Pergamon

Adv. Space Res. Vol. 14, No. 12, pp. (12)139–(12)141, 1994

0273–1177/94 $7.00 + 0.00

RELATIVE ABUNDANCE OF H^+ AND He^+ IN OUTER IONOSPHERE

I. Kutiev and S. Stankov

Geophysical Institute, Bulgarian Academy of Sciences, Acad. G. Bonchev Str., block 3, Sofia 1113, Bulgaria

ABSTRACT

A mathematical model is used to study the relative abundance of H^+ and He^+ ions in the topside ionosphere. It is found that the daytime light-ion densities are strongly coupled with the neutral densities. This fact arises difficulties in modelling the ion composition for IRI without taking into account any particular reference atmosphere. As an example, the transition heights between O^+-H^+ and O^+-He^+ are shown, plotted against the neutral densities. The supposed linear dependance gives a clear evidence that all light-ion ionization below these heights will experience stronger influence by the neutral atmosphere.

INTRODUCTION

The ion composition in IRI is not in correspondance with recent satellite observations. There are at least two reasons for that. First, the IRI ion composition data base is very limited /1/. Also, no data from the well-known satellites as AE-E, AE-C, DE-2, etc. is considered there. The second reason is the great variability of the light ion densities /2/.

When the transition surfaces (hereafter O^+ - H^+ transition will be denoted by TL(H^+) and O^+ - He^+ transition - by TL(He^+)) are defined experimentally, this will reduce in a substantial extent the uncertainties in the determination of the height profiles of light ions. Still, the TL cannot determine the light ion profiles with the necessary accuracy, because the different neutral densities will give them different proportions with O^+.

The simple combination of satellite data measured at different altitudes will not yield real vertical profile data. The reason for this is the different conditions, at which the data are obtained. Every vertical profile measured in this way will be an average in time or latitude.

This paper will consider some theoretical relations on optimizing the ion composition obtained.

THEORETICAL CONSIDERATIONS

If we consider that electron density is reliably determined in IRI, then the relative densities or percentage of O^+, H^+, and He^+ can be obtained under the following assumptions. At daytime, the production and the losses of these ions depends on the neutral density and composition and they both form upward flows which fill the plasmasphere. At night however, the ion densities considered depend mainly on compensation flows from the plasmasphere and are not strictly coupled with the neutral atmosphere. Therefore, a theoretical intervention in the model is more reliable at daytime than at nighttime. To determine nighttime ion proportions, more empirical relations are needed.

The altitude O^+ profile is strongly connected to the neutral model when we restrict the diffusion velocity $\nu(O^+)$ to change its sign around h_mF: below h_mF the velocity will be negative, above h_mF - positive. In doing this, we can find coupled neutral (from MSIS, for example) and O^+ profiles. The next step is to attribute to each couple an H^+ and He^+ profile. For both light ions we assume photochemical equilibrium at 600 km. In /3/ is shown that at this height

$$He^+ = 63.3\frac{n(He)}{n(N_2)}$$

The corresponding value of H^+ can be taken from the charge-exchange two-way reaction

$$\frac{H^+}{O^+} = \frac{9}{8}\frac{n(H)}{n(O)}$$

The initial values of O^+, H^+, and He^+ at 500 km are used as boundary values in a F-region model, where height profiles of these ions are obtained till 600 km. These profiles are very sensitive to the value of upward diffusion flow. In the transition region, where O^+ and H^+ have comparable densities, we put the condition that O^+ flow will fully convert itself into H^+ flow through charge exchange. This condition strongly reduces the limits of H^+ and O^+ mutual variations.
At the same time the upward flow of He^+ ions is restricted to a reasonable limit of ~ $1.0\times10^5 cm^2/s$.

THE F-REGION MODEL

Introducing the polarization field as a variable with its own equation, we decouple the equations of continuity and momentum and obtain a set of seven first-order differential equations for the three ions considered:

$$\frac{kT_i}{n_i}\frac{dn_i}{ds} + k(1-\alpha)\frac{dT_i}{ds} + m_i g \sin I - eE + \sum_i m_i \nu_i (v_i - v_j) = 0$$

$$B\frac{d}{ds}(\frac{1}{B}n_i v_i) = P_i - L_i$$

$$eE + \frac{kT_e}{n_e} - \frac{dn_e}{ds} + k\frac{dT_e}{ds} = 0$$

where $i = 1(H^+)$, $2(O^+)$, and $3(He^+)$.
The energy balance equations are not solved; instead, theoretical expressions from /4/ are adopted for T_e and T_i:

$$T_e(h) = [T_{eb}^{7/2} - 0.45\Phi_e(h_b - h)]^{2/7}$$
$$T_i(h) = (T_n(h) + bT_e^{-0.5})/(1 + bT_e)^{-1.5}$$

where $b = 1.0\times10^{12}/n$, n being the total neutral number density

$$n = n(O) + n(O_2) + n(N_2) + n(He) + n(H)$$

RESULTS

In this paper we consider only the TLs obtained from calculated profiles. In Fig.1 TL(H^+) variations are shown . The left two panels display the relation between TLs and the total neutral density, while the right two panels show the TL relation with n(H)/n(O) and n(He)/n(N_2). These ratios give a measure for the rate of the H^+ and He^+ recombination. Also, TL(H^+) and TL(He^+) are in a linear relation with the neutral densities.

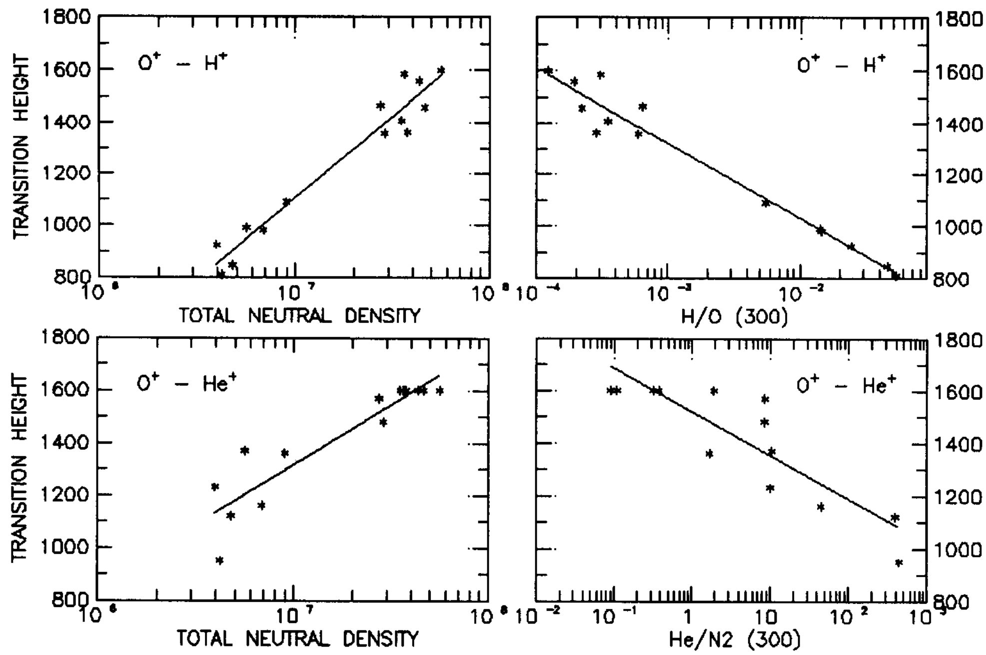

Fig.1. TLs versus neutral densities:
The upper 2 panels display the relation between TL(H^+) with the TD and H/O at 300 km.
The lower 2 panels display the relation between TL(He^+) with the TD and He/N_2 at 300 km.

The linear dependance shown in Fig.1 gives:

$$TL(H^+) = 275.482\ln(TD) - 3332.280$$

$$TL(H^+) = -125.795\ln(R_1) + 451.683$$

$$TL(He^+) = 198.702\ln(TD) - 1885.410$$

$$TL(He^+) = -72.026\ln(R_2) + 1519.780$$

where R_1 = H/O, R_2 = H/N_2, and TD is the total neutral number density.

DISCUSSION

Results from Fig.1 show how sensitive the TLs are to the neutral amosphere changes. Although the ratios H/O and He/N_2 yield lower scatter of the points, the total neutral density still can be used in describing TLs behaviour. Once TLs are so influenced by atmosphere changes this is valid to the same extent to whole light-ion height profiles. This gives rise to the question of how neutral and ionized reference model to be used jointly. It is difficult to be achieved even because these models are described by different solar and geomagnetic indexes.

ACKNOWLEDGEMENTS

This work is carried out under grant NZ 14/91 of Bulgarian National Scientific Research Foundation.

REFERENCES

1. D. Bilitza, *Adv.Space Res.* 11, #10, 183 (1991).
2. H.C. Booker, *J.Atm.Terr.Phys.* 39, 619 (1977).
3. R.A. Heelis, W.B. Hanson and G.J. Bailey, *J.Geophys.Res.* 95, #A7, 11313 (1990).
4. I. Kutiev, N. Bankov, R. Koleva, *Bulg.Geophys.J.* 26, #1, 30 (1990).