Monitoring the atmosphere duct by ground-based dual-channel microwave radiometer

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Abstract

In this paper, a new technique is presented for monitoring the atmosphere duct from the brightness temperatures by a ground-based dual-channel microwave radiometer and the surface measurements of pressure, temperature and water vapor. We chose radiosone datas of Beijing, Qingdao, Hami, and Nanjing to analyzing the condition of retrieving the atmosphere duct. Based on historical radiosonde data and the learning vector quantization neural network (LVQ method), the feasibility for monitoring atmospheric duct by microwave radiometer is attempted and demonstrated with results simulated by historical duct data.

1. Introduction

The knowledge of profiles of atmosphere variables, such as temperature, refractivity and water vapor, is relevant to several applications in the fields of meteorology, telecommunications, radio astronomy, air traffic safety, etc. Such profiles are commonly obtained from radiosonde measurement, launched every 12 hours from meteorological stations. However, it is often desired to have continuous measurements in real time, to follow the evolution of the state of the atmosphere. Ground-based dual-channel microwave radiometry has been proven to be a powerful tool to perform continuous atmospheric sounding.

Retrievals of atmosphere duct profiles using the learning vector quantization neural network (LVQ method) have been reported. The neural network of microwave radiometer data was nearly as good as an optimized statistical retrieval in terms of overall rms error, it better reproduced the essential features of the profiles. Nonstandard refraction (anomalous propagation) of electromagnetic radiation in the lower troposphere may cause radio or radar signals to propagate so that the curvature of their path is greater than the earth's surface curvature. So monitoring the atmosphere duct became more and more important. In this paper, we used the LVQ method to retrieving atmosphere duct by the brightness temperature measuring by ground-based dual-channel microwave radiometer. The simulation testified that it is feasible and effective.

2. Algorithm Formulation

2.1 Theory of atmosphere duct

Propagation of microwave and millimeter-wave electromagnetic radiation in the atmosphere is determined by gradients of the refractive index of air. Because it is very close to unity, this refractive index n is represented by a scaled quantity called the radio refractivity N. These expressions are given by

$$N = (n-1)\times 10^6 = \frac{77.6}{T}\left(p + \frac{4810e}{T}\right) \tag{1}$$

Where $T(K)$ is the atmospheric temperature, $p(hPa)$ is the total atmospheric pressure, and $e(hPa)$ is the water vapor pressure. The constants are empirically derived from dielectric constant measurements and are valid for radio frequencies between 1 and 100 GHz. Modified refractivity M, which takes the earth's curvature into account, is related to radio refractivity N by:

$$M = N + \frac{z}{10^{-6} r_e} \approx N + 0.157z \tag{2}$$

Where r_e is the earth's radius and z is altitude in meters. When $\partial N/\partial z$ is equal to or more negative than $-0.157m^{-1}$, microwaves are refracted down toward the earth's surface. If this gradient extends to the earth's surface or is very strong, microwaves originating within this layer will become trapped and propagate along the surface.this layer behaves like a waveguide and can lead to propagation over the horizon.

2.2 Radiosonde data selection

There are three reasons for us to choose radiosonde data according to the diversity of different climate area in China:

First reason: it has four high frequency atmosphere duct district and four non atmosphere duct district. The high frequency duct district is the region that the probability of duct occurring greater than 5%, as shown in Figure 1 :

Second reason: the imbanlance distribution of precipitation in different climatic area, as shown in Figure 2.

Third reason: there are five climate area in China, respectively are: plateau climate area, tropical monsoon district, subtropics monsoon moist climate area, temperate zone monsoon climate area and temperate zone mainland climate area, as shown in Figure 3.

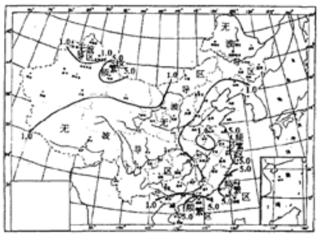


Figure 1 The distribution of duct

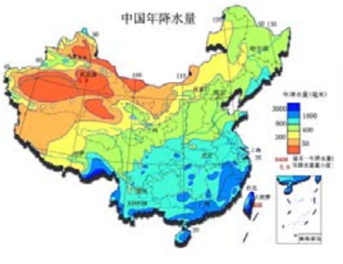


Figure 2 Precipitation

Figure 3 Five climate area

Accordance with upon three reasons, we select Beijing, Qingdao, Hami, Nanjing radiosonde datas provided by the national weather bureau form 1986 to 1995 as the research objects. Experiment device is the ground-based dual-channel microwave radiometer developed by the Chinese Research Institute of Radiowave Propagation, which has two channel, respectively are 23.8 and 31.65GHz, exceed broadband antenna, and feed source is cone ripple horn.

2.3 The learning vector quantization neural network (LVQ method)

All neural networks were standard feed forward networks with input, hidden and output layers with full connection between adjacent layers. A standard back propagation algorithm was used for training. The problem of monitoring atmosphere duct is a method to distinguish duct from refractivity profiles. The self-organization mapping net (SOM) is a important type of non supervise learning algorithm in all kinds of neural networks. There are a lot of neural networks for assorted model, such as SOM algorithm, ART algorithm and LVQ method, etc. The simulation result showed that the LVQ method is the best algorithm in the radiometer retrieving region. Especially, the LVQ method is the learning algorithm in the state for training competition layer. It is evolved from the Kohonen algorithm (present in 1981)[1]. The structure networks of LVQ method is shown in Figure 4.

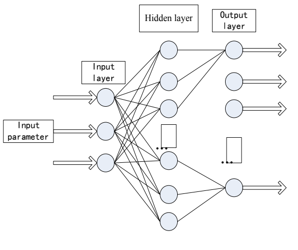


Figure 4 Diagram of the LVQ network algorithm

The topology of the net that we used was a standard feed forward perception with one hidden layer. The activation function of each node of the perception has been the logistic function, which is defined as follows:

$$f(x)=\frac{1}{1+e^{-x}} \tag{3}$$

For determing when the training phase had to be stopped, we considered the early stopping proceduce, which allows one to optimize the generalization properties of the net, avoiding an overtraining effect. This is achieved by constantly evaluating the performances of the net during the learning process, either on the training set or on a different independent validation set. In the training set the overall error in the retrieval of the correct output keeps on decreasing with the training until it reaches a value of convergence. Conversely, the error on the validation set will see a minimum value, after which it will start increasing if the process is continued. This is the point when the learning phase must be interrupted.

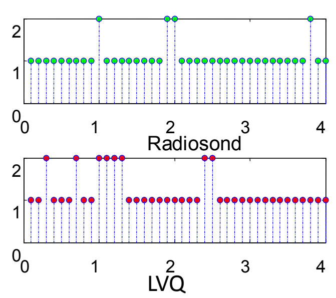
3. Implementation and Simulations

First, simulation results indicated that not all of the atmosphere duct could be monitoring by the microwave radiometer based on the analysis on the radiosonde data. The intensity and thickness of atmosphere duct has an effect on the output. Table 1 is shown the relationship for duct condition and radiometer.

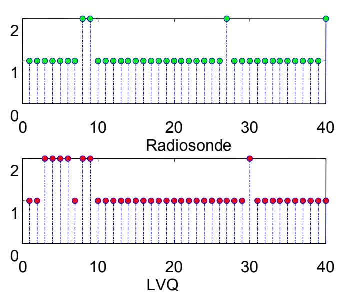
Table 1 The qualification to monitoring duct

Station	duct thickness (H)	duct intensity (M)
Beijing	H>=200m	M>=6
Qingdao	H>=200m	M>=6
Hami	H>=150m	M>=5
Nanjing	H>=300m	M>=7

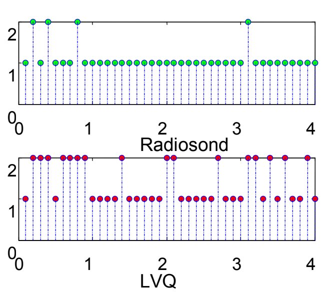
Second, we chose the data that satisfy demand on the historical radiosonde in the four stations. The data was divided two parts, 90% data for training and 10% data for simulating in the experiment. Because the LVQ method was used to solve the problem of classify, so the output parameter is "1" or "2". The "1" represents no atmosphere duct, and the "2" represents that there is atmosphere duct occurring.



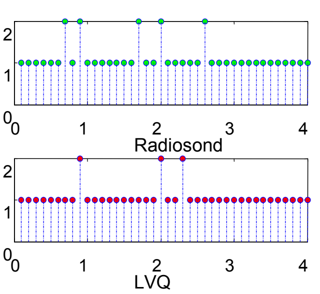
(a)Beijing—July in 1992



(b)Qingdao—April in 1994



(c)Hami—July in 1990



(d)Nanjing—July in 1993

Figure 5 Diagram of the LVQ network algorithm

Figure 5 plots the simulation results contrasted with the LVQ method and historical radiosonde data. In this case, the precision of separate atmosphere duct occurring or no from Beijing, Qingdao, Hami and Nanjing are 22.5%, 51.5%, 72.8% and 40%. Because the historical data from 1986-1995 has most 200 day occurs atmosphere duct, so the quantity of modeling is not enough. In the later research, the precision will improve on the abundant historical radiosonde data was used. Whereas, the false alarm rate of monitoring atmosphere duct is also high. The results can't satisfy the actual demand now, but as a explore idea it has the value for us to research deeper in the further.

4. Summary and Discussion

We conclude from our analysis that reasonably accurate atmosphere refractivity profiles of duct that can be obtained from microwave radiometers. We have presented the LVQ technique to monitor the atmosphere duct by analyzing of brightness temperature measuring by the ground-based dual-channel microwave radiometer. The performances of the algorithm are rather satisfactory. The reliability of the described procedure has been analyzed through some attributes including accuracy, flexibility and robustness. The LVQ method and other neural network will investigate to retrieve duct profiles in the further.

5. Acknowledgments

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