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Research Article

EFFECTS OF SOLAR AND LUNAR ECLIPSE ON IONOSPHERE NEAR THE CREST OF EQUATORIAL IONIZATION ANOMALY REGION BHOPAL

Rashmi C. Gupta, C.Suryanshu and A.K.Gwal

Department of Physics AISECT University Raisen, India

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ABSTRACT

In the present paper effects of solar and lunar eclipse on ionosphere near the crest of equatorial ionization anomaly region Bhopal (23.2 degree N, 77.6 degree E) have been studied .For present study two sets of consequent solar and lunar eclipse,which occurred in the year of 2014,have been chosen. As a fact solar eclipse always occurs about two weeks before or after a lunar eclipse. Our objective is to study the variation in TEC,amplitude scintillation indexS4 and interplanetary parameters during the eclipses.

INTRODUCTION

Theory indicates that after sunset the thermosphere is no longer receives the solar radiations and recombination occurs,as a result TEC would decay slowly and steadily.(Young, Yuen and Roelafs,1970) [1] studied the nighttime enhancement. (N.Balan, P.B.Rao and K.N. Iyer,1986) [2] also observed the solar variations of nighttime anomalous enhancements in TEC for a low latitude region.

The enhancement features such as frequency of occurrence, amplitude and duration are directly correlated with solar radiations.(N.Balan,G.J. Bailey and R. Balachandran Nair,1991) observed that the time of nighttime enhancement is independent of magnetic and solar activity. (N. Balan and P.B. Rao,1987)[4] suggested the latitudinal variations of nighttime enhancements in total electron content. It was shown that the TEC enhancements have small correlation with geomagnetic storms at low latitude. N. Balan, G.J Bailey,R.Balachandran Nair and J.E.Titheridge !994, reported that the enhancement features and their variation with solar activity also support the fact that the enhancement increases post sunset in equatorial region.

Solar radiation is blocked during solar eclipse.The eclipse turns off the ionospheres source of high energy radiations said Bob Marshal a space scientist at university of Colorado Boulder. The ionosphere undergoes from daytime condition to nighttime conditions and then back again after eclipse, without ionizing radiation

Hiding of the optical rays during solar eclipse which causes direct reduction in photo ionization,destroy the previous photo chemical equilibrium and results in the depletion in electron density.
Significant decrease in electron temperature reported by several scientists (e.g.,Evans 1965, Stubbe 1970, Salah et.al. 1986).

Density,Temperature,Velocity and Bz The measurements at Sondrestrom radar station show obvious reduction in the electron density,temperature, and ion velocity occurred during the solar eclipse period.The magnetic field measurements indicates pronounced decrease in X, Z and total field B and found enhancement in Y component.

The reduction in ionization in E layer is observed by Chapman S. The effect of a solar eclipse on the Earth's magnetic field [6] The Sun's extreme ultraviolet output is highly variable said Phil Erickson, a principal investigator of a third study and space scientist at Massachusetts institute of technology Haystack observatory in Westford Massachusetts. The ultraviolet output creates variability in ionospheric weather because our planet has a strong magnetic field, charged particles are also affected along magnetic field lines all over the planet.

Corresponding author:* **Rashmi C. Gupta
Department of Physics AISECT University Raisen, India

The automated communication or navigation signals gets affected by ionosphere's behavior during the eclipse. During day-night cycles the concentration of charged atmospheric particles, or plasma undergo alternate increases and decreases with the Sun. In the day time ionospheric plasma is dense, Earle said that when the Sun sets production goes away, charged particles recombine gradually through the night and the density drops.

The denser the plasma the more likely these signals are to bump into charged particles along their way from the signal transmitter to receiver. These interactions refract or bend,the path taken by the signals.

In the induced artificial night the scientists expect stronger signals. Since the atmosphere and ionosphere will absorb less of the transmitted energy.

The receivers are used to monitored the phase and amplitude of the signal. When the signal waggles up and down that's entirely produced by changes in the ionosphere.

Impact of solar Eclipse on Magnetic field

The ionospheric effects during eclipse imply an increase of the effective reflaction heights,reduction in the concentration of the F layer maximum and decrease in total electron content of the ionosphere (Cohen 1984,Afraimovich et.al 2000).

Our approach is to observe the variation in interplanetary parameters on the eclipse day (during the eclipse period) and compare it with the result on the day before and day after.

During solar eclipse phenomenon the ionosphere content may disturb by high activity on the Sun and the effects on our terrestrial environment are high. Solar activity during solar eclipse can cause the loss of lock of signals and degrading the accuracy of world wide navigation systems such as the GPS. GPS signals can be disturbed hence has potential to degrade the reliability and accuracy because of the satellite signals distortion as they propagate through the ionosphere layers. The ionosphere is a dispersive medium that bend the GPS radio signal and changes its speed as the signal passes through the various ionosphere layers to reach GPS receivers. There are many disturbances in the ionosphere such as amplitude scintillation,phase scintillation and TEC inclination.

Effect of Lunar Eclipse

The earthquakes are mainly occurred in dark moon day or after a few days of lunar eclipse. Aframovich et.al. (2000,2001) have also reported the ionospheric total electron content's effect during earthquake using sophisticated and accurate measurement of Total Electron Content using GPS. Lunar variation in ionospheric parameters shows different trend therefore the study of lunar daily variation are to be found.

The unique geometrical alignment of the Sun,the Earth and the Moon during an eclipse and effective tidal forces may be responsible for the observed phenomenon during eclipses. The gravitational tidal forces due to the Moon can cause variations in atmosphere, ionosphere and magnetospheric plasmas .

The primary cosmic rays particles,mostly protons, some alpha particles and a few heavier nuclei interect with the nuclei of atmosphere gasses and give rise to secondary cosmic rays, consisting of a hard component and soft component.

Since the cosmic rays being high energy charged particles penetrate into the lower atmospheres and are also filtered by the geomagnetic field. The filtering effect becomes variable in time with the magnetospheric currents that grow during the periods of magnetic activity allowing particles of a given energy to penetrate to lower latitudes where these particles produce ionization (Devendra Singh and R.P. Singh, The role of cosmic rays in the Earth's atmospheric processes).Ref 8

The ion production rate peaks at different heights depending on the energy of cosmic ray particle. It increases with latitude and decreases with solar activity.

Below the 15km altitude the production is by cascades of secondary particles. The ionization rate increases with geomagnetic latitudes and both the height of the peak and the slope of the ionization rate after the peak also increase. Near the ground there is about twenty percent variation between the equatorial region and the higher latitudes.

The space weather affects in many cases are related to geomagnetic storms. Usually a storm is said to occur when a sufficiently intense and long lasting interplanetary convection electric field, through a substantial energization in the magnetosphere . Ionosphere system leads to an intensified ring current strong enough to exceed some threshold value quantifying the storm "Dst" index.

METHODOLOGY

Methodology and Database

In the present study, ionosphere's TEC data have been used by ground. In this case we have measured the ionosphere's variation in the equatorial region.

The TEC measurement are obtained from the network of GPS Ionospheric TEC and Scintillation Monitors (GISTM) established in India under the Satellite based Augmentation System project – GAGAN (GPS Aided Geo Augmented Navigation) to study and develop the ionospheric model for GAGAN .The primary purpose of the GSV4004 GISTM is to collect ionospheric scintillation and TEC data for all visible GPS satellites . The observations from equatorial station Bhopal have been chosen.

The ionospheric scintillations have been measured using a 12 channel dual frequency NovAtel GPS receiver with embedded software to calculate and store TEC values in HDD of the PC via and RS -232 cable. The primary purpose of the GSV 4004 GISTM is to collect ionospheric scintillations and TEC data for all visible GPS satellites.

In order to detect the occurrence of amplitude and phase scintillation activity the analysis took into consideration that the S4 measurements from the GPS satellites must exceed values of 0.5.

We have chosen the dates in the year of 2014 on which the Solar and Lunar eclipse had occurred.

Total Lunar Eclipse (15 April 2014)
Annular Solar Eclipse (29 April 2014)
Total Lunar Eclipse (08 October 2014)
Partial Solar Eclipse (23 October 2014)

For the present study, solar index, dst index, kp index, Ap index,proton density, proton temperature and IMF magnitude were obtained from the OMNI Website. The individual parameters with the time have been calculated. These values are depicted in figures.

RESULTS AND DISCUSSION

Annular solar eclipse (29 April 2014)

[It was not observed at our equatorial station]
Figure 1(a),figure 1(b),Figure 1(c), Figure 1(d)

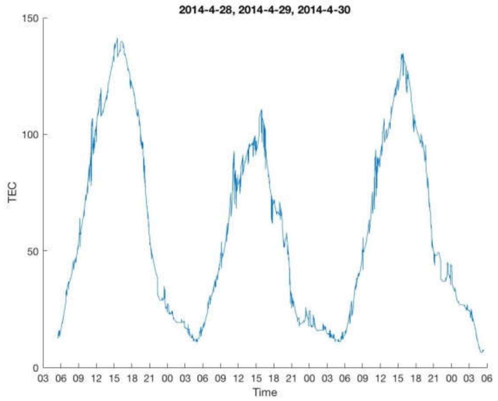

Figure 1(a)

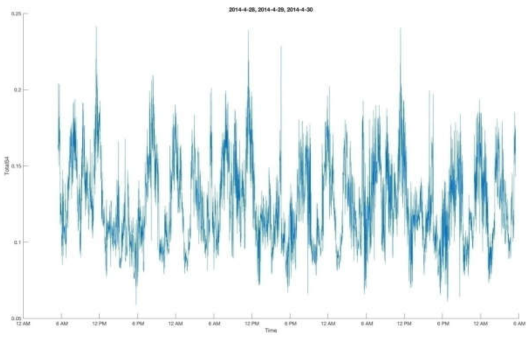

Figure 1(b)

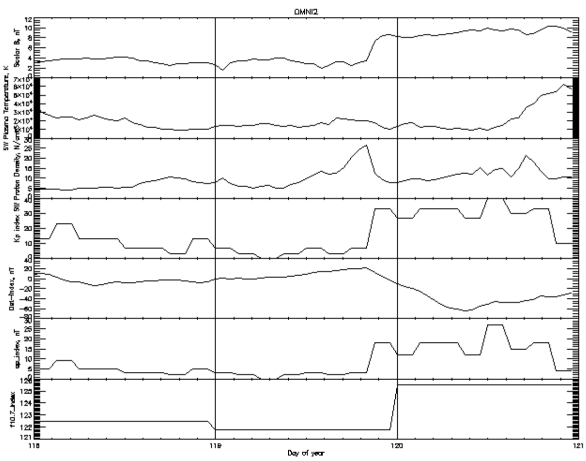

Figure 1(c)

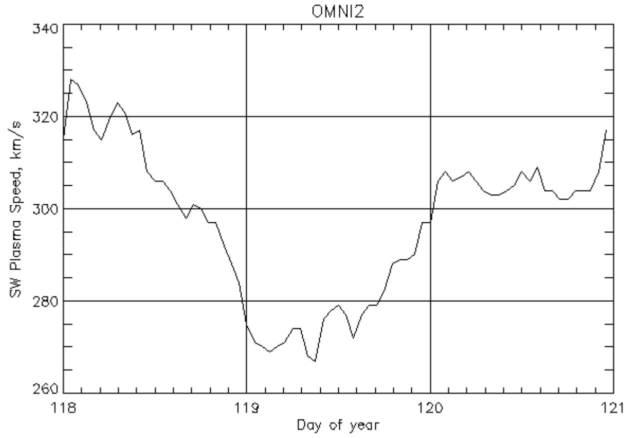

Figure 1(d)

Total Electron Content – Figure 1(a) shows the variation in TEC during the annular solar eclipse . It is clearly observed from the figure that TEC inclined on the eclipse day as compared to the previous day. In night hours TEC becomes minimum as the electrons start rejoining after sunset which supports the theory.

Amplitude Scintillation Index S4 – The variation in amplitude is represented in figure1(b).Frequent change in amplitude is observed during the eclipse day. Some peaks was higher than the value of (0.2) but the average value of the peaks on eclipse day was lesser than the previous day and next day.

Interplanetary Magnetic Field – The continuous variation in IMF has been observed on the solar eclipse day [Figure 1(c)].

Proton Temperature –The proton temperature gets down and very small change has been observed during the day [Figure 1(c)].

Proton Density- High variation in proton density has been found throughout the eclipse day [Figure 1(c)].

Kp Index – It was also shown much variation but it’s value was higher on next day[Figure 1(c)].

Ap Index – The variation was higher on next day as compared to the eclipse day.
The variation pattern was also similar to the Kp Index [Figure 1(c)].

Dst Index – The value of Dst index was higher than previous day but no sign of geomagnetic storm was occurred. Next day the value reached to (-60) which was the indication of geomagnetic storm [Figure 1(c)].

Solar Index – The value of solar index was lower than it’s value on previous day while it increased on the next day[Figure 1(c)].

Plasma Speed – Plasma speed got down on eclipse day. The average value was around 300-320 Km/s on previous day and next day. While on the eclipse daythe average value was around 270-280 Km/s [Figure 1(d)].

Partial Solar Eclipse (23 October 2014)

[It was visible in most of North America(not visible at our equatorial station)]

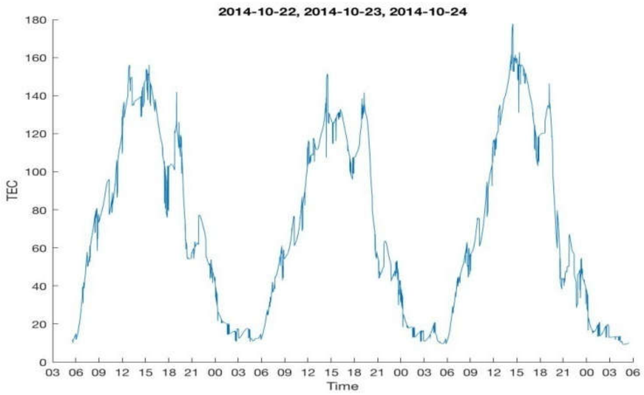

Figure 2(a)

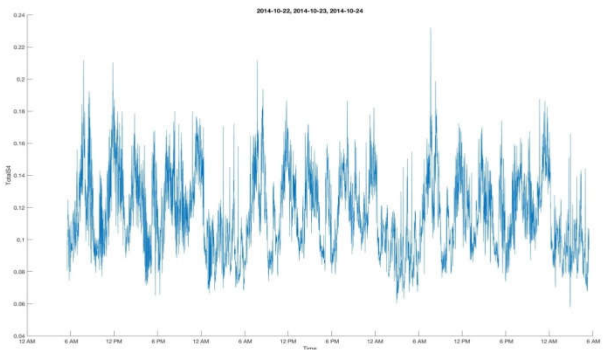

Figure 2(b)

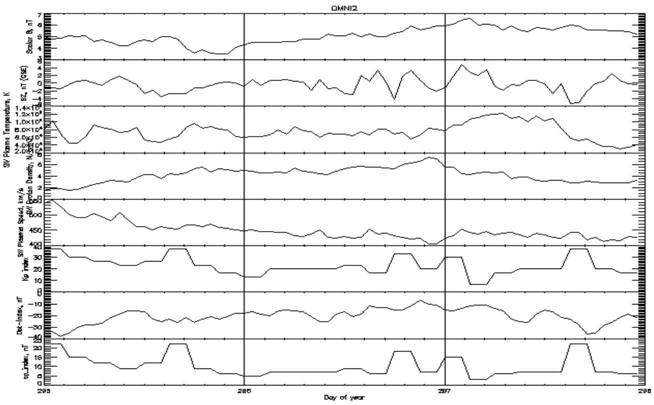

Figure 2(c)

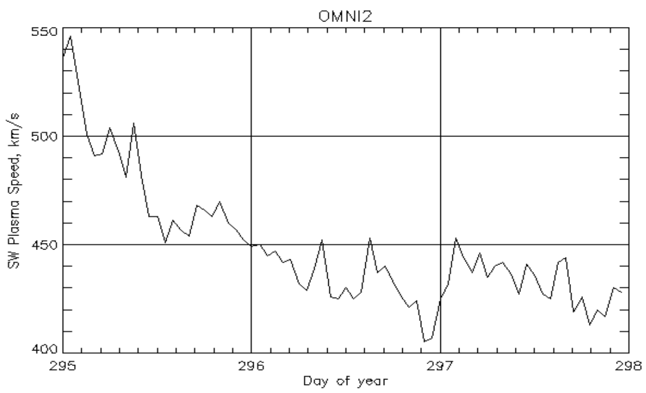

Figure 2(d)

Figure 2(a), Figure 2(b), Figure 2(c),Figure 2(d)

Total Electron Content – Very less TEC variation have been observed as compared to the previous day and next day. It may be due to the eclipse was not observed on the equatorial area [Figure 2(a)].

Amplitude Scintillation IndexS4 – On the day of partial eclipse the variation in amplitude was slower than the previous day and next day. Many peaks have been observed higher than the value of (0.16) but the average value of the peaks was lesser than the average value of peaks on previous day and next day [Figure 2(b)].

Interplanetary Magnetic Field – Very less variation has been observed in IMF on the eclipse day. It was volatile on previous day and the more changes was seen on next day [Figure 2(c)].

Proton Temperature – Frequent but slight changes in proton temperature have been observed during the eclipse day while on the next day the rise in proton density was observed [Figure 2(c)].

Proton Density – It has been volatile throughout the eclipse day .The decrease was observed in the late hours [Figure 2(c)].

Kp Index – The Kp Index has been higher in the evening hours.It has been more volatile on previous day and next day [Figure 2(c)].

Ap Index – The variation pattern of changeability was nearly similar to the Kp index [Figure 2(c)].

Dst Index – The Dst index has been changing from (-10nT) to (-30nT).There was no indication of geomagnetic storm [Figure 2(c)].

Solar Index – The solar index was higher than previous day and next day [Figure 2(c)].

Plasma Speed – It has been observed that the plasma speed was lesser than the previous day .The average plasma speed was (430 - 440 Km/s) while on previous day the average plasma speed was (480 – 500 Km/s) .It was also raised on next day[Figure 2(d)].

Total Lunar Eclipse (15 April 2014)

[It was observed throughout the western hemisphere (not visible at our equatorial station)]

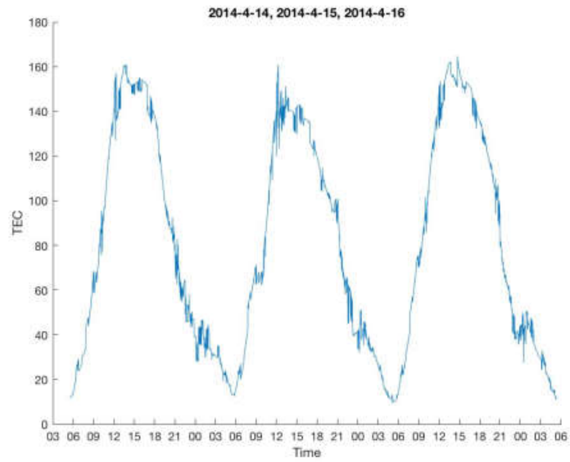

Figure 3(a)

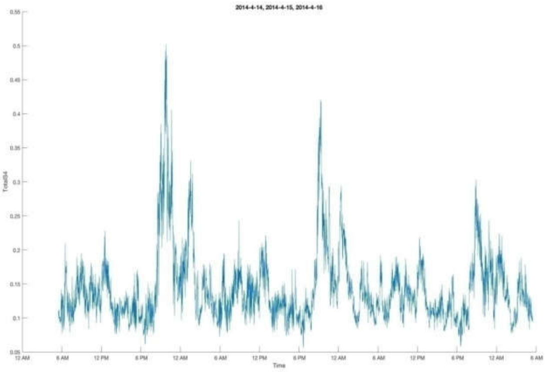

Figure 3(b)

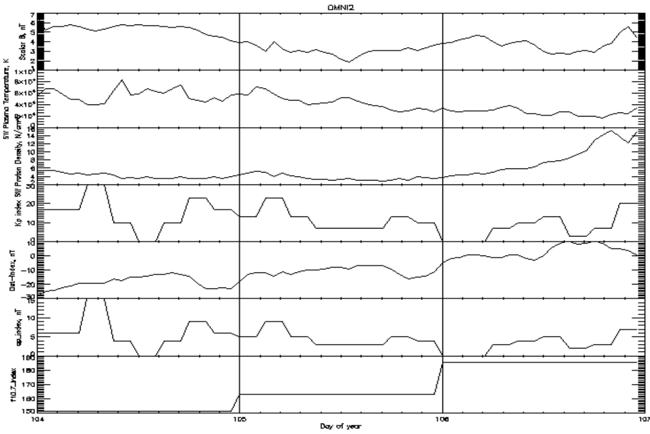

Figure 3(c)

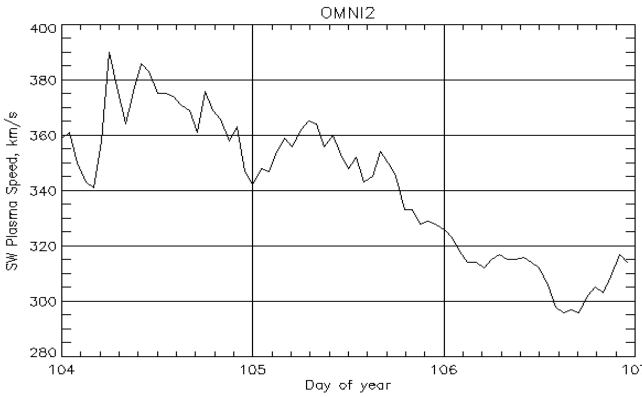

Figure 3(d)

Figure 3(a), Figure 3(b), Figure 3(c),Figure 3(d)

Total Electron Content – The figure 3(a) shows the TEC variation during the lunar eclipse. The maximum TEC was around the 150 *10to power 16 per meter square.

While it was around 160*10to power 16 per meter square on previous day and next day .

Amplitude Scintillation Index S4 – Variation in amplitude scintillation index is shown in figure 3 (b) .The amplitude remains higher side in the night. The Value was varying between (0.35) to (0.5).

While the value of the amplitude was slightly less but it was varying between (0.3) to (0.45).

Interplanetary Magnetic Field –The value of IMF was less than the value of IMF on previous day and next day. Figure 3(c)

Plasma Temperature– The value of plasma temperature was less than the previous day. The decrease was continued on next day. Figure 3(c)

Kp Index – The variation in Kp index was lesser than the previous day. Figure 3(c)

Ap Index - It was also less variable than previous day . Figure 3(c)

Dst Index – It was higher than previous day and the rise was continued on next day.There was no indication of geomagnetic storm. Figure 3(c)

Solar Index – It was higher than previous day but the value was less than the value of next day. Figure 3(c)

Plasma Speed – Plasma speed was highly variable on the day. The average plasma speed on the day was lesser than the average plasma speed on the previous day but the fall in the plasma speed was continued on the next day too. Figure 3(d)

Total Lunar Eclipse (08 October 2014)

[Some of penumbral eclipse was visible at our equatorial station.]

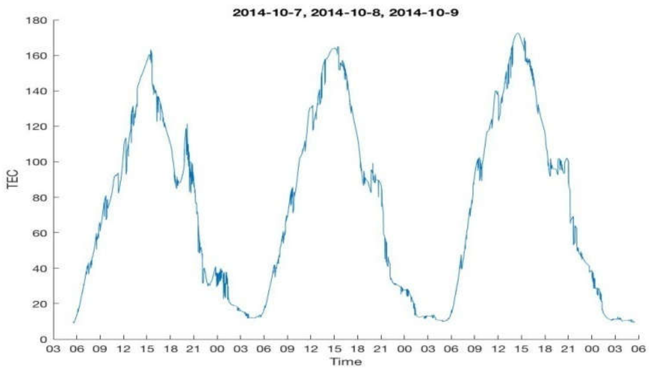

Figure 4(a)

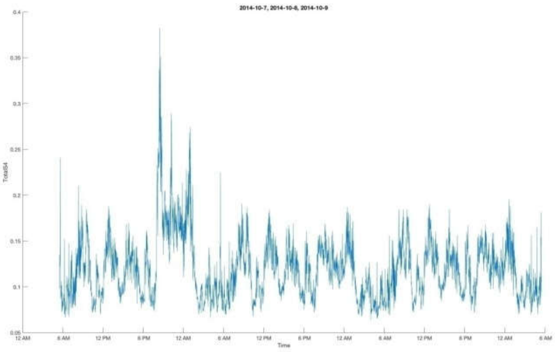

Figure 4(b)

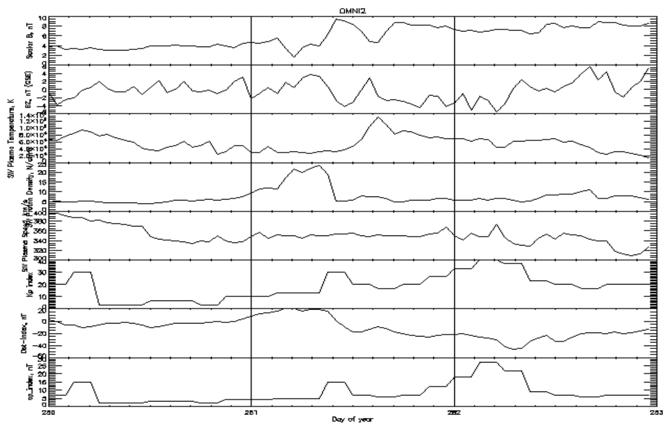

Figure 4(c)

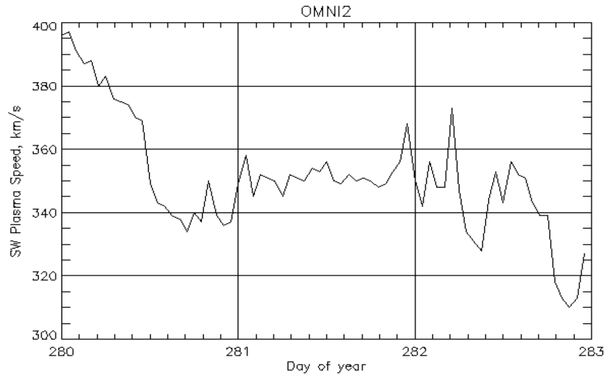

Figure 4(d)

Figure 4(a), Figure 4(b), Figure 4(c), Figure 4(d)

Plasma Speed –Plasma speed was highly variable on the day. The average plasma speed on the day was lesser than the average plasma speed on the previous day but the fall in the plasma speed was continued on the next day too.

Total Lunar Eclipse (08 October 2014)

[Some of penumbral eclipse was visible at our latitude station]

Total Electron Content – The TEC variation is shown in figure 4(a) .The value of highest TEC was around 160*10to power 16 per meter square, which was similar to previous day and next day's highest value of TEC.

Amplitude Scintillation Index S4 – The amplitude scintillation index variation is shown in figure 4(b) .It varies from 0.2 to 0.4 which was higher during eclipse night.

Interplanetary Magnetic Field – The variation in IMF is shown in fig ( ) on eclipse day, which was higher and more volatile on next day after the lunar eclipse. Figure 4(c)

Plasma Temperature –It was also higher on the next day after the eclipse and reached to maximum scale. Figure 4(c)

Proton Density – The proton density was also higher next day after the eclipse.It was volatile too. Figure 4(c)

Kp Index – Variation in Kp index was observed. Figure 4(c)

Dst Index –The Dst Index was reached to -40 nT. There was no indication of geomagnetic storm. Figure 4(c)

Ap Index –The variation in Ap index was similar to Kp index . Figure 4(c)

Solar Index – The solar index was higher than previous day but the fall in the solar index has been observed on next day . Figure 4(c)

Plasma Speed – The plasma speed was average around 360 km per second .It decreased to around 350 Km per second . Figure 4(d)

CONCLUSION

It has been observed that the total electron content decreases on solar eclipse days while the TEC variation pattern was normal during total lunar eclipse days. It may be because of the total lunar eclipse was not visible at our equatorial station .On the other hand small variation in proton density was found on the eclipse days.

The fluctuation in amplitude scintillation index has been observed during the eclipse period. The high fluctuation was seen during lunar eclipse while in the period of solar eclipse it was volatile. It may be due to radio signals that propagate through regions where irregular plasma density experienced perturbations in amplitude and phase i.e. scintillation.

Interplanetary magnetic field (IMF) is a part of Sun's magnetic field therefore variation in IMF has been observed on eclipse days. The IMF is a vector quantity which have three components Bx, By, and Bz .The third component Bz gets affected by disturbances of solar wind. The interaction of the solar wind with the magnetosphere and ionosphere produces change in magnetic field. It was also found that the clear variation in plasma speed was seen during all the eclipses.

Magnetic activity indices (Ap index, Kp index, Dst index) describe variation in the geomagnetic field created by the irregular current system. It has been observed the variation in these indices was approximately similar to the previous days of the eclipse but clearly different pattern was found on the next days of the eclipse. There was no sign of geomagnetic storm.

Small change in proton temperature was experienced during eclipse days. A measure of thermal kinetic energy per particle is plasma temperature. To sustain ionization, high temperatures are required. Ions and electrons tend to recombine at low temperatures.

The potential amount of solar energy is measured by solar index. The solar intensity is highest at noon. Small variation in solar index has been observed but during the partial solar eclipse day sudden rise was seen and sudden fall was observed at midnight.

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