

SOUTHWEST TROPICAL INDIAN OCEAN EXPERIMENT

Cruise Report  
(SK-290)

Submitted to

NATIONAL CENTRE FOR ANTARCTIC AND OCEAN RESEARCH

Headland Sada, Vasco-da-Gama, Goa.

By

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## 1. Introduction

South-western region of the tropical Indian Ocean (5°S to 10°S and 50°E to 80°E) is unique due to the significant sea surface temperature variations observed there in different timescales, in comparison with the other regions of Indian Ocean. Aforementioned SST variations in the South West Tropical Indian Ocean (SWTIO) cannot be explained by the surface heat flux anomalies alone. Apart from this, due to the shallow mixed layer, the surface layer of SWTIO is highly sensitive to the atmospheric fluxes. Vertical turbulence effectively exchanges heat with the thermocline and this mixing brings the cold thermocline water to the surface. Interestingly, SST in SWTIO is much warmer (28°C annual mean) than the surface waters from other upwelling tropical regions like eastern equatorial Pacific Ocean or Atlantic Ocean. Presence Indonesian through flow and of Seychelles Chagos thermocline ridge plays an important role in regulating the different physical processes in this region. Apart from this, during austral summer, MJO initiation takes place around the SWTIO region. The physical changes associated with ocean and atmosphere occurring during these processes is not well documented. Since above mentioned processes shows maximum activity during October to December period a scientific cruise was conducted over SWTIO from 27<sup>th</sup> October

to 21<sup>st</sup> November, 2011. This experiment was designed to address following objectives,

- 1) To identify the presence of Indonesian throughflow and possible influence on the stratification and SST in SWTIO.
- 2) To study the dynamics of Saline front in SCTR.
- 3) Investigation of turbulence structure and mixing in SCTR region.
- 4) To delineate source waters present in SCTR related to the Subtropical cell.
- 5) To investigate the role of air-sea interaction in MJO initiation and maintenance.

## 2. List of Participants

<b>Sl No.</b>	<b>Name</b>	<b>Institute</b>	
1	Dr. Denny P. Alappattu	NCAOR, Goa	Chief Scientist
2	Mr. Jenson V. George	NCAOR, Goa	
3	Mr. Santhosh Muraleedharan	SPL, TVM.	Deputy Chief Scientist
4	Mr. Akhil Babu	NIO, Goa	
5	Mr. Ullas Nanappan	NIO, RC Kochi	
6	Mr. Prashob Peter	CUSAT, Kochi	
7	Mr. Ratheesh kumar	CUSAT, Kochi	
8	Mr. Kumara Swami Munnoor	Mangalore	

		university
9	Mr. Bibin Abraham	NCAOR, Goa
10	Mr. Sandesh S. Dicholkar	NCAOR, Goa
11	Mr. Biju V. Nair	NORINCO
12	Mr. Thachezhath Baiju	NORINCO
13	Mr. Kaliraj Vijayaraghavan	NORINCO
14	Mr. Barreto Ryan Damaciano	NORINCO

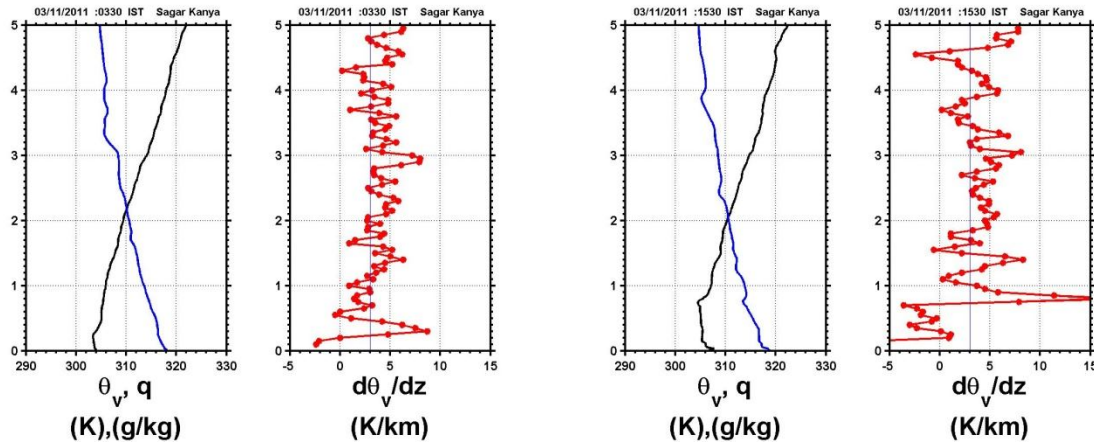
### **3. Observations and Data/Sample Collection Carried Out During the Cruise**

#### **3.1 Atmospheric Science**

The objective of the expedition was to study the Atmospheric Boundary Layer features in the Tropical Indian Ocean through a suite of different instruments.

##### *The GPS sonde:*

The Dr Pisharoty sonde developed by ISRO was used to study the vertical thermodynamic and dynamic profile of the Atmosphere. Balloon borne GPS sonde ascents were conducted regularly everyday at 0330 and 1530 local time. The idea was to characterise the atmospheric boundary layer during the convective period of the day and 12 hours after during night time. The profiles show some variation as shown in the figure below



**Figure 1.** Virtual Potential temperature (black line) and Specific Humidity profiles (blue line biased by 300 g/kg) along with the rate of change of virtual potential temperature with height (red line) shows there is variation in the atmospheric mixed layer height as the day progresses for a clear sky day.

Besides the regular ascents of GPS sonde there was a time series of ascents conducted at 4 hour interval at times 0330, 0730, 1130, 1530, 1930, 2330 LT respectively for 4 days. It covered the investigation of atmospheric boundary layer for cloudy days as well as clear sky days in the location 8°S 68°E.

NRG systems Inc. Automatic Weather Station was also used to collect surface meteorological data through wind sensors fitted at 7m height and 10 m height. The temperature and humidity sensors were at 10m height. This data was sampled at an interval of 10 minutes.

In addition to these instruments this time we conducted a pilot experiment to observe the fluxes in the atmospheric boundary layer through sonic

anemometer. The sonic anemometer was fixed to a pole in front of the ship. The sonic anemometer is sensitive to the rolling and pitching of the ship. Hence a pitch, roll and yaw sensor was fitted near to the sonic anemometer. The data from this instrument will be used to correct the readings of sonic anemometer affected due to ship movement. This is one of the first times that the sonic anemometer is used in conjunction with the GPS sonde ascents to characterise the atmospheric boundary layer in the Indian Ocean. The ship was made stationery half an hour before and after a balloon borne GPS sonde ascent so that data of surface fluxes is collected from the sonic anemometer.

A total of 76 GPS sonde ascents were conducted in the campaign. The vertical thermodynamic profiles through this data along with the surface data through automatic weather station and sonic anemometer form a valuable data set to conduct Atmospheric Boundary layer studies.

Another experiment conducted in course of this cruise is the GPS sonde ascents with timings coinciding with the recently launched Megha Tropiques satellite over pass. The present expedition SK-290 provided a unique opportunity for the validation of this satellite data over the ocean. A total of 14 GPS sonde

ascents were conducted for the purpose since 16 November 2011 when the overpass co-ordinates became available.

### 3.2 Physical Oceanography

To have a better understanding of diurnal variation of thermohaline structure of Upper Ocean, a time series CTD observations were carried out at three hour interval at 8°S and 68°E from 7/11/2011 14:00 hrs to 09/11/2011 12.00 hrs. Eight simultaneous XBT- XCTD- CTD observations were also carried out at the Time series location (8°S, 68°E) to understand the depth error associated with the XCTD and XBT.

#### Time Series CTD Observations

SN	Station	Date	Time (hrs)	CTD (SBE)	Maximum Depth	Wind Speed (kts)	Wind Direction	Water Samples/MPN
1	TS0114	07/11/11	14:00	911 plus	500m	16	107	Water Samples
2	TS0118	07/11/11	18:00	911 plus	500m	11	117	Water Samples + MPN
3	TS0122	07/11/11	22:00	911 plus	1000m	21	94	nil
4	TS0200	08/11/11	00:00	911 plus	500m	18	108	Water Samples + MPN
5	TS0203	08/11/11	03:00	911 plus	500m	19.7	90	nil
6	TS0206	08/11/11	06:00	911 plus	500m	16	56	Water Samples + MPN
7	TS0209	08/11/11	09:00	911 plus	500m	10	48	nil
8	TS0212	08/11/11	12:00	911 plus	324m	13	44	nil
9	TS0220	08/11/11	20:00	911 plus	296m	4	200	nil

10	TS0221	08/11/11	21:00	911 plus	2000m	8.5	115	nil
11	TS0300	09/11/11	00:00	911 plus	500m	15.6	117	Water Samples + MPN
12	TS0303	09/11/11	03:00	911 plus	500m	19.9	102	nil
13	TS0306	09/11/11	06:00	911 plus	500m	15	90	Water Samples + MPN
14	TS0309	09/11/11	09:00	911 plus	500m	30	330	nil
15	TS0312	09/11/11	12:00	911 plus	500m	10.6	110	MPN

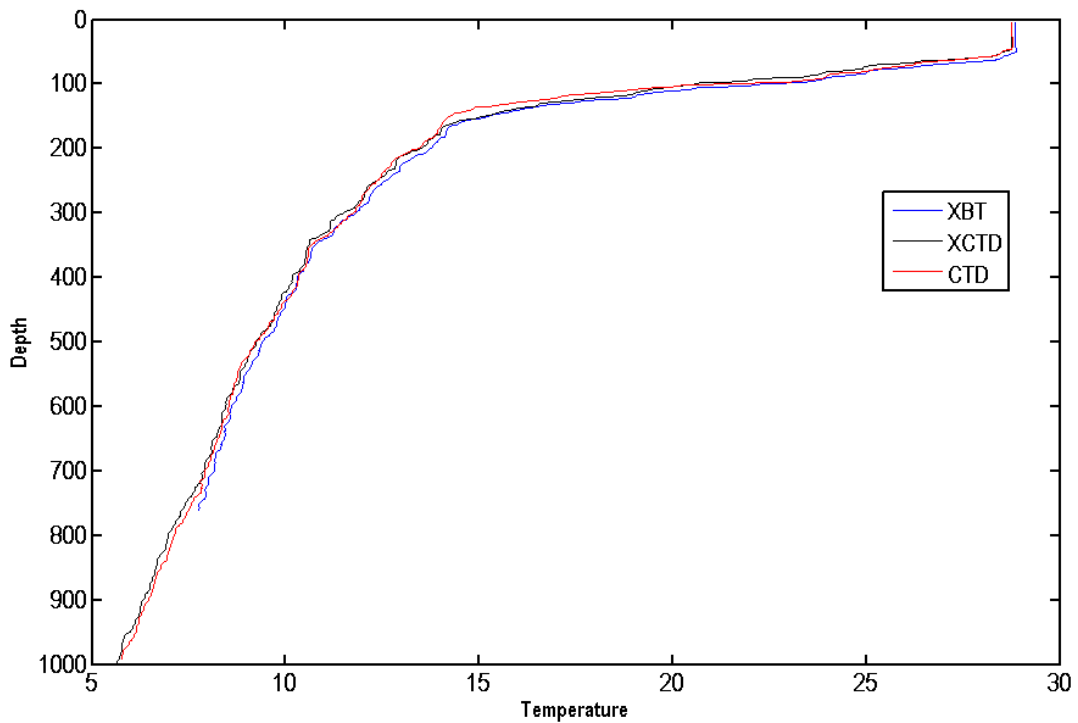
CTD-XCTD-XBT Comparison

SN	Station	Date	Time	CTD (SBE)	Wind Speed (kts)	Wind Direction	SST	Operation
1	TS0122	07/11/11	22:00	911 plus	21	94		CTD+XCTD+XBT
2	TS0221	08/11/11	21:00	911 plus	8.5	115		CTD+XCTD+XBT
3	TS0622	11/11/11	22:00	19plus	14	125		CTD+XCTD+XBT
4	TS0720	12/11/11	20:00	19plus	10.2	005		CTD+XCTD+XBT
5	TS0806	13/11/11	06:00	19plus	4.4	86		CTD+XCTD+XBT
6	TS0812	13/11/11	12:00	19plus	5.4	83.2		CTD+XCTD+XBT
7	TS0818	13/11/11	18:00	19plus	7.3	103		CTD+XCTD+XBT
8	TS0821	13/11/11	21:00	19plus	9.3	113		CTD+XCTD+XBT



Multi plankton Net

SN	STN	Date	Time	Volume Filtered (m <sup>3</sup> )			
				0 – 60m	60 – 150m	150 – 300m	300– 500m
1	TS0118	07/11/11	18:00	28	29	43	66
2	TS0200	08/11/11	00:00	21	27	43	64
3	TS0206	08/11/11	06:00	15	28	46	56
4	TS0300	09/11/11	00:00	17	27	47	66
5	TS0306	09/11/11	06:00	19	29	54	68
6	TS0312	09/11/11	12:00	17	29	48	62



**Figure 2:** XBT, XCTD and CTD Comparison at station TS0122

### XBT Firings and Drifter Deployment

No.	Probe type	latitude	longitude	Sl.no	Date & time
1	Xbt	10 56.63N	74 14.23E	1114773	31/10/11 , 21:26
2	Xbt	9 36.443N	74 20.408E	1114769	01/11/11 , 07:07
3	Xbt	8 59.211N	74 22.25E	1114777	01/11/11
4	Xbt	7 57.739N	74 23.72E	1114772	01/11/11 , 19:05
5	Xbt	6 59.46N	74 25.36E	1114767	2/11/11 , 01:17
6	Xbt	5 57.742N	74 27.223E	1114771	02/11/11 , 08:10
7	Xbt	5 0.255N	74 29.793E	1114775	02/11/11 , 14:08
8	Xbt	3 59.129N	74 50.499E	1114776	02/11/11 , 21:58
9	Xbt	3 0.450N	75 12.754E	1114770	03/11/11 , 05:08
10	Xbt	1 59.476N	75 24.733E	1114774	03/11/11 , 12:08
11	Xbt	1 1.099N	75 26.023E	1114937	03/11/11 , 19:04
12	Xbt	01.611N	75 25.544E	1114941	04/11/11 , 02:02
13	Xbt	1 1.300S	75 10.866E	1114945	04/11/11 , 10:46
14	Xbt	2 0.196S	74 6.724E	1114936	04/11/11 , 22:44
15	Xbt	2 59.381S	72 56.893	1114940	05/11/11 , 10:27
16	Xbt	4 1.868S	71 46.014S	1114944	05/11/11 , 21:27
17	Xbt	5 0.097S	70 39.638E	1114935	06/11/11 , 08:00
18	Xbt	5 59.564S	69 47.03E	1114939	06/11/11 , 17:49
19	Xbt	7 0.734S	68 51.774E	1114943	07/11/11 , 02:19
20	Xbt	7 59.953S	68 0.0200E	1114942	07/11/11 , 13:05
21	Drifters	4 0.304N	74 50.028E	54129	02/11/11 , 21:50
22	Drifters	2 0.770N	75 24.619E	53642	03/11/11 , 11.50

23	Drifters	0 03.05	75 25.03	53933	04/11/11 , 02:13
24	Drifters	1 59.106S	74 7.901E	55608	04/11/11,22:39
25	Drifters	4 00.29S	71 47.81E	53936	05/11/11 , 21:09
26	Drifters	1 52.613N	75 15.368E	53641	18/11/11 , 08:00
27	Drifters	2 53.363N	75 20.894E	53932	18/11/11 , 18:26
28	Drifters	3 26.546N	75 22.885E	55562	18/11/11 , 23:17

### 3.3 Biological Studies

Water samples were collected from South West Tropical Indian Ocean (8°S 65°E) for analyzing the characteristics and diurnal variations of biological parameters like chlorophyll *a* and phytoplankton assemblage. 8 different standard depths were selected for sample collection, viz; surface, 20m, 50m, 75m, 100m, 150m, 200m and from the depth of Deep Chlorophyll Maxima (DCM). Daily 4 collections were made with 6 hours' interval, starting from midnight (00:00 Hrs). Water samples were used to analyze total chlorophyll *a*, fractionated chlorophyll (Macrophytoplankton, Microphytoplankton, Nanophytoplankton, and Picophytoplankton) and phytoplankton species density and diversity.

Date	Time Series	Time	Depths (m)	Parameters
07.11.2011	TS 01	12:00	0, 20, 50, 75, 100, 150, 200 and DCM	Total Chl <i>a</i> , Fraction, Phytoplankton
07.11.2011	TS 01	18:00	0, 20, 50, 75, 100, 150, 200 and	Total Chl <i>a</i> , Fraction,

			DCM	Phytoplankton
08.11.2011	TS 02	00:00	0, 20, 50, 75, 100, 150, 200 and DCM	Total Chl <i>a</i> , Fraction, Phytoplankton
08.11.2011	TS 02	06:00	0, 20, 50, 75, 100, 150, 200 and DCM	Total Chl <i>a</i> , Fraction, Phytoplankton
09.11.2011	TS 03	00:00	0, 20, 50, 75, 100, 150, 200 and DCM	Total Chl <i>a</i> , Fraction, Phytoplankton
09.11.2011	TS 03	06:00	0, 20, 50, 75, 100, 150, 200 and DCM	Total Chl <i>a</i> , Fraction, Phytoplankton

Another set of water samples, from surface, were collected for analyzing the above said biological characteristics along with physical parameters such as Wind direction and Wind speed, chemical parameters like pH, Dissolved Oxygen, Salinity and Nutrients. The stations and details are as follows.

Sl. No.	Date	Time	Location
1	14.11.2011	11:20	6°59.48'S 68°54.17'E
2	14.11.2011	14:30	6°40.93'S 69°14.74' E
3	14.11.2011	19:10	6°20.14'S 69°37.76' E
4	14.11.2011	22:30	6°00.42'S 69°58.83' E
5	15.11.2011	01:55	5°40.93'S 70°19.97'E
6	15.11.2011	06:32	5°20.70'S 70°42.11' E
7	15.11.2011	10:00	4°59.98'S 71°05.05' E
8	15.11.2011	19:30	4°40.01'S 71°23.70' E
9	15.11.2011	22:20	4°20.88'S 71°41.24'E

10	16.11.2011	01:20	4°00.97'S 71°58.83'E
11	16.11.2011	04:30	3°40.90'S 72°16.61'E
12	16.11.2011	07:30	3°20.71'S 72°36.54'E
13	16.11.2011	10:30	3°00.97'S 72°54.19'E
14	16.11.2011	13:20	2°40.93'S 73°13.98'E
15	16.11.2011	17:05	2°20.92'S 73°33.40' E
16	16.11.2011	20.05	2°00.90'S 73°55.44' E
17	16.11.2011	23:05	1°40.91'S 74°14.49' E
18	17.11.2011	01:45	1°20.94'S 74°33.83' E
19	17.11.2011	06:02	1°00.91'S 74°54.91' E
20	17.11.2011	08:20	0°40.94'S 74°04.41'E
21	17.11.2011	11.45	0°20.80'S 75°04.73'E
22	17.11.2011	12:50	0°00.97'S 75°07.07'E
23	17.11.2011	23:15	0°20.01'N 75°08.58'E
24	18.11.2011	01.13	0°40.03'N 75°10.63'E
25	18.11.2011	04:48	1°00.00'N 75°12.34' E
26	18.11.2011	07:10	1°22.63'N 75°12.44' E
27	18.11.2011	09:03	1°40.01'N 75°14.13' E
28	18.11.2011	11:45	2°00.15'N 75°16.64' E
29	18.11.2011	13:50	2°20.06'N 75°19.83' E
30	18.11.2011	17:15	2°42.61'N 75°20.21' E
31	18.11.2011	20:10	3°00.06'N 75°20.27' E
32	18.11.2011	22:20	3°20.06'N 75°20.76' E
33	19.11.2011	00:45	3°40.01'N 75°25.15' E

34	19.11.2011	02:50	4°00.23'N 75°30.36' E
35	19.11.2011	06:24	4°20.66'N 75°31.59' E
36	19.11.2011	08:30	4°40.04'N 75°33.06' E
37	19.11.2011	13:30	5°00.00'N 75°37.83' E

### Total Suspended Matter (TSM)

#### Time Series:

A study has been carried out to decipher the changes in TSM during different time periods. 5 liters of sea water samples were filtered to measure the Total Suspended Matters in the study area. Samples were collected from different depths like 0m, 20m, 50m, 75m, 100m, 150m and 200m for each time interval.

Following are the details of the study:

Date	Time Series	Time	Depths (m)
07.11.2011	TS 01	12:00	0, 20, 50, 75, 100, 150, 200
07.11.2011	TS 01	18:00	0, 20, 50, 75, 100, 150, 200
08.11.2011	TS 02	00:00	0, 20, 50, 75, 100, 150, 200
08.11.2011	TS 02	06:00	0, 20, 50, 75, 100, 150, 200
09.11.2011	TS 03	00:00	0, 20, 50, 75, 100, 150, 200
09.11.2011	TS 03	06:00	0, 20, 50, 75, 100, 150, 200

### Transect- Surface Samples:

The Surface samples were analyzed to find the distribution of TSM in the open ocean. Station locations and details are given below:

Sl. No	Date	Time	Location
1.	14.11.2011	11:20	6°59.48'S 68°54.17'E
2.	14.11.2011	14:30	6°40.93'S 69°14.74' E
3.	14.11.2011	19:10	6°20.14'S 69°37.76' E
4.	14.11.2011	22:30	6°00.42'S 69°58.83' E
5.	15.11.2011	01:55	5°40.93'S 70°19.97'E
6.	15.11.2011	06:32	5°20.70'S 70°42.11' E
7.	15.11.2011	10:00	4°59.98'S 71°05.05' E
8.	15.11.2011	19:30	4°40.01'S 71°23.70' E
9.	15.11.2011	22:20	4°20.88'S 71°41.24'E
10.	16.11.2011	01:20	4°00.97'S 71°58.83'E
11.	16.11.2011	04:30	3°40.90'S 72°16.61'E
12.	16.11.2011	07:30	3°20.71'S 72°36.54'E
13.	16.11.2011	10:30	3°00.97'S 72°54.19'E
14.	16.11.2011	13:20	2°40.93'S 73°13.98'E
15.	16.11.2011	17:05	2°20.92'S 73°33.40' E
16.	16.11.2011	20.05	2°00.90'S 73°55.44' E
17.	16.11.2011	23:05	1°40.91'S 74°14.49' E
18.	17.11.2011	01:45	1°20.94'S 74°33.83' E

19.	17.11.2011	06:02	1°00.91'S 74°54.91' E
20.	17.11.2011	08:20	0°40.94'S 74°04.41'E
21.	17.11.2011	11:45	0°20.80'S 75°04.73'E
22.	17.11.2011	12:50	0°00.97'S 75°07.07'E
23.	17.11.2011	23:15	0°20.01'N 75°08.58'E
24.	18.11.2011	01:13	0°40.03'N 75°10.63'E
25.	18.11.2011	04:48	1°00.00'N 75°12.34' E
26.	18.11.2011	07:10	1°22.63'N 75°12.44' E
27.	18.11.2011	09:03	1°40.01'N 75°14.13' E
28.	18.11.2011	11:45	2°00.15'N 75°16.64' E
29.	18.11.2011	13:50	2°20.06'N 75°19.83' E
30.	18.11.2011	17:15	2°42.61'N 75°20.21' E
31.	18.11.2011	20:10	3°00.06'N 75°20.27' E
32.	18.11.2011	22:20	3°20.06'N 75°20.76' E
33.	19.11.2011	00:45	3°40.01'N 75°25.15' E
34.	19.11.2011	02:50	4°00.23'N 75°30.36' E
35.	19.11.2011	06:24	4°20.66'N 75°31.59' E
36.	19.11.2011	08:30	4°40.04'N 75°33.06' E
37.	19.11.2011	13:30	5°00.00'N 75°37.83' E

### 3.4 Chemical Oceanography

Water samples were collected from 8°S, 68°E using Niskin water sampler from different standard depths, varying from 0 to 200 meter were sub-sampled,



during each time interval, were analysed to generate pH, dissolved oxygen and nutrient profile .

To recreate the paleo environment using geochemical proxies, representative sediment samples were sampled using gravity corer at specified locations, Details are shown in table. The core samples were subsampled and kept in deep freezer for further analysis.

Details of coring

Date	31/10/11	15/11/11	17/11/11	19/11/11
Location	Location	Location	Location	Location
Latitude	11 <sup>0</sup> 37 N	4 <sup>0</sup> 59 S	0 <sup>0</sup> .059 S	4 <sup>0</sup> 59 N
Longitude	74 <sup>0</sup> 24 E	71 <sup>0</sup> 05E	75 <sup>0</sup> 07 E	75 <sup>0</sup> 37E
Time	10 : 45AM	10: 10 AM	1: 45 PM	11:30AM
Depth	1423 m	3900	4332m	2243
Length of the core	4.60 m	1.60 m	Surface sediments	5.58 m

**4. Summary**

A scientific cruise was conducted over south west tropical Indian Ocean during October-November, 2011 to study (i) the presence of Indonesian throughflow and possible influence on the stratification and SST in SWTIO (ii) the

dynamics of saline front in SCTR (ii) Turbulence structure and mixing in SCTR region. (iv) Source waters present in SCTR related to the Subtropical cell and (v) The role of air-sea interaction in MJO initiation and maintenance. Oceanographic measurements were affected by the failure in CTD and MPN. XCTDs and XBTs were launched in regular intervals. Deep sea coring operations also successfully carried out. Extensive surface layer and upper air measurements were carried out during the cruise.