Eco. Env. & Cons. 28 (February Suppl. Issue) : 2022; pp. (S307-S312)

ISSN 0971–765X

DOI No.: http://doi.org/10.53550/EEC.2022.v28i02s.051

Temperature trend and variation analysis in the eastern plain zone of Uttar Pradesh

Devegowda S.R.[1]*, Saket Kushwaha[2], P.S. Badal[3], Avdhesh Sharma[3] and Nagaveni M.[4]

[1]Faculty of Agriculture, Sri Sri University, Odisha, India
[2]Rajiv Gandhi University, Itanagar, India
[3]Department of Agricultural Economics, Banaras Hindu University, Varanasi, India
[4]ICAR-Indian Institute of Oilseeds Research, Hyderabad, India

(Received 29 June, 2021; Accepted 31 July, 2021)

ABSTRACT

The Eastern Plain Zone of Uttar Pradesh faces latent heat stress in the Rabi crop production. This study mainly concentrates on the minimum and maximum temperature data of the eastern plain zone. Data for the period 1981-2018 collected on a monthly and yearly basis to calculate trend and variation. Sen's Slope Estimator and the Mann-Kendall (MK) test was used for pattern and slope magnitude determination. Maximum temperature decreased over the years for all the districts of Eastern Plain Zone (EPZ) whereas a significant increase in the minimum temperature was noticed. The majority of districts revealed a significant decrease in the maximum temperature in January, July and December months whereas minimum temperature significantly increased in February, April, May and October months.

Key words: *Temperature, Trend, Variation, Mann-Kendall Test, Sen's Slope estimator*

Introduction

Temperature is the essential climate quantitative for crop production. There has been great interest in India in recent decades concerning extreme values of temperature that have been observed, particularly during the warmest part of the year in April and May, the period preceding the onset of the summer monsoon. Such observations are consistent with global trends in temperature (Ross *et al.,* 2018). In their fifth assessment report, the Intergovernmental Commission on Climate Change (IPCC) reported that the warming of the global climate system is unequivocal and this warming has accelerated since the 1950s (IPCC, 2014). Pre-monsoon season, for India as a whole, the frequency of hot days and nights has increased, however, a statistically significant trend is observed for hot nights (Kothawale *et al.,* 2010). The Eastern plain zone of Uttar Pradesh is dominated by a rice-wheat cropping system. An increase in the temperature adversely affect crop production, day temperature 25 to 32 °C and night temperature 15 to 20 °C is preferable. Temperature beyond 35 °C affects both the pollen shedding as well as the grain filling (Bapuji Rao *et al.,* 2014), both upland and lowland rice spikelet sterility induced with less than 1 hr of exposure to an air temperature of at least 33.7 °C and higher, based on a controlled environment experiment. Lowland indica rice exhibited a 7% reduction in spikelet fertility by per 1 °C increase of temperature above 29.6 °C whereas spikelet 2.4% fertility was reduced by per 1 °C increase above 33°C for upland japonica rice (Jagadish *et al.,* 2015). The optimum temperature for wheat anthesis and grain filling ranges from 12 to 22 °C (Shewry, 2009). Plants exposed to temperatures above >24°C during

*Faculty of Agriculture, Sri Sri University, Assistant Proffsor

the reproductive stage significantly reduced grain yield and yield reduction continued with increasing duration of exposure to high temperature (Prasad & Djanaguiraman, 2014).

Materials and Methods

Monthly data of minimum and maximum temperature for the period (1981– 2017) over 12 districts of Eastern Plain Zone (EPZ) of Uttar Pradesh (Table 1) collected from NASA POWER monthly basis dataset with a horizontal resolution of 1° latitude by 1° longitude ("POWER Data Access Viewer," n.d.). The time series analysis of minimum and maximum temperature data collected on a monthly and yearly basis.

Analysis of Annual and Monthly Temperature Trend

Statistically, the Trend is a significant change over time that can be detected by parametric and non-parametric processes, while time series trend analysis consists of trend magnitude and statistical significance. Statistical significance trend analysis was performed in the analysis was done by using Man-Kendall test while the magnitude of the trend was determined by Sen's estimator method.

Mann–Kendall Test

The Mann-Kendall test statistic S (Mann, 1945; Kendall, 1975) calculated by using the formula

$$S = \Sigma_{i-1}^{n-1}\Sigma_{j=i+1}^{n}\ sgn(x_j - x_i) \qquad \text{(i)}$$

Where,

x_j and x_i are annual values in years j and i, j > i respectively, n is the number of data points and sgn ($x_j - x_i$) is calculated using equation (ii)

$$sgn(x_j - x_i) = \begin{cases} 1, & if\ x_j - x_i > 0 \\ 0 & if\ x_j - x_i = 0 \\ -1, & if\ x_j - x_i < 0 \end{cases} \qquad \text{(ii)}$$

A positive or negative value of S indicates a trend that is increasing or decreasing. If the number of data values are 10 or more, the S-statistics are roughly distributed and the test is performed with normal distribution with the mean and variation as shown in the following equations (iii) & (iv).

$$E(S) = 0 \qquad \text{(iii)}$$

$$\text{Var}\ (S) = \frac{n(n-1)(2n+5) - \Sigma_{i=1}^{n} t_i(t_i-1)(2t_i+5)}{18} \qquad \text{(iv)}$$

Where n is the number of groups tied (zero difference between comparable values) and t_j is the number of data points in the group tied with i^{th} value. Use the equation to calculate the standard normal distribution (Z-statistics) (v).

$$Z = \begin{cases} \dfrac{S-1}{\sqrt{Var\ (S)}} & if\ S > 0 \\ 0 & if\ S = 0 \\ \dfrac{S-1}{\sqrt{Var\ (S)}} & if\ S < 0 \end{cases}$$

Statistically, using the Z- value, the significance of the trend is assessed. A positive Z value shows an upward (increasing) trend, while a downward (decreasing) trend is indicated by a negative value. In this study, significance levels $\alpha = 0.1$, $\alpha = 0.05$ and $\alpha = 0.01$ were used.

Table 1. Districts of Eastern Plain Zone of Uttar Pradesh

District	Latitude	Longitude	Normal Rainy Days	Annual Rainfall (mm)
Ambedkar Nagar	26°47′N	82°12′ E	14	1028.9
Ayodhya	26°66′ N	81°95′ E	-	970.8
Azamgarh	26°03′ N	83°13′ E	54	1103.5
Ballia	25°44′ N	84°11′ E	55	999.5
Barabanki	26°56' N	81°13' E	67	1002.7
Chandauli	25°16′N	83°16′E	48	1056.4
Ghazipur	25°35′N	83°34′E	40	976.7
Jaunpur	25°44′N	82°41′E	46	1097.9
Mau	25°57′ N	83°36′ E	50	1117.3
Sant Ravidas Nagar	25°22′N	82°28′E	47	1052.3
Sultanpur	26°16′ N	82°05′ E	59	1005
Varanasi	25°18′N	83°03′E	48	1081.7

Source: (Department of Agriculture Cooperation & Farmers Welfare, n.d.)

Sen's Slope Method of Estimation

For the prediction of the magnitude (true slope) of hydro-metrological time series results, Sen's non-parametric estimator method was used. Sen's slope estimator method uses a linear model for the trend analysis. The slope (T_i) of all data pairs is calculated using equation (vi) (Sen, 1968).

$$T_i = \frac{x_j - x_k}{j-k} \text{ for i=1, 2, 3……..n} \qquad \text{(vi)}$$

Where, x_j and x_k are data values at time j and k (j > k) separately.

The median of these n values of T_i is represented by Sen's slope of estimation (true slope) which is calculated using equation (vii)

$$Q_i = \begin{cases} T_{\frac{n+1}{2}} & \text{for n is odd} \\ \frac{1}{2}\left(T_{\frac{n}{2}} + T_{\frac{n+2}{2}}\right) & \text{for n is even} \end{cases} \qquad \text{(vii)}$$

Sen's estimator Q_{med} is calculated using the above equation depending upon the value of n is either odd or even and then is computed using 100 (1 – α) % confidence interval using a non-parametric test depending upon normal distribution. A positive value of indicate an increasing (upward) trend while a negative value of represent downward or decreasing trend of time series data.

Annual and Monthly Temperature Variability

It can be measured by using the coefficient of variation. The standard deviation as a percentage of means is called the coefficient of variation.

$$CV = \frac{\sigma}{\mu} \times 100$$

Where, CV = Co-efficient of variation, σ = Standard deviation of the variable, μ = Mean of the variable

Results and Discussion

Annual maximum temperature pattern of eastern plain zone

Annual data of maximum temperature collected for all the 12 districts of EPZ collected to know the temperature trend for the period (1981- 2018). All the districts indicated a negative trend. The Eastern

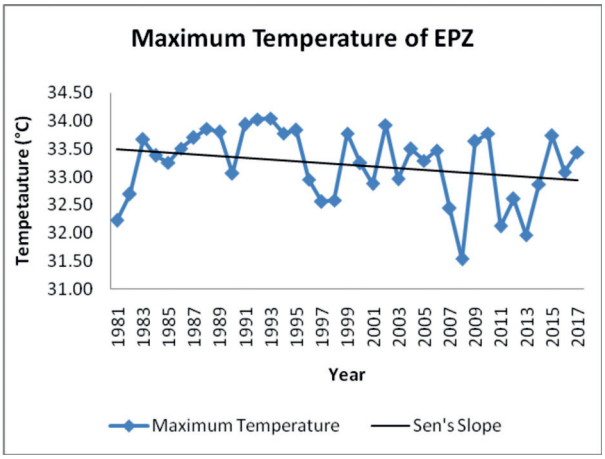

Fig. 1. Annual maximum temperature of EPZ

Table 2. Maximum temperature trend in districts of Eastern Plain Zone for the period 1981-2018.

District	Minimum	Maximum	Mean	SD	CV	MK trend	Signific. (α)	Slope
Ambedkar Nagar	31.44	34.1	33.20	0.70	2.09	-0.19	↓*	-0.019
Ayodhya	31.23	34.63	33.05	0.78	2.37	-0.18	↓	-0.021
Azamgarh	31.24	34.04	33.10	0.69	2.10	-0.24	↓**	-0.023
Ballia	30.95	34.23	32.95	0.73	2.22	-0.11	↓	-0.009
Barabanki	31.28	34.73	33.15	0.80	2.41	-0.15	↓	-0.018
Chandauli	32.09	34.39	33.33	0.62	1.85	-0.06	↓	-0.004
Ghazipur	31.34	34.22	33.13	0.67	2.02	-0.10	↓	-0.010
Jaunpur	32.01	34.45	33.51	0.67	1.99	-0.10	↓	-0.010
Mau	31.34	34.22	33.13	0.67	2.02	-0.10	↓	-0.010
Sant Ravidas Nagar	32.08	34.91	33.58	0.74	2.20	-0.08	↓	-0.010
Sultanpur	31.52	34.38	33.26	0.74	2.21	-0.18	↓	-0.020
Varanasi	32.09	34.39	33.33	0.62	1.85	-0.06	↓	-0.004
Eastern Plain Zone	31.53	34.04	33.23	0.64	1.93	-0.15	↓	-0.011

Where, (↑) indicates increasing trends; (↓) indicates decreasing trend;*** 0.01 level of significance; ** 0.05 level of significance;* 0.1 level of significance

plain zone also followed the same negative trend (Fig 1). Whereas Ambedkar Nagar and Azamgarh showed a significant decrease in the annual maximum temperature (Table 2). Similar result decrease in the maximum temperature for thirteen districts of Uttarakhand (Yadav *et al.*, 2014).

Annual minimum temperature pattern of eastern plain zone

Minimum temperature collected for the period 1981-2018. Mann-Kendall test and Sen's slope estimator applied for the collected data. Results indicated a significant increase in the minimum temperature over the years in the eastern plain zone of Uttar Pradesh (Fig 2). Azamgarh, Ballia, Ghazipur and Mau showed an increase in trend. Ambedkar Nagar, Ayodhya and Barabanki increase in trend with 0.1 level of significance. Chandauli, Jaunpur, Sant Ravidas Nagar, Sultanpur and Varanasi indicated an increase in the minimum temperature with the 0.05 level of significance (Table 3). Similar result of increase in the annual minimum temperature noticed in the Uttarakhand (Yadav *et al.*, 2014).

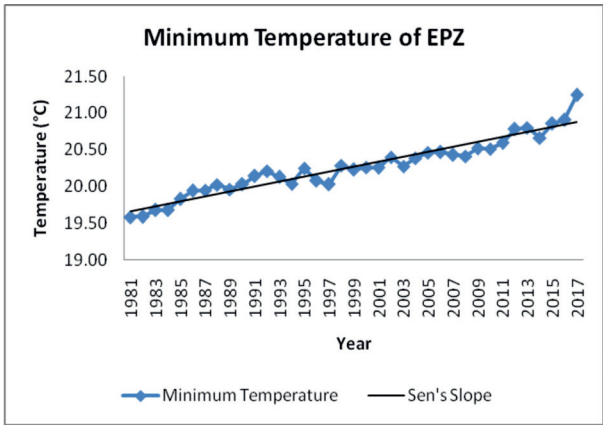

Fig. 2. Annual minimum temperature of EPZ

Monthly maximum temperature pattern in districts of EPZ

Monthly temperature data for all the 12 districts were collected for the period 1981-2018 and analyzed to know the monthly trend in the temperature. Monthly data indicated decreasing trend for all the months except in September where it followed an increasing trend for the entire districts. Ambedkar Nagar showed a significant decrease trend in January, July, November and December with 0.1, 0.05, 0.1 and 0.01 levels of significance. Ayodhya revealed an increase in maximum temperature trend for February and September where it exhibited a significant decrease trend in July, November and December with the level of significance 0.05, 0.1 and 0.05 respectively. Azamgarh indicated a significant decrease in the maximum temperature in January, July, August, November and December with the level of significance 0.05, 0.1, 0.1, 0.05 and 0.05 respectively. Ballia district also followed the same trend with a level of 0.05 for January and 0.1 level of significance for December. Barabanki and Sultanpur indicated a similar trend 0.05 level of significance for July wherein the December month Brabanki significant 0.1 and Sultanpur significant with 0.05. Chandauli, Sant Ravidas Nagar and Varanasi followed a similar trend in February, September and

Table 3. Minimum temperature trend in districts of Eastern Plain Zone for the period 1981-2018.

District	Minimum	Maximum	Mean	SD	CV	MK trend	Signific. (α)	Slope
Ambedkar Nagar	19.39	20.86	20.14	0.37	1.84	0.21	↑*	0.011
Ayodhya	19.13	20.56	19.97	0.39	1.95	0.20	↑*	0.012
Azamgarh	19.43	20.77	20.13	0.36	1.80	0.15	↑	0.011
Ballia	19.51	21.15	20.23	0.41	2.02	0.16	↑	0.012
Barabanki	19.09	20.51	19.92	0.40	2.00	0.23	↑*	0.014
Chandauli	19.5	21.38	20.27	0.40	1.98	0.27	↑**	0.018
Ghazipur	19.56	21.13	20.28	0.39	1.93	0.19	↑	0.013
Jaunpur	19.61	21.26	20.31	0.38	1.89	0.25	↑**	0.016
Mau	19.56	21.13	20.28	0.39	1.93	0.19	↑	0.013
Sant Ravidas Nagar	19.65	21.52	20.35	0.41	2.00	0.27	↑**	0.017
Sultanpur	19.37	20.91	20.12	0.39	1.93	0.24	↑**	0.014
Varanasi	19.5	21.38	20.27	0.40	1.98	0.27	↑**	0.018
Eastern Plain Zone	19.58	21.24	20.19	0.37	1.88	0.25	↑**	0.015

Where, (↑) indicates increasing trends; (↓) indicates decreasing trend;*** 0.01 level of significance; ** 0.05 level of significance;* 0.1 level of significance

October increase trend in the maximum, Chandauli revealed decrease with 0.1 level significance in January whereas Sant Ravidas Nagar and Varanasi in the July month. Ghazipur and Mau indicated a similar trend at 0.05 level of significance in January and December. Jaunpur revealed a significant decrease in January, July and December with 0.1, 0.1 and 0.05 levels of significance respectively (Table 5).

Monthly minimum temperature pattern in districts of EPZ

Minimum temperature increasing over the period for all districts in the eastern plain zone of Uttar Pradesh. All the districts showed a negative trend in January, July and December months. In July month Ayodhya, Brabanki and Sultanpur revealed a significant decrease. February noticed a significant increase in the minimum temperature in Ayodhya, Balli, Barabanki, Ghazipur and Mau districts. All the districts noticed an increasing trend in the March, June and November months. In April month all the districts noticed a significant increased trend 0.1 level of significance whereas Ballia, Ghazipur and Mau increased 0.05 level of significance. May month also noticed significant minimum temperature for all the districts 0.1 level of significance for Ballia, 0.05 for Ambedkar Nagar, Ayodhya, Azamgarh, Barabanki, Ghazipur, Mau and Sultanpur, 0.01 level of significance for Chandauli, Jaunpur, Sant Ravidas Nagar and Varanasi. August month showed a nega-

Table 5. Monthly maximum temperature trend in districts of Eastern Plain Zone for the period 1981-2018.

District	Month											
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Ambedkar Nagar	↓*	↓	↓	↓	↓	↓	↓**	↓	↑	↓	↓*	↓***
Ayodhya	↓	↑	↓	↓	↓	↓	↓**	↓	↑	↓	↓*	↓**
Azamgarh	↓**	↓	↓	↓	↓	↓	↓*	↓*	↑	↓	↓**	↓**
Ballia	↓**	↓	↓	↓	↓	↓	↓	↑	↑	↓	↓	↓*
Barabanki	↓	↓	↓	↓	↓	↓	↓**	↓	↑	↓	↓	↓*
Chandauli	↓*	↑	↓	↓	↓	↓	↓	↓	↑	↑	↓	↓
Ghazipur	↓**	↓	↓	↓	↓	↓	↓	↑	↑	↓	↓	↓**
Jaunpur	↓*	↓	↓	↓	↓	↓	↓*	↓	↑	↑	↓	↓**
Mau	↓**	↓	↓	↓	↓	↓	↓	↑	↑	↓	↓	↓**
Sant Ravidas Nagar	↓	↑	↓	↓	↓	↓	↓*	↓	↑	↑	↓	↓
Sultanpur	↓	↓	↓	↓	↓	↓	↓**	↓	↑	↓	↓	↓**
Varanasi	↓	↑	↓	↓	↓	↓	↓*	↓	↑	↑	↓	↓

Where, (↑) indicates increasing trends; (↓) indicates decreasing trend; *** 0.01 level of significance; ** 0.05 level of significance; *0.1 level of significance

Table 6. Monthly minimum temperature trend in districts of Eastern Plain Zone for the period 1981-2018.

District	Month											
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Ambedkar Nagar	↓	↑	↑	↑*	↑**	↑	↓	↓	↑	↑**	↑	↓
Ayodhya	↓	↑*	↑	↑*	↑**	↑	↓*	↓	↑	↑***	↑	↓
Azamgarh	↓	↑	↑	↑*	↑**	↑	↓	↓	↑	↑**	↑	↓
Ballia	↓	↑*	↑	↑**	↑*	↑	↓	↑	↑	↑*	↑	↓
Barabanki	↓	↑*	↑	↑*	↑**	↑	↓*	↓	↑	↑***	↑	↓
Chandauli	↓	↑	↑	↑*	↑***	↑	↓	↑	↑	↑**	↑	↓
Ghazipur	↓	↑*	↑	↑**	↑**	↑	↓	↑	↑	↑*	↑	↓
Jaunpur	↓	↑	↑	↑*	↑***	↑	↓	↓	↑*	↑**	↑	↓
Mau	↓	↑*	↑	↑**	↑**	↑	↓	↑	↑	↑*	↑	↓
Sant Ravidas Nagar	↓	↑	↑	↑*	↑***	↑	↓	↓	↑	↑**	↑	↓
Sultanpur	↓	↑	↑	↑*	↑**	↑	↓*	↓	↑	↑**	↑	↓
Varanasi	↓	↑	↑	↑*	↑***	↑	↓	↓	↑	↑**	↑	↓

Where, (↑) indicates increasing trends; (↓) indicates decreasing trend; *** 0.01 level of significance; ** 0.05 level of significance; * 0.1 level of significance

tive trend for the majority of districts except for Chandauli, Ghazipur, Ballia and Mau. In September month all the districts indicated an increasing trend, Jaunpur showed an increasing trend with a 0.1 level of significance. Ballia and Mau exhibited an increasing trend for October month with 0.1 level of significance, whereas Ambedkar Nagar, Azamgarh, Chandauli, Jaunpur, Sant Ravidas Nagar, Sultanpur and Varanasi with the level of significance 0.05, Ayodhya and Barabanki indicated an increasing trend with the level of significance 0.01 (Table 6).

Annual maximum temperature pattern of eastern plain zone

Yearly maximum temperature data showed the highest variation for the Barabanki district and lower variation for the Chandauli and Varanasi districts. Ambedkar Nagar, Ayodhya, Azamgarh, Ballia, Ghazipur, Jaunpur, Mau, Sant Ravidas Nagar and Sultanpur indicated variation 2.09, 2.37, 2.10, 2.22, 2.02, 1.99, 2.02, 2.20 and 2.21 respectively. EPZ showed variation 1.93 (Table 2).

Annual minimum temperature pattern of eastern plain zone

Yearly minimum temperature data showed the highest variation for the Ballia district and lower variation for the Azamgarh district. Ambedkar Nagar, Ayodhya, Barabanki, Chandauli, Ghazipur, Jaunpur, Mau, Sant Ravidas Nagar, Sultanpur and Varanasi indicated variation 1.84, 1.95, 2.00, 1.98, 1.93, 1.89, 1.93, 2.00, 1.93 and 1.98 respectively. EPZ showed a variation of 1.88 which is more than the minimum variation EPZ districts (Table 3).

Conclusion

Maximum temperature decreased over the period for the districts of the eastern plain zone. Azamgarh and Ayodhya districts indicated a significant decrease in the maximum temperature. All the districts exhibited a significant increase in the minimum temperature except Azamgarh, Ghazipur and Mau where the increase in the temperature is not significant. The majority of the districts are a significant decrease in the maximum temperature in the January, July and December months whereas in case of minimum temperature majority of districts indicated an increase in February, April, May and October month. Barabanki district exhibited the highest variation and lower variation for the Chandauli and Varanasi districts in the maximum temperature. Minimum temperature data showed the highest variation for the Ballia district and lower variation for the Azamgarh district.

Acknowledgment

The authors sincerely acknowledge the necessary advice received from the Department of Agricultural Economics, Institute of Agricultural Sciences, Banaras Hindu University, Uttar Pradesh, India for successful conduct of this research work.

References

Bapuji Rao, B., Santhibhushan Chowdary, P., Sandeep, V. M., Rao, V. U. M. and Venkateswarlu, B. 2014. Rising minimum temperature trends over India in recent decades: Implications for agricultural production. *Global and Planetary Change.* 117: 1–8.

Department of Agriculture Cooperation & Farmers Welfare. n.d.. Home | Department of Agriculture Cooperation & Farmers Welfare | Mo A&FW | GoI. Retrieved January 15, 2021, from http://agricoop.nic.in/en

Jagadish, S. V. K., Murty, M. V. R. and Quick, W. P. 2015. Rice responses to rising temperatures - challenges, perspectives and future directions. *Plant, Cell and Environment.* 38: 1686–1698.

Kothawale, D. R., Revadekar, J. V. and Kumar, K. R. 2010. Recent trends in pre-monsoon daily temperature extremes over India. *Journal of Earth System Science.* 119(1): 51–65.

POWER Data Access Viewer. n.d. Retrieved January 15, 2021, from https://power.larc.nasa.gov/data-access-viewer/

Prasad, P. V. V. and Djanaguiraman, M. 2014. Response of floret fertility and individual grain weight of wheat to high temperature stress: sensitive stages and thresholds for temperature and duration. *Functional Plant Biology.* 41(12): 1261.

Ross, R. S., Krishnamurti, T. N., Pattnaik, S. and Pai, D. S. 2018. Decadal surface temperature trends in India based on a new high-resolution data set. *Scientific Reports.* 8(1): 1–10.

Sen, P. K. 1968. Estimates of the Regression Coefficient Based on Kendall's Tau. *Journal of the American Statistical Associatio.* 63(324): 1379–1389.

Shewry, P. R. 2009. Wheat. *Journal of Experimental Botany.* 60: 1537–1553.

Yadav, R., Tripathi, S. K., Pranuthi, G. and Dubey, S. K. 2014. Trend analysis by Mann-Kendall test for precipitation and temperature for thirteen districts of Uttarakhand. *Journal of Agrometeorolog.* 16(2): 164–171.