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A climatological study of severe Heat Waves in India

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ABSTRACT. Results of a climatological study of severe heat waves in India based on observations extending over a period of 51 years are presented. Their period of occurrence, frequency, intensity, persistency, extent, development and decay are discussed with the help of 4 diagrams and 7 tables.

1. Introduction

During the period, March to July, spells of abnormally hot weather occasionally occur in certain parts of India. These spells are sometimes observed to move progressively from one region to the other. Due to this they are called heat waves. A heat wave is considered to be severe on days when maximum temperature remains 8°C or more above its daily normal. Prolonged heat waves of severe intensity may cause at places serious problems to water supply. Particularly to agriculturists this is a disastrous phenomenon since it often leads to drought. Unlike under severe cold wave conditions, biological strain imposed by severe heat waves cannot be easily mitigated. Consequently, severe heat waves sometimes claim heavy toll of live-stock and human lives.

On this important weather phenomenon there does not seem to have been made so far any detailed study in India. In this paper are presented the results of a climatological study of severe heat waves in India based on all observations published in the *Indian Daily Weather Reports* during the period of 51 years from 1911 to 1961. In the case of Jammu-Kashmir useful data were readily available only for the years 1911 to 1950. Hill station data for this region alone are not excluded from the study.

A phenomenon like severe heat wave which is of prime interest to agriculturists could have been more profitably studied if adequate network of observatories was available for each district. In its absence, severe heat waves could be studied in respect of each meteorological sub-division only. Even some of these sub-divisions are ill-represented by observatories and have, therefore, been modified to some extent. Thus, in Punjab are included Delhi and Himachal Pradesh. Similarly, West Bengal includes sub-Himalayan West Bengal also. North Assam comprising the whole of NEFA has been excluded from the study.

Total number of severe heat waves experienced in each sub-division is given in Table 1. Particulars of the severest waves in each sub-division for different months are given in Tables 2 to 6. In Table 7 are given the maximum durations of severe waves in each sub-division for different months. Temperature refers to day-time maximum temperature and its departure above its daily normal is the measure of the intensity of the waves.

2. Frequency

Jammu-Kashmir experiences the maximum number of severe heat waves in the country with an average of 3 waves in 2 years. In the plains of India, Uttar Pradesh East has the maximum incidence of severe waves — one wave a year on the average. However, there is no region in India where severe waves occur every year. The available statistics do not suggest any periodicity in the incidence of severe heat waves in any region or in the country as a whole. The following regions have not so far experienced any heat wave of severe intensity — (*i*) Coastal Mysore, (*ii*) Interior Mysore South, (*iii*) Kerala, (*iv*) Madras State, (*v*) Bay Islands and (*vi*) Arabian Sea islands.

In frequency and location of the incidence of severe heat waves in the country there is a systematic variation from month to month. This is discussed below with the help of Fig. 1.

March — 18 per cent of the total number of severe waves occur in this month. Saurashtra-Kutch is the most vulnerable region for these waves. There are two distinct regions that are free from waves. They are — (*i*) Bihar (plains and plateau) and West Bengal, and (*ii*) the regions south of about Lat. 20°N excluding Madhya Maharashtra and Konkan (Fig. 1 a).

April — From March to April there is a large decrease in the frequency of severe waves. Only 7 per cent of the waves occur in April and of these, the maximum number is observed in south Assam. Moreover, the waves are restricted to a much smaller part of the country. The western parts of India from Jammu-Kashmir to Konkan constitute one belt that is susceptible to waves. Similar region extends from Jammu-Kashmir to Assam

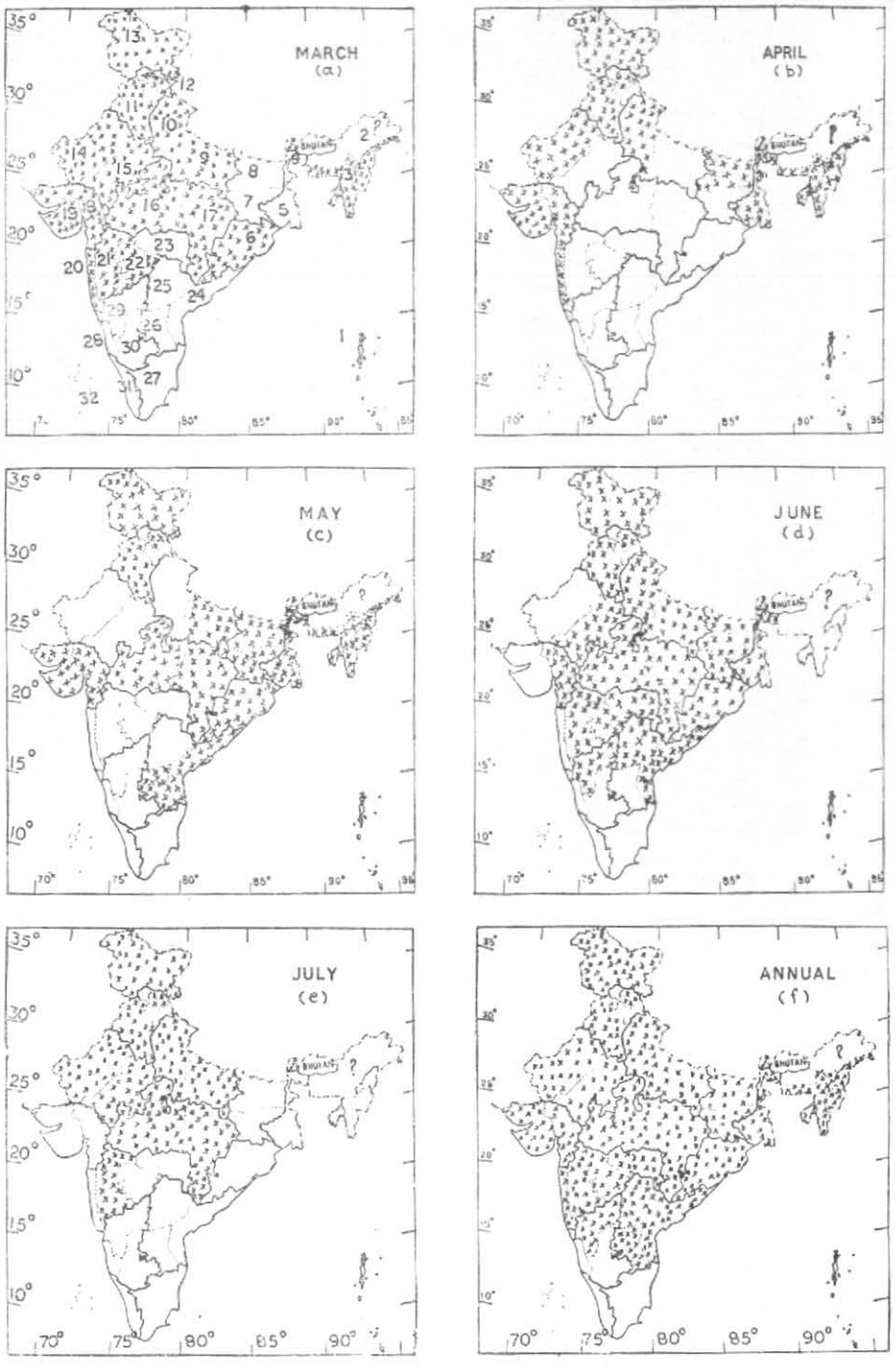


Fig. 1. Regions susceptible to severe heat waves

(1. Bay Islands, 2. N. Assam, 3. S. Assam, 4. Sub-Himalayan West Bengal, 5. Gangetic West Bengal, 6. Orissa, 7. Bihar Plateau, 8. Bihar Plains, 9. Uttar Pradesh (E), 10. Uttar Pradesh (W), 11. Punjab, 12. Himachal Pradesh, 13. Jammu-Kashmir, 14. Rajasthan (W), 15. Rajasthan (E), 16. Madhya Pradesh (W), 17. Madhya Pradesh (E), 18. Gujarat, 19. Saurashtra-Kutch, 20. Konkan, 21. Madhya Maharashtra, 22. Marathwada, 23. Vidarbha, 24. Coastal Andhra Pradesh, 25. Telangana, 26. Rayalaseema, 27. Madras State, 28. Coastal Mysore, 29. Interior Mysore (N), 30. Interior Mysore (S), 31. Kerala, 32. Arabian Sea Islands)

TABLE 1

Total No. of severe heat waves — 1911-1961

Sub-divisions	Mar	Apr	May	Jun	Jul	Total
South Assam	3	14	3			20
West Bengal		1	11	12		24
Bihar Plains		1	7	23		31
Bihar Plateau			5	28		33
Uttar Pradesh East	7		2	37	8	54
Uttar Pradesh West	3	2		22	10	37
Punjab	13	2	1	19	11	46
Jammu-Kashmir*	14	6	13	18	9	60
Rajasthan East	2			1	6	9
Rajasthan West	9	2			1	12
Saurashtra-Kutch	25	7	3			35
Gujarat	3	1	1	1		6
Madhya Pradesh West	2		1	19	4	26
Madhya Pradesh East	4		3	32	1	40
Orissa	2		2	23		27
Coastal Andhra Pradesh			3	12		15
Vidarbha				10		10
Telangana				7		7
Interior Mysore North				5		5
Marathwada				1		1
Madhya Maharashtra	1			6	1	8
Rayalaseema			1			1
Konkan	2	1				3

*Based on data 1911 to 1950

TABLE 2

Maximum intensity (departure of maximum temperature) of severe heat waves — March

Sub-divisions	Maximum departure (°C)	Place	Year
Jammu-Kashmir	11·7	Skardu	1921
Punjab	11·1	Hissar	1945
Saurashtra-Kutch	10·5	Dwarka/Rajkot	1951
Uttar Pradesh East	10·0	Kanpur	1938
Gujarat	9·9	Deesa	1921
Konkan	9·9	Ratnagiri	1921
Rajasthan West	9·7	Bikaner	1921
Madhya Pradesh East	9·4	Pendra	1953
Rajasthan East	9·3	Jaipur	1921
Uttar Pradesh West	8·9	Agra	1938
Madhya Maharashtra	8·7	Ahmednagar	1914
Madhya Pradesh West	8·6	Neemuch	1921
Orissa	8·3	Balasore	1953
South Assam	8·2	Gauhati	1923

TABLE 3

Maximum intensity (departure of maximum temperature) of severe heat waves — April

Sub-divisions	Maximum departure (°C)	Place	Year
Saurashtra-Kutch	11·7	Veraval	1955
Jammu-Kashmir	11·1	Dras	1925
South Assam	10·6	Dhubri	1939
Bihar Plains	10·0	Purnea/Patna	1958
Rajasthan West	10·0	Jodhpur	1958
Punjab	9·0	Hissar	1958
Konkan	8·9	Bombay	1955
Gujarat	8·3	Surat	1952
Uttar Pradesh West	8·0	Jhansi	1958
West Bengal	8·0	Jalpaiguri	1958

TABLE 4

Maximum intensity (departure of maximum temperature) of severe heat waves — May

Sub-divisions	Maximum departure (°C)	Place	Year
Jammu-Kashmir	11·5	Skardu	1915
Madhya Pradesh West	11·1	Nowgong	1931
Uttar Pradesh East	11·0	Gorakhpur	1958
Bihar Plateau	11·0	Dumka	1958
West Bengal	10·0	Berhampur	1954/1958
Madhya Pradesh East	9·4	Pendra	1954
Bihar Plains	9·2	Purnea	1916
South Assam	9·0	Gauhati/Dhubri/Silchar	1960
Coastal Andhra Pradesh	9·0	Masulipattam	1912
Orissa	8·3	Chandbali	1934
Gujarat	8·0	Deesa	1932
Saurashtra-Kutch	8·0	Bhavnagar/Veraval/Dwarka	1960
Punjab	8·0	Hissar	1957
Rayalaseema	8·0	Anantapur	1956

TABLE 5

Maximum intensity (departure of maximum temperature) of severe heat waves — June

Sub-divisions	Maximum departure (°C)	Place	Year
Orissa	12·5	Balasore	1926
Madhya Pradesh East	12·2	Satna	1931
Jammu-Kashmir	12·1	Skardu	1914
Coastal Andhra Pradesh	11·8	Kakinada	1923
Bihar Plateau	11·6	Chaibasa	1926
Bihar Plains	11·4	Gaya	1926
West Bengal	11·4	Burdwan	1926
Uttar Pradesh East	11·2	Allahabad/ Varanasi	1926
Uttar Pradesh West	11·1	Roorkee	1931
Madhya Pradesh West	10·5	Nowgong	1926
Punjab	10·5	Ambala	1919
Interior Mysore North	10·1	Belgaum	1915
Vidarbha	9·2	Nagpur	1926
Telangana	9·0	Nizamabad	1926
Madhya Maharashtra	8·9	Malegaon/ Sholapur	1915/ 1953
Rajasthan East	8·3	Jaipur	1931
Gujarat	8·0	Deesa	1931
Marathwada	8·0	Aurangabad	1915

Uttar Pradesh East is, however, conspicuously free from severe waves (Fig. 1 b).

May — Incidence of severe waves increases in this month to 11 per cent of the total. Jammu-Kashmir is the most susceptible region of all. From Figs. 1 (b) and 1 (c) it seems there is a general tendency for the waves to shift their activity from the west to the eastern parts of India in the month of May. Uttar Pradesh West and Rajasthan (East and West) form a large belt remarkably free from severe waves. This is the only month when severe waves have been observed as far south as Rayalaseema.

June — This is the month of maximum frequency of severe waves in the country. Nearly 54 per cent of the total waves occur in this single month and of these the maximum number affect Uttar Pradesh East. Practically the entire west coast from Saurashtra-Kutch to Kerala does not experience any wave. Another interesting feature is that Rajasthan West which is the hottest part of India remains free from severe waves in this month also (Fig. 1 d).

TABLE 6

Maximum intensity (departure of maximum temperature) of severe heat waves — July

Sub-divisions	Maximum departure (°C)	Place	Year
Uttar Pradesh West	11·0	Jhansi	1958
Madhya Pradesh West	11·0	Hoshangabad	1960
Punjab	10·9	Ambala	1911
Jammu-Kashmir	10·5	Skardu	1930
Uttar Pradesh East	9·8	Lucknow	1911
Rajasthan East	9·0	Jhalawar	1960
Rajasthan West	8·0	Bikaner	1947
Madhya Pradesh East	8·0	Satna/Jabalpur	1958
Madhya Maharashtra	8·0	Poona/Jalgaon	1960

In Interior Mysore North, and Madhya Maharashtra there is a remarkable tendency for more waves to occur during the first half of June. Similar tendency for the waves to occur in the second half of this month is noticed in Uttar Pradesh (East and West), Punjab and Madhya Pradesh West.

July — Practically the whole of the Peninsula becomes free from severe heat waves in this month (Fig. 1 e). Uttar Pradesh West and Punjab are the two regions having the maximum risk of severe waves. The incidence of the waves for the country as a whole is very much less in this month — about 10 per cent of the total.

3. Intensity

8° to 9° C is the usual intensity of severe heat waves in India. However, in Uttar Pradesh East and Bihar Plateau waves often attain an intensity of 9° to 10°C. In Assam during the month of April this much of severity is not unusual.

The severest wave on record in the country is that of June 1926. It lasted from the 10th to 16th. On the 13th, its intensity reached as high as 12·5°C (22·5°F) above normal at Balasore in Orissa (Fig. 2).

It is important to remember that the highest temperature is usually, but not always, reached during the most intense wave. This is because the intensity of the wave is a measure of the departure of maximum temperature from its normal which is different for different days and stations. Irrespective of the departure of maximum temperature, the highest maximum temperatures ever recorded during the years 1881 to 1964 are depicted by isotherms in Fig. 3. Alwar in Rajasthan East

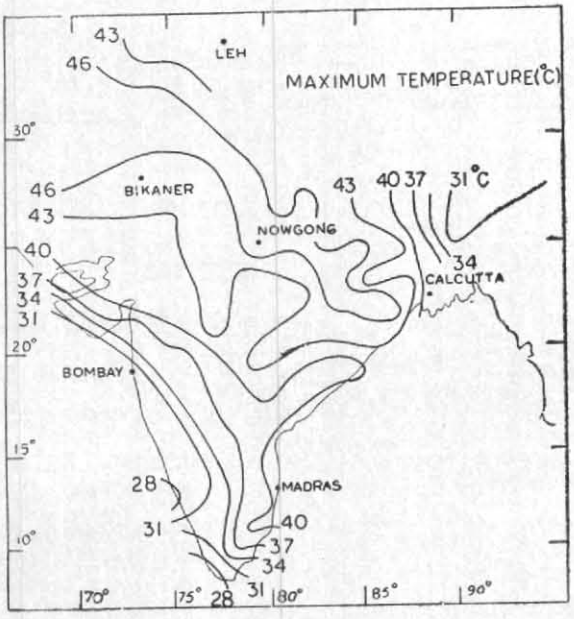


Fig. 2. Severest heat wave in India on 13 June 1926

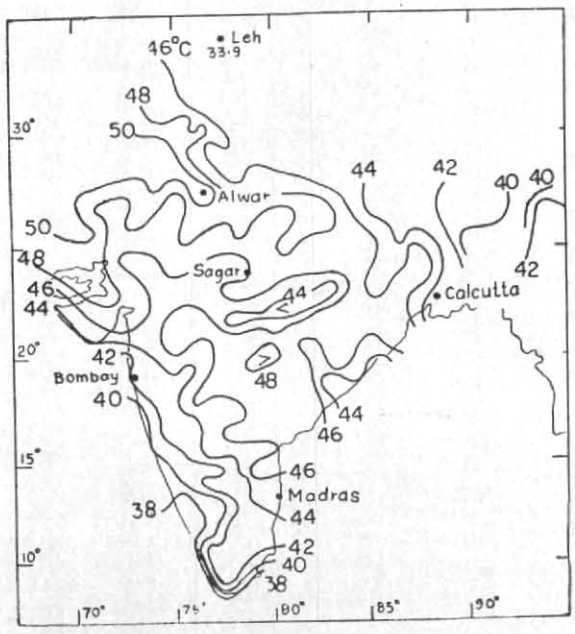
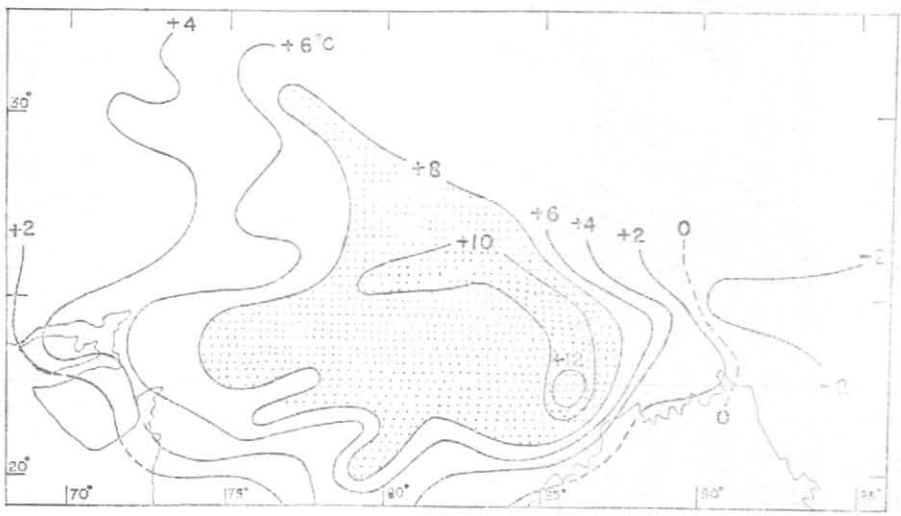


Fig. 3. Highest maximum temperature (°C) ever recorded in India during the years 1881 to 1964

TABLE 7

[Maximum duration (No. of days) of severe heat waves

Station	Mar	Apr	May	Jun	Jul
South Assam	2	13	4		
West Bengal		1	7	12	
Bihar Plains		1	3	8	
Bihar Plateau			5	10	
Uttar Pradesh East	3		3	8	9
Uttar Pradesh West	2	1		8	8
Punjab	7	2	1	7	6
Jammu-Kashmir	15	4	9	10	3
Rajasthan East	6			2	3
Rajasthan West	7	4			1
Saurashtra-Kutch	6	5	2		
Gujarat	5	2	3	1	
Madhya Pradesh West	2		1	6	3
Madhya Pradesh East	2		1	8	1
Orissa	1		3	6	
Coastal Andhra Pradesh			2	8	
Vidarbha				3	
Telangana				2	
Interior Mysore North				4	
Marathwada				1	
Madhya Maharashtra	1			3	1
Rayalaseema			1		
Konkan	1	1			



(Departure of Maximum temperature in °C)

Fig. 4. Severe heat wave of the largest extent on 26 June 1926

holds the record for the highest temperature of 50·6 °C or 123°F (on 10 May 1956).

4. Persistency

Severe heat waves generally last for a day or two in any region except in Bihar Plateau where their average period of stay is of the order of 4 to 5 days. In West Bengal, Bihar Plains, Madhya Pradesh East, Uttar Pradesh and Punjab there is a tendency for the waves to persist longer in the month of June than in the other months.

The total period of stay of the waves in the country, however, is generally 5 to 6 days. The maximum stay of a wave in the country was 15 days in the month of March 1921. This was confined to the State of Jammu-Kashmir. In the plains of India there was an unusual wave that lingered for 12 days (20 June to 1 July 1926). The longer the stay of a wave, the more intense it may turn out to be.

5. Areal extent

The area covered at a time by severe heat waves varies from a part of a sub-division to nearly one-fourth of the country. As the season advances upto the end of June, the waves tend to cover larger area. In July they seldom extend beyond an area of 300,000 to 400,000 sq. km. The wave of 26 June 1926 affected the largest area so far on a single day in India (Fig. 4).

6. Development, movement and decay

Severe heat waves have not so far been observed to migrate from the neighbouring countries. They develop *in situ* within the country itself or expand from West Pakistan to affect northwest India. Occasionally two waves are observed on the same day in two different parts of India. Those that develop in western India very rarely survive when they cross about Long. 78°E. Punjab and Saurashtra-Kutch are the regions most favourable for their development in western India. Generally they develop near Ambala or Veraval and expand to cover larger area. Finally they begin to shrink giving rise to an apparent movement. Shrinking may take place from all sides or from one or more directions with or without losing intensity of the wave. Waves disappear suddenly as a result of cloudy weather with or without precipitation.

Waves that generally exhibit actual movement are those that form east of about 78°E. They shrink and decay early if their movement is towards the south. No waves have so far been observed in the country to move towards the west. Jammu-Kashmir and Assam are the two regions where waves develop *in situ* and invariably die within the region itself. Fig. 1 which shows the regions that are not susceptible to severe waves indicates the climatological improbabilities of a wave penetrating certain regions in different months.

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