Monitoring 3rd of March 2011 Dust Storm in Iraq Using Meteosat 9 Images

Azhar Kahdom and Abdul kareem Abdul Ali
Ministry of Science & Technology ,Space Technology & Communications Directorate
Space& atmospheric Science Center, Baghdad,Iraq.

Abstract

Dust storms phenomenon were studied qualitatively in this research with the aides of Meteosat-9 images that has been used for monitoring the path and coverage of the dust storm. The monitoring of dust storm movement were done by using true colour composite image supplied by Europe's meteorological satellite agency EUMETSAT. The Image processing techniques are applied by using ERDAS 8.4 package, where in the first step the images are corrected by Geometric Correction technique for the purpose of obtaining images from which to read the real geographical coordinates. Dust storm coverage area was calculated by using the supervise classification mechanism, as well as been identifying and tracking the change of dust cloud during different stages of dust storm period. The speed of dust storm were calculated by identifying the front pattern of the dust cloud and found to be (37.62) km / h.

مراقبة العواصف الغبارية الهابة على العراق ليوم الثالث من اذار ٢٠١١ باستخدام صور القمر (Meteosat 9)

أزهار كاظم و عبد الكريم عبد علي

مركز علوم الفضاء والجو، دائرة تكنولوجيا الفضاء والاتصالات، وزارة العلوم والتكنولوجيا

الخلاصة

تم في هذا البحث دراسة ظاهرة العواصف الترابية باستخدام الصور الفضائية للقمر الاصطناعي (Meteosat-9) والمأخوذة بواسطة المتحسس (SEVIRI Sensor) حيث تم مراقبة مسار العاصفة التي تعرض لها العراق بتاريخ 3-3-2011 من خلال التتبع الزمني للصور الفضائية المتعاقبة . طبقت تقنيات المعالجة الصورية على الصور الفضائية باستخدام برنامج (ERDAS 8.4) حيث تم اولا تصحيح الصور هندسيا (Geometric Correction) لغرض تحويلها الى صور تقرأ الاحداثيات الجغرافية الحقيقية و تم حساب مساحة العاصفة وتتبع تغير المساحة اثناء مراحلها خلال مراحل العاصفة المختلفة وتم ذلك من خلال تطبيق تقنية التصنيف الموجه (Supervise Classification) ومن ثم حساب سرعتها حيث وجدت (37.62) كم / ساعة .

1- Introduction

The dust (dust or sand) storm is defined as a large mass of air carrying dust particles that can move in very high speed reaching more than 30 km/hr. Dust storm causes a decrease in visibility to (1000-500) meters and in severe storms be up to 10 meters. The shape and size of the dust particles are directly dependant on the source of dust emission and characteristics of the chemical composition and dust physical properties and the wind speed carrier.

Email:abdulkareemabed@yahoo.com

Usually the size of dust particles (clay and silt) are bigger than dust particles. The sand particles are usually the lowest rate in the size distribution of the particles (PSD). Clay and silt dust particles are characterized by irregular forms and they may be with leaf shapes while the sand particles are closed to the oval and spherical shapes. When the wind speed increases the wafting lifting capacity are growing and then the sky covered with brown colour that is because of the spread of dust particles in the air and this leads to reducing the visibility level. Smaller particles arise as a result in higher ground levels while the larger particles are in the lower levels that is because of the inability of the air to carry the large particle of relatively large weight.

Phenomenon of dust storms have been studied deeply by a number of researchers. In 1972 the researcher (Vindgradov) has used satellite data to study the phenomenon of dust storms. Where he managed, through his analysis of the images taken by satellite (I TOS-1) over Iraq and the Arabian Gulf, to distinguish movement and transportation storms from there sources. Also, describing it as a form of quasi-parallel segments of different speed and its visibility less than (1 km) and called this as Great Shamal. The storm extends to cover spaces (500-600) km in length and (20-40) km in width [4]. Auterman in In 1977 conducted his study on using Landsat satellite images taken dust storms followed the coast of Iran and Pakistan. The researcher pointed out those storms that it was in the form of parallel cloud tapes started from point sources and cross over to a distance of up to (100) km and looks at first glance a narrow funnel-shaped spread gradually to about (2) kilometers [5]. In the same year, Patrison reach a mathematical relationship between visibility and the concentration of dust particles in the dust storm [6]. In (1994) Raupach et al, put into a mathematical relationship from which to estimate the amount of dust transportation in dust storm [7]. In (2001) Hazem Hamood, wrote that the reflectance values recorded by TM and MSS landsat sensors are affected by weather factors such as: dust, humidity, and temperature. And he mentioned clearly that dust has the most prominent effect on reflectance and was much bigger than the rest of the factors [8].

In this research the 03 March 2011 dust storm are studied by using Meteosat-9 images taken by the sensor (SEVIRI). Image processing techniques are applied using ERDAS 8.4 were geometrical correction and supervised classification techniques were used to analyze this phenomena.

1-1 Geometric Correction

The data of raw digital image contain large geometric distortions. So the purpose of geometric correction is to correct the location of pixels of the image. Geometric correction is done by taking well known ground targets (ground control points taken from reference map) and relating them to their respective locations in the image.

The example of the correction mechanism is the conversion of the distorted pixel by using the two polynomial equations to obtain the correct coordinate [9].

$xo = a1 + a2\ x + a3\ y + a4\ x\ y + a5\ x^2$ ……..(1)

$yo = b1 + b2\ x + b3\ y + b4\ x\ y + b5\ x^2$ **……..** (2)

Equations show the relationship between the coordinates geometrical correction pixel (x_o, y_o) with the geometrical coordinates (x, y) of the distorted raw data and constants calculated via using the control points

1-2 Digital Classification

Classification process in digital image processing includes a wide range of theoretical methods are used for decision-making in the diagnosis of the image (or part of image) for interpreting the meaning of boundaries and the changing rate in the value of pixels in the digital image. All classification algorithms are based on the assumption that the image for different regions has different characteristics where it is possible to distinguish each type of features and these features vary depending on the goals in the image

Features in different images are based on the intensity and intensity variability of gray and color attributes of the image. In this work the supervised classification has been applied to Metiosat 9 satellite images to identify and isolate the dust cloud. The classification was conducted by using the Maximum Likelihood method which states that any element return to the class whose probability density function has the greatest of other classes. The probability density function for the homogeneous region imposed Gaussian distribution as given the following equation [10]:

$$p(g_h \mid N_i) = \frac{1}{\sqrt{2\pi V_N{}^2}} e^{\frac{(g_h-\mu)^2}{2V_N{}^2}} \quad \ldots\ldots\ldots\ldots \quad ..(3)$$

V_N, μ represent the average and standard deviation of the elements of band gh for the region in the image within heterogeneous class N_i. The classification within the image can be accomplished by (Bay rules') and probability P (g_h / N_i) for each class which are given by the following

$$p(N_i \mid g_h) = \frac{p(g_h \mid N_i)p(N_i)}{p(g_h)} \quad \ldots \quad \ldots \quad \ldots\ldots..(4)$$

Where:

$$p(g_h) = \sum_{i-1}^{N_i} p(g_h \mid N_i)p(N_i) \quad \ldots\ldots \quad \ldots\ldots..(5)$$

NT represents the total number of classes and the term p(g_h | N_i) acts as calibration factor (does not represent probability) and thus equation (4) simplifies to

$$p(N_i \mid g_h) = A_\circ p(g_h \mid N_i)p(N_i) \quad \ldots\ldots \ldots\ldots(6)$$

Where A_o is constant of value equal to [(1/ p(g_h)]. The value of p (N_i) has no practical significance and so we can be consider it as constant value for each class N_i for the following condition[10].

$$p(N_i \mid g_h) \rangle p(N_j \mid g_h) \quad \text{For all Ni} \neq \text{Nj} \quad \ldots\ldots\ldots\ldots\ldots..(7)$$

2- Material & Methods

2-1 The study area

The study area included the Iraq region which is the geographical location between the longitudes (38° 45'- 48 ° 45') and latitudes(29 ° 15 '- 38 ° 15'). Iraq is located in the Middle East region in the western part of the continent of Asia. Iraq's borders from the West Jordan and Syria and from the north is Turkey and from east Iran, and to the south by Saudi Arabia, Kuwait and the Arabian Gulf. Iraq total area is (437 072) km^2 and is characterized by a continental climate due to its location away from the oceans and seas.

Iraq is characterized by hot and dry summer and cold winter. A majority of the rainfall occurs from December through April. Iraq lies most of the year under the influence of a high pressure area. This system leads to decline warm dry winds of the upper atmosphere this caused Shamal wind. Shamal result from strong northwest winds that are funneled into the gulf by the mountains of Turkey and Iraq to the northeast and the high plains of Saudi Arabia to the southwest. The winds most commonly are strongest in the Spring to Summer and hence the Shamal events are as well, although they can occur at any time of year. During that time of year the polar jet stream to the north moves southward to become close to the subtropical jet to the south. The proximity of the two jet streams promotes the formation of strong but often dry cold fronts which create the Shamal.

2-2 data and image processing:

A series of weather geostationary satellites is operated by EUMETSAT (Europe's meteorological satellite agency) one of them is Meteosat-9. They orbit in the earth's equatorial plane at a height of 38,500 km. At this height, the speed of the satellite is the same as the earth's rotation, and the satellite appears to be stationary over a certain point on the equator. This orbit allows the satellite to continually observe the same area: 42% of the earth's surface. The data produced by Meteosat-9 are available from EUMETSAT. operates Meteosat-9 provide weather images for Europe and Africa. The main payload on this satellite is the Spinning Enhanced Visible and Infrared Imager (SEVIRI) which builds up images of the Earth's surface and atmosphere in 12 different wavelengths once every 15 minutes . Figure (1) illustrates satellite image taken by SEVIRI of Meteosat-9. Six sequential images been selected to study the behavior of 3 march 2011 dust storm with 3 km spatial resolution. These images were obtained using three spectral channels, two of them are located within the visible spectrum band (VIS) and the third channel is infrared (IR) channel. A detailed study of a dust storm as atmospheric phenomenon occurred on (03/03/2011) was conducted depending on the ERDAS 8.4

program. This was done through time tracking of successive images where one hour time difference between the images have been chosen. The image series illustrate the dust storm path and direction over the study area.

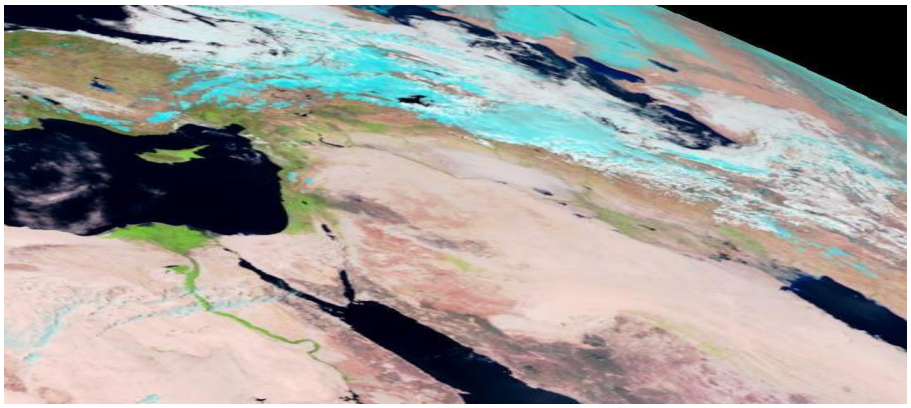

Figure 1- The satellite image (Meteosat-9)

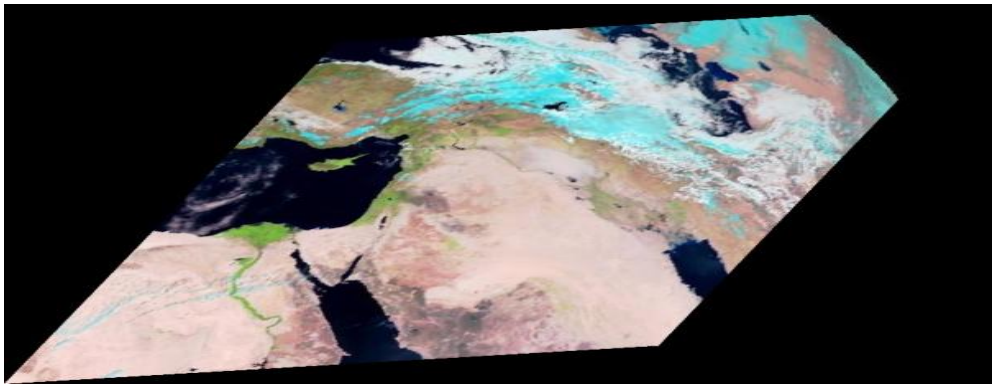

Figure 2- Satellite images geometrically corrected.

Figure 2- shows the satellite image after making the geometric correction.

3- Results and Discussion

3-1 Pre-processing,

Geometric Correction; Geometric correction was carried out on satellite image for the purpose of obtaining digital image containing the geographical coordinates of the area.

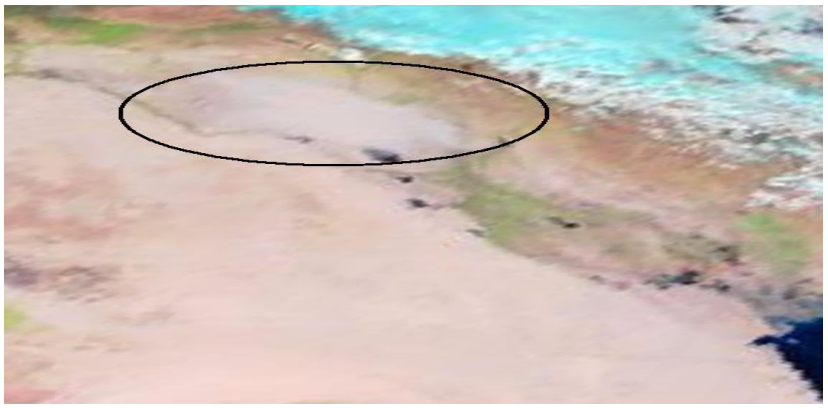

Figure 3-The study region that have been deducted from the geometrically corrected image.

Deducting the study region from satellite images;

The study area was truncated from the satellite image to include all parts of Iraq to display the dust storm. Figure (3) shows the deducted region containing the dust storm cloud within geometrically corrected image.

3-2 Post-processing

Image classification;

The supervised classification was applied on satellite images by using Maximum Likelihood method. This method has given good results when it was applied on the truncated images as shown in classified images in figure (4).

After applying the classification process the class ratio of dust storm was calculated as well as the area of the storm. Table (1) shows the percentages of dust storm in the satellite image. Through figure (5) we note that there is an increase in the area of dust storm cloud during the six hours that have been selected for the purpose of monitoring the dust storm.

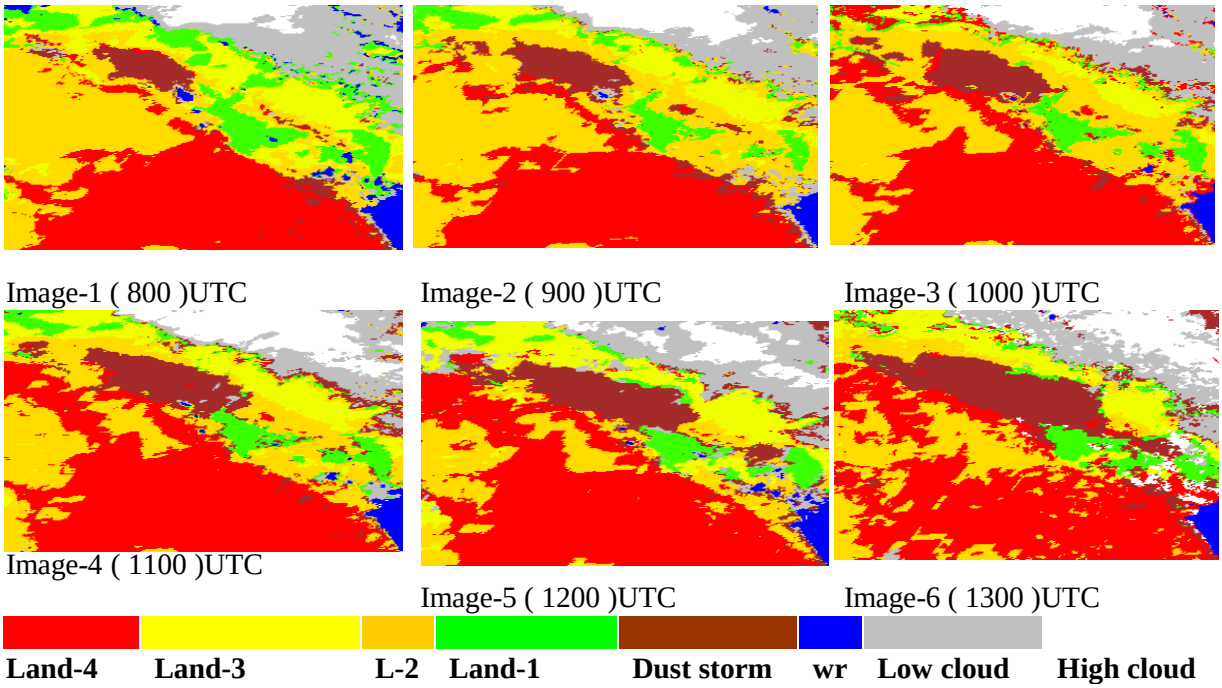

Figure 4- Satellite images, classified

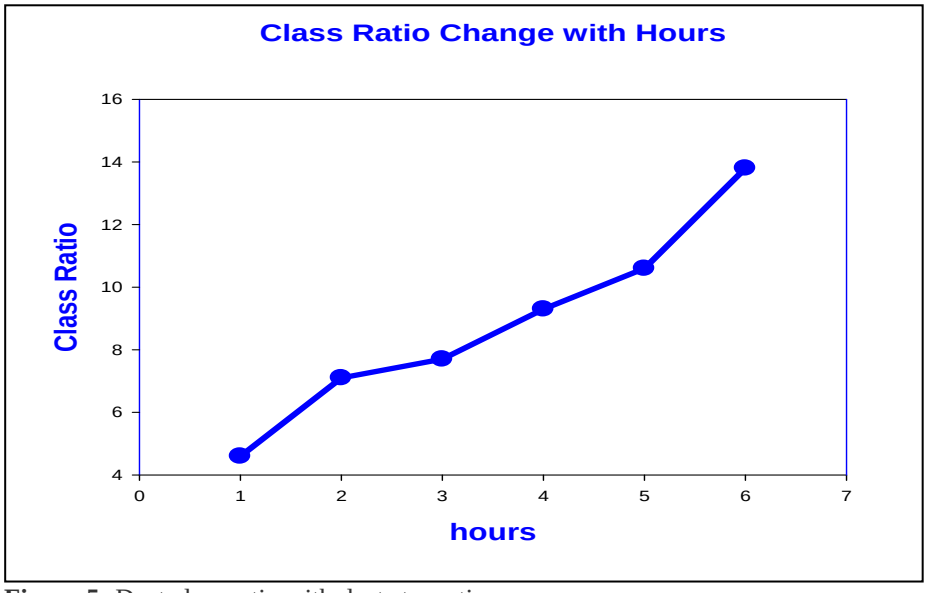

Figure 5- Dust class ratio with dust storm time

Table 1- shows the proportion of class and area of dust storm in satellite images

Images	Dust Class Ratio %	Area dust storm (m)
Image-1	**4.6**	**414000**
Image-2	**7.1**	**639000**
Image-3	**7.7**	**693000**
Image-4	**9.3**	**837000**
Image-5	**10.6**	**954000**
Image-6	**13.8**	**1242000**

Determine a storm front;
Dust storm movement pattern can be determined from the storm front. Storm Front is the boundary between the air mass of dust-free air mass and dust-bearing particles. Figure (6) shows the front pattern movement through the identification of a storm front and the highlight change in the area covered by the storm.

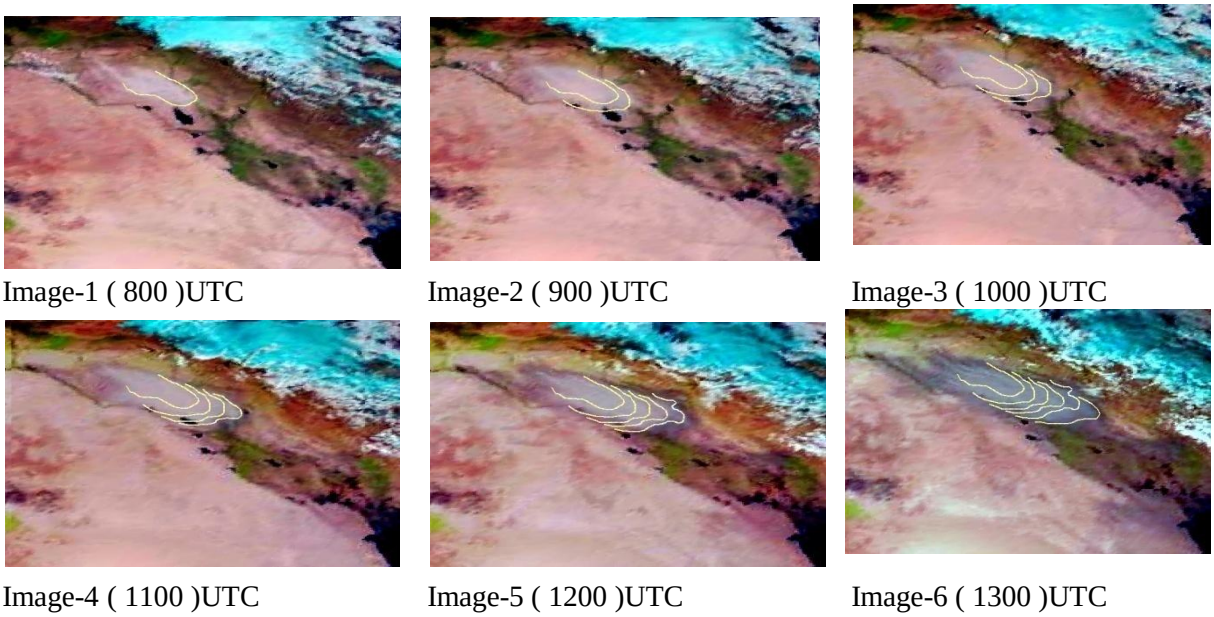

Image-1 (800)UTC Image-2 (900)UTC Image-3 (1000)UTC

Image-4 (1100)UTC Image-5 (1200)UTC Image-6 (1300)UTC

Figure 6- Shows satellite images after determine the front

Estimation the speed of the dust storm ;
Depending on identifying a dust storm front one can estimate scientifically the speed of the storm. This can be done through the following steps:

1- Identify specific points representing good intensity of the storm front in the first and the sixth image.

2- Calculation of displacement between the two corresponding points

3- Calculation of Time

The first image was at the time 800 UTC while the sixth at (1300) UTC. Therefore the time difference between capturing images will be (5) hours and through knowledge of displacement(188.10818 km) accordingly the dust storm speed is (37.62 km / h).

4- Conclusions*:*

The dust storms are natural weather phenomena which have increased in recent decades in Iraq due to the drought caused perhaps from climate change taking place in the earth. The dust storm phenomena

occurs in areas characterized by drought and lack of rain and become a prominent feature of the climate of Iraq.

1- The Maximum Likelihood method showed a good possibility to distinguish dust storm from cloud and classified it from other attractions (clouds - ground - water) easily and thus the calculation of the class storm proportion was taking place in all dust storm progressives. It was found that the percentage covered by the storm began gradually to increase. The area covered by the storm was increased from 4.6 in the first image to 13.8 in sixth.

2- The method for determining the front storm showed good possibility to know the pattern of dust storm and how it moved. According to this determination the dust speed can be easily known. The speed of the storm, which have been identified from the images were (37.62 km \ h) and lies within the range of wind speed that can cause the movement of dust particles to initiate dust storm

4- References

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