



NATIONAL TRANSPORTATION SAFETY BOARD

Office of Aviation Safety
Washington, D.C. 20594

August 28, 2017

Group Chairman's Factual Report

METEOROLOGY

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A. AIRCRAFT ACCIDENT

Location: Hayden, Alabama
Date: March 25, 2017
Time: 1433 central daylight time
1933 coordinated universal time
Airplane: Cessna T210L; Registration: N6563D

B. METEOROLOGIST

Don Eick
Senior Meteorologist
Operational Factors Division (AS-30)
National Transportation Safety Board

C. SUMMARY

On March 25, 2017, about 1433 central daylight time, a Cessna 210L, N6563D, was destroyed during an uncontrolled descent and subsequent inflight breakup near Hayden, Alabama. The pilot and three passengers were fatally injured. Instrument meteorological conditions prevailed and an instrument flight rules flight plan was filed. The flight originated from Kissimmee Gateway Airport (ISM), Orlando, Florida, and was destined for Mc Kellar-Sipes Regional Airport (MKL), Jackson, Tennessee. The personal flight was conducted under the provisions of 14 *Code of Federal Regulations* Part 91.

D. DETAILS OF THE INVESTIGATION

The National Transportation Safety Board's (NTSB) Senior Meteorologist traveled to Birmingham, Alabama and Atlanta, Georgia, during the period from April 6-12, 2017 to interview National Weather Service (NWS) forecast office, Center Weather Service Unit (CWSU), and Federal Aviation Administration (FAA) air traffic control personnel and review the weather displays, products, and other weather support provided to the flight during the period. The remainder of the meteorological phase of this investigation was conducted from the Washington D.C. office, collecting data from official 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 Coordinated Universal Time (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.

The main wreckage site was located at latitude 33.909152° N and longitude 86.732672° W, at an elevation of approximately 720 feet (ft). Prior to the accident, the aircraft had been cruising at

a pressure altitude of 10,000 ft, and had climbed to 12,000 ft immediately prior to the rapid descent and in-flight break up.

E. FACTUAL 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 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 FAA Advisory Circular “Aviation Weather Services”, AC 00-45H.

1.1 Surface Analysis Chart

The southeast section of the NWS Surface Analysis Chart for 1300 CDT (shown as 1800Z on chart) on March 25, 2017 is included as figure 1 with the approximate accident site marked by a red star. The chart depicted a low pressure system over Missouri at 1007-hectopascals (hPa)¹ associated with an occluded front. The triple point² of the system was located over northeast Missouri, where the occluded frontal system split into a stationary front across northern Missouri eastward across Illinois, Indiana, Ohio, into Pennsylvania, and a cold front extending southward across eastern Missouri southward through Arkansas into Louisiana, where the front became stationary and extended southwestward along the Texas Gulf coast. A squall line³ was depicted ahead of the cold front from southeastern Louisiana into southern Mississippi, with an outflow boundary⁴ depicted from the end of the squall line northward across western Alabama, immediately west of the accident site at the time of the analysis. The accident site was located ahead of the cold front and the outflow boundary, in the warm air sector of the front.

¹ Hectopascals (hPa) - is the new standard for reporting sea level pressure used by the NWS and is interchangeable with the term millibars (mb) with the same units. Standard sea level pressure is 1013.25-hPa.

² Triple point – is where the cold front catches up to the warm front, forcing warm air aloft and forming the occluded front. The triple point is where the three fronts meet.

³ Squall Line – is a line of active thunderstorms, either continuous or with breaks, including contiguous precipitation areas resulting from the existence of the thunderstorms. The squall line is a type of mesoscale convective system distinguished from other types by a larger length-to width ratio.

⁴ An outflow boundary, also known as a gust front, is a storm-scale or mesoscale boundary separating thunderstorm-cooled air (outflow) from the surrounding air similar in effect to a cold front, with passage marked by a wind shift and usually a drop in temperature and a related pressure jump. Outflow boundaries can persist for 24 hours or more after the thunderstorms that generated them dissipate, and can travel hundreds of miles from their area of origin. New thunderstorms often develop along outflow boundaries, especially near the point of intersection with another boundary.

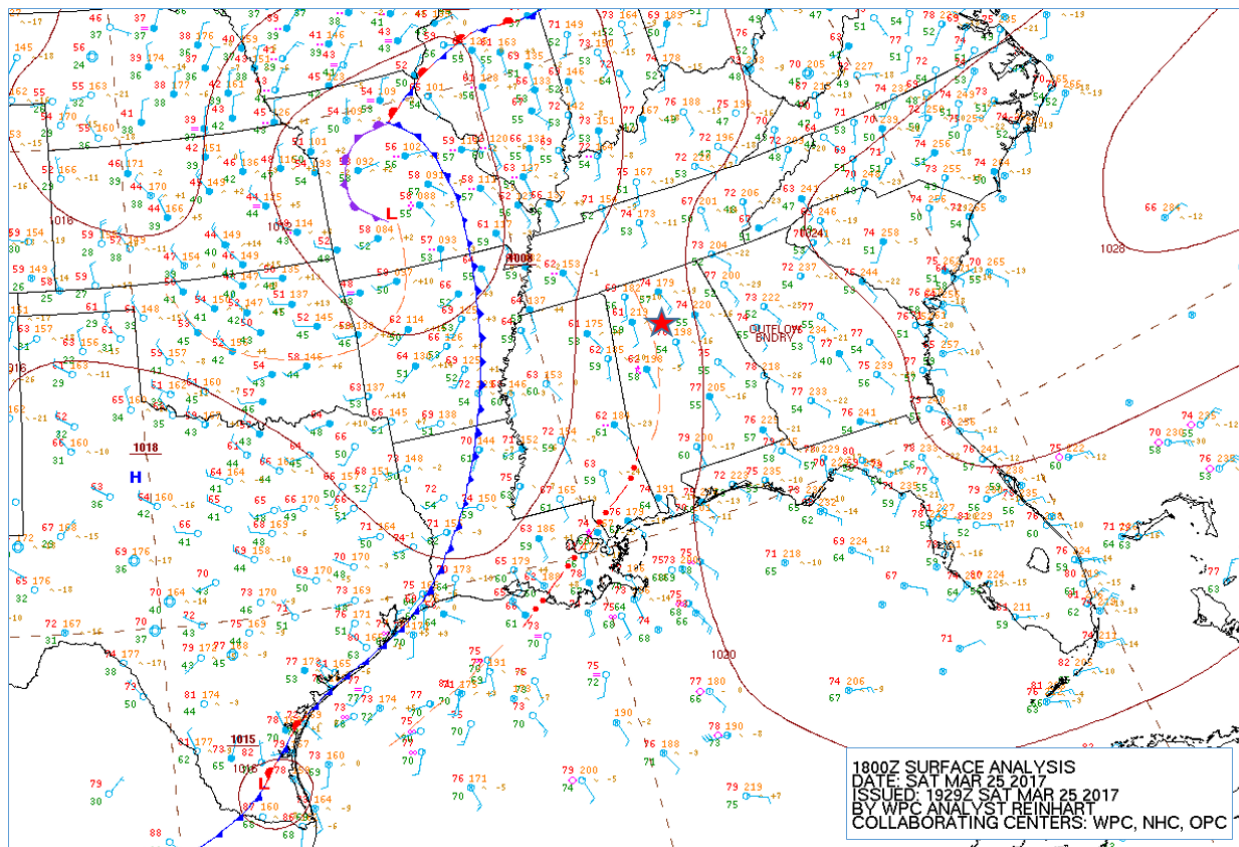


Figure 1- Southeast section of the NWS Surface Analysis Chart for 1300 CDT

The station models on the surface analysis depicted a large area of cyclonic or counterclockwise wind flow into the occluded frontal system over Missouri. In the immediate vicinity of the accident site the chart depicted southerly winds sustained at 5 to 15 knots, and broken to overcast sky cover. One station immediately south-southwest of the accident site and behind the outflow boundary reported a thunderstorm and rain showers. Ahead or east of the outflow boundary the station models indicated temperatures in the mid to upper 70's degrees Fahrenheit (F), while west of the boundary the temperatures were in the low 60's. Dew point temperatures were in the 50's to near 60's near the Gulf Coast immediately south.

1.2 Regional Radar Mosaic

The NWS National Radar Mosaic for 1430 CDT is included as figure 2 and depicted a line of echoes stretching from Tennessee southward across Alabama to west of Birmingham to Mobile, Alabama, with another area immediately south of Mobile in the Gulf of Mexico. This line of echoes was in the immediate vicinity of the accident site, which is enclosed in the red circle. A second more defined line of intense echoes associated with the squall line extended behind the first line from southeast Mississippi, to southeastern Louisiana, and into the Gulf of Mexico. A third area was located behind the two lines west through north of Jackson, Mississippi with an area of intense echoes.

The radar mosaic depicted the first broken line of echoes in the immediate vicinity of the accident site enclosed in the red circle, the echoes were immediately west of the Birmingham, AL area at the time.

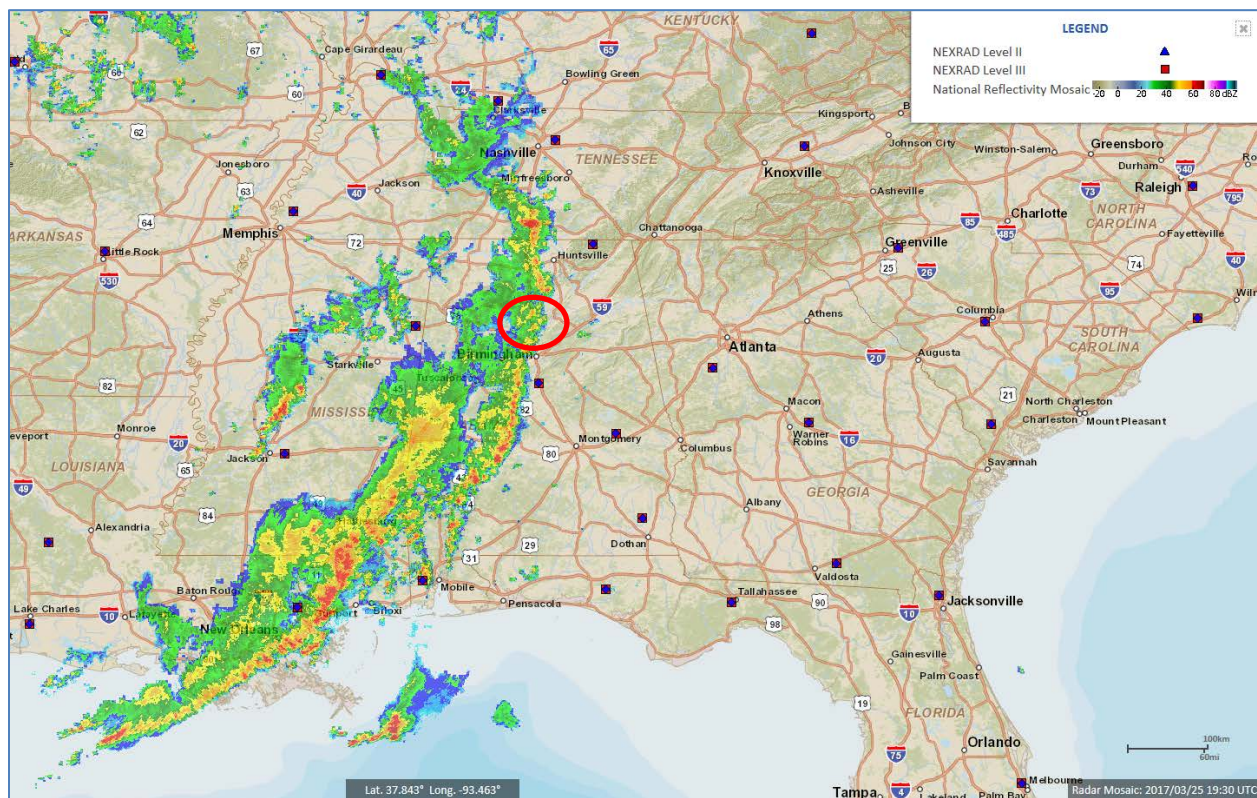


Figure 2 - Southeast section of the National Radar Mosaic for 1430 CDT

Figure 3 is a close-up of the National Radar Mosaic for 1425 CDT between Decatur and Birmingham, AL with a circle over the Hayden area and the accident site. The closest NWS weather radar will be further documented in section 5.0 of this report.

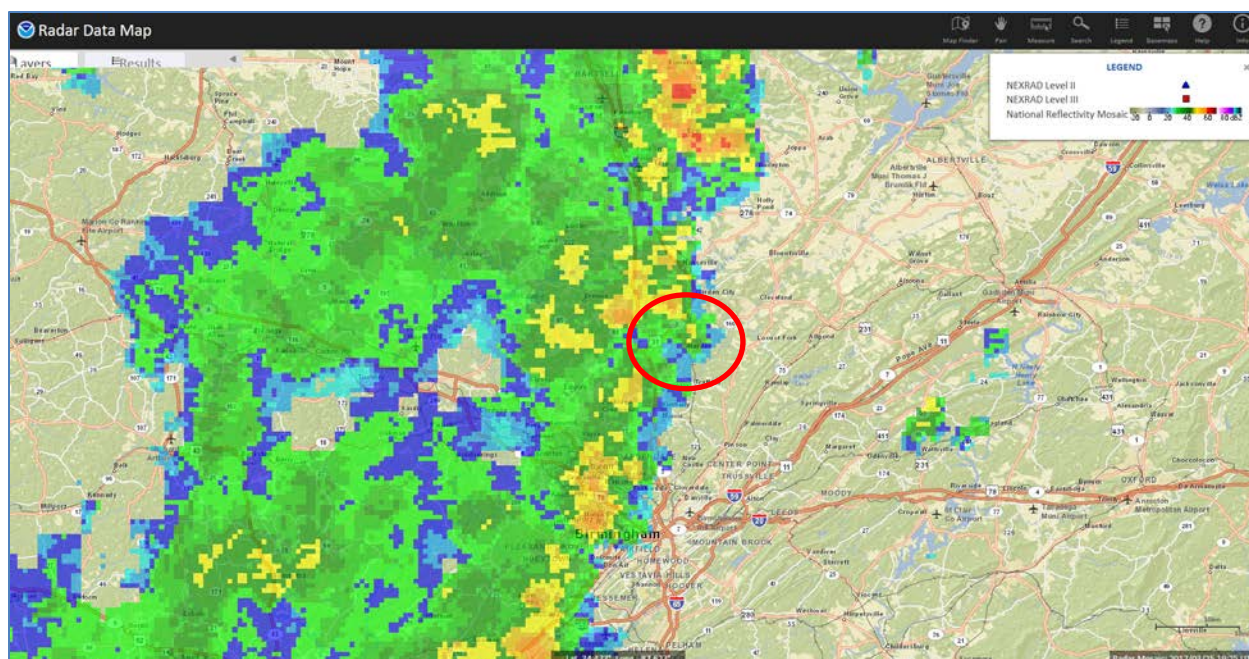


Figure 3 – Close-up of the National Radar Mosaic for 1425 CDT

1.3 Convective Outlook

The NWS Storm Prediction Center (SPC) located in Norman, Oklahoma, is responsible for predicting and issuing watch areas for organized severe thunderstorms and other severe weather events across the United States. The morning Convective Outlook graphic depicting where the SPC was expecting organized thunderstorms and severe weather for the day is included as figure 4. The chart depicted a slight risk of organized severe thunderstorms⁵ over western Alabama, eastern Mississippi, and southeastern Louisiana during the period, with a marginal area of thunderstorms through western Tennessee and the rest of Alabama. A slight risk implied an area of organized severe thunderstorms of scattered coverage were possible across the region, with either short-lived and/or isolated severe storms were possible. A marginal risk was for more isolated severe storm coverage. The convective outlook is typically used in preflight weather briefings to highlight areas where thunderstorms and severe thunderstorms can be expected, and with the narrative given more detailed information on the meteorological aspects favoring the development of the storms. While all thunderstorms are potentially hazard to aviation, a severe thunderstorm implied a higher hazard or threat level with potential severe to extreme turbulence, heavy rain, wind shear, wind gusts of 50 knots or greater, large hail, and a thunderstorm capable of producing a tornado. The FAA recommended⁶ avoidance of a severe or intense thunderstorm is at least 20 miles.

⁵ Severe thunderstorm – is defined as a thunderstorm which produces damaging winds of 50 knots or more, hail of one inch or larger, or a tornado. Severe thunderstorms imply severe to extreme turbulence, severe icing, frequent lightning, and a higher potential for low-level wind shear including gust fronts and microbursts.

⁶ Advisory Circular AC 00-24B – “Thunderstorms” dated February 19, 2013, and Airman’s Information Manual section 7-1-26 Thunderstorm Flying.

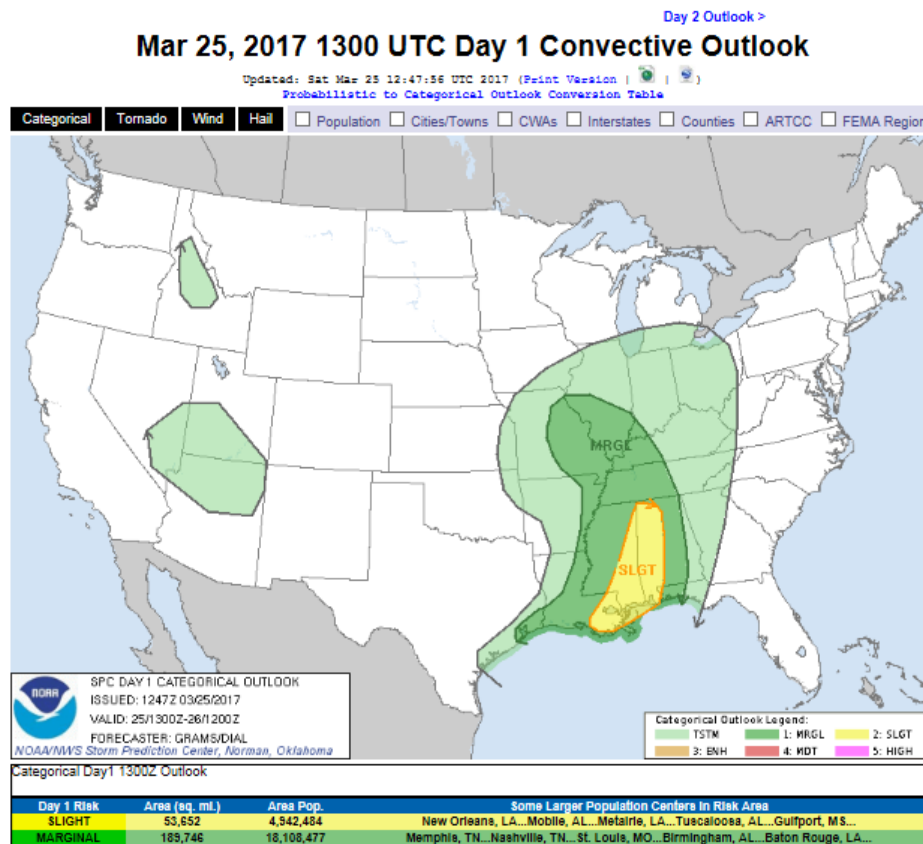


Figure 4 - NWS Convective Outlook issued at 0747 CDT for Thunderstorms

1.4 Significant Weather Prognostic Chart

The NWS 12-hour Significant Weather Prognostic Chart valid for the period is included in figure 5, depicted the expected conditions at approximately 1900 CDT. The chart continued to depict the low pressure system over Missouri with the occluded front wrapping around the low with a stationary to cold front extending eastward, and a cold front extending south-southwest across western Tennessee, western Mississippi and southeastern Louisiana. A large area of precipitation was expected along and ahead of the fronts from the gulf coast northward to the Great Lakes. The dark green areas represented a greater than 50% probability of precipitation over the region, and the red hatching indicating the potential for thunderstorms. The chart depicted that precipitation and thunderstorms were likely to be encountered along the route of flight from the Florida panhandle, into Alabama and Tennessee ahead of the frontal system.

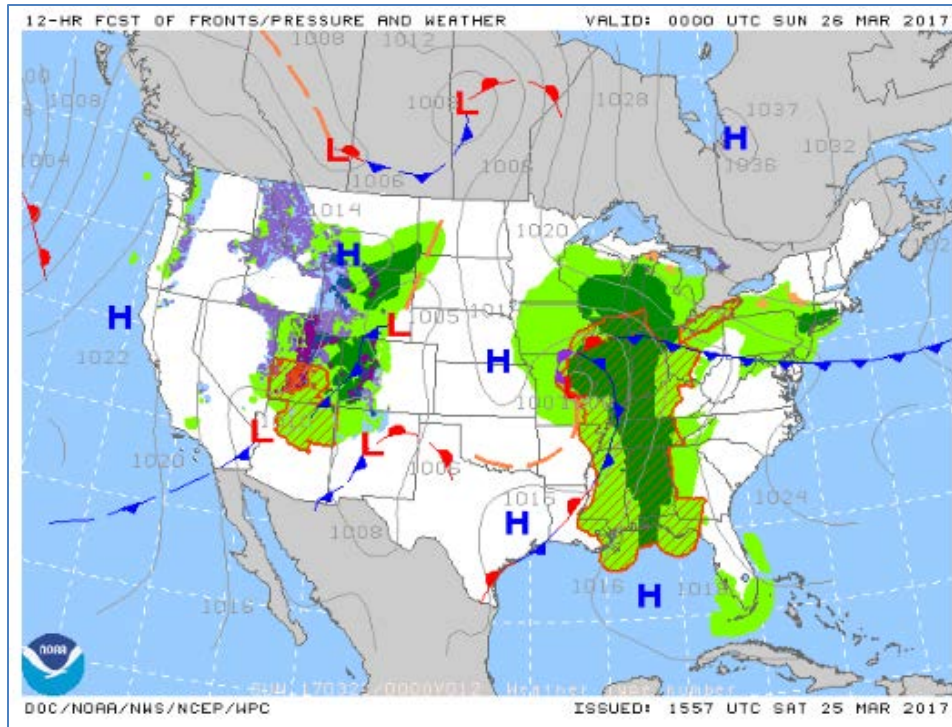


Figure 5 - Significant Weather Prognostic Chart valid for 1900 CDT

1.5 Constant Pressure Charts

The upper air charts or constant pressure charts for 850-, 700-, 500-, and 300-hPa for 0900 CDT on March 25, 2017 as prepared from the NWS SPC are included as figures 6 through 9 to help define the vertical structure of the atmosphere.

The 850-hPa chart (figure 6) depicted the approximate conditions at 5,000 ft and depicted the height contours by a dark line, the isotherms or lines of equal temperature as a red dashed line for temperatures above freezing and blue dashed lines below freezing temperatures at 2° Celsius (C) intervals. The green contours on the 850-hPa chart are dew point temperature at or above 8° C, to help identify areas of moisture. The chart depicted a closed upper level low pressure system over Missouri associated with the occluded fronts low with a short wave trough extending south-southwest into Texas. The contour and wind observations indicated a south-southeasterly wind over Florida at 10 to 15 knots with winds becoming south-southwesterly at 35 to 40 knots over Alabama. The wind flow and dew point temperatures indicated a flow of warm moist air streaming northward from the Gulf of Mexico across Louisiana, Mississippi, and western Alabama and Tennessee at this time.

The 700-hPa chart (figure 7) depicted the approximate conditions at 10,000 ft with the low pressure system over western Missouri with the trough extending south-southwest. A converging wind pattern was noted over Alabama with winds from the southwest at 25 knots. The temperature over the Birmingham area was depicted at 3° C.

The 500-hPa chart (figure 8) depicted the conditions at approximately 18,000 ft or of the mean atmosphere. The isotherms on the chart have been reversed to red, with all temperatures at this level below freezing. The chart continued to depict the low pressure system tilting back to the southwest portion of Missouri to eastern Kansas, with a trough extending southwestward and another short wave trough to the south. The station model for Birmingham indicated a wind from the south-southwest at 45 knots with a temperature of -14° C.

The 300-hPa chart (figure 9) depicted the approximate conditions at 30,000 ft and highlighted the boundaries of the jet stream over the region, with isotachs or lines of equal wind speed indicated by a blue line, with the areas of winds greater than 70 knots shaded in blue. In addition, areas of divergence are indicated in yellow. The chart continued to depict the vertical structure of the upper level low over western Missouri with a sharp or high amplitude trough extending southward. A diffluent area of wind flow was noted ahead of the trough over Louisiana, Mississippi, and Alabama with a southwest wind of 50 knots over Alabama. Large divergence values were noted over Louisiana and Mississippi, and southwestern Alabama at this time, supporting rising air over the region.

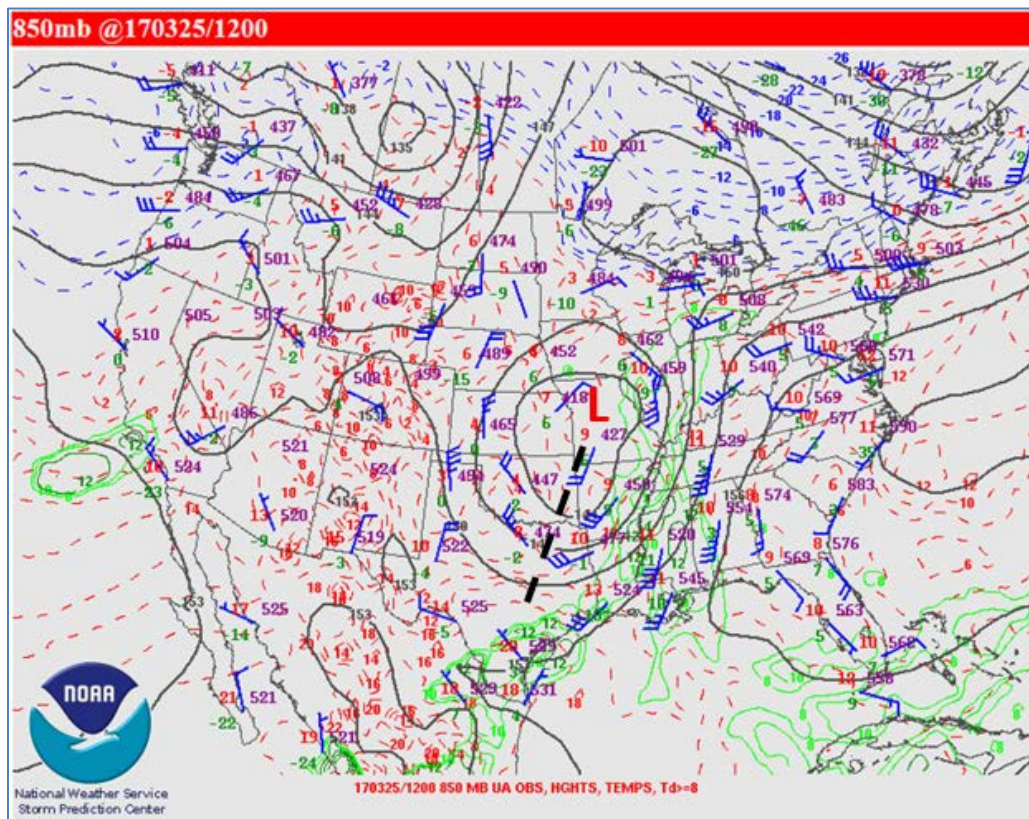


Figure 6 - 850-hPa constant pressure chart for 0700 CDT

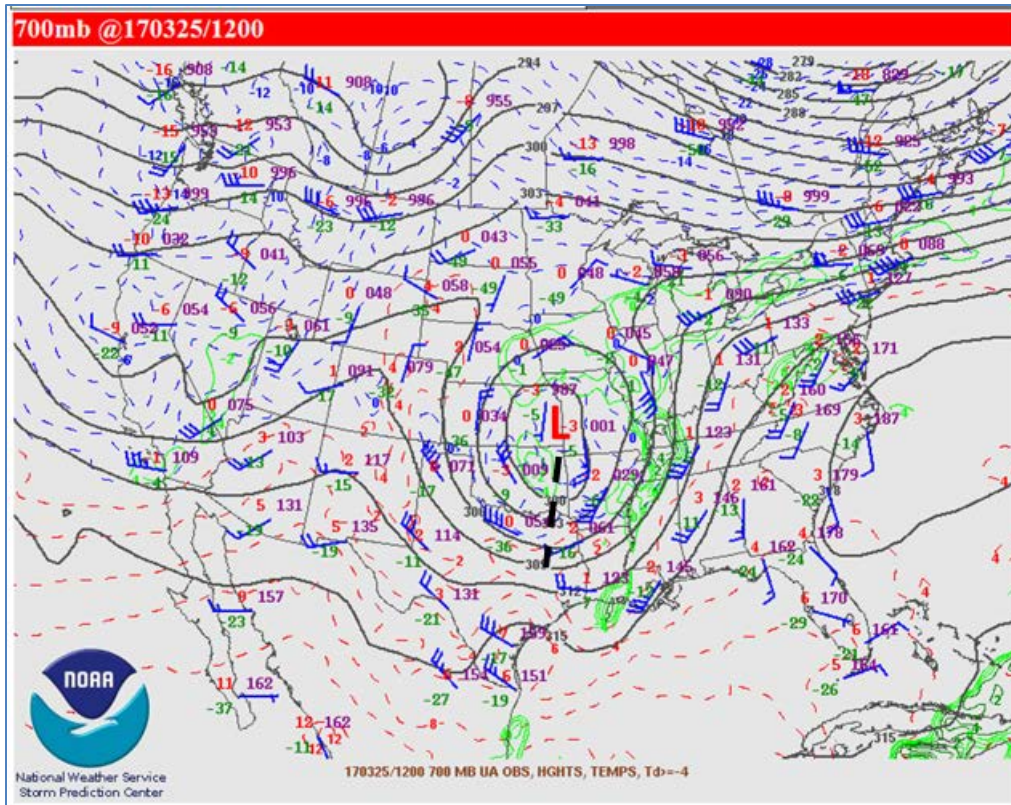


Figure 7 - 700-hPa constant pressure chart for 0700 CDT

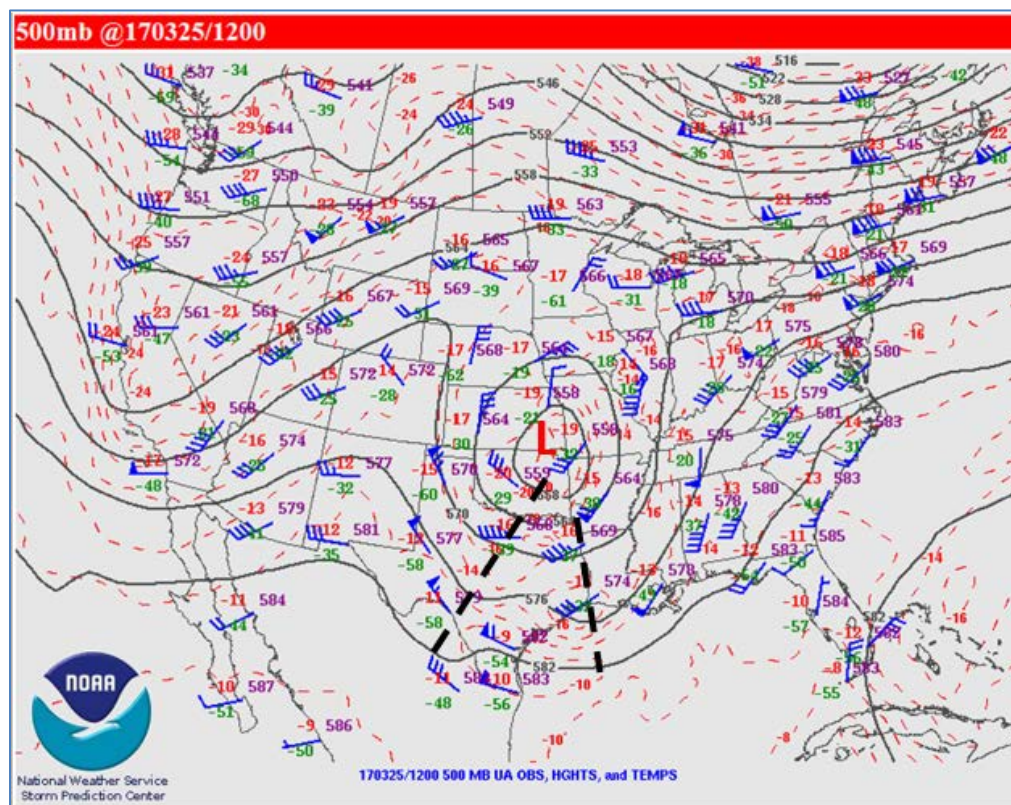


Figure 8 - 500-hPa constant pressure chart for 0700 CDT

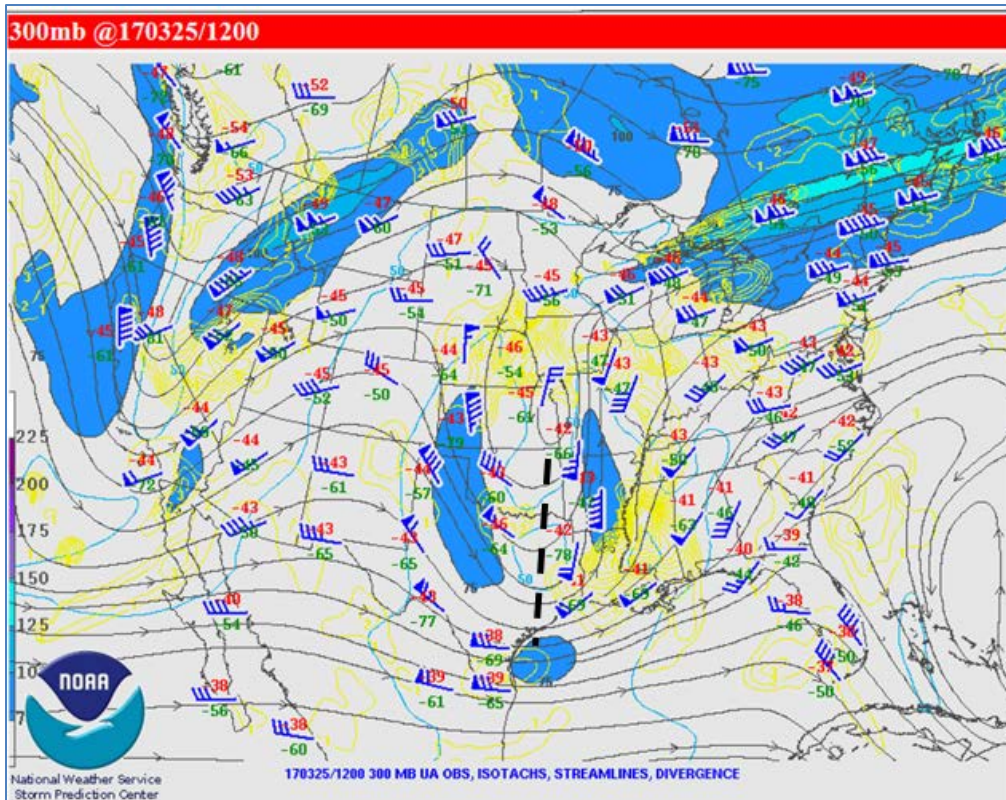


Figure 9 - 300-hPa constant pressure chart for 0700 CDT

2.0 Surface Observations

The closest weather reporting location to the accident site was from Birmingham-Shuttlesworth International Airport (KBHM) located 25 miles south of the accident site at an elevation of 650 ft. The airport had a federally installed and maintained Automated Surface Observation System (ASOS), which was also augmented by contracted NWS certified weather observers. The official NWS Meteorological Aerodrome Reports (METARs) and special reports (SPECIs) surrounding the period were documented. The cloud heights are reported above ground level (agl) in the following observations. The magnetic variation over the area was estimated at 3° West based on the sectional chart for the area. The following conditions were reported surrounding the period:

KBHM routine weather observation at 1353 CDT, wind from 160° at 14 knots gusting to 19 knots, visibility 10 miles, a few clouds at 4,700 ft, ceiling broken at 6,000 ft, temperature 26° C, dew point temperature 13° C, altimeter 30.10 inches of mercury (Hg). Remarks; automated observation system with a precipitation discriminator, peak wind from 200° at 28 knots occurred at 1307 CDT, lightning distant⁷ northwest, sea level pressure 1018.7-hPa, temperature 25.6° C, dew point 12.8° C.

⁷ Distant - with regards to lightning means beyond 10 miles but less than 30 nautical miles of the airport location point (ALP).

KBHM routine weather observation at 1453 CDT, wind from 260° at 16 knots, visibility 10 miles, ceiling broken at 4,600 ft, broken at 5,500 ft, temperature 21° C, dew point temperature 12° C, altimeter 30.09 inches of Hg. Remarks; automated observation system with a precipitation discriminator, sea level pressure 1018.2-hPa, temperature 20.6° C, dew point 11.7° C.

KBHM special weather observation at 1502 CDT, wind from 260° at 17 knots gusting to 22 knots, visibility 10 miles, ceiling overcast at 4,600 ft, temperature 20° C, dew point 12° C, altimeter 30.09 inches of Hg. Remarks; automated observation system with a precipitation discriminator, wind shift occurred at 1442 CDT, lightning distant south and southwest, temperature 20.0° C, dew point 12.2° C.

KBHM special weather observation at 1509 CDT, wind from 260° at 15 knots gusting to 23 knots, visibility 8 miles, thunderstorms in vicinity⁸ with moderate rain, ceiling broken at 4,500 ft, overcast at 5,500 ft, temperature 19° C, dew point 14° C, altimeter 30.10 inches of Hg. Remarks; automated observation system with a precipitation discriminator, wind shift occurred at 1442 CDT, lightning distant south and southwest, rain began at 1506 CDT, thunderstorm vicinity southwest moving northeast, hourly precipitation less than 0.01 inches, temperature 18.9° C, dew point 13.9° C.

KBHM special weather observation at 1523 CDT, wind from 240° at 11 knots gusting to 20 knots, visibility 2 ½ miles in thunderstorm and heavy rain and mist, ceiling broken at 4,500 ft in cumulonimbus clouds, overcast at 5,500 ft, temperature 17° C, dew point 14° C, altimeter 30.10 inches of Hg. Remarks; automated observation system with a precipitation discriminator, wind shift occurred at 1442 CDT, rain began at 1506 and thunderstorm began at 1520 CDT, occasional lightning in-cloud overhead, thunderstorm overhead and moving northeast, hourly precipitation 0.02 inches, temperature 16.7° C, dew point 14.4° C.

The raw observations and the general flight categories⁹ reported surrounding the period were as follows:

VFR METAR KBHM 251753Z 18012G21KT 10SM SCT046 BKN060 24/12 A3014 RMK AO2 SLP198 T02440122
 10244 20172 58016=

VFR METAR KBHM 251853Z 16014G19KT 10SM FEW047 BKN060 26/13 A3010 RMK AO2 PK WND
 20028/1807 LTG DSNT NW SLP187 T02560128=

⁸ Vicinity - indicates weather phenomena occurring beyond the point of observation, or between 5 and 10 statute miles.

⁹ 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 ft 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.

Accident 1933Z

VFR METAR KBHM 251953Z 26016KT 10SM BKN046 BKN055 21/12 A3009 RMK AO2 SLP182 T02060117=
VFR SPECI KBHM 252002Z 26017G22KT 10SM OVC046 20/12 A3009 RMK AO2 WSHFT 1942 LTG DSNT S
AND SW T02000122=
VFR SPECI KBHM 252009Z 26015G23KT 8SM VCTS RA BKN045 OVC055 19/14 A3010 RMK AO2 WSHFT
1942 LTG DSNT S AND SW RAB06 TS VC SW MOV NE P0000 T01890139=
IFR SPECI KBHM 252023Z 24011G20KT 2 1/2SM +TSRA BR BKN045CB OVC055 17/14 A3010 RMK AO2
WSHFT 1942 RAB06 TSB20 OCNL LTGIC OHD TS OHD MOV NE P0002 T01670144=
MVFR SPECI KBHM 252038Z 25008KT 5SM +TSRA BR BKN044CB OVC055 17/15 A3009 RMK AO2 WSHFT
1942 LTG DSNT S RAB06 TSB20 OCNL LTGIC NE TS NE MOV NE P0017 T01670150=
MVFR SPECI KBHM 252043Z 25009KT 5SM VCTS -RA BR SCT044 BKN055 OVC070 17/15 A3010 RMK AO2
WSHFT 1942 LTG DSNT S RAB06 TSB20 TS VC S MOV NE P0020 T01670150=
MVFR SPECI KBHM 252051Z 25010KT 3SM VCTS +RA BR FEW044 BKN055 OVC075 17/14 A3009 RMK AO2
WSHFT 1942 LTG DSNT S RAB06 TSB20 P0023=
MVFR METAR KBHM 252053Z 24008KT 3SM VCTS +RA BR BKN049 BKN060 OVC075 17/15 A3009 RMK AO2
WSHFT 1942 LTG DSNT S RAB06 TSB20 SLP185 TS VC S MOV NE P0024 60024 T01670150
55004=
IFR SPECI KBHM 252101Z 24007KT 2 1/2SM VCTS RA BR BKN060 OVC075 17/15 A3009 RMK AO2 LTG
DSNT SE AND S TS VC S MOV NE P0002 T01670150=
IFR SPECI KBHM 252112Z 25008KT 1 3/4SM +RA BR BKN047 BKN060 OVC075 17/15 A3009 RMK AO2 LTG
DSNT SE P0006 T01670150
MVFR SPECI KBHM 252129Z 18005KT 3SM RA BR BKN049 OVC070 16/15 A3009 RMK AO2 LTG DSNT NE
P0016 T01610150
MVFR METAR KBHM 252153Z 00000KT 4SM RA BR FEW055 BKN075 OVC090 16/15 A3008 RMK AO2
SLP183 P0024 T01610150
MVFR SPECI KBHM 252253Z 25007KT 4SM RA BR BKN075 OVC090 16/15 A3008 RMK AO2 SLP182 P0018
T01610150
MVFR METAR KBHM 252353Z 12005KT 4SM RA BR BKN075 OVC090 16/14 A3009 RMK AO2 SLP184 P0015
60081 T01560144 10261 20156 55001
VFR METAR KBHM 260053Z 00000KT 8SM RA OVC080 16/15 A3009 RMK AO2 SLP186 P0012 T01560150
MVFR METAR KBHM 260153Z 00000KT 4SM RA BR BKN075 OVC090 16/14 A3011 RMK AO2 SLP192 P0014
T01560144
VFR METAR KBHM 260253Z 03005KT 10SM FEW080 SCT095 SCT120 15/14 A3006 RMK AO2 RAE48
SLP175 P0012 60038 T01500144 58008

The observations indicated southerly winds at 14 knots gusting to 20 knots with a wind shift to the southwest being reported at 1442 CDT. At the time of the accident lightning was observed to

the northwest of the airport, with thunderstorms reported in the vicinity at 1509 CDT and over the airport at 1520 CDT with in heavy rain which caused localized IFR conditions. The rain began at 1506 CDT and continued through 2148 CDT, or for over 6 ½ hours with 1.19” of rainfall being recorded at the station.

A plot of the observations with the regional radar image from the NWS Aviation Weather Center (AWC) website at 1400 and 1500 CDT is included in figure 10. KBHM depicted VFR conditions prevailing during the period and shows a shift in the wind from the south to the west prior to the leading edge of the precipitation at KBHM. Several heavy to extreme cells are also identified along the leading edge of the line. The left image depicts the conditions reported at 1400 CDT with wind from the south at approximately 15 knots gusting to 20 knots, visibility of 10 miles, with ceiling broken at 6,000 ft, temperature of 78° F, dew point temperature of 55° F, and an altimeter of 30.10 inches of Hg. At 1500 CDT on the right, KBHM reported winds from the west at 15 knots, visibility 10 miles, ceiling broken at 4,500 ft, a temperature of 69° F, dew point of 53° F, and an altimeter of 30.09 inches of Hg. The edge of the band of echoes was just reaching the KBMH airport, and had already moved over the accident site by this time.

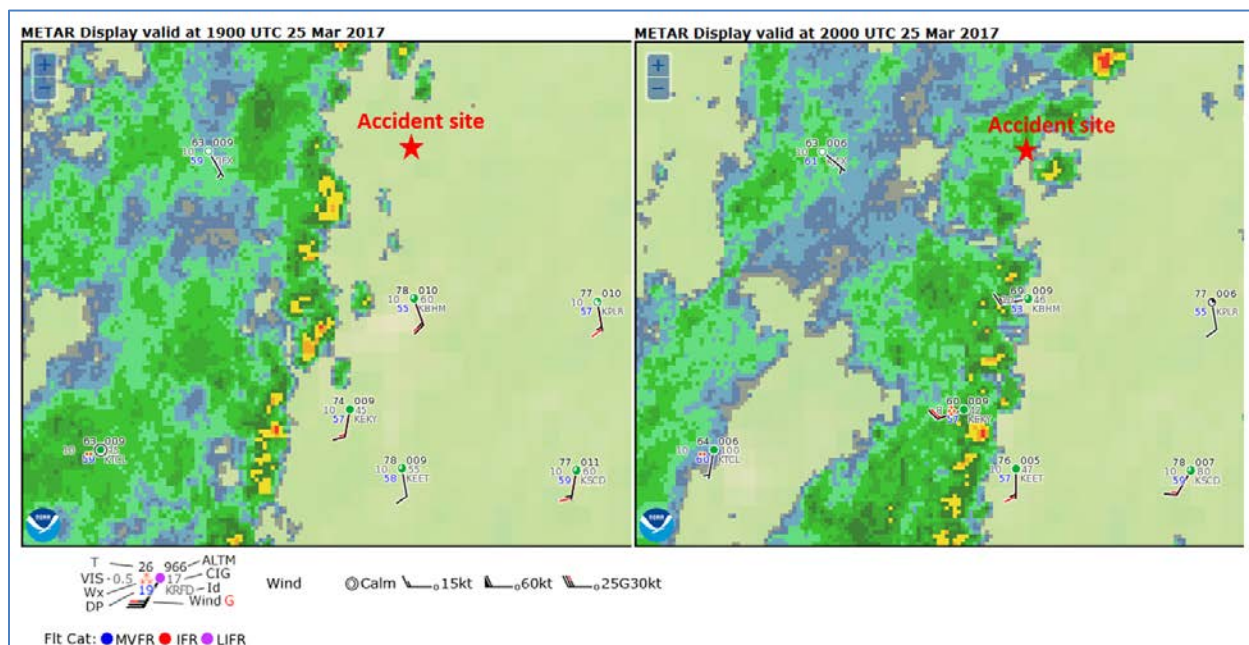


Figure 10 - METAR display from AWC website at 1400 CDT on the left and 1500 CDT on the right

3.0 Sounding

The vertical structure of the atmosphere was documented by the NWS balloon launched instrument package or rawinsonde observation (RAOB) prior to the accident, a high-resolution numerical model for the approximate time of the accident, and by two instrumented aircraft reports about the time and after the accident.

3.1 Rawinsonde Observation

The closest upper air sounding or rawinsonde observation (RAOB) was from the NWS Birmingham (KBMX) Weather Forecast Office (WFO), site number 72230, location about 45 miles south of the accident site in Calera, Alabama, an elevation of 584 ft. A special mid-day sounding was launched for the 1300 CDT (1800Z¹⁰) period and is plotted on a standard Skew-T log P diagram¹¹ from the surface to 500-hPa or 18,000 ft utilizing RAOB software¹² as figure 11. The sounding depicted the observed upper air conditions immediately prior to the accident and the period the thunderstorms and rain showers moved across the Birmingham area.

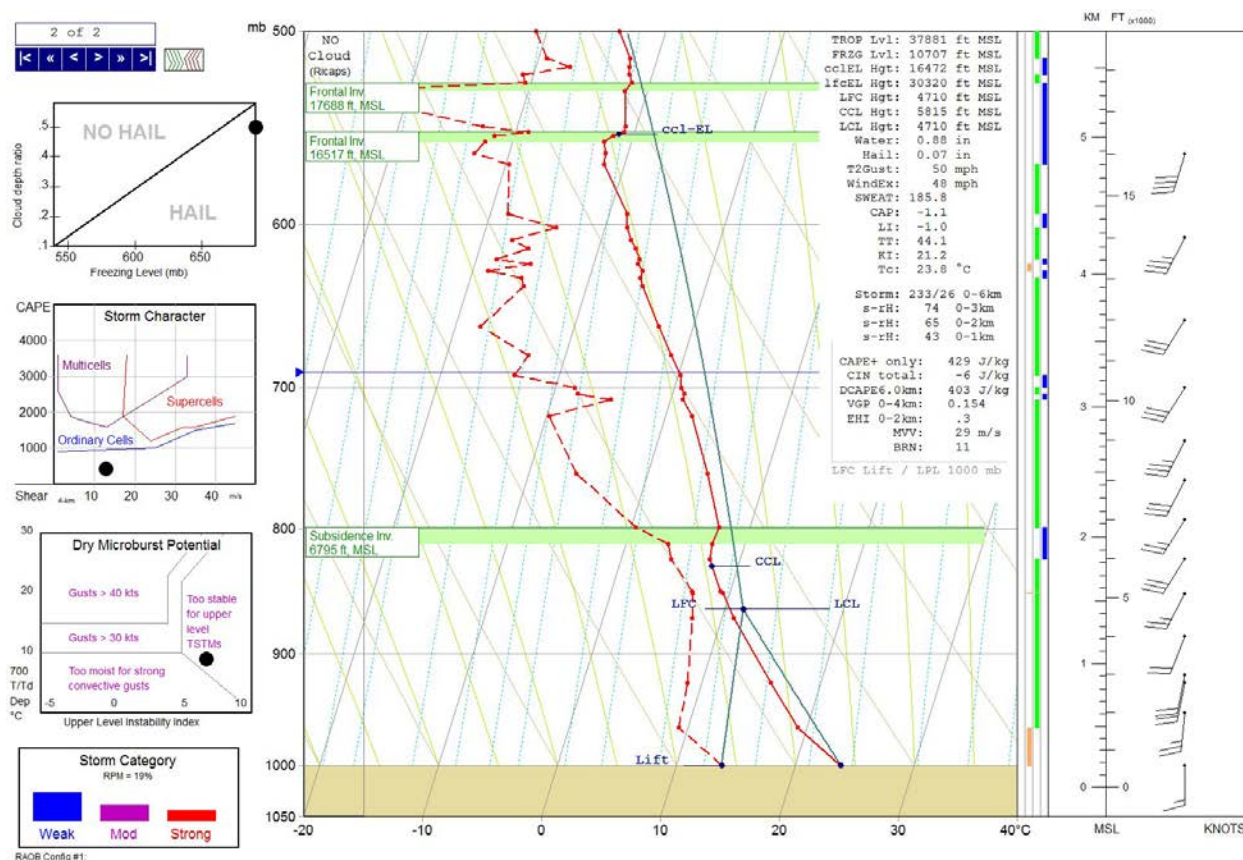


Figure 11 - KBMX 1300 CDT upper air sounding to 18,000 feet

¹⁰ The sounding is typically launched within the period about 60 minutes prior to the scheduled observation period of 0000Z and 1200Z, or a midday launch of 1800Z. In this case, the actual launch was near 1700Z or 1200 CDT on March 25, 2017 for the special midday observation.

¹¹ 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.

¹² RAOB software – The complete Rawinsonde Observation program is an interactive sounding analysis program developed by Environmental Research Services, Matamoras, Pennsylvania.

The KBMX sounding depicted a surface temperature of 23.8° C, with a dew point of 13.8° C, and a relative humidity of 54%. The lifted condensation level (LCL)¹³ and the level of free convection (LFC)¹⁴ were identified at 4,126 ft agl, with the convective condensation level (CCL)¹⁵ at 5,231 ft agl. A temperature inversion (indicated by green shading on diagram) caused by substance was located immediately above these levels at 6,200 ft, where temperature increased with height and created a stable layer. The equilibrium level (EL)¹⁶ or expected top of convective clouds was at 30,320 ft with the tropopause at about 37,900 ft. The freezing level was identified about 10,700 ft and is depicted by a horizontal blue line on the diagram. The precipitable water content of the atmosphere was 0.88 inches.

The stability parameters indicated a conditional unstable environment with a Lifted Index (LI)¹⁷ of -1.0, a K-Index¹⁸ of 21.2, and a Convective Available Potential Energy (CAPE)¹⁹ of 429 Joules/kilogram (J/kg). The maximum vertical velocity (MVV) of the potential updrafts was 29 meters/second or 58 knots. The microburst index or WINDEX indicated potential outflow winds of 42 knots. The overall atmosphere sounding indicated by RAOB program indicated a weak to moderate potential for severe thunderstorms, small hail, and favored ordinary type cell formation.

The wind profile indicated a surface wind from the south or 180° at 13 knots with wind direction slowly veering to the south-southwest and with increasing wind speeds with height through 18,000 ft with wind speeds to 50 knots. The level of maximum wind was identified in the stratosphere at

¹³ Lifting Condensation Level (LCL) - The height at which a parcel of moist air becomes saturated when it is lifted dry adiabatically.

¹⁴ 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.

¹⁵ 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.

¹⁶ Equilibrium Level (EL) - On a sounding, the level above the level of free convection (LFC) at which the temperature of a rising air parcel again equals the temperature of the environment. The height of the EL is the height at which thunderstorm updrafts no longer accelerate upward. Thus, to a close approximation, it represents the height of expected (or ongoing) thunderstorm tops. However, strong updrafts will continue to rise past the EL before stopping, resulting in storm tops that are higher than the EL. This process sometimes can be seen visually as an overshooting tops or anvil dome. The EL typically is higher than the tropopause, and is a more accurate reference for storm tops

¹⁷ 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 ft 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.

¹⁸ 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.

¹⁹ Convective Available Potential Energy (CAPE) – is a measure of the amount of energy available for convection. CAPE is directly related to the maximum potential vertical speed within an updraft; thus, higher values indicate greater potential for severe weather.

43,000 ft from 235° at 70 knots. The mean 0 to 6 kilometer or 18,000 ft wind was from 200° at 34 knots, with the expected storm motion from 230° at 26 knot. The wind at 12,000 ft or N6563D cruising altitude was from 210° at 29 knots, with a temperature of -3.3° C.

Figure 12 is a table listing of the KBMX sounding elements; height, pressure, temperature, dew point, relative humidity (RH), wind direction and speed, clear air turbulence (CAT), low-level wind shear (LLWS), and icing potential as derived by the observed data.

Height (ft-MSL)	Pres (mb)	T (C)	Td (C)	RH (%)	DD / FF (deg / kts)	CAT (FAA)	LLWS	Icing - Type (AFGWC method)
584	1001	15.6	12.8	83	120 / 5		LIGHT	
612	1000	15.4	10.4	72	130 / 7			
1118	982	14.8	10.1	73		XTR	LIGHT	
1952	953	15.2	9.2	67	160 / 35			
2512	934	14.4	6.4	59		MDT		
2780	925	13.6	6.6	63	170 / 35			
3000	918				170 / 35	MDT		
3936	887	11.2	7.3	77	180 / 35			
4877	857	9.4	5.2	75				
5036	852	9.4	4.4	71		SVR		
5100	850	9.6	2.6	62	200 / 37			
5325	843	10.0	-7.0	29				
5650	833	10.2	-16.8	13		MDT		
6000	822				210 / 35			
6849	797	7.4	-4.6	42		SVR		
7000	793				210 / 25			
7121	789	6.6	1.6	70		MDT		
8000	764				220 / 30			
8340	754	4.6	-0.4	70				
8590	747	4.2	-0.8	70		LGT		
8950	737	4.4	-6.6	45	210 / 28			
9168	731	4.2	-5.8	48				
9315	727	4.4	-10.6	33				
9425	724	4.4	-10.6	33				
10172	704	3.4	-10.6	35		LGT		
10324	700	3.2	-10.8	35	225 / 27			
10553	694	2.8	-14.2	27		LGT		
11000	682				225 / 32			
11210	677	2.0	-15.0	27		LGT		
12000	657				215 / 32			
14000	608				215 / 31	LGT		

Figure 12 - KBMX 1300 CDT sounding data

3.2 Numerical Model Sounding

A High Resolution Rapid Refresh (HRRR) numerical model was also reviewed from archive data from the NOAA Air Resource Laboratory database for the approximate location of the accident at 1400 CDT and is included as figure 13. The model sounding depicted a similar vertical structure of the atmosphere with slightly more moisture, with a precipitable water value of 1.08 inches and a slightly more unstable airmass with a lifted index of -2.0, with a similar MVV of the potential updrafts. The conditions at 12,000 ft indicated a forecast wind from 195° at 32 knots, with a temperature of -3.3° C.

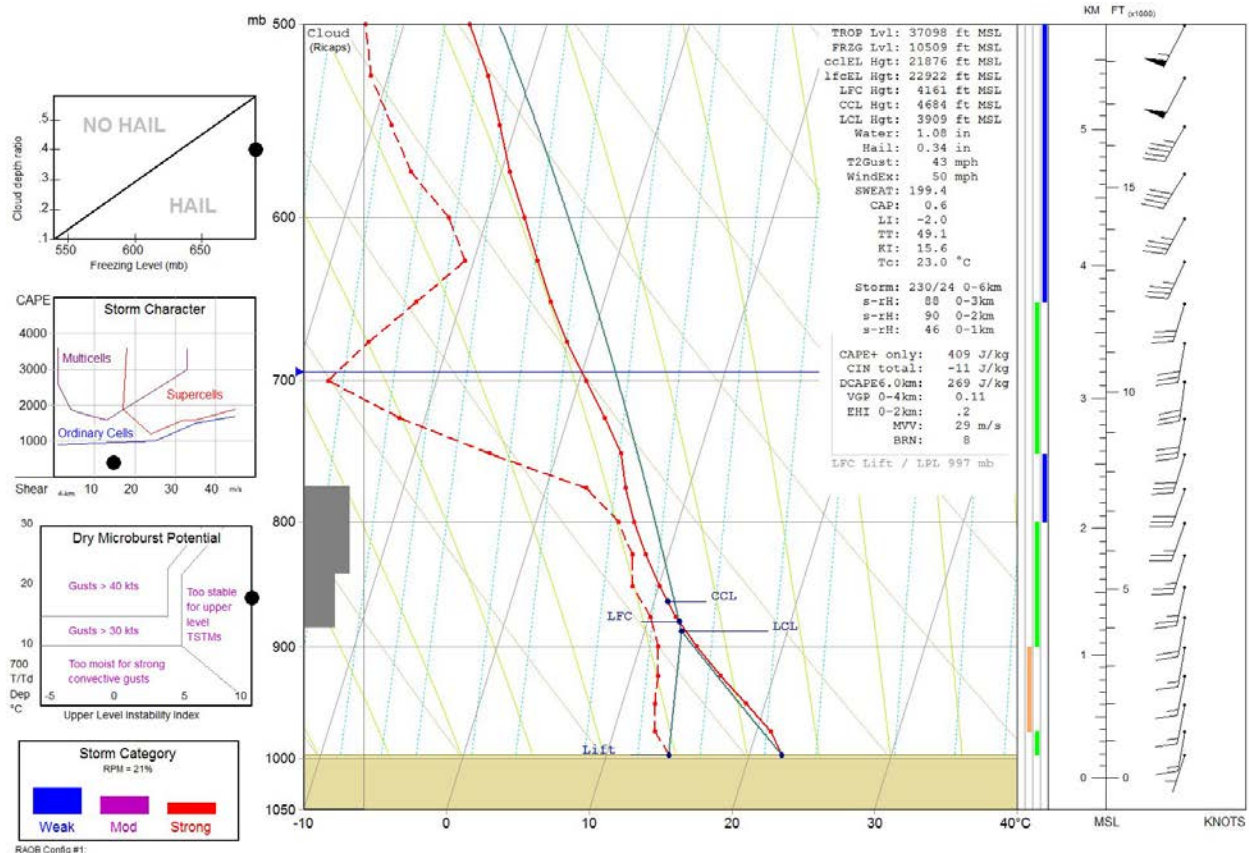


Figure 13 - HRRR 1400 CDT numerical model sounding

3.3 Aircraft Meteorological Data Relay Observations

An aircraft identified as #10959 descended into the KBHM area and landed at 1432 CDT, the aircraft was equipped with Aircraft Meteorological Data Relay (AMDAR) instrumentation and provided a descent sounding near the time of the accident. Figure 14 is the plot of the descent sounding vertical temperature profile and text output. The temperature profile showed several bumps or jumps in the data at 10,850 ft pressure altitude, and at 4,830 ft and 2,830 ft. An isothermal layer was depicted between 5,700 through 4,700 ft where temperature did not change with altitude. The freezing level was indicated at about 9,800 ft. The wind profile indicated low-level wind from the south-southeast, which veered to the southwest through 5,000 ft and backed to the south-southwest through 10,000 ft. The observed wind at 12,450 ft was identified from 230° at 44 knots with a temperature of -5.0° C

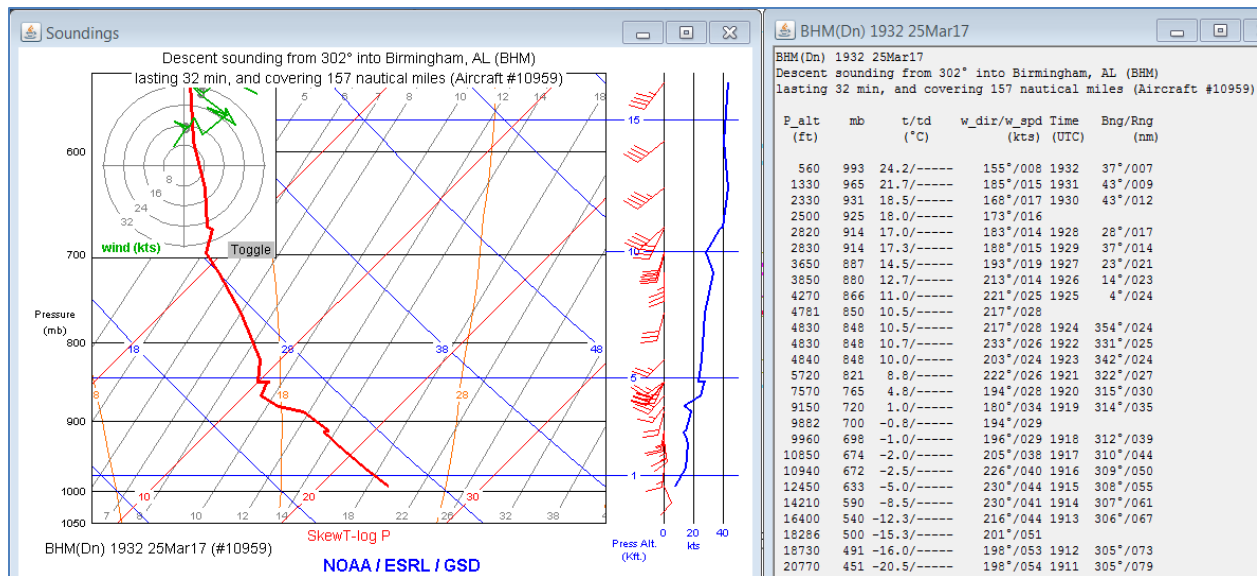


Figure 14 - AMDAR report from aircraft #10959 landing at KBHM at 1432 CDT

Another AMDAR sounding from aircraft #11104 inbound to KBHM, landed after the accident at 1605 CDT and is included as figure 15. The sounding also showed several jumps in data and indicated westerly low-level winds to approximately 20 knots and colder air below 3,000 ft indicated on the temperature curve receding. With the lowest temperature below 1,000 ft decreased about 10° C, from 24.2° C to 14.3°C within the approximately 90 minutes.

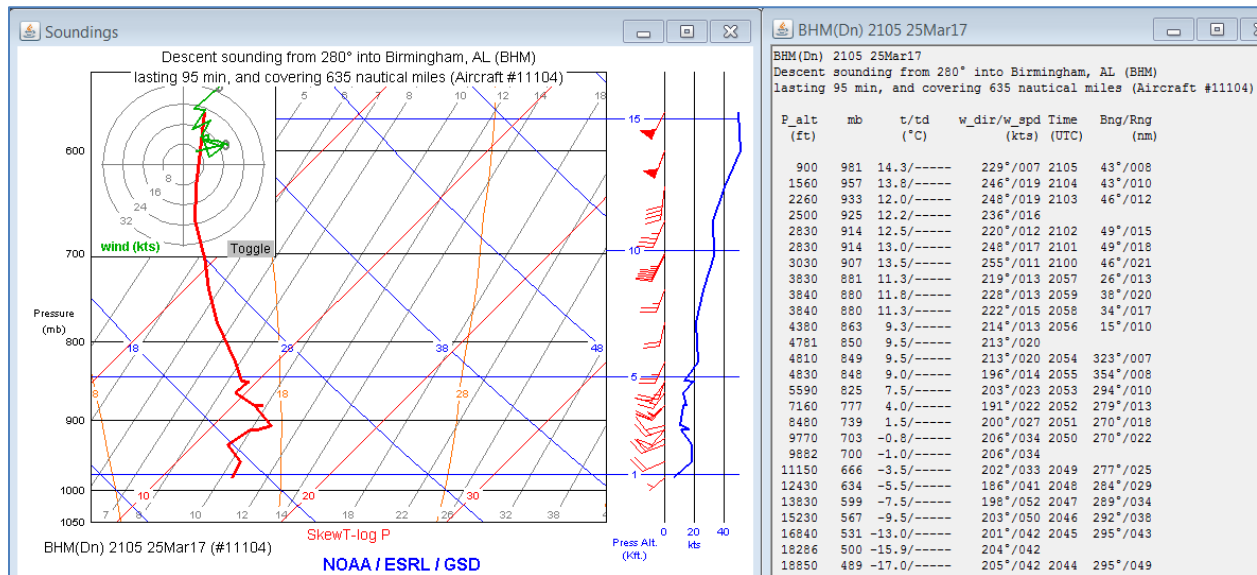


Figure 15 - AMDAR report from aircraft #11104 landing at KBHM at 1605 CDT

4.0 Satellite Imagery

The Geostationary Operational Environmental Satellite number 13 (GOES-13) data was 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. Both the infrared long wave and visible band imagery were obtained surrounding the time of the accident. The infrared long wave imagery (band 4) at a wavelength of 10.7 microns (μm) provided standard satellite image with radiative cloud top temperatures with a resolution of 4 km. The visible imagery (band 1) at a wavelength of 0.65 μm provided a resolution of 1 km.

The GOES-13 infrared satellite image at 1415 CDT at 3X magnification with a standard MB temperature enhancement curve applied is included as figure 16, with the frontal positions from 1300 CDT overlaid. The last radar position is depicted by a white square and the pressure systems and associated frontal boundaries overlaid from their 1300 CDT reported positions. The image depicted an area of high clouds extending from the Ohio Valley southward to the Gulf of Mexico with several areas of enhanced clouds associated with stronger convection and higher clouds. The image depicted a scattered area of enhanced clouds over northern Alabama with a more solid area over southwestern Alabama into southern Mississippi and Louisiana where the highest and colder cloud tops were noted in the blue shades with tops near 40,000 feet associated with the squall line were noted. The last radar location of N6563D was located under or in an area of enhanced clouds associated with cumulus congestus to cumulonimbus type clouds with a radiative cloud top temperature of 233° Kelvin or -40.16° C, which corresponded to cloud tops near 30,000 ft based on the KBMX and model soundings.

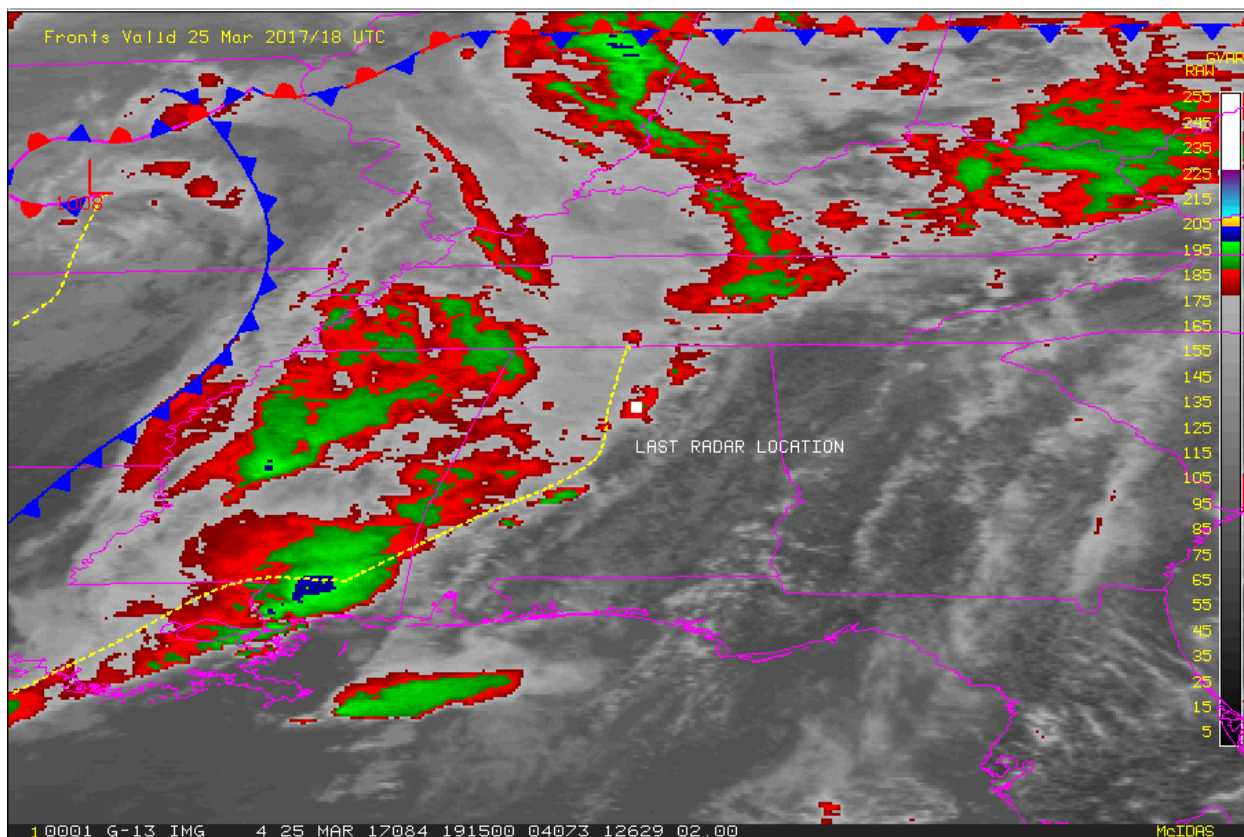


Figure 16 - GOES-13 infrared image at 3X magnification for 1415 CDT

The GOES-13 visible image at 2X magnification at 1415 CDT is included as figure 17 with the flight track of N6563D overlaid (attachment 1) and continued to depict a line of cumuliform clouds

[illegible]

5.0 Weather Surveillance Radar

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.

5.1 Volume Scan Strategy

The WSR-88D is a computer controlled radar system, which automatically creates a complete series of specific scans in a specific sequence known as a volume scan. Individual elevation scans are immediately available on the WSR-88D's Principle Users Processor. Products that require data from multiple elevation scans are not available until the end of the volume scan, which can range from 4 to 10-minutes depending on the scan being utilized.

The WSR-88D operates in several different scanning modes, identified as Mode A and Mode B. Mode A is the precipitation scan and has multiple scanning strategies, which are used when significant weather echoes are present or severe weather is occurring or is anticipated. The most common is the non-severe convective mode where the radar makes 9 elevation scans from 0.50° to 19.5° every six minutes. This particular scanning strategy is documented as volume coverage pattern 21 (VCP-21). Mode B is the clear air mode, which is used when there is no detectable precipitation or when precipitation intensity is light and/or areal extent is small, such as light stratiform precipitation or snow. In the clear air mode the radar makes 5 elevation scans during a ten minute period. During the period surrounding the accident the KBMX WSR-88D radar was operating in the precipitation mode VCP-212 where the radar makes 14 different elevation scans in 4 ½ minutes. This mode is typically used by the NWS during periods when rapidly evolving wide spread severe convection is expected, and allows for improved low-level vertical resolution of the storms. The following chart provides an indication of the different elevation angles in this VCP, and the approximate height and width of the radar beam with distance from the radar site.

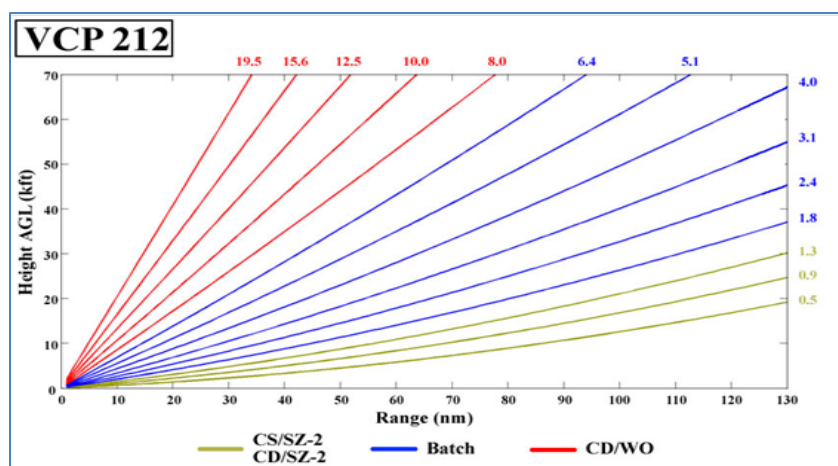


Figure 18 - VCP 212 scanning strategy diagram

5.2 Beam height Calculations

Assuming standard refraction²⁰ of the 0.95° radar beam of the KBMX WSR-88D with an antenna height of 759 ft and a distance of 45 miles from the radar, the following table shows the approximate beam height and width information of the radar display over the site of the accident. The heights have been rounded to the nearest 10 ft.

²⁰ Standard Refraction in the atmosphere is when the temperature and humidity distributions are approximately average, and values set at the standard atmosphere.

Antenna elevation	Beam center	Beam base	Beam top	Beam width
0.5°	2,980 ft	1,120 ft	4,850 ft	3,730 ft
0.9°	4,550 ft	2,690 ft	6,420 ft	3,730 ft
1.3°	6,120 ft	4,260 ft	7,990 ft	3,730 ft
1.8°	8,080 ft	6,220 ft	9,950 ft	3,730 ft
2.4°	10,430 ft	8,570 ft	12,300 ft	3,730 ft

Based on the radar height calculations, the 2.4° elevation scan depicts the conditions encompassing the altitude between 8,570 and 12,300 ft over the accident site. With the lower antenna elevations capturing the descent from altitude and the conditions under the aircraft.

5.3 Reflectivity

Reflectivity is the measure of the efficiency of a target in intercepting and returning radio energy. With hydrometeors²¹, 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 (dBZ²²), and is a general measure of echo intensity. The chart below relates the NWS video integrator and processor (VIP) intensity levels versus the WSR-88D's display levels, precipitation mode reflectivity in decibels, and rainfall rates.

NWS VIP/DBZ CONVERSION TABLE

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

²¹ 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.

²² dBZ - 10 log Ze

Air traffic control (ATC) weather display systems also use radar weather processors with the ability to determine precipitation intensity, with controllers instructed²³ to describe the intensity to pilots based on the following table. One exception is that the centers weather and radar processor (WARP) system does not display light intensity echoes below 30 dBZ. This table is also referenced for pilots in Advisory Circular AC 00-24C - “Thunderstorm” for describing echo strength.

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

5.4 Base Reflectivity

Base reflectivity products are displays of the individual elevation angle scans depending on the VCP being employed by the radar operator. The resolution is 0.5° X 250 meters (0.13 miles) with 16 levels of intensities and provides detailed analysis of meteorological events. The base reflectivity imagery is typically used to determine precipitation intensity, movement, and trends, and can determine the location and motion of wind shear lines and boundaries such as gust fronts, synoptic fronts, sea breezes, and wind-shifts. It also provides significant storm structural features during severe convection, such as hook echoes. Thus, the low-level elevation scan will be first documented and the various other elevation scans to define the conditions relating to the accident.

Figure 19 is the KBMX WSR-88D base reflectivity image for the lowest 0.44° elevation scan at 1423:24 CDT with the flight track of N6563D overlaid. N6563D is operating at 10,000 ft at the time. A line of echoes is evident running north-northeast to the south-southwest with several embedded areas of strong to intense cells along the leading edge with a trailing area of lighter precipitation. A large area of false echoes associated with ground clutter surrounds the KBMX radar antenna with echoes of -10 to 10 dBZ. Embedded immediately ahead of the line of echoes and in the ground clutter pattern was a thin line of echoes around 5 to 10 dBZ, which has propagated outward and can be seen in an animation of the radar data, which is included as attachment 2.

Figure 20 is the next KBMX WSR-88D 0.44° elevation scan at 1428:05 CDT with the flight track for the same corresponding period. The accident airplane had climbed to 12,000 feet between this period and made a slight course deviation and had reached the leading edge of the line. Several vertical deviations in altitude are noted by this time. The thin line is located approximately under the flight path at this time.

Figure 21 is the KBMX WSR-88D 0.44° elevation scan image at 1432:55 CDT with the corresponding flight track.

²³ FAA Joint Order 7110.65W - Air Traffic Control, section 2-6-4 “Weather and Chaff Services”.

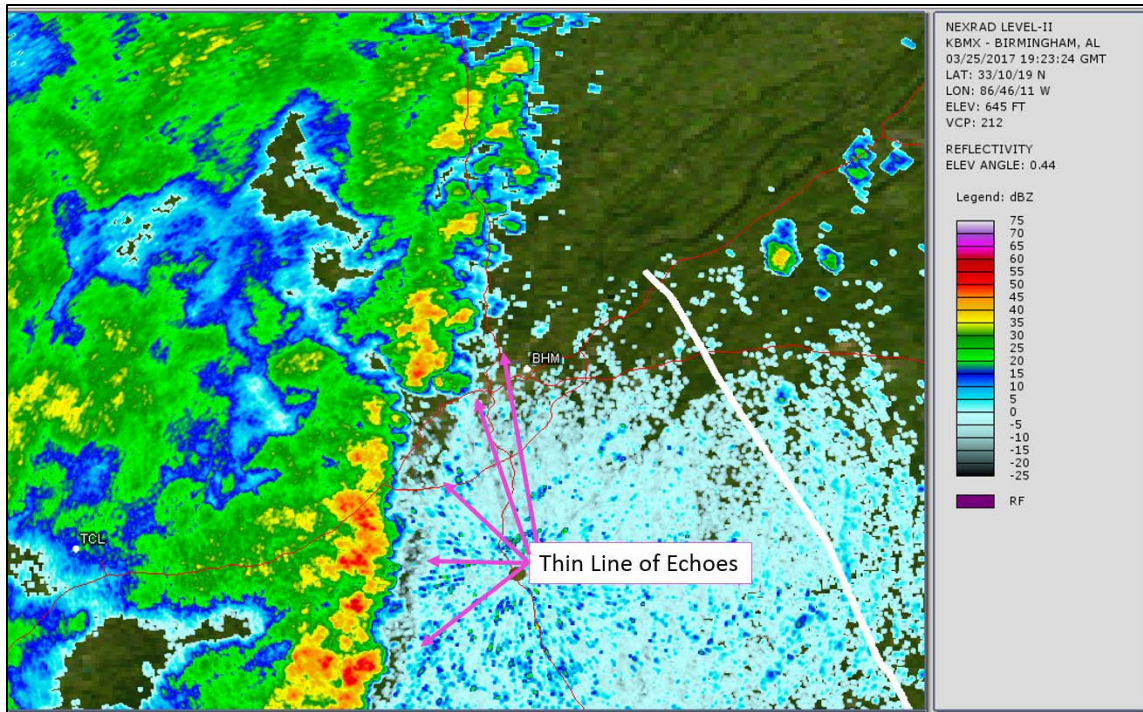


Figure 19 - KBMX WSR-88D 0.4° base reflectivity image for 1423 CDT

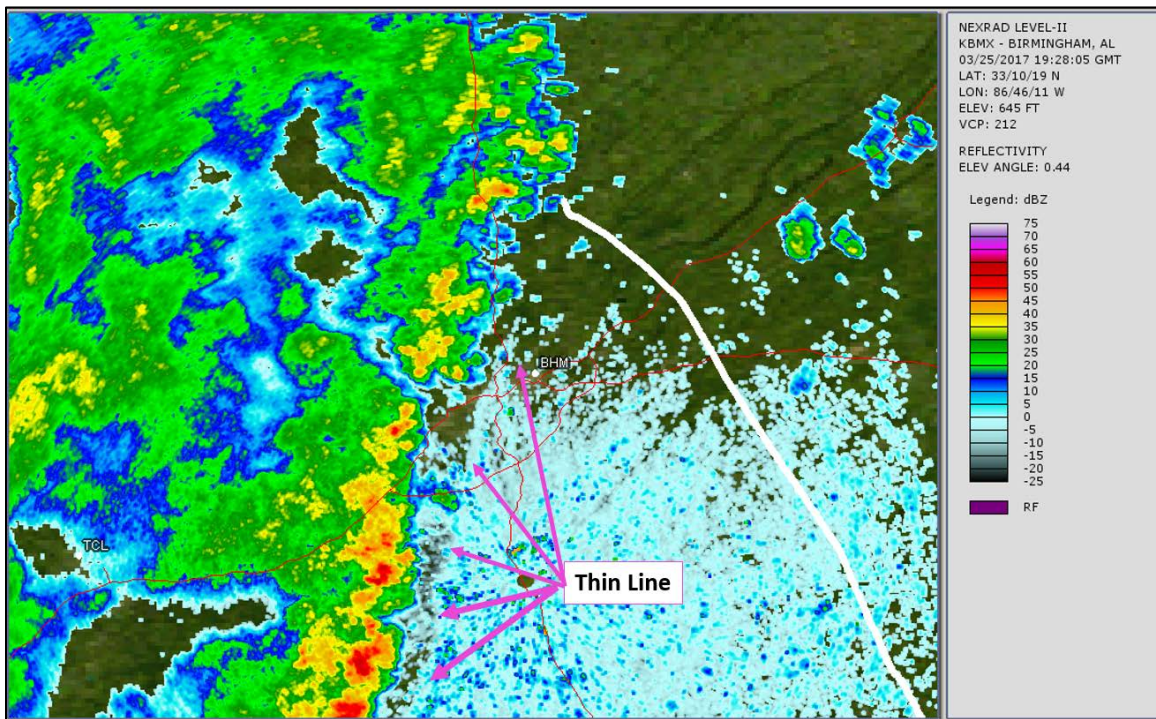


Figure 20 - KBMX WSR-88D 0.4° base reflectivity image at 1428 CDT

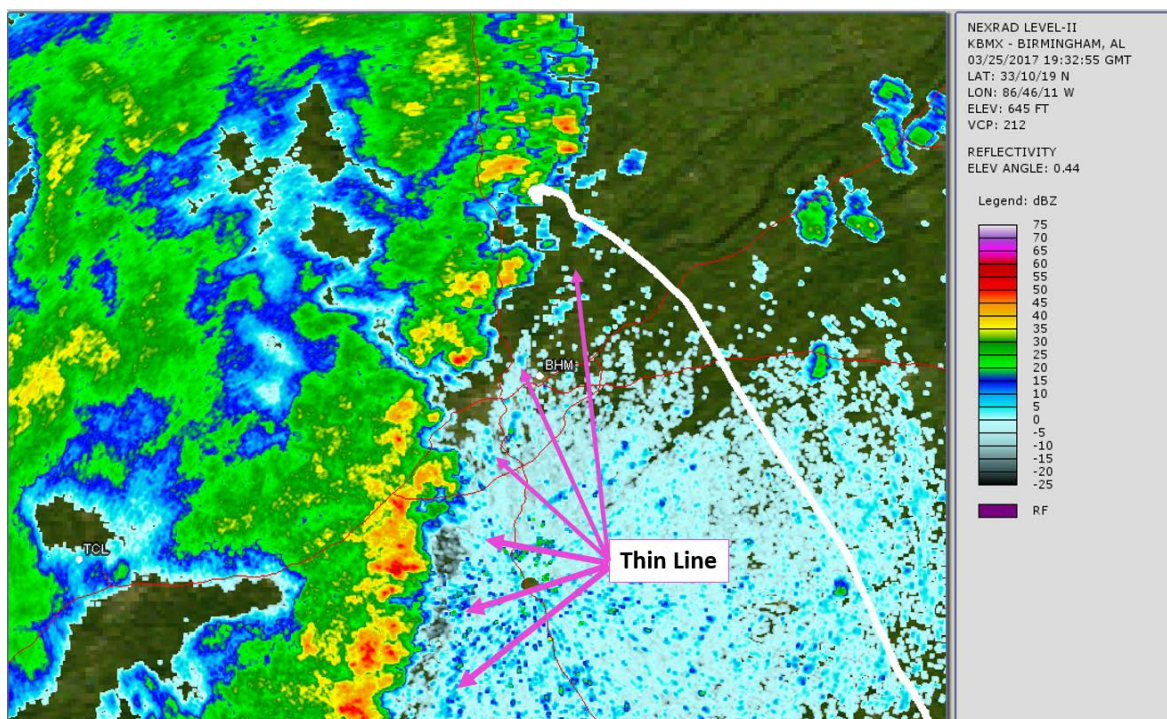


Figure 21 - KBMX WSR-88D 0.4° base reflectivity image at 1433 CDT

Figures 22 through 24 are the KBMX WSR-88D 2.4° base reflectivity images at 1423, 1428, and 1433 CDT with the flight track overlaid. Echoes of 5 to 30 dBZ extend over the flight track.

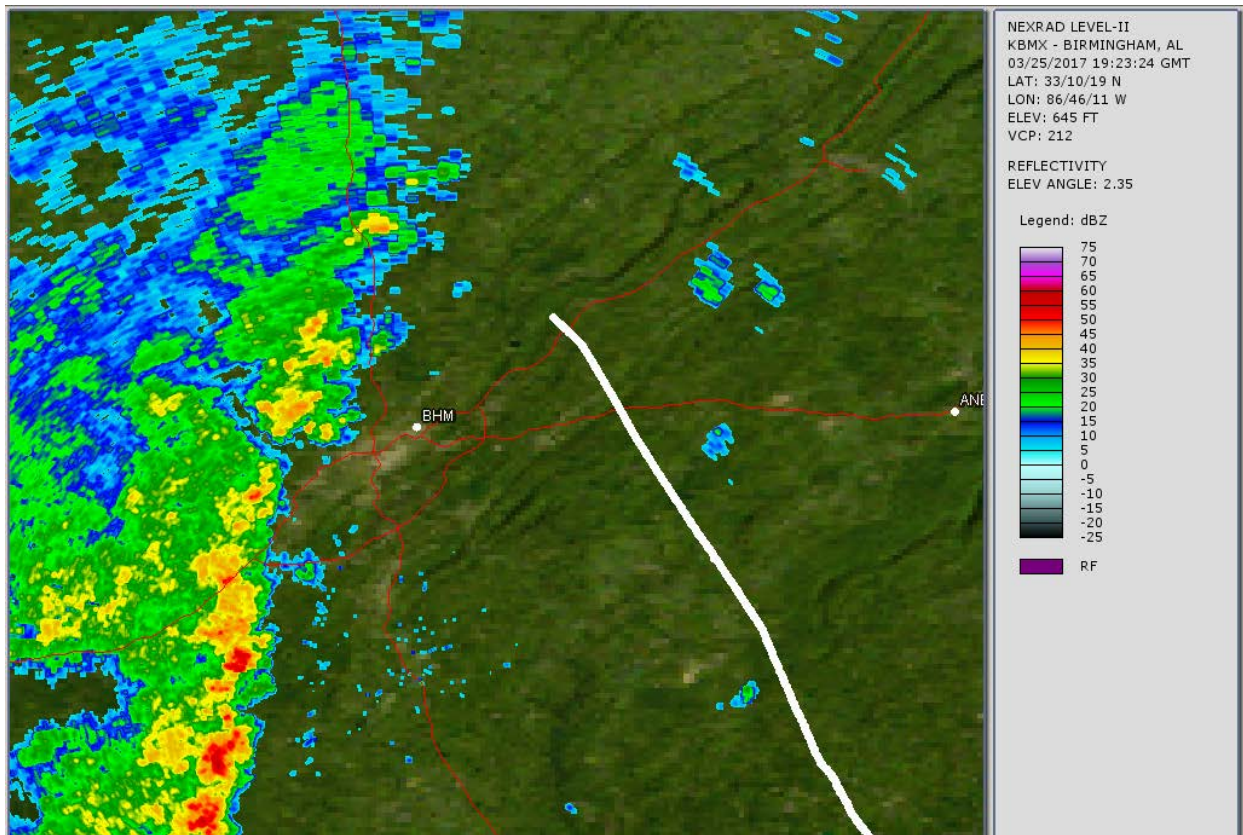


Figure 22 - KBMX WSR-88D 2.4° base reflectivity image at 1423 CDT

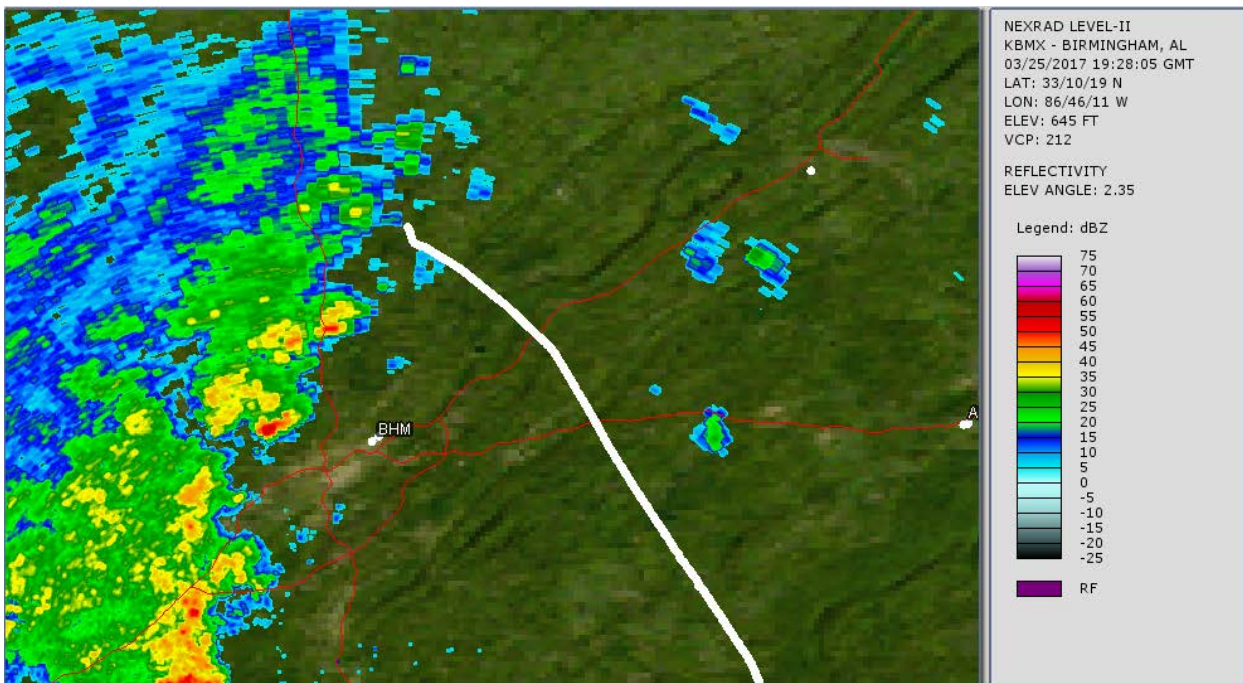


Figure 23 - KBMX WSR-88D 2.4° base reflectivity image at 1428 CDT

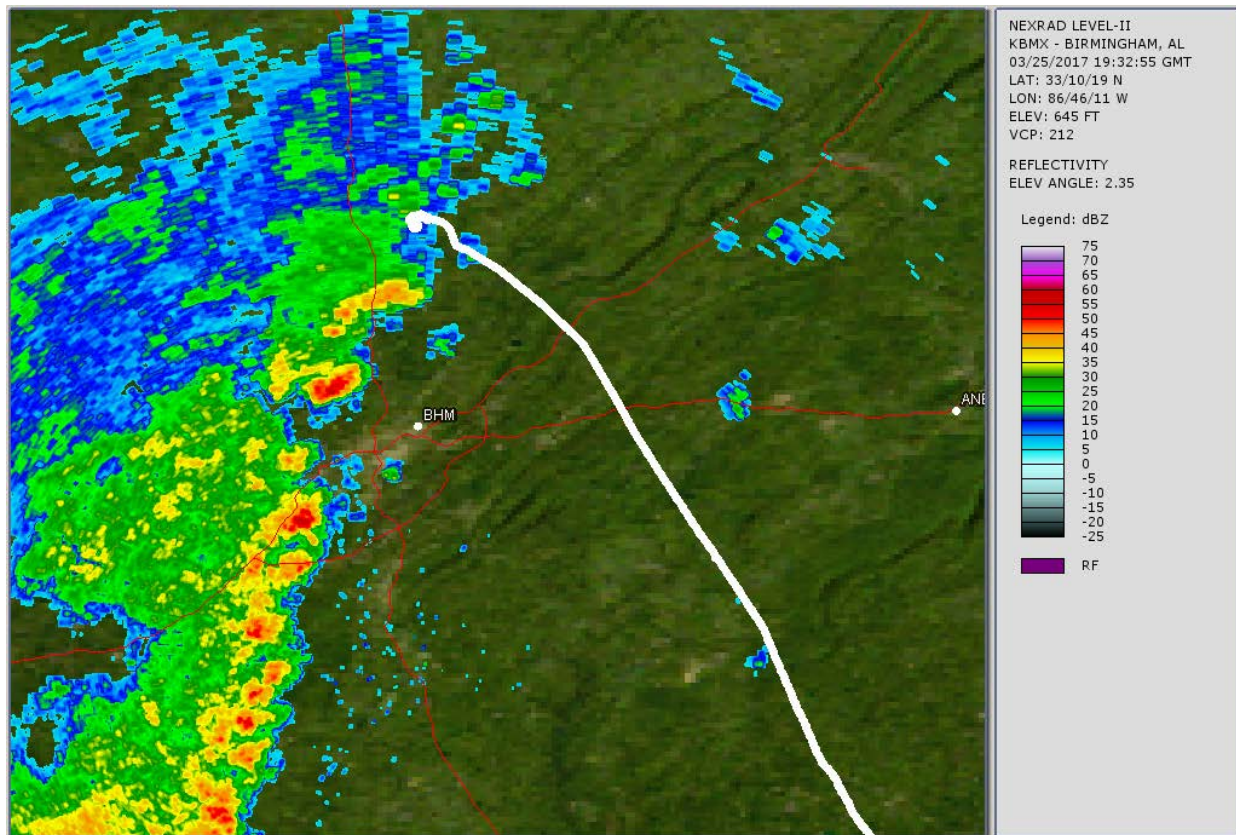


Figure 24 - KBMX WSR-88D 2.4° base reflectivity image at 1433 CDT

Figures 25 through 27 are the KBMX WSR-88D base reflectivity slices at 0.44°, 1.2° and 2.35° with the corresponding flight tracks overlaid for 1428, 1432, and 1437 CDT. The strongest intensity of the echoes appears in the 1.2° elevation scans between 4,000 and 8,000 ft with heavy to extreme intensity echoes located immediately north, west, and south of the accident site during the period. In figure 25 the accident airplane is clear of echoes during this period up to 1428 CDT, and then enters echoes. Figure 26 at 1432 CDT depict echoes of 5 to 35 dBZ or light to moderate intensity along the flight track at all elevation scans with echoes of 45 dBZ or heavy intensity echoes within 5 miles northwest of the track. Immediately south of the area another strong intensity echo with reflectivity's of 55 dBZ or extreme intensity echoes is being to develop or surge upwards and move to the north-northeast. Figure 27 is the base reflectivity images at 1437 CDT immediately after the accident. Echoes of 5 to 15 dBZ or light intensity echoes continue over the track at lower elevation scans.

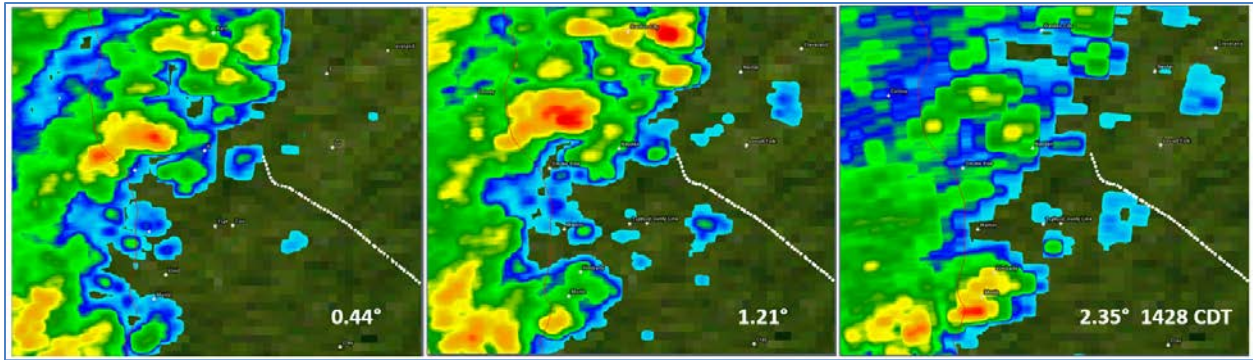


Figure 25 - KBMX WSR-88D base reflectivity images at 0.44°, 1.21°, and 2.35° for 1428 CDT

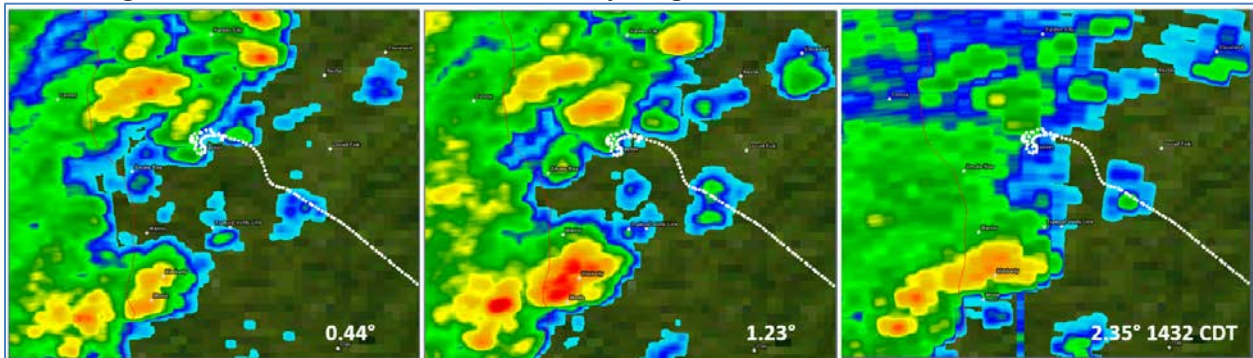


Figure 26 - KBMX WSR-88D base reflectivity images at 0.44°, 1.23°, and 2.35° for 1432 CDT

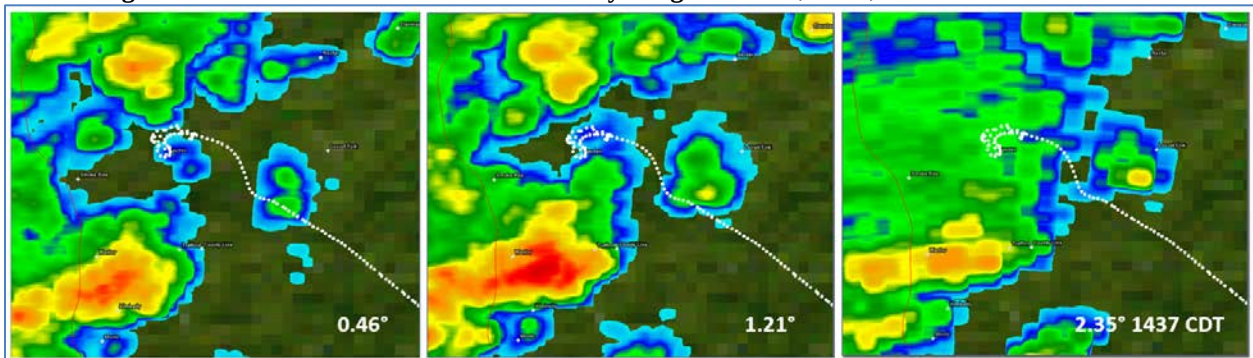


Figure 27 - KBMX WSR-88D base reflectivity images for 0.46°, 1.21°, and 2.35° at 1437 CDT

GR2 Analysis software was also utilized to help reconstruct a 3-dimensional cross section along the general route of flight when the accident airplane encountered the line of echoes is included in figure 22. The image depicted echoes reaching 38.0 dBZ at 12,000 ft with echo tops near 20,000 ft across the line. Immediately northwest of the aircraft at this time were echoes of 56.0 dBZ being depicted below 7,000 ft. The next scan at 1433 CDT is included as figure 23. The image depicted echoes of 43.0 dBZ over the vicinity of the airplane with echo tops still in the range of 20,000 feet. The heavier core of reflectivities immediately northwest had begun to weaken and were in the range of 43 dBZ below 5,000 ft.

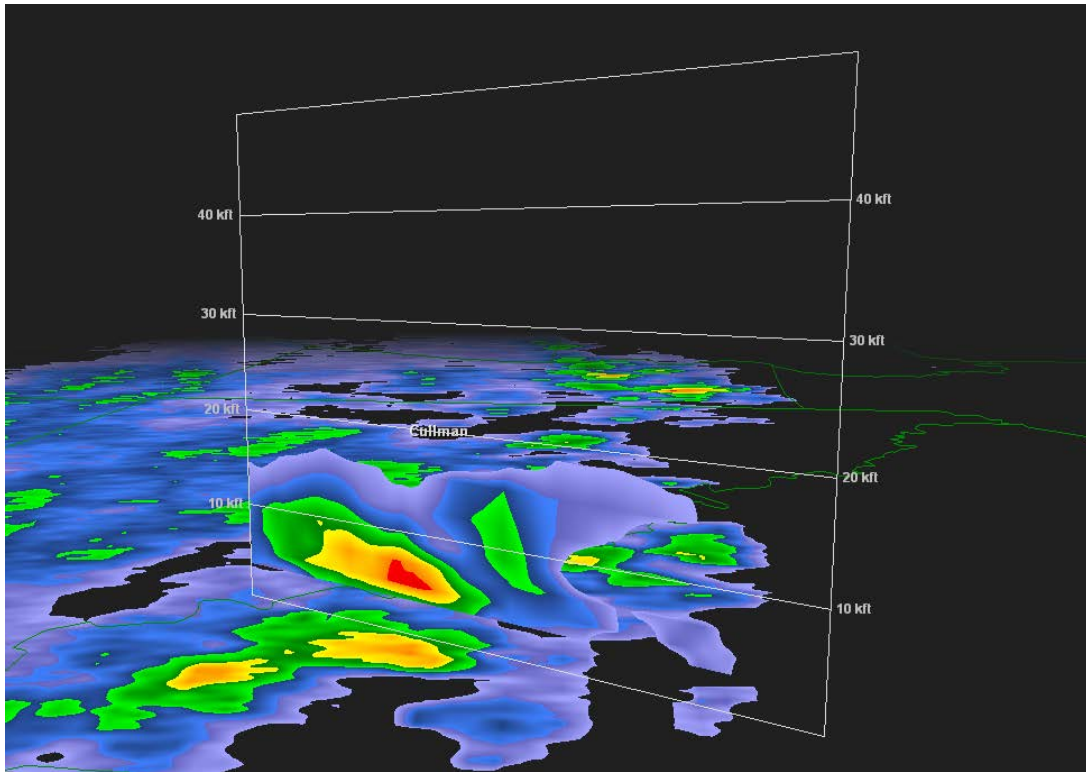


Figure 28 - KBMX WSR-88D vertical cross section at 1428 CDT

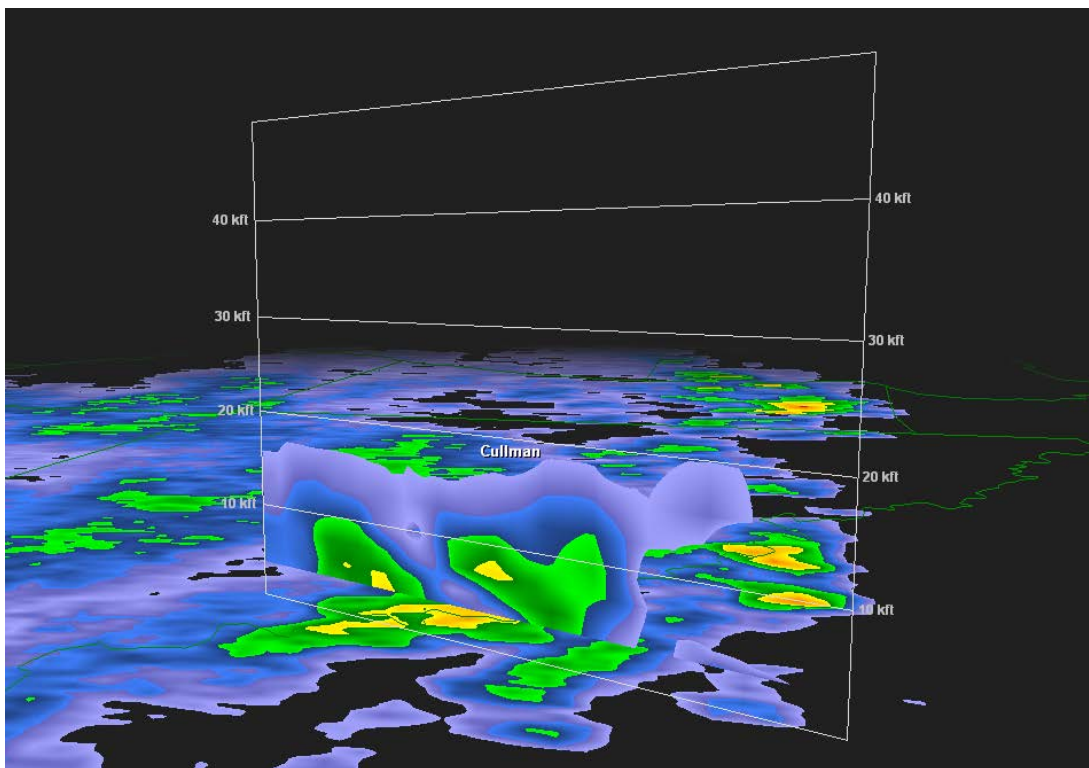


Figure 29 - KBMX WSR-88D vertical cross section at 1432 CDT

5.5 Spectrum Width

The WSR-88D spectrum width (SW) product was also reviewed surrounding the period of the accident. The SW product displays mean radial velocity spectrum width estimates. The product is typically used to evaluate wind shear conditions across the beam or turbulence. It is usually used in conjunction with other products for its maximum utility.

The KBMX WSR-88D spectrum width product for 2.35° for 1428 and 1432 CDT are included in figure 27. The images depict turbulence conditions along the leading edge of the echoes with shears between 6 and 12 knots. Similar echoes were also identified at low altitudes along the fine line or the outflow boundary moving across the area.

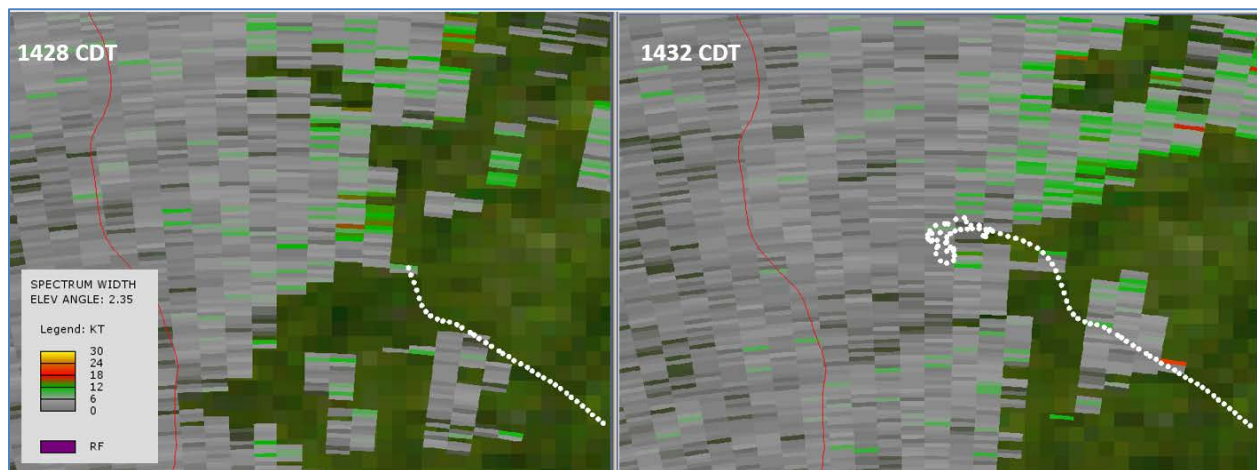


Figure 30 - KBMX WSR-88D Spectrum Width (SW) Product for 2.35° at 1428 and 1432 CDT

Attachment 2 is a plot of selected WSR-88D images with the communication between air traffic control and the aircraft added with altitude information along the flight track.

5.6 Composite Reflectivity

Composite reflectivity images utilize all the elevation scans during the volume scan to create the image, and is composed of the highest reflectivity value from any elevation angle scan of a volume scan by the radar. As such, it provides a synopsis of the most important reflectivity features in the entire coverage area, and can help determine some storm structural features and intensity trends in storms when compared to base products. Composite images are not available until the end of the volume scan period and are also used by inflight weather in the cockpit displays, and in the generation of some Air Traffic Control (ATC) weather displays.

A search of the NWS NCEI database indicated that for some unknown technical problems no Level III radar data was being saved for several days surrounding the date of the accident for many southeastern radar sites. As a result, the composite reflectivity imagery and echo tops products were not available for reproduction.

6.0 Lightning Data

A review of the Earth Networks total lightning archive for March 25, 2017 between 1330 and 1500 CDT detected 35 lightning flashes within an about 50 mile radius of the accident site. Figure 31 is the KBMX WSR-88D base reflectivity image at 1432 CDT with the location of the lightning flashes in magenta. The closest cluster of flashes were located about 18 miles southwest of the accident site recorded between 1346 and 1355 CDT, with a larger cluster 26 miles south-southwest of the KBHM airport and 49 miles south-southwest of the accident site.

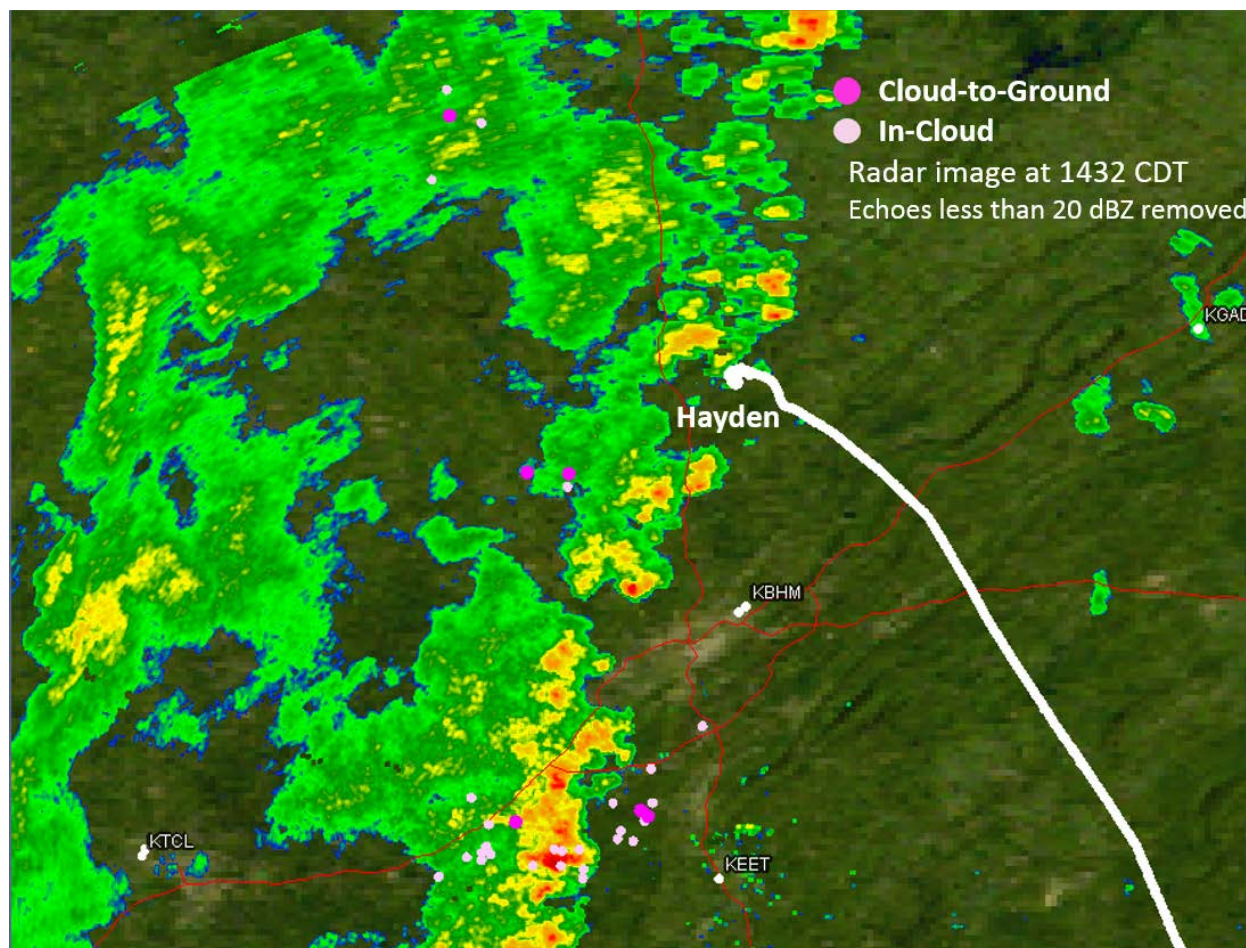


Figure 31 - Lightning Flashes detected between 1330 and 1500 CDT

7.0 Pilot Reports

A search of the NWS database provided the following pilot reports or PIREPs in the system that were being distributed. The following reports were recorded over Alabama surrounding the period from 1200 through 1900 CDT. The reports are in plain language taken from standard code and abbreviations, and converted to local time. Only the reports below 18,000 ft were considered due to accident airplanes altitude capability. The reports were as follows:

Mobile Regional Airport (MOB) routine pilot report; Over – 15 miles north of MOB (located 200 miles south-southwest of the accident); Time – 1225 CDT; Flight Level – 1,500 ft; Type aircraft – Canadair Regional Jet; Sky cover – cloud bases at 1,500 ft.

Montgomery Regional Airport (MGM) routine pilot report; Over – 5 miles north of the MGM VORTAC²⁴ (located 107 miles south-southeast); Time – 1300 CDT; Flight Level – 7,500 ft; Type aircraft - Canadair Regional Jet; Sky cover – overcast clouds bases at 4,500 ft with tops at 7,500 ft; Remarks – during climb.

MGM routine pilot report; Over – 30 miles northwest of the MGM VORTAC; Time – 1326 CDT; Flight Level – 9,000 ft; Type aircraft – Cessna Golden Eagle multiengine airplane (C414); Sky cover – clouds bases at 8,800 ft.

Pryor Field (DCU), Decatur routine pilot report; Over – 10 miles south of DCU VORTAC; Time – 1405 CDT; Flight Level – 13,000 ft; Type aircraft – Pilatus PC-12 single engine turboprop, Temperature – minus 8° C; Icing – light rime icing conditions between 13,000 and 15,000 ft; Remarks – entered by Memphis ARTCC (ZME).

Accident 1433 CDT

DCU routine pilot report; Over – 10 miles south of DCU VORTAC (located approximately 40 miles north); Time – 1455 CDT; Flight Level – 10,000 ft; Type aircraft – Canadair Regional Jet; Turbulence – moderate turbulence between 10,000 and 15,00 ft with updrafts 5,000 ft/minute; Remarks – entered by ZME.

MGM routine pilot report; Over – 10 miles north of the MGM VORTAC; Time – 1430 CDT; Flight Level – 9,000 ft; Type aircraft – Canadair Regional Jet; Sky cover – broken clouds at 4,200 ft; Remarks – during descent.

Huntsville International Airport (HSV) urgent pilot report; Over – 40 miles northeast of HSV VORTAC (located 42 miles north); Time – 1630 CDT; Flight Level – 5,500 ft; Type aircraft – Boeing C-17 Globemaster heavy military transport jet; Turbulence – moderate to severe turbulence between 5,500 to 8,500 ft; Remarks – entered by ZME.

MGM routine pilot report; Over – 15 miles northwest of the MGM VORTAC; Time – 1805 CDT; Flight Level – 5,000 ft; Type aircraft – Canadair Regional Jet (CRJ2); Weather – heavy rain; Turbulence – moderate turbulence at 5,000 ft; Remarks – encountered during descent and entered by Atlanta ARTCC (ZTL) Flight Data.

Other reports in the surrounding area relevant to the investigation:

Memphis International Airport (MEM), Memphis, TN routine pilot report; Over – 65 miles northeast of MEM VORTAC (near the destination and 156 miles west-northwest of the accident

²⁴ VORTAC is a navigation aid consisting of a co-located VHF omnidirectional range (VOR) beacon and a distance measuring equipment (DME), which provides azimuth and range information. Unless otherwise noted the station name is collocated with the city.

site); Time – 1056 CDT; Flight Level – 18,000 ft; Type aircraft – McDonnell Douglas DC-10 heavy air carrier jet; Icing – light rime icing from 20,000 to 18,000 ft; Remarks – entered by ZME.

Key Field (MEI), Meridian, MS routine pilot report; Over – 30 miles east of MEI VORTAC (130 miles southwest of the accident site); Time – 1131 CDT; Flight Level – 13,000 ft; Type aircraft – Cessna 310 multiengine airplane; Icing – light rime icing.

Roscoe Turner Airport (CRX), Corinth, MS routine pilot report; Over – 36 miles east of Holly Springs, MS VORTAC (95 miles northwest of the accident site); Time – 1232 CDT; Flight Level – 12,000 ft; Type aircraft – Piper Aztec multiengine airplane; Temperature – 0° C; Turbulence – light chop; Icing – light clear type icing at 12,000 ft.

MEM routine pilot report; Over – 35 miles east-southeast of MEM VORTAC; Time – 1236 CDT; Flight Level – 12,000 ft; Type aircraft – Piper Aztec multiengine airplane; Temperature – 0° C; Icing – light mixed type.

8.0 Area Forecast

The Area Forecast (FA) is a forecast of visual flight rules (VFR) clouds and weather conditions over an area as large as the size of several states. It must be used in conjunction with the AIRMET Sierra (IFR) bulletin for the same area in order to get a complete picture of the weather. The area forecast together with the AIRMET Sierra bulletin are used to determine forecast enroute weather and to interpolate conditions at airports which do not have a terminal forecast (TAF) issued. The NWS AWC located in Kansas City, Missouri, issues the FA at regular intervals and issues specials reports as necessary usually in the form of an AIRMET. The forecasts current at the time of the accident were issued at 1245 and 1345 CDT and were as follows:

FAUS42 KKCI 251745
FA2W
-MIAC FA 251745
SYNOPSIS AND VFR CLDS/WX
SYNOPSIS VALID UNTIL 261200
CLDS/WX VALID UNTIL 260600...OTLK VALID 260600-261200
NC SC GA FL AND CSTL WTRS E OF 85W
.
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...HI PRES RDG OFF THE SERN US CSTLN EXTDS INTO ERN NC-SE
GA. RDG WL SLOLY WKN AND RETREAT EWD. LOW LVL MSTR WL GRDLY INCRS
OVR THE SERN US.
.
GA
WRN SXNS...SCT-BKN050 TOPS 080 BKN CI. BECMG 0306 BKN030-040
BKN100 TOPS FL180. WDLY SCT -SHRA/ISOL -TSRA. CB TOPS FL370.
OTLK...MVFR CIG SHRA.
ERN SXNS...BKN050 TOPS 080 BKN CI. 05Z BKN025-030 TOPS 070.
OTLK...MVFR CIG.

.
FL

WRN PNHDL...BKN040 TOPS 080. BECMG 2201 BKN030 BKN100 TOPS 150.
WDLY SCT -SHRA/-TSRA. CB TOPS FL420. BECMG 0306 BKN020-030 TOPS
060. OTLK...MVFR CIG.

ERN PNHDL...SCT-BKN040-050 TOPS 080. 00Z SCT050 SCT-BKNK CI. 05Z
BKN040 BKN120 TOPS 150. WDLY SCT -SHRA/ISOL -TSRA. CB TOPS FL370.
OTLK...VFR.

PEN...SCT-BKN050 TOPS 080. 00Z SCT050 SCT-BKN CI. OTLK...VFR.

.
CSTL WTRS

ATLC WTRS...BKN040-050 TOPS 080. OTLK...VFR.

GULF WTRS E OF 85W...SCT050 BKN CI. OTLK...VFR.

....

FAUS44 KPCI 251845

FA4W

-DFWC FA 251845

SYNOPSIS AND VFR CLDS/WX

SYNOPSIS VALID UNTIL 261300

CLDS/WX VALID UNTIL 260700...OTLK VALID 260700-261300

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...CDFNT XTND FRM LO PRES IN MO THRU ERN AR AND LA/TX

GULF COAST. HI PRES OVR TX. 13Z...LO PRES CNTRD ACRS OK PNHDL.

WRMFNT XTNDG ACRS OK INTO NE TX/NRN AR. CDFNT XTNDG FRM LO PRES
IN IL STRETCHED ACRS WRN TN INTO MS.

.
TN

ERN...BKN050 TOP 100. AFT 00Z SCT -SHRA/TSRA. CB TOPS FL450.

BECMG 0507 BKN025 TOP FL350. VIS 3-5SM -SHRA BR. OTLK...MVFR CIG

VIS SHRA.

WRN...BKN040 TOP FL350. SCT -SHRA/TSRA. CB TOPS FL450. BECMG 0406
BKN100-120. OTLK...VFR.

.
AL

NRN...BKN025-030 LYRD FL350. WND S G25KT. TIL 02Z SCT -SHRA/TSRA.

CB TOPS FL450. OCNL VIS 3-5SM BR. OTLK...MVFR CIG SHRA.

SRN...BKN025-030 LYRD FL350. TIL 01Z SCT -SHRA/TSRA. CB TOPS

FL450. OCNL VIS 3-5SM BR. OTLK...MVFR CIG SHRA.

....

The previous forecast available prior to departure to the flights departure from Kissimmee, FL and available for briefing was as follows for the route:

FAUS42 KPCI 250845

FA2W

-MIAC FA 250845

SYNOPSIS AND VFR CLDS/WX

SYNOPSIS VALID UNTIL 260300

CLDS/WX VALID UNTIL 252100...OTLK VALID 252100-260300

NC SC GA FL AND CSTL WTRS E OF 85W

.
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...09Z NO SGFNT FNTS OR LOWS. RDG FM INTL WTRS OFF NC/SC
CST TO THE SRN APLCNS. 03Z NO SGFNT FNTS...LOWS OR HIGHS.

.
GA

NRN...BKN CI. 12Z BKN030 TOP 100. 17Z BKN050 TOP FL200.
OTLK...VFR BECMG 2301 MVFR CIG TSRA W 1/2...VFR BECMG 0002
MVFR CIG SHRA E 1/2.
W CNTRL-SWRN...SCT060 WITH BKN CI ABV. 12Z BKN020 TOP 070. BECMG
1517 BKN050 TOP FL200. OTLK...VFR BECMG 2301 MVFR CIG TSRA.
E CNTRL-SERN...BKN CI. 11Z BKN050 TOP 080. BECMG 1618 SCT050
WITH BKN CI ABV. OTLK...VFR.

.
FL

WRN 1/2 PNHDL...SCT020 WITH BKN CI ABV. 11Z BKN020 TOP 080. WDLY
SCT -TSRA DVLPG 17-19Z. TS POSS SEV. CB TOP FL420. OTLK...MVFR
CIG TSRA.
ERN 1/2 PNHDL...SCT060 WITH BKN CI ABV. BECMG 1012 BKN020 TOP
070. 15Z BKN040. OTLK...VFR.
NRN PEN...SCT030. 16Z BKN040 TOP 070. OTLK...VFR.
W CNTRL-SWRN...SKC. 18Z SCT-BKN040 TOP 070. OTLK...VFR.
E CNTRL...SCT040. OTLK...VFR.
SERN-FL KEYS...SCT-BKN050 TOP 090. WDLY SCT -SHRA. BECMG 1416
SCT030 SCT050. OTLK...VFR.

FAUS44 KKKI 251153 AAA

FA4W

-DFWC FA 251153 AMD

SYNOPSIS AND VFR CLDS/WX

SYNOPSIS VALID UNTIL 260400

CLDS/WX VALID UNTIL 252200...OTLK VALID 252200-260400

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...SYNOPSIS...10Z SFC LOW WCNTRL MO. CDFNT SWD THRU
SCNTRL MO-CNTRL AR-NW LA-SE TX-SCNTRL TX. QSTNRY FNT NEWD FROM
LOW THRU NERN MO-N HLF IL-FAR N IN. SFC HIGH FAR SE NM. BY 04Z
SFC LOW FAR NERN MO. CDFNT SWD FROM LOW THRU SW IL-MO
BOOTHEEL-XTRM E AR-NERN LA...CONTG AS WRMFNT THRU UPR TX CSTL
PLAINS-TX HILL COUNTRY. QSTNRY FNT EWD FROM LOW THRU NERN IL-FAR
N IN.

.
TN

W...BKN020 BKN070 TOP 160 W. BKN CI E. SCT -SHRA W. **11Z BKN020
BKN070 THRUT. SCT -SHRA/ISOL -TSRA. CB TOP FL320. BECMG 1719 WDLY
SCT -TSRA POSS SEV. CB TOP FL400. OTLK..VFR SHRA.**
MIDDLE...SCT070 SCT CI. 14Z BKN070 TOP 160. WDLY ST -SHRA. 21Z

BKN030 BKN070 W. WDLY SCT -TSRA POSS SEV. CB TOP FL400.
 OTLK..MVFR CIG TSRA.
 E...SCT CI. 15Z SCT080. 19Z BKN-SCT080 TOP 160. WDLY SCT -SHRA.
 OTLK..VFR SHRA.
 .
AL
 NW HLF...SCT060. OCNL BKN060 TOP 120 N SXNS. **BECMG 1416 BKN030.**
SCT -TSRA POSS SEV. CB TOP FL420. OTLK..MVFR CIG TSRA SHRA.
 SE HLF...BKN060 TOP 120 N SXNS. SCT CI S SXNS. 13Z SCT-BKN060
 THRUT. BECMG 1719 SCT -TSRA POSS SEV. CB TOP FL440. OTLK..MVFR
 CIG TSRA SHRA.

The forecast available at the time of any preflight planning, expected from 1100 CDT MVFR conditions to prevail with broken clouds at 3,000 ft with scattered thunderstorms and light rain with a 30 to 50% probability of occurrence with thunderstorms possibly severe, and with cumulonimbus cloud tops to 42,000 ft. The forecast for western Tennessee was similar with broken clouds at 2,000 ft and with widely scattered thunderstorms and light rain or about 20% probability of occurrence, again with possible severe thunderstorms with tops to 40,000 ft.

9.0 Winds and Temperature Aloft Forecast

The NWS winds and temperature aloft forecast current for the period of the flight was as follows:

WINDS ALOFT FORECASTS
 DATA BASED ON 251200Z
 VALID 251800Z FOR USE 1400-2100Z. TEMPS NEG ABV 24000

FT	3000	6000	9000	12000	18000	24000	30000	34000	39000
MLB	1215	1507+11	1210+07	1009+01	0923-11	3510-25	292339	283548	284948
PIE	1008	9900+09	1411+07	1410+01	1418-11	2508-26	273440	274347	275349
JAX	1416	1708+07	1511+06	1712+01	1721-12	2218-26	252739	262850	275252
TLH	1715	9900+09	1912+05	1915+00	1930-13	2134-26	233941	244550	245651
PFN	1716	2010+09	2011+04	2117-01	2028-13	2140-26	234641	245350	245750
CSG	1716	2217+09	2016+04	2018-01	2037-14	2145-26	224842	234952	235452
MGM	1720	2126+09	2026+05	2026-02	2140-14	2146-27	225642	235551	235551
ATL	1715	2219+09	2219+04	2221-01	2042-14	2145-26	224542	224452	234954
BHM	1826	2130+08	2030+04	2034-03	2152-14	2152-27	215843	225552	235653
HSV	1827	2133+08	2030+04	2037-03	2056-15	2152-27	215342	215352	225854
MEM	2040	2238+07	2246+02	2146-02	2242-17	2141-31	197244	216850	225152

The forecast for 9,000 ft for BHM area was from 200° at 30 knots with a temperature of 4° C and at 12,000 ft the wind was from 200° at 34 knots with a temperature of -3° C.

10.0 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 Air Route Traffic Control Center's (ARTCCs).

There are four basic types of inflight aviation weather advisories: the Significant Meteorological Advisory (SIGMET), the Convective SIGMET, the Airmen's Meteorological Information (AIRMET), and the Center Weather Advisory (CWA). All of these advisories use the same location identifiers (either VORs, airports, or well-known geographic areas) to describe the hazardous weather areas. The Severe Weather Watch Bulletins (WWs), with the associated Alert Messages (AWW) supplements these advisories.

10.1 Center Weather Advisory

CWA's are advisories issued by the CWSU's for conditions meeting or approaching AIRMET or SIGMET criteria, and typically are issued for thunderstorms, turbulence, icing, and low ceilings and visibility conditions.

The Atlanta ARTCC NWS CWSU issued the first advisory for the route in CWA number 101 at 1404 CDT with a one hour valid period until 1510 CDT. The advisory was as follows:

*FAUS21 KZTL 251904
ZTL1 CWA 251905
ZTL CWA 101 VALID UNTIL 252010
FROM 40S BNA-25W MGM-45S MEI-40S BNA
AREA HVY-EXTRM PCPN IN SHRA AND ISOLD EMBDD TS. MAX TOPS NR FL430.
MOVG FROM 22035KTS. EXP LTL CHG IN COVRG/INTST THRU PD.
=*

The advisory warned of heavy to extreme precipitation in rain showers and isolated embedded thunderstorms, with maximum tops near 43,000 feet and moving from 220° at 35 knots. The trend was to expect little change in coverage or intensity throughout the period. A plot of the CWA over the GOES-13 visible satellite image at the time of issuance is included below as figure 32. The accident site was located on the approximate line of the advisory.

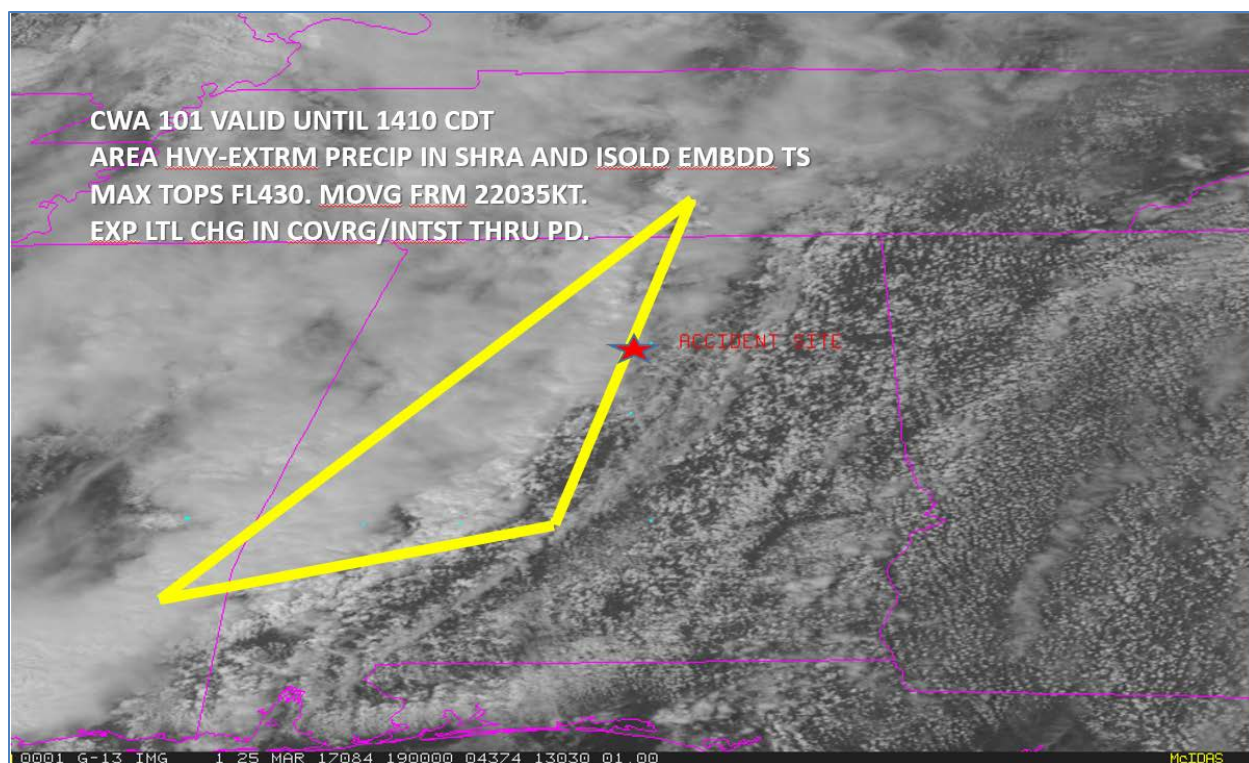


Figure 32 - Plot of CWA 101 over GOES-13 visible image at 1400 EDT

A review of the ATC recordings and transcripts indicated that the advisory was broadcasted prior to the flight being on the Atlanta's controller's frequency, and was not broadcasted by the Birmingham Terminal Radar Approach Control Facilities (TRACON) or tower. It is therefore unknown if the flight received this information from other sources, or on the previous controllers broadcast before switching frequencies.

10.2 Convective SIGMET

The NWS AWC issues Convective SIGMETs for the conterminous U.S. for severe surface weather associated with thunderstorms with winds greater than 50 knots, hail of 1 inch in diameter or larger, tornadoes, embedded thunderstorms, lines of thunderstorms, or thunderstorms greater than or equal to VIP level 4 affecting 40% or more of an area of at least 3,000 square miles. Any Convective SIGMET implies severe or greater turbulence, severe icing, and low-level wind shear in gust fronts and microbursts. The advisories were issued hourly at 55 minutes past the hour, and are valid for 2 hours. An outlook is also included and is valid for a 6 hour period indicating where convection is expected which may meet issuance criteria.

The advisories issued by the AWC on March 25, 2017 surrounding the period of the accident were as follows:

Convective SIGMETs 60C and 61C were issued at 1255 CDT for two areas of thunderstorms over western Alabama, Mississippi, southeastern Louisiana, and for the immediate coastal waters. Convective 60C impacted the route of flight, but did not extend over the location of the accident.

The advisory was current until 1455 CDT, but are often superseded by the next hourly updated forecast. The AWC depiction of the advisories is included as figure 33 with the advisory in red and the outlook in orange, followed by the text of the advisory.

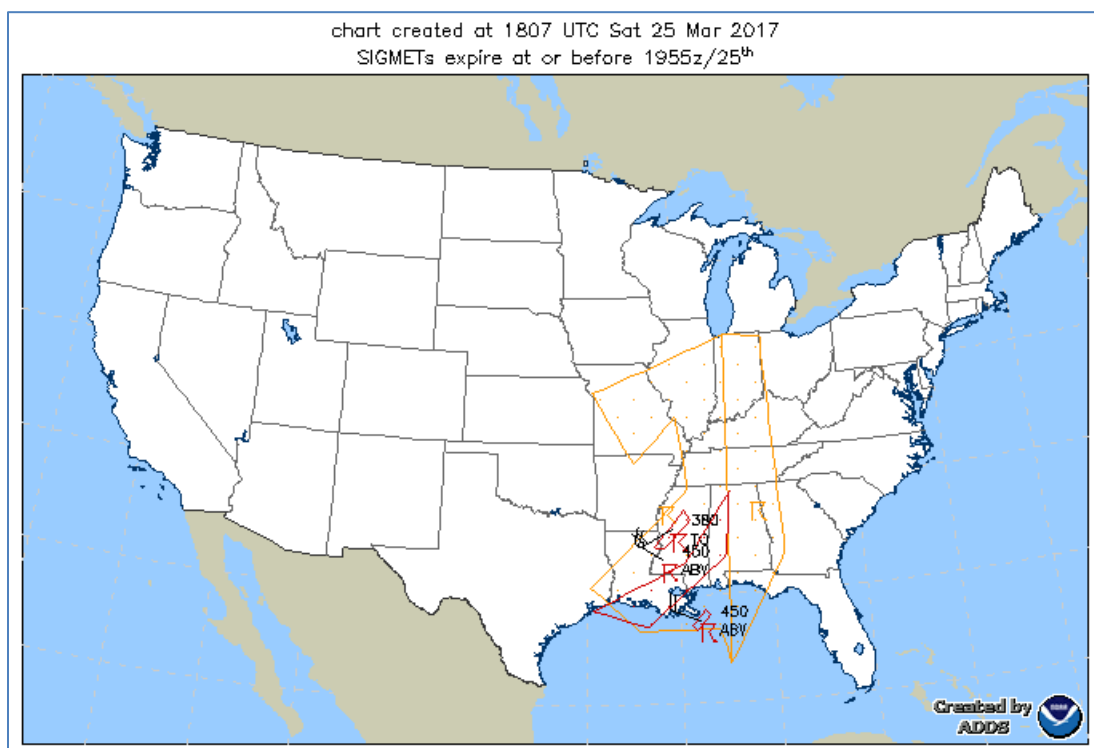


Figure 33 - Convective SIGMETs current for 1255 CDT

*MKCC WST 251755
CONVECTIVE SIGMET 60C
VALID UNTIL 1955Z
AL MS LA TX AND LA TX CSTL WTRS
FROM 20E MSL-60WSW MGM-90WSW LEV-50SE IAH-30ENE MCB-20E MSL
AREA TS MOV FROM 30025KT. TOPS ABV FL450.*

*CONVECTIVE SIGMET 61C
VALID UNTIL 1955Z
MS LA
FROM 40NE SQS-40W IGB-40WSW MHZ-40ESE MLU-40NE SQS
AREA TS MOV FROM 24020KT. TOPS TO FL380.*

Figure 34 is the depiction of the three separate Convective SIGMETs issued at 1355 CDT for portions of southwestern Alabama, southern Mississippi, and Louisiana, which were valid until 1555 CDT. In the hour prior to the accident, no Convective SIGMETs were current for the route flight, although the outlook area warned of potential issuance of advisories over the region. The text of the advisories were as follows:

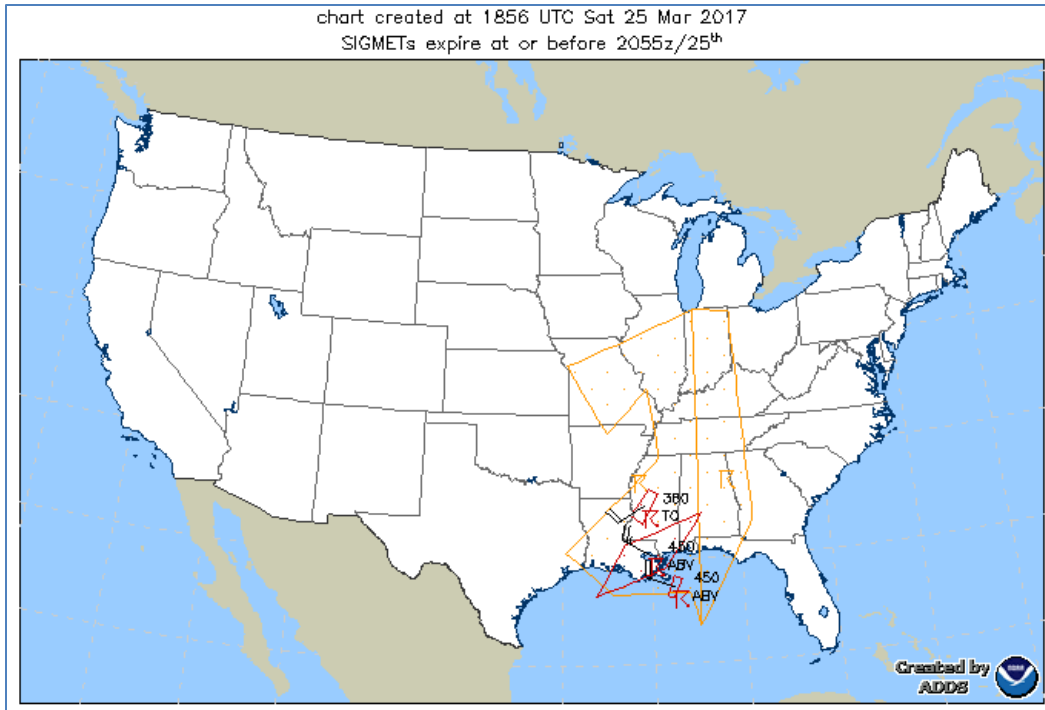


Figure 34 - Convective SIGMETs and outlook current at 1356 CDT

WSUS32 KPCI 251855

SIGC

CONVECTIVE SIGMET 63C

VALID UNTIL 2055Z

AL MS LA AND MS LA CSTL WTRS

FROM 40W MGM-40ESE HRV-110S LCH-20NNW LSU-40W MGM

AREA TS MOV FROM 30025KT. TOPS ABV FL450.

WSUS32 KPCI 251855

SIGC

CONVECTIVE SIGMET 64C

VALID UNTIL 2055Z

MS LA

FROM 10ESE SQS-40ESE SQS-30NNW MCB-50ESE MLU-10ESE SQS

AREA TS MOV FROM 24020KT. TOPS TO FL380.

WSUS32 KPCI 251855

SIGC

CONVECTIVE SIGMET 65C

VALID UNTIL 2055Z

MS LA CSTL WTRS

FROM 80E LEV-80SE LEV

LINE TS 20 NM WIDE MOV FROM 29020KT. TOPS ABV FL450.

NRN PTN MOV FROM 29010.

After the accident at 1455 CDT, the NWS AWC issued Convective SIGMET 2E for a line of thunderstorms 20 miles wide moving to the north-northeast at 15 knots with tops to 34,000 ft. The graphic plot of the advisory is included in figure 35 with the text following. The accident site was located within the boundary of this advisory:

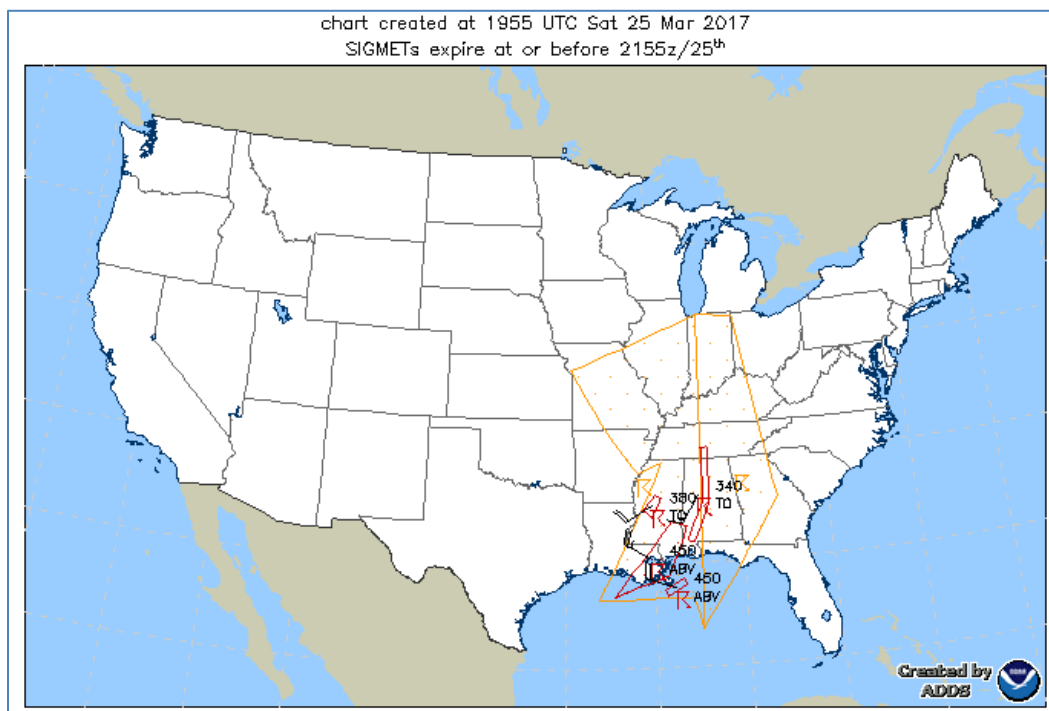


Figure 35 - Convective SIGMETs current at 1455 CDT

WSUS31 KPCI 251955

SIGE

CONVECTIVE SIGMET 2E

VALID UNTIL 2155Z

TN AL

FROM 40SSW BNA-50NW MGM-30NE SJI

LINE TS 20 NM WIDE MOV FROM 21015KT. TOPS TO FL340.

WSUS32 KPCI 251955

SIGC

CONVECTIVE SIGMET 66C

VALID UNTIL 2155Z

AL MS LA AND MS LA CSTL WTRS

FROM 20SSW MEI-50SE MEI-50ENE LEV-110SSE LCH-20SSW MEI

AREA SEV TS MOV FROM 30025KT. TOPS ABV FL450.

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

WSUS32 KPCI 251955

SIGC

CONVECTIVE SIGMET 67C

VALID UNTIL 2155Z

MS

FROM 20ESE SQS-40ESE SQS-10S MHZ-30WNW MHZ-20ESE SQS

AREA SEV TS MOV FROM 24020KT. TOPS TO FL380.

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

10.3 AIRMET

The NWS AWC had a series of AIRMETs current for the period, with only an advisory of for potential turbulence below 10,000 ft current for the destination area. AIRMET Tango is depicted in figure 36 followed by the text bulletin. No other advisory was current for any significant icing or IFR conditions were current outside of convective activity. The freezing level depiction was included in AIRMET Zulu and indicated the varied from 10,000 to 14,000 ft over the planned route of flight. Figure 37 is the depiction of the freezing level at 1300 CDT on March 25, 2017.

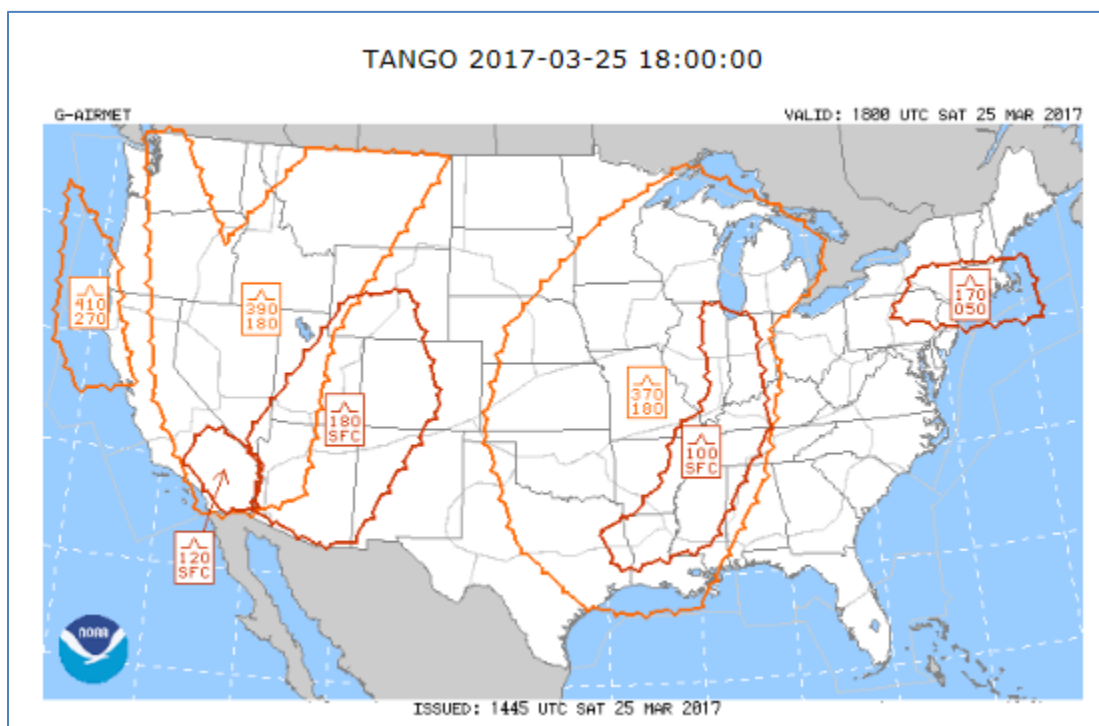


Figure 36 - AIRMET Tango for turbulence

WAUS44 KKKI 251445

2017084 1449

WA4T

DFWT WA 251445

AIRMET TANGO UPDT 2 FOR TURB VALID UNTIL 252100

AIRMET TURB...OK TX AR TN LA MS AL AND CSTL WTRS
FROM OSW TO RZC TO 60ESE BWG TO 40W CEW TO 130ESE LEV TO 120SSW
LCH TO 40NE LRD TO 60WSW SJT TO 50W LBL TO OSW
MOD TURB BTN FL180 AND FL370. CONDS CONTG BYD 21Z THRU 03Z.

AIRMET TURB...OK TX AR TN LA MS AL KS MO WI LM MI IL IN KY
FROM 40WNW PMM TO 50SW FNT TO FWA TO CVG TO 60WSW MGM TO 30SE
LSU TO 40NW IAH TO 50SW LBB TO 50SW LBL TO 30NW ICT TO 20SSW RZC
TO 60E SGF TO 20SSW BDF TO 40SSW BAE TO 40WNW PMM
MOD TURB BLW 100. CONDS CONTG BYD 21Z THRU 03Z.

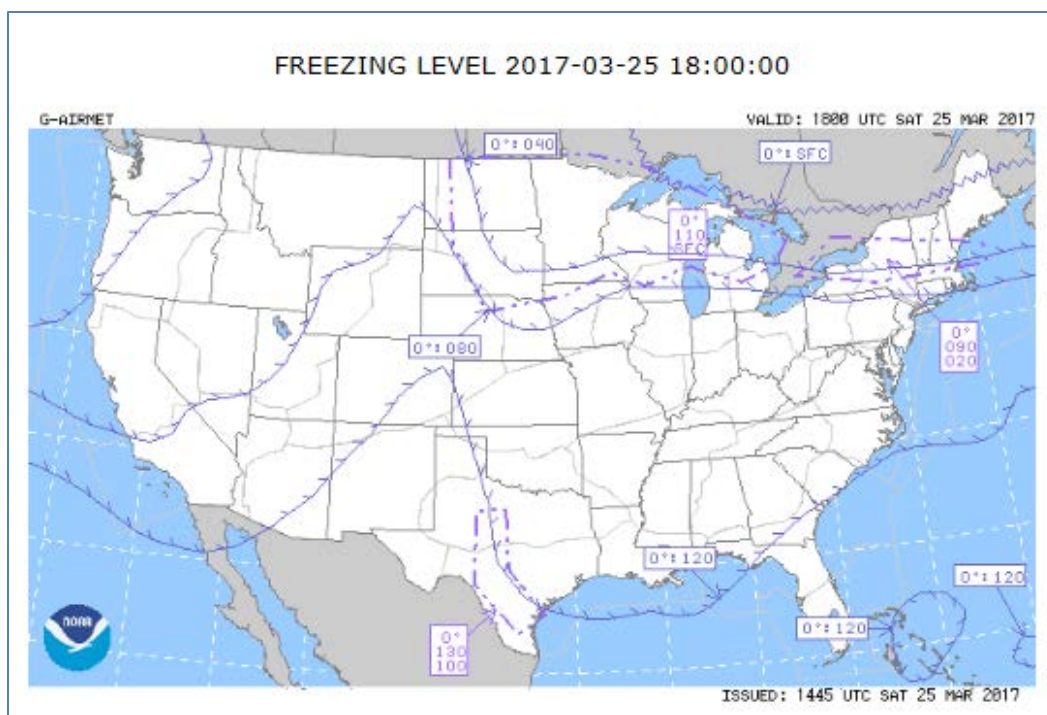


Figure 37 - AIRMET Zulu freezing level depiction for 1300 CDT

10.4 Severe Weather Forecast Alerts

There were no Severe Weather Forecast Alerts issued surrounding the period for severe thunderstorms.

11.0 Other Thunderstorm Related Products

The various other convective weather products used by the NWS AWC and SPC to document the region.

11.1 Convective Outlook Bulletin

The NWS SPC issued the following Convective Outlook (AC) bulletin at 1130 CDT (see section 1.3 for the graphic version of the product) for where the NWS was expected significant thunderstorm development in the next 24 hours:

ACUS01 KWNS 251632
SWODY1
SPC AC 251630

Day 1 Convective Outlook
NWS Storm Prediction Center Norman OK
1130 AM CDT Sat Mar 25 2017

Valid 251630Z - 261200Z

...THERE IS A SLIGHT RISK OF SEVERE THUNDERSTORMS ACROSS THE CENTRAL GULF COAST STATES...

...THERE IS A MARGINAL RISK OF SEVERE THUNDERSTORMS FROM THE GULF COAST TO THE MIDDLE MS RIVER VALLEY...

...SUMMARY...

Isolated strong to locally severe thunderstorms may occur through the afternoon and early evening hours across the central Gulf Coast States northward into the middle Mississippi River Valley.

...Gulf Coast/lower MS River Valley/Mid-South...

Well ahead of the synoptic cold front, the outflow-focused remnants of last night's convection continue to decelerate while slowly progressing into western AL, while otherwise stalling along coastal LA. It appears the strongest/most organized convection will remain semi-focused this afternoon across southeast LA and possibly near-coastal portions of MS/AL into the FL panhandle. Low/mid-tropospheric winds should continue to gradually weaken during the day, but some additional heating/destabilization will nonetheless support some stronger mostly linear storms capable of locally damaging winds and possibly a tornado.

Otherwise, a few stronger storms could redevelop this afternoon across the Mid-South/Lower MS River Valley vicinity near/just ahead of the synoptic front within a modestly unstable environment. However, semi-prevalent cloud cover and weakening mass convergence should limit any such risk.

...Middle MS River Valley...

The slow-moving closed/cold cyclone will continue to drift east-northeastward today from the Ozarks toward central/southern IL by tonight. Immediately ahead of this nearly stacked low, locally stronger heating (60s F surface temperatures) and moderately steep lapse rates, as noted between 850mb-650mb in the 12Z observed sounding from Springfield MO, could support some stronger updrafts this afternoon. Marginally severe and gusty winds could occur, and sufficient low-level moisture/ambient vorticity could allow for a few funnels.

..Guyer/Mosier.. 03/25/2017

11.2 Convective Forecasts

The Traffic Flow Management (TFM) Convective Forecast (TCF) formerly called the Collaborative Convective Forecast product (CCFP) is a high confidence graphic representation of forecast convection meeting specific criteria for coverage, intensity, and echo top height. It is designed to provide airline and air traffic management units a convective product to help management traffic across the National Air Space (NAS). It is available at the AWC website and are issued every 2 hours with a 4-, 6-, and 8-hour forecast for convection.

The TCF products generated at 0600 CDT are included as figure 38 through 40. The initial 4-hour forecast expected an area of sparse echoes with 25 to 39% coverage and tops to 29,000 ft over Mississippi and another area over Louisiana. The 6-hour forecast valid for 1200 CDT merged the areas over southern Mississippi and Louisiana with the same coverage but with echo heights increasing to 34,000 ft. The 8-hour forecast valid for 1400 CDT expanded the area slightly into southwestern Alabama to the southwest of the Birmingham area, into southeastern Mississippi, and Louisiana with tops to 34,000 ft.

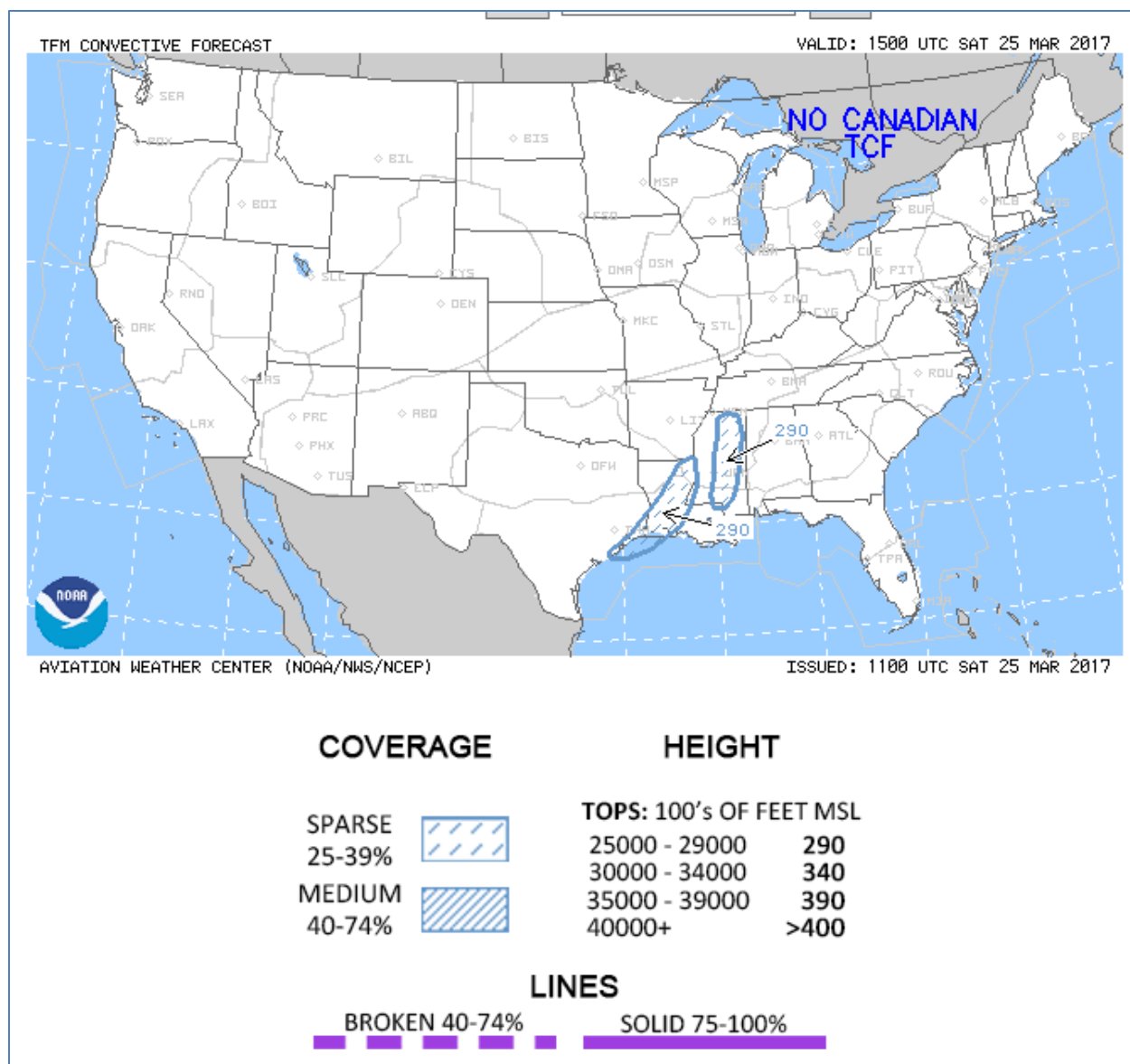


Figure 38 - TCF 4-hour forecast issued at 0600 CDT with valid time of 1000 CDT

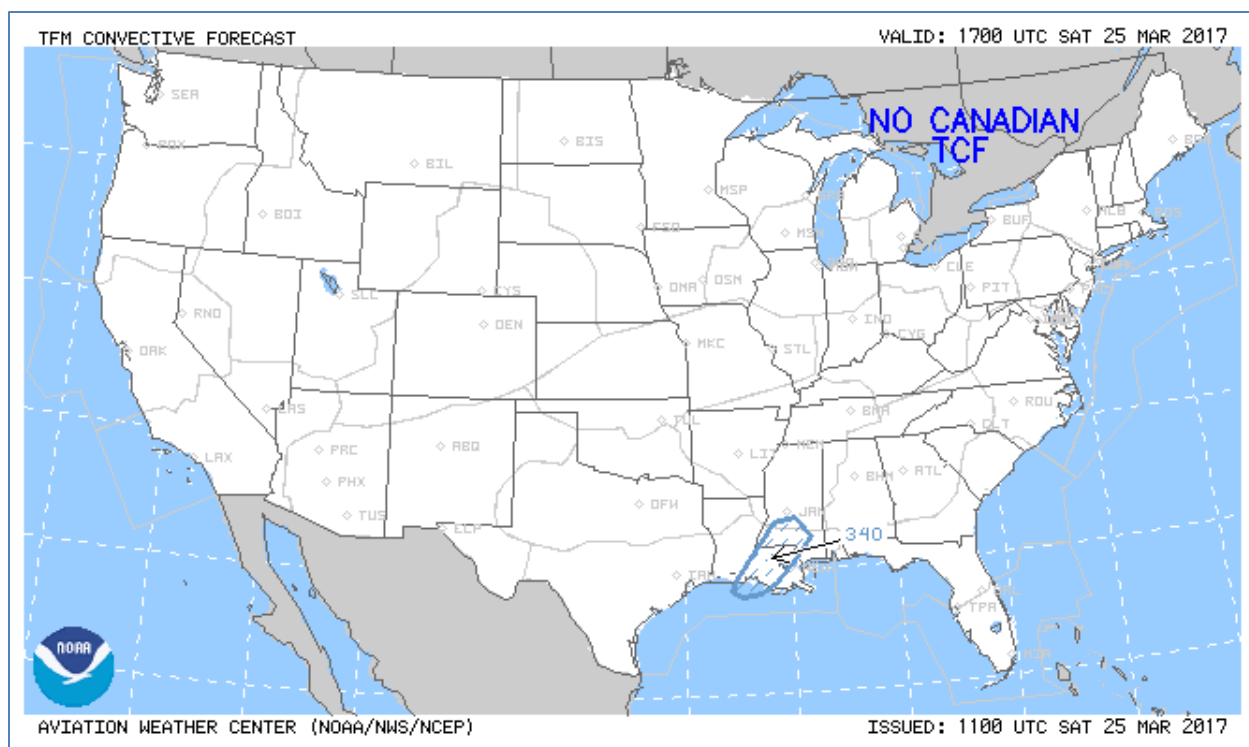


Figure 39 - TCF 6-hour forecast issued at 0600 CDT with valid time 1200 CDT

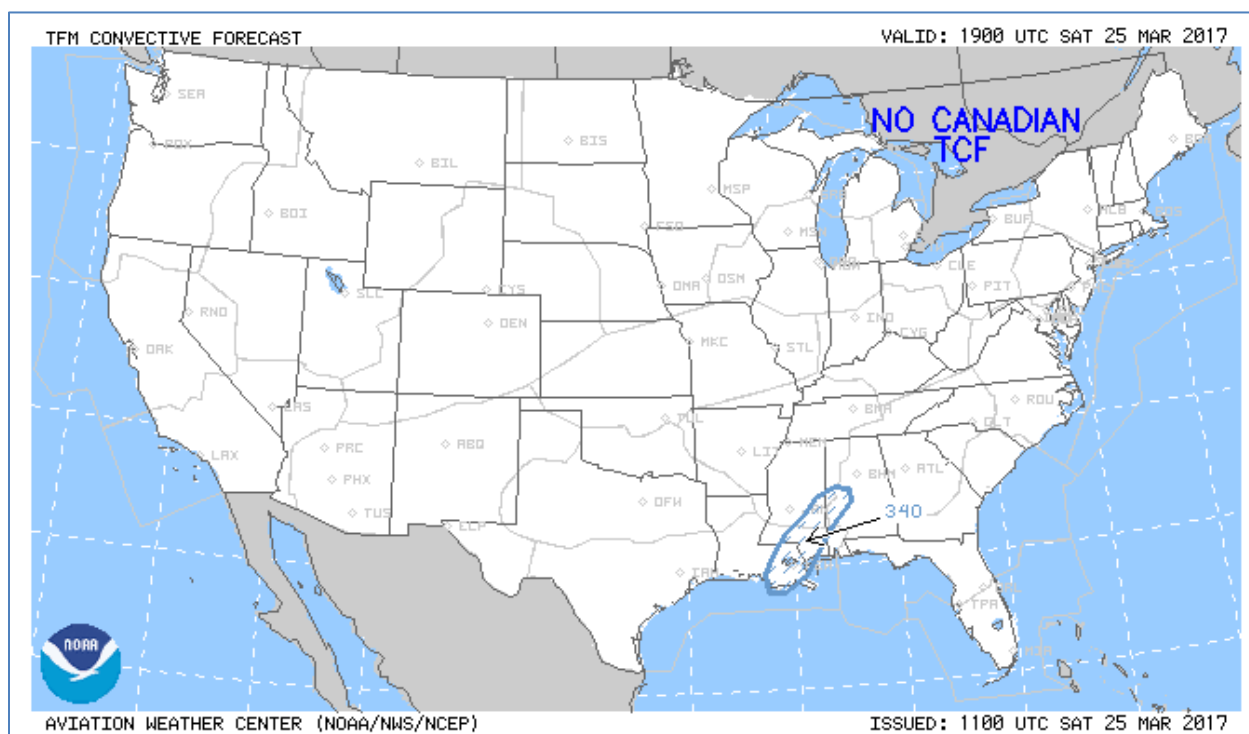


Figure 40- TCF 8-hour forecast issued at 0600 CDT with valid time of 1400 CDT

Figures 41 through 43 are the next TCF forecasts issued at 0800 CDT for 4-, 6- and 8-hour forecasts. The 4-hour forecast continued to depict a sparse area of echoes over eastern Mississippi, western Alabama, and southeastern Louisiana with tops between 29,000 and 34,000 ft. The 6-hour forecasts (figure 42) increased the cover to 40 to 74% over southern Alabama and Louisiana with tops to 34,000 ft and with sparse area of echoes over the Birmingham area at this time with tops to 29,000 ft. The 8-hour forecast (figure 43) had a medium coverage of echoes extending south of Birmingham, Alabama through southeastern Mississippi and Louisiana with tops to 34,000 ft.

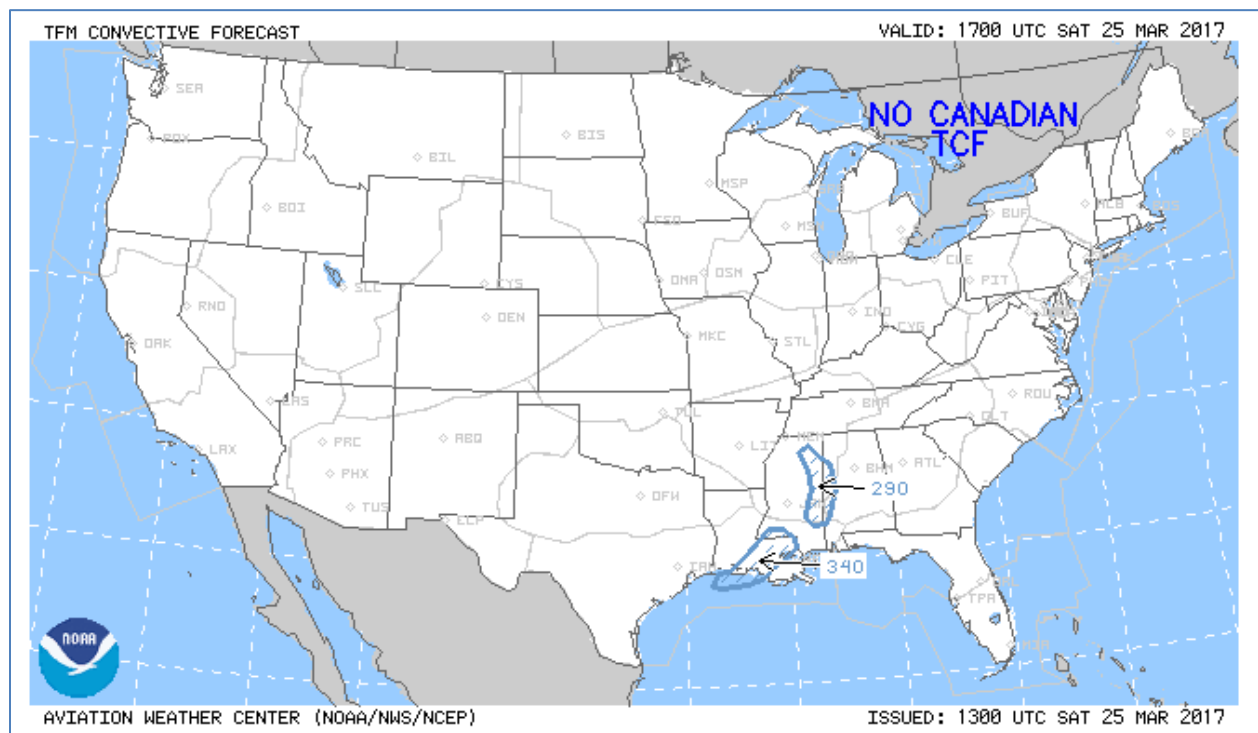


Figure 41 – TCF 4-hour forecast issued at 0800 CDT and valid at 1200 CDT

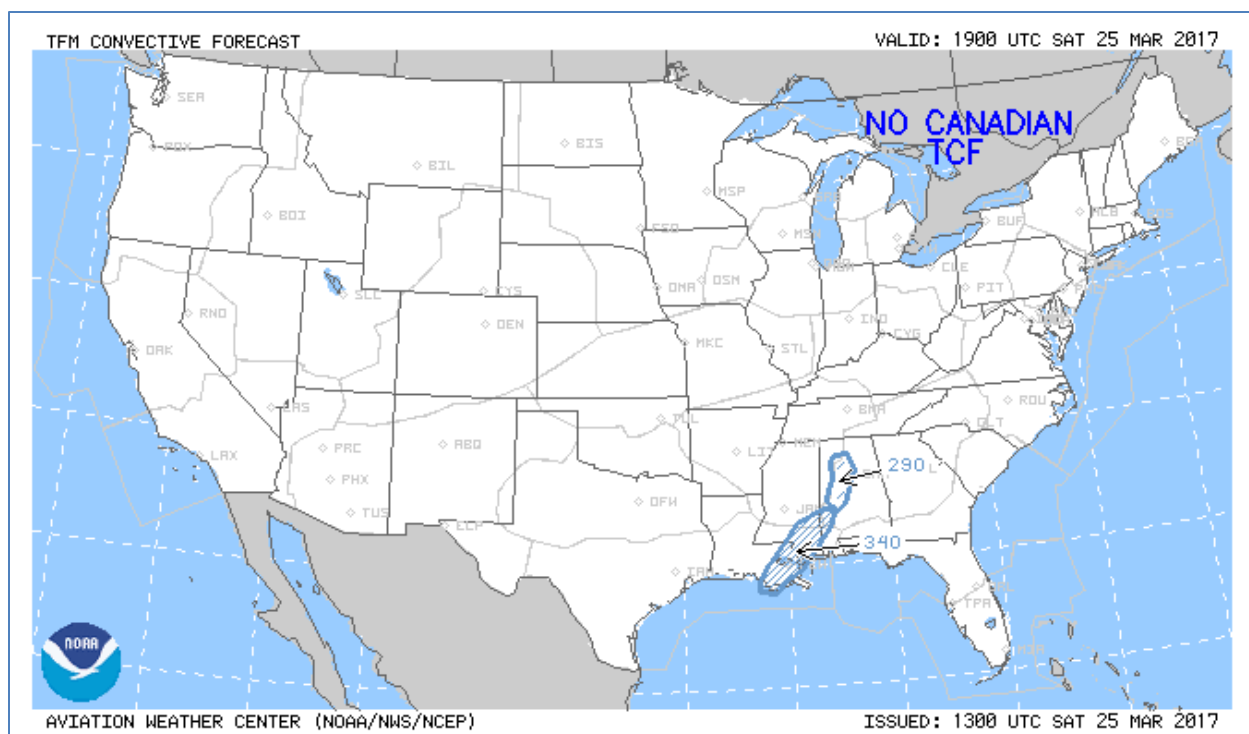


Figure 42 - TCF 6-hour forecast issued at 0800 CDT and valid at 1400 CDT

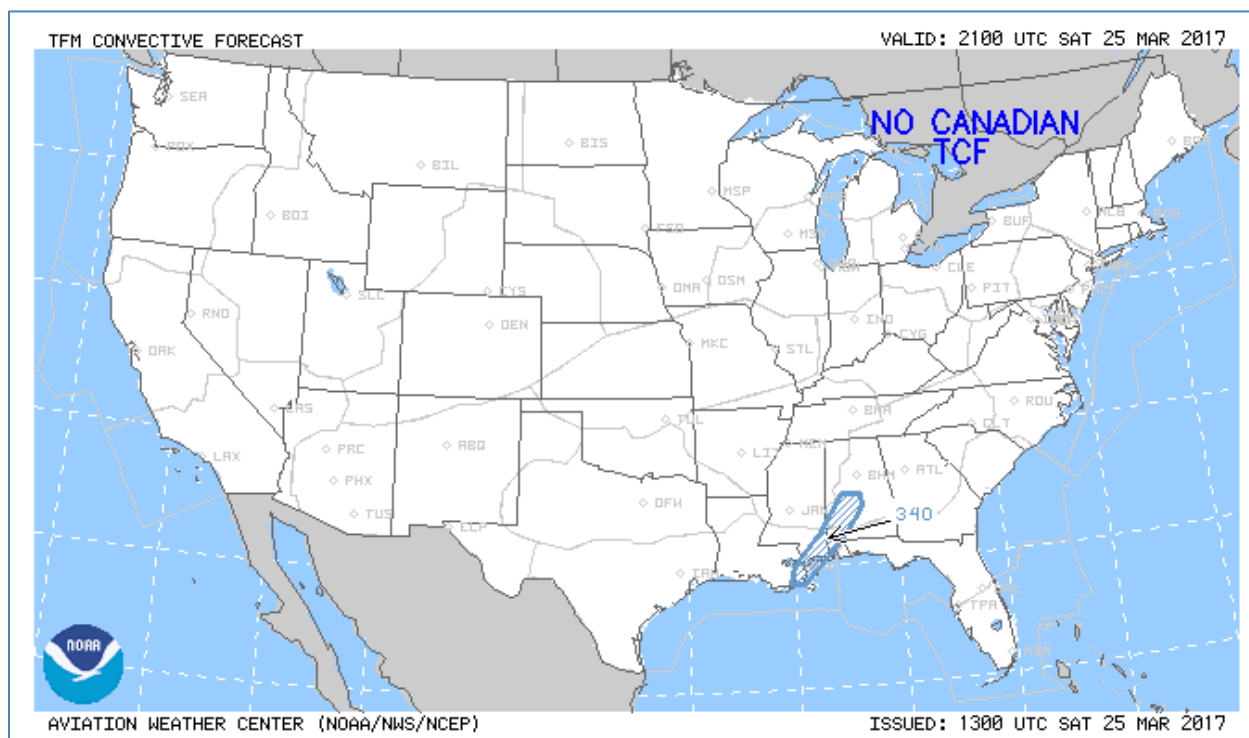


Figure 43 - TCF 8-hour forecast issued at 0800 CDT and valid for 1600 CDT

Figure 44 is the TCF 4-hour forecast issued at 1000 CDT and valid at 1400 CDT immediately prior to the accident. The chart depicted a sparse area of echoes over northern Alabama with coverage of 25 to 39%, and echo tops to 29,000 ft. Coverage increased to a medium 40 to 74% over southern Alabama, southeastern Mississippi and Louisiana, with tops to 34,000 ft.

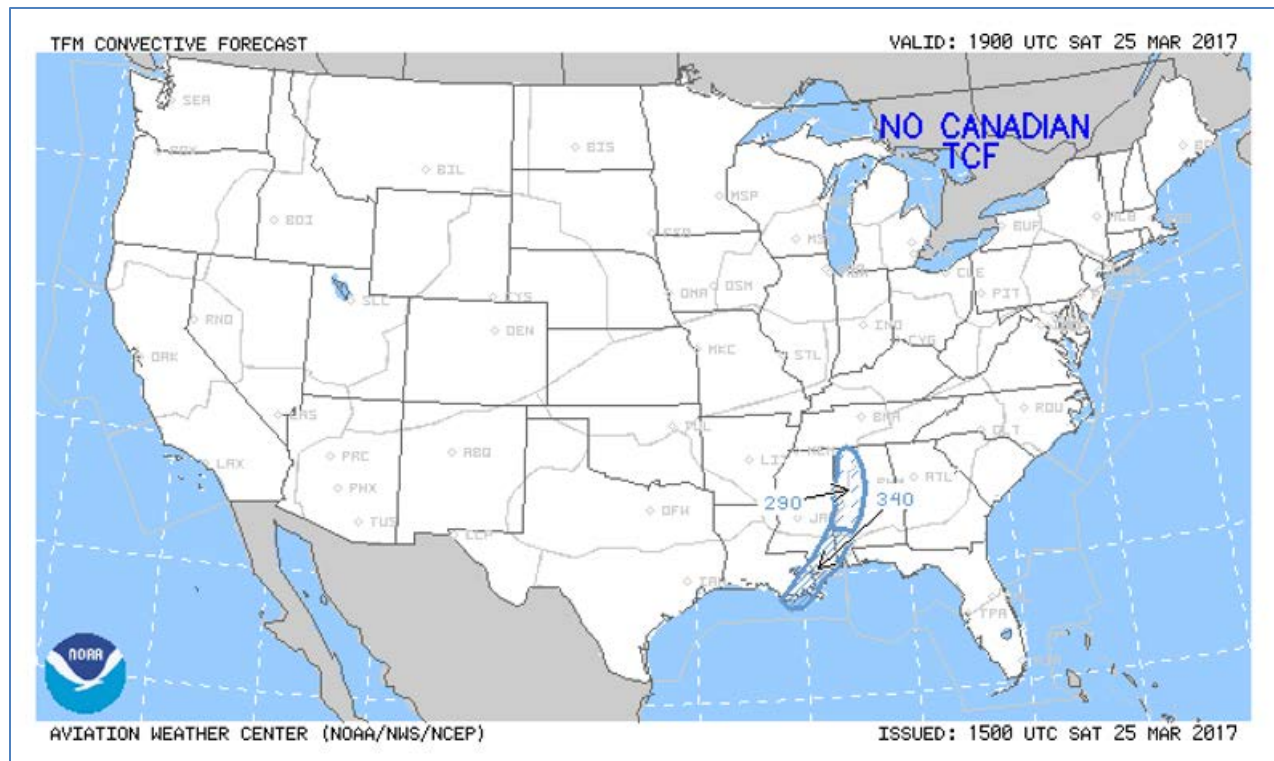


Figure 44 - 4-hour TCF forecast valid for 1400 CDT

The next TCF 4-hour forecast issued after the flight departed was issued at 1200 CDT and was valid for 1600 CDT is included as figure 45. The chart continued to depict an area of area of echoes of 25 to 39% coverage over the area with tops to 34,000 ft.

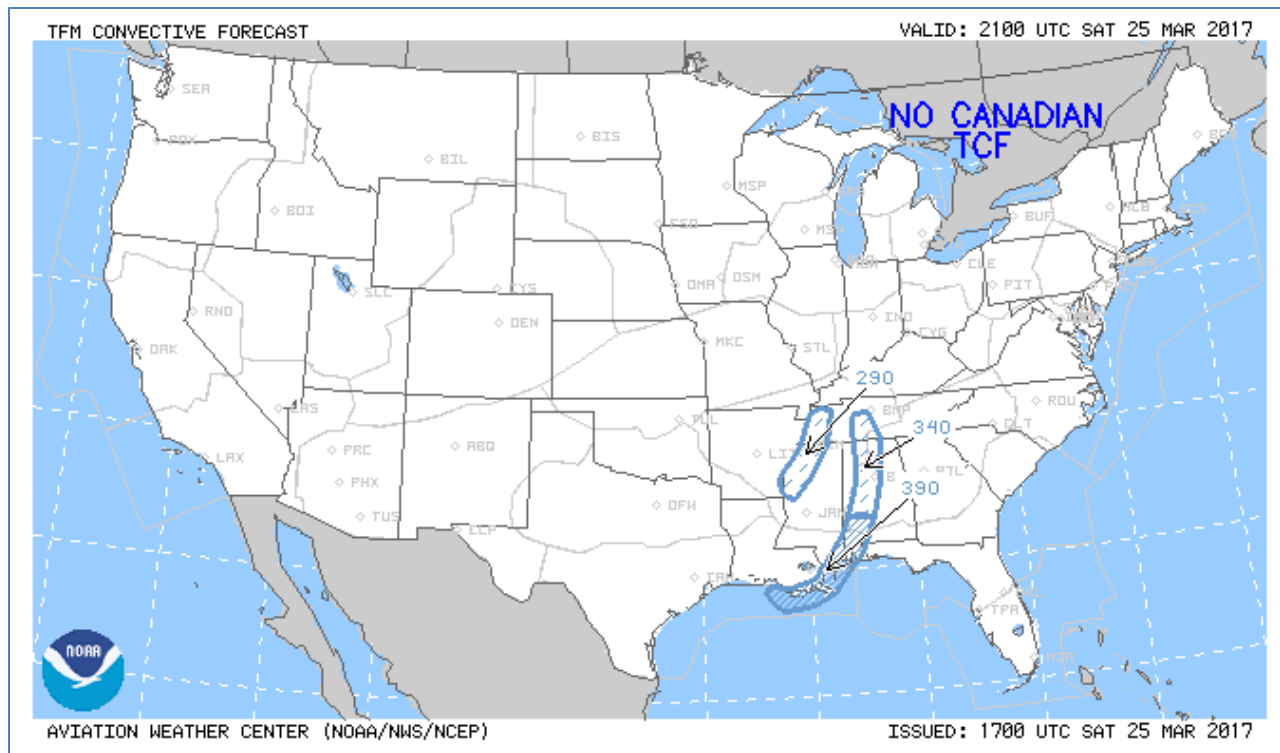


Figure 45 - TCF 4-hour forecast issued at 1200 CDT and valid for 1600 CDT

11.3 Mesoscale Discussion

The NWS SPC issued a Mesoscale Discussion number #330 at approximately 1200 CDT describing an area of potentially severe thunderstorms developing over the region. Figure 46 is the graphic of the advisory followed by the text. The graphic depicted a squall line over western Alabama into southeast Mississippi, and Louisiana ahead of the cold front with a scalloped line ahead of the squall line indicated where the SPC expected storms developing which included the accident site. The advisory identified a prefrontal line of thunderstorm extending from central Alabama into southeast Mississippi into Louisiana, which was continued to be monitored for further organization and intensification; however, the current stability fields and wind structure was thought to limit the severe weather threat across the region. The risk of a few instances of strong damaging winds gusts and hail was still possible across the region but no formal Weather Watch was being considered at that time, which downplayed the convective outlook (AC) bulletins and graphic (section 1.3) of a slight risk of severe thunderstorms.

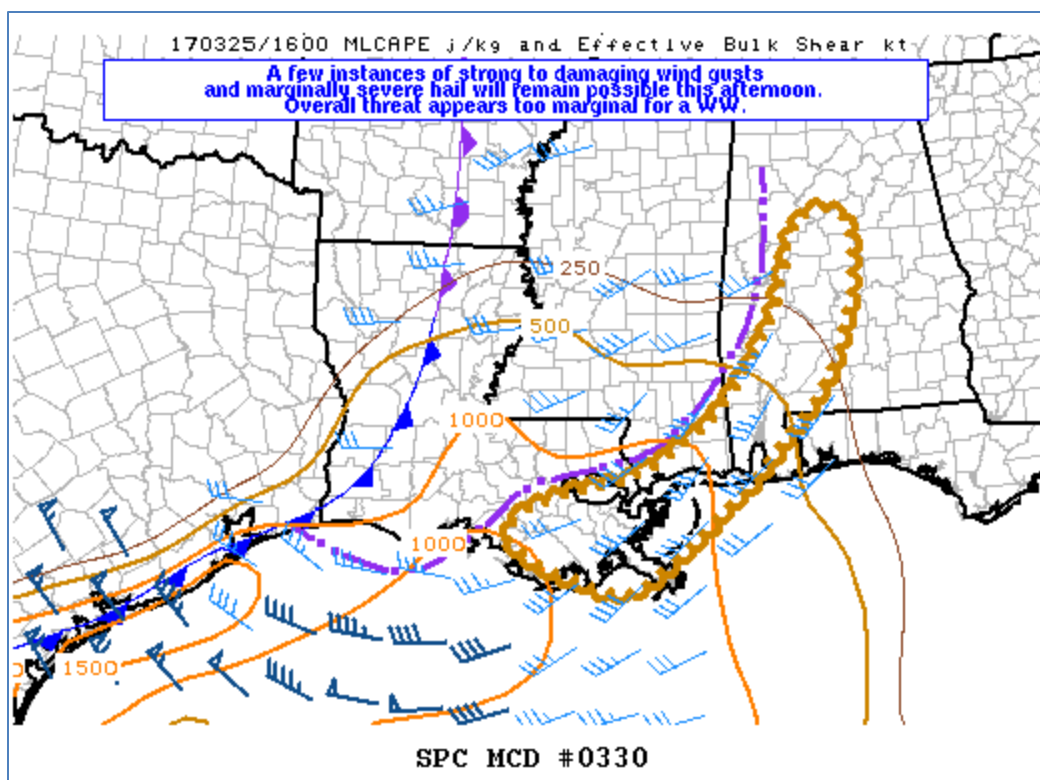


Figure 46 - Mesoscale Discussion #330 issued at 1200 CDT

Mesoscale Discussion 0330
NWS Storm Prediction Center Norman OK
1208 PM CDT Sat Mar 25 2017

Areas affected...southeast LA...southeast MS and southwest AL

Concerning...Severe potential...Watch unlikely

Valid 251708Z - 251945Z

Probability of Watch Issuance...20 percent

SUMMARY...A few instances of strong to damaging wind gusts and marginally severe hail will remain possible through mid afternoon. At this time the overall threat appears marginal, and a WW will probably not be necessary in this area unless storms begin to show evidence of greater organization and intensification.

DISCUSSION...As of mid day a broken line of pre-frontal thunderstorms extends from west central AL through southeast MS into southeast LA and is moving east at 15-20 kt. Diabatic warming of the boundary layer and modest low-level moisture advection have resulted in marginal instability with MLCAPE at or below 500 J/kg over west central through southwest AL to around 1000 J/kg over southeast MS. The primary low-level jet will remain north of this region, and winds aloft will gradually weaken in wake of a vorticity maximum moving through the base of the upper low circulation. Thus vertical wind profiles will become less favorable for storm organization as the atmosphere destabilizes this afternoon. Primary threat will be from a few strong to damaging wind gusts with stronger storms within the line.

..Dial/Guyer.. 03/25/2017

ATTN...WFO...BMX...MOB...LIX...LCH...

LAT...LON 29619129 30009096 30338962 30768885 31268828 32248765
33268728 33138660 31368705 29178943 29229056 29619129

11.4 Storm Reports

A review of the NWS SPC Storm Reports indicated that only one severe weather report was received by the NWS office for strong wind damage 1 mile north-northeast of Hillsboro, Lawrence County, Alabama at 1308 CDT, which was located about 50 miles north-northwest of the accident site. The report indicated that a large tree was knocked down and several sheds were blown down by high winds near the intersection of Highway 20 and Country Road 217. Figure 47 is a map of the severe weather reported on March 25, 2017, and identified the high wind report by a blue square, large hail reports in green, and tornadoes by a red triangle.

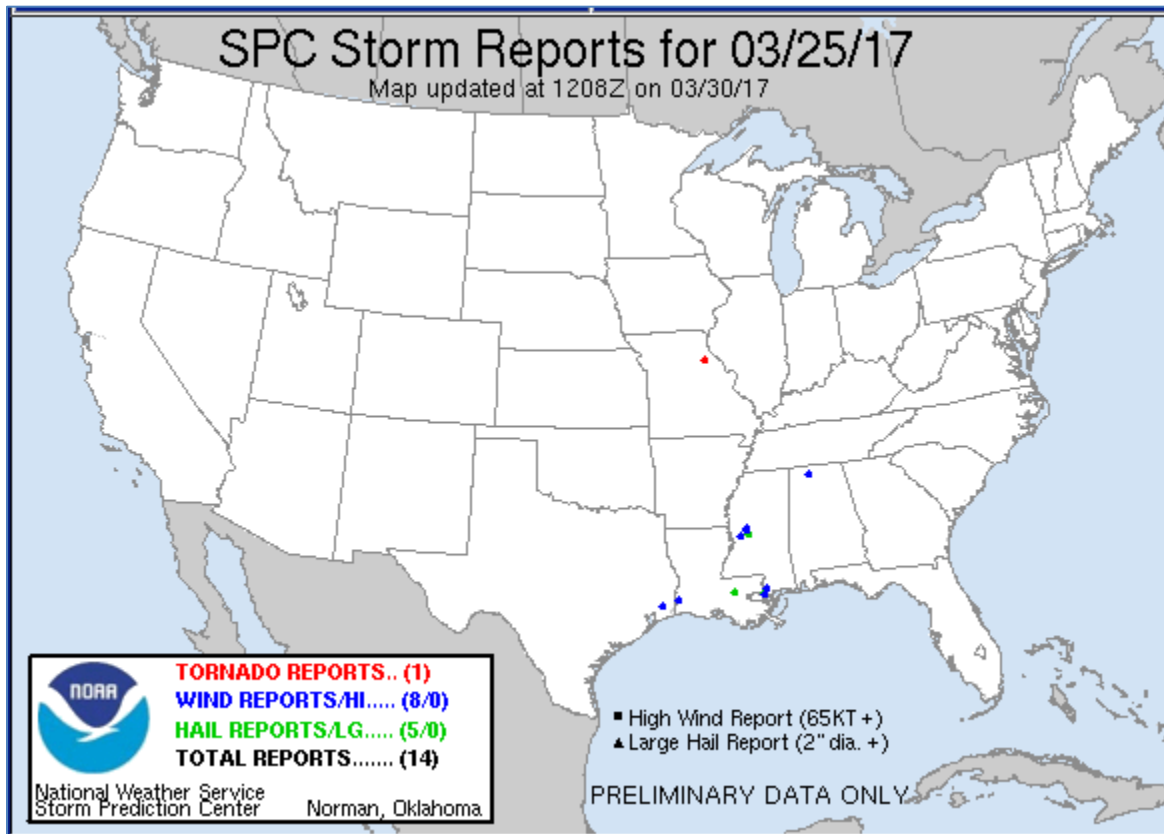


Figure 47 - NWS Storm Reports for March 25, 2017

12.0 Terminal Forecast

The NWS KBMX weather forecast office (WFO) was responsible for issuing the KBHM Terminal Aerodrome Forecast or TAF. The forecast that was current at the time of the accident was issued at 1225 CDT and was current for a 24-hour period. The forecast was as follows:

TAF KBHM 251725Z 2518/2618 19015G25KT P6SM VCSH OVC040
TEMPO 2518/2521 19015G25KT 4SM TSRA OVC020CB
FM252200 17010G20KT P6SM VCSH BKN025
FM260000 17010KT P6SM VCSH BKN025
FM261200 18010KT P6SM BKN020=

The forecast expected southerly winds from 190° at 15 knots gusting to 25 knots, visibility better than 6 miles with rain showers in the vicinity, overcast clouds at 4,000 ft agl, with a temporary period between 1300 and 1600 CDT of visibility 4 miles in thunderstorms and moderate rain overcast clouds at 2,000 ft agl in cumulonimbus clouds.

The forecast valid prior to N6563D departure was issued at 1128 CDT and was as follows:

TAF AMD KBHM 251628Z 2516/2612 16015G25KT P6SM VCSH OVC040
FM251800 15020G30KT 4SM RA VCTS OVC020CB
FM252200 17010G20KT P6SM VCSH BKN025
FM260000 17010KT P6SM VCSH BKN025

The forecast expected from 1300 through 1700 CDT, winds from the 150° at 20 knots gusting to 30 knots with 4 miles visibility in moderate rain with thunderstorms in the vicinity, ceiling overcast at 2,000 ft agl in cumulonimbus clouds.

13.0 NWS Area Forecast Discussion

The NWS BMX WFO issued the Area Forecast Discussion (AFD) at approximately 1230 CDT discussing the reasoning behind the forecast and the current weather conditions over the region was as follows:

FXUS64 KBMX 251729
AFDBMX
Area Forecast Discussion
National Weather Service Birmingham AL
1229 PM CDT Sat Mar 25 2017

.UPDATE...
For 18Z Aviation.

.DISCUSSION...

Upper level low pressure was analyzed across southeast Kansas with a surface low analyzed across southeast Missouri. Two pre-frontal disturbances are inferred from regional NEXRAD mosaics with the first moving across our western and into our central counties, resulting in light shower activity with the second and more robust line of showers and storms extending from southwest Tennessee through north-central Mississippi and into west-central Louisiana.

A review of global model output indicates most models position the upper level low across eastern Oklahoma compared to the current position based upon satellite. Models take the upper level low into central Missouri toward 00z tonight, however, attempting to correct the misplacement of the current position, the upper low may be even further north into northeast Missouri by 00z tonight. Good news is with the upper level support and dynamics pulling northeast tonight will result in decreasing severe potential this evening and overnight.

Surface observations indicate temperatures range from the mid to upper 50's southeast to the low 60's west-central with highest temperatures across our northwest counties. The surface dew point field shows more of a spread across the CWA this morning with readings in the low 50's east to the mid to upper 50's west with highest values southwest. Surface wind fields remain out of the southeast throughout the CWA this morning with speeds ranging from 3-8 knots east to a range of 2-10 knots west. Winds remain breezy at times with gusts generally from 3-5 knots east to the range of 9-14 knots west. The low level advection pattern will support continued increases in temperature and dew point values through early afternoon.

The KBMX 12Z sounding indicates a reduced layer of dry air compared to last evening's 00Z sounding roughly between 450mb and 850mb. The light showers moving east across the CWA are encountering this drier layer and this is keeping rainfall amounts on the light side. Expect this layer to continue to moisten over the next few hours as the line of storms approach from the west. Weak subsidence inversions in the lower levels are limiting instability, higher temperatures and dew points will be required along with steepening lapse rates aloft to realize additional instability. Low level shear is impressive with 0-1 km SRH values of 314 m2/s2 and 0-3 km SRH of 347 m2/s2 but bulk shear values are generally less than 40 knots and the absence of a low level jet along with marginal upper jet winds (not much more than 50 kts) are providing more marginal dynamical support.

The main concern will be with the line of showers and thunderstorms presently pushing through west-central Mississippi. While some airmass recovery is expected after this line moves east across our area, the level of instability obtained does not appear to be sufficient to support an organized severe weather threat. With that said, upper level forcing will still remain sufficient to encourage the development of shower and thunderstorm activity as the surface front nears from the west this afternoon and evening.

.AVIATION...

18Z TAF Discussion.

Line of TSRA with occasional TSRA continues moving east and is presently located near TCL. Expect RA at all terminals with TSRA most likely across our southern terminals. Winds will remain gusty out of the south through this evening and CIG's will fall into MVFR category once the storms arrive. CIG's may locally improve behind the line, however, the surface cold front remains further west and additional RA with some TSRA is currently ongoing across central MS. SHRA will remain possible at all sites tonight through Sunday morning as the cold front moves east across the area.

.BMX WATCHES/WARNINGS/ADVISORIES/...

None.

14.0 Preflight Weather Briefing

The pilot used a computer or iPad to access an online weather briefing source through ForeFlight, which he had a subscription, and filed an IFR flight plan. He obtained a low-altitude route briefing between Kissimmee, FL to Jackson, TN at 0606 CDT (1106Z) and again at 1134 CDT (1634Z) or approximately 20 minutes prior to departure. The briefing included all the relevant reports and forecast, advisories, and notices to airmen (NOTAMs) for the route. A copy of the 110 page briefing is included as Attachment 4.

A review of the briefing indicated that the Convective Outlook and Area Forecasts documented above were included in the document. The TAFs for KBHM and other station were forecasting MVFR conditions with thunderstorms and/or rain showers and overcast cloud cover. At the time of the briefing, other than the AIRMETs Tango there were no advisories current for the route for thunderstorms or other hazardous weather.

15.0 Weather in the Cockpit Displays

The pilot had access to XM Weather Satellite displays through his subscriptions, which allowed the pilot to access ground based NEXRAD composite weather displays on his iPad inflight to provide the pilot with an increased situational awareness of the weather conditions. As noted in AC 00-24C, the composite reflectivity product is created at the end of all the elevation scans, and as a result the image has an inherent latency. And unlike airborne weather avoidance radar, weather data linked from ground based weather surveillance radar system is not real-time information. The radar data displays recent weather rather than current weather conditions. As the current location of a thunderstorm cell may be different than the broadcast weather product.

The XM Weather Satellite composite reflectivity images issued at 1400 through 1430 CDT (1900-1930Z) on March 25, 2017 were provided by Baron Services, Inc. and included as figures 48 through 54. An “X” marks the accident location on the images and is located within the red circle on the first image, which also includes a reflectivity scale for reference for the images. The images clearly depict a line of moderate echoes with broken heavy to extreme intensity cells along the leading edge moving northeastward with time. Echoes are observed over the accident site after 1420 CDT and continue through the time of the accident at 10 to 30 dBZ, with 40 to 45 dBZ or heavy intensity echoes immediately west and northwest of the accident site.

XM COMPOSITE AT 1900UTC

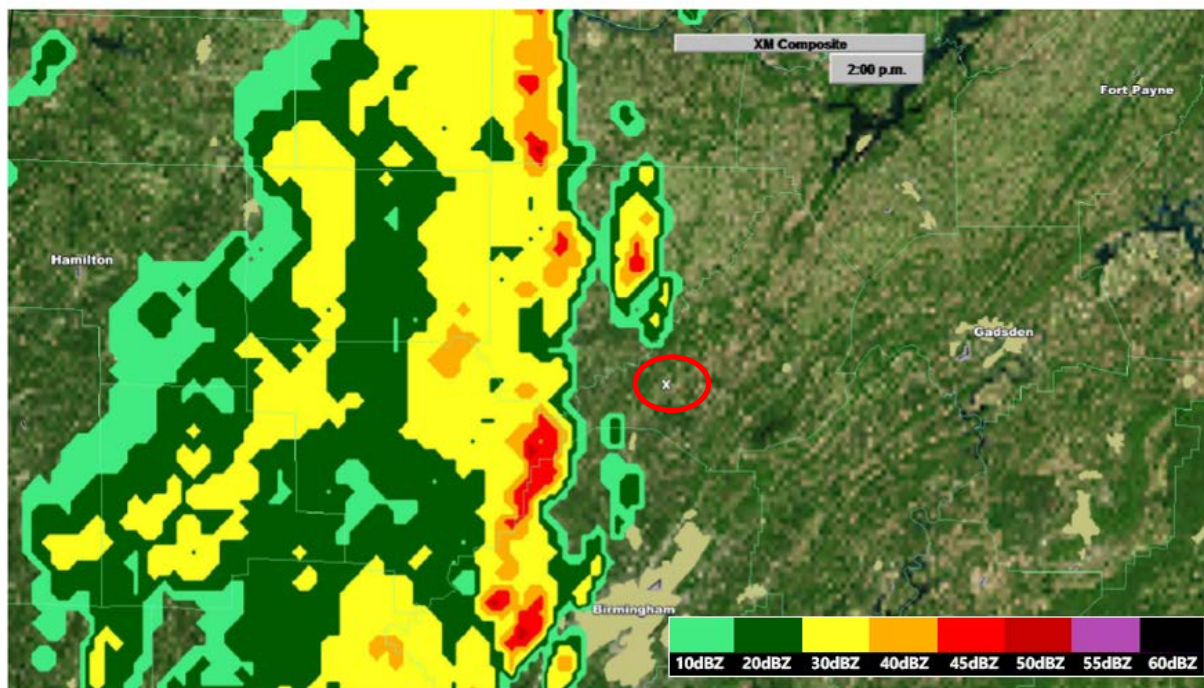


Figure 48 - XM Weather composite radar image at 1400 CDT

XM COMPOSITE AT 1905UTC

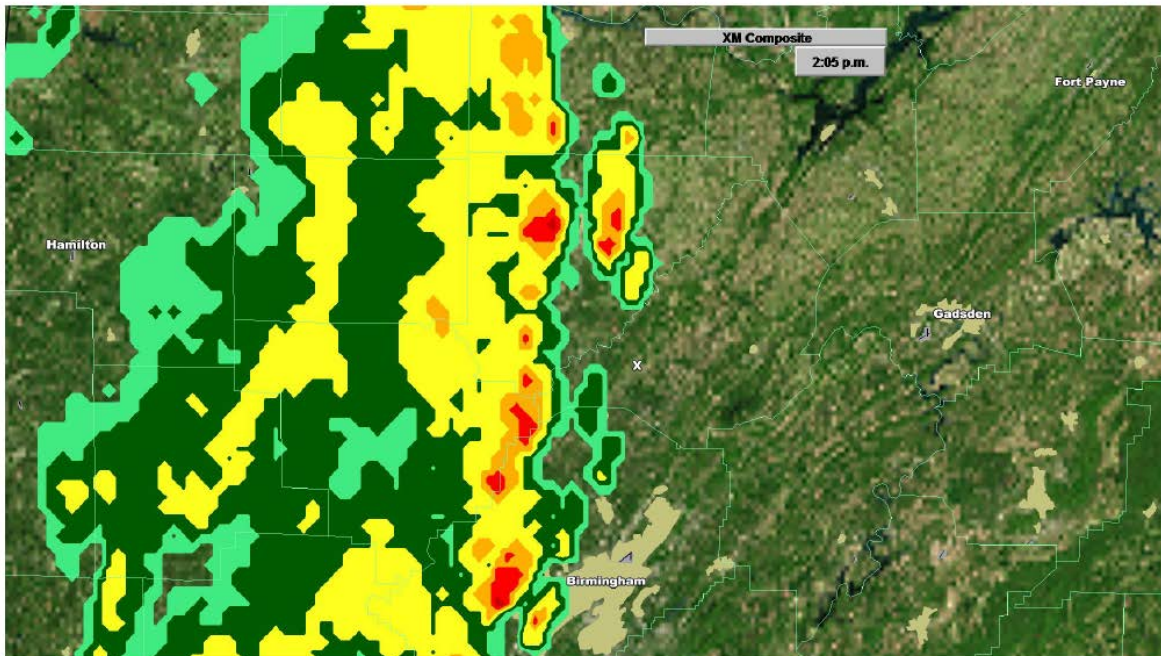


Figure 49 - XM Weather composite radar image at 1405 CDT

XM COMPOSITE AT 1910UTC

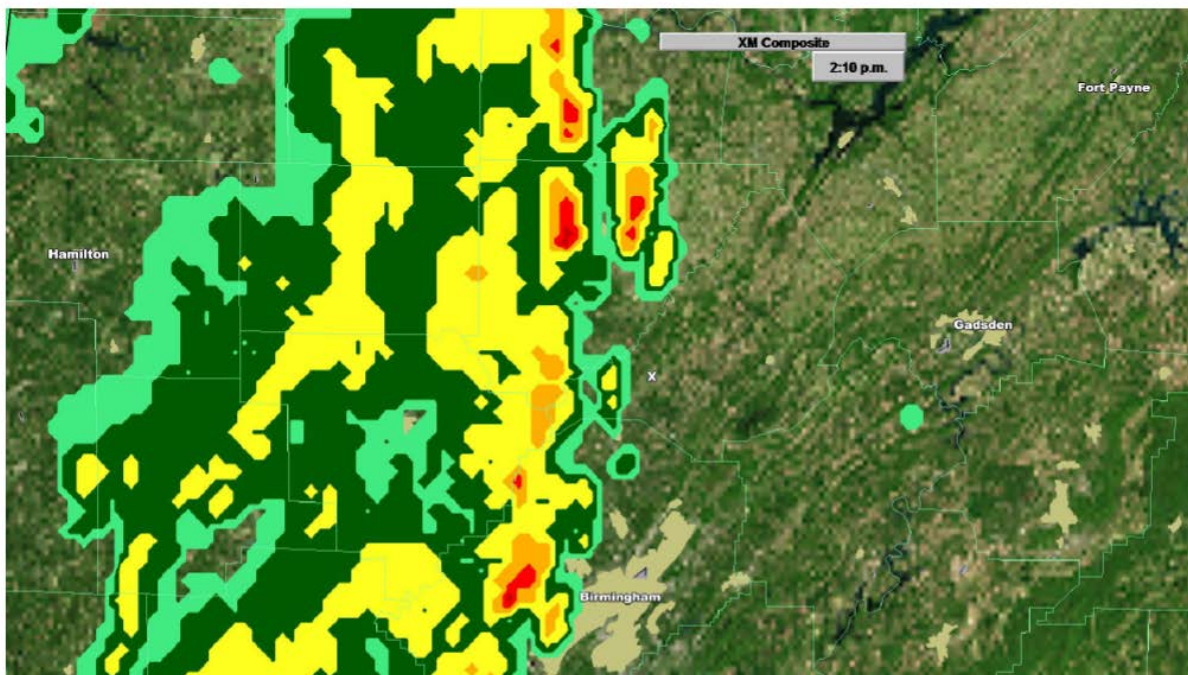


Figure 50 - XM Weather composite radar image at 1410 CDT

XM COMPOSITE AT 1915UTC

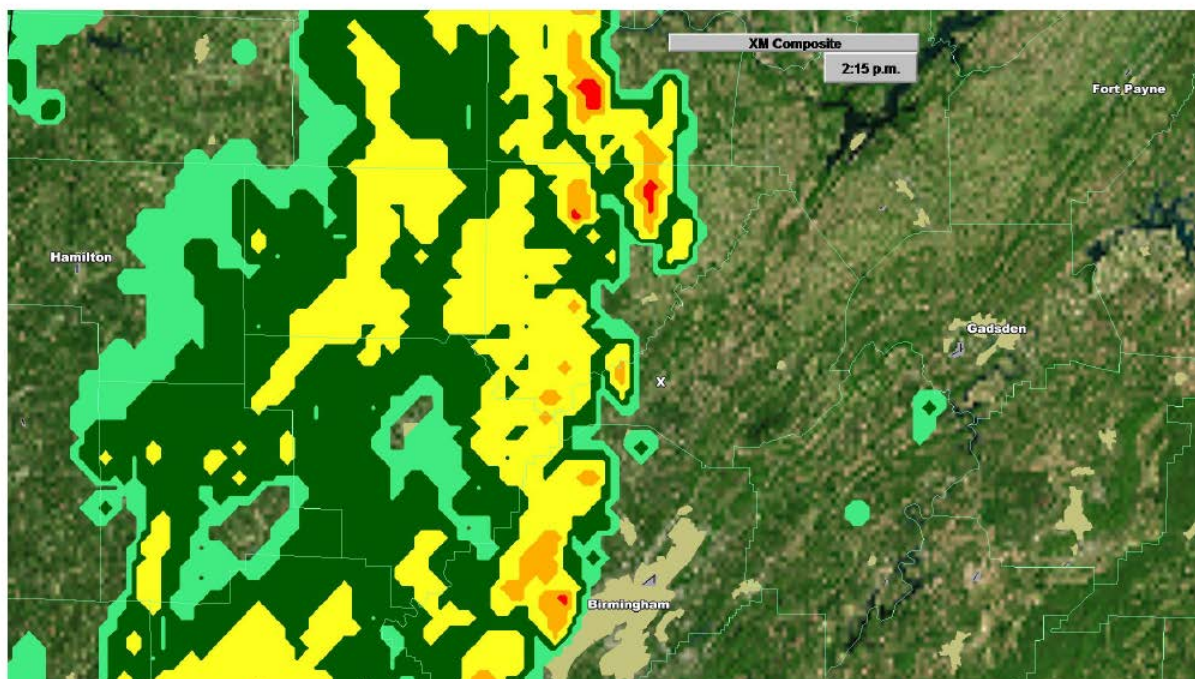


Figure 51 - XM Weather composite radar image at 1415 CDT

XM COMPOSITE AT 1920UTC

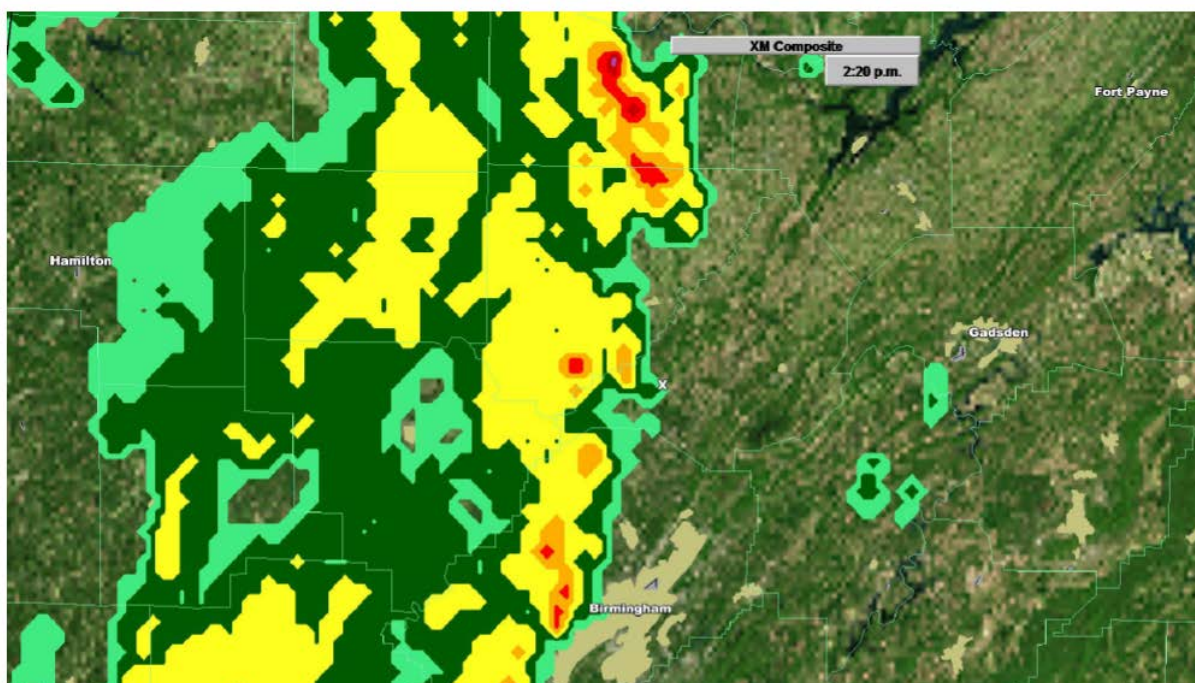


Figure 52 - XM Weather composite radar image at 1420 CDT

XM COMPOSITE AT 1925UTC

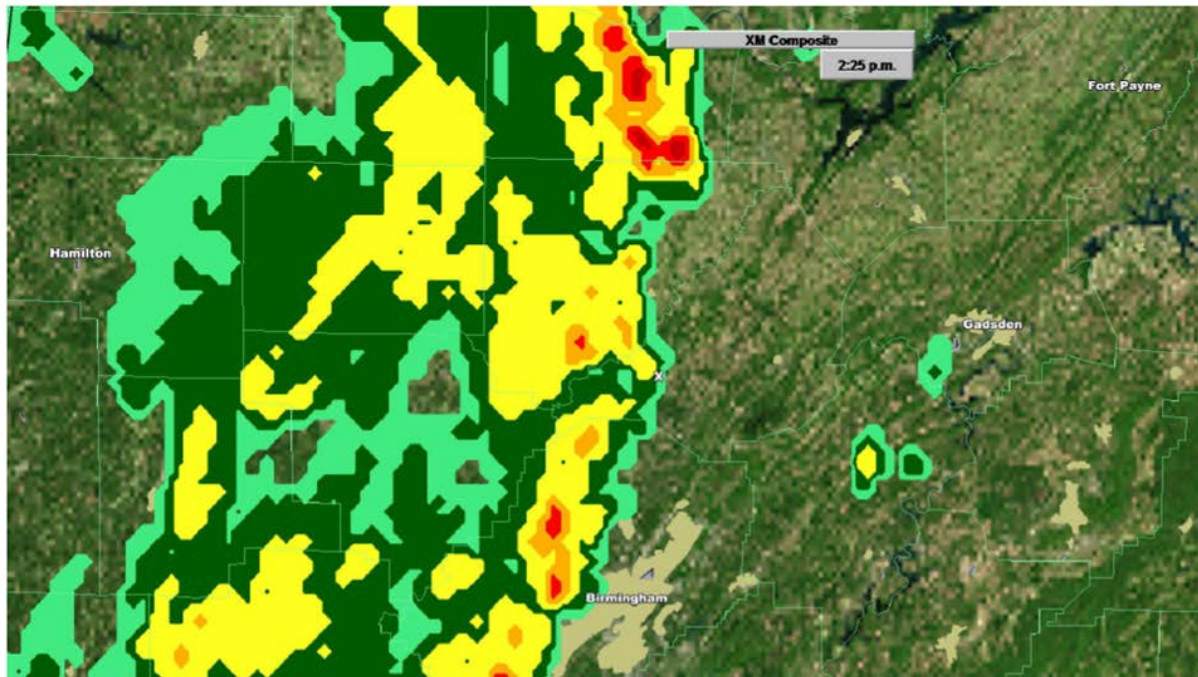


Figure 53 - XM Weather composite radar image at 1425 CDT

XM COMPOSITE AT 1930UTC

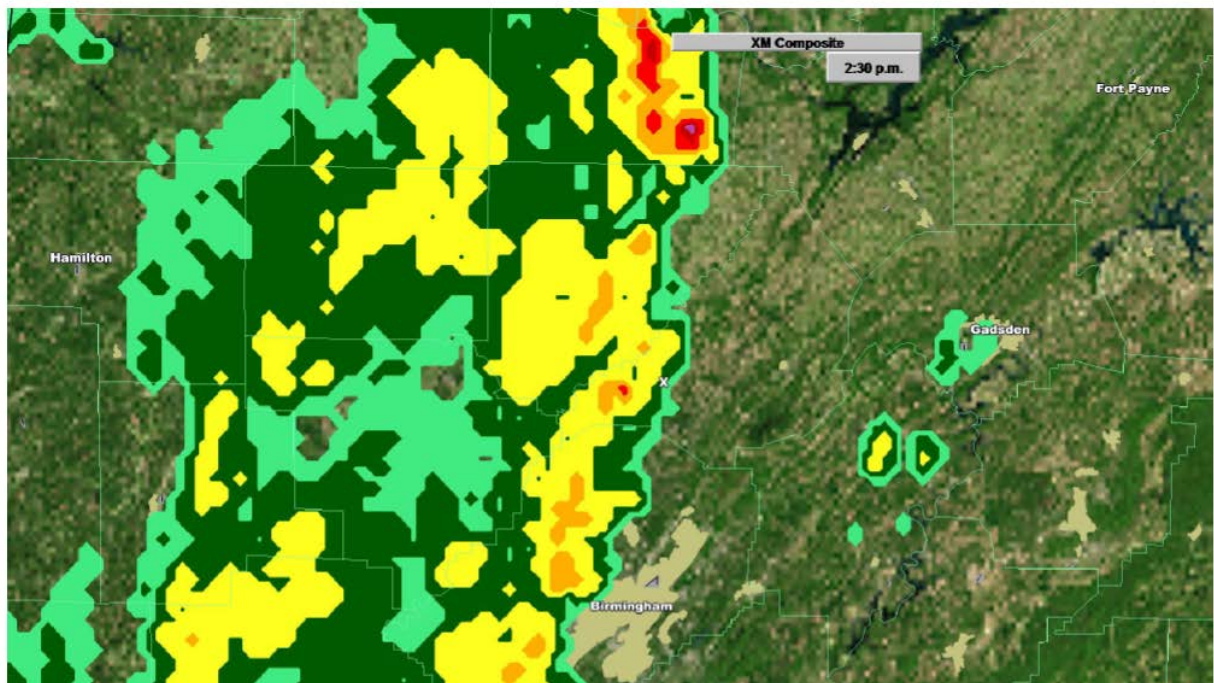


Figure 54 - XM Weather composite radar image at 1430 CDT

16.0 FAA Weather Displays

The FAA Consolidated Storm Prediction for Aviation (CoSPA) weather display, which integrates several of the NWS and FAA weather systems into a single display, with lightning and convective initiation and growth into a single display surrounding the period were documented. The CoSPA display is of vertical integrated liquid (VIL) which is the vertical estimation of the mass of water, or liquid water content in a column of air. VIL uses the full volume scan of all the elevation scans and looks similar to reflectivity images. The VIL levels 1 through 6 are based on the following table:

VIP or VIL Levels	VIL (digital VIL)	VIL (kg/m ²)	Past and Current VIL
1	16	0.15	Level 1
2	74	0.76	Level 2
3	133	3.47	Level 3
4	160	6.92	Level 4
5	181	12.0	Level 5
6	219	31.6	Level 6

The CoSPA image at 1425 CDT showing the full extent of the line is apparent in figure 55, with intensity marked in VIP of VIL levels 1 through 6 in various colors, similar to reflectivity values. Also included are the echo tops or the highest detection of 18 dBZ in hundreds of feet, cell movement indicated by a black arrow with the speed in knots, and cloud-to-ground lightning strikes with the white “+” symbols from the National Lightning Detection Network (NLDN).

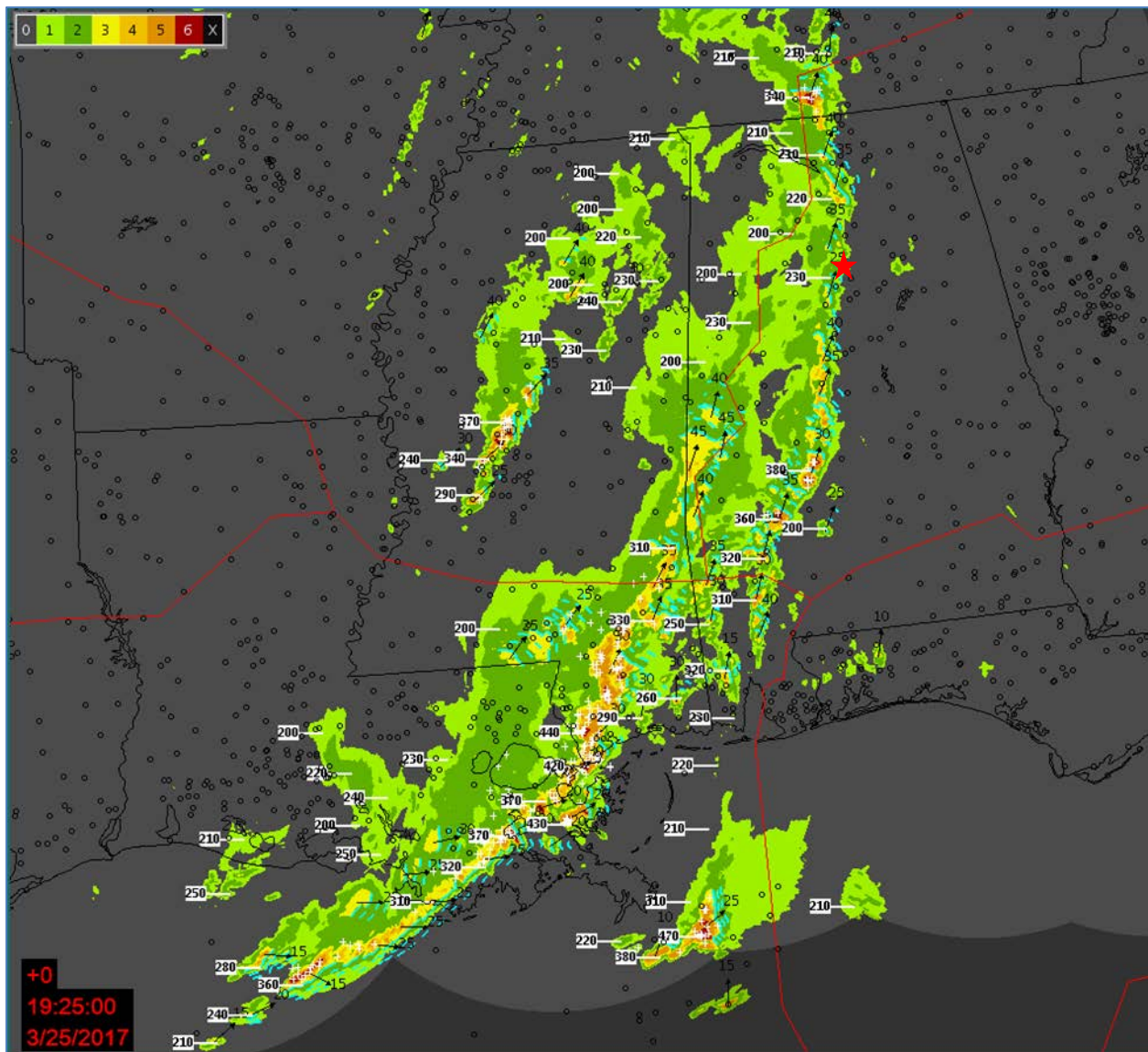


Figure 55 – CoSPA radar image at 1425 CDT showing a significant line of echoes stretching across Tennessee southward through Alabama, Mississippi into Louisiana

Figures 56 through 59 are close up images of the CoSPA radar images every 5-minutes from 1415 through 1430 CDT with the approximate accident site marked by the red star and KBHM identified.

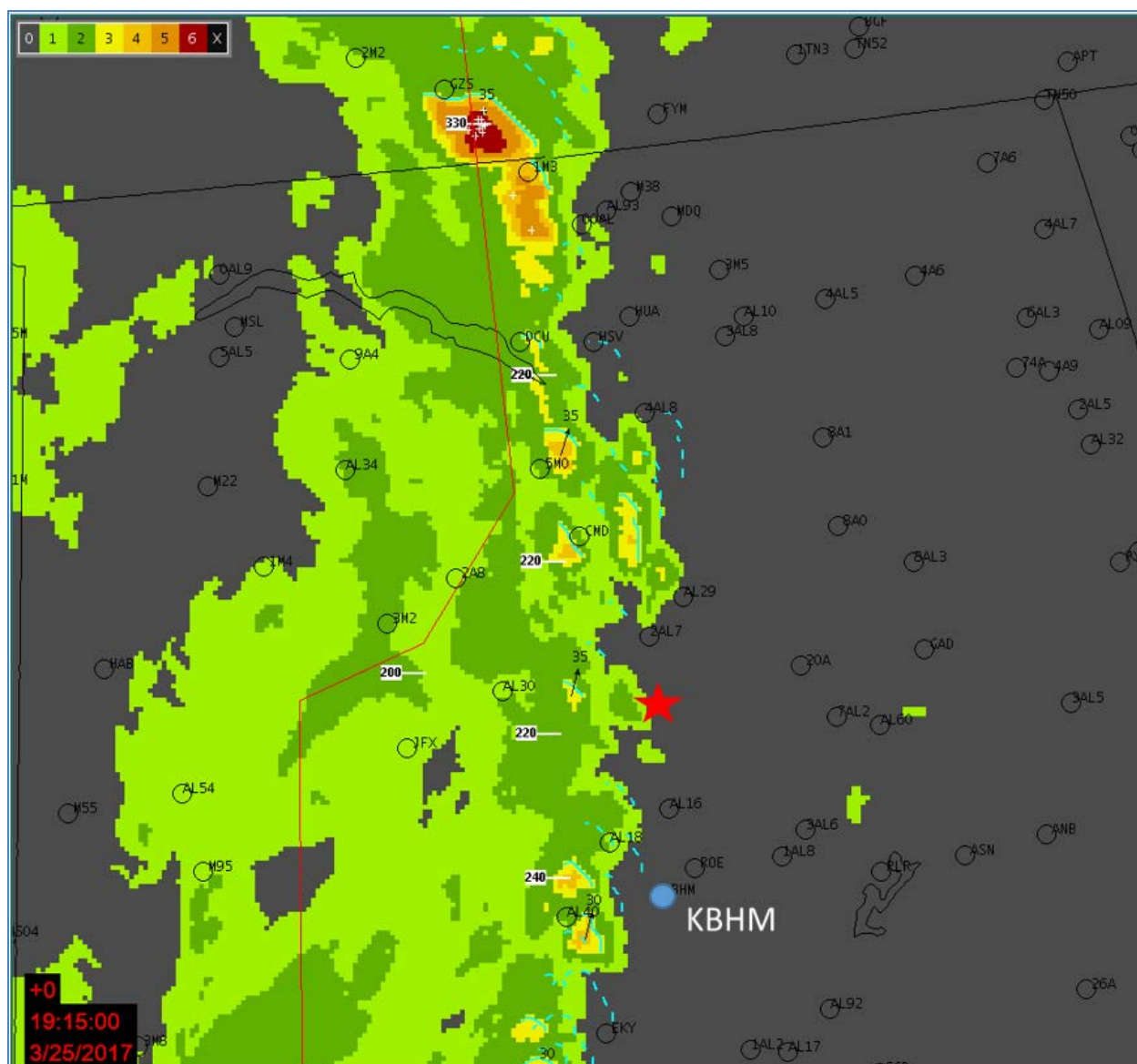


Figure 56 - CoSPA image at 1415 CDT

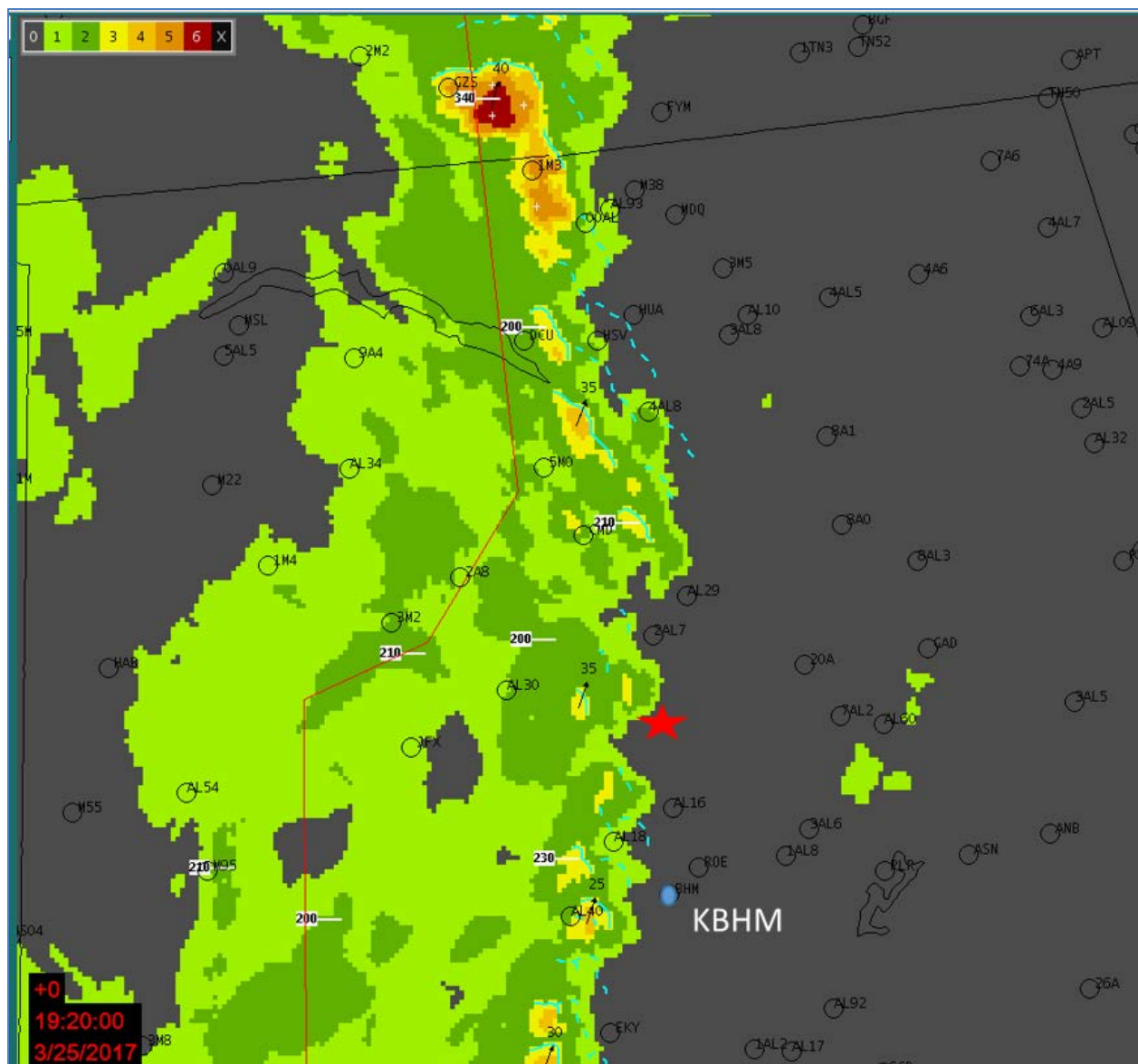


Figure 57 - CoSPA image at 1420 CDT

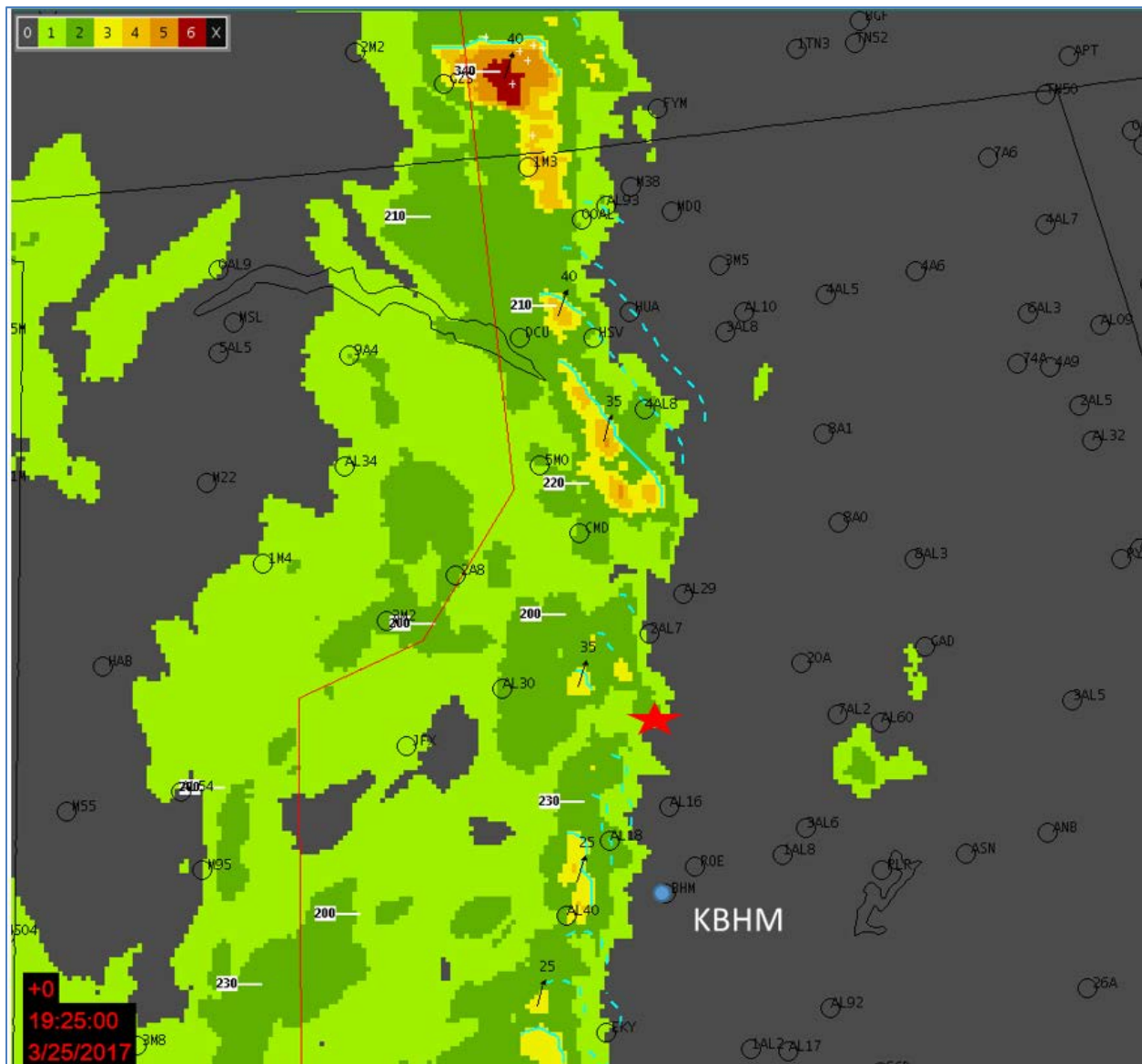


Figure 58 - CoSPA image at 1425 CDT

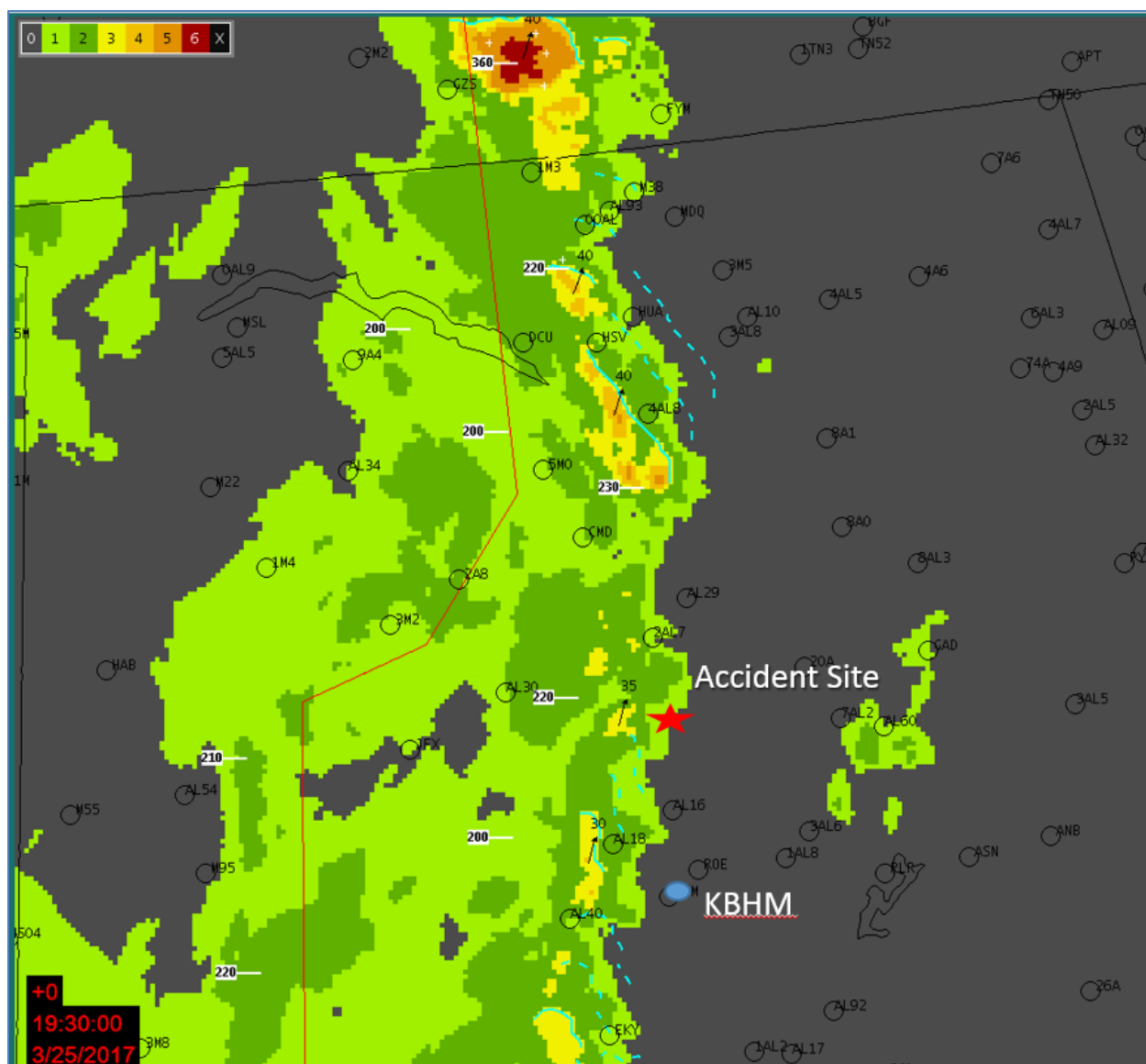


Figure 59 - CoSPA image at 1430 CDT

17.0 Interview with Birmingham Forecast Office

The NTSB Meteorologist met with the NWS KBMX WFO on April 7, 2017 at their office in Calera, AL, and met with the office's Science and Operations Office (SOO) and acting Meteorologist-In-Charge (MIC). After an introduction, the general synoptic conditions and forecasts issued on March 25, 2017 were reviewed. During the period, the forecast office was at normal staffing of 4 forecasters on duty with one additional meteorologist on an overlap due to their 9 hour shift schedule so the office had 5 meteorologists on duty during the afternoon hours.

Due to initial forecast of potential severe weather across the area during the afternoon hours, the office decided to launch an additional mid-day upper air sounding at 1300 CDT to better define the atmosphere stability and general aid in forecasting. This sounding is documented in section

3.1 of this report. The sounding indicated a more stable atmosphere with a wind profile, while strong to short line storms did not support long-lived storm development, and thus the risk of severe thunderstorms was minimal for the area. Therefore, no weather warnings or watches were issued for their forecast region during the period.

The Birmingham TAF was also issued by their office and reflected the cloud bases between 4,500 to 5,000 ft agl over the region with winds from the south at 25 knots, and expected to shift to the west with the line of activity. With general VFR conditions with a temporary period of MVFR conditions in rain and thunderstorms. The highest wind was reported from the south at 28 knots prior to the event.

The office also discussed the fact the KBHM ASOS wind sensor is extremely accurate with regards to reporting wind conditions due to its location on the field, and that contract weather observers are still staffed at the airport. The ASOS had also been upgraded with an Automatic Lightning Detection and Reporting System (ALDARS). Lightning data was also reviewed and some lightning was detected near the time of the accident, but not in the cell located in the immediate vicinity of the accident site.

A detail review of the KBMX WSR-88D was conducted during this period. The base reflectivity imagery for 0.5° degrees depicted a line of activity with embedded higher reflectivity cells, which developed and quickly dissipated due to the unfavorable wind profile. The fine line was also identified moving out ahead of the main band of echoes, which was identified moving across the Hayden area about the time of the accident, and through KBHM at 1442 CDT with rain shortly thereafter when the main line moved through the airport with approximately ½ inch of rain. This fine line under the accident site raised the potential of some vertical perturbation or turbulence being generated along the leading edge, which may have produced turbulence that may have occurred along the accident flight track.

The base reflectivity also depicted a strong reflectivity core immediately west of the accident site with reflectivity's reaching 53 dBZ or extreme intensity for a short period of time. The accident site was located immediately east of this area, but was in the leading or eastern edge of this echo.

A review of the spectrum width product also showed some strong shear along the leading edge, with minimal activity with the main band of weather. The radial velocity data did not show any significant circulation features or microbursts over the area. The dual polarization images did not detect any significant hail and echo tops were relatively low near 34,000 ft. With cells moving north-northeast at 35 knots.

A review of storm or damage reports from their office indicated no reports of any wind, hail, or tornadoes being reported across their warning area; however, a single report north from the Huntsville area reports a tree blown over, large branches, and a shed damaged near 1400 CDT. Which was likely associated with one of the stronger more intense cells, but was not long lived.

18.0 Center Weather Service Unit (CWSU) Interviews

On April 11, 2017 between 1000 and 1230 EDT, the ATC group and Weather Specialist met with the Meteorologist-In-Charge of the ZTL NWS CWSU. After a brief introduction, he provided his background and experience information, and discussed his role in the operation of the office. With regards to staffing levels at the CWSU, he indicated that they were at full staffing levels plus one, with normal staffing a morning and afternoon forecaster working an 8-hour shift with a 15-minute overlap for shift turnovers. The normal operating hours for the ZTL CWSU were from 0530 to 2115 local. An additional new position or Aviation Service Meteorologist (ASM) position designed to support the Traffic Management Unit (TMU) directly, and assist in training and other technical support was used during the week. The staff levels also allowed for flexibility to adjust for severe weather or other high workload conditions. He also indicated that the unit is often requested to remain open after 2100 local to provide support when weather threatens the area, and that overtime approval was not an issue or a concern. The MIC and CWSU meteorologist interviewed did not feel underutilized, and had a good working relationship with their users, or the air traffic controllers and TMUs at the center.

When asked about who are their direct users they indicated the TMU position was their most frequent user of their forecast and support, which was located immediately next to their position, but also the various other supervisor positions, and individual controllers who utilize them as needed during various weather situations. A separate CWSU meteorologist interviewed also indicated that he often had controllers come up for briefing, or answer specific weather questions such as cloud or echo top information, and he indicated he would “go out on the floor” as necessary to provide additional warning during severe weather situation to support the various sectors.

The collection and dissemination of PIREPs was also discussed. The CWSU did not directly enter the PIREP observations, and that role was designated to flight data center, which are staffed 24 hours. However, the meteorologist said he would remind users of the importance of soliciting PIREPs where icing or turbulence, and other hazardous weather conditions exist.

The CWSU also supported the daily standup briefing during the day, and provided 3 briefing spread sheets at 0550, 1230, and an evening 2030 EDT update. The morning briefing was posted on the WARP display and played. The 0550 and 1230 EDT briefings warned of a line of thunderstorms ahead of a cold front was moving eastward into the Mississippi Valley. Thunderstorms and rain showers were expected after 1800Z over Tennessee and Alabama, into Mississippi, and Alabama west of their airspace with potential west and southwest arrive and departure gates into Atlanta impacted after 2100Z. Both briefings indicated that no flight hazards were expected for their airspace during the period in their briefing. The briefings included a 12-hour forecast from the NWS WPC 12-hour significant weather prognostic chart (figure 5) of the frontal systems location and forecast precipitation, which included thunderstorms and rain showers over 50% coverage over Alabama in the 1230 briefing. The current TAFs for ATL and CLT, and arrival and departure gate impact forecasts, and wind profiles for the 2 airports. The two briefing sheets are included as Attachment 4. There was no mention of any potential KBHM weather impacts during the period.

A review of the CWSU products issued during the period indicated that CWA number 101 was issued at 1404 CDT (1904Z), immediately prior to the accident for an area of heavy to extreme precipitation in rain showers and isolated embedded thunderstorms over Alabama, which extended over the accident site, with maximum tops to 43,000 ft. The storms were moving to the NNE at 35 knots with little expected change in coverage or intensity through the period. The forecast was only good for 1 hour. When the CWSU MIC was asked about the short validity period, it was disclosed that coordination with the AWC with an expected Convective SIGMET would have forced the requirement for a cancellation message and required all sectors to read that message, so they issue short validity periods to reduce controller workload and unnecessary broadcasts. A Convective SIGMET was issued at 1955Z, which extended the warning over Alabama during the period after the accident.

The ATC group and Weather Specialist reviewed the CoSPA archive weather displays surrounding the period. The CoSPA provided levels 1-6 intensity, with echo tops, movement, growth and decay information and lightning data and was used by the meteorologist as one of their primary radar system being displayed. The unit also had access to the Earth Networks lightning data for total lightning to help identify active convective locations. The supervisor positions have the capability to display the CoSPA radar images for a more complete review of the weather conditions, while the individual air traffic controllers have access to a Weather And Radar Processor (WARP) weather displays, which are documented in the ATC Specialist Factual Report. The WARP system displays over 30 dBZ echoes and while displayed for controllers use, the meteorology group used CoSPA and TDWR for more real-time use. A recent problem was also discovered in the upgrade to WARP with the Selector Mosaic Generator (SMG), which allows for higher resolution images to 1 kilometer, and more frequent scanning updates over the former Base Mosaic Generator (BMG) which relied on the 6-minute composite reflectivity imagery and had a slight latency issue. The new WARP SMG was reported to show more ground clutter, radar spikes, and other false echoes, that impact their confidence in controller providing accurate weather information, so a local decision was made to turn off the SMG on March 30th until the manufacturer, Harris Corporation, makes some corrections or modification to the program. At the time of the accident on March 25th, the new higher resolution and updated rate SMG was being used by the controllers on their WARP displays. A replay of the WARP and flight track also indicated the higher resolution and update was being used and no false echoes were identified during that period.

Other tools used by the CWSU were reviewed during their normal shift from weather cameras, Terminal Doppler Weather Radar (TDWR) displays and their Vertical Azimuth Display (VAD) Wind Profilers (VWP), GR2 Radar analysis program which can provide a 3-d radar cross sections, other WARP generated weather products, lightning data, 1-minute ASOS displays and other satellite displays.

19.0 Numerical Model of Convectively Induced Turbulence

Research from the National Center for Atmospheric Research (NCAR) has shown that the leading edge of convective clouds is often where some of the most intense updrafts and turbulent mixing takes place in a developing thunderstorm. Figure 60 is a still image of a vertical slice

through an idealized numerical model of an area of cumulonimbus type clouds and the turbulent kinetic energy (TKE) generated, with the turbulence indicated in blue shades of values of $>7 \text{ m}^2/\text{s}^2$. This model image shows turbulence below the cloud base, and in areas within the cumulus clouds towers along the leading edge through the upper boundaries or echo tops where convectively induced turbulence (CIT) can be encountered. The model shows the turbulence is possible prior to reaching the precipitation echo and in light echoes near the leading edge. The Clark-Hall cloud model was developed by the National Center for Atmospheric Research (NCAR) and depicts a convective storm near Fort Collins and Greeley, Colorado on June 24, 1992.

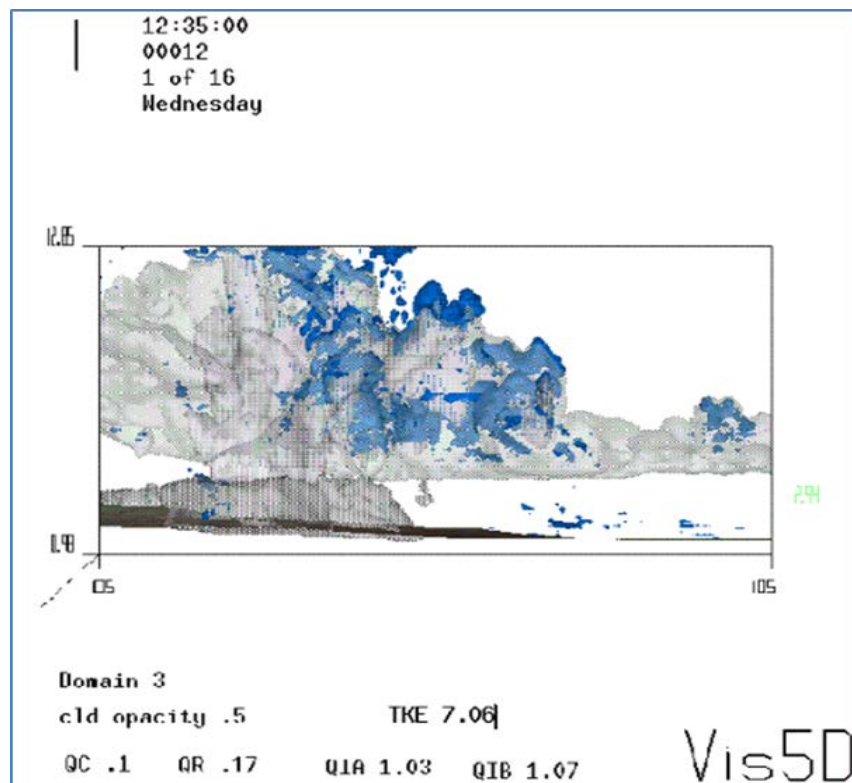


Figure 60 - NCAR Clark-Hall numerical model of turbulence in developing cumulus clouds

20.0 Turbulence Reference

The following turbulence categories based on the FAA turbulence reporting criteria and the International Civil Aviation Organization (ICAO) quantitative reporting values, based on Lester²⁵:

Turbulence Category	Aircraft Response	Aircraft Vertical Acceleration Magnitude (g)	Passenger Experience	Eddy Dissipation Rate (EDR)
Light	Momentarily causes slight, erratic changes in altitude and/or attitude (pitch, roll, yaw)	0.2 – 0.5	A slight strain against seat belts; unsecured objects may be displaced slightly; food service may be conducted with little difficulty walking	0.1 – 0.3
Moderate	Similar to light turbulence but greater intensity; changes in altitude, attitude, and/or airspeed occur; the aircraft remains in control at all times	0.5 0 - 1.0	Definite strain against seat belts; unsecured objects are dislodged; food service and walking are difficult	0.3 – 0.5
Severe	Large, abrupt changes in altitude, attitude, and/or airspeed; aircraft may be momentarily out of control	1.0 – 2.0	Occupants are forced violently against seat belts; unsecured objects are tossed about; food service and walking are impossible	0.5 – 0.7
Extreme	The aircraft is violently tossed about is practically impossible to control; it may cause structural damage	> 2.0	Truly frightening	> 0.7

Advisory Circular AC 00-24C “Thunderstorms” lists several hazards associated with thunderstorms and warns pilots that penetration of any thunderstorm can lead to an aircraft accident and fatalities to those on board. Concerning turbulence, the AC states the following:

- (1) Potentially hazardous turbulence is present in all thunderstorms, and severe thunderstorms can destroy an aircraft. The strongest turbulence within the cloud occurs between the updrafts and the downdrafts.*
- (2) It is almost impossible to hold a constant altitude in a thunderstorm, and maneuvering is an attempt to do so greatly increases stress on the aircraft. Stresses are least if the aircraft is held in a constant attitude.*
- (3) At lower altitudes, the gust front is also a well-known location for turbulence. Often a roll cloud or shelf cloud on the leading edge of the storm marks the top of the extreme turbulence zone. Gust fronts often move far ahead (up to 15 miles) of associated precipitation. The gust front causes a rapid and sometimes drastic changes in surface wind ahead of an approaching storm.*

Regarding icing the AC indicates the following:

- (1) Updrafts in a thunderstorm also support abundant liquid water with relatively large droplet sizes and when carried above the freezing level, the water droplets may become supercooled. As the upward current of air cools to a temperature of about -15° C, the remaining water vapor sublimates as ice crystals. Above this level, at lower temperatures, the amount of supercooled water decreases.*

²⁵ Lester, P.F. 1994: Turbulence: A New Perspective for Pilots. Jeppesen Sanders, 280 pp.

- (2) *Supercooled water freezes on impact with an aircraft. Clear icing can occur at any altitude above the freezing level but at high levels, icing from smaller droplets may be rime or mixed rime and clear icing. The abundance of large, supercooled water droplets makes clear icing very rapid between 0°C and -15°C, and encounters can be frequent in a cluster of cells. Thunderstorm icing can be extremely hazardous.*

With regards to data-linked NEXRAD mosaic imagery the advisory circular advises that latency issues are involved and the data should not be used for route selection to avoid thunderstorms entirely, or as a sole means for negotiating a path through a thunderstorm area or tactical maneuvering. The AC recommends diverting and waiting out the thunderstorm on the ground if unable to navigate around an area or a line.

If a flight is unable to avoid penetrating a thunderstorm, the AC recommends the pilot to do the following before entering the storm:

- *Tightening seat belts and shoulder straps, and secure all loose objects.*
- *Plan and hold a course to take the aircraft through the storm in a minimum time.*
- *Penetration at altitude below the freezing level or above -15° C to avoid the most critical icing layers.*
- *Turn the pitot heat, carburetor heat or other anti-ice systems on.*
- *Establish power settings for turbulence penetration airspeed as recommended in the aircraft flight manual.*
- *Turn up cockpit lighting.*
- *Disengage autopilot altitude and speed hold functions.*
- *If using airborne weather radar, use tilt function to monitor developing activity.*

In addition, the circular recommends the following during the penetration:

- *Keep your eyes on the flight instruments.*
- *Don't change power settings, maintain the recommended turbulence penetration airspeed.*
- *Maintain constant attitude, allow the altitude and airspeed to fluctuate.*
- *Don't turn back once in the thunderstorms. A straight course through the storm most likely will get the aircraft out of the hazards most quickly. In addition, turning maneuvers increase stress on the aircraft.*

F. LIST OF ATTACHMENTS AND APPENDICES

Appendix 1 – Lightning data spread sheet

Attachment 1 – Flight track of N6563D

Attachment 2 – KBMX 0.5 degree base reflectivity animation showing outflow boundary

Attachment 3 – Radar images and transcript information

Attachment 4 – Pilot Preflight Weather Briefing

Attachment 5 – CWSU Briefing Sheets

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APPENDIX 1 - LIGHTNING

Table of Lightning Flashes between 1330 and 1500 CDT (1830Z-2000Z) over the region, with the flash type where CG – is for a cloud-to-ground strike and IC - is an in-cloud strike, time in UTC, latitude, longitude, peak current, and in-cloud flash height in msl, where 0 – is on the ground.

Flash Type	Time	Latitude	Longitude	Peak Current	IC height
CG	1830:12.0223501	34.27807	-87.16936	37272	0
IC	1833:07.4829811	34.18707	-87.19678	-2458	18111
IC	1830:50.0499085	34.31714	-87.17541	-1527	18275
CG	1855:56.4325685	33.76236	-86.99729	-4041	0
CG	1846:29.5068666	33.76347	-87.05897	-6220	0
IC	1835:21.6838695	34.26915	-87.12536	-12223	17819
IC	1851:42.5878038	33.74406	-87.00111	2375	12169
IC	1907:54.1670311	33.20527	-87.12514	-3660	17573
IC	1909:28.9585167	33.20951	-87.14646	-5393	19673
IC	1911:04.3597627	33.21355	-87.11226	-4405	19458
IC	1933:57.2209585	33.22156	-87.01991	-846	12143
IC	1937:27.6727306	33.19709	-87.01042	-7017	18436
IC	1938:54.0113293	33.17932	-86.97854	2666	7123
IC	1954:50.7559121	33.26217	-86.88939	-10405	11418
IC	1959:51.9591487	33.39896	-86.80603	-8700	15854
IC	1851:42.5878038	33.74406	-87.00111	2375	12169
IC	1915:23.3186905	33.1815	-87.18671	4730	8733
IC	1933:16.6489796	33.19744	-87.05114	11656	19204
IC	1946:10.0035637	33.23605	-86.92845	-3013	14467
IC	1947:05.7061146	33.2478	-86.92348	-1128	13759
CG	1957:10.7678853	33.26826	-86.88364	-37141	0
IC	1906:05.6837417	33.29545	-87.1401	10353	11105
IC	1955:33.7068134	33.28802	-86.93505	642	545
IC	1957:10.5585929	33.22089	-86.98423	1740	11828
CG	1918:46.7016290	33.26027	-87.07399	-4472	0
IC	1939:57.5081104	33.19196	-86.97722	-3867	12835
IC	1959:15.2718117	33.28813	-86.87781	3604	19599
IC	1908:45.0514846	33.21566	-87.12476	-4581	15732

IC	1912:05.9135897	33.2186	-87.11553	-8448	19430
IC	1915:23.2491565	33.25696	-87.11446	2329	18204
CG	1958:15.4802675	33.2759	-86.89308	-8486	0
IC	1910:32.5518271	33.22562	-87.11836	3953	16855
IC	1944:59.5588245	33.23297	-86.90593	-10562	20038
IC	1958:15.1300987	33.33762	-86.88004	-3892	15814
IC	1933:16.5477931	33.21864	-87.00883	-6392	14226