Kodaikanal Obs. Bull. (1997) 13, 197-203

Preliminary Results of Ionosonde Measurements at Waltair (17.7° N) during the Total Solar Eclipse of October 24, 1995

P.V.S. Rama Rao, DSVVD Prasad, P. Sri Ram and P.T. Jayachandran
Department of Physics, Andhra University, Visakhapatnam 530 003, India

Abstract

The digital ionosonde system at Waltair was operated continuously from 23rd to 27th October 1995. The maximum percentage of obscuration (81%) of the solar disc occuired at 08.44 hrs IST as seen from Waltair on the eclipse day, i.e. 24th October 1995. A study on the temporal variation of h'F, $f_0 F_1$, $f_0 F_2$ and dh'F/dt on the eclipse day are presented. The h'F showed an oscillatory behaviour during the course of the eclipse. Thereafter, the h'F decreased upto 12 Hrs IST merging with the control day trend of variation thenceforth. In comparison with the temporal variation of $f_0 F_2$ on the control day, $f_0 F_2$, dropped by about 15% around 09.14 Hrs IST (i.e., about 30 minutes after maximum obscuration of the solar disc) on the eclipse day. On the other hand, $f_0 F_1$ decreased by as much as 50% on the eclipse day with no time lag between the time of maximum obscuration and the time of maximum decline of $f_0 F_1$.

Key Words : Digital Ionosonde, Ionosphere, Electron density

Introduction

A total solar eclipse occurred on 24th October 1995 over the Asian sector. It started during the sunrise hours in Iraq and terminated near Indonesia during pre-sunset hours. The totality path region passed from west to eastern sector of northern India. Waltair (17.7°N, 83.3°E, Dip 20°N), is to the south-west of Calcutta and the solar obscuration was 81%. A digital ionosonde was operated round-the-clock at Waltair during 23-27 October 1995 at 15 minutes interval. However on the eclipse day, data were obtained for every five minutes, and during the eclipse, data were collected for every one minute. The first contact of the solar eclipse was at 07:33 IST and the maximum obscuration was at 08:44 IST and the last contact was at 10:08 IST over Waltair.

As the present eclipse (low sunspot activity and no geomagnetic effects) event started during the morning hours, when ionization begins, the ionosonde observations are expected to give interesting results compared to those of the eclipse which occurred on 16th February 1980 (high sunspot activity period), when the obscuration was nearly 100% and the time of occurrence was in the afternoon hours. In this paper, the preliminary results obtained during the total solar eclipse of October 24, 1995 are presented.

Data

The digital ionosonde system (KEL-IPS 42) situated at Nagarampalem field station (11 Km from Waltair) is operated continuously during the total solar eclipse period from 23rd to 27th October 1995. The data were obtained at every 5 minutes interval on 23rd, 24th and 25th and at every 15 minutes on 26th and 27th October 1995. The important ionospheric parameters namely $f_0 F_2$, $f_0 F_1$ and $h' F$ were scaled from the ionograms of the eclipse day (24th October 1995) and of the control days (25th and 26th October 1995).

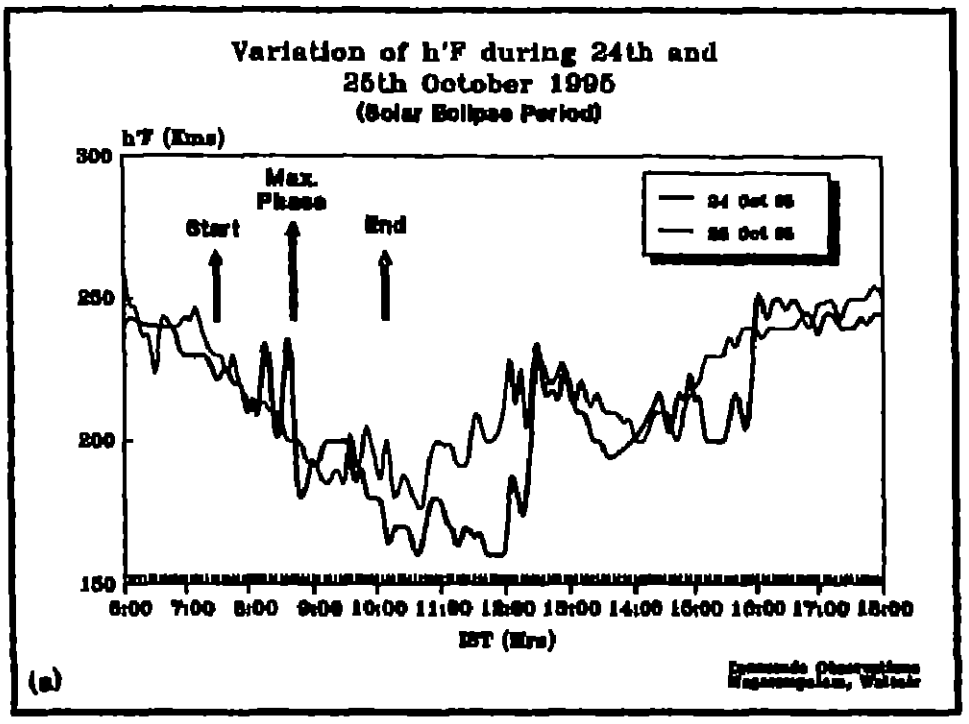
Results

1. h'F (Minimum virtual height of F-layer)

The variations of h'F as a function of time from 06:00 Hrs to 18:00 Hrs on 24th and 25th October 1995 are presented in Fig. 1a. The first contact (07:33 Hrs), the maximum phase (08:44 Hrs) and the last contact (10:08 Hrs) of the solar eclipse are indicated by arrows in the figure. The figure shows a general decrease in h'F from morning hours to the noontime and beyond. However, on the eclipse day, after a lapse of about 30 minutes from the starting phase of the solar eclipse, a sudden and significant oscillatory type of increase and decrease in h'F is seen. A sharp increase of about 40 Kms in the height of the F-layer is seen twice and then a sudden decrease in the height of F-layer of about 60 Kms is observed. The layer has again showed a gradual increase in height of about 25 Kms and the trend continued for about 30 minutes. Subsequently, the height has shown a significant but gradual decrease upto 12:00 IST followed by a sudden increase and attained the regular trend of variation. The time rate of change of h'F (d h'F/dt) also exhibited an oscillatory trend during the eclipse time, with d h'F/dt varying from +20 m/s to −20 m/s in comparison with ±5 m/s variation on the control day. Further, significant quasi-periodic variations are also seen throughout the day, both on eclipse as well as control days.

Height variations at different frequencies

It is observed that the variations in h'F are significant only at the lower frequencies (less than 4 MHz). A typical plot showing the height variation at three different frequencies (3.7 MHz, 4 MHz and 5.2 MHz) on the eclipse day is presented in Fig.1b. It is seen from this figure that there is a slight height rise at the three different frequencies after the first contact. About 30 minutes after the maximum phase, a steep fall in height is observed at lower frequencies ($\leq$ 4 MHz), while a small dip is observed at 5.2 MHz after the last contact.



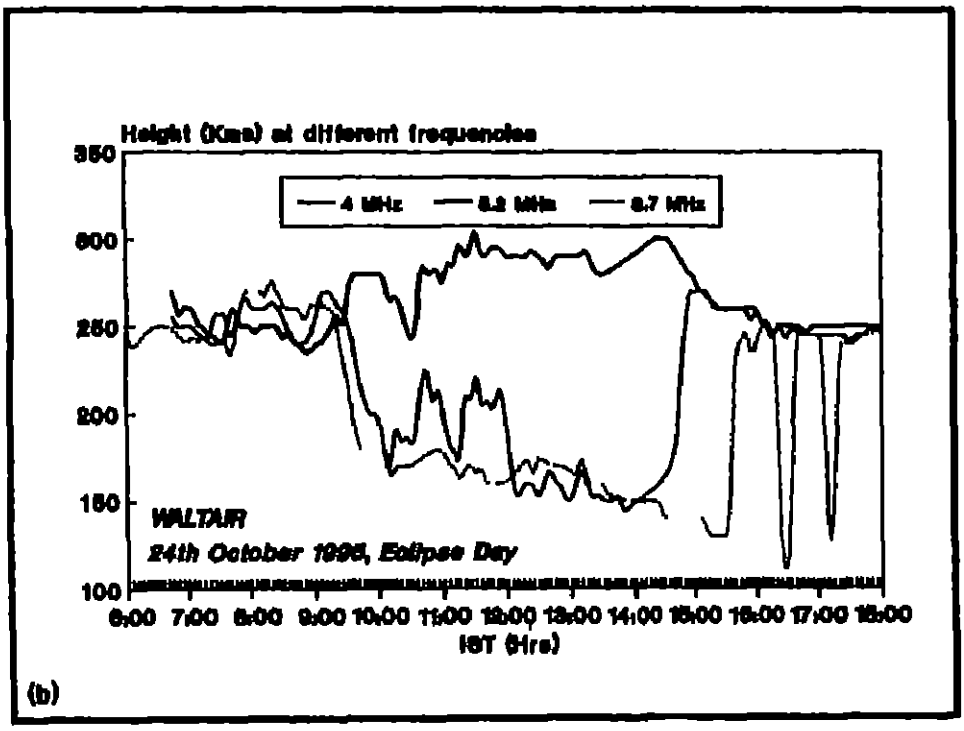


Figure 1 : Variation of (a) minimum virtual height of F-layer (b) height variation at three different frequencies on the eclipse day.

$f_0 F_2$ (critical frequency of F_2 layer)

Another important parameter namely, the critical frequency of F_2-layer, which is a measure of the maximum electron density of the peak of F-layer is studied for the above two days (24th and 25th) and the results are presented in Fig.2a. It is but natural to expect a decrease in the electron density as the solar radiations are obscured either partly or fully. It is seen from this figure that the $f_0 F_2$ on these two consecutive days followed more or less the same trend of increase from 06:00 to 08:00 IST. However, on the eclipse day, $f_0 F_2$ started decreasing from about 08:00 IST i.e. after a delay of nearly 30 minutes from the first contact. The minimum in $f_0 F_2$ is observed at about 09:15 IST i.e. nearly 30 minutes after the maximum phase of the eclipse, from where it started increasing to join the regular diurnal trend. The approximate maximum decrease in $f_0 F_2$ is about 15%.

The $f_0 F_2$ has also shown quasi-periodic variations on both the days, similar to those observed in h'F.

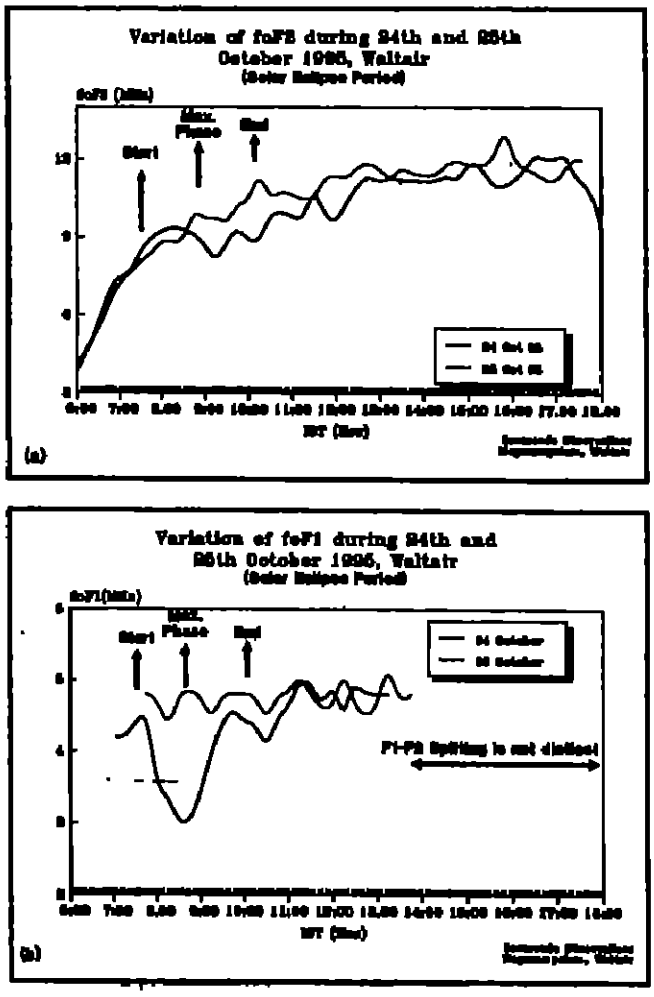


Figure 2 : Eclipse and control days variation of (a) $f_0 F_2$ and (b) $f_0 F_1$ at Waltair.

$f_0 F_1$ (critical frequency of F_1 layer)

It is known from the earlier studies on the ionosphere during the solar eclipse, that the lower regions of the ionosphere (E and F_1) are observed to be more affected than the higher regions (F_2 region and above). The values of $f_0 F_1$ with five minute interval from 06:00 Hrs to 18:00 Hrs. IST on 24th and 25th October 1995 are presented in Fig. 2b. It is clearly seen from this figure that there is a distinct depletion in the electron density of F_1 layer by about 50% at the maximum phase of the solar eclipse. Unlike $f_0 F_2$, the variations in $f_0 F_1$, have shown a significant decrease without much of a time delay with the onset of the eclipse. The variations of $f_0 F_1$, also show significant superposition of quasi-periodic variations. One of the reasons for observing a significant decrease in $f_0 F_1$ compared to that in $f_0 F_2$ is due to the effect of collisions and a subsequent loss of ionization which is more in the denser (lower) regions (E and F_1 regions) compared to that in the less denser (upper) regions (F_2).

Though there is a general decrease in both $f_0 F_2$ and $f_0 F_1$, a comparison of these two parameters reveals that near the first and last contacts the ratio between $f_0 F_2$ and $f_0 F_1$ remained around 1.65. About 20 minutes after first contact, the ratio has increased to 3 and again reduced to 1.65, 40 minutes after the maximum phase of the obscuration. Again after the last contact an increase in the ratio to a value of 2.2 is observed. In addition to these features, a damped type of oscillatory variations is also observed in both the parameters.

Discussion

Owing to the reduction in solar radiation during eclipses, the chemical equilibrium in the ionospheric layers is disturbed. Since the recombination coefficients are higher in lower regions of the ionosphere, significant reduction in the ionization is observed in these regions. In the altitude range of 140 to 170 Kms the NO^+ is the dominant ion and its loss rate is higher when compared with that of O^+, which becomes dominant above 170 Kms (Banks and Kockarts, 1973). The same reason holds good for the late response in the upper regions when compared with that of the lower regions of the ionosphere. In the present study, the ionospheric response to the solar eclipse is observed only upto 4 MHz and at altitudes around 200 Kms. While in the upper regions, less significant variations are observed. The present eclipse event occurred in the morning hours, and hence the production process should be dominant. In addition to ionosonde measurements at Waltair, a UV-B photometer (Niranjan and Thulasiraman, 1996) and a HF Doppler radar (Rao and Anjaneyulu, 1996) were also operated. The optical studies revealed significant decrease in UV flux, while the HF Doppler studies showed a long period oscillatory pattern comparable to the eclipse duration with maximum amplitudes confined to the eclipse interval. A comparison of the periods of the wave like variations obtained from the data of HF Doppler (at 5.5 MHz) and the ionosonde (at 5.6MHz) shows that there is good correspondence in the components with periods of 12,17 and 30 minutes. From the ionosonde measurements at an anomaly crest station, Ahmedabad (Dip 32°N), Chandra *et al.* (1996) also reported about 50% decrease in $f_0 E$ and $f_0 F_1$, while 15% decrease in $f_0 F_2$.

From the earlier studies made at Waltair during an eclipse event in the afternoon hours of 16th February 1980, Rama Rao *et al.* (1982) reported a 14% depletion in ionospheric total electron content (for obscuration of 99%), but no wave-like variations were observed. During the same event, the phasepath studies made at Waltair (Raj *et al.* 1982), a large amplitude with long period damped oscillatory perturbations are reported. A comparison of the above two studies indicates that the short period oscillations are observed at Waltair when the totality path is away by about 550 Kms (present study and Rao and Anjaneyulu, 1996), while they are not seen when the totality path is much closer (Rama Rao *et al.*, 1982; Raj *et al.*, 1982). The local time difference between the earlier and present eclipse occurrences, did not show much of a difference in the ionosphere over Waltair.

These studies at Waltair, a low latitude station, however differ from midlatitude observations (Matsoukas, 1970 and Anastassiades, 1970) where a slight increase in $f_0 F_2$ is reported. The ionosonde measurements at a low latitude station, Bangkok (Laan, 1970) at a similar event of total solar eclipse also showed an initial increase in $f_0 F_2$, but decreased 25 minutes after the maximum phase. At the same time, $h'F_2$, has shown a substantial increase. The interesting feature observed in this study (Laan, 1970) is the formation of $f_0 F_{1.5}$, which is not observed in the present study. This feature is observed only at stations whose magnetic dip angles are $\leq 10°$ N (Laan, 1970 and references therein).

Summary

The digital ionosonde measurements during the solar eclipse event observed on 24th October 1995, have revealed that the electron densities in the lower F-region (F_1) are more reduced (50%) when compared with those (20%) of upper F-region (F_2). The critical frequencies of both these layers showed a damped type of oscillations. The minimum virtual height of the F-layer showed prominent wave-like oscillations which are found to be more significant between 3 to 4 MHz. The general occurrence of sporadic - E (E_S) and E-layer was not seen on this day.

Acknowledgements

The authors express sincere thanks to Department of Science and Technology (Government of India) for financial assistance provided to carryout the experiment. Two authors (PSR and PTJ) thank the CSIR (Government of India) for awarding research fellowships.

References

Anastassiades M, 1970, 'The annular solar eclipse on May 20, 1966 and the ionosphere', Ed by Anastassiades M, Plenum Press.

Banks PM and Kockarts G, 1973 'Aeronomy-Part B', Academic Press.

Chandra H., Vyas GD and Sharma SK, 1996, Proc National Space Sci Symp, Paper No.TSE-03.

Laan Jan E Van Der, 1970, J Geophys Res. 75, 7, 1970.

Matsoukas Demetrius, 1970, 'Electron content measurements by beacon S-66 satellite during the May 20, 1966 solar eclipse' Ed. by M Anastassiades, Plenum Press.

Niranjan K. and Tulasiraman S., 1996, Proc. National Space sci Symp, Paper No.TSE-14.

Raj P.E., Srirama Rao M, Jogulu C and Rao BM, 1982, Ann Geophys, 38, 51.

Rama Rao, P.V.S., Rao BVPS, Niru D and Niranjan K., 1982, Proc Ind National Sci Acad, 48A, 3, 434.

Rao B.M. and Anjaneyulu P., 1996, Proc National Space Sci Symp, Paper No.TSE-15.