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ESTABLISHMENT OF SOURCES OF SOLAR STREAM TYPES ON A SPACE WEATHER PARAMETER COMPLEX

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Abstract. This study was aimed to the establishment of solar sources of 18 solitary large-scale disturbances registered near the Earth. Among the causes the following types of phenomena of solar activity and their composite combinations were assumed: flashouts (sf), coronal holes (CH), actuated fibrils (SDF), heliospheric current sheet (HCS). Using the artificial neural network the classification of events was established according to parameters of the solar wind (PSW) and interplanetary magnetic field (IMF), and separately by values of dynamic pressure of the solar wind (SW). The result of this work was the separation of the considered events by 4 classes: intensive streams such as sf-CH (class 1) and weak intensity streams such as sf-CH (class 2), middle intensity streams such as CH-SDF, SDF (class 3) and weak intensity streams such as CH-SDF, SDF (class 4). In addition, the analysis of dynamics of Dst index allowed us to select 4 groups of basic complexes of space weather parameters.

1. Introduction

An important problem of Solar – Terrestrial physics is the determination of sources of geoeffective disturbances in Solar Wind (SW). These disturbances are conditioned by the manifestation of solar activity and connected with large-scale streams of the solar plasma. The sources of such streams are, for example, the most typical phenomena of solar activity: "flashouts" (sf), coronal "holes" (CH), actuated "fibrils" (protuberances) (SDF) and their different composite combinations *[Ivanov, 1996; Ivanov, Romashets, 2000]*. It is also important to identify the type of the geomagnetic disturbance by the shape of the large-scale disturbances of solar wind parameters (PSW) and interplanetary magnetic field (IMF). A natural continuation of such studies is the work on the determination of the solar sources responsible for various global geomagnetic disturbances (GGD). Such studies are carried out with application of various procedures, including statistical, but often they do not provide a complete answer on posed questions *[Gonzalez et. al., 1994; Tsurutani et. al., 1995]*.

In this study the attempt of the complex classification of GGD (described by Dst index) produced by changing of PSW and IMF was performed. For solving the classification task a self-training artificial neural network, such as Kohonen layer *[Medvedev and Potemkin, 2002],* has been designed and used. For classification the data on disturbances of SW density, velocity and components IMF during selected geomagnetic disturbances were applied. For estimation of the operational efficiency of the designed neural network, the obtained results were compared with the results of the magnetohydrodynamic method *[Barkhatov et all, 2002]* based on the same experimental material. In the study 18 large-scale events of 1979 were analyzed, everyone of a duration of 72 hours, using some data from the OMNI data base *[http://www.ngdc.noaa.gov]*. The final classification of events was fulfilled in view of Dst index. On the basis of numerical experiments the deduction about solar surces of GGD were made.

2. Comparison of neural networks results with those of MHD modeling

Preliminary classification of large-scale events was fulfilled in two numerical neural network experiments involving different combinations of PSW and IMF. In this study a checkout of operational efficiency of the created classification neural network based on the material used in the study *[Barkhatov et all, 2002]* was performed. According to studies *[Ivanov, 1996; Ivanov, Romashets, 2000]* the events registered in the neighborhoods of the Earth on days 14.12, 28.10, 08.05 were related to combinations CH+SDF+HCS; the events of 18.05, 21.04, 03.09 were related to CH+SDF; and the event of 18.09 - to SDF. In the remaining events there were consequences of solar flares (sf): (sf+CH) for events of 5.04 9.01 22.03, 12.08, 26.06, 29.08; (sf+CH+SDF) for events of 4.03, 8.12, 20.10; and (sf+CH+HCS) for events of 4.02, 18.02. Thus, it is possible to expect a separation of the events into three basic classes, containing one of the cause - sf, CH or SDF.

In the first experiment the solitary disturbances in SW were classified in view of parameters N, V, Bz. Taking into account the fact of selection of three basic classes, the neural network was orientated to the classification in three classes. However, a result of the operation of neural network was the division of the events in two classes only. This division showed that the first start of the neural network was reduced into the division of the events into classes according their intensity. The events of intensive class contain the combinations of consequences of flashouts only. The events of the weak intensive class have been subjected to the further classification. As a result it was possible to identify 4 subclasses. The results of neural network classification and determination of streams types agree *[Barkhatov et all, 2002]* and are presented in Tabl. 1. The obtained classes basically contain identical types of source of streams, except 4 events (03.09, 18.09, 20.10, and 04.03). Moreover, only in one of them (18.09) there is no combination of streams.

By reviewing the events, which have fallen into each class, it is possible to note, that in 5 classes found by neural network the existence of consequences of sf and CH most probably are related to the phenomena energetics. The point is that events containing consequences of sf have fallen into classes 1, 2.3, 2.4. For each of these classes similar variations of the parameters N, V, Bz are typical. However, the events have not been referred by neural network to the same class because of various amplitudes of the analyzed parameters N and V, and also because of differences in the preferred sign Bz. As to the event chosen into class 2.4, it is, while keeping all indications of class 1, different by the considerable variability of concentration and component Bz. The events containing consequences CH have fallen into classes 2.1 and 2.2. The neural network divided these events into classes according to the level of amplitudes of the parameters participating in the classification and the preferred sign of Bz. Class 2.2 is characterized with major amplitudes in PSW and major southern component Bz. We should note, that fifth event in the class 2.3 referred in *[Ivanov, 1996; Barkhatov et all, 2002]* to that, contained the significant negative Bz. That meets the consequences of flashout, therefore the neural network referred it to a class containing flashout. A more careful analysis of this event requires changing its type from sf-CH-SDF *[Barkhatov et all, 2002]* to CH-SDF-HCS, in agreement with classification suggested by neural network.

	№ class (neural network)	**Date of event**	**The established source of stream type, agrees to** *[Ivanov, 1996, Barkhatov et all, 2002]*	**Coincidence with MHD results**
Intensive events	**1**	18.02 05.04 13.08 29.08	sf-CH-HCS sf-CH sf-CH sf-CH	100%
Weak intensive events	**2.1**	20.10 28.10 14.12	sf-CH-SDF CH-SDF-HCS CH-SDF-HCS	67%
	2.2	04.03 21.04 08.05 18.05 08.12	SDF CH-SDF CH-SDF-HCS CH-SDF CH-SDF-HCS (sf-CH-SDF)	80%
	2.3	09.01 04.02 26.06 03.09 18.09	sf-CH sf-CH sf-CH CH-SDF SDF	60%
	2.4	22.03	sf-CH	–

Tabl. 1. Results of classification of the large-scale disturbances in Solar Wind on the basis of N, V, Bz

A checkout of the hypothesis about the division of events into intensive and weak intensity groups was fulfilled during the second numerical experiment. Here the classification of the investigated events was applied with the account of dynamic pressure of SW, $P=NV^2$. The neural network classification upon 4 classes supports the division noted in the previous classification (Tabl. 2). Also, the classification of the event 22.03, which, in our opinion, should be referred to the class of intensive events, is improved as well as the classification of the event 03.09, which is moved from the class 2.3 sf-CH to the class 2.1 CH-SDF. Event 26.06 is moved from the class 2.3 to the "alien" class 2.1

The implementation of the numerical experiments 1 and 2 divides the considered events into 4 classes:

Class 1: intensive streams such as sf-CH (100 % of coincidence with MHD results);

Class 2 (2.1): weak intensity streams such as CH-SDF, SDF (60 % of coincidence with MHD results);

Class 3 (2.2): middle intensity streams such as CH-SDF, SDF (60 % of coincidence with MHD results);

Class 4 (2.3): weak intensity streams such as sf-CH (75 % of coincidence with MHD results).

The performed classification of single large-scale events registered in the neighborhood of the Earth confirms the results of alternate MHD examinations and in addition allows making an assumption about the intensity of initial solar streams called large-scale disturbances in the SW. The SDF class in the neural network classifications was not put in a separate position in connection with the weak intensity of the given type of stream source and was referred in the present study to the dominating class of streams CH-SDF.

	№ class (neural network)	**Date of event**	**The established source of stream type, agree to** *[Ivanov, 1996, Barkhatov et all, 2002]*	**Coincidence with MHD results**
Intensive events	1	22.03 05.04 13.08 29.08	sf-CH sf-CH sf-CH sf-CH	100%
Weak intensive events	**2.1**	20.10 28.10 14.12 03.09 26.06	sf-CH-SDF CH-SDF-HCS CH-SDF-HCS CH-SDF sf-CH	60%
	2.2	04.03 21.04 08.05 18.05 18.02	SDF CH-SDF CH-SDF-HCS CH-SDF sf-CH-SDF	60%
	2.3	09.01 04.02 18.09 08.12	sf-CH sf-CH SDF CH-SDF-HCS (sf-CH-SDF)	75%

Tabl. 2. Results of classification of the solitary large scale disturbances in Solar Wind on the basis of $P=NV^2$.

3. Classification of solar streams in view of global geomagnetic disturbances

The main numerical experiment was aimed to the selection of groups of GGD in which some solar streams are reduced. For this purpose a classification of the same 18 events was carried out taking into consideration parameters NV^2, Bz, and Dst. In this case the neural network offers a division in groups shown in Tabl. 3. This numerical experiment has allowed to allocate the groups corresponding to the same type of geomagnetic disturbances for one stage of classification.

The result of this final experiment, carried out in view of modifications in parameters N, V, NV^2, and Dst lead to the selection onto 4 groups with following peculiarities:

Group 1: Weak global geomagnetic disturbances (GGD) (-50 < Dst nT) with previous very weak (-5 < Bz <5 nT) disturbances of Bz. Events are the response to initial sources of streams which type is preferentially the same as CH without taking into account their intensity (classes 3 and 4).

Group 2: GGD type of intermediate intensity storms (-100 < Dst nT) with previous middle (-10 < Bz <10 nT) disturbances of Bz. Events are the response to initial sources of streams which type preferentially such as sf without taking into account their intensity (classes 1 and 2).

Group 3: GGD such as an intensive storm (-150 <Dst <50 nT) with the sudden commencement and the previous strong (-20 <Bz <20 nT) disturbances of Bz. They can be produced by different types of stream sources.

Group 4: GGD type of intermediate storms with previous medium (-5 <Bz <20 nT) disturbances of Bz on the background of the recovery phase of the previous storm. They can be produced by different types of sources of streams, but with advantage of sf.

№ class (neural network)	Date of event	The established source of stream type, agree to *[Ivanov, 1996, Barkhatov et all, 2002]*	Coincidence with MHD results
1	18.02 08.05 18.05 26.06 03.09 20.10 08.12 14.12	sf-CH-HCS CH-SDF-HCS CH-SDF sf-CH CH-SDF sf-CH-SDF CH-SDF-HCS (sf-CH-SDF) CH-SDF-HCS	63%
2	04.02 22.03 21.04 13.08 28.10	sf-CH sf-CH CH-SDF sf-CH CH-SDF-HCS	60%
3	29.08 18.09	sf-CH SDF	50%
4	09.01 04.03 05.04	sf-CH SDF sf-CH	67%

Tabl. 3. Results of classification of the large-scale disturbances in Solar Wind on the basis of NV^2, Bz, Dst

As a result, the first of the obtained groups corresponds to the events due to solar sources, containing CH of different intensity, and second one – containing sf, also independently on their intensity. Thus, in some cases (Groups 1 and 2) the determination of the sources of the solar stream by the analysis of the dynamics of the SW hydrodynamic pressure, Bz, and the index of global geomagnetic activity Dst is possible. The determination on the basis of magnetic observations does not depend on amplitudes of N and V, but is determined by the dynamics of these parameters as well as by the Bz value *[Gonzalez et. al., 1994; Tsurutani et. al., 1995]*. We should note, that in all of the carried out experiments on classification the neural network offers a qualitative - quantitative estimate of classes. To our opinion it is a key to the GGD classification method.

Conclusion

In our study the "tying" of disturbances of the magnetic field of the Earth to the particular primary source on the Sun was investigated. In spite of the fact that streams from various solar sources are strongly modified on the way to the Earth, the dynamics of the Dst index contains some information on solar disturbances of a particular nature. The suggested procedure of classification of geomagnetic disturbances allows creating new standards for exposition of the space weather. The results can be used for the predictions of global geomagnetic disturbances on the basis of complex observations of the active processes on the Sun.

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