



## Identification of Dust Storm Sources in Iraq using Space Monitoring Tools

**Abdulkareem A. A. Mohammed, Maath Ismail Alomari**

Directorate of Space Technology & Communication  
Ministry of Science & Technology, Iraq

### Abstract

The earth cover (soil types) of Iraq is characterized by its variation in its geological and mineral contents. A large area of Iraq can be a source for dust storms that occur in Iraq and neighboring countries. These areas are located in the north western and western parts of Iraq which are characterized by their dryness and minimum vegetation during summer season. The prevailing wind direction in Iraq comes from the northwest and is known as (Shamal). This cold wind front meets a warm air front from the west on areas of soft and light soil cover in north western part of Iraq. This process leads to rise of huge amount of suspended dust and hence to the creation of dust storm which propagate in most parts of Iraq (middle and south).

In this research we observe the occurrence frequency of dust storms as observed from space images and meteorological data. The source of dust storm is also indicated using these space tools.

### تحديد مصادر العواصف الغبارية في العراق باستخدام وسائل المراقبة الفضائية

عبد الكريم عبد علي محمد و معاذ اسماعيل العمري

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

### الخلاصة

تتميز تربة العراق بكونها متنوعة من حيث المكونات الجيولوجية والمعدنية. هنالك مناطق عديدة من العراق تعتبر مصدرا كبيرا للعواصف الترابية التي يشهدها العراق والمنطقة والتي تتركز في المناطق الغربية والشمالية الغربية وتتميز بالجفاف وقلة الغطاء النباتي في فصل الصيف. ولكون الرياح السائدة في العراق هي من نوع الشمال الباردة والتي تصدم مع جبهات الموجات الدافئة والحارة فوق مناطق الجفاف وتؤدي هذه العملية إلى صعود رياح سطحية إلى الأعلى حاملة معها كميات هائلة من دقائق الأتربة مؤدية إلى عواصف ترابية تجتاح المنطقة متجهة نحو الجنوب والجنوب الشرقي.

يستعرض البحث العواصف الغبارية التي حصلت في العراق كما رصدت في الصور الفضائية والبيانات الانثوائية واعتمادا على الأدوات الفضائية تم تحديد مصادر تلك العواصف الغبارية.

### 1. Introduction

Iraq has a great diversity of climate, [1] soil types and natural resources. Iraq, Figure 1-, is situated in Southwest Asia and is bounded on the east by Iran on the south by Kuwait and the Arabian Gulf, on the west by Saudi Arabia, Jordan and Syria and on the north by Turkey.

Iraq can be divided into four main geographic regions. These are the desert in the west and southwest, the rolling upland between the Tigris and Euphrates rivers, the highlands in the north and northeast and the alluvial plain through which the Tigris and Euphrates rivers flow.

The climate is subtropical, hot, and dry, except in the mountains which are located in the northeast of Iraq which are cooler and semi-arid. Iraq geography is contrasting from snowy mountain peaks in the North to sea level at the Gulf, from desert sands to the pasture and green area and wet land (marshes).

The mainly continental climate of Iraq brings a wide range of temperatures, i.e. hot summers, particularly in the south, and cold winters, especially on the north higher ground. The climate can be generally described as mostly desert like with mild to cold winters and dry, hot, and cloudless summers.

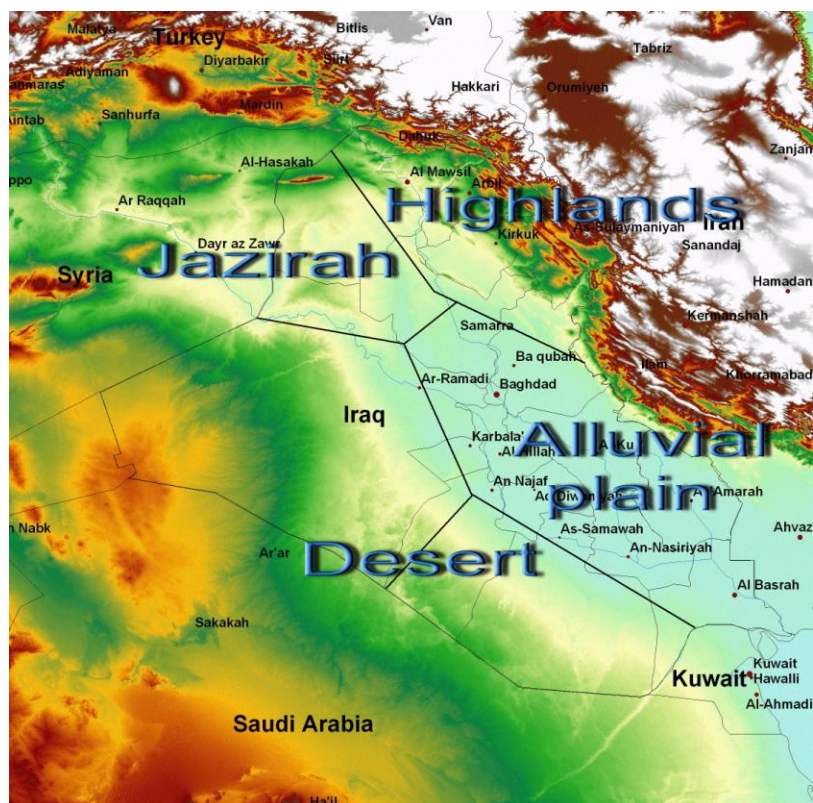


Figure 1- Physiographic map of Iraq

Dust and sand storms are a persistent severe problem in Iraq and other areas in the Middle East, but they are most prevalent in the spring and summer months due to the strong (north-westerly shamal) winds that characterize the weather during the winter-spring seasonal transition and the big arid and semi arid land near Iraq [1], figure 2- illustrates arid lands of the worlds[2].

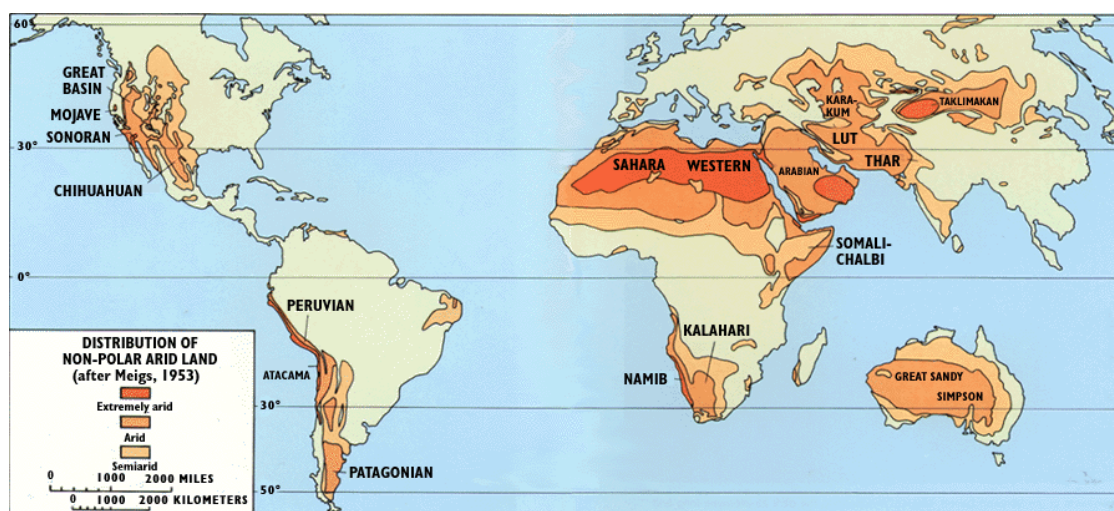


Figure 2- Arid Lands of the World, Map courtesy of United States Geographical Survey [2]

## 2. Physiography and land cover of Iraq

Soil cover varies according to the geological content and the physical condition of the land cover which depends on its mineral contents in relation to the basic rocks in addition to erosion types. In addition to the geomorphology and the plant cover we can classify the soil types in Iraq according to the geographic regions. There are four main geographic regions of Iraq figure 1-. These are the desert in the west and southwest, the rolling upland between the Tigris and Euphrates rivers, highlands in the north and northeast and the alluvial plain through which the Tigris and Euphrates rivers flow [3].

### 2-1 Desert region:

The desert region is located in the west and south west of the Euphrates and it is part of the Syrian desert which runs west into Syria and south into Saudi Arabia. Here and there on this sparse wasteland is a pattern of waterways, dry all year except for the brief floods during the winter rains. The soil in this region is a result of mechanical erosion, due to wind effect .The soil in this region is mostly sand with gypsum and salty detritus materials, and this region is characterized by the presence of sand dunes.

### 2-2 Rolling upland region “Jazirah”:

The uplands region running between an area north of the Tigris and Euphrates is called Al Jazirah, Arabic for “the island ” . It is actually part of a larger area which extends westward into Syria and Turkey. Although there is more water in this area, running in deep cut valleys, it is still dry enough to be considered a desert. Its soil is characterized by its inclusion of sand and gypsum and calcite detritus. Its thickness varies from one location to another, its color is mostly brown. It also contains large proportion of conglomerate and calcareous material which belongs to Bakhteiari Formation.

### 2-3 Highlands region:

Iraq's northeastern highlands extend into the Turkish and Iranian borders. The area begins as broad steppes and blends into mountains ranging from 1,000 to 3,750 meters in height. Except for a few valleys, the only useable area is some of the foothills and steppes used for grazing. Soil and rainfall conditions make some agriculture possible. It contains residual soil as a result of chemical erosion and it is usually thin in thickness and red to brown in color. It is characterized by its low salt contents and its clay of monmorlenite type. This region is located in north and north east of Iraq.

### 2-4 Alluvial plain region:

The alluvial plain begins north of Baghdad and extends to the Gulf. Here the Tigris and Euphrates rivers lie above the level of the plain in many places, and the whole area is a delta interlaced by the channels of the two rivers and by irrigation canals. Intermittent lakes, fed by the rivers in flood, also characterize southeastern Iraq. There is also a fair amount of marshland in this area. It consists of clay deposits mainly from Tigris and Euphrates rivers with a thickness that reaches 4 meters. This soil is

rich in CaCo<sub>3</sub> and CaS<sub>2</sub>, NaCl, as a result of evaporation of underground water during summer season, to the south of Iraq, the soil is salty due to shallow water table.

The map in Figure 3- represents the classification of soil types in Iraq from the compilation of Buring (1961) soil classification (ability of soil of agricultural activity) , space based supervised classification of soil types (hassan, 1990) and the geological map of Iraq (Directory of exploration and geological survey of Iraq , 2000).[4]

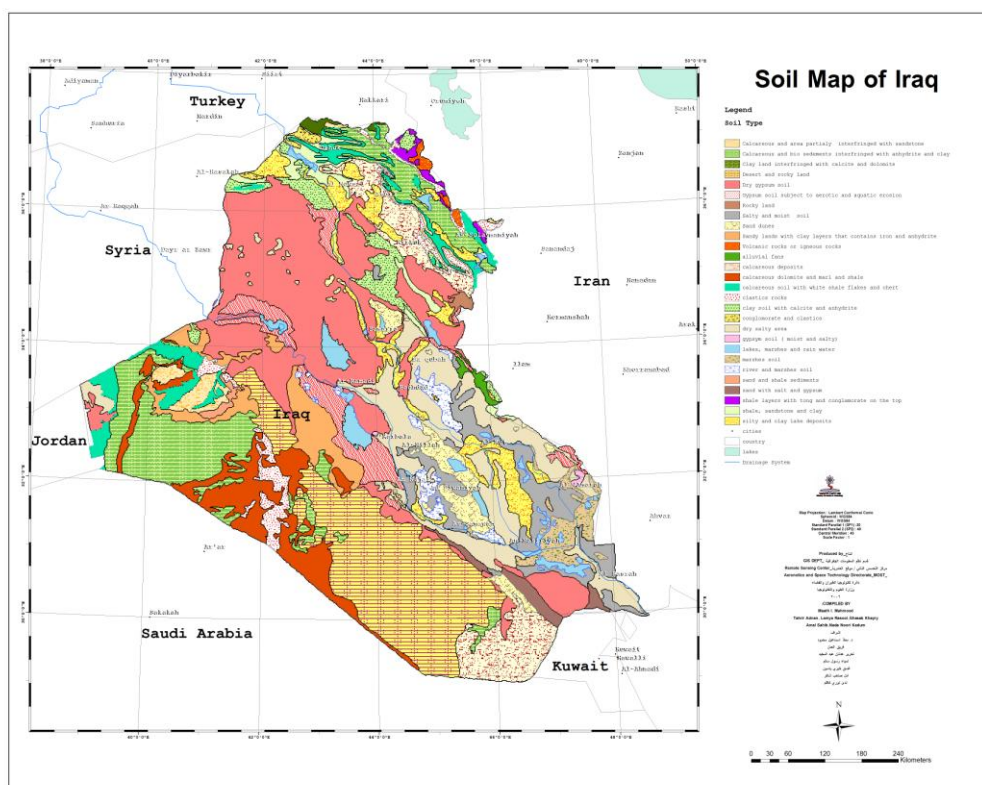


Figure 3- Generalised soil map of Iraq[3]

### 3. Iraq climate. Dust and Sand Storm Formation

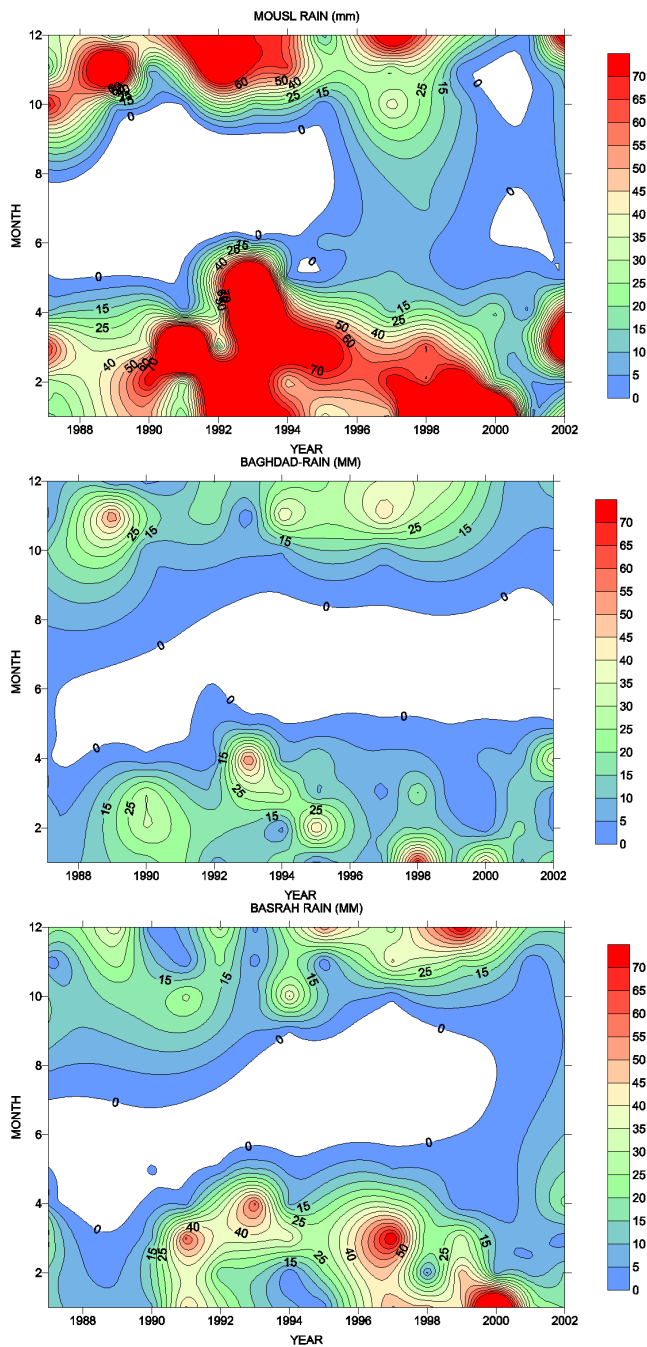
Iraq's mainly continental climate brings a wide range of temperature, with hot summers, particularly in the south, and cold winters, especially on the higher ground. The climate can be described as mostly desert like with mild to cold winters and dry, hot, and cloudless summers [1]. The mountains in the north along the Iran and Turkish borders, receive heavy snows during the winters and are sources of floods in the spring. In the mountainous region, summers can be a little cooler and humidity is lower than in the south. During winter months (October to April) snow often falls on the mountains.

The southern area around the Gulf has extremely high humidity and some of the highest temperatures recorded anywhere in the world. Rainfall is heaviest in the north-east and falls mostly between October and May. On the central plain, however, less than 152mm falls annually. Desert areas receive virtually little rainfall. Average Mean Annual rainfall in mm of ten years intervals for years from 1970-2005, in some Iraqi meteorological stations are illustrated in table 1-, [5].

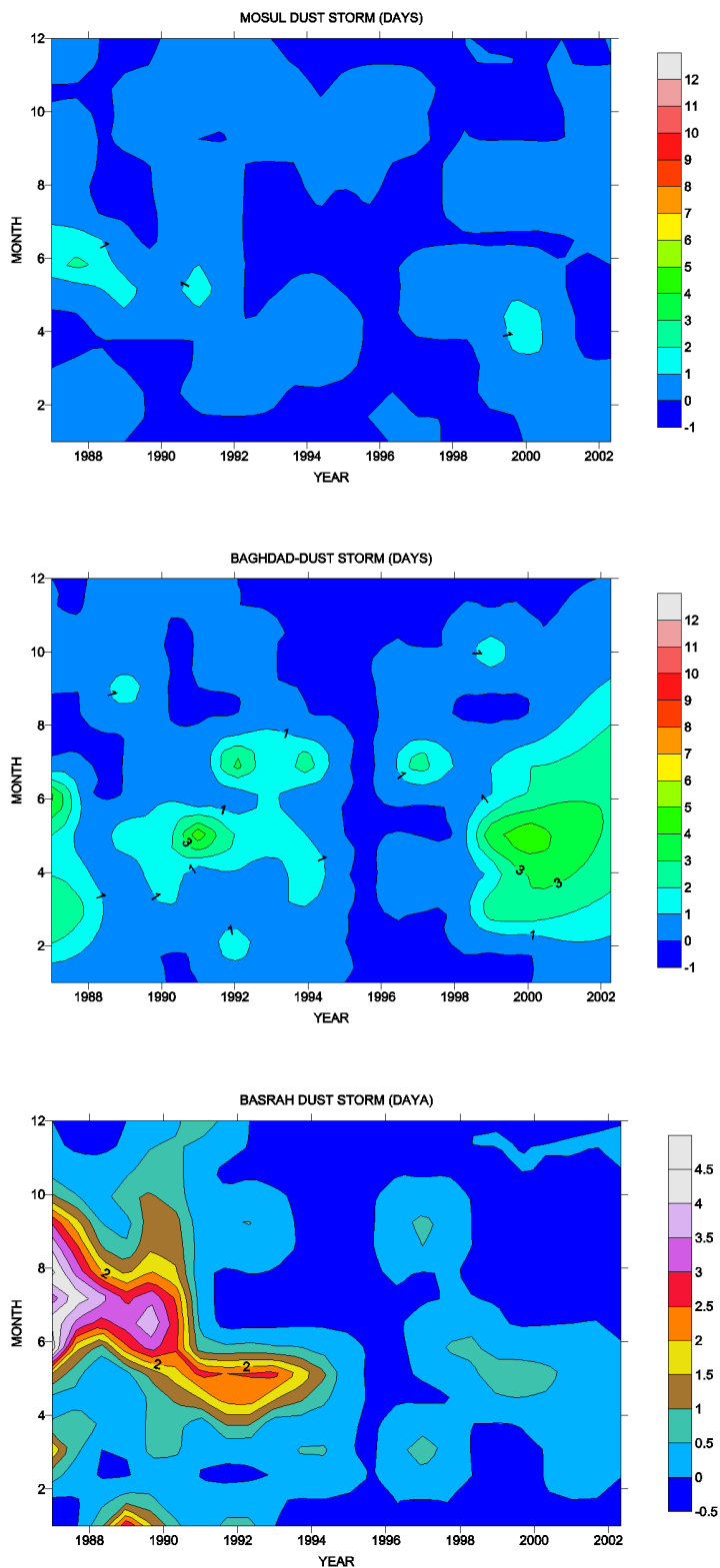
From, Figure 4- we can see that for Mosul area and for fifteen years data rain, dust storm and wind speed [5], the wind speed exceeds 6m/s when its accompanied by increase in the rain quantity, with inverse relation with dust storms occurrences. Speed of 4m/s and more correlated to frequency and occurrence of dust storms. Occurrence of dust storm is concentrated in march to June, with a maximum of 2-3 days in June 1988.

**Table 1-** Average Mean Annual rainfall in mm of ten years intervals for years from 1970-2005, in some Iraqi meteorological stations [5]

City	Years Data	Average Means Annual rainfall in mm
Baghdad	1970-1979	138
	1980-1989	100
	1990-1999	86
	2000-2005	37
Basra	1970-1979	132
	1980-1989	116
	1990-1999	110
	2000-2005	33
Mosul	1980-1989	327
	1990-1999	323
	2000-2005	152



**Figure 4-** Contour map of rain, dust storms, and wind speed for Mosul Baghdad and Basra and for the period 1987-2002. a) Rain contour maps.



**Figure 4-** Contour map of rain, dust storms, and wind speed for Mosul, Baghdad and Basra and for the period 1987-2002. b) Dust storm contour maps.

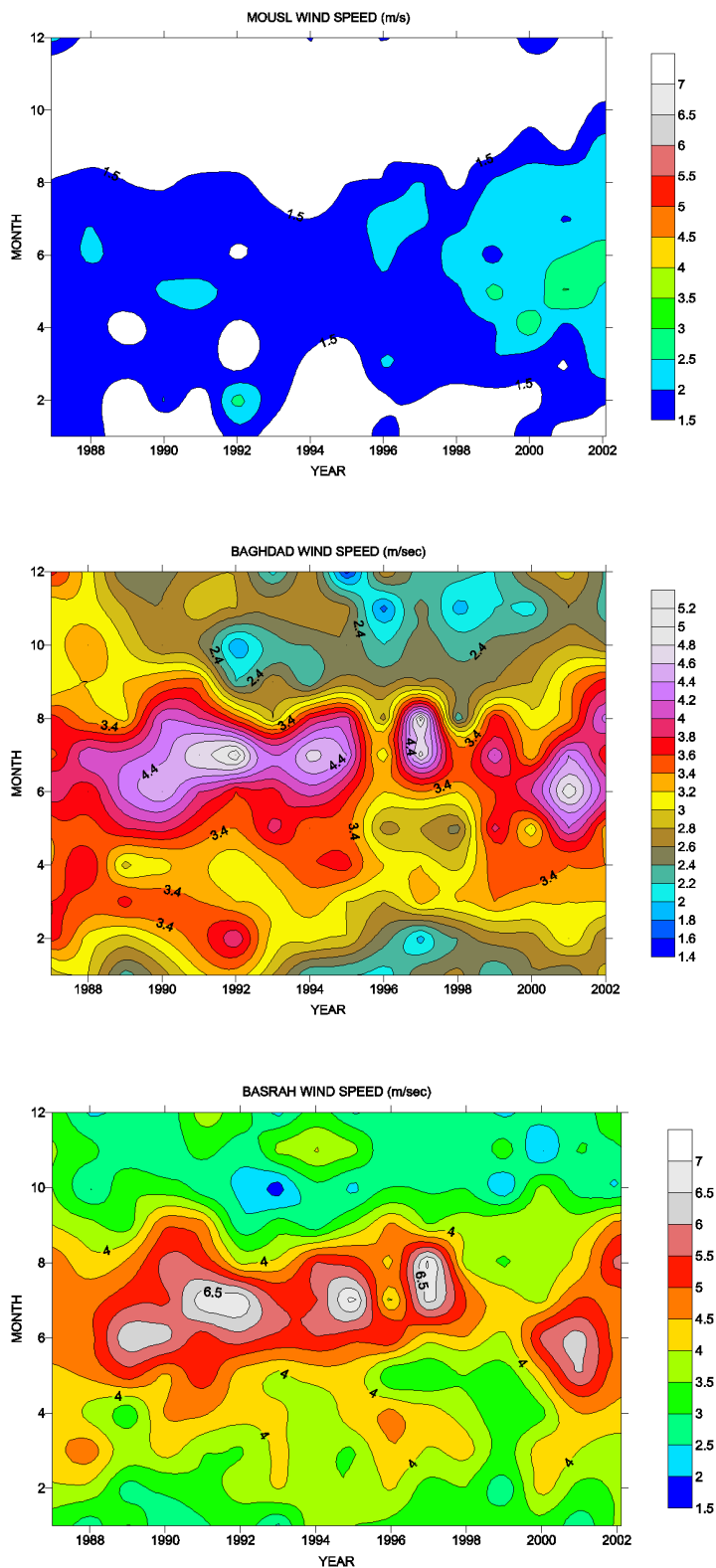


Figure 4- Contour map of rain, dust storms, and wind speed for Mosul, Baghdad and Basra and for the period 1987-2002. c) Wind speed contour maps.

As for Baghdad area, we observe that the occurrence of dust storm is normally accompanied with dry or minimum rain (April-August). Wind speed has greater influence on the occurrence of dust storms as well as the dry seasons, we also observe an increase in the number of dusty days after 1999-

As for Basrah the dust storms occurs frequently between April to October and most of dust storms occurs between the year 1987 to 1994 these were associated with sharp dry seasons and high wind speeds exceeding 4-6 m/s .

Generally, comparing the occurrence of dust storms in the three cities (Mousel, Baghdad and Basrah) , we observe an increase in the number of the days of dust storms (in the three periods ( 1987- 1997), (1994-1997) and (1997-2002). We also notice a surprising increase in the number of dust storms in Baghdad with a decrease in the south (Basrah) while the opposite is observed in the first period (1987-1993). These odd observations can be attributed to wide spread dry seasons for above period rather than wind speed effect.

#### **4. Sources and mechanism of Sand storms formation**

In addition to its arid climate (i.e., extreme heat, low humidity and little precipitation) the most notable natural hazard in Iraq (and surrounding areas) are dust and sand storms [6]. These storms are most prevalent in the spring and summer when a prevailing northwesterly wind – known locally as the “shamal” – kicks up the fine desert sand and the silt along the Tigris and Euphrates river basins. The recent frequent occurrence of sand and dust storms in Iraq has generated considerable public and academic interests. Dust and sand storms occur when the strong (mostly dry) storms – that often accompany well-defined cold fronts – stir up these particles. Dust and sand lift both ahead of and (even more so) behind cold fronts (since winds tend to be stronger behind the front than ahead of it). This seasonal trend can best be characterized as a combination of two separate weather systems: the sub-tropical jet stream pushing up from south of the Arabian Peninsula and a polar front jet stream pushing down from the European continent. When these two systems come into close proximity, they create much more dynamic weather than is usually found in this region, especially the strong northwesterly “shamal” winds (shamal winds at several Southwest Asia international airports have been recorded as high as 43 knots or 49 mph). The larger the particles, the stronger the wind required to lift them into the air. But for there to be any long-range transport, there also needs to be considerable vertical motion. The vertical speed determines how much the particulate matter is lifted into the air. Another factor that influences the impact of the shamal is the dampness of the sand. Even a very small amount of precipitation can keep a tremendous amount of sand from entering the air (although the very dry conditions that predominate in Iraq mean that there is a high probability that strong sandstorms can arise — as recent events have shown).

The unique topography and human intervention within the region also contribute to the frequency and intensity of dust and sand storms in this area. The natural funnelling of large air masses by the high mountains in Turkey and Iran, combined with the high plateaus in Saudi Arabia, help to funnel air across the Mediterranean into the Gulf. Furthermore, many Iraqi wetlands have been drained for agriculture or seriously deprived of water by reservoirs upstream. This exacerbates dust as wind lifts dry silt from exposed lake and marsh beds.

Depending on location, it is not unusual for Iraq to encounter 20 to 50 days of blowing sand and dust each year. Dust and sand storms can persist for days, however, because the air is so dry in this region, there are wide diurnal temperature differences that can influence dust and sand storms (especially during the summer months). In other words, rapid heat loss at night lowers the temperature inversion, helping to settle the dust and sand. Therefore, dust and sand storms generally subside at the source soon after sunset and are strongest in the late morning and afternoons.

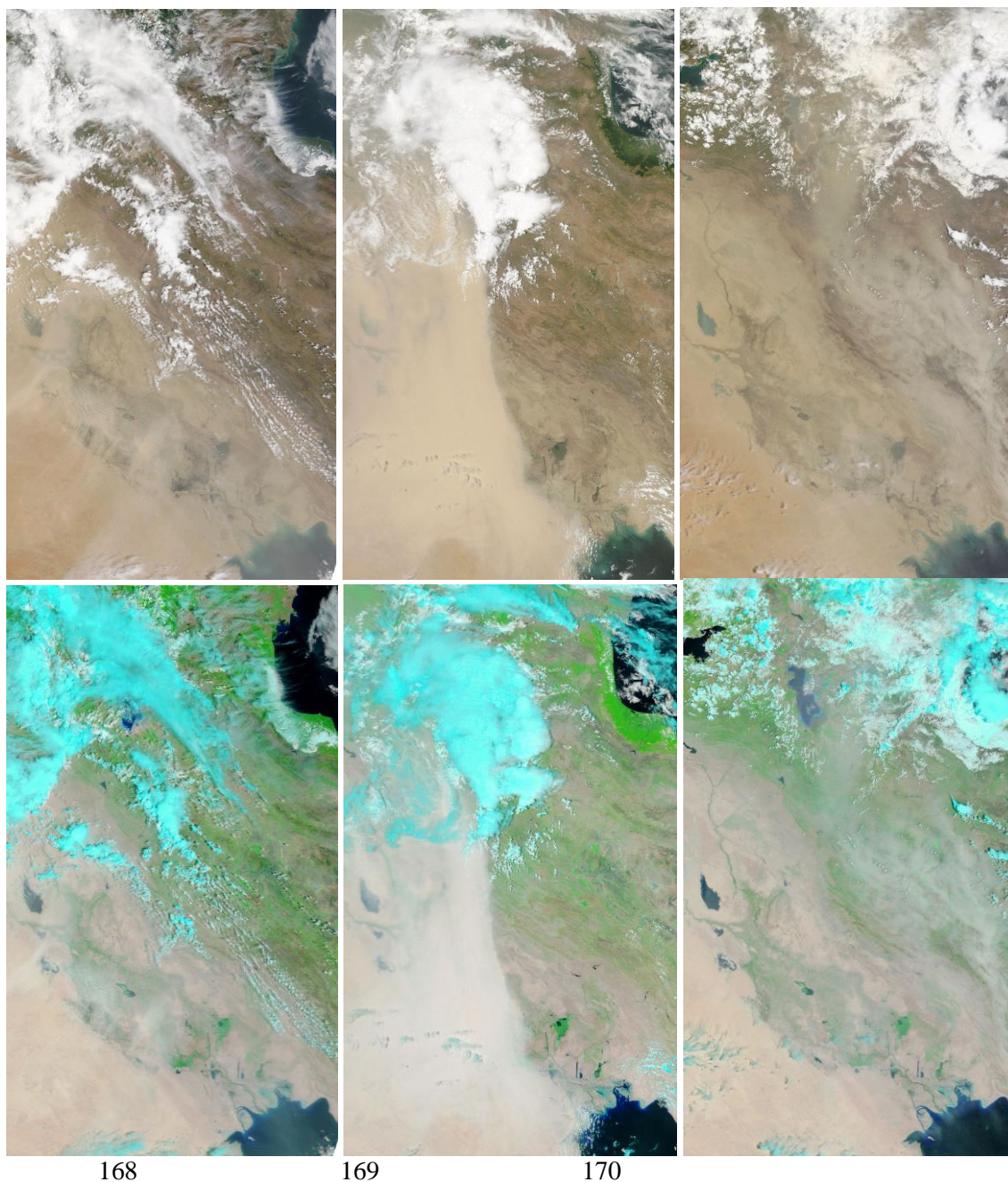
#### **5. Space images observation on a dusty day**

Figure 5- shows three consecutive days (168-169-170) for the year 2009 that illustrate the formation and movement of the dust storm from the west towards East. The concentration of the dust can be observed clearly from true colour MODIS RGB composite (1-4-3) that can differentiate clouds (white colour) and dust (light brown) [7,8].

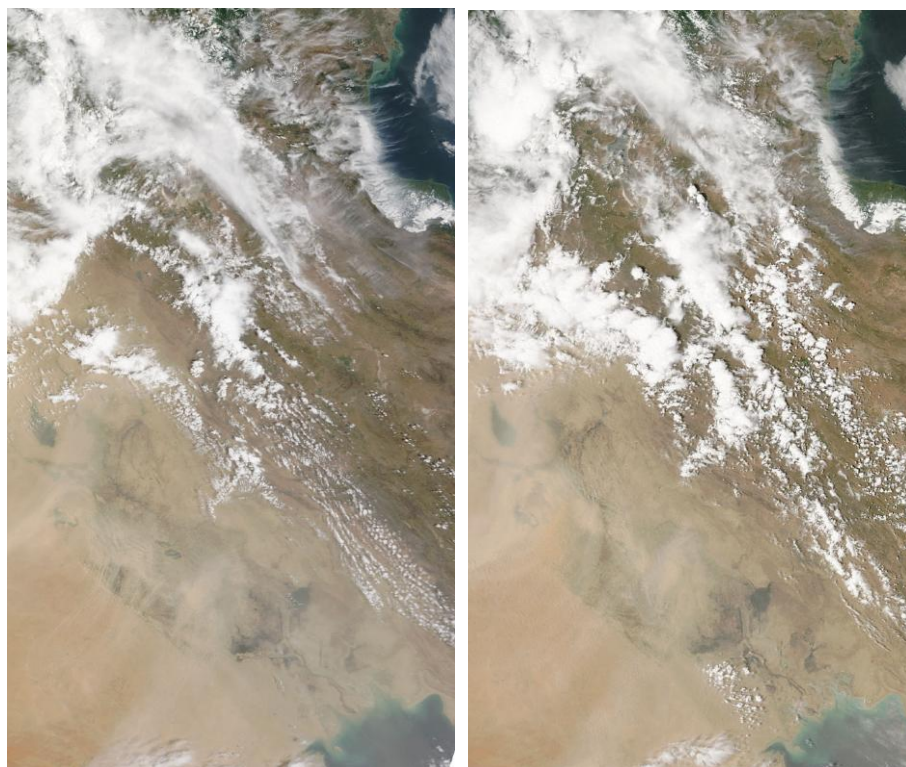
Another MODIS composite (7-2-1) increase the possibility of identifying and separating the clouds from the dust storms in the area [9]. For dust and cloud movement direction detection we can use



Aqua and Terra images for the same area with a time difference of three hours. As seen in figure 6- on day 168, the presence of the cloud indicates a movement from the west towards north east. In the south and middle parts of Iraq suspended and rising dust continue to build up till day 169 where a large dust storm hits Iraq and most of the surrounding region. We can observe that the clouds in the north (Iran region) moved toward the south while the dust moved from the Northwest toward East and southeast an indication of Alshamal wind effect.

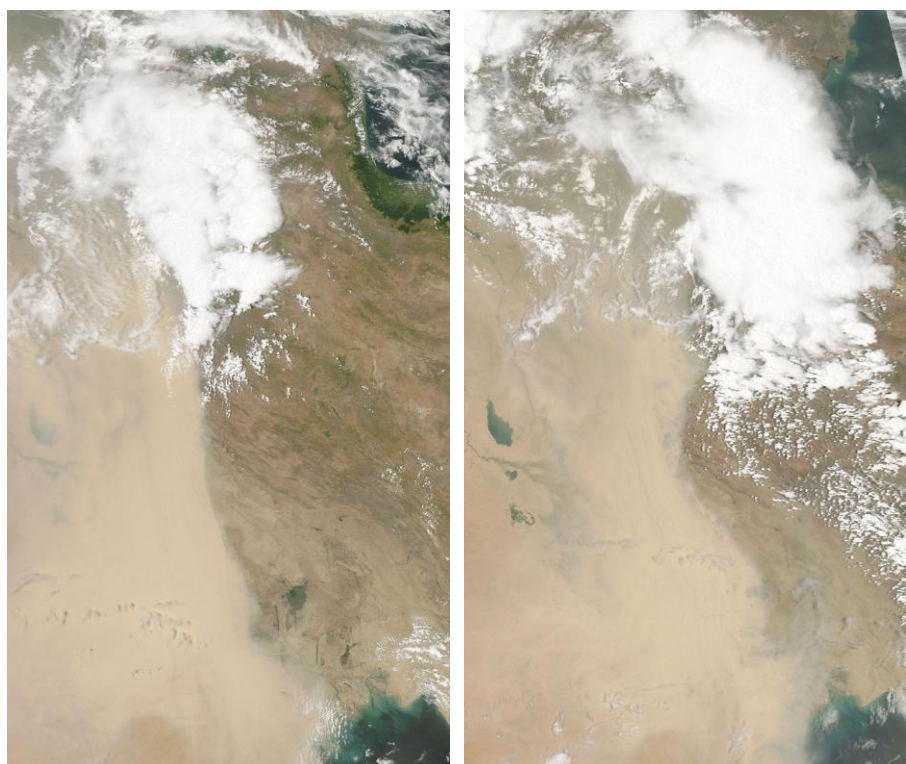


**Figure 5-** Terra MODIS images (true color composites the top images ,followed by 7-2-1 composites) for days 168,169 and 170, 17-18-19/June/2009



(Terra)168

(Aqua)168



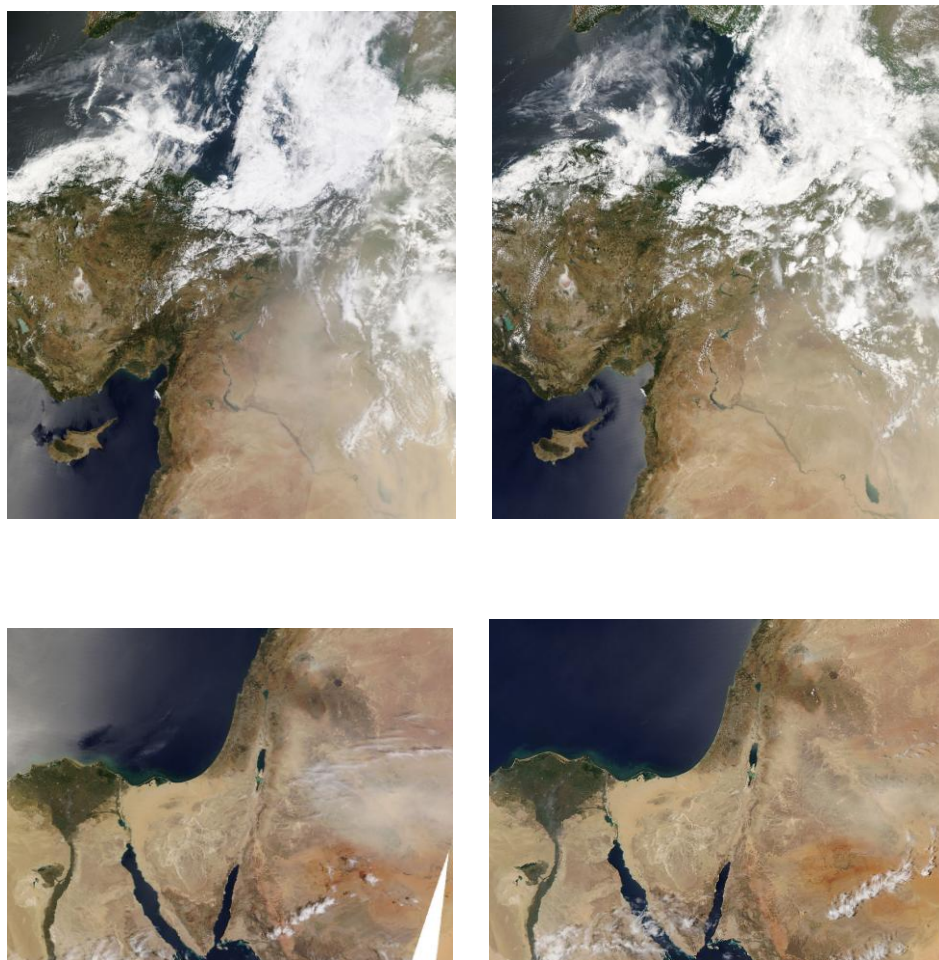
(Terra)169

(Aqua)169

**Figure 6-** Terra and Aqua MODIS images (true color composites the top images for day 168 followed by day 169 ) dated 17-18/June/2009

For the purpose of identifying dust sources from satellites images (Aqua and Terra), Figure 7- there is no clear evidence of the actual source for the dust storm, but we believe that they originate from Jordan , Syrian desert and Aljazira part of Iraq. For a detailed study we suggest to monitor the

meteorological satellite images over short periods, through their life cycle (originating, concentration, movement and dissipation) taking into consideration the availability of these images.



**Figure 7-** Terra and Aqua MODIS images (true color composites the top images (Europe) and ( for Jordan and Egypt) at the Bottom for day 169 dated 18/June/2009 showing the wide spread dust storm location.

## **6. Conclusion**

- 1- The most probable source of suspended and rising dust in Iraq is located in Aljazeera region surrounding Tharthar Lake. They are mostly light brown in color suggesting fine clay material.
- 2- The Middle East and Iraq are affected by climatic change, and is indicated by the decreasing rainfall in the last three decades with a remarkable increase in the frequency of regional dust storm that happen in Iraq specially the last 10 years.
- 3-Determining dust storm sources in Iraq is important because of the high frequency of it and this has a direct effect on human life and health and other economical and civilian services. This study using sun synchronous polar orbit satellite (Aqua and Terra) shows that their MODIS images can supplement the view of observation.
- 4-Monitoring dust storm and their transportation it can be done through geostationary satellite which can give high rate of images per day, but it requires that at least one MODIS image to be present in the area. Using MODIS will give more precise view on the dust coverage area.
- 5-The MODIS images via Terra and Aqua will give us dust storm movement. As we get two images a day with around three hours separation. Using MODIS composites help in identifying and separating clouds from the dust storm spatial distribution.

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