THE MARCH 2009 DUST EVENT IN SAUDI ARABIA
Precursor and Supportive Environment

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When large-scale atmospheric instability, high surface winds, and dry, rich dust sources are available, giant dust storms are inevitable.

There is growing interest in atmospheric dust. Desert dust aerosols represent a significant fraction (about 30%–50%) of the naturally occurring tropospheric aerosols, second only to maritime aerosols (d’Almeida et al. 1991; Charlson and Heintzenberg 1995) and dust emission estimates range from about $10 \times 10^8$ tons yr$^{-1}$ (Miller et al. 2004) to $30 \times 10^8$ tons yr$^{-1}$ (Mahowald et al. 1999). Airborne dust has both direct and indirect effects on climate. The direct effect is caused by altering Earth’s radiation budget through the scattering and absorption of radiation (Tegen et al. 1997; A. Jayaraman et al. 1998; S. Jayaraman et al. 2001; Haywood and Boucher 2000; Satheesh and Ramanathan 2000; Harrison et al. 2001; Sokolik et al. 2001; Bangert et al. 2012), whereas the indirect effect is caused by affecting atmospheric cloud nucleation and optical properties (Levin et al. 1996; Wurzler et al. 2000; Penner et al. 2001; Nakajima et al. 2001; Bangert et al. 2012). Moreover, dust particles are believed to serve as reaction surfaces for reactive gas species in the atmosphere (Dentener et al. 1996) and for moderating photochemical processes (Dickerson et al. 1997). In addition to the impacts of aerosols on climate,
the distribution and transport of aerosols have significant implications for human and environmental health (Harrison and Yin 2000; Griffin et al. 2001; Griffin 2007), chemical fluxes among continents (Jaffe et al. 1999), and oceanic biogeochemical cycles (Young et al. 1991). Mineral dust may play a significant role in some marine biogeochemical processes and could serve as a source of trace metals that are essential to some marine biological processes. Iron (Fe), which could be a limiting nutrient for phytoplankton in some ocean regions, is supplied by dust (Falkowski et al. 1998; Fung et al. 2000); thus, the global carbon cycle could well be modulated by dust.

In some seasons in certain regions of the Middle East, especially in Saudi Arabia, dust storms are a very frequent phenomenon and a better knowledge of their spatial and temporal distribution is of prime importance. Arid and semiarid regions around the Arabian Sea are some of the most important source regions of global dust (Pease et al. 1998). During summer, more than 30% of the time there is a level of airborne dust that reduces visibility to below 11 km in Saudi Arabia and its neighboring countries (Kutiel and Furman 2003). In Saudi Arabia, dust storms are considered among the most severe environmental problems. For instance, the 5-yr analysis of Riyadh air quality index showed that on average approximately 29% of the time the air was polluted, of which 74% was attributed to high air particulate (dust) concentrations (Alharbi and Moied 2005).

Much excellent work has been undertaken on Middle East dust, including Saudi Arabian dust, by several key researchers. The climatology of dust storms in the Middle East at a monthly time scale has been studied by Middleton (1986) and more recently by Kutiel and Furman (2003). In both studies, averages were presented, whereas the year-to-year variability based on Total Ozone Mapping Spectrometer (TOMS) measurements has been investigated by Barkan et al. (2004). Ackerman and Cox (1989) investigated the temporal and spatial distribution of dust loading over the southwest summer monsoon region that includes Saudi Arabia using five years of surface weather observations.

Dust activity over the Arabian Peninsula has also been monitored using the TOMS aerosol index (Prospero et al. 2002) and the Infrared Difference Dust Index product derived from the infrared channel of the Meteosat satellite (Léon and Legrand 2003). Dust particle size distribution during sand/dust storms in Riyadh, Saudi Arabia, have been assessed by Ahmed et al. (1987) while dust aerosol influences on shortwave radiation fluxes due and their impact on synoptic-scale systems and the diurnal cycle over the Saudi Arabian region have been investigated by Kutiel and Furman (2003). In both studies, average concentrations less than 1,000 μg/m³, the model either substantially over- or underpredicted the PM₁₀ concentrations or missed the events entirely. Another effort to model dust events in Saudi Arabia was made by Barnum et al. (2003). Their model used a global dust source database, which was developed using topography and dust sources regions identified using satellite data from TOMS, originally described by Ginoux et al. (2001). Although the model indicated some of the dust events over Saudi Arabia, these events were underestimated because of underrepresentation of the dust source regions in the Ginoux source database.

In order to better understand dust source regions and production, Grini et al. (2005) introduced two new erodibility factors to simulate dust production and compared them with two earlier erodibility factors obtained by different methods [the method of Ginoux et al. (2001) and the method of Zender et al. (2003)]. They found that all four methods agreed on high erodibility in southern Saudi Arabia, while the new erodibility factors demonstrated high erodibility in northern Saudi Arabia as well. The erodibility...
factors obtained by the method of Ginoux et al. (2001) and the method of Zender et al. (2003) predicted higher emissions in eastern Saudi Arabia, near the Arabian Gulf and in southern Iraq, consistent with TOMS. However, determining the exact source regions from TOMS was difficult since advection distributes the dust throughout this area.

All the previous studies mentioned above have either used surface or satellite observations and/or models to characterize the large-scale dust loading of the atmosphere over the Arabian Peninsula. However, gaps remain in our understanding of the atmospheric conditions responsible for triggering severe dust storms in Saudi Arabia. Such a shortage of knowledge represents a major uncertainty in the ability of operational dust forecasting models to predict dust storms, especially their magnitude; therefore, it is vital to give precursor and triggering mechanisms for dust storms in Saudi Arabia much more consideration.

THE DUST STORM OF 10 AND 11 MARCH 2009. The dust storm of 10 and 11 March 2009 was one of the most severe dust storms to be recorded on the Arabian Peninsula due to both the large scale and severity of the event. The gigantic dust plume, originating on 10 March 2009, impacted several cities in the northeastern, eastern, and central parts of Saudi Arabia and most of Kuwait, covering a distance of about 1,500 km and an area of approximately 300,000 km². However, no media statement had been released prior to the event reaching Riyadh, alarming and recommending precautions for sensitive populations. Consequently, this dust storm, which left thousands of people choking on heavily dust-polluted air, is associated with an enormous increase in respiratory hospital admissions in the city of Riyadh. In addition, the associated low visibility resulted in many group car accidents in several parts of the city. During the event, hourly visibility of 50 m was reported in Riyadh and Qaisumah, whereas hourly visibility of 100 m was reported in Hafr Al-Batin and Dhahran.

METHODS. The methodology adopted for this study is an integrated approach of synoptic analysis. This approach requires an investigation of several weather parameters and satellite imagery to identify the meteorological conditions that led to the strong winds capable of generating the March 2009 dust event as well as the associated supportive environmental conditions. The investigation of these parameters requires analysis of pressure fields for different levels of the atmosphere, horizontal maps of wind velocity, as well as rainfall data records. The satellite imagery is used as a tool to visually aid in identifying the source areas of the dust storm event along with its spatial scale, as well as to determine the position of the upper-level jet stream and the cold frontal system responsible for the March 2009 dust event. All weather maps in this study were provided by the National Oceanic and Atmospheric Administration (NOAA)/Earth System Research Laboratory (ESRL) Physical Sciences Division via their website (www.cdc.noaa.gov/Composites/Day/) while rainfall data, visibility records, wind speed and wind direction data, and temperature and pressure measurements were provided by the Presidency of Meteorology and Environment in Saudi Arabia. The images used in this study are from the National Aeronautics and Space Administration (NASA)’s Moderate Resolution Imaging Spectroradiometer (MODIS) acquired from NASA’s online MODIS Rapid Response System website (http://rapidfire.sci.gsfc.nasa.gov/) and Meteosat acquired from the Natural Environment Research Council (NERC)’s online Satellite Receiving Station website (www.sat.dundee.ac.uk/). The locations referred to in this paper are shown in Fig. 1.

RESULTS AND DISCUSSION. Synoptic analysis. The outbreak of the severe dust storm that impacted the city of Riyadh on 10–11 March 2009 was marked by the passage of a cold front that was coincident with the propagation of a preexisting synoptic-scale upper-tropospheric jet streak over the northern and central parts of Saudi Arabia. A detailed description of the synoptic situation from 0000 UTC 7 March 2009 to 1200 UTC 11 March 2009 is provided below.

![Fig. 1. The locations of the cities and plateaus referred to in this study (source: www.googleearth.com).](image-url)
The upper-level jet streak. Over the Arabian Peninsula, the upper jet streaks, areas of high-speed winds embedded within the jet stream, are found in the subtropical jet stream located between 25° and 35° latitude in spring. One of the important mechanisms responsible for the generation and maintenance of conditions favorable for severe and unstable atmospheric conditions is the process whereby the increase in the magnitude of lower-tropospheric winds is coupled with mass and momentum adjustments through transverse direct and indirect circulations accompanying upper-tropospheric jet streak propagation (Means 1952; Petterssen 1956; Reiter 1963; Newton 1967; Danielsen 1974; Brill et al. 1985). The patterns of vertical motion associated with jet stream propagation were the focus of research and discussion of past studies. A pattern of meridional circulation featuring rising motion in the northern side of the jet axis and sinking in the southern side (in the Northern Hemisphere) was first proposed by the Chicago group in 1947 and supported by Riehl and Twedes in 1953 (Eltantawy 1960). On the other hand, based on the potential temperature field, a reverse pattern of circulation with rising motion in the southern side of the jet axis was suggested by Palmen and Newton in 1948 and supported by Namias and Clapp in 1949 (Palmen and Newton 1948; Namias and Clapp 1949). Eventually, Murray and Daniels (1953) confirmed the circulation pattern suggested by the Chicago group in the exit region and the reverse circulation pattern in the entrance region of the jet stream.

Low-level strong winds can often be dynamically linked to an upper-level jet stream. Uccellini and Johnson (1979) described this coupling as the following (again relating to a Northern Hemisphere case): the low-level strong wind, approximately perpendicular to the axis of the upper jet stream, develops downstream from the nose of the upper-level jet streak in the subtropical jet stream (STJ). At the nose of the upper-level jet streak, supergradient winds deflect the air to the right, creating strong divergence in the left side of the jet and convergence in the right as mass is transported from the left to the right. The air transported to the right side of the jet is then forced to descend and downward vertical motion develops, resulting in low-level divergence below the upper-level convergence. Compensating for the supergradient winds aloft, the air surges northward underneath the upper-level jet streak toward the low-level region in the left side of the jet. Air then rises toward the upper-level region in the left side of the jet, forming a complete perpendicular circulation around the nose of the upper jet streak. The close proximity and coupling processes between upper-level jet streaks and the associated strong surface wind are responsible, particularly during spring, for many dust storms in Saudi Arabia. The classical pattern of the motion associated with jet stream propagation is depicted in Fig. 2.

During 7–11 March 2009, upper jet streaks propagated over northern Saudi Arabia and southern Iraq, resulting in generation and maintenance of conditions favorable for unstable atmospheric conditions in northern and central parts of Saudi Arabia. For instance, the highly unstable atmospheric conditions in the city of Qaisummah and associated downward transport of momentum were associated with extremely strong surface winds: south to southeasterly winds of 14 m s$^{-1}$ on 9 March, north to northeasterly winds of 28 m s$^{-1}$ on 10 March, and northeasterly to southeasterly winds of 12 m s$^{-1}$ on 11 March. These strong winds were related to the upper jet streak propagation discussed here, as well as the passage of the cold front discussed below. Figure 3 shows the surface pressures, the 850- and 700-hPa pressure heights as well as the 200-hPa winds during 7–9 March 2009, while Fig. 4 shows the same charts during 10–11 March 2009.

On 7 and 8 March the jet streak seen at 200 hPa moved eastward to be located above northwestern Saudi Arabia. On 9 March the core of the jet streak temporarily retreated westward before continuing on its eastward progression on 10 March. As a consequence of the upper jet

![Fig. 2. The classical pattern of the motion associated with jet stream propagation (modified after Palmen and Newton 1948).]()}
streak movement on 9 March, the surface high in the region underneath the right-front quadrant of the upper-level jet streak was weakened by reduced convergence aloft. The 850-hPa pressure-height chart clearly shows the weakening of the high pressure ridge over central and northeastern parts of Saudi Arabia between 8 and 9 March and the significantly reduced pressure gradient.

By 10 March, the nose of the upper jet streak had progressed eastward while its rear approached the northwestern part of Saudi Arabia. As a result of upper-level divergence at the right rear of the jet streak...
and associated atmospheric motion, the high pressure cell that had been over central and northeastern parts of Saudi Arabia on the 850-hPa pressure-height chart was forced to progressively retract to the east and was eventually replaced with low pressure. In doing so and ahead of the next advancing high, the pressure contours become tightly packed and the pressure gradient increased considerably (row 1, column 1 of Fig. 4). Consequently, strong surface winds, linked in part to the mass adjustments through the entire troposphere associated with the upper-level jet streak, developed along the northeasterly trough-to-ridge flow zone.

**The cold front passage and associated dust storm outbreaks.** Strong pre- and postfrontal surface winds that develop because of the locally strong surface pressure gradients are often associated with the passage of early spring cold fronts in Saudi Arabia. Low pressure systems over the Mediterranean are the source of these frontal systems that impact northern parts of Saudi Arabia during spring season. The prefrontal wind that is also often associated with intense surface heating (and hence instability) is one of the common synoptic events triggering intense dust storms on the Arabian Peninsula, particularly in the first two months of the spring (March through April). Similar intense springtime fronts that can trigger dust activity have been reported from other parts of the arid subtropical world, including from Central Australia (Smith et al. 1995; Reeder et al. 2000; Strong et al. 2010). On the Arabian Peninsula the dust activity results from Mediterranean upper-level troughs and their associated surface cold fronts traversing the northern region of Saudi Arabia with strong winds.

**Fig. 4.** The 24-h mean of surface synoptic pressures, 850-, and 700-hPa pressure heights and wind speeds at 200 hPa on 10 and 11 Mar 2009. This figure was created using the NOAA/ESRL Physical Sciences Division website (www.cdc.noaa.gov/Composites/Day/).
The Mediterranean cold fronts often approach dust source areas in central Saudi Arabia such as those in the Qasim region and deflation of dust occurs ahead of the front in the warmer air sector. However, in this case study no prefrontal dust storm was observed. This is mainly due to the arrival time of the front at the dust source areas. When the front approaches dust source areas during the night hours as this front did, less mixing takes place, producing little if any dust. Another significant restraining factor is the weakening of the surface high over central and northeastern parts of Saudi Arabia on 9 March, with a significant decrease in pressure gradient promoted by the approach of the upper-level divergence on the right-rear side of the streak as was discussed previously. This weakening of high pressure and the associated decrease in the pressure gradient resulted in a low surface prefrontal wind speed that was not strong enough to entrain dust ahead of the front.

As the trough and the associated cold front continue moving, they often get squeezed between a slow-moving anticyclone ahead and a strong anticyclone developing behind. This has the effect of rapidly intensifying the pressure gradient again, particularly behind the front, resulting in postfrontal dust storms. This is one of the most frequent synoptic events in Saudi Arabia to deflate dust particles, with strong and gusty north to northeasterly winds occurring behind the front.

On the late morning of 10 March 2009, a massive dust storm swept across central Saudi Arabia, extending from the Qasim area in Saudi Arabia to Kuwait behind the cold front, which passed through the region with no precipitation. As the storm moved southward, it swept behind it large quantities of dust from the Qasim area as well as from the Adibdibah and As-Summan Plateau dust source areas. Figure 5 is a MODIS satellite image of the dust storm for approximately 1000 local time on 10 March. As the powerful Mediterranean low pressure area moved across the southern part of Iraq and northern part of Saudi Arabia, the postfrontal dust storm took place under the influence of a strong band of postfrontal winds generated by, and to the west of, the low pressure area that was centered over the eastern part of Saudi Arabia, with a relatively strong pressure gradient to its southwest (Fig. 4). This strong pressure gradient and associated strong postfrontal winds along the northeasterly trough-to-ridge flow zone were due to both the mass adjustments through the entire troposphere associated with the upper-level jet streak discussed earlier as well as the squeezing effect applied to the trough and its associated cold front between a slow-moving anticyclone ahead and a strong anticyclone developing behind.

The position and progression of the front on 10 March 2009 from 0000 to 1200 UTC can be clearly seen in the Meteosat infrared images as a band of clouds on a northeast–southwest axis while the position of the upper-level jet stream can be seen as a band of clouds on a west–east axis over the northern part of the Arabian Peninsula (Fig. 6). Also, the position of the polar jet stream associated with the cold front and the jet streak associated with the subtropical...
jet stream and their interaction during 7–13 March 2009 are depicted in Fig. 7. This interaction is a common precursor for severe conditions of instability, producing the conditions required for most of the massive dust storms in Saudi Arabia through promoting upper-level convergence and subsidence during merging of the wind flow and upper-level divergence and lifting during spreading of the wind flow (Alharbi 2009).

On the next day (11 March), as the surface low pressure area moved farther eastward, another severe dust storm was triggered in the western region of Iran (Fig. 8) by a similar scenario of a strong band of postfrontal winds generated by, and to the west of, the low pressure trough that was extending along the eastern part of the Arabian Gulf, with a relatively strong pressure gradient to the southwest, as shown in Fig. 4.

Impact of the dust event on ground-based measurements. The ground-based measurements of aerosol optical thickness (AOT) and meteorological parameters were noticeably affected by the massive dust storm event that took place on 10 and 11 March 2009. Figure 9 shows the impact of this dust event on ground-based measurements of AOT at 500 nm as well as five key meteorological variables (temperature, visibility, wind speed and direction, and atmospheric pressure). Measurements of AOT were conducted by a CIMEL sun photometer (CE-318) installed on the rooftop of Solar Village (24.91°N, 46.41°E, 764 m), whereas measurements of meteorological parameters were obtained from Riyadh Airport records provided by the Presidency of Meteorology and Environment. The effects of this storm were associated with an increase in AOT and wind speed, and a reduction in temperature and visibility, for the two days following the storm in comparison with conditions before the storm. On the morning of 10 March, the AOT was around 0.396, until around midday when it jumped to 1.713 (an increase of 330% immediately after the storm), indicating the increased aerosol loading associated with the arrival of the dust storm. AOTs remained at these high values for the next three hours, then decreased gradually to reach a value of 0.919 by the end of the day. On the day of the dust storm, and before the arrival of the storm, the weather was relatively benign; the temperature was ~28°C, the air pressure had dropped to its minimum, and the local wind was relatively light from 160° to 180° (southerly). Around noon local time, with the arrival of the dust plume, there were dramatic changes in weather conditions. The wind swung to a northerly direction and wind speed rapidly increased to a maximum of 30 m s⁻¹. Following this, winds then began to drop once again. Air temperature dropped by about 6°C within an hour to reach 22°C at 1300 on 10 March. The temperature continued to decrease, until it reached its daily minimum of about 14°C at 0700 on
11 March. The detailed description of the impact of this severe dust storm on meteorological parameters, aerosol properties, and infrared atmospheric radiation is provided in another paper (Maghrabi et al. 2011).

**Supportive environmental conditions.** One of the most important and necessary factors for the formation and development of strong dust storms is the availability of source areas rich in soil fines. The dust source areas for this event extend across two regions: the Qasim region and the Adibdibah and As-Summan Plateau region. The characteristics of these two dust source regions and their prior environmental conditions are discussed below.

**The Qasim region.** The Qasim region, lying some 500 km northwest of Riyadh (Fig. 1), is an active dust source region and agriculturally important for Saudi Arabia. The aerosol index (AI) values over this region are equal to or greater than 3 for at least 17 days out of the 33 dustiest days observed in the city of Riyadh over the 2000–03 period (Alharbi 2009). An important dust source of the region is the Wadi Al-Rimah, which represents the remains of a very old river system dating back to the late Tertiary (Al-Sayari and Zotl 1978). Surficial deposits of this region represent loose superficial material washed in by surface runoff following episodic precipitation. The wadi floor is of low gradient and the deposition of silt-size (2–20 μm) materials by runoff occurs over short distances, whereas the high clay (smaller than 2 μm) contents of this region have been enriched by fine-grained material carried downstream (Mashhady et al. 1980). The two most active source areas in the region are centered at around 26.28°N and 44.12°E and 25.55°N and 43.23°E (Alharbi 2009).

![Fig. 7. The latitudinal vertical cross section (from 1,000 to 10 hPa) of zonal wind speed in m s⁻¹ at 42°E for the period 7–13 Mar 2009. This figure was created using the NOAA/ESRL Physical Sciences Division website (www.cdc.noaa.gov/Composites/Day/).](image-url)
The Adībdībah and As-Summan Plateau region. This region is a major source of frequent dust storms in Saudi Arabia. It extends from the borders of Saudi Arabia with Iraq and Kuwait in the north into the northern part of the eastern corridor of Ad-Dahna Desert in the south. It features Al values similar to those observed in the Qasim region during the dustiest days observed in Riyadh during the period 2000–03 (Alharbi 2009). Wadi Al-Batin, which extends northeastward from the eastern corridor of the Ad-Dahna Desert into Kuwait and southwestern Iraq, is the main fluvial fan in this region with vast amounts of old alluvial deposits. This wadi extends over a distance of about 75 km into Kuwait and can be traced for another 700 km southwest as the great Wadi Al-Rimah in Saudi Arabia (both of these wadis were part of an old river system in the past). Although the wadi is normally a dry riverbed with low-lying sandstone plain, isolated irregular hills, aeolian deposits, and playas (locally called Khabrat) in deflation depressions, it becomes a raging river following torrential rainfalls. Under the influence of fluvial action, small particles are removed from the soil and rock matrix and are transported to depositional basins and alluvial plains, as described in Australia by Bullard and McTainsh (2003) and globally by Prospero et al. (2002). After drying up, these tiny particles become vulnerable to wind deflation. Another important feature in this region is the scattered patches of lands with particularly high water tables. These areas become marshes when it rains and are quite susceptible to wind deflation after drying up.

Rainfall records for the two regions. Monthly rainfall data for three weather stations in three different areas (Qasim, Hafr Al-Batin, and Qaisummah) located along the path of the observed dust plume in the two regions of Saudi Arabia are examined.

Comparison of monthly total precipitation values shows that during the 2003–09 period precipitation peaked sharply from January to April and again in November and December (Fig. 10). The only apparent difference is that Qasim site received somewhat more precipitation each year. In Saudi Arabia, the dust season extends from March to September (Alharbi 2009). During the dust season, the annual frequency and intensity of dust storms increases sharply following months of relatively high amounts of rainfall. For instance, the observed high dust storm frequency of occurrence and intensity of Arabian dust storms in 2006 (Alharbi 2009) as well as the observed higher dust storm frequency of 2009 were associated with torrential rainfall during November and December of 2005 and 2008, respectively. The monthly rainfall data for Qasim, Hafr Al-Batin, and Qaisummah stations shows that the years of 2005, 2008, and 2009 feature the highest amounts of precipitation recorded in the seven years (2003–09) during November and December. During such episodic torrential rainfall and runoffs, fluvial delivery of fine-grained sediment from the surrounding higher areas takes place and temporary crusts form on tidal flats and wadis. Soon after the wet winter, these temporary evaporative crusts would become rich and vulnerable alluvial sediment particles loosely bound to the surface and ready to be deflated by wind.

Concluding comments. This study provides synoptic weather system evidence to further

Fig. 8. (top) MODIS and (bottom) METEOSAT Visible satellite images, showing dust storms sweeping across the Arabian Gulf and central Saudi Arabia, originating in the western region of Iran behind a cold front on 11 Mar 2009. [MODIS image was obtained from MODIS website (http://rapidfire.sci.gsfc.nasa.gov/subsets/) and METEOSAT Visible image was obtained from NERC Satellite Receiving Station, Dundee University, Scotland (www.sat.dundee.ac.uk/), courtesy of EUMETSAT (www.eumetsat.de/).]
explain the major role played by the coincidence of a cold front passage with intense upper-level jet streak propagation in the development of severe dust storms on the Arabian Peninsula in March 2009. By world standards, the 10 March 2009 dust event was a large-scale, long-duration event of severe intensity. By investigating surface pressure and upper-level pressure-height charts, horizontal maps of wind velocity, as well as relevant satellite imagery, the meteorological conditions that led to the strong winds capable of producing this severe dust event have been identified. Propagation of an upper-level jet stream over northern Saudi Arabia and southern Iraq led to the development of relatively strong northeasterly trough-to-ridge flow over northern and central parts of Saudi Arabia, linked to mass adjustments through the entire troposphere associated with the upper-level jet streak. This relatively strong surface flow became even stronger as the trough and cold front associated with a powerful Mediterranean low pressure area moved across the southern Iraq and the northern part of Saudi Arabia became squeezed between a slow-moving anticyclone ahead and a strong anticyclone developing behind, triggering the 10 March 2009 severe dust storm. As the surface low pressure area moved farther eastward on 11 March, a second less-severe dust storm was triggered in the western regions of Iran by a similar scenario of strong postfrontal winds generated by, and to the west of, the low pressure trough.

In the geographical sector where the major plume of the 10 March 2009 dust storm originated there exist several rich dust source areas extending across two regions—namely, the Qasim region and the Adidibah and As-Summan Plateau region. During episodic torrential rainfall and runoffs, fluvial delivery of fine-grained sediment from the surrounding higher areas in these regions takes place and temporary crusts form in evaporative tidal flats and wadis. Eventually, these evaporative tidal flats and wadis became active areas for dust emissions. The intensity and frequency of dust storms triggered from these active areas of dust emissions seem to be dominated by a response to the amount of precipitation during November and December.

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