MAUSAM, **63**, 4 (October 2012), 543-552

551.509.33

Verification and usability of location specific medium range weather forecast for Kullu valley

MOHAN SINGH and S. S. BHARDWAJ

Dr. Y. S. Parmar University of Horticulture & Forestry,

Bajaura, Kullu -175 125 (H. P.) India

(*Received 23 March 2011, Modified 11 October 2011*)

e mail : jangra_ms@live.com

सार – कृषि के क्षेत्र में मौसम की अहम भूमिका रहती है। वर्षण, तापमान, आर्दता, पवन की गति और दिशा, शुष्कन स्थितियाँ, शुष्क तथा आर्द्रता का दौर सबसे महत्वपूर्ण मौसम घटक सूचनाएँ हैं जो कृषि योजना और प्रचालन में अहम भूमिका निभा सकते है। सूखा और बाढ़, शीत और उष्ण लहर, ओले, झंझावात, उष्ण कटिबंधीय तूफान जैसी प्रतिकूल मौसम घटनाएँ उत्पादन को भीषण रूप से प्रभावित करती है। मौसम की अनियंत्रित घटनाएँ मानव के नियंत्रण से बहार है। इनके विनाशकारी प्रभाव को कुछ हद तक अनुकूल अथवा कम किया जा सकता है यदि घटना का पूर्वानुमान समय से पहले कर लिया जाए और कृषकों को सुधार के उपाय करने की उचित सलाह दी जाए। एन. सी. एम. आर. डब्ल्यू. एफ./आई. एम. डी. से प्रत्येक मंगलवार और शुक्रवार को प्राप्त होने वाले मौसम पूर्वानुमानों की जाँच करने के प्रयास किए गए। वर्ष 2000–2001 से 2009–2010 के दौरान विभिन्न जाँच तकनीकों जैसे – रेडियो स्कोर (आर. एस.), क्रिटिकल सक्सेस इंडेक्स (सी. एस. आई.), हेड़के स्किल स्कोर (एच. एस. एस), हानसेन एण्ड कुइपर्स स्कोर (एच. के.) रूट मीन स्केयर एरर (आर. एम. एस. ई.), उपयोगिता विश्लेषण तथा सह संबंध अभिगम का उपयोग करके साप्ताहिक, मौसमी और वार्षिक आधार पर जाँच विश्लेषण किया गया। विश्लेषण से यह पता चलता है कि 2005–2006 के दौरान वार्षिक आधार पर रेशियों स्कोर सबसे अधिक (74.6) रहा तथा उसके बाद 2004–2005 (72.9) और 2003–2004 (72.7) में रहा। एच. के. स्कोर का मान 24 और 42 के बीच रहा। पूर्वानुमान अधिकांश प्राचलों के लिए उपयोगिता रेंज के भीतर पाया गया परंतु सुधार की अभी भी गुंजाइश है। सहसंबंध विश्लेषण से पता चला है कि पिछले वर्षों में प्रेक्षित और पूर्वानुमानित मानों के बीच उच्च सहसंबंध रहा। अतः विभिन्न उपभोक्ता समूहों के बीच पूर्वानुमान व्यापक रूप से उपयुक्त रहा।

ABSTRACT. Weather plays a crucial role in agriculture. Precipitation, temperature, humidity, wind speed and direction, drying conditions, dry and wet spells are the most important weather elements information about whom could play a significant role in farm planning and operations. Inclement weather events like drought and floods, cold and heat waves, hails, squalls, tropical storms severely affect the production. Occurrences of erratic weather are beyond human control. It is possible to adapt or mitigate their malevolent effect to some extend if the occurrence of the events is predicted well in advance and farmers are suitably advised to take ameliorative measures. Attempts were made to verify the weather forecasts received on every Tuesday and Friday from NCMRWF/IMD. The verification analysis was carried out on weekly, seasonal and annual basis using various verification techniques, *viz*., Ratio Score (RS), Critical Success Index (CSI), Heidke Skill Score (HSS), Hanssen and Kuipers Score (HK), Root Mean Square Error (RMSE), usability analysis and correlation approach during 2000-01 to 2009-10. The analysis depicted that ratio score on yearly basis was highest (74.6) during 2005-06 followed by 2004-05 (72.9) and 2003-04 (72.7). The value of H.K. score ranged between 24 and 42. The forecast found within quite usability range for most of the parameters but improvements are still possible. The correlation analysis showed that there was high correlation between observed and predicted values over the years. Hence, the forecast was found widely applicable among different user groups.

Key words – Location specific, Medium range weather forecast, Prediction scores, Verification, Usability.

1. Introduction

Indian farmers are still dependent on seasonal rains and other weather parameters which are highly variable both in time and space. Weather is an important factor determining the agricultural crop growth and productivity. The vagaries of weather encountered during crop season often create crisis in food production. Meanwhile, weather modification is not feasible. But day-to-day farm operations can be re-oriented according to three to ten day weather forecasts to sustain the crop production. The utility of weather forecast further depends upon the

accuracy and applicability at micro levels. 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). The meteorological service in India in co- ordination with the state agricultural department and state agricultural universities has formulated a scheme called agromet advisory scheme (De, 1997). An agriculture relevant forecast is not only useful for efficient management of farm inputs but also leads to precise impact assessment (Gadgil, 1989), also an aberrant or unfavourable weather events such as drought, flood, cold waves and heat waves, etc. cause a great reduction in production. The accurate weather forecast based agromet advisories 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.

Verification is the assessment and quantification of the relation between a matched set of forecasts and observations. It is important to note that no single verification measure provides complete information about the accuracy, quality and reliability of the forecast. Hence, it is desirable to include as many as scores/indices as possible in any summary of forecast verification.

2. Material and methods

The study was conducted at agromet field unit (AMFU), Seobag (32° N, 77° E and 1350 m amsl) for the period 2001-2010. The area has sub temperate to temperate climate and falls in the Kullu valley located in the transition zone between the greater Himalaya (Rohtang) to the north and the lesser Himalaya (Hansu) to the south is a wide and open along the main course of the Beas River. Agriculture has been the dominant economic and land use activity in the region for centuries, at times employing ~90% of the population (Singh, 1992). The increased transportation capacity from 1950 (construction of National Highway 21) led to a shift from subsistence crop agriculture to commercial horticultural orchards.

It is very important to make people aware about the inclement weather and climate through participatory approach. Starting of agromet advisory services is one of the right steps in this direction. The location specific medium range weather forecast was received regularly at AMFU from NCMRWF, Noida and recently forecast is received from IMD, Pune on every Tuesday and Friday. Verification is the assessment and quantification of the relation between a matched set of forecasts and observations. Forecast verification was carried out into four seasons as per standard of IMD, *i.e*., summer season (March-May), monsoon season (June-September), post-monsoon season (October-November) and winter season (December-February). Forecasted daily weather parameters, *viz*., rainfall, cloud cover, wind speed, wind direction, maximum and minimum temperature were verified against actual weather parameters recorded at agro meteorological observatory located at AMFU, Seobag. The usability/correctness was verified for all of forecasted weather parameters. The various skill scores like ratio score (RS), critical success index (CSI), Heidke skill score (HSS) and Hanssen & Kuipers Score (HK) were calculated for rainfall prediction. Verification of weather prediction and feedback from the end users are giving very encouraging results. The contingency table approach offer a simple and easily understandable picture of forecast success and failure, which can serve as the starting point for examination of the strengths and weaknesses of the forecasts (Murphy and Winkler, 1987; Murphy *et al*., 1989). But no single verification measure provides complete information about the accuracy, quality and reliability of the forecast. Hence, it is desirable to include as many scores/indices as possible in any summery of forecast verification. Similar methods were used by few researchers (Tripathi and Mishra, 2000; Rana *et al*., 2005; Mishra, 2006; Chauhan *et al*., 2008; Rao, 2008; Dakhore *et al*., 2008; Tripathi *et al*., 2008; Lunagaria *et al*., 2009). Making use of all the above mentioned indices/scores and relationships the accuracy, reliability and skills of the weather forecast from 2000-01 to 2009-10 were analyzed on seasonal and annual basis and verified with the observed parameters for the Kullu valley of Himachal Pradesh. The results are very encouraging and people wants the services must continue with wider circulation and publicity for the economic benefit of the farming communities (Prasad Rao and Manikandan, 2008; Singh *et al*., 2008; Gill *et al*., 2010).

The accuracy of rain/no-rain is given by ratio score (RS), which measures the proportion of correct forecasts out of all forecasts (Woodcock, 1976). It varies from 0 to 1 with 1 indicating perfect forecast. Hanssen & Kuipers score (HK) is the ratio of economic saving over climatology due to forecaster to that of a hypothetical set of perfect forecasts (Woodcock, 1981) and varies from -1 to +1 with 0 indicating no skill. Heidke skill score (HSS) expresses as decimal fraction the percentage of forecasts that are correct and varies from 1 to minus infinity. Critical success index (CSI) of an event is a measurement of relative forecasting accuracy in a category (Schaefer, 1990) and varies from 0 to 1 with 1 indicating perfect forecast. The root mean square error (RMSE) as all six major weather parameters was worked out for the absolute error between observed and forecasted weather data. The critical values of error structures given by Rathore *et al.,* (1999) were followed to

TABLE 1

Skill scores of rainfall forecast for Kullu valley (2000-01 to 2009-10)

Period	R. Score	CSI	HSS	HK	RMSE
		Pre-monsoon (March-May)			
2000-01	78.4	0.24	0.32	0.58	6.66
2001-02	48.6	0.14	-0.09	-0.11	7.45
2002-03	77.4	0.25	0.30	0.57	6.66
2003-04	75.0	0.36	0.39	0.34	7.82
2004-05	80.0	0.47	0.49	0.49	8.26
2005-06	65.1	0.33	0.45	0.21	6.35
2006-07	71.1	0.35	0.33	0.31	1.41
2007-08	73.6	0.29	0.27	0.14	11.1
2008-09	52.2	0.35	0.26	0.23	8.31
2009-10	49.1	0.29	0.17	0.13	13.2
Mean	**67.05**	**0.31**	**0.29**	**0.29**	**7.72**
		Monsoon (June-September)			
2000-01	62.3	0.25	0.65	0.75	9.32
2001-02	71.0	0.48	0.05	0.58	8.84
2002-03	66.2	0.34	0.28	0.35	7.77
2003-04	63.2	0.42	0.26	0.26	6.35
2004-05	61.0	0.24	0.11	0.11	2.65
2005-06	72.3	0.40	0.93	0.41	4.35
2006-07	66.9	0.42	0.32	0.34	1.82
2007-08	50.0	0.33	0.11	0.12	12.2
2008-09	73.8	0.11	0.22	0.33	5.71
2009-10	86.7	0.47	0.46	0.46	3.90
Mean	**67.3**	**0.34**	**0.33**	**0.37**	**6.34**
		Post-monsoon (October-November)			
2000-01	62.3	0.65	0.55	0.48	5.35
2001-02	78.9	0.62	0.13	0.47	1.29
2002-03	83.9	0.16	0.21	0.33	2.35
2003-04	90.6	0.25	0.41	0.26	2.69
2004-05	84.4	0.28	0.36	0.29	1.85
2005-06	92.5	0.00	0.14	0.00	3.21
2006-07	83.3	0.33	0.36	0.27	0.61
2007-08	75.0	0.31	0.54	0.28	0.91
2008-09	57.3	0.35	0.36	0.29	8.24
2009-10	73.7	0.40	0.38	0.68	6.80
Mean	**78.2**	**0.33**	**0.34**	**0.34**	**3.33**
		Winter (December-February)			
2000-01	71.2	0.65	0.52	0.46	6.35
2001-02	78.7	0.44	0.23	0.58	4.67
2002-03	65.0	0.26	0.19	0.31	3.68
2003-04	73.6	0.41	0.43	0.38	5.64
2004-05	77.1	0.47	0.48	0.46	5.62
2005-06	71.2	0.31	0.74	0.54	3.24
2006-07	71.2	0.37	0.37	0.35	1.21
2007-08	68.7	0.35	0.34	0.32	11.7
2008-09	61.2	0.38	0.36	0.34	7.62
2009-10	60.8	0.32	0.26	0.27	6.72
Mean	**69.9**	**0.39**	**0.39**	**0.40**	**5.64**

consider success and failure cases for analysis. Considering the difficulties in forecasting the exact weather condition, due to difficulties in the observing system, spatial variability in the meteorological elements

and precision required for agro meteorological and other applications, numerical thresholds were used.

Observed	*Predicted*	
	Rain	No Rain
Rain	H (YY)	M (YN)
No Rain	F (NY)	Z (NN)

Where,

H = Predicted and observed
M = Observed but not predicted
F = Not predicted but observed
Z = Neither predicted nor observed
N = Total number of observation
fi = Predicted values
oi = Observed values

(*i*) Ratio Score (RS) = (H + Z)/(H+M+F+Z)
(*ii*) Critical Success Index (CSI) = (H)/(H+M+F)
(*iii*) Heidke Skill Score (HSS) = $(ZH-FM)^2/[(Z+M)(M+H)+(Z+F)(F+H)]$
(*iv*) Hanssen & Kuipers score (HK) = (HZ – MF)/[(Z+F)(H+M)]
(*v*) Root Mean Square Error (RMSE) = $\{1/N \sum(fi - oi)^2\}^{1/2}$

3. Results and discussion

3.1. *Rainfall*

The forecasted values of weather parameters with actual recorded weather parameters were verified for applicability/usability. The rainfall was verified with skill scores and RMSE and results are presented Table 1 and Fig. 1. The performance of rainfall was excellent in post-monsoon season as it was not rainy season for Kullu valley. The performance of rainfall forecast was at par in the remaining three seasons, *i.e*., Pre-monsoon, monsoon and winter seasons. The highest value (92.5%) of ratio score was calculated in post-monsoon season during 2005-06 (Table 1). The lowest value of ratio score (50.0%) was found in monsoon season during 2007-08. The HK score was found positive during all the seasons and years except negative only during 2001-02 in pre-monsoon season. The positive value of HK score in monsoon season and annual basis indicates that the reliability of forecasts is satisfactory. On annual basis the ratio score was highest (74.6%) during 2005-06, CSI was highest (55.2%) during 2005-06, HSS highest (41.6%) during 2003-04 and HK score was highest (42.5 %) during 2002-03. The scores are showing the decreasing trend from 2007-08 to 2009-10 onwards as compared to earlier years (Fig. 1).

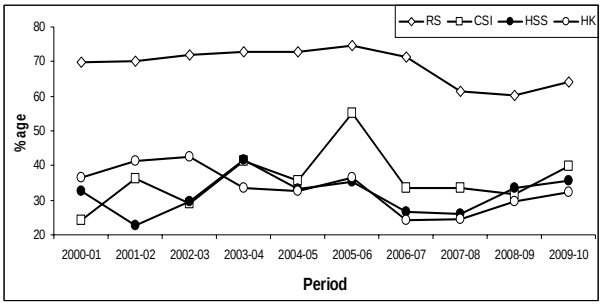

Fig 1. Trend in different skill scores in Kullu valley

The performance of cumulative weekly rainfall was excellent in post-monsoon, winter and pre-monsoon seasons. Its performance was poor for monsoon season and was found to improve. The more fluctuations (extreme events) in rainfall was observed during pre-monsoon season as the value of RMSE was higher and some time HS & HK scores were found negative during this season. The highest percent (96%) of correct rainfall was found in post monsoon season during 2000-01 and lowest (26.8%) in monsoon season during 2007-08 (Table 2). During last ten years the highest percentage of correct rainfall (65%) was observed during 2000-01 and 2006-07 but, higher percentage of unusable forecast was observed during 2007-08 & 2008-09, respectively. The Correlation Coefficient (CC) was found significant during 2000-01 and 2009-10 (Table 5).

3.2. *Cloud cover*

The realized categorical cloud cover correct forecasts varies from 22.7 % to 58.3 % in pre-monsoon season, 26.5 % to 58.9 % in monsoon season, 34.4% to 63.8 % in post monsoon season and 22.9 % to 58.9 % in winter season. On an average the correct percentage was higher in post monsoon season whereas it was at par in the remaining three seasons. The total usable forecast for cloud cover was 56-80 % in pre-monsoon season, 56-93% in monsoon, 64-98 % in post monsoon season and 54-84% in winter season (Table 2). On an average the cloud cover forecast was 78% usable in post monsoon season and 70% in other three seasons in Kullu valley. The annual correct forecast for cloud cover varies from 35-54 % and total usable forecast (correct + usable) varies from 62-86 % (Table 5). Annual basis the cloud cover forecast was 70 % usable (with CC = 0.49) per year.

3.3. *Temperature*

The correct and usability analysis of maximum and minimum temperature forecast was done using error structure and correlation regression. Forecast for

TABLE 2

Usability skill of rainfall and cloud cover for Kullu valley (2000-01 to 2009-10)

Period	Rainfall			Cloud cover (CC)		
	Correct	Usable	Unusable	Correct	Usable	Unusable
			Pre-monsoon (March-May)			
2000-01	60.9	14.7	24.4	46.7	34.2	19.1
2001-02	59.4	15.1	39.5	41.8	20.9	37.3
2002-03	73.1	00.0	26.9	56.7	20.7	22.6
2003-04	58.3	08.3	33.4	58.3	20.8	20.9
2004-05	67.5	17.5	15.0	41.5	21.9	36.6
2005-06	59.1	18.1	22.8	22.7	36.4	40.9
2006-07	67.5	19.3	13.2	36.1	19.3	44.6
2007-08	62.1	10.6	27.3	46.9	22.7	30.4
2008-09	36.7	22.2	41.1	52.2	17.8	30.0
2009-10	30.9	36.3	32.8	49.0	19.4	31.6
Mean	**57.6**	**16.2**	**26.2**	**45.2**	**23.4**	**31.4**
			Monsoon (June-September)			
2000-01	57.4	15.6	27.0	56.7	39.7	03.6
2001-02	47.5	08.5	44.0	26.5	29.4	44.1
2002-03	54.7	09.4	35.9	38.8	19.4	41.9
2003-04	41.7	23.6	34.7	43.1	20.8	36.1
2004-05	51.4	22.2	26.4	42.3	19.7	38.0
2005-06	59.3	10.9	29.8	45.3	32.8	21.9
2006-07	58.3	21.3	20.4	39.8	23.3	36.9
2007-08	26.8	07.1	66.1	58.9	12.5	28.6
2008-09	70.7	09.3	20.0	47.7	27.7	24.6
2009-10	77.3	16.0	06.7	56.0	18.7	25.3
Mean	**54.5**	**14.4**	**31.1**	**45.5**	**24.4**	**30.1**
			Post-monsoon (October-November)			
2000-01	96.0	00.0	04.0	57.8	39.6	2.6
2001-02	77.4	03.2	19.4	56.3	28.1	15.6
2002-03	81.3	00.0	18.7	60.0	15.0	25.0
2003-04	59.4	09.4	31.2	63.8	19.4	16.8
2004-05	75.0	12.5	12.5	34.4	40.6	25.0
2005-06	91.6	00.0	08.4	44.4	41.7	13.9
2006-07	76.2	16.7	07.1	59.5	19.0	21.5
2007-08	93.7	00.0	06.3	50.0	18.7	31.3
2008-09	48.0	13.3	38.7	42.7	21.3	36.0
2009-10	57.0	29.0	14.0	51.0	16.0	33.0
Mean	**75.6**	**08.4**	**16.0**	**52.0**	**25.9**	**22.1**
			Winter (December-February)			
2000-01	48.7	07.6	43.7	34.8	48.7	16.5
2001-02	64.6	12.5	22.9	50.0	23.9	26.2
2002-03	53.6	03.4	43.0	25.5	27.7	46.8
2003-04	57.7	17.3	25.0	58.9	17.9	23.2
2004-05	64.6	16.7	18.7	22.9	33.3	43.8
2005-06	58.3	06.3	35.4	52.1	22.9	25.0
2006-07	66.1	15.3	18.6	54.2	01.7	44.1
2007-08	48.3	08.3	43.4	48.3	21.7	30.0
2008-09	40.0	17.5	42.5	51.3	27.6	21.7
2009-10	47.5	32.5	20.0	51.7	15.0	33.3
Mean	**54.9**	**13.7**	**31.4**	**45.0**	**24.0**	**31.0**

TABLE 3

Usability skill of temperatures for Kullu valley (2000-01 to 2009-10)

Period	Maximum (*T*-max)			Minimum (*T*-min)		
	Correct	Usable	Unusable	Correct	Usable	Unusable
			Pre-monsoon (March-May)			
2000-01	47.5	35.3	17.2	47.5	23.9	28.6
2001-02	38.3	11.7	50.0	48.4	22.6	29.0
2002-03	46.2	09.6	44.2	47.3	10.9	41.8
2003-04	22.4	28.6	49.0	29.2	37.5	33.3
2004-05	52.5	25.0	22.5	45.0	32.5	22.5
2005-06	25.0	20.4	54.6	27.3	37.3	45.4
2006-07	49.4	15.7	34.9	48.2	19.3	32.5
2007-08	31.8	25.7	42.5	54.5	18.1	27.4
2008-09	38.9	32.2	28.9	50.0	18.9	31.1
2009-10	10.3	14.8	74.9	38.1	22.7	39.3
Mean	**36.2**	**21.9**	**41.9**	**43.6**	**24.4**	**32.0**
			Monsoon (June-September)			
2000-01	54.7	30.7	14.6	44.4	28.9	26.7
2001-02	53.3	20.0	26.7	38.3	25.0	36.7
2002-03	37.1	22.9	40.0	48.1	12.9	39.0
2003-04	30.6	19.4	50.0	45.1	19.7	35.2
2004-05	51.4	13.8	34.8	62.5	18.1	19.4
2005-06	59.4	17.2	23.4	51.6	25.0	23.4
2006-07	67.0	08.7	24.3	68.9	10.7	20.4
2007-08	53.6	23.2	23.2	53.6	19.6	26.8
2008-09	21.5	16.9	61.6	41.5	15.4	43.1
2009-10	12.0	17.3	70.7	38.7	26.7	34.6
Mean	**44.1**	**19.0**	**36.9**	**49.3**	**20.2**	**30.5**
			Post-monsoon (October-November)			
2000-01	55.8	35.6	05.6	56.8	43.2	00.0
2001-02	43.8	09.4	46.8	23.5	20.5	53.0
2002-03	66.7	23.3	10.0	41.4	41.4	17.2
2003-04	27.8	25.0	47.3	37.5	28.1	34.4
2004-05	46.8	15.6	37.6	65.6	15.6	18.8
2005-06	52.8	22.2	25.0	50.0	22.2	27.8
2006-07	76.2	19.0	04.8	66.7	16.7	16.6
2007-08	81.3	06.3	12.4	68.7	25.0	06.3
2008-09	36.0	18.7	45.3	44.0	21.3	34.7
2009-10	31.0	16.0	53.0	55.0	23.0	22.0
Mean	**51.8**	**19.1**	**29.1**	**50.9**	**25.7**	**23.4**
			Winter (December-February)			
2000-01	36.8	48.7	14.5	57.8	30.8	06.4
2001-02	25.0	11.4	63.6	47.5	22.5	30.0
2002-03	30.0	37.5	32.5	21.9	22.0	56.1
2003-04	38.5	26.9	34.6	42.8	25.0	32.2
2004-05	25.0	22.4	52.1	50.0	22.9	27.1
2005-06	45.8	10.4	43.8	43.7	14.6	41.7
2006-07	50.8	17.0	32.2	67.8	16.9	15.3
2007-08	36.7	21.7	41.6	38.4	21.6	40.0
2008-09	25.0	17.5	57.5	50.0	17.5	32.5
2009-10	20.8	25.8	53.4	04.6	04.2	88.2
Mean	**33.4**	**23.8**	**42.8**	**42.5**	**19.8**	**37.7**

TABLE 4

Usability skill of wind for Kullu valley (2000-01 to 2009-10)

Period	Wind speed (WS)			Wind direction (WD)		
	Correct	Usable	Unusable	Correct	Usable	Unusable
			Pre-monsoon (March-May)			
2000-01	46.7	34.2	19.1	28.6	29.8	41.6
2001-02	85.3	05.8	08.9	31.6	13.2	55.2
2002-03	94.3	05.7	00.0	27.8	22.2	50.0
2003-04	89.6	10.4	00.0	10.4	16.7	72.9
2004-05	75.0	20.0	05.0	37.5	15.0	47.5
2005-06	88.8	11.2	00.0	22.7	25.0	52.3
2006-07	80.7	12.0	07.3	14.5	22.9	62.6
2007-08	95.4	04.6	00.0	27.3	18.1	54.6
2008-09	58.9	20.0	21.1	33.3	25.6	41.1
2009-10	68.0	12.3	19.3	18.0	13.5	68.5
Mean	**78.3**	**13.6**	**08.1**	**25.2**	**20.2**	**54.6**
			Monsoon (June-September)			
2000-01	56.7	39.7	03.6	22.0	28.6	49.4
2001-02	67.2	18.0	14.8	16.7	41.7	41.6
2002-03	85.1	14.9	00.0	23.9	14.9	61.2
2003-04	73.3	17.3	09.4	20.2	20.2	59.6
2004-05	76.4	23.6	00.0	26.4	26.4	47.2
2005-06	90.6	09.4	00.0	25.0	23.4	51.6
2006-07	81.6	14.6	03.8	39.8	21.4	38.8
2007-08	100	00.0	00.0	30.4	19.6	50.0
2008-09	93.8	06.2	00.0	24.6	23.1	52.3
2009-10	100	00.0	00.0	22.6	22.7	54.7
Mean	**82.5**	**14.4**	**03.1**	**25.2**	**24.2**	**50.6**
			Post-monsoon (October-November)			
2000-01	57.8	39.6	02.6	25.3	21.1	53.6
2001-02	71.4	25.7	02.9	11.1	14.8	74.1
2002-03	100	00.0	00.0	32.3	25.8	41.9
2003-04	96.4	03.6	00.0	22.8	25.7	54.5
2004-05	90.6	09.4	00.0	28.1	25.5	46.4
2005-06	83.3	16.7	00.0	33.3	25.0	41.7
2006-07	90.5	09.5	00.0	11.9	09.5	78.6
2007-08	93.7	06.3	00.0	37.0	00.0	62.5
2008-09	68.2	25.2	06.6	22.7	28.0	49.3
2009-10	96.0	03.0	01.0	23.0	18.0	59.0
Mean	**84.8**	**13.9**	**01.3**	**24.7**	**19.3**	**56.0**
			Winter (December-February)			
2000-01	34.8	48.7	16.5	28.0	10.0	62.0
2001-02	83.7	13.9	02.4	05.1	22.5	72.5
2002-03	94.9	05.1	00.0	54.5	09.1	66.4
2003-04	80.8	11.5	07.7	32.1	21.4	46.5
2004-05	75.0	25.0	00.0	18.7	33.3	48.0
2005-06	83.3	16.7	00.0	22.9	35.4	41.7
2006-07	89.8	08.4	01.8	33.9	23.7	42.4
2007-08	88.3	11.7	00.0	30.0	21.7	48.3
2008-09	63.8	23.8	02.7	25.0	25.0	50.0
2009-10	100	00.0	00.0	33.3	19.2	47.5
Mean	**79.4**	**16.5**	**04.1**	**28.4**	**22.1**	**49.5**

TABLE 5

Annual usability skill of weather forecast for Kullu valley (2000-01 to 2009-10)

Period	Rainfall	CC	WS	WD	*T*-max	*T*-min
			Correct			
2000-01	65.3	48.3	79.5	19.6	56.3	54.8
2001-02	54.4	40.5	75.7	11.1	41.2	40.0
2002-03	64.2	42.5	92.0	30.3	42.7	40.8
2003-04	52.5	54.2	82.3	21.5	30.1	39.6
2004-05	61.9	35.9	78.1	27.0	44.3	56.3
2005-06	65.1	41.7	86.9	25.5	46.9	43.8
2006-07	65.2	44.6	84.3	27.2	60.0	62.4
2007-08	50.5	51.0	94.4	29.8	53.4	50.5
2008-09	47.4	48.7	71.1	26.8	30.9	46.8
2009-10	48.9	49.0	88.2	24.0	18.0	33.8
Mean	**57.5**	**45.6**	**83.3**	**24.3**	**42.4**	**46.9**
			Usable			
2000-01	06.3	37.1	08.4	31.4	39.1	30.9
2001-02	10.1	25.9	16.2	28.3	14.1	23.0
2002-03	03.7	21.8	08.0	16.9	22.4	19.0
2003-04	16.2	19.8	12.3	20.6	24.4	26.6
2004-05	18.2	27.1	20.8	25.5	18.7	21.9
2005-06	09.4	32.8	13.1	27.1	17.2	22.4
2006-07	18.8	17.1	11.8	20.6	13.9	15.3
2007-08	08.1	19.2	05.6	18.1	22.2	15.1
2008-09	16.1	23.2	01.0	25.5	21.9	18.4
2009-10	30.2	19.4	04.9	17.6	18.4	18.4
Mean	**13.7**	**24.3**	**10.2**	**23.2**	**21.2**	**21.1**
			Unusable			
2000-01	29.4	14.6	12.1	49.0	04.6	14.3
2001-02	35.5	33.6	08.1	60.6	44.7	37.0
2002-03	32.1	35.7	00.0	52.8	34.9	40.2
2003-04	31.3	26.0	05.4	57.9	45.5	33.8
2004-05	19.9	37.0	01.1	47.5	37.0	22.8
2005-06	25.5	25.5	00.0	47.4	35.9	33.8
2006-07	16.0	38.3	03.9	52.2	26.1	22.3
2007-08	41.4	29.8	00.0	52.1	24.4	34.4
2008-09	36.5	28.1	18.8	47.7	47.2	34.8
2009-10	20.9	31.6	06.9	58.4	63.6	47.8
Mean	**28.9**	**30.0**	**05.6**	**52.6**	**36.4**	**32.1**

CC – Correlation coefficient, WS – Wind speed, WD – Wind direction

maximum temperature was usable from 53 to 96 per cent in the region. The correct forecast was higher in post monsoon season (52%) followed by monsoon (44%) pre-monsoon and winter season. Similar trend was observed for the minimum temperature. The highest correct forecast (81%) was found in post monsoon during 2007-08 and lowest (10%) in pre-monsoon season during 2009-10. The highest (94.4%) usable forecast for maximum temperature was observed in post monsoon during 2000-01 and lowest (25%) usable in pre-monsoon during 2009-10. On an average the forecast for maximum temperature was 71 per cent in post monsoon season, 63 per cent in monsoon and 58 per cent in pre-monsoon & winter season (Table 3). Average annual correct forecast was 42 percent with 20.6 per cent of coefficient of variation but, the average annual of total usable forecast was 64 per cent (CC = 0.54) with the 19 per cent of coefficient of variation (Table 5). The RMSE value varies from 0.94 to 2.32 and CC varies from 0.39 to 0.78 among all the years which indicate that forecast was within the usable limits (Table 6).

Like maximum temperature similar results & trends were observed in minimum temperature also. Forecast for minimum temperature was usable from 54 to 86 per cent in the region. The correct forecast was higher in post monsoon season (51%) followed by monsoon (49%) pre-

TABLE 6

RMSE and Correlation Coefficient of weather forecast for Kullu valley (2000-01 to 2009-10)

Period	Rainfall	CC	WS	WD	*T*-max	*T*-min
			RMSE			
2000-01	8.9	3.1	2.6	155.5	4.6	3.2
2001-02	7.5	2.7	1.8	90.3	4.2	2.4
2002-03	7.6	2.6	1.8	101.3	3.1	2.3
2003-04	8.8	2.7	1.7	133.7	2.9	2.3
2004-05	9.7	2.7	1.7	115.9	2.6	2.5
2005-06	7.8	2.7	1.7	105.5	2.5	3.4
2006-07	7.6	0.2	0.2	99.7	3.1	0.2
2007-08	10.8	2.5	1.6	96.4	3.1	2.6
2008-09	7.6	2.5	7.4	156.6	3.9	2.6
2009-10	7.9	2.6	2.2	176.4	3.9	2.9
Mean	-	-	-	-	-	-
			Correlation Coefficient			
2000-01	0.65	0.56	0.75	0.33	0.78	0.93
2001-02	0.44	0.51	0.71	0.29	0.53	0.83
2002-03	0.39	0.49	0.85	0.11	0.44	0.67
2003-04	0.51	0.51	0.81	0.23	0.53	0.59
2004-05	0.45	0.39	0.79	0.19	0.59	0.48
2005-06	0.52	0.41	0.88	0.26	0.66	0.49
2006-07	0.43	0.52	0.81	0.21	0.59	0.38
2007-08	0.49	0.51	0.91	0.19	0.49	0.41
2008-09	0.55	0.48	0.71	0.39	0.44	0.43
2009-10	0.68	0.49	0.88	0.36	0.39	0.46
Mean	**0.51**	**0.49**	**0.81**	**0.76**	**0.54**	**0.56**

monsoon and winter season. Similar trend was observed for the minimum temperature. The highest correct forecast (68%) was found in post monsoon and monsoon during 2007-08 & 2006-07, respectively and lowest (4.6%) in winter season during 2009-10. The highest (100%) usable forecast for minimum temperature was observed in post monsoon during 2000-01 and lowest (12%) usable in winter season during 2009-10. On an average the forecast for minimum temperature was 77 per cent in post monsoon season, 70 per cent in monsoon and 68 per cent in pre-monsoon and 53 percent in winter season (Table 3). The average usability of minimum temperature forecast was 68 per cent (with CC = 0.56) but the value of CC varies from 0.38 to 0.93 among the years (Table 5).

3.4. *Wind speed and direction*

The wind speed as well as its direction plays very important roles in successful agricultural production. They affect the evapotranspiration process, lodging and spraying operations etc. Accurate and well in advance prediction of wind speed and direction can help farmers in deciding the different inter cultural operations. The error structure analysis of last years data showed that wind speed was most and wind direction was least accurately predicted among all six weather parameters for the Kullu valley. The correct forecast for wind speed was highest (84.8%) in post monsoon season followed by SW monsoon (82.5%) and winter & pre-post monsoon season (Table 4). Similarly the usability was highest (98.7 %) in post monsoon season and followed by the other three seasons. The correct percentage of wind speed for last ten years was 83.3% and the usability 95.4%, respectively with CC varies from 0.71 to 0.91 and with 29% of coefficient of variation.

The predominant wind direction forecasts were verified with the afternoon observations. The accuracy of wind direction forecast was showing somewhat but non-significant increasing trend with annual usability of 47.4 per cent having 12 per cent of coefficient of variation with CC value varies from 0.11 to 0.39 during the last ten years (Table 5). The correct forecast for wind direction was highest (28.4%) in winter season followed by other three seasons with 25% of correct forecast (Table 4). Similar trend was observed for the usability of the wind direction

forecast. The highest correct forecast for wind direction was observed only 54.5 per cent in winter during 2002-03 and lowest of 5.1 per cent in the same season during 2001-02.

4. Conclusions

The location specific medium range weather forecast verification procedure to diagnose the merits and limitations in formulation of subjective forecasts was described. Forecast verification serves many purposes, include assessing the state-of-art of medium range weather forecasting and providing users with information needed to make effective decision-making in their day-to-day farming activities. Utilizing the above formulations, performance of location specific weather forecasts in terms of quality, accuracy, reliability, usability and skill, during the last ten years are presented. The results indicate the variability in accuracy, reliability, usability and skill of weather parameters, up to five days. Forecasted wind speed was found to be most acutely comparable with observed during all the seasons and years. Rainfall forecast performance was good with low RMSE considering all seasons but in monsoon season its performance was not so good. The scores are showing decreasing trend from 2007-08 to 2009-10 onwards as compared to earlier years. Cumulative weekly rainfall forecast performance was satisfactory, but there were high numbers of failure in monsoon season. Maximum and minimum temperature forecast was good and usable in all the seasons and years but a drastic decrease was observed during 2009-10 year. Among all the weather parameters the wind direction was poorly forecasted but, now it is improving.

References

Chauhan, Vikram Singh, Chaudhari, Ganesh, B. and Pandey, V., 2008, "Medium range weather forecast verification for middle Gujarat region", *J. Agrometeorol*., **10** (Special issue), 90-93.

Dakhore, K. K., Patel H. R., Pandey, V. and Shekh, A. M., 2008, "Economic impact assessment using agro-advisory services in middle Gujarat agro climatic zone", *J. Agrometeorol*. (Special issue- Part 2), 541-544.

De, U. S., 1997, "Application of meteorology and climatology to agriculture", Lecture notes on Refresher Course on Operational Techniques in Agrometeorology, IMD, **1**, 1.1-1.5.

Gadgil, S., 1989, "Monsoon variability and its relationship with agricultural strategies", In: International Symposium on Climate Variability and Food Security in Developing Countries, Feb. 5-7, 1987, New Delhi, India., 249-267.

Gill, K. K., Kingra, P. K. and Ritu, 2010, "Economic impact analysis of agro-advisory services during kharif season in central plain agroclimatic region of Punjab", *J. Agrometeorol*., **12**(1), 141-143.

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

Mishra S. K., 2006, "Verification study of medium range weather forecasting and economic impact analysis of weather – based agro advisories in wheat crop", M. Sc. Thesis submitted in the Department of Agril. Meteorology, Narender Dev University of Agricultural and technology, Faizabad (U. P.).

Murphy, A. H., Brown, B. G. and Chen, Y. S., 1989, "Diagnostic verification of temperature forecasts", *Wea. Forecast*., **4**, 485-501.

Murphy, A. H. and Winkler, R. L., 1987, "A general framework for forecast verification", *Mon. Wea. Rev*., **115**, 1330-1338.

Prasada Rao, G. S. L. H. V. and Manikandan, N., 2008, "Economic impact of Agrometeorological advisory services over the central zone of Kerala", *J. Agrometeorol* (Spl. issue- Part 1), 230-234.

Rana, R. S., Prasad, R. and Kumar, Suresh, 2005, "Reliability of medium rage weather forecast in mid Hill Region of Himachal Pradesh", *J. Agrometeorol*., **7**, 292-303.

Rao, A. S., 2008, "Weather based agro-advisory services for food security in the Indian arid region", *J. Agrometeorol* (Special issue- Part 2), 535-540.

Rathore, L. S., Trivedi, H. K. N. and Singh, S. V., 1999, "In: Guide for Agrometeorological Advisory Services", Deptt. of Science & Technology (NCMRWF), New Delhi, 73-77.

Schaefer, C. T., 1990, "The critical success index as an indicator of warning skill", *Wea. and Forecasting*, **5**, 570-575.

Seeley, M. W., 1994, "The failure of serving agriculture with weather/climate information and forecasting: some indications and observations", *Agric. and Forest Meteorol*., **69**, 47-59.

Singh, M. G., 1992, "Himachal Pradesh: History, Culture and Economy", Minerva Book House, Shimla, India.

Singh, Surender, Rao, V. U. M. and Singh, Diwan, 2008, "Economic evaluation of weather - based advisories in semi-arid region in India", *J. Agrometeorol*. (Spl. issue- Part 1), 225-229.

Tripathi, P. and Mishra, R. S., 2000, "Usability assessment of medium range weather forecast for crop production and management", Proc. International Conference on Managing Natural Resources for Agriculture Production, held at IARI, New Delhi, **2**, 618-619.

Tripathi, P., Mishra, S. R. and Mishra, S. K., 2008, "Verification analysis of success probability and usability of medium range weather forecasting in eastern U. P.", *Int. J. Agric and Stat. Sci*., **4**, 437-446.

Woodcock, F., 1976, "The evaluation of yes/no forecast for scientific & administrative purposes", *Mon. Wea. Rev*., **83**, 249-252.

Woodcock, F. 1981, Hanssen and Kuipers' discriminant related to the utility of yes/no forecasts, *Mon. Wea. Rev*., **109**, 172-173.