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Application of Neural Network Methodology in Analysis of VLF/LF Signal

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A method of estimating of the VLF/LF signals sensitivity to seismic processes using neural network approach is proposed. The trained neural network is used in forecast mode for the automatic detection of abnormal changes in the signal related to seismic activity above a certain threshold.

We applied the back propagation technique, based on three layer perceptron (Fig. 1). Such type of neural network is called supervised. It involves two main stages of solving the problem: the training of the network and recognition (the prediction itself). In the supervised scheme of teaching, the network is learned to the relation between the known for teacher input–output pairs, called the training set.

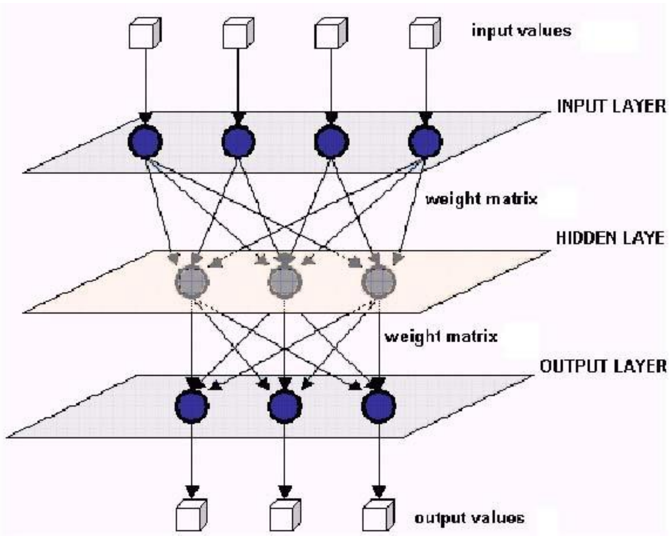

Fig 1. Three layer perceptron.

In order to train a neural network, we created the teaching database that included both catalog of seismic events from 2005 to 2007 and corresponding data (amplitude and phase of the LF signal), measured in the regime of monitoring for the receiving station in Petropavlovsk-Kamchatsky from the Japan transmitter JJY. To distinguish the precursory effects not related to the global perturbations in the lower ionosphere, the seismic events were excluded from the database in the days when the magnetic field activity index Dst and the flux of relativistic electrons and protons exceeds the given thresholds. After many experiments with teaching and testing of neural networks it was found the optimal properties for forming of teaching database. As a result, the training samples included features calculated from the amplitudes and phases of the signals measured for 5 days before the 40 seismic events of magnitude M equal or more than 5.5, which occurred at a depth of not more than 150 km. The ratio of the radius of the zone display precursors to the distance from the epicenter of the earthquake to the axis of the line "transmitter - receiver" was not less than 0.7 for these examples.

Additionally the total teaching data base included 40 examples for lack of seismic event during some days. Each example contained the input and output data for teaching of the neural network.

The mean and dispersion values of the phases and amplitudes in night-time for five days before the seismic event are used as input data. Thus the number of the input neurons in three layer perceptron was equal to 20. The corresponding level of correlation with the seismic event (the meaning of correlation is equal to 1) or lack of it (the meaning of correlation is equal to 0) is used as output data. Thus the number of the output neurons in three layer perceptron was equal to 1. Then the neural network was trained using 80 examples of teaching database.

To predict a seismic event from LF data we have chosen twelve time intervals in 2003, 2005, 2006, 2007. The time intervals were lasting from 6 to 8 days including the day of seismic events of magnitude M equal or more than 5.5.

For six of the twelve time intervals the neural network has detected changes in LF signal indicating the earthquake of magnitude M equal or more than 5.5 a few (2-3) days in a row before the earthquake, including the day itself. These results are shown in Figures 2-4.

For the other three time intervals neural network has detected changes in a signal indicating an earthquake on the third and fourth day before the earthquake.

For the rest three time intervals correlations between the seismic events of magnitude M equal or more than 5.5 and changes in the signal were not found.

We discuss the results of the prediction on the example presented in Fig. 2. These results are formed as the output (single neuron) of the previously trained neural network. It makes a sense of the correlation coefficient ranges from 0 to 1. In fact, we get an answer about the degree of correlation with the seismic event of magnitude M equal or more than 5.5.

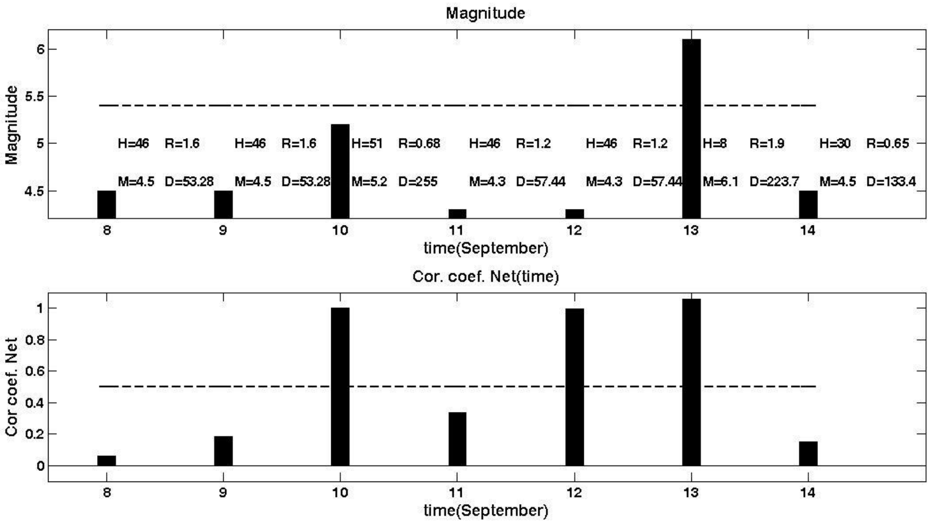

Fig 2. The neural network prediction results for September 8-14, 2003.

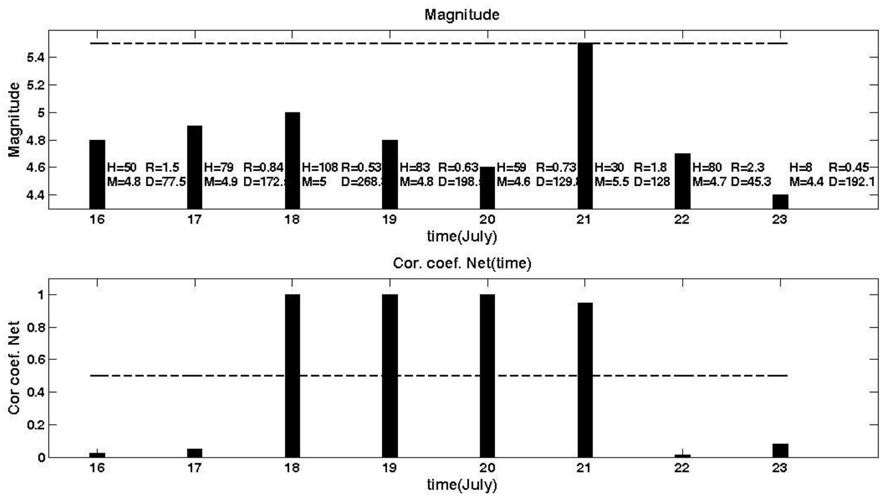

Fig 3. The neural network prediction results for July 16-23, 2003.

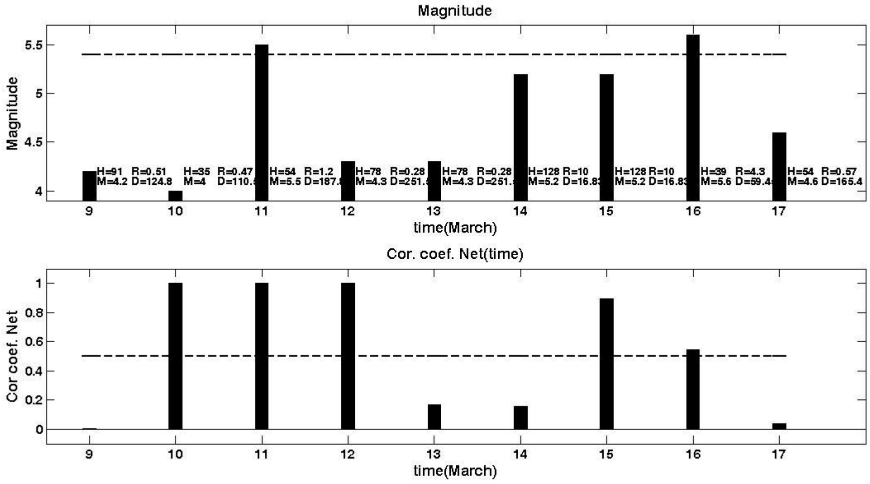

Fig 4. The neural network prediction results for March 9-17, 2005.

Step by step procedure for recognition (prediction) is performed with a shift in one day until the day of seismic event of magnitude M equal or more then 5.5. The dashed line in this diagram represents the threshold value of the correlation coefficient of 0.5.

In comparison with network output the actual values of the magnitudes are presented on the first bar chart of the Fig. 2. Each column is marked with the following parameters: M - magnitude, H - depth, D - distance from the epicenter to the receiver, R - the ratio of the radius of the zone display precursors to the distance from the epicenter of the earthquake to the axis of the line "transmitter - receiver“. The dashed line represents the threshold at which the magnitude of seismic events is equal to 5.5.

For nine of the twelve time intervals the neural network has recognized successfully changes in LF signal indicating the earthquake of magnitude M equal or more than 5.5 a few days before the earthquake including the day itself.

These results confirm that short-term prediction of seismic events on changes in the LF signal is possible. Mean and dispersion calculated from the amplitudes and phases of the signals for the night period detected the correlation with seismic events.