Variations in the Atmospheric Electric Field at Tropical Station during 1930–1987

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ABSTRACT

The variations noticed in the atmospheric electric field recorded at Pune (18°32′N, 73°51′E, 559 m ASL), a tropical inland station located in Deccan Plateau, India, during the period 1930–1987, have been examined in relation to the variations observed in the Angstrom turbidity coefficient (β) and selected meteorological parameters. The monthly and annual mean values of the atmospheric electric field, Angstrom turbidity coefficient (β), rainfall, temperature and relative humidity for the years 1930–1938, 1957–1958, 1964–1965, 1973–1974 and 1987 were considered in the study.

The results of the above study indicated gradual increases in the atmospheric electric field over the period of study (1930–1987) which is statistically significant at less than 5% level. The increases noticed during different periods varied from 30 to 109%. The increase noticed during the period (1930–1938) and (1973–1974) was maximum (109%). The Angstrom turbidity coefficient also showed systematic increases during the period of study, which is consistent. The diurnal curve of the atmospheric electric field at the station by and large, showed a double oscillation, which is generally observed in the continental environments.

I. INTRODUCTION

A study of the variations in atmospheric electrical parameters in relation to atmospheric aerosols and meteorological parameters collected at any station over a long period would be of significant importance for the climate related studies. A long series of systematic observations of atmospheric electric field were recorded at a tropical inland station, namely, Pune (18°32′N, 73°51′E, 559 m ASL), since 1930. In order to examine the long term variations in atmospheric electric field, the monthly data for the period 1930–1938, 1957–1958, 1964–1965, 1973–1974 and 1987 were examined. The observations of the atmospheric electric field during the period 1930–1965 were carried out by India Meteorological Department, at the Meteorological Office, Pune. The Indian Institute of Tropical Meteorology, also carried out similar observations at the same site during the years 1973–1974. Also, similar observations were carried out by the Institute at its new campus located about 3 km southwest of the earlier site. The results of the study undertaken utilizing the data for the period 1930 to 1969 were reported (Choudhuri and Gopinath, 1968; Mani and Huddar, 1972). Since identical instruments were used for recording the atmospheric electric field during the entire period (1930–1987), it was considered worthwhile to examine the data for any possible long term variations. Also, the diurnal variations in the atmospheric electric field were examined. In addition to the atmospheric electric field, data of other parameters obtained from the observations recorded at the Meteorological Observatory, Pune during the corresponding period were also considered. These include (i) Angstrom turbidity coefficient (β) which may be an index of the suspended particulates in the atmosphere; (ii) Rainfall (iii) Temperature (iv) Relative humidity. The results of the study are presented below.

II. DATA AND ANALYSIS

For the study of long term variations in the atmospheric electric field, analysis of the continuous data series for the entire period 1930–1987 is required. However, the present investigation is restricted to the analysis of the atmospheric electric field data for the five episodes viz., 1930–1938, 1957–1958, 1964–1965, 1973–1974 and 1987 since these data could only be procured for the study.

The monthly mean values of atmospheric electric field for the periods 1930–1938, 1957–1958, 1964–1965 were taken from the publication of Choudhuri and Gopinath (1968). The atmospheric electric field data for the periods 1973–1974, 1987 were extracted from the records of the Institute. The atmospheric electric field in both the above cases was recorded using a radioactive sensor and an electrometer (Choudhuri and Gopinath, 1968; Mary Selvam et al., 1980). The minimum value of the electric field which the instrument can record is 2 Vm^{-1} in the highest sensitivity range. The data of atmospheric electric field recorded on fair weather days were only considered in the study. This would minimize the local effects, if any, on the long term variations of the atmospheric electric field at the station. The monthly data of Angstrom turbidity coefficient (β), rainfall, temperature and relative humidity were obtained from the India Meteorological Department, Pune. The data of Angstrom turbidity coefficient (β) were not available for the period 1930–1938. Hence data of β for the four episodes, namely, 1957–1958, 1964–1965, 1973–1974 and 1987 could only be considered and the variations noticed in β with respect to 1957–1958 were computed and the results are presented in the Tables 1,2,3 and 4. Also, the data of β during the monsoon season were not available on many days. During the monsoon season due to cloud–formation, it is not possible to undertake the solar radiation observations required for the computation of β on many days. Hence, the variations noticed in β during the monsoon seasons could not be studied.

III. METEOROLOGICAL CONDITIONS

A brief summary of the existing meteorological conditions during the four seasons is given below.

(i) *Pre–monsoon (March–May)*

The weather is very hot with daytime maximum temperature reaching 40°C. Surface winds are mostly gusty and cumulonimbus development takes place during afternoon / evening hours when synoptic conditions are favourable. The dust content in the atmosphere is maximum during this season.

(ii) *Monsoon (June–August)*

The air flow in the lower troposphere is westerly which brings a large influx of moist air from the Arabian sea. Under the influence of large–scale convergence due to synoptic systems, the region gets light continuous / intermittent rain from cumulus and strato–cumulus type clouds. Prominent weather developments take place in the area when there is a trough of low pressure off the west–coast. The atmosphere is relatively free from dust during this season.

(iii) *Post–monsoon (September–October)*

The weaterly flow weakens in the lower troposphere and the easterly flow sets–in accompained by a rapid fall in the minimum temperature by the end of October.

(iv) *Winter (November–February)*

Fair weather conditions exist with clear skies. The relative humidity is very low. Surface winds are light and least gusty. The daily surface minimum temperatures occasionally go down to 3 or 4°C when incursion of dry polar continental air takes place into the region in the wake of low–pressure system (western disturbances) moving across the far north western parts of the country. Low–level inversions are present during morning and evening hours and dust haze occurs during morning hours.

IV. RESULTS AND DISCUSSION

The annual mean values of atmospheric electric field, Angstrom turbidity coefficient (β), rainfall, temperature and relative humidity for the years 1930–1938, 1957–1958, 1973–1974 and 1987 are given in Table 1. The seasonal mean values of the above parameters for the same period are given in Table 2. The percentage variations noticed in the above parameters during different years and seasons as compared to the values observed during 1930–1938 were computed and the results are given in Tables 3 and 4 respectively. The diurnal variations of atmospheric electric field observed during different seasons for the same periods (1957–1958, 1964–1965, 1973–1974 and 1987) are shown in Figure 1. The data of humidity and Angstrom turbidity coefficient for the period 1930–1938 were not readily available and hence they could not be considered in the present study.

The variations noticed in different parameters are discussed below.

Table.1. Annual Mean Values of Different Parameters Recorded at Pune during Different Periods

Parameters	Period				
	1930–38	1957–58	1964–65	1973–74	1987
Atmospheric Electric Field (Vm^{-1})	67	63	87	140	97
Angstrom Turbidity Coefficient (β)	NA	0.002	0.051	0.105	0.058
Rainfall (cm)	73.0	70.0	62.0	78.0	72.0
Temperature (℃)	31.5	32.3	32.0	31.6	31.0
Relative Humidity (%)	62.0	61.0	61.0	61.0	65.0

NA: Data not available

(i) *Atmospheric Electric Field*

The annual mean values of atmospheric electric field showed consistent increase, over the years 1930 to 1987 (Table 1). The average value during 1930–1938 was 67 Vm^{-1} and it showed a gradual increase over the years since 1964–1965 reaching 140 Vm^{-1} during 1973–1974. The lower value of the atmospheric electric field (97 Vm^{-1}) observed during 1987 may be attributed to the change in the observational site as mentioned in Section 1. The percentage increases noticed with respect to the initial period (1930–1938) were in the range from 30 to 109% (Table 3). The maximum increase of 109% (significant at less than 5% level) was observed during the period 1973–1974 as compared to the value of 1930–1938. This increase in atmospheric electric field may be attributed to the variations in the atmospheric electric conductivity resulting from urban effects over the period 1930–1974. Since the measurements of atmospheric electric field were carried out at the same location and using the identical instruments, the variations noticed in the electric field cannot be attributed to uncertainties

Table 2. Seasonal Mean Values of Different Parameters for Different Periods

Season	Parameters	Periods				
		1930–38	1957–58	1964–65	1973–74	1987
Pre–monsoon	Atmospheric Electric Field (Vm^{-1})	60.0	35.0	51.0	105.0	96.0
	Angstrom Turbidity Coefficient (β)	NA	0.033	0.058	0.113	0.065
	Rainfall (cm)	7.0	9.0	6.0	5.9	17.8
	Temperature (℃)	36.7	36.9	37.1	37.4	35.6
	Relative Humidity (%)	NA	41.0	40.0	44.0	45.0
Monsoon	Atmospheric Electric Field (Vm^{-1})	58.0	35.0	58.0	65.0	28.0
	Angstrom Turbidity Coefficient (β)	NA	NA	NA	NA	NA
	Rainfall (cm)	35.0	47.8	42.4	52.2	18.8
	Temperature (℃)	28.9	30.1	29.3	29.0	29.6
	Relative Humidity (%)	NA	80.0	78.0	74.0	77.0
Post–monsoon	Atmospheric Electric Field (Vm^{-1})	67.0	101.0	124.0	156.0	97.0
	Angstrom Turbidity Coefficient (β)	NA	0.008	0.031	0.213	0.029
	Rainfall (cm)	26.0	12.5	10.0	20.6	26.4
	Temperature (℃)	30.0	31.0	31.2	29.2	30.2
	Relative Humidity (%)	NA	73.0	69.0	75.0	75.0
Winter	Atmospheric Electric Field (Vm^{-1})	79.0	109.0	137.0	230.0	167.0
	Angstrom Turbidity Coefficient (β)	NA	0.016	0.052	0.072	0.061
	Rainfall (cm)	30.4	2.0	3.6	0.0	9.0
	Temperature (℃)	30.4	31.2	30.6	30.3	29.1
	Relative Humidity (%)	NA	58.0	60.0	55.0	67.0

NA–Data not available

involved in the measurement or local conditions surrounding the site of observations.

The electric field during winter and post–monsoon seasons showed systematic increases (Tables 2 and 4). The increases noticed during the winter season would be representative of the fair weather conditions existing in the atmosphere. During the pre–monsoon and monsoon seasons the variations noticed are not systematic. This may be due to some local effects on the atmospheric electric field resulting from the thunderstorms forming during the pre–monsoon and layered type clouds forming during the summer monsoon season. Also, the number of fair weather days is small during the above two seasons particularly during the summer monsoon season.

The increase noticed in the atmospheric electric field during the winter season of 1973–1974 was maximum, namely, 191% which is significant at 5% level. The maximum increase noticed in the atmospheric electric field during winter could be attributed to the increases in the dust load in the lower atmosphere (Khemani et. al., 1985). The results of the present study are in agreement with those reported by Choudhuri and Gopinath (1968) and Mani and Huddar (1972). These studies also indicated increasing trend in the atmospheric electric field recorded at Pune during the period 1930–1969. Results of the simultaneous measurements of atmospheric aerosols, atmospheric electric field, small ion concentration and atmospheric electric conductivity made during 1967–1969 at Pune were repored by Mani and Huddar (1972). The results showed marked increase in the atmospheric electric field and aerosol concentration; and a decrease in small ion and conductivity which are in agreement with the present study.

Also, the results of the present study are in agreement with those of Cobb and Wells (1970) who had shown that over the past half century the atmospheric electric conductivity decreased by at least 20 per cent in the North Atlantic and attributed to an increase of the fine–particle aerosol pollution in the area. The results of the present study are further corroborated from the variations noticed in the Angstrom turbidity coefficient (β) which is an index of the suspended particulates in the atmosphere (Table 3).

Table 3. Percentage Variations Noticed in *Different Parameters during Different Years*

Parameters	Period			
	1957–58	1964–65	1973–74	1987
Atmospheric Electric Field (Vm^{-1})	−6	+30	+109*	+24
Angstrom Turbidity Coefficient (β)	NA	+2450	+5150*	+2000*
Rainfall (cm)	−4	−15	+7	−2
Temperature (℃)	+3.0	+1.5	+0.3	−1.5
Relative Humidity (%)	−2	−2	−2	+5

* Significant at less than 5% level

As already stated in Section 2, the variations noticed in β could only be studied for the four episodes, namely, 1957–1958, 1964–1965, 1973–1974 and 1987. The mean values of β showed large variations ranging from 0.002 during 1957–1958 to 0.105 during 1973–1974. The large variations in β could partly be due to the clouds present during the time of observation of the solar radiation. The values of β are particularly high during the pre–monsoon and post–monsoon seasons (Table 2), which may be due to the cloudy sky conditions at the time of observations. As a consequence, the percentage variations in β (Tables 3 and 4) are also

Table 4. Percentage Variations Noticed in Different Parameters during Different Seasons. The Computations are with respect to the initial Period

Seasons	Parameters	Periods			
		1957–58	1964–65	1973–74	1987
Pre–monsoon	Atmospheric Electric Field (Vm^{-1})	−42	−15	75	50
	Angstrom Turbidity Coefficient (β)	NA	75	242	96
	Rainfall (cm)	+29	−14	−16	+154
	Temperature (℃)	0.5	1.0	2.0	−2.9
	Relative Humidity (%)	NA	−2	10	12
Monsoon	Atmospheric Electric Field (Vm^{-1})	−39	0	12	−51
	Angstrom Turbidity Coefficient (β)	NA	NA	NA	NA
	Rainfall (cm)	+36	+21	+49	−46
	Temperature (℃)	4	1.4	0.3	2.4
	Relative Humidity (%)	NA	−7	−7	−4
Post–monsoon	Atmospheric Electric Field (Vm^{-1})	50	85	133*	50
	Angstrom Turbidity Coefficient (β)	NA	288	2562	263
	Rainfall (cm)	−52	−62	−21	+2
	Temperature (℃)	3	4	−2.6	0.6
	Relative Humidity (%)	NA	−5	3	3
Winter	Atmospheric Electric Field (Vm^{-1})	38	73	191*	111
	Angstrom Turbidity Coefficient (β)	NA	225	350	281
	Rainfall (cm)	−61	−30	00	73
	Temperature (℃)	2.6	0.6	−0.3	−4.2
	Relative Humidity (%)	NA	3	−3	16

* Significant at less than 5% level NA: Data not available.

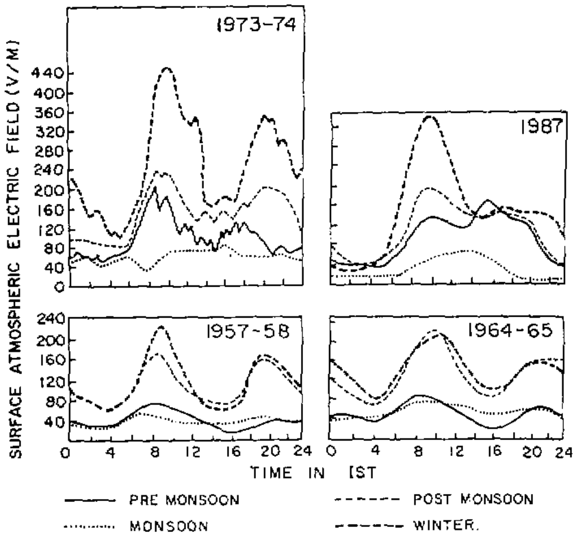

Fig.1. Diurnal variation of atmospheric electric field during different seasons / periods.

very high. This point is to be kept in view while interpreting the results in respect of β. However, there is a systematic increasing trend in the value of β, which may be attributed to the increase in the atmospheric pollution over the period of observations 1957–1987. The variations observed in β are consistent with the variations noticed in the atmospheric electric field.

The diurnal curve of the atmospheric electric field (Figure 1) showed, by and large, a double oscillation which is generally observed in the continental environments (Chalmers, 1967; Israel, 1973; Mary Selvam et. al., 1980). The diurnal pattern over the period of the study shows no significant change. However, an increase in the amplitude is evident during the winter (Figure 1).

(ii) *Meteorological Parameters*

The annual rainfall was maximum during 1973–1974 and minimum during 1964–1965 (Table 1). There is no definite trend in the variation of rainfall which could be attributed to climatic scale fluctuations. The temperature appears to indicate a small decreasing trend (1.3°C) during the period 1957–1987 (Table 1). The humidity data did not show any significant variations during the period of the study (Tables 3 and 4).

V. CONCLUSIONS

The study of the atmospheric electric field, Angstrom turbidity coefficient (β) and selected meteorological parameters recorded at a tropical inland station during 1930–1987 suggested the following.

(1) The electric field showed significant gradual increase over the period of study (1930–1987). The increases noticed during different periods varied from 30 to 109% and the maximum increase of 109% (significant at less than 5% level) was noticed during the periods (1930–1938) and (1973–1974).

(2) The Angstrom turbidity coefficient (β) also showed systematic increases during the period of study which is consistent with the variations noticed in the atmospheric electric

field. The variations noticed in the meteorological parameters are not systematic.

(3) The diurnal curve of atmospheric electric field showed, by and large, a double oscillation which is generally present in the continental environments.

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