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NONLINEAR CONNECTION OF RING CURRENT AND AURORAL ELECTROJETS ACTIVITY WITH SOLAR WIND AND INTERPLANETARY MAGNETIC FIELD PARAMETERS

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The influence of Solar wind and Interplanetary Magnetic Field (IMF) concrete parameters on ring current and auroral electrojets current systems during geomagnetic storms main phases is investigated. The manifestation degree of these heliogeophysical parameters in considered current systems was determined with use of standard linear correlations and nonlinear connections established on the base of artificial neural networks.
The analysis of linear correlations and neural network experiments show that Solar wind velocity, Bz component IMF and less Solar wind concentration have an impact on auroral electrojets development during the geomagnetic storm main phase. The influence of By component expressed poorly. It is founded that Solar wind density has the greater influence on eastward electrojet while Solar wind velocity has the greater influence on westward electrojet. The IMF Bz component is the strongest agent determining intensity of ring current symmetric and asymmetric parts. It means that Bz component dynamics directly drive a ring current behaviour. The Solar wind density and velocity have not an evident influence on a ring current. Perhaps it's due to ring current contents up to 80 % ionospheric ions during magnetic storm main phase.

1. Introduction

The geomagnetic storm main phase is an interval of the greatest increase in ring current activity which is frequently accompanied by auroral electrojets intensification. The question on connection of these current systems is still not clear, but it is no doubts that their activation has the general solar source. The establishment of Solar wind (PSW) and Interplanetary Magnetic Field (IMF) parameters which have the greatest influence on magnetospheric and ionospheric current systems dynamics is one of the key problems.
It is well known that Bz component IMF is one of the key parameters determining a ring current development during magnetic storms [Tsurutani et al., 1992; Gonzalez et al., 1994]. The statistical research for 130 geomagnetic storms carried out in work [Lyatsky and Tan, 2003] shows that during storm development peaks in absolute values not only Bz component but also By component IMF are observed. Besides within several hours before depression of Dst index which show a ring current development degree, growth of Solar wind velocity and density is marked.
The research of auroral response on variations of Solar wind and Interplanetary Magnetic Field parameters shows that growth of Solar wind dynamic pressure frequently leads to typical substorms occurrence [Kokubun et al., 1977; Zhou and Tsurutani, 2001]. Development of a typical substorm is accompanied by generation or intensification a two-vortical current system such as DP2 [Sergeev et al., 1996; Nightingales, etc., 2006].

2. Used data

For the current research 30 isolated geomagnetic storms of various intensity for 2001-2003 have been selected. The influence of PSW and IMF on ring current and auroral electrojets current systems is carried out during the main phases of these storms. Indices SYM, ASY defined intensity of ring current symmetric and asymmetric parts and AU, AL indices – intensity of eastward and westward polar electrojets development.
As primary geoeffective PSW and IMF we considered: Solar wind velocity V, its density N or their combination, IMF components By and Bz. These data have been taken from satellite ACE with a two-hour advancing of a considered geomagnetic storm main phase. This advancing time include the time necessary to carry PSW to magnetospheric boundary and time to inside-magnetosphere processes development. Therefore the search of linear correlations has been made with shift of values AU, AL, SYM, ASY indices relatively PSW and IMF.
Thus, all 16 pairs of indices have been considered: N-AU, N-AL, V-AU, V-AL, By-AU, By-AL, Bz-AU, Bz-AL, N-SYM, N-ASY, V-SYM, V-ASY, By-SYM, By-ASY, Bz-SYM, Bz-ASY. It allows to investigate the influence of each interplanetary environment parameter on the concrete current system development.

3. The search of linear correlations

The analysis of the results received by linear correlations calculation for the specified pairs of indices allows to establish the common features of PSW and IMF influence on magnetospheric and ionospheric current systems development during geomagnetic storm. The established dependences have been assigned as a basis of nonlinear connections search between corresponding indices.

The main results of linear correlations are:
1. The Solar wind velocity and its density have greater influence on a ring current (SYM, ASY) in comparison with auroral electrojets. It is expressed in sharp increase of correlation at the fixed delay. The correlation analysis allows to establish the typical advancing times of PSW and IMF By component displaying in symmetric and asymmetric currents. They are about 70-80 minutes. The consideration of received correlation connections between SYM and ASY indices and PSW and IMF parameters gives that these parameters become apparent in ring current symmetric part more often in comparison with its asymmetric part.
2. IMF components By and Bz have the greatest influence on auroral electrojets. It is marked for geomagnetic storms of any intensity. Further on importance follow the Solar wind density and then the Solar wind velocity. For storms of strong intensity the Solar wind velocity influence is greater than for storms of average intensity and weak storms. Typical advancing times of PSW and IMF displaying in electrojets are 70-80 minutes.

4. The search of nonlinear connections and neural network reconstruction

In all series of completed neural network experiments the PSW and IMF values have been used as training sequence, and as test sequence – values of magnetospheric and ionospheric currents indices. For this research the Elman neural network has been chosen which contained 4 hidden layers with 6 neurons in everyone. Experience has shown that such network configuration is optimum because the increase of layers quantity or neurons in layer frequently leads to its overload.
The performance of neural network experiments for each pair of indices was carried out in such sequence:

1. For chosen training parameter (PSW or IMF) typical advancing times of the reconstructed parameter (AU, AL, SYM, ASY) were proposed on the basis of linear correlations. This time was equaled to 80 minutes and takes into account time of PSW and IMF carrying to magnetosphere boundary.
2. Neural network has been trained on one of thirty events. On network input feed values of the training parameter and its first derivative taking into account established advancing time.
3. Trained neural network used for the reconstruction of others 29 events. The correlation coefficient between real and reconstructed sequences was calculated for an estimation of reconstruction efficiency.

Completed neural network experiments show that successful reconstruction of ring current and auroral electrojets intensity indices on the PSW and IMF parameters data is possible. Neural network reconstruction was considered successful if correlation between real and reconstructed values were in an interval from 0.4 up to 0.9. Fig. 1 shows examples of ring current and auroral electrojets intensity indices reconstruction on the PSW and IMF data.

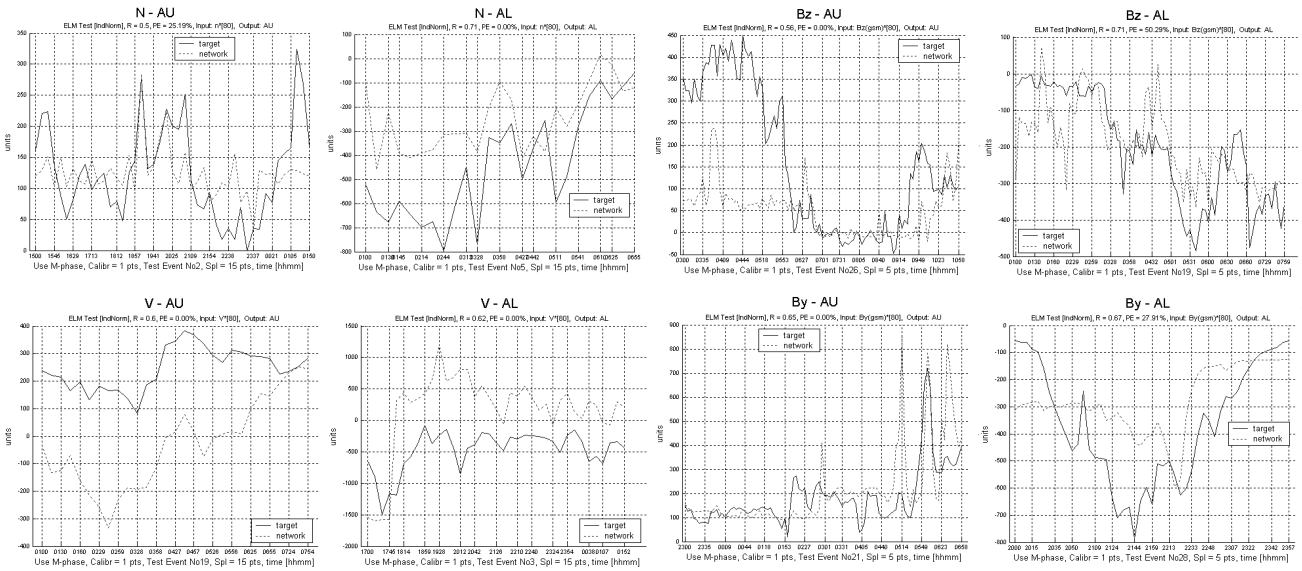

Fig. 1. Examples of neural network reconstruction of auroral electrojets and a ring current intensity indices on the PSW and IMF data. The solid line shows real values of indices and dashed line – the values of indices reconstructed by neural network.

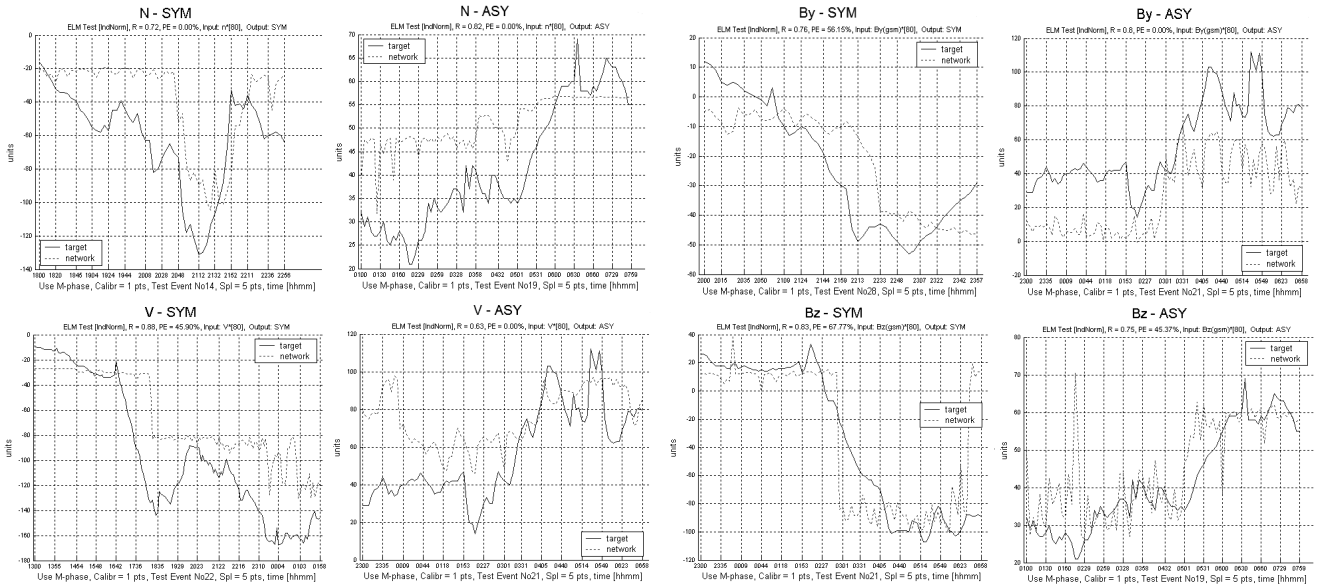

Fig. 1. (continue) Examples of neural network reconstruction of auroral electrojets and a ring current intensity indices on the PSW and IMF data. The solid line shows real values of indices and dashed line – the values of indices reconstructed by neural network.

For influence degree estimation of concrete parameter (PSW or IMF) on ring current and auroral electrojets current systems development for each examined pair of indices have been calculated a statistical weight of successful reconstruction:

$$W = \frac{N}{2C_m^n},$$

here N – number of cases with correlation coefficient > 0.4, C_m^n – the general number of events combinations from $m=30$ on $n=2$. Statistical weights are submitted on diagrams Fig. 2.

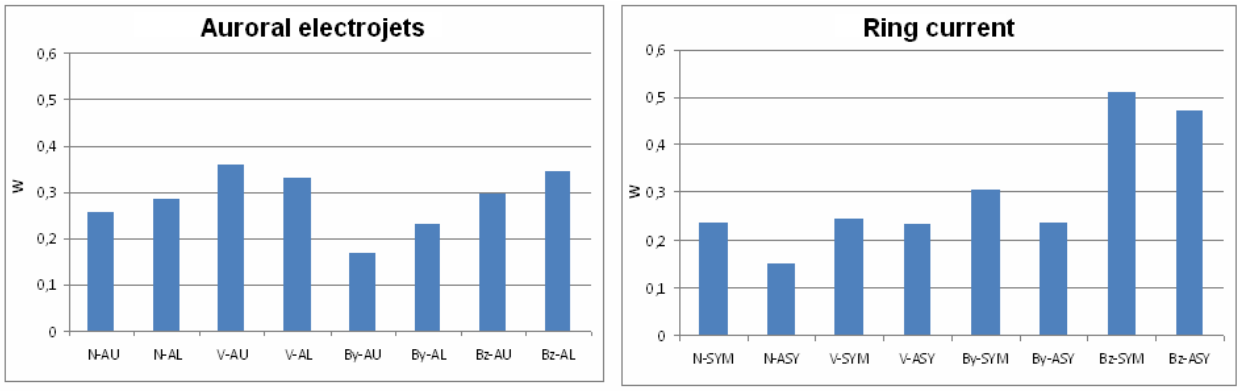

Fig. 2. Statistical weights values for considered pairs of indices

The distribution of successful reconstruction statistical weights for auroral electrojets indices and ring current symmetric and asymmetric parts indices has shown:

1. Solar wind velocity, IMF component Bz and to a lesser degree Solar wind density have the greatest influence on auroral electrojets development during the main phase of a geomagnetic storm. Influence of By component expressed poorly.
2. Statistical weights for westward electrojet (AL) are in the main higher than for eastward electrojet (AU). It can means that on the main phase of a magnetic storm westward electrojet developed more strongly than eastward electrojet. Westward electrojet is caused by intensive magnetic reconnection on day time

magnetopause connected with IMF Bz component and accordingly with transfer of magnetic streams from a Solar wind to magnetosphere.

3. It is necessary to note that values of statistical weights for Solar wind density and velocity concerning eastward and westward electrojets are various. Solar wind density has the greater influence on eastward electrojet while Solar wind velocity has the greater influence on westward electrojet. It can be caused by different nature of auroral electrojets – westward electrojet is connected to explosive processes of substorm (rapid transfer of IMF Bz component from Solar wind to magnetosphere), and eastward electrojet is caused by stationary magnetospheric convection.
4. As expected the strongest agent determining the intensity of ring current symmetric and asymmetric parts is IMF Bz component. It means that dynamics of Bz component directly drive a ring current behaviour.
5. Solar wind density and velocity have no clear influence on a ring current. Perhaps it's due to ring current contents up to 80 % ionospheric ions during magnetic storm main phase.

Conclusion

In current work the influence of Solar wind and Interplanetary Magnetic Field parameters on ring current and auroral electrojets development during the main phases of magnetic storms is investigated.
According to the preliminary linear correlation analysis for pairs N-AU, N-AL, V-AU, V-AL, By-AU, By-AL, Bz-AU, Bz-AL, N-SYM, N-ASY, V-SYM, V-ASY, By-SYM, By-ASY, Bz-SYM, Bz-ASY it has been established that on ring current intensification significant influence have Solar wind velocity and density. Auroral electrojets development in the greater degree determined by IMF By and Bz components. Typically advancing times for PSW and IMF relatively magnetospheric and ionospheric current systems are about 80 minutes.
The results received on the basis of nonlinear connection research for each pair of indices show that on auroral electrojets development during geomagnetic storm main phase the greatest influence have Solar wind velocity, IMF component Bz and to a lesser degree Solar wind density. Influence of By component expressed poorly. It is established that on the geomagnetic storm main phase westward electrojet developed more strongly than eastward electrojet. For a ring current the strongest agent determining intensity of its symmetric and asymmetric parts is IMF component Bz. Dynamics of Bz component directly drive a ring current behaviour. Solar wind density and velocity have no clear influence on a ring current. Perhaps it's due to ring current contents up to 80 % ionospheric ions during magnetic storm main phase.

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References

Gonzalez W. D., J.A. Joselyn, Y. Kamide, H.W. Kroehl, G. Rostoker, B. T. Tsurutani, and V. M. Vasyliunas, What is a geomagnetic storm? // J. Geophys. Res., 99, 5771, 1994.

Kokubun S., McPherron R., Russel C. Triggering of substorms by solar wind discontinuities // J. Geophys. Res. V. 82. P. 74-86. 1977.

Lyatsky W. and Tan A. Solar wind disturbances responsible for geomagnetic storms // Journal of Geophysical Research, V. 108, N. A3, 1134, doi:10.1029/2001JA005057, 2003.

Sergeev V.A., Pellinen R.J., Pulkkinen T.I. Steady magnetospheric convection: A review of recent results // Space Sci. Rev. V. 75. P. 551–604. 1996.

Solovyev S.I., A.V. Moiseev, E.S. Barkova, K. Yumoto, and M. Engebretson Influence of the Solar Wind Plasma Density on the Auroral Precipitation Characteristics // Geom. and Aeronomy V. 46. N1. P. 44–54. 2006.

Tsurutani B. T., W. D. Gonzalez, F. Tang, and Y. T. Lee, Great magnetic storms. // Geophys. Res. Lett., 19, 73, 1992.

Zhou X., Tsurutani B.T. Interplanetary shock triggering of nightside geomagnetic activity: Substorms, pseudo-breakups, and quiescent events // J. Geophys. Res. V. 106. P. 18.957-18.967. 2001.