CRUISE REPORT

ORV SAGAR KANYA
CRUISE 200
(23rd January – 04th March 2004)

NATIONAL CENTRE FOR ANTARCTIC AND OCEAN RESEARCH

PILOT EXPEDITION TO SOUTHERN OCEAN EXPEDITION

National Centre for Antarctic & Ocean Research (NCAOR), Goa and the Department of Ocean Development was the nodal agency for organizing the Pilot Expedition to Southern Ocean. The cruise was of multidisciplinary nature and first of its kind to this part of the ocean on the initiation of NCAOR. Apart from NCAOR other participating institutions include NIO, Goa; NIO RC, Kochi; CMLRE, Kochi; IISc, Bangalore; SPL, Trivandrum; SAC, Ahemdabad; IITM, Pune; IMD, Pune; CUSAT, Kochi; CMFR, Kochi / Mangalore; Annamalai Univeristy, Chennai.

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22.Mr.Satish Kumar	*ELECT.*

[3.1] *INTRODUCTION*

[3.1.1] Background

The National Centre for Antarctic & Ocean Research (NCAOR) an autonomous institution at Goa, fully funded by the Department of Ocean Development (DOD), Government of India, initiated way back in September 2001 for a Pilot Cruise utilizing the services of the research vessel ORV Sagar Kanya aimed at studying the Southern Ocean upto 55 deg S latitude. A brain storming session was held at NCAOR and a blue print for scientific plan was drawn out for the multi-disciplinary and multi-institutional cruise in the Southern Ocean.. As part of the approved programme of NCAOR/ ODD during the X plan period the Southern Ocean received a major impetus, and in order to carry out scientific investigations, an implementation plan meeting was held at NCAOR in August 2003 involving 12 National Laboratories / Institutes. The discussions culminated in preparing a comprehensive scientific plan covering the major scientific interests and disciplines.

[3.1.2] Importance of Pilot Expedition in Southern Ocean

The Southern Ocean represents 10% of the world oceans and comprises several physically and biologically distinct regimes, latitudinally separated by fronts (Strutton et al. 2000). This region is characterized by high production of nutrients and low chlorophyll (HNLC) zone, also sometimes referred as one of the HNLC regions of the world. Added to this there is low utilization of these nutrient rich waters and therefore, needs further studies. Further, this is also the region of major wind stress and in turn the mixed layer gets deepened specially during the winter. Lastly, the waters of the Southern Ocean directly or indirectly affect the Indian Ocean and thereby the Indian climatic regime. As also the Indian Ocean is land locked on its northern extremity and therefore there is no exchange with the north pole waters. Therefore, the southern ocean and its waters need to studied in detail and the need to have such a cruise in this part of the world is aptly justified. This is also the region where there is complete paucity of data and the scientific community is looking for sea truth data from this region.

[3.1.3] This report has been divided into different sections covering different disciplines and the major objectives of these studies and some preliminary observations made. The broad areas include :

[a] Atmospheric Sciences

[b] Physical Oceanography

[c] Biological Oceanography

[d] Chemical Oceanography

[e] Geological Sampling

[f] Satellite Remote Sensing

[3.1.4] Objectives of the Pilot Expedition to Southern Ocean

[1] Atmospheric Aerosol Observations

[2] To measure Surface-met and upper atmospheric parameters over southern ocean using Automatic Weather Station and Radiosondes respectively.

[3] Physical oceanographic studies were aimed at understanding the temperature -salinity (T-S) structures, morphology of circumpolar fronts, circulation regimes in the water column and air-sea interaction processes pertaining to the Indian Ocean sector of the Southern Ocean

[4] The objectives of the Biology group were,

(i) To estimate latitudinal variations in the primary productivity, chlorophyll content and planktonic forms in relation to the nutrient availability, current patterns and other related environmental parameters.

(ii) Qualitative studies in the bacterial fauna below the euphotic zone and in the waters off bottom and their role in the decomposition/mineralisation process.

(iii) Qualitative studies on the macro and micro benthos.

(iv) Observations on marine mammals and avian fauna.

(iv) Determination of the bacterioplankton abundance below the euphotic zone and off bottom waters in the Indian Ocean sector of Southern Ocean.

(vii) Qualitative study of benthic fauna in the Indian Ocean sector of the Southern Ocean.

(viii) Assessment of microbial diversity at the sea bottom using 16Sr DNA based techniques.

(ix) Identify and enumerate harmful algal species.

(x) Survey for algal blooms – if any – and collect related environment data.

(xi) Qualitative and quantitative analysis of mesozooplankton in the Indian Ocean sector of Southern Ocean up to 1000m depth.

(xi) Estimation of Primary production, Chlorophyll *a* and qualitative & quantitative study of phytoplankton groups in the Indian Ocean sector of Southern Ocean.

(xii) Microzooplankton studies in the Indian Ocean sector of Southern Ocean.

[5] Sea water samples were collected for analyses of dissolved oxygen (DO) studies

[6] To understand the water mass circulation and physico-chemical behavior of the cold region the water samples were collected in a regular interval. Further to understand the biogeochemistry of the ocean the various depth of water columns were collected.

[7] The geological exploration during this expedition were carried out with the following objectives:

To understand spatial patterns of sedimentation as well as distribution of microfauna along the various geographic/ oceanic fronts within the Indian sector of the Southern Ocean.

a. To document and quantify the different microfauna preserved in the sediments so as to make a database for multiple microfossils.
b. Establish a relationship between the different types of microfossils viz. calcareous versus siliceous microfossils against the geochemical parameters and therefore search better proxies for getting the past information better.
c. To decipher the temporal variations in the various oceanographic processes during the geological past and its implications on the Indian Ocean circulation dynamics in particular and global climate system in general.

[4.1] ATMOSPHERIC SCIENCES

[4.1.1] Atmospheric Aerosol Observations

The role of atmospheric aerosols in modifying the radiation budget of the earth atmosphere system with implications to regional and global climate is being increasingly understood and recognized. Nevertheless, there still persist large uncertainties in the regional radiative forcing estimates due to aerosols. This arises mainly because of the lack of adequate knowledge of aerosol properties and the large variations in these properties over rather short scales, both spatially and temporally. Aerosol influences the radiation budget of the earth atmosphere system broadly in two different ways. The first is the direct effect in which aerosols scatter and absorb the incoming solar and outgoing terrestrial radiations, thereby altering the radiative balance of the earth-atmosphere system. The second is the indirect effect in which aerosols modify the microphysics and thereby the radiative properties and lifetime of clouds. Thus the radiative impacts of aerosols depends on the relative abundance of the scattering and absorbing aerosols. Significant variations in their abundance can occur regionally and seasonally at locations far away from potential sources as a result of changes in airmass types and prevailing meteorological conditions.

In this context Southern Ocean assumes significance. Its remote location and hostile conditions are impediments to do research in this region. Consequently, the Southern Ocean has been visited by research expeditions less frequently than has been the case for region closer to the ports. For these reasons, our understanding of the aerosol properties over the Southern Ocean have lagged behind our knowledge of better studied region. The objective of the study was to investigate the aerosol properties over a major sector of the Southern Ocean largely untouched by other national programs. The experimental details of the measurements carried out onboard Sagar Kanya is given in Table.1.

Table.1

Serial No	Instruments used	Use
1	Aethalometer	Black Carbon aerosol mass concentration
2	Microtops Sunphotometer	Aerosol Optical Depth
3	High Volume Sampler	Aerosol samples for chemical analysis

[4.1.2]*Aerosol Black Carbon*

The black carbon also known as the "greenhouse aerosol" affects the climate by absorbing solar energy that in turn heats up the atmosphere. The magnitude of this effect may depend on how black carbon is mixed with other aerosol components. Modeling studies showed that, the magnitude of the direct radiative forcing from black carbon can be the second most important component of global warming after CO_2. Thus, with such importance in the atmosphere, accurate determination of black carbon ambient mass concentration and its atmospheric behavior including long-term trends and light absorbing characteristics is required so that it can be modeled properly and its consequences better understood.

Continuous and near-real-time measurements of BC mass concentration were made onboard using an Aethalometer (figure.1). The instrument was kept inside the ship's cabin and ambient air was taken through an inlet pipe from the front-end region of the ship. The air intake was from a height of about 12m from the sea level. From the preliminary assessment of measurements, it is clear that the BC mass concentration over Southern Ocean is very low compared to tropical oceanic regions. This is due to the pristine nature of the airmass prevailing over Southern Ocean. Because of the anthropogenic nature of the origin of BC, even the low BC concentrations observed is surprising, and can be due to long range transport.

[4.1.3] Aerosol Optical Depth (AOD)

Optical depth is a measure of the transmittance of a vertical atmospheric column of unit cross-sectional area. A large optical depth implies less atmospheric transmittance. The optical depth is a result of the combined effect of scattering and absorption in a vertical column. One of the major contributors to the extinction of radiation in the atmosphere is aerosols. The optical depth due to aerosols is aerosol optical depth (AOD) and is a very important parameter controlling the aerosol radiative forcing.

The spectral AOD measurements were made onboard using a hand held Microtops sunphotometer (figure.2) at wavelengths 380, 500, 675 and 870 nm. The instrument manually aimed at the Sun, makes measurements of the direct solar irradiance and derive AOD based on its calibration, and the observation co-ordinates and time as recorded using a global position system (GPS) receiver attached to it. A typical spectral variation of AOD is shown in figure.3. It is observed that the AOD values over the Southern Ocean are typical of its pristine nature.

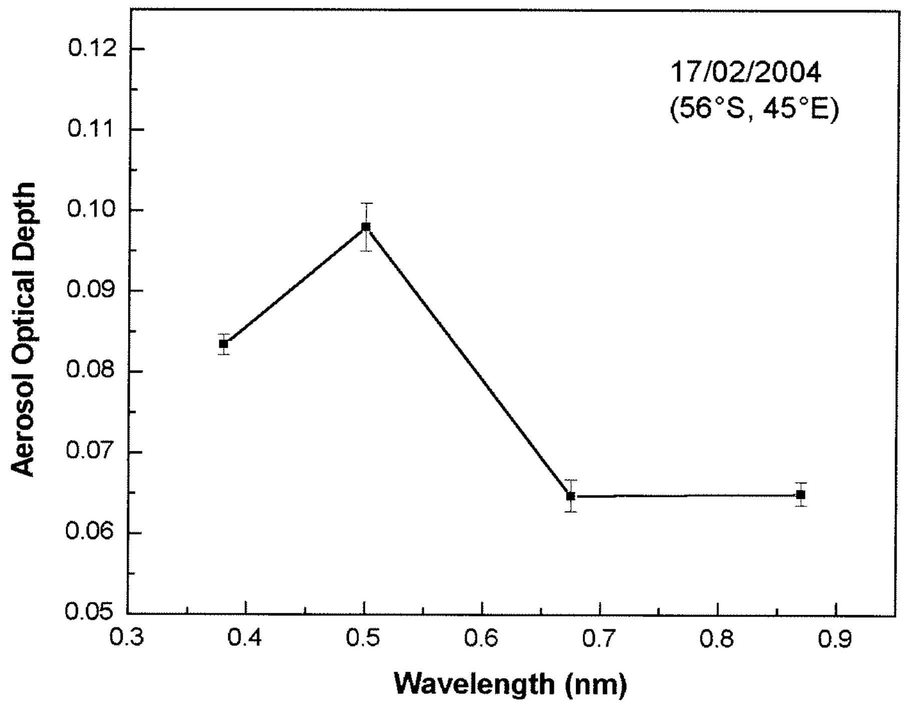


Figure.3. Typical spectral variation of aerosol optical depth.

[4.1.4] Aerosol Samples

Since radiative impact of the aerosols depends on its chemical composition, chemical speciation of aerosol is very important. Aerosol samples were collected onboard using a High Volume Sampler (figure.4). The instrument was operated at the bow side deck of the ship just below the bridge at ~ 10m above the water level and operated only when the ship was in motion at the normal cruising speed so that the instrument aspirates the clean oceanic air coming on to the ship, uncontaminated by ship's exhaust or any possible ship based emissions. About 12 aerosol samples were collected for chemical analysis.

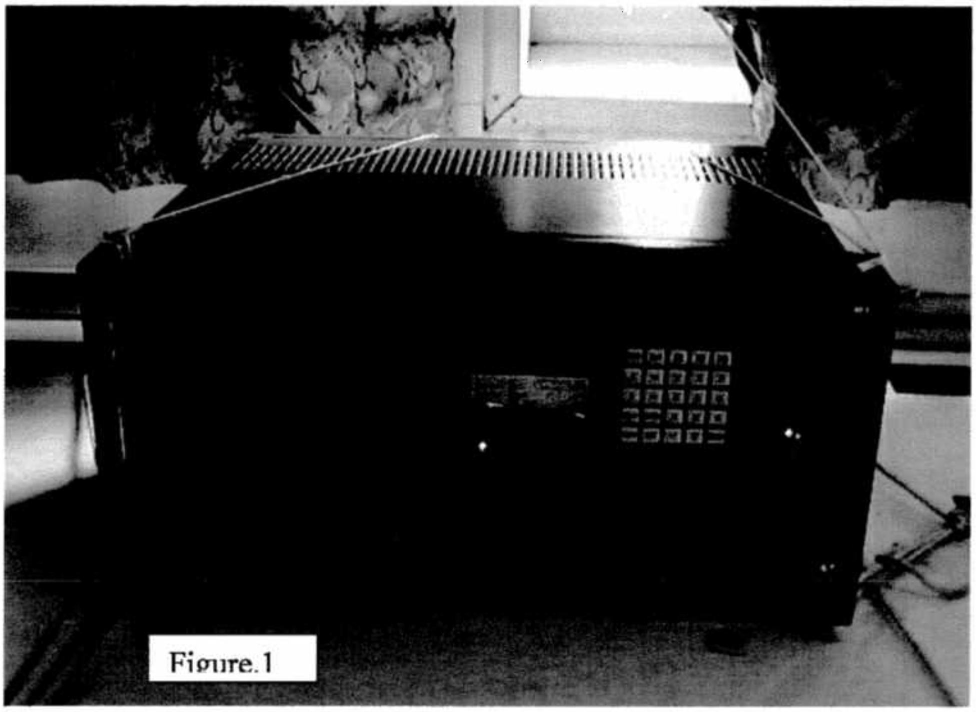


Figure.1

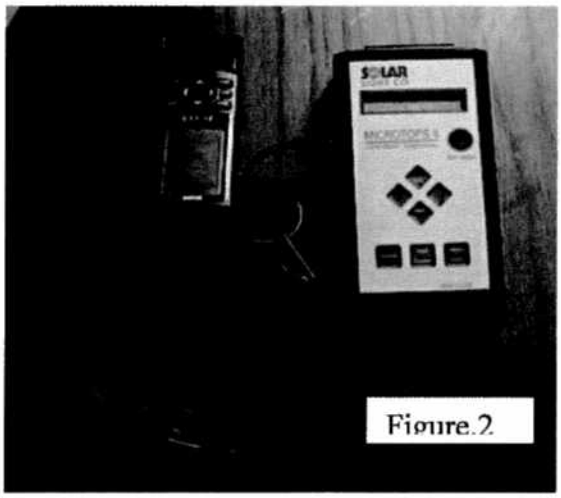


Figure.2

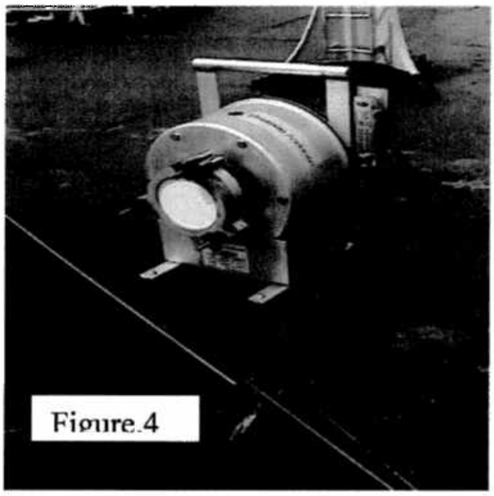


Figure.4

[4.2] Automatic Weather Station & Radiosonde

Objective:

To measure Surface-met and upper atmospheric parameters over southern ocean using Automatic Weather Station and Radiosondes respectively.

[4.2.1] Automatic Weather Station:

An Automatic Weather Station (AWS) was installed by Indian Institute of science (IISc) at the bow of the forecastle deck which is about 10.5m above sea level. Various meteorological parameters like air temperature, pressure, relative humidity, rainfall, solar radiation, wind speed and wind direction were continuously measured and stored as one minute average interval using Campbell's scientific CR21X datalogger.

[4.2.2] Radiosonde:

Upper atmospheric parameters were measured using high precision Vaisala GPS Radiosondes. Radiosondes measured parameters like air temperature, relative humidity, pressure, wind speed and wind direction. The measurements were recorded using Vaisala MW15 receiver. As proposed Radiosondes were launched at every 2.5° S latitude and about 13 radiosondes were launched between 24th January to 16th February 2004. Majority of the launches rose more than 20 Km height.

[4.2.3] Comparison of AWS:

The Southern ocean cruise provided an opportunity to compare the reliability of ship AWS with that of our own. An exercise was carried out to determine the response of the two stations under identical weather condition and the results of which where plotted (fig. 5-10.)

[4.2.4] Temperature and relative humidity response:

The temperature trend of Sagarkanya AWS (fig. 5) agrees with that of IISc and the relative humidity variation (fig. 5) although following the same trend, differs by about 5% RH. The cause of which may be due to difference in height of the two sensor locations.

[4.2.5] Pressure and shortwave radiation response :

The pressure variation (fig. 6) between two sensor is about 1mbar (height differnce being 10m), while the shortwave radiation compares well with that of IISc radiation sensor.

[4.2.6] Wind sensor response:

Sagarkanya AWS has two wind sensor installed on either side of the radome. For final wind computations a practice followed is that sensor indicating higher winds is taken as the reference. This criteria is followed considering that either of the wind sensor are observing the maximum winds when it is directly facing it. Fig. 8 & 9 satisfies this thumb rule but fig.10 fails to do so. The cause may be due to obstructions onboard which are affecting the final wind computations.

Overall the sagarkanya AWS compares well with that of IISc and the data can be used for scientific analysis.

[4.2.7] METEOROLOGICAL OBSERVATIONS

Pilot Expedition to the Southern Ocean was organized by Dept of Ocean Development to carry out more scientific research in the Indian sector of Southern ocean. India Meteorological Department has participated in this expedition to have more data base of this so far unexplored region.

Sagar Kanya Cruise No. 200 commenced from Port Louise, Mauritius by the evening of 23 rd January 2004. Recording of the meteorological synoptic observations started from 00 GMT of 24th January 04. These observations were recorded every three hours i.e. at 00, 03, 06, 09, 12, 15, 18 and 21 hrs GMT. Six hourly observations of 00, 06, 12 and 18 hrs GMT were forwarded by e-mail to I.M.D. headquarters at New Delhi on real time basis. Meteorological parameters such as pressure, dry and wet bulb temperature, sea surface temperature, wind speed and direction, clouds, visibility, present and past weather at the time of the observation were included in these observations. 296 synoptic observations were recorded up to 29 th February 04. Necessary help and hydrogen gas was provided to the scientists of IISc, Bangalore for 14 radio sonde ascents.

As we proceeded to south, temperature started decreasing and the lowest temperature of 0.8 deg. Celsius was recorded on 18 th and 19 th February 04. Foggy conditions prevailed from 9 th February to 13 th February. Intermittent snow fall was experienced on 18 th February. The ship experienced increase in wind speed from 18 th February. On 19th February when the ship was at 53.6 S/ 51.6 E between 06 and 09 GMT a maximum wind speed of 61 knots was recorded. The lowest pressure of 987.6 hPa was recorded at 15 GMT on 19 th February at 53.4 deg. S / 52.3 deg. E. The sea was rough with swell height reaching around 8 meters. Earlier this cruise was planned to go upto 55 deg. S Lat. As weather conditions were favourable, it was extended up to 56 deg. S lat. We reached it on 17 th February and after successfully carrying out all scientific operations, Sagar Kanya started her return voyage. On 25 th February at 21 GMT , sea surface water temperature abruptly increased by 4.1 deg. Celsius than that of recorded at 18 GMT after crossing 44.6 deg. S latitude.

Meteorological observation programme further continues.

List of Weather Sensors installed :

Sl No.	Equipment	Make	Measuring Range
1	Temperature & Humidity Sensor	ROTRONICS	Temperature : -40 to +60 °C Rel. humidity : 0 to 100 %
2	Pressure	VAISALA	800 to 1060 mbar
3	Wind monitor	YOUNG	Wind speed : 0 to 60 m/s Wind dir. : 0 to 360°
4	Solar Radiation	EPPLEY	Short wave : 0 to 2000 w/m^2 Long wave : 0 to 2000 w/m^2
5	Raingauge	YOUNG	0.1mm Resolution

Launch details of Radiosonde:

Sl No.	Date	Time (GMT)	Latitude	Longitude	Max. height (m)
1	24-1-04	1513	22.57S	54.91E	19029
2	25-1-04	1234	24.99S	52.53E	23043
3	27-1-04	1317	27.52S	50.38E	22756
4	29-1-04	1228	30.01S	46.18E	19936
5	31-1-04	2245	32.55S	44.92E	20158
6	02-2-04	1133	35.00S	45.00E	17180
7	04-2-04	0724	37.51S	44.94E	20592
8	06-2-04	0255	40.07S	44.99E	20376
9	08-2-04	0353	42.52S	45.10E	21053
10	10-2-04	0246	45.03S	45.15E	22507
11	11-2-04	1821	47.51S	45.24E	21278
12	13-2-04	1358	49.99S	45.00E	14645
13	16-2-04	0924	55.01S	45.01E	18839

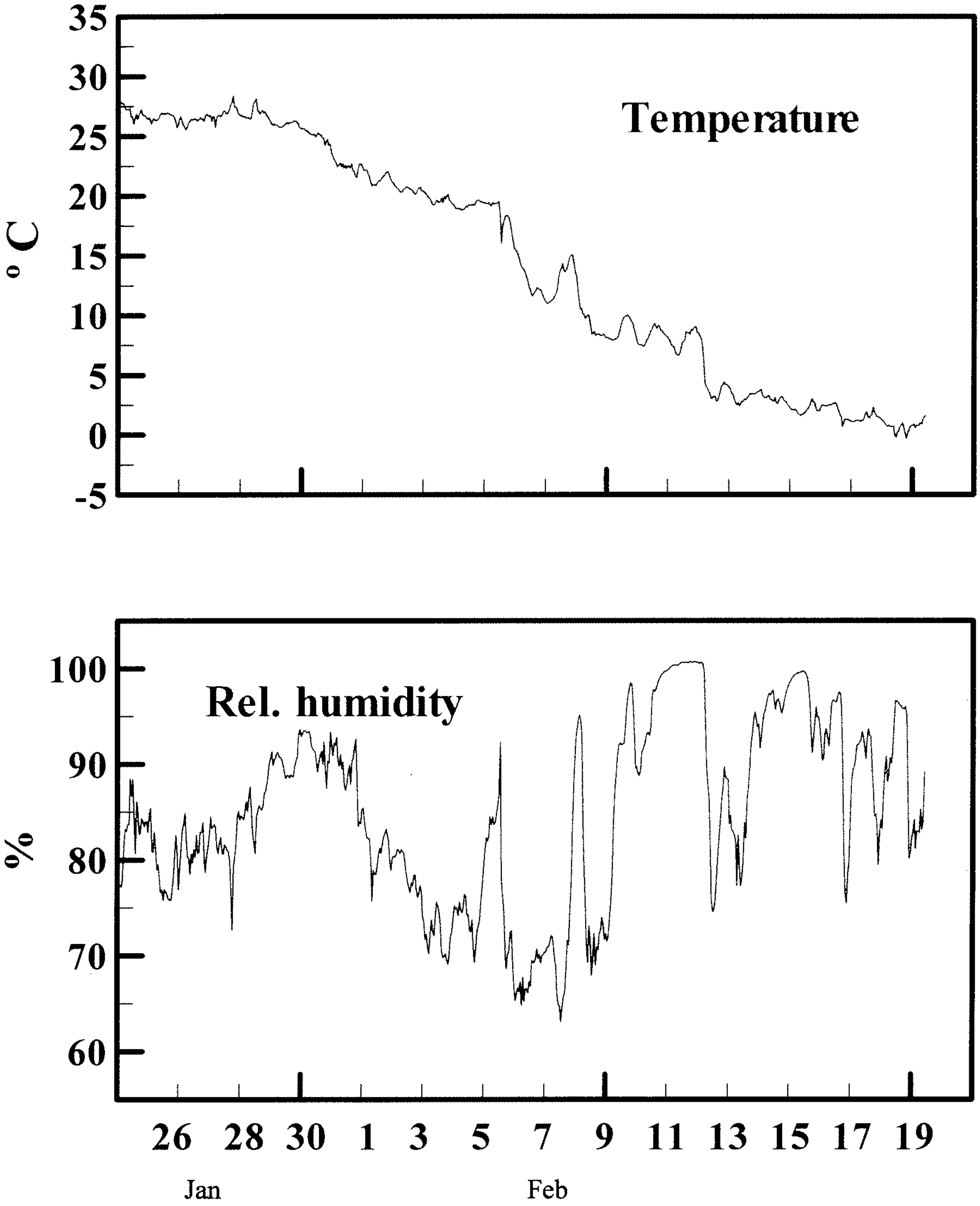


Fig 1. Hourly variation of air temperature and relative humidity from 24th Jan – 19th Feb 2004.

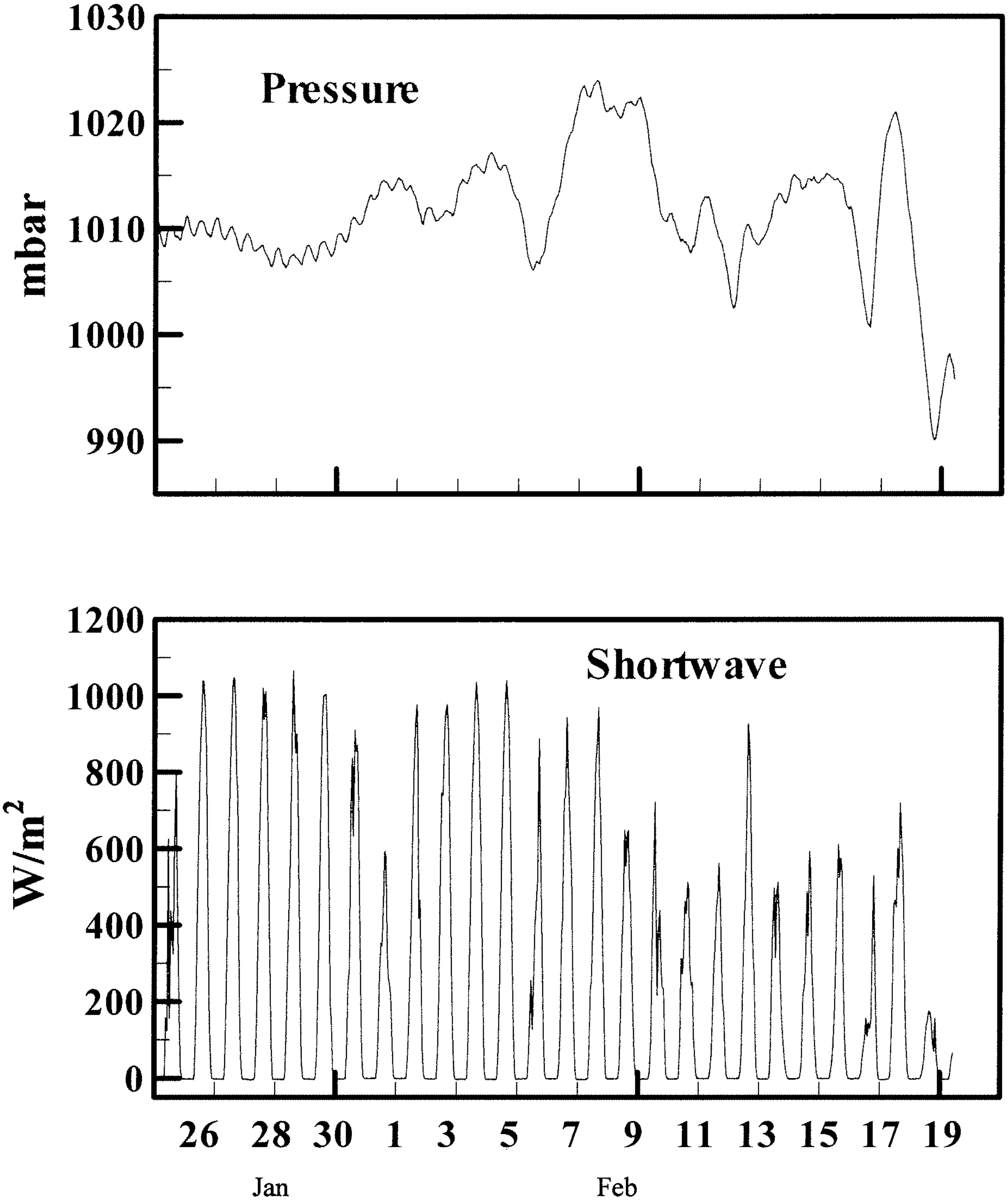


Fig 2. Hourly variation of atmospheric pressure and short wave radiation from 24th Jan – 19th Feb 2004.

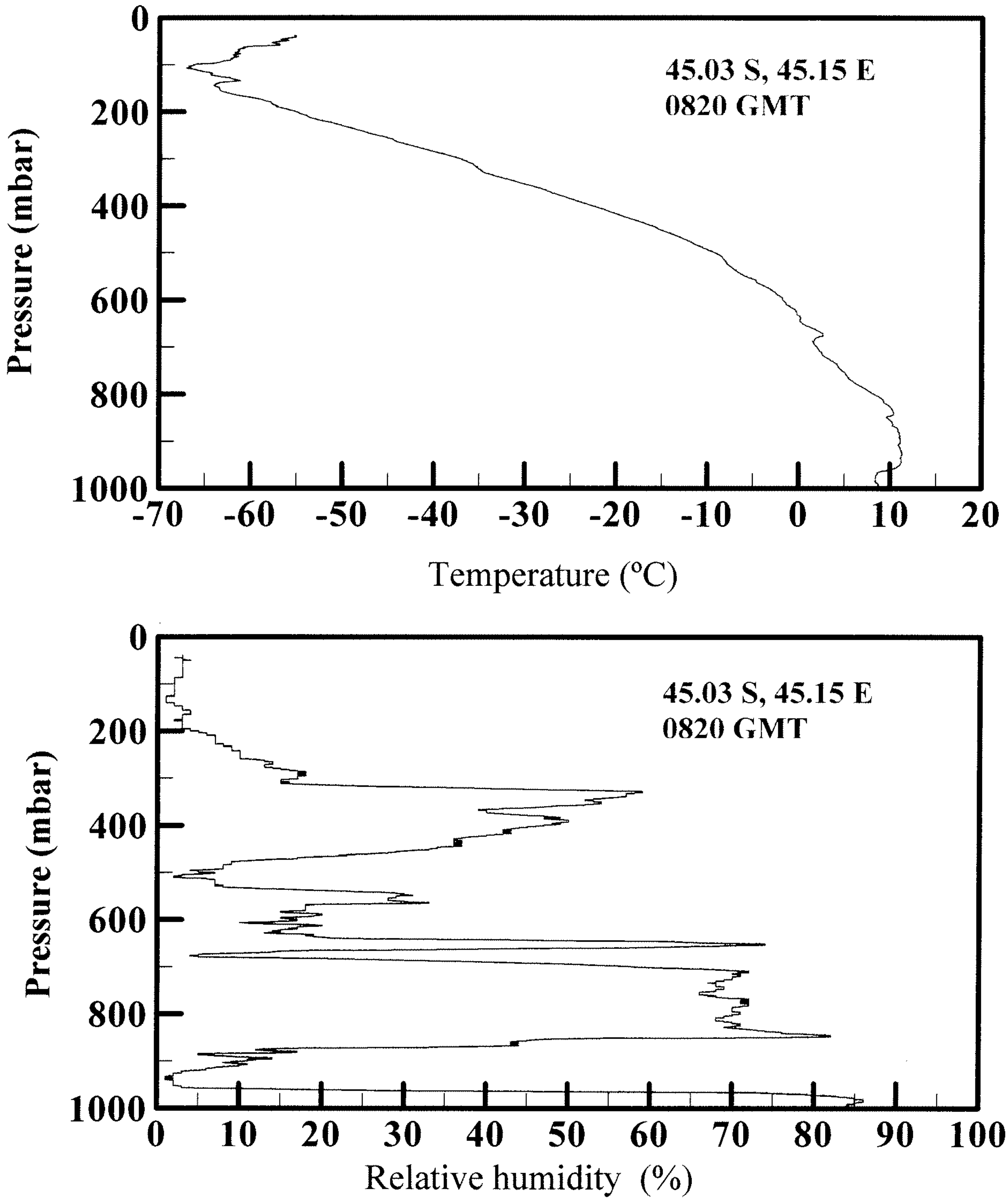


Fig 3. Vertical variation of air temperature and relative humidity on 10th February 2004.

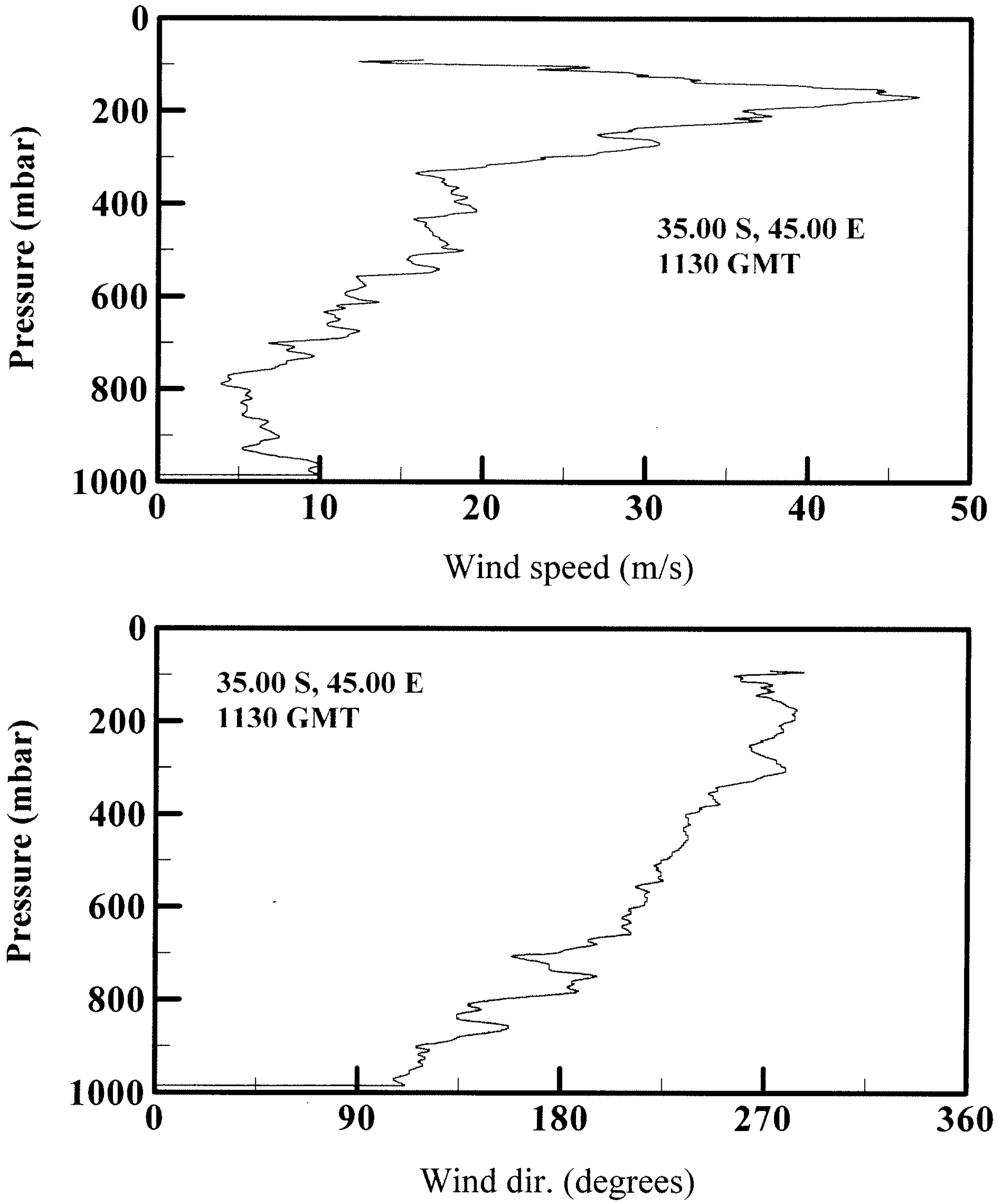


Fig 4. Vertical variation of wind speed and wind direction on 2nd February 2004.

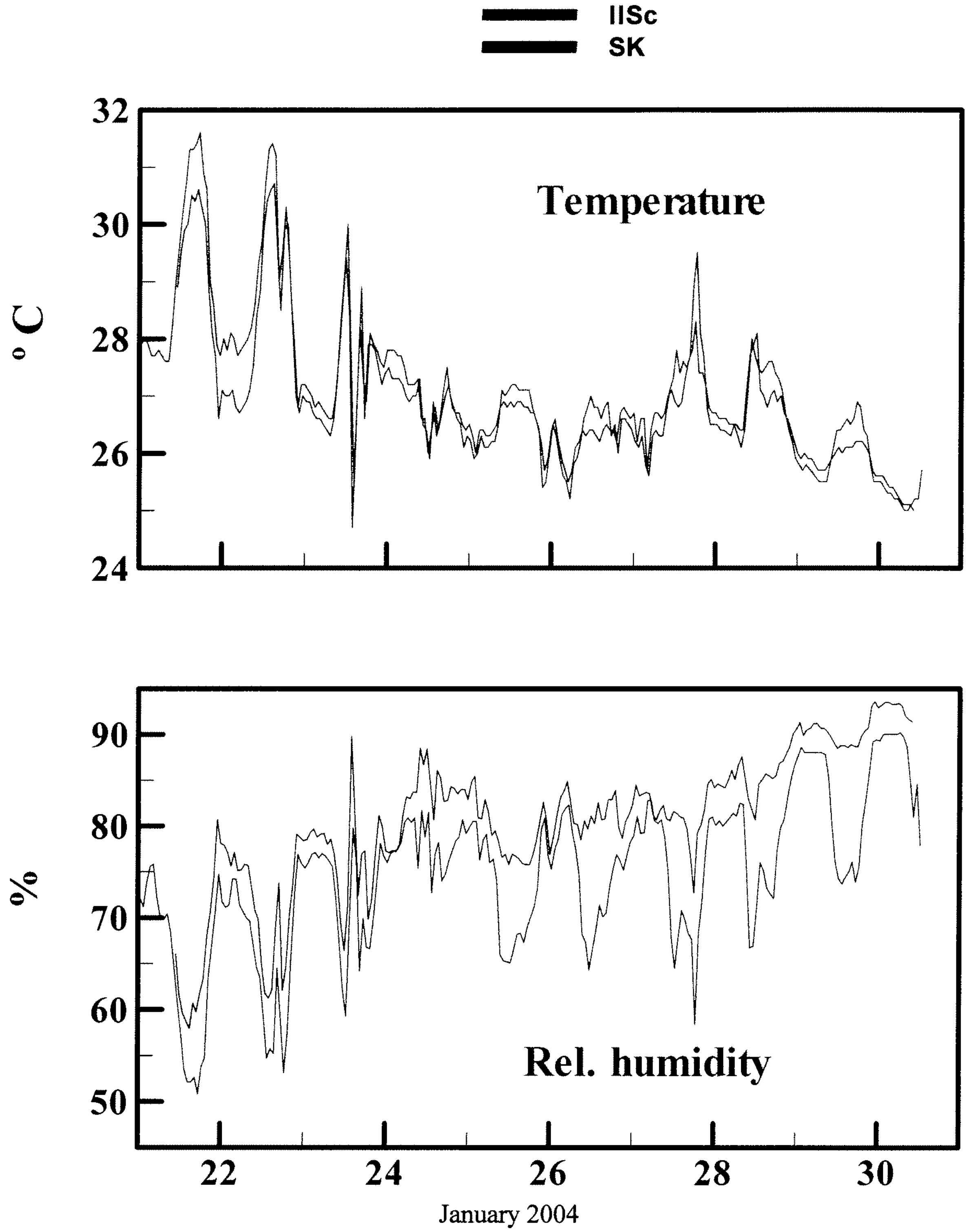


Fig 5. Temperature and relative humidity comparison between IISc and SK AWS data

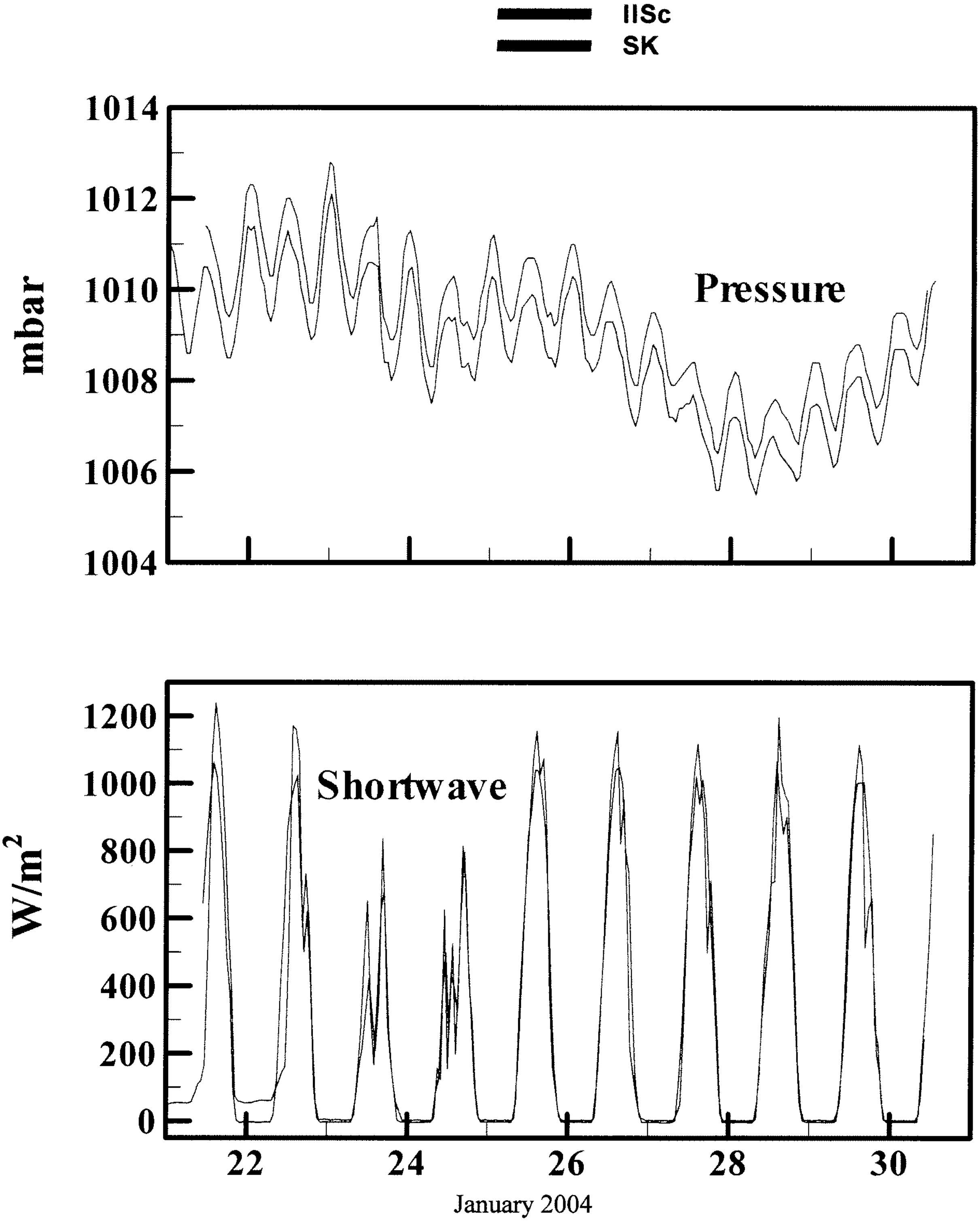


Fig 6. Pressure and shortwave radiation comparison between IISc and SK AWS data

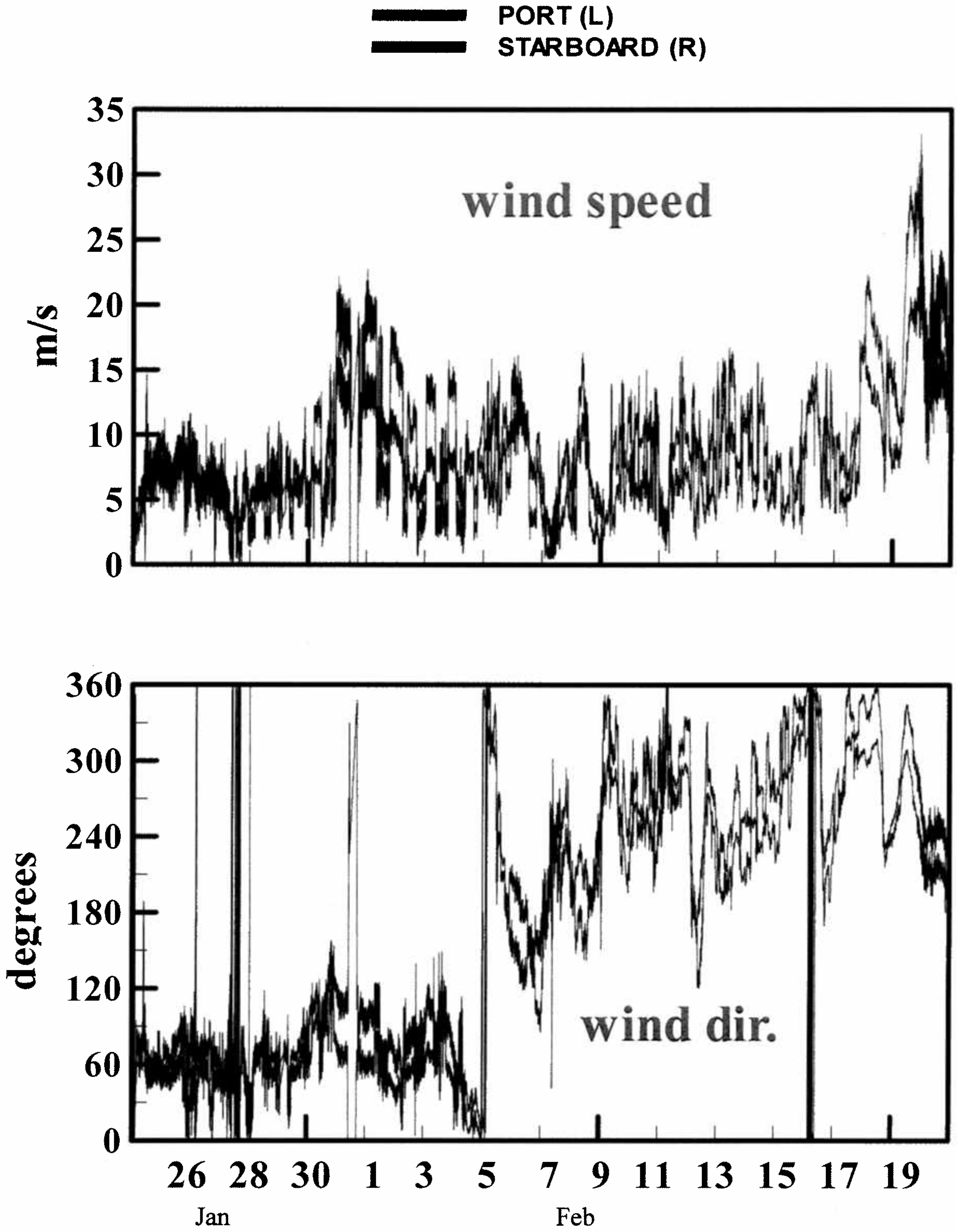


Fig 7. Variation of wind speed and direction from 24th Jan – 19th Feb 2004.

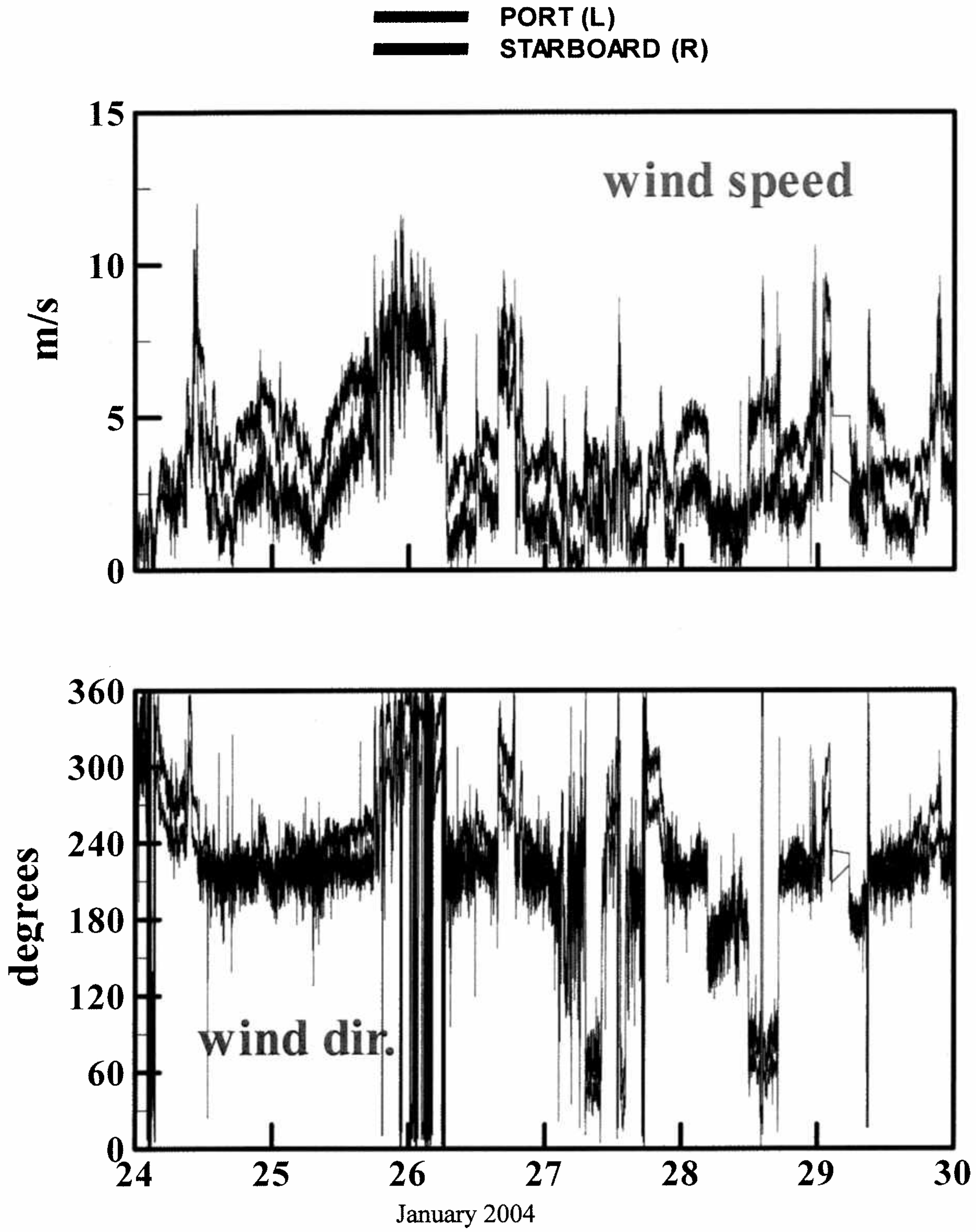


Fig 8. Variation of relative wind speed and direction

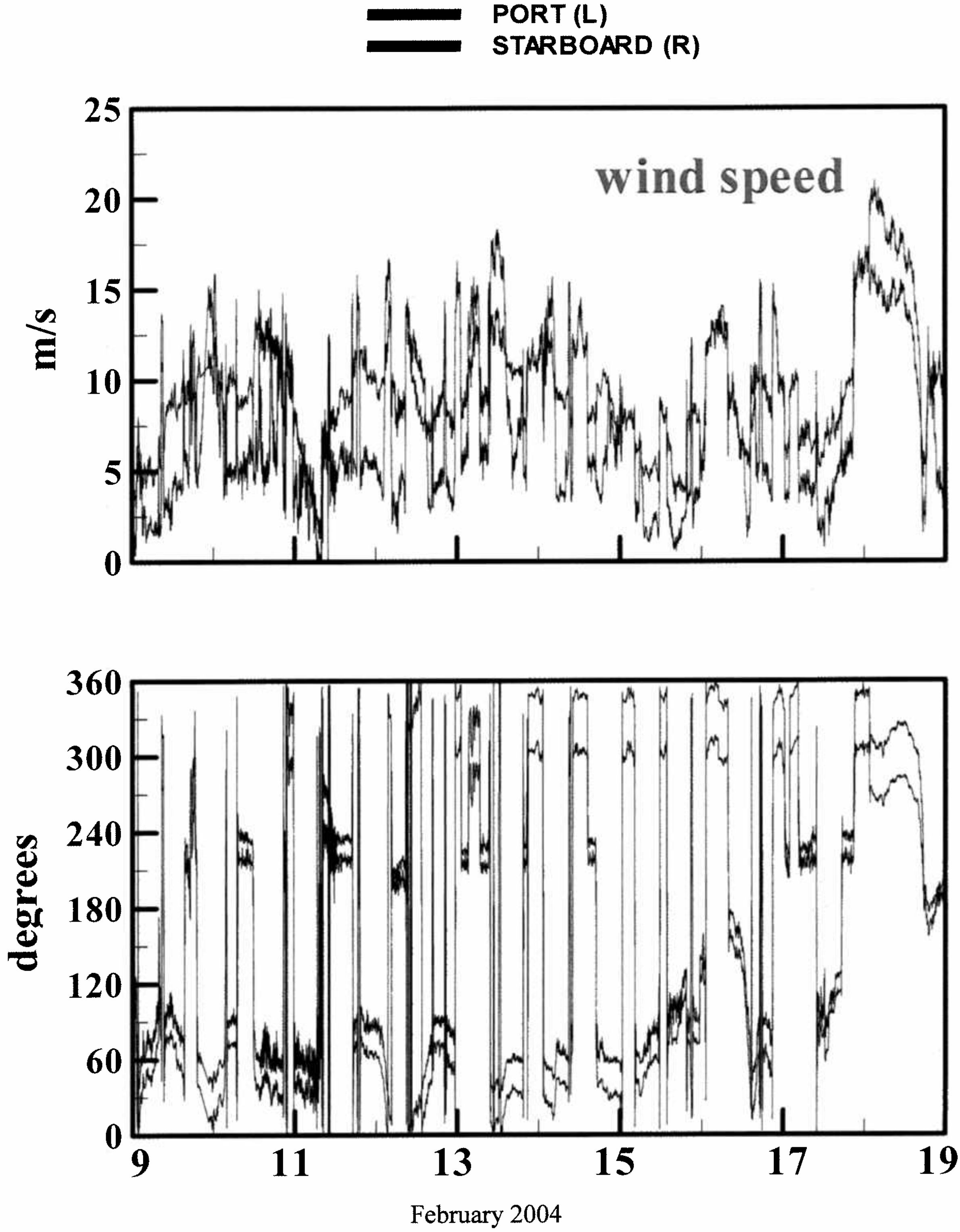


Fig 9. Variation of relative wind speed and direction

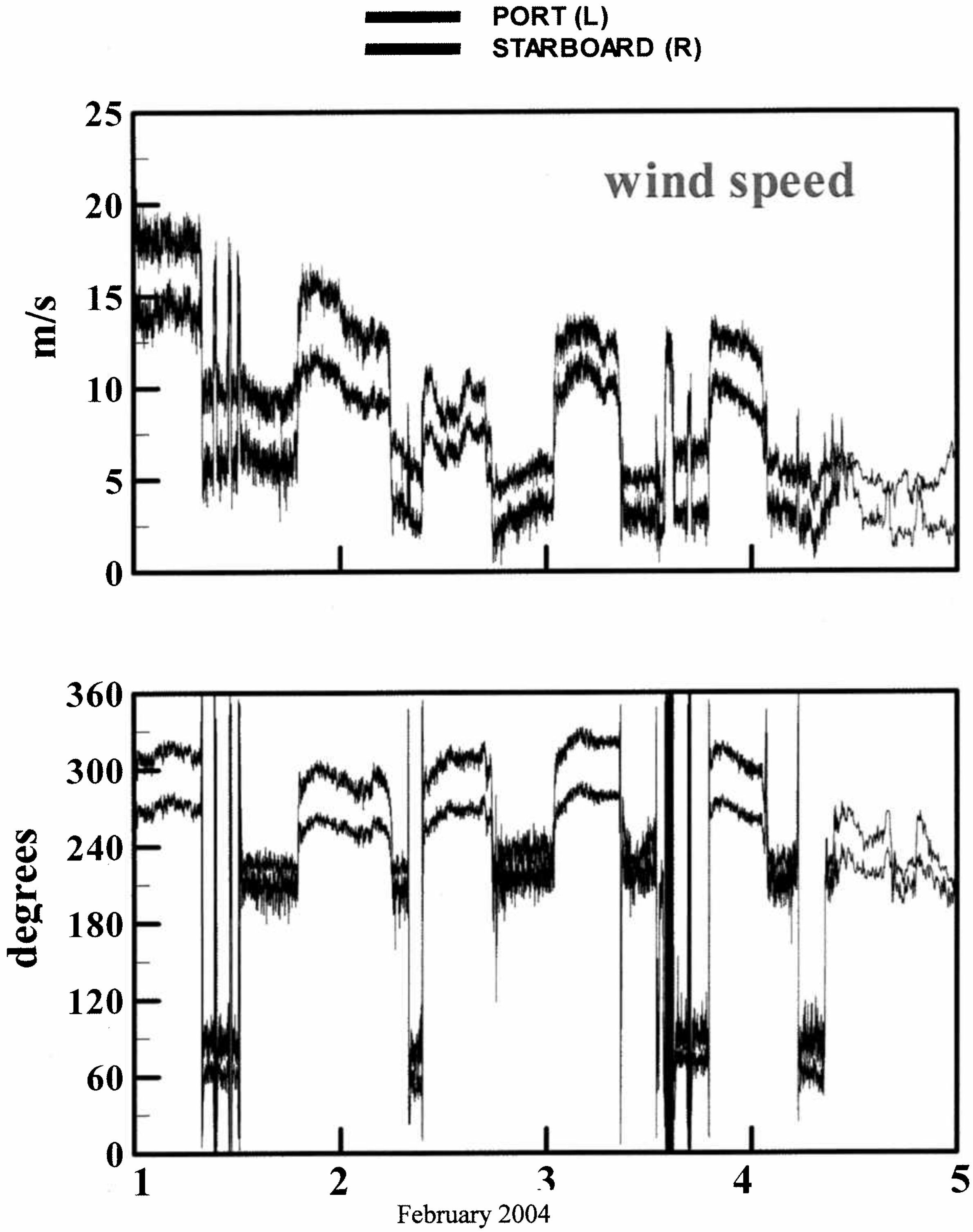


Fig 10. Variation of relative wind speed and direction

[5.1] PHYSICAL OCEANOGRAPHY

[5.1.1] Studies carried out :

Physical oceanographic studies were aimed at understanding the temperature -salinity (T-S) structures, morphology of circumpolar fronts, circulation regimes in the water column and air-sea interaction processes pertaining to the Indian Ocean sector of the Southern Ocean. For this purpose, CTD and XBT systems were used onboard ORV Sagar Kanya to obtain the required temperature & salinity profiles in the water column. Apart from obtaining the T-S profiles, a hull-mounted Acoustic Doppler Current Profiler (ADCP) (Make: RD Instruments Inc., USA) was operated along the ship's track in the study area. Thermo-Salinograph (T-S Graph) was also put into use for recording surface temperature and salinity data along ship's track, but the data was not found to be reliable and its sensors need to be calibrated. A ship-borne wave Recorder (Make: IOS, UK) was operated at CTD stations to record the wave data for 15 minutes period.

[5.1.2] CTD Data Studies:

CTD casts were taken along three sections, viz., a diagonal section (TR-1) off southeastern coast of Madagascar; two meridional sections (TR-2 and TR-3) each along 45°E and 57.5°E respectively during pilot expedition on board ORV Sagar Kanya (SK 200th cruise). Fig. 1 shows the locations of CTD stations spaced at sixty nautical miles. In total, 38 CTD stations were occupied between 25°S and 56°S. Out of which, 8 were occupied till 30.7°S along TR-1 section. Thereafter, TR-2 section was covered meridionally involving CTD stations 9 to 34 from 31°S to 56°S over the Madagascar Ridge, southwestern part of the Madagascar Basin, Southwestern Indian Ridge, Lena Seamount and northern part of the South Indian Basin. On ship's return track, 4 CTD stations were occupied between 48 and 45°S along 57.5°E meridion (TR-3 section) in sub-

Antarctic waters. Table 1 presents the details of the CTD stations occupied during the expedition.

A CTD (Make: Sea-Bird Electronics Inc., USA, Model: SBE 9/11) with temperature sensor (Range: -5.0 to +35°C, Resolution: 0.0003°C and Accuracy: ± 0. 001°C); conductivity sensor (Range: 0 to 7 Siemens/meter(S/m), Resolution: 0.00004 S/m and Accuracy: ± 0.0001 S/m) and pressure transducer (Range: 0 to 10000 psia; Resolution: 0.01 ppm and Accuracy: ± 0.005 % Full Scale) was deployed . Also at a few locations, temperaure and salinity depth profiles were taken with another CTD (Make: Idronaut S.r.l, Italy, Model: Ocean Seven 320) having temperature sensor (Range: -5.0 to +45°C, Resolution: 0.0001°C and Accuracy: ± 0. 001°C); conductivity sensor (Range: 0 to 7 Siemens/meter (S/m), Resolution: 0.00001 S/m and Accuracy: ± 0.0001 S/m) and pressure transducer (Range: 0 to 7000 db; Resolution: 0.001% and Accuracy: ± 0.05 % Full Scale). Water samples for chemical and biological analyses were collected with a 12-bottle rosettle sampler used with the CTD. Salinities of the water samples were estimated with the help of a ship-borne salinometer (Make: Guildline Inc., Canada, Model: Autosal) for regressional analysis between CTD salinity and Autosal salinity datasets. Data processing of temperature and salinity (conductivity) fields collected by SBE 9/11 CTD system was followed using software routines of 'Seasave' supplied by the manufacturer. ASCII data files were made containing CTD data at one meter interval and the same were used for constructing the vertical structures of thermo-haline fields along different sections. SBE Seacat CTD profiler was also operated at few stations. T,S depth profiles obtained by Idronaut CTD and SBE Seacat Profiler are compared reasonably (Fig. 2) well. A small bias of consistent nature in the salinity profiles between the two is, however, seen.

The preliminary results of CTD data analysis indicate the presence of different water mass regimes in the study area. Fig3. depicts the vertical structure of salinity along 45 °E (TR-2). It is clearly seen that the Sub-Tropical Front (STF) around 41°S separates the high saline sub-tropical waters of the north from the fresher waters of the sub-Antarctic region. Further, the low-salinity surface waters sink around 47°S latitude to intermediate depths of about 1200 m and then spread northward along 27.0 potential density (σ_θ) surface. Temperature-salinity (T-S) plots for selected stations representing various regions in the study area are shown in Fig. 4. As one proceeds from north to south, Sub-Tropical Waters with comparatively high thermal and low salinity gradients in the upper water column are separated from a distinct water type having low thermal and high salinity gradients in the region south of 50°S. Stns. # 14 and 20 in the sub-tropical waters exhibit salinity minimum around 27.25 σ_θ surface, suggesting the presence of Antarctic Intermediate Watermass (AIW), while all stations show the presence of a high salinity watermass around 27.7 σ_θ surface. Below this deeper water mass, salinity slowly decreases. Lowest bottom temperatures below 0°C are found at Stn.# 34 in the South Indian Basin.

[5.1.3] XBT Observations:

XBT observations were taken at 78 locations to obtain temperature profiles in the water column up to 760m depth mostly along the ship track in addition to the CTD observations to augment information on thermal structure. Fig. 5 shows the locations of XBT observations starting from 22° 34.5'S; 54° 55.5'E. The T-7 XBT probes of SIPPICAN Inc., USA were deployed with hand-held launcher when ship was underway. Details of XBT observations are given in Table-2 along with sea surface temperature (SST) measurements taken with a bucket thermometer simultaneously. Temperature profiles for two regions (35°S - 40°S and 49°S - 55°S) representing the Sub-Tropical and Antarctic waters are presented in Fig. 6. Some of the preliminary results from these XBT observations are described following:

35° – 40° S

Temperature profiles north of STF show variation of sea surface temperature from 22.2°C to 19.9°C and mixed layer thickness varies from 50m to 70m. At the depth of 760m, temperatures are varied between 9.9°C and 7.2°C. Thermocline is prominent between 50m and 150m depth at 35.5°S only. However, temperature profile at 38.5°S is a distinct one with temperatures generally lowered in the observed water column.

49° - 54°S

The meridional variation of surface temperature is around 2°C (from 4.2°C to 2.1°C) between latitudes of 49°30' and 53°30'S. The vertical variations of temperatures in this region are quite different from those observed in the previous region. A temperature minimum layer is observed in the depth range of 100m - 200m with temperatures reduced from surface values by about 1.3°C. At 52°30'S, lowest temperatures (~ –0.07°C) are encountered in the minimum layer. Below this layer, temperature gradually increases by about 2°C at around 350m depth and thereafter, it remains more or less uniform with depth.

Further processing and analysis of currents data obtained with ADCP is planed as a part of the studies on water mass structure and the circulation in the Indian Ocean sector of the Southern Ocean.

PILOT EXPEDITION TO SOUTHERN OCEAN (SK-200)
CTD STATION LOCATION MAP

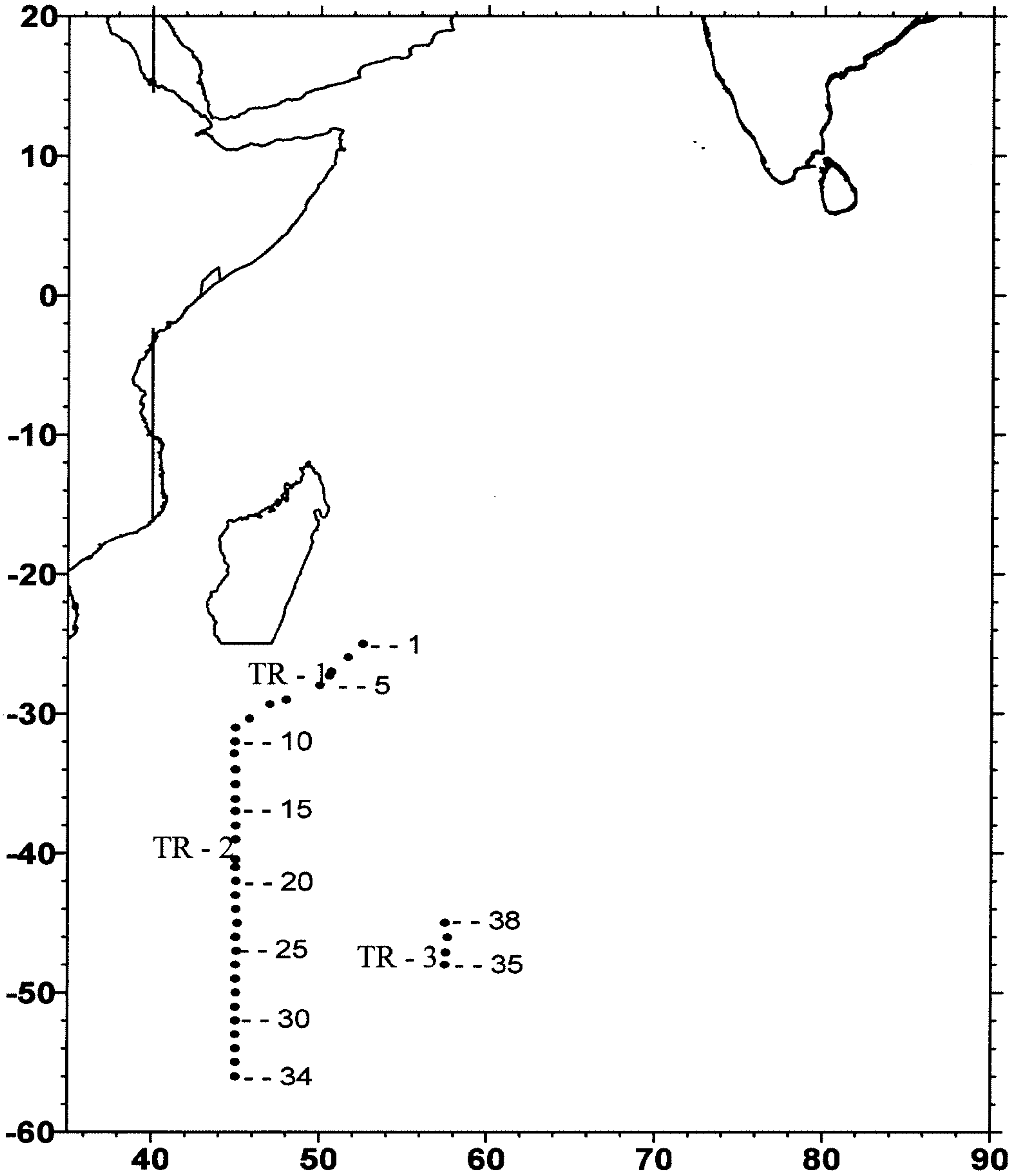


Fig. 1

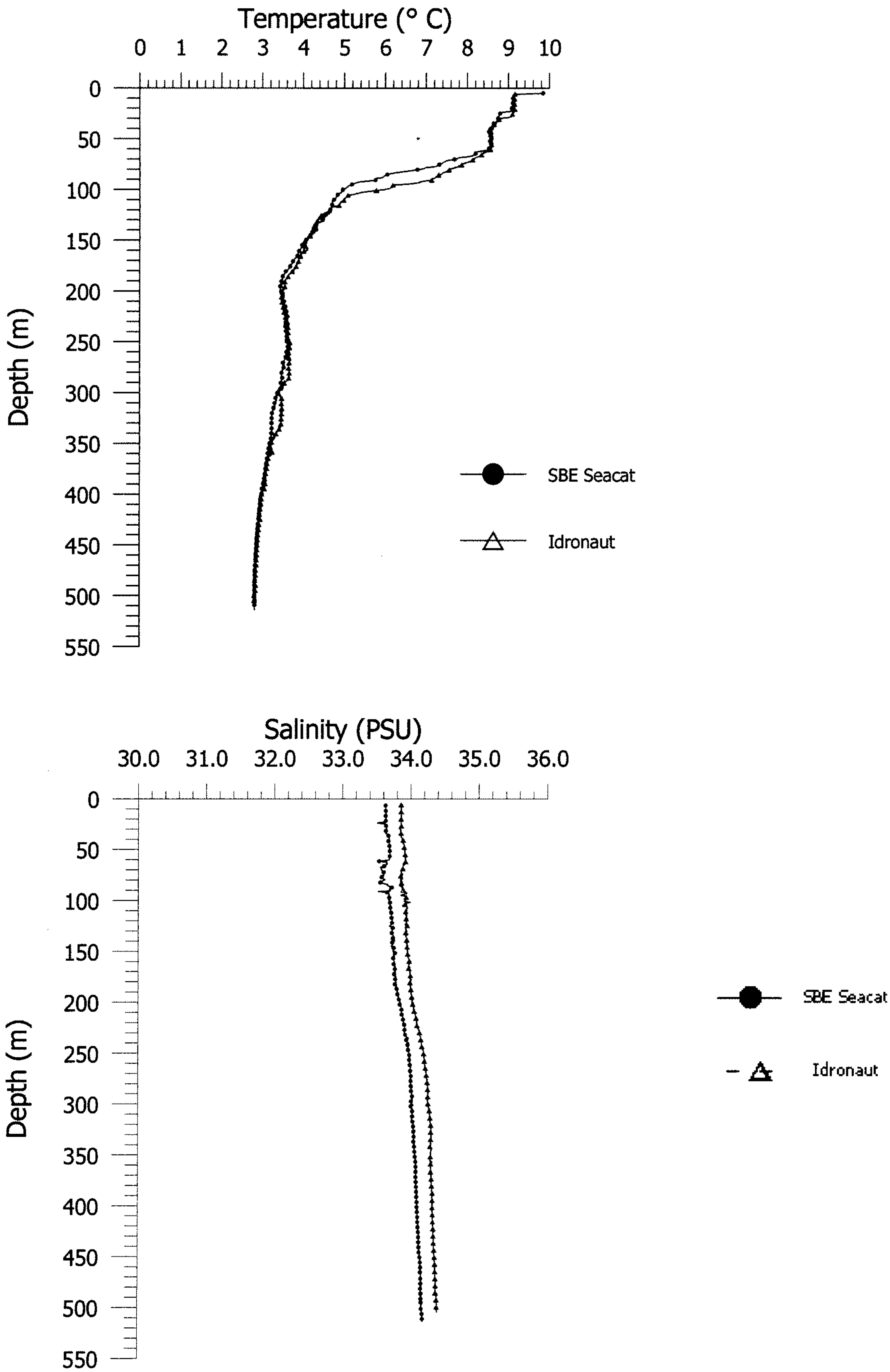


Fig. 2: Comparison of TS profiles

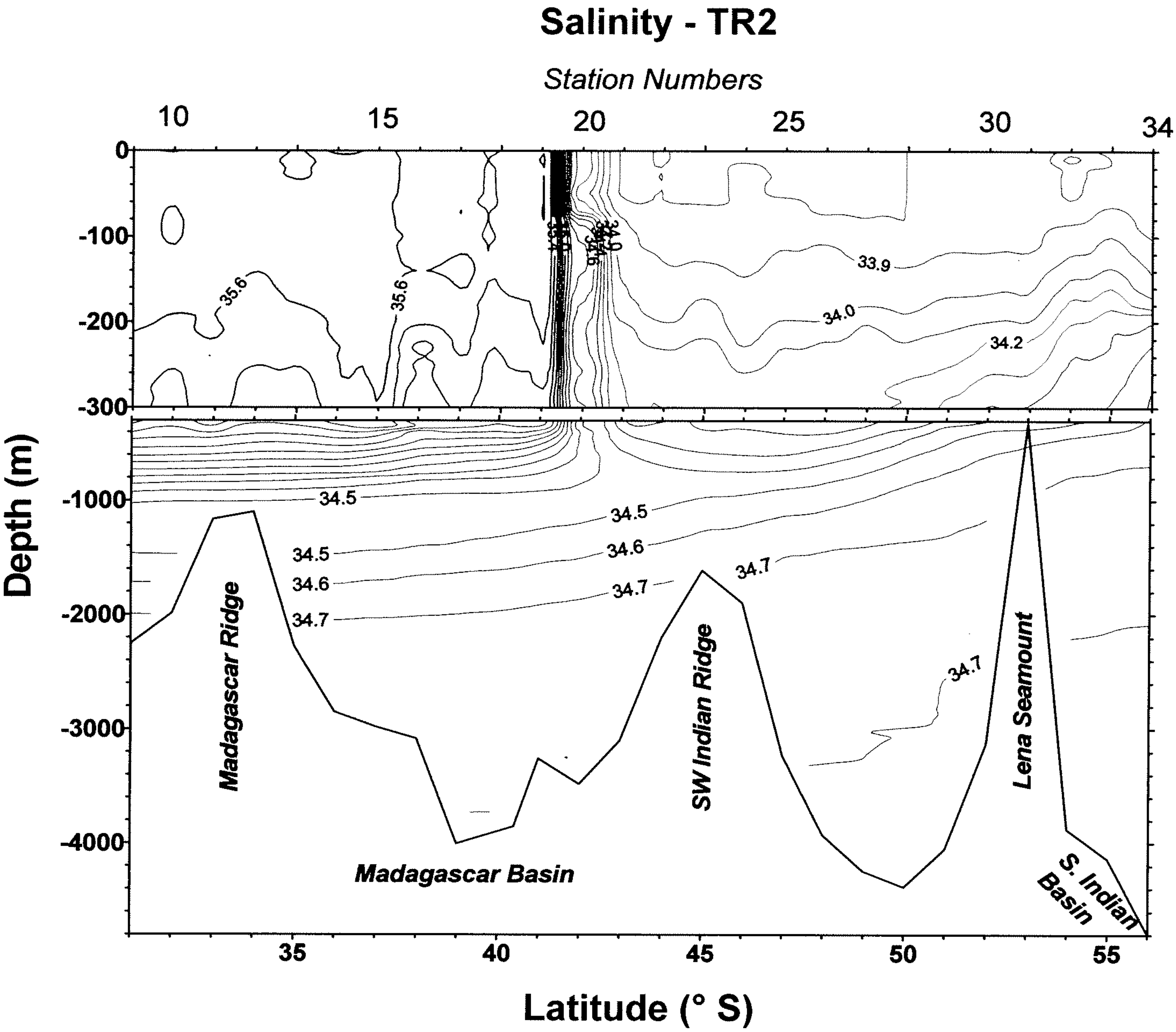
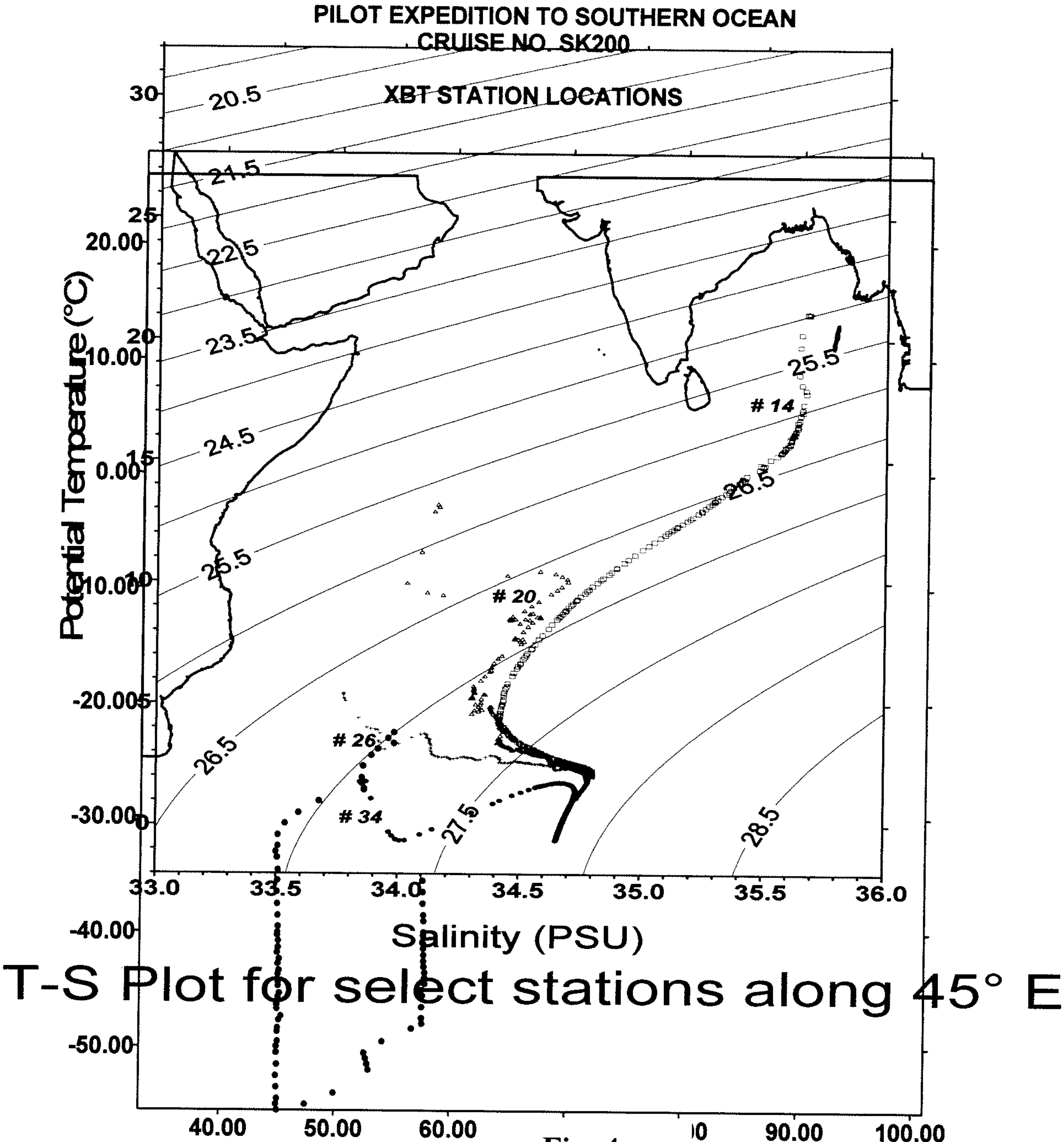

Salinity - TR2
Station Numbers
10
15
20
25
30
34
0
-100
-200
-300
-1000
-2000
-3000
-4000
Depth (m)
35.6
35.6
33.9
34.0
34.2
34.5
34.5
34.5
34.6
34.6
34.7
34.7
34.7
34.7
Madagascar Ridge
Madagascar Basin
SW Indian Ridge
Lena Seamount
S. Indian Basin
35
40
45
50
55
Latitude (° S)

Fig. 3



T-S Plot for select stations along 45° E

Fig. 4

Fig. 5

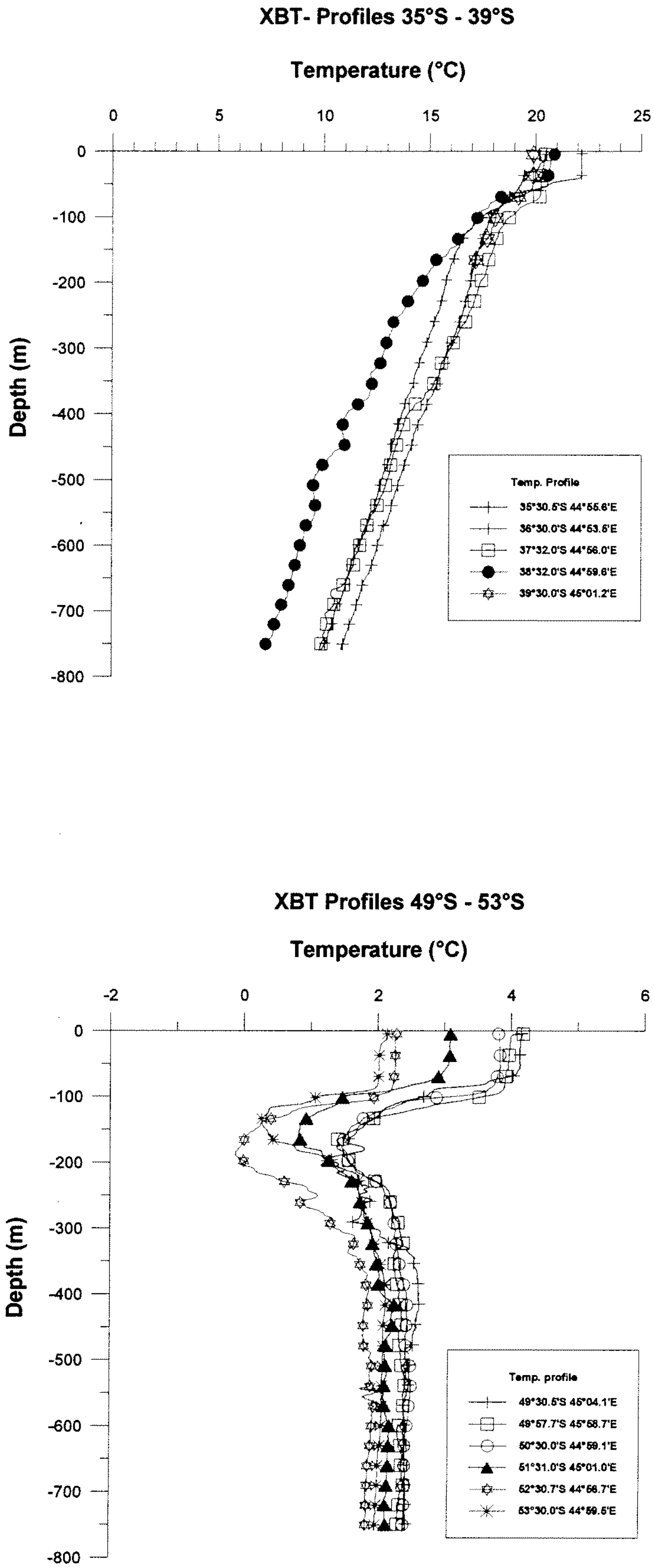

XBT- Profiles 35°S - 39°S
Temperature (°C)
0
5
10
15
20
25
0
-100
-200
-300
-400
-500
-600
-700
-800
Depth (m)
Temp. Profile
35°30.5'S 44°55.6'E
36°30.0'S 44°53.5'E
37°32.0'S 44°56.0'E
38°32.0'S 44°59.6'E
39°30.0'S 45°01.2'E
XBT Profiles 49°S - 53°S
Temperature (°C)
-2
0
2
4
6
0
-100
-200
-300
-400
-500
-600
-700
-800
Depth (m)
Temp. profile
49°30.5'S 45°04.1'E
49°57.7'S 45°58.7'E
50°30.0'S 44°59.1'E
51°31.0'S 45°01.0'E
52°30.7'S 44°56.7'E
53°30.0'S 44°59.5'E

Fig. 6

Table 1 : DETAILS OF CTD OBSERVATIONS

Sr No.	Stn. No.	Lat ° ' "	Lon ° ' "	Date D M Y	Time GMT	Sonic Depth (m)	Oper. Depth (m)	CTD Casts	Instru-ment	SST BKT (°C)	Water Sampling Details
1	Ctd 1	25 02 18	52 32 21	25 01 04	15 02	5150	5061	Deep	SBE 911	27.4	MB
2	Ctd 2	25 58 52	51 40 47	26 01 04	11 50	5198	2008	Deep	SBE 911	27.7	MB
3	Ctd 3	26 59 53	50 41 00	27 01 04	02 22	4775	2026	Deep	SBE 911	27.6	MB
4	Ctd 3A	27 16 52	50 33 42	27 01 04	11 08	5245	198	Shallow	Seacat	27.0	MB
5	Ctd 4	27 59 48	50 00 00	27 01 04	18 15	4976	4902	Deep	Idronaut	26.6	Chem., MB,Coco
6	Ctd 6	28 59 26	47 59 31	28 01 04	19 05	2779	2006	Deep	Idronaut	26.0	Chem., MB,Coco
7	Ctd 7	29 19 30	47 00 47	29 01 04	03 55	3069	1981	Deep	Idronaut	25.7	Chem., MB,Coco
8	Ctd 8	30 20 28	45 48 12	29 01 04	16 40	1778	1751	Deep	SBE 911	25.9	Chem., MB,Coco
9	Ctd 9	31 00 39	44 59 40	30 01 04	05 55	2251	2197	Deep+Sh.	SBE 911	25.5	Chem.,Bio, MB,Coco
10	Ctd 10	32 00 00	44 57 27	31 01 04	13 52	1988	1903	Deep	SBE 911	24.6	Chem., MB,Coco
11	Ctd 11	32 50 30	44 54 06	01 02 04	06 54	1166	1051	Deep+Sh.	SBE 911	22.5	Chem.,Bio, MB,Coco
12	Ctd 12	34 00 05	44 59 12	02 02 04	00 45	1100	1062	Deep	SBE 911	21.6	Chem., MB,Coco
13	Ctd 13	35 04 46	44 59 46	02 02 04	12 17	2275	2197	Deep+Sh.	SBE 911	22.3	Chem.,Bio, MB,Coco
14	Ctd 14	36 08 08	44 59 37	03 02 04	03 33	2850	2795	Deep+Sh.	SBE 911	20.6	Chem., Bio,MB,Coco
15	Ctd 15	36 59 16	44 59 17	03 02 04	20 17	2979	754	Deep+Sh.	SBE 911	20.0	Chem.,Bio, MB,Coco
16	Ctd 16	38 00 44	45 00 07	04 02 04	11 02	3081	2604	Deep	Seacat	20.7	MB
17	Ctd 17	39 00 00	45 00 00	05 02 04	05 20	4004	3724	Deep	SBE 911	20.4	Chem.,Bio, MB,Coco
18	Ctd 18	40 26 04	45 00 03	06 02 04	08 03	3854	3302	Deep	SBE 911	18.5	Chem., MB,Coco
19	Ctd 19	41 00 22	44 59 52	06 02 04	20 50	3256	3000	Deep+Sh.	SBE 911	18.1	Chem.,Bio, MB,Coco
20	Ctd 20	41 59 44	45 00 48	07 02 04	17 27	3480	3384	Deep+Sh.	SBE 911	13.2	Chem., MB,Coco

21	Ctd 21	43 01 11	45 00 27	08 02 04	09 15	30 97	2948	Deep+Sh.	SBE 911	10.3	Chem.,Bio, MB,Coco
22	Ctd 22	44 00 15	45 01 36	09 02 04	10 16	2205	2100	Deep	SBE 911	8.6	Chem., MB,Coco
23	Ctd 23	45 01 23	45 06 08	10 02 04	03 00	1613	1503	Deep+Sh.	SBE 911	8.5	Chem.,Bio, MB,Coco
24	Ctd 24	46 00 45	45 00 25	10 02 04	16 08	1897	1804	Deep	SBE 911	7.5	Chem.
25	Ctd 25	47 00 25	45 03 42	11 02 04	04 10	3227	2995	Deep+Sh.	SBE 911	7.0	Chem.,Bio, MB,Coco
26	Ctd 26	47 59 36	45 00 24	11 02 04	23 00	3927	3000	Deep	SBE 911	5.5	Chem., MB,Coco
27	Ctd 27	48 59 42	45 00 28	12 02 04	19 46	4245	3200	Deep	SBE 911	4.8	Chem.,Bio, MB,Coco
28	Ctd 28	49 59 33	45 00 54	13 02 04	14 20	4383	3600	Deep	SBE 911	3.7	Chem., MB,Coco
29	Ctd 29	51 00 15	44 59 46	14 02 04	04 37	4051	3600	Deep	SBE 911	2.6	Chem.,Bio, MB,Coco
30	Ctd 30	51 59 51	44 59 56	14 02 04	19 07	3129	3050	Deep	SBE 911	2.6	Chem., MB,Coco
31	Ctd 31	53 00 00	44 59 45	15 02 04	06 12	319	301	Shallow	SBE 911	2.2	Chem.,Bio, MB,Coco
32	Ctd 32	53 59 49	45 00 09	15 02 04	19 50	3876	3850	Deep	SBE 911	2.2	Chem., MB,Coco
33	Ctd 33	54 59 50	45 00 14	16 02 04	17 25	4137	4121	Deep+Sh	SBE 911	2.2	Chem.,Bio, MB,Coco
34	Ctd 34	56 00 14	45 00 25	17 02 04	11 45	4814	4780	Deep	SBE 911	1.9	Chem.,Bio, MB,Coco
35	Ctd 35	47 59 32	57 30 39	22 02 04	08 00	4515	3356	Deep+Sh	SBE 911	7.8	Chem.,Bio, MB,Coco
36	Ctd 36	47 06 59	57 32 50	23 02 04	02 55	4326	3374	Deep	Seacat	9.2	MB
37	Ctd 37	46 01 08	57 39 12	24 02 04	01 36	4385	4132	Deep+Sh	Idr+seacat	9.5	Chem.,Bio, Coco
38	Ctd 38	44 59 55	57 29 55	24 02 04	18 10	4378	4225	Deep	Idronaut	11.3	Chem.,Bio,,Coco

Chem. - Chemical Analysis for Dissolved Oxygen, pH, Nutrients and Trace metals.
Bio. - Biological analysis for Primary productivity, Chlorophyll, MPN & Bongo, Benthic.
MB – For Planktonic Foraminifera using modified Bongo.
Coco – Analysis for cocolithophorids & Diatoms.

Table-2 Locations of the XBT Observations

Sl. No.	Date	Time(GMT)	Latitude	Longitude	SST
1.00	24/01/2004	15:22	22 34.0	54 54.5	27.10
2.00	24/01/2004	19:50	23 04.8	54 24.8	27.00
3.00	24/01/2004	23:25	23 30.0	54 53.9	27.00
4.00	25/01/2004	3:40	24 00.0	53 30.5	27.50
5.00	25/01/2004	8:30	24 33.1	52 57.1	28.00
6.00	25/01/2004	13:15	24 59.3	52 31.5	27.80
7.00	25/01/2004	5:28	25 30.5	52 15.3	27.30
8.00	26/01/2004	20:22	26 31.0	52 08.5	27.40
9.00	26/01/2004	13:45	27 33.5	52 21.1	27.40
10.00	27/01/2004	13:25	28 34.0	48 27.0	26.60
11.00	28/01/2004	8:26	29 35.0	46 40.7	25.90
12.00	29/01/2004	1:15	30 30.5	45 31.8	25.40
13.00	30/01/2004	1:00	31 31.2	44 54.8	24.60
14.00	30/01/2004	22:17	32 30.0	44 55.0	24.50
15.00	31/01/2004	15:40	33 00.0	44 44.3	22.70
16.00	31/01/2004	20:03	33 30.0	44 52.6	22.00
17.00	1/2/04	8:25	34 35.0	44 58.2	22.20
18.00	2/2/04	8:47	35 30.5	44 55.6	20.50
19.00	3/2/04	16:21	36 30.0	44 53.5	20.10
20.00	4/2/04	7:46	37 32.0	44 56.0	20.40
21.00	4/2/04	16:15	38 32.6	44 59.6	20.40
22.00	5/2/04	20:52	39 30.0	45 01.2	19.30
23.00	6/2/04	2:09	40 00.5	44 59.6	18.50
24.00	6/2/04	5:40	40 16.2	44 58.8	19.20
25.00	6/2/04	18:00	40 45.5	45 04.0	18.10
26.00	7/2/04	11:50	41 20.0	45 03.4	19.50
27.00	7/2/04	15:07	41 46.5	44 59.2	16.40
28.00	8/2/04	2:23	42 20.0	45 08.6	12.20
29.00	8/2/04	6:20	42 45.0	45 03.0	10.40
30.00	8/2/04	23:16	43 20.0	45 08.6	8.50
31.00	9/2/04	2:15	43 41.0	45 03.7	8.50
32.00	9/2/04	16:52	44 21.0	45 05.0	8.20
33.00	9/2/04	19:39	44 41.5	45 05.0	8.20
34.00	10/2/04	8:43	45 20.0	45 11.0	7.70
35.00	10/2/04	11:47	45 40.0	45 05.1	7.30
36.00	10/2/04	21:20	46 21.0	44 59.0	7.60
37.00	10/2/04	23:52	46 40.0	44 59.5	7.50
38.00	11/2/04	17:00	47 20.0	45 20.3	7.10
39.00	11/2/04	19:39	47 40.0	45 10.0	5.60
40.00	12/2/04	6:30	48 22.0	45 04.0	5.20
41.00	12/2/04	8:44	48 40.0	45 02.0	5.00

42.00	13/02/2004	10:05	49 30.5	45 04.1	4.60
43.00	13/02/2004	20:02	49 57.7	44 58.7	3.90
44.00	14/02/2004	0:14	50 30.0	44 59.1	3.90
Sl. No.	**Date**	**Time(GMT)**	**Latitude**	**Longitude**	**SST**
45.00	14/02/2004	15:36	51 31.0	45 01.0	3.00
46.00	15/02/2004	4:43	52 30.7	44 56.7	2.40
47.00	15/02/2004	12:39	53 30.0	44 59.5	2.40
48.00	16/02/2004	5:49	54 30.0	45 04.1	2.40
49.00	16/02/2004	9:08	55 00.0	45 00 2	2.20
50.00	17/02/2004	8:28	55 31.3	45 04.0	2.00
51.00	18/02/2004	12:41	55 00.0	47 29.0	1.50
52.00	19/02/2004	1:38	54 00.5	49 57.7	1.80
53.00	20/02/2004	8:41	52 00.0	52 57.9	4.70
54.00	20/02/2004	14:39	51 29.0	52 51.0	4.50
55.00	20/02/2004	19:05	51 00.1	52 44.0	4.30
56.00	20/02/2004	23:49	50 31.0	52 35.0	4.20
57.00	21/02/2004	12:16	49 30.0	54 09.0	5.10
58.00	22/02/2004	2:14	48 23.0	56 40.9	6.00
59.00	22/02/2004	14:09	47 56.7	57 34.5	7.30
60.00	22/02/2004	17:54	47 28.7	57 33.0	7.30
61.00	23/02/2004	14:32	46 30.0	57 33.0	9.20
62.00	24/02/2004	14:20	45 31.0	57 35.2	11.50
63.00	25/02/2004	17:29	45 02.2	57 30.1	11.30
64.00	25/02/2004	18:44	44 30.0	57 47.8	11.90
65.00	25/02/2004	23:01	43 58.1	57 47.2	16.00
66.00	26/02/2004	3:11	43 30.0	57 47.2	18.20
67.00	26/02/2004	8:28	43 00.0	57 42.5	18.80
68.00	26/02/2004	12:51	42 30.0	57 40.3	19.90
69.00	26/02/2004	17:16	41 58.6	57 40.1	19.90
70.00	26/02/2004	21:30	41 25.0	57 39.1	18.50
71.00	27/02/2004	0:17	41 00.0	57 39.0	18.50
72.00	27/02/2004	4:52	40 19.0	57 39.7	18.20
73.00	27/02/2004	7:07	40 00.0	57 39.6	18.20
74.00	27/02/2004	14:27	38 59.9	57 39.1	19.00
75.00	27/02/2004	17:23	38 30.0	57 38.0	19.10
76.00	27/02/2004	22:20	37 30.0	57 33.9	19.10
77.00	28/02/2004	6:27	36 30.0	57 33.9	19.70
78.00	28/02/2004	13:15	35 30.0	57 31.2	22.00

[6.1] BIOLOGICAL OCEANOGRAPHY

[6.1.1] Sampling Details : The Biological stations are given in Fig.1. Sampling details are attached as Annexure–I.

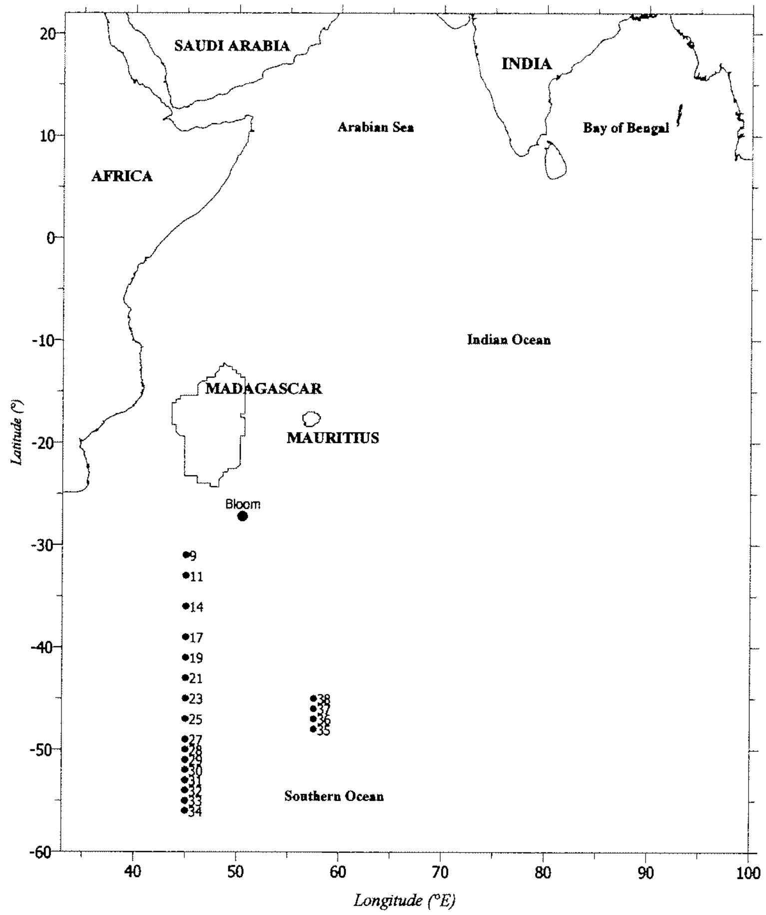


Fig.1

[6.1.2] Scientific Objectives and expected outcome

Late Antarctic spring and early summer are periods of intense productivity in the Southern Oceans, the southern boundary of which extends up to 40°S in the Indian Ocean sector, corresponding to the subtropical convergence. The equator ward flowing low saline polar surface water is expected to sink below the more buoyant tropical waters at around 55°S and form the Antarctic Intermediate Waters (AIW) spreading at a depth of 1000m under main thermocline of the subtropical ocean. The surface waters rich in phosphate and nitrate are exposed to irradiance resulting in phytoplankton blooms mostly of diatoms. Silicate levels will be expectedly low in the surface waters by late summer which also correspond to a period of maximum zooplankton production dominated mostly by copepods in the surface waters north of 55°S and by euphausids in the south.

[6.1.3] Primary Productivity studies

Estimation of primary production using ^{14}C technique, estimation of chlorophyll pigments by flourometric analysis and the qualitative and quantitative study of phytoplankton composition. A total of 18 stations were worked out for primary productivity studies (14 stations of primary production ^{14}C technique) along the latitudes 45°E and 57°30'E.

Primary production was measured by ^{14}C technique by deck incubation. Water samples for primary productivity determination were collected mostly during morning (5 am to 6 am) from surface, 10,25,50,75,100 & 125m depths through CTD/Rossette sampler. Incubation experiments were done for 24 hours after the inoculation of 1 ml of $NaH^{14}CO_3$ (activity 5µCi) to each 300ml capacity light and dark bottles. After the incubation, samples were filtered through 47mm GF/F (nominal pore size 0.7µm) filters with gentle suction. These were exposed to concentrated HCl fumes to remove excess inorganic carbon and kept in scintillation vials for further analysis at the onshore laboratory.

For estimation of Chlorophyll pigments, One litre of water sample from each, standard depths corresponding to the PP experiments were filtered through GF/F filters and kept in refrigerator for later onshore flourometric analysis.

For the qualitative and quantitative study of phytoplankton, one litre of sea water samples drawn from the predetermined depths in the euphotic water column were fixed in 1% Lugol's iodine and preserved in 3% formaldehyde solution. The samples were stored in dark at low temperature (5°C) for identification and enumeration of phytoplankton species in the onshore lab.

Expected outcome of the work

- Rate of primary production in the Indian Ocean sector of southern ocean in relation to the environment.

- Quantification of phytoplankton biomass (chlorophyll) from different depths in the euphotic water column and its latitudinal variation.

- Identification and enumeration of phytoplankton groups in the euphotic zone.

- Variations in phytoplankton species composition with a view to establish key functional groups of phytoplankton and relate patterns in the data to measured environmental variables.

[6.1.4] Secondary Productivity Studies

(i) Microzooplankton

Microzooplankton was collected from 15 stations along the 45°E longitude starting from 31°S to 55°S latitudes. Only two collections were made from 57°30' longitude (45° & 48°S). The samples were collected from seven depths, surface, 10, 25, 50, 75, 100 and 120 using CTD rosette. Five litres of sea water was initially filtered through a 200μm bolting net and later through a 20μm sieve. The concentrated microzooplankton sample was transferred to 100ml of filtered sea water and preserved using acid logol's iodine and kept in dark.

Expected outcome of the work

- Enumeration and identification of microzooplankton upto species level from different water masses.

- Differentiate autotrophs, heterotrophs, mixotrophs, and grazing.

- Calculate carbon content (PgC) by using appropriate biovolume to carbon conversion ratio (Gifford and Caron 2000)

(ii) Mesozooplankton

Mesozooplankton was collected from 18 stations along the 45°E longitude starting from 31°S to 55°S latitudes. Four collections were made from 57° 30' E longitude (45°-48°S). Horizontal hauling was made by Bongo net (meshsize-300 μ) and vertical hauling by Multiple Plankton Net (meshsize-200μ). Samples were collected from four different depth strata up to 1000 m (viz. 0-TT,TT-BT,BT-500,500-1000) using Multiple Plankton Net. After the measurement of live biomass, zooplankton samples were preserved in 4% formalin for further qualitative and quantitative studies.

Preliminary analysis of the data gave biomass in the range of 20 to 4910 ml/1000 m^3 for Bongo and between 11 – 3571 ml/1000 m^3 for MPN collection at 45°E transect. Along the 57°30'E transect the values ranged from 120 to 500 ml/1000m for Bongo and 228 to 246 ml/1000m3 for MPN collections. The mixed layer show higher biomass in comparison with other strata with an increasing trend in the biomass from north to south of the transect (Fig. 3).

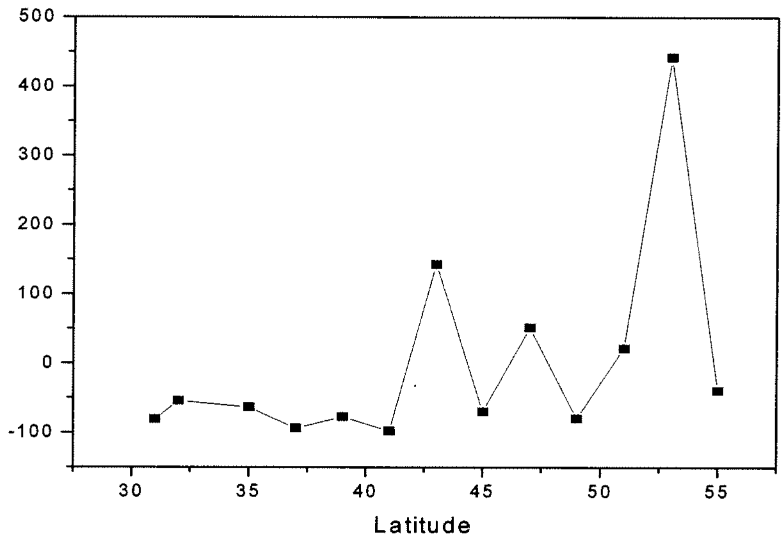


Fig. 3 % Variation of Mesozooplankton Biomass in the Mixed Layer with Latitude

<u>Expected outcome of the work</u>

- Mezozooplankton standing stock, its vertical, horizontal distribution and trophic relations.

- Qualitative and quantitative representation of the mesozooplankton with respect to latitude and physico-chemical parameters and abundance .

- Species diversity and abundance.

[6.1.5] Benthic Productivity Studies

Sediment samples were collected using Van Veen Grab and Gravity corer from 7 stations along 45°E, starting from 32°S to 53°S latitude. Approximately 5-10gm of sediment from the sampler were aseptically transferred using a sterile stainless steel spatula into sterile container and kept at –18°C for molecular analysis.

Sub samples of meio fauna analysis were removed using a glass corer and preserved in neutralized seawater-formalin for further studies onshore. For macro fauna sediment samples were sieved onboard using 0.5mm sieve and the segregated fauna were preserved in neutral formalin. Approximately 200 gms of sediment were collected for the study of water content, sediment texture and organic matter.

Expected Outcome

- Numerical abundance and species diversity of both macro and meiofauna.

- Correlation of benthic fauna with sediment characteristics.

Preliminary Results

Preliminary observations indicate predominance of polycheates in the sediment samples.

[6.1.6] Studies on Bacterioplankton

About 500 ml of sea water from CTD Niskin samplers corresponding to depths immediately below the euphotic zone and off the sea bottom were collected in autoclaved Teflon bottles. The bottles were then kept in the dark at –10°C. Bacterial abundance to be determined following Diamidino-2-phenylnidole (DAPI) assay at the on shore lab using Fluorescence microscope.

Expected Output

- Composition of bacterial fauna below the euphotic zone and off bottom.
- Estimates of bacterial abundance and their role in the process of decomposition and mineralisation.

[6.1.7] Harmful Algae in the Indian Ocean Sector of Southern Ocean

Water samples (1 litre each) from surface to 150m were collected using Niskin samplers. Samples were stained in Lugol's iodine solution and preserved in 4% formalin for on shore lab analysis.

Expected output

Identification and enumeration of harmful algal species in the euphotic zone and reporting on blooms including environmental features.

An extensive bloom of the Cyanobacteria *Trichodesmium erythraeum* was detected on 27.1.2004 at 27°14'S, 50°32'E. SST and SSS at the locations were 27.11°C and 34.84 ppt respectively. The dissolved oxygen values were 3.8 ml/litre at surface, 4.4 ml/litre at 50m and 4.1 ml/litre at 100m depths.

[6.2] Observations on Avian fauna in the Indian Ocean sector of Southern Ocean

[6.2.1] Avian Fauna

The avian fauna along the ship route were monitored by visual observations using binoculars. The objectives were to identify the major species, assess their latitudinal distribution and prepare a report including occurrence of Juvenile birds.

Preliminary Results

White-chinned Petrels were observed throughout the ship route from 31°S to 56°S along with few numbers of wandering albatross. Yellow nosed albatross were dominant from 40°S to 53°S. Black-browed albatrosses and Giant petrels were sighted between 43°S to 56°S. Bird density and the occurrence of juveniles were maximum near Walters's shoal, Melville Bank, Danilevskij sea mount, Galliieni knoll, Prince Edward and Marion Islands, Crozet Islands along the 45°E transect and near Kerguelen Island near the 57°E transect.

[6.2.2] *Sightings of marine mammals*

Scientific rationale

The Southern Ocean is arguably the most dynamic of the world oceans. Many aspects of its circulation, water masses and the response of Southern Ocean to climate change remain unknown primarily due to the lack of high-resolution ocean observations. Although Atlantic and Pacific sector of Southern Ocean has received significant attention during the last decade, the Indian Ocean part of the Southern Ocean has to be studied in much detail, as there is paucity of data.

Similar to the physical and chemical mechanisms, the biological database of the Southern Ocean also remains largely incomplete. One of the important constituents of marine life is marine mammals, many of which face threat of extinction, while many more are in a highly vulnerable state. For fulfilling the international objectives of protection, conservation and management of marine mammals, accurate database and R & D programs on their habitats, distribution, behaviour, abundance, migration, biology, population dynamics and pollutant load are imperative. Since the marine mammals of the Southern Ocean are poorly studied, it was felt prudent to participate in the present cruise programme to get a first hand information on status of their abundance and distribution based on sightings and photoidentication.

Expected outcome

- The study is expected to generate firsthand information on the species composition, school structure, and geographical and seasonal distribution of cetaceans from the Southern Ocean. The results of the present study could have long term implications on the conservation of marine mammals and henceforth to maintain of their ecological balance in the region
- Analysis of water samples from various depths would indicate levels of heavy metals and can thus deduct their possible effects on the marine cetaceans
- Analysis of zooplankton biomass would indicate its possible correlation with the occurrence of baleen whales
- Analysis of hydrographical data from the area of whales and dolphin sightings would indicate their possible correlation

Area of Investigation

Studies were carried out in the Indian Ocean sector of the Southern Ocean from Port Louis (20^0 09'S & 57^0 30'E) to the position 31^0 S & 45^0 E and further along the meridian 45^0 E to 56^0 S latitude. The return leg was along 57^0 E longitude back to Port Louis. The pilot phase of the expedition has covered a total of 38 stations.

Material and Methods

Round the clock watch of whales and dolphins was carried out mainly from the bridge of the vessel. Occasionally other colleagues were requested to watch from either bow or stern of the vessel. Binoculars, digital still camera and digital video camera were employed to observe and record appearance of these animals in the form of spouts, dorsal fin, upper body and caudal fluke. Published pictures of whole animal, size of spouts and shape of dorsal and caudal flukes of different species were used to identify the sighted cetacean. Only if the species of a whale or a dolphin is unmistakably identified based on the reported description, its name was recorded. In doubtful cases the species name was mentioned, accompanied by "possible" in parenthesis. All others were treated as "unidentified". Exact location of the sighted cetaceans along with hydrographical and geographical data and a detailed description (to the possible extent) along with numbers were recorded. It is anticipated that based on the present detailed description, the species identity could be ratified in consultation with other experts.

For trace metal analysis water samples were collected in 100 ml plastic containers from different depths using CTD rosette sampler and digested with Conc. HNO_3 (0.1 ml). Sediment samples were also collected in polythene covers from stations where Grab was operated and preserved for the same purpose.

The MPN was used to collect zooplankton samples at various depths according to the occurrence of mixed layer. After taking displacement volume, the samples were preserved at 5% formalin for qualitative analysis.

Results & Discussion

A total of 21 whales and dolphins were sighted in the area between 22^0 S and 53^0 S latitudes during the present cruise. On board identification of cetaceans is a tricky affair since it has to be done based on occasional appearance of certain body parts as well as spouts from the blow holes in the case of whales. Under these circumstances it is most desirable to make a detailed description of the features noticed during the sightings for later use.

During the present cruise only 10% of the sighted marine mammals could be unmistakably identified. Thirty eight percent falls in the category of "possible" while 52% were "unidentified". It is hoped that this picture would certainly improve once other expert consultancy is sought for ratification of species identity based on present detailed descriptions. Eighty six percent of the sighted cetaceans were whales while the remaining dolphins. The species encountered during the present cruise (identified and "possible") include sei whale

(*Balaenoptera borealis*), minke whale (*B. acutorostrata*) and blue whale (*B. musculus*).

A perusal of the occurrence of whales indicates their possible abundance around Bob Fischer Ridge, Deacon Seamount and near Prince Edward Islands (Fig. 1)

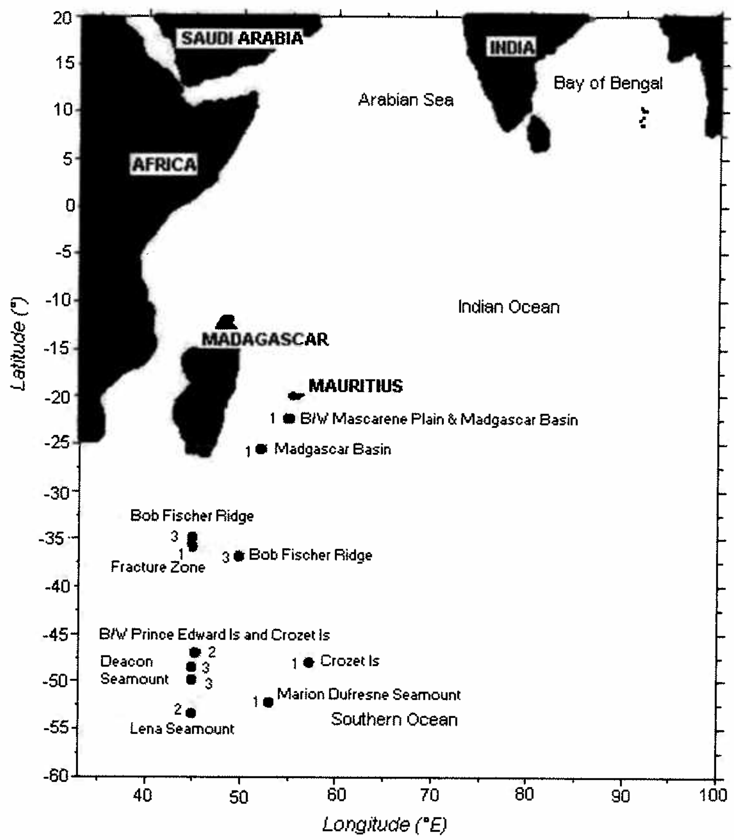


Fig.1 Map of the cruise track showing cetacean sightings

They were also recorded from Mascarene plain, Madagascar basin, Fracture zone, around Crozet island, Lena seamount and Marion Defresne seamount. Based on the present results, it is recommended to make more intensive search surveys especially in two regions, one between 35^0 and 37^0 S latitude (45^0 E longitude) and the other between 48^0 and 53^0 S latitude (45^0 E longitude) where maximum cetaceans were sighted. During such attempts, darting equipment shall be employed to get skin tissue and blubber samples from the whales and dolphins for molecular level identification of species and analysis of heavy metals.

[7.1] CHEMICAL OCEANOGRAPHY

[7.1.1] Dissolved Oxygen:

Sea water samples were collected for analyses of dissolved oxygen (DO) studies in all stations (32) from surface to near bottom extending up to ~ 4000 m water depth (Table 1). The samples were obtained through the CTD carousel, fitted with Niskin/Go-Flo bottles, and sub-sampled for DO without much turbulance in the bottles and no air bubbles are trapped. Details on sampling stations for DO analyses are given below in Table 1. Dissolved oxygen was analysed by the Winkler titration method and nutrients by spectroscopic methods using SKALAR Autoanalyser with the nutrients standards supplied by NIO, Goa. Standards were prepared to estimate the concentration of nitrite, nitrate, phosphate and silicate in the sea water.

Sea water samples collected for DO were fixed with Winkler reagent A and B. 50% of HCl (3 ml) was added to dissolve the precipitate. The solution was transferred into the beaker and titrated against thiosulphate solution. The amount of dissolved oxygen in the sample was calculated and the concentrations were obtained in μM units.

The preliminary results of analysis indicated the concentrations of DO in the surface layer ranged from ~180 to 360 μM. There was a significant increase in the DO concentrations in the surface layer between station 19 (41° S) and 20 (42° S) latitudes suggesting a boundary between two distinctive water masses viz. Sub-Tropical water masses and Sub-Antarctic water mass. There was an inverse relationship (r = 0.98) with sea surface temperature.

North of Sub-Tropical Front (STF), DO concentration decreases in general with depth reaching to a minimum at inter-mediate depths (1000-2000 m) and then slowly increase to ~200 µM in the deeper and near bottom depths. South of STF, the depth of intermediate oxygen minimum is somewhat decreasing ~ 500 m. Further studies are required to compare with nutrients and physical parameters.

Table 1. Performance chart for chemical studies during the cruise SK-200 (Pilot Studies in the Southern Ocean)

Date	Station No.	Lat.	Long .	Dissolved Oxygen (DO)
27 01 04	4	27 59 48	50 00 00	✔
28 01 04	6	28 59 26	47 59 31	✔
29 01 04	7	29 19 30	47 00 47	✔
29 01 04	8	30 20 28	45 48 12	✔
30 01 04	9	31 00 39	44 59 40	✔
31 01 04	10	32 00 00	44 57 27	✔
01 02 04	11	32 50 30	44 54 06	✔
02 02 04	12	34 00 05	44 59 12	✔
02 02 04	13	35 04 46	44 59 46	✔
03 02 04	14	36 08 08	44 59 37	✔
03 02 04	15	36 59 16	44 59 17	*
05 02 04	17	39 00 00	45 00 00	✔
06 02 04	18	40 26 04	45 00 03	✔
06 02 04	19	41 00 22	44 59 52	✔
07 02 04	20	41 59 44	45 00 48	✔
08 02 04	21	43 01 11	45 00 27	✔
09 02 04	22	44 00 15	45 01 36	✔
10 02 04	23	45 01 23	45 06 08	✔
10 02 04	24	46 00 45	45 00 25	✔
11 02 04	25	47 00 25	45 03 42	✔
11 02 04	26	47 59 36	45 00 24	✔
12 02 04	27	48 59 42	45 00 28	∘
13 02 04	28	49 59 33	45 00 54	✔
14 02 04	29	51 00 15	44 59 46	✔
14 02 04	30	51 59 51	44 59 56	✔
15 02 04	31	53 00 00	44 59 45	+
15 02 04	32	53 59 49	45 00 09	✔

16 02 04	33	54 59 50	45 00 14	✔
17 02 04	34	56 00 14	45 00 25	✔
22 02 04	35	47 59 32	57 30 39	°
24 02 04	37	46 01 08	57 39 12	✔
24 02 04	38	44 59 55	57 29 55	✔

✔ Column Sampling
* Surface Sampling (0,10,25,50 and 100 m); (° - 0,10,25,50,75 and 100 m); (+ - 0,10,25,50,75,100,150,200 and 300 m)

[7.1.2] Nutrient and related chemical analysis

Details of sampling:

The water columns were collected at different depths (say, 0, 10, 25, 50, 100, 200, 500, 750, 1000, 1500, 2000, 3000 / max. depth and in some cases near bottom) with the help of Niskin water samplers, which were attached during the CTD operations. The details of water samples collected with position, time and maximum depths were given in annexure I (table). The samples were collected in contamination free sampling containers and preserved at 4°C and analysed within 24 hours as per scientific procedures.

Methodology:

pH determination:

The pH of the water samples were determined immediately after the collection with the help of Digital pH meter ELICO model: LI 127 with automatic temperature compensation (ATC) probe.

Nutrient Analysis:

The well proven method of continuous analysis numerous water samples have been achieved with the help sophisticated facility available onboad -Autoanalyser (Skalar) instrument.

High quality chemical reagents (Analytical grade) were used along with contamination less good quality purified water (Milli-Q). The standards for the analysis were pre-calibrated with the help of Scientists, COD, NIO, Goa and were utilized with proper care and preservation.

Scientific procedure of Nutrient Analysis

The scientific procedure adopted for the analysis were followed with help of literatures (example: K. Grasshoff, 1963 and Walker O Smith et al, 2003).

Silicate:

The water samples were acidified and allowed to react with ammonium molybdate to form molybdo-silic acid, followed by reducing agent ascorbic acid to form blue colour dye and was measured at 810 nm.

Phosphate:

Water samples were mixed with ammonium molybdate and potassium antimonyl tartarate in acidic medium at 40 °C complex, which can be reduced to intense blue colour and measured at 880 nm.

Nitrate:

Water samples passed through cadmium column to reduce to nitrite and diazotized with colouring agent and measured at 540 nm.

Nitrite:

Water samples were allowed to react diazotizing with sulfanilamide with diazonium compund in acid medium in presence of α-naphthylenediamine dihydrochloride to form reddish-purple colour and was measured at 540 nm.

Dissolved Oxygen:

The dissolved oxygen of water samples were determined immediately after the collection in collaboration with NIO participant. The data observed will be supportive to interpretation of biological activities along with nutrient data.

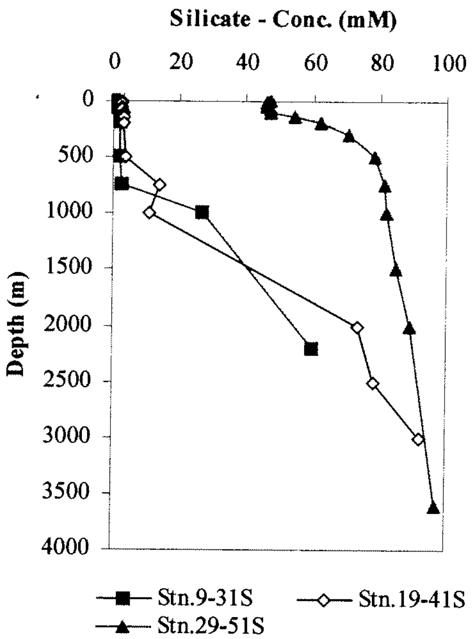
Expected Results:

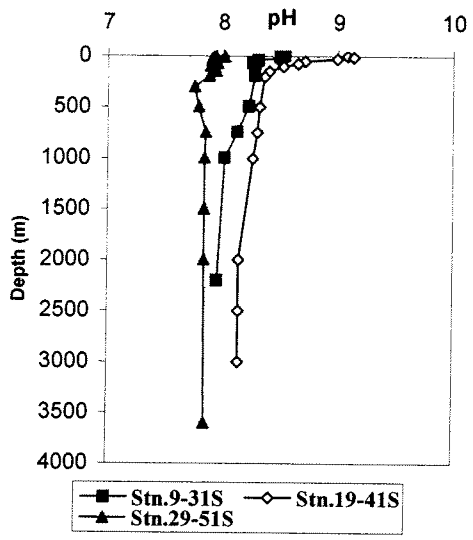
The nutrient analysis data were collected in the form of peaks from recorder and were calculated with reference to the calibrated standards of each nutrient. The nutrient values calculated in the cold region were having unique signatures of the water mass circulations and biogeochemical activities in the region of the study.
Some of nutrient and pH value – depth profiles were attached with this preliminary repot as annexure II and III.

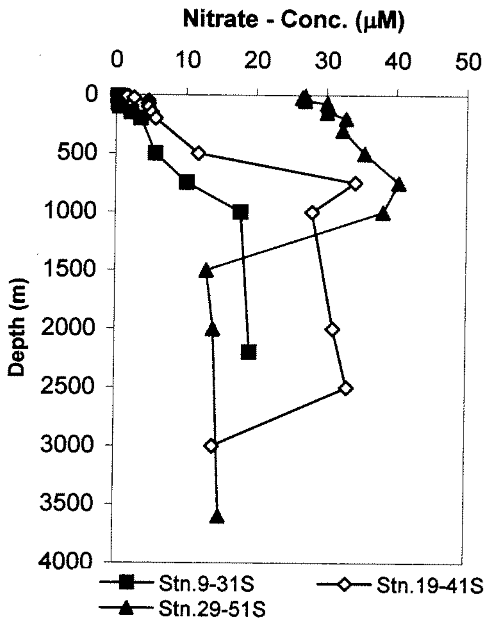
The further process of the data will be done after referring with various literatures and discussions with experts at land.

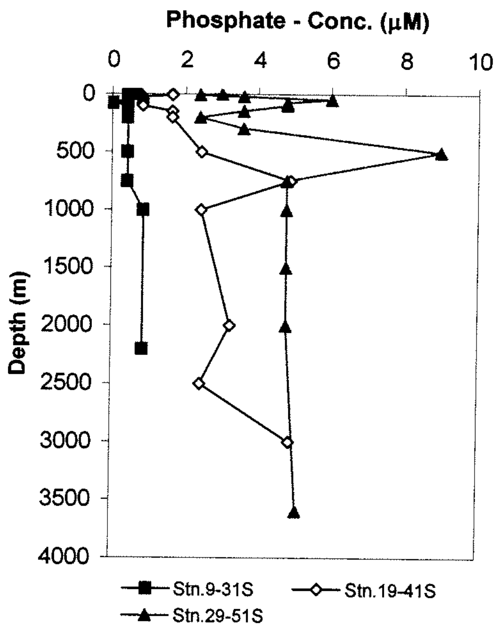
Conclusion:

The nutrient data observed shows correlation with other oceanographic observations like salinity, temperature and also with pH of the corresponding samples measured. The quantum of data collected will be expected to support various aspects of oceanography and biogeochemistry. Hence, it will be expected to view in multi-angle to understand the water columns at different depths and different geological positions.


Silicate - Conc. (mM)
0 20 40 60 80 100
Depth (m)
0 500 1000 1500 2000 2500 3000 3500 4000
Stn.9-31S
Stn.19-41S
Stn.29-51S


pH
7 8 9 10
Depth (m)
0 500 1000 1500 2000 2500 3000 3500 4000
Stn.9-31S
Stn.19-41S
Stn.29-51S


Nitrate - Conc. (µM)
0 10 20 30 40 50
Depth (m)
0 500 1000 1500 2000 2500 3000 3500 4000
Stn.9-31S
Stn.19-41S
Stn.29-51S


Phosphate - Conc. (µM)
0 2 4 6 8 10
Depth (m)
0 500 1000 1500 2000 2500 3000 3500 4000
Stn.9-31S
Stn.19-41S
Stn.29-51S

[8.1] GEOLOGICAL SAMPLING

[8.1.1] Studies conducted and samples collected :

The present geological exploration as part of the pilot expedition to the Southern Ocean represents the first comprehensive scientific effort to understand the Southern Ocean processes and its influence on global climate system on a spatial and temporal scale. In order to achieve this, various methods like water sampling, vertical net sampling, surface sediment sampling as well as subsurface sediment sampling were carried out to study the modern, living and the dead assemblages raining to the sea floor as well as their past oscillations.

In order to understand the modern day micro faunal assemblage in this part of the oceans, systematic plankton net vertical hauls were carried out at two depths (surface and 200/100 m) at CTD stations to decipher the changes from surface with depth at nearly all locations. This would give us time control for the sediments we have collected, and therefore the proxies can be tagged with the modern day parameters which have been collected at each station e.g. DO, Temperature (SST), salinity, nutrients etc. This will be the first hand information on the modern distribution of pelagic microfauna in relation to the modern day parameters. Additionally, water samples were systematically collected using standard water samplers attached to the CTD system at various intervals up to a depth of 200 m and filtered using a Millipore vaccum filtration unit onto 0.4μ membrane filters, to ascertain the distribution pattern of coccolithophorids and also diatoms. The Southern Ocean region is one of the best-known High Nutrient Low Chlorophyll Zone (HNLC). Therefore, it is of much interest as to how these two different microfauna, one at nanno level (coccolithophorids; size ~10^{-9} m) and other microscopic (diatoms) and different composition behave to these conditions and across the oceanic fronts and changing conditions. Further, it will provide information on the coccolithophorid population and how the carbonate flux is changing with depth and also with changing SST pattern and in turn reflect upon the carbon sequestration in this ocean. This study is interesting as this region is also known with less carbonate preservation in sediments but on the contrary siliceous microfauna are known to dominate. The idea is to develop a cause-factor relationship between the two different microfaunal groups and their influence on the oceanic carbon and silica cycle.

Surficial and subsurficial sediment records were collected using various techniques like grab and coring. There were a total of 17 stations attempted for sediment sampling. Surface sediment samples were collected using a Van Veen Grab, whereas subsurface samples were collected using Gravity or Piston Coring technology. For surface sediment sampling, a total of 6 attempts were made using a Van Veen Grab. Out of these 3 attempts were successful with moderate sediment sample collection, from water depths varying from 2984 to 3285 m. A grab sampling at the Lena seamount (Stn. No. 31; Water depth 336m) brought few rock pieces, which appears to be weathered volcanic rock fragments. The partial success of the grab sample collection may be attributed to the rocky bottom or hard and compact sediment available. The sediment collected varied from sandy silt to silty sand, with large presence of shells and benthic organisms.

A total of 12 coring attempts were made during this expedition. Of these 5 attempts were made using gravity coring technology. Only 2 attempts were successful with a recovery of sediment records of 72 cm and 489 cm length, respectively. The relative failure of gravity coring method during this expedition may be attributed to the seafloor characteristics, consisting mainly of carbonate hardgrounds. However, the piston coring method had been highly successful in this cruise with a recovery of 6 well-preserved sediment cores, out of the total 7 attempts. The length of the sediment cores collected using this method varied between 392 cm and 1018 cm.

Scientific objectives and expected outcome:

The geological exploration during this expedition were carried out with the following objectives:

d. To understand spatial patterns of sedimentation as well as distribution of microfauna along the various geographic/ oceanic fronts within the Indian sector of the Southern Ocean.

e. To document and quantify the different microfauna preserved in the sediments so as to make a database for multiple microfossils.
f. Establish a relationship between the different types of microfossils viz. calcareous versus siliceous microfossils against the geochemical parameters and therefore search better proxies for getting the past information better.
g. To decipher the temporal variations in the various oceanographic processes during the geological past and its implications on the Indian Ocean circulation dynamics in particular and global climate system in general.

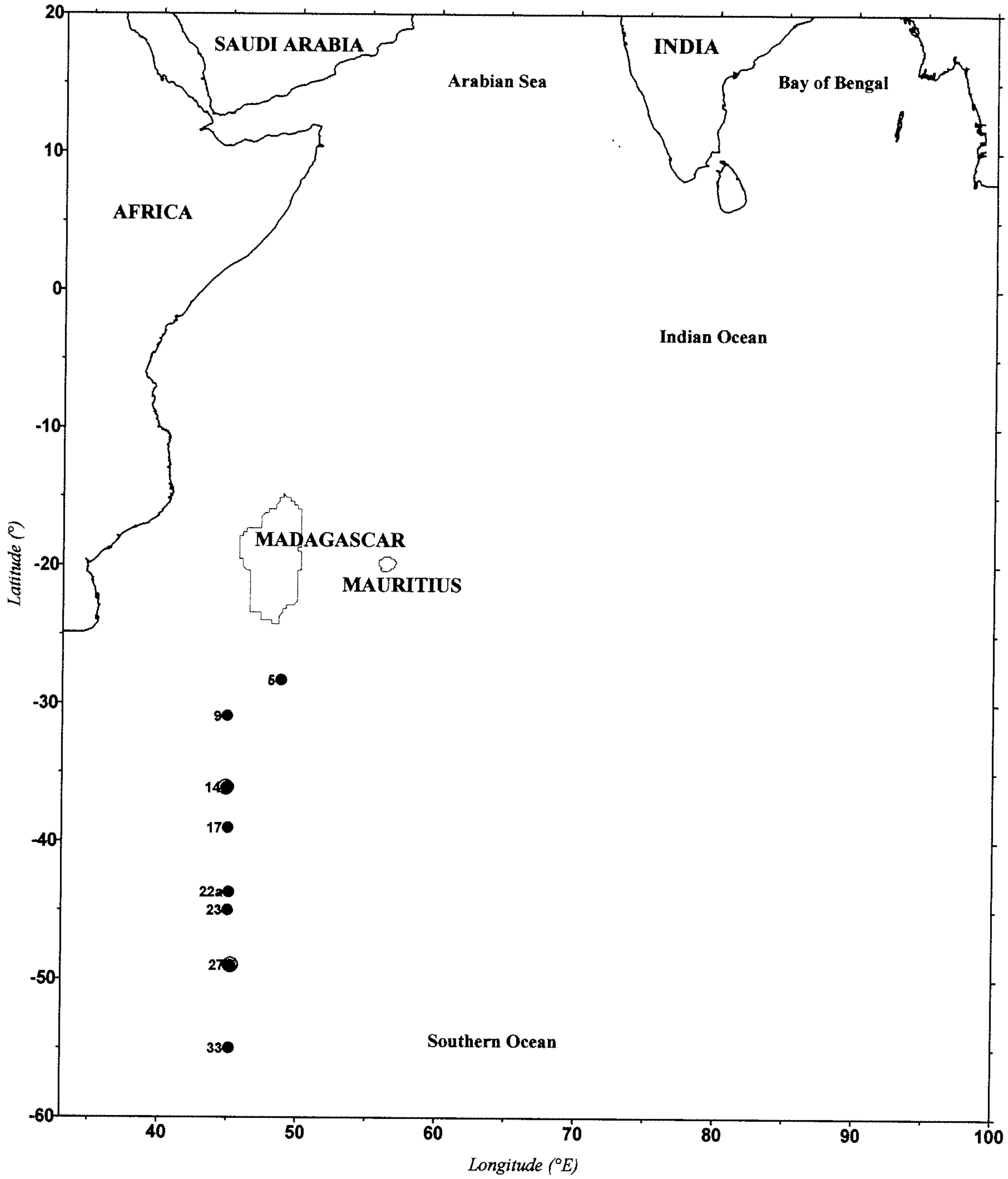
The water, vertical net, surface sediment as well as subsurface sediment sampling carried out during this expedition will provide excellent opportunity to understand the influence of Southern Ocean dynamics on the distribution and preservation of microfauna and/or sediments as well as its influence on global climate system on a spatial and temporal scale. The proposed studies are very important as unlike other major oceans, the Indian Ocean processes are greatly influenced by the Southern Ocean watermasses, as Indian Ocean is land-locked to the north and there is no connection to the north-pole waters. It is of great significance to study the modern fauna using net sampling and water sampling so as to understand how far the Southern Ocean waters affect the fauna, and in turn will help in identifying the correct proxies for deciphering the past, beyond the instrumental capabilities. The micropalaeontological, sedimentological, geochemical as well was isotope studies proposed on the sediment samples will provide important insights into the modern as well as past variations in biological and sedimentation response to the oceanic and climate changes.

Preliminary observations on the samples collected:

Although a series of studies at onshore laboratories are required on the various types of samples collected, based on the visual and preliminary laboratory studies, certain interesting observations were made. The core collected from Station 5 revealed systematic changes in sediment type and colour with presence of several banded intercalations, suggesting intermittent large-scale environmental variations during the time represented by it. A piston core collected at Station 14 from 2730 m water depth revealed abundance of manganese (?) micro-nodules and occasionally larger nodules (~5 cm diameter) distributed throughout the core below 75cm from the sea floor. They certainly points to some large scale changes in the bottom water conditions compared to the modern times during their deposition. A gravity core collected at Station No. 27 from 4389 m water depth revealed excellent variations in sediment type and colour, with alternate layers of dark and light bands. It was found that the darker layers are abundant in rock fragments and debris of various size and shape. Most interestingly, preliminary investigations revealed that the above core consists of layers of siliceous and carbonaceous sediments, indicating dramatic changes in the oceanic chemistry during the past. Further, a piston core collected from the Antarctic waters (Station No. 33) revealed siliceous sediments interspersed with rock debris and rock fragments throughout that may indicate presence of ice rafted debris (IRD) in this region. In order to confirm this, further detailed investigations will be required that may ultimately unravel the importance of Southern Ocean in modulating the global circulation system during the geologic past as well as the possible inter-hemispheric linkages.

Geological sampling location and details:

Sl. No.	Station No.	Latitude ° '	Longitude ° '	Depth (m)	Type of sampling	Core length (cm)	Remarks
1	5	28 19.29	48 43.56	2296	Piston Core	588	
2	9	30 55.94	44 52.45	2256	Gravity Core	72	
3	11	32 50.18	44 52.67	1150	Gravity Core	--	No recovery
4	12	33 59.47	44 56.90	1082	Gravity Core	--	No recovery
5	13	35 00.85	44 59.52	2233	Van Veen Grab		No recovery
6	14	36 06.97	44 50.31	2730	Piston Core	592	
7	15	37 00.00	44. 59.00	2984	Van Veen Grab		Sediment
8	17	39 01 71	44 58.17	4022	Piston Core & Van Veen Grab	392	No grab recovery
9	19	40 58.88	45 03.53	2532	Piston Core	--	No recovery
10	21	43 09.00	44 59.00	3210	Van Veen Grab		Sediment
11	22a	43 41.50	45 04.30	2720	Piston Core	754	
12	23	44 59.82	45 00.83	1423	Piston Core	763	
13	25	47 08.00	44 58.00	3285	Van Veen Grab		Sediment
14	27	49 00.34	45 13.11	4377	Gravity Core	489	
15	31	52 59.00	44 58.00	336	Van Veen Grab		Rock fragments
16	32	45 00.57	53 44.24	3741	Gravity Core	--	No recovery
17	33	55 00.76	45 09.47	4204	Piston Core	1018	



Location map showing stations from where sediment cores were successfully retrieved. Red dots indicate piston core locations and red dots with blue circle indicate gravity core locations.

[9.1] SATELLITE VALIDATION

The specific objective of the team was related to the following:

- Validation of satellite derived oceanic parameters over the unique Southern Ocean Region with steep SST gradients associated with frontal systems

- Studies of the Southern Ocean Circulation and its influence on the Antarctic Sea Ice Extent

Towards realization of the above, data from the following instruments onboard were of relevance.

CTD/XBT	- for obtaining Temp., Salinity, Density surface values and profiles
ADCP	- for near surface and subsurface current
Thermo-Salinograph	- for near surface Temp. and Salinity
Wave Recorder	- for wave height
AWS	- for surface Met./Ocean data – P,T,H, Winds
Met. Data	- Surface and Upper Air Weather parameters

All the above instruments were operated as feasible, some in continuous mode and some in quasi-continuous mode. As many as 38 closely spaced CTD casts were taken, mostly during the N-S transect along 45 E. The attached Table lists the CTD Stations with details of observations made. Preliminary data analysis shows good quality T and S profiles. Sample T-S profile over the region of Southern Ocean influenced by Antarctic Waters at Stations # 18 and 27 is enclosed. Data collected from other instruments require initial processing using instrument specific S/W for extraction of parameters of interest.

The data collected during SK#200 would be a good beginning to look at the reliability of satellite based estimation of oceanic parameters, particularly over the data void region of Southern Ocean where one encounters low SST and very high spatial (latitudinal) gradient. Besides satellite based geophysical parameters, the high resolution thermal and color images would help in delineating eddy and other circulation features in the region. Similar data collected during different seasons would be useful in understanding the circulation and its influence on sea ice distribution.

LOSSES / DAMAGES DURING SK 200:

1. One 12 – liter Niskin bottle was found broken during CTD operation at station 22 on 9th February 2004.
2. SBE 9/11 CTD system was fallen on the deck resulting in breakage of eight of 12–liters capacity and two of 5–liters capacity Niskin bottles during sever sea state conditions encountered on 19th February 2004.
3. CTD winch cable (Galvanized type) was cut twice during the cruise – 200 ms length on 28th January 2004 and also another 200 ms on 4th February 2004. About 1200 ms (150+350+700) of CTD cable (stainless steel type) was also cut on three occasions due to development of kinks during the cruise.

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Write-up for Submission to Journal of Geological Society of India:

The National Centre for Antarctic & Ocean Research (NCAOR) an autonomous institution at Goa, fully funded by the Department of Ocean Development (DOD), Government of India, initiated for the first a multidisciplinary and multi-institutional Pilot Cruise utilizing the services of the research vessel ORV Sagar Kanya aimed at studying the Indian Sector of the Southern Ocean upto 55 deg S latitude. The question that *comes to the mind* immediately is, why such a Pilot Expedition in Southern Ocean ? The answer is loud and clear -The Southern Ocean represents 10% of the world oceans and comprises several physically and biologically distinct regimes, latitudinally separated by fronts (Strutton et al. 2000). This region is characterized by high production of nutrients and low chlorophyll (HNLC) zone, also sometimes referred as one of the HNLC regions of the world. Added to this there is low utilization of these nutrient rich waters and therefore, needs further studies. Further, this is also the region of major wind stress and in turn the mixed layer gets deepened specially during the winter. Lastly, *and one of the important aspects is* the waters of the Southern Ocean directly or indirectly affect the Indian Ocean and thereby the Indian climatic regime. As also the Indian Ocean is land locked on its northern extremity and therefore there is no exchange with the north pole waters. Therefore, the southern ocean and its waters need to studied in detail and the need to have such a cruise in this part of the world is aptly justified. This is also the region where there is complete paucity of data and the scientific community is looking for sea truth data from this region. With all this is mind the ship sailed for its 1st Leg from Cochin to Mauritius on 1st January 2004 and collected enroute data which included XBT and CTD profiles, collection of water samples as also sediment samples for the geologists and biologists who were interested in knowing about the benthic community. The 2nd Leg for the Southern Ocean leg sailed on 23rd January 2004 from Port Louis, Mauritius. The 12 participating institutions covered different disciplines which included :
[a] Atmospheric Sciences [b] Physical Oceanography [c] Biological Oceanography
[d] Chemical Oceanography [e] Geological Sampling and [f] Satellite Remote Sensing

The major objectives of the Expedition were :

[1] Atmospheric Aerosol Observations
[2] To measure Surface-met and upper atmospheric parameters over southern ocean using Automatic Weather Station and Radiosondes respectively.

[3] Physical oceanographic studies were aimed at understanding the temperature -salinity (T-S) structures, morphology of circumpolar fronts, circulation regimes in the water column and air-sea interaction processes pertaining to the Indian Ocean sector of the Southern Ocean

[4] The objectives of the Biology group were,

- To estimate latitudinal variations in the primary productivity, chlorophyll content and planktonic forms in relation to the nutrient availability, current patterns and other related environmental parameters.
- Qualitative studies in the bacterial fauna below the euphotic zone and in the waters off bottom and their role in the decomposition/mineralisation process.
- Qualitative studies on the macro and micro benthos.
- Observations on marine mammals and avian fauna.
- Determination of the bacterioplankton abundance below the euphotic zone and off bottom waters in the Indian Ocean sector of Southern Ocean.
- Qualitative study of benthic fauna in the Indian Ocean sector of the Southern Ocean.
- Assessment of microbial diversity at the sea bottom using 16Sr DNA based techniques.
- Identify and enumerate harmful algal species.
- Survey for algal blooms – if any – and collect related environment data.
- Qualitative and quantitative analysis of mesozooplankton in the Indian Ocean sector of Southern Ocean up to 1000m depth.
- Estimation of Primary production, Chlorophyll a and qualitative & quantitative study of phytoplankton groups in the Indian Ocean sector of Southern Ocean.
- Microzooplankton studies in the Indian Ocean sector of Southern Ocean.

[5] Sea water samples were collected for analyses of dissolved oxygen (DO) studies

[6] To understand the water mass circulation and physico-chemical behavior of the cold region the water samples were collected in a regular interval. Further to understand the biogeochemistry of the ocean the various depth of water columns were collected.

[7] The geological exploration during this expedition were carried out with the following objectives:

- To understand spatial patterns of sedimentation as well as distribution of microfauna along the various geographic/ oceanic fronts within the Indian sector of the Southern Ocean.
- To document and quantify the different microfauna preserved in the sediments so as to make a database for multiple microfossils.
- Establish a relationship between the different types of microfossils viz. calcareous versus siliceous microfossils against the geochemical parameters and therefore search better proxies for getting the past information better.
- To decipher the temporal variations in the various oceanographic processes during the geological past and its implications on the Indian Ocean circulation dynamics in particular and global climate system in general.

The cruise culminated at Port Lois, Mauritius on 4th March 204 after reaching 56 degree south and completing 38 stations of CTD profiles close to the bottom were completed apart from the regular meteorological data, aerosol data collection and XBT's fired at every half degree. Eight sediment cores (6 piston and two gravity cores) were collected across the cross section from the subtropical to subantarctic region and each one has a different story in the offing. The samples are being analysed and results of each group should be out in a few months from now.
Apart from the fury of the forties and fifties which the team sportingly faced we also saw some beautiful outstanding ice bergs on our way telling us to stand apart always.

M. Sudhakar

National Centre for Antarctic & Ocean Research