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Gustiness and temperature at Nagpur

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ABSTRACT. Ten years autographic records of wind and temperature have been utilised for the present study. The seasonal and diurnal variations of mean wind speed, average range of gusts and gustiness along with the temperature variations have been worked out.

The influence of diurnal ground temperature variations on gustiness has also been brought out.

1. Introduction

The Munrow D.P.T. anemograph has been functioning at the present site on the terrace of Regional Meteorological Centre building, Nagpur aerodrome, since 1954. The head of the anemograph is 15·6 m above the ground and 5·8 m above the building. S and M thermograph records temperature at 4 ft above the ground.

In this study, the diurnal and seasonal variations of mean wind speed, average range of gusts, mean gustiness and mean temperature have been discussed.

The varions parameters under study have the following definitions in accordance with India Meteorological Department practice. Mean wind speed V, at any speicfied hour, is the mean speed during a period of duration 10 minutes immediately preceding the hour (IST) obtained from the speed ribbon of anemographic chart. The speed is estimated correct to 1 kmph. Mean range of gust R_g is the average width of the speed ribbon ignoring solitary lulls or gusts during the 10-minute interval preceding immediately the hour. Gustineas of wind G is the quotient R_g/V. Temperature is recorded at the exact hour.

The anemograph and thermograph data of period of 10 years, from January 1955 to December 1964, have been utilised for the present study

Jagannathan and others (1964) have studied in detail surface wind characteristics at Poona. Present attempt of study aims at finding out any direct effect of temperature on wind elements.

2.1. Mean hourly wind speed V

Table 1(a) shows the mean hourly speed in kmph in different months. Winds are weak, 5-7 kmph during October to April and strongest during monsoon period in June to August months. Winds are minimum about 1-2 hours after sunrise in the months January to May and at 22-23 IST in months June to December. Wind has maximum speed sometime between 11 A.M. to 2 P.M. during the year.

2.2. Mean hourly range of gust R_g

It will be seen from Table 1(b) that the range of gust is largest in months of May and June, and least during winter months. Winds are most gusty around noon hours, the range of gusts being about 10 kmph; and least gusty between 21-01 hours during July to December and about the time of sunrise during January to April.

2.3. Mean hourly gustiness G

The gustiness (*see* Table 1c) is largest between 11 and 15 hrs and least during late night and early morning hours. Winds are most gusty in May and June months, and are least gusty in January.

2.4. Mean hourly temperature

Table 1 (d) shows the mean hourly temperature variations. Temperature records peak value between 2 to 4 P.M. and lowest temperature is between 6 to 7 A.M. during the year. Highest temperature is recorded in May and lowest in December.

3.1. Wind speed

(i) Diurnal, semi-diurnal and 8-hourly oscillations

The values of the first three harmonics, amplitudes and corresponding phase angles, are given in Table 2 (a). The calculated and actual values are shown in Fig. 1 (a).

The three harmonics account for about 95 per cent of the variations practically in all months. The diurnal variations of mean wind speed in any month can be represented at any time t reckoned from 00 IST by the following function—

$$V_t = A_0 + A_1 \sin\left(\phi^\circ_1 + \frac{\pi}{12} t\right) + A_2 \sin\left(\phi^\circ_2 + \frac{\pi}{6} t\right) + A_3 \sin\left(\phi^\circ_3 + \frac{\pi}{3} t\right) \quad (1)$$

where, A_o is the mean amplitude and A_1, A_2, A_3 are the amplitudes of the three harmonics and ϕ_1, ϕ_2, ϕ_3 are the corresponding phase angles.

(ii) Seasonal variations

The mean wind speeds are strong during May to August, being over 9 kmph and become 5 kmph during October to January.

The following equation represents the seasonal variations of mean daily wind speed—

$$V_t = 6{\cdot}5+2{\cdot}9 \sin\left(289^\circ + \frac{\pi}{6} t\right) + \\ +0{\cdot}9 \sin\left(91^\circ + \frac{\pi}{3} t\right) \qquad (2)$$

where, V_t is the mean daily wind speed at time t reckoned from 16 January. First term on the right hand side is mean wind speed for the year as a whole. Second term is annual oscillation amplitude which is maximum on 29 June and is 2·9 kmph. Third term is bi-annual oscillation which is one third of annual variation and attains its maximum on 15 January and 15 July.

Fig. 2 (a) shows the harmonic dials of 24-hour, 12-hour and 8-hour waves separately. The vertices of the polygon represent the vectors corresponding to different months, the distance from origin being the amplitude and the angle measured in anti-clock direction from the positive x-direction being phase angle.

24-hour wave—The amplitudes are generally small during November to February, being smallest in December. From February, the amplitude steadily increases reaching nighest in July and then decreasing again. The time of maximum is delayed from 11-16 hrs in November to 13-24 hrs in March. With the change of season, the oscillation tends to occur earlier and during monsoon, *i.e.*, July to September, the maximum occurs almost at the same time around 12-00 hrs.

12-hour wave—The amplitudes in November to January of 12-hour oscillations are comparable with diurnal wave, being of the order of 1 kmph; otherwise in other months these are smaller than 24-hour wave. The maximum occurs around midnight in all months except during May and June when it occurs around 9-10 P.M. During winter months, secondary maxima are perceptible as the amplitudes of diurnal and semi-diurnal waves are almost of the same order.

8-hour wave—During the months May and June, this wave is more predominant than semi-diurnal wave. It has an amplitude of the order of 1 kmph. The maximum in amplitude occurs sometime at midnight. The amplitudes of this wave in winter are small. The seasonal variations of the amplitudes of these waves are represented by the following equations—

Amplitude of the diurnal wave

$$A_{1t} = 2{\cdot}9+1{\cdot}7 \sin\left(249^\circ + \frac{\pi}{6} t\right) + \\ + 0{\cdot}3 \sin\left(57^\circ + \frac{\pi}{3} t\right) \qquad (3)$$

Amplitude of semi-diurnal wave

$$A_{2t} = 0{\cdot}8+0{\cdot}2 \sin\left(196^\circ + \frac{\pi}{6} t\right) + \\ + 0{\cdot}2\sin\left(350^\circ + \frac{\pi}{3} t\right) + 0{\cdot}2\sin\left(225^\circ + \frac{2\pi}{3} t\right) \qquad (4)$$

Amplitue of 8-hour wave

$$A_{3t} = 0{\cdot}6 + 0{\cdot}4 \sin\left(310^\circ + \frac{\pi}{6} t\right) + \\ + 0{\cdot}2 \sin\left(161^\circ + \frac{\pi}{3} t\right) \qquad (5)$$

The diurnal wave has a mean amplitude of 2·9 kmph with an annual oscillation of 1·7 kmph amplitude; the maximum occurring on 6 August and a half-yearly oscillation of amplitude 0·3 kmph, only one-sixth of annual oscillation, the maxima occurring on 2 February and 2 August.

The semi-diurnal oscillation has a mean amplitude of 0·8 kmph, with annual, bi-annual and 4-monthly oscillations of 0·2 kmph amplitude.

The 8-hour oscillation has a mean value of 0·6 kmph which is quite comparable to mean semi-diurnal oscillation. The annual oscillation has an amplitude of 0·4 kmph, maximum occurring on 10 June and half-yearly oscillation has an amplitude of 0·2 kmph and maxima occur on 10 December and 10 June.

3·2. Mean range of gusts R_g

Diurnal, semi-diurnal and 8-hour fluctuations

The values of mean R_g in different months, the amplitudes and corresponding phase angles of the diurnal, semi-diurnal and 8-hour oscillations are given in Table 2 (b).

(i) Daily maxima and minima—The maxima in the range of gusts are smallest during November to January and largest during May to August. Ir winter, time of maxima is around noon which is delayed to 1 P.M. in March and with the advance of it occurs before noon and remains so during the monsoons. It is again delayed to 1230 P.M. in

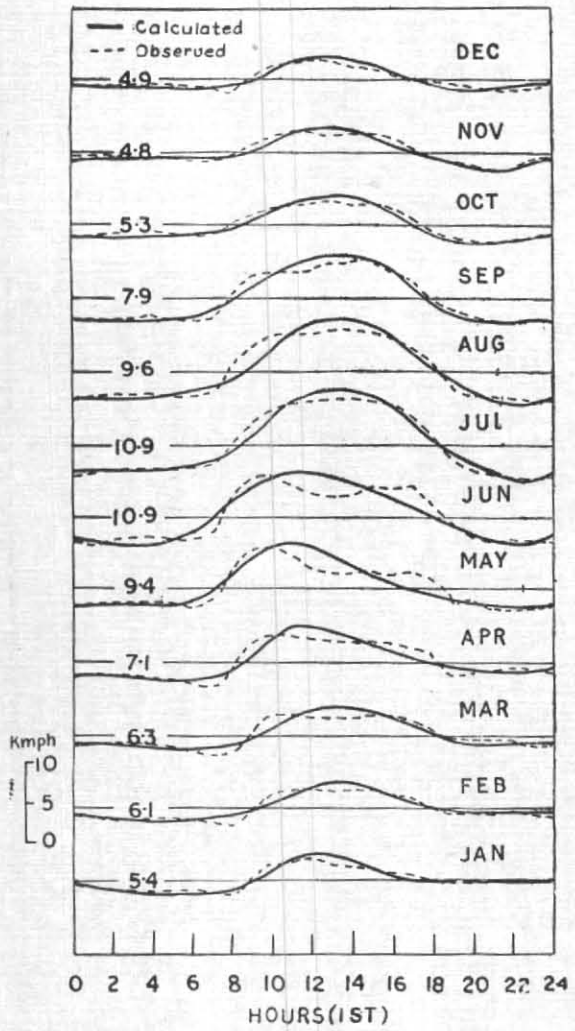

Fig. 1(a). Diurnal variations of wind speed—Nagpur

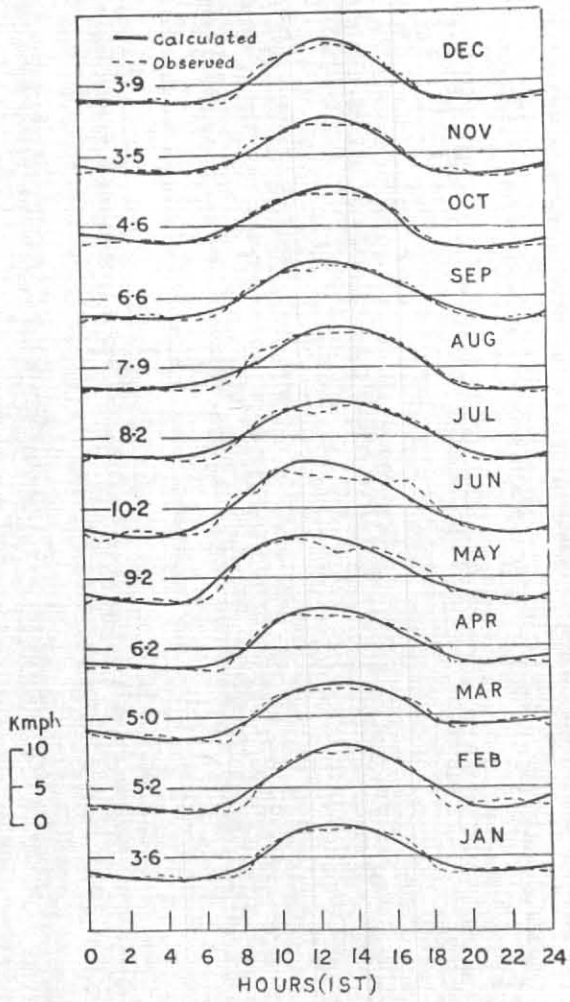

Fig. 1(b). Diurnal variations of average range of gusts—Nagpur

October. The minima are smallest again in November to January and greatest in May to August, being of the order of 6 kmph when greatest. The minima occurring between 5-6 A.M. during October to April and 3-4 A.M. during rest of the period.

(*ii*) *Seasonal variation*—The following equation represents the seasonal variations of the average range of gusts.

$$R_{gt} = 6{\cdot}2 + 3{\cdot}0 \sin\left(285^\circ + \frac{\pi}{6}t\right) + $$

$$+ 0{\cdot}3 \sin\left(126^\circ + \frac{\pi}{3}t\right) + 0{\cdot}7 \sin\left(42^\circ + \frac{2\pi}{3}t\right) \quad (6)$$

where R_{gt} is the average range of gusts on any day, t reckoned from 16 January. The annual mean of average range of gusts is 6·2 kmph. The amplitude of the annual oscillation is 3·0 kmph, the maximum occurring on 2 July which is nearly the same time as for the annual maximum of mean wind speed. The half-yearly variations have maxima of 0·3 kmph, one tenth of annual oscillation and occur on 29 December and 29 June.

The 4-monthly oscillations have amplitude about one fourth of annual oscillation and more than double the half-yearly oscillation. Its first maximum occurs on 1 February and is repeated every four months.

Fig. 2 (b) shows the harmonic dials of 24-hour, 12-hour and 8-hour waves. The calculated and actual values are shown in Fig. 1 (b).

24-hour wave—The amplitudes are smallest in January and March. The time of maximum in March is 1352 hours and goes on advancing to 1128 hrs in October and then it gets delayed. The time of maximum suddenly changes from 1220 hrs

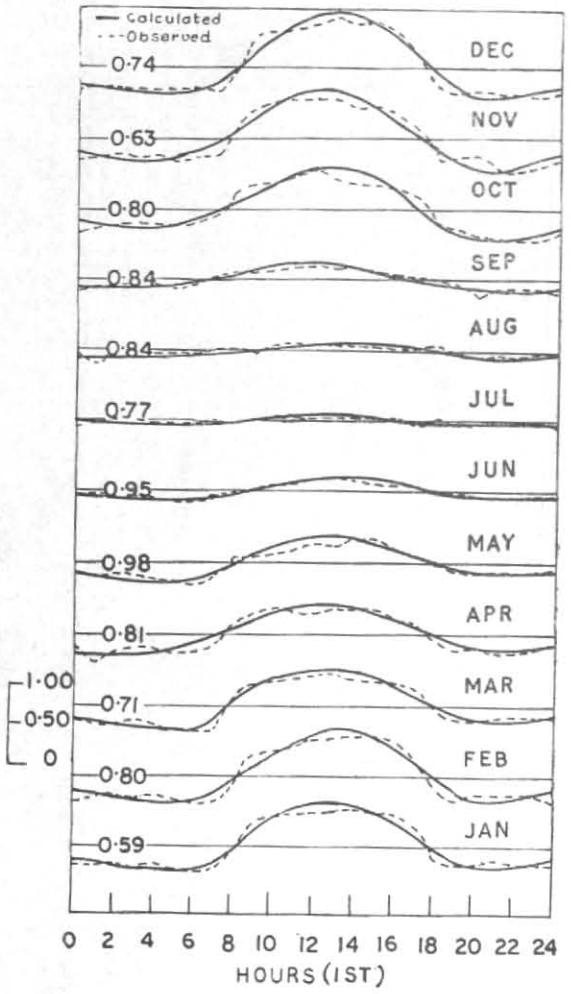

Fig. 1(c). Diurnal variations of gustiness—Nagpur

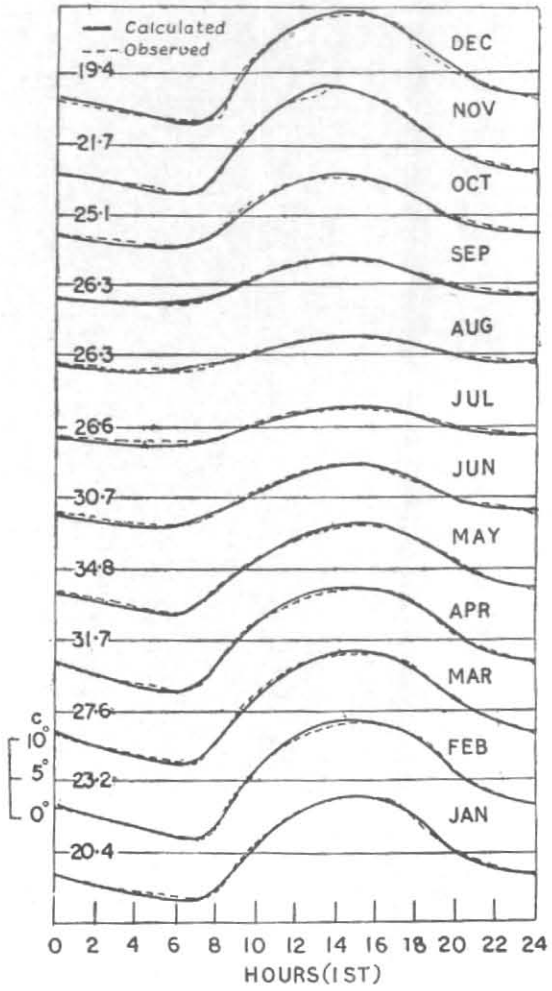

Fig. 1(d). Diurnal variations of temperature—Nagpur

in January to 1336 hrs in February and again from 1308 hrs in April to 1140 hrs in May. The amplitude maxima is greatest in June, being 4·4 kmph. In premonsoon and monsoon, the amplitude maximum has an order of about 4·0 kmph.

12-hour wave—The amplitudes are generally much smaller than 24-hour wave. The amplitude maximum is smallest, 0·8 kmph in June and gradually decreases to 1·8 kmph in December and after that the amplitude starts decreasing again. The amplitude maxima is minimum during May to September, being about 1·0 kmph. The time of maxima during September to February occurs around midnight, then recesses by half-hour in March and April, occurring earliest at 2302 hrs in May. It starts getting delayed in monsoon and shifts from 2328 hrs in June to 0026 hrs in July and August respectively. The second maximum occurs after 12 hours again.

8-hour wave—The amplitude maxima are significant in May and June, being 1·0 kmph and 0·9 kmph. These are of same order as 12-hour wave. The time of maxima in both cases being 0024 and 0020 hrs respectively.

The seasonal variations of the amplitudes of above oscillations are represented by equations given below —

Amplitude of the diurnal oscillation

$$A_{1t} = 3\cdot6 + 0\cdot6 \sin\left(280^\circ + \frac{\pi}{6}t\right) +$$

$$+0\cdot1 \sin\left(202^\circ + \frac{\pi}{3}t\right) + 0\cdot2 \sin\left(63^\circ + \frac{2\pi}{3}t\right) \quad (7)$$

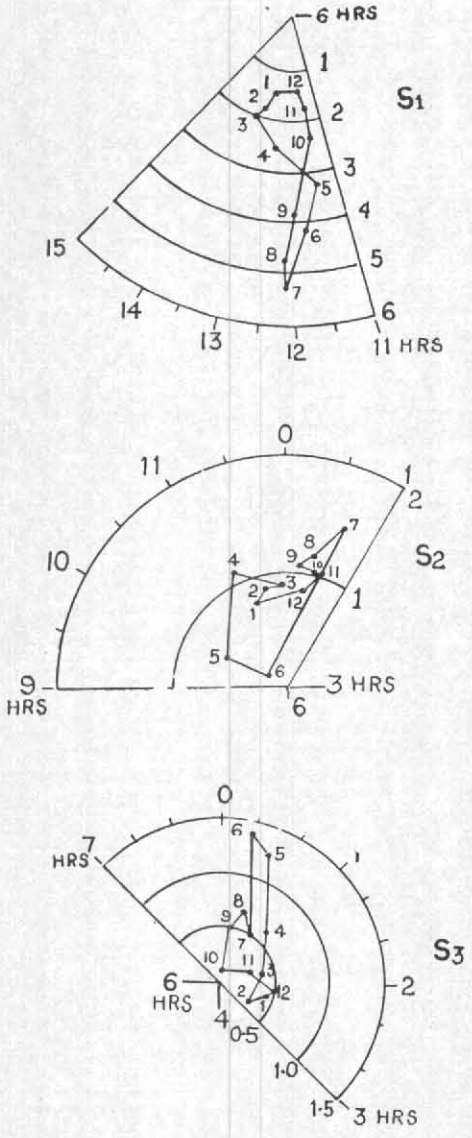

Fig. 2(a). Harmonic dials—Mean wind speed (kmph)

S_1 — Diurnal wave

S_2 — Semi-dirunal wave

S_3 —8-hourly wave

(i) Vertices of polygon represent the vectors corresponding to the different months

(ii) The distance from the origin is amplitude

(iii) The angle measured anti-clockwise from positive direction is the phase angle

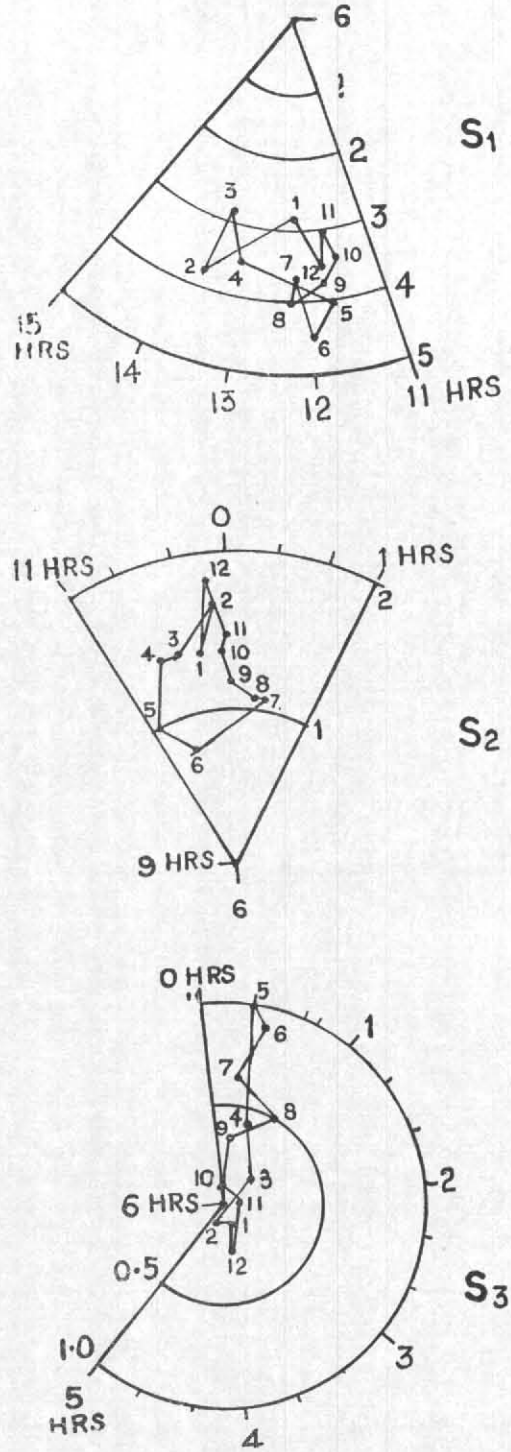

Fig. 2(b). Harmonic dials—Range of gusts (kmph)

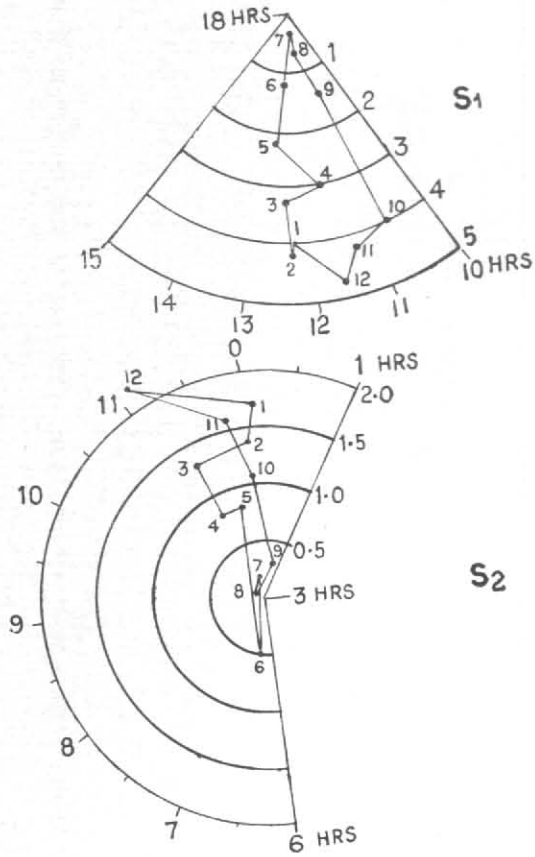

Fig. 2(c). Harmonic dials—Gustiness
S_1—Diurnal wave
S_2—Semi-diurnal wave

Amplitude of the semi-diurnal oscillation

$$A_{2t} = 1{\cdot}3 + 0{\cdot}3 \sin\left(110^\circ + \frac{\pi}{6}t\right) + $$

$$+ 0{\cdot}1 \sin\left(324^\circ + \frac{\pi}{3}t\right) + 0{\cdot}2 \sin\left(249^\circ + \frac{2\pi}{3}t\right) \quad (8)$$

Amplitude of 8-hourly oscillation

$$A_{3t} = 0{\cdot}4 + 0{\cdot}4 \sin\left(299^\circ + \frac{\pi}{6}t\right) +$$

$$+ 0{\cdot}2 \sin\left(163^\circ + \frac{\pi}{3}t\right) \quad (9)$$

The diurnal wave of average range of gust has a mean amplitude of 3·6 kmph. The amplitude of the annual oscillation is 0·6 kmph, the maximum in the oscillation occurring on 5 July; the half-yearly and 4-monthly oscillations have amplitudes of 0·1 and 0·2 kmph, the maximum in the former occurring on 19 November and also after six months, in the latter case it occurs on 26 February and repeated after every four months.

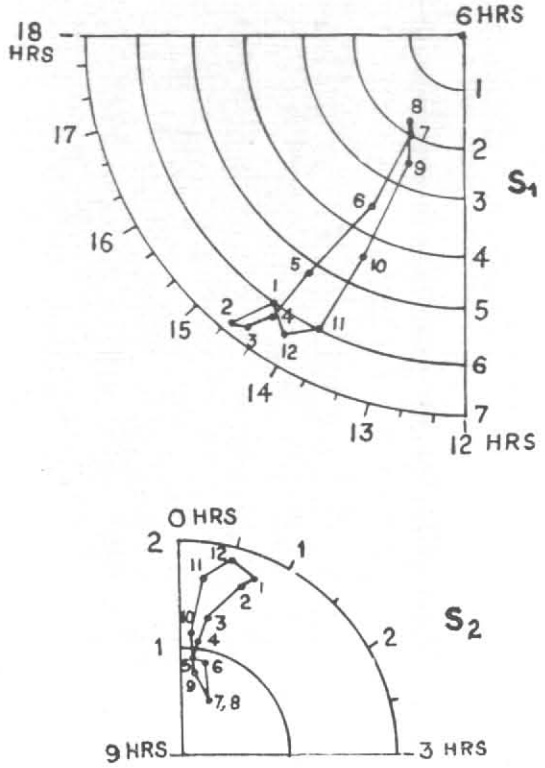

Fig. 2(d). Harmonic dials—Temperature (°C)
S_1—Diurnal wave
S_2—Semi-diurnal wave

3·3. Gustiness of wind

24-hour, 12-hour and 8-hour oscillations

The values of mean gustiness in different months, the amplitudes and phase angles of the diurnal, semi-diurnal and 8-hour fluctuations are given in Table 2 (c). The calculated and actual values are shown in Fig. 1 (c).

(*i*) *Daily maxima and minima*—The maximum gustiness has little seasonal variations. The maximum gustiness is lowest in the months of July and August, being 0·86 and 0·96 respectively; while during October to December and January to May, it is of the order of 1·3 and 1·2. The times of maxima are between 1200 to 1400 hrs all around the year. The minimum gustiness is of the order of 0·4 during October to April and about 0·7 during May to September. The minima occur between 5-7 A.M. during January to August and 7-8 P.M. in October to December.

(*ii*) *Seasonal variation*—The following equation represents the seasonal variations of gustiness—

$$G_t = 0{\cdot}78 + 0{\cdot}12 \sin\left(296^\circ + \frac{\pi}{6}t\right) +$$

$$+ 0{\cdot}03 \sin\left(283^\circ + \frac{\pi}{3}t\right) + 0{\cdot}05 \sin\left(61^\circ + \frac{2\pi}{3}t\right) \quad (10)$$

where G_t is the mean gustiness on t day reckoned from 16 January. The mean gustiness for the year as a whole is 0·78. The amplitude of the annual oscillation is 0·12, the maximum of the oscillation occurring on 19 June. The half-yearly fluctuation has an amplitude of 0·03, the maximum occurring on 18 October and after six months again. The 4-monthly oscillation maxima is 0·05 and occurs on 25 January and repeated every four months.

Fig. 2(c) shows harmonic dials for 24-hour, and 12-hour waves separately.

24-hour wave—The amplitude of 24-hour wave is smallest in July, being 0·03 and than increases to 0·47 in December. It again decreases after December. The time of occurrence of maxima in the oscillation being around 10-11 hrs in August to October; the rest of the year, it occurs between 11-13 hrs.

12-hour wave—The amplitudes are smaller than those of 24-hour fluctuation. In July to September, they are least, being of the order of 0·02. During October to December, the amplitudes increases from 0·05 to 0·22 and decreases afterwards to 0·05 in June. The time of occurrence of maximum is generally between 23-24 hrs except during June and August when the maxima occur at 1824 hrs and 2218 hrs respectively.

The seasonal variations of the amplitudes of the harmonics are represented by the following equations—

$$A_{1t} = 0{\cdot}25 + 0{\cdot}19 \sin\left(95^\circ + \frac{\pi}{6}t\right) + 0{\cdot}03 \sin\left(246^\circ + \frac{\pi}{3}t\right) \quad (11)$$

$$A_{2t} = 0{\cdot}10 + 0{\cdot}09 \sin\left(92^\circ + \frac{\pi}{6}t\right) + 0.03 \sin\left(180^\circ + \frac{\pi}{3}t\right) \quad (12)$$

The above two equations represent (*i*) diurnal wave amplitude variations and (*ii*) semi-diurnal wave amplitude variations respectively. The 8-hourly variations of amplitudes of gustiness are insignificant.

The diurnal wave of gustiness has a mean amplitude of 0·25. The amplitude of annual oscillation is 0·19 and occurring on 10 January. The half-yearly oscillation has an amplitude of 0·03 and occurs on 29 October and 29 April. The semi-diurnal wave has annual mean amplitude of 0·10 and annual oscillation is of 0·09 amplitude. The maximum in the annual oscillation occurs on 14 January. The semi-diurnal wave has an amplitude of 0·03 and maxima occur on 1 December and 1 June.

3.4. Temperature

Diurnal, semi-diurnal and 8-hourly variations

The values of temperature in different months and the amplitudes of the harmonics are given in Table 2(d). The calculated and actual values are shown in Fig. 1(d).

(*i*) *Daily maxima and minima*—The maximum temperature is least in December, 26·8°C and goes on slowly increasing till May, when it reaches its highest of 40·5°C. The occurrence of maxima is around 14-15 hrs throughout the year; during winter occurring near 14 hrs and with the advance of the season gradually shifting towards 15 hrs. The minimum in temperature is 13·0°C, occurring in December. The time of minimum is around 07 hrs during winter shifting to 06 hrs in monsoon months.

(*ii*) *Seasonal variations*—The following equation fits in to represent the seasonal variations of the temperature—

$$T_t^\circ = 26{\cdot}1^\circ + 5{\cdot}7^\circ \sin\left(314^\circ + \frac{\pi}{6}t\right) + 2{\cdot}6^\circ \sin\left(260^\circ + \frac{\pi}{3}t\right) + 1{\cdot}0^\circ \sin\left(84^\circ + \frac{2\pi}{3}t\right) \quad (13)$$

where T°_t is the temperature at any time of the year reckoned from 16 January. The annual mean of temperature is 26·1°C. The annual oscillation amplitude is 5·7°C and the time of occurrence of its maximum is sometime around 31 May. The biannual and 4-monthly oscillation have maximum amplitudes of 2·6°C and 1·0°C respectively. Half-yearly oscillation has maxima occurring on 20 April and 20 October. The 4-monthly maximum occurs on 17 January and repeated every four months.

Fig. 2(d) shows the harmonic dials of two oscillations.

24-hour wave—The amplitudes are least during July and August, being about 2°C and slowly increasing as the winter sets in to 6·3°C in December, highest amplitude being 6·8°C in February. The time of maxima being between 1330-1430 hrs throughout the year.

12-hour wave—The maximum in amplitude is highest again in winter months as in the case of 24-hour oscillation, being 1·9°C in December and then slowly decreasing to 1·1°C in March. During July and August, the amplitude maxima is least, being 0·5°C. The time of occurrence of the maxima is between 00—01 hrs throughout the year.

The 8-hourly oscillation has significant amplitude only in February to May, ranging between

0·5° to 0·7°C. The time of occurrence being 0127 hrs in February and shifting to 0048 hrs in May. It is repeated every 8-hours.

The seasonal variations of the above oscillations are represented by the following equations—

24-hour oscillation

$$T°_{1t} = 4·8° + 2·2° \sin (33° + \frac{\pi}{6} t) + + 0·7° \sin (231° + \frac{\pi}{3} t) \quad (14)$$

12-hour oscillation

$$T°_{2t} = 1·2° + 0·7° \sin (93° + \frac{\pi}{6} t) + + 0·1° \sin (173° + \frac{\pi}{3} t) \quad (15)$$

The 8-hourly oscillation has an amplitude of annual oscillation of 0·3°C and is not significant as compared to other oscillations.

The diurnal oscillation has an annual mean amplitude of 4·8°C. The maximum amplitude of the annual oscillation is 2·2°C and the maximum occurs on 13 March. The half-yearly oscillation has a maximum amplitude of 0·7°C and occurs on 5 May and 5 November. The semi-diurnal amplitude has 1·2°C annual mean. The annual oscillation in this case is 0·7°C and the maximum occurs on 14 January. The half-yearly oscillation is only of 0·1°C amplitude and, therefore, not significant at all.

4. Discusssion

Gustiness at any time shows the state of the atmosphere. High gustiness ratio means the atmosphere is in turbulent condition. A low gustiness value indicates conditions of stable equilibrium and laminar flow. The influence of particular direction and topography on gustiness (Carruthers 1943) has not been investigated here. The ground temperature variations have been investigated to see if they give any insight in gustiness structure. The ground temperature fluctuations are indicative of state of the lower atmosphere. During cloudy nights, the radiation is prevented to go into the troposphere, hence fluctuations in ground temperature are less on these nights and these in turn affect the gradient of temperature in the lower atmosphere (Sutton 1949).

In Tables 2(c) and 2(d) are given the values of the diurnal, semi-diurnal and 8-hourly fluctuations.

The diurnal temperature oscillations are least during June and August and so are the gustiness fluctuations. During the months from November to April, the diurnal oscillations are comparable, being 6°C and the diurnal gustiness amplitude is also highest during these months. On the other hand, the diurnal temperature fluctuations seem to be related inversely to the mean wind speed and mean range of gusts oscillations. This can be seen from amplitude (A_1) columns of various elements [*see* Tables 2(a) to 2(c)].

The time of maxima of diurnal gustiness amplitude is generally towards noon, about two hours earlier than the diurnal temperature amplitude maxima oscillation. Towards noon, the lapse rate attains its maximum (Sutton 1949) and with the descent of the sun, the lapse rate decreases and before sunset an isothermal state is reached in the lower atmosphere.

From Figs. 1(b) and 1(c) it can be seen that the range of gusts and gustiness have minimum values before sunrise between 06—07 hrs and 19—21 hrs after sunset during winter months (October to March). At Nagpur after sunset and before sunrise inversion exists during tnese winter months (Five years data, 1958—1963, of radiosonde ascent 00 GMT and 12 GMT were examined for this purpose). Inversion implies approach to laminar flow and hence the reason for the gustiness fluctuations to be minimum.

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TABLE 1

Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
					(a) Mean hourly wind speed (kmph)—Nagpur							
1	4·6	4·9	5·0	5·6	7·1	7·2	7·4	6·3	5·1	4·0	4·3	4·3
2	4·5	4·6	5·2	5·4	7·2	7·9	7·6	6·6	5·2	4·3	4·3	4·3
3	4·3	4·7	5·2	5·5	7·3	8·2	7·7	6·5	5·3	4·5	4·4	4·1
4	4·3	4·7	5·1	4·9	7·3	8·2	7·5	6·6	5·6	4·6	4·4	4·5
5	4·1	4·8	4·4	5·1	7·3	8·1	7·5	6·4	5·2	4·2	4·0	4·3
6	4·2	4·5	4·0	4·4	6·7	7·9	7·5	6·4	5·3	4·1	3·7	4·1
7	3·7	4·1	3·8	3·9	7·9	9·3	8·0	7·0	5·5	3·9	3·6	3·9
8	3·5	3·7	4·2	6·3	11·9	13·3	10·9	9·9	8·2	5·3	4·0	3·3
9	5·7	6·4	6·8	9·2	13·9	15·6	13·5	12·4	10·5	6·3	5·5	5·2
10	7·4	8·1	8·7	10·3	14·1	15·7	15·1	13·9	11·5	7·3	6·6	6·5
11	7·8	8·3	8·8	10·4	13·3	14·7	15·9	14·2	11·6	7·8	7·2	7·0
12	8·0	8·5	8·4	9·9	11·7	13·7	16·4	14·3	11·6	8·0	7·3	7·3
13	7·2	8·1	8·6	9·7	11·3	13·4	16·5	14·7	12·3	8·4	7·1	2·7
14	7·2	8·3	8·4	9·3	11·2	13·5	16·7	14·7	12·1	8·1	7·2	6·6
15	6·6	8·3	8·7	9·5	11·4	14·5	16·4	14·6	12·6	8·1	6·8	6·2
16	6·4	7·6	8·5	9·2	11·0	14·3	16·1	14·0	11·2	7·7	6·5	5·8
17	5·9	7·3	8·1	8·6	11·5	14·7	14·7	12·5	10·3	6·0	5·0	4·8
18	5·3	5·8	6·6	7·9	10·2	12·4	12·0	10·9	7·8	4·1	4·1	4·8
19	5·4	5·4	5·7	5·4	7·5	10·1	9·1	7·9	6·4	3·8	3·7	4·4
20	5·3	5·7	5·9	5·8	7·6	8·4	7·5	6·6	5·6	3·4	3·5	3·8
21	5·1	5·7	5·8	5·9	6·8	7·8	7·0	6·4	5·3	3·1	2·7	3·4
22	4·9	5·9	5·8	6·2	6·7	7·9	6·8	6·3	4·8	3·4	2·5	3·5
23	4·6	5·3	5·0	6·1	6·8	7·5	6·7	5·7	5·1	3·7	3·5	3·6
24	4·7	5·1	5·1	5·5	6·9	7·6	6·9	5·8	5·0	3·9	3·9	4·1
Mean	5·4	6·1	6·3	7·1	9·4	10·9	10·9	9·6	7·9	5·8	4·8	4·9
					(b) Mean hourly range of gusts (kmph) —Nagpur							
1	1·6	2·7	2·9	3·9	6·7	6·2	5·8	5·1	4·2	2·5	1·8	2·0
2	1·6	2·8	2·9	4·0	6·7	7·2	5·9	5·3	4·2	2·7	1·9	1·9
3	1·6	2·5	3·1	3·7	6·6	7·4	6·1	5·3	4·4	2·9	2·1	1·9
4	1·6	2·6	2·9	3·8	6·5	7·0	5·7	5·4	4·6	2·9	1·9	2·1
5	1·4	2·6	2·1	3·7	6·2	7·0	5·6	5·2	4·2	2·8	1·7	1·8
6	1·3	2·4	2·0	3·3	5·9	7·1	5·5	5·1	4·2	2·9	1·6	1·9
7	1·2	2·3	1·9	3·3	7·5	8·8	6·1	5·7	4·8	3·1	1·7	1·7
8	2·0	3·1	3·6	5·9	11·5	11·9	8·1	7·0	7·0	4·9	3·0	2·5
9	4·7	6·1	6·1	8·6	13·0	11·2	9·9	9·7	8·6	6·4	5·3	5·4
10	6·3	8·1	7·9	10·1	13·7	15·3	11·6	11·5	9·5	7·9	6·0	7·5
11	7·2	9·4	8·5	10·4	14·2	14·9	11·9	12·1	10·3	8·3	7·1	8·0
12	7·4	9·9	8·5	10·2	13·7	14·4	11·2	12·1	10·1	8·9	7·6	8·7
13	7·2	9·7	8·6	10·3	12·2	14·4	12·3	12·1	11·0	8·9	7·5	9·0
14	7·3	10·1	8·5	9·9	12·7	13·8	12·4	12·3	10·5	8·5	7·3	8·5
15	6·7	9·8	8·3	9·7	13·1	14·0	12·2	12·0	10·3	8·3	6·9	7·9
16	6·5	8·8	7·5	8·9	11·8	13·4	11·6	11·5	9·0	7·4	5·9	6·8
17	4·9	7·2	6·7	7·8	10·9	13·7	10·7	10·3	8·5	5·4	3·9	3·9
18	2·3	4·3	4·9	6·3	9·8	11·3	9·1	8·6	6·5	3·1	1·7	2·0
19	1·8	2·7	3·4	4·1	7·2	9·1	7·3	6·5	5·0	2·5	1·7	1·9
20	2·2	3·4	3·7	4·2	7·0	7·6	5·8	5·5	4·4	2·2	1·4	1·7
21	2·3	3·6	3·9	4·4	6·1	7·3	5·3	5·4	4·2	2·0	1·0	1·6
22	2·3	4·1	4·1	4·6	6·1	7·2	5·5	5·3	3·9	2·2	1·0	1·7
23	2·1	3·2	4·7	4·4	6·6	6·9	5·6	4·8	4·2	2·1	1·4	1·7
24	1·8	2·9	3·3	4·2	6·2	7·2	5·5	4·9	4·0	2·3	1·6	1·8
Mean	3·6	5·2	5·0	6·2	9·2	10·2	8·2	7·9	6·6	4·6	3·5	3·9

TABLE 1 (*contd*)

Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
					(c) Mean hourly gustiness of wind—Nagpur							
1	0·33	0·54	0·47	0·45	0·80	0·92	0·73	0·70	0·74	0·59	0·98	0·47
2	0·36	0·56	0·48	0·61	0·86	0·88	0·80	0·81	0·79	0·61	0·44	0·47
3	0·32	0·52	0·52	0·65	0·83	0·88	0·81	0·81	0·79	0·64	0·40	0·46
4	0·36	0·56	0·47	0·66	0·78	0·84	0·71	0·78	0·80	0·63	0·43	0·46
5	0·28	0·51	0·41	0·61	0·76	0·81	0·75	0·79	0·73	0·63	0·37	0·46
6	0·28	0·46	0·40	0·60	0·71	0·82	0·72	0·78	0·81	0·65	0·35	0·49
7	0·30	0·49	0·38	0·67	0·87	0·94	0·79	0·87	0·88	0·74	0·41	0·43
8	0·49	0·67	0·77	0·94	1·06	0·94	0·76	0·87	0·93	1·01	0·75	0·70
9	0·85	1·05	0·97	1·07	1·05	0·99	0·77	0·80	0·90	1·13	1·01	1·17
10	0·94	1·12	1·02	1·13	1·09	1·03	0·82	0·91	0·95	1·15	1·08	1·19
11	0·99	1·18	1·05	1·10	1·17	1·08	0·82	0·92	0·99	1·21	1·10	1·23
12	1·01	1·27	1·08	1·09	1·23	1·10	0·79	0·91	1·01	1·30	1·13	1·26
13	1·05	1·28	1·11	1·15	1·20	1·14	0·80	0·90	0·98	1·18	1·13	1·36
14	1·07	1·30	1·05	1·12	1·28	1·09	0·82	0·89	1·00	1·13	1·03	1·28
15	1·00	1·30	1·02	1·16	1·29	1·05	0·81	0·87	0·94	1·12	1·06	1·32
16	1·01	1·25	1·00	1·01	1·16	1·05	0·79	0·85	0·89	1·04	0·95	1·19
17	0·86	1·05	0·93	0·97	1·07	1·00	0·75	0·87	0·88	0·95	0·76	0·89
18	0·46	0·70	0·70	0·76	1·02	0·94	0·81	0·92	0·86	0·61	0·36	0·46
19	0·36	0·50	0·56	0·62	0·90	0·97	0·73	0·80	0·76	0·56	0·37	0·42
20	0·37	0·57	0·52	0·66	0·86	0·87	0·78	0·78	0·67	0·49	0·42	0·48
21	0·42	0·56	0·57	0·59	0·89	0·87	0·76	0·82	0·71	0·48	0·25	0·43
22	0·57	0·59	0·58	0·59	0·87	0·89	0·75	0·79	0·74	0·44	0·26	0·42
23	0·36	0·57	0·55	0·64	0·89	0·86	0·76	0·85	0·71	0·45	0·31	0·38
24	0·34	0·50	0·55	0·70	0·87	0·91	0·70	0·81	0·68	0·51	0·35	0·43
Mean	0·59	0·80	0·71	0·81	0·98	0·95	0·77	0·84	0·84	0·80	0·62	0·74
					(d) Mean hourly temperature (°C)—Nagpur							
1	16·71	19·17	23·72	27·89	31·51	28·51	25·29	25·04	24·66	22·53	17·98	15·52
2	16·29	18·55	23·12	27·33	30·97	28·21	25·18	24·92	24·52	22·17	17·55	15·15
3	15·71	17·98	22·52	26·73	30·46	27·89	24·99	24·76	24·31	21·81	17·16	14·65
4	15·31	17·41	21·95	26·22	30·08	27·73	24·92	24·67	24·18	21·59	16·82	14·26
5	14·81	16·93	21·35	25·76	29·58	27·49	24·85	24·60	24·04	21·34	16·44	13·86
6	14·45	16·42	20·83	25·11	29·31	27·29	24·78	24·39	23·88	21·10	16·02	13·47
7	14·10	15·97	20·65	25·72	30·29	27·98	24·94	24·63	24·17	21·37	16·00	13·23
8	15·25	17·92	23·24	28·77	32·57	29·09	25·55	25·24	25·18	23·13	18·25	14·91
9	18·59	21·74	26·80	31·63	34·55	30·51	26·33	26·15	26·40	25·30	21·79	18·55
10	21·39	24·55	29·31	33·56	36·14	31·52	26·94	26·78	27·36	26·94	24·42	21·56
11	23·62	26·79	31·37	35·21	37·56	32·69	27·93	27·42	28·23	28·47	26·35	23·76
12	25·19	28·42	32·74	36·39	38·62	33·68	28·20	27·97	28·90	29·33	27·51	25·22
13	26·20	29·44	33·66	37·26	39·38	34·46	28·63	28·27	29·13	29·69	29·00	26·04
14	26·84	30·13	34·26	37·82	40·02	34·84	28·95	28·41	29·38	29·83	28·25	26·46
15	27·18	30·45	34·48	38·01	40·18	34·78	28·91	28·43	29·20	29·73	28·17	26·58
16	27·12	30·51	34·49	37·90	40·03	34·30	28·61	28·18	28·90	29·37	27·80	26·30
17	26·56	30·11	34·02	37·47	39·49	33·43	28·31	27·93	28·42	28·64	26·79	25·38
18	24·29	28·50	32·84	36·33	38·58	32·72	27·84	27·43	27·55	27·07	24·31	22·54
19	22·09	25·87	30·40	34·21	36·90	31·69	27·13	26·76	26·62	25·68	22·41	20·68
20	20·55	24·03	28·57	32·46	35·41	30·24	26·61	26·24	26·07	24·78	21·07	19·13
21	19·38	22·77	27·09	31·14	34·30	30·11	26·22	25·93	25·72	24·08	20·10	18·08
22	18·56	21·72	26·10	30·04	33·50	29·60	25·95	25·66	25·43	23·62	19·40	17·32
23	17·97	20·86	25·26	29·43	32·81	29·13	25·70	25·46	25·18	23·22	18·85	16·72
24	17·32	20·02	24·54	28·75	32·02	28·64	25·30	25·19	24·80	22·73	18·22	16·10
Mean	20·37	23·18	27·64	31·71	34·76	30·69	26·59	26·27	26·34	25·15	21·65	19·40

TABLE 2(a)

Components of diurnal, semi-diurnal and 8-hourly wave (mean wind speed in kmph) —Nagpur

Month	Mean amplitude A_0 (kmph)	First harmonic			Second harmonic			Third harmonic		
		A_1	ϕ_1	T_1 hr-min	A_2	ϕ_2	T_2* hr-min	A_3	ϕ_3	T_3† hr-min
January	5·4	1·5	256	12—56	0·8	111	23—18	0·4	343	02—23
February	6·1	1·8	252	13—12	0·9	102	23—36	0·3	321	02—52
March	6·3	2·0	249	13—24	0·9	93	23—54	0·4	12	01—44
April	7·1	2·5	262	12—32	1·1	113	23—14	0·6	53	00—49
May	9·4	3·2	282	11—12	0·6	155	21—50	1·2	72	00—24
June	10·9	4·1	273	11—48	0·2	150	22—00	1·4	79	00—15
July	10·9	5·3	268	12—08	1·5	69	00—42	0·5	67	00—31
August	9·6	4·8	268	12—08	1·2	80	00—20	0·7	72	00—24
September	7·9	3·9	270	12—00	1·1	84	00—12	0·5	83	00—09
October	5·3	2·3	279	11—24	1·1	76	00—28	0·1	99	23—48
November	4·8	1·7	281	11—16	1·1	75	00—30	0·3	26	01—25
December	4·9	1·4	276	11—36	0·9	83	00—14	0·4	344	02—21

TABLE 2(b)

Components of diurnal, semi-diurnal and 8-hourly waves of mean range of gusts (kmph)

Month	Mean amplitude A_0 (kmph)	First harmonic			Second harmonic			Third harmonic		
		A_1	ϕ_1	T_1 hr-min	A_2	ϕ_2	T_2 hr-min	A_3	ϕ_3	T_3 hr-min
January	3·6	2·9	265	12—20	1·4	98	23—44	0·1	311	03—03
February	5·2	3·7	261	13—36	1·7	92	23—56	0·1	241	04—39
March	5·0	2·9	257	13—52	1·4	105	23—30	0·2	45	01—00
April	6·2	3·5	268	13—08	1·4	108	23—24	0·4	65	00—33
May	9·2	4·0	275	11—40	1·0	119	23—02	1·0	75	00—20
June	10·2	4·4	270	12—00	0·8	106	23—28	0·9	72	00—24
July	8·2	3·7	266	12—16	1·1	77	00—26	0·6	75	00—20
August	7·9	4·0	266	12—16	1·1	80	00—20	0·5	57	00—44
September	6·6	3·7	272	11—52	1·2	90	00—00	0·3	78	00—16
October	4·6	3·4	278	11—28	1·4	89	23—58	0·1	85	00—07
November	3·5	3·0	274	11—44	1·5	90	00—00	0·1	17	01—37
December	3·9	3·5	274	11—44	1·8	94	23—52	0·2	273	03—56

A_1, A_2, A_3 and ϕ_1, ϕ_2, ϕ_3 are amplitudes and phase angles of first, second and third harmonic components respectively

T_1, T_2 and T_3 indicate the time (IST) of occurrence of maxima of three harmonics respectively

*Second maximum occurs after 12 hours

†The other two maxima occur at an interval of 8 hours

(The amplitudes of the harmonic components are in kmph)

TABLE 2(c)

Components of diurnal, semi-diurnal and 8-hourly waves of mean gustiness of wind—Nagpur

Month	Mean amplitude A_0 (kmph)	First harmonic			Second harmonic			Third harmonic		
		A_1	ϕ_1	T_1 hr-min	A_2	ϕ_2	T_2 hr-min	A_3	ϕ_3	T_3 hr-min
January	0·59	0·39	266	12—16	0·14	90	00—00	0·03	95	23—53
February	0·80	0·41	266	12—16	0·17	87	00—06	0·03	114	00—28
March	0·71	0·32	264	12—24	0·13	110	23—20	0·05	77	00—17
April	0·81	0·30	275	11—40	0·08	108	23—24	0·05	112	00—31
May	0·98	0·22	259	12—44	0·08	98	23—44	0·03	124	23—15
June	0·95	0·12	261	12—56	0·05	258	18—24	0·02	105	23—40
July	0·77	0·03	270	12—00	0·02	104	23—32	0·01	311	03—03
August	0·84	0·06	268	12—08	0·01	141	22—18	0·02	85	00—07
September	0·84	0·14	289	10—44	0·05	72	00—36	0·01	79	00—15
October	0·80	0·39	290	10—40	0·11	90	00—00	0·05	80	00—13
November	0·63	0·41	282	11—12	0·16	98	23—44	0·06	70	00—27
December	0·74	0·47	276	11—36	0·22	117	23—06	0·03	116	23—25

TABLE 2 (d)

Components of diurnal, semi-diurnal and 8-hourly waves of mean temperature (°C)—Nagpur

Month	Mean amplitude A_0 (°C)	First harmonic			Second harmonic			Third harmonic		
		A_1 (°C)	ϕ_1	T_1 hr-min	A_2 (°C)	ϕ_2	T_2 hr-min	A_3 (°C)	ϕ_3	T_3 hr-min
January	20·4	6·0	234	14—24	1·8	69	00—42	0·4	7	01—51
February	23·2	6·8	231	14—36	1·7	71	00—38	0·6	25	01—27
March	27·6	6·6	232	14—32	1·4	81	00—18	0·7	30	01—20
April	31·7	6·1	235	14—20	1·1	85	00—10	0·7	47	00—57
May	34·8	5·2	235	14—20	0·9	85	00—10	0·5	54	00—48
June	30·7	3·5	241	13—56	0·9	81	00—18	0·1	62	00—37
July	26·6	2·0	240	14—00	0·5	70	00—40	0·2	29	01—21
August	26·3	1·9	238	14—08	0·5	70	00—40	0·1	27	01—24
September	26·3	2·5	244	13—44	0·8	82	00—16	0·1	36	01—12
October	25·1	4·3	245	13—40	1·2	86	00—08	0·3	45	01—00
November	21·7	5·9	244	13—44	1·7	83	00—14	0·4	41	01—05
December	19·4	6·3	239	14—04	1·9	75	00—30	0·2	76	00—19