Report of ORV Sagar Kanya Cruise No.219 (Period: 19 April – 7 May 2005)

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under DST funded project (Ref.No: 48/ICRP/011/2002)-ARMEX- Phase II: Physics of the south-eastern Arabian Sea warm pool using upper ocean observations from a mooring

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National Institute of Oceanography, Goa

Contents	**Pg. No**

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1. Summary:

ORV Sagar Kanya cruise (No.219) was conducted in the southeastern Arabian Sea from 19 April to 07 May 2005 with a primary objective to understand the dynamics of warm pool in the region under ARMEX (Arabian Sea Monsoon Experiment) as a part of Indian Climate Research Programme (ICRP). This cruise was undertaken as a collaborative project between NIO, NIOT and IISc funded by DST, Govt.of India. The Department of Ocean Development (DOD), Govt. of India had also supported the cruise by allotting necessary ship time.

The cruise was started on the morning of 19 April 2005 at Kochi with 24 participants from different organizations viz., NIO(Goa); NIOT(Chennai); IISc (Bangalore); SPL/VSSC (Thiruvananthpuram); Andhra University (Vizag) and NORICO (Ship's AMC Party). During the cruise, the main emphasis was on the deployment and retrieval of a deep-sea weather buoy (ARMEX buoy) specially configured to moor recording current meters at five different depths (2, 7, 15, 25, 37 m) in the upper ocean with routine surface meteorological and wave sensors. The buoy with current meters mooring was deployed at 8.3°N; 72.68°E west of Minicoy island on 21 April 2005 to measure the oceanic flow field. Observations on temperature and salinity structures in upper 500 m water column were repeatedly made through the casts of CTD (Conductivity-Temperature-Depth) recorder (both Idronaut & SBE-Seacat) near the buoy location as well as at the eastern, western, northern and southern locations each situated about 7 miles apart from the ARMEX buoy. A zig-zag ship track was followed to generate a time-series data on the zonal and meriodional gradients in temperature and salinity fields. In addition to hydrological observations, surface meteorological parameters (incident & reflected short-wave radiation, incident & emitted long-wave radiation, air temperature, humidity, atmospheric pressure, wind speed & direction) were recorded onboard the ship. Measurements of surface aerosol characteristics were also made. ARMEX buoy was successfully retrieved on 4 May 2005 with current meters. NIOT team swapped the existing DS-7 buoy with reconfigured ARMEX buoy having one acoustic current meter and DS-6 buoy with retrieved DS-7 buoy on 5 May 2005. A hydrographic section between Kochi and the ARMEX buoy location was covered twice during onward and return legs of the ship to take temperature-salinity profiles at selected locations. This cruise was ended at Kochi on the morning of 7 May 2005 after successful completion of buoy & mooring operations and hydrographical observations.

2. Cruise Track:

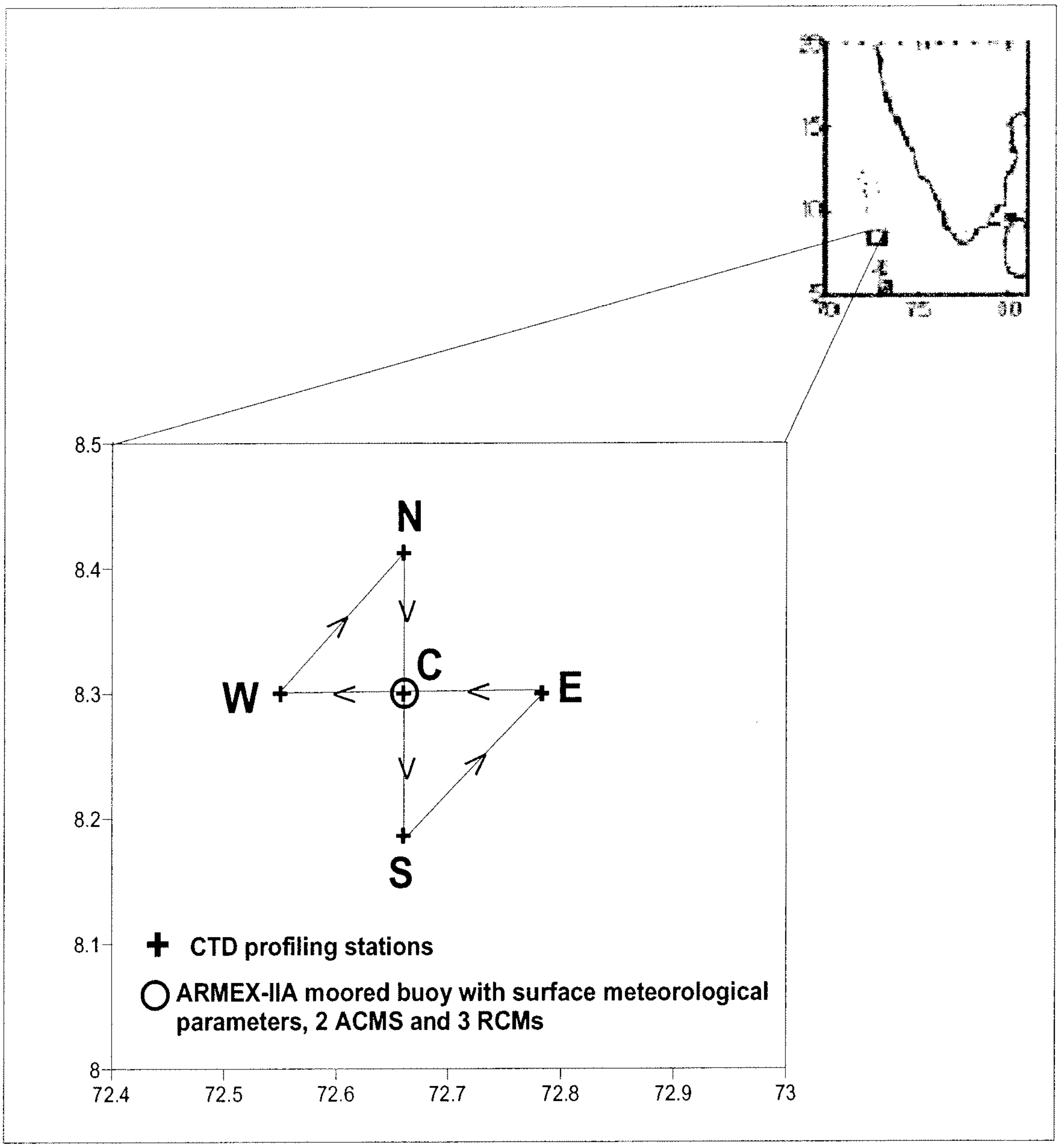


Fig. 1 Study area for Time Series observations during 21 April - 4 May 2005 onboard ORV Sagar Kanya under ARMEX - II A Program

3. Introduction:

A broader area of warm pool develops in the southeastern Arabian Sea during spring period with the incidence of high surface temperatures and the warm pool collapses prior to the onset of the summer monsoon over the area. The importance of warm pool studies is felt as atmospheric onset vortexes form over this region accelerating the progress of the onset of the summer monsoon along the west coast of India. The absence of the onset atmospheric vortex in certain years causes considerable delay in the onset of the summer monsoon affecting the population.

An observational programme in the southeastern Arabian Sea aimed at understanding the warm pool dynamics was started during the year 2003 as a part of ARMEX (Arabian Sea Monsoon Experiment) Phase II programme – a subcomponent of Indian Climate Research Programme (ICRP). However, the role of ocean currents in the dynamics of the warm pool is not clearly understood. Though efforts to measure the ocean currents through the deployment of surface buoy with the mooring of recording current meters in March 2003 were made but they were not successful since we could not retrieve the current meteres due to loss of surface buoy. It is therefore decided to try for another current meter mooring by pooling up the existing resources at NIO, NIOT and IISc provided sufficient ship time is made available. Now with the allotment of ship time by the Department of Ocean Development (DOD) and extension of funding support by the Department of Science & Technology (DST), Govt. of India, it has been possible to take up this (No: 219) cruise with an emphasis on the measurement of currents in the upper layer of the warm pool region in the southeastern Arabian Sea together with observations on thermo-haline structures and surface meteorological fields. A deep-sea weather buoy specially configured to moor recording current meters at five different depths (2, 7, 15, 25, 37 m) in the upper ocean with routine surface meteorological and wave sensors was deployed at 8.3°N; 72.68°E west of Minicoy Island to measure flow field during the cruise period. Observations on temperature and salinity structures in upper 500 m water column were repeatedly made through the casts of CTD

(Conductivity-Temperature-Depth) recorder at the buoy location as well as at the eastern, western, northern and southern locations situated about 7 miles apart from the ARMEX buoy. The observations around the buoy are intended to study the upper ocean heat balance of the warm pool. An observational component for studying the characteristics of the atmospheric aerosols over the warm pool area is also included.

Keeping this moored buoy at the centre (C) for surface meteorological observations and upper ocean temperature, salinity and current measurements, 4 stations were chosen representing the middle points of each side of a square for time series measurements of temperature, salinity and chlorophyll (only during day time). The middle-points are designated as North (N), East (E), South (S) and West (W) stations. The vessel moved between these stations in the order of stations from **C** to **S, E,** again to **C, W, N** and finally to **C** completing one cycle. These station locations and ship's track around the ARMEX buoy are shown in Fig. 1. This movement of the vessel was maintained during the time series measurements from 21 April to 4 May 2005. This track has allowed more measurements of temperature and salinity at the centre location closer to the ARMEX moored buoy. The zig-zag track of the ship for the observations at these 5 stations was meant to obtain the horizontal temperature and salinity gradients as required for the estimates of heat advection, an important process playing its role in the dynamics of the warm pool. The distances between **C** and **W**; **C** and **E**; **C** and **N** and **C** and **S** stations are selected as 7 nm (nautical mile) or equivalently about 10 km. The distances between **S** and **E** and **W** and **N** stations are the same around 13 km. Moving between the stations, 131 profiles of temperature and salinity were totally obtained with IDRONAUT CTD during the deployment of ARMEX buoy from 21 April to 4 May 2005. The number of CTD profiles at the central location (**C**) is 44 while at stations **E**, **S**, **W** and **N**, the total profiles are 22, 22, 22 and 21 respectively. Temperature and salinity profiles collected using the SEACAT CTD at the stations have numbered 64 with respective distribution of 21, 10, 12, 11 and 10 profiles at the **C**, **E**, **S**, **W** and **N** stations.

4 Cruise Participants:

4.1 Scientific complement

	Names of persons	Organisation
1.	V Ramesh Babu (Chief Scientist)	NIO, Goa
2.	V S N Murty (Dy.Chief Scientist)	-do-
3.	Areef A Sardar	-do-
4.	Murali Krishna Surisetty	-do-
5.	Sadashiv T Khalap	-do-
6.	Yogesh V Agarvadekar	-do-
7.	Dorairaj Sivakumar	NIO, Chennai
8.	G Senthil Kumar	-do-
9.	Mani Athiaman	-do-
10.	Venkatarangan Ragunath	-do-
11.	Panisiluvai Johnson	-do-
12.	Leslin Jerslin	-do-
13.	Delvar Thibursiano-	-do-
14.	M V Subrahmanyam,	Andhra University, Vizag
15.	Vijayakumar S Nair	SPL(VSSC), Thiruvananthapuram
16.	Denny P Alappattu	-do-
17.	Senju T Panicker	IISc, Bangalore
18.	Vinayak Bhat	-do-
19.	Karumathil M Jaya Krishnan	NORINCO
20.	Praveen R Rodrigues	-do-

21.	Govindarajulu Ramkumar	-do-
22.	Hafizpur Rahman	-do-
23.	Girish Y Madar	-do-
24.	V C Sharathchandran	-do-

4.2 Ship's Complement:

1.	Capt K S Pandian	Master
2.	Satyendera Pratap	Chief Officer.
3.	Kalyan Singh	2^{nd} Officer.
4.	D. Chakraborty	2^{nd} Officer
5.	Dr. Ramdas P G	Medical Officer
6.	Shankar Menon	Radio Officer
7.	P Bhagwan Das H	Purser
8.	G Narayan More	Chief Engineer
9.	M Sudipta	2^{nd} Engineer
10.	Das Haridhan	4^{th} Engineer
11.	K Abdul Rob	4^{th} Engineer
12.	M P M Chezhiyan	4^{th} Engineer
13.	P Dhananjoy	Electrical Officer
14.	Furtado A B S Freddy	Catering Officer

5 Work Accomplished:

Participants from various organizations viz., NIO, NIOT, IISC, SPL (VSSC) and Andhra University took part in the cruise to carry out different tasks. The following are the working disciplines in which the individual groups are involved.

NIO: Cruise Coordination & reporting;
Current meters mooring;
(RCMs, Acoustic Release & Floats availability)
Hydrological observations (CTD, RCMs);
Surface meteorological and sea surface temperature observations;
(Portable met kit & Bucket Thermometer)
(Currents & CTD data collection, validity, processing
& salinity analysis)

NIOT : Data buoy operations;
Buoy electronics- met & wave sensors, Acoustic Current Meteres;
Data storage & communications;
Mooring design;
Mooring Hardware (data buoy, ropes,floats, anchor weights etc.);
Buoy deployment & retrieval

IISc: Atmospheric observations (Fast sensors & AWS);
Measurements of atmospheric aerosol properties;
Surface meteorological and sea surface temperature observations;
(Portable Met Kit & Bucket Thermometer)

SPL(VSSC): Measurements of atmospheric aerosol properties;
Surface meteorological and sea surface temperature observations;
(Portable Met Kit & Bucket Thermometer)

Andhra University : Radiation & skin temperature measurements;
Surface meteorological and sea surface temperature observations;
(Portable Met Kit & Bucket Thermometer)

NORINCO: AMC related works
(Instruments maintenance & operations; data collection etc)

4.1 Ocean current measurements with RCMs:

[NIO Team: V.S.N. Murty, Yogesh V. Agarvadekar, Sadashiv Khalap, Areef Sardar and V. Ramesh Babu]

As a part of collaborative project between NIO, NIOT and IISc on the measurements of currents in the southeastern Arabian Sea, NIO was to make the availability of few recording current meters (RCMs) and some essentials of mooring hardware viz., Acoustic Release & rings and sub-surface floats etc. For the mooring of RCMs, NIOT had provided a surface buoy (ARMEX buoy) fitted with a mast housing surface meteorological sensors for measurements of atmospheric pressure, air temperature, humidity. The buoy was also provided with a sensor for measuring sea surface temperature (at 30 cm depth) and near-surface UCM sensors for recording currents and water temperature, salinity at 2 and 7 m. Three RCMs (two RCM-7s (Sl. Nos. 11166 & 11168) and one RCM-9 (by NIO Sl. No. 998) of M/s Aanderaa Instruments, Norway were made available for moorng. These RCMs were set to record the currents at 15, 25 and 37 m depths at every 10 minutes interval together with temperature and conductivity measurements. Fig. 2 shows the configuration of current meter mooring with surface buoy as designed by NIOT. Prior to deployment, the RCMs were checked thoroughly and necessary accessories are fitted (eg. Battery, O-ring, zinc anode etc) and pre-deployment checklists were prepared. Each RCM has an internal Data Storage Unit (DSU) for recording of the data.

For the requirements of buoyancy, 8 glass floats were used. Necessary notifications were so that it could be connected to the 5/8 "size chain using 3/8" bolts. The attachment of glass floats to the mooring line required minor modifications incorporated by fabricating a stainless steel (SS304 grade) plate (450mm x 50mm x 3mm) and drilling necessary holes on the plates as well as on the hard hats. These plates were fabricated at NIO workshop before the starting of the cruise. Due to non-availability of original acoustic release rings, the same were to be fabricated for their use during the mooring. Mild steel material (grade

EN-8) was selected for fabrication of rings that were to be used during a short period of less than a forth night. Four rings of 6"(2nos) and 8"(2nos) diameters were fabricated at NIO workshop and out of them, two rings each of 6" and 8" internal diameters were subjected to a destructive testing on a tensile testing machine. The test revealed a safe working load of the fabricated rings at around 8 tons considering a factor of safety of 2.

A pre-tested Acoustic Release (Make: MORS, France and Sl. No. 724) has been attached to the mooring line at 20 m above the anchor weights. Acoustic Release (Model: AR 661-B2S, Make: IXSEA /Oceano, France) forms an essential part of the mooring configuration as it detaches sinker weights on interrogation and helps in the retrieval of the RCMs. For interrogation with the acoustic release, a transmitter (Acoustic Deck Unit , Model:TT-301 B) with a battery and a charger was kept ready to transmit "RANGE" tele-command codes. Two unique command codes were selected for releasing and ranging of the acoustic release. In fact, the transmitter sends signals in a low frequency range of 8-16 khz for propagation in water towards ranging and releasing of acoustic release. Prior to the deployment of the ARMEX buoy, the acoustic release mechanism was tested on board the ship as well at a lowered depth of 200 meters and the interrogation commands for ranging and releasing were tested. Upon receipt of its own release code, the acoustic release' underwater unit sends back an acknowledgement pulse at a frequency (8 or 12 khz in general) and 3 seconds later the motor is activated (release durations from 1.5 to 3.0 seconds). At the end of the release, a second pulse is transmitted and the motor rotation makes the hook free and open. The check list of the acoustic release is given in *Appendix 'A'*. The range of the acoustic release from the ship was verified in the vicinity of buoy once the sinker weights attached at the end of the mooring line reached the bottom. The slant ranges of the acoustic release were also obtained when the ship was away by few kilometers from buoy location.

The ARMEX moored buoy was deployed successfully on 21 April 2005 around 0900 hrs IST at 08° 18'N and 72° 40' and the same with moored RCMs was also successfully recovered on 4 May 2005 at about 1200 hrs IST after 13 days of deployment. After completing the after-recovery checks, the RCMs were opened up and the DSUs were collected. The final readings of the DSUs were read. It was found that two RCMs located at 15 m and 25 m recorded the data for the deployment period while the last RCM moored at 37 m depth could not record the data more than 3 days due to heavy drainage of the battery voltage. Fig. 3 shows an variation in the magnitude of currents measured at the depth of 2m, 7m, and 15m during the buoy deployment.

4.2 Buoy Operations (Deployment & retrieval of the buoys, Measurements of Ocean Currents, surface waves and meteorological fields):

(NIOT Team: D Siva Kumar, G Senthil Kumar, M Athiaman, V Ragunath, P Johnson and L Jerslin)

NIOT, Chennai under the National Data Buoy Programme, had deployed two moored data buoys (DS6 and DS7) in the area off Minicoy Island during 2003 year in order to provide support for the ARMEX studies and continued to maintain them. In addition to these two buoys, it was decided to deploy an additional ARMEX buoy with moored current meters during this cruise. NIOT team had carried out additional modifications and arrangements both electronically and mechanically.

An acoustic current meter (Make:FSI-Falmouth instruments) was moored at 7 meters depth in addition to the usual one at 2 meters depth. In order to integrate the additional current meter, special interface high quality cable of 10 meters length was prepared and cable moulding was carried out in-house at NIOT. Additional interface underwater connectors were fitted on the buoy for this current meter and all the necessary modifications were carried out in the electronic hardware of the buoy system at NIOT. The software of the buoy system was also modified to accommodate additional current meter.

A special frame was mechanically fabricated at NIOT to protect the current meter at 7 m depth from external damages. The mooring configuration as shown in Fig.2 was prepared to moor additional recording current meters including those of RCMs provided by NIO. ARMEX buoy was subjected to test on board on 19/4/2005 evening and perfect data acquisition and transmission from the buoy were ensured till 21/4/2005. Buoy mooring preparations were carried out on board enroute to its deployment location. ARMEX buoy was deployed on 21/4/2005 at 8.55AM.

ARMEX buoy was retrieved on the forenoon of 4 May 2005 and the same was swapped in place of the existing DS7 buoy on the morning of 5 May 2005 after removing the additional current meter. The retrieved DS7 buoy was serviced and tested on board the ship for its swapping with the existing partially faulty DS6 buoy. After ascertaining perfect data acquisition and transmission from the buoy DS7, it was swapped in place of DS6 on the afternoon of 5/5/2005 so as to provide continuous support for the ARMEX studies.

4.3 Temperature-salinity measurements:

[Team: NIO- V. Ramesh Babu, V.S.N. Murty, S. Murali Krishna, Yogesh Agarvadekar, M. Subrahmanyam & NORINCO Engineers]

A generation of time-series data on thermo-haline structures in upper 500m water column around the ARMEX buoy was planned through the Conductivity-Temperature-Depth (CTD) casts during deployment period till its retrieval. Temperature-salinity profiles up to 1000m were also collected at few locations along onward and return legs of the ship between Kochi and ARMEX buoy deployed location west of Minicoy Island.

The temperature and salinity profiles in the upper ocean 500/1000 m were collected using two CTDs - a) Make: IDRONAUT, Italy & Model: 316 and b) Make: SBE, USA & Model; SEACAT 19]. Five stations were occupied along a section normal to the coast from Kochi port to the ARMEX Moored buoy deployed west of Minicoy Island.

The IDRONAUT CTD (ID-CTD) has one pressure sensor, two sets of temperature and conductivity sensors (T1/C1 and T2/C2) and one each oxygen and chlorophyll sensors. At the beginning, the ID-CTD was operated with T1/C1 sensors selection, though the REDAS software stores the conductivity and temperature raw data also from the T2/C2 sensors. As per the REDAS software, the data were acquired with 10.109 Hz (cycles per second) with online smoothing and de-spiking. The RAW data files were used for extraction into ASCII TEXT files with the (smoothed) downcast data opting the depth bins at 1 m interval instead of original pressure bins. The ID-CTD was lowered up to 500 m at most of the stations. At each station, water sampling was done at pre-selected depths. The water samples were analyzed for salinity using the ship borne salinometer (AUTOSAL). A total of about 250 water samples were collected and analyzed. Fig. 4 shows a typical AUTOSAL salinity profile obtained at the eastern station (TS-39) on 24 April 2005. The presence of low salinity waters in the surface layer (<30 m) and sub-surface salinity maximum in the depth range of 50-125 m is a conspicuous feature of the depth-salinity profile. The ID-CTD salinity data from the first 79 profiles from T1/C1 sensor pack are noted to be slightly higher than those compared with the AUTOSAL salinity values. A regression line is fitted between the ID-CTD salinity values (from the processed downcast text files) at the sampling depths and the corresponding AUTOSAL values and the correlation coefficient is 0.94. The regression equations are meant for correcting the ID-CTD salinity values from profiles 1 to 79.

At station TS-64 (IDRONAUT raw data file: 219ts080.irw), a large deviation in salinity was noticed from 500 m depth to the surface, while acquiring the data during upcast. On the subsequent profiles, the salinity profiles during both downcast and upcast showed an unusual shift towards low salinity. This shift is more conspicuous with the T1/C1 sensors compared to that with using

T2/C2 sensors. Therefore, the ASCII data files are extracted from this station onwards with selected T2/C2 sensors till the end of the CTD observations. Fig. 5 shows the original salinity profiles acquired with T1/C1 and T2/C2 sensor packs at two stations (TS-37 and TS-97) occupied in about a week interval (24^{th} April and 30^{th} April) and a large shift in salinity is evident. It was noticed that the conductivity sensor C1 measured lower conductivity by 0.043 ms/cm compared to that measured by C2 sensor giving rise to relatively lower salinity values. However, on comparison, the salinities showed less deviation (with C1 sensor the salinities were further lowered) from the salinity values obtained using AUTOSAL, which in turn were consistent with the depth. For the purpose of checking the drift in the ID-CTD salinity, even after selecting the T2/C2 sensors, water sampling in the upper 500 m was continued from #TS-64 for AUTOSAL analysis and subsequent regression relationship. Another liner regression line has been obtained with a correlation coefficient of 0.83 to correct the *.TXT data files from this station onwards. The comparison of same profiles after applying corrections shows reasonable improvement, given the temporal variation in salinity (in one week duration) in the study area (Fig. 6). The second regression line for the T2/C2 sensor pack is to be used to correct the salinity from the #TS-64 profile onwards. The profiles of temperature obtained from T1 and T2 sensors showed a negligible deviation of –0.00044°C suggesting that the temperature sensors are stable during the observational period. Fig. 7 shows the depth – temperature profiles around noon in the upper 140 m at the central station on two different dates, i.e., 24^{th} April and 30^{th} April 2005. Higher temperatures (31.0°C) were noticed in the top 5 m on 24^{th} April. On this day, the sea surface was glossy and the maximum sea surface temperature measured (using bucket thermometer) was around 32.5°C during 1400-1600 hrs. The maximum sea surface skin temperature measured by the Infrared Pyrometer was around 33.5°C on this day. Within this week period, a distinct cooling in the depth range of 90-140 m. Fig. 8 shows the depth-salinity (corrected) profiles in the upper 140 m on 24^{th} April and 30^{th} April. Low salinity waters are noticed at sea surface with a steep increase with depth in the upper 75 m on 24^{th} April. After a week period, salinity increased in the upper 40 m and a homogeneous mixed layer (of 40 m thick) is developed. At subsurface depths, there occurs two salinity maxima centered at 70 m and 110 m depth, separated by a weak salinity minimum at 100 m depth on 24th April. The values of the salinity maxima were decreased by 30th April, suggesting the effect of active mixing processes. Further analysis of the data is planned at NIO.

Since the ID-CTD showed a drift in salinity, the SEACAT 19 CTD profiler (make: SEABIRD Electronics, USA and Model 2815) was operated at all the stations up to 500 m depth at five time series stations (C, N, E, S and W) from the TS-64 onwards. Using the SEASOFT package, the processed salinity profiles are binned with 2 m and 5 m intervals separately. It was noticed that the SEACAT salinities are slightly lower to that of AUTOSAL salinity values. Therefore, the SEACAT salinity values from the 2 m bin files are compared with the AUTOSAL salinity values obtained from water sampling at a number of stations. A total of 183 pairs of salinity values are used for comparison. The scatter plot between SEACAT salinity and AUTOSAL salinity using these 183 pairs results in a linear regression line with a higher correlation coefficient of r=0.93. This regression line will be used to correct the SEACAT salinity profiles. On the return leg, the SEACAT CTD was lowered up to 1000 m depth.

The calibration coefficients are not available for chlorophyll sensor of the IDRONAUT CTD system. Therefore it was decided to obtain chlorophyll of the water samples using an onboard flouro-meter (FLOU-IMAGER M32B) for the measurement of chlorophyll from 26 April. During the cruise, the AMC Engineers operated this instrument. The water samples obtained in the upper 120 m during the day- time only were used for the chlorophyll analysis.

During the time series observations around the ARMEX moored buoy, the Bucket thermometer was used to obtain the sea surface temperature (SST) at hourly intervals. The surface water samples collected in the bucket thermometer were utilized for AUTOSAL analysis for obtaining the sea surface salinity (SSS). The surface meteorological data on wind speed and wind direction, air temperature (dry bulb and wet bulb) and atmospheric pressure were obtained at 3 hourly intervals.

4.4 Atmospheric Boundary Layer measurements:

(Team: Vinayak Bhatt, IISc)

The objective of these measurements has to study the air- sea interaction processes in detail. As a part of studies on the large-scale system monsoon it is very important to understand the pre-monsoon conditions prevailing over the Arabian Sea. The following instruments/sensors were installed and operated by IISc on board the ship during the cruise.

a) Fast sensors. These sensors measured atmospheric parameters at 10 Hz for direct estimation of the sensible and latent heat fluxes. The instruments included a sonic anemometer that measured 3 components of wind velocity and air temperature, a tilt sensor for instantaneous rolling and pitching angles of the ship and an accelerometer for ship acceleration. These instruments were operated continuously through the cruise period.

b) Slow sensors. The response time of these sensors is at least a few seconds. The data from these sensors is used for understanding the atmospheric variations and also for estimating fluxes. The instruments to measure wind speed and direction, air temperature and relative humidity, incoming and outgoing/reflected components of solar and long-wave radiation and pressure were installed. An automatic rain gauge was also installed.

The following are Instruments and brief descriptions about them.

1. Temperature sensor(Make :- Retronix, Range :- -40 to 60 C)
2. Relative Humidity sensor(Make :- Retronix, Range :- 0 to 100%)

3. Pressure Sensor (Make :- Vaisala, Range :- 800 to 1060 hpa, Accuracy at 20 deg C 0.3 hpa)
4. Wind sensor i. Wind speed (Rotor type, Make :- Young, range :- 0 to 60 m/s)
   ii. Wind direction (Range: - 360 deg mechanical, 355 electrical)
5. Rain gauge (Make :- Young)
6. Radiation sensors (Make: - Eppley lab.)

Figs. 9 to 13 show typical examples of diurnal verifications of various surface meteorological fields as measured by slow sensors.

4.5 Radiation and skin surface temperature measurements:

(Team: M.V. Subrahmanyam, Andhra University)

The radiation measuring instruments- Albedometer and Pyrgeometer, (Make: Kipp & Zonen, Netherlands) were installed onboard ORV Sagarkanya on 18^{th} April 2005 and started collecting the data of incoming & reflected short-wave and incoming & outgoing long-wave radiative fluxes. The IR-Pyrometer (Make: Heitronics, Germany) was installed and the ocean surface skin temperature data were recorded at 1min interval from 21 April 2005. Tilt Sensor was installed and information on ship's pitching & rolling also was collected at regular intervals from 28 April 2005. Diurnal variations of radiative fluxes and skin surface temperature on a day of glossy sea surface of 24 April 2005 are presented in Figs. 14 and 15.

4.6 Atmospheric Aerosol Studies:

(Team: V S Nair & D P Alappattu / SPL; S T Panicker/ IISc)

Characterisation of spatio-temporal heterogeneities in aerosol properties over Indian landmass and surrounding ocean is one of the main objectives of ISRO Geosphere Biosphere Programme (I-GBP). Atmospheric Aerosol Group of Space Physics Laboratory (SPL) and Indian Institute of Science (IISc) have participated in this cruise for measuring different aerosol parameters over the Arabian Sea during pre-monsoon period. The tremendous potential of aerosols to modify the climate through the direct and indirect interaction with solar radiation and clouds got the attention of the scientific community very recently. So we need an exact physical characteristics database of atmospheric aerosols present over the land as well as over the ocean.

The aerosol study group has the following objectives:

1. Measurement of the number size distribution of atmospheric aerosols
2. Recording of Black Carbon (SOOT) in Marine Atmosphere.
3. Estimation of the Aerosol Optical Depth (AOD) and its spatial and temporal variations.
4. Collection of aerosol samples for chemical analysis.

Following instruments were used to collect the necessary data on aerosol properties during the cruise:

1. Microtops Sun Photometer
2. Microtops Ozone Monitor
3. Aethalometer
4. Grimm Optical Particle Counter
5. High Volume Sampler

Sun Photometer & Ozone Monitor:

Sun Photometer is an instrument used for measuring the Aerosol Optical Depth (AOD) at five different wavelengths (340 nm, 380 nm, 500 nm, 675 nm, and 870 nm). AOD is a measure of extinction of solar radiation due to Atmospheric Aerosols and it is the one of the major inputs required for the calculation of radiative forcing. Spectral dependence of AOD demands a multi wavelength Sun Photometer for understanding its variation with different wavelengths of solar radiation. Microtops Sun Photometer and Ozone Monitor are handy, accurate instruments, which can be synchronized with Global Positioning System (GPS).

Grimm Optical Particle Counter

Grimm Optical Particle Counter (OPC) is a sophisticated instrument used for measuring the number size distribution of atmospheric aerosols very accurately. This instrument can count the particles in fifteen different size ranges. Now we are operating the instrument in 0.3 micrometer to 20-micrometer range. It counts the number of particles present per litre in the particular size range. It takes data every one-minute and stores in an internal memory card. We can interface the instrument to a Personal Computer (PC) and online mode of operation is also possible.

Aethalometer

Aethalometer is an instrument used for measuring the Black Carbon (BC) or Soot present in the Atmosphere. We are using one portable Aethalometer for cruise and air borne measurements. Black Carbon (BC) is one of the major anthropogenic Aerosol that can absorb solar radiation in the visible region. So its impacts on our climate are higher than other scattering type Aerosols. Aethalometer sucks the air from the ambient at a rate of 3.0 litres per minute and deposit the aerosols on a quartz fibre filter tape. Then it measures the amount of Black Carbon present in the air.

High Volume Sampler

Chemical composition of atmospheric aerosols is also an important topic of Aerosol Science. High Volume Sampler (HVS) is an instrument used for collecting atmospheric aerosols from different locations. Main working part of the High Volume Sampler (HVS) is a motor that continuously suck the air from the ambient for three to six hours depending on the concentration of aerosols and deposit on a filter paper placed just in front of the mouth of the motor. Through a series of chemical analysis of the aerosols collected on the filter paper from different location reveals the chemical composition or chemical constituents of aerosols in that location.

Figs. 16 to 18 present the diurnal variability of AOD (500 nm); Number of aerosols distributed size wise and Black Carbon during certain days of the cruise.

6. Recommendations:

a) Sufficient stock of CTD sensors especially those accuracy drifting past is to be maintained. It is recommended to have a minimum four sets of conductivity and temperature sensors for both Idronaut and SBE 911 CTD systems so that the situation will be comfortable even if two sets of the sensors are sent at a time to the manufacturers for calibration. Routine calibration of CTD sensors has to be given an utmost importance as quality of data is more important than mere collection of large quanity of lesser accurate data.

b) Air-conditioning was not effective in the port dry and wet laboratories of the ship and some of the ship's cabins. Remedial measures are to be taken to control the temperatures.

c) The thermo-salinograph was to be calibrated as it was giving erroneous data.

7. Acknowledgements:

We acknowledge the Department of Ocean Development (DOD), Govt. of India for allotting the ORV Sagar Kanya time to facilitate the current meter moorings under ARMEX Phase II project. The funding support of Dept. of Science & Technology (DST), Govt. of India for organizing the cruise is very much appreciated. The participants thank the Capitan, Officers and Crew members of *ORV Sagar Kanya* for their good cooperation extended during the cruise.

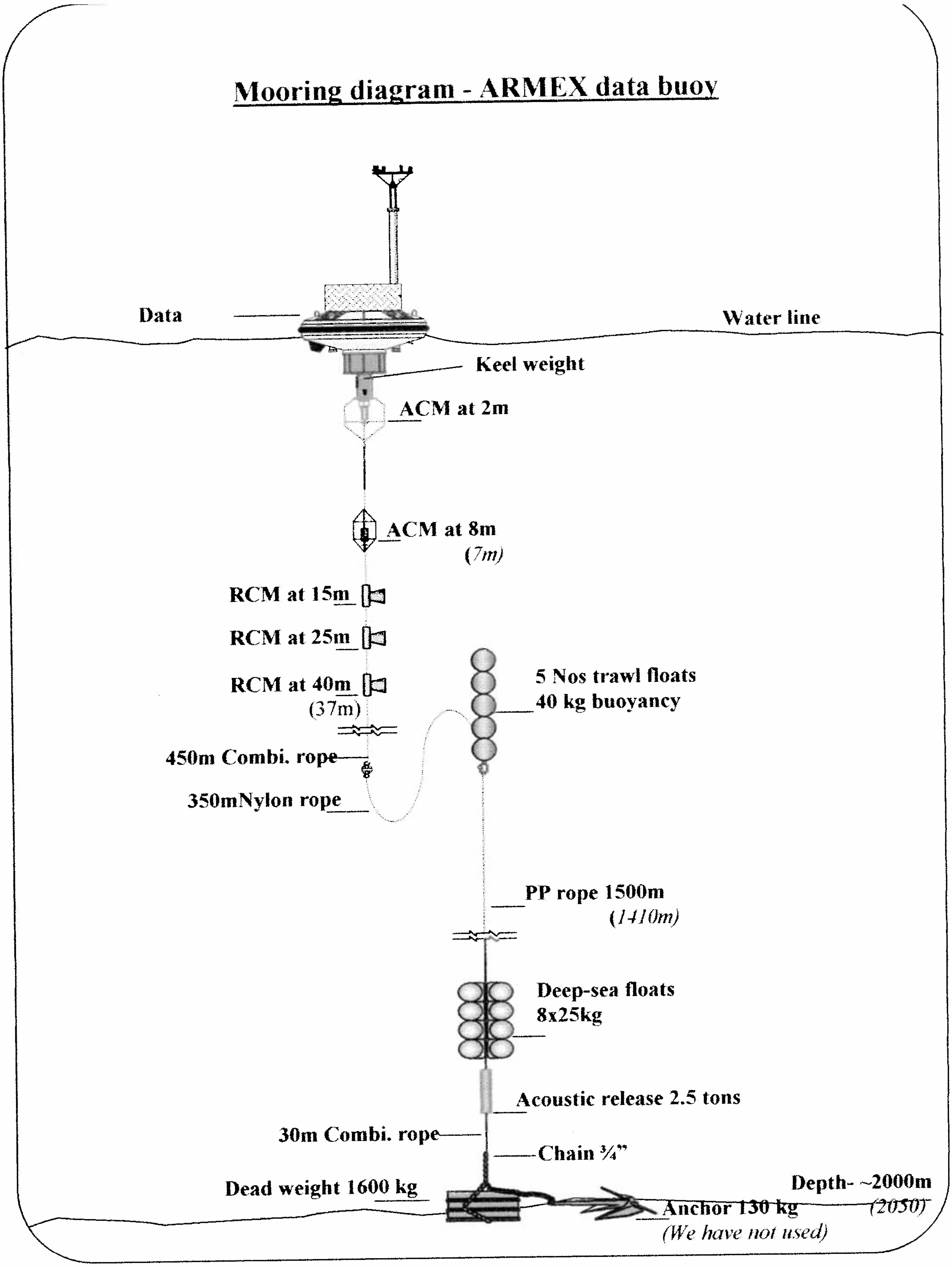
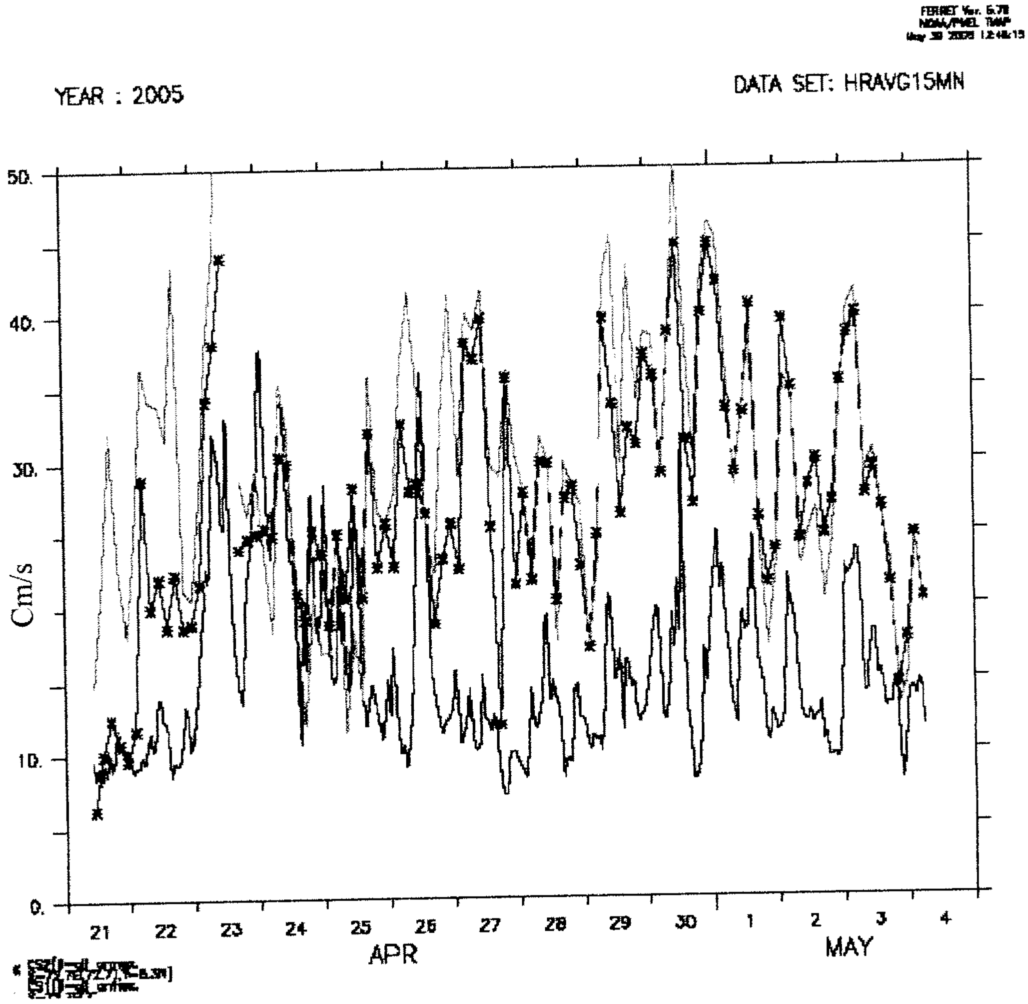


Fig.2 The configuration of Current Meter mooring



Current Speed (Cm/s)

Fig. 3 Variation of current speed at 2 m (green), 7 m (red) and 15 m (black)

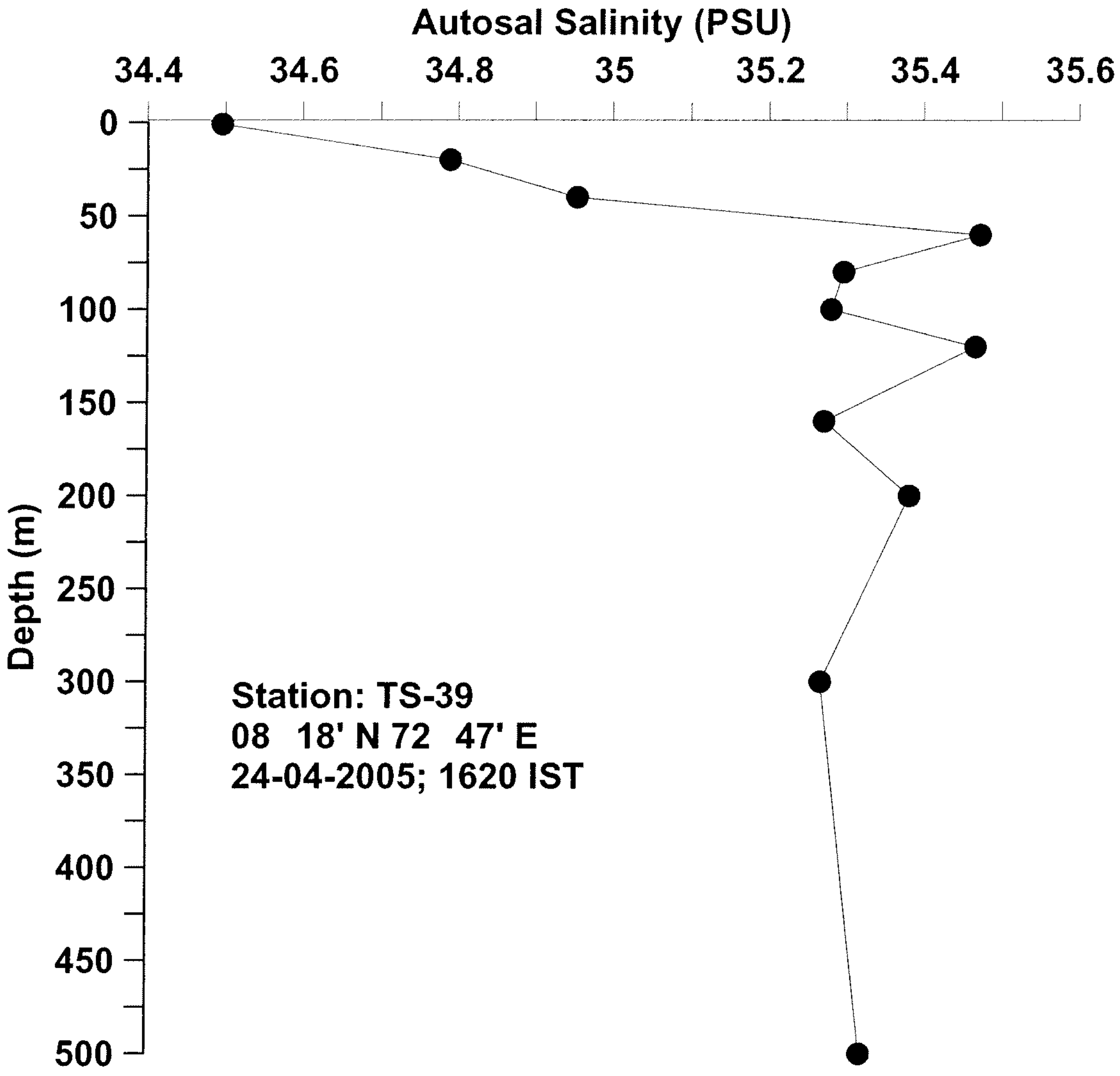


Fig. 4 Vertical Profile of AUTOSAL Salinity at the Eastern location on 24 April 2005

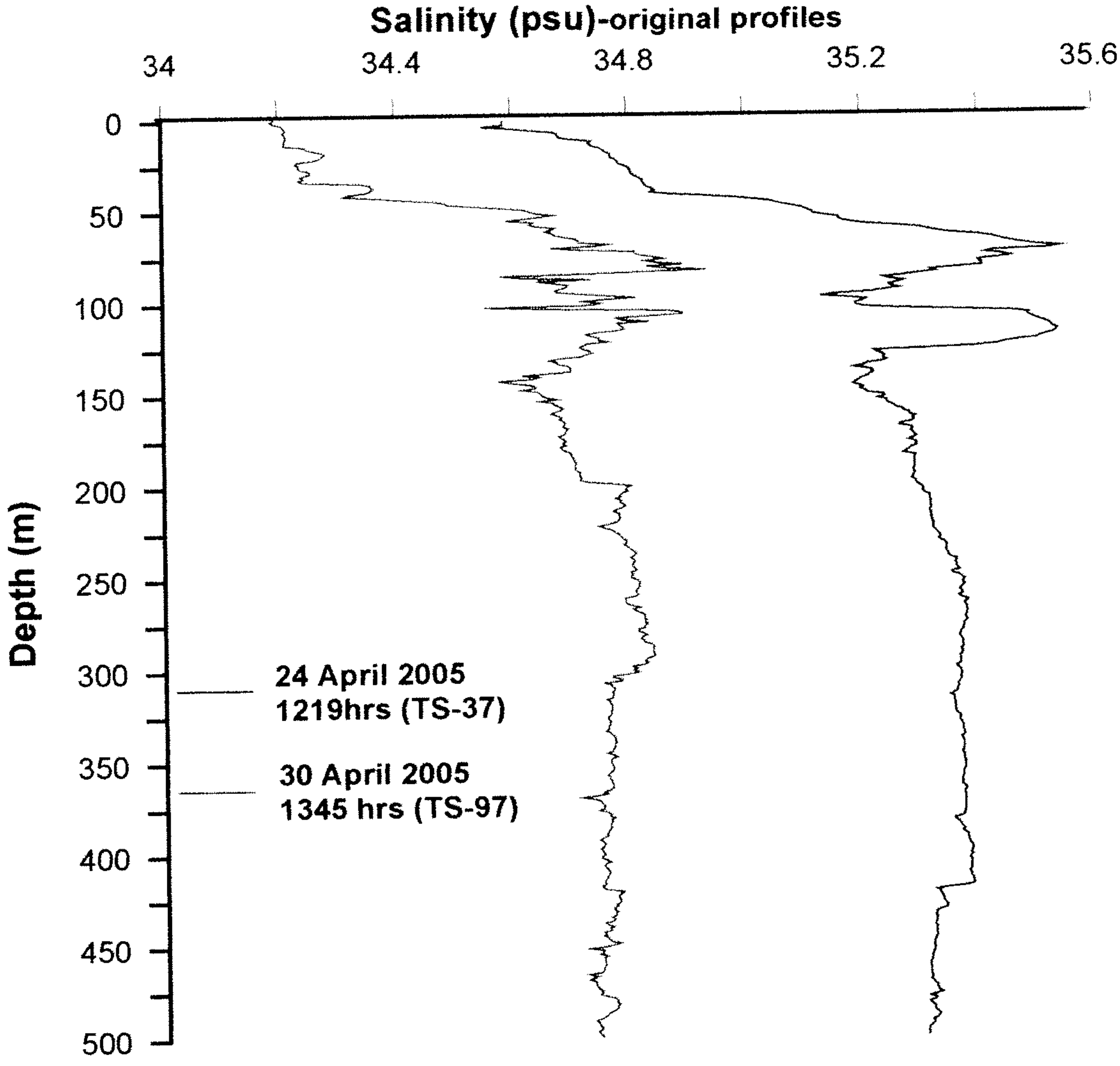


Fig. 5 Vertical Profiles of IDRONAUT CTD Salinity (Original and uncorrected) at the Central Location on 24 and 30 April 2005

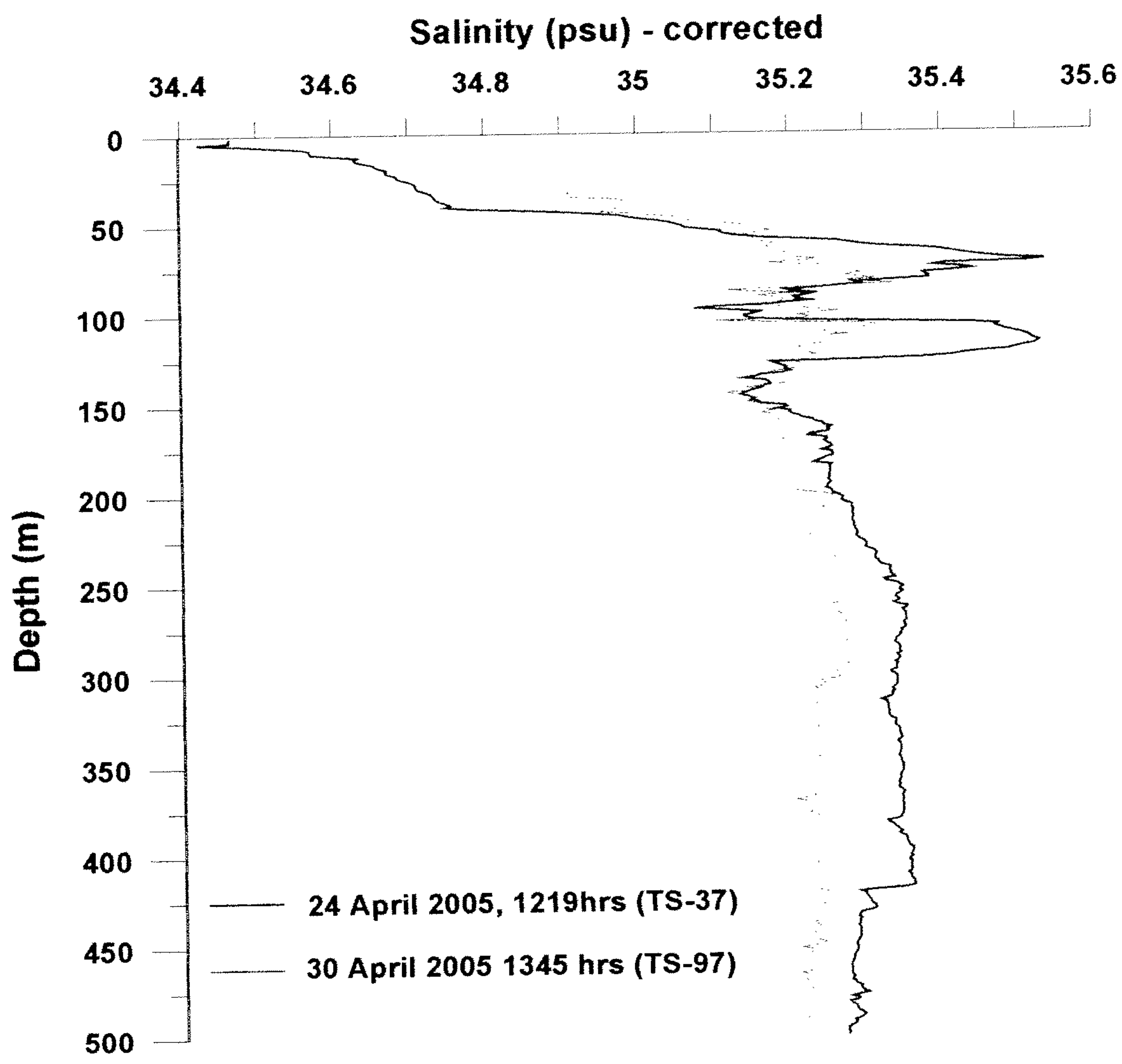


Fig. 6 Vertical Profiles of IDRONAUT CTD Salinity (corrected) at the Central Location on 24 and 30 April 2005

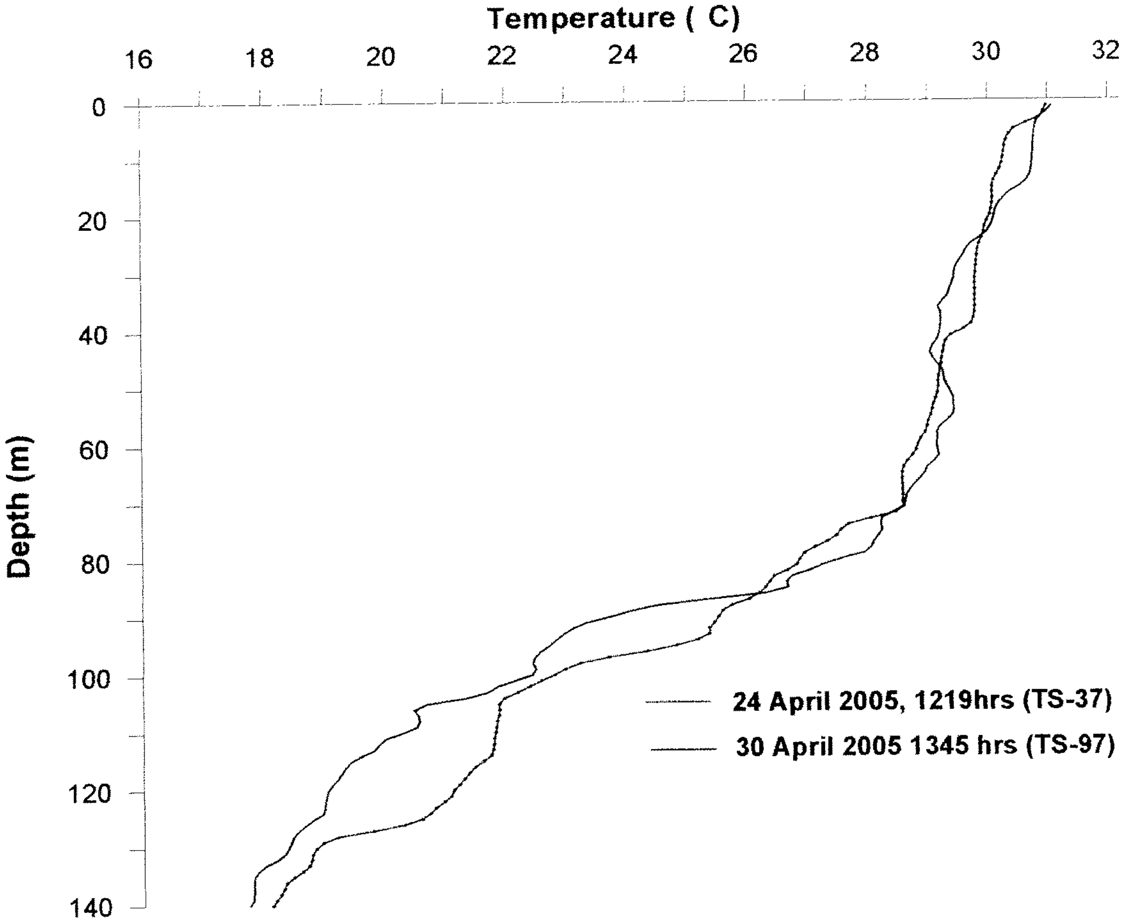


Fig. 7 Vertical Profiles of IDRONAUT CTD Temperature in the upper 140 m at the Central Location on 24 and 30 April 2005

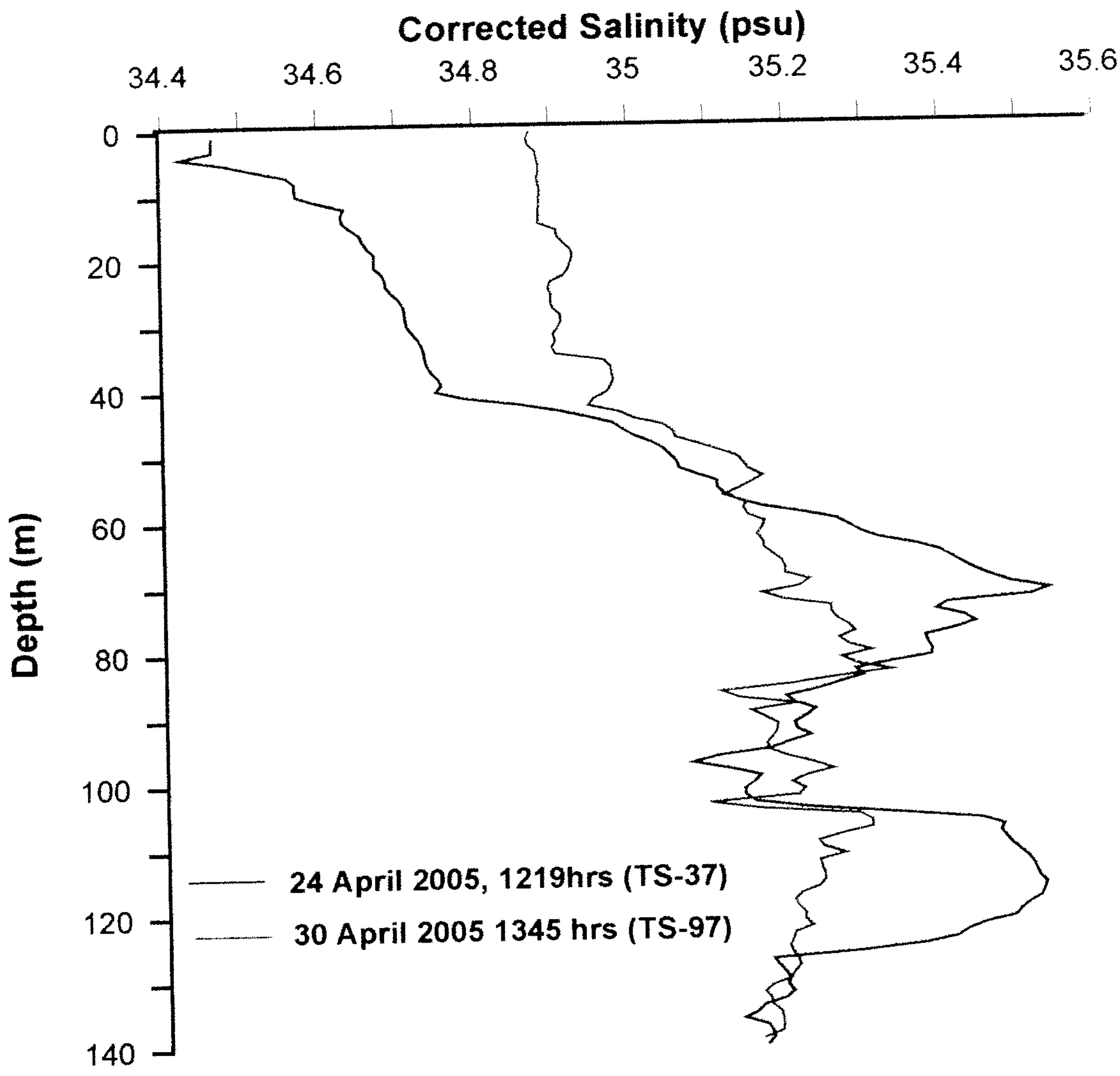


Fig.8 Vertical Profiles of IDRONAUT CTD Salinity (corrected) at the Central Location on 24 and 30 April 2005

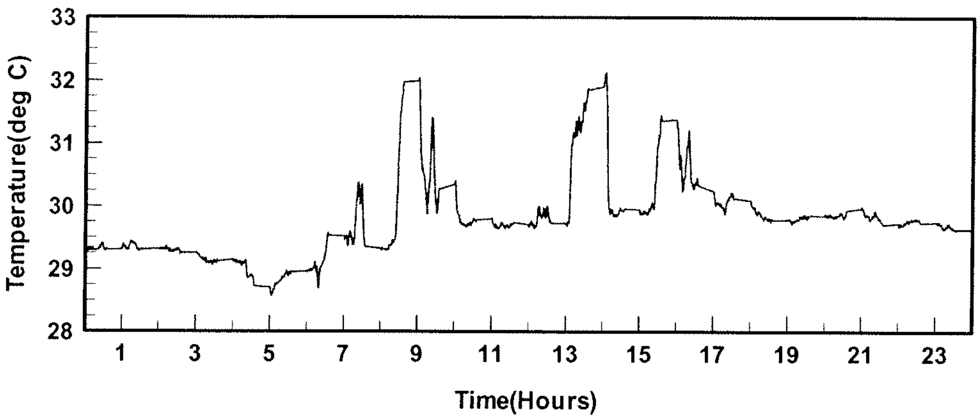


Fig.9 Diurnal variation of surface air temperature

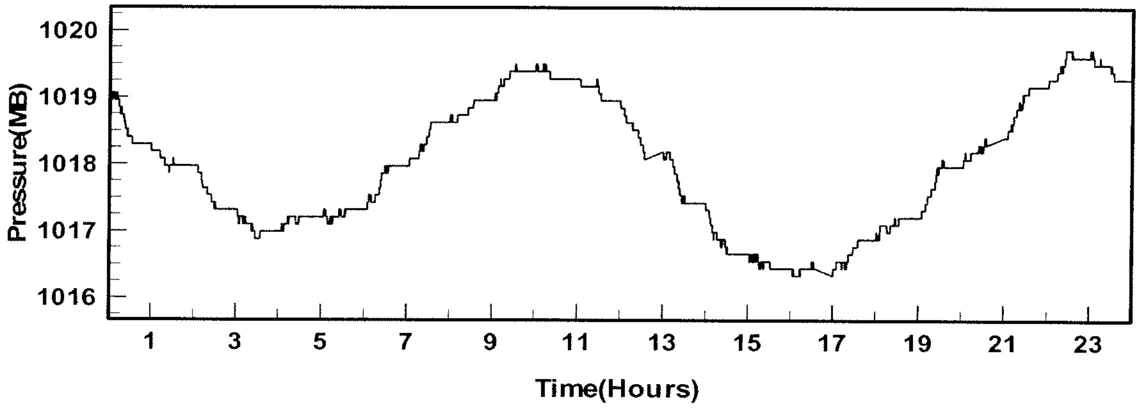


Fig. 10 Diurnal variation of surface atmospheric pressure

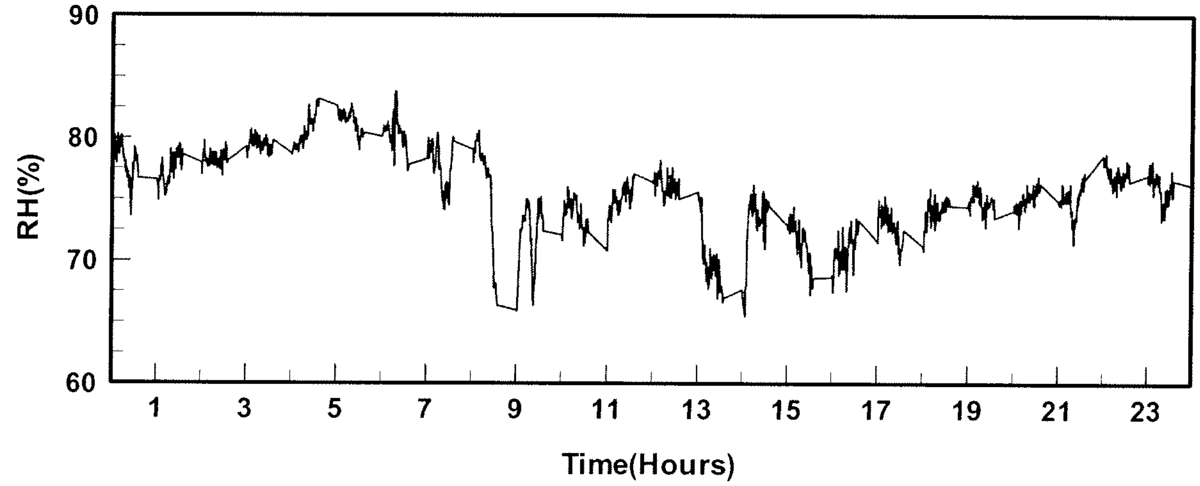


Fig. 11 Diurnal variation of surface relative humidity

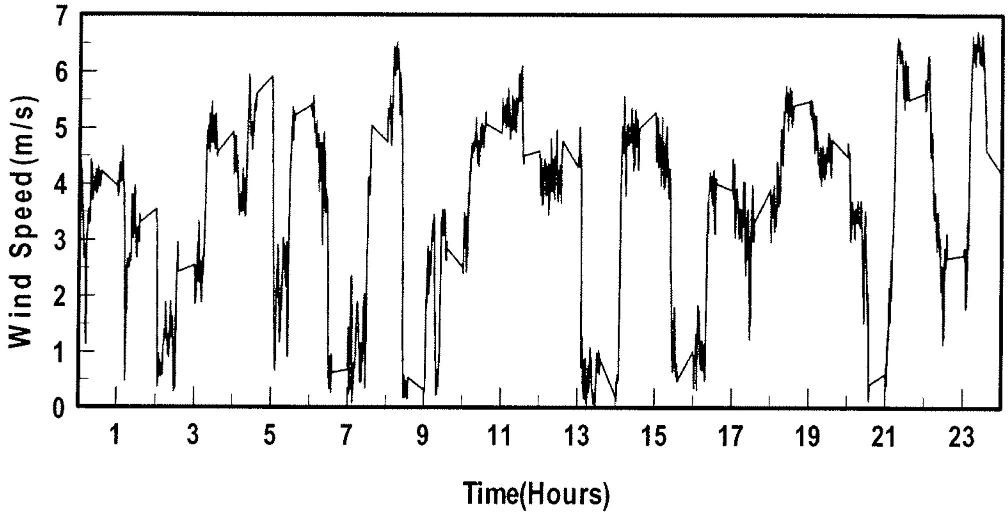


Fig. 12 Diurnal variation of surface wind speed

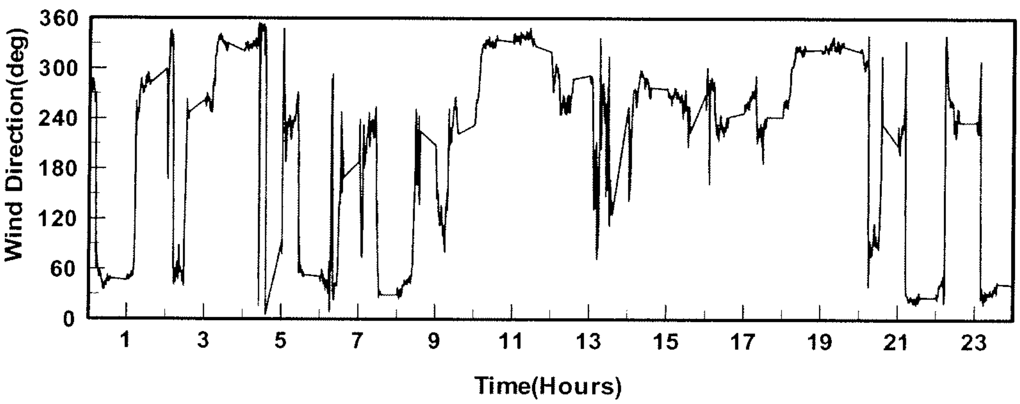


Fig. 13 Diurnal variation of surface wind direction

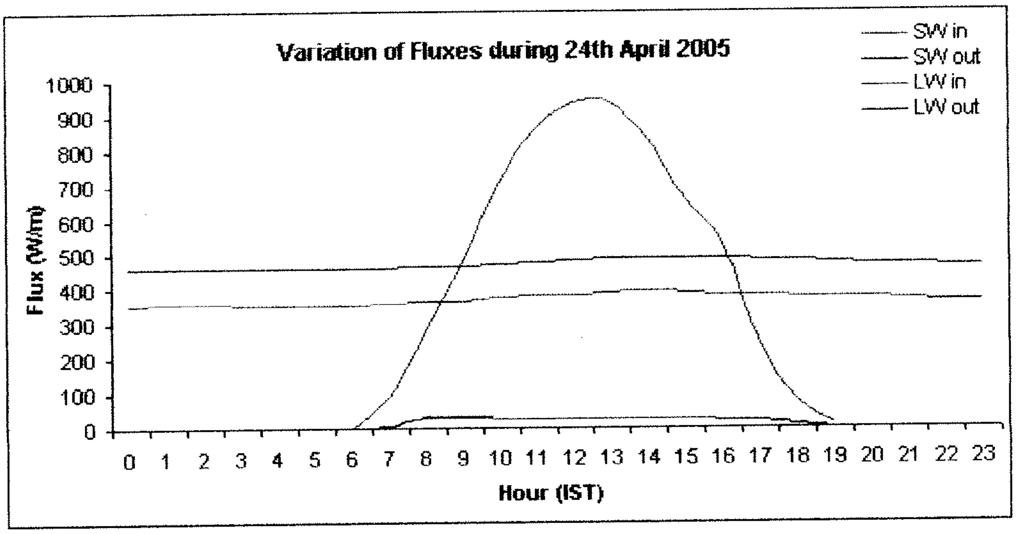


Fig. 14 Diurnal variation of radiative fluxes during 24/04/2005

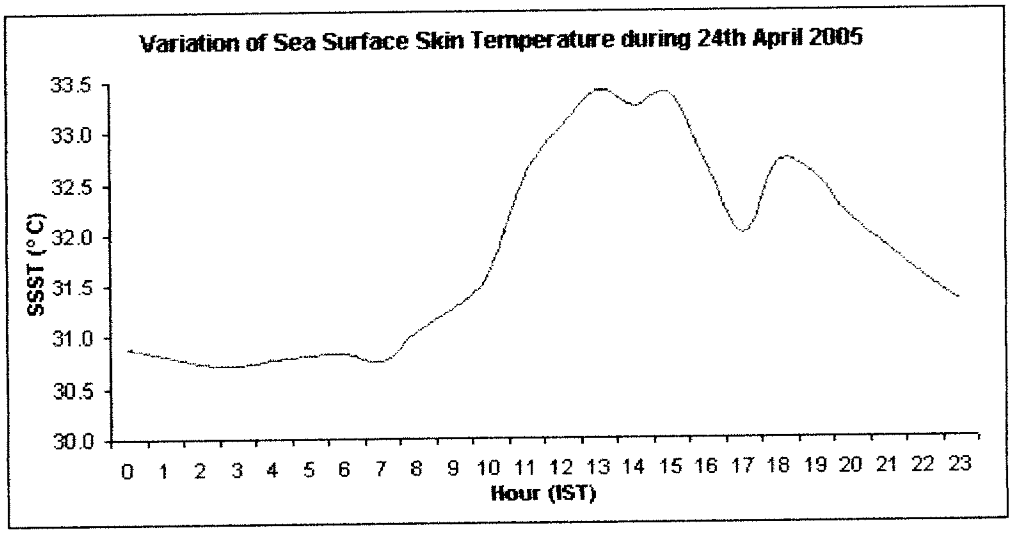


Fig.15. Diurnal variation of Sea Surface Skin Temperature during 24/04/2005

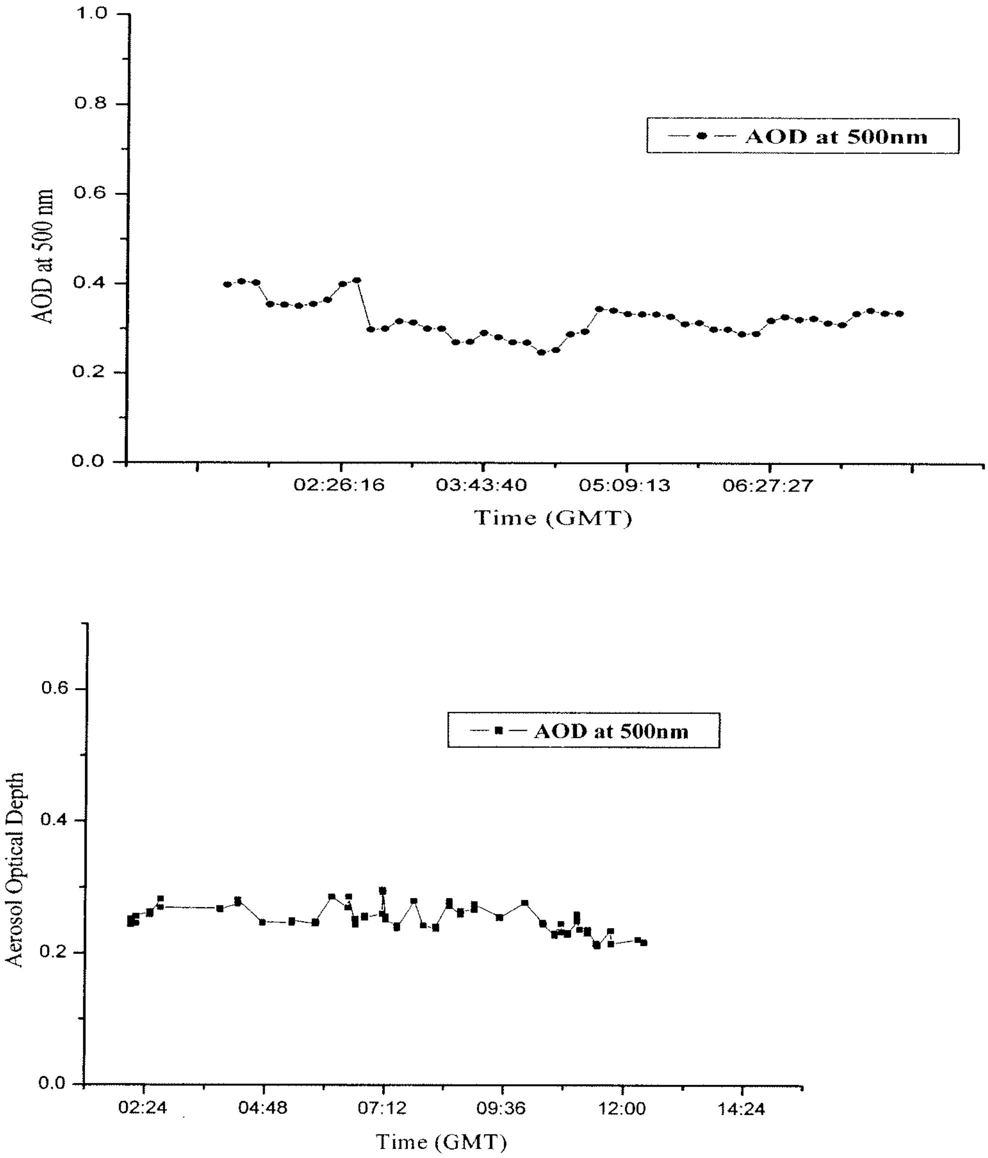


Fig.16 Aerosols Optical Depth at 500nm on 21-04-2005 and 29-04-2005

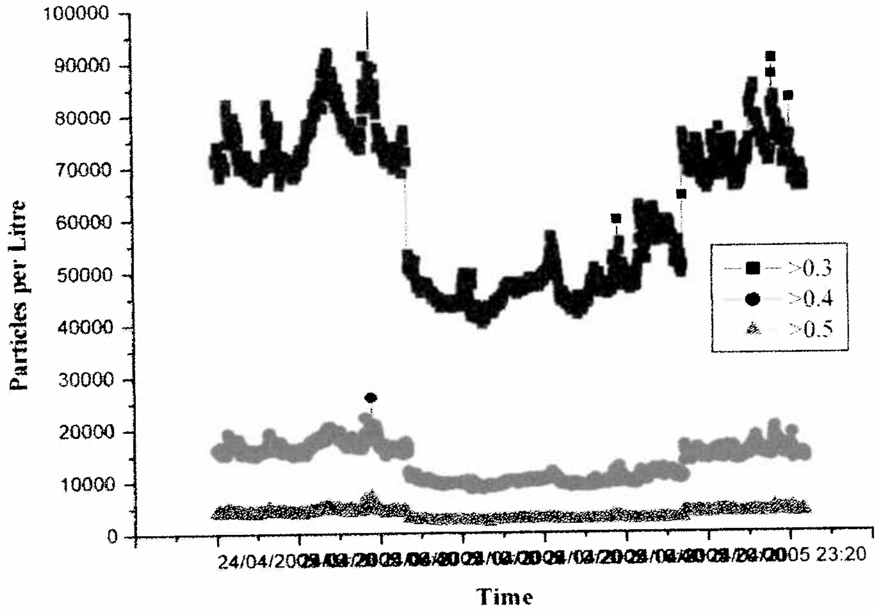


Fig.17 Number size distribution of Aerosols on 22-04-2005 and 24-04-2005 in three different size ranges (0.3μm, 0.4μm, 0.5 μm).

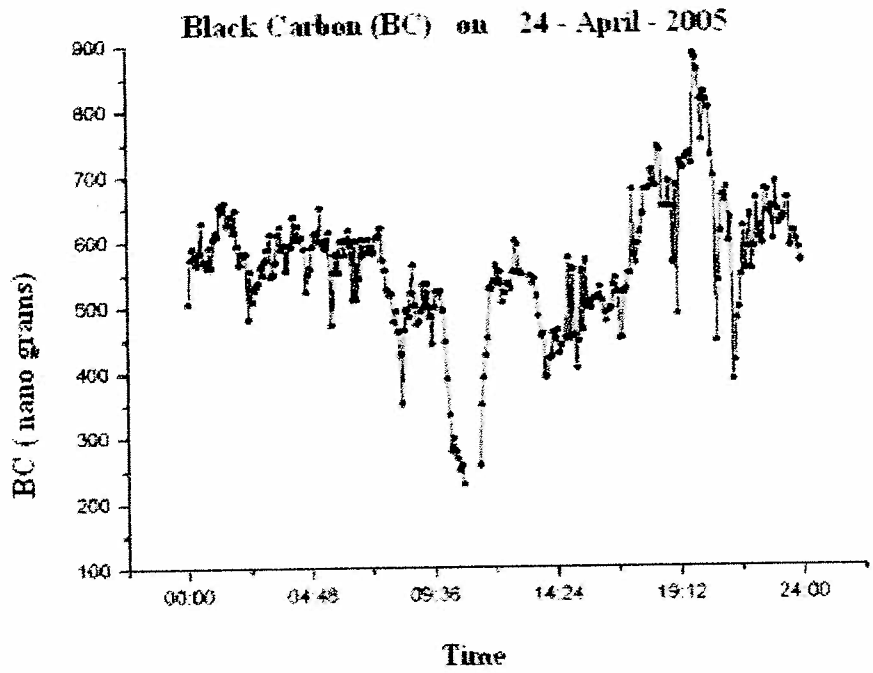


Fig.18 Diurnal variation of Black Carbon present in the surface air mass.

Appendix 'A'

Acoustic Release (Model: AR 661 B2S – DDL) Turnaround Checklist for ORV Sagar Kanya cruise (No.219)

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1) AR 661 B2S-DDL S/N: 724

INT-RANGE CODE: **4B70** RELEASE CODE: **4B79** FREQUENCY: **12.OKHz**

Step 1	-RECOVERY *Inspect exterior and clean with fresh water.*	*OK*
Step 2	-REPLACE BATTERIES Old Battery voltage New Battery voltage	-- 9.70 (D) & 9.54 (9v) Volts
Step 3	-Inspect /clean O-rings and grooves Very lightly grease O-rings and metal face seal	**OK**
Step 4	-Close housing, purge with nitrogen	**OK**
Step 5	-Tighten all bolts	**OK**
Step 6	-SYSTEM TEST Release command Acknowledgement pulse Release after 3 seconds Execution pulse Interrogate/ranging command Single transpond	 **OK** **OK** **OK** **OK** **OK** **OK**
Step 7	-RE-ARMING Insert release ring and fit locking shaft	**OK**

Comments: Nil

Organisation: NIO, Goa

Checks carried by: Areef A.Sardar

Deployment Date: 21/04/2005

Cruise: SK-219

Station: ARMEX BUOY-6

Retrieval Date : 04/05/2005