MAUSAM, 49, 4 (October 1998), 481-486

551.577.1:551.576.1:551.515.4(547.1 MAH)

Initial development of precipitation and onset of cloud electrification in thunderstorms at Pune

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(Received 17 December 1996, Modified 4 July 1997)

सार — विद्युत क्षेत्रों में एक मिनट के अंतराल के आंकड़ों और भू-तल पर वर्षा के माप के अभिलेखों का प्रयोग करते हुए पुणे में वर्ष 1973 में आए 14 तूफानों के सिलसिले में मेघ विद्युतीकरण के शुरू होने और वर्षा के समय अनुक्रम के आरम्भिक पंजीयन की जाँच की गई है। यह अध्ययन मेघ विद्युतीकरण के तीव्रीकरण और वर्षण के आरम्भिक विकास के मध्य संबंधों का पता लगाने के लिए किया गया है। 14 तूफानों के संयुक्त परिणामों के अध्ययन से पता चलता है कि जिन क्षेत्रों में वर्षा हुई वहां मेघ विद्युतीकरण के आरम्भ होने के कम से कम 3-7 मिनट पहले वर्षा के बादल बने। अन्य कार्यकर्ताओं द्वारा प्रकाशित अन्य अनुपूरक अध्ययनों और उपर्युक्त परिणाम से पता चलता है कि अधिकतर मामलों में विद्युत क्षेत्र के तीव्र होने के ठीक पहले तूफानों में वर्षा के बादल बनने आरम्भ हो गए थे। इस परिणाम का पहले किए गए अध्ययनों के परिणामों के साथ निकट संबंध है।

ABSTRACT. Using one-minute interval data of electric field and the records of rainfall measured at the ground surface, time sequence in the initial registration of precipitation and the onset of cloud electrification was examined for a series of 14 thunderstorms of the year 1973 at Pune to study the relationship between the initial development of precipitation and intensification of cloud electrification. The combined result of the 14 storms studied, each of which yielded precipitation, indicated in-cloud development of precipitation at least 3-7 minutes in advance of onset of cloud electrification. It is inferred from the other supplementing studies published by other workers and from the above result that in most cases the precipitation development in thunderstorms is initiated well before the electric field begins to intensify. This result is in close agreement with the result of previous studies.

Key words — Precipitation and electrification growth in thunderstorms.

1. Introduction

Considerable amount of literature on studies covering a wide range of topics concerning the thunderstorms, such as: thermodynamical and radar observations, analysis of surface and synoptic features of the storms and their forecasting, climatology of their diurnal and seasonal variation etc., is available that has dealt with the thunderstorms over the Indian region. To quote some of these studies, the works of Mukherjee and Chaudhury (1979), Biswas and Gupta (1989), Mandal (1989), Chatterjee *et al.* (1996) may be mentioned, although many more studies remain to be cited. As regards the observational studies pertaining to the electrical, microphysical and dynamical conditions associated with precipitation from these clouds in the Indian region, one may refer to a review article by Kamra (1976) which summarises the work accomplished until the mid-seventies of this century and also to some recent studies by Selvam *et al.* (1977); Kamra and Sathe (1983), Selvam *et al.* (1991), Manohar and Kandalgaonkar (1995) and Kandalgaonkar *et al.* (1996). It is noted from the above studies that apart from the topics discussed in these studies, there is yet another important topic of the thunderstorms that appears to have received less attention of the researchers in this part of the continent.

This topic is with regard to the identification of real time sequence between the development of initial precipitation and electrification in the thunderstorms, to understand whether precipitation leads electrification or *vice-versa*, since intense electrification, precipitation and convection are the remarkable aspects of the thundercloud. A satisfactory understanding of how a thunderstorm works requires a continuing series of investigations to explore the complicated interrelationships among these phenomena. Until the recent times the major effort has been devoted to studies of how precipitation causes electrification (vonnegut, 1994). Such a study is interesting but intricate, because, unlike the other rain-bearing clouds, the growth of electrification and precipitation in the thunderstorms is so intense and rapid that

TABLE 1

Chronological details of thunderstorms at Pune during 1973

Dates of thunder-storms Year (1973)	Time of registration of initial precipitation at the ground (IST) A hr	Time when initial electric field intensified and became maximum (IST) B hr	Maximum electric field (k Vm^{-1})	Amount of rainfall (mm)	A-B(min) Category I	A-B(min) Category II
03 Apr	1757	1801	+8.29	2.0	-04	–
08 Apr	1850	1850	-6.22	0.4	00	–
22 May	1517	1457	-6.48	26.6	—	+20
31 May	1655	1658	+6.22	0.6	-03	–
02 Jun	2136	2134	+3.88	2.0	—	+02
03 Jun	1659	1709	+5.51	5.6	-10	–
04 Jun	1529	1535	+5.99	18.3	-06	–
05 Jun	2157	2032	+5.63	0.7	—	+85
06 Jun	1755	1833	-4.53	12.5	-38	–
27 Jun	1942	1918	-9.72	3.5	—	+24
30 Jun	1501	1527	-2.69	11.1	-26	–
19 Sep	1420	1506	-7.31	61.2	-46	–
01 Oct	1515	1526	+4.25	2.0	-11	–
04 Oct	1440	1637	-6.98	22.7	-117	–

N.B.—For Category I the median and the mean is -10.5 and -18 minutes respectively for eight storm days except on 08 April 1973 and 04 October 1973. For Category II the median and the mean value is +22 and +33 minutes respectively for four storm days.

these two phenomena appear to occur almost simultaneously and are difficult to resolve unless a series of experiments are performed.

This short communication reports the results of comparison of the time of initial precipitation (rainfall) and enhancement of electric field at the ground surface in real time during the evolution of 14 thunderstorms of the year 1973 at Pune (18°32′ N, 73°51′ E, 559 m asl).

2. Instrumentation

2.1. *Measurement of electric field and rainfall*

The potential gradient (electric field) was measured by the potential equalization method (Chalmers, 1967) and rainfall by the standard float-type self recording raingauge of India Meteorological Department (IMD). The details of the instrumentation, measurement accuracy, sign convention etc. in respect of potential gradient (electric field) and rainfall are described in a recent study (Kandalgaonkar *et al.* 1996) referred above. During thunderstorms these instruments were installed on the floor of the terrace of the three storey building of the office of Agricultural Meteorology Division of the IMD at Shivaji Nagar, Pune-5. The surroundings of the observation site and campus details are also described (Kandalgaonkar *et al.*, 1996).

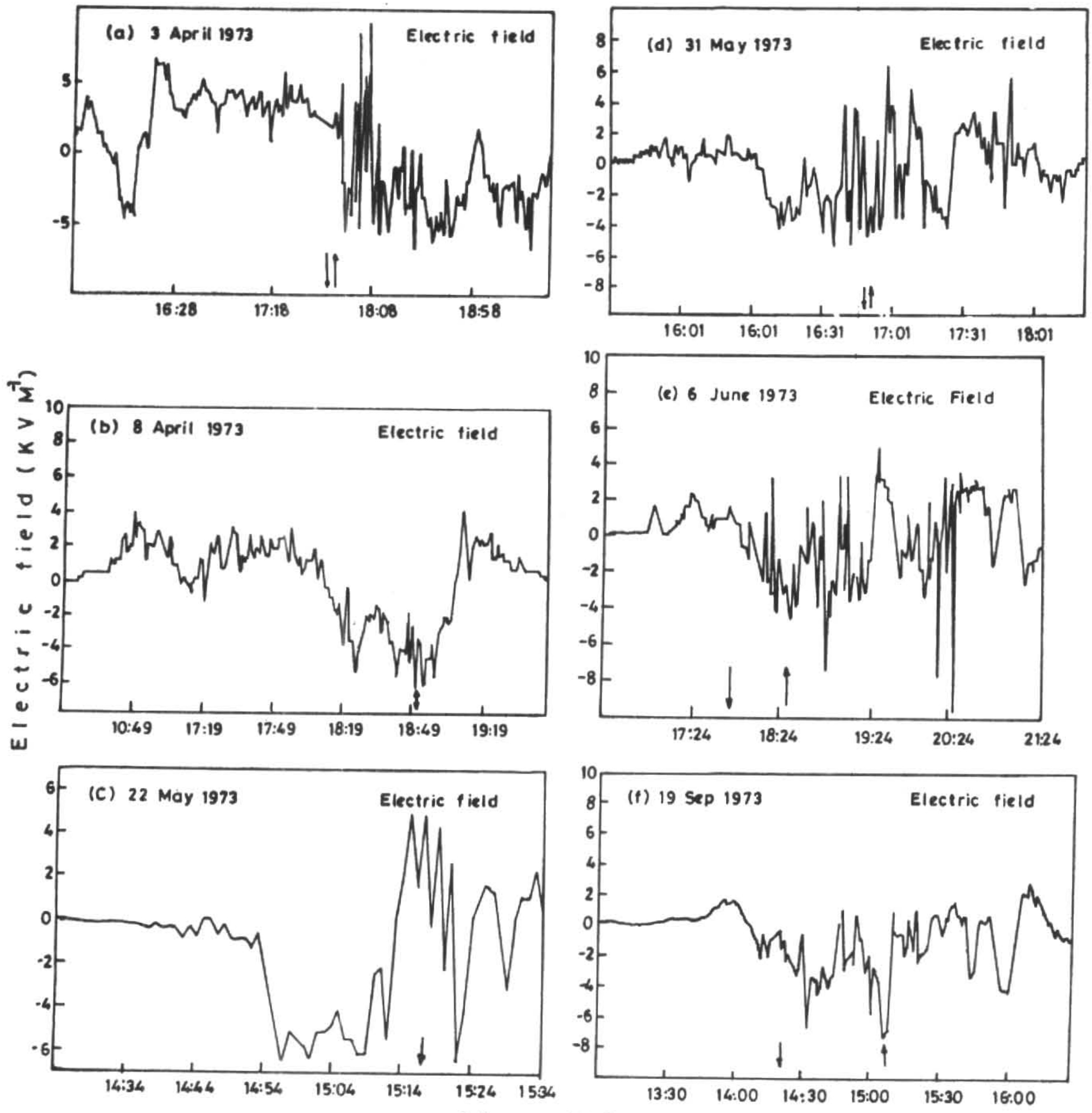
3. Data and method of analysis

One-minute interval observations from the continuous records of electric field for 14 thunderstorm days in the year 1973 and the daily records of rainfall at Pune form the data sets used in this study. Chronological details of the fourteen dates of thunderstorms studied in this work are given in column 1 of Table 1. Figs.1(a-f) shows the six diagrams indicating the variation of electric field (k Vm^{-1}) at one-minute interval for the six representative storm days out of the total fourteen storms investigated in this study (See column 1 of Table 1). These diagrams are useful for studying the growth of storm electrification with time during the course of the storm on individual day Fig.2 (a-f) present the tracings of the original records of rainfall charts corresponding to the six representative storm days for which electric fields data are furnished [Figs.1(a-f)]. The arrow mark (↓) drawn along the time axis in Figs.1(a-f) indicates the arrival of precipitation and is drawn at the time when initial precipitation was registered at the ground as evidenced from the rainfall charts furnished above; and the arrow mark (↑) corresponds to the time when electric field intensified and became maximum in the neighbourhood of initial registration of precipitation Table 1 provides the listing of the notings of above quantities, described above, for the fourteen storms under investigation.

A survey of the literature showed that the above procedure of analysis is similar to that of Reynolds and Brook (1956) and Dye *et al.* (1986, 1989) which also investigated the association between precipitation formation and storm electrification of the thunderstorms.

4. Results and discussion

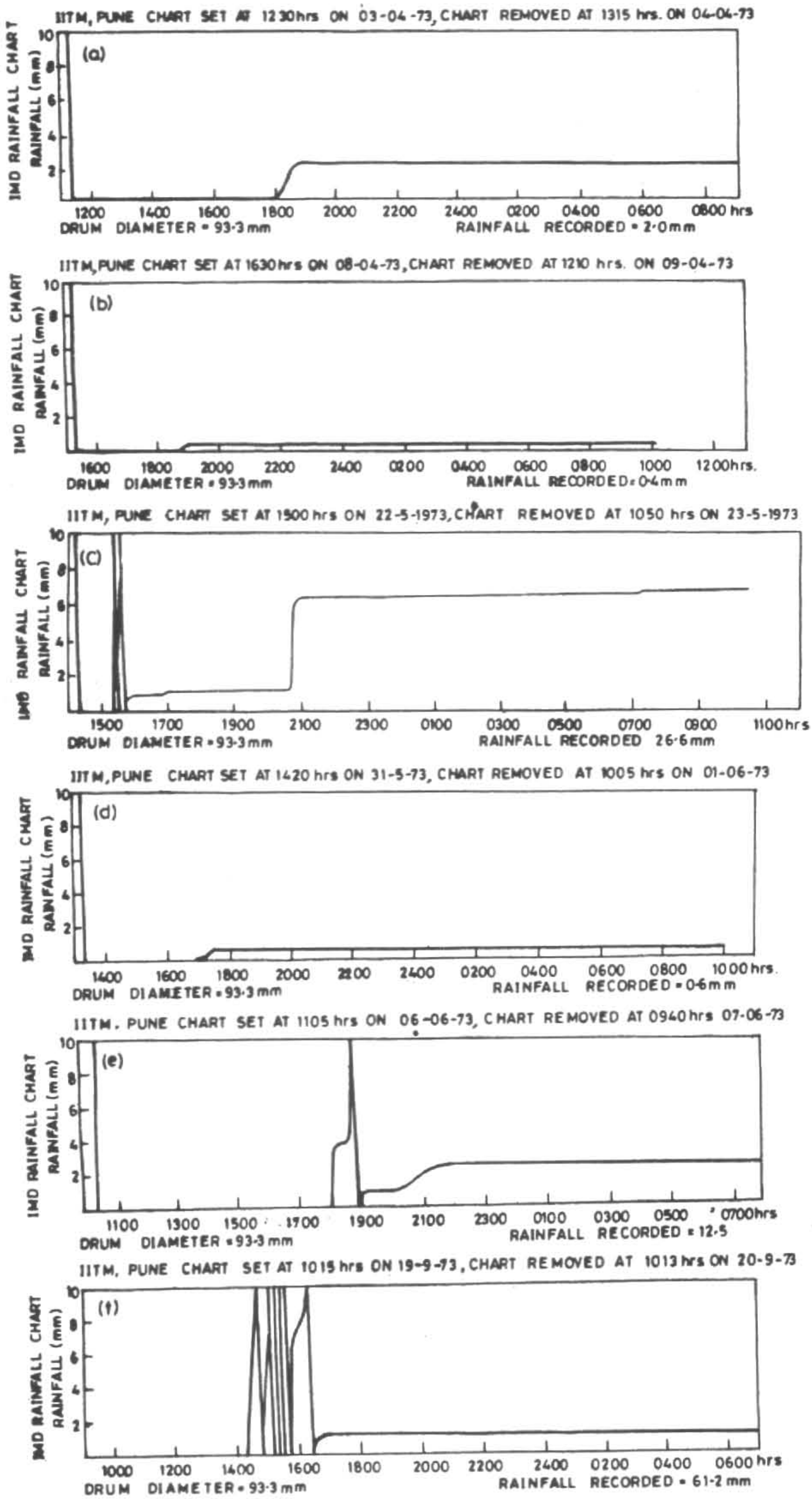
The principle objective of the present work is to study the relationship between "initial" development of precipitation and cloud electrification during the life cycle of a thunderstorm, as evidenced from the ground based observa-



Figs.1(a-f). One-minute interval electric field data for thunderstorms at Pune on six representative days (see diagrams a-f). In these diagrams arrow mark (↓) indicates the arrival of rainfall and is drawn at the time when it commenced as evidenced from the rainfall charts on that day. Arrow mark (↑) is drawn at the time when electric field intensified and became maximum in the neighbourhood of precipitation commencement

tions of electric field and rainfall records for a series of thunderstorms in the year 1973 at Pune. This kind of comparison between time sequence of the initial precipitation and electrification may help in identifying which of these two processes develop first and is the probable cause of the other. It is believed that the correspondence between the development of initial precipitation and onset of electrification in a thunderstorm is like the cause and effect between the two phenomena.

A careful examination of the time lapse between initial precipitation (column marked A of Table 1) and intensification of cloud electrification (column marked B of Table 1) on individual days indicated that out of the 14 storm days, each of which yielded precipitation, the time of règistration



Figs. 2 (a-f). Charts of rainfall record on six representative days as in Fig.1.

of initial precipitation at the ground preceded that of intensification of cloud electrification on 9 days (category I); and only 4 days precipitation lagged behind electrification (category II). [See A-B values as shown in last column of Table 1]. There was only one day when precipitation and cloud electrification time was coincident (08 April 1973). It is noted from Table 1 that the range of the variation in time lag between events A and B in the I category was between -03 to -46 minutes with most values lying around the median value-10.5 and the mean of these 8 values was -18 minutes (with the exception of one value being -117 minutes). The range of variation in the time age between the events A and B in the II category was between +02 to + 85 minutes with the median value +22 and the mean of these four values was +33 minutes. The gross algebraic mean time (-144 and +131 minutes for the 8 and 4 cases respectively) indicated initial precipitation occurrence at the ground 1 minute in advance of the intensification of cloud electrification. This is obvious since the time resolution of the two parameters is less than a minute (Kandalgaonkar *et al.*, 1996). It is also noted that out of the 14 storms, each of which yielded precipitation, there was a tendency for the initial precipitation to occur before the onset of cloud electrification on ~ 64% occasions, and only on ~ 29% occasions it was the opposite way.

Since precipitation is measured at the ground, we may have to give allowance for the time taken by the precipitation to reach the ground to realise the time for the precipitation formation within the cloud. Jayaratne *et al.*, (1995) studied the rain gush phenomenon of the thunderstorms in Gaborne, Botswana; a tropical region of South Africa. According to them, the probable minimum time for the precipitation elements to reach the ground surface, from the freezing level (5 km above ground) would be in the range 2-6 minutes. The height of the freezing level during the premonsoon season over Pune region is also reported as about 5 km above ground level (Manohar and Kandalgaonkar, 1995). Analogy in the situation thus favours us to accept this time in the present study. Now since the effect on ground electric field of in-cloud electrification is instantaneous, the gross result suggests that initially precipitation within the cloud must have been formed at least 3-7 minutes in advance from when cloud electrification intensified. Dye *et al.* (1986) studied similar sequence using in-cloud observations of related parameters. Significant points of their study showed that the precipitation development was initiated well before the electric field began to intensify. Similarly the cloud was dynamically active for at least few tens of minutes before field intensification began, reaching a peak near the time of maximum precipitation development. During this early period the fields were 100 to 200 Vm^{-1} in the disturbed weather sense but with negligible field increases. Apparently, no mechanism was producing appreciable field enhancement during such times. Electrification was picked up and proceeded quite rapidly only slightly after the peak in precipitation development. Their results, when summarised, indicated that the electric field inside the cloud did not exceed 100 V m^{-1} until 5 mm graupel, ice particle concentrations of 10 L^{-1}, and reflectivities of 35 dBz were present, but then rapidly electrified to produce a single intracloud discharge 8 minutes later, near the peak of microphysical development. Reynolds and Brook (1956) who also studied similar relationship for New Mexico region, found a similar delay between initial precipitation formation and the subsequent intensification in cloud electrification in a majority of the cases studied by them. These authors reported that the electrification of the New Mexico storms which they investigated followed the development of precipitation and also appeared to be associated with a surge in growth of the cloud. Further, Dye *et al.* (1989) studied the relationship between initial precipitation development and the onset of cloud electrification for 20 storms of varying electrical activity by using aircraft and ground based observations of several related parameters. These authors studied the storms which were electrically active as well as ones in which no electrical enhancement was observed. Electric field inside these clouds showed negligible enhancement and did not exceed 1 k V m^{-1} until reflectivities at 6 km above mean sea level (about -10°C) exceeded approximately 40 dBz and cloud tops exceeded 8 km. The onset of electrification occurred during or immediately after convective growth within the cloud. Their results showed that initial precipitation led cloud electrification by about 15 minutes on an average, while in particular cases this time lag was of the order of many tens of minutes as well as very rapid in few cases.

To summarise the results of the present study it may be mentioned that the results of previous case studies mentioned above and the present ones have provide a detailed account to suggest that (*i*) if the cloud electrification is associated with the formation of precipitation, then, the build-up of cloud electrification follows precipitation formation in a very rapid sequence in most of the cases and (*ii*) once the development of initial precipitation and electrification in the evolution of thunder-cloud has been picked up, the further cycles of precipitation and electrification growths follow the patterns described in the well known rain gush phenomena *i.e.*, the most common observations of the occurrence of a brief but heavy spell of rain that closely follows an event of a nearby lightning flash. These results are based on systematically organised sets of one point observations of electric field and precipitation of 14 thunderstorms which developed over Pune. The facility of weather radar observations would have greatly added support to the significance of these results. However, since these results are derived on more than a couple of sets of observations, the generality of the inference which is in fair agreement with previous results may not be overlooked.

Acknowledgements

We express our sincere gratitude to Dr (Mrs.) A.M. Selvam for guidance and valuable help in this study. We are thankful to Dr. A.S.R. Murty for encouragement in our studies. The authors are thankful to the anonymous referee of this paper for taking keen interest in this study and for offering constructive comments.

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