

## A climatological study of severe Cold Waves in India

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**ABSTRACT.** Results of a climatological study of severe cold waves in India based on observations extending over a period of 51 years are presented. The main aspects considered are the period of occurrence, frequency, intensity, persistency, extent, development and decay.

### 1. Introduction

In the cold weather period from November to March, winds in the lower levels of the atmosphere over India are mainly from the northern latitudes. These winds are relatively cold and dry. In the transition months of October and April such winds occasionally appear and reappear. Sometimes they are remarkably cold and cause spells of cold weather. These cold spells occurring during the period October to April can progressively travel from one region to the other. Perhaps due to this they are called "cold waves". A cold wave is considered to be severe on days when night minimum temperature drops below its daily normal by 8°C or more.

In this paper are presented the results of a climatological study of severe cold waves in India based on all observations published in the *Indian Daily Weather Reports* during a 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 cold 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 cold 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 here. Thus, Assam sub-division in this paper includes Manipur and Tripura and excludes Northeast Frontier Agency (NEFA). Similarly, in Punjab are included Delhi and Himachal Pradesh. West Bengal includes sub-Himalayan West Bengal also.

Total number of severe cold waves experienced in each sub-division during the years 1911 to 1961 is given in Table 1. Maximum intensity of cold

waves in each sub-division for different months is given in Table 2. In Table 3 are given the maximum durations of severe cold waves in each sub-division for different months. Temperature refers to night minimum temperature and its departure is below its daily normal.

### 2. Period of severe cold waves

From Table 1 it can be seen that during the 51 years Bihar Plateau experienced two waves and Rajasthan East and Saurashtra-Kutch one wave each in October. Apparently severe cold wave is a freak phenomenon in this month.

Therefore, for all practical purposes, November to April can be taken as the period of severe cold waves in India. Jammu-Kashmir, Punjab, Uttar Pradesh (West), Rajasthan (East and West), Madhya Pradesh (West), Saurashtra-Kutch, Gujarat and Madhya Maharashtra are the regions where severe cold waves may occur in all the months November to April.

### 3. Frequency of severe cold waves

Jammu-Kashmir is the region of maximum number of severe cold waves. In this region, 4 severe cold waves occur in a year on the average. In Punjab and Uttar Pradesh (West) which are adjacent to Jammu-Kashmir much less number of severe cold waves is experienced. On the average one wave occurs in every two years in Punjab and Uttar Pradesh (West). This is also the case in the lower levels of Kashmir south of Ladakh. Probably, the cold stream reaching these low-lying regions generally warm up in descent along the slopes of the high mountain ranges in the north.

Severe cold waves from West Pakistan also invade the regions Punjab and Uttar Pradesh (West). However, Rajasthan and Saurashtra-Kutch have greater incidence of severe cold waves than the Punjab and Uttar Pradesh (West). On the average one severe cold wave may be expected to occur in a year in Rajasthan (West and East) and Saurashtra-Kutch.

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TABLE 1  
Number of severe cold waves during the years 1911 to 1961

Sub-divisions	October	November	December	January	February	March	April	Total
Assam					1			1
West Bengal			1	4	2	6		13
Orissa					3	2		5
Bihar Plains		1		3	1	4	2	11
Bihar Plateau	2	1	1		3	5	2	14
Uttar Pradesh East					2	4	2	8
Uttar Pradesh West		4	3	5	10	10	6	38
Punjab		1	3	5	4	9	6	28
Jammu and Kashmir*		7	32	62	45	29	8	183
Rajasthan East	1	4	6	12	12	7	10	52
Rajasthan West		4	4	15	15	10	8	56
Madhya Pradesh East			1	3	6	7	4	21
Madhya Pradesh West		1	4	15	21	12	8	61
Gujarat		2	1	6	11	8	3	31
Saurashtra-Kutch	1	3	5	13	16	6	1	45
Madhya Maharashtra		1	3	7	13	3	2	29
Marathwada				2	2			4
Vidarbha			1	6	12	4	1	24
Telengana		1		1	1	2		5
Rayalaseema			2		1			3
Interior Mysore North		2	1	4	3			10

\*Based on data 1911 to 1950

TABLE 2  
Maximum Intensity (departure of minimum temperature) of severe cold waves, 1911 to 1961

Sub-divisions	Maximum departure of minimum temperature (°C)						
	October	November	December	January	February	March	April
Assam					8.3		
West Bengal			8.0	10.0	8.3	10.0	
Orissa					9.5	9.0	
Bihar Plains		8.0		10.0	8.0	10.8	8.0
Bihar Plateau	9.0	9.5	8.0		10.0	10.0	11.0
Uttar Pradesh East					8.0	8.0	8.4
Uttar Pradesh West		9.2	8.1	9.2	10.5	11.1	8.9
Punjab		8.3	9.5	10.5	10.0	9.7	10.5
Jammu-Kashmir		19.1	15.5	19.4	18.4	19.7	15.0
Rajasthan East	8.0	9.2	9.5	10.5	11.1	11.3	10.5
Rajasthan West		11.7	9.0	12.2	10.5	11.9	13.7
Madhya Pradesh East			8.0	8.3	10.5	10.5	8.8
Madhya Pradesh West		8.2	9.0	11.0	12.8	10.2	9.5
Gujarat		8.7	10.5	12.8	11.7	11.8	10.5
Saurashtra-Kutch	9.0	9.4	9.0	12.2	12.2	10.0	8.0
Madhya Maharashtra		8.0	8.1	11.1	12.2	10.3	10.7
Marathwada				9.5	10.1		
Vidarbha			8.0	9.0	10.5	9.0	9.0
Telengana		8.0		8.0	8.9	8.3	
Rayalaseema			8.0		8.3		
Interior Mysore North		8.3	8.0	9.0	9.0		

TABLE 3  
Maximum duration (number of days) of severe cold waves, 1911 to 1961

Sub-divisions	October	November	December	January	February	March	April
Assam					2		
West Bengal			1	1	2	2	
Orissa					4	1	
Bihar Plains		1		1	1	1	4
Bihar Plateau	3	3	1		5	4	3
Uttar Pradesh East					1	1	1
Uttar Pradesh West		3	2	7	4	4	2
Punjab		6	4	3	3	4	3
Jammu-Kashmir		30	16	17	11	11	9
Rajasthan East	1	1	2	8	4	3	4
Rajasthan West		5	7	6	4	4	5
Madhya Pradesh East			1	2	8	3	1
Madhya Pradesh West		1	5	8	4	4	7
Gujarat		2	2	4	2	2	2
Saurashtra-Kutch	2	1	6	5	4	3	1
Madhya Maharashtra		1	1	5	3	2	1
Marathwada				1	2		
Vidarbha			1	3	3	2	2
Telengana		2		1	1	1	
Rayalaseema			1		1		
Interior Mysore North		1	1	1	1		

In Madhya Pradesh (West) which is almost in the centre of the country there is a tendency for severe cold waves to occur more frequently than in Rajasthan (West/East) and Saurashtra-Kutch during the months January to March. In February, the number of severe cold waves is distinctly more than that in Rajasthan and Saurashtra-Kutch.

The frequency of severe cold waves progressively decreases towards Assam in the east and Rayalaseema in the south. Severe cold waves have not so far penetrated Interior Mysore (South) and the following coastal regions south of about Lat. 20°N—Konkan, Coastal Mysore, Kerala, Madras State and Coastal Andhra Pradesh. The islands in the Bay of Bengal and the Arabian Sea have also not so far experienced severe cold waves.

Assam is practically free from severe cold waves. Only one wave was experienced in this part of the country during the years 1911 to 1961. In Rayalaseema severe cold wave is not so rare. It may be expected once in every 15 years on the average.

For the country as a whole, the month of February is the period of maximum incidence of severe cold waves. Jammu-Kashmir can be expected

to experience on the average one severe cold wave a year in this month. Table 1 shows that in the plains of India they are too infrequent to be a problem even in this month except perhaps in Rajasthan (West), Madhya Pradesh (West) and Saurashtra-Kutch where they occur in this month once in about 3 years on the average.

It may, however, be pointed out that Punjab, Uttar Pradesh, Bihar and West Bengal experience the maximum number of severe cold waves in the month of March.

Jammu-Kashmir is the only region where severe cold waves occur every year. Even here they do not occur in the same month every year. The available statistics do not suggest any periodicity in the incidence of severe cold waves in any region or in the country as a whole.

#### 4. Intensity of severe cold waves

Except in Jammu-Kashmir, Uttar Pradesh (West), Rajasthan (West), Madhya Pradesh (West) and Saurashtra-Kutch, their intensity elsewhere in the country is of the order of 8 to 9°C (14 to 16°F) below normal. Only under exceptional cases they were more than 10°C.

In Jammu-Kashmir cold waves are usually very intense with temperature dropping 10 to 12°C

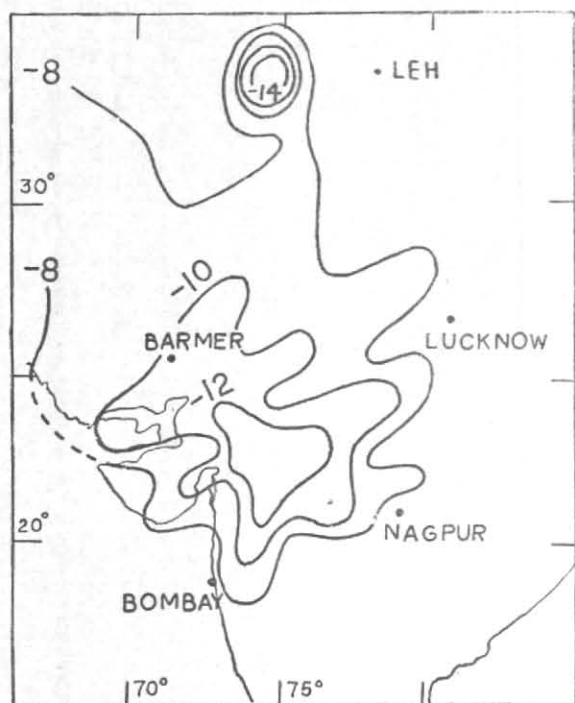


Fig. 1. Severest cold wave in the plains of India on 1 February 1929

(Departure of min. temp. in °C)

below normal. 9 to 10°C is the usual departure of minimum temperature in association with severe cold waves in Uttar Pradesh (West), Rajasthan (West), Madhya Pradesh (West) and Saurashtra-Kutch during the months January to March. In the other months, their intensity is less than 10°C. February seems to be the month most favourable for the occurrence of very severe cold waves (departure 10°C or more) in the country as a whole.

The severest cold wave on record in the country is that of March 1911. This caused a departure of 19.7°C (35.4°F) at Dras on the 23rd. This wave, however, was confined to a small area in the mountain ranges of Ladakh. In the plains of India the severest cold wave of appreciable extent was perhaps that prevailed from 30 January to 2 February 1929. Its intensity was maximum on 1 February when minimum temperature dropped by 12°C below normal over a considerable area in Madhya Pradesh (West) and its adjoining parts of Saurashtra-Kutch, Gujarat and Madhya Maharashtra (Fig. 1). An examination of the lowest minimum temperature records shows that the minimum temperatures recorded on 1 February 1929 at Indore (-2.8°C) and Malegaon (-0.6°C) are the lowest ever recorded in Madhya Pradesh (West) and Madhya Maharashtra respectively.

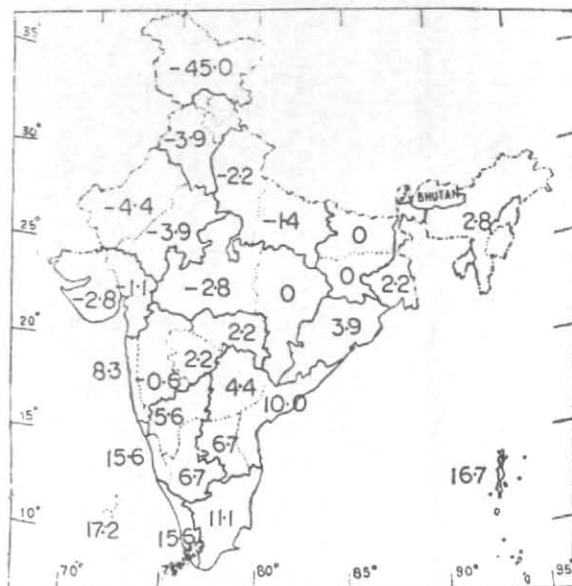


Fig. 2. Lowest minimum temperature (°C) during the years 1881-1964

It is important to remember that the lowest minimum temperature is not always experienced at a station in association with the severest cold wave the intensity of which is judged by the departure of minimum temperature from the normal. Irrespective of the departure of minimum temperature, the lowest minimum temperatures ever recorded in each sub-division during the years 1881 to 1964 are given in Fig. 2. This shows that in India the lowest temperature of -45°C (-49°F) was experienced in Jammu-Kashmir (at Dras on 28 December 1910). In the plains of India, Rajasthan (West) has on record the lowest temperature of -4.4°C (24°F) at Jaisalmer on 4 January 1949.

Severe cold waves decrease in intensity usually at about Long. 80°E or Lat. 20°N. There is, however, a small region south of Lat. 20°N where severe cold waves very often penetrate. This comprises the western parts of Nasik, Ahmednagar and Poona districts. This region is situated where the Western Ghats slope steadily and end in numerous spurs and gorges. From the slopes on the three sides of the gorges, cold dense air may collect at nights in the gorges. The air movement being restricted in the gorges, the trapped air can cool further by radiation. This phenomenon seems to get aggravated in this region when severe cold waves prevail near about Lat. 22°N and Long. 70° to 75° E.

##### 5. Persistency of severe cold waves

In Jammu-Kashmir severe cold waves last for a period of 4 to 5 days except in April when they

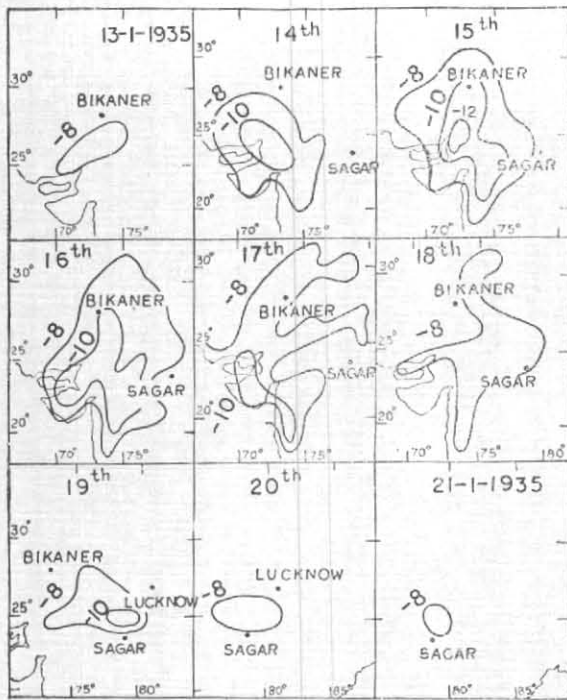


Fig. 3. Development and decay of the most persistent severe cold wave in the plains of India (Departure of minimum temperature in °C)

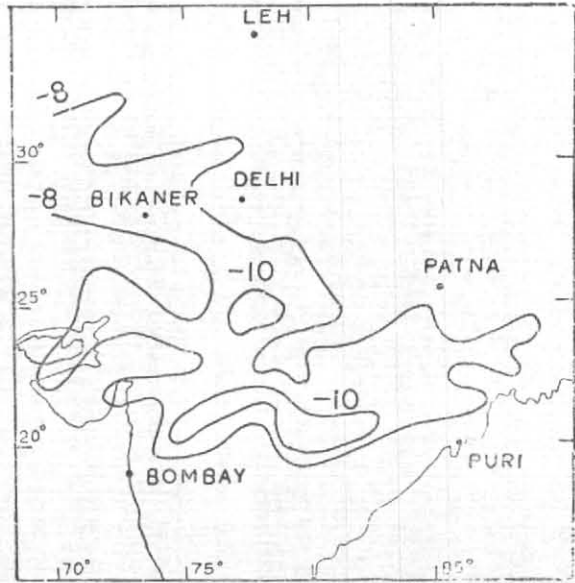


Fig. 4. Severe cold wave of the largest extent in India on 12 February 1950 (Departure of minimum temperature in °C)

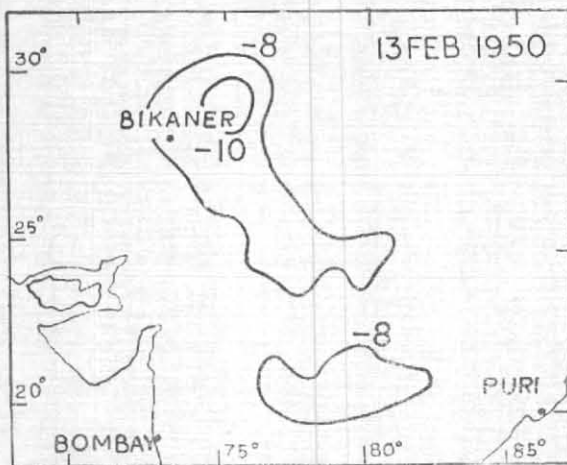


Fig. 5. Decay of the severe cold wave of the largest extent on 13 February 1950 (compare w. th Fig. 6)

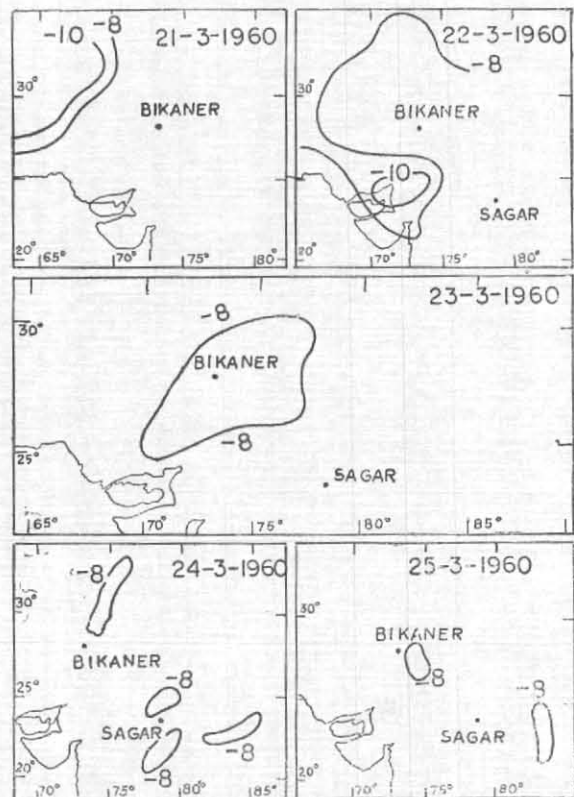


Fig. 6. Development and decay of a severe cold wave in March 1960 (Departure of minimum temperature in °C)

last for a day on the average. In Rajasthan, Saurashtra-Kutch and Madhya Pradesh (West) they last for 2 to 3 days particularly in the month of January. Elsewhere they usually persist for a day or two. Over a small area in Ladakh in Jammu-Kashmir, a severe wave persisted for 30 days in November 1917. This can be considered as the wave of the longest duration over any area in India.

So far we have considered the persistency of the waves over different sub-divisions where they dissipate or wherefrom they migrate to adjacent regions. If we follow the course of each wave and consider it as a moving phenomenon, it is seen that severe cold waves usually have a life span of about 4 to 5 days in the plains of India. In an exceptional case it lingered in the country for a maximum period of 9 days from 13 to 21 January 1935. The longevity of this interesting wave is depicted in Fig. 3.

#### 6. Extent of severe cold waves

In the months of January, February and March severe cold waves generally prevail at a time over an area of 5,00,000 sq. km. In the other months they are usually of small extent about 2,00,000 sq. km. As a rule, the greater the intensity of the wave, the smaller the area it covers at a time.

Exception to this is noticed in Jammu-Kashmir. In this region severe cold waves are mostly confined to Ladakh. They generally cover either its eastern or the western half at a time irrespective of their intensity.

Of all the severe cold waves on record, perhaps the wave of 12 February 1950 prevailed over the largest area so far. Practically the whole of north India from Rajasthan to Bengal was in the grip of this wave on that day (Fig. 4).

#### 7. Development and decay of severe cold waves

Severe cold waves in India are sometimes an extension of those that prevail in the adjacent countries (West Pakistan, Russia or China) to the west of Long. 75°E. Occasionally the part of the wave extending to the plains of India gets detached from the rest and continues to move eastwards. In such cases its life in India is usually longer. On the other hand if the severe wave does not get detached and continues to move in India as an extended one from the adjacent country, its life

is generally not more than a day beyond Rajasthan (East).

Very often severe cold waves develop *in situ* within the country itself and they account for the higher incidence of severe cold waves in certain isolated regions. Rajasthan, Saurashtra-Kutch and Madhya Pradesh (West) are the regions where severe cold waves develop locally almost in all the months. The first two regions are semi-arid regions where large nocturnal cooling of air takes place. Probably due to this some of the waves of moderate intensity get intensified into severe ones when they reach Rajasthan and Saurashtra-Kutch. Over the northern parts of Madhya Pradesh (West) some of the cold waves get intensified into severe ones, perhaps as a result of radiational cooling favoured by the stagnation of air close to the hill ranges of the area.

Severe cold waves that develop locally in these regions generally die out there itself except those of Rajasthan which may travel or expand to the east or south. As they travel some of them expand with or without further intensification.

Severe cold waves sometimes shrink surprisingly fast as it happened on 13 February 1950 (Figs. 4 and 5). Shrinking of wave may take place at different times from different sides or from all sides almost simultaneously (Fig. 3). Some of the waves continue to move as they shrink (Fig. 6).

There have been many instances when severe cold waves disintegrated into small pools of cold air before they dissipated completely. As cold pools they may be found at altogether different places in any direction (Fig. 6).

As pointed out earlier, Long. 86°E and Lat. 20°N are the critical boundaries where severe cold waves normally begin to decay. Beyond this area their stay is almost always limited to a day.

#### 8. Acknowledgement

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