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EFFECTS OF THE LONG –TERM VARIATIONS OF THE SOLAR WIND ON THE NEAR-EARTH SPACE

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Abstract. There are a lot of the data of the solar wind parameters accumulated during epoch of the satellite exploration of the Space. It is possible to study interconnection between the long - term variations of the parameters of the solar wind and of the near - Earth Space during the last 4 cycles of the solar activity. We analyze quasi – stationary variations of the solar wind parameters during the solar cycle 23 in comparison with the correspondent changes in the cycles 20, 21 and 22. It was found that the main peculiarities of the cycle 23 are unusually low values of the solar wind magnetic field. We suggest that such long - term variations of the solar activity could change geoefficiency of the solar wind parameters which is expressed as diminishing of the electromagnetic energy transferred into the near – Earth Space. Therefore the global electric circuit parameters are changing correspondingly producing significant variations in the Earth ionosphere and atmosphere and indirectly in the planet climate. The latest experimentally observed low values of the ground surface electric field, low concentration of the charged particles in the ionosphere, increasing area of the ice cover in the Arctic could be attributed to these changes in the solar wind parameters.

1. Introduction

The Sun rotates around its axis but its various zones and layers turn with different velocities. The resulting shear due to difference in speed between adjacent regions twists and intensifies magnetic fields. Giant loops of hot plasma contained by the magnetic fields lift off the Sun's surface. The Sun produces a constant stream of particles which billow out into the space. In fact, 1 million tons of particles come from the Sun every second. This stream of particles is called the solar wind. A non-stop solar wind consisting of electrons and charged atoms travels past the Earth and far beyond the outermost planets. Near the Earth the plasma density is only about 6 particles per cubic centimeter, compared to 2.5 x 10^{19} molecules /cm^3 in the Earth's sea level atmosphere. Nevertheless, it is responsible for such specific phenomena as: forming structure of magnetosphere, dynamic processes and structure of electric fields inside magnetosphere. It is possible to speak about a specific kind of the solar activity influence on the Earth – the energy of the solar wind connected with vast areas of the Sun surface but stipulated by the solar magnetic fields. This kind of the solar activity can determine long –term variations of some parameters of the near-Earth space. The aim of this paper is to try to show direct connection between the solar wind magnitude field and the parameters of the high latitude ionosphere.

2. Experimental data

In this paper we used data of the solar activity and the parameters of the solar wind accumulated in the epoch of satellite explorations. As a level of the solar activity the number of Sun spots (W) was used. Results of analysis of the long – term variations of full vector of the magnetic field of the solar wind will be presented here. Period of observation is 42 years (from 1965 till 2010). The data were taken from INTERNET OMNI system. The hourly values of different parameters of the solar wind were used as original material. Afterwards the averaged monthly and annual values were calculated from it. The long – term variations (1965 – 2007 years) of such parameters of the solar wind as its density and velocity, three components and full vector of interplanetary magnetic field (IMF) were studied.
In this paper we used data of the hourly values of ionospheric parameters of the station Sodankyla, Finland (Φ' = 64.0°) from 1965 till 2007 years.
Results of comparison of the solar activity and the values of the IMF full vector with parameters of the ionosphere are presented below.

3. Results of experimental data analysis

Existence of long term experimental data of ionosphere were using for study of connection f_0 F2 и h_{max} F2 with solar activity expressed by Sun spot number and full vector of the magnetic field of the solar wind which is connected with large magnetic fields of the Sun. Mean annual values of number of Sun spot (W), full vector of IMF (Bsw), critical frequency (h_{max} F2) and of altitude of maximum of F2 layer (h_{max} F2) are presented on Figure 1.
Similarity of long –term variations of the Sun spot number and the f_0 F2 shows that EUV radiation is the main source of energy of ionization of atmosphere. The value of the coefficient correlation between these two parameters is very high and equal 0.95 with high level of statistical confidence. Asymmetry of cyclic solar activity is clearer in variations of the values of full vector IMF, rather than in W dynamics.

Long –term variations of the noon values of h_{max} F2 demonstrate tendency to increasing from 20 to 21 and 22 cycle and decreasing to 23 cycle (see Fig. 1, middle right panel).

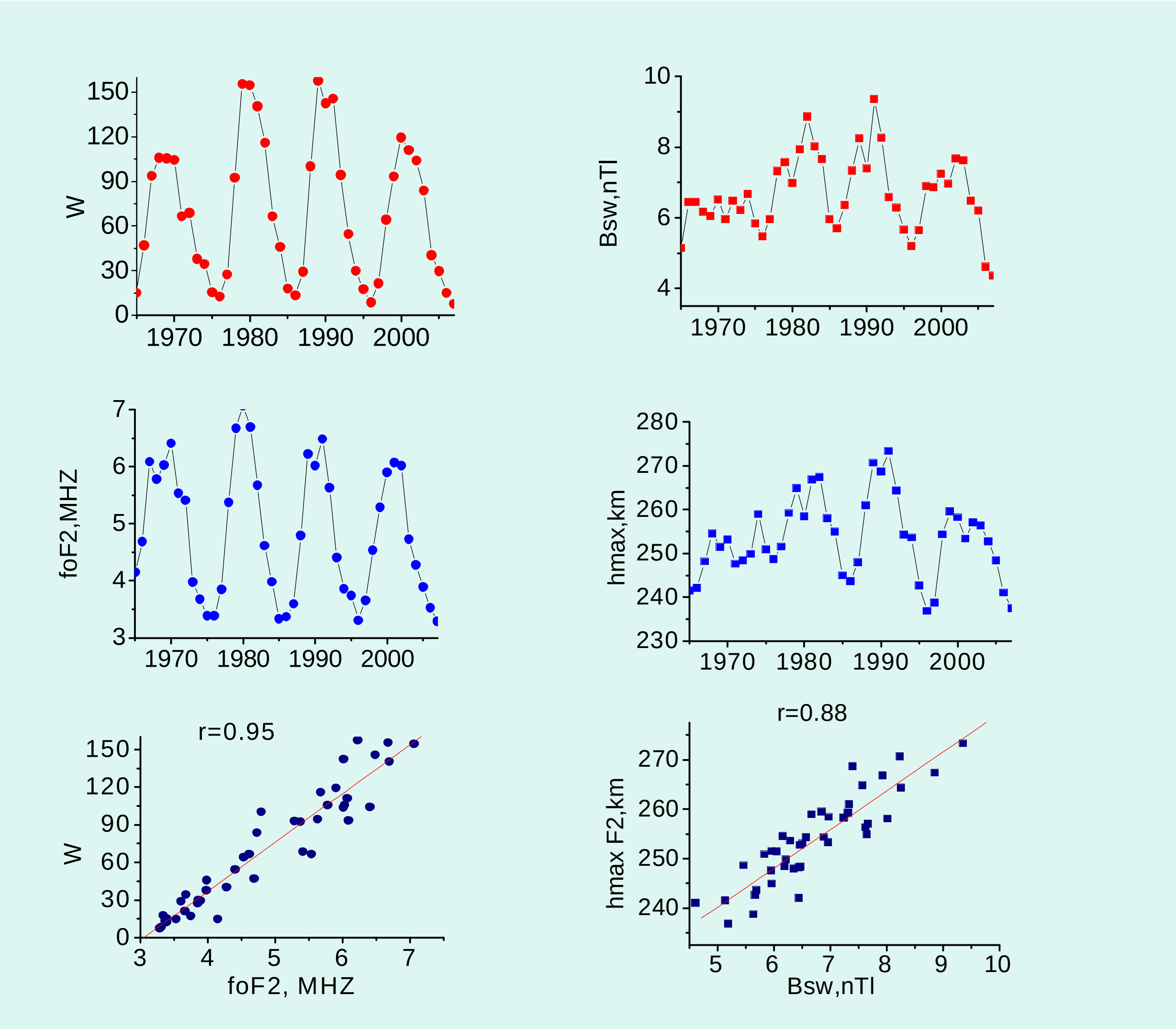

Figure 1. Long – term (1965 -2007) variations of annually averaged values of the Sun spot number (W), full vector of the IMF (Bsw), critical frequency (h_{max} F2), values of altitude of maximum of F2 layer (h_{max} F2) on station Sodankyla together with the statistical relations between them.

One can see maximum values of Bsw и h_{max} F2 during 21 and 22 cycles and minimum during 20 and 23 cycles. The value of the coefficient correlation between Bsw and h_{max} F2 is equal 0.88. High value of the coefficient correlation between of the full vector IMF and altitude of maximum of F2 layer indicates physical mechanism connection of these parameters. Such physical mechanism can be electric drift of F2 layer under influence of electric field which is connected with IMF. Simulations and experimental data show that electric drift changes of altitude of maximum of F2 layer (h_{max} F2) can be several kilometers for ten minutes. Importance of distribution of electric fields in magnetosphere and ionosphere is confirmed by a high value of the coefficient correlation between of the full vector IMF and altitude of maximum of F2 layer. It means also that value of the full vector of the solar wind magnetic field determines character of the electric fields distribution in the near-Earth space. The results of the recent studies showed that other processes in the near-Earth space besides ionospheric dynamics are closely connected with value of the full vector of the solar wind magnetic field. Analysis of experimental data showed that both horizontal and vertical components of the IMF averaged annually do not demonstrate any notable deviations from their zero values. Annually averaged values of Bx, By, and Bz components are equal to $^{+}$/- 0.4 nT. No any periodicity was discovered in variations of these parameters during the period of observations. The solar wind velocity value averaged for the whole period of observations (40 years) turns out to be 444 km s^{-1}. Spectral analysis of the solar wind velocity data revealed two distinct maximums of power spectra equal to 5 and 10 years. The most definite maximums of the solar wind velocity values were observed in 1974, 1984, 1994, and 2004, i.e. in the years of minimal solar activity.
Approximately the same periods of oscillations (5 and 10.8 years) are observed in variations of the solar wind density. One can find in the long-term variations of the solar wind density some evidences of existence of cyclic

variations close to 40 years. Maximal extreme of such variations could be seen in 80-90 years of the last century while its lowest values are seen in 1968-1972 and in 2005-2007 [1]. Too short period of the reliable satellite measurements of the solar wind parameters makes this statement a bit dubious but some correspondent variations in the climatic characteristics indirectly confirm this suggestion. There are some evidences that the solar wind energy could effectively influence some processes in the Earth's middle atmosphere at the high latitudes where impact of the solar UV radiation is not too strong [2, 3, 4]. Observed connections of temporal variations of the temperature of the middle atmosphere with parameters of the solar wind can be explained in the framework of the global electrical circuit driven by energy of the solar wind. It was discovered that the temperature of the stratosphere increases during disturbances of the solar wind if the conductivity of the Earth's surface is high. Vice versa-the temperature of the stratosphere above places covered by ice has a negative correlation with energy of the solar wind. The stratospheric layer with increased concentration of ions created by galactic or solar charged particles is an important element of the global electric circuit in the polar region for understanding of this mechanism. Long –term variations of the different kind of the solar activity can influence on electromagnetic energy and fluxes of galactic or solar charged particles which enter the near - Earth Space and change the Earth climate and weather. Declining phase of the cycle 23 was characterized by extremely low energy of the solar wind. During this period parameters of the solar wind (its density and velocity as well as value of full vector of its magnetic field) had the lowest values for the several last decades. It is worth to note that this period of unusually low energy of the solar wind coincided with significant decrease of the sea ice cover in the Arctic. Figure 2 demonstrates long – term variations of the solar wind density (left panel) and sea ice cover area in the East-Siberian sea (right panel) for period 1970 – 2010.

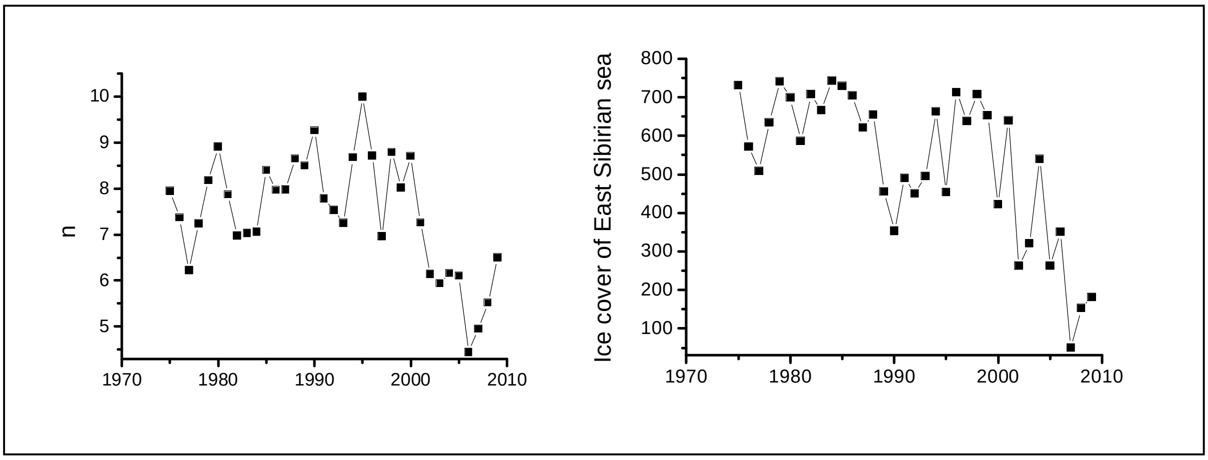

Figure 2. Long – term variations of the solar wind density in cm^{-3} (left panel) and sea ice cover area in the East-Siberian sea in km^2 x 10^3 (right panel) for period 1970 – 2010.

One can see a notable similarity between variations of the two data sets: the smaller sea ice cover area corresponds to the lowest values of the solar wind density. The correlation coefficient between these two parameters is comparatively high – 0.71. Of course a possible influence of the solar UV radiation on the ice formation is also significant and due to it the abovementioned correlation coefficient does not exceed a value of 0.71. Nevertheless the relation between the solar wind energy and the sea ice cover area is evident. For a time being only tentative physical explanation of the found relation could be proposed. So far the solar wind energy contribution to energetic balance of the Earth atmosphere was ignored in any atmospheric and climatic research. Traditionally this energy was attributed entirely to sustain a definite level of geomagnetic activity expressed as intensity of the geomagnetic substorms and storms but no with parameters of solar wind especially with his density. The solar wind energy determines values of electric field of global electrical circuit including his value on the ground surface. A role of the electric fields intensity on the sea ice formation has not been studied properly. Nevertheless it was found that the electric field in its influence on the water changes a structure of the water [5]. Most probably this process could accelerate probability of appearance of the nuclei of the ice formation. In this case the enhanced intensity of electric field promotes formations of the ice nuclei and vice versa decreased solar wind density will correspond to lesser sea ice cover area. Figure 3 demonstrates this relation clearly. Here periodicity of the sea ice cover area in the Laptev Sea in the Eastern part of the Arctic Ocean is shown for period 1924-2003. The thick black curve of the Figure 3 represents approximation by the polynome of the third degree variations of the sea ice cover area in the Laptev Sea.

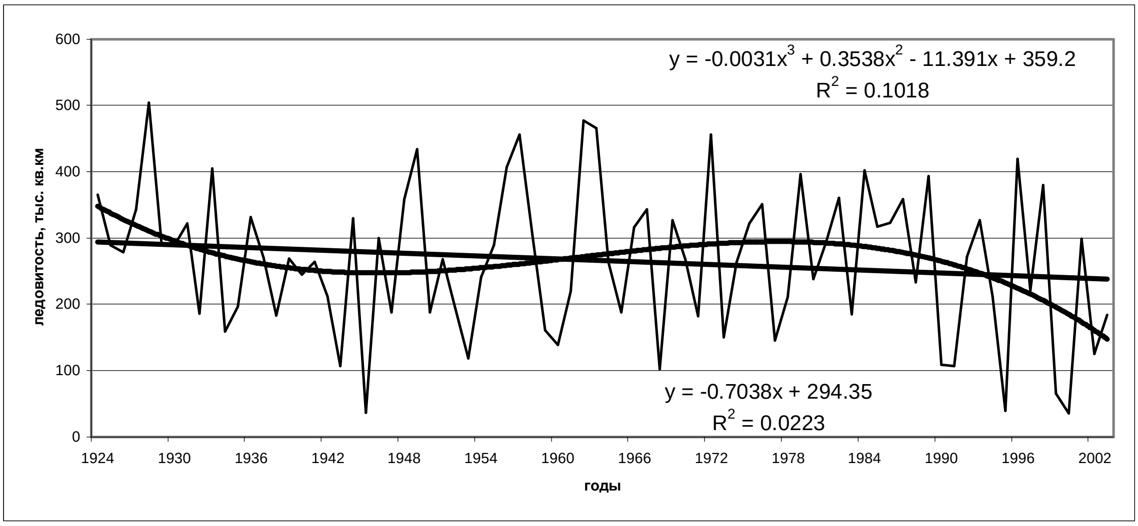

Figure 3. Long – term variations and periodicity of the sea ice cover area in the Laptev.

Summary

The investigations of the long – term variations of the ionospheric parameters which have been done in this paper allow us to determine the main factors responsible for formation of the both polar and auroral ionospheres.

It was shown that the main factor which determined the polar and auroral ionosphere in their long – term variations is the solar UV radiation. The long – term trends of ionospheric parameters are different in various cycles of the solar activity. The fact of the solar UV radiation influence on the middle atmosphere and ionosphere is a well know phenomenon. However, it is shown in this paper that the solar UV radiation is a main factor of formation of ionosphere during the last 4 cycles of the solar activity in the polar and auroral latitudes.

An original achievement of this investigation is establishing of the fact that the long – term variations of the height of maximum ionization in the F2 layer directly depend on the value of the full vector of the solar wind magnetic field, which determines magnitude of the ionospheric electric field and vertical drift of the whole F2 layer. Obtained high correlation coefficients between values of the height of maximum ionization in the F2 layer and full vector of the solar wind magnetic field are the reliable evidence of the important role of the electric fields in formation of the high – latitude ionosphere. A rather good similarity between the long-term variations of the solar wind density and the sea ice cover area in the Arctic was found.

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