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Study of Electric Field Changes Accompanied by Atmospheric Radio Noise at 10 kHz at Mexico Valley

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Abstract. In the last years we are involved in an effort to develop and extend techniques to search electromagnetic radiation in a portion of the radiofrequency spectrum and point discharge currents, the results of both types of measurements are then used to improve the understanding of the atmospheric electric perturbations. These atmospheric electromagnetic characteristics have been compared with the amount and pattern of rainfall recorded simultaneously at two different stations.

Studies are made of thunderstorms distributions, severity as manifested by count rate, and life span as indicated by the duration of events activity. We have carefully examined the way in which the local phenomena such as atmospheric electrostatic field variations including heavy rain and local thunderstorms are affected by external influences such as orographic effects, on the earth-ionosphere electric circuit.

Resumen. Desarrollar y alcanzar nuevas técnicas que permitan investigar en la atmósfera circunvecina la radiación electromagnética en la región del espectro de radiofrecuencia y las corrientes de descarga puntual fue un objetivo establecido en nuestro experimento. Los registros obtenidos se han usado para mejorar nuestra comprensión de las perturbaciones eléctricas atmosféricas. Estas características electromagnéticas han sido comparadas con las configuraciones y cantidades de lluvia registradas simultáneamente por dos diferentes estaciones.

Se ha estudiado la distribución, la severidad y el lapso de la vida de las tormentas tomando en cuenta la intensidad y la duración de la actividad de los eventos eléctricos. Examinamos cuidadosamente cómo son afectados los fenómenos locales tales como variaciones del campo electromagnético, intensas precipitaciones y tormentas, por influencias externas tales como efectos orográficos sobre el circuito tierra-ionósfera.

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1. Introduction

In this work we present some preliminary results of a study began in 1983 in an attempt to gather information about the atmospheric electricity in Mexico. We present and discuss data on the correlation of the atmospheric radio noise and the variations of the corona current that flows from sharp objects on the Earth's surface toward the base of the cloud, the occurrence of rainfall and thunderstorms. The measurements of the electromagnetic activity were taken with a metal point sensor as a point-discharge current detector and an omnidirectional antenna as a radiowave frequency sensor. The sensors are installed at the same place.

2. The Arrangement of the Measuring System

The arrangement of the sensors for the measurement of the point-discharge current (E_k) and the antenna for the measurement of the 10 kHz atmospheric radio noise (E_{10}) is shown in Fig. 1.

To support the antenna a 3 m cylindrical metallic structure was erected, carrying a 8.2 m cylindrical tube 0.04 m in diameter as single pole antenna at the top. The original height of the antenna was 7.5 m but this was later extended to 11.22 m. The point-discharge current sensor was a stainless-steel hypodermic needle 0.002 m in diameter and 0.09 m long.

This detector system was installed at a fairly open observatory site with a mean spacing of about 30 m between the experimental instruments at the laboratory site. Figure 1 shows the point-discharge current detector build following the design proposed by Church [2]. We used a hypodermic needle (9 cm No. 14) as the corona sensor. The needle was installed at 11.25 m altitude and at the top of the omnidirectional antenna, connected via coaxial cable to the Elec-

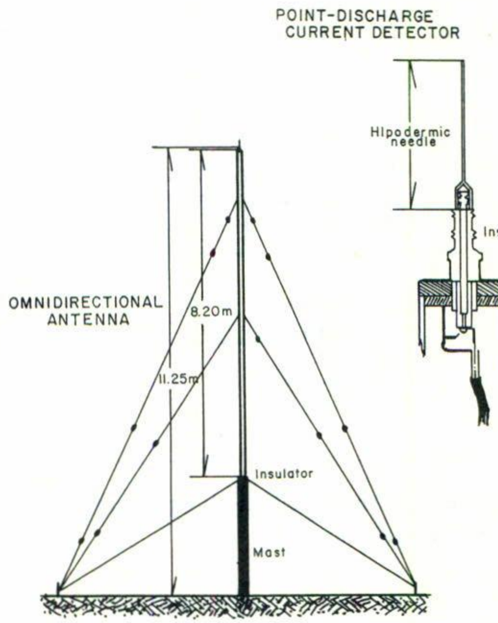

FIGURE 1. **Arrangement of the point-discharge current sensor (E_k) and the atmospheric radio noise antenna at the University City station (U.C.) at an elevation of 2.2 km (a.s.l.) and 19.3 and 260.8 geographic coordinate.**

trometer which was settled in the instrument rack, where a.c. power was available. The Electrometer output was connected via coaxial cable to a MFE analogical recorder, as depicted in Fig. 2.

An iron tube (0.68 m mean diameter and 8.20 m long) prepared as omnidirectional antenna was installed over an insulator block and a mast (3.0 m altitude) Fig. 1. The atmospheric radio noise at 10 kHz was measured using the omnidirectional antenna connected via coaxial cable to the receiver.

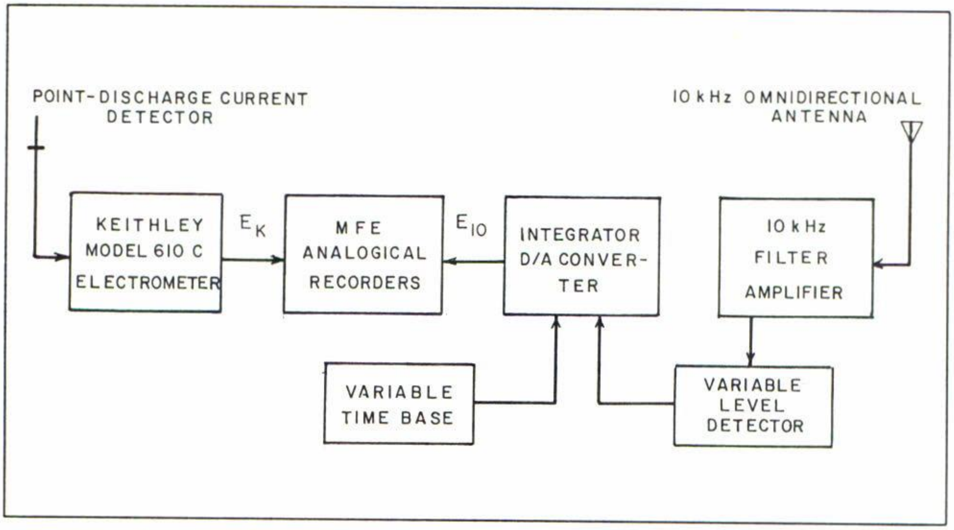

FIGURE 2. Block diagram of the point-discharge current and 10 kHz receiver data recording system.

The receiver output is connected to an integrator-D/A converter and from it, output signals were provided to the analogical recorder system. The point-discharge currents were measured using a Keithley model 610 C Electrometer connected up in the linear current mode. The discharge currents and the 10 kHz atmospheric radio noise signals were simultaneously recorded on a routine basis on strip-chart double pen recorders run at chart speeds of 25, 50 or 100 m/hr, Fig. 7.

Instrumental errors associated with cables and electronics were reduced at the data processing phase either though correction for coupling or calibrations for other instrumental errors.

During 1982 and the early part of 1983, a 10 kHz receiver as well as an integral-D/A converter was developed at our laboratory. The detector systems were installed in March 1983, but had to be modified in order to make some interfacing and sensitivity changes. The system at the campus of the University City was activated in early July and is still operating continuously. The observatory is located at an elevation of 2.2 Km (a.s.l) on the south side of the Mexico City Valley.

3. Operations and Measurements

During the eighteen months operational period, two types of weather systems were covered. The following descriptions are based on an examination of a draft copy of the *Centro de Ciencias de la Atmósfera* (CCA) rainfall recorder at University City station, (U.C.). The weather in Mexico City is characterized by a rainfall season (June–September) during which there is much rain and intense thunderstorm activity, and a dry season (October-May) during which there is little rainfall. A characteristic feature of the local weather is the high level rainfall and thunderstorm activity, in the south of the Mexico City Valley where the measurements were made, the conditions are particularly favorable for point-discharge and 10 kHz atmosphere radio noise studies. Several thunderstorm systems passed through the U.C. during the 1983 and 1984 wet season, ranging in intensity from weak to strong. Also shower activity and isolated convective cells activity occurred during the dry and wet seasons.

All the point-discharge and 10 kHz radio noise data, simultaneously registered are stored in our laboratory, and these will be made use of in future studies. We will discuss the behaviour of the point-discharge currents induced by the rapid potential gradient changes accompanying lightning discharge during a thunderstorm as a function of the 10 kHz atmospheric radio noise activity of the cumulus stage of the cloud development.

Physical phenomena in the atmosphere affects signals transmitted from long distances but for our studies these experimental problems, generally speaking, are not serious. Furthermore, a criterion used in the design of the instruments was the minimization of the effects of the atmospheric processes mentioned above providing sufficient ground screen and good ground conductivity.

Several thousand hours of point-discharge currents and atmospheric radio noise data were collected. Our first objective was to become familiar with atmospheric electrical detectors as a research tool so that it may be introduced as an operational system at the earliest possible date at our laboratory.

4. Data and Method of Analysis

The traditional technique used to deduce global variations in atmospheric electricity has involved the amassing and averaging of large amounts of data from one or several more or less carefully sited terrestrial observatories. There is a tacit assumption inherent in such a technique; namely, that large local effects will cancel when taking an average over many sites and long periods of thus yielding universally applicable results. This assumption neglects however, the effect of the frequent large concentrations of space charge in well localized regions at the surface as recently measured by various investigators [3].

On the basis of the classical picture of atmospheric electricity, some essential variations in the ionic mobility will be compared with the results of measurements of the atmospheric radio noise variations around the central frequency of 10 kHz. The Earth's electric and magnetic fields do not exist independently, they are both parts of the Earth's electromagnetic field, which must be studied by simultaneous measurements of its components.

We will call an "event" to the observation, in the record of point-discharge currents, of a train of peaks of point-discharge current that begins with an initial peak at t_0 and is followed by rapid oscillations of the current and ends at the initial value of the current. These events sometimes coincide with passage of clouds overhead but trains of peaks are also recorded with a clear sky. We will call an "event" in the atmospheric radio noise record, the observation of an increase in the count rate to a value at least twice the background level, the event's life span is the duration of the increased activity.

The observations were averaged to produce mean hourly punctual-discharge currents and atmospheric radio noise rated for each hour of the day. In this procedure only days without any missing data were included.

Figure 3 summarizes results for the total data registered between July 6, 1983–December 12, 1984, by the analogical recorder. Plotted in the upper histograms is the 10 kHz atmospheric radio noise (E_{10}), while in the histogram at the bottom appears the point-discharge current (E_k). The length of each bar in the histogram gives the number of events measured during each hour of the day. Uncertainty inherent in presently available records varies from about 1 to 5 min. Four our present analysis of a thunderstorm moving at the speed of 10 m/sec, the associated discrepancies in time resolution are not significant. Further, synchronized timing and central monitoring for quality control should also go far in removing uncertainties in time resolution and instrument calibrations.

Our attention will be focused on the difference of characteristics between the two histograms of Figure 3. The most noteworthy feature in the upper E_{10} histogram is the large peak centered at 1300 LT, whilst in the lower E_k histogram the most prominent feature is the mid-afternoon peak centered at 16300 LT, and also a second peak appears centered at 0730 LT in the early morning. The latter peak can be taken as evidence of a coherent semidiurnal wave, that possibly will have connection with the solar semidiurnal tidal fields in the tropics, Lindzen [3]. The rainfall histogram (dotted lines) were superposed for comparison on both histograms.

Rain-intensity data from the tipping-bucket rain-gauge adjacent to the detectors system have been used to obtain a relationship between atmospheric electromagnetic variations and surface-rain intensity. For the period covering eighteen months operations, cumulative distribution of rain-intensity were prepared, Fig. 4, covering only times when precipitation were $\geq$ 1 mm/h. Rainfall measurements at two different locations 9 km apart at Mexico City, Fig. 4, are notable to provide any information in the precipitation development if the cloud systems were dynamically active for at least some time

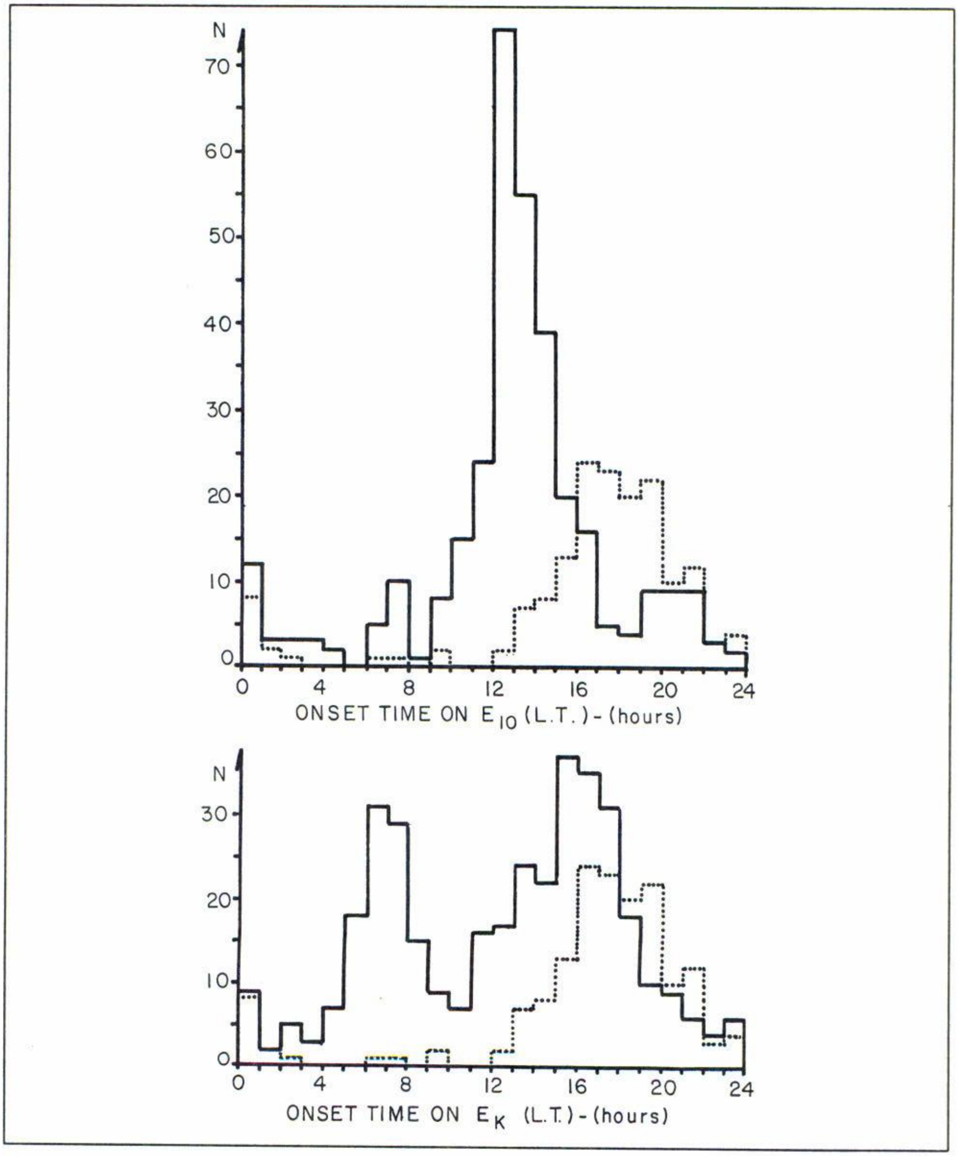

FIGURE 3. Histograms of the total data of the point discharge and 10 kHz radio noise registered by the analogical recorder, between July 6, 1983 and December 12, 1984. The rainfall histogram (dotted lines) at U.C. station were superposed. Number of events ar denoted by N.

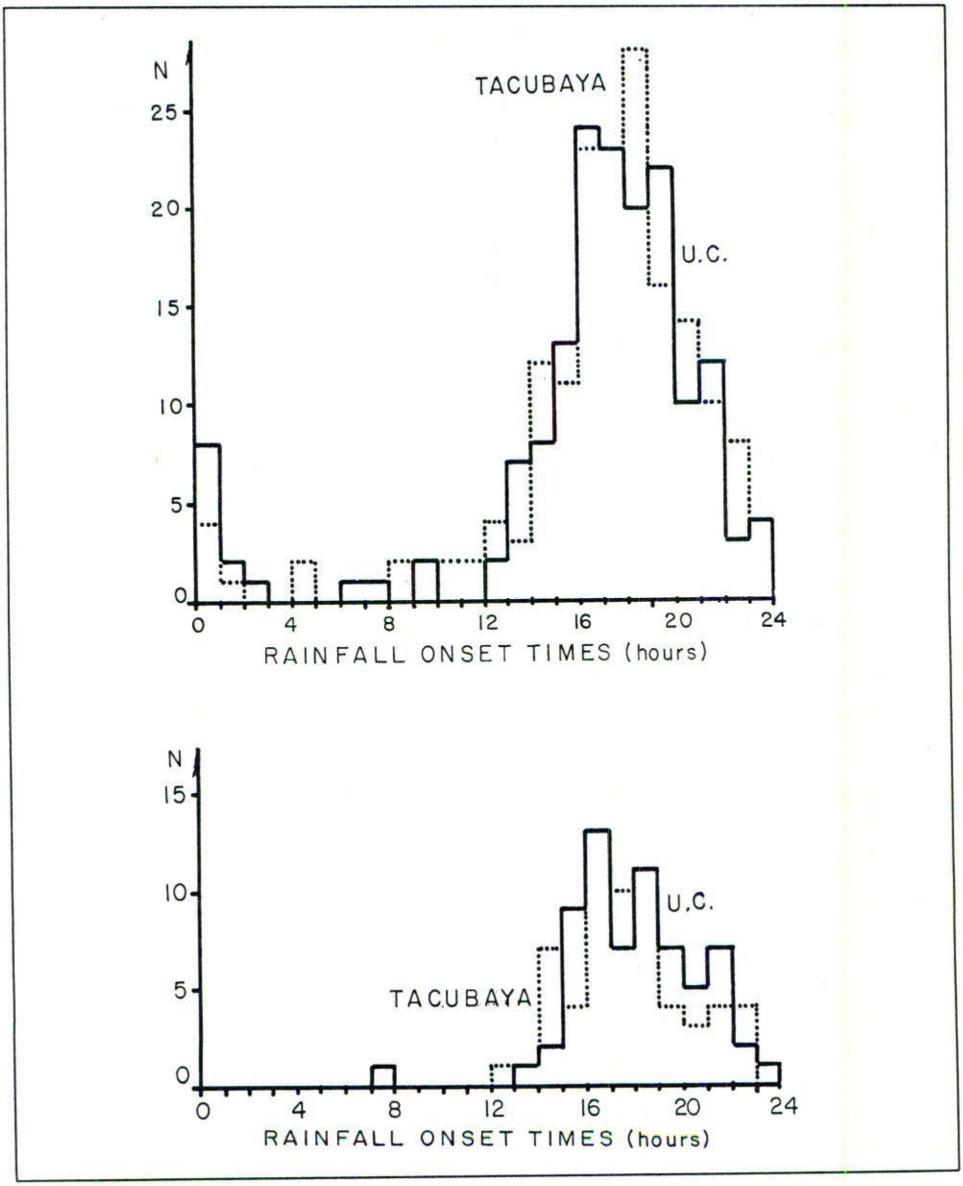

FIGURE 4. Histograms from records of raining activity at two different stations placed at Mexico City. Only precipitations ≥ 1 mm/h in the upper histogram and only precipitation ≥ 5 mm/h in the lower histogram.

before field intensification began. It may be mentioned here that the rain-intensity data from the U.C. station, was compared more recently with data acquisition at the Tacubaya station collected for the same period. The rain-intensity measurements of both station, were not intentionally correlated but a coefficient of correlation of 0.96 was obtained.

Figure 5 is a stem-and-leaf displays from the length records of rainfall, E_{10} and E_k events. Here our attention will be focused on the large amount of less than two and four hours length for the rainfall and E_k events respectively. This feature does not appear in the almost widespread distribution of the atmospheric radio noise, E_{10}. Examination of the data duration between wet and dry seasons for rain-gauge and both detectors shows the large peak for events less than four hours duration for the rainfall and as well as for the point-discharge current during the wet season.

5. Discussion

The comparison between the onset time display of the rainfall and the atmospheric radio noise data at the lower histogram of Fig. 3, shows a striking relationship and they can be associated to the thundercloud life cycle, Takahashi [4,5], and the atmospheric radio noise. The developing stage of the thundercloud life cycle can be related to the atmospheric radio noise so that the early and late mature stages as well as the dissipation stage corresponds to the afternoon activity of the point-discharge currents as shown in the lower diagram of Fig. 5.

When the convective part of the cloud system approached the experimental site, the two detectors were simultaneously operating and recording the occurrence of high counting rate in the E_{10} detector and a large irregular pulses in the E_k sensor, Fig. 7. A temporal correspondence between convective growth, precipitation development and electrification in thunderstorms seems to occur as was demonstrated by Workmann [1], and it is clear that in the thunder weather over high mountains, which usually has many conducting

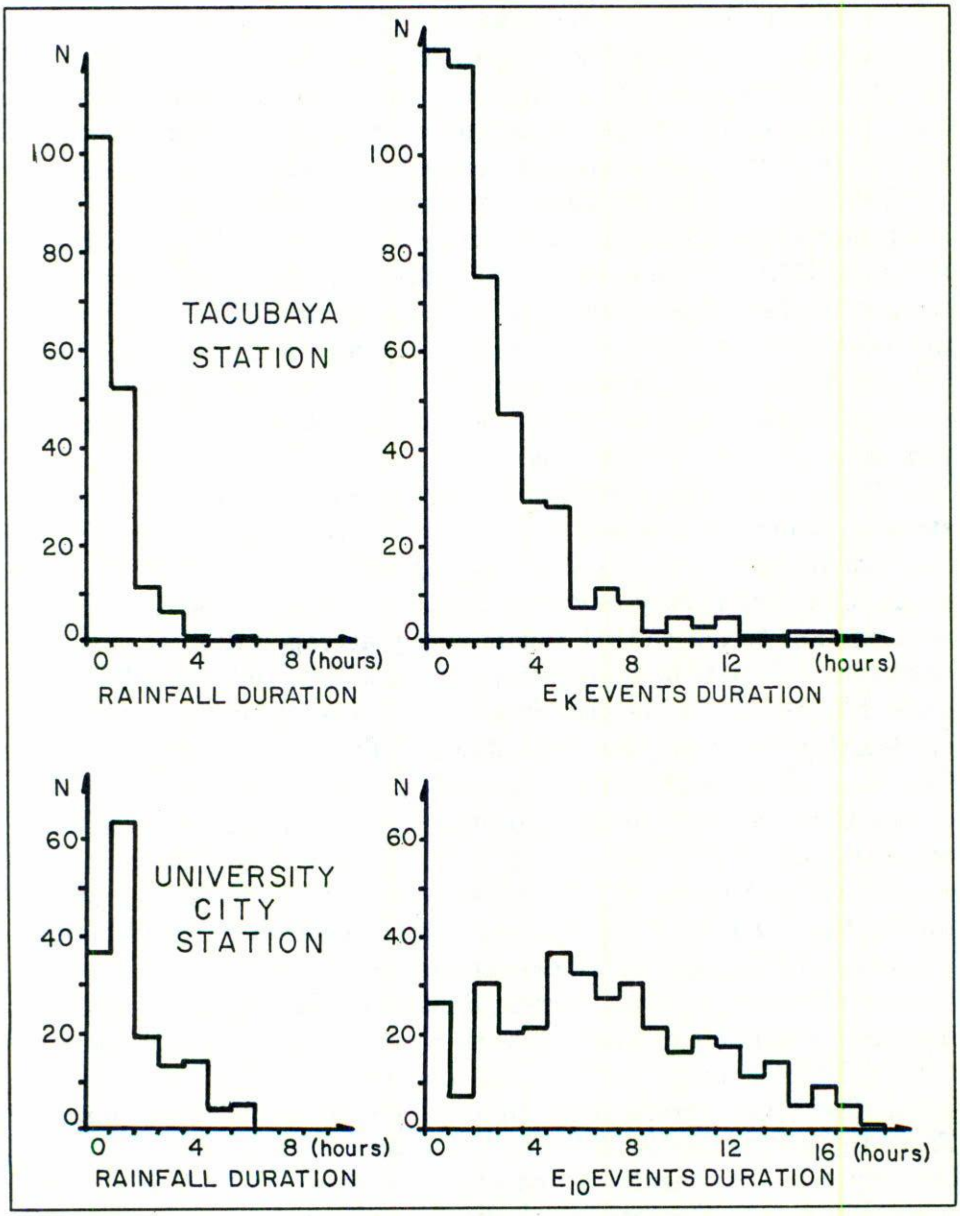

FIGURE 5. **Stem-and-leaf displays from the length records of rainfall, point-discharge current (E_k) and 10 kHz radio noise (E_{10}) events.**

points such as trees and radio aerials. The point-discharge-current into the air will be effective in providing relatively great amount of charge to the convective mechanism. Such a behavior is of interest both in the study of the atmospheric processes themselves and in the study of their effects on electromagnetic wave propagation.

The electromagnetic field of the earth should be studied by simultaneous measurements of its components. The large peak centered at 0730 LT from the point-discharge current shows no counterpart in the atmospheric radio noise diagram of Fig. 3. About 80 per cent of the events of this E_k large peak were produced during the dry season and, as was observed on a preliminary draft to the weather conditions, only 6 per cent of events occurred during the presence of cirrostratus clouds.

The diurnal variations of the surface electric field well understood in urban area as well as over oceans, (Ogawa [5]). The former has two maxima: one in the morning and the other in the afternoon. The oceans only have one maximum about 2000 UT. But, it is important to notice that this annually averaged diurnal variation of electric field was deduced using the data obtained on undisturbed days. Meanwhile, using disturbed days in the E_k or E_{10}, or in both electrical phenomena, we have obtained fluctuations of the electric field and the air-earth current superimposed upon the diurnal variations that has two maxima for the E_k: one at 0730 LT and the other at 1640 LT. The morning peak appears only during the dry season while the second maxima appears during the wet as well as during the dry season, Fig. 6. No clear explanation of this difference has been hitherto given. The air at the observatory site altitude has low conductivity and the current density of the air in fair weather, does not seem to be changing with time. It is at the present time rather difficult to prove that the observed 0730 LT peak in the point-discharge current, was directly related to local phenomena. From the analysis of solar and geomagnetic activity data and from our experimental results probably can emerge another interesting possibility, and extraterrestrial effect on the atmospheric electrical variation following solar activity.

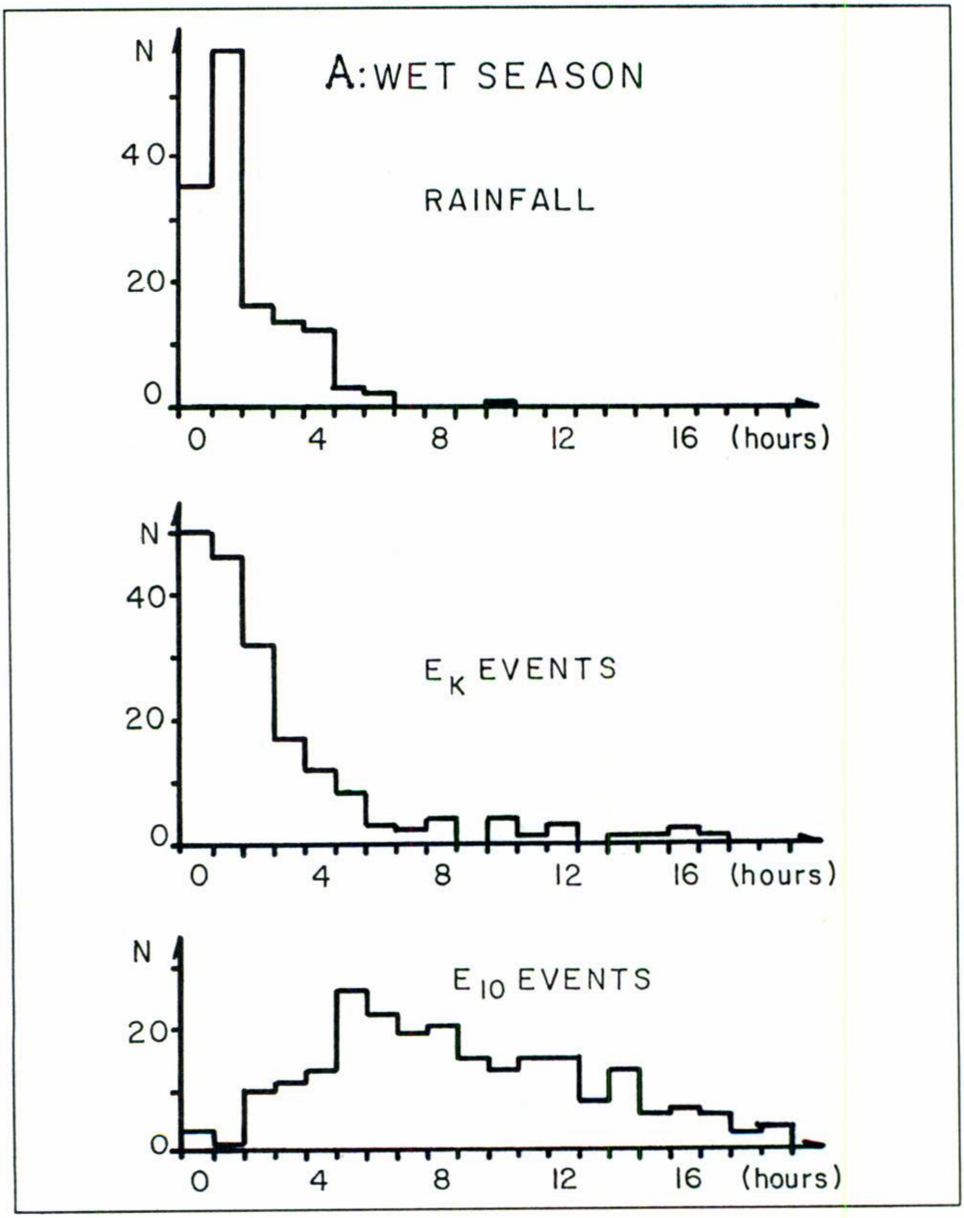

FIGURE 6. Stem-and leaf displays from the duration records: A) rainfall, E_k and E_{10} events occurred at wet season.

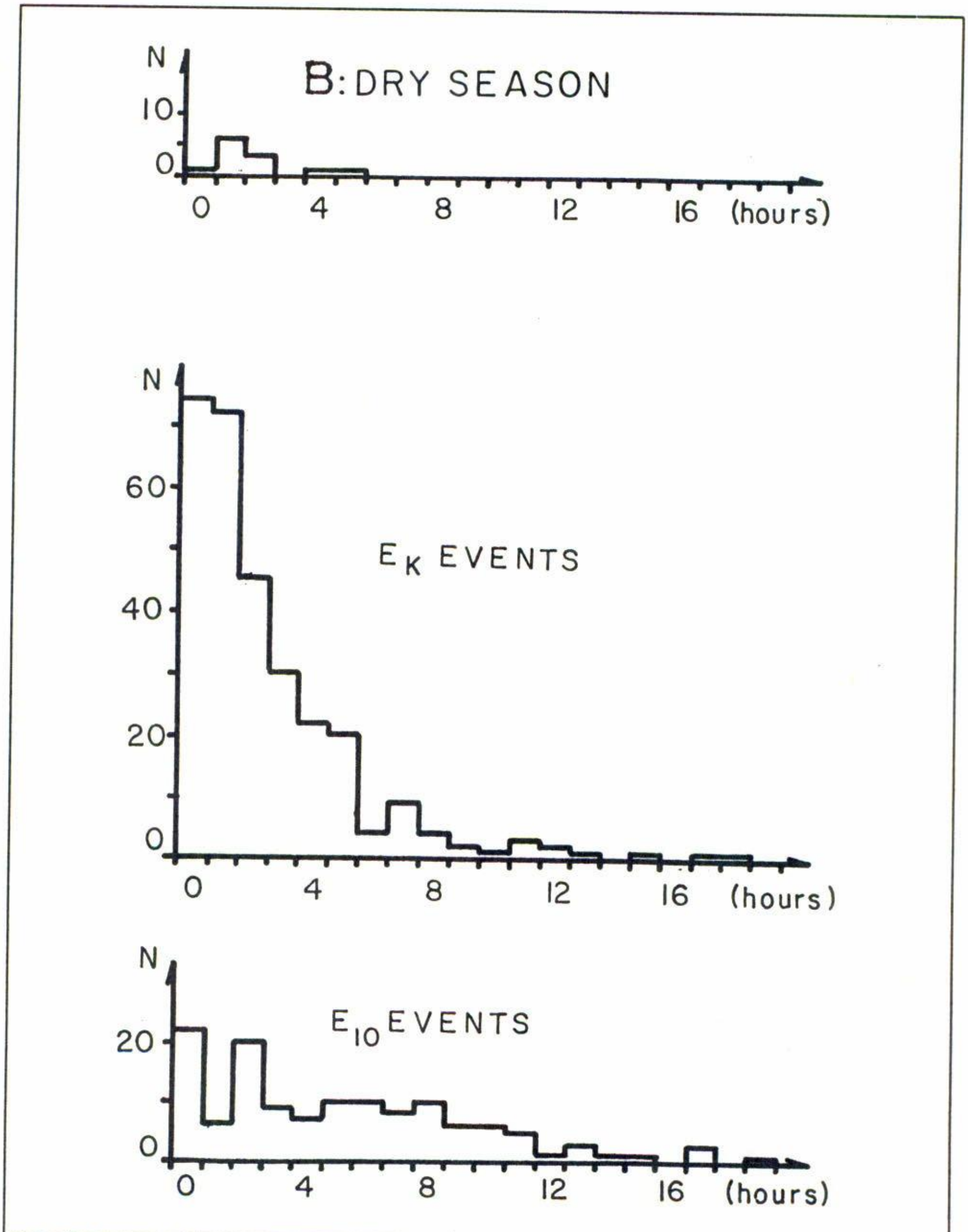

FIGURE 6. (*continued*) ... B) rainfall, E_k and E_{10} events occurred at dry season.

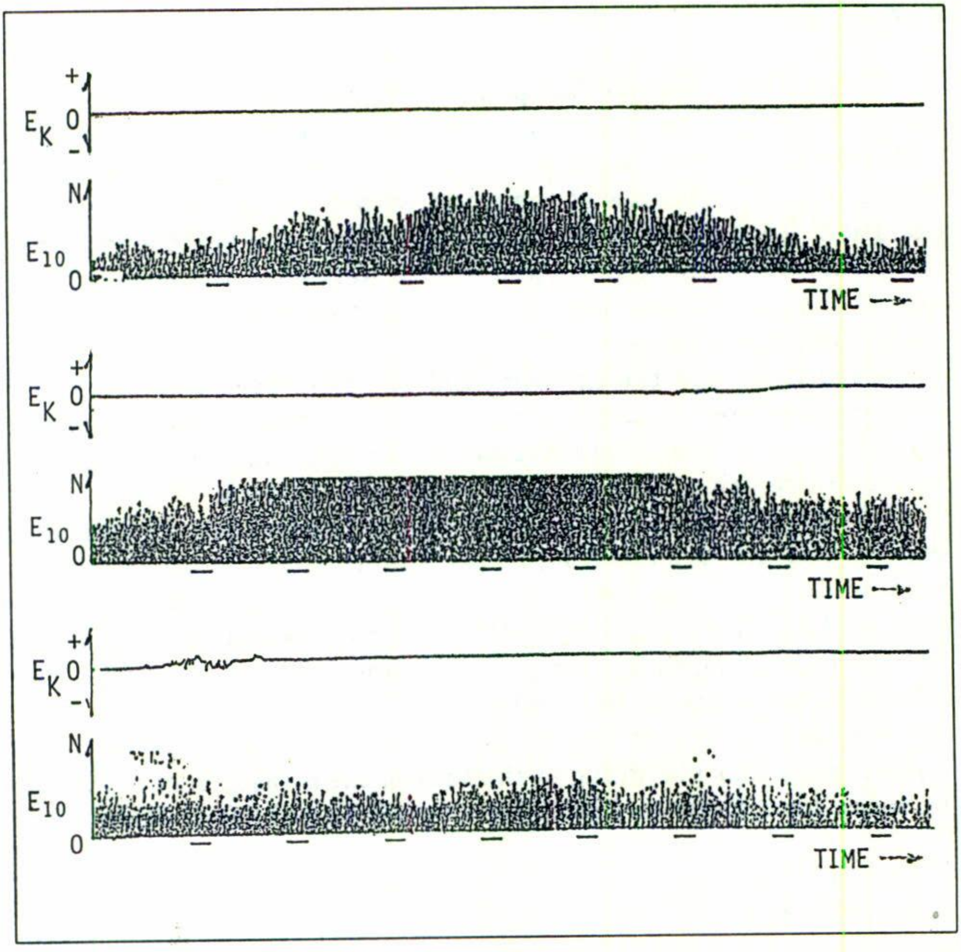

FIGURE 7. From the analogical recorders three pairs of simultaneous records (E_k and E_{10}) are presented as typical example of the different types of atmospheric electric events.

No simultaneous records of wind speed were available for examination for the period covered in this report. Therefore no point-discharge current wind speed-electric field relationship was studied. We will be able to make expected wind measurement in the vicinity of two sensors as soon as possible.

6. Conclusion

This is the first time that point-discharge current measurements have been made in our University. The data presented here was collected along mountain slopes and at the southern part of one of the most populous cities of the world with a very high degree of air pollution. Also, the altitude of the observatory site and the fact that the structure of the atmosphere due to mixing of the tropical and the medium latitude masses of air, gives rise to be very important experimental problems.

We believe that the experimental questions raised in this study cannot be ignored in an attempt to study variations in atmospheric electricity. Therefore, it is necessary to continue this kind of research in the future using more detailed observational data.

The present investigation has revealed interesting effects and it will be even more interesting to see how this results are compared with similar statistics from recent alike observations made at other places. Also, ideas regarding the question whether the variations produced by orography, air pollution and heating anomalies can affect the atmospheric electricity.

A full discussion of the relation of their data with the meteorological conditions prevailing at the time of the measurements will not be made here, these and other results will be published elsewhere.

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