Diyala Journal for Pure Science



# Study of the Synoptic Characteristics of a Severe Dust Storm over Iraq Using Regional Climate Model 4

**Nadia M. Abed [1], Monim H. Al-Jiboori [*1] and Mohamed M. Abdel Wahab [2]**

[1] Department of Atmospheric Sciences – College of Science – Mustansiriyah University – Iraq
[2] Department of Astronomy and Meteorology – Faculty of Science – Cairo University – Egypt

[1*] mhaljiboori@gmail.com

**Received: 2 January 2018** **Accepted: 15 July 2019**

**DOI:** https://dx.doi.org/10.24237/djps.15.04.422C

## Abstract

This study includes a detailed description of dust storms occurred in 3 May, 2005. The research analyses the synoptic conditions for the pressure system movements, temperatures changes and the wind time distribution. The condition leads to enhancement or reduces the dust storm that heading to Iraq. The analysis of the synoptic situation accompanied with the selected day is illustrated using the reanalysis data of ERA-Interim. Also, Back-Trajectories from Noaa Hysplit model backward trajectories is also used for three cities in Iraq (Mosul, Baghdad and Basra). In this study, a simple classification for the selected case is created based on the total amount of the dust in the atmospheric column (dust_load) simulated by the regional climate model of RegCM4.

**Keywords**: RegCM4, Synoptic analysis, Back trajectory, Dust storm.

Diyala Journal for Pure Science

# Study of the Synoptic Characteristics of a Severe Dust Storm over Iraq Using Regional Climate Model 4

**Nadia M. Abed, Monim H. Al-Jiboori and Mohamed M. Abdel Wahab**

# دراسة الخصائص الساينوبتيكية لعاصفة ترابية شديدة فوق العراق باستخدام RegCM4

**نادية محمد عبد[1]، منعم حكيم خلف[1] و محمد مجدي عبد الوهاب[2]**

[1]قسم علوم الجو – كلية العلوم – الجامعة المستنصرية – العراق
[2] قسم الفلك والارصاد الجوية – كلية العلوم – جامعة القاهرة – مصر

## الخلاصة

تشمل هذه الدراسة وصفاً للعاصفة الترابية في 3 آيار 2005. يحلل البحث الظروف الشاملة لحركات نظام الضغط، وتغير درجات الحرارة وتوزيع وقت الرياح. تؤدي الظروف المناخية هذه الى تعزيز او تقليل العاصفة الترابية التي تتجه إلى العراق. وتوضح التحليلات للحالات الموجزة المصحوبة باليوم المختار باستخدام بيانات إعادة التحليل (ERA-Interim) ومسار العواصف من أنموذج Noaa Hysplit ومسار العواصف في دراسة حالة اختيرت لثلاث مدن في العراق (الموصل، بغداد والبصرة). في هذه الدراسة، يتم إنشاء تصنيف بسيط للحالة المختارة استناداً إلى الكمية الإجمالية للغبار في عمود الغلاف الجوي (تحميل الغبار) الذي يحاكيه أنموذج المناخ الإقليمي RegCM4.

**الكلمات المفتاحية:** أنموذج المناخ الاقليمي، العواصف الغبارية، مسار العواصف، الحالة الساينوبتيكية.

## Introduction

The term dust storm is used when the particulate particles suspended in the atmosphere extend at large distances and affect the cities. Dust or dust storms, according to the World Meteorological Organization (WMO), are defined as the amount of airborne dust in different sizes due to surface lifting due to air and wind movement, which reduces visibility to less than 1,000 meters [1]. Atmospheric phenomena known as dust storms are caused by the transfer of mineral dust from the surface of the earth to the surrounding air, which is usually associated with dry and semi-arid regions, but can occur as a result of changes in the surface of the earth such as low vegetation and others [2].

The dust storm occurs when wind speed rapidly changes with height (i.e. shear stress formed). It means that the wind has reached a high speed. It can lead to erosion of the surface of the soil, which is prone to erosion due to the size and dryness of the particles, and turbulence near the Earth's surface [3]. The characteristics and type of the earth's surface in terms of roughness and vegetation play a major role in determining the wind's ability to lift dust particles in addition to the speed of the surrounding wind [4].

Local winds associated with a particular area are affected by wind systems generated in other larger adjacent areas. Land uses, physical factors, the stability of the surface, the resistance of erosion dependent on the surface features and the degree of coverage of surfaces resistant to erosion (e.g., rocks, plant litter, or snow cover) are minor to originate and rise local dust. It is important to note that most of the dust comes from particulate surfaces, especially from dry metal that transmits soil formations. Dust particles with diameter < 20 μm, that have a significant impact on weather and climate, can transport thousands of kilometers from their source areas [5].

Dust is transported by the prevailing wind and transported vertically through convection processes, as well as the adiabatic vertical movement associated with the frontal systems. Atmospheric dust settles on the surface of the earth through molecular adjustment, gravity (dry deposition) and wet deposition with precipitation. Large particles are established more rapidly than small particles in dry sedimentation processes.

Wet deposition can occur either under a cloud, when rain drops, snow or cold stones drift dust as they fall, or inside a cloud [5]. This paper focuses on the study of the characteristics of severe dust storms prevailing in Iraq. Synoptic patterns analysis will also be described.

## Materials and Methods

### Regional Climate Model

Regional Climate Model version 4 (RegCM4) is offered as a part of hands-on extended laboratory sessions during a series of workshops on Weather Physics and Climate Group organized at the International Center for Theoretical Physics (ICTP).
RegCM4 was originally developed at the National Center for Atmospheric Research (NCAR) and it was mostly applied to regional climate studies and seasonal prediction around the world. More details about this model are available online [6].

It is useful to view grid configuration models to obtain a simulation system that analyzes the data of high-pressure surfaces. As these models must simulate numerical models in vertical direction to determine the work of the original model [7].

The determination of the coordinates of a specific area within the model is based on the type of surface as shown in figure 1, which shows the leveling of the levels as the pressure level gradually decreases towards the top of the model. Without dimensions, σ-coordinate is used to define the model levels [8 and 9].

$$\sigma = \frac{(p - pt)}{(ps - pt)} \quad (1)$$

where p is the pressure, pt is a specified constant top pressure, *ps* is the surface pressure. It can be seen from the equation that σ is zero at the top and one at the surface, and each model level is defined by a value of σ. A typical vertical resolution is defined as a list of values between zero and one that does not necessarily have to be evenly spaced. The resolution in the border layer is usually more precise than before, and the number of levels may vary depending on the user's request. Horizontal grid Arakawa has a stunning B-load of velocity variables with respect to numerical variables.

The number of layers of models is always less than the number of full sigma levels. The difference specified in the model is, of course, critically dependent on the staggering network where gradients are inserted or mean intermediate terms are represented in the equation.

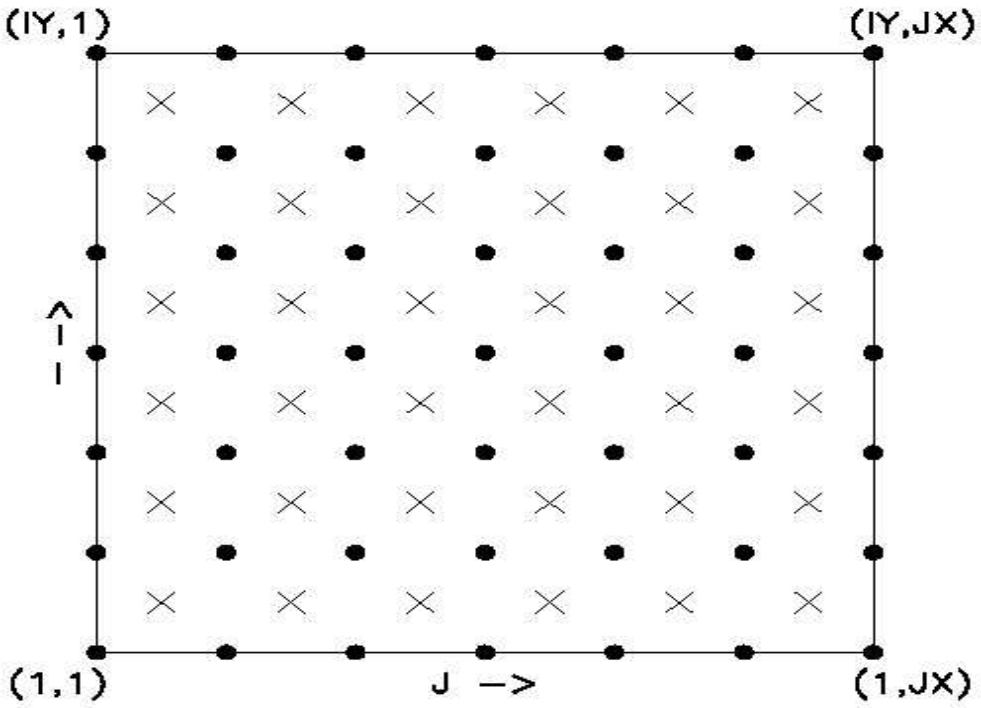


**Figure 1:** The schematic representation for horizontal Arakawa B-grid and a dot-and-cross is the grid points [10]

**Installation and instructions of RegCM4**

In order to simulate the model, it is necessary to obtain the zone data for the study as well as to determine the weather conditions of the oceanic and oceanic factors for an integrated simulation and guessing within the RegCM4 model. In the RegCM4 / PreProc / Terrain / domain. param file, there are several data sets that can be chosen to use for the initial and boundary conditions. figure 2 shows the installation and instructions of RegCM4.

Diyala Journal for Pure Science

# Study of the Synoptic Characteristics of a Severe Dust Storm over Iraq Using Regional Climate Model 4

Nadia M. Abed, Monim H. Al-Jiboori and Mohamed M. Abdel Wahab

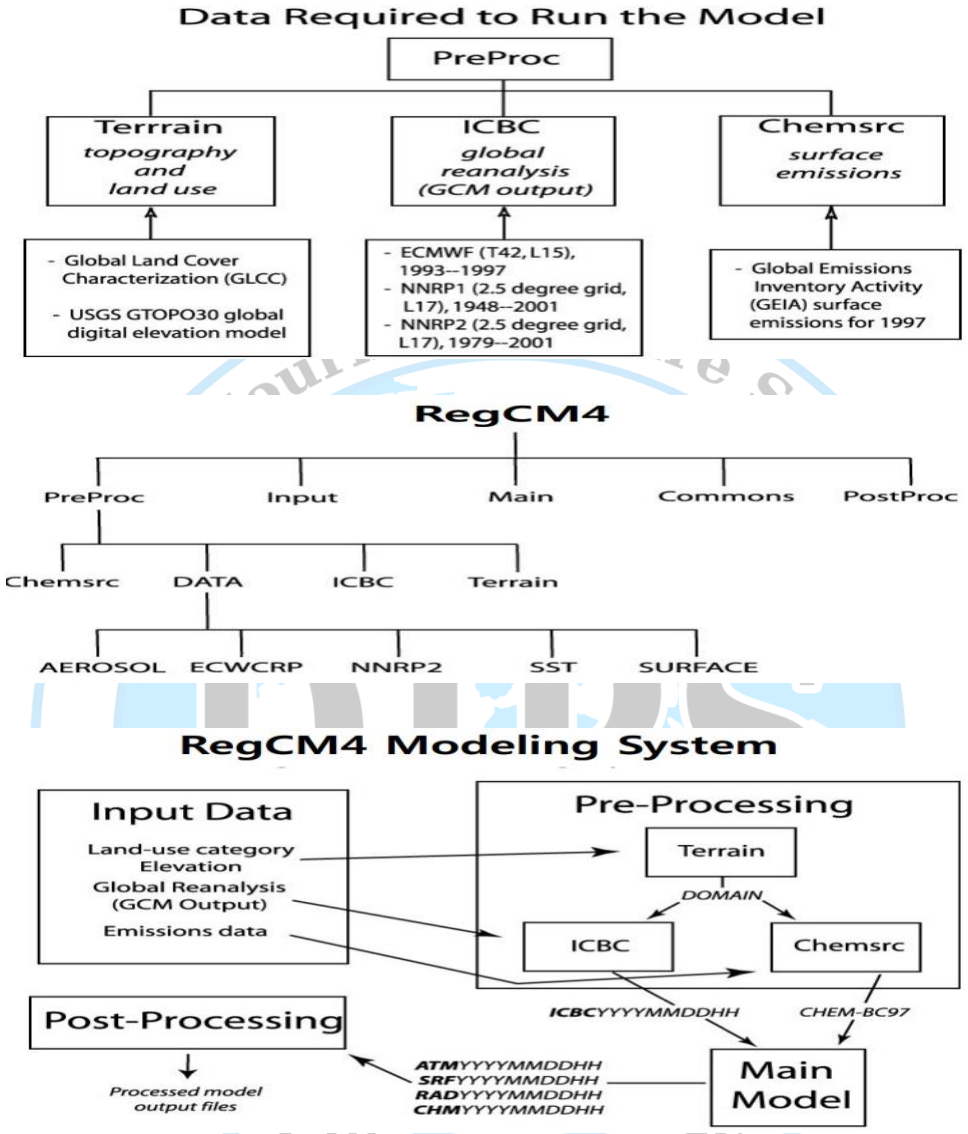


**Figure 2:** Flowchart for installation and instructions of RegCM4 [10]

## Studied domain

Because Iraq is exposed to many dust storms due to its locations in the north east of Arabian Peninsula, one of most arid regions in the world. Iraq is boarded by Zagrouse Mountains from the east and the desert of Arabian Peninsula from the south, from where the most of the dust

storms comes as shown in figure 3, which displays the topography of Iraq and the surrounding regions.

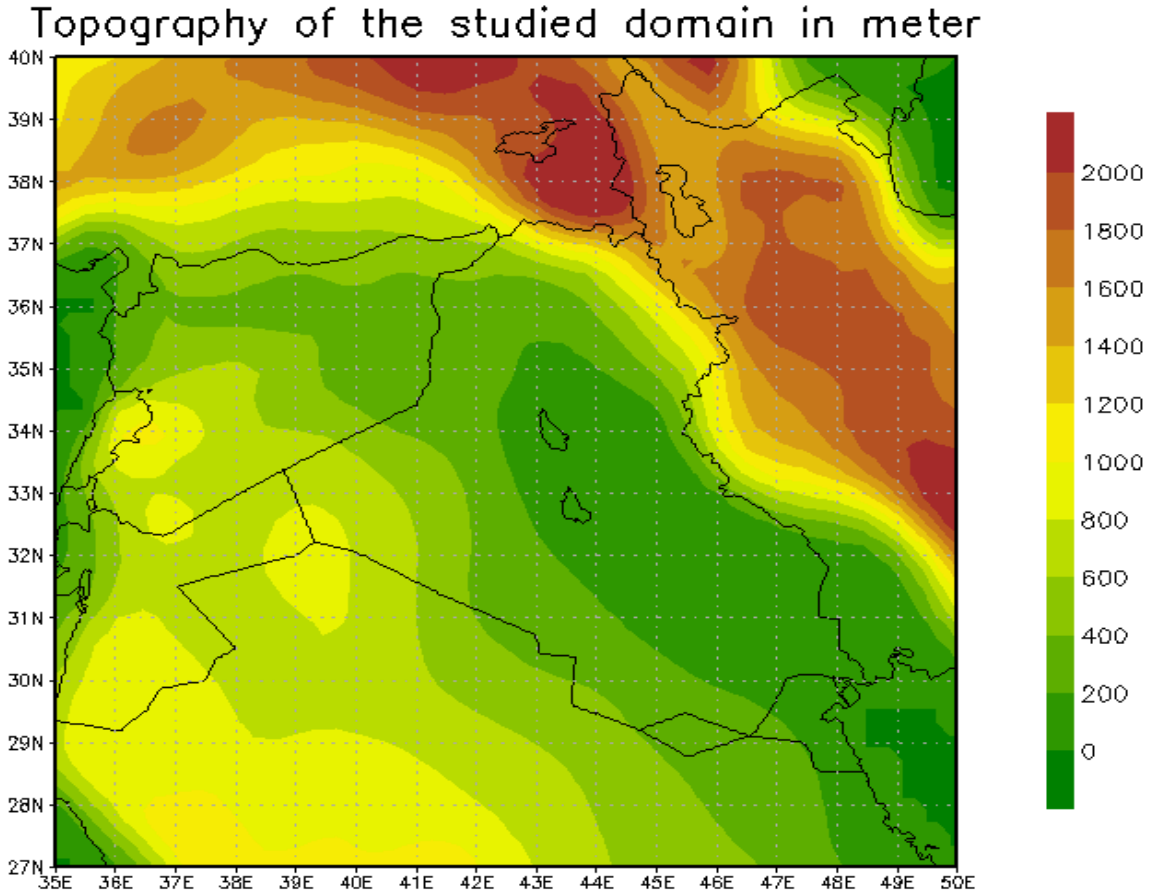


**Figure 3 :** Map of elevations (m) of Iraq induced by RegCM4.

## Data and methodology

The case of dust storm blowing over Iraq is selected of date 03 May 2003. To study the synoptic situation during this case, we used the reanalysis data of ERA-Interim available in [11] for the studied area shown in figure 3 at every 3 hours with spatial resolution of 0.125 degree, for the parameters of sea level pressure, air temperature at 2 m and 850 hPa and wind speed and its

direction at 10 m and 850 hPa. We also used the dataset of ERA-Interim as the meteorological field for the initial and boundary conditions (ICBC) of the regional climate model of RegCM4 as will be shown in the next subsection.

Among the tools used to study the dust patterns is the back trajectory offered by the National Oceanic and Atmospheric Administration (NOAA). Air Resources Laboratory's (ARL) Hybrid Single-Particle Lagrangian Integrated Trajectory model (HYSPLIT) that is online version [12] was adapted in this work. The trajectories were drawn using the global archived dataset of NCEP/NCAR reanalysis (for period from 1948 to present) with spatial resolution of 2.5 degree available at [13].

The back-trajectories were plotted for 48 hours before every dust case, over different locations to cover the whole area of Iraq; Mosul in the north, Baghdad in the center, and Basra in the south of Iraq.

## Result and discussion

### The synoptic description of case study

The following Table describes the case study by satellite imagery. These images are taken by the Moderate Resolution Imaging Spectroradiometer (MODIS) spectroscopy on NASA's Aqua satellite.

**Table 1:** The date of the case and its description

| Date | Description | Visibility |
|---|---|---|
| 03 May 2005 | A veil of dust from the arid landscape of southern Iran, Afghanistan and Pakistan hung on the Arabian Sea. It seems that, Oliver Green, S-shaped trajectory of the River Indus in the west of Pakistan under the soil washed away | Reduced to 100 m over Baghdad |

**The case study of 03 May 2005**

Figures 4 and 5 show the synoptic two levels 1000 and 850 hPa charts for 02, 03 and 04 May, 2005. The upper air chart for 850 hPa depicts a low-pressure area that Geopotential height approximates the actual height of a pressure surface. Since cold air is denser than warm air, it causes pressure surfaces to be lower in colder air masses, while less dense, warmer air allows the pressure surfaces to be higher. Thus, heights are lower in cold air masses, and higher in warm air masses

An immense dust storm spanning hundreds of kilometers is washing over Saudi Arabia. The light dust plume is narrow in the north, over Iraq, and widens into a massive cloud in Saudi Arabia.

Waves of dust spread eastward over the Arabian Gulf. The upper and surface pressure charts show the development of the low pressure the north-western wind rising the dust from Syrian plateau and western part of Iraq with high wind speeds over western parts of Syria and Iraqi alluvial plain, moving the dust towards the Arabian Gulf, and towards the south west, activating the dust.

The wind speed is accelerated especially over Syria and Iraq reaching to 7.6 m / s, blowing towards the east carrying the dust to Iran that witnessed an intense dust storm especially its western parts.

The comparison between the wind direction and speed between both sets of data shows a high compatibility in simulating the wind direction for the tested days.

Closing contours with their steep gradients last in north of Iraq for most of this period. Wind directions had ranges from west to west north.

Diyala Journal for Pure Science

# Study of the Synoptic Characteristics of a Severe Dust Storm over Iraq Using Regional Climate Model 4

Nadia M. Abed, Monim H. Al-Jiboori and Mohamed M. Abdel Wahab

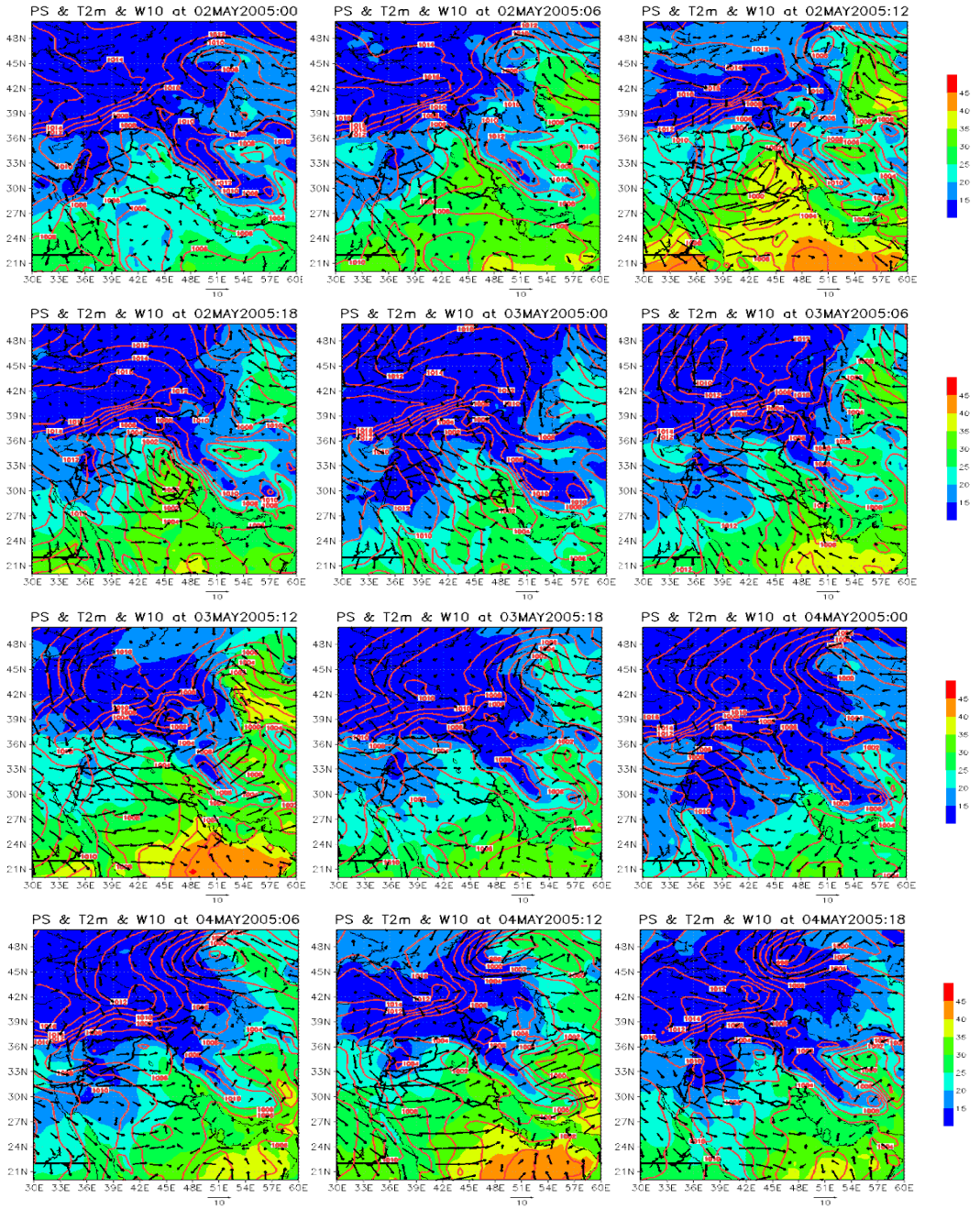


**Figure 4:** Contours of surface pressure (in hPa), air temperature at 2 m shaded (in °C), and wind at 10 m in vectors (in m/sec) during 02-04 May 2005, every 6 hours

Diyala Journal for Pure Science

# Study of the Synoptic Characteristics of a Severe Dust Storm over Iraq Using Regional Climate Model 4

Nadia M. Abed, Monim H. Al-Jiboori and Mohamed M. Abdel Wahab

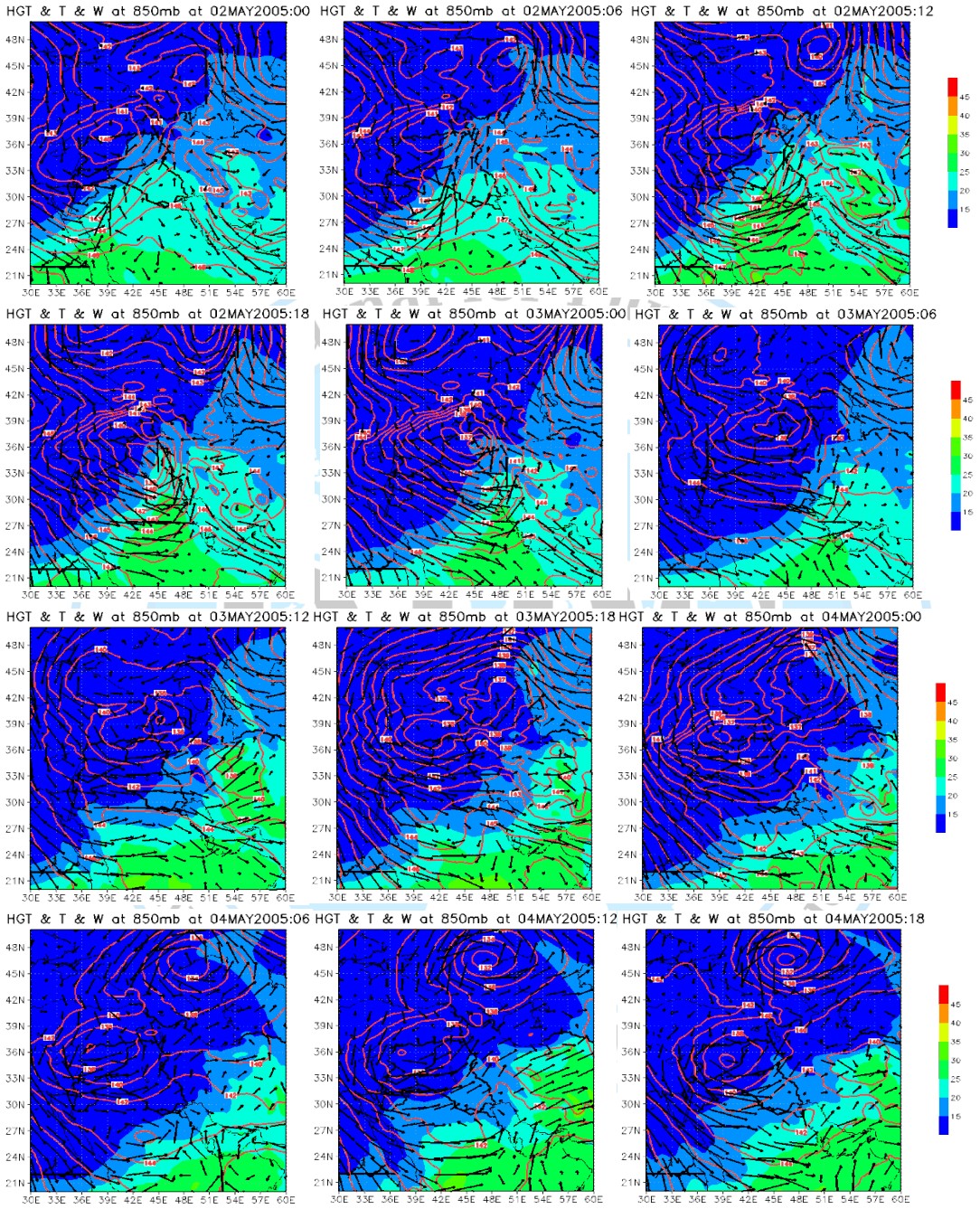


**Figure 5:** Contours of pressure height (in geopotential height), air temperature in shaded (in °C), and wind in vectors (in m/sec), all of them at 850 hPa during 02-04 May 2005, every 6 hours

Diyala Journal for Pure Science

# Study of the Synoptic Characteristics of a Severe Dust Storm over Iraq Using Regional Climate Model 4

Nadia M. Abed, Monim H. Al-Jiboori and Mohamed M. Abdel Wahab

## Back-trajectories by NOAA hyspilt model

In this part of study, we could draw the backward trajectories ending in specific time for selected case study by using reanalysis global meteorology data from 1948 up to present, and enter starting time (year, month, day, hour) Default: 0 0 0 0 enter the two digit values for the UTC time 48 hour as well as choose the latitude and the longitude to the selected stations on 10 meter altitude.

Figure 6 shows NOAA Hysplit backward trajectories for three stations in Iraq (Mosul, Baghdad and Basra) at 48 hours and 10 m height on 03 May 2005. As from the figure, the source of dust storms for Mosul on 10 m height is coming from Turkey, for Baghdad it is from Lebanon on 500 m height, and lastly it comes from Jordan on 10 m height towards Basra.

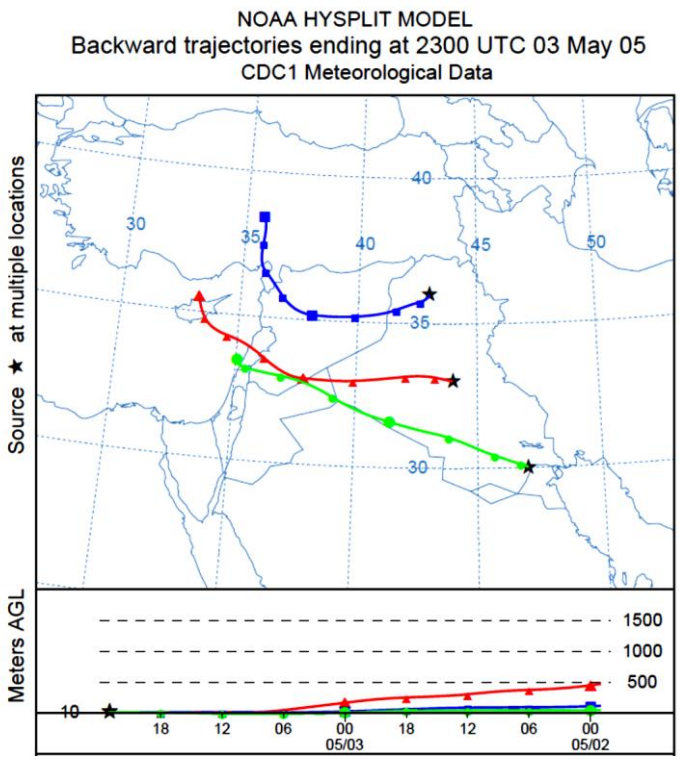


**Figure 6:** NOAA Hysplit backward trajectories for three stations in Iraq (Mosul-Baghdad-Basra)

## Conclusions

When analyzing the synoptic state of the selected case study by using the reanalysis data of ERA-Interim, the analysis gives a synoptic condition that confirms dust storms on these dates coming from different regions and under different conditions. The back-trajectories from Noaa Hysplit model backward trajectories for the case studied for three Iraqi cities (Mosul, Baghdad and Basra) at 10 m height and 48 hours provided good description for the wind speed or dust storm path.

## References

1. G.H. McTainsh, J. R. Pitblado, Earth Surface Processes and Landforms, 12(4), pp. 415 – 424(1987).
2. D. S. Thomas, Aeolian landscapes and bedforms. In Arid Zone Geomorphology: Process, Form and Change in Drylands (ed. Thomas, D.S.G.), 3rd Ed. (Wiley, 2011), pp. 427–454
3. G. F. Wiggs, Sediment mobilisation by the wind, In Arid Zone Geomorphology: Process, Form and Change in Drylands, ed. By D.S.G. Thomas, 3rd Ed. (Wiley, 2011), pp. 455–486
4. J. R. Giles, F.S. Wiggs, R.M. Bailey, Earth Surface Processes and Landforms, 41 (10), pp.1421-1436 (2016)
5. J. Goldman: Dust storms, sand storms and related NOAA activities in the Middle East. NOAA magazine, 2003, Internet data.
6. http://www.ictp.trieste.it/pubregcm/RegCM4
7. J. S. Pal, E. E. Small, E. A. B. Eltahir JOURNAL OF GEOPHYSICAL RESEARCH Atmospheres, 105(D24), pp.29,579–29,594 (2000).
8. F. Giorgi, G. T. Bates, S. J. Nieman, Journal of Climate, 6(1), pp.75–95(1993a).
9. F. M. Giorgi, M. R. Marinucci, G. T. Bates, *Monthly Weather Review*, 121(10), pp.2794–2813(1993b).

10. N. Elguindi, B. Xunqiang, F. Giorgi, B. Nagarajan, J. Pal, F. Solmon, S. Rauscher, A. Zakey, G. Giuliani, Regional Climatic Model RegCM User Manual Version 4.1. The Abdus Salam International Centre for Theoretical Physics Strada Costiera, pp. 11 I – 34151(2011), Trieste, Italy.
11. http://apps.ecmwf.int/datasets/data/interim-full-daily/levtype=sfc/.
12. https://www.ready.noaa.gov/hypub-bin/trajtype.pl?runtype=archive.
13. https://www.ready.noaa.gov/gbl_reanalysis.php.