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THE STUDY OF THE LOWER POLAR IONOSPHERE NONUNIFORM STRUCTURE

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Abstract. This paper is devoted to the problem of the neutral gas motion influence on the distribution of the high-latitude lower ionosphere ionized component. Using the spaced sensors measurements of the back scattered (partially reflected) signal amplitude time-altitude diagrams of the cross-correlation functions maxima distribution were calculated and plotted. An analysis of the diagrams has shown the presence of a regular diurnal structure of electronic density irregularities concentration of certain transversal scales in the region of the mesopause. By results of the generalized correlation analysis the cases of an amplification and decrease of the ordinary wave amplitude on the supposed turbulence of neutral gas have been detected. It is guessed, that a considerable influence on the forming of the electron density distribution and the irregularities size renders neutral atmosphere turbulence caused by velocity fluctuations.

Introduction

Among different methods of the lower polar ionosphere irregular structure research there is a partial radioreflections technique [Belrose and Burke, 1964]. The method allows one to obtain information about some features of the ionosphere in the certain altitude range by the analysis of the time-altitude magnetoionic component amplitudes distribution. The possibilities of the method are essentially extended by use of spaced sensors measurements of the partial reflected waves for the lower ionosphere dynamics investigation by the diffraction pattern changes observations [Briggs, 1984]. The diffraction pattern passing through the spaced sensors is accompanied by the appearance of the temporal relative delays in the fading records. The distance between the sensors describes the resolution of the spaced antennae system for the observation of moving irregularities with a certain transversal scale [Mirkotan and Kushnerevskiy, 1964]. The spaced sensors' system in the observatory Tumanny is located at the corners of an isosceles rectangular triangle of the receiving antennae [Tereshchenko et al., 2001]. And the distance at the equal legs is 164 m. Such structure allows one to observe the irregularities with the transversal scales from about 100 m to some kilometers (more precise limits are not evaluated yet). The cross-correlation of records' intervals permits to reveal the degree of similarity between variations of the back-scattered signal. Using the possibility of the radar to make observations with 1 km height resolution, one can calculate profiles of the cross-correlation function maxima for the of the areas of irregularities grouping in the certain transversal sizes.

Another use of the correlation functions is an estimation of the transversal velocity of the irregularities. One of the methods for the determination of the ionized component velocity on the basis of the statistical investigation of spatial and temporal diffraction pattern changes is the generalized correlation analysis [Khudukon et al., 1994]. This method was designed for the calculation of a drift velocity of small-scale irregularities in the F region ionosphere by spaced sensors measurements of a cosmic radio source scintillation. The results of the correlation analysis were characterized by the high level of stability because of the use of the large degree of the diffraction pattern contour approximation by the second order curve – ellipse. The ellipses collection from different levels allows one to increase the statistical reliability which protects one from the influence of different destabilizing factors. These peculiarities resulted in the application of the generalized correlation analysis to the partial reflections data.

Some features of the method realization encompassed in an account of the effect of the diffraction pattern expansion at the ground level, which influenced the estimated velocity [Sato, 1989]. There also were developed criteria of yield of the correct results on the basis of efficient use of the statistical method under the pseudo-steady conditions. The approximation consisted in the use of the output parameters with the factor of 1/2. The pseudo-steady interval was found from the amplitude records analysis by the duration and character of the fading and was chosen to be 100 sec. Thus, each collection of the parameters is a statistical mean for the process occurring for the time interval.

The correlation analysis allows one to reveal the altitude velocity components profiles. Whereas, the complex analysis of the velocities, the cross-correlation function maxima profiles and the averaged height variations of the back scattered signal amplitude permits to perform a qualitative estimation of the influence of the neutral gas turbulence on the signal amplitudes' rise. Investigations, carried out for the explanation of the intensive reflections from the D and lower part E region irregularities have been performed most widely since about 1990. And in some papers [Gurevich et al., 1997a; Shlegel and Gurevich, 1997; Gurevich et al., 1997b] there was described the process of the back-scattering by the neutral turbulence. In these papers as an alternative to the Farley-Buneman and gradient drift mechanism of the plasma irregularities generation, which mainly can not be realized in the lower ionosphere, the turbulence is suggested as a defining factor. The obtained expressions for characteristic functions of the plasma fluctuations wave number do not contradict with measurements carried out by radar and rocket methods.

This paper considers preliminary results of the nonuniform lower ionosphere structure study by the spaced sensors measurements of the back scattering signals using the correlation analysis. Furthermore, an attempt is undertaken to explain the observed effects by the phenomenon of the neutral atmosphere turbulence.

The analysis of the time-altitude cross-correlation functions maxima diagrams

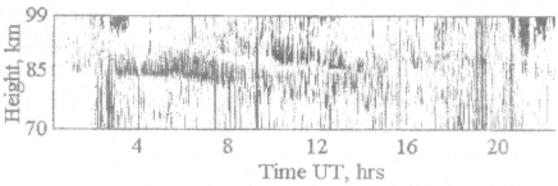

Fig.1. The time-altitude diagram of the cross-correlation function maxima for one receiving pair.

On the basis of the approach described in the previous section the data of the spaced sensors measurements for the experiment of August, 1999 were processed. The characteristics and technical conditions of the observations are given in paper [Tereshchenko et al., 2001]. An example of the daily distribution of the cross-correlation maxima values for 06.08.99 is depicted in Fig. 1.

In the figure a daily course of the process of the electron density irregularities concentration with the transversal scale more then about 100 m is shown. The high correlation displays darker colors and the low – light color. The low correlation suggests either the absence of the irregularities or the presence of small-scale irregularities the transversal scale of which is less then 100 m. So, situations are possible, when in the low correlation area some processes, causing the phenomenon of the Polar Mesosphere Summer Echo (PMSE), will be occurring in HF and VHF bands. Indeed, the combined superficial analysis of available HF radar data revealed the presence of overlapped time-altitude areas during PMSE and low cross-correlation regions in the calculated diagrams. Furthermore, the height profile corresponding to such periods mainly looks as a dip in the curve with values less then 0.5, as shown in Fig. 2.

The calculations of the time-altitude distributions of the cross-correlation functions' maxima for the experiment of August, 1999 and the observation of variations of regions with the high correlation allows one to distinguish a regular daily pattern of the irregularities concentration with the scale from 100 m to approximately 3 km. In the first half of day from 0 to 8 – 12 UT the irregularities mainly group at the height of about 85 km in the layer 2 – 4 km thick. From 12 to 20 UT the irregularities group at heights 87 – 91 and 77 – 83 km. Naturally, the described structure is generalized, and during the day different variations in temporal and altitude bounds are possible.

The obtained results, namely revealing from the experimental material the regular features in the nonuniform structure of the lower ionosphere, allow one to confirm indirectly theoretical assumptions about the role of the neutral gas turbulence in the ionized component distribution in the D and lower part of the E region. So, it is possible that the regularity of the inhomogeneities concentration at certain heights from 87 to 91 km is caused by an extensive turbulence, which appears as a result of a change of neutral wind directions. It is known that the height interval is characterized by the change of the wind direction from northwest to southeast in August at 69° latitude [Portnyagin and Solovjova, 2000]. It is logical to assume that such velocity fluctuation is sufficient for a vortex generation. The high-density neutral gas, carrying away and retaining the ionized component, forms the observed distribution.

The analysis of wind field irregularities influence on the back scattering

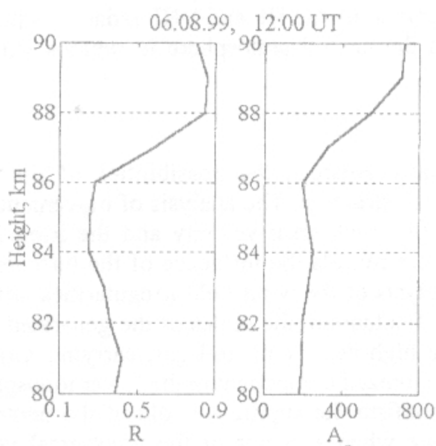

Fig.2. The profile of the cross-correlation function maxima R and the ordinary wave amplitude.

By the summer data of the spaced sensors measurements of 1999 and 2000 the transversal wind velocities were obtained by the generalized correlation analysis at the heights, mainly, of 79 – 93 km Absolute values of the velocity vectors vary in general within the range of 20 – 60 m/s. The strong west and week north components are dominating in wind directions. A comparison of the results with the global empirical wind model for the upper mesosphere/lower thermosphere [Portnyagin and Solovjova, 2000] revealed a good agreement of the wind direction during the time period and at the mentioned altitudes.

Unfortunately, measurements of the velocity are not continuous because of the difficulties in the data processing. Therefore a formation of the velocity altitude profiles is possible only when favorable conditions are realized. Basically, the process steadiness during the studied time interval has the principal importance. The steadiness is expressed in the elliptic contours constancy of the diffraction pattern formed by the back-scattered wave at the ground level. The height resolution of the measurements for the experiments of 1999 and 2000 is 1 km and gaps are caused by failure to carry out the conditions of the correlation analysis.

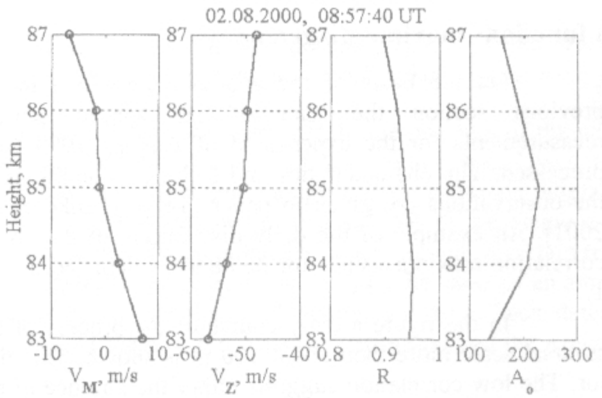

Fig.3. The altitude profiles of the wind components with the cross-correlation profile and the ordinary wave amplitude.

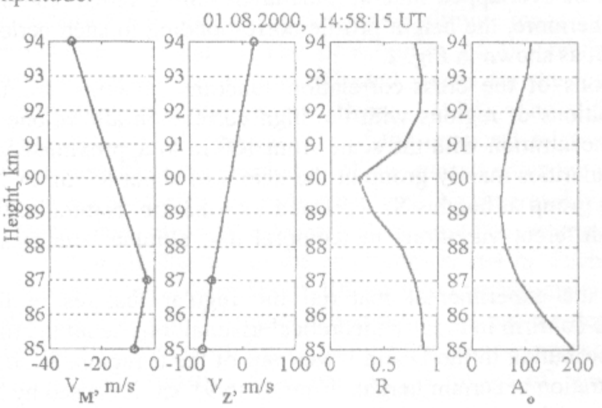

Fig.4. The example of small-scale irregularities generation.

The determination of the local turbulence cases is based on the registration of moments when the velocity fluctuation is expressed most obviously, i. e. there is a change of the one or both velocity component direction at an altitude. It was supposed, that at such fluctuation the energy And uniformly distributed ionized component account for the more considerable neutral gas density is carried away to the vortex motion forming the irregularities. The combined analysis with the height profile of the ordinary wave amplitude will allow one to say definitely about the increase of the back-scattered wave intensity and bind up the effect with the neutral gas turbulence. An additional analysis of the cross-correlation functions' maxima profiles allows one to determine the relative transversal irregularities scales.

By the examples (Fig. 3) of variations of the meridional V_M and zonal V_Z velocity components with the correlation profile R and the ordinary wave amplitude A_O are depicted. It is seen that at heights, where the change of the meridional component direction appears, the increased, compared to the background, amplitudes are observed. The high cross-correlation values say that the transversal scale of the irregularities is more than 100 m.

In Fig. 4 a similar case with the change of one of the wind component direction is depicted but the amplitude at the heights of the V_Z sign change demonstrates the minimum. The decrease of the cross-correlation R less than 0.5 displays the presence of small-scale formations. These facts demonstrate that the irregularities with the scale less than 100 m were generated in the observed region. Accordingly, the radar operating at the 115.4 m wave length can not detect such formations and therefore there is the decreasing amplitude.

The preliminary observations allow us to bind up the velocity fluctuation with the irregularities scale. The large energy dissipation form either one or a series of small-scale turbulence and the minor energies are able to generate the large-scale irregularities (more then 100 m), which ensure the amplitude splashes of the magnetoionic component of the radar. The small-scale formations can be mainly observed by the HF and VHF radar. It is possible, that the PMSE phenomenon is caused by the turbulence process in the neutral atmosphere in regions with high gradient of the neutral gas velocity.

Conclusions

The method of the spaced sensors measurements essentially enlarges the possibilities of the partial reflections technique for the research of the ununiform lower ionosphere structure. The analysis of movement of the diffraction pattern across the spaced sensors allows us to estimate the transversal velocity and the irregularities scales. The discovered regular daily distribution of certain irregularities reveals the influence of the turbulence on the regular non-uniform structure. At the same time, the complex analysis of the wind field irregularities, affecting the intensive back-scattering, displays the dependence of the velocity fluctuation, the scales of the generated vortex and the wave amplitude. So, the dependence is reached because the high-density neutral gas, carrying away and retaining the ionized component forms the observed distribution of the ionized component in the lower ionosphere.

The presented examples and the qualitative interpretation confirm the significant role of the neutral gas motion in the irregularities forming and, in particular, the turbulence when a vector of the transversal velocity direction changes. The relation of the transversal scales and the value of the velocity fluctuation is of great interest but it demands the statistical filling for the results.

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