DETECTION OF FOG OVER LAND USING HJ-1 DATA

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Abstract – Fog is a kind of meteorological disaster, which has a serious impact on social economic activities and daily life of human beings. In this paper, the fog detection model based on the characteristics of HJ-1 satellite is put forward firstly. Then the model is tested by HJ-1B data and synchronous MODIS data in southern China at January 9th, 2009. By comparing the experiment results of HJ data and MODIS data, it shows that HJ data is suitable for fog detection.

Keywords: fog, detection, cloud, HJ, disaster

1. INTRODUCTION

Fog is a kind of meteorological disaster, which has a serious impact on social economic activities and daily life of human beings. Researches on fog monitoring based on remote sensing techniques have been carried out for many years. In the early stage, fog and stratus were discriminated by their different reflectance characteristic from other clouds in the visible band (Gurka, 1974). With the increasing development of satellite remote sensing technology, numerous data source have been used to fog detection. Eyre (Eyre, 1984), Turner (Turner, 1986) used dual-channel different temperature method to detect fog and stratus cloud at night by NOAA/AVHRR data. The above method has also successfully applied to GOES-8+ data and Meteosat SEVIRI data (Lee, 1997; Cermak, 2007; Cermak, 2008). Due to the contribution of reflectance solar energy in mid-infrared band during daytime, the "dual-channel different temperature method" is not suitable for fog detection at daytime. With the extensive application of MODIS data, fog detection at daytime using EOS/MODIS data becomes a new focus point. Bendix (Bendix, 2006) developed a radiative transfer-based classification scheme for EOS/MODIS data to detect fog. Ma (Ma, 2007) analyzed the spectral characteristic of water, cloud, snow, surface features and fog based on spectral profiles sampling from fifteen EOS/MODIS images of Eastern China. Lv (Lv, 2009) used SBDART radiative transfer model to simulate the radiation characteristics of fog and cloud using EOS/MODIS data.

In this paper, the characteristics of HJ satellite will be analyzed, and a fog detection model is proposed. Then this model is used to detect fog at daytime by HJ-1 data and synchronous MODIS data. The two results are compared in order to prove the fog detection capability of HJ-1 data.

2. CHARACTERITICS OF HJ-1 SATELLITE

HJ-1 optical satellites launched firstly in small satellite constellation for environment and disaster monitoring and forecasting now are composed of two satellites called HJ-1A and HJ-1B. The two optical satellites operate in the same orbit plane with a phase difference of 180 degrees. Strict orbit configuration control can ensure continuous ground imaging and territory coverage every 2 days. The satellites are equipped with two multispectral CCD cameras (HJ-1A and HJ-1B), the hyper-spectral camera (HJ-1A), the infrared camera (HJ-1B) and Ka-band communication testing equipment (HJ-1A).

According to previous research, it could be known that near-infrared (3.9μm) and mid-infrared (11.8μm) band play an important role in fog detection. So HJ-1B satellite data, in which 1-4 are CCD bands and 5-8 are IRS bands, are chosen to detect fog in this paper. The main parameters of HJ-1B satellite can be seen in following tables (Bai, 2009).

Table 1. Main Parameters of the Multispectral CCD Camera

Item	Performance	
Ground Pixel Resolution / m	30	
Swath Width / km	360	
Numbers of Spectrum Band	4	
Spectrum Band / μm	0.43-0.52	0.52-0.60
	0.63-0.69	0.76-0.90

Table 2. Main Parameters of the Infrared Camera

Item	Performance	
Ground Pixel Resolution / m	150, 300	
Swath Width / km	720	
Numbers of Spectrum Band	4	
Spectrum Band / μm	0.75-1.10	1.55-1.75
	3.50-3.90	10.5-12.5

3. FOG DETECTION MODEL

In the light of the above characteristics of HJ-1B data, the fog detection model is proposed. The algorithm is as follows:

1. Using the radiance of B3 to distinguish low-reflection surface. Therefore fog, cloud and snow could be extracted.

2. Using the radiance of B2 and B6 to calculate NDSI. NDSI and the radiance of B4 are combined to identify snow. So fog and cloud could be extracted.

3. Fog has strong temperature inversion phenomenon, so the difference value of brightness temperature between fog and the surface is small. The above feature can be used to distinguish low stratus and fog from high clouds and middle clouds. Furthermore, brightness temperature in different regions may vary widely because the width of HJ image is about 700km. So it should not be set a single average brightness temperature of surface to compute the difference value of brightness temperature between fog and the surface. In this paper, a dynamic method to gain different average brightness temperature of surface in different regions is put forward. Firstly band 8 is used to compute the brightness temperature image. When calculating the brightness temperature difference for each fog and cloud pixel, searching the surface pixel with 10 pixel steps along the eight directions around the pixel. (1) If no surface pixels in eight directions, the corresponding pixel value is the average of the surface pixels of the whole brightness temperature image; (2) If one or several directions could gain surface pixels, the corresponding pixel value is the average of these surface pixels in eight directions.

4. The radiation energy of band 7 composes of two parts: target's own thermal radiation (emitted part) and the reflection of solar radiation (reflected part). It is known that the emitted part of fog is bigger than most type of clouds. Therefore band 7 can be used to distinguish fog from middle clouds and low stratus.

The emitted radiation of band 7 can be approximated as

$$ER = \varepsilon_{B7} B_{B7}(\mathrm{T_{B8}}) = (1 - \mathrm{A_{B7}})\mathrm{B_{B7}}(\mathrm{T_{B8}}) \quad (1)$$

Where ε_{B7} = the radiance of band 7

A_{B7} = the albedo of band 7

$B_{B7}(T_{B8})$ = radiation energy of band 7 which is calculated by Planck function and the brightness temperature of band 8.

The reflected radiation of band 7 can be approximated as

$$RR = \pi^{-1} A_{B7} B_{B7}(\mathrm{T_{sun}}) \Omega_{\mathrm{sun}} \cos\zeta \quad (2)$$

where Ω_{sun} = the solid angle of the sun subtended at the earth, of which the value is 6.8×10^{-5} sr.

T_{sun} = the temperature of the sun in band 7, of which the value is 5888k.

ζ = sun zenith

Therefore, the albedo of band 7 can be expressed as

$$A_{B7} = \frac{B_{B7}(\mathrm{T_{B7}}) - \mathrm{B_{B7}}(\mathrm{T_{B8}})}{\pi^{-1} B_{B7}(\mathrm{T_{sun}}) \Omega_{\mathrm{sun}} \cos\zeta - B_{B7}(T_{B8})} \quad (3)$$

4. EXPERIMENT

4.1 Preprocessing of HJ-1B Data

Firstly, CCD data and IRS data are calibrated by HJ calibration equations. Then geometric correction and projection of CCD data and IRS data are done. CCD data and IRS data of HJ-1B satellite have different geographical coverage, so it needs to splice and cut the above data to find common area.

4.2 Results and Analysis

The original image of HJ-1B satellite shown in Figure 1 covers the central and eastern regions of Sichuan province and most part of Chongqing city of China. The time of CCD data is at 11:49AM on January 9^{th}, 2009 (UTC+8) and the time of IRS data is at 11:48AM on Janruay 9^{th}, 2009 (UTC+8). The time of the corresponding MODIS image shown in Figure 2 is at 12:00

AM on January 9th, 2009 (UTC+8). The time of the surface synoptic observations (SYNOP) data provided by Hubei Provincial Bureau of Meteorology is at 11:00AM on Januray 9th, 2009 (UTC+8). The difference in time between images and SYNOP data is about 48 minutes.

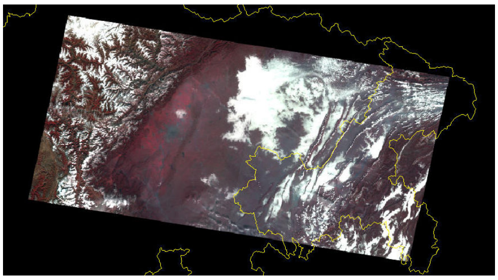

Figure 1. The false color image of HJ-1B satellite (Composing of B4, B3, B2)

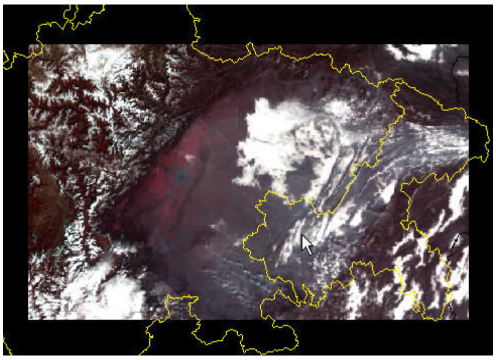

Figure 2. The false color image of MODIS (Composing of B2, B1, B6)

Table 3. Comparison of HJ-1B and MODIS

Spectrum Band / μm	HJ-1B	MODIS
0.43-0.52	B1	B3
0.52-0.60	B2	B4
0.63-0.69	B3	B1
0.76-0.90	B4	B2
0.75-1.10	B5	--
1.55-1.75	B6	B6
3.50-3.90	B7	B20
10.5-12.5	B8	B31

The result obtained by HJ-1B data and fog detection model is shown in Figure 3 and the result obtained by MODIS data and fog detection model is shown in Figure 4. In the result images, red nodes indicate fog sites, yellow nodes indicate light fog sites and green nodes indicate no fog sites.

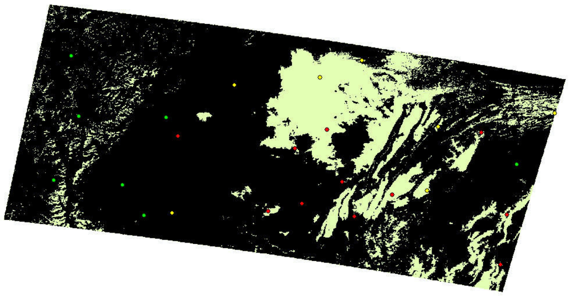

Figure 3. The result of HJ-1B data

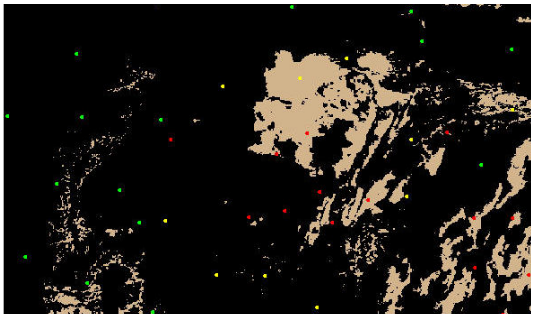

Figure 4. The result of MODIS data

Probability of Detection (POD) and False Alarm Ratio (FAR) are two accuracy assessment index of fog detection proposed by (Bendix, 2004).

$$POD = \frac{yy}{yy + ny} \quad (4)$$

$$FAR = \frac{yn}{yy + yn} \quad (5)$$

where yn = percentage of SYNOP sites classified as fog in fog detection results but there is actually no fog in SYNOP data

ny = percentage of SYNOP sites classified as no fog in fog detection results but there is actually fog in SYNOP data

yy = percentage of SYNOP sites classified as fog in fog detection results and there is really fog in SYNOP data

Table 4 is the accuracy assessment table of fog detection with HJ-1B data and MODIS data, in which the same SYNOP sites are selected to assess accuracy in order to the comparability of the results of these two data.

Table 4. Accuracy Assessment Table of Fog Detection

RS / SYNOP	HJ-1B		MODIS	
	Fog	No Fog	Fog	No Fog
Fog	14	4	10	8
No Fog	1	6	0	7
Overall accuracy	80.00%		72.00%	
POD	77.77%		55.55%	
FAR	6.66%		0	

The HJ-1B image on the left is the plateau region distributed of a large amount of snow-capped mountains. When removing ice using NDSI, some fragmented pixels are left. These pixels in result image are mistaken for fog. The central HJ-1B result image has 4 sites which are classified as no fog in fog detection. But actually these sites have fog in SYNOP data. It can be seen from the image that some small pieces of fog distribute around these four sites. And we know that the time of SYNOP data is about one hour earlier than the time of the image. Therefore it could be speculated that the fog in SYNOP data has dissipated. From table 4, it can be seen that most of accuracy assessment index of HJ-1B result image is better than the ones of MODIS result image. So it is proved that HJ data can be used to detect fog at daytime.

5. CONCLUSION

The fog detection model put forward in this paper is tested by HJ data and corresponding MODIS data. The good result of HJ data indicates that HJ data is suitable for fog detection. However, HJ data has two problems: (1)the time resolution is not high; (2)the time of passing territory is a little late. With the improvement of HJ satellite constellation in the future, there will be better application in the field of fog detection.

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