J. Ind. Geophys. Union (January 2016)
v.20, no.1, pp: 123-127

Trend analysis and extreme events of temperature during post monsoon and winter seasons over Varanasi, Uttar Pradesh, India

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ABSTRACT

The cold wave can be described as a rapid fall in temperature that affects agriculture, industries, commerce and other social activities. The aim of the present study is to find out the inter-annual and intra-seasonal variability of temperature for the post monsoon and winter seasons. The frequency of cold wave and severe cold wave has also been studied for four decades from 1971-2010. Frequency of cold wave and severe cold wave days for the four decades for the month of January is the highest among all the months. The number of cold wave events was more during post monsoon season than winter season and opposite in the case of severe cold wave events.

Key Words: Extreme temperature,Cold wave, severe cold wave, trend analysis, decadal.

INTRODUCTION

Varanasi is situated in the northern part of India, located on the banks of the holy river, Ganges. During summer, weather can be as hot as 45° C with high humidity as Varanasi (25°20'N, 83°0'E) lies at the Tropic of cancer (Bhatla and Tripathi, 2014). Torrential rains and high humidity accompany the monsoons that usually occur in late June or early July for about two months. The winters are pleasant here and temperature dips down to about 7°C.In January, 13, 1989 temperature even reduced to 2°C. Extreme weather that lies outside normal range can be destructive. A particular combination of atmospheric conditions can lead to destructive and extreme ranges of one or more weather elements. These conditions can include a storm, excess precipitation or droughts with very high levels of sunshine duration and temperatures.

The temperature of air plays an important role and is recognized as the state of climate globally because of its ability to prevent the energy exchange process over the surface of earth with reasonable accuracy (Vinnikov et al., 1990; Thapliyal and Kulshrestha, 1991).Studying Secular trends in the annual mean maximum and minimum temperatures over India, Pramanik and Jagannathan (1954) concluded that there is no general tendency for an increase or decrease in these temperatures. Jagannathan and Parathasarathy (1973) analysed the time series of mean annual temperatures over a set of eight Indian stations and reported an increasing trend in the mean annual temperatures of Kolkata, Mumbai, Bangalore and Allahabad, and a decreasing trend at Cochin. On decadal trends in climate over India, Srivastava et al. (1992) indicated that the diurnal asymmetry of temperature trends over India is quite different from that observed over many other parts of the globe. Rupa Kumar et al. (1994) have shown that the countrywide mean maximum temperature increased by 0.6°C and the mean minimum temperature decreased by 0.1°C and concluded that most of the increases in mean surface air temperature over India are due to the increase in daytime temperature. Sinha Ray and De (2003) have summarized the existing information on climate change and on trends in the occurrence of extreme events over India. Rainfall and surface pressure averaged over the country as a whole shows no significant trend .However, an increasing trend of the order of 0.35°C over the last 100 years has been found in temperature records. In contrast, extreme maximum and minimum temperature shows an increasing trend in the south and a decreasing trend in the north of India. Kothawale (2005) examined the extreme temperature variations in India for the period 1970-2002 and observed that the number of hot days is maximum over central parts and minimum along west coast of India during the summer season. Arora et al (2005) analysed the trends in temperature time series of 125 stations distributed over the whole of India. De et al (2005a) studied the spatial pattern and variation of heat and cold wave with special reference to their impact. De et al. (2005b) studied extreme weather events that occurred in India during the 1991-2004. The maximum number of cold waves occurred in Jammu & Kashmir followed by Rajasthan and Uttar Pradesh during 1901-1999.

The cold wave and severe cold wave is a weather phenomenon that is marked by cooling of the air, or the invasion of very cold air, over a large area. It can also be described as a rapid fall in temperature that affects agriculture, industries, commerce and other social activities. Cold waves that bring unexpected freezes and frosts during the growing season in mid-latitude zones can kill plants during the early and most vulnerable stages of growth, resulting in crop failure as plants die before they

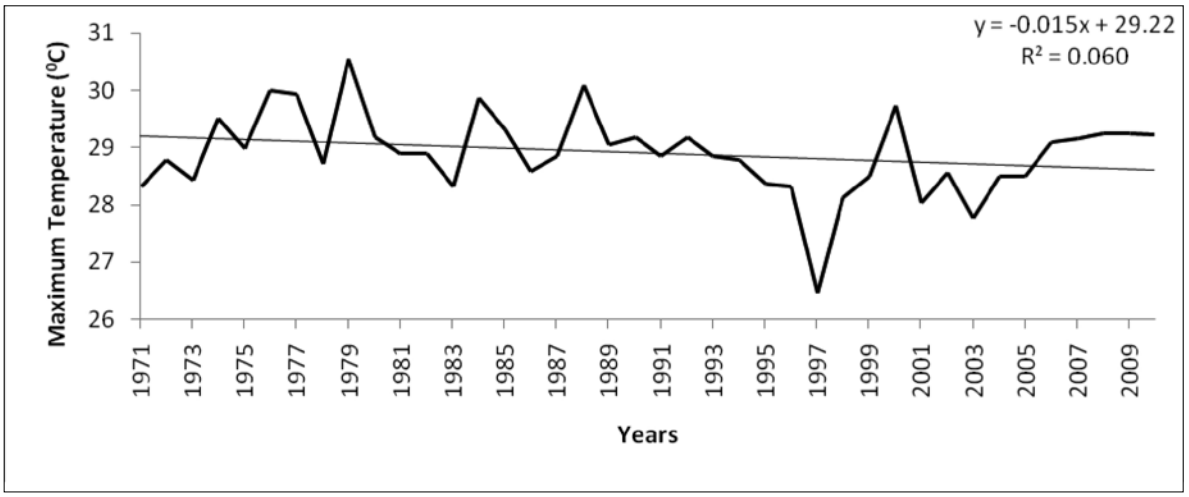

Figure 1. Variation of mean maximum temperature during post monsoon season for the 1971-2010.

can be harvested economically. Such cold waves have caused famines. The northern parts of India, especially the Hilly regions and the adjoining plains are affected by cold/severe cold waves. In the present study, inter-annual and intra-seasonal variability of temperature have been analysed for the post monsoon and winter seasons. The study of cold wave and severe cold wave has also been done for the period of 1971-2010 and also for the four decades viz. 1971-1980, 1981-1990, 1991-2000 and 2001-2010.

DATA AND METHODOLOGY

The daily temperature data of Varanasi for the post and winter monsoon season (October, November, December, January and February months) provided by India meteorological department (IMD) for the period 1971-2010 was used for the present study. From each of these months data of mean monthly maximum and minimum temperatures, decadal mean maximum and minimum temperature during post monsoon and winter season are taken for analysis. In addition, frequency of cold and severe cold wave has been taken in the same manner.

Frequencies of extreme temperature events were calculated for two criteria, namely, cold and severe cold wave days as per IMD criteria (http://www.imd.gov.in/doc/termglossary.pdf).

a. When normal minimum temperature is equal to 10°C or more
   i. Cold Wave Departure from normal is -5°C to -6°C.
   ii. Severe Cold Wave Departure from normal is -7°C or less.
b. When normal minimum temperature is less than 10°C
   i. Cold Wave Departure from normal is -4°C to -5°C.
   ii. Severe Cold Wave Departure from normal is -6°C or less.

However, this criterion is not applicable for those stations whose normal minimum temperature is below 0°C.

RESULTS AND DISCUSSION:

Mean maximum & minimum temperature during post monsoon and winter season:

Figure.1 represents interannual variation of mean maximum temperature during post monsoon season, for 1971-2010 over Varanasi. The highest mean maximum temperature in the year 1979 was 30.6^{0}C, while lowest mean maximum temperature of 26.5^{0}C was observed in the year 1997. From 1971 to 1995, there was a minor fluctuation of temperature, approximately between 29^{0}C to 31^{0}C.Thereafter, fall of mean maximum temperature of about 2^{0}C was observed during 1997. A rise of 3.5^{0}C in mean maximum temperature is found from the year 1997 to 2000. There is small declining trend of mean maximum temperature observed during post monsoon season from 1971-2010. The variation of mean maximum temperature for winter season over Varanasi from 1971-2010 is shown in Figure.2. The highest mean maximum temperature observed was 27.6^{0}C in the year of 2006 and lowest mean maximum temperature was 21.6^{0}C in 2003. A rapid increase of about 6^{0}C was observed in mean maximum temperature from 2003 to 2005. Minimum fluctuation of about 1^{0}C was seen during 1985 to 1995.This did not show any pattern/trend.

Figure.3 shows the variation of mean minimum temperature of post monsoon season from 1971 to 2010. It shows larger variations of temperature over 40 years (1971-2010). Lowest mean minimum temperature of 11.6^{0}C was observed in the year 1991. From 1979 to 1991, a gradual fall in mean minimum temperature of about 6^{0}C was observed. A major rise of about 4^{0}C mean minimum temperature was observed on two occasions, from 1991 to

Figure 2. Variation of mean maximum temperature during winter season for the 1971-2010.

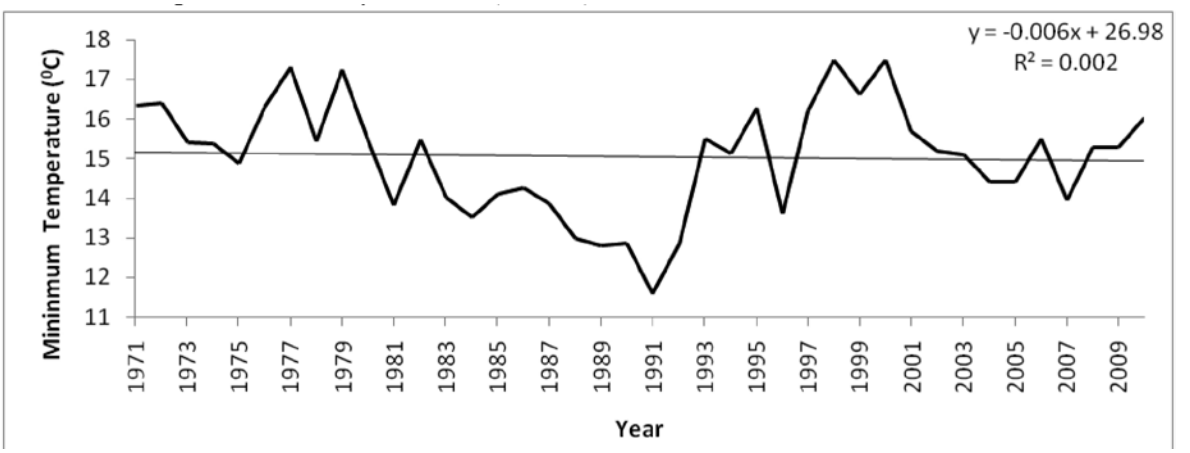

Figure 3. Variation of mean minimum temperature during post monsoon season for the 1971-2010.

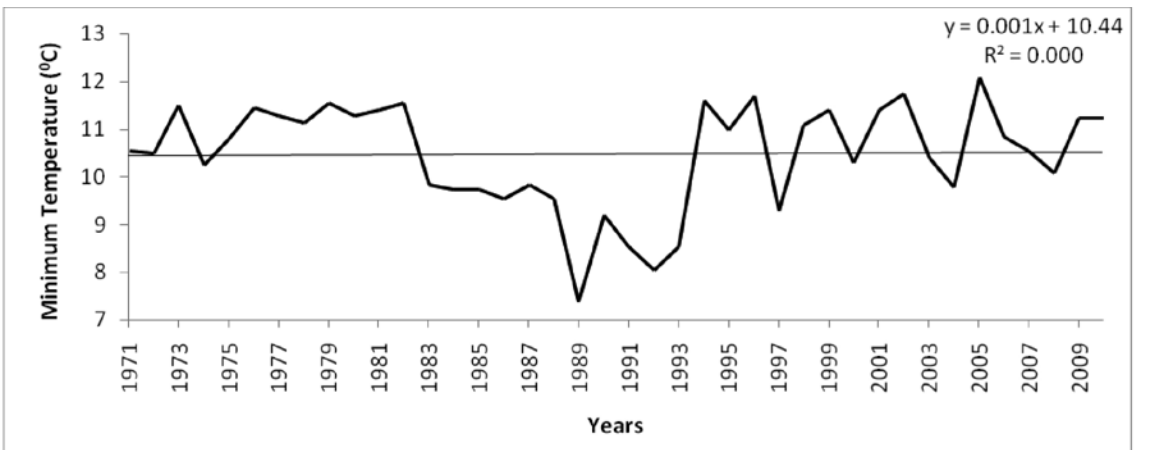

Figure 4. Variation of mean minimum temperature during winter season for the 1971-2010.

1993 and 1996 to 1998. The mean minimum temperature of winter season from 1971-2010 is shown in Figure.4. The lowest mean minimum temperature was observed in the year 1989 (7.4^{0}C) and the highest mean minimum temperature in the year 2005 (12.1^{0}C).

Frequency of cold wave and severe cold wave:

Table 1 shows that the occurrence of cold wave days for the months of October to February, post monsoon season and winter season for the four decades viz. 1971-1980, 1981-

Table 1. Frequency of cold wave days for the months of October to November, Post monsoon season and Winter season for the four Decades 1971-1980, 1981-1990, 1991-2000, 2001-2010 and also for the whole period 1971-2010.

Duration	October	November	December	Post Monsoon Season	January	February	Winter Season
1971-1980	0	0	3	3	0	4	4
1981-1990	16	1	10	27	20	3	23
1991-2000	10	10	9	29	26	2	28
2001-2010	3	4	6	13	10	4	14
1971-2010	29	15	28	72	56	13	69

Table 2. Frequency of severe cold wave days for the months of October to November, Post monsoon season and Winter season for the four Decades 1971-1980, 1981-1990, 1991-2000, 2001-2010 and also for the whole period 1971-2010.

Duration	October	November	December	Post Monsoon Season	January	February	Winter Season
1971-1980	0	0	0	0	0	0	0
1981-1990	0	0	1	1	10	4	14
1991-2000	2	0	0	2	8	0	8
2001-2010	0	0	0	0	4	0	4
1971-2010	2	0	1	3	22	4	26

1990, 1991-2000, 2001-2010 and also for the whole period 1971-2010. No cold wave was found in October during the decade 1971-1980, which abruptly increased in the next decade (i.e. 1981-1990) to the level of 16. Then again it gradually declined in next two decades. Also in the month of November, there was no significant cold wave during the first two decades (1971-1980, 1981-1990). An increase in cold wave was observed in next decade 1991-2000 .It again declined in recent decade (2001-2010). In December, less frequency of cold wave (3) is found during 1971-1980.It has shown an increasing trend in next two decades. Once again frequency of cold wave declined in recent decade. Occurrence of cold wave was not observed during the first decade, while the next two decades experienced an increase in the cold wave events in the month of January. However, the cold wave decreased significantly during the recent decade 2001-2010. A little variation of frequency of cold wave was found during all four decades in the month of February. The frequency of cold wave days was significant during the months of October, November, December and February, while January experienced the highest number of cold wave days for the period 1971-2010. Table 1 reveals that the lowest frequency in 1971-1980 in the post monsoon season with a magnitude of 3 has been followed by an abrupt increase in frequency to 27 in 1981-1990 and 29 in 1991-2000.Once again a falling trend of 13 has been noticed in recent decade . There is a little variation in the frequency of cold wave in winter season. Thus, the above details clearly show that during the decade 1981-1990, the rise in number of cold and severe cold wave days resulted in decrease of minimum and maximum temperatures.

Table 2 shows the occurrence of severe cold wave days for each month of post monsoon season and winter season during all four decades (1971-2010). The frequency of severe cold wave days is significant (26) in the month of January while there was no severe cold wave in the month of November for the whole period 1971-2010. It also shows that severe cold wave was observed during the decade 1991-2000, while in the other 3 decades (1971-1980, 1991-2000, and 2001-2010), there was no severe cold wave in October. In the month of December and February severe cold wave events occurred during the decade of 1981-1990 with a frequency of (1) in December and (4) in February, while no severe cold wave events occurred in the other three decades (1971-1980, 1991-2000, 2001-2010). No frequency of cold wave was observed during the first decade 1971-1980, while next two decades experienced increase in the cold wave events in the month of January. The Table 2 shows that only two decades 1981-1990 having frequency of 1 and 1991-2000 with a frequency of 2 reported severe cold waves in the post monsoon season. However, in winter season, no event was observed in decades of 1971-1980, 1991-2000, and 2001-2010 while in decade of 1981-1990, severe cold wave occurred with a frequency of 4.

CONCLUSIONS

The following conclusions are drawn:

- Mean maximum temperature of post monsoon season during 40 years (1971-2010) shows a small decreasing trend in temperature, while winter season does not show any trend of temperature.

- A large fluctuation in the seasonal mean minimum temperature was observed during the entire period of study over Varanasi in both post monsoon and winter seasons ,with no remarkable trend.
- Frequency of cold wave and severe cold wave days was maximum for the month of January, among all the months from October to February. In the post monsoon season, frequency of cold waves was minimum in the decade 1971-1980. The next two decades (1981-1990 and 1991-2000) showed maximum frequency followed by a decrease again in frequency in the latest decade i.e. 2001-2010.
- Frequency of cold wave was large during 1981-1990 and 1991-2000 ,decreasing thereafter significantly in the recent decade 2001-2010 in all the months and also in post monsoon season.
- The number of cold wave events was more during post monsoon season than winter season and in the case of severe cold wave events, it was reverse.

The variations in results clearly show the importance of micro scale studies i.e. how local variations contribute to climate change. Therefore, in addition to large scale circulation, regional and local changes also play an important role in influencing the climate in a given area.

ACKNOWLEDGEMENTS

The authors wish to express sincere thanks to India Meteorological Department for providing the necessary data. One of the authors (AT) acknowledges with thanks the financial assistance in the form of a fellowship provided by the University Grants Commission for research. Anonymous reviewers and Editor of the journal significantly helped in enhancing quality of the manuscript.

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