Mausam, (1981) **32**, 3, 263-268

551 .594

The nature of diurnal variation of atmospheric electric field

S. CHAUDHURI

Indian Institute of Tropical Meteorology, Pune

(*Received 4 January 1979*)

ABSTRACT. Diurnal variation of atmospheric electric field for a single station Kew has been analysed for two consecutive years 1974-75. Harmonic analysis shows that the constant term is the primary factor in determining the value of the parameter at any time while the diurnal variation of the parameter is almost entirely governed by the diurnal and semi-diurnal components of harmonic analysis. Analysis also shows that diurnal component is most significant during winter, whereas the semi-diurnal component is in equinox. During summer the two components become minmium. Attempt is also made to explain the physical significance of the two components with the help of existing theories.

1. Introduction

The phenomena of atmospheric electric field had been known since long back. Attempts were also made to explain the nature of this field and its variation. The grouping of data of atmospheric electric field according to the type of diurnal variation and its quantitative study will convey an important insight into the inherent relationships between atmospheric electric field and the causes governing it. In this paper two years potential gradient data of Kew are used to investigate the nature of diurnal variation of atmospheric electric field by using harmonic analysis. The harmonic analysis will be able to isolates all the components of different periodicity (*viz.*, their amplitude, phase etc) in addition to the mean value of the parameter over which different components are superimposed. The analysis will also help to find out the significance of any component caused by any physical phenomenon.

2. Data and method of analysis

In the present study, two years data of atmospheric electric field have been utilised for a single station Kew (51 deg. 21′ N, 00 deg. 19′ W) during the period 1974 and 1975. The location of this station makes the local time almost coincidence with the Greenwich Mean Time. The data used in this analysis are the monthly hourly (in GMT) mean values of atmospheric electric field considering (*i*) all the days of a month and also for (*ii*) normal and fair weather days for each month of the two years. The data were obtained from the 'Result of ground observations of atmospheric electricity, published by USSR Chief Administration of the Hydrometeorological Service'. Diurnal variations of atmospheric electric field are drawn for each month of the two years 1974 and 1975. The diurnal variation curves for three different seasons, namely, winter, equinox and summer are also drawn for these two years. The values for the seasonal diurnal curves for three different seasons are obtained by averaging the monthly hourly values for November, December, January and February. Similarly equinox values are obtained from the average of the monthly hourly values of March, April, September and October and summer values from May, June, July and August. Harmonic analysis is applied

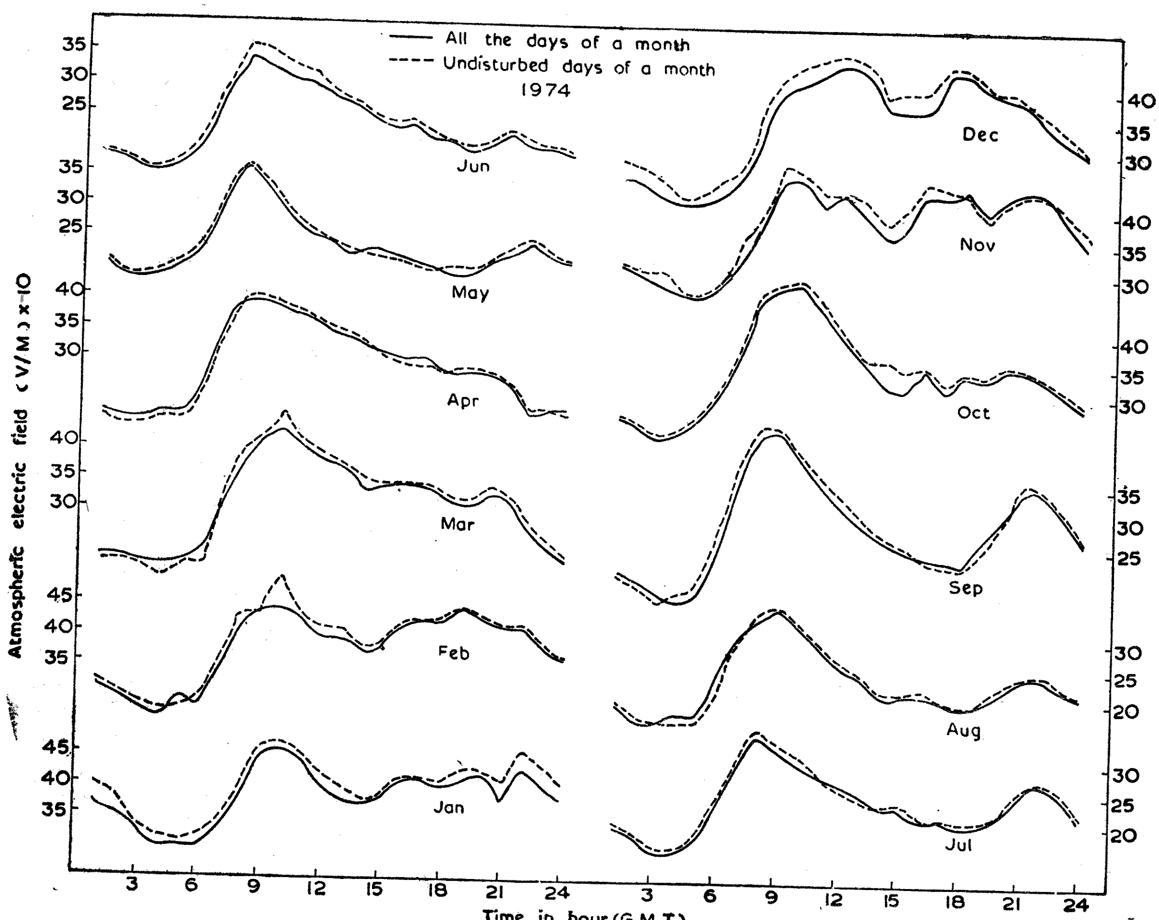

Fig. 1. Monthly diurnal variation of the atmospheric electric field at Kew during 1974

on each of these diurnal variation curves. The significance of any component is judged by comparing the amplitude, the percentage variance among different harmonics as well as the phase (time of maxima) term of individual harmonic.

3. Result and discussion

Figs. 1 and 2 show typical diurnal variation of atmospheric electric field for each month of the year 1974 and 1975 respectively. Fig. 3 shows diurnal variations according to season (winter, equinox and summer) for the same two years. The striking features of these curves are as follows :

(1) In almost all the curves diurnal double fluctuation of the atmospheric electric field dominates throughout the year except for the month April 1974 and May 1975 in Figs. 1 and 2 respectively which show single oscillation.

(2) In almost all cases the maxima occur at around 0900 and 2100 GMT. Whereas the first minimum occurs around 0400 GMT, the second minimum varies almost throughout the year. During the winter month the position of the second minima lies around 1400 GMT but for the other month of the year it is shifted to 1800 to 1900 GMT. A close look on the Figs. 1 and 2 also shows the distance between the diurnal maxima is minimum during the winter month but separates further away from one another as the day becomes longer.

To gain better insight into the characteristic tendencies of the above diurnal variation curves of atmospheric electric field (Figs. 1-3). Fourier analysis is applied to these sets of curves. The result of the Fourier analysis is discussed considering only the first few harmonics because the sum of the variance accounted by the first few harmonics is almost 90 per cent of the diurnal variation. The following are the important conclusions:

(*i*) Presence of strong semi-diurnal component of 12-hour periodicity (1st harmonic) is

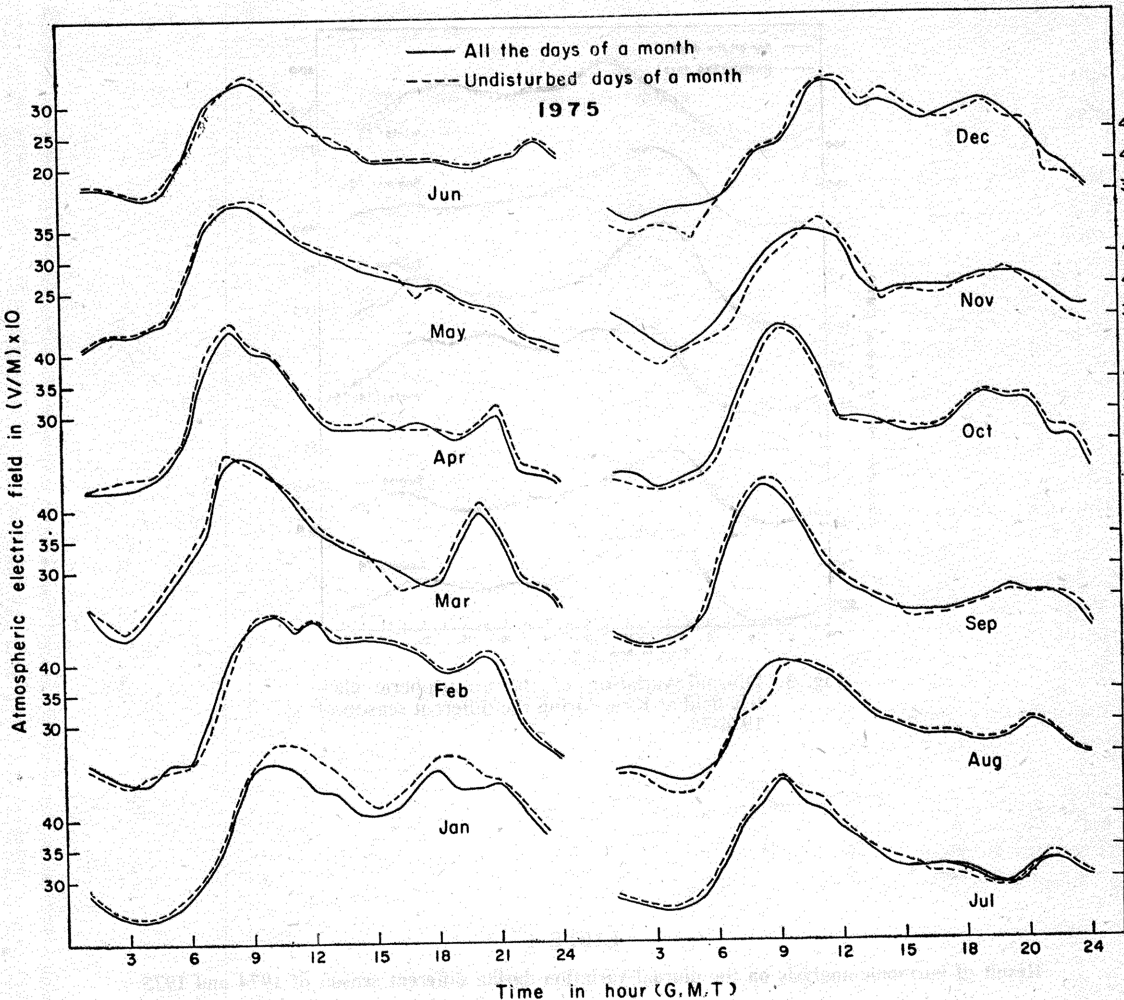

Fig. 2. Monthly diurnal variation of the atmospheric electric field at Kew for 1975

noticeable almost throughout the year. The variation is characterized by the midnight (0000 GMT) and noon (1200 GMT) peaks with a maximum of 2-hour deviation on both sides of the given peak values. Another important feature is that this component is most significant around equinox months but not so during summer months as can be observed from the amplitude of the semi-diurnal component.

(*ii*) Diurnal component of 24-hour periodicity (fundamental) is also noticeable but its peak appears at different time in winter months (Jan, Feb, Nov, Dec) than rest of the year. In winter months this component peaks around 1500 GMT but in equinox months (Mar, Apr,) Sep, Oct) and in summer months (May, June, July, August) the peak appears around 1900 GMT. The component is most significant around winter months and has got minimum value during summer as can be observed from the amplitude of this component.

(*iii*) Comparing the amplitude and the variance accounted by the different harmonics, it is clear that while the amplitudes of the diurnal and semi-diurnal components are quite comparable, the former is more predominant throughout the year except for the months September and October. The variance accounted by the semi-diurnal component is generally in between 7.5 and 71 per cent. This value becomes minimum during a winter month but in summer months and in equinox months it is comparatively high. On the other hand the variance accounted by the diurnal component is inside the limiting values of 18 to 88 per cent. This value becomes maximum during a winter month.

(*iv*) The amplitude of the second harmonic, *i.e.*, the component with 8 hour periodicity is much less. The effect of second harmonic and

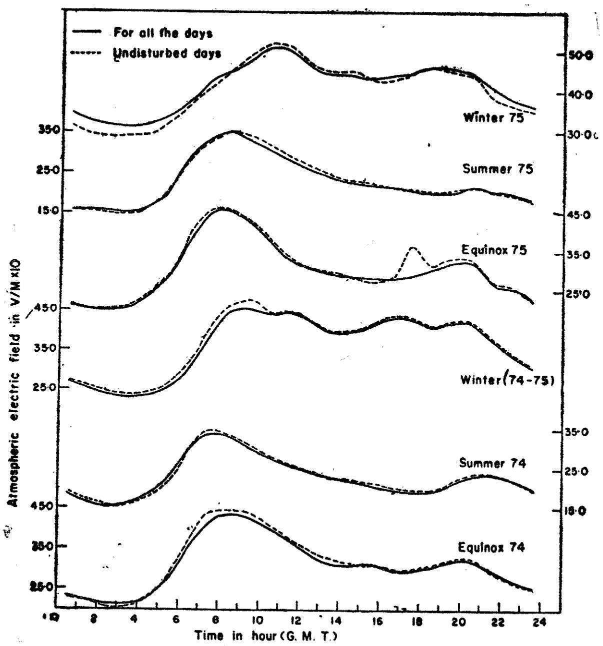

Fig. 3. Diurnal variation of the atmospheric electric field at Kew during the different season of 1974-75

TABLE 1

Result of harmonic-analysis on the diurnal variation during different season of 1974 and 1975

Season and year	Constant term in V/M	Amplitude in V/M: Funda-mental	Amplitude in V/M: Ist har-monic	Time of maxima: Funda-mental h m	Time of maxima: Ist har-monic h m	Variance (in %) accounted by: Funda-mental	Variance (in %) accounted by: Ist har-monic	Amplitude (in %) of mean value (constant term): Funda-mental	Amplitude (in %) of mean value (constant term): Ist har-monic
Equinox 1974	315.25	68.70	59.04	18–24	00–29 12–29	54.50	40.25	21.79	18.72
Summer 1974	231.00	45.84	45.79	19–56	00–21 12–21	43.75	43.66	19.84	19.82
Winter 1974-75	365.17	91.07	52.24	15–36	00–03 12–03	74.23	21.64	24.94	14.30
Equinox 1975	300.50	68.08	69.97	19–08	01–33 13–33	45.29	47.83	22.66	23.28
Summer 1975	227.21	64.27	44.68	19–15	00–18 12–18	63.01	30.46	28.29	19.66
*Winter 1975	412.29	72.06	38.08	16–03	11–36 23–36	74.85	20.91	17.48	9.24

*The data for January and February of 1976 were not available.

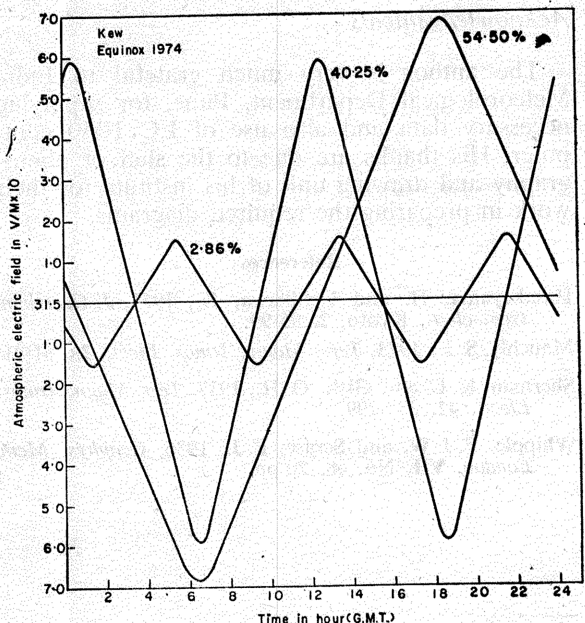

Fig. 4. Harmonic analysis on a seasonal diurnal curve of equinox 1974 showing different components are superimposed over the mean value (centre solid line)

also higher harmonics are not at all comparable to the fundamental and 1st harmonic both in amplitude as well as the variance accounted by the harmonics.

(*v*) The constant term of harmonic analysis, *i.e.*, the mean level of atmospheric electric field also varies considerably 230 to 400 V/M during 1974 and 190 to 425 V/M during 1975. It is also very interesting to note that this parameter follows some annual periodicity showing its minimum value during summer month (May-August) and maximum value during winter month (November-February). The values during any equinoxtial months (March, April, September, October) are always in between the two limiting values but very close to maximum value. Moreover the fundamental (diurnal-component) is found to be 8 to 34 per cent of this mean value and that for 1st harmonic (semi-diurnal component) the corresponding value is 7 to 24 per cent of the mean value during this two years period. Thus, it appears as if that the mean level of atmospheric electric field is playing the dominent role in controlling the absolute value of atmospheric electric field at a particular time and place. On the other hand the different component variations such as diurnal and semi-diurnal components etc are mainly responsible in controlling the nature of diurnal variation of the parameter. Table 1 shows only a portion of the result of harmonic-analysis applied to the seasonal diurnal variation curves of 1974 and 1975 as given in Fig. 3.

Thus, it is evident from the result of harmonic analysis that the observed atmospheric electric field consists of several parts, *viz.*, (*i*) the mean level of atmospheric electric field as given by the constant term of harmonic anaysis, (*ii*) the diurnal component, and (*iii*) the semidiurnal component which are mainly responsible for the entire observed effect. Fig. 4 illustrates a typical result of harmonic analysis on diurnal variation of atmospheric electric field for equinox of 1974 (details of second harmonic are not given in Table 1). The diagram shows the amplitude, the phase and the variance accounted by the different harmonics which are superimposed above the mean level of the field.

The presence of semi-diurnal component of 12-hour periodicity may be explained as due to production of nuclei and their upward dissipation due to convection current caused by the atmospheric exchange processes taking place near the surface of the earth. The production of nuclei is at minimum in the early hour of the morning and their dissipation by austauch is maximum in the early afternoon (depending on season). At these time the conductivity $\triangle$ is greatest near the ground and so from the relation of electric field $E = i / \triangle$ (i is the steady state current flowing in the radial direction) will show a minimum. Thus the two daily minima can now be explained. Again the concentration of nuclei in the lower atmosphere is maximum at the late morning due to lightning of fires and other local pollution and also at around midnight due to partial subsidence of suspended nuclei. At these time the conductivity will be minimum and the electric field will be maximum at the surface layer. Thus the double oscillation diurnal variation of atmospheric electric field can be explained as shown by the semi-diurnal component of harmonic analysis. The double oscillation in the diurnal variation of atmospheric electric field above the land is limited strictly to lowest atmosphere and vanishes remaining only a single oscillation in majority of cases when measured at a sufficient height (300 metre) as discussed by Hatakeyama and Uchikawa (1951). Apart from this double oscillation of 12 hour periodicity governed entirely by local condition the presence of the diurnal component may be strongly controlled by the diurnal variation of global thunderstorm activity. The diurnal variation of global thunderstorm expectation shows a broad maximum around 14 to 19 GMT (Whipple and Scrase 1936). Thus the correlation among the diurnal variation of thunderstorm activity all over the earth with the diurnal component of atmospheric electric field not only shows agreement as regards time of maxima and minima, but both shows a gradual rise and a rapid fall afterwards. Experimental result confirmed that whenever there is no local source of pollution hour by hour variation of atmospheric electric field shows a single oscillation having a maximum around 19 GMT. This maximum had been verified over ocean and polar region (Mauchly 1923) as well as over regions free from local pollution (Sherman and Gish 1937).

It will be interesting to study the presence of the semi-diurnal component, if any, in the diurnal variation of atmospheric electric field at any highly populated and industrial continental station showing generally a single oscillation characteristic and to confirm if the harmonic analysis of the variation brings out the presence of a significant semidiurnal component. Similar analysis for continental station free from local pollution, would help identify probable reasons for such observed variations.

Acknowledgements

The author is very much grateful to India Meteorological Department, Pune, for supplying necessary data and also use of EC 1040 computer. His thanks are due to the staff of photography and drawing unit of his institute for their work in preparing the required diagrams.

References

Hatakeyama, H. and Uchikawa, K., 1951, *J. Geomagn. Geo. elect.*, Kyoto, **2,** 95-99.

Mauchly, S. J., 1923, *Terr. Magn. Atmos. Elect.*, **28,** 61-81.

Sherman, K. L. and Gish, O. H., 1937, *Terr. Magn. Atmos. Elect.*, **42,** 289-299.

Whipple, F. J. W. and Scrase, F. J., 1936, *Geophys. Mem. London,* **VII,** No. 68, 20 pp.