Short-term forecasting of atmospheric meteorological parameters based on the results of the neural network of a three-band microwave radiometric system

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Abstract. The article considers a variant of inclusion of a neural network into the microwave radiometric system of remote sensing of the atmosphere to perform short-term forecasting of meteorological parameters, based on current measurements of power of own radio-thermal emission of the atmosphere in three frequency bands. The initial data for the training of the neural network - the results of daily microwave radiometric measurements in three frequency bands and data on atmospheric meteorological parameters in the near ground layer obtained using a mobile meteorological station - are indicated. The results of forecasting the temperature and humidity of the near ground layer of the atmosphere based on the current results of microwave radiometric measurements for the current moment and with a two-hour lead time are presented.

1. Introduction

The problem of short-term forecasting of atmospheric meteorological parameters from microwave radiometric sensing data can be solved by including into the system a neural network, providing the construction of the most probabilistic data on weather conditions with its proper training and education [1, 2]. When building a neural network for microwave radiometric system, it is necessary to take into account the specific conditions of its functioning: a large volume of continuously incoming measurement data, as output signals of microwave radiometric system, and measurement data of meteorological parameters by weather station in the surface layer of the atmosphere with the need to quickly solve the problem of automatic selection of key features from the data set and the construction of the most probabilistic relationships [3, 4].

Determination of the main regularities of output signals of microwave radiometric systems when measuring the radio-thermal radiation of the atmosphere under the influence of various destabilizing factors depends on a large number of factors of unequal importance, so for their detection it is possible to use neural network technologies [5, 6].

The application of neural networks will allow to reduce considerably the time for search of dependences of resulting data on input parameters, due to the network retraining and selection of input
weight coefficients of each of neurons on each network layer at all training stage with a possibility of their additional training, based on newly obtained actual data [7, 8].

2. Principles of construction and operation of a microwave radiometric system neural network

Inclusion of the neural network into the remote sensing systems is a modern direction of their improvement, so Google Research uses the MetNet neural network for precipitation forecasting with an interval from 2 min to 8 h [9, 10], and NOAA uses the physical model for precipitation forecasting with 7-8 h prediction [11- 14, 15].

A neural network was built for a three-band microwave radiometric system, whose task is ultimately to make ultra-short-term forecasts of hazardous phenomena, while establishing the dependence of the level of microwave radiometric signals of the atmospheric monitoring system on the state of the atmosphere, which will allow to make forecasts with the "local features", characteristic only for a particular geographical area of the system location [16].

In the process of the neural network development there was created a prototype of the information database, based on PostgreSQL, into which 99 million data records from the analog-to-digital converter of the microwave radiometric system output unit were loaded, including the signal magnitude data from 8 radiometric channels, as well as about 21 thousand measurements of weather conditions (temperature, humidity, wind speed, precipitation, etc.) [17].

To solve the problem of consistency between measurements of atmospheric meteorological parameters carried out with a period of 5 minutes and data of microwave radiometric system signals received after 0.1 second, we compared weather data and median values of output signals in the range ±2.5 minutes (which corresponds to approximately 3000 measurements), which reduced the influence of statistical nature of microwave radiometric system measurements on the prediction results.

Figures 1 and 2 show the results of applying the median to the radiometric data (the data are shown for one day). Figure 2 shows graphical dependences, clearly displaying the relationship between the data of radiometric measurements and values of meteorological parameters in the application of correlation processing of median values.
Figure 1. Averaged data of each radiometric measurement channel by median value (humidity readings are reduced by a factor of 10 for clarity).

Figure 2. Correlation dependences of signal value and temperature and humidity for each channel of the microwave radiometric system for one day.
For the microwave radiometric system of remote sensing of the atmosphere we designed a direct propagation neural network with two hidden layers with the SoftMax neuron activation function, for which the input data were a set of microwave radiometric results for one year, and as the output - current values of meteorological parameters and values of weather parameters with a two-hour preemptive time.

3. Functioning results of the microwave radiometric neural network
To assess the efficiency of the neural network functioning, we introduced normalized meteorological parameters - temperature and humidity, the values of which were determined by the formula:

\[
n_{i,\text{nor}} = \frac{n_i - \text{min}(n)}{\text{max}(n) - \text{min}(n)},
\]

where \( n_i \) - current measurement value; \( \text{min}(n) \) - the minimum value of measurements; \( \text{max}(n) \) - maximum measurement value.

Figures 3-4 show the results of neural network training - on the abscissa axis - serial number of measurement in the data sample of interest from the database, on the ordinate axis - normalized values of experimental and predicted values of the meteorological parameter in the interval from 0 to 1. For clarity, the data is shown in one figure.

Neural network training was performed for 100 thousand epochs, which is enough to check the possibility of neural network training and to visualize the experiment.
Figure 3. Neural network training result (blue graph - experimental data, orange - predicted) to the data of temperature measurements in the surface layer of the atmosphere and the results of measurements of its radio-thermal emission by microwave radiometric system.
According to the results of the numerical experiment, the root mean square error for temperature recorded at the same time as the microwave radiometric signals (figure 3a and 4a) was 0.0026, for humidity - 0.0092, and 0.0038 for temperature, 0.016 for humidity - with a two-hour lead time (figure 3b and 4b).

The conducted numerical experiment showed the fundamental possibility of applying neural networks for weather phenomena forecasting using multi-frequency microwave radiometric signals as input data. Increasing the number of epochs would presumably lead to improved performance.

**Conclusion**

The possibility of applying neural networks for establishing the dependence of the level of microwave radiometric signals of the atmospheric monitoring system on the atmospheric state itself, as well as for forecasting the atmospheric state based on the statistical data collected for the past periods, brings atmospheric monitoring to a qualitatively new level. Inclusion of mathematical models of the relationship between the radio-luminous temperature of the atmosphere and its meteorological parameters in the numerical experiment as part of the dependences from the weight coefficients of the trained neural network, will allow to reduce the CPU time for predicting dangerous weather phenomena and solve the problem of reliable short-term prediction of the development of dangerous atmospheric phenomena.

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