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D-Region Model Study for Udaipur*

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On the basis of a simplified ion-chemical scheme a D-region model is prepared. Multifrequency absorption results measured at Udaipur match with the electron density profile obtained from the scheme. The results are compared with positive ion and electron concentrations measured at the same solar zenith angle position over Thumba. The scheme used is slightly different from that of the existing ones in both negative and positive ion sides.

In the study of mesosphere the six-ion scheme of Mitra and Rowe[1] has led to the establishment of reactions leading up to $NO^+ H_2O$. Using this scheme, models matching with the multifrequency A_1 absorption for Udaipur (lat., 24°35′ N; long., 73°42′E) have been prepared in this study. The results have been compared with positive ions measured over Thumba[2] and different electron density (N_e) profiles of low latitudes.

The scheme used in the present study is the modified form of Mitra and Rowe scheme[1]. This modification has been dealt with by Mitra[3].

The steady state continuity equations for all the positive and negative ions have been framed and solved simultaneously with an arbitrary initial value of N_e. The equations are then iterated until plasma neutrality condition is achieved. The various parameters used in the analysis are as follows.

Rate coefficients, recombination coefficients and photodetachment coefficients which have been used in the present study are given in Table 1. The values of photodetachment coefficients γ_2 and γ_3 of X^- and Y^- category ions have been adjusted by trial and error, keeping in view the following. (i) The values of λ (ratio of negative ions to electrons) should match the experimental values or theoretical estimate of others such as Rowe *et al.*[4] and (ii) the values of γ_2 should be much higher than γ_3. This is due to the estimates of the photodetachment coefficients made for individual negative ions of X^- and Y^- categories[5]. Values less than 10^{-15} for the rate coefficient K_{11} have been used in this study. It is found that the appropriate value of K_{11} is 10^{-17} $cm^3 sec^{-1}$. Further, the value of the lumpsum rate coefficient K_6 converting $NO^+ H_2O$ to $H^+(H_2O)_n$ has been adjusted to match the concentration of NO^+H_2O with the observed one. Chakrabarty *et al.*[6] suggested the value of this rate coefficient to be 3.3×10^{-10} $cm^3 sec^{-1}$, but it is found that with this value the concentration of NO^+H_2O does not match the measured one. The appropriate value of K_6 has been found to be 5×10^{-11} $cm^3 sec^{-1}$. The values of recombination coefficient of water cluster positive ions with electron K_{25} have been computed as suggested by Mitra[3].

Table 1—List of Reaction Rates Depicted in the Scheme

Reaction rates	Reference No.
$K_1 = 2 \times 10^{-31}(300/T)^{4.4}[M]$	18
$K_2 = \frac{1.5 \times 10^{+6}}{T^{5.4}}[M]\exp[-2450/T]$	19
$K_3 = 7 \times 10^{-30}(300/T)^3[M]$	19
$K_4 = 10^{-9}$	20
$K_5 = 10^{-9}$	20
$K_6 = 5 \times 10^{-11}$	
$K_7 = 2.8 \times 10^{-30}(300/T)$	21
$K_8 = 3 \times 10^{-10}$	21
$K_9 = 1.5 \times 10^{-9}$	21
$K_{10} = 4.4 \times 10^{-10}$	22
$K_{11} < 10^{-15}$	23
$K_{12} = 1.4 \times 10^{-10}$	21
$K_{13} = 5 \times 10^{-11}$	21
$K_{14} = 1.4 \times 10^{-29}(300/T)\exp(-600/T)$	24
$K_{15} = 10^{-31}$	25
$K_{16} = 1.5 \times 10^{-10}$	20
$K_{17} = 2 \times 10^{-10}$	21
$K_{18} = 6 \times 10^{-10}$	20
$K_{19} = 10^{-30}$	3
$K_{20} = 1.1 \times 10^{-11}$	20
$K_{21} = 10^{-7}$	26
$K_{22} = 4 \times 10^{-7}(300/T)$	26
$K_{23} = 2 \times 10^{-7}(300/T)$	26
$K_{24} = 2.3 \times 10^{-6}(205/T)$	21
$K_{25} = 10^{-5}$ to 10^{-6}	26
$\gamma_1 = 0.33$	3
$\gamma_2 = 0.5$, 0.2 and 0.05 at 60, 65 and 70 km, respectively	
$\gamma_3 = 10^{-2}$, 5×10^{-3} and 10^{-3} at 60, 65 and 70 km, respectively	

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CIRA-72 (Ref. 7) has been consulted for temperature and profiles of N_2 and O_2. Concentration of minor neutral constituents is taken from Mitra[8]. Ion-pair production rates of different wavelength ranges 1-1025.7Å and 1-1215.7 Å have been provided by Mitra[9]. Ionization production from $O_2(^1\Delta g)$ due to solar radiation in the wavelength range 1027-1118 Å has been computed as indicated by Paulsen *et al.*[10] Ion-pair production rates for moderate activity at $\chi = 30°$ used in the present study are shown in Fig. 1.

In the process of computing N_e, positive and negative ion densities have also been computed. Negative ion density profiles are shown in Fig. 2. It is found that X^- category ions which contain mainly CO_3^- ion dominate over other ions at all the heights. Quiet daytime measurements of negative ions are not available and thus cannot be compared with the computed ones. However, our results agree with the rocket measurements of Narcisi[11] during PCA conditions in that CO_3^- ion dominates over other ions at all the heights between 60 and 80 km.

The concentrations of different positive ions NO^+, O_2^+, NO^+H_2O and $H^+(H_2O)_n$ as computed by the present model are shown in Fig. 3, which are compared with the measured ones. One can see that the agreement for the molecular ions NO^+ and O_2^+ above

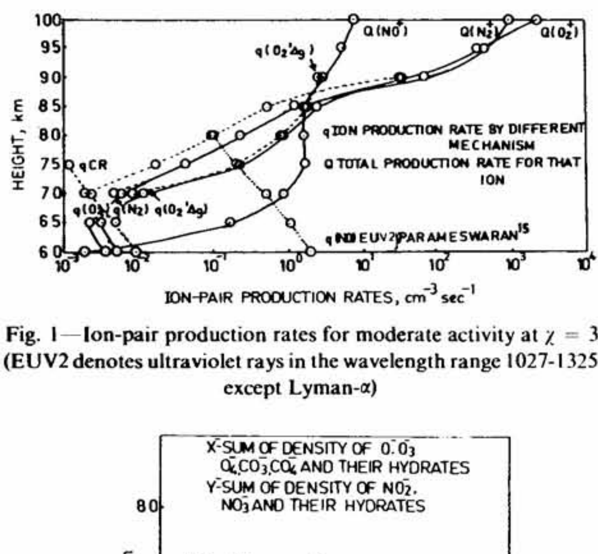

Fig. 1—Ion-pair production rates for moderate activity at $\chi = 30°$ (EUV2 denotes ultraviolet rays in the wavelength range 1027-1325 Å except Lyman-α)

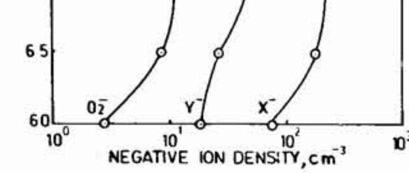

Fig. 2—Computed profiles of negative ions

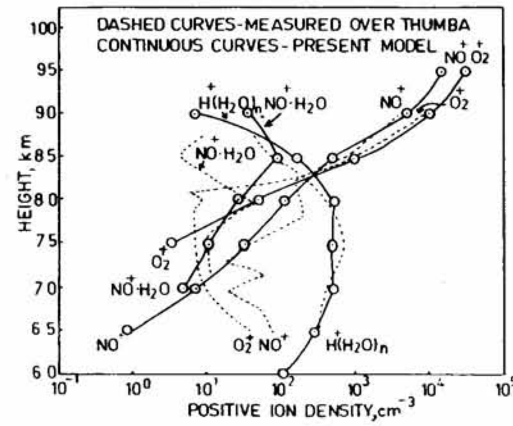

Fig. 3—Computed positive ion density compared with rocket profile[12]

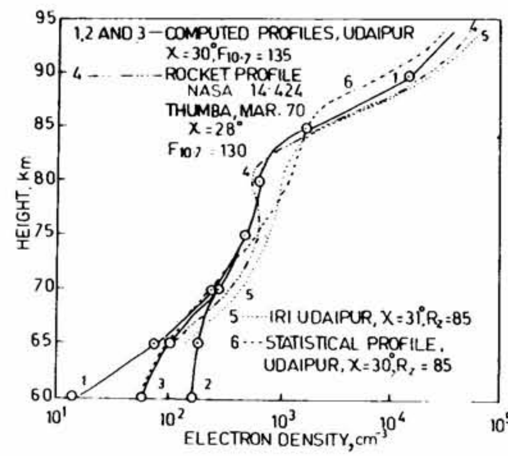

Fig. 4—Computed electron density profiles along with observed and theoretical models

75 km is quite good, but below this height the agreement is poor. Further, the cross-over of O_2^+ over NO^+ in both the profiles is at about 83 km suggesting that the appropriate value of K_{11} is $10^{-17}cm^3sec^{-1}$. The agreement in the total concentration of water cluster positive ions is extremely good at all the heights. Though the concentration of NO^+H_2O matches well up to 80 km, yet it differs above this height. The situation may be improved when the lumpsum rate coefficient K_6 is taken as temperature dependent.

In Fig. 4, the present model N_e profile (No. 1) has been depicted along with other N_e profiles[12-14] (Nos. 4-6) under identical conditions (moderate activity, $\chi = 30°$ and low latitudes), for comparison. One can see that the agreement between the rocket profile[12] (No. 4) and computed profiles (Nos. 1-3) is quite good above 70 km whereas below 70 km the computed values are low in comparison to others as was also the case with positive molecular ions. Recently, Parameswaran[15] has pointed out that not only Lyman-α but the whole wavelength range 1027-1325 Å ionizes nitric oxide and

Table 2—Experimental and Computed Total Absorption for Different N_e Profiles at Various Wave Frequencies

Frequency MHz	Experimental total absorption at $\chi = 30°$ dB	Total absorption (dB) for			
		Present model (Profile No. 3)	Rocket profile[12] (Profile No. 4)	IRI model[14] (Profile No. 5)	Statistical[13] (Profile No. 6)
2.3	45.31	45.05	57.50	49.85	31.86
2.5	40.51	42.94	53.44	47.16	31.54
2.8	38.59	39.62	43.61	47.10	30.43
3.0	36.22	33.87	39.83	40.39	29.42

this ionization dominates over other ionizations in the height range 60-70 km. If we include this ionization, the computed N_e (profile 2) becomes much higher than that expected in this height range. It looks that Parameswaran[15] has overestimated this ionization. If this ionization is reduced by a factor of 10, then the agreement with other profiles in this height range is quite good (profile 3). This ionization slightly improves the disagreement in the NO^+ ion concentration also, but the concentration of O_2^+ ion is not affected. The disagreement in computed and measured O_2^+ ion may not be very serious, since in the mass-spectrometer measurements 32 positive ions are recorded which may be sulphur ions as suggested by Narcisi[16].

Experimental measurements of multi-frequency ionospheric absorption of radiowaves are in progress at Udaipur since 1972 using A_1 technique. For the present study, those measurements have been taken which were made during moderate activity period and at $\chi = 30°$. These are shown in Table 2 along with the computed values. Total ionospheric absorption of the radio waves of frequencies 2.3, 2.5, 2.8 and 3.0 MHz has been computed using Sen-Wyller theory[17] for different N_e profiles shown in Fig. 5. These frequencies have been found to be reflected from the E-region. Therefore, the model D-region N_e profile (No. 3) has been smoothly joined with the Chapman E-region profile with $f_0E = 3.5$ MHz which is appropriate under the same conditions at this latitude. It may be seen that the measured values of absorption agree very well with the computed values for the model N_e profile (No. 3).

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