



## **Analysis of synoptic situation for dust storms in Iraq**

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### **Abstract**

Dust storms are considered major natural disasters that cause many damages to society and environment in Iraq and surrounded deserted regions. The aim of this research is to analyze and study the synoptic patterns leading to the formation of dust storms in Iraq. Analysis are based on satellite images, aerosols index and synoptic weather maps. Two severe dust storms occurred over Iraq on February 22, 2010, and on December 10, 2011 were analyzed. The results showed that dust storms form when a low-pressure system forms over Iran causing Shamal winds blow; they carry cool air from that region towards warmer regions like eastern Syria and Iraq. In some cases, this low-pressure system is followed by a high-pressure system bringing more cold air to the region and pushing dust toward south. Dust storms are initiated from source regions near Iraq-Syria borders by the existence of negative vertical velocity, which causes dust particles to be lifted upwards, and the strong westerly wind drives dust to travel eastward.

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**Keywords:** Dust storms; Aerosols index; Synoptic patterns; Iraq.

### **1. Introduction**

Dust storms may cause a variety of problems. One of the major problems is a considerable reduction of visibility that limits various activities. Environmental impacts of dust storms, reported in the literature include reduced soil fertility and damage to crops, a reduction of solar radiation and in consequence the efficiency of solar devices, damage to telecommunications and mechanical systems, dirt, air pollution, increase of respiratory diseases and so on [1].

Countries located in the arid and semiarid belt of the world including Iraq have been concerned with the dust storm phenomenon. In Iraq, dust storms occurrence has dramatically increased over the past ten years because of desertification, droughts and possible results of climate change. Since 2003 dust and sand storm in Iraq and surrounded countries were of major concern by research community. Kutiel and Furman [2] studied the spatial and temporal characteristics of dust storms in the Middle East by an analysis of the visibility reduction in that region. Anderson [3] has analyzed the impact of 25-27 March 2003 dust storm on military operation. Bartlett [4] used an imperial analysis to forecast dust storms for Al Udeid air base in Qatar. He concluded that seasonal patterns and dust storm type offers operators within the region a quick synopsis of possible dust prone periods and duration of events. A source-receptor model has been used to identify potential source areas of mineral dust reaching eastern Mediterranean region by Gullu et al. [5]. Ming et al., [6] employed the real time dust forecasting of the U.S. Navy's Coupled Ocean's Atmospheric Mesoscale Prediction System (COAMPS) to study the case of March 2003 dust storm. Khalid [7] used TOMS AI data to determine the origin of dust storm sources in Iraq. Desouza et al., [8] studied the evolutionary characteristics of a dust storm over Oman on 2 February 2008 by analyzing the weather associated with it. They concluded that the weakening of the

inversion in the lower troposphere and the formation of a mixed layer due to transfer of horizontal momentum from upper air towards the surface led to strong surface winds and these strong winds lifted a large amount of dust particles off the ground, resulting in the dust event under study. Maghrabi [9] investigated the impact of dust storm on meteorological parameters in central Saudi Arabia. Khoshhal et al., [10] explored the recognition and assessment of atmospheric circulation patterns transferring dust storms. They suggested that the temporal and spatial investigation of dust storms shows the interference of various factors in their occurrence and expansion. Al-Dabbas et al., [11] studied eight dust storms that occurred between December 2008 and March 2009 to determine the dust load of these storms.

## 2. Material and method

### 2.1 Sources of data

The source of data used in thesis includes the following:

- True color satellite images of dust storms captured by the Moderate Resolution Imaging Spectroradiometer (MODIS) on board Aqua and Terra satellites which are operated by the National Aeronautics and Space Administration (NASA) [12].
- The Total Ozone Mapping Spectrophotometer (TOMS) aerosol data, which are given in units called the aerosol index. The Aerosol Index (AI) is defined as the difference between the observations and model calculations from a pure molecular atmosphere with the same surface reflectivity and measurement conditions. The Index can be interpreted in terms of optical depth if the index of refraction, particle size distribution, and the height of the aerosol layer are known from other measurements [13].
- Daily data of principle meteorological elements for surface and 1000 mb pressure levels provided by the National Oceanic and Atmospheric Administration (NOAA), US Department of Commerce [14].

### 2.2 Method

Daily TOMS AI data for Iraq were analyzed for each true satellite image of case studies under investigation to determine the strength and direction of storm and areas of high concentration of dust. In order to determine the synoptic situation of dust storms, NOAA data was analyzed for each dust storm. The analyses include daily maps of the following meteorological parameters:

- Surface pressure [Pascal]
- 1000 mb geopotential height [m]
- Zonal component of surface wind [m/s]

## 3. Results and discussion

### 3.1 Dust storms occurrence during 2003-2012

More than 80 dust storms were captured by the MODIS sensor over Iraq during the period of 2003 to 2012. Figure 1 shows a histogram of number for storms per month during that period. It is seen that dust storms could occur any time in the year in Iraq but most likely during the months of March to June. Figure 2 gives the total annual number of dust storms for the 10 years period. No obvious trend is apparent, that is the number of storms can vary from one year to another. This could be attributed to the variability of rainstorms among other factors. All these dust storms were synoptically analyzed by Ibrahim [15]. Three cases of severe dust storms are selected and will be discussed in the following subsections.

### 3.2 The dust storm of February 22, 2010

A dense plume of dust swept from Syria into Iraq on February 22, 2010. The image of the dust storm, which is shown in Figure 3, was captured by the MODIS on board NASA's Aqua satellite in the early afternoon (Iraq local time). It is seen that distinct plumes were raised from many point sources in the Syrian Desert. Within a few kilometers, the plumes blend into a dense cloud that completely obscures eastern Syria and western Iraq. The veil of dust is thick enough that the ground beneath was not visible, which means that daylight on the ground was probably reduced.

The TOMS AI map in Figure 4 indicates that the storm was severe and rather unusual one, the values of AI have reached more than 125 almost all over Iraq with maximum values of more than 150 in the north and in a small region in the south near the border with Saudi Arabia.

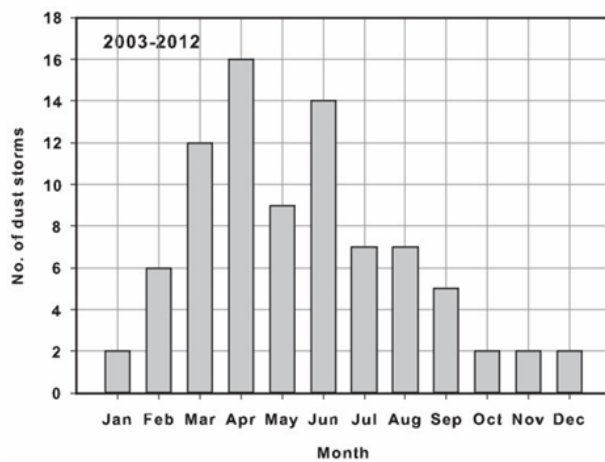


Figure 1. Number of dust storms per month in Iraq for the period 2003-2012

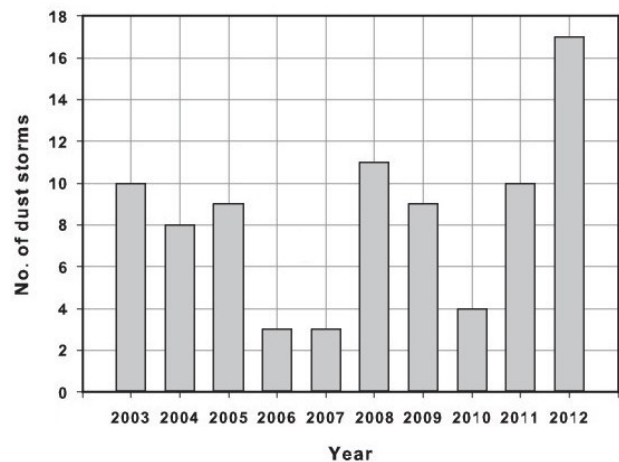


Figure 2. Total annual number of dust storms in Iraq

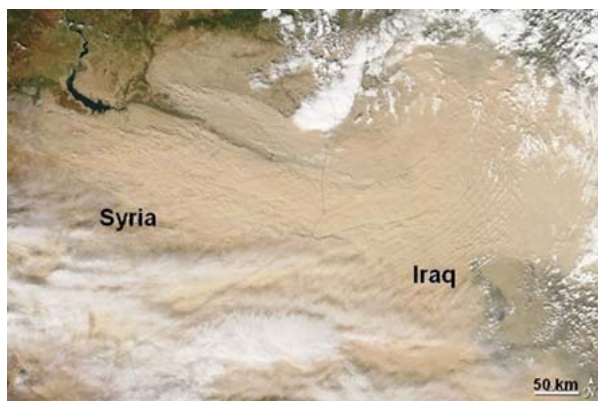


Figure 3. MODIS image of February 22, 2010 dust storm

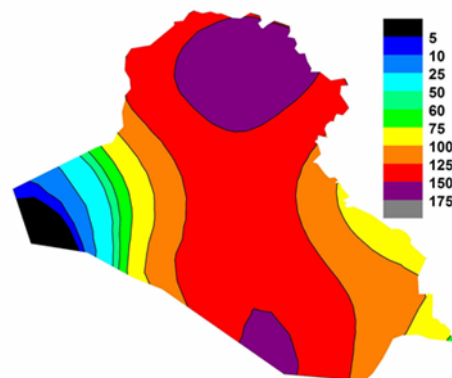


Figure 4. TOMS AI of February, 2010 dust storm

Figure 5 shows the synoptic daily maps for February 22, 2010. The surface pressure and geopotential height maps indicate that the area was dominated by a low-pressure system. Two distinct centers of system were located over Iran. It is also seen that a high-pressure system was formed over the Mediterranean sea. Dynamically, low-pressure system is produced by counterclockwise spin in the northern hemisphere while high-pressure system is produced by clockwise spin. The synoptic situation of this case study is a typical situation for the Shamal wind. The zonal wind map shows that high positive values (positive values indicates wind blows from the west) of the wind occurred over Syria and in the western plateau of Iraq, which are believed to be the major sources of dust storm in the area. The vertical velocity map indicates that the area was dominated by negative values of vertical velocity. Negative vertical velocity is produced by ascending motion of air. The heavy cloud cover just north of the dust storm, as seen on the MODIS image was caused by this low-pressure system.

### 3.3 The dust storm of December 10, 2011

On December 10, 2011 dust plumes blew through Syria and Iraq. Figure 6 shows the natural-color image of that storm. This image was captured by MODIS on Aqua satellite. The dust plumes arise from discrete points in Syria and northwestern Iraq, and blow toward the southeast. Over Iraq, the dust was thick enough to completely hide the Euphrates River Valley. The image also shows that an arc of dust was formed northward forming a ripple pattern near the Iraq-Iran border.

Immediately north of the dust is a cloud bank, and the clouds may be associated with the same weather pattern that has stirred the dust.

The TOMS AI in Figure 7 shows an interesting pattern of concentric circles with values of AI reaching more than 45 in the center of the storm, which was located just over the middle of the country. The AI

pattern suggests that part of the storm was moving north east since the gradients of AI is stronger towards northeast.

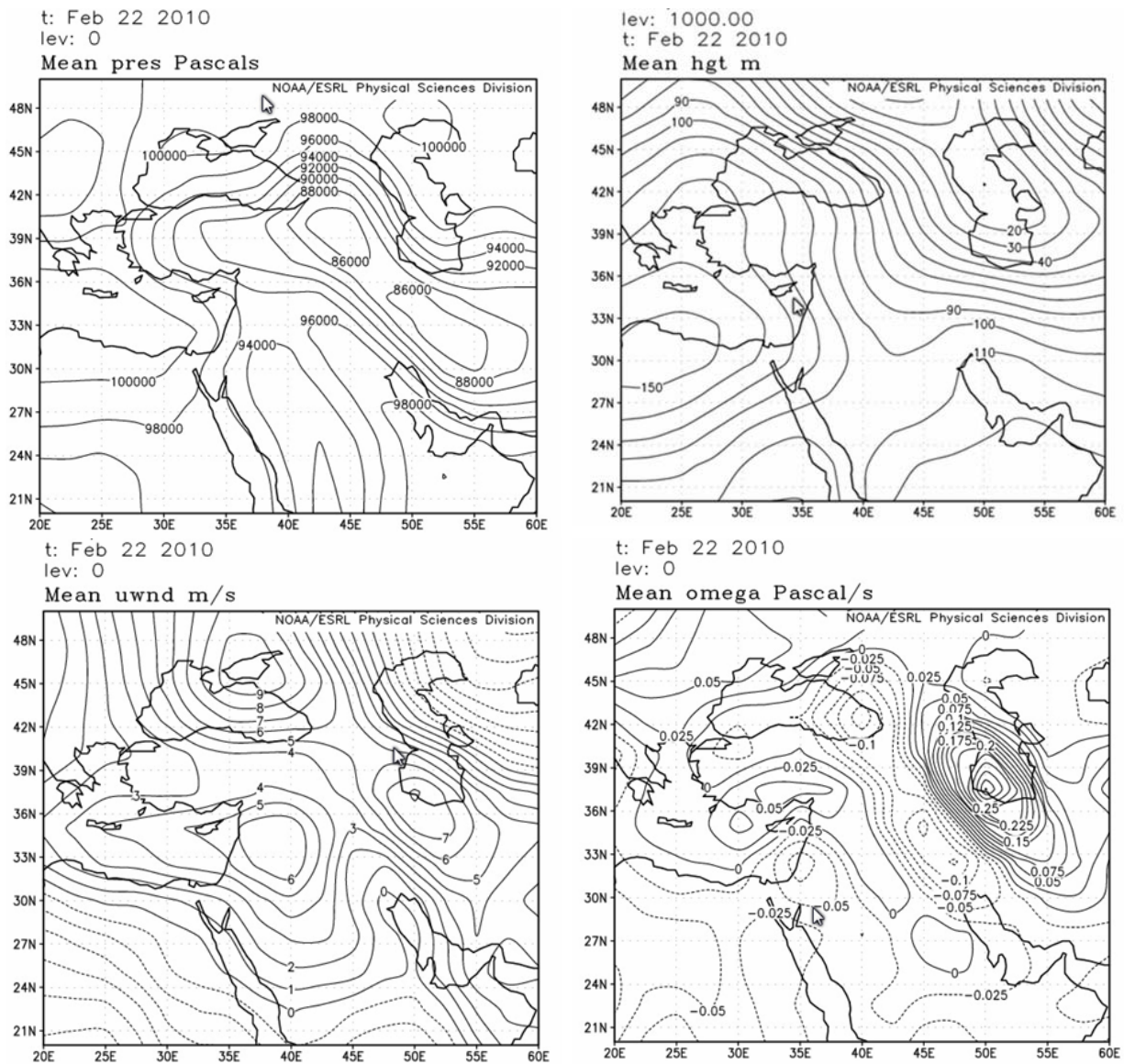


Figure 5. Synoptic maps for February 22, 2010

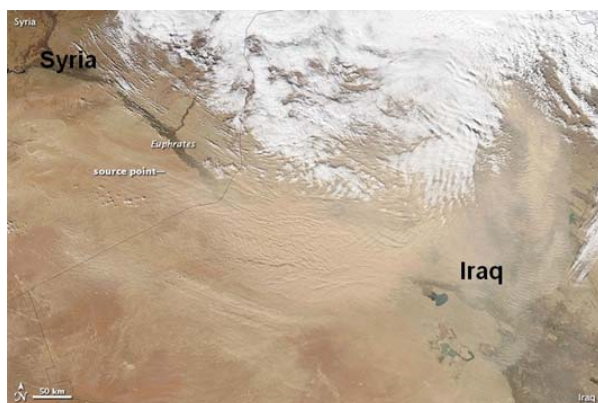


Figure 6. MODIS image of December 10, 2011 dust storm

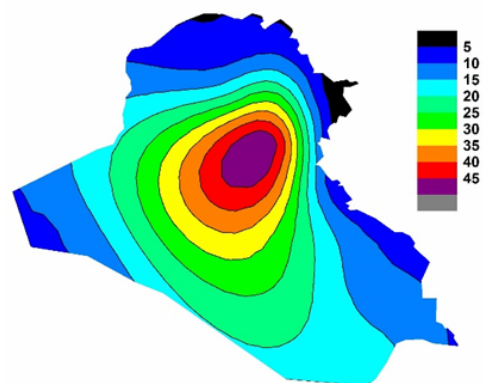


Figure 7. TOMS AI of December 10, 2011 dust storm



Figure 8 gives the synoptic maps of this storm. The surface pressure map indicates that a low pressure system was located over Iran and extending toward eastern Turkey. This low resulted in a cloud bank over north part of Iraq (as seen on MODIS image) and the dust storm was associated with formation of cloud. The geopotential height maps illustrates that the low center was just located over the Iraq-Syria border, the region of dust sources. The zonal component of the wind indicates that the wind was westerly over Syria and heading toward Iraq and wind speed was more than 5 m/s in the Iraq-Syria-Jordan border. This suggests that this strong wind may have stirred the dust storm from that border region and move it toward north east of Iraq. The vertical velocity map indicates that the air near the surface was ascending causing the dust to below.

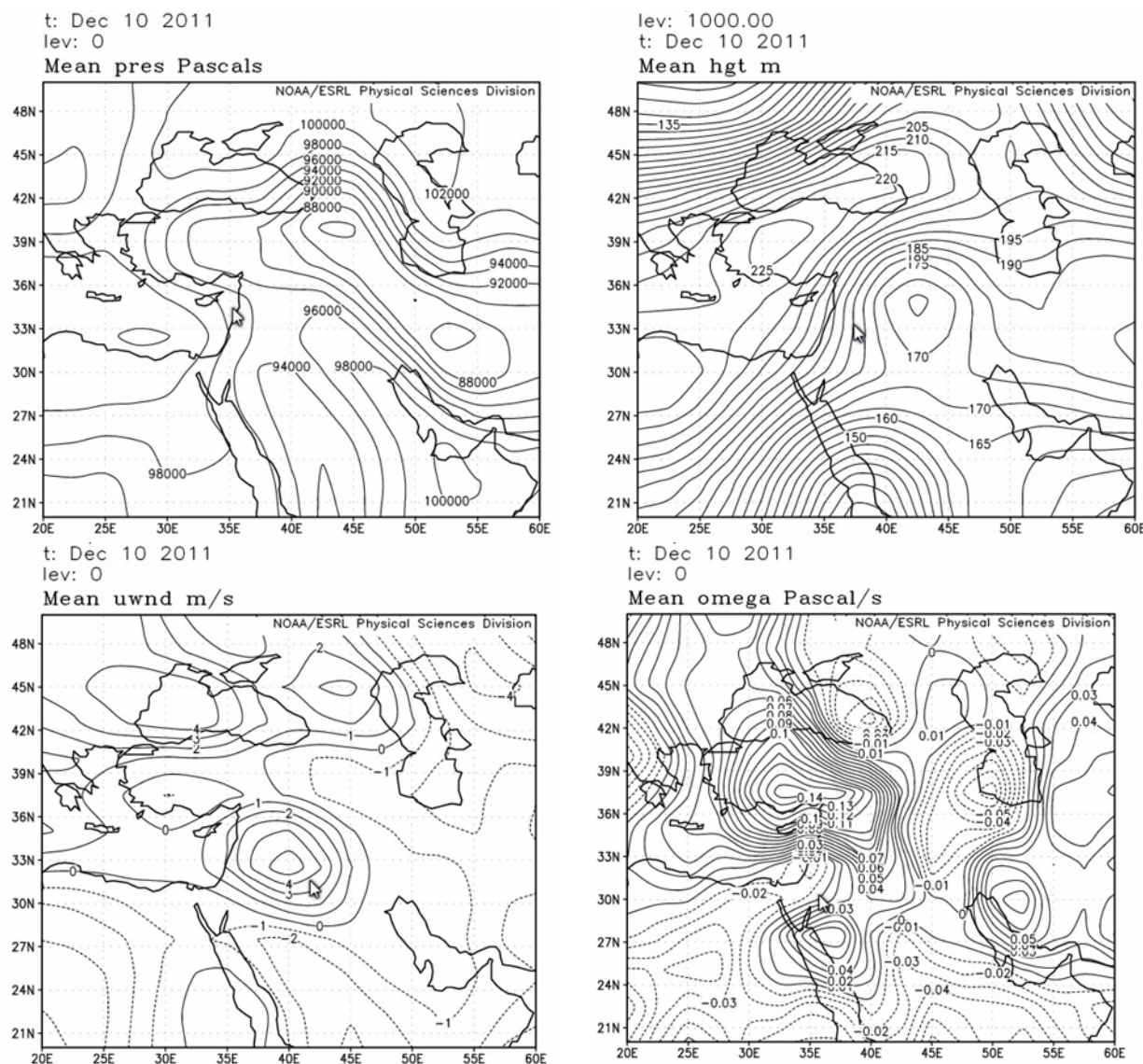


Figure 8. Synoptic maps for December 10, 2011

#### 3.4 The dust storm of June 18, 2012

In the afternoon on June 18, 2012, a thick dust clogged the skies over Syria and Iraq. Figure 9 shows the MODIS image captured on the same day. The satellite sensor could barely detect the area between Tigris and Euphrates Rivers. This dust storm was moving southeastward towards western Iran and the Arabian Gulf. The TOMS AI data of Figure 10 suggests that two storms were initiated on that day, the first one was heading southward to Kuwait and Saudi Arabia with a maximum of AI more than 50. The second storm was moving toward south east to western part of Iran. The AI reached more than 45 in both storms. Figure 11 illustrates that the pressure pattern of this case is similar to the previous cases. The geopotential height map illustrate that a trough was approaching Iran bringing cooler air to the region.

The zonal component of the wind was westerly over entire Iraq. A strong gradient of negative vertical velocity was located in the northern and western part of Iraq.

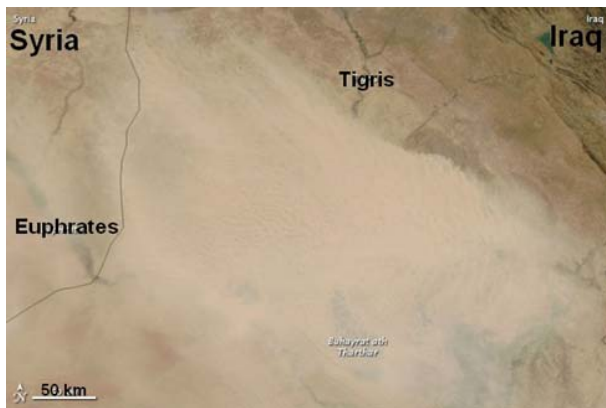


Figure 9. MODIS image of June 18, 2012 dust storm

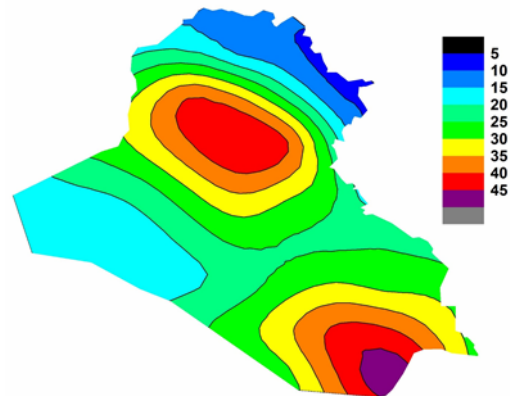


Figure 10. TOMS AI of June 18, 2012 dust storm

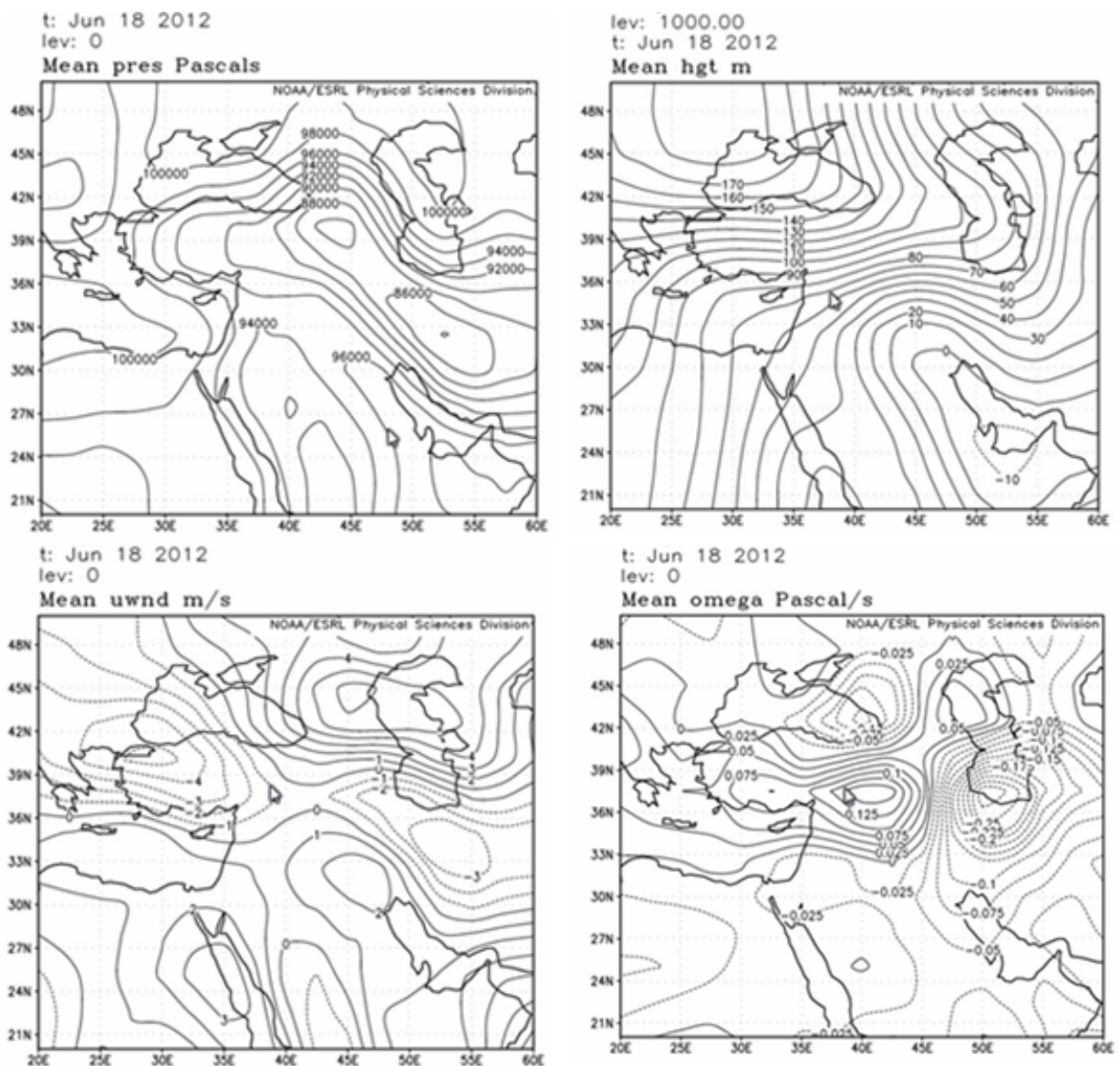


Figure 11. Synoptic maps for June 18, 2012

#### 4. Conclusion

The most important reason of the occurrence of dust storms in Iraq is the passage of a low-pressure system over Iran they carry cool air from that region towards warmer region or warmer air of areas like eastern Syria and Iraq. In some cases, this low-pressure system is followed by a high-pressure system brining more cold air to the region and pushing dust toward south. During winter and spring, dust storms are often associated with the formation of cloud in nearby area. Both dust and cloud are formed by the same meteorological phenomena.

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#### References

- [1] Warner, T.T. Desert Meteorology. Cambridge University Press, 2004.
- [2] Kutiel, H., Furman, H. Dust storms in the Middle East: sources of origin and their temporal characteristics. *Indoor Built Environ* 2003, 12, 419-426.
- [3] Anderson, J. An Analysis of a Dust Storm Impacting Operation Iraqi Freedom, 25-27 March 2003. M.Sc. Thesis, Dept. of Meteorology, Naval Postgraduate School, 2004.
- [4] Bartlett, K.S. Dust Storm Forecasting for Al Udeid Ab, Qatar: An Empirical Analysis. M.Sc. Thesis, Dept. of Meteorology, Air Force Institute of Technology, 2004.
- [5] Gullu, G., Dogan, G., Tuncel, G. Source Regions of Dust Transported to the Eastern Mediterranean. *Proceedings of the Third International Symposium on Air quality Management at Urban Regional and Global Scales*. 26-30 September 2005, Istanbul-Turkey, 2005.
- [6] Ming, L., Westphal, D.L., Walker, HOLT, A.L.R.T., Richardson, K.A., Miller, S. COAMPS Real-Time Dust Storm Forecasting during Operation Iraqi Freedom. *Weather and Forecasting*, 22, 192-206, 2007.
- [7] Khalid, O.L. Determination of dust storms source regions using TOMS and meteorological data. M.Sc. Thesis, Dept. of Atmospheric Sciences, Al-Mustansiriyah University (in Arabic), 2009.
- [8] Desouza, N.D., Simon, B., Qureshi, M.S. Evolutionary characteristics of a dust storm over Oman on 2 February 2008. *Meteorol Atmos Phys* 114,107-121, 2011.
- [9] Maghrabi, A.H. The impact of the March 10, 2009 dust storm on meteorological parameters in central Saudi Arabia. *World Renewable Energy Congress* 2011. 8-13 May 2011, Linkoping, Sweden, 719-723, 2011.
- [10] Khoshhal, J., Mousavi, S.H., Kashki, A. Synoptic analysis of Ilam dust storms (1987-2005) *Geography and Environmental Planning Journal* 23rd Year, 46 (2), 5-10, 2012.
- [11] Al-Dabbas, M.A., Abbas, M.A., Al-Khafaji, R.M. Dust storms loads analyses in Iraq. *Arabian J. of Geosciences*, 5 (1), 121-131, 2012.
- [12] <http://modis.gsfc.nasa.gov/>
- [13] <http://ozoneaq.gsfc.nasa.gov/>
- [14] <http://www.esrl.noaa.gov/psd/data/gridded/data.ncep.reanalysis.html>
- [15] Ibrahim, M.K. Analysis and study of synoptic patterns of dust storms in Iraq using satellite and NCEP data. M.Sc. Thesis. Dept. of Atmospheric Sciences, Al-Mustansiriyah University, 2013.



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