Impact of heat waves over India

During the period March–July, spells of hot weather occasionally occur over certain parts of India. These spells are often seen to move from one region to another. Hence, this phenomenon is termed as a heat wave. Several deaths are reported when the heat waves become severe.

The discomfort due to the heat wave is different in different regions. In places where the normal temperature itself is high, people become adapted to that temperature. For the same temperature, people from colder regions often feel more discomfort compared to the people from the hotter regions. Considering these aspects, India Meteorological Department (IMD) has defined heat wave under two categories. The first category includes places where the normal maximum temperature is more than 40°C. In such regions if the day temperature exceeds by 3 to 4°C above the normal, it is said to be affected by a heat wave. Similarly, when the day temperature is 5°C or more than the normal, severe heat wave condition persists. The second category considers the regions where the normal maximum temperature is 40°C or less. In these areas, if the day temperature is 5–6°C above the normal, then the place is said to be affected by a moderate heat wave. A severe heat wave condition exists when the day temperature exceeds the normal maximum temperature over the place, by 6°C.

Prolonged severe heat wave condition may cause serious problems to water supply, cause moisture stress in the soil and adversely affect agriculture. When an area is affected by severe heat wave and also followed by delayed onset of monsoon, then the situation becomes more miserable for the inhabitants because of water scarcity and delay in sowing operations. The duration of the heat wave is in general 5 to 6 days but sometimes it may go up to 15 days. However, severe heat wave generally does not last for more than 4 to 5 days.

Data for the occurrence of heat waves and the loss of human lives due to heat waves for the period 1978 to 1999 were collected from IMD. A recent study[1] has shown that the average annual loss of human life due to heat wave over India is 153.

In the present study it is noticed that Jammu & Kashmir (J&K) experiences the maximum number of heat waves in the country with an average of 3 waves in 2 years. However, the loss of human lives in J&K is almost nil – this is mainly due to the very definition of a heat wave. The normal maximum temperature over J&K itself is low and therefore heat wave conditions are not a serious threat. It has also been noticed that deaths due to heat wave are more over the regions where the normal maximum temperature itself is more than 40°C. Maximum frequency of heat waves over most of the states was found to be in the month of May. However, the number of heat waves over Bihar, Rajasthan and Uttar Pradesh (UP) is more during the month of June compared to other months. The casualties due to heat waves were found to be maximum in Rajasthan.

Table 1 indicates the loss of human lives due to heat waves along with their total number of occurrences during the above-mentioned period. It may be noticed that the loss of human lives is maximum in Rajasthan followed by Bihar, UP and Orissa.

Table 2 indicates the loss of lives due to heat waves during the El-Nino year, and before and after it. Casualties are more in the year succeeding El-Nino year over India, which confirms the finding that severe heat wave during May and June is preceded by warm ENSO events[2]. Table 3 lists the loss of

Table 1. Total number of heat waves associated with loss of human lives (1978–1999)

State	Month*					
	March	April	May	June	July	Total*
Andhra Pradesh	–	7(21)	8(447)	3(7)	–	18(475)
Assam	–	1(–)	1(–)	1(26)	–	3(26)
Bihar	–	5(112)	9(182)	14(477)	–	28(771)
Gujarat	2(–)	1(10)	4(24)	–	–	7(34)
Haryana	1(–)	1(–)	1(5)	7(31)	2(1)	12(37)
Himachal Pradesh	–	–	1(–)	–	–	1(–)
Karnataka	–	1(2)	1(3)	–	–	2(5)
Madhya Pradesh	1(–)	1(–)	5(121)	6(44)	–	13(165)
Maharashtra	2(–)	6(12)	23(110)	4(121)	–	35(243)
Orissa	–	1(7)	10(430)	4(92)	–	15(529)
Punjab	–	1(–)	7(22)	7(92)	2(–)	17(114)
Rajasthan	1(–)	5(8)	16(733)	19(882)	1(2)	42(1625)
Tamil Nadu	–	–	1(20)	1(3)	–	2(23)
Uttar Pradesh	1(–)	3(23)	8(167)	10(496)	1(–)	23(686)
West Bengal	–	10(51)	12(24)	6(83)	–	28(158)
Delhi	–	–	1(24)	3(25)	–	4(49)
Chandigarh	–	–	2(1)	1(1)	–	3(2)

*Number of heat waves followed by the total number of deaths within brackets.

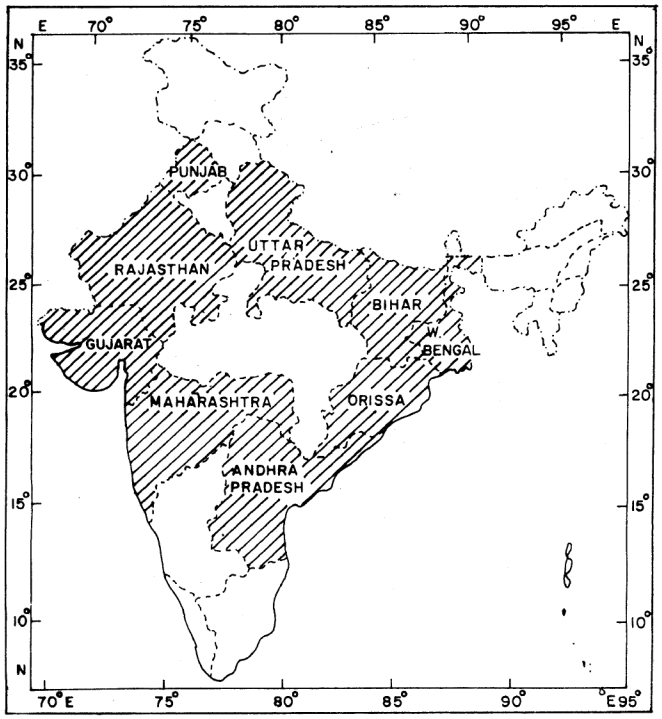

Figure 1. Regions affected by severe heat waves during May–June 1998.

Table 2. Loss of lives over India

El-Nino year	Year preceding El-Nino	During El-Nino year	Succeeding year
1982	63	11	185
1987	155	90	924
1997	20	17	1550

Table 3. Loss of lives and number of spells of heat waves during 1978–1999

Year	No. of deaths	No. of spells of heat waves
1978	368	9
1979	365	8
1980	106	8
1981	63	4
1982	11	2
1983	185	13
1984	58	9
1985	141	4
1986	155	5
1987	90	7
1988	924	17
1989	43	10
1990	2	2
1991	250	4
1992	114	5
1993	73	6
1994	234	9
1995	410	34
1996	17	9
1997	8	9
1998	1550	33
1999	163	16

lives and number of spells of heat waves. It may be seen that there are many years not preceded by El-Nino events with heavy loss of human lives due to heat waves, e.g. during 1978, 1979, 1985, 1986, 1991, 1994 and 1995.

In the present study the authors considered heat waves in a smaller spatial scale. It has been noticed that the states of Bihar, Orissa, Punjab, parts of Maharashtra and UP are always affected by heat waves in the year succeeding El-Nino event. However, in the case of some major El-Nino events, additional states like Rajasthan, Gujarat, Andhra Pradesh, Haryana, Madhya Pradesh and even West Bengal are affected by heat waves.

Over Bihar, Punjab and parts of Maharashtra more than 50% of the drought years are associated with El-Nino events[3]. Hence in these states human suffering is more both due to excessive heat as well as scarcity of water. Therefore, there is a need to study heat waves in association with El-Nino and the occurrence of drought using a larger data set. The total area in the country under heat waves may sometimes reach 800,000 sq km (ref. 4).

Generally heat waves develop in the north-western parts of India and from this area they progress to neighbouring subdivisions of the country. On some occasions, heat waves also develop *in situ*. The favourable factors responsible for severe heat waves are given in an earlier study[1]. They are: (i) There should be a region of warm dry air and appropriate flow pattern for transporting hot air over the region; (ii) There should be little or no moisture present in the upper air over the area; (iii) The sky should be practically cloudless to allow maximum insolation over the region; (iv) The lapse rate should approach dry adiabatic; (v) Finally, there should be a large amplitude anticyclonic flow or the thickness values should be considerably above normal in all layers.

The synoptic situations associated with heat waves are given in another study[4]. At 850 hPa level during March–April the anticyclone over the Arabian Sea sometimes spreads as far as the east coast of India, giving rise to northerly or north-easterly winds over west Bay of Bengal and the anticyclone of the Bay of Bengal becomes a part of the anticyclone over the Indo-China region. At 700 hPa an anticyclone lies over the north peninsula which maintains westerly flow in the north and north-easterly flow in the south. At 500 hPa the anticyclone moves towards the south resulting in a strong westerly flow to the north of 15°N. As the season advances in May, these two anticyclones over the sea areas disappear, which gives a zonal flow with a feeble trough in the eastern half of the peninsula. There is a tilt in the trough as it runs in a north-north-easterly to south-south-westerly direction in the lower level.

At 500 hPa a ridge lies over the north peninsula resulting in westerly to north-westerly flows to the north of 20°N and north-easterly flows in the southern peninsula.

Figure 1 shows the states affected by severe heat waves during May–June 1998 when 1550 human lives were lost. It may also be noted that loss of human lives in a region due to heat waves does not only depend on the number of heat wave spells but also on the socio-economic condition of the people, e.g. during the period under study there

were 17 spells of heat waves over Punjab compared to 15 over Orissa but the loss of lives in Punjab was 114 compared to 529 in Orissa.

To conclude it may be mentioned that the impact of heat waves over Bihar, Punjab and parts of Maharashtra (Marathwada, Vidarbha and Madhya Maharashtra) is more as it may create water scarcity and adversely affect agriculture if heat waves occur during years succeeding El-Nino events; also, these places have high probability of concurrent El-Nino and drought during the south-west monsoon season. The impact also depends upon the socio-economic condition of the inhabitants.

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S. K. CHAUDHURY
J. M. GORE
K. C. SINHA RAY*

India Meteorological Department, Shivajinagar, Pune 411 005, India
**For correspondence.*
e-mail: ksinha_ray@hotmatil.com

Is there any change in extreme events like heavy rainfall?

The problem of climate change has been a major thrust area of recent scientific research. In the scenario of increased CO_2 and thereby increase in global temperature, a question often raised by the climate research community is whether there is any increase in the extreme events like droughts and heavy rainfall spells? Some studies in India have dealt with changes in rainfall over the subcontinent as a whole and in some smaller spatial scales. But so far, there are no studies dealing with trends in heavy rainfall spells over various stations in India.

Srivastava *et al.*[1] have shown that there is no trend in the all-India rainfall during the monsoon season as well as the annual rainfall. However, they found a decreasing trend in rainfall over some hilly areas of north-east India. Srivastava *et al.*[2] studied trends in rainfall during the south-west (SW) monsoon season and that of annual rainfall over 35 sub-divisions of India and over all districts of India based on a long series of rainfall data. Their study

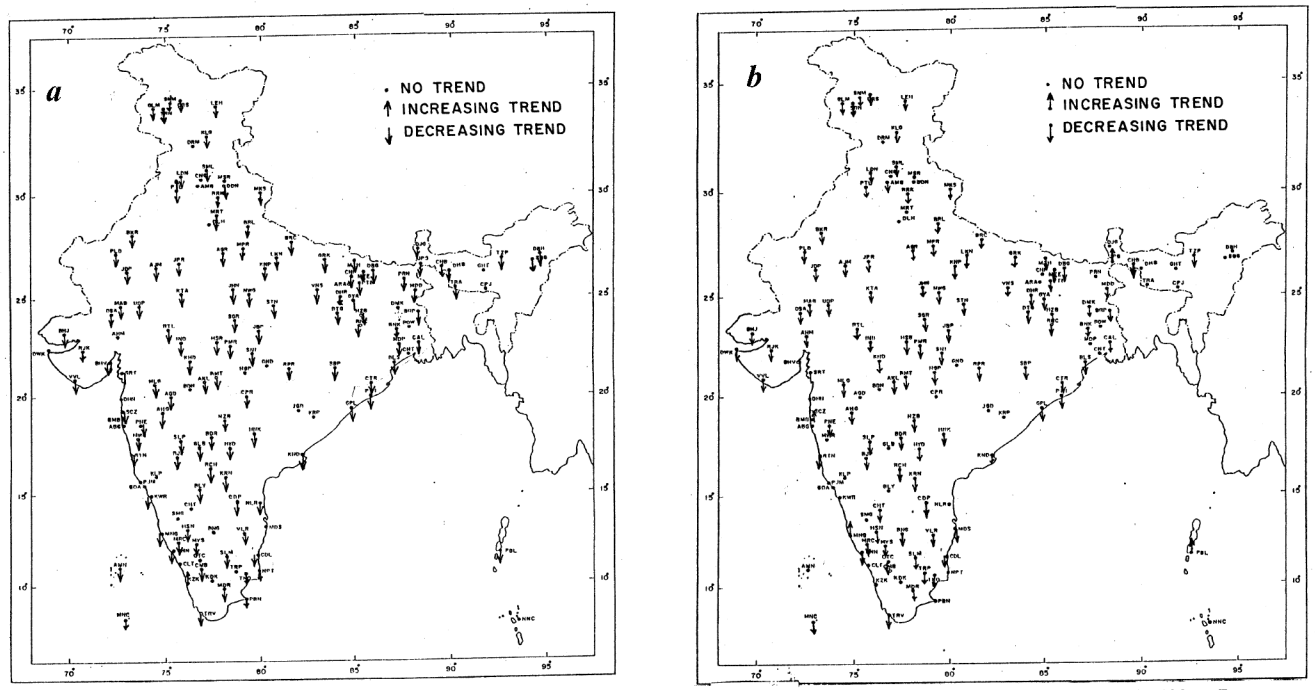

Figure 1 ***a, b.*** Trends in the frequency of rainfall ≥ 7 cm in 24 h (1901–1990). ***a***, January to February; ***b***, March to May.