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Analysis and Monitoring Dust Storms by using TERRA MODIS Satellite Images in Iraq

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ABSTRACT

Dust storms can be considered as a natural hazard, every year between 100 and 120dust storm are cover large areas of Iraq, the dust aerosol arise to the atmosphere, reducing visibility, effecting on human health, as well as the causes of desertification, **objective**: this paper is aim to monitor, enhance and study a big dust storm happened in 1/9/2015 in covered all Iraq, **results**: the enhancement techniques on the satellite images acquired by MODIS satellite, isolate the storm completely from other features, helping us to measure the distance and area that storm occupied. **Conclusions**: the enhancement and classification techniques shows a new dust features (the very fine arise dust), the distance that storm crossed is **947 km**, and its speed was **19.74 km/hour** .while the area that dense dust storm occupied is **34431.56 km²**.

INTRODUCTION

Dust storms are one of the weather phenomena that do not take a great deal of atmosphere, but they also have an effect on the weather, And on the human environment. as observed that this phenomenon began to worsen in the last decade on the level of Iraq as a result of a lot of environmental and climatic factors, dust storm occur when a strong wind blows above sandy areas, lifting the sand particles from the ground carrying these sand particles in the same direction of the wind blows with speed between 20 to 40 km ,reducing visibility to 500 to 1000 m (Merchant, C.J., *et al*., 2006). Dust storm can impact the climate changes and cause great damages to people health, agriculture , ground transport and the microwave signal attenuation caused by dust (DI. Mei, *et al*., 2008). Remote sensing has shown to be a valuable tool in detecting, mapping and forecasting. It is very necessary to monitor the disasters timely and accurately**,** The Terra satellite is the flagship of NASA's Earth Science Missions**,** Provides global data on the state of the atmosphere, land, and oceans, as well as their interactions with solar radiation and with one another. One of the sensors on board of terra is MODIS (Moderate *Resolution Imaging Spectroradiometer)* A 36-band spectroradiometer measuring visible and infrared radiation (0.4–14.5 μm with spatial resolutions of 250 m, 500 m, and 1 km at nadir) for derivation of products ranging from land vegetation and ocean chlorophyll fluorescence to cloud and aerosol properties, fire occurrence, snow cover on land, and sea ice in the oceans, (Barnes, W.L., *et al*., 2003). the data acquired from NASA earth data, In this study, ARC GIS 10.2 and ERDAS 2014, and google pro maps program were used from enhancement , measuring and classification. The filters were used are: low pass, high pass, brightness inversion and histogram equalization, also the unsupervised classification technique was used to classify the features of the satellite image. The enhancement helps to detect many features(the very fine arise dust) , detecting the boundaries of the storm also the determining the density gradient of storm which enable to estimate the optical depth thickness and the area that dust storm occupied.

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2. Data used and software:

In this study, ARC GIS 10.2 and ERDAS 2014 softwares. The satellite image that used is TERRA MODIS satellite image (multi-spectral image) with resolution of 250 m over Iraq in 31/8/2015, 1/9/2015, 2/9/2015.

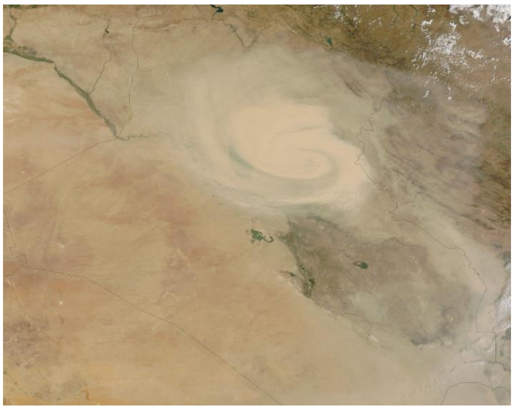


Fig. 1: show the dust storm over Iraq.

MATERIALS AND METHODS

3.1-Image Enhancements:

Image enhancement is the process of making an image more interpretative for a particular application. Enhancement makes important features of raw, remotely sensed data more interpretative to the human eye. Enhancement techniques are often used instead of classification techniques for feature extraction, studying and locating areas and objects on the ground and deriving useful information from images, (Faust, Nickolas, L., 1989).

3.1.1 Spatial enhancement:

Spatial enhancement are procedure that effecting directly on the pixels, the image processing for spatial domain can be expressed by the formula below, (Gonzalez, R.G and P. Wintz, 1977):

$$g(x, y) = T[f(x, y)] \qquad (1)$$

Where:

f (x, y): input image

g (x, y): image processing

T: operator on (f) define over some neighborhood of (x, y)

Spatial enhancement modifies pixel values based on the values of surrounding pixels. Spatial enhancement deals largely with spatial frequency, which is the difference between the highest and lowest values of a contiguous set of pixels. Spatial frequency is the number of changes in brightness value per unit distance for any particular part of an image, (Jensen, j.R., 1986).

There is many ways to enhance digital images including:

A- Filtering

B- Contrast enhancement

A-Filtering:

Filtering consider an Important way to improve digital images, as used to remove noise from images, by (Smoothing) images or sharpen the image details (Sharping), and use filters that affect the picture elements combined. And For the purpose using these filters, the Convolution process shape (3x3) been used, Convolution is a general purpose filter effect for images .It works by determining the value of a central pixel, by adding the weighted values of all its neighbors together ‡ The output is a new modified filtered image, A convolution is done by multiplying a pixel’s and its neighboring pixel's color value by a matrix, (ERDAS, 1999).

The following formula is used to derive an output data file value for the pixel being convoluted (in the center):

$$V = \left[\frac{\sum_{i=1}^{q} \left(\sum_{i=1}^{q} F_{iJ} d_{ij} \right)}{F} \right]$$

Where:
Fij = the coefficient of a convolution kernel at position i,j (in the kernel)
dij = the data value of the pixel that corresponds to fij
q = the dimension of the kernel, assuming a square kernel (if q=3, the kernel is 3 × 3)
F = either the sum of the coefficients of the kernel, or 1 if the sum of coefficients is zero
V= the output pixel value
The most important filters that were used in this process are:

1 - L0W Pass Filter:

Low pass filter remove high frequency components while keeping low frequencies unaffected. edges and other sharp details in an image represent the high frequency component .so the whole effect of low pass filtering is image blurring, (Gonzalez, R.G and P. Wintz, 1977).

Neighborhoods averaging are accomplished by using a mask similar to the one below (Umbaugh, S., 1998):

$$1/9\begin{bmatrix}1 & 1 & 1\\ 1 & 1 & 1\\ 1 & 1 & 1\end{bmatrix}$$

Low pass filter window

2- High-Pass Filter:

By High pass filter sharpening is achieved by highlighting details (edges) using edge detectors. This done by highlighting the fine details in an image or to enhance details that have been blurred, (Gonzalez, R.G and P. Wintz, 1977).

0	-1	0
-1	4	-1
0	-1	0

3x3 masks

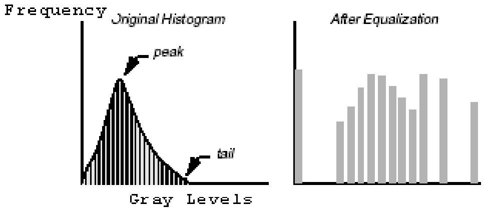
B- Contrast Enhancement:

Contrast enhancement does not depend on the neighbors based technique, but it use the pixel based technique, it add new value for each element in the image according to the transformation equations as these equations change the value of each element in the image, regardless of the values of neighboring elements, This equations adjust the intensity variation of gray levels ,so that, to extend Contrast levels of the digital image, producing high-contrast image, by Darkening the image, or produce low contrast image, by whitening the image, (ERDAS, 1999).

The most important techniques to improve the contrast are the histogram equalization.

1-Histogram Equalization:

Histogram equalization redistributes pixel values so there will be the same number of pixels with each value within a range. So the final result is flat histogram. The Contrast is increased at the peaks of the histogram and it lessened at the tails. Histogram equalization can also separate pixels into distinct groups if there are few output values over a wide range. This can have the visual effect of a crude classification, (Gonzalez, R.G and P. Wintz, 1977).



Histogram equalization (8)

2-Brightness Inversion:

The brightness inversion functions produce images that have the opposite contrast of the original image. Dark detail becomes light, and light detail becomes dark. This can also be used to invert a negative image that has been scanned to produce a positive image. Brightness inversion has two options: inverse and reverse. Both options convert the input data range (commonly 0 - 255) to (0 - 1.0). A min-max remapping is used to simultaneously stretch the image and handle any input bit format. The output image is in floating point format, so a min-max stretch is used to convert the output image into 8-bit format.

Inverse is useful for emphasizing detail that would otherwise be lost in the darkness of the lower DN(digital number) pixels. This function applies the following algorithm (Pratt, William K., 1991):

DNout = 1.0 if 0.0 < DNin < 0.1

Reverse is a linear function that simply reverses the DN values:

DNout = 1.0 - DNin

3.2 Unsupervised Classification:

Unsupervised classification is more computer-automated. It enables to specify some parameters that the computer uses to uncover statistical patterns that are inherent in the data. These patterns do not necessarily correspond to directly meaningful characteristics of the scene, such as contiguous, easily recognized areas of a particular soil type or land use (Jensen, J.R., 1996). They are simply clusters of pixels with similar spectral characteristics. In some cases, it may be more important to identify groups of pixels with similar spectral characteristics than it is to sort pixels into recognizable categories. Unsupervised training is dependent upon the data itself for the definition of classes. This method is usually used when less is known about the data before classification. It is then the analyst's responsibility, after classification, to attach meaning to the resulting classes. Unsupervised classification is useful only if the classes can be appropriately interpreted, (ERDAS, 1999).

RESULTS AND DISCUSSION

4.1 Detection of sand storm by Applying enhancement filters on 1/9/2015 dust storm:

1.low pass filter:

Low pass filter softens the satellite images and the disposal of elements with high intensity and brightness of the image and to maintain the Brightness of the image rate. Figures (4) show, enhanced data with low pass filter. The low pass filter had enhanced the dust storm slightly, but it didn't add any new details for the dust storm to terra satellite image.

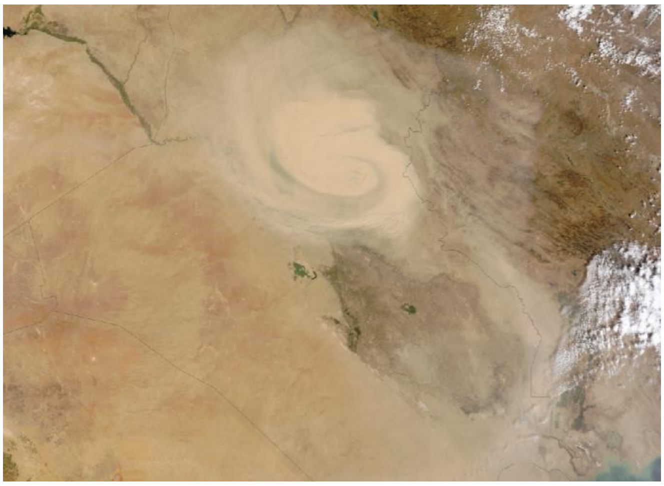


Fig. 2: Showing the enhanced image with low pass filter.

2. High Pass Filter:

After applying high pass filter, good results are obtained such as increasing the clarity of image features, and isolates the dust storm completely from the other features, so that the boundaries of the storm can be recognized easily .figure (3) show enhanced data with high pass filter.

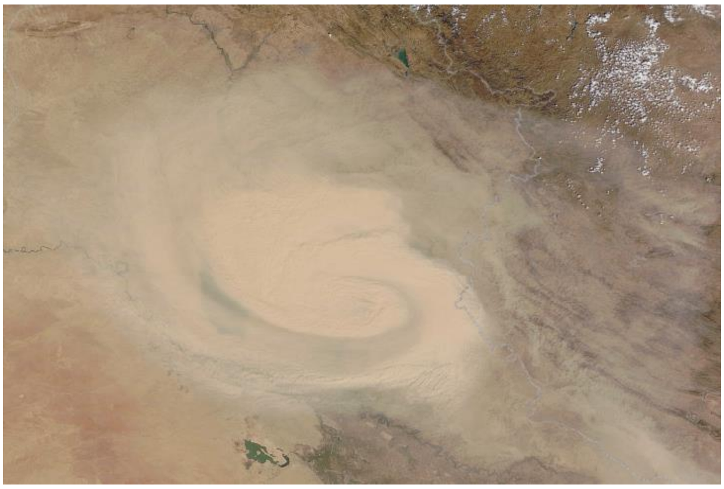


Fig. 3: Illustrated the enhanced image with high pass filter.

3. Brightness Inversion Enhancement:

The application of this filter is allowed both linear and nonlinear reversal of the image intensity range .dark detail becomes light and light detail becomes dark. It gives new details for dust storm, distinguishing between the satellite image features. In addition to the boundaries of the dust storm can be determined, also it shows good result in detecting the density gradient of dust storm, see figure (4).

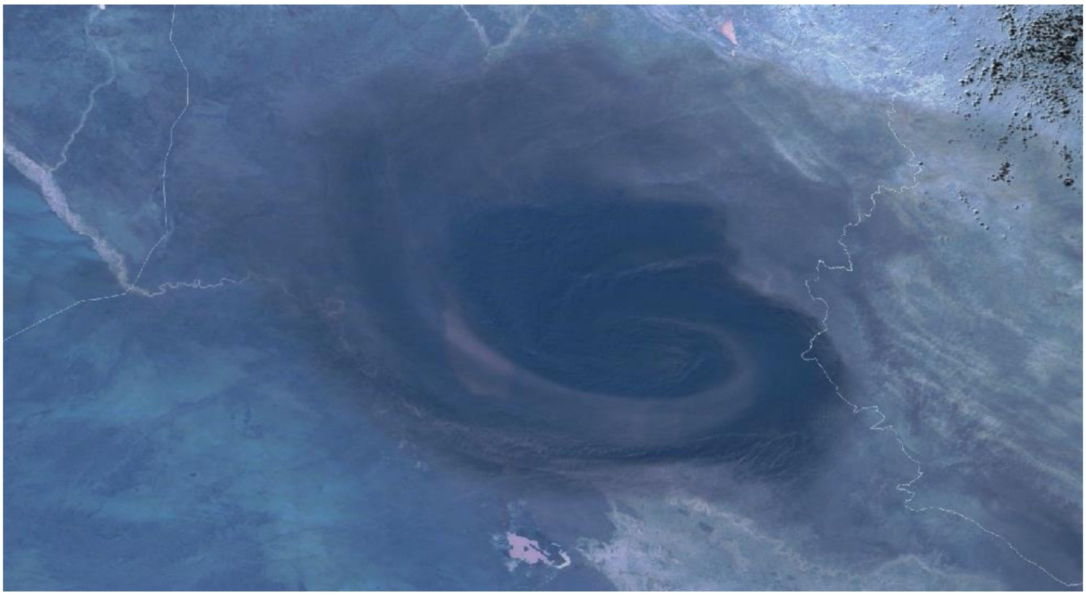


Fig. 4: Producing the image with brightness inversion enhancement.

4- Histogram equalization enhancement:

Histogram equalization showed a great benefit in increasing the contrast between the image features and more clarity for the phenomena of dust storm, also this leads to more clarity to the features the satellite image. Therefore, this technique is useful in getting new details of dust storm even the very fine dust storm, showing figure (5).

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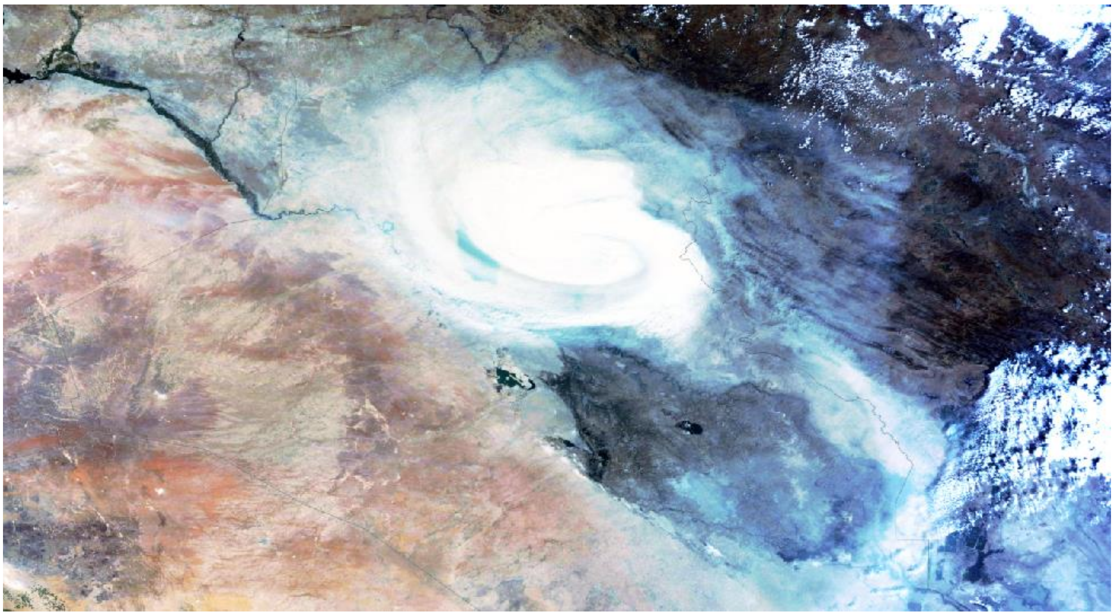


Fig. 5: Represented image with histogram equalization enhancement.

In detecting many features and details which it is not possible to detect by the original image ,in figure (6) one can notice from first image to the right(brightness inversion) the boundaries very clearly ,also the density gradient of dust storm which enable to estimate the optical depth thickness and the area that dust storm occupied for the second image to the left(histogram equalization) new details for the dust storm which is a very fine dust that cannot be distinguish from dusty yellow land in the original color image.

In the third image (high pass filter) the clarity of the features of the image increased and the dust storm completely isolated from other features

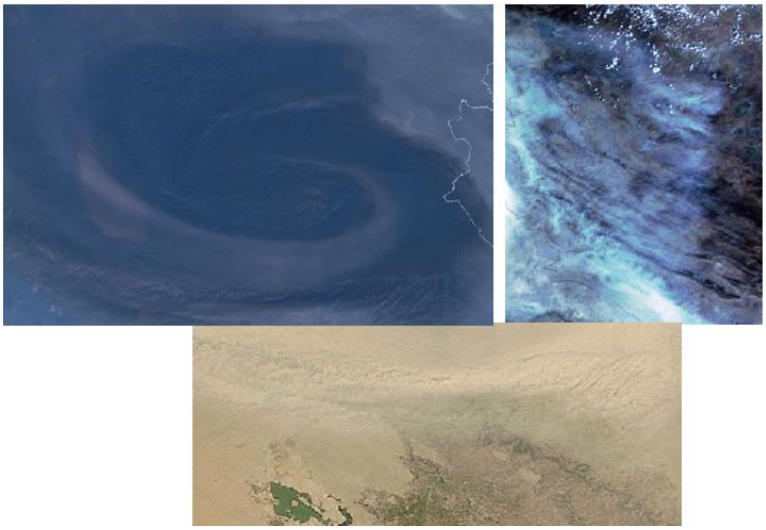


Fig. 6: shows new features for the enhanced images.

4.2 Detection of Dust Storm by Unsupervised Classification:

When applying the Unsupervised Classification, the trial and error methods are used to determine the appropriate number of classes, in the first time (5) classes used, but good results were not given to distinguish dust storms patterns, then by using (10) classes, it show good results in discrimination patterns of dust storms. Figure (7) shows the dust storm classes, the red color represent the dense arising dust regions , the pink color represent the moderate arising dust regions ,and the yellow color shows a fine arising dust regions, while the green color represent the very fine arising dust regions.This technique enables to know many new details, separating the dust storm from the rest of the image features, the density and area of the dust storm, also it showed details of the areas of a very fine dust which is not recognizable in the original satellite image.

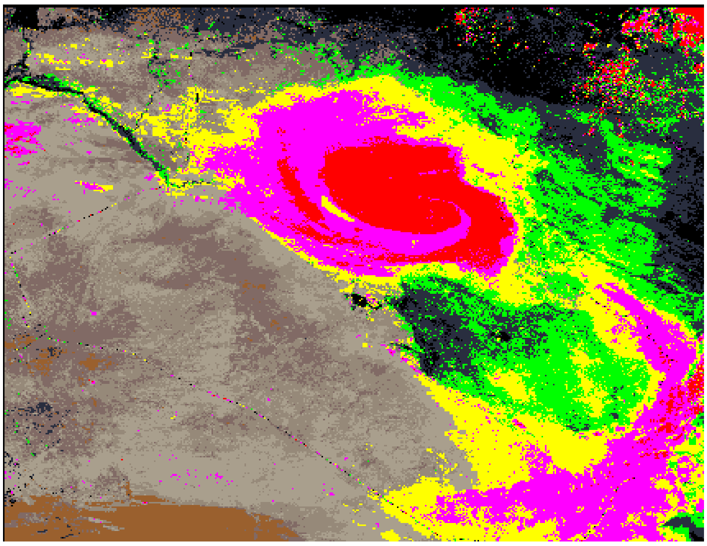


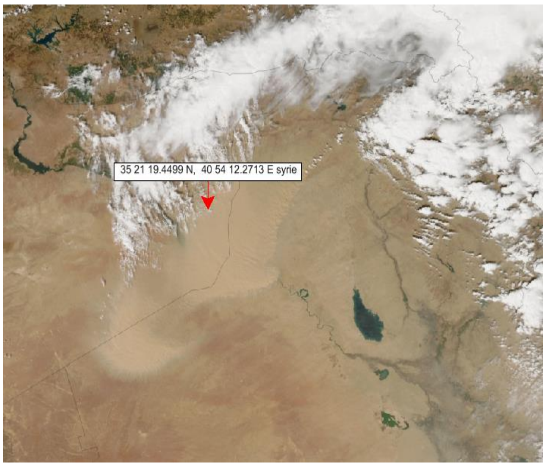
Fig. 7: Showing the Unsupervised classification image.

Row	Color	Red	Green	Blue	Opacity	
0		0	0	0	0	Unclassified
1		0	0	0	1	no dust
2		0.161	0.18	0.247	1	no dust
3		0.604	0.376	0.18	1	no dust
4		0	1	0	1	very fine dust
5		0.506	0.416	0.396	1	no dust
6		0.588	0.537	0.475	1	no dust
7		1	1	0	1	fine dust
8		0.663	0.624	0.553	1	no dust
9		1	0	1	1	moderate dust
10		1	0	0	1	dense dust

4.3 Determination the speed and the area of dust storm:

1- Speed of dust storm:

Estimating the speed of dust storms by using georeferenced images for the day before and after 1/9/2015 to know where the formation of storm begin and where it ends in Iraq, figure (8- a) shows where the dust storm formed in 31/8/2015, figure (8-b) appears where the dust storm ends in 2/9/2015. Using (distance measuring tool) in Erdas to calculate distance that dust storm crossed applying it on MODIS satellite images that have been enhanced with high pass filter (figure 8-c).



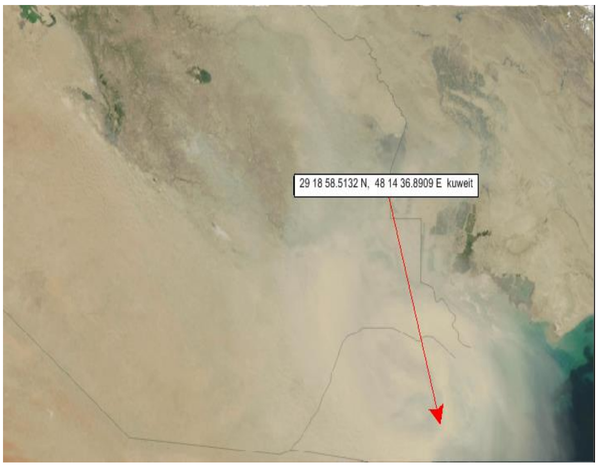


Fig. (8-a) **Fig. (8-b)**

From the georefrance images above one can see that this images is forming in syria (north west of iraq)(35 21 19.1692 N 40 57 25.2590 E) and its end at arabian golf in kuweit (south of iraq) ,(29 30 35.3107 N 48 7 3.9855 E) after using the mosicaing technique in erdas , one can find the distance that dust storm crossed .

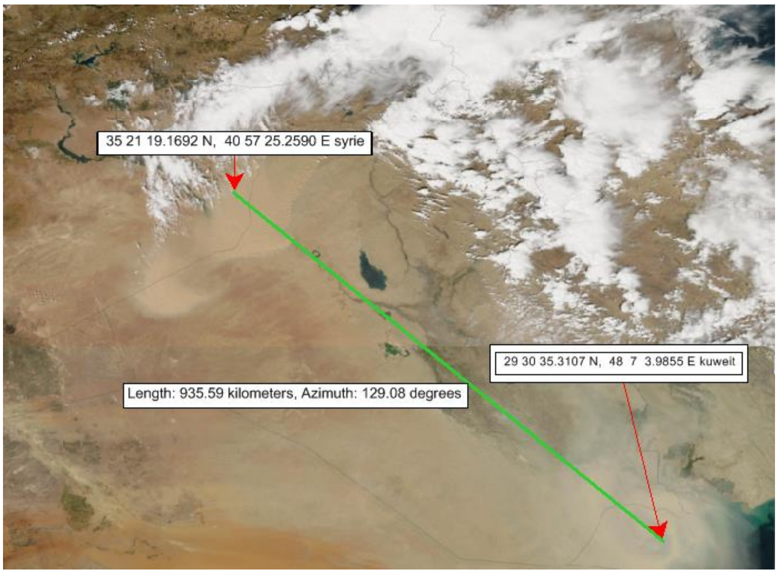


Fig. 8-c: shows the distance that dust storm crossed during 48 hour.

The distance that dust storm travelled to in 48 hours is 947.63 km. By using the formula:

Velocity = distance/time

Measuring the speed of the dust storm is equal to:

Velocity = 947.63km/48 hour= 19.74 km/hour.

By comparing between the speed of dust storm that is calculated by satellite image and the speed that computed by the Iraqi meteorological organization. The results are very close, which shows that can be rely on images satellites to calculate the speed of the dust storm

Table 1: The speed that were calculated by Iraqi meteorological organization

Station	Wind speed km/h
Baghdad	20 km/h
Baiji	------
Mosul	24 km/h
Basra	11.1 km/h
	Average 18.333 km/h

2-Determination of the area of dust storm:

A- Area of dust storm can be calculated by the number of pixels for it, for computing the area of dense dust (class 10) number of pixels is as below

	Color of class	class Description	No.of pixels
Class 10		Dense dust	550905

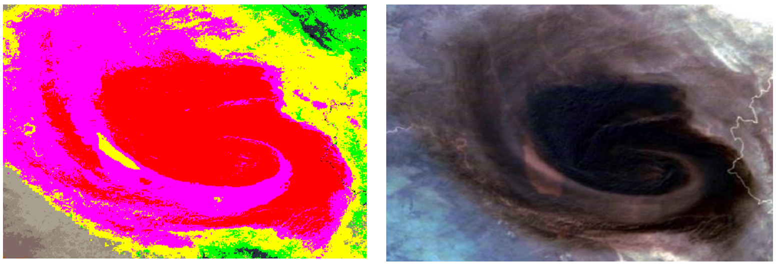


Fig. 9: show the dense dust in red color, to the right a false color image show the dense dust.

By knowing the spatial resolution for the image which is 250 m, area of dense dust storm can be calculated by using the formula below:-

Area= no.of pixels x spatial resolution
Area = 550905 x (250x250)
Area = 34431562500 m^2/ 1000000
Area = 34431.56 km^2.

B- Area can also be measured by using (ERDAS) for the georeferenced image, By drawing the borders of the dense storm ,the brightness inversion enhanced image been used because the boundaries of a dense storm can be clearly noticed, for the same dust storm, the measured area for dense dust is **34203.84 km^2** as in figure (13).

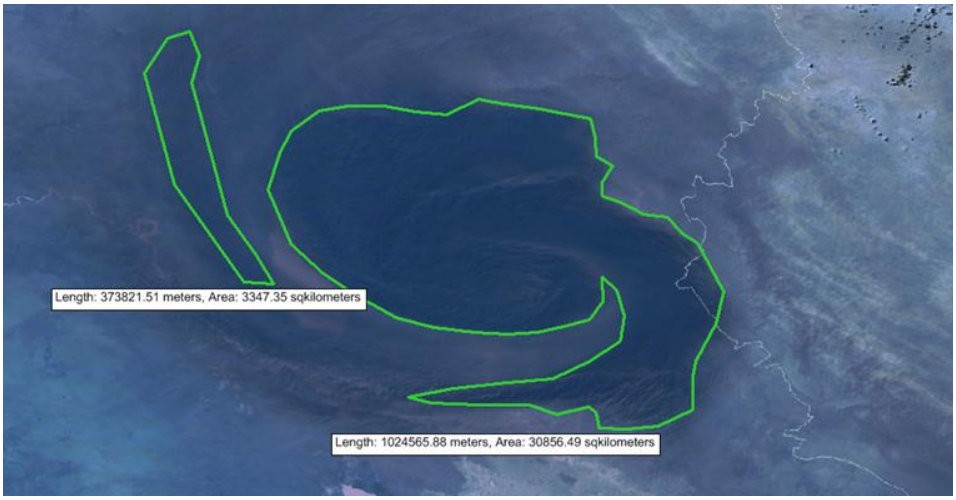


Fig. 10: Producing the borders of the dense storm by ERDAS.

Conclusions:

1- Good results are given by detecting many features and details which it is not possible to detect by the original image.

2- The boundaries very clearly, also the density gradient of dust storm which enables to estimate the optical depth thickness and also the area that dust storm occupied.

3- Histogram equalization that can be recognizes new details for the dust storm which is a very fine dust which cannot distinguish from the original image.

4- High pass filter is given the clarity of the features of the image increased and the dust storm completely isolated from other features.

5- In Brightness inversion, the boundaries very clearly, also the density gradient of dust storm, which enables to estimate the optical depth thickness and the area that dust storm occupied.

6- Speed of dust storm is determined by knowing the distance and time that dust storm crossed from the georeferenced images. Using Erdas measuring tool. The speed that measured for the case that been studied is 19.74 km/hour

7- Area of Storm is calculated relying on the georeferenced satellite images by knowing the number of pixels that represent the storm and the image resolution. It is a very accurate way to measure area for the case that been studied is 34431.56 km^2.

Also area is measured using automated measuring tool in Erdas which given 34203.84 km^2. The reason of the difference in measuring area is that when using measuring tool, storm boundaries must be drawn manually.

8_ classification technique (Unsupervised Classification) is an efficient and effective system gave good results in identifying new patterns of dust storms that could not be distinguished and identified using image enhancement techniques.

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