Climatic evidence of human onslaught in western Himalaya, India

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ABSTRACT

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Twentieth century surface temperature records from Dehradun, Mukteswar and Shimla in western Himalaya show increase in maximum and minimum temperatures up to 1950s. During the later part of the 20th century, this trend in maximum temperature relatively increased; however, the minimum temperatures showed rapid cooling. This cooling trend in minimum temperature dampened the warming impact of maximum temperature during the late 20th century. Large-scale deforestation and land degradation are attributed to be responsible for such anomalies. The increased rate of warming in maximum temperature and cooling in minimum temperature resulting into increase in Daily Temperature Range (DTR) could be taken as a measure of human pressure on the fragile ecosystem in western Himalaya.

Key-words: Temperature, daily temperature range (DTR), land degradation, western Himalaya, India.

INTRODUCTION

Instrumental records of recent climate show that global mean temperature has increased by 0.6±0.2 °C over the last century (Jones & Moberg 2003). Increase in both maximum and minimum temperatures, latter at relatively higher rate, is largely responsible for such warming (Jin & Dickinson 2002). However, contrary to this the mean temperature records from western Himalayan region do not show warming during the latter part of the 20th century. Nonetheless, rapid contraction of glaciers (Dhobal et al. 2004) and migration of certain tree line plant species to upper elevations in western Himalaya (Dubey et al. 2003) provide unambiguous evidence of significant climatic warming. Detailed analyses of maximum and minimum temperature data of Dehradun, Mukteswar, and Shimla in western Himalaya and possible causes of accelerated decrease in minimum temperature resulting into decrease in mean temperature during the latter part of the 20th century have been discussed in the preset paper.

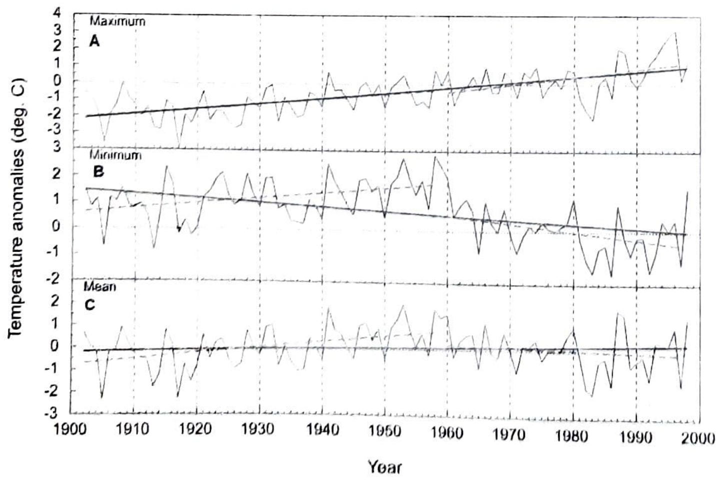
DATA AND METHODS

The instrumental temperature (maximum and minimum) records for Dehradun, Mukteswar, and Shimla were obtained from India Meteorological Department, Pune. The above three stations were chosen for analyses as maximum and minimum temperature records span over the entire 20th century. The mean monthly temperature records were converted into anomalies relative to 1961-1990 mean. For the existence of strong coherence among temperature of these stations, shown by high correlations, mean maximum and minimum temperature series were developed by merging the temperature anomaly data of above stations. Mean maximum and minimum temperature series developed were converted into annual (January-December) means. Correlation analyses among temperature data of stations were performed in two sub periods, 1902-1959 and 1960-1998 to see any change in temporal relationship during the 20th century. The above two sub-periods were chosen due to the presence of diverging trends in minimum temperature series in two sub-periods. Trends in maximum, minimum and mean temperature series were calculated using linear regression and significance level tested using student's t-test.

RESULTS AND DISCUSSION

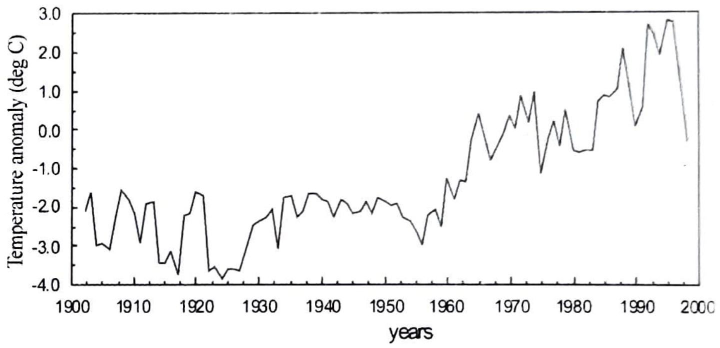
The mean maximum annual temperature of Dehradun, Mukteswar and Shimla showed high correlations in two sub-periods (1902-1959, r= 0.61-0.81; 1960-1998, r=0.72-0.84). However, in case of mean minimum annual temperature the correlations weakened during second sub-period (1902-1959, r= 0.61-0.71; 1960-1998, r=0.19-0.33). Drastic decrease in correlations among three station's minimum temperature during second sub-period shows that night temperatures are much influenced by local site factors. The correlations in case of mean annual temperature series were also relatively weaker in the second sub-period (1902-1959, r= 0.78-0.88; 1960-1998, r=0.47-0.76).

The trend analyses in maximum temperature series (1902-1998) showed increase in temperature at the rate of+3.2°C/100 years (p= 0.0001), being relatively higher in second sub period (+4.4 °C/100 years; p= 0.004) compared to the first (+3°C/100 years; p=0.0001) (figure 1A). The mean minimum temperature series showed cooling trend in the 20th century (-1.5°C/100 years; p=0.0001), however, the minimum temperatures increased during the first sub-period (+2°C/100 years; p=0.001) and decreased



Text-figure 1. Annual temperature variations over the western Himalaya (observational data). The straight lines represent the linear trend (continuous lines: trend for 1901 to 1998, broken lines: trends for 1901 to 1959 and 1960 to 1998 respectively); (A) Maximum temperature; (B) Minimum temperature; (C) Mean temperature.

rapidly during the second sub-period (-2.9°C/100 years; p=0.02) (figure 1B). The mean temperature series (1902-1998) showed warming (+0.51°C/100 years; p=0.13) with higher rate in first sub-period (+2.7°C/100 years; p=0.0001), whereas cooling in second sub-period (-0.96°C/100 years; p=0.47) (figure 1C). The cooling in mean temperature during the second sub-period, though not significant, is largely due to the accelerated cooling in minimum temperature.



Text-figure 2. Annual variation in daily temperature range (DTR) during the observation period (1901-1998).

The daily temperature range (DTR) in western Himalayan region increased (figure 2) in the first sub-period largely due to rise in maximum temperature at higher rate compared to the rate in minimum temperature and during the second sub-period due to accelerated cooling in minimum temperature. Previous study also showed that increase in DTR in northwest India has been largely due to decrease in minimum temperatures (Rupa Kumar et al. 1994). However, global temperature records, contrary to those observed in western Himalaya show that DTR has decreased over large parts of the earth due to higher rate of rise in minimum temperature than maximum temperature (Easterling et al. 1997, Dai et al. 2001). Possible reasons for higher rate of warming in maximum temperature and abrupt cooling in minimum temperature in western Himalaya during the second sub-period are discussed below.

The human population in western Himalayan states has increased by around three times in last fifty years of the 20th century (Anonymous 2001). To meet the needs of growing population agriculture has expanded in forest areas. One case study in Garhawal region of western Himalaya showed that 50% of the agriculture land expansion during 1963-1993 took in forest area (Sen et al. 2002). At lower elevations around habitations the large canopy oaks known to promote soil water infiltration have been heavily degraded for their excessive use as fodder and fuel wood needs (Anonymous 2000). The soil water infiltration is greatly reduced due to the loss of forest cover and increased run off (Negi 2002). The studies have shown that forested sites have colder average temperature relative to the cleared sites (Meher-Homji 1991, Lewis 1998). The most important cause for this is the amount of heat required for evapotranspiration in a forest, which is about 10% of the net radiative heat flux reaching at the ground surface (Lewis 1998). In the absence of forests this amount of surplus heat absorbed by ground increases the surface temperature. Besides this, the higher rate of warming in maximum temperature could also be due to positive feedback of change in surface albedo due to the retreating glaciers in western Himalaya.

Increased population and grazing pressure coupled with the developmental activities like construction of roads and hydroelectric power projects leading to large-scale deforestation have made the slopes prone to soil erosion. Increased population pressure in recent times has led to the increased use of steep slopes for agriculture causing soil erosion, landslides, and moisture deficiency in dry periods (Rautela et al. 2002). On naked slopes, the rainwater gushes down the slopes unimpeded at great speed and carries with it large quantities of soil and other loose material. Most of the water flows away during the rainy periods with the result that on the one hand floods are more frequent and more severe and, on the other, little water is available during the dry periods. Ground water supplies are also reduced as much less water is absorbed in the soil than before. Degradation of soil due to erosion has led to increase in barren land from 3.76% of total geographic area in 1966 to 5.68% in 1991 in Himachal Pradesh, western Himalaya (Bhati & Zingel 1997). Daytime warming of barren slopes followed by rapid cooling of moisture deficient low thermal inertia soils by terrestrial radiation loss at night increases the diurnal temperature range. The decrease in correlations in minimum temperatures during the second sub-period indicates that the degree of night cooling is largely dependent on local site conditions, i.e., degree of deforestation and land degradation.

Precipitation records for Shimla show slight decrease (25.5 cm/100 years) during the 20th century (Borgaonkar et al. 1996). Such precipitation trends for Dehradun and Mukteswar records could not be calculated due to presence of data gaps. Due to the existence of strong spatial heterogeneity in precipitation in the Himalayan region (Yadav & Singh 2002, Yadav et al. 2004) the missing precipitation values could not be estimated. Though some reduction in soil moisture during the 20th century could be attributed to decrease in precipitation trend as indicated in records from Shimla, no abrupt decrease in precipitation similar to minimum temperature records during the latter part of the 20th century is noticeable. This indicates that decrease in precipitation in no way is related to abrupt decrease in minimum temperatures since 1960.

CONCLUSION

The temperature records for Dehradun, Mukteswar, and Shimla show that the maximum temperatures increased at higher rate during the latter part of the 20th century relative to the early part of the 20th century. However, contrary to this minimum temperature decreased at accelerated rate since 1960s. Deforestation and positive feedback of changes in land surface albedo due to added land areas, vacated by the recession of glaciers, could be responsible for the higher rate of increase in maximum temperature in addition to the natural course of change in temperature, if any. However, rapid decrease in minimum temperature since 1960s could be attributed to large-scale land degradation leading to soil moisture deficit. Day warming and night cooling resulting into accelerated increase in the DTR could be taken as a measure of human pressure on the fragile western Himalayan ecosystem.

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