Overview of Initial Performance of BOLTEK Storm Tracker : A Lightning Detector

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Abstract

This paper discusses the lightning activity measured by the instrument, a Boltek Storm Tracker installed at Indian Institute of Tropical Meteorology (IITM), Pune, India. The potential of the instrument is judged by operating the same during the recently occurred thunderstorms over the Pune region. From the records it is seen that the instrument is capable of detecting the lightning strokes up to 500 kilometers. Details of some of the lightning events are presented in this paper.

Key words: Lightning, stroke density, spatial and temporal variation

1. Introduction

Lightning, the thunderbolt from mythology has long been feared as an atmospheric flash of super natural origins; the great weapon of the God. It is a global phenomenon that can be used as a measure of some of the variables in global change. Lightning activity is associated with thunderstorms that produce heavy rainfall in many climatic regions and, therefore, can be used to increase our knowledge of the distribution, structure, and variability of thunderstorms at the local, regional, and global scale over the land and ocean. Any information about the lightning parameter and its spatial distribution are of fundamental interest for the design of lightning protection systems and are of increasing importance for weather forecasting and climatology. Today scientific rather than mystical techniques are used to explain lightning with experimental procedures replacing intuitive concepts. In the past, observations could only be locally, and obtaining a global picture was difficult; indeed, until recently, the most accessible global lightning data set was based upon the record of 'thunderdays'. Different techniques such as: Lightning Location and Protection (LLP), Lightning Position and Tracking System (LPATS), Surveillance et Alerte Foudre par Interferometrie Radiometrique System (SAFIR); Austrian Lightning Detection and Information System (ALDIS) were used for studying lightning activity brought out somewhat a revolution with the development of sensors consisting for lightning detection and mapping systems (Mackerras, 1985; Mackerras and Darveniza, 1992; Mackerras and Darveniza, 1994; Baral and Mackerras, 1992; Baral and Mackerras, 1993; Schulz et al.,

2005). The Optical Transient Detector (OTD) mounted on Micro Lab-1 Satellite was orbiting the earth from April 1995–1999 while the Lightning Imaging Sensor (LIS) is installed on the Tropical Rainfall Measuring Mission (TRMM) satellite in November 1997 (Christian, 1999a; Boccippio *et al.*, 2000a; Boccippio *et al.*, 2000b). In addition to this considerable work has been carried out over the tropical and extra tropical regions on thunderstorm related parameter viz. lightning by examining the flash data collected through different techniques during the last two decades (Mackerras and Darveniza, 1994; Schulz *et al.*, 2005; Boccippio *et al.*, 2000a; Boccippio *et al.*, 2000b; Thotappallippi *et al.*, 1992; Price and Rind, 1994; Orville, 1994; Orville *et al.*, 1997; Hodnaish *et al.*, 1997; Yair *et al.*, 1998; Pinto *et al.*, 1999; Boccippio *et al.*, 2000c; Nesbitt *et al.*, 2000; Williams *et al.*, 2000; Petersen and Rutledge, 2001; Toracinta *et al.*, 2002). However, the studies over the Indian region are sparse except few studies reported elsewhere (Aiya and Sonde, 1963; Aiya, 1965; Manohar *et al.*, 1999; Kandalgaonkar *et al.*, 2003). The results of the studies made by (Kandalgaonkar *et al.*, 2003) over the Indian region are found to be encouraging and were in good agreement with the earlier studies. However, it was noticed that the data recorded through satellites (LIS) have got their own limitations. One of them is the coincidence of satellite pass and occurrence of thunderstorm. Recently an equipment Boltek Storm Tracker, have procured and installed at the Institute's Building, IITM, Pashan, Pune. This instrument could enable us to determine statistically meaningful area densities of stroke and the count over this region. To the best of our knowledge this is the first lightning report for this region.

2. Instrumentation

The Storm Tracker is installed on the terrace (nearly 40 ft above the ground level) of the Institute building at Pashan, Pune ($18^{\circ}32'N$, $73^{\circ}51'E$, 559 m a.s.l.), India. The position of the antenna is facing to the north direction (Figure 1). It detects the lightning discharges (IC and CG of either polarities) up to the radial distance of 500 kilometers by sensing the radio signal produced by the lightning. It has two built in alarms. The close storm alarm will activate if a thunderstorm is detected closer than the preset distance and the severe storm alarm activates if the number of lightning strikes per minute exceed the preset limit. A low level frequency radio signals (10 KHz to 200 KHz) produced by lightning discharges travels several hundred miles and are traced by the antenna of the storm tracker. The storm tracker uses a direction finding antenna to determine the direction of the lightning signal comes from. The tracker receiver looks at the signal to calculate the approximate distance for the lightning strike. Once it knows the distance and direction it plots on the real time map. The storm tracker includes the software package Lightning 2000. The software can process all the available sensor information in real time and can therefore compute a separate location for each individual in the flash. The lightning strike

data will be logged on the hard disk of the computer. Thus, the storm tracker detects where the lightning is, receives early warning of developing and approaching thunderstorm, signals about the near and severe storm alarms, determines the direction of thunderstorm, follows developing and decaying storms and records all data to computer for further analysis. A storm will be displayed in the analysis window as a wedge-shaped box see (figure 2). From the position of the wedge box the tracker classifies the storms as nearby (storm inside the red circle), regional (storm between yellow and red circles) and distant (storm beyond yellow circle). The detection efficiency of the hardware has been estimated by the manufacturer with a series of measurements with the data sets of several storms. The detection efficiency for CG and IC strokes is about $85\% \pm 6\%$ and $20\% \pm 6\%$. This study is the first lightning study in India by Boltek Storm Tracker where the data have been collected personally on 4th May 2004, which was the first nearby thunderstorm occurred over Pune after its installation. The storms on this day recorded by the tracker have been analysed only to study the spatial and temporal variation and not to examine the dynamics at this stage. Hence the authors have given more importance to the stroke density, distance and time.

Figure 1 : Antenna of the Boltek Storm Tracker

Figure 2 : Sample record of lightning activity on 4 May 2004

+CG	-CG	-IC	+IC	-CID	+CID	Leader	known	Un (seconds)
⚡	⚡	⬅	➡	■	■	⬢	?	90
■	■	■	■	■	■	■	■	300
■	■	■	■	■	■	■	■	600
⊗	⊗	⊗	⊗	■	■	■	⊗	900
⊗	⊗	⊗	⊗	■	■	■	⊗	1200
⊗	⊗	⊗	⊗	■	■	■	⊗	1800

Nomenclature of the dots

3. Data

The lightning stroke density values recorded by the tracker on 4th May 2004 at IITM forms the data set for the present study. For analysis the storms appearing from either direction (0-360° bearing) have been considered. The minute interval density value of each storm and their corresponding distances are used to study the spatial and temporal variations.

4. Observations

The tracker was installed in summer of 2004 and in operation from April 2004. The equipment used was manufactured by Boltek Inc., USA,. Figure 2 shows the record of nearby thunderstorm on 4 May 2004 with nomenclature of the dots. On this day the weather has started developing at about 1430 hrs IST (personal observation) as quite number of distant storm were approaching from different bearings. At about 1500 hrs IST the regional storms with minimum lightning activity started approaching. The storms were developing at a slow rate for nearly 2 to 3 hours. At about 1800 hrs the activity has again picked up and the peak activity started at about 1900 hrs. Thus the activity of this day persists for longer duration (4 to 5 hrs) in which the peak activity is noticed only between 19:01 to 20:02 hrs. IST. Therefore, the analysis period in the present study is ~ 5 hours.

5. Results

5.1 Spatial variation of lightning stroke density

Figure 3 shows the spatial variation of the stroke density. For this purpose the stroke density was classified in the distance range 0-10, 10-20 130-140 Km. From each class interval the mean stroke density values and their standard deviation have been worked. The vertical bars show the standard deviation of the mean density. It is seen from this figure 3 that the magnitude of density value in each class interval increases with decrease of distance from the origin. The inverse trend observed suggests that the stroke density increases as the storm approaches closer to the observational point. This result is in agreement with the earlier studies (Pierce, 1955; Jacobson and Krider, 1976; Pradeep Kumar and Rai, 1985). The analysis also suggests that the radial range of lightning strike points underneath a cloud is in the order of 10 km (as stroke density is highest = 0.6/min/deg. up to 10 km and then onwards it decreases rapidly). This result is in agreement with our earlier studies (Manohar and Kandalgaonkar, 1995; Krider, 1998; Hatakeyama, 1958; Feteris, 1952). Pierce (1955) and Illingworth (1971) have studied the lightning channel geometry and suggested that, underneath a storm, at closer distance, the occurrence of lightning strike is usually small, because at closer distance the lightning channel gets a very small solid angle which is required for its horizontal development during its vertical propagation to the ground. In thunderstorm environment this information is

always useful for taking the safety measures of the power transmission lines and wireless technology.

Figure 3 : Spatial variation of lightning stroke density on 4th May 2004

5.2 Temporal variation of lightning stroke density and strike distance

Figure 4a, shows the scatter plot of the temporal variation of stroke density and the strike distance. From this figure it was noticed that with increase in the time lapse the magnitude of the stroke density increases while the lightning strike distance is reduced (Figure 4b). The main feature of the above result can be seen from the straight line trend between stroke density and time lapse. This analysis may provide some insight into the sequence of the lightning activity from the beginning to the end of the storm. Thus the observed temporal variation of the stroke density and the strike distance may appear to be consistent if the consideration of the developing, mature and decay phase of the storm is made. Fuquay (1982) reported that usually during the developing to the mature stage of the storm the radar echo dimension are at their maxima and the development of electrical activity is on it increases, while during the mature to decay stage the storm occupied area dwindles but the electrical activity is at its peak. These features are reflected from the above figures 4a and 4b.

The results drawn in this short contribution are based on the single day observation. The storms recorded on this day have been analyzed only to study the behavior (spatial and temporal variation of the stroke density). Many more observations with this new equipment at different locations may be useful to ascertain the results and accuracy of the instrument. The advantage of this instrument is that it provides maximum information to the researchers working in the field of Atmospheric Electricity as well as the ground duty pilots in Air Force and Civil Aviation Department as compare to its cost.

Figure 4a : Temporal variation of stroke density on 4th May 2004 Figure 4b : Temporal variation of strike distance on 4th May 2004.

6. Conclusions

The analysis of the lightning activity recorded by Boltek Storm Tracker on 4th May 2004 suggest the following :

1. The spatial variation of the activity suggested that the radial distance of lightning strike underneath the storm tended to cluster within the distance of 10 km.
2. The temporal variation of the stroke density and strike distance suggest that with increase in time lapse the magnitude of the stroke density increases while the strike distance is reduced.

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