N91-32721

A STUDY OF POINT DISCHARGE CURRENT OBSERVATIONS IN THE THUNDERSTORM ENVIRONMENT AT A TROPICAL STATION DURING THE YEAR 1987 AND 1988

G.K. MANOHAR, S.S. KANDALGAONKAR AND S.M. SHOLAPURKAR
INDIAN INSTITUTE OF TROPICAL METEOROLOGY, PUNE - 411 008, INDIA

ABSTRACT

In the present paper the results of the measurements of point discharge current observations at Pune, India, during the years 1987 and 1988 are presented by categorising and studying their number of spells, polar current average durations and current magnitudes in day-time and night-time conditions. While the results have shown that the thunderstorm activity occupies far more day-time than the night-time the level of current magnitudes remains nearly the same in the two categories.

INTRODUCTION

It is well-known that high electric field beneath the thunderstorms produce electric discharge (point discharge current - PDC) at the tips of grounded natural and artificial objects. Most of the recent laboratory and field observational studies on PDC (Ette [1]; Dawson [2]; Standler and Winn [3]; Rahman and Saunders [4] and Sivaramkrishnan [5]; Kamra [6]; Kamra and Varshneya [7]; Rao and Ramanadham [8]; Selvam et al., [9]; Kamra [10] and Manohar et al., [11]) were concerned with the relative efficiencies of the natural and artificial objects and the splashing of rain-drops on sea surface to produce discharges; the net amount of annual charge transferred to the earth by PDC and the functional relationship of electric field and PDC along and aloft the ground surface etc.

In the present work the authors recorded a total of 266 spells of PDC during 41 thunderstorms of the years 1987 and 1988 at Pune (18°32'N, 73°51'E, 559 m ASL). The total duration of the thunderstorm activity on each day, when PDC spells were recorded, was arbitrarily grouped in two major periods : day-time (D) and night-time (N). The PDC activity thus separated in two time periods was studied in details. Results pertaining to some other aspects of the subject matter are also described. In this respect the present work is a deviation from the routine as it has attempted to locate differences in the seasonal day-time (D) and night-time (N) PDC activity.

INSTRUMENTATION, DATA AND METHOD OF ANALYSIS

The point discharge element consisted of a platinum/10% iridium needle 0.5 mm diameter and about 2 cm long erected on a mast on the third floor terrace at height 14 meters above ground level. Current through the needle was carried by a coaxial cable and fed to an operational amplifier system. The output from the amplifier system was recorded on a 1 mA strip chart ink recorder run at speed 1 cm per minute during the entire life period of thunderstorm. The instrument could record current in the range ± 0.05-4.50 μA. The recording system was calibrated in the laboratory before its installation during the seasons. During the two years namely 1987 and 1988 at Pune thunderstorm activity was noticed on 41 days which primarily occurs during the pre and post-monsoon seasons (March-early June and September-November). The total span of the thunderstorm activity was reckoned as the duration between the first and last spell of PDC. Each spell of PDC of either polarity, which occurred during the span of thunderstorm on a day, was analysed for per spell average current intensity by using 1 minute interval values during the spell. There were a total of 266 such spells of current in the range of a few minutes to an hour or so. The initial and the end timings as well as the duration in minutes of each spell was noted.

This data was then classified into day-time (D) and night-time (N) periods. Spells during the period 1200-2200 hours IST were termed as (D) time and during period 2200-1200 hours IST as (N) time (actually no thunderstorm activity was noticed beyond premorning hours) since in the tropical region major thunderstorm activity is restricted to AN-night hours and in very exceptional cases the activity persists beyond night hours.

A detailed statistics of PDC activity during the (D) and (N) time periods of pre and post monsoon seasons of the years 1987 and 1988 of either polarity is furnished in Table I.

Daily total duration of PDC and the daily span of thunderstorm activity was used to obtain the ratio of the two quantities. The daily ratios thus obtained were then plotted against daily durations of thunderstorms. A line of best fit for the data points was obtained by the method of the least squares (Fig. 1).

As explained earlier, there were a total of 217 and 49 spells of PDC during (D) and (N) time periods in the two years 1987 and 1988 (Table I). Frequency distribution of number of spells of PDC in time interval 1-10, 11-20, 21-30 .... minutes was made and expressed as percentage of the total in each category (Fig. 2).

Daily surface data on maximum air temperature, evaporation, sun-shine duration and humidity in the AN hours was obtained from IMD (India Meteorological Department) Observatory Pune on all the days of thunderstorms. The mean values of the above parameters and some other information in relation to the thunderstorm activity for the two seasons for the two years is given in Table II.

RESULTS AND DISCUSSIONS

1. In Table I a detailed statistics of the PDC activity of either polarity for (D) and (N) time category for the pre and post-monsoon seasons of the years 1987 and 1988 is furnished. The data sets indicated that mutual comparison in many ways among the data can be made and may reveal useful informations. Some salient features of the PDC in the (D) and (N) are described.

(i) From Sr.No. 4 it is noted that the respective positive (D) durations : 639, 527, 692 and 317 were higher than the (N) : 42, 98, 71 and 89 in the range 3.6 to 15.2 and similarly the negative (D) durations were higher than the (N) in the range 2.3 to 9.4.

(ii) From a similar comparison it is also noticed that positive as well as negative (D) number of spells were higher than the (N) in the range 3 to 7 times.

(iii) Also, from Sr.No. 5 it is noted that the per spell positive duration during the (D) was higher than the (N) in the range 1.0 to 2.5 times whereas the per spell negative duration during (D) was higher than the (N) in the range 0.9 to 1.6.

(iv) And, from Sr.No. 6 it is noted that the positive (D) average current was higher than the (N) in the range 0.93 to 1.9 whereas the negative (D) average current was higher than the (N) in the range 0.78 to 1.2.

2. In Figure 1 the daily spans of thunderstorm durations and PDC ratios as explained earlier are plotted for 31 days data out of 41 days (data on 10 days was not considered when activity was at odd hours - see Table II). The equation for the straight line fitted by the regression method is $Y = -456.56X + 544.59$. For the maximum value of $X = 1$ the value of Y comes as 88 minutes. For lower values of X the values of Y increase. This feature perhaps suggests that thunderstorm activity of prolonged durations may be comparatively less efficient in producing point discharges than the brisk ones.

3. As explained earlier, in Figure 2 is shown the frequency distribution of (D) and (N) number of spells of PDC. The (D) figure indicates that the distribution is exponentially decreasing with a long tail and is governed by the equation $Y = 0.01 + 58.6e^{-0.05X}$. It is noticed from figure that (D) point discharge currents of durations 1-10 minutes have maximum frequency and during (N) the maximum frequency occurs for currents with durations 11-20 minutes. It is to be noted that the extreme edge of spell durations of PDC during (D) extends upto 90 minutes whereas during night time a cut-off occurs between 50-60 minutes.

4. In Table II we have furnished the values of meteorological and related thunderstorm parameters during the two seasons of the two years to serve the purpose of general interest. We have also given at Sr. No. 3 of this table the details of the occasions when thunderstorm activity was at odd hours. From this information it is to be noted that occasions of thunderstorm activity at odd hours are higher and more frequent during the post-monsoon seasons. Information at Sr.No. 4 of this table also suggests that the post monsoon thunderstorms either may be relatively weakly electrified or the activity may be occurring from isolated cells active at different times unlike the massive heat thunderstorms active during limited time and over area. At Sr.No. 5 of the same table meteorological ground based information in relation to thunderstorm situations is furnished. Inter seasonal comparison of the mean values of the four surface meteorological parameters brings out the difference between them which promote the development of thunderstorm activity. Pre monsoon season values, particularly of the maximum air temperature and humidity, 38.3°C and 38% respectively, are strikingly different from those in the postmonsoon, 31.9°C and 70%.

The observation of nearly two times higher value of humidity, at the surface levels, in the AN hours in the postmonsoon season needs some consideration.

Such higher value of humidity suggests that ions are immobilized in the lowest region of the atmosphere that may inhibit the magnitude of PDC which is perhaps reflected from the day-time pre monsoon season average value (.55 μA) and post monsoon season value (.34 μA, Table I, Sr.No. 5).

CONCLUSIONS

The relative estimates obtained of PDC in the D and N time conditions need a back-up before generalization could be possible. Since different parts of the world have different thunderstorm activities at different times such estimates would be of significance in the earth's electric budget studies and in planning some crucial activities such as air navigation, safety of power line system etc.

ACKNOWLEDGEMENT : The authors are thankful to Dr(Mrs.) A. Mary Selvam and Dr. A.S.R. Murty for support and encouragement in pursuing the studies. Thanks are also due to Sh. M.I.R. Tinmaker for typing the manuscript.

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TABLE I. STATISTICS OF THE POINT DISCHARGE CURRENT ACTIVITY, PUNE

Year	1987								1988							
Season	Premonsoon				Postmonsoon				Premonsoon				Postmonsoon			
S.N 1. Total days of Thunderstorms	7				16				10				8			
2. Duration of PDC in minutes	1098				1303				1410				917			
3. Positive and Negative duration in minutes	+		-		+		-		+		-		+		-	
	681		417		625		678		763		647		406		511	
4. Daytime/Nighttime (D) (N)	D	N	D	N	D	N	D	N	D	N	D	N	D	N	D	N
durations in minutes.	639	42	355	62	527	98	528	150	692	71	585	62	317	89	357	154
No. of spells	18	3	15	4	33	6	46	8	30	5	20	3	27	9	28	11
5. Average duration per spell and	35	14	24	15	16	16	11	19	23	14	29	21	12	9	13	14
ratio of D/N per spell duration	2.5		1.6		1.0		0.6		1.6		1.4		1.3		0.9	
6. Av. current per min. (μA)	.59	.31	.73	.62	.43	.46	.34	.35	.35	.30	.55	.66	.28	.21	.32	.41

TABLE II. SOME CHARACTERISTICS OF METEOROLOGICAL AND THUNDERSTORM PARAMETERS, PUNE

S.No	Year / Season	1987 Premonsoon	1987 Post monsoon	1988 Premonsoon	1988 Post monsoon
1.	Av. time of initiation and ceasation of Thunderstorm activity	1612/1900 IST	1617/1852 IST	1630/2000 IST	1827/2033 IST
2.	Duration of PDC (minutes) mean max. mini.	 157 351 100	 81 218 8	 141 246 30	 115 294 3
3.	Occasions when activity was at odd hours.	On one occasion activity started after 2200 hrs and ended at midnight.	On three occasions activity persisted during midnight time.	On one occasion activity ended at midnight hours.	On one occasion activity started and ended in the early morning hours. On two occasions activity started after midnight and ended subseqently.
4.	Mean ratio of PDC duration to total duration of thunderstorm activity	.91	.45	.75	.64
5.	Mean values of surface i. Max air temp °C ii. Evaporation (mm) iii. Sun-shine (hrs) iv. Humidity (%)	 38.3 8.6 8.1 30	 31.9 3.5 4.6 70	 38.0 8.6 8.2 38	 31.1 5.4 6.6 69

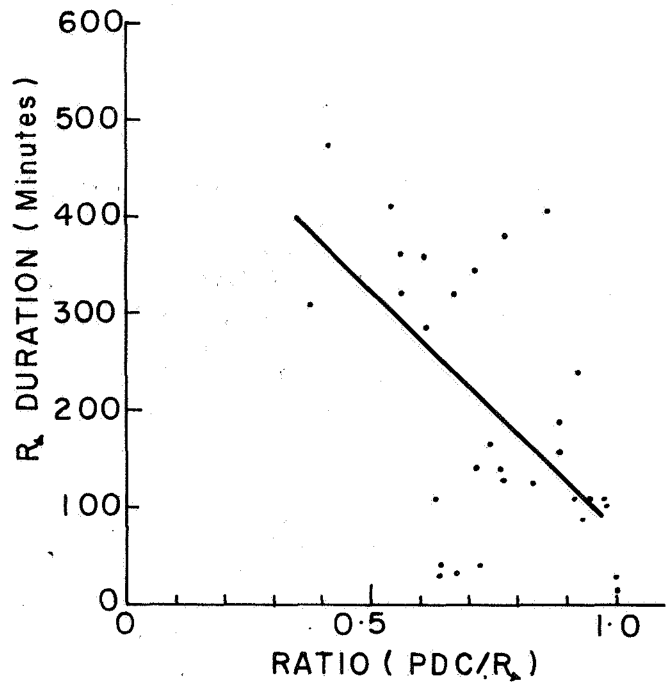

Figure 1. Daily Ratios of (PDC/R) Duration Versus Thunderstorm Duration

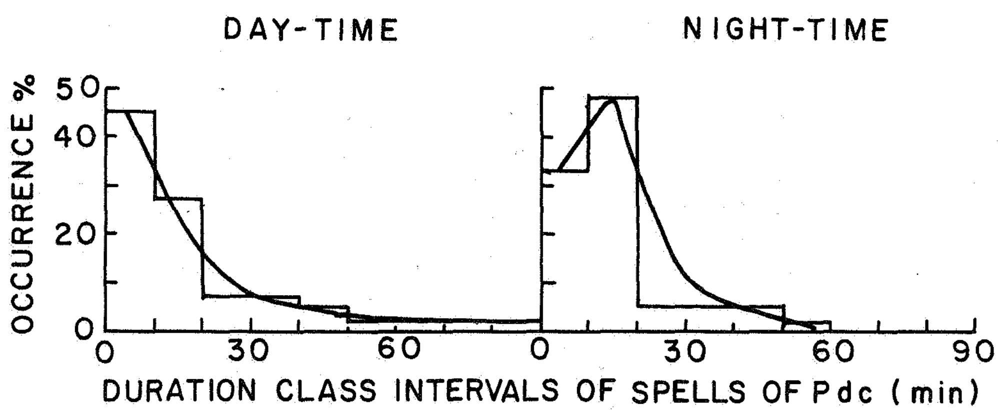

Figure 2. Frequency Distribution of Number of Spells of PDC in Given Time Intervals for Day-Time and Night-Time Conditions

PORTABLE COMBINED OPTICAL AND ELECTRIC FIELD CHANGE INTRACLOUD LIGHTNING DETECTOR

Ralph Markson
Airborne Research Associates
46 Kendal Common Road
Weston, MA 02193
(617)899-1834

BACKGROUND

Optical lightning detection has been used at research institutes for years and movie cameras equipped with optical lightning detectors were operated by astronauts on several Space Shuttle missions to detect lightning in clouds within the field of view during daylight and at night. The optical lightning detector reported here is the first such device available commercially. The addition of a flat plate antenna section, which responds to electric field changes, provides the advantages of both types of detectors in a single compact unit. Flat plate antenna sensors also have not been available as an inexpensive commercial product in the past. By combining both signals in a coincidence circuit false alarms are essentially eliminated.

OPTICAL LIGHTNING DETECTION

Lightning emits optical signals which in some respects are easier to detect and interpret and more reliable indicators than longer wavelength electromagnetic radiation. In daylight, depending on background light intensity, cloud-to-ground lightning can be observed visually, but intracloud lightning is rarely seen. At night the human eye sees essentially all lightning from clouds within the field of view. The optical lightning detector provides close to nighttime visual sensitivity during daylight. Intracloud lightning in the upper portion of brightly sunlit clouds is sensed as easily as cloud-to-ground discharges. The optical lightning detector offers some important advantages over other types of lightning detection including:

- -- ability to report intracloud lightning
- -- close to 100% detection efficiency within about 20 km or further (depending on visibility)
- -- can determine if specific clouds contain lightning
- -- low cost (less than 1% of mapping systems)
- -- no installation or maintenance
- -- no requirement for AC power
- -- no requirement for communications between remote sensors and central processor
- -- reliability
- -- portability
- -- simplicity of operation

The limitations of an optical detector are:

- -- does not provide range
- -- azimuth may be inaccurate if light is reflected from other clouds
- -- nearby clouds or rain can block view of more distant lightning (but flat plate antenna will sense them)

INDUCTION FIELD CHANGE LIGHTNING DETECTION

The current second generation optical lightning detector includes a flat plate field change detector in order to improve performance. The antenna is the shiny metal plate on the end of the instrument. This section can be operated independently or in coincidence with the optical section. Improvements include:

- -- coincidence mode: elimination of false optical signals which can occur from reflections off raindrops or other objects or from windows within buildings

- -- field change mode: ability to detect distant lightning when optical visibility is obstructed

- -- omnidirectional (no need to aim instrument at clouds)

Electric field change detection has been selected as the best way to use non-optical emissions, rather than "sferics" type emissions such as one hears on an AM radio. The problem with using radio static signals for lightning detection is that such signals decrease slowly (1/R) with distance in the far field and are reflected from the ionosphere. Thus they propagate for long distances; one has no idea if the flashes are nearby or a few hundred miles away. If range is purposely limited by reducing sensitivity, only the more energetic cloud-to-ground flashes are received and the earlier intracloud discharges are missed. However, by sensing VLF field changes in the "near field" where signal intensity decreases rapidly with distance ($1/R^3$), one can eliminate reception of distant signals without decreasing sensitivity for nearby flashes.

Use of this flat plate antenna section makes it possible to survey for lightning for about 50 km in all directions on days with limited visibility without having to point the detector at specific clouds. Such omnidirectional sensing can be done before there are any nearby visible clouds. It is best to use this mode outdoors since electric signals are screened from the interior of buildings with metal structure.

When threatening clouds appear, the instrument can be switched to the "optical" or "both" (coincidence) mode to see if these clouds contain lightning. In any of the three operational modes the unique staccato sound signature characteristic of lightning (caused by the strokes within each flash) can be heard; this is useful for distinguishing lightning from any noise sources.

DISTANCE TO LIGHTNING

In the early part of a storm, when lightning is occurring only once every few minutes or a few times per minute -- so that individual flashes (beeps from the instrument) can be associated with subsequent thunder -- it is possible to determine the distance to the discharge. This classic "flash to bang" method works because sound travels 1 mile in 5 seconds. The technique is useful for distances up to about 8 km, or possibly as much as 15 km on occasion, depending on sound propagation and lightning frequency.

RANGE

The detector's range is essentially line-of-sight. However, it is capable of picking up lightning from clouds behind those in the foreground because of light transmission through the thin veil of high cirrus clouds which is often present near thunderstorms. Thus, the range is not usually restricted to the closest clouds and it is on the order of 50 km with other clouds between the source and detector. The range can be as much as 150 km in clean air with no clouds between the detector and clouds with lightning.

CIRCUIT FEATURES

The accompanying block diagram shows the components of the circuitry. A highpass filter and bandpass filter restrict signals essentially to lightning (and strobe lights when operated in the purely optical mode). The detection threshold automatically adjusts to a level just below that of the variable background light intensity to maximize sensitivity. The timing diagram illustrates how the optical and field change sections trigger when the threshold is exceeded and how the signal is maintained for 50 ms to aid in hearing the pulses (strokes). This diagram illustrates how both signals must be on for the coincidence circuit to respond.

PHYSICAL SPECIFICATIONS

The M-10 dimensions are 18 cm (7.0 in) x 10 cm (3.8 in) x 3.5 cm (1.3 in). It weighs 450 gm (1 lb). A fitting in the base allows it to be mounted on a camera tripod so it can easily be pointed toward suspicious clouds without having to hold it in position by hand for an extended period of time. (It also can be supported by any convenient object.) It can be heard 20 meters away when background noise is low. The instrument is powered by two 9 volt alkaline transistor batteries which are inserted into molded housings when the back plate is removed. The detector beeps every 3 seconds when the batteries need replacement.

APPLICATIONS

To date over 100 optical lightning detectors are being used at universities and golf courses as well as government laboratories and field test sites. A half dozen observers covering the KSC test area could tell with 100% reliability if any visible clouds over or near the region contained any kind of lightning.