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AUTOMATED REAL TIME QUALITY CONTROL SYSTEM FOR MOORED BUOY DATA

by

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11. Abstract (Maximum 100 words):

Systematic real-time meteorological and oceanographic observations are necessary to improve oceanographic services and predictive capability of short and long-term climatic changes. Time series observations are vital to improve the understanding of ocean dynamics and its variability. Moored Buoys are one of the sources for time series data. Considering the importance of ocean observations to the country like India having a long coastline Government of India has established the National Data Buoy Programme (NDBP) in 1997 at National Institute of Ocean Technology (NIOT). INCOIS is playing a key role in acquiring the Moored Buoy data from NIOT, deciding the quality of the data with the help of quality control procedures and dissemination of Data. This document provides the details about the Real Time Quality Control procedures on Moored Buoy Data.

12. Keywords: Moored Buoy, Quality Control.

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APPENDIX

ABSTRACT

Systematic real-time meteorological and oceanographic observations are necessary to improve oceanographic services and predictive capability of short and long-term climatic changes. Time series observations are vital to improve the understanding of ocean dynamics and its variability. The existing systems for collecting the ocean related information are remote sensing, ships of opportunity and moored / drifting / profiling platforms. Among these the moored buoys play an important role in providing long-term, time series, surface / subsurface observations at a location.

Considering the importance of ocean observations to the country like India having a long coastline of about 7500 km, Government of India has established the National Data Buoy Programme (NDBP) in 1997 at National Institute of Ocean Technology (NIOT) Chennai. A network of twelve moored buoys has been established both in Arabian Sea and Bay of Bengal during the implementation period of 1997-2002, which has subsequently been increased to forty seven and poised for further growth. INCOIS is playing a key role in acquiring the Moored Buoy data from NIOT, deciding the quality of the data with the help of quality control procedures and dissemination of Data.

Some times bad observation may be transmitted from the buoys. More serious are erroneous, but apparently reasonable observations that might lead to an incorrect operational decision. So, in that context, preventing these “mishaps” becomes very important. The data should undergo extensive quality control analysis to ensure that they meet accuracy standards. Real-time quality control is routinely performed on a daily basis. How ever quality control involves automatic flagging of data that fall outside of broad error specifications. Questionable data are not automatically removed. Rather, for each error alert, the suspect data are further checked for validity.

Details of data reception, processing and quality control algorithms are described as a reference for moored buoy real time quality control program. Several plots and figures are also included for quick looks.

1. INTRODUCTION

Moored buoy observations are critically important to meteorological and oceanographic programmes to improve oceanographic services and predictive capability of short and long term climatic changes through data assimilation. These observations include data such as atmospheric pressure, air temperature, humidity, wind, currents and wave data for both operational and research purposes. Transmitting via satellite, they operate unattended, predictably, controllably.

Quality Control is the fundamental component of any ocean data assimilation system. It is likely that decisions made at the quality control step can affect the success or failure of the entire system. Accepting erroneous data can cause an incorrect analysis, while rejecting extreme data can miss important events and anomalous features.

An integrated, end-to-end system should ensure that the results of the quality control procedures are recorded for independent analysis and later use. If the quality control is carried out well, then it can reduce the duplication of effort among the chain of users of the ocean data.

A typical Moored Buoy is shown in **Figure 1** and its characteristics are described below.

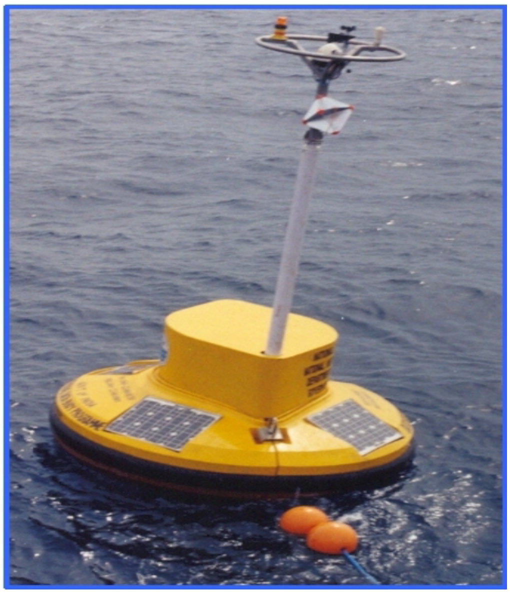

Figure 1: View of 2.2m dia Moored Buoy

<u>Buoy profile:</u>

Diameter	: 2.2 m.
Overall height with	: 6.5 m mast and keel.
Weight	: 700 kg.
Reserve Buoyancy	: 2000 kg.

<u>Characteristics:</u>

- Can carry a suit of meteorological and Oceanographic sensors up to 16 nos.
- Operable from 20 m water depth to full ocean depth.
- 20 w x 4 nos solar panels ensure constant recharging of the batteries.

The sensor Specifications of a typical buoy are given in **Table 1.**

2. BUOY NETWORK

The network of data buoys deployed both in Arabian Sea and Bay of Bengal during 1997 – 2008 is shown in **Figure 2**. The buoys which are currently transmitting the data are represented with green circle. The buoys which are under maintenance are represented by red circle.

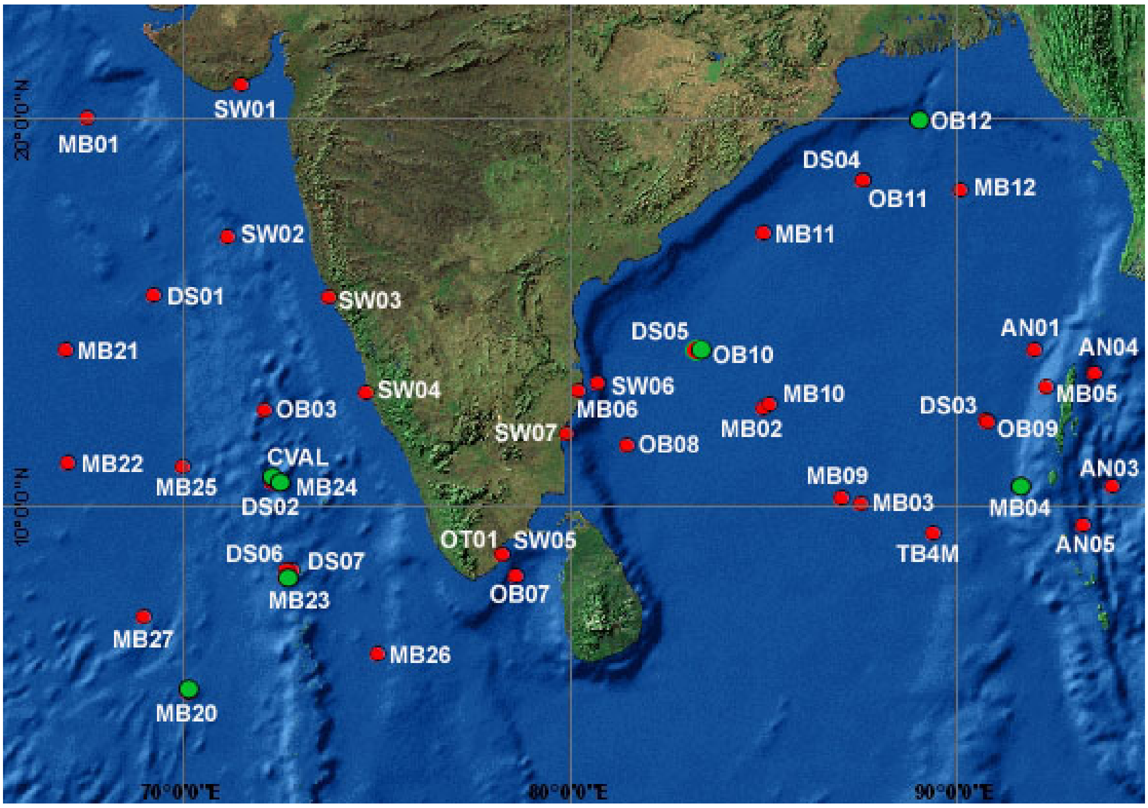

Figure 2: Network of Buoys deployed in Indian Ocean

3. DATA FLOW AND PROCESSING AT INCOIS

3.1. DATA PATHS: The main sources of Moored Buoy Data for INCOIS are NIOT and INSAT (Satellite). The paths are described below.

3.1.1 NATIONAL INSTITUTE OF OCEAN AND TECHNOLOGY

Data is collected from different Moored Buoy sensors around the Coast through 1.2m VSAT Terminal at INCOIS. Data is received through Sky Edge Modem and further processed at Application Server.

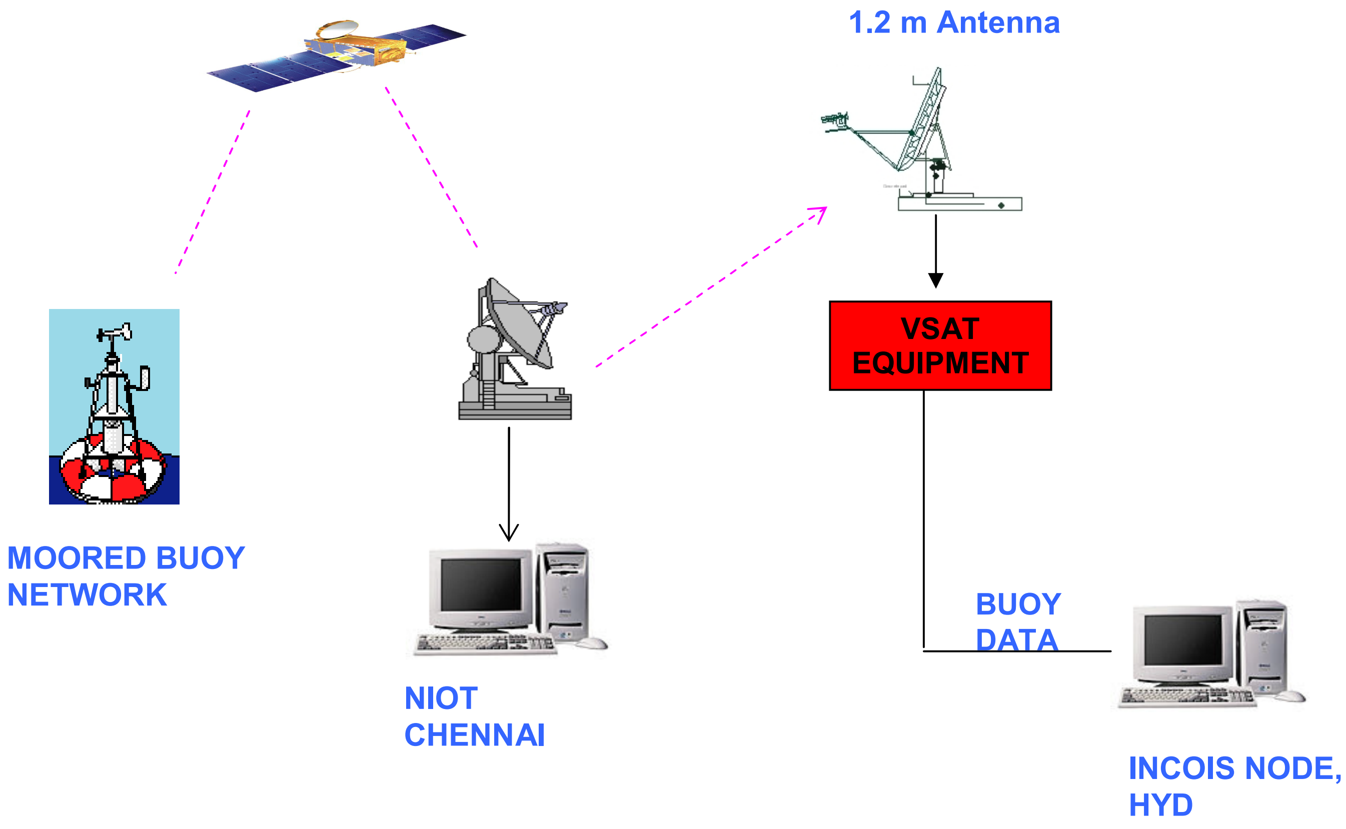

Figure 3: Moored Buoy Data Path from NIOT

3.1.2 INSAT 3A/KALPANA (SATELLITE)

We are using the existing setup installed at INCOIS for National Tsunami Early Warning System (NTEWS) for receiving the Low Cost Buoy data of NIOT.

The Low Cost Buoy Data is transmitted by UHF- Band Transmitter as primary through DRT Transponder of INSAT 3A/ KALPANA Satellite. It will be receiving from INSAT 3A Satellite to HUB station through 3.8mtr Antenna..

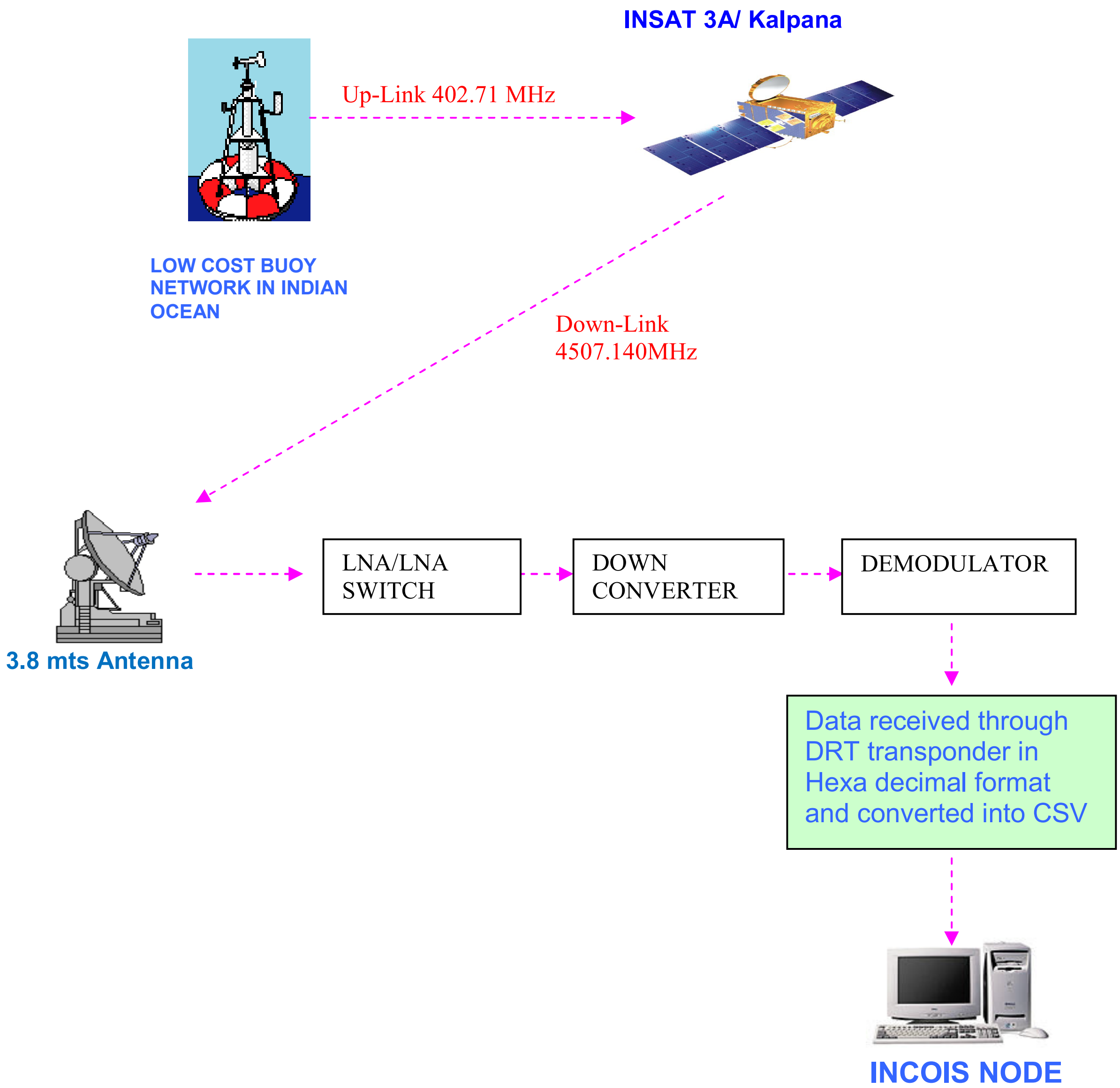

Figure 4: Moored Buoy Data Path from INSAT

3.2 DATA PROCESSING:

- Extract the raw datasets which are in excel format from the sources in different time intervals using java code.
- Perform automatic quality control checks on raw data with Oracle trigger and store the data into the database along with the quality flags.

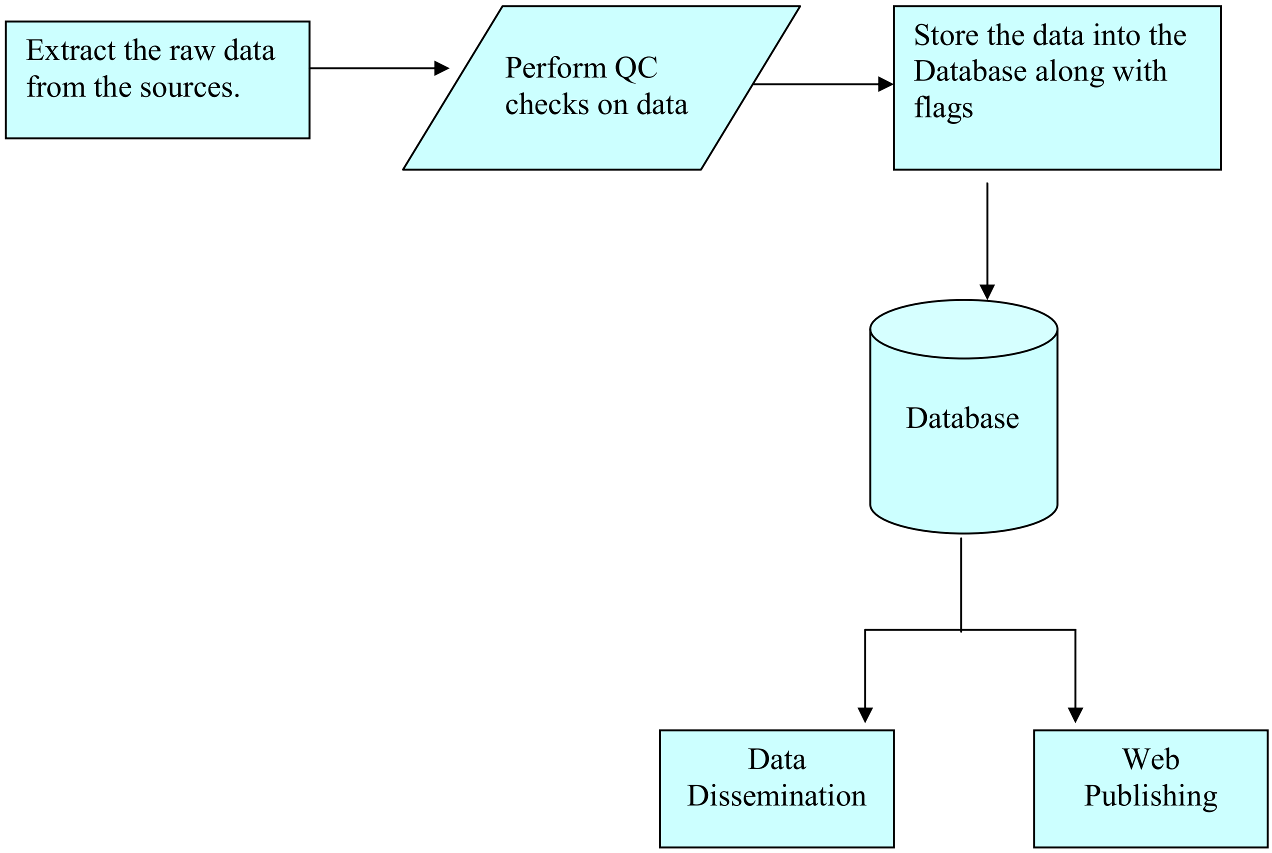

Figure 5: Data Processing flow at INCOIS

3.3 DATA DISSEMINATION

INCOIS has developed an automatic dissemination system for sharing the real time quality controlled data.

Dissemination Procedure:

The data will be retrieved from the database on hourly basis after applying quality control procedures and disseminated in 2 formats.

1. CSV (Comma Separated Values).
2. GTS (Global Telecommunication System).

The various users receiving the Moored Buoy data are

1. India Meteorological Department, Delhi.
2. NAVY.
3. Coast Guard.
4. National Institute of Ocean and Technology.

3.4 WEB PUBLISHING:

INCOIS is publishing the daily status report of Moored Buoy data in the format shown in **Table 5**. The Buoys that are currently transmitting data are listed first. The Buoys preceded by ‘ ***** ‘ are under maintenance. The availability status of Humidity, Air Pressure, Air Temperature, Wind Direction, Wind Speed, Wind Gust, Water Temperature and Wave Parameters are given in **Table 5.**

If the Buoy is transmitting data then the status will be represented by ‘ **Y** ’ or else it will be ‘ **N** ‘ followed by Last Receiving Date of the parameter. The real time plots for one of the currently transmitting buoy are also shown in **Figure 16**.

4.1 QUALITY CONTROL ALGORITHMS

(i) Impossible Date Test:

The test requires that the observation date and time from the float be sensible.

- ❖ Year greater than 1997
- ❖ Month in range 1 to 12
- ❖ Day in range expected for month
- ❖ Hour in range 0 to 23
- ❖ Minute in range 0 to 59

Action: If any one of the conditions is failed, the date should be flagged as bad data.

(ii) Stuck Value Test

This test looks for consecutive identical measurements (O_1, O_2) of each parameter of an individual buoy.

Action: If $O_2 = O_1$ then O_2 should be flagged as wrong. Where O_2 is the measurement being tested and O_1 is the previous value.

(iii) Impossible Location Test

The test requires that the observation latitude and longitude from the float be sensible.

- ❖ Latitude in range 0 to 30.
- ❖ Longitude in range 70 to 100.
- ❖ The change in Buoy position from the deployment position should not greater than 6 Nano Meters.

Action: If either latitude or longitude fails, the position should be flagged as bad data.

(iv) Spike Test

The difference between sequential measurements, where one measurement is quite different than adjacent ones, is a spike. The difference between 2 consecutive measurements is to be compared with the threshold values given by TAO data quality control program. The threshold values for some of the parameters are shown in **Table 2**.

Test Value = | O_2 - O_1| ("| | " represents MOD and gives the absolute value).

Where O_2 is the measurement being tested as a spike, and O_1 is the previous value.

Action: If the Test Value crosses the threshold value of the corresponding parameter then O_2 should be flagged as wrong.

(v) Correlation Test

This test looks for correlation between related parameters of an individual buoy. Abnormal change in any of the following parameters should be checked for similar changes in other parameter.

$$\text{Test Value} = O_{AT} - O_{SST}$$

Where O_{AT} is Air temperature observation and O_{SST} is Water Temperature observation.

Action: If Test Value > 1.4 then the observation will be flagged as bad data.

(vi) Range Test

This test checks range limits for each parameter. The Lower and Upper Limits for the ranges are shown in **Table 3**.

Action: if the value fails this test it should be flagged as bad data.

4.2 QUALITY FLAGS

The process of quality control consists of performing various checks and depending on the results may change the value or leave the data unchanged. In both cases the data should be flagged according to predefined quality control codes. It is strongly advised that the original value be preserved with the data. Possible list of quality flags are given in **Table 4**

5. GRAPHICAL REPRESENTATION OF DATA BEFORE AND AFTER QC

This section shows the results of Real Time Quality Control applied to data obtained from 2 buoys (CVAL and OB12), currently transmitting data for the period October 2008.

Plots for the Buoy CVAL, October 2008

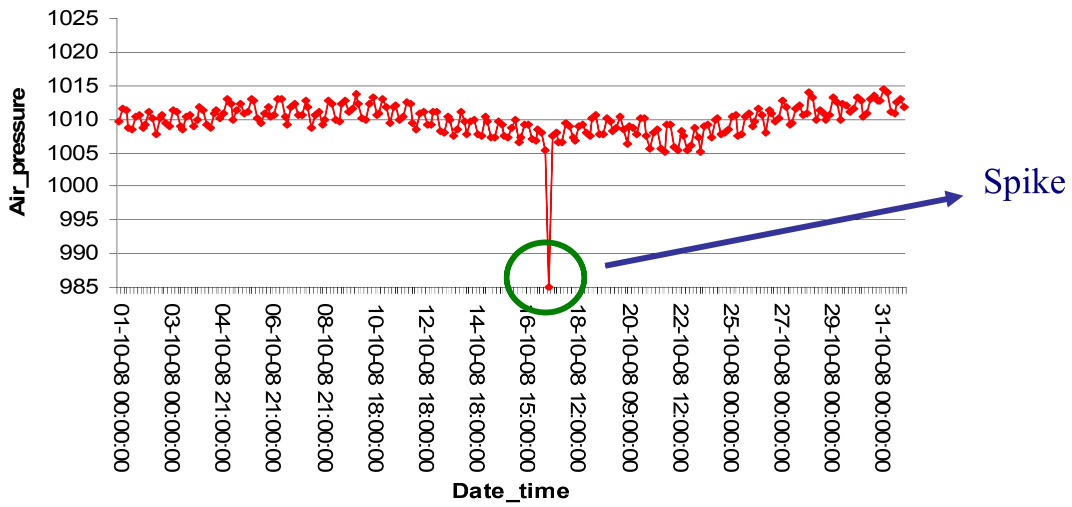

Figure 6a: Air Pressure Plot before QC

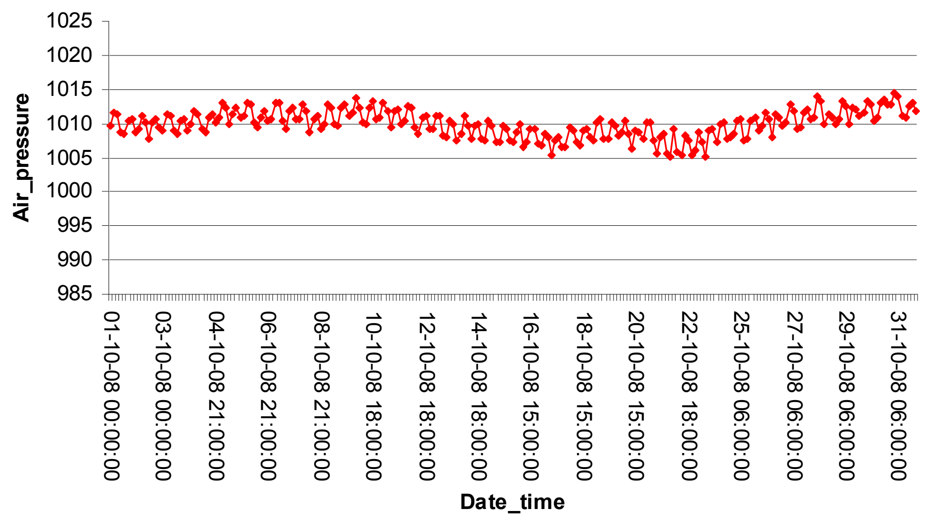

Figure 6b: Air Pressure Plot after QC

Observe the spike in **Figure 6a** on 17/10/2008. It is because of the observation that crossed the range limit. So it is flagged as ' 4 ' (referred in Section 4.2) during quality control procedure.

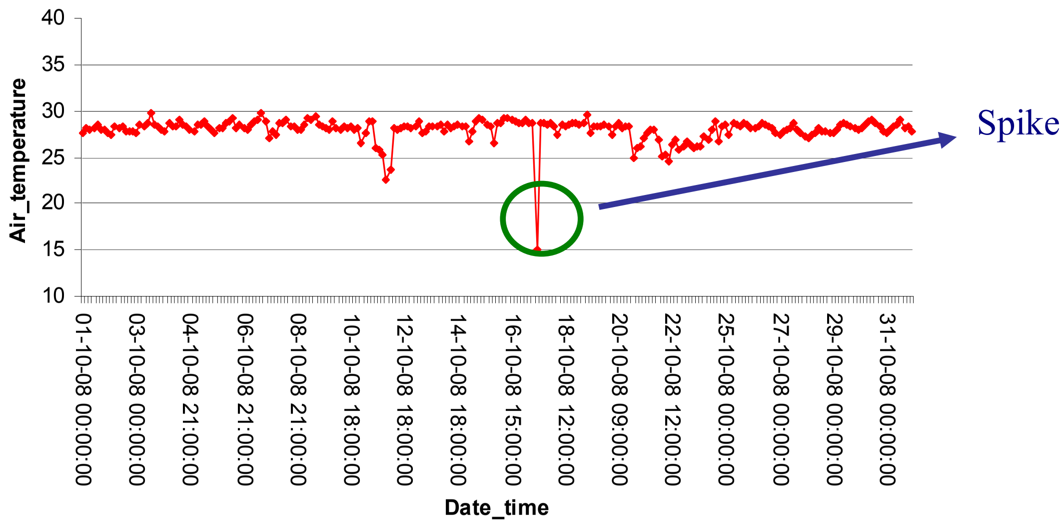

Figure 7a: Air Temeprature Plot before QC

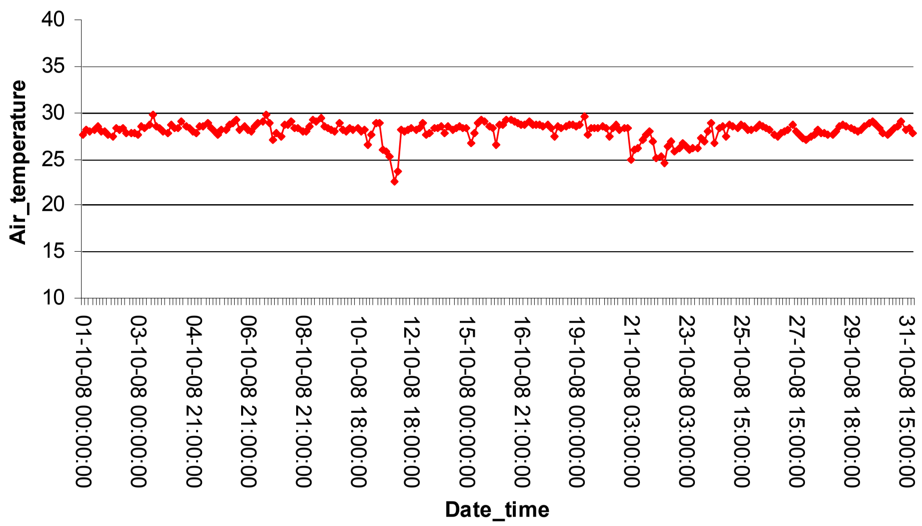

Figure 7b: Air Temeprature Plot after QC

The air temperature observation on 17/10/2008 crossed its range limit. So, it is flagged as ' 4 ' after applying range and spike tests.

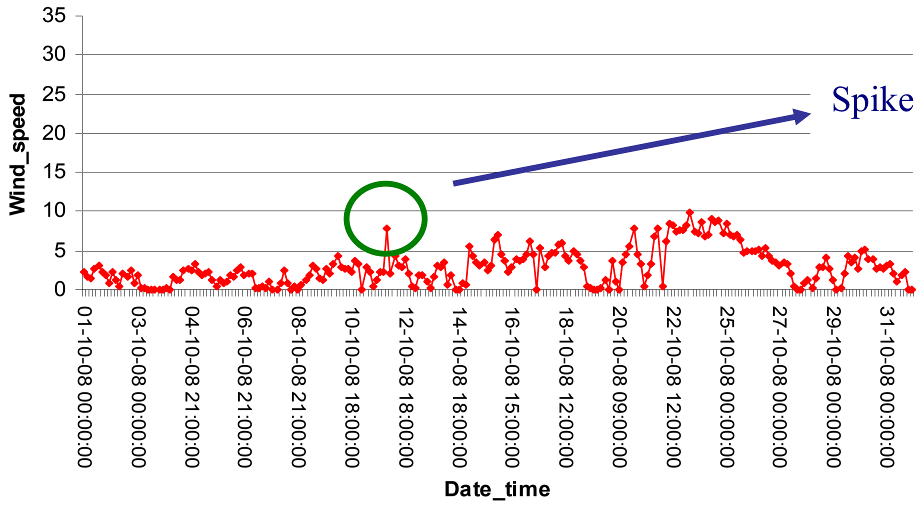

Figure 8a: Wind Speed Plot before QC

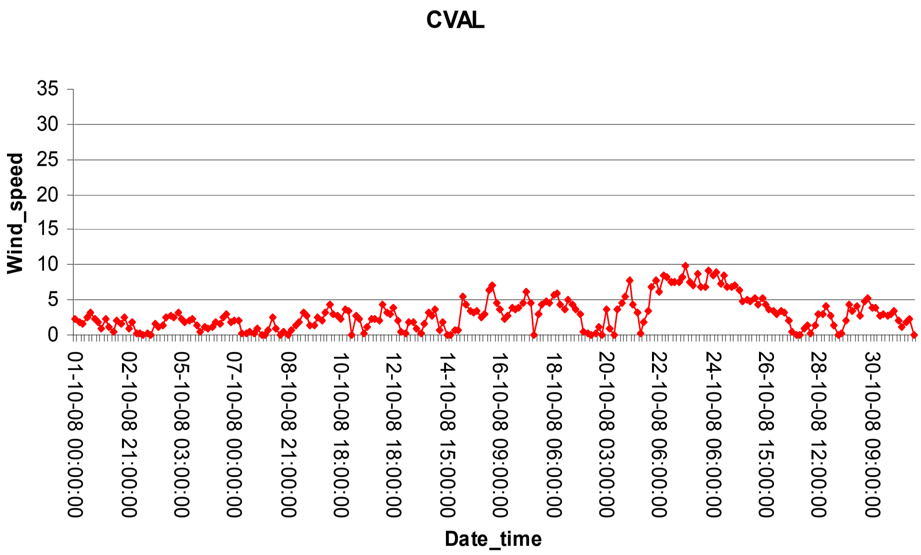

Figure 8b: Wind Speed Plot after QC

Observe few spikes in wind speed observations in **Figure 8a** which are flagged as ‘ **4** ‘ and ignored in**Figure 8b** .

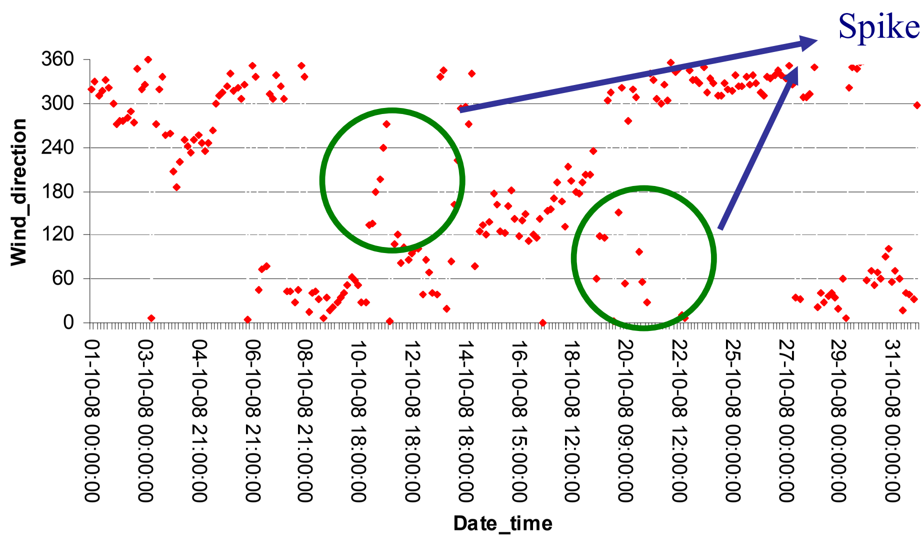

Figure 9a: Wind Direction Plot before QC

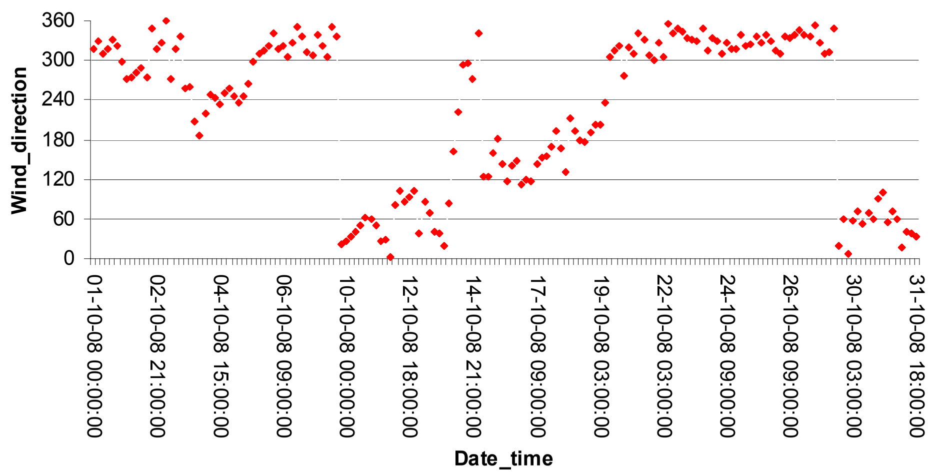

Figure 9b: Wind Direction Plot after QC

Here in **Figure 9b** most of the observations are ignored after quality control as the difference between the consecutive observations is crossing the threshold limit (referred in **Table 2**).

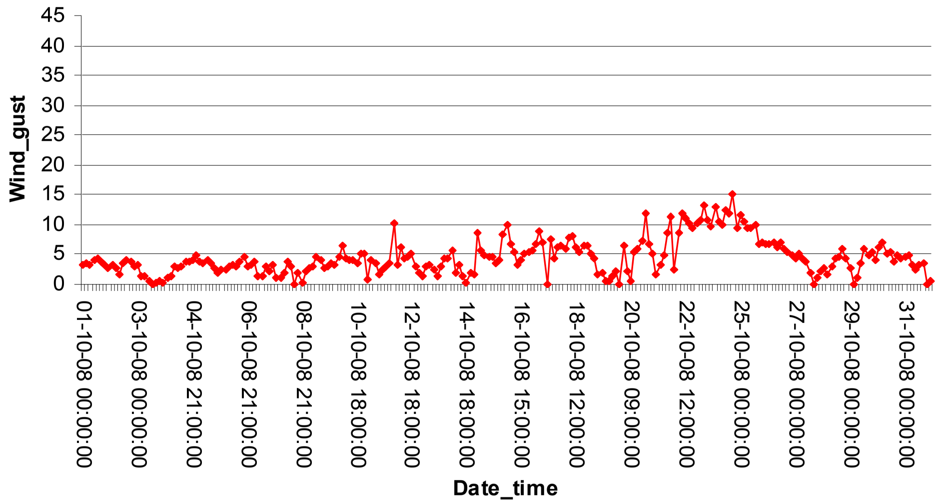

Figure 10a: Wind Gust Plot before QC

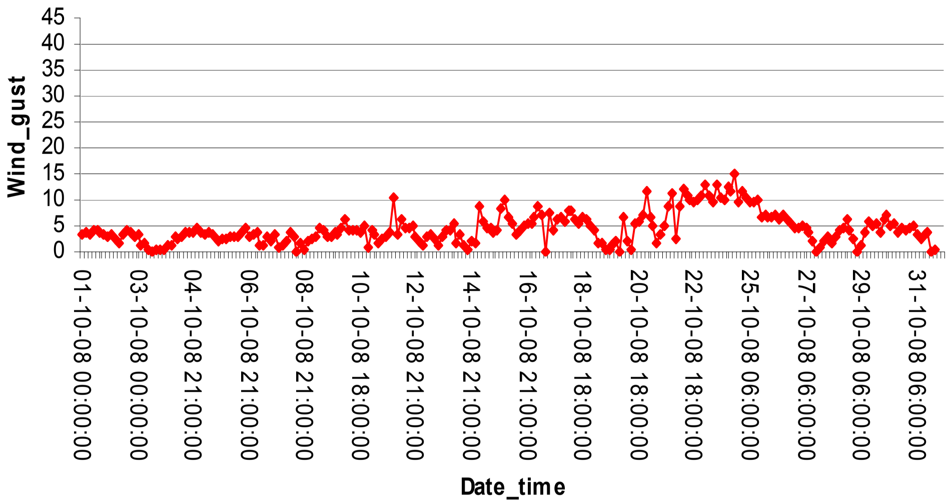

Figure 10b: Wind Gust Plot after QC

Here there is no change in data after Quality Control. All the observations are flagged as ‘ **1** ‘.

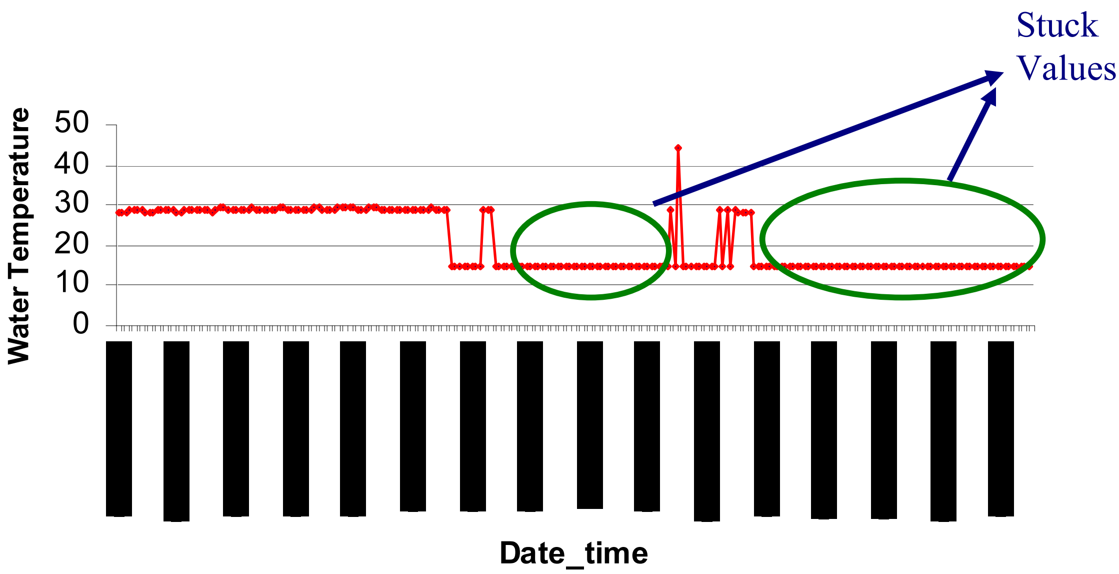

Figure 11a: Water Temperature Plot before QC

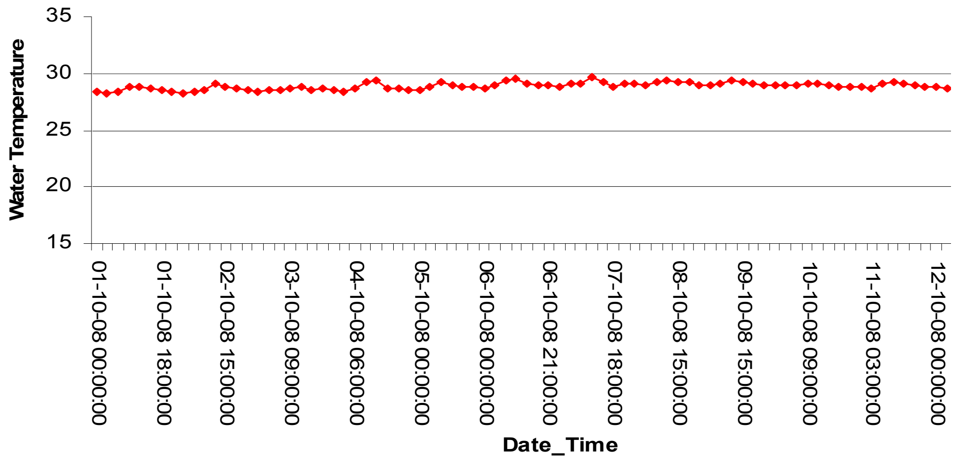

Figure 11b: Water Temperature Plot after QC

Observe the identical values in **Figure 11a**. These observations are the result of sensor failure. These are flagged as ‘ **3** ‘ after stuck value test.

Plots for the buoy OB12, October 2008

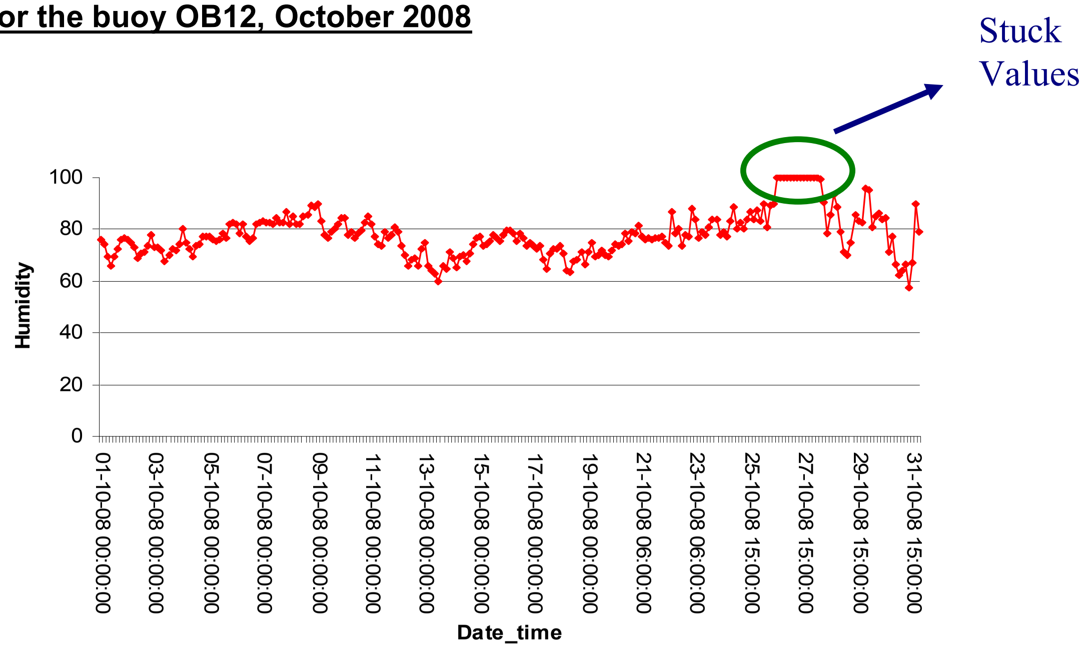

Figure 12a: Humidity Plot before QC

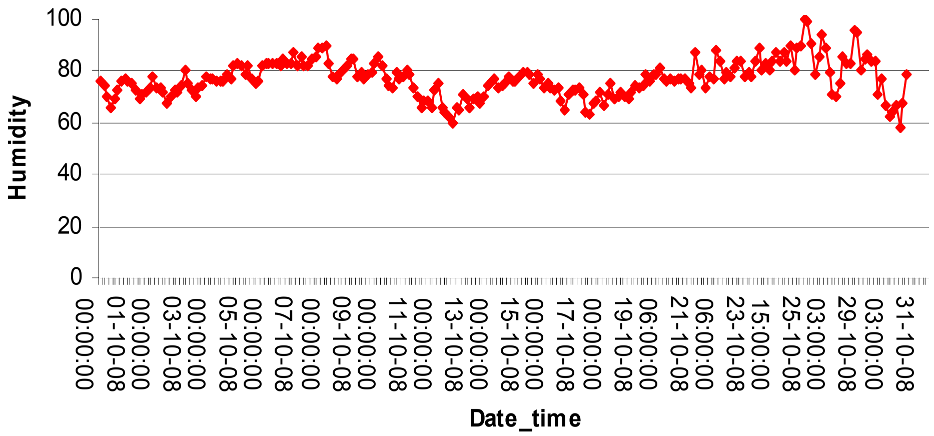

Figure 12b: Humidity Plot after QC

Observe some identical consecutive measurements in **Figure 12a** which are flagged after Quality Control.

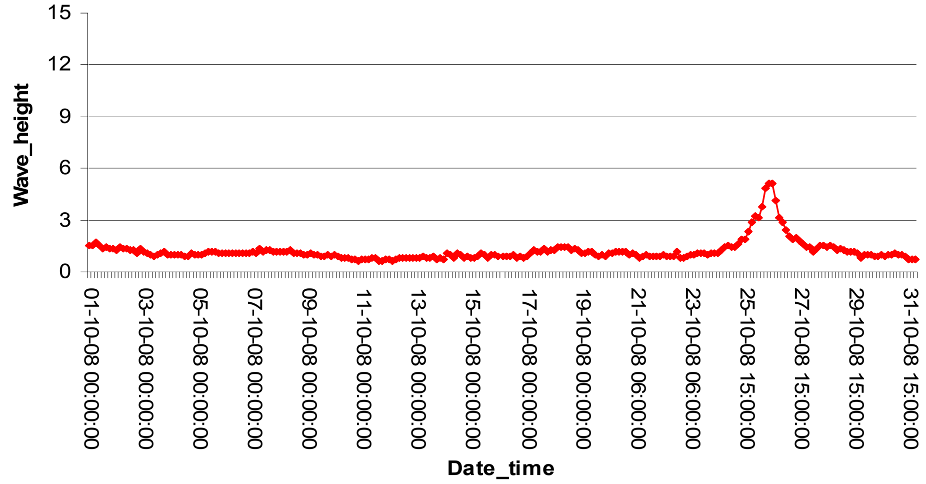

Figure 13a: Wave Height Plot before QC

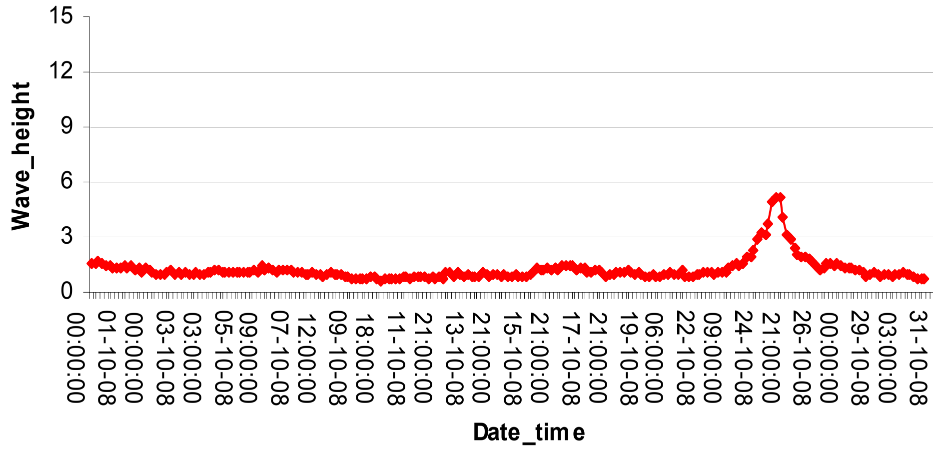

Figure 13b: Wave Height Plot after QC

Here there is no change in data after Quality Control. All the observations are flagged as ‘ **1** ‘.

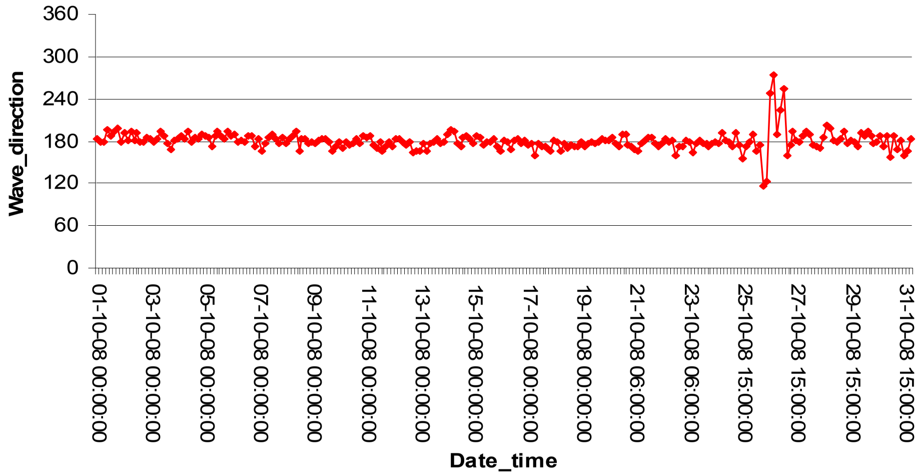

Figure 14a: Wave Direction Plot before QC

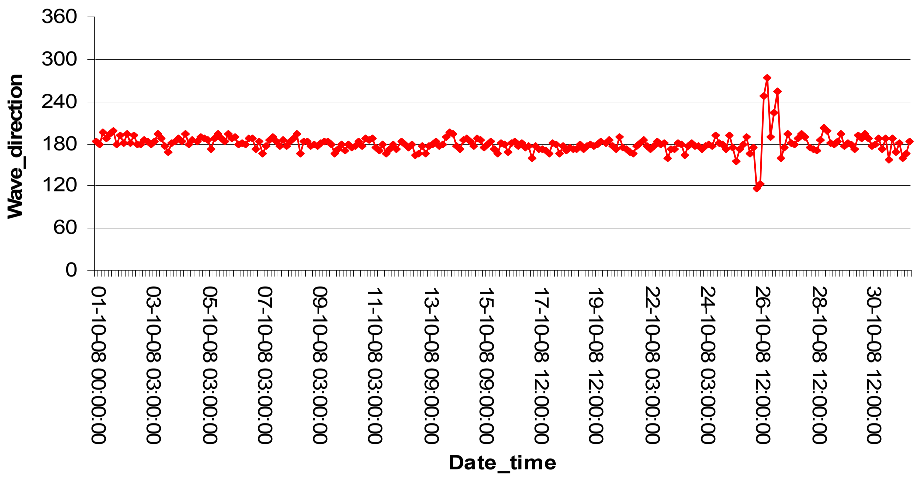

Figure 14b: Wave Direction Plot after QC

Here there is no change in data after Quality Control. All the observations are flagged as ‘ **1** ‘.

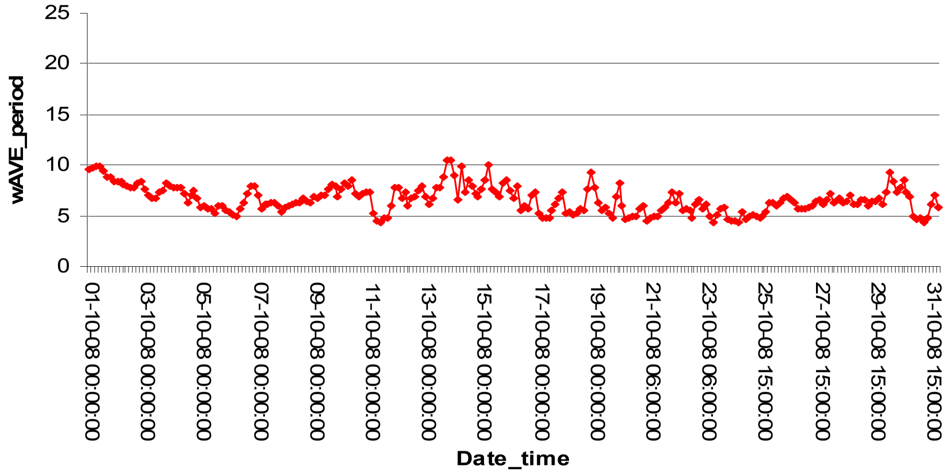

Figure 15a: Wave Period Plot before QC

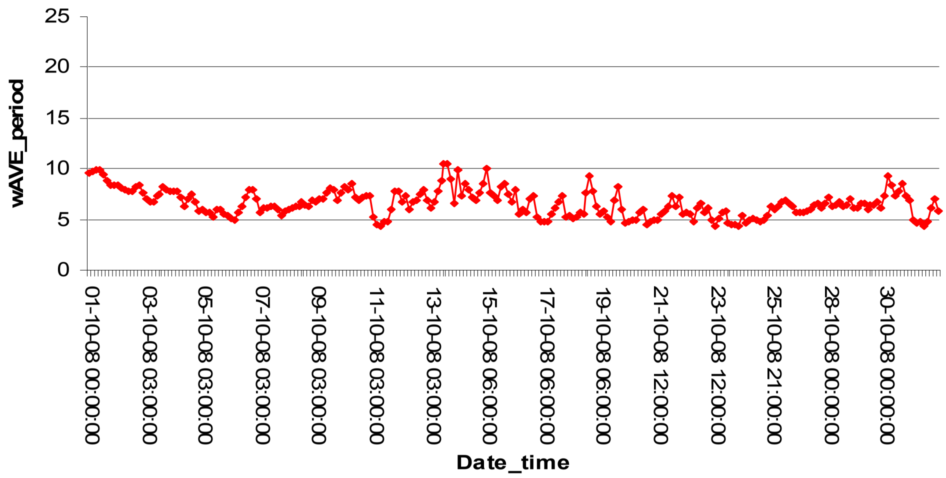

Figure 15b: Wave Period Plot after QC

Here there is no change in data after Quality Control. All the observations are flagged as ‘ **1** ‘.

6. FUTURE PLANS

INCOIS is planning to perform Delayed Mode Quality control on Moored Buoy Data. Data that have passed gross error checks but which are unusual relative to neighboring data are examined on a case by case basis. Corroborating information such as problems with battery failures, damaged sensor will be checked. Consistency with other variables is also checked. Data values that are ultimately judged to be erroneous are then flagged finally.

7. SOFTWARES USED

- Java – J2sdk1.4.2 (For front end programming).
- JXL package – To extract the input data which is in excel format.
- Oracle 10g - Database for storing raw data as well As processed data.
- TOAD – Interface for oracle to view the data and manipulate the data in an effective manner.
- JFREE chart – To design the plots for various sets of data.
- JCreator – Interface to write java code.

8. ACKNOWLEDGEMENTS

The authors thank Director, INCOIS for his constant encouragement and suggestions in improving the Report. The authors also thankful to Mr. A. Murali Krishna and Syed Mahaboob Moinudeen for providing infrastructure information.

9. BIBLIOGRAPHY

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2. Handbook of Quality Control Procedures and Methods for Surface Meteorology Data by Shawn R. Smith, J. Parks Camp and David M. Legler, August 1996

3. http://www.ndbc.noaa.gov/realtime.pdf, accessed on 28th November 2008.

4. http://www.pmel.noaa.gov/tao/proj_over/qc.html, accessed on 28th November 2008.

5. http://niot.res.in/op/ndbp/ndbp_about.php, accessed on 28th November 2008.

Table 1: Buoy Sensor Specifications

Sensor	Range	Accuracy	Resolution	Duration / Freq.
Air pressure	800 – 1100 hPa	± 0.1 hPa	0.01 hPa	5 sec, **1 Hz**
Air temperature	10 – 50oC	± 0.1oC	0.01oC	10 min, **1 Hz**
Wind* (spd, dir)	0 – 60 ms-1, 0 – 360o	± 1.5% FS, ± 3.6o	0.07 ms-1, 0.1o	10 min, **1 Hz**
Water Temp**	-5 – 45oC	± 0.1oC	0.01oC	10 min, **1 Hz**
Conductivity**	2 – 77 m mho cm-1	± 0.06 mmho cm-1	0.01 m mho cm-1	10 min, **1 Hz**
Surf. Cur.** (spd, dir)	0 – 6 ms-1, 0 – 360o	± 3% FS, ± 2o	0.005 ms-1, 0.36o	10 min, **1 Hz**
Wave** (full spectrum)	± 20m, 0 – 360o	± 10 cm, ± 5o	1 cm, < 0.1o	17 min, **1 Hz**
Humidity & Air Temp.*	Humidity 0:100% Air Temp:-40 to + 60c	Humidity± 1%RH Air Temp… ±3 oC	-	10 min, **1 Hz**

* Sensor at 3 m above the sea surface

** Sensor at 3 m depth below the sea surface

Table 2: Threshold values referred from TAO Quality Control document

Parameter	Daily parameters that will generate error alerts
Barometric pressure	BP changes > 5 mb from previous day
Air temperature	Daily AT changes > 5°C from previous day
Relative humidity (RH)	Daily RH changes >20% from previous day
Wind direction	direction varies more than 90° from previous day
Wind Speed	Speed changes more than 5 m/s from previous day
SST	SST changes > 5°C from previous day
Current Direction	direction varies more than 90° from previous day
Current Speed	speed change greater than 50 cm/s from previous day
Salinity	Salinity > 0.5 psu from previous day

Table 3: Maximum and Minimum ranges for the parameters given by NIOT.

Sl No.	Parameter	Range	
		Lower limit	**Upper limit**
1	Humidity	0	100
2	Air pressure	985	1025
3	Air Temperature	10	40
4	Wind Direction	0	360
5	Wind Speed	0	35
6	Wind Gust	0	45
7	Current Speed	0	300
8	Current Direction	0	360
9	SST Skin	15	35
10	SST3m	15	35
11	Conductivity	20	65
12	Salinity	15	40
13	Wave height	0	15
14	Wave Direction	0	360

15	Wave period	0	25
16	Wave Period at Spectral Peak	0	30
17	Zero Crossing Period	0	30
18	Unidirectivity Index	0	1

Table 4: Quality Flags

Flag Value	Meaning
0	No quality control
1	Good
2	Probably good
3	Doubtful or Stuck Value
4	Out of Range or Spike
9	No Data or Missing value

Table 5: Daily Status of Moored Buoy Data

Buoy ID	Humidity	LRD	Air Pressure	LRD	Air Temp	LRD	Wind Direction	LRD	Wind Speed	LRD	Wind Gust	LRD	SST	LRD	Wave Parameters	LRD
CVAL	Y	-	Y	-	Y	-	Y	-	Y	-	Y	-	N	10/22/2008	N	-
OB12	Y	-	Y	-	Y	-	Y	-	Y	-	Y	-	Y	-	Y	-
OB10	Y	-	Y	-	Y	-	Y	-	Y	-	Y	-	Y	-	Y	-
MB23	Y	-	Y	-	N	10/20/2008	Y	-	Y	-	No Sensor	-	Y	-	No Sensor	-
MB24	N	3/11/2008	Y	-	Y	-	Y	-	Y	-	No Sensor	-	N	-	No Sensor	-
MB26	Y	-	Y	-	N	-	Y	-	Y	-	No Sensor	-	Y	-	No Sensor	-
MB04	N	3/11/2008	Y	-	Y	-	Y	-	Y	-	No Sensor	-	Y	-	No Sensor	-
MB09	Y	-	Y	-	Y	-	Y	-	Y	-	No Sensor	-	Y	-	No Sensor	-
MB20	Y	-	Y	-	N	-	Y	-	Y	-	No Sensor	-	Y	-	No Sensor	-
* OB11	N	2/10/2008	N	2/10/2008	N	10/2/2008	N	10/2/2008	N	10/2/2008	N	10/2/2008	N	-	N	10/2/2008
* OB03	N	23/4/2008	N	22/8/2008	N	4/23/2008	N	8/22/2008	N	8/22/2008	N	8/22/2008	N	6/14/2008	N	-
* OB09	N	16/8/2008	N	18/8/2008	N	8/16/2008	N	8/16/2008	N	8/16/2008	N	8/16/2008	N	-	N	8/16/2008
* EB06	N	-	N	-	N	8/15/2008	N	-	N	-	N	-	N	8/15/2008	N	-
* DS04	N	14/8/2008	N	14/8/2008	N	8/14/2008	N	-	N	-	N	8/14/2008	N	8/14/2008	N	8/14/2008
* DS05	N	-	N	21/6/2008	N	6/21/2008	N	6/21/2008	N	6/21/2008	N	6/21/2008	N	6/21/2008	N	6/21/2008
* DS01	N	4/6/2008	N	4/6/2008	N	6/4/2008	N	6/4/2008	N	6/4/2008	N	6/4/2008	N	6/4/2008	N	6/4/2008
* OB08	N	-	N	30/5/2008	N	5/30/2008	N	5/30/2008	N	5/30/2008	N	5/30/2008	N	5/30/2008	N	-
* DS06	N	-	N	10/1/2008	N	1/10/2008	N	1/10/2008	N	-	N	-	N	1/10/2008	N	-
* MB11	N	9/11/2008	N	9/11/2008	N	11/9/2008	N	11/9/2008	N	11/9/2008	No Sensor	-	N	11/9/2008	No Sensor	-
* MB22	N	29/10/2008	N	29/9/2008	N	10/29/2008	N	10/29/2008	N	10/29/2008	No Sensor	-	N	10/29/2008	No Sensor	-
* MB06	N	-	N	27/9/2008	N	9/27/2008	N	9/27/2008	N	9/27/2008	No Sensor	-	N	9/27/2008	No Sensor	-
* MB05	N	24/9/2008	N	25/9/2008	N	9/24/2008	N	9/25/2008	N	9/24/2008	No Sensor	-	N	9/25/2008	No Sensor	-
* MB03	N	8/9/2008	N	9/9/2008	N	9/9/2008	N	9/9/2008	N	9/9/2008	No Sensor	-	N	9/9/2008	No Sensor	-
* MB27	N	-	N	2/9/2008	N	8/24/2008	N	9/2/2008	N	-	No Sensor	-	N	-	No Sensor	-
* MB02	N	-	N	1/9/2008	N	9/1/2008	N	9/1/2008	N	9/1/2008	No Sensor	-	N	-	No Sensor	-
* MB25	N	20/8/2008	N	20/8/2008	N	-	N	8/20/2008	N	8/20/2008	No Sensor	-	N	8/20/2008	No Sensor	-

*** Buoy under Maintenance** **Y – Transmitting Data** **LRD – Last Receiving Date**

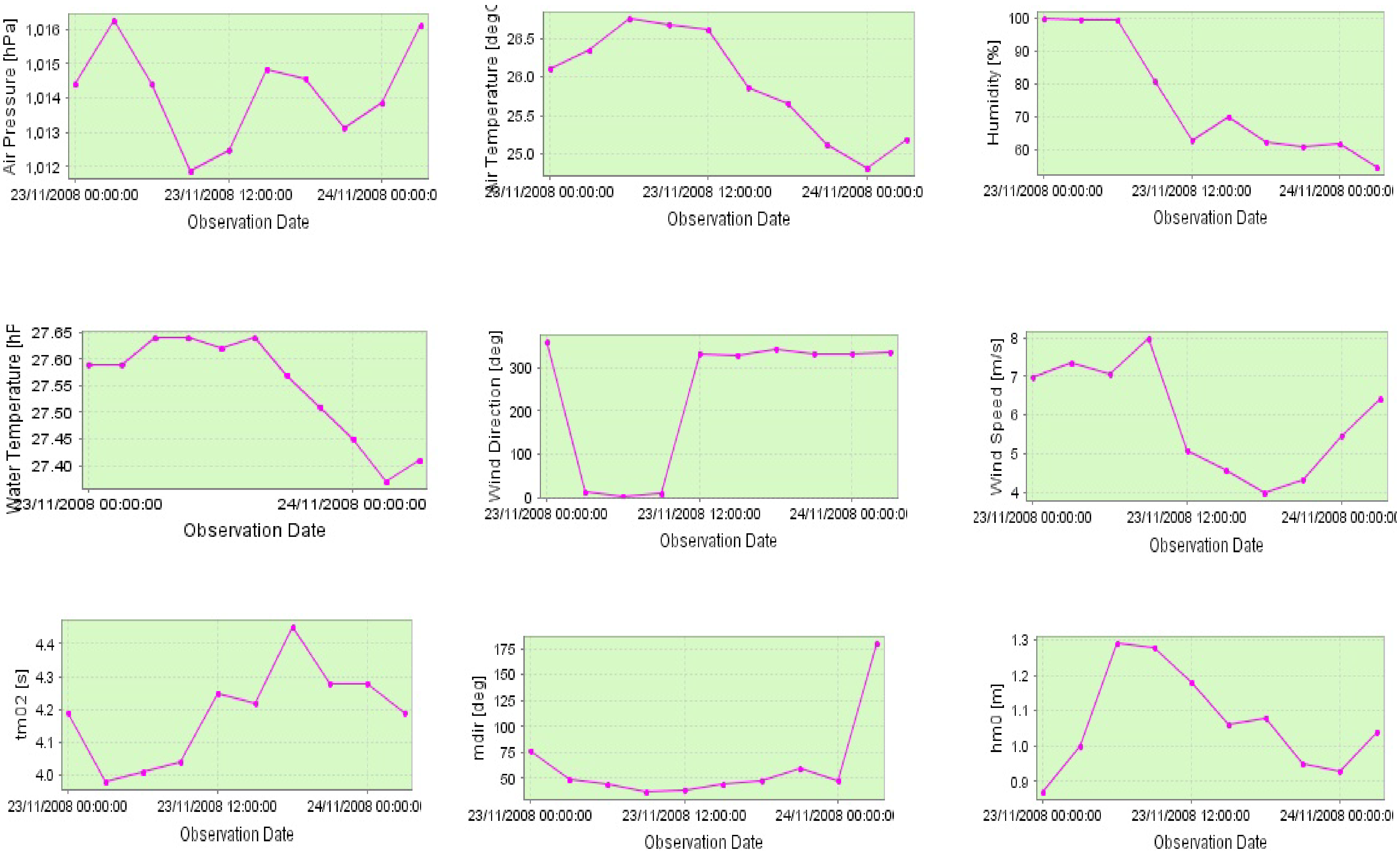

Figure 16: Snap shot of real time plots for the buoy OB12 on 24/11/2008