"Physics of Auroral Phenomena", Proc. XXXVII Annual Seminar, Apatity, pp. 75-77, 2014
© Kola Science Centre, Russian Academy of Science, 2014
Polar Geophysical Institute

IDENTIFICATION OF PLASMA STREAMS IN THE SOLAR WIND BY NEURAL NETWORK CLASSIFICATION APPROACH

N.A. Barkhatov, S.E. Revunov, A.B. Vinogradov *(Nizhniy Novgorod State Pedagogical University, Nizhniy Novgorod, Russia)*

The paper presents a new method for the identification of plasma streams in the solar wind by self-learning neural classification network on their spectral features in magnetic hydrodynamic range. To do this, the wavelet skeleton spectrums of solar wind parameters of the interplanetary magnetic field recorded in Earth orbit by patrol spacecraft is calculate. Algorithm for classification of wavelet skeleton spectral images for plasma streams in the solar wind on the Earth's orbit, based on neural network processing of compressed data on the main magnetic and dynamic parameters of the flow is propose. A neural network like Kohonen layer differentiated by frequency ranges performs the classification. Specifically, analyzes and establishes the spectral features of solar plasma flows in the form of magnetic clouds (MC), corotating interaction regions (CIR), shock waves (Shocks) and high-speed streams from coronal holes (HSS).

1. Introduction

One of the problem of modern geliogeophysics is the problem of identification of geoeffective structures in near-Earth space, in the solar wind flow is presented. In turn, this identification of flows is not possible without their preliminary classification. Universal algorithm for determining the signs of both transient (like shock waves) and long (like magnetic clouds) processes is requires. In this paper an algorithm based on the compression of spectral information about the basic parameters of the MHD plasma flows and their representation in the form of wavelet skeleton spectral patterns we propose.

Have repeatedly noted that the spectral composition of disturbances with periods ranging from 10 to 90 minutes, associated with the solar plasma flows, driven by their type [*Wawrzaszek and Macek, 2010; Tessein et al., 2011; Steed et al., 2011 and references therein*]. However, most researches in this area on the study of the nature of the turbulence of the solar streams without regard to their membership of a certain type are focused. Thus, it is a persistent task differentiate types of flows of characteristic features by correlation-spectral method obtained. In the present study on the refinement of the plasma flow of the solar wind from the characteristic spectral features of wavelet variations of velocity, density, temperature, magnetic field we are focuses. We assume that each type of geoeffective flow not just a specific set of disturbed parameters (velocity, density, pressure, temperature, size of the field), and the characteristic fundamental links between them [*Barhatov et al., 2013*] is characterized. These links in the synchronization of associated with perturbed parameters of the wave packets is performed. The proposed approach allows us to quantify the level of synchronization between the disturbed parameters of plasma formation, presented in the form of compressed wavelet images (skeletons) [*Revunov et al, 2013*]. According to the results of this assessment with classification neural network concludes supplies flow to a particular type is proposed. Classification feature in this case is the degree of coherence of oscillatory processes in the parameters of the solar wind flow in a specific frequency range is performed.

2. Correlation-spectral data processing method

Works of proposed algorithm for identification of plasma flows in the solar wind by classification neural network approach on 24 of these types of events for plasma flows on ACE and Wind spacecraft during the period from 2000 to 2007 by catalogues NASA (*http://cdaw.gsfc.nasa.gov*) and NOAA (*http://ngdc.noaa.gov*) was performed. Within each event wavelet spectrums of one minute data for density N, velocity V, temperature T, pressure P, module and component of the interplanetary magnetic field | B |, Bx, By, Bz was received. Each type of the analyzed flow of six events is presented: MC (28.07.2000, 29.12.2000, 12.04.2001, 28.05.2001, 09.08.2001, 17.04.2002), CIR (27.07.2003, 05.04.2005, 07.05.2007, 20.09.2007, 27.09.2007, 25.10.2007), Shocks (19.12.2002, 27.02.2003, 14.07.2003, 17.07.2003, 12.04.2004, 22.07.2004), HSS (01.03.2000, 26.07.2003, 20.11.2004, 04.07.2006, 29.07.2007, 17.12.2007).

The use of wavelet analysis allows spectrums at a specific frequency range is obtain. This usually gives the opportunity to limit the scope of the search features of the original signal [*Daubechies, 2001*]. In the present study, as a basic wavelet in all numerical experiments Daubechies of the fourth order is selected. Large-scale wavelet transform coefficients in two ranges MHD periods: 2-30 min (8.3-0.6 mHz) and 31-60 min (0.6-0.3 mHz) were considered. Further specification of information (postprocessing) by calculating the wavelet skeleton spectrums, which reflecting the internal dynamics of the processes of different types and sizes can be achieved. An example of the results of the postprocessing of the wavelet transform to obtain skeletons that characterize the process of changing mode of pulsation at a specific frequency at a specific time (calculate window with constant time interval and growing with a period) in Fig. 1 is shown.

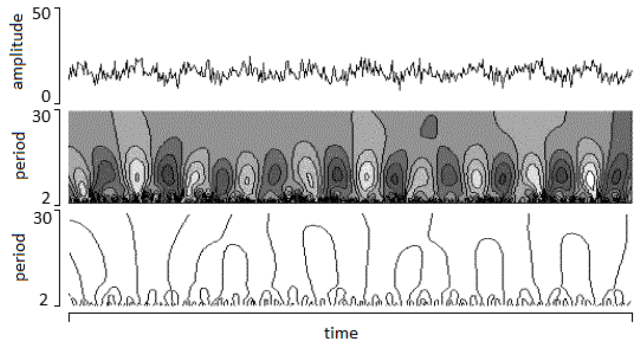

Figure 1. Example of input data, wavelet spectrum and the corresponding of local maxima or "wavelet skeleton" of the spectrum (the result of post-processing) is demonstrated

The resulting images of the wavelet skeleton for one minute data of density, velocity, temperature, pressure, module and component of the interplanetary magnetic field to quantify the consistency of the obtained spectrums was used. Obtained for this work skeleton images according to a previously known types of plasma flows (MC, CIR, Shocks, HSS) in order to obtain material for training and testing the classification neural network are grouped. Within each group looks for moments of coincidence skeletons (synchronizing the change of oscillation modes) for parameter sets flows is proposed. The presence and/or absence of sync points within selected flow stream as a unique feature of this type is used. Subtraction of skeleton spectrums matrices from each other with record values of the difference in absolute value a labeled matrix are provides, where at times 100% synchronization corresponds to zero difference.

The resulting picture with markers by a Gaussian filter to blur is processed. In this step unit, not grouped markers will be screened (blown out), and the existing group of markers will be visible (see Fig. 2). Then the histogram of the distribution likely to appear moments oscillation synchronization parameters in the stream on a scale from 0 (white, less likely) to 1 (black, most likely) we calculate. To obtain classification features of each type of individual flow histogram likely to appear moments oscillation synchronization parameters in this flow at given periods are summarized. Thus, the neural network are classified cumulative histogram comprising a compressed information of the stream.

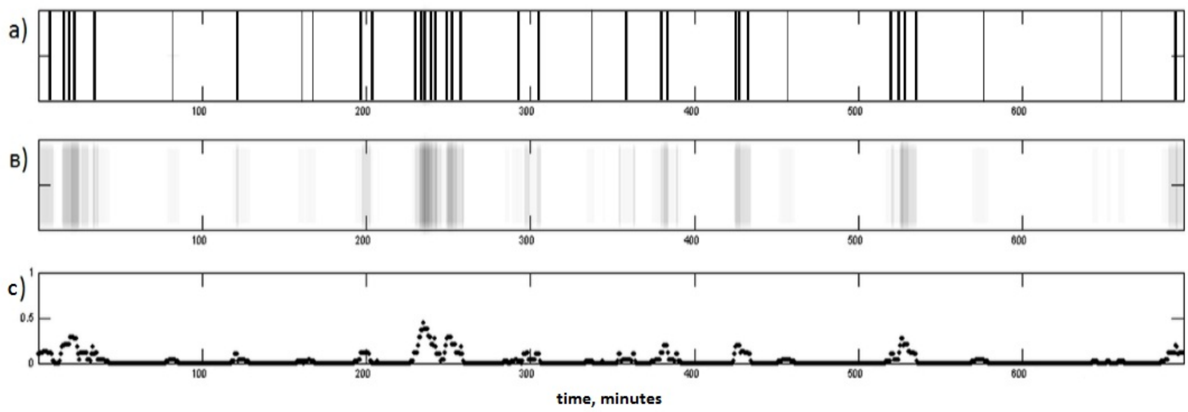

Figure 2. Example of histogram for moments of oscillations synchronization for the flow parameters: (a) on the markers; (b) processed by a Gaussian filter; (c) within scale from 0 (less likely) to 1 (most likely)

3. Classification artificial neural network and the classification results

Classification of obtained summary histograms with a self-learning neural network like Kohonen layer (see Fig. 3) is performed. This self-learning system, adjustable by self-imposed on the input data. In this case, the neural network generalization and compression imposes information performs. The number of nodes (k) of the neural network (the number of candidate classes or neurons in the competitive layer) in advance is given. In this case, the number of classes to four (MC, CIR, Shocks, HSS) is equal. Number of inputs (n) of each neuron in the classification layer by the size of the input image is determined. In our case it is 1400 (the total size of the histogram of each event).

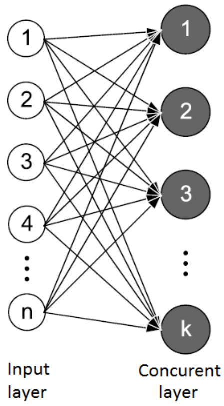

Figure 3. Architecture of Kohonen classification artificial neural network

Training neural networks on total histograms obtained for the five events was performed. The sixth event always be reserved and used for testing the trained network. With classification self-learning neural network work consistently as input numerical series (additional histograms for training events №1-5 for each type of flow) is receives. In this information in a concise form information about the coherence of oscillatory processes in the solar wind parameters in a particular frequency range is contains. Then, to verify the trained neural network histogram test events №6 is used. Test results of neural networks, trained for two ranges of periods in the summary table 1 is presented. The numbers in the cells the number of successes classification when you walk through the test events was indicate.

Table 1

Specific period interval 2-30 min			
MC	**HSS**	**Shocks**	**CIR**
3 (50%)	3 (50%)	4 (66%)	5 (83%)
Specific period interval 30-61 min			
MC	**HSS**	**Shocks**	**CIR**
6 (100%)	4 (66%)	2 (33%)	3 (50%)

Conclusion

Performed by the neural network classification of spectral features of flows differentiated by frequency bands separation of skeleton images of disturbances on all analyzed parameters (N, V, T, P, | In |, Bx, By, Bz) showed. This confirms the existence of the internal connections between the components of the wave dynamics in different plasma flows. It is shown that in the period range 2-30 min neural network performs reliable (in more than 50% of cases) the identification of the type of flows CIR (83%) and Shocks (66%). In the period range of 31-60 minutes - a reliable identification of the flow-type MC (100%) and HSS (66%). The proposed method in the online mode, monitoring of near space for the detection of geoeffective structures in the solar wind flow and forecasting global geomagnetic disturbances can be applied. Further development of methods of classification due to the improvement summation technique histograms in which each type of flow the most consistent set of parameters will be used.

Acknowledgements. RFBR grant 12-05-00425 and the program of the Ministry of Education and Science «Development of Scientific Potential of Higher Education, 2014-2016» supported this work.

References

Barkhatov N.A., Revunov S.E., Shadrukov D.V. Qualifying solar plasma flows by analysis and is within magnetospheric low-frequency oscillations during magnetic storms // Privolzhskiy scientific journal, NNGASU, № 1, p. 106-112, 2013

Daubechies I. Ten lectures on wavelets. ¬Izhevsk: NITs «Regular and Chaotic Dynamics», 2001, 464 p.

Revunov S.E., Shadrukov D.V., Serebryakova R.I. Analysis of spatio-temporal dynamics of low-frequency (2-8 mHz) magnetic disturbances during magnetic storms // Messenger of UNN N.I. Lobachevsky, 2013, № 5 (1), 83-91

Steed, K., C. J. Owen, P. Démoulin, and S. Dasso, Investigating the observational sig-natures of magnetic cloud substructure // J. Geophys. Res. –2011. –V.116, A01106, doi:10.1029/2010JA015940.

Tessein, J. A., C. W. Smith, B. J. Vasquez, and R. M. Skoug, Turbulence associated with corotating interaction regions at 1 AU: Inertial and dissipation range magnetic field spectra // J. Geophys. Res. –2011. –V.116, A10104. doi:10.1029/2011JA016647

Wawrzaszek, A., and W. M. Macek, Observation of the multifractal spectrum in solar wind turbulence by Ulysses at high latitudes // J. Geophys. Res. –2010. –V.115, A07104. doi:10.1029/2009JA0151763.