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Solar-Terrestrial Relations and Physics of Earthquakes Precursors

A neural network system for estimation of the geomagnetic field disturbance

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Abstract.
The paper presents our software system for estimation the degree of disturbance of the geomagnetic field. The system automatically classifies registered geomagnetic data and determines the state of the geomagnetic field for the current day. The results of approbation of the system showed the prospect of its application in problems of estimation and prediction of space weather. The system allows us to allocate weak disturbances of the geomagnetic field, which may occur before strong magnetic storms.

1 Introduction

The work is devoted to the development of automatic software tools for analysis of geomagnetic data, allocation and estimation of geomagnetic disturbances during periods of increased solar activity and magnetic storms. This paper presents a method developed by the authors and expert software system based on it, which performs classification of recorded variations of the geomagnetic field (H-components of the geomagnetic field are used) and determines its state in an automatic mode.

The recorded variations of the geomagnetic field have a complex structure, therefore classic data analysis methods are ineffective for the task and lead to loss of information [1, 2]. The shortcoming of the used classical methods and approaches is also an insufficient degree of automation, that is very important in the problems of operational data processing and space weather forecast [3, 4]. Papers [2, 5, 6] show that adaptive wavelet decomposition is effective way for analysis of such data. Wavelet transform is used in processing and analyzing complex data structures and it allows us to investigate nonstationary dynamic dependences [1]. In this work we use wavelet transform in conjunction with neural networks. Neural networks are widely used in data classification and pattern recognition[7, 8]. Currently, they are being developed in the field of physics, and, in particular, geophysics [9–11].

2 Description of the method

A characteristic of the geomagnetic field is K-index [3, 12]. We considered three possible states of the geomagnetic field:

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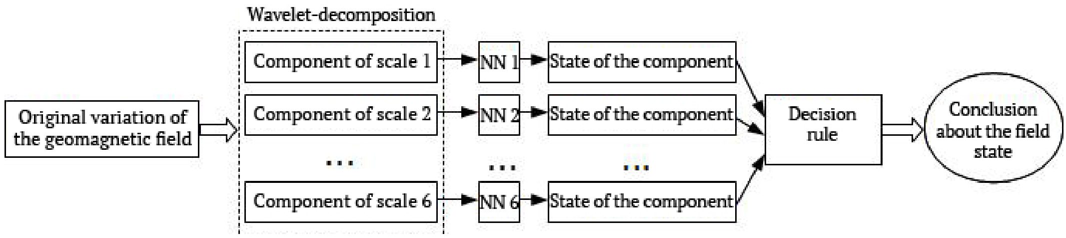

Figure 1. Architecture of the software system

1) "quiet" state (class 1, if the total sum of the daily K-index $\sum K \leq 10$);
2) "weakly disturbed" state (class 2, if $10 < \sum K \leq 18$);
3) "disturbed" state (class 3, if $\sum K > 18$).

Estimation of the geomagnetic disturbance is carried out in accordance with the algorithm described below.

Step 1. Decomposition of the analyzed variation of the geomagnetic field on a different scale components. Using multiresolution wavelet decomposition [13], we obtain the coefficients of the detailing components for the scales $j = -1, -2, ..., -6$ and calculate their absolute values. Obtained coefficients characterize disturbance of the geomagnetic field and in periods of high geomagnetic activity, their absolute values increase significantly [14].

Step 2. Estimation of the state of obtained multiscale components based on radial neural networks. The vectors of the absolute values of coefficients of the scales $j = -1, -2, ..., -6$ are the input vectors of radial neural networks [15]. In the radial layer of each neural network, assesment of proximity measure of the input vector and and example formed during the construction of the network is carried out. The output layers of neural networks determine the probability of belonging of input images to the appropriate class. The process of construction and training of neural networks is described in detail in the paper [14].

Step 3. Estimation of the geomagnetic field state based on team of neural networks. Based on obtained decisions of neural networks, a decision about the state of the geomagnetic field is formed using the following rule:

- if all the components have a "quiet" state, or only one of the components has a "weakly disturbed" state, the geomagnetic field has a "quiet" state (class 1);
- if at least one of the components has a "disturbed" state, the geomagnetic field has a "disturbed" state (class 3);
- in other cases, the field has "weakly disturbed" state (class 2).

Architecture of the software system is shown in Fig. 1.

3 The results of work of the software system

During the study we analyzed geomagnetic field data obtained at the "Paratunka" station (Kamchatka Krai, data registration is carried out by the Institute of Cosmophysical Research and Radio Wave Propagation FEB RAS) for 2013 year, which included 182 quiet variations, 97 weakly disturbed and 40 disturbed. Events of 2013 year with total sum of daily K-index 19 and greater were studied. The system has detected weak disturbances of the field on the eve of the 11 out of 13 such events, while in four cases total per day K-index does not exceed the value of 10. Thus, the system is sensitive to small variations of the geomagnetic field and allows us to detect weak disturbances.

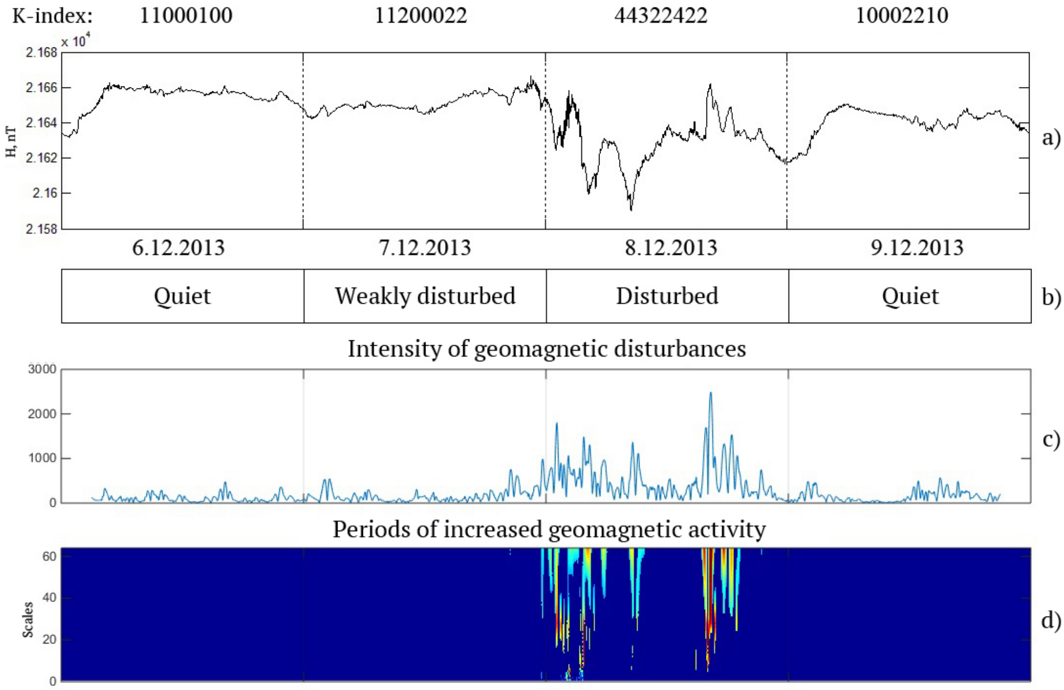

Figure 2. Results of data processing for the period 6-9 December 2013

Fig. 2-4 show the results of data processing. The upper part of Fig. 2-4 shows the values of K-indexes, below the analyzed variations of the geomagnetic field are shown (Fig. 2-4 a) and the results of work of the software system are shown (Fig. 2-4 b). Also, Fig. 2-4 c, d show the results of estimation of the geomagnetic field state obtained on the basis of the algorithm described in [9] and implemented in the software system «Aurora» (this system was developed in IKIR FEB RAS, http://www.ikir.ru:8280/lsaserver/). It can be seen that before the analyzed events, the system detected weak disturbances of the field, although the K-index on the eve of the first 2 events corresponds to the quiet state. The results of applying the algorithm [9] also confirmed the emergence of weak disturbances in the geomagnetic field.

According to the resource [16], a gradual beginning of the storm was recorded at high latitudes on December 7 at 20-00 UT, on December 13 the field was from quiet to very quiet, on June 27 a gradual onset of the storm was recorded at 22-00 UT.

4 Conclusion

The results of the study showed the prospects of application of the developed software system for the analysis of geomagnetic data and estimation of the geomagnetic field state. The system is sensitive to small variations of the geomagnetic field and allows us to automatically allocate weak disturbances that may occur on the eve of magnetic storms. Open access to the system is organized on the website of IKIR FEB RAS (http://www.ikir.ru:8280/lsaserver/).

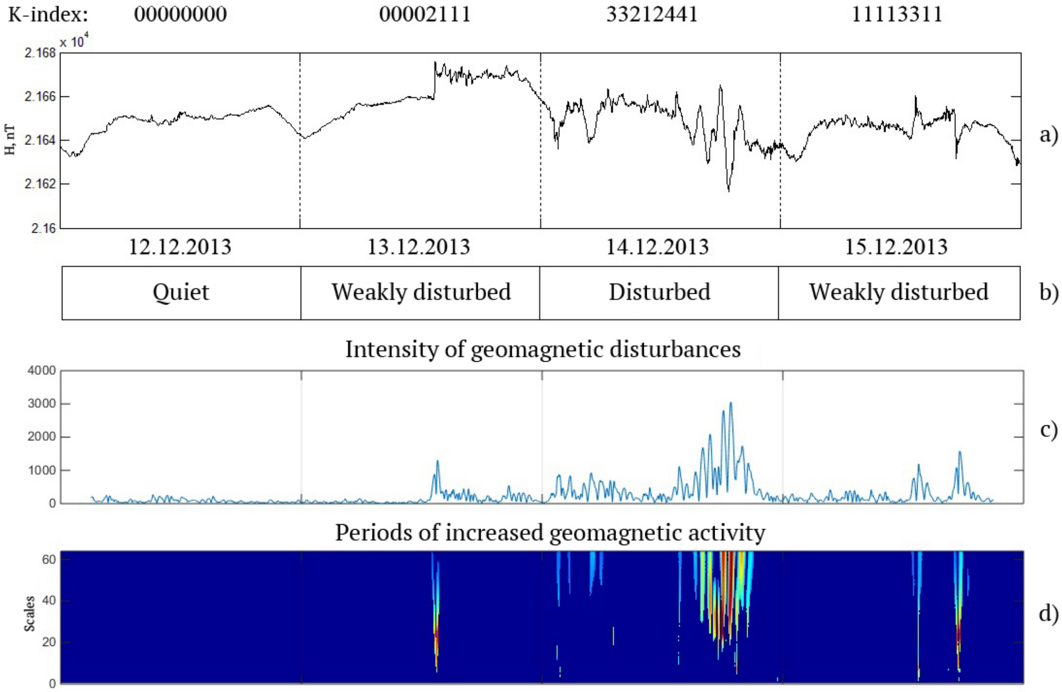

Figure 3. Results of data processing for the period 12-15 December 2013

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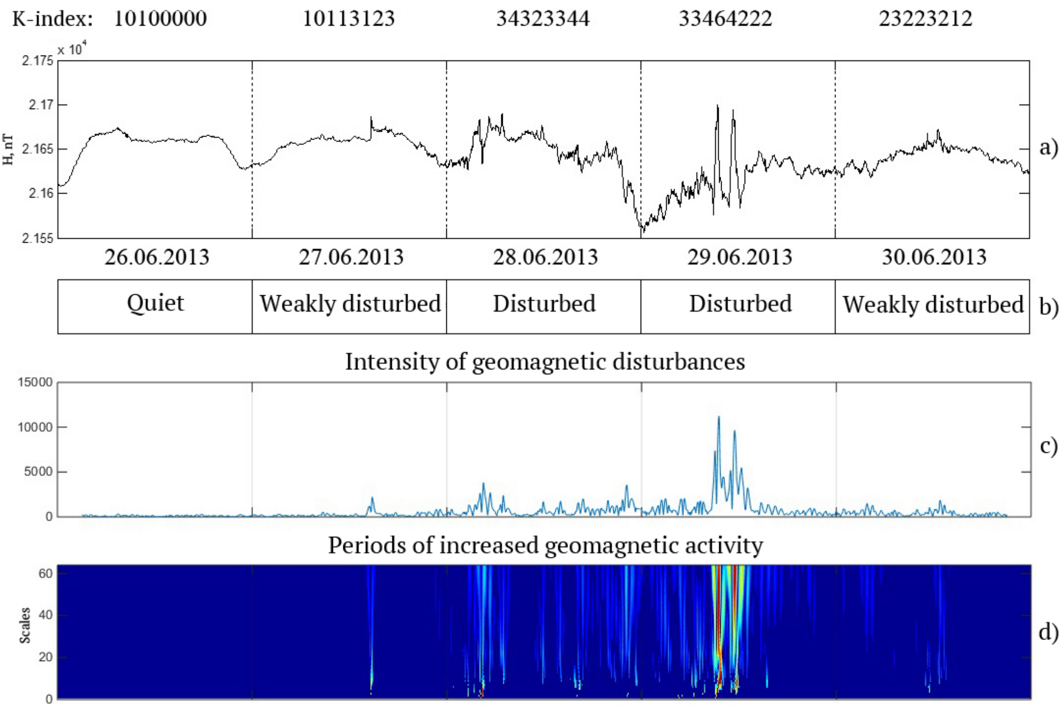

Figure 4. Results of data processing for the period 26-30 June 2013

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