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THE RESPONSE OF THE POLAR LOWER IONOSPHERE TO POWERFUL SOLAR FLARES ON DECEMBER, 5-14, 2006

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Abstract. The results of observations of the polar lower ionosphere above Tumanny (69.0 N, 35.7 E) using the partial reflection method during powerful solar flares in the period from 5 December till 14 December 2006 are presented. During these events the strong change of the lower ionosphere structure and extraordinary high increase of the electron concentration up to values of $3{\cdot}10^3$ cm^{-3} at heights of 50-60 km were found.

Introduction

Solar flares are not predicted yet, thus regular observations of the lower ionosphere are not conducted, and each observable solar flare and its influence on the D region represent a unique event. Therefore, studies of ionospheric effects of solar flares remain still actual [Mitra, 1974; Tereshchenko et al., 2006]. This paper presents the results of observations of ionospheric effects of the solar flares obtained by the partial reflections instrument located near a settlement Tumanny, Murmansk region.

Observations and analysis

According to satellite observations during the period from 5 December till 14 December 2006 on the Sun there were 4 X-ray flares of class X, 5 flares of class M and 30 flares of class C [http://goes.ngdc.noaa.gov/data/avg/2006]. Disturbances on the Sun were accompanied by powerful emissions of solar plasma and emission of high energy solar particles. In Fig. 1 an example of spatial-temporal changes of amplitude of ordinary wave reflections as results of measurements on December, 13-14, 2006 is presented.

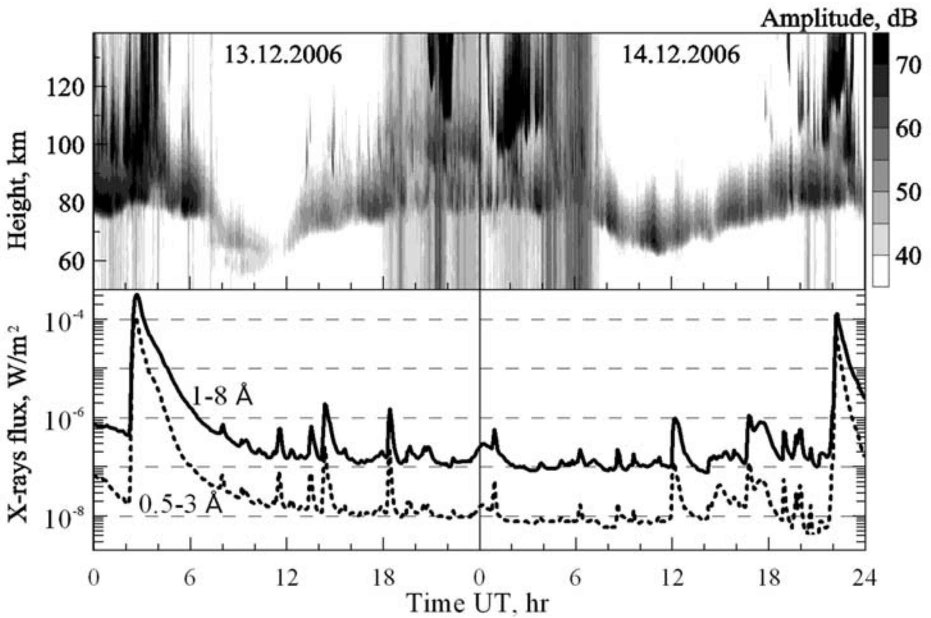

Figure 1. Amplitude of radio echo of the ordinary wave as a function of the time and height, and the X-ray flux

Time in hours (UT) is given on the abscissa axis, on the ordinate axis represents the height in km. Change of intensity from light to dark shows growth of amplitude from 20 up to 80 dB. In the same Figure the temporal profiles of X-ray radiation of the Sun in ranges 0.5-3 Å and 1-8 Å are presented (according to the GOES-10satellite data). Registration of scattered signals was conducted in the height interval from 50 up to 140 km with a step of 1.5 km. Amplitudes of received radiowaves were averaged for every minute at all heights with the help of an inverse function (geometrical averaging). On the basis of these averaged data by the method of differential absorption a profile $N_e(h)$ was calculated. During disturbances observed radio reflections have well defined layered structure.

Thus in the lower part of the D region the distribution of amplitudes of reflections remains horizontal-layered, and at heights of the E region it can appear close to vertical-layered distribution. In conformity with the used theory, which considers that reflections occur from irregularities of electron concentration Δ*N*/*N*, these measurements will allow to study a fine structure of the lower ionosphere. Figure 2 shows the height–time dependence of the electron density N_e in the ionospheric D region and the data of the GOES-10 satellite on high-energy protons during these events.

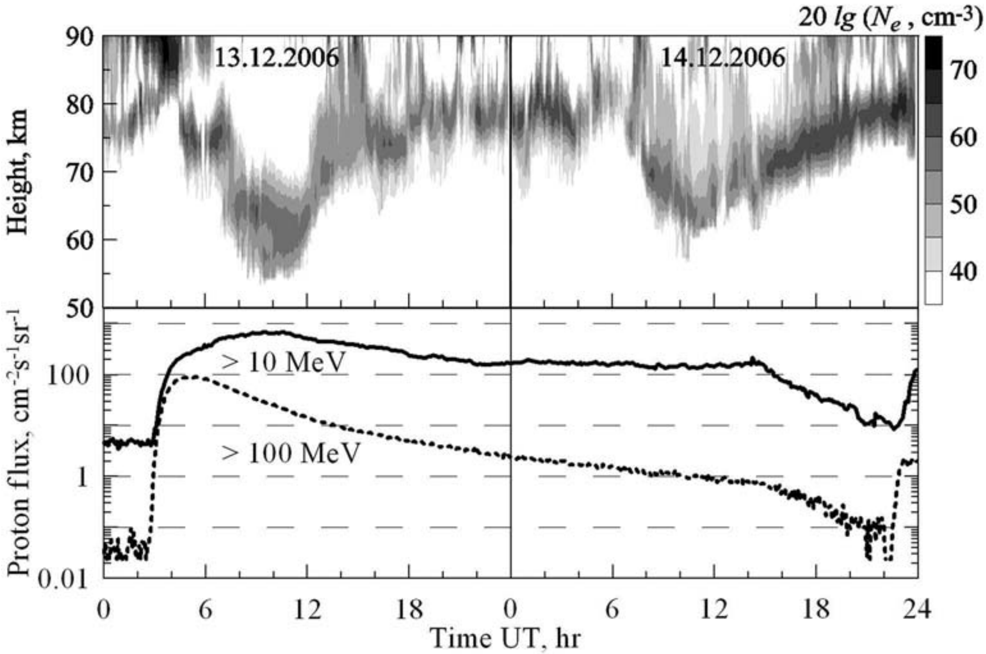

Figure 2. Diurnal variations in the electron density in the D region of the polar ionosphere and fluxes of high-energy solar protons

From comparison of the satellite and ground data it is seen, that observed disturbances in the ionosphere can be attributed to penetration of high-energy participles. Powerful flares of X-ray radiation of class X have taken place when the region of observation was on the dark side of the Earth. For the obvious reason they have not changed a position of the region of reflections. In Figure 2 it is seen, that at heights of 50-60 km electron concentration reached the values of 10^3 cm^{-3}, i.e. it increased approximately by an order and more.

Strong flares of solar corpuscular radiation lead to the abnormal phenomena in near-earth space: changing of the vertical structure of the ionosphere and magnetosphere and shift of the auroras to more lower latitudes (Fig. 3).

Consequences of solar flares were seen in full absorption of medium radiowaves in the E region and in partial absorption in the D region, and also in substantial growth of electron concentration and its gradients in comparison with corresponding values during quiet and moderate solar activity.

The reason why the electron concentration increase occurs during powerful solar flares can be variations in the ion and neutral composition of the ionospheric D region. These variations lead to a significant depletion of the effective recombination coefficient at altitudes below 90 km. The decrease in the effective recombination coefficient is accompanied by an increase in the electron concentration.

Conclusions

With the help of the method of partial reflections a strong change of the structure of the ionosphere and the extraordinary high increase of the electron concentration at heights of 50-60 km up to $3 \cdot 10^3 \cdot см^{-3}$ is revealed. It is shown that the behaviour of the electron concentration in the D region of the ionosphere is controlled by the solar protons penetrating to these heights. Ionospheric effects of solar flares is accompanied by strengthening of absorption of medium radiowaves.

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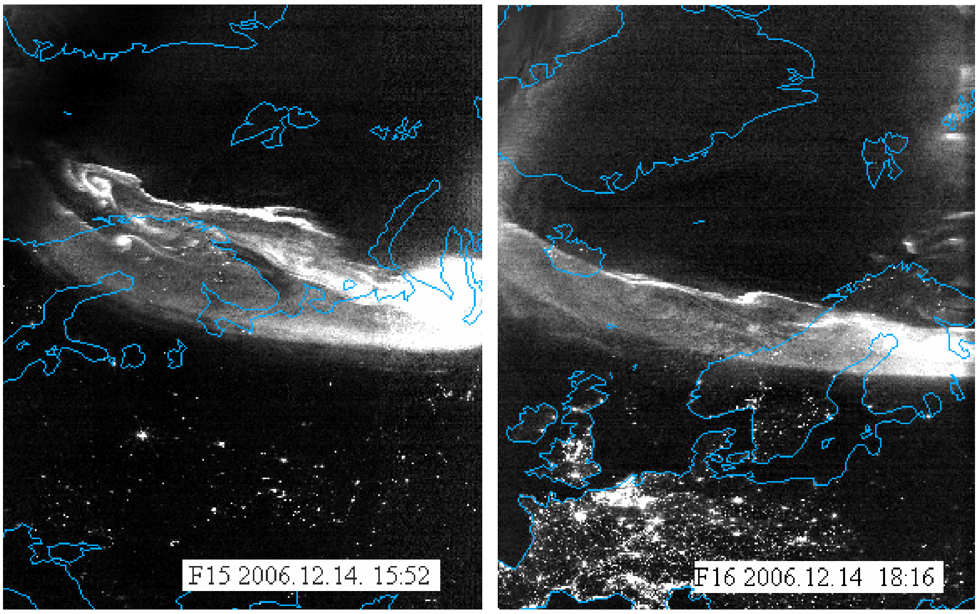

Figure 3. Pictures of polar lights from the DMSP satellites [http://spidr.ngdc.noaa.gov/spidr/dataset.do]