Long term Variability and Trends of Significant Climatic Events at Lucknow District of Uttar Pradesh

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ABSTRACT

Variability in climatic events like heat waves, cold waves, frost, heavy precipitation and droughts provide evidence of climate change. Occurrence of these events and trend analysis were done by utilizing daily maximum temperature, minimum temperature and rainfall data for Lucknow district which lies in central agro climatic zone of Uttar Pradesh for the period of 37 years (1975-2011) with the IMD criteria. The maximum number of heat waves was observed in the year 1995 (22) and minimum in the years 1989 and 2006 (1). The maximum number of severe heat waves was observed in the year 1987 (11). The month June has been found the most susceptible for occurrence of heat waves. On an average 4 heat waves could be expected in the month of June. An increasing trend of heat waves was noticed and pointed towards rising of maximum temperature over the region. Maximum number of cold waves was observed in the year 1976-77 (28) out of which 12 events were severe. On an average 4 cold waves were observed per year during the period 1975-2010. The trend analysis revealed that cold waves are becoming less frequent. On an average, 2 frost events per year could be expected. The month January was found to be more susceptible to frost condition. The decreasing trend of frost events was noticed at annual time scale. Maximum occurrence of heavy rainfall events was observed in the year 1980 (6). Annually, 2 heavy rainfall events could be expected. A decreasing trend of heavy rainfall events were noticed over annual time scale. The meteorological droughts of different intensities viz. mild, moderate and severe showed that central zone of Uttar Pradesh is prone to mild to moderate type of drought.

Keywords: *Climate change, cold wave, drought, frost, heat wave, heavy rainfall.*

1. Introduction

Indian agriculture is facing challenges due to several factors such as increased competition for land, water and increasing climatic variability. The climatic variability is associated with global warming will result in considerable seasonal and annual fluctuations in food production. Extreme fluctuations in weather beyond certain tolerable limits during critical phases of crop development can have a significant impact on yield. Droughts, heavy precipitation events, hot and cold extremes, heat waves and cold waves and frost are known to negatively impact agricultural production and farmer's livelihood. The excessive positive departure from the normal maximum temperature results in heat wave during summer months. The rising maximum temperature during the pre-monsoon months often persists till June and sometimes in July over the northern parts of the country. On the other hand, temperature can drop down markedly below normal for a short period and chance of occurrence of extreme events like cold waves and frost increases in northern parts of India during rabi season. The maximum number of occurrence of cold waves has been reported in Jammu & Kashmir followed by Rajasthan and Uttar Pradesh (De et al., 2005). Similarly, droughts directly damage crops and degrade the land and desiccate the underground reservoir. Malnutrition and starvation are other impacts. On the other hand, significantly heavy rains are responsible for damage of standing crops and reduced production.

2. Materials and Methodology

The long term variability study of climatic events of heat wave, cold wave, frost, heavy to very heavy rainfall and drought was done by utilizing daily maximum temperature, minimum temperature and rainfall data of Lucknow district for the period of 37 years (1975-2011) which was collected from Agrimet Division, India Meteorological Department (IMD), Pune. IMD defines heat wave based on departure of maximum temperature from its normal. If the normal maximum temperature of plain area is > 40°C then departure of temperature 4 to 5°C above normal is called heat wave and departure of

temperature? 6°C above normal is called as severe heat wave. If the normal maximum temperature of plain area is? 40°C, departure of temperature 5 to 6°C above normal is called heat wave and departure of temperature? 7°C above normal is called as severe heat wave. Similarly if normal minimum temperature of an area is <10°C then departure of temperature -4 to -5°C from its normal is called as cold wave and departure of temperature - 6°C or less from its normal temperature is called as severe cold wave. Similarly if normal minimum temperature of an area is ?10°C then departure of temperature -5 to -6°C from its normal is called as cold wave and departure of - 7°C from its normal temperature is called as severe cold wave.

Frost generally occurs when the grass minimum temperature falls to nearly 0°C. It has been found that on an average, grass minimum temperature reaches 0°C when minimum temperature in the screen is 3.5°C. Therefore a day having minimum temperature ?3.5°C has been categorized as frost day (Bhan and Attri, 2007). This relationship has been used for computation of frost events.

Heavy and very heavy rainfall events were calculated on the basis on amount of rainfall received in a day. The rainfall amounts received in a day is between 64.5 to 124.4 mm is called as heavy rainfall and amount received in a day is between 124.5 to 244.4 mm is called as very heavy rainfall. Based on annual rainfall deficit from normal, years were classified as mild, moderate and severe drought years when rainfall deficit was upto 25, 26-50 and > 50 per cent, respectively.

3. Results and Discussion

3.1 Heat waves

The data on heat wave and severe heat wave conditions are presented in Table 1. On an average, 10 heat wave events were observed annually during the period 1975-2010. The study revealed that maximum events of heat wave (22) were observed in the year 1995 out of which 9 events were observed as severe heat waves. A considerable higher numbers of heat wave events were also observed in the years of 1975, 1984, 1985, 1999, 2005 and 2010. On an average, maximum heat wave events were found to have occurred in the month of June. Around 4 heat waves could be expected in the month of June. The trends of occurrence of heat waves are presented in the Fig.1. An increasing trend of heat wave was noticed at annual time scale because of continuous rising of maximum temperature over north India (Pant, 2003).

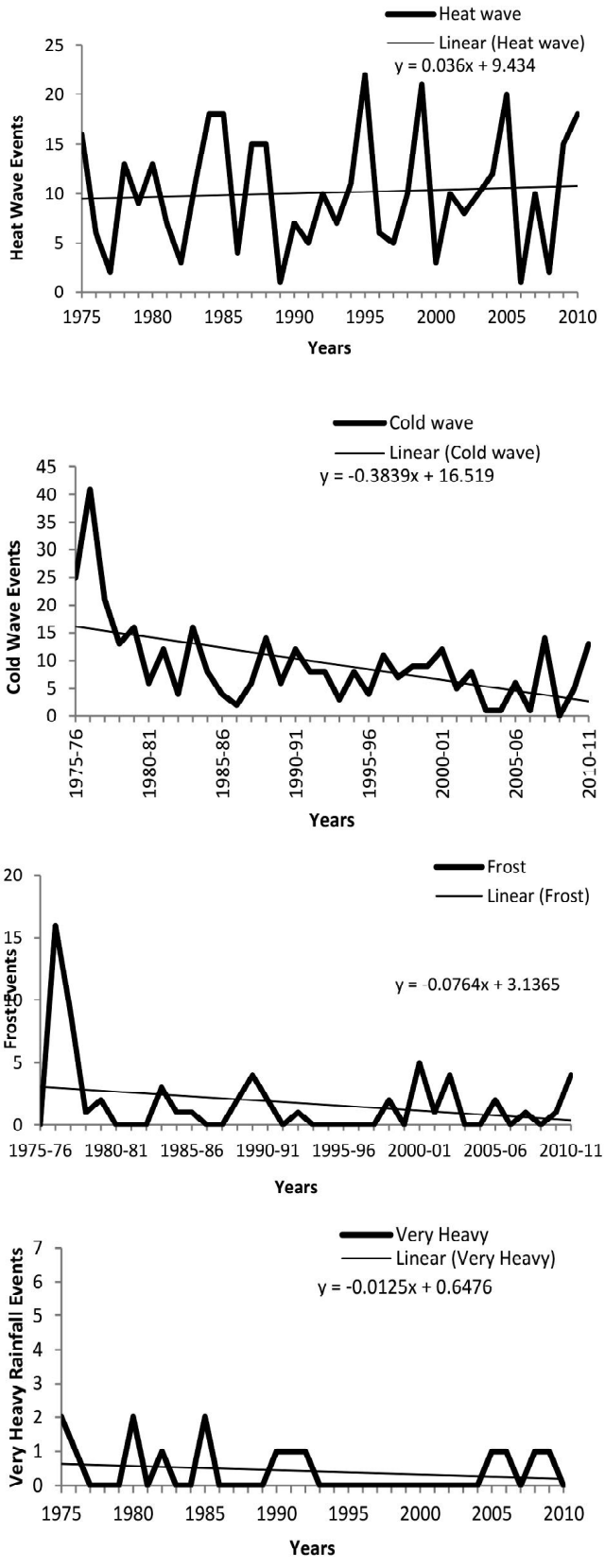

Fig.1 Trends of heat wave, cold wave, frost and very heavy rainfall events at Lucknow (1975-2011).

TABLE 1

Occurrence of heat wave and severe heat wave events at Lucknow (1975- 2010).

	April		May		June		Total	
Years	**Heat wave**	**Severe heat wave**	**Heat wave**	**Severe heat wave**	**Heat wave**	**Severe heat wave**	**Heat wave**	**Severe heat wave**
1975	5	0	7	0	4	3	16	3
1976	0	0	0	0	6	3	6	3
1977	2	0	0	0	0	0	2	0
1978	1	0	10	5	2	0	13	5
1979	1	0	1	0	7	2	9	2
1980	7	1	6	1	0	0	13	2
1981	0	0	1	0	6	2	7	2
1982	0	0	0	0	3	0	3	0
1983	0	0	0	0	11	8	11	8
1984	6	0	12	3	0	0	18	3
1985	2	0	7	1	9	4	18	5
1986	0	0	0	0	4	2	4	2
1987	0	0	1	0	14	11	15	11
1988	5	0	10	5	0	0	15	5
1989	0	0	1	0	0	0	1	0
1990	1	0	0	0	6	0	7	0
1991	1	0	4	0	0	0	5	0
1992	0	0	1	0	9	2	10	2
1993	0	0	4	1	3	0	7	1
1994	0	0	5	2	6	0	11	2
1995	1	0	7	2	14	7	22	9
1996	0	0	6	0	0	0	6	0
1997	0	0	2	0	3	1	5	1
1998	0	0	5	0	5	0	10	0
1999	12	3	5	0	4	0	21	3
2000	2	0	1	0	0	0	3	0
2001	8	0	2	0	0	0	10	0
2002	4	0	4	0	0	0	8	0
2003	5	0	2	0	3	0	10	0
2004	5	0	6	0	1	1	12	1
2005	1	0	4	0	15	10	20	10
2006	1	0	0	0	0	0	1	0
2007	2	0	2	0	6	0	10	0
2008	2	0	0	0	0	0	2	0
2009	3	0	1	0	11	6	15	6
2010	10	2	3	1	5	0	18	3
Average	**2.4**	**0.2**	**3.3**	**0.6**	**4.4**	**1.7**	**10.1**	**2.5**

3.2 Cold waves

The data on cold wave and severe cold wave conditions are presented in Table 2. About 4 average annual cold wave events were observed during the period 1975-1976 to 2010-11. The study revealed that maximum events of cold wave i.e. 28 were observed during 1976-77 and out of which 12 events were severe cold waves. It was also observed that January and February months are more susceptible to cold wave conditions. The trends of occurrence of cold waves are presented in the Fig.1. The trend analysis revealed that cold waves are becoming less frequent. This may be due to continuous rising of minimum temperature over region. In India, rising of minimum temperature during winter season were also reported by Rupa Kumar et al. (2002).

TABLE 2

Occurrence of cold wave and severe cold wave events at Lucknow (1975-76 to 2010-11).

	December		January		February		Total	
Years	**Cold wave**	**Severe cold wave**	**Cold wave**	**Severe cold wave**	**Cold wave**	**Severe cold wave**	**Cold wave**	**Severe cold wave**
1975-76	8	2	1	0	3	0	12	2
1976-77	12	6	11	4	5	2	28	12
1977-78	0	0	7	4	4	3	11	7
1978-79	3	1	0	0	2	0	5	1
1979-80	0	0	4	0	5	1	9	1
1980-81	0	0	0	0	0	0	0	0
1981-82	2	0	0	0	2	0	4	0
1982-83	0	0	0	0	0	0	0	0
1983-84	0	0	3	2	10	5	13	7
1984-85	1	0	0	0	2	1	3	1
1985-86	0	0	0	0	1	0	1	0
1986-87	0	0	0	0	0	0	0	0
1987-88	2	1	0	0	0	0	2	1
1988-89	0	0	2	1	3	0	5	1
1989-90	2	1	3	2	0	0	5	3
1990-91	0	0	1	0	0	0	1	0
1991-92	0	0	0	0	2	0	2	0
1992-93	0	0	2	0	2	1	4	1
1993-94	0	0	0	0	0	0	0	0
1994-95	2	0	0	0	1	0	3	0
1995-96	1	0	0	0	0	0	1	0
1996-97	3	0	0	0	1	0	4	0
1997-98	3	0	0	0	0	0	3	0
1998-99	0	0	2	0	1	0	3	0
1999-00	0	0	0	0	6	1	6	1
2000-01	0	0	4	1	1	0	5	1
2001-02	0	0	0	0	0	0	0	0
2002-03	0	0	3	3	0	0	3	3
2003-04	0	0	0	0	0	0	0	0
2004-05	0	0	0	0	0	0	0	0
2005-06	1	0	1	0	0	0	2	0
2006-07	0	0	0	0	0	0	0	0
2007-08	1	0	1	0	7	4	9	4
2008-09	0	0	0	0	0	0	0	0
2009-10	0	0	1	0	0	0	1	0
2010-11	0	0	3	2	1	0	4	2
Average	**1.1**	**0.3**	**1.4**	**0.5**	**1.6**	**0.5**	**4.1**	**1.3**

3.3 Frost

The data on frost events and its trends are presented in the Table 3 and Fig.1. Annually about 2 frost events could be expected during the period 1975-1976 to 2010-11. The study revealed that maximum events of frost i.e. 16 were observed during the period 1976-77. However, considerable higher frost events were also observed during 1977-78 and 2000-01. The month January is most susceptible for frost conditions than other months. The decreasing trends of frost events were observed at annual time scale. This may be due to continuous rising of minimum temperature in winter season over region (Rupa Kumar et al., 2002).

TABLE 3
Occurrence of frost events at Lucknow (1975-76 to 2010-11).

Years	December	January	February	Total
1975-76	0	0	0	0
1976-77	5	9	2	16
1977-78	0	8	1	9
1978-79	1	0	0	1
1979-80	0	2	0	2
1980-81	0	0	0	0
1981-82	0	0	0	0
1982-83	0	0	0	0
1983-84	0	2	1	3
1984-85	1	0	0	1
1985-86	0	1	0	1
1986-87	0	0	0	0
1987-88	0	0	0	0
1988-89	0	2	0	2
1989-90	1	3	0	4
1990-91	0	2	0	2
1991-92	0	0	0	0
1992-93	0	1	0	1
1993-94	0	0	0	0
1994-95	0	0	0	0
1995-96	0	0	0	0
1996-97	0	0	0	0
1997-98	0	0	0	0
1998-99	0	2	0	2
1999-00	0	0	0	0
2000-01	0	5	0	5
2001-02	0	1	0	1
2002-03	0	4	0	4
2003-04	0	0	0	0
2004-05	0	0	0	0
2005-06	0	2	0	2
2006-07	0	0	0	0
2007-08	0	0	1	1
2008-09	0	0	0	0
2009-10	0	1	0	1
2010-11	0	4	0	4
Average	**0.2**	**1.4**	**0.1**	**1.7**

3.4 Heavy and very heavy rainfall

The data on heavy and very heavy rainfall events during south west monsoon season and its trend are presented in the Table 4 and Fig. 1. The total number of heavy rainfall events was observed as 60 out of which 15 were observed as very heavy rainfall events during the period 1975-2010. Annually about 2 heavy rainfall events could be expected. In the year 1980, 6 heavy rainfall events were noticed out of which 2 events were observed as very heavy rainfall events. It was noticed that the years 1986, 1988 and 2008 experienced 4 heavy rainfall events. On the other hand 2 very heavy rainfall events were observed 1975, 1980 and 1985. The decreasing trends of very heavy rainfall events were observed at annual time scale.

TABLE 4

Occurrence of heavy to very heavy rainfall events at Lucknow (1975-2010)

	June		July		August		September		Total	
Years	**Heavy**	**Very Heavy**	**Heavy**	**Very Heavy**	**Heavy**	**Very Heavy**	**Heavy**	**Very Heavy**	**Heavy**	**Very Heavy**
1975	1	2	0	0	1	0	1	0	3	2
1976	0	1	0	0	2	0	0	0	2	1
1977	0	0	1	0	0	0	0	0	1	0
1978	0	0	1	0	1	0	1	0	3	0
1979	0	0	0	0	0	0	0	0	0	0
1980	1	0	2	0	2	1	1	1	6	2
1981	0	0	1	0	1	0	1	0	3	0
1982	0	0	0	0	0	0	2	1	2	1
1983	0	0	0	0	0	0	1	0	1	0
1984	0	0	0	0	0	0	0	0	0	0
1985	0	0	0	0	0	0	2	2	2	2
1986	2	0	2	0	0	0	0	0	4	0
1987	0	0	0	0	0	0	0	0	0	0
1988	0	0	2	0	2	0	0	0	4	0
1989	0	0	0	0	0	0	0	0	0	0
1990	0	0	1	1	0	0	0	0	1	1
1991	0	0	0	0	1	1	1	0	2	1
1992	0	0	0	0	0	0	0	1	0	1
1993	0	0	0	0	0	0	0	0	0	0
1994	0	0	1	0	0	0	0	0	1	0
1995	0	0	0	0	0	0	0	0	0	0
1996	0	0	0	0	0	0	0	0	0	0
1997	0	0	1	0	0	0	1	0	2	0
1998	0	0	0	0	0	0	0	0	0	0
1999	0	0	1	0	0	0	1	0	2	0
2000	0	0	1	0	1	0	0	0	2	0
2001	0	0	0	0	0	0	0	0	0	0
2002	0	0	1	0	0	0	2	0	3	0
2003	0	0	0	0	1	0	1	0	2	0
2004	0	0	0	0	0	0	1	0	1	0
2005	0	0	1	0	0	0	0	1	1	1
2006	1	0	1	1	0	0	0	0	2	1
2007	0	0	0	0	1	0	0	0	1	0
2008	0	0	3	0	1	0	0	1	4	1
2009	0	0	0	0	2	0	1	1	3	1
2010	0	0	2	0	0	0	0	0	2	0
Average	**0.1**	**0.1**	**0.6**	**0.1**	**0.4**	**0.1**	**0.5**	**0.2**	**1.7**	**0.4**

3.5 Drought occurrence and impact

The occurrence of meteorological drought of different intensities viz., mild, moderate and severe over a period of 1975-2010 was analysed and presented in the Table 5 and Fig. 2. The drought of different intensities showed that Lucknow district experienced 15 drought years out of which 3 (20%) mild, 11 (73%) moderate and 1 (7%) severe intensity of drought years were observed.

TABLE 5
Occurrence of drought with different intensity at Lucknow (1975-2010)

Category	Drought years	Rainfall Range (mm)
Mild	1994, 2002, 2007	756.2-763.2
Moderate	1977, 1979,1983, 1984, 1992, 1993, 1995, 1998, 1999, 2004, 2005	492.9-713.0
Severe	1987	410.4

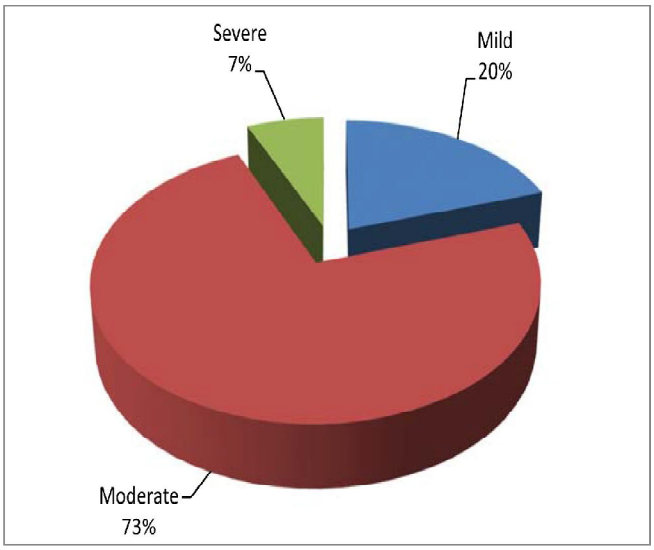

Fig.2 Meteorological drought intensities at Lucknow (1975-2010).

4 Recommendations

a) Adjustment of the cropping sequence and planting season with modification of crop management practices for heat wave conditions.

b) Changing the microclimate by irrigating and smoking the field at night during cold wave and frost occurrence.

c) Planning of watershed development which involves construction of structures like check dams, contour bunds, percolation tanks, development of rainwater harvesting and construction of wells alongwith in situ conservation of rainwater, contour cultivation, sowing on ridges.

d) The conjunctive use of surface and ground water resources in order to increase the production per unit of water.

e) Use of harvested rain water and ground water resources through micro-irrigation and other efficient water saving techniques for enhancing productivity. In addition, better irrigation scheduling can improve irrigation efficiency.

f) Drought-tolerant breeds of livestock and varieties of crops must be explored for resilience of farming systems.

g) Establishment of seed, fodder and feed bank for meeting immediate demand in drought prone areas.

h) Incorporation of agro-forestry, agri-horti systems to enhance perennial component of vegetation in farm lands.

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