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Climatic Uncertainties and Recent Experiences in Medium-Range Weather Forecasting Over Kashmir

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Successful crop management and production require a precise and thorough understanding of agroclimatic conditions of a region. A crop experiences a range of weather conditions during its vegetative and reproductive phases. Although the agronomic inputs at optimum levels decide satisfactory and stable crop yields, the range of weather and climatic optimum prevalent at important crop stages determine the ultimate yields. Thus, even with all inputs at our disposal, we cannot afford to ignore the environmental conditions experienced by the crop. Systematic and continuous measurements of weather elements provide basic data input for tuning any type of computer-based forecasting system. This data also forms the basis for characterizing the climate of a region. We have, therefore, made an attempt to characterize the weather pattern over temperate Kashmir (India) based on location specific data, further presenting results of forecast analyses done at our level. The analysis is based on medium-range weather forecasts received from the National Centre for Medium Range Weather Forecasting, New Delhi.

The Indian Union consists of a number of states. Our study area lies in the states of Jammu and Kashmir. It is located in the northwest corner of India, bordering Pakistan. Its geographical position is between 30°17' N and 37°5' N (latitude) and 73° 26' E and 80°30' E (longitude). Its altitude is 300–8,400 m. Therefore, the state experiences a host of macroclimatic conditions—namely, subtropical valley temperate, dry temperate, and cold arid. The scope of this presentation is restricted to the valley temperate zone, which covers the beautiful valley of Kashmir. It is the cold humid zone (1,500–2,500 m msl), with two cropping seasons, locally called *Kharif* (summer season, from May to October) and *Rabi* (winter season, from October to May). During the summer season, transplanted rice is the most important crop in irrigated areas. Maize is the sec-

Month	Corresponding met. weeks	Max. temp. (° C)	Min. temp. (° C)	RH %	Total rainfall (mm)	Sunshine hours (total)
January	1 to 5	5.8	-1.2	79	48	64.5
February	6 to 9	9.3	0.6	73	84	88.5
March	10 to 13	13.3	4.0	70	135	110.0
April	14 to 18	19.3	7.8	60	131	205.0
May	19 to 22	24.1	11.6	58	71	194.0
June	23 to 26	28.4	15.5	57	34	257.0
July	27 to 31	28.6	18.2	64	114	233.0
August	32 to 35	28.6	17.7	66	70	208.0
September	36 to 39	27.0	13.0	63	30	200.0
October	40 to 44	21.2	5.6	67	34	231.0
November	45 to 48	14.7	0.8	72	26	135.0
December	49 to 52	8.4	-0.9	79	59	62.0

Table 1. Average of meteorological parameters (1983 to 1994).

ond most important crop for rainfed conditions (locally called *karewas*). Such rainfed lands experience water scarcity at critical growth stages during the summer season. The valley temperate region becomes agriculturally dormant after winter sowing, from November onward. Some important temperate fruits—namely, apples, pears, walnuts, almonds, and sweet cherries—are grown at the higher elevations while peaches, plums, apricots, pomegranates, and strawberries are grown in the lower elevations.

Our study area is near the world-famous Shalimar Gardens, where the meteorological observatory is located. Twelve years of daily data have been averaged weekly and monthly (Table 1). Important meteorological parameters measured include temperature, total rainfall, and total hours of bright sunshine. The rice-growing period is from June to September. Mean maximum temperatures during the year range from 5.8°C in January to around 28°C for June, July, and August. Similarly, mean minimum temperature varies between -1.2°C and 18.2°C. The relative humidity increases during winter months.

Many interannual variations exist for rainfall. We calculated a coefficient of variation (CV) value of 20%, which by itself is indicative of the uncertain rainfall over the region. The entire Indian subcontinent is fed by the monsoon rains, whereas our region receives 48% of its precipitation through southwest monsoons and the remaining 52% as a result of western disturbances. These western disturbances are formed as a result of strong narrow currents concentrated along a quasi-horizontal axis, usually in the upper troposphere. As we observe from Table 1, most of the precipitation (rain and snow) is concentrated between January and July, with the highest amount occurring in March. Irregular rainfall coupled with high temperatures from August onward results in moisture stress for rainfed crops like maize, beans, and so forth. Rice, being the main crop of the summer season, is subjected to erratic and untimely rains. Our 12-year average shows that July had 114 mm of rain while June had 34 mm of rain. Drastic deviations of monthly rainfall also occurred in July 1995 (350 mm) and June 1996 (185.2 mm). Consequently, the rice crop suffered severe damage during both years.

Another parameter, hours of bright sunshine, is of immense importance to summer crops in the region. Table 1 indicates that the maximum number of hours of bright sunshine occurs in June. It then decreases until September. January, February, and December are months with a minimum of sunshine. We have already noted that rice is the most important crop of the summer season. Nursery establishments of rice commence in April. Transplanting is done by the first fortnight of June, and the crop matures by the end of September. It is important to note that there is a decrease in total sunshine hours from April to May and again from June to September. This decrease in solar energy at two points in time is probably the major climatic constraint in rice production, the first decrease affecting nursery growth and the second affecting the reproductive and maturity phases. The former results in delayed transplanting and the latter is reflected in yield.

Climatic uncertainties and consequent failures to achieve high production levels have led scientists to further characterize the agricultural climate faced by a crop or cropping system. The next step would be to predict weather behavior. Information on weather 3–10 days in advance has been termed *medium-range weather forecasting* (MRWF). It is vital information that ensures the effectiveness of modern farming practices like sowing of photosensitive varieties, need-based application of fertilizer/ pesticides/insecticides, efficient irrigation, and harvesting planning. Since weather in one place may be affected in 1–2 days by weather systems that travel toward the region, it becomes imperative to take global circulation into account while forecasting. In our forecasting system, a super computer located at Delhi is fed global weather data that is processed using the T8OL18 global circulation model (GCM). The output is further matched or cross-checked with (for example) statistical models, synoptic conditions, and the current week's weather to produce a forecast valid for the next 3 days. During the period under report, we received a total of 120 days'

Meteorological parameter	*Overall picture*			*Seasonal breakdown*					
				Summer			Winter		
	C	U	Un	C	U	UN	C	U	Un
Precipitation	42.5	12.5	45.0	38.0	9.0	53.0	48.1	16.7	35.2
Max. temperature	35.8	26.6	37.5	34.8	24.2	41.0	37.0	29.6	33.4
Min. temperature	46.6	29.2	24.2	48.5	30.3	21.2	44.4	27.4	26.2

C: correct; U: usable; Un: unusable

Table 2. Forecast and reality for 120 days' reports (all values in percentages).

Measure	*Seasonal*		*Daily*					
	Summer (66)	Winter (54)	Summer d-1 (22)	Summer d-2 (22)	Summer d-3 (22)	Winter d-1 (18)	Winter d-2 (18)	Winter d-3 (18)
Ratio score	63.60	68.50	68.20	68.20	54.50	77.80	56.00	72.00
H.K. score	0.34	0.35	0.53	0.43	0.03	0.35	0.50	0.42
RMSE	11.32	7.80	7.70	14.90	10.20	6.00	10.20	6.50

(figures in parentheses indicate total reports; 'd' indicates the day)

Table 3. Nonprobabilistic and quantitative verification of precipitation: seasonal and daily.

forecast for our region. The parameters were mainly precipitation and temperature. Using some statistical procedures, we tried to verify the reliability of the forecasts. Tables 2 and 3 give the results of our analysis. In the case of overall reliability of the forecast, we found that less than 50% of the forecasts were correct. Minimum temperatures could be forecasted relatively more accurately than maximum temperatures. Seasonal analysis showed a better forecast skill for precipitation and minimum temperatures for the winter season. Because of the importance of precipitation for crop production, we conducted more analyses, the results of which are given in Table 3. The accuracy of predicting rain vs. no-rain cases is assessed by ratio score, while H.K. score is the ratio of economic saving of a hypothetical set of perfect forecasts compared to forecasts based on climatology. RMSE is a measure of the average degree of correspondence between individual forecasts and actual observations (the higher the RMSE, the lower the forecast's reliability). Analysis showed that precipitation events were more accurately forecasted for the winter season than for the summer season. Further, the daily reliability of forecasts was greater for the first day of the forecast period in both the seasons. We observed an RMSE of 11.32 for summer forecasts and 7.8 for winter, which is indicative of the irregular behavior of summer precipitation. We have observed that summer season rainfall varies from 30 mm in September to as high as 114 mm in July (Table 1), but we have not been able to forecast rainfall events very accurately. This compounds the problem of climatic uncertainties, especially during a season that is very important for crop production.

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