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THE RESPONSE OF THE IONOSPHERE TO THE PARTIAL SOLAR ECLIPSE ON 29 MARCH 2006 ACCORDING TO OBSERVATIONS AT MIDDLE AND HIGH LATITUDES

V.V. Belikovich[1], V.D. Vyakhirev[1], E.E. Kalinina[1],V.D. Tereshchenko[2], S.M. Chernyakov [2], V.A. Tereshchenko[2]

[1]*Radiophysical Research Institute*, *Nizhniy Novgorod*, *603950*, *Russia*;
E-mail:*belik@nirfi.sci-nnov.ru*)
[2]*Polar Geophysical Institute*, *Murmansk*, *183010*, *Russia*;
E-mail:*vladter@pgi.ru*)

Abstract. Results of simultaneous observations of the ionospheric electron density variation during the partial solar eclipse on 29 March 2006 by vertical sounding and partial reflection methods are presented. Some evidences in favour of the linear law of recombination at heights of the lower part of D-region were obtained.

Introduction

The most of studies of responses to solar eclipses concerns the behavior of the ionosphere at heights more than 100 km. Influence of eclipses on the *D* region of the ionosphere was much less investigated [Al'pert, 1972; Farges et al., 2003]. Thus, the results of ionospheric observations of the 29 March 2006 solar eclipse obtained by the method of partial reflections (MPR) near Nizhniy Novgorod and by the method of vertical sounding using a digital ionospheric station near Murmansk are of interest. Below we will describe these observations.

Results of observations and the analysis

The partial solar eclipse of 29 March 2006 at Nizhniy Novgorod began at t_1 = 10:16 UT. The maximal phase of the eclipse φ = 0.696 was at t_2 = 11:21 UT. The ending of the eclipse was at t_3 = 12:24 UT. Similar parameters for Murmansk were φ = 0.346, t_1 = 10:23, t_2 = 11:11 and t_3 = 11:58 UT.
Results of measurements by the method of partial reflections are presented in Figures 1-3.

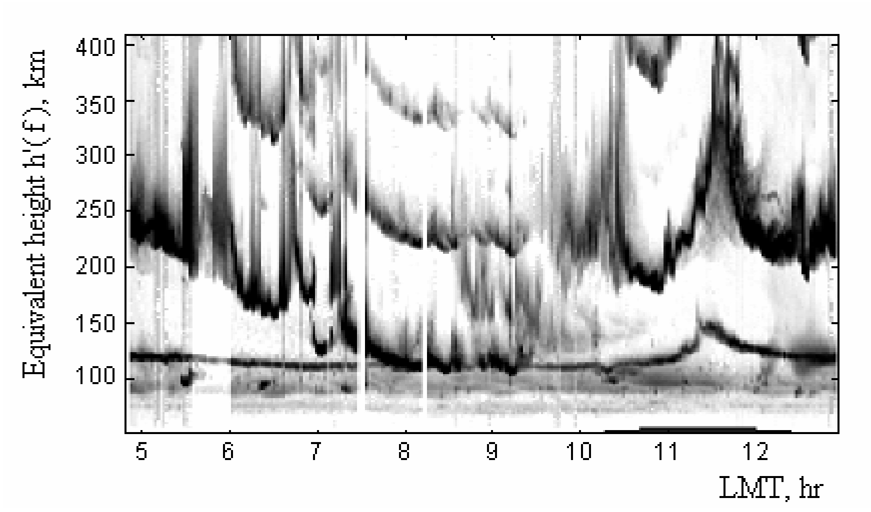

Figure 1. Partial reflection signals obtained at middle latitude on 29 March 2006

The change of intensity from light to dark shows an increase of the amplitude from 0 up to 50 dB. In the Figure the scattered signals from the *D* region mirror the reflected signals of extraordinary components from the heights higher than 100 km and signals of ordinary components at the heights of 120-230 km. The well noticeable double and triple reflections are seen. During the solar eclipse (14:16 – 16:24 LMT) substantial increase of the heights of mirror reflections also is well visible.

In Figure 2 the behavior of the electron concentration at the heights of 77 and 91 km is shown by solid lines, the dotted lines indicate mean values obtained by the MPR at N. Novgorod during control days. Variations of minimal frequency of reflection f_{min} from ionograms obtained every 5 minutes in Murmansk are designated by solid dark line.

Curve f_{min} in Figure 2 shows variations from 1.5 till 2.3 MHz. The period of eclipse in N. Novgorod is marked by a triangle on the time axis and in Murmansk – by three vertical lines. It is seen, that electron concentration during the eclipse approximately 4-5 times less. At the height of 77 km it achieves minimum practically at the maximal phase of the eclipse. The delay does not exceed 2 minutes. At the same time at the height of 91 km the delay makes 30-31 minutes. In 36 minutes after the maximal phase of the solar eclipse the minimal frequency of the reflection from the polar ionosphere also reaches its minimum. It mans that the change of the lower ionosphere structure at middle latitudes and in the auroral zone during the solar eclipse occurs synchronously.

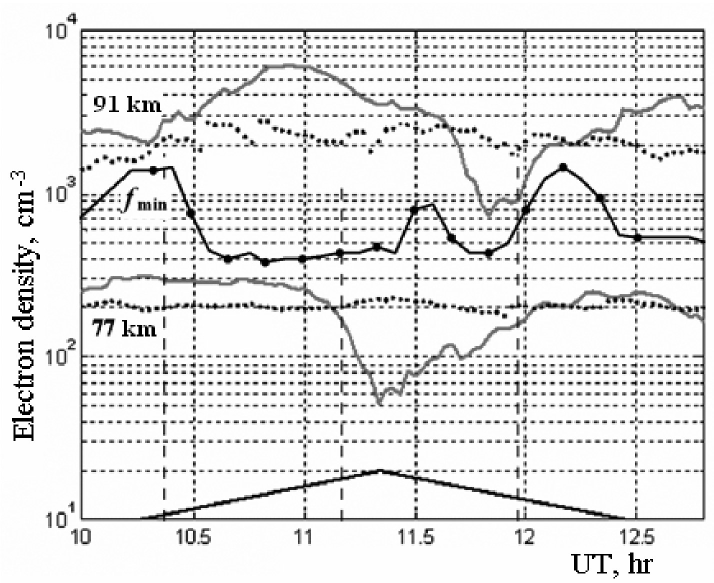

Figure 2. Temporal behavior of electron concentration at heights 77 and 91 km at middle latitudes and minimal frequency of reflection f_{min} in the auroral zone

According to the equation $\tau = 1/(2\alpha_{eff}N_e)$ which describes inertance of the ionosphere it can be possible to estimate a value of an effective coefficient of recombination α_{eff}. Calculations give the following values: $3.3{\cdot}10^{-5}$ cm$^3{\cdot}$s^{-1} at the heights 77 km and $2.7{\cdot}10^{-7}$ cm$^3{\cdot}$s^{-1} at the height 91 km. The calculations are in good agreement with results of other measurements. In this case it is reasonable to accept that in the lower part of the *D* region linear law of recombination operates.

In Figure 3 curves of changes of critical frequencies of various regions of the ionosphere for every 5 minutes during the period from 09:29 till 13:15 UT on 29 March 2006 are shown. The dashed curves constructed from hour data designate variations of critical frequencies for the rather quiet day on 28 March 2006.

From Figure 3 it is seen, that during the eclipse critical frequencies of all regions of the ionosphere decrease. Thus, relative reduction of a critical frequency (electron concentration) in the ionosphere decreases, as expected, with increase of height. By our estimations concentration of electrons has gone down by 20 % in the *E* region and 15 % in the *F*1 layer. Time shift of the response of the ionosphere for the solar eclipse decreases with increasing of height. Time delays of the effect are 34, 30 and 19 minutes for the maximum heights of the ionospheric layers *E*, *F*1 and *F*2. For the delay an effective coefficient of recombination has values: $5{\cdot}10^{-9}$, $1.8{\cdot}10^{-9}$ and $1.7{\cdot}10^{-9}$ cm$^3{\cdot}$s^{-1}. It does not contradict predictions of a theory according to which one has to expect decreasing of α_{eff} with increasing of height in the ionosphere. Let us note, the with reduction N_e at heights of the *E* and *F*1 layers of the ionosphere a quasiperiodic process with duration about two hours with amplitude $\Delta f_o \approx 0.1$ MHz and the period of fluctuations of 15 minutes and more was observed.

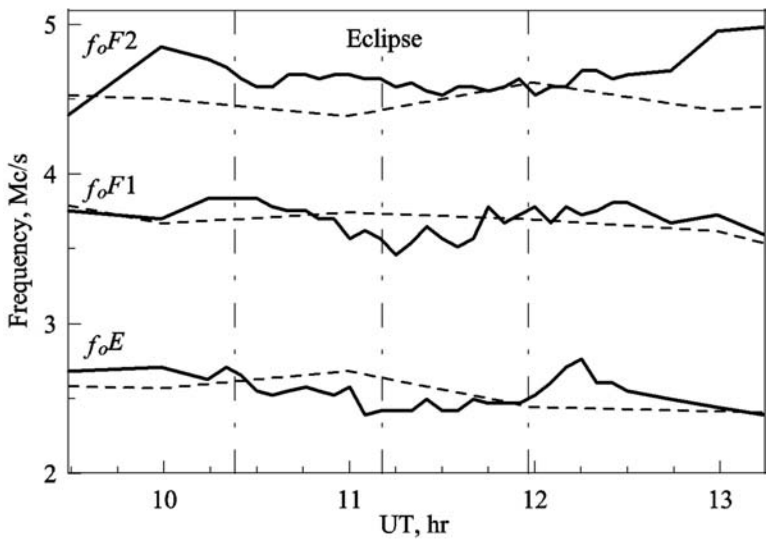

Figure 3. Change of critical frequencies f_oE, f_oF1, f_oF2 during the partial solar eclipse of the 29 March 2006 in the auroral zone

Figure 4 shows the change of virtual heights of reflection of ordinary and extraordinary waves at the fixed frequencies of sounding of the ionosphere. It is well seen, that the effect of the eclipse is in quasiperiodic fluctuations of virtual heights of reflection and in their increase at frequencies of 3.5-5 MHz practically right after the maximal phase of the eclipse. The virtual heights at these frequencies during the period from 11:05 till 11:45 UT increased approximately by 20-40 km (5-10 %).

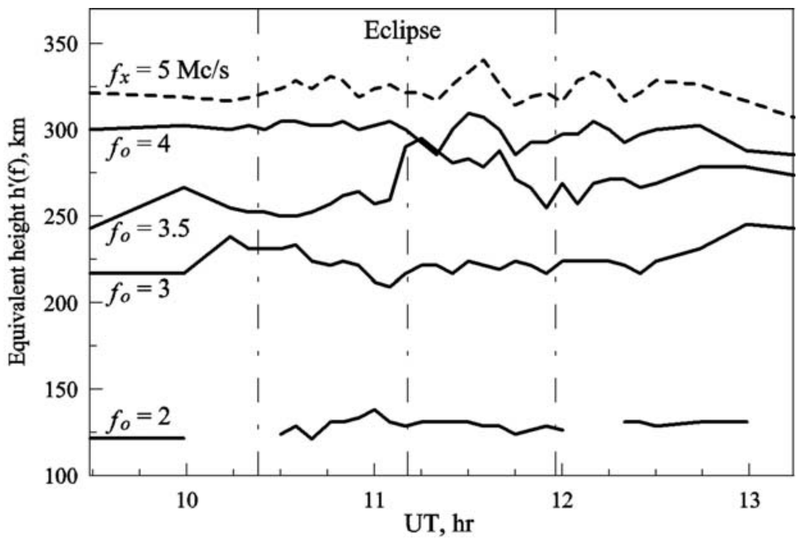

Figure 4. Time dependences of virtual heights of reflection of ordinary and extraordinary waves on fixed frequencies

One of the interesting issues is the problem of variations of ozone content during a solar eclipse. There is no a simple answer to this in the literature. According to the photochemical theory during a solar eclipse there must be observed the same course of ozone as during transition from day to night, but only during a shorter time interval. Most of the authors, who studied the issue, found rather noticeable increase of the total content of ozone during eclipses. In Fig. 5 time variations f_{min} and total ozone content (TOC) are shown.

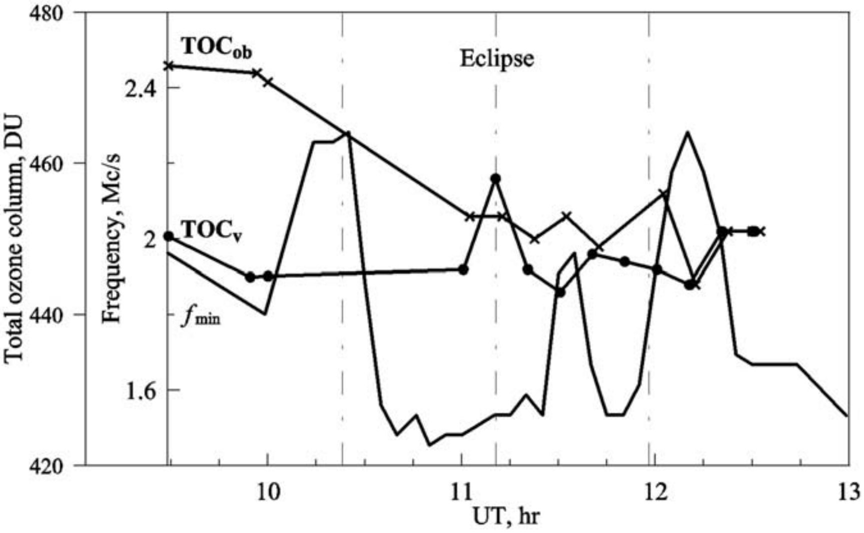

Figure 5. Minimal frequencies of reflection and total content of ozone in zenith and along the line of sight to the Sun on 29 March 2006 in Murmansk

Measurements of TOC were performed with device M-124 under favorable conditions of observations in Murmansk. In Fig. 5 it is seen that TOC changes in antiphase with $f_{\min}$, i. e. with total electron content in the lower ionosphere. Such temporal behaviour can be explained by changes of atomic oxygen concentration during a solar eclipse.

Conclusions

The carried out observations of the response of the ionosphere to the solar eclipse qualitatively corresponds to the results of the earlier researchers. In Murmansk as well as in N. Novgorod the increase of virtual heights of reflections and decreasing of electron concentration in the ionosphere were noted. Evidences in favour of the linear law of recombination at heights of the lower part of the D region are obtained. Wavelike changes of the electron concentration with periods of 15 minutes and more, which can be produced by propagation of acoustic-gravitational waves in the polar ionosphere, are detected. Increasing of total ozone content in the polar ionosphere during decreasing of the total electron content of the lower ionosphere caused by the solar eclipse was registered.

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