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Seasonal Oscillation of the Diurnal Range of Temperature in India and neighbourhood

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ABSTRACT. The seasonal oscillation of the diurnal aperiodic amplitude of air temperature at 4 ft above ground has been studied with reference to the data of 167 climatological stations in India and neighbourhood.

It has been found that the annual and half-yearly oscillations account for nearly 90–95 per cent of the variation except at a very few stations associated with special features.

The amplitude of the annual oscillation is largest (9–10°F) over a track extending from the Gulf of Cambay on the west to Bihar on the east and decreases towards the coast and towards the Himalayas. The maximum in the oscillation occurs generally in February; the notable exception being the southeast Peninsula where it is very much delayed being as late as May and over the Coromandel coast.

The half-yearly amplitude is much smaller in magnitude with highest values of 4–5°F over the northwestern part of the country decreasing towards the coast and the Himalayas; the maximum in the oscillation occurs generally in May advancing by two to three months in the south Peninsula outside the west coast.

Regression equations for representing distribution of the components of the two oscillations as linear functions of latitude, longitude and elevation have been derived. The fit of these representations has been found to be fairly good in the case of the annual and half-yearly amplitudes and generally for phase angles of the annual oscillation. The significance of the gradients with respect to the positional co-ordinates have been discussed.

1. Introduction

The range between the mean temperature of the hottest and the coldest time of the day is usually referred to as the diurnal periodic amplitude while the difference between the maximum and minimum temperatures of the day is called the diurnal non-periodic amplitude. It is obvious that the non-periodic amplitude is always greater than the periodic amplitude and the disparity is most pronounced in winter. In the present study we will be concerning ourselves with the non-periodic amplitude and this will be referred to as the diurnal range of temperature.

As the diurnal range of temperature is the difference between the maximum and minimum temperatures, all factors which affect the maximum and minimum temperatures individually may be expected to affect the range as well. Thus the factors to be considered may be topography, soil characteristics, continentality, the latitude and time of the year which determine the solar elevation and above all the thermal structure of the atmosphere as well as the extent and nature of clouding.

Fig. 1 shows the seasonal march of the diurnal range of temperature at a few representative stations. The smaller annual range at the coastal locations against a large annual range in the purely continental locations is well-known. Again in hilly locations the nature of the terrain has considerable influence as seen from the curves for Dras, Khatmandu, Darjeeling and Kodaikanal.

2. Scope of the study and data

Jagannathan (1948 b) has expressed the diurnal range of temperature in each of the

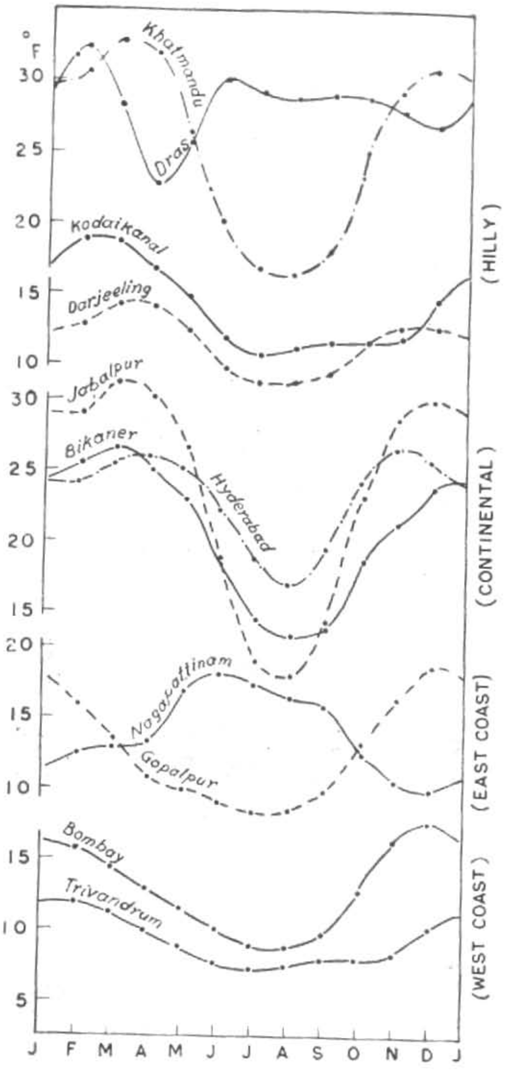

Fig. 1. Mean diurnal range of temperature at representative stations

months as a linear function of latitude, longitude and elevation of the station. In the present study attempt has been made (*i*) to represent the month to month variation of the diurnal range of temperatures at each of the stations as a function of time with a view to study the nature of its seasonal variation and (*ii*) to determine the extent of the dependence of the various parameters representing the seasonal oscillation on the latitude, longitude and elevation. The list of stations, their positional coordinates and elevation above sea level are the same as are given in Table 1 of Jagannathan's earlier paper (1948 a) and as such they are not repeated here. The monthly mean diurnal ranges of air temperature at the different stations are given in Tables 1 to 4 of the second paper (1948 b). The mean diurnal range of temperatures at these 167 meteorological stations distributed throughout India and neighbourhood have been utilised in the foregoing study. The location of the stations and the layout of the regions are given in Fig. 2 for reference.

3. Graduation of the seasonal march

The seasonal march of the mean diurnal range of air temperature has been represented by the following function of time—

$$R_t = \overline{R} + a_1 \sin\left(\frac{2\pi}{P}t + \alpha_1\right) + \\ + a_2 \sin\left(\frac{2\pi}{P/2}t + \alpha_2\right) + \epsilon_2 \quad (1)$$

where $\overline{R}$ is the mean diurnal range of temperature for the year as a whole, a_1 and a_2 are the amplitudes of the annual and half-yearly oscillations, α_1 and α_2 are the phase angles in the respective oscillations, P the periodic time, *viz.*, 24 solar hours, and ϵ_2 the error after fitting up two harmonics.

4. Discussion of Results

4.1. Tables 1(a) to 1(d) give the mean diurnal range of temperature, the amplitudes and phase angles of the annual and half-yearly oscillations together with the percentage of seasonal variation left unaccounted

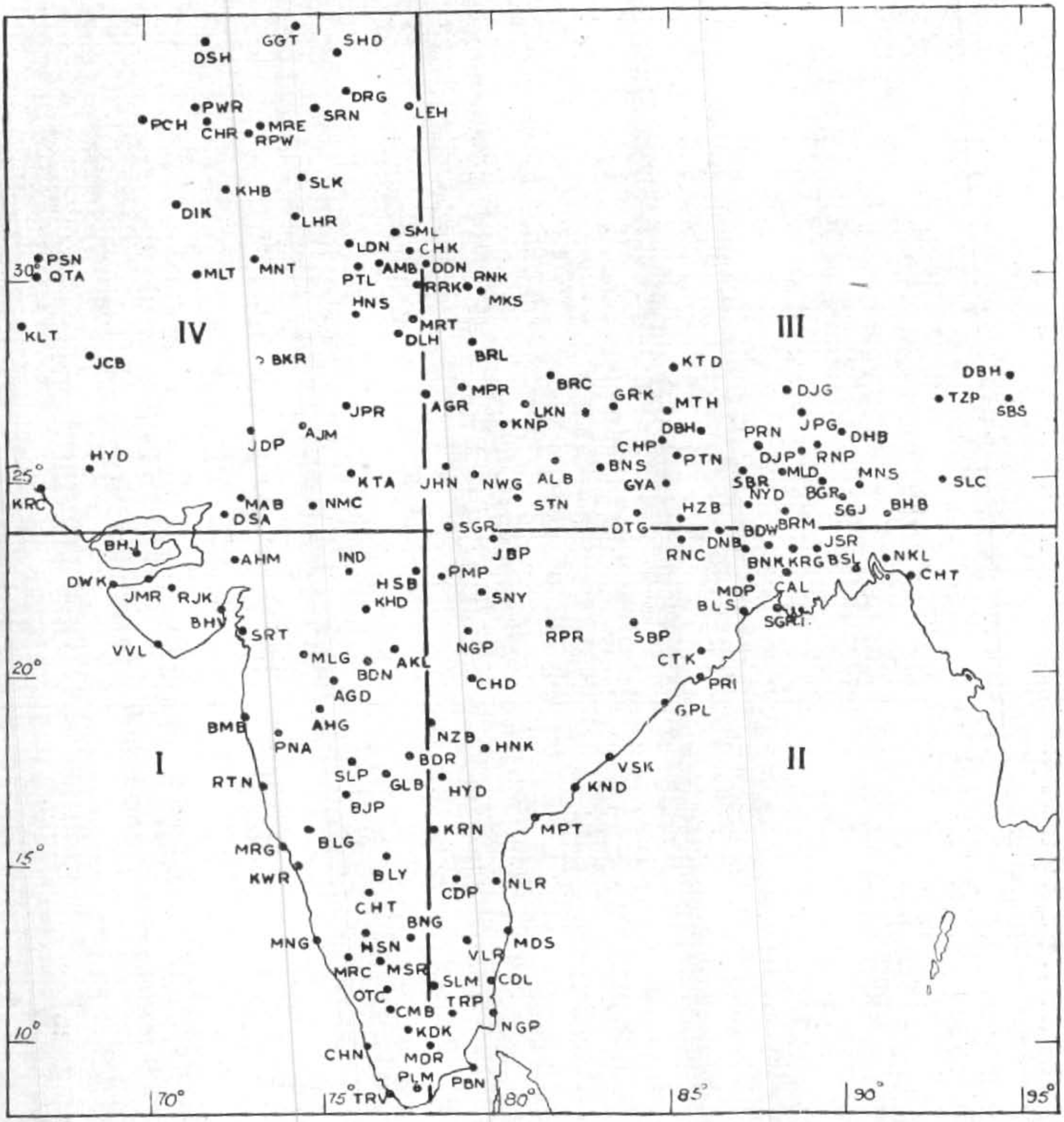

Fig. 2. 167 Meteorological stations and the four divisions

TABLE 1(a)

Seasonal variation of diurnal range of temperature—Region I

S. No.	Station	Mean daily range of temp. (°F)	Annual Oscillation a_1	α_1	D_{x1}	Half-yearly Oscillation a_2	α_2	D_{x2}	Percentage of variance unaccounted ε_2
1	Bhuj	22·7	6·9	72° 37′	3 Feb	4·1	244° 51′	27 Apr	4·5
2	Dwarka	11·5	6·7	104 03	30 Dec	2·1	151 58	15 Jun	0
3	Jamnagar	21·4	7·5	78 51	26 Jan	1·7	208 06	17 May	10·0
4	Rajkot	26·8	8·9	67 50	8 Feb	3·8	233 04	4 ,,	1·7
5	Veraval	13·5	9·9	93 00	12 Jan	1·0	239 03	1 ,,	2·9
6	Surat	21·6	10·7	78 04	27 ,,	1·1	209 15	16 ,,	4·5
7	Bhavnagar	24·4	7·4	72 49	3 Feb	3·0	232 25	4 ,,	1·5
8	Ahmedabad	24·0	7·2	60 38	15 ,,	3·9	236 21	2 ,,	0·6
9	Indore	24·3	9·4	67 23	8 ,,	4·0	232 30	4 ,,	1·0
10	Akola	25·8	9·5	68 49	7 ,,	3·0	229 50	6 ,,	0·7
11	Amraoti	22·9	6·9	55 08	20 ,,	3·1	235 41	3 ,,	0·9
12	Buldhana	19·7	5·4	50 03	25 ,,	2·1	219 43	11 ,,	4·3
13	Khandwa	25·0	10·5	73 30	2 ,,	3·4	224 34	8 ,,	0·9
14	Hoshangabad	23·5	8·9	60 37	15 ,,	3·9	233 57	4 ,,	1·4
15	Bombay	13·0	4·2	94 37	11 Jan	1·1	188 19	26 ,,	0·1
16	Ratnagiri	14·0	6·7	97 09	8 ,,	1·7	161 26	10 ,,	0·5
17	Marmagao	11·0	3·6	84 40	21 ,,	0·7	139 55	21 Jun	1·0
18	Karwar	13·4	6·7	91 08	14 ,,	1·6	130 29	25 ,,	0·4
19	Malegaon	26·9	10·0	66 33	10 Feb	2·7	237 02	2 May	0·2
20	Ahmednagar	25·6	8·7	63 04	12 ,,	2·2	236 57	2 ,,	1·2
21	Poona	24·9	11·2	63 31	12 ,,	2·9	252 08	24 Apr	1·2
22	Sholapur	24·5	6·6	53 06	22 ,,	1·4	240 00	1 May	1·7
23	Bijapur	22·8	5·6	56 52	18 ,,	1·7	223 13	9 ,,	6·0
24	Belgaum	20·5	9·7	55 52	19 ,,	3·2	270 15	15 Apr	1·8
25	Aurangabad	24·5	7·0	60 41	15 ,,	2·6	226 25	7 May	1·4
26	Bidar	20·7	4·2	40 34	7 ,,	1·0	234 00	3 ,,	1·3
27	Gulbarga	23·7	6·0	55 02	20 ,,	1·4	218 44	11 ,,	0
28	Raichur	20·6	4·0	33 33	14 Mar	0·7	237 08	2 ,,	4·2
29	Chitaldrug	19·5	5·3	47 06	28 Feb	1·6	263 37	19 Apr	1·8
30	Hassan	20·6	7·7	58 32	17 ,,	1·7	311 16	25 Mar	0·4
31	Bangalore	20·3	5·1	40 28	7 Mar	1·1	334 39	13 ,,	2·5
32	Mysore	20·4	5·0	48 51	26 Feb	1·4	322 14	19 ,,	2·8
33	Mangalore	13·4	4·2	80 53	25 Jan	1·2	127 39	27 Jun	4·8
34	Calicut	11·9	4·0	78 34	27 ,,	0·5	148 22	17 ,,	1·6
35	Cochin	12·8	3·5	78 38	27 ,,	0·6	111 58	5 Jul	1·4
36	Trivandrum	9·2	2·1	67 07	8 Feb	0·6	28 33	16 Feb	3·7
37	Palamcottah	17·9	2·3	349 55	28 Apr	2·1	322 58	19 Mar	7·6
38	Coimbatore	20·2	4·3	52 25	23 Feb	1·9	338 34	11 ,,	1·7
39	Bellary	22·4	5·9	51 37	24 ,,	0·8	282 28	9 Apr	1·4
40	Mercara	15·2	7·6	61 24	14 ,,	1·9	292 25	4 ,,	0·3
41	Ootacamund	16·9	6·3	62 32	13 ,,	0·7	325 30	18 Mar	4·6
42	Kodaikanal	14·1	3·9	47 19	28 ,,	1·1	348 14	6 ,,	2·5

TABLE 1(b)

Seasonal variation of diurnal range of temperature—Region II

S. No.	Station	Mean daily range of temp. (°F)	Annual Oscillation a_1	α_1	D_{x_1}	Half-yearly Oscillation a_2	α_2	D_{x_2}	Percentage of variance unaccounted ε_2
1	Chittagong	15·6	7·1	79° 46′	27 Jan	0·8	80° 22′	20 Jan	2·0
2	Noakhali	15·3	8·1	82 07	23 ,,	1·5	123 52	30 ,,	0·7
3	Barisal	15·5	7·1	73 50	1 Feb	0·5	154 05	13 ..	1·8
4	Jessore	17·6	7·8	65 48	10 ,,	0·6	219 11	11 May	1·5
5	Calcutta	16·2	6·8	63 00	12 ,,	0·7	200 15	20 ,,	0·8
6	Saugor Island	12·0	5·0	109 21	5 Jan	1·5	139 26	26 ,,	1·1
7	Midnapur	19·3	7·7	61 00	14 Feb	1·7	222 59	9 ,,	1·1
8	Burdwan	18·4	7·9	56 19	17 ,,	1·3	235 35	3 ,,	0·3
9	Bankura	19·5	7·2	53 22	20 ,,	2·5	228 13	6 ,,	0·9
10	Krishnagar	19·4	8·5	63 19	12 ,,	0·9	228 25	6 ,,	0·4
11	Balasore	18·1	7·4	69 51	6 ,,	1·6	188 52	26 ,,	0·1
12	Puri	11·7	4·8	108 34	26 Dec	1·6	144 47	18 Jun	0·8
13	Gopalpur	12·8	5·0	101 36	1 Jan	1·1	145 30	18 ,,	0·6
14	Cuttack	18·4	6·7	53 33	22 Feb	1·5	234 2	3 May	2·2
15	Sambalpur	20·7	9·3	53 15	22 ,,	3·1	226 46	7 ,,	2·4
16	Purulia	21·3	6·9	55 16	20 ,,	2·6	230 27	5 ,,	0
17	Ranchi	18·7	6·3	53 14	22 ,,	2·7	224 34	8 ,,	2·8
18	Jubbulpur	23·7	9·6	65 51	10 ,,	4·3	229 33	6 ,,	0·3
19	Seoni	23·0	8·4	59 38	16 ,,	3·8	231 57	5 ,,	1·0
20	Nagpur	23·2	8·3	59 32	16 ,,	3·2	233 25	4 ,,	0·9
21	Raipur	21·1	7·8	55 40	10 ,,	2·8	222 03	9 ,,	1·6
22	Chanda	24·2	9·9	61 54	13 ,,	2·7	226 35	7 ,,	0·4
23	Nizamabad	23·4	9·2	62 43	13 ,,	2·2	216 08	12 ,,	0·2
24	Hyderabad	20·8	6·3	54 58	20 ,,	1·6	228 43	6 ,,	0·4
25	Hanamkonda	19·8	5·7	55 38	19 ,,	2·1	234 18	3 ,,	4·4
26	Pamban	10·2	1·0	320 05	26 May	1·3	316 57	22 Mar	8·6
27	Madurai	19·5	3·2	340 21	7 ,,	1·7	351 52	5 ,,	0·4
28	Negapatam	14·0	3·7	327 40	20 ,,	0·6	63 09	29 Jan	8·3
29	Trichinopoly	20·0	3·5	357 17	19 Apr	1·9	349 34	6 Mar	10·3
30	Salem	21·8	4·1	29 37	18 Mar	1·4	6 03	26 Feb	3·3
31	Cuddalore	15·7	2·4	309 18	8 Jun	0·8	54 07	3 ,,	12·6
32	Vellore	18·5	4·2	17 53	30 Mar	1·2	324 31	18 Mar	3·8
33	Madras	16·1	1·9	336 03	11 May	1·5	40 54	10 Feb	16·0
34	Cuddapah	21·1	4·5	36 59	11 Mar	0·4	258 15	21 Apr	0·6
35	Kurnool	22·6	6·5	59 02	10 Feb	0·5	184 07	28 May	0·6
36	Nellore	18·5	3·8	357 10	19 Apr	0·9	307 35	27 Mar	7·4
37	Masulipatam	16·0	2·9	18 53	29 Mar	0·7	97 25	12 Jan	13·8
38	Cocanada	14·3	3·4	21 06	25 ,,	0·7	248 40	27 Apr	2·4
39	Vizagapatam	11·6	1·2	77 02	29 Jan	0·2	105 18	8 Jan	9·4
40	Pachmarhi	18·9	8·1	71 28	4 Feb	3·2	227 28	7 May	1·2

TABLE 1(c)
Seasonal variation of diurnal range of temperature—Region III

S. No.	Station	Mean daily range of temp. (°F)	Annual Oscillation a_1	Annual Oscillation α_1	Annual Oscillation D_{x1}	Half-yearly Oscillation a_2	Half-yearly Oscillation α_2	Half-yearly Oscillation D_{x2}	Percentage of variance unaccounted ε_2
1	Dibrugarh	15·6	4·9	93° 26′	12 Jan	1·3	43° 42′	9 Feb	8·5
2	Sibsagar	15·6	4·9	80 47	24 ,,	0·9	138 20	21 Jun	0·9
3	Tezpur	16·2	5·3	80 25	24 ,,	0·4	156 35	12 ,,	4·3
4	Dhubri	14·8	7·7	66 26	9 Feb	0·5	227 54	7 May	1·1
5	Silchar	18·6	6·8	81 30	23 Jan	0·7	111 00	5 Jan	1·1
6	Comilla	17·4	7·6	78 57	30 ,,	0·6	131 56	25 Jun	0·8
7	Narayanganj	15·7	7·2	69 07	6 Feb	0·2	153 25	14 ,,	0·7
8	Bogra	18·1	8·4	60 57	14 ,,	1·2	280 27	10 Apr	1·4
9	Mymensingh	15·9	7·2	69 22	5 ,,	0·2	260 11	20 ,,	0·7
10	Rampur Boalia	18·2	8·5	58 45	16 ,,	1·1	245 13	28 ,,	1·6
11	Faridpur	16·4	8·3	68 43	6 ,,	0·5	82 57	19 Jan	4·1
12	Berhampur	18·0	8·1	50 49	24 ,,	1·3	258 50	21 Apr	1·7
13	Malda	19·4	8·9	58 25	17 ,,	1·6	254 41	23 ,,	1·0
14	Sirajganj	17·4	9·0	62 12	13 ,,	0·8	260 52	20 ,,	1·9
15	Dinajpur	19·1	9·4	66 34	9 ,,	0·9	256 38	22 ,,	1·1
16	Rangpur	18·8	8·3	70 23	4 ,,	1·3	236 44	2 May	2·1
17	Jalpaigari	18·1	6·8	71 19	5 ,,	1·0	252 31	24 Apr	3·3
18	Hazaribagh	18·9	6·6	48 27	26 ,,	2·7	230 35	5 May	4·7
19	Daltonganj	24·2	8·9	65 00	10 ,,	4·2	227 16	7 ,,	1·3
20	Purnea	20·2	9·5	62 40	12 ,,	1·6	241 44	30 Apr	2·0
21	Bhagalpur	19·6	7·9	61 51	13 ,,	2·5	231 13	5 ,,	2·1
22	Dharbangah	18·2	8·0	57 57	17 ,,	2·1	239 20	1 May	3·2
23	Motihari	21·5	9·1	63 22	12 ,,	2·8	239 10	1 ,,	3·0
24	Chapra	20·4	7·7	53 12	22 ,,	3·0	234 26	3 ,,	2·1
25	Patna	18·7	7·5	52 51	22 ,,	2·7	234 50	3 ,,	1·6
26	Gaya	26·8	7·0	53 59	29 ,,	3·2	224 33	8 ,,	0·3
27	Naya Dumka	19·9	7·7	61 10	14 ,,	2·2	232 57	4 ,,	1·5
28	Gorakhpur	21·0	6·1	63 57	11 ,,	3·6	263 47	19 Apr	12·8
29	Banaras	22·9	8·6	60 39	15 ,,	4·2	235 21	3 May	0·4
30	Allahabad	23·3	8·1	61 26	13 ,,	4·6	232 50	4 ,,	0·8
31	Cawnpur	23·5	9·2	63 20	12 ,,	3·3	213 58	14 ,,	8·9
32	Lucknow	24·0	8·0	67 00	8 ,,	5·0	232 37	4 ,,	0·5
33	Bahraich	22·4	7·5	62 50	12 ,,	4·0	234 36	3 ,,	0·1
34	Jhansi	22·2	6·6	69 56	5 ,,	3·8	230 39	5 ,,	2·4
35	Agra	22·6	6·0	70 14	5 ,,	4·4	235 12	3 ,,	1·9
36	Mainpuri	24·5	6·9	65 33	10 ,,	5·3	236 19	2 ,,	0
37	Bareilly	22·8	6·7	63 06	12 ,,	4·8	233 11	4 ,,	1·4
38	Dehra Dun	20·5	5·4	56 10	19 ,,	4·5	233 40	4 ,,	2·2
39	Nowgong	23·7	8·7	64 25	11 ,,	4·8	235 46	3 ,,	2·0
40	Satna	22·1	8·8	64 33	11 ,,	4·3	228 19	6 ,,	0·7
41	Saugor	21·4	6·4	58 03	17 ,,	3·9	229 11	6 ,,	4·1
42	Darjeeling	11·6	2·3	61 09	14 ,,	1·2	256 38	22 Apr	1·7
43	Kathmandu	25·6	8·1	61 41	5 ,,	3·0	241 37	30 ,,	0
44	Mukteswar	15·7	1·9	38 39	8 Mar	2·4	234 17	3 May	1·5
45	Raniket	14·4	2·1	31 23	16 ,,	2·3	231 56	5 ,,	5·2

TABLE 1(d)

Seasonal variation of diurnal range of temperature—Region IV

S. No.	Station	Mean daily range of temp. (°F)	Annual Oscillation a_1	α_1	D_{x_1}	Half-yearly Oscillation a_2	α_2	D_{x_2}	Percentage of variance unaccounted ε_2
1	Meerut	24·1	6·4	70° 51′	3 Feb	5·6	234° 54′	3 May	2·4
2	Roorkee	24·2	6·2	66 58	8 ,,	5·6	228 20	6 ,,	0·1
3	Delhi	21·1	4·7	67 30	7 ,,	3·8	228 46	6 ,,	2·6
4	Sirsa	27·3	5·6	67 26	7 ,,	4·0	223 21	9 ,,	10·7
5	Patiala	23·3	4·8	79 38	25 Jan	4·9	232 55	4 ,,	2·8
6	Ambala	25·2	5·0	81 22	4 ,,	5·6	232 20	4 ,,	0
7	Ludhiana	23·8	3·6	64 44	10 Feb	5·3	231 11	5 ,,	2·8
8	Lahore	27·8	3·8	89 12	16 Jan	5·6	229 16	6 ,,	3·8
9	Sialkot	24·7	2·4	82 14	23 ,,	5·2	229 21	6 ,,	5·1
10	Rawalpindi	26·4	2·1	117 30	20 Dec	5·3	218 25	11 ,,	6·5
11	Khushab	25·8	3·6	110 33	25 ,,	4·1	214 25	13 ,,	4·3
12	Montgomery	26·9	2·6	91 51	13 Jan	4·3	236 01	2 ,,	3·2
13	Multan	25·8	3·4	85 28	19 ,,	4·0	233 56	4 ,,	4·3
14	Srinagar	21·9	4·5	223 39	4 Aug	4·6	236 12	2 ,,	6·9
15	Dras	28·4	0·8	170 59	26 Oct	2·1	56 08	2 Feb	53·2
16	Leh	25·8	2·7	245 23	12 Aug	1·4	252 02	24 Apr	3·5
17	Skardu	22·1	4·0	237 17	20 ,,	0·6	219 42	11 May	11·0
18	Gilgit	20·7	5·2	259 04	29 Jul	1·2	222 13	9 ,,	4·4
19	Peshawar	26·2	1·7	177 52	20 Oct	3·9	209 09	16 ,,	3·5
20	Dera Ismail Khan	27·1	3·7	102 42	31 Dec	4·2	218 59	11 ,,	3·9
21	Quetta	29·6	5·2	227 07	31 Aug	3·7	244 36	28 Apr	4·5
22	Kalat	35·7	6·3	239 16	18 ,,	2·9	239 11	1 May	5·4
23	Pishin	33·7	5·1	233 25	31 ,,	3·1	241 32	30 Apr	7·6
24	Jacobabad	30·0	2·8	95 55	8 Jan	4·3	226 58	7 May	10·8
25	Hyderabad (Sd)	25·1	4·3	65 23	10 Feb	4·2	239 46	1 ,,	1·8
26	Manora	12·8	5·8	101 12	2 Jan	1·2	180 46	31 ,,	2·9
27	Bikaner	23·2	3·3	70 55	4 Feb	2·5	227 48	7 ,,	10·4
28	Jodhpur	24·6	5·3	78 21	28 Jan	3·8	235 00	3 ,,	4·5
29	Jaipur	25·0	5·4	75 48	30 ,,	4·8	236 30	2 ,,	1·8
30	Ajmer	23·3	7·7	83 19	23 ,,	4·1	225 43	8 ,,	2·5
31	Kotah	22·1	6·5	73 15	2 Feb	3·3	226 23	7 ,,	2·8
32	Deesa	27·3	9·0	76 34	29 Jan	5·0	231 23	5 ,,	1·0
33	Neemuch	24·3	7·8	72 42	2 Feb	4·1	229 34	6 ,,	2·1
34	Simla	11·0	1·6	18 17	29 Mar	1·8	227 17	7 ,,	14·3
35	Chakrata	14·8	2·9	59 37	5 Feb	2·8	237 15	2 ,,	1·5
36	Murree	14·3	1·5	297 36	18 Jun	1·5	227 23	7 ,,	4·7
37	Cherat	16·1	3·7	263 42	24 Jul	2·2	236 17	7 ,,	5·6
38	Parachinar	22·4	0·9	238 19	20 Jun	2·1	217 32	12 ,,	21·2
39	Drosh	20·8	4·1	254 44	2 Aug	1·3	212 01	14 ,,	4·7
40	Mount Abu	13·8	2·9	52 16	23 Mar	2·6	216 28	12 ,,	2·7

after the first two harmonics have been fitted. In the same tables are also given the dates of occurrence of maxima in the oscillations.

The frequencies of stations for which the error variance lies within specified limits are given below—

	Error variance (per cent)			
	1	>1-5	>5-10	>10
Region I	13	26	3	0
Region II	18	14	4	4
Region III	13	28	3	1
Region IV	3	24	7	6
Total	47	92	17	11

It is seen that out of the 167 stations, for 83 per cent of the stations the first two harmonics account for 95 per cent or over of the seasonal variation while for about 10 per cent of the stations the error variance is between 5 and 10 per cent. For about 7 per cent of the stations the error variances are larger than 10 per cent indicating that for these stations higher harmonics should contribute significantly towards the variance. These stations are mainly confined to (*i*) the coastal regions of southeastern Peninsula where the drier southwest monsoon over this area and the wet northeast monsoon introduce higher order waves and (*ii*) the northwestern Himalayas where the incidence of western disturbances during the late winter and early spring introduce considerable clouding and reduce the diurnal range during these months.

Dras (53 per cent) and Pachmarhi (21 per cent) are the only two stations having more than 20 per cent error variance. For Dras harmonics of the third and fourth order have also been fitted. The equation upto the fourth harmonic obtained is —

$$\begin{aligned} R_t = 28{\cdot}4 &+ 0{\cdot}8 \sin(30t+170^\circ\,59') + \\ &+ 2{\cdot}1 \sin(60t+56^\circ\,08') + \\ &+ 1{\cdot}1 \sin(90t+354^\circ\,53') + \\ &+ 0{\cdot}4 \sin(120t+276^\circ\,59') \end{aligned} \qquad (2)$$

where R_t is the diurnal range at time t months. The third and fourth harmonics account for 12 and 3 per cent of the variance leaving behind an error variance of 38 per cent still to be accounted by higher harmonics.

Thus except for a few stations associated with special features, for all the stations the annual and half-yearly waves adequately represent the seasonal variation.

4·1·1. *Annual oscillation*—Fig. 3 shows the spatial distribution of the amplitude in the annual oscillation and Fig. 4 shows the distribution of the dates of occurrence of the maxima in the oscillation. The following important features are revealed by these figures.

The annual amplitude shows considerable variation over the different areas. The amplitudes are smaller over the coastal regions of the Peninsula and over the Himalayas and are smallest in the southeast of the Peninsula and also in the northwestern parts except probably the extreme northwest Kashmir. The amplitudes are large over an area extending from Gujarat, Bombay Deccan on the west to north Bihar and Bengal on the east. They are largest over the Bombay Deccan. The increasing gradient towards the ghat regions in the Peninsula and the decreasing gradient towards the western Himalayas are noteworthy. The maximum in the oscillation occurs in January over the north Andhra coast, over the west coast and over the extreme northwestern parts. The occurrence is delayed slightly inland, and very much delayed over the southwest Peninsula to as much as May end over the Coromandel coast.

4·1·2. *Half-yearly oscillation*—The spatial distribution of the half-yearly amplitudes and that of date* of maxima in the oscillation are shown in Figs. 5 and 6.

The half-yearly amplitude is much less variable. The lowest values of the order of 1°F are obtained over the coastal regions and over the Himalayas; inland they are slightly larger with maximum about 4–5°F over the northwest.

*Only one date of maxima is given; the other date is six months later

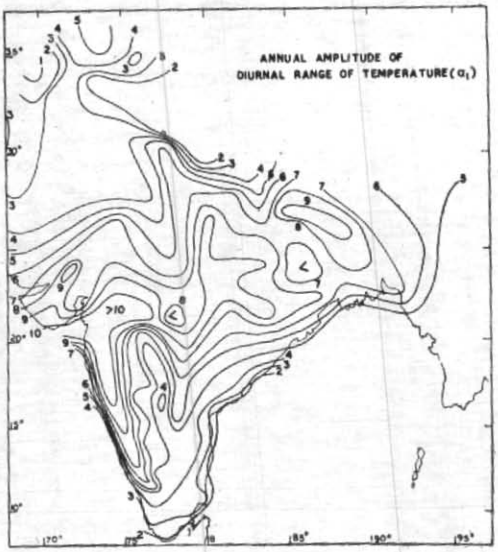

Fig. 3

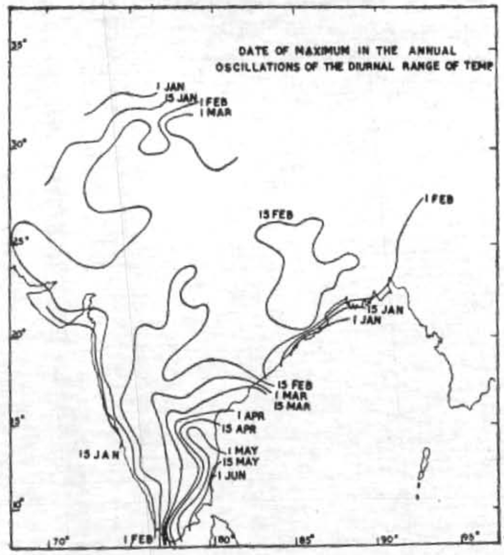

Fig. 4

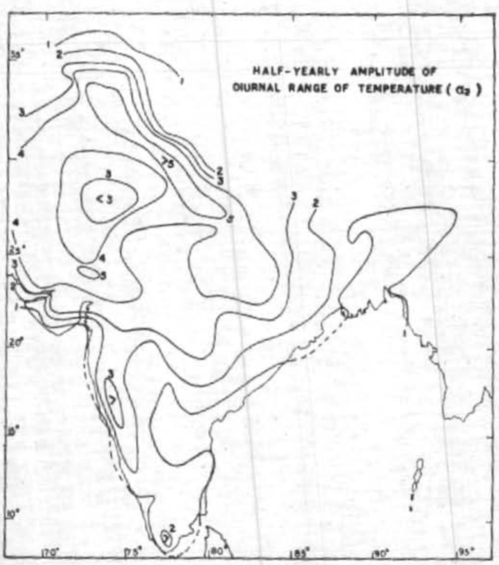

Fig. 5

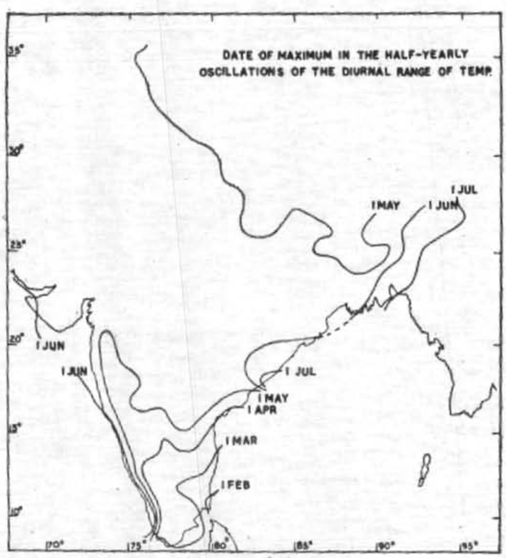

Fig. 6

The maximum in the half-yearly oscillation occurs early in May (and again in November) in practically the whole of the country. Over the west coast of the Peninsula, north Andhra coast and the extreme northeast it is delayed by a month or so. In the sub-Himalayan regions it occurs slightly earlier than May and in the southeastern regions it is advanced by two or three months.

4.2. *Relationship with latitude, longitude and elevation*—In this section the dependence of the component vectors of the annual and half-yearly oscillations on their positional co-ordinates, *viz.*, latitude, longitude and elevation above sea level are studied. The values of the amplitudes a_1 and a_2 and the dates of occurrence of maxima, D_{x_1}, D_{x_2} have been correlated with latitude, longitude and elevation of the stations in each of the regions separately. The C.Cs. in respect of the annual oscillation are given in Table 2(a) and those in respect of the half-yearly oscillation in Table 3(a).

4.2.1. *Annual oscillation*—The high correlation between the amplitude and latitude indicates the close relationships between the two. In the Peninsula the amplitude increases northward and in the north India it decreases towards the Himalayas. The C.Cs with the longitude are small; those for regions I and II are just significant at the 5 per cent level while those for the other regions are not significant.

The C.Cs. with elevation are also small, those for regions II and IV are significant at the 5 per cent level and the rest insignificant.

In regard to the date of maximum in the oscillation, the correlation coefficients are generally small except in the case of latitude for regions II and IV, for longitude in region III and for elevation in regions III and IV.

4.2.2. *Half-yearly oscillation*—In region I the increase of amplitude northward is significant at the 1 per cent level while in the eastern regions (II and III) a slight increase with latitude is indicated. In region III a significant decrease of amplitude eastwards is noted. In regard to elevation in region II the amplitude increases with increase of altitude while in the northwestern region (IV) the amplitude shows significant decrease with increase of altitude.

None of the C.Cs. of the date of maximum with latitude are significant. A delaying of the occurrence of maximum towards east in region III and towards west in region IV are also seen. The significant negative C.C. with altitude in region I indicates a delaying of the occurrence of the maximum in the oscillation with increase of altitude.

4.3. *Regression equations*—For a proper appreciation of the relationships indicated by the correlation coefficients, it is necessary to eliminate the inter-relationships between the variates. Thus if

$$H = \dot{H}(\varphi, \lambda, h) \qquad (3)$$

is the harmonic component under consideration to a first approximation it can be expressed as

$$H = H_0 + b_1\varphi + b_2\lambda + b_3h \qquad (4)$$

For this purpose, the partial regression coefficients b_1, b_2 and b_3 have been determined by the usual method,* and are given in Tables 2(b) and 3(b) along with their standard errors. In the same tables are also given the multiple C.Cs. which are measures of closeness of fit of the planes fitted to represent the H-surfaces.

The origin of co-ordinates has been taken as 8°N, 60°E and mean sea level. The units for latitude, longitude are minutes and that for height 1 ft, amplitudes are in degrees F and D_x in months.

4.3.1. *Annual oscillation*

Out of the 8 multiple C.Cs., 4 are between 0·7 and 0·8 indicating that over about 50 to 60 per cent of the spatial variations of the harmonic components are accounted by the plane (4); three are between 0·6 and 0·7 and

*For the computation of the regression coefficients the matrices of multiplier given on p. 88 of *India met. Dep. Sci. Notes*, **10**, No. 121 have been used

TABLE 2(a)

Correlation coefficients between the components of the annual oscillation of diurnal range of temperature with Latitude, Longitude and Elevation

Component	Region	Correlation coefficient with		
		Latitude	Longitude	Elevation
a_1	I	+·6761†	—·3820*	—·0433
	II	+·7972†	+·3217*	+·3593*
	III	—·5858†	+·0889	—·2918
	IV	—·6096†	—·0099	—·3919*
D_{x_1}	I	+·2236	+·0667	+·2985
	II	+·5818†	+·2564	+·2341
	III	+·1843	—·5189†	+·4884†
	IV	—·6579†	+·3447*	—·6365†

*Significant at 5 per cent level †Significant at 1 per cent level

TABLE 2(b)

Regression coefficients between components of the annual oscillation of the diurnal range of temperature with Latitude, Longitude and Elevation

Component	Region	Latitude		Longitude		Elevation		Multiple C.C.
		R.C.	S.E.	R.C.	S.E.	R.C.	S.E.	R
a_1	I	+·0064	±·0012	—·0012	±·0024	+·0004	±·0002	·7141†
	II	+·0100	·0016	—·0045	·0018	—·0002	·0005	·8442†
	III	—·0061	·0026	—·0014	·0008	—·0006	·0001	·7919†
	IV	—·0053	·0014	+·0007	·0012	—·0001	·0001	·6411†
D_{x_1}	I	+·0023	·0010	+·0011	·0020	+·0004	·0001	·4629*
	II	+·0101	·0033	—·0041	·0038	—·0003	·0010	·6090†
	III	—·0009	·0005	—·0006	·0002	+·0001	·0001	·6842†
	IV	—·0066	·0012	+·0060	·0011	—·0004	·0001	·8853†

*Significant at 5 per cent level †Significant at 1 per cent level
R.C.—Regression Coefficient S.E.—Standard Error

one 0·46. The multiple C.Cs. except that for the date of occurrence of maximum in the oscillation in region I are significant at the 1 per cent level, the latter being significant only at the 5 per cent level.

The regression coefficients of amplitude on latitude are significant at the 5 per cent level in all the four regions. The amplitude increases northward at the rate of about 4°F for every 10° of latitude over the western half of the Peninsula and at the rate of 6°F for every 10° latitude over the eastern half. Over north India the amplitude decreases northward at the rate of 3–4°F for every 10° latitude.

The regression coefficients of date of occurrence of maximum on latitude are significant except in region III. The occurrence of the maximum is delayed northwards in the Peninsula being as much as 6 months

TABLE 3(a)

Correlation coefficients between the components of the half-yearly oscillation of diurnal range of temperature with Latitude, Longitude and Elevation

Component	Region	Correlation coefficient with		
		Latitude	Longitude	Elevation
a_2	I	+·6620†	—·2407	—·1442
	II	+·3663*	—·2348	+·6440†
	III	+·3315*	—·8661†	+·0686
	IV	—·3017	+·1771	—·6758†
D_{x_2}	I	—·0955	—·2827	—·6386†
	II	+·0995	+·2882	—·2355
	III	—·1075	+·4354†	—·1449
	IV	—·1901	—·1771	+·2452

*Significant at 5 per cent level † Significant at 1 per cent ievel

TABLE 3(b)

Regression coefficients between components of the half-yearly oscillation of the diurnal range of temperature with Latitude, Longitude and Elevation

Component	Region	Latitude		Longitude		Elevation		Multiple C.C. R
		R.C.	S.E.	R.C.	S.E.	R.C.	S.E.	
a_2	I	+·0030	±·0006	+·0011	±·0011	+·00004	±·0001	·6803†
	II	+·0029	·0008	—·0026	·0009	+·0002	·0002	·7389†
	III	+·0012	·0013	—·0050	·0004	—·0002	·0001	·9023†
	IV	+·0003	·0010	+·0017	·0009	—·0003	·0001	·7160†
D_{x_2}	I	—·0008	·0006	—·0006	·0012	—·0004	·0001	·6712†
	II	+·0005	·0011	—·0016	·0016	—·0001	.0004	·3534
	III	+·0009	·0015	+·0014	·0004	—·00003	·0001	·4544*
	IV	+·0002	·0005	+·00001	·0004	+·00003	·00003	·2563

*Significant at 5 per cent level † Significant at 1 per cent level
R.C.—Regression Coefficient S.E.—Standard Error

for 10° of latitude over the east Peninsula-region II. In north India the date of maximum advances northwards; in particular in northwest India, the advancement is of the order of 4 months in 10° latitude.

The regression coefficients of amplitude on longitude are not significant except in region II where amplitude decreases eastward at the rate of 2°F for every 10° longitude. The regression coefficients of date of occurrence of maximum on longitude in the two northern regions are significant; the date of occurrence of the maximum in the oscillation is delayed by as much as 3½ months for every 10° longitude eastwards in the northwestern region while a slight advancing of the date is noticed in region III.

The regression coefficients of amplitude with elevation in region III and date of occurrence of maximum with elevation in

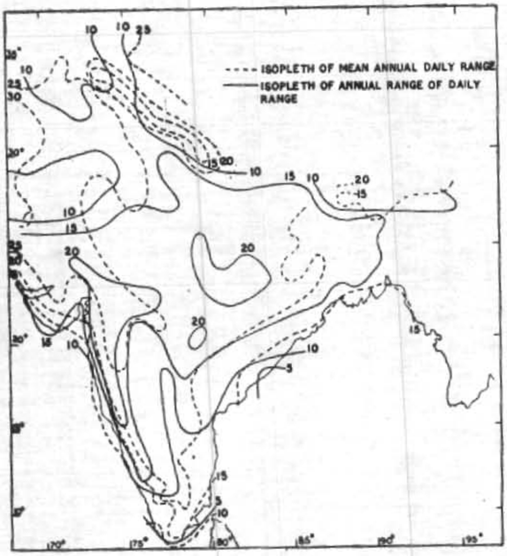

Fig. 7

regions I and IV are significant indicating that the amplitude decreases at the rate of 0·6°F for every 1000 ft of elevation over the northeastern India. In the western Peninsula predominated by the western ghats, the date of occurrence of the maximum in the oscillation is delayed by about 12 days for every 1000 ft; while in northwest India the occurrence of the maximum in the oscillation is advanced by about the same period.

4.3.2. *Half-yearly oscillation*

The multiple C.Cs. in respect of amplitude in all the four regions are between 0·7 and 0·9 and significant at the 1 per cent level; while in the case of those for the date of occurrence of the maximum in region I, it is significant at the 1 per cent level and in region III it is significant at the 5 per cent level; the other two being insignificant.

In the Peninsula the amplitude in the oscillation increases at the rate of 1·7°F for every 10° of latitude. The date of occurrence of maximum is not affected by latitude.

The amplitude shows a decrease eastward at the rate of 1·5°F for every 10° longitude in the eastern Peninsula and about 3° F for every 10° longitude in the northeastern region. The date of occurrence of maximum in the latter region (region III) is delayed by about 1 month for every 10° longitude eastward.

In the region IV the amplitude decreases at the rate of 0·3°F for every 1000 ft of elevation while in region I it increases at the rate of 4°F; in the other regions elevation does not appear to have any effect. The date of occurrence of the maximum in the oscillation advances by about 10 days in 1000 ft of elevation in regions I and III.

5. Mean daily range and annual range of daily range of temperature

The spatial distribution of the annual range* of the daily range of temperature is shown in Fig. 7 superimposed on the distribution of the mean annual daily range. The partial regression coefficients of the annual range on latitude, longitude and elevation are given in Table 4. In the same table are also given the partial regression coefficients connecting the mean annual daily range with latitude, longitude and elevation.

In the Peninsula—The mean daily range increases northward over the whole Peninsula at the rate of 7–9°F for every 10° latitude. The annual range, however, is unaffected by latitude in the western Peninsula but increases northwards at the rate of 10°F for 10° latitude over the eastern Peninsula.

The mean daily range increases from the coast inland while the annual range decreases eastwards over the entire Peninsula.

Altitude does not have any effect on the mean daily range as well as the annual range.

In North India—Latitude does not have any effect on the mean daily range while the annual range of daily range decreases northward at the rate of 5–7°F for every 10° latitude.

The mean daily range decreases eastwards at the rate of 5°F for every 10° longitude while the annual range of daily range is

*It is the range between the highest and lowest monthly ranges of temperatures

TABLE 4

Regression Equations

Region	Latitude R.C.	Latitude S.E.	Longitude R.C.	Longitude S.E.	Elevation R.C.	Elevation S.E.	Multiple C.C. (R)
			a—Mean annual daily range of temperature‡				
I	+·0164	±·0025	—·0170	±·0048	+·0004	±·0004	·74†
II	—·0121	·0031	—·0145	·0036	—·0005	·0009	·71†
III	—·0014	·0037	—·0088	·0011	—·0009	·0002	·79†
IV	+·0038	·0047	—·0088	·0042	—·0003	·0003	·37
			b—Annual range of daily range of temperature				
I	+·0029	±·0030	—·0119	±·0058	+·0007	±·0004	·48*
II	+·0181	·0030	—·0091	·0034	—·0001	·0009	·84†
III	—·0121	·0038	—·0065	·0012	—·0012	·0002	·83†
IV	—·0083	·0031	—·0038	·0028	—·0005	·0002	·64†

*Significant at 5 per cent level † Significant at 1 per cent level ‡ Adapted from Jagannathan (1948b)
R.C.—Regression Coefficient S.E.—Standard Error

unaffected by the longitude except in the eastern region where it decreases eastwards at the rate of 4°F for every 10° longitude.

Over the eastern Himalayas the mean daily range decreases at the rate of 0·9°F for every 1000 ft while the annual range decreases at the rate of 1·2°F for every 1000 ft.

6. General Remarks

It is seen that the daily range of temperature shows considerable seasonal variation. The predominating influence of the state of the sky is brought out clearly. The range is largest over an area where the sky is clearest.

The component waves in the oscillation show more clearly the operating influences. Except over the southeast Peninsula the minimum in the annual wave occurs generally in August when the clouding is most and over the southeast Peninsula in October, November due to the same cause. The largest amplitudes occur over an area extending from east to west between 20° and 25° N and parts of Deccan. The decrease of amplitudes in the Peninsula and steeply towards the coasts indicates the maritime character of the locations. The smaller amplitudes in the sub-Himalayan regions are due to the effect of slopes and convex topography which help to drain out colder denser air of the night by katabatic action and thus inhibits the lowering of the minimum temperature. These features are also noticed at other hill stations in the south as well, *e.g.*, Pachmarhi, Mount Abu. Stations in sheltered valleys exhibit larger amplitudes due to the lowering of the minimum temperature, *e.g.*, Leh, Kathmandu.

The half-yearly oscillation which is about half the annual oscillation attains its maximum in May with the solar insolation and again in November. In the south Peninsula the maximum occurs in January–February and July–August with the northward and southward passage of the Sun.

7. Acknowledgement

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