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Wet bulb temperature distribution over India

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ABSTRACT. The distribution of wet bulb temperature over India for four representative months and for the year have been studied. A general discussion on human comfort has been made. Effective temperature diagrams drawn at three selected stations have been utilized for the evaluation of inferences.

1. Introduction

Wet bulb temperature is one of the parameters that is representative of moisture content of the atmosphere. Further, in biometeorological studies, wet bulb temperature has a direct application (Haldane 1905, Leonard Hill 1911-14). The author is, however, not aware of any publication on the study of spatial distribution of wet bulb temperature excepting that of Doraiswamy (1945). This study is based on observational data of 26 stations at 0830 and 1800 hours. However, Malurkar (1951) studied the wet bulb potential temperatures in and near India, based on the data at 0800 hr LT. Wet bulb temperature is practically the same as wet bulb potential temperature at stations where elevations are low and pressure differences from sea level are less than 50-60 mb.

In the present study the spatial distribution of wet bulb temperature with special reference to human comfort has been made.

2. Data and Analysis

2.1. *Spatial distribution of wet bulb temperature* (T_w) — Available monthly data of mean daily wet bulb temperature based on autographic records at 45 stations have been utilized in this study. The stations with their details are given in Table 1. Isolines for four representative months (January, April, July and October) and annual isolines delineating the distribution of T_w are shown in Fig. 1. Fig. 2 represents the isolines of monthly mean daily range of T_w for the month of January (as the isolines in the other three months, *viz*., April, July and October are not deviating much from the annual map, these are not presented here) and annual. Figs. 3 and 4 respectively represent (*i*) the annual range (highest mean maximum *minus* lowest mean minimum of 12 months) and (*ii*) mean extreme annual range of T_w. The ratio of mean diurnal range to mean daily T_w for the four seasons (Winter : Dec to Feb; Pre-monsoon : Mar-May; Monsoon : Jun to Sep; Post monsoon : Oct and Nov) and annual are shown in Table 1.

2.2. *Effective temperature diagrams* — Effective temperatures have been obtained from the nomogram of ASHRAE (1967) using monthly mean hourly data of wet bulb temperature, dry bulb temperature and wind speed at Madras, Poona and Jodhpur for a period of ten years, 1957-66. Fig. 5 shows the mean effective temperature diagrams at these three selected stations. Generally the value of effective temperature taken for the discomfort by many workers in India on the basis of Malhotra's (1967) work is 75° F. On the basis of this limit, the discomfort periods in Fig. 5 are discussed.

3. Discussion

3.1. In Peninsular India, there is practically no correspondence with latitude, orographic contrasts like land sea distribution, which control the moisture regime and the T_w distribution. (*i*) In winter (January) the region of high and low T_w values are seen respectively over the coastal belts and northwest India. The diurnal range of T_w is small over south Peninsular India and large over northeast India (with a secondary region over northwest India). (*ii*) By summer (April) not only does T_w increases markedly but also the pattern of variation over north India changed markedly. Still the regions of high and low T_w are confined respectively to coastal belts and northwest India. The region of slightly higher T_w values is more towards the east coast. A decrease in the diurnal variation of T_w is also seen. The diurnal range of T_w is small along the coastal belts and large over northeast and northwest India. (*iii*) During the southwest monsoon season (July) higher values of T_w

TABLE 1

Mean daily range/mean of T_w at different stations

Station	Co-ordinates		Height (m)	Period of data	Season				Annual
	Lat. (°N)	Long. (°E)			1	2	3	4	
Port Blair	11°40′	92°43′	0079	1957-66	0·12	0·10	0·07	0·10	0·09
Dibrugarh	27 28	94 55	0106	1957-66	0·40	0·20	0·09	0·29	0·19
Gauhati	26 11	91 45	0054	1957-66	0·38	0·16	0·06	0·21	0·17
Agartala	23 53	91 15	0016	1963-66	0·39	0·16	0·07	0·19	0·18
Calcutta	22 39	88 27	0006	1957-66	0·23	0·15	0·08	0·15	0·13
Saugar Island	21 39	88 03	0003	1958-64	0·11	0·06	0·04	0·06	0·05
Sriniketan	23 39	87 42	0059	1960-66	0·24	0·14	0·06	0·15	0·12
Imphal	24 46	93 54	0781	1962-65	0·84	0·24	0·08	0·38	0·25
Asansol	23 41	86 59	0126	1963-66	0·39	0·16	0·08	0·20	0·16
Jharsuguda	21 55	84 05	0230	1957-66	0·19	0·13	0·07	0·13	0·11
Jamshedpur	22 49	86 11	0129	1957-66	0·25	0·17	0·07	0·16	0·11
Gaya	24 45	84 57	0116	1957-66	0·39	0·18	0·06	0·16	0·19
Allahabad	25 27	81 44	0098	1957-66	0·37	0·17	0·06	0·22	0·15
Lucknow	26 52	80 56	0111	1957-66	0·44	0·19	0·06	0·28	0·17
New Delhi	28 35	77 12	0216	1957-66	0·44	0·19	0·09	0·25	0·22
Gwalior	26 14	78 15	0207	1963-66	0·59	0·24	0·08	0·32	0·20
Amritsar	31 38	74 52	0234	1957-66	0·59	0·26	0·09	0·35	0·22
Pathankot	32 14	75 38	0312	1963-66	0·34	0·18	0·08	0·23	0·17
Srinagar	34 05	74 15	1586	1957-66	—	0·38	0·20	0·68	—
Dehradun	30 19	78 02	0682	1963-66	0.40	0·23	0·10	0·32	0·20
Jodhpur	26 18	73 01	0224	1957-66	0·39	0·17	0·07	0·23	0·17
Barmer	25 45	71 23	0194	1963-66	0·39	0·19	0·06	0·25	0·13
Jaipur	26 49	75 48	0390	1957-66	0·41	0·18	0·07	0·25	0·15
Jagdalpur	19 05	82 02	0553	1957-66	0·30	0·14	0·06	0·20	0·14
Bhopal	23 17	77 21	0523	1957-66	0·32	0·21	0·07	0·19	0·15
Indore	22 43	75 48	0567	1963-66	0·37	0·26	0·07	0·24	0·17
Ahmedabad	23 04	72 38	0055	1957-66	0·23	0·13	0·08	0·14	0·12
Veraval	20 54	70 22	0008	1957-66	0·35	0·16	0·03	0·22	0·24
Bombay	18 54	72 49	0011	1957-66	0·17	0·08	0·06	0·12	0·09
Vengurla	15 52	73 38	0009	1957-66	0·16	0·07	0·05	0·10	0·08
Aurangabad	19 53	75 20	0581	1963-66	0·34	0·17	0·08	0·31	0·20
Poona	18 32	73 51	0559	1957-66	0·38	0·21	0·09	0·23	0·17
Nagpur	21 06	79 03	0310	1957-66	0·37	0·20	0·08	0·27	0·19
Visakhapatnam	17 43	83 14	0003	1957-66	0·15	0·10	0·07	0·11	0·10
Hyderabad	17 27	78 28	0545	1957-66	0·24	0·15	0·07	0·17	0·14
Gannavaram	16 32	80 48	0024	1963-66	0·14	0·09	0·07	0·09	0·09
Anantapur	14 41	77 37	0350	1963-66	0·17	0·14	0·10	0·14	0·13
Tiruchirapalli	10 46	78 45	0088	1957-66	0·08	0·08	0·07	0·07	0·08
Madras	13 00	80 11	0016	1957-66	0·09	0·07	0·08	0·07	0·08
Mangalore	12 52	74 51	0022	1957-62	0·10	0·06	0·06	0·08	0·07
Bangalore	12 58	77 35	0921	1957-66	0·13	0·11	0·08	0·11	0·19
Coimbatore	12 02	77 03	0400	1963-66	0·15	0·12	0·09	0·12	0·14
Trivandrum	08 29	76 57	0064	1957-66	0·09	0·07	0·06	0·07	0·07
Shillong	25 34	91 53	1500	1957-66	0·38	0·27	0·11	0·28	0·21
Kodaikanal	10 14	77 28	2343	1957-66	0·50	0·32	0·21	0·33	0·31

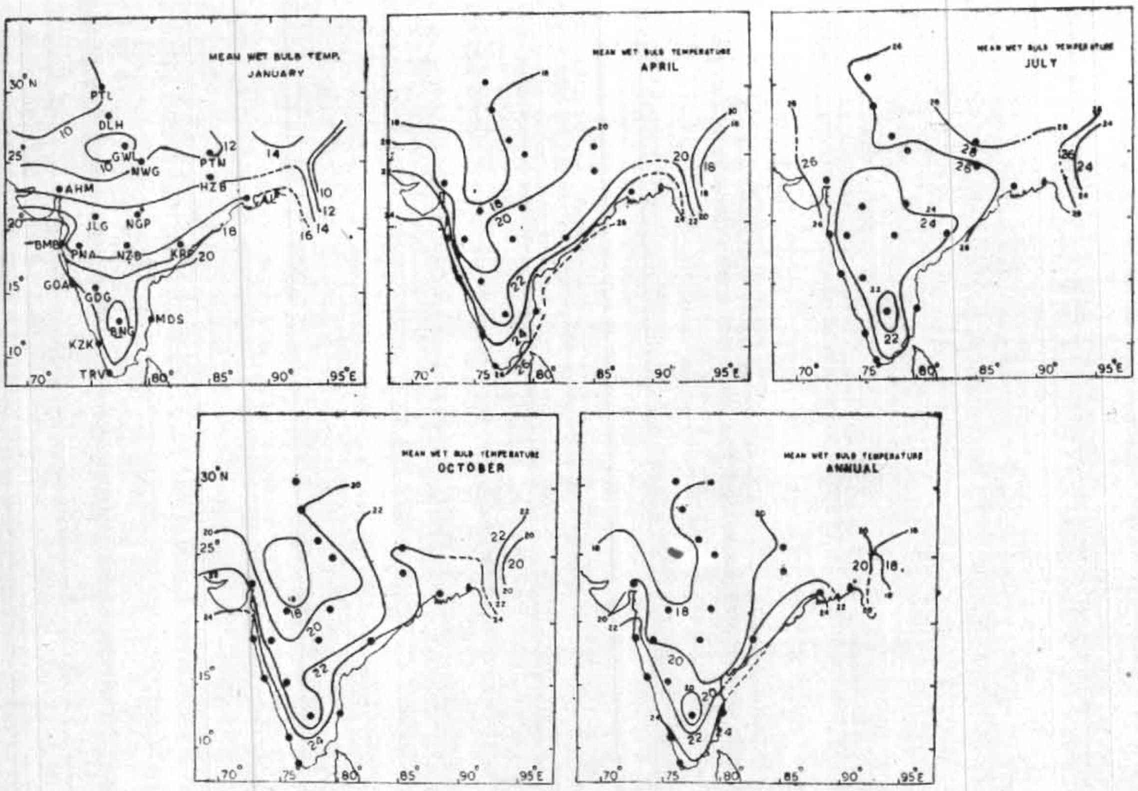

Fig. 1. Variation of T_w (°C) over India (4 representative months and annual)

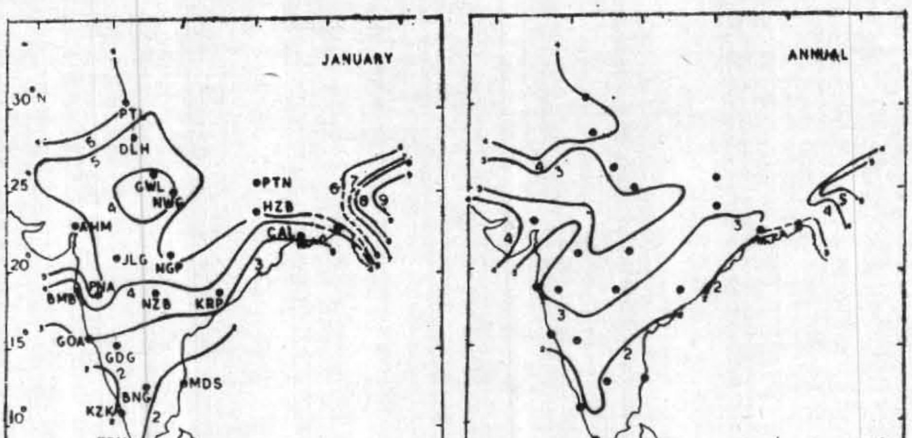

Fig. 2. Variation of diurnal range of the Tw (°C) over India (January and annual)

are seen over north India (comparatively higher over Bihar region) and lower values in Peninsular India. The diurnal range of T_w shows larger values towards east and smaller values towards west coast. (*iv*) In post monsoon season (October) the pattern of distribution of T_w is similar to April.

3.2. The range of T_w over India in January of 10°-20°C and with south to north gradient is 10°C. This pattern is seen upto April with uniform rise of temperature by 2°C per month. From April onwards the gradient is decreasing by 2°C per month upto June and from June to September the gradient is uniform with 4°C. The gradient again

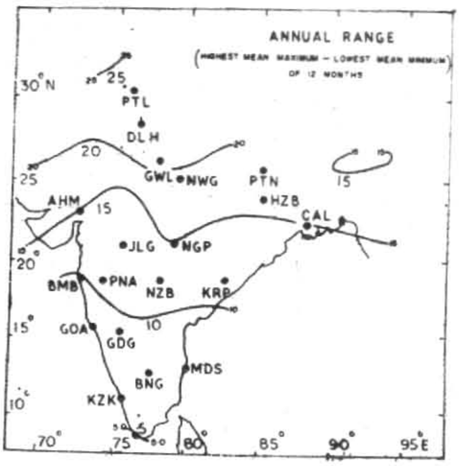

Fig. 3. Annual range

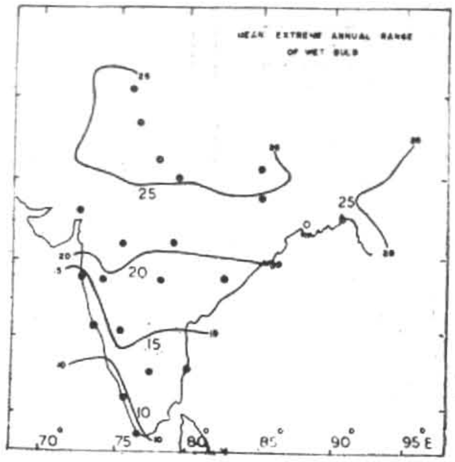

Fig. 4. Mean extreme annual range of wet bulb temperature

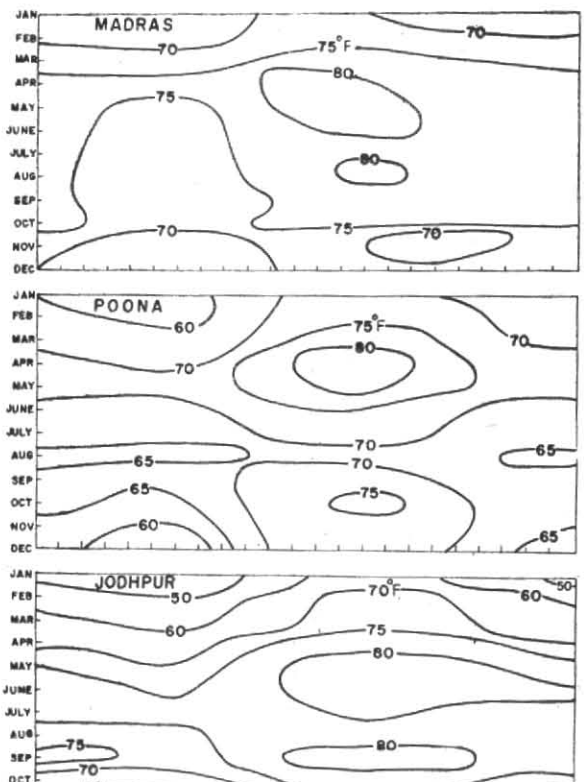

Fig. 5. Effective temperature diagrams

increases from September to December, with December value being highest, *i.e.*, 12°C. The highest isotherm of 28°C (in July) is passing through parts of Bihar and Uttar Pradesh, which is the region where frequent heat wave conditions exist in this season. The terms of discomfort are given by WMO (*see* Ref.) in terms of T and h as 20°C, 85 per cent; 25°C, 60 per cent; 30°C, 44 per cent and 35°C, 33 per cent but it is seen from the equation postulated by Reddy (1976), T_w is a function of both T and h and also heat and cold waves are dependent on relative sensation of human body, that the definitions of heat and cold waves in terms of T_w are more appropriate than in terms of T_w.

3.3. It is seen from Table 1 that the ratio of mean daily range to mean T_w is increasing with height. The values are lowest along the coastal belt. The ratio is highest in winter and lowest in monsoon season.

3.4. Along the east coast the discomfort starts from the end of March and continues upto the middle of October. In the northwest coast the discomfort starts from the end of April and ends by the middle of July. In northwest India the discomfort starts from the end of May and ends by the middle of September. In the central parts and north India (except NW India) the discomfort starts from the end of May and with severe conditions in July, ends by the beginning of October. A general agreement is also found between the conclusions drawn by the author here on discomfort and the radiation discomfort results in an earlier work (Philip and Reddy 1974).

3.5. From Fig. 5 it is seen that Madras experiences discomfort from March to October between 1100 and 0200 IST and April being uncomfortable throughout the day; Poona experiences discomfort in April and May months between 1000-1900 IST, and Jodhpur experiences discomfort from May to October between 1000-2400 IST while June and July being uncomfortable throughout the day. This type of feature is also generally seen from Figs. 1 and 2, where the association of high T_w (*i.e.*, greater than discomfort limit) with lower diurnal range is associated with maximum period of the day being uncomfortable and high T_w associated with higher diurnal range is associated with less period of the day being comfortable.

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W. M. O. — *Tech. Note* No. 65.

ERRATA

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Page 269 Column 1, 2nd line from bottom

Read ....may not be reliable when the cloud top is more than......

for ....may be reliable when the cloud top is more than......

Vol. 26 No. 4 (October 1975)

Page 509 Col. 2, para 2, line 3

Read near 6°N, 95°E *instead* near 60°N, 95°E