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THE ROLE OF THE ATOMIC OXYGEN CONCENTRATION IN THE IONIZATION BALANCE OF THE LOWER IONOSPHERE DURING SOLAR PROTON EVENTS

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Abstract. It is shown that during a Solar Proton Event (SPE), when the ionization of the mesosphere is of a high degree, experimental data on the electron density obtained with the incoherent scatter technique as well as with partial reflection technique may be used as a criterion for choosing the atomic oxygen profile. The influence of the atomic oxygen concentration on the ionization balance at mesospheric altitudes during SPE on 17 January 2005 is investigated.

Introduction

For construction of the fullest and detailed models of the lower ionosphere it is necessary to determine a role of small components of the top atmosphere of the Earth: oxide of nitrogen, vapor of waters, atoms of oxygen, etc. at formation of structure and composition of the ionosphere at heights of the D region in various geophysical conditions. As concentration of small components are poorly known; there are difficulties of theoretical simulation of electron density and ionic structure of the D region [Danilov, 1989; Zadorozgnyi, 1982]. In this paper the influence of variations of atomic oxygen concentration on altitudinal distribution of the charged particles concentration of ionospheric plasma of various grades and an effective factor of recombination are considered during the event of the penetration of solar protons (SPE) to mesospheric heights.

Results of observations and model calculations

Experimental data on the atomic oxygen concentration at heights lower than 80 km are absent. Therefore one uses the high-altitude profiles of atomic oxygen $N_O(h)$ received in diffuse-photochemical models for quiet geophysical conditions (Fig. 1 profiles 1-3) [Zadorozgnyi, 1982]. It is seen, that the disorder in theoretical estimations of atomic oxygen concentration is very great.

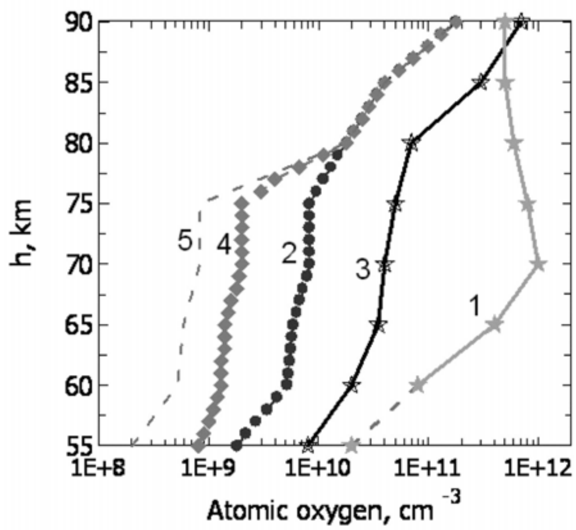

Figure 1. Profiles of atomic oxygen

According to model calculations, during SPE the concentration of the atomic oxygen at heights of 40-75 km is 2 - 8 times less in comparison with quiet conditions. It occurs because of increase of the concentration of the oxide nitrogen and odd hydrogen at SPE. According to these estimations in Fig. 1 profiles $N_O(h)$ at heights h < 80 km with concentration of particles is 4 and in 10 times less (profiles 4 and 5) than in quiet conditions (profile 2). At heights $h \geq 80$ km the concentration of the atomic oxygen is obtained from the model MSIS-2002. All profiles $N_O(h)$ presented in Fig. 1 have been used as entrance parameters for model calculations of the electron concentration and ion composition during SPE on 17 January 2005.

For computation of the ionization rates we used data on differential solar proton fluxes in the energy range 2.4-300 MeV measured with the GOES-10 satellite [http://spidr.ngdc.noaa/spidr]. Ionization rates produced by both soft and hard X-rays during a strong solar flash with maximum intensity (j_1(λ=0.5-3.0 Å)= 9.2×10^{-5} W/m^2 and j_2 (λ=1.0-8.0Å)= 4.1×10^{-4} W/m^2) at 09:50 UT on 17 January 2005 [http://ftp.ngdc.gjv/STP/Solar data] have been also calculated and taken in account.

Fig. 2 shows the model and the measured (by methods of partial reflections (h ≤ 62 km) and incoherent scattering (h ≥ 70 km)) profiles of the electron concentration $N_e(h)$ in the D region of the ionosphere during the considered event. For calculation of theoretical N_e-profiles of the electron concentration of D-region the model of ionic chemistry has been used [Smirnova et al., 1988; Kirkwood and Osepian, 1995; Osepian and Smirnova, 1996].

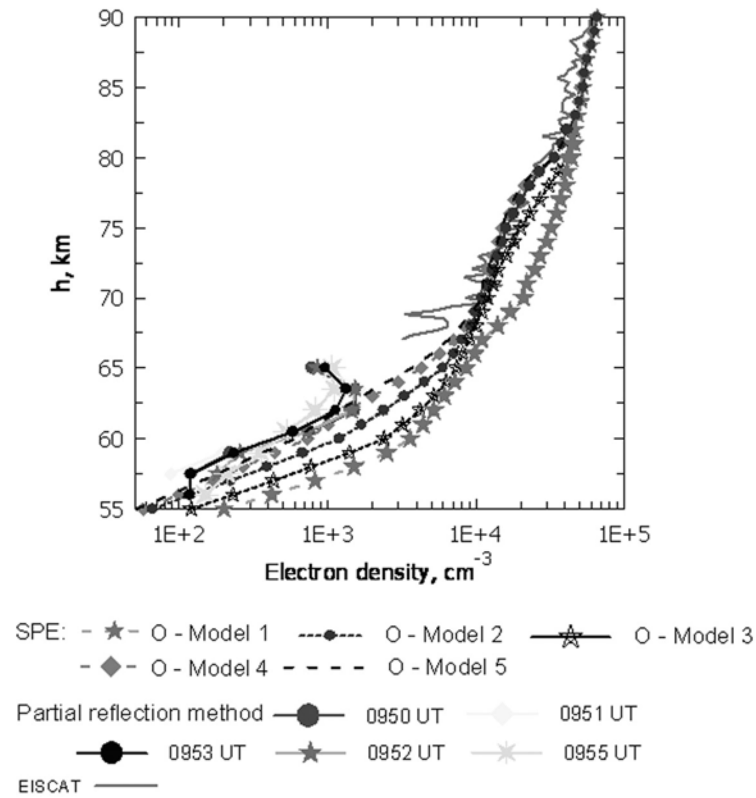

Figure 2. Profiles of the electron concentration at 09:50 UT of 17.01.2005

It is seen that the electron density calculated on the basis of $N_O(h)$ profiles 1-3 with high concentration of atomic oxygen in all cases exceeds for 2-6 times the measured values N_e in the lower part of the D region at h < 70 km. $N_e(h)$ profiles calculated on the basis of the profiles 4 and 5 practically coincide and reproduce the size and the form of the experimental $N_O(h)$ profile in all the considered intervals of height.

On the basis of the results of the theoretical simulation, we shall estimate the influence of variations of atomic oxygen concentration on the ionic profile and an effective factor of recombination at different heights of the region of the mesosphere. Fig. 3 presents the profiles of the parameter f^+ describing ratio at the given height in the ionosphere between total amount of ions-bundles and amount of usual ions.

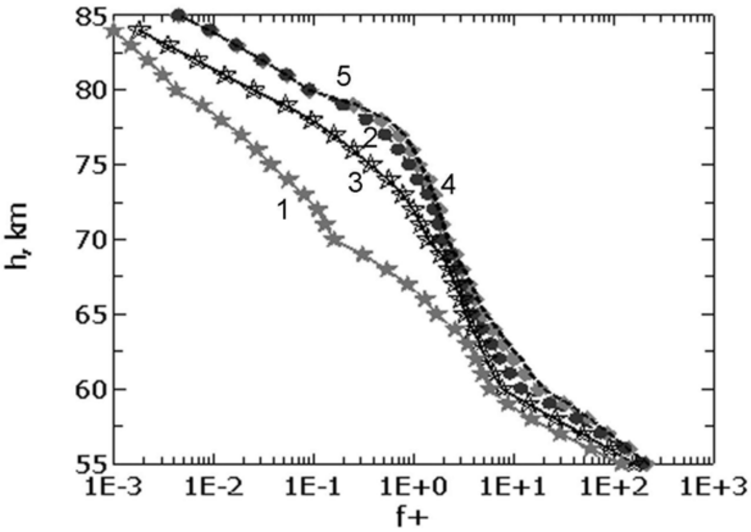

Figure 3. Profiles of the parameter f^+ for five models $N_O(h)$

It is seen that with reduction of the atomic oxygen concentration the share of bundles in total amount of positive ions and the interval of heights in which they prevail increases.

Fig. 4 shows the profiles of the parameter λ^- determining the ratio of the negative ions concentration to the electron concentration. Reduction $N_O(h)$ under conditions of SPE leads to changing of total density of negative ions in all the considered intervals of height.

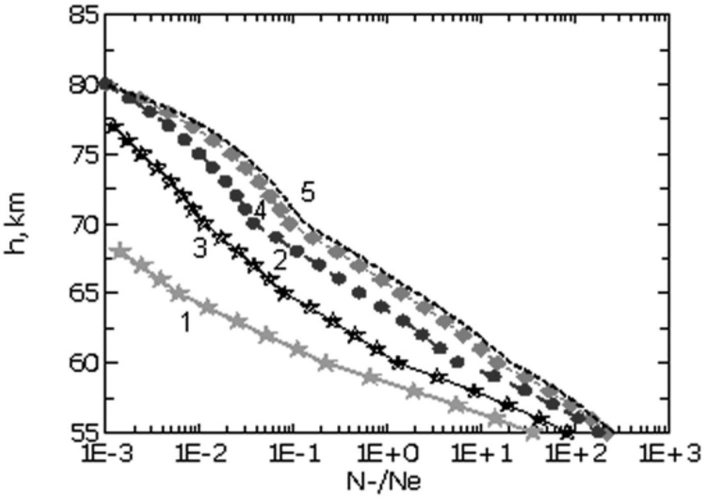

Figure 4. Profiles of the parameter λ^- for five models $N_O(h)$

Fig. 5 presents the profile of an effective factor of recombination $\alpha_{eff}(h)$ in the daytime winter ionosphere for conditions of penetration of solar protons (profile $N_O(h)$ in Fig. 1). As one can see, its form and size differs from the corresponding profile under conditions of auroral electrons penetration. In the interval of heights of 67-76 km an effective factor of recombination $\alpha_{eff}(h)$ is defined by the factor of dissociative recombination of simple hydrated bundles ${}^+\mathrm{Cl}_1^+$ ($\alpha_{eff} \approx 2\times10^{-6}$ cm^3 s^{-1}).

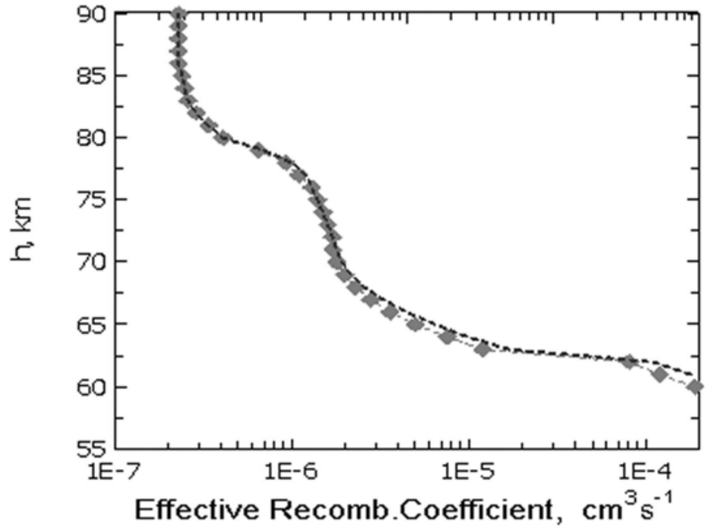

Figure 5. A profile of an effective factor of recombination under conditions of SPE at 09:50 UT of 17 January 2005

At heights more than 80 km where ion O_2^+ is the prevailing ion for any model of atomic oxygen, the effective factor of recombination is determined by the factor of dissociative recombination of ions O_2^+ ($\alpha_{eff} \approx 2.2\times10^{-7}$ cm^3 s^{-1}). At heights less than 67 km α_{eff} is determined by factors of dissociative recombination of complex proton-hydrated bundles Cl_1^+ and mutual neutralization of positive and negative ions.

Conclusions

On the basis of the model calculations and measurements of electron concentration by methods of partial reflections and incoherent scattering influence of variations of concentration of atomic oxygen on ionic profile, altitudinal distribution of electrons and an effective factor of recombination at heights of the D region of the polar ionosphere is investigated.

It is shown, that the choice of a profile of atomic oxygen $N_O(h)$ in the mesosphere is the basic factor influencing on accuracy of model of the specified parameters. The profile of atomic oxygen during period of SPE in the daytime winter mesosphere is constructed. Calculation of an effective factor of recombination for these conditions is made.

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