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DISTURBANCES OF HELIOGEOPHYSICAL PARAMETERS DISPLAYING IN THE MAXIMUM OBSERVED FREQUENCIES ON IONOSPHERIC OBLIQUE SOUNDING TRACES

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Abstract. The influence of heliogeophysical parameters on maximum observed frequencies (MOF) variations on short-wave (SW) ionospheric traces of oblique sounding Inskip – Rostov-on-Don and Cyprus – Rostov-on-Don in December 2006 г, traces Inskip – Rostov-on-Don, Norilsk – Rostov-on-Don and Irkutsk – Rostov-on-Don in March, 2007 is executed. The key parameters of the interplanetary space which have the greatest influence on MOF variations on subauroral, mid-latitude and low-latitude ionospheric traces are established. The analysis of received results shows that changes of Interplanetary Magnetic Field components By and Bz are revealed in MOF of Norilsk – Rostov-on-Don subauroral trace. At middle latitude traces Inskip – Rostov-on-Don and Irkutsk – Rostov-on-Don the influence of Bx, By and Bz Interplanetary Magnetic Field components is more evident. At low-latitude trace Cyprus – Rostov-on-Don the influence of Interplanetary Magnetic Field module and its components By and Bz is marked. Solar wind density and velocity are revealed in MOF variations on all traces.

1. Introduction

The studying of the maximum observed frequencies at SW oblique sounding traces is the effective tool for diagnostics of ionosphere condition. Analysis of MOF variations on various ionospheric oblique sounding traces helps to reveal interplanetary space parameters which have the greatest influence on variations of ionospheric density both in high and middle latitudes.

It is well known that on location of plasma ring and main ionospheric trough changes of ionospheric density has appreciable influence at high latitudes. Moving of these structures for one's turn is substantially determined by Solar wind velocity and by quantity and orientation of Interplanetary Magnetic Field components By and Bz [Kolesnik et al., 2001; Mikhailov et al., 1998; Yokoyama et al., 1998; Ahmed and Sagalin, 1973; Caan, 1980]. The middle and low latitude ionosphere basically exists due to x-ray and ultra-violet ionizing radiation. However a displaying of interplanetary space parameters in density variations at these latitudes must not map out.

The basic purpose of current research is the establishment of key interplanetary space parameters which have the greatest influence on the maximum observed frequencies of subauroral trace Norilsk – Rostov-on-Don, mid-latitude traces Inskip – Rostov-on-Don and Irkutsk – Rostov-on-Don and low-latitude trace Cyprus – Rostov-on-Don.

2. Used data

The influence of interplanetary space parameters on variations of maximum observed frequencies has been carried out for subauroral, mid-latitude and low-latitude SW ionospheric oblique sounding traces Inskip – Rostov-on-Don and Cyprus – Rostov-on-Don in December 2006 г, Inskip – Rostov-on-Don, Norilsk – Rostov-on-Don and Irkutsk – Rostov-on-Don in March, 2007. Solar wind (PSW) and Interplanetary Magnetic Field (IMF) parameters have been taken from spacecraft ACE for times corresponding to the specified intervals. The data of x-ray radiation have been taken from spacecraft GOES for wavelengths range 1-8 Ang (XL) and 0.5-3 Ang (XS).

The removal of a daily variation from initial data at each of considered traces is made. It allows us to study only MOF disturbances. For this purpose all initial MOF sequences has been approximated by Gauss function:

$$f = a_1 \cdot \exp\left(-((x-b_1)/c_1)^2\right) + \ldots + a_8 \cdot \exp\left(-((x-b_8)/c_8)^2\right).$$

Further calculated values of Gauss function were subtracted from initial sequence. The received result (Rez F) represents so-called MOF "residuals" which contain only MOF disturbances (DMOF). Further in this work under MOF it will be meant Rez F values (DMOF). The example of daily variations removal on Fig. 1 for trace Inskip - Rostov-on-Don on March, 16-31 2007 is represented. Here the top panel is the initial MOF data approximated by Gauss function and the bottom panel is MOF "residuals" (Rez F).

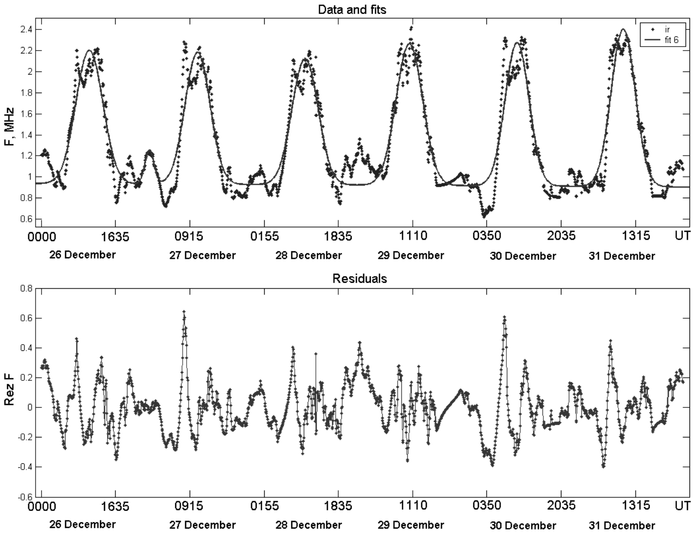

Fig. 1. The removal of MOF daily variation: on the top panel points show original MOF data (F) and continuous line is their approximation by Gauss function; on the bottom panel is result (Rez F, MHz) of removal Gauss function values from original MOF values (DMOF).

3. Search of linear correlations and their estimation

At the first investigation phase the search of linear correlations between DMOF on each trace with examined interplanetary space parameters has been executed. At correlation calculation has been entered the time delay from 0 to 300 minutes which allowed to establish time of ionosphere reaction on disturbances of each parameter.

For each oblique sounding trace has been calculated the statistical weight. It allows to carry out a quantitative estimation of influence each of parameters on DMOF taking into account a time delay. The statistical weight represents the relation of day quantity in which high correlation (> 0.5) between DMOF and examined parameters was marked to total quantity of researched days on each trace. Fig. 2 submits the total histogram of statistical weights for each trace.

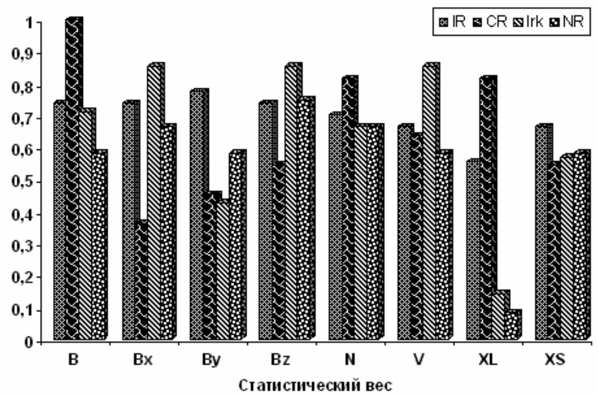

Fig. 2. The statistical weights calculated for each of examined parameters for all researched oblique sounding traces

The analysis of the received results for IMF module and components shows that on DMOF on subauroral trace Norilsk – Rostov-on-Don the greater influence have components By and Bz IMF in comparison with other mid-latitude and low-latitude traces. At mid-latitude traces Inskip – Rostov-on-Don and Irkutsk – Rostov-on-Don the influence of Bx and Bz components is more evident. At low-latitude trace Cyprus – Rostov-on-Don influence of IMF module on DMOF is marked. Solar wind density and velocity have an effect in DMOF on all traces. At Norilsk – Rostov-on-Don trace influence of these parameters is less evident in comparison with other mid-latitude and low-latitude traces.

Long-wave X-ray radiation has the greatest influence on DMOF of low-latitude trace Cyprus - Rostov-on-Don.

4. Nonlinear connections and MOF restoration on examined traces

Addition and specification of previous results received on the basis of linear correlations have been carried out by search of nonlinear connections between interplanetary space parameters and DMOF at each examined trace. For this purpose the Elman neural network with internal nonlinear memory has been chosen. The received results are used for development of a neural network restoration technique witch allows to receive MOF data on one trace by other trace data.

On the first stage of neural network experiments characteristic time delays of DMOF reaction on changes in heliogeophysical parameters are established. For each trace DMOF restoration by values of concrete heliogeophysical parameter is carried out with time delays from 0 till 300 minutes DMOF relatively this parameter. Calculated time delays contain a transfer time of Solar wind disturbance from spacecraft up to magnetospheric boundary and also reaction time of magnetosphere-ionosphere system on approached disturbance. Results of the first stage experiments are collected in Table 1 where established characteristic time delays for each of used additional parameters are submitted.

Table 1. Interplanetary space parameters and characteristic time delays of DMOF reaction on changes in given parameters

Interplanetary space parameter	**Time delay, min**
B	100–140
Bx	80
By	120–200
Bz	60–80
N	220–280
V	not received
XL	20–30
XS	0–10

On the second stage of neural network experiments the influence of heliogeophysical parameters on DMOF on each trace is established taking into account received time delays. For this purpose it was carried out a neural network restoration of DMOF on Cyprus – Rostov-on-Don, Norilsk – Rostov-on-Don and Irkutsk – Rostov-on-Don traces by DMOF data on Inskip – Rostov-on-Don trace and by values of chosen heliogeophysical parameter. The influence degree each of parameters was determined by increase of DMOF restoration efficiency at considered trace under its addition.

Results of executed neural network experiments show that DMOF data restoration of Cyprus – Rostov-on-Don trace by DMOF data of Inskip – Rostov-on-Don trace in December 2006 is possible. Attracting of IMF module B as additional parameter improved restoration quality on 4-6 %, parameter Bx – on 4-7%, parameter By – on 8%. Influence of other parameters appeared less evident. Thus for traces Inskip – Rostov-on-Don and Cyprus – Rostov-on-Don the most considerable is influence of IMF module and components Bx and By in comparison with Solar wind parameters. Probably it is connected with location of reflection points of examined traces – at middle and low latitudes. Therefore changes in Solar wind density and velocity are not shown in DMOF.

Restoration of Norilsk – Rostov-on-Don DMOF data by Inskip – Rostov-on-Don DMOF data appeared difficult due to long night intervals on Norilsk – Rostov-on-Don trace. For the given pair of traces it was not possible to reveal a nonlinear correlation connections between DMOF. Entering of additional parameters also has no influence on level of nonlinear correlation connections. It can be explained by the specified location of trace Norilsk – Rostov-on-Don in subauroral region unlike three other traces. It leads to significant difference of DMOF behaviour in this region from DMOF at middle and low latitudes.

Research of nonlinear connections between DMOF variations on Inskip – Rostov-on-Don and Irkutsk –Rostov-on-Don traces shows that restoration of Irkutsk – Rostov-on-Don DMOF data does not occur without attraction of additional parameters. However entering of additional parameters allows to receive such restoration. The main influence has such parameters as IMF module B (restoration quality increase by 40 %), components By and Bz (restoration quality increase by 30 and 40 %), Solar wind density (restoration quality increase by 40 %).

On the third stage of neural network experiments MOF data restoration of traces Cyprus – Rostov-on-Don and Irkutsk – Rostov-on-Don by MOF data of trace Inskip – Rostov-on-Don is executed. Thus the results received at the first and second stages were taken into account. Restoration was carried out by initial MOF data of trace Inskip - Rostov-on-Don, i.e. a daily course was taken into account. Input additional parameters which have the greatest influence on a level of nonlinear connection are used. For additional parameters also established earlier time delays are considered. As additional input parameter also we added a solar zenith angle which provides restoration of MOF daily course. For example at restoration of Irkutsk – Rostov-on-Don MOF data by Inskip – Rostov-on-Don MOF data neural network input feed: Inskip – Rostov-on-Don MOF data, IMF module B with time delay 120 minutes, components By and Bz with time delays 120 and 60 minutes, accordingly, Solar wind density N with time delay 240 minutes and solar zenith angle. On Fig. 3 results of such restoration are submitted. The solid line corresponds to real MOF values of Irkutsk - Rostov-on-Don trace, a dashed line – to the restored values by neural network. The high value of correlation coefficient (0.8) between real and restored sequences is marked.

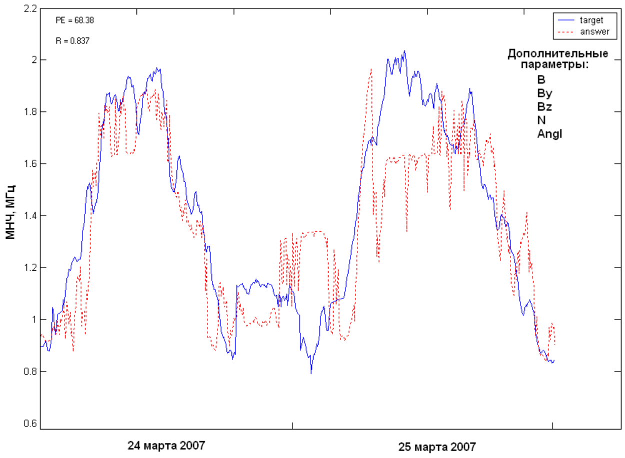

Fig. 3. Results of MOF restoration by neural network for trace Irkutsk - Rostov-on-Don by MOF data of trace Inskip - Rostov-on-Don with attraction of additional parameters (see the text). A solid line - real MOF values of Irkutsk - Rostov-on-Don trace, a dashed line – the values restored by neural network

Similar neural network restoration of MOF data has been carried out for trace Cyprus - Rostov-on-Don. In this case as additional parameters were used: IMF module B with time delay 140 minutes; components Bx and By IMF with time delays 80 and 160 minutes, accordingly; a solar zenith angle. The correlation coefficient between real and restored sequences in this case has made 0.9.

5. Conclusions

Influence of interplanetary space parameters on DMOF behaviour at subauroral Norilsk – Rostov-on-Don, mid-latitude Inskip – Rostov-on-Don and Irkutsk – Rostov-on-Don and low-latitude Cyprus – Rostov-on-Don oblique sounding traces is investigated. Calculation of linear correlations and search of nonlinear connections with use of Elman neural network allows to establish a key parameters with characteristic time delays which have the greatest influence on DMOF at these traces. It is established, that on DMOF of all researched oblique sounding traces the main influence have Interplanetary Magnetic Field module and its components.

Typical time delays of DMOF for researched traces relatively heliogeophysical parameters are calculated. Their values for IMF module B and component By are 100-140 and 120-200 minutes, accordingly. For IMF components Bx and Bz the values of time delays are 60-80 minutes.

The analysis of the received results allow to develop a neural network restoration technique of initial MOF values of traces Irkutsk – Rostov-on-Don and Cyprus – Rostov-on-Don by MOF data of Inskip - Rostov-on-Don trace. At neural network restoration the most effective interplanetary space parameters with established time delays were used. Thus high correlation coefficients (more than 0.8) between real and restored sequences are achieved.

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