AILA-2009 and its Effects on VLF sferics

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***Abstract*— On May 25, 2009, remarkable effects on the recording on VLF sferics over Kolkata (latitude: 22.56° N, longitude: 88.5° E) at 3 kHz and 9 kHz are observed due to severe cyclonic storm, AILA, followed by severe thundershowers and lightning. The results and analyses of the recorded data along with other characteristics will be presented in this paper.**

***Index Terms*— Atmospheric depression, Severe cyclonic storm, Thunderstorm and lightning, VLF sferics.**

I. Introduction

THE lightning discharges are observed on the continents in near equatorial zones. The electromagnetic signals from lightning discharges are called sferics. The signals from lightning are spread out along the Earth-ionosphere waveguide. The world data about lightning discharges are used for the study of weather prediction, storms, cyclones, tsunami and other irregular, as well as complicated weather phenomena [1]-[6].

In the area of atmospheric electricity, we are taking continuous records of VLF sferics at frequencies 3 kHz and 9 kHz from Kolkata (latitude: 22.56° N, longitude: 88.5° E) 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 activity, as well as concentration and nature of aerosol content in the lower atmosphere [7]-[12].

There are thermodynamic models of tropical cyclones from which its maximum potential intensity are estimated [13]-[15]. In these works, the role of the ocean to provide the establishment of the environment suitable for cyclone development and then to provide additional energy require for the development of intense cyclone have been analyzed. Influences of tropical cyclone of the atmosphere and its role on climatic processes are also considered. 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 [16], [17].

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 [6]. 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 paper, the analyses of the observed effects on sferics at frequencies 3 kHz and 9 kHz recorded from Kolkata on the event of this AILA will be reported. Some specific studies about the very high enhancements of the signal amplitudes will be exhibited.

II. 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 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 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. Cyclonic low level circulation formed on May 21, 2009 at 0830 hrs IST. On the next day morning, the area maintained at low pressure. The system started to move in Northward direction, become strengthened which formed depression on May 23, 2009 at 1130 hrs IST at latitude: 16.5° N, longitude: 88.0° E 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

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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. 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. It continued with strong and vigorous exposition. Deep depression developed on May 26, 2009 at 0830 hrs IST over Sub-Himalayan West Bengal and Sikkim, followed by depression at 1130 hrs IST near Bagdogra, developing low pressure at the Sub-Himalayan and neighbourhood regions on May 27, 2009 at around 1430 hrs IST. 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 on May 23, 2009 (~10-20 knot), 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 sector, METEOSAT measured the sea surface temperature (SST) as about 28° C, which was about 0.5 to 1.0° C above normal.

III. EXPERIMENTAL ARRANGEMENTS

For the observation of power spectrum of VLF sferics at 3 kHz and 9 kHz, a straight horizontal copper wire of 8 SWG having 120 m length is used in the form of an inverted L type antenna. The antenna, which is installed 30 m above the ground, is capable of receiving vertically polarized atmospherics in the ELF-VLF bands from near and far sources of lightning discharges.

The antenna is mounted between the roof tops of two buildings. Due to wall effect, the effective height is assumed to be reduced by 20%. The high value of antenna height gives appreciable emf induced in the antenna. The large horizontal length yields large antenna capacitance even with large height. 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 Fig. 1.

The VLF receivers were tuned at these two frequencies. 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.

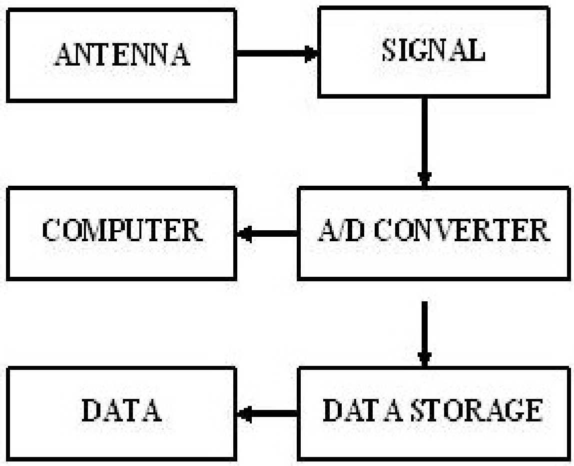

Figure 1. Block diagram of VLF measurement system

IV. RESULTS

The VLF spectral characteristics of the sferics at 3 kHz and 9 kHz have been studied during the AILA occurrence period at Kolkata. The levels of sferics at 3 kHz and 9 kHz during AILA are shown in Fig. 2 and Fig. 3. The levels have vastly enhanced than their ambient values maintained during the 15 adjacent days. The observations showed correspondence with the satellite and RADAR measurements.

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. The intensity of 3 kHz sferics (in arbitrary unit) starts to increase from about 1100 hrs IST, maintains some static value up to 1300 hrs IST and then increases till 1900 hrs IST. After that it started to decrease. The value increased from about 20 to 130 unit, an increase of 6.5 times 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 observed enhancement beyond the standard deviation indicates the occurrence of severe cyclonic storms, AILA.

Similar plots for sferics at 9 kHz have been shown in Fig. 3. The nature of variation is almost similar to that of 3 kHz sferics. The amplitude of sferics starts to increase from about 1100 hrs IST and becomes maximum at 1200 hrs IST, remains constant up to 1900 hrs IST. Then it started decreasing. It increased from 20 to 140 unit, i. e., an increase of 7 times during the peak hour of occurrence over Kolkata. 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 unit at about 0800 hrs IST of the next morning

(May 26, 2009).

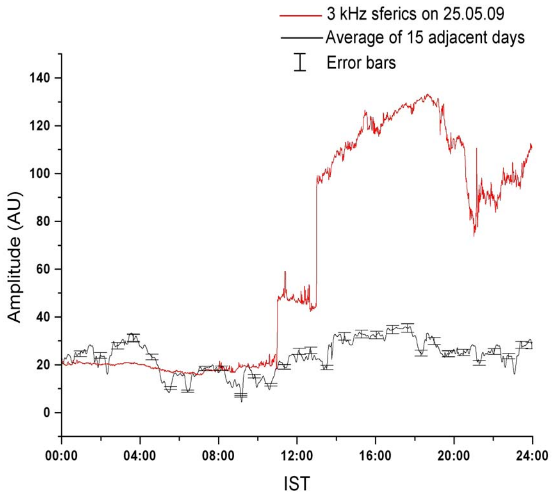

Figure 2. Temporal variation of sferics at 3 kHz on May 25, 2009, by the red coloured curve. The average of adjacent 15 days of occurrence of AILA is shown by the black coloured curve. The standard deviations are shown by error bars.

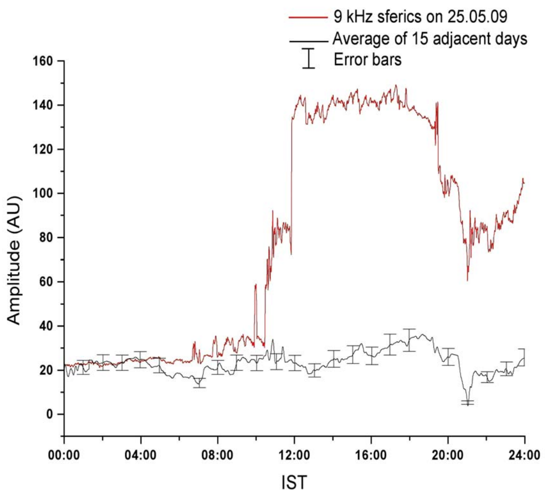

Figure 3. Temporal variation of sferics at 9 kHz records of May 25, 2009 are shown by the red coloured curve while the average of adjacent 15 days of occurrence of AILA is given by the black coloured curve. The standard deviations are shown by error bars.

V. Discussion

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 Figs. 2 and 3. The cumulative effects due to the generation of these lightning transients in large number and the proportional magnitude of the received signals affect the 9 kHz signal more. Hence, the increase in 9 kHz amplitude is greater than that in 3 kHz.

VI. Conclusion

Very uncommon natural phenomenon with high devastation capacity over a vast area from the surface of the sea towards landfall, covering several thousand square kilometres, started from the Bay of Bengal (latitude: 16.5° N, longitude: 88.0° E) on May 23, 2009 at 1130 hrs IST, crossed over Kolkata (latitude: 22.56° N, longitude: 88.5° E) on May 25, 2009, at about 1430 hrs IST and ended at the Sub-Himalayan and neighbourhood regions on May 27, 2009 at around 1430 hrs IST.

The effects of AILA on 3 kHz and 9 kHz sferics at Kolkata have been studied and the outcome of the analyses is presented in this paper. The change in values of amplitude of sferics shows that 9 kHz is more sensitive to thunderstorm and lightning relative to 3 kHz.

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