Analysis of Dust Storms Using Satellite Imagery and Surface Observation on Iraq

Hussain Zaydan Ali[1], Saad H. Farraj[2], and Sadeq A. Rashid[2]
[1]Ministry of Science and Technology-Baghdad-Iraq (hussainzayali53@yahoo.com)
[2]Iraqi Meteorological Organization and Seismology-Iraq

Abstract

In most areas in Iraq, dust storms can be classified by the prevailed broad meteorological conditions. Examining the most common events that occurred in Iraq is important, specially the dust storms which caused by prefrontal and postfrontal winds that primarily occurred in the winter, and dust storms caused by persistent northerlies upon which occurred in summer. The objectives of this paper is concentrated on analyzing the synoptic situation leading up to such event south of Iraq and to conduct a complete case study of the meteorological conditions that led to the dust storm. The case study has been included an analysis of the lower level that will be used to assess the placement and timing of the surface cold front and the associated strong winds which lifted the dust. These analyses will be compared with the satellite imagery.

Keywords: Dust sources, Dust storms, Aerosol Index, Satellite images.

تحليل العواصف الغبارية باستخدام صور الاقمار الاصطناعية والمشاهدات الارضية في العراق

حسين زيدان علي[1] وسعد حلبوص فرج[2] وصادق عطية راشد[2]

[1]وزارة العلوم والتكنولوجيا، بغداد، العراق

[2]الهيئة العامة للانواء الجوية والرصد الزلزالي، العراق

خلاصة

يمكن تصنيف العواصف الغبارية بواسطة الشروط الانوائية المسببة لها. كما تم دراسة العواصف الغبارية في العراق. العواصف الغبارية في العراق تتولد من الرياح قبل الجبهة وبعد الجبهة التي تحدث بشكل رئيسي في الشتاء والعواصف الغبارية الناشئة من الرياح الشمالية في الصيف. ان الهدف من هذه الدراسة هو تحليل الموقف الساينوبتيكي المؤدي الى العواصف الغبارية في جنوب العراق و دراسة الحالة من حيث الظروف الانوائية التي سببتها. كما ستتضمن الدراسة الحالية تحليل المعلومات الأولية الستوى الاسفل والمستخدمة لتقييم موقع وزمن سطح الجبهة الباردة والرياح القوية المصاحبة التي أدت الى رفع الغبار. سوف تقارن هذه التحاليل مع صور الأقمار الاصطناعية.

كلمات مفتاحية: مصادر الغبار، العواصف الغبارية، معامل العوالق، صور الأقمار الاصطناعية.

Introduction

For more than two decades, Total Ozone Mapping Spectrometer (TOMS) instruments have been providing useful global data on the long range transport of smoke and dust plumes. TOM's measures back scattered radiances in the near Ultra Violet (UV) region of the spectrum and from these measurements, the TOMS ozone retrieval algorithm computes an absorbing Aerosol Index (AI), which is a qualitative measure of the presence of UV absorbing aerosols such as mineral dust and smoke. At the present time, the long term data recorded by the aerosol information from the TOMS instrument is continued by the Ozone Monitoring Instrument (OMI) flown on the EOS Aura spacecraft (launched July 2004). In spite of the fact that the Aerosol Index is a qualitative indicator of the presence of the absorbing aerosols, many scientists have used it in variety of applications with the encouraging results [1, 2, 3]. For example, AI has been used in identifying the sources of air pollution over the globe, understanding the transport of air pollution across the oceans and continents, air quality forecast models, and radiation energy balance, and climate forcing studies [4, 5, 6]. The AI differentiated between absorbing and non absorbing aerosols, because it provides a measure of absorption of UV radiation by smoke and desert dust. AI positive values were associated with UV absorbing aerosols, mainly mineral dust, smoke and volcanic aerosols. However, negative values are associated with non absorbing aerosols (for example, sulfate and sea salt particles) from both natural and anthropogenic sources [7].

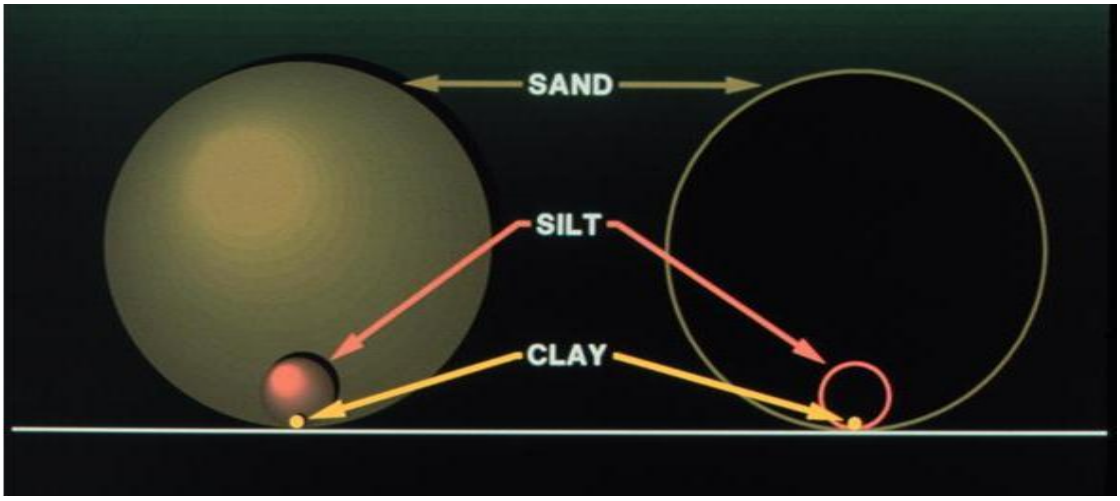

Figure (1): Particule size distribution [8].

The transport of dust can be described to three processes depending on particle size (Figure (1)) and wind strength. These processes are creep, saltation, and suspension, as shown in Figure (2). Creep refers to a process by which particles slide or roll over the surface, generally without breaking contact with the surface. This process is favored by large particles or lower wind speeds and will not usually result in large-scale dust storms [9]. Saltation is a process by which the particles may get airborne for short distances before falling back to earth. Although the particles do not travel far from their source regions in this process, they can contribute to much larger scale dust transport by disrupting the surface at each impact, thus kicking up much finer particles which are then more susceptible to the third process, suspension.

Suspension occurs when the particles are held aloft by the air currents and can result in the dust plume being carried far away from the source region if the lofted particles are small enough for the air currents to keep them airborne [9]. Generally the wind speeds required activating particle movement and thus initiate the three processes (Creep, Saltation, and Suspension) summarized above will depend on the size of the particles.

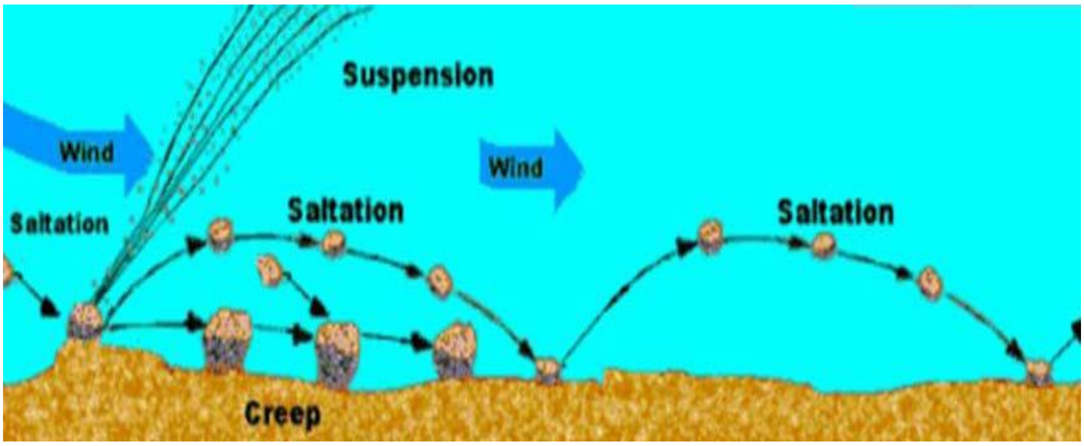

Figure (2): Dust transport processes [9].

Materials and Methods:

The objectives for this paper were conducting a complete case study of the meteorological conditions that led to the dust storm. The lower level analysis will be used to asses the placement and timing of the surface cold front and the associated strong winds which lifted the dust. This analysis has been compared with satellite images. The following case was discussed using maps for the distribution of sea level pressure, surface temperature, and surface wind speed. A southerly flow ahead of the advancing cold front, which gradually increases in intensity with time, as the cold front approaches. These winds activate dust particles in the source regions and commence the dust storm process. The winds do not actually shift to a more northerly component until after the passage of the cold front. At the surface, the winds vary in intensity. The surface winds over a wide spread area were clearly strong enough for the activation of dust and sand from the source regions in the area. The postfrontal dust storm occurred in 25 / 3 / 2011 has been discussed by a prognostic weather map, when the dust storm moved across Iraq. Dense dust storms with visibility less than 1 km were predicted along the associated cold front. In the winter months, frontal passage leads to strong northwesterly winds on the backside of the front. The resulting dust storm was referred to as a Shamal. The Shamal produced the most widespread hazardous weather known to the region

Results and Discussion:

Figures 3-14 show a cold front generated sandstorm stretching to the south of Iraq. The front has passed and lies to the south of the dust front. Strong northwesterly postfrontal flow was picked up dust along a front and appeared to be moving to the south and east. The winter Shamal was generally characterized by durations of 24-36 hours. Sustained winds typically reach high values with stronger gusts.

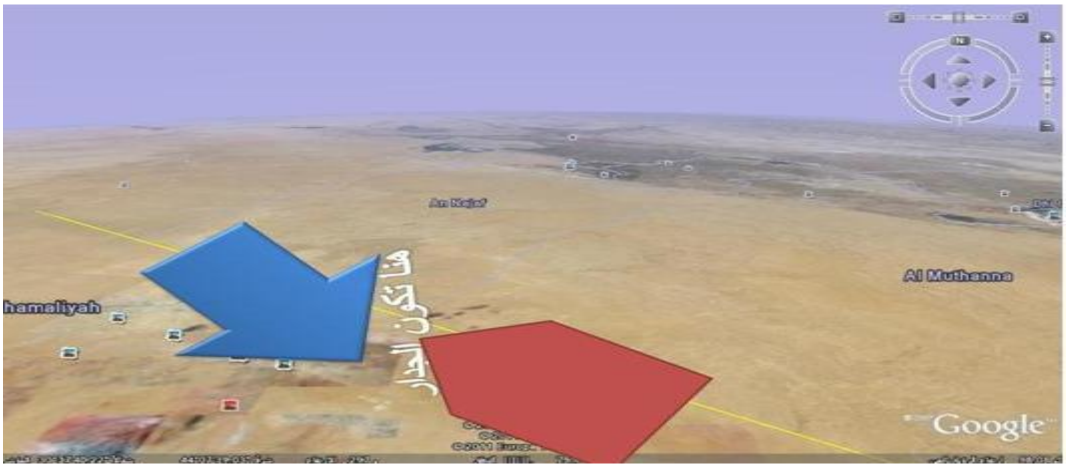

Figure (3) Satellite image indicating storm wall position

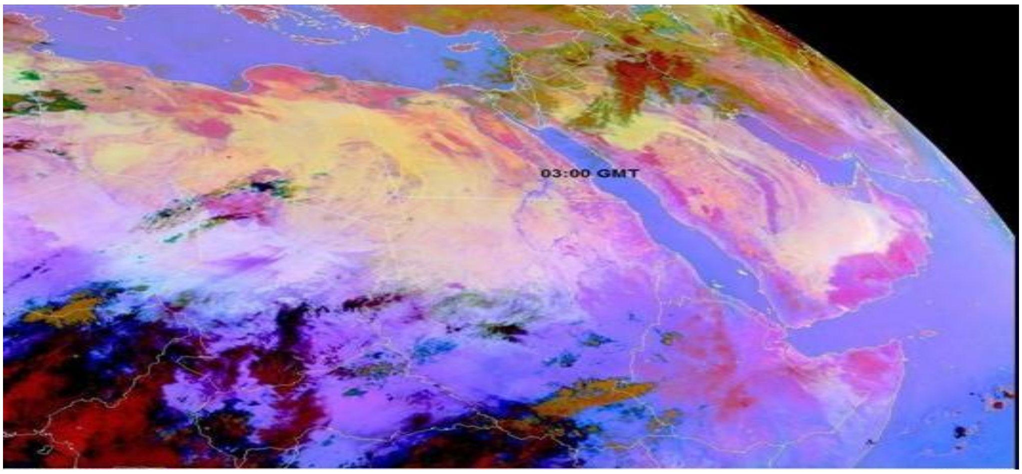

Figure (4) METEOSAT image at 03:00 GMT.

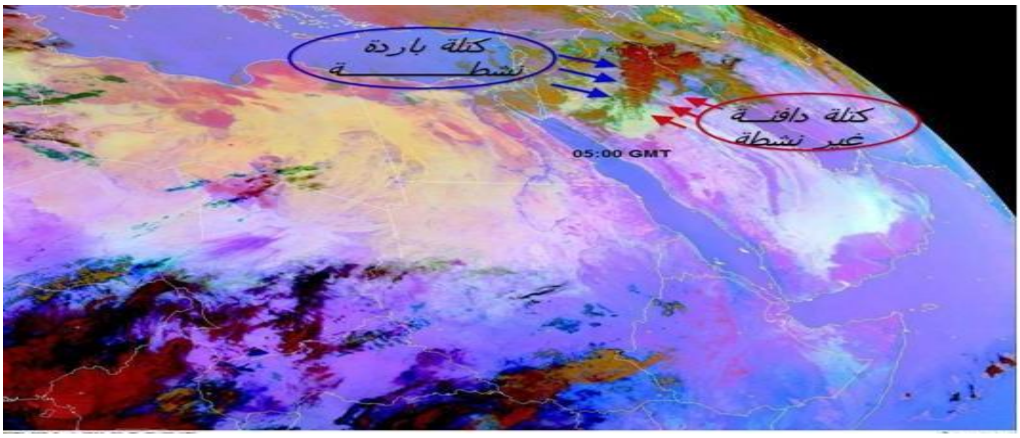

Figure (5) METEOSAT image at 05:00 GMT

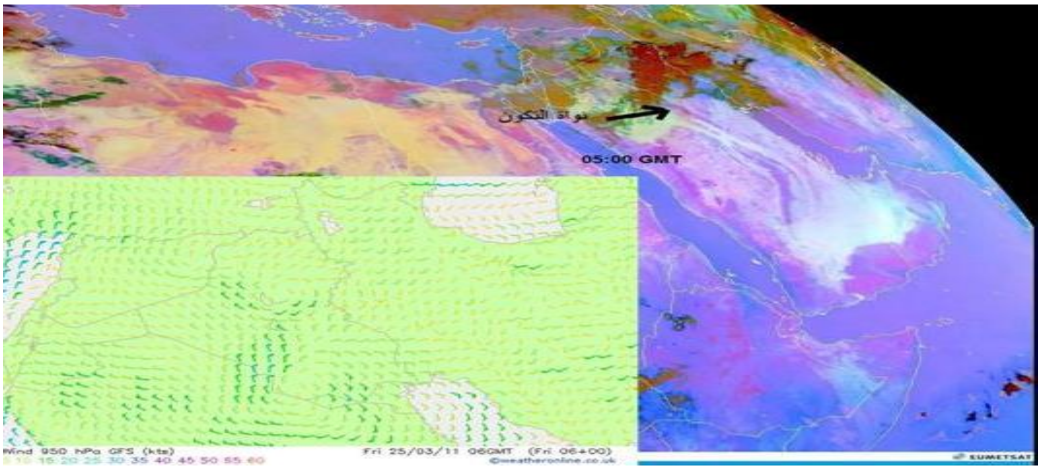

Figure (6) METEOSAT image and wind chart at 05:00 GMT

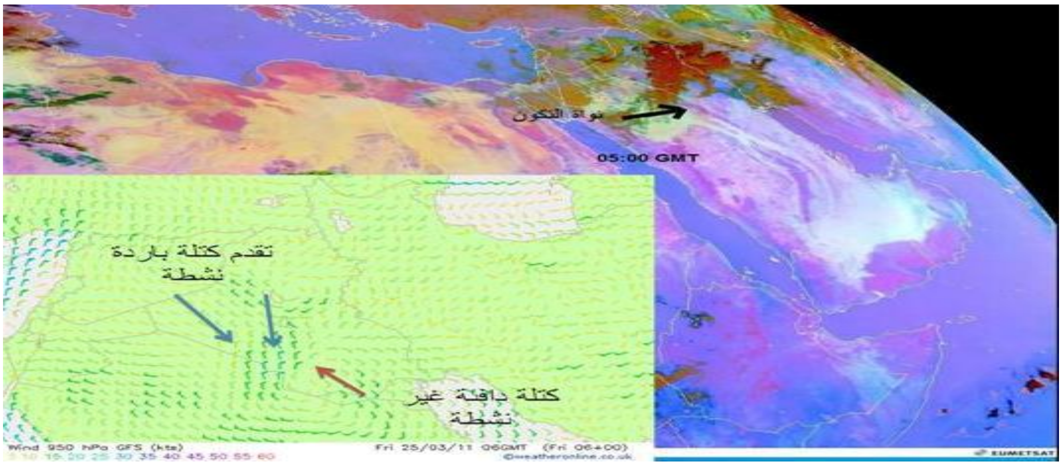

Figure (7) Wind chart indicating advance of cold front

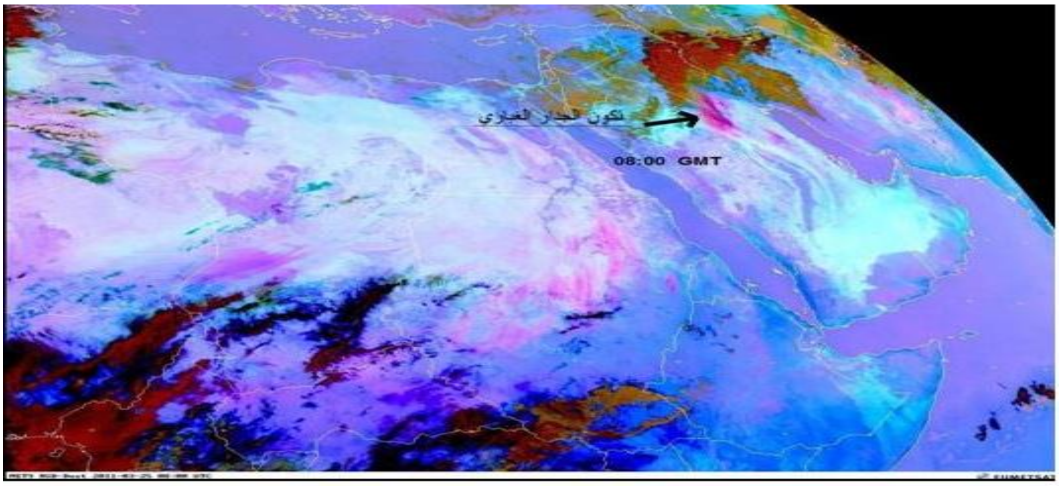

Figure (8) Formation of storm wall.

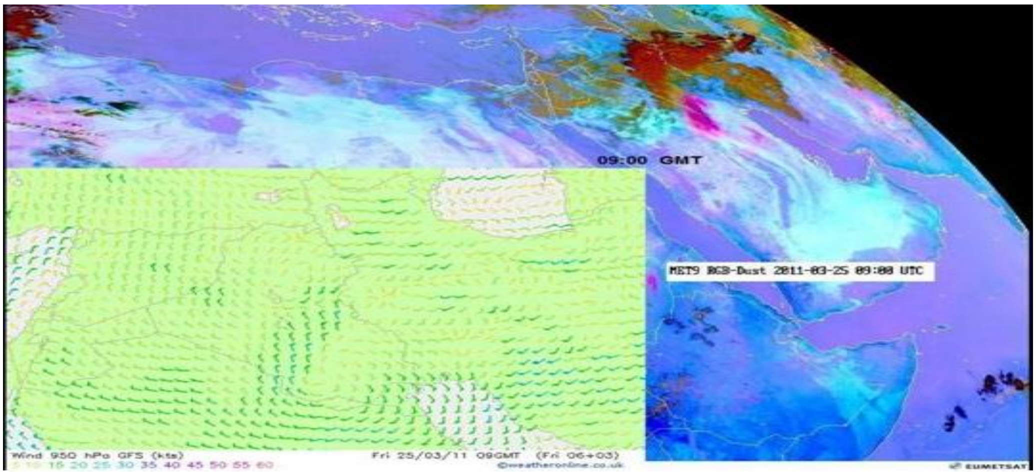

Figure (9) Wind chart overlaid on satellite image at 09:00 GMT

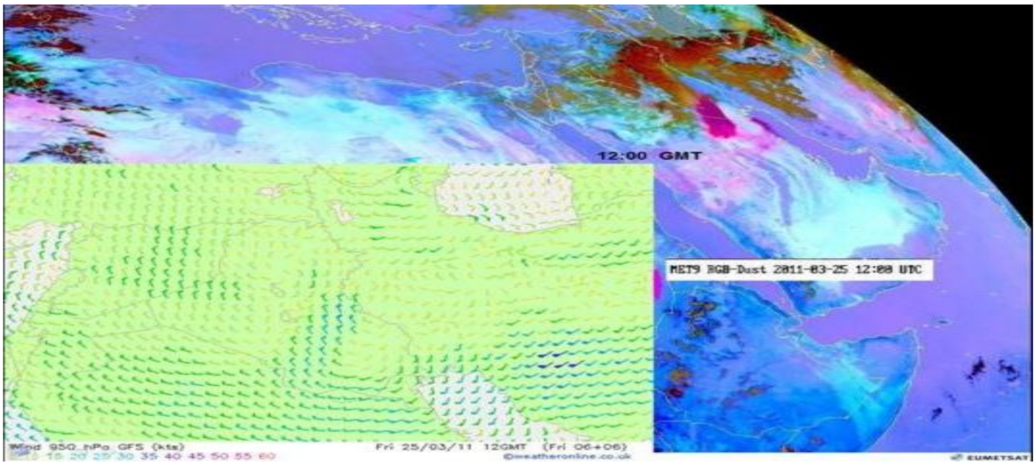

Figure (10) Wind chart overlaid on satellite image at 12:00 GMT.

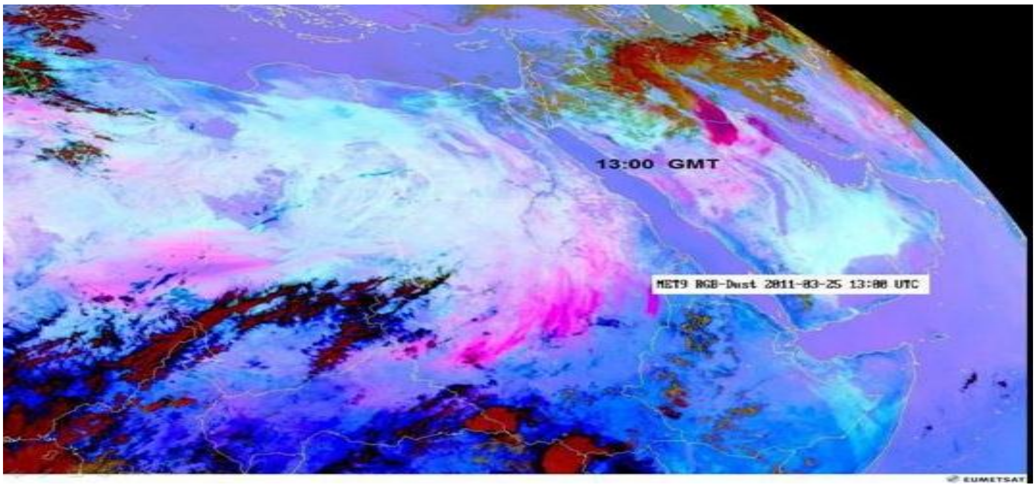

Figure (11) Satellite image at 13:00 GMT

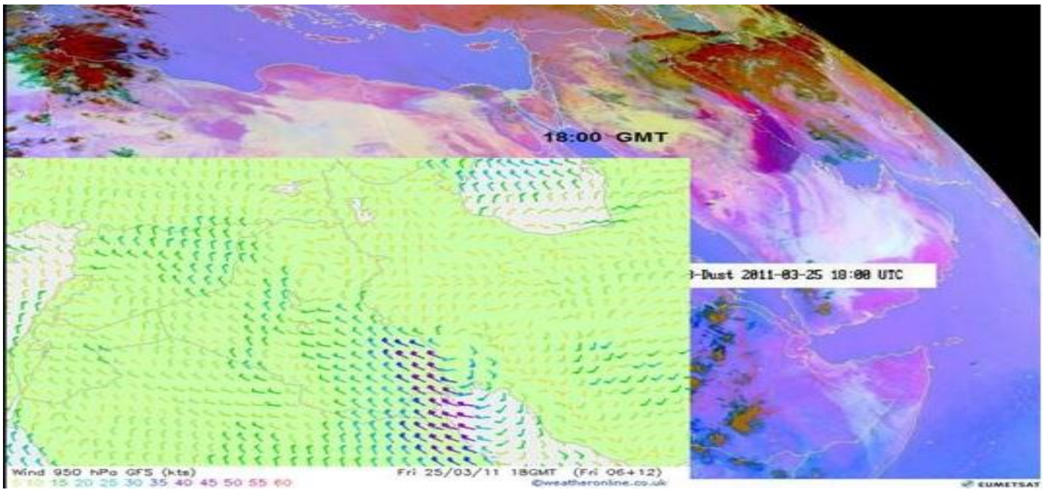

Figure (12) Wind chart overlaid on satellite image at 18:00 GMT

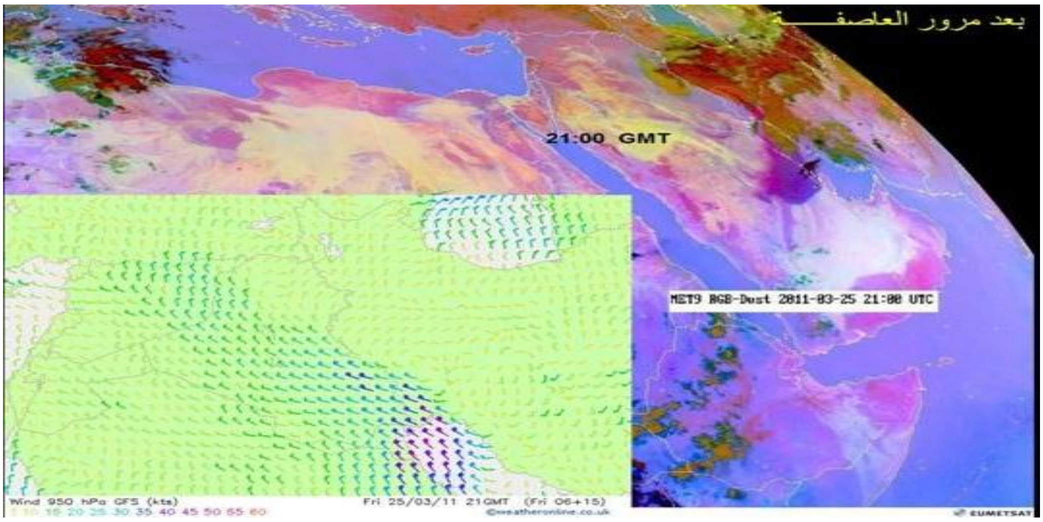

Figure (13) Wind chart overlaid on satellite image at 21:00 GMT

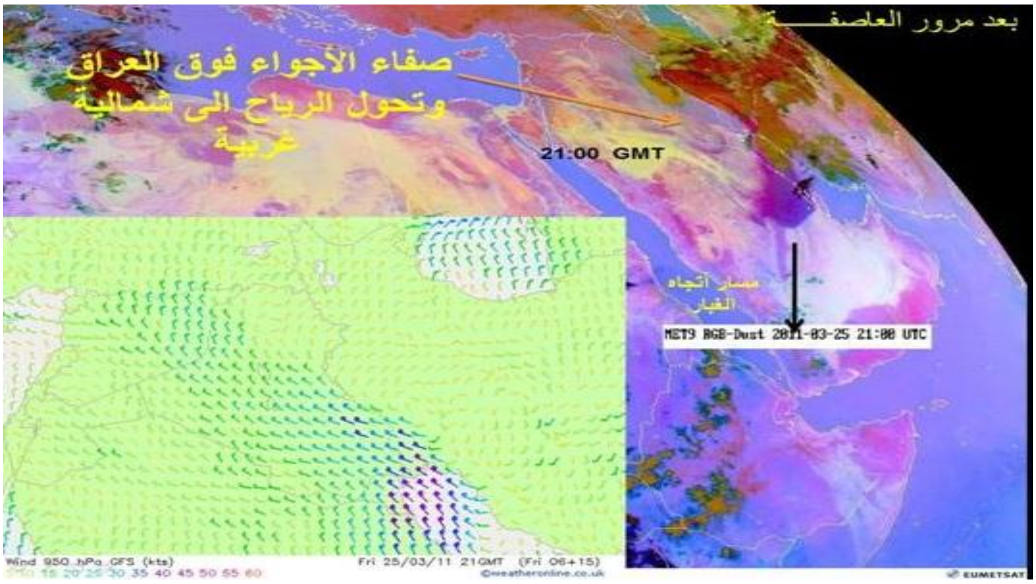

Figure (14) the clear weather at 12:00 GMT

The lower level has been analyzed in figures (15-26) that use to asses the placement and timing of the surface cold front and the associate strong winds which lifted the dust.

Figure (15) Temperature measurements during dust storm

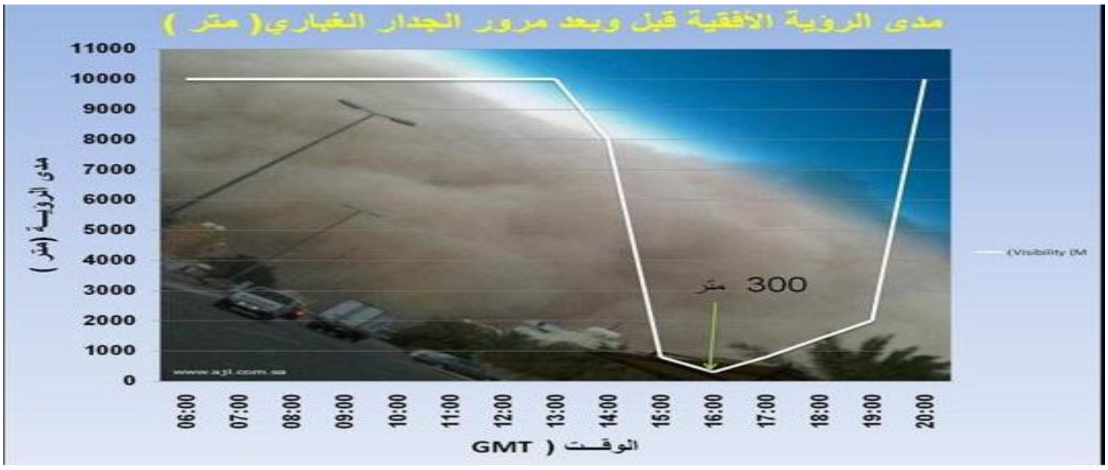

Figure (16) Visibility during dust storm

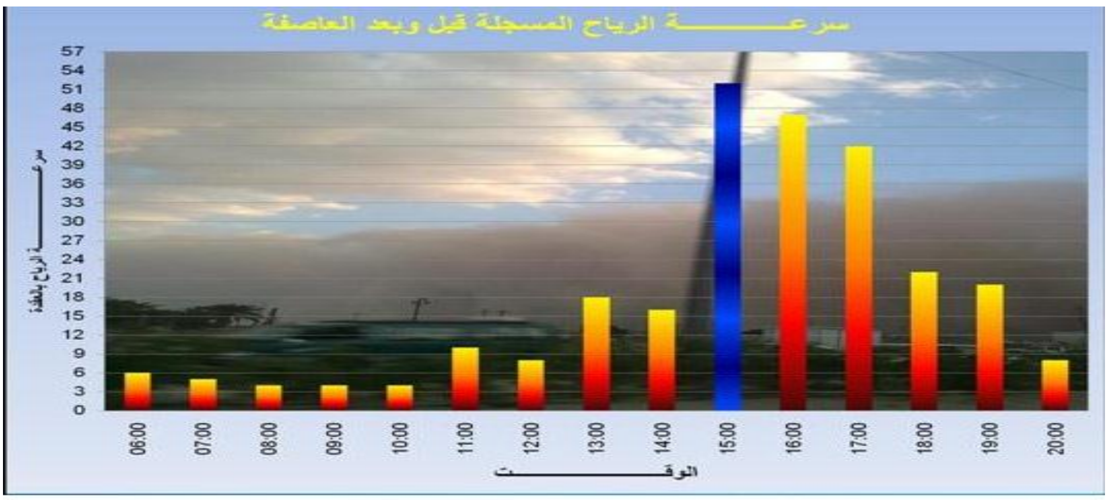

Figure (17) Wind velocity measurement.

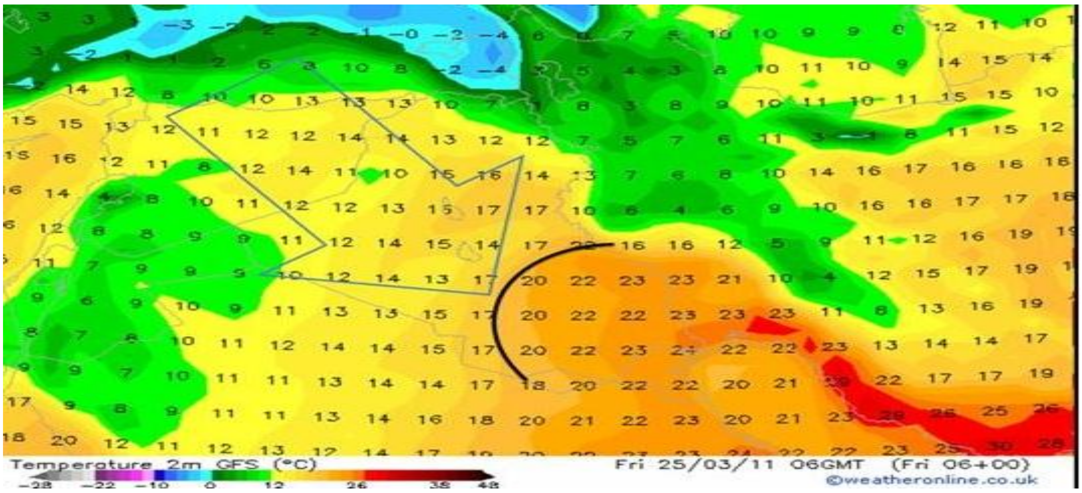

Figure (18) Surface temperature at 06:00 GMT.

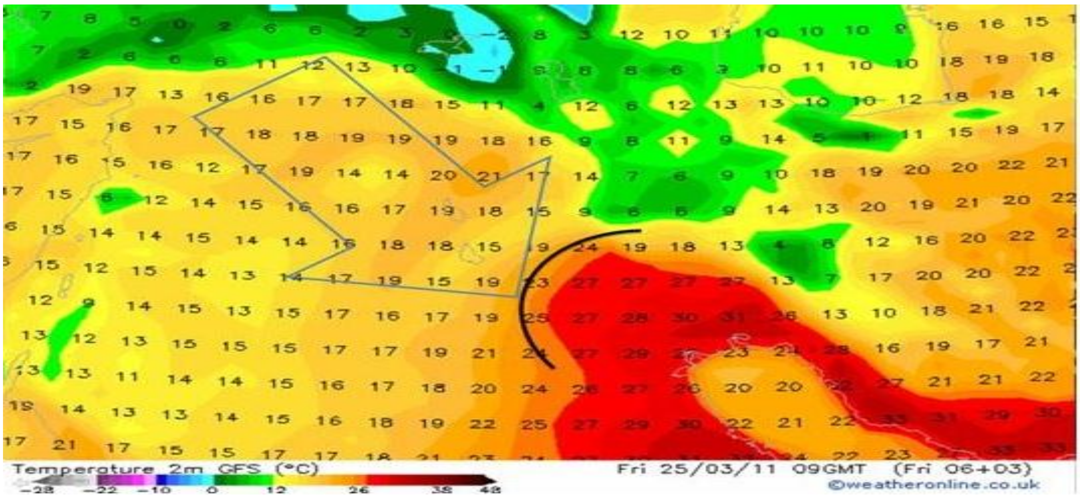

Figure (19) Surface temperature at 09:00 GMT.

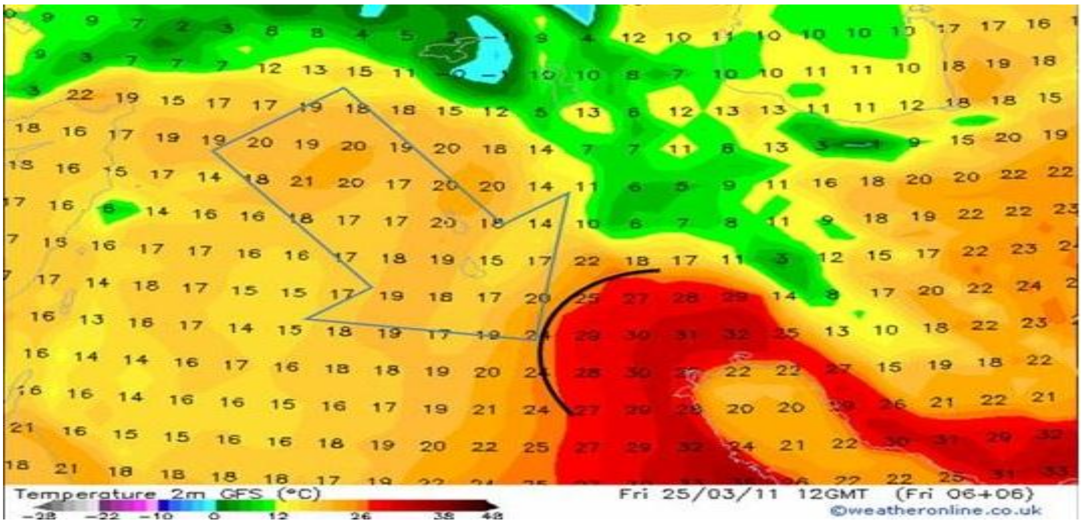

Figure (20) Surface temperature at 12:00 GMT.

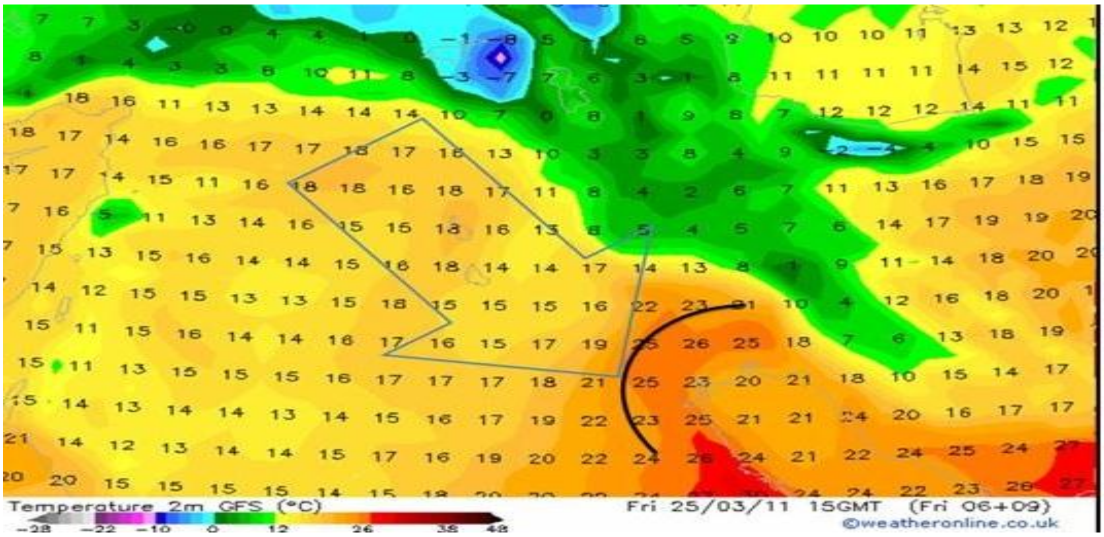

Figure (21) Surface temperature at 15:00 GMT.

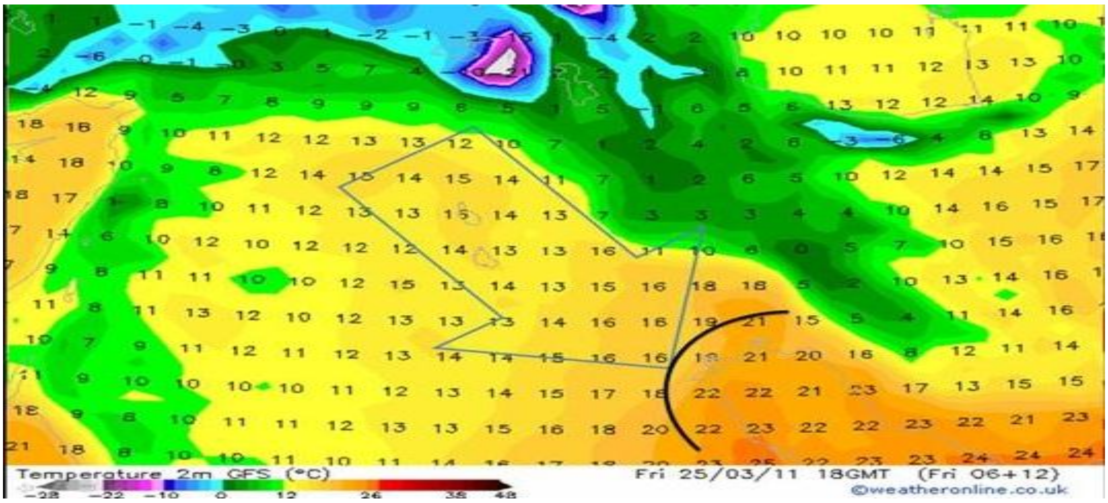

Figure (22) Surface temperature at 18:00 GMT.

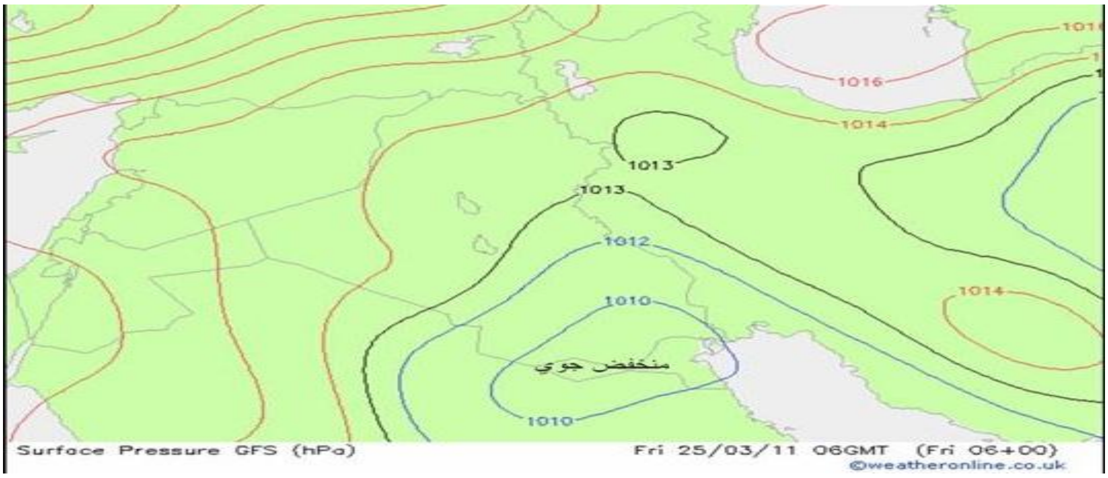

Figure (23) Surface pressure at 06:00 GMT

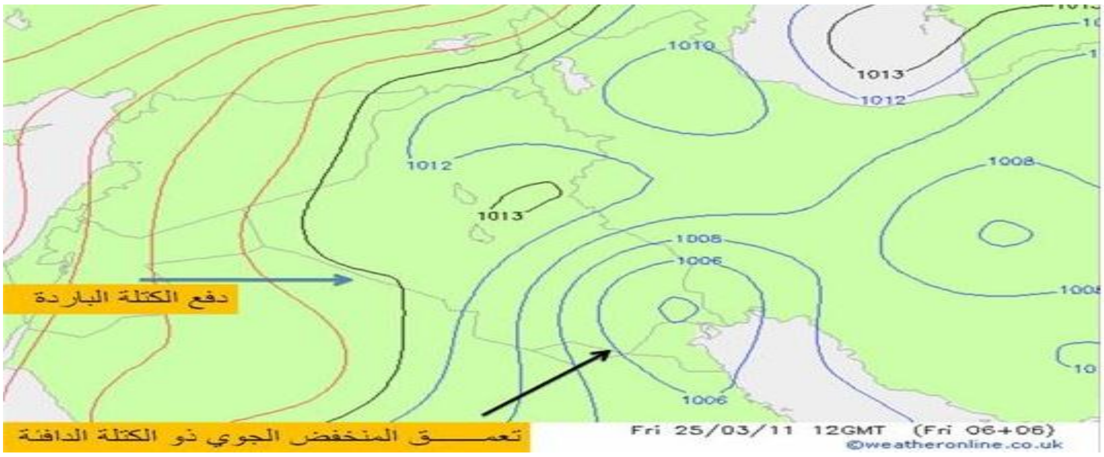

Figure (24) Surface pressure at 12:00 GMT.

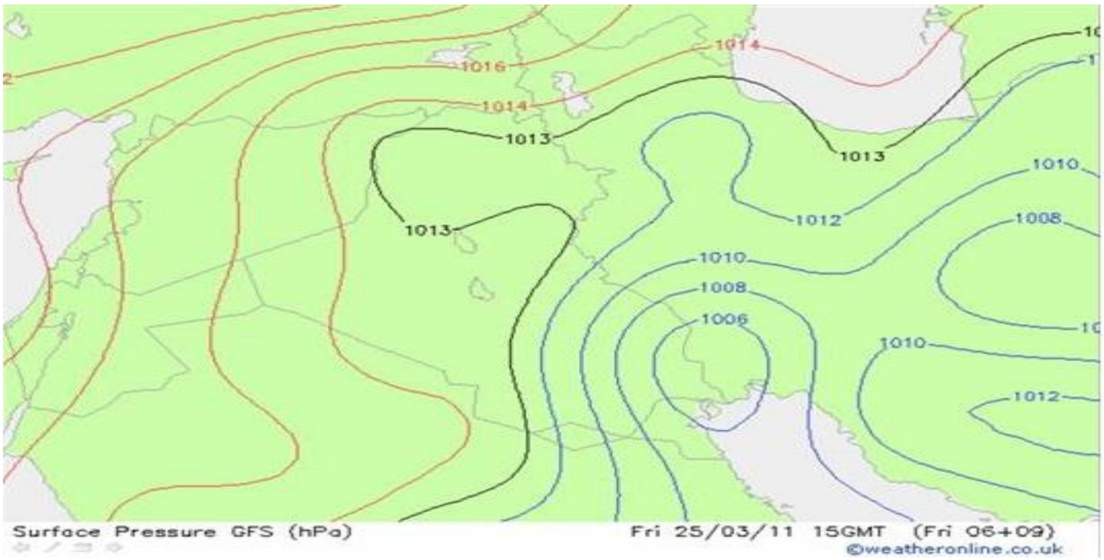

Figure (25) Surface pressure at 15:00 GMT.

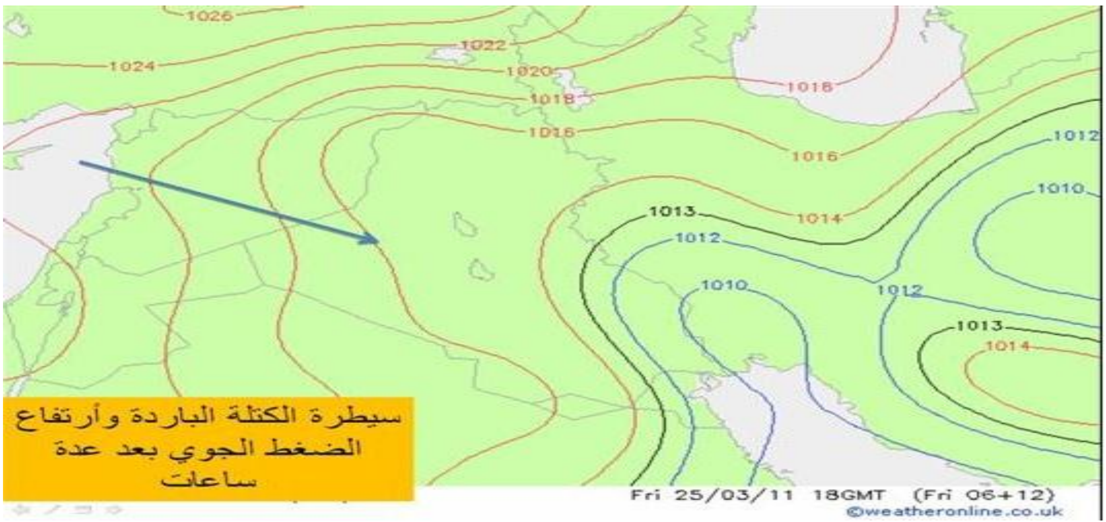

Figure (26) Surface pressure at 18:00 GMT.

The technology of satellite remote sensing has many advantages such as: wide coverage, continuous in the space and monitoring natural disasters quickly, so it can act as an important role in the dust storm monitoring, shown in figure (27). Remote sensing can monitor the scope of dust storm, its intensity grade and its moving trace.

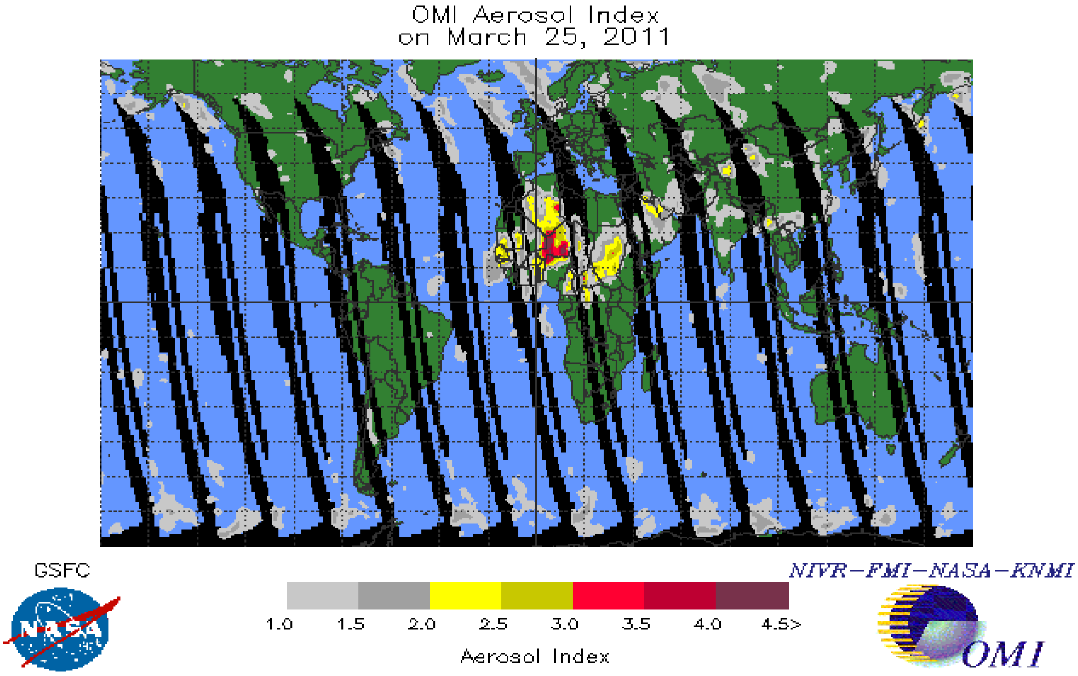

Figure (27) Ozone Monitoring Instrument image.

Conclusions:

In summary, this paper describe the big systems were critical to forecast where the wind would be sufficiently strong to mobilize dust, combined with a sufficiently unstable boundary layer and an appropriate source region, to excite a dust storm. In conclusion, remote sensing technique plays an important role in monitoring and analyzing dust storm. The dust storm formation has been analyzed related to the local weather system, short-term precipitation, soil moisture, and extent of deforestation, long-term increased drought, land use/land coverage changes, as well as other human activities, that produced a document for the nature, extent, causal factors associated with the severe sand and dust storms experienced in Iraq itself. Dust storms are a symptom and cause of desertification. They are often an early warning that the depravation of environment.

References

1. Herman, J. R., Bhartia P. K., Torres O., Hsu N. C., Seftor C. J., and Celarier E., (1997). “Global distribution of UV absorbing aerosols from Nimbus-7 TOMS data”, J. Geophys. Res., Vol. 102, pp. 16911-16922.
2. Herman, J. R., Krotkov N., Celarier E., Larko D., and Labow G., (1999). “Distribution of UV radiation at the Earth's surface from TOMS measured UV backscattered radiances”. J. Geophys. Res., Vol.104, 12059–12076.
3. Herman, J. R., and Celarier E. A., (1997). “Earth surface reflectivity climatology at 340–380 nm from TOM's data”. J. Geophys. Res., Vol.102, 3–28.
4. Prospero, J. M., Ginoux P., Torres O., and Nicholson S. E., (2002). "Environmental characterization of global sources of atmospheric soil dust derived from the Nimbus7 TOMS absorbing aerosol product”. Rev. Geophys., 40, 1, 1002
5. Torres, O., Bhatia P. K., Herman J. R., Sinyuk A, Ginoux P., and Holben B., (2002). “A long-term record of aerosol optical depth from TOMS observations and comparison to AERONET measurements”, J. Atmos.Sci. 59,398–413.
6. Torres, O., and Bhartia P. K., (1999), “Impact of troposphere aerosol absorption on ozone retrieval from backscattered ultraviolet measurements”. J. Geophys. Res., Vol.104, 21569–21577.
7. Torres, O., Bhartia P. K., Herman J. R., Ahmad Z., and Gleason J., (1998). “Derivation of aerosol properties from satellite measurements of backscattered ultraviolet radiation: Theoretical basis”, J. Geophys. Res., Vol. 103, pp. 17099-17110.
8. http://www.cnr.uidaho.edu/.
9. [COMET Program, 2003, “Forecasting dust storms”, http:// meted.ucar.edu/mesoprim/dust/.