A NEW APPROACH TOWARDS CLASSIFICATION OF CLIMATES

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The basic requirements from a general stand point, for a rational system of classification of climates, have been enumerated with particular reference to the study of the arid zones. Some of the limitations of Thornthwaite's "moisture index", based on potential evapotranspiration, have been pointed out.

The significance of the diurnal range of temperatures as a composite climatic factor has been stressed, and a strong negative correlation between the annual average of diurnal temperature range and the average annual precipitation has been established for 150 non-coastal stations in India and neighbourhood. A new climatic index has been defined in terms of the logarithm of the ratio of these two variables, to enable classification of climates on a linear scale.

A nomo-gram has been worked out for quick evaluation of this new climatic index, thereby avoiding the necessity of tedious computational work. A climatic map has been prepared from the data of 182 stations in India and neighbourhood including 32 coastal stations. The map clearly brings out the rapid increase in aridity from western Rajasthan, across West Pakistan, towards further west.

Various schemes for classification of climates have been put forward from time to time, but mostly from the point of view of the agricultural meteorologist, whose interest lies mainly in the characteristics of natural vegetation. Naturally he regards temperature and precipitation as the most important climatic elements that can be used for defining climatic types.

Thornthwaite's[1] new system of classification based on potential evapotranspiration has attracted wide attention and is generally regarded as the most rational approach in relation to plant and forest ecology. His empirical formula defining a "moisture index", requires the knowledge of the mean monthly temperature and precipitation, together with the local latitude. This method was applied by Subrahmanyam[2] for studying the climatic types of India and neighbourhood. He, however, pointed out the difficulty of ascertaining the validity of any existing scheme of climatic classification in the absence of a reliable vegetation map of India.

Apart from the agricultural meteorologist, there are others, *e.g.* the clothing scientist, bio-climatologist, nutrition chemist, designers of various service equipment and so on who are equally interested in climatic classification, though for different reasons.

Lately, scientific efforts have largely been directed towards the study of arid-zone problems in many countries including ours. Unfortunately, climatological studies of the various arid regions appear mostly to be qualitative in approach. It is important not only to be able to define the boundaries of the arid regions with reasonable precision but also to grade them in terms of degrees of aridity.

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REQUIREMENTS FOR A GENERAL SCHEME OF CLIMATIC CLASSIFICATION

From the foregoing, one cannot escape the conclusion that the need exists for a fresh approach towards the development of a rational scheme of climatic classification from a general stand point. Such a scheme should meet a few basic requirments as enumerated below :

1. It should reasonably account for the recognised climatic types of particularly well known regions.
2. It should, in a fair measure, reflect the combined effect of the major climatic elements.
3. Classification should be on a linear scale so that equal changes in the climatic index will indicate equal changes in the climate in any region, arid or humid. In other words, the scale should be equally sensitive throughout its range.
4. In particular, it should be capable of distinguishing arid regions of varying degrees of aridity.

Thornthwaite's method of classification in terms of his "moisture-index", I_m, as applied by Subrahmanyam[2] to Indian climates, was examined in the light of the above requirements. The broad conclusions arrived at may be summarised as follows—

1. The climatic scale is not linear, being highly compressed for the arid type (I_m —60 to —40), and progressively spreading out towards the humid type (I_m 20 to 100). No upper limit has been prescribed for the perhumid type, which may very well approach 1000 or so, as in the case of Cherapunji. Thus the entire dry climates from dry subhumid to arid type lie in the range 0 to —60 as compared to the range 0 to about 1000 for moist climates from moist subhumid to perhumid type.
2. The very low sensitivity of the scale in the Arid Zone makes it virtually impossible to compare different arid regions with any precision, although we know that conditions prevailing in Western Rajasthan are quite mild as compared to those prevailing in the interior parts of West Pakistan well removed from the sea or from the mountains in the north.
3. The method of computing the moisture index I_m, does not appear to be valid in the case of high altitude stations. The potential evapotranspiration values[2] evaluated for high altitudes are always far lower than those for the plains (Table 2). This cannot be justified on physical grounds. Lowered temperature lowers the saturation vapour pressure of water thereby lowering the evaporation rate. But this effect is opposed by the corresponding lowering of atmospheric vapour pressure at high altitude. It appears, therefore, that the computational procedure needs suitable modification to be applicable to high altitude stations. Otherwise the moisture index will always over estimate the humidity as will be evident in the case of Darjeeling, Simla, Srinagar and Ootacamund, the four high altitude stations listed by Subrahmanyam[2] (Table 4).
4. Subrahmanyam's analysis on the basis of Thornthwaite's scheme reveals that most sections of India are more arid than indicated by earlier schemes. He has also labelled a region in Central Deccan as completely arid[2] (Fig. 1), which is not supported by any previous climatic map. Further evidence is therefore, necessary to substantiate these findings.

In view of the above, an attempt has been made in this paper to indicate a new line of approach towards classification of climates from a general stand point.

DIURNAL TEMPERATURE RANGE AS A COMPOSITE CLIMATIC FACTOR

Precipitation is by far the most important single climatic element dominating the climatic type, although as stated earlier, a satisfactory scheme of climatic classification should reflect the combined effect of the major climatic elements. It is hardly feasible to incorporate these elements individually in any formula for practical use. A question now naturally poses itself. Is there any simple measureable parameter which can more or less serve the same purpose? The "diurnal range of temperatures" seems to be the best answer provided by nature.

Typical arid regions, such as Sind (excluding coastal stations), Baluchistan, Western Rajasthan (west of Aravalli) and most of Ladakh area are characterised by a large diurnal range of temperatures. The humidity being generally low, radiation exchange with the surroundings is high. This, together with clear skies and bare ground almost without vegetation, result in high insolation during day time, followed by a very rapid cooling during night.

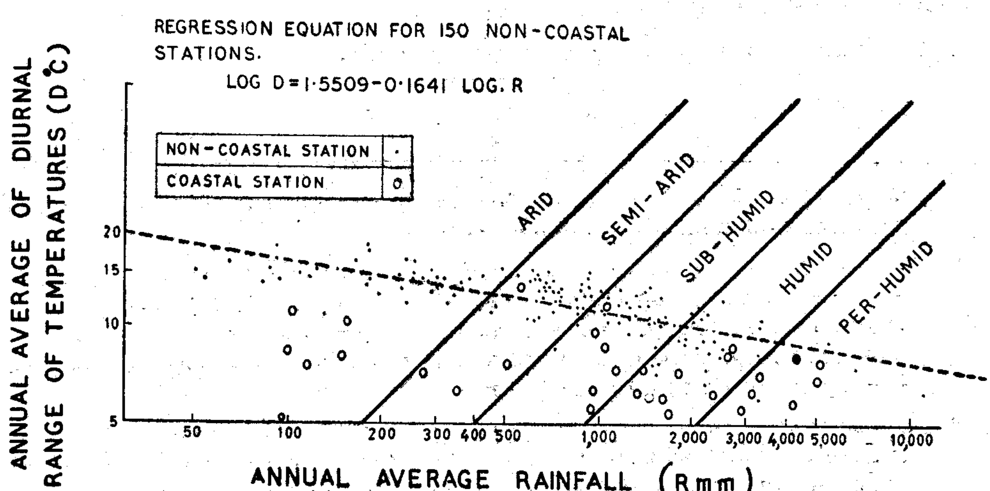

FIG. 1—Relationship between diurnal range of temperatures and precipitation with reference to climatic types in India and neighbourhood.

At the other extreme, we have the highly humid regions typical examples being, the mountains of Assam and Burma, northern part of West Bengal including Darjeeling and most of East Pakistan. The climatic elements are invariably opposite to those prevailing in arid regions, resulting in a relatively small diurnal range of temperatures.

The combined effect of the major climatic elements is thus well reflected in the diurnal range of temperatures, which may, therefore, be regarded as a composite climatic factor, comparable in importance to the single element of precipitation.

The above hypothesis was further tested by plotting in Fig. 1, the annual average of diurnal range of temperatures (D°C) against the annual average rainfall (R mm), both on logarithmic scales, for 150 non-coastal stations in India and neighbourhood. The relevant climatic data[3] for these stations have been presented in Appendix I, and include height above mean sea level in meter, latitude, longitude, annual averages of daily maximum and minimum temperature in °C and annual average rainfall in mm. The annual average of the diurnal temperature range is simply the difference between the corresponding maximum and minimum temperatures and has been shown in column 8 of Appendix I.

The linear regression equation between log D and Log R works out to be

$$\text{Log } D = 1\cdot5509 - 0\cdot1641 \text{ log } R \quad (1)$$

and is represented by the continuous line through the scatter in Fig. 1.

Analysis of variance as summarised in Table 1 indicates a highly significant correlation between the two variables log D and log R.

TABLE 1

ANALYSIS OF VARIANCE WITH RESPECT TO LOG D AND LOG R

Sources of variation	D.F.	Sum of squares	Mean squares	F
Regression	1	0·6958	0·6958	331†
Deviation from regression	148	0·3058	0·0021	..
Total ..	149	1·0016	..	..

†Highly significant.

Coastal stations, which were excluded from the above analysis, offer an interesting study. Presence of vast surfaces of water naturally tend to raise the humidity and lower the diurnal range of temperatures even in the absence of rains. For example, Charbar in Iran and Jacobabad in West Pakistan have nearly the same annual rainfall (100 mm and 92 mm respectively). But the annual average of the diurnal range of temperatures is 16·4°C for Jacobabad as compared to only 8·5°C for Charbar, which is a coastal station. Climatic data[3] for 32 coastal stations have been presented in Appendix II, and the corresponding points have also been shown in Fig. 1 as open circles.

A NEW CLIMATIC INDEX IN TERMS OF D AND R

The foregoing discussions are meant to bring out the basic idea that it is possible to express the overall climatic feature of any place in a fairly quantitative manner, in terms of two simple parameters, namely (*i*) D, the annual average of diurnal range of temperatures, and (*ii*) R, the annual average rainfall.

We now proceed to define a new climatic index, I_{clm}, as a function of D and R, the main object being to achieve a linear scale of climatic classification on the basis of the following assumptions—

1. 'I_{clm}' is in the nature of a dryness index, in contrast with Thornthwaite's moisture index 'I_m' so that I_{clm} is positive for all dry climates and negative for all moist climates, its value increasing algebraically with increasing dryness.

2. Change in I_{clm} is proportional to the fractional changes in D and R, and not to their actual changes.

3. D and R are equally important in their control over I_{clm}.

Assumption (2) is obvious on physical grounds, and ensures linearity of the scale of I_{clm}, while assumption (3) follows as a first approximation, from the discussions in the preceding section.

The first two assumptions can be mathematically expressed in the differential form

$$\partial I_{clm} = a \frac{\partial D}{D} - b \frac{\partial R}{R} \qquad (2)$$

zero value of I_{clm} corresponding to transition from moist to dry climate. 'a' and 'b' are positive constants, the negative sign with 'b' implying that dryness increases with decreasing rainfall.

The third assumption states that

$$a=b,$$

whence equation (2) becomes,

$$\partial I_{clm} = a \left(\frac{\partial D}{D} - \frac{\partial R}{R} \right).$$

Integration yields

$$I_{clm} = a \log \frac{D}{R} + k \qquad (3)$$

Now, let $\frac{D_o}{R_o}$ be the value of the ratio $\frac{D}{R}$ when $I_{clm} = 0$.

Then we must have

$$0 = a \log \frac{D_o}{R_o} + k \qquad (4)$$

from equation (3) and (4), we get

$$I_{clm} = a \log \left(\frac{D/R}{D_o/R_o} \right) \qquad (5)$$

Equation (5) defines the climatic index I_{clm} as proportional to the logarithm of the dimensionless ratio $\left(\frac{D/R}{D_o/R_o}\right)$. The constant '$a$' is also dimensionless, and its value depends only on the arbitrary choice of the size of the unit of I_{clm}. Constancy of the ratio D/R implies constancy of the climatic index.

EVALUATION OF CONSTANTS

Since the constant 'a' in eqn (5) depends on the size of the unit of I_{clm}, we choose the size in such a way that the three climatic types, semi-arid, sub-humid and humie occupy a range of 20 units each, the zero value lying in the middle of the sub-humid type We follow the terminology of Thornthwaite and the proposed scheme of classification in terms of the new climatic index I_{clm} is indicated in Table 2.

TABLE 2

PROPOSED SCHEME OF CLIMATIC CLASSIFICATION IN TERMS OF THE NEW CLIMATIC INDEX, I clm

Climatic type		Range of I_{clm}
ARID		+31 and above
SEMI-ARID		+11 to +30
SUB-HUMID	Dry	0 to +10
	Moist	—1 to —10
HUMID		—11 to —30
PER-HUMID		—31 and below.

For evaluation of the constants of equation (5), we must know two stations having two different border line climates. Since that is not practicable, we have no alternative other than to fall back on the generally accepted boundaries between semi-arid, arid and sub-humid, humid types. We, therefore, assume that the arid-zone starts a little west of the Aravalli, near our West Pakistan border while the humid-zone starts a little east of the West Bengal, East Pakistan border. We select a few stations on either side of each border well removed from the sea or the mountains and take the mean climatic index as representative of the particular border line climate.

(a) Fixing the border between Arid and Semi-arid climates

We select four stations from Appendix I close to the conventional boundary between arid and semi-arid zones in India. The stations are Jodhpur and Hissar on the Arid side and Ajmer and New Delhi on the semi-arid side of the border. The mean value of $\log \frac{D}{R}$ for these four stations is found to be 2·4560. Taking $I_{clm} = +30$ for the border line climate, we have from eqn. (5).

$$+30 = a\left(\bar{2}.4560 - \log \frac{D_\circ}{R_\circ}\right) \qquad (6)$$

(b) Fixing the border between Sub-humid and Humid climates

In this case, the four stations selected are Jessore and Bogra on the sub-humid side and Narayangunj and Faridpur on the humid side of the border. The mean value of $\log \frac{D}{R}$ for these stations is found to be $\bar{3}$·7430 while I_{clm} for this border climate is —10. Hence from eqn. (5), we have

$$-10 = a\left(\bar{3}.7430 - \log \frac{D_\circ}{R_\circ}\right) \qquad (7)$$

From equations (6) and (7) the constants work out to be

$$a = 56 \text{ and } \log \frac{D_\circ}{R_\circ} = \bar{3}\cdot 9212, \text{ whence } \frac{D_\circ}{R_\circ} = \frac{1}{120}.$$

On substitution of these values of the constants, eqn. (5) finally takes the form,

$$I_{clm} = 56 \log \frac{120\,D}{R} \qquad (8)$$

With the help of eqn. (8), a simple nomogram as presented in Fig. 2, has been prepared for quick evaluation of the new climatic index I_{clm}, avoiding tedious computationa work.

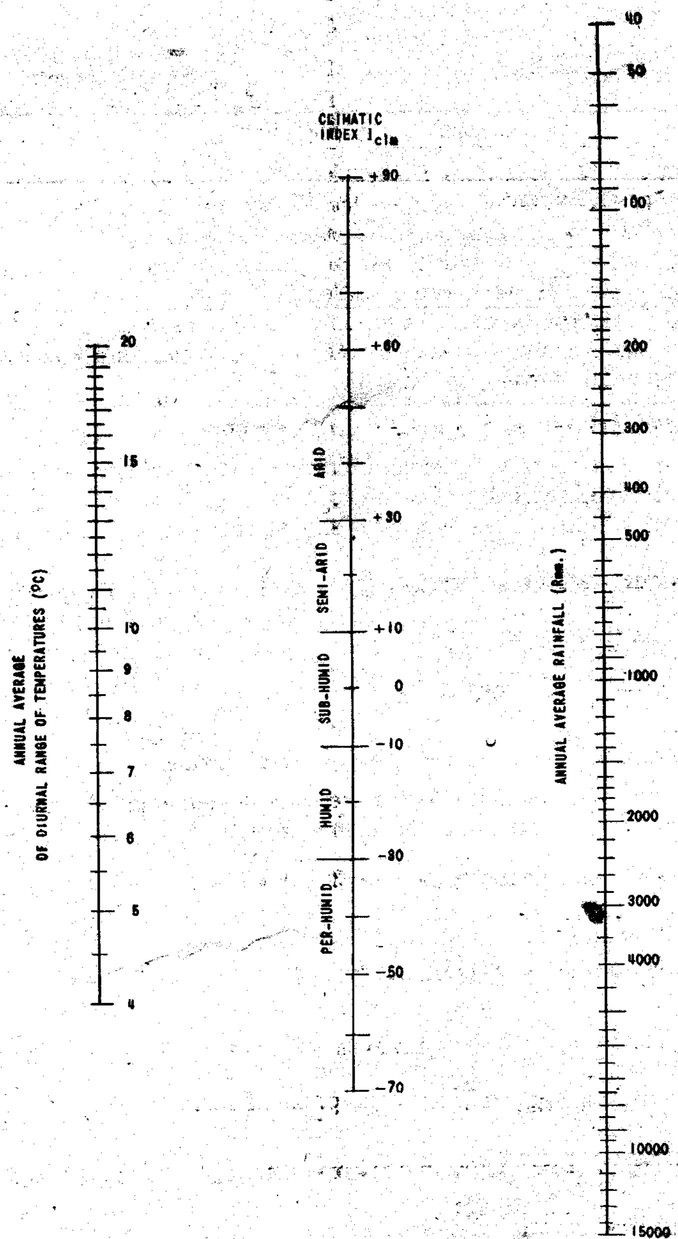

FIG. 2—Nomogram for evaluation of climatic index in relation to climatic types.

CLIMATIC MAP OF INDIA IN TERMS OF THE NEW CLIMATIC INDEX

The nomogram in Fig. 2 was used to determine I_{clm} for all the 182 stations listed in Appendices I and II. The extreme values obtained are +86 for Nokkundi in Baluchistan and —63 for Cherrapunji in Assam. Further classification of arid and per humid climates was, therefore, considered desirable. A tentative scheme for the same is presented in Table 3.

TABLE 3

TENTATIVE SCHEME FOR CLASSIFICATION OF ARID AND PERHUMID CLIMATES

Climatic type		Range of I_{clm}
ARID	Extreme	+71 to +90
	Moderate	+51 to +70
	Mild	+31 to +50
PER-HUMID	Moderate	—31 to —50
	Extreme	—51 to —70

All the 182 stations in India and neighbourhood as listed in Appendices I and II were classified in terms of the new climatic index according to the scheme proposed in Tables 2 and 3 and have been shown in a map in Fig. 3.

DISCUSSIONS

The main object of the present study, namely definition of a climatic index which will enable classification on a linear scale, seems to have been achieved. For example, the new climatic index ranges from 0 to +90 for the entire dry climates and from 0 to —70 for the entire moist climates. If the zero of the scale, which is by no means absolute, is shifted by ten units to the positive side, all the possible climatic types will be evenly distributed on either side of the zero value.

The new climatic index seems to be capable of grading arid regions of different degrees of aridity. Western Rajasthan to the west of Aravalli, is mildly arid. Almost whole of West Pakistan is moderately arid. Only Jacobabad is a border line case (I_{clm} +73). Nokkundi and Dalbandin in Baluchistan, and Zahidan and Seistan in Iran are extremely arid. The map in Fig. 3 clearly demonstrates the rapid increase in aridity from western Rajasthan, across West Pakistan, towards further west. It will be rather interesting to study the climatic features of the famous deserts all over the world, in terms of the new index.

Most of India according to the present classification falls in the semi-arid zone, which is in good agreement with earlier systems of classification. In Northern India, there is a progressive decrease in I_{clm} from West to East. The Northern tip of West Bengal, most of East Pakistan and Assam are humid, while Darjeeling is moderately perhumid, and Cherrapunji is extremely perhumid. Practically all the coastal stations of Burma are moderately perhumid.

The entire eastern coast of India is considerably drier than the western coast below a latitude of about 20° N.

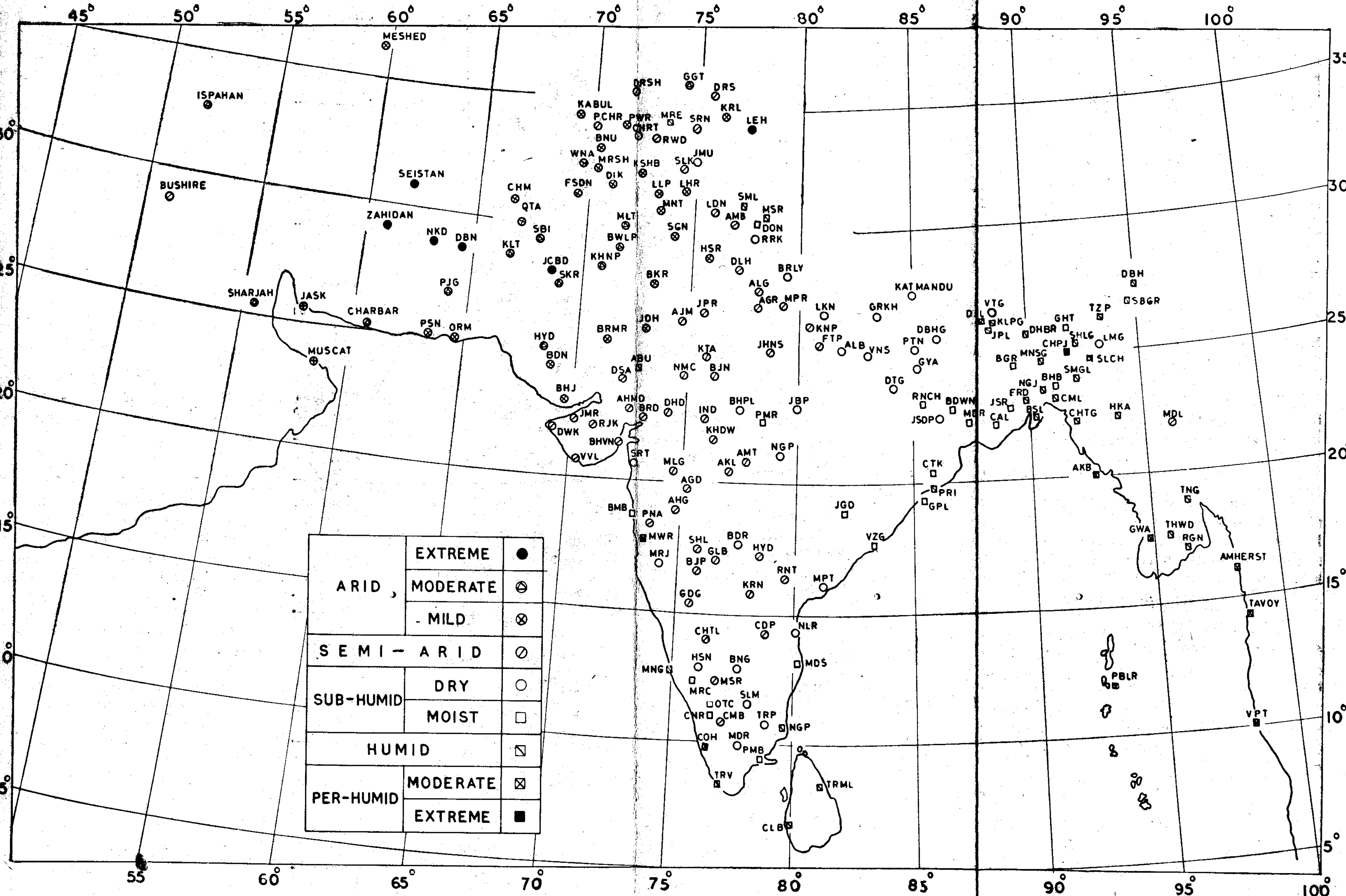

FIG. 3—Stations in India and neighbourhood classified in terms of new climatic index (Iclm).

Contrary to Subrahmanyam's findings, and in agreement with earlier schemes[2], none of the stations studied in the central Deccan has been found to be typically arid.

The present study is neither elaborate nor exhaustive, its sole purpose being to indicate a possible new line of approach from a general standpoint which may overcome the major limitations of Thornthwaite's scheme.

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2. SUBRAHMANYAM, V. P., *Indian J. Met. Geophys.*, **7**, 253 (1956).
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APPENDIX I

TEMPERATURE AND RAINFALL DATA[3] OF 150 STATIONS IN INDIA AND NEIGHBOURING COUNTRIES EXCLUDING COASTAL STATIONS

Serial No.	Station	Height above M.S.L. (*Meters*)	Lat. N	Long. E	Annual average of: Daily max. temp. °C	Daily min. temp. °C	Diurnal range of temp. °C	Annual average of rain fall (*mm*)
1	2	3	4	5	6	7	8	9
			° ′	° ′				
1	Abu	1,202	24 36	72 43	24·3	16·6	07·7	1,564
2	Agra	169	27 10	78 02	32·5	17·3	15·2	679
3	Ahmedabad	50	23 02	72 35	34·7	21·5	13·2	742
4	Ahmednagar	656	19 05	74 55	32·1	17·9	14·2	601
5	Ajmer	485	26 27	74 37	31·2	18·4	12·8	528
6	Akola	282	20 42	77 02	34·1	19·9	14·2	817
7	Aligarh	187	27 53	78 04	31·6	18·6	13·0	784
8	Allahabad	98	25 27	81 44	32·3	19·1	13·2	1,062
9	Ambala	272	30 23	76 46	31·2	17·3	13·9	837
10	Amraoti	370	20 56	77 47	33·3	20·9	12·4	852
11	Aurangabad	580	19 53	75 20	32·4	19·2	13·2	719
12	Badin	9	24 38	68 54	33·3	19·8	13·5	231
13	Bahawalpur	117	29 24	71 47	33·2	17·6	15·6	144
14	Bangalore	920	12 58	77 35	28·9	17·8	11·1	866
15	Bannu	385	33 00	70 36	30·8	16·6	14·2	282
16	Bareilly	173	28 22	79 24	30·9	18·3	12·6	1,083
17	Barisal	3	22 42	90 22	30·1	21·4	08·7	2,055
18	Barmer	194	25 45	71 23	33·6	20·2	13·4	301
19	Baroda	35	22 18	73 15	34·1	19·0	15·1	932
20	Bhopal	500	23 16	77 25	31·3	18·5	12·8	1,329
21	Bhuj	104	23 15	69 48	32·8	20·1	12·7	346
22	Bider	..	17 55	77 32	31·4	20·7	10·7	857
23	Bijapur	594	16 49	75 43	32·6	20·0	12·6	513
24	Bikaner	224	28 00	73 18	33·3	20·2	13·1	291
25	Bogra	19	24 51	89 23	30·3	20·1	10·2	1,760

APPENDIX I—*contd.*

1	2	3	4	5	6	7	8	9
		(*Meters*)	° ′	° ′	°C	°C	°C	(*mm*)
26	Brahmanbaria	10	23 59	91 07	30·8	19·6	11·2	1,992
27	Brijnagar	321	24 32	76 10	32·3	18·6	13·7	926
28	Burdwan	32	23 14	87 51	31·7	21·2	10·5	1,515
29	Calcutta	6	22 32	88 20	31·4	21·2	10·2	1,600
30	Chaman	1,314	30 55	66 28	25·7	12·7	13·0	195
31	Cherat	1,302	33 50	71 54	22·4	13·7	08·7	725
32	Cherrapunji	1,313	25 15	91 44	20·5	14·2	06·3	10,801
33	Chitaldrug	733	14 14	76 26	30·8	19·9	10·9	643
34	Coimbatore	408	11 00	76 58	31·8	21·1	10·7	590
35	Comilla	9	23 28	91 11	30·2	20·4	09·8	2,385
36	Coonoor	1,747	11 21	76 48	21·4	12·6	08·8	1,512
37	Cuddapah	130	14 29	78 50	35·2	23·7	11·5	769
38	Cuttack	27	20 29	85 52	32·7	22·3	10·4	1,523
39	Dalbandin	849	28 54	64 26	30·7	12·6	18·1	92
40	Daltonganj	221	24 03	84 04	31·9	18·6	13·3	1,186
41	Darbhanga	49	26 10	85 54	30·5	19·6	10·9	1,270
42	Darjiling	2,265	27 03	88 16	14·8	8·8	6·0	3,211
43	Dessa	142	24 14	72 12	34·7	19·3	15·4	613
44	Dehra Dun	680	30 19	78 02	27·4	15·7	11·7	2,160
45	Dera Ismail Khan	174	31 49	70 55	32·0	17·1	14·9	231
46	Dhubri	35	26 01	89 59	28·2	20·1	08·1	2,485
47	Dibrugarh	106	27 28	94 55	27·3	18·4	08·9	2,800
48	Dohad	333	22 50	74 16	32·8	19·5	13·3	715
49	Dras	3,063	34 26	75 46	9·0	—5·4	14·4	649
50	Drosh	1,436	35 34	71 47	22·3	11·1	11·2	450
51	Faridpur	14	23 37	89 51	29·8	20·6	09·2	1,805
52	Fatehpur	114	25 56	80 50	32·4	19·1	13·3	885
53	Fort Sandeman	1,406	31 21	69 27	26·5	12·1	14·4	275
54	Gadag	650	15 25	75 38	30·4	19·9	10·5	620
55	Gauhati	55	26 11	91 45	29·3	19·2	10·1	1,612

APPENDIX I—*contd.*

1	2	3	4	5	6	7	8	9
		(*Meters*)	° ′	° ′	°C	°C	°C	(*mm*)
56	Gaya	111	24 49	85 01	31·7	19·7	12·0	1,190
57	Gilgit	1,490	35 55	74 23	22·3	11·2	11·1	132
58	Gorakhpur	77	26 45	83 22	31·1	19·3	11·8	1,274
59	Gulbarga	458	17 21	76 51	33·7	20·6	13·1	746
60	Haka	1,859	22 39	93 37	20·2	11·8	8·4	2,270
61	Hassan	960	13 00	76 09	28·8	17·4	11·4	889
62	Hissar	221	29 10	75 44	32·3	17·4	14·9	426
63	Hyderabad	542	17 26	78 27	32·4	20·2	12·2	747
64	Hyderabad (Sind)	29	25 23	68 25	34·1	20·2	13·9	180
65	Indore	555	22 43	75 54	31·6	17·7	13·9	882
66	Ispahan	1,771	32 40	51 44	23·1	07·9	15·2	112
67	Jacobabad	57	28 17	68 29	35·3	18·9	16·4	92
68	Jagdalpur	553	19 05	82 02	30·9	18·2	12·7	1,605
69	Jaipur	436	26 55	75 50	32·2	18·1	14·1	610
70	Jalpaiguri	83	26 32	88 43	29·2	19·1	10·1	3,270
71	Jammu	366	32 44	74 55	29·4	18·9	10·5	1,069
72	Jamnagar	18	22 29	70 04	31·9	20·0	11·9	472
73	Jamshedpur	129	22 49	86 11	32·3	20·3	12·0	1,360
74	Jessore	8	23 10	89 13	30·9	19·9	11·0	1,645
75	Jhansi	251	25 27	78 35	32·9	20·2	12·7	936
76	Jodhpur	224	26 18	73 01	33·2	19·2	14·0	361
77	Jubbulpore	392	23 10	79 57	31·3	17·6	13·7	1,462
78	Kabul	1,815	34 30	69 13	19·8	5·2	14·6	317
79	Kalat	2,016	29 02	66 35	22·3	3·7	18·6	178
80	Kalimpong	1,202	27 04	88 28	21·2	14·6	06·6	2,190
81	Kanpur	126	26 26	80 22	31·7	18·9	12·8	912
82	Kargil	2,682	34 34	76 08	15·2	3·1	12·1	240
83	Katmandu	1,337	27 42	85 12	25·4	12·0	13·4	1,415
84	Khandwa	318	21 50	76 22	33·5	19·4	14·1	781
85	Khanpur	91	28 39	70 41	34·2	17·7	16·5	165

APPENDIX I—*contd.*

1	2	3	4	5	6	7	8	9
		(*Meters*)	° ′	° ′	°C	°C	°C	(*mm*)
86	Khushab	187	32 18	72 22	31·9	17·5	14·4	386
87	Kotah	257	25 11	75 51	33·3	20·8	12·5	750
88	Kurnool	281	15 50	78 04	34·3	22·0	12·3	630
89	Lahore	214	31 35	74 20	31·8	16·1	15·7	488
90	Leh	3,520	34 09	77 34	12·7	—1·3	14·0	83
91	Lucknow	113	26 52	80 56	32·1	18·9	13·2	1,016
92	Ludhiana	248	30 56	75 52	31·2	17·6	13·6	691
93	Lumding	..	25 45	93 11	29·2	18·2	11·0	1,305
94	Lyallpur	184	31 26	73 06	31·5	16·9	14·6	306
95	Madura	133	09 55	78 07	33·7	23·4	10·3	873
96	Mahabaleshwar	1,381	17 56	73 40	23·6	16·1	7·5	6,635
97	Mainpuri	157	27 14	79 03	32·6	18·4	14·2	710
98	Malegaon	437	20 33	74 32	33·4	18·4	15·0	548
99	Mandalay	77	21 59	96 06	32·6	21·1	11·5	872
100	Mercara	1,152	12 25	75 44	24·5	16·3	08·2	3,240
101	Meshed	946	36 17	59 36	21·2	06·1	15·1	255
102	Midnapore	45	22 25	87 19	32·2	21·5	10·7	1,495
103	Miraj	554	16 49	74 41	31·4	18·9	12·5	653
104	Miranshah	925	33 57	70 07	26·6	14·6	12·0	326
105	Montgomery	558	30 39	73 08	32·5	17·9	14·6	256
106	Multan	126	30 12	71 31	32·3	18·3	14·0	179
107	Murree	2,168	33 55	73 23	15·8	08·1	07·7	1,510
108	Mussoorie	2,115	30 27	78 05	17·5	10·1	07·4	2,225
109	Mymensingh	19	24 46	90 24	29·6	20·5	09·1	2,325
110	Mysore	768	12 18	76 42	30·2	19·0	11·2	792
111	Nagpur	311	21 09	79 07	33·4	21·2	12·2	1,251
112	Narayanganj	8	23 37	90 30	30·3	21·4	08·9	1,875
113	Neemuch	494	24 28	74 54	31·5	18·1	13·4	765
114	New Delhi	218	28 35	77 12	31·6	18·1	13·5	666
115	Nokkundi	680	28 49	62 45	32·2	16·7	15·5	50

APPENDIX I—*contd.*

1	2	3	4	5	6	7	8	9
		(*Meters*)	° ′	° ′	°C	°C	°C	(*mm*)
116	Ootacamund	2,243	11 24	76 44	18·9	9·4	9·5	1,394
117	Pachmarhi	1,076	22 28	78 26	26·7	16·0	10·7	2,022
118	Panjgur	969	26 58	64 06	29·8	14·1	15·7	122
119	Parachinar	1,729	33 52	70 04	21·3	8·8	12·5	743
120	Patna	53	25 37	85 10	30·9	20·5	10·4	1,186
121	Peshawar	354	34 01	71 35	29·4	15·8	13·6	345
122	Poona	558	18 32	73 51	31·9	18·0	13·9	673
123	Quetta	1,673	30 10	67 01	23·2	6·7	16·5	240
124	Rajkot	132	22 18	70 50	33·8	19·1	14·7	630
125	Ranchi	655	23 23	85 20	28·9	18·5	10·4	1,480
126	Rawalpindi	510	33 36	73 07	28·9	14·4	14·5	924
127	Rentichintala	106	16 33	79 33	34·6	23·4	11·2	713
128	Roorkee	274	29 51	77 53	30·1	19·0	11·1	1,050
129	Salem	278	11 39	78 10	33·8	22·0	11·8	978
130	Seistan	..	31 02	61 30	28·0	13·3	14·7	54
131	Shillong	1,500	25 34	91 53	21·1	11·9	9·2	2,150
132	Sholapur	479	17 40	75 54	33·7	20·3	13·4	6 1
133	Sialkot	253	32 30	74 32	30·5	16·8	13·7	809
134	Sibi	134	29 33	67 53	34·4	19·5	14·9	118
135	Sibsagar	97	26 59	94 38	27·5	18·8	8·7	2,495
136	Silchar	29	24 49	92 48	30·3	19·7	10·6	3,280
137	Simla	2,201	31 06	77 10	16·9	9·7	7·2	1,550
138	Sriganganagar	177	29 55	73 53	32·7	16·4	16·3	255
139	Srimangal	21	24 19	91 44	30·9	18·6	12·3	2,500
140	Srinagar	1,586	34 05	74 50	19·9	6·6	13·3	660
141	Sukkur	67	27 42	68 54	34·0	19·6	14·4	94
142	Tavoy	6	14 05	98 12	31·2	22·1	9·1	5,460
143	Tezpur	79	26 37	92 47	28·7	19·6	9·1	1,845
144	Thararawaddy	15	17 40	95 48	32·5	21·4	11·1	2,215

APPENDIX II—*contd*

1	2	3	4	5	6	7	8	9
		(*Meters*)	° ′	° ′	°C	°C	°C	(*mm*)
145	Toungoo	48	18 55	96 28	32·2	21·4	10·8	2,115
146	Trichinopoly	78	10 49	78 42	34·5	23·7	10·8	870
147	Varanasi	76	25 18	83 01	32·0	19·3	12·7	1,041
148	Wana	1,358	32 18	69 44	24·8	9·6	15·2	291
149	Yatung (Chumbe)		27 29	88 55	13·5	2·1	11·4	967
150	Zahidan		29 30	60 53	25·4	8·9	16·5	65

APPENDIX II

TEMPERATURE AND RAINFALL DATA[3] OF 32 COASTAL STATIONS IN INDIA AND NEIGHBOURING COUNTRIES

Serial No.	Station	Height above M.S.L. (*Meters*)	Lat. N	Long. E	Annual average of Daily max. temp.	Annual average of Daily min. temp.	Annual average of Diurnal range of temp.	Annual average of rain-fall (*mm*)
1	2	3	4	5	6	7	8	9
			° ′	° ′	°C	°C	°C	
1	Akyab	09	20 08	92 55	29·7	21·9	07·8	5,150
2	Amherst	22	16 05	97 34	30·2	23·3	06·9	5,050
3	Bhavnagar	17	21 45	72 12	34·2	20·6	13·6	561
4	Bombay	11	18 54	72 49	30·4	23·2	07·2	1,809
5	Bushire	04	28 59	50 49	27·7	20·4	07·3	275
6	Charbar	08	25 17	60 37	29·4	21·9	08·5	100
7	Chittagong	27	22 21	91 50	29·5	20·7	08·8	2,735
8	Cochin	03	09 58	76 14	29·7	24·3	05·4	2,930
9	Colombo	07	06 54	79 53	29·9	23·9	06·0	2,368
10	Dwarka	11	22 22	69 05	29·1	22·8	06·3	354
11	Gopalpur	17	19 16	84 53	30·2	22·9	07·3	1,155
12	Gawa	03	17 35	94 35	29·6	21·4	08·2	4,365
13	Jask	04	25 45	57 45	30·5	22·9	07·6	117
14	Madras	686	13 04	80 15	33·4	23·8	09·6	1,268
15	Mangalore	22	12 52	74 51	30·7	23·6	07·1	3,292
16	Masulipatam	03	16 11	81 08	32·3	23·6	08·7	1,055
17	Muscat	05	23 45	58 35	30·6	25·4	05·2	96
18	Negapatam	09	10 46	79 51	32·2	24·8	07·4	1,400
19	Nellore	20	14 27	79 59	34·1	24·2	09·9	989
20	Ormara	05	25 15	64 39	29·6	21·4	08·2	153
21	Pamban	11	09 16	79 18	30·9	25·4	05·5	944
22	Pasni	03	25 16	63 28	30·2	19·5	10·7	157
23	Port Blair	80	11 40	92 43	29·4	23·1	06·3	3,150
24	Puri	06	19 48	85 49	30·1	23·8	06·3	1,363
25	Rangoon	05	16 46	96 11	31·4	22·9	08·5	2,620

APPENDIX II—*contd.*

1	2	3	4	5	6	7	8	9
		(*Meters*)	° ′	° ′	°C	°C	°C	(*mm*)
26	Sharjah	05	25 20	55 24	31·2	19·9	11·3	104
27	Surat	12	21 12	72 50	33·1	21·3	11·8	1,055
28	Trincomalee	07	08 35	81 15	30·7	24·8	05·9	1,645
29	Trivandrum	64	08 29	76 57	29·8	24·5	05·3	1,696
30	Veraval	08	20 55	70 22	29·5	21·9	07·6	504
31	Victoria Point	48	09 59	98 35	29·7	23·9	05·8	4,210
32	Vizagapatam	38	17 42	83 18	30·5	24·2	06·3	963