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Studies on VLF atmospherics during the tropical cyclone "AILA" and several monsoon period thunderstorms over north-east India

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सार – इस शोध पत्र में अप्रैल 2009 से अक्तूबर 2009 की अवधि के दौरान भौतिकी विभाग, त्रिपुरा विश्वविद्यालय द्वारा वी. एल. एफ. वायुमंडलीय अथवा स्फेरिक्स की अभिलाक्षणिक विविधता को चार अलग – अलग आवृतियों में दर्ज किया गया है। इस शोध पत्र में उत्तर पूर्व भारत के 76 सक्रिय गर्ज के साथ तूफान वाले अधिकाँश दिनों के आँकड़े प्रयुक्त किए गए। इनसे प्राप्त परिणामों में मानसून के दौरान स्फेरिक्स परिवर्तन में कई प्रकार की विशेषताएँ दर्शाई गई हैं। इन क्रमिक गिरावट, क्रमिक वृद्धि (जी. एफ. जी. आर.), क्रमिक वृद्धि अचानक गिरावट (जी. आर. एस. एफ.), क्रमिक वृद्धि क्रमिक गिरावट (जी. आर जी. एफ.), क्रमिक गिरावट अचानक वृद्धि (जी. एफ.एस. आर.), आकस्मिक वृद्धि क्रमिक गिरावट (एस. आर. जी. एफ.), अचानक गिरावट अचानक वृद्धि (एस. आर. एस. एफ.) अचानक गिरावट अचानक वृद्धि (एस. एफ. एस. आर.) अचानक गिरावट क्रमिक वृद्धि (एस. एफ. जी. आर.) तथा कठोर (Spiky) स्वरूप में दर्शाया गया है। मानसूनी सक्रिय गर्ज के साथ तूफानों वाले अधिकांश दिनों में सभी प्रकार के पैटर्नों में (जी. आर जी. एफ.) की आवृति अधिकतर प्रकरणों में दर्ज हुई है (प्रत्येक आवृति में औसतन लगभग 37 प्रतिशत घटनाएँ दर्ज हुई हैं) हमारी प्रेक्षणात्मक अवधि के दौरान 23–26 मई की अवधि में बंगाल की खाड़ी में 'आईला' नामक एक तीव्र उष्णकटिबंधीय चक्रवात आर.एस.एम.सी. पदनामः बी. ओ. बी. ओ.2, जे. टी. डब्ल्यू. सी. पदनामः ओ. टू. बी. आया था। 25 मई 2009 के उष्ण के उष्णकटिबंधीय चक्रवात के दौरान सभी प्रकार के सामान्य मानसूनी अवधि की अभिलाक्षणिक विशेषताओं में एस.आर.एस.एफ. (प्रत्येक आवृति में 86 प्रतिशत के औसतन दर से घटित) आवृति अधिकतर प्रकरणों में देखी गई है। जब चक्रवात बंगाल की खाड़ी के तटों से टकराया उस दिन के स्फेरिक्स के अलग–अलग आवृति वितरणों के अनुसार वृद्धि और गिरावट का गंभीरता से विश्लेषण किया गया। मानसूनी दिनों और 'आइला' चक्रवात सक्रिय दिवस के सभी के सभी प्रकार के पैटर्नों का तुलनात्मक अध्ययन किया गया। हमारे निष्कर्ष के अनुसार प्रचंड चक्रवात 'आइला' और अन्य गर्ज भरे तूफान वाले मानसूनी दिनों के दौरान उत्तर पूर्व भारत में बादलों की सूक्ष्म संरचना में काफी अंतर दिखा। चक्रवाती गतिविधि के दौरान स्फैरिक्स के देखे गए बदलाव की संभावित व्याख्या को गर्ज भरे तूफान वाले बादलों की तड़ित गतिविधि के आधार पर समझाया गया है।

ABSTRACT. The present work reports the characteristic variations in VLF atmospherics or sferics at four discrete frequencies recorded at the Department of Physics, Tripura University, during the period from April 2009 to October 2009. Data from 76 active thunder days over North-East India is considered for the present investigation. Results show several types of features in the variation of sferics during the monsoon period. These are termed as gradual fall gradual rise (GFGR), gradual rise sudden fall (GRSF), gradual rise gradual fall (GRGF), gradual fall sudden rise (GFSR), sudden rise gradual fall (SRGF), sudden rise sudden fall (SRSF), sudden fall sudden rise (SFSR), sudden fall gradual rise (SFGR) and spiky. During the Monsoon thunder active days, amongst all the patterns, GRGF occurred in most of the cases in all frequencies (average occurrence rate around 37% in each frequency). During our observational period, a severe tropical cyclonic storm named "AILA" (RSMC Designation BOB02, JTWC Designation 02B) occurred over the Bay of Bengal during 23-26 May 2009. Among several characteristic features during normal Monsoon period, SRSF (average occurrence rate around 86 % in each frequency) dominated the sferics on the 25 May, 2009, when the cyclone struck the coastal areas of the Bay of Bengal. The sferics of that day has been analyzed critically with respect to discrete frequency distribution of rise rate and fall rate of the intensity of the sferics. A comparison is made for all the patterns for the Monsoon days and the AILA cyclone active day. Our findings show substantial difference in the microstructure of clouds producing severe cyclonic storms like AILA and other thunderstorms during Monsoon seasons over North-East India. The possible interpretation of the observed variations in sferics is explained on the basis of the electrical activity that occurs inside a thunder-cloud especially during cyclonic activity.

Key words – VLF atmospherics, Tropical cyclone, Monsoon cloud, Electrical activity inside thundercloud, Microstructure of cloud.

1. Introduction

Electromagnetic radiation from lightning generating thunderstorms has been observed for many years using ground and space based instrumentation. The methodology behind monitoring of lightning activity has also become sophisticated day by day with the advancement in its detection technology. Presently, some ground based networks such as the National Lightning Detection Network (LNDN) (Biagi *et al*., 2007) and satellite based instrumentations like Optical Transient Detector (OTD) (Buechler *et al*., 2000) and the Lightning Imaging Sensor (LIS) (Yuan *et al*., 2011) are being used for observing the time and the location of individual lightning strokes. Studies of electrical characteristics of thunderclouds are also possible with the help of sensitive instruments onboard on an aircraft.

Lightning return stroke current propagates both upward and downward from the junction point, where the upward connecting discharge channel contacts the downward propagating stepped leader, which lies several tens of meters above the ground (Cooray *et al*., 2004). Both upward and downward current waves contribute to radiation pulse from a few Hertz to several Mega Hertz (De *et al*., 2010). An active thundercloud may be regarded as an electrical generator suspended in an atmosphere of low electrical conductivity. Some high lightning flash region commonly "hot spots" are observed in the tropical region of the Earth (Boccippio and Goodman, 2000). The majority of thunderstorms on the Earth occur within the tropical regions between 30º N to 30º S of the equator. Thus the tropical region is the belt of the majority of the globe's thunderstorm activity.

Lightning associated electromagnetic pulses, known as radio atmospherics or sferics is an efficient and widely used tool for both scientific investigations of lightning strokes and engineering assessments of the interference environment during thunderstorms (Wood and Inan, 2002, Haklander and Delden, 2003, Ingmann *et al*., 1985, Cherna and Stansbury, 1986). In this paper, we are reporting the results of measurements of lightning electrical characteristics during monsoon period in the state of Tripura in North-East India. As the lightning activity is concentrated mainly in the tropical region of the Earth and we are located at the tropical region, the knowledge of the nature of tropical thundercloud activity over North-East India demands some special meteorological interest (Goswami *et al*., 2010). In addition, North-East India is in the close vicinity of the Great Himalayas and the Bay of Bengal, hence the site is ideal for studying effect of the mountain-land-sea contrast on the characteristics of sferics during tropical thunderstorms (Guha and De, 2009). During the period of data collection, a severe tropical cyclone occurred on 25 May 2009, over the Bay of Bengal, in which the sferics showed typical electrical behaviour of cyclonic activity other than the monsoon thunderstorm activity. The exact electrical processes during a thunderstorm are not yet exactly understood. However, it is rather difficult to construct an empirical model for lightning parameters to understand the spectral details of radiated electromagnetic energy.

2. Experimental arrangement

We arranged our experimental setup to receive the VLF sferics at the roof of the Department of Physics, Tripura University (latitude : 23.50º N, longitude : 91.25º E) at a height of 20 meter from the ground using a loop antenna of one square meter in area with its axis pointing towards geographic North-South direction. The induced voltage was then fed to a preamplifier near the loop antenna. The preamplifier unit was run with the help of batteries to remove unwanted harmonic distortion coming from AC-DC power supplies. The whole arrangement was made waterproof. The signal from the preamplifier was taken to the laboratory with the help of RG-54 shielded coaxial cable. It was then fed to a 24 bit sound card of a P-IV 2.66 GHz laptop computer. The internal clock of the computer was synchronized with GPS receiver automatically at an interval of two minutes. At the input of the sound card, proper protection was taken to ensure the elimination of surge voltages. The signal was then processed online with the help of Spectrum Lab V2.7b14 software VLF receiver. The software VLF receiver collected data by using the sound card at a sampling of 48 kHz. The FFT of the pre-amplified signal was done at 65,536 points using "Hann FFT window function" to get the Fourier spectrum. Four digital band-pass filters were designed with a Q-factor of 300 at four frequencies 4, 7, 9 and 11 kHz within the software receiver. We took these particular four discrete frequencies according to their noise figures during normal and disturbed atmospheric conditions for the last two year had been better than other frequencies. The r.m.s. value of the signal within the each frequency band at the desired frequency was recorded at a sampling rate of one second. The overall receiver was calibrated to produce input voltage in dB scale above 1 μV.

3. Observational results

Ground measurements of sferics at discrete frequencies are being continued at our station from September 2008. In this paper, we analyze the sferics pattern of 76 thunder active days and a severe cyclonic activity "AILA" on 25 May 2009 during the observation period from May 2009 to October 2009 using 4, 7, 11 and

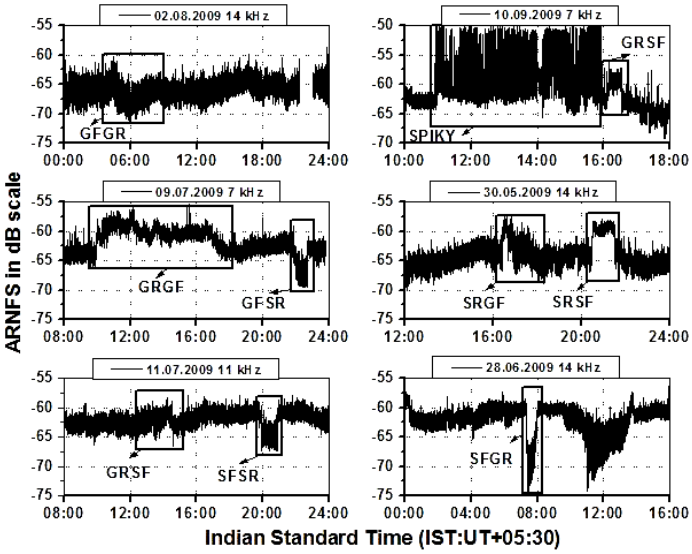

Fig. 1. Patterns of sferics of all the nine events during several thunder activity

14 kHz discrete VLF sferics. During the monsoonal thunder activity we got nine specific patterns of sferics. The specific patterns as an example at different frequencies are shown in the Fig. 1. They are termed as Gradual fall gradual rise (GFGR), Gradual rise sudden fall (GRSF), Gradual rise gradual fall (GRGF), Gradual fall sudden rise (GFSR), Sudden rise gradual fall (SRGF), Sudden rise sudden fall (SRSF), Sudden fall sudden rise (SFSR), Sudden fall gradual rise (SFGR) and Spiky. It is evident from the observations that during the monsoon thunderstorm period gradual rise and gradual fall (GRGF) event is mostly occurred with 37% average percentage of occurrences in each frequency. So the event GRGF is the most prominent feature of the monsoonal thunder activity over the North east India region Sarkar *et al*., 1980 observed several patterns like gradual rise of atmospherics, steady recovery of atmospherics and sudden enhancement of atmospherics at 10 and 20 kHz sferics during monsoon, pre-monsoon and post-monsoon thunderstorms discussed the variations in terms of charge separation process inside thunderclouds. Several workers are also reported several distinct patterns in the integrated field intensity of atmospherics (IFIA) at different frequencies characterized the dynamic electrical behavior of the thunderstorm activity and also confirmed that the GRGF event mainly occurred in the monsoonal thundercloud activity (Sarkar *et al*., 1982, Bhattacharya *et al*., 1994, Guha *et al*., 2009).

But during the cyclonic activity we observe typical variation of sferics at frequencies 4, 7, 11 and 14 kHz as shown in the Fig. 2. The patterns of sferics are completely different with the sferics variation in the monsoonal thunderstorm activity. Fig. 3 shows the variation in the average percentage occurrence in the discrete four frequencies of the nine events in the monsoonal thunderstorm activity and in the cyclonic day. On the other hand, during the cyclonic activity of AILA, sudden rise and sudden fall (SRSF) event is mostly effective and the percentage of occurrences of the SRSF event at that day is around 86%.. De *et al*., 2011 also reported 16.3 dB increase of IFIA for 3 kHz and 16.9 dB increases for 9 kHz respectively recorded from Calcutta during the cyclonic activity "AILA". They also observed that the sferics variation during the cyclonic activity is consisting of sharp steps rather than gradual enhancement in Pre monsoon or Post monsoon thunderstorm activity. Bhattacharya and Bhattacharya, 1983 also observed sudden enhancement and then distinct fall in the IFIA at 30 kHz recorded from Calcutta during two Pre monsoon tornados over the Gangetic West Bengal. Our observation is quite different from the observation reported by the De *et al*., 2011, as we observed several sudden rise and sudden fall (SRSF) event where as De *et al*., 2011 only observed an increase in the sferics level during the cyclone activity.

Fig. 4 depicted the variation of rise rate and fall rate of sferics per minute for the all discrete frequencies. It shows the typical frequency dependence in two different manners for the rise rate and the fall rate of sferics. The rise rate graph show peak at 7 kHz and then decreases at both sides of the frequency range but the fall rates for different frequencies show quite small variation with

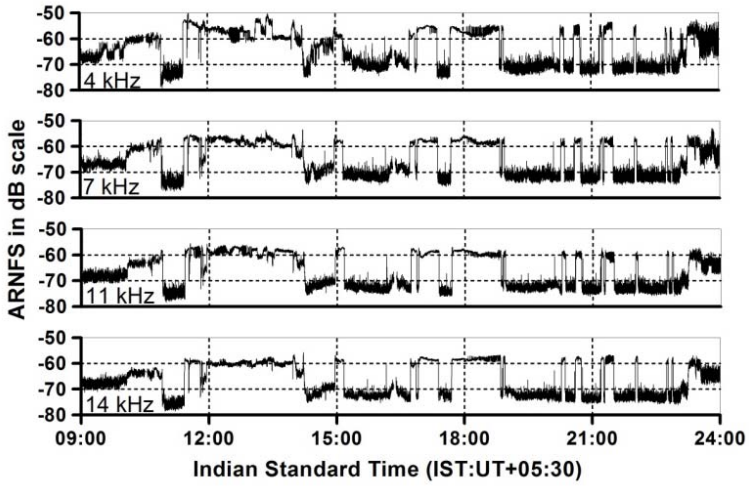

Fig. 2. Patterns of sferics during the cyclonic activity "AILA" on May 25, 2009

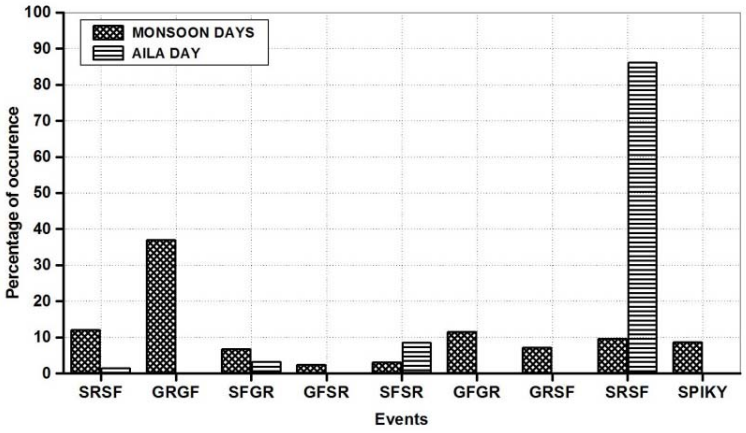

Fig. 3. Percentage of occurrence variation in the monsoon days and in the cyclonic activity "AILA"

maxima at 4 kHz and 7 kHz and minima at 11 kHz and 14 kHz. The average rise rate change is 0.10 dB/min for each frequency whereas the average fall rate change is 0.03dB/min, which is 3.33 times lesser than the rise rate change of sferics in monsoonal thunderstorm days. But during the "AILA" cyclonic activity the sferics show typical sferics variation as shown in the Fig. 2. The event SRSF is predominant during the cyclonic activity. The rise rate and fall rate variation of SRSF in the AILA active day and in the monsoon days are shown in the Fig. 5. In the monsoon days the rise rate and the fall rate show peak at 4 kHz and then decreases. The average rise rate for SRSF during the monsoonal thunderstorm days is 0.63 dB/min whereas the average fall rate change is 1.25 dB/min. But the rise rate and fall rate of SRSF in the cyclonic activity "AILA" increases with frequency. Both show minima at 4 kHz and maxima at 14 kHz. The average rise rate of SRSF in "AILA" is 12.84 dB/min whereas the average fall rate change is 8.29 dB/min.

4. Discussion

The complex electrical processes inside the thunderclouds and the breakdown of lightning producing channel are not yet understood to scientific community completely. The different patterns of frequency distribution during the monsoon thunderstorms and also during the "AILA" may be related to the different physical mechanism associated with the formation and then dissipation of the different types of thunderstorms (De *et al*., 2009).

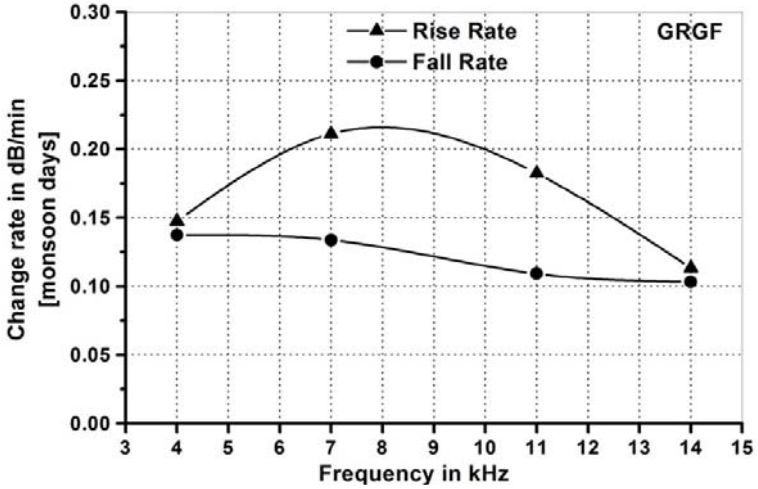

Fig. 4. Rise rate and fall rate variation with frequency for the event GRGF during monsoonal thunder activity

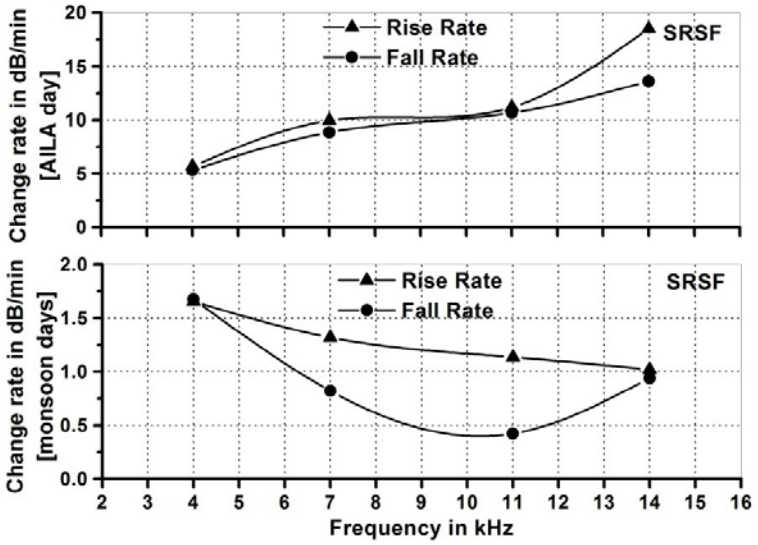

Fig. 5. Rise rate and fall rate variation with frequency for the event SRSF during the cyclonic activity (above) and monsoonal thunder activity (below)

The monsoon thundercloud over the North East India originates from the Bay of Bengal. The monsoon thunderclouds develop under the influence of the southwest monsoon current and the easterly wave trough line. The gradual rise in the sferics level in the monsoon period occurred mainly due to the fact that the monsoon cloud gradually approach the observational site and whose speed is highly governed by the easterly wave (Sarkar *et al*., 1980). The different stages of enhancements or decrements in the record of the atmospherics may be attributed closely to the processes inside the formation of cumulonimbus cloud structure.

During the Cyclonic activity, the presence of several sudden rise and sudden decrease in the sferics level indicates the rapid developing and dissipating of the charge centers inside the thunderstorm. The occurrences of the peaks in the sferics change rate in the discrete frequency response curve are the characteristics of the particular thunderstorm and indicate the typical characteristics of the thunderstorm. Due to the vigorous charge separation during the precipitation and during the lightning processes several enhancement and decrement in the sferics level occurred during the AILA cyclone activity. Furthermore, the local topology of the North-

East India is concerned, it is very important to study the lightning characteristics over this region because of the presence of the mountains and hills in the local terrain that can modify largely the lightning density.

5. Conclusions

In the present study, we are confined to a particular Monsoon season in tropical region in Eastern and North-Eastern India. As already pointed out, these thunderstorms happen mainly in an area between mountain-land-sea regions (The Himalayas-North-East India-The Bay of Bengal). As evident from satellite and different ground based observations, the Himalayan region is one of the intense lightning producing zones in Asia continent. The Bay of Bengal is also an active region of depression and cyclone.

The study of lightning electrical characteristics is essential for the basic understanding of its microphysics as well as to protect sensitive instruments from harmful interference from the lightning stroke. The frequency of air-travels and rocket launches has also increased in the last decade. Taking into consideration of the above, we believe that more initiative must be taken to explore the electrical characteristics of different thunderstorm especially in tropical regions like India. Coordinated networked stations in synchronized mode must be set up to study the physics of thunderstorms. The results may give new places of interest concerning the mechanism of thunderstorm evolution and to predict its future behavior more accurately.

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