NATIONAL TRANSPORTATION SAFETY BOARD

Office of Aviation Safety
Washington, D.C. 20594

August 16, 2016

Weather Study

METEOROLOGY

DCA16FA199

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A. ACCIDENT

Location: Italy, Texas
Date: July 6, 2016
Time: 1148 central daylight time
1648 Coordinated Universal Time (UTC)
Airplane: Bell 525 experimental Aircraft; Registration: N525TA

B. METEOROLOGIST

Don Eick
Group Chairman
National Transportation Safety Board
Operational Factors Division (AS-30)
Washington, D.C.

C. SUMMARY

On July 6, 2016, about 1148 central daylight time, a Bell 525 experimental helicopter, N525TA had an inflight breakup and impacted terrain in Italy, Texas. The helicopter was destroyed by impact forces and a postcrash fire, and both test pilots received fatal injuries. The flight from Arlington Texas was operating under an experimental certificate issued by the Federal Aviation Administration for research and development, under the provisions on Title 14 Code of Federal Regulations Part 91. Visual meteorological conditions prevailed at the time of the accident.

D. DETAILS OF THE INVESTIGATION

The National Transportation Safety Board's (NTSB) Senior Meteorologist was not on scene for this investigation and conducted the meteorology phase of the investigation from the Washington D.C. office, collecting data from official National Weather Service (NWS) sources including the Weather Prediction Center (WPC) and the National Center for Environmental Information (NCEI). All times are central daylight time (CDT) based upon the 24 hour clock, local time is +5 hours to UTC, and UTC=Z. Directions are referenced to true north and distances in nautical miles. Heights are above mean sea level (msl) unless otherwise noted. Visibility is in statute miles and fractions of statute miles. NWS airport and station identifiers use standard International Civil Aviation Organization (ICAO) 4-letter station identifiers versus International Air Transport Association (IATA) 3-letter identifiers which deletes the initial country code designator "K" for U.S. airports. Both codes are used intermittently in this report.

The accident site was located at latitude 32° 14' 46.0" N and longitude 096° 55' 11.7" W, at an elevation of 482 feet. The helicopter had been operating at an altitude of 2,000 feet or at a density altitude of 4,000 feet when the in-flight break event began.

E. FACTUAL INFORMATION

1.0 Synoptic Situation

The synoptic or large scale migratory weather systems influencing the area were documented using standard NWS charts issued by the National Center for Environmental Prediction (NCEP) located in Camp Springs, Maryland. These are the base products used in describing weather features and in the creation of forecasts and warnings. Reference to these charts can be found in the joint NWS and Federal Aviation Administration (FAA) Advisory Circular "Aviation Weather Services", AC 00-45G.

1.1 Surface Analysis Chart

The southcentral portion of the NWS Surface Analysis Chart for 1000 CDT (1500Z) on July 6, 2016 is included as figure 1 depicting the conditions prior to the accident, with the approximate accident site within the red circle. The chart depicted a cold front extending from the Great Lakes southwestward through Iowa and Nebraska and becoming stationary as it extending northwestward. Several low pressure systems at 1007-hectopascals (hPa) were identified south of the front to the north and west of the accident site associated with troughs of low pressure, which influenced the pressure and wind fields. The most significant one was located over northwestern Missouri, with a trough extending southwestward to another low in western Kansas, with another trough extending southward into the Texas panhandle to another low, and a trough extending southward across western Texas, southeastern New Mexico and into Mexico. An outflow boundary was also identified over eastern Missouri, southern Illinois, into Indiana associated with thunderstorms. The chart also depicted two high pressure systems, one over Colorado at 1016-hPa to the northwest and the other to the east in the Gulf of Mexico off the Florida panhandle at 1022-hPa. The high pressure system over the Gulf of Mexico was the dominate system over the south with a high pressure ridge extending westward across southern Texas and the accident site, with an increasing pressure gradient developing over Texas with warm moist southerly flow from the Gulf of Mexico streaming northward into the central plains.

The station models in the vicinity of the accident site indicated wind from the south sustained at 10 to 15 knots, visibility unrestricted, scattered clouds, temperatures in the mid 80's degrees Fahrenheit (°F), with dew point temperature in the low 70's F.

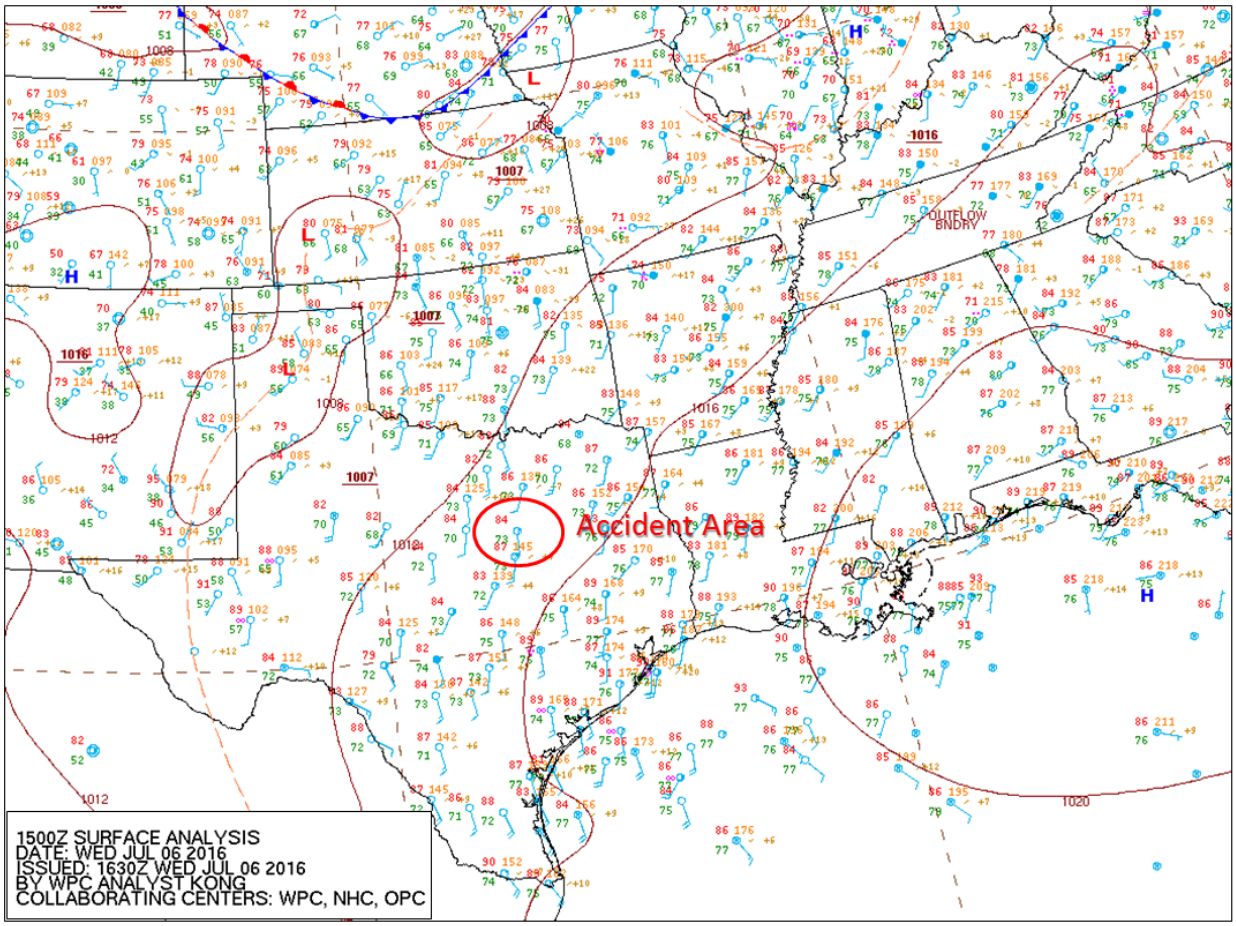

Figure 1 - Southcentral section of the NWS Surface Analysis Chart for 1000 CDT

1.2 Constant Pressure Charts

The NWS 850-hPa constant pressure chart for 0700 CDT (1200Z) on July 6, 2016 is included as figure 2 and depicted the conditions at approximately 5,000 feet over the country. The chart depicted a high pressure over central Florida with a ridge extending westward into southeastern Texas. A short wave trough was depicted extending from a low pressure system over Wyoming southward through New Mexico and extreme southwestern Texas to another low pressure system depicted over northern Mexico, or to the southwest of the accident site. The resultant pressure pattern resulted in a band of south to southwesterly winds at 30 to 40 knots Texas. The station model for Fort Worth, Texas depicted a southwest wind at 30 knots, temperature 24° Celsius (C), and a temperature-dew point depression or spread of 13° C, with a height of 1,536 meters[1] (m) or 5,040 feet, heights had increased 10 meters or 32 feet during the previous 12 hours.

Figure 3 is the NWS 700-hPa chart for 1200 CDT depicting the conditions at approximately 10,000 feet. The high pressure system continued to be depicted with the center off the east coast of Florida with the ridge extending across the Gulf of Mexico and into southeastern Texas. A short wave trough with less amplification was still depicted from Wyoming into New Mexico.

[1] Height requires add a prefix of 1 to the height in meters on the 850-hPa chart (plotted 536 meters is 1,536 meters).

The resultant wind flow over Texas was from the southwest to west at 10 to 20 knots. The Fort Worth station model depicted a west-southwest wind at 15 knots, a temperature of 14° C, and a temperature-dew point spread of 16° C, and a height of 3,207 meters[2], or 10,520 feet.

Figure 4 is the NWS 500-hPa constant pressure chart for 0700 CDT which depicted the conditions of the mean atmosphere at approximately 18,000 feet. The chart continued to depict the high pressure system off Florida with several other high pressure systems being depicted along the ridge westward over Louisiana and over the Texas and Mexico border. The result was a weak gradient over Texas with a complex wind flow pattern with winds under 10 knots. The Fort Worth station model depicted a northwest wind at 15 knots, a temperature of -9° C, a temperature-dew point spread of 5° C, with the station model shaded indicating near saturated conditions at that level, a height of 5,930 meters[3] or 19,460 feet, with a 10 meter or 32 feet fall in height over the 12 hours. An aircraft report immediately south of Fort Worth at 18,000 feet indicated a wind from the northwest at 10 knots, temperature -7° C, and a 3° C temperature-dew point spread.

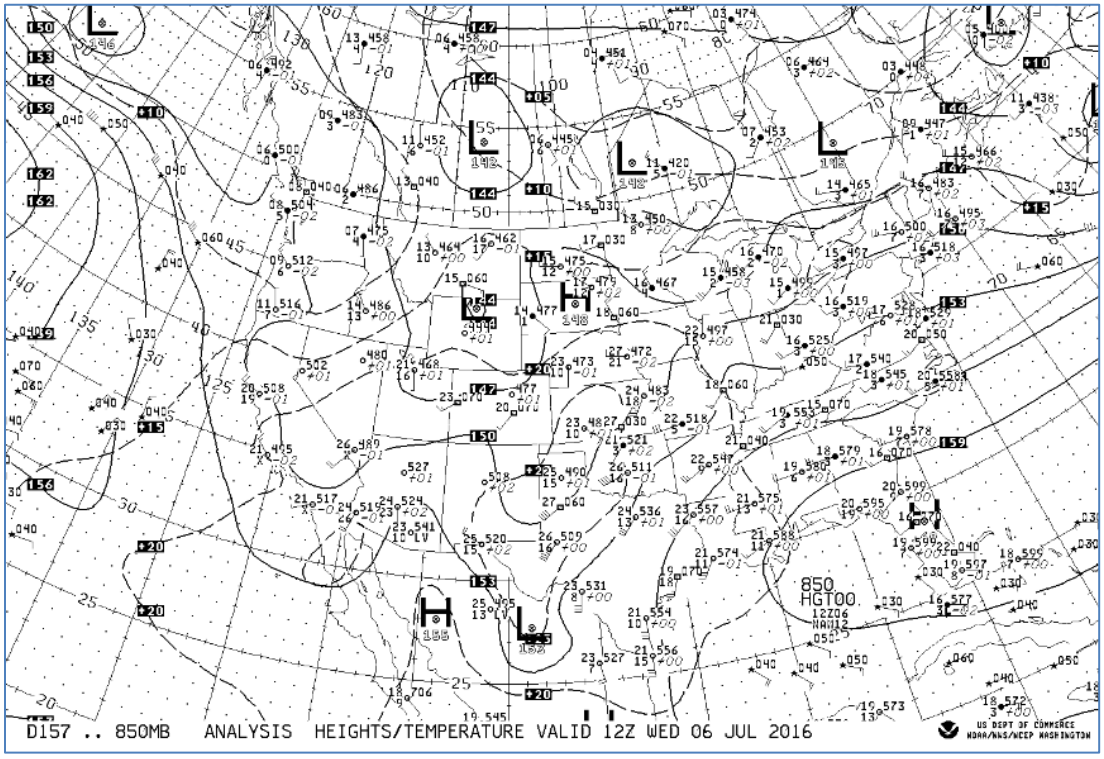

Figure 2 - NWS 850-hPa constant pressure chart for 0700 CDT

[2] Height requires adding prefix of 2 or 3, which ever brings the height closer to 3,000 meters.

[3] Height requires adding a suffix of 0 on all charts above 500-hPa.

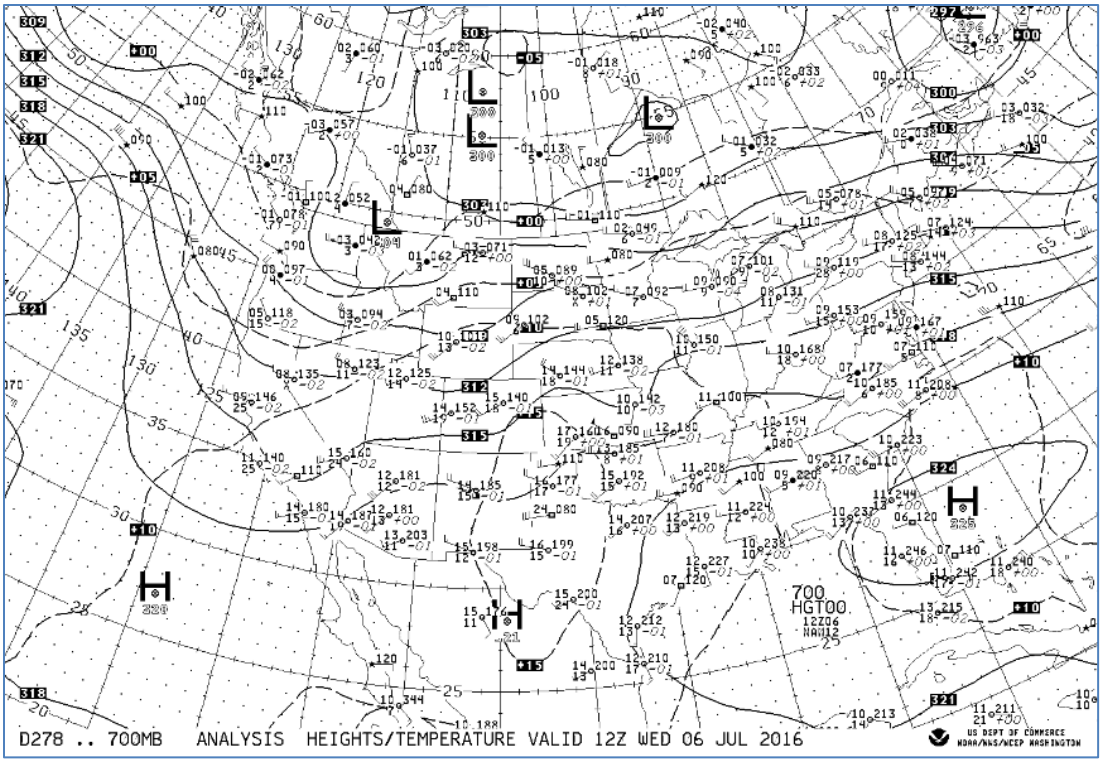

Figure 3 - NWS 700-hPa constant pressure chart for 0700 CDT

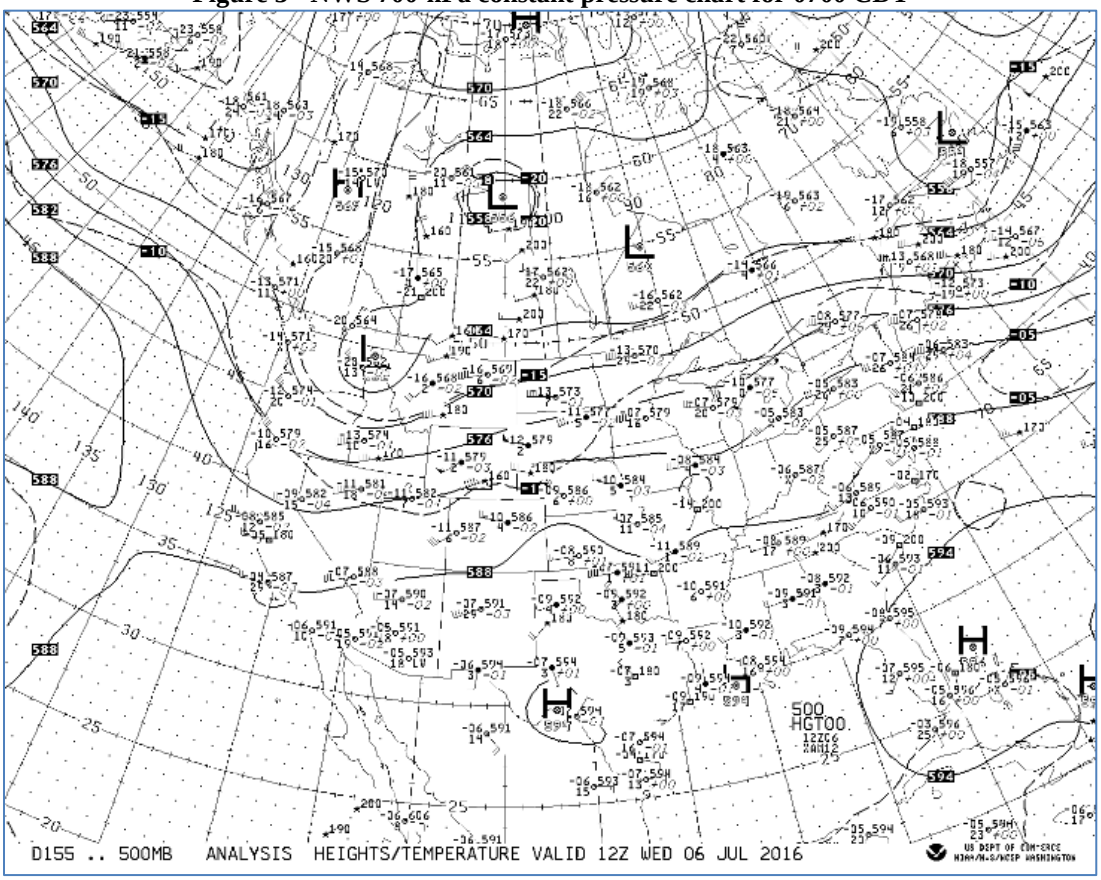

Figure 4 - NWS 500-hPa constant pressure chart for 0700 CDT

1.3 National Radar Mosaic

The southcentral portion of the NWS National composite radar mosaic for 1150 CDT (1650Z) on July 6, 2016 is included as figure 5, with the approximate accident site located within the red circle. The National radar depicted some significant weather echoes associated with a line of convection over Iowa, Missouri into northern Arkansas, with scattered echoes over portions of Illinois and Indiana. Over Texas there were no significant weather echoes identified during the period and none in the general vicinity of the accident site.

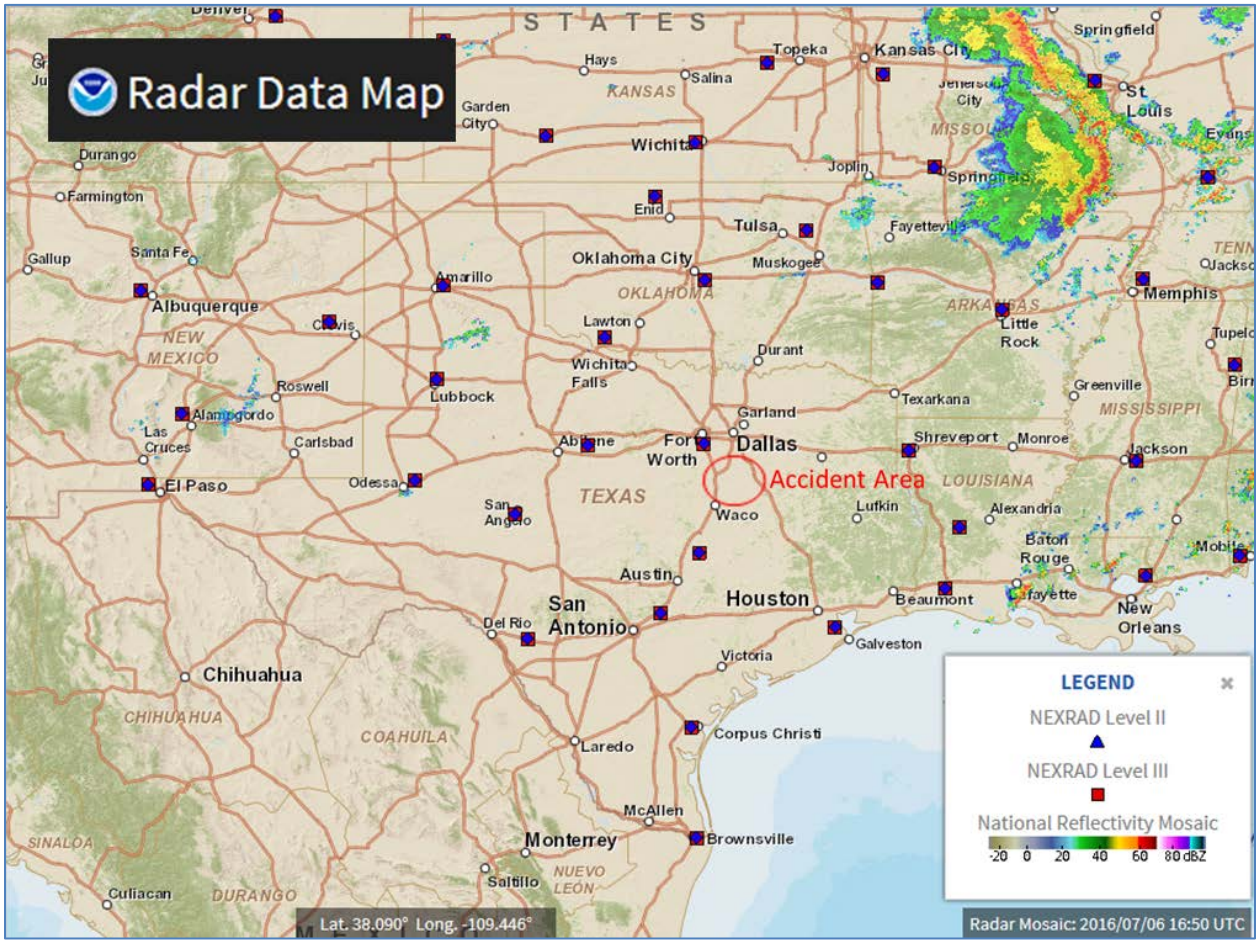

Figure 5 - NWS National Radar Mosaic for 1150 CDT

2.0 Surface Observations

The official NWS Meteorological Aerodrome Reports (METARs) and special reports (SPECIs) surrounding the period were documented for the departure and the closest airport to the accident site. The cloud heights are reported above ground level (agl).

2.1 Mid-Way Regional Airport (KJWY), Midlothian/Waxahachie, Texas

The closest weather reporting location to the accident site was from Mid-Way Regional Airport (KJWY), located approximately 12 miles north of the accident site at an elevation of 727

feet and a magnetic variation of 6°E. The airport had an Automated Weather Observation System (AWOS) and issued observations every 20 minutes. The following conditions at the time of the accident:

Mid-Way Regional Airport at 1155 CDT, automated, wind from 180° at 15 knots gusting to 20 knots, visibility 10 statute miles, scattered clouds at 3,000 feet agl, temperature 32° C, dew point temperature 24° C, altimeter 29.97 inches of mercury (Hg). Remarks: automated weather observation system with a precipitation discriminator, temperature 31.6° C, dew point 24.1° C.

The observation provided a calculated relative humidity of 63%, a station pressure of 29.19" of Hg, with a density altitude of 3,175 feet. No precipitation was recorded on July 6, 2016 at the station. The raw observations in standard code and the general flight categories[4] surrounding the period were as follows:

MVFR	*METAR KJWY 061355Z AUTO 20017G23KT 10SM BKN018 27/23 A2999 RMK AO2 T02720232=*
VFR	*METAR KJWY 061415Z AUTO 19017G25KT 10SM SCT020 28/23 A2999 RMK AO2 T02770232=*
VFR	*METAR KJWY 061435Z AUTO 18016G20KT 10SM SCT022 29/24 A2998 RMK AO2 T02850235=*
MVFR	*METAR KJWY 061455Z AUTO 19017G24KT 10SM BKN022 29/23 A2998 RMK AO2 T02870234=*
MVFR	*METAR KJWY 061515Z AUTO 19016G22KT 10SM BKN024 30/24 A2998 RMK AO2 T02950236=*
VFR	*METAR KJWY 061535Z AUTO 18017G21KT 10SM SCT026 29/23 A2998 RMK AO2 T02940234=*
MVFR	*METAR KJWY 061555Z AUTO 20015G19KT 10SM BKN026 30/24 A2998 RMK AO2 T03040240=*
MVFR	*METAR KJWY 061615Z AUTO 20016G21KT 10SM BKN028 31/24 A2998 RMK AO2 T03070237=*

[4] As defined by the NWS and the FAA Aeronautical Information Manual (AIM) section 7-1-7 defines the following general flight categories:

- Low Instrument Flight Rules (LIFR*) – ceiling or lowest layer of clouds reported as broken, overcast or the vertical visibility into a surface based obscuration below 500 feet agl and/or visibility less than 1 statute mile.
- Instrument Flight Rules (IFR) – ceiling between 500 to below 1,000 feet agl and/or visibility 1 to less than 3 miles.
- Marginal Visual Flight Rules (MVFR**) – ceiling from 1,000 to 3,000 feet agl and/or visibility 3 to 5 miles.
- Visual Flight Rules (VFR) – ceiling greater 3,000 feet agl and visibility greater than 5 miles.

* By definition, IFR is a ceiling less than 1,000 feet agl and/or visibility less than 3 miles while LIFR is a sub-category of IFR.
**By definition, VFR is a ceiling greater than or equal to 3,000 feet agl and visibility greater than 5 miles while MVFR is a sub-category of VFR.

VFR *METAR KJWY 061635Z AUTO 19015G21KT 10SM SCT030 31/24 A2998 RMK AO2 T03110236=*

Accident 1648Z

VFR *METAR KJWY 061655Z AUTO 18015G20KT 10SM SCT030 32/24 A2997 RMK AO2 T03160241=*

2.2 Hillsboro Municipal Airport (KINJ), Hillsboro, Texas

The next closest weather reporting location was from Hillsboro Municipal Airport (KINJ) located 14 miles southwest of the accident site at an elevation of 686 feet. The airport had an AWOS and reporting the following conditions near the time of the accident:

Hillsboro Municipal Airport weather at 1156 CDT, automated, wind from 170° at 14 knots gusting to 22 knots, visibility 10 statute miles, scattered clouds at 3,400 feet agl, temperature 31° C, dew point temperature 23° C, altimeter 29.97 inches of Hg. Remarks: automated observation system with a precipitation sensor.

The calculated relative humidity was 61% with a density altitude of 3,006 feet. The raw observations and general flight categories surrounding the period were as follows, and indicated the highest wind gust of 24 knots immediately prior to the accident:

MVFR *METAR KINJ 061256Z AUTO 18014G19KT 10SM BKN018 26/23 A2997 RMK AO2=*

VFR *METAR KINJ 061316Z AUTO 18018G23KT 10SM SCT018 26/23 A2997 RMK AO2=*

VFR *METAR KINJ 061336Z AUTO 18017G23KT 10SM SCT018 27/23 A2998 RMK AO2=*

MVFR *METAR KINJ 061356Z AUTO 19018G21KT 10SM BKN020 27/23 A2999 RMK AO2=*

MVFR *METAR KINJ 061416Z AUTO 20014G22KT 10SM BKN022 28/23 A3000 RMK AO2=*

MVFR *METAR KINJ 061436Z AUTO 19018G22KT 10SM BKN022 28/23 A2999 RMK AO2=*

VFR *METAR KINJ 061517Z AUTO 18019G24KT 10SM SCT024 29/23 A2998 RMK AO2=*

VFR *METAR KINJ 061537Z AUTO 18019KT 10SM SCT026 29/23 A2998 RMK AO2=*

VFR *METAR KINJ 061557Z AUTO 18014G24KT 10SM SCT028 30/23 A2998 RMK AO2=*

VFR *METAR KINJ 061617Z AUTO 18018G24KT 10SM SCT030 31/23 A2998 RMK AO2=*

VFR *METAR KINJ 061636Z AUTO 19016G22KT 10SM SCT030 31/23 A2998 RMK AO2=*

Accident 1648Z

VFR *METAR KINJ 061656Z AUTO 17014G22KT 10SM SCT034 31/23 A2997 RMK AO2=*

2.3 Arlington Municipal Airport (KGKY), Arlington, Texas

The helicopter departure from Arlington Municipal Airport (KGKY), Dallas, Texas at approximately 1030 CDT, which is located approximately 26 miles north-northwest of the accident site. The airport lists an elevation of 628 feet and had a federally installed and maintained Automated Surface Observation System (ASOS). The following conditions were reported at the time of departure and at the approximate time of the accident:

Arlington Municipal Airport special weather observation at 1015 CDT, wind from 190° at 13 knots gusting to 18 knots, visibility 10 statute miles, scattered clouds at 2,500 feet agl, temperature 29° C, dew point temperature 23° C, altimeter 29.96 inches of Hg. Remarks: automated observation system with a precipitation sensor, temperature 29.4° C, dew point 22.8° C.

Arlington Municipal Airport weather observation at 1153 CDT, wind from 160° at 13 knots gusting to 22 knots, visibility 10 statute miles, a few clouds at 3,400 feet agl, temperature 32° C, dew point temperature 23° C, altimeter 29.95 inches of Hg. Remarks: automated observation system with a precipitation sensor, sea level pressure 1013.1-hPa, temperature 32.2° C, dew point 22.8° C.

At the time of departure the density altitude was calculated at 3,070 feet, with a station pressure of 29.29 inches of Hg, and a relative humidity of 58%. The general flight category and raw observations surrounding the period were as follows, a wind gust to 25 knots was observed prior to departure:

VFR *METAR KGKY 061253Z 17012G17KT 10SM SCT015 26/23 A2995 RMK AO2 SLP131 T02610228=*

MVFR *SPECI KGKY 061305Z 18013G19KT 10SM BKN015 26/23 A2995 RMK AO2 T02610228=*

VFR *SPECI KGKY 061343Z 18011G21KT 10SM SCT017 27/23 A2996 RMK AO2 T02720228=*

VFR *METAR KGKY 061353Z 18011G25KT 10SM FEW019 28/23 A2996 RMK AO2 SLP134 T02780228=*

MVFR *SPECI KGKY 061435Z 18011G20KT 10SM BKN023 28/23 A2996 RMK AO2 T02830228=*

MVFR *METAR KGKY 061453Z 17012G19KT 10SM BKN024 29/23 A2996 RMK AO2 SLP134 T02940228 51007=*

VFR *SPECI KGKY 061515Z 19013G18KT 10SM SCT025 29/23 A2996 RMK AO2 T02940228=*

Departure 1530Z

VFR *METAR KGKY 061553Z 17012KT 10SM FEW028 30/23 A2995 RMK AO2 SLP131 T03000228=*

Accident 1648Z

VFR *METAR KGKY 061653Z 16013G22KT 10SM FEW034 32/23 A2995 RMK AO2 SLP130 T03220228=*

VFR METAR KGKY 061753Z 17014G21KT 10SM CLR 33/23 A2994 RMK AO2 SLP127 T03280233 10328 20250 56007=

2.4 Map of Local Area

The regional sectional map over Texas is included as figure 6 depicting the location of the accident site by a red star, and the closest weather reporting locations at Hillsboro (INJ), Mid-Way Regional (JWY), and Arlington (GKY) depicted within a red circle. The accident site is located within an area of relatively level terrain with two towers under 1,000 feet to the southeast between the accident site and the town of Italy, Texas located approximately 4 ½ miles southeast.

A review of the observations over the region depicted on the map up to the time of the accident reported numerous stations reported southerly winds with gusts from 20 to 31 knots over the region.

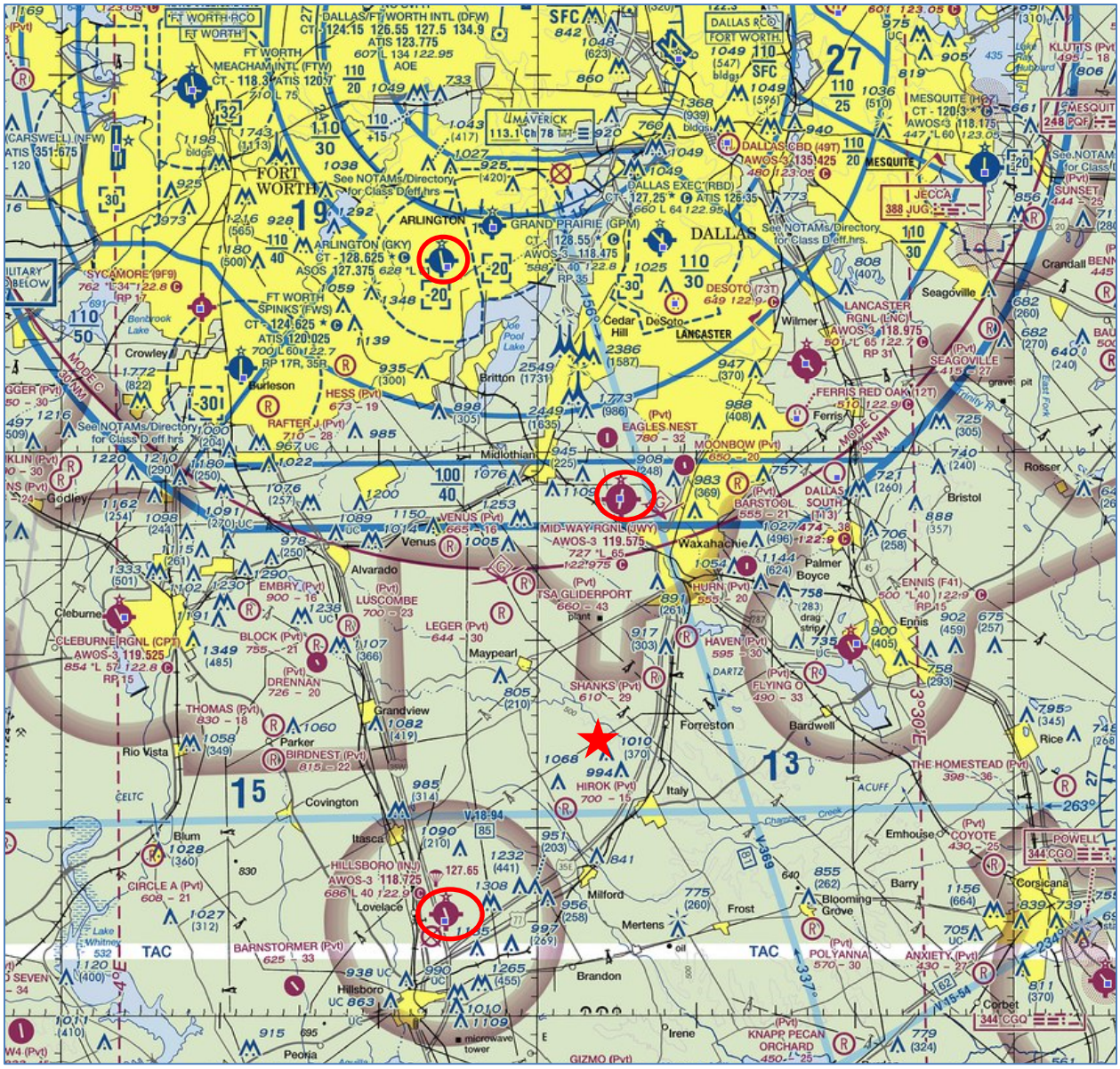

Figure 6 - Sectional map of the local area with accident site marked

3.0 Upper Air Sounding

The closest NWS upper air sounding from Fort Worth (KFTW), station number 72249, was located 40 miles north of the accident. The 0700 CDT (1200Z) observation was plotted on a standard Skew-T log P diagram[5] from the surface to 500-hPa or 18,000 feet utilizing RAOB software[6], and is included as figure 7.

[5] Skew T log P diagram – is a standard meteorological plot or thermodynamic diagram using temperature and the logarithmic of pressure as coordinates, used to display winds, temperature, dew point, and various indices used to define the vertical structure of the atmosphere.

[6] RAOB – (The complete Rawinsonde Observation program) is an interactive sounding analysis program developed

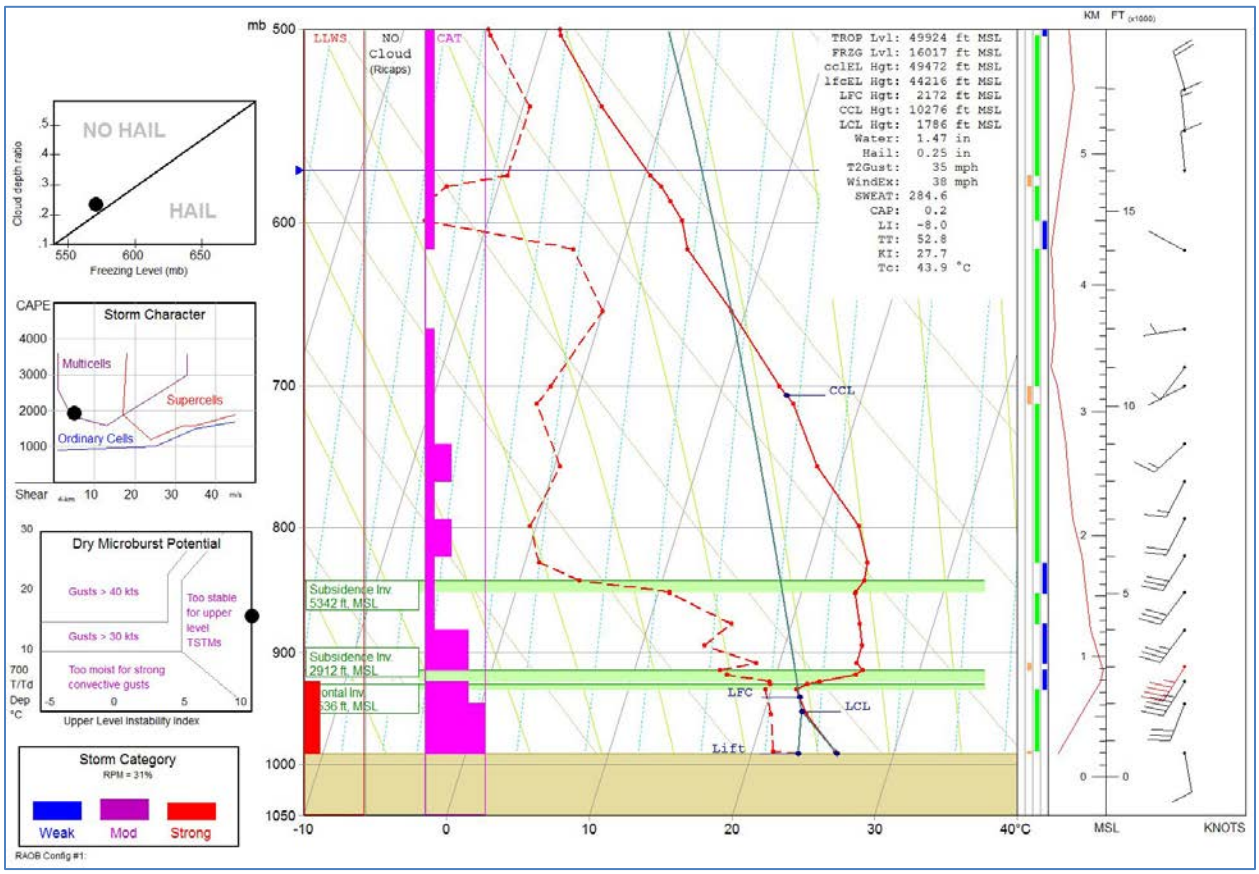

Figure 7 - Fort Worth 0700 CDT sounding plot

The NWS Fort Worth sounding depicted a surface temperature of 26.0° C (78.8° F), a dewpoint temperature of 23.3° C (73.9° F), a relative humidity of 85%, with a density altitude of 2,429 feet to the International Standard Atmosphere (ISA). The lifted condensation level (LCL)[7] was identified at 1,143 feet agl, the level of free convection (LFC)[8] at 1,529 feet agl, and the convective condensation level (CCL)[9] at 9,633 feet agl. A defined frontal and subsidence inversion was noted above the LCL and LFC at 1,893 feet agl (2,536 feet msl) where a low-level jet stream was identified. A second inversion due to subsidence was located above this level at approximately 5,000 feet with winds decreasing in speed above this level. The freezing level was identified at approximately 16,000 feet. The precipitable water value was 1.47 inches.

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by Environmental Research Services, Matamopras, Pennsylvania.

[7] Lifting Condensation Level (LCL) - The height at which a parcel of moist air becomes saturated when it is lifted dry adiabatically.

[8] Level of Free Convection (LFC) -The level at which a parcel of saturated air becomes warmer than the surrounding air and begins to rise freely. This occurs most readily in a conditionally unstable atmosphere.

[9] Convective Condensation Level (CCL) - The height to which a parcel of air, if heated sufficiently from below, will rise adiabatically until condensation starts. This is typically used to identify the base of cumuliform clouds, which are normally produced from surface heating and thermal convection.

The atmosphere was characterized as unstable based on the Lifted Index[10] of -8.0, and the K-Index[11] of 27.7, which indicated a 40% probability of airmass type convection if given a sufficient lifting source. The color coded bar on the right side of the sounding indicates the stability of the layer with green being conditional unstable, and blue stable.

The wind profile indicated surface wind from the 170° at 8 knots with winds increasing rapidly above the surface and the low-level temperature inversion, where a low-level jet stream was identified at approximately 2,900 feet with wind from 210° at 45 knots. The low-level wind maximum resulted in a strong vertical wind shear and a high potential for shallow layers capable of producing localized severe turbulence. The greatest shears occurred at approximately 1,700 feet and 2,540 feet msl with a 12.8 KT/1000FT at that time. At the accident helicopters approximate altitude of 2,000 feet msl (density altitude of 4,000 feet) the wind was from 200° at 32 knots.

The observed and derived sounding parameters are provided below in figure 8 with the height, pressure, temperature, dew point temperature, relative humidity, wind direction and speed, and clear air turbulence (CAT), and low-level wind shear (LLWS) potential.

Height (ft-MSL)	Pres (mb)	T (C)	Td (C)	RH (%)	DD/FF (deg/kts)	CAT (FAA)	LLWS
643	990	26.0	23.3	85	170/8		
702	988	25.8	21.5	77			
1713	954	23.0	20.5	86		XTR	LIGHT
2000	944				200/32		
2382	932	21.8	19.6	87			
2536	927	22.4	19.8	85		SVR	LIGHT
2598	925	23.2	19.7	81	210/43		
2786	919	25.6	16.6	58			
2912	915	26.0	16.0	54	210/45		
3102	909	25.4	18.4	65			
3583	894	25.4	14.4	51		SVR	
4000	881				215/35		
4170	876	24.8	15.8	57			
5003	851	23.8	10.8	44		LGT	
5037	850	23.8	10.8	44	215/31		
5342	841	24.2	4.2	27			
5823	827	24.0	1.0	22		LGT	
6000	822				210/28		

Figure 8 - Sounding observed and derived parameters

[10] Lifted Index (LI) - A common measure of atmospheric instability. Its value is obtained by computing the temperature that air near the ground would have if it were lifted to 500-hPa or approximately 18,000 feet and comparing that temperature to the actual temperature at that level. Negative values indicate instability - the more negative, the more unstable the air is, and the stronger the updrafts are likely to be with any developing thunderstorms.

[11] K-Index - The measure of thunderstorm potential based on the vertical temperature lapse rate, the moisture content of the lower atmosphere and the vertical extent of the moist layer. The higher the K-Index value the greater the probability of air mass type thunderstorm development across the region.

4.0 Aircraft Sounding

The NWS Aircraft Meteorological Data Relay (AMDAR) database was also reviewed for any instrumented aircraft operating in the vicinity surround the period that could provide additional information on the wind environment near the time of the accident. Figure 9 is an aircraft identified as #5011 departed from Dallas Love Field (KDAL) approximately 37 miles north of the accident site at 1128 CDT (1628Z), which provided an updated temperature and wind profile over the region near the time of the accident. The heights are based on pressure altitude from the aircraft. The surface or 680 feet conditions indicated a temperature of 29.6° C, with winds from 193° at 7 knots. A defined temperature inversion was noted between 3,350 to 4,960 feet, with a low level wind maximum at the top of the inversion from 225° at 25 knots.

Another ascent sounding was obtained from an aircraft #8470 departing from Dallas Love Field at 1151 CDT (1651Z) and is included as figure 10. That aircraft also reported a defined temperature inversion from 3,230 to 4,390 feet with a wind maximum at the top of the inversion from 230° at 33 knots. The near surface conditions at 500 feet indicated at temperature of 31.0° C and a wind from 220° at 11 knots.

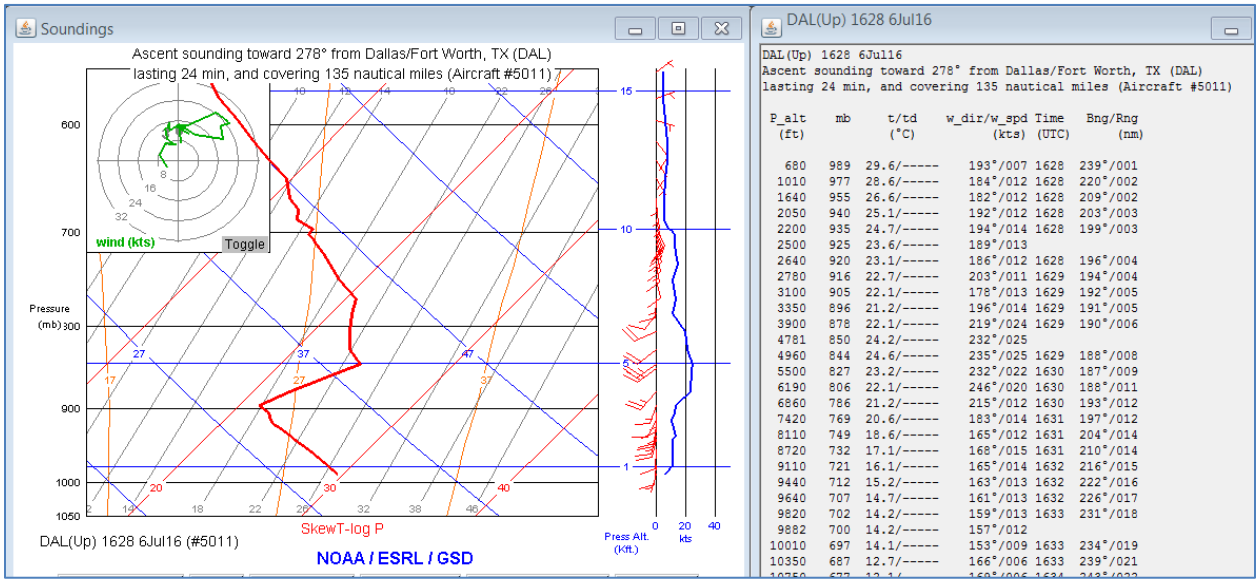

Figure 9 – Aircraft #5011 ascent sounding from Dallas Love Field at 1128 CDT

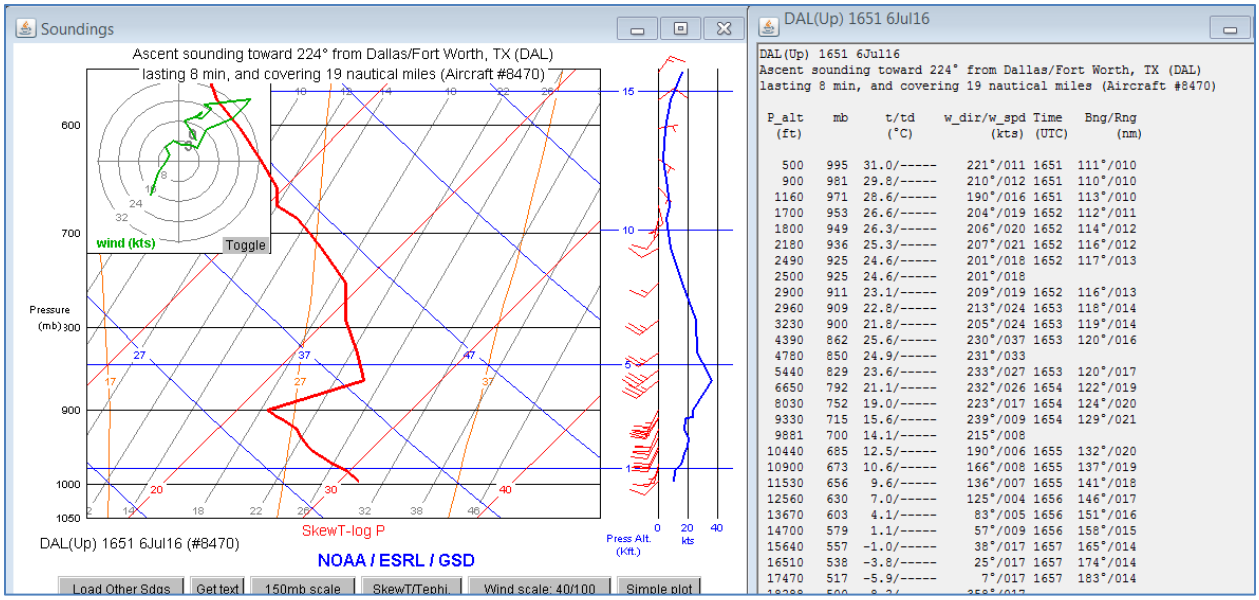

Figure 10 - Aircraft #8470 ascent sounding from Dallas Love Field at 1151 CDT

5.0 Satellite Imagery

The Geostationary Operational Environmental Satellite number 13 (GOES-13) data was obtained from an archive at the Space Science Engineering Center (SSEC) at the University of Wisconsin-Madison in Madison, Wisconsin, and processed using the Man-computer Interactive Data Access System (McIDAS) software. Both the infrared long wave and visible band imagery were obtained surrounding the time of the accident and reviewed, with the visible imagery being documented below due to the lack of any significant cloud features. The visible imagery (band 1) at a wavelength of 0.65 µm provided a resolution of 1 km.

Figure 11 is the GOES-13 visible image at 1145 CDT at 2X magnification with the accident site marked by the red square. The area is characterized as having thin scattered to broken fair weather cumulus clouds over the region with little or no vertical development, with several cloud streets[12] oriented with the low-level wind flow noted to the east and southeast of the accident site. No defined towering cumulus, cumulonimbus clouds, or outflow boundaries are identified immediately in the immediate vicinity of the accident site, with the nearest towering cumulus clouds to the northwest and north near the Oklahoma border, where some vertical development is noted in the clouds.

[12] Cloud street – or horizontal roll vortices are counter-rotating air that are parallel to the ground and appear as rows of cumulus clouds aligned parallel to the low-level wind.

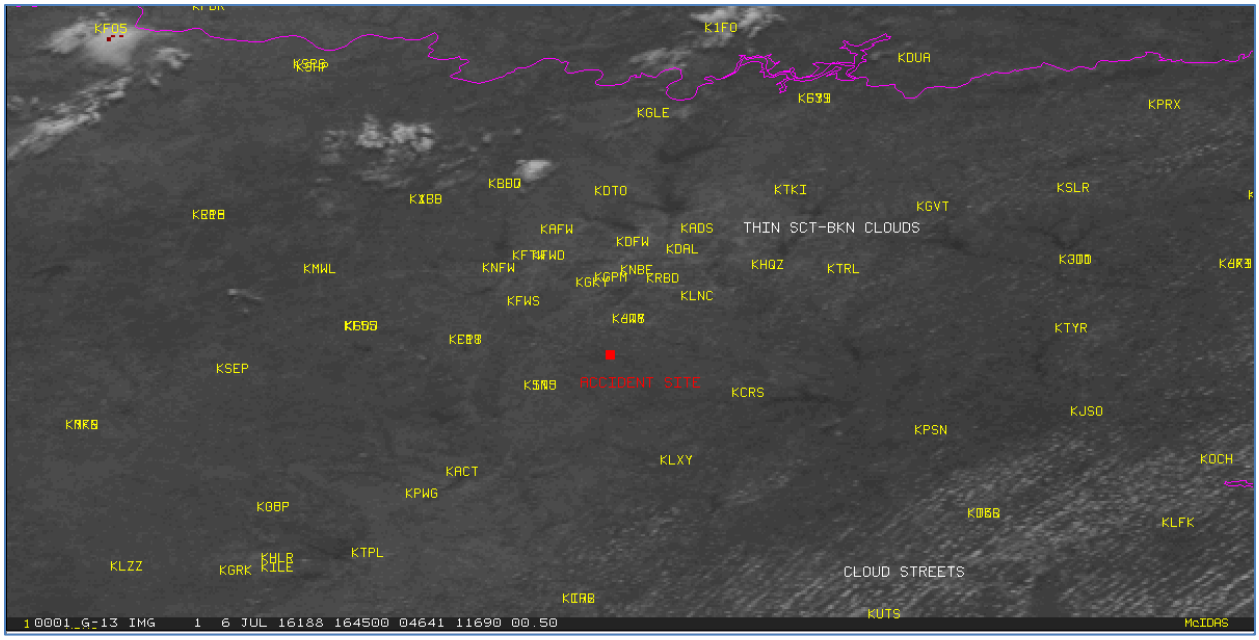

Figure 11 - GOES-13 visible satellite image at 1145 CDT

6.0 Weather Radar Data

The NWS Fort Worth (KFWS) Weather Surveillance Radar-1988, Doppler (WSR-88D) located 28 miles northwest of the accident site data was reviewed for conditions in the vicinity of the accident with the absence of any significant weather echoes. The level II and III archive data was obtained from the NWS NCEI utilizing the Hierarchical Data Storage System (HDSS) and displayed using the NWS NEXRAD Interactive Viewer and Data Exporter and GR2 software programs.

The WSR-88D is a S-band 10 centimeter wavelength radar with a power output of 750,000 watts, with a 28-foot parabolic antenna concentrating the energy into a 0.95° beam width. The radar produces three basic types of products reflectivity, radial velocity, and spectral width. During the period the KFWS WSR-88D was operating in the clear air mode (VCP-32) updating every 10 minutes.

Figure 12 is the KFWS WSR-88D 0.5° base reflectivity image at approximately 1152 CDT (1652Z) with the approximate accident site marked by the red star. The WSR-88D detected several small single very light reflectivity echoes of 20 dBZ or less in the immediate vicinity of the radar site, with the echoes oriented parallel to the low-level wind field or in cloud streets as identified in the satellite imagery. Several small echoes of 19 dBZ were identified 3 miles west of the accident site, with no echoes identified over the accident site. No outflow boundaries or defined echoes associated with any rain showers or thunderstorms were detected over the area.

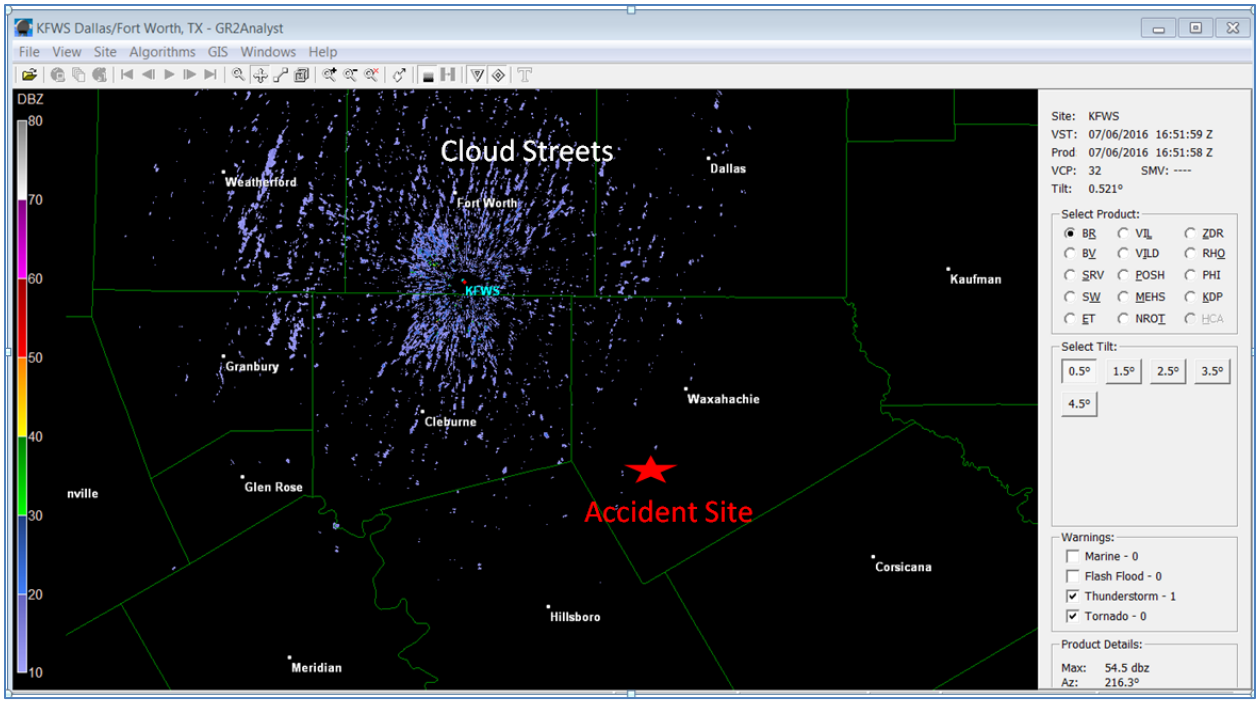

Figure 12 –Dallas/Fort Worth WSR-88D 0.5° base reflectivity image at 1152 CDT

One of the secondary products generated is the Vertical Azimuth Display (VAD) Wind Profile commonly abbreviated VWP, which can provide a real time wind profile close to the radar. Figure 13 is a VWP of the winds from 1016 through 1156 CDT at 10 minute intervals. At the approximate time of the accident the maximum wind was identified at 6,000 feet with a wind from 211° at 29 knots, with the wind at 2,000 feet from the south at 20 knots at the time of the accident.

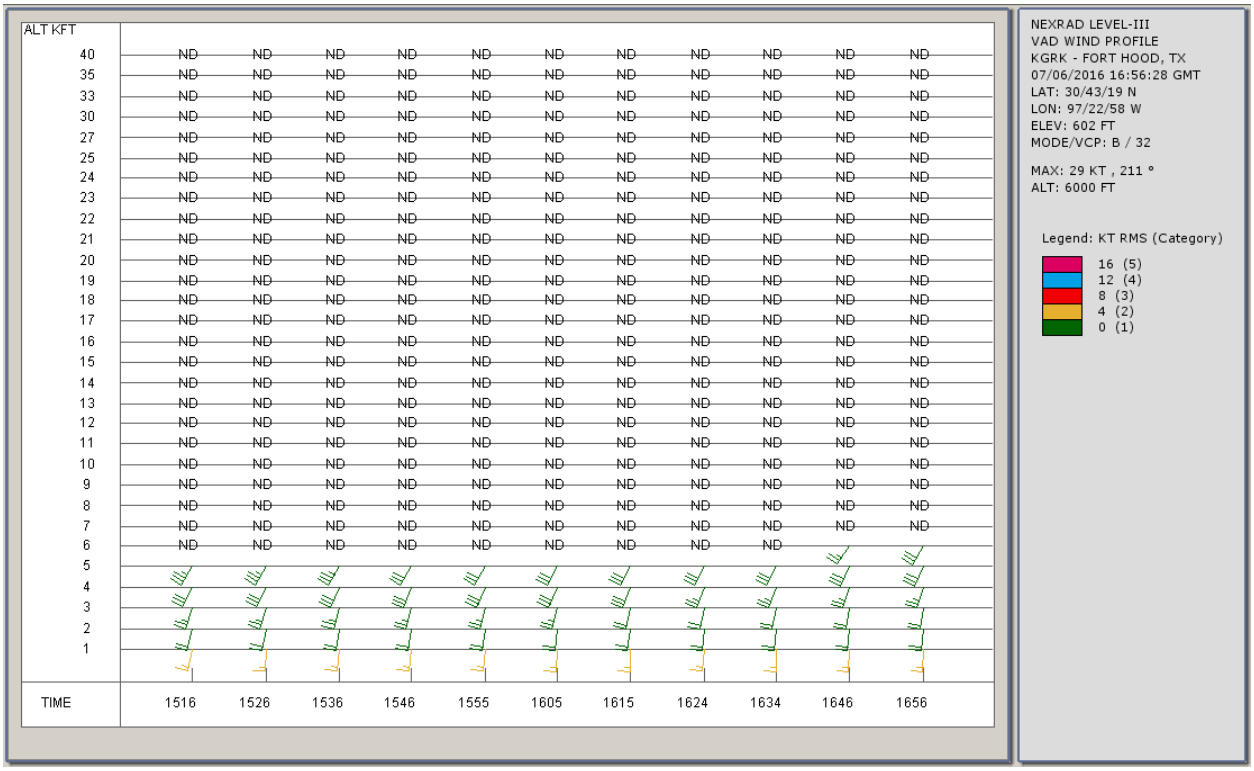

Figure 13 - Dallas/Fort Worth WSR-88D Vertical Azimuth Display (VAD) Wind Profile

7.0 Pilot Reports

The following pilot reports or PIREPs were collected in the immediate area surrounding the time of the accident. The reports are taken from standard code and abbreviations, with the time concerted to local time and are as follows:

Dallas-Fort Worth International Airport (DFW) routine pilot report (UA); over – location 3 miles south of DFW; Time – 0657 CDT; Flight level – 2,000 feet; Type aircraft – Airbus A-319 air carrier jet; Sky conditions – broken.

Dallas Love Field (DAL) routine pilot report (UA); Over – 4 miles northwest of DAL; Time – 0700 CDT; Flight level – 1,800 feet; Type aircraft – Boeing 737 air carrier jet; Sky cover – scattered clouds at 1,800 to 2,000 feet; Temperature – 26° C; Wind – from 195° at 35 knots.

David Wayne Hook Memorial Airport (DWH), Houston routine pilot report (UA); Over – 1 mile north of DWH; Time – 0855 CDT; Flight level – 300 feet; Type aircraft – Embraer Phenom 300 business jet; Wind – 15 knot gain in airspeed.

David Wayne Hook Memorial Airport (DWH) routine pilot report (UA); Over – 1 mile north of DWH; Time – 0858 CDT; Flight level – 300 feet; Type aircraft – Cessna 172 Skyhawk light single engine airplane; Wind – 15 knot gain in airspeed.

David Wayne Hook Memorial Airport (DWH), Houston routine pilot report (UA); Over – DWH; Time – 0921 CDT; Flight level – landed; Type aircraft – Cessna 172 Skyhawk light single engine airplane; Wind – encountered 10 knot gain in airspeed on short final.

Dallas-Fort Worth International Airport (DFW) routine pilot report (UA); over – location 2 miles south of DFW; Time – 0937 CDT; Flight level – 2,500 feet; Type aircraft – Boeing 767 air carrier jet; Sky conditions – thin broken clouds with tops at 3,100 feet.

Austin-Bergstrom International Airport (AUS) routine pilot report (UA); over – location 6 miles west of Centex VORTAC; Time – 1108 CDT; Flight level – 3,600 feet; Type aircraft – Boeing 737 air carrier jet; Turbulence – moderate turbulence from 3,600 to 3,100 feet during descent.

8.0 Terminal Aerodrome Forecast

The closest Terminal Aerodrome Forecast (TAF) to the accident site and available for preflight planning was issued for the departure Arlington Municipal Airport at 0751 CDT and was an amended forecast. The forecast was as follows:

TAF AMD KGKY 061251Z 0613/0712 17013G23KT P6SM FEW025 SCT250
FM061800 19017G27KT P6SM FEW045 SCT180
FM070000 18014KT P6SM SCT150=

The forecast expected VFR conditions to prevail with winds from 170° sustained at 13 knots with gusts to 23 knots, visibility better than 6 miles, with a few clouds at 2,500 feet agl and scattered clouds at 25,000 feet. After 1300 CDT the winds were expected to increase from 190° at 17 knots gusting to 27 knots, with a few clouds at 4,500 feet, and scattered clouds at 18,000 feet. There was no mention of any low-level wind shear in the forecast.

The forecast was amended again within the hour of the accident at 1008 CDT, with slight modification to the wind and cloud heights. The forecast continued to expect VFR conditions with wind from 190° at 17 knots gusting to 27 knots, and was as follows:

TAF AMD KGKY 061508Z 0615/0712 19017G27KT P6SM SCT030
FM070000 18014KT P6SM SCT150=

9.0 Area Forecast Discussion

The NWS Dallas/Fort Worth, Texas Weather Forecast Office was responsible for the issuance of the Arlington TAF. The Area Forecast Discussion issued at 0700 CDT describing the conditions influencing the area and the reasoning behind the forecast was as follows:

Area Forecast Discussion...UPDATED
National Weather Service Fort Worth TX
700 AM CDT WED JUL 6 2016
.AVIATION...
12 UTC TAF cycle
Concerns...MVFR cigs at Waco on Wednesday. VFR elsewhere with breezy southerly winds. Potential for MVFR cigs Thursday morning. For the Metroplex TAF sites...VFR conditions should prevail through the afternoon hours. The tight surface pressure gradient combined with boundary layer mixing should foster

sustained winds of 15-18 kt with gusts to near 27-28 kt across all Metroplex TAF sites. *Wind speeds should subside after sunset, though speeds are expected to remain near 10-12 kt overnight into Thursday morning. Some model guidance does hint that MVFR cigs will be possible Thursday morning, but stratus climatology suggest that it's unlikely to occur this far to the north and west. As a result, will keep the all Metroplex TAF sites VFR through the entire TAF cycle, but will keep close monitor on the latest model guidance, especially if rapid moisture transport to the north is forecast by the general model consensus.*

.

For the Waco TAF site...MVFR ceilings have just grazed the Waco TAF site over the last 1-2 hours. Daytime heating, combined with a veering low level jet should result in the erosion of the stratus deck across Central TX in just a few hours. Breezy southerly winds are also expected at the Waco TAF site through the afternoon hours before relaxing towards sunset. Additional low level moisture should stream northward with the onset of the low level jet Thursday morning. This combined with a bit of a persistence forecast yields sufficiently high confidence for inclusion of stratus around FL025 Thursday morning at the Waco TAF site for a few hours. Bain

10.0 Area Forecast

The NWS Area Forecast issued at 0445 CDT for the Dallas Fort Worth regional forecast area and valid until 1700 CDT was as follows:

DFWC FA 060945
SYNOPSIS AND VFR CLDS/WX
SYNOPSIS VALID UNTIL 070400
CLDS/WX VALID UNTIL 062200...OTLK VALID 062200-070400
OK TX AR TN LA MS AL
.
SEE AIRMET SIERRA FOR IFR CONDS AND MTN OBSCN.
TS IMPLY SEV OR GTR TURB SEV ICE LLWS AND IFR CONDS.
NON MSL HGTS DENOTED BY AGL OR CIG.
.
SYNOPSIS...SUBTRPCL RDG LIES OVR THE ERN GLFMEX THRU FL WITH LTL CHG EXP. S-SW LOV LVL FLOW WL COVER MUCH OF THE FA AREA. WK LOW IS OVR SW KS WITH TROF TO NW TX. LTL CHG EXP.
.
NWRN TX
SCT CI. 16Z WND SWLY G25KT. OTLK...VFR.
.
SWRN TX
SCT CI. 20Z OCNL SCT070. ISOL -TSRA OVR THE MTNS. CB TOPS FL400.OTLK...VFR.
.
N CNTRL TX
SCT CI. 16Z OCNL SCT050. WND S/SW G25KT. OTLK...VFR.
.
NERN TX
BKN015-020 TOPS 040. 16Z SCT040. OTLK...VFR.
.
SERN TX
SCT-BKN015-025 TOPS 040. 15Z SCT040. OTLK...VFR.
.
S CNTRL TX
NRN SXNS...BKN-OVC015-020 TOPS 040. 16Z SCT040. OTLK...VFR.
SRN SXNS...SCT-BKN020-025 TOPS 040. 15Z SCT040. OTLK...VFR.
.

The forecast for northcentral Texas was for high cirriform clouds with occasional scattered clouds at 5,000 feet msl after 1100 CDT with wind from the south to southwest gusting to 25 knots.

11.0 In-Flight weather Advisories

In-flight Aviation Weather Advisories are forecasts to advise en route aircraft of development of potentially hazardous weather. All inflight aviation weather advisories in the conterminous U.S. are issued by the Aviation Weather Center (AWC) in Kansas City, Missouri, or by the 20 Center Weather Service Units. There are four types of inflight weather advisories: the Significant Meteorological Information (SIGMET), the Convective SIGMET, the Airmen's Meteorological Information (AIRMET), and the Center Weather Advisory (CWA).

The Severe Weather Watch Bulletins (WWs) with the associated Alert Message (AWW) supplement these Inflight Aviation Weather Advisories.

Prior to the accident the only NWS advisories applicable to the area was AIRMET Tango update 1 issued at 0345 CDT and was valid until 1000 CDT. The advisory warned of the potential for low-level wind shear over the region, with conditions ending between 0700 to 1000 CDT. A graphic plot of the advisory is included as figure 14 with the text bulletin following. The AIRMET was not reissued after the time of cancelation of 1000 CDT, and the next issuance of AIRMET Tango update 2 removed the hazard.

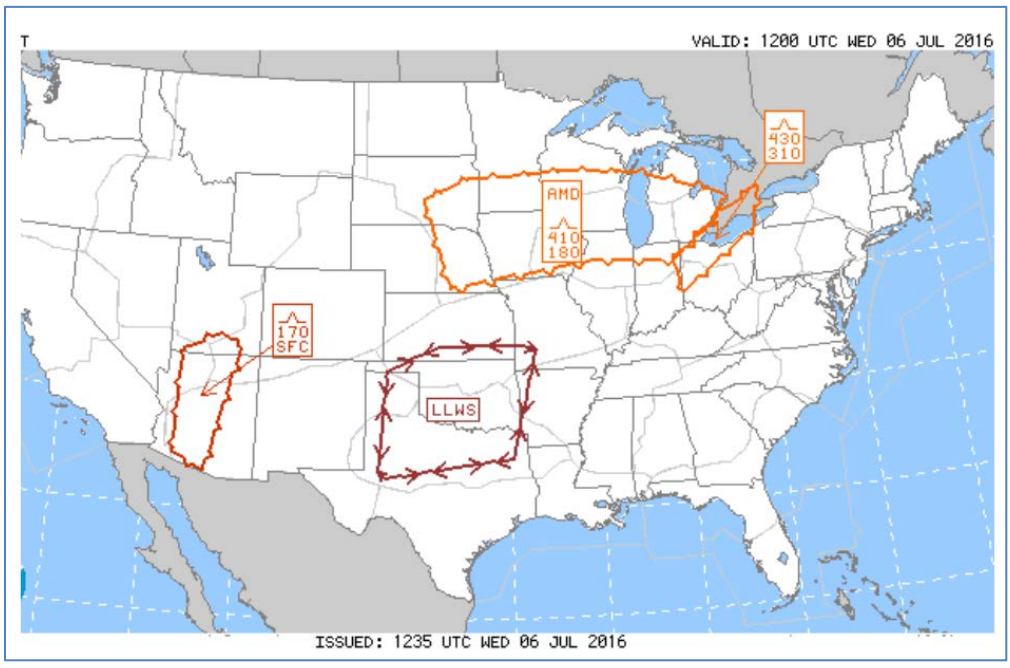

Figure 14 - G-AIRMET Tango for turbulence and low-level wind shear

AIRMET Tango update 1 issued at 0345 CDT and valid until 1000 CDT:

WAUS44 KKCI 060845

WA4T
DFWT WA 060845
AIRMET TANGO UPDT 1 FOR TURB AND LLWS VALID UNTIL 061500
.
NO SGFNT TURB EXP OUTSIDE OF CNVTV ACT.
.
LLWS POTENTIAL...OK TX AR KS MO
BOUNDED BY 60WNW ICT-20N SGF-20SSW GGG-40S MAF-70WSW LBL-60WNW ICT
LLWS EXP. CONDS ENDG 12-15Z.
.

AIRMET Tango update 2 issued at 0945 CDT and valid until 1600 CDT:

WAUS44 KKCI 061445
WA4T
DFWT WA 061445
AIRMET TANGO UPDT 2 FOR TURB VALID UNTIL 062100
.
NO SGFNT TURB EXP OUTSIDE OF CNVTV ACT.
....

There were no Center Weather Advisories or Meteorological Impact Statements issued by the NWS Center Weather Service Unit Meteorologist surrounding the period regarding the low-level wind shear condition.

A general forecasters guide to turbulence used by the NWS is expect light turbulence within 5,000 feet of the surface with winds of 15 knots or greater, and moderate with surface winds of 30 knots or more. Based on the observations over the region prior to the accident, light turbulence could be expected. However, the NWS does not issue advisories for light intensity conditions but only for moderate and greater conditions.

12.0 Winds and Temperature Aloft Forecast

The NWS Winds and Temperature Aloft forecast current at the time was issued at 0903 CDT and valid for 1300 CDT, and for use between 0900 and 1600 CDT. The forecast was as follows:

FBUS31 KWNO 061403
FD1US1
DATA BASED ON 061200Z
VALID 061800Z FOR USE 1400-2100Z. TEMPS NEG ABV 24000

FT	*3000*	*6000*	*9000*	*12000*	*18000*	*24000*	*30000*	*34000*	*39000*
DAL	*1919*	*2223+23*	*1814+17*	*1809+10*	*0106-08*	*3405-16*	*291434*	*261743*	*241753*
CLL	*1921*	*2027+20*	*2118+15*	*2108+09*	*9900-08*	*2506-17*	*320732*	*300842*	*281053*
HOU	*1817*	*2020+18*	*1917+14*	*1909+08*	*2406-07*	*2606-18*	*990032*	*020542*	*011053*
ABI		*2319+26*	*2208+20*	*2107+12*	*9900-08*	*2510-17*	*301534*	*322243*	*322352*

13.0 Reference Material Regarding Cloud Streets and Horizontal Roll Vortices

The satellite and weather radar imagery both depicted the existence of low level cloud streets over the region at the time of the accident. Cloud streets are a sign of organized convection, and are formed by counter-rotating horizontal vortex rolls that are nearly aligned with the mean wind in the low–level boundary layer. The clouds are formed by alternating horizontal vortices or rising and sinking air as illustrated in figure 15.

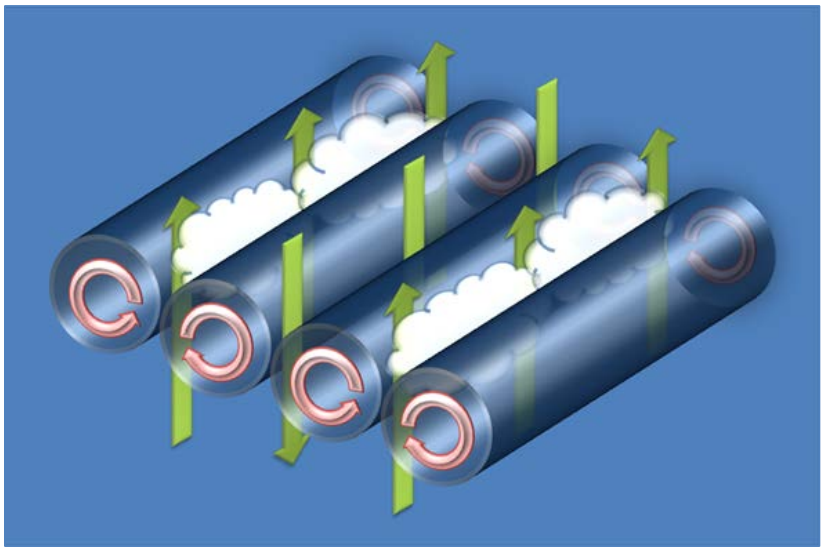

Figure 15 - Horizontal Convective Rolls

The conditions favorable for formation include a moderate low-level wind flow, an unstable layer of air that is capped by a temperature inversion. A relative strong low-level vertical shear is commonly found within the lowest layer and the top of the inversion. With sufficient moisture present, the rising air saturates to create the low cumulus clouds below the inversion, with the sinking air between the vortices evaporating the moisture and creating a clear zone, with the next vortex producing a parallel roll of cloud. The parallel row of clouds which typically extend downstream and form parallel to the low-level wind field. The spacing of the cloud streets is typically 3 times the height of the inversion height as indicated in figure 16.

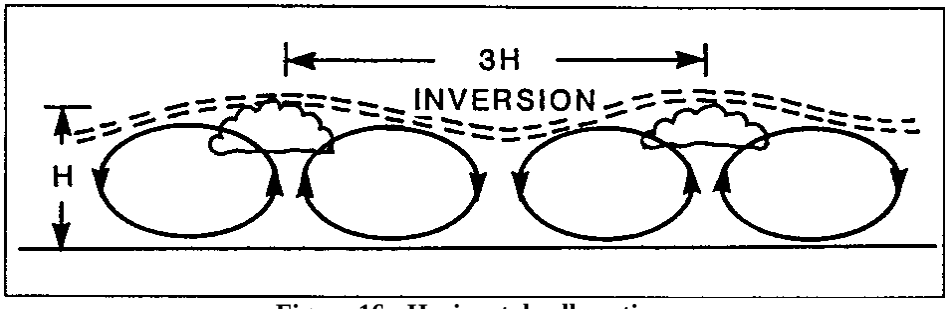

Figure 16 - Horizontal roll vortices

14.0 Witness Statements

A review of the witness interviews indicated that most described the atmospheric conditions as “moderate at best” and varied from “a little bumpy” to “pretty bumpy” or “rough”. The pilot of the chase helicopter describing the conditions with winds of 15 to 20 knots, and “a bit choppy”, and further clarified as conditions as light chop. They also reported that at the first time of the 175 Knot flight test the flight called “knock-it-off” due to encountering a thermal or choppy turbulence conditions, it was the second attempt when the accident occurred.

Submitted by:

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Don Eick
Senior Meteorologist