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Research Article

INTER-COMPARISON OF METEOROLOGICAL ELEMENTS OF AUTOMATIC WEATHER STATIONS AND CONVENTIONAL OBSERVATIONS OVER BIHAR REGION

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ABSTRACT
To contribute reliable meteorological information to the end users (farmers, researchers, government agencies etc) it is essential to validate the automatic weather station data with the actual observation data. The study discusses the comparison of meteorological elements (temperature, pressure, relative humidity, wind speed and wind direction) of conventional and automatic weather station (AWS) data for 6 nearly collocated stations over Bihar region. The results show that the performance of AWS data is comparable with the conventional data. Temperature and humidity data obtained from AWS is in usable range (> 70 %) for day to day weather forecasting. The pressure values 40-50 % lies within meteorological permissible limit. Wind speed and direction is a crucial one and quite comparable with the conventional observations. The correlation coefficients between two data sets are strong except winds speed. The t – test shows mixed type significance at 95 % confidence in almost all the parameters. For maximum temperature all the stations data are statistically non-significant except Patna.

Keywords: *Conventional Observation, Automatic Weather Station, Temperature, Pressure and Relative Humidity*

INTRODUCTION
The state of Bihar is located in the eastern part of the Republic of India. It covers an area of 94,163 square km bounded by 24.2 $^{\circ}N$ to 37.31 $^{\circ}N$ latitude and 83.20 $^{\circ}E$ to 88.18 $^{\circ}E$ longitude. Topographically, Bihar is divided into three divisions:
1. Sub – Himalayan foot hills
2. The Indo Gangetic Plain
3. The Southern Plateau region

The state has meteorologically only one sub-division with 38 districts. There are 4 departmental and 7 part time observatories along with state of art 28 automatic weather stations (AWS) and automatic rain gauges spread in whole state of Bihar. India Meteorological Department (IMD) is the nodal agency to issue the weather forecast. The state of the atmosphere is predicted with the help of observations (conventional as well as remote) of meteorological elements. The conventional observations are based on surface as well as upper air observations. IMD is maintaining a network of 559 departmental meteorological and 3500 non-departmental observatories from where we are getting daily data of meteorological elements. To meet the increasing demand of precise weather forecasting in various sectors of government as well as commercial, IMD has increased the density of latest state of art AWS at par with the developed countries technologies. IMD is augmented the surface observational network in the recent years by installing around 675 unmanned satellite based AWS during 2007-2012 from which the meteorological data is received in near real time basis. In the modernization initiative of IMD there is a plan of installing 2000 AWS and 4000 ARGs all over the India in a phased manner during next 5 years. The utility of the AWS data is increased where the actual observations are difficult. The AWS or ARGs data is available hourly in 24 x7 without interruption for daily weather analysis. To ascertain the quality of the data its comparison with the conventional observations are essential. Time to time validation provides a guidance or check the status of the sensors and a need of calibration or replacement of the faulty sensors. Present paper deals with the comparison of the AWS and conventional data over Bihar region. This study is useful in monitoring the health of AWS and judicious use of the data in weather forecasting. The meteorological center Patna observatory and AWS are adjacent and during bad weather conditions it is very difficult to come every hour from automatic traffic control (ATC) building forecasting office at Jai Prakash Narayan Airport (JPNI) to observatory (~0.5 km) to take current observations. This current precise information of meteorological elements is essential in aviation forecasting, especially during dense fog or squally weather. Considering above facts it is essential to know accurately the bias, threshold or tolerance limit of using the AWS data by comparing it conventional observations. In past, Vashistha *et al.*, (2005), Amudha *et al.*, (2008) have reported that, deviations of AWS data from the co-located synoptic surface observatory data were within acceptable limits and thus AWS network performance was satisfactory. Similar results were reported by Datar *et al.*, (1983), Ranalkar *et al.*, (2012) and Ranalkar *et al.*, (2008b about the performance of AWS observations are comparable to the conventional measurements. Conventional and automatic observations have different type of instruments and recording methodologies. The averaging of wind speed (per second vector average in AWS and three minutes scalar in conventional) is different in both cases which affect the accuracy of validation (Ranalkar, 2012). To increase the accuracy of validation an alternative method for calculating the AWS wind gust and maximum/minimum temperatures, considering the response time of the mechanical anemometer and of the mercury thermometer as a parameter for comparison with the electronic sensors is suggested by Powell, 1993 and Lockhart,1995. Similar analysis of synoptic hours (0300 & 1200 UTC) data of Automatic Weather Stations (AWS) and Conventional Weather Stations (CWS), is compared by Sentelhas *et al.*, (1997), Fisch and Santos (1997), Souza *et al.*, (2003), Teixeira *et al.*, (2003) and found that quality of meteorological data from automatic stations depends on the good condition of its sensors, which requires a new management strategy in preventive and corrective maintenance, replacement of sensors and equipment, and this requires budgetary allocations at significant levels.

MATERIALS AND METHODS

Data and Methodology

The IMD AWS meteorological data (temperature, relative humidity, pressure, wind speed and wind direction, in the present case) is measures at fixed intervals and transmitted hourly through INSAT -3D satellite to the earth station at Pune. The accuracies of the above said parameters are $\pm 2^{\circ}C$, $\pm 3\%$, 0.2 hPa, 1.2 m/s and 1° respectively. All the departmental and part time observatories of IMD conventional data are provided at synoptic hours. In the present study the 0300 and 1200 UTC conventional as well as AWS data of nearly collocated stations (Table 1) are utilized and taken from meteorological centre Patna. The six stations AWS data of Bihar region is compared with the conventional data for the year 2014. The difference between conventional and AWS data is called bias for the present study (Bias = $Obs_{conventional} - Obs_{aws}$**)**. The data is statistically analysed and error structure of each element is computed to know the permissible tolerance of each element. The tolerance limit of the meteorological elements justifies the usability of the data in weather forecasting or its applicability in the numerical weather prediction models. The criteria of error structure of meteorological elements are given below in Table 2. Other statistical parameters like mean, standard deviation (SD), standard error (SE) etc were computed and given in Table 4. The level of significance at 95 % is also computed assuming that there is no difference in the data of conventional and AWS stations.

Table 1: Details of AWS in Bihar region

S. No	Stations	District	Lat	Long	Remarks
1	Patna	Patna	25.36	86.02	Collocated
2	Muzaffarpur	Muzaffarpur	24.26	85.8	06 km
3	Gaya	Gaya	24.79	85.00	08 km
4	Supaul (State)	Supaul	26.12	86.6	02 km
5	Darbhanga	Darbhanga	26.11	85.84	08 km
6	Sabour	Bhagalpur	25.15	87.11	07 km

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Table 2: Criteria of Meteorological elements error structure

Meteorological element	Correct	Usable	Incorrect
Maximum or minimum temperature	$\pm 1\ ^{\circ}C$	$\pm 2\ ^{\circ}C$	$> \pm 2\ ^{\circ}C$
Relative humidity	± 10 **%**	± 20 **%**	$> \pm 20$ **%**
Pressure	± 1 **hPa**	± 2 **hPa**	$> \pm 2$ **hPa**
Wind Speed	± 2 **m/s**	± 4 **m/s**	$> \pm 4$ **m/s**
Wind Direction	± 30 **degree**	± 40 **degree**	$> \pm 40$ **degree**

Table 3: Error Structure of meteorological elements

	Muzaffarpur	**Supaul**	**Darbhanga**	**Gaya**	**Sabour**	**Patna**
Error structure	Max-Temp	Max - Temp	Max-Temp	Max-Temp	Max-Temp	Max-Temp
Correct	45.48	41.64	58.40	48.90	43.84	24.93
Usable	23.84	29.86	23.42	27.20	34.25	25.21
Unusable	30.68	28.49	18.18	23.90	21.92	49.86
RMSE	2.98	1.94	1.83	2.03	1.93	2.93
Correlation	0.91	0.96	0.96	0.96	0.95	0.96
Error structure	Min-Temp	Min - Temp	Min-Temp	Min-Temp	Min-Temp	Min-Temp
Correct	36.75	25.62	55.25	43.56	35.70	68.77
Usable	41.88	40.22	30.11	27.63	33.42	27.40
Unusable	21.37	34.16	14.64	28.77	31.51	3.84
RMSE	2.22	1.98	1.66	1.95	2.32	1.09
Correlation	0.94	0.93	0.93	0.95	0.94	0.97
Error structure	Max-RH	Max-RH	Max-RH	Max-RH	Max-RH	Max-RH
Correct	52.60	52.50	41.92	60.55	36.99	43.84
Usable	33.15	33.15	41.64	26.30	42.74	41.10
Unusable	14.25	14.79	16.44	13.42	20.27	15.70
RMSE	3.44	3.43	3.54	3.36	3.86	3.59
Correlation	0.87	0.84	0.73	0.74	0.61	0.80
Error structure	Min-RH	Min-RH	Min-RH	Min-RH	Min-RH	Min-RH
Correct	67.40	61.10	30.68	53.30	21.37	62.47
Usable	19.18	26.03	20.82	29.67	29.04	24.11
Unusable	13.42	12.88	48.49	17.03	49.59	13.42
RMSE	3.03	3.27	4.49	3.62	4.59	3.24
Correlation	0.78	0.79	0.76	0.77	0.76	0.85
Error structure	Max-Speed	Max-Speed	Max-Speed	Max-Speed	Max-Speed	Max-Speed
Correct	98.90	99.45	98.36	95.07	96.44	99.73
Usable	0.0	0.0	0.0	0.55	0.0	0.0
Unusable	0.0	0.0	0.0	0.0	0.0	0.0
RMSE	0.07	0.83	0.65	1.3	1.18	0.48
Correlation	0.47	0.25	0.29	0.28	0.30	0.22
Error structure	Min-Speed	Min-Speed	Min-Speed	Min-Speed	Min-Speed	Min-Speed
Correct	99.73	99.73	100.0	100.0	100.0	99.45
Usable	0.0	0.0	0.0	0.0	0.0	0.0

Unusable	0.0	0.0	0.0	0.0	0.0	0.0
RMSE	0.12	0.41	0.21	0.29	0.46	0.49
Correlation	0.20	0.15	-0.05	-0.20	-0.14	0.03
Error structure	Max-Wind-dir	Max-Wind-dir	Max-Wind-dir	Max-Wind-dir	Max-Wind-dir	Max-Wind-dir
Correct	31.30	38.74	37.36	33.97	21.92	26.92
Usable	-59.27	-48.20	-56.31	-53.31	-65.47	-58.79
Unusable	64.26	54.26	57.96	57.73	71.78	65.93
RMSE	23.22	21.66	10.2	20.01	29.76	28.89
Error structure	Min-Wind-dir	Min-Wind-dir	Min-Wind-dir	Min-Wind-dir	Min-Wind-dir	Min-Wind-dir
Correct	25.75	17.80	34.72	41.09	22.80	31.40
Usable	-62.73	-67.39	-58.33	-52.87	-61.53	-57.57
Unusable	67.94	73.69	59.16	53.69	68.95	62.25
RMSE	22.45	23.27	5.63	7.8	28.98	19.50
Error structure	Max-Press	Max-Press	Max-Press	Max-Press	Max-Press	Max-Press
Correct	33.52	23.90	28.85	38.46	23.80	30.3
Usable	10.71	13.50	11.26	10.19	09.70	15.7
Unusable	55.77	62.91	59.89	51.37	68.13	53.99
RMSE	3.35	3.11	3.23	3.87	4.18	2.49
Correlation	0.88	0.92	0.91	0.94	0.87	0.97
Error structure	Min-Press	Min-Press	Min-Press	Min-Press	Min-Press	Min-Press
Correct	29.4	33.52	28.57	41.76	27.47	29.95
Usable	11.81	08.24	08.79	09.62	15.93	13.19
Unusable	58.79	58.24	62.64	48.63	56.59	56.87
RMSE	3.34	3.51	4.19	3.70	3.22	5.78
Correlation	0.91	0.92	0.84	0.89	0.92	0.77

Table 4: Meteorological element statistical analysis:

Max-temp	**mean**	**SD**	**SE**	**P-value**	**mean**	**SD**	**SE**	**Significance**
MZF	29.23	6.57	0.34	0.064	30.14	6.64	0.34	NSG
SUP	29.46	5.7	0.3	0.017	30.51	6.09	0.31	NSG
DAR	30.39	6.71	0.35	0.404	30.81	6.69	0.35	NSG
GAYA	31.57	13.31	0.69	0.975	31.59	6.5	0.34	NSG
SAB	29.76	6.16	0.322	0.33	30.2	6.15	0.322	NSG
PATNA	29.05	6.89	0.364	0.0003	30.91	7.06	0.36	SG
Min-temp	mean	SD	SE	P-value	mean	SD	SE	Significance
MZF	19.87	6.92	0.362	0.034	20.92	6.49	0.34	SG
SUP	19.5	7.9	0.41	0.0041	18.08	6.02	0.315	SG
DAR	21.29	12.38	0.64	0.927	21.19	16.38	0.857	NSG
GAYA	20.3	6.64	0.34	0.001	19.05	7.25	0.379	SG
SAB	20.12	6.55	0.34	0.0016	18.62	6.31	0.33	SG
PATNA	20.63	6.6	0.345	0.006	91.74	6.55	0.344	NSG
Max-R.H	mean	SD	SE	P-value	mean	SD	SE	Significance
MZF	85.73	17.01	0.89	< 0.0001	74.81	18.45	0.87	SG
SUP	80.67	18.31	0.95	< 0.0001	70.8	19.34	1.01	SG
DAR	71.79	12.35	0.65	< 0.0001	60.13	11.87	0.62	SG
GAYA	80.69	17.74	0.92	< 0.0001	73.81	19.91	1.04	SG
SAB	92.64	8.48	0.44	< 0.0001	78.33	16	0.83	SG
PATNA	87.19	17.87	0.93	< 0.0001	76.27	18.31	0.95	SG
Min-R.H	mean	SD	SE	P-value	mean	SD	SE	Significance
MZF	56.35	18.83	0.985	0.092	58.8	20.26	1.06	NSG

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SUP	59.85	16.16	0.85	0.487	58.93	19.46	1.01	NSG
DAR	53.61	20.28	1.061	0.0067	49.93	16.11	0.84	SG
GAYA	54.58	22.53	1.18	< 0.0001	62.72	22.43	1.17	SG
SAB	56.8	17.18	0.89	< 0.0001	65.01	19.25	1.01	SG
PATNA	68.8	26.31	1.37	0.012	64.35	21.45	1.12	SG
Max-wind-speed	mean	SD	SE	P-value	mean	SD	SE	Significance
MZF	1.29	1.21	0.063	0.14	1.46	1.83	0.96	NSG
SUP	3.03	2.41	0.12	< 0.0001	1.7	0.92	0.04	SG
DAR	3.5	3.2	0.17	0.016	3.03	2.1	0.126	NSG
GAYA	3.82	2.89	0.15	< 0.0001	1.23	1.24	0.06	SG
SAB	3.84	3.31	0.17	< 0.0001	1.5	1.01	0.05	SG
PATNA	1.87	1.8	0.094	< 0.0001	0.82	0.9	0.04	SG
Min-wind-speed	mean	SD	SE	P-value	mean	SD	SE	Significance
MZF	0.224	0.378	0.019	< 0.0001	0.376	0.53	0.28	SG
SUP	0.401	0.639	0.033	< 0.0001	1.8	0.85	0.044	SG
DAR	0.39	0.56	0.029	0.96	0.39	0.65	0.034	NSG
GAYA	0.22	0.366	0.019	< 0.0001	1.11	1.23	0.064	SG
SAB	0.36	0.69	0.03	< 0.0001	0.59	0.59	0.03	SG
PATNA	2.32	1.71	0.89	< 0.0001	0.96	0.98	0.051	SG
Max-wind-direction	mean	SD	SE	P-value	mean	SD	SE	Significance
MZF	89.12	104.12	5.45	< 0.0001	123.56	123.26	6.77	SG
SUP	155.13	117.61	6.18	< 0.0001	170.19	90.76	4.75	SG
DAR	115.67	11.85	5.85	< 0.0001	52.17	92.31	4.83	SG
GAYA	134.21	140.11	7.33	2.90E-02	113.42	115.84	6.06	SG
SAB	127.78	101.69	5.32	0.0002	159.23	115.84	6.15	SG
PATNA	157.46	103.65	5.42	< 0.0001	113.24	113.96	5.96	SG
Min-wind-direction	mean	SD	SE	P-value	mean	SD	SE	Significance
MZF	58.1	110.37	5.78	< 0.0001	140.59	119.09	6.23	SG
SUP	119.69	93.15	4.87	< 0.0001	175.53	94.87	4.96	SG
DAR	121.63	109.54	5.73	< 0.0001	73.08	109.93	5.76	SG
GAYA	180.72	120.67	6.31	< 0.0001	141.05	132.08	6.91	SG
SAB	127.58	101.92	5.32	< 0.0001	172.81	107.05	5.68	SG
PATNA	115.07	122.3	6.4	< 0.0001	145.78	106.59	5.57	SG
Max-Pressure	mean	SD	SE	P-value	mean	SD	SE	Significance
MZF	1004.08	7.08	0.387	0.3363	1004.58	6.72	0.35	NSG
SUP	1005.46	7.08	0.371	0.0018	1007.04	6.527	0.34	SG
DAR	1005.44	7.1	0.372	0.05	1004.4	7.566	0.396	NSG
GAYA	1004.39	9.383	0.491	0.0006	1006.52	8.04	0.421	SG
SAB	1008.38	6.43	0.337	0.0001	1006.25	7.41	0.388	SG
PATNA	1007.21	8.03	0.421	0.0056	1008.33	7.731	0.405	SG
Min-Pressure	mean	SD	SE	P-value	mean	SD	SE	Significance
MZF	1003.15	7.74	0.405	1.82E-01	1003.53	8.03	0.421	NSG
SUP	1007.25	8.48	0.444	9.50E-03	1008.83	7.864	0.412	SG
DAR	1008.22	7.11	0.372	5.18E-02	1007.23	6.74	0.353	NSG
GAYA	1007.75	7.82	0.41	2.18E-01	1008.44	7.19	0.377	NSG
SAB	1004.61	7.07	0.37	7.10E-03	1006.04	7.28	0.38	SG
PATNA	1008.53	6.61	0.34	6.17E-01	1008.79	7.33	0.384	NSG

Abbreviations used: MZF =Muzaffarpur; SUP=Supaul; DAR= Darbhanga; SAB= Sabour; SD =Standard error

RESULTS AND DISCUSSION

In this study 6 stations (out of 28) of Bihar region which are nearly collocated to the conventional observatories of the year 2014 is taken for comparison of air temperature, humidity, pressure, wind speed and direction meteorological elements.

The observation recorded at 0300 universal time coordinate (UTC) is taken as minimum and 1200 UTC time is maximum for all the above said elements throughout the work.

In spite of inherent limitations like exposure of the station, skilled staff and timely accurate dissemination of the data the comparison shows quite energetic results. In overall, systematic difference has been observed in the data set with very small discrepancies.

The discrepancies may be as a result of difference between sensitive of screens and their designs. Few exceptional cases with higher degree of fluctuation may be due to human errors or short term instrumental errors. For brevity, the graphs of inter-comparison between AWS and conventional data, figures 1 (a-j) is shown for Patna station only.

Temperature

The maximum and minimum temperatures are associated with other meteorological variables, such as: availability of solar energy, cloudiness and geographic parameters such as topography, altitude and latitude of the station (WMO, 1983). Measurement of parameters at AWS and surface observatory are different. For example, mercury in glass thermometer is used in observatory whereas thermistors/Pt100 sensor is used in AWS.

There is a marked deviation in maximum and minimum temperatures values, this may be due to random errors or outliers present in the data. The results of maximum temperature comparison are statistically non-significant except Patna and for minimum temperature Darbhanga and Patna are statistically non-significant (Table 4).

Figures 2 (a) and 2 (f) shows the AWS maximum temperature is generally higher as compared to conventional observations and reverse is the case for minimum temperature in most cases. But in both cases, more than 70 % cases the temperature difference between conventional and AWS lays 1 to 2 degree limit and can be used in day to day forecasting (Table 3). The possible cause may be the human error while taking observation or Rusting in the connecter between sensor cable and sensor logger interface.

Pressure

This is very sensitive weather parameter especially for aviation forecasting. The data comparison shows mixed type of response between actual and AWS data, figures 2 (b) and 2 (g). The feasibility analysis (Table 3) shows that 30-45 % pressure data lay within the permissible range (1 ~2 hPa). Few exceptional cases of more difference between the data are due to outliers in data quality or human errors while proper setting of barometers.

Humidity

It is well known that, mechanical hygrometers based on the change in length of hygroscopically sensitive hairs are used to measure the relative humidity.

Non-linear response to humidity changes, changes in zero point require frequent cleaning and recalibration; sensitivity to destruction or errors. The results of bias in figures 2© and 2 (h) shows that humidity values observed from conventional measurements are generally higher than AWS relative humidity except in one or two cases of minimum values of relative humidity.

Table (3) shows that more than 80 % cases the relative humidity is usable for day to day weather forecasting, although there is a significant difference in both the values (Table 4). The difference may be due to the way of measurement of relative humidity in both conventional and AWS (based on the change of capacity). The performance of the AWS affected in case of pollutant present in the atmosphere.

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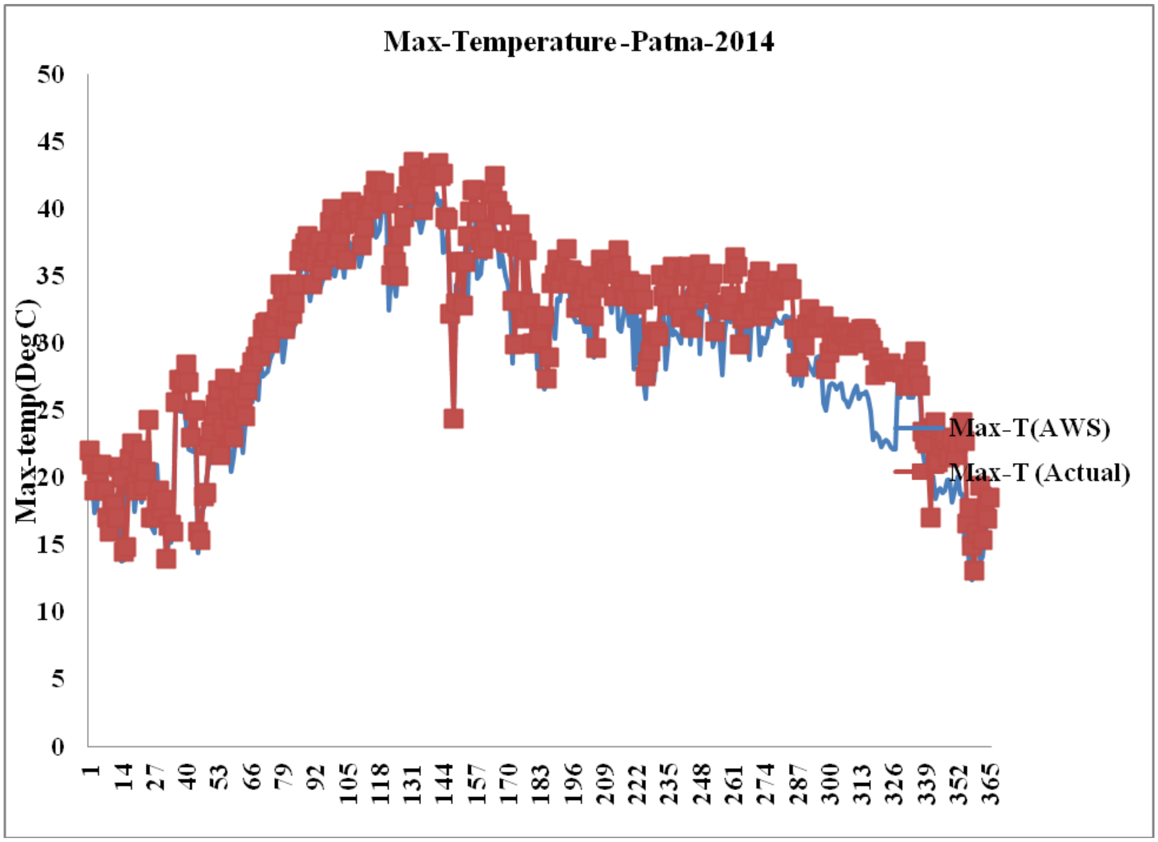

Figure 1(a): Maximum temperature of Patna (2014)

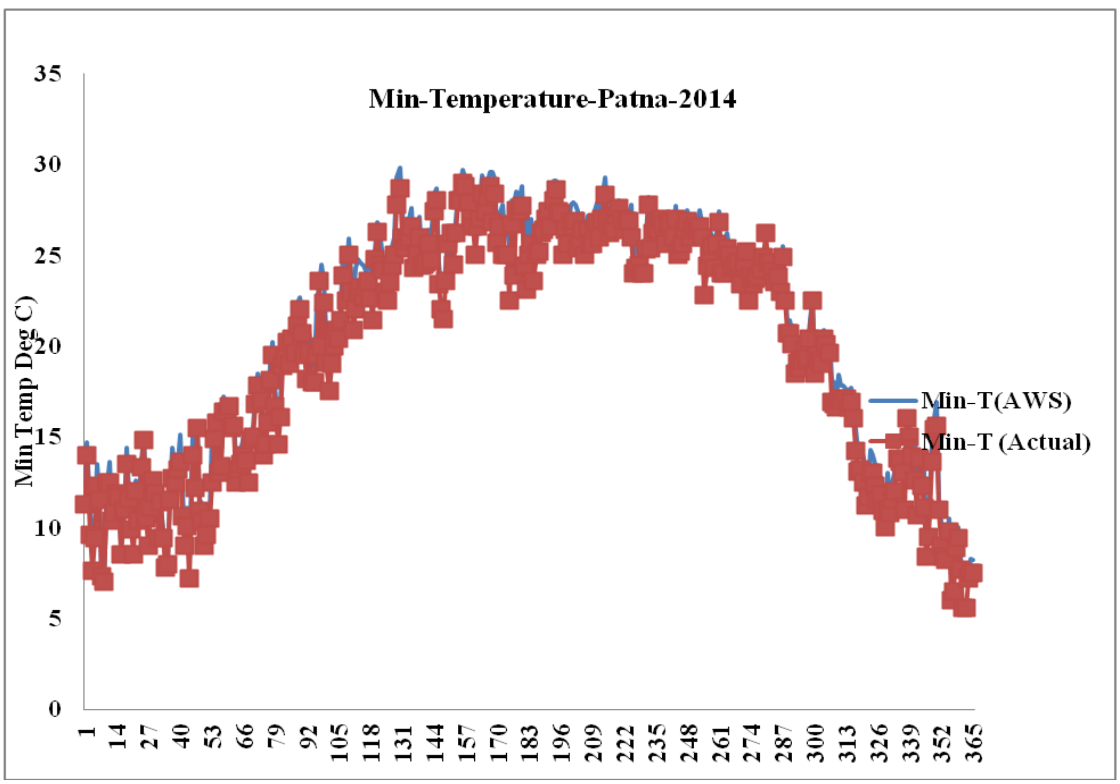

Figure 1(b): Minimum temperature of Patna (2014)

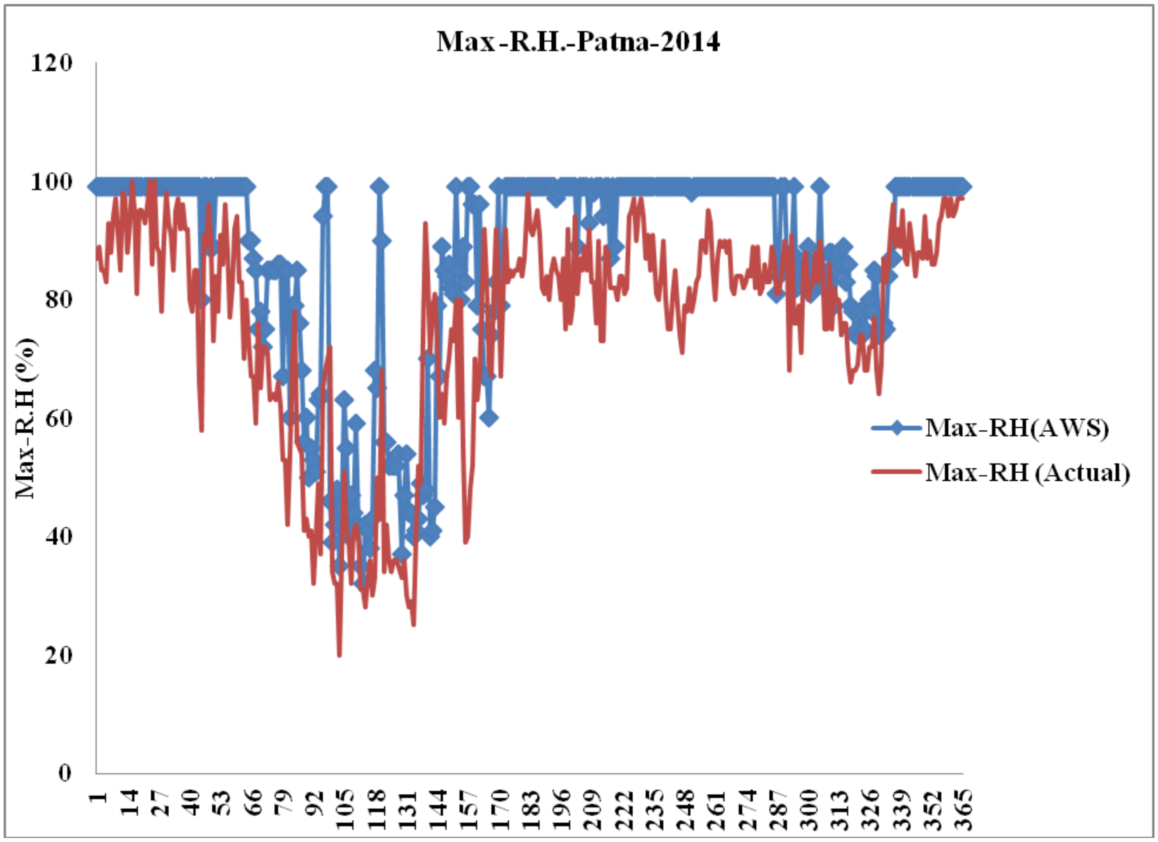

Figure 1©: Maximum relative humidity of Patna (2014)

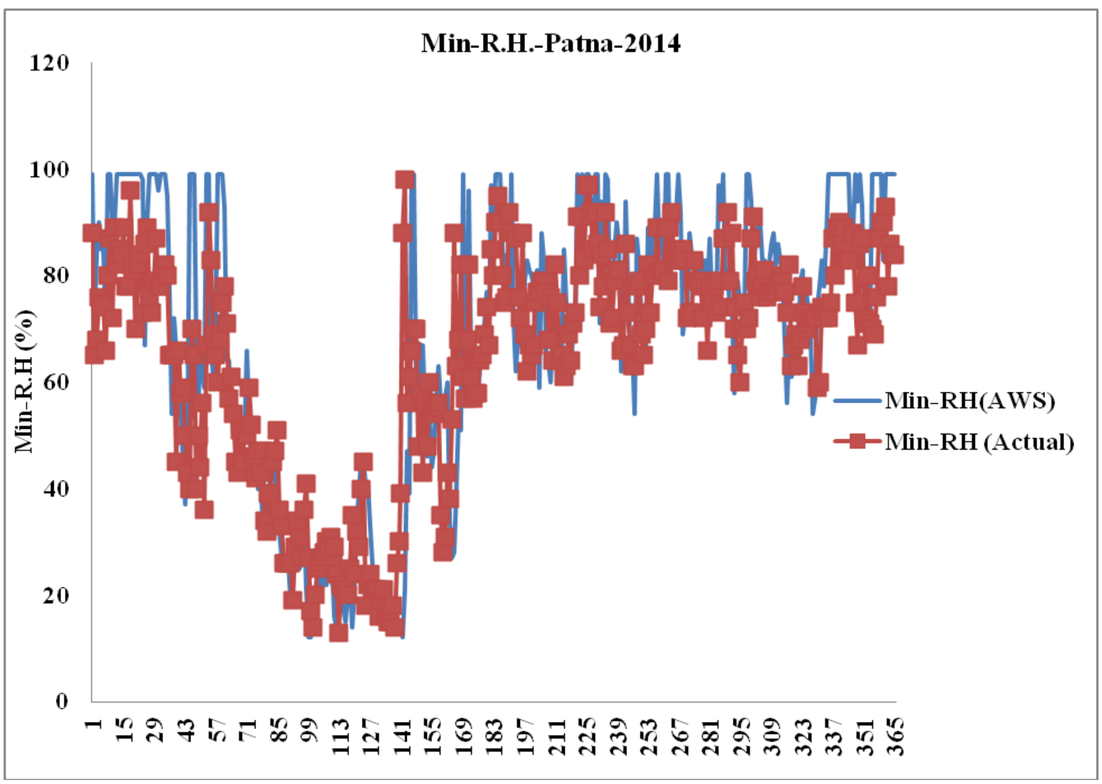

Figure 1 (d): Minimum relative humidity of Patna (2014)

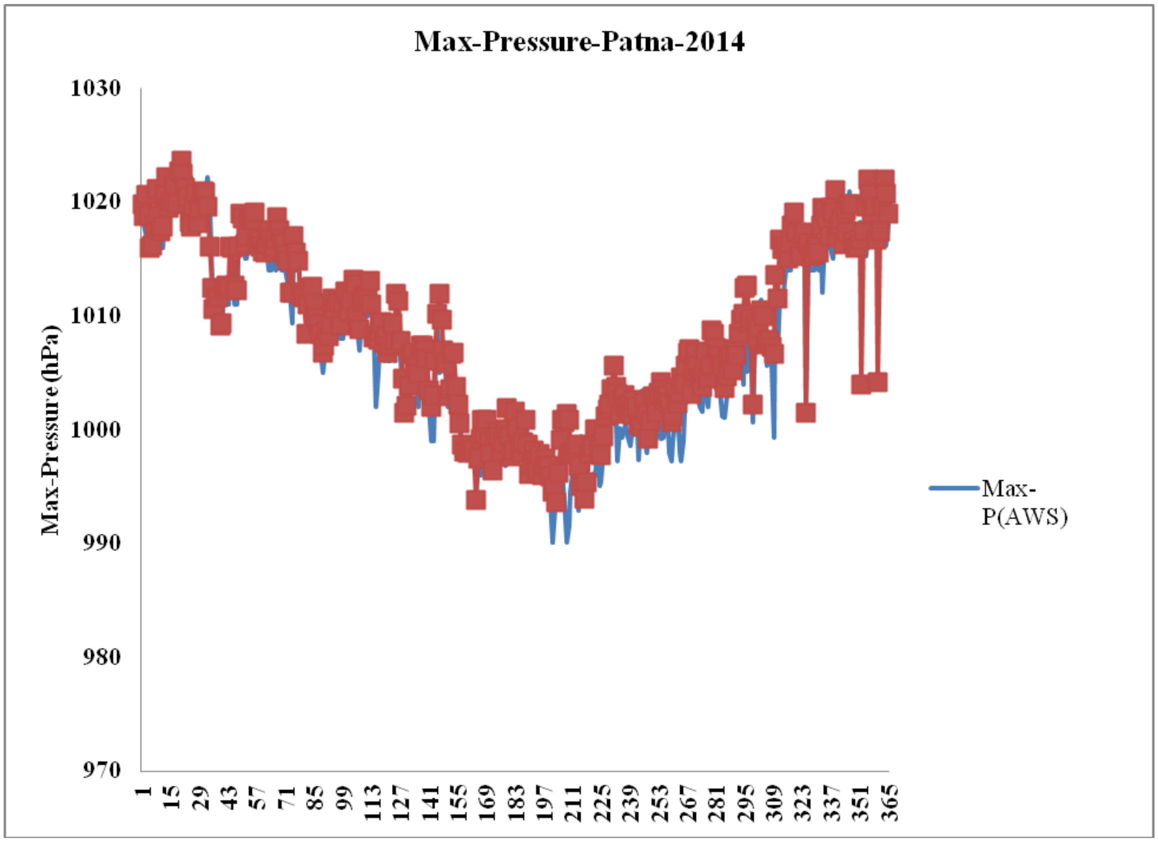

Figure 1 (e): Maximum pressure of Patna (2014)

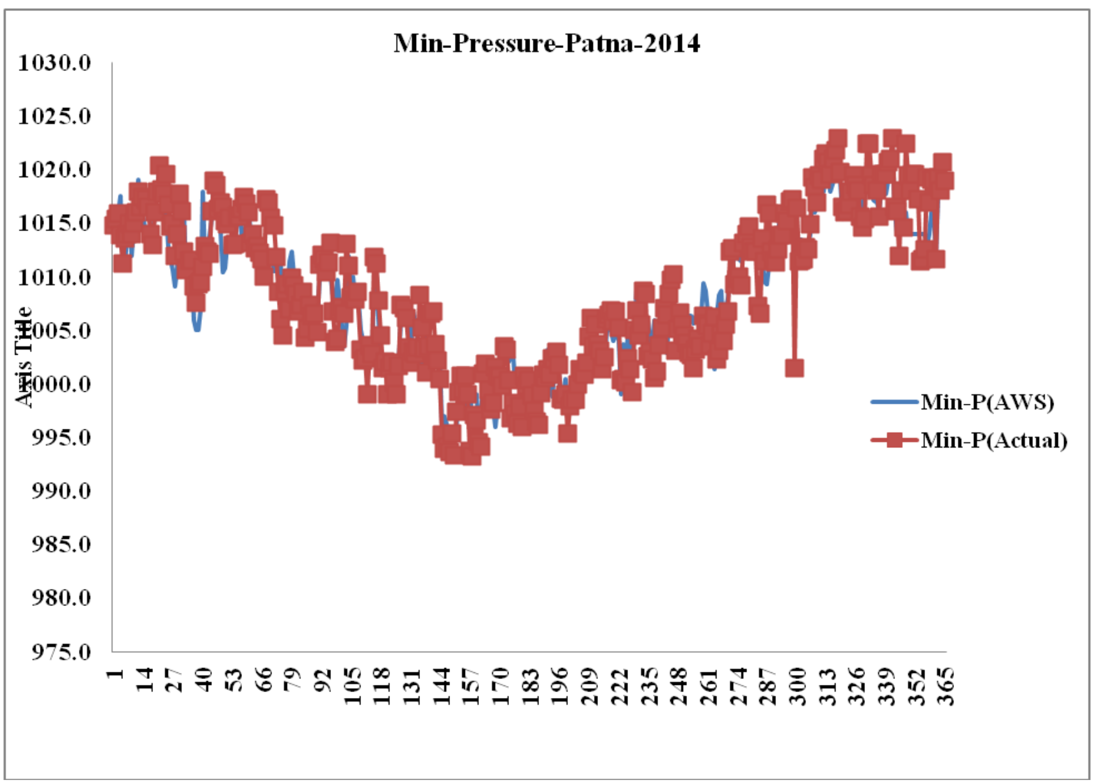

Figure 1(f): Minimum pressure of Patna (2014)

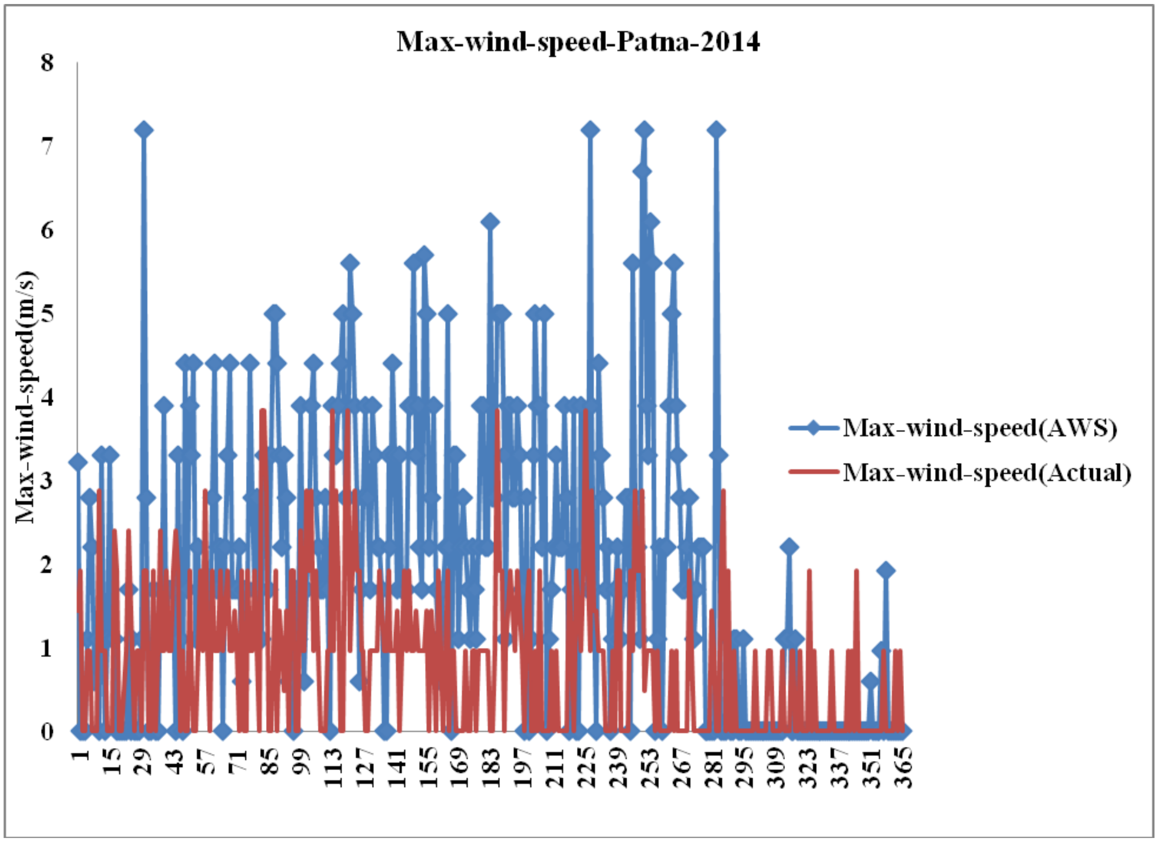

Figure 1 (g): Maximum wind speed of Patna (2014)

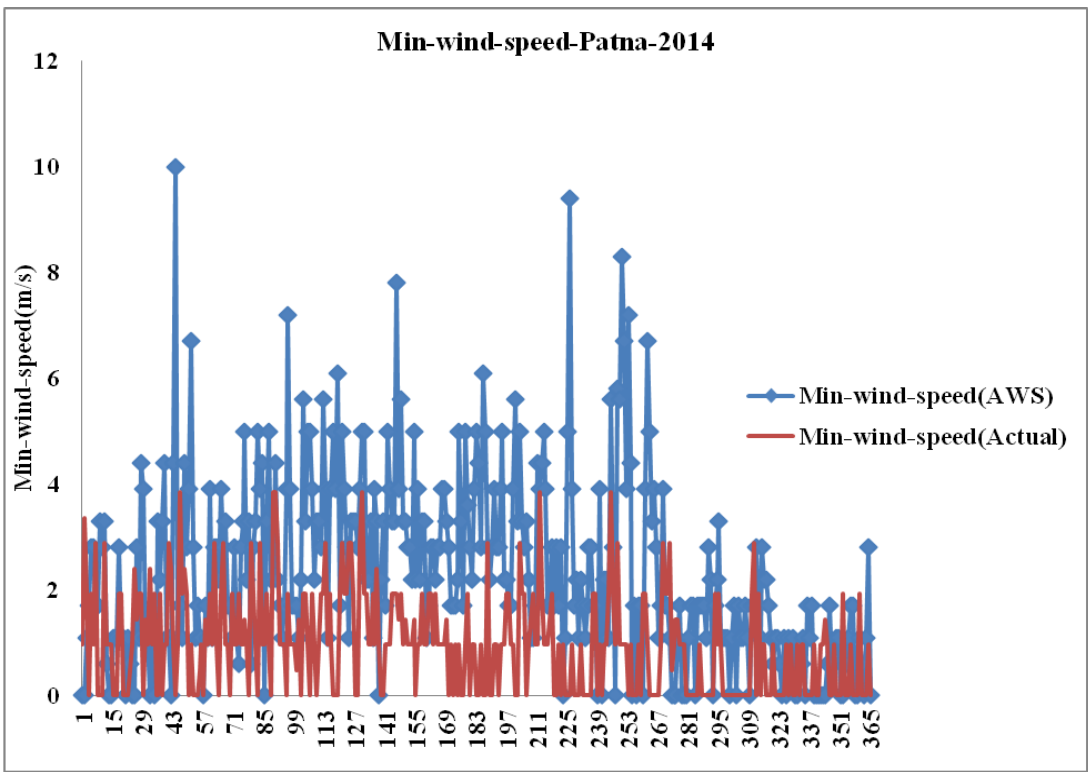

Figure 1 (h): Minimum wind speed of Patna (2014)

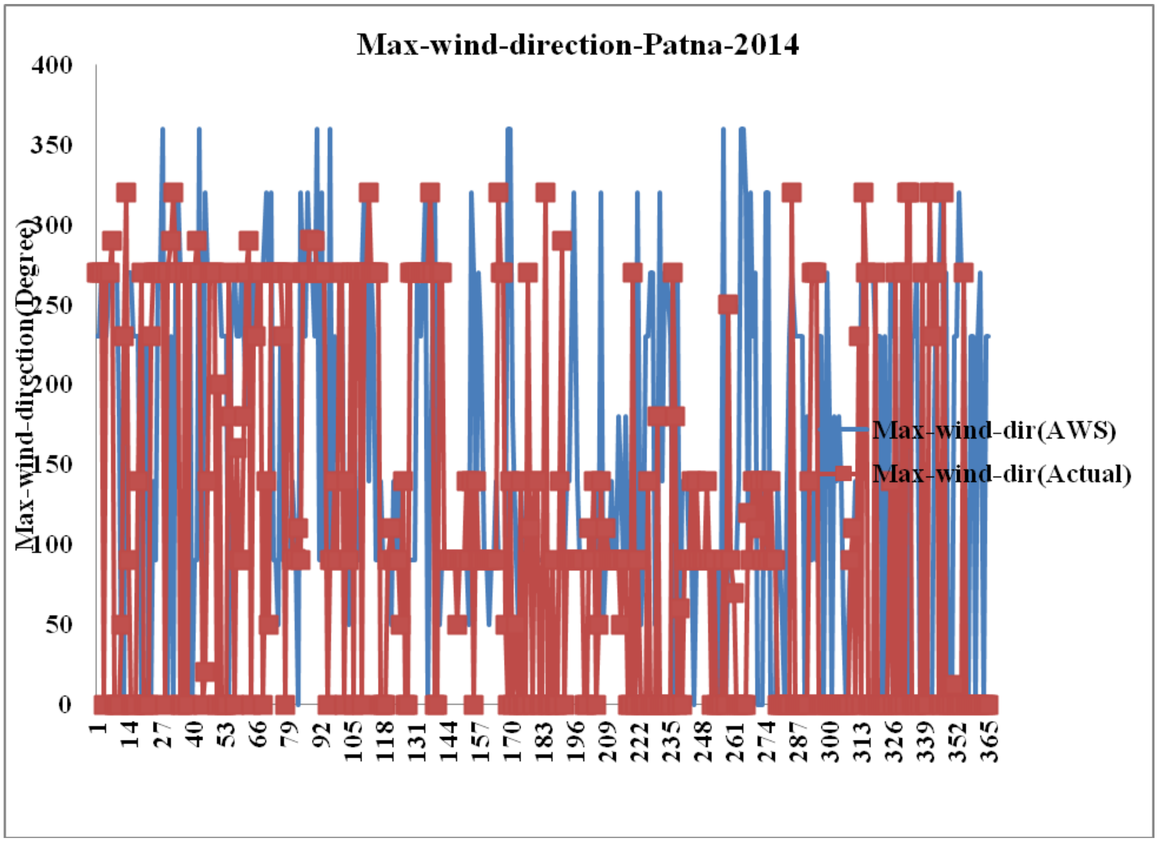

Figure 1 (i): Maximum wind direction of Patna (2014)

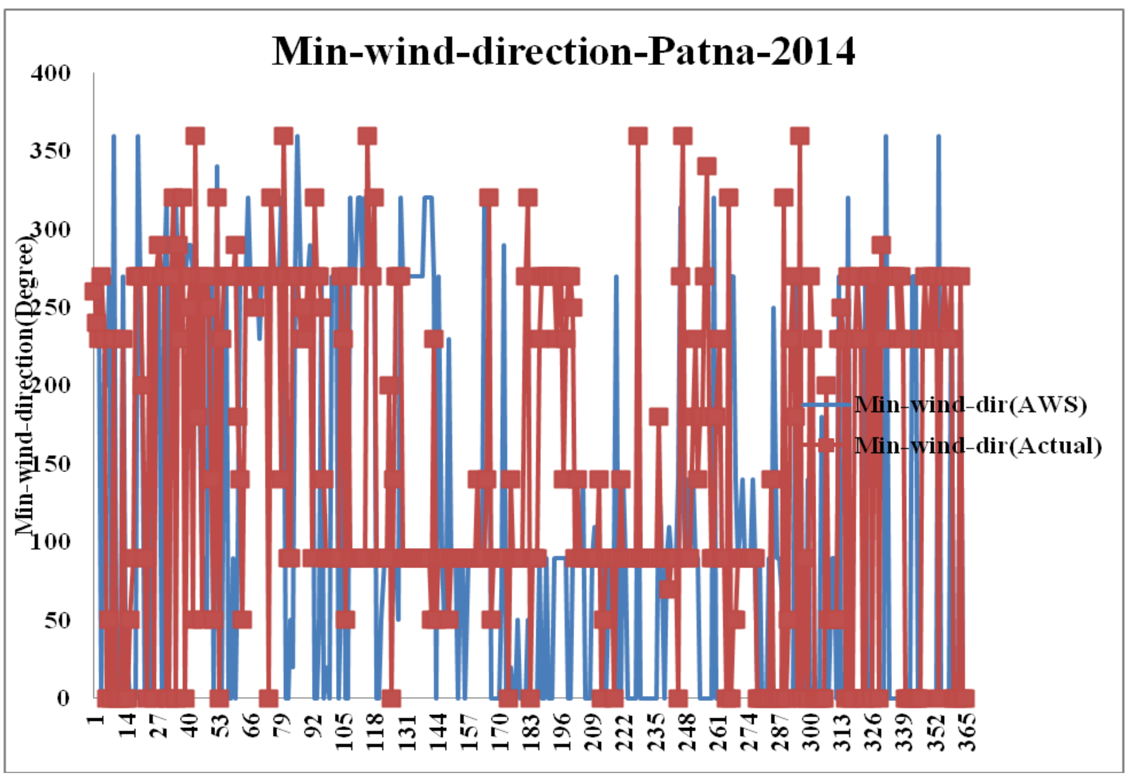

Figure 1 (j): Minimum wind direction of Patna (2014)

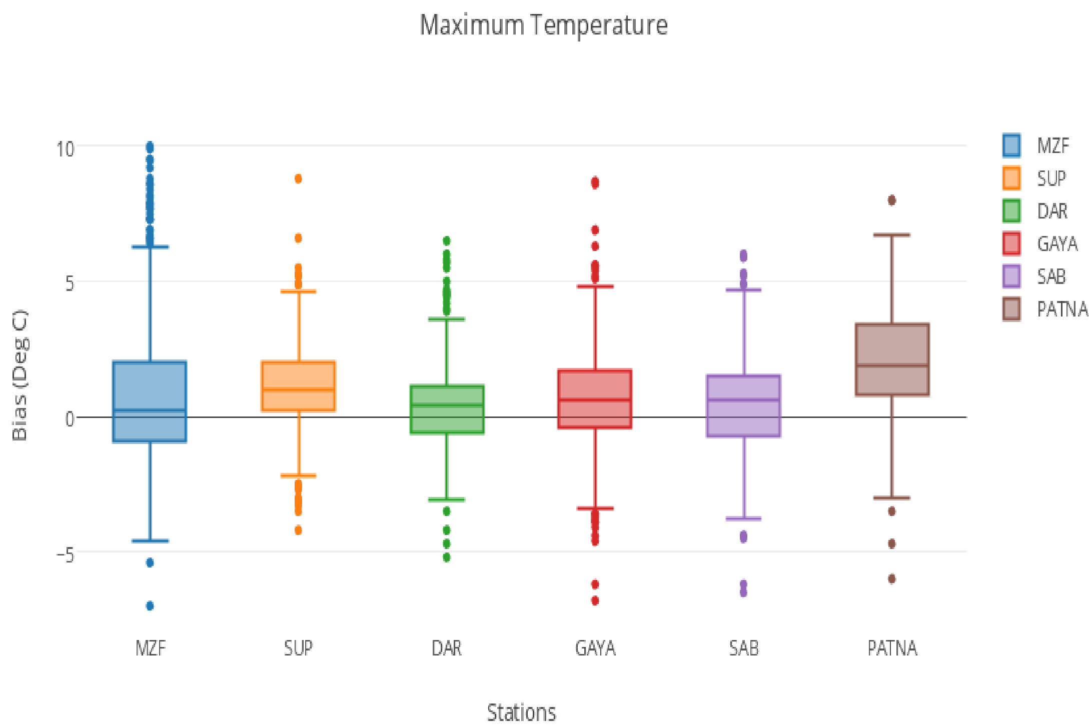

Figure 2 (a)

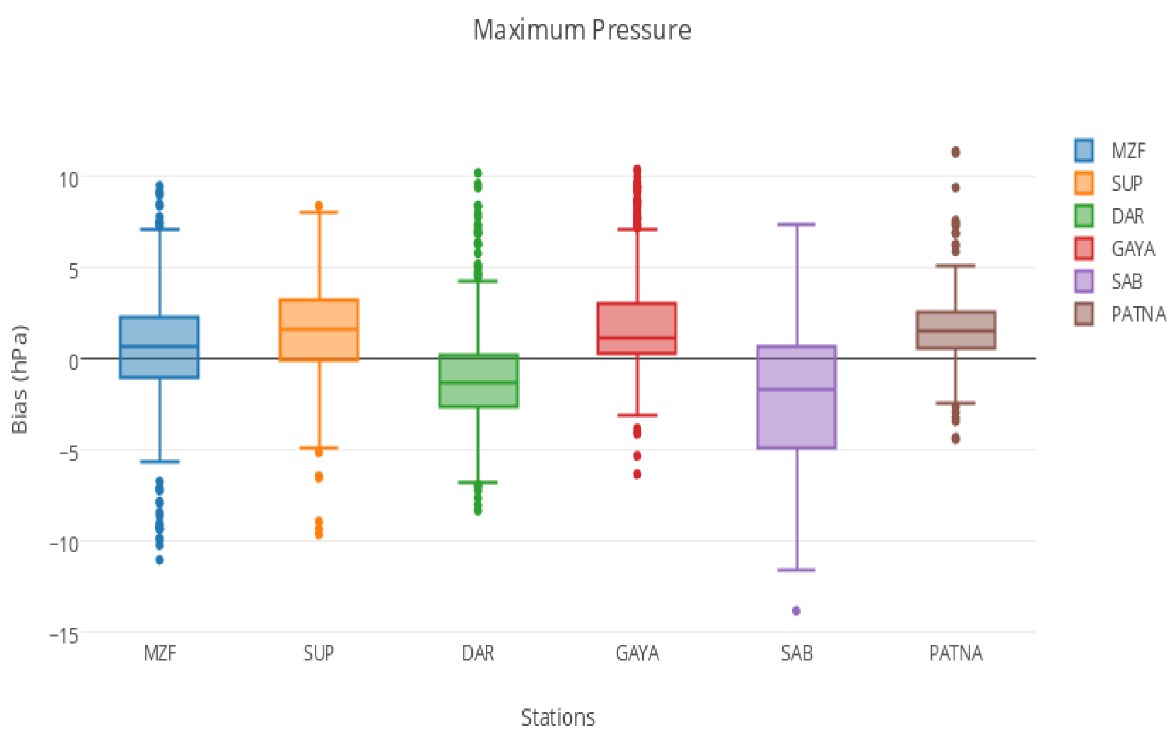

Figure 2 (b)

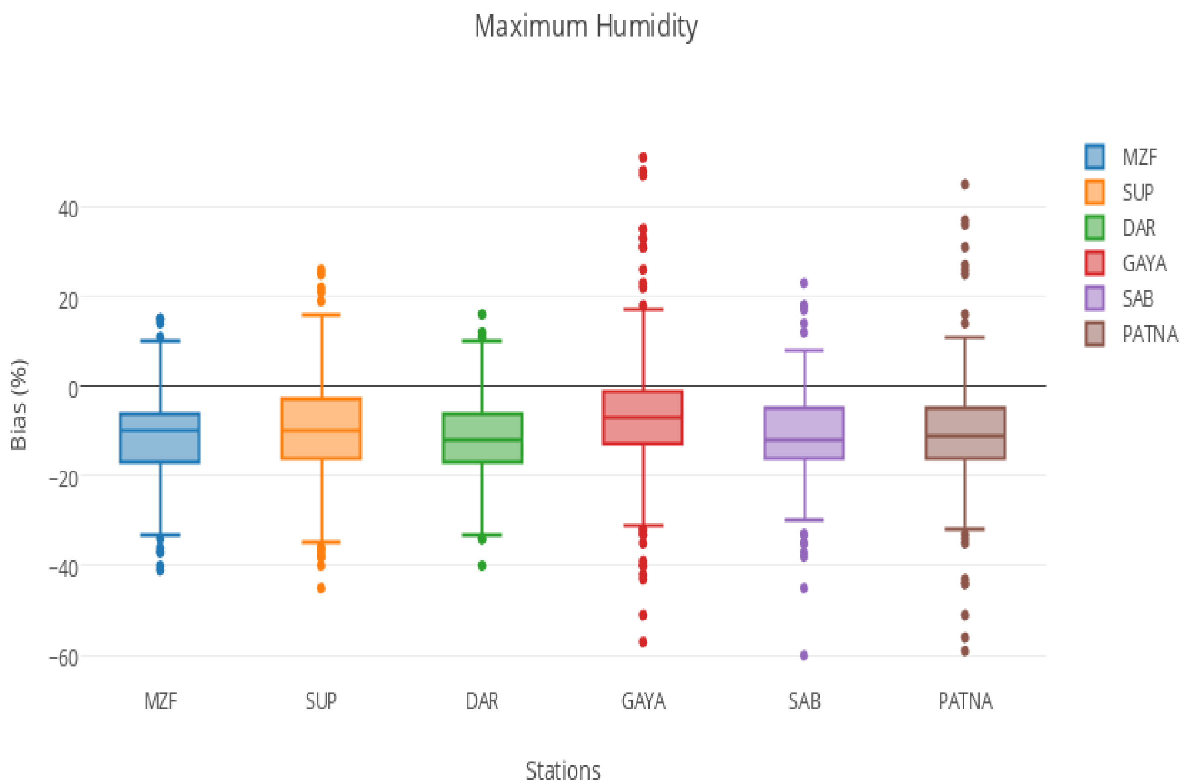

Figure 2 (c)

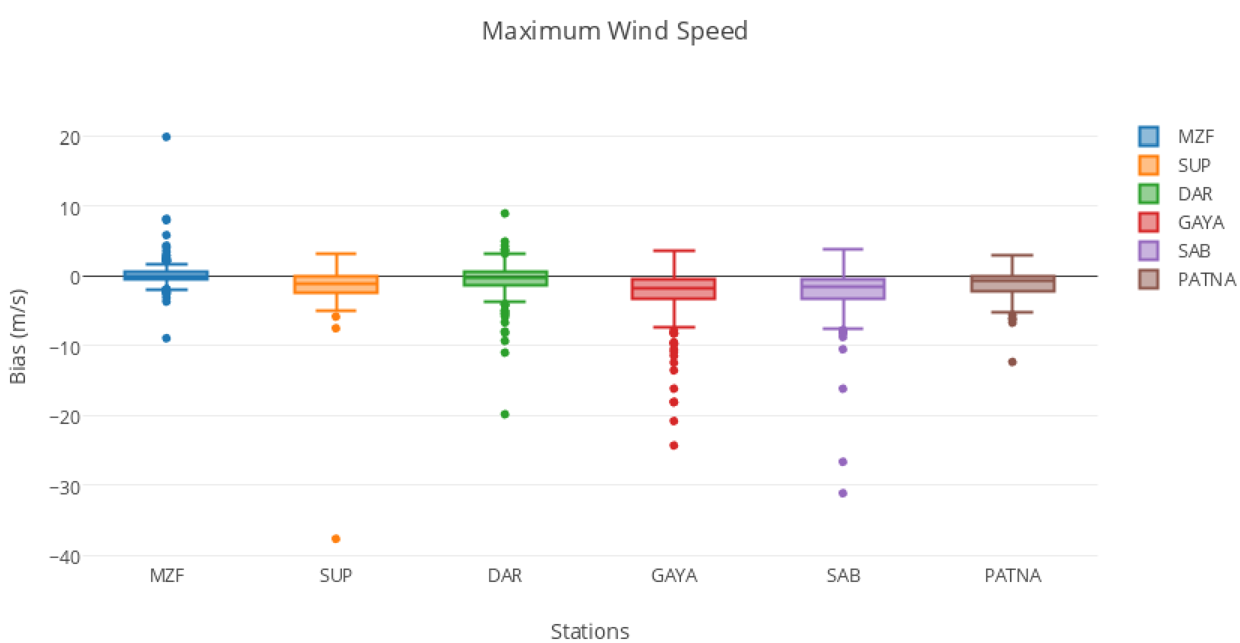

Figure 2 (d)

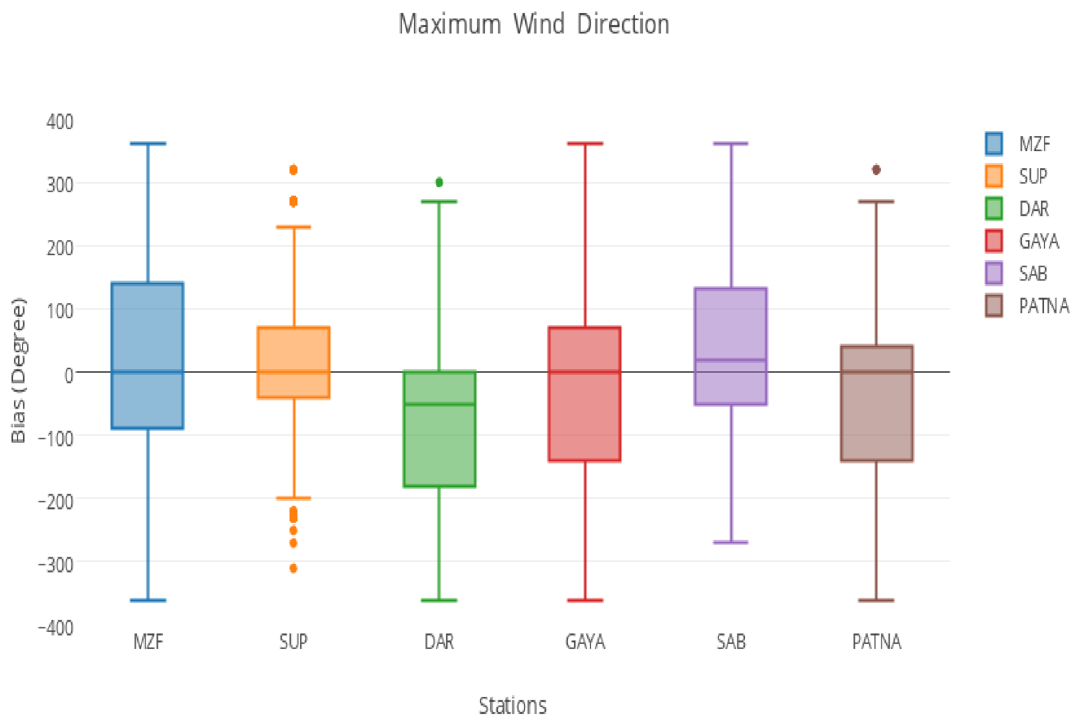

Figure 2 (e)

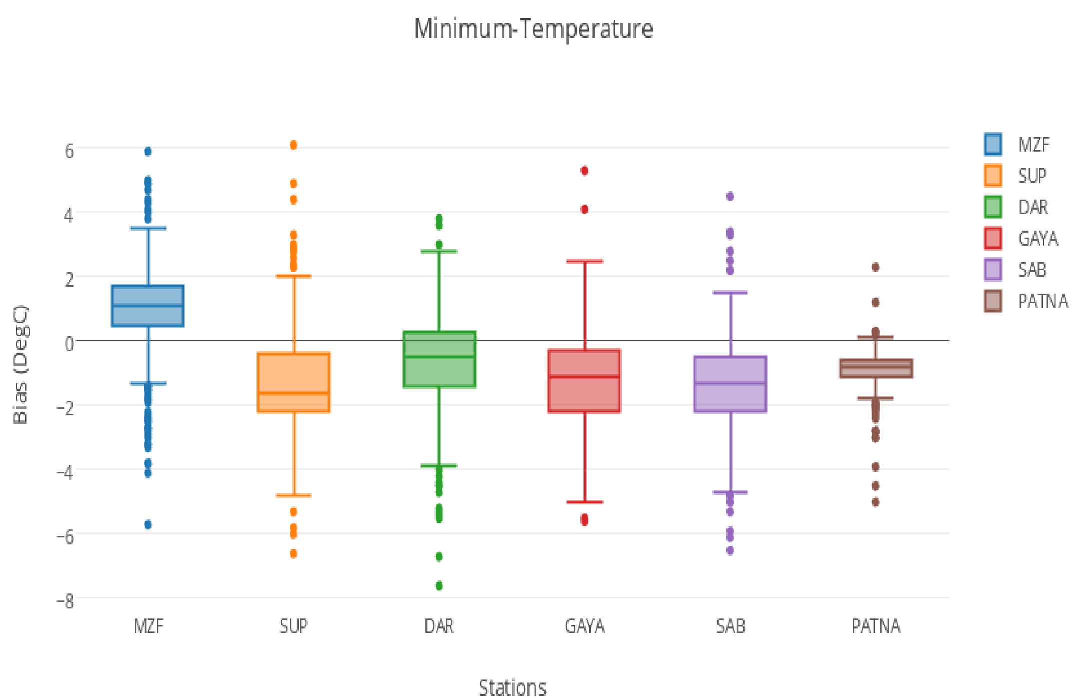

Figure 2 (f)

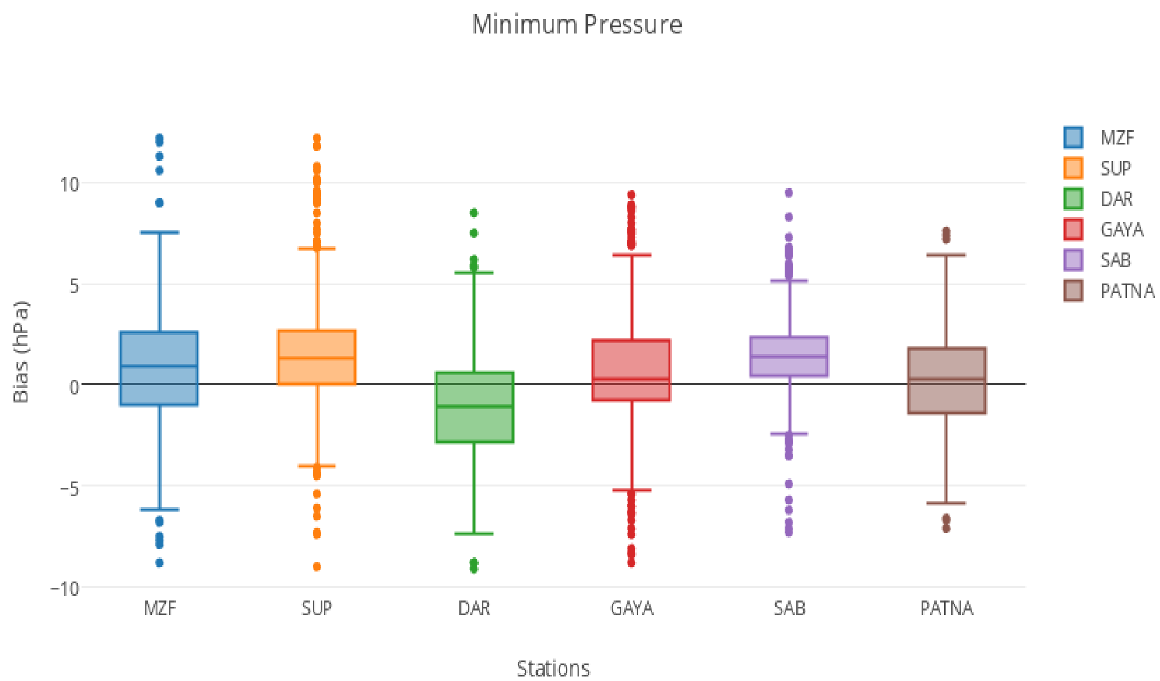

Figure 2 (g)

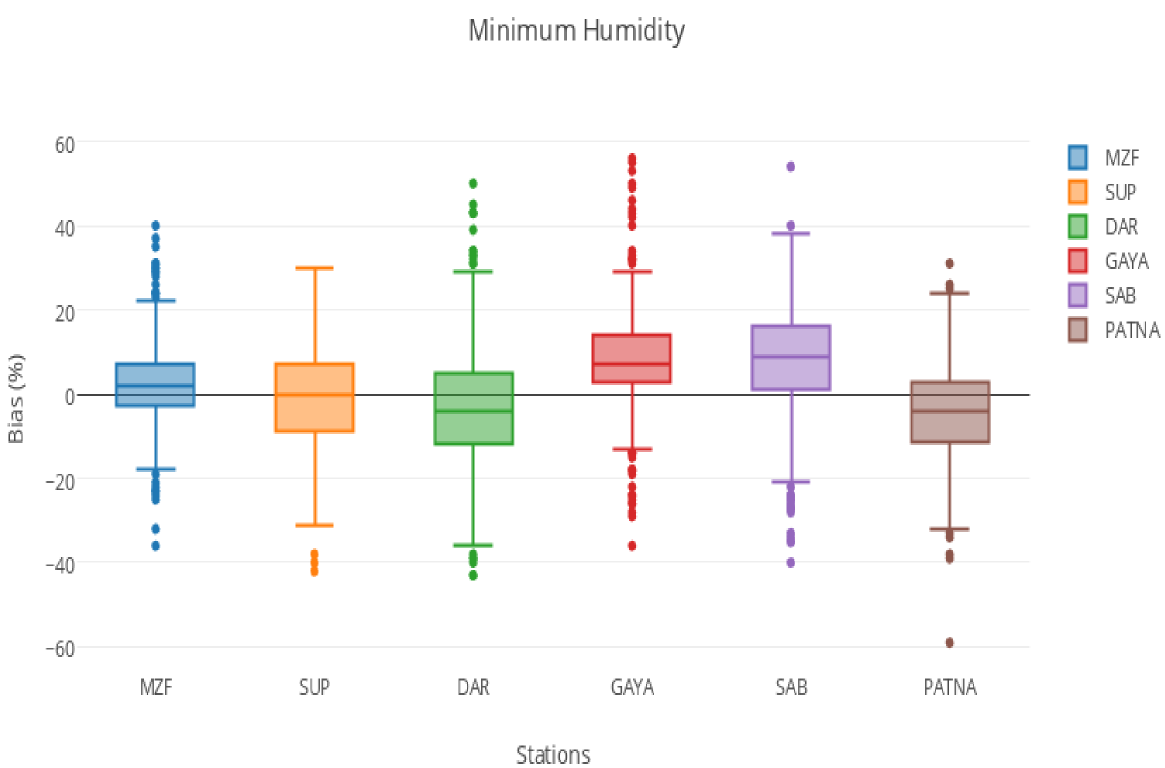

Figure 2 (h)

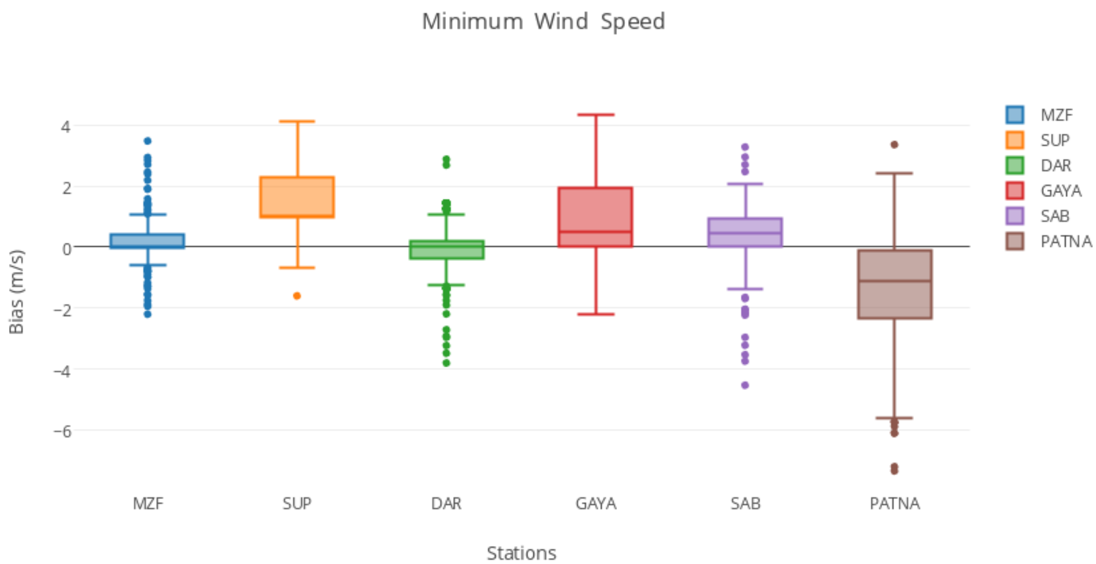

Figure 2 (i)

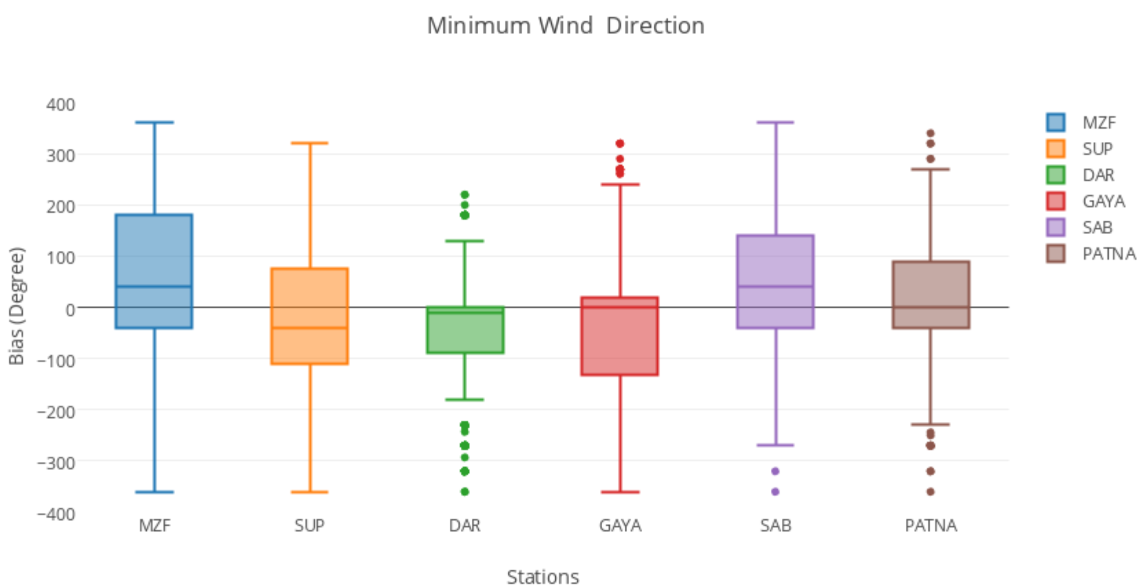

Figure 2 (j)

Figures 2 (a): Bias in maximum temperature; 2 (b) same for maximum pressure; 2 (c) same for humidity; 2 (d) same for wind speed; 2(e) same for wind direction and figures 2(f,g,h,i,j) for minimum bias of the said elements

Wind

A winds measurement from automatic and conventional measurement differs in their averaging and recording methodology both. Conventionally, Wind van measured the wind direction by the mechanical action of the wind on the vane; the needle will be turned in the direction from which the wind blows. Wind speed is measured by cup anemometers. This is a small wind mill device with cups on a vertical axis of rotation assume an angular velocity, which is linear over a large range and function of the wind speed irrespective of the direction of wind. Wind measurements influenced to a large extent by topography and surface cover around the observation point. Hence, wind vane, moving cup anemometer is used in observatory for wind measurements and ultrasonic wind sensor is used in AWS. The inherent instrument biases would also affect the reliability of data. Similarly, different averaging intervals are employed at surface observatory and AWS. For example, at AWS, wind is sampled for every second starting from three minutes prior to full hour UTC and vector average is taken over the samples collected (180 samples). On the other hand, at the conventional observatories scalar average is taken for measurement of wind. The Bias results obtained between actual and AWS wind speed and direction are shown in figures 2 (d,e) and 2 (i,j). The results show that AWS observed slightly higher value as compared to the conventional value. Wind direction have mixed type of response in some cases it has positive bias and in some cases negative bias. In most cases the results are statistically significant at 95 % confidence level. Meteorologically, wind speed observations are within permissible range and can be utilized for forecasting. On the other hand the wind directions shows marked difference and in 40 to 60 % cases data can be utilized judiciously for day to day weather forecasting.

Conclusion

IMD is exploring the network of automatic instruments because, despite the automatic stations provide data with better characterization of weather conditions, according to the usage time of the action, are subject to physical damage (signal interference, disconnect cables and oxidation, among others) and therefore these conditions may generate inaccurate data or interruption in the data series. Apart from all the limitations the overall AWS data performance is satisfactory and very useful for the remote places. Some of the salient points of the study are given below:

1. More than 70 % AWS temperature data is in usable range and can be utilized for daily weather forecasting or assimilation in numerical weather modes.
2. Box plots shows positive bias of the order of 2 to 3 degree for maximum temperature and mixed type (both positive and negative) bias for minimum temperature of the same order.
3. Maximum relative humidity values shows negative bias (Conventional values are lesser than AWS data value) of the order of 10-20 % almost all the stations and minimum relative humidity values shows mixed type of bias of almost the same order as the maximum relative humidity.
4. More than 70 % AWS relative humidity (R.H) values are usable for forecasting except the minimum R.H of Darbhanga and Sabour, which is usable of the order of ~50 %.
5. The pressure values are 30-45 % are in permissible range (1 ~2 hPa) and shows both positive and negative bias of the order of 3 to 5 hPa for the stations.
6. The correlation coefficients are > 0.70 for almost all the sations for all the parameters except wind speed which shows poor correlation, this might be due to the different averaging criteria of the winds in conventional and AWS data.
7. The results obtained for the all the meteorological parameters have mixed type of statistical significance at 95 % confidence. For example, maximum temperature all the stations are statistically non-significant except Patna.
8. Erratic behaviour of the sensor can easily be monitored by seeing the bias between the met parameters.

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REFERENCES

Amudha B, Anjan A, Ranalkar M, Vashistha RD and Rudra Pratap (2008). *Effect of Non-Wooden Radiation Shield on Measurements of Air Temperature and Humidity in Automatic Weather Stations at Climatologically Different Indian Stations Pune and Mumbai*, WMO TECO, 27-29 November, Petersburg **2** 37.

Datar SV, Krishnaiah S and Vashistha RD (1983). Automatic transmission of surface meteorological data from remote stations via satellite. *Journal of IETE* **29**(8) 403-412.

Fisch G and Santos JM (1997). Comparison between conventional and automatic meteorological observations in the Paraíba Valley region, SP. In: *Brazilian Congress Agrometeorologia, Piracicaba Proceedings* **10** 246-248.

Lockhart TJ (1995). Wind Characterization Standard. Memorandum to Attendees of the Wind Standards Workshop of 10/29-30/1992, Meteorological Standards Institute 11.

Powell MD (1993). Wind Measurement and Archival Under the Automated Surface Observing System (ASOS) User Concerns and Opportunity for Improvement. *Bulletin of the American Meteorological Society* **74** 615-623.

Ranalkar M, Misra RP, Anjan Ajit and Krishnaiah S (2012). Network of Automatic Weather Stations: Pseudo random sequence type. *Mausam* **63**(4) 587-306.

Ranalkar MR, Amudha B, Niyas NT, Pratap Rudra and Vashistha RD (2008b). Preliminary results of the performance of Automatic Weather Station in the perpetual frost climate of East Antarctica. *WMO Technical Conference on Instruments and Methods of Observations, St. Pertersberg, Russian Federation* **2** 39.

Sentelhas PC, Moraes SO, Piedade SMS, Pereira AR, Angelocci LR, Marin FR (1997). Comparative analysis of meteorological data from station conventional and automatic. *Journal of Agrometeorology*, Santa Maria **5**(2) 215-221.

Souza IA and Galvani E (2003). Comparative study of meteorological elements monitored y conventional and automatic weather stations in Maringa region. *Acta Scientiarum Technology* **25**(2) 203-207.

Teixeira AHC, Bassoi LH, Peis VCS, Silva TGF, Ferriira MNL and Maia JLT (2003). Estimated water consumption of guava, using stations automatic and conventional agrometeorological. *Brazilian Journal of Fruits*, Jaboticabal - SP **25**(3) 457-460.

Vashistha RD, Amudha B and Pratap Rudra (2005). Present status of surface meteorological observations in India. *WMO Technical Conference on Instruments and Methods of Observations Bucharest, Romania* **1265**(82).

WMO (1983). *Guide to Meteorological Instruments and Methods of Observation*, 5th edition. Geneva, World Meteorological Organization **8** 230.