An Automated, Dynamic Threshold Cloud Detection Algorithm for FY-2C Images

Liu Jian and Xu Jianmin

National Satellite Meteorological Center, Beijing, 100081, China

Abstract

This paper describes an updated operatiofal cloud detection method of FY-2C. Compared with FY2B three channels, FY2C adds one shortwave infrared channel and split infrared channel. Research results testified that shortwave infrared and split infrared channels can be help to detect low cloud and cirrus cloud, especially at night.

1 Introduction

FY-2C was launched on October 24 2004. It has five channels. Except visible，infrared and water vapor channel, it splits infrared channel in two (10.3-11.3µm,11.5-12.5µm)and adds one shortwave infrared channel(3.5-4.0µm). Table 1 is FY-2C majmr characteristics of VISSR compared with FY-2B.Compared with FY-2B，FY-2C offers more useful information to detect cloud.

Table 1 FY-2C major instrument characteristics compared with FY-2B

Name	FY-2C	FY-2B
Wavelength(µm)	VIS 0.55-0.90 IR1 10.3-11.3 IR2 11.5-12.5 IR3 3.5-4. WV 6.3-7.6	VIS： 0.5-1.05 IR： 10.5-12.5 WV ：6.3-7.6
Resolution (KM)	VIS: 1.25 IR1/2/3 WV :5	VIS: 1.44 IR/WV :5
Noise performance	VIS S/N=1.5 (Albedo=0.5%) S/N=50 (Albedo=95%) IR1/IR2 NEDT=0.4-0.2K(300K) IR3 NEDT=0.6-0.5K(300K) WV NEDT=0.5-0.3K(300K)	VIS S/N=6.5 (Albedo=24%) S/N=43 (Allbedo=95%) IR NEDT=0.5-0.65K(300K) WV NEDT=1K (300K)
Quantification precision (bit)	VIS： 6 IR/WV：10	VIS： 6 IR/WV ：8

In FY-2B operational cloud detection method, one-dimension and /or two- dimension histogram analysis was used first to get dynamic infrared and / or visible cloud detection threshold. Brightness temperature difference between infrared and water vapor channel was used to detect high cloud. Spatial uniformity test was used to detect broken cloud over the ocean. Multi-day clear composite map was used to distinguish cloud from snow. The disadvantage of FY-2B operational cloud detection method is always failed to detect low cloud, thin cirrus, especially at night and at high latitude in winter.

2 FY2C cloud detection

2.1 Updated night cloud detection- brightness Temperature Difference method

Based on FY-2B cloud detection, we updated FY-2C cloud detection on two aspects, The first one was we added brightness temperature difference between split infrared channels and brightness temperature difference between short infrared channel and infrared window channel to detect low cloud, thin cloud, especially at night time. The temperature difference methods were used to improve FY-2C cloud detection. Many research and operational results showed several infrared window threshold and temperature difference techniques are practical.

Differences between B T11 and BT12 are widely used for cloud screening with AVHRR measurements, and this technique is often referred to as the split window technique. Saunders and Kriebel (1988) used BT11-BT12 differences to detect cirrus clouds. Brightness temperature differences are greater over thin clouds than over clear or overcast conditions.

The basis of the split window technique for cloud detection lies in the differential water vapour absorption that exists between the window channels(11 and 12μm). These spectral regions are considered to be part of the atmospheric window, where absorption is relatively weak. Thresholds will vary with moisture content of the atmosphere as the long wave infrared windows exhibit some water vapour absorption. Threshold cloud detection techniques are most effective at night over water. Over land, the threshold approach is further complicated by the fact that the emissivity in the infrared window varies appreciably with soil and vegetation type.

At night the difference between the brightness temperatures measured in the shortwave (3.75 μm) and in the longwave (11 μm) window regions. $TB_{3.75}$-TB_{11} can be used to detect partial cloud or thin cloud within the sensor field of view. Small or negative differences are observed only for the case where an opaque scene (such as thick cloud or the surface) fills the field of view of the sensor. Negative differences occur at night over extended clouds due to the lower cloud emissivity at 3.75 μm.

Infrared window tests at high latitudes are difficult. Distinguishing clear and cloud regions from satellite IR radiances is a challenging problem due to the cold surface temperatures. Yamanouchi et al. (1987) describes a nighttime polar (Antarctic) cloud/surface discrimination algorithm based upon brightness temperature differences between the AVHRR 3.7 and 11μm channels and between the 11 and 12μm channels. Their cloud/surface discrimination algorithm was more effective over water surfaces than over inland snow-covered surfaces. A number of problems arose over inland snow-covered surfaces. First, the temperature contrast between the cloud and snow surface became especially small, leading to a small brightness temperature difference between the two infrared channels. Second, the AVHRR channels are not well calibrated at extremely cold temperatures (< 200 K). The same problem was found by FY-2C. When the temperature is lower, short infrared channel data (3.75μm) of FY-2C isn't useable.

2.2 cloud detection confidence

The cloud detection tests rely on thresholds. Sometimes, pixel can be labeled as cloudy easily by threshold. But thresholds are never global. Although dynamic threshold method was used in every small area, it seems unrealistic to label a pixel as cloudy just lower or higher a little than threshold. Cloud detection is done one by one test by different channels. Different tests may produce inconsistent results. Which one is correct and how to evaluate them is a problem.

Now many research and operational cloud detection schemes use confidence flag to indicate a confidence level for each pixel. Confidence flags convey strength of conviction in the outcome of the cloud mask algorithm tests for a given pixel. When performing spectral tests, as one approaches a threshold limit, the certainty or confidence in the outcome is reduced. Therefore, a confidence flag for each individual test, based upon proximity to the threshold value, is assigned for the FOV. Figure 1 is a graphical representation how a confidence level is assigned for a special test(B.Reed, 2002). The final determination is a combination of the confidences of all applied tests.

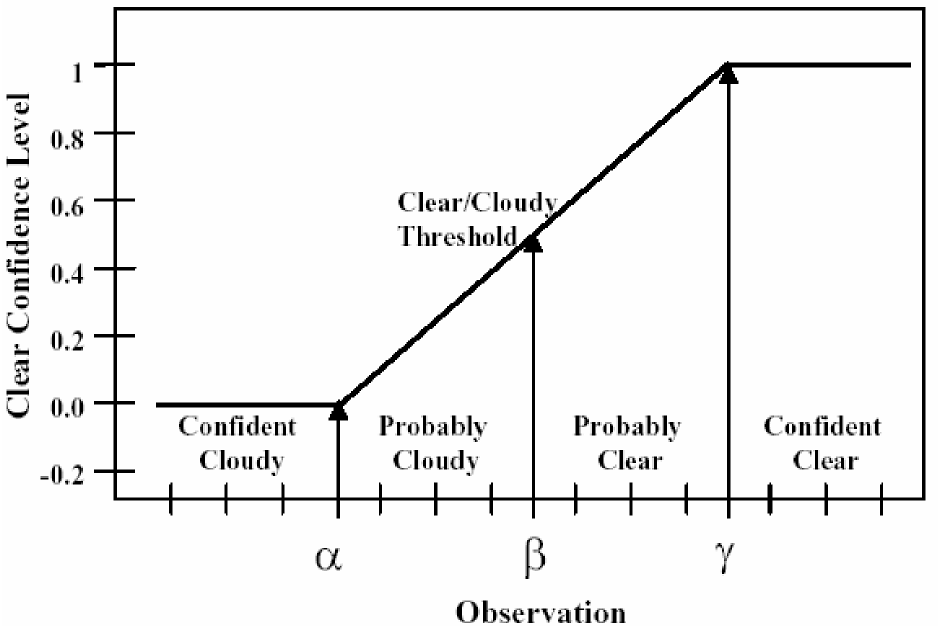

Figure1 **A graphical depiction of three thresholds used in cloud screening (B.Reed,2002)**

The order of tests is also important for final cloud detection. Tests are arranged according to their availability. For example, the single infrared brightness temperature threshold was the first test over sea. In FY-2C cloud detection schemes, it was used single channel and an initial threshold to identify confident clear /cloudy pixel at pixel level. Then the minimum and the maximum value foe confident clear and cloudy were calculated and take them as α and γ. Dynamic threshold (β) was gotten for each selected area by one or two histogram analysis.

2.3 FY-2C cloud detection schemes

2.3.1 Threshold and Difference Tests

- IR threshold cloud test: The first infrared test to apply over the oceans is a simple threshold test. Over open ocean then IR1 brightness temperature is less than 267K, we assume the pixel to be confident cloudy. Most condition can be satisfied except polar area.

- Cloud test (IR1-WV): This test can be used to detect strong convective cloud or very thicker cloud when brightness temperature difference between infrared window and water vapor channel is negative value. This test can be used over either land or ocean surface.

- Cloud test (IR1-IR2): This test can be used to find thin cirrus.

- Cloud test (IR1-SIR): This cloud test rely on brightness temperature difference test BT3.7-BT11. It can be used to detect partial cloud or thin cloud. At night negative value of BT3.7-Bt11 was observed over extended clouds.

- Reflectance threshold test: Visible threshold test are best used in combination with infrared window observations during daytime. Low reflectance measurements will result from thin cirrus cloud or cloud free conditions. Using this test, we should be careful about sun glint. For ocean, this test can get better cloud detection result.

2.3.2 Uniformity test

When the single field of view tests don't definitively determinate an obstructed FOV, spatial and temporal consistency tests are often useful.

- Composite clear map test: Composite clear map is a good tool to help detect cloud, especially over land surface.

- The infrared window spatial uniformity test is most effective over water. Most ocean regions are well suited for spatial uniformity tests. We don't apply this test in coast region. The method is based upon the computation of the mean and standard deviation for a group of pixels using 11 micron brightness temperature.

2.3.3 Cloud mask algorithm

The tests detailed in the above are applied as follows. Single pixel threshold tests are used first. Dynamic histogram analysis is used to get threshold.

- Thick High Clouds(Group 1): Thick high clouds are detected with threshold tests that rely on brightness temperature in infrared and water vapor bands.

- Thin Clouds (Group 2): Thin clouds tests rely on brightness temperature difference tests BT11-BT12, and BT3.7-BT11.

- Low Clouds (Group 3): Low clouds are best detected using solar reflectance test and brightness temperature difference BT3.7-BT11.Spatial uniformity test is also used over land surface.

- High Thin Clouds(Group 4): This test is similar to Group1, but it are spectrally turned to detect the presence of thin cirrus. Brightness temperature difference test BT11-BT12 and spatial uniformity test are applied. Temporal uniformity test is also used.

2.3.4 Ancillary data

A number of ancillary data set are necessary. First each pixel must be tagged as being land or water. Each land pixel must be designated as digital elevation Model. Each land pixel should be classified if it is sand.

3 Discussion

Figure 2 was FY-2C infrared window image at night in winter. There are convective cloud and thin cirrus over tropic area. On the north hemisphere, there are larger areas covered by low cloud. On high latitude of south hemisphere, a lot of cellular clouds cover the ocean.

Stratus has smooth texture and higher temperature at the top over land, it is so difficult to detect if just uses single infrared channel at night. In some areas, such as south- west part of china, status always maintains several days, even several weeks during the winter. Under this condition, clear composite map sometimes fails too. Brightness temperature differences between shortwave infrared and infrared and between split infrared windows are helpful to detect stratus at night. Stratus has negative brightness temperature difference value between shortwave infrared and infrared bands and positive brightness temperature difference between split infrared windows band. Figure 3 is a cloud detection image corresponding to figure 2.

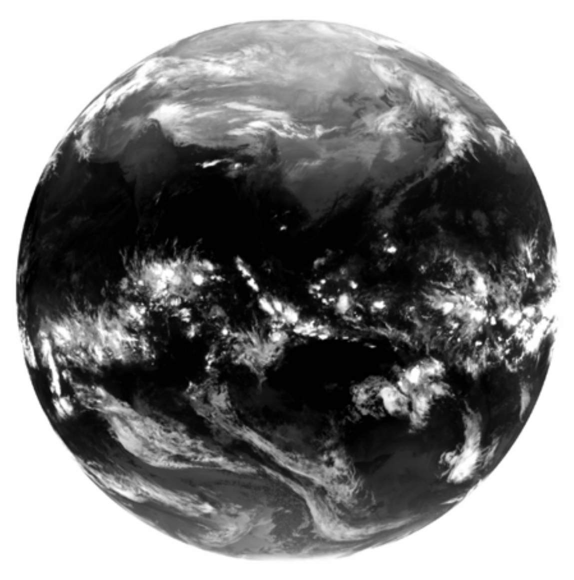

Figure2 FY-2C IR1 image at 1200（GMT）

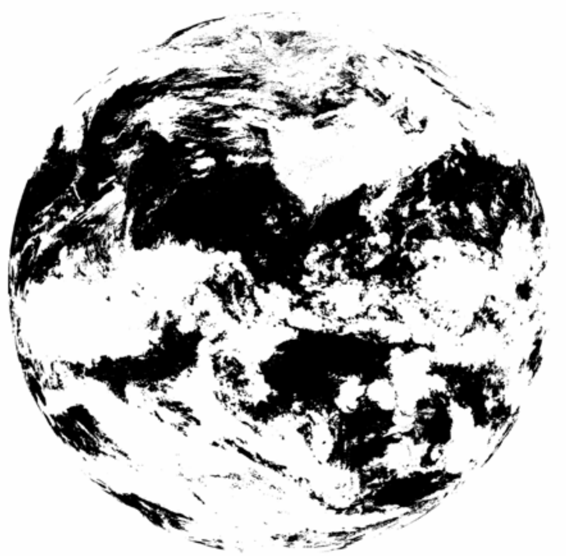

Figure 3 FY-2C cloud detection image corresponding to figure 1

Compared with FY-2B, FY-2C multi-channel data can improve cloud detection, especially at night, but there are still a lot of unsolved problems. For example, in high latitude regions, the cloud detecting methods failed sometimes due to strong surface temperature inversions. There are still a lot of errors in polar area in winter.

Referance

Bonnie Reed, 2002, VIIRS Cloud Mask(VCM) visible /infrared imager/radiometer suite algorithm theoretical basis document, Version 5

Saunders, R. W. and K. T. Kriebel, 1988. An improved method for detecting clear sky and cloudy radiances from AVHRR data, *International Journal of Remote Sensing,* 9, 123-150.

Yamanouchi, T., K. Suzuki, and S. Kawaguci, 1987. Detection of clouds in Antarctica from infrared multispectral data of AVHRR. *J. Meteor. Soc. Japan*, 65, 949-962.