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A CLIMATOLOGICAL STUDY OF MINIMUM TEMPERATURE AT DEHRADUN IN DOON VALLEY

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Abstract

Climate change is one of the major global challenges and has gathered the interest of researchers, scientists, planners, and politicians. Interest in climate change has increased over the last three decades due to a persistent increase in global warming associated with the greenhouse effect. Agriculture is highly exposed to climatic changes, as farming activities directly depend on its prevailing conditions. The effect of these changes will be on crop production, water availability, heat stress in plants and incidences of flood and drought risks. Knowledge of the extent of such change and of related phenomena will help to answer the questions posed by society about adaptation strategies. In this study, forty one years of daily data (1967-2007) on minimum temperatures at Dehradun, located in Doon valley of Uttarakhand at an altitude of 640 m above mean sea level were collected. The collected data were analyzed and interpreted to find trends and anomalies in minimum temperature, extreme values of minimum temperature, events having zero or negative minimum temperature, the daily departure of minimum temperatures from the normal, persistence of minimum temperature for number of days, frequency of cold waves and frost severity index.

Results from the analysis revealed that the total numbers of events when minimum temperature recorded either zero or negative were counted as 52 out of total 3700 observations during 1967-2007 and out of which maximum number of such events (37) occurred in the month of January. The magnitude of minimum temperature indicated an increasing trend both seasonally and annually. The summers and winters at Dehradun were found to be warmed at the rate of 1.7°C/100 year and 1.46°C/100 year, respectively. Coefficient of variability in minimum temperature varied from 17 to 26 per cent. Markedly below normal temperature were found to be rare at Dehradun. Persistence in minimum temperature for one day was found to be maximum for the month of January. Also, maximum number of cold waves at Dehradun occurred during January and decadal frost severity index was more during 1967-76. The results of this study may be extremely beneficial for farmers, agricultural research workers and the planners of the Doon Valley.

Introduction

The greenhouse gases in the atmosphere play an important role in controlling the temperature of the Earth. The anthropogenic emission of various gases has increased considerably since the Industrial Revolution (1750 onward), with an increase of 70per cent between 1970 and 2004 (Singh et al., 2008). Climate change and global warming arising from anthropogenic-driven emissions of greenhouse gases and land-use and land-cover change have emerged as one of the most important environmental issues in the last two decades (Arora et al., 2005; Singh et al., 2008). Weather records from land stations and ships indicate that the global mean surface temperature has warmed up approximately by 0.6±0.2°C since 1850 and it is expected that, by 2100, the increase in temperature could be 1.4-5.8°C (Singh et al., 2008). Available records show that the 1990s have been the warmest decade of the millennium in the Northern Hemisphere and 1998 was the warmest year. Temperature variations influence hydrological cycle, water resources, flood and drought frequencies, natural ecosystems, agriculture, architecture, power generation and its use, including electrical power for heating and cooling; melting of snow and the effects of freezing and icing on transportation systems; flowering and harvesting dates; and society and economy (Ramos, 2001; Ventura et al., 2008; Rehman, 2009). Also, temperature plays an indispensable role in sowing time, germination, incidence of disease, crop quality, duration of crop and development of different growth phases of plants as a source of energy (Wang, 1960). A linear relationship between plant growth and development with temperature has been established. Moreover, a disruption of water supply through climate change can result in social and economic losses that often take years to recover (Haris et al., 2010). Several attempts in literature have been made to study the behavior of minimum temperature, frequency and severity of cold waves in different parts of India (Raghvan, 1967; Pant and Hingane, 1988; Jain and Dubey, 1991; Deosthali and Payyappali, 1997; Singh, 2003; Yadav and Dixit, 2006). However, very few studies on minimum temperature behavior have been undertaken in Himalayan region due to remoteness, inhospitable terrain, inaccessibility and sparse meteorological network. The studies done by Samui and Gupta (1992) for two hill stations in Sikkam, Attri et al., (1995) for Gangtok and Murthy et al., (2004) for Ranichauri in Uttrakhand are worth mentioning studies in the literature from Himalayan region. The diurnal temperature variations in the region are small therefore, temperature plays an important role in crop growth and agricultural production. The temperatures fall rapidly during October and drops down to sub-zero temperatures during winter. The temperature below freezing point destroys the standing crops. Therefore, to fill the research gap, an attempt in the present paper has been made to study the minimum temperature variations at Dehradun located in Doon Valley. The results derived from the analysis of long term (1967-2007) minimum temperature records may be extremely beneficial for agricultural scientists, extension workers and farmers of the valley.

Study Area

Dehradun is situated in the western part of Uttarakhand state at the foothills of Himalayas in the fertile Doon Valley. It is well known for its salubrious climate and natural beauty. It is surrounded by river Song on the east, river Tons on the west, Himalayan ranges on the north and Sal forests in the south. The high hills in the east and north and Siwaliks in the south offer an interesting topographical setting to the city. During the summer months, the temperature ranges between 36°C and 16.7°C. The winter months are colder with the maximum and minimum temperatures touching 23.4°C and 5.2°C respectively. Dehradun experiences heavy to moderate showers during late June to mid August. Most of the annual rainfall (about 2000 mm) is received during the months from June to September, July and August being the rainiest months of the season. Dehradun has been emerging as a important business, educational and cultural destination in north India after becoming the capital of newly carved out state of Uttarakhand since 1999. The population of the city is increasing rapidly and it has registered about 40 per cent growth during the last decade. Also, the wafting fragrance of rice, tea, mango and litchi gardens add to the beauty of Doon Valley.

Objectives of the Study

The objectives of the present study are:

i) To find out the trends and anomalies in annual and seasonal minimum temperature and;
ii) To identify the frequency and severity of minimum temperature conditions.

Materials and Methods

The daily minimum temperature data recorded by the meteorological observatory located at New Forest, Forest Research Institute, Dehradun in Doon Valley of Uttarakhand for the period from December 1967 to February 2007 were collected from the published records. The New Forest area lies between 30°19'55" to 20° 21' 16" North latitudes and 77° 58' 40" to 77° 1' 00" East longitudes. The elevation of the meteorological observatory is about 640.08 m above mean sea level. This observatory corresponds to class 'A' meteorological observatory of Indian Meteorological Department, Pune.

From the daily minimum temperature data monthly, seasonal and yearly averages were derived. To determine a trend in minimum temperatures 3-year and 5-year moving averages technique has been adopted. The seasonal averages taken into consideration were December to March for winter season, April to May for summer season, June to September for the monsoon season, and October to November for the post-monsoon season.

For better understanding of the observed trends in minimum temperature, anomalies were also computed. Anomalies are more accurate than absolute temperature to describe climatic variability. To analyze anomalies in minimum temperature, the average annual and seasonal minimum temperatures were calculated. Folland et al., (1999) suggested 30 years as a standard period for calculating the average used to analyze the anomalies. For the present purpose, the relative anomalies and comparison were made with the results obtained using the average from the whole data set. The temperature anomalies obtained were plotted against time and the linear trends observed were represented graphically. The linear trend value, represented by the slope of a simple least-square regression line with time as the independent variable shows the magnitude of rise or fall in temperature.

A set of minimum temperature indices suitable for monitoring climatic extremes during December, January and February were also calculated for finding the extreme values of minimum temperature with standard deviation and coefficient of variability, events having zero or negative minimum temperature, the daily departure of minimum temperatures from the normal and persistence of minimum temperature for number of days. These were classified into three categories viz; no change (within ± 1°C), rise (>1°C) and fall (<1°C). The frequency of cold waves has also been computed as per criteria given by Indian Meteorological Department as moderate and severe types (When daily minimum temperature is below 6 to 7°C from the normal, the cold waves are categorized as moderate and if it is above normal by 7°C, the cold waves are considered as severe).

Frost Severity Index is an indicator to know the effects of low temperature on crops. Hence, an attempt was also made to calculate the frost severity index in the present study. It was calculated as the number of days per month with daily minimum temperature below zero (T min < 0°C), and the percentage with respect to the month and finally the index was averaged over decades.

Results and Discussion

Annual Trends and Anomalies in Minimum Temperature

The annual minimum temperature trends with two time interval moving averages and their anomalies are presented in Fig. 1. The trend in minimum temperature from 1967-2007 at Dehradun indicates the increasing trend and these results are in agreement with the temperature trends at Ranichauri in the mid Himalayan region of Uttarakhand (Murty et al., 2004). Moreover, the results are also in conformity with the global trends and the studies in other mountainous region of the world (Bhutiyani et al., 2007). The increasing trend in annual minimum temperature at Dehradun was noticed from the year 1983. The increase in magnitude of minimum annual temperature was observed to be 0.98°C/100 year. The data on 3 year and 5 year moving averages closely followed the trend line and an increase of 0.007°C/year in minimum temperature was observed. The annual minimum temperature ranged between 12.2°C in 1989 to 14.5°C in 1985. Positive anomaly of about 0.9°C in annual minimum temperature was observed during 1985. It was also observed from the analysis that negative anomalies are more prominent in annual minimum temperature at Dehradun. Temperature increase at Dehradun is primarily attributed to global warming and global climate change. This climate warming at Dehradun will result into fatal effects on natural ecosystems. One of the obvious effects of temperature increase in the Doon Valley may lead to change in hydrological cycle and decrease agricultural productivity.

Seasonal Trends and Anomalies in Minimum Temperature

The seasonal trends of minimum temperature and anomalies have been demonstrated in Fig. 2 and 3 with linear trends. The difference in trend and its magnitude in minimum temperature from year to year can be observed from these figures. The seasonal analysis revealed that the minimum temperature showed that there is an overall increasing trend in all seasons. The warming in minimum temperature was particularly noteworthy during summer and winter seasons while it was very less during monsoon and post monsoon season. The increase in magnitude of minimum temperature for summer season was observed to be 1.70°C/100 year followed by 1.46°C/100 year for the winter season at Dehradun. The seasonal results are in good agreement with the findings of other studies on climate change in the Himalaya. The Kosi Basin in the central Himalaya in India has experienced a similar positive trend in temperature in the last century (Sharma et al., 2000). The lowest magnitude of increase in temperature during monsoon can be attributed to predominantly cloudy days producing lower variations. The standard deviation of minimum temperature was found to be the lowest for winter and monsoon seasons whereas it was

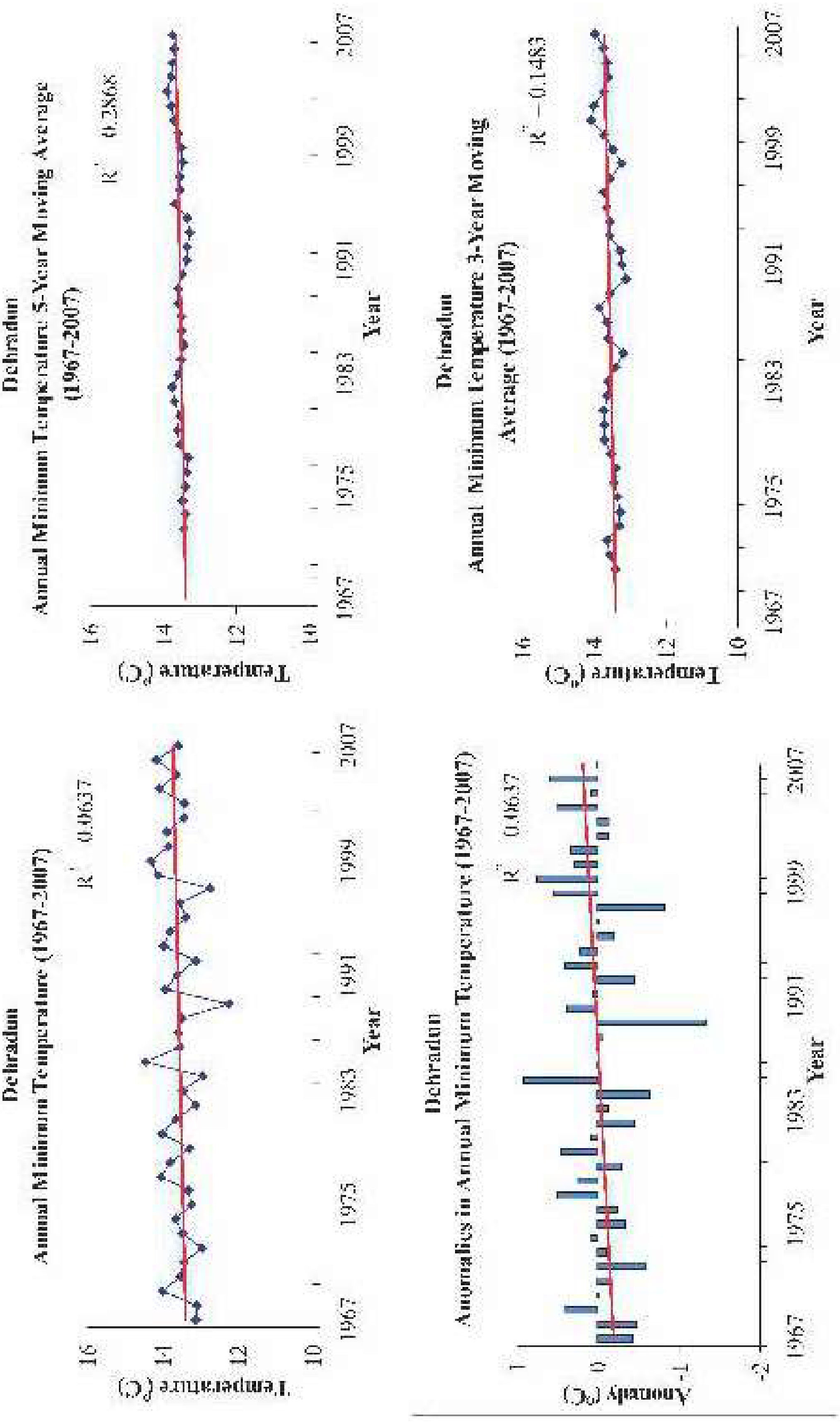

Fig. 1

Source: Compiled by Authors

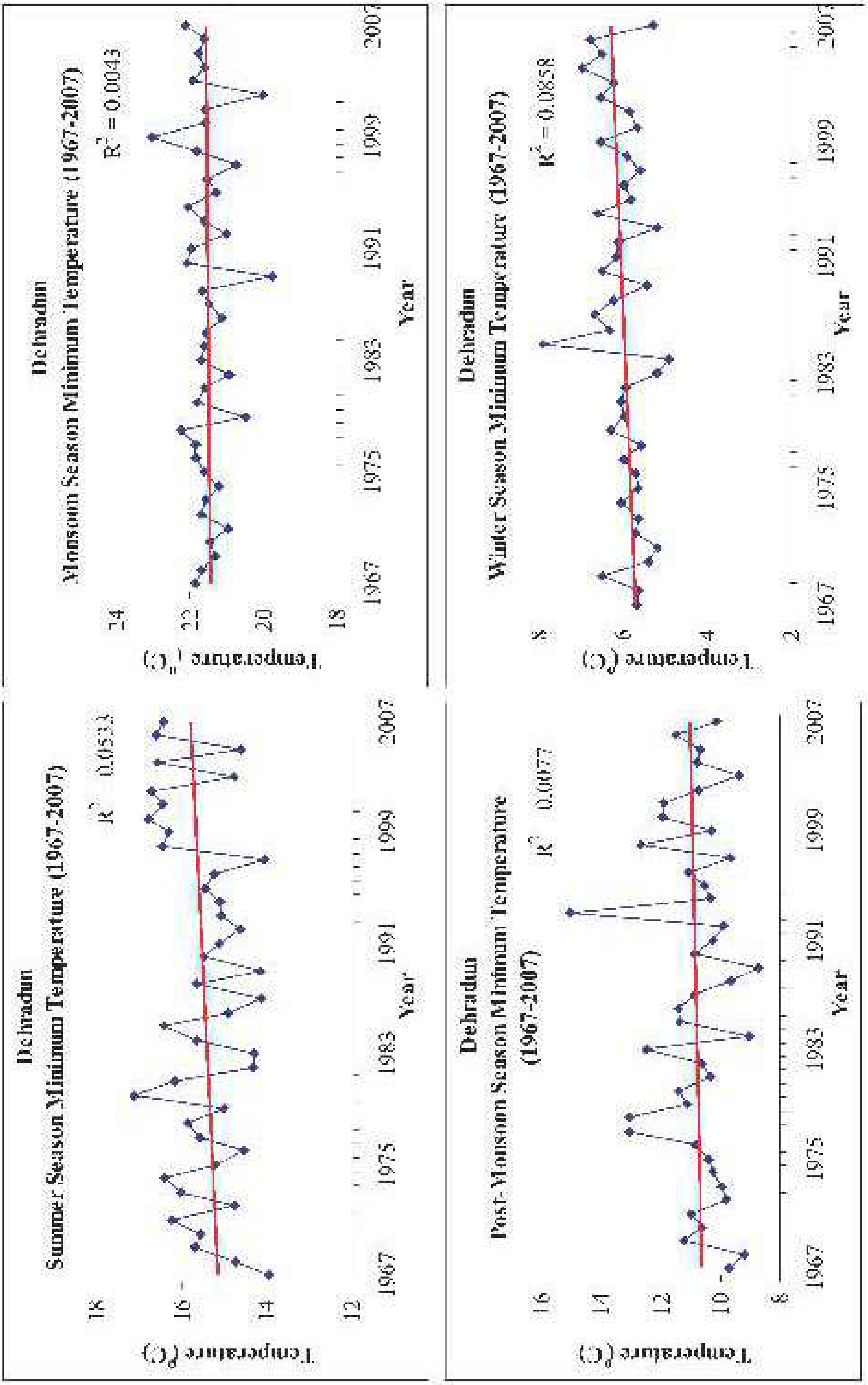

Fig. 2

Source: Compiled by Authors

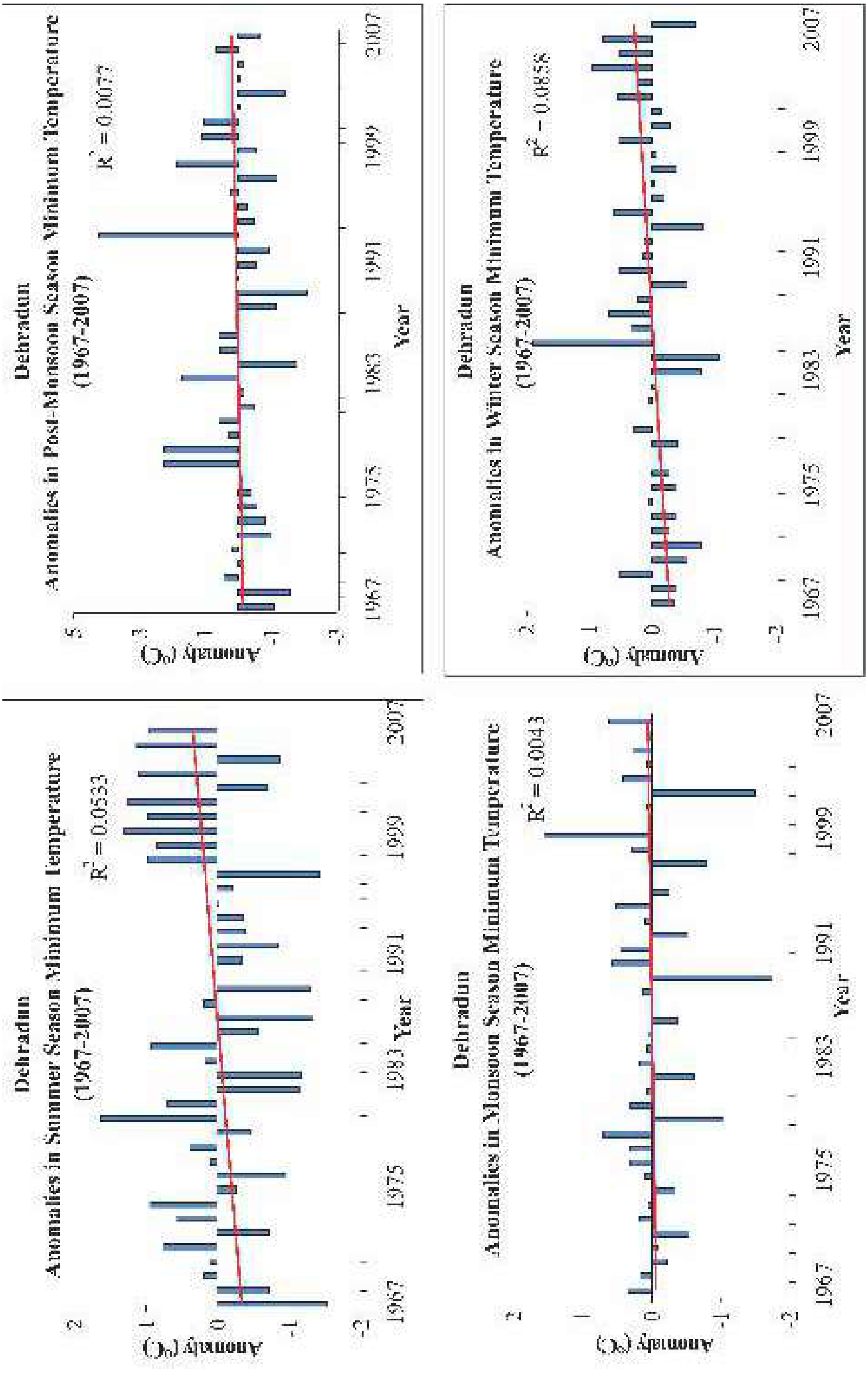

Fig. 3

Source: Compiled by Authors

observed maximum for the post-monsoon season. Also, highest coefficient of variability (11.2 per cent) was recorded for the post-monsoon season. Anomalies in minimum temperature were found to be more vigorous during monsoon season at Dehradun. However, maximum anomaly in minimum temperature was observed during the post-monsoon season and it was revealed from the analysis that a positive anomaly of about 4.2°C was observed during the year 1993. Similarly, a negative anomaly of about 1.74°C was recorded in 1989 during the monsoon season.

Extreme Temperature

The highest and lowest minimum temperature recorded at Dehradun in three months of winter season during 1969 to 2007 has been presented in Table 1. The highest minimum temperature of 15.3°C was recorded on February 2, 1976 and lowest of -2.5°C on January 6, 2007 followed by -2°C on February 9, 1974. The standard deviation and coefficient of variability were observed lowest in the month of December (0.85) and February (17.15 per cent) respectively. On the other hand, the highest standard deviation (1.02) and coefficient of variability (25.68 per cent) were observed during the month of January (Table 1).

The number of events with zero or negative values recorded at Dehradun have been presented in Table 2. The total number of events when minimum temperature recorded either zero or negative was counted as 52 out of total 3700 observations during 1967-2007 and the maximum number of such events (37) occurred in the month of January followed by December and February. The analysis demonstrated only 4 events when minimum temperature was recorded either zero or negative during the month of February. Maximum events with zero or negative values were recorded during the year 2007 on 11 occasions and followed by the year 1967, 1972 and 1973 on 6 occasions each year.

Departure of Minimum Temperature

The data on percentage number of cases of departure of minimum temperature from the normal values under different categories are presented in Table 3. The cases of nearly normal (+1.4 to -1.4 °C) minimum temperature were observed to be maximum in all the months varying from 39.1 per cent in February to 43.2 per cent in January and 50.7 per cent in December. It was followed by below normal category (-1.5 to -3.4 °C) in all the months representing the highest number of per cent cases during December (24.2 per cent), January (23.2 per cent) and February (20.5 per cent). Markedly, below normal minimum temperature (≤-5.5°C) was rare at Dehradun during 1967-2007 and maximum events of markedly below normal minimum temperature were observed during February (0.8 per cent)

Table 1
Dehradun: Extreme Values of Minimum Temperature (°C) (1967-2007)

Month	Highest			Lowest			Mean (T min °C)	SD	CV (%)
	Date	Year	Value	Date	Year	Value			
December	23	1988	11.6	31	2007	-1.1	4.4	0.85	19.26
January	1	1985	13.1	6	2007	-2.5	4.0	1.02	25.68
February	2	1976	15.3	9	1974	-2	5.9	1.01	17.15

Source: Compiled by Authors

Table 2
Dehradun: Number of Events with Zero or Negative Values of Minimum Temperatures (1967-2007

Years	December	January	February	Total
1967	-	6	-	6
1972	-	4	2	6
1973	6	-	-	6
1974	-	2	2	4
1976	1	-	-	1
1977	-	1	-	1
1983	1	-	-	1
1984	-	1	-	1
1988	-	2	-	2
1989	-	2	-	2
1990	-	1	-	1
1991	-	3	-	3
1992	-	1	-	1
1993	-	4	-	4
2000	-	1	-	1
2003	-	1	-	1
2007	3	8	-	11
Total (17)	**11**	**37**	**4**	**52**

Source: Compiled by Authors

and followed by January (0.1 per cent). Markedly, above normal (≥+5.5 °C) minimum temperature departure cases were found to be maximum in the month of January (3.5 per cent) followed by February and December.

Persistence in Minimum Temperature

Table 4 represents the percentage number of continuous days by which minimum temperature either did not change or rise or fall continuously. This analysis revealed that the persistence for all categories in all the months decreased with increase in number of days except the no change category. Changes that persisted for one day at Dehradun were found varying from 37.9 per cent in December to 47.2 per cent in January. About 44 per cent of total cases were observed for the changes lasting for one day and 26 per cent for two days when all the months were taken together. It is important to note that the changes were persistently lasting more than seven days for the category of no change at Dehradun while in respect of rise and fall categories, there were no major changes lasting for more than three days. Maximum occurrence of one day persistence was observed in the month of January (47.2 per cent) followed by February (46.2 per cent). Similarly, two days persistence was observed in the month of February (30.1 per cent) followed by January (27.6 per cent). The analysis of minimum temperature at Dehradun also revealed that continuous days ≥7 in no change category were observed to be maximum in the month of December (12.8 per cent) followed by January (5 per cent).

Table 3
Dehradun: Number of Cases (%) of Departure of Minimum Temperature from Normal (1967-2007)

Months	Nearly normal (+1.4 to -1.4 °C)	Above normal (+1.5 to+3.4 °C)	Appreciably above normal (+3.5 to +5.4 °C)	Markedly above normal (?+5.5 °C)	Below normal (-1.5 to -3.4 °C)	Appreciably below normal (-3.5 to -5.4 °C)	Markedly below normal (≤-5.5°C)
December	645 (50.7)	181 (14.2)	62 (4.9)	32 (2.5)	307 (24.2)	44 (3.5)	-
January	549 (43.2)	188 (14.8)	110 (8.7)	44 (3.5)	296 (23.2)	83 (6.5)	1 (0.1)
February	453 (39.1)	211 (18.2)	109 (9.4)	30 (2.6)	237 (20.5)	109 (9.4)	9 (0.8)

Source: Compiled by Authors

Table 4
Dehradun: Occurrence of Persistence in Minimum Temperature (1967-2007)

Months	Number of continuous days						
	1	2	3	4	5	6	≥7
			No change				
December	126 (9.9)	110 (8.7)	117 (9.2)	68 (5.4)	80 (6.3)	60 (4.7)	163 (12.8)
January	157 (12.3)	124 (9.8)	66 (5.2)	52 (4.0)	25 (2.0)	30 (2.4)	64 (5.0)
February	155 (13.4)	116 (10.0)	63 (5.4)	72 (6.2)	15 (1.3)	24 (2.1)	8 (0.7)
			Rise				
December	192 (15.1)	76 (6.0)	18 (1.4)	4 (0.3)	-	-	-
January	217 (17.1)	98 (7.7)	39 (3.1)	8 (0.6)	-	-	-
February	186 (16.1)	108 (9.3)	27 (2.3)	8 (0.7)	-	-	-
			Fall				
December	164 (12.9)	86 (6.8)	3 (0.2)	4 (0.3)	-	-	-
January	226 (17.8)	128 (10.1)	33 (2.6)	4 (0.3)	-	-	-
February	194 (16.8)	124 (10.7)	45 (3.9)	8 (0.7)	5 (0.4)	-	-
			Total				
December	482 (37.9)	272 (21.4)	138 (10.9)	76 (6.0)	80 (6.3)	60 (4.7)	163 (12.8)
January	600 (47.2)	350 (27.6)	138 (10.9)	64 (4.9)	25 (2.0)	30 (2.4)	64 (5.0)
February	535 (46.2)	348 (30.1)	135 (11.6)	88 (7.6)	20 (1.7)	24 (2.1)	8 (0.7)

(Figures in the parenthesis indicate % occurrence of persistence in minimum temperature)
Source: Compiled by Authors

Table 5
Dehradun: Frequency of Cold Waves (1967-2007)

Month	Moderate	Severe	Total
December	4	-	4
January	6	1	7
February	-	4	4
Total	**10**	**5**	**15**

Source: Compiled by Authors

Table 6
Dehradun: Frost Severity Index (1967-2007)

Year	December	January	February	Decadal
1967-1976	11.2	12.9	7.01	31.1
1977-1986	-	-	-	-
1987-1996	-	-	5.9	5.9
1997-2007	9.6	11.2	-	20.8

Source: Compiled by Authors

Frequency of Cold Waves

The incidence of moderate and severe cold waves during the months of December, January and February has been highlighted in Table 5. The maximum numbers of cold waves were recorded in the month of January (7) where 6 and 1 numbers were calculated for moderate and severe cold waves, respectively. Severe cold waves at Dehradun were restricted to the months of January and February during 1967-2007, whereas month of February experienced the maximum number of severe cold waves. However, maximum number of moderate cold waves occurred in the month of January and December.

Frost Severity Index

Frost hazards occur when the minimum temperature falls below freezing point, which destroys standing crops. Frost risk is a topic of great interest in Doon Valley, a region known for orchards. Table 6 shows the mean frost severity index at Dehradun for the months of December, January and February and its average over the selected decades. The time series did not show a clear trend, 1977-86 had the lowest index of the entire period while the 1967-76 decade has the highest frost severity index followed by 1997-2007. Analysis on frost severity index revealed that month of January is very crucial for orchards and crops in Doon valley. Therefore, timely interventions need to be undertaken on behalf of the farmers to counteract the frost severity in the region.

Conclusion

The hydrological response and crop productivity of an area depends on various climatic variables, in particular temperature and rainfall. Global warming is likely to have significant impacts on the hydrological cycle, which in turn will affect water resources systems and crop productivity. An understanding of trends and the magnitude of variations due to climatic changes would provide useful information for the planning, development and management of water resources and agriculture. The present study dealt with the determination of trend and the magnitude of changes in seasonal and annual minimum temperatures at Dehradun. The study has confirmed that Doon Valley has warmed at night during the last four decades. The analysis of minimum temperature showed an increasing trend both seasonally and annually at Dehradun. Warming effect appeared more pronounced during summers and winters. The increase in magnitude of minimum temperature for summer season was observed to be 1.70°C/100 year followed by 1.46°C/100 year for the winter season at Dehradun. Moreover, markedly below normal minimum temperature were found to be rare at Dehradun. Persistence in minimum temperature for one day was found to be maximum for the month of January. It is considerable that the increase in night temperature in Doon Valley is not a healthy signature for crop production and water resources in the region. However, the results obtained in the present study are based on the data available for 41 years and it is understood that a long term data would provide a better picture of such climatic variations with time. Finally, to understand the climatic variations in totality, it is suggested that similar analysis is urgently needed to examine the trend of other climatological variables at Dehradun.

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