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STUDY OF THE IONOSPHERIC D-REGION USING PARTIAL REFLECTIONS AT MIDDLE AND HIGH LATITUDES

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Abstract. Investigations of D-layer ionosphere by means of partial reflection technique have been performed with observational facilities located in different latitudinal regions: in Vasil'sursk near Nizhniy Novgorod (56.1°N, 46.1°E) and in Tumanny (Murmansk region, 69.0°N, 35.7°E). Estimations of electron density both in the polar and mid-latitude D region are presented, with their distinctions being revealed and discussed. An attempt is made to explain the latitudinal variations in electron density at D-layer altitudes.

Introduction

A distinction has been known for a long time as to midlatitude and auroral ionosphere. It is caused both by different solar illumination conditions and corpuscular ionization, the latter being effective in the auroral zone. Many aspects of this difference for the E- and F-regions of the ionosphere have been profoundly studied, the study is still ongoing while the D- region remains the least explored part of the ionosphere. It is so due to complexity of photochemical processes at lower ionospheric heights, in which minor atmospheric components such as nitric oxide NO, hydroxyl OH, atomic oxygen O and meteoric ions play a principal role. In this respect, investigations of the lower ionosphere conducted by the Radiophysical Research Institute (RRI) and Polar Geophysical Institute (PGI) with applying partial reflection technique in two spatially separated sites are of particular interest.

The basic purpose of the undertaken research is to compare the electron density profiles under quiet conditions, i.e. in the absence of corpuscular ionization in the auroral zone. In this case the profiles at middle and high latitudes differ only due to distinctions in temperature, atmospheric density, and concentration of small components.

Method of measurements and data processing

The measurements were conducted at two points. RRI conducted measurements in Vasil’sursk near Nizhniy Novgorod, and PGI - in Tumanny, Murmansk region. The parameters of installations are listed in the Table.

Table. Radar technical parameters

Points	**Vasil'sursk**	**Tumanny**
Transmitter	Pulsing	
Pulse power, kW	50	50
Pulse length, μs	25	15
Operational frequency, MHz	2,95	2,7
Antenna	Transmitting-receiving	
Quantity of vibrators in each of two linear polarizations	12	32
Bandwidth of receiving device, kHz	70	35
Pulse repetition rate, pulse per second	25	2
Step of the data removal, km	1,4	1
Quantity of binary digits an analog-digital converter	12	12

From the Table one can see, that the parameters of the installations are rather close, which allows one to compare confidently the data obtained in both sites. We note, however, that in Vasil’sursk the sine and cosine components of a signal could be identified, which enabled to find amplitude and phase of the signal, while in Tumanny only the amplitude was detected. The measurements at both locations were conducted within the complex program. The observational periods were from 26.07 to 08.08 and from 16.09 to 23.09 2002. In the present paper only the summer cycle measurements are analysed. Recording of scattered signals was conducted in the daytime in the altitude range of 60-130 km, nearly permanently. The amplitudes of the ordinary and extraordinary components of the signal were averaged on a minute time scale at all the heights considered. These data were utilised for common presentation of observational results, and then averaged again on 10-60 min time intervals. From these averaged data $N(h)$-profile was calculated by using radiowave differential absorption technique. The procedure of data processing is described in detail in the paper [Belikovich and Belikovich, 2001].

Results from observations in Vasil'sursk

Samples of the data obtained in Vasil'sursk on 28.07.02 are given below. Fig. 1a displays high-altitude - time behaviour of the ordinary component amplitude for a scattered signal. It is clearly seen that the scattered signals exceed the noise level only beginning from the height of ~70 km and increase on the whole reaching the level of regular reflection. The increment of the noise level in the morning hours can be easily seen. For the evening hours its value appears to be nearly the same. Due to the good resolution at high-altitudes, the change in the height of the regularly reflection from the E-region is distinguished. The radioecho is typically discrete and only occasionally has a diffuse character, being observed at 3-5 and 9-10 a.m. in our example

Fig. 1b shows the diurnal behaviour of electron density isolines based on the 30-minute averaged data.

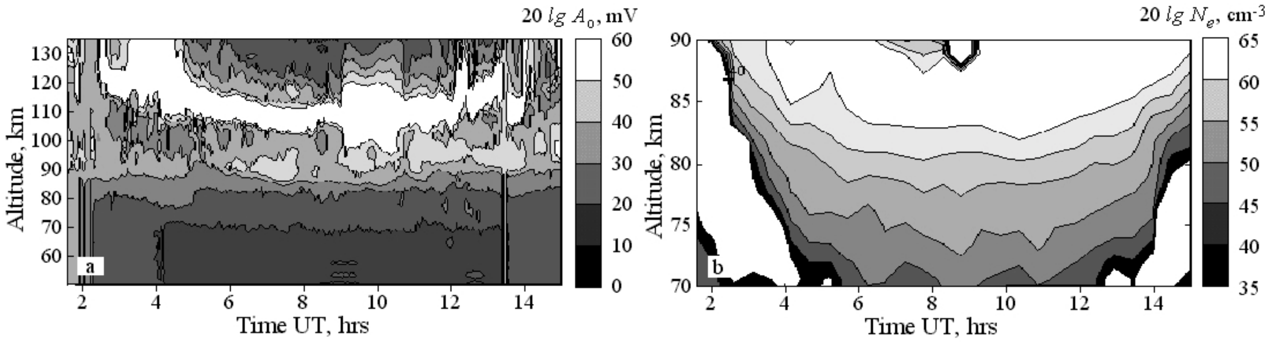

Fig. 1. Time-altitude picture of the ordinary wave amplitude and electron density on 28.07.02

One can see an increase in the electron concentration in the morning and reduction in the evening. The diurnal behaviour of the electron density $N(t)$ on the contiguous days is quite similar. Behaviour $N(t)$ at fixed heights of 75 and 83 km for July 26-28 is given in Fig. 2.

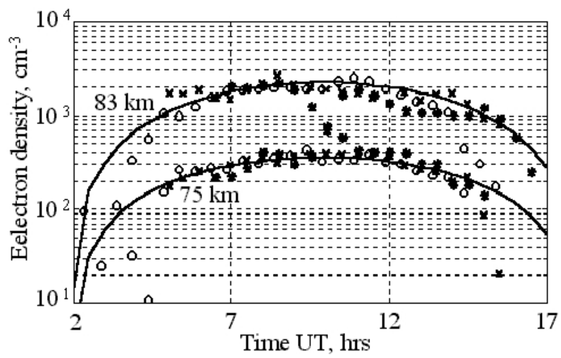

Fig. 2. Time variation of electron density at altitudes of 75 and 83 km and its approximation by a function of $\cos\chi$ for Vasil'sursk

It is seen from Fig. 2 that the electron density can be approximated by function $N(t) = N_0(\cos\chi)^k$, where χ is the solar zenith angle, $k = 1 \pm 0.1$. It should be noted that the value of index k has been used in the paper [Belikovich et. al., 1992] in developing the empirical model of D-region.

Results of observations in Tumanny

Samples of typical data obtained in Tumanny are shown in Fig. 3. Fig. 3a demonstrates the time variations of the ordinary wave amplitudes reflected at heights 60-129 km for August 8. It is well seen, that the scattered signals, as well as in middle latitudes, exceed the noise level only beginning from heights of ~70 km and reach maximum at the altitude of ~90 km. At heights of 100-120 km the diffuse reflections from E-region of the ionosphere are observed, which are registered from 4 UT to 14 UT. At the beginning and at the end of the day the noises exceeding a normal hum noise by 20-30 dB are seen. Fig. 3b shows the high-altitude - time dependence of the electron concentration for this case. As we see from the Figure, there is a clear diurnal variation in electron concentration. Besides, the polar ionosphere is more changeable, and its electron concentration is considerably higher than at middle latitudes.

In Fig. 4 we have shown the results obtained from the radar at Tumanny testing range at altitude of 80 km in the previous years. The height of 80 km was chosen as typical one for the upper D-region (75-90 km).

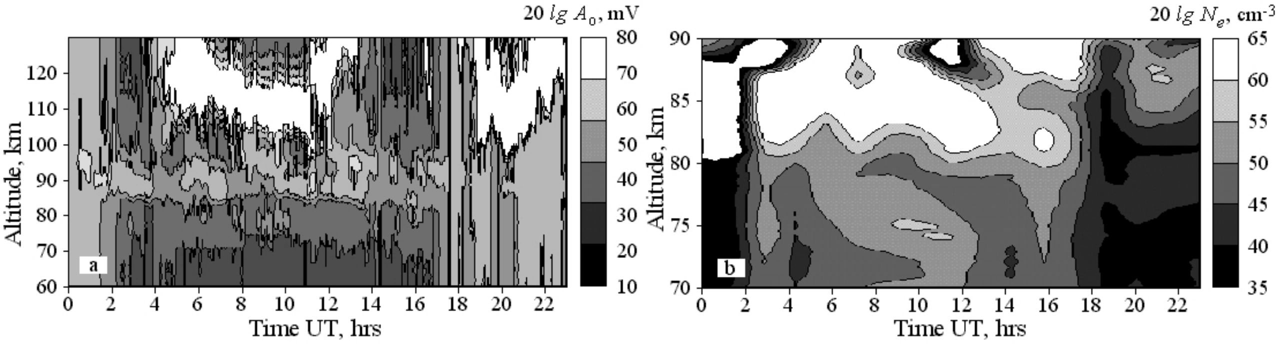

Fig. 3. Time-altitude picture of the ordinary wave amplitude and electron density 8.08.02

It shows the electron concentration versus solar zenith angle for several arbitrarily chosen days of day-night measurements in different seasons (autumn, summer, spring, winter). The most typical feature of Fig. 4 is presence of a strong scattering of *N* quantities at a fixed value of χ. The least scattering corresponds to summer data, which testifies a strong solar influence, while the greatest one, exceeding two orders of magnitude, is observed for winter, spring and autumn measurements at major zenith angles χ.

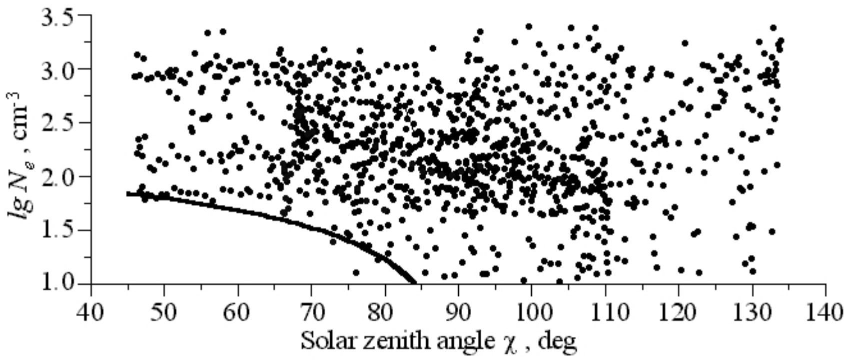

Fig. 4. Electron density as a function of solar zenith angle at altitude of 80 km (for autumn, summer, spring and winter of 1999-2002)

The cause of scattering is a strong variability of N_e in the auroral zone depending on the level of geomagnetic disturbance, intensity of energetic particle precipitation (mostly of 10-100 keV electrons) and other factors. Despite of the scattering, in Fig. 4 it is possible to find the lower envelope for the whole set of *N* quantities (the solid curve in Fig.4), which can be considered as a dependence of the electron concentration on $\cos\chi$ under quiet conditions. It suggests that in the auroral zone at altitude of 80 km the solar control is essential.

From Fig. 4 it is also seen, that there is an upper bound for $\lg N$ quantities, which is approximately 3.1 in spring, 3.2 in autumn, 3.3 in winter and in summer. Note, that the above values for the upper bound of *N* at altitude of 80 km are consistent with the rocket measurements on the Island of Heis ($\lg N = 3.1$) and at Molodezhnaya Station ($\lg N = 3.3$) [Vanina and Danilov, 1998].

Comparison of data obtained in Vasil'sursk and Tumanny

Keeping in mind that it would be most correct to compare the behaviour of the electron concentration at middle latitudes and in the auroral zone under quiet conditions, we performed a comparison for 13-15 UT. In these hours the zenith angles of the Sun in Vasil'sursk and Tumanny are comparable (see Fig. 5), so that the correction of the data on the difference in χ is not required. Besides, according to absorption measurements in Loparskaya [Belikovich et. al., 1986; Beloborodova et. al., 1972], at this time of the day the probability of auroral perturbations is minimum. Another reason for using this time interval is that in this period the electron concentration is not so great, although the amplitude of extraordinary component exceeds the noise level well enough. The results of comparison of the electron concentration in the two sites are given in Fig. 6.

The averaging time of the $N(h)$-profiles for Vasil'sursk is 3 days, and for Tumanny it is 6 days. From Figure 6 one can see that the electron concentration in the auroral zone is higher than that at midlatitudes. This difference is maximum and reaches factor 6 at altitude of 74 km (above 85 km the data of Tumanny seem not to be quite reliable). This conclusion should be considered as a preliminary one, for (1) it is based on a restricted observational material and (2) scattering of individual measurements in Tumanny is rather significant. Let's note that a number of $N(h)$-profiles obtained in Tumanny display a drop at altitude of 80 km.

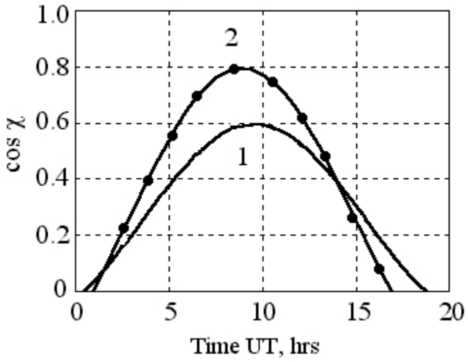

Fig. 5. Daily variation of a cosine solar zenith angle for Tumanny –1 and for Vasil'sursk -2

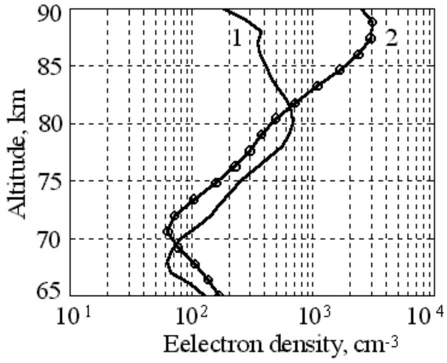

Fig. 6. Average electron density profiles for Tumanny –1 and for Vasil'sursk -2

At the first glance, higher electron concentration in the auroral zone is quite expected, considering higher flow of galactic cosmic rays and smaller value of the effective recombination coefficient. However, to determine quantitatively the contributions of these factors from the obtained data is hardly possible. The drop in the profile of the electron concentration at altitude of 80 km can be related to the noctilucent clouds, which are frequently observed in summer at the polar mesopause. There is a hypothesis that they consist of aerosols, in which an intensive recombination of electrons and ions proceeds. All these points require additional experimental testing for other seasons.

Conclusions

Thus, observations and their analysis have shown that in summer at the middle latitudes the diurnal behaviour of the electron concentration at heights of 70 - 90 km follows the cosine of the solar zenith angle with an apparent exponent close to unity. The values of the apparent exponent appear to be much higher than the ones obtained earlier (~0,5). Under quiet conditions the variation of the electron concentration at altitude of 80 km in the irradiated period at high latitudes obeys the same law as at middle latitudes. In summer in the auroral zone the electron concentration at heights of 70 - 80 km is approximately factor 4 higher than at middle latitudes. The polar lower ionosphere is more variable than the midlatitude one. Therefore, for their comparison to be correct quiet periods should be tested. To distinguish them it is necessary to conduct longer cycles of observations.

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References

Belikovich V.V., Belikovich V.V. Signal processing in method of partial reflections // Geomagnetism and aeronomy. - 2001. - V. 41, № 5. - P. 667 - 671.

Belikovich V.V., Benedictov E.A., Vyakhirev V.D., Lerner A.M. Empirical model of distribution of electron concentration of the midlatitude ionospheric D-region // Geomagnetism and aeronomy. - 1992. - V. 32, № 6. - P. 95 - 103.

Belikovich V.V., Benedictov E.A., Vyakhirev V.D., Goncharov N.P., Grishkevich L.V., Vaciljev E.B., Mizun Yu.G. The profiles of electron concentration in the lower ionosphere of high latitudes // Highlatitude ionosphere and magnetosphere-ionosphere connections. – Apatity: PGI KSC USSR, 1986. - P. 134 - 140.

Beloborodova A.A., Belikovich V.V., Benedictov E.A., Petrova G.A., Pyatsi Z.M., Rapoport Z.C., Tolmacheva A.V. Abnormal absorbtion of cosmic radiation in auroral zone during IGP // Ionospheric Researhes. – M: Nauka, 1972, №20. - P. 75 - 84.

Vanina L.B., Danilov A.D. Electron concentration in the upper D-region of high latitudes. 1. The morphological analysis of measurings // Geomagnetism and Aeronomy. - 1998. - V.38, №5. – P. 109-118.