Bull. Astr. Soc. India (1998) **26**, 325-327

D-region electron density profiles during total solar eclipse of October 24, 1995

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Abstract. The electron density profiles in the ionospheric D-region are computed during the Total Solar Eclipse of October 24, 1995 employing the estimated occultation, neutral atmospheric model, effective recombination coefficient and GOES-7 measured X-ray flux in the 1-8 Å band. The computations are done for Diamond Harbour under totality condition and Bombay in the partial eclipse condition. It is found that the reduction in the D-region electron density with respect to the pre-eclipse values ranges from 0.006 cm^{-3} at 55 km to 123 cm^{-3} at 85 km for Diamond Harbour. The maximum reduction at a height of 85 km occurs after a delay of 20 minutes for Diamond Harbour from the ground totality condition. The electron density decrease for the partial eclipse condition for Bombay is much less.

1. Introduction

A Total Solar Eclipse (TSE) provides an opportunity to study the upper and lower ionospheric effects associated with an accurately controlled withdrawal and reintroduction of solar radiation. Earlier eclipse effects of ionization in E and F region using HF vertical sounding (Beynon and Brown 1956), the recombination effects in the D-region using riometers (Hunsucker 1965), and variations of electron and ion temperature, electron concentration, and drift velocity using incoherent scatter radars (Baron and Hunsucker 1973) were studied. Radio beacon studies of eclipse effects were reviewed by Cohen (1984). The generation of atmospheric gravity waves by the moving bow wave front of the solar eclipse was unambiguously shown by Cheng et al. (1992). There have not been systematic studies on the electron density profiles in the D-region during TSE. In this paper theoretical study of D-region electron density profiles during the TSE of October 24, 1995 are reported.

2. Computation of electron density profiles

Integrated X-ray flux data in the 1-8 Å and 0.5-4 Å bands measured by GOES-7 satellite for the eclipse day is obtained from the Solar Geophysical Data Bulletins. The X-ray spectrum was derived from integrated flux I (1-8). Hence the flux per unit wavelength interval between 1-8 Å is computed. The height profiles of electron production rate $Q_x(\chi,z)$ due to solar X-ray radiation incident at a zenith angle χ at an altitude z is computed for the height range

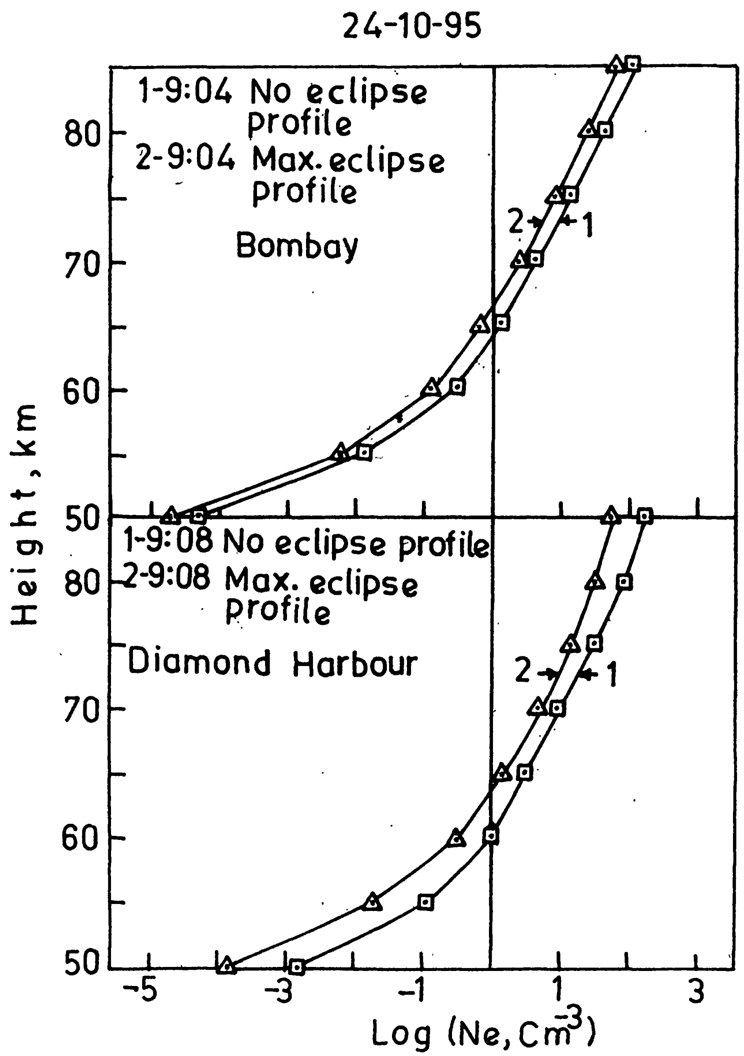

Figure 1. Electron density profiles for total and partial eclipse conditions.

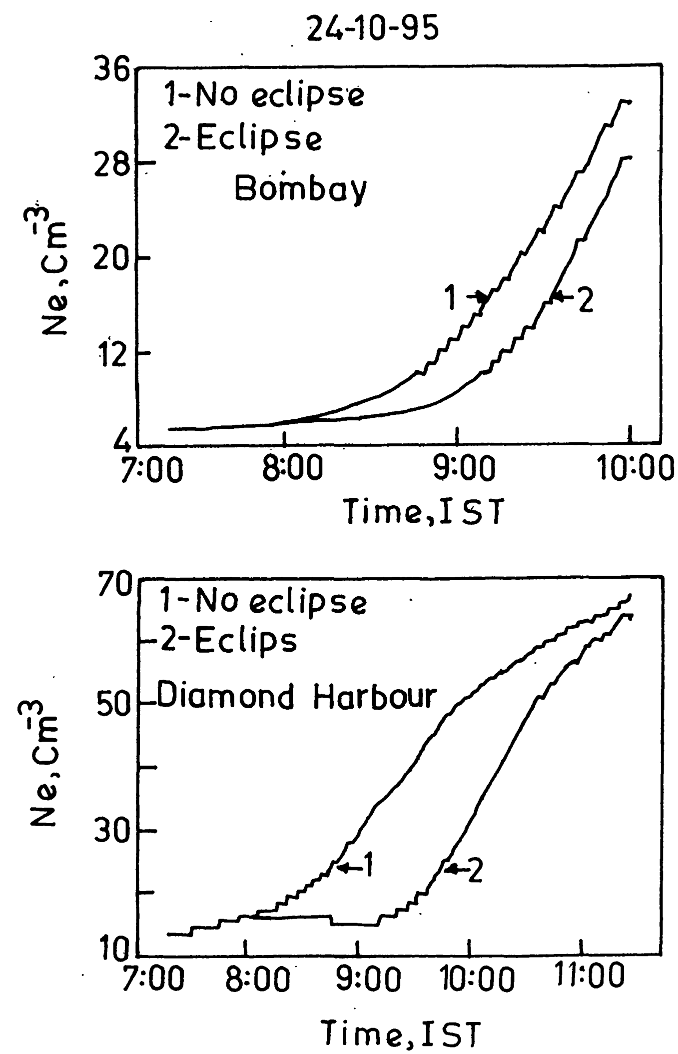

Figure 2. Variation of electron density at 75 km with time for total and partial eclipse conditions.

50-85 km using the neutral atmospheric model described by Deshpande et al., 1985. The other inputs, viz, the absorption cross section σ_{ij}, the photo ionization yield η_{ij} (Subscripts i and j refer to wavelength and neutral species respectively) and the Chapman function $Ch(\chi,x,\beta)$ are also taken from Deshpande et al., 1985.

$$Q_x(\chi,z) = \sum_i Q_i(\chi,z) \tag{1}$$

$$Q_i(\chi,z) = \phi_i(z) \sum_j \eta_{ij}\, \sigma_{ij}\, n_j(z) \tag{2}$$

$$\phi_i(z) = \phi_i(\infty) \exp\left[-Ch(\chi,x,\beta) \sum_j \sigma_{ij} \int_z^{\infty} n_j(z)\, dz \right] \tag{3}$$

Having obtained the production rate Q(z) profiles for the appropriate value of χ during the withdrawal and reintroduction of ionizing source(sun) from the above equations the electron continuity equation

$$\frac{dN(z,t)}{dt} = Q_x(z,t) - \alpha(z)\, N^2(z,t) \tag{4}$$

is solved numerically using Runge-Kutta method and the electron density N(z,t) as a function of height (z) and time (t) is obtained. α profiles are taken from Balachandra Swamy & Shetty (1988). The variation of electron density profiles for the eclipse phase is thus obtained.

4. Results and discussion

The important results are summarised as follows; The electron density decreases at all altitudes consequent to the obscuration. The decrease in electron density at partial eclipse condition is much smaller than in totality condition. There is a delay of 20 minutes for the electron density decrease with respect to the time of maximum obscuration.

The decrease of electron density in the D-region during the solar eclipse may cause a rise in the effective reflection height of VLF radio waves. In the present eclipse it was planned to study this effect but the results are yet inconclusive. VLF phase measurements during the solar eclipse of 23 Sep. 1987 at Kaojong (24°95 'N, 121° 15 'E) (in Taiwan) showed a maximum phase delay of 2.3 micro seconds which corresponds to a height rise of 3.2 km taking the normal daytime VLF reflection height to be 80 km. A delay of 8 min. for the VLF phase with respect to the time of maximum occultation was also obtained. Our present computations also show a height increase of ~about 3 km and a time delay of about 20 min for the maximum depletion in electron density at 80 km with respect to the time of maximum obscuration.

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