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Verification and usability of medium range weather forecast for north bank plain zone of Assam, India

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सार – मार्च 2009 से फरवरी 2014 में असम के उत्तरी छोर के मैदानी क्षेत्र के जिले का प्रतिनिधित्व करते हुए सोनितपुर के लिए भारत मौसम विज्ञान विभाग द्वारा जारी स्थान विशिष्ट बहु-मॉडल समुच्चय (MME) मौसम पूर्वानुमान का विश्लेषण किया गया और इनकी सटीकता प्रमाणित की गई। मार्च 2009 से फरवरी 2014 तक के अनुपात स्कोर, हौनसेन और क्यूपर्स (HK), स्कोर संसूचन प्रायिकता (POD) हैदके स्किल स्कोर (HSS), फॉल्स अलार्म अनुपात (FAR), क्रिटीकल सक्सेस इंडेक्स (CSI) और वर्षा के लिए RMSE तथा अन्य प्राचलों के लिए RMSE अर्थात अधिकतम और न्यूनतम तापमान, पवन गति, सुबह और दिन की सापेक्षिक आर्द्रता उपयोज्य विश्लेषण व सहसंबंध पद्धति जैसी विभिन्न सत्यापित तकनीकों का उपयोग करते हुए मौसमी और वार्षिक (मार्च-फरवरी) आधार पर पूर्वानुमान संबंधी आँकड़ों के सत्यापन का विश्लेषण किया गया। वर्षा के अनुपात स्कोर मॉनसून पूर्व और मॉनसून ऋतुओं की तुलना में मॉनसूनोतर और शीत ऋतुओं में अधिक थे जिससे सोनितपुर में लगाए गए मल्टी मॉडल का निष्पादन दो अन्य ऋतुओं की अपेक्षा मॉनसूनोतर और शीतऋतुओं में बेहतर पाया गया है। मॉनसून पूर्व ऋतु में वर्षा और पवन गति का बहुत अच्छा निष्पादन देखा गया है। मॉनसून ऋतु में वर्षा का निष्पादन कमज़ोर पाया गया और अन्य प्राचल बेहतर पाए गए हैं। मॉनसूनोतर ऋतु में वर्षा का उत्कृष्ट निष्पादन देखा गया किन्तु न्यूनतम तापमान पूर्वानुमान के लिए कमजोर निष्पादन देखा गया। शीतऋतु में, सभी वर्षों में वर्षा के पूर्वानुमान का निष्पादन उत्कृष्ट था। अलग-अलग ऋतुओं के पूर्वानुमानित और प्रेक्षित मानों से सहसंबंध गुणांक प्राप्त हुए। मॉनसून और वार्षिक आधार को छोड़कर सभी ऋतुओं में वर्षा अत्यधिक सहसंबंधित थी। इसलिए विभिन्न उपयोगकर्ता समूहों के लिए पूर्वानुमान व्यापक रूप से उपयुक्त पाया गया है।

ABSTRACT. Location specific multi-model ensemble (MME) weather forecast issued by IMD for Sonitpur, representing district of north bank plain zone of Assam during March, 2009 to February, 2014 has been analyzed and verified for its accuracy. Analysis of the verification of the forecast data, were carried on seasonal and annual (March-February) basis using various verification techniques, *viz*., ratio score, Hanssen and Kuipers (H.K) Score, probability of detection (POD), Heidke skill score (HSS), false alarm ratio (FAR), critical success index (CSI) and RMSE for rainfall, and RMSE for other parameters (*viz*., maximum and minimum temperature, wind speed, morning and afternoon relative humidity), usability analysis and correlation approach during March, 2009 – February, 2014. The ratio score of rainfall was higher during post monsoon and winter seasons as compared to pre-monsoon and monsoon seasons, indicating the performance of multi-model ensemble under Sonitpur worked better in post-monsoon and winter seasons than in the other two seasons. Very good performance was observed for rainfall and wind speed during pre-monsoon season. During monsoon season, performance of rainfall was found poor and other parameters were found excellent. During post-monsoon excellent performance was observed for rainfall and wind speed but poor performance was observed for minimum temperature forecast. In winter, the forecasting performance of rainfall was excellent during all years. Correlation-coefficients were derived between the forecasted and observed values during different seasons. Rainfall was highly correlated during all seasons except monsoon and annual basis. Hence, the forecast was found widely applicable among different user groups.

Key words – MME forecast, Weather parameter, Usability, RMSE, Verification.

1. Introduction

Among all the natural resources, climate plays a decisive role on the type of farming system and weather displays its influence on agricultural operations and farm production through its effect on plant growth and development. Weather cannot be managed in favour of crop growth, but its effects can be minimized by adjusting with the advanced knowledge of aberrant or unfavorable weather events such as drought, flood, cold wave and heat wave, etc. Agricultural operations can be delayed or advanced with the help of advanced information on weather from 3 to 10 days.

Accurate, usable and reliable weather forecast is the only answer/method through which farmers can be advised to save their crops from aberrant weather and minimize their input and labour cost to derive maximum benefit from agriculture. An estimate made by the agri-business, a community in western countries, indicates that the forecast can be put to economical use if it is 50 to 60% correct (Seeley, 1994). Hence, the accurate weather forecast based agromet advisories in terms of rainfall and temperature forecast, prepared on the need-based agricultural operations can contribute immensely to benefit the farmers through minimizing the production losses. The forecast verification is essential to judge the usability of the weather forecast for preparation of effective weather based agromet advisories for farmers. The verification of forecast improves the confidence of the farmers for its reliability and applicability in day to day field works.

The reliability and accuracy of medium range weather forecast were studied by several authors (Tripathi *et al.*, 2008; Chauhan *et al.*, 2008; Lunagaria *et al.*, 2009; Chaudhari *et al.*, 2010; Khichar *et al.*, 2010; Mishra *et al.*, 2010; Sahu *et al.*, 2012) for different Agro-climatic zones of India. In this paper, an attempt has been made to verify the accuracy and usability of medium range weather forecast for north bank plain zone, Assam.

2. Data and methodology

The North Bank Plain Zone (NBPZ) of Assam consisting of five districts, *viz.,* Dhemaji, Lakhimpur, Sonitpur, Darrang and Udalguri. As the crops and cropping pattern of all districts of NBPZ is similar, we took Sonitpur as representing district of NBPZ for forecast verification. The all weather parameters including rainfall of Sonitpur district is more or less uniform due to absence of hilly areas, so the forecast weather parameters were compared and verified against the observed weather parameters recorded at agro-meteorological observatory located at B. N. College of Agriculture campus, located on the NE of India having latitude of 26°42′ N, longitude of 93°15′ E, altitude of 104 meter above sea level, having the humid climatic type. More than 65% of the annual rainfall is received during monsoon season (June to September). Medium range forecast (forecast given for the period of five days) was issued by India Meteorological Department, New Delhi on various weather parameters *viz.*, amount of rainfall (mm), maximum and minimum temperature (°C), surface mean wind speed (kmph) and both morning and afternoon relative humidity (%) and sent to Regional Meteorological Centre, Guwahati on every Tuesday and Friday for value addition. IMD, New Delhi generates these district level forecast from day-1 to day-5 based on a Multi Model Ensemble technique using forecast products available from number of models of India and other countries which include: T-254 model of NCMRWF, T-799 model of European Centre for Medium Range Weather Forecasting (ECMWF), United Kingdom Met Office (UKMO), National Centre for Environmental Prediction (NCEP), USA and Japan Meteorological Agency (JMA). The grid spacing or resolution of these models is 48-50 km. From 2009 onwards, T-574 (resolution - 22 km) model was also introduced and applied in IMD. After receiving the MME forecast, (*i*) Previous performance history of MME, (*ii*) prevailing synoptic conditions and (*iii*) topography and climatic condition of the respective district are considered and accordingly value additions to the MME value are done. After value addition, RMC, Guwahati sent these forecast to the centre on every Tuesday and Friday.

The study was conducted at agromet field unit (AMFU), Sonitpur (Assam) for five years during March 2009 to February 2014. The daily values of these medium range forecast of weather parameters like rainfall (mm), maximum and minimum temperature (°C), maximum and minimum relative humidity (%) and mean wind speed (kmph) for day -1 to day-5 of Sonitpur during the study period was compared and verified for the four seasons separately as per IMD standard *viz.*, pre-monsoon (Mar-May), monsoon (Jun-Sep), post-monsoon (Oct-Nov) and winter (Dec-Feb) against the observed weather parameters recorded at agro-meteorological observatory located at B. N. College of Agriculture campus, Sonitpur under Assam Agricultural University. The forecast were verified using ratio score, Hanssen and Kuipers (HK) Score, Probability of detection (POD), Heidke Skill Score (HSS), False alarm ratio (FAR), Critical Success index (CSI) and RMSE for rainfall, and RMSE for other parameters. Similar methods were used by few researchers (Singh *et al*., 2005; Tripathi *et al.*, 2008; Chauhan *et al.*, 2008; Lunagaria *et al.*, 2009; Chaudhari *et al.*, 2010; Khichar *et al.*, 2010; Mishra *et al.*, 2010; Sahu *et al.,* 2012).

The verification scores were calculated and have been used for verifying the rainfall and temperature forecasts are as follows:

In the following 2 × 2 contingency table, if Y stands for occurrence of rain and N stands for non-occurrence then

	Forecasted	
Observed	Rain	No Rain
Rain	A (YY)	B (YN)
No Rain	C (NY)	D (NN)

where, A = No. of hits (predicted and observed)

TABLE 1

Seasonal usability percentage between observed and predicted weather parameter during March 2009 to February 2014

Season	Years	Rainfall	Max temperature	Min temperature	Wind speed	Morning RH	Afternoon RH
Pre-monsoon	2009-10	62.2	55.4	47.8	97.8	59.8	45.7
(Mar-May)	2010-11	55.0	58.7	89.1	98.9	85.9	76.1
	2011-12	68.9	54.4	82.6	100.0	77.2	73.9
	2012-13	82.7	40.2	77.2	100.0	80.4	60.9
	2013-14	67.6	57.6	91.3	100.0	83.7	75.0
Monsoon	2009-10	32.8	47.5	89.3	98.4	82.0	71.3
(Jun-Sep)	2010-11	34.6	61.5	95.1	96.7	93.4	81.2
	2011-12	31.0	57.4	97.5	100.0	98.4	86.1
	2012-13	31.1	68.0	78.7	100.0	100.0	90.2
	2013-14	23.2	67.2	57.4	100.0	100.0	87.7
Post-monsoon	2009-10	90.2	78.7	39.3	98.4	88.7	78.7
(Oct-Nov)	2010-11	97.7	59.0	54.1	98.4	88.5	88.3
	2011-12	96.0	85.3	54.1	100.0	88.5	95.1
	2012-13	87.5	82.0	37.7	100.0	85.3	98.4
	2013-14	91.3	68.9	57.4	100.0	98.4	88.5
Winter	2009-10	100.0	76.7	45.6	98.9	72.2	85.4
(Dec-Feb)	2010-11	100.0	80.0	26.7	100.0	80.0	86.7
	2011-12	100.0	84.6	52.8	100.0	84.6	84.6
	2012-13	100.0	88.9	26.7	100.0	48.9	94.5
	2013-14	97.4	78.9	74.4	100.0	92.2	81.1
Annual	2009-10	73.3	61.9	59.7	98.4	73.4	69.5
(Mar-Feb)	2010-11	69.9	64.9	69.9	98.4	87.4	82.4
	2011-12	76.0	68.0	75.4	100.0	88.0	84.2
	2012-13	74.6	68.5	58.6	100.0	80.0	85.2
	2013-14	69.0	68.0	70.1	100.0	93.7	83.0

B = No. of false alarms (predicted but not observed)

C = No. of misses (observed but not predicted)

D = No. of correct predictions of no rain (neither predicted nor observed)

The total number of cases (*M*) is given by:

$$M = A + B + C + D$$

Ratio Score (RS), also known as the Accuracy, Hit Rate or Percentage Correct, measures the proportion of correct forecasts. It describes the success rate of correct forecast of occurrence and non-occurrence of rainfall to the total number of events. The *RS* varies from 0 to 100 with 100 indicating perfect forecasts.

$$\text{Ratio Score} = \frac{\text{Correct Forecast}}{\text{Total Forecast}} = \frac{A + D}{M}$$

Hanssen and Kuipers (H. K.) Scores:

$$HKS = \frac{A * D - B * C}{(A + C)(B + D)}$$

The score has a range of -1 to +1, with 0 representing no skill. Negative values would be associated with "perverse" forecasts, and could be converted to positive skill simply by replacing all the yes forecasts with no and *vice-versa*. A drawback of this score is that it tends to converge to the POD for rare events, because the value of "D" becomes very large.

Critical success index (threat score) measures relative forecast accuracy (*e.g.*, rain or no rain). It also varies from 0 to 1 with 1 indicating perfect forecast and is defined as the ratio of the number of hits (*i.e.,* correct event forecasts) to the number of events which occurred plus the number of false alarms (incorrect event forecast) (Schaefer, 1990).

$$\text{Critical Success index (CSI)} = \frac{\text{Hits}}{\text{Hits} + \text{False alarms}} = \frac{A}{A + B + C}$$

Probability of detection (POD) is the ratio of correct rain forecast.

$$\text{Probability of detection (POD)} = \frac{\text{Correct rain forecast}}{\text{Rain Observation}} = \frac{A}{A + C}$$

Since POD uses only the observed events A and C, it is sensitive only to missed events and not false alarms. Therefore POD can generally be improved by systematically over-forecasting the occurrence of the event. The POD is incomplete by itself and should be used in conjunction with either the false alarm ratio (FAR) below or the false alarm rate (FA).

False alarm ratio (FAR) is the ratio of correct rain forecast

$$\text{False alarm ratio (FAR)} = \frac{\text{False alarm}}{\text{Hits} + \text{False alarms}} = \frac{B}{A + B}$$

Since FAR is dependent on A and B only and does not include C, and therefore, is not sensitive to missed events. FAR can be improved by systematically by under forecasting the events. It also is an incomplete score and should be used in connection with the POD above.

Heidke Skill Score (HSS) is the ratio of correct rain forecast

$$\text{Heidke Skill Score (HSS)} = \frac{\text{Correct Forecast} - (\text{Correct Forecast})_{\text{random}}}{\text{N} - (\text{Correct Forecast})_{\text{random}}}$$

$$\text{HSS} = \frac{2(AD - BC)}{(A + C)(C + D) + (A + B)(B + D)}$$

The HSS ranges from negative values to +1, Negative values indicate that the standard forecast is more accurate than the forecast; skill is negative. The HSS represents the fraction by which the forecast improves on the standard forecast. A perfect forecast gives a HSS of 1, no matter how good the standard forecast is.

The error structures as suggested by IMD were followed to discriminate between correct, usable and unusable forecasts (Singh, *et al.*, 1999). The error structure for verification of Quantitative Precipitation (QP) was as follows:

	Observed rainfall ≤ 10 mm	*Observed rainfall > 10 mm*
Correct	diff ≤ 0.2 mm	diff ≤ 2% of obs
Usable	0.2 mm < diff ≤ 2.0 mm	2% of obs < diff ≤ 20% of obs
Unusable	diff > 2.0 mm	diff > 20% of obs

Usability (probability of success rate) = correct + usable

where, diff stands for Absolute difference of observed and forecasted rainfall in mm and obs stands for observed rainfall in mm.

Correlation coefficient (*r*) and Root Mean Square Error (RMSE) of all weather parameters were worked out for the absolute error between observed and forecasted data for obtaining the skill of the model in forecasting. The RMSE values indicate the degree of error in the forecast. The lower values of RMSE indicate less difference between observed and forecasted values.

$$\text{Root mean square error (RMSE)} = \frac{(F - O)^2}{n}$$

where, F = Forecasted value, O = observed value, n = number of observations

The critical values of error structures given by Rathore *et al.* (1999) were followed to consider success and failure cases for analysis, which mentioned below:

	Error structure for verification of temperature forecast (°C)	*Error structure for verification of wind speed forecast (kmph)*	*Error structure for verification of relative humidity forecast (%)*
Correct	diff ≤ 1.0 °C	diff ≤ 2 m/s (7.2 kmph)	diff ≤ 10 %
Usable	1.0 °C < diff ≤ 2.0 °C	2 m/s < diff ≤ 4 m/s (7.2 – 14.4 kmph)	10% <diff ≤ 20%
Unusable	diff > 2.0 °C	diff >4 m/s (14.4 kmph)	Diff >20%

Usability (probability of success rate) = correct + usable

where, diff stands for Absolute difference of observed and forecasted.

3. Results and discussion

The usability (probability of success rate in percentage) of daily weather parameters, *viz.*, rainfall, maximum and minimum temperature, wind speed, morning and evening relative humidity for four seasons

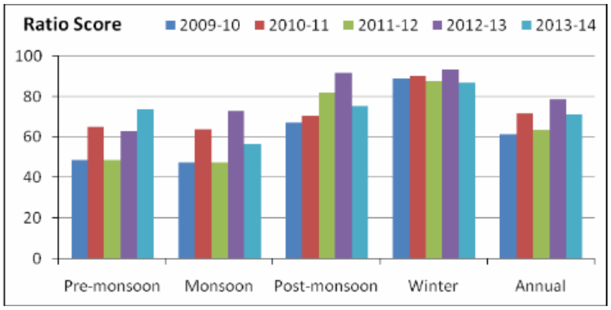

Fig. 1. Seasonal verification of daily rainfall forecast based on ratio score

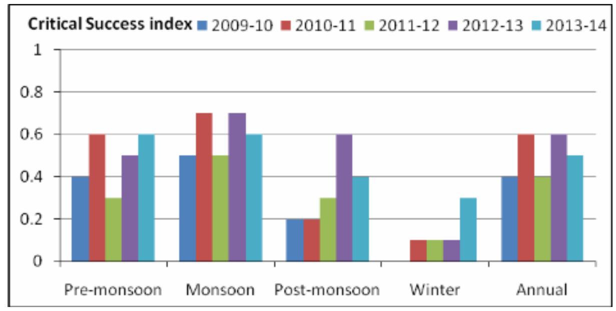

Fig. 2. Seasonal verification of daily rainfall forecast based on critical success index

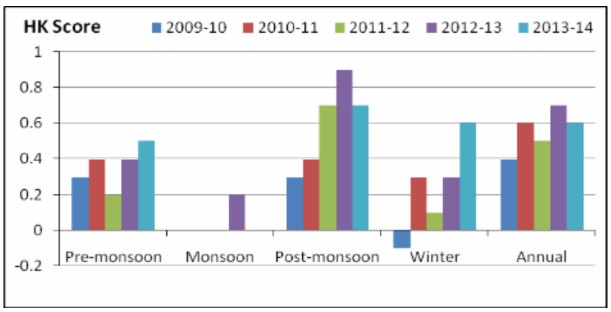

Fig. 3. Seasonal verification of daily rainfall forecast based on H K Score

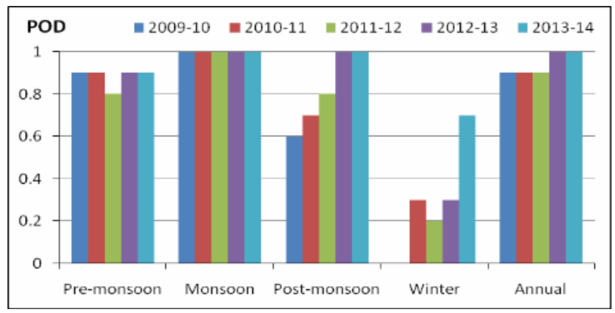

Fig. 4. Seasonal verification of daily rainfall forecast based on Probability of Detection

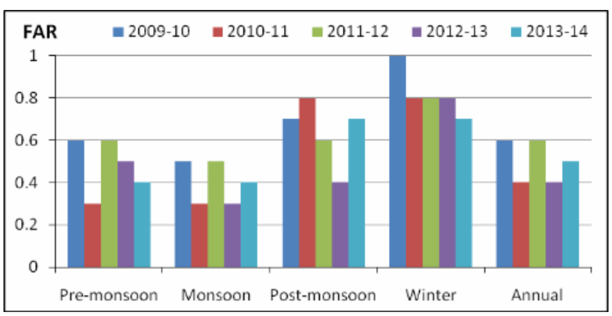

Fig. 5. Seasonal verification of daily rainfall forecast based on False Alarm Ratio

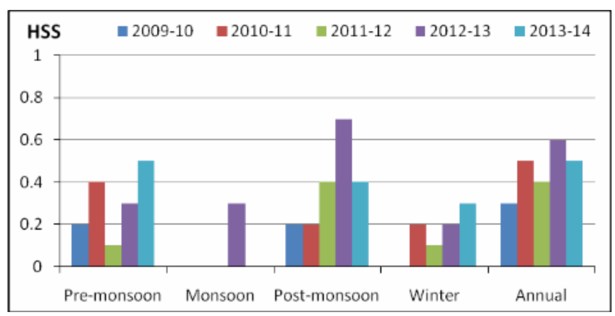

Fig. 6. Seasonal verification of daily rainfall forecast based on Heidke Skill Score

Figs. 1-6. Analysis of seasonal rainfall forecast during March, 2009 to February, 2014

and 5 years (March, 2009 to February, 2014) are presented in Table 1 and Fig 7-12. The daily weather parameters were computed from a contingency table summed for the whole season and worked out the usability based on the threshold values as stated above section.

The results indicated that during pre-monsoon, post-monsoon and winter seasons, the performance of rainfall was excellent as they are not rainy seasons for Sonitpur and the usability varied from 55.0% to 68.9%, 90.0% to 97.6%, and 100.0%, respectively, whereas the usability during monsoon season which is the main rainfall receiving season, recorded the lower percentage of usability varying from 31.0% in 2011 to as high as 34.6% in the year 2010. The corresponding qualitative analysis results (ratio score, critical success index, HK score, probability of detection, false alarm ratio and Heidke Skill Score) are presented in Figs. 1-6. During pre-monsoon, post-monsoon and winter seasons, the ratio score ranged from 48.9 to 93.3%, indicating moderate to very good

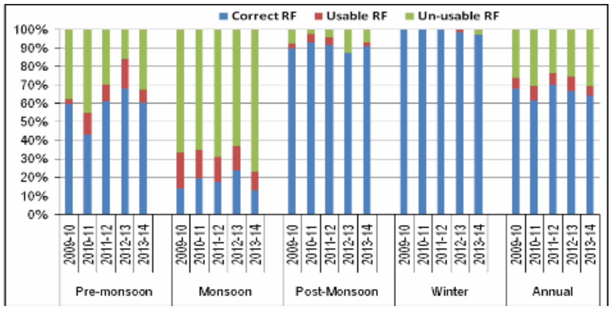

Fig. 7. Seasonal verification of daily rainfall forecast during March, 2009 to February, 2014

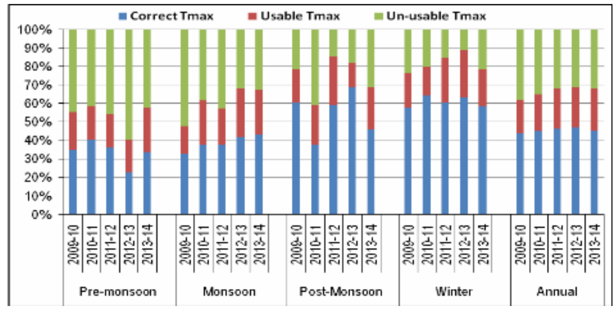

Fig. 8. Seasonal verification of daily maximum temperature forecast during March, 2009 to February, 2014

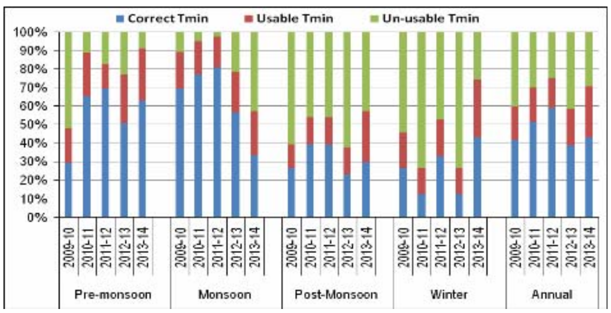

Fig. 9. Seasonal verification of daily minimum temperature forecast during March, 2009 to February, 2014

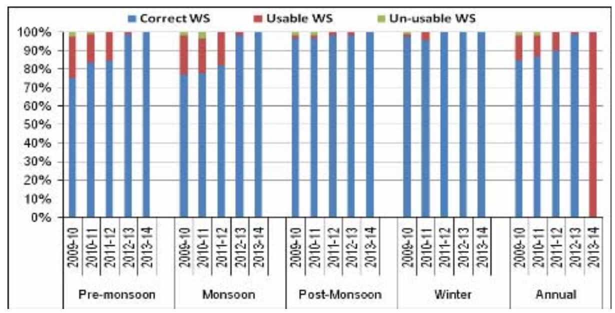

Fig. 10. Seasonal verification of daily wind speed forecast during March, 2009 to February, 2014

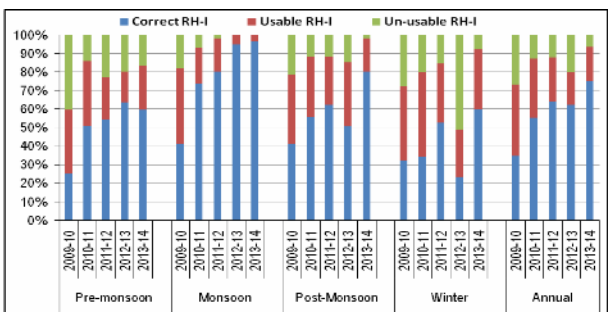

Fig. 11. Seasonal verification of daily morning relative humidity forecast during March, 2009 to February, 2014

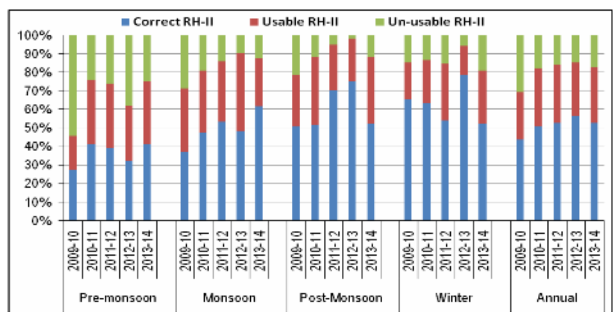

Fig. 12. Seasonal verification of daily afternoon relative humidity forecast during March, 2009 to February, 2014

Figs. 7-12. Usability of seasonal and annual forecast of different parameters during March, 2009 to February, 2014

forecast of rain during these seasons. The results revealed that the HK scores were negative during winter season (2009-10). Mostly the HK scores were 0.18 to 0.37 in pre-monsoon and winter seasons, because rainfall does not occur in these seasons and the no rainfall forecasts become 100% correct. The critical success index is highest (0.69) in monsoon, 2011 and lowest (0.0) in winter 2009-10. Likewise the probability of detection (POD) is the highest value during monsoon season in all 5 years and lowest during winter 2011-12. The False alarm ratio (FAR) is highest during all season except monsoon season revealed that perfect forecast of rain during these seasons. Heidke Skill Score (HSS) is positive in all three seasons of the five years except monsoon where the HSS is zero. HSS is zero in winter during 2009-10 where as non-zero during monsoon 2012. Similarly, from the Table 2, it is revealed that the RMSE values of rainfall were lower, varying from 8.2 to 18.7 mm, 5.1 to 10.1 mm and 1.1 to 2.7 mm in pre-monsoon, post-monsoon and winter seasons, respectively but during monsoon season it is

TABLE 2

Seasonal RMSE between observed and predicted weather parameter during March, 2009 to February, 2014

Season	Years	Rainfall (mm)	Max temperature (°C)	Min temperature (°C)	Wind Speed (kmph)	Morning RH (%)	Afternoon RH (%)
Pre-monsoon	2009-10	18.7	5.4	3.6	6.4	4.4	4.8
(Mar-May)	2010-11	16.2	4.5	3.0	5.5	3.6	4.0
	2011-12	11.6	3.3	1.9	5.2	3.5	4.0
	2012-13	8.2	4.9	1.8	3.0	3.3	4.3
	2013-14	9.2	3.3	1.4	2.8	3.3	3.7
Monsoon	2009-10	21.7	3.4	1.6	6.0	3.7	4.0
(Jun-Sep)	2010-11	18.3	2.5	1.2	6.5	3.4	4.0
	2011-12	26.9	2.5	1.0	5.7	2.5	3.3
	2012-13	23.0	2.8	1.8	2.5	2.1	3.4
	2013-14	33.6	2.9	3.2	1.4	2.0	3.1
Post-monsoon	2009-10	9.8	5.9	4.8	4.7	3.9	3.6
(Oct-Nov)	2010-11	6.2	6.3	4.9	4.2	3.4	3.5
	2011-12	5.1	1.9	3.5	3.3	3.1	2.9
	2012-13	10.1	1.8	3.5	2.4	3.3	2.7
	2013-14	7.1	2.4	2.8	3.8	2.6	3.4
Winter	2009-10	1.9	2.4	3.5	4.9	4.0	3.3
(Dec-Feb)	2010-11	2.5	2.0	4.4	4.6	3.9	3.3
	2011-12	1.1	4.2	4.1	3.6	3.6	3.6
	2012-13	1.4	1.5	4.2	2.3	4.4	2.8
	2013-14	2.7	2.3	2.4	3.7	3.5	3.5
Annual	2009-10	16.2	4.3	3.3	5.6	4.0	4.0
(Mar-Feb)	2010-11	13.6	3.8	3.4	5.5	3.6	3.7
	2011-12	16.7	3.1	2.7	4.8	3.2	3.5
	2012-13	14.6	3.1	2.9	2.6	3.3	3.4
	2013-14	20.2	2.8	2.6	0.0	2.8	3.4

varying from 18.3 to 33.6 mm which is comparatively higher value in all five years.

The pre-monsoon forecast verification in Table 1 and Figs. 7-12 depicts those percentages of usability for daily rainfall, maximum temperature, minimum temperature, wind speed, morning and afternoon relative humidity were 55.0-82.7, 40.2-58.7, 47.8-91.3, 97.8-100.0, 59.8-85.9 and 45.7-76.1, respectively. Very good performance was observed for rainfall and wind speed. There was gradual improvement in forecast for wind speed (97-100%) during these five years.

The seasonal verification of daily forecasted values with the observed parameters for monsoon season as presented in Table 1 and Figs. 7-12 revealed that percentages of usability (correct + usable) for rainfall, maximum temperature, minimum temperature, wind speed, morning and evening relative humidity were 23.2-34.6, 47.5-68.0, 57.4-97.5, 96.7-100.0, 82.0-100.0 and 71.3-90.2, respectively. Overall, seasonal forecasting performance of daily rainfall was found poor and performance of maximum temperature as well as afternoon relative humidity was found average. Performance of minimum temperature, wind speed and morning relative humidity were found excellent. The performance of minimum temperature, morning and afternoon relative humidity forecast during 2013-14 showed marked improvement over previous five years' forecast.

TABLE 3

Seasonal correlation coefficient between observed and predicted weather parameter

Season	Years	Rainfall	Max temperature	Min temperature	Wind Speed	Morning RH	Afternoon RH
Pre-monsoon	2009-10	0.21	0.15	0.58*	-0.05	-0.02	0.36*
(Mar-May)	2010-11	0.39*	0.51*	0.57*	0.07	0.22	0.47*
	2011-12	0.31*	-0.01	0.85**	0.41*	0.27	0.40*
	2012-13	0.48	0.51	0.87**	-0.09	0.44*	0.52
	2013-14	0.42	0.20	0.90**	0.40*	0.40*	0.50
Monsoon	2009-10	0.08	-0.25	0.25	-0.14	0.02	0.20
(Jun-Sept)	2010-11	0.46*	0.39*	0.55*	0.22*	0.04	0.32
	2011-12	0.22	0.26*	0.47*	0.30*	0.06	0.00
	2012-13	0.20	0.38	0.36	0.03	0.26	0.17
	2013-14	0.27	0.40	0.20	0.10	0.60*	0.50
Post-monsoon	2009-10	0.07	0.19	0.29	0.14	0.00	0.06
(Oct-Nov)	2010-11	0.62**	0.02	0.34	0.46*	0.18	0.08
	2011-12	0.23	0.80**	0.94**	0.15	0.18	0.47*
	2012-13	0.32	0.32	0.82**	0.02	0.37*	0.92**
	2013-14	0.51	0.30	0.90**	-0.20	0.00	0.60*
Winter	2009-10	-0.03	0.43*	0.54*	0.30*	0.22*	0.42*
(Dec-Feb)	2010-11	0.27*	0.69*	0.50*	0.36*	0.06	0.33
	2011-12	0.18	0.44*	0.31*	0.28*	-0.22	0.53*
	2012-13	0.02	0.83**	0.58*	0.16	0.20	0.76**
	2013-14	0.81**	0.60*	0.50*	0.10	0.00	0.40*
Annual	2009-10	0.26*	0.43*	0.84**	0.16	-0.03	0.52*
(Mar-Feb)	2010-11	0.53*	0.55*	0.86**	0.29*	0.29*	0.63*
	2011-12	0.37*	0.71**	0.91**	0.37*	0.07	0.62*
	2012-13	0.38	0.69**	0.91**	0.15	0.35*	0.65*
	2013-14	0.42	0.70**	0.90**	0.00	0.20	0.60*

*, **Significant at P = 0.05 and P = 0.01 level, respectively

The post-monsoon forecast verification depicted in Table 1 and Figs. 7-12 revealed that percentages of usability for rainfall, maximum temperature, minimum temperature, wind speed, morning and evening relative humidity were 87.5-97.6, 59.0-85.3, 37.7-57.4, 98.4-100.0, 85.3-98.4 and 78.7-98.4, respectively. Excellent performance was observed for rainfall and wind speed but poor performance was observed for minimum temperature forecast. The forecast of rainfall, maximum temperature, morning and afternoon relative humidity was excellent during 2010-11, 2011-12, 2012-13 and 2013-14 respectively, but it was very poor for the year 2009-10 for all the four parameters.

The usability analysis of winter season presented in Table 1 and Figs. 7-12 showed the percentages of usability for rainfall, maximum temperature, minimum temperature, wind speed, morning and evening relative humidity were 100.00, 76.7-88.9, 26.7-74.4, 98.9-100.0, 48.9-92.2 and 81.1-94.5, for all five years respectively. The forecasting performance of rainfall was excellent as they are not rainy seasons for Sonitpur along with wind speed. Average performance was observed for maximum temperature, morning and afternoon relative humidity. Forecasting was found very poor for minimum temperature during 2010-11 as compared to excellent performance during winter seasons of the years 2009-10, 2011-12, 2012-13 and 2013-14.

The verification of forecasted values with the observed parameters for the whole year as a whole presented in Table 1 and Figs. 7-12 revealed that the percentages of usability for rainfall, maximum temperature, minimum temperature, wind speed, morning and afternoon relative humidity were 69.0-76.0, 61.9-68.5, 58.6-75.4, 98.4-100.0, 73.4-93.7 and 69.5-85.2, for all five years respectively. Overall annual forecasting performance of rainfall was found satisfactory and performance of wind speed was found excellent during 2009-10 to 2013-14.

The values of seasonal RMSE presented in Table 2 showed that in pre-monsoon, values are lower which results there is a good performance of forecast. Interestingly, there was gradual decreasing of RMSE values for daily total rainfall, daily average maximum and minimum temperature, daily average wind speed, daily average morning and afternoon relative humidity during March 2009 to February 2014, which revealed an improvement in forecast accuracy year to year for pre-monsoon season. The RMSE values are higher in post-monsoon as compared with pre-monsoon followed by monsoon season which indicated that accuracy of forecast is higher during post-monsoon season. The RMSE values are lowered as compared with other seasons indicated that accuracy of forecast is higher during winter season.

Values of correlation coefficients (*r*) presented in Table 3 showed that minimum temperature forecast was significantly correlated with observed during all the review periods. Rainfall was highly correlated during all seasons except monsoon and annual basis. No significant correlation was observed for morning relative humidity during most seasons except pre-monsoon season of the year 2011-12. Wind speed was highly correlated on annual basis pre-monsoon of the year 2011-12, monsoon of 2010-11, 2011-12 and post-monsoon of the year 2010-11 and winter of all five years, whereas no significant correlation was observed during other seasons. Maximum temperature was significantly correlated on annual basis, during pre-monsoon of 2010-11 and monsoon seasons of the year 2010-11, post-monsoon of 2009-10, 2011-12 and monsoon of all five years but no significant correlation was observed during other seasons. Significant correlation for afternoon relative humidity was observed in all seasons and annual basis except monsoon of 2011-12 and post monsoon of 2009-10, 2010-11 seasons.

4. Conclusions

Forecasted wind speed was found to be most accurately comparable with observed wind speed during all the years in all the seasons. Rainfall forecast performance was very good with low RMSE considering all seasons of five year forecast except monsoon season but its daily forecast still needs to improve. The geographic location and topography of the region give rise to various weather phenomena and also controls the spatial patterns of climate parameters. The frequency of thunderstorm activities during pre-monsoon and monsoon seasons together with in situ source of moisture as well as vegetation of the region play dominant role in sudden development of weather phenomenon which may be difficult to capture under the scale of medium range.

Minimum temperature forecasts were average in rest of the seasons and year as a whole and needs improvement, especially in post-monsoon and winter seasons. Maximum temperature performance was average in all seasons. Morning and afternoon relative humidity performance was average in all the seasons and annual basis with high RMSE. So the usability (percent of success probability), accuracy and reliability of dominant weather parameters in a particular season, for example, rainfall in monsoon season and minimum temperature in winter season, were comparatively less. The accuracy of forecasting of all the weather parameters has improved significantly in spite the fact that the region/area experiences pre-dominantly humid sub-tropical climate with hot, humid summers, severe monsoons and mild winter.

This may be attributed to the efforts of IMD in qualitative data inputs and models hence providing help in planning to winter and summer crops.

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