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ON THE INFLUENCE OF CORPUSCULAR FLUXES AND OF ELECTRON PHOTOLOOSENING REACTION ON THE FORMATION OF THE D-LAYER OF THE IONOSPHERE

by

Yu. A. Bragin
O. K. Kostko
A. I. Repnev
E. G. Shvidkovskiy

(USSR)

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SUMMARY

Concentrations of electrons in the D-layer of the ionosphere are computed on the basis of data on direct measurements, pointing to a comparatively high and constant in time content of charged particles between the altitudes of 60 and 80 km [1, 2].

The daytime increase of electron concentration in the lower ionosphere may be explained by the photoloosening reaction of electrons. The assumption is advanced that one of the principal ionizing agents sustaining a high degree of ionization in the 60 - 80 km altitude range in the course of a day are particles arriving from radiation belts.

* * *

It is customary to consider that in middle latitudes at daytime and at quiet Sun the D-layer of the ionosphere owes its origin in the upper part to nitrogen oxide ionization process by solar radiation in the line L_α, and in its lower part — to ionization of molecular oxygen and molecular nitrogen by cosmic rays [3, 4]. It is assumed at the same time that the nitrogen oxide is formed near the mesopause on account of indirect effects of X-ray radiation [3, 4]. But, as is assumed, in the nighttime the basic ionizing agent are the cosmic rays.

However, when discussing the results of measurements of electron concentration in the lower ionosphere, it is noted that the high concentration of electrons may not always be explained by emission in the line L_α [5, 6], and in these cases the presence is assumed of an additional source of ionization in the form of corpuscular fluxes. Certain indirect effects, such as, for example the night sky glow do indeed point to the existence of such fluxes (see [6, 7]).

* [O VLIYANII KORPUSKULYARNYKH POTOKOV I REAKTSII FOTOOTLIPANIUA ELEKTRONOV NA OBRAZOVANIYE D-SLOYA IONOSFERY]

Another viewpoint consists in that one of the fundamental agents, ionizing the atmosphere in the 60-80 km altitude range in middle latitudes could be either the X-ray or corpuscular fluxes (see respectively [8] and [9 - 11]), though during the quiet Sun the energy of X-ray fluxes and of electron fluxes is insufficient for the formation in D-layer of the ionosphere of the observed concentrations of charged particles [6].

The insufficient number of experimental data is the cause of the impossibility to finally accept either theory of lower ionosphere formation. Yet the measurements of concentrations of positive ions in the lower ionosphere [12, 13] point to high content in it of charged particles, in daytime, as well as in nighttime, the existence of which being not explainable by the ionizing action of cosmic rays and emission in the line L_α.

A somewhat different approach is proposed below in order to explain the nature of the D-layer and of its daily variations. Measurements [1, 2] have shown that the concentration of positive ions (and consequently the total concentration of charged particles) above 60 km is $>10^3$ cm^{-3} and rises with height. At the same time, the ion concentration in nighttime at 60 to 80 km altitude is not less than in daytime. This is in contradiction with references [4, 14], where a decrease of charged particles is forecast at passage from day to nighttime.

For the calculation of the daytime and nighttime profiles of electron concentration we shall postulate the following:

1) The concentration of positive ions is identical at day and night.
2) The atmosphere is electrically neutral

$$N^+ = N^- + N_e, \tag{1}$$

where N^+, N^- and N_e are respectively the concentrations of positive and negative ions and electrons.

We shall take into account the effects of electron adhesion to atoms and of their photoloosening from negative ions by making use of the well known relation

$$\lambda \approx \frac{a}{d + f} \tag{2}$$

where a is the rate of electron adhesion, d is that of electron photoloosening from negative ions, f is the rate of electron loosening from negative ions during collisions, and λ is the ratio of concentrations of negative ions to electrons

$$\lambda = \frac{N^-}{N_e} \tag{3}$$

Combining the first and the third equations, we obtain

$$N = \frac{N^+}{1 + \lambda} . \tag{4}$$

We shall take for N^+ the experimental values obtained in [1, 2]; then the problem of electron concentration in the D-layer will be reduced to the calculation of λ-profiles for the day and night time.

The λ-profiles, constructed by applying the most probable rates of the enumerated reactions borrowed from the works [14 - 17] (solid lines), are represented in Fig.1 For comparison we have indicated by dashed lines the λ-profiles which it is customary to assume as the most typical for middle latitudes [18]. In Fig.2 we brought out the results of computation of electron concentration in daytime (median heavy curve) and nighttime (lower heavy curve), obtained from the averaged experimental concentrations of positive ions (upper heavy curve). The thin dashed and solid lines denote respectively the night and daytime profiles of electron concentration obtained experimentally by various authors at middle latitudes during a quiet Sun [13] (the denotations in Fig.2 are the same as in [13]). As may be seen from Fig.2, the last profiles and our calculations for the profiles of N_e are in agreement within the limits of scattering of separate curves. In particular, the computation agrees qualitatively with the fact that the observed diurnal concentrations of electrons are found to be higher, as an average, than the nighttime ones. This may mean that in the formation of daytime and nighttime ionosphere the essential role is played by the indicated aeronomic reactions; consequently, the rise of diurnal electron concentration may possibly be explained by the effect of electrons' photoloosening from negative ions.

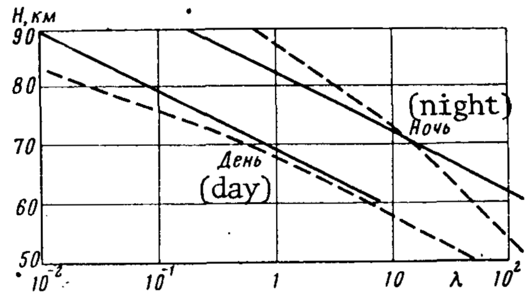

Fig.1

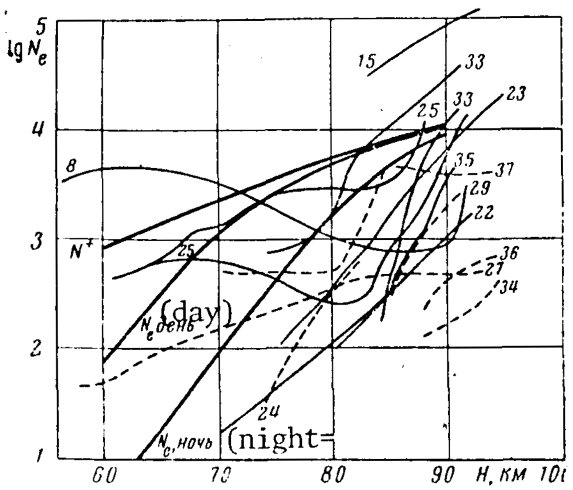

Fig.2

The comparatively high content of charged particles in the 60 - 80 km altitude range in day and nighttime must naturally be sustained by a sufficiently strong agent, acting in the course of the day, for the relaxation times of ion formation processes at these altitudes are in all cases less than one hour [4]. Naturally, the formation of the ionosphere in nighttime cannot be explained by the actions of ultraviolet or X-ray radiations, whereas cosmic particles begin to intensely ionize the atmosphere below 50 km. Electrons with energy $\sim 10^5$ ev, and protons with energy $\sim 10^7$ ev may penetrate to the altitude range 60 - 70 km. Particles with such energies are present in the Earth's radiation belts. This provides the basis to assume that one of the possible ionizing agents may be the particles arriving from the Earth's radiation belts.

Let us estimate the magnitude of these particles' fluxes. If we assume that the effective recombination coefficient α_{ef} in the 60 – 80 km altitude range lies within the range $5 \cdot 10^{-7} \div 5 \cdot 10^{-8}$ [15, 17, 19], the rate of ion formation at $N^+ \approx 5 \cdot 10^3 \text{cm}^{-3}$

$$g = \alpha_{ef} (N^+)^2 \tag{5}$$

is situated within the limits 0.1 — 10 $\text{cm}^{-3}.\text{sec}^{-1}$.

At incidence of electrons with energies of $5 \cdot 10^5$ ev, their greater part (80%) [20, 21] is absorbed in the air column at altitudes from 80 to 50 km. Analogously, for the absorption of protons with energy 10^7 ev, 5 to 10 km of atmosphere will be required at altitudes of 60 and 70 km. For the sake of simplicity we shall assume that in these atmosphere layers, protons as well electrons are absorbed fully and uniformly. As an average a 35 ev energy is required for the formation of a pair of charged particles during air ionization by fast electrons [21].

Taking the above into account the intensity of corpuscles' ionizing fluxes may be estimated by the following approximate formula

$$Q = \frac{35gh}{E} \text{ cm}^{-2} \cdot \text{sec}^{-1}, \tag{6}$$

where E[ev] is the energy of the ionizing particle, h[cm] is the height of the atmosphere column where the greatest corpuscle energy absorption takes place. (The quantity E/35h is the mean number of pairs of charged particles formed by a single electron or proton with energy E per 1 cm of path). The estimates of corpuscle fluxes lead to values of $10 \div 10^3$ $\text{cm}^{-2}\cdot\text{sec}^{-1}$ for electrons and of $1 \div 10^2$ $\text{cm}^{-2}\cdot\text{sec}^{-1}$ for protons.

In the estimates brought out above the basic uncertainty is linked with the lack of knowledge of the values of the effective recombination coefficient. The errors determined by the adopted simplifications and by factual measurement errors of N^+, may probably modify the results obtained by one order.

In conclusion it should be noted that the data of work [22] also point to the presence of corpuscular fluxes in nighttime; conclusion is derived in this work of sustenance during the night of high electron temperature by corpsucle fluxes from the protonosphere; this conclusion is arrived at on the basis of measurements of electron temperature in nighttime at middle latitudes, and above 100 km. The latest direct measurements in the lower ionosphere [23] of fluxes of hard corpuscles of same energies, which have also been utilized for the present estimates, corroborate the above data.

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**** THE END ****

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