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Analyzing the synoptic patterns associated to dust events over west Asia during summer months - Case Studies

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Abstract: *West Asia including Arabian Peninsula, Syria, Iraq and Iran has been recognized as one of the most important primary sources of dust. During summer season, the dust usually driven by the north-westerly wind called Shamal wind which can impact land and people at great distance away where the dust finally settles. This study aims to characterize the dominated synoptic patterns in summer associated to four sever dust events during June, July, August and September for West Asia region extended from 24° to 40° N latitudes and 34° to 60°E longitude by analyzing the synoptic situation for the surface and the upper air level by using surface and upper air charts at 850 hPa, 10m wind speed and direction from ERA-I reanalysis data, and space-borne observations data from MODIS/Aqua and Terra. The results show that the studied dust events were triggered by a surface low pressure patterns associated to the Indian Monsoon over Iran and south-eastern Arabian Peninsula accompanied by high pressure system over the eastern Mediterranean and northern Africa. This study presents the four phases of the Indian Monsoon during June to late September. The onset starts in June, while the most active phase of the Monsoon occurred in July and August and the last phase occurs in September.*

Keywords: *dust events, MODIS, Monsoon, summer Shamal, synoptic analysis.*

I. Introduction

Mineral dust is a natural aerosol abundant in the atmosphere which has a substantial effect on weather and climate. Due to the frequent occurrence of dust storms over desert dust sources, the impacts of the problem are on different sectors and it is considered as serious hazard. Local and regional dust events have impacts on different sectors, such as health, aviation, marine navigation, agriculture, water resources and climate through perturbing the atmospheric radiative flux and changing the temperature and precipitation [1] [2] [3]. Mineral dust emissions are mainly result from wind erosion in the arid and semi-arid regions of the world, and the wind is the main driver of emissions, in addition to the surface characteristics which play a key role for their spatial distribution, intensity and frequency as it will be explained later.

The main dust source in west Asia is Tigris and Euphrates alluvial plain in which dust activities have intensified in Iraq in recent years. This is due to many reasons related to the climate of Iraq which characterize by sub-tropical, continental, arid to semi-arid with dry hot summers and cooler winters. The precipitation reaches a maximum in the mountain ranges and is a critical water source for the rest of Iraq. The primary soil types in Iraq are silt and clay, with fine and very fine particles smaller than 70 µm in diameter) in which they can be easily lifted and transported by the wind [4]. Marshland is currently dry due to natural and man-made causes and they considered as a significant sources of dust within Iraq [5]. Moreover, the new dam construction projects on Tigris and Euphrates rivers decreases the humidity and water content of soil in the downstream areas, which consequently lessen the threshold friction velocity of the soil and its resistance against wind erosion [6]. Due to all the above reasons, Iraq becomes a prone to dust storms.

The Empty Quarter (or Al-Rub' Al-Khali desert) considered as one of the largest sand deserts in the world which occupies much of the southern interior of the Arabian Peninsula and it is connected to the An Nafud sand sea in the north by the Ad-Dahna, a sand corridor and central Saudi Arabia. The Arabian Peninsula affected by dust from Tokar Gap in north-eastern Sudan, near the Red Sea in summer season. South-western Iran and areas on the Iranian coast of the Arabian Gulf are also active dust sources. In general under different synoptic and mesoscale weather conditions, most of the region (apart from Turkey) is a potential dust source [7].

Dust particles that reached up to several kilometers due to the vertical mixing are carried by strong wind aloft over distances of thousands of kilometers affecting land and people at great distances where the dust finally settles.

Sand and Dust Storms (SDS) are a major problem in west Asia which has a wide concern by research community. Some of the studies include the research of Kutiel and Furman (2003) [8] who studied the spatial and temporal characteristics of dust storms in the Middle East by analyzing the visibility reduction in that region. Meshaal (2009) [9] has discriminated the pattern of dust storms using MODIS Terra Satellite. Mohammed (2010) [10] studied the dust storms and their relation with some meteorological parameters and main types of synoptic patterns associated with occurrence of dust storms for selected stations in Iraq during the period (1971-2007). Hamidi et al. (2013) [6] analyzed the synoptic patterns of 12 sever dust storms from 2003 to 2011 for the Middle East focusing on the Tigris and Euphrates alluvial plain based on NCEP-NCAR reanalysis Data and they found that Shamal is the main type of synoptic dust storms which is related to the anticyclones located over northern Africa to Eastern Europe and the monsoon trough over Iraq, southern Pakistan and Indian Subcontinent with the highest frequency in June and July. Ibrahim (2013) [11] investigated the synoptic situations for dust storms that occurred in Iraq for the period of 2003 to 2012 using meteorological observations, satellite images and Aerosol Index (AI). The objective of this study is to characterize the synoptic patterns dominated in summer associated to four sever dust events during June, July, August and September according to the Earth Observatory website: (http://earthobservatory.nasa.gov/NaturalHazards/category.php?cat_id=7&m=12&y=2015) for West Asia region by analyzing the synoptic situation for the surface and the upper air level using surface and upper air charts at 850 hPa, 10m wind speed and direction from ERA-I reanalysis data, and space-borne observations data from MODIS/Aqua and Terra.

II. Meteorological features generating dust events

Across the many dust source regions on Earth, a number of generic meteorological phenomena can be identified and classified to four processes which can locally be modified by topographic effects and are usually characterized by marked diurnal cycles [12]:

1. Large-scale monsoon circulations

The most notable monsoon circulations are the Indian and West African monsoons that affecting many dust source regions associated with the formation of marked continental heat lows during the hottest part of the year. For the Indian summer monsoon, the lowest mean-sea level pressure is typically found near the Pakistan-Indian border and the strong pressure gradient to the subtropical anticyclone over the southern Indian Ocean drives a powerful circulation with strong and persistent winds affecting dust sources on the Horn of Africa, the eastern flank of the Arabian Peninsula, southern parts of Pakistan and north-western parts of India. It tends to generate strong northerly winds across Turkmenistan, eastern Iran and Afghanistan directed into the heat low, and north-westerly summer Shamal winds, which frequently carry dust, blow across the Tigris and Euphrates river valleys of Iraq and the Arabian Gulf states into the heat low over the Arabian Peninsula [12].

2. Mobile Synoptic scale systems

The primary control on episodic, large, intense dust events in many source regions are the synoptic-scale weather systems. In order to drive strong winds capable to emit dust from source regions, a sufficiently large low-level pressure gradient should be established which is frequently extra tropical cyclonic disturbances and particularly the trailing cold fronts associated with them, but it can also occur with anticyclones or with tropical African easterly waves [13]. In west Asia, summer Shamal and frontal dust storms in non-summer season are the two main kinds of synoptic scale dust storms. The frontal dust storms in Tigris and Euphrates rivers alluvial plain has two types: prefrontal (or Sharqi) and postfrontal (or winter Shamal) dust storm. Another kind of frontal dust storm rarely occurs in Tigris and Euphrates river alluvial plain is the Shear lines which is very frequent in winter and occur over west of Arabian Peninsula, the Red Sea and equatorial Africa [6].

3. Convection systems

Convective dust storms occurred in west Asia region and have three types: moist convection (or haboobs) and inversion downburst as mesoscale events, dry convection (or dust devils) as microscale events.

III. Methods

The methodology used in this study consists of analyzing the synoptic patterns which generating dust events including the surface and upper air charts at 850 hPa, 10m wind speed and direction using ERA-I reanalysis data, Space-borne observations data from MODIS/Aqua and Terra for West Asia region centered over Iraq extended from 24° to 40° N latitudes and 34° to 60°E longitude.

A. ERA-I Reanalysis data

The European Centre for Medium-Range Weather Forecast (ECMWF) ERA-Interim (ERA-I) Reanalysis outputs were used which includes the Mean Sea Level Pressure (MSL), Geopotential height at 850 hPa and 10m wind speed. It is the latest global atmospheric reanalysis produced by ECMWF as a transition between ERA-40 and a future reanalysis project. It provides information on a large variety of surface parameters (3-hourly), describing weather as well as ocean-wave and land-surface conditions and 6-hourly upper-air parameters (37 pressure levels up to 1 hPa) on a 0.25◦ × 0.25◦ grid. ERA-I uses an improved atmospheric model and a more sophisticated data assimilation method (4D-Var) for atmospheric analysis compared to ERA-40.

Reanalysis data provide a multivariate, spatially complete, and coherent record of the global atmospheric circulation. Unlike archived weather analyses from operational forecasting systems, a reanalysis is produced with a single version of a data assimilation system including the forecast model used and is therefore not affected by changes in method [14].

B. Space-borne observations data

The Moderate Resolution Imaging Spectro-radiometer (MODIS) aboard the Terra satellites passes north-south across the Equator in the morning, and Aqua satellites that pass south-north over the Equator in the afternoon. MODIS (Terra & Aqua) view the entire Earth's surface every one to two days. Its detectors measure 36 spectral bands between 0.405 and 14.385 µm, and it acquires data at three spatial resolutions: 250m, 500m, and 1,000m.

Most Satellite sensors applied algorithms in order to retrieve Aerosol Optical Depth (AOD) which is defined as the vertically integrated aerosol extinction and can be considered as an optical measure of the whole amount of aerosols (all types) with some wavelength dependence. MODIS comprises two aerosol algorithms, one used to derive the aerosols over land and the other used over ocean [15]. MODIS AOD algorithm over land works only over low ground reflectance (over dark vegetation).To calculates AOD over bright areas such as deserts, MODIS/Aqua-Deep Blue AOD product has been included in the analysis which provides information over arid and semi-arid areas and it is able to distinguish dust plumes from fine-mode pollution particles even in complex aerosol environments [16], [17]. The reliability and availability of MODIS AOD product in near real-time lead to a most widely use in aerosols studies. The advantages of using satellites data is the large spatial coverage and their availability in near real-time, while the including of all types of aerosols can limits the applications who involved in a particular aerosol type (like dust) which might be limited to seasons and regions in some cases, when or where that type dominates the aerosol composition [18].

IV. Results and Discussion

1. The case study of June, 2012

Fig. 1 shows the Sea level pressure, geopotential height for the level 850 hPa and wind barbs in knots from ERA-Interim reanalysis at 12:00 UTC from 1 to 4 June 2012 Fig. 2 shows MODIS products of AOD and Satellite images from Aqua satellites for 1, 3 and 4 June at 07:25 UTC**,** 10:25 UTC and 07:55 UTC respectively.

Sea level pressure chart on 1 June shows a low pressure system centered over Iran associated to the Monsoon with a ridge axis over the eastern Mediterranean associated to the sub-tropical high, and the upper air chart for 850 hPa shows the low pressure system over Iran with a ridge stretching easterly towards Iraq and Syria, this west – east synoptic systems lead to pressure gradients that generate a north-westerly airflow (summer Shamal) as shown in Fig. 1 where the north-westerly wind is blowing over Syria and Iraq with highest surface wind speed over Syria, northern and south-eastern Iraq, western Iran and north-eastern Saudi Arabia where the dust source in Ad-Dahna Desert is activated, a central division of the Arabian Desert, which considered as a potential dust source in the Arabian Peninsula as shown in (Fig. 2 A). In addition to this synoptic pattern, the effect of the terrain sloping to the west and south west in central KSA and the low elevations of the lower Tigris-Euphrates alluvial plain [19] helped in generating the north-westerly wind flow over the Arabian Gulf.

The next day, 850 hPa charts shows an intensification in the trough over Iran and eastern Iraq, while the ridge was extending eastward over Syria, Jordan, Iraq and to northwest/central KSA, and the surface chart shows the stretching of the trough toward the north west over Syrian plateau and lower Tigris-Euphrates river basin that considered as potential dust sources as shown in Fig. 1. The surface wind speed was about 20 knots over western Iran and south-eastern Iraq and it blew dust towards the south east over the Arabian Gulf region and towards eastern KSA.

The low pressure system is intensified on 3 June over south-western parts of Iran extending towards the northwest (as well as in 850 hPa) affecting Iraq and the gulf region, this leads to increase the surface wind speed over central and southern Iraq, north and eastern KSA and the Arabian Gulf as shown (Fig. 1). Moreover an intense ridge was over the Caspian Sea extending southward, this pressure gradient (clear in 850 hPa chart) strength the speed of wind at the surface to reach 20 knots over northern Iran and southern Iraq that kicked up the dust over that region. Aqua/MODIS image (Fig. 2 B) taken at 10:25 UTC shows a pale cloud of dust hovering over Al Tharthar lake (to the north of Baghdad) with a long beige veil of dust extended from the southeastern Iraq reaching Kuwait and the Arabian Gulf, dipping into northeastern Saudi Arabia with another brown veil of dust extended from the southeastern Iraq hovering over Kuwait and the northern parts of Arabian Gulf.

The trough over western Iran continue stretching towards the north -west on 4 June as shown in the mean sea level chart with a intense ridge axis over Caspian Sea leading to activate dust sources in Iran while the north westerly wind about 10 knots at the surface was dominating over Iraq moving towards the Arabian Gulf region and the north-eastern parts of KSA. MODIS/AOD image and Aqua/MODIS image taken at 07:55UTC show dust plumes moved towards the southeast hovering over the Gulf especially Kuwait and Qatar as shown in Fig. 2 C.

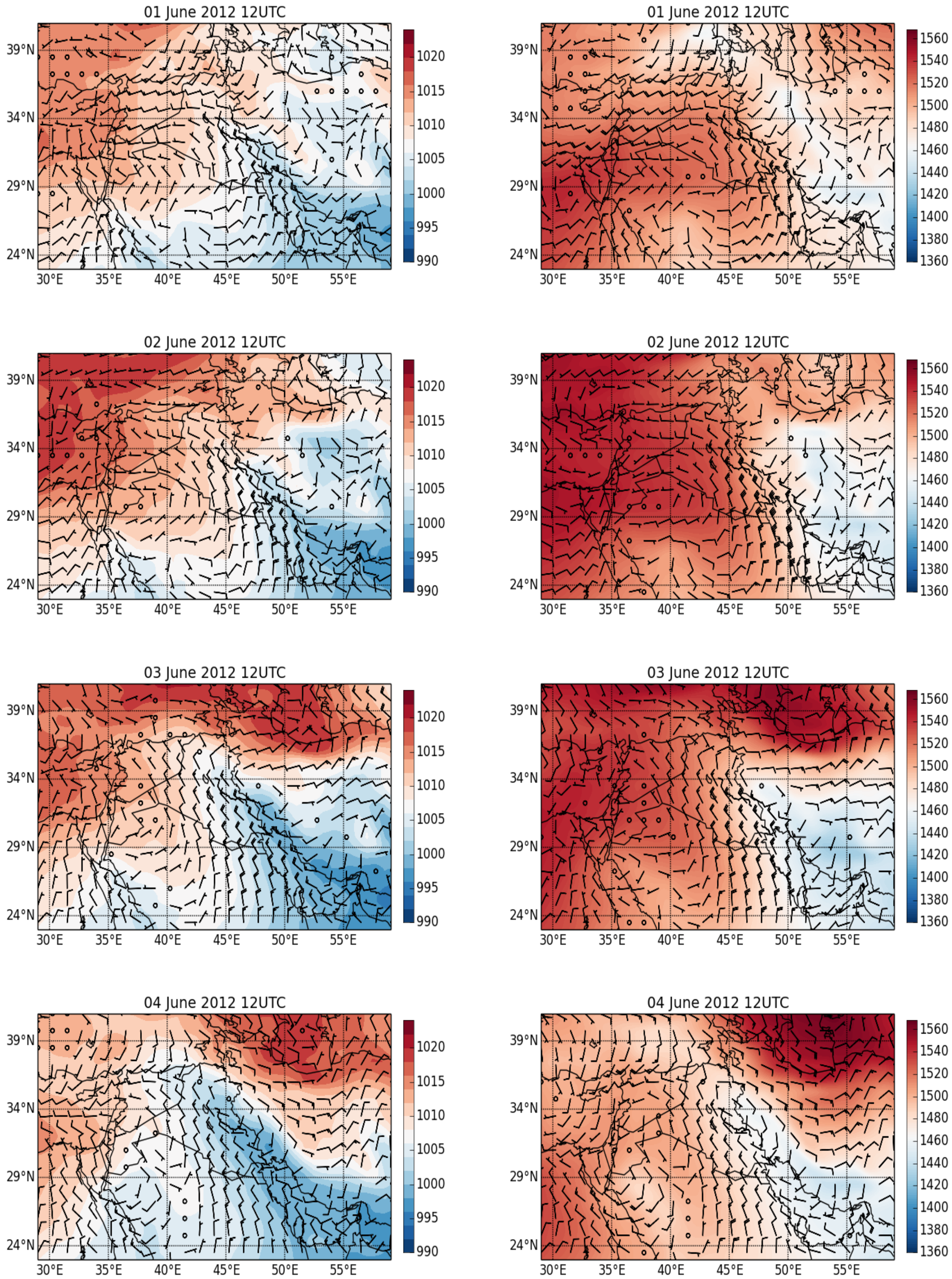


Fig.1 Sea Level Pressure (left) and Geopotential height (m) at 850 (hPa) (right) using ERA Interim Reanalysis data with spatial distribution of wind barbs at 12:00 UTC for the days 1,2,3,4 June 2012.

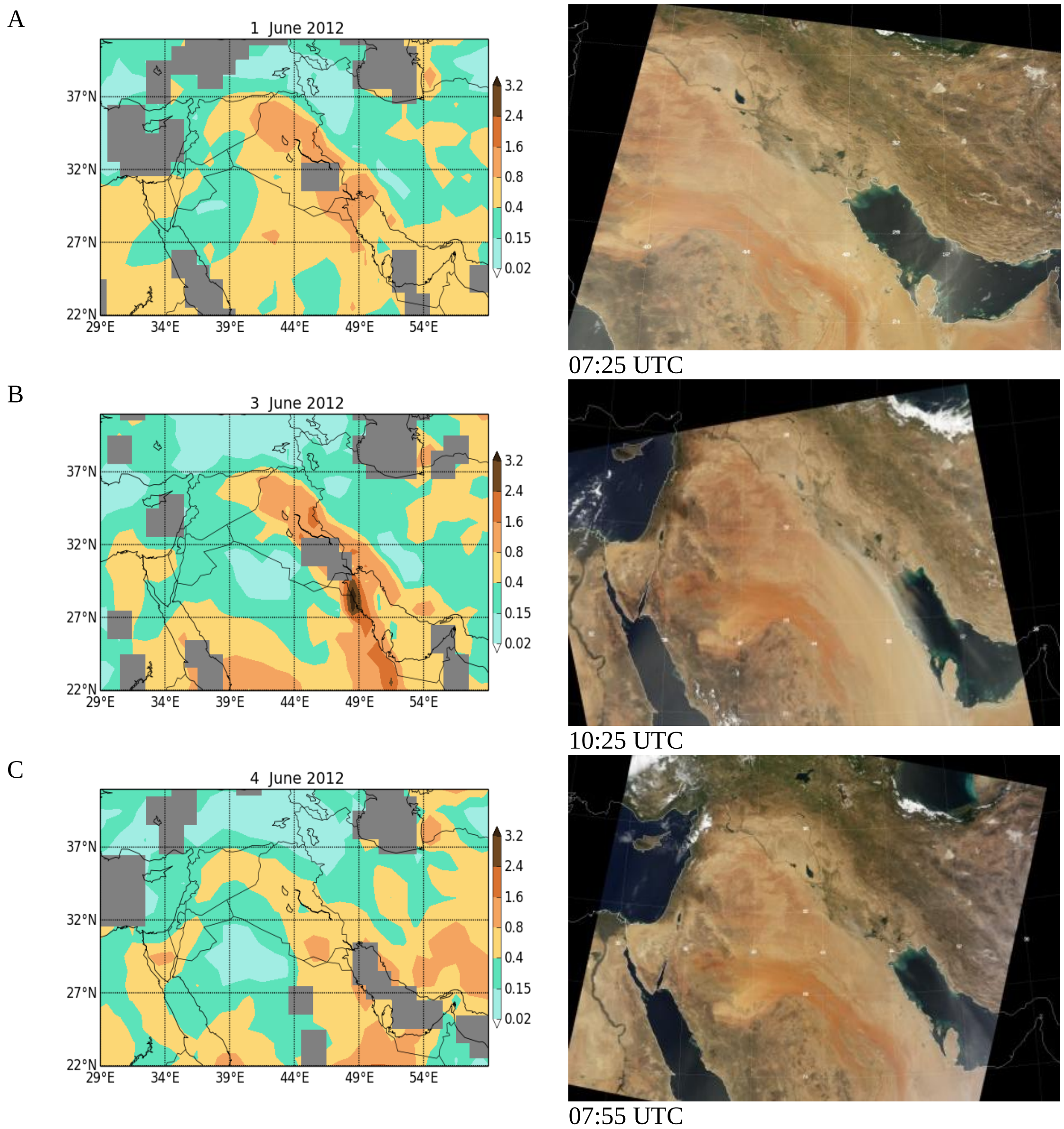


Fig. 2 (left) MODIS/Aqua daily Aerosol optical Depth AOD at 550 nm (over Land and Ocean, (right) MODIS/Aqua images, for (A) 1 June, (B) 3 June, (C) 4 June 2012.

2. The case study of July, 2009

Fig. 3 shows the Sea level pressure, geopotential height for the level 850 hPa and wind barbs in knots from ERA-Interim reanalysis at 12:00 UTC for the days 1,3,5,8 July 2009 and Fig. 4 shows MODIS products of AOD and Satellite images from MODIS/Aqua for 1, 3, 4 and 5 July at 10:05 UTC, 08:15 UTC, 10:35 UTC, and 08:00 UTC respectively.

In the first week of July, Iraq experienced a dust outbreak, it raged over Iraq for more than a week and spread eastward to Iran and also hovered over the Arabian Peninsula and the Arabian Gulf. This case was very intense due to the low pressure systems that were dominating the study area as it will be shown here.

On 1 July, a low pressure system centered over central Iran associated to the Indian Monsoon extending towards the north-west with a combination of a ridge axis over the eastern Mediterranean extending eastward and another ridge axis over the Caspian Sea extending southward. The upper air chart for 850 hPa depicts a low pressure area over Iran stretching north-westward while a ridge stretching easterly towards Iraq and Syria as shown in Fig. 3. This is an ideal synoptic situation for Shamal wind over the region in which the north-westerly surface wind about 10 knots is blowing over Syria and Iraq kicking up the fine sediments from the arid and semi arid regions with highest wind speed over lower Tigris-Euphrates basin, north and eastern parts of Saudi Arabia (KSA) that activated the dust sources in those regions. Also the wind is blowing towards eastern Iraq activating the dust in the sources near the borders between Iraq and Iran. MODIS AOD image and Aqua/MODIS Satellite image (Fig. 3 A) taken at 10:05 UTC, show the activation of dust sources in eastern Syria and the Syrian-Iraqi borders with a notable dust plume over Mosul (to the north of Iraq), AL-Tharthar Lake, Baghdad, and the alluvial plain in southern of Iraq in which the latter is considered as a potential dust source. The dust was moving from the northwest to the south and the south-east of Iraq that affected the western provinces of Iran. Also an active dust plume is hovering over Saudi Arabia which includes many potential dust sources, over the Caspian Sea region in which the dust activity is on its peak in June and July, and finally the Red Sea region.

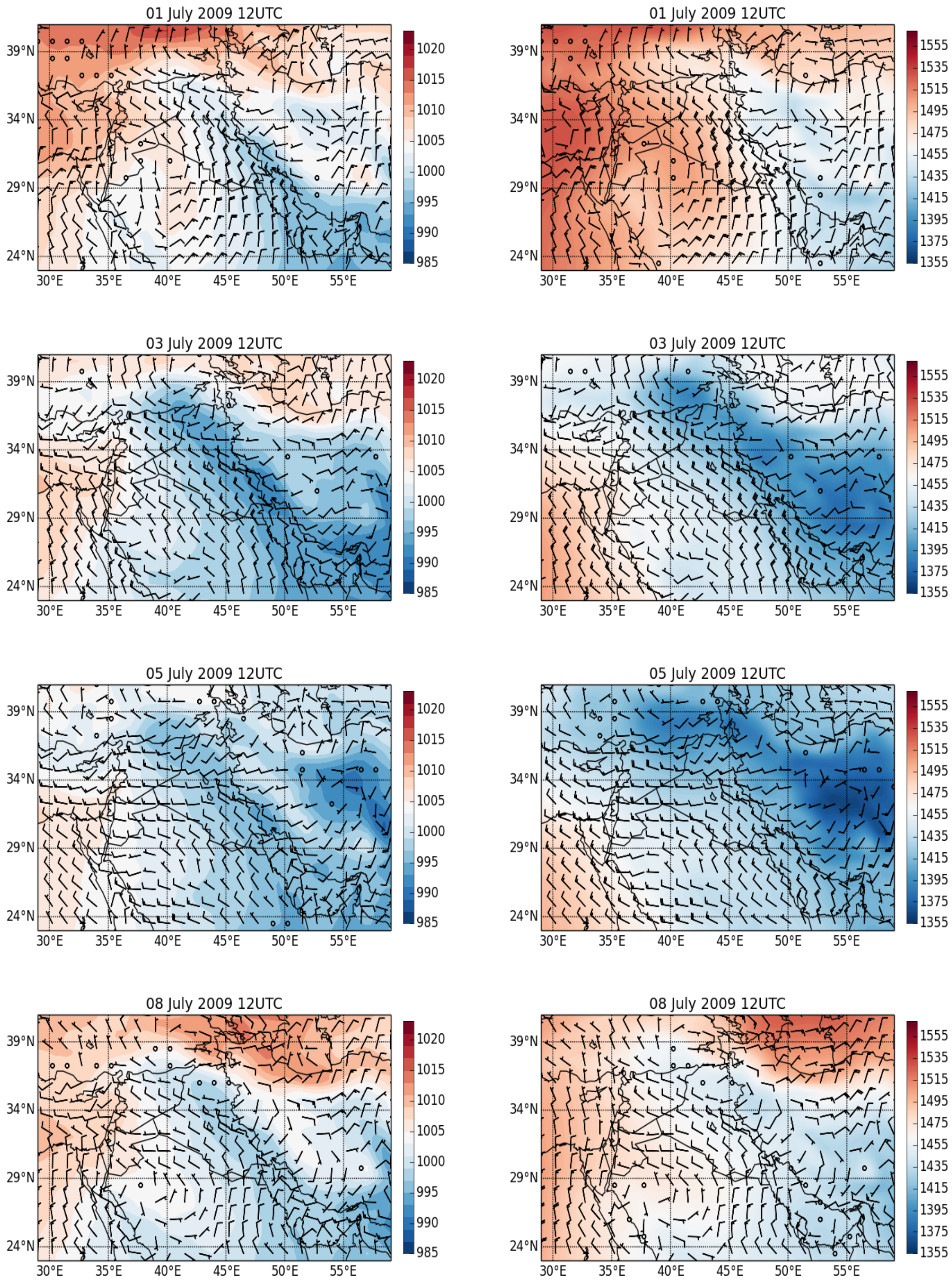


Fig.3 Sea Level Pressure (left) and Geopotential height (m) at 850 (hPa) (right) using ERA Interim Reanalysis data with spatial distribution of wind barbs at 12:00 UTC for the days for the days 1,3,5,8 July 2009.

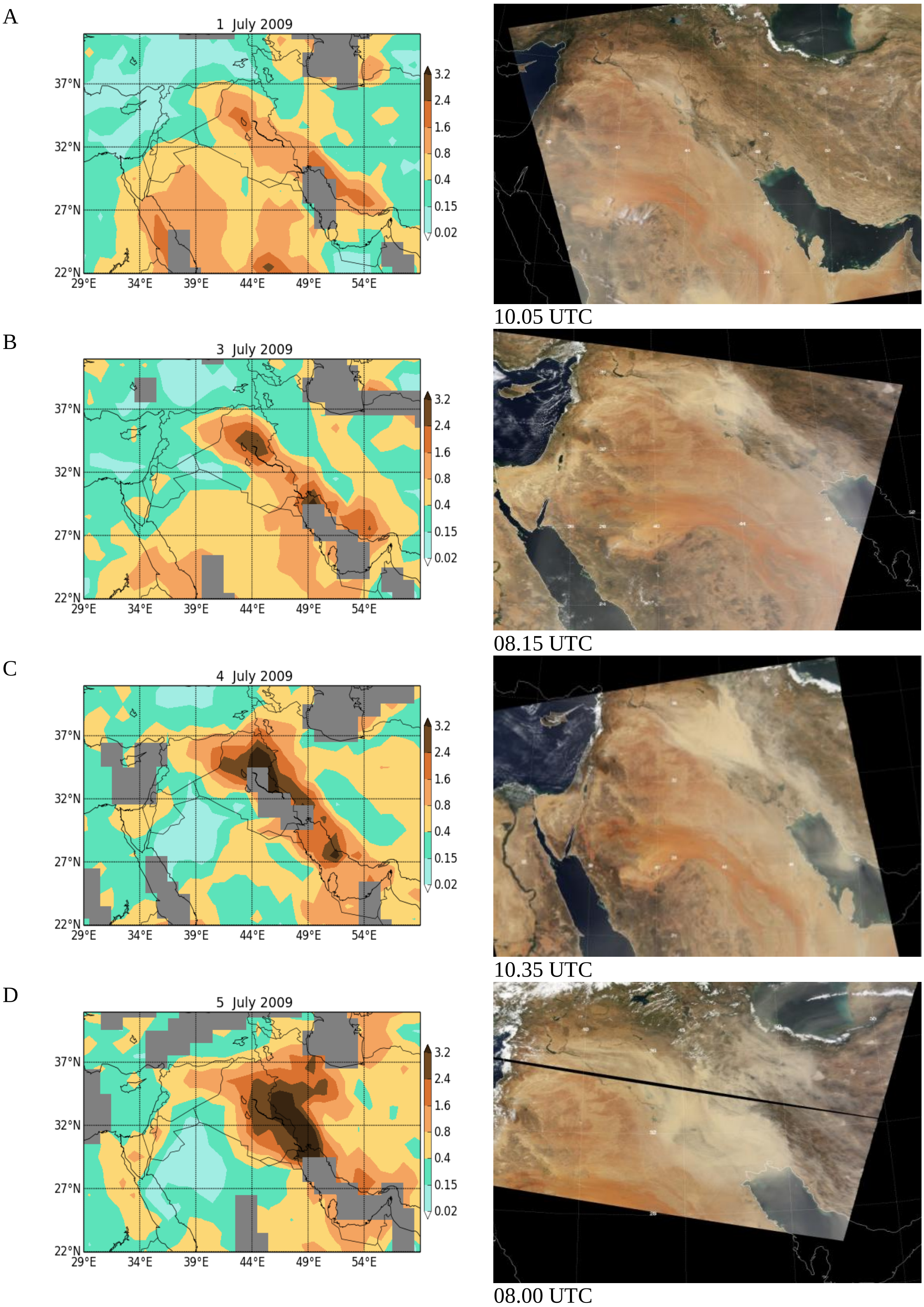


Fig. 4 (left) MODIS/Aqua daily Aerosol optical Depth AOD at 550 nm (over Land and Ocean, (right) MODIS/Aqua images, for (A) 1 July, (B) 3 July, (C) 4 July, (D) 5 July 2009.

In the follow days, the low pressure system over south-western Iran was getting more intense driving the synoptic situation to be worse. The upper and surface pressure charts shows the development of the low pressure on 3 July which became more intense over southern Iran extending north-westward controlling the region in which the north-westerly wind rising dust from Syrian plateau and western Iraq with high speed over west parts of Syria and Iraqi alluvial plain in which they considered as potential dust sources, moving the dust towards the Arabian Gulf, and towards the south west, activating the dust in Ad-Dahna desert in central KSA (Fig. 4 B); moreover, the ridge over the Caspian Sea was intensified also that create a large pressure gradient leading to accelerate the wind speed to reach 15 knots that activated the dust sources in northern parts of Iran as shown in Fig. 4 B in MODIS AOD image.

The trough had the domination over the region for the next days and this is clear especially in the upper air charts (Fig. 3) leading to generate a massive dust plume over Syria and Iraq which completely obscured the view of the land surface below, the lakes of al-Habbaniyah and Tharthar according to Aqua/MODIS image taken at 10:35 UTC on 4 July, in which it was moving towards southeast hovering over the western parts of Iran and its southern coast extending to the Arabian Gulf.

On 5 July the trough axis is extending towards the north-west controlling the region with a secondary low centered over the borders between Turkey, Syria and Iraq, this synoptic situation accelerated the wind speed especially in Syria and in Iraq. The wind is blowing towards the east carrying the dust to Iran that witnessed an intense dust storm especially its western parts, and blowing south-eastward in which dust plume was spreading widely over most parts of Iraq, Iran and the Arabian Gulf region (Fig. 4 D).

On 6-9 July the same synoptic situation continued over the region with a notable intension in the ridge over northern Iran according to the surface chart on 8 July (as well as in 850 hPa) that generate a pressure gradient leading to accelerate the wind and provoking the dust over source regions moving it towards the southeast and getting more intense over the Arabian Gulf region and the centre of the Arabian Gulf. The activated potential dust sources in central parts of Iran and the region between the Caspian and Aral Seas, together with dust advection from north-east of Iraq caused in a wide spreading dust plume over Iran which lasts till 9 July as well as the continuous dust plume that was hovering over Syria, Iraq and the Gulf region.

3. The case study of August, 2005

Fig. 5 shows the Sea level pressure, geopotential height for the level 850 hPa and wind barbs in knots from ERA-Interim reanalysis at 12:00 UTC for the days 6, 7,9,11 August 2005 and Fig. 6 shows MODIS products of AOD and Satellite images from MODIS/Aqua for 6, 7, 8, 9 August at 07:40 UTC 08:25, 10:40 UTC, 09:45 UTC respectively.

On 6 August there is a high level trough over south-western Iran, extending north-westward over Iraq, Syria and KSA that generate a significant decrease in the pressure values at the surface represented by low pressure area centered over south-western Iran stretching towards the north-west as shown in Fig. 5. Also high pressure systems are seen represented in a ridge associated with sub-tropical high pressure system over eastern Mediterranean extending eastward with another ridge over the Caspian Sea. The presence of this synoptic situation generate a strong north-westerly wind at the surface especially over south-eastern Iraq that reaching 20 Knots and over Syria and eastern KSA that reached to 10 knots which lead to provoke the dust in central and south-eastern parts of Iraq and transported it towards Kuwait and the Arabian Gulf (Fig. 6 A).

On 7 August, the upper level chart at 850 hPa shows the development of the trough over Iran which was more intense extending towards the west that surpassed the ridge in which it has the domination over Syria, Turkey Iraq and KSA. This situation lead to accelerate the surface wind over Syria to reach 15 knots that raised more dust from arid and semi arid regions in the Syrian Desert and its extension region in western parts of Iraq and moved it towards the southeast in which the Iraqi alluvial plain witnessed a strong wind speed (about 20 Knots) especially south eastern Iraq which leads to transport more dust to the Gulf region, western regions of Iran and eastern KSA as shown in Fig. 6 B, C in which Terra/MODIS image taken at 08:25 UTC on 7 August shows a dust plume entered Iraq from the north-west moving towards the southeast of Iraq . It was thick over northern and south-eastern parts of Iraq, while the Aqua/MODIS image taken at 10:40 UTC on 8 August shows a thick dust plume overrunning Iraq ripping through the lower Tigris and Euphrates river valleys and moving southward to the Arabian Gulf and some of it spilled eastward across Iran-Iraq borders.

On 9 August, the surface and 850 charts show a low pressure circulation over Iran and a trough axis extending north-westerly with the combination of the ridge over eastern Mediterranean that lead to increase the pressure gradient over that region (very clear in the upper air chart) which increased the surface wind speed to reach 15 knots over Syria raising the dust again and transporting it towards the east and the southeast where the north-westerly wind about 10 knots over Iraq was carrying it and raising more dust from sources in western Iraq and Tigers-Euphrates river valley towards the gulf region and western Iran (Fig. 6 D) that shows a pale plume of dust crossing several hundreds of kilometers from Iraq reaching the Arabian Gulf in the southeast and over the western parts of Iran. Wind barbs shows a high wind speed over the Arabian Gulf especially over its western side in which it witnessed a sever dust storm.

The ridge over the Caspian Sea continued its progressing towards the south which created a significant pressure gradient over northern Iran that lead to a dust plume generation. This synoptic situation controlled over the region in the days after 11 August, which leads to dominate the strong north westerly wind that maintained the dusty weather in Syria, Iraq, western parts of Iran and the gulf region.

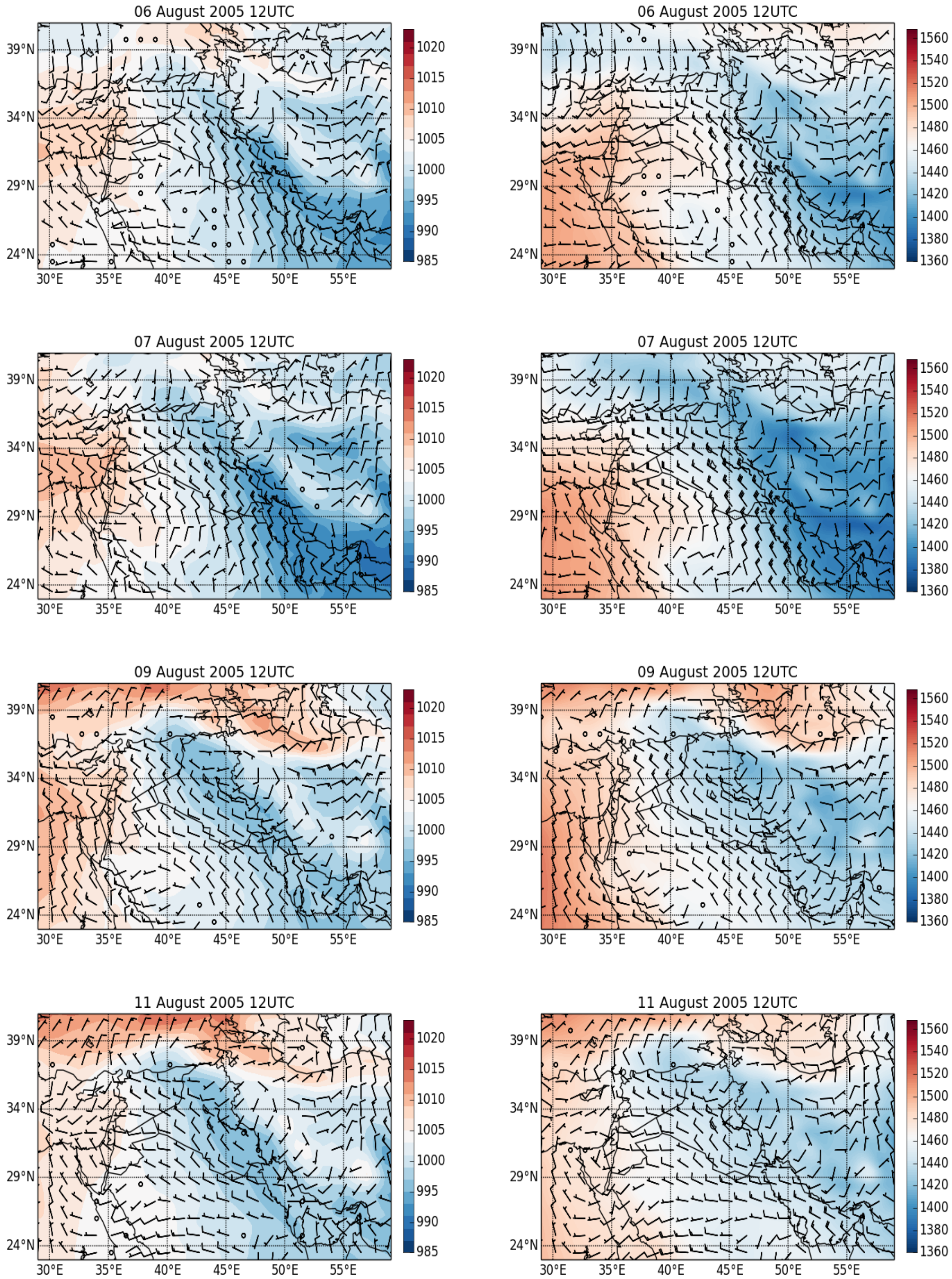


Fig.5 Sea Level Pressure (left) and Geopotential height (m) at 850 (hPa) (right) using ERA Interim Reanalysis data with spatial distribution of wind barbs at 12:00 UTC for the days for the days 6, 7,9,11 August 2005.

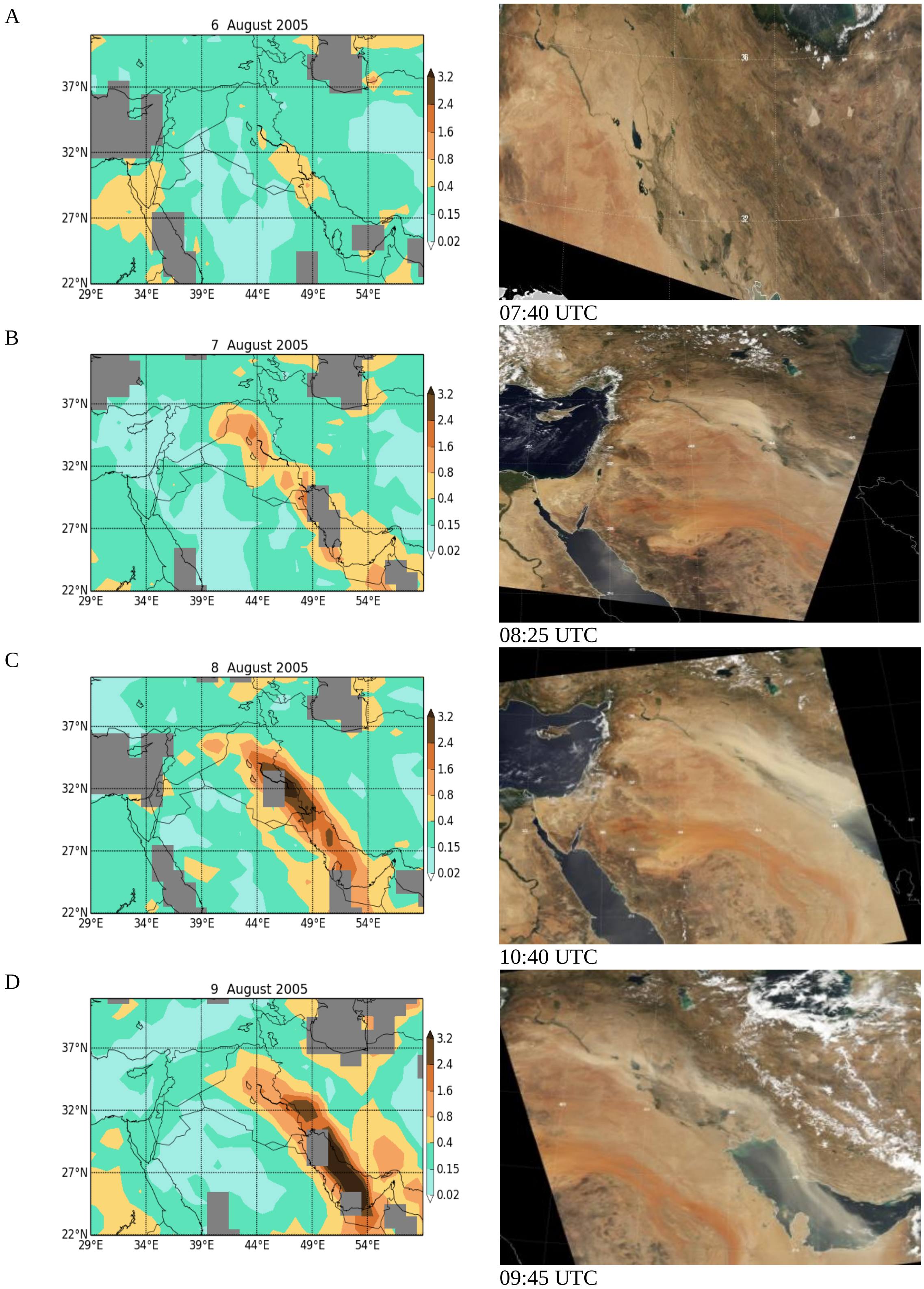


Fig. 6 (left) MODIS/Aqua daily Aerosol optical Depth AOD at 550 nm (over Land and Ocean, (right) MODIS/Aqua- Terra images, for (A) 6 August, (B) 7 August 8, (C) 8 August, (D) 9 August 2005

4. The case study of September, 2008

Fig. 7 shows the Sea level pressure, geopotential height for the level 850 hPa and wind barbs in knots from ERA-Interim reanalysis at 12:00 UTC for the days 14,15,16,17 September 2008 and Fig. 8 shows MODIS products of AOD and Satellite images from MODIS/Aqua and Terra 14, 15, 16, 17 September at 10:15 UTC, 07:45 UTC, 08:25 UTC, 07:30 UTC respectively.

On 14 September, 850 hPa chart shows a low pressure over Iraq which is a part of trough over Iran, covering Syria and north-eastern KSA which established a trough at the surface associated to the Monsoon thermal low over Iran with axis extending north-westward over Iraq, Syria clear over northern Iraq. The trough was overtaken by an extended ridge stretching from the Eastern Mediterranean towards the east.

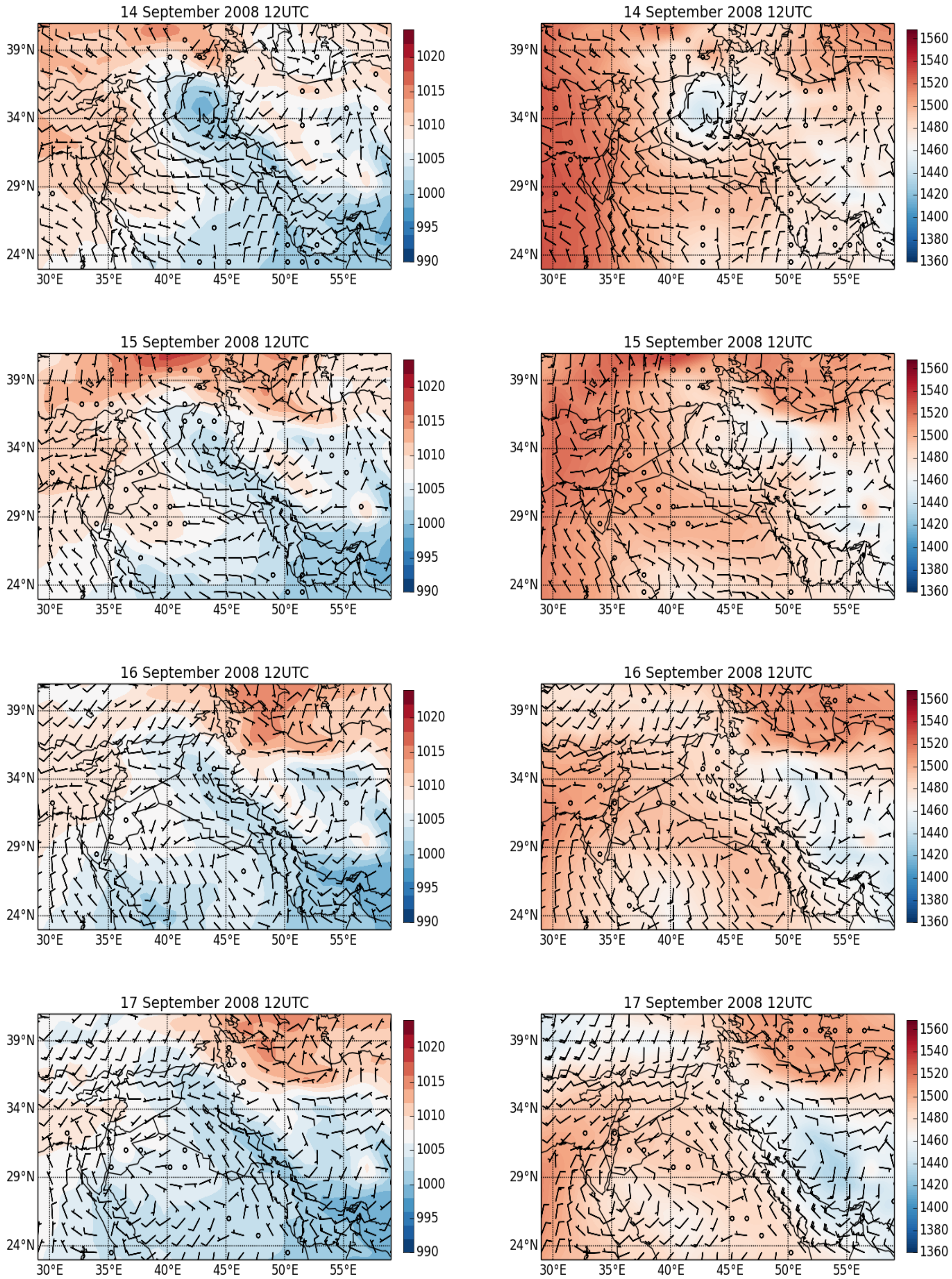
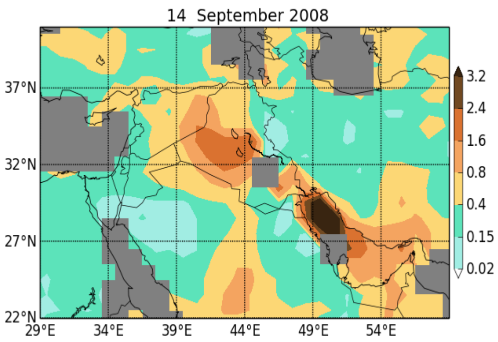
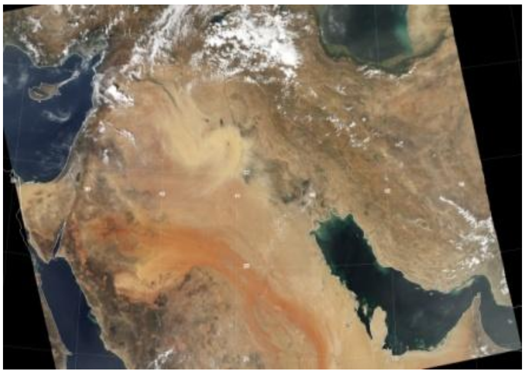


Fig.7 Sea Level Pressure (left) and Geopotential height (m) at 850 (hPa) (right) using ERA Interim Reanalysis data with spatial distribution of wind barbs at 12:00 UTC for the days for the days 14,15,16,17 September 2008.

A strong surface wind of 15 knots blew over north-western Syria to north-western Iraq provoking the dust towards western Iran and to the south-east towards northern Arabian Gulf, and a strong wind over Jordan blowing towards northern KSA activating the sources in central KSA as shown in Fig.8 A where Aqua /MODIS sensors captured an Image at 10:15 UTC showing a massive dust plume spreading over Syria, north-western parts of Iraq taking the cyclonic shape extending south-eastward.

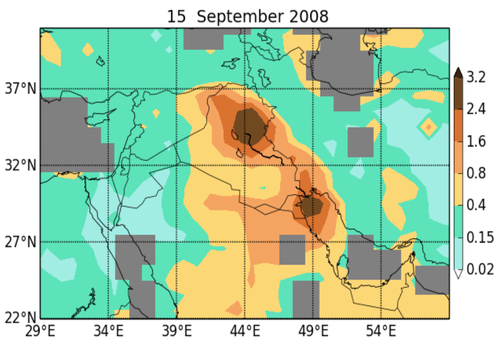
A

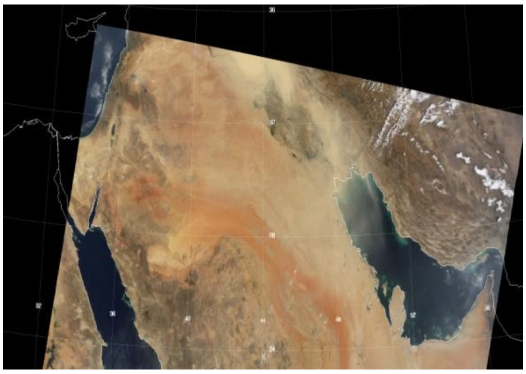




10.15 UTC

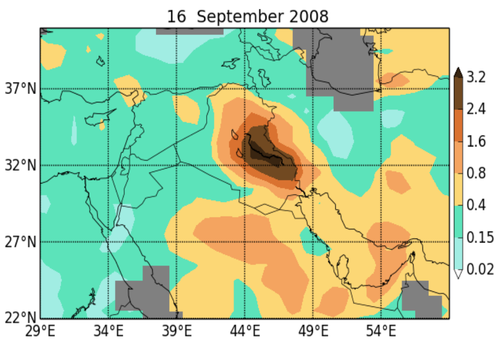
B

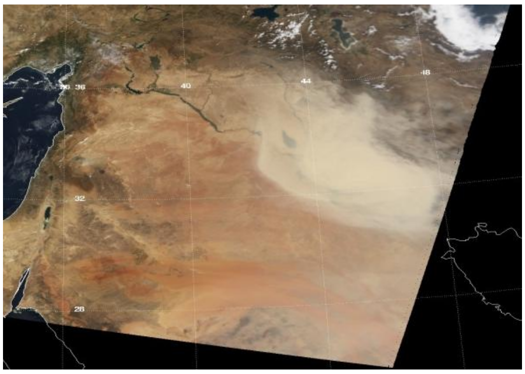




7.45 UTC

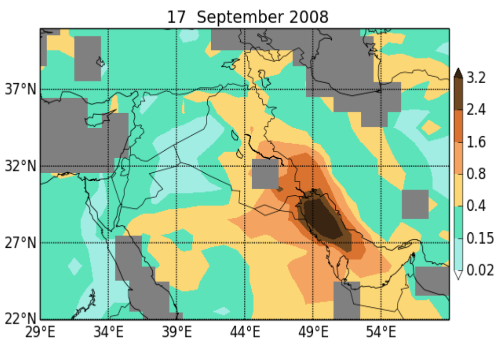
C

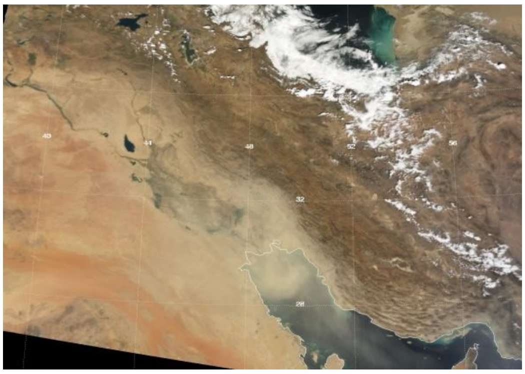




08.25 UTC

D





07.30 UTC

Fig.8 (left) MODIS/Aqua daily Aerosol optical Depth AOD at 550 nm (over Land and Ocean, (right) MODIS/Aqua-Terra images, for (A) 14 September, (B) 15 September, (C) 16 September, (C) 17 September

2008.

On 15 September the upper level trough was stretching towards the south-east while the eastern Mediterranean ridge continued its advection towards the east which leads to strong pressure gradient over northern Iran and southern Turkey that enhanced the surface trough over the region and lead to surface pressure gradient which in turn maintained the strong surface wind speed over Syria and Iraq that blew easterly towards western Iran, south-easterly towards the Arabian Gulf and north-westerly wind from southern Iraq towards eastern KSA. This synoptic situation leads to hovering dust over the region as shown in Terra /MODIS image taken at 07:45 UTC in which an intense dust plume is hovering over north-western, southern Iraq and also over the northwestern part of the Arabian Gulf (Fig.8 B).

The conflict between the two different pressure patterns continued on 16 September in which the 850 hPa shows the development of the trough over Iran which became more intense in northeastern of the Arabian Gulf which enhanced the surface trough that leads to a strong wind over Syria blew towards the south-east of 10 knots over the lower Tigris-Euphrates river basin leading to generate a massive dust plume obscuring the view of the south and the southeastern parts of Iraq and hovering over eastern Saudi Arabia and western parts of Iran as shown in Fig.8 C. Also Fig.7 shows a strong wind between 15 to 20 knots over the Arabian Gulf which interpret the existence of dust over that region which was transported from southern Iraq.

The same synoptic situation continued on 17 September in which the region was affecting by the extension of the intense trough. The strong north-westerly wind maintained the dust emission in eastern Syria and Iraqi alluvial plain especially over south-eastern Iraq that reached to 10 knots transporting dust towards the south and south-east causing an intense dust storm over northern Arabian Gulf as shown in Fig.8 D.

V. Conclusion

The chosen studied cases in this research were intense and considered as natural hazards. They occurred during the summer months from June to September. They triggered by a surface low pressure patterns associated to the Indian Monsoon over Iran and south-eastern Arabian Peninsula accompanied by high pressure system over the eastern Mediterranean and northern Africa leading to strong pressure gradients that generate north-westerly winds provoking dust from arid and semi arid regions in Syria and Iraq, transporting dust across the Tigris and Euphrates river valleys towards Kuwait and some parts of Arabian Peninsula. The study case of June represents the onset of the Indian Monsoon, while July and August case studies represent the active stages of Monsoon in which it get more intense and thus the dust events were so intense especially during July. September study case represents the final stage of the thermal Monsoon low with late summer Shamal wind.

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