A study of total lightning characteristics of thunderstorms over Gangetic West Bengal

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Abstract

We report the preliminary results of observation of total lightning characteristics of pre-monsoon summer time thunderstorms over the Gangetic West Bengal (GWB) around Kolkata. We have analysed 35 thunderstorms during March to early June 2018 over GWB. Total lightning flash rate, which includes both in-cloud (IC) and cloud-to-ground (CG) lightning, has been found to increase rapidly during the initial stage of the thunderstorm much before the occurrence of damaging wind and intense lightning. Four categories of lightning rate curves are found and out of which two categories tend to produce damaging wind, intense lightning and heavy rainfall. Samples of both in-cloud and cloud to ground lightning electric field waveforms are also presented here.

1 Introduction

Lightning discharge radiates electro-magnetic energy in a very wide radio frequency range, from below 1 Hz to near 300 MHz, with a maximum radiation energy in the frequency spectrum near 5 to 10 kHz (Rakov and Uman, 2003). Because of this wide range of radiation frequency, there are many ground based and satellite based methods to monitor lightning activity in the atmosphere. Recently, there has been increasing interest in ground based lightning detection networks because of its potential use in meteorological applications.

There are approximately 2000 thunderstorms at any given moment on earth, with a global lightning flash rate of 50 flashes per second. Since lightning is closely related to cloud micro-physics and dynamics, a variety of severe weather elements like heavy rainfall, hail, down bursts, gust fronts, flash floods, tornadoes etc are connected to lightning (Rakov and Uman, 2003; Williams et al, 1989;1999). The frequency of violent thunderstorms associated with severe lightning and gusty wind is substantially increasing through out the globe possibly due to climate change effects. Recent studies have shown that increase in total lightning rate (i.e., IC and CG flash rate) can produce severe thunderstorm alert which generate high wind, hail storm, tornadoes with a sufficient lead time ranging from 10 minutes to 1 hour (Liu and Heckman, 2011; Liu et al., 2014).

In recent years, different parts of Indian sub-continent are affected by severe thunderstorms, dust storms, flash floods, heavy rainfall etc. causing a considerable damage to agriculture, properties and even human lives. According to the National Crime Bureau Record, lightning is also responsible for more death in every year than in any other natural calamity in India. In this work, we have studied total lightning characteristics of pre-monsoon thunderstorms, locally known as “Nor’wester or Kalboishakhi", over the Gangetic West Bengal (GWB) around Kolkata. Intense lightning associated with the Nor’wester during the active stage of thunderstorm are the main reason of fatalities in this region. This paper attempts to study the short-term prediction criteria of severe weather phenomena associated with thunderstorms over GWB based on total lightning measurements.

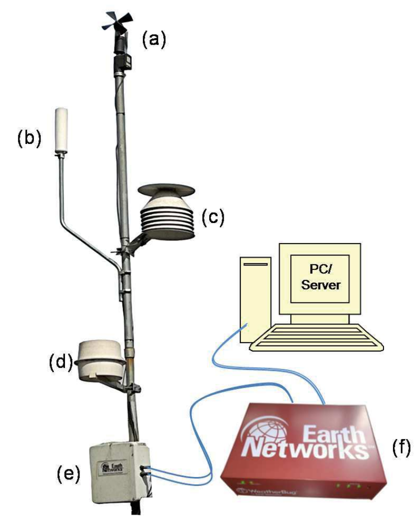

Figure 1. Total lightning sensor along with weather instruments: (a) Wind speed and direction sensor (b) Integrated in-cloud (IC) and cloud-to-ground (CG) lightning detection sensor (c) Sensor Shelter (d) Rain Gauge (e) Lightning Remote Box (f) Network appliance (see Midya et al., 2018 for details).

2 Experimental data

We have used Earth Networks total lightning data over the GWB to study the pre-monsoon thunderstorm events. The sensor of Earth Networks, installed at the Calcutta University (shown in Figure 1), is an integrated IC and CG lightning sensor operating in a frequency range from 1 Hz to 12 MHz (spanning the ELF, VLF, LF, MF, and HF ranges) and measures the electromagnetic signals from each lightning discharge (Heckman et al., 2014). The whole electric field waveforms are transferred from the censor to the central data processor of Earth Networks via internet. Central processor will then geolocate the individual lightning event and calculate the associated lightning parameters (such as peak current, multiplicity, differentiate lightning types etc.)based on waveform characteristics from multiple sensors (at least four). Each lightning discharge consists of several strokes. Individual strokes occurring within 700 ms and 10 km of the first stroke detected by the sensor are clustered into a flash. A flash is further classified as a CG flash if it contains at least a return stroke, otherwise it is classified as a IC flash. In Figure 2, we have presented a sample of electric field waveforms for four types of flash (positive IC, negative IC, positive CG and negative CG) observed on a Nor'wester day of April 17, 2018 over Kolkata. In addition, we also use weather and thunderstorm data from Indian Meteorological Department (IMD), Kolkata Centre.

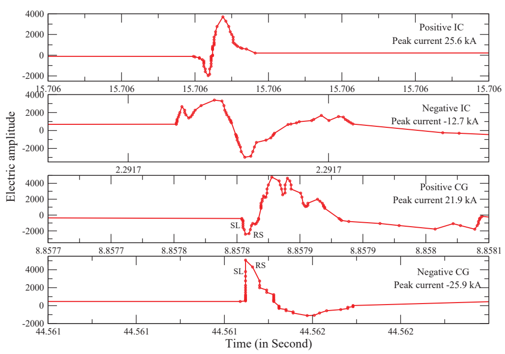

Figure 2. Typical waveform for four types of lightning flash recorded at Kolkata. Note the presence of stepped leader (SL) and return stroke (RS) in case of CG flashes.

3 Results and Discussion

In this work, we have analysed total lightning measurements of 35 thunderstorms during March to early June 2018 over GWB around Kolkata. We analyse the time evolution of total (IC+CG) flash rate, IC rate, CG rate, IC/CG ratio, peak current, multiplicity of individual lightning flash produced by all the thunderstorm events (severe and non-severe) in relation to severe weather parameters. Figure 3, presents an example of severe thunderstorm event occurred on April 17, 2018. A total 10,541 flashes were registered during 17:30 IST to 22:00 IST, of which of which 7,403 were in-cloud (IC) lightning (70.24 %) and 3,138 were cloud-to-ground (CG) lightning (29.76%). Further, out of all CG flashes, 17% flashes were positive CG. First panel of Figure 3, shows the spatial distribution of IC (red dots) and CG (green dots) flashes. Blue circle represents the location of the sensor. Lower panel shows the time evolution of different types of lightning flash rate per minute (CG flash rate-black curve; IC flash rate-red curve; total flash rate-blue curve) thorough out the life cycle of the thunderstorm.

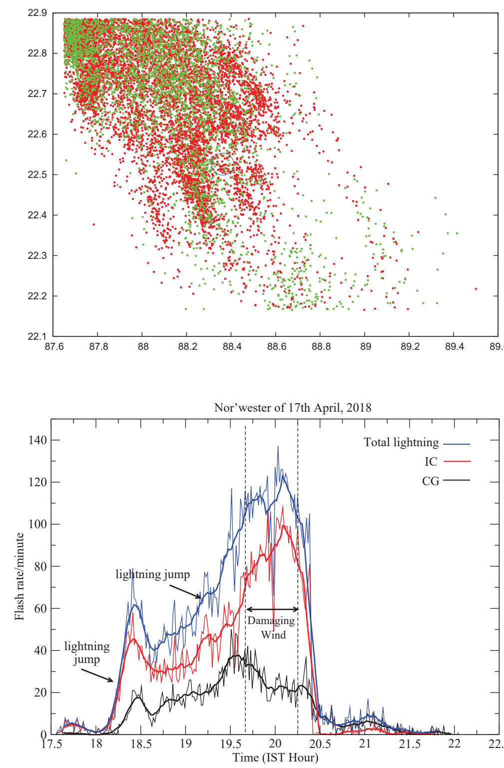

Figure 3. Distribution of IC (red dots) and CG (green dots) flashes around Kolkata (first panel) for the thunderstorm of April 17, 2018. Temporal evolution of lightning flash rates corresponding to the event (second panel).

Total lightning flash rate is increased gradually from 10-20 flasher per minute during the initial stage and reached to a peak about 120-130 flashes per minute during the active stage of thunderstorm. Lightning jumps are seen prior to both peaks. The dashed vertical lines are used to identify the time when Nor'wester hit the region with peak wind speed 98 km/hr recorded by IMD, Kolkata. The prominent lightning jumps occurred about 40 minutes to 1 hour well ahead of the peak damaging wind, intense lightning and heavy rainfall. This shows a possibility of predicting severe weather associated with thunderstorms. It is also to be noted that, the thunderstorm ended with a sudden decrease in IC flash rate and the CG flash rate peaked before the IC flash rate.

We have analysed all the thunderstorm events of this pre-monsoon season and found consistent lightning jumps well before thunder squalls and heavy rainfall. Figure 4, shows lightning flash rate for all the thunderstorm events for the month of May, 2018. Black lines show CG flash rate, red line show IC flash rate and blue lines represent total lightning (CG+IC) flash rate. Green vertical lines are the starting times of thunder squalls associated with the corresponding thunderstorms as recorded by IMD, Kolkata. We have found four types of lightning flash rate curves so far. Type I shows sharp initial increase in flash rate followed by slow

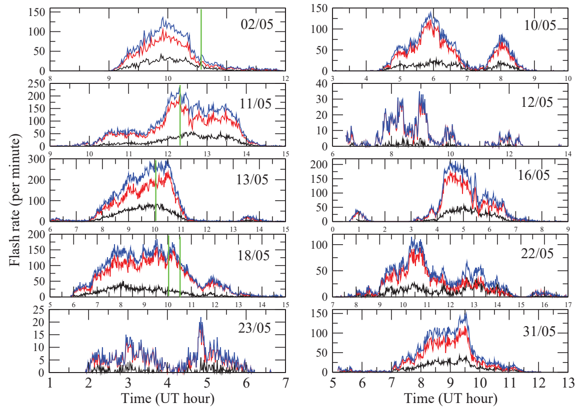

Figure 4. Lightning flash rates (CG flash rate-black curve; IC flash rate-red curve; total flash rate-blue curve) and corresponding thunder squall timings for all the thunderstorm events of May, 2018.

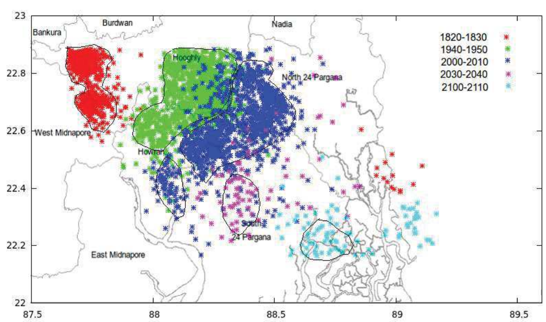

Figure 5. Temporal evolution of lightning cells during the Nor'wester event of April 17, 2018.

decay; Type II shows slow and gradual increase in flash rate but sharp decline followed by less lightning; Type III shows symmetric distribution of flash rate around the peak and Type IV shows low count rate with 2/3 peaks with no features. Type II and Type I are found to produce high damaging wind with intense lightning.

It is also possible to track the life cycle of a thunderstorm cell using the total lightning activity which is frequently done by the weather radar system. When the lightning flash rates are high enough, thunderstorm cells can be identified with total flashes occurring in clusters which can be be used for early warning of severe storms [Betz et al. 2008; Liu et al. 2014]. In Figure 5, we present an example of time evolution of lightning cells as 10 minutes snapshot of total lightning activity in the GWB region around Kolkata for the thunderstorm event of April 17, 2018.

4 Conclusions

Statistical analysis of total lightning data corresponding to all the thunderstorm events in connection with other meteorological parameters such as CAPE index,cloud top height, surface temperature, radar data is being done. We hope, the analysis would give more insight about total lightning characteristics of thunderstorms and help to develop a methodology of predicting severity of thunderstorms over Gangetic West Bengal.

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