MAUSAM, **70**, 4 (October 2019), 841-852

L E T T E R S

551.509.5 (540.49)

DISTRICT LEVEL WEATHER FORECAST VERIFICATION IN CHHATTISGARH

1. Chhattisgarh is 26th state of India and geographical area of the state covers about one-third of undivided Madhya Pradesh. The Chhattisgarh extends south east of Madhya Pradesh from 17°46' N to 24°05' N latitude and from 80°15' E to 84°20' E longitude. Chhattisgarh has a tremendous agricultural potential with a diversity of soil and climate, mountains, plateau, rivers, natural vegetation and forest. The temperature goes down upto 1 °C in Chilpi and Surguja. The annual rainfall ranges from 800 mm to 1700 mm in different years. Diversified crops and cropping systems are the typical characteristics of Chhattisgarh. Rice is the major crop of the region, on the other hand *kharif* potato are being grown in plateau area of northern hills, while in Bastar plateau, crops like coconut and wide range of tuber crops, spices and medicinal plants are grown.

Weather continues to affect the agriculture and production of crops in the State and agriculture depends upon favourable weather and as well as adverse and extreme weather in the form of dry spell, heavy rainfall or cyclone which hampers crop prospects in Monsoon season as rice is main food crop of the State in *Kharif* season. Weather information and forecasting is increasingly beneficial to farming as agricultural operations from crop sowing to harvesting is determined by weather. Typical application of weather forecast in the State is onset of monsoon for sowing of rainfed rice in monsoon season and rainless periods in intra-season for mitigation of dry spells and forecast of minimum temperature to take up wheat sowing, maximum temperature during grain development/maturity stage of wheat in summer.

District level weather forecast for 27 districts in the State is issued twice in week on Tuesday and Friday to Agrometeorological Field Units (AMFUs) in the State to provide agrometeorological advisories to farmers. AMFUs prepare Agrometeorological Advisory Bulletin (AAB) and disseminate to farmers through multichannel dissemination system. It is aimed to take benefit of optimum weather to increase the production and to minimise the effect of adverse weather on crop production. District level weather forecast from multi model-ensemble (MME) technique (Rathore *et al*., 2011; Roy Bhowmik and Durai, 2012) is subjected to moderation considering the observed data, satellite imageries, climatology of the region and prevailing synoptic condition of the region and neighbourhood as per guidelines and issued to AMFUs. Five NWP models were considered for model-ensemble are: (*i*) National Centre for Medium Range Weather Forecasting (NCMRWF) (presently it uses IMD GFS T-1534), (*ii*) European Centre For Medium Range Weather Forecasting (ECMWF T-799), (*iii*) Japan Meteorological Agency (JMA T-959), (*iv*) United Kingdom Meteorological Office (UKMO) and (*v*) National Centre for Environmental Prediction Global Forecast System (NCEP GFS).

Following check list has been taken for value addition as per guidelines of Agrimet Division, Pune.

(*i*). Preparation of following working chart by Scientific Assistant

(a) District level observation of the parameter, (b) Trend of observed value (observed value-previous day's observed value, (c) Climatological value of the day, (d) MME forecast value of the day, (e) MME error (day 1 to day 5) on the basis of previous forecast values

(*ii*). Analysis by Forecaster In-Charge

(a) Make analysis of current synoptic conditions on the basis (*i*) synoptic weather charts/ model analysis fields, model diagnostic products, (*ii*) Satellite Picture, DWR products,

(b) Analysis of future synoptic conditions based on model forecast products of (*i*) GFS, (*ii*) UKMO, (*iii*) COLA etc.

(c) Analyse the consistence/forecast behaviour of these models on the basis of performance of previous forecasts to identify the most consistent model.

(*iii*). Forecaster should have through knowledge on the (a) previous performance history of MME, (b) prevailing synoptic condition, (c) topography and climatic condition of the respective district and accordingly value addition to the MME value may be done above (*i*) and (*ii*).

(*iv*). For the MC/RMC where number of district is considerably more, value addition may be done taking a representative district of the respective homogeneous region.

Value addition was done for all the districts as per the guidelines preceded. Current observations and MME model forecast are matched and trend obtained from the MME model are applied to current observation for value addition. Value addition was done initially for rainfall, temperature and relative humidity and subsequently other parameters. The parameters for which the observed data and MME model output are closely matching are identified and value addition to those parameters are avoided to save time for effective value addition to other parameters.

Verification of moderated forecasts is helpful to estimate the accuracy of forecast with a view to improve the forecast accuracy. Quality of agromet advisories is depends on accuracy of forecast issued. On the basis of feedback received from farmers in Bastar region of the State, it has been found that farmers are making use of AABs in crop management and adjusting farming operations according to medium range weather forecasting. It has been found that if a forecast of sufficient skill can be generated, returns to the framers can increase substantially as losses many times are high (Chaudhary, 2011). So, the quantitative forecasts for 7 weather parameters, *viz*., rainfall, maximum and minimum temperatures, wind speed and direction, relative humidity and cloudiness is verified as per methodology (Chhatopadhyay *et al*., 2016) with reference to Departmental and non-departmental observatory data.

2. Verification of rainfall is carried out both qualitative and quantitative for rainfall and quantiative for other parameters in each season. This is done by taking district average rainfall available from district rainfall summary generated through District Rainfall Monitoring. For other parameters, Departmental observatory data of Ambikapur, Bilaspur, Raipur, Jagdalpur and Non-departmental observatory data of Durg and Rajnandgaon has been used for verification of the districts respectively. Districts for which AWS data available is also taken up for verification. The accuracy of a forecast is some measure of difference of observed data and forecast data. Accuracy of a forecast is defined as how many days in the season the forecast was close to the actual weather (correct and usable) based on error structure and expressed as percent. Error structure for verification of quantitative district level weather forecast, if the forecast parameter is out by one stage compared to observed, it is considered as correct forecast and if the same is out by two stages and more than that it is considered as partially correct and wrong forecast respectively. The forecast has been verified with the help of observed data using the following error structure for rainfall and temperature for different districts in the state.

Parameter	*Modified error structure*
Rainfall	if rainfall difference is
	$\pm$ 25% - correct
	$\pm$ 50% - usable
	>50% <-50% - incorrect (Unusable)

Thus, for better interpretation of the results in different categories, following criteria was made to observe the worthiness of the forecast.

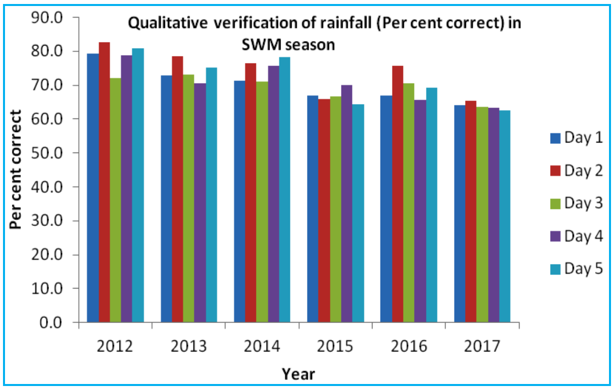
Good	:	Correct and usable forecasts for >70% days in the district
Moderate	:	Correct and usable forecasts for 50-70% days in the district
Poor	:	Correct and usable forecasts for <50% days in the district

Temperature for observed maximum or minimum temperature

Temperature	$\pm$ 1 °C - correct
	$\pm$ 2 °C - usable
	>$\pm$ 2 °C - incorrect
Relative humidity	$\pm$ 10% - correct
	$\pm$ 20% - usable
	>$\pm$ 20% - incorrect
Wind direction	$\pm$ 30° - correct
	$\pm$ 40° - usable
	>$\pm$ 40° - incorrect
Wind speed	$\pm$ 2 m/s -correct
	$\pm$ 4m/s- usable
	>$\pm$ 4 m/s - incorrect
Cloud cover	$\pm$ 2 octa - correct
	$\pm$ 3 octa - usable
	>$\pm$ 3 octa - incorrect

Percent correct and usable forecast is added and given as percent correct.

3. Results of qualitative verification of rainfall is better than quantitative verification. Qualitatively rainfall is correct in 71 percent days in Monsoon season. Day 2 value additions are more correct during 2012, 2013, 2016



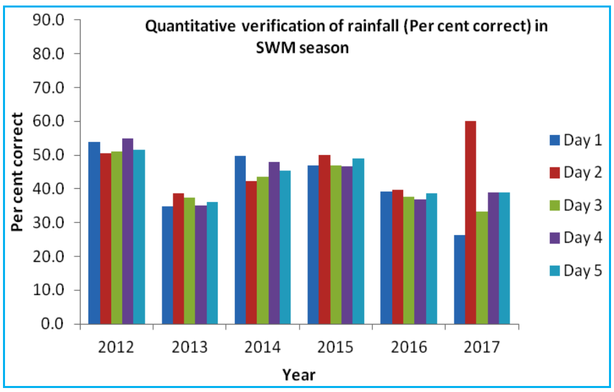


Fig. 1. Verification of rainfall in monsoon season

and 2017 (Fig. 1). Day 4 value additions are more correct in 2015 and Day 5 value additions are more accurate in 2015. Percent correct in quantitative verification is 43 percent. District wise category of forecast accuracy indicates better forecast in 2012, 2014, 2015 and 2016. Maximum temperature forecast is successively good in the years with more than 45 percent correct forecast. Forecast of accuracy minimum temperature is above 60 percent. RH forecast is correct by more than 70 percent. Forecast accuracy of wind speed is above 90 percent and wind direction is less than 70 percent correct. Cloud cover forecast is more than 70 percent correct.

Quantitative verification of rainfall indicates that Day 1 value addition is more correct in 2014, Day 2 value addition is more correct in 2013, 2015, 2016 and 2017. During 2013, model forecast is far from maximum accuracy and therefore more bias correction of the model forecast is required. Rana *et al.* (2013) found that forecast are 36-53 percent correct during Monsoon season in Himachal Pradesh from Day 3 to 5. Forecast is 65 percent correct in Monsoon season in middle Gujarat region in 2005 (Chauhan *et al*., 2008). Similar results of low percent correct rainfall in Monsoon have also been reported by Chaudhari *et al.* (2010) for high rainfall zone of Konkan in Maharashtra, Lunagaria *et al.* (2009) for middle Gujarat agro climatic zone of Gujarat and Sarmah *et al*. (2015) in north bank plain zone of Assam. Global Spectral Model is most efficient in predicting precipitation in the 2.54-12.8 mm range but the efficiency decreases rapidly for higher thresholds in a study from West Bengal, Andhra Pradesh and Rajasthan (Mandal *et al*., 2007).

District wise category of forecast accuracy (Fig. 2) indicates in better rainfall forecast in the years 2012, 2014, 2015 and 2016. Number of districts with moderate forecast is significant even more than poor forecast districts in 2012 with very good accuracy in quantitative verification. More than 50 percent districts had moderate forecast in most of days in 2012. Nearly 50 percent district forecast is moderate in 2014 and 2015. This indicates skill improvement in forecast accuracy after value addition in succussive years. In contrary, poor forecast districts are more in 2013, 2016 and 2017.

Forecast accuracy of maximum temperature is better when compared to rainfall (Fig. 3). Mean percent correct forecast of maximum temperature was invariably better (above 70 percent) in Day 2 forecast in comparision with other days. Forecasts are more than 50 percent correct in 2012, 2013, 2015, 2016 and 2017 and above 45 percent in 2014. Maximum temperature forecast is successively good in the years. Chauhan *et al*. (2008) observed that forecast of maximum temperature was 80 percent correct in middle Gujarat region in Monsoon season. Rana *et al.* (2013) observed forecast of maximum temperature in Himachal Pradesh was 31-72 percent correct.

Forecast of accuracy minimum temperature is above 60 percent in all the years and days (Fig. 3). There is no significant difference in percent correct among days of forecast in most of the years. Day 3 forecast is more accurate in 2014 compared to other days. Forecast of 2012, 2013, 2015, 2016 and 2016 is better with more than 80 percent days of correct forecast. Chauhan *et al*. (2008) observed that forecast of maximum temperature was 92 percent correct in middle Gujarat region in Monsoon season. Rana *et al*. (2013) reported 60 percent correct minimum temperature foreacast from Day 3 to 5.

Maximum RH forecast accuracy was very good in Monsoon season as above 90 percent correct forecast is issued in all the years irrespective of days (Fig. 3). There is little difference in correct forecast percent among days of forecast. Prediction of maximum RH is very good when compared to rainfall and temperature. Minimum RH forecast accuracy is improved over years as forecast accuracy is reached to more than 80 percent in 2017 from more than 70 percent in 2012 (Fig. 3). There is no significant difference in percent correct in forecast days in 2014, 2015, 2016 and 2017 and correct forecast percent

Fig. 2. Districtwise forecast category of rainfall in monsoon season

range from more than 80 and up to 100 percent. Forecast was more accurate (more than 80 percent) forecast in Day 2 during 2012 and 2013. The percent correct forecast of maximum and minimum RH is in agreement with the results of Sarmah *et al*. (2015).

Forecast accuracy of wind speed in above 90 percent in all the 5 days in all years. There is no variation in percent correct forecast among days in most of the years except 2014 (Fig. 3). Day 2 forecast is less than 90 percent correct in 2014. Rana *et al*. (2013) reported 99 percent correct wind speed foreacast from Day 3 to 5. Chauhan *et al*. (2008) observed that forecast of wind speed was 97 percent correct in middle Gujarat region in Monsoon season. Accuracy of wind direction is moderate only as compared to wind speed in monsoon season as percent correct is less than 70 percent in all days and years of study (Fig. 3). Forecast is better in 2012, 2013, 2015, 2016 and 2017 as percent correct in most of days are above 50 percent. Forecast in 2014 is more than 50 percent in Day 2 whereas other days are more than 40% correct. Rana *et al*. (2013) reported 17-23 percent correct wind speed foreacast from Day 3 to 5. Chauhan *et al*. (2008) observed that forecast of wind direction was 78 percent correct in middle Gujarat region in Monsoon season.

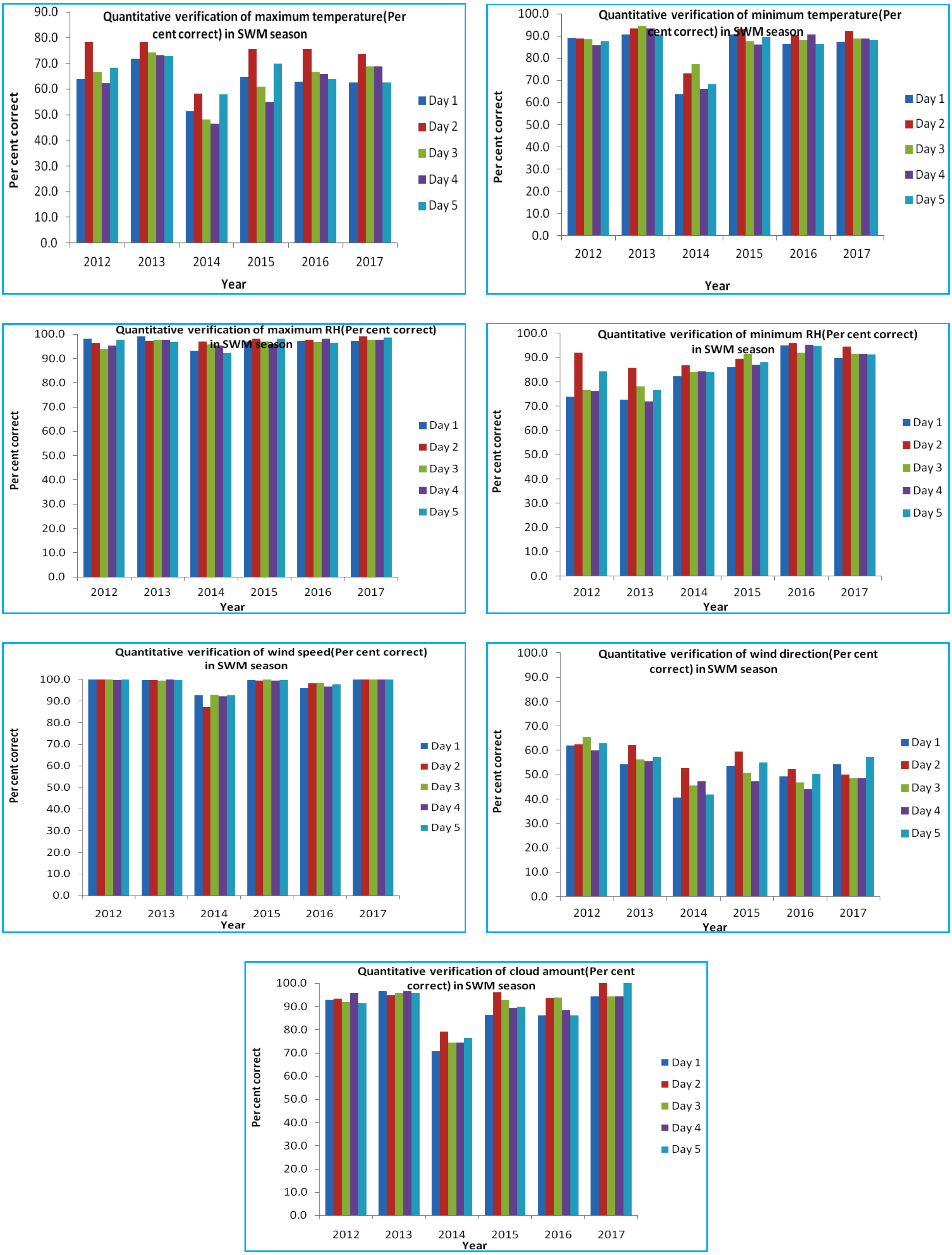


Fig. 3. Verification of temperature, RH, wind and cloud in monsoon season

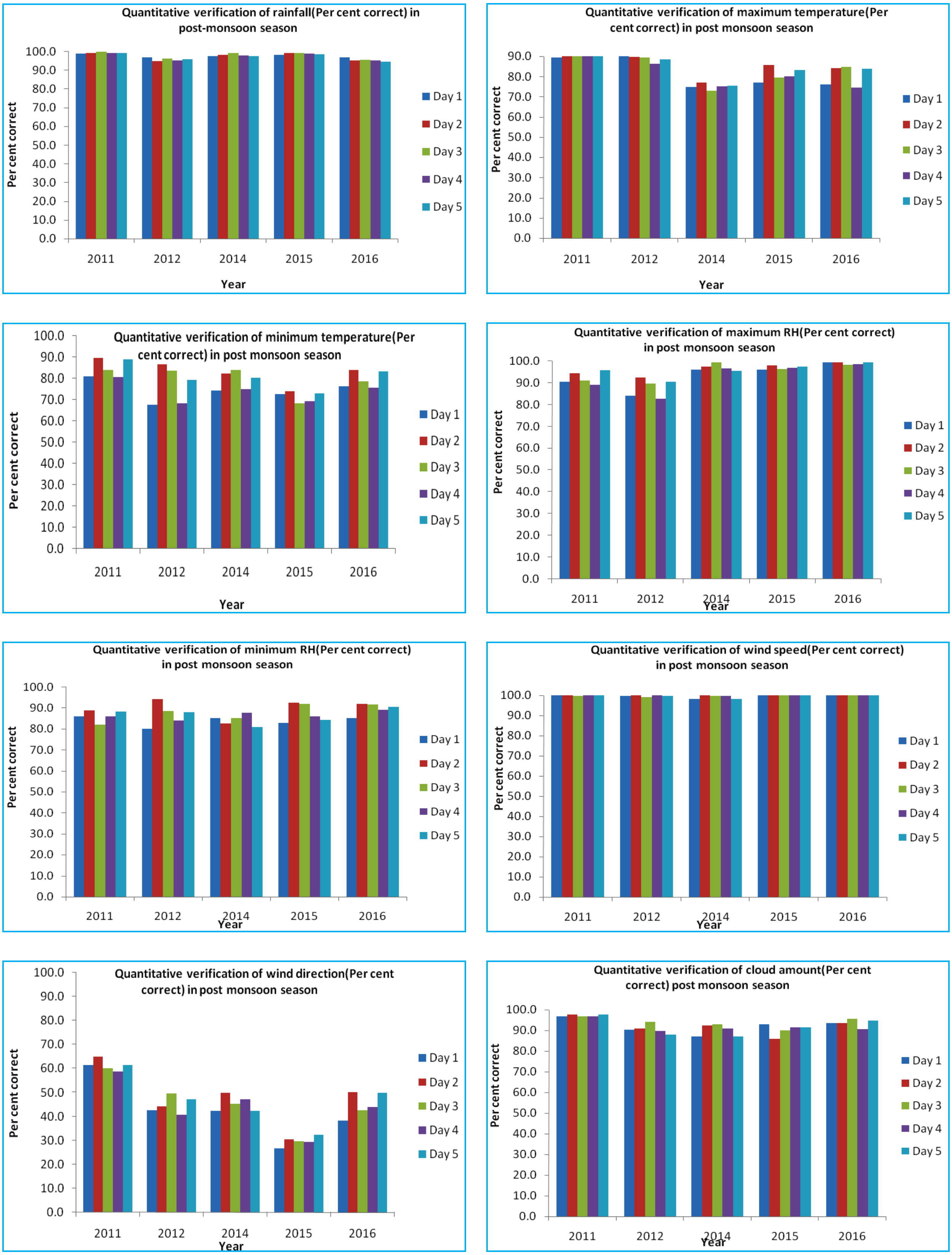


Fig. 4. Verification of forecast in Post monsoon season

Cloud cover forecast is more than 70 percent accurate in all the days and all years (Fig. 3). During 2012, 2013, 2015, 2016 and 2017 forecast percent correct is above 80 percent. Forecast percent is correct to the extend of 70-80 percent. Rana *et al.* (2013) observed cloud forecast are correct by 59-80 percent in Himachal Pradesh.

Forecast accuracy of rainfall in post monsoon season is 96-99 percent correct in all the years of study (Fig. 4). Percent correct forecast of maximum temperature is 75-92. Percent correct forecast of minimum temperature is 71-85. Percent correct of maximum RH forecast is 88-99. Forecast accuracy of minimum RH in post monsoon is consistent in successive years and it range from 84-90 percent correct. Wind speed forecast is most accurate in post monsoon season as forecast accuracy is close to 100 percent in all the years. Wind direction forecast in post monsoon season range from 30-61 percent correct in different years. Cloud cover forecast in post monsoon season is accurate in the range of 90-97 percent.

There is no significant difference in rainfall forecast among days of forecast validity in post monsoon season. Sahu *et al.* (2011) also obtained 95 percent correct forecast in post monsoon season in south saurashtra zone. Forecast accuracy of maximum temperature is very good in 2011 and 2012 as percent correct is 91 and 92 respectively in these years. Percent correct is lowest in 2014 (75 percent) and in recent years accuracy was improved (82 percent). Day 2 forecast is more accurate in 2014 and 2015 and Day 3 forecast is more accurate in 2016. Chauhan *et al.* (2008) reported maximum temperature forecast in post monsoon season is 89 percent correct. Minimum temperature in Day 2 forecast is more accurate in 2011, 2012, 2015 and 2016 and Day 3 forecast is more accurate in 2014. Forecast accuracy of minimum temperature is highest (85 percent correct) in 2011 and in subsequent years percent correct foecast decreased marginally and it was lowest (71 percent) in 2015. Chauhan *et al.* (2008) also reported 86 per correct minimum temperature forecast in middle Gujarat.

Maximum RH in Day 2 forecast is more accurate in 2012, 2015 and 2016 and Day 3 forecast is more accurate in 2014. Forecast accuracy of maximum RH during post monsoon is increased from 92 percent in 2011 to 99 percent in 2016. Minimum RH in Day 2 forecast is more accurate in 2011, 2012, 2015 and 2016. Forecast accuracy of minimum RH in post monsoon is consistent in successive years and it range from 84-90 percent correct. Sarmah *et al.* (2015) observed 85-98 percent and 79-98 percent correct forecast of maximum and minimum RH respectively in post monsoon season in Assam.

Wind speed forecast is most accurate in post monsoon season as forecast accuracy is close to 100 percent in all the years. Rana *et al*. (2013) also reported 100 percent correct forecast of wind speed in Western Himalayas. Wind direction in Day 2 forecast is more accurate in 2011, 2014 and 2016. Day 3 forecast is more accurate in 2012. Wind direction forecast is 30-61 percent correct in different years. Chauhan *et al*. (2008) obtained 45 percent correct forecast of wind direction in post monsoon season in middle Gujarat.

Cloud cover forecast in post monsoon season is accurate in the range of 90-97 percent. There is no difference in days of forecast in 2011. Day 3 forecast is more accurate in 2012, 2014 and 2016. Rana *et al*. (2013) obtained 58-81 percent correct forecast of cloud cover in western Himalaya.

Rainfall forecast during winter season is very good in all the years and days as forecast accuracy was 97-100 percent [Fig. 5(a)]. Forecast accuracy of maximum temperature and minimum temperature of Day 1 is improved in recently in 2017 compared to Day 2. Forecast of maximum RH and minimum RH in all the days are improved recently in 2015, 2016 and 2017. Wind speed forecast was more than 96 percent correct in winter. Cloud forecast during winter season is improved upto 95 percent during recent years (2014-17).

Forecast accuracy of Day 2 rainfall forecast is more accurate compared to other days in 2012 to 2016. Chauhan *et al.* (2008) reported 100 percent accuracy in winter rainfall forecast in middle Gujarat. Percent correct forecast of maximum temperature was consistent in the subsequent years with highest forecast accuracy in 2014. Forecast accuracy is 65-91 percent in all the years and days. Chauhan *et al*. (2008) also obtained 80 percent correct maximum temperature forecast in winter season in middle Gujarat region.

Percent correct minimum temperature forecast was more accurate in Day 1 in 2014 and 2017 while more accurate in Day 2 in 2012, 2013, 2015 and 2016. Best forecast accuracy is noticed in 2014. Forecast accuracy is 53-91 percent in all the years and days. Value addition improved the model forecast in most of the years [Fig. 5(b)]. Chauhan *et al*. (2008) also obtained 78 percent correct minimum temperature forecast in winter season in middle Gujarat region.

Maximum RH in Day 2 forecast is more accurate in 2013-2017 but there is no significant difference in accuracy among days of forecast. Forecast accuracy of maximum RH in winter is significantly improved in recent years as percent correct is above 90 percent in 2015-2017

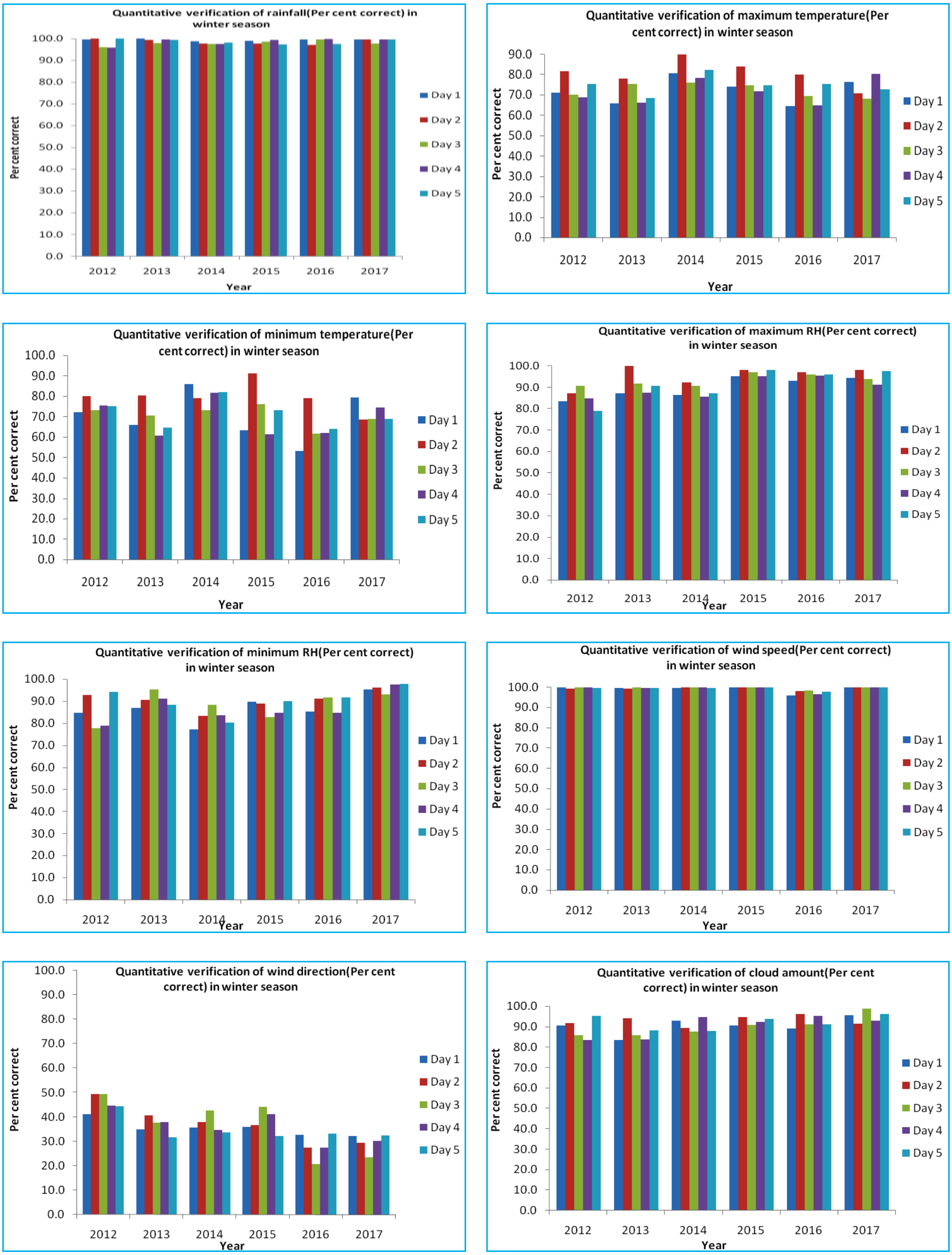


Fig. 5(a). Verification of forecast in winter season

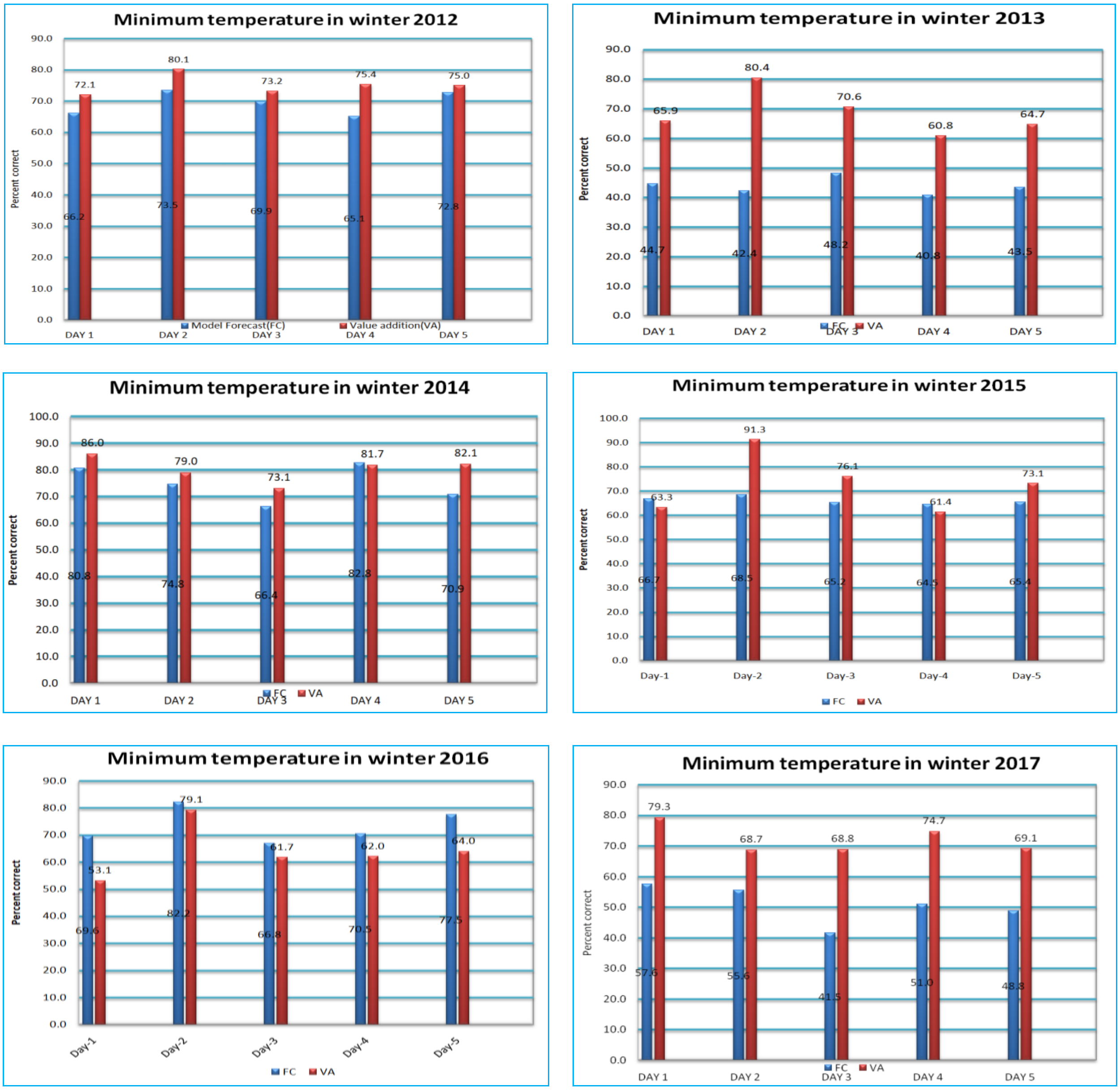


Fig. 5(b). Percent correct forecast of minimum temperature in model forecast and value addition

as compared to 85-91 percent in previous years (2012-2014). Sarmah *et al*. (2015) obtained 49-92 percent correct forecast in maximum RH in winter in Assam. Minimum RH in Day 1 forecast was more accurate in 2012 and Day 3 accuracy was more in 2013, 2014 and 2016. Highest mean accuracy of 96 percent was noticed in 2017 for forecast of minimum RH in winter season and forecast is consistent in years. The results are in agreement with Sarmah *et al*. (2015). Minimum accuracy of 83 percent is noticed in 2014. There is no difference in different days in accuracy of wind speed. Wind speed forecast was more than 96 percent correct in all the years and in all the days. Also, consistent accuracy is achieved over years. The results are in agreement with Chauhan *et al.* (2008). Wind direction in Day 3 forecast is more accurate in 2014 and 2015. Accuracy of wind direction forecast is 21-49 percent correct in all the years and days. During recent two years accuracy is decreased (28 percent in 2016 and 30 percent in 2017). Results are close with those obtained by Rana *et al*. (2013). Cloud forecast during winter season is improved during recent years (2014-17) as forecast is 91-95 percent correct during these years. Rana *et al*. (2013) obtained 46-69 percent correct cloud forecast in western Himalaya.

Fig. 6. Verification of forecast in summer season

Rainfall forecast in summer season is consistent in succeesive years and percent correct forecast is 94-100 (Fig. 6). Forecast accuracy of maximum temperature during summer season is 61-81 percent in different years and Day 2 and Day 3 forecasts are more accurate than other days. Forecast accuracy of minimum temperature in summer season is consistent in years as percent forecast correct range from 72-81 percent and Day 2 is more accurate. Forecast accuracy is 83-95 percent in maximum RH during summer season. Forecast accuracy is 84-98 percent correct in minimum RH during summer season. Forecast accuracy of wind speed in summer season is consistent in succussive years and percent correct is 97-100 percent. Wind direction forecast in summer season is 34-46 percent correct. Percent correct forecast of cloud cover in summer season is 88-94 percent.

There is no difference in days of rainfall forecast. The accuracy is in agreement with Chuahan *et al*. (2008). Maximum temperature in Day 2 forecast is more accurate in 2012, 2013, 2015 and 2016. Day 3 forecast is more accurate in 2014. Forecast of maximum temperature in summer season is consistent in succussive years as percent correct forcast range from 72-81 percent except in 2014 (61 percent). Chauhan *et al*. (2008) obtained 91 percent correct forecast of maximum temperature in summer in middle Gujarat. Minimum temperature in Day 2 forecast is more accurate in 2013-16. In 2017, Day 1 forecast is more accurate. Forecast accuracy of minimum temperature in summer season is consistent in years as percent forecast correct range from 72-81 percent. The results are in agreement with Chauhan *et al*. (2008).

Maximum RH in Day 2 forecast is more accurate in 2012-16 and Day 1 forecast is more accurate in 2017. Forecast accuracy is 83-95 percent in maximum RH during summer season and it is consistent over the years. Minimum RH in Day 1 forecast is more accurate during 2012 and 2013 and Day 2 forecast is more accurate in 2014 and 2015. Forecast accuracy is 84-98 percent correct in minimum RH during summer season. Sarmah *et al*. (2015) observed 60-86 percent usability in maximum RH and 46-76 percent usability in minimum RH forecast in summer in Assam.

There is no differences in days of forecast of wind speed in different years. Forecast accuracy of wind speed in summer season is consistent in succussive years and percent correct is 97-100 percent. The results are in agreement with Chauhan *et al*. (2008). Wind direction in Day 1 forecast is more accurate in 2013, 2014 and 2017. Wind direction forecast in summer season is 34-46 percent correct in different years and prediction is less accurate in 2014. Chauhan *et al*. (2008) obtained 64 percent correct forecast of wind direction in summer in middle Gujarat. Cloud cover in Day 3 forecast is more accurate in 2012, 2013, 2015, 2016 and 2017. Percent correct forecast of cloud cover in summer season is 88-94 percent in different years. Rana *et al*. (2013) obtained 61-75 percent correct forecast of cloud cover in summer season in western Himalaya.

4. (*i*) Qualitative verification of rainfall in Monsoon season is 71 percent correct and quantitative verification indicates 43 percent correct. So, betterment of model forecast in Monsoon rainfall is envisaged for greater accuracy in quantitative verification. Minimum temperature forecast is more than 60 percent correct and maximum temperature is more than 45 percent correct. RH and cloud cover forecast is correct by more than 70 percent. Forecast accuracy of wind speed is above 90 percent and wind direction is less than 70 percent correct.

(*ii*) Forecast accuracy in post-monsoon, winter and summer seasons are more than 70 percent correct except for wind direction.

(*iii*) Rainfall forecast in post-monsoon, winter and summer seasons is more than 90% and can be usable. Rainfall and maximum temperature forecast in Monsoon season and wind direction forecast in all the seasons has to be improved.

Authors are thankful to Director General of Meteorology for encouragement and providing facilities. The contents and views expressed in this letter are the views of the authors and do not necessarily reflect the views of the organizations they belong to.

References

Chattopadhyay, N., Roy Bhowmik, S. K., Singh, K. K., Ghosh, K. and Malathi, K., 2016, "Verification of district level weather forecast", *Mausam*, **67**, 829-840.

Chaudhari, J. N., Zagade, M. V., Mahadkar, U. V. and Talathi, M. S., 2010, "Assessment of weather based Agromet advisories in high rainfall zone of Konkan in Maharashtra", *Agro meteorological services for farmers* (Vyas Pandey ed.), AAU, Anand, 172-177.

Chaudhary, J. L., 2011, "Challenges in District Level Weather Forecasting for Tribal Region of Chhattisgarh State", *Challenges and Opportunities in Agro meteorology*, Attri, S. D., Rathore L. S., Sivakumar, M. V. K., Dash, S. K., (eds), Springer, Berlin, Heidelberg, 257-262.

Chauhan, V. S., Chaudhari, G. B. and Pandey, V., 2008, "Medium range weather forecast verification for middle Gujarat region", *J. Agrometeorology,* **10**, 90-93.

Lunagaria, M. M., Mishra, S. K. and Pandey, V., 2009, "Verification and usability of medium range weather forecast for Anand region", *J. Agrometeorol.*, **11**, 228-233.

Mandal, V., De, U. K. and Basu, B. K., 2007, "Precipitation Forecast Verification of the Indian Summer Monsoon with Intercomparison of Three Diverse Regions", *Weather and Forecasting*, **22**, 428-443.

Rana, R. S., Sood, R., Aditya, R. and Shekhar, J., 2013, “Validation of medium range weather forecasts in sub-temperate and sub-humid climate of western Himalayas”, *Indian J. Agrl. Sci.* **83**, 1357-1363.

Rathore, L. S., Roy Bhowmik, S. K. and Chattopadhayay, N., 2011, “Integrated Agro-advisory Services of India”, Challenges and opportunities of Agro-meteorology, 195-205 (Springer publication).

Roy Bhowmik, S. K. and Durai, V. R., 2012, “Development of multi-model ensemble based district level medium range rainfall forecast system for Indian region”, *J. Earth system Sci.*, **121**, 273-285.

Sahu, D. D., Chopada, M. C. and Kacha, H. L., 2011, “Verification of medium range rainfall forecast under south Saurashtra agro climatic zone, Gujarat”, *J. Agrometeorol*., **13**, 65-67.

Sarmah, K., Neog, P., Rajbongshi, R. and Sharma, A., 2015, “Verification and usability of medium range weather forecast for north bank plain zone of Assam, India”, *Mausam*, **66**, 585-594.

M. RAJAVEL,
PRAKASH KHARE,
M. L. SAHU* and
J. R. PRASAD**

Meteorological Centre, Raipur, India

**Meteorological Centre, Goa, India*

***Regional Meteorological Centre, Nagpur, India*

(*Received 3 May 2018, Accepted 10 April 2019*)

email: m_rajmet@yahoo.co.in