

Discomfort index over India in different months of the year

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सार — थोम के असुविधा सूचकांक की समानरेखाओं को दर्शाने वाले मानचित्रों के आधार पर देश के विभिन्न भागों में सुबह और शाम के समय वर्ष के विभिन्न महीनों में मानवीय सुविधा और असुविधा का अध्ययन किया गया है। इस सूचकांक की गणना भारत की वेधशालाओं की जलवायु सारणी (1931-1960) के आधार पर की गई है। सिएल एवं पाससेल के द्रुतशीतन पवन सूचकांक से सर्दियों के महीनों (नवम्बर से मार्च तक) में दिल्ली में होने वाली असुविधा का सूत्यांकन किया गया है और प्राप्त परिणामों का थोम के असुविधा सूचकांक से प्राप्त परिणामों से मिलान किया गया है।

ABSTRACT. Human comfort and discomfort over the different parts of the country in the morning and evening hours for the different months of the year are studied on the basis of maps showing the isopleths of Thom's discomfort index, computed from the *Climatological Tables of Observatories in India* (1931-1960). Discomfort over Delhi for the winter months (November to March) has also been evaluated from Siple and Passel's wind chill index and the results compared with those obtained from Thom's discomfort index.

1. Introduction

The main meteorological factors that largely influence the physiological sensation of human comfort are temperature, relative humidity and wind speed. A number of indices utilising some of these factors have been proposed by different scientists, based on the physiological feeling of a large number of people. The human comfort during different hours in the various months of the year has been determined for some selected stations in India by Venkiteshwaran and Swaminathan (1967) utilising Thom's index. Prasad and Pawar (1982) studied the diurnal variation of Thom's index for Bombay for the different months of the year.

A detailed study of the discomfort over the whole of the country in different months in the morning and evening hours has been made using Thom's index and the results are presented in this paper.

For Delhi alone the discomfort during winter has been evaluated using wind chill index of Siple and Passel (1945) and the results compared with those obtained by using Thom's index.

2. Data and the method of study

Thom (1959) has defined his discomfort index by the expressions :

$$D.I. = 0.4 (t_d + t_w) + 15$$

where t_d and t_w are the dry bulb and wet bulb temperatures in °F. The formula reduces to :

$$D.I. = 0.72 (T_d + T_w) + 40.6$$

when the temperature values are expressed in °C.

Climatological mean values of T_d and T_w for 0830 and 1730 IST for different months of the year for the various observatories in India have been taken from the *Climatological Table of Observatories in India (1931-1960)* and the values of Thom's discomfort index calculated for the different observatories for the different months separately for 0830 IST (morning) and 1730 IST (evening) and plotted on relevant charts. These have been analysed and the zones of comfort and discomfort determined for morning and evening hours in different months.

Strong winds add considerably to the discomfort during winter. Discomfort index due to Thom does not take account of the wind. The effect of wind on the discomfort at Delhi during the winter season has been studied both in the early morning (0530 IST) and the evening (1730 IST) hours by the use of wind chill index of Siple and Passel (1945). This index is given by the formula :

$$k = (10\sqrt{v} + 10.45 - v) (33 - T_a)$$

where, v the wind speed is expressed in metres per second and T_a is the atmospheric temperature in °C. The values of the temperature and wind speed have been

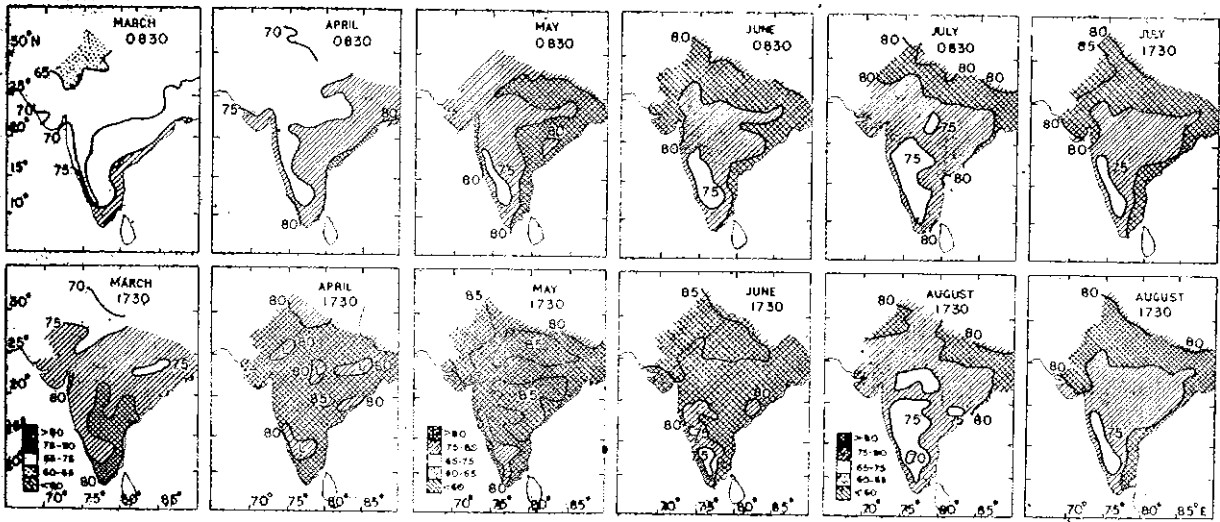


Fig. 1

Fig. 2

Fig. 3

Figs. 1-3. Thom's Index

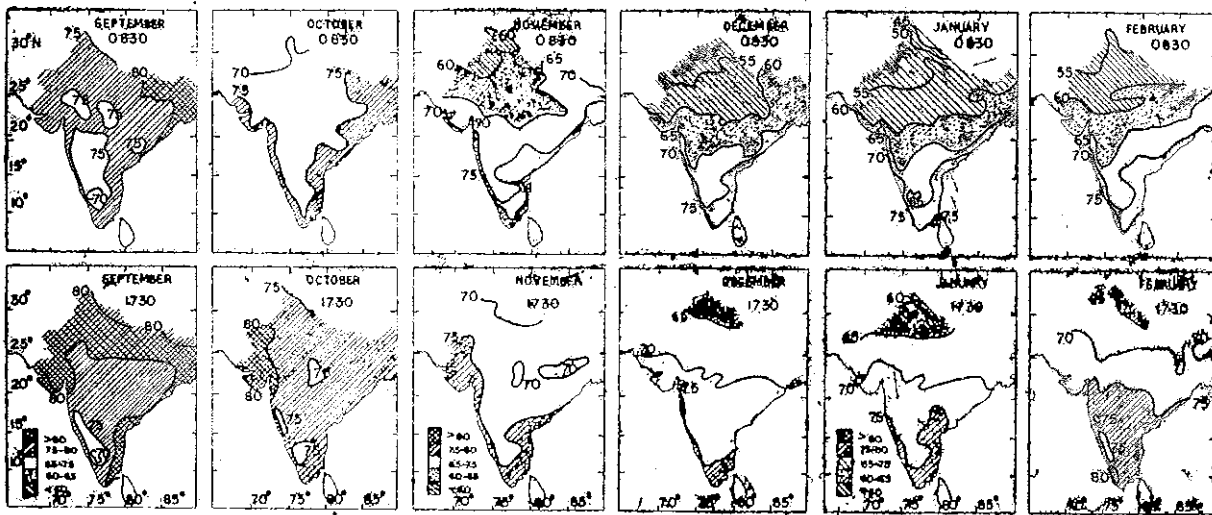


Fig. 4

Fig. 5

Fig. 6

Figs. 4-6. Thom's Index

collected from the aerological data for Delhi for the winter months of November, December, January, February and March for the years 1968 and 1969. These are compared with Thom's discomfort for the same hours of observations.

3. Results

3.1. Discomfort index due to Thom

When the values of the discomfort index are greater than 80 all people feel uncomfortable due to hot humid weather. When they lie between 75 and 80 about half the people feel uncomfortable. When they lie between 65 and 75 people feel quite comfortable. About 50% of the people feel uncomfortable due to dry cold weather when the index value lies between 65 and 60 and almost all people feel uncomfortable when Thom's index falls below 60.

Isopleths of Thom's index at intervals of 5 units are drawn for each month and each hour of observation. From these the zones of comfort and partial and total discomforts on the higher and lower sides have been delineated for different months of the year separately for the morning and evening hours (*vide* Figs. 1 to 6). Data over Assam, Jammu & Kashmir, Himachal Pradesh and the hilly regions of west Uttar Pradesh and of Punjab have not been considered in this study since there is a steep variation due to change in orography. The salient features over the rest of the country are given below.

3.1.1. Pre-monsoon season

Morning hours — It is quite comfortable in the morning hours of March over most parts of the country. People living in coastal Orissa, coastal Andhra Pradesh, eastern parts of Rayalaseema and most parts of Tamil Nadu, Kerala and coastal Karnataka feel partially uncomfortable due to higher values of D.I. West Rajasthan, Punjab and Haryana fall under partial discomfort zone due to low temperature and dryness.

In April a narrow strip along Kerala and the east coast of India is quite uncomfortable with D.I. values exceeding 80. Partial discomfort is felt over east Uttar Pradesh, northeast India, southeast Madhya Pradesh, Vidharbha, Marathwada and the remaining parts of Andhra Pradesh and of Tamil Nadu, coastal Karnataka, Goa, Konkan and south Gujarat State.

During May, most parts of the country to the east of longitude 78 deg. E and the coastal regions of Maharashtra and south Gujarat States are uncomfortable. Interior parts of Karnataka and adjoining south Madhya Maharashtra are comfortable, while the rest of the country is partially uncomfortable with D.I. values between 75 and 80.

Evening hours — In March, north Rajasthan, Punjab Haryana and northwest Uttar Pradesh are the comfortable regions. Most parts of Andhra Pradesh, Tamil Nadu and Kerala are quite uncomfortable, while the remaining parts of the country are partially uncomfortable (D.I. values between 70 and 75).

During April most parts of the country are uncomfortable, D.I. being above 80 with only small pockets being partially uncomfortable (D.I. between 75 and 80).

In May almost the entire country is uncomfortable with large areas in north Peninsula and north India having D.I. values even greater than 85. Some parts of interior Karnataka and adjoining areas are the only regions with partial discomfort.

3.1.2. Monsoon season

Morning hours — Interior Karnataka and adjoining south Madhya Maharashtra are the only regions where weather is comfortable during June.

It is quite uncomfortable in Gujarat State, west and northeast Rajasthan, Punjab, Haryana, Uttar Pradesh, Bihar plains, West Bengal, Orissa, coastal Andhra Pradesh and coastal Tamil Nadu. It is partially uncomfortable over rest of the country.

Completely uncomfortable area has somewhat decreased and is confined to northwest Rajasthan, Punjab, Haryana, Uttar Pradesh, Bihar plains, West Bengal and coastal Orissa. It is quite comfortable in south Madhya Maharashtra, Marathwada and adjoining Telangana, interior Karnataka and north interior Tamil Nadu and partially uncomfortable elsewhere over the country.

In August the area of absolute discomfort has shrunk further to northwest Rajasthan and adjoining areas of Punjab and of Haryana, east Uttar Pradesh, Bihar plains and West Bengal, while the comfortable zone has extended further to southwest Madhya Pradesh.

In September the uncomfortable zone has reduced further and is restricted to Bihar plains, West Bengal and coastal Orissa, while the comfortable zone remains practically unaltered.

Evening hours — Extreme south interior Karnataka is the only region which is comfortable in June. The remaining parts of west Peninsula are partially uncomfortable. The rest of the country is uncomfortable. The index exceeds 85 over Uttar Pradesh, Punjab, Haryana, northeast and west Rajasthan and adjoining Gujarat State.

By July the comfortable zone extends from south interior Karnataka to south Madhya Maharashtra across some parts of north interior Karnataka. It is uncomfortable over Gujarat State, Rajasthan, Punjab, Haryana, Uttar Pradesh, Bihar plains, West Bengal, coastal Orissa, coastal Andhra Pradesh and coastal Tamil Nadu with index values exceeding 85 over northwest Rajasthan. It is partially uncomfortable over the rest of the country.

August and September patterns are almost similar to that of July except that D.I. values exceeding 85 are not present.

3.1.3. Post monsoon season

Morning hours — It is partially uncomfortable with D.I. values exceeding 75 over Bihar plains, West

TABLE 1
Number of days within specific ranges of Thom's and Siple and Passel's index

Thom's index	Siple and Passel						Total	Thom's index	Siple and Passel						Total
	<50	50-100	100-200	200-400	400-600	>600			<50	50-100	100-200	200-400	400-600	>600	
November (00 GMT)							January (12 GMT)								
45							45								
45-50				1.0	3.5	1.5	6.0	45-50			5.0	0.5		5.5	
50-55			0.5	5.0	4.5	0.5	10.5	50-55		1.5	7.0	5.0		13.5	
55-60			1.5	2.5	1.5		5.5	55-60		3.0	5.5	2.0		10.5	
60-65			5.5	2.0			7.5	60-65		1.0	0.5			1.5	
65			0.5				0.5	65							
Total			8.0	10.5	9.5	2.0	30.0	Total		5.5	18.0	7.5		31.0	
November (12 GMT)							February (00 GMT)								
45							45				1.0	3.0	4.0		
45-50							45-50			1.5	2.0	4.0	7.5		
50-55				0.5			0.5	50-55			1.0	8.0	0.5	9.5	
55-60		2.0	6.0	4.5	0.5		13.0	55-60		1.0	2.0	3.5		6.5	
60-65		5.5	3.0	1.0			9.0	60-65				1.0		1.0	
65	0.5	5.0	1.5				7.0	65							
Total	0.5	12.5	10.5	6.0	0.5		30.0	Total		1.0	4.5	15.5	7.5	28.5	
December (00 GMT)							February (12 GMT)								
45					0.5	0.5	1.0	45			3.5	2.0		5.5	
45-50				8.5	5.5	8.0	22.0	45-50		1.0	1.5	4.5	1.0	8.0	
50-55			2.0	5.0			7.0	50-55		2.5	5.0	3.0		10.5	
55-60			0.5	0.5			1.0	60-65			0.5	3.5	0.5	4.5	
65								65							
Total			11.0	11.5	8.5		31.0	Total		3.5	7.0	14.5	3.0	28.5	
December (12 GMT)							March (00 GMT)								
45								45			3.5	2.0		5.5	
45-50		0.5	0.5	1.5			2.5	45-50			1.0	1.5	4.5	1.0	8.0
50-55		2.5	7.5	0.5			12.5	50-55		2.5	5.0	3.0		10.5	
55-60		6.5	6.0	0.5			13.0	60-65			0.5	3.5	0.5	4.5	
60-65	1.0	1.0	1.0				3.0	65							
65								65							
Total	1.0	10.5	17.0	2.5			31.0	Total		3.5	7.0	14.5	3.5	28.5	
January (00 GMT)							March (12 GMT)								
45				1.0	3.5	4.5		45							
45-50			3.5	6.0	4.5	14.0		45-50				2.0		2.0	
50-55		2.5	6.0			8.5		50-55			1.5	3.0		4.5	
55-60		2.0	2.0			4.0		55-60		3.5	7.5	2.5		13.5	
60-65								60-65		2.0	6.5	2.0		10.5	
65								65		0.5				0.5	
Total		8.0	15.0	8.0		31.0		Total		6.0	15.5	9.5		31.0	

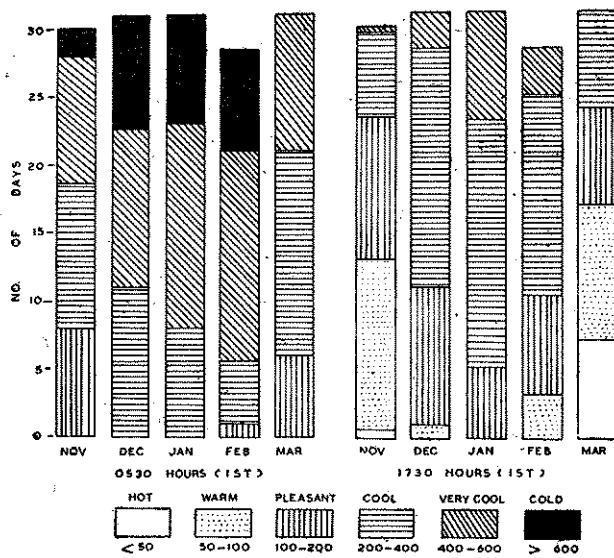


Fig. 7. Siple's and Passel's index

Bengal, Orissa, most parts of Andhra Pradesh and of Tamil Nadu and along the west coast and comfortable over the rest of the country in October.

In November partially uncomfortable areas with D.I. values exceeding 75 are confined to coastal Karnataka, Kerala and coastal Tamil Nadu.

It is partially uncomfortable with D.I. values between 65 and 60 over west and northeast Madhya Pradesh, west and central parts of Uttar Pradesh and east and southwest Rajasthan. It is uncomfortable with D.I. values less than 60 over northwest Rajasthan, Punjab and Haryana. It is comfortable over the rest of the country.

Evening hours — In October, Gujarat State and southwest Rajasthan are quite uncomfortable with D.I. values exceeding 80. It is partially uncomfortable over the rest of the country except for small pockets of comfortable zones in south interior Karnataka and west Madhya Pradesh.

In November southwest Rajasthan, Gujarat State, west coast, Tamil Nadu, Rayalaseema and coastal Andhra Pradesh are partially uncomfortable (D.I. between 75 and 80), while the rest of the country is quite comfortable.

3.1.4. Winter months

Morning hours — A very narrow coastal strip off the extreme south Peninsula is the only region with partial discomfort, with D.I. values exceeding 75. Andhra Pradesh, Karnataka, Konkan and the remaining parts of Kerala and of Tamil Nadu are generally comfortable. North Madhya Pradesh, Uttar Pradesh, north Gujarat State and northwest India are quite uncomfortable with D.I. values below 60; over north Rajasthan, Punjab and Haryana the values are below 55. It is uncomfortable over the rest of the country.

January pattern is similar to December. In February the absolutely comfortable zone has further extended north to Gangetic West Bengal, Orissa, southeast Madhya Pradesh and eastern parts of Vidharbha and Marathwada. Northeast and southwest Madhya Pradesh, southeast Uttar Pradesh, Gujarat State and remaining parts of Maharashtra are partially uncomfortable with D.I. values between 60 and 65. It is quite uncomfortable over the rest of the country (D.I. less than 60). However, D.I. values less than 55 are restricted to northwest Rajasthan and western parts of Punjab.

Evening hours — In December the partial uncomfortable zone (D.I. between 75 and 80) is restricted to Tamil Nadu and west coast. It is partially uncomfortable with D.I. values less than 65 over northwest Uttar Pradesh, north Haryana and Punjab. It is comfortable over the rest of the country.

In January the uncomfortable zone with D.I. values exceeding 75 is confined to south coastal Andhra Pradesh, eastern parts of Telangana, Rayalaseema, Tamil Nadu, Kerala, coastal Karnataka and adjoining south Konkan. The partially uncomfortable zone with D.I. values less than 65 are confined to northwest Uttar Pradesh, Haryana, Punjab and northwest Rajasthan. Over the rest of the country it is quite comfortable.

In February it is quite uncomfortable with D.I. values exceeding 80 over the central parts of Kerala. It is generally partially uncomfortable over Andhra Pradesh, Karnataka, Tamil Nadu, west Kerala, Maharashtra State and south Gujarat region. It is comfortable over the rest of the country.

3.2. Wind chill index

Wind chill index of Siple and Passel has been computed for 0530 and 1730 IST for every day for the winter months of November, December, January, February and March for the years 1968 and 1969 for Delhi. According to them the weather is hot, warm, pleasant, cool, very cool, cold, very cold and bitter cold when K values are respectively less than 50, 50-100, 100-200, 200-400, 400-600, 600-800, 800-1000 and 1000-1200. At Delhi, however, the value rarely exceeds 800. For each of these days and the hours of observations, Thom's discomfort index has also been computed. Contingent tables showing the number of days when Thom's index were below 45, 45-50, 50-55, 55-60 and 60-65, with corresponding ranges of Siple and Passel's index have been prepared for the months of November, December, January, February and March, separately for 00 and 12 GMT and are given in Table 1. The salient features show by these tables are given below :

(i) The two indices are closely related. Being winter, the discomfort is due to low temperature, low humidity and high winds. Where Thom's index is more than 65 (actually between 65 and 75) it is quite comfortable. The discomfort increases, as the value of Thom's index decreases. It will be seen from the table that, in general, low values of Thom's index correspond to large values of Siple and Passel's chill index,

(ii) During early morning hours, according to Thom absolutely comfortable days (D.I. greater than 65) are practically *nil* during the winter months. These are about 7 to 8 days of partial discomfort (D.I. between 60 and 75) in November and 10 to 11 days in March. The remaining days in December, January and February are absolutely uncomfortable (D.I. less than 60). December and January are the most uncomfortable months with D.I. values being less than 50 on about 20 days of the month.

Afternoon hours are absolutely comfortable (D.I. values greater than 65) on about 7 days in November and 5 days in March and partially uncomfortable on about 10 days in November, 2 to 4 days in each of the months December, January and February and 13 days in March.

(iii) *Morning hours* — During November it is pleasant (K between 100 and 200) on 8 days and cool (K between 200 and 400) and very cool (K between 400 and 600) on 10 days each and cold (K greater than 600) on 2 days. The discomfort increases with advance of winter, 11 days each in December being cool and very cool and 8 days cold while during January 8 days are cool, 15 days very cool and 8 days cold. In February 1 day is pleasant 4 days are cool, 15 days very cool and 8 days cold. Discomfort becomes much less in March where 6 days are pleasant, 15 days cool and 9 days very cool.

(iv) *Evening hours* — In November, 12 days are warm (K between 50 and 100), 10 days pleasant and 6 days cool, while in December only one day is warm, 10 days pleasant, 17 days cool and 2 to 3 days very cool. During January 5 to 6 days are pleasant, 18 days cool and 7 to 8 days are cold whereas in February 3 days are warm, 7 days pleasant, 15 days cool and 3 days very cool. In March 7 days are hot (K less than 50), 10 days warm, 7 days pleasant and the remaining days cool.

(v) It would appear from the above that Siple and Passel's wind chill index is a better parameter for assessing human comfort than Thom's index over north

India in winter. Histograms showing the number of days falling in each category in each of the months, November to March are shown in Fig. 7 separately for early morning (0530 IST) and evening (1730 IST).

4. Conclusion

(1) In December, January and February, northwest India, most parts of Uttar Pradesh, Gujarat State and of Madhya Pradesh are uncomfortable in the morning hours with D.I. values being less than 55 in northwest India during January and February mornings.

(2) D.I. values exceed 80 in the morning hours over eastern-half of the country in May and Gujarat State and area north of latitude 25 deg. N in June. The area decreases progressively from June to September. In the evening hours, absolute discomfort prevails over the whole of the country in April and May and the country outside west Peninsula in June, in Gujarat State and areas north of latitude 25 deg. N from July to September.

(3) Though there is a general agreement between the comfortability or otherwise as assessed by Thom's index and Siple and Passel's index, the latter appears to be better suited to assess human comfort in north India during winter.

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