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Heat wave and cold wave days in different States of India

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ABSTRACT. Criteria for defining heat and cold wave days have been proposed based on human comfort. Using these criteria the extent the Indian sub-continent that is affected by heat and cold waves and the frequencies of heat and cold wave days in different states of India have been presented and discussed. Cold air out-breaks from the continental anticyclone over the Asian mainland across the eastern parts of the Himalayan ranges has been suggested as a secondary source of cold waves in northeast India.

1. Introduction

The occurrence of heat waves in summer and cold waves in winter, as they are called, which leads to crop failure and even human deaths when they are severe and prolonged, is well known to the public in India. A climatological study of severe heat waves and severe cold waves was made by Raghavan (1966, 1967). He considered that when the maximum temperature was more than the normal by 8°C or more, the stations had a severe heat wave. Similarly when the minimum temperature was below the normal by 8°C or more, the station had a severe cold-wave. Rai Sircar and Datar (1963) in their study of cold waves took −4°C deviation from the normal minimum temperature to identify cold waves while Bedi and Parthasarathy (1967) took −6°C and −7°C deviation from the normal for cold waves and −8°C or more deviation for severe cold waves. Hariharan (1956) took the 50°F and 40°F isotherms to delineate the areas affected by cold waves in his study. The India Meteorological Department (1968) takes 6°C departure from the normal maximum or minimum temperature for defining heat and cold waves respectively. In this paper, the frequencies and extent of occurrence of heat and cold waves in the Indian sub-continent according to a new criterion based on human comfort in different states are presented.

2. Temperature limits for heat and cold waves

Lee (1950) made a critical study of the various meteorological factors that affect the heat balance of the human body and developed an equation for the strain *G* (*see*, Appendix). He has also prepared a strain chart and indicated the strain ranges for different degrees of comfort and discomfort. According to that chart, best comfort is felt by a person doing moderate work with moderate air movement and wearing normal clothing, between the temperature and humidity limits of 75°F/90 per cent R. H. and 85°F/10 per cent R.H. None feels comfortable when the temperature is more than 97°F, however low the relative humidity is, and when the temperature is less than 65°F however high is the relative humidity.

When a day is to be categorized as hot or cold on the basis of the maximum or minimum temperatures which are instant values, the 97°F limit can further be increased and the 65°F limit can be reduced. Considering the difference of the human activity and exposure to weather in general during day and night, the lower limit 65°F can be reduced by a considerable extent. Also, keeping the range of minimum and maximum temperature variation in the country in view, it would be reasonable to take cases of maximum temperature between 100 and 110°F as moderate heat waves and greater than 110°F as severe heat waves. Similarly cases of minimum temperture between 55° and 45° F may be taken as moderate cold waves and less than 45° F as severe cold waves. In this connection it may be mentioned that Skerman (1958) in his study of heat waves in Queensland took 100°F maximum temperatue as the criterion for heat waves.

3. Data and analysis

Maximum and minimum temperature data from about 170 stations in India have been taken from

TABLE 1

Frequency of severe/total heat wave days

	April			May			June		
	100%	75%	50%	100%	75%	50%	100%	75%	50%
Jammu & Kashmir	0	0	0	0	0	0	0	0	0
Punjab	0/8	0/10	0/13	2/3	8/19	14/34	2/4	5/16	9/29
Rajasthan	0/5	0/12	0/17	2/10	5/23	10/34	0/5	0/15	2/23
Uttar Pradesh	0/2	0/12	0/19	0/1	3/12	7/27	0	0/5	0/14
Madhya Pradesh	0/9	0/15	0/21	1/11	2/20	7/31	0/1	0/6	0/11
Gujarat	0/1	0/13	0/21	0/1	0/13	0/24	0	0	0/5
Bihar	0/4	0/10	0/18	0/1	0/3	2/16	0	0	0/1
West Bengal	0	0	0/11	0	0	0/5	0	0	0
Assam	0	0	0	0	0	0	0	0	0
Orissa	0	0	0/14	0	0	0/9	0	0	0
Maharashtra	0	0/3	0/8	0	0	0/5	0	0	0
Telangana	0/7	0/17	0/24	0/4	0/15	2/24	0	0/2	0/7
Coastal Andhra Pradesh and Rayalaseema	0	0	0/9	0	0	0/13	0	0	0/7
Karnataka	0	0	0/4	0	0	0	0	0	0
Tamil Nadu	0	0	0/5	0	0/1	0/7	0	0	0/1
Kerala	0	0	0	0	0	0	0	0	0

TABLE 2

Frequency of severe/total cold wave days

	December			January			February		
	100%	75%	50%	100%	75%	50%	100%	75%	50%
Jammu & Kashmir	18/18	29/29	30/30	24/24	30/30	30/30	10/10	27/27	28/28
Punjab	11/18	15/25	17/29	12/15	17/24	20/30	4/10	8/19	10/27
Rajasthan	0	4/10	11/27	0	4/10	12/30	0	1/6	5/20
Uttar Pradesh	0	5/16	11/30	0	6/14	11/27	0	0/7	2/18
Madhya Pradesh	0	0/6	2/24	0	0/2	2/18	0	0/1	0/9
Gujarat	0	0/2	0/13	0	0/3	0/14	0	0/1	0/8
Bihar	0/1	0/15	2/25	0/1	2/10	6/25	0/1	0/10	0/16
West Bengal	0	0/5	0/12	0	0/6	0/15	0	0	0/7
Assam	0/2	0/12	0/23	0/7	0/17	0/25	0	0/1	0/11
Orissa	0	0/3	0/10	0	0/4	0/10	0	0/1	0/3
Maharashtra	0	0	0	0	0	0	0	0	0
Telangana	0	0	0/2	0	0	0/5	0	0	0
Coastal Andhra Pradesh and Rayalaseema	0	0	0	0	0	0	0	0	0
Karnataka	0	0	0	0	0	0	0	0	0
Tamil Nadu	0	0	0	0	0	0	0	0	0
Kerala	0	0	0	0	0	0	0	0	0

the Indian Daily Weather Reports published by the India Meteorological Department for the years 1954-56. The data from Jammu and Kashmir during these years were very inadequate, therefore, data for the period 1969-71 were used for that State.

The whole of India was divided into 16 divisions nearly corresponding to the States except Andhra Pradesh and Assam. Adjoining areas have also been grouped under Assam. Island areas have been omitted. In each division, the number of stations ranged from 5 to 17 depending on the size. Since the stations were uniformly distributed, it was assumed that the temperatures at the stations represent the thermal conditions in the division. It was assumed that the whole division was affected by a heat wave when all the stations reported more than 100°F maximum temperature. When only 50 per cent of stations reported more than 100° F maximum temperature, it was assumed that 50 per cent of the division was affected by a heat wave. Similar procedure was adopted to specify the per cent-area affected by severe heat waves, cold waves and severe cold waves. The frequency of occurrence of different thermal spells in each division in terms of the per cent area affected has been evaluated. With this procedure, the maximum number of days of cold or heat waves in a month would be 30, but it is possible for the total number of cold wave and severe cold wave days affecting less than 50 per cent area in a division in a month to be more than 30. This arises because a certain part of the area may have cold wave conditions while simultaneously a certain other part may have severe cold wave. Therefore, it is desirable to study the frequencies of the thermal spells that have affected more than 50 per cent area of the divisions. The cumulative frequencies of different per cent areas affected by heat waves, cold waves etc in each division, are calculated and presented in Tables 1 and 2.

The highest maximum and the lowest minimum temperatures recorded in 50 years at different stations in India in different months were also examined to study the spatial limits of occurrence of heat and cold waves.

4. Results and Discussion

The 100°F and 110°F isotherms of 'record maximum temperature' in the months, April, May and June are shown in Fig. 1 which are the months of high frequency of heat waves. These isotherms indicate the limits of the areas affected by heat waves and severe heat waves. Almost every part of India at one time or other experienced heat waves excepting a thin strip of land along the west coast south of 20°N latitude. Severe heat waves were also experienced by most of the States in the country in these three months. In April, Mysore Kerala, Tamil Nadu, Assam and some parts of Maharashtra and Jammu & Kashmir did not experience severe heat waves. Parts of coastal Andhra have experienced severe heat waves. In the month of May, a similar situation existed but the area affected by severe heat waves on the east coast spreads from coastal Andhra to the north into Orissa as well as to the south into north Tamil Nadu. In June, the situation was again similar to that in May except that there was a general shrinking of the area affected by heat waves and severe heat waves in west peninsular India.

Assam and parts of Jammu & Kashmir were practically free of heat waves in these three months.

The 55°F and 45°F isotherms of 'record minimum temperature' are shown in Fig. 2 for the months of December, January and February which are the months of high frequency of cold waves. They indicate the boundaries of the areas affected by cold waves and severe cold waves respectively. Here again the coastal places of peninsular India were free of cold waves and those of northern India were free of severe cold waves. Severe cold waves were practically confined to northern India. Freezing temperatures have occurred in north west India.

4.1. *Frequency of heat wave days* : Widespread heat wave conditions were practically absent in the months of March, July and August in any of the States, but occassionally they occurred in Telangana, Gujarat and Madhya Pradesh in March, and Rajasthan, Punjab and Haryana in July and August. The number of severe heat wave/total heat wave days in each State, affecting 50, 75 and 100 per cent of the areas in April, May and June when the frequencies were high are presented in Table 1.

In none of the coastal States 100 per cent of the area was ever under the influence of heat waves. Widespread heat wave days have frequently occurred in Madhya Pradesh, Rajasthan, Punjab and Telangana and occassionally in Bihar and Uttar Pradesh in April and May. Severe heat waves were experienced state-wide by Punjab, Rajasthan, Uttar Pradesh and Madhya Pradesh and by limited areas of Telangana and Bihar in the months of May. There was a large drop in the heat wave occurrences in most States in June which can be attributed to the onset of the south-west monsoon. But Punjab and Rajasthan continued to have widespread heat waves while

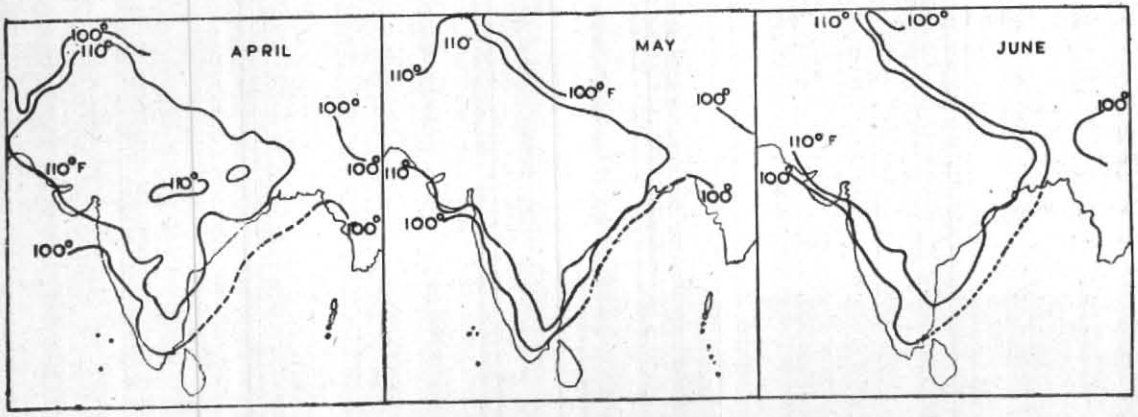

Fig. 1. Isotherms of highest recorded temperature (°F) during April, May and June

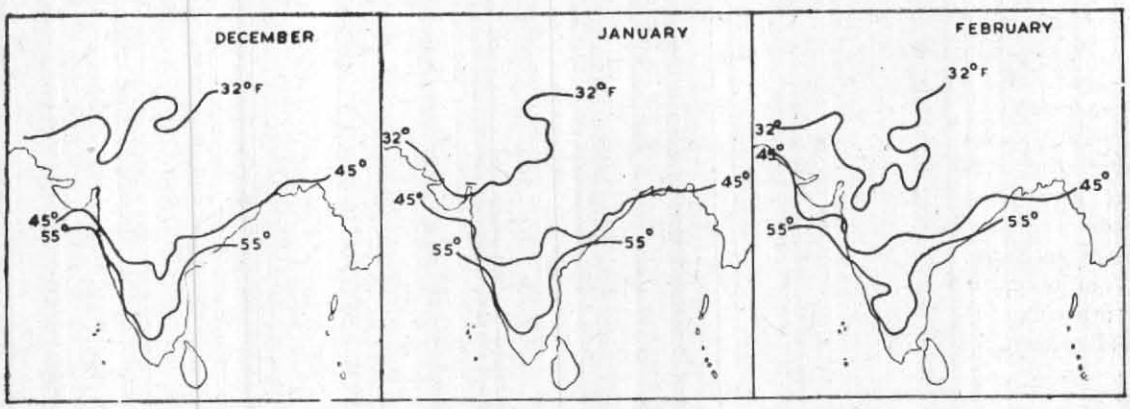

Fig. 2. Isotherms of lowest recorded temperature (°F) during December, Januray and February

they occurred in limited areas of Telangana, Andhra and Gujarat.

4·2. *Frequency of cold wave days*· Several of the states have experienced cold waves from November to March while severe cold waves were practically confined to the period, December to February. Jammu and Kashmir experienced extremely low temperatures throughout the period November to March. Frequency of severe cold wave/total cold wave days for the months of December to February are presented in Table 2.

Frequent cold waves have occurred, in parts of Punjab, Uttar Pradesh, Rajasthan and Bihar in the month of November which have spread to Madhya Pradesh, West Bengal, Orissa and Assam in December. Severe cold weve days were frequent state-wide in Punjab and partly in Uttar Pradesh and Rajasthan. Occasionally they occurred in parts of Madhya Pradesh and Bihar. In January, similar conditions continued except for a slight increase of severe cold wave days but by February there was a rapid decrease.

The smaller frequency of cold wave days in West Bengal than in Bihar or Assam in general may be due to the maritime effect. But the greater frequency in Assam than in Bihar in January shows that there should be a secondary source in northeast India for the incidence of cold-waves, besides the western disturbances that enter the country across Northwest Frontier wich are supposed to be responsible for the cold waves in India. The secondary source could be cold air out-breaks from the continent anticyclone over the Asian main land across eastern parts of the Himalayan ranges.

5. Conclusion

The frequency of heat and cold wave days is quite high in North India. For the country as a whole, the maximum frequency of severe heat waves/total heat wave days occurs in May.

Frequency of cold wave days is maximum and equally high in January and December while that of severe cold wave days is maximum in January.

The divisions that have experienced frequent heat wave days over major areas during the three summer months in the decreasing order are: Rajasthan, Punjab, Madhya Pradesh, Telangana, Uttar Pradesh, Gujarat and Bihar. Similarly, high frequencies of cold wave days occurred in Jammu and Kashmir, Punjab, Uttar Pradesh Bihar, Assam and Rajasthan. There appears to be a secondary source of cold waves in northeast India which may be due to cold air out-breaks from the continental anticyclone over the Asian mainland across the eastern parts of the Himalayan ranges.

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APPENDIX

$$G = a \left\{ \frac{(M - W) - \frac{5.55\,(34 - t)}{I_a + I_c} - 0.00033V\,(46 - p)}{\frac{c - p}{r_a + r_c}} \right\} d$$

where M is the rate of energy liberation (metabolic rate), W is the energy expended in external work, V is the volume of respired air, t and p are the ambient temperature and vapour pressure, I_a is the resistivity of the ambient air to the outward passage of heat, I_c is the resistivity of the coat or clothing to the outward passage of the heat while r_a and r_c are similar resistivities for the outward passage of water vapour.