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THE RADAR MEASUREMENTS OF ELECTRON DENSITY IN THE LOWER IONOSPHERE

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Abstract. Seasonal and diurnal behaviour of the polar low ionosphere medium frequency (MF) echoes was studied using the Polar Geophysical Institute (PGI) radar at Tumanny (69.0°N, 35.7°E) at 2.7 MHz. During the measuring period in 1999 the intensive radioreflections from mesospheric layers at the altitude range of 74-99 km were detected. Calculations of electron concentration were carried out by technique of differential absorption. The analysis of the data has shown that there are regions of lower electron density at the same heights near the mesopause, where reflections were more intensive. The life times of these areas are from one minute to some hours. The electron density minimum near the polar mesopause was observed during short-term rocket experiments only. The nature of the phenomena is not clear now and demands a further research.

Introduction

During many years the PGI carries out research of the lower ionosphere using of MF sounding ata fixed frequency [Vlaskov and Bogoljubov, 1998; Tereshchenko et al., 2001]. Studying amplitudes of waves with the ordinary and extraordinary polarizations, partially reflected from D-region irregularities, allows one to obtain information about concentration of electrons, frequency of collisions and other parameters of a medium. Nowadays the method of partial reflections (MPR) is the most simple and informative for terrestrial monitoring of the D-region. The purpose of the present paper is the exposition of some outcomes of the researches obtained in 1999 using the MPR at the frequency 2.7 MHz.

Methods of determination of the electron density

The electron concentration in the MPR can be obtained in two ways: by the method of differential absorption and by the correlation method [Rapoport, 1972]. At the heart of these ways there are the radiation of two wave modes as alternating pulses, the separate reception of signals, partially scattered by irregularities of electron concentration and of collision frequency, and the measurement of their amplitudes depending on the time of a delay, determining the height of reflection.

In the method of differential absorption, for the definition of concentration as a function of height, the difference of absorption along trajectories of propagation of ordinary A_o and extraordinary A_x waves is used. Thus it is supposed, that the profile of an electron collisions frequency is known from other independent data. The second mode of measuring of the electron concentration in the D-region of the ionosphere is based on the use of correlation properties of a scattered field. Values of electron concentration in this method are obtained using the spatial correlation coefficient between amplitudes of ordinary and extraordinary waves [Benediktov et al., 1971].

For demonstration of an application opportunity of these methods data of registrations of medium waves' reflection amplitudes for 28.07.1999 (Fig. 1) were used. Here each $A_{o,x}$ value corresponds to the amplitude of a signal averaged by readout in the range of 2 km heights and by time for the period of 5 minutes. On the left in the same figure the profile of the coefficient of correlation between amplitudes of signals of two characteristic modes ρ_{ox} (h) is shown. On the right in Fig. 1, $N(h)$-profiles, found by the correlation method (a continuous curve) and the standard method of differential absorption (dotted line), are presented.

The conformity between both profiles of concentration can be considered as satisfactory though the correlation method gives lower values of electron concentration at heights close to 80 and 90 km and higher values between these heights and in the bottom part of the ionosphere. It may be caused by neglect of collisions effects at calculations in the bottom part of an ionospheric layer and also by the difference of the distribution of components of reflected signals' field at the point of reception from a normal distribution. Additional studies therefore are necessary for an experimental check of the correlation method.

Experimental results

For the period of measuring in 1999 by the method of partial reflections there was received a large array of values of electron density in an interval of heights between 70 and 100 km. The analysis of these data displays, that the electron concentration in summer is higher, than in winter. The summer changes of density have the legibly expressed diurnal variation, which testifies of the strong solar influence upon the structure of the lower ionosphere. The winter variations are not chaotic fluctuations and, apparently, also have a regular course. These results do not bring in new information in the usual representations about the behavior of the ionosphere and confirm suitability of the method of differential absorption for the definition of a medium parameters.

A characteristic feature of the summer data is the registration of areas of the lowered electron density in the polar mesosphere at heights close to the mesopause (Fig. 2a). Radio-echoes from these areas have the increased intensity (Fig. 2b, c).

The existence of areas of the lowered electron density may last from one minute to several hours. Previously the minimum of electron concentration in the vicinity of the polar mesopause was registered only in very short-term rocket experiments. The observations indicated the presence of intensive radio-reflections from mesospheric layers at the altitude range of 74-99 km. Usually, these reflections look like 2 or 3 of distinct layers, which are located at heights 74-82, 82-89 and 89-99 km.

Strong MF reflections from the area close to mesopause (85-86 km) are the closest to properties of the Polar Summer Mesospheric Echo (PMSE), which was discovered for the first time by observations of radio-echoes in HF and VHF bands [Vlaskov and Bogoljubov, 1998]. The number of echoes from mesospheric heights has a seasonal course. In summer there are observed much more intensive radio-echoes than in winter, and in winter there are more numerous than in spring and in autumn. Fig. 3 illustrates the time-altitude variations of the electron density and magnetoionic components amplitude during winter. A distinctive feature of these observations was the registration of sharp gradients of electron density at the same heights, where reflections were more intensive. The analyses of digital ionograms in Loparskaya (68.6°N, 33.3°E) have shown that intensive sporadic E-layers are observed during strong MF radar returns appearance from the mesopause region.

The properties of winter medium waves echoes are similar to the properties of polar mesospheric echoes, which are observed in summer. In middle latitudes strong mesospheric radio-reflections, not dependent on the season, were found in the HF range in the frequency interval 8-9 MHz [Karashtin et al., 1998].

For the explanation of the reasons of intensive reflections occurrence a few hypotheses are suggested. One of them is connected to the formation of negative ions due to attachment of electrons to aerosols and dusts. Another explanation is based on connection of fluctuations of oxide nitrogen concentration with temperature of the neutral gas at heights of the summer mesopause. The temperature minimum may reduce the quantity of formation of oxide nitrogen and, hence, the electron concentration. The occurrence of radio-echoes in a winter period may be connected to the disappearance (a spontaneous ignition and burning out [Nikolaev and Fomin, 1997] of hydrogen in the middle ionosphere, with the transfer of water vapour to the area of the mesopause and its cooling due to the luminescence of hydroxyl.

Conclusions

Thus, on the basis of MF sounding of the ionosphere 2.7 MHz at the frequency special conditions for scattering of radio-waves at heights of the polar mesosphere and lower thermosphere (70-100 km) were established. Observations have shown, that in the separate periods this area of the terrestrial atmosphere is capable of a very intensive scattering of radio-waves. A characteristic feature of these observations is the registration of sharp gradients of electron concentration at the same heights where reflections were intensive. Radar measurements of sharp gradients and the minimum of electron concentration for the first time confirm the data of rocket studies in this area of the lower ionosphere.

References

Benediktov E. A., Grishkevich L. V., Ivanov A. A., Komrakov G. P. Correlation method of the determination of electron density in the ionospheric D-region // Isvestiya VUZ. Radiofizika. - 1971. - V. 14, N9. - P. 1452-1454 (in Russian).

Karashtin A. N., Shlyugaev J. V., Berezin I. V., Komrakov G. P. Seasonal behavior of mid-latitude mesospheric HF echoes // Isvestiya VUZ. Radiofizika. - 1998. - V. 41, N10. - P. 1248-1257 (in Russian).

Nikolaev Yu. A., Fomin P. A. About the nature of noctilucent clouds and of the Earth`s ozone layer // Physics of combustion and explosion. - 1997. - V. 33, N4. - P. 3-13 (in Russian).

Rapoport Z. T. Study of the ionospheric D- region by partial reflections method // Geomagnetism and ionospheric height layers. - M.: VINITI. 1972. - V. 1. - P. 172-189 (in Russian).

Vlaskov V. A., Bogoljubov A. A. Observations of polar mesospheric summer echoes by partial reflection radar // Vestnik MSTU, Proc. of Murmansk State Technical University. - 1998. - V. 1, N2. P. 3 - 22 (in Russian).

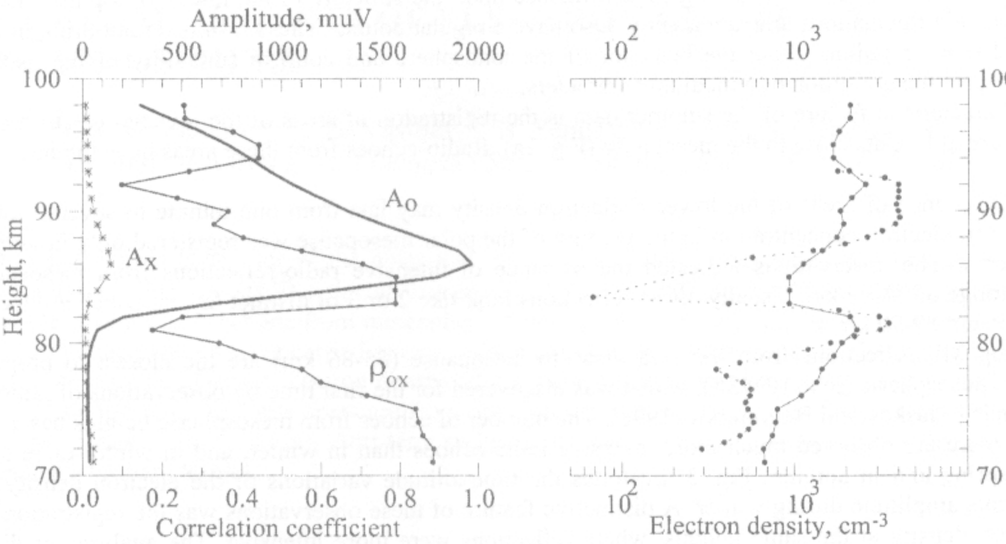

Fig. 1. Amplitudes of reflections of two characteristic waves, the correlation coefficient and electron density, as a function of the height in the polar ionosphere (28.07.99 02:50 - 02:55 UT).

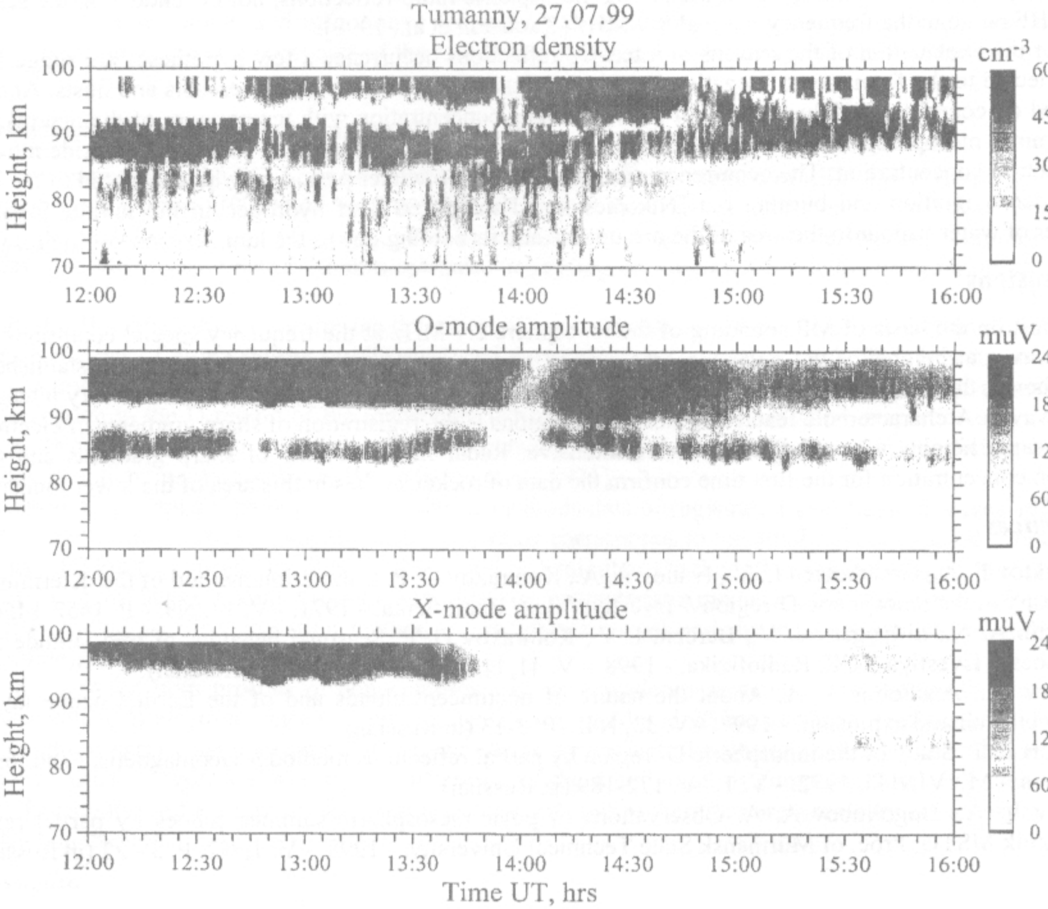

Fig. 2. Electron density and amplitudes of two modes of the reflected signals as a function of time and height.

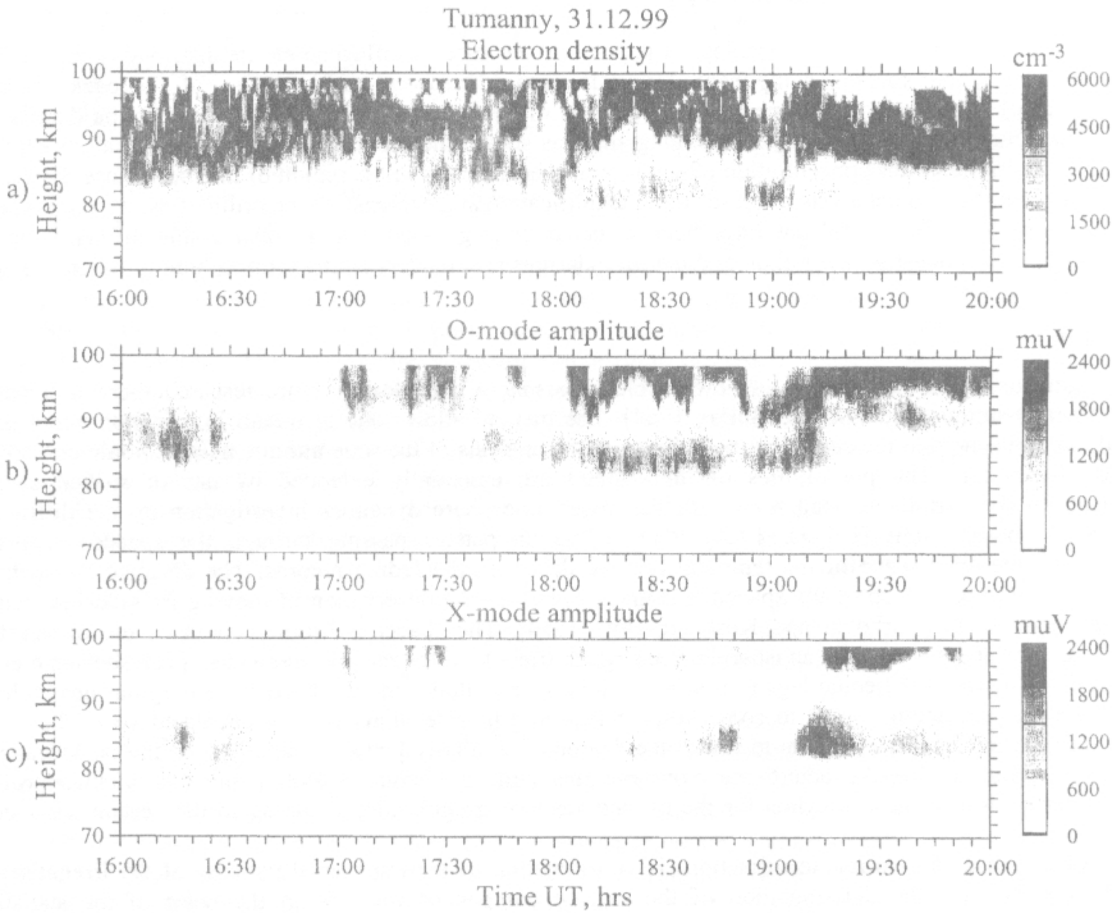

Fig. 3. The same data as in Figure 2., but for winter conditions.