An Automated, Dynamic Threshold Cloud Detection Algorithm

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Abstract: An operational scheme for cloud detection for FY-2C data is presented. The scheme consists of two major parts: total cloud detection and high cloud detection. Cloud detection separates cloud from underline surface, for every pixel, it is either clear pixel or is cloudy pixel. High cloud detection separates high cloud from other cloud types.
Key words: cloud detection, dynamic threshold

1. Introduction

Clouds are generally characterized by higher reflectance and lower temperature than the underlying earth surface. As such, simple visible and infrared window threshold approaches offer considerable skill in cloud detection. However, there are many surface conditions when this characterization of clouds is inappropriate, most notably over snow and ice. Additionally, some cloud types such as thin cirrus, low stratus at night, and small cumulus are difficult to detect because of insufficient contrast with the surface radiance.

The International Satellite Cloud Climatology Project (ISCCP) has developed cloud detection schemes using visible and infrared window radiances. The AVHRR Processing scheme Over cLoud Land and Ocean (APOLLO) cloud detection algorithm uses the five visible and infrared channels of the AVHRR. The NOAA Cloud Advanced Very High Resolution Radiometer (CLAVR, Stowe *et al*., 1995) and the Moderate Resolution Imaging Spectroradiometer (MODIS) (Ackerman *et al*., 1997) also uses a series of spectral and spatial variability tests to detect a cloud. Additionally, spatial coherence of infrared radiances in cloudy and clear skies has been used successfully in regional cloud studies.

The above algorithms are noted as they have been incorporated into current global cloud climatology or have been run in an operational mode over long time periods. FY2C was launched on 2004. It has one visible channel, one water vapor channel, one near infrared channel and two infrared split channels. Now it has been an important data source for weather analysis. Building on above works, this paper described an operational cloud detection method for FY satellite.

2. Cloud Detection Methods

Cloud detection approach includes histogram analysis, threshold detection, deviation analysis, and so on. Infrared and visible channels are basic data; water vapor and near infrared channel are also used.

Dynamic threshold is used with visible and infrared channel data to create a cloud mask for each pixel on a single image automatically. Histogram analysis was used to get dynamical threshold for each small area of pixels. For an area that contain either clear pixels or cloud pixel, it would appear a peak that is corresponding to low grey

level (high temperature or low reflectance). This peak possibly represented clear surface. Then the value that was the first and the maximum scaled second derivate might be decided as threshold. Figure 1 was an example that shows how to get dynamic cloud detection threshold. In this step, three factors should be considered. First, the size of analyzed area was important. If the area was larger, it would contain more complex information, it would be difficult to gain distinct peak value in histogram. On the country, its information was too less to calculate peak value.

Second, different types of surface have different properties. We must think about surface properties and topography. In some area, there is great elevation difference between neighbor pixels. If there were more than two kinds of surface types or the DEM difference was so larger, we should analysis dynamic thresholds for every kind of surface type and adjust according to different surface properties when it was used to detect cloud for each pixel. So the surface classification data and DEM data are necessary ancillary data to detect cloud.
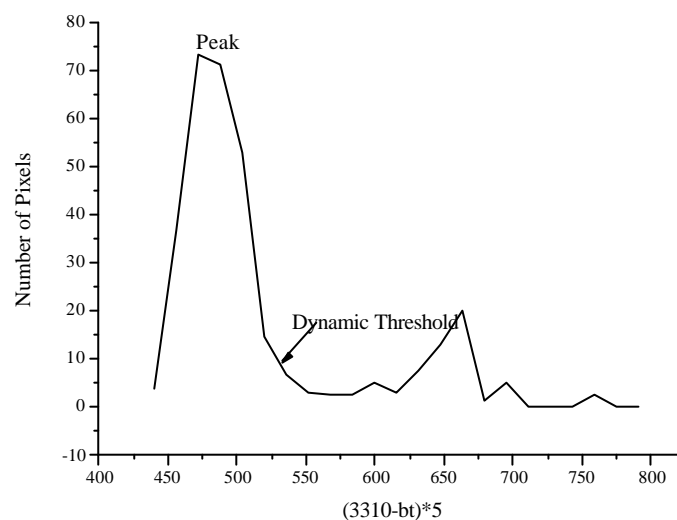

Fig 1. Histogram processing for selecting dynamic threshold at the maximum of the scaled second derivate.

After getting the value in histogram, it should be judged if it was cloud detection threshold. Clear radiance has periodic value during one day. Gotten peak value was compared with the periodic curve before 24 hour. If there was great difference between two values, gotten value might be invalid to detect cloud. When this appeared, it showed cloud detection threshold wasn't gotten. Figure 2 showed the relationship between the threshold and daily curve to judge threshold 's usefulness.

In order to get more accurate threshold, smoothed analysis area method was used. The histogram analysis area is at the center and four neighbor areas were also used. Because cloud properties have more changes in latitude than in longitude, the surround analysis areas aren't square. They would be rectangle.

Third, if the peak value wasn't found in histogram, that means pixels of the area had the similar properties. At this situation, we used another kind of cloud detection method. Clear pixel and cloud pixel have clearly contract at reflectance at the most

case. So the visible channel is very useful to detect cloud. In reflectance image,
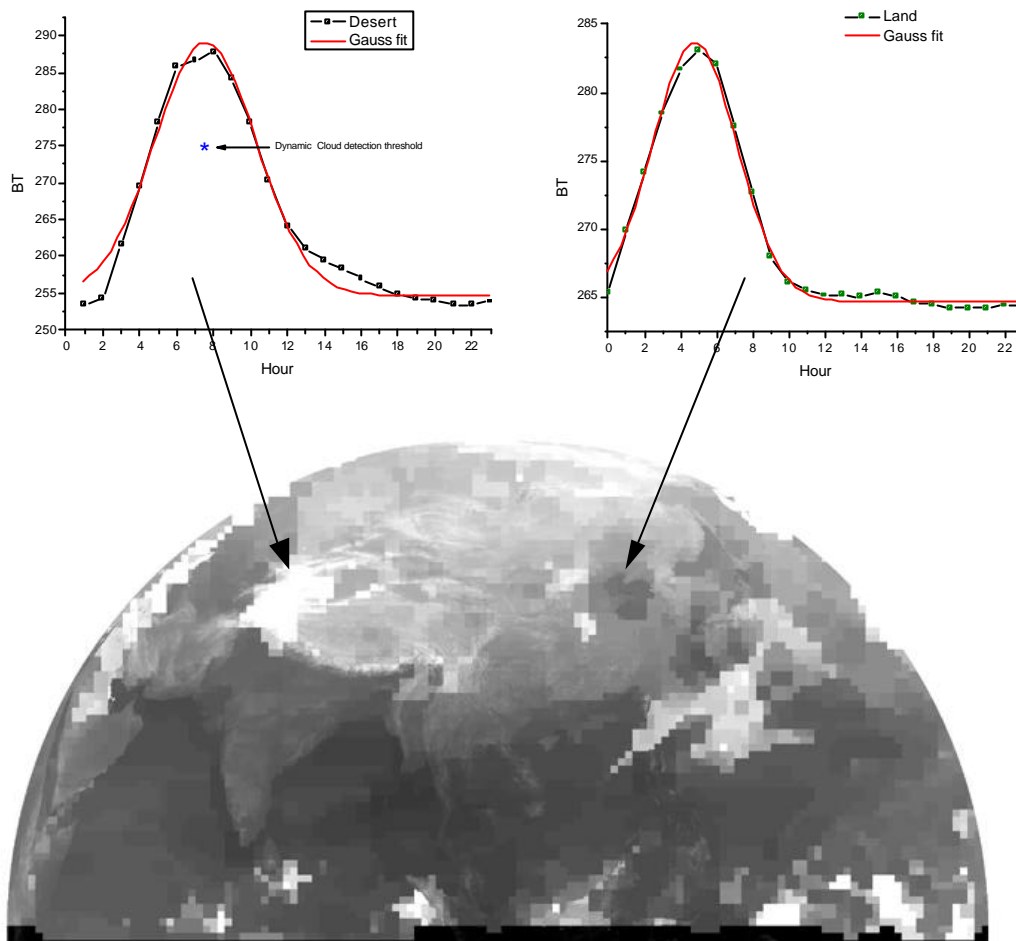

Fig2 To judge the usefulness of cloud detection threshold

dynamic cloud detection threshold is much easier to find than infrared channel. But when sun zenith is too large or at night, visible channel data are invalid.

Except dynamic threshold method, we also used some simple but very useful methods to detect cloud. For example, brightness temperature difference between infrared and water vapor channel was used to detect cloud. It is well known that at most cases, brightness temperature at infrared channel is larger than water vapor channel. If brightness temperature difference between infrared and water vapor channel appeared negative, it showed the pixel was covered by deep convective cloud.

The brightness temperature difference test is used to detect cirrus clouds during the day and night over a variety of surfaces. The thresholds are dependent on the satellite zenith angle and $11\mu m$(Saunders and Kriebel, 1988). We used radiative transfer model to build a look-up table for clear/cloud detection under various conditions.

At night the difference between the brightness temperatures measured in the shortwave ($3.7\mu m$) and in the longwave ($11\mu m$) window regions can be used to detect partial cloud or thin cloud within the FOV. Small or negative differences are observed only for the case where an opaque scene (such as thick cloud or the surface) fills the FOV of the sensor. Negative differences occur at night over extended clouds due to the lower cloud emissivity at $3.7\mu m$.

Cloud always was mixed with snow in single channel. Dynamic threshold method sometimes failed for the case. Deviation method can help to detect broken cloud at sea. Sea has uniformity properties. If sea pixels were polluted by small and broken cloud, the deviation of these pixels would become larger. At that time, 15-day composite clear data and numerical weather forecasting data are also used as ancillary data to help cloud detection.

For high cloud detection, infrared and water vapor channels are used simultaneously. The pixels with high (low) correlation between the two channels around it are defined as high (low) level cloud.

In high plateau region, pixels pass through both total and high cloud detections are identified high cloud. In other regions, pixels pass through total or high cloud detections are identified as cloudy.

3. Discussion

Fig. 3 was a FY-2C cloud detection result. Different grey levels all represent cloud. This cloud detection method is an operational method. Detecting results shows that the algorithm performs well for most cases. But in high latitude regions, the cloud detecting methods failed sometimes due to strong surface temperature inversions. Some surface conditions may make this approach inappropriate, most notably over snow and ice. In addition, some cloud types such as thin cirrus, low stratus at night, and small cumulus are difficult to detect because of insufficient contrast with the surface radiance.
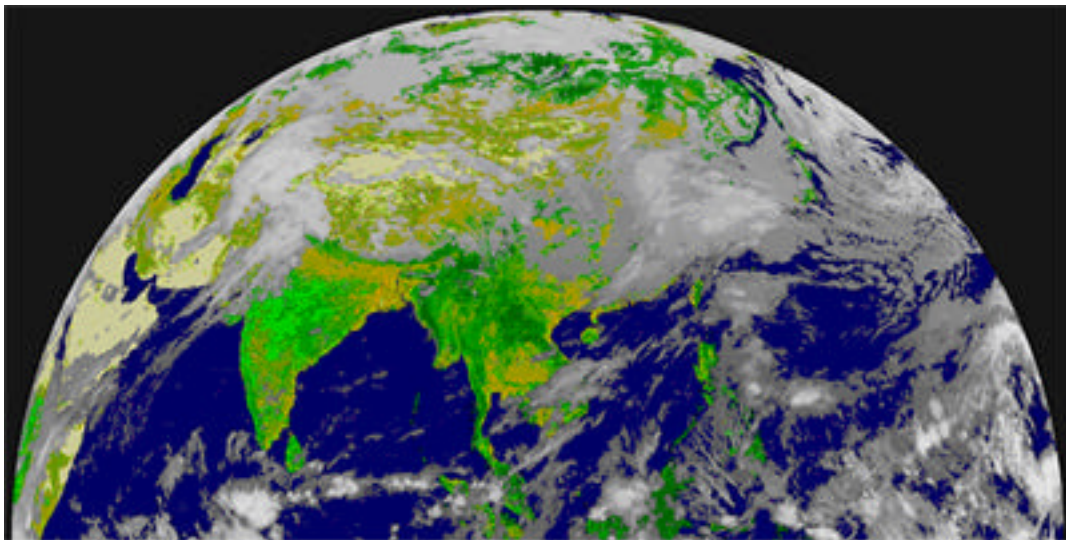

Fig. 3 an example of cloud detection result

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