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Monitoring dust storm using normalized difference dust index (NDDI) and brightness temperature variation in Simi arid areas over Iraq

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Abstract

Dust storms are a natural phenomenon occurring in most areas of Iraq. In recent years, the study of this phenomenon has become important because of the danger caused by increasing desertification at the expense of the green cover as well as its impact on human health. In this study is important to devote the remote sensing of dust storms and its detection. Through this research, the dust storms can be detected in semi-arid areas, which are difficult to distinguish between these storms and desert areas. For the distinction between the dust storm pixels in the image with those that do not contain dust storm can be applied the Normalized Difference Dust Index (NDDI) and Brightness Temperature variation (BTV). MODIS sensors that carried by the Terra and Equa satellite images have been used in different bands and different resolution and the cases studied in 1/9/2015, 16/6/2016/ 20/2/2016.

Key words

Dust storm, NDDI, brightness temperature, MODIS.

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مراقبة عواصف الغبار باستخدام موشرالفرق الطبيعي (NDDI) وتباين درجة حرارة السطوع في المناطق القاحلة للعراق

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الخلاصة

العواصف الترابية ظاهرة طبيعية تحدث في معظم مناطق العراق. في السنوات الأخيرة، أصبحت دراسة هذه الظاهرة مهمة بسبب الخطر الناجم عن زيادة التصحر على حساب الغطاء الأخضر وكذلك تأثيره على صحة الإنسان. في هذه الدراسة من المهم تكريس الاستشعار عن بعد للعواصف الترابية والكشف عنها. للتمييز بين بكسل عاصفة الغبار في الصورة مع تلك التي لا تحتوي على عاصفة ترابية يمكن تطبيق مؤشر غبار الفرق (NDDI) والتباين في درجة حرارة السطوع (BTV). تم استخدام أجهزة استشعار المتمثلة بالقمر الصناعي مودس (MODIS) التي تحمل المتحسسات صور الاقمار الصناعية مثل تيرا (Terra) و اكوا (Equa) استخدمت في نطاقات مختلفة وبدقة مختلفة والحالات التي تمت دراستها في 1/9/2016، /16/6/2016 .20/2/2016

Introduction

Iraq is exposed to many dust storms, that lead to desertification and lack of green cover because of the climate change and global warming which increasing these storms in recent years [1]. Remote sensing is important for detecting and monitors these storms. There are several can be used ways to detect dust storms, for semi-arid areas is difficult to detect and determine these Storms [2]. In this research, for detection the storm and isolate it from the yellow lands as well as clouds can be used the Normalized Difference Dust Index (NDDI). Also the Brightness Temperature Variation (BTV) used as another method for the detection of dust storms [3].

Data used

MODIS (Moderate Resolution Imaging Spectroradiometer) is a key instrument aboard the Terra (originally known as EOS AM-1) and Aqua (originally known as EOS PM-1) satellites surface reflectance data used, such a data can be found in MODIS products MOD9GA, MYD9GA, and the MODIS Corrected Reflectance imagery is available only as near real-time imagery [4]. MODIS surface reflectance data used, such a data can be found in MODIS products MOD9GA, MYD9GA, and it Corrected Reflectance imagery that is only available in the choses photo in real time. Table 1 includes some bands of MODIS. The resolution of the sensor is about 500 m and 250 m (the bands 1 and 2 have 250 m and the bands 3 -7 have 500m while the bands 8 - 36 are 1 km that are represented the sensor resolution. Band 1 is used to sharpen Band 3, 4, 6, and 7, imagery resolution is 250 m, and the temporal resolution is daily.

The MODIS Brightness Temperature layer is calculated from MODIS Calibrated Radiances and is available from both the Terra (MOD02) and Aqua (MYD02) satellites. The MODIS Brightness Temperature, Band 31, 32 layers is the brightness temperature, measured in Kelvin (K), calculated from the top-of-the-atmosphere radiances. It does not provide an accurate temperature of neither clouds nor the land surface, but it does show relative temperature differences which can be used to distinguish features both in clouds and over clear land. It can be used to distinguish land, sea ice, and open water over the polar regions during winter (in cloudless areas). The spatial resolution of the imagery and sensor is 1km, while the resolution of tempolar is daily [5,6]. Three satellite images are used with different dates for dust storm such as1- 9-2015, 16/6/2016 and 20/2/2016, shown Fig.1.

Table 1: Some band settings of MODIS [5].

MODIS Band Used	The range of spectral /µm
1	0.620-0.670
2	0.841-0.876
3	0.459-0.479
4	0.545-0.565
5	1.230-1.250
6	1.628-1.652
7	2.105-2.155
31	10.780-11.280
32	11.770-12.270

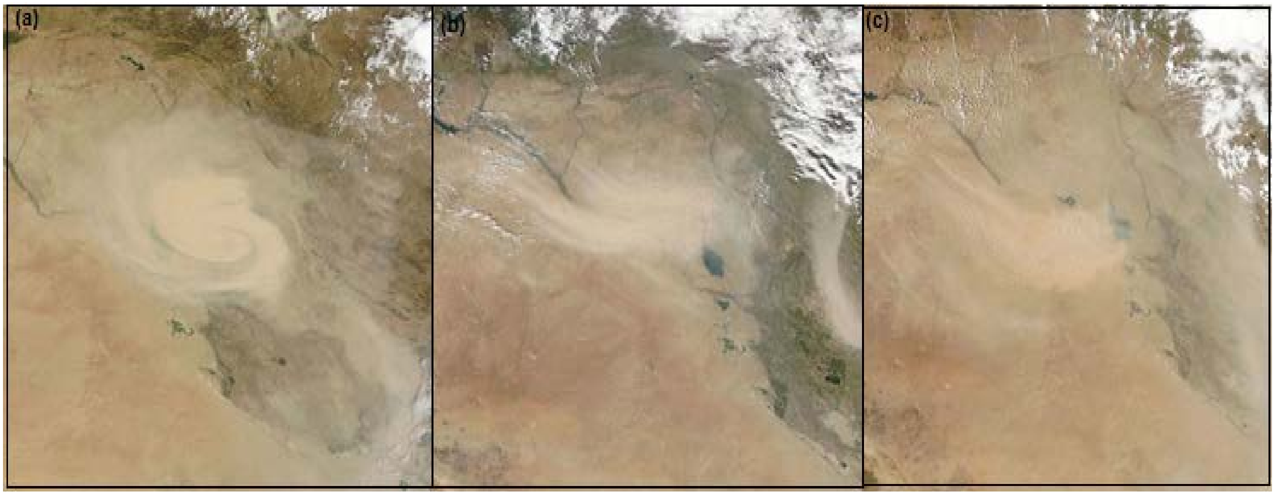

Fig.1: (a) MODIS terra true color (b1,b4,b3) 1/9/2015, (b) MODIS equa true color(b1, b4, b3) (c) MODIS terra true color (b1, b4, b3).

Study area

Table 2: The location of Iraq relative to longitude and latitude.

Country	Longitude	Latitude
Iraq	44° 21' 41.3568" E	33° 18' 46.0980" N

The study area represents as the map of Iraq through which the dust storm from neighboring countries passes, shown Fig.2.

Fig.2: Representing the map of Iraq through which the dust storm from neighboring countries passes.

Methodology of work

1. The NDDI

An algorithm is made up the visible wavelengths which called the NDDI. Many features can analyzed by the spectral signatures such as soil, water, grass and urban residential while the dust (sand and soil) is showing clear through the reflectance, it increases with bands (0.4 - 2.5 μm) for the band 3 has less value (0.469 μm) and the maximum band value 7 (2.13 μm) in MODIS. Spectral feature of sand and soil makes that it easy to distinguish between dust, cloud and bright surface, which have a heigh reflection for band 3. The mathematically is written the formula as [3]:

$$NDDI=(\rho 2.13\mu m-\rho 0.469\mu m)/(\rho 2.13\mu m+\rho 0.469\mu m) \quad (1)$$

where

$\rho 2.13\mu m-\rho 0.469\mu m$ are reflectance at the top of atmosphere (TOP).

2. Brightness temperature variation

A high accuracy results achieved by the NDDI index during night cannot be implemented the visible index. Thermal infrared radiation can be implemented as an important variable for dust determination. The range of bands such as 31(11um) and 32(12um) suggested as a good combination to extract a dust storm. In this work, the algorithm is implementation by bands 31 and 32 differ during the dust storm. The equation for extracting dust storm is [7]:

$$\Delta T = \{B32 - B31(B32 - B31) >= 1K\} \quad (2)$$

ΔT produces a dust region that containing greater than 1 k, and for other objects the ΔT has less than 1k. Therefore, 1 k threshold is set to separate the dust from other objects [7, 8].

Interpretation and discussion of results

1. NDDI index

After applying the NDDI index algorithm on the terra and Equa satellite images, checking the curves of spectral behavior for the classes, this indicates that the clouds have a great reflection, and band 7 has a low reflection MODIS, in band 7 the dust has a different stoke, it has a high reflection and low reflection in band 3. The clouds have much lower brightness temperature than dust in the thermal spectrum. Therefore, clouds and dust have differences in behaviors that are useful for distinguishing between them. Also Over bright surface can be discrimination of dusty from non-dusty pixels. Fig.3 illustrated the curves of spectral behavior [9, 10].

2. Brightness temperature variation

While NDDI index is not applicable during the night, Brightness temperature variation (BTV) can be used. The dust in the air in this situation, the radiation is absorption in a band 32 more than band 31 of MODIS, the attenuation of radiation through a dust storm is greater in band 31 than in band 32. Brightness temperature of band 31 has a value lower than the band 32 and the difference between these bands which are long wave thermal infrared rays will detect dust and aerosols in the air [11, 12].

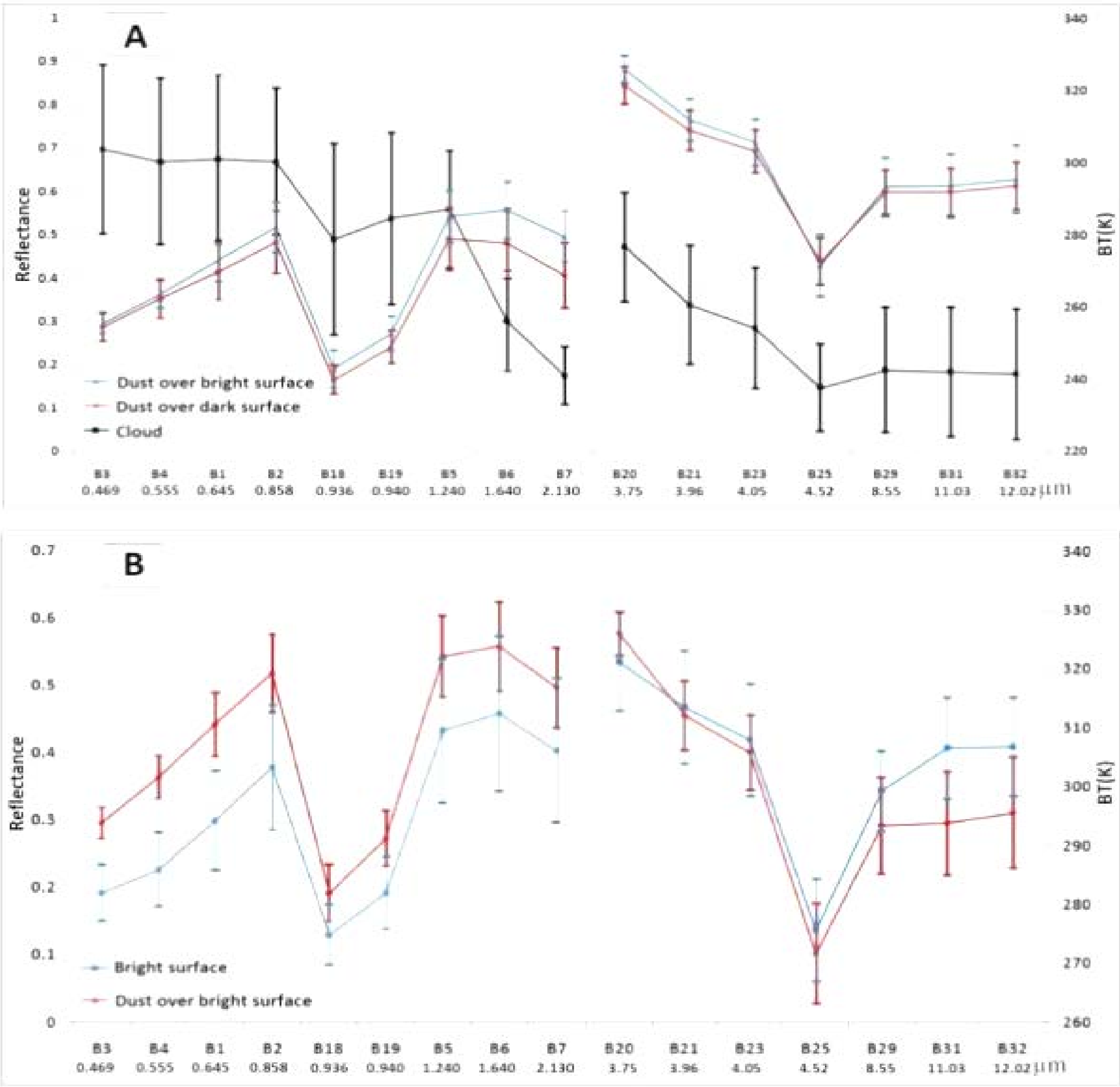

Fig .3: A repersenting the curves of spectral for f dust on a bright surface, in optical and thermal bands are showing the dust on a dark surface and cloud,(B) illustrating the curves of spectral for a bright surface and dust on a dark surface,(Response curves of dust and cloud (left y-axis corresponds to B8, B3, B4, B1, B2, and B7; right y-axis corresponds to B20, B29, B31, and B32). Red line: the reflectance/bright temperature of the cloud) [3].

3. Results and discussion

Band SWIR and short wave visible band VIS, the index showed to be a valuable tool in detecting the rising dust and separating the storm from the clouds and bright dusty surface. Figs.3-5 shows the dust storm clearly (inside the red box), NDDI values lower than 0.05 represent clouds and water bodies, while NDDI values less than equal to 0.18 for surface features (0.05 < NDDI ≤ 0.18) and higher than 0.18 and NDDI greater than 0.18 for SDS. A dust storm can be separated from water; ice and ground features (except ground sand and dust) using the NDDI index. Fig.6 shows the difference between bands 31 and 32 TIR. MODIS uses a temperature brightness band 31 (11um) to separate dust, ground sand and airborne. This threshold 275 K of brightness temperature is suitable for Iraq. This algorithm depends on the difference brightness temperature when dust is in the air, and the dust storm can be extracted from other complex objects. MODIS data with multi-spectrum merit bands and high temporal resolution are approved to be the remote sensing preparedness database upon detection of a dust storm.

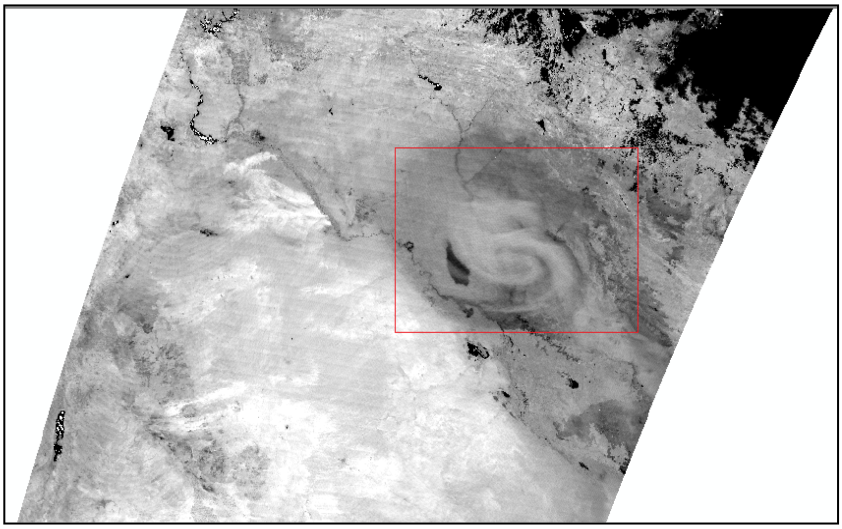

Fig. 4: Applying NDDI index on 1/9/2015 MODIS terra satellite image.

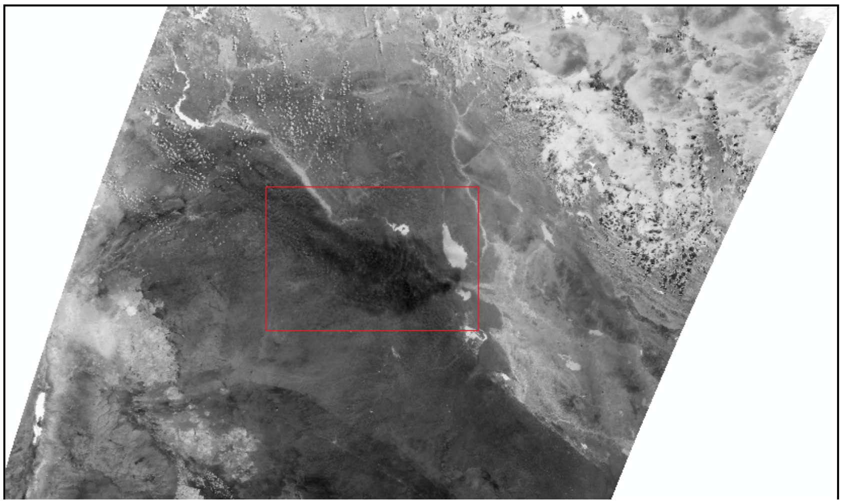

Fig. 5: Effecting NDDI index on 16/6/2016 MODIS terra satellite image.

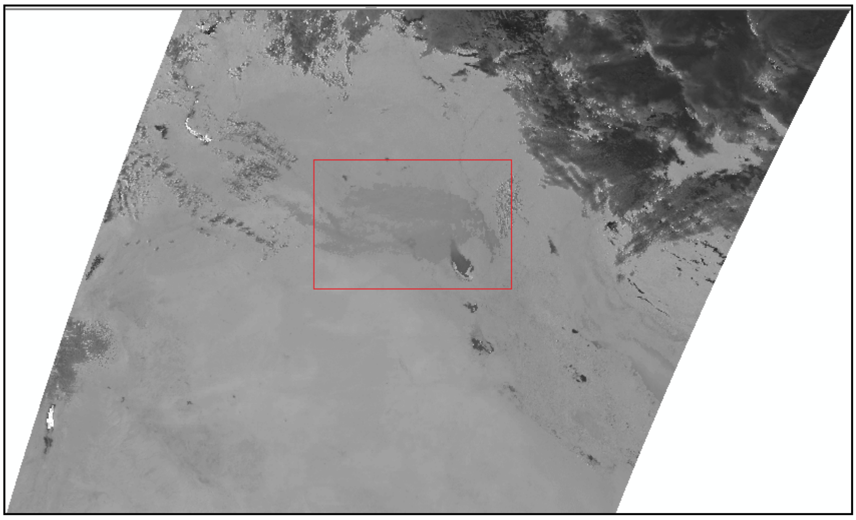

Fig.6: Applying NDDI index on 20/2/2016 MODIS terra satellite image.

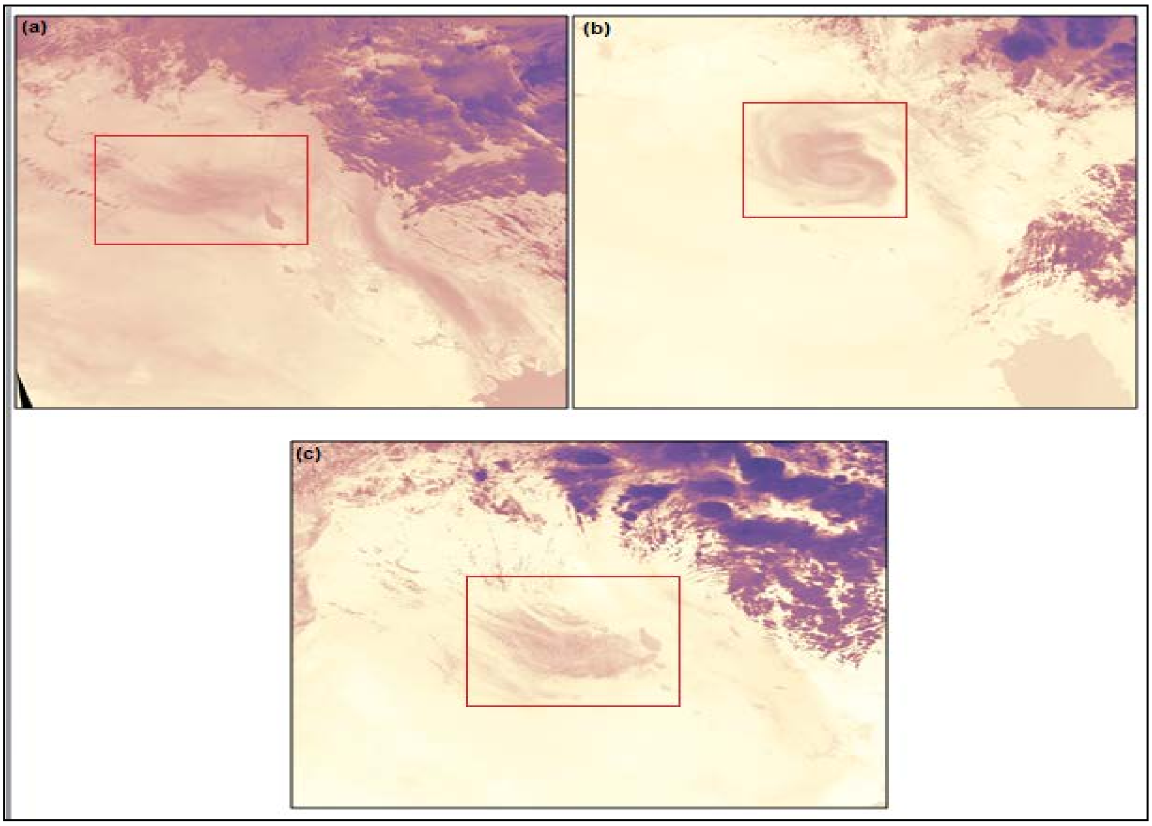

Fig.7: (a) Applying BTD on 16/6/2016 MODIS image, (b) using BTD on 1/9/2015 M0DIS image, (c) by BTD on 20/2/2016 MODIS image.

Conclusions

1. NDDI index are valuable tools to extract dust storms and separating the storm from the clouds and bright dusty surface during daylight.
2. BTV can be extracted dust storm from other features and this algorithm is built on the vary a temperature brightness during a dust is in the air.

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