OBSERVATION OF DUST STORM CONCENTRATIONS BY USING METEOSAT 9 DATA ARCHIVES

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Abstract

In this research we used archive thermal channels data of the meteorological satellites EUMETSAT 9 to extract a composite space images to detect and monitoring dust storms in Iraq. The study relies on the idea of extracting different concentrations for dust storm by using the variations spectral reflectance within the dust cloud so that it can distinguish the airborne dust from the land features which is normally drought land. After identifying concentration groups and determines the extent of the digital values, a study was conducted to the concentration changes for each group along the dust storm track these mechanism is done by taking capable dust product produced in this work. Many methods of image processing and its related steps were used in this research to standardize and arrange for rectifying the row data of images for analysis ,producing composite images for detection the dust storm and digitizing the different concentrations shapes by using many software's ( Global Mapper , Erdas imagine , Arc gis 9.3 ). The aim of this research is to produce a composite image for detecting the dust storm and to distinguish the dust density within dust cloud by using the thermal bands provided by SEVIRI- Meteosat 9 data.

INTRODUCTION:

For the purpose of monitoring the dust storm by using meteorological satellite, the benefits of using Meteosat 9, which is the Meteosat second generation (MSG) data is their suitability as a complete coverage of Iraq and surrounding countries.

Meteosat second generation (MSG) carries the instrument SEVIRI (Spinning Enhanced Visible and Infrared Instrument) The SEVIRI has been available on board MSG since its launch in August 2002, but the data have been available only since February 2004. SEVIRI provides measurements in 12 spectral channels every 15 min.

Different methods to distinguish between dust storms and other objects like clouds, smoke….etc. can be found in the literatures. Bart. DE P. and at el (2008) present a new algorithm to retrieve aerosol optical depth (AOD) over a desert using the window channels centered at 8.7, 10.8, and 12.0 mm of (SEVIRI. The presence of dust aerosols impacts the long wave outgoing radiation, allowing the aerosols over the desert surfaces to be detected in the thermal infrared (IR) wavelengths. [1]

Ghedira.H. and et al (2009) he detected the dust by making mask pixels with moving dust from SEVIRI HRV and the two other visible channels (R01 and R02). This will be helped with a second neural network system that detects and extracts predefined features in the dust and sand storm fields. [2]

Legrand M. and et al (2001) used an infrared difference dust index (IDDI) for studying dust in Meteosat-IR imagery. IDDI is a satellite dust product designed for climatologically application dust extracted from midday Meteosat-IR imagery. he mentioned in his study that his product takes advantage of the impact of dust aerosols on the thermal infra-red radiance outgoing to space simulating how aquasi-linear relationship between satellite response to dust and shortwave optical depth ,with a sensitivity depending on particle size distribution and radiative surface properties . [3]
Romano, F. (2013) mentioned that the dust aerosol detection algorithm validate of 15 case studies selected between 2007 and 2011. The MSG-SEVIRI visible channel reflectances are used for detecting dust-contaminated pixels over sea. [4]

STUDY AREA:

The case study is a dust storm occurred at 12/4/2011 and it’s located between Latitude (41° 19’ 52”, 24° 57’ 9”) N and longitude (32° 45’ 24”, 59° 04’ 44”) E, Figure 1 shows the study area location on satellite Google Earth Image.

SELECTION OF SEVIRI CHANNELS FOR DUST DETECTION:

The channels of SEVIRI are: 3 visible channels (0.6, 0.8 and 1.6 μm), 8 infrared channels (3.9, 6.2, 7.3, 8.7, 9.7, 10.8, 12.0 and 13.4 μm) and one High-Resolution broadband Visible channel (HRV) (0.4–1.1 μm). Table 1

In this research we used thermal channels (IR12.0, IR10.8 and IR3.9) to produce a dust storm product and then determine the concentrations of dust as shown in flow chart in Figure 2.

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**Table 1**

<table>
<thead>
<tr>
<th>Channel</th>
<th>Wavelength (μm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visible</td>
<td></td>
</tr>
<tr>
<td>IR12.0</td>
<td>12.0</td>
</tr>
<tr>
<td>IR10.8</td>
<td>10.8</td>
</tr>
<tr>
<td>IR3.9</td>
<td>3.9</td>
</tr>
<tr>
<td>IR11.5</td>
<td>11.5</td>
</tr>
<tr>
<td>Others</td>
<td></td>
</tr>
<tr>
<td>HRV</td>
<td>0.4–1.1</td>
</tr>
</tbody>
</table>

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**Figure 1:** The study area

**Figure 2:** shows flow chart of methodology of the research
<table>
<thead>
<tr>
<th>Band</th>
<th>Band width</th>
<th>Primary Uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>VIS 0.6</td>
<td>0.56 - 0.71 µm</td>
<td>Visible - Surface, clouds</td>
</tr>
<tr>
<td>VIS 0.8</td>
<td>0.74 - 0.88 µm</td>
<td>Visible - Surface, clouds</td>
</tr>
<tr>
<td>IR 1.6</td>
<td>1.50 - 1.78 µm</td>
<td>Near Infrared - Surface, cloud phase</td>
</tr>
<tr>
<td>IR 3.9</td>
<td>3.48 - 4.36 µm</td>
<td>Shortwave Infrared - Surface, clouds</td>
</tr>
<tr>
<td>IR 8.7</td>
<td>8.30 - 9.10 µm</td>
<td>Surface, clouds</td>
</tr>
<tr>
<td>IR 10.8</td>
<td>9.80 - 11.80 µm</td>
<td>Long wave Infrared - Surface, clouds</td>
</tr>
<tr>
<td>IR 12.0</td>
<td>11.00 - 13.00 µm</td>
<td>Surface, clouds</td>
</tr>
<tr>
<td>WV 6.2</td>
<td>5.35 - 7.15 µm</td>
<td>Water vapor - High level clouds</td>
</tr>
<tr>
<td>WV 7.3</td>
<td>6.85 - 7.85 µm</td>
<td>Water vapor</td>
</tr>
<tr>
<td>IR 9.7</td>
<td>9.38 - 9.94 µm</td>
<td>Ozone</td>
</tr>
<tr>
<td>IR 13.4</td>
<td>12.40 - 14.40 µm</td>
<td>Cirrus cloud height</td>
</tr>
<tr>
<td>High Res VIS,1 km: HRV</td>
<td>0.5 - 0.9 µm</td>
<td>Broadband visible (0.4 - 1.1 µm)</td>
</tr>
</tbody>
</table>

Table 1: shows the thermal bands are used to extract composite image RGB, Red extracted from the subtracted (IR12.0 – IR 10.8), Green extracted from the subtracted (IR10.8 –IR3.9), Blue (IR 10.8) for dust storm case acquired at date 12/4/2011.[6]

**METHODOLOGY:**

The first step in this research was to produce a composite image enable detecting the dust storm on the Iraqi land using Meteosat9 thermal channels (IR 12.0, IR10.8, and IR 3.9).

For the purpose of identifying the intensity of the spread of dust in a cloud of dust storm, several steps carried out via taking four classes (groups) of digital number values. These tasks is carried out by downloading a sequential images i.e. (10:00 UTC-14:00 UTC) of the dust storm at 12/4/2011.

1- **Step one – dust detection**

RGB composite imagery assign individual wavelengths or channel differences to the intensities of the red, green, and blue components of a pixel color.

Final color assignments of the composite are therefore related to the characteristics of image pixels. Products may simplify the interpretation of data from multiple bands by displaying information in a single image. [5]

Dust detection is successfully carried out by using the difference between the brightness temperatures at channels centered at 10.8 µm and 12.0 µm; because in the atmosphere the mineral dust absorption is stronger at 10.8 µm than it is at 12.0 µm. [4]

![Image](image.png)

*Figure 3: shows the subtraction image between the thermal bands (IR12.0-IR10.8)*

Using the subtraction between the thermal bands of Meteosat 9 –SEVIRI using band IR12.0 –IR10.8 for RED and for the GREEN band using the subtraction between the thermal bands (IR10.8-IR3.9)
and for the BLUE we used the thermal band IR10.8, we combined all these bands in RGB composite image, Figure (4-a) shows dust coverage of the dust storm in magenta color. [6] [7]

A true color RGB composite image of 250 m spatial resolution was produced from MODIS-AQUA data channels (1, 4, and 3) for the same date 12/4/2011 at 10:58 UTC by using ERDAS imagine software. Figure (4-b) shows the dust cloud in brown color and the clouds in white color. The comparison between the METOSAT product and the MODIS product gives a good indication that the METEOSAT product can be used for the monitoring the dust storm and the dust intensity within dust cloud.

2- Step two – the extraction of dust concentration

By using the subtraction between the thermal bands of SEVIRI (IR12.0 –IR10.8) this will give us an image of subtraction in gray scale. This image can be displayed in false color to extract the values of the digital number DN. the gradient in color intensity of the false color image is utilized to determine the classes(groups) of the concentrations. The method of extracting the concentration is shown in Figure 5.
Figure 5: shows the method of extract the concentrations of dust storm using subtraction image of the thermal bands of Meteosat 9

Four concentrations of dust storm were identified ranging from the highest concentration to lower concentration, where the highest concentration iterative DN is few compared to the fourth concentration which is an iterative DN is high and cover a wide area as shown in Figure 6. The area of high concentration is presented in red color and the lowest concentration is blue.

Figure 6: four concentrations of dust storm, the area of highest concentration is presented in red color and the lowest concentration is blue.

RESULTS AND DISCUSSIONS:

For monitoring the dust concentration of dust storm cloud, selected concentrations are computed by using the Arc GIS software using the Raster calculator applying the equation:

\[ A = (a \geq \text{min}) \text{ and } (a < \text{max}) \]

where \( a \) = DN value

<table>
<thead>
<tr>
<th>Concentration class</th>
<th>Concentration range (DN)</th>
<th>Maximum value (DN)</th>
<th>Minimum value (DN)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class 1</td>
<td></td>
<td>255</td>
<td>240</td>
<td>High concentration</td>
</tr>
<tr>
<td>Class 2</td>
<td></td>
<td>235</td>
<td>200</td>
<td>2(^{nd}) concentration</td>
</tr>
<tr>
<td>Class 3</td>
<td></td>
<td>198</td>
<td>177</td>
<td>3(^{rd}) concentration</td>
</tr>
<tr>
<td>Class 4</td>
<td></td>
<td>176</td>
<td>144</td>
<td>Low concentration</td>
</tr>
</tbody>
</table>

Table 2: shows the maximum and the minimum values of Digital number (DN) used in method of determined the four concentrations.
DUST CONCENTRATION ALONG DUST STORM HAD BEEN MONITORED FOR TWO CASES STUDIES AS BELOW:

Case one: monitored the first concentration along the dust storm

In images shown in Figure 7 (a, b, c and d), highest concentration (DN, 255-240) was extracted in four different times per the dust storm day along its trajectory. It has been observed that the highest dust concentration decreases and faded at 13:15 UTC.

Figure 7 (a): highest concentration (Class 1) appears in red color at time 10:00 UTC

Figure 7 (b): highest concentration (Class 1) appears in red color at time 11:00 UTC
Case two: monitoring the first and the second concentrations along the dust storm

The second concentration (DN, 235-200) was taken in Four different times along dust storm per day and its appears as a dust cloud spread along the wind direction.

For monitoring the shape of the wave front of the dust storm and its variation along the trajectory we merge the two highest concentrations of the dust storm (DN, 255-240 and 235-200) will give a good indication about the change in the wave front. This method gives a good observation to the dust cloud area and its variation and its expansion to larger areas along the dust storm trajectory as shown in Figure 8 (a, b, c and d).
Figure 8 (a): shows the merge of the two highest concentrations of the dust storm at time 10:00 UTC

Figure 8 (b): shows the merge of the two highest concentrations of the dust storm at time 11:00 UTC

Figure 8 (c): shows the merge of the two highest concentrations of the dust storm at time 12:00 UTC
Figure 8 (d): shows the merge of the two highest concentrations of the dust storm at time 13:15 UTC

CONCLUSIONS:
1- The use of archival data for Meteosat 9 images gave a good opportunity to detect a dust cloud. The remote sensing software's (ERDAS imagine, ARC GIS and Global Mapper) were used in processing steps for indicating the dust concentrations, coverage and expansion area along the dust storm trajectory.
2- Use of thermal spectral band IR3.9 to produce a composite image RGB shown in Figure (4-a) was effective in the process of discrimination dust over the area of Iraq in magenta color, which is characterized by being a desert area. This product has the ability to detect dust, day or night because of the use of thermal bands.
3- The overall result in this research give a primary vision about the dust deposited along the dust storm trajectory.
4- The processing method in this research is considered as an effective methodology for obtaining aerosol optical depth AOD

References:
6- Kahák. J., 2011 “Overview of the IR channels and their applications - ppt", EUMeTrain 14 June 2011,