Effects of Solar Eclipse of July 22, 2009 on VLF Signals and Atmospheric Electricity Parameters over Kolkata

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***Abstract*— Some experiments on July 22, 2009, the day of solar eclipse, were undertaken at Kolkata (latitude: 22.56° N, longitude: 88.5° E) to observe the effect of solar eclipse on various parameters of the atmospheric electricity which are directly related to global thunderstorm activity and solar irradiation. Significant changes are observed in their values during the eclipse period than their ambient values for the same period in the adjacent five days, which will be presented here along with their interpretation.**

Index Terms— **Atmospheric electricity, global electric field, potential gradient, solar eclipse.**

I. INTRODUCTION

THE atmospheric electric field near the Earth's surface is governed by global thunderstorm and lightning activities [1], [2]. These put the Earth-ionosphere waveguide into resonance producing various characteristic spectra [3]. The disturbances in the ionosphere during solar eclipse have been reported in terms of VLF amplitude of sferics, amplitude and phase changes of transmitted signals [4]-[6], as well as changes in the Earth's near surface vertical electric potential gradient [7], [8]. The outcome of the results of experimental observations on atmospheric parameters and their analyses during the solar eclipse will be presented here.

II. PHYSICAL SITUATION DURING ECLIPSE

The eclipse started at 05:28.8 IST ON 22 July, 2009 and continued upto 07:30.9 IST, which was visible (maximum about 91.1 %) from Kolkata (latitude: 22.56° N, longitude: 88.5° E) throughout the period. The local sunrise and sunset period were 05:04 IST and 18:21 IST, respectively. The temperature was 28.4° C at the start of the eclipse which gradually falls to 26.2° C at the greatest phase at 06:26.4 IST. The relative humidity was 84.8 % at the start and increases to 87.2 % at the greatest phase. The sky was clear at the beginning of the eclipse and it remained clear about only 10 minutes period from the start, then partly cloudy for about 40 minutes. Then it became almost clear till the end of eclipse. The relative humidity at that time was 91.2 %. There was no rainfall during the eclipse period. The thundershower occurred around 09:00 IST which continued upto 10:20 IST. The sun was visible after the end of eclipse till sunset time at 18:21 IST.

III. EXPERIMENTAL ARRANGEMENT

We take observations from Kolkata. The vertical electric field is measured with an ac field-mill. The output is recorded by digital data acquisition system that uses a PCI 1050, 16 channel 12 bit DAS card (Dynalog) which has a 12 bit A/D converter, 16 digital input and 16 digital outputs. The data are recorded at a sample rate of one data per second.

The variation of sferic signals and subionospheric transmitted signals are being recorded continuously by VLF receivers from Kolkata. A straight horizontal copper wire of 8 SWG having 120 m length is used in the form of an inverted L type antenna. It is installed 30 m above the ground, capable of receiving vertically polarized atmospherics in the ELF-VLF bands from near and far sources of lightning discharges. The observations of power spectrum of sferics and subionospheric transmitted signals are carried out by this antenna.

The ground conductivity during the eclipse was measured by gerdien condenser (ion-counter). The air-earth current is being measured continuously.

IV. OBSERVATIONS AND ANALYSES

A. Vertical Electric Potential Gradient

Some marked deviations are observed in the values of vertical electric potential gradient during the period of solar eclipse on 22 July, 2009. Figure 1 depicts the temporal variation of vertical electric potential gradient on 22 July, 2009, during the solar eclipse (continuous line) and its values averaged over other 5 days adjacent to the date of occurrence (dotted line) along with the standard deviations from the average value plotted as error bars. It is found that there is a dip in the values of vertical potential gradient before the eclipse (around 03:00 IST) and a dip after the eclipse (around 13:30 IST). At the start of the solar eclipse, it starts to decrease from about 05:30 IST and reaches minimum during the eclipse

Manuscript received September 1, 2009. The authors acknowledge with thanks the financial support from Indian Space Research Organization (ISRO) through S K Mitra Centre for Research in Space Environment, University of Calcutta, Kolkata, India, for carrying out the study.

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978-81-8465-152-2/09/$26.00©2009 CODEC

period (07:00 IST). The minimum value is around 90 V.m^{-1}. Then it rapidly increases and reaches the normal level around 10:30 IST, again starts decreasing, becomes minimum around 13:00 IST. Then it again starts increasing and comes to a normal level at around 14:00 IST. The average value of the potential gradient of 5 adjacent days (3 days before the eclipse and 2 days after the eclipse) of solar eclipse is around 145 V.m^{-1}. It is significant that the continuous curve shows prominent variations from the average values during the period of eclipse since the variation is well beyond the standard deviation of the average trend. During the other period of the day of the eclipse, the continuous curve lies within the range of standard deviation of the average plot that reflects the similar trend of changes. Changes in ionization and conductivity of the medium during solar eclipse may be responsible for such result.

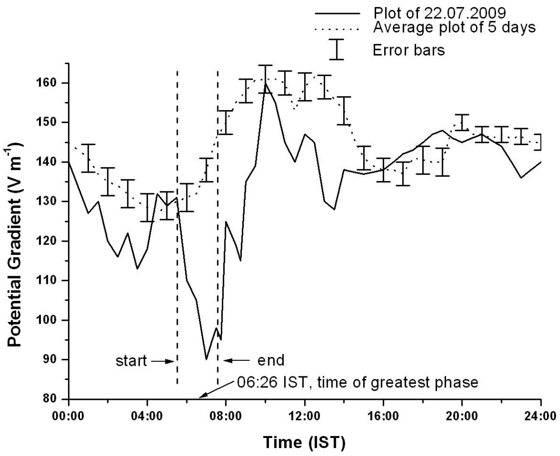

Figure 1. Temporal variation of atmospheric vertical electric potential gradient over Kolkata is presented by the continuous line curve during solar eclipse on July 22, 2009. The dotted line curve indicates averaged value over adjacent five days. The standard deviations from the average are shown by error bars.

B. VLF sferics and subionospheric transmitted signals

The VLF receivers were tuned at 1 kHz and 5 kHz 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.

The temporal variation of the sferics at 1 kHz on 22 July, 2009 (continuous line) together with its normal trend obtained from the average of 5 days adjacent to the day of occurrence of solar eclipse (dotted line) is shown in Fig. 2. Standard deviations are denoted by error bars. The amplitude (in arbitrary unit) is higher in the early morning (~02:00 IST) on the eclipse day than the average value. Then it starts to decrease from about 04:00 IST, maintains some lower value during the period of eclipse and starts increasing from about 08:30 to 09:00 IST. Within this period, the curve shows a zigzag nature. The minimum value of the sferics amplitude (~1.0 AU) during the period of eclipse is far beyond the average of about 1.7 AU. Then the level follows the average trend upto local midnight.

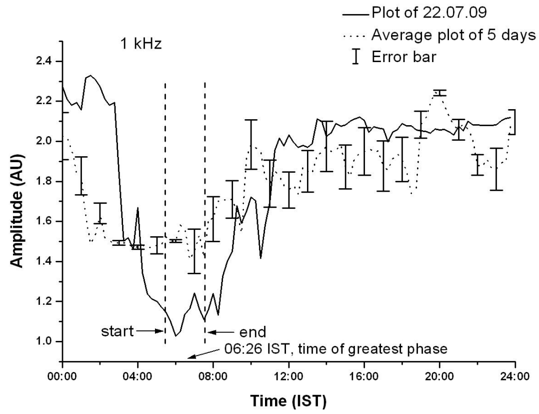

Figure 2. The 1 kHz sferic signal amplitude fluctuations, during the period of eclipse, are depicted by continuous line curve. The dotted line curve depicts the average value of adjacent 5 days. The standard deviations from the average are shown by error bars.

Similar curves for sferics at 5 kHz are shown in Fig. 3. The nature of variation of amplitude is almost similar. During the period of eclipse, the value decreases from the average value. The minimum value shows 1.45 AU while the average value is about 1.9 AU. In both the cases of 1 and 5 kHz, amplitude starts decreasing before the start of eclipse.

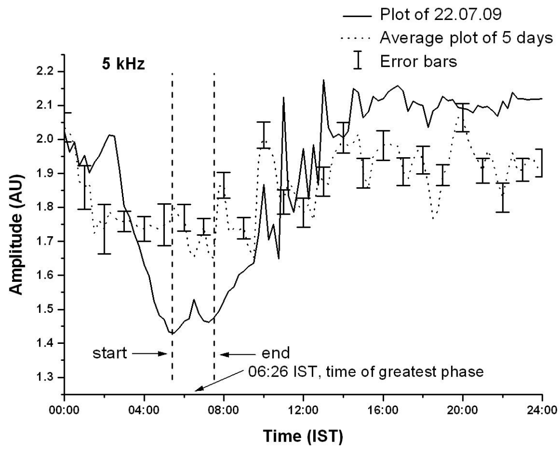

Figure 3. The 5 kHz sferic signal amplitude fluctuations, during the period of eclipse, are depicted by continuous line curve. The dotted line curve depicts the average value of adjacent 5 days. The standard deviations from the average are shown by error bars.

Continuous recording of a subionospheric VLF signal of 19.8 kHz frequency transmitted from North West Cape, Australia, (latitude: 21.82° S; longitude: 114.16° E) is also being carried out from Kolkata. About 65% of the signal propagation path (5665 km), the occurrences of the eclipse are 1% to 91% of the totality. Greater than 60% of the totality occurs within 1/10th of the propagation path and greater than 40% of the totality occurs on the 1/4th of the propagation path. The variation of amplitude of 19.8 kHz signal is presented in Fig. 4., where it starts to decrease from the average value of adjacent 5 days at about 02:30 IST, reaches its minimum almost at the beginning of the eclipse, 05:30 IST, eventually reached its normal value at about 09:00 IST. Then it follows the average trend up to local midnight.

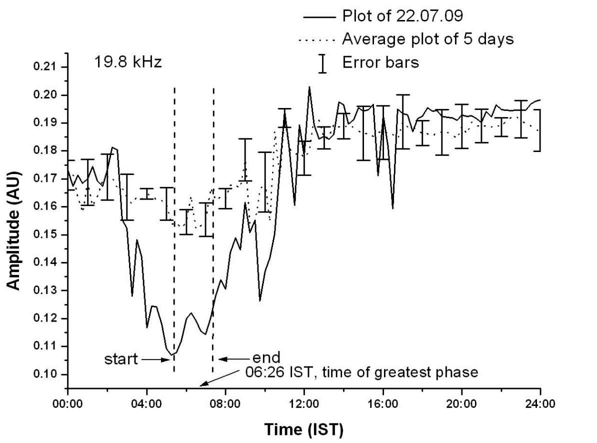

Figure 4. Variation of 19.8 kHz subionospheric signal, transmitted from North West Cape, Australia, (latitude: 21.82° S; longitude: 114.16° E) during the period of eclipse, has been shown by continuous line curve. The dotted line curve depicts the average of adjacent 5 days. The standard deviations from the average are shown by error bars.

C. *Ground level conductivity and point discharge current.*

Ground level conductivity is measured continuously by Air-ion counter (Gerdien condenser). During the period of eclipse, its value increases and reaches the maximum almost at the time of greatest phase of eclipse. It starts changing from 2×10^{-13} mho.m^{-1} at the beginning of eclipse to 3×10^{-13} mho.m^{-1}, at the time of greatest phase, shown by the continuous line curve (Fig. 5). Then, it starts decreasing slowly and attains the average value ~ 1.75×10^{-13}mho.m^{-1}, shown by dotted line curve. Error bars on the five days average curve show the standard deviation of conductivity parameter. The variation influenced the vertical electric potential gradient values, measured during the period. The leakage current measurement by point discharge method in the laboratory showed sudden decrease in its value during the periods of solar eclipse which is in support of lowering of vertical electric potential gradient at the surface of the Earth (as measured).

V. DISCUSSION

The vertical electric potential gradient at the surface of the Earth starts decreasing as the eclipse begins and reaches its minimum value at around 07:00 IST which is closer to the time of greatest phase. Immediately after, its value sharply enhances upto the end of eclipse. The potential gradient reduced slightly during the next about fifteen minutes and then grows sharply to reach its ambient value. In the absence of solar radiation during the eclipse, ionization and recombination processes get perturbed in the lower D-region of the ionosphere and an overall instability in the space charge distribution was attained. Atmospheric temperature dropped by 2.2º C and relative humidity increased by 2.4 % during the period. These factors grow the instability more [9]. From the time of the greatest phase, the charge distribution in the perturbed state introduces nonlinearity in the medium. Heuristically it may be said that the random migration of ions in the process of transportation enhances the conductivity (supported by our measurement), which is responsible for the observed fall of potential gradient.

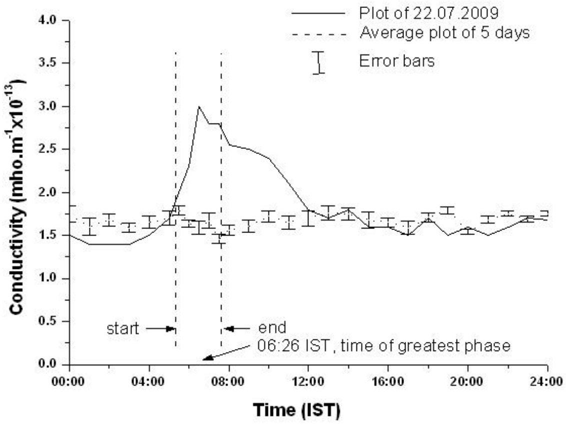

Figure 5. Temporal variation of ground level conductivity at Kolkata is presented by the continuous line curve during solar eclipse on July 22, 2009. The dotted line curve represents averaged value over adjacent five days. The standard deviations from the average are shown by error bars.

The July is the most effective month of monsoon season in Kolkata. At the time of solar eclipse, July 22, 2009, the fall of potential gradient was much steeper as shown in Fig. 1. During monsoon season, the location of the Asia-Australia thunderstorm centre is nearer to Kolkata than the other thunderstorm regions. So the influence of this centre would affect more in the value of the potential gradient over Kolkata. Uneven distribution of the thunderstorm regions over the globe influences the value of potential gradient which produce a bite-out zone in the curve during the post-eclipse period. Also, Kolkata is a densely populated and polluted city. So, Kolkata falls under small-scale fair weather condition where fluctuation of electric field is perturbed by ionization and different aerosol contents that are produced locally. Due to the presence of large number of pollutant particles in air near the surface of the Earth, the collision rate between those particles is increased that produce large number of ions which are accumulated near the 2 m level from the ground [7]. This increases the atmospheric conductivity. This may be the other possible reason of low value of potential gradient over Kolkata during the eclipse.

Moreover, surface potential gradient should also depend on change of pressure, temperature, formation of dense fog which also govern the conductivity of the medium. Thus the meteorological effects may also play some role for the lowering of potential gradient during eclipse [10], [11].

The increase of ionization at the ground level may also be explained in terms of the atmosphere becoming stably stratified before and during the greatest phase of the eclipse. Radioactive emissions from the soil are therefore least well-mixed and enhance the ionization rate near the surface [12], thereby increasing the surface conductivity and decreasing the potential gradient.

These are supported by ground level conductivity and point discharge current.

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