

Variation of Electron Collision Frequency in the Ionosphere

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Received 30 September 1980; revised received 7 May 1981

The effective collision frequency of electrons in the height range 100-460 km has been computed using the incoherent backscatter radar data of electron density and temperature and the neutral composition model given by L G Jacchia [*Special rep. No. 375* (Smithsonian Astrophysical Observatory, Massachusetts, USA), 1977]. It is found that the collision frequency varies with height and time of the day. The variations are similar to the experimental observations although the latter are an order of magnitude higher.

1. Introduction

The effective electron collision frequency (ν_g) is an important parameter for the study of various problems of ionospheric and aeronomical interest such as attenuation of radio waves and temperature distribution of various gas components. An experimental¹ as well as theoretical^{2,3} study of this important parameter has been made in the literature earlier. Its seasonal, temporal, solar and latitudinal variations have been studied in detail²⁻⁴ theoretically. However, a study of diurnal variation of (ν_g) has not been attempted earlier because the direct experimental observations of collision frequency⁵ were limited and the detailed observations of electron gas parameters were not available. In this paper an attempt is made to study the diurnal as well as the height variations of (ν_g).

In the region above 200 km the electron-ion collisions completely dominate over the electron-neutral collisions². The diurnal and height variations above 200 km are therefore essentially those reflected by the electron-ion collisions. However, for the sake of completeness, we will include in our analysis the electron-neutral collisions as well.

The electron-ion collisions have been computed using the experimental hourly values of electron and ion temperatures T_e and T_i and the electron density N_e taken on 12, 13 and 14 August 1974, from 0600 to 1800 hrs, from the Arecibo incoherent backscatter radar (geomag. lat., 18.4°N; long. 66.8°W). All the three days chosen for analysis are quiet days. The mean 10.7 cm solar flux for the period is 93.5 units and the mean zurich sunspot number is 67. The electron-neutral collisions have been derived from the neutral composition taken from the Jacchia⁶ model corresponding to the exospheric temperature of 900°K.

2. Electron Collision Frequency

The effective electron-ion collision frequency (ν_{ei}) is given by²

$$\langle \nu_{ei} \rangle = \frac{8\pi}{3} \frac{z^2 e^4}{(2\pi m)^{1/2}} \frac{N_e}{(k T_e)^{3/2}} \ln \Lambda \quad \dots (1)$$

where

$$\Lambda = \frac{k^{3/2}}{1.78 z e^3} \frac{T_e^{3/2}}{(2\pi N_e)^{1/2}} \left(\frac{2 T_i}{T_e + T_i} \right)^{1/2} \quad \dots (2)$$

e Electron charge

m Electron mass

N_e Electron density

T_e Electron temperature

T_i Ion temperature

z Degree of ionization of the plasma

k Boltzmann's constant

In the present analysis the diurnal variation of $\ln \Lambda$ which appears in Eq. (1) is within 10% of its maximum value although its height variation is quite significant. Thus, for a particular height taking $\ln \Lambda$ to be invariable, Eq. (1) may be written as

$$\langle \nu_{ei} \rangle = C N_e T_e^{-3/2} \quad \dots (3)$$

where C is a constant.

The effective electron-neutral collision frequency in the height range 100-500 km has been computed by including the contribution of the neutral species, namely, N_2 , O_2 , N , O and He using the following expression³.

$$\langle \nu_{en} \rangle = n [a T_e^{1/2} + b T_e + c T_e^{3/2} + d T_e^2] \quad \dots (4)$$

where the constants a , b , c and d have been taken from Aggarwal and Setty³. In Eq. (4), n is the concentration of neutral species for which (ν_{en}) is being calculated. The

effective total electron collision frequency profile (ν_{θ}) is the given by the sum (ν_{ei}) + (ν_{en}).

3. Results

In Fig. 1 (a-h) the diurnal variations of N_e and T_e for the three day period, 12-14 Aug. 1974, for a series of fixed heights from 0600 to 1800 hrs using the observations of Arecibo radar have been plotted. The variations of N_e and T_e are opposite to each other⁷⁻⁹ except for heights 152.7 and 203.1 km. The

corresponding (ν_{ei}) variation are shown in Fig. 2. It is clear from Figs. 1 and 2 that the computed (ν_{ei}) varies closely in parallel with N_e ; however, the former variations are slightly magnified because of inverse variations of T_e . The effects of T_e and $\ln \Lambda$ on (ν_{ei}) are small.

The diurnal variation of (ν_{ei}) is asymmetric; the morning values being lower than the evening values and (ν_{ei}) passes through a maximum between 1200 and 1400 hrs. A comparison of these variations with the

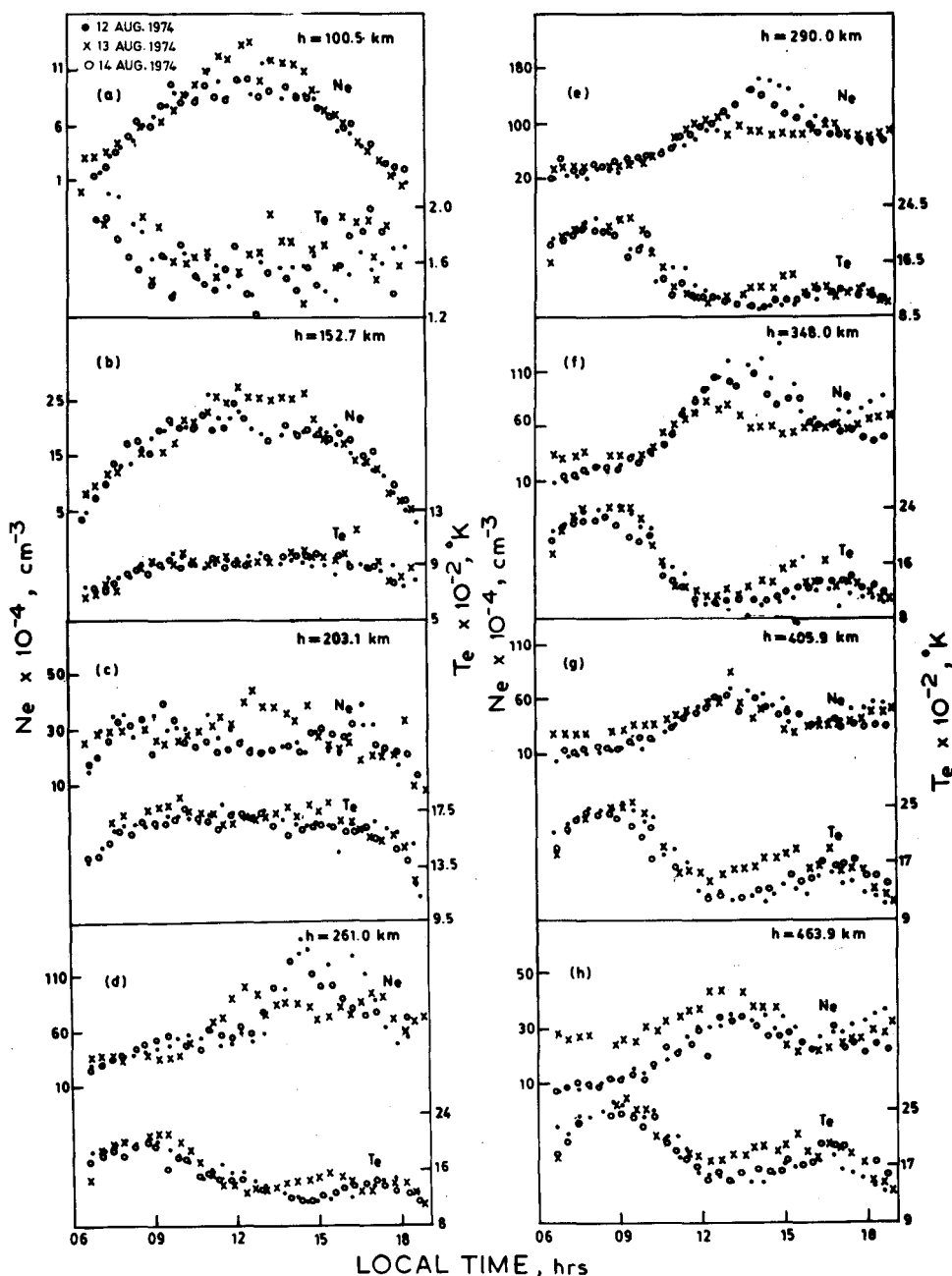


Fig. 1—(a-h) Diurnal variations of N_e and T_e for a series of fixed heights

experimental results of Setty *et al.*⁵ shows a close similarity although the latter are an order of magnitude too high. This discrepancy has already been highlighted in earlier²⁻⁴ reports. Recent Russian experiments^{10,11} have been designed to look into this problem.

Fig. 3 shows the diurnal and height variations of (v_{ei}) . The peak of (v_{ei}) and maximum variation both occur at 300 km. The calculated height profile of (v_{en}) along with the resulting (v_g) corresponding to the exospheric temperature 900°K and 14 hrs 19 m LMT for 14 Aug. 1974 is also shown in Fig. 3. It is found that (v_{en}) does not show significant diurnal variation. It is observed that (v_{ei}) dominates over (v_{en}) above 200 km.

The mass plots of (v_{ei}) plotted for a series of heights, as a function of the square of the plasma frequency f_N^2 [in (MHz)²], are found to be near straight line graphs. The slope of straight line for each height yields a T_e which is in fair agreement with the assumed T_e for that height, from the radar data. The heights 152.7 and 203.1 km are however exceptions. The T_e derived from the slopes are higher than the radar data.

The inverse N_e - T_e variation has been utilized in constructing models of T_e in the ionospheric F-region⁷⁻⁹. The following expression for T_e has been given by Brace and Theis⁸,

$$T_e = P_1 + (P_2 h + P_3) \exp (P_4 h + P_5 N_e + P_6 N_e h).. (5)$$

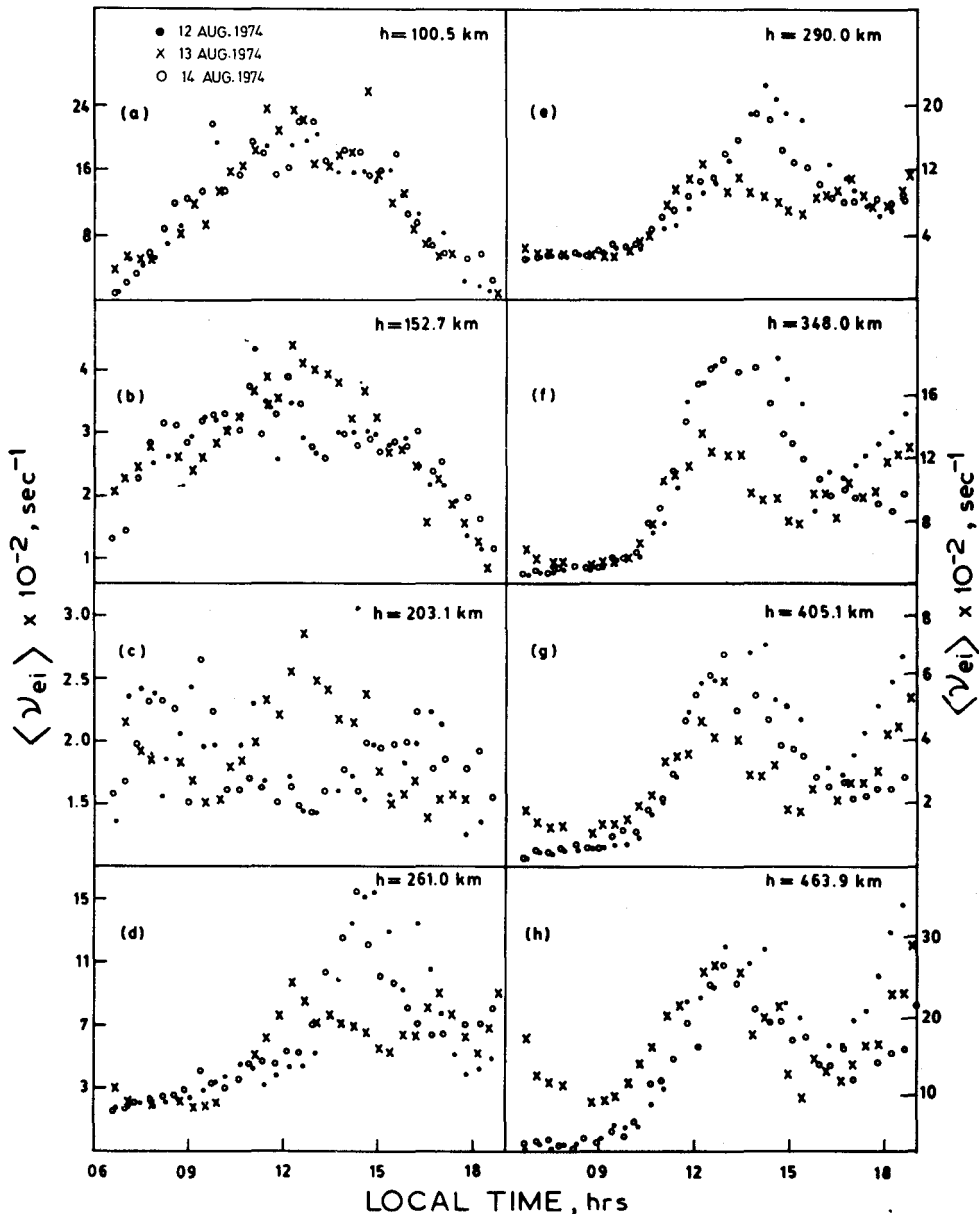


Fig. 2—(a-h) Diurnal variations of (v_{ei}) for a series of fixed heights

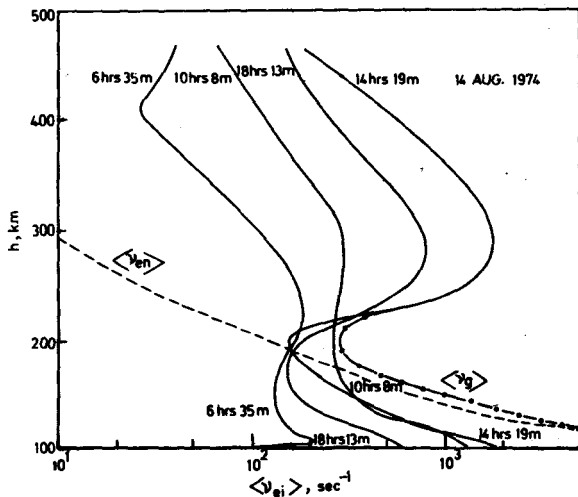


Fig. 3—Height profiles of (ν_{ei}) , (ν_{en}) and (ν_g)

where P_1, P_2, P_3, P_4, P_5 and P_6 are constants, for the height variation of T_e . The diurnal average of T_e for a fixed height calculated from Eq.(5) is progressively lower than the radar values for heights above 200 km.

It is concluded that (ν_{ei}) which is dominant above 200 km, shows pronounced diurnal and height variations. It is thus imperative to take the diurnal variation of (ν_{ei}) into account while analyzing the radio wave absorption and other propagation data.

Acknowledgement

The work reported in this paper has been carried out under the research project "Middle Atmosphere Programme" financed by the University Grants Commission, New Delhi. The Arecibo data used in this analysis were kindly made available to us by Prof. James CG Walker. Thanks are due to Dr Narinder Nath for helpful discussions.

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