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Delayed Mode Quality Control procedures for Moored Buoys in the Indian Seas

by

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11. Abstract (Maximum 100 words):

Quality of the data plays a significant role in bringing out acceptable results in oceanography. Quality checking is a phase in data management where the data is pooled from different resources. Therefore certain constraints are employed on the data values taking into consideration the accuracy of the instruments, acceptable levels of parameters based on the location of interest. Delayed mode quality control involves rechecking of the entire dataset that had undergone real time quality checking. Real time quality control cleans the data based on the instrument standards; whereas delayed mode is based on long term mean of data and comparing them with the climatological datasets available for the region. Also visually flagging the outliers for those parameters where the standard data is not available to compare.

12. Keywords: Moored Buoy, Quality Control.

13. Security classification: **Unrestricted**

CONTENTS

1. INTRODUCTION

Indian National data buoy program had started in 1997 and a series of buoys were moored at different locations to monitor the oceanographic and meteorological conditions in the Indian seas. Parameters that are measured are atmospheric pressure, atmospheric temperature, humidity, sea surface temperature at skin and 3m of depth, wind, wave and ocean currents. The data from these buoys is transmitted via satellites. The deployment and maintenance of buoys is undertaken by the National Institute of Ocean Technology (NIOT) from the beginning of the program and the data reception was held in NIOT from 1997 to 2007 and later from 2007 till date, it is being received at INCOIS. In the initial stages, the buoy technology was provided by OCEANOR, Norway and later in the recent period, the moored buoy technology is indigenised and being built at NIOT. As on date, there are about 62 buoys deployed in the Indian waters, out of which 12 buoys are in active state. Most of the buoys measure at every 3 hours (00:00, 03:00, 06:00, 09:00, 12:00, 15:00, 18:00, 21:00). There are certain buoys which provide observations every 1hour depending on their measuring parameters. They are designated as:

1. Deep Sea Buoy (DS)
2. Shallow Water Buoy (SW)
3. Met-Ocean Buoy (MB)
4. Ocean Buoy (OB)
5. Bay of Bengal Data Buoy (BD)
6. Arabian Sea Data Buoy (AD)
7. Andaman & Nicobar Buoy (AN)
8. Ocean Technology Buoy (OT)

During the initial stages of the NDBP program, the naming convention that was followed is based on their purpose and region of deployment. To avoid confusion in naming conventions, the buoys that are being deployed and recently are names mostly as Arabian Sea Data buoy (AD) and Bay of Bengal Data buoy (BD) depending on their region of deployment. Following table presents the purpose of deployment and the list of parameters each of these buoys measure.

Table 1: Different types of Buoys and their specific purpose

Sl. No	Buoy Type	Purpose of Deployment	Parameters measured
1	Deep Sea Buoy (DS)	For Deep Sea measurements	Humidity, Air Pressure, Air Temperature, SST, Conductivity, Wind, Current and Wave Parameters
2	Shallow Water Buoy (SW)	For coastal and shallow water measurements	Humidity, Air Pressure, Air Temperature, SST, Conductivity, Wind, Current and Wave Parameters
3	Met-Ocean Buoy (MB)	Exclusive marine meteorological measurements	Humidity, Air Pressure, Air Temperature, Wind parameters
4	Ocean Buoy (OB)	Oceanographic measurements	Humidity, Air Pressure, Air Temperature, SST, Conductivity, Wind and Wave Parameters
5	Bay of Bengal Data Buoy (BD)	Bay of Bengal Data buoys	Humidity, Air Pressure, Air Temperature, SST, Conductivity, Wind Parameters
6	Arabian Sea Data Buoy (AD)	Arabian Sea Data Buoys	Humidity, Air Pressure, Air Temperature, SST, Conductivity, Wind Parameters
7	Andaman & Nicobar Buoy (AN)	Exclusively deployed in the vicinity of Andaman and Nicobar Islands	Humidity, Air Pressure, Air Temperature, SST, Conductivity, Wind, Current and Wave Parameters
8	Ocean Technology Buoy (OT)	Ocean Technology demonstration buoys	Humidity, Air Pressure, Air Temperature, SST, Conductivity, Wind, Current and Wave Parameters

The main aim of data centre is to ensure that the data are of consistent standard and can be utilised on a long term basis. Quality control in data management is an essential part whenever data is applied for a certain study. These checks depend upon the climatic condition of the region, presumed accuracy of the instrument and the expected accuracy of the parameter. Data values are not changed or deleted but flagged if they are bad or doubtful. However, it is not possible to set rigid standards of quality control for all the data types, all regions and seasons. Good analysis needs better data and in order to achieve this, data measured by moored buoys are subjected to two stages of quality control. Once the raw data is received, the preliminary processing and quality check is implemented in the real-time quality control (RTQC) followed by a detailed quality check is conducted on the data in delayed mode quality control (DMQC).

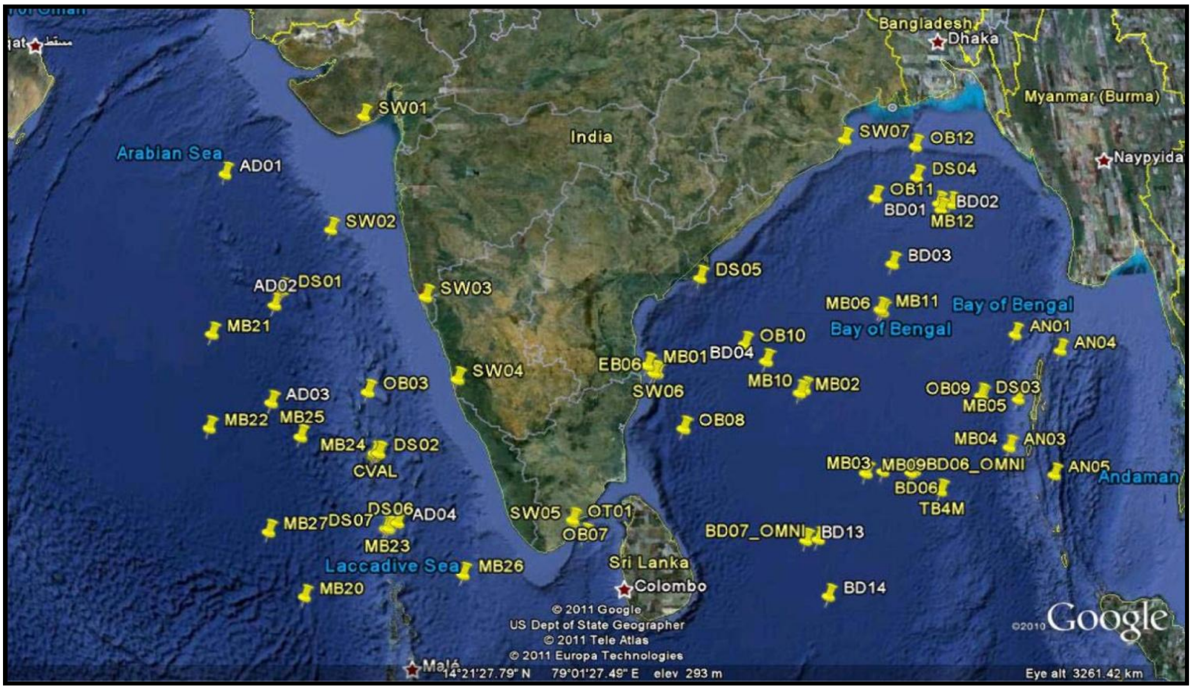
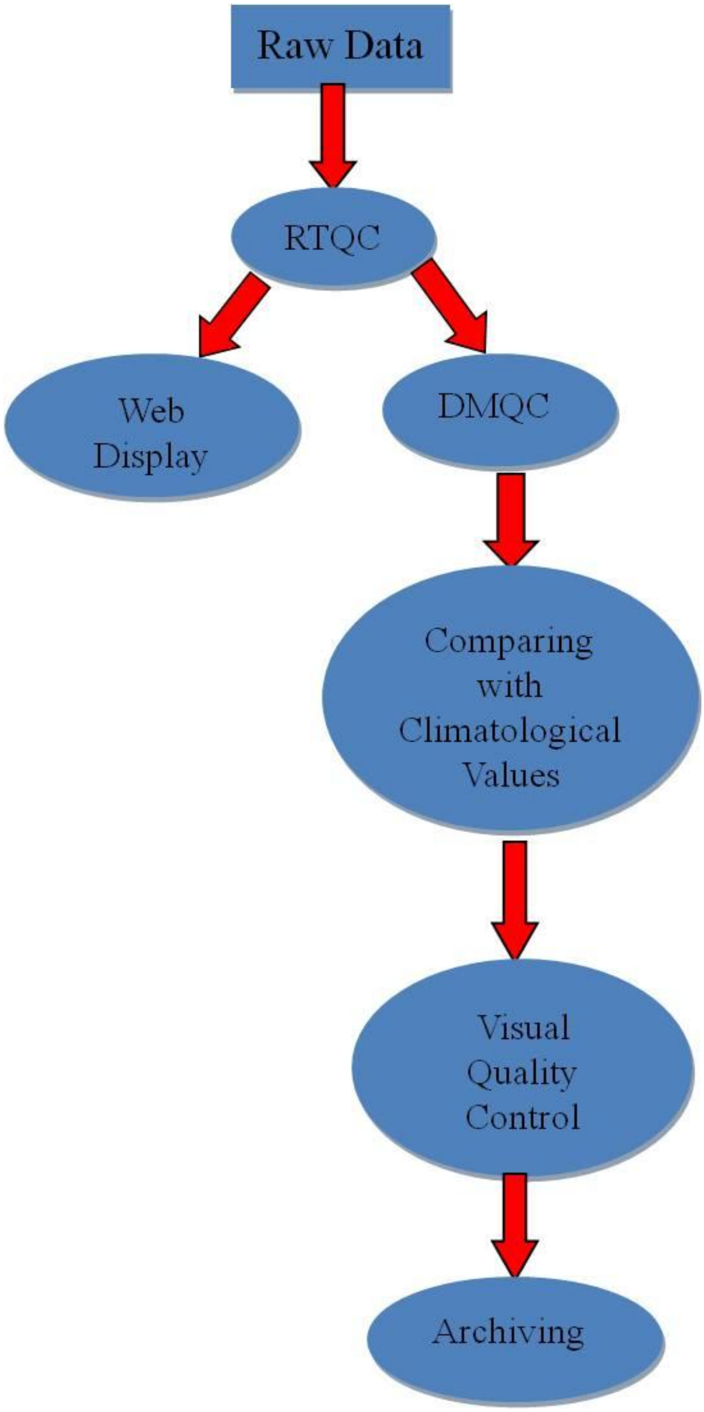


Figure 1: Locations Moored Buoys in the Indian Ocean

Figure 1 shows the locations of moored buoys in the Arabian Sea and the Bay of Bengal. As on date, there are twelve floats which are providing data and the rest are inactive. The active floats are labelled in white colour and the inactive floats shown in yellow. The data that was received from the old buoys was quality checked and then archived. The data from active floats is subjected first to real time quality control and then to delayed mode quality control.

Flow chart showing various stages in *in-situ* quality control



2. REAL TIME QUALITY CONTROL

The RTQC procedures were automated at INCOIS and require no manual intervention. This is the first phase in quality control that cleans the data based on the specifications of the instrument / sensor, transmission losses, etc. A complete schematic of data reception, sensor specifications and RTQC procedures that are being employed in INCOIS were well documented by Sridevi *et al.*, (2009). Listed below are the seven different steps followed:

1. **Impossible date test:** The test requires that the observation date and time from the buoy be sensible.
2. **Impossible location test:** Data from buoys which have drifted by more than 1^o of latitude or 5^o of longitudes are flagged.
3. **Stuck Value Test:** This test looks for consecutive identical measurements of each parameter of an individual buoy.
4. **Spike Test:** The difference between sequential measurements, where one measurement is quite different from the adjacent ones, is a spike.
5. **Range Test:** This checks the range limits for each parameter.
6. **Correlation Test**: This test looks for correlation between related parameters of an individual buoy. Abnormal change in any of the parameters should be checked for similar changes in other parameter.
7. **Seasonal Test:** This test applies to only certain regions of the Indian Ocean where conditions can be further qualified.

These tests are performed on the data as and when they are received in the data centre and the output is disseminated through web for online visualization. The following table shows the data range that is incorporated in RTQC based on sensor specifications.

2.1 Buoy specifications and range of measurements

Table 2: Range, accuracy and resolution of various parameters measured by buoys

Sensor	Range	Accuracy	Resolution
Air Pressure	800 – 1100 hPa	± 0.1 hPa	0.01hPa
Air Temperature	10 – 50^{o}C	± 0.01^{o}C	0.01^{o}C
Wind* (Speed & Direction)	Speed: 0 – 60 ms^{-1} Direction: 0 – 360^{o}	Speed: ± 1.5% F.S Direction: ± 3.6^{o}	Speed: 0.07 ms^{-1} Direction: 0.1^{o}
Water Temperature**	-5 – 45^{o}C	± 0.1^{o}C	0.01^{o}C
Conductivity	2 – 77 m mho cm^{-1}	± 0.06 m mho cm^{-1}	0.01 m mho cm^{-1}
Surface Currents (Speed & Direction)	Speed: 0 – 6m s^{-1} Direction: 0 – 360^{o}	Speed: ± 3 % FS Direction: ± 2^{o}	Speed: 0.005 ms^{-1} Direction: 0.36^{o}
Wave	Height: ± 20m Direction: 0 – 360^{o}	Height: ± 10 cm Direction: ± 5^{o}	Height: 1 cm Direction < 0.1^{o}
Humidity*	0 – 100%	1% Rel. Hum	Not Available

* Sensor above 3 m above the sea surface

** Sensor at 3 m below the sea surface

Continuity of the measurements is paramount for any successful observation platform. This helps immensely in arriving at the statistics based on each of parameter and also the platform. Individual time series and statistical summaries are generated and examined for their gross error checks which are deviated from other neighbouring data. Since in this phase quality checking is done with uniform conditions for all the buoys, there is a possibility that certain observations will get wrongly flagged as bad. These can be rectified in DMQC. After the erroneous data is flagged in RTQC, data is again subjected to DMQC once in every month to further refine the quality of the products.

3. Delayed Mode Quality Control

In the initial phase of DMQC, following the latest climatology based on ICOADS (International Comprehensive Ocean and Atmospheric Data Sets) available up to 2010, certain ranges for all parameters were set. The values which are falling beyond these ranges were flagged as outliers. Surface salinity ranges were obtained from the world ocean atlas 2009. The following table shows the range extremities adopted based on the ICOADS data for all the parameters in DMQC:

Table 3: Parameter ranges implemented in DMQC as observed from climatological data.

Parameter	**Range**
Air Pressure	985 – 1025 hPa
Air Temperature	20 – 40^{o}C
Wind* (Speed & Direction)	Speed: 0 – 35 ms^{-1} Direction: 0 – 360^{o}
Water Temperature**	20 – 35^{o}C
Conductivity	20 – 65 m mho cm^{-1}
Surface Currents (Speed & Direction)	Speed: 0 – 300cm s^{-1} Direction: 0 – 360^{o}
Wave	Height: 0 – 15 Period: 0 - 25sec Direction: 0 – 360^{o}
Humidity*	0 – 100%
Salinity	15 – 40 PSU

* Sensor above 3 m above the sea surface

** Sensor at 3 m below the sea surface

Most of the outliers are eliminated at this stage and further refinement is carried out in the following stages:

1. By comparing with the long term data and climatological data products from other sources and also comparing with other quality data products of similar nature available from other platforms.
2. The data is observed visually for all the synoptic hours and all the parameters and the obvious spikes are flagged. Also for certain data products, standard comparative datasets are not available; such parameters are quality controlled in the VQC stage.

Detailed description of the above mentioned schema is penned in the following lines:

3.1. Comparison with standard long term datasets

In the second stage of DMQC, the datasets are compared with standard long term datasets and climatological values at those locations for the respective parameters. Daily and weekly mean values are computed from the 3hourly measurements and are then compared with the available long term data products for those locations. If there are less than four measurements for a day, daily mean for that particular day is not computed. Three standard deviations of the long term mean is considered as the outer limit and the measurement values that are greater than this limit are considered as outliers and are flagged. The standard long term data set considered for such exercise is the International Comprehensive Ocean-Atmosphere Data Set (ICOADS) of National Ocean and Atmospheric Administration (NOAA).

3.2 Visual Quality Control

A visual quality control (VQC) tool was developed in house using open source tools. Java Swings is the main tool that was extensively made use of in the design. This tool links the host system to the database which contains the buoy data and the climatological data. Once this tools is accessed, it fetches the data of a particular buoy of interest and also the climatology of the particular location. If the data between two time steps is called, the corresponding climatological mean as well as the standard deviation of the climatology is also fetched. This will enable to visually identify the outliers that are well beyond three standard deviations and the values which were wrongly flagged as bad. Once these are resolved, they can be flagged accordingly and could be saved to the database immediately. For certain parameters where standard data sets are not available to compare with, VQC is a good tool to identify and flag the spikes and other erroneous values. After this stage of quality control, data is archived and is retrieved on request.

4. Quality Flags

After subjecting the data to different stages of DMQC, they are flagged according to their quality as follows:

Table 4: Flags assigned to the data and their description

Quality Flag	Description
0	No QC
1	Good Data
3	Stuck Value
4	Bad Data
8	Out of Range
9	No data

5. Plots of the parameters before and after DMQC

Data plots for the buoys DS01 (Lat: 15.481°N and Lon: 69.248°E) for October 2007, DS03 (Lat: 12.189°N and Lon: 90.726°E) and SW06 (Lat: 13.167°N and Lon: 80.691°E) are taken as a representative buoys depending on their measured parameters, for showing the pictorial representation of the quality of data. The data is plotted over the mean values obtained from ICOADS data and between 3 standard deviation limits. Those exceeding these limits are automatically flagged as outliers and those data points which are missed during DMQC and also, outliers of those parameters which do not have standard data sets to compare are flagged during the VQC stage. In the RTQC stage, the data is classified into two categories as 1.Good and 2. Bad that can be seen in the data plots of those before DMQC stage. Post DMQC, Data is classified into 1. Good 2.Doubtful 3. Stuck and 4. Bad; shown in different colours. Flag 8 (Out of Range) is also shown as bad data (outlier) in the plot but in the database, it is retained as Flag 8. In the DMQC graphs, the green lines show the three standard deviation limit set as the upper and lower limit of the parameter value based on ICOADS climatology.

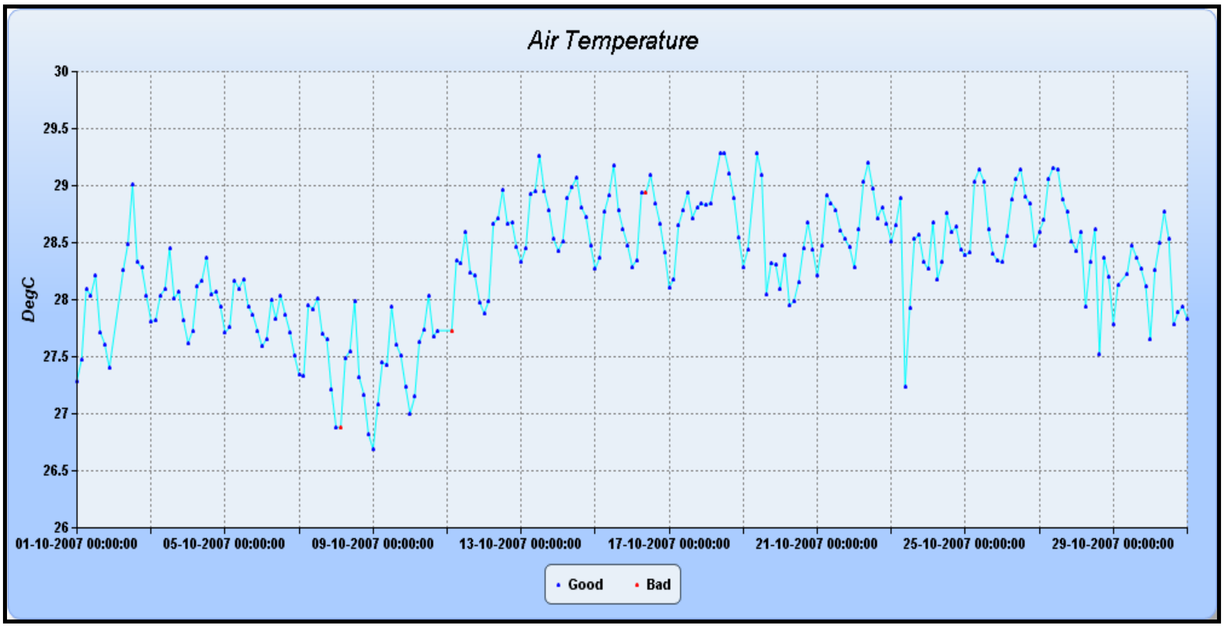


Figure 2: Air Temperature Plot before DMQC

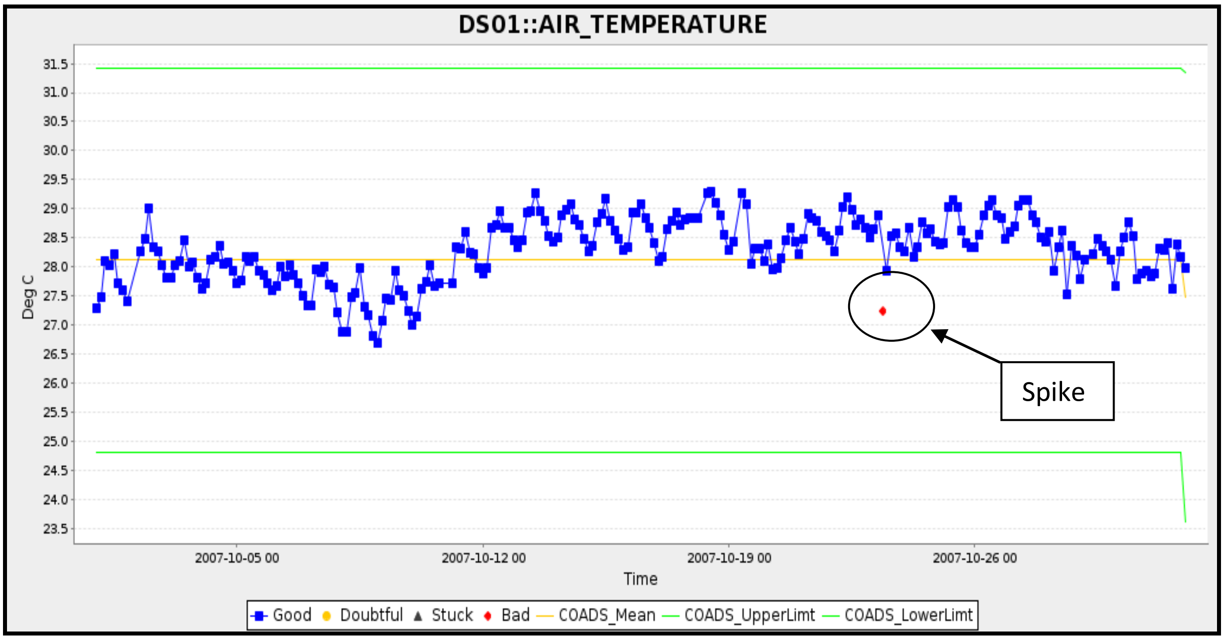


Figure 3: Air Temperature plot after DMQC

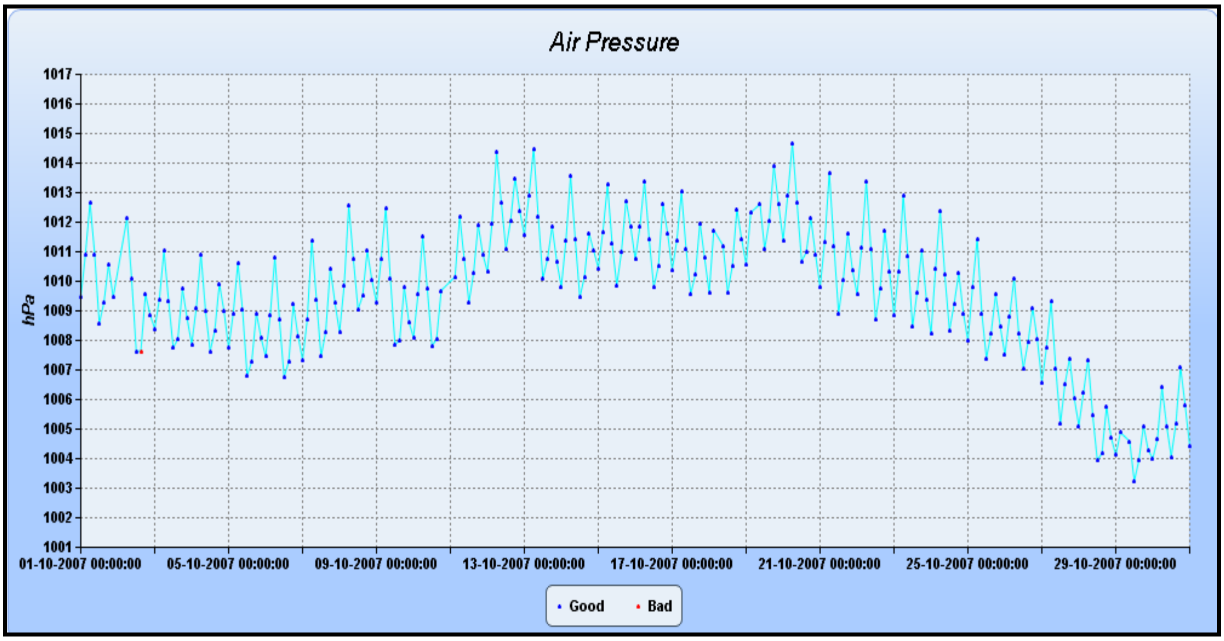


Figure 4: Air Pressure plot before DMQC

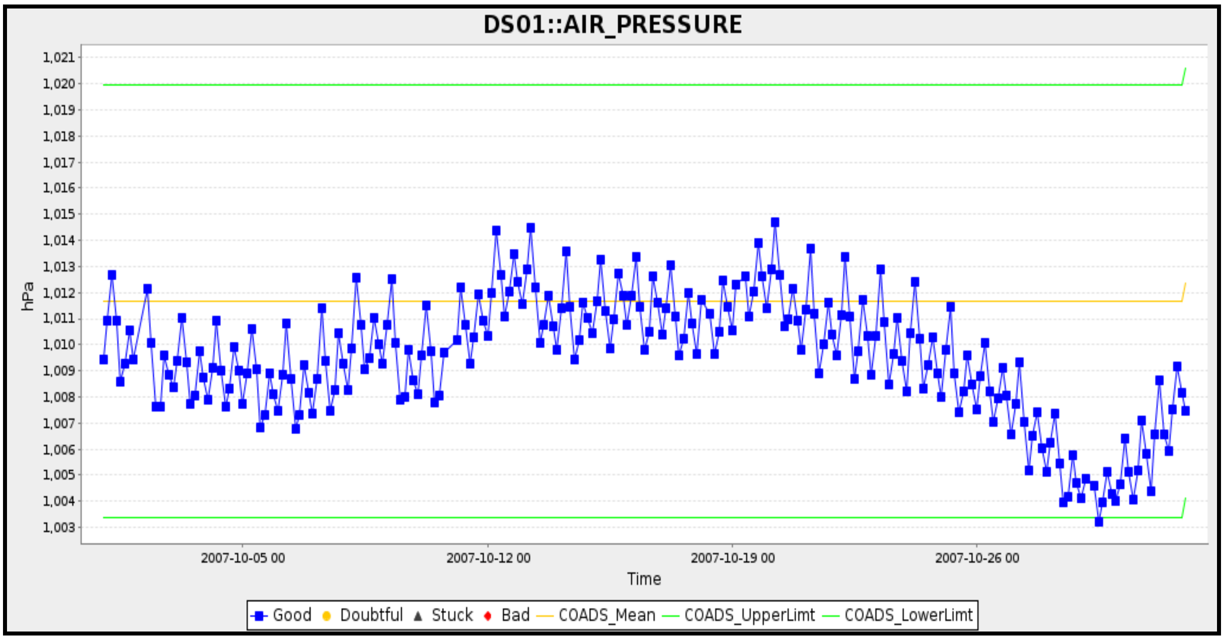


Figure 5: Air Pressure Plot after DMQC

Figs 4 and 5 show the Air Pressure before and after DMQC where it is observed that there are no outliers in the values.

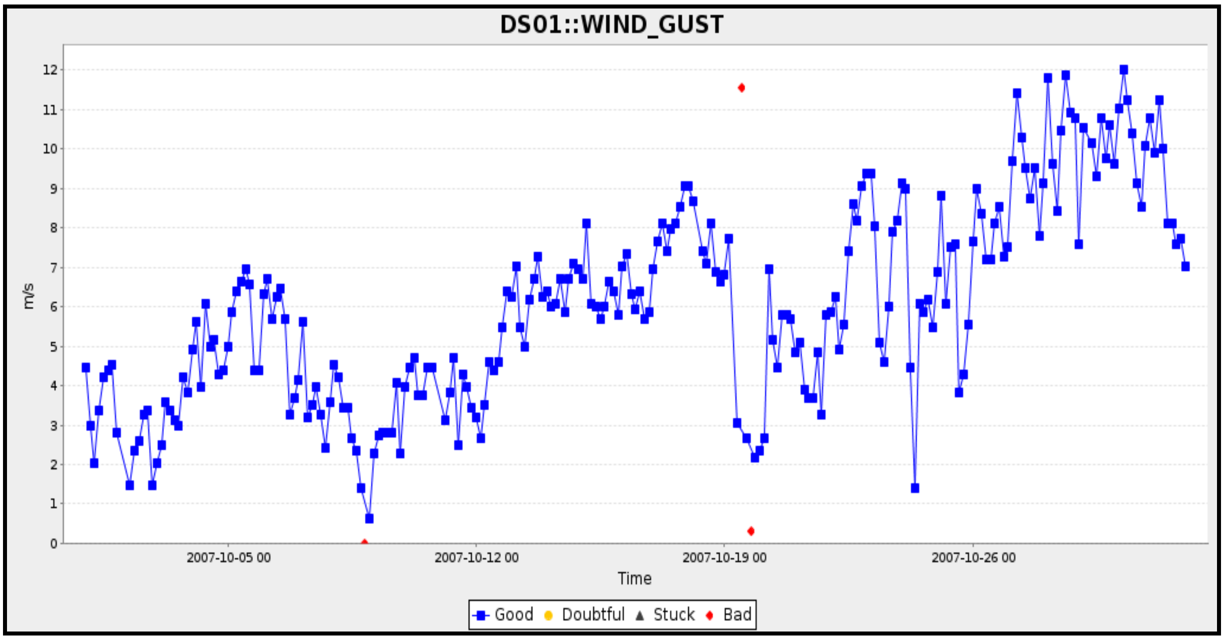


Figure 6: Wind Gust plot after DMQC

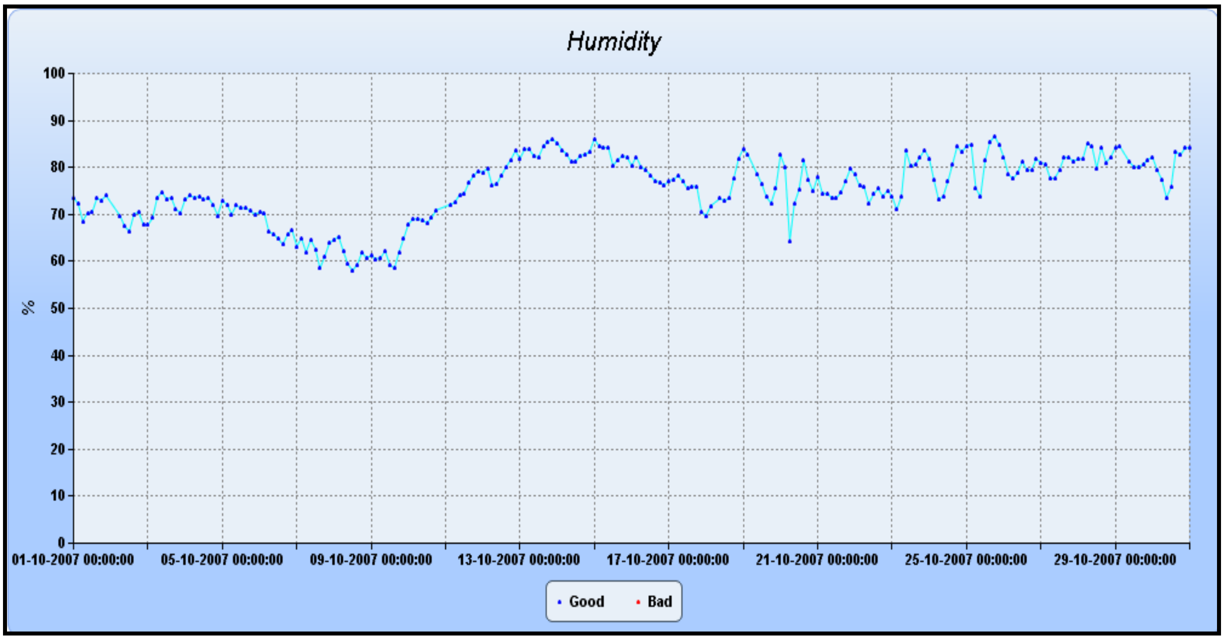


Figure 7: Humidity plot before DMQC

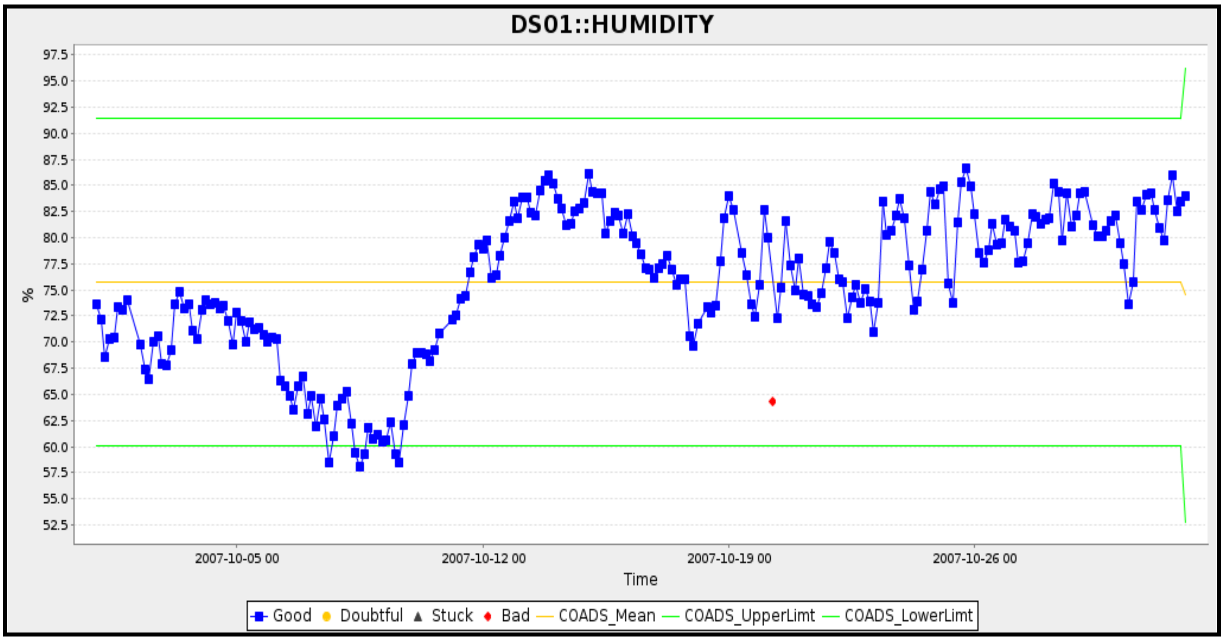


Figure 8: Humidity plot after DMQC

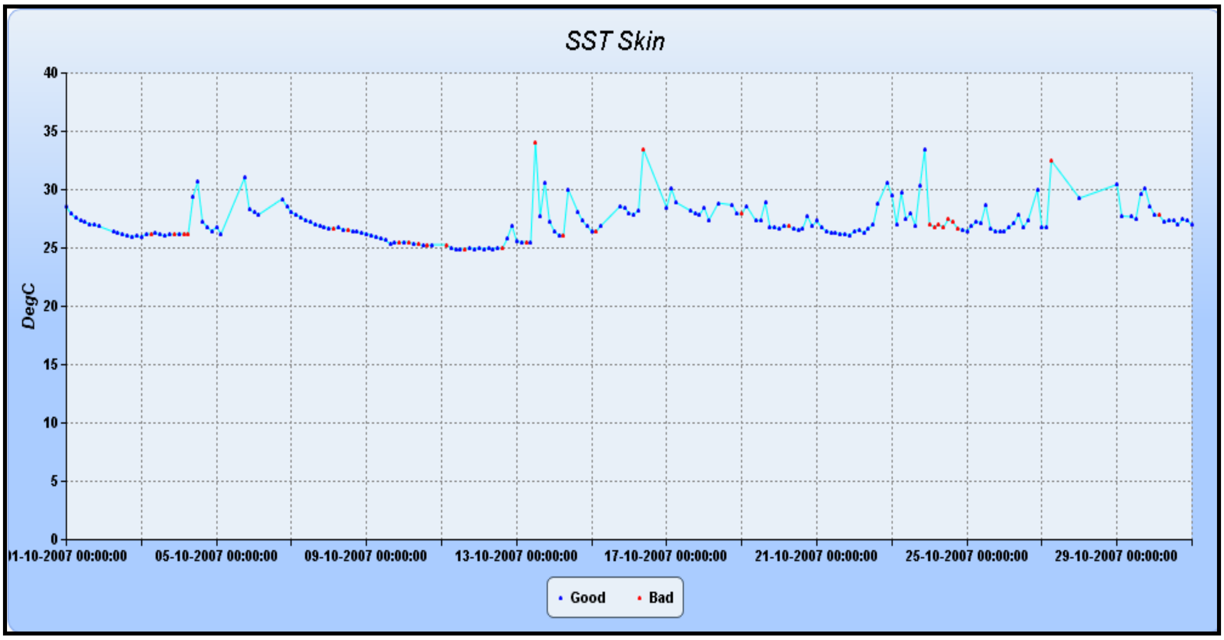


Figure 9: SST plot after DMQC

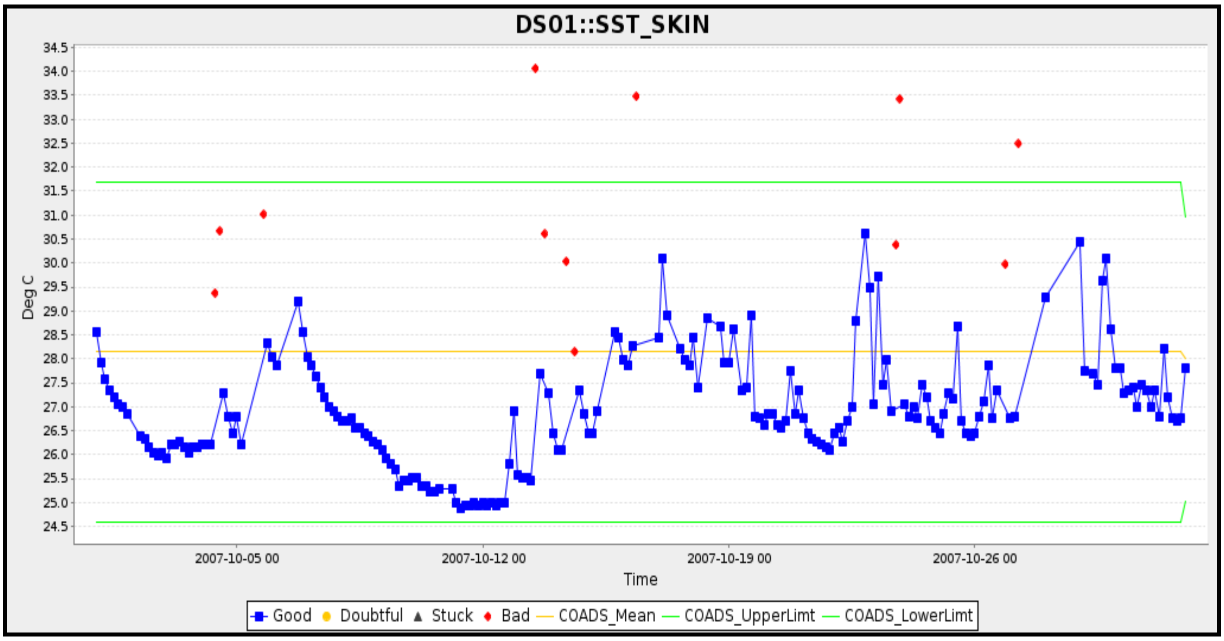


Figure 10: SST plot after DMQC

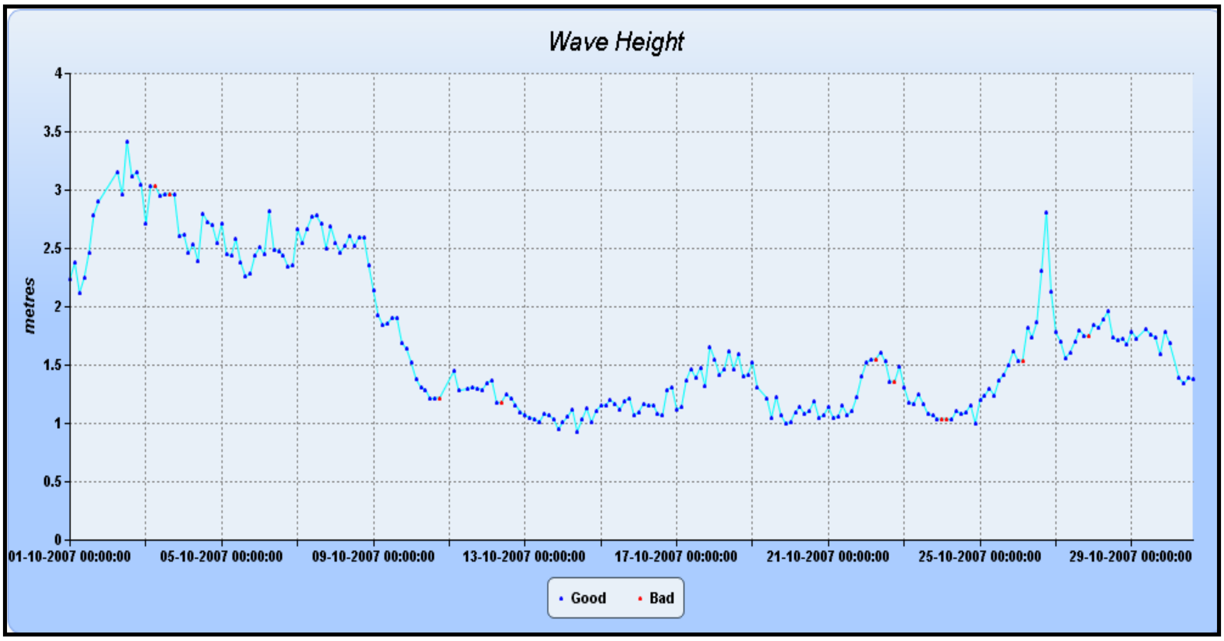


Figure 11: Wave Height before DMQC

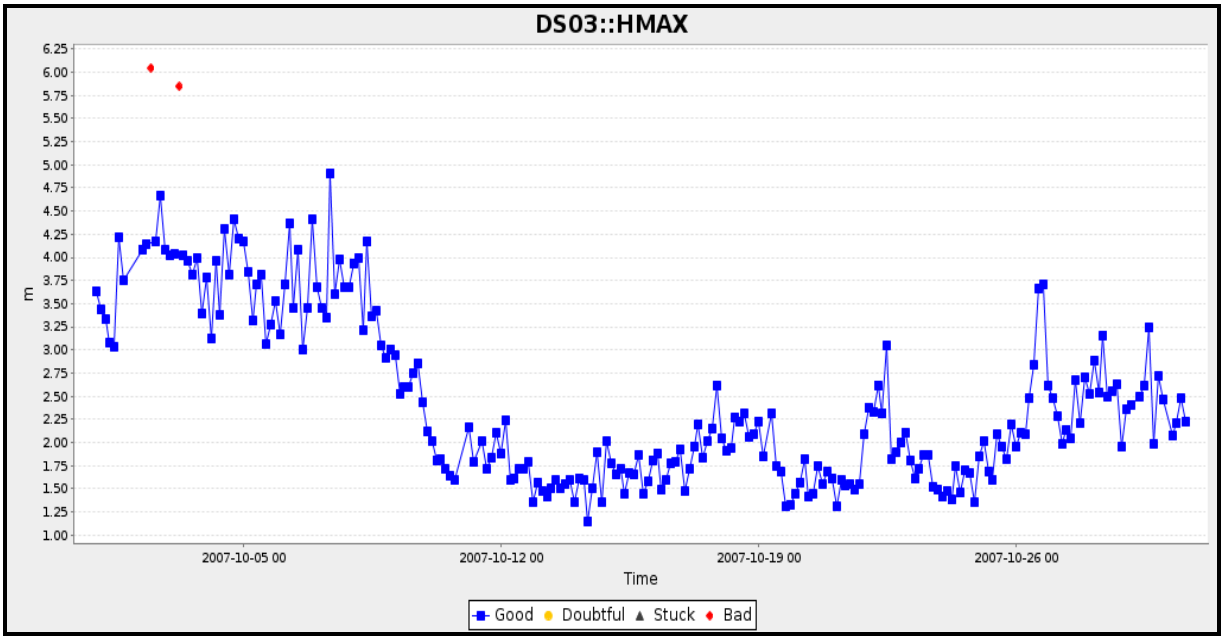


Figure 12: Wave Height after DMQC

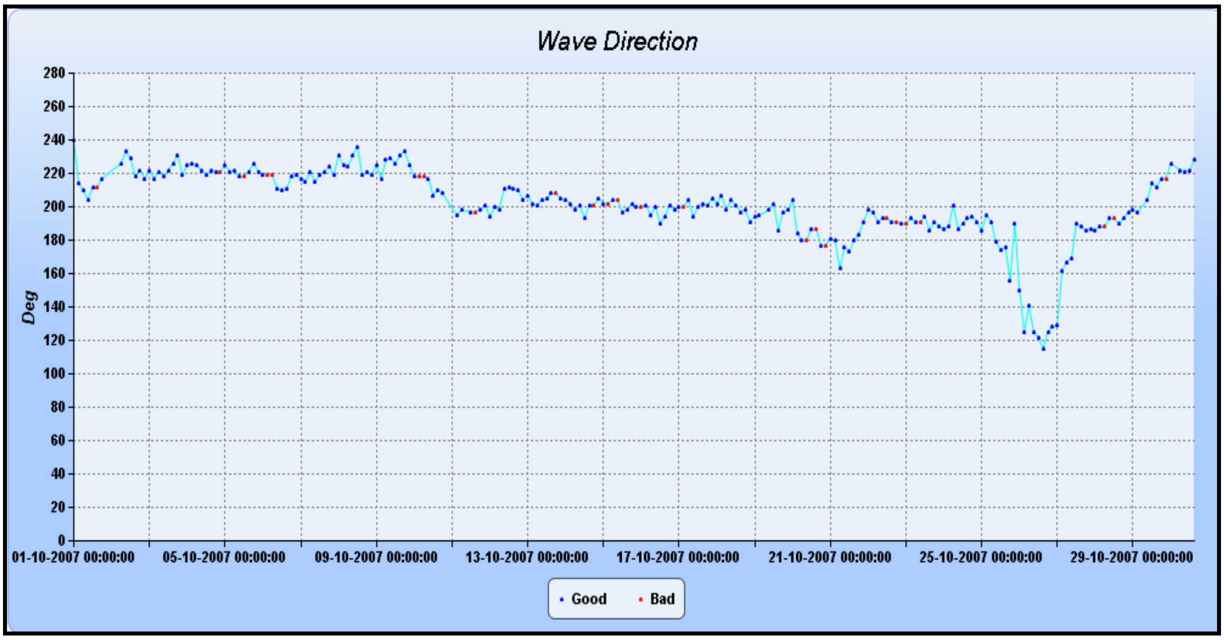


Figure 13: Wave Direction before DMQC

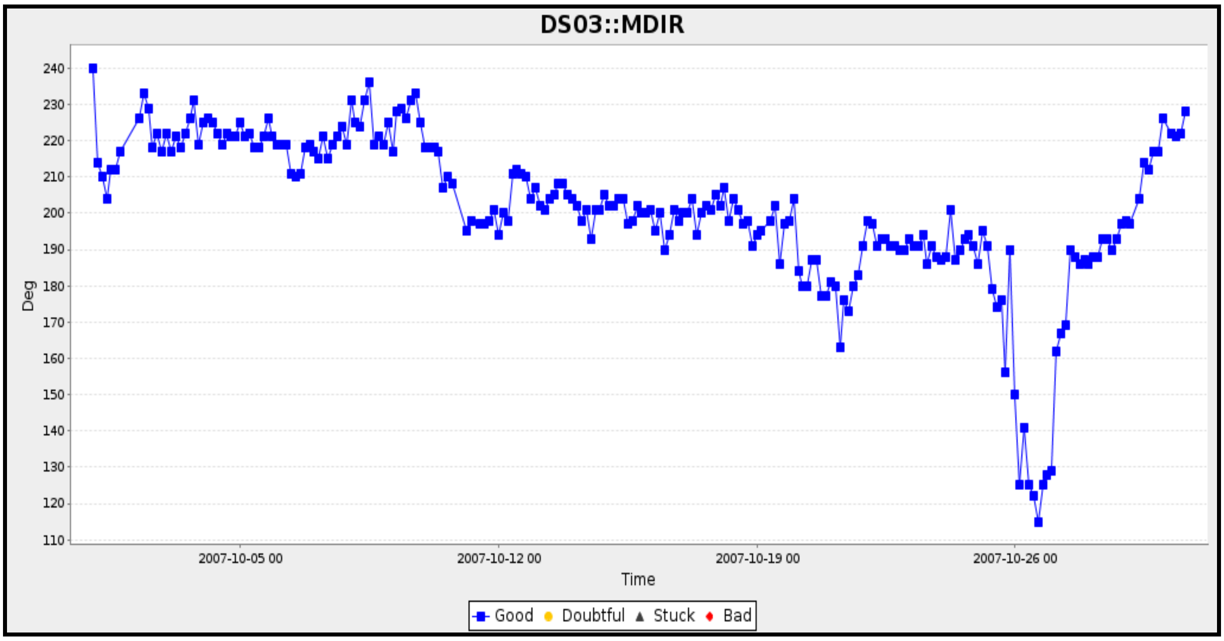


Figure 14: Wave Direction after DMQC

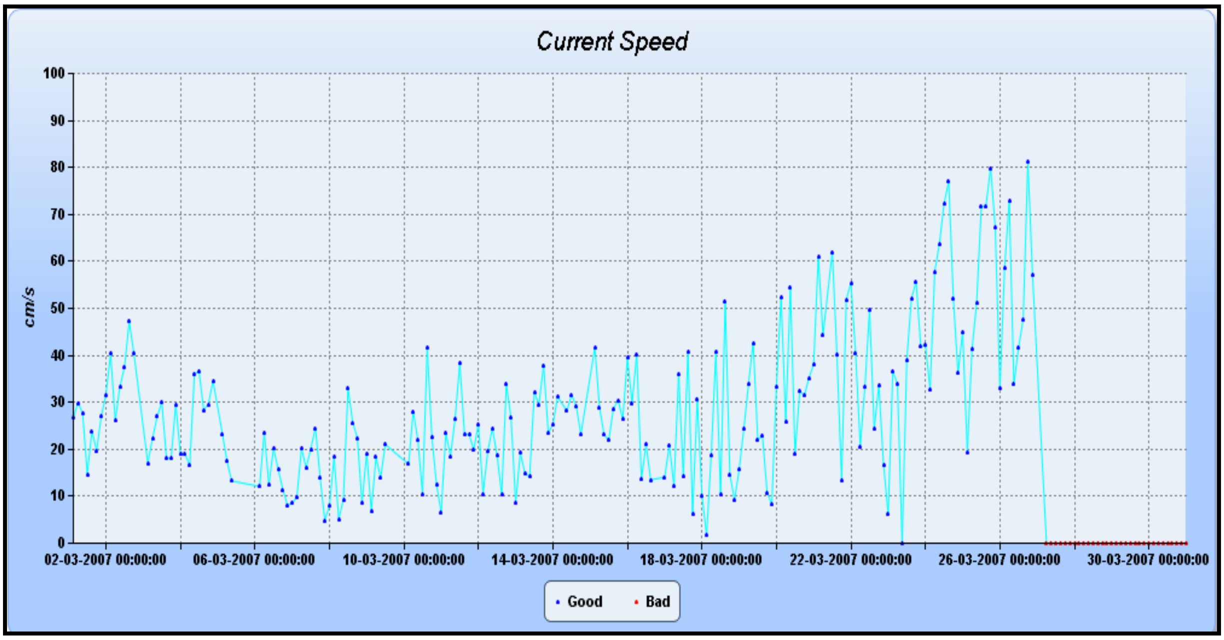


Figure 15: Current Speed before DMQC

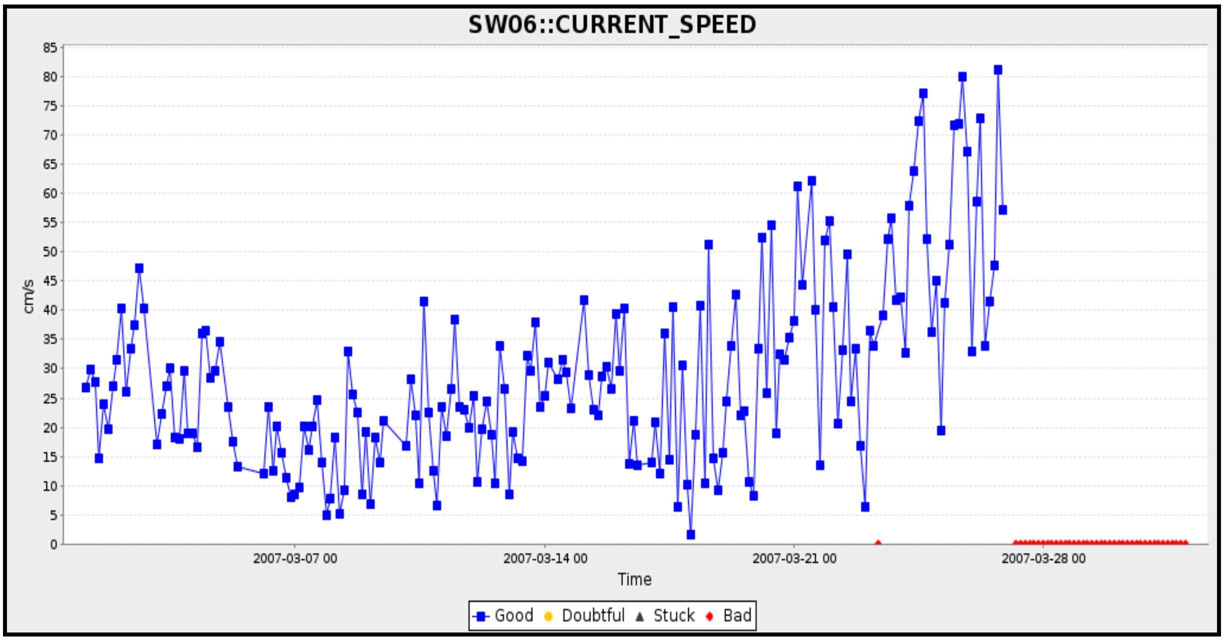


Figure 16: Current Speed after DMQC

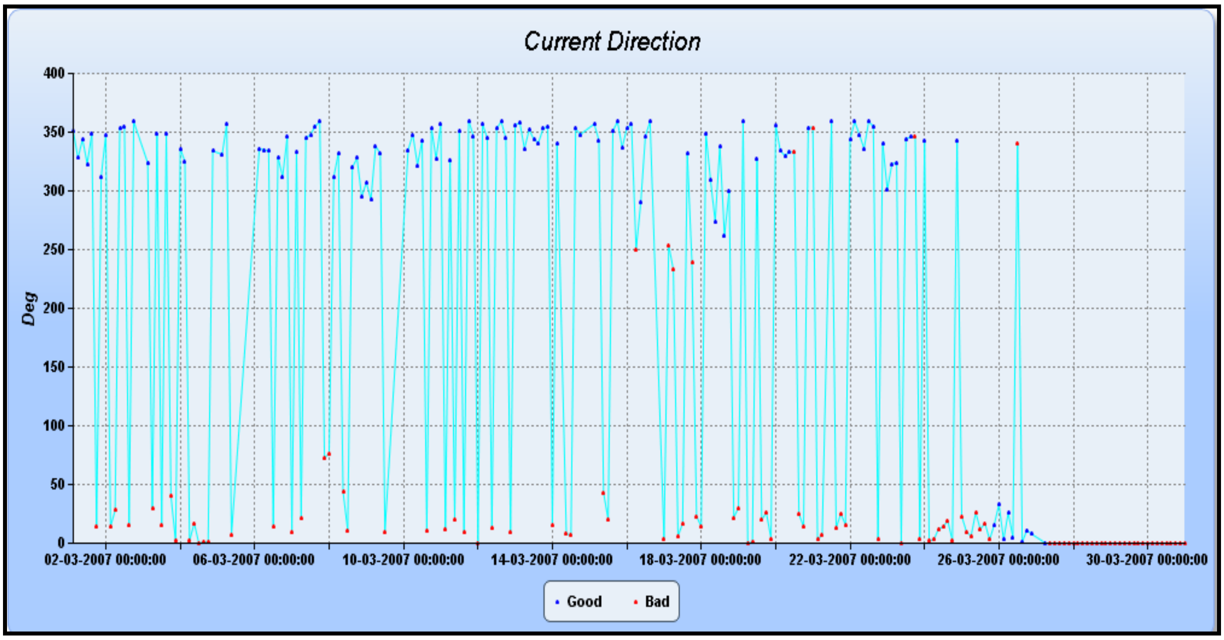


Figure 17: Current Direction before DMQC

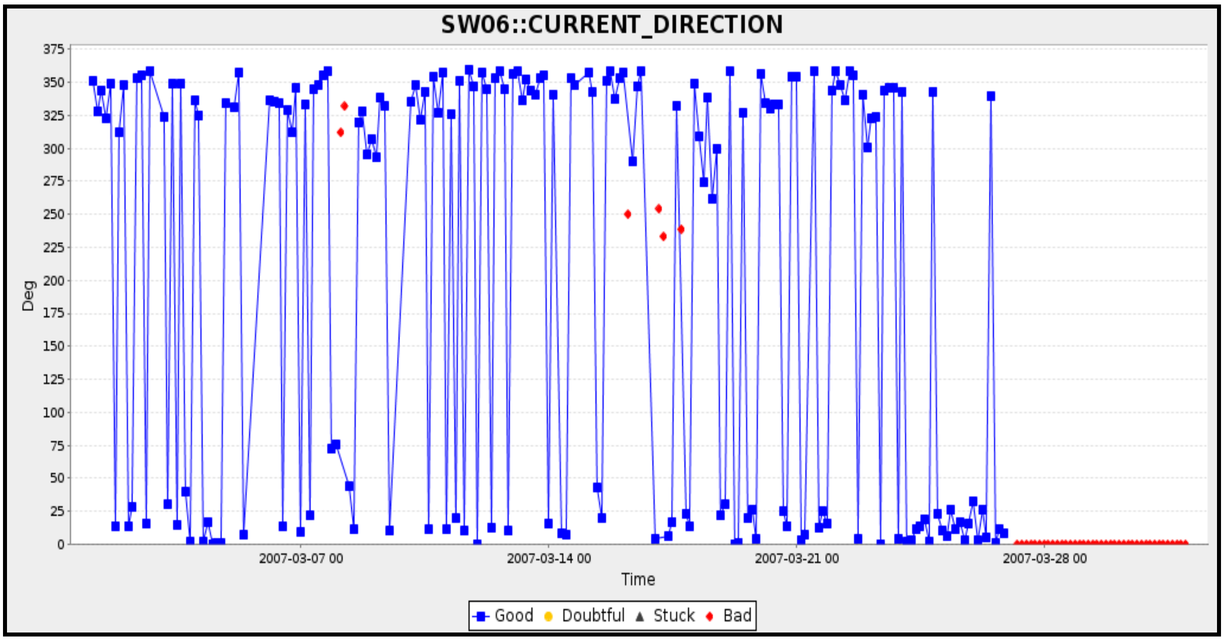


Figure 18: Current Direction after DMQC

6. Bibilography

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Web Links

1. www.pmel.noaa.gov/tao/proj_over/qc.html
2. www.oceandatastandards.org