



Research Article

ANALYSIS OF WEATHER FORECAST OF INTERMEDIATE ZONE OF JAMMU REGION TO ISSUE BIWEEKLY AGROMET ADVISORY

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Abstract: The weather forecast and real time weather for Reasi district of J&K was compared to assess the validity and accuracy of weather forecast during 2018-19. The results indicated that highest value of correct forecast for rainfall (70.76 %), maximum temperature (52.33 %) & minimum temperature (52.33 %) was found in post monsoon season. The highest correct value of evening relative humidity (Min. RH) was also found in the post monsoon season (76.41%). The highest correct values of morning relative humidity (Max. RH) was found in the monsoon (79.84 %) season. The accuracy of weather forecast in advance is found to be useful for farmers for doing appropriate field operations and crop management practices.

Keywords: Weather forecast, Agro-advisory, CSI, H.K. Score, HSS score, Forecast validation

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Introduction

Weather forecast can help the farmer community to increase agriculture production, reduce losses, risks, reduce costs of inputs, improve quality of yield, increase efficiency in the use of water, labor and energy and reduce pollution with judicious use of agricultural chemicals. Weather forecast based Agro advisory is implemented through five tier structure to set up different components of the service spectrum. It includes meteorological (observed & forecasted weather), agricultural (prepare weather forecast based agricultural operations), extension (two-way communication with user) and information dissemination (Mass Media, Information Technology, Telecom) agencies. In India, the numerical weather prediction models have made big improvement in the development of weather forecast reliability and accuracy [1]. The Agro Advisory Bulletins are issued twice a week i.e. Tuesday and Friday. District level weather forecast generated under this service is the useful to the user community. User community based on these forecasts and its use in agromet advisory services could save losses / damages of the crops. Agromet Advisory services for agriculture that is, the provision of accurate and locally-appropriate climate and weather information play a vital building block for increasing the resilience of communities to climate change, diseases, and disasters [2]. This indeed has a potential to change the face of India in terms of food security and poverty alleviation [3]

Materials and Method

Medium range forecast is issued by India Meteorological Department, New Delhi issued and value added by Meteorological Centre, Srinagar on various weather parameters viz., amount of rainfall, cloud cover, maximum and minimum temperature, wind speed and direction for Reasi district. The observed meteorological data of Reasi was compared to value added forecast to assess the validity of weather forecasts for the months of March 2018 to February, 2019. For the analysis of the verification of the forecast data, the year was divided into four groups on seasonal basis viz., pre, (March-May), monsoon (June-September),

Post monsoon (October- December), winter (January-February). Different verification methods were used to assess the reliability of forecast values of weather parameters. The forecast of rainfall, cloud cover, temperature, wind speed and direction have been verified by calculating the error structure. Different scores such as threat score, H.S. score, true skill score and ratio score were calculated to test the weather forecast for rainfall during 2018-19. Similar methods were used by [4]

During 2018-19 based on forecasts of 365 days, crop weather bulletins were prepared and issued on each Tuesday (53) and Friday (52) by Agromet field Unit-Chatha, Jammu for the benefit of farmers of Reasi district. Total of 105 bulletins were prepared. Verification with observed and forecast value of Reasi district was analyzed. Verification of forecast was done on day basis i.e first day, second day, third day, fourth day and Fifth day.

Table-1 Day of Issue of Forecast/agromet advisory

Day of Issue of Forecast / agroadvisory	1 st Day	2 nd Day	3 rd Day	4 th Day	5 th Day
Tuesday	Tuesday	Wednesday	Thursday	Friday	Saturday
Friday	Friday	Saturday	Sunday	Monday	Tuesday

The validation methods as suggested by [5] were used.

Error structure

Rainfall: Correct $\pm 10\%$, Usable $\pm 20\%$,

Temperature: Correct $\pm 1^\circ\text{C}$, Usable $\pm 2^\circ\text{C}$

Relative humidity Correct $\pm 10\%$, Usable $\pm 20\%$,

Cloud cover: Correct $\pm 10\text{kt}$, Usable $\pm 20\text{kt}$

Wind speed: Correct $\pm 3\text{ kmph}$, Usable $\pm 6\text{ kmph}$

Wind direction: Correct $\pm 10^\circ$, Usable $\pm 30^\circ$

The rainfall data has been compared by using the following statistical tools:

Table-2 The following 2*2 contingency Table is used for calculation of the various skill scores and verification of the rainfall forecast [6, 7].

Event forecasted	Event observed		
	Yes	No	Marginal total
Yes	H(YY)	F(NY)	YY+NY (H+F)
No	M(YN)	Z(NN)	YN+NN (M+Z)
Marginal total	YY+YN (H+M)	NY+NN (F+Z)	N(YY+NY+YN+NN) N(H+F+M+Z)

Y= Yes and N= No

First letter in the pair is observed rainfall while the second depicts the predicted rainfall.

YY (H) = No. of hits (Rainfall has been observed as well as forecasted)

NY (F) = No. of false alarms (Rainfall has been predicted but not observed)

YN (M) = No. of misses (Rainfall has been observed but not predicted)

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

Total no. of cases is given by N and this also represents the number of days for which the forecast is given.

The contingency Table is a useful way to see what types of errors are being made.

Threat Score or Critical Success Index (CSI)

Threat score (TS) measured the fraction of observed and / or forecast events that were correctly predicted. Threat score was calculated using the following formula:

$TS = \text{hits} / (\text{hits} + \text{misses} + \text{false alarms})$

where Hits means forecast for rainfall was yes and it was observed, miss means no forecast for rainfall but it was observed, false alarm means forecast for rainfall was yes but it was not observed and correct negative means no forecast for rainfall and it was not observed.

The value of threat score ranges between 0 to 1, 0 indicates least accuracy of forecast, and 1 indicate perfect forecast. It explains about how well did the forecast yes event correspond to observed yes events[8].

Heidke Skill Score (H.S. Score)

Heidke skill score (H.S. Score) measured the fraction of correct forecasts after eliminating those forecasts which would be correct due purely to random chance. Its value ranges between minus infinity to 1, 0 indicates no skill and 1 indicates perfect score. The H.S. score was calculated as follows:

$H.S. \text{ Score} = \{(\text{hits} + \text{correct negative}) - (\text{expected correct}) \text{ random}\} / \{N - (\text{expected correct}) \text{ random}\}$

(Expected correct) random = $\{(\text{hits} + \text{misses}) (\text{hits} + \text{false alarms}) + (\text{correct negative} + \text{misses})$

$(\text{correct negative} + \text{false alarms}) / N$ (This is formula and it cannot be changed)

H. S. score explain the accuracy of the forecast relative to that of random chance.

Hanssen and Kuipers (True skill score)

Hanssen and Kuipers (True skill score) was calculated as follows:

$HK \text{ score} = \{ \text{hits} / (\text{hits} + \text{misses}) \} - \{ \text{false alarms} / (\text{false alarms} + \text{correct negatives}) \}$

The value of HK score ranges between -1 to 1, 0 indicates no skill and 1 indicate perfect score.

It explains how well did the forecast separate the yes event from the no event

Forecast accuracy (ACC) or Ratio Score

Ratio score was calculated as follows:

$\text{Ratio score} = (\text{hits} + \text{correct negative}) / N$

Where N is total number of forecast

It ranges between 0 to 1, 0 indicates no skill and 1 indicate perfect score. Sometimes, this score is multiplied by 100% and it is referred to as the percent correct, or the percentage of forecast correct (PFC).

It explains fraction of the total forecast events when the categorical forecast correctly predicted event and non-event.

The root means square error (RMSE)

The root means square error (RMSE) was calculated using the following formula:

$RMSE = \sqrt{1/N \sum (F_i - O_i)^2}$

where,

N = Sample size/ no. of observations

F_i = Forecasted value

O_i = Observed value

The RMSE values indicate the degree of error in the forecast. The lower values of RMSE indicate less difference between observed and forecasted value.

Results and Discussion

Forecast verification serves the role of identifying the accuracy of forecasts, with the goal of improving future predictions and also emphasizes accuracy and skill of prediction. Verification with observed and quantitative forecast for 4 weather parameters viz., rainfall, maximum and minimum temperatures, and relative humidity for Reasi District was analyzed.

Usability analysis of the forecasted weather parameters in relation to observed ones using critical values was carried out. The season-wise analysis (Correct percentage) is given in [Table-3-7]. Following results were obtained

Table-3 Correct percentage of rainfall forecast for Reasi during 2018-19

Day	Monsoon	Post monsoon	Pre monsoon	Winter
Day 1	31.43	65.38	51.85	35.29
Day 2	82.35	65.38	62.96	35.29
Day 3	37.14	76.92	65.38	41.18
Day 4	33.33	73.08	65.38	38.89
Day 5	34.29	73.08	57.69	44.44
Mean	43.70	70.76	60.65	39.01

Correct values for rainfall in [Table-3] expresses accuracy ranged from 31.43-65.38 percent, 35.29-82.35 percent, 37.14-76.92 percent, 33.33-73.08 percent and 34.29-73.08 percent for first, second, third, fourth and fifth day respectively for four seasons viz. monsoon, post monsoon, pre monsoon and winter. The correct forecast for rainfall was found to be maximum (70.76 %) in post monsoon season followed by pre monsoon season (60.65 %), monsoon season (43.70 %) and winter season (39.01 %).

Table-4 Correct percentage of Maximum Temperature forecast during 2018-19

Day	Monsoon	Post Mon.	Pre-Mon.	Winter
Day 1	66.67	69.23	59.26	52.94
Day 2	37.5	44.44	46.15	17.65
Day 3	34.38	46.15	42.31	23.53
Day 4	54.29	50	57.69	38.89
Day 5	64.79	51.85	48	50
Mean	51.52	52.33	50.68	36.60

Error structure (correct) for maximum temperature in [Table-4] expresses accuracy ranged from 52.94-69.23 percent, 17.65-46.15 percent, 23.53-46.15 percent, 38.89-57.69 percent and 48.0-64.79 percent for first, second, third, fourth and fifth day respectively for four seasons viz. monsoon, post monsoon, pre monsoon and winter. The correct maximum temperature values were found to be highest in the post monsoon season (52.33 %) followed by monsoon season (51.52 %), pre monsoon season (50.68 %) and winter season (36.60 %).

Table-5 Correct percentage of Minimum Temperature forecast for Reasi during 2018-19

Day	Monsoon	Post Mon.	Pre-Mon.	Winter
Day 1	81.82	80.77	70.37	76.47
Day 2	43.75	62.96	46.15	35.29
Day 3	40.00	65.38	42.31	47.06
Day 4	57.14	65.38	50.00	55.56
Day 5	73.53	91.30	56.00	66.67
Mean	59.248	73.158	52.966	56.21

Correct values for minimum temperature in [Table-5] expresses accuracy ranged from 70.37-81.82 percent, 35.29-62.96 percent, 40.0-65.38 percent, 50.0-65.38 percent and 56.0-91.30percent for first, second, third, fourth and fifth day respectively for four seasons viz. monsoon, post monsoon, pre monsoon and winter.

The correct minimum temperature values were found to be highest in the post monsoon season (52.33 %) followed by monsoon season (51.52 %), pre monsoon season (50.68 %) and winter season (36.60 %).

Table-6 *Correct percentage of Minimum Relative Humidity forecast for Reasi during 2018-19*

Day	Monsoon	Post Mon.	Pre-Mon.	Winter
Day 1	63.34	80.77	62.96	70.59
Day 2	65.63	81.48	53.85	82.35
Day 3	59.38	76.92	65.38	58.82
Day 4	68.57	61.44	69.23	61.11
Day 5	68.57	81.48	61.57	72.22
Mean	65.09	76.41	62.59	69.01

Error structure (correct) for Minimum Relative Humidity in [Table-6] expresses accuracy ranged from 62.96-80.77 percent, 53.85-82.35 percent, 58.82-76.92 percent, 61.11-68.57 percent and 61.57-81.48 percent for first, second, third, fourth and fifth day respectively for four seasons viz. monsoon, post monsoon, pre monsoon and winter. The highest correct value of evening relative humidity (Min. RH) was found in the post monsoon season (76.41%) followed by winter season (69.01 %), monsoon (65.09 %) and pre monsoon season (62.59 %).

Table-7 *Correct percentage of Maximum Relative Humidity forecast for Reasi during 2018-19*

Day	Monsoon	Post- Mon	Pre-Mon	Winter
Day 1	87.88	80.77	77.78	76.47
Day 2	78.93	74.07	46.15	29.29
Day 3	78.13	80.77	53.85	82.35
Day 4	68.57	65.38	61.54	61.11
Day 5	85.71	66.67	65.38	72.22
Mean	79.84	73.53	60.94	64.28

Error structure (correct) for Maximum Relative Humidity in [Table-7] expresses accuracy ranged from 76.47-87.88 percent, 29.29-78.93 percent, 53.88-82.35 percent, 61.11-68.57 percent and 65.38-85.71 percent for first, second, third, fourth and fifth day respectively for four seasons viz. monsoon, post monsoon, pre monsoon and winter. The maximum correct values of morning relative humidity (Max. RH) were found in the monsoon season (79.84 %) followed by post monsoon season (73.53 %). In the winter & pre monsoon season the correct values were 64.28 and 60.94 percent, respectively.

To verify the forecast, 2 X 2 contingency Table-[Table-2] between forecasted daily and observed rainfall events was made and based upon this Table-, different scores for evaluating the skill rainfall forecast were worked out.

Validation of rainfall forecast over different seasons revealed following facts:

Table-8 *Threat Score/CSI for 2018-19*

Day	Monsoon	Post- Mon	Pre-Mon	Winter
Day 1	0.76	0.33	0.38	0.45
Day 2	0.37	0.37	0.56	0.27
Day 3	0.6	0.17	0.36	0.5
Day 4	0.65	0.29	0.33	0.36
Day 5	0.67	0.43	0.45	0.6
Mean	0.61	0.32	0.42	0.44

It is a measure of relative forecasting accuracy (e.g. rain or no rain). It varies from 0 to 1 with 1 indicating perfect forecast and it is the ratio of the number of hits (correct event forecast) to the number of events which occurred plus the number or false alarms (incorrect event forecasts). Threat score value was higher during monsoon season (0.61) followed by winter(0.44) and pre monsoon, pre monsoon season(0.42) and minimum in post monsoon season (0.32) indicating that observed rainfall during monsoon was nearer to the predicted compared to other seasons. Similar observations were also reported by [9].

Table-9 *Ratio Score during 2018-19*

Day	Monsoon	Post- Mon	Pre-Mon	Winter
Day 1	82.86	76.92	70.37	64.71
Day 2	64.71	76.92	84.62	52.94
Day 3	71.43	80.77	73.08	70.59
Day 4	75.76	80.77	76.92	61.11
Day 5	75.29	84.62	76.92	72.22
Mean	74.01	80.0	76.38	64.31

[Table-9] shows the efficiency of rainfall forecast as measured by Ratio score ranged from 64.71 percent to 82.86 percent for first day, 52.94 to 84.62 percent for second day, 70.59 to 80.77 percent for third day, 61.11 to 80.77 percent for fourth day and 72.22 to 84.62 percent for fifth day. The efficiency of rainfall was good for day all 5 days. Results indicate that the performance of ensemble multi model under Reasi region to be better in all the seasons. Similar observations were also reported by [10].

Table-10 *RMSE during 2018-19*

Day	Monsoon	Post- Mon	Pre-Mon	Winter
Day 1	18.2	4.55	5.46	11.72
Day 2	12.7	4.55	4.32	0.41
Day 3	23.72	4.06	13.11	13.26
Day 4	27.37	3.31	4.11	13.05
Day 5	17.94	5.16	4.12	4.15
Mean	19.99	4.33	6.22	8.52

RMSE calculated for all the five days during pre-monsoon, post monsoon and winters seasons was less than 5 indicating forecast value in agreement with observed value. RMSE ranged from 4.55 to 18.2, 0.41 to 12.7, 4.06 to 23.72, 3.31 to 27.37 and 4.12 to 17.94 for I, II, III, IV and V day respectively [Table-10]. Rainfall forecast performance was very good with low RMSE during all the 5 days in all the seasons. Similar results were obtained by [4].

Table-11 *Hanssen and Kuipers (True skill score) during 2018-19*

Day	Monsoon	Post- Mon	Pre-Mon	Winter
Day 1	0.62	0.52	0.01	0.29
Day 2	0.22	0.52	0.61	0.10
Day 3	0.42	0.20	0.36	0.41
Day 4	0.56	0.49	0.41	0.20
Day 5	0.23	0.83	0.58	0.44
Mean	0.41	0.51	0.39	0.29

It is defined as the ratio of economic saving over climatology due to the forecast to that of a set of perfect forecasts, it ranges between -1 to +1 with 0 indicating no skill. The HK score [Table-11] was recorded almost ≥ 0.50 during 5 days in all the seasons which denote the forecast for rainfall is almost perfect during the year 2018-19. The positive HK scores indicated the reliability of forecast to be satisfactory in all the seasons. Similar observations were also reported by [11].

Table-12 *Heidke Skill Score (H.S. Score) during 2018-19*

Day	Monsoon	Post- Mon	Pre-Mon	Winter
Day 1	0.64	0.37	0.35	0.29
Day 2	0.23	0.37	0.61	0.08
Day 3	0.42	0.18	0.33	0.41
Day 4	0.53	0.34	0.36	0.2
Day 5	0.44	0.52	0.47	0.43
Mean	0.45	0.36	0.42	0.28

It accounts for all correct forecast (events and non-events) that would be made due to chance. It varies from -1 to +1 with 0 indicating no skill compared with random or chance forecast. The average HSS score value represented to the trend of HK score. [Table-12] shows the value of HS skill score ranged from 0.29 to 0.64, 0.08 to 0.61, 0.18 to 0.42, 0.2 to 0.53, 0.43 to 0.52 for I, II, III, IV and V day respectively indicating correctness of forecast. Similar observations were reported by [12].

Table-13 *Correlation Coefficients between observed and forecasted values for rainfall during different seasons during 2018-19*

Day	Monsoon	Post- Mon	Pre-Mon	Winter
Day 1	0.6	0.15	0.49	-0.11
Day 2	0.46	0.15	0.42	-0.11
Day 3	0.24	0.0	-0.01	0.63
Day 4	0.69	0.69	0.76	0.13
Day 5	0.51	0.61	0.44	0.21
Mean	0.50	0.32	0.42	0.15

Correlation coefficients were derived between the forecasted and observed values during 2018-19 for different seasons [Table-13].

It was observed that the forecast and observed values were better for all 5 days in monsoon, post monsoon & pre monsoon season as compared to winters season. Rainfall was highly correlated during monsoon followed by pre monsoon season, post monsoon and winter season. Similar observations were reported by [8].

Conclusion

In Conclusion, the performance of multi model (ENSEMBLE) for Reasi district of Jammu and Kashmir has been found to be quite accurate in all the seasons based on the various tools used in this study. The higher accuracy of rainfall prediction was noticed for all 5 days during all seasons. The medium range weather forecasts with rainfall as one of the most important parameters were used for preparing agromet advisory bulletins for the farmers of study area which were very useful for scheduling of sowing, irrigation, agricultural operations and management of pest and diseases of field crops.

Application of research: As weather forecast is in agreement with observed weather, user community based on these forecasts and its use in agromet advisory services could save losses / damages of the crops. The farmers feel it to be useful since they receive weather-based advices on appropriate field operations and management.

Research Category: Agrometeorology

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Author statement: All authors read, reviewed, agreed and approved the final manuscript. Note-All authors agreed that- Written informed consent was obtained from all participants prior to publish / enrolment

Study area / Sample Collection: Reasi district of Jammu Region

Cultivar / Variety / Breed name: Nil

Conflict of Interest: None declared

Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors.
Ethical Committee Approval Number: Nil

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