

DUST STORM DETECTION BASED ON MODIS DATA

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ABSTRACT:

Dust storm is a kind of meteorological disaster which usually takes place in the northern china in spring. It becomes a very important environmental issue and one of the major natural hazards. Its enormous damage on society and life rise extensive concern and research. It is important to know the causation, transportation and radiation effect of dust storm. So we can use a science and efficient approach to avoid the disaster. The government and researchers in China focus on a rapid and effective approach for quick extraction of storm information and timely and correctly warning. The storm usually occurred in the desert, Gobi and hungeriness. Therefore due to the limited ground environmental and climatic observations in the relevant regions, satellite remote sensing of objectivity, real-time and macro-scope view, has become an important approach to detect dust storms in China. It is reported that dust storm happened in western Gansu and Neimenggu on March 14th 2009. MODIS 1B data of relevant regions were used to detect the dust storm. The key point was to analyze the character of dust storm from MODIS data, and build a appropriate rule to extract the dust information. This research used two kinds of algorithms to separate the dust from other objects such as cloud, ground surface and desert surface. The results showed a macro-scope view of the dust storm, and it accorded to the report of weather information services. In conclusion, remote sensing technique can play an important role in monitoring and analyzing dust storm. MODIS provides high quality data source with multi-spectral bands, appropriate spatial resolution and high temporal resolution.

1. INTRODUCTION

Dust storms is a very important environmental issue, and one of the major natural hazards in the northern China (Seinfeld et al., 2004). Major dust storms, usually from the Mongolian desert, occur over these regions nearly every spring. Due to the limited ground environmental and climatic observations in the relevant regions, satellite remote sensing (RS) has become an important approach to detect dust storms in China. As we know, RS can not only provide initial parameters for model simulations but also be used for verification and validation of model simulations (Liu et al., 2005). Multi-satellite observations such as TOMS, SeaWiFS, AVHRR, and the Chinese FY-1C/D series have been used in China dust storm monitoring. But at the present time, RS of dust storms can only provide near global horizontal coverage with limited vertical resolutions (Qu et al., 2006).

As a key research instrument of the NASA Earth Observing System (EOS) missions, MODIS was successfully launched onboard the Terra and Aqua satellites. MODIS senses the Earth's entire surface in 36 spectral bands, spanning from the visible (0.415 μm) to the infrared (14.235 μm) regions of the spectrum with spatial resolutions of 1 km, 500 m, and 250 m at nadir, respectively; Therefore, MODIS products could be very useful to determine dust storm properties and monitor dust transport.

The dust storm formation mechanisms are very complex. They are related to the local weather system, short-term precipitation, soil moisture, and extent of deforestation, long-term increased drought, land use/land coverage changes, as well as other human activities. The important part in this paper is to extract

dust information from remote sensing images. The key point is to separate the dust from other objects such as cloud, ground surface and desert surface which were very confusion factors. So an appropriate discriminant condition is essential to exclude the disturbing information. This research applied two kinds of algorithms to extract the dust information, and compared them from the dust detection results.

2. MATERIALS AND METHOD

2.1 MODIS Data

As a key research instrument of the NASA Earth Observing System (EOS) missions, MODIS was successfully launched onboard the Terra and Aqua satellites. MODIS senses the Earth's entire surface in 36 spectral bands, spanning from the visible (0.415 μm) to the infrared (14.235 μm) regions of the spectrum with spatial resolutions of 1 km, 500 m, and 250 m at nadir, respectively. It can observe the same region on earth four times a day. And it has 36 spectral bands, which provide sufficient information to extract dust storm. In this paper, 7 bands were used to build algorithms for dust information extraction, the band settings were described in Table1. The level 1B data of MODIS were used. Because the brightness temperature was applied as variables, so the preprocessing of MODIS data included the temperature calculation using MODIS tools.

2.2 Method

When dust storm happens, mounts of dust particle float in air and form dust-cloud. It influenced the course of radiative transfer. Dust particle reflect, scatter and absorb the solar

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radiation, and also cover the radiation from the underlying surface, and it scatters radiation, which change the satellite detection values. We studied on this change and set up efficient algorithm to extract dust.

band number	spectral range/ μm
1	0.620-0.670
3	0.459-0.479
7	2.105-2.155
20	3.660-3.840
29	8.400-8.700
31	10.780-11.280
32	11.770-12.270

Table1. Some band settings of MODIS

From the true-color image of MODIS, we can see a coarse extension of the dust storm (Figure1). But there was slightly difference showed in true color between dust and the earth surface, especially in desert region. Therefore, researchers seek to a resultful band combination to compose pseudo-color image which could figure the dust storm area clearly. In this paper, we used 20(R), 1(G) and 29(B)(Guo et al., 2006) combination(Figure2). From the pseudo-color image, the dust storm region was yellow. It was an efficient and brief way of qualitative analysis. For a quantitative analysis of dust storm, we used the multi-spectral bands of MODIS to form a algorithm. The algorithm separated the dust information from other objects such as cloud and desert.



Figure1. MODIS true-color image (04:00 UTC, March 14, 2009)

A respected algorithm is composed with visible bands called normalized difference dust index (NDDI) (Qu et al., 2006). Through analyzing the spectral signatures of sand, grass, soil, urban residential and water, it is clear that the reflectance of dust (sand and soil) generally increases with wavelength between 0.4 and 2.5 μm with a minimum value in MODIS band 3 (0.469 μm) and a maximum value in MODIS band 7 (2.13 μm). This spectrum characteristic of sand and soil makes it easy to distinguish dust from cloud, which has the highest

reflectance in MODIS band 3. Written mathematically, the formula is:

$$\text{NDDI} = (\rho_{2.13\mu\text{m}} - \rho_{0.469\mu\text{m}}) / (\rho_{2.13\mu\text{m}} + \rho_{0.469\mu\text{m}}) \quad (1)$$

where $\rho_{2.13\mu\text{m}}$ and $\rho_{0.469\mu\text{m}}$ are reflectances at the top of atmosphere (TOA) in the 2.13- and 0.469- μm bands, respectively. For clouds, the NDDI value is negative (NDDI < 0.0). For the surface features, the NDDI value is lower than dust pixels. The threshold is 0.26 in this area. It suggests that NDDI can effectively separate dust storm from water or ice clouds and ground features (except ground sand and dust) with a threshold of 0.26. As to identify airborne and ground sand and dust, the thermal infrared bands were applied. The band 31 was suggested to be a sensitive variable for dust. The brightness temperature of MODIS band 31 (11 μm) was used to separate the airborne and ground sand and dust. The brightness temperature threshold of 275 K is suitable for this region.

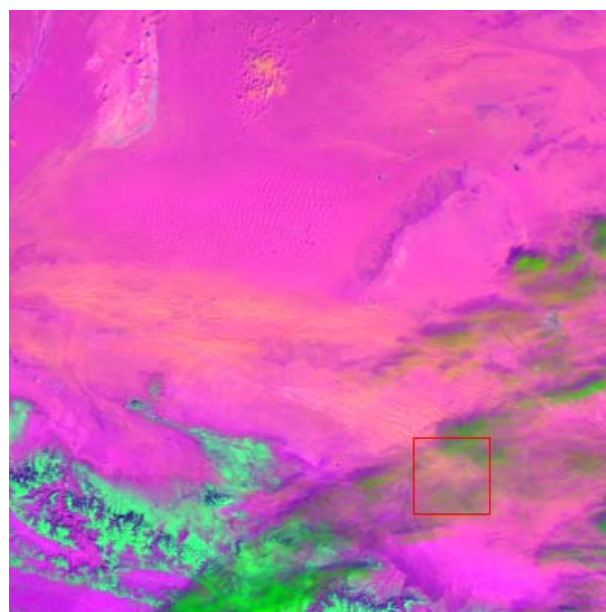


Figure2. MODIS pseudo-color image (20(R), 1(G) and 29(B))

The NDDI index and brightness temperature achieved a high accuracy outcome. But the visible index could not be applied during night. So the dust characteristics of thermal band were analyzed in this research. According to the radiative transfer analysis, the floating dust strongly back-scatter the solar radiation. It altered the surface reflectance evidently. Also, it disturbed the long wave radiation of underlying surface. It was quite obvious on the long wave radiation transformation. So the thermal infrared radiation could be used as crucial variable to identify dust.

The band 31(11 μm) and band 32(12 μm) were proposed to be a good combination to extract dust storm (Luo et al., 2003). In the situation with on dust in air, the drip absorbs more radiation in MODIS band 32 than band 31. When dust storm occurs, the attenuation of dust on radiation is more in band 31 than in band 32. Therefore, the brightness temperature of band 31 is less than the value of band 32. This research applied the algorithm using the variation of band 31 and band 32 during the dust storm. Written mathematically, the formula of dust storm extraction is:

$$\Delta T = \begin{cases} T_{12} - T_{11} (T_{12} - T_{11} \geq 1K) \\ 0 (T_{12} - T_{11} < 1K) \end{cases} \quad (1)$$

Where T_{11} represent the brightness temperature of band 31(11 μ m)
 T_{12} represent the brightness temperature of band 32(11 μ m)

According to the experience, the ΔT of dust region was more than 1 k, and ΔT the other objects were less than 1k. So, the threshold of 1 k was settled to separate the dust from other objects. Another discriminant condition was that the brightness temperature of band 31 and band 32 were all less than 290k, which reduced errors of commission.

3. RESULTS

We apply NDDI to monitor dust storm by using MODIS data over the Badanjilin desert of Inner Mongolia and Minqin county of Gansu.. Fig. 3 shows a subsetting dust storm image exacted by NDDI from the MODIS at 4:00 UTC, March 14, 2009. Fig. 4 shows the subsetting dust storm image for the same region extracted with measurement of thermal bands. NDDI is computed with the visible bands reflectance measurements at TOA from MODIS. The result showed that the threshold of 0.26 is suitable for this region. The deep blue region represented the objects such as cloud and water, which was separated easily by NDDI. The green region represented the ground dust. The brightness temperature of band 31 played an import role in separating the airborne and ground dust. The red region represented the dust storm.

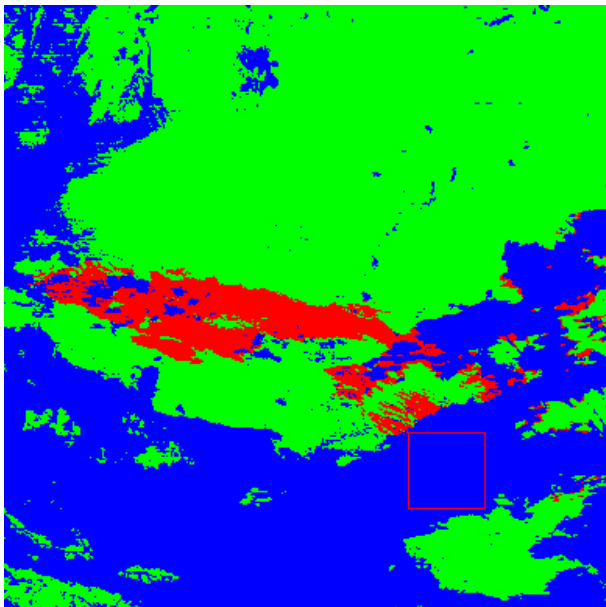


Figure3. Dust region extracted using NDDI

The thermal bands measurements result showed a larger area of

dust storm. Especially in the region with cloud covered(red frame), the dust was extracted. We can conclude that the thermal bands measurements behaved an efficient and high accuracy way to extracted dust. From the result, we can see a beginning of the dust storm. It was mostly from the Badanjilin desert and had the trade of moving to east

CONCLUSIONS

Dust storms are a symptom and cause of desertification. They are often an early warning that the depravation of environment. Once they progress from slight to serious and severe categories they contribute to the spread of desertification through the transport and deposition of sediments that can destroy crops, habitation and infrastructure and render areas uninhabitable. After the devastating dust storms that swept across several provinces of Northern China in March, 2009, there was much interest in examining and analyzing experiences with dust storm arises and transport rules. There was a need to document the nature, extent, causal factors associated with the severe sand and dust storms experienced in China itself and which threatened the lives and livelihoods of millions of people.

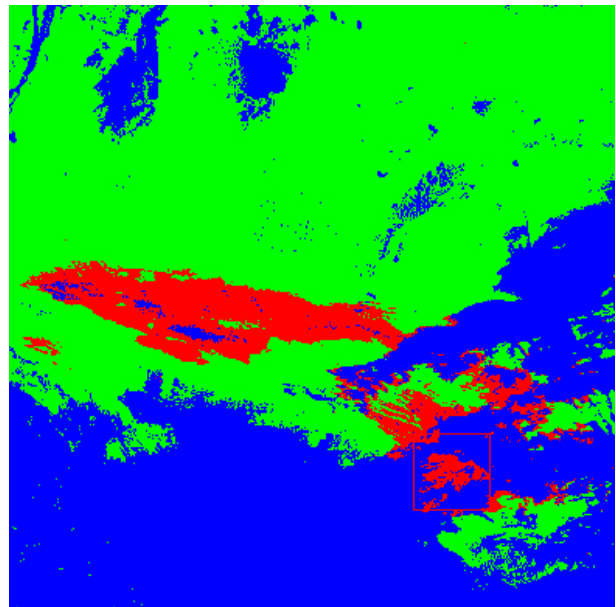


Figure4. Dust region extracted through brightness temperature caculation

This paper used two algorithm to extract dust information. The formulation formed by band 31 and band 32 showed a higher accuracy. This algorithm are built on the difference of brightness temperature when dust existing in air. The dust storm was extracted from other complex objects. MODIS data with its merit of multi-spectrum bands and high temporal resolution were approved to be a aptitude database for remote sensing on detection of dust storm.

Due to the long-range transport of sediments impacting the neighbouring countries, especially those downwind of the source, there was much interest in getting international cooperation so that the collective wisdom of experts from many countries could be distilled in this monograph.

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