CHAPTER 5

SHAMAL

5.1 INTRODUCTION

Shamal is an Arabic word that means north and is the name given by the local inhabitants to the above normal northerly to north-westerly wind that blows in the Gulf region. There is no universally accepted definition of a Shamal. The UK Meteorological Office Glossary (1991) defines it as "a hot, dry north-westerly wind which blows with special persistence in summer over Iraq and the Persian Gulf", adding that "it is often strong during the daytime but decreases at night." However, Rao, et al (2001) simply define it as a northerly to north-westerly wind with a mean hourly speed of 17 knots, or more, that blows for at least three hours in a day.

The Shamal is the only persistently strong wind in the region that can last for several days with winds that can reach strong to gale force over the open sea and routinely produces 3m to 4m (10 ft to 12 ft) wind waves. Given the numerous oilrigs in the Gulf it is clear that the wind and sea waves can be at least a nuisance and, at worst, a threat to oil production. Marine warnings for the offshore areas are issued by the ADIA weather office when the wind reaches, or is expected to reach, force 6 (22 to 27 knots) on the Beaufort wind scale.

5.2 SCOPE OF THE STUDY

This chapter examines the winter and summer synoptic conditions under which Shamal winds occur at ADIA by way of a statistical analysis as well as case studies and proposes a methodology for forecasting the Shamal. Shamal events researched were from 1992 to 2003 in the ADIA data base.

5.3 METHOD

Shamal events are researched using surface observations at ADIA, the 1200 UTC and 0000 UTC atmospheric soundings at ADIA, as well as Eta GFS NWP. Case studies of a winter and a summer Shamal are presented and discussed, along with statistical data and the wind's effect on the sea state in the Gulf Sea.

5.4 THE WINTER AND SUMMER SHAMAL

The Shamal can be divided into the long and persistent Shamal of summer and the more intermittent winter Shamal. Membery (1983) refers to the wind as being particularly persistent over Iraq and the Gulf in summer from May to early July. This is when there is a quasi-permanent high pressure cell over northern Saudi Arabia and the summer Asian low to the north-west. The enhanced gradient between these two pressure system results in an intensified and persistent north-westerly wind over the Gulf Sea. The Shamal is enhanced by a lee low effect west of the Zagros Mountains, immediately inland over south-western Iran. However, during the summer months, an approximately north-south trough from the Iran/Asian low to the southern Arabian Peninsula heat low often lies across the UAE so that the Shamal is often restricted to the western Gulf Sea and western UAE (Rao, et al 2003).

In winter Shamal conditions develop in association with mid-latitude upper air troughs that pass from west to east through the region, mainly during the months of November to March. In character with these baroclinic systems, a surface low pressure cell exists below the south-westerly flow ahead of the trough and a surface high pressure cell follows to the west of the low pressure cell. This surface low usually passes to the north across Syria, Iraq and northern Iran, while a secondary low usually develops and moves from the Red Sea across Saudi Arabia to southern Iran (Rao, et al 2001).

The greater persistence of the summer Shamal is borne out by Rao, et al (2001) in a study at Doha, in neighbouring Qatar, where they found that 51% of Shamal days occurred in the summer months of May to July compared with 26% during the winter months of November to March. They also found that the Shamal is strongest between 0600 to 1100 UTC, that is, 1000 to 1500 local UAE time.

No statistics of Shamal days over the UAE could be found. Using Rao, et al's (2001) definition, an inspection was made of all days from 1992 to 2003 (inclusive) when the wind reached, or exceeded, 17 knots for three hours or more. As ADIA is some distance inland from the open sea, a lower wind limit of 15 knots was also considered so as to compensate for the increased friction on the wind overland. The selection of this lower limit resulted in nearly double the average monthly Shamal events at ADIA (figure 5.1). It was discovered that the Shamal at ADIA is more prevalent during the spring and summer months from March to August with a distinct drop during the autumn and winter months. The 15 knot limit events also revealed a peak during May to July, which is in accord with findings of Membery (1983) and Rao, et al (2001). The Shamal is also strongest and most frequent during the later part of the afternoon and early evening (figure 5.2), being most prevalent from about 0900 UTC to 1500 UTC (1300 to 1900 local time) and least frequent overnight. It was also noted that low cloud most often accompanied the Shamal in winter, but there was virtually no low cloud associated with the summer Shamal (figure 5.1).

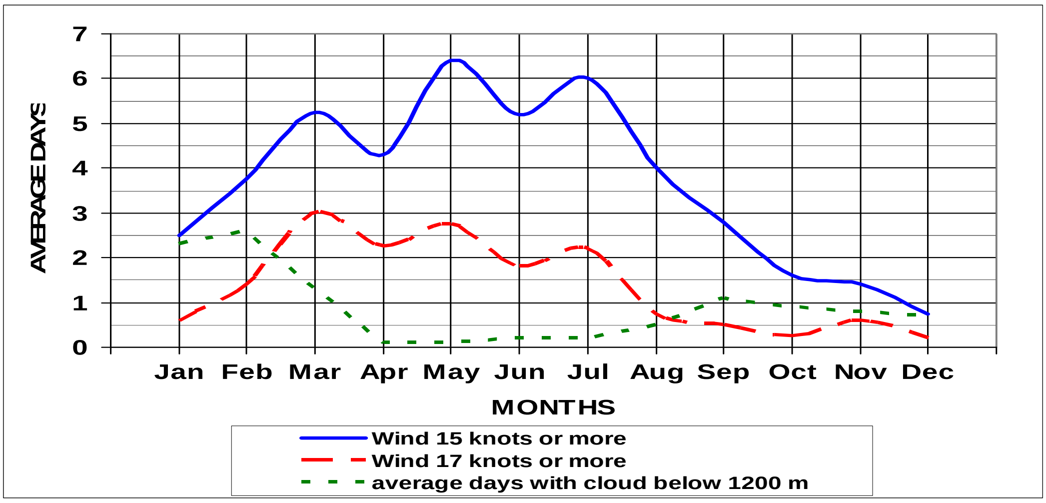

Figure 5.1. The average number of Shamal days per month, daily duration 3 hours, or more, at ADIA for the years 1992 to 2003.

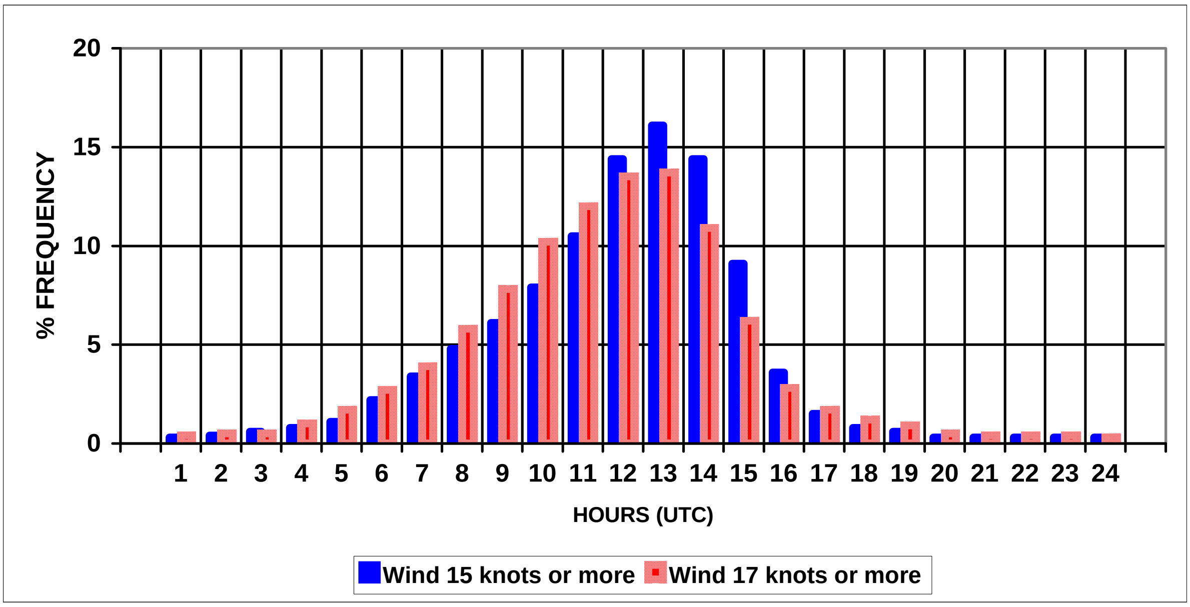

Figure 5.2. The daily hourly frequency of the Shamal at ADIA from 1992 to 2003, inclusive. Wind speed ≥ 15 knots in blue and ≥17 knots in red.

5.5 WINTER SHAMAL: 13TH TO 19TH NOVEMBER 2003

5.5.1 INTRODUCTION

A south-easterly to southerly wind blows off the desert ahead of a surface low approaching from the west and when the upper air trough is about a ¼ wavelength away, west of the surface low, cloudy weather occurs, sometimes attended by light rain and/or a brief thunderstorm line squall. A following surface anticyclone can cause a marked pressure rise and a fresh to strong Shamal wind blows. The flow of air from the north, off southern Iran, facilitates the development of a lee low, which strengthens the pressure gradient. Occasionally these systems will produce more persistent cloudy weather and heavier rain. For example, on the night of the 26th/27th December 2004 16 mm of rain fell at ADIA and for the first time in recorded history light snow fell on the Musandam part of the Hajar Mountains in the vicinity of Ras Al Khaimah.

However, as will be seen in this November 2003 case study, although an upper air trough was present it was too far north to have much effect other than to produce middle and high cloud over the rest of the Gulf with no secondary lee low developed.

5.5.2 NWP MODEL DATA

The NWP model gave adequate advance warning of the beginning of Shamal winds and predicted that it would last for several days due to the semi-stationary nature of an anticyclone. The model indicated that the winter anticyclone over Iran would cause a dry south-easterly to southerly wind to blow over the UAE from the Arabian Peninsula desert. By the 11th the gradient collapsed. On the 12th a low pressure cell of about 1012 hPa was predicted over the Strait of Hormuz with a weak trough extending north-westward along the Gulf and a high pressure ridge would develop over northern Saudi Arabia (figure 5.3a).

The following day, the 13th, a 5 hPa pressure gradient was expected across the southern Gulf Sea between the now established ridge over Saudi Arabia and the low pressure cell that was now east of the Strait of Hormuz. The Shamal was expected to reaching 15 to 25 knots over the sea (figure 5.3b). The strongest gradient (7 hPa) and maximum wind (20 to 30 knots), was predicted on the 14th (figure 5.3c), with wind speed moderation predicted on the 15th and 16th.

By the 18th (figure 5.3d), a weakened pressure gradient meant that the wind experienced at ADIA was more likely to be in the form of a moderate sea breeze, while the north/south pressure gradient meant that there should still be little, or no, early morning land breeze. However, later model runs indicated a delay in the reduction of the pressure gradient by a day to the 19th (figures 5.3d and 5.3e).

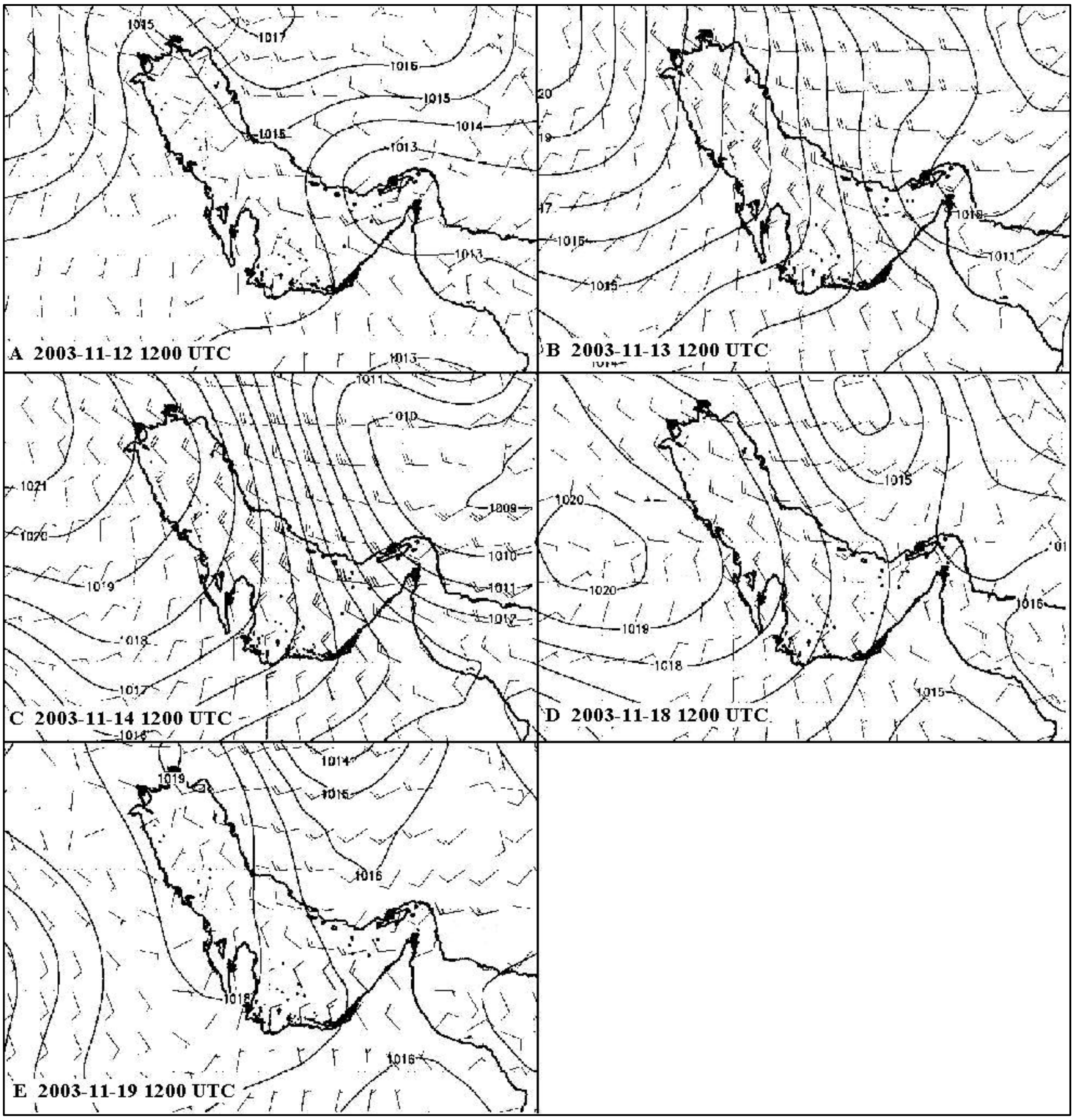

Figure 5.3. Eta GFS prognostic fields of surface pressure (hPa) and wind (knots) 2003-11-12 to 2003-11-19 at 1200 UTC. The fields for the 12th to the 14th are from the 2003-11-11 0000 UTC model run. The 18th and 19th are from the 2003-11-17 1200 UTC model run.

Apart from showing the persistence and depth of the Shamal, the sequence of time cross sections at Abu Dhabi reflect the change from a dry environment on the 11th, with south-easterly winds in the lower levels, to more moist boundary layer conditions associated with the Shamal below 900 hPa (figures 5.4a and 5.4b). The surface pressure averaged about 1015 hPa, which means that the 900 hPa pressure level in the time sections is about 1050 metres MSL (±3450 feet). Note the lack of an early morning south-easterly land breeze from the 13th onward. At best the wind near the surface becomes lighter, backs to westerly and on one occasion to south-westerly. The 10 metre winds in figure 5.5, unfortunately with a six hour break early on the 18th, show no such inclination for the wind to back in the early hours of the morning.

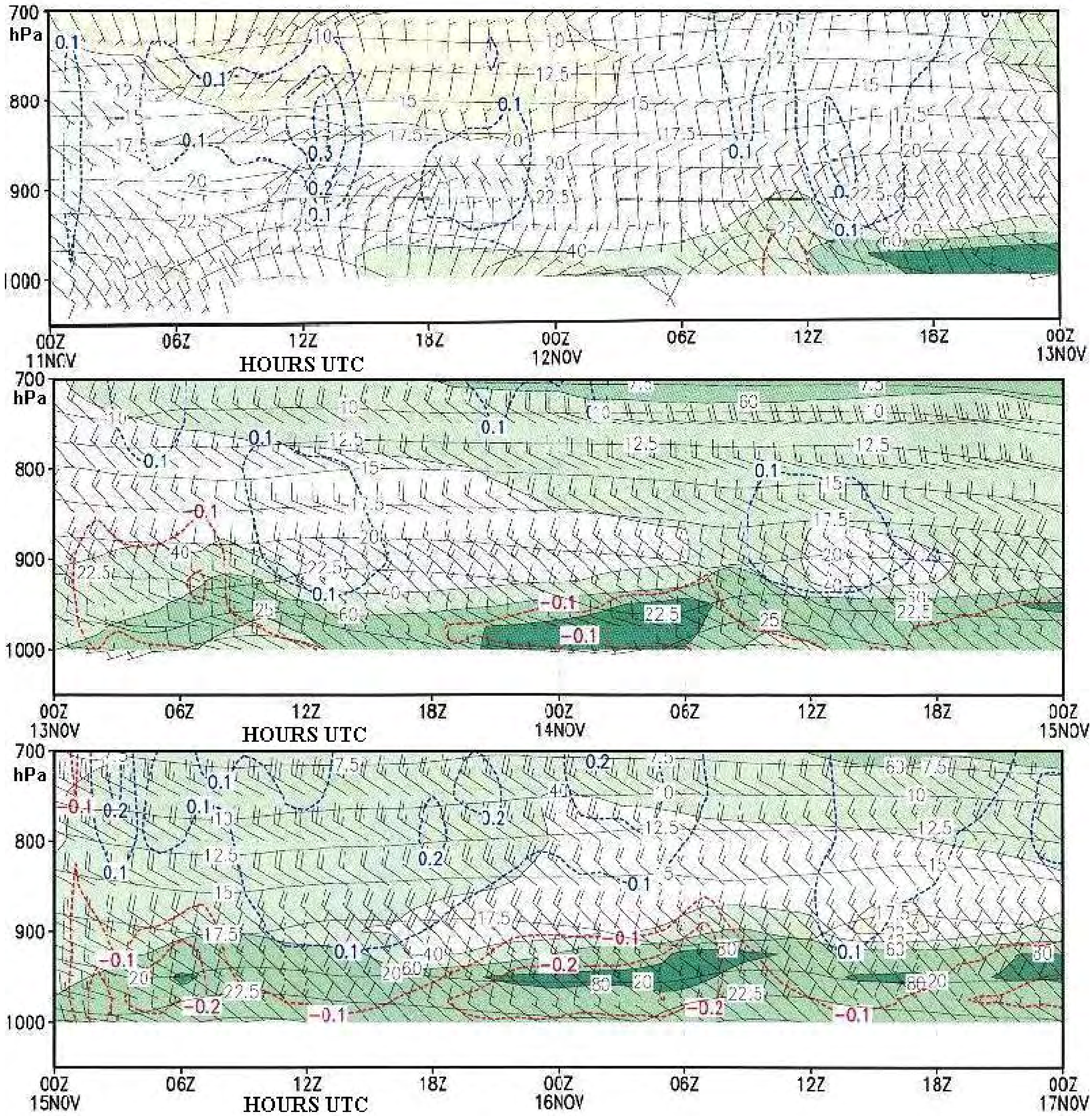

Figure 5.4a. Time cross-sections of wind, dew point and vertical motion at ADIA from 2003-11-11 to 2003-11-17, extracted from Eta model runs. The sequence reflects the change from a dry environment on the 11th, with south-easterly winds in the lower levels, to moister boundary layer conditions associated with the Shamal.

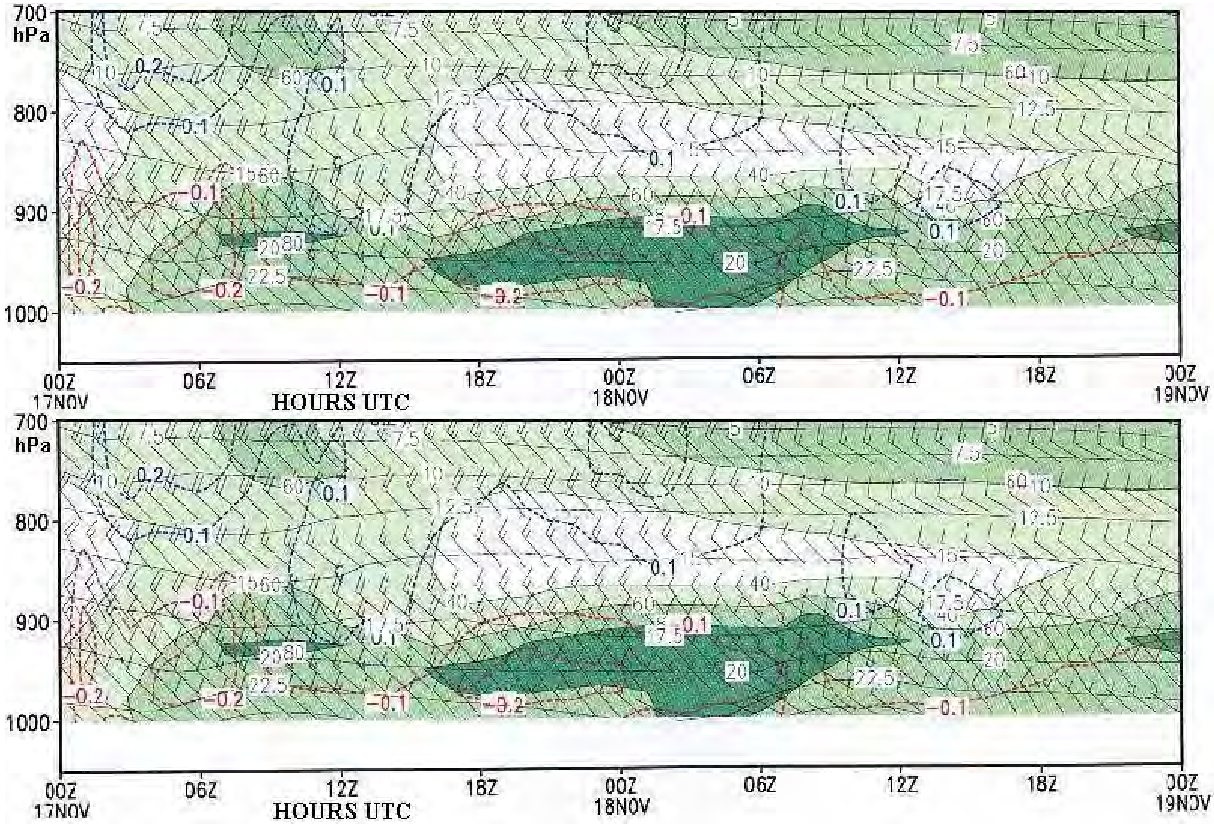

Figure 5.4b. As figure 5.4a, but for 2003-11-17 to 2003-11-19.

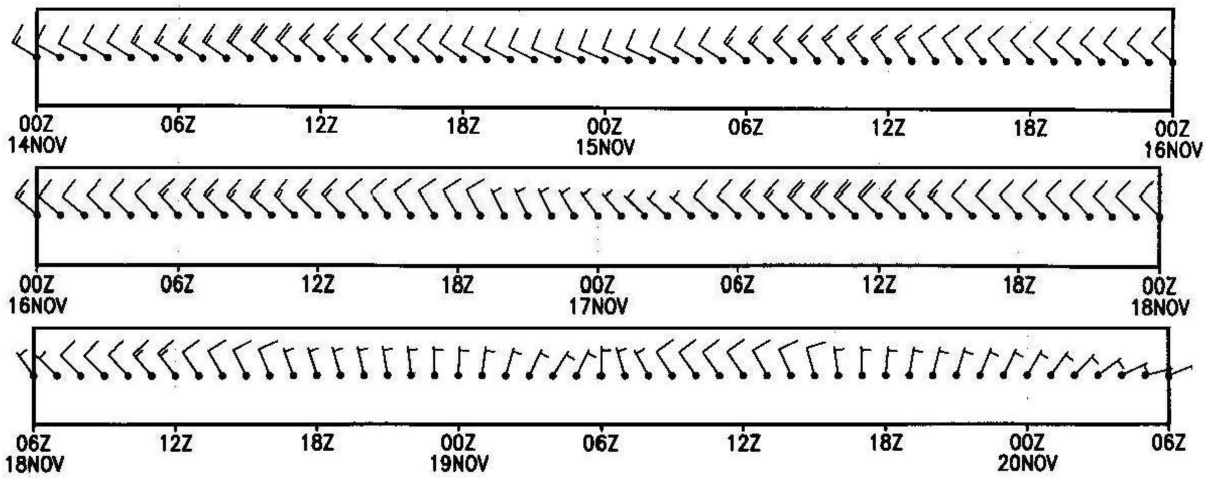

Figure 5.5. Eta model 10 metre prognostic winds (in knots) for the period 2003-11-14 to 2003-11-20. Data for 2003-11-18 0000Z to 0600Z is missing.

The accumulation of moisture inland of the coast, due to the Shamal, is indicated in the surface fields at 0300 UTC on the 15th and 16th (figure 5.6). Although there is an accumulation of low level moisture over the land during Shamal conditions, fog does not occur along the coast. This is not always valid inland and will be discussed in the section 5.7.

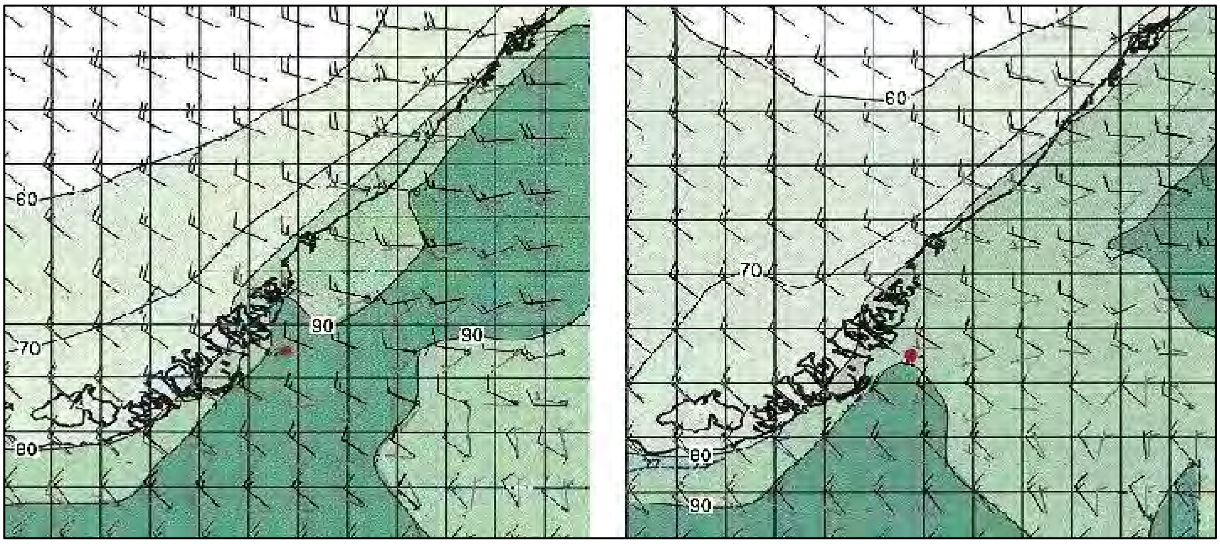

Figure 5.6. Eta model prognoses of surface relative humidity, wind (knots) at 10 metre (black), 950 hPa (grey) and downward vertical motion (blue lines) for 2003-11-15 0300 UTC (T+27) and 2003-11-16 0300 UTC (T+27).

5.5.3 OFFSHORE WIND AND SEA STATE

The feathers on the winds plotted on the marine charts (figures 5.7a to 5.7d) are rounded to the nearest 5 knots, so it is not possible to accurately identify Shamal conditions using Rao's 17 knot minimum limit (Rao, et al 2001). Nevertheless, 20 knot winds from the north-west qualify and are clearly evident over the southern Gulf Sea from the 12th and continued until the 18th.

Wind waves in the Gulf Sea increased from 0.5 m to 1 m on the 11th (figure 5.7a) to 1.5 to 2.5 m later on the 12th. From the 14th to the 18th wind waves reported were generally 2 to 3 m. At Sir Abu Nu'ayr island (±25¼°N 54¼°E) to the north-north-west of Abu Dhabi the wind waves increased from 0.5 m prior to the Shamal to 4 m on the 14th (figure 5.7c) decreasing to 2 to 3 m from the 15th and became approximately 1 m on the 19th. The Pearson product-moment coefficient of correlation (Harper 1977) between the wind speed and visually observed wind wave height at Sir Abu Nu'ayr was +0.67 (figure 5.8). In general 2.5 m wind waves result from a wind of 15 knots reaching 3 to 4 m when the wind exceeded 20 knots. These wind and sea wave conditions, during this period, caused helicopter flights to the oil rigs to be cancelled.

Overall the observed winds were about 5 to 10 knots stronger over the western Gulf. Due to the "L" shape of the Gulf, the western part of the Gulf, toward Qatar, is exposed to a longer uninterrupted flow of air from the north. The wind here tends to be stronger and the sea rougher than the eastern part, toward Dubai and the Strait of Hormuz, which are sheltered from the Shamal by the land area of Iran to the north. Local sailors have long known of the shorter fetch and the shelter to be found from the brunt of the wind in the lee of the land to the north. Thesiger (1994), during his trip in a Dhow from Dubai to Bahrain in 1948 mentions how they sheltered for days in the lee of southern Iran to avoid a gale and a very rough sea that broke over the ship. The normally four day trip eventually took 11 days. Friction over land rapidly reduced the wind speed to mere 5 to 15 knots inland.

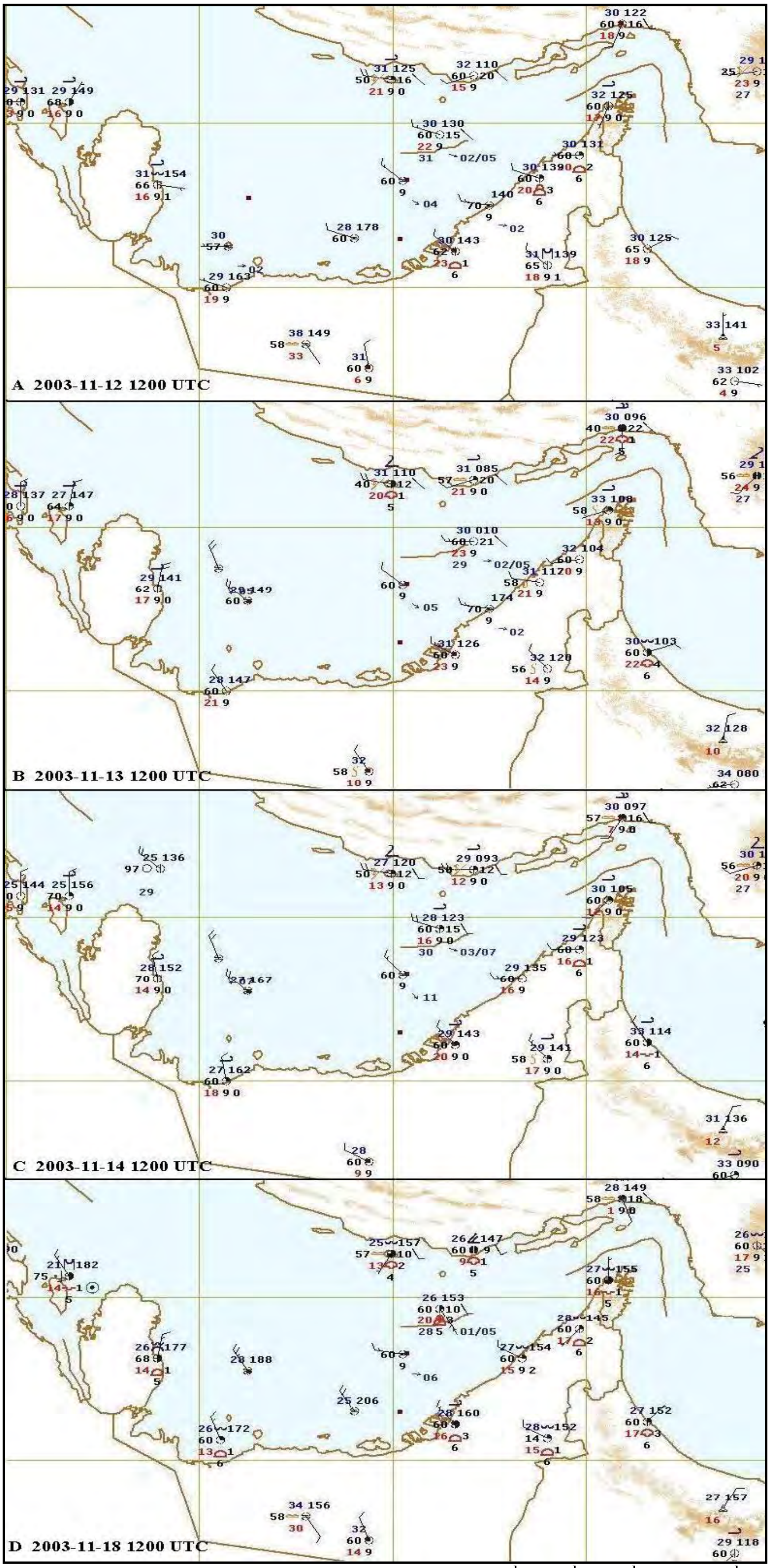

Figure 5.7. Surface observations for the 12th, 13th, 14th and 18th November 2003. Note, the wind direction at Bu Hasa inland in the south-west of the UAE is often erroneous.

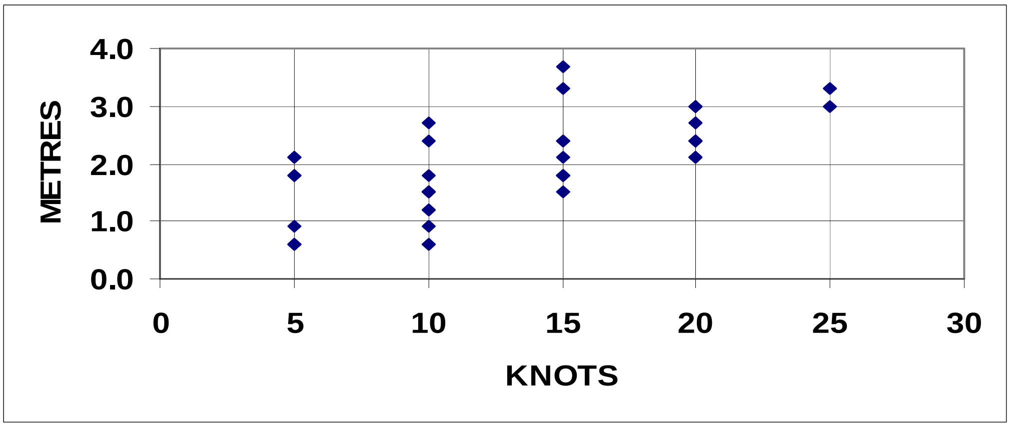

Figure 5.8. Wind speed (to nearest 5 knots) and wind wave height (metres) scatter graph of 3 hourly observations from 0000 UTC on the 11th to 1500 UTC on the 19th. The graph does not show all 51 scatter points due to superimposing of similar observations.

5.5.4 SURFACE OBSERVATIONS

Characteristically, the Shamal brings cold air from the north over the UAE and there is a noticeable drop in temperature. The maximum temperature at Abu Dhabi decreased from 35°C on the 10th and 11th to 32°C on the 12th (figure 5.9), 30°C on the 14th (figure 5.11) and 28°C on the 16th (figure 5.13). While the dew point temperature during the day fell from about 23°C to 16°C, the relative humidity during the day remained about 60% to 50%.

As predicted by the NWP model, the surface observation graphs (figures 5.9 to 5.15) reflect the lack of a south-easterly land breeze with the wind on most mornings, either blowing from the north-west, or at the most being deflected to the south-west, due to a weak land breeze effect. Notice the higher temperatures on the nights of the 13th/14th (figure 5.10) and the 15th/16th (figure 5.12) when the wind remained onshore overnight and the nocturnal land thermally induced pressure gradient, forced by radiation cooling, was unable to overcome the synoptic scale pressure gradient. The colder continental and warmer maritime air effect is particularly noticeable late on the 16th and the 18th when the wind became light from the south-south-west at 1900 UTC and then again became an onshore north-westerly at 2000 UTC (figures 5.13 and 5.15).Eventually, an approaching surface low pressure cell to the south-east of the UAE caused the surface wind to veer to a south-easterly land breeze during the nights of the 19th and 20th (figure 5.16).

The NWP model can fail to correctly predict these early morning changes in wind direction, as is revealed in a comparison of the surface observations (figures 5.8 to 5.14) with the forecast winds in figure 5.5. The model incorrectly maintained northerly to north-westerly winds on all nights. This is a dilemma for the forecaster who has to decide whether the wind will remain north-westerly, or back to south-westerly. If it is any consolation, the observations show that on most occasions the wind will back to south-westerly and it will decrease and if it does not turn to south-westerly, it will at least back as far as west-north-westerly.

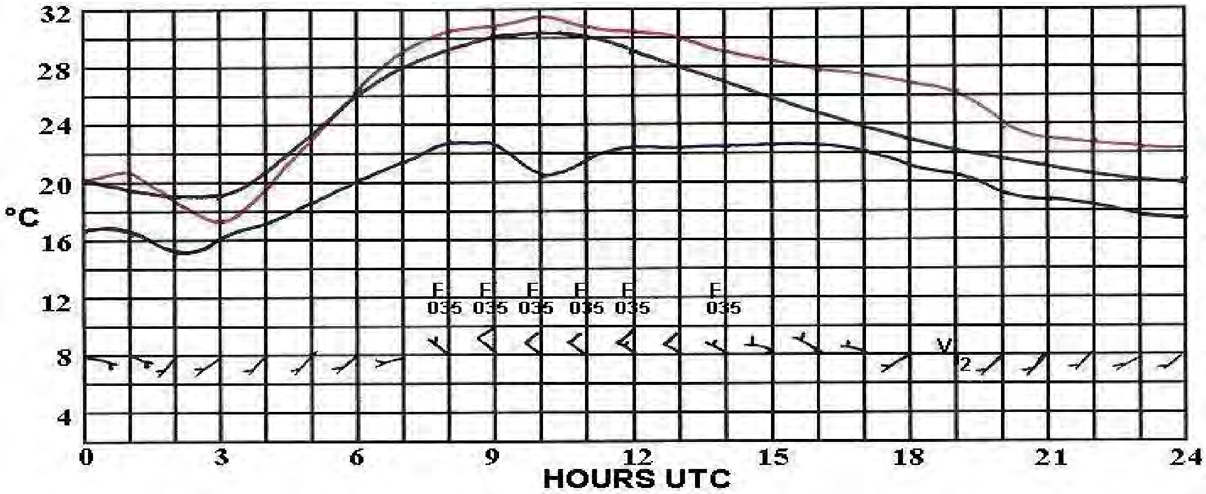

Figure 5.9. Surface observations on 2003-11-12. Air temperature (°C); red line; dew point temperature (°C), blue line; mean monthly temperature, black line. and wind flags (full feather = 10knots). F = few oktas. S = scattered, B = broken and O = overcast. The cloud is at 3500 feet AGL.

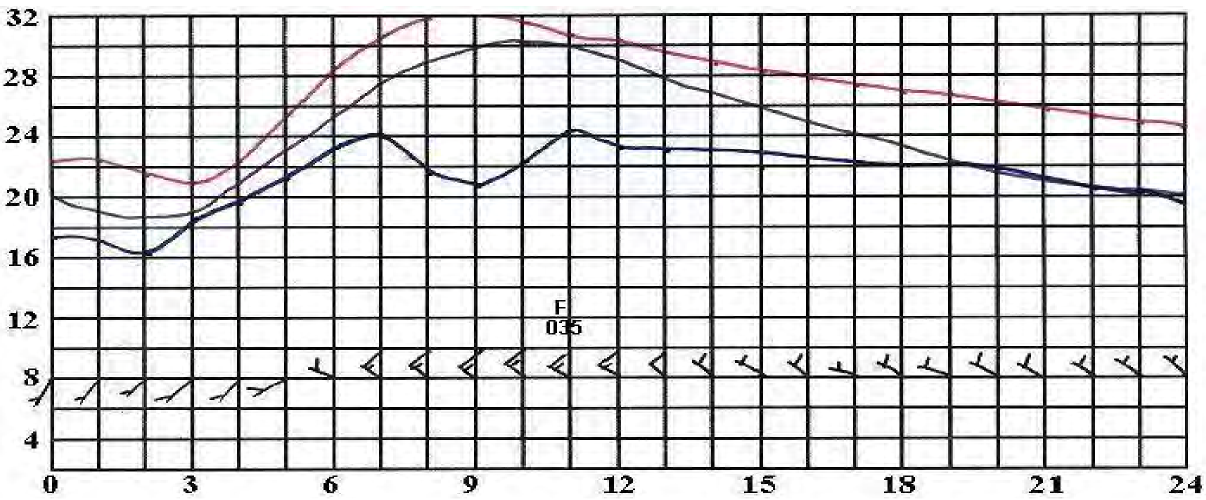

Figure 5.10. As figure 5.9, but for 2003-11-13. The cloud is at 1100 m (3500 ft) AGL.

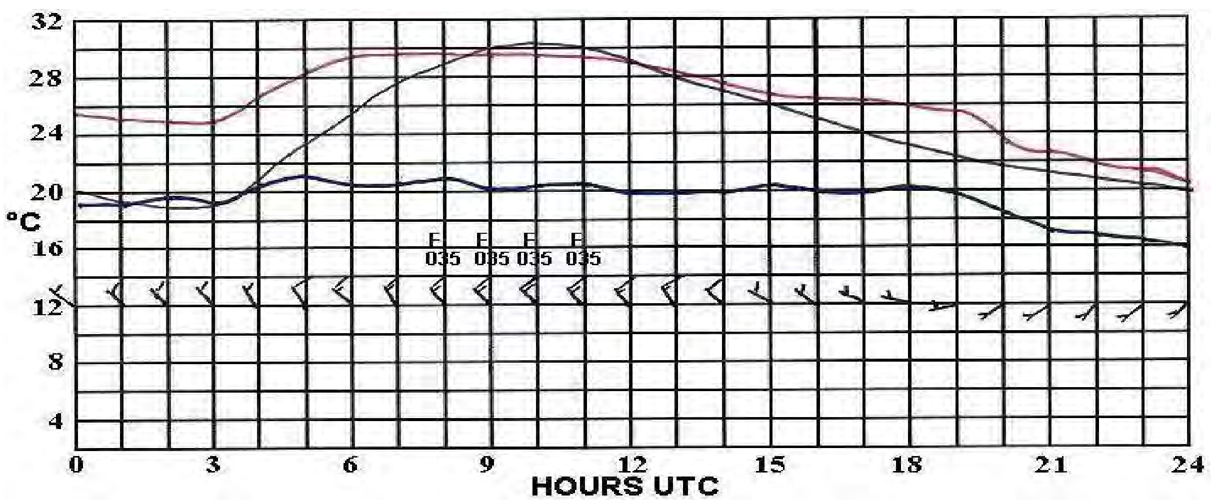

Figure 5.11. As figure 5.9, but for 2003-11-14. The cloud is at 900 m (3000 ft) AGL.

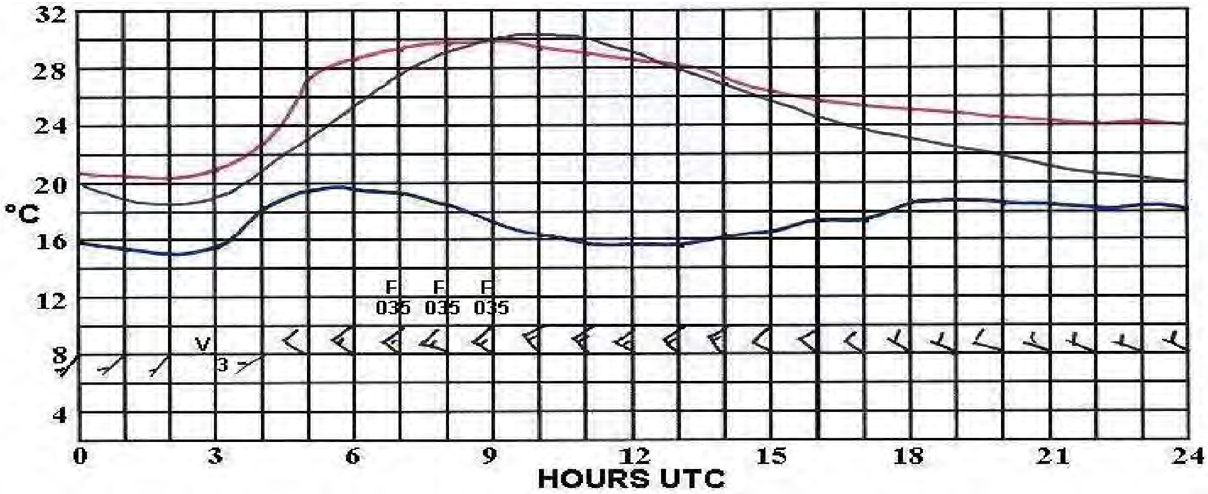

Figure 5.12. As figure 5.9, but for 2003-11-15. The cloud is at 1100 m (3500 ft) AGL.

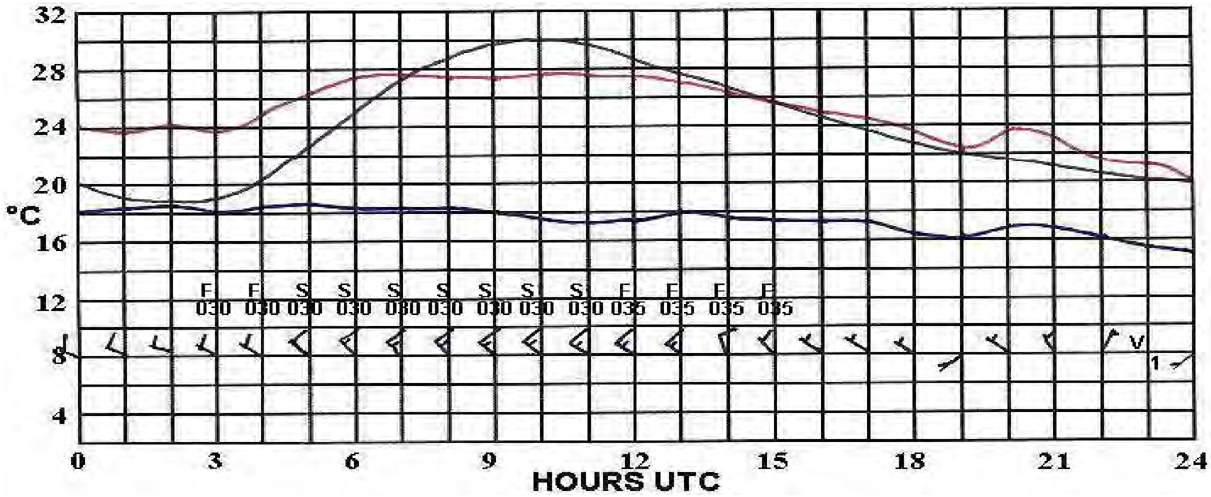

Figure 5.13. As figure 5.9, but for 2003-11-16.The cloud is at 900 – 1100 m (3000 - 3500 ft) AGL.

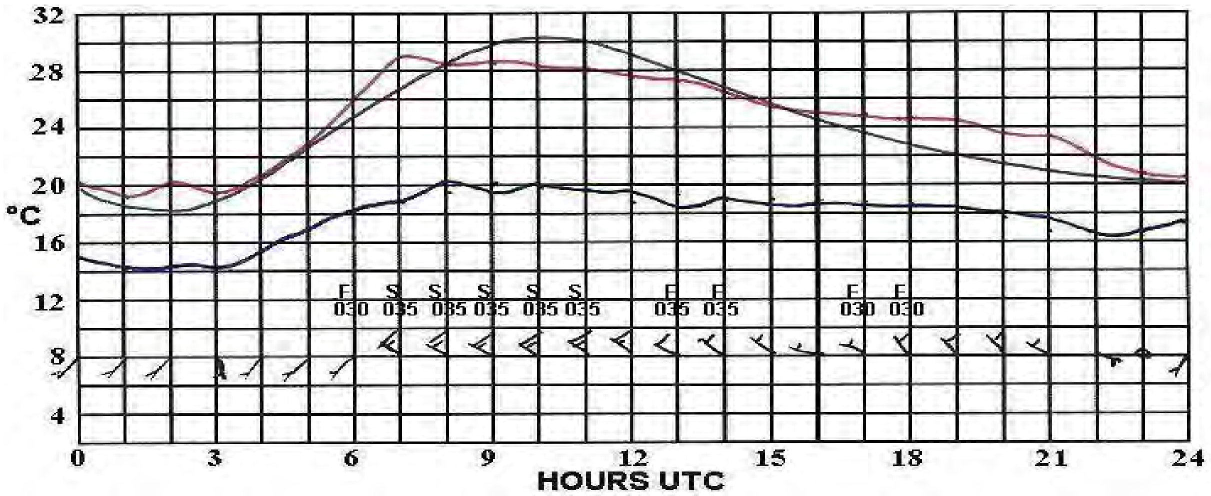

Figure 5.14. As figure 5.9, but for 2003-11-17. The cloud is at 900 – 1100 m (3000 - 3500 ft) AGL.

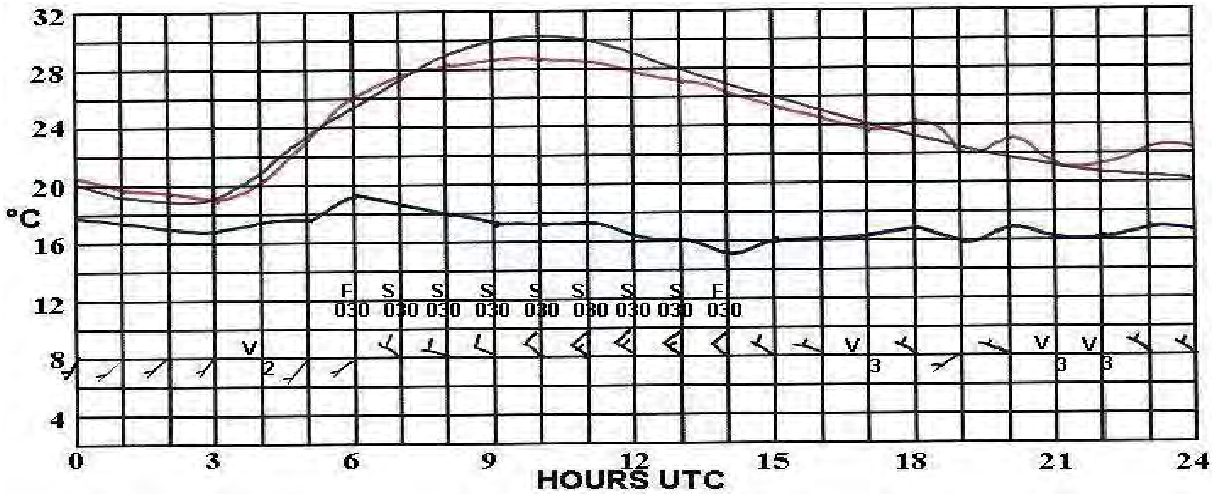

Figure 5.15. As figure 5.9, but for 2003-11-18. The cloud is at 900 m (3000 ft) AGL.

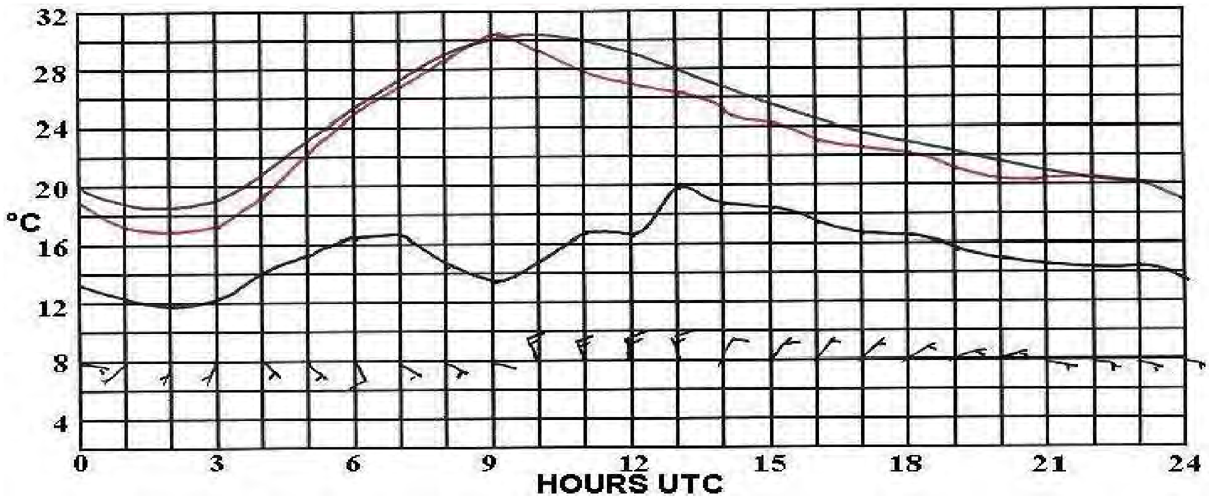

Figure 5.16. As figure 5.9, but for 2003-11-20.

During this Shamal event, low cloud occurred on most days when the wind was from the north-west with a longer path over the Gulf Sea, but it is absent on the 20th when the wind was from the land to the north (figure 5.16). With enough moisture and impetus cloud also forms further inland, such as at Al Ain low cloud during the day from the 16th to the 19th.

In the winter months it is routine for the Shamal to cause scattered to broken stratocumulus to form along the coastal belt. This was clearly illustrated by the analysis of Shamal days with winds greater than 15 knots and cloud days in figure 5.1. The percentage likelihood of cloud with the Shamal is less than 15% in the summer months, increasing to over 90% in December and January. This can be attributed to cooler and stable air over the warm Gulf becoming unstable and mechanical turbulence being strong enough to raise moisture to the lower lifted condensation level in the cooler winter conditions (Taha, et al 1981), but insufficient during the much hotter and drier summer months, in spite of the more humid surface conditions. Daytime convection heating also plays a role, as the cloud is more prevalent during the late morning and afternoon with the cloud dissipating later in the afternoon and early evening.

Figure 5.17. Winter Shamal Stratocumulus arriving over Abu Dhabi from the Gulf Sea.

5.5.5 ATMOSPHERIC SOUNDINGS

The three atmospheric soundings at 0000 UTC and 1200 UTC on the 14th (figure 5.18) and 0000 UTC on the 15th (figure 5.19), based on personal experience, were chosen as being representative of the profiles that occur during winter Shamal conditions. The first morning sounding was made on a night when the wind remained from the north-west overnight and the second morning sounding when the wind turned to south-westerly.

What is immediately apparent when comparing the two morning temperature profiles is the reduced surface radiation cooling inversion when the wind remained onshore north-westerly, than when it was offshore from the south-west on the morning of the 15th.

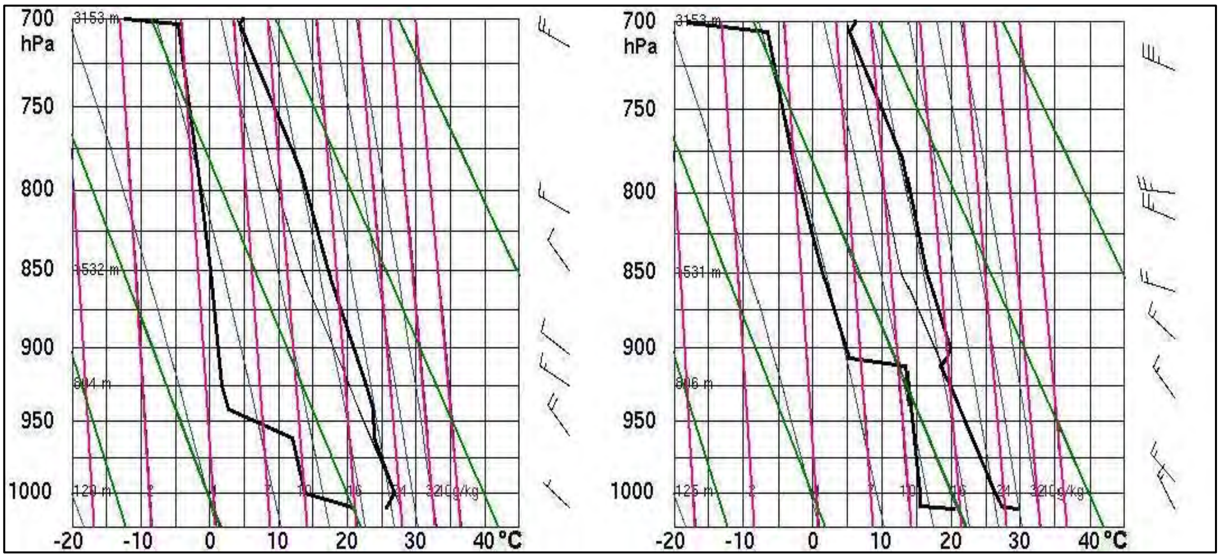

Figure 5.18. Atmospheric soundings at ADIA 2003-11-14 at 0000 UTC on the left and 1200 UTC on the right. The dry adiabatic lapse rate lines are in green and the mixing ratio lines in pink (courtesy of the University of Wyoming).

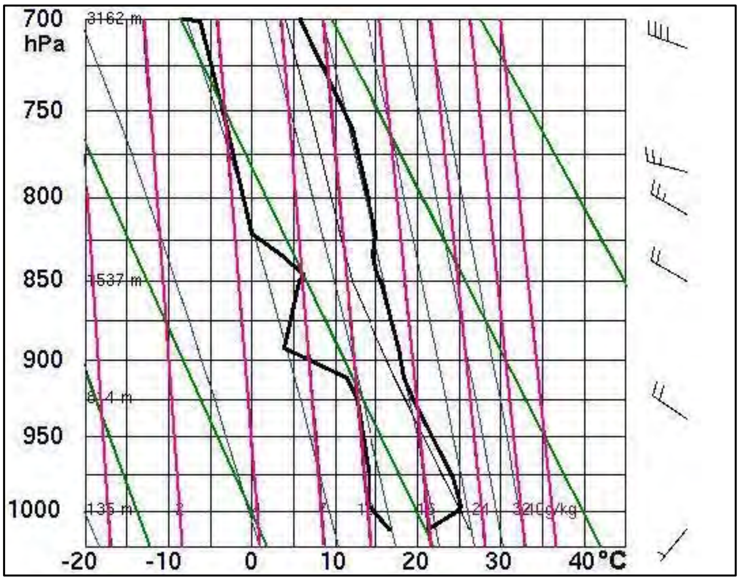

Figure 5.19. As figure 5.18 but for 2003-11-15 at 0000 UTC (courtesy of the University of Wyoming).

Furthermore, the DALR temperature lines and the constant mixing ratio dew point profiles below 960 hPa on the morning of the 14th (figure 5.18 left) and 910 hPa in the other two soundings (1200 UTC in figure 5.18 right and 0000 UTC figure 5.19) clearly indicate efficient turbulent mixing of the atmosphere (Stull 2000). Generally, mixing occurred to a depth of about 900 m to 1200 m MSL (table 5.1) where a temperature inversion was present on most of the afternoon soundings.

The strength of the low level winds at 0000 UTC in table 5.1 bear testimony to the robust turbulent mixing and emphasise why fog does not occur at ADIA in Shamal conditions. Notice the change from the south-easterly desert wind associated with the anticyclone that was to the north-east of the UAE on the 10th and 11th before the Shamal started.

Table 5.1. Winds at 150 m and 900 m above MSL at ADIA on 10th to 20th November 2003 and temperature inversions in metres above t MSL.

	0000 UTC		**1200 UTC**		
	150 m	**300 m**	**150 m**	**300 m**	**Inversion**
10th	140°26	135°18			
11th	125°12	145°12	360°02	010°02	
12th	355°08	355°11	300°11	315°13	
13th	305°13	305°14	300°15	295°16	Not available
14th	315°18	315°18	315°14	320°15	919 m
15th	255°10	270°13	320°18	315°17	No inversion
16th			315°15	320°16	977 m
17th	335°10	335°11	305°17	310°18	1170 m
18th	340°08	340°09	320°17	320°17	1210 m
19th	320°13	325°14	330°12	330°13	907 m
20th			335°15	345°11	

5.6 SUMMER SHAMAL: 28TH APRIL TO 2ND MAY 2003

5.6.1 INTRODUCTION

In summer, high temperatures over the Asian continent and the Arabian Peninsula create a marked surface "heat low," which is enhanced by the movement of the equatorial low pressure belt northward to the Gulf. When there is a ridge of high pressure over northern Saudi Arabia, the north to south pressure gradient is strengthened and the resultant north-westerly wind can persist over the Gulf for extended periods. The phenomenon is known locally as the "forty day Shamal." As the time the air spends over the Gulf is relatively short, the Shamal is rather dry, apart from the surface moisture trapped beneath a subsidence inversion, which causes the very humid summer weather over the UAE. Weather associated with mid-latitude systems seldom reaches the UAE in summer, but the associated Shamal often brings dust from the deserts of Saudi Arabia, Kuwait and Iraq.

The summer Shamal has many characteristics similar to the winter Shamal described above. What is significantly different is the drier air in circulation as depicted by the NWP model analysis and prognosis. Another notable aspect is the markedly lower temperatures experienced at Abu Dhabi with the onset of the summer Shamal.

As in the winter study, the research indicated that the summer Shamal wind was caused by the approach of a ridge of high pressure from the west over Saudi Arabia. This resulted in a 6 hPa to 8 hPa pressure gradient over the Gulf between the ridge and a low pressure cell over the Strait of Hormuz. And, as before, the Eta NWP model gave good advance warning of the onset of the 20 to 30 knots Shamal over the Gulf.

5.6.2 SEQUENCE OF EVENTS AND OFFSHORE CONDITIONS

Day 1: 28th April

On the 28th surface high pressure intensified over north-western Saudi Arabia and began to ridge south-eastward, east of the Gulf Sea. The wind over the Gulf at this time was generally north-easterly 5 to 10 knots due to a weak low pressure cell at the surface to the south of the UAE and the sea waves in the Gulf were low at 0.5 m. Along the coast of the UAE a 10 to 15 knots north-westerly sea breeze developed during the afternoon, decreasing to 5 knots inland. At about 1800 UTC, over the northern Gulf, north of Qatar, the north-westerly Shamal began to blow at 15 to 25 knots and the wind waves in the area began to increase.

Day 2: 29th April

By 0000 UTC on the 29th, the wind was blowing at 20 to 30 knots over the Gulf with sea waves 1.5 m to 2.1 m. Thirty minutes later the Shamal, at 10 knots, reached Abu Dhabi Airport. By 0300 UTC (0700 UAE time) it was blowing at 10 to 15 knots along the UAE coast, but reached 25 knots along the western part of the coast. During the day the wind reached 30 knots over the Gulf Sea creating 3 to 4m. Unfortunately the GFS NWP model slightly underestimated the wind by predicting not more than 25 knots over the southern Gulf.

Although the eastern Gulf tends to be sheltered from the Shamal, by 0900 UTC the eastern part of the Gulf had a west-north-west wind in excess of 20 knots and 3 m wind waves. By 1200 UTC (1600 UAE time) all the offshore oilrigs and island reports gave 3 to 4 m wind waves. The wind speed quickly moderated once it crossed the coast, decreasing to 10 to 15 knots, but, it was still strong and turbulent enough to lift sand and reduce the visibility further inland to 6000 metres.

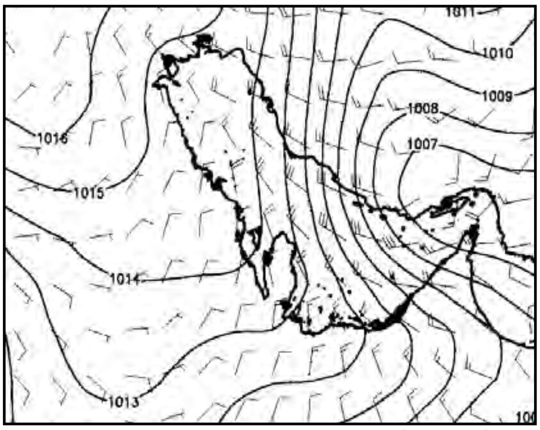

Figure 5.20. Eta model GFS fields for 2003-04-30 1200 UTC. Surface pressure (hPa) and wind (knots) are plotted. A strong pressure gradient with a near gale Shamal is indicated.

Overnight, on the 29th to the 30th, the wind along the coast decreased to 5 to 10 knots due to the land breeze effect and even backed to south-westerly along the coast from Dubai and further eastward to the Musandam Peninsula.

Day 3: 30th

The wind blew at 20 to 30 knots on the 30th with deep-sea wind waves of 2 to 3 m and up to 3 to 4 m at oilrigs in the middle of the Gulf. The Eta NWP model correctly predicted the 6 to 7 hPa pressure gradient across the Gulf and a 30 knots westerly wind extending into the eastern part of the southern Gulf (figure 5.20). Throughout the night of the 30th the wind was 25 to 30 knots and occasionally reached 35 knots in the north. Due to the opposing land breeze effect, along the UAE coast the wind decreased to 10 knots and backed to its original direction of south-west east of Dubai. Inland it decreased to 5 knots.

Day 4: 1st May

The strong to gale force wind persisted over the sea and by 0600 UTC (1200 UAE time) the wind speed was 15 knots at ADIA, averaging 18 to 20 knots in the afternoon with gusts up to 25 knots and the visibility down to 7 km. Inland at Al Ain the wind picked up to 15 knots in the afternoon with similar gusts as at ADIA, but in this sandy environment the visibility went down to 4500 m.

Day 5: 2nd

By the 2nd, the ridge of high pressure had weakened considerably, but the approach of a surface tropical low pressure cell from the east over Oman, maintained a large enough pressure gradient to cause a 15 to 20 knots Shamal over the Gulf Sea and 10 to 15 knots inland. The wind waves decreased to 1 to 2 m, but remained 2 to 2.5 m in the deep-sea.

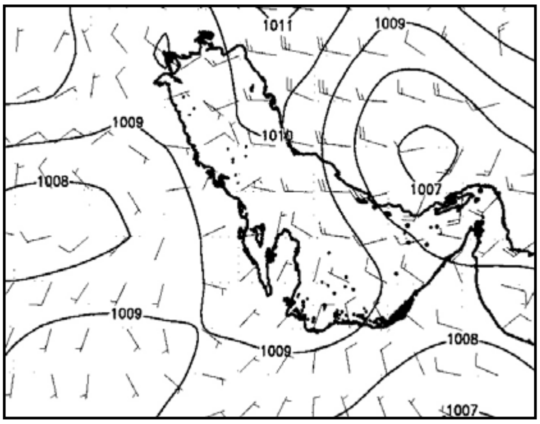

Figure 5.21. As figure 5.20, but for 2003-05-04 1200 UTC.

Days 6 and 7: 3rd and 4th

Theoretically the 3rd and 4th are post-Shamal days, because the wind had dropped to about 10 knots over the sea, while the wind waves fell to 0.5 m inshore and 1 m in the deep-sea. The surface pressure pattern, albeit a weak pressure gradient, remained more or less the same. Now the ridge was further to the east than before and resulted in a weak pressure gradient was over the eastern Gulf (figure 5.21). This gradient that was weak enough for an easterly to south-easterly land breeze to overcome the Shamal in the early hours of the morning.

5.6.3 NWP MODEL DATA

Although the Shamal brings cooler air from the north and, apart from low level moisture that evaporates into the air during its passage over the Gulf, it remains dry continental air. The NWP model prognostic time cross sections at Abu Dhabi on the 28th and the 29th correctly reflect the dry conditions that prevailed prior to the Shamal, as well as the increase and persistence in surface moisture after its onset on the 29th (figure 5.22). Comparison of these time cross-sections with those in the previous winter study (figures 5.2a and 5.2b) clearly show the different conditions, while, about 150 kilometres inland. At Al Ain, the air is even drier than at the coast (figure 5.23).

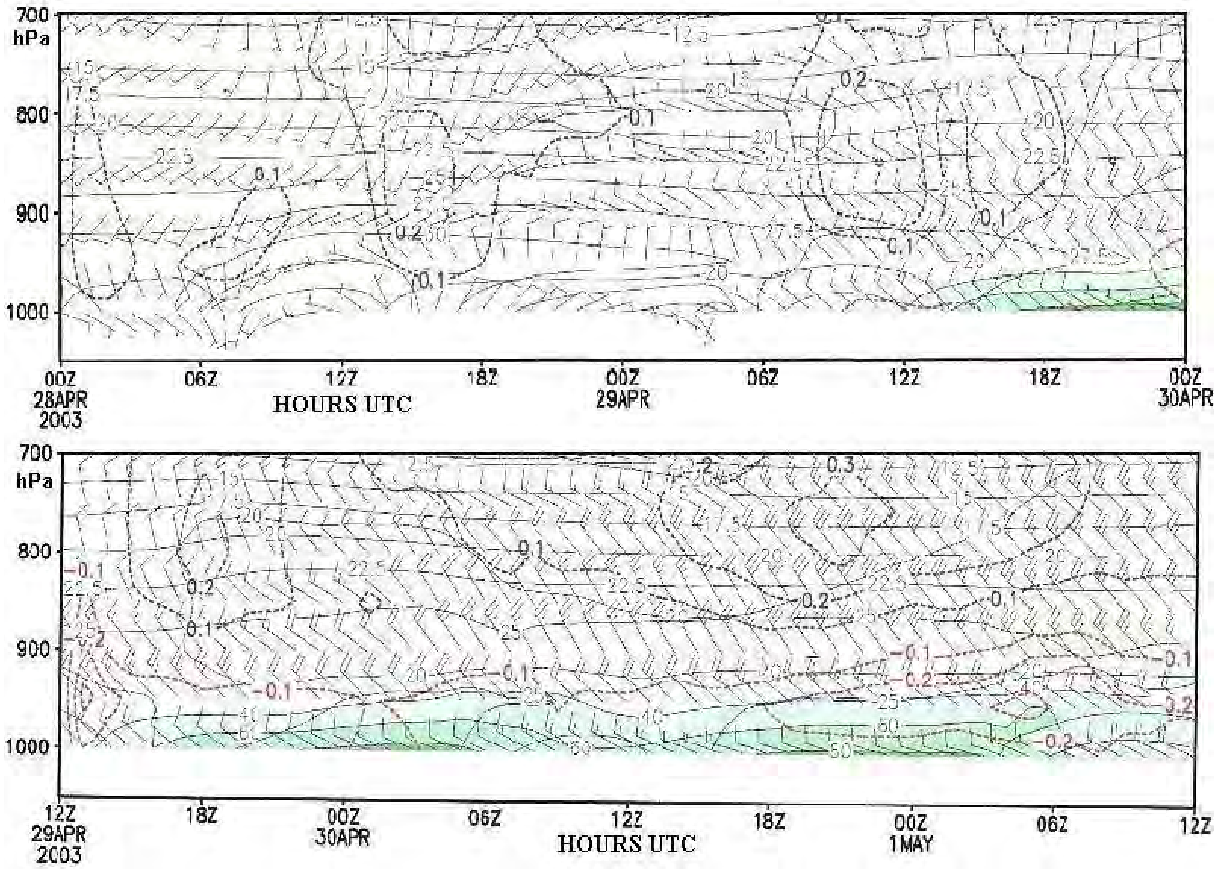

Figure 5.22. Time cross-sections of wind, dew point and vertical motion at ADIA from 2003-05-28 to 2003-05-01 extracted from Eta model runs. Notice the persistence and depth of the Shamal from the 29th, and dryness.

5.6.4 SURFACE OBSERVATIONS

As in winter months, the Shamal brings cooler and moister air from the Gulf Sea. However, due to the very high temperatures, there is not usually much relief from the heat and the increased surface moisture simply helps to make the weather even more humid and unbearable.

On the 28th, when the dry (pre-Shamal) southerly flow was dying, air temperatures reached into the low forties, while dew point temperatures were below 14°C and off the bottom of the chart (figure 5.24). Even though they increased during the afternoon sea breeze they still were not high enough to appear on the chart except at 1700 UTC at 16˚C.

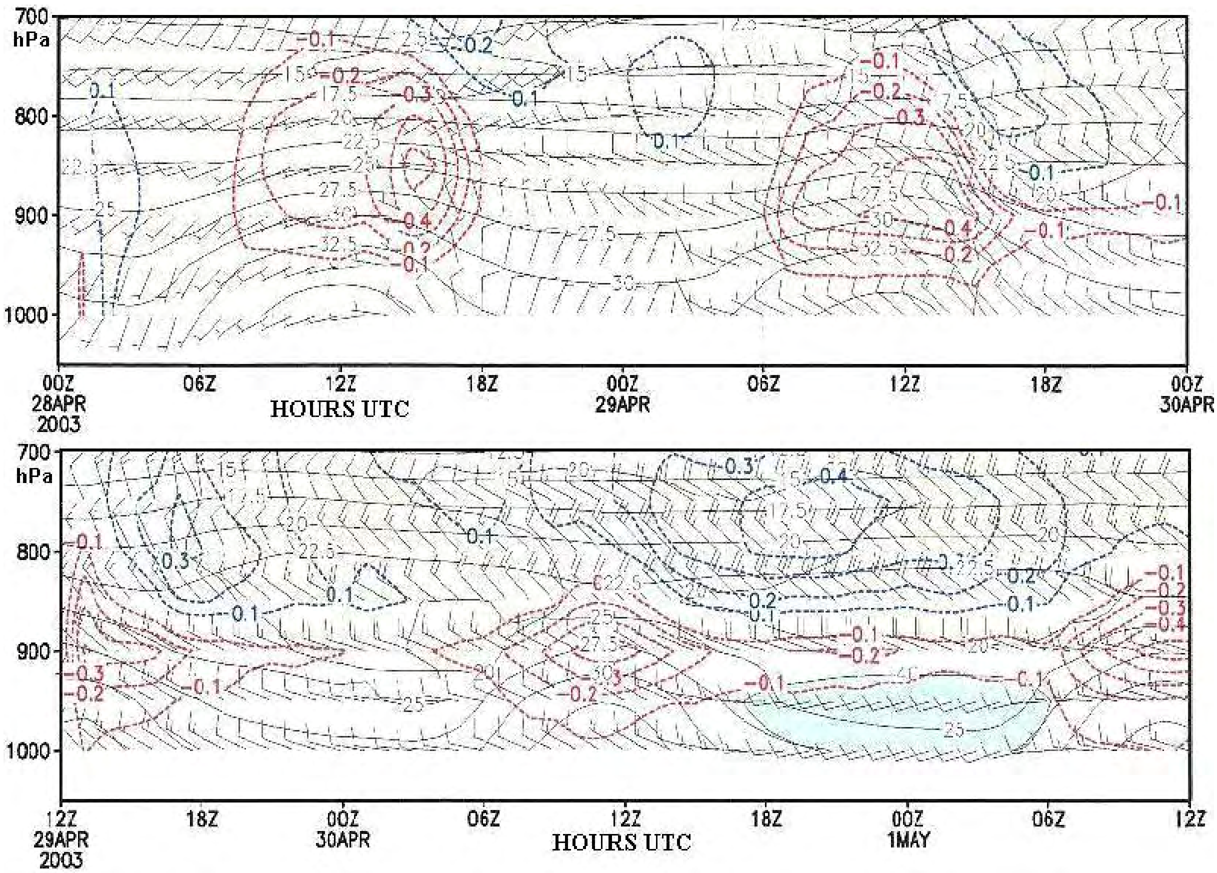

Figure 5.23. As figure 5.22, but at Al Ain for 2003-05-28 to 2003-05-01. Notice the even drier air at Al Ain than at ADIA.

The effect of the Shamal can be seen the following day (the 29th) when there was an immediate jump in the dew point temperature to about 20˚C, about 11°C lower day temperatures and hazy conditions that reduced the visibility to 8000 metres (figure 5.25). The temperature and dew point traces on the 30th and the 1st (figures 5.26 and 5.27) are almost carbon copies of each other. The difference being the wind which was strong enough on the 1st May to raise dust and reduce the visibility to 7000 metres even though the airport is only about 15 kilometres inland (figure 5.27).

Note the total absence of low level cloud that was so evident in the winter study, due to the hotter and drier continental air (Rao, et al 2003).

5.6.5 ATMOSPHERIC SOUNDINGS

Unfortunately, only the soundings at 0000 UTC on the 29th and the 30th at ADIA are available during this summer Shamal event (figure 5.28). Both soundings, the one immediately prior to the Shamal reaching the airport and the one during the Shamal, typify the summer atmospheric profile in that the air is very dry, apart from a shallow surface layer of moist air brought from the Gulf by the Shamal. A comparison of these soundings with those in the previous winter event (figures 5.18 and 5.19) clearly show the difference in moisture above the boundary layer.

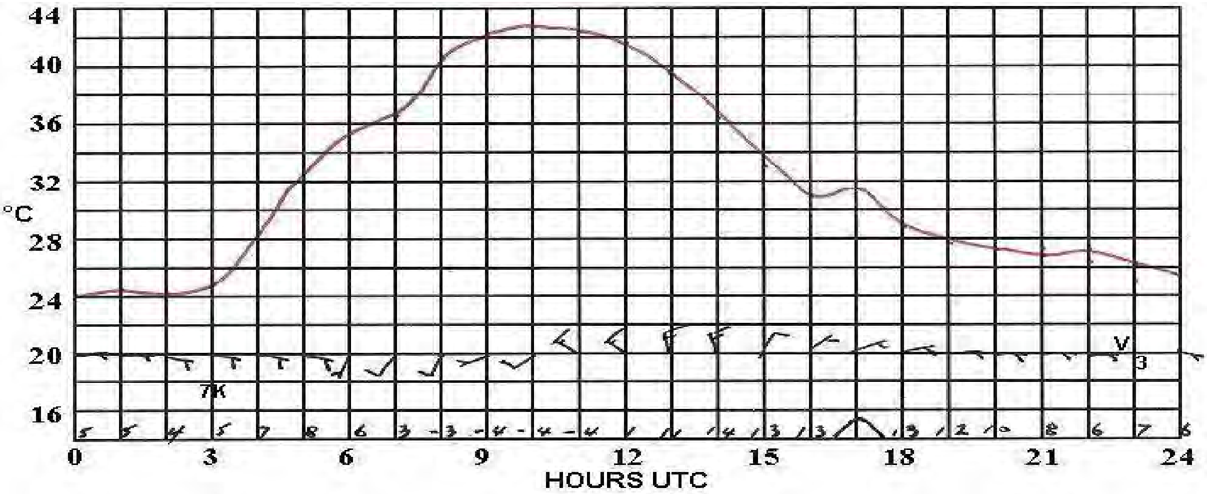

Figure 5.24. Surface observations on 2003-04-28. Air temperature (°C), red line; dew point temperature (°C) written at the bottom of the chart. Wind feathers in tens of knots.

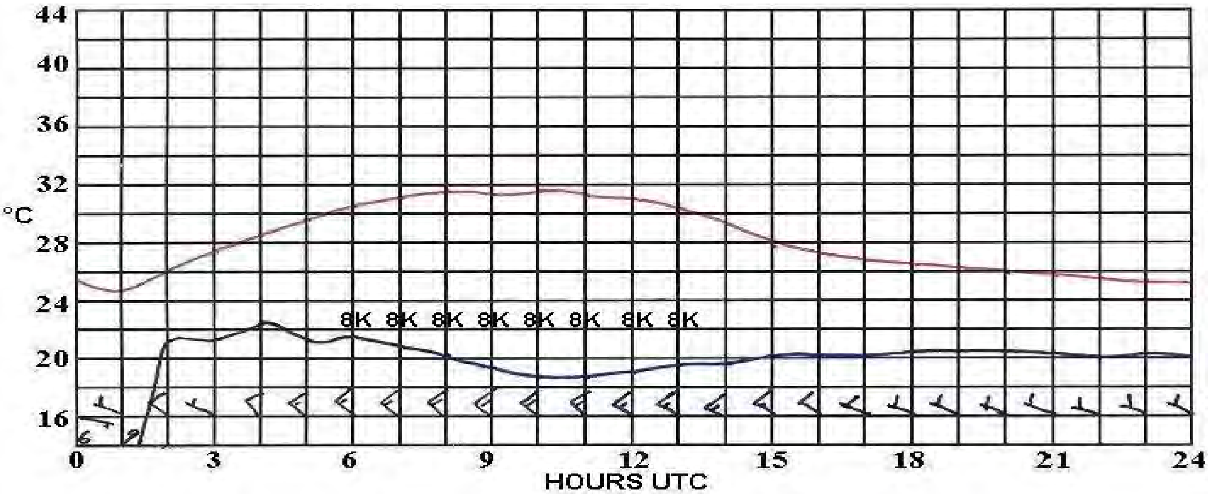

Figure 5.25. As figure 5.24, but for 2003-04-29. Dew point temperature (°C), blue line and visibility in kilometres.

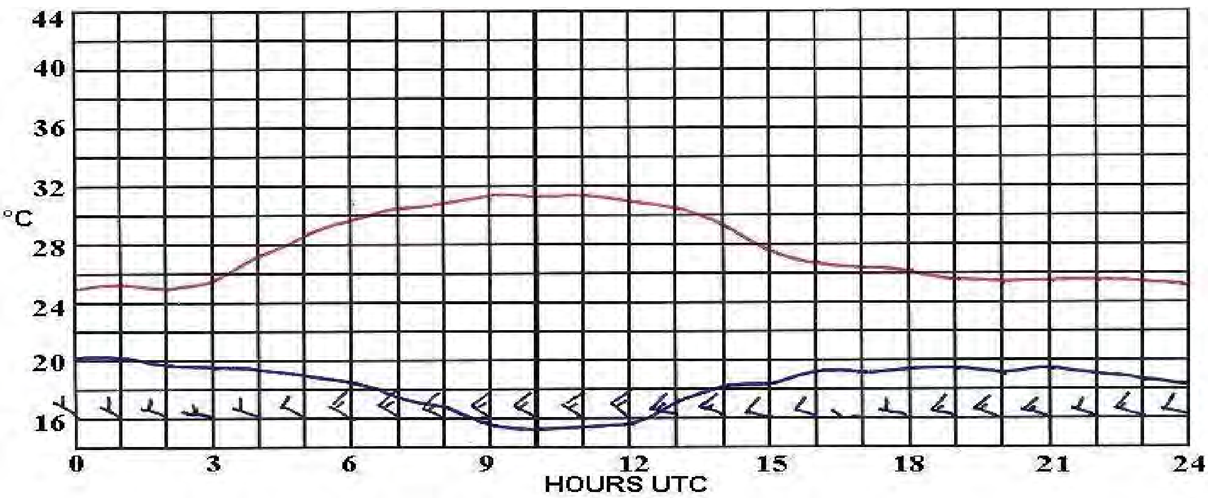

Figure 5.26. As figures 5.24 and 5.25, but for 2003-04-30.

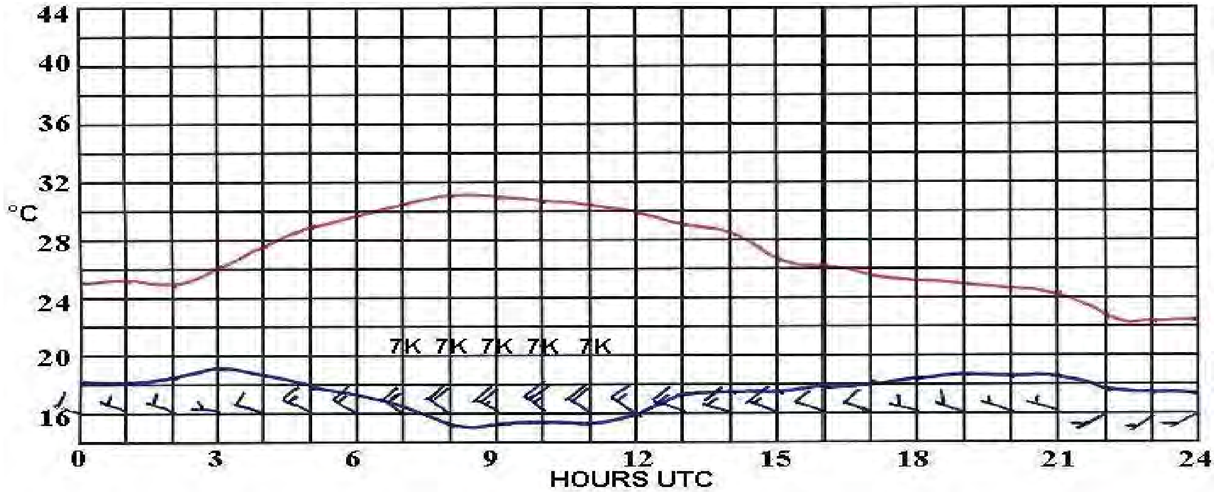

Figure 5.27. As figures 5.24 and 5.25, but for 2003-05-01.

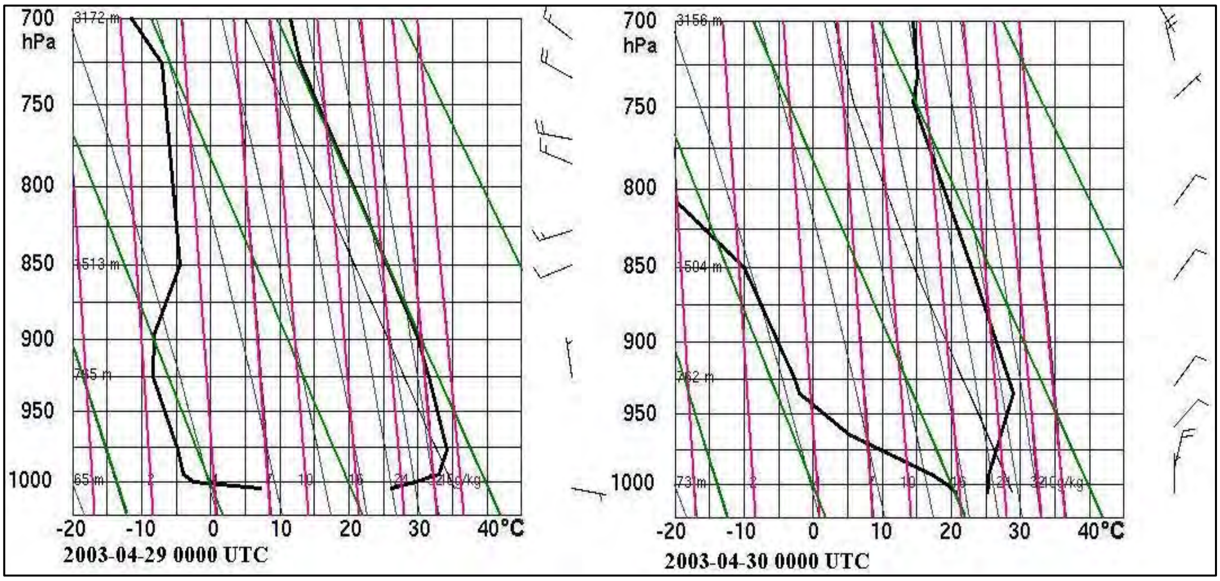

Figure 5.28. As figure 5.18, but for 2003-04-29 and 2003-04-30 (courtesy of the University of Wyoming).

5.7 DISCUSSION

An interesting aspect of the April/May 2003 event was that on the 3rd and 4th May the visibility deteriorated after the wind had abated, but while it was still from the north. The reason for this is that dust, which had been lifted by the northerly wind over Iran, was carried southward to the UAE. Visibility at the oilrigs over the south-western part of the Gulf deteriorated to 6000 to 7000 metres on the 2nd and by the 3rd it was down to 3000 metres at the oilrigs in the east and down to 2000 metres over the land. The following day the visibility was just as bad to start with, but it gradually improved during the day. The deterioration was worst over the eastern part of the UAE where the Gulf narrows to the Strait of Hormuz. In the west, the longer traverse across the sea meant less sand arrived over the western UAE and the visibility did not deteriorate to less than 6000 to 8000 metres.

Another peculiarity of the Shamal (and the sea breeze) is that the wind often blows stronger about 150 kilometres inland at Al Ain in the afternoon than at Abu Dhabi. The wind might blow north-westerly at 15 knots at ADIA, but at Al Ain it can reach and, at times, exceed 20 knots with wind gusts in excess of 30 knots between 0900 and 1300 UTC. Under these conditions sand is whipped up and the visibility can be reduced to 2000 to 3000 metres. Two possible reasons for this phenomenon are proposed. Firstly, the land surface at Al Ain is hotter than at the coast resulting in a near surface super adiabatic temperature lapse rate which in turn promotes convection (producing thermals) that initiates the sea breeze (Hsu 1988 and Riehl 1954) which in turn enhances the Shamal. Secondly solar radiation heating of the Hajar mountain western slope promotes an upslope anabatic wind (Riehl 1954) that will also contribute to the Shamal wind.

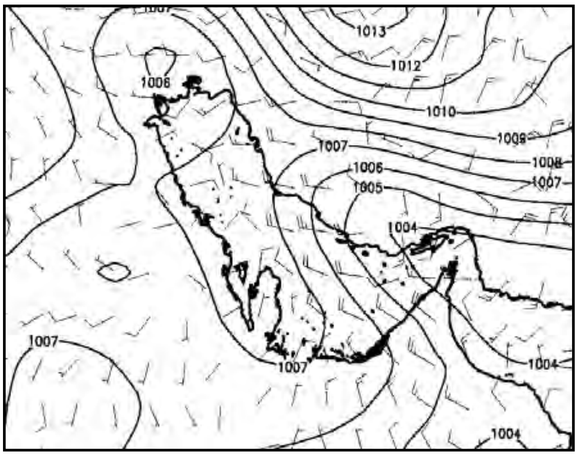

Figure 5.29. As figure 5.20, but for 2003-05-05 1200 UTC.

An example of this occurred during a Shamal on the 5th of May 2003 when a surface ridge the anticyclone over Qatar produced a 4 hPa pressure gradient across the Emirates (figure 5.29).

During intense daytime heating the unstable condition near the surface causes turbulent eddies that transport momentum to the surface. Air below the inversion becomes thoroughly mixed and the surface wind, enhanced by downward flux of momentum and limited only by friction, nears the free air wind speed about 1 km above the ground (Membery 1983). Consequently, the Shamal intensified during the day from about 5 knots before sunrise to an average of 15 knots from the north-north-west and reached 18 knots at its peak at ADIA during the afternoon from 1000 to 1200 UTC. However, at Al Ain, from shortly before 1000 UTC until 1400 UTC, the wind came from the north-west at 15 to 20 knots with wind gusts of up to 35 knots. The visibility was reduced to 4000 metres in blowing sand.

In table 5.2 it can be seen that the wind in the free air at ADIA was 25 to 30 knots at 1000 feet at 0000 UTC and 1200 UTC, respectively. This increase in the wind with altitude to a maximum low level jet at about 300 m, before tapering off up to 900 m, closely resembles the wind profile presented by Membery (1983) in a study of Shamal events at Bahrain during June and July in 1980 (figure 5.30).

Table 5.2. Low level winds at ADIA 5th May 2003.

metres	**0000 UTC**	**1200 UTC**
MSL	**° True/knots**	**°True/knots**
150	290°17	340°21
300	315°25	330°30
600	310°27	315°28
900	305°23	305°24

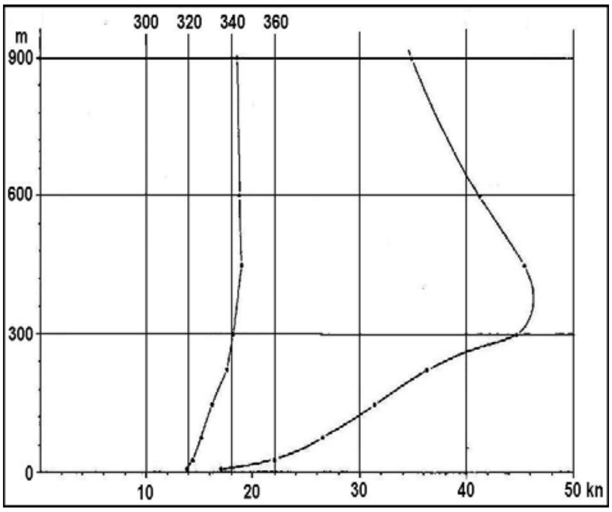

Figure 5.30. Boundary layer wind profile at Bahrain, June and July 1980 (Membery 1983).

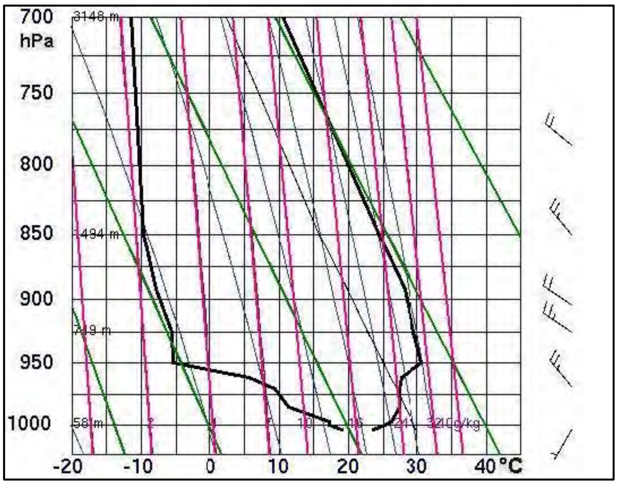

Figure 5.31. As figure 5.18, but for 2003-05-05 0000 (courtesy of Wyoming).

Unfortunately no 2003-05-05 1200 UTC atmospheric temperature sounding is available inland at Al Ain, but the atmospheric sounding at ADIA at 0000 UTC shows that the air was stable with a marked surface temperature inversion (figure 5.31), but with sufficient daytime heating the environmental lapse rate would be equal to, or exceed, the dry adiabatic and convection would promoted. The maximum temperature at ADIA during the afternoon was 36°C and at Al Ain 38°C. These temperatures are high enough for dry convection up to about 950 hPa (±460 metres MSL) at ADIA (and probably higher) and about 900 hPa (±900 metres MSL) at Al Ain. 900 metres being adequate depth of convection required to encourage sea breeze development (UKMO 1997).

The result was that, apart from the wind being retarded to some extent by surface friction over the land (Riehl 1954), it became stronger during the day approaching the free air speed at 300 metres at the top of the turbulent layer. The convection enhanced sea breeze plus the anabatic upslope wind against the Hajar Mountains contributed to make the wind stronger and gustier at Al Ain. This turbulent wind lifted sand from the desert floor and caused the poor visibility.

As ADIA is not more than about 15 kilometres from the coast, the onshore wind travelled a short distance over the desert sand before reaching the airport. The wind did not have enough time to lift the dust off the desert floor before reaching ADIA. For this reason the visibility remained better than at Al Ain. However, if the wind is strong enough, usually about 20 knots, or more, the visibility becomes drastically reduced at ADIA, irrespective of the stability of the atmosphere (see table 6.6 in chapter 6 on dust storms,).

In the NWP data section 5.5.2 in the winter case study, reference was made about fog not forming along the coast under Shamal conditions, but that this is not always valid inland. On the 24th December 2003 Shamal conditions developed during the afternoon and intensified the following day (figure 5.32). As usual the model indicated high surface moisture (95% relative humidity, or greater) along the coast at 0300 UTC (0700 local time) on the 25th, as well as inland, particularly toward the Liwa Oasis region and Empty Quarter (figure 5.33). Also as usual, fog did not form along the coast, but it did occur inland at Al Ain and Radoum (which is part of the Liwa Oasis).

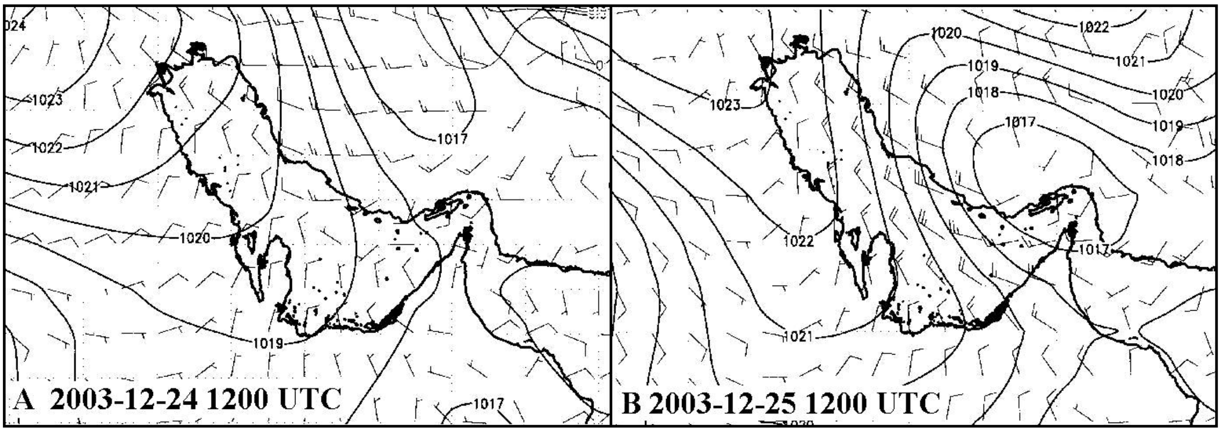

Figure 5.32. 1200 UTC Eta GFS surface pressure (hPa) and wind (knots) fields on the 24th and 25th December 2003.

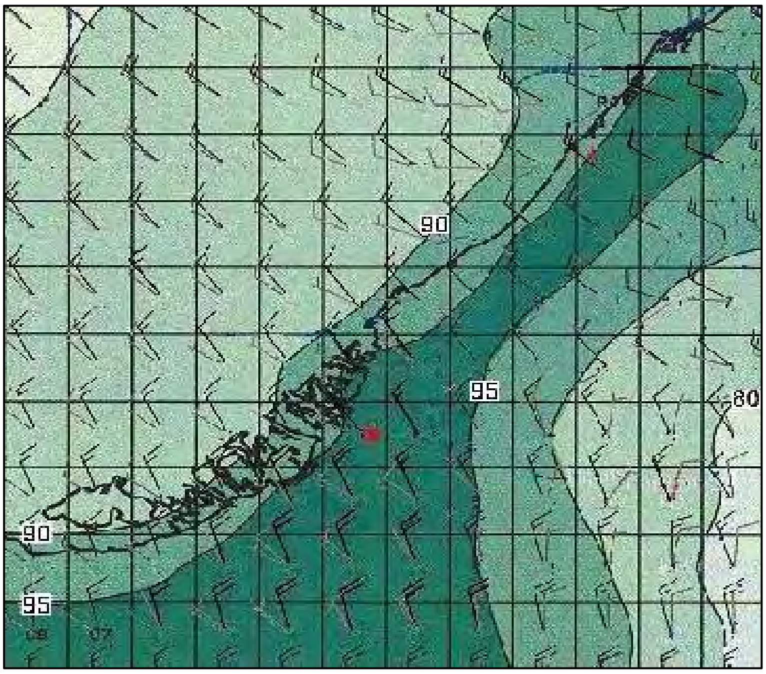

Figure 5.33. Eta model prognoses of surface relative humidity and wind (knots) at 10 metres (black) and 950 hPa (grey) with downward vertical motion (blue lines) for 2003-12-25 0300 UTC.

The fog began to form at Al Ain in a light north-westerly wind between 1930 UTC and 2000 UTC (2330 to 2400 UAE local time). The visibility remained below 1000 metres until 0200 UTC (06:00 local time) and being down to 100 metres for about 2 hours. Observations at Radoum are not received during the night, the first observation being the one at 0300 UTC when fog was reported with a light north-westerly wind and 800 metres visibility.

As a matter of interest, during his first crossing of the Empty Quarter, Thesiger (1994), in the Liwa area at Bir Balagh, noted that the camp was enveloped in thick mist in the morning (±15th 16th December 1946) and that "the cloak which had covered my sleeping-bag was drenched. Each night for the past week we had had this soaking dew, the result of the northerly winds which carried the moisture inland from the Persian Gulf."

5.8 SUMMARY

The Shamal at ADIA is markedly more prevalent during the spring and summer months especially from May to July. Diurnally it blows the strongest during the afternoon and evening from 1300 to 1900 local time (0900 to 1500 UTC) and is at its lightest overnight.

Markedly lower temperatures are experienced after the Shamal begins, although in summer it brings little in the way of relief from the very hot and humid weather. Apart from shallow surface moisture the air aloft remains very dry in summer. This is in contrast to the winter months when the air is moister, a contrast that is clearly anticipated by the NWP models.

The Shamal is most likely when a surface anticyclone approaches from the west and/or deepening of the surface low over Iran. The NWP models give ample warning of the beginning and duration of the Shamal events with a good indication of the pressure gradients and wind velocities to be expected across the Gulf.

Typically a ≥ 5 hPa pressure gradient across the UAE produces wind speeds >20 knots and a wind of 20 to 25 knots over the sea quickly decreases to about 10 to 15 knots when it crosses the coast. A pressure gradient of this strength is strong enough to maintain a north-westerly to west-north-westerly wind during the night. Although, more often than not the wind tends to back to south-westerly and become lighter, due to the influence of the overnight land breeze effect. When this happens, a low level jet of stronger winds up to 30 knots to 40 knots at about 300 metres (1000 feet) MSL can develop with attendant wind shear. The NWP model is not inclined to identify the backing of the wind and usually incorrectly maintains a north-westerly wind throughout the night.

The wind can be stronger and gustier inland at Al Ain in the afternoon than at ADIA. It is suggested that this is due to the hotter conditions inland with increased instability producing stronger thermals and a stronger sea breeze as well as an anabatic effect associated with the Hajar Mountains to the east of Al Ain. Both help to overcome the retarding friction effect of the land as the air moves inland from the sea and produce a strong and gusty wind that lifts sand and reduces the visibility.

Under strong Shamal conditions the wind can carry dust from further afield, such as from Iran, resulting in poor visibility over the Gulf and the UAE. During the summer event discussed in this chapter the visibility was worst over the eastern Gulf Sea and the eastern part of the UAE where there was a shorter sea traverse and less time for the sand to fall out of the atmosphere before reaching the islands and oilrigs offshore and the UAE coast. This resulted in the visibility decreasing to 2000 to 3000 metres in the east as opposed to 6000 to 7000 metres in the west. Dust carried by the Shamal is also discussed in the chapter on dust and sand storms.

Strong winds and very rough seas hamper helicopter operations to the oil rigs. The wind is strongest with the biggest waves over the western part of the Gulf where there is a longer fetch and no protection from the land to the north in Iran. Wind waves quickly build up to 2 to 3 m with wind speeds of 20 to 25 knots and readily reach 4 m at times such as during the winter Shamal of the 13th to 19th November 2003 when the wind speed was 20 to 30 knots. A lighter wind with a smaller wind waves occur in the lee of the Iranian coast in the eastern Gulf Sea.

Low cloud associated with the Shamal forms as a result of turbulent mixing of the maritime air beneath a temperature inversion that varies from about 900 metres to 1200 metres above the surface. In the winter months it is routine for scattered to broken stratocumulus to occur at ADIA. The percentage likelihood of cloud is over 90% during December and January and decreases to less than 15% in the summer months. This can be attributed to mechanical turbulence being strong enough to raise moisture to the lifted condensation level in the cooler winter conditions, but during the much hotter summer months, in spite of the more humid surface conditions, drier air entrainment above prevents condensation from taking place.

Although there is an accumulation of surface moisture inland from the coast, marked turbulent mixing near the surface prevents fog from occurring at Abu Dhabi during Shamal conditions. There is less certainty whether this is also valid further inland when the Shamal drops sufficiently overnight, as there is sufficient reason to believe that further inland toward the Liwa Oasis and the Empty Quarter fog occurs more often than is reported.

5.9 FORECAST CHECKLIST

The Eta NWP model post processing products give ample evidence to identify Shamal winds. Of particular use to identify Shamal conditions are the Eta model surface wind and pressure patterns and pressure gradient and the GRADS surface time cross sections at ADIA and Al Ain.

Important considerations when forecasting a Shamal are:

- Wind speed ≥ 17 knots.
- ≥ 5 hPa pressure gradient across the UAE.
- A surface low, or trough, passing to the east.
- A surface anticyclone approaching from the west and/or deepening of the surface low over Iran.
- Friction effect. 20 - 25 knots over the sea decelerates to 10 - 15 knots when it crosses the coast
- The Eta model does not always identify backing of the wind to south-westerly overnight.
- Wind shear. A 30 – 40 knot low level jet ± 300 metres (1000 feet) MSL can develop during the night.
- Poor visibility. A strong Shamal can carry dust from far away in Saudi Arabia and Iran. See the chapter on dust storms.