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# Acquisition of High Resolution Upper Ocean Spatial Thermo-haline Structure by Underway Conductivity Temperature and Depth (UCTD) System in the Bay of Bengal

by

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# DOCUMENT CONTROL SHEET

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1. Rudnick, D. L., and J. Klinke, 2007: The underway conductivity temperature–depth instrument. J. Atmos. Oceanic Technol.,24, 1910–1923, doi:10.1175/JTECH2100.1

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**Abstract (100 words)**

First time in the Indian ocean, Underway Conductivity-Temperature-Depth (UCTD) instrument was used measure the upper ocean thermo-haline strucuture with 500 m spatial resolution. The UCTD system was installed onboard ORV Sagar Nidhi and operated in the Bay of Bengal region during November-December 2013. While Argo float may provide the vertical structure at one place and drift according to the current, UCTD provide vertical structure with a spatial resolution of 100 m, if we operate in the top 150 m water column. Around 190 profiles with a spatial resolution of 500m and vertical resolution of 0.25 m temperature and salinity upto 150 m were acquired during this pilot cruise which was dedicated to characterize and study the upper ocean sub-mesoscale (1-10km) variability in the Bay of Bengal. The acquired data processed using standard Matlab tools and compared with onboard Thermosalinogrph.

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# Acquisition of high resolution upper ocean spatial thermo-haline structure by Underway Conductivity Temperature and Depth (UCTD) system in the Bay of Bengal

**Abstract:**

First time in the Indian ocean, Underway Conductivity-Temperature-Depth (UCTD) instrument was used measure the upper ocean thermo-haline strucuture with 500 m spatial resolution. The UCTD system was installed onboard ORV Sagar Nidhi and operated in the Bay of Bengal region during November-December 2013. While Argo float may provide the vertical structure at one place and drift according to the current, UCTD provide vertical structure with a spatial resolution of 100 m, if we operate in the top 150 m water column. Around 190 profiles with a spatial resolution of 500m and vertical resolution of 0.25 m temperature and salinity upto 150 m were acquired during this pilot cruise which was dedicated to characterize and study the upper ocean sub-mesoscale (1-10km) variability in the Bay of Bengal. The acquired data processed using standard Matlab tools and compared with onboard Thermosalinogrph.

## 1.Introduction:

Considering the importance of spatial variability of thermo-haline structure that are exist in the Bay of Bengal, where the frontal regions are dominant, it is imperative to measure temperature and salinity with a spatial resolution of 1 km in the top 100-150 m of the water column. The UnderwayCTD (UCTD) provides research-quality CTD profiles from moving vessels. The compact system offers fast and deep profiling, and can be installed on practically any vessel. UCTD is an effective tool for acquiring conductivity and temperature profiles at ship transit speeds, optimizing valuable ship time. It was procured from Oceanscience, USA and installed onboard ORV Sagar Nidhi on the rail rod, at the ship aft during November -December SN82 cruise.

The UCTD operates under the same principle as an expendable probe. By spooling tether line both the probe and a winch aboard ship, the velocity of the line through the water is zero, the line drag is negligible, and the probe can get arbitrarily deep. Recovery is accomplished by reeling the line back in.

### 1.1 UCTD System:

The UCTD System consist of following components,

- ***Sea-Bird CTD Probe***
- ***Tail Spool***
- ***Tail Spool Re-winder***
- **Winch with Level Wind**
- **Spectra Line**
- **Davit and Block**
- **Power Supply**
- **UCTD software**
- **Bluetooth Software**

**Figure 1: UCTD system installed onboard ORV Sagar Nidhi on rail rod at aft.**


**Figure 2: Tail spool Re-winder, indicating the stopping terminal of spectra line.**

**Figure 3: UCTD Probe.**

### 1.2 UCTD Probe Specifications:

Conductivities can be measured from 0 to 9 S/m, pressure range is 0 to 2000 m and range of temperature sensor is -5º to 43º C.

| parameter | Salinity (psu) | Temperature (C) | Depth (dbar) |
|---|---|---|---|
| Range | 0 to 42 | -5 to 43 | 0 to 2000 |
| Resolution | 0.005 | 0.002 | 0.5 |
| Accuracy | +/-0.05 | +/-0.02 | +/-1 |

**Table:1 Sensor specification.**

## 2. Operation and Data Acquisition:

Underway CTD system was used extensively during the cruise (SN8), with about 190 underway CTD casts being collected during 15 November to 02 December 2013. Each UCTD system consists of a battery-powered, internally recording CTD with a tail spool, a tail-spool winder, and a winch (Figure 1 and 2). In “free cast” mode, a length of line is wound on the tail spool with the winder, and the probe is dropped over the stern while underway, the probe falls nearly vertically through the water as the tail spool unwinds and the winch, set to free spool, pays out line to compensate for the ship’s forward motion. We used "tow-yo" mode, there is no line wound to tail spool and probe pulls line trough water which enables denser horizontal resolution. The probes were calibrated by the manufacturer (SeaBird) and this is the first time we were using this probe.

The horizontal sampling of the data was made about 500 m, even this can be increased to 100 m further, but due to availability of single winch it is restricted to go for 500 m interval. There were 2 UCTD probes, which were used continuously during the cruise with regular charging.

The acquired data logged in the excel spread sheet, with an entry made each time the data were offloaded from the instrument. Each cast has a separate data file, and the header of these files is the authoritative record of the cast name. The header information provides the time the instrument was turned on, and the time the cast actually starts is determined by counting the number of 16 Hz scans until the instrument pressure exceeds 1 dbar. The position of each cast can be determined by matching this time with the 1Hz records with ship's GPS positions.

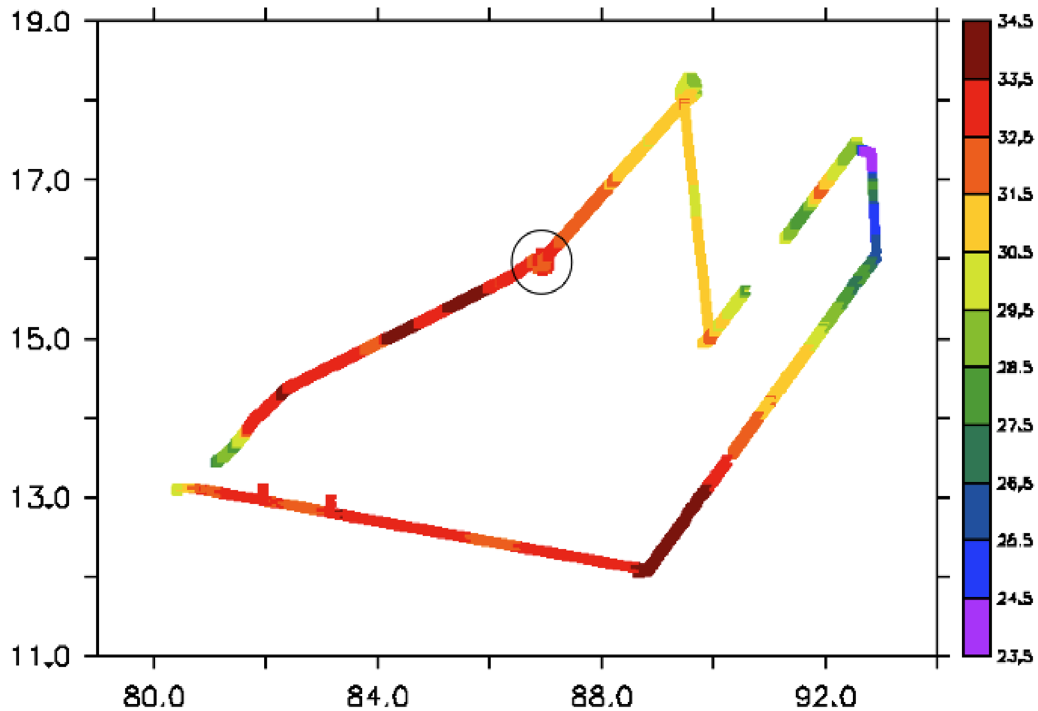


**Figure 4 : Sea surface salinity (psu) measured by the thermosalinograph along the track of the Sagar Nidhi, 15 November to 2 December 2013, circle in figure where the intense observation made with UCTD.**

### 3. Data Processing:

The CTD probe samples conductivity, temperature, and depth at a sampling rate of 16 Hz while descending vertically through the water column at ~4 meters per second. Data are stored internally in flash memory and downloaded wirelessly via Bluetooth to a host computer after recovery

The data record for each cast is stored in an ascii (text) file and contains the pressure, temperature, and conductivity output by the instrument. The header of each file contains the time the instrument was turned on (i.e., when the magnet was removed), and the scan number stored in the file can be used to precisely determine the time the cast actually started.

The conductivity has been lagged by one scan (1/16 second) in an attempt to better align it with the slower temperature measurement for estimation of salinity from temperature and conductivity. While this does a reasonably good job of reducing the salinity spiking that results from the mismatch of the temperature/conductivity time responses, this lag- alignment procedure best suited when compared with other *in-situ* observation data.

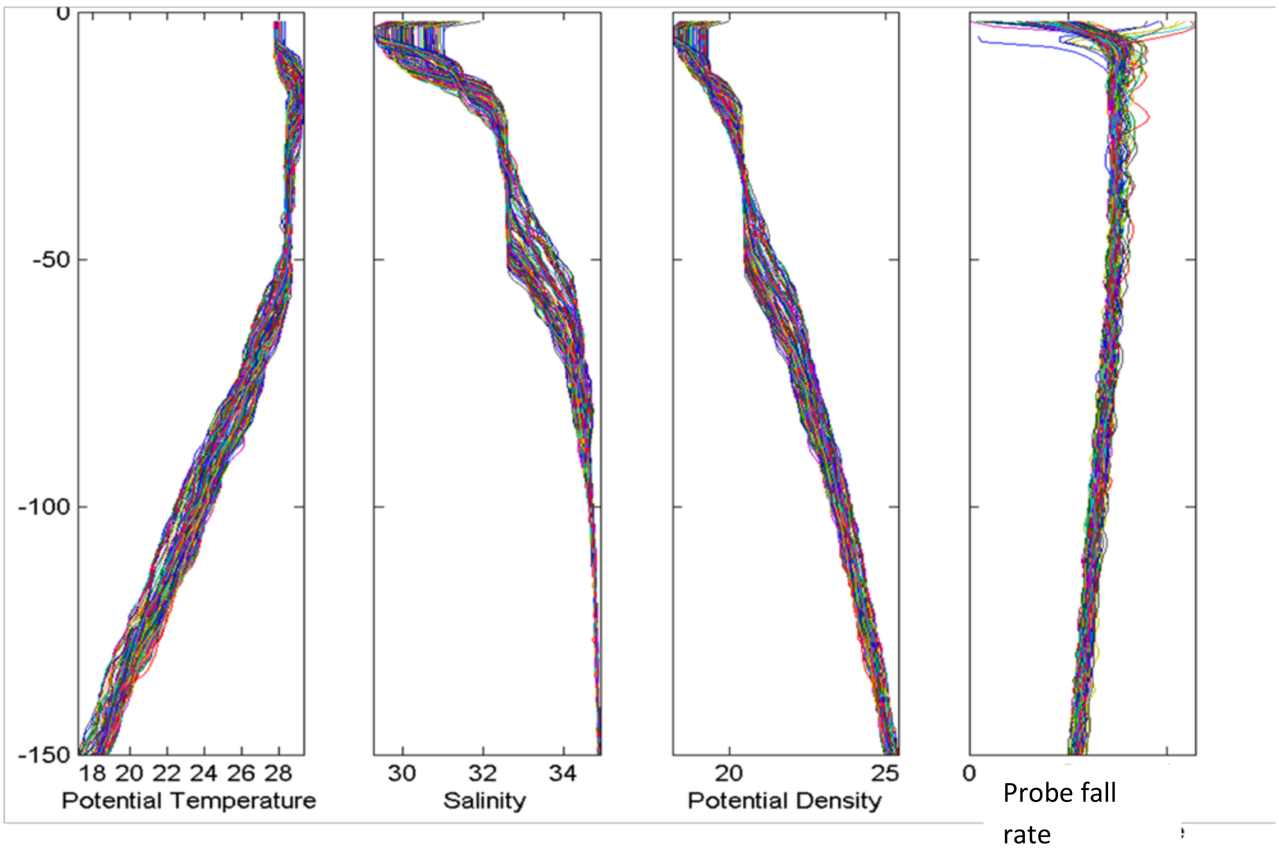


**Figure 5: (a) Potential Temperature (b) Practical salinity(PSU) (c) Potential density and (d) Probe fall rate of the data acquired during SN82 Cruise.**

```
*UCTD Data File:
*FileName = C:\Documents and Settings\UOP\Desktop\ASIRI_Data\111713_024743.asc
*Software Version 1.1
*StatusData:
*DeviceType=90745 UCTD
*Version=CTD
*SerialNumber=70200135
*DateTime=17 Nov 2013 03:06:07
*Bluetooth active
*Bluetooth connected
*Power:
*MainBatteryVoltage= 3.84
*SampleMemorySummary:
*SamplesStored=34430
*NumberCasts=41
*Stop seconds=65
*SamplesFree=653698
*Binary transfer block size=1 kbytes
*Cast start= wait disabled
ConfigurationData:
*DeviceType=90745 UCTD
*Version=CTD
*SerialNumber=70200135
*Settings:
*ReplyFormat=plain text
*BlueToothBaudRate=9600
*CalibrationCoefficients:
*Temperature:
*CalDate=19-Jul-13
*Coefficients:
*A0=9.235179e-04
*A1=2.711299e-04
*A2=-1.361287e-06
*A3=1.699934e-07
*Conductivity:
*CalDate=19-Jul-13
*Coefficients:
*G=-9.765886e-01
*H=1.301270e-01
*I=-3.288909e-04
*J=4.291643e-05
*PCOR=-9.570000e-08
*TCOR=3.250000e-06
*SLOPE=1.000000e+00
*Pressure:
*CalDate=18-Jul-13
*SerialNumber=2115029
*Coefficients:
*A0=5.684672e-01
*A1=8.978222e-03
*A2=7.199894e-11
*PTEMP A0=-8.627662e+01
*PTEMP A1=3.728603e-02
*PTEMP A2=6.505262e-07
*TC A0=5.239817e+05
*TC A1=-6.535828e+00
*TC A2=3.849344e-01
*TC B0=1.022238e+02
*TC B1=-3.613312e-03
*TC B2=0.000000e+00
*RANGE=2.900000e+03
*OFFSET=0.000000e+00

*Cast 41 17 Nov 2013 02:47:43 1040 3.83 normal end

1  5.21917 26.907   -0.125
2  5.22167 27.478    0.250
3  5.22083 27.675    0.875
4  5.21958 27.740    1.250
5  5.21979 27.761    1.594
6  5.21958 27.767    1.938
7  5.21917 27.769    2.156
8  5.21896 27.770    2.313
9  5.21938 27.771    2.563
10  5.21938 27.771    2.844
11  5.21979 27.772    3.031
12  5.22000 27.772    3.188
```

# UCTD data processing

Raw data:

- ASCII format, with header (asterisks)
- 4 columns:
  - Scan number
  - Conductivity (S/m)
  - Temperature (C)
  - Pressure (dbar)

Discard everything but downcasts: dp/dt > 0
(data is very noisy on upcast)

| | | | |
|---|---|---|---|
| 1 | 5.21917 | 26.907 | -0.125 |
| 2 | 5.22167 | 27.478 | 0.250 |
| 3 | 5.22083 | 27.675 | 0.875 |
| 4 | 5.21958 | 27.740 | 1.250 |
| 5 | 5.21979 | 27.761 | 1.594 |
| 6 | 5.21958 | 27.767 | 1.938 |
| 7 | 5.21917 | 27.769 | 2.156 |
| 8 | 5.21896 | 27.770 | 2.313 |
| 9 | 5.21938 | 27.771 | 2.563 |
| 10 | 5.21938 | 27.771 | 2.844 |
| 11 | 5.21979 | 27.772 | 3.031 |
| 12 | 5.22000 | 27.772 | 3.188 |
| 13 | 5.22000 | 27.773 | 3.469 |
| 14 | 5.21958 | 27.773 | 3.781 |
| 15 | 5.22000 | 27.772 | 3.969 |
| 16 | 5.22000 | 27.772 | 4.188 |
| 17 | 5.22021 | 27.772 | 4.375 |
| 18 | 5.22021 | 27.772 | 4.531 |
| 19 | 5.22000 | 27.772 | 4.719 |
| 20 | 5.22021 | 27.772 | 4.844 |
| 21 | 5.22042 | 27.772 | 5.094 |
| 22 | 5.22042 | 27.772 | 5.281 |
| 23 | 5.22042 | 27.772 | 5.531 |
| 24 | 5.22042 | 27.772 | 5.750 |
| 25 | 5.22042 | 27.772 | 5.938 |
| 26 | 5.22063 | 27.772 | 6.156 |

Before computing salinity, lag T by 1 scan (i.e. delete the first value of T and the last values of C and P).

To compute salinity in MATLAB:

S = sw_salt(C*10/sw_c3515, T, P);

**Table 2: Data processing flow for correcting the salinity spiking.**

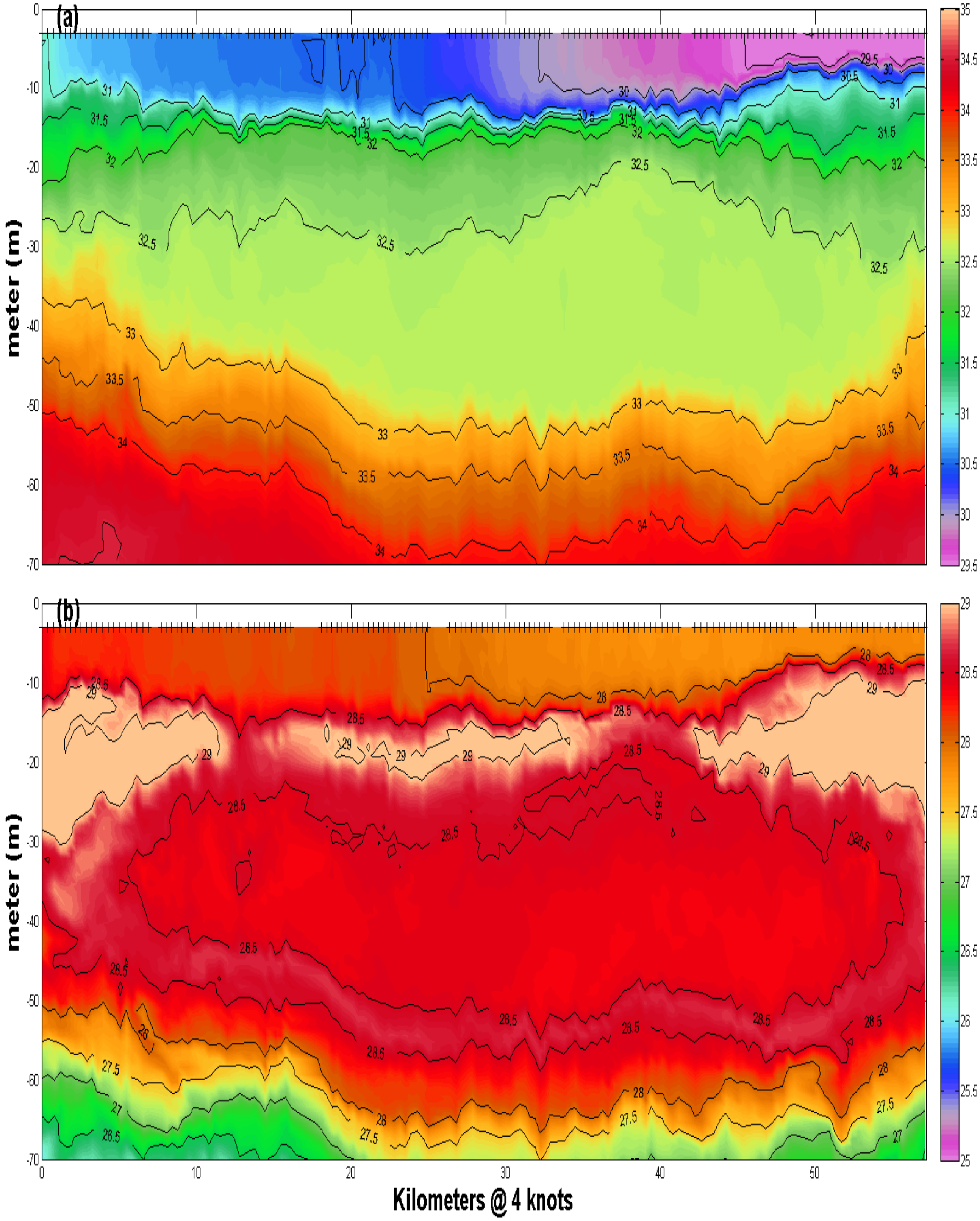


**Figure 6: (a) Salinity (PSU) and (b) Temperature, tow-yo profiles from SN82 cruise. The tic mark in the top label shows the CTD profile acquired during the cruise.**

Data quality was monitored continuously during UCTD operations, primarily by use of an automated script that compares a near-surface value of salinity from each cast to the shipboard thermosalinograph (TSG; 3-m intake) and compares T-S profiles of nearly co-located UCTD and shipboard CTD casts. The TSG and shipboard CTD were regularly compared with UCTD which had given good results; the acquired salinity and temperature are shown in figure 5 and 6. Figure 6 shows the Space-depth salinity and temperature upto 70 m depth. From the salinity plot, it is can be clearly seen the freshwater pool in the later part of the plot and inbetween there may a salinity front at about 25-30 Km from the start. Also, existence of 1-2º C thermal inversion at about 20 m is clearly visible in the temperature record.

**4. Summary and Conclusion:**

There is a lack of research quality spatial upper ocean thermo-haline data in the Bay of Bengal to study the spatial variability of this structure and its interaction between the ocean and atmosphere. The Underway conductivity- temperature -Depth (UCTD) instrument developed by Oceanscience provides the research quality data from moving vessel. When compared with XBT , the major advantage are cost per profile decreases as number of profiles increases (apart from salinity information), sensors can be calibrated post-deployment which improves the quality of the observations and majorly there is no hazardous paraphernalia left in the ocean. First time in the Bay of Bengal, a high resolution data acquired from UCTD during SN82 cruise. The acquired data post processed using the Matlab tool and compared the available TSG at 3m which provided well matching outcome. This high resolution quality data can be used for understanding the upper ocean processes, especially spatial variability and also it can be used for assimilation in different ocean models such as ROMS, MOM and HYCOM which could be a wonderful data for the precise better simulation of ocean parameters.

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1. Rudnick, D. L., and J. Klinke, 2007: The underway conductivity temperature–depth instrument. J. Atmos. Oceanic Technol.,24, 1910–1923, doi:10.1175/JTECH2100.1