Study on Cloud Classifications by using AVHRR, GMS-5 and Terra/MODIS satellite data

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ABSTRACT

This paper presents the automated pixel-scale neural network classification methods being developed at National Satellite Meteorological Center (NSMC) of China to classify clouds by using NOAA/AVHRR and GMS-5 satellite imageries. By using Terra satellite MODIS imageries, a automated pixel-scale threshold techniques has been developed to detect and classify clouds. The study focuses on applications of these cloud classification techniques to the HUAIHE and the Yangtze River drainage basin. The different types of clouds show more clearly on this cloud classification image than single band image. The results of the cloud classifications are the basis of studying cloud amount, cloud top height and cloud top pressure. Cloud mask methods are widely used in SST, LST, and TPW retrieval schemes. Some case studies about cloud mask and cloud classification in satellite imageries, which relate with the study of Global Energy and Water Cycle Experiment (GEWEX) in the HUAIHE and the Yangtze River drainage basin are illustrated.

Key words: cloud mask and classification, neural network, satellite imagery, MODIS data.

NOAA/AVHRR NEURAL NETWORK CLOUD CLASSIFICATION TECHNIQES

The field of neural networks can be thought of as being related to artificial intelligence, machine learning, parallel processing, statistics, and other fields. The attraction of neural networks is that they are best suited to solving the problems that are the most difficult to solve by traditional computational methods. We use the Back-Propagation (BP) neural network in this cloud classification study, which is used wildly in many fields.

In this study, the sample database of clouds, land and water is built based on AVHRR 5 channels data which includes more than thirty thousands 8*8 pixels samples and more than twenty thousands one pixel samples. Theory analysis and experiment show that not only 5 channel data can be used to distinguish clouds and land and water but also the band combination with each other can do so. For example, the differences of AVHRR channel 4 and 5 can be used to distinguish water particle cloud and ice particle cloud because the biggest absorption difference between water particles and ice particles is near 12μm. Based on theory analyses and experiments, 80 features are extracted from 5 channels AVHRR data for 8*8 pixels samples, which involve spectrum features, gray features, channel difference features and the gray scale statistical features. 20 features are selected using step-by-step distinguish analysis method, which includes spectrum features, gray features. 20 features are extracted from 5 channel AVHRR data for single pixel samples.

The inputs of our AVHRR automatic cloud classification system are 5 AVHRR channels data and outputs are classified gray image. Cloud classified image involves cumulonimbus, cumulus congestus, cumulus, cirrus, middle cloud, low cloud and land, water and unknown pixel.

Cloud classification experiment of sample database is done using neural network method. This neural network model has 20 input nodes, 2 hidden layers and 4 output nodes (20-40-15-4). More than three thousands samples selected randomly are used to train the neural network model. The other independent samples are used for testing. Testing result shows classification accuracy is about 78% for single pixel sample database and 79% for 8*8 pixels samples database. Table 1 shows classification experiment results. Although classification accuracy of 8*8 pixels samples is a little better than single pixel sample, but when neural network model is used in the practical application to one satellite image single pixel cloud classification neural network model is better.

Table 1. Single pixel cloud classification experiment results

Calcul-ation Fact	1	2	3	4	5	6	7	8	9	Right sample numbers	Total numbers of each sysm	Accu-rate ratio %
1	2207	157	25	335	21	0	0	0	45	2207	2835	77.8
2	158	1119	41	457	0	0	0	0	158	1119	2091	53.0
3	29	3	684	76	133	223	121	0	0	684	1269	53.0
4	165	214	7	7186	435	0	3	0	194	7186	8374	85.0
5	38	6	16	450	1822	1	47	0	13	1822	2400	75.0
6	0	0	554	107	126	1648	413	0	0	1648	2856	57.0
7	1	0	5	0	2	0	1935	33	6	1935	1982	97.0
8	0	1	2	0	1	1	28	330	13	330	376	87.0
Total Accurate ratio of cloud classification 77.8%												

The CASE of NOAA/AVHRR Cloud Classification

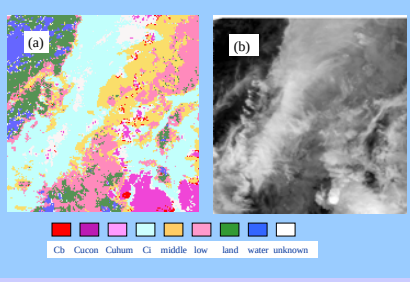

Fig 1. NOAA/AVHRR Cloud and surface classification case study. (a) is NOAA-11 at 5 on July 20 in 1992 UTC the region is 30 ~35 N 140 ~145 E classified color image, (b) is channel 4 cloud image at the same time. In this case, cumulonimbus (red), cumulus congestus (purple), cumulus humilis (light purple), cirrus (cyan), middle cloud (yellow), low cloud (pink), land (green), water (blue), and unknown (black) is marked. But some of multiple level clouds and boundary pixels are not recognized because of having no such samples in learning sample set.

GMS-5 NUERAL NETWORK CLOUD CLASSIFICATIONT TECHNIQUES

Sample database of clouds, land and water is built based on GMS-5 four channels data which includes several thousands of one pixel samples. Sample database is also collected from the GMS-5 satellite imageries from June to August in 1998. GMS-5 has two window channels with little atmospheric absorption. They can show thermal characters of surface well. The water vapor channel detects middle-high level water vapor in the atmosphere. Additionally there is a visible band. Theory analysis and experiment show that not only four channels data can be used to distinguish clouds and lands and water but also the difference between channels can do so. For example, the brightness temperature difference between channel 3 and channel 4 can be used to distinguish thin cirrus. On the basis of theory analyses and experiment, 20 features are selected as the input of the cloud classification neural network model.

Figure 2 is a clouds classification case study using trained neural network model, Figure 2(a) is infrared channel (channel 3) satellite imagery of GMS-5 at 6:00 on June 24 in 1999 UTC the region is 0 ~60 N 70 ~150 E. Figure 2(b) is the visible (channel 1) satellite imagery at the same time. Figure 2(c) is GMS-5 cloud classified color image at the same time. In this case, water, land, low-level cloud, middle-level cloud, multi-level cloud, cirrus and cumulonimbus are showed with different color. The low-level cloud in the up-right of the imagery is clearly shown in the classification image but it is hard to be distinguished in the infrared imagery. Over the HUAIHE and the Yangtze Rive drainage basin there are a MEIYU front cloud system lasted from June 22 to July 3.

GMS-5 Cloud Classification Result

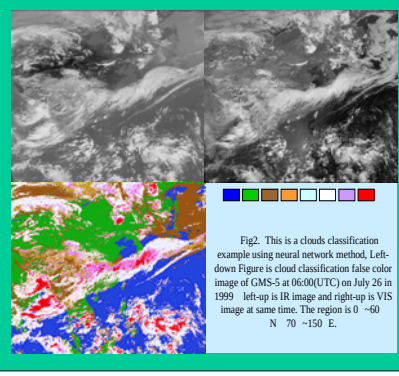

Fig2. This is a clouds classification example using neural network method, Left-down Figure is cloud classification false color image of GMS-5 at 06:00(UTC) on July 26 in 1999 left-up is IR image and right-up is VIS image at same time. The region is 0 ~60 N 70 ~150 E.

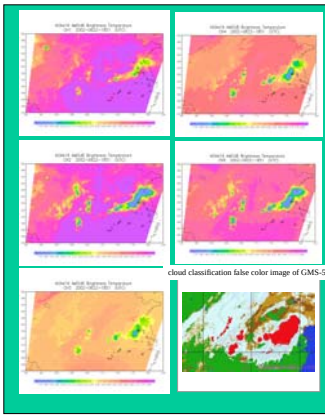

Fig3. Compare NOAA16/AMSU-B Images with GMS5 Cloud Classification Image.

It is consistent the convective cloud in microwave bright temperature images with Cb cloud system in GMS5 cloud classification image.

cloud classification false color image of GMS-5

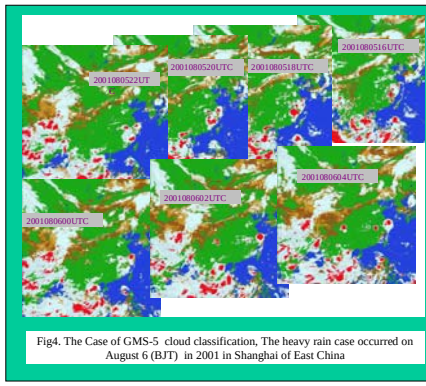

Fig4. The Case of GMS-5 cloud classification, The heavy rain case occurred on August 6 (BJT) in 2001 in Shanghai of East China

MODIS CLOUD MASK AND CLOUD CLASSIFICATION TEST CASES

A simple cloud mask test is done using some thresholds as follows: BT_{11}, BT_{11}- BT_{12}, BT_{11}- $BT_{3.9}$, $BT_{12.9}$, $R_{0.66}$, $R_{0.87}$, $R_{0.87}$/ $R_{0.66}$, $R_{1.6}$. By applying one of these thresholds, a pixel will be classified as cloud or non-cloud. Different thresholds testing give different results. When multi-thresholds method is applied, pixel will be classified as cloud if most of the thresholds testing flag this pixel as cloud. After above processing, land-sea mask data is applied to imagery to distinguish the land and water body. Figure 5 is an example of the cloud mask using MODIS data over China (6 July 2001). The left image is composed image of band1, band2 and band4 and the right one is cloud mask image, green regions are land, blue regions are water, white areas are cloudy.

These thresholds, BT_{11}, BT_{11}- BT_{12}, $R_{0.66}$, $R_{1.6}$, $BT_{3.9}$, are used in the cloud classification test on the basis of cloud mask. Figure 6 is an example of the cloud classification using MODIS data over China (6 July 2001). The left image is composed image of band1, band2 and band31 and the right one is cloud classified imagery. In cloud classified imagery, the green regions are land, blue regions are water, white cumulonimbus, cyan areas are cirrus, and dark yellow areas are low-level cloud. Over the Yangtse Rive drainage basin there are outer cloud system of the tropical cyclone.

MODIS Cloud Mask Result

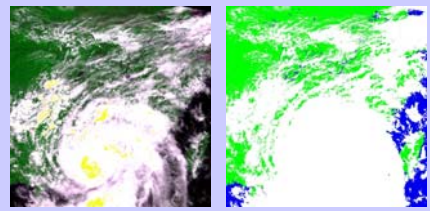

Fig 5. An example of the cloud mask using MODIS data over China (6 July 2001) . The left image is combination by ch1/2/4 and the right one is cloud mask image, green regions are land, blue regions are water, white areas are cloudy.

MODIS Cloud Classification Result

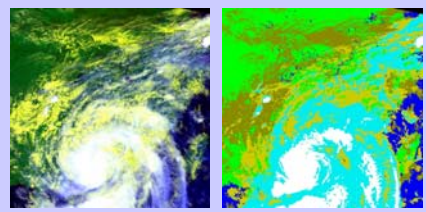

Fig6. An example of the cloud classification using MODIS data over China (6 July 2001) . The left image is composed image of band1, band2 and band31 and the right one is cloud classified imagery. In cloud classified imagery, the green regions are land, blue regions are water, white cumulonimbus, cyan areas are cirrus, and dark yellow areas are low-level cloud.

SUMMARY AND CONCLUSION

This paper discussed cloud mask and cloud classification methods using the different satellite data. Some conclusions can be drawn from the study as follows:

The different cloud classification methods have their advantage and disadvantage.

In this paper we discussed the automated pixel-scale neural network method, the automated 8*8 pixels neural network method, and the automated pixel-scale multi-spectrum thresholds technique to detect and to classify clouds. For neural network cloud classification methods it has higher classification accuracy for one better sample database, but if some case did not occur in this sample database the neural network model can not recognize it. A perfect sample database that it includes almost all case in the different season and in the different area will need large resources. For pixel-scale multi-spectrum threshold technique it is relatively easy to adapt thresholds to varying meteorological conditions, earth surface types, viewing geometry using external data. One of the main disadvantages is that the thresholds need to be tuned frequently.

Using MODIS data, we can distinguish between cloud free and cloudy situation more exactly and recognize the different types of clouds more easily. Snow and low cloud is more easily distinguished using MODIS bands 6 (1.64μm), and bands 6 is helpful for distinguishing between the ice cloud and water cloud. MODIS has measurements at three wavelengths in the window, 8.6, 11, and 12μm, which are very useful in determination of cloud free atmospheres, and their combination are helpful in determining the thin cirrus.

It shows that using pixel-scale methods are more suitable for practical application than 8*8 pixels scale methods through testing using AVHRR data. Although classification accuracy of 8*8 pixels samples is a little better than single pixel sample, but when neural network model is used in the practical application for a satellite image single pixel cloud classification neural network model is better.

Although the spatial resolution of the GMS-5 data is lower than AVHRR and MODIS data, but its higher time resolution makes it reflect weather system evolution process better. It can show clearly that the meso-scale convective cloud clusters in the MEIYU front evolve with time.

Cloud mask result is the foundation of other studies such as SST and LST (land surface temperature), TPW (total precipitable water) retrieval and vegetation study using these satellite data. The output of cloud classification can be used to modify the NWP output cloud.

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