Report on the Sixth National Expedition to Southern Ocean

23 December 2011 - 06 February 2012

National Centre for Antarctic and Ocean Research
Ministry of Earth Sciences, Govt of India
Headland Sada, Vasco-da-Gama, Goa-403804

PREFACE

The 2011-12 expedition to the Indian sector of Southern Ocean, which incidentally was the 6th expedition to this region and the 61st cruise of ORV Sagar Nidhi, sailed from Goa on 25th December 2011 with 20 scientists, representing 9 different research institutions and universities of India and 3 engineers from NORINCO Pvt. Ltd., Chennai. This is the third successive expedition that ORV Sagar Nidhi was making to the Southern Ocean. Originally the ship was scheduled to leave Goa on 15th December, 2011 after loading the equipments and materials and embark on the expedition on 28th December, 2011 from Port Louis (Mauritius) and disembark on 2nd February, 2012 at Port Louis (Mauritius), after completing the sampling and observations at 40 stations in the proposed cruise track **(Fig. 1)**. However, due to some last minutes changes in the ship's schedule, the ship sailed from Goa with all scientists, equipments and materials on 25th December, 2011. This necessitated rescheduling of the cruise track and as a result of the time loss, only 21 stations **(Fig. 2)** could be sampled. The ship called on Port Louis (Mauritius) on 6th February 2012 where all the scientists disembarked.

During this expedition, it was proposed to carry out high resolution sampling in the water column of the Subtropical Front (STF), to understand the various biogeochemical processes and biological productivity potential. It was also intended to make extensive study on atmospheric parameters so as to link with climate variability and biogeochemical cycling. This region was selected for investigation during the expedition mainly because of previous experiences, wherein it showed maximum gradients in temperature, salinity and nutrients over a very small area. Satellite images though showed STF as a productive region, *in situ* observations were not in accordance with it. This contrast could mainly be due to the discrete and few sampling locations which may not be enough to explain the food-web dynamics and biogeochemistry in relation to the prevailing oceanographic conditions. A time-series observation for 48 hr was also conducted to understand the short-tem variations, both in hydrography, biological productivity and biogeochemistry. This was the basis for making the extensive sampling with in STF. However, a few stations were also sampled in the Polar Front up to 53ºS, mainly for comparative purpose.

Of the 21 stations sampled, CTD and microstructure profiler (turbulence measurement) were operated at all the stations. Nine stations were sampled for

multidisciplinary parameters, where water samples up to 1000 m depth were collected using the rosette system attached to CTD for all chemical and biological parameters, Multiple Plankton Net (MPN) was operated for stratified sampling of mesozooplankton and WP net was hauled for surface mesozooplankton. Primary productivity estimation using ^{14}C was made at selected stations. XCTDs and XBTs were launched at an interval of 10 nautical miles along 53º30'E and 57º30'E and at 30 nautical mile along 40ºS and 43ºS. Different experimental studies were also conducted, particularly microcosm experiments on bacteria to understand the response to nutrient alterations, Photosynthetic irradiance and phytoplankton physiology, bacterial carbon turnover etc. Squid jigging was carried out, mostly at night time, to study the biological and biochemical characteristics of the squid species inhabiting this water. Atmospheric studies were carried out all along the cruise track.

Besides, continuous underway observations were made for ocean currents, atmospheric parameters and bathymetric data by operating Acoustic Doppler Current Profiler (ADCP), Automatic Weather Station (AWS), Multi-beam, Echo-sounder and Sub-bottom profiler.

During this expedition, the NCAOR participants also volunteered to deploy ARGO floats (INCOIS), Drifters and XBTs (NIO) and collect water samples for specific studies for JNU and NIO. NCAOR also collected surface water samples from off Kochi to 13ºS along the cruise track for studying the phytoplankton diversity and biomass in relation to nutrient concentration and for estimation of specific organic carbon components and bacterial abundance.

The meticulous planning and execution of Southern Ocean Expedition 2011-12, the extensive and high resolution sampling of various critical hydrographic, chemical, biological and atmospheric parameters, no doubt, would result in generating high quality data that could be used to explain the implications of various atmospheric processes/climatic variations on the biogeochemical processes, biological productivity potential and carbon cycling in and around STF of the Indian Sector of Southern Ocean.

ACKNOWLEDGEMENTS

On behalf of all participants, I express our sincere gratitude to Dr. Shailesh Nayak (Secretary, MoES), Shri Rasik Ravindra (Director, NCAOR), Dr. N. Anil Kumar (Coordinator, SO Programme) for extending all the facilities and support for the successful completion of the expedition. Director, NIOT, Dr. Rajasekhar, (Head VMC) and members of Vessel Management Cell are gratefully acknowledged for extending the logistic support for the expedition. Mr. Ghanshyam (OSSG, NCAOR) helped us in many ways from the planning stage to the end of the expedition and we are indebted to the services he has rendered. The NORINCO engineers (Mr. K.M. Jayakrishnan, Mr. Ebin James and Mr. N. Dhanasekaran) did an excellent job in maintaining all the onboard equipments/instruments and ably supported the scientists in operating CTD and MPN, even at odd hours and in very rough sea conditions, for which we express our gratitude to them. Captain S. William (Master), Captain S.N. Viswanathan (Additional Master) and all other officers and crew of ORV Sagar Nidhi did everything possible to make the expedition a memorable, eventful and above all a successful one and we place on record our sincere gratitude to each and every one of them.

(Dr. C.T. Achuthankutty)
Chief Scientist

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1. NEED FOR THE EXPEDITION

The Southern Ocean (SO) is a source and sink for several intermediate and deep water masses of the world oceans. Many aspects of its circulation, water masses and response to climate change remain unknown primarily due to the lack of high resolution sea truth observations. Since studies in the Indian sector of the Southern Ocean are sparse, it is imperative that more systematic scientific investigations need to be carried out for a comprehensive understanding on the physical and biogeochemical processes *vis-à-vis* the food web dynamics, for a realistic estimation of biological productivity and carbon cycling.

The National Centre for Antarctic and Ocean Research (NCAOR, Goa), as the nodal agency for planning and coordinating the scientific expeditions to the Indian sector of the Southern Ocean, has so far launched five expeditions (January-March 2004 [Pilot Expedition], January-April 2006, January-April 2009, January-March 2010 and January-March 2011), involving about a dozen leading institutions in the country, to understand the complexities of this dynamic ocean. The results obtained from theses expeditions are quite encouraging as they provided sufficient baseline data/information on various physical, biological and biogeochemical processes that are responsible in modulating the global warming and climate variability.

Frontal waters are highly complex systems formed at the confluence of distinctly different water masses, resulting in the redistribution of physico-chemical constituents and formation of sharp gradient features. In the Southern Ocean, among the various frontal waters identified, the Subtropical Front (STF) waters show maximum gradients in temperature, salinity and nutrients over a very small area (<200 nautical miles wide). Conversely, the Polar Front (PF) waters receive highly productive Antarctic coastal waters from the south and high nutrient-low chlorophyll (HNLC) waters from the north, resulting in sporadic blooms and high biological biomass. Therefore, during the 5th expedition (SOE-2011), time-series observations were also carried out at STF and PF, besides the regular sampling at the meridional stations. The time-series and the meridional studies showed distinct spatial distribution of phytoplankton biomass and diel variations, closely linked to nutrient variations. Both phytoplankton biomass (chl *a*) and

mesozooplankton biomass showed a meridional increase with maximum biomass in the Polar Front. Although satellite images showed productive waters in STF, the productivity signatures could not be captured in the *in situ* observations. This may be due to discrete and few sampling locations within the STF. It appears that such discrete sampling points within the fronts therefore are not enough to explain the prevailing food-web dynamics and biogeochemistry in relation to the oceanographic conditions.

Hence, it was proposed to make high resolution sampling in the Subtropical Front during the 6th Indian Scientific Expedition to the Indian Ocean sector of the Southern Ocean (SOE-2011-12) with the following focal scientific themes:

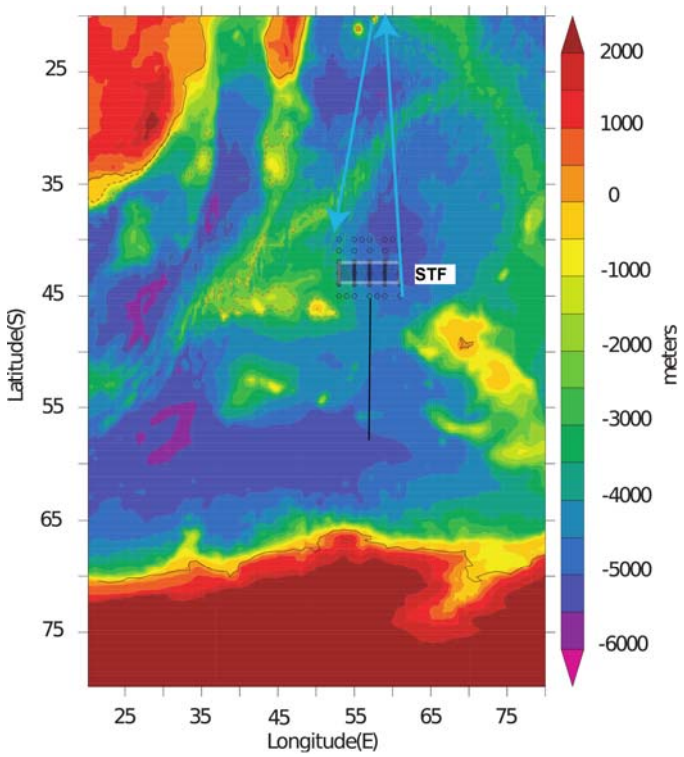
1. Water column dynamics
2. Biogeochemistry
3. Food web dynamics
4. Atmospheric sciences

2. CRUISE TRACK AND SAMPLING STRATEGY

The 6th expedition to the Indian Sector of the Southern Ocean was the 3rd successive expedition of ORV Sagar Nidhi to this pristine region which was incidentally the 61st cruise of ORV Sagar Nidhi. The expedition was originally proposed to start on 28th December 2011 from Port Louis (Mauritius) with the ETA at the 1st station on 3rd January 2012 and reach Port Louis on 2nd February 2012, after completing all the observations and sampling. Accordingly, the ship was to sail from Goa on 15th December 2011, after loading all the scientific equipments and materials required for the expedition. A total of 40 stations were originally proposed to be sampled, 34 stations with in STF (40ºS - 45 ºS Lat; 53º30'E - 58º30'E Long) and 6 stations between 50ºS - 57ºS Lat, along 57º30'E Long (**Fig. 1**). However, this could not be accomplished due to some unavoidable last minute changes made in the ship's schedule. The ship was made available for the expedition on 23rd December 2011 at Goa. The ship sailed on 25th December 2011 via Galle (Sri Lanka) to the sampling location and was to call on Port Louis on 2nd February 2012. Due to the rescheduling of the expedition, the ETA at the 1st station was delayed by almost 10 days and reached on 12th January 2012 (late night). Also, due to a snag developed to one of the thrusters, the speed of the ship was

considerably reduced and the ship reached Port Louis only on 6th February 2012. As a result, the entire expedition schedule had to be revised and only 21 stations could be sampled due to paucity of time (**Fig. 2**).

Figure 1: **Originally proposed cruise track**



2.1 Revised Cruise Itinerary:

Boarding at Goa: 23/12/2011 (1300 hr)

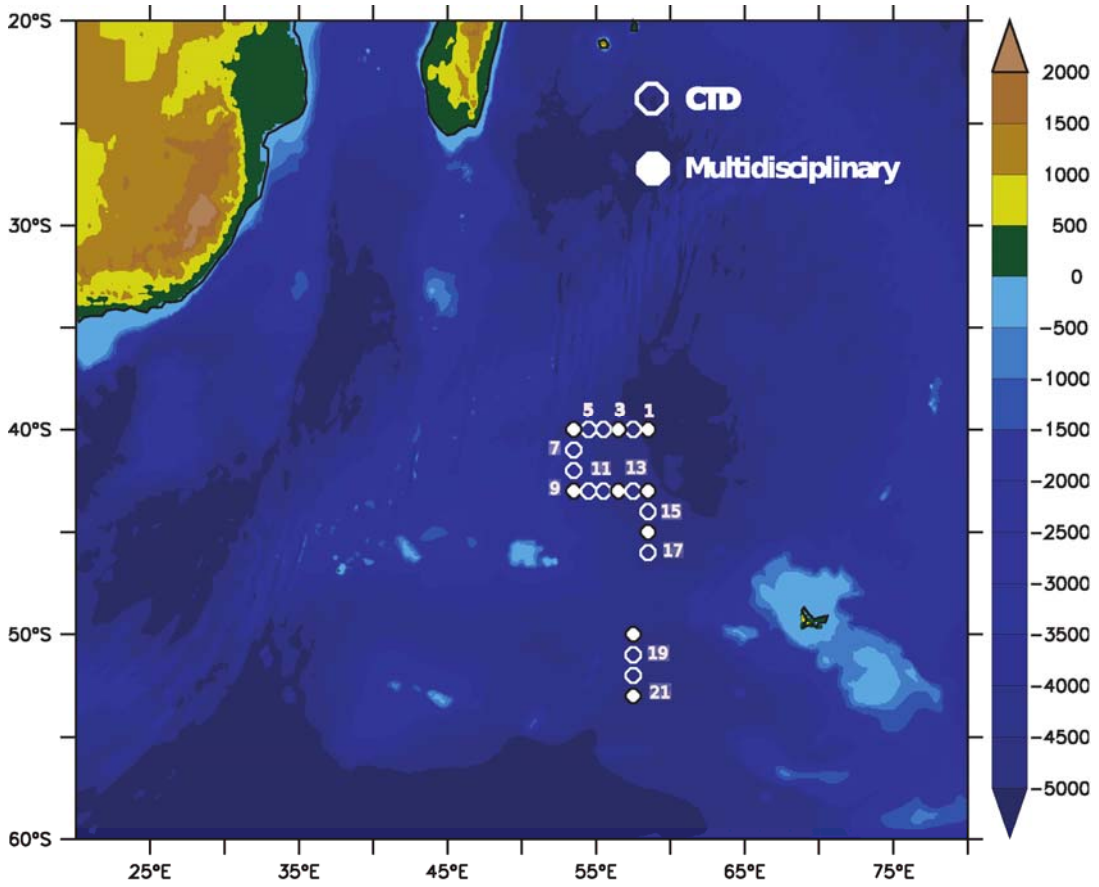
Sailing from Goa: 25/12/2011 (0600 hr)

Arrival at 1st station: 12/01/2012 (2330 hr)

Completion of sampling: 23/01/2012 (1745 hr)

Arrival at Port Louis, Mauritius: 06/02/2012 (0645 hr)

Figure 2: **Revised cruise track**



Location of observations during Southern Ocean cruise 2011-12 (SN 061) onboard R.V. Sagar Nidhi. Filled/empty circle indicates location of multidisciplinary/CTD observations Background represents topography of the region derived from ETOPO5 dataset.

The geographic locations of the stations, time occupied at each stations and the type of equipments used at each station are listed in **Table 1.**

2.2 Physical Parameters:

As can be seen from the cruise track (**Fig. 2**) and Table 1 that observations and sampling were done at an interval of 1 degree, (both latitudinal and longitudinal transects) for physical parameters. At all the 21 stations, CTD (SEABIRD 911 plus, USA) was deployed for profiling the water column up to a depth of 1000 m which was equipped with probes for profiling dissolved oxygen (SBE 43), underwater PAR sensor (Biospherical), fluorescence (WETLabs ECO-FL-NTU) and turbidity. A newly acquired

Microprofiler (MP, Sea & Suntech, Germany) was deployed at all the stations (except at Stn. 13) up to a maximum depth of 500 m to measure the turbulence characteristics. XCTDs were fired at selected locations to measure high resolution vertical structure of water column. Also, continuous observations of atmospheric surface layer parameters using automatic weather station (AWS) and monitoring of water current profiles with in the upper 750 m using Acoustic Doppler Current Profiler (ADCP, make – RDI, 38 KHz, Velocity accuracy $\pm$1.0% $\pm$ 0.5 cm/s) were carried out.

Table 1: Station details

Station & Location	Date & Sampling Time	Equipments Operated
Stn. 1 (Time Series): 40ºS, 58º30'E	13/01/2012: 00:30 hr - 15/01/2012: 04:35 hr	CTD, MPN, MP, WP
Stn. 2: 40ºS, 57º30'E	15/01/2012: 11:05 - 12:45 hr	CTD, MP
Stn. 3: 40ºS, 56º30'E	15/01/2012: 18:20 - 22:20 hr	CTD, MP, MPN, WP
Stn. 4: 40ºS, 55º30'E	16/01/2012: 05:40 - 06:50 hr	CTD
Stn. 5: 40ºS, 54º30'E	16/01/2012: 13:00 – 14:35 hr	CTD,MP,XCTD
Stn. 6: 40ºS, 53º30'E	16/01/2012: 20:05 hr - 17/01/2012: 00:27 hr	CTD, MP, MPN, WP, XCTD
Stn. 7: 41ºS, 53º30'E	17/01/2012: 06:50 - 09:10 hr	CTD, MP, WP
Stn. 8: 42ºS, 53º30'E	17/01/2012: 15:25 – 17:10 hr	CTD,MP,XCTD
Stn. 9: 43ºS, 53º30'E	18/01/2012: 00:00 – 04:35 hr	CTD,MP,MPN,XCTD, WP
Stn. 10: 43ºS, 54º30'E	18/01/2012: 08:20 - 09:30 hr	CTD, MP, XCTD
Stn. 11: 43ºS, 55º30'E	18/01/2012: 14:30 – 16:20 hr	CTD, MP, XCTD
Stn. 12: 43ºS, 56º30'E	18/01/2012: 20:30 hr - 19/01/2012: 00:05 hr	CTD,MP,MPN,XCTD, WP
Stn. 13: 43ºS, 57º30'E	19/01/2012: 04:45 – 05:45 hr	CTD
Stn. 14: 43ºS, 58º30'E	19/01/2012: 10:15 -14:35 hr	CTD,MP,MPN,XCTD, WP
Stn. 15: 44ºS, 58º30'E	19/01/2012: 21:45 - 23:40 hr	CTD, MP, XCTD
Stn. 16: 45ºS, 58º30'E	20/01/2012: 08:15 - 13:20 hr	CTD,MP,MPN,XCTD, WP
Stn. 17: 46ºS, 58º30'E	20/01/2012: 20:15 - 22:20 hr	CTD,MP,XCTD
Stn. 18: 50ºS, 57º30'E	22/01/2012: 05:32 - 10:40 hr	CTD,MP,MPN,XCTD, WP
Stn. 19: 51ºS, 57º30'E	22/01/2012: 18:00 - 19:50 hr	CTD,MP,XCTD
Stn. 20: 52ºS, 57º30'E	23/01/2012: 03:15 - 04:55 hr	CTD,MP,XCTD
Stn. 21: 53ºS, 57º30'E	23/01/2012: 12:55 - 17:45 hr	CTD,MP,MPN,XCTD, WP

(CTD – Conductivity-Temperature-Depth, XCTD – Expendable CTD, XBT – Expendable Bathy Thermograph, MP – Microprofiler, MPN – Multiple Plankton Net, WP – WP-equivalent Net).

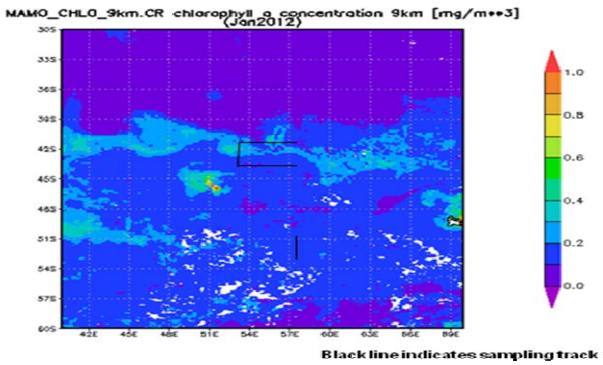
2.3 Multidisciplinary Parameters:

At an interval of 2 degrees (both latitude and longitude), water samples were collected in 24 Niskin bottles of 5 L capacity mounted on a rosette sampler along with CTD, at prefixed depth intervals (surface, 10, 30, 50, 75, 100, 120, 200, 500 & 1000 m and DCM depth as per the fluorescence profile), for measuring all physical (salinity, isotope studies), chemical (DO, DIC, TOC, nutrients, POC, DCHO, PCHO, TEP, SPM) and biological parameters (bacteriological studies, primary production, pigment characterization, phytoplankton diversity, heterotrophic nanoflagellate grazing, photosynthetic irradiance, micro-zooplankton) from 9 stations. Multiple Plankton Net (Hydro-Bios, Germany) was operated up to a depth of 1000 m for collecting meso-zooplankton (>200 µm in size) from 4 depth strata (1000- 500 m, 500 m-bottom of thermocline, thermocline (TC) and mixed layer depth (MLD) from 9 stations (**Fig. 2**)**.** A WP equivalent net was hauled at the surface layer for collecting the surface meso-zooplankton from all multidisciplinary stations and also from Stn. 7.

2.4 Time Series Sampling:

At Stn. 1 (40ºS, 58º30'E), a time-series observation was carried out for 2 days, starting at 00.30 hr on 13th January 2012 and ending at 04.35 hr on 15th January 2012. Multidisciplinary sampling (**Table 1**) was carried out at 6 hourly interval and CTD and Microprofiler (MP) observations were carried out at 3 hourly interval.

Figure 3: **Satellite imagery of chlorophyll distribution in SO during January 2012**



As can be seen from **Figure 3**, the northern transect of the rescheduled cruise track was located in chlorophyll distributed area in the STF and the meridional transect was cutting through the chlorophyll rich zone and extending to the chlorophyll depleted southern transect. It is hoped that the high resolution sampling strategy adopted for this expedition, both within chlorophyll present and depleted locations in the STF would provide insights in to the hydrodynamic features that are primarily responsible for regulating the biogeochemical cycles and biological productivity processes in this front.

2.5 Atmospheric studies:

Aerosol optical depth was measured using Microtops Sunphotometer throughout the cruise track at every 30 minute interval, starting from Goa to 53ºS and on retun up to 23ºS30' along 57º30'E. Aethalometer was used to measure the ambient black carbon mass concentration starting from Goa to 53ºS and on return up to 23ºS30' along 57º30'E. The aerosol differential mass concentration was measured using Quartz Crystal Microbalance. The weather parameters such as temperature, pressure, wind speed and wind direction were determined using Kestrel 400 Pocket Weather Monitor. Garmin GPS 12 was used to geo-tag the data.

3. PARTICIPANTS

3.1 Institutions and Participants:

1) **National Centre for Antarctic and Ocean Research (NCAOR), Goa**
   Dr. C.T. Achuthankutty (Visiting Scientist) **- Chief Scientist**
   Dr. P.V. Bhaskar (Scientist C)
   Dr. Nuncio Murukesh (Scientist B)
   Dr. Deepti V. Gauns Dessai (Research Scientist B)
   Dr. Ravidas K. Naik (Research Scientist B)
   Ms. Melena A. Soares (Research Scientist B)
   Mr. Jenson V. George (Research Fellow)

2) **National Institute of Oceanography (NIO), Goa**

Dr. N. Ramaiah (Scientist G) – **Deputy Chief Scientist**

Mr. Ram Murti Meena (Technical Assistant)

3) **National Institute of Oceanography, Regional Centre (NIO-RC), Kochi**

Ms. C.K. Haridevi (Scientist B)

4) **Central Institute of Fisheries Technology (CIFT), Kochi**

Dr. Puthra Pravin (Senior Scientist)

Mr. K.V. Aneesh Kumar (SRF)

5) **CAS in Marine Biology, Annamalai University (CASM), Parangipettai**

Dr. K. Sivakumar (Assistant Professor)

6) **Centre for Marine Living Resources and Ecology (CMLRE), Kochi**

Ms. R. L. Minu (Research Fellow)

Ms. Thara Gopalakrishnan (Research Fellow)

7) **Indian Institute of Science (IISc), Bangalore**

Dr. K. Mohan (Postdoctoral Fellow)

Mr. Prasanna K. Naidu (Ph.D. Student)

8) **Goa University (GU), Goa**

Mr. Hulswar Shriwardhan (Research Fellow)

Ms. Maria Fernandes (Research Fellow)

9) **National Institute of Ocean Technology (NIOT), Chennai**

Mr. D. Narendra Kumar

3.2 Ship Officers and Crew:

Sr. no.	Name	Designation
1	Sowrimuthu William	Master
2	Sendurpandian Nadar Viswanathan	Additional Master
3	Udayavanan Senkathirvanan	2nd Officer
4	Sandeep Sekhar	2nd Officer
5	Shahul Hameed Asif Ali Khader	Chief Engineer
6	Lionel Morais Kingsly	2nd Engineer
7	Kuppuraj Thanasekaran	3rd Engineer
8	Pugalenthi Venkataraman	Electrical Officer
9	Antony Arokiasamy	Electrical Officer
10	Annepu Hemachandrasekhar	Able Seaman
11	Paramasivan Aravind	Able Seaman
12	Antony Vimal Walter Nirmal	Able Seaman
13	Kothandan Santhosh	Ordinary Seaman
14	Singh Jagdeep	Ordinary Seaman
15	Murari Dev Kamal	Ordinary Seaman
16	Karuppiah Hariharan	Ordinary Seaman
17	Venkateswaran Ranjan	Ordinary Seaman
18	Mohanaranga Ethirajulu	Fitter
19	Velu Sasikumar	Fitter
20	Ponnalagu Renganathaprabu	Oiler
21	Sethu Basker	Oiler
22	Thulaisingam Palanivelan	Chief Cook
23	Muthu Palani Mani	Cook
24	Santhanam Siluvai Santiagu Rayappan Pathusan	Assistant Cook
25	Singh Raman	Assistant Cook
26	Ghorai Utpal	General Steward
27	Yadav Gautam	General Steward
28	Viswanathan Valampuri Nathan	General Steward
29	Karuppannan Balasubramaniam	Doctor

3.3 NORINCO Engineers

1	Narayanan Dhanasekaran
2	Ebin James
3	Karumathil Melayil Jayakrishnan

4. WORK ELEMENT & DATA

4.1 Physical processes: (NCAOR)

The subtropical front of the southern Hemisphere represents the northward limit of the Antarctic Circumpolar Current (ACC) and is characterised by a strong thermal gradient. Climatic implications of STF include the opening and closing of "Indian Gate way" in to the Atlantic resulting in "Aghulhas leakage" that influence the Atlantic meridional Overturning Circulation (AMOC) (Biostach, etal., 2008). Agulhas leakage is a result of north-south excursion of the STF in association with the north-south movement of the westerly wind belt. The SST gradient with in the front also results in strengthening/weakening the storm tracks and the annular modes that in turn controls the north-south movement of the westerly wind belt. This region is also characterised by high chlorophyll values which in turn may have an important role in determining the SST gradients across the front.

Keeping all these in mind, high resolution observations were carried out at STF to understand the physical characteristics and the biophysical coupling. Similar observations were made at the Polar front as well, but only from a few stations.

Objectives

Physical observations were undertaken to understand the physical processes and to compliment the biological process studied along the Subtropical and Polar fronts. The objectives identified for this study are,

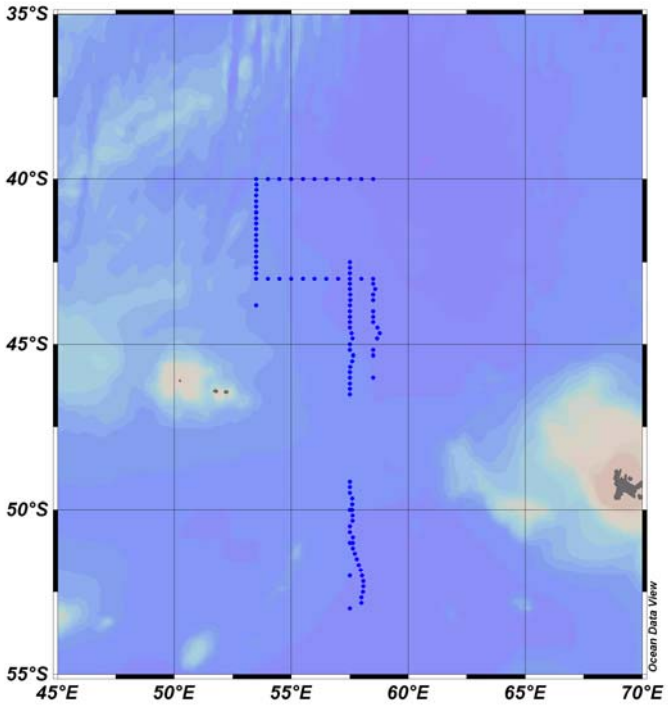
- Understanding the diurnal variations of physical properties as well as the chlorophyll concentrations.
- High resolution structure of the fronts.
- Mechanism of maintenance of DCM in the frontal regions.
- Influence of mixed layer dynamics, Meridional transport, euphotic zone variations and eddies on the chlorophyll distribution.
- Monitor the changes in the oceanic thermohaline structure along the fronts
- Understand the heat content and heat and mass transport in the study region.

Methodology

A CTD with accessory sensors (Oxygen Sensor: Make: SBE 43, Biospherical PAR light sensor: Model No: QCP2300L-HP, and Flurometer (ETLabs ECO-FL-NTU) was used to collect data at 1-degree interval along the transect as shown in **Figure 2**.

CTD data were collected with in the upper 1000 m of the water column. Time series observations of the vertical structure of temperature, salinity, fluorescence, turbidity, Dissolved Oxygen and Photosynthetically Avaliable Radiation (PAR) were made over a period of 48 hours (3 hourly interval) at Stn. 1 (40S,58^{0}30'E). Dense underway profiling of upper ocean temperature and salinity was carried out with expendable conductivity-temperature-depth probes (XCTDs; Make: Tsurumi Seiki Company Limited, Japan; type: XCTD1, XCTD-3; terminal depth: 1000 m; temperature/salinity accuracy: ±0.02 °C/±0.03 mS cm−1) at a sampling interval of 10 nautical miles along 53^{0}30'E and 57^{0}30'E and at 30 nautical mile interval along 40ºS and 43ºS (**Fig. 4**).

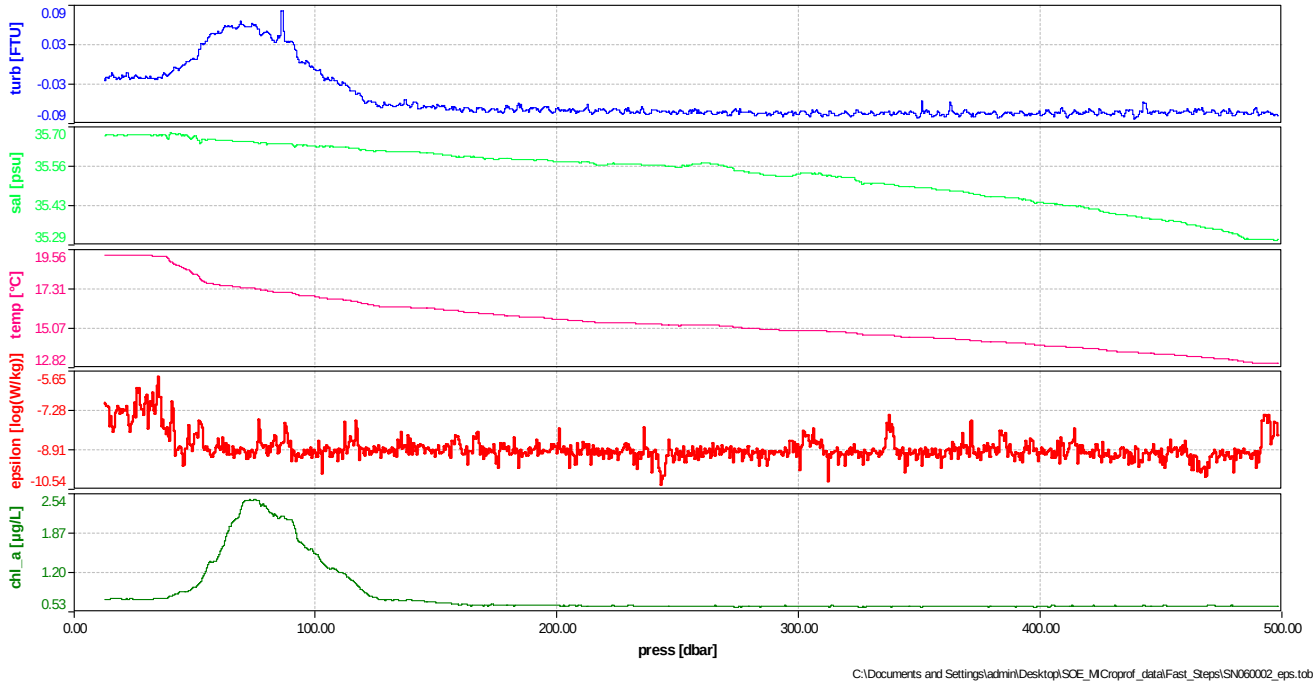
Figure 4: Locations of XCTD deployment



A 37.8 KHz ADCP was used to monitor flow fields along the transects with in the upper 750 m (Make: RDI; Velocity accuracy ±1.0% ± 0.5 cm/s). An automated weather station

was operated underway to record the surface atmospheric characteristics. At CTD locations a Microstructure Profiler (MP) was employed to study the turbulence characteristics. The instrument was operated up to a maximum depth of 500 m and data on vertical shear in horizontal velocities, temperature and salinity were recorded (**Figure 5** is a sample output). It can be seen from the figure (red graph) that maximum turbulence was in the surface layers. The data generated can be used to calculate vertical flux of nitrate through eddy diffusion as well as heat and salt fluxes associated with eddy diffusion.

Figure 5: Sample output from the Microstructure Profiler at 40ºS, 53º30'E



Comparison of XBT/XCTD and CTD were also made at specified locations (**Table 2**) to study the temperature bias compared to the CTD.

Table 2: Locations where XBT/XCTD/CTD comparisons were made

No.	Lat	Long	Stn	Sr. No.	Date
1	4000S	5830E	TS15	1114981	14.01.2012
2	4000S	5830E	TS15	1114972	14.01.2012
3	4000S	5830E	TS15	1114977	14.01.2012
4	4000S	5830E	TS15	1114973	14.01.2012
5	4000S	5630E	Stn3	1114979	15.01.2012
6	4000S	5630E	Stn3	1114976	15.01.2012
7	4000S	5630E	Stn3	1114971	15.01.2012
8	4000S	5630E	Stn3	1114980	15.01.2012
9	4100S	5330E	Stn7	1114970	17.01.2012
10	4100S	5330E	Stn7	1114974	17.01.2012
11	4100S	5330E	Stn7	1114975	17.01.2012
12	4100S	5330E	Stn7	1114978	17.01.2012
13	4200S	5330E	Stn8	1114854	17.01.2012
14	4200S	5330E	Stn8	1114858	17.01.2012
15	4200S	5330E	Stn8	1114855	17.01.2012
16	4200S	5330E	Stn8	1114851	17.01.2012
17	4400S	5830E	Stn15	1114852	19.01.2012
18	4400S	5830E	Stn15	1114860	19.01.2012
19	4400S	5830E	Stn15	1114856	19.01.2012
20	4400S	5830E	Stn15	1114859	19.01.2012
21	4600S	5830E	Stn17	1114861	20.01.2012
22	4600S	5830E	Stn17	1114857	20.01.2012
23	4600S	5830E	Stn17	1114853	20.01.2012
24	5000S	5730E	Stn18	1105550	22.01.2012
25	5000S	5730E	Stn18	1105551	22.01.2012
26	5000S	5730E	Stn18	1105552	22.01.2012
27	5000S	5730E	Stn18	1105553	22.01.2012
28	5100S	5730E	Stn19	1105557	22.01.2012
29	5100S	5730E	Stn19	1105556	22.01.2012
30	5100S	5730E	Stn19	1105555	22.01.2012
31	5100S	5730E	Stn19	1105554	22.01.2012
32	5200S	5730E	Stn20	1105558	23.01.2012
33	5200S	5730E	Stn20	1105559	23.01.2012
34	5200S	5730E	Stn20	1105560	23.01.2012
35	5200S	5730E	Stn20	1105561	23.01.2012
36	5300S	5730E	Stn21	1066920	23.01.2012
37	5300S	5730E	Stn21	1066916	23.01.2012
38	5300S	5730E	Stn21	1066925	23.01.2012
39	5300S	5730E	Stn21	1066921	23.01.2012

4.2 Biogeochemistry and Foodweb Dynamics: (NCAOR, NIO-RC, CMLRE)

The carbon biogeochemistry and food web dynamics in STF was investigated during the expedition. The major objectives of the investigation were,

- Investigate the fate of carbon dioxide in the STF waters – biotic exchanges.
- Study the types of food web and their dynamics prevailing in the STF waters – classical / microbial/ multivorous.
- Identify the role and major components of organic carbon – Carbon inventory and biogeochemistry.

Methodology

Seawater samples from 9 multidisciplinary stations (7 in STF & 2 in PF; **Fig. 2**) was collected at predetermined depths (0, 10, 30, 50, DCM, 100, 120, 200, 500, 1000 m) for various biological, chemical and biochemical parameters (see **Table 3** for details). Stn. 1 (40ºS, 58º30'E) of this transect was a time-series station which was sampled for all the parameters at 6 hourly interval for 2 days.

Table 3: Sampling details for biological and chemical parameters

Stn	Depths (m)	Biology (up to 200 m)	Chemistry
1 (TS)	0, 10, 30, 50, DCM, 75, 100, 120, 200, 500, 1000	Chl *a*, total pigments, Phytoplankton & total bacterial abundance	DO, DIC, TOC, nutrients, POC, DCHO, PCHO (All depths), TEP (up to 200m)
3	Same as above	Same as above	Same as above
6	Same as above	Same as above	Same as above
9	Same as above	Same as above	Same as above
12	Same as above	Same as above	Same as above
14	Same as above	Same as above	Same as above
16	Same as above	Same as above	Same as above
18	Same as above	Same as above	Same as above
21	Same as above	Same as above	Same as above

BIOLOGY

Chlorophyll a, pigments & phytoplankton diversity: Chlorophyll *a* and pigment samples (up to 200 m depth) were filtered through GF/F filters and kept frozen at -20° C for further analysis. Samples for total phytoplankton abundance were fixed with Lugol's iodine and stored in cool dark place for further enumeration.

Primary production: For phytoplankton productivity studies (PP) (see **Table 4** for details), water samples were collected from eight depths (0, 10, 30, 50, 75, 100, 120 and DCM) from stations 1, 7, 9, 13 and 18. Water samples were dispensed into Nalgene bottles (250ml; 2 light and 1 dark bottle) and spiked with ^{14}C and incubated on deck for 12 hours with continuous flow of sea water. Bottles were wrapped with appropriate density filters to compensate for light intensity. After the incubation, water samples were filtered through GF/F (0.7µm; 47mm) and stored in scintillation vials for analysis. Similarly, to study the effect of extended day time on primary productivity, samples from two depths (10 m and DCM) were collected from station 1 at T_9 hour. One set of samples (2 light and 1 dark bottle) was terminated at every three hours (0600 hr, 0900 hr, 1200 hr, 1500 hr, 1800 hr and 2100 hr) and one set was continuously incubated for 12 hr (0600 - 1800 hr) and another for 15 hr (0600 - 2100 hr).

Microzooplankton: Water samples (5L) were collected from standard depths (0, 10, 30, 50, 75, 100, 120 m and DCM) from time series and all multidisciplinary stations. Samples were filtered through 200 µm and 20 µm mesh in that order and fixed using Lugol's iodine 0sampling details are given in **Table 5**.

Table 4: Sampling details for PP, P/I, HNF and Copepod grazing

Stations	Parameters	Depth of sampling (m)	No. of samples to be analyzed
1 (T_1)	Phytoplankton productivity	0, 10, 30, 50, 75, 100, 120, DCM	24
	HNF	"	8
	Phytoplankton productivity (3h, 12h and 15h)	10 and DCM (62 m)	48
1 (T_9)	HPLC	"	10
3	HNF	0, 10, 30, 50, 75, 100, 120, DCM	8
	Copepod grazing		1
6	HNF	0, 10, 30, 50, 75 (DCM), 100, 120	8
	Copepod grazing		1
7	Phytoplankton productivity	0, 10 (SCM), 30, 50, 75, 100, 120	21
	HNF	"	7
	Copepod grazing		1
9	Phytoplankton productivity	0, 10, 30, 50 (DCM), 75, 100, 120 and 200	24
	HNF	"	8
	Photosynthesis-Irradiance study	10 and 200m	36
	Copepod grazing		1
12	HNF	0, 10, 30, 50 (DCM), 75, 100, 120	7
	Copepod grazing		1
13	Phytoplankton productivity	0, 10, 30, 50 (DCM), 75, 100, 120 and 200	24
	HNF	"	8
	Photosynthesis-Irradiance study	10 and 200	36
14	HNF	0, 10, 30 (DCM), 50, 75, 100, 120	7
	Copepod grazing		1
16	HNF	0, 10, 30 (DCM), 50, 75, 100, 120	7
	Copepod grazing		1
18	Phytoplankton productivity	0, 10 (DCM), 30, 50, 75, 100, 120 and 200	24
	HNF	"	8
	Photosynthesis-Irradiance studies	10 and 200	36
	Copepod grazing		1
21	HNF	0, 10, 30, 50, 75 (DCM), 100, 120	7
	Copepod grazing		1

Mesozooplankton: Mesozooplankton samples were collected using Multiple Plankton Sampler from all the multidisciplinary stations and time series station from 4 depth strata (1000-500 m, 500 m-bottom of thermocline, Thermocline layer and Mixed layer depth). One deep cast up to 2000 m was made at time series station T_{16}. Displacement volumes were taken and composition (up to group level) were analyzed onboard and preserved in 5% formaldehyde for further studies. Sampling details are given in **Table 6.**

Mesozooplankton samples were collected from the surface layer using WP equivalent net from 9 multidisciplinary stations including the time series station. Their displacement volume was taken and preserved in 5% formaldehyde. For dry weight estimation, samples from stations 1 (Time series - T_3, T_7, T_{15}, T_{16}) and other regular 3, 18 and 21 were stored in -20°C for further analysis. Sampling details are given in **Table 7**.

Table 5: Sampling details of Microzooplankton

Stn No.	Sampling depth	Volume of water filtered	DCM (m)
1(T1)	0,10,30,50,75,100,120, DCM	5 L	60
1(T3)	as above	Same as above	50
1(T5)	as above	Same as above	53
1(T7)	as above	Same as above	40
1(T9)	as above	Same as above	62
1(T11)	as above	Same as above	76
1(T13)	as above	Same as above	75
1(T15)	as above	Same as above	65
1(T16)	as above	Same as above	65
3	as above	Same as above	50
6	as above	Same as above	75
9	as above	Same as above	50
12	as above	Same as above	50
14	as above	Same as above	30
16	as above	Same as above	30
18	as above	Same as above	50
21	as above	Same as above	78

***Photo physiology of Phytoplankton*:** Photosynthesis-irradiance (P/I) experiments were conducted onboard to study the adaptation of phytoplankton to different light intensities.. Water samples from euphotic (10 m) and non-euphotic (200 m) depths from stations 9, 13 and 18 (**Table 4**) were dispensed in to the culture flasks (60 ml), each into 18 bottles for each depth and spiked with ^{14}C and incubated in a light gradient incubator for 3 hours and later filtered through GF/F (0.7µm; 25mm) and stored in scintillation vials for laboratory analysis.

Table 6: Sampling details of mesozooplankton using MPN

Stn No.	Depth of haul (m)	Volume of water filtered (m3)
1(T_1)	1000-500	155
	500-90	137
	90-30	29
	30-0	16
1(T_3)	1000-500	166
	500-95	125
	95-35	22
	35-0	10
1(T_5)	1000-500	173
	500-65	156
	65-15	134
	15-0	19
1(T_7)	1000-500	164
	500-45	137
	45-10	18
	10-0	5
1(T_9)	1000-500	149
	500-80	117
	80-10	20
	10-0	6
1(T_{11})	1000-500	125
	500-75	109
	75-5	18
	5-0	5

1(T_{13})	1000-500 500-80 80-15 15-0	102 71 11 3
1(T_{15})	1000-500 500-85 85-18 18-0	108 89 17 6
1(T_{16})	2000-1500 1500-1000 1000-500 500-0 500-300 300-74 74-18 18-0	118 94 88 92 49 61 17 4
3	1000-500 500-120 120-18 18-0	99 77 24 8
6	1000-500 500-60 60-28 28-0	124 111 9 4
9	1000-500 500-72 72-35 35-0	90 91 9 8
12	1000-500 500-70 70-28 28-0	84 66 19 12
14	1000-500 500-300 300-45 45-0	130 49 56 20
16	1000-500 500-80 80-60 60-0	126 107 8 18

18	1000-500 500-300 300-90 90-0	82 41 47 21
21	1000-500 500-140 140-50 50-0	115 97 26 14

Phytoplankton pigment characterization and taxonomy: For studying the phytoplankton pigment characterization using HPLC, 2 L of seawater was filtered through GF/F (0.7µm; 47mm) from stations 1 (T_9), 7 and 13 (PP sampling stations) and for taxonomy 1 L of seawater was collected from stations 7 and 13 (PP sampling stations) and fixed using Lugol's iodine and kept in dark undisturbed until analysis.

***Grazing studies*:** To estimate the abundance of heterotrophic nanoflagellates (HNF) which are the immediate grazers of phytoplankton, 100 ml of water samples from eight depths (0, 10, 30, 50, 75, 100, 120 and DCM) were collected from Stns. 1, 3, 6, 7, 9, 12, 13, 14, 16, 18 and 21and fixed with glutaraldehyde (25%) and stored in 5 °C until analysis (**Table 4**).

To study the impact of grazing of copepods on phytoplankton, copepods were collected from stations 3, 6, 7, 9, 12, 14, 16, 18 and 21 (**Table 4**) using WP equivalent net (surface hauling). The collected sample were immediately deep frozen (-20 °C) until their gut content analysis were done.

Table 7: Sampling details of mesozooplankton using WP-equivalent net

Station No.	Time(hrs)	volume of water filtered (m3)
1(T1)	00:30-00:40	108.63
1(T3)	07:20-07:30	173.1
1(T5)	12:40-12:50	142.82
1(T7)	18:45-18:55	123.76
1(T9)	00:50-01:00	135.25
1(T11)	06:20-06:30	127.88
1(T13)	12:50-13:00	126.52
1(T15)	18:05-18:15	108.21
1(T16)	00:17-00:27	160.75
3	18:50-19:00	129.37
6	00:10-00:20	58.49
9	04:00-04:10	83.55
12	22:35-22:45	54.66
14	14:00-14:10	57.66
16	12:50-13:00	132.2
18	10:05-10:15	76.78
21	17:20-17:30	29.46
21	17:35-17:35	30.05

Total bacterial abundance: Water samples for total bacterial abundance were collected from all the depths up to 200 m from all the multidisciplinary stations (**Table 3**). The samples were fixed with 0.22 um filtered formalin and stored in cool dark place for further enumeration.

***Carbon uptake experiment*:** Bacterial carbon uptake experiment was carried out over a period of 7 days at the time-series station. Seawater from surface, 48 m (DCM), 50 m and 120 m was filtered through 200 μm mesh and 150 ml from each depth was redistributed in 3 sterile polycarbonate screw-capped flasks (1 control and 2 tests). Each flask was inoculated with 1 ml ^{14}C-glucose (Sp. Activity: 11470 MBq/mmol). The flasks were incubated at room temperature (18º C) in dark and sub-sampled at 0, 12, 24, 48, 72, 96, 120 & 168 hr. The sub-samples were filtered through 0.2 μm cellulose nitrate filters. Both the filter paper and filtrate (1 ml) was transferred into scintillation vials and stored

at 4°C. To enumerate bacterial abundance, 1 ml of sample from each flask was transferred to microtubes and fixed with 0.2 μm filtered formalin and stored at 4°C. The analyses will be carried out at NCAOR.

CHEMISTRY

Dissolved oxygen was analyzed using Metrohm dossimat. Similarly alkalinity was measured using Metrohm potentiometer. Both pH meter and potentiometer were used for measuring pH. Nutrients samples were stored at -20ºC as the auto-analyzer was not operable. TOC samples were also stored at -20° C. DIC samples were fixed with mercuric chloride and stored at 4°C. Samples for POC & PCHO were filtered through pre-ashed GF/F filters and stored at -20° C.

Preliminary results

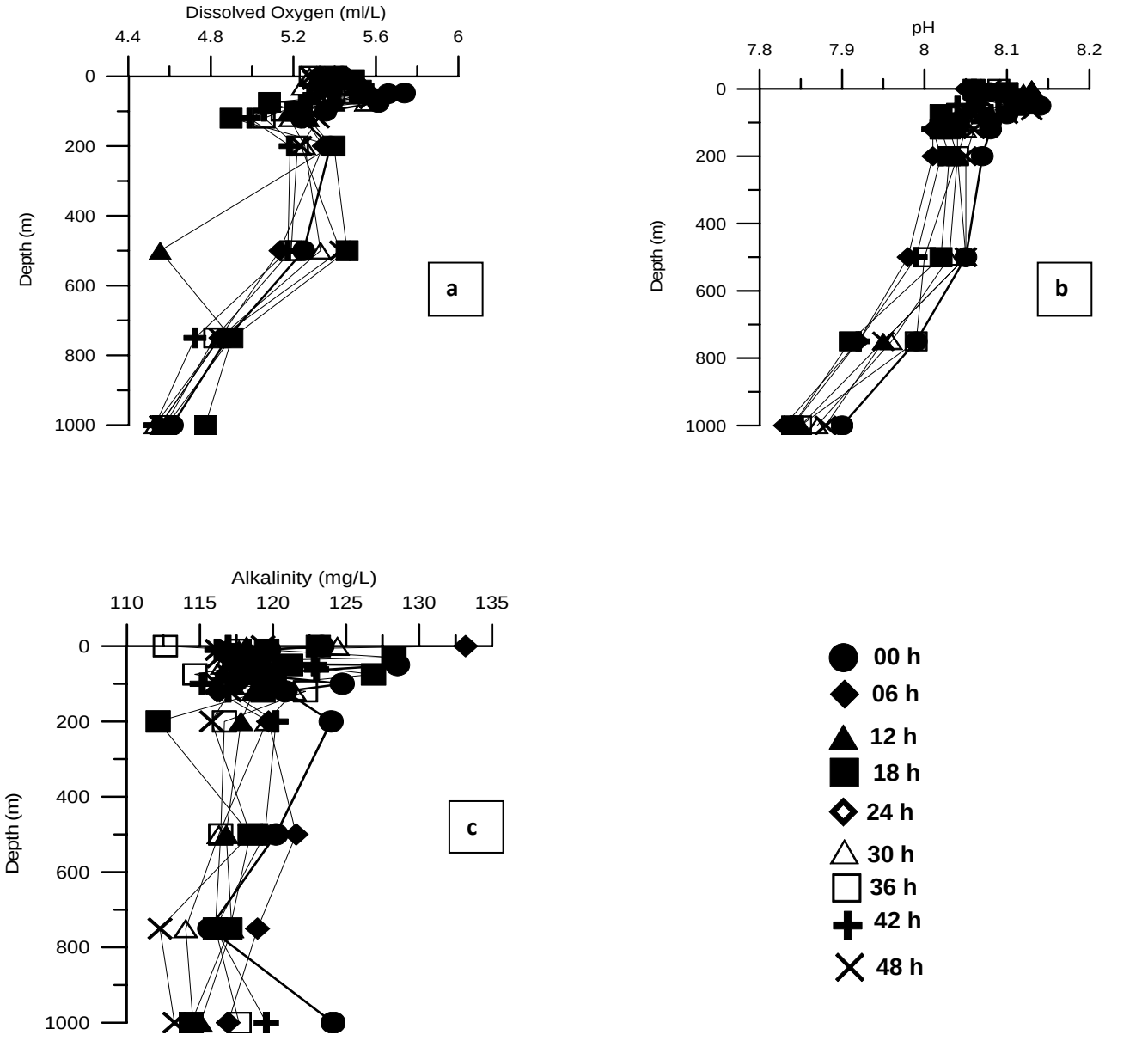
Time-series study:

Dissolved oxygen concentrations generally declined with depth. The vertical profiles ranged from 4.53 to 5.74 $ml.l^{-1}$ during the period of observation and did not show any significant changes in the overall trends (**Fig. 6 a**).

Vertical profiles of **pH** too did not show any significant change in the overall trends and values ranged from 8.06 to 8.13 in surface waters and 7.83 to 7.90 at 1000 m depth (**Fig. 6b**). However, a decrease in pH with depth was observed.

The surface **alkalinity** ranged from 112.64 (200 m) to 133.18 $mg.l^{-1}$ (surface)and did not show any specific trend with depth (**Fig. 6c**).

Figure 6: Vertical profiles of (a) DO, (b) pH & (c) Alkalinity in Time series samples

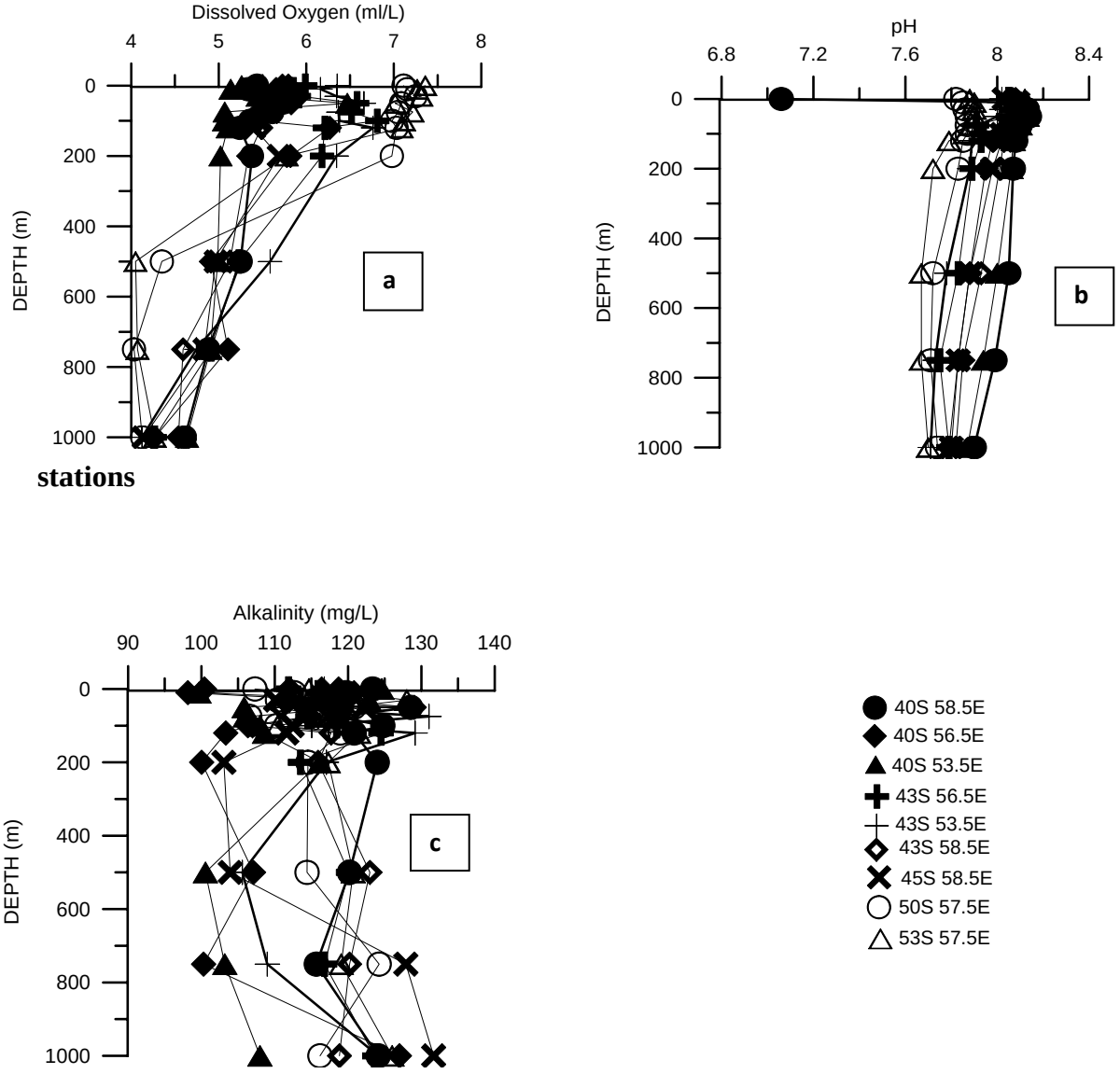


Multi-disciplinary stations:

Dissolved oxygen concentrations showed clear meridional variations. In general, DO concentrations showed a decreasing trend with increasing depth at all stations. The vertical profiles of DO ranged from 4.27 to 6.47 $ml.l^{-1}$, 4.12 to 6.81 $ml.l^{-1}$ and 4.03 to 7.36 $ml.l^{-1}$ along 40ºS, 43ºS and PF transects, respectively. At 45ºS 58º30' E station, the DO concentrations showed lesser vertical variations, ranging from 4.14 to 5.75 $l.l^{-1}$ (**Fig.**

7a). Vertically, the DO concentrations decreased by almost 2 $ml.l^{-1}$ between 120 m and 500 m depth in the PF stations as compared to <1 $ml.l^{-1}$ along the 40ºS transect.

Figure 7: Vertical profiles of (a) DO, (b) pH & (c) Alkalinity in multidisciplinary stations



Spatially, the surface **pH** values decreased considerably from 8.12 along 40ºS transect to 7.85 at the PF stations. Vertically, pH values declined with depth at all stations, the decline was more marked at STF stations than at PF stations (**Fig. 7b**). The surface **alkalinity** values showed both meridional and zonal variations. For instance, the surface alkalinity along 40ºS transect ranged from 100.42 to 124.61 $mg.l^{-1}$ and increased

from east to west. Moreover, the average surface alkalinity values declined from 116.13 ± 13.61 mg.l^{-1} along 40ºS transect to 110.98 ± 5.2 mg.l^{-1} along PF transect. Unlike pH, vertical profiles of alkalinity did not show any specific trend at any station (**Fig. 7c**).

Mesozooplankton biomass and composition:

- Mesozooplankton biomass in the surface layer of multidisciplinary stations varied from 0.02ml.m^{-3} to 6.44 ml m^{-3} with an average of 0.89 ml m^{-3}.
- Vertical distribution of biomass and population density in different depth layers showed reduction from surface to the deeper waters and 80% of the biomass and density occurred in MLD and thermocline.
- Foraminifera, medusae, siphonophores, polychaetes, pteropds, gastropods, ostracods copepods, isopods, amphipods, euphausiids, decapods, chaetognaths, salps, doliolids, fish eggs, fish larvae, amphioxus and pyrosoma were observed, of which, copepods formed the dominant group at most of the stations.
- Swarming of Pyrosoma and abundance salps were observed at diurnal station (40°S, 58°30'E) and diurnal variation of biomass and density showed an irregular pattern both at surface and in vertical structure (**Figs. 8, 9 & 10**).

Figure 8: Diurnal variation of surface mesozooplankton biomass at Stn. 1

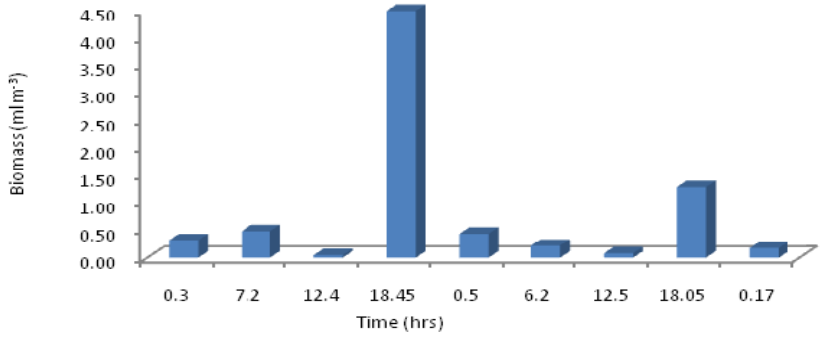


Figure 9: Diurnal variation of mesozooplankton biomass in different depth layers at Stn. 1

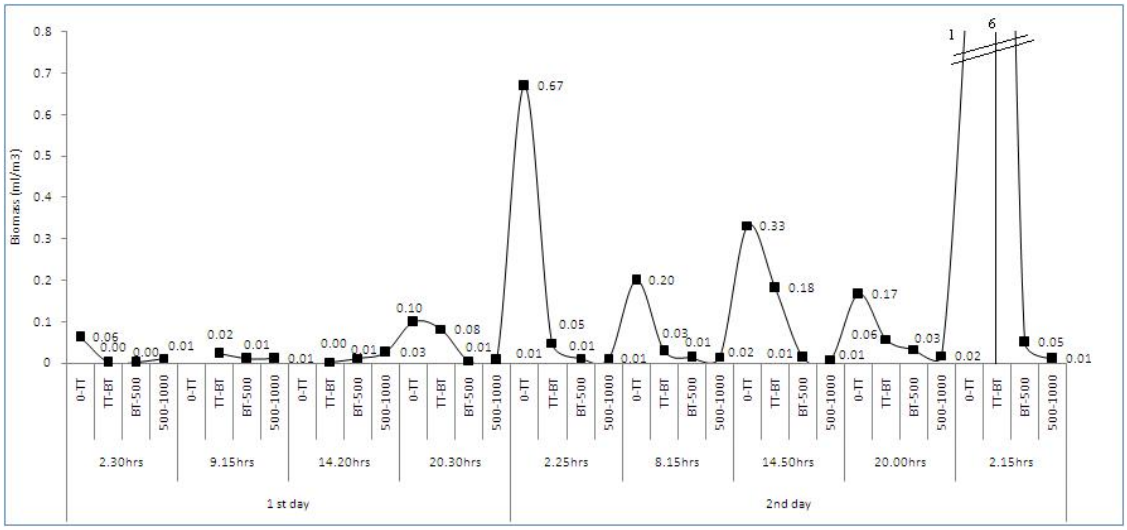
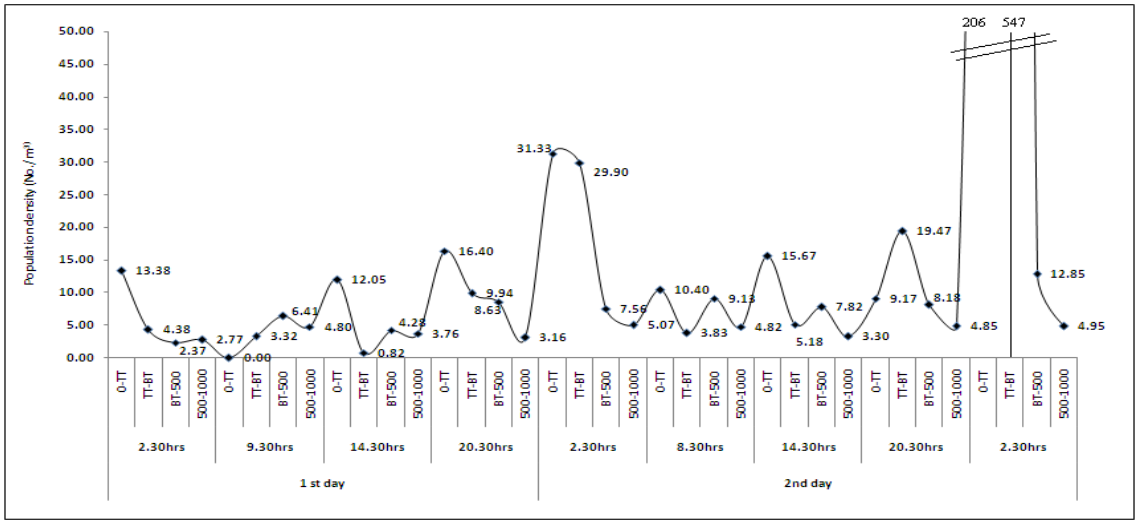


Figure 10: Diurnal variation of mesozooplankton diversity in different depth layers at Stn. 1



4.3 Bacterial Phylogenetic Diversity in STF and PF: (NIO)

One of the aims of this proposal is to obtain the diversity of bacterial community through culture dependent (selective and non selective growth on specific and general bacteriological media) and culture independent (molecular, DGGE, ARDRA and 16S rRNA gene sequencing) protocols. The other aim is to collate the diversity analyses data

obtained through the conventional as well as molecular analyses of community diversity with the main idea of differentiating the top down and/or top up controls *in situ*. This would enable to infer how the microbial assemblages and their variability (spatial and between ecotypes) are controlled as a consequence of differences imminent between the two ecologically contrasting oceanic fronts. The third aim is to understand the controlling chemical factors and the ratios of a mixture of them that would, in the overall, govern the growth and ecological functioning of prokaryote community and are essential not only in deciphering the bacterially mediated trophodynamic mechanisms, but also their relevance in the biogeochemical processes in these ecotypes. This expedition would provide an ideal opportunity for comparing the bacterial assemblages between STF and PF and examine their responses to nutrient alterations.

Objectives

- To elucidate the phylotype similarities/differences across (spatial and vertical) the two disparate water masses of subtropical (STF) and polar (PF) fronts.
- To correlate the extant bacterial community/phylotype assemblages with relevant biological and chemical characteristics of the STF and PF regimes.
- To understand the differences in bacterial community responses in terms of preferential growth, proliferation and phylotype dominance under nutrient amended microcosms set up onboard at the prevailing temperatures in the STF and PF regions.

Sampling strategy

Water samples collected were from 5 depths [Surface, Deep Chlorophyll Maximum, 200 m, 500 m and 1000 m] at Stn.1 (40 °S, 58°.30'E), Stn. 3 (40°S, 56°30'E), Stn. 6 (40°S, 53° 30'E), Stn. 12 (43°S, 56°30'E), Stn. 14 (43°S, 58°30'E), Stn. 16 (45°S, 58°30''E) in the STF and Stn. 18 (50°S, 57°30''E) and Stn. 21 (53°S, 58°30'E) in the PF. At Time Series Station (Stn. 1), sampling was carried out at every 6 hr interval from two depths i.e., surface and DCM, the latter oscillated between 50 and 75 m during the 48hr period of the sampling duration.

Onboard Analyses

Enumeration of Culturable Bacterial Populations:

All the 49 water samples collected during this expedition were plated on the following media for enumerating culturable bacterial populations and some physiological groups:

A) Seawater Nutrient Agar (75% aged seawater+25% deionised water)

B) Gelatin Agar (with 2% w/w gelatin; 50% aged seawater+50% deionised water)

C) Starch Agar (1% w/w soluble starch; 50% aged seawater+50% deionised water)

D) Tween 80 Agar (1% v/w tween 80; 50% aged seawater+50% deionised water)

Seawater nutrient agar was used for counting the general populations of bacteria (total viable counts, TVC). Gelatin agar was used for enumerating proteolytic bacteria. Similarly, starch agar was used for enumerating amylase producing bacteria and tween 80-agar was used for enumerating the lipolytic bacteria. Aliquots of 0.2 to 0.4 ml samples were spread-plated onto replicates of two plates each of the above media. Further, in order to not miss out enumerating the general population, membrane filtration procedure was followed wherein up to 5 ml sample was filtered onto 0.2 μm pore-sized pre-sterilized cellulose acetate membrane filters. The plates were incubated appropriately as described below. In addition, a representative set of 300 individual colonies grown on these three media were randomly picked out and inoculated onto a medium [prepared with 25% aged seawater+75% deionised water] fortified with 2% (w/w) ß-glucoside, such that, the *per cent* of general as well as proteolytic, amylotic and lipolytic populations capable of breaking down this complex carbohydrate polymer could be estimated.

While all the plates with membrane filter-retained cells were incubated at 4 and 10 °C, the ones spread plated with fractions of a milliliter were incubated at 4, 10 and 20° C for allowing the growth of bacteria on all the four above mentioned media. In order to check what proportions of bacteria grew -and how fast- all five samples from all depths at Stn. 1 were plated onto each of these media and incubated at 4, 10 and 20° C variously

from 4 days (at 20°C) to 16 days (at 4° and 10°C) before recording the final counts of viable/culturable bacteria.

A select set of plates were kept aside to carry back to the NIO for isolating as many morphotypes as possible in order to do a polyphasic taxonomic analysis including that of 16S rRNA gene sequencing to establish the phylogenetic composition of culturable bacterial communities in these regions. In addition, samples from all these stations and depths were also preserved for estimating total viral: bacterial ratios with a view to delineate the impact of bacteriophages, if any, on the regulation of bacterial populations.

***Collection/Retention of Metagenomic DNA*:**

As one of the main goals of this proposal, water samples from all five depths from stations 1, 9, 12, 16 and 21 were processed for collection of DNA from microbial communities at these locations. As much as 2.5 litres of 200 μm mesh-sized bolting silk passed seawater sample from each depth was subjected to peristaltic filtration through multi-folds invaginated 0.2 μm pore-sized Sterivex cartridge. In all, 25 samples were processed, and the DNA that will be extracted back home at the NIO, will be subjected to culture independent molecular methods such as DGGE, ARDRA, DNA library generation, cloning and 16S rRNA gene sequencing of atleast 300 clones from each sample so as to delineate both spatial and vertical heterogeneity with in the microbial communities in the STF, in particular.

***Microcosm Experiment*:**

To address the third pre-set objective, one 15 day long onboard microcosm experiment was set up in the STF on January 13, 2012. Over 120 Litres of seawater was drawn from DCM depth of 60 m at Stn. 1, passed through 200 μm mesh-sized bolting silk and distributed in 5 litre volumes to 20 numbers of 5L borosilicate glass flasks. A set of 6 flasks was set aside as one unit so as to sample thrice, once every 5 days, during the expedition. Stock solutions cobaltous chloride, cuprous chloride and ferrous sulphate were individually added in to three flasks to attain 8, 11 and 9 μM concentrations, respectively of Co, Cu and Fe. A mixture of their stock solution was added to one flask to

attain ~1, 1.2 and 1 μM and, to another flask to attain ~2, 2.4 and 2 μM concentrations each of Co, Cu and Fe. One flask was set aside as unamended control. Eighteen of these flasks were subjected to 12 hr Light:12hr Dark cycles with light levels ~500 $\mu E.m^{-2}s^{-1}$ during the lit period. One flask with no amendment and, the other with ~2, 2.4 and 2 μM concentrations each of Co, Cu and Fe were set in dark for 15 days to check the response of bacteria in the absence/reduction of 'live' chlorophyll.

As planned, a set of six flasks was taken out on day 5, 10 and 15 and sampled. In all, from this experiment, we have 20 sets of samples to examine various following parameters from each set.

i) Culturable, proteolytic, amylolytic, lipolytic and ß-glucosidase-producing bacterial populations.
ii) Total bacterial/viral abundance
iii) Metagenomic analyses through a suite of culture-independent approaches
iv) Nutrients (NO_3, NO_2, SiO_4, PO_4, NH_3)*
v) Total organic carbon
vi) Dissolved inorganic carbon*
vii) pH and alkalinity*
viii) DOC turnover rates*
ix) Chlorophyll *a**
x) HPLC based phytopigment profiling*
xi) Phytoplankton generic/species composition*

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*will be analysed through collaboration with NCAOR colleagues

While the results for parameters i) and vii) are already available, we need to analyses the samples back home for the results on rest of the numerous parameters listed above. Due to truncation of the ship time south of 40°S from the planned 33 days to <18 days, there was no time available for setting up the microcosm experiment in the PF as was planned and, approved.

Preliminary results

Some salient results on culturable populations can be summarized as follows.

- Their number capable of growth at 20 °C is surprisingly high, often far more than those generally recorded from the oligotrophic regions for instance, of the Equatorial Indian Ocean.
- The visible colonies on all the four tested media were formed around or after 16 days of incubation at 4 and 10 °C *vis a vis* the lab temperature of 19±2°C. Though they take time to grow, the number of colony forming units at 4 and 10°C was substantial, often over 50% of those growing at the lab temperature.
- In the microcosms too, the number of colony forming units went up with the increasing duration of the experiment. Close to 40% of the TVC on general, seawater nutrient agar were amylolytic, ~50% proteolytic and >75% lipolytic. Interestingly enough, the precipitates that formed initially in the microcosms amended with Cu and Fe salts decreased with increasing duration of the experiment.

Variations in the numbers of culturable and physiological groups at the Time Series location (Stn. 1) are depicted in **Figure 11**. Often, there was no discernible difference in the abundances of culturable populations, suggesting quite well mixed surface layer in this STF location.

Figure 11: Variations in abundance of culturable and physiological groups from Time Series analyses at Station 1

4.4 Marine Actinomycetes in Southern Ocean: (CAS in Marine Biology)

Actinomycetes were initially considered as one of the major groups of soil microbes. However, they have been increasingly isolated from various marine samples, deep sea sediments and near hydrothermal vents. In fact, distribution of actinomycetes in the sea water remains largely undescribed. it is now widely accepted that culture-based techniques are inadequate for studying actinomycetes diversity and application of molecular phylogenetic techniques would result in the discovery of many novel actinomycetes. Since no report is available on the diversity of marine actinomycetes from Indian sector of Southern Ocean, an attempt has been made to study the diversity of this important group during this expedition with the following objectives:

Objectives

- Isolation of marine actinomycetes from sea water.
- Taxonomic investigations of micromophologically unique actinomycetes to know the generic diversity.
- Construction of actinomycetes specific 16S rRNA gene clone libraries.
- Sequencing the different PCR clones to analyze the phylogenetic relationship of actinomycetes.

Onboard Observations and Sampling Strategy

1) Culturable Diversity

Water samples were collected from the stations shown in Table below for the isolation of marine actinomycetes and the media viz. Kuster's Agar, Starch Caesin Agar, AI Agar and AV Agar were used for isolation using spread plate method. These plates were kept for incubation at 10 and 20ºC for growth of the isolates. Further, 300 ml of water samples from each stations and the incubated plates will be carried to the main laboratory in refrigerated condition (4ºC) for detailed analysis.

Sampling details for Culturable Diversity

Stn No.	Depth	Incubation Temperature (ºC)
1	DCM	20
16	DCM	20
18	DCM	10
20	DCM	10

2) Culture Independent Diversity

Water samples were collected from locations shown in the Table below for studying the culture independent marine actinomycetes. From each station 10 L sample was collected and filtered through 0.2 µm filter paper and washed with TE buffer. Three millilitre of the liquid was transferred to a vial and was stored in -20 ºC. Further, 2½ L of water was filtered using sterivex filter system from the given locations and the samples were stored in -20ºC for construction of actinomycetes specific 16S rRNA gene clone libraries and sequencing the different PCR clones to analyze unculturable diversity of actinomycetes.

Sampling details for Culture Independent Diversity

Stn. 1	Depth	Vol. water (L)
1.	Surface	15
2.	DCM	15
3.	500 m	15
4.	1000 m	15

Stn. 16	Depth	Vol. water (L)
1.	DCM	15

Stn. 18	Depth	Vol. water (L)
1.	Surface	15
2.	DCM	15

Stn. 20	Depth	Vol. water (L)
1.	DCM	15

In addition, surface water samples (15 L) were also collected for the culture independent diversity studies form Equator and 25ºS for culture independent diversity study.

4.5 Biology and Biochemistry of Southern Ocean Squids: (CIFT)

Cephalopods are exclusively marine predators and voracious carnivores with high metabolic and conversion rates. They feed on live prey throughout their life. Cephalopod resources of the Southern Ocean are considered as distinct with other oceans with high level of endemism in squids. Cephalopods pay an important role in the ecology of SO and acts as a linkage between abundant mesopelagic fishes, crustaceans, sea birds and whales. Our knowledge on the food and feeding ecology of cephalopods in the SO is limited to the commercial species. More work is needed on the biology of cephalopods for better understanding of their role in marine ecosystems of the SO. Oceanic squids are a comparatively less exploited group and the information is scanty. Hence, during the SO expedition it is proposed to investigate the biochemical composition of oceanic squids and characterize protein and bioactive peptides. It also aims at the pharmacological evaluation of protein and bioactive peptides.

Objective

- To study the biological and biochemical characteristics of oceanic squids

Work carried out onboard

1. Fishing- squid jigging
2. Collection and storing of squid samples for studies on biological parameters
3. Collection of squid samples for biochemical and molecular studies

1) Fishing - Squid Jigging:

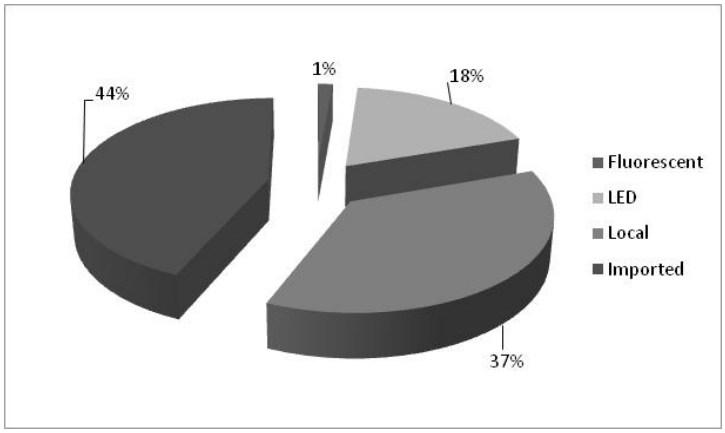
Squid jigs of various makes and types were rigged onboard for hand jigging during the first week of January 2012. Hand operated squid reels were fabricated onboard using available materials and the same rigged with various types of jigs and loaded on the reels for the fishing operations.

Squid jigging operations were carried out during nights for eleven days and one jigging operation was carried during day time. Different types of jigs were operated (local jigs, jigs with LED lights and imported jigs). Hand lines were operated most of the

stations and two stations hand reel operations were carried out. The details of the squid jigging operations are given in **Table 8**. Catch was obtained only from the hand jig operations. The percentage catch from various jigs operated is shown in **Figure 12**. Total number of 71 squids, approximately weighing 60 kg was landed by squid jigging. Three species were identified namely; *Sthenoteuthis oualaniensis, S. bartrami* and *Todarodes filippovae.* The first species was caught at 0^0 S and 77.3^0 E Long. *S. bartrami* was caught at 40^0 S and 53^0 to 58^0 E Long. *Todarodes filippovae* was caught at 43^0 S Lat and 53^0 to 58.3^0 E Long. *S. ovalaniesis and S. bartrami* are widely reported from the tropical Indian Ocean and *T. filippovae* is a typical southern ocean species.

Due to very rough seas and strong currents and winds during the cruise, squid jigging operations could not be carried out at few stations. It was also observed that the aggregation of squids was very less and most of the squids were caught by throwing the jigs far away from the ship. Due to non aggregation of squids close to the vessel, the hand reel jigging operations could not be carried out. However, hand reel jigging operations were tried during day time sending the jigs at deeper depths (up to 100 m). About 10 squids escaped during hauling operations due to strong current and rough sea.

Figure 12: Percentage catch from various types of jigs



2) Collection and storing of squid samples for studies on biological parameters: Morphometric measurements were taken as per the scheduled proforma. The length weight data of the different squids landed is given in **Table 9**. Identification of the species and determination of the sex were carried out. The squids were dissected and the

gut of the individual species were collected and stored in 5% formalin in plastic containers for further analysis in the laboratory. Beaks (both lower and upper) of squids were collected and preserved for further studies. Whole squid samples of representative species were stored in -20^0 C for laboratory studies. The heads of the squids were preserved for the collection of statolith for advanced studies.

3) Collection of squid samples for biochemical and molecular studies: Representative samples were taken for the biochemical analysis in the lab. The samples were preserved in their respective reagents for the analysis of peptides, amino acids, lipids as per standard methodologies. The samples of ink sac were collected and stored for the studies on bioactive compounds. Mantle piece of squids of different species were preserved in 70% ethanol for molecular studies. The gladius (pen) of squids also were collected for taxonomic as well as biochemical studies.

Table 8: Details of squid jigging operations

Sl No.	Date	Stn No.	Lat	Long	Wind speed	Sea state	Time of operation		Atm temp ^{0}C	Sea temp ^{0}C	No of jigs	Jigging type	Jig type	Catch (Nos)	Species	Total (Nos)	Weight (g)
							from	To									
1	30.12.12		0.029 S	77.34 E			23:21	23:30	28.3	28.6	1	Hand	LED	1	*Sthenoteuthis oualaniensis*	1	250.00
2	12.01.12 to 13.01.12	TS1	40 S	58.30 E	4.2	rough	23:30	4:00	14.4	17.6	7	Hand	local	6	*Sthenoteuthis bartrami*	9	8300.00
													LED	3	*Sthenoteuthis bartrami*		
3	12.01.12 to 13.01.12		40 S	58.30 E	4.2	rough	23:30	0:00	14.4	17.6	7	Reel	Blue				
													Red				
													Flur				
4	13.01.12 to 14.01.12	T 7	40 S	58.30 E	6.7	calm	21:00	3:00	16.3	18		Hand	local	9	*Sthenoteuthis bartrami*	21	16500.00
													LED	3	*Sthenoteuthis bartrami*		
													Red	9	*Sthenoteuthis bartrami*		
5	14.01.12 to 15.01.12	T 16	40 S	58.30 E	20.6	rough	21:00	4:00	18.2	18.1	6	Hand	local	8	*Sthenoteuthis bartrami*	24	24200.00
													LED	6	*Sthenoteuthis bartrami*		

													Red	10	*Sthenoteuthis bartrami*		
6	15.01.12	ST 3	40. 00 S	58.30 E	20.6	rough	21:30	22:30	18.2	18.1	1	Hand	Red	1	*Sthenoteuthis bartrami*	1	300.00
7	16.01.12 to 17.01.12	ST 6	40.00 S	53 E	24.1	rough	20:00	3:00	19.3	19	7	Hand	local	1	*Sthenoteuthis bartrami*	9	8700.00
													Red	8	*Sthenoteuthis bartrami*		
8	18.01.12	ST 9	43.00 S	53.30 E	17.9	rough	0:00	4:45	10.8	11.3	4	Hand	local	2	*Todarodes filippovae*	4	600.00
													Red	1	*Todarodes filippovae*		
													Flour esent	1	*Todarodes filippovae*		
9	18.01.12 to 19.01.12	ST 12	43.00 S	56.30 E	36.5	v. rough	22:00	0:00	13.1		4	Hand	Red	1	*Todarodes filippovae*	1	300.00
10	19.01.12	ST 15	43.00 S	58.30 E	18.6	v. rough	22:30	23:40	9.3		6		Red	1	*Todarodes filippovae*	1	350.00
11	22.01.12	ST 18	50.00 S	57.30 E		v. rough	6:30	8:00			8	Reel	Mixe d	0			0.00
12	23.01.12		52.00 S	57.30 E		v. rough	5:32	4:30			4	hand	Red				0.00
															Total	71	59500.00

Table 9: Morphometric measurements (length – weight data) of squids

Sl No	Species	Sex	Dorsal mantle length (cm)	Weight (gm)
1	*Sthenoteuthis bartrami*	Female	28.00	590.00
2	*Sthenoteuthis bartrami*	Female	28.10	650.00
3	*Sthenoteuthis bartrami*	Female	28.90	750.00
4	*Sthenoteuthis bartrami*	Female	30.00	700.00
5	*Sthenoteuthis bartrami*	Female	25.30	420.00
6	*Sthenoteuthis bartrami*	Female	25.50	460.00
7	*Sthenoteuthis bartrami*	Female	22.00	300.00
8	*Sthenoteuthis bartrami*	Female	37.00	1355.00
9	*Sthenoteuthis bartrami*	Female	32.00	815.00
10	*Sthenoteuthis bartrami*	Female	26.20	385.00
11	*Sthenoteuthis bartrami*	Female	26.50	470.00
12	*Sthenoteuthis bartrami*	Female	29.00	665.00
13	*Sthenoteuthis bartrami*	Female	21.60	265.00
14	*Sthenoteuthis bartrami*	Female	28.60	595.00
15	*Sthenoteuthis bartrami*	Female	30.00	620.00
16	*Sthenoteuthis bartrami*	Female	30.00	665.00
17	*Sthenoteuthis bartrami*	Female	31.00	785.00
18	*Sthenoteuthis bartrami*	Female	36.00	1305.00
19	*Sthenoteuthis bartrami*	Female	24.00	1025.00
20	*Sthenoteuthis bartrami*	Female	29.50	695.00
21	*Sthenoteuthis bartrami*	Female	30.20	740.00
22	*Sthenoteuthis bartrami*	Female	30.30	735.00
23	*Sthenoteuthis bartrami*	Female	28.00	380.00
24	*Sthenoteuthis bartrami*	Female	34.00	995.00
25	*Sthenoteuthis bartrami*	Female	34.50	1075.00
26	*Sthenoteuthis bartrami*	Female	32.40	1105.00
27	*Sthenoteuthis bartrami*	Female	29.90	750.00
28	*Sthenoteuthis bartrami*	Female	30.00	695.00
29	*Sthenoteuthis bartrami*	Female	31.50	800.00
30	*Sthenoteuthis bartrami*	Female	28.80	560.00
31	*Sthenoteuthis bartrami*	Female	35.00	1045.00
32	*Sthenoteuthis bartrami*	Female	30.20	735.00
33	*Sthenoteuthis bartrami*	Female	32.70	1090.00
34	*Sthenoteuthis bartrami*	Female	35.60	1175.00
35	*Sthenoteuthis bartrami*	Female	34.10	1107.00
36	*Sthenoteuthis bartrami*	Female	29.00	805.00
37	*Sthenoteuthis bartrami*	Female	22.50	830.00

4.6 Suspended Particulate Matter and Elemental Chemistry: (GU)

Objectives

- To study the distribution and component/elemental composition of suspended particulate matter in Southern Ocean with space and depth.
- To understand source and factors controlling the source with time.
- To understand role of climate variation on distribution of suspended particulate matter.

Sampling and onboard analysis: Locations of sampling stations are shown in **Table 10**. Surface water samples (5 L) were collected from all the listed stations to study the spatial distribution of SPM. In addition water samples (5 L) were collected at various depths (100, 200 and 1000 m) from selected stations (indicated with * in the Table) to study the vertical distribution of SPM. Samples from different depths were collected with the help of a rosette water sampler attached with CTD. Surface water samples were collected using a pre-cleaned bucket wherever convenient. On the return voyage, surface water was collected at every degree interval till 28^0S maintaining the same longitude of 57.5^0E. Salinity was also measured using the Autosal. Collected water samples (5L) were immediately vacuum-filtered through pre-weighed Millipore filters having pore size of 0.45μm. Filter papers were then oven dried at 60^0C on the shipboard laboratory. The TSM (milligram per litre) concentration will be then obtained by re-weighing the filters and subtracting from the original filter paper weights. The Scanning electron microscope (SEM) photographs of the TSM will be obtained to understand the various components present in it. Further, digestion of the filters containing suspended matter will be done for selected samples to analyse selected metals present in it.

Table 10: Details of SPM sampling stations

Station No.	Latitude ^{o}S	Longitude ^{o}E
1	40	58.5
2*	40	57.5
3	40	56.5
4	40	55.5
5	40	54.5
6	40	53.5
7	41	53.5
8*	42	53.5
9	43	53.5
10	43	54.5
11	43	55.5
12	43	56.5
13*	43	57.5
14	43	58.5
15	44	58.5
16*	45	58.5
17	46	58.5
18*	50	57.5
19*	51	57.5
20*	52	57.5
21*	53	57.5

(*Samples collected at 100, 200 and 100m depths)

4.7 Carbon flux Over the Southern Ocean: (IISc)

The Southern Ocean covers nearly 20% of the global ocean area. It is well known that the presence of circum-global current is responsible for mixing of water masses and most of the ventilation of deep-sea water masses, including CO_2, takes place in the Southern Ocean. During summer SO acts as important sink of atmospheric carbon dioxide. The mechanism which demonstrates the sinking of carbon is through regional productivity. The factors responsible for enhancing the productivity of SO are nutrient supply, availability of sunlight, favorable wind condition etc. Because of its important role in carbon cycle, the Southern Ocean will continue to receive ample attention, despite the extraordinary challenges of working in as hostile an environment as the Antarctic region. Clear signs of warming is seen in both Antarctic Bottom Water and Antarctic Circumpolar Current. Planktic foraminifera thrive in various environments of the upper

water column and are sensitive to changes occurring in the temperature, salinity, nutrients, food availability, mixed layer depth, etc.

Objectives

- To understand the role of the Southern Ocean in the global carbon cycle.
- To understand the potential responses to global warming by measuring the rise in atmospheric CO_2 levels using stable isotope proxies.

Methodology

Air samples were collected in 3 L glass flasks using indigenously designed battery operated air sampler with moisture trap (see details in **Table 11**). Suitable flushing time was provided before the air samples were collected. Samples were collected at high pressure with minimum pressure at 0.9 Kg/cm^2 and maximum pressure of 1.2 Kg/cm^2. Care was taken to ensure no breath or engine exhaust contamination occurred to the samples during collection. Surface (1-5 m) seawater samples were collected using bucket cast during the expedition. Separate deployment of a rosette containing a conductivity, temperature, depth profiler and Niskin bottles were made to collect seawater at depths at sample locations. Rainwater was collected whenever it was raining (**Table 12**). Plankton samples were collected by means of 0–1000 m vertical plankton net tows (MPN, mesh size 200 μm) (**Table 13**). Plankton net samples were filtered and individual planktic foraminifera picked under microscope.

Concentration of CO_2 shall be measured using a Gas Chromatography (*Thermo Fisher - Chemito GC 8610*). An isotope ratio mass spectrometer (*Thermo Fisher- MAT 253*) shall be used for isotopic analysis of $\delta^{18}O$ in water and $\delta^{13}C$ measurement for all species of carbon in air, fromaminifera and water.

Table 11: Air sampling locations

Air samples					
Sample number	**Latitude (S)**			**Longitude (E)**	
	Deg	**Mins**		**Deg**	**Mins**
1	14	23	N	74	05
2	10	40	N	75	10
3	02	47	N	78	46
4	0	59	N	77	33
5	05	09	S	75	18
6	11	02	S	72	51
7	16	28	S	70	16
8	19	56	S	68	40
9	25	06	S	66	14
10	31	16	S	63	09
11	35	03	S	61	13
12	40	00	S	56	30
13	39	59	S	54	06
13a	42	13	S	53	30
14	43	11	S	58	35
15	50	35	S	57	30
16	51	16	S	57	40
17	48	35	S	57	34
18	46	11	S	57	28
19	41	45	S	57	39

Table 12: Rain water sampling locations

Rain water samples					
Sample number	Latitude (S)			Longitude (E)	
	Deg	Mins		Deg	Mins
1	0	58	S	77	08
2	2	21	S	76	31
3	8	11	S	73	58
4	10	55	S	72	54
5	11	41	S	72	33
6	25	51	S	65	52
7	39	59	S	55	28
8	50	00	S	57	30

Table 13: Details of water and foraminifera sampling locations

SOE/2011-2012/STN	Latitude	Longitude	Particulars
	10 27.752 N	75 22.653 E	Water with foraminifera samples
	10 28.353 N	75 22.637 E	-do-
	7 30.941 N	78 11.576 E	-do-
1			
2	40 00.570S	57 29.785E	200 M
3	40 00.060S	56 30.071E	200 M
4	39 59.727S	55 30.384E	200 M
5	39 59.847S	54 27.971E	200 M
6	40 00.001S	53 29.971E	200 M
7	41 S	53 30 E	200 M
8	42 00.743S	53 30 E	200 M
9	42 59.958S	53 30.110E	200 M
10			200 M
11	42 59.984S	55 29.811E	200 M
12	42 59.880S	56 30.226E	MPN
13	43 00.107S	57 30.299E	MPN
14	43 04.697S	58 34.412E	SURFACE
15	44 00.128S	58 29.997E	SURFACE
16	45 00.167S	58 29.941E	WATER 0,50,100,200,500,1000M FORAMS 0,200
17	46 00.094S	58 30.316E	WATER 0,50,100,200,500,1000M FORAMS 0,200
18	50 S	57 30E	WATER 0,50,100,200,500,1000M FORAMS 0,200
19	51 00.073S	57 30.037E	WATER 0,50,100,200,500,1000M FORAMS 0,200
20	51 59.698S	57 30.339E	WATER 0,50,100,200,500,1000M FORAMS 0,200
21	52 59.993S	57 30.163E	WATER 0,50,100,200,500,1000M FORAMS 0,200

4.8 Atmospheric studies- Aerosol Radiative Forcing over Southern Ocean: (GU)

Objectives

- To generate aerosol optical depth (AOD)
- To measure black carbon prevailing (if at all) in the Southern Ocean region.

Onboard sampling and analysis

Parameters Measured:

1. Aerosol Optical Depth
2. Black Carbon Mass Concentration
3. Aerosol Differential Mass concentration

4. Weather Parameters
    a. Temperature
    b. Pressure
    c. Wind Speed
    d. Wind direction
5. Ambient Aerosol Samples

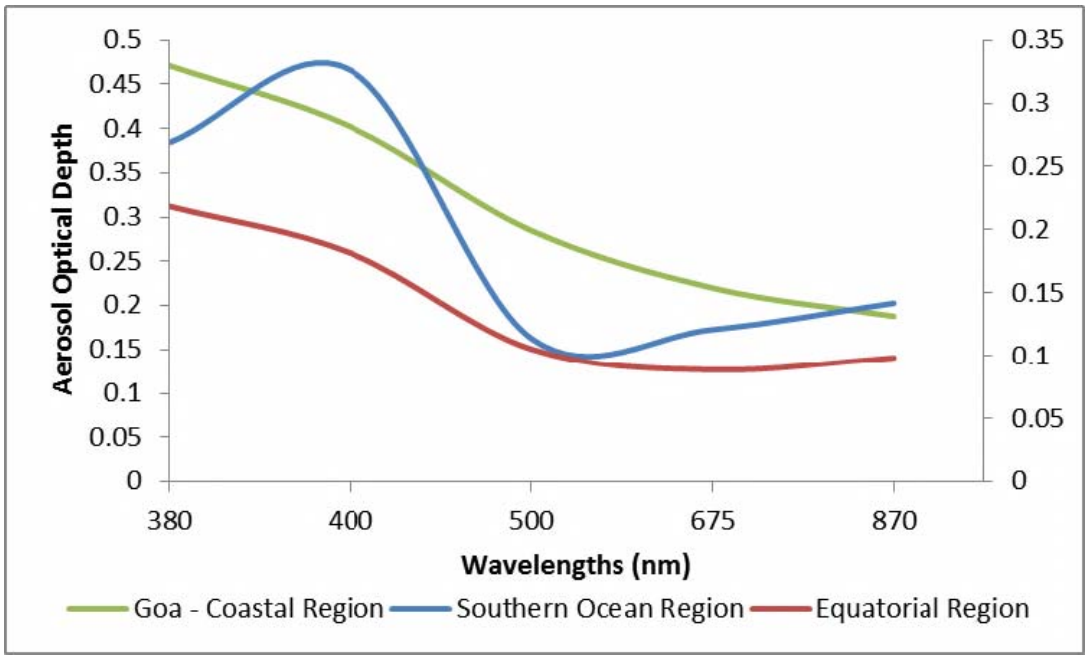
Operational details

a. Sunphotometer
    i. Operational since 25 December 2011.
    ii. Measuring Aerosol Optical Depth.
b. Aethalometer
    i. Operational since 26 December 2011.
    ii. Measuring Black Carbon Mass Concentration.
c. Weather Tracker operational since 29 December 2011.
    i. Measuring the weather parameters.
d. Quartz Crystal Microbalance
    i. Operational at designated stations.
e. High Volume Aerosol Sampler.
    i. Operational at designated stations

The **Microtops II Sunphotometer** was used to measure the Aerosol Optical Depth at the 5 channels every 30 minutes interval, beginning from Goa to 53^{o}S to 23º30'S, 57º30' E, i.e. approximately a day before reaching Mauritius. In most of the regions in the Southern Ocean, due to the cloud cover or rough sea conditions, this operation was difficult. However, some days due to availability of clear sky, the data was obtained, giving a specific pattern. This data will be analysed first for its correctness and then the information that it provides about the aerosols present will be interpreted.

A typical pattern seen in different locations is shown in **Figure 13**.

Figure 13: A typical pattern of Aerosol Optical Depth seen in different regions; based on data collected; Goa - Coastal Region on Left Axis, Southern Ocean and Equatorial Regions on Right axis

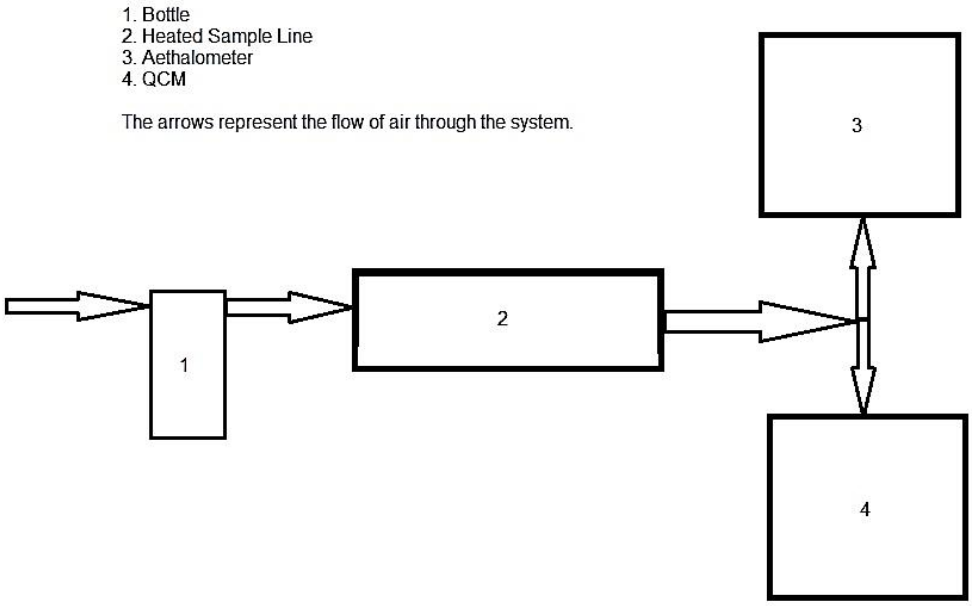


The **Aethalometer** was used to measure the ambient black carbon mass concentration throughout the cruise beginning from Goa to 53^{o}Sto 23.5^{o}S, 57.5^{o}E. The instrument was placed in the bow of the ship in order to prevent contamination from all kinds of exhaust that the ship may generate. Even if contamination is present, it can be easily detected from the plots of Black Carbon mass concentration v/s time and taking help of the weather parameter-wind direction. The data will be downloaded from the instrument later for analysis and interpretation.

The aerosol differential mass concentration was measured using **Quartz Crystal Microbalance**. According to the designated stations, the QCM was operated to measure the aerosol differential mass concentration. The data will be downloaded from the instrument later for analysis and interpretation. Initially, the instrument was run considering the humidity levels i.e. when the relative humidity was less than 75%. Later the inlet of the instrument was joined with the outlet of heated sample line. The Heated Sample line was initially used only for Aethalometer air inlet. A bottle was inserted in the

air inlet line to collect condensed water or the water entering the pipe as a result of the waves splashing on the deck to protect the instruments. This change in apparatus enabled the use of instrument even at relative humidity above 75%. A schematic representation of the new apparatus is shown in **Figure 14**.

Figure 14: Schematic representation of the apparatus used for safe running of Aethalometer and QCM



Weather parameters – temperature, pressure, wind-speed and wind-direction were determined using the ***Kestrel 4500*** **Pocket Weather Monitor**.

i. The weather tracker was placed near and exactly above the inlet of the Aethalometer to help track the wind direction to help filter out the error points from Black Carbon mass concentration data.
ii. The data was generated at every 10 minute interval. The data was downloaded every day. The data will be processed to convert the apparent wind speed and direction to true wind speed and direction.
iii. This data forms the auxiliary data supporting other instrument-data in error correction and to understand the general ambient atmospheric conditions prevalent during the cruise.

The **High Volume Aerosol Sampler (HVS)** was used to retrieve the samples of the ambient aerosols. According to the designated stations, the aerosol samples were collected on 4 inch quartz fibre filter paper. These samples will be used to measure the aerosol mass concentration. The samples will also be processed later to identify the chemical composition of the collected aerosols.

GARMIN GPS 12 was used to geo-tag the data**.**

5. ADDITIONAL WORK DONE by NCAOR

NCAOR scientists carried out additional sampling which was not proposed in the original work plan, to collect additional data on surface phytoplankton diversity, chlorophyll, pigments, bacterial abundance, nutrients and some components of organic carbon, enroute STF with out stopping the ship. Further, work proposed by some other institutions such as NIO, JNU and INCOIS , but their scientist could not be accommodated due to non-availability of berths onboard the ship, was also voluntarily done by NCAOR scientists so that these institutions are not denied of deployment of their equipments/data and sample collection. The details are given below:

5.1 *Phytoplankton biomass, diversity and related studies*: (NCAOR)

Sea -surface water samples were collected from 11 stations using a clean plastic bucket off Kochi, off Sri Lanka and up to 13ºS (see **Table 14** for location details). Aliquots of sea water samples were filtered for chlorophyll *a* (chl *a*), total pigments, particulate organic carbon (POC), particulate carbohydrates (PCHO) and dissolved carbohydrates (DCHO). Aliquots of samples were also collected for nutrients, dissolved inorganic carbon (DIC) and pH/Alkalinity, total phytoplankton abundance and bacterial abundance.

Table 14: Sampling details of surface seawater for biological and chemical parameters between Kochi and 13ºS.

Latitude	Long E	Biology	Chemistry
9° 53.38 N	76° 0.966	Chl *a*, total pigments (HPLC), Phytoplankton & total bacterial abundance (microscopy) TEP	DIC, TOC, nutrients, POC, DCHO, PCHO, UA
2° 59.177N	78° 51.883	Same as above	Same as above
2° 00.26 N	78° 26.161	Same as above	Same as above
1° 03.00 N	78° 01.184	Same as above	Same as above
0° 00.83	77° 34.080	Same as above	Same as above
0° 59.38 S	77° 07.810	Same as above	Same as above
1° 59.79 S	76° 41.445	Same as above	Same as above
3° 00.01 S	76° 15.176	Same as above	Same as above
4° 00.98 S	75° 49.276	Same as above	Same as above
11° 01.56 S	72° 51.383	Same as above	Same as above
11° 59.54 S	72° 22.818	Same as above	Same as above
13° 02.04 S	71° 48.599	Same as above	Same as above

5.2 POC and REE in STF water column: (Prof. A.L. Ramanathan, JNU)

Water samples (**Table 15**) were collected for Jawaharlal Nehru University by NCAOR (Dr. P.V. Bhaskar) . The sampling was a continuation of JNU's work during previous expedition (SOE2010-11).

Table 15: Station locations (original and modified) for particulate organic carbon (POC) and rare earth elements (REE)

Proposed locations		Modified locations	
Latitude S	**Longitude E**	**Latitude S**	**Longitude E**
40.00	53.50	40.00	53.50
40.00	57.50	40.00	57.50
43.00	58.50	43.00	58.50
45.00*	53.50*	45.00	58.50
45.00	57.50	50.00	57.50
50.00	57.50	52.00	57.50
52.00	57.50	53.00	57.50

*Not sampled as the location was within the EEZ of Crozet Islands

The main purpose was to study the $\Delta^{13}C$ ratios of particulate organic carbon in seawater. In continuation with previous year's sampling, 2 L of seawater from 7 depths (surface, 30, 50, 100, 200, 500 & 1000 m) was filtered through pre-combusted GF/F filters in duplicates and the filters were stored frozen at -20°C. In addition, 1 liter of seawater from each depth was acidified with 3 ml of concentrated HCl (pH < 1.5) and stored at 4°C. The sampling details are given below.

5.3 Routine Monitoring of Upper Ocean Thermal Fields in the Seas Around India: (Dr. V.V. Gopalakrishna, NIO, Goa)

NCAOR physical oceanography scientists (Mr. Jenson V. George and Dr. M. Nuncio) carried out this work onboard. This research project is funded by MoES.

Objectives

- To collect high quality temperature / salinity profiles in the Indian Ocean.
- To understand and document the variability of thermal fields on different time scales.

Table 16: Locations of Lagrangian drifters deployment

No.	Date	Time (hr)	Lat	Long	Sr.No.
1	04.01.2012	11.00	13°32'S	71°35'E	84620
2	05.01.2012	10.25	16°25'S	70°18'E	93504
3	06.01.2012	09.25	19°01'S	69°06'E	113733
4	07.01.2012	11.00	22°01'S	64°42'E	44709
5	08.01.2012	13.21	25°00'S	66°16'E	44706
6	10.01.2012	08.41	31°00'S	63°18'E	113734
7	11.01.2012	16.30	35°00'S	61°13'E	79585
8	12.01.2012	19.25	39°15'S	58°54'E	98678
9	17.01.2012	07.15	40°52'S	53°30'E	98671
10	19.01.2012	17.09	43°00'S	58°30'E	98668

The main purpose of participating in the expedition was to validate XBT / XCTD probe fall rate equation in the Southern Ocean region. Simultaneous deployment of XBTs and XCTDs were made at a few CTD stations and drifters were deployed at selected locations (**Table16**).

5.4 Deployment of ARGO floats: (INCOIS)

NCAOR physical oceanography scientists (Mr. Jenson V. George and Dr. M. Nuncio) deployed 10 numbers of ARGO floats as per details given in **Table 17** in predetermined locations suggested by INCOIS.

Table 17: **Locations of ARGO floats deployment**

No.	Date	Time (hr)	Lat	Long	Sr. No.
1	10.01.2012	14.00	31°11'S	63°13'E	5766
2	11.01.2012	16.30	35°00'S	61°13'E	5767
3	15.01.2012	02.00	40°00'S	58°30'E	5768
4	17.01.2012	00.00	40°00S	53°30'E	5769
5	19.01.2012	15.30	43°00S	58°30'E	5770
6	20.01.2012	13.30	45°00S	58°30'E	5774
7	22.01.2012	10.15	50°00S	57°30'E	5771
8	22.01.2012	20.53	51°00S	57°30'E	5772
9	23.01.2012	04.45	52°00S	57°30'E	5773
10	28.01.2012	16.40	42°00S	57°30'E	5775

5.5 Isotope Finger Printing of Waters of India (IWIN): (Dr. P.M. Muraleedharan, NIO, Goa)

It has been estimated that by the year 2050, the demand for water will almost triple to ~1,450 km^3/yr. Whichever way the demand is met, there will be large scale modification of the natural hydrological cycle in the country not just due to engineered structures and controlled stream flows but also by changing the residence time of water in aquifers and by increasing water vapour content of the atmosphere over India, significantly during non monsoon months.

Realizing the importance of stable isotope in hydrology, Department of Science and Technology, Govt. of India has decided to promote the research for investigating the spatial and temporal fingerprinting of water sources of India using stable isotopes and tritium as a national program. The aim of this study is to improve understanding of the geographic and seasonal evolution of the components of the local and regional hydrological cycles, interactions between the various components and controls exercised by geographic factors and climatic forcing. The National Institute of Oceanography has taken the responsibility of collecting surface water samples from Arabian Sea and southern ocean besides collecting other upper air and surface meteorological parameters. Since several National Institutes are involved in organizing expeditions over the surrounding oceans, NIO would be looking forward to associate with them in data collection and dissemination programs by making use of the ships of opportunity.

Objectives

- Identifying dominant sources of water vapour supply (Arabian Sea, Bay of Bengal, Southern Ocean, local and long distant continental sources) at different locations within the country during different seasons.
- Quantifying the partitioning of vapours into rain and re-partitioning of rain into various components as evapotranspiration, soil moisture, stream flow and groundwater.
- Quantification of the extent and rates of interactions between these components.

- Controls that geographical and climatic factors exercise over the entire hydrological cycle both temporally and spatially.

Sampling

Surface water samples were collected from 65 stations (100 ml & 50 ml) every day at around 0900 hr, 1300 hr and 1800 hr along the cruise track. The sampling was started at 0º.019'N, 77º42'E and continued up to 52º30'S, 57º30'E. Water temperature, wind speed and wind direction were also noted at each station. (Acknowledge the help rendered by Ms. R.L. Minu and Ms. Thara Goplakrishnan (CMLRE) for help in sampling). Isotopic analyses and salinity measurements will be carried out once the samples are brought to NIO.

6. Suggestions for improving/adding facilities on ORV Sagar Nidhi

Laboratories

1. The autoanalyzer did not work during this cruise. Although the NORINCO engineers did try their level best, the instrument could not be made functional. The reason: Electronic spares for the autoanalyzer were not available. Moreover, communication with the engineers in India was not fast enough as it took about 24 to 36 hours to receive replies to their queries via emails.

   Suggestion: Keep stock of all consumables, electronic and hardware spares. Also, faster communication via internet facility would save lot of time. Also, engineers on both side would benefited from realtime analyses of the problem.
2. There are some instruments onboard including the autoanalyzer which are not covered under AMC.

   Suggestion: All instruments onboard may be included under AMC and required consumable, hardware and electronic spares may be kept for repairs/replacement. Working of all instruments is an integral part of the success of the cruises.
3. The microscope lenses needs frequent cleaning for removing the fungus which has already grown. Also spare bulbs have to be stocked.

   Suggestion: AMC for microscope maintenance is required.

4. The vertical deep-freezers and refrigerators in Lab. 2 do not have appropriate baskets to ensure safety of the samples. As SO is particularly choppy and rough, safety of samples should be of high priority. In the present scenario, frozen samples fall out when the doors are opened, resulting in damage/breakage of sample bottles.

   Suggestion: Vertical freezers should be replaced with horizontal freezers. It may occupy more space, but the samples will remain safe even during rough sea condition and will be easy to handle. If replacement is not possible, the vertical freezers should be provided with basket racks and not plain racks as the latter cannot provide any support to samples during choppy conditions.
5. The sample collection room gets flooded in no time due to inadequate drainage facility.

   Suggestion: Alternate efficient drainage mechanism needs to be provided.
6. Seawater supply in the sampling area and wet lab is inadequate and the taps are not working properly. Moreover, there is no continuous supply of seawater in the lab.

   Suggestion: Improve the existing seawater supply system and repair freshwater taps.
7. Currently, the ship's position is available only in Lab 1, where the AWS is connected to the PC. Otherwise, there is no display of GPS information in any other lab.

   Suggestion: GPS display unit may be made available in wet lab, Lab 2 and Lab 3. Additionally, similar display unit should be installed in Chief Scientist's cabin, officer's day room & mess room for proper station management.
8. A suitable dissection table may be provided with freshwater facility in the main deck.
9. The present laminar flow is inappropriately placed to carry out any proper microbiological work. It is too low and difficult to work for long hours squatting on the floor. Also, it is close to the door connecting the wet lab and the instrument lab. This is extremely inconvenient. The filters also need replacement.

Suggestion: The present laminar flow may be replaced with a table top laminar flow and placed in Lab 3. This would result in more space in wet lab which is presently very narrow and congested and difficult to work. Also, the laminar flow area will remain clutter free and easy to work with.

10. The autoclave installed in the wet lab is too small and is of very little use for autoclaving purposes onboard during the expedition. The need for large scale media preparations is generally too large onboard. The vertical autoclave currently placed in Lab 1 is faulty as it is leaking at the bottom and through a side pipe.

    Suggestion: A suitable replacement may be installed and the same may be purchased from a Certified Manufacturer.

11. The Environmental chamber and –20º C deep freezer in Lab 1 are not maintaining the set temperature.

    Suggestion: Needs repair/maintenance.

12. A 3 m X 3 m enclosure for housing the laminar flow, autoclave and a temperature controlled [from 10 to 50 °C] incubator in a row allowing close to 1.5 m long working space will help all microbiological sample processing and analysis.

    Suggestion: A suitable area may be identified either in Lab 1 or Lab 3.

14. A suitable working area for radioactive studies need to be identified and facilities created.

    Suggestion: A suitable place may be identified in Lab 1.

15. An automated XCTD/XBT launching system may be installed in the aft. This will be extremely useful when carrying out frequent deployments in harsh weather conditions. Presently the slide door of lab no.1 has to be opened and closed every 1 hr when 10 mile XCTD operations were going on.

    Suggestion: A suitable location in the aft may be identified and necessary infrastructure for launching XCTD/XBT be developed.

Scientists' Cabins

1. None of the scientists' cabins have a wall clock. This is a must as the ship's time keeps changing during the course of the expedition to Southern Ocean. A wall clock which follows ship-time and is controlled from the bridge may be installed in all scientists' cabins.
2. None of the bathrooms have a shower curtain.
3. There is a need for retractable cloth line in the bathroom to dry the inner wears of scientists. Currently, these are being dried in the cabin, making it inconvenient for movement and looking shabby.
4. Pedestal fans are not provided in all cabins. This is a must as the room can become stuffy and also in case of AC failure.
5. Some scientist rooms do not have a TV. Similarly, the Scientists & Officers day room does not have a proper DVD player. Currently, the scientists have to depend on the ship's common entertainment.
6. All scientist's cabins may be provided speaker phones.
7. The cabin door of cabin 2-08 is in a bad shape. It needs to be replaced/repaired. The hot water supply in the same cabin can not be controlled (temperature control in bathroom does not work). This needs to be repaired.

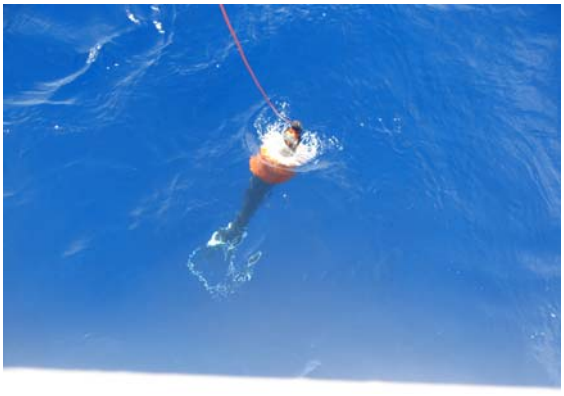
Chief Scientist's cabin

1. Using the PC in the way it is presently placed is a pain both for the neck and the hand. The table on which it is placed is so high and there is no leg place to sit and work comfortably. It is fixed to the right end of the table and moving mouse is not possible. Also there is no place to keep a book or paper. It should be placed on the left side of the short table next to the entrance door.
2. The hydraulic system of the chair is not working. The chair may be replaced.
3. The intercom is in the day room and during night no one can contact the chief scientist even in emergency. An intercom may be connected in the bed room.
4. GPS display facility may be provided in the cabin for monitoring the stations.
5. Intercoms may be replaced with speaker phones.
6. There is no shower curtain in the bathroom.
7. Provision may be made in the bathroom for drying inner wears.
8. The cabin door and bed room door are not closing properly.

7. Activities

Expedition Team

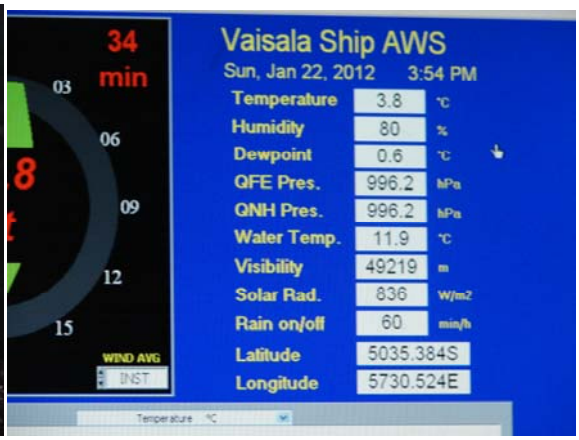
Scientists onboard ORV Sagar Nidhi



Microprofiler operation

Multiple Plankton Net hauling

CTD operation



AWS Display

XCTD launching

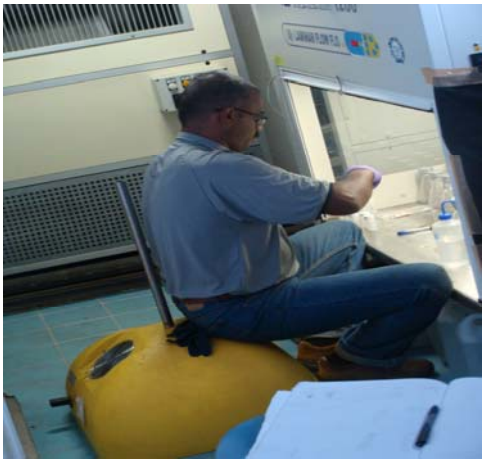
WP net hauling

Preparation of standards

Chemical analysis

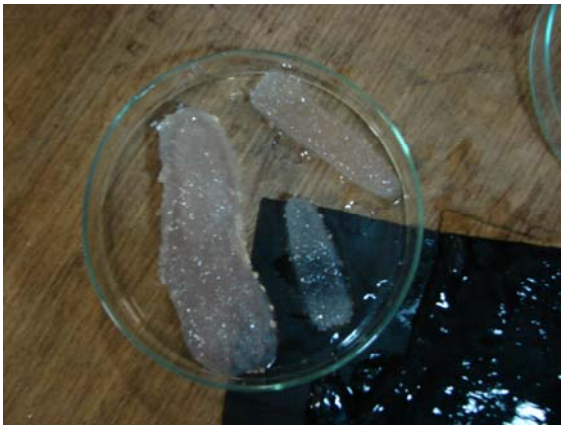
Seawater filtration

Preparation for P/I experiment



Bacteriological studies

A large salp



Pyrosoma sp

A large oceanic squid

Microcosm experimental setup

Mesozooplankton collection

Zooplankton sorting and counting

Birthday celebration

Christmas celebration

Play time

Enjoying snow fall onboard

Republic day–National Flag hoisting