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THE RADAR OBSERVATIONS OF THE LOWER POLAR IONOSPHERE DURING THE SOLAR ECLIPSE OF 1999 AUGUST 11

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Abstract. In this paper preliminary results of the radar observations of the lower polar ionosphere at the Tumanny observatory measuring complex (69.0° N, 35.7° E) are introduced. The data analysis revealed that during the period from 10:56 to 11:03 there was a sharp drop of the intensive reflection region within the limits 91 to 86 kms, and the culmination of the case was at 10:54. Then the height of the region was more smoothly restituted up to the former position. Furthermore, the intensive reflection from the mesopause during 10:59 – 11:10 was also a possible consequence of the eclipse. This fact can be explained with a negative change of the mesopause temperature which was the reason of the vertical wind field nonuniform structure. In turn, the wind field irregularity could generate variations of the refraction index and, as a consequence, intensive partial reflections. Moreover, it is possible that the five-minute lag was involved with the delay of a spatial wave process of temperature changes, which was formed by the moving Moon shadow. The analysis of electron density variations during the solar eclipse revealed a significant alteration above 94 km.

Introduction

It is well known that temporal and spatial changes of main ionospheric parameters are, in general, controlled by the solar activity [Al'pert, 1972]. In spite of the short-term nature of such phenomenon as an eclipse of the sun in the practice of the ionosphere researches it is of great importance. The results of different ionospheric parameters' measurements during solar eclipses allowed to solve the a problem of the role of the corpuscular and ultraviolet solar radiation in the ionospheric regions' ionization (i. e. to determine ionization sources), to obtain the information about velocities of different processes, which modify the electron density [Whitten and Poppoff, 1968], and to estimate effects of the solar activity influence on radio propagation characteristics in VLF, LF, MF, HF bands [Vilenskiy and Yampol'skiy, 1983].

The clear representation of the physical processes, occurring during the solar eclipse in the ionosphere, makes the phenomenon a convenient instrument for examination of some hypotheses and new investigation techniques [Borisov et al., 2000]. It is natural to expect certain changes of D-region structure for the solar eclipse above the Kola peninsula of 1999 August 11.

The data analysis and results interpretation

For the Tumanny observatory (Kola peninsula; 69.0° N, 35.7° E) the eclipse beginning time was at 09:57 UT. The maximum phase occurred 0.45 at 10:54. The eclipse extremity was reached at 11:50. For the ionospheric reaction to the solar eclipse there was used the MF vertical sounding radar of the Polar Geophysical Institute (PGI). Measurements of the magnetoionic components amplitudes of the signals scattered in the lower ionosphere were carried out at 2.72 MHz with the time resolution 1 sec and the height resolution 2.25 km. The results of observations are given in Fig. 1 (top and middle panel). The bottom panel of the figure shows the electron density values determined by the differential absorption technique. The hatched vertical strip correspond to the time when the transmitter did not operate. Furthermore, the geophysical condition was quiet during the solar eclipse observation.

When the solar disk began to be covered by the Moon there occurred a decrease of the flow of the solar ionized radiation (FIR). For the ordinary component of the back scattered wave the ionosphere reaction to the FIR decrease was discovered with the rise of the intensive echo height from 90 km to 95 km during the period 10:06 - 10:32. Further, on from 10:32 to 10:52 the height did not change and then from 10:52 to 10:56 the height was sharply reduced to 86 km. Then from 10:56 to 11:06 the height of the reflection increased again up to 91 km and did not change further till the eclipse extremity. As a possible consequence of the ionospheric reaction to the solar eclipse there was observed an appearance of the intensive mesospheric echo at the height range 86 - 89 km during the period from 10:50 to 10:58 and at the heights 82 - 84 km from 11:06 to 11:08. The solar eclipse effect was discovered also by the electron density variations in the height range 70 - 78 km and above 92 km during the period from 10:50 to 11:10 (see the bottom panel of Fig. 1).

A decrease of the radio reflections' intensity in three - four times is well explained by the diminution of the ultraviolet radiation flow, which is one of the main ionized agent for D-region. For the determination of possible causes of the intensive echo height variations and the appearance of the Polar Mesosphere Echo there were carried out profiles calculations of the time lags of the radioreflections from in a neighborina altitude levels, the transversal velocity (in spaced sensors measurements), the neutral gas temperature (on MSISE-90) and there was performed the sliding spectral analysis of ordinary wave records.

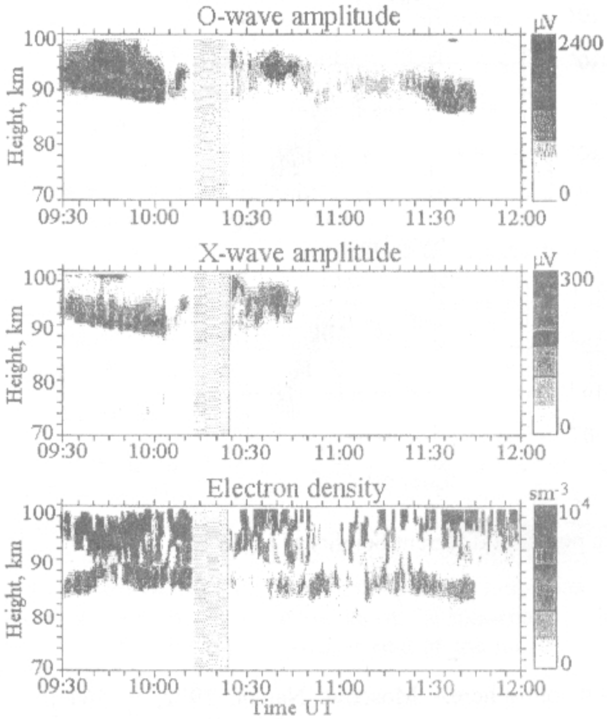

Fig. 1. The time-altitude diagrams of the magnetoionic components amplitude and the electron density variations during the solar eclipse.

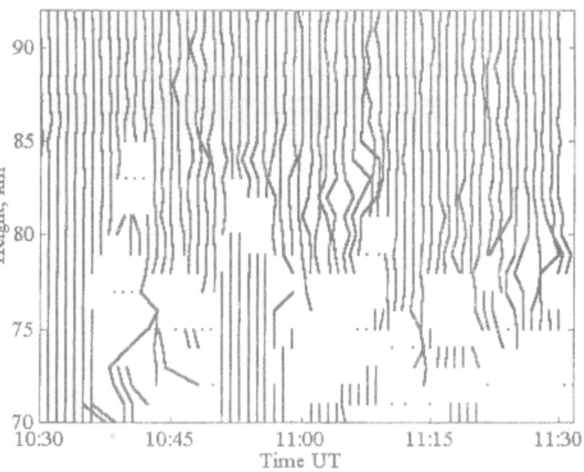

Fig. 2. The profiles of the time lags variations (Δh = 5 km).

Fig. 2 shows the profiles (with a five-minute statistical average) of the records time lags reflected from neighbor in a levels (Δh = 5 km). The calculations demonstrate the motion of the ionized layer (negative lags correspond to the downward motion and positive lags – upward motion). The results of the transversal velocity are presented in Fig. 3. It is interesting to note that the downward motion of the ionized layer is ceased at 11:05 (the moment of the velocity direction change).

The model MSISE-90 demonstrates two coldest areas with the temperature of 150 K during periods from 08:00 to 10:00 and from 18:00 to 20:00 in the height range of 85-91 km. The eclipse culmination occurs during the predicted rise of the medium temperature after the first minimum.

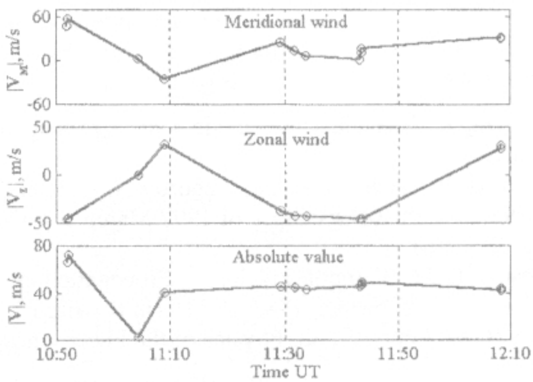

Fig. 3. The wind transversal velocity in the height range of 73-86 km.

The spectra of the amplitude fluctuations power were calculated for the 5-minute interval at 11:05 (see Fig. 4).

The analysis of spectral curves reveals an exceeding of the cut-off frequency for the internal gravity waves spectrum in the height range of 82-84 km in comparison with the spectra for 80 and 86 km. Such processes occurred as a result of the temperature effect and they are an evidence of variations of the medium temperature with a minimum value at the intermediate heights, i. e. at 82-84 km. Consequently, there is a local cooling of the investigated area during the solar eclipse. I. e., the third temperature minimum appeared in the diurnal variation. The temperature decrease of the ionosphere causes the change of the transversal wind direction, a short-term descent of the scattered layer and the appearance of intensive radioreflections from the mesopause. The further smooth uprise of the layer is effected by the restoration of the equilibrated condition of the dynamic system disturbed by the local perturbation of the temperature field.

Conclusions

Thus, the results confirm the process of the temperature control for the non-uniform structure of the lower ionosphere. During the investigation there were discovered characteristic features of the behavior for the intensive mesospheric radioecho, the electron density, the wind velocity and the time lags of signals reflected from neighboring levels. It is shown, that the mesosphere cooling, caused by the eclipse, can be a reason of Polar Mesosphere Echo formation. The life-time of the signal varres from 2 to 4 minutes.

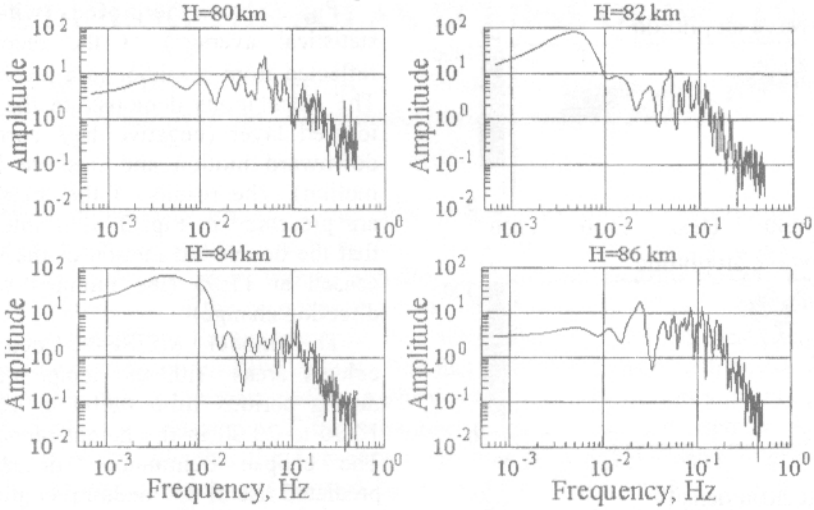

Fig. 4. The spectra of the amplitude fluctuation power at different heights at 11:05 UT.

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