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Response of the mid-latitude ionospheric F2 to the total solar eclipses of solar cycle 23

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A study of the response of the mid-latitude ionospheric F2 to the total eclipses of solar cycle 23 is presented using five-minute resolution ionospheric foF2 data obtained from 14 mid-latitude ionosonde stations located in the path of totality of eclipse. The changes in foF2 are analysed using D(foF2), the normalised deviation of critical frequency F2 from the quite days reference. The D(foF2) variation of the ionosphere in the path of totality, as recorded by the ionosonde stations in this path, is characterized by simultaneous decrease in electron density at elapsed time of totality. The present analysis revealed that sudden Sun radiation removal by the Moon reduces the electron production processes in the ionospheric F2-layer. The impact of total solar eclipse is clearly evident simultaneously with the time of maximum occultation as decrease in the electron density in all ionospheric stations. The results, further, suggest that the maximum electron density of F2-layer redistribution processes were observed not at the time of totality of eclipse but shortly before and after the elapsed time (i.e. about 4 min to few hours). It is noteworthy that mainly response of electron density in ionospheric F2 region varies with the sun intensity. Also, an increase in maximum obscuration of eclipse causes reduction in electron density production processes and the transport processes in the F-layer are affected due to the presence of the westward electric field which may in turn lead to the decrease in foF2 of ionospheric F2 region. This result obtained was reasonably in good agreement with the earlier study of ionospheric response to total solar eclipse using different measurement and methods.

Keywords: Total solar eclipse, F2 region critical frequency, Ionospheric F2 electron density, Solar X-ray flare

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1 Introduction

Solar eclipses provide unique opportunities to study the behaviour of the ionosphere and to investigate its effect on the terrestrial atmosphere. The physical processes in the ionosphere during this short term nighttime conditions have been studied effectively in the past decade using different methods[1-15]. In one of these studies, Le *et al.*[10] showed that there is an almost consistent behaviour at low altitude where there are larger depletions in electron concentration and decrease in electron temperature during solar eclipses and these variations at low altitude are almost synchronous with the solar radiation variation. The largest relative change in electron concentration (Ne) occurred at the F1-layer heights[7]. The F2-layer at middle latitudes is thought to be largely controlled by plasma diffusion. Here, the F2-layer behaviour during solar eclipses may be quite different; this may be accompanied with various amplitudes of decreases or even a small increase in the electron concentration. According to Lung-Chih & Jann-Yenq[5], the reduction in F2-region (referred to two control days) occurred after the start of the solar eclipse, the maximum reduction in foF2 was observed not at the time of the eclipse maximum but somewhat later. Two consequences have so far been recognized over the years for the variation in the electron density of ionospheric F2 according to Paul *et al.*[16] and reference therein; the generation of gravity waves due to the transit of locally cooled region of the atmosphere moving at supersonic speed and a reduction in the plasma density as the source of ionization is switched. The Earth's atmosphere may produce wave motions due to localized time dependent heating or cooling action. A solar eclipse, by interfering with the heat balance in the shadowed portion of the atmosphere, is expected to generate atmospheric gravity waves (AGW). These AGWs could interfere to produce a bow wave detectable at large distances from the eclipse path at ground level and at ionospheric heights. The gravity waves could manifest themselves as travelling ionospheric disturbances (TIDs) and from high latitude where molecular oxygen heating begins towards the equator.

According to Gerasopoulos *et al.*[17], the decrease in solar radiation causes change in the photochemistry of the atmosphere with night time chemistry dominating. The abrupt switch off of the sun induces changes in the ionosphere. In the ionosphere, both photochemistry and dynamics result in change in the reflection heights and the electron concentrations. It is noteworthy that the ionospheric behaviour is governed by photochemical processes, so the decrease in solar radiation during solar eclipse leads to the decrease in electron production rate and electron concentration[7]. On the contrary, the ionization at the upper heights of the bottom side ionosphere is maintained and consistent fluctuations are observed mainly between the first contact and the maximum occultation as a special feature of the ionospheric response to the solar eclipse[6]. Gerasopoulos *et al.*[6] also pointed out that the return of the ionospheric plasma towards a new equilibrium state, which is forced by the solar eclipse effects, is likely to be accompanied by induced wave motions excited in the neutral atmosphere that could cause significant variations in the electron and ion densities. A study of the 11 August 1999 eclipse, Yue *et al.*[18] using data from thirteen European ionosonde station as well as stimulated ionospheric data showed a greater decrease of electron density in F-region than E-region at all latitudes.

Different methods and measurements had been used to investigate the ionospheric effect during solar eclipse. Of which, the normalized deviation of critical frequency D(foF2) has been used in this study to examine the effects at mid-latitude ionospheric F2 region using data from 14 ionosonde stations in the path of total eclipse for the period under consideration. The eclipse period was characterized with low geomagnetic disturbance and solar flare activity, which alleviated significantly the problem of detecting the ionospheric response to the eclipse. Although, Nayak *et al.*[15] has recently showed that eclipse effect in the F2 region is larger at high solar activity than at low solar activity. This characteristic ensured that variation in the F2 region represented real changes not storm time variation.

2 Data and Analysis

The total solar eclipse of solar cycle 23 occurred with path of totality passing through the Earth's, when the Moon passing the Earth is obscure completely by the Sun. The path of totality across the Earth with time of commencement and duration of eclipse were shown in the Table 1. All the paths of totality were found from NASA (National Aeronautics and Space Administration) Eclipse service (http://eclipse.gsfc.nasa.gov). The eclipse period was characterized by a low geomagnetic disturbance (Dst $\geq$ -25nT), which alleviated significantly the problem of detecting the ionospheric response to the eclipse.

The ionospheric data used in this study consisted of 5-minute values of foF2 obtained from Space Physics

Table 1 — Total solar eclipses in solar cycles 22 and 23

Date of total eclipse, yyyy-mm-dd	Time of commencement, hh:mm:ss UT	Duration of visibility, mm:ss	Geographical region of eclipse visibility	Path of totality in the geographical region
1997-03-09	01:24:50	02:50	Asia, Alaska	Mongolia, China, Siberia
1998-02-26	17:29:27	04:09	North, Central and South America	Galapagoes, Colombia, Venezuela, Caribbean
1999-08-11	11:04:09	02:23	East of North America, North Africa, Europe, Asia	England, Europe, Middle East, Turkey, India
2001-06-21	12:04:46	04:57	East of South America, Africa	South Atlantic, South Africa, Madagascar
2002-12-04	07:32:15	02:04	South Africa, Antarctica, Indonesia, Australia	South Africa, South India, South Australia
2003-11-23	22:50:22	01:57	Australia, New Zealand, Antarctica, South America	Antarctica
2006-03-29	10:12:22	04:07	Africa, Europe, West Asia	Central Africa, Turkey, Russia
2008-08-01	10:22:12	02:27	Northeast of North America, Europe, Asia	North Canada, Greenland, Siberia, Mongolia, China
2009-07-22	02:36:25	06:39	South Africa, Antarctica, Southeast Asia, Australia	South India, Sumatra, Borneo
2010-07-11	19:34:38	05:20	South India, Sumatra, Borneo	South Pacific, Easter Island., Chile, Argentina

Interactive Data Resource (SPIDR) network (http://spidr.ngdc.noaa.gov) for ionosonde stations located in the mid-latitudes paths (Table 2). These stations lie at a very close range along the paths of eclipse totality under consideration and are located in the longitudinal zones: Euro-African sector (Ashkhabad, Athens, Rome, Rostov, San Vito, Sofia, Juliusruh, Madimbo, Louisvale); American sector (Bermuda, Fairford, Moscow, Goosebay). To examine the variation of the eclipse effects with the eclipse magnitude, which is defined as the fraction of the Sun's diameter occulted by the Moon, an analysis of the critical frequency of the ionospheric foF2 from the solar cycle 23 was performed. These ionosonde stations that have recording data for foF2 during the eclipse events are listed in Table 2 with their percentage of maximum obscuration (http://www.chris.obyrne.com/Eclipses/calculator.html). Concentrations are solemnly on total solar eclipse event that occur during the daylight only for the period under consideration.

The solar activity data used in this study consisted of Geostationary Operations Environmental Satellites (GOES 10) with 1-minute resolution values of X-ray 1-8 Å obtained from Space Physics Interactive Data Resource (SPIDR) (http://spidr.ngdc.noaa.gov) and GOES X-ray flares characteristics obtained from http://www.ngdc.noaa.gov. The X-ray flare classes are A, B, C, M, and X corresponding to increasing levels of the measured solar X-ray flux. The levels are: A $\geq 10^{-8}$, $10^{-6} <$ B $\geq 10^{-7}$, $10^{-6} \leq$ C $< 10^{-5}$, $10^{-5} \leq$ M 10^{-4}, and X $\geq 10^{-4}$ W m^{-2} (Ref. 19).

Using a modified form of the analysis of Chukwuma[20], the percentage change in amplitude of foF2 due to the total solar eclipse was calculated. In this scheme, the F2 region response to total solar eclipse can also be mostly conveniently described in terms of D(foF2), that is, the normalized deviations of the critical frequency foF2 from the reference:

$$D(foF2) = \frac{foF2 - (foF2)_{ave}}{(foF2)_{ave}} \times 100\%$$

Hence, the data analyzed consisted of *D*(foF2) values of respective 5-minute values of foF2 for the aforementioned period of total eclipse. The *D*(foF2) variations are described in terms of percentage of the critical frequency from the reference[21]. The reference for each 5-minute is the average value of foF2 for that 5-minute calculated from the five quite days. The use of *D*(foF2) rather than foF2 provides a first-order correction for temporal, seasonal and solar cycle variation so that total solar eclipse effects are better identified[20].

Furthermore, in analyzing *D*(foF2) changes in the ionosphere for solar eclipse, positive and negative changes are presently defined by changes in amplitude, the maximum absolute value of *D*(foF2) of more than or equal to 10% regarded as large effect[22]. However, any phenomenon that causes effective change in the electron concentration of F2 region or critical frequency can be regarded as ionospheric disturbance. An important criterion used in choosing the reference period is these days must be devoid of not only of any significant geomagnetic activity but also, there must be an absence of any considerable

Table 2 — Mid-latitude stations with their code, geographic coordinates and maximum obscuration in solar cycle 23

Date, yyyy-mm-dd	Station (Code)	Geographic latitude	Geographic longitude	Maximum obscuration, %	Difference between LT and UT, h
1999-08-11	Bermuda (BJJ32)	32.2°N	-64.4°W	84.6	-4
1999-08-11	Sofia (SQ143)	42.7°N	23.4°E	93.8	+1
1999-08-11	Rostov (RV149)	47.2°N	39.7°E	78.3	+3
1999-08-11	Juliusruh (JR055)	54.6°N	13.4°E	80.3	+1
1999-08-11	Rome (RO041)	41.8°N	12.5°E	79.8	+1
1999-08-11	Ashkahbad (AS237)	37.9°N	58.3°E	78.1	+4
1999-08-11	Goosebay (GSJ53)	53.3°N	-60.4°E	43.1	-4
1999-08-11	San Vito (VT139)	40.6°N	17.8°E	80.4	+1
1999-08-11	Moscow (MO155)	55.5°N	37.6°E	59.2	+3
1999-08-11	Fairford, UK (FF051)	51.7°N	-1.5°E	95.4	0
2002-12-04	Louisvale (LV12P)	28.5°S	21.2°E	67.0	+1
2002-12-04	Madimbo (MU12K)	22.4°S	30.9°E	100.0	+2
2006-03-29	Athens (AT138)	38°N	21.2°E	78.1	+2
2006-03-29	San Vito (VT139)	40.6°N	17.8°E	64.1	+1

solar activity. This follow the fact that Chukwuma (Ref. 21 and references therein) have shown the high solar flares activity results in ionospheric disturbances due to their effects on thermospheric neutral density[23]. Of which, Nayak *et al.*[15] has recently showed that eclipse effect in the F2 region is larger at high solar activity than at low solar activity. Figure 1 (a-c) shows that the X-ray fluxes for the solar flares during 11 August 1999, 6 December 2002, and 29 March 2006 path of totality of eclipse for solar cycle 23 at mid-latitude ionosphere do not exceed 10^{-4} W m^{-2} which indicates that the reference period is characterised of low solar activity.

3 Results

The plots illustrating *D*(foF2) *vs* time (hrs UT) during solar cycle 23 for mid-latitude are depicted in Figs (2-4). The shaded region represents the path of eclipse totality at individual ionosonde station ionosphere at their respective local time. The result is confined to the solar eclipse event that occurs during the daylight only. Figure 1 (a-c) presents a plot of solar X-ray flares during the quite days (GOES 10 with 1-minute resolution value of 0.1-0.8 nm).

3.1 Ionospheric response of total solar eclipse

3.1.1 Total solar eclipse on 11 August 1999

The *D*(foF2) variations of 11 Aug 1999 are presented in Fig. 2. The *D*(foF2) plot show the existence of negative variation of ionospheric F2 region in all the stations during the period 01:00-04:00 hrs UT with the largest depletion value at the periods except for Ashkhabad and Fairford that are with paucity of data, and all these stations are exceeded by an enhancement in foF2. The ionospheric F2-layer of Bermuda responded with depletion at an interval of 00:00-00:55 hrs UT with consistency of 21%. Thereafter, the electron density changed its trend with a consistent positive peak amplitude value of 4% in the early morning of eclipse totality before daylight. The eclipse event for this year started at 11:04:09 hrs UT (07:04:23 hrs LT) with low variation of electron density changes in the ionosphere. That is, the electron density decreased far below the reference level due to the sudden shutdown of the Sun radiation to the ionosphere during the period. Preceding this, the ionosphere recorded its peak negative amplitude of 25% within time interval of 09:00-09:45 hrs UT. The largest enhancement value for the day was recorded at an interval of 05:00-05:45 hrs UT with average peak value of 4% which is below the reference value. The *D*(foF2) variation of Sofia responded with low electron density of 1% at the elapsed time of eclipse totality. Preceding this, the ionosphere emerged with depletion with peak depletion in electron density of 25% at an average within time interval of 00:00-00:55 hrs UT. Thereafter, the *D*(foF2) increased in its amplitude to a positive phase of 5% below the reference level at an interval of 1 hour from 05:00 hrs UT. In daylight, the ionosphere recorded an average peak value of 11% during 12:00-12:55 hrs UT noon, which is the minimum depletion in electron density. The *D*(foF2) plot of Rostov responded mostly with depletion than enhancement. The plot emerged with depletion and had its minimum negative effect during 00:00-03:00 hrs UT with an average of 16% depletion in electron density, sharply it enhanced positively to an average peak value of 10% which lasted for almost 1 hour. During the daylight, the ionosphere responded with minimum amplitude of electron density 16% at an interval of 12:00-12:55 hrs UT. This points out the fact that largest response of electron density in ionospheric F2 region does not coincide with the duration of the totality. The peak depletion that was recorded by the ionosphere at the totality phase was 14%. Thereafter, the maximum enhancement during the daylight emerged from negative phase of electron density with an average value of 5% in time interval of 17:00-18:00 hrs UT. Following the data from Juliusruh, the electron density recorded a depletion of 13% at the elapsed time of eclipse totality. The minimum depletion value during the daylight was recorded at 10:55 hrs UT with 13% depletion. The plot showed that large amplitude of electron concentration was recorded not during the daylight but at night and midnight with peak negative and positive amplitude of 23% during 03:00-03:55 hrs UT and 13% during 19:00-19:25 hrs UT. The ionosphere at Rome responded with similar characteristic of electron density variation as Juliusruh. The only difference was that the electron density of the ionospheric F2-layer increased by 1% and the positive amplitude decreasd by 4% to that of Juliusruh during the same time period. The ionosphere at Ashkhabad had a maximum obscuration of 78.1% total eclipse with electron density processes of 10% depletion on ionospheric F2-layer. During time interval 00:00-03:55 hrs UT, the ionosonde station has no recorded data for critical frequency foF2. At around 07:30 hrs UT, the ionosphere responded with negative amplitude of 10% and was preceded with no effect.

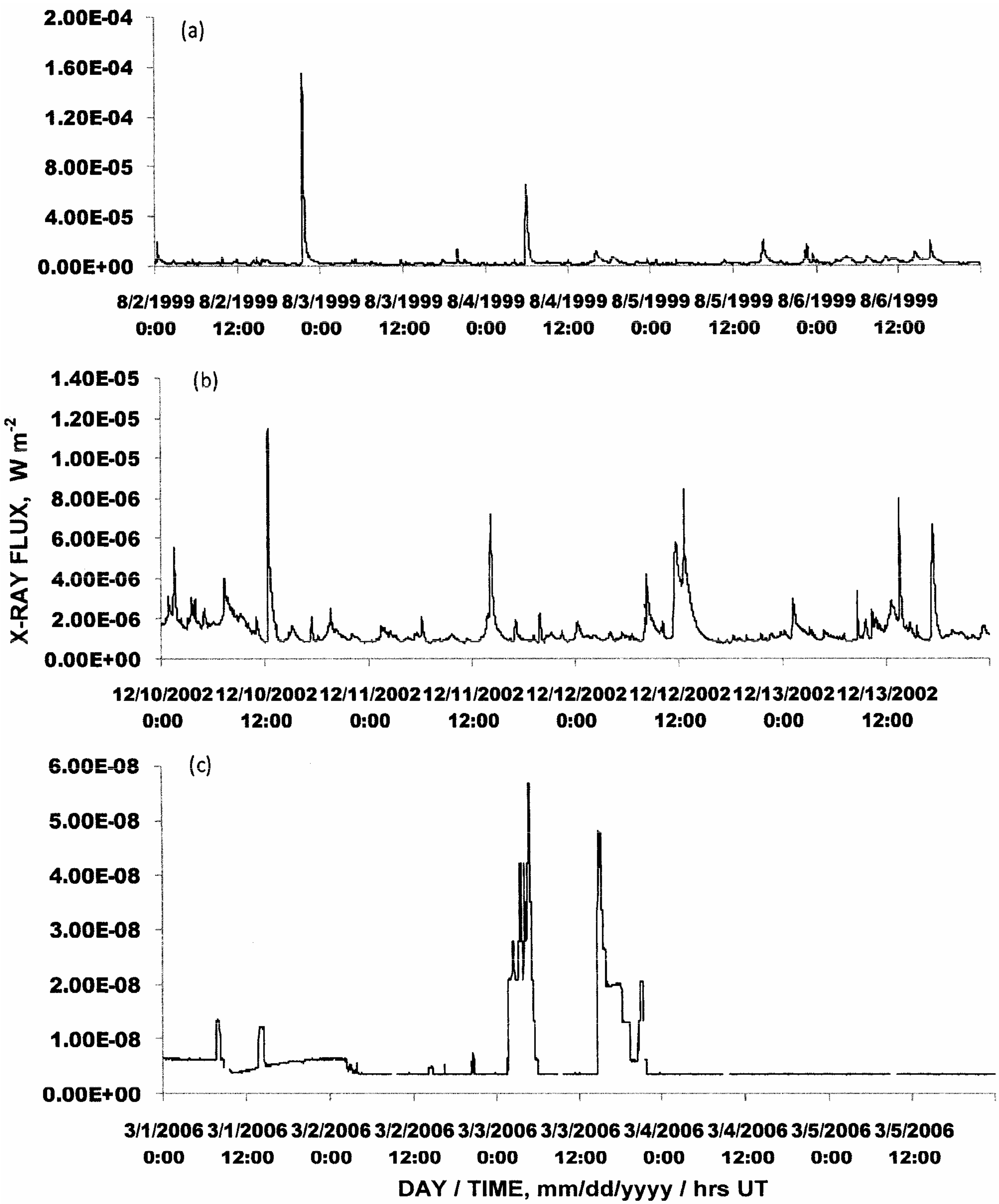
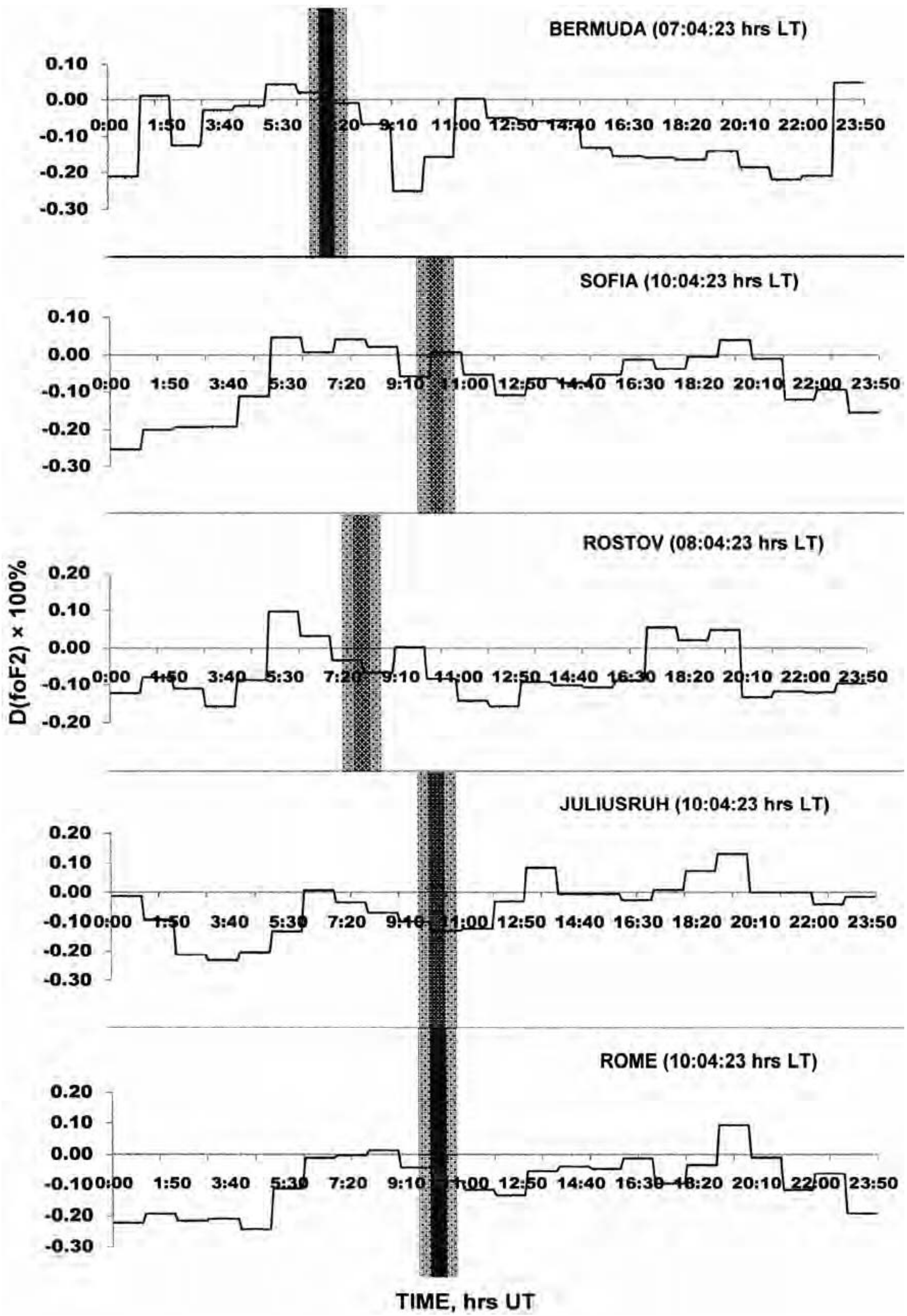


Fig. 1(a-c) — X-ray fluxes for GOES 10 Solar X-ray flare 1.8 Å for the reference days during the year of total eclipse for solar cycle 23 at mid-latitude


BERMUDA (07:04:23 hrs LT)
SOFIA (10:04:23 hrs LT)
ROSTOV (08:04:23 hrs LT)
JULIUSRUH (10:04:23 hrs LT)
ROME (10:04:23 hrs LT)
D(foF2) × 100%
TIME, hrs UT

(*contd.*)

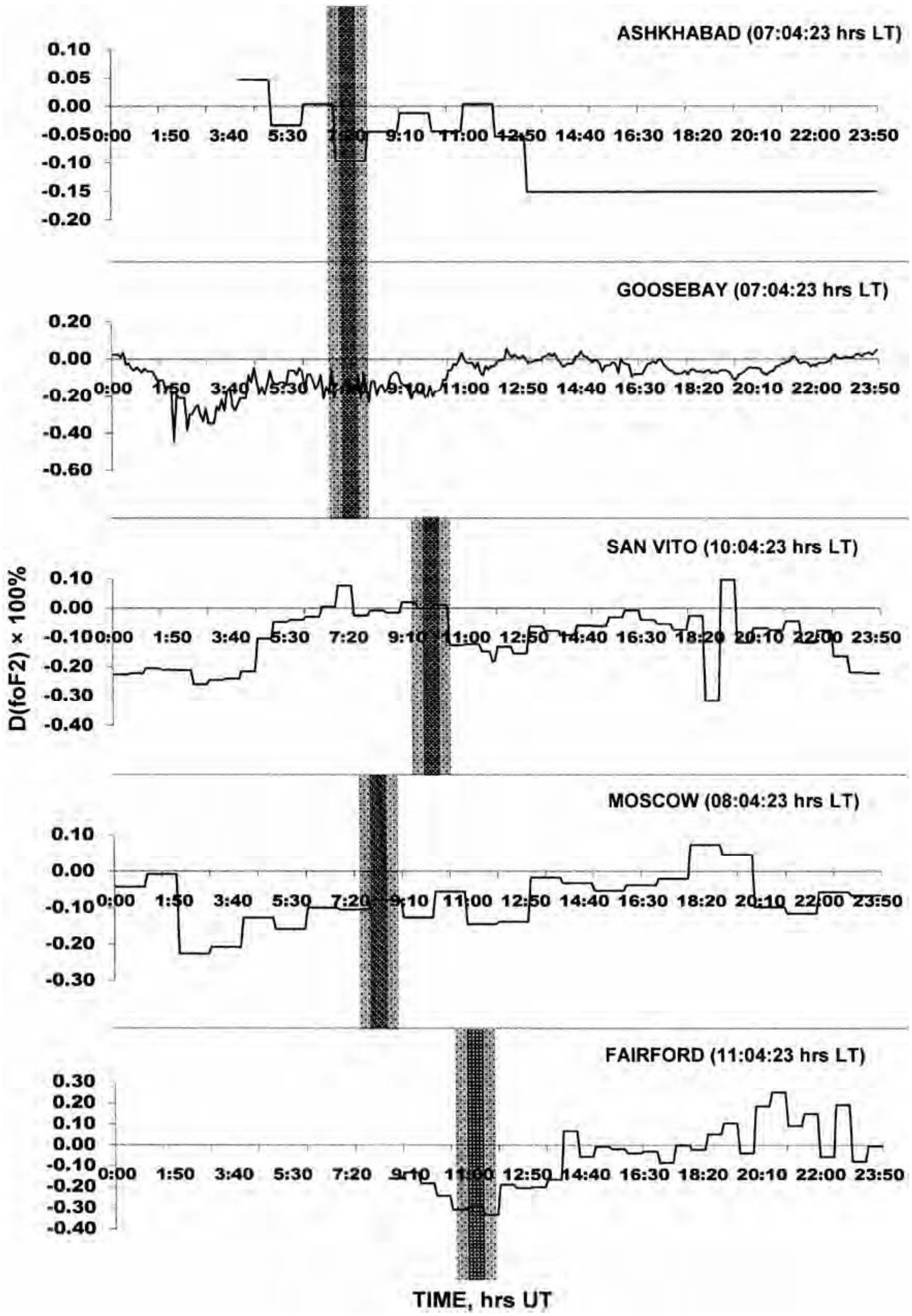


Fig. 2 — Variations of D(foF2) for mid-latitude station in the path of total eclipse for 11 August 1999

The peak amplitude of electron density was recorded at 13:00 hrs UT with 15%, and electron concentration production processes in ionospheric F2 was consistent with 15% depletion throughout the day. The ionosphere at Goosebay responded with 16% depletion at elapsed time of eclipse which was exceeded by 23% depletion at 08:00 hrs UT, the peak electron density value at the daylight and 21% depletion at 09:20 hrs UT. The minimum peak depletion of foF2 was experienced at 01:55 hrs UT midnight with 44% depletion. The *D*(foF2) of San Vito responded with a consistent value of electron density decrease at the midnight with peak depletion of 26% during 02:30-02:55 hrs UT. Thereafter, foF2 increased to the peak positive amplitude of 8% at 07:30 hrs UT in the morning. Immediately after, it depleted and remained inconsistent till the time when Sun disk was covered completely by the Moon. The electron density during this period was 12% and large electron density variation on ionospheric F2 was recorded at 11:50 hrs UT pre-noon. At the late hours of the daylight, the ionosphere recorded the largest variation of 32% depletion in electron density during 18:30-19:00 hrs UT. Depletion of electron density was mostly observed than enhancement at the ionospheric F2 region of Moscow. The *D*(foF2) emerged it records with depletion in electron density with peak amplitude of 23% at 02:10 hrs UT; thereafter, it emerged in a step fixed with a consistent electron density value which always lasted for periods of 1 hour till the point of totality commencement. During the elapsed time of total eclipse, the ionospheric F2-layer recorded a depletion of 14% and an enhancement of 7% in the late hours of the daylight. The ionosonde station at Fairford indicated a paucity of data from 00:00 hrs UT midnight to around 08:20 hrs UT in the morning. Starting from 08:30 hrs UT, the ionosphere decreased in step fixed manner till around 10:30 hrs UT, some minute before the sudden total blackout with electron density depletion of 31%. At this period of totality, the ionosphere recorded 29% depletion in electron density, thereafter, it increased to 33% with fixed electron density value during 11:30-11:55 hrs UT. Soon after, the electron density increased to the positive phase with an average enhancement value of 7% within an interval of 14:00-14:25 hrs UT. The maximum enhancement of electron density in ionosphere occurred at night with peak enhancement value of 25% during 20:30- 22:55 hrs UT.

3.1.2 Total solar eclipse on 4 December 2002

In 4 December 2002 total eclipse, only Louisvale and Madimbo ionosonde station had a recorded data for ionospheric critical frequency foF2 as depicted in Fig. 3 and at this stations, the percentage of maximum obscuration of total eclipse were 67 and 100%, respectively. The *D*(foF2) variation at Louisvale responded with a step consistent variation of electron density which lasted for 3 hours from the early minute of midnight with peak ionospheric F2 value of 24% at 02:30 hrs UT. Thereafter, the atmosphere appeared to indicate reasonable increase in electron density processes at the totality period with 18% depletion; this depletion emerged to an enhancement of 12% at 13:30 hrs UT noon. At this station, the large positive and negative effects of eclipse on the ionospheric F2 region did not occur in the daylight but at night and midnight. The atmosphere at Madimbo with 100% obscuration responded with moderate effect at the period of eclipse totality with 10% depletion; the large eclipse effects in the atmosphere was at 06:55 hrs UT with 15% depletion of electron density, this was preceded with a depletion of 21% at 04:30 hrs UT.

3.1.3 Total solar eclipse on 29 March 2006

On 29 March 2006, the only available ionosonde stations in the path of eclipse totality were in Euro-African sector as show in Fig. 4. The *D*(foF2) of these stations appear mostly with positive enhancement of electron density than depletion. The peaks enhancement of Athens on average time interval of 05:00, 09:10, 10:25 and 18:00 hrs UT are 19, 15, 2, and 49%, respectively. During the sudden lightout, the atmosphere emerged with the least enhancement percentage of 1%, which is below the reference level. The minimum amplitude of foF2 that was recorded by the ionosphere was at 16:30 hrs UT on average time interval with 15% depletion. It was this that emerged to the peak enhancement recorded by the atmosphere at the station with 49% at 18:00 hrs UT daylight. The eclipse recorded notable effect on the ionospheric F2 region during the period of activity at San Vito, since the electron densities neither increased nor decreased but remained constant (i.e. no input of energetic particle, proton and electron to increase the production of electron density processes). The maximum foF2 variation registered before and after the event with peak enhancement of 68% at 02:00 hrs UT midnight and 61% at 08:30 hrs UT. The ionosonde recorded a peak depletion of 16% during the time range 15:30-15:40 hrs UT daylight, soon after, the atmosphere emerged with positive

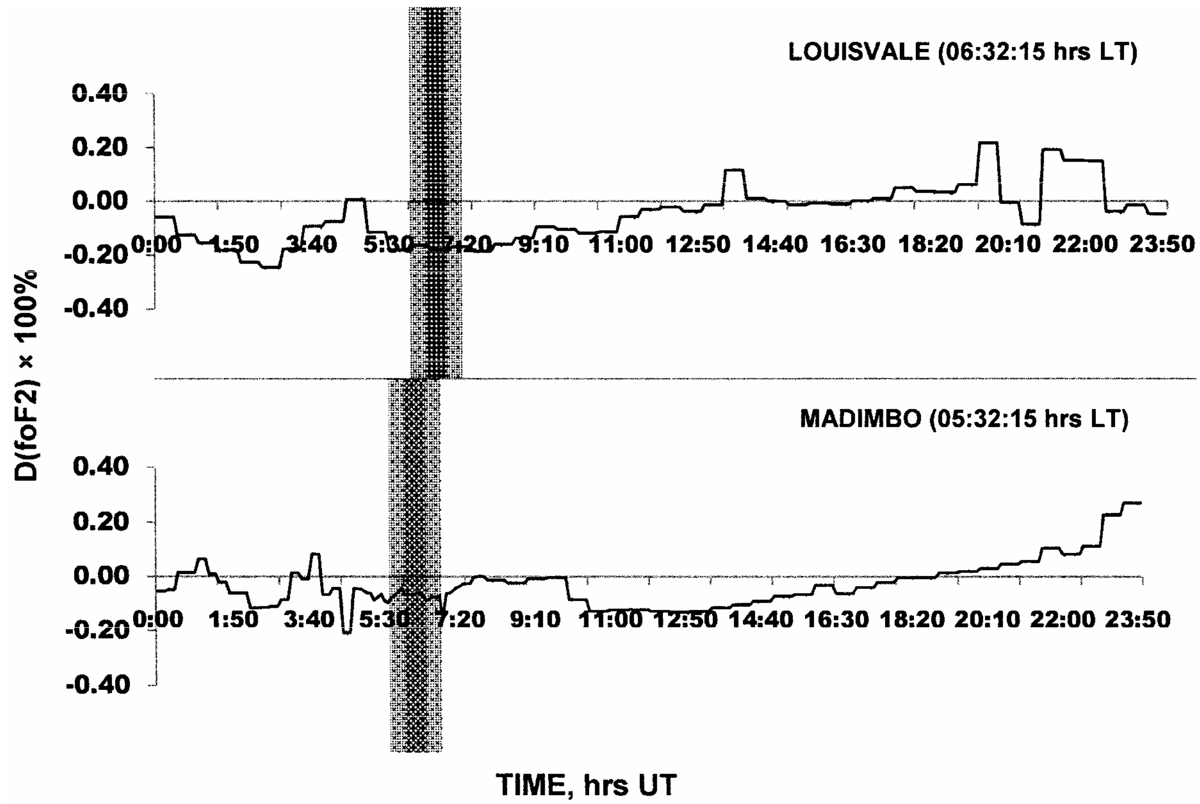


Fig. 3 — Variations of D(foF2) for mid-latitude station in the path of total eclipse for 4 December 2002

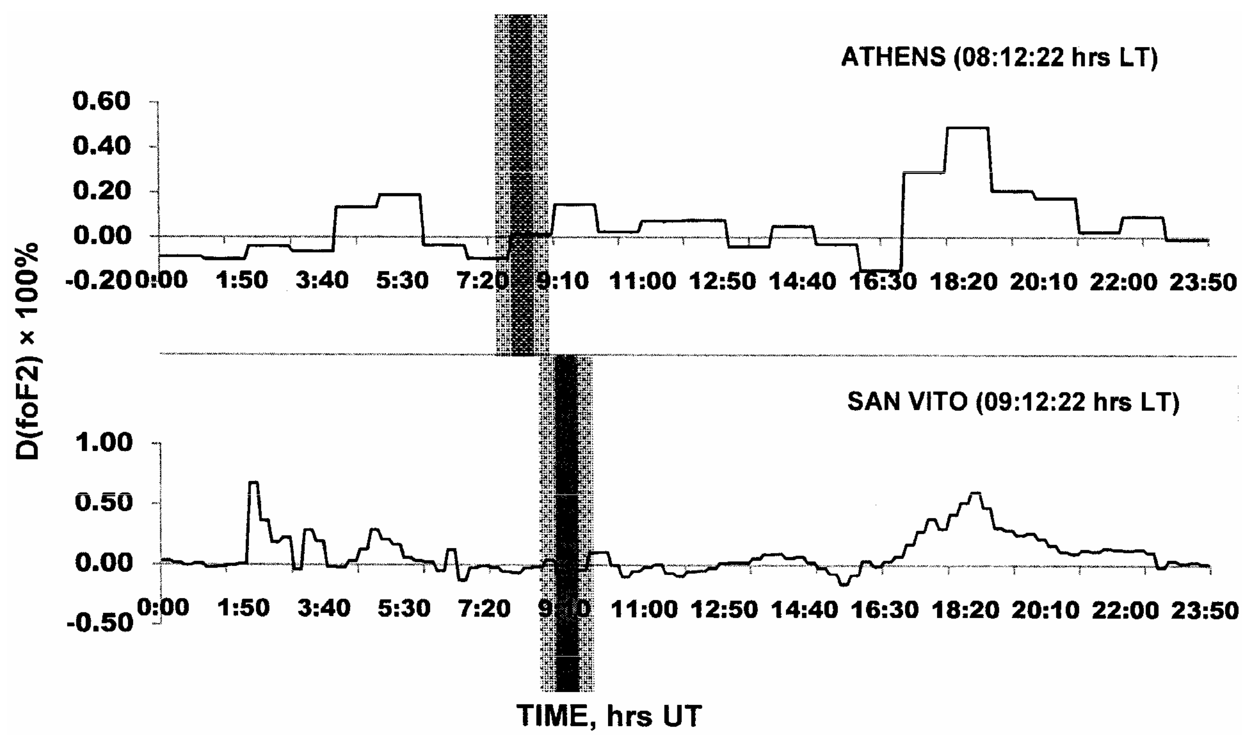


Fig. 4 — Variations of D(foF2) for mid-latitude station in the path of total eclipse for 29 March 2006

enhancement of 42% at 08:00 hrs UT which is the peak enhancement value of the electron density during the daylight variation.

4 Discussions

According to Nayak *et al.*[15], ionospheric response at low altitudes (D, E and F1 regions) is governed mainly by photochemical processes so that the decrease of solar radiation during an eclipse is expected to decrease the electron production rate and hence, the electron concentration. However, the F2-layer behaviour may be quite different as it is governed by photochemical processes as well as by electrodynamical and neutral forcing. When the F-layer is normally in a state of quasi-equilibrium, the obscured changes in electron density during eclipse are almost entirely due to loss by recombination and production by photo-ionization[24].

The F2-layer behaviour during solar eclipses shows quite different variation in amplitude of electron density. There is decrease, increase, or remain unchanged in electron density during the totality periods. As regards the changes observed in the F2 region, the maximum electron density variation in this region did not coincide with the eclipse totality phase but occur somewhat later (i.e. at about 4 min to few hours before or after the totality phase of eclipse). The possible reason for this may be that during the presence of the eclipse, the ionization production is reduced and the transport processes in the F-layer are affected due to the presence of the westward electric field which may in turn lead to the decrease in foF2. The electron density in all the stations is known to fluctuate with maximum variation on ionospheric F2-layer at non-eclipse period and did in fact undergo comparable variations on several occasions during the periods preceding and following the total eclipse. This transient variation in electron density of F2-layer was attributed to TIDs as manifestations of AGWs generated by the movement of the shadow of a solar eclipse[16].

The eclipse event of 11 August 1999 had its totality at 11:04:09 hrs UT with simultaneous slower reaction of electron density across the ionosphere at all the ionosonde stations situated along the path. The *D*(foF2) of all the station responded differently in electron density depletion, of which some responded with low variation and some with high variation in the ionospheric F2-layer. The atmosphere along the path of total eclipse on 4 December 2002 also responded with depletion in electron density as recorded by the ionosonde station at Louisvale and Madimbo. The event occurred at around 07:32:15 hrs UT with is totality which elapsed for a period of 2 minute 4 seconds from the commencement time. The *D*(foF2) of Louisvale responded to the totality with an average of 18% depletion at the elapsed time and Madimbo with the highest percentage of maximum obscuration, surprisingly, responded with no variation, i.e. no increase or decrease in the *D*(foF2) at the elapsed time. This points to the fact that maximum obscuration of an eclipse reduces the electron production processes of the ionospheric F2-layer. The ionospheric F2 resulted during 29 March 2006 total solar eclipse responded differently compared to others with simultaneous enhancement. The profound electron density variation was on non totality period (i.e. control periods). This result confirmed the reduction of electron density production processes at the totality period, which is as a result of sudden sun shutdown. The sun releases energetic particles and large amount of proton and electron into the terrestrial earth atmosphere. These increased the production process of ionospheric F2-layer electron concentration.

5 Conclusions

In the present research work, an analysis on the changes in foF2 was conducted using normalize deviation of critical frequency F2 (*D*(foF2)) on the ionosphere at the mid-latitude path of total solar eclipse during solar cycle 23 events on the basis of the 5 minute resolution data derived from 14 mid-latitude ionosonde stations. Here, the F2-layer at middle latitudes is thought to be largely controlled by plasma diffusion; the F2-layer behaviour during solar eclipses may be quite different. They accompanied with various amplitudes of decreases or even a small increase in the electron density.

The *D*(foF2) variation of all the ionosphere of the path of totality as recorded by the ionosonde stations along these paths, are characterized by simultaneous decrease in election density at the elapsed time of totality. The results further suggest that the maximum foF2 variation were observed not at the time of totality of eclipse but shortly before or after the elapsed time; the largest electron density variation of the ionospheric F2 is much observed at the midday and night. This point to the fact that maximum obscuration of an eclipse reduces the electron production processes of the ionospheric F2-region. This peak electron density behaviour of the ionospheric F2-layer follows the local balance of plasma production, loss and transport; the ionospheric plasma redistribution processes significantly affect the shape of the electron density profile[25]. In this regard, sun releases energetic particles and large amount of proton and electron into the terrestrial earth atmosphere which increases the redistribution process of ionospheric F2-layer electron concentration. This result obtained was reasonably in good agreement with the previous study of ionospheric response to total solar eclipse using different measurement and methods.

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