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THE DISPLAYING OF HELIOGEOPHYSICAL DISTURBANCE IN MID-LATITUDE IONOSPHERIC INDEX

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Abstract. The connection between Solar-magnetospheric parameters with ionospheric index IAI was established and the estimation of their contribution extent to the index value was conducted. The key parameters are considered: AE index, the values of the geomagnetic field horizontal component, the values of the long-wave X-ray radiation in the range of 1-8 Å. The degree of each parameter contribution and their total contribution (40%) in the overall level of ionospheric disturbance was evaluated. A neural network operative diagnostics technique of the mid-latitude ionosphere with account of the heliogeophysical activity level was developed and the most efficient neural network input parameters were established. Achieve maximum efficiency of index values IAI reconstruction was 75%.

Introduction

Currently it has been established that the level of midlatitude ionosphere disturbance has influence of Solar-magnetospheric activity. A number of recent works dedicated to finding the most effective parameters that significantly disturbed the ionospheric ionization layers. In [Liu et al., 2007] noted that the ionospheric disturbance is dependent on the Solar cycle, which results in almost linear electron density increase of the ionosphere at middle and low latitudes from minimum to maximum eleven-year cycle. A number of other studies found the dependence of the critical frequency of the ionospheric layer F2 on the sunspot number, the variations of Solar radio emission at a wavelength of 10.7 cm (F10.7) and ultraviolet (EUV) [Balan et al.1993, 1996; Liu et al., 2003 ; Lăstovĭcka et al., 2008]. In [Liu et al., 2007], for example, pointed out that the plasma density at the top of the daytime ionosphere depends linearly on the index F10.7 and has a clear non-linear dependence of EUV. The rate of ionosphere concentration changes increases with increasing EUV. In addition, the magnetospheric parameters may affect on the density variations of ionospheric ionization. In [Barkhatova et al, 2009], for example, revealed the dependence of the critical frequency of the ionospheric layer F2 from index SYM-D which characterizes the D-component of symmetric part of low-latitude field disturbance. In [Zubova and Namgaladze, 2011] it is marked ionospheric response to the April, 2002 geomagnetic disturbances by the electron density decrease in 2 and more times. The effect was accompanied by the ion and electron temperatures increase.

This study assessed the influence degree of Solar-magnetospheric parameters for the index IAI, developed earlier [Barkhatova et al., 2011; Barkhatov and Barkhatova, 2012] based on the classification of variations F2 layer critical frequencies. The contribution of each parameter in the general level of the midlatitude ionospheric disturbances is revealed. Based on the established results, neural network method for reconstruction of IAI was made with maximum efficiency reached 75%.

1. The data used and processed

The estimation of ionospheric disturbance level was conducted on the data of mid-latitude vertical sounding station Moscow (55° N, 37° E) for the full cycle of Solar activity from 1975 to 1986. The disturbance level of auroral region described by AE index, the geomagnetic activity level was assessed using the values of geomagnetic field horizontal component (MF) and the current level of solar activity - using the values of the X-ray (XL) in the range of 1-8 Å. The latter parameter was chosen for reasons of its close association with the values of EUV. The data used resolution was 1 hour. Based on the original values of the critical frequencies were calculated ionospheric index IAI values. The method of creating the index is described in [Barkhatova et al., 2011; Barkhatov and Barkhatova, 2012].

Analysis of IAI values dependence from marked above Solar and geophysical parameters required indexing the actual values of these parameters. For AE index, whose values are non-negative, was leaded in five classes corresponding to a different level of auroral disturbance. Each of the derived classes was assigned a value from 0 to 4 by analogy with IAI index. The AE index boundary values for these classes are based on its values analysis at the minimum (1975) and maximum (1982) considered Solar cycle. Note that the auroral disturbances with the AE index value less than 500 nT accepted background. The rest of disturbances were arbitrarily divided into classes with each new class of consistent increase in the AE index values for 300 nT. The result was a new parameter CAE (classificated AE) whose values are subsequently compared with IAI index values. A similar scheme has been classified the values of the long-wavelength X-rays (XL). To select a background level the mean value of the sequence data was subtracted. This resulted to small negative values in the sequence of cleared XL, which is taken as the background (zero) level. Remaining disturbances were divided into classes which assign a value from 1 to 4. Each new class correspond an increase in XL intensity for 3 times. Thus has been obtained a new parameter CXL (classificated XL). Classification of geomagnetic field horizontal component was carried out by a procedure similar to the classification of ionospheric disturbance [Barkhatova et al., 2011; velvet and Barkhatova, 2012]. For this the maximal and minimal values of the horizontal component in the international quiet and disturbed days for 1975 and 1982 was determined. On the basis of these values assigned 7 classes of magnetic disturbance and a new parameter CMF (classificated MF) which characterizes the current magnetic disturbances at observed station. Table 1 shows the range of values for each of the received parameters.

Table 1.

Helio-geophysical parameter	Range of parameter values	Index values
AE	AE < 500	0
	500 ≤ AE < 800	1
	800 ≤ AE < 1100	2
	1100 ≤ AE < 1400	3
	AE ≥ 1400	4
XL	XL < 0	0
	$0 < XL < 0.1 \cdot 10^{-5}$	1
	$0.1 \cdot 10^{-5} \le XL < 0.3 \cdot 10^{-5}$	2
	$0.3 \cdot 10^{-5} \le XL < 0.9 \cdot 10^{-5}$	3
	$XL > 0.9 \cdot 10^{-5}$	4
MF	-10.5 < MF <16	0
	16 ≤ MF < 25	1
	-15 ≤ MF < 10.5	-1
	25 ≤ MF < 40	2
	-47 ≤ MF < -15	-2
	MF > 40	3
	-80 ≤ MF < -47	-3
	MF ≤ -80	-4

2. Estimation of the Solar-magnetospheric parameters impact on index IAI

Before direct assessment of the effects of each parameter on the index IAI, it is essential to delete all regular events from the values of each index because that can be superimposed on the desired effect and distort them. The phenomenon of terminator passage can not be removed from the index IAI values within procedure of its creation because the time of sunrise varies depending on the season. To observe the effect of the terminator passage the daily sunrise at station Moscow by Solar zenith angle values was determined. Next we consider the time interval from 2 hours before sunrise and 2 hours after. For each hour of the interval was conducted summary values IAI during the year (Figure 1).

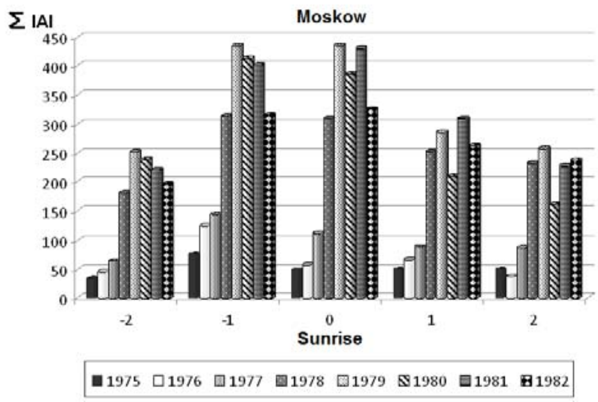

Fig. 1. Histogram of summary values IAI versus time before (negative values) and after (positive) pass the terminator through the station Moscow from 1975 to 1982. On x-axis are conditional hours ("0" corresponds to the sun rising above the horizon), the y-axis - the total value of the index IAI for the year

Analysis of the results presented in Fig. 1 shows that the greatest values the total annual index IAI receives at sunrise. This result can be considered as successful demonstration of the influence of the terminator passage on ionospheric disturbances. To correct the observed effect of the index data IAI was produced subtracting the contribtion of disturbance caused by terminator passage. Next was searched a relationship between index IAI disturbances and disturbances of indexed Solar-magnetospheric parameters and assessed the level of these relations. To do this, the index IAI compared with indexed values of parameters (CAE, CMF, CXL). The coincidence of thought disturbances found in the case when both parameters are non-zero. To quantify description of connection between IAI index and indexed parameters introduced additional index ICom. If at this time the value of the indexed parameter or IAI was zero, then the corresponding value ICom assumed to be zero. In assessing the impact of auroral disturbances on the variations in the values IAI the index ICom was calculated as absolute value of quotient CAE/IAI (Fig. 2). In assessing the connection between CMF or CXL parameters with IAI the additional index ICom was taken as 1 in the case of non-zero values of both indices.

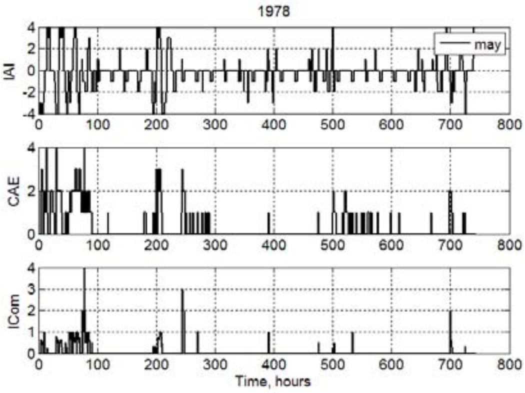

Fig. 2. Index IAI values (upper panel) at the station Moscow, index CAE (middle panel), parameter ICom (lower panel) for May 1978.

Made calculating of ICom demonstrates reflection of the changes announced heliogeophysical parameters to our proposed index IAI. Overall the total contribution of auroral disturbances, geomagnetic disturbances and disturbances caused by influence of long-wavelength X-rays into midlatitude ionospheric disturbances is about 40%.

3. Reconstructing of the ionospheric disturbance index values

The method of index IAI values reconstructing may be useful to assess the expected level of ionospheric response to the Solar-magnetospheric parameters disturbances. As a tool to reconstructing IAI was used neural networks of the following types: a feed forward network FF (double-layer, 5 neurons in the layer), Elman network ELM (double-layer, 5 neurons in the layer), neuro network FUZZY (2-5 rules on the input parameter depending on the amount of input data, the form of the rules is "bell").

Neural network experiments were carried out in several stages:

1. Reconstructing the IAI only by history. The correlation coefficient between the real and reconstructed sequences for the feed forward network (FF) was 0.66 for the network Elman - 0.64, and for Fuzzy network - 0.73. Thus the network Fuzzy is the most preferred in this case.

2. Reconstructing the IAI by only one additional parameter. To the input fed parameters one by one XL, MF, AE. Note that in this case the input of the neural network did not serve first derivative of index IAI. Correlation coefficients were low for each of the parameter.

3. Reconstructing the IAI only one additional parameter to include the first derivative of IAI. Compared with the first experiment, the addition of the input parameter XL to feed forward network increases the reconstruction quality at 6%, the parameter MF - 8%, and the parameter AE - 6%. Note that use of additional parameters at feed forward network gives best results whereas in their absence the best result gives network Fuzzy.

4. Reconstructing the IAI for pair combinations of parameters with the inclusion of the IAI first derivative. In this experiment the input submitted by one pair of parameters XL, MF, AE in combination with the IAI first derivative (d (IAI)). In this case the most effective is also feed forward network. Imposition of combinations of two additional parameters increases the average recovery efficiency at 1-2%. Corresponding correlation coefficients between the real and the reconstructed sequence are shown in Table 2.

Table 2

Neural network type	XL+d(IAI)	MF+d(IAI)	AE+d(IAI)
FF	0.72	0.74	0.72
ELM	0.70	0.68	0.68
FUZZY	0.70	0.69	0.71

Thus by the results of neural network experiments it can be concluded about the possibility of effective recovery which can call short-term forecasting of index IAI values. The preferred type of neural network is a feed forward with the following input parameters: the IAI first derivative and the pair of parameters combination: the geomagnetic field horizontal component plus index AE or geomagnetic field horizontal component plus long wavelength X-rays intensity. In this case the recovery efficiency is 75%. Fig. 3 shows an example of reconstructed IAI index values (gray) by feed forward neural network with input parameters: the IAI first derivative and combination MF + AE, associated with the real values of the index IAI (black).

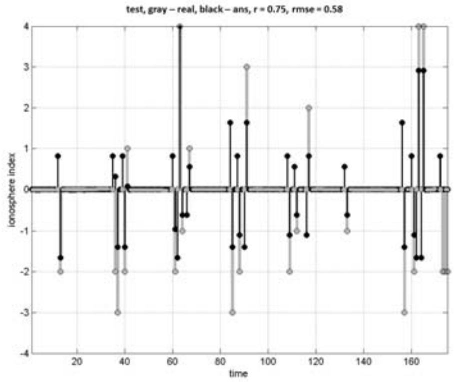

Fig. 3. Example of IAI index values reconstructed by feed forward network with addition of the IAI first derivative and the pair of parameters MF + AE (black dots), the actual value of the index IAI (gray dots).

Conclusions

This study is devoted to establishment of connection of Solar-magnetospheric parameters with an ionospheric IAI index and estimation of their contribution to the index value.

The main results are as follows:

1. Reliability of index IAI demonstrated by influence of terminator passage effect on ionospheric disturbances.
2. Confirmed the dependence of IAI values variations on geomagnetic activity (AE and the geomagnetic field horizontal component values) and the current solar activity (long-wave X-ray radiation in the range of 1-8 Å). The total contribution of Solar-magnetospheric activity is about 40%.
3. A neural network method for reconstruction of IAI index values taking into account the level of heliogeophysical activity was developed. The preferred type of neural network is a feed forward with the following input parameters: the IAI first derivative and the combination of pair of parameters: the geomagnetic field horizontal component plus index AE or geomagnetic field horizontal component plus long wavelength X-rays intensity. In this case the recovery efficiency is 75%.

Thus the previously introduced index IAI is useful for the assessment of ionospheric disturbances and can be used to study the effects of Solar and geomagnetic activity on ionospheric processes.

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References

Balan, N., Bailey G.J., Jayachandran B. Ionospheric evidence for a nonlinear relationship between the solar e. u. v. and 10.7 cm fluxes during an intense solar cycle // Planet. Space Sci., 41, 141–145, 1993.

Barkhatov N.A., Barkhatova O.M. Revealing of ionospheric disturbances classes on f2 critical frequencies long-term data. Geomagnetism and Aeronomy, 2012, V. 52, P. 510-518.

Barkhatova O.M., Levitin A.E., Dodonova I.A., Kosolapova N.V. Classification of ionospheric disturbances at mid-latitudes on long-term observations. Proc. of 34th Annual Seminar "Physics of auroral phenomena", Apatity, 1-4 March 2011, PGI KSC RAS, P. 125-128.

Barkhatova O.M., Smirnova A.S., Ulybina R.I. The account of Solar-magnetosphere connections in the problem of the prognosis of subauroral ionosphere parameters // Radiophysics and Quantum Electronics. 2009. V.52, N.2. P.109–117.

Lăstovĭcka, Yue X., Wan W. Long-term trends in foF2: their estimating and origin // Ann. Geophysicae. V. 26. № 3. P. 593–598. 2008.

Liu J.Y., Chen Y.I., Lin J.S. Statistical investigation of the saturation effect in the ionospheric foF2 versus sunspot, solar radio noise, and solar EUV radiation // Journal of Geophysical Research, V. 108, N. A2, 1067, doi:10.1029/2001JA007543, 2003.

Liu L., Wan W., Yue X., Zhao B., Ning B., Zhang M.-L. The dependence of plasma density in the topside ionosphere on the solar activity level // Ann. Geophysicae. V. 25. № 6. P. 1337–1343. 2007.

Zubova Yu.V., A.A. Namgaladze Investigation of the ionospheric F-layer response to the FAC2 variations during April 16 and 17, 2002 using the Upper Atmosphere Model // Physics of Auroral Phenomena, Proc. XXXIII Annual Apatity Seminar, P.159-160, 2011.