

Occurrence of Widespread Dust – Followed by Thunderstorm over Qatar on 4th February 2010 - A Case Study

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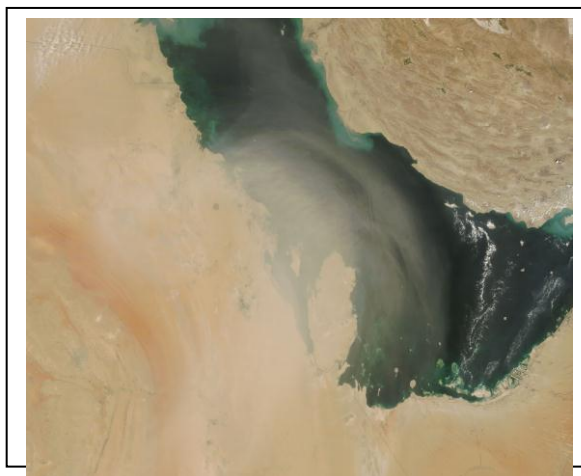
Abstract

The study is mainly concentrated to examine the reason for the occurrence of unprecedented widespread dust followed by thunderstorm over Qatar and neighbouring areas of the Middle East on 4th February 2010, which paralyzed normal life affecting road and air traffic. The baroclinic trough over Saudi Arabia flanked by High on the east and the existing low level strong winds, dynamically influenced by the approaching upper level perturbations initiated the KAUS (southerly) dust event over the desert belts of Arabian Peninsula. These dusts blanketed over Qatar around 0600 UTC. The cold air High over Saudi Arabia at 04/0600 UTC initiated north westerly Shammal which triggered dust event over parts of the Arabian Peninsula. The enhanced convergence due to the synoptic scale forcing of cold air under-running warm moist air triggered some convective activities over Qatar. The synoptic analysis of the event and the concluding remarks regarding the essential parameters to look for foreshadowing the event are brought out in the study.

Introduction

The unprecedented widespread dust followed by a mild thundershower over Qatar on 4th February 2010 which caused foggy and dusty weather with considerable reduction in visibility, paralyzed the normal life and affects the road and air traffic movement. The sandstorm on Thursday has caused as many as 121 accidents across the country according to traffic officials.

This phenomenon triggered to take up this case study to do a brief analysis to find out how this occurred and also to examine how advance we can forecast the same.



Winter Climatology of Qatar Peninsula

Dust events are an important weather phenomenon in the Middle-east countries both in summer and in winter. In the winter, pre-winter and post-winter months, the weather over Qatar and the neighbourhood is generally influenced by the mid-latitude frontal systems (Anthony, 1997; Athol, 1994). These systems mostly originate over the Mediterranean and Gulf region. When these wave systems are deep and extend more southward, they yield some precipitation sometimes accompanied by thunderstorms (Tamim et al, 2009; QNV 2030).

The chance of thunderstorm occurrence increases when the westerly wave system interacts with a surface low/trough emerged from Red Sea across southern Arabia (Walter, 1991). Also, at times the frontal systems trigger strong northwesterly winds (winter shammals) for a day or two causing rough sea conditions over offshore areas (Jochenkerkmann, 2007; Wilkerson, 1991).

Another weather phenomenon which is more common in winter season is the fog. Most of the fog may be categorized as radiation fog which occurs under clear night (radiation cooling) and light wind conditions. However, many of the fog days reported are found to be due to the drifting of radiation fog formed over inland areas by the light land-breeze (Brody et al, 1980).

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Data Sources

The current weather charts, hourly data and satellite cloud imageries from Qatar Meteorological department and other online sources were used in this synoptic study.

Discussion

Surface and Lower Troposphere Features

The analyzed surface charts of 03/0000 to 0600 UTC (Figure 1) Reveals that,

1. The Turkish Low (998 mb) flanked by the Saybran High of 1025 mb.
2. The Low Pressure (1007 mb) over Red Sea flanked by the Sub tropical High of 1024 mb.
3. The Arabian Sea High of 1028 mb flanked by the Low in the West.
4. The Maltis island isobaric High of 1030 mb.

The Turkish Low flanked by the Saybran High in the west with strong pressure gradients - ensures cold air flow from continental Europe and maritime air from the Mediterranean Sea towards middle-east. The strong surface westerly winds in the Mediterranean area of 30 knots confirm the same. The low pressure over the red sea flanked by the Subtropical High ensures strong westerly winds in the northern Arabian Peninsula.

The Low flanked by High (1028 mb) at 03/0600 UTC in the west over Arabian Sea ensures strong south-easterly winds over Qatar & UAE. As the High moves to the central Arabian Sea, southeasterly winds veered into southerly winds. As the frontal system approaches further east, winds reached to maximum gale force speed. Subsequent analysis reveals that the Turkish Low moves northeastward under the influence of the 500 mb upper air trough and the frontal system swept along the Gulf region under the influences of the low formed at 03/1500 UTC in Southern Euphrates-Tigris valley (Figure 1) and the retrogression of 500 mb upper air trough.

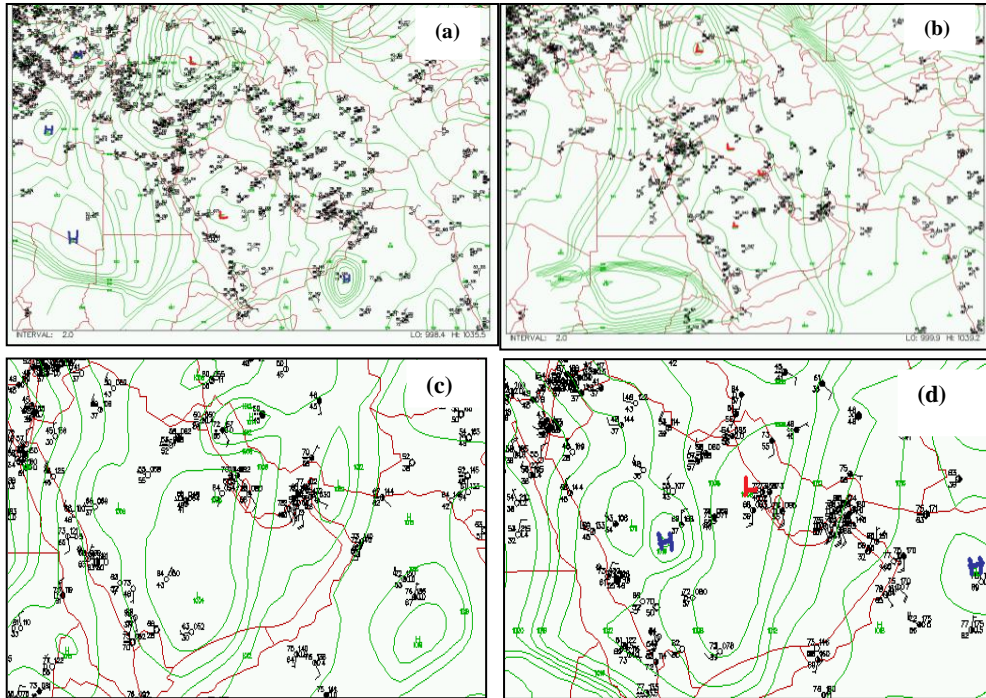


Figure 1: Surface analyzed charts (a) Surface 03/0600 UTC (b) Surface 03/1500 UTC (c) Surface 04/0000 UTC (d) Surface 04/0600 UTC

The temperature field shown in Figure 2 at 850 mb on 03/0000 UTC reveals that strong warm air advection from southern part of Saudi Arabia to Iraq and the northern Arabian Peninsula with a pool of cold air streaming from the west. The strong southerly wind of 30 knots over Riyadh, 35 knots in Al-Qaisumah and 25 knots in Kuwait at 03/0000 UTC (Figure 2) indicates strong Low level Jet (LLJ) in the said areas. The favorable environment for the formation of this LLJ is with the approach of a cold front and surface based temperature inversion in the said areas. This LLJ advects strong warm air from the South. The 03/1200 UTC charts (Figure 2) implies the strong west/northwesterly winds with 30 to 40 knots over eastern Mediterranean which pushes the Baroclinic zone of cold air towards east. As the Polar Jet stream invades south (Figure 5, Sat Pictures from 03/0000 UTC to 03/1200 UTC) the baroclinic zone is dragged further southeastward along the Gulf region. The above synoptic situation gives out a clear clue that frontal system is invading Qatar Peninsula and the possibility of strong Frontal turbulence and Low level wind shear turbulence. Though warm air advection subsides at 03/1200 UTC, the ridge development at 300 mb at 03/1200 UTC and 04/0000 UTC confirms strong warm air advection in the next coming hours. The charts at 04/0000 UTC given in Figure 2 confirms a strong southerly LLJ in Qatar Peninsula and is much instrumental in transporting warm air from the south. High equivalent potential temperature (Theta-E) of 324K value at 850 mb level at 04/1200 UTC (Figure 2) indicates the strong potential for thunderstorm development. The close grading of Theta-E implies distinct cold air advection is present in the region. The persistence of LLJ at 04/1200 UTC further confirms the transport of warm-moist air to Gulf region as adequate moisture availability. A region with a relatively high Theta-E is often the region with the most instability. Prevailing warmer low level temperatures and the anticipated higher low level dew points in view of the approaching frontal zone increases the instability. The LLJ over the moisture source (Gulf region) will often bring in higher Theta-E values, also increases the instability.

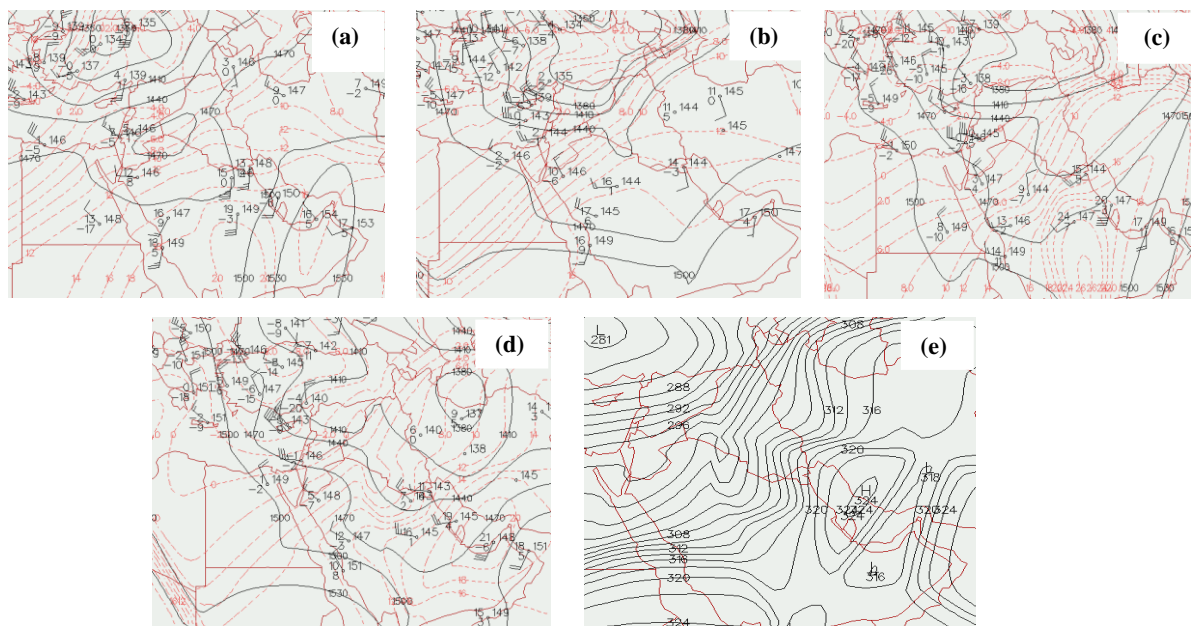


Figure 2: 850 mb analysed charts (a) 03/0000 UTC (850 mb) (b) 03/1200 UTC (850 mb)
(c) 04/0000 UTC (850 mb) (d) 04/1200 UTC (850 mb) (e) 850 mb theta-E

The temperature field at 700 mb at 03/1200 UTC reveals warm air spreading from the northern Saudi Arabia to some parts of Gulf region, Iraq and Iran. On the other hand, there is a pool of cold air present in the western part especially over Syria, Jordan, & Iraq. (Refer Figure 3), this cold pool of air moves eastwards at 03/1200 UTC due to the strong westerly winds of about 35 to 50 knots. The frontal cloud deck in water vapour (WV) imagery of 03/0000 & 1200 UTC also shows the same. The satellite water vapour (WV) imagery of 03/0000 & 1200 UTC reveals that Polar Front Jet is invading

to south results in the formation of a shortwave trough development at 03/0000 UTC and a mesoscale low in southern Euphrates-Tigris Valley at 03/1500 UTC. Both these shortwave trough & meso-scale low drives the frontal system further south eastward along the Gulf region.

The 700 mb charts of 04/0000 and 04/1200 UTC (Figure 3), reveals strong south westerly winds of about 25 to 30 knots crossing the dry line sector in the Gulf region at 04/0000 UTC and about 40 to 50 knots speed at 1200 UTC. The charts also reveal moisture advection at 700 mb and shows strong potential for thunderstorm development. Temperature gradients are also seen strong in the region of the cold front from the advection charts of 04/0000, 1200 & 05/0000 UTC. The strong westerly wind of about 45 to 50 knots drives the cold front along Iran. The retrogression of 500 mb upper air trough at 04/1200 UTC along with the 700 mb trough at 05/0000 UTC overcome the blocking Zagros mountains and drives the frontal system across Iran.

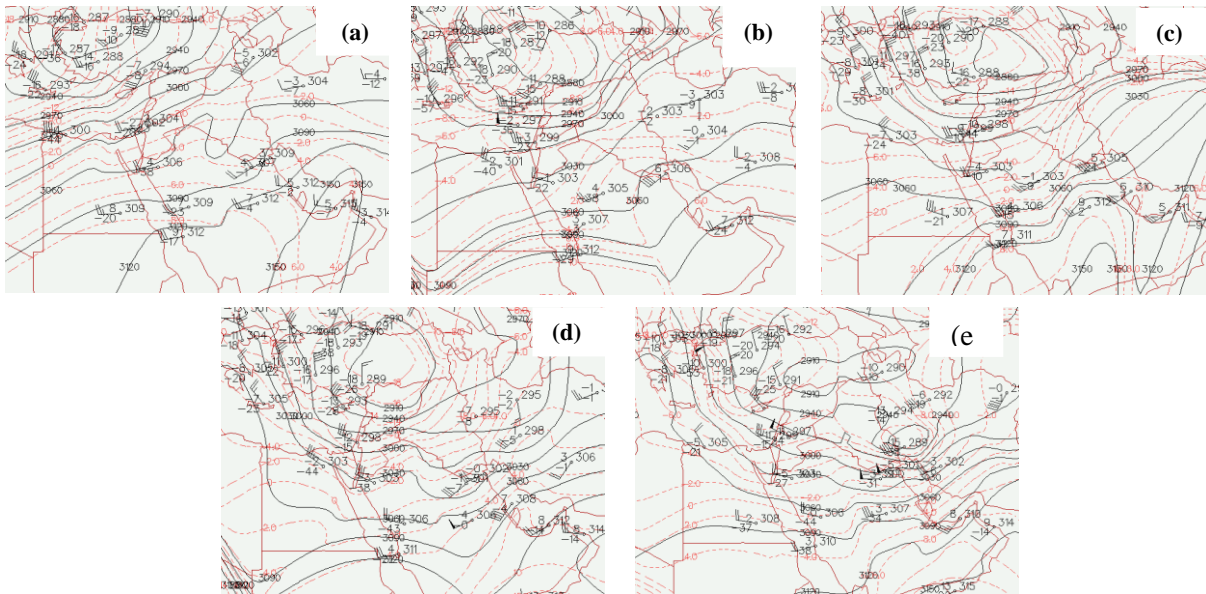


Figure 3: 700 mb analyzed charts (a) 03/0000 UTC (b) 03/1200 UTC (c) 04/0000 UTC (d) 04/1200 UTC (e) 05/0000 UTC

Middle and Upper Tropospheric Features

The wind field at 500 mb chart reveals that strong cold air advection (CAA) is coming from west (Figure 4) the 500 mb charts from 02/1200 UTC to 04/0000 UTC reveals that upper air trough at 500 mb is moving eastward and then retrogresses at 04/1200 UTC. The wind field at 500 mb chart reveals that strong cold air advection (CAA) is coming from the west. The 500 mb charts from 02/1200 UTC to 04/0000 UTC reveals that upper trough at 500 mb is moving eastward and then retrogresses at 04/1200 UTC. After this retrogression of 500 mb upper trough, the frontal system intensified further & shifted eastwards. Under the influence of the surface low and the upper level 500 mb a new mesoscale low formed (as a result of Sub-tropical Jet crossing the frontal system & mountain effect) over Iran just above the northern Gulf region which further enhances the cold frontal flow and the frontal system swept across the Gulf region and moves to Iran. (Strong cold air advection is witnessed clearly from the temp advection charts.) Strong southwesterly to a westerly stream of winds at 500 mb favored the development of a thunderstorm. These strong winds indicate the dry air intrusion from the south west. Satellite pictures also reveal the same. The upper diffluent areas spreading over Qatar and the horizontal speed shear of more than 15 knots at 04/1200 UTC favors Thunderstorm development. (Dammam 65 knots; Abu Dhabi 45 knots)

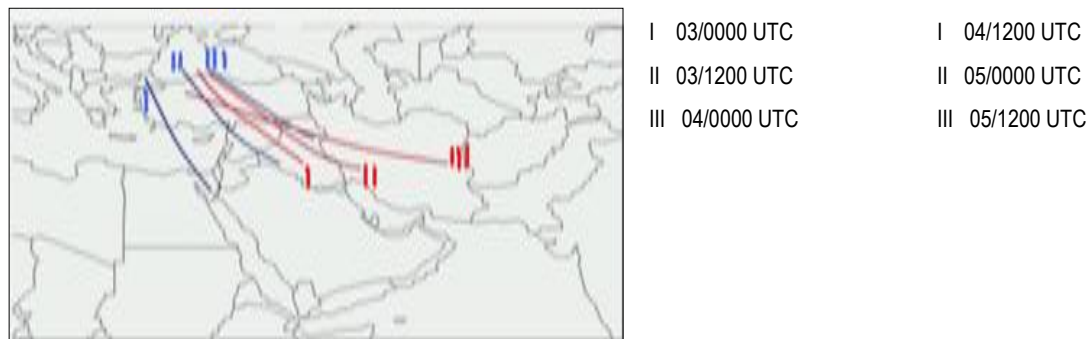


Figure 4: 500 mb trough positions from 03/0000 UTC to 05/1200 UTC

The analyzed 300 mb charts at 04/0000 UTC and 04/1200 UTC reveals that the Polar front Jet is invading the South and pushes the Subtropical Jet further downwards. The Ridge development at 03/1200 UTC and 04/0000 UTC further confirms strong warm air advection (WAA) from the south. The 200 mb analyzed charts from 03/0000 to 04/0000 UTC shows Subtropical Jet is spreading over the region. Initially it moves northwards and crosses the frontal system and then southward as the polar front jet dips to south. The jet axis positions at 300 mb and 200 mb are shown in Figure 6.

Satellite Discussion

The satellite pictures of water vapor (WV)-imagery from 03/0000 UTC to 05/0000 UTC (Figure 5) reveals clearly the polar jets invasion to south and Subtropical Jet position in the Arabian Peninsula. The jet axis through dark stripe is clearly recognizable in satellite pictures. Due to the inadequate presence of moisture in the Arabian Peninsula, the frontal cloud deck is not so clear. The cloud deck brightens from 04/0600 UTC onwards. The Stratospheric dry intrusion (Potential Vorticity anomaly) is visible on 03rd itself and baroclinic leaf structure is clearly visible at 04/1200 UTC onwards which enhances further from 05/0000 UTC.

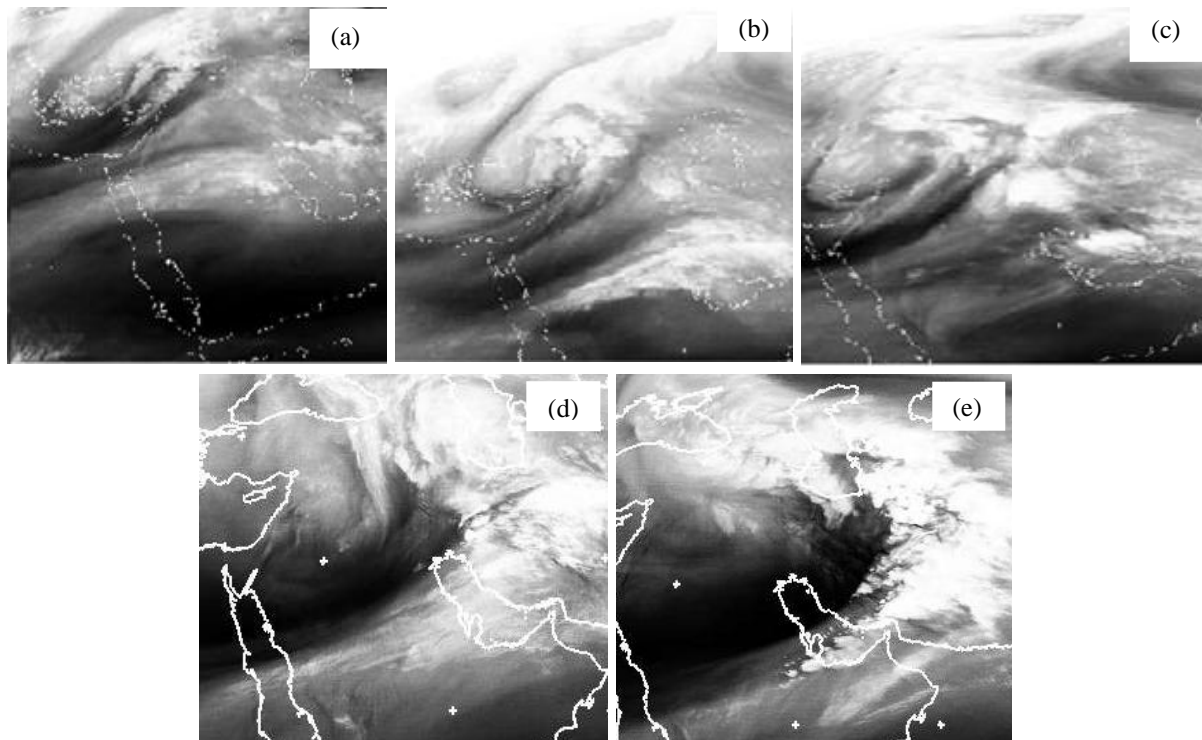


Figure 5: Water Vapour Imagery from 03/0000 UTC to 05/0000 UTC (a) 03/0000 (b) 03/1200 UTC (c) 04/0000 UTC (d) 04/1200 UTC (e) 05/0000 UTC

Position and Interaction of Jet Stream

The position and interaction of the Jet Stream inferred from the charts are given in Figure 10

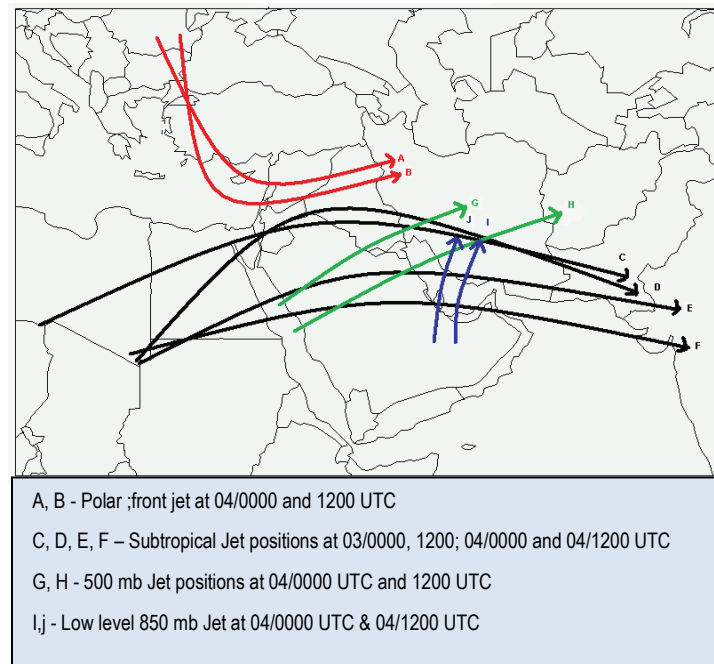


Figure 6: Position of the Jet stream at various levels

Position and Movement of the Cold Front

The location and subsequent sequential movement of a cold front across Qatar to time is given in the Figure

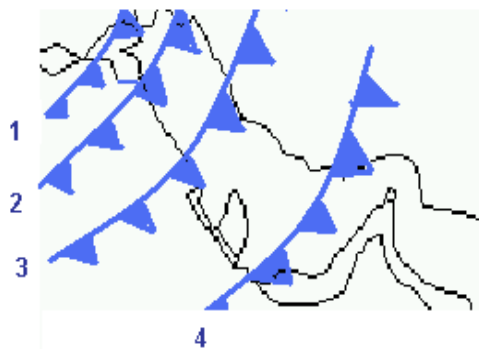


Figure 7: Position of cold front, (1) 04/0000 UTC (2) 04/0600 UTC (3) 04/1200 UTC (4) 04/1800 UTC

Dust Event and Source

The fine sand desert belt regions over Arabian Peninsula and the massive sand dunes over Qatar provide the source region for this major Dust event.

The analyzed surface charts from 03/0000 UTC to 03/0600 UTC reveals that, a steady stream of cold air advects into Syria, Jordan and Iraq from Mediterranean area. The polar front jet invades south, evident in 03/0000 to 03/1200 UTC Satellite water vapor (WV) –imagery which pushes the Sup-tropical Jet downwards thereby steers the frontal system moving southeastwards. The shortwave trough at 700 mb at 03/0000 UTC also gives a hint of the approaching cold front. As these two Jet Streams cross the frontal zone, two mesoscale Lows are formed at 03/1500 UTC in southern Euphrates-Tigris valley. These Low

draws out the cold air further southeastwards along the Gulf region. These lows merge with the Saudi Arabian Low and flanked by High in the East generates Strong Pressure gradient force over Qatar and UAE.

The Approaching cold front signals LLJ over Qatar & UAE. Due to this, low level wind shear is anticipated in the said areas which are evident from the 850 mb analyzed charts. The strong southerly surface winds due to the strong pressure gradient force and the wind shear turbulence results LLJ, which trigger the dust event in Qatar at 04/0600 UTC. (The wind shear turbulence is evident from the morning RS data's of Qatar & UAE). In UAE, the event is initiated early due to the funneling effect of surface wind of the Zagros Mountains. (The massive sand dunes in Mesaieed and in the Saudi Arabian peninsula are the source regions of fine sand for the initiation of the dust event.)

Thunderstorm

The Subsequent analysis after 03/1500 UTC reveals that the meso-scale surface low formed at 03/1500 UTC in the lower Euphrates-Tigris valley influences and retrogrades the upper trough towards the surface Low, generating a triggering mechanism in the lower troposphere and is seen clearly in 500 mb charts from 04/1200 UTC.

Triggers

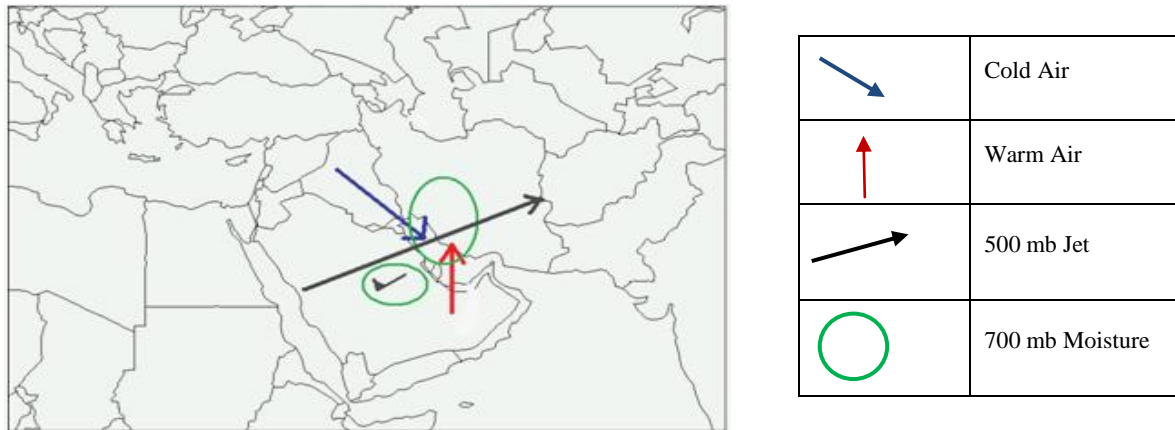


Figure 8: Lines of Interaction

The brightening of the frontal cloud deck after 04/0600 UTC indicates upper trough is strengthening. The mesoscale upper-level (500 mb) low formed over the northern Gulf region in Iran at 05/0000 UTC further enhances the frontal system and the Strong winds at from 700 mb to 500 mb and the Jet streams overcome the blocking Zagros mountains and drives the frontal system in Iran. Figure 7 & 8 shows the Intersecting upper and LLJ streams. The Intersecting low-level Jet and warm fronts and the speed of the cold front after the retrogression of 500 mb trough might be the main triggering force behind the occurrence of thunderstorm besides the other factors.

Frontal Environment Conditions:

The following conditions were noticed during the periods which normally are prerequisite for the occurrence of frontal convergence and thunderstorms.

- Low level Jet advecting warm moist air to the area from the South.
- Strong cold air from the northwest under running warm moist air over the area
- Large low level convergence up to 850 mb level
- High equivalent potential temperature value over the region (324 K)
- High positive vorticity advection noticed at 850 mb level (identified from Jet streaks)

- f. The strong Subtropical Jet at 200 mb (> 85 knots) is identified as a strong
- g. Surface convergence and strong wind at 850 mb (>30 knots) act as moderate potential
- h. The wind at 500 mb (>70 knots) upstream and 45 knots downstream may be a moderate potential parameter
- i. Satellite imagery indicates dry air intrusion into the area and 700 mb chart indicates good moisture advection

Though Qatar received only mild thunderstorm, the coastal and interior areas of Iran get large thunderstorm activities.

(The frontal passage was seen roughly between 04/1500 and 1600 UTC which was evident from the meteograms of Qatar)

Conclusion

The study leads to the conclusion that all the main conventional parameters required for the occurrence of widespread dust and thunderstorm associated with the passage of frontal convergence were present on the day of the event. Strong pressure gradient and presence of Southerly Low Level Jet (>30 knots) in the warm sector are ideal conditions to predict dust event well in advance. Velocity divergence associated with the spreading of subtropical westerly Jet Stream over the area and the presence of low level southerly jet in the warm sector; besides good moisture advection at 700 mb are good indications to foresee the occurrence of a thunderstorm.

Acknowledgement

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