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ABOUT THE POLAR LOWER IONOSPHERE BEHAVIOR DURING THE SOLAR ECLIPSE ON 1 AUGUST 2008

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Abstract. Ground-based observations by the methods of partial reflections and vertical sounding for the polar lower ionosphere conditions on 1 August 2008 (the day of the 0.81 partial solar eclipse in Murmansk) and also during the control days were executed. Changes of the reflected signals parameters during the eclipse were found out and explained. Values of electron concentration, effective recombination coefficients and parameters of wave processes in the polar lower ionosphere were determined and features of its behavior during this event were revealed.

Introduction

Ionospheric effects of solar eclipses are studied for a long time and successfully modeled [*Alpert*, 1972; *Boytman et al*., 1999]. The reaction of the ionosphere to the total solar eclipse is similar to the disturbance of environment within a short-term night. However physical processes in the ionosphere, which are accompanying a solar eclipse, depend on geophysical conditions, parameters of solar activity and the degree of disturbance of the near-earth environment [*Akimov et al*., 2002; *Rishbath and Garriott*, 1975]. Neutral wind, plasma ionized components drift, turbulence, photochemical and wave processes play an important role in the lower ionosphere dynamics [*Danilov*, 1989].

Observations during the concrete solar eclipse allow to specify accompanying physical processes in the ionosphere and to monitor its dynamics. Therefore the research of solar eclipse ionospheric effects, still, remains actual. The given article, being continuation of works [*Belikovich et al.*, 2008; *Tereshchenko et al*., 2001], is devoted to summary of observation results of processes in the polar lower ionosphere, accompanying the solar eclipse on 1 August 2008.

Parameters of the eclipse and results of observations

The partial solar eclipse on 1 August 2008 in Murmansk began at t_1 = 08:46 UT. The peak phase of the eclipse took place at t_2 = 09:51 UT and the maximum value of the partial eclipse was 0.81. The end of the eclipse (t_3) was at 10:56 UT. During the eclipse weather in Murmansk was cloudy. Therefore we illustrate how the Moon covered the solar disk with photographs made by us in Saint Petersburg and submitted in Figure 1. The solar eclipse in Saint Petersburg had the following parameters: φ = 0.61, t_1 = 08:49 UT, t_2 = 09:55 UT and t_3 = 11:01 UT.

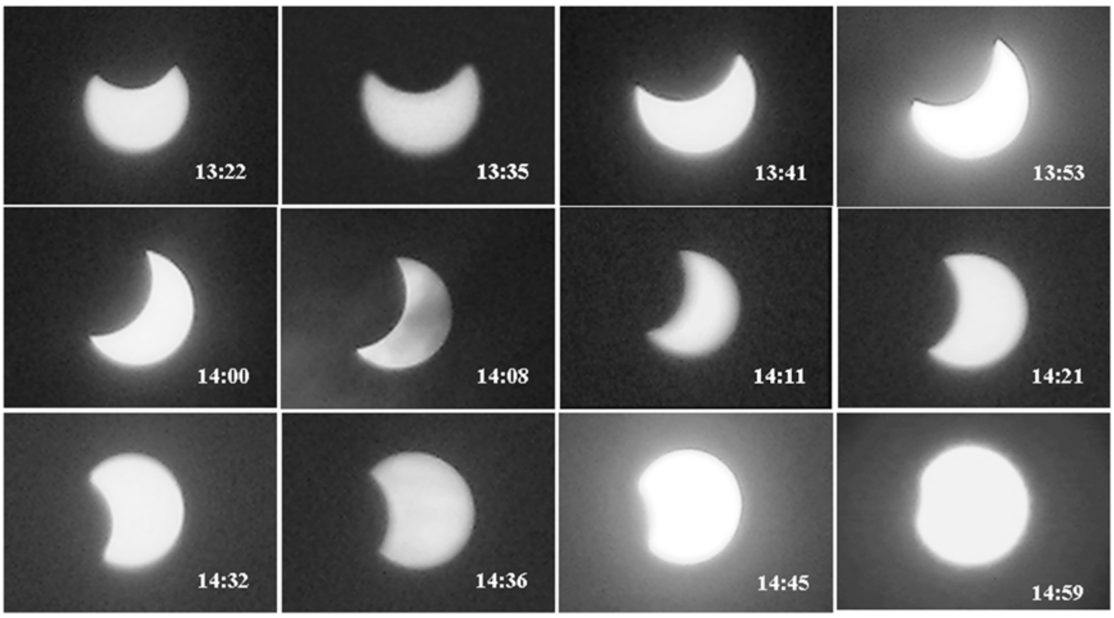

Figure 1. The solar eclipse above Saint Petersburg on 1 August 2008 (Moscow summer time)

Measurement results by the method of partial reflections of amplitudes of the received signals during the day of the eclipse are submitted in Figure 2. We shall note that according to our data day of the eclipse essentially did not differ from the near control days on 31 July and on 2 August 2008.

In the Figure signals scattered from regions of the mesosphere and the lower thermosphere are well visible. The typical feature of the registered reflections is the well-defined height layer structure. Observable echoes exceed the level of noise from the height about 70 km and on the average grow, reaching at the heights of the *E* region of the mirror reflection level.

During 90 minutes in the morning, noise from interfering radio stations is visible. Also, during the solar eclipse the increase of the reflecting layer height by 15-20 km for the extraordinary wave is well visible. It is marked by vertical lines and the dark strip on the axis of time. For the first time, similar rise of the mirror reflections height of the extraordinary wave was noticed in the auroral zone during the eclipse on 11 August 1999 [*Tereshchenko et al.*, 2001] and at the middle latitudes during the eclipse on 29 March 2006 [*Belikovich et al.*, 2008].

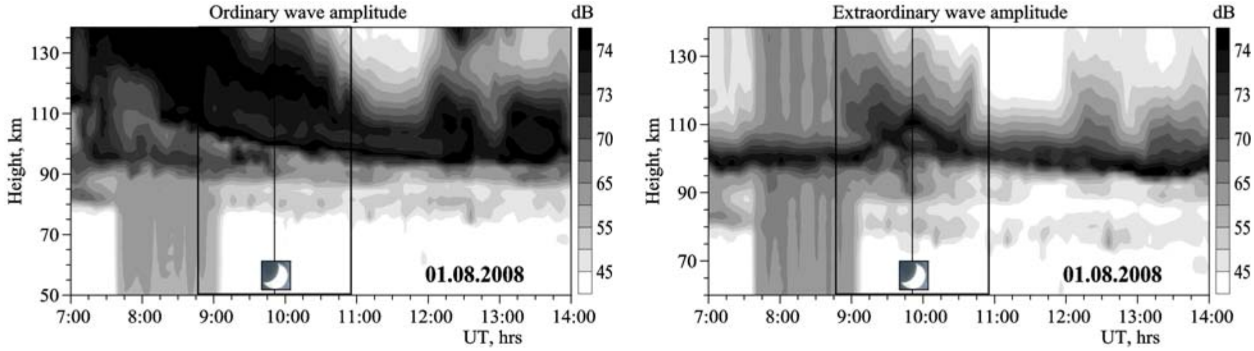

Figure 2. The general view of the signals received at the frequency of 2.66 MHz on 1 August 2008 at high latitudes

For reception of electron concentration profiles N_e (h) the difference of absorption along the trajectory of propagation of ordinary and extraordinary waves (the differential absorption method) [*Belikovich et al.*, 2003] was used. At the same time, it was supposed that the collision rate profile of electrons is known from other independent data. Using the data, changes of the *D* region structure of the polar ionosphere were established for various events.

Results of measurements of high-altitude structures of electron concentration with the minute averaging, received by the method of partial reflections during the eclipse, are submitted in Figure 3.

In the Figure it is visible that during the covering of the solar disk by the Moon the structure of the lower ionosphere is changing. Noticeable reduction of electron concentration occurs from the height about 70 km. In the maximal phase of the eclipse at the heights from 75 up to 85 km its value was lower approximately in 2-3 times than it was prior to the beginning of the eclipse.

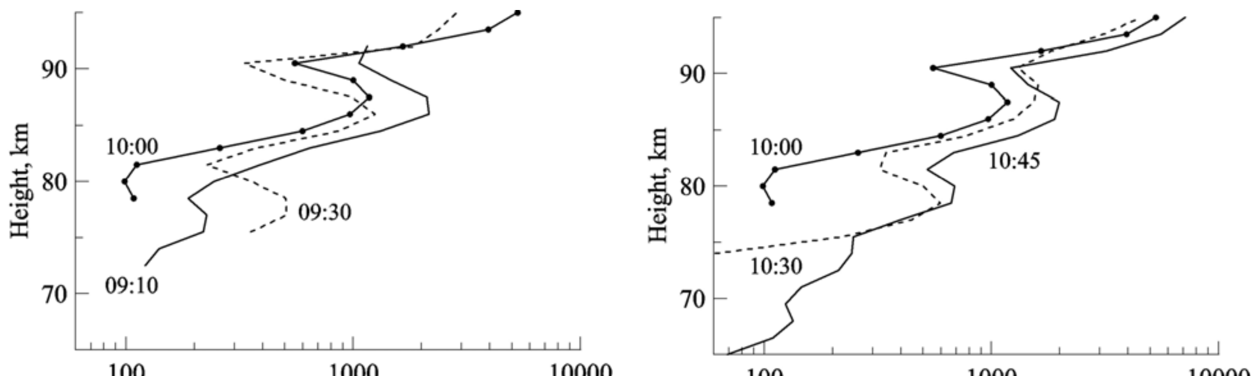

Figure 3. Behavior of electron concentration in *D* region of the polar ionosphere during the solar eclipse (v. Tumanny)

In Figure 4 continuous curves show behavior of electron concentration at heights of 77 and 89 km at the day of the eclipse; dot curves show average values of electron concentration during the control days.

It is well visible that electron concentration during the eclipse decreases approximately in 4-5 times. At the height of 77 km it reaches the minimum with delay, from the maximal phase of the eclipse, approximately in 15 minutes.

However, at the height of 89 km to determine of the delay is not possible because of wave disturbances of electron concentration.

According to the equation $\tau = 1/(2\alpha_{\varepsilon\phi\phi}N_e)$, describing inertance of the ionosphere, it is possible to estimate value of effective recombination coefficient α_{eff}. Calculations show that at the height of 77 km the recombination coefficient is equal $2.0{\cdot}10^{-6}$ cm^3 s^{-1}. It well coordinates with the results of other measurements and model calculations. The calculated value α_{eff} allows to consider that the basic losses of electrons at the height of 77 km in the polar ionosphere are the result of dissociative recombination of positive proton-hydrated ion-bunches with the mass number of 37 amu.

In Figure 5 continuous curves are shown behavior of total electron content. It was calculated with five-minute averaging in the range of heights from 55 up to 110 km during the eclipse. The shaped line plots variations of the minimal frequency of reflection f_{min}. The variations were obtained from ionograms, which were taken every 5 minutes. Three vertical lines mark the duration of the eclipse.

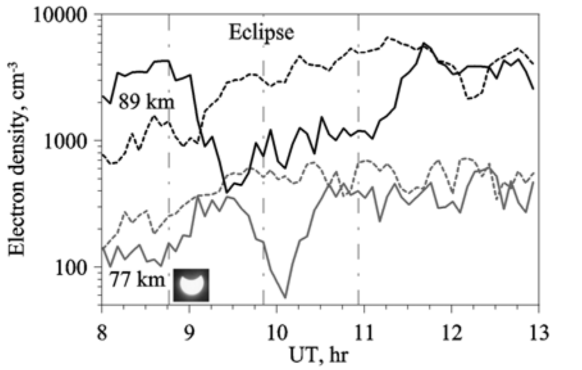

Figure 4. Temporal behavior of electron concentration at high latitudes

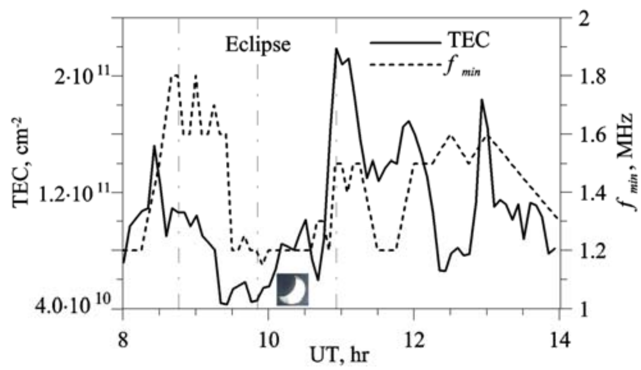

Figure 5. Change of the total electron content in the lower ionosphere and the minimal frequency of reflection during the solar eclipse

In the Figure 5, it is visible that to the maximum phase of the eclipse total electron content (TEC) has decreased in 2.5 times, and the minimal frequency of reflection has decreased in 1.4 times. It shows essential influence of the solar eclipse on the lower ionosphere. Also, the effect of the eclipse can be seen in similar quasi-periodic variations of the considered parameters. We note that temporal variation of the minimal frequency of reflection submitted in Figure 5 is similar to changes f_{min} during the eclipse on 29 March 2006 [*Belikovich et al.*, 2008].

Results of the spectral analysis of two-hour series of the given variations of amplitude of extraordinary polarization signals during the eclipse and in the control day are submitted in Figure 6. It is visible that the temporal behavior of amplitude of partial scattered signals during the eclipse has variations with the periods of 20-50 minutes. Disturbances of such type can be explained by propagation of acoustic-gravity waves in the ionosphere [*Sauli et al.*, 2007].

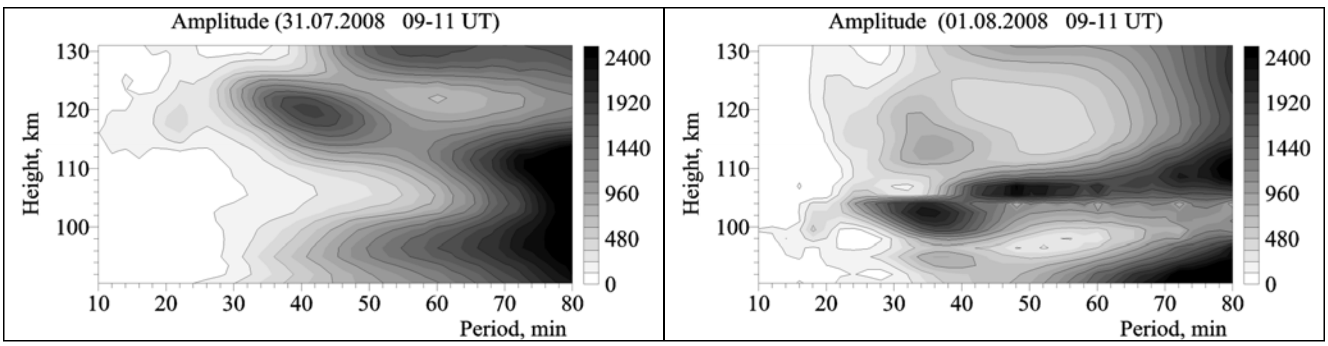

Figure 6. Power-density spectra of fluctuations of extraordinary wave amplitude

The reason of the waves origin can be movement of the lunar penumbra on the surface of the Earth with supersonic speed as it happens at passages of the solar terminator in the morning and in the evening. For separation of acoustic-gravity waves, generated by sliding of the lunar shadow, from the fluctuations, which present in the ionosphere, wavelet-transformation of the researched series was used. For consideration, the periods in the range from 15 up to 60 minutes were taken. Results of the analysis on the basic of the Morlet wavelet have shown presence of significant variations with the periods of 20-40 minutes at heights of the *E* region shortly before the maximal phase of the solar eclipse.

At first fluctuations with the period of 40 minutes have appeared, and then the ones with the period of 20 minutes have appeared. Hence observable variations of ionospheric parameters during the eclipse are caused by distribution of acoustic-gravity waves, generated by supersonic movement of the lunar shadow.

Conclusions

The carried out observations of the response of the lower ionosphere on the solar eclipses show that qualitatively they correspond to earlier carried out researches. The increase in the virtual height of reflections and reduction of electron concentration in the ionosphere are marked during the eclipses. Experimental evidences are received that the basic losses of electrons in the lower *D* region of the polar ionosphere are the result of dissociative recombination of positive ion-bunches of water with the weight of 37 amu. Wavy changes of electron concentration with the periods from 20 to 50 minutes, which can be caused by propagation of acoustic-gravity waves in the polar ionosphere, are found out.

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