Studies on the effects of AILA-2009 on VLF Integrated Field Intensity of Atmospherics

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Abstract

Remarkable effects on the records on Integrated Field Intensity of Atmospherics (IFIA) over Kolkata (latitude: 22.56° N, longitude: 88.5° E) at 3 kHz and 9 kHz are observed due to severe electrical activity in a thunderstorm, AILA, followed by severe thundershowers and lightning. The analyses and evaluation of the recorded data have been presented here.

1. Introduction

The lightning discharges are observed on the continents in near equatorial zones. In the area of atmospheric electricity, we are taking continuous records of ELF-VLF IFIA at frequencies 3 kHz and 9 kHz from Kolkata to detect and interpret different solar and geophysical events. The variation of air-temperature, electric field, air-earth current and conductivity over the surface of the Earth at tropical latitudes (±25°) and temperate latitudes (±60°) during the fair-weather and also under disturbed conditions are interrelated with the solar radiations, global thunderstorm activities as well as with the concentration and nature of aerosol content in the lower atmosphere [1, 2, 3, 4].

There are thermodynamic models of tropical cyclones from which its maximum potential intensity are estimated [5, 6, 7]. The characteristics of cyclone as well as the distribution of the epicenters of cyclones are being determined through the recording of electromagnetic radiation of thunderstorm discharges by VLF receiver systems at Kamchatka [8, 9].

A strong thunderstorm front was passed over the Northern part of Bay of Bengal during May 23-26, 2009. Strong lightning discharges were visually observed in Kolkata (www.imd.gov.in/section/nhac/dynamic/AILA.pdf). On May 25, 2009, remarkable effects on the sferics were detected due to severe cyclonic storm, AILA, followed by deep thundershowers and lightning.

In this work, the morphological structure of IFIA during intense cyclone has been analyzed. Nature of IFIA in relation to tropical cyclone is also considered. The results of analyses and scientific explanation of the observed effects on sferics at frequencies 3 kHz and 9 kHz recorded from Kolkata on the event of this AILA are reported.

2. General Features of AILA

AILA, a severe cyclonic storm, crossed over Kolkata on May 25, 2009, at about 1430 hrs IST. Due to South-West monsoon over the Bay of Bengal, the horizontal pressure gradient, North-South wind gradient and relative vorticity had been increased. It developed upper air-cyclonic circulation which extended upto mid-tropospheric level and became associated with convective cloud cluster. Low pressure area formed over the said region due to the influence of cyclonic circulation. It transformed into a depression that intensified to a deeper one. The system moved along the northerly direction and converted to cyclonic storm. This signature further increased to form AILA.

AILA was detected and tracked by Conventional Cyclone Detection Radar (CDR) at Paradip and Doppler Weather Radar (DWR) at Kolkata. INSAT, METEOSAT, WINDSAT satellites monitored the phenomenon AILA.

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Cyclonic low level circulation formed on May 21, 2009 at 0830 hrs IST over Bay of Bengal (latitude: 16.5° N, longitude: 88.0° E) at a distance of 600 km from Sagar Island. INSAT image for severe cyclone is shown in Fig. 1. On the next day morning, the area maintained low pressure. The system started to move in Northward direction, become strengthened which formed depression on May 23, 2009 at 1130 hrs IST and gradually became further intensified during its propagation. It then changed to a deep depression and converted to a cyclonic storm at latitude: 18.5° N, longitude: 88.5° E on May 24, 2009 at 1730 hrs IST accompanied by severe thunderstorm, lightning, wind shear, turbulence, rainfall and other meteorological outcomes. This severe cyclonic storm (AILA) that happened near Sagar Island (latitude: 21.5° N, longitude: 88.0° E) on May 25, 2009 at 1130 hrs IST crossed over Sagar Island on May 25, 2009 at around 1330 to 1430 hrs IST. INSAT image during landfall of AILA is depicted in Fig. 2. It then slowly diminished, converted into cyclonic storm at the Gangetic West Bengal, close to Kolkata, on May 25, 2009 at 2030 hrs IST. It crossed Kolkata with wind speed 100 to 110 km h^{-1} along with strong lightning. Deep depression developed on May 26, 2009 at 0830 hrs IST over Sub-Himalayan West Bengal and Sikkim. INSAT measured the intensity of the cyclone at different locations during its movement in terms of T number. It changed from a value of T1.0 to a maximum value T3.5 at the time of severe cyclonic storm occurred on May 25, 2009 at 1130 hrs IST. METEOSAT and WINDSAT measured the wind shear of the storm. The former showed the value of wind shear (~10-20 knot) on May 23, 2009, whereas the later measured the value (~25-30 knot) at the same time. Strong southerly surge of the monsoon current led the wind speed relatively stronger in the South-East sectors. METEOSAT measured the sea surface temperature (SST) at about 28° C, which was about 0.5 to 1.0° C above normal.

3. Experimental Arrangements

The recordings of the VLF sferics are made by computerized data acquisition system through a PCI 1050, 16 channel 12 bit DAS card. A block diagram of the recording system is given in Figure 1. The VLF receivers were tuned at 3 kHz and 9 kHz. The overall gain of the amplifiers is around 40 dB. The rms value of the signals is recorded in a computer. The recorded data were analyzed using Origin 5.0.

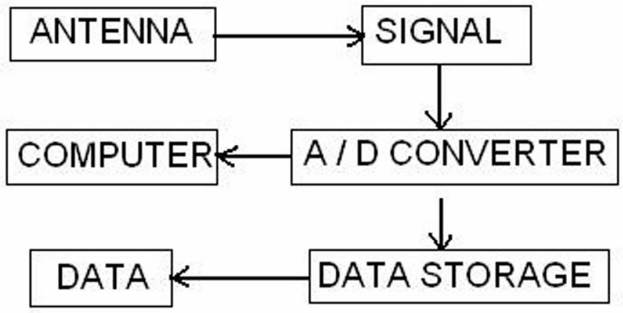

Figure 1. Block diagram of VLF measurement system

4. Observational Results

The levels of sferics at 3 kHz and 9 kHz during AILA are shown in Figures 2 and 3, respectively. The levels have vastly enhanced from their ambient values maintained during the 15 adjacent days. Figure 2 depicts the temporal variation of the sferics at 3 kHz on May 25, 2009 (red coloured curve) together with its normal trend obtained from the average of 15 days adjacent to the day of occurrence of AILA (black coloured curve). Error bars denote standard deviations. During the day of AILA, the IFIA at 3 kHz exhibited a step-like increase from the ambient value at about 1100 hrs IST, and continued up to 1300 hrs IST and then increased following another step which is again followed by gradual increase till 1830 hrs IST. The time required for enhancement from ambient level to maximum level is 7 hr 30 min. After that, it started to decrease. The value increased from about 20 to 130 units, an increase of 6.5 times or 16.3 dB during the period of crossing of AILA over Kolkata. Then the level decreases to some extent until local midnight, although the value remaining significantly higher than the average value. The nature of decrease of IFIA from the maximum value also consisted of two sharp steps. The observed enhancements are well above the standard deviation, indicates the occurrence of severe cyclonic storms, AILA.

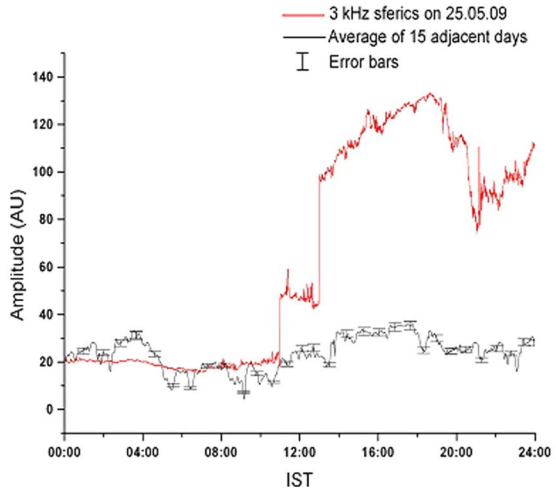

Figure 2. Temporal variation of sferics at 3 kHz on May 25, 2009 are shown by the red coloured curve. The average of adjacent 15 days of occurrence of AILA is shown by the black coloured curve. The standard deviations are shown by error bars.

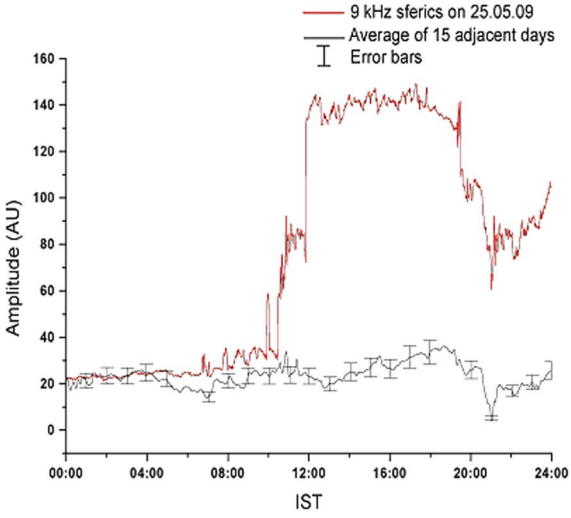

Figure 3. Temporal variation of sferics at 9 kHz on May 25, 2009 are shown by the red coloured curve while the average of adjacent 15 days of occurrence of AILA is given by the black coloured curve. The standard deviations are shown by error bars.

Similar plots for IFIA at 9 kHz are shown in Figure 3. The nature of variation is almost similar to that of 3 kHz. A comparative study of the observations at two frequencies is shown in Table 1.

Table 1: Various features of IFIA during AILA

Frequency (kHz)	Enhancement in 1st step (dB)	Enhancement in 2nd step followed by a small gradual increase (dB)	Overall Enhancement (dB)	Time interval from ambient level to maximum (hr)	Magnitude of principal fall (dB)	Time for the principal fall (hr)
3	8	8.3	16.3	7.5	4.2	2.25
9	12	4.9	16.9	7.5	7.4	2.35

It is to be noted that the enhancement of amplitude at 9 kHz is more than that at 3 kHz. The value starts to decrease from about 1900 hrs IST when AILA started to reduce its outrage and gets converted into a cyclonic storm. The amplitude came down to normal level of 20 units at about 0800 hrs IST of the next morning (May 26, 2009).

5. Discussion

The present observation shows that in the case of AILA, thunderstorm enhancement in IFIA start 7.5 hours prior to the main phase. These times are 4.25 and 5.5 hours in the case of pre-monsoon- and post-monsoon thunderstorms. The lightning begins during cumulus stage and its intensity becomes maximum during matured stage. The lightning activity decays out during dissipating stage. According to the record of IFIA, AILA is characterised by two-step enhancement from ambient level to the maximum value. The instability and relative wind conditions at different layers of the atmosphere may have favoured such occurrence. It is worth mentioning that as severe thunderstorm, lightning, rainfall, wind shear, turbulence and other meteorological outcome pass through the near ground surface of the atmosphere, the effective energy of AILA gets randomized. The collision rate between the constituent particles of the medium is increased instantaneously. Also, lightning discharges enhance non-linear electromagnetic coupling [9]. As a result, instability is produced causing ionization in the region. The relative

electron-ion drift velocity may exceed the value for the onset of Kelvin-Helmholtz instability. The compressivity property of the medium driven by the velocity shears at the frontal path of AILA increases the growth rate of Kelvin-Helmholtz instability which generates electromagnetic field. This field interacts with the VLF Sferics thereby exhibiting the observed effects in the Sferics signals at these two frequencies.

Severe cyclonic storm, AILA accompanied with thunderstorm and lightning. Sferics generated mainly from the lightning discharges propagates through the Earth-ionosphere waveguide throughout the globe maintaining an ambient value in its amplitude. Lightning generated transient atmospheric intensity within several kilometers from the Earth's surface enhances the VLF amplitude during the occurrence of AILA as shown in Figures 2 and 3. The magnitude of the received signals affect the 9 kHz signal more as because intensity of lightning generated electromagnetic waves are dominated surrounding 9-10 kHz. Hence, the increase in 9 kHz amplitude is greater than that in 3 kHz.

6. Conclusion

Studies are made sufficiently about the cause and the effects of AILA, but how to stop such paradigm and devastations! The answer is beyond the existing knowledge. Only the location of its origin and its nature by high power radar systems are determined, so that people can be alerted much in advance to take care for safety and survival. Our work here is an attempt to resolve some characteristic aspects of the problem.

7. Acknowledgments

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8. References

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