Southwest Asian Dust Storm of 25-27 March 2003

By
Richard H. Grumm
National Weather Service
State College Pennsylvania
Draft V_1.0

1. Introduction

On Tuesday, 25 March a strong dust storm limited visibility and in all likelihood reduced military activity over Iraq. This dust storm was relatively well forecast and has been referred to as a ***Shamal.*** It is unclear whether this event would truly classify as a Shamal as this term is often used to speak about a 40-day low intensity dust event in the Persian Gulf region. A ***Shamal*** is defined as "a summer northwesterly wind blowing over Iraq and the Persian Gulf often strong during the day but decreasing during the night." This definition appears linked to heat lows and the intensity of a low-level inversion modulating the winds in the boundary layer. Other, less strict, definitions suggest that the Shamal is a wind and dust storm. They begin in the spring, often defined to begin in February and are at peak intensity during the spring. A key feature with the more intense spring Shamal is an intense low-level jet (LLJ), the interaction with the subtropical jet, and a surface cyclone moving through the region. The longer duration events, which tend to be weaker, appear to be more thermally driven. The event of 25-27 March 2003 clearly met the loser definition of a ***Shamal.***

Forecasting a strong dust storm requires knowledge of the strength of the LLJ. It will be shown that the Shamal of 25-27 March 2003 was associated with a very anomalous surface cyclone that tracked across northern Iraq. The 500 hPa heights and mean sea level pressure fields were on the order of 2-5 standard deviations below seasonal norms. This

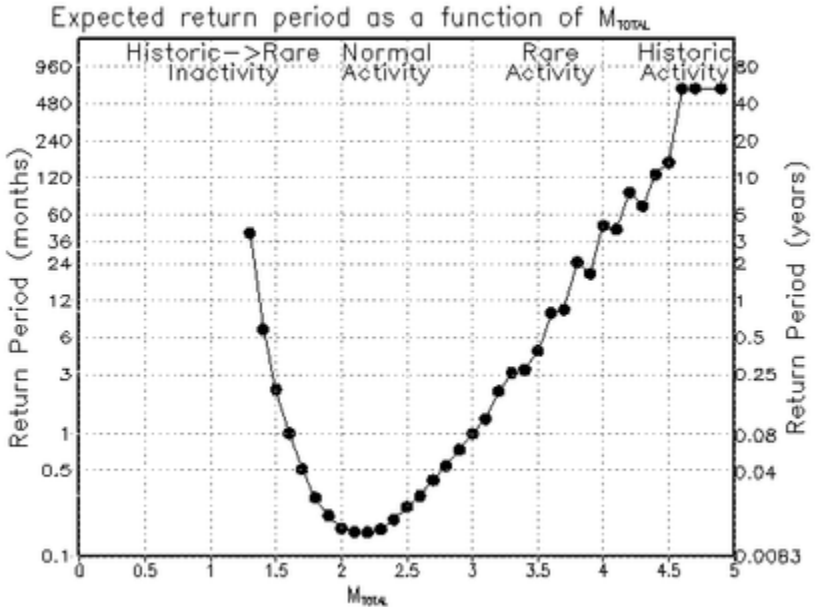


Figure 1. Integrated total anomaly or MTOTAL in standard deviations from normal of vertically integrated winds, moisture, temperature, and height anomalies over eastern North America and the adjacent western Altantic.

was a storm of record proportion and was more than likely at least a once in a decade type of event. Based on the work of Hart and Grumm (2001) and Grumm and Hart (2001), the return period of total anomalies (MTOTALs) is shown in Figure 1. These data show that large storm systems with MTOTAL of 4 or larger are rare events occurring with frequencies on the order of once per year. Large MTOTALS, on the order of 4.5 or more are typically associated with historic weather events. For some perspective on this, the so-called superstorm of March 1993 (Kocin et al 1995) had an MTOTAL of 4.576 and was the third largest MTOTAL over the eastern United States. The 500 hPa height anomaly with this storm was on the order of 5.1 standard deviations (SDs) below normal; about what the National Centers for Environmental Predictions (NCEPS) Global Forecast System (GFS) forecast the 500 hPa low to be as it crossed northern Iraq. Unfortunately no comparable MTOTAL climate exists for that region. However, the standardized anomaly data set (Hart and Grumm 2001) extends over the entire northern hemisphere and allows the anomalies associated with this storm to be evaluated. Clearly, it was a very intense and every anomalous storm.

It will be shown that overall; the NCEP GFS forecast this anomalous storm quite well several days in advance. The 850 hPa winds and wind anomalies were excellent forecast tools to identify how strong the low level jet would be. The NCEP Medium Range Forecast Ensemble System (MREF) provided useful guidance as to potential storm and its potential severerity.

This paper will examine the performance of the NCEP GFS and MREF systems in forecasting the Dust Storms over southwest Asia (SWA) on 25-27 March 2003. It will be shown that this dust storm and its unusual severity could have been anticipated by the strength of the anomalous storm associated with the equally anomalous low-level jet. All forecast data indicated that this was not going to be just another dust storm.

2. Method

All MREF and GFS data were archived in near-real time at the joint PSU-NWS website during the event. This is part of the normal data flow.

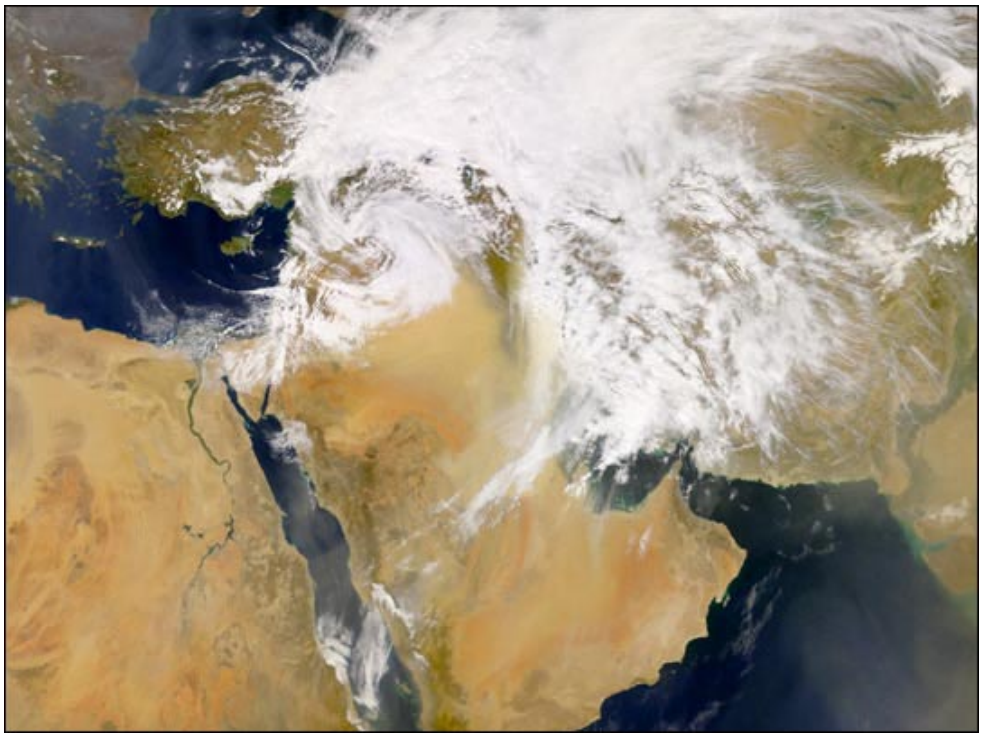


Figure 2 NOAA MODIS image from 26 March showing the deep cyclone over the northern Arabian peninsula and the dust over Iraq and much of SWA. From the website at http://earthobservatory.nasa.gov/NaturalHazards/. Data was collect between 0830 and 1000 UTC 26 March 2003.

The Climatic anomalies database is maintained on the same network and was developed as describe in Hart and Grumm (2001). The dataset contains centered means and standard deviations at standard pressure levels of heights (H), winds (u and v components), and moisture (q). Additional data contains the mean-sea level pressure (MSLP) database. Derived data include a shear and precipitible water climatology. MTOTAL are based on the vertically integration of the pressure level data (H, U, V and q) moisture. NTOTAL would refer to the integration of a single variables total departure in the vertical. All anomalies at a specified level and or for a specified parameter are expressed as standard deviations (SDS) above or below normal.

Operational use of climatic anomalies has revealed that big weather events in the eastern United States are often associated with anomalies of critical fields at individual levels on the order of +/- 3SDs from normal. See Grumm and Hart (2001) for results related to snowstorms. Severe weather examples can be found following the links to the severe weather event of **28 April 2002** and the largest US Severe weather outbreak of **10-11 November 2002.** The interface off of http://nws-sc.met.psu.edu/ has an accessible list of cases.

3. Results

a) overview

The dust storms that struck SWA and of particular interest, Iraq on 25-27 March 2003 became rapidly well known due to

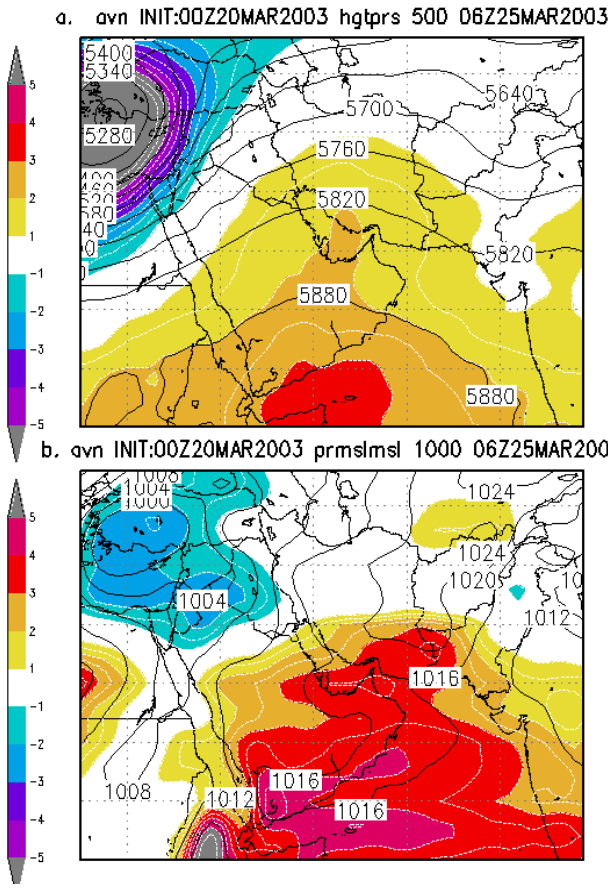


Figure 3 GFS 500 hPa heights (m) and MSLP (hPa) forecasts initialized 0000 UTC 20 March valid at 0600 UTC 25 March 2003. MSLP contours every 4 hPa and heights every 60 m. Shading shows departures standard deviations from the 30-year climatology. Light dashed lines show intermediate 0.5 SD anomaly contours.

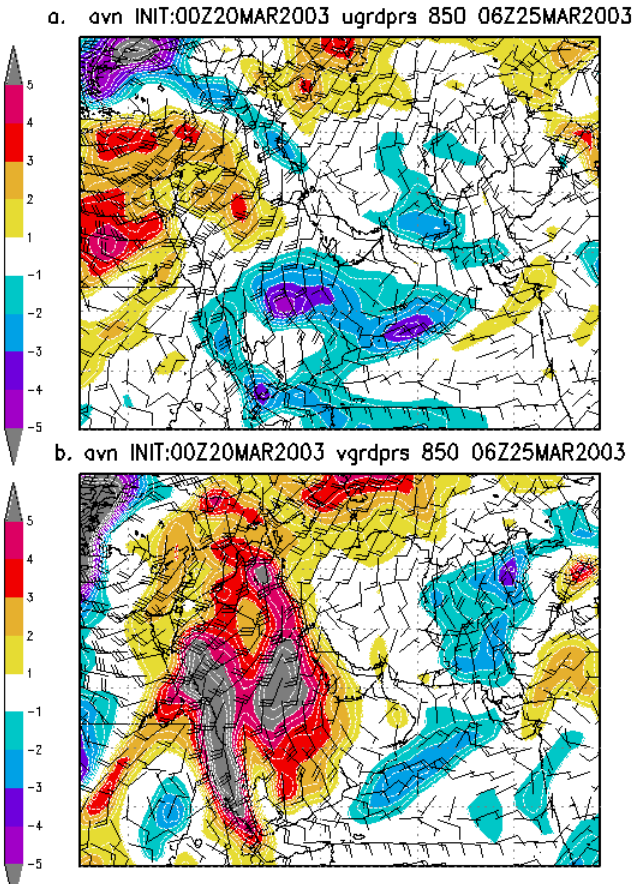


Figure As in Figure 3 except 850 hPa U (upper) and V (lower) winds and anomalies.

the media coverage of the War on Iraq. Television cameras showed night like conditions in the afternoon as iron colored dust obscured the horizon and reduced visibility dramatically. Photo grammatically; this may be the single best documented dust storm in history. The Air Force Weather Agency provided an after the fact description and satellite image to verify how intense this event was (see **Appendix I** for more information).

The MODIS image in Figure 2 clearly shows the strong cyclone passing to the north and the resulting dust storm south and east of the vigorous surface cyclone. No surface observations were available however; media camera data suggested extremely low visibilities ranging from a few feet to a kilometer at times.

Historically, sandstorms have played a role in the Middle East. In the Battle of Badr around the 7th century AD, Mohammed defeated the superior forces of the Meccan chiefs by taking advantage of a sandstorm. The large Meccan forces were defeated, firmly establishing Mohammed. (adopted from J.M Fritsch). Fortunately, this dust storm did not turn the tide of the war and was more an inconvenience.

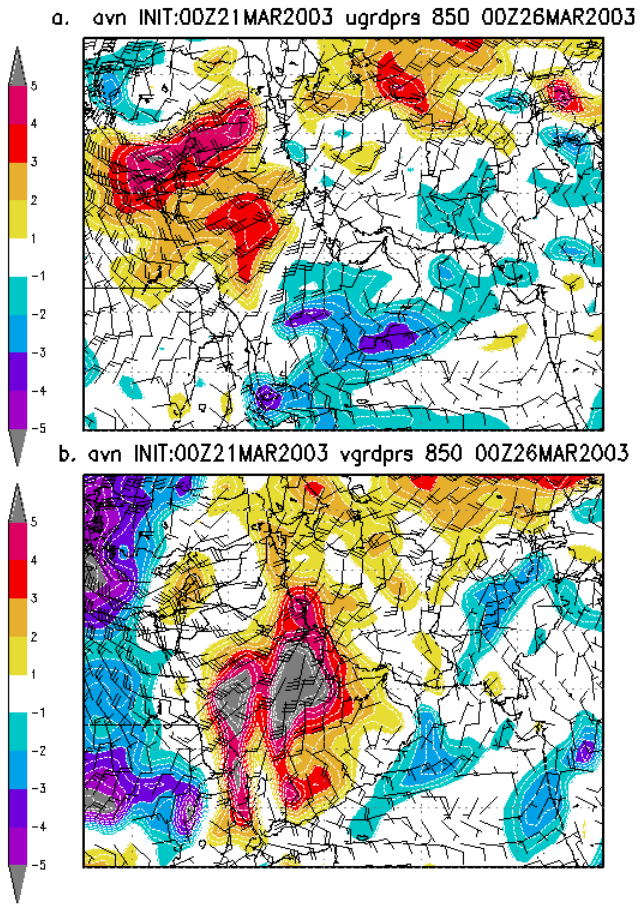


Figure 4 As in Figure 4 except initialized at 0000 UTC 21 March and Valid at 0000 UTC 26 March 2003.

b) GFS Forecasts

The GFS forecast initialized at 0000 UTC 20 March 2003 valid at 0600 UTC 25 March 2003 is shown in Figure 3. The 5280 m 500 hPa low near Greece was forecast to be on the order of -6SD below the 30-year normal. The MSLP forecast showed a surface cyclone on the order of -2.5SDs below normal. To compound the situation, anomalously high heights and pressures were located along the southern Arabian Peninsula.

The strong gradient produced 850 hPa southerly winds on the order of +5SDs above normal in the region of interest. The strongest and most anomalous easterly winds were well north of the surface and 850 hPa cyclone. The large area of anomalous 850 hPa southwesterly winds over the Arabian Peninsula was quite impressive. The GFS was forecasting a strongly synoptic scale event at 5 days in length. Forecasts initialized at 1200 UTC 20 March showed a 996 hPa low over southern Iraq which represented about a -3.5 SD pressure anomaly in the region (not shown).

GFS forecasts from the 21st continued to show the trend for this very strong system to move through the region. For brevity, only the 850 hPa winds are shown from the 0000 UTC 21 March GFS. These data are valid at 0000 UTC 26 March to show the shift of the southwesterlies to the east and influx of anomalous westerlies moving into the region (Fig. 5). Although difficult to see, the intermediate anomaly contours show that the 850 hPa southerly wind anomalies were on the order of +6 to +6.5SDs above normal. The color scale was never designed for such large anomalies. The surge of anomalous westerlies into the region were on the order of +4.5SDs above normal.

Shorter range forecasts from 0000 UTC on 24 March valid at 1200 UTC 25 March show the continued presence of an extremely anomalous system. A large are of +5.5SD southerlies were forecast over much of Saudi Arabia with a tongue of +4SD anomalies moving up the Tigris-Euphrates valley. An anomalous westerly jet was present to the northwest, with winds of 55 kts and anomaly of +5SD above normal. This region of the world is well mixed in late

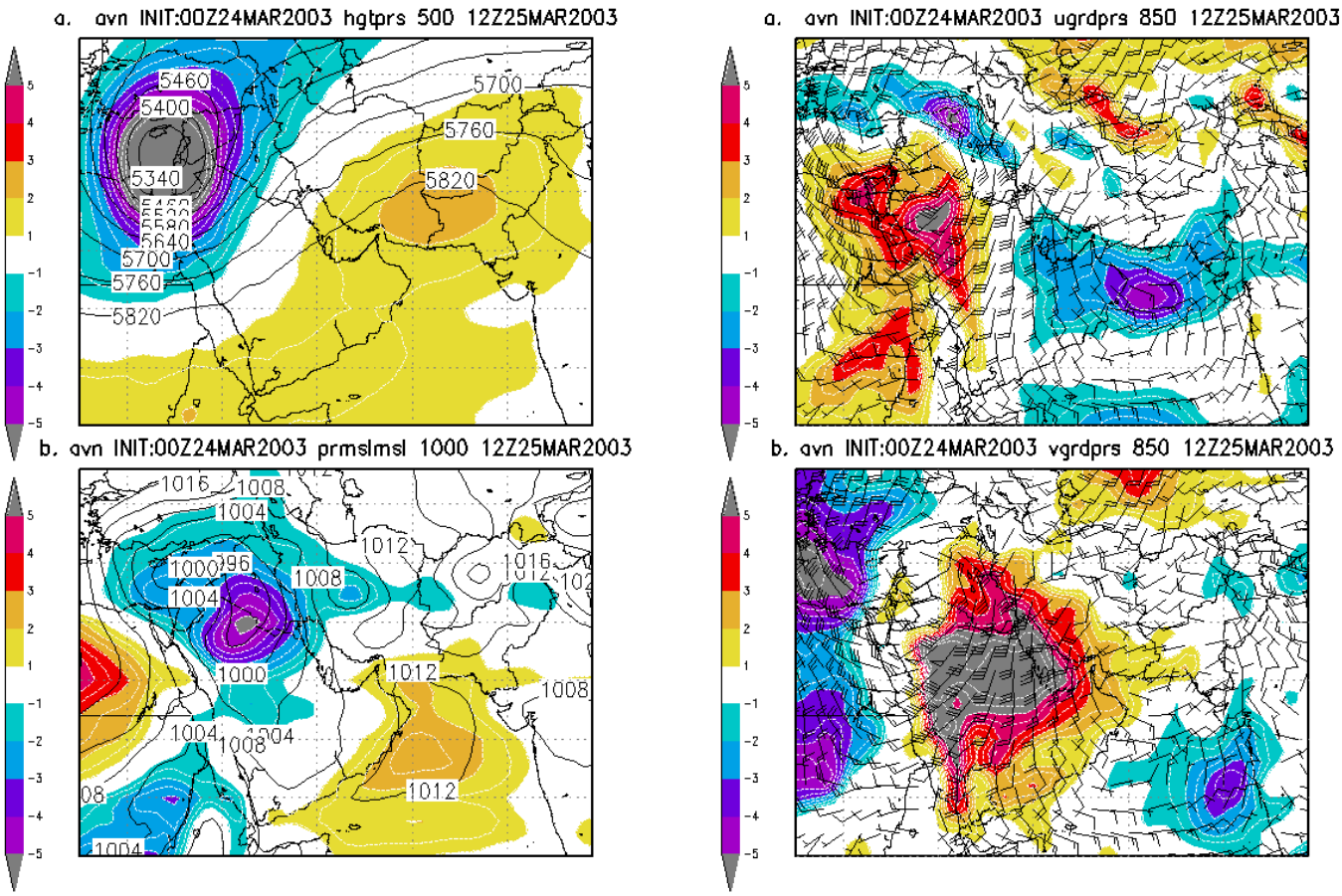


Figure 5 As in Figure 5 except GFS intialized at 0000 UTC 24 March 2003 showing (left) 500 hPa and MSLP and (left) 850 hPa winds.

March and these 850 hPa winds would easily mix to the surface. Similar wind anomalies were present, although with stronger absolute wind speeds at 700 hPa. Mixing between 850 and 700 hPa would imply wind gusts in the 70kt range were likely (700 hPa winds not shown). Forecasts of the surface cyclone trended toward a deeper cyclone, on the order of -5SDs below normal. The 500 hPa low was forecast farther south. The large ridge to the ahead of the system contributed to the large pressure and height gradients and the subsequently large wind anomalies.

c) MREF forecasts

Unlike the single GFS forecasts, the MREF forecasts show a blend of several (as many as 12) NCEP GFS model runs for the event. When available, the operational GFS and control run of the MREF system are used in the ensembles. Then coarser model run using 5 positive and 5 negative perturbations are used. These data are posted on a coarser grids. A weighting system is used to ensure that the operational model and control run provide a higher impact in the system. The details of the individual models is not likely too important and the higher resolution GFS can be used to access a single models strength of the solution. Consensus forecasts provide a

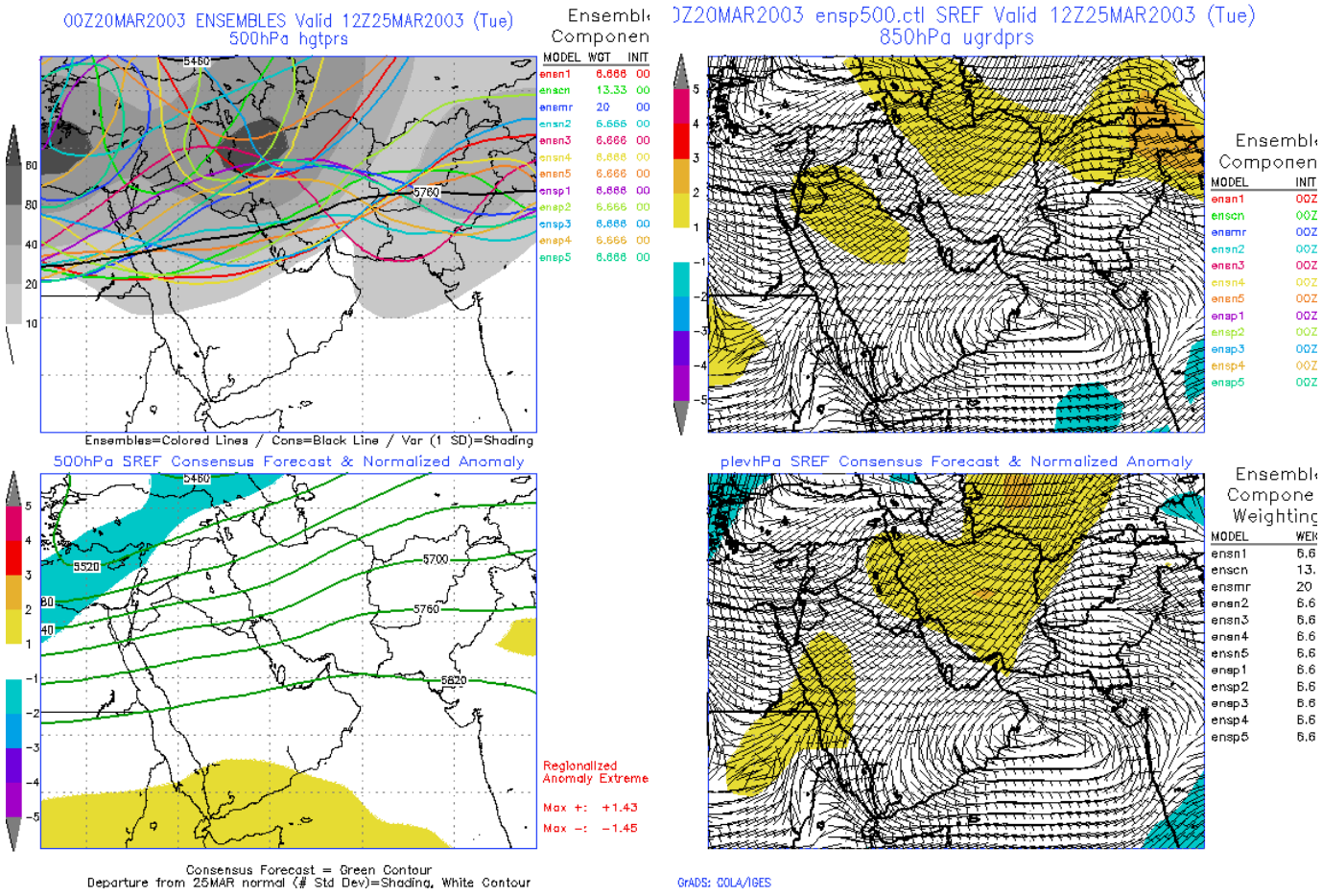


Figure 6 MREF forecasts of 500 hPa heights and 850 hPa winds. Upper panel for heights shows 5460 and 5760 m contours from each member, the consensus forecast, and the dispersion about the consensus forecast. The lower panel shows the consensus forecast and the departure of this field from the 30-year climatology. The winds show the consensus winds and the departures from the 30-year climatology.

good mid-ground forecast solution, not necessarily the most likely outcome.

The 500 hPa height and 850 hPa wind forecasts from the MREF initialized at 0000 UTC 20 March 2003, valid at 1200 UTC 25 March is shown in Figure 7. The 500 hPa spaghetti plot (upper left) showed there was large disagreement with the speed of the upper-level trough moving through the region. This resulted in the bimodal 60 m dispersion areas, one over Iran and the over near western Turkey. The timing difference likely smoothed out the consensus forecast in the lower panel, but despite this, the forecasts called for a 1SD below normal trough in the area of interest.

This timing error also produced a more rapid, than observed, exit of the anomalous southerlies into Iran and stronger westerlies into north Saudi Arabia. Though difficult to see, the dark blue spaghetti in the upper right panel from the operational GFS showed a closed 5460m contour over the eastern Mediterranean.

Forecasts initialized at 0000 UTC 21 March showed a similar timing error with large areas of variation about the

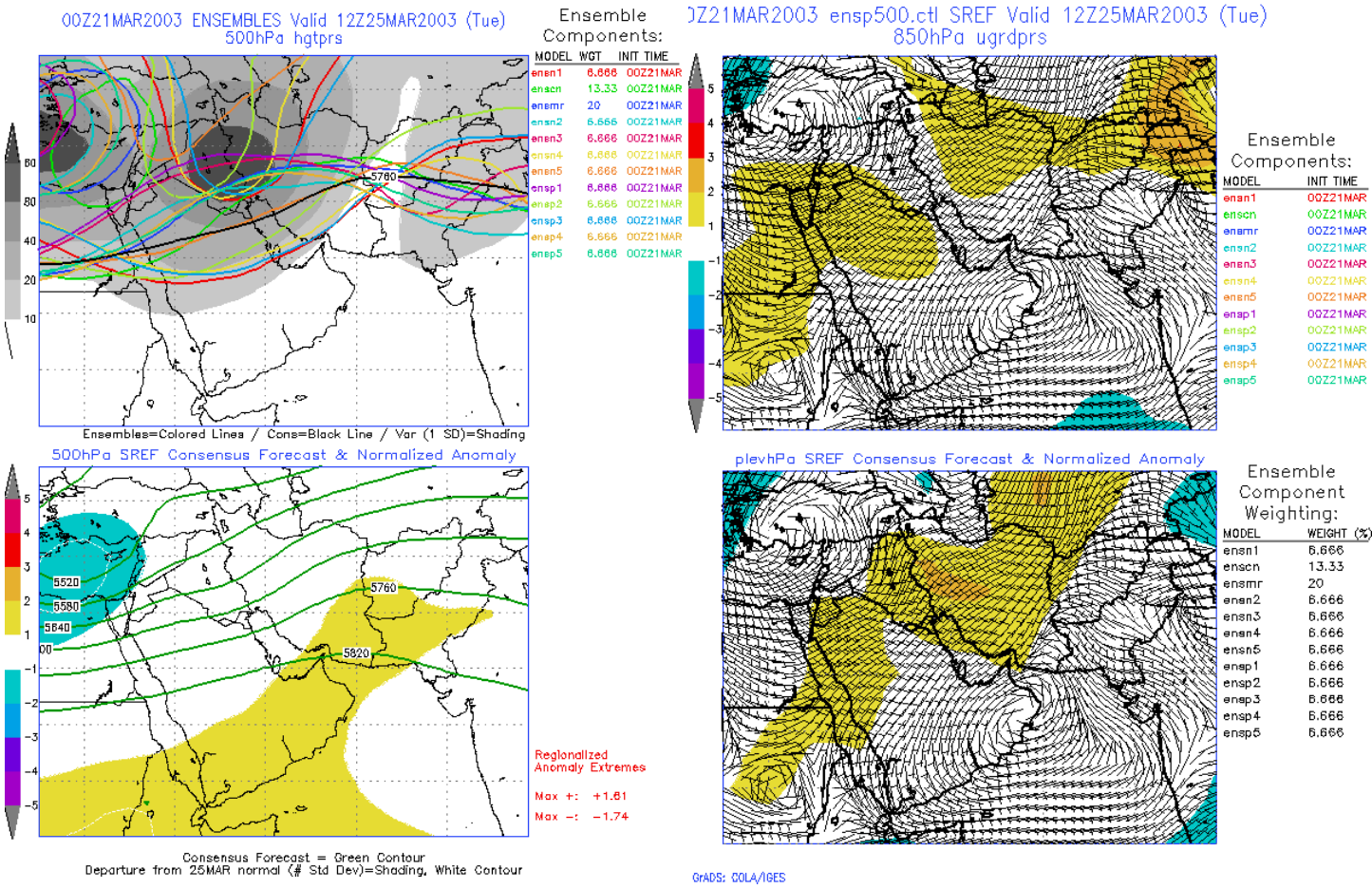


Figure 8 As in Figure 7 except initialized at 0000 UTC 21 March 2003.

mean over Iraq. The consensus 500 hPa height field showed a more anomalous 500 hPa low center over the eastern Mediterranean on the order of -1.74 SDS below normal. Wind anomalies on the order of 2SDS above normal were confined to Iran with a broader area of +1SD 850 hPa wind anomalies over most of SWA.

The forecasts from 0000 UTC 23 March 2003 showed more agreement and convergence on a deeper 500 hPa low in the eastern Mediterranean, on the order of -2.48SDS below the 30-year climatological mean values. The winds were also forecast to be much stronger over the region with wind anomalies on the order of +2 to +3 SDS above normal in the southerlies over Iraq.

In addition to the winds and deep upper level trough, the MREF was also forecasting a high probability of precipitation over the region. The probability of 0.20 inches of QPF for the 24 hour period ending 1200 UTC 26 March 2003 is shown in Figure 10. These data show a relatively high chance of at least 0.20 inches of QPF and over a 90% chance in the northeastern portion of the country. Consensus 850 hPa temperature forecasts (not shown) were on the order of +2C, thus with the exception of higher terrain, the precipitation would have been rain. The

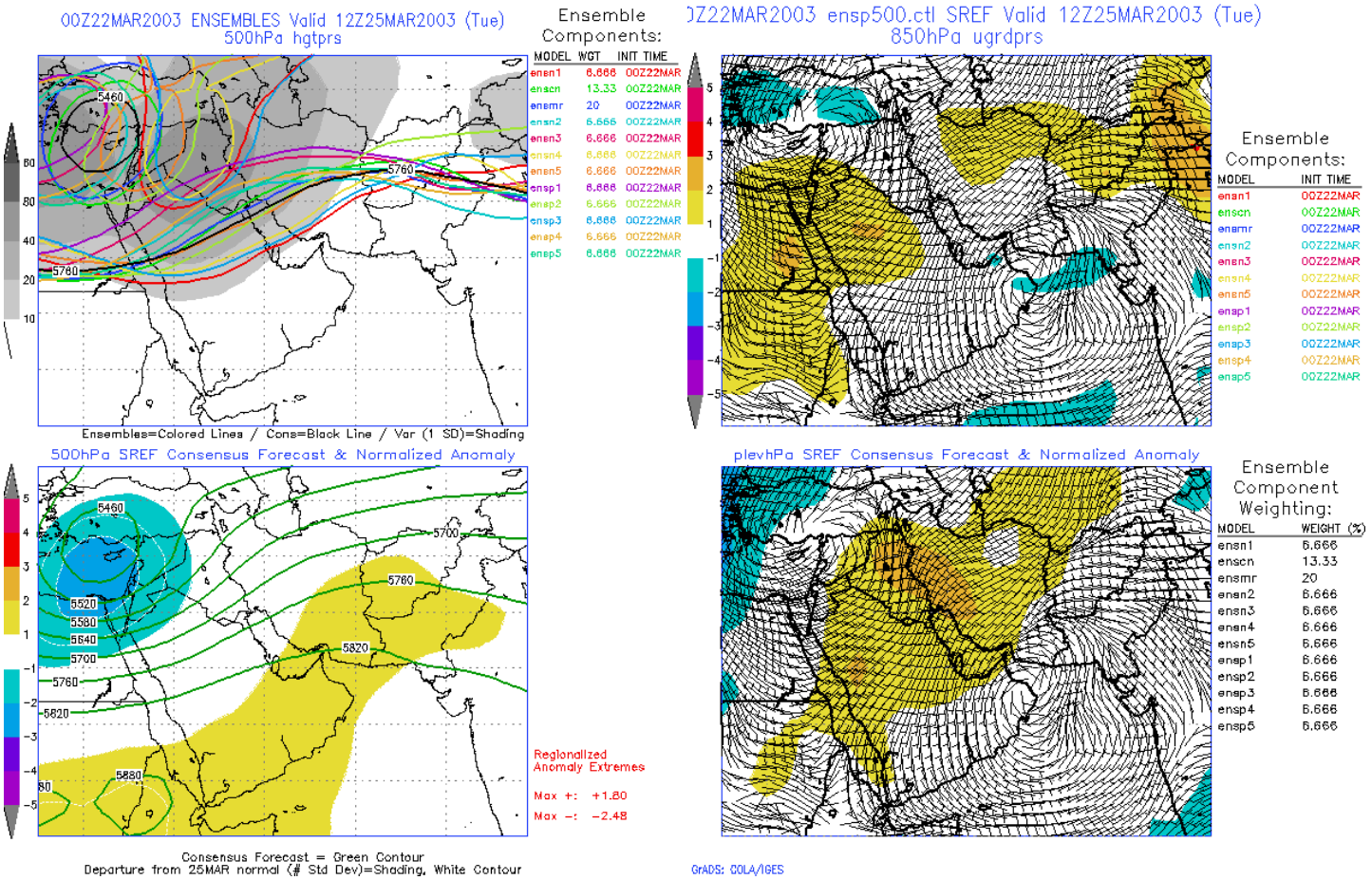


Figure 9. As in Figure 8 exept initialized at 0000 UTC 22 March 2003.

850 and 700 hPa temperatures were also forecast to be on the order of -1SD below normal (not shown).

4. Discussion

An anomalously strong surface cyclone and accompanying upper level trough swept across SWA on the 25-27 of March 2003. This system, combined with an above normal ridge to the southeast produced anomalously strong low-level southwesterly winds over SWA. These winds resulted in a massive dust storm which impacted many aspects of the war with Iraq. Meteorologically, many parameters, such as the MSLP, heights, and winds were very anomalous with this system and these anomalies were well forecast by the NCEP GFS. The MREF did not perform as well due to model divergence.

The GFS forecasts foretold the potential from very anomalous conditions at least 5 days in advance of this event. The 500 hP height anomalies, on the order of -5SDS below normal were rather impressive and suggested, based on experiences with anomalies as a forecast tool in the United States, of a storm of near historic proportions. No data is available with which to gage this storm to other recent dust storms. There was a report of a large dust storm on 26 February 1991 during operation Desert Storm which will be examined for comparison purposes. Various websites

suggest there were dust storms, of lesser magnitude on 7 and 13 March 2003 and 20 February 2003. The conditions associated with these storms has not been examined.

The MREF forecasts were not as clear as far out as the GFS forecasts for the potential for such an anomalous event. Part of the problem with the MREF was the large variation of the progression of the upper-level trough. The bimodal variation about the consensus forecast is

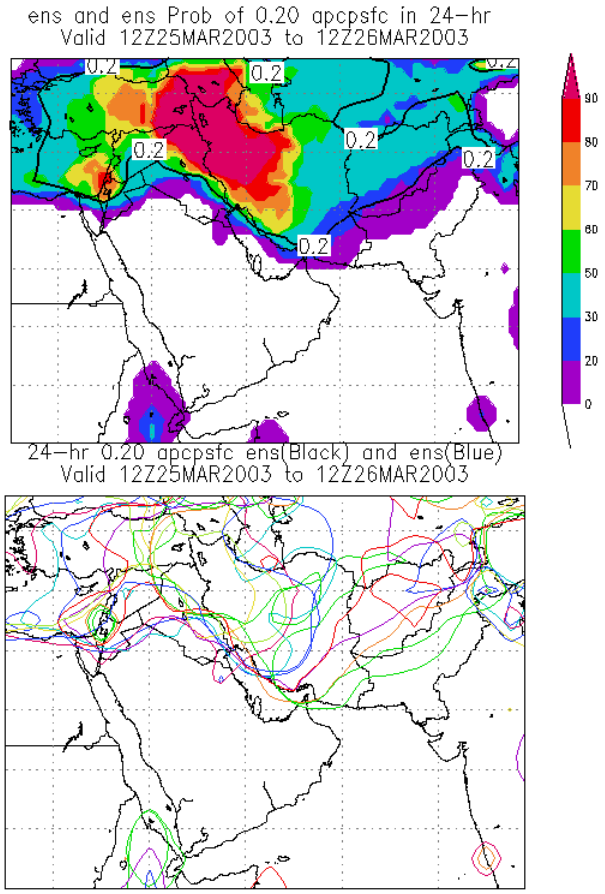


Figure 10 24 hour quantitative precipitation forecast for the period ending at 1200 UTC 26 March 2003. Upper panel shows percentage chance of 0.20 inches or more. Lower panel shows spaghetti plot of each models 0.20 inch forecast.

a fairly classic translational error signal. It took several days for the MREF to converge on more consistent GFS forecast. With little experience using the MREF outside the United States, it appears that the low resolution members in this case may have degraded the higher resolution GFS and Control run solutions. The GFS QPFs must have been reasonable based on the rain, thunderstorms displays, and standing water shown from the embedded reporters on 26-28 March 2003.

One critical aspect of this event is how telling the climatic anomalies were. For planning purposes, the blending of climatic anomalies with model forecasts provides a valuable tool in forecasting the potential severity and impact a weather system may have. The large anomalies with the upper level cyclone and the LLJ indicated that this would be a dust storm of unusual strength, as it was. The GFS verifying wind image (Fig A1) shows just how anomalous the LLJ ended up being, it was underforecast.

5. Acknowledgments

Air Force Weather Agency for dust descriptions and image in Appendix I.

6. Reference

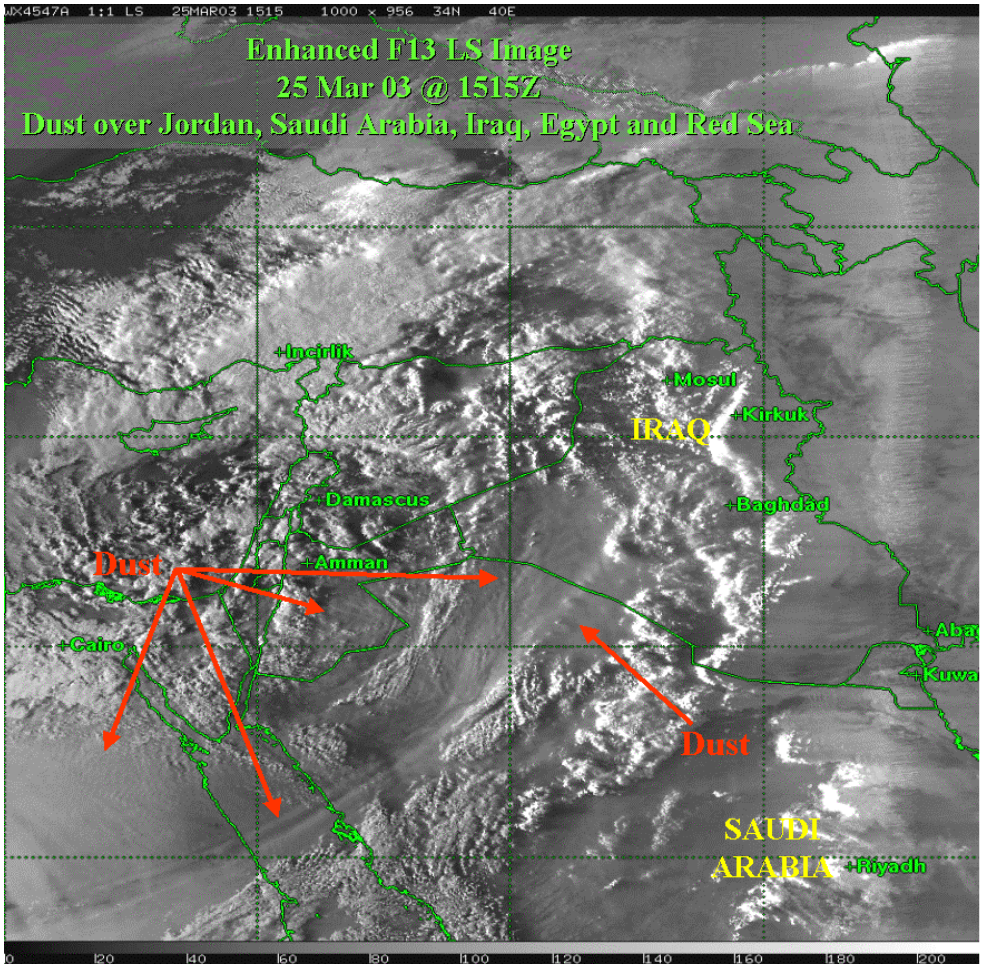
Grumm, Richard H., Robert Hart, 2001: Standardized Anomalies Applied to Significant Cold Season Weather Events: Preliminary Findings. *Weather and Forecasting*,**16**,736–754.

Hart,R.E, and R.H. Grumm, 2001: Using normalized climatological anomalies to rank synoptic-scale events objectively. *Mon. Wea. Rev.*,**129**,2426-2442.

Kocin, P.J., P.N. Schumacher,
R.F.Morales Jr., and L.W. Uccellini,
1995: Overview of the 12-14 March
1993 Superstorm. Bull. Amer. Meteor.
Soc.,76, 165-182

Appendix I:

Three Day Dust Event Near Iraq. The information in this Appendix comes from the ***Metsat Applications Branch***, Air Force Weather Agency(AFWA):



Air Force Weather Agency anonotated image of the storm system and dust over Southwest Asia valid at 1515 UTC 25 March 2003. Courtesy USAF.

On 25 - 27 March 2003, a strong weather system in the Middle East caused wide spread dust storm events. These events were a series of dust/sand storms that became nearly continuous and impacted operations throughout the theater. On the first day, several moderate to strong thunderstorms swept west to east through Iraq and Kuwait. In front and behind these storms, strong winds caused blowing dust reducing visibilities to near zero at times. On the second day, the storm center passed across northern Iraq passing into Iran by 21Z. West and southwesterly strong winds from this low blew across central and southern areas of Iraq, keeping the dust storms going through out most of the operational theater. By Day 3, most of Iraq had clearing skies as the dust settled under an approaching High pressure center. But Kuwait and the Persian Gulf were still experiencing the blowing dust, impacting ground and carrier operations around Kuwait and Sea operations in the Gulf.

Appendix II – Related Data

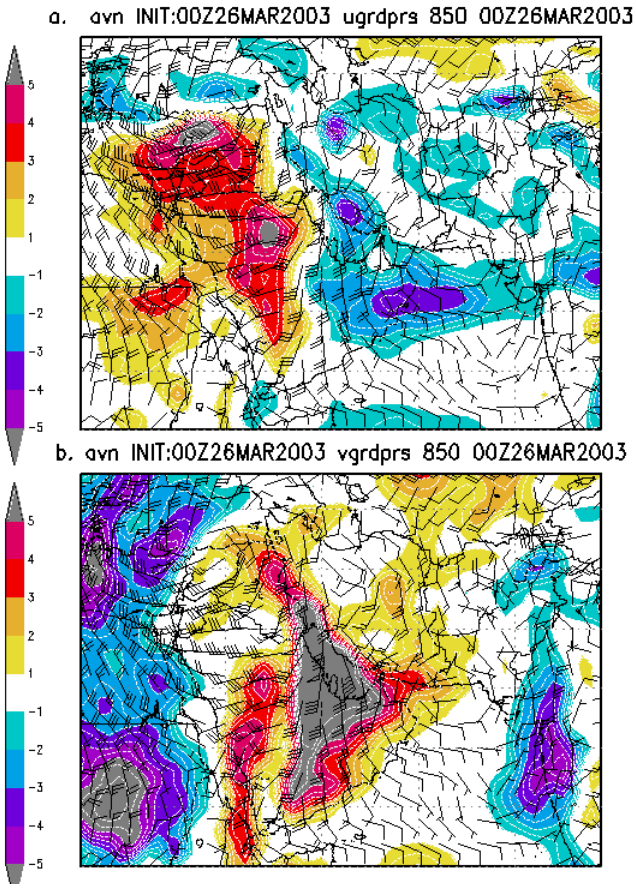


Figure A1 What verified! WOW.

25 March 2003	Dust	
13 March 2003	Dust	
7 March	Dust	
20 Feb		

http://www.osei.noaa.gov/updaterecent.html