P1.22 THE 24 FEBRUARY 2007 NORTH TEXAS DUST STORM: AN IMPACT WEATHER EVENT

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1. INTRODUCTION

Impact weather can be defined as a weather event that causes a substantial departure from the normal routine. The event must be forecastable with sufficient lead time to allow decision makers to take appropriate action that results in a saving of lives and and/or a reduction in property damage or other adverse economic impacts.

On 24 February 2007, a wind and dust storm impacted North Texas. Impacts included the closure of the Dallas-Fort Worth and Dallas Love airports that resulted in the cancellation of over 500 flights, loss of electric power by more than 90,000 customers, and the rapid spread of wildfires across the area which required the evacuation of thousands of people.

The strong winds were well forecast by the operational numerical weather prediction models as early as three days prior to the event, and local forecasters alerted decision makers well in advance of the storm. A High Wind Warning, Blowing Dust Advisory, and Red Flag Warning were all in effect at the time of the event.

2. SYNOPTIC AND SURFACE FEATURES

A mid-latitude cyclone moved into the Southern Plains on 24 February 2007. Accompanying this system were strong winds through a deep layer of the troposphere. Synoptic scale and mesoscale subsidence within an extensive layer of the atmosphere, including deep mixing in the lower levels, provided nearly ideal conditions for transporting higher wind speeds aloft to the surface. As a result, westerly winds sustained in excess of 40 mph, and gusts between 50 and 60 mph, were common across the WFO Fort Worth-Dallas County Warning Area (CWA) (Table 1).

A large dust cloud developed near Lubbock, Texas and moved eastward, reducing visibilities to less than a mile in some locations across North Texas. Strong winds and dry conditions also led to many grass and wildfires across the region.

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2.1 Features at 500hPa

At 0000 UTC 23 February, a mid level trough moved over the Pacific Coast, while mid level ridging developed across the central United States. By 1200 UTC 23 February, stronger winds were reported on the western side of the trough. Twelve hours later, at 0000 UTC 24 February, a mid level jet streak of 95 kts was moving down the southwest side of the trough, coincident with a strong baroclinic zone. Downstream of the trough, a region of difluence and upward motion were apparent over Kansas, western Oklahoma, and Texas. The trough moved over the Rocky Mountains by 1200 UTC 24 February, and strong mid level cyclogenesis ensued, resulting in a cut-off low developing over eastern New Mexico, southeast Colorado, and the Oklahoma and Texas Panhandles (Fig 1).

Also at 1200 UTC 24 February, a strong mid level jet maximum was noted rounding the base of the trough, with wind speeds of 120 kts at El Paso (EPZ), 95 kts at Midland (MAF), and 80 kts at both Fort Worth (FWD) and Norman (OUN). The main axis of mid level difluence and upward motion had also shifted into eastern Oklahoma and Texas, Arkansas and Louisiana. Consequently, the majority of showers and thunderstorms, including severe thunderstorms, occurred to the east of WFO Fort Worth-Dallas' county warning area on 24 February, near the warm conveyor belt of the mid level cyclone. Throughout the day, the mid level cyclone deepened as it moved east across southern Kansas (Fig 2).

2.2 Development in the Mixed Layer

On 24 February, wind speeds at 700hPa increased and wind directions veered from the southwest at 1200 UTC to westerly at 0000 UTC. As the cyclone deepened, winds increased from the 1200 UTC values of 70 kts at MAF and 45 kts at FWD and OUN to 65 kts at FWD and Shreveport (SHV) and 90 kts at Little Rock (LZK) by 0000 UTC.

Several smaller circulations were noted on visible satellite imagery moving around the primary circulation associated with the upper low. The Rapid Update Cycle (RUC) at 1800 UTC analysis of 700hPa vorticity depicted one particularly strong circulation across southwest Oklahoma. On visible satellite imagery, the developing dust plume appeared to wrap into the northern and eastern peripheries of this circulation. By 2200 UTC, the mid level circulation elongated and translated into eastern Oklahoma, swinging the dust plume from eastern Oklahoma into central Texas (Figs 3 and 4).

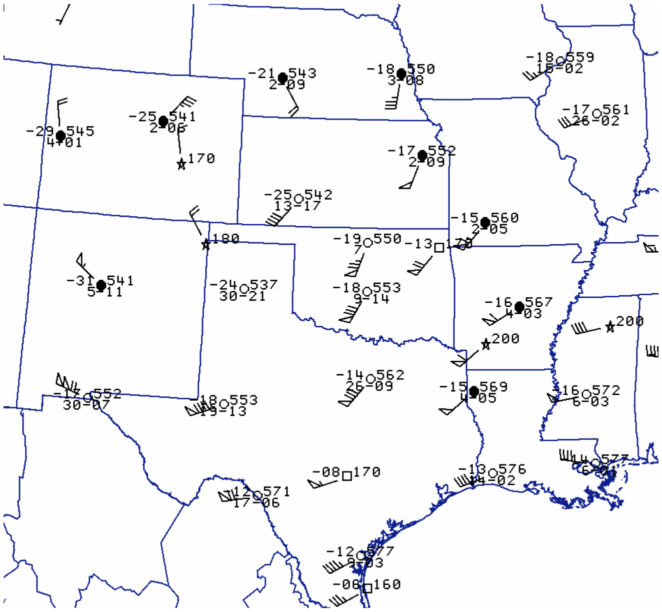

Figure 1. 500hPa RAOBs at 1200 UTC 24 February 2007. Note the strong height falls at Dodge City, KS and Amarillo, TX.

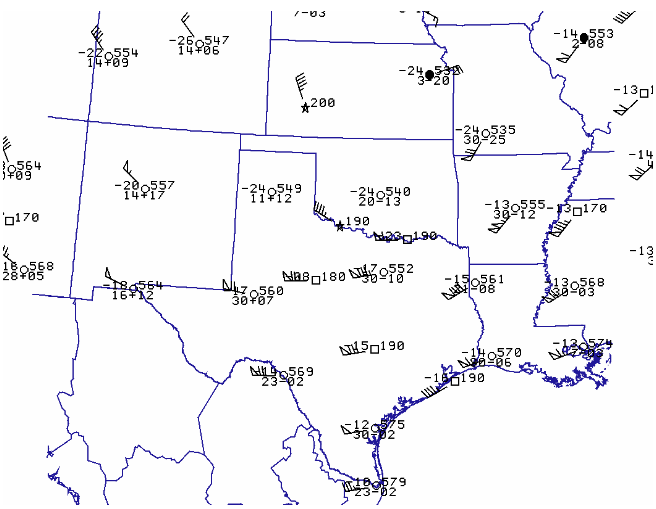

Figure 2. 500hPa RAOBs at 0000 UTC 25 February 2007. Note the strong height falls at Topeka, KS and Springfield, MO.

A strong low level jet (LLJ) was present along and just to the east of the Interstate 35 corridor on the morning of 24 February. The 1200 UTC analysis at 850hPa indicated a 50-60 kt maximum extending from Brownsville to Fort Worth to Springfield, MO. Winds just to the west of the LLJ axis were strong as well, with a west wind of 45 kts noted at MAF at 1200 UTC.

Winds were also abnormally strong at 925hPa, or roughly 700m above ground level at Fort Worth, with 40 kts measured at FWD at 1200 UTC.

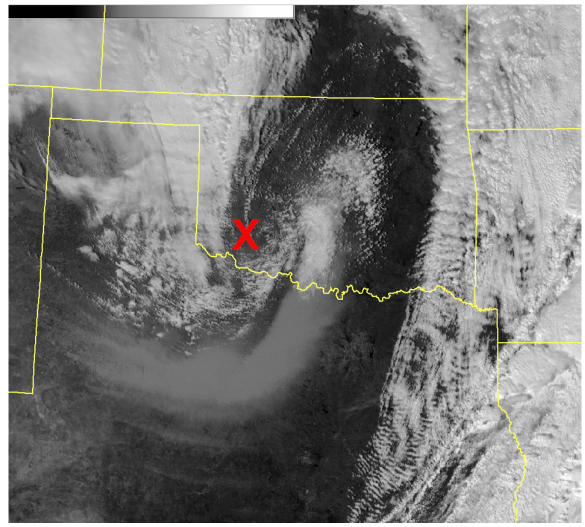

Figure 3. GOES East visible imagery at 1932 UTC 24 February 2007. The X indicates a 700hPa relative vorticity maximum from the Rapid Update Cycle analysis at 2000 UTC.

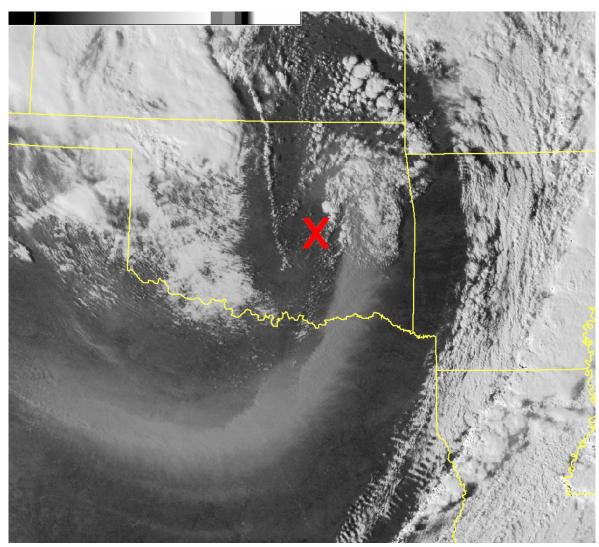

Figure 4. GOES East visible satellite Imagery at 2155 UTC 24 February 2007. The X indicates a 700hPa relative vorticity maximum from the Rapid Update Cycle analysis at 2000 UTC.

2.3 Mid and Upper Level Vertical Motions

An atmospheric cross section from near Childress to College Station, Texas was examined to determine vertical circulations as a result of frontogenesis and jet circulations aloft (Fig 5).

The RUC analysis of total divergent Q supported synoptic scale sinking motions, possibly related to cold air advection, across the region. Total divergent Q increased in magnitude from northwest to southeast over the region between 1800 UTC and 2000 UTC (Fig 6). Convergent Q was present farther southeast, nearer to the southern extent of the warm conveyor belt.

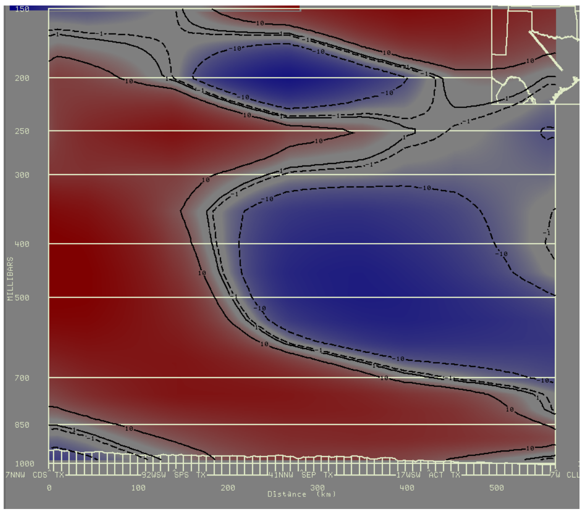

Figure 5. Cross-section of divergent Q (red shading) and convergent Q (blue shading) at 1800 UTC from Childress to College Station, TX.

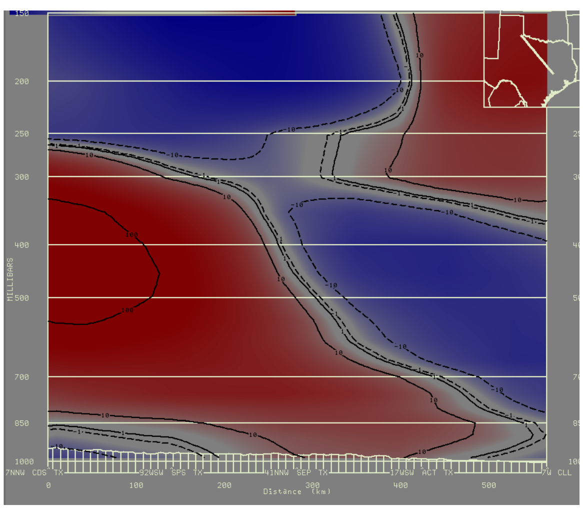

Figure 6. Same as Fig 5, but for 2000 UTC.

Cyclonically curved jet streaks at 300hPa, 500hPa, and 700hPa placed North Texas within the right exit region of the wind maxima. RUC forecasts of divergent Q-vectors normal to the isentropes over western Oklahoma and the Texas Panhandle indicated strong subsidence, likely associated with the sinking branches of the transverse jet circulations. This subsidence spread eastward into North Texas through the afternoon hours.

Strong frontogenesis was analyzed in the 700-300hPa layer along the gradient of divergent and convergent Q from Wichita Falls to Dallas, Texas. This frontogenesis was at mid levels, near the 650-400hPa layer, while near Waco the frontogenesis was lower in the atmosphere, between 850 and 700hPa. Ageostrophic wind streamlines showed broad-scale downward motions throughout the lower half of the troposphere as a result of the frontogenetical circulation.

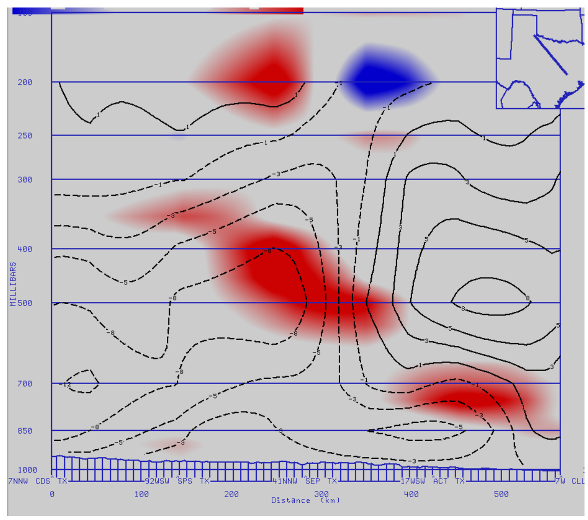

Figure 7. Cross-section of frontogenesis (red shading), frontolysis (blue shading) and vertical motion (black contours) at 2000 UTC from Childress to College Station, TX.

A diagnosis of tropospheric folding, using the one to two PVU contours (Fig 8), showed stratospheric air was folded down to the 500hPa and 600hPa levels near Fort Worth. In the RUC cross-section below, the 1.5 PVU contour extends to about 600hPa near Fort Worth. The image is wind speed, with brighter colors representing higher values. The image indicates that wind speeds near 120 kts were present just southeast of the area of strongest tropospheric folding. The folding through a deep layer of the atmosphere implied that stronger winds within the upper troposphere and lower stratosphere were transported at least into mid levels. Once these higher winds were transported into mid levels, other processes assisted with mixing higher momentum from mid levels into the boundary layer.

2.4 Sounding Analysis

A moist boundary layer was in place over North Texas during the early morning hours on 24 February. At the time the 1200 UTC FWD rawindsonde was released, showers and thunderstorms were present across eastern portions of the forecast area (Fig 9). The 1200 UTC FWD sounding depicted some moisture in the lower levels, but this moisture quickly moved eastward. However, a mixed layer developed within the lowest 100hPa. Backing winds with height were apparent throughout the 700-200hPa layer, implying cold air advection and associated subsidence within that layer. The 1200 UTC MAF sounding was much drier than that from FWD, with a mixed layer extending from the surface to around 750hPa. At 0000 UTC, the FWD sounding wind profiles indicated that backing of winds with height continued within the 700-200hPa layer (Fig 10). The mixed layer extended from the surface through approximately 750hPa.

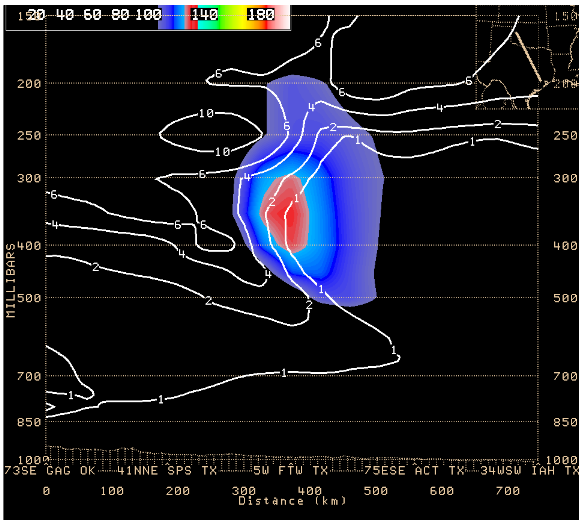

Figure 8. Cross-section of potential vorticity (white contours) and wind speed (colors) at 2200 UTC from Gage, OK to near Waco, TX.

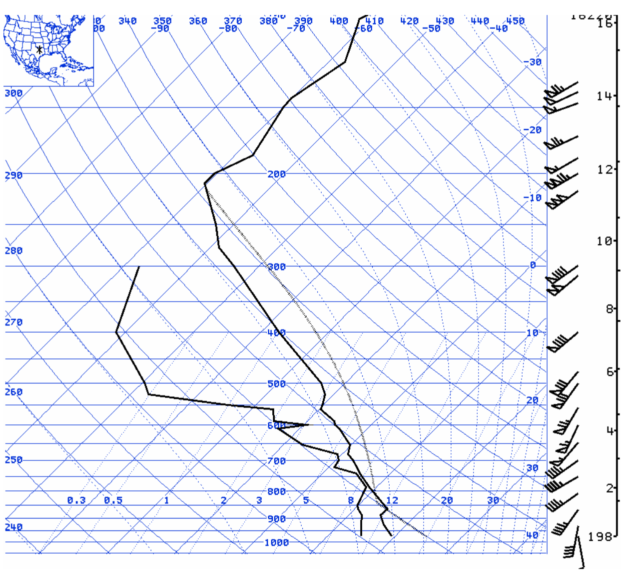

Figure 9. FWD sounding at 1200 UTC 24 February 2007.

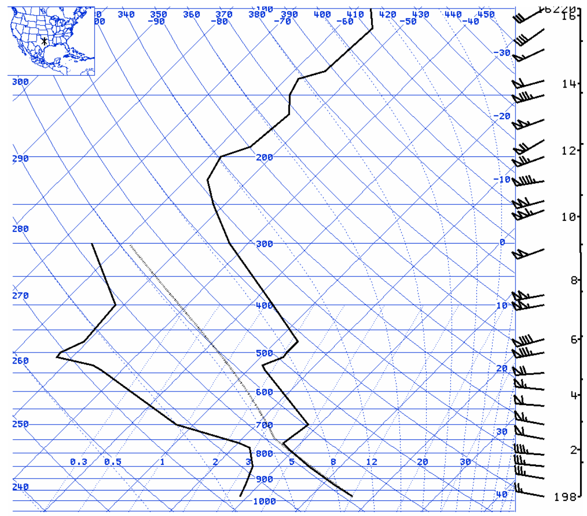

Figure 10. FWD sounding at 0000 UTC 25 February 2007.

2.5 Surface Features

The surface low deepened slightly during the day, with minimum pressures falling from 988hPa over central Kansas at 1400 UTC to 985hPa at 2000 UTC. RUC analysis and surface analysis depicted the strongest pressure gradient along the west side of the surface cyclone, over eastern Colorado and western Kansas. Surface dewpoint depressions between 40 and 50F were observed at many sites in the Fort Worth CWA as a broad dry slot, indicative of a strong, deep layer of subsidence, rotated across Texas south of the mid level cyclone during the day.

Maximum wind gusts across the area were reached between 1800 and 2000 UTC (Figs 11 and 12). At Waco Regional Airport, the maximum gust of 48 kts occurred at 1833 UTC, while DFW reached a maximum gust of 49 kts at 2003 UTC.

3. OBSERVATIONS

Transportation of higher momentum aloft to the surface was aided by both synoptic scale and mesoscale subsidence acting in unison over North Texas.

Synoptically, in the upper and mid levels, cyclonically curved jet streaks at 300hPa, 500hPa, and 700hPa placed North Texas in the right exit region of the jet maxima. Q-vector analysis showed a broad area of enhanced subsidence in the 700-300hPa layer from the Texas Panhandle eastward into much of North Texas. Q-vector convergence, or forcing for rising motion, was present farther southeast of the Fort Worth CWA, where the warm conveyor belt was more influential.

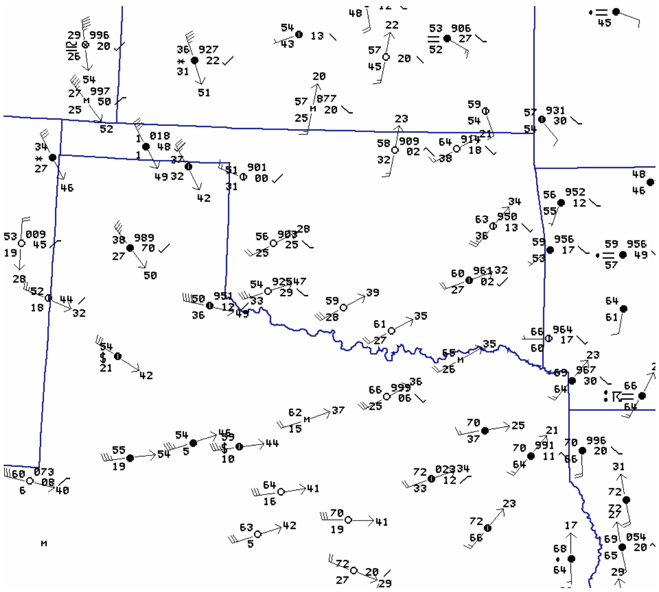

Figure 11. Surface observations from 1800 UTC 24 February 2007.

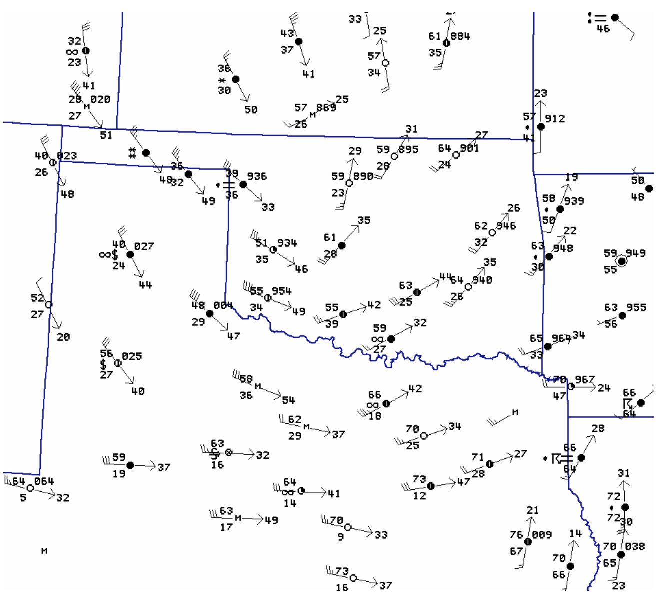

Figure 12. Surface observations from 2000 UTC 24 February 2007.

The FWD soundings at 1200 UTC and 0000 UTC indicated cold air advection within the mid levels. RUC analysis of 500hPa and 700hPa temperatures and winds showed the cold air advection increased through the day from the Texas Panhandle eastward to just south of the Red River, as the upper low pivoted into eastern Kansas. Additional sinking motions were likely aided by anticyclonic vorticity advection increasing with height in the atmosphere.

In the mesoscale, strong frontogenesis existed along the gradient between Q-vector divergence and convergence, and the associated frontogenetical circulations likely assisted with momentum transport. Cross sections also indicated tropospheric folding was present, providing some transport of winds in the 300-200hPa layer to 500hPa, or slightly below.

A broad dry slot, evident in the water vapor imagery and RUC 1000-500hPa relative humidity fields, engulfed North Texas from 1700 UTC through the remainder of the day, with surface dewpoint depressions increasing from 40F to 50F during the time of highest observed winds at mid-afternoon.

Time of day and wind direction also played a role in enhancing momentum transport. Daytime turbulent mixing created steep low level lapse rates, nearly dry adiabatic from the surface up to 700hPa. This unstable mixed layer was nearly ideal for allowing momentum transport from mid levels to low levels. The westerly wind direction resulted in downslope flow from west Texas into central Texas. Low level warming, associated with downslope flow, assisted in maintaining a deepening boundary layer with a dry adiabatic lapse rate conducive for deep mixing.

The combination of these factors resulted in higher winds aloft sufficiently mixing to the surface, causing an 11-hour period of gusts in excess of 30 kts. Although the magnitude of the pressure gradient was not abnormally strong across North Texas, deep mixing up to 700hPa and subsidence through much of the atmospheric column allowed strong winds to reach ground level. The aforementioned factors of this event were similar to those related to the San Joaquin Valley, California dust storm in 1991 (Pauley *et al.* 1996).

4. WEATHER SERVICES BEFORE AND DURING THE EVENT

The Area Forecast Discussion (AFD) issued by WFO Fort Worth-Dallas on the morning of 20 February (four days before the event) indicated a strong dry line/squall line would likely move through North Texas that Saturday, and that the line would move through the western half of the region in the morning, be east of Interstate 35 by midday, and end in the east by evening. Although initial indications were for a rain and wind event, the timing of the event was excellent.

The AFD issued the following morning (three days before the event) called attention to strong surface winds with possible gusts to 35-40 mph, especially north of Interstate 20. A major wildfire concern due to dry air and strong gusty winds was indicated in the AFD issued on the morning of 22 February (two days before the event). An impact to high profile vehicles was also noted. A Fire Weather Watch for Saturday was issued that afternoon. This provided more than adequate lead time to the impacted fire agencies. By that evening, the likelihood of a Wind Advisory was also mentioned for Saturday.

By midday on Friday, 23 February, WFO Fort Worth-Dallas, in collaboration with the Fort Worth Center Weather Service Unit, indicated that expected steep lapse rates would result in mixing of strong lower tropospheric winds from the west-southwest, which is a cross wind for all major runways at both Dallas-Fort Worth and Dallas Love airports. Major delays were expected. A Red Flag Warning and Wind Advisory were issued.

On the morning of the event the Red Flag Warning remained in effect and a High Wind Warning was issued, with the likelihood of afternoon winds reaching 40 mph for an hour or two indicated. The aviation section of the AFD issued early Saturday morning noted that the expected cross winds would severely hamper operations at the Dallas-Fort Worth Airport. Blowing dust was first mentioned in the AFD issued at 9:40 am CDT, as dust had been noted in the satellite imagery and surface reports from west Texas. The dust was primarily a nuisance, reducing visibilities to one mile. No motor vehicle accidents due to poor visibility were reported in north central Texas, although several did occur in west Texas. Reports of wildfires caused by downed power lines were mentioned shortly after noon. A Blowing Dust Advisory was issued for 1:00–6:00 pm CDT as the extent of the dust plume became more apparent on satellite imagery.

Numerical model guidance prior to the event was very good. The Global Forecast System (GFS)-based model output statistics (Table 2) from all model runs leading up to the event indicated winds in excess of 30 knots were likely, although the predicted timing of the event was consistently a bit slow.

5. PREPARATIONS FOR THE EVENT

Decision makers often have a variety of options from which to choose. For example, in the case of this event that occurred on a Saturday, they might authorize overtime in advance. The Fort Worth Fire Department has the option of canceling training activities, deferring maintenance on equipment, pre-positioning units and -- when wildfires are expected -- transferring staff from traditional fire engines to smaller trucks that can more easily negotiate rough terrain (J. Peacock, Fort Worth Fire Department 2007, personal communication).

Airports, and in some instances airlines, have the option to increase the separation between arriving or departing aircraft, closing runways (when the crosswinds exceed 25 kts), diverting inbound aircraft to alternate airports, initiating a ground stop, holding inbound planes at their departure city, and/or canceling flights.

6. THE DUST STORM

Dry adiabatic lapse rates in the low levels and sustained wind speeds in excess of 30 mph have been shown to be conducive for dust storm development (Parkinson 1936). The strong westerly winds that were transported to the surface did indeed pick up dirt and dust across west Texas, near Lubbock, and push a large plume toward the Fort Worth CWA. At one time the plume was an estimated 400 miles long, 70 miles wide, and extended to an altitude of 17,500 ft (Fig 13).

Visibilities within the plume were reduced to one mile or less. The lowest visibilities, which implied the passage of the dust plume, occurred in early to mid-afternoon. This agrees with previous research that showed the highest frequency of airborne dust occurring between noon and 8 pm LST, due to the maximum thermal instability that typically occurs during that time (Orgill and Sehmel, 1976).

7. IMPACTS OF THE EVENT

Impacts included the closure of the Dallas-Fort Worth and Dallas Love airports for several hours, which resulted in the cancellation of over 500 flights, most between 2:00 and 5:00 pm CDT. That forced over a thousand people to spend the night at the airport. The flight cancellations also affected other terminals across the nation. Long lines were reported at Los Angeles International Airport, as airlines had to rebook passengers whose flights had been canceled.

More than 90,000 customers in the Dallas-Fort Worth Metroplex lost electric power during the event. By 9:00 pm CDT power had been restored to about 56,000, and all power was restored by 6:00 p.m. CDT Sunday, an indication that the electric utilities were prepared for the event.

Downed power lines were one source of the many wildfires which spread rapidly due to the strong and gusty winds. The Fort Worth Fire Department reported about half of the dispatches on the day of the event were directly related to the strong winds, including reports of downed trees on homes and vehicles, downed and arcing power lines and grass fires. About 95 homes were evacuated across Texas due to fires. One fire that began about 1:30 pm CDT at Fort Hood, Texas resulted in the closure of the post exchange, the base commissary, and the evacuation of an estimated 6,500 people from military housing on the base.

The Dallas Area Rapid Transit system was impacted by several failed signals and switches, and also stuck crossing gate arms. In some instances, passengers had to change trains in order to continue to their destinations. Several windows in a Dallas office building blew out, scattering glass onto the street and sidewalk.

Two Fort Worth high school students were injured when they were struck by a wind-blown table as they were running in a track meet.

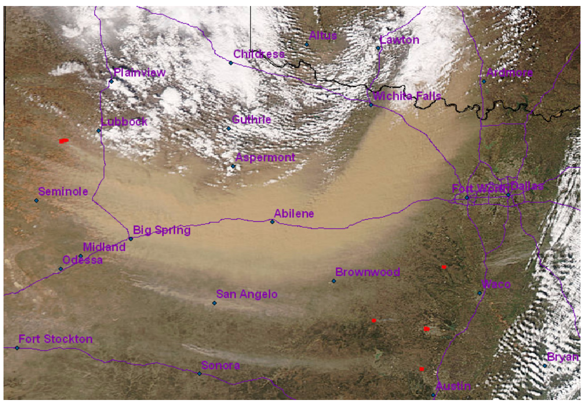

Figure 13. Satellite Imagery taken 1920 UTC 24 February 2007. Red pixels indicate large fires. Image courtesy of MODIS Rapid Response Project at NASA/GSFC.

8. SUMMARY

On 24 February 2007 a wind and dust storm impacted North Texas. The strong winds were well forecast by the operational numerical weather prediction models as early as three days prior to the event, and local forecasters alerted decision makers well in advance of the storm, reducing the impacts of the event.

9. REFERENCES

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Parkinson, G.R., 1936: Dust Storms over the Great Plains: Their Causes and Forecasting. *Bull. Am. Meteor. Soc.,* 17, 127-135.

Pauley, P.M., N.L. Baker, and E.H. Barker, 1996: An Observational Study of the “Interstate 5” Dust Storm Case. *Bull. Am. Meteor. Soc.,* 77, 693-720.

10. ACKNOWLEDGMENTS.

Sincere thanks to Greg Patrick of WFO Fort Worth-Dallas for his guidance, insightful discussions, and review of this paper.

Table 1. Maximum Wind Gusts across the WFO Fort Worth-Dallas County Warning Area

Dallas-Fort Worth Airport	56 mph	Stephenville	58 mph
Dallas Love	48	Comanche	48
Fort Worth Meacham	58	Paris	53
Dallas Executive	51	Sulphur Springs	55
Dallas Addison	46	Greenville	45
Fort Worth Alliance	55	Terrell	53
NAS Fort Worth	53	Corsicana	54
Fort Worth Spinks	49	Waxahachie	49
Arlington	47	Hillsboro	53
Grand Prairie	55	Cleburne	54
Lancaster	52	Granbury	54
Mesquite	46		
		Waco	55
Sherman/Denison	56	Waco McGregor	49
Gainesville	53	Temple	46
Mckinney	49	Killeen Gray	47
Denton	55	Killeen Skylark	48
Decatur	54	Fort Hood	53
Bridgeport	51	Gatesville	53
Graham	53	Hearne	39
Mineral Wells	56	Palestine	47

Table 2. Global Forecast System-based Model Output Statistic wind speed forecasts (in knots) for Dallas-Fort Worth Airport from the 12 model runs prior to the event. The observed sustained winds and gusts are provided for comparison.

Model Run		**Model Verification Time (UTC)**									
Date	**Time UTC**	**24 Feb 0000**	**0300**	**0600**	**0900**	**1200**	**1500**	**1800**	**2100**	**25 Feb 0000**	**0300**
22Feb	**0000**	20	19	20	20	23	-	33	-	19	-
	0600	21	18	20	20	22	25	30	-	21	-
	1200	20	19	22	21	19	24	32	34	20	-
	1800	21	19	21	18	20	24	33	33	22	15
23Feb	**0000**	20	20	21	20	23	25	34	34	22	17
	0600	21	20	23	22	21	26	33	31	21	16
	1200	18	18	21	21	20	26	33	34	22	17
	1800	16	17	20	19	19	27	34	34	22	17
24Feb	**0000**	-	-	20	20	16	25	33	35	22	17
	0600	-	-	-	-	-	26	33	36	23	17
	1200	-	-	-	-	-	-	30	34	23	18
	1800	-	-	-	-	-	-	-	-	26	20
Observed Wind		**14**	**15**	**21G28**	**28G35**	**28G36**	**40G51**	**24G33**	**24**	**15G24**	**17**