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Testing the MODIS Thermal Modes for Dust Storms Monitoring

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Abstract

Climate change is one of the global issues that is receiving wide attention due to its clear impact on all living organisms. This is essential for Iraq since it was classified as the fifth most vulnerable country to climate change. One of the manifestations of these changes in Iraq is the increasing frequency and severity of dust storms. In this study, the Normalized Difference Dust Index (NDDI) spectral index for Moderate Resolution Imaging Spectroradiometer (MODIS) sensor bands was used to measure and track the dust storm that occurred on May 16, 2022, as well as to test the validity of one of the daily products of this sensor, MOD11A1, to measure surface temperature and emissivity before and after the storm. It was found that the MOD09GA product is effective in monitoring and detecting dust storms. The areas close to the Syrian borders were identified as the origin of this storm. On the other hand, the MOD11A1 product is not suitable for daily monitoring due to the large number of missing pixels that cannot be compensated by conventional statistical methods or spatial interpolation techniques, as the percentage of missing data sometimes equals half or more of the scene, despite the fact that both products are from the same location and time of capture and under the same weather conditions. Therefore, it’s not suitable for daily monitoring of dust storm phenomena. The average of these data for eight days after image processing can be relied upon to monitor other phenomena or applications.

Article Info.

Keywords:
Dust storms, Emissivity, LST, MODIS, Remote Sensing.

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1. Introduction

Remote sensing data has been employed extensively to identify and map land risks globally. Multispectral satellite sensors are the favored tool for mapping, imaging and monitoring land dangers due to the low expense of such images and the ability to map extremely severe surface expressions of land risks [1]. Land Surface Temperature (LST) is becoming an important element in thermal environment science at both the local and global scales,. It is widely employed in many geophysical fields, including hydrology [2], and acts as a crucial boundary condition for energy flow between the atmosphere and the earth [3]. The Moderate Resolution Imaging Spectroradiometer (MODIS) platform TERRA and AGUE satellite Modes were used in this paper. The surface's reflectance and temperature may be calculated after considering atmospheric correction factors, e.g. water vapors, or other particles when satellite scanner data are considered as observed spectral radiances. All energy flows' impacts are combined in the surface temperature. More details about the condition of the estimations of the thermal characteristics of the topmost layer of the ground are based on estimates of the atmosphere, particularly its boundary layer, and multitemporal values of surface temperature. Sand and dust storms are atmospheric events that result from the erosion and transport of mineral sediments from the ground [4]. Dust storms are a common occurrence in arid and semi-arid (dryland) regions, although they can occur everywhere.

Dry, ungrounded sediments. In Iraq, dust storm occurs regularly. Dust occurrences in Iraq have become more frequent as a result of their emission from active local dust sources or their passage from abroad. The form and size of the dust particles are directly influenced by the emission source, chemical composition, physical features, and wind speed [5]. The detection and monitoring of these storms and measuring LST before and after dust rely greatly on remote sensing [6, 7].

This study aims to test the effectiveness of one of the MODIS (MOD11A1) products for monitoring daily changes in temperature and emissions during dust storms.

1.1. Area of Interest and Data Used

The Middle East, a region of Asia's western continent, is where Iraq is situated. Syria and Jordan are Iraq's neighbors to the west, while Iran is to the east, Turkey is to the north, Saudi Arabia is to the south, Kuwait is to the Southeast, and the Arabian Gulf is to the south, as shown in Fig. 1. The area of Iraq is (437072) km^2 and has a continental climate due to its remoteness from oceans and seas [8]. Dust and sand storms are most frequent in Iraq's spring and summer months, the same as in other parts of the Middle East because of the strong north-westerly shamal winds that characterize the weather during the winter-spring seasonal shifting and desert regions [9, 10]. Iraq, the area of interest, is a complete MODIS scene with a 1200 km x 1200 km area extent to "Coordinates: 35.0468, 43.0305" in the MODIS data index. The scene region reflects the country of Iraq and a section of each bordering country, except Kuwait. The scenarios selected can be characterized as travel by outsiders or active local makers of dust in Iraq Fig. 1.

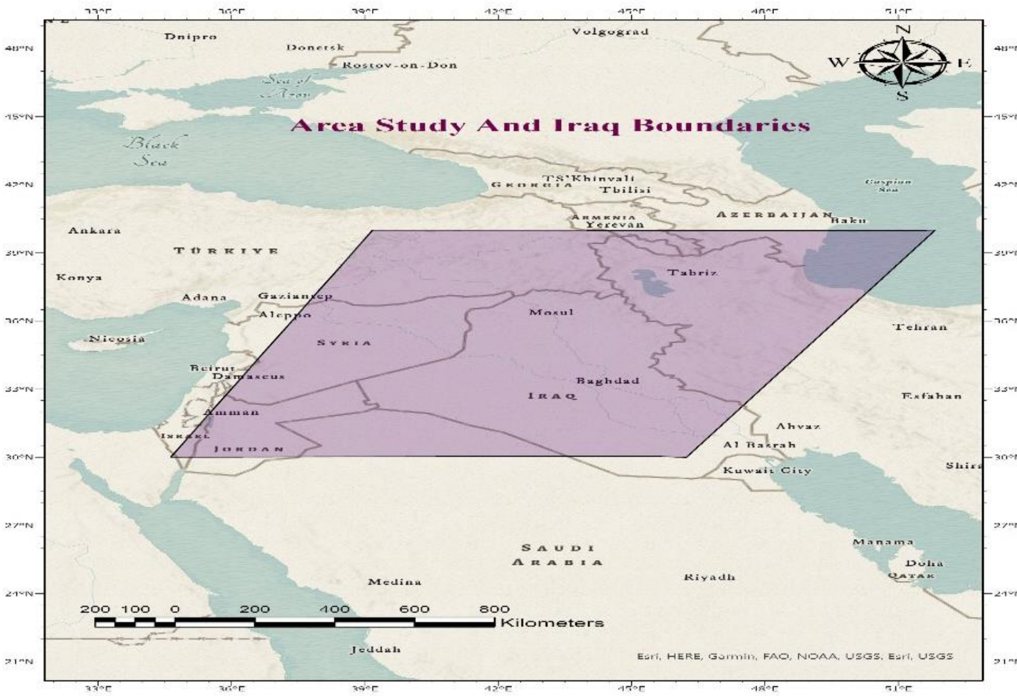

Figure 1: Study area and Iraq boundaries.

MODIS offers more than 40 standard data items from the raw data. The MODIS sensor has three alternative nadir ground spatial resolutions: 250m, 500m, and 1000m, and calibrated at high radiometric sensitivity (12 bit) in 36 spectral bands ranging wavelengths from 0.4 m to 14.4 m [11]. The available data consists of two bands for

MOD11A1 and MODO9GA daily monitoring with (926.62 × 926.62 m^2) spatial resolution and without georeferencing HDF format. Some of the details of the satellite image are highlighted in Table 1. MODIS product MOD09GA band (2,3,4) RGB is shown in Fig. 2. In this paper, the Normalized Difference Dust Index (NDDI) was applied, and LST with dust that occurs in 2022-5-16 was calculated.

Table 1: Some of the information for data used [11].

Sensor products	MODIS/MOD11A1-MOD11A2	Data Type	16-bit signed integer
Data time	Daily	Units	Kelvin
Spatial resolution	926.62 × 926.62 m	Projection	Sinusoidal
Format	HDF	Revista time	2 times a day
Scene dimensions	1200 × 1200 Km^2	Orbit	polar

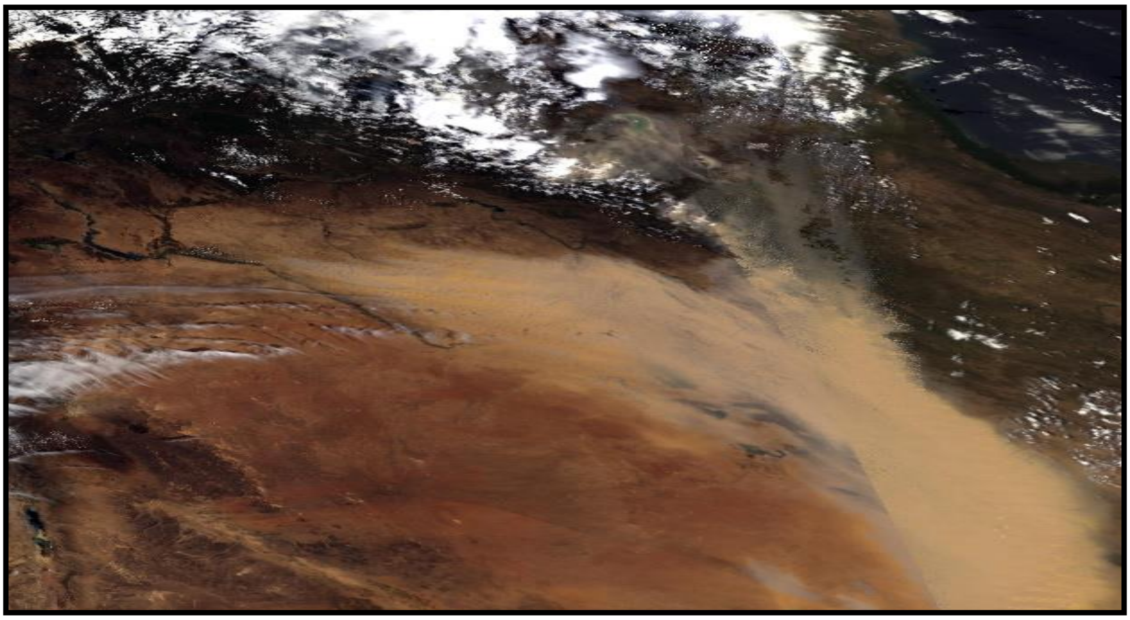

Figure 2: RGB band of MOD09GA 2022-5-16.

2. Methodology

This study applied the NDDI in ENVI to detect the area of dust over Iraq that happen on 2022-5-16 and calculate LST from MOD11A1 for the same data and location. The methodology of this work is shown in Fig. 3:

2.1. Scale Factor

The "LST" SDS's accurate calibration formula is

$$\text{ST} = \text{the SDS data in uint16} \times 0.02 \quad (1)$$

where 0.02 is scale factor calibration its constant for Two-Mode (MOD09GA and MOD11A1), which yields a value between 150 and 1310.7K.

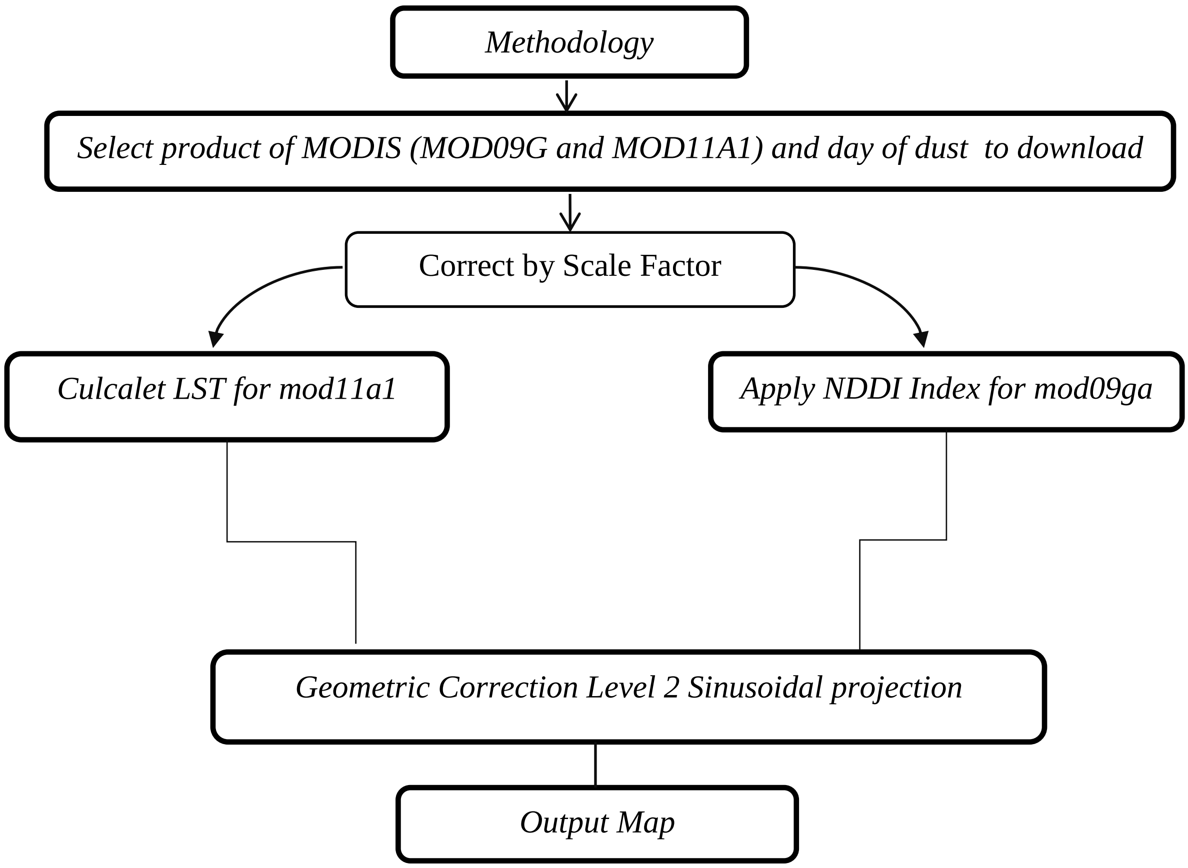

Figure 3: Diagram presenting the methodology used in this research.

2.2. Apply NDDI Index for MOD09GA

Visible wavelengths are used to generate the NDDI algorithm. Band 3 in MODIS has a low reflectance for dust (0.469 m), while band 7 has the greatest band reflectance for dust (2.13 m); hence it rises with bands (0.4 - 2.5 m). It is simple to discern between dust, clouds, and bright surfaces, because of the spectral characteristic of sand and dirt as showen Fig.4, The mathematical formula is expressed as:

$$\mathrm{NDDI} = b_7 - b_3 \,/\, b_7 + b_3 \quad (2)$$

where: b_7 is with 2.13μm wavelength and b_3 is 0.469 μm is the reflectance at the top of the atmosphere (TOP) [12].

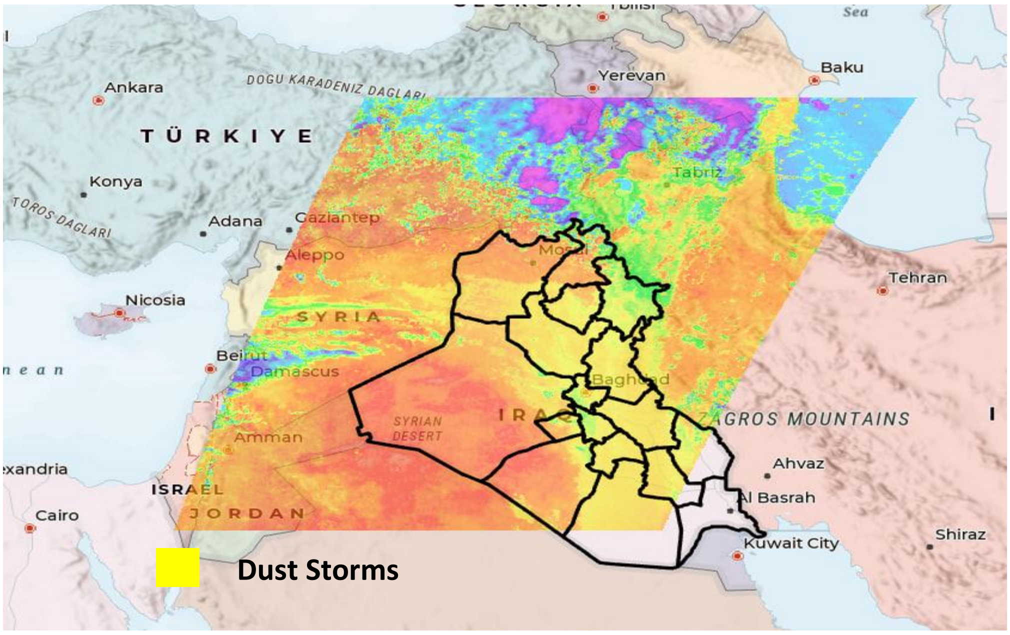

Figure 4: Apply NDDI for 2022-5-16 By Terra Scane.

2.3.Calculate LST for MOD11A1

The land surface temperature is a great indicator of the energy balance on the ground due to the crucial components in the physics governing land-surface operation on both local and global sizes [13]. Although traditional temperatures of the environment are monitored with thermometers on Earth, land surface temperatures are typically assessed through remote sensing techniques that recover satellite thermal infrared information [13].

The technique used to recover the LST of MODIS datasets needs transformation by the scale factor and convert from kelvin to Celsius (°C) degrees from the MOD11A1 product during day and night time. In equation (1), LST with Kelvin degree must be converted to Celsius degrees a follows [11] shown Fig.5 :

$$\text{LST}\ (\text{C}^{\circ}) = (\text{the SDS data in uint16} \times 0.02\ ) - 273.15 \qquad (\mathbf{3})$$

2.4.Geometric Correction

The raw digital image data has substantial geometric distortion. Consequently, the objective of geometric rectification is to modify the positions of the image pixels. Geometric correction was carried out using well-known ground targets (ground control points collected from a reference map). No geolocation is included with MODIS data level 2. To obtain the pixel position from band 31 and 32 emissivity, we georeferenced the sinusoidal projection after finishing the data processing and extraction.

3. Result and Discussion

There are many ways to monitor and identify hotspots of dust storms. Some of these are suitable for certain regions, and others are not, and some of them overlap to a large extent with other atmospheric, such as clouds; but in this research, the point of origin and detection of the dust storm was determined on 2022-5-16, as shown in Fig. 6, using the NDDI, which depends on the reflectivity product of the sensor MODIS in the third and seventh bands. The results of this indicator were that the storm erupted from the nearby areas on the Iraqi-Syrian border. It covered a wide part of the provinces of Iraq, covering an area of more than half of Iraq, as shown in Fig.4. This proves the effectiveness of the indicator and the validity of the data of this product, the MOD09GA.

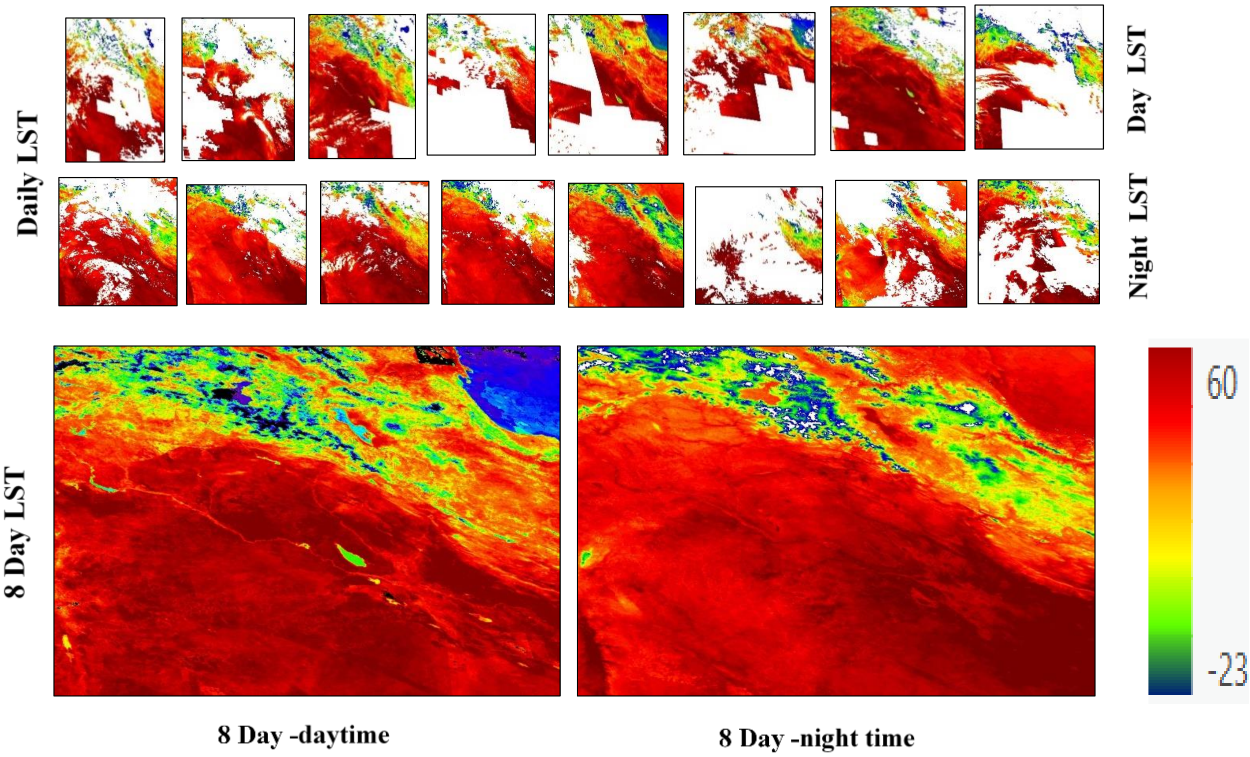

Figure 5: LST for day & night time for MOD11A1.

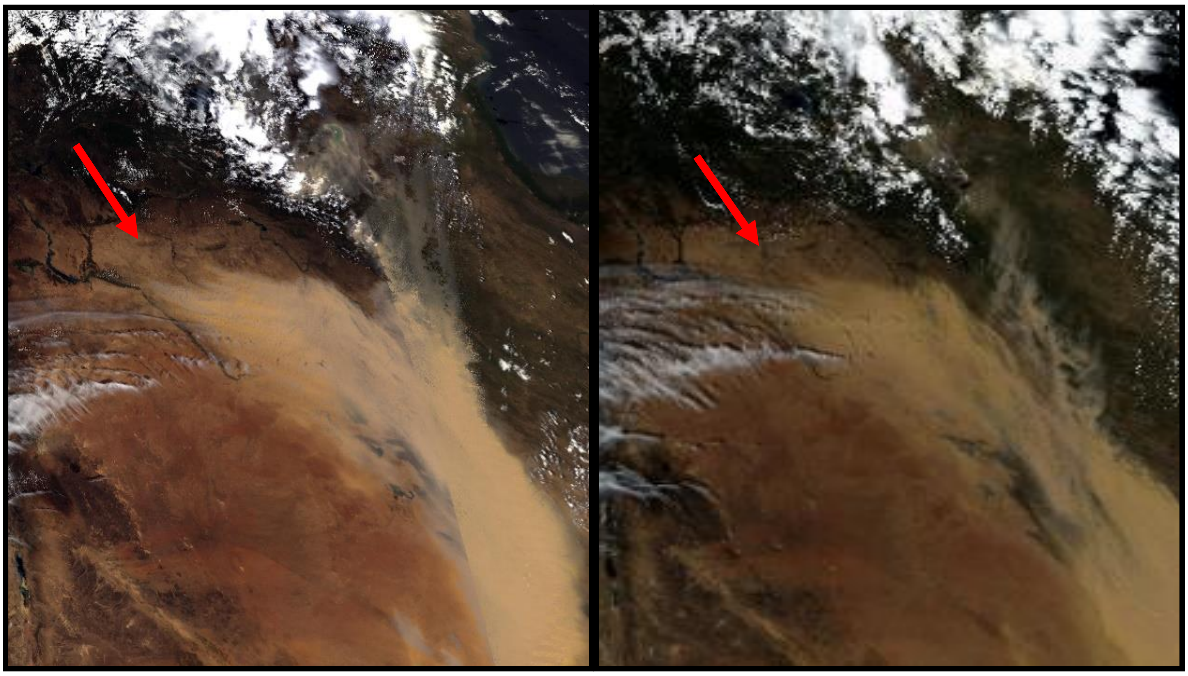

Figure 6: Detect the source by Terra & Aque platform.

The series of images in Fig. 5 represents the daily product of MOD11A1 to monitor storms night and day. They show that there is a loss of data of an amount that cannot be estimated or compensated by the known statistical methods for processing lost image data [14,15], such as spatial interpolation or methods of filling, because all of these methods or others are predictive methods which cannot be relied upon to find the difference between the temperatures before and after the storm. It needs daily data that cannot be replaced by other sensor data when the storm is over.

The last section of the series of images is a compilation of eight images for eight days, the best pixels from each of the daily images and their representation as an average of eight days during night and day.

4. Conclusion

Through the study of different products, reflectance and emissivity and LST, it was found that a product cannot be suitable for daily monitoring of dust storms due to the number of missing pixels; while reflectance data represents an effective and comprehensive product for monitoring these phenomena, taking into consideration that the acquisition time for both products is the same, and at the same location, meaning that both products are working under the same weather conditions, including dust and others.

Acknowledgments

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Conflict of interest

Authors declare that they have no conflict of interest.

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اختبار المود الحراري للمتحسس لمراقبة العواصف الترابية MODIS

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الخلاصة

تعد التغييرات المناخية واحدة من الأمور التي تلقى الاهتمام الواسع عالمياً لما لها من تأثيرات واضحة على سائر الكائنات، خاصة بعد تصنيف العراق كخامس دولة اكثر هشاشة للتغييرات المناخية. واحدة من مظاهر هذه التغييرات هي ازدياد وتيرة العواصف الترابية بالتكرار والشدة على ارض العراق، تم في هذا البحث استخدام المؤشر الطيفي NDDI لباندات المتحسس MODIS لقياس و تتبع العاصفة الترابية التي حدثت بتاريخ 16-5-2022 و كذلك اختبار صلاحية احد منتجات هذا المتحسس MOD11A1 اليومية لقياس درجة حرارة السطح و الأنبعاثية قبل و بعد العاصفة. وجدت ان المنتج MOD09GA هو فعال في مراقبة العواصف الترابية والكشف عنها وتم تحديد المناطق القريبة من الحدود السورية هي بؤرة انطلاق هذه العاصفة، بينما المنتج MOD11A1 هو غير صالح للمراقبة اليومية لكونه يحتوي على عدد كبير من البكسلات المفقودة التي لا يمكن تعويضها بالطرق الإحصائية المعتادة او طرق الاستيفاء المكانية لان نسبة البيانات المفقودة تعادل أحيانا نصف المشهد او اكثر بالرغم من كون المنتجين هما لنفس الموقع وبنفس وقت الالتقاط و نفس الظروف الجوية و بالتالي لا تصلح للمراقبة اليومية المناسبة لظاهرة العواصف الترابية و يمكن الاعتماد على معدل هذه البيانات لثمانية أيام بعد اجراء المعالجة الصورية عليها لمراقبة ظواهر أخرى او تطبيقات أخرى.

الكلمات المفتاحيه: العواصف الترابية ، الابتعاثية ، درجة حرارة سطح الأرض ، مقياس طيف التصوير ذو الدقة المتوسطة ، الاستشعار عن بعد.