



## **NATIONAL TRANSPORTATION SAFETY BOARD**

Office of Aviation Safety  
Washington, D.C. 20594

July 17, 2020

### **Weather Study**

# **METEOROLOGY**

DCA20CA038

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## **A. ACCIDENT**

Location: near Alexandria, Louisiana  
Date: December 16, 2019  
Time: About 1323 central standard time  
1923 Universal Coordinated Time (UTC)  
Aircraft: Envoy Air flight 3960, EMB-135KL; Registration: N805AE

## **B. METEOROLOGIST**

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Meteorology Specialist  
Operational Factors Division (AS-30)  
National Transportation Safety Board

## **C. SUMMARY**

On December 16, 2019 at about 1323 CST, Envoy Airlines flight 3960, EMB140, N805AE, enroute from Dallas-Ft Worth International Airport (KDFW), Dallas, Texas, to Gainesville Regional Airport (KGNV), Gainesville, Florida encountered severe turbulence and a passenger was seriously injured. Flight was operating as a 14 *Code of Federal Regulations* Part 121 flight that departed at 1231 local and landed 1542 local.

## **D. DETAILS OF THE INVESTIGATION**

The National Transportation Safety Board's 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 standard time (CST) based upon the 24-hour clock, local time is -6 hours from UTC, and UTC=Z. NWS airport and station identifiers use the standard International Civil Aviation Organization 4-letter station identifiers versus the International Air Transport Association 3-letter identifiers, which deletes the initial country code designator "K" for U.S. airports. Directions are referenced to true north and distances in nautical miles. Heights are in feet (ft) above mean sea level (msl) unless otherwise noted. Visibility is in statute miles and fractions of statute miles.

The turbulence location was identified approximately 15 miles southwest of the Alexandria, Louisiana VORTAC<sup>1</sup>. A review of the aircraft's flight track and altitude deviations indicated that

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<sup>1</sup> A VORTAC is a radio-based navigational aid for aircraft pilots consisting of a co-located VHF omnidirectional range (VOR) beacon for azimuth data and a tactical air navigation system (TACAN) beacon for distance. Unless otherwise noted the station is typically collocated with the city of the same name.

the turbulence encounter likely occurred at latitude 31.1075° N and longitude 092.7165° W, at an altitude of 37,000 ft (FL370<sup>2</sup>).

## **E. WEATHER INFORMATION**

### **1.0 Synoptic Conditions**

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) and the Weather Prediction Center (WPC) located in College Park, 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 00-45H change 2.

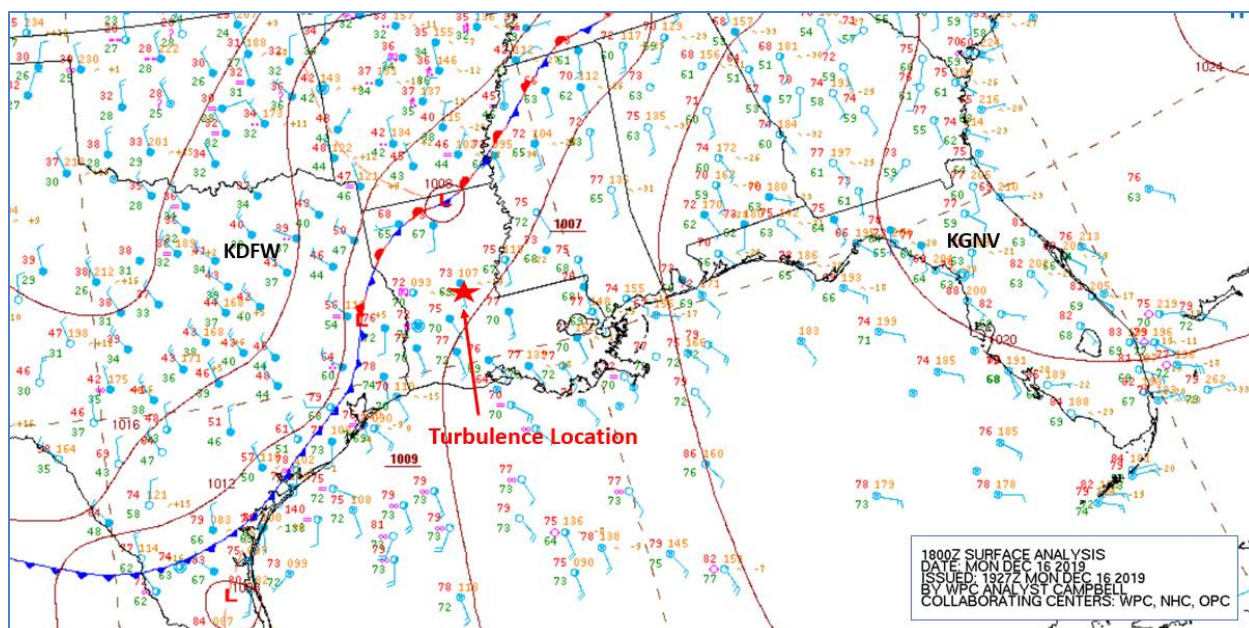
### **1.1 Surface Analysis Chart**

The southcentral section of the NWS high resolution Surface Analysis Chart for 1200 CST is included as figure 1 with the approximate turbulence location indicated by a red star. The chart depicted a low-pressure system at 1007-hectopascals (hPa)<sup>3</sup> over northern Louisiana along a stationary front which extended from Tennessee, northwestern Mississippi, northern Louisiana into eastern Texas. A second low-pressure system at 1009-hPa was located over eastern Texas associated with a frontal wave with a cold front that extended southward from the low into southern Texas. To the east, of the turbulence location, a high pressure ridge extended southwestward over central Florida into the Gulf of Mexico. The turbulence location was located in the warm air sector ahead of the frontal wave in an area with southerly winds of 5 to 15 knots. The area was located in a warm and moist environment associated with a tropical airmass from the Gulf of Mexico.

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<sup>2</sup> Flight Level (FL) –a level of constant atmospheric pressure related to a reference datum of 29.92 inches of mercury. Each is stated in three digits that represent hundreds of feet.

<sup>3</sup> Hectopascals is the new NWS reference for reporting sea level pressure and is interchangeable with the former term millibar (mb) with the same units. Standard sea-level pressure is 1013.25-hPa at 59° Fahrenheit (F) or 15° Celsius (C).



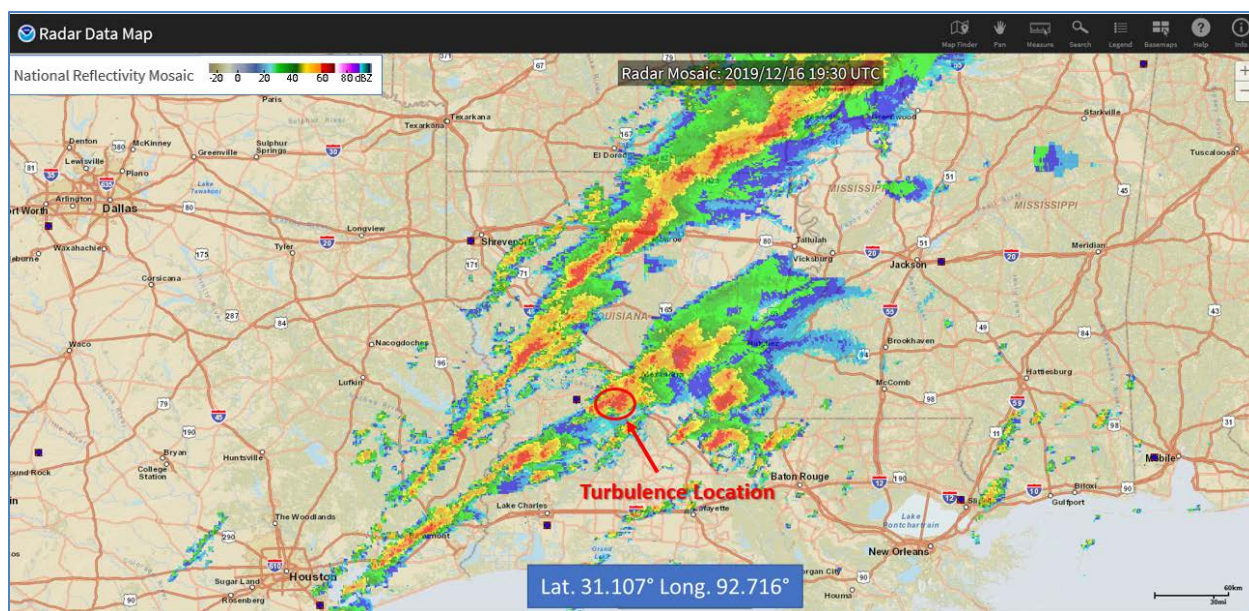
**Figure 1 -Southcentral section of the NWS high resolution Surface Analysis Chart for 1200 CST**

The station models in the immediate vicinity of the turbulence location indicated a temperature of 73° F, a dew point temperature of 68° F, with southerly winds of 5 to 10 knots. Several stations immediately west reported thunderstorms and rain showers. An extensive area of overcast cloud cover was depicted over the area, which extended back behind the front into the KDFW area. A strong temperature gradient was noted over the area with a temperature of 28° F over northern Oklahoma to a temperature of 77° F near New Orleans, immediately southeast of the turbulence location.

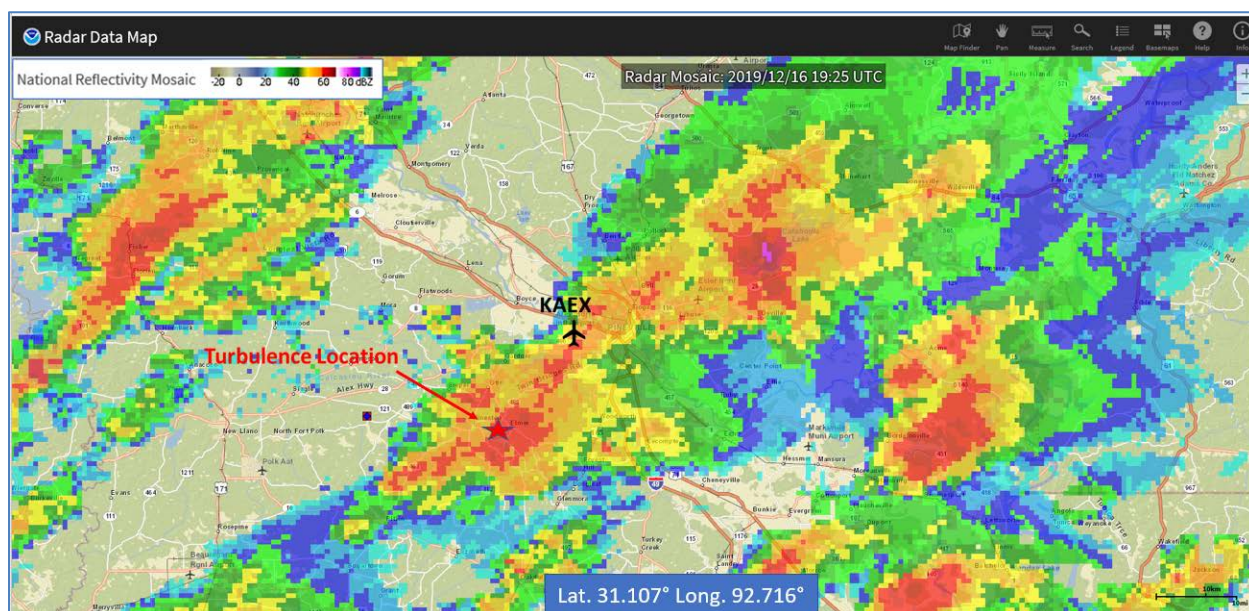
## 1.2 National Composite Radar Mosaic

The National Composite Radar Mosaic obtained from the NWS NCEI archive for 1330 CST for the southcentral United States is included as figure 2 with the approximate turbulence location located within the red circle. The image depicted a band or line of strong convection extending along the general vicinity of the frontal location over northwest Mississippi, into northern Louisiana, into eastern Texas. A second line of extreme intensity echoes extended over central Louisiana in the general vicinity of the turbulence location southwestward to the Houston, Texas area. Several other isolated heavy to extreme echoes were also identified ahead of the line northwest of the Baton Rouge area.

Figure 3 is a close-up of the National Composite Radar Mosaic for 1325 CST with the turbulence location and the closest weather reporting location noted. The turbulence location was within an area of heavy to extreme echoes. Based on the presence of echoes in the vicinity of the turbulence location the closest NWS surveillance weather radar will be documented in detail in section 5.0 of this report.



**Figure 2 - National Composite Radar Mosaic for 1330 CST with the turbulence location within the red circle**



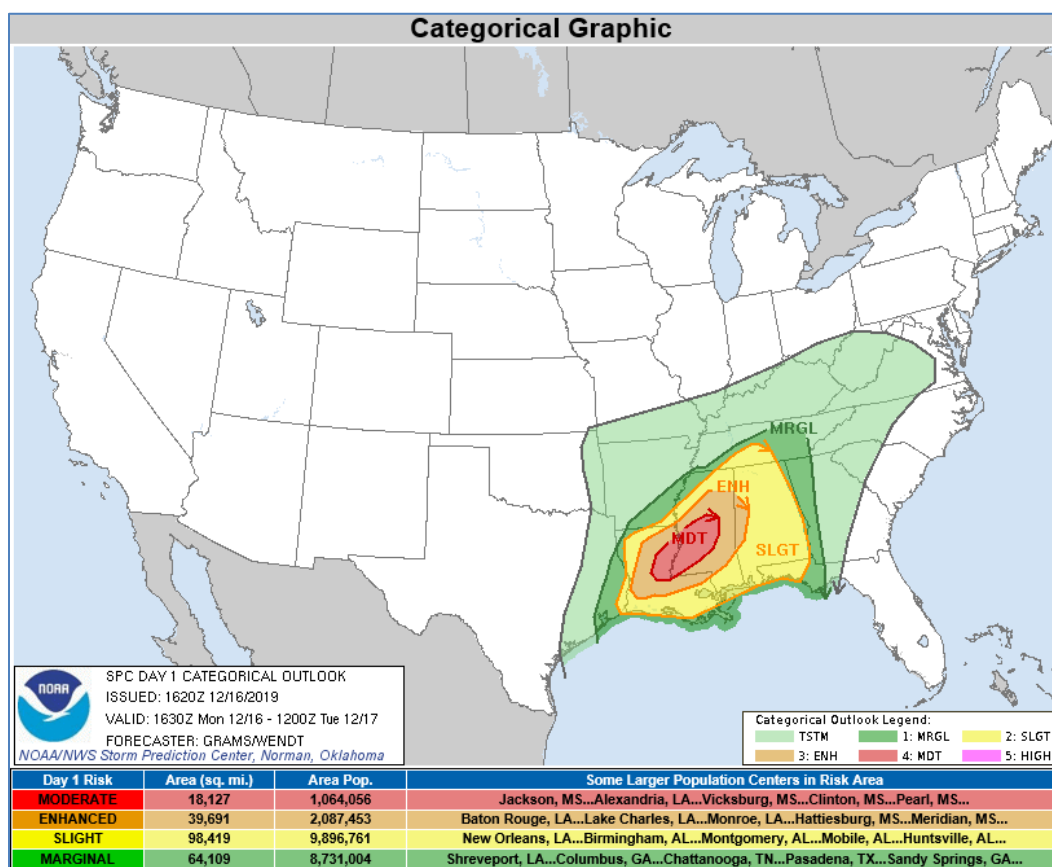
**Figure 3 - Close-up of the National Composite Radar Mosaic for 1325 CST over the turbulence location**

### 1.3 Convective Outlook

The NWS Storm Prediction Center (SPC) is tasked with providing timely and accurate forecasts and watches for severe thunderstorms and tornadoes over the contiguous United States. One of their primary products highlighting the expected areas of organized thunderstorms is the Convective Outlook (AC). The intent of the chart is to identify to users like NWS forecasters, emergency managers, media, dispatchers and pilots where the NWS SPC expects organized

thunderstorms and severe thunderstorms<sup>4</sup> to form. The SPC Convective Outlook current prior to the accident airplanes departure was issued at 1020 CST and is included as figure 4 followed by the text bulletin issued with the graphic. The Day 1 Convective Outlook expected a moderate risk of severe thunderstorms over Louisiana and Mississippi with Alexandria highlighted as one of potential city's impacted by the expected thunderstorms during the period.

The Day 1 Convective Outlook narrative indicated that widespread severe thunderstorms were expected during the period over northern and central Louisiana with tornadoes and damaging winds the primary risks. The outlook indicated that semi-discrete supercell thunderstorms<sup>5</sup> were expected given the stability and wind profiles across the region.



**Figure 4 – NWS Storm Prediction Center's Day 1 Convective Outlook issued at 1020 CST**

SPC AC 161620  
Day 1 Convective Outlook  
NWS Storm Prediction Center Norman OK

<sup>4</sup> A severe thunderstorm is one that produces a tornado, large hail over 1.0 inch in diameter, or outflow winds greater than 50 knots. While all thunderstorms imply the likelihood of severe turbulence, a severe thunderstorm implies a high likelihood of severe to extreme turbulence, wind shear, and a high probability of encountering hail.

<sup>5</sup> Supercell Thunderstorm - Potentially the most dangerous of the convective storm types. Storms possessing this structure have been observed to generate the vast majority of long-lived strong and violent (F2-F5) tornadoes, as well as downburst damage and large hail. It is defined as a thunderstorm consisting of one quasi-steady to rotating updraft which may exist for several hours. Supercells usually move to the right of the mean wind.

1020 AM CST Mon Dec 16 2019

Valid 161630Z - 171200Z

*...THERE IS A MODERATE RISK OF SEVERE THUNDERSTORMS NORTHEAST LA TO CENTRAL MS...*

*...SUMMARY...*

*Numerous to potentially widespread severe thunderstorms are anticipated across parts of the Lower Mississippi Valley and Deep South with tornadoes and damaging winds as the primary hazards. The peak tornado risk is expected through early evening, centered on northern and central Louisiana into central Mississippi.*

*...Lower MS Valley and Deep South...*

*Primary changes this outlook are to increase tornado and wind probabilities across parts of LA/MS. In addition, the SLGT risk has been expanded north for wind into middle TN near the expected surface cyclone track.*

*Gradual expansion of surface-based thunderstorms is expected across the Sabine and Lower MS Valleys, along/ahead of the surface cold front. Activity should grow in coverage and move across the Mid-South and MS/AL regions through this evening into tonight. Several tornadoes will be possible across the entire region, but with greatest potential in a corridor from northern/central LA across central MS where semi-discrete supercells are most probable and should access the most favorable CAPE/shear parameter space. Damaging gusts should be the most common convective event area-wide. Severe hail is most probable over southwestern parts of the outlook area, essentially collocated with greatest tornado probabilities.*

*12Z soundings sampled the pronounced elevated mixed layer overlying the rich low-level moisture plume (characterized by upper 60s to low 70s surface dew points) emanating northeast from the western Gulf. Abundant cloud coverage will be a limiting factor, but moderate surface-based buoyancy characterized by MLCAPE of 1000-2000 J/kg will persist in the ambient environment ahead of the front across LA through parts of MS. Relatively backed surface winds, beneath a 40-60-kt southwesterly LLJ, will contribute to enlarged hodographs and 300+ effective SRH.*

*Given potential for sustained warm-sector supercells, such as progged by the HRRR, HRRR-P and WRF-ARW, such an environment will support a risk for multiple significant tornadoes. Otherwise, regardless of warm-sector convective density, a band of thunderstorms should evolve close to the front and shift across the remainder of the outlook area through the period. This activity will offer a risk for numerous to widespread damaging winds and embedded QLCS tornadoes. It will eventually encounter gradually weaker low-level and mid-level lapse rates and less inflow-layer moisture content with northeast/eastern extent. This should result in a somewhat lesser threat for damaging winds and tornadoes tonight.*

*..Grams/Wendt.. 12/16/2019*

## **1.4 High Level Significant Weather Prognostic Chart**

The NWS NCEP High Level Significant Weather Prognostic Chart valid for 0000Z on December 17, 2019 is included as figure 5. The chart is a forecast of significant en route weather phenomena between FL250 through FL630. The chart depicted three jet streams by a bold green line over the United States during the period: a subtropical jet stream at predominantly at FL400, a polar jet at FL340, and an arctic jet at FL280. The subtropical jet was moving east-northeast along the Texas and Louisiana Gulf Coastal into northern Texas and Georgia with winds averaging 110 knots at

FL410. A polar jet paralleled the subtropical jet across Oklahoma and Arkansas with winds of 120 knots at FL370 with the jet increasing to 160 knots across the Ohio Valley into New York as the jet entered a ridge and turned east-southeast off the east coast. An arctic jet was located over the northern Great Lakes into New England with winds of 180 knots at FL280. The chart depicted an area of moderate clear air turbulence (CAT) by a yellow dashed line over Louisiana northeastward into the Ohio Valley and New England between FL250 and FL410. An area of isolated embedded cumulonimbus<sup>6</sup> was depicted by a red scalloped line extending over Louisiana, Mississippi, and Tennessee between the subtropical and polar jet stream, with tops to FL420. The chart also depicted an upper level low centered over Colorado with the tropopause at FL250, with the tropopause noted over the Gulf of Mexico south the turbulence location near FL500.

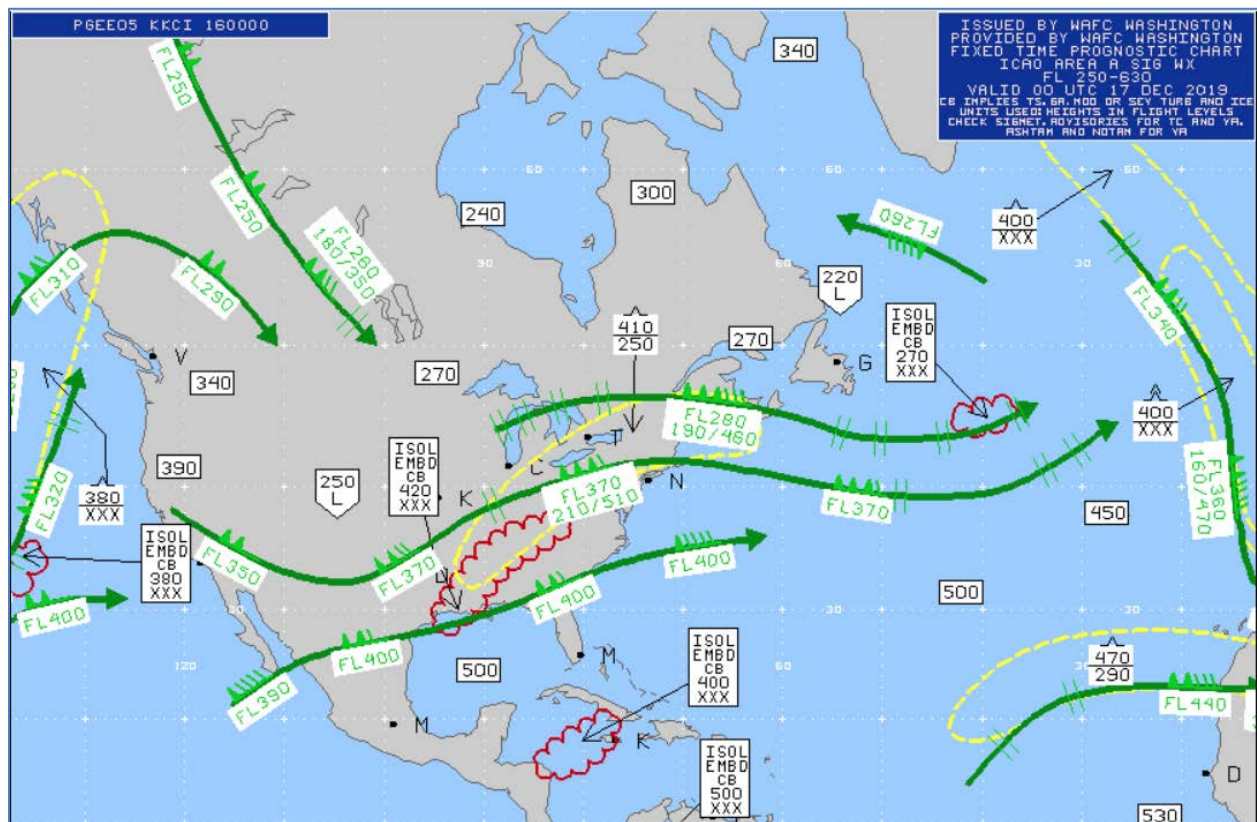


Figure 5 - High Level Significant Weather Prognostic Chart valid for 1800 CST

## 2.0 Surface Observations

The official observations issued surrounding the accident site were documented using standard meteorological aerodrome reports (METARs) and specials (SPECI). Cloud heights are reported above ground level (agl) in the following section, and the magnetic variation was estimated at 3° east based on the latest sectional chart for the area.

<sup>6</sup> Isolated – means coverage less than 4/8<sup>th</sup>. The inclusion of CB shall be understood to include all weather phenomena normally associated with cumulonimbus (i.e. thunderstorm, moderate or severe icing, moderate or severe turbulence, and hail).

## 2.1 Alexandria, Louisiana

The closest weather reporting station to the turbulence location was from Alexandria International Airport (KAEX), Alexandria, Louisiana, located approximately 18 miles north-northeast at an elevation of 86 ft. The airport had a federally installed and maintained Automated Surface Observation System (ASOS) that was augmented by air traffic control personnel. The following conditions were reported immediately surrounding the time of the turbulence encounter.

*Special weather observation for KAEX at 1319 CST, wind from 250° at 17 knots gusting to 22 knots, visibility 1/2 mile in thunderstorm, heavy rain, and fog, ceiling broken at 2,000 ft agl, overcast at 3,400 ft, temperature 19° C, dew point temperature 18° C, altimeter 29.77 inches of mercury (Hg). Remarks: automated station with a precipitation discriminator, peak wind from 260° at 38 knots occurred at 1257 CST, wind shift occurred at 1259 CST, lightning distant<sup>7</sup> all quadrants, pressure falling rapidly<sup>8</sup>, hourly precipitation since 1253 CST 0.74 inches, temperature 18.9° C, dew point 17.8° C.*

### **Turbulence encounter 1323 CST**

*Special weather observation for KAEX at 1341 CST, wind from 210° at 13 knots, visibility 2 miles in thunderstorm, heavy rain, and mist, scattered clouds at 2,100 ft agl, ceiling broken at 4,800 ft agl, overcast at 10,000 ft, temperature 19° C, dew point temperature 19° C, altimeter 29.80 inches of Hg. Remarks: automated station with a precipitation discriminator, peak wind from 260° at 38 knots occurred at 1257 CST, wind shift occurred at 1259 CST, lightning distant all quadrants, hourly precipitation since 1253 CST 1.04 inches, temperature 19.4° C, dew point 18.9° C.*

The general flight categories<sup>9</sup> and raw observations for KAEX from 1153 CST through 1453 CST were as follows:

VFR METAR KAEX 161753Z 16007KT 7SM -RA FEW029 SCT050 OVC095 22/21 A2983 RMK AO2 LTG DSNT SW AND W RAB46 PRESFR SLP102 P0000 60003 T02220206 10228 20200 58026

MVFR SPECI KAEX 161811Z 16009KT 3SM VCTS RA BR FEW055 BKN090 OVC110 22/21 A2982 RMK AO2 LTG DSNT SW AND W P0003 T02170206

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<sup>7</sup> Distant means within 10 to 30 miles from the airport.

<sup>8</sup> Pressure falling rapidly – falling at a rate at least 0.06 inch per hour and the pressure change totals 0.02 inches or more at the time of observation. Rapidly falling pressure is commonly observed during outflow or gust front passages, and near rapidly deepening low pressure systems or mesolows.

<sup>9</sup> As defined by the NWS and the FAA Aeronautical Information Manual (AIM) section 7-1-7 defines the following general flight categories based on weather conditions reported:

- Low Instrument Flight Rules (LIFR\*) – ceiling below 500 ft above ground level (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 ft agl and/or visibility 3 to 5 miles.
- Visual Flight Rules (VFR) – ceiling greater 3,000 ft agl and visibility greater than 5 miles.

\* By definition, IFR is a ceiling less than 1,000 ft 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 ft agl and visibility greater than 5 miles while MVFR is a sub-category of VFR.

**IFR** SPECI KAEX 161819Z 17010KT 1 3/4SM +TSRA BR FEW050 BKN075 OVC090 22/21 A2983 RMK AO2 LTG DSNT S-W TSB13 P0010 T02170206

**MVFR** SPECI KAEX 161836Z 02007KT 3SM TSRA BR FEW035 BKN048 OVC085 21/21 A2979 RMK AO2 LTG DSNT ALQDS TSB13 PRESFR P0023 T02110206

**LIFR** SPECI KAEX 161849Z 24027G43KT 3/4SM +TSRA BR FEW013 BKN029 OVC070 19/17 A2979 RMK AO2 PK WND 25043/1847 LTG DSNT ALQDS TSB13 P0055

**LIFR** METAR KAEX 161853Z 24011G43KT 190V280 1/2SM +TSRA FEW013 BKN024 OVC039 20/16 A2982 RMK AO2 PK WND 25043/1847 WSHFT 1839 LTG DSNT ALQDS TSB13 SLP099 P0067 T02000161

**LIFR** SPECI KAEX 161900Z 25016G38KT 3/4SM +TSRA FEW013 BKN024 OVC039 20/16 A2979 RMK AO2 PK WND 26038/1857 WSHFT 1840 LTG DSNT ALQDS P0022 T02000156

**LIFR** SPECI KAEX 161919Z 25017G22KT 1/2SM +TSRA FG BKN020 OVC034 19/18 A2977 RMK AO2 PK WND 26038/1857 WSHFT 1859 LTG DSNT ALQDS PRESFR P0074 T01890178

**Turbulence encounter 1923Z**

**IFR** SPECI KAEX 161941Z 21013KT 2SM +TSRA BR SCT021 BKN048 OVC100 19/19 A2980 RMK AO2 PK WND 26038/1857 WSHFT 1859 LTG DSNT ALQDS P0104 T01940189

**MVFR** METAR KAEX 161953Z 18008KT 3SM -TSRA BR SCT031 BKN050 OVC090 19/19 A2978 RMK AO2 PK WND 26038/1857 WSHFT 1859 LTG DSNT ALQDS SLP087 P0109 T01940189

**VFR** SPECI KAEX 162007Z 16005KT 10SM -RA SCT037 BKN050 OVC090 20/19 A2976 RMK AO2 LTG DSNT ALQDS TSE01 P0001 T02000189

**VFR** SPECI KAEX 162038Z 21005KT 10SM VCTS -RA FEW022 SCT039 BKN060 21/19 A2977 RMK AO2 LTG DSNT ALQDS TSE01 P0002 T02060189

**VFR** METAR KAEX 162053Z 25005KT 10SM FEW027 SCT100 SCT120 21/19 A2978 RMK AO2 LTG DSNT ALQDS RAE52 TSE01 SLP086 P0002 60178 T02060194 56016

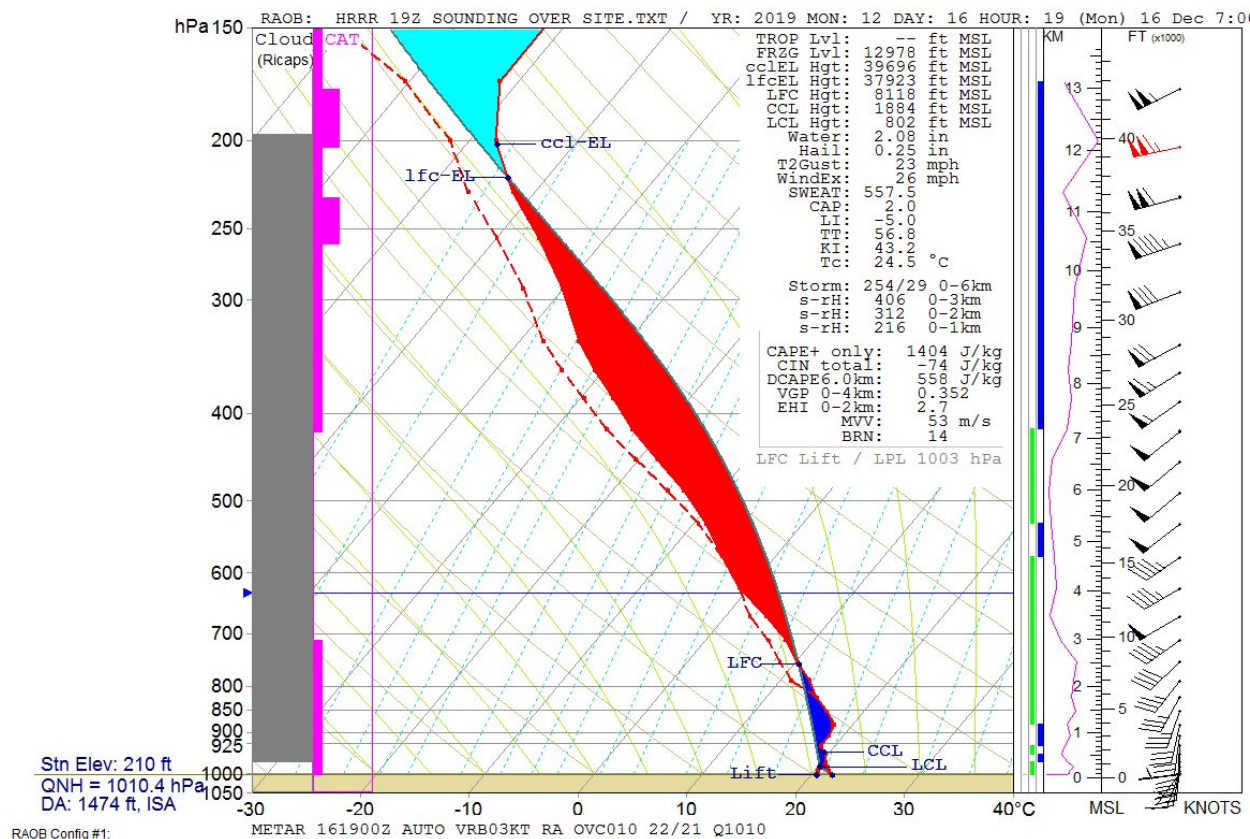
The observations indicated that LIFR to IFR conditions were being reported at KAEX during the period of the turbulence encounter due to thunderstorms and heavy rain. The thunderstorms were associated with strong gusting winds to 43 knots, lightning, with approximately 1.78 inches of rainfall reported during the period from 1153 CST through 1453 CST.

### 3.0 Sounding

To determine the vertical structure and state of the atmosphere over the accident site a High-Resolution Rapid Refresh (HRRR)<sup>10</sup> numerical model data was retrieved from the NOAA Air

<sup>10</sup> The HRRR is a National Oceanic and Atmospheric Administration (NOAA) real-time three-kilometer resolution, hourly-updated, cloud-resolving, convection-allowing atmospheric model, initialized by three-kilometer grids with three-kilometer radar assimilation. Radar data is assimilated in the HRRR every 15 minutes over a one-hour period.

Resources Laboratory and plotted on a standard Skew T log P diagram<sup>11</sup> using The Complete Rawinsonde Observation Program (RAOB) software<sup>12</sup>. Figure 6 is the HRRR numerical model sounding for 1300 CST over the turbulence coordinates from the surface through 150-hPa or approximately 45,000 ft.



**Figure 6 - HRRR numerical model sounding for 1300 CST over the turbulence location**

The HRRR sounding indicated an expected surface temperature of 22° C, a dew point temperature of 21° C, with a relative humidity of 90%. The lifted condensation level (LCL)<sup>13</sup> was at about 590 ft agl or 800 ft msl, the convective condensation level (CCL)<sup>14</sup> at 1,880 ft (which corresponded to the ceiling reported at KAEX), and the level of free convection (LFC)<sup>15</sup> at about 8,100 ft. The equilibrium level based on CCL-EL was at 40,000 ft and represented the expected cloud tops. That layer also had a relative humidity that was greater than 90%. The precipitable

<sup>11</sup> 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.

<sup>12</sup> RAOB software – The complete RAWinsonde OBServation program is an interactive sounding analysis program developed by Environmental Research Services, Matamoras, Pennsylvania, for plotting and analyzing upper air data

<sup>13</sup> Lifted Condensation Level (LCL) - the level at which a lifted parcel becomes saturated. The LCL height corresponds to cloud base height for forced ascent.

<sup>14</sup> Convective Condensation Level (CCL) - The level in the atmosphere to which an air parcel, if heated from below, will rise dry adiabatically, without becoming colder than its environment just before the parcel becomes saturated.

<sup>15</sup> Level of Free Convection (LFC) - the last level where a parcel becomes buoyant, or "warmer" than the environmental temperature at the same level. The LFC represents the bottom of the layer containing CAPE.

water<sup>16</sup> content was 2.08 inches, with the freezing level at about 12,980 ft. The model sounding indicated that the atmosphere was characterized as unstable based on the Lifted Index<sup>17</sup> of -5.0 and the Convective Available Potential Energy (CAPE)<sup>18</sup> of 1,404 Joules/kilogram. The moderately unstable airmass and the Energy-Helicity Index (EHI) was 2.7 and favored storm rotation and supercell development. The Maximum Vertical Velocity (MVV) was estimated at 53 meters/second or approximately 106 knots, which supported strong updrafts. Studies<sup>19</sup> have shown that strong updrafts of 30 m/s and greater support the development of large hail and severe storms. The HRRR 1300 CST sounding supported the development of strong to severe thunderstorms across the region and favored supercell development.

The HRRR wind profile indicated a surface wind from the south from 260° at 3 knots with wind rapidly increasing in speed and veering clockwise to the southwest with height. The mean 0 to 6 kilometer or 18,000 ft wind was from 230° at 25 knots, the expected storm motion was from 255° at 29 knots. The level of maximum wind was at approximately 39,000 ft from 260° at 117 knots. At 37,000 ft the wind was from 250° at 114 knots with a temperature of -56° C. The RAOB algorithm indicated the potential for light to moderate turbulence between 34,000 and 42,000 ft.

#### **4.0 Satellite Imagery**

The Geostationary Operational Environmental Satellite number 16 (GOES-16) imagery data were obtained from an archive at the Space Science Engineering Center at the University of Wisconsin-Madison in Madison, Wisconsin, and processed using the Man-computer Interactive Data Access System (McIDAS) software. The infrared long wave and visible imagery were obtained for times surrounding the time of the accident, with the images closest to the time of the accident documented below. The infrared long wave imagery (band 13) at a wavelength of 10.3 microns (μm) provided radiative cloud top temperatures with a nominal spatial resolution of 2 km. The visible (band 2) at a wavelength of 0.64 μm provided images at a resolution of 0.5 km.

Figure 7 is the GOES-16 infrared image at 1321 CST at 2X magnification with a standard MB temperature enhancement curve applied to highlight the higher and colder cloud tops normally associated with deep convection. The image depicted several bands of enhanced clouds associated with cumulonimbus clouds extending from eastern Mississippi, southeastern Arkansas, Louisiana, into southeastern Texas. The turbulence location (marked by a white square) was in an area of enhanced clouds with a radiative cloud top temperature of 220 Kelvin or -56° C, which corresponded to cloud tops near 40,000 ft based on the HRRR sounding.

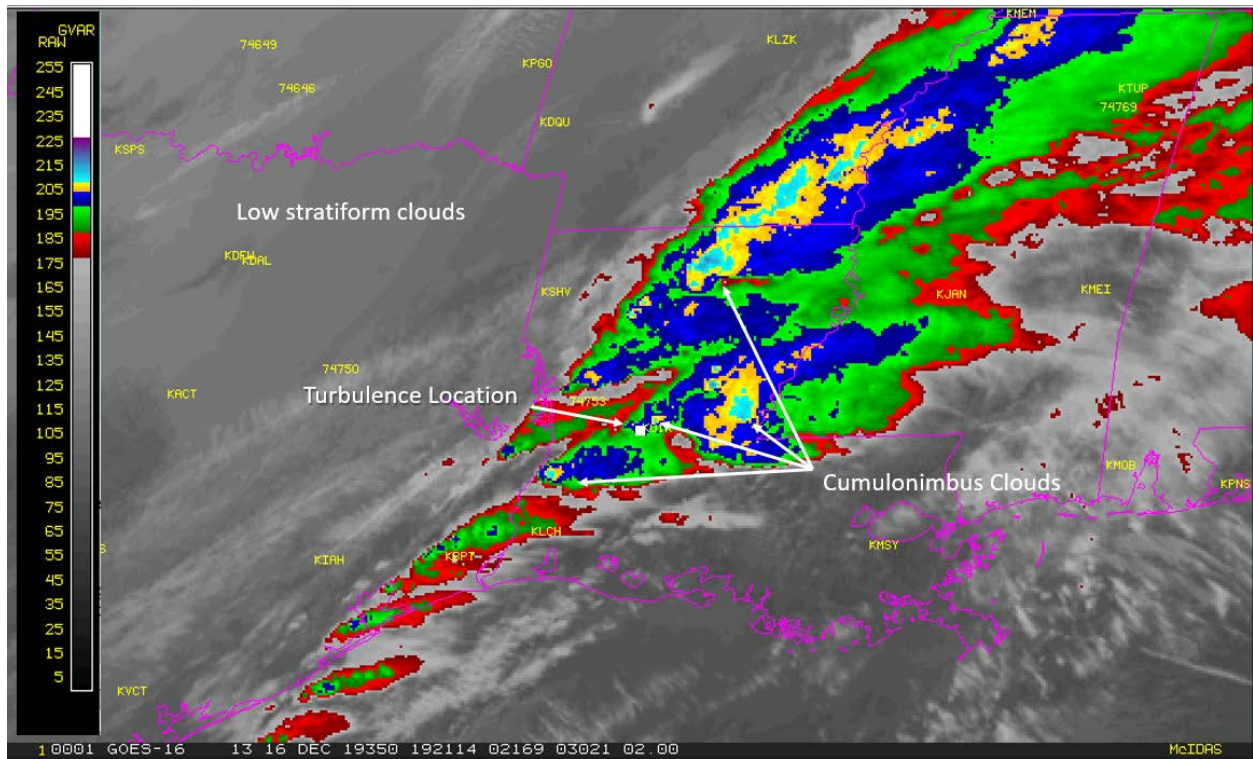
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<sup>16</sup> Precipitable Water (PW) is a measure of the depth of liquid water at the surface that would result after precipitating all of the water vapor in a vertical column over a given location, usually extending from the surface to 300 mb.

<sup>17</sup> Lifted Index (LI) - the difference between the lifted parcel temperature at 500 hPa and the 500 hPa temperature in the sounding. Negative values denote parcels that are warmer than the background 500 hPa temperatures and are thus buoyant or "unstable".

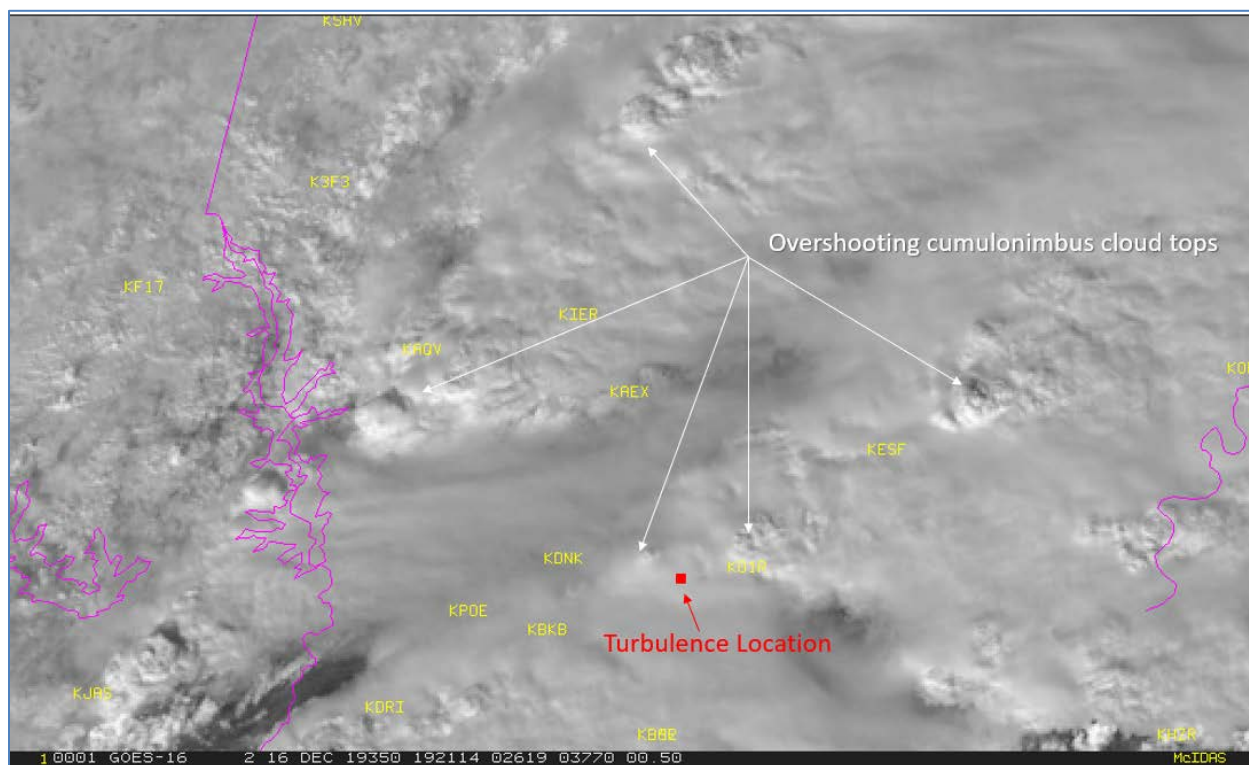
<sup>18</sup> Convective Available Potential Energy(CAPE) - is a measure of instability through the depth of the atmosphere and is related to updraft strength in thunderstorms. SPC forecasters often refer to "weak instability" (CAPE less than 1000 Jkg-1), "moderate instability" (CAPE from 1000-2500 Jkg-1), "strong instability" (CAPE from 2500-4000 Jkg-1), and "extreme instability" (CAPE greater than 4000 Jkg-1).

<sup>19</sup> Modahl,A.C., The Influence of Vertical Wind Shear on Hailstorm Development and Structure, Department of Atmospheric Studies, Colorado State University, March 1969.



**Figure 7 - GOES-16 infrared image at 1321 CST at 2X magnification with a standard MD enhancement curve**

Figure 8 is the GOES-16 visible image for 1321 CST at 2X magnification. The two lines of cumulonimbus clouds can be identified embedded in low clouds which extended back into the Dallas Fort Worth area. The turbulence location (red square) was in the immediate vicinity of an area of overshooting cloud tops, where strong updrafts are typically found.



**Figure 8 - GOES-16 visible image at 1321 CST at normal magnification**

## 5.0 Weather Surveillance Radar Imagery

The closest Weather Surveillance Radar 1988 Doppler (WSR-88Ds) were located approximately 14 miles west from the turbulence encounter at the Department of Defense (DOD) Fort Polk (KPOE) and 65 miles south of and the NWS Lake Charles, Louisiana, radar sites. The level II and III archive data were obtained from the NCEI using the Hierarchical Data Storage System and displayed using the NWS NEXRAD Interactive Viewer and Data Exporter software.

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<sup>20</sup>. Reflectivity product is the most often used product that requires minimum interpretation skills to interpret.

### 5.1 Volume Scanning Strategies

During the period the KPOE and KLCH WSR-88D were operating in the precipitation mode volume scan pattern 212 (VCP-212), where the radar makes 14 different elevation scans in 4 ½ minutes. This scanning strategy is used during periods when rapidly evolving severe convection

<sup>20</sup> Federal Meteorological Handbook Number 11, WSR-88D Meteorological Observations further defines the principle, products, and use of the radar products documented in this report.

is expected and provides increased low-level vertical resolution. Figure 9 is a chart depicting the various elevation scans by distance and height used in this scanning strategy assuming a standard refraction<sup>21</sup> of the WSR-88D radar beam.

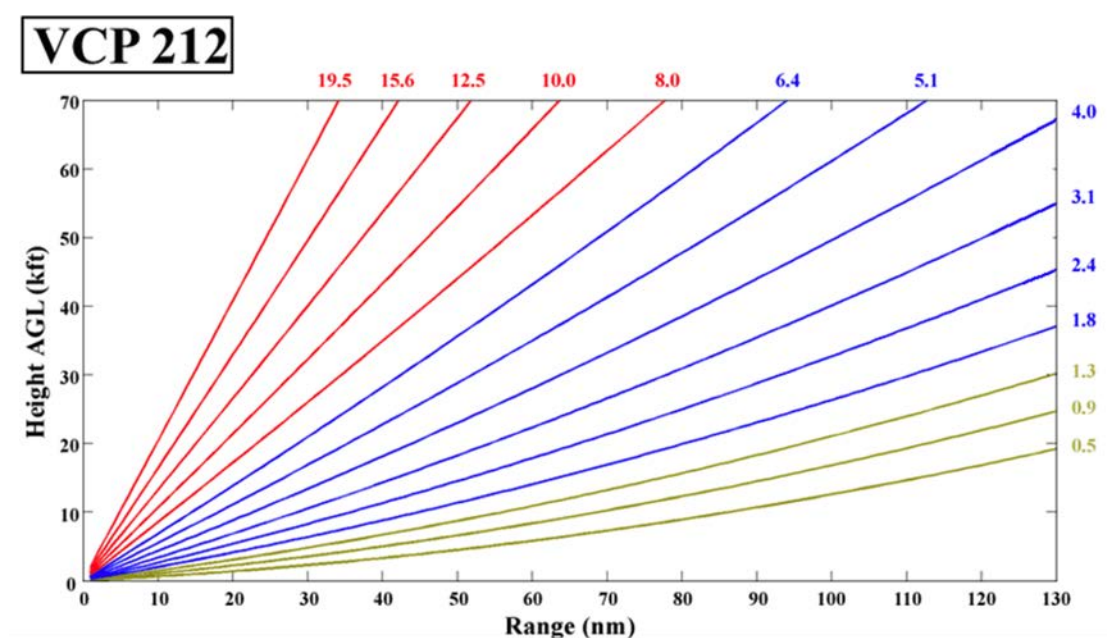


Figure 9 - VCP-212 scanning strategy

Based on the above chart, the KPOE WSR-88D antenna located 14 miles west of the turbulence location and was able to provide details of the echoes at low levels. However, the KPOE WSR-88D highest 19.5° elevation beam scanned the altitude below 32,000 ft and was not able to capture the conditions at the accident airplanes' flight level. While the NWS KLCH WSR-88D located about 65 miles south, the 5.1° elevation scan was able to capture the conditions at 37,000 ft over the turbulence location.

## 5.2 Reflectivity

Reflectivity is the measure of the efficiency of a target in intercepting and returning radio energy. With hydrometeors<sup>22</sup>, it is a function of the drop size distribution, number of particles per unit volume, physical state (ice or water), shape, and aspect. Reflectivity is normally displayed in decibels (dBZ<sup>23</sup>) and is a general measure of echo intensity. Figure 10 relates the NWS former

<sup>21</sup> Standard Refraction in the atmosphere is when the temperature and humidity distributions are approximately average, and values set at the standard atmosphere.

<sup>22</sup> Hydrometeors are any product of condensation or sublimation of atmospheric water vapor, whether formed in the free atmosphere or at the earth's surface. Hydrometeors are classified as; (a) Liquid or solid water particles suspended in the air: cloud, water droplets, mist or fog. (b) Liquid precipitation: drizzle and rain. (c) Freezing precipitation: freezing drizzle and freezing rain. (d) Solid (frozen) precipitation: ice pellets, hail, snow, snow pellets, and ice crystals. (e) Falling particles that evaporate before reaching the ground: virga. (f) Liquid or solid water particles lifted by the wind from the earth's surface: drifting snow, blowing snow, blowing spray. (g) Liquid or solid deposits on exposed objects: dew, frost, rime, and glaze ice.

<sup>23</sup> dBZ - 10 log Ze

video integrator and processor (VIP) intensity levels (1-6) versus the WSR-88D's display levels (0-15), precipitation mode reflectivity in decibels (DBZ), and rainfall rates.

| <b>NWS VIP/DBZ CONVERSION TABLE</b> |               |               |             |
|-------------------------------------|---------------|---------------|-------------|
| NWS VIP                             | WSR-88D LEVEL | PREC MODE DBZ | RAINFALL    |
| 0                                   | 0             | < 5           |             |
|                                     | 1             | 5 to 9        |             |
|                                     | 2             | 10 to 14      |             |
| 1<br>Very Light                     | 3             | 15 to 19      | .01 in/hr   |
|                                     | 4             | 20 to 24      | .02 in/hr   |
|                                     | 5             | 25 to 29      | .04 in/hr   |
| 2<br>Light to Moderate              | 6             | 30 to 34      | .09 in/hr   |
|                                     | 7             | 35 to 39      | .21 in/hr   |
| 3<br>Strong                         | 8             | 40 to 44      | .48 in/hr   |
| 4<br>Very Strong                    | 9             | 45 to 49      | 1.10 in/hr  |
| 5<br>Intense                        | 10            | 50 to 54      | 2.49 in/hr  |
| 6<br>Extreme                        | 11            | 55 to 59      | >5.67 in/hr |
|                                     | 12            | 60 to 64      |             |
|                                     | 13            | 65 to 69      |             |
|                                     | 14            | 70 to 74      |             |
|                                     | 15            | > 75          |             |

**Figure 10 - NWS VIP levels, WSR-88D levels, reflectivity and rainfall rates**

The FAA has taken the NWS previous VIP Levels 1 to 6 intensity levels and has redefined the intensity levels for pilots in Advisory Circular AC 00-24C - "Thunderstorm". That AC further defines echoes less than 30 dBZ as "light" in intensity, "moderate" echoes 30-40 dBZ, "heavy" with echoes of >40-50 dBZ, and "extreme" intensity with echoes above >50 dBZ. These are the new standard radio phraseology terms used by air traffic controllers to describe weather conditions to pilots as shown in figure 11.

| Reflectivity (dBZ) Ranges | Weather Radar Echo Intensity Terminology |
|---------------------------|------------------------------------------|
| < 30 dBZ                  | Light                                    |
| 30 – 40 dBZ               | Moderate                                 |
| >40 – 50 dBZ              | Heavy                                    |
| >50 dBZ                   | Extreme                                  |

**Figure 11 - ATC terminology of reflectivity and intensity levels**

The WSR-88D provides two basic type of reflectivity images: composite and base reflectivity images.

### 5.3 Composite Reflectivity Images

Composite reflectivity images utilize all elevation scans during each volume scan to create the image. It is composed of the greatest echo intensity (reflectivity) from any elevation angle seen from the radar. It is used to reveal the highest reflectivity in all echoes. Composite reflectivity image is one of the last radar image views, necessitated by the need for all elevation scans to be completed before this image can be produced.

Figures 12-13 are the KPOE WSR-88D composite reflectivity images at 1318 and 1325 CST respectively with the flight track and turbulence location overlaid. The images depict echoes up to 56.5 dBZ under the flight track and the turbulence location surrounding the period the airplane overflew the echoes.

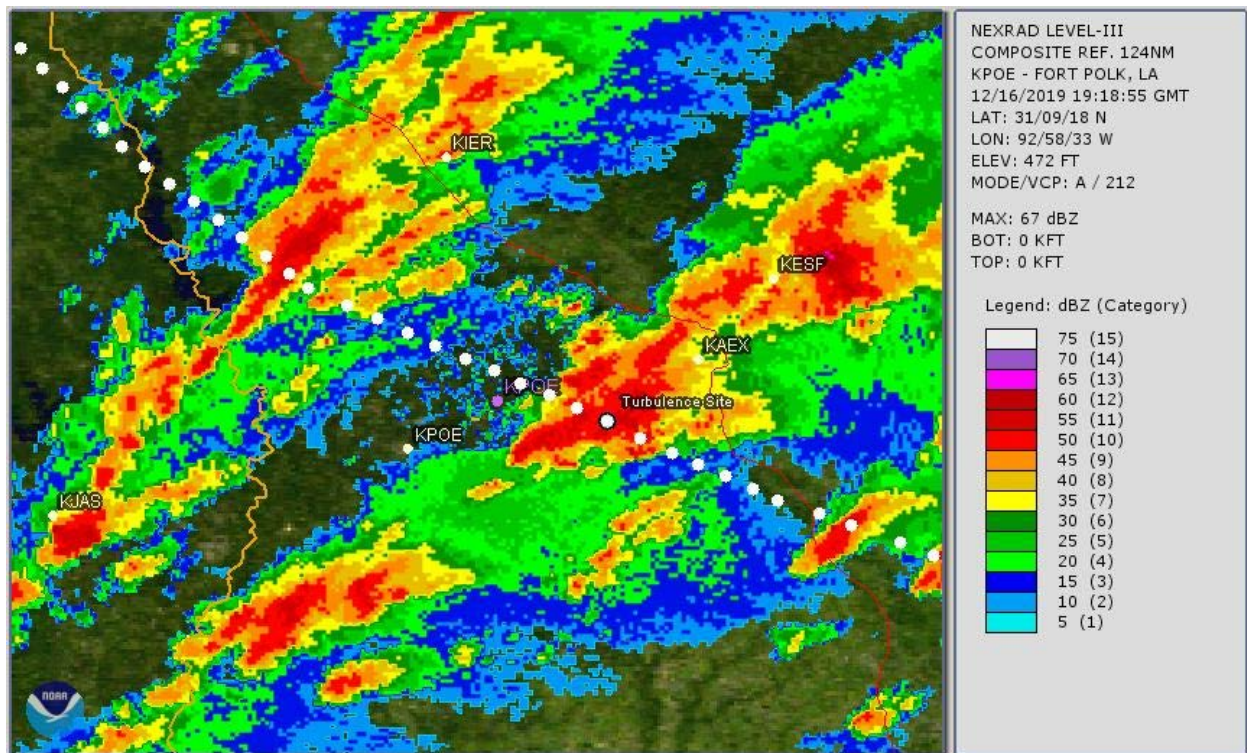


Figure 12 - KPOE WSR-88D composite reflectivity image at 1318 CST with the flight track overlaid

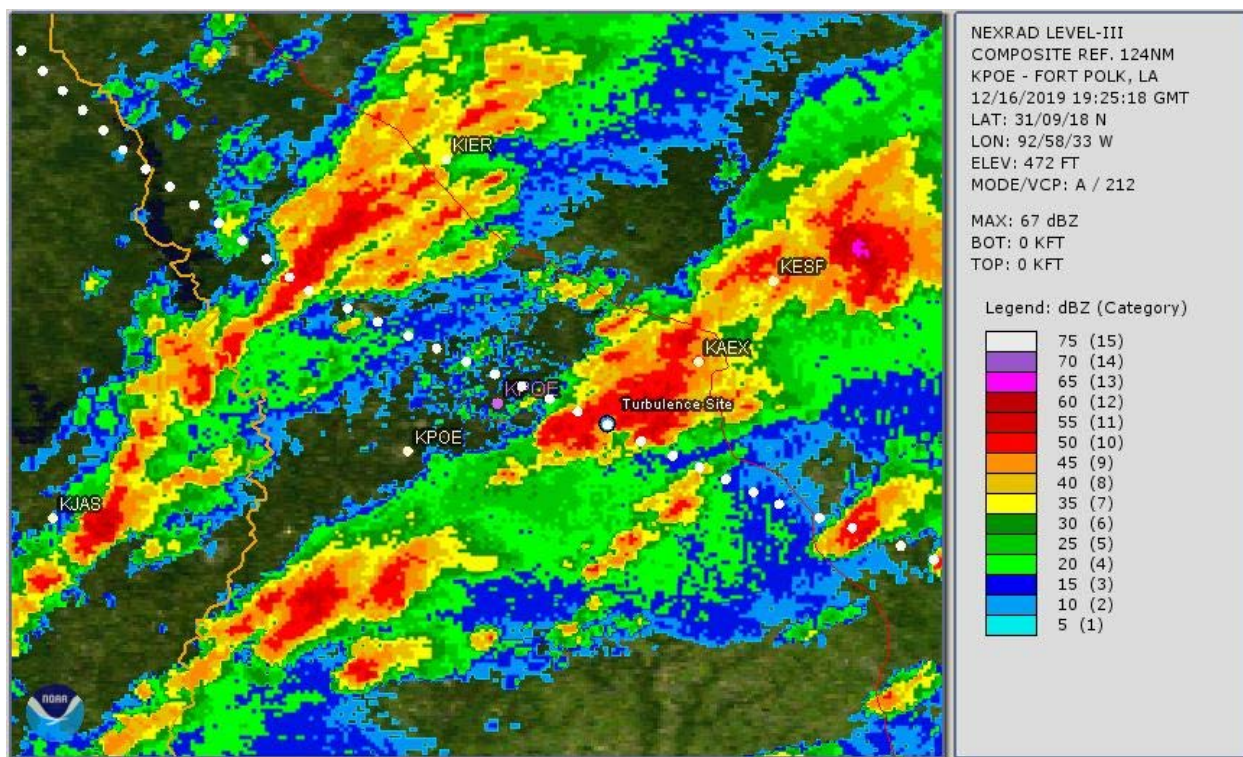


Figure 13 - KPOE WSR-88D composite reflectivity image at 1325 CST with the flight track overlaid

#### 5.4 Base Reflectivity Images

The NWS WSR-88D base reflectivity images are the individual elevation scan images for the VCP being operated. The lowest 0.5° base reflectivity elevation scan is often the one radar product distributed by vendors and also available on NWS sites, unless the user has the analysis software to open and view all the VCP scanning elevations for storm structure and to identify other features.

Figures 14 and 15 are the KLCH WSR-88D 0.5° and 5.13° base reflectivity images for 1325 CST depicting the lowest elevation scan and the scan that depicted the conditions at the aircraft's altitude during the turbulence encounter. The images depict heavy to extreme echoes up to 55 dBZ at the lowest elevation scan and light intensity echoes near 23.0 dBZ along the flight path at altitude with moderate intensity echoes of 37.0 dBZ approximately 5 miles east.

Figures 16 and 17 are the KPOE WSR-88D 0.5° and 19.4° base reflectivity images for 1325 CST depicting the lowest and highest elevation scans over the area at the time of the turbulence event. The lowest elevation scan also showed extreme intensity echoes to 60 dBZ and the highest scan depicting the conditions near 23,000 ft over the turbulence event with heavy intensity echoes of 46.5 dBZ under the track.



Figure 14 - KLCH WSR-88D 0.5° base reflectivity image at 1325 CST with the flight track overlaid



Figure 15 - KLCH WSR-88D 5.13° base reflectivity image at 1325 CST with flight track overlaid



Figure 16 - KPOE WSR-88D 0.5° base reflectivity image at 1325 CST with the flight track overlaid



Figure 17 - KPOE WSR-88D 19.4° base reflectivity image at 1325 CST depicting the conditions near

## 5.5 Echo Tops Image

The KLCH WSR-88D High Resolution Echo Tops (EET) product was also obtained, which provides the echo top information with a resolution of 0.54 miles X 1° in 1,000 ft intervals in the vertical. The height values provided are the highest sample volume of 18.5 dBZ. Echo top heights can differ significantly from visual cloud top heights.

Figure 18 is the KLCH WSR-88D enhanced echo tops product for 1325 CST depicted echoes of 18.5 dBZ up to 40,000 ft over the turbulence location with maximum echo tops to 44,600 ft approximately 5 miles east.



Figure 18 - KLCH WSR-88D echo tops product for 1325 CST with flight track

## 5.6 High Layer Composite Reflectivity

The KLCH WSR-88D High Layer Composite Reflectivity (NHL) for the layer between 33,000 to 60,000 ft was also documented. This product was previously intended for use in the FAA Weather And Radar Processor (WARP) display available to the Air Route Traffic Control Center (ARTCC) controllers weather display. The product has a resolution of 2.2 x 2.2 miles. The display is useful for identifying those weather systems with extensive vertical development. Figure 19 is the KLCH WSR-88D high layer composite reflectivity image at 1325 CST with the flight track overlaid. The image depicted moderate intensity echoes 30 to 40 dBZ on the high layer display with heavy intensity echoes over 50 dBZ immediately east of the turbulence location, and several extreme echoes surrounding the flight path.

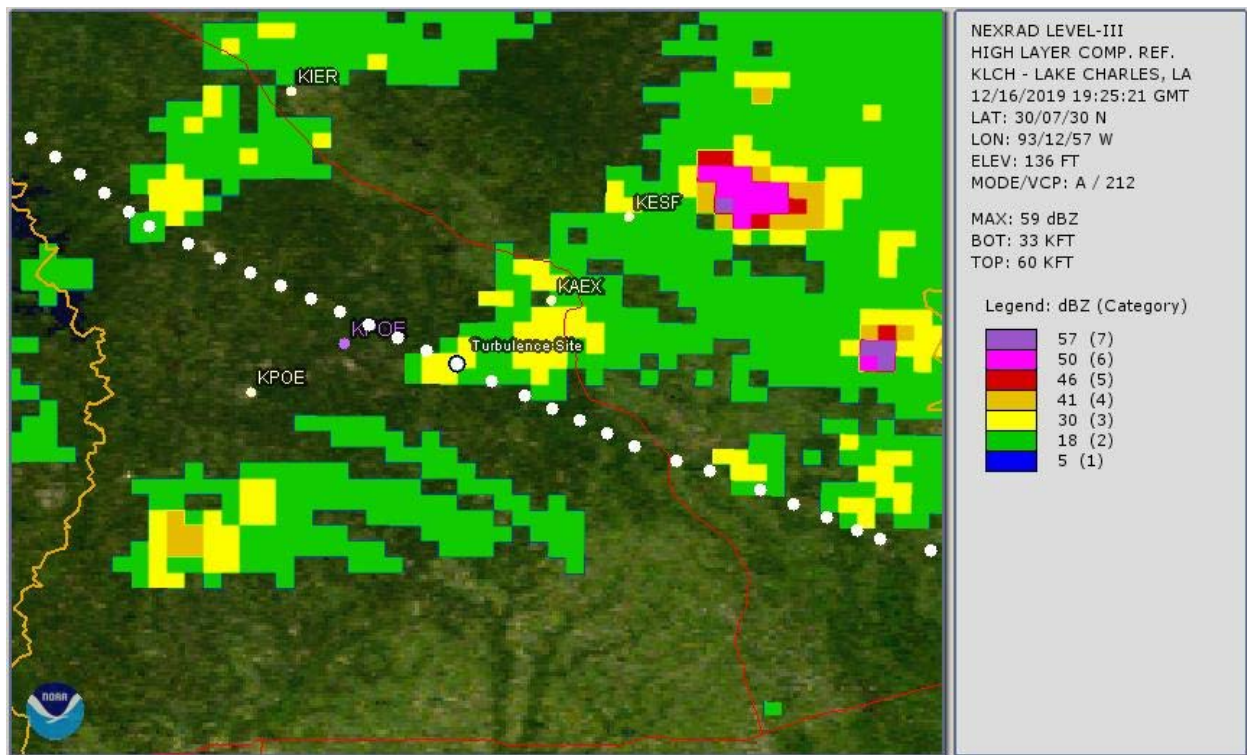


Figure 19 - KLCH WSR-88D high layer composite reflectivity image at 1325 CST with flight track overlaid

## 5.7 Cross Section Image

A cross section plot along the approximate flight path at 1325 CST from the KLCH WSR-88D utilizing the GR2Analysis software<sup>24</sup> is included as figure 20. The image depicted several heavy to extreme intensity echoes reaching the 20,000 ft level and moderate intensity echoes through 30,000 ft, and with light intensity echoes through 37,000 ft. The WSR-88D detected to very light intensity echoes of 5 dBZ up to approximately 42,000 ft over the turbulence location.

<sup>24</sup> GR2Analysis software version 2.12 developed by Gibson Ridge Software, LLC (GRS) and provides weather data viewers for weather radar data.

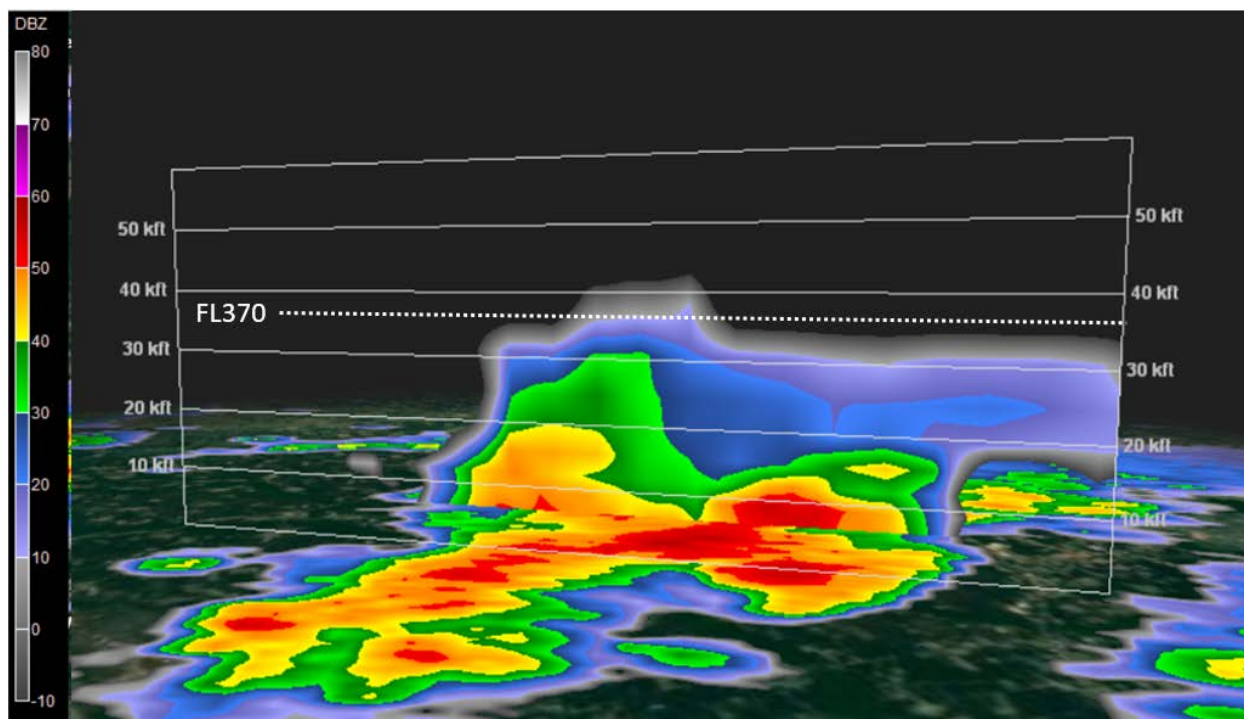


Figure 20 - KLCH WSR-88D cross section along the flight track at 1325 CST

## 6.0 Pilot Reports

A search of the NWS data base provided the following pilot reports (PIREPs) within approximately 100 miles along the route of flight between 1000 and 1500 CST. The reports are provided in standard format in code and abbreviations and followed by a decoded report in plain language with time converted to local CST. The report recorded by air traffic control relating to the accident is included in bold italic print. The reports surrounding the period were as follows:

*LFK UA /OV LFK090050 /TM 1620 /FL200 /TP E145 /TB MOD 200-170 /RM FM ZHU AWC-WEB*

*Angelina County Airport (LFK), Lufkin, Texas routine pilot report (UA); Over – LFK VORTAC on 090° azimuth at 50 miles; Time – 1020 CST; Flight Level – 200; Type aircraft – Embraer EMB-145; Turbulence – moderate between 20,000 and 17,000 ft; Remarks – from Houston ARTCC (ZHU) entered through AWC - website.*

*ESF UUA /OV SWB225040 /TM 1637 /FL340 /TP E175 /TB SEV /RM FM ZHU AWC-WEB*

*Esler Regional Airport (ESF), Alexandria, Louisiana urgent pilot report (UUA); Over – Sawmill VORTAC (SMF), Winnfield, Louisiana on 225° azimuth at 40 miles; Time – 1037 CST; Flight Level – 270; Type aircraft – Embraer EMB-175; Turbulence – severe; Remarks – from ZHU ARTCC through AWC – website.*

*LFK UA /OV LFK090014 /TM 1639 /FL270 /TP E75L /TB MOD /RM ZFW AWC-WEB*

*LFK routine pilot report; Over – LFK VORTAC on 090° azimuth at 14 miles; Time – 1039 CST; Flight Level – 270; Type aircraft – Embraer EMB-175L; Turbulence – moderate; Remarks – from Dall-Fort Worth ARTCC (ZFW) entered through AWC – website.*

*MLU UA /OV MLU360020/TM 1652/FL410/TP B738/TB LGT/RM ZFW AWC-WEB/*

*Monroe Regional Airport (MLU), Monroe, Louisiana, routine pilot report; Over – MLU VORTAC on 360° azimuth at 20 miles; Time – 1052 CST; Flight Level – 410; Type aircraft – Boeing B-737; Turbulence – light; Remarks - ZFW ARTCC entered through AWC – website.*

*BTR UA /OV LSU /TM 1706 /FL380 /TP A320 /TB MOD CHOP /RM FM ZHU AWC-WEB*

*Baton Rouge Metropolitan Airport – Ryan Field (BTR), Baton Rouge, Louisiana routine pilot report; Over – 45° azimuth and 10 miles from the Fighting Tiger VORTAC (LSU); Time – 1106 CST; Flight Level – 380; Type aircraft – Airbus A320; Turbulence – moderate chop; Remarks – entered by ZHU ARTCC through the AWC website.*

*ESF UA /OV AEX045010/TM 1733/FL330/TP E145/TB MOD 330-240/RM FM ZHU AWC-WEB/*

*ESF routine pilot report; Over – AEX VORTAC on 045° azimuth at 10 miles; Time – 1133 CST; Flight Level – 330; Type aircraft – Embraer EMB-145; Turbulence – moderate between 33,000 and 24,000 ft; Remarks - ZHU ARTCC entered through AWC – website.*

*ESF UA /OV SWB /TM 1734 /FL340 /TP B737 /TB MOD /RM FM ZHU AWC-WEB*

*ESF routine pilot report; Over – SMF VORTAC; Time – 1134 CST; Flight Level – 340; Type aircraft – Boeing B-737; Turbulence – moderate; Remarks - ZHU ARTCC entered through AWC – website.*

*SHV UA /OV EMG180040 /TM 1746 /FL340 /TP B737 /TB MOD CAT/RM AWC-WEB*

*Shreveport Regional Airport (SHV), Shreveport, Louisiana routine pilot report; Over – Elm Grove VORTAC on 180° azimuth at 40 miles; Time – 1146 CST; Flight Level – 340; Type aircraft – Boeing B-737; Turbulence – moderate clear air turbulence; Remarks – entered from AWC website.*

*LFT UUA /OV LFT315035 /TM 1834 /FL360 /TP CRJ /TB SEV /RM FM ZHU AWC-WEB*

*Lafayette Regional Airport/Paul Fournet Field (LFT), Lafayette, Louisiana urgent pilot report; Over 315° azimuth and 35 miles from LFT VORTAC; Time – 1234 CST; Flight Level – 360; Type aircraft – Bombardier CRJ; Turbulence – severe; Remarks - ZHU ARTCC entered through AWC – website.*

*ESF UA /OV SWB230015/TM 1843/FL370/TP NMRS/TB MOD CHOP FL370-390/RM FM KZHU AWC-WEB/*

*ESF routine pilot report; Over – SMF VORTAC on 230° azimuth at 15 miles; Time – 1243 CST; Flight Level – 370; Type aircraft – numerous aircraft; Turbulence – moderate chop between FL370-390; Remarks - ZHU ARTCC entered through AWC – website.*

*BTR UA /OV LSU320025 /TM 1849 /FL340 /TP A321 /TB MOD CHOP /RM FM KZHU AWC-WEB*

*BTR routine pilot report; Over – 320° azimuth and 25 miles from the LSU VORTAC; Time – 1249 CST; Flight Level – 340; Type aircraft – Airbus A321; Turbulence – moderate chop; Remarks – entered by ZHU ARTCC through the AWC website.*

*MLU UA /OV MLU270030 /TM 1925 /FL390 /TP B737 /TB MOD /RM ZFW AWC-WEB*

*MLU routine pilot report; Over – MLU VORTAC on 270° azimuth at 30 miles; Time – 1325 CST; Flight Level – 390; Type aircraft – Boeing B-737; Turbulence – moderate; Remarks - ZFW ARTCC entered through AWC – website.*

*SHV UA /OV KSHV/TM 1948/FL003/TP CRJ2/SK OVC003/RM RPTD B003 DURD SHV*

*SHV routine pilot report; Over – KSHV; Time – 1348 CST; Altitude – 300 ft; Type aircraft – Canadair CRJ-200; Sky cover – overcast clouds bases at 300 ft; Remarks – base at 300 ft during descent into SHV.*

### ***Turbulence Encounter 1923Z***

***ESF UUA /OV AEX180015 /TM 1926 /FL370 /TP E135 /TB SEV /RM FM KZHU AWC-WEB***

***ESF urgent pilot report; Over – AEX VORTAC on 180° azimuth at 15 miles; Time – 1326 CST; Flight Level – 370; Type aircraft – Embraer EMB-135; Turbulence – severe; Remarks - ZHU ARTCC entered through AWC – website.***

***ESF UA /OV SWB/TM 1940/FL340/TP E170/TB INTMT LGT-MOD/RM ZFW AWC-WEB/***

***ESF routine pilot report; Over – SWB VORTAC; Time – 1340 CST; Flight Level – 340; Type aircraft – Embraer EMB-170; Turbulence – intermittent light-to-moderate; Remarks - ZFW ARTCC entered through AWC – website.***

***ESF UA /OV SWB045018/TM 1943/FL350/TP E170/TB CONS MOD/RM ZFW AWC-WEB/***

***ESF routine pilot report; Over – SWB VORTAC on 045° at 18 miles; Time – 1343 CST; Flight Level – 350; Type aircraft – Embraer EMB-170; Turbulence – continuous moderate; Remarks - ZFW ARTCC entered through AWC – website.***

***MLU UA /OV KRSN258016/TM 1944/FL440/TP C25A/SK TOP AROUND FL400/TB LGT/RM ZFW AWC-WEB***

***MLU routine pilot report; Over – Ruston Regional Airport (KRSN), Ruston, Louisiana, 258° at 16 miles; Time – 1344 CST; Flight Level – 440; Type aircraft – Cessna Citation; Sky cover – tops around 40,000 ft; Turbulence – light; Remarks - ZFW ARTCC entered through AWC – website.***

***MLU UA /OV MLU/TM 2043/FL200/TP SW4/TA M08/TB CONS LGT CHOP/IC LGT-MOD RIME/RM DURD FROM FL200 ZFW AWC-WEB/***

***MLU routine pilot report; Over – MLU VORTAC; Time – 1443 CST; Flight Level – 200; Type aircraft – Swearingen Metroliner; Temperature – minus 8° C; Turbulence – continuous light chop; Icing – light-to-moderate rime type icing; Remarks – during descent from 20,000 ft entered by ZFW ARTCC entered through AWC – website.***

Of the 19 PIREPs reported over the area all but one reported encountering turbulence ranging from light (2), light-to-moderate (2), moderate (11), and severe (3). Three of the reports were urgent reports, with one believed to be the accident airplane. One PIREP reported cloud tops near 40,000 ft immediately after the accident. None of the PIREPs specifically noted anything about the convection across the area or indicated the turbulence encountered was in clouds or in the clear air above.

For reference figure 21 is from the Aeronautical Information Manual (AIM), Safety of Flight, section 7-1-23, PIREPs Relating to Turbulence, Turbulence Reporting Criteria Table which describes the turbulence intensities and reaction inside the aircraft.

**Turbulence Reporting Criteria Table**

| Intensity | Aircraft Reaction                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Reaction Inside Aircraft                                                                                                                                                                                    | Reporting Term –Definition                                                                                                                                                                                                                                                                                                |
|-----------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Light     | Turbulence that momentarily causes slight, erratic changes in altitude and/or attitude (pitch, roll, yaw). Report as <b>Light Turbulence</b> ; <sup>1</sup><br>or<br>Turbulence that causes slight, rapid and somewhat rhythmic bumpiness without appreciable changes in altitude or attitude. Report as <b>Light Chop</b> .                                                                                                                                                                                 | Occupants may feel a slight strain against seat belts or shoulder straps. Unsecured objects may be displaced slightly. Food service may be conducted and little or no difficulty is encountered in walking. | Occasional—Less than <sup>1</sup> / <sub>3</sub> of the time.<br><br>Intermittent— <sup>1</sup> / <sub>3</sub> to <sup>2</sup> / <sub>3</sub> .<br><br>Continuous—More than <sup>2</sup> / <sub>3</sub> .                                                                                                                 |
| Moderate  | Turbulence that is similar to Light Turbulence but of greater intensity. Changes in altitude and/or attitude occur but the aircraft remains in positive control at all times. It usually causes variations in indicated airspeed. Report as <b>Moderate Turbulence</b> ; <sup>1</sup><br>or<br>Turbulence that is similar to Light Chop but of greater intensity. It causes rapid bumps or jolts without appreciable changes in aircraft altitude or attitude. Report as <b>Moderate Chop</b> . <sup>1</sup> | Occupants feel definite strains against seat belts or shoulder straps. Unsecured objects are dislodged. Food service and walking are difficult.                                                             | <b>NOTE</b><br><br>1. Pilots should report location(s), time (UTC), intensity, whether in or near clouds, altitude, type of aircraft and, when applicable, duration of turbulence.<br><br>2. Duration may be based on time between two locations or over a single location. All locations should be readily identifiable. |
| Severe    | Turbulence that causes large, abrupt changes in altitude and/or attitude. It usually causes large variations in indicated airspeed. Aircraft may be momentarily out of control. Report as <b>Severe Turbulence</b> . <sup>1</sup>                                                                                                                                                                                                                                                                            | Occupants are forced violently against seat belts or shoulder straps. Unsecured objects are tossed about. Food Service and walking are impossible.                                                          | <b>EXAMPLES:</b><br><br>a. Over Omaha. 1232Z, Moderate Turbulence, in cloud, Flight Level 310, B707.                                                                                                                                                                                                                      |
| Extreme   | Turbulence in which the aircraft is violently tossed about and is practically impossible to control. It may cause structural damage. Report as <b>Extreme Turbulence</b> . <sup>1</sup>                                                                                                                                                                                                                                                                                                                      |                                                                                                                                                                                                             | b. From 50 miles south of Albuquerque to 30 miles north of Phoenix, 1210Z to 1250Z, occasional Moderate Chop, Flight Level 330, DC8.                                                                                                                                                                                      |

<sup>1</sup> High level turbulence (normally above 15,000 feet ASL) not associated with cumuliform cloudiness, including thunderstorms, should be reported as CAT (clear air turbulence) preceded by the appropriate intensity, or light or moderate chop.

**Figure 21 - Aeronautical Information Manual Turbulence Reporting Criteria for PIREPs**

## 7.0 NWS Forecasts

The standard aviation weather forecasts issued surrounding the period were documented and are included below.

### 7.1 Terminal Aerodrome Forecasts

The NWS Lake Charles (KLCH), Louisiana Weather Forecast Office (WFO) was responsible for the issuance of the Terminal Aerodrome Forecast (TAF) for KAEX. A TAF is a concise statement of the expected meteorological conditions at an airport during a specified period (usually 24 hours). TAFs are valid for a 5 mile radius around an airport's center point with cloud heights reported in agl. The forecasts issued surrounding the period relevant to the preflight planning and the time of the accident were as follows.

The forecast current prior to departure and available for preflight planning was an amended forecast issued at 0857 CST and was as follows.

*AMD TAF KAEX 161457Z 1615/1712 13007KT P6SM VCSH BKN012 BKN025  
TEMPO 1615/1619 3SM TSRA SCT015 OVC025CB  
**FM161900 19016G25KT P6SM VCTS BKN025CB OVC040**  
**TEMPO 1619/1622 VRB20G30KT 2SM +TSRA OVC015CB**  
FM162200 30012G20KT 6SM SHRA OVC025  
TEMPO 1622/1624 2SM +TSRA OVC025CB  
FM170300 32012G18KT P6SM OVC015=*

The forecast for KAEX from 1300 through 1600 CST expected wind from 190° at 16 knots gusting to 25 knots, visibility better than 6 miles with thunderstorms in the vicinity, ceiling broken at 2,500 ft agl in cumulonimbus clouds, overcast at 4,000 ft, with a temporary period between 1300 and 1600 CST of winds variable at 20 knots gusting to 30 knots, visibility 2 miles in thunderstorms and heavy rain, ceiling overcast at 1,500 ft in cumulonimbus clouds.

The next TAF for KAEX was issued at 1235 CST and was as follows.

***TAF KAEX 161835Z 1619/1718 17012G20KT 3SM TSRA SCT015 OVC025CB**  
**TEMPO 1619/1620 VRB25G40KT 1SM +TSRA BKN007CB OVC015**  
FM162000 20014G22KT P6SM VCTS SCT012CB SCT025 BKN040  
FM162100 22013G21KT 5SM -SHRA SCT015 BKN025 OVC040  
TEMPO 1621/1624 VRB22G35KT 2SM +TSRA BKN012CB OVC020  
FM170000 32012G18KT P6SM VCSH OVC020  
FM170300 35012G18KT P6SM OVC015=*

The forecast from 1235 through 1400 CST expected winds from 170° at 12 knots gusting to 20 knots, visibility 3 miles in thunderstorms and moderate rain, scattered clouds at 1,500 ft, ceiling overcast at 2,500 ft in cumulonimbus clouds, with a temporary period of variable winds at 25 knots gusting to 40 knots, visibility 1 mile in thunderstorms and heavy rain, ceiling broken at 700 ft in cumulonimbus clouds, overcast at 1,500 ft.

Both forecasts issued during the period expected southerly winds with generally MVFR conditions with IFR conditions in thunderstorms and moderate to heavy rain. The forecasts verified and properly forecast thunderstorms impacting during the period.

## **7.2 Area Forecast Discussion**

The NWS Area Forecast Discussions (AFD) are issued by each WFO to describe the short term weather conditions within their region with an aviation section that includes the general conditions as it relates to the creation of the TAF. These are useful for additional aviation-related issues that cannot be encoded into the TAF. The discussion also gives some reasoning behind the forecast. These are generated roughly every 6 hours and corresponds to the release of the latest TAFs for that office. The long term and marine sections have been excluded. The forecast discussion issued at 1134 CST was as follows.

*FXUS64 KLCH 161734  
AFDLCH*

*.UPDATE...*

*Sctd convection has been developing this morning acrs the area ahead of a cold front that extends from NW LA acrs E Cntl TX into SE TX near Houston. The atmosphere remains ripe for severe convection with abundant instability and strong deep layer shear. KLCH 12Z sounding shows MU CAPE in excess of 2500 J/kg with sfc-6KM shear of 45 KT and sfc-1KM SRH of 195 m2/s2, and this has been evident as developing storms strengthen and quickly acquire supercellular characteristics. Several SVR and TOR warnings have already been issued this morning, along with Tornado Watch 700. The Watch will remain in effect through 6 PM, with an eastward extension into the Acadiana region possible later this afn.*

*The cold front is still on track to progress acrs the CWA this afn into this evening. The strongest convection will shift eastward this afn, with activity tapering off after FROPA. Much colder temperatures are poised behind the front, with a 20 to 30 degree gradient noted in recent obs (mid-upper 70s ahead of the front and 40s/50s behind).*

*The other change this morning was to upgrade the Gale Watch to a Gale Warning over the coastal waters for tonight. Sustained winds are expected to remain between 20 and 30 KT, but frequent gusts to gale force can be expected as the much colder airmass overspreads the relatively warmer waters.*

*.PREV DISCUSSION... /issued 540 AM CST Mon Dec 16 2019/*

*AVIATION...*

*Overall, meteorological reasoning remains unchanged from the previous TAF package with only minor changes made to the short term period to better reflect current conditions. MVFR ceilings will persist through the morning as showers begin to develop. Enough instability is expected by mid-morning to allow for thunderstorms to develop along and ahead of an approaching cold front. These thunderstorms are expected to become more widespread during the afternoon and some will be strong to severe with strong, gusty winds. TEMPO groups remain relatively unchanged and reflect the most likely timing of the strongest storms and frontal passage. Behind the front, gusty northwesterly winds will develop and continue through Tuesday morning.*

The discussion indicated that scattered convection had already began developing across the region and that the atmosphere was conducive for severe convection. Several of the present storms had quickly acquired supercellular characteristics<sup>25</sup> and several severe thunderstorm and tornado warnings had already been issued by the KLCH WFO. The TAF discussion indicated that MVFR conditions were to prevail before strong to severe thunderstorms impacted the stations.

### 7.3 Graphic Turbulence Guidance

The Graphic Turbulence Guidance (GTG) was developed by the National Center for Atmospheric Research (NCAR) and is now run operationally at NOAA NCEP and is available to users on the AWC website<sup>26</sup> from the surface to 45,000 ft. The current GTG version 3.0 model is generated from the NOAA Rapid Refresh (RAP) numerical model with a horizontal spacing of 13.5 kilometers with 50 vertical levels, and provides a computer-generated four-dimensional

---

<sup>25</sup> Supercell characteristics include the presence of a hook echo, a weak echo region (WER), a bounded weak echo region (BWER), and a V-notch.

<sup>26</sup> <http://www.aviationweather.gov/turbulence/gtg>

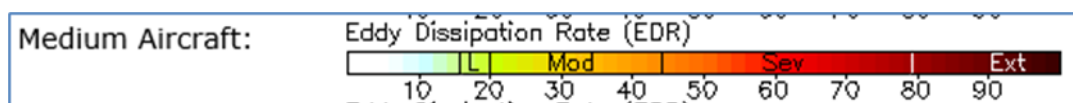
forecast related to the expected intensity of atmospheric turbulence provided in Eddy Dissipation Rate (EDR). EDR ( $\text{m}^{2/3} \text{s}^{-1}$ ) is aircraft independent and is the International Civil Aviation Organization (ICAO) standard for turbulence reporting. EDR varies from close to 0, “smooth”, to near 1, “extreme” for most aircraft types. NCAR defines the following EDR values to various aircraft weight classes and turbulence intensities and is included as figure 22, the Embraer EMB-135 fits the medium weight category<sup>27</sup>.

| AC weight class | Estimated EDR Threshold * 100 |          |        |         |
|-----------------|-------------------------------|----------|--------|---------|
|                 | Light                         | Moderate | Severe | Extreme |
| Light           | 13                            | 16       | 36     | 64      |
| Medium (Large)  | 15                            | 20       | 44     | 79      |
| Heavy           | 17                            | 24       | 54     | 96      |

**Figure 22 - Aircraft weight classes and estimated EDR threshold values for turbulence**

While the current GTG model does not consider Convectively Induced Turbulence (CIT) associated with cumulus type clouds, a new version of the GTGN for “Nowcast” model uses a higher HRRR grid resolution which resolves convection better, adds convective induced turbulence (CIT) parameterization, includes in situ observations of EDR from aircraft, utilizes the WSR-88D reflectivity, spectrum width, and NEXRAD/NCAR Turbulence Detection Algorithm (NTDA), and produces a 3-dimensional mosaic of EDR with an update rate of 5-minutes, with a 2 km horizontal 3,000 ft vertical resolution. This new GTGN version 4 is being run at AWC in a demonstration and evaluation phase and plans to transition to operations in late 2020 to operational use and specifically addresses convectively induced turbulence.

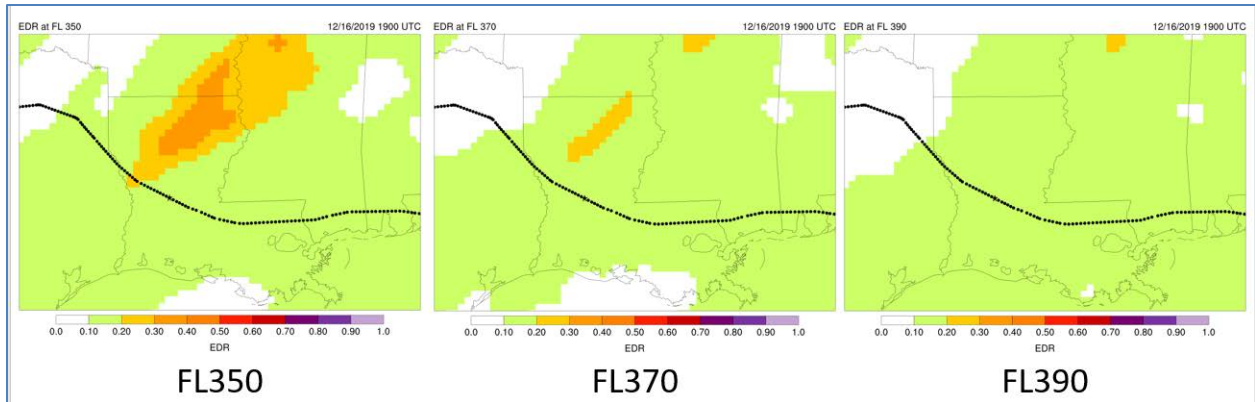
The NCAR was contacted and requested to re-run the current GTG and GTGN models for comparison (see Attachment 1). The output is referenced to EDR values, which are further defined for a medium category aircraft with the turbulence intensity in figure 23 which depicts values on a scale of 0 to 1.00. NCAR researchers have documented that moderate turbulence is typically encountered with EDR values between 0.20 and 0.43, severe between 0.44 and 0.79, and extreme with values over 0.80.



**Figure 23 - Medium weight class EDR values for turbulence**

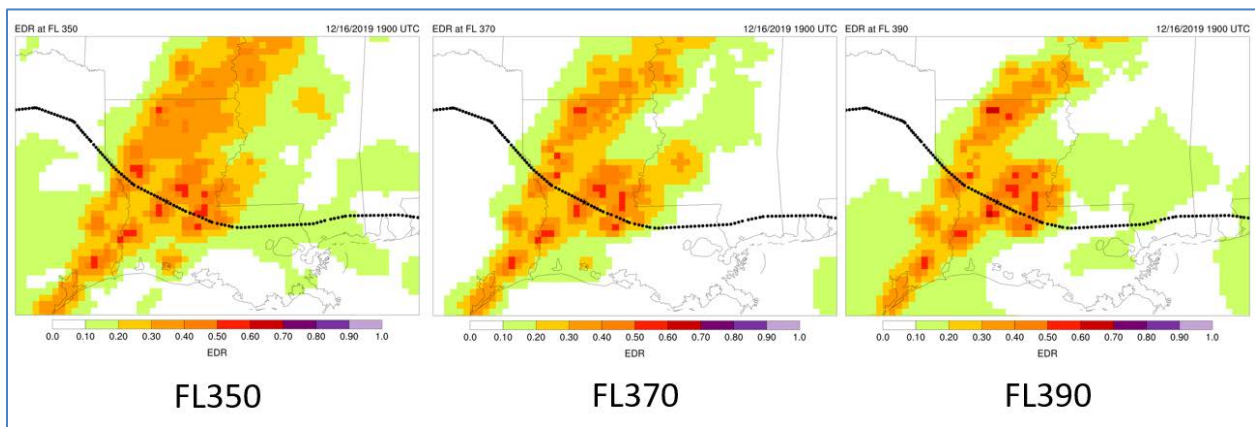
Figure 24 is the NCAR 2-hour GTG forecast model data for ran from 1100 CST and valid at 1300 CST for FL350, FL370, and FL390 with the flight track overlaid. The GTG depicted potential for EDR values of 0.10 to 0.30 at FL350, which would correspond to light to moderate turbulence for a medium sized aircraft. With values of EDR between 0.10 and 0.20 at FL370 and FL390, which corresponded to light turbulence.

<sup>27</sup> Medium (or large) category aircraft – is defined as an aircraft with a maximum takeoff weight between 15,500 to 300,000 pounds (examples include A320, B737, MD80, and Gulfstream business jets).

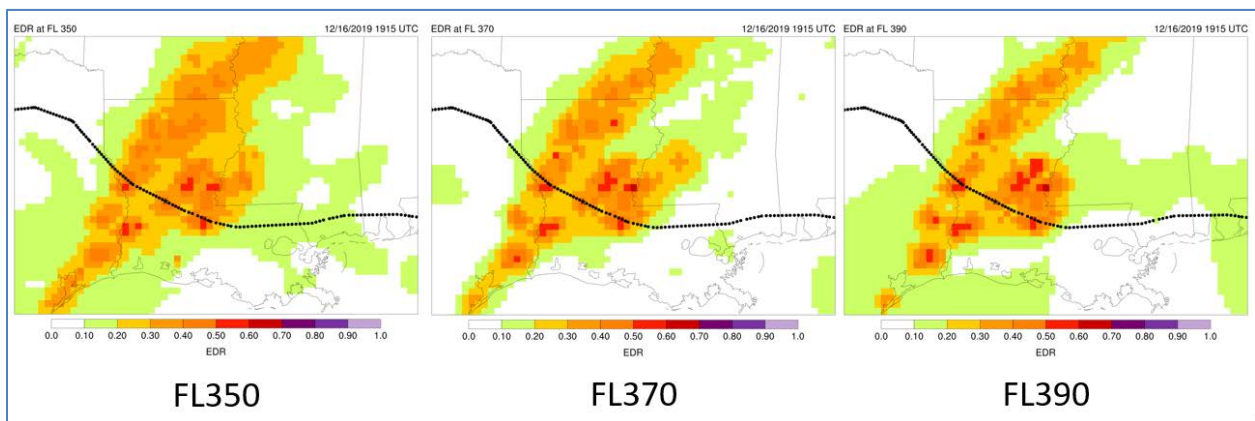


**Figure 24 - NCAR GTG model run at 1100 CST and valid for 1300 CST for FL350, FL370, and FL390**

Figures 25-27 are the GTGN model data for 1300, 1315, and 1330 CST for FL350, FL370, and FL390 with the flight track overlaid. The GTGN nowcast EDR values between 0.3 to 0.6, which correspond to moderate to severe turbulence for a medium category aircraft.



**Figure 25 - NCAR GTGN model data for 1300 CST for FL350, FL370, and FL390**



**Figure 26 - NCAR GTGN model data for 1315 CST for FL350, FL370, and FL390**

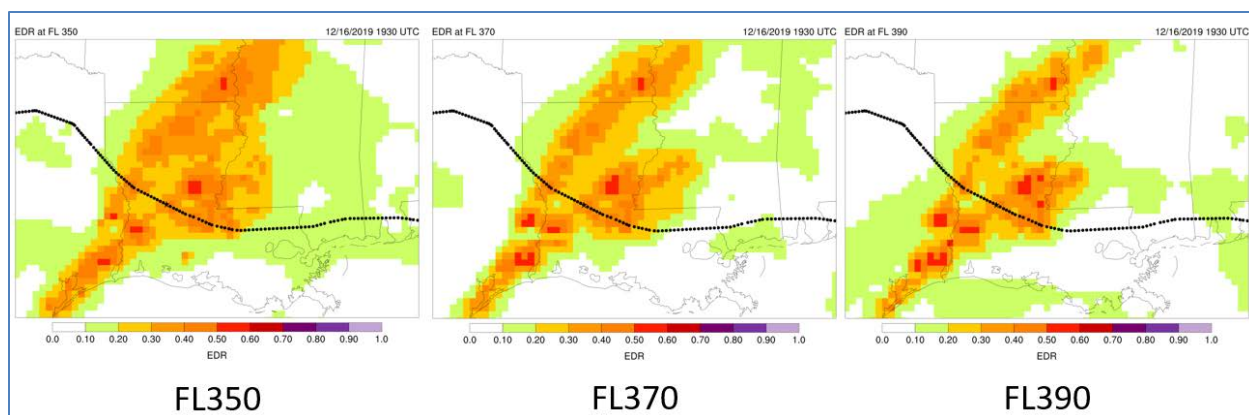


Figure 27 - NCAR GTGN model data for 1330 CST for FL350, FL370, and FL390

NCAR also provided a cross section along the flight track of the GTGN for 1300, 1315, and 1330 CST and is included as figure 28. The NCAR cross section depicted EDR values of 0.3 to 0.5 from near the surface through approximately 40,000 ft, indicating a deep layer of turbulence associated with the echoes. At 1300 CST higher values of EDR of 0.5 to 0.7 were noted near and above the cloud tops to between 40,000 and 45,000 ft.

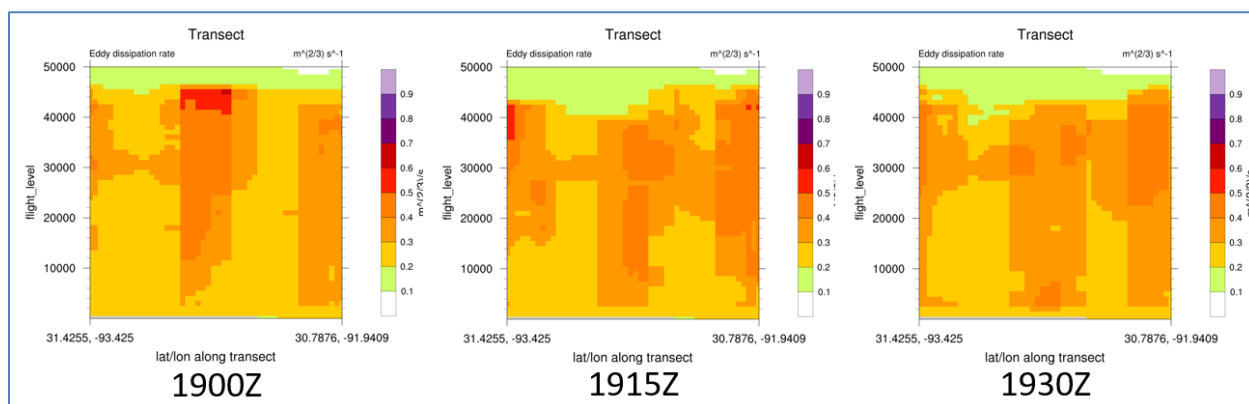


Figure 28 - NCAR GTGN Cross section along flight track between 1300, 1315, and 1330 CST

## 7.4 Winds and Temperature Aloft Forecast

The Winds and Temperature Aloft Forecast<sup>28</sup> (FB) current for the route of flight was valid for 1200 CST and for use between 0800 and 1500 CST was as follows.

### WINDS ALOFT FORECASTS

DATA BASED ON 161200Z

VALID 161800Z FOR USE 1400-2100Z. TEMPS NEG ABV 24000

| FT  | 3000 | 6000    | 9000    | 12000   | 18000   | 24000   | 30000  | 34000         | 39000         | 45000  | 53000  |
|-----|------|---------|---------|---------|---------|---------|--------|---------------|---------------|--------|--------|
| DAL | 3229 | 2722+10 | 2434+05 | 2348-01 | 2469-16 | 2579-29 | 248744 | 740850        | 741052        | 741059 | 257567 |
| SPS | 3420 | 2930+03 | 2642-02 | 2456-04 | 2470-18 | 2583-31 | 751045 | 741053        | 750950        |        |        |
| SHV | 2523 | 2342+11 | 2338+06 | 2342+01 | 2361-13 | 2370-27 | 249341 | <b>741848</b> | <b>750854</b> | 750060 | 247769 |
| LCH | 2050 | 2250+13 | 2338+08 | 2332+04 | 2354-12 | 2368-25 | 259338 | <b>750446</b> | <b>761456</b> |        |        |

<sup>28</sup> Derived from FBUS31 KWN0 winds aloft bulletin.

The turbulence occurred between Shreveport (SHV) and Lake Charles (LCH), Louisiana forecast locations. The forecast for SHV for 34,000 ft expected a wind from 240° at 118 knots with a temperature of -48° C, and for 39,000 ft from 250° at 108 knots with a temperature of -54° C. At LCH the forecast for 34,000 ft was from 250° at 104 knots with a temperature of -46° C, and for 39,000 ft from 260° at 114 knots with a temperature of -56° C.

## **8.0 NWS Inflight Weather Advisories**

Inflight Aviation Weather Advisories are forecasts to advise en route aircraft of development of potentially hazardous weather. Inflight aviation weather advisories in the conterminous U.S. are issued by the NWS AWC, as well as from the Center Weather Service Units (CWSU) associated with FAA ARTCCs. There are four basic types of inflight aviation weather advisories: the Significant Meteorological Information (SIGMET), the Convective SIGMET, the AIRMET, and the Center Weather Advisory (CWA). Inflight advisories serve to notify enroute pilots of the possibility of encountering hazardous flying conditions which may not have been forecast at the time of the preflight briefing. Whether or not the condition described is potentially hazardous to a particular flight is for the pilot and/or flight dispatcher to evaluate on the basis of experience and the operational limits of the aircraft. The following advisories were current during the period.

### **8.1 CWA**

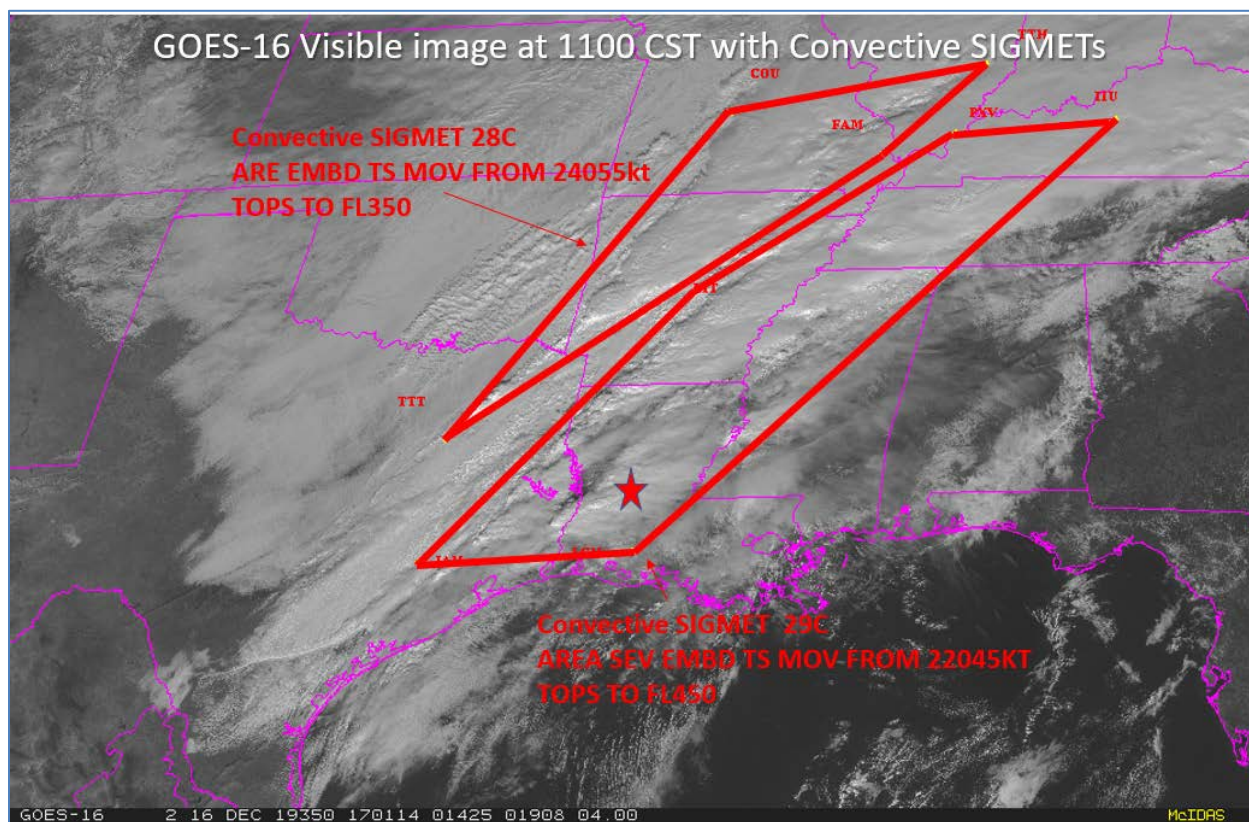
The NWS Houston CWSU was responsible for the airspace over the region where the accident occurred. Prior to the accident at 0902 CST the CWSU issued CWA number 101 valid until 1000 CST for an area of scattered rain showers and thunderstorms producing heavy precipitation, with tops to FL390. The advisory was as follows.

*FAUS21 KZHU 161502  
ZHU1 CWA 161500  
ZHU CWA 101 VALID UNTIL 161600  
FROM 25SE MLU-55WNW MCB-5W LCH-30NW LCH-25SE MLU  
AREA OF SCT SHRA/TSRA WITH MOD-HVY PCPN. MOV FM 22030KT. TOPS TO FL390.*

No further advisories were issued from the ZHU CWSU for the area.

### **8.2 Convective SIGMETs**

The NWS AWC issued several Convective SIGMETs for an area for severe embedded thunderstorm with tops to and above FL450 over the area between 1055 through 1355 CST which encompassed the turbulence location. Convective SIGMET imply the potential for severe or greater turbulence, severe icing, and potential low-level wind shear, and advised users to see Weather Watch number 700. Figures 29 through 31 are the advisories issued at approximately 1100, 1200, and 1300 CST plotted with the accident site followed by the text of the advisories applicable to the turbulence event in bold italic print. Convective SIGMETs are issued hourly and are issued with a valid period of 2-hours, but are subsequently updated or replaced by the next hourly issued advisory.



**Figure 29 - Convective SIGMETs 28C and 29C issued at 1055 CST and valid through 1255 CST**

WSUS32 KKC1 161655

SIGC

-MKCC WST 161655

CONVECTIVE SIGMET 28C

VALID UNTIL 1855Z

IL MO AR TX OK

FROM 50SW TTH-50SE FAM-60SE TTT-50SSW COU-50SW TTH

AREA EMBD TS MOV FROM 24055KT. TOPS TO FL350.

**CONVECTIVE SIGMET 29C**

**VALID UNTIL 1855Z**

**TN KY AL IL MS LA MO AR TX**

**FROM 30SSE IIU-40E LCH-30W IAH-40NNE LIT-30SW PXV-30SSE IIU**

**AREA SEV EMBD TS MOV FROM 22045KT. TOPS TO FL450.**

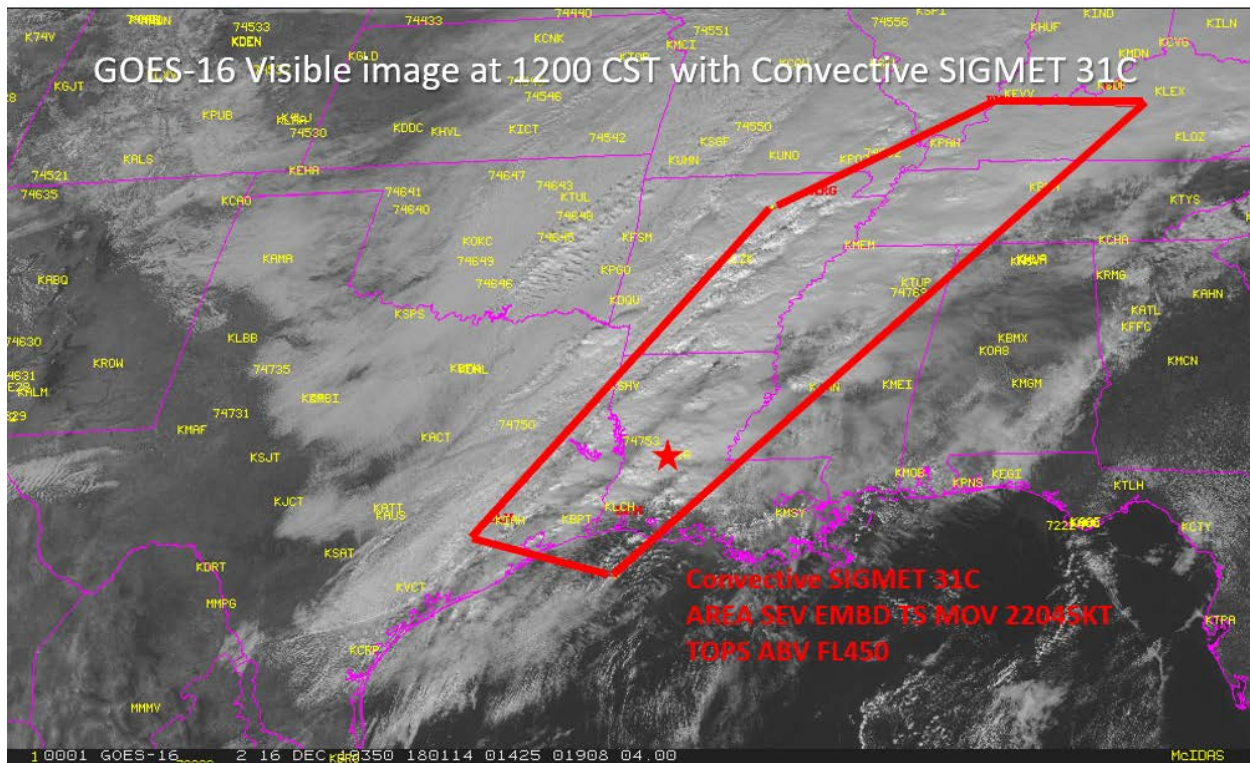
**TORNADOES...HAIL TO 1 IN...WIND GUSTS TO 50KT POSS.**

OUTLOOK VALID 161855-162255

FROM TTH-VUZ-70SSW LSU-90SSW LCH-CRP-50NNW TUL-TTH

REF WW 700

WST ISSUANCES EXPD. REFER TO MOST RECENT ACUS01 KWNS FROM STORM  
PREDICTION CENTER FOR SYNOPSIS AND METEOROLOGICAL DETAILS.

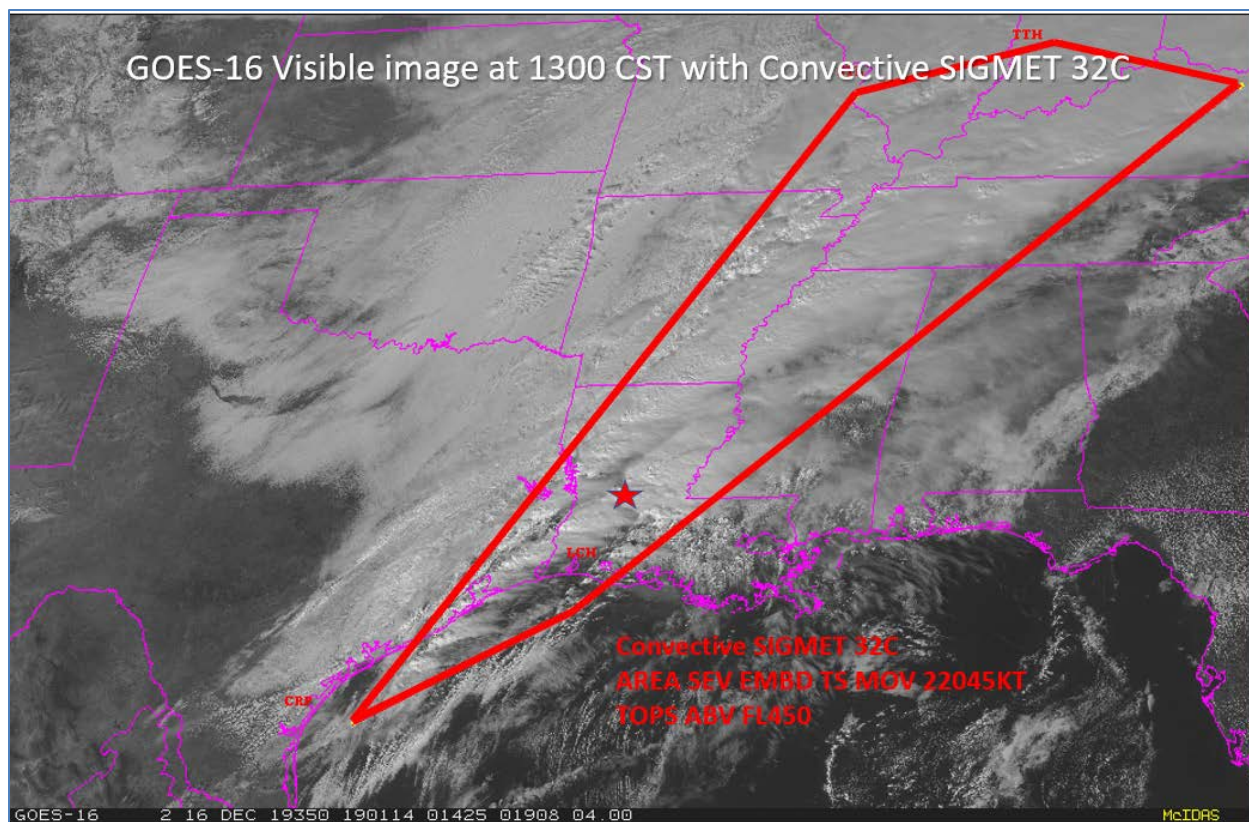


**Figure 30 - Convective SIGMET 31C issued at 1155 CST and valid until 1355 CST**

WSUS32 KNCI 161755  
 SIGC  
 -MKCC WST 161755  
 CONVECTIVE SIGMET 30C  
 VALID UNTIL 1955Z  
 IN IL MO AR TX OK  
 FROM TTH-50SW ARG-40WNW GGG-50SW STL-TTH  
 AREA EMBD TS MOV FROM 24055KT. TOPS TO FL380.

**CONVECTIVE SIGMET 31C**  
**VALID UNTIL 1955Z**  
**TN KY IN AL IL MS LA MO AR TX AND LA TX CSTL WTRS**  
**FROM PXV-40SE IJU-70S LCH-30SW IAH-50WSW ARG-PXV**  
**AREA SEV EMBD TS MOV FROM 22045KT. TOPS ABV FL450.**  
**TORNADOES...HAIL TO 1 IN...WIND GUSTS TO 50KT POSS.**

OUTLOOK VALID 161955-162355  
 FROM TTH-VUZ-70SSW LSU-90SSW LCH-CRP-50NNW TUL-TTH  
 REF WW 700  
 WST ISSUANCES EXPD. REFER TO MOST RECENT ACUS01 KWNS FROM STORM  
 PREDICTION CENTER FOR SYNOPSIS AND METEOROLOGICAL DETAILS.



**Figure 31 - Convective SIGMET 32C issued at 1255 CST and valid through 1455 CST**

*WSUS32 KPCI 161855*

*SIGC*

*-MKCC WST 161855*

***CONVECTIVE SIGMET 32C***

***VALID UNTIL 2055Z***

***TN KY IN AL IL MS LA MO AR TX AND LA TX CSTL WTRS***

***FROM 30ESE TTH-60WSW HNN-60S LCH-60ESE CRP-30SSE STL-30ESE TTH***

***AREA SEV EMBD TS MOV FROM 22045KT. TOPS ABV FL450.***

***TORNADOES...HAIL TO 1.5 IN...WIND GUSTS TO 65KT POSS.***

*OUTLOOK VALID 162055-170055*

*FROM TTH-CEW-60SSE LEV-60S PSX-STL-TTH*

*REF WW 700*

*WST ISSUANCES EXPD. REFER TO MOST RECENT ACUS01 KWNS FROM STORM PREDICTION CENTER FOR SYNOPSIS AND METEOROLOGICAL DETAILS.*

### 8.3 Weather Watch Notification Messages

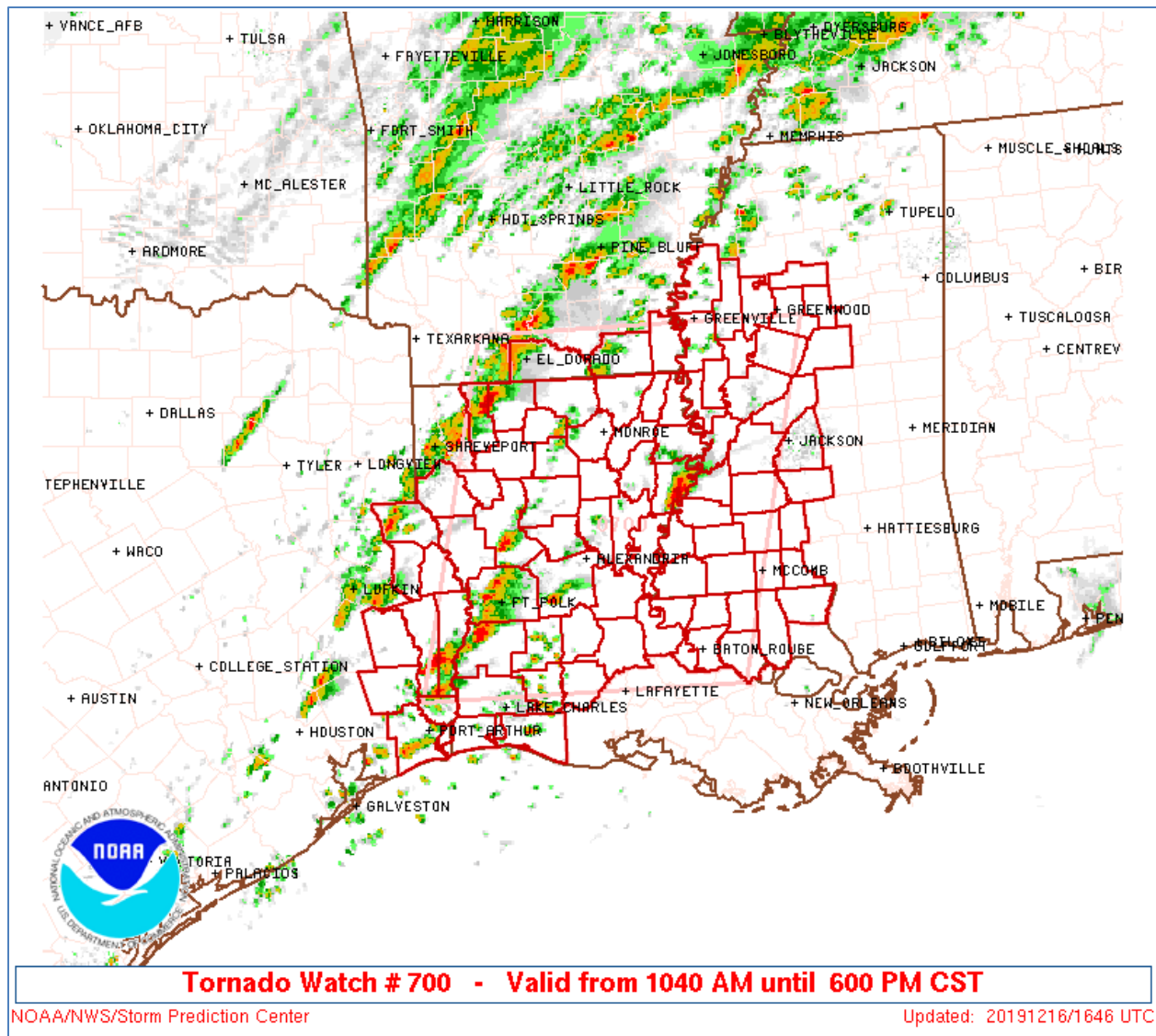
The NWS SPC issues Aviation Watch Notification Messages (SAW) to provide an area threat alert for the aviation meteorology community to forecast organized severe thunderstorms that may produce tornadoes, large hail, and/or convective damaging winds as indicated in Public Watch Notification Messages.

At 1040 CST the NWS SPC issued SAWs message for Weather Watch number 700 for potential tornadic thunderstorms that extended over portions of southern Arkansas, Louisiana, Mississippi, eastern Texas, and coastal waters. The advisory was valid from 1040 through 1800 CST and warned of potential severe thunderstorms with hail surface and aloft to 1.5 inches, wind gusts to 65 knots, with cumulonimbus cloud tops to 45,000 ft. The advisory also included a warning of extreme turbulence with the storms. The advisory was as follows with the initial radar and counties impacted in figure 32, with the Public Advisory following.

*SAW0  
WW 700 TORNADO AR LA MS TX CW 161640Z - 170000Z  
AXIS..100 STATUTE MILES EAST AND WEST OF LINE..  
25W LFT/LAFAYETTE LA/ - 70NNE MLU/MONROE LA/  
..AVIATION COORDS.. 85NM E/W /37E LCH - 60ENE ELD/  
HAIL SURFACE AND ALOFT..1.5 INCHES. WIND GUSTS..65 KNOTS.  
MAX TOPS TO 450. MEAN STORM MOTION VECTOR 24040.*

*LAT...LON 30199406 33439330 33438983 30199072*

*THIS IS AN APPROXIMATION TO THE WATCH AREA. FOR A  
COMPLETE DEPICTION OF THE WATCH SEE WOUS64 KWNS  
FOR WOU0.*



**Figure 32 - Weather Watch number 700 issued at 1040 CST and valid through 1800 CST**

*URGENT - IMMEDIATE BROADCAST REQUESTED*

*Tornado Watch Number 700*

*NWS Storm Prediction Center Norman OK*

*1040 AM CST Mon Dec 16 2019*

*The NWS Storm Prediction Center has issued a*

*\* Tornado Watch for portions of Far southern Arkansas  
Louisiana  
Western and central Mississippi  
Far eastern Texas  
Coastal Waters*

*\* Effective this Monday morning and evening from 1040 AM until 600 PM CST.*

*\* Primary threats include...*

*Several tornadoes and a couple intense tornadoes likely  
Widespread damaging winds likely with isolated significant gusts to 75 mph possible  
Isolated large hail events to 1.5 inches in diameter possible*

*SUMMARY...Several supercells are expected to develop and progress east-northeast across the Sabine and Lower Mississippi Valleys this afternoon. Tornadoes and damaging winds are anticipated, with the peak tornado risk across portions of northern and central Louisiana into western Mississippi.*

*The tornado watch area is approximately along and 100 statute miles east and west of a line from 25 miles west of Lafayette LA to 70 miles north northeast of Monroe LA. For a complete depiction of the watch see the associated watch outline update (WOUS64 KWNS WOU0).*

*PRECAUTIONARY/PREPAREDNESS ACTIONS...*

*REMEMBER...A Tornado Watch means conditions are favorable for tornadoes and severe thunderstorms in and close to the watch area. Persons in these areas should be on the lookout for threatening weather conditions and listen for later statements and possible warnings.*

*AVIATION...Tornadoes and a few severe thunderstorms with hail surface and aloft to 1.5 inches. Extreme turbulence and surface wind gusts to 65 knots. A few cumulonimbi with maximum tops to 450. Mean storm motion vector 24040.*

*...Grams*

### **8.3.1 Severe Weather Reports**

The NWS WFO reported the following severe weather reports in Louisiana and Mississippi between 1200 and 1415 CST immediately surrounding the period to verify their products, watches and warnings and to record the weather damage. Figure 33 is the severe weather reported on December 16, 2019 across the southcentral United States which included approximately 222 reports across Louisiana, southeastern Arkansas, Mississippi, Alabama, and Tennessee.

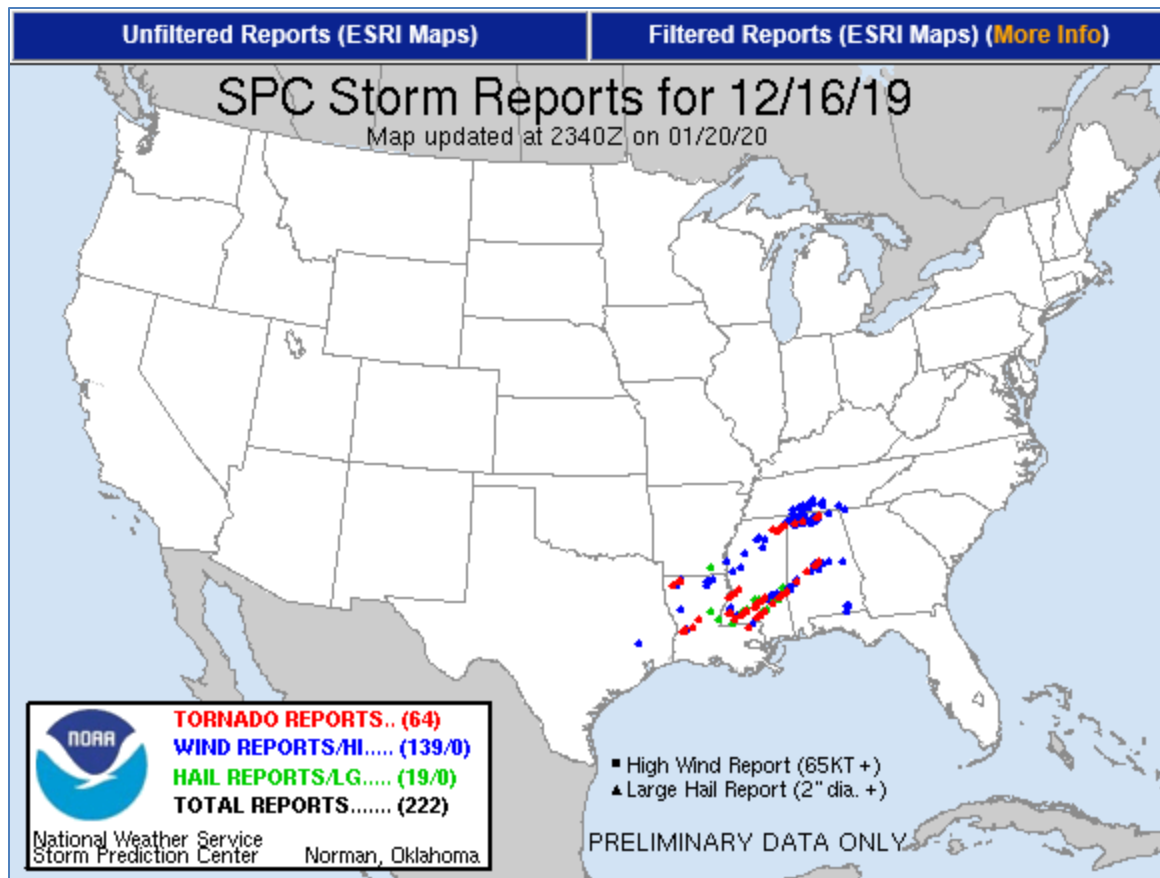


Figure 33 - NWS SPC Storm Reports reported on December 16, 2020

### Tornado Reports

| Time  | Location         | County  | State | Lat. Long.  | Comments                                                                                                                                           |
|-------|------------------|---------|-------|-------------|----------------------------------------------------------------------------------------------------------------------------------------------------|
| 1808Z | 1 SSW EDWARDS    | HINDS   | MS    | 32.32 90.61 | POWER POLES SNAPPED AND TREES DOWNED ON MOUNT MARIAH ROAD. (JAN)                                                                                   |
| 1808Z | EDWARDS          | HINDS   | MS    | 32.33 90.61 | MULTIPLE TREES DOWN ON HOMES AND VEHICLES IN EDWARDS. (JAN)                                                                                        |
| 1808Z | EDWARDS          | HINDS   | MS    | 32.33 9.060 | STORM CHASE OBSERVED CONE TORNADO IN EDWARDS ... TDS ALSO NOTED ON KGDX RADAR. (JAN)                                                               |
| 1809Z | EDWARDS          | HINDS   | MS    | 32.33 90.60 | TREES ON HOMES CAUSING ROOF DAMAGE OFF OF ASHCOT CIRCLE. (JAN)                                                                                     |
| 1848Z | 4 WNW ALEXANDRIA | RAPIDES | LA    | 31.31 92.54 | VIDEO FROM AIR TRAFFIC CONTROL TOWER AT THE ALEXANDRIA INTERNATIONAL AIRPORT OF A LARGE TORNADO ON THE GROUND JUST SOUTHEAST OF THE AIRPORT. (LCH) |
| 1850Z | 2 NW ALEXANDRIA  | RAPIDES | LA    | 31.32 92.49 | TORNADO SEEN CROSSING LA 1 (LCH)                                                                                                                   |

## Hail Reports

| Time  | Size | Location        | County    | State | Lat. Long.  | Comments                                                                                                                                                   |
|-------|------|-----------------|-----------|-------|-------------|------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1938Z | 1.75 | 12 ESE ACME     | CONCORDIA | LA    | 31.22 91.64 | MOTORIST REPORTED GOLF BALL SIZE HAIL VIA SOCIAL MEDIA WHILE TRAVELING ALONG HWY 15 JUST NORTH OF BLACK HAWK. TIME AND LOCATION ESTIMATED VIA RADAR. (JAN) |
| 1940Z | 1.25 | 5 SSE RHINEHART | CATAHOULA | LA    | 31.58 91.98 | PICTURE RELAYED VIA SOCIAL MEDIA ... HAIL WAS JUST LARGER THAN A QUARTER. (JAN)                                                                            |

## Wind Damage

| Time  | Speed | Location       | County      | State | Lat. Long.  | Comment                                                                                               |
|-------|-------|----------------|-------------|-------|-------------|-------------------------------------------------------------------------------------------------------|
| 1857Z | UNK   | ROBELINE       | NATCHITOCHE | LA    | 31.69 93.30 | NATCHITOCHE PARISH SHERIFF REPORTS DOWN POWER POLE AND LINES IN ROBELINE. (SHV)                       |
| 1942Z | UNK   | 2 E GREENVILLE | WASHINGTON  | MS    | 33.41 91.03 | TREES DOWN IN THE CITY OF GREENVILLE AND ALSO METCALFE. (JAN)                                         |
| 1950Z | UNK   | STERLINGTON    | OUACHITA    | LA    | 32.70 92.07 | SEVERAL TREES AND POWER LINES REPORTED DOWN IN THE STERLINGTON AREA. (SHV)                            |
| 1955Z | UNK   | 2 N MONROE     | OUACHITA    | LA    | 32.54 92.08 | SEVERAL TREES AND POWER LINES REPORTED DOWN MONROE AREA. (SHV)                                        |
| 2002Z | UNK   | 3 W COLLINSTON | MOREHOUSE   | LA    | 32.69 91.93 | NUMEROUS LARGE BRANCHES DOWN JUST SOUTH OF THE INTERSECTION OF PERRYVILLE RD AND OLD MONROE RD. (JAN) |
| 2009Z | UNK   | MER ROUGE      | MOREHOUSE   | LA    | 32.78 91.79 | SOCIAL MEDIA REPORT OF A TREE DOWN IN THE MER ROUGE AREA. (JAN)                                       |

## 9.0 Other Convective Weather products

### 9.1 Traffic Flow Management Convective Forecast

The Traffic Flow Management (TFM) Convective Forecast (TCF) is used by air traffic management decision-makers in support of convective weather mitigation strategies within the National Air Space. It is designed to meet the needs of TFM decision makers at the FAA Air Traffic Control System Command Center (ATCSCC), Air Route Traffic Control Center (ARTCC) Traffic Management Units (TMU), and airline and corporate Flight Operations Centers (FOC). The charts are updated every 2-hours and provide a 4-, 6-, and 8-hour forecast of convective coverage, intensity, and tops. The TCF 4-, 6-, and 8-hour forecasts issued at 1000 CST prior to the accident airplanes release for 1400, 1600, and 1800 CST is included as figure 34. The chart depicted an area of expected echoes over 40 dBZ with sparse or 25 to 39% coverage of

thunderstorms over Louisiana, Arkansas, and Mississippi with tops to 34,000 ft through 1600 CST, with coverage increasing to over 40 to 75% by 1800 CST to 34,000 ft.

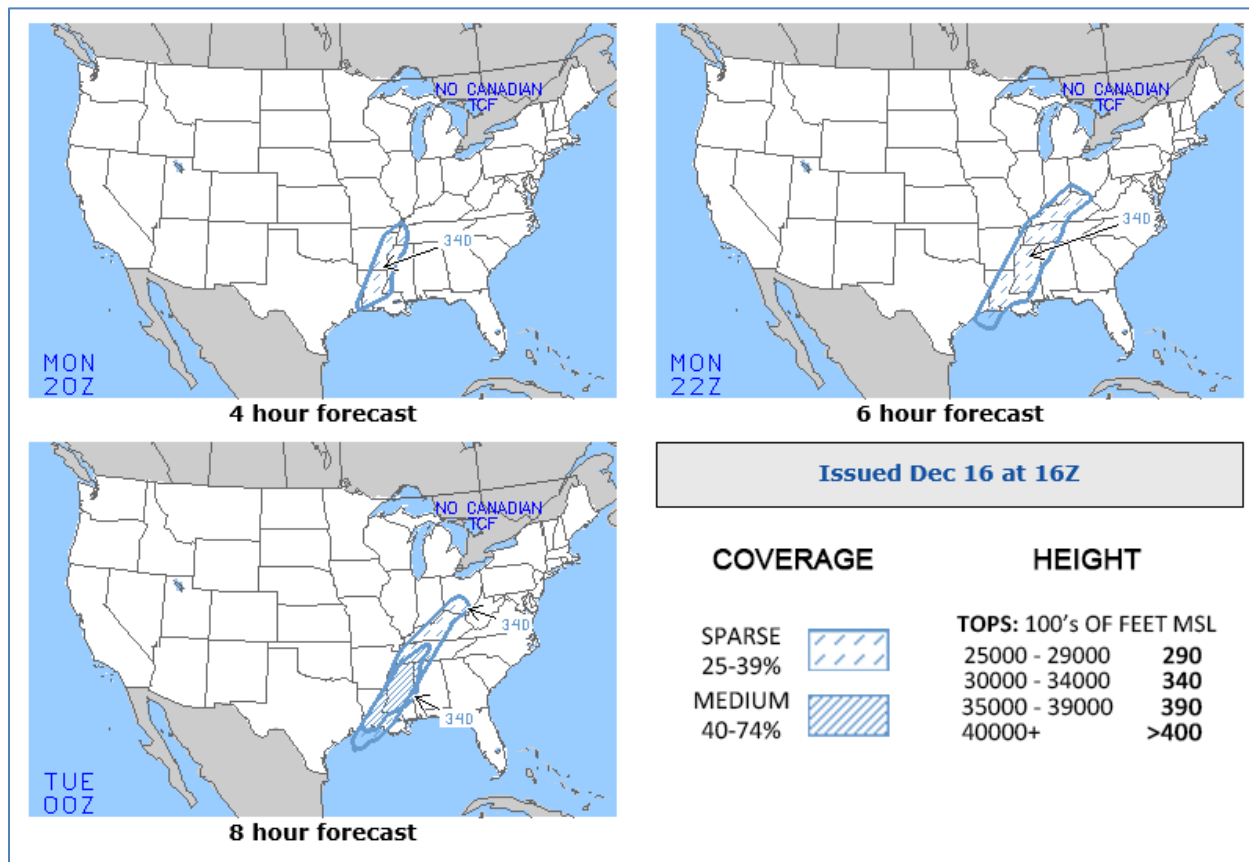
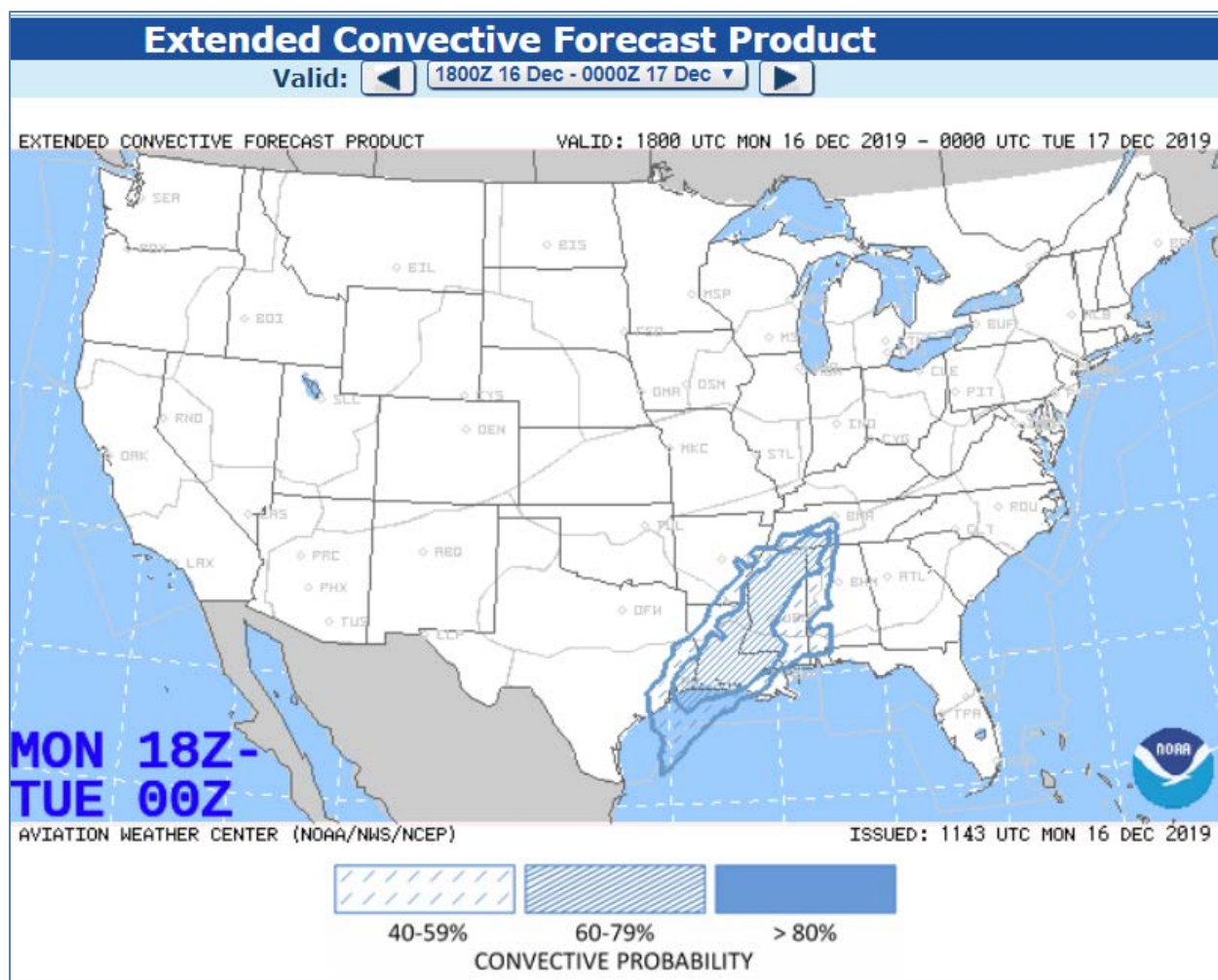


Figure 34 – Traffic Flow Management Convective Forecast issued at 1000 CST for 4-, 6-, and 8-hour

## 9.2 Extended Convective Forecast Product

Another convective weather forecast product available at the NWS AWC website is the Extended Convective Forecast Product (ECFP) Planning Tool. The ECPT is a graphical representation of the forecast probability of thunderstorms beyond 8-hours outwards to 72-hours. It is intended to enhance the TFM Collaborative Forecast (TCF) and provide support for the long range planning for thunderstorms that are expected to impact the National Airspace System. The ECFP like the TCF is intended for FAA Traffic Managers at ARTCC, ATCSCC, airline and aviation industry dispatch and flight planners, and private weather vendors supporting airline/FAA.

The ECFP issued at 0543 CST and valid for the period between 1200 and 1800 CST is included as figure 35, which depicted an area of thunderstorms expected with coverage between 60 and 80% over extreme southeast Texas, Louisiana, and Mississippi which extended over the turbulence location.



**Figure 35 - Extended Convective Forecast Product valid between 1200 and 1800 CST**

## 10.0 Preflight Weather Briefing

The flight release and weather document issued to flight 3960 issued at 1241 CST is included as Attachment 2. The weather document included METAR and TAFs for departure and destination airports, winds and temperatures aloft, company issued SIGMEC<sup>29</sup> advisory for convection, NOTAMs, and a few PIREPs.

Figure 36 is the SIGMEC advisory that was included in the weather document plotted over the GOES-16 visible satellite image at the time of issuance along with the approximate turbulence location immediately southeast of the advisory.

<sup>29</sup> SIGMEC is the airlines Enhanced Weather Information System (EWINS) providers Significant Meteorological Condition Advisory equivalent to a NWS SIGMET.



Submitted by:

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Donald Eick  
Senior Meteorologist