A DUST-STORM PROCESS DYNAMIC MONITORING WITH MULTI-TEMPORAL MODIS DATA

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ABSTRACT:

In recent years, the frequency of dust storm is rising. Dust storm can impact the climate changes and cause great damages to people. It is very necessary to monitor the disasters accurately. In this paper, a dust storm process occurred in April, 2006 has been monitored. According to the reflect and absorb characteristic of dust storm, the scope of dust storm is extracted successfully;and the intensity grades are estimated, then the moving trace is monitored by multi-temporal data. Result shows greet agreement with the meteorological department monitoring. Conclusion can be gotten: the dust storm process dynamic monitoring with multi-temporal data has great application prospect.

1. INTRODUCTION

Dust storm, a general name of sand storm and dust storm, is the weather condition which means strong wind draws much sand and dust near the ground surface into the sky, making air very foul, causing visibility less than 1km .Dust storm is a complex process influenced by the interaction of earth-atmosphere system, mainly caused by high wind speed, bared soil and dry air condition etc. It often takes place in arid and semi-arid areas. In recent years, the frequency of dust storm is rising. Dust storm can impact the climate changes and cause great damage to people. It is very necessary to monitor the disasters timely and accurately.

At present, the ground based measurement method and remote sensing technology are two main methods for monitoring dust storm (Li Haiping, Xiong Liya,Zhuang Dafang, 2003). When dust storm happens, the environmental condition is often very bad. The sites for measuring dust storm are usually laid sparsely. As a result, because of low temporal and spatial resolution, traditional ground based measurement method cannot meet the requirements of dust storm monitoring and forecasting very well. The technology of satellite remote sensing has many advantages, such as: wide coverage, continuous in the space and monitoring natural disasters quickly, so it can act as an important role in the dust storm monitoring. Remote sensing can monitor the scope of dust storm, its intensity grade and its moving trace.

Lots of researchers in China and abroad have done numerous experiments on monitoring dust storm by the technology of satellite remote sensing. Luo Jingning (Luo Jingning,Fan Yida,Shi Peijun,2003) has constructed a comparable dust storm intensity index to solve this problem： because of different satellite platforms ,monitoring time and areas, a comparable monitored result cannot be given by using multi-source remote sensing data; Guo Ni (Guo Ni,Liang Yun,2006) has constructed two dust indexes to discriminate dust storm processes happened in 2002-2005; Li Qing (Li Qing,Wang Qiao,Wang Wenjie,2006) has monitored a strong dust storm process occurred in the northwest of China in 2003 by MODIS data; Liu Sanchao (Liu Sanchao,Liu Qinhuo,Gao Maofang,2006) has extracted dust storm areas by combining Terra and Aqua images at daytime and nighttime;John J. Qu(John J. Qu, Menas Kafatos，2006) has proposed a normalized difference dust index(NDDI) to identify dust and cloud; J. K. Roskovensky (J. K. Roskovensky ,K. N. Liou, 2005)has combined short-wave reflectance ratio tests with long-wave brightness temperature differences to produce individual parameters to detect cirrus and dust. However, many researchers only focused on accurately identifying whether a pixel is contaminated by dust storm and then limit the areas of dust storm distribution. In these years, more and more satellites have been sent to the space, it has become possible to make certain the moving trace of the dust storm using the multi-temporal satellite images obtained from different satellite sensors. In this paper, the scope of dust storm is extracted successfully and then the moving trace and intensity grades are monitored by multi-temporal data. The results can help related departments grasp the moving trends of dust storm in macroscopic view and provide a basis for them to make decisions.

2. DATA

In this paper, the data used to monitor dust storm disaster is MODIS data. MODIS sensors, boarded on both Terra and Aqua satellites, have 36 channels. Its spectrum range is 0.4μm～14.385μm,covering from visible to infrared. At least 4 MODIS images can be obtained every day. The timeliness of data is increasing, so dust storm can be monitored dynamically. In this paper, 4 MODIS images are chose to monitor a dust storm process happened in northwest of China on April 16-17, 2006 (see table 1).

Image	Data	GMT	Satellite	Latitude（N°）	Longitude(E°)
1	2006/04/16	3:50	Terra	35-50	90-125
2	2006/04/16	5:30	Aqua	35-50	95-125
3	2006/04/16	14:55	Terra	30-45	90-125
4	2006/04/17	2:55	Terra	30-50	90-125

Table 1 Four images used in this study

3. METHOD AND ANALYSIS

When the dust storm happens, lots of dusts particles get together to form a dust layer. The thick dust layer can absorb and reflect surface radiation and solar radiation, emitting and radiating at the same time, so the values of sensors change. Among the 36 channels of MODIS, the visible and near infrared channels are used to measure objects' reflection while the thermal infrared channels are used to measure objects' brightness temperature. Comparing spectrum characteristic among dust、ground and cloud, some significance characteristics can be found: Cloud has high reflection but low brightness temperature; ground has low reflection but high brightness temperature; the reflection and brightness temperature of dust storm are between the two.So in this paper, based on the reflection and brightness temperature of dust storm, the discriminate functions have been constructed to extract the scope of dust storm and estimate the dust storm intensity grades.

2.1 The Scope of Dust Storm Extraction

The scope of dust storm extraction is that dust storm is separated from cloud、snow、ground, etc and the boundary of dust storm is depicted accurately (Fan Yida,Shi Peijun,Wang Xiushan,2002). Since the 31, 32 bands of MODIS are in the thermal-IR window, absorption by other atmospheric gases is negligibly small and dust has a higher emissive at band 32 than at band 31,the BTD (brightness temperature difference) between the band 31 and band 32 can be used to detect the dust storm. Four interested regions: sand, cloud-sand, cloud and land, are chosen (see figure 1).From figure 2, the threshold -1K of BTD can be used to identify sand from other objects. But if the threshold of -1K is used, some dust storm areas cannot be detected. In order to extract the scope of dust storm accurately, the threshold of 0K is used. In this way, ground and cloud should be separated farther. However, the infrared radiance is primarily sensitive to the upper cirrus cloud layer, especially when the upper-layer cirrus are thick, the BTD cannot be possible to detect dust under cirrus cloud, thus other bands should be considered

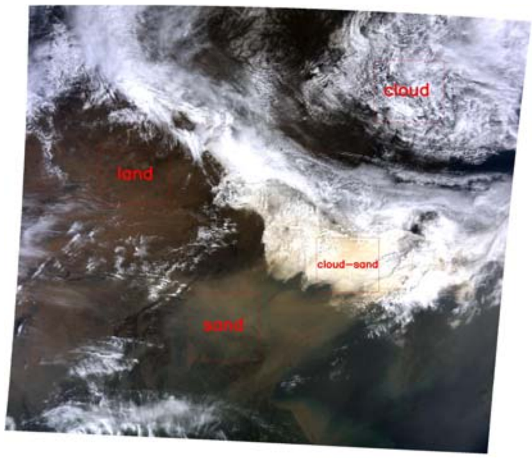

Figure 1.The MODIS true color image on April, 17, 2006, divided into four regions: sand, cloud-sand, cloud and land.

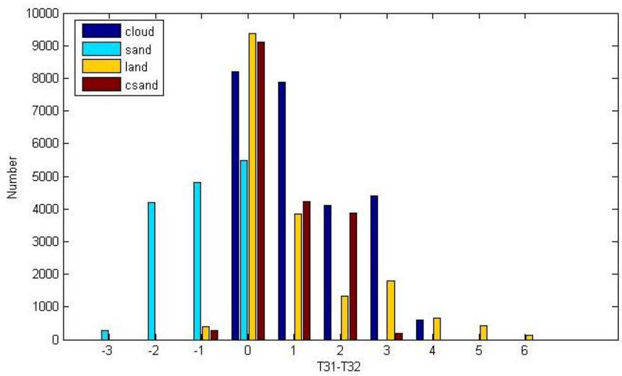

Figure 2. Comparison of the brightness temperature difference (BTD) between the 31 band and the 32 band for four regions: sand, cloud-sand, cloud and land.

At daytime, based on the reflection of different objects, ground and cloud can be separated. The reflection of dust storm was similar to that of ground, increasing with the wavelength. According to the spectral characteristic, the reflection of cloud and snow reaches the maximum at the third band of MODIS(0.459μm-0.479μm),but the minimum at the seventh band(2.105μm -2.155μm).Based on the difference among the reflection of dust storm 、cloud、snow, the normalized difference dust index (NDDI) (John J. Qu, Menas Kafatos,2006) can be used to eliminate the influence of cloud and snow effectively. The NDDI can be written as

$$NDDI = \frac{(b7 - b3)}{(b7 + b3)}$$

where b3,b7 are reflection at the third band and the seventh band of MODIS.

NDDI > 0 can be used to remove the influence of cloud. However，the reflection of water is close to 0 at the seventh band. If there is water, NDDI>0 cannot get a perfect result. So the influence of water should be removed firstly. The seventh band can be used to remove the influence of water, and then, the twenty-sixth band is used to detect cloud.

At nighttime, there is no reflectance information, so the temperature of 11μm is used. The concrete process has been showed in figure 3:

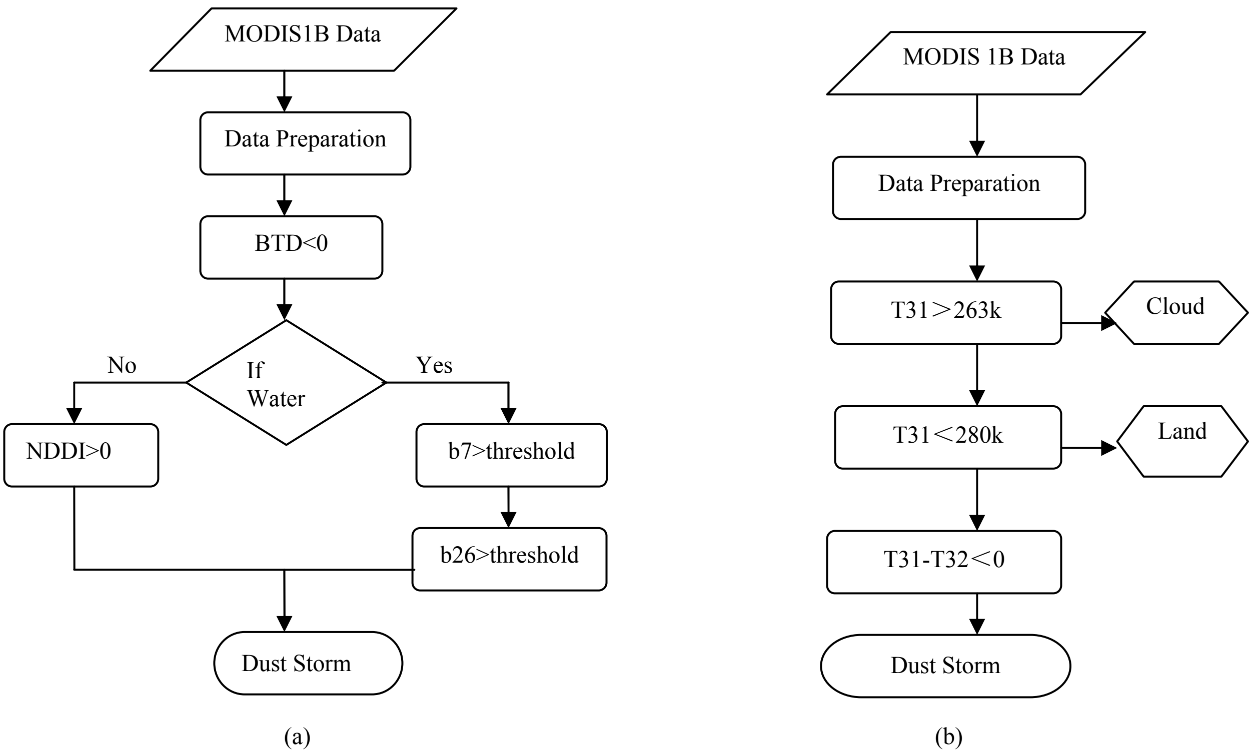

Figure 3.The concrete process for dust storm detection :(a) at daytime ;(b)at nighttime.

2.2 The Intensity Grades of Dust Storm Estimation

Based on the extracted scope of dust storm, dust storm can be estimated as strong dust storm、medium intensity dust storm、weak dust storm. Because dusts particles emit and radiate, backscattering solar radiation at the shortwave infrared band, the twentieth band,, the brightness temperature of dust storm at this band is especially high and the band is very sensitivity to reflect the blowing sand and strong dust storm.. Comparing images of all the channels, it can be found easily that at the twentieth band, the color of dust storm areas is obviously light, but at the other bands, that is dark. At the thermal infrared band, the thirty-first band, dusts particles only emit and radiate electromagnetic wave, so values of sensors are lower. So the brightness temperature difference between the twentieth band and the thirty-first band can be used to estimate the intensity grades of dust storm.

4. CASE STUDIES

A dust storm process occurred in the northwest of China on April, 16-17, 2007.According to the dust storm dynamic monitoring process, four MODIS images are chosen to monitor the scope of dust storm, its intensity and its moving trace,. Result shows dust storm occurred in mid west of Inner Mongolia province and Mongolia, and its central area is in the middle of Inner Mongolia province (see figure 4(b)), then moving to the east, influencing Gansu, Shanxi, Hebei, Tianjin, Shandong provinces, while its intensity changes form weak to strong(see figure 4(d)(e)(g)). In order to verify the method put forward in this paper and compare with the monitoring results, the 1,4,3 bands are chose to synthesis true color images(see figure 4(a)(c)(f)), As shown in the true color images, the top construction of dust storm area is uniform, having texture along with wind, unclear in boundaries. At the desert area, larger sand dune can be discriminated. At the cloud area, especially at medium、altostratus cloud area, the height of different clouds distinct greatly, texture scattered, irregular in boundaries. The monitoring result at night (see figure 4(e)) cannot be compared to the true color images, but it is consistent with the monitoring result of meteorological department. The monitoring result of meteorological department shows: dust storm happened in middle of Inner Mongolia on March, 26, and dust storm also happened at the Hexi Corridor of Gansu, in the mid east of Inner Mongolia, in the north of Ningxia, on March, 27

According to images in this period, the moving trace of dust storm can be monitored: dust storm happens at the west of Inner Mongolia, the north of Gansu, on April, 16, then moving to Shanxi, Hebei, Tianjin, Shandong, influencing Bohai Sea. Its central area moves from west to east.

5. CONCLUSION AND FUTURE WORK

In this paper, Terra and Aqua satellite data are combined to describe the dust-storm moving trace. According to the dust storm monitoring process mentioned above, multi-channel threshold methods have been used to extract the scope of dust storm, its intensity, and then monitoring its moving trace. Result shows greet agreement with the meteorological department monitoring. Conclusions can be gotten: ① Multi-temporal data has high timeliness, so it can be used to monitor the moving trace of dust storm; ②The intensity grades of dust storm should be estimated by the temperature difference between the twentieth band and the thirty-first band.

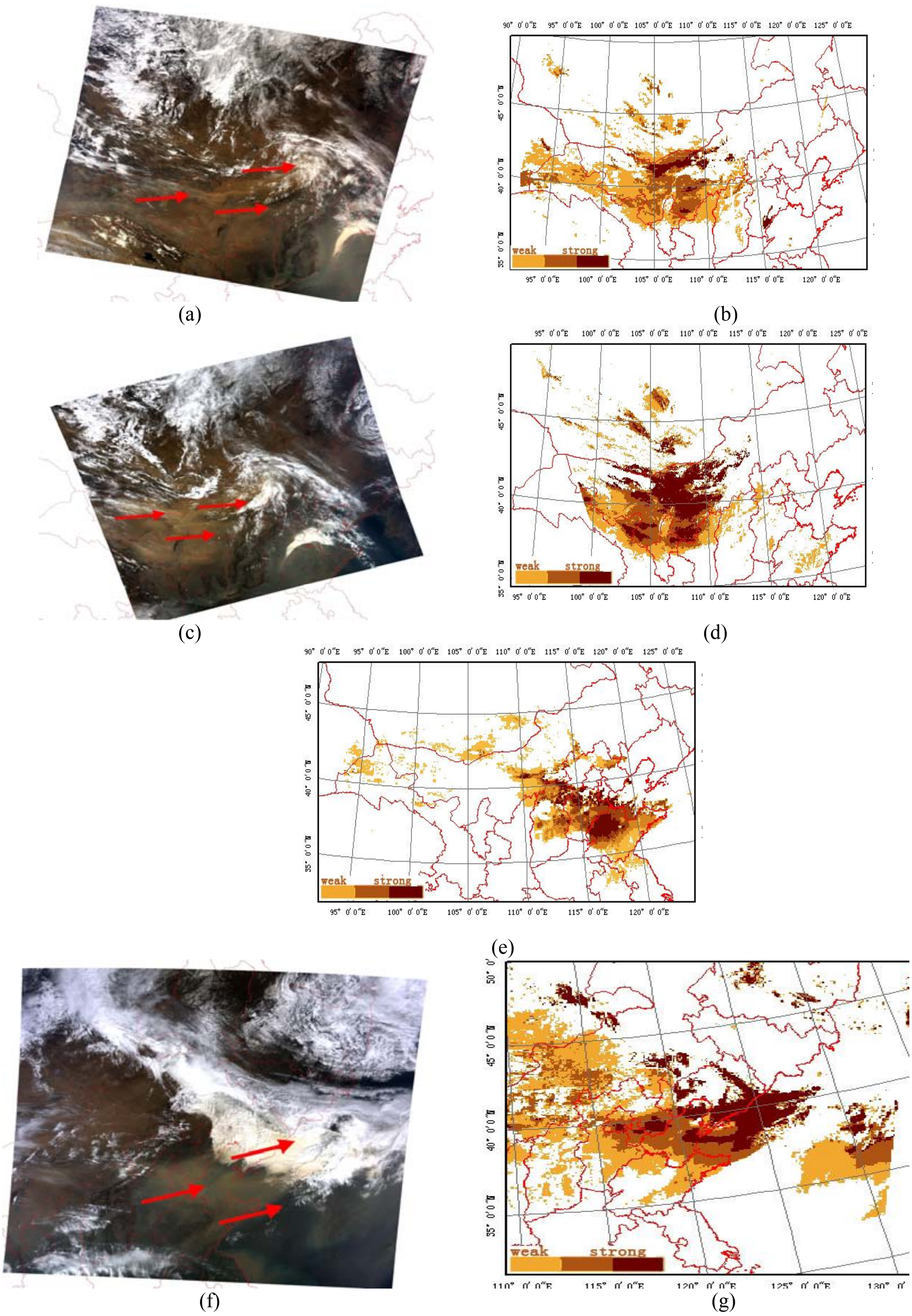

Figure 4. (a) Terra true color image(April,16,2006); (b) Terra image monitor result(April,16,2006);(c) Aqua true color image (April,16,2006);(d)Aqua image monitor result(April,16,2006); (e)Terra image monitor result(April,16,2006); (f) Terra true color image (April, 17, 2006); (g) Terra image monitor result (April, 17, 2006)

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