A NEW TECHNIQUE FOR ESTIMATING D-REGION EFFECTIVE RECOMBINATION COEFFICIENTS UNDER DIFFERENT SOLAR FLARE CONDITIONS

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Abstract. Under solar flare conditions, the intensity of the solar X-rays below 10 Å increases by several orders of magnitude, while the increase in intensity of H-Lα is small. Photo-ionization rates in the various wavelength bands in the XUV spectrum have been presented graphically as a function of altitude under quiet, M3, X4, and outstanding flare conditions to show the relative importance of solar X-rays below 10 Å in the height range between 50 and 90 km. Presuming the total time constant for recombination of the ions with electrons remains constant at each altitude under different flare conditions, one can obtain the effective recombination coefficient \( \psi_{\text{eff}} \) under these conditions with a knowledge of the quiet time recombination coefficient, the production rate profiles and \( \lambda \) profiles. The importance of the ratio \( \lambda \) of negative ions to electrons below 70 km in lowering the effective electron loss rates has been highlighted.

1. Introduction

It has been well established that under solar flare conditions, the intensity of the solar X-rays below 10 Å increases by several orders of magnitude, while the intensity of solar H-Lα of wavelength 1215.6 Å increases by small factors. The X-rays emitted from solar flares cause increased D-region ionization over the entire sunlit hemisphere. The increased electron production rates under solar flare conditions considerably alter the photochemistry of the D-region. Detailed knowledge of the X-ray spectrum makes it possible to estimate the electron production rates, but estimates of the resulting electron densities are complicated by a decrease in loss rate, associated with the intense radiation. Several experimenters (Popoff et al., 1971; Montbriand and Belrose, 1972) in the past have estimated the effective recombination coefficient under quiet and disturbed conditions by using the relation \( \psi_{\text{eff}} = q/N_e^2 \) from in situ measurements of electron production through solar fluxes and electron density during these conditions. No theoretical model for \( \psi_{\text{eff}} \) has been attempted. Such a model, if available, can readily be used for studies involving flares, storms, energetic particle precipitations, etc. In this paper, it has been attempted to give the effective recombination coefficient model under different degrees of disturbed conditions in the D-region of the ionosphere. Though the model has been given for flare conditions, it could possibly be applied to other disturbed conditions such as storms, energetic particle precipitations, etc.

2. Rates of Electron Production

The photoionization rates of the major neutral constituents \( N_2 \) and \( O_2 \), taken from the CIRA (1971) model atmosphere, have been computed using the well-known Chapman
production function (Equation (1)) by a standard procedure using the representative event spectra below and above 20 Å from satellite measurements compiled by Deshpande and Mitra (1983) from various sources, ionization and absorption cross sections for quiet, M3, X4, and outstanding flare conditions

\[ q(\lambda, z, x) = \sum I_\infty(\lambda) \eta(j, \lambda) \eta_j(z) \sigma_j(\lambda, \lambda) \exp(-\tau(\lambda, z, x)), \]  

(1)

where

\[ \tau(\lambda, z, x) = \sum \sigma_j(\lambda, \lambda)n_j(z) Ch(x, z); \]  

(2)

and \( \sigma_j(\lambda, \lambda) \) is the absorption cross section at wavelength \( \lambda \) for the \( j \)th type atmospheric constituent with concentrations \( n_j(z) \) and scale height \( H_j(z) \) at altitude \( Z \). \( Ch(\chi, z) \) is simply the secant of the solar distance when \( \chi \) is less than 75°. The scale height \( H_j(z) \) is given by

\[ H_j(z) = \frac{RT(z)}{M_j g(z)}, \]  

(3)

where \( R \) is the universal gas constant for one gram molecule of the gas, \( M_j \) is the mean molecular mass of the \( j \)th constituent in a.m.u. But

\[ g(z) = g_0(z) \left(1 + \frac{z}{R_e}\right)^{-2}, \]  

(4)

where \( R_e \) is the radius of the Earth and \( g_0(z) \) is the acceleration due to gravity on the surface of the Earth.

The photoionization rates of NO, ionized by H-Lα, of metastable \( O_2(1\Delta_g) \), ionized by UV radiation in the wavelength band 1027–1118 Å (Huffman et al., 1971) have been separately computed using Equations (5) and (6). The height distributions of the minor neutral constituents NO, \( O_2(1\Delta_g) \), and \( O \) are taken from Mitra (1977) compiled from various sources.

The photoionization rates of the minor neutral constituent NO, ionized by H-Lα have been computed from the relation

\[ q(NO^+) = I_\infty, L_\alpha \sigma_l(NO, L_\alpha) [NO] \exp(-\sigma_\chi(O_2, L_\alpha) [O_2] H(O_2) \sec \chi), \]  

(5)

where \( I_\infty, L_\alpha \) = intensity of the solar Lα line at the top of the atmosphere.

The photoionization rates of \( O_2(1\Delta_g) \) in the wavelength range 1027–1118 Å is calculated by using the empirical relation of Paulsen et al. (1972)

\[ q(O_2^+) = [O_2(1\Delta_g)] \{0.549 \times 10^{-9} \exp(-2.406 \times 10^{-20}[O_2] H(O_2) \sec \chi) + 2.164 \times 10^{-9} \exp(-8.508 \times 10^{-20}[O_2] H(O_2) \sec \chi)\}. \]  

(6)

The galactic cosmic rays (GCR) ionize all neutral particles. The photoionization rates of the various constituents by GCR have been computed from the relation (Velinov,