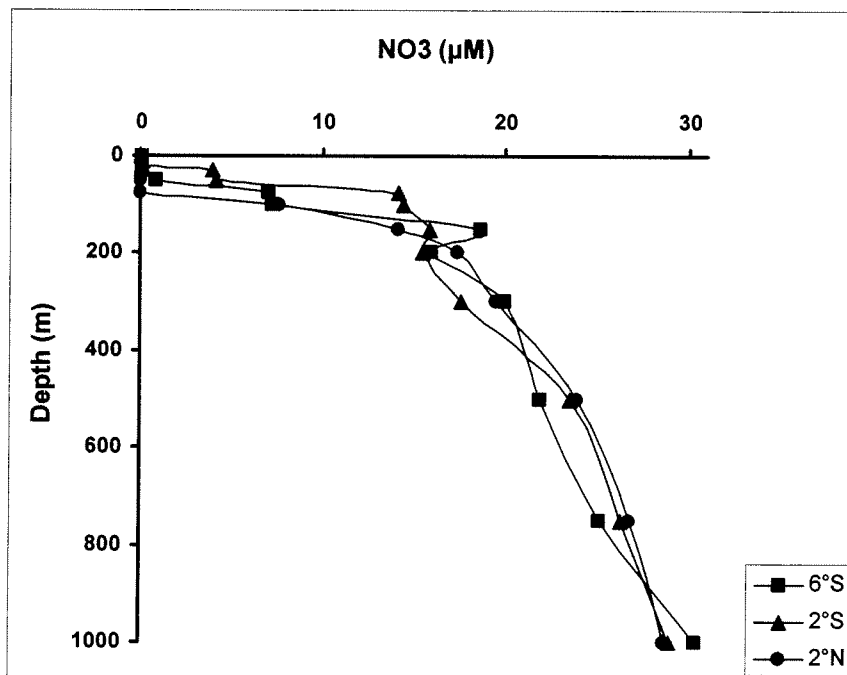


Fig. 6: Vertical Variation of NO₃ (µM) at 6°S, 2°S and 2°N

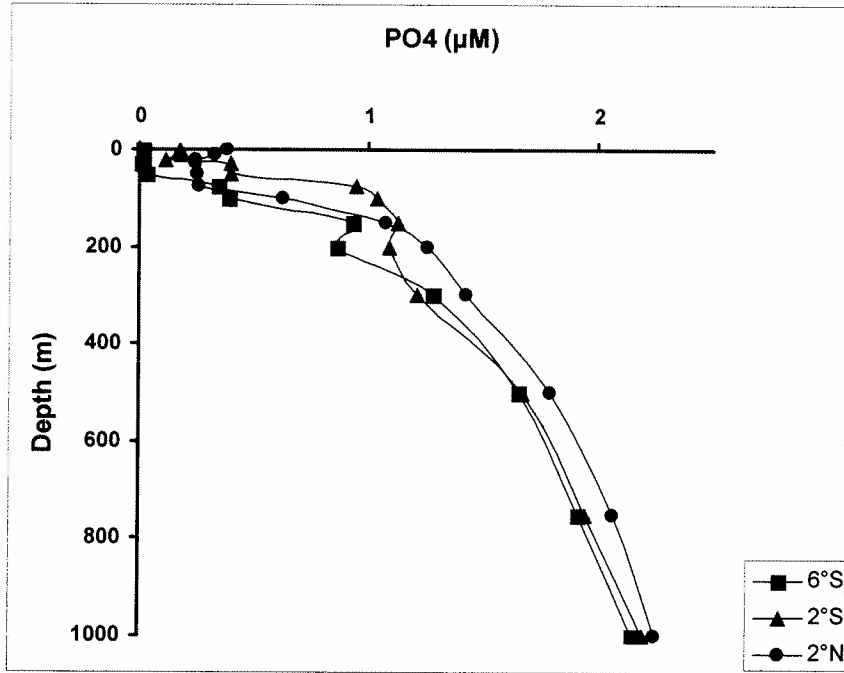


Fig. 7: Vertical Variation of PO4 (μM) at 6°S, 2°S and 2°N

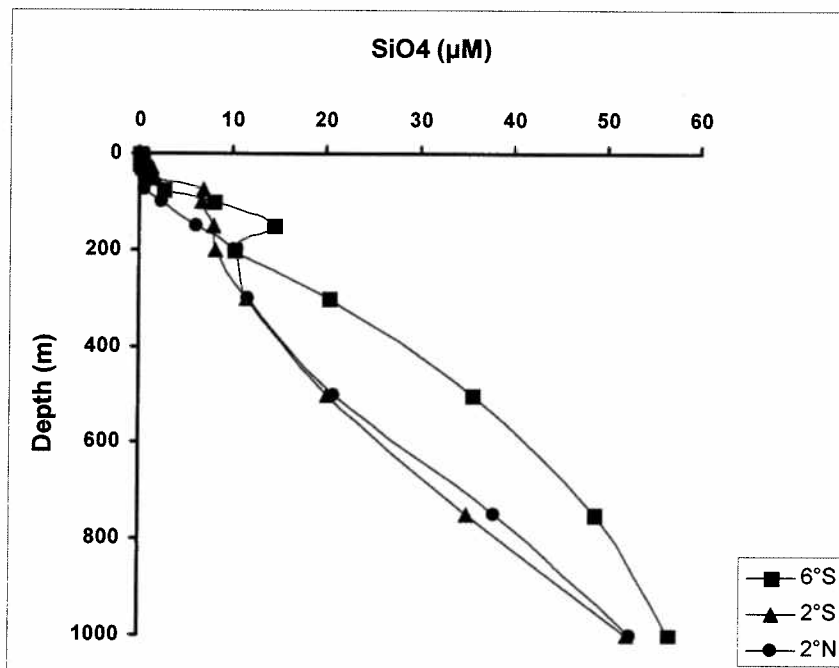


Fig. 8: Vertical Variation of SiO4 (μM) at 6°S, 2°S and 2°N

11. Biological oceanographic studies

The data collected from this expedition shall be used to understand the biological aspects of tropical Indian Ocean during southwest monsoon. This study may enlighten the total quantity of chlorophyll, abundance, viability and culturability of bacteria. The water samples collected shall be used to prepare samples for ATP analysis and microscopic studies using diatoms obtained from the said samples.

Procedure:

For chlorophyll:

Water samples were collected from various latitudes such as 10°S, 6°S, 4°S, 3°S, 2°S, 1°N and 2°N along 65°E meridional transect. All these latitudes the sample collection were made from surface, 50m, 60m, 70m, 80m, 100m, 125m, 150m, 200m depths. Chlorophyll estimation shall be carried out by Strickland and Parsons standard procedure (Practical handbook of seawater analysis, 1968). Surface samples for chlorophyll analysis was collected from almost all stations from 10°S to 10°N in triplicates to study the surface chlorophyll distribution in Indian Ocean during southwest monsoon.

For Microbiological studies:

Water samples were collected from 8 depths viz. 0m, 50m, 75m, 100m, 150m, 200m, 500m and 1000 meters. 5 ml sample preserved with buffered formalin for direct count of bacteria and 200 ml sample is kept in cool place for further microbiological analysis.

For Diatoms:

For diatom studies a quantity of 1 litre water samples (1L) were collected from 10°S, 6°S, 4°S, 3°S, 2°S, 1°N and 2°N at various depths [surface, 50m, 100m, 150m and 200m]. Further surface samples were collected at 1° latitude interval from 10°S to 10°N.

Expected outcome:

The data collected shall be useful to understand the vertical and surface distribution of chlorophyll during the SW monsoon season. Further this data can be used to study abundance, viability and culturability of bacteria.

Table 6. Biological observations

Sl. No	Latitude	Longitude	Observations
1	10S	65E	<p>For chlorophyll estimation water samples were collected from 7 depths viz 0m, 50m, 75m, 100m, 125m, 150m and 200m and filtered through GF/F filter paper.</p> <p>For ATP analysis water samples were collected from 9 depths viz. 0m, 50m, 75m, 100m, 150m, 200m, 500m, 750m, 1000m and filtered through 0.22μ filter paper.</p> <p>5 ml sample collected from same depth was preserved with 250μl buffered formalin for direct count of bacteria and 200 ml sample was collected and kept in fridge for further microbiological analysis.</p> <p>Collected 1L water sample from 5 std depths viz. 0m, 50m, 100m, 150m, 200m and preserved with buffered formalin.</p>
2	6S	65E	<p>For chlorophyll estimation water samples were collected from 7 depths viz 0m, 50m, 75m, 100m, 125m, 150m and 200m and filtered through GF/F filter paper.</p> <p>For ATP analysis water samples were collected from 9 depths viz. 0m, 50m, 75m, 100m, 150m, 200m, 500m, 750m, 1000m and</p>

			<p>filtered through 0.22μ filter paper.</p> <p>5 ml sample collected from same depth was preserved with 250μl buffered formalin for direct count of bacteria and 200 ml sample was collected and kept in fridge for further microbiological analysis.</p> <p>Collected 1L water sample from 5 std depths viz. 0m, 50m, 100m, 150m, 200m and preserved with buffered formalin</p>
6	5S	65E	<p>Sea surface samples were collected in triplicates and filtered through GF/F filter paper for chlorophyll estimation.</p> <p>300ml sample filtered through 0.22μ filter paper for ATP analysis.</p> <p>Preserved 5ml sample for direct bacteria count and collected 200 ml sample for further microbiological analysis.</p> <p>Collected 1L sea surface sample and preserved with buffered formalin.</p>
7	4S, 3S, 2S, 1N, 2N.	65E	<p>For chlorophyll estimation water samples were collected from 7 depths viz 0m, 50m, 75m, 100m, 125m, 150m and 200m and filtered through GF/F filter paper.</p> <p>For ATP analysis water samples were collected from 9 depths viz. 0m, 50m, 75m, 100m, 150m, 200m, 500m, 750m, 1000m and filtered through 0.22μ filter paper.</p>

			<p>5 ml sample collected from same depth was preserved with 250µl buffered formalin for direct count of bacteria and 200 ml sample was collected and kept in fridge for further microbiological analysis.</p> <p>Collected 1L water sample from 5 std depths viz. 0m, 50m, 100m, 150m, 200m and preserved with buffered formalin.</p>
10	9 S, 8 S, 7 S, 5 S, 1 S, 0.5 S, 0, 0.5 N, 3 N, 4 N, 5N, 6N, 7 N.	65E	<p>Sea surface samples were collected in triplicates and filtered through GF/F filter paper for chlorophyll estimation.</p> <p>300ml sample filtered through 0.22µ filter paper for ATP analysis.</p> <p>Preserved 5ml sample for Direct bacteria count and collected 200 ml sample for further microbiological analysis.</p> <p>Collected 1L sea surface sample and preserved with buffered formalin.</p>

Zooplankton studies:

Collection of zooplankton samples that aid to describe prevalent biological diversity variations along the 65 ° E North-South transect.

Sample type: Zooplankton

Collected with Multi-plankton Net hauled vertically

Depth intervals: 0-100, 100-200, 200-300, 300-400 m

Mesh size : 200 microns

From 1 °N to 10° S Bongo Net deployed to collect duplicate sample from 0-100 m

Date	Latitude	Time	MPN Depth(till)m	Bongo net Depth(m)
01/08/08	9° S	20:30- 21:10	400	Not Deployed
02/08/08	8° S	17:45 – 18:15	400	“ “
03/08/08	7° S	15:25 – 15:25	400	“ “
04/08/08	6° S	4:27 -5:05	400	“ “
04/08/08	5 °S	18:30 – 19:05	400	“ “
05/08/08	4 °S	12:05 – 12:55	100 - 500	0-100
08/08/08	3 °S	22:3 – 23:00	400	Not Deployed
09/08/08	2 °S	15:37 – 16:00	400	“ “
10/08/08	1 °S	1:44 – 2:10	400	“ “
10/08/08	0 °	20:37 – 21 :07	400	“ “
11/08/08	1° N	10:00 – 11:05	400	100
12/08/08	2 °N	7:32 – 8:30	400	100
12/08/08	3 °N	19:58 – 20:43	400	100
13/08/08	4 °N	8:25 – 9:18	400	100
13/08/08	5 °N	18:15 – 19:15	400	100
14/08/08	6 °N	3:12– 4:10	400	100
14/08/08	7 °N	14:05 – 14-46	400	100
15/08/08	8° N	00:10 – 00:53	400	100
15/08/08	9° N	11:45 – 12:33	400	100
15-16/08/08	10° N	23:25 – 00:10	400	100

In Total Samples collected at 20 stations with MPN at all of these while Bongo Net was deployed for 11 of these stations.

Samples were transferred into 500 ml containers and preserved in buffered formalin solution for later examination and identification.

After completion of the expedition vessel has arrived at Murrugao port on 19th August at 0500hrs