

National Transportation Safety Board

Office of Aviation Safety

Washington, DC 20594



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METEOROLOGY

Specialist's Factual Report

November 5, 2024

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A. ACCIDENT

Location: Franklin, Tennessee
Date: May 15, 2024
Time: 1202 central daylight time (CDT)
1702 coordinated universal time (UTC)
Airplane: Beech V35-TC, N47WT

B. METEOROLOGY SPECIALIST

Paul Suffern
Senior Meteorologist
National Transportation Safety Board
Washington, DC

C. DETAILS OF THE INVESTIGATION

The NTSB's Senior Meteorologist travelled for this investigation. On May 16, 2024, an air traffic control (ATC) work group was formed in support of this investigation, which included the NTSB Senior Meteorologist. On-site investigative work began on May 20, 2024, and concluded on May 25, 2024. In addition, data for this investigation were collected from official National Oceanic and Atmospheric Administration (NOAA) National Weather Service (NWS) sources including the Weather Prediction Center (WPC) and the National Center for Environmental Information (NCEI). This Specialist's Factual Report contains the meteorological factors pertinent to the weather surrounding the accident time. All times are central daylight time (CDT) and are based upon the 24-hour clock, where local time is -5 hours from UTC. Directions are referenced to true north and distances are in nautical miles. Heights are above mean sea level (msl) unless otherwise noted. Visibility is in statute miles and fractions of statute miles. NWS station identifiers use the standard International Civil Aviation Organization 4-letter station identifiers versus the International Air Transport Association 3-letter identifiers, which deletes the initial country code designator "K" for U.S. airports.

The accident site was located at approximate latitude 35.8391° N, longitude 87.0729° W, at an altitude of 980 feet (ft).

D. FACTUAL INFORMATION

1.0 Synoptic Situation

The synoptic or large-scale migratory weather systems influencing the area were documented using standard NWS charts issued by the National Center for Environmental Prediction and the WPC, located in College Park, Maryland. These are the base products used in describing synoptic weather features and in the creation of forecasts and warnings for the NWS. Reference to these charts can be found in the Federal Aviation Administration (FAA) "Aviation Weather Handbook", FAA-H-8083-28.¹

1.1 Surface Analysis Chart

The NWS Surface Analysis Chart centered over the Tennessee Valley of the United States for 1300 CDT is provided as figure 1 with the location of the accident site within the black circle. The chart depicted a low-pressure system at 1006-hectopascals (hPa) located in southern Ohio. Another low-pressure system at 1003-hPa was in western North Carolina. A dissipating cold frontal boundary stretched from the 1006-hPa low-pressure system southwestward across central Kentucky and through northwestern Tennessee north of the accident site. The accident site was located south of the frontal boundary on the "warm" side of the front.

The station model closest to the accident site depicted an air temperature of 73°F, dew point temperature 61°F, partly cloudy skies, and a west wind at 5 knots.

¹ [FAA-H-8083-28](#)

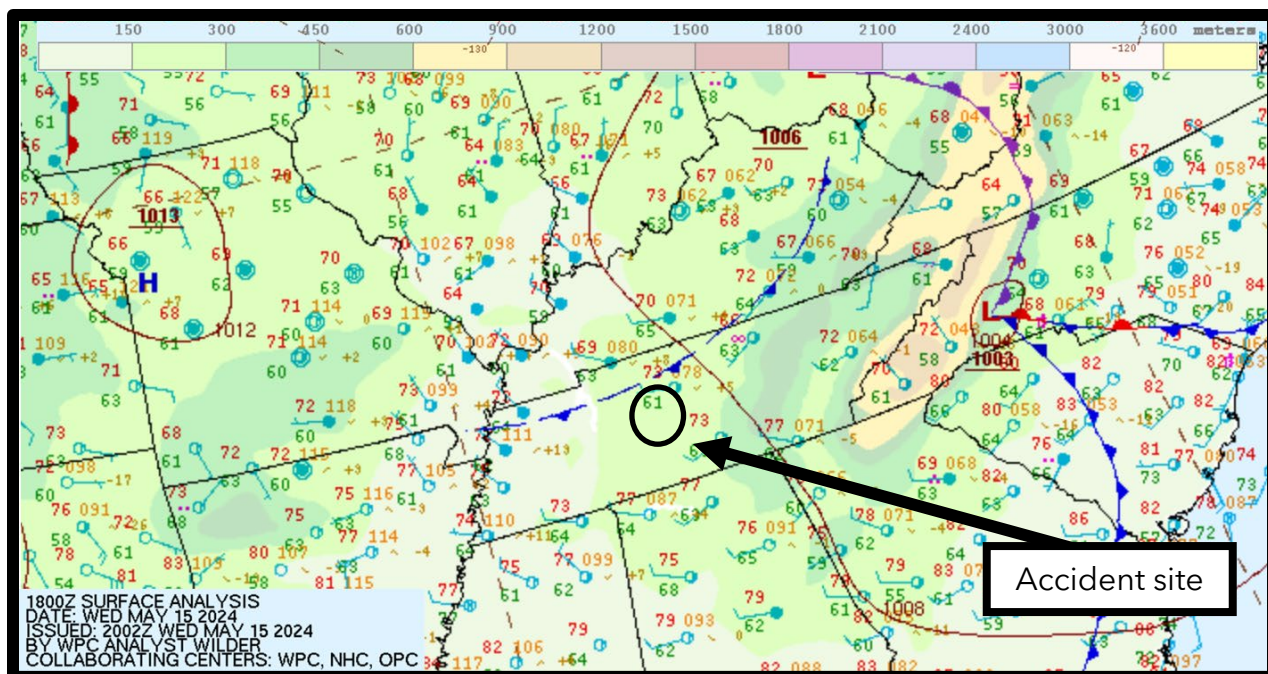
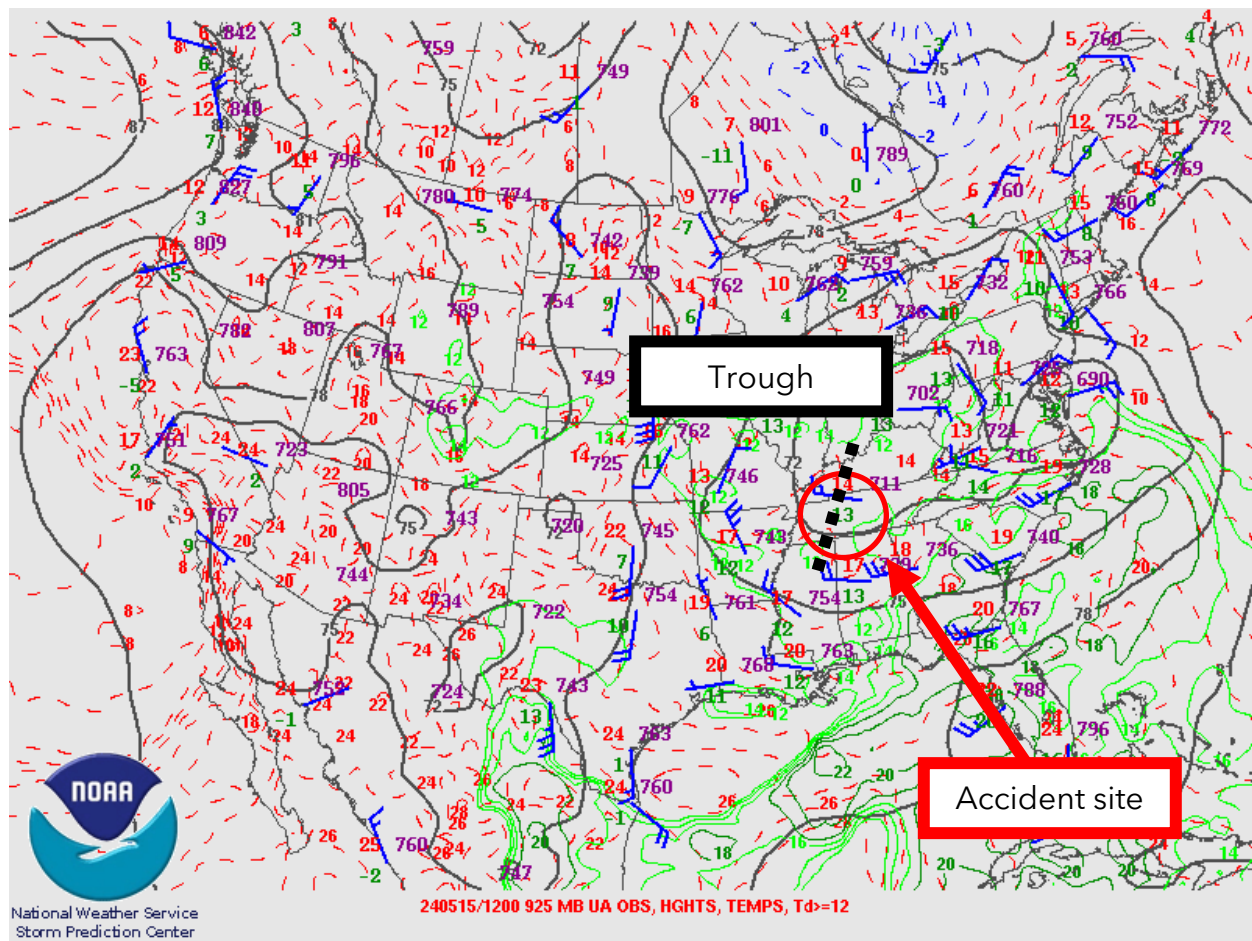


Figure 1. NWS Surface Analysis Chart for 1300 CDT.

1.2 Upper Air Charts

The NWS Storm Prediction Center (SPC) issued Constant Pressure Charts for 0700 CDT at 925-, 850-, and 700-hPa, which are presented in figures 2 through 4. The charts indicated a low- and mid-level trough² at 925- through 700-hPa above the accident site. Troughs and fronts can act as lifting mechanisms to help produce clouds and precipitation if sufficient moisture is present. The 925-hPa constant pressure chart depicted a northwest wind around 15 knots (figure 2) becoming a southwest 15-knot wind by 700-hPa (figure 4).

² Trough - An elongated area of relatively low atmospheric pressure or heights, and is associated with a wind shift and rising motion.



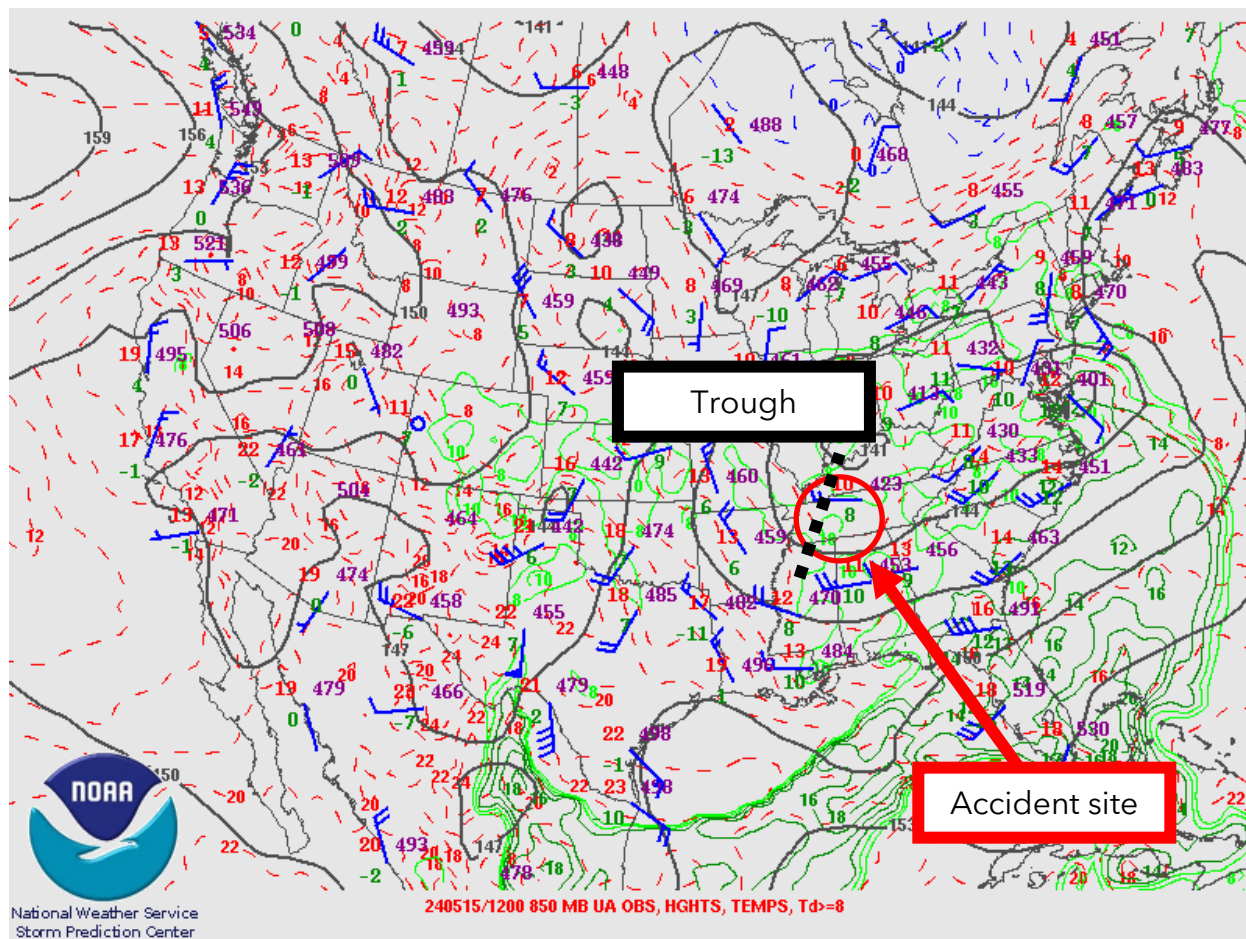


Figure 3. 850-hPa Constant Pressure Chart for 0700 CDT.

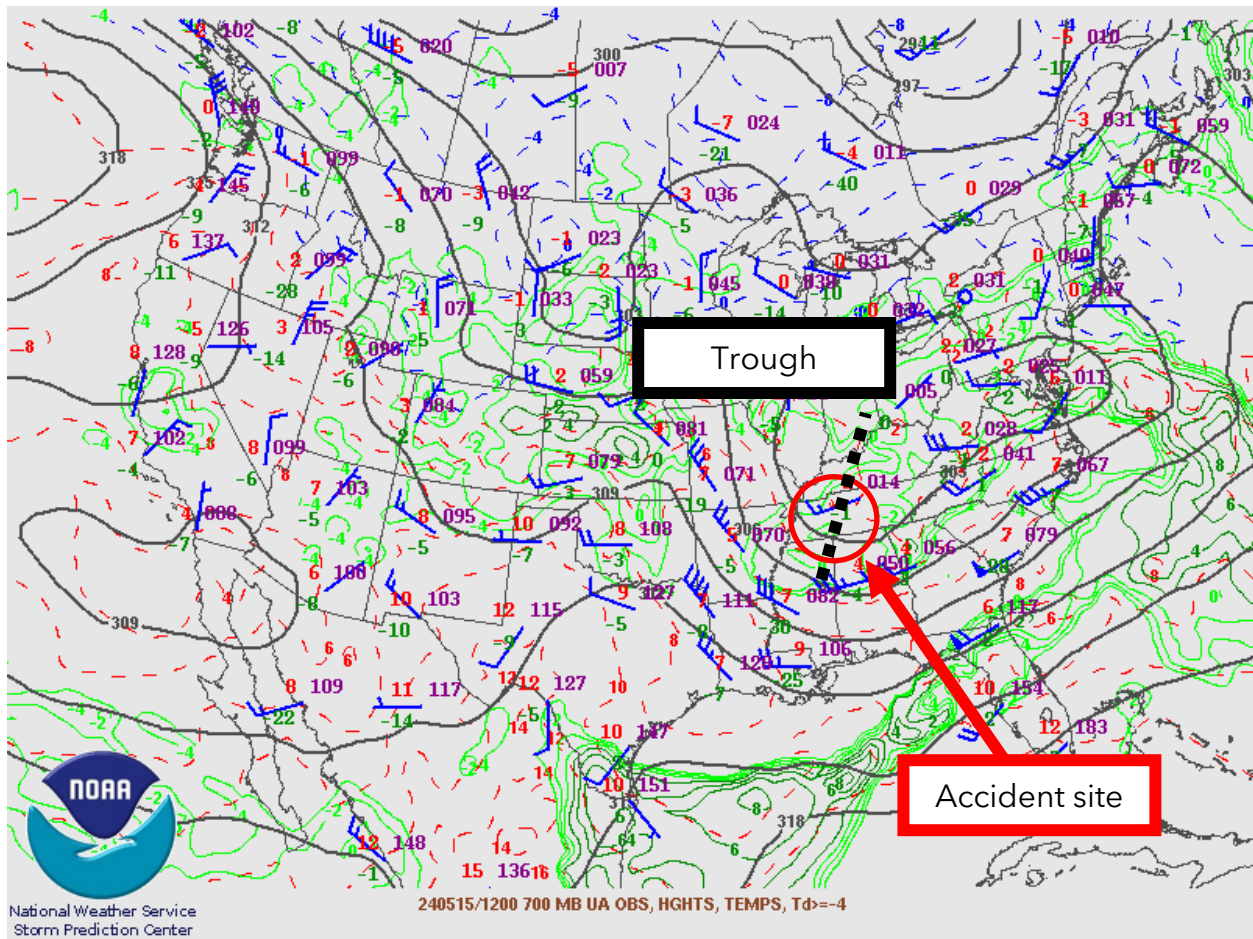


Figure 4. 700-hPa Constant Pressure Chart for 0700 CDT.

2.0 Storm Prediction Center Convective Outlook

The SPC issued a Day 1 Convective Outlook at 1130 CDT (figure 5) with the accident site located in an area where a chance of thunderstorms was predicted. The SPC defines the “TSTM” area as an area where a 10% or higher probability of thunderstorms is forecast during the valid period. Similar SPC forecasts for the accident site were issued in the 0800 and 0700 CDT Day 1 Convective Outlooks.

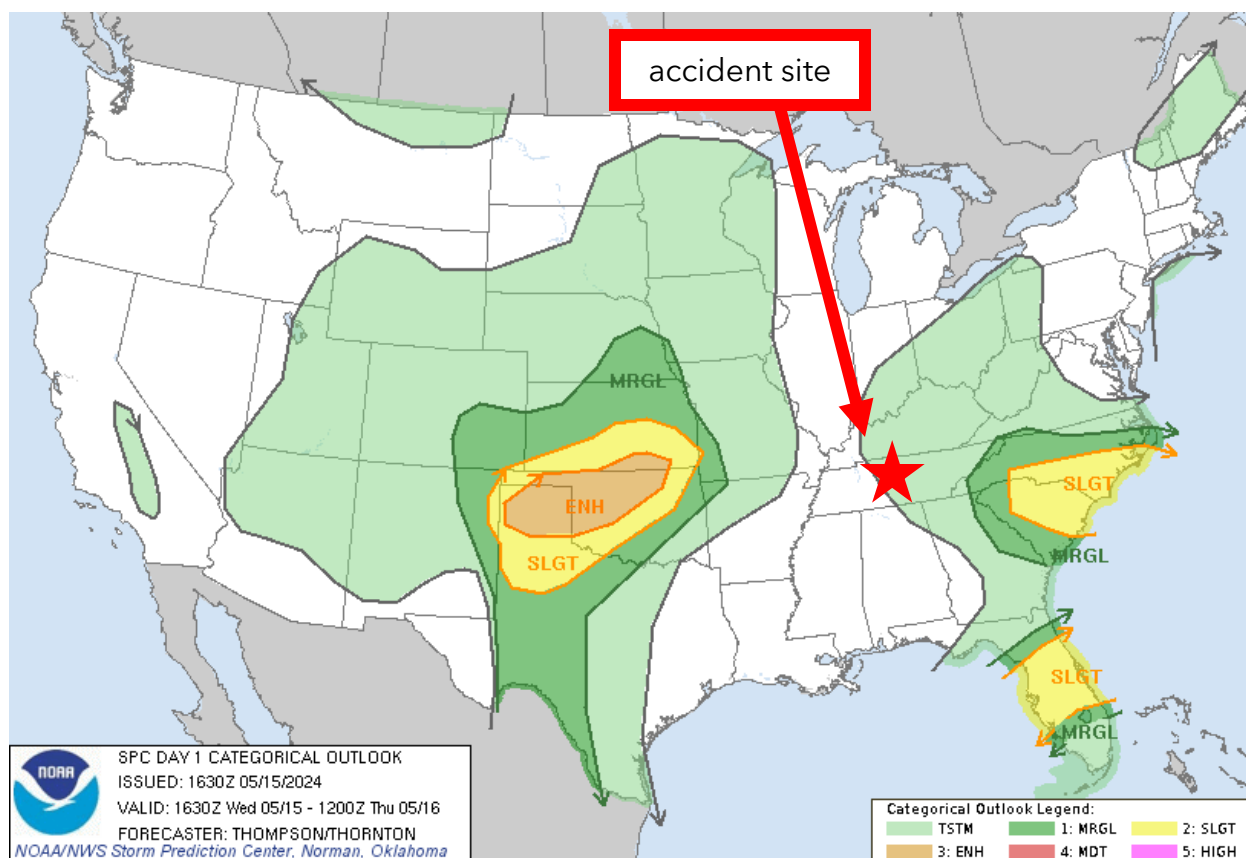


Figure 5. SPC day 1 Convective Outlook valid at the time of the accident.

3.0 Surface Observations

The area surrounding the accident site was documented using official Aviation Routine Weather Reports (METARs) and Aviation Selected Special Reports (SPECIs)³. The following observations were taken from standard code and are provided in plain language. A magnetic variation⁴ of 3.5° west was indicated over the area.

³ Latest criteria for SPECIs can be found in the Federal Meteorological Handbook: [Federal Meteorological Handbook Number 1, Surface Weather Observations and Reports \(icams-portal.gov\)](https://www.federalmetbook.com/)

⁴ Magnetic variation - The angle (at a particular location) between magnetic north and true north. Latest measurement taken from <https://skyvector.com/>

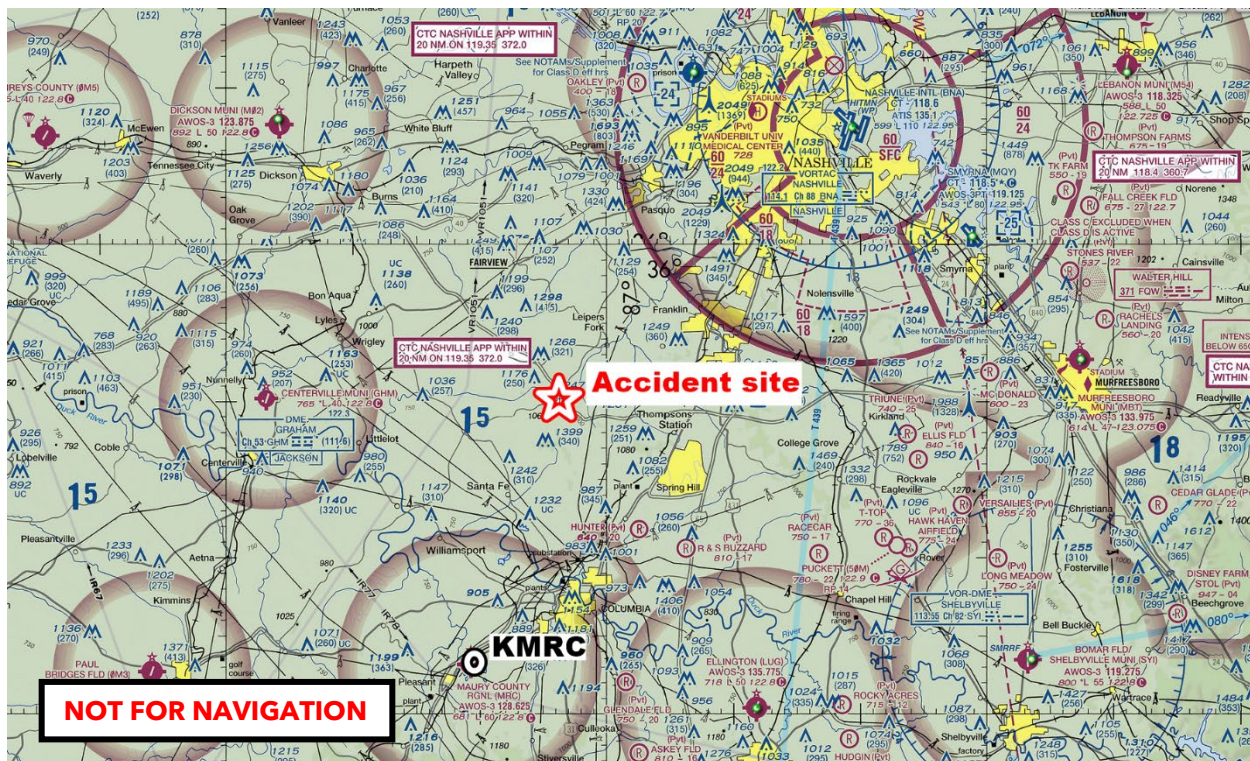


Figure 6. FAA sectional aeronautical chart of the accident area with the locations of the accident site and surface observation site noted.

Maury County Regional Airport (KMRC) had the closest official weather station to the accident site. KMRC had an Automated Weather Observing System (AWOS⁵) and its longline⁶ reports were not augmented. The KMRC AWOS was located 18 miles south-southwest of the accident site, at an elevation of 681 ft, and issued the following observations surrounding the accident time:⁷

[1030 CDT] METAR KMRC 151530Z AUTO VRB05KT 10SM FEW022
SCT033 OVC041 22/19 A2976 RMK A01

⁵ AWOS - Automated Weather Observing System is equipped with meteorological instruments to typically observe and report temperature, dewpoint, wind speed and direction, visibility, cloud coverage and ceiling up to 12,000 feet, and altimeter setting. AWOS are maintained by the FAA. Certain AWOS may have different reporting or observational equipment.

⁶ "Longline" refers to the dissemination of weather observations with the intent that they are available in near-real time to national databases and accessible to the general global public from a large number of vendors. This does not include public accessibility to observations from a reporting station's Very High Frequency (VHF; line-of-site) or telephone broadcast, where applicable. Longline dissemination of weather observations is the primary vehicle through which the weather observations are distributed.

⁷ The bold sections of products in this report are intended to highlight the text that directly reference the weather conditions that affected the accident region around the accident time. The local times in this section next to the METARs are provided for quick reference.

[1055 CDT] METAR KMRC 151555Z AUTO VRB05G10KT 10SM SCT022
BKN044 OVC050 22/18 A2976 RMK A01

[1110 CDT] METAR KMRC 151610Z AUTO 33004G12KT 10SM SCT023
BKN033 BKN043 22/18 A2976 RMK A01

[1130 CDT] METAR KMRC 151630Z AUTO 25005KT 10SM BKN024
BKN037 BKN043 22/18 A2976 RMK A01

**[1155 CDT] METAR KMRC 151655Z AUTO VRB04KT 10SM FEW026
SCT035 BKN050 22/17 A2976 RMK A01**

ACCIDENT TIME 1202 CDT

**[1210 CDT] METAR KMRC 151710Z AUTO VRB04G10KT 10SM
SCT025 SCT030 BKN035 22/17 A2977 RMK A01**

[1230 CDT] METAR KMRC 151730Z AUTO VRB04G11KT 10SM FEW025
SCT036 BKN060 23/18 A2977 RMK A01

The bold type observations decoded in plain language were as follows:

KMRC weather at 1155 CDT, automated, wind variable at 4 knots, visibility 10 statute miles or greater, few clouds at 2,600 ft above ground level (agl), scattered clouds at 3,500 ft agl, broken ceiling at 5,000 ft agl, temperature of 22°C, dew point temperature of 17°C, and an altimeter setting of 29.76 inches of mercury (inHg). Remarks, automated station without a precipitation discriminator.

KMRC weather at 1210 CDT, automated, wind variable at 4 knots with gusts to 10 knots, visibility 10 statute miles or greater, scattered clouds at 2,500 ft agl, scattered clouds at 3,000 ft agl, broken ceiling at 3,500 ft agl, temperature of 22°C, dew point temperature of 17°C, and an altimeter setting of 29.77 inHg. Remarks, automated station without a precipitation discriminator.

The observations from the KMRC AWOS around the accident time identified VFR⁸ conditions.

⁸ 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 below 500 ft above ground level (agl) and/or visibility less than 1 statute mile.
- Instrument Flight Rules (IFR) - ceiling between 500 to below 1,000 feet agl and/or visibility 1 to less than 3 miles.
- Marginal Visual Flight Rules (MVFR**) - ceiling from 1,000 to 3,000 ft agl and/or visibility 3 to 5 miles.
- Visual Flight Rules (VFR) - ceiling greater 3,000 ft agl and visibility greater than 5 miles.

4.0 Upper Air Sounding

A High-Resolution Rapid Refresh (HRRR)⁹ model sounding was created¹⁰ for the approximate accident site coordinates for 1200 CDT. The HRRR sounding was plotted on a standard Skew-T Log P diagram¹¹ from the surface to 500-hPa (or approximately 18,500 ft) using the RAOB¹² software package and is included as figure 7. The sounding depicted an elevation of 922 ft over the grid point. The sounding depicted the lifted condensation level (LCL)¹³ and the level of free convection (LFC)¹⁴ at 2,305 ft, and the convective condensation level (CCL)¹⁵ at 3,097 ft. The freezing level was located at 12,040 ft. The precipitable water value was 1.25 inches.

* 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.

⁹ The HRRR is a NOAA real-time three-kilometer resolution, hourly-updated, cloud-resolving, convection-allowing atmospheric model, initialized by three-kilometer grids with three-kilometer radar assimilation. Radar data is assimilated in the HRRR every 15 minutes over a one-hour period.

¹⁰ HRRR sounding was created using NOAA Air Resource Laboratory: [READY Archived Meteorology \(noaa.gov\)](https://ready.noaa.gov/).

¹¹ Skew T log P diagram - is a standard meteorological plot 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 - (The complete Rawinsonde Observation program) is an interactive sounding analysis program developed by Esonde Research Services, The Villages, Florida.

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

¹⁴ 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 CCL - The level in the atmosphere to which an air parcel, if heated from below, will rise dry adiabatically, without becoming colder than its environment just before the parcel becomes saturated.

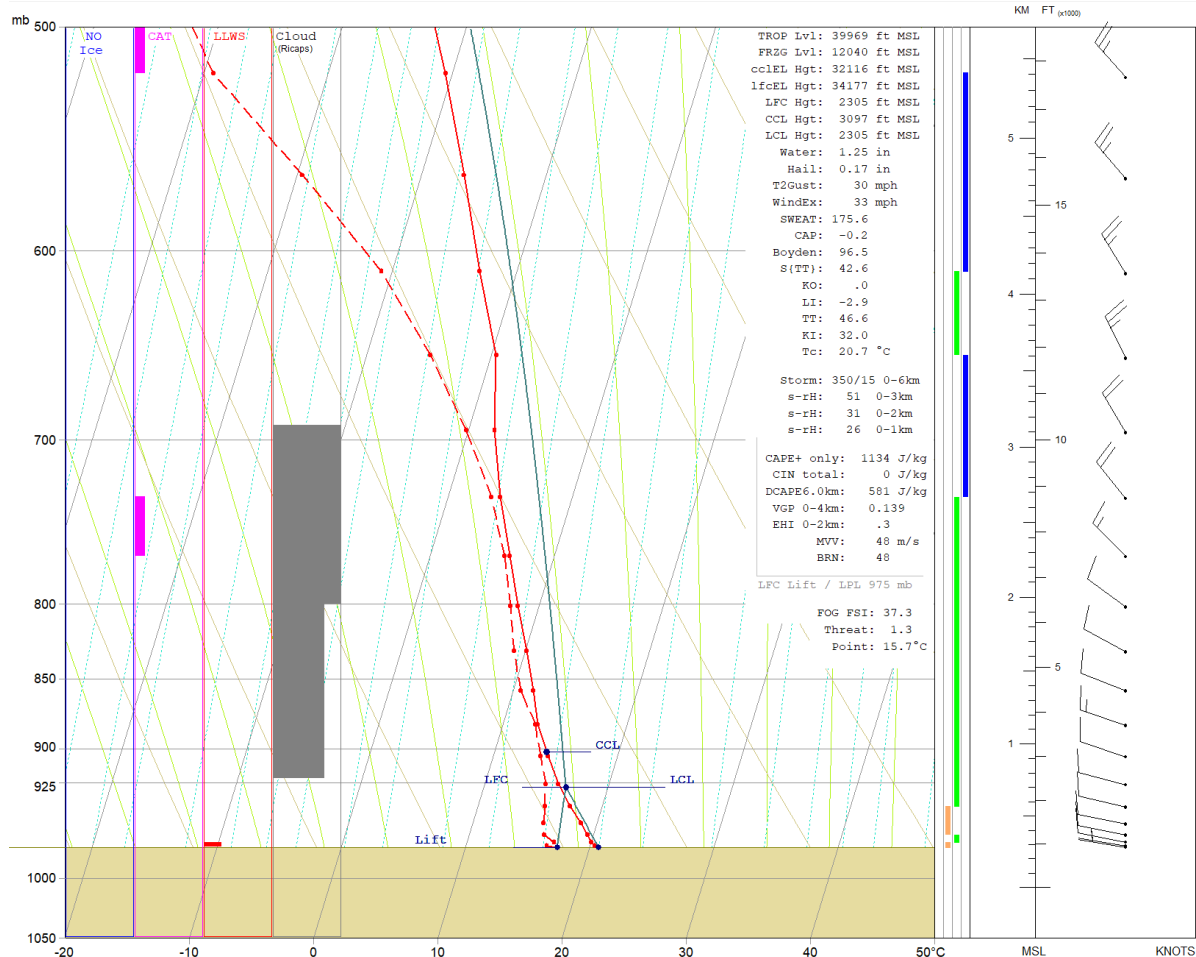


Figure 7. 1200 CDT HRRR sounding.

The 1200 CDT HRRR sounding indicated a conditionally unstable atmosphere from the surface through 9,000 ft, then a stable atmosphere from 9,000 ft through 12,000 ft. There was a Convective Available Potential Energy (CAPE)¹⁶ of 1,134 Joules/kilogram (J/kg), and the maximum vertical velocity (MVV) for this atmosphere was calculated as 48 meters/second (about 9,450 ft per minute).¹⁷ RAOB indicated cloud cover between 2,500 ft and 10,500 ft. No icing was indicated below 15,000 ft.

¹⁶ Convective Available Potential Energy (CAPE) - CAPE is a measure of the amount of energy available for convection and is directly related to the maximum potential vertical speed within an updraft.

¹⁷ MVV is not usually considered a realistic estimate for maximum vertical velocity in a storm. Anecdotes suggest considering a value of MVV/2, however it is not well understood when or where such a half-value should be applied.

The 1200 CDT HRRR sounding wind profile indicated a near-surface wind from 280° at 5 knots with the wind becoming northwesterly by 10,000 ft. The wind speed increased to 20 knots by 10,000 ft. The northwest wind increased from 25 knots by 12,000 ft. RAOB indicated very light clear air turbulence in two layers above 8,000 ft. At the accident aircraft's altitude around the time of the accident¹⁸ (~9,000 ft) the temperature was 4.2°C, the dew point temperature was 3.5°C, and the wind was from 323° at 18 knots.

5.0 Satellite Data

Geostationary Operational Environmental Satellite number 16 (GOES-16) visible and infrared data were obtained from an archive at the Space Science Engineering Center at the University of Wisconsin-Madison in Madison, Wisconsin, and processed using the Man-computer Interactive Data Access System software. Visible and infrared imagery (GOES-16 bands 2 and 13, respectively) at wavelengths of 0.64 microns (μm) and 10.3 μm, respectively, were retrieved for the period from 0900 CDT through 1500 CDT and reviewed, and the closest images to the time of the accident were documented.

Figure 8 presents the GOES-16 visible image at 1201 CDT at 3X magnification with the accident site highlighted with a red square. There was cloud cover indicated above the accident site with the cloud cover moving from northwest to southeast (attachment 1). Figure 9 presents the GOES-16 infrared image at 1201 CDT at 8X magnification with the accident site highlighted with a red square. Cloud cover was indicated above the accident site with lower brightness temperatures (yellow and green colors; higher cloud tops) located north and east of the accident site. The brightness temperature of 278 Kelvin¹⁹ would have been near 8,000 ft based on the vertical temperature profile provided by the 1200 CDT HRRR sounding. It should be noted these figures have not been corrected for any parallax error.

¹⁸ See ATC and track data located in the docket of this investigation.

¹⁹ around 5°C

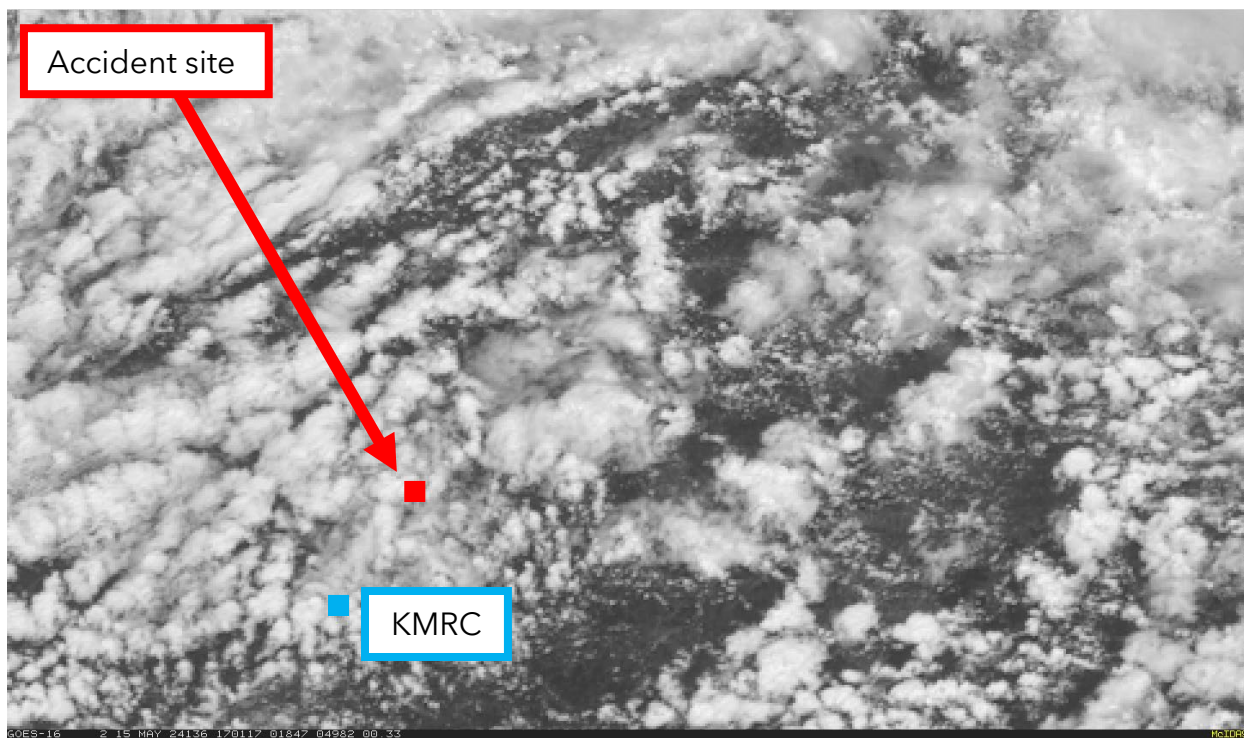


Figure 8. GOES-16 visible image at 1201 CDT.

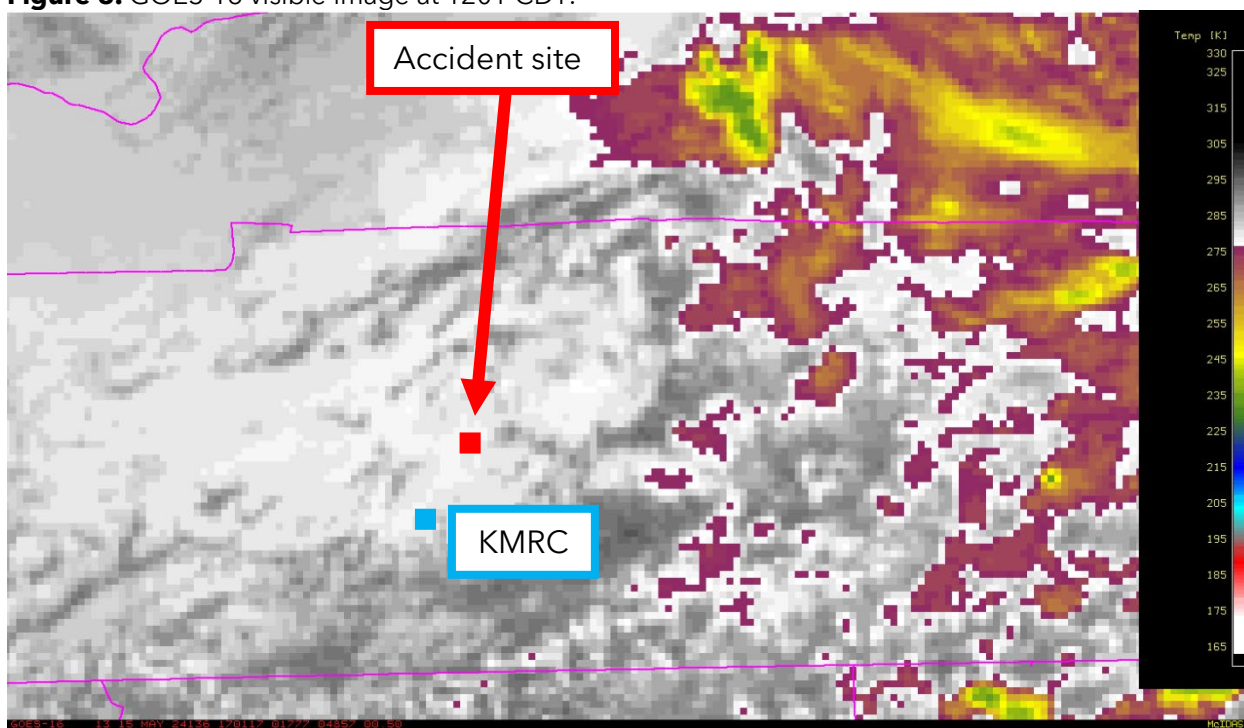


Figure 9. GOES-16 infrared image at 1201 CDT.

6.0 National Radar Imagery

A regional view of the NWS National Reflectivity Mosaic is included as figure 10 for 1205 CDT with the approximate location of the accident site marked by a white and black circle. The mosaic imagery depicted echoes of 20 to 45 dBZ²⁰ above the accident site.

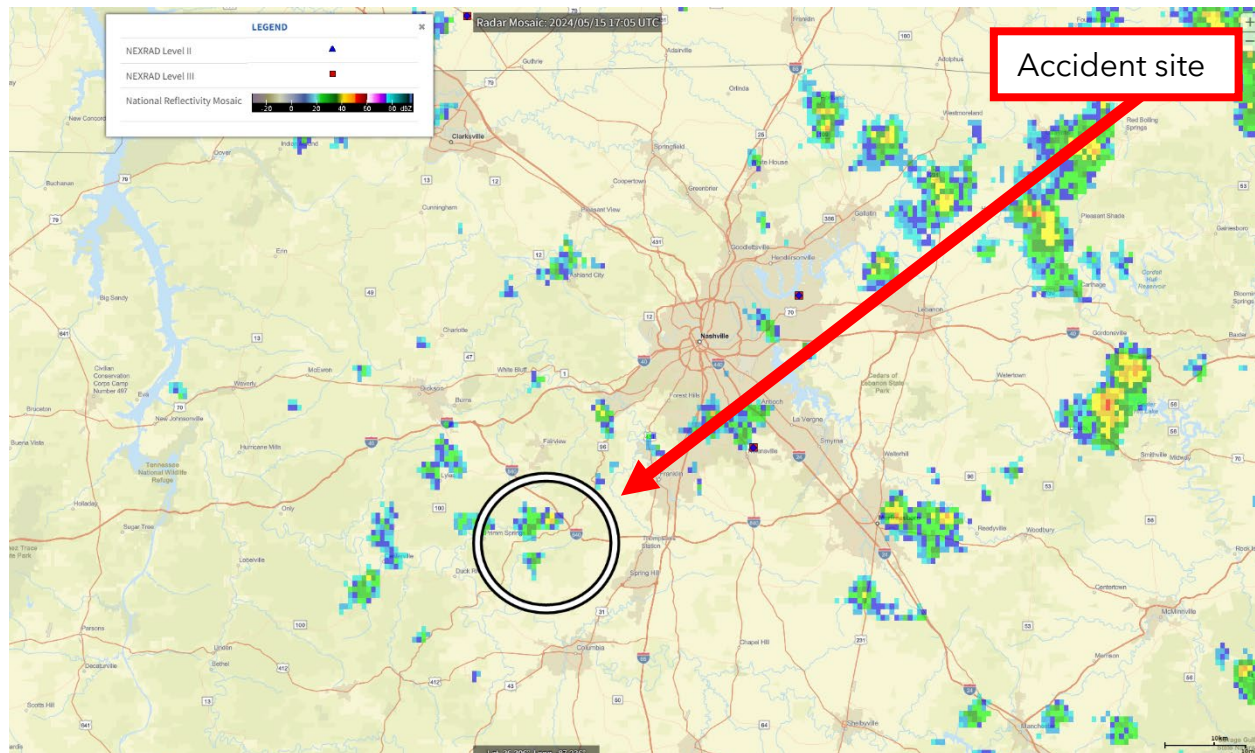


Figure 10. National Reflectivity Mosaic for 1205 CDT.

7.0 Weather Surveillance Radar Imagery

The closest NWS Weather Surveillance Radar-1988 Doppler (WSR-88D)²¹ to the accident site was from Nashville (KOHX), Tennessee, located 35 miles northeast of the accident site. The Level II archive radar data were obtained from the NCEI utilizing the NEXRAD Data Inventory Search and displayed using the NOAA's Weather and Climate Toolkit software.

²⁰ dBZ - A non-dimensional "unit" of radar reflectivity which represents a logarithmic power ratio (in decibels or dB) with respect to radar reflectivity factor, Z.

²¹ The WSR-88D is an S-band 10-centimeter wavelength radar with a power output of 750,000 watts, and with a 28-foot parabolic antenna that concentrates the energy between a 0.87° and 0.96° beam width. The radar produces three basic types of products: base reflectivity, base radial velocity, and base spectral width.

7.1 Volume Scan Strategy

During the period surrounding the accident, the KOHX WSR-88D radar was operating in the precipitation mode VCP-215²² (figure 11). The following figure 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.

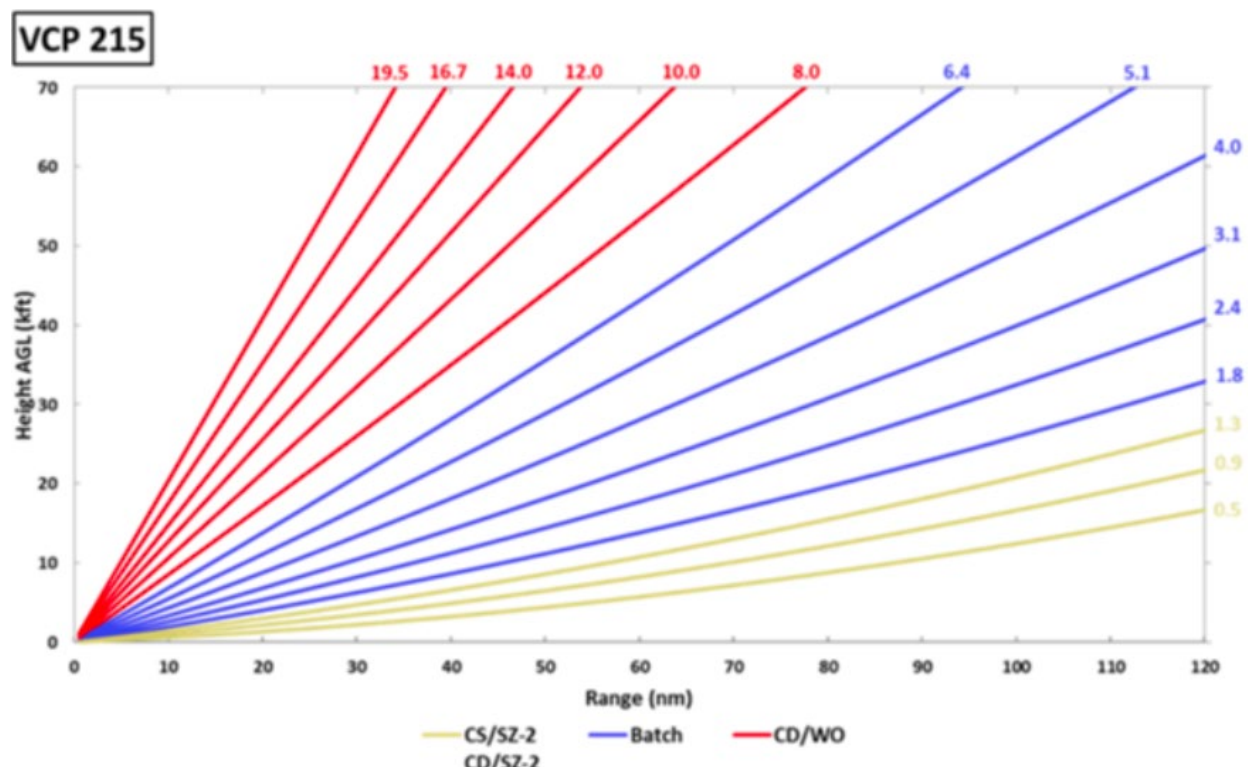


Figure 11. VCP-215 precipitation Mode Scan Strategy.

²² Contiguous Surveillance (CS)--The low Pulse Repetition Frequency (PRF) scan of the split cut. Gives a high R_{max} value to determine proper target location and intensity, but a low V_{max} value limits the velocities that can be measured.

Contiguous Doppler (CD)--The high PRF scan of the split cut. Gives a low R_{max} value causing more range folded (multiple trip) echoes, but a high V_{max} value to get higher, more accurate velocity values. Batch Mode - Uses alternating low and high PRFs on each radial for one full rotation at each elevation angle. The two resulting data sets (low PRF and high PRF) are combined to resolve range ambiguity.

Used in the middle elevation angles.

W - With range unfolding (W)

WO - Without range unfolding (WO)

7.2 Beam Height Calculation

Assuming standard refraction²³ of the KOHX WSR-88D radar beam with the antenna elevation at 676 ft, and considering a beamwidth²⁴ of 0.95°, the following table shows the approximate heights for the 0.5°, 1.3°, and 1.8° radar beams' centers, tops and bases over the accident site. These heights have been rounded to the nearest 10 ft.

ANTENNA ELEVATION	BEAM CENTER	BEAM BASE	BEAM TOP
KOHX 0.5°	3,340 ft	1,580 ft	5,100 ft
KOHX 1.3°	6,310 ft	4,550 ft	8,080 ft
KOHX 1.8°	8,170 ft	6,400 ft	9,930 ft

Based on the radar height calculations, the elevation scans reviewed from KOHX listed in the above table combined to depict conditions between 1,580 ft and 9,930 ft over the accident site.

7.3 Reflectivity

Reflectivity is the measure of the efficiency of a target in intercepting and returning radio energy. With hydrometeors²⁵ 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 dBZ and is a general measure of echo intensity. The FAA Aviation Weather Handbook also defines the echo intensity levels and weather radar echo intensity terminology associated with those levels. For dBZ values less than 30 the weather radar echo intensity terminology should be "light." For dBZ values between 30 and 40, the terminology should be "moderate." "Heavy" terminology is used for dBZ values greater than 40 dBZ to 50 dBZ, inclusive. Finally, any dBZ values above 50 dBZ shall be described as "extreme."

²³ Standard Refraction in the atmosphere is when the temperature and humidity distributions are approximately average, and values set at the standard atmosphere.

²⁴ Beamwidth - the angular separation between the half power points on the antenna radiation pattern, where the gain is one half the maximum value.

²⁵ Hydrometeors are any product of condensation or sublimation of atmospheric water vapor, whether formed in the free atmosphere or at the earth's surface; also, any water particles blown by the wind from 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 glazed ice.

7.4 Base Reflectivity Data and Lightning Data

Figures 12-19 present the KOHX WSR-88D base reflectivity images for the 0.5°, 1.3°, and 1.8° elevation scans initiated at times between 1148:58 and 1203:00 CDT with resolutions of 0.5° X 250 m. These images depicted portions of reflectivity values between 20 and 43 dBZ along the accident flight track in the last 4 minutes of flight.

There were no lightning flashes²⁶ reported within 25 miles of the accident site within 10 minutes prior to and following the accident time.²⁷

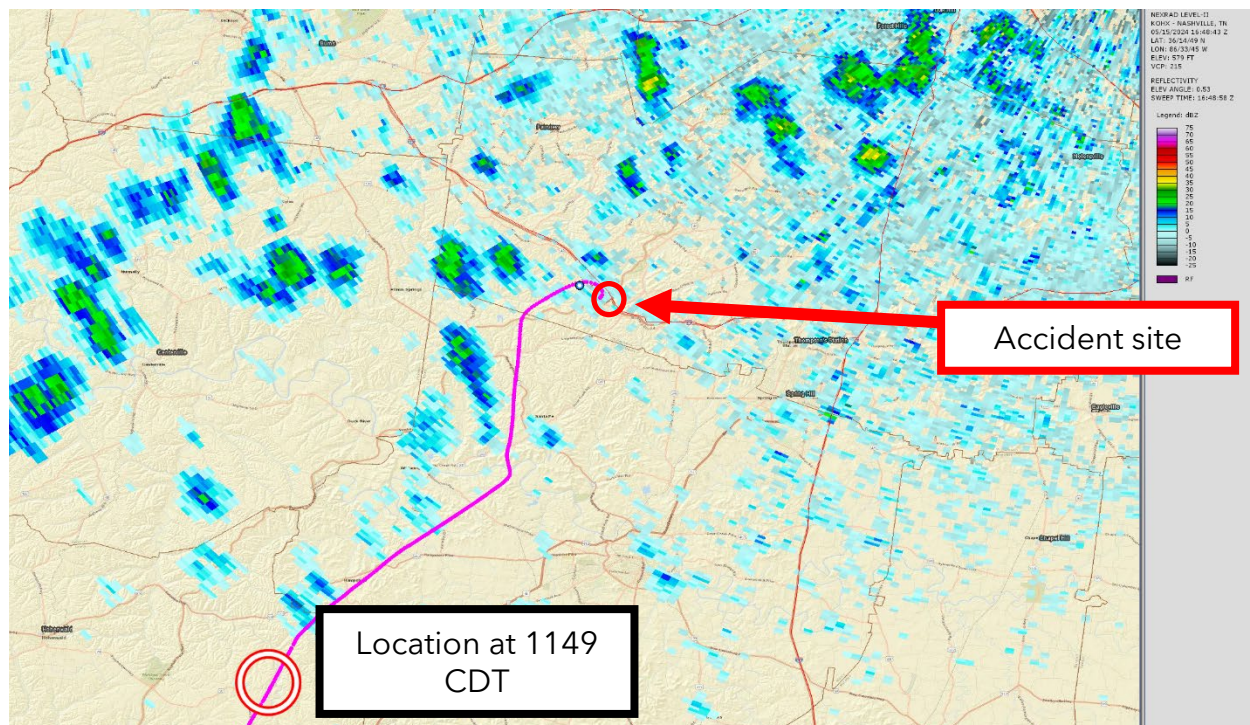


Figure 12. KOHX WSR-88D reflectivity for the 0.53° elevation scan initiated at 1148:58 CDT with the accident site marked with the red circle and the location of the accident aircraft in the red/white circle. The pink dots are the airplane flight track points.

²⁶ Lightning Flash – This is one contiguous conducting channel and all the current strokes/pulses that flow through it. There are two types of flashes: ground flashes and cloud flashes.

²⁷ A review of Earth Networks Total Lightning network and GOES-16 Geostationary Lightning Mapper (GLM) was done.

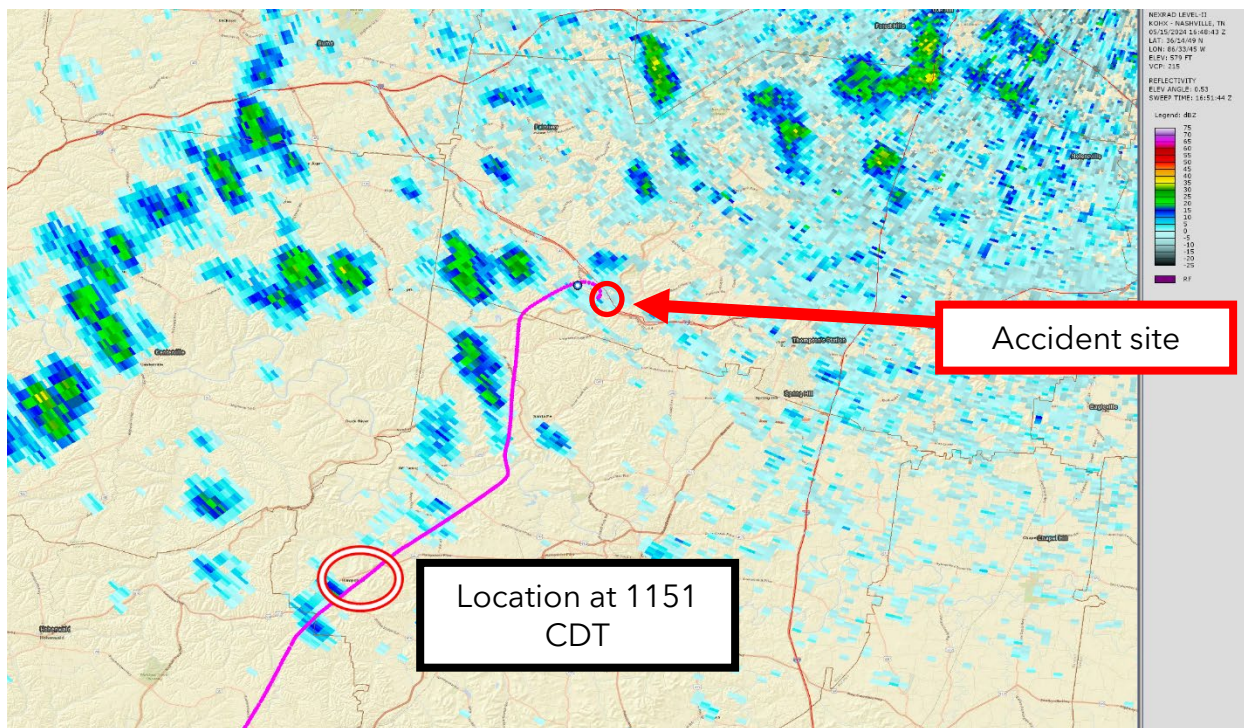


Figure 13. KOHX WSR-88D reflectivity for the 0.53° elevation scan initiated at 1151:44 CDT with the accident site marked with the red circle and the location of the accident aircraft in the red/white circle. The pink dots are the airplane flight track points.

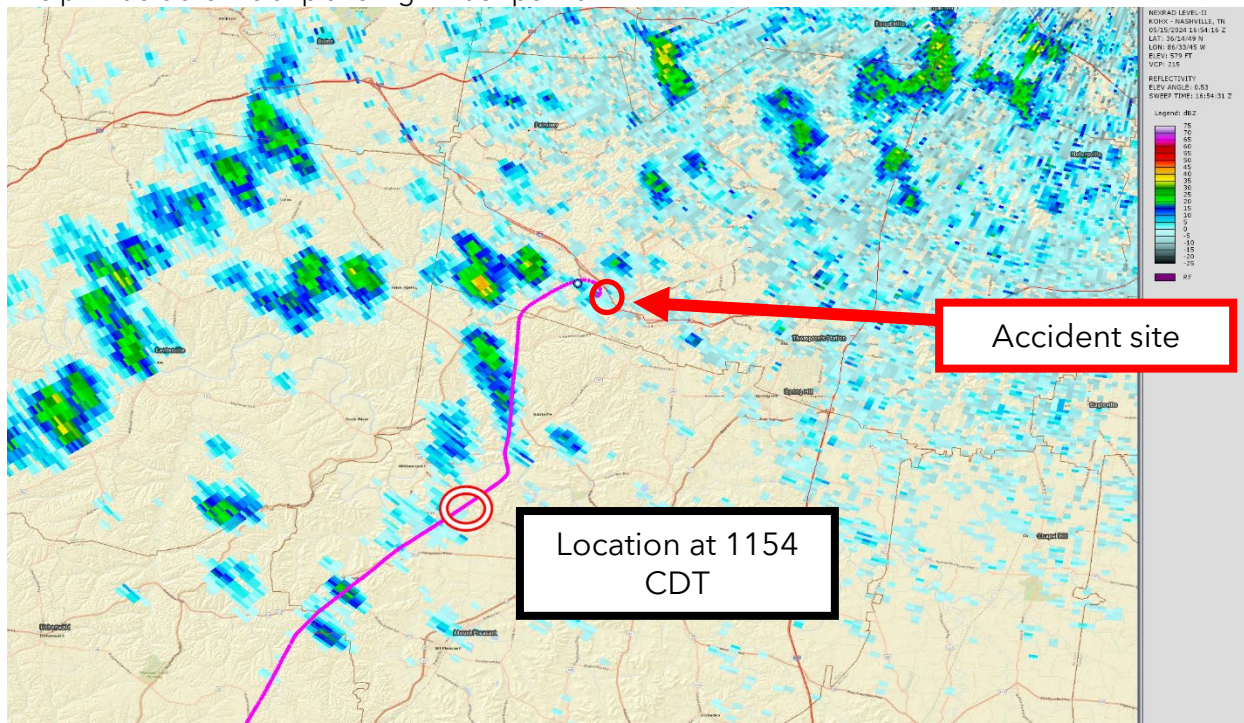


Figure 14. KOHX WSR-88D reflectivity for the 0.53° elevation scan initiated at 1154:31 CDT with the accident site marked with the red circle and the location of the accident aircraft in the red/white circle. The pink dots are the airplane flight track points.

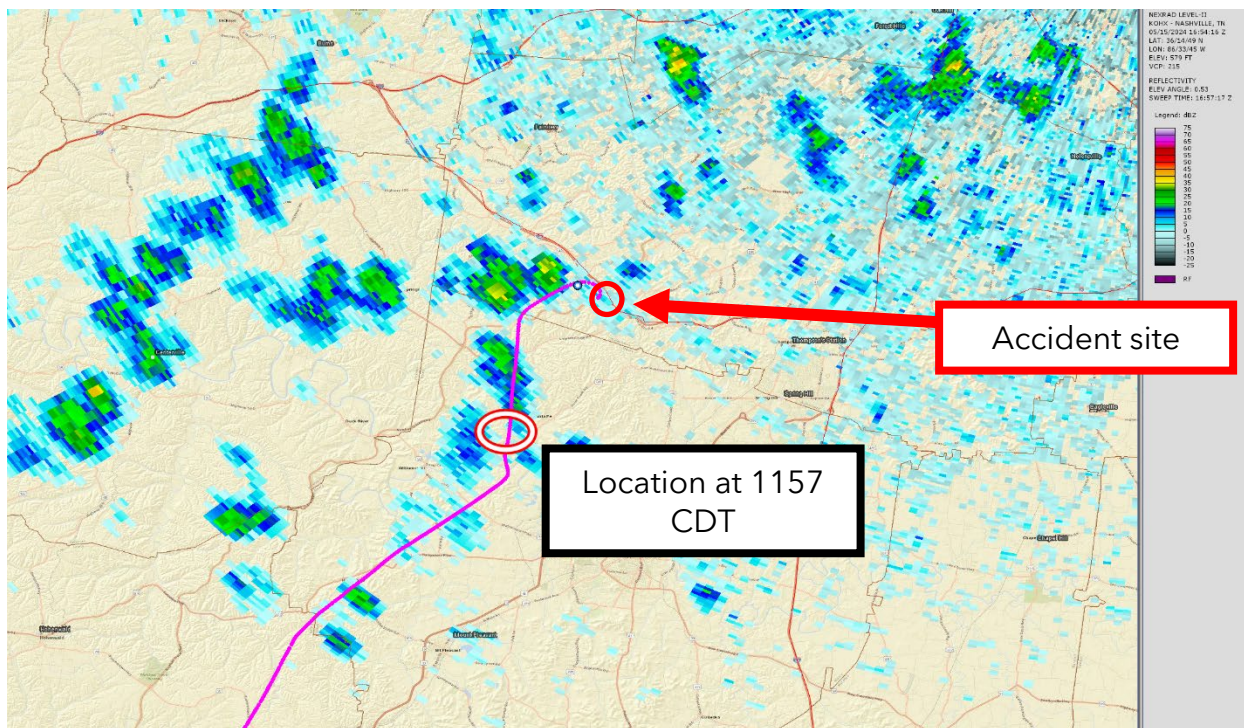


Figure 15. KOHX WSR-88D reflectivity for the 0.53° elevation scan initiated at 1157:17 CDT with the accident site marked with the red circle and the location of the accident aircraft in the red/white circle. The pink dots are the airplane flight track points.

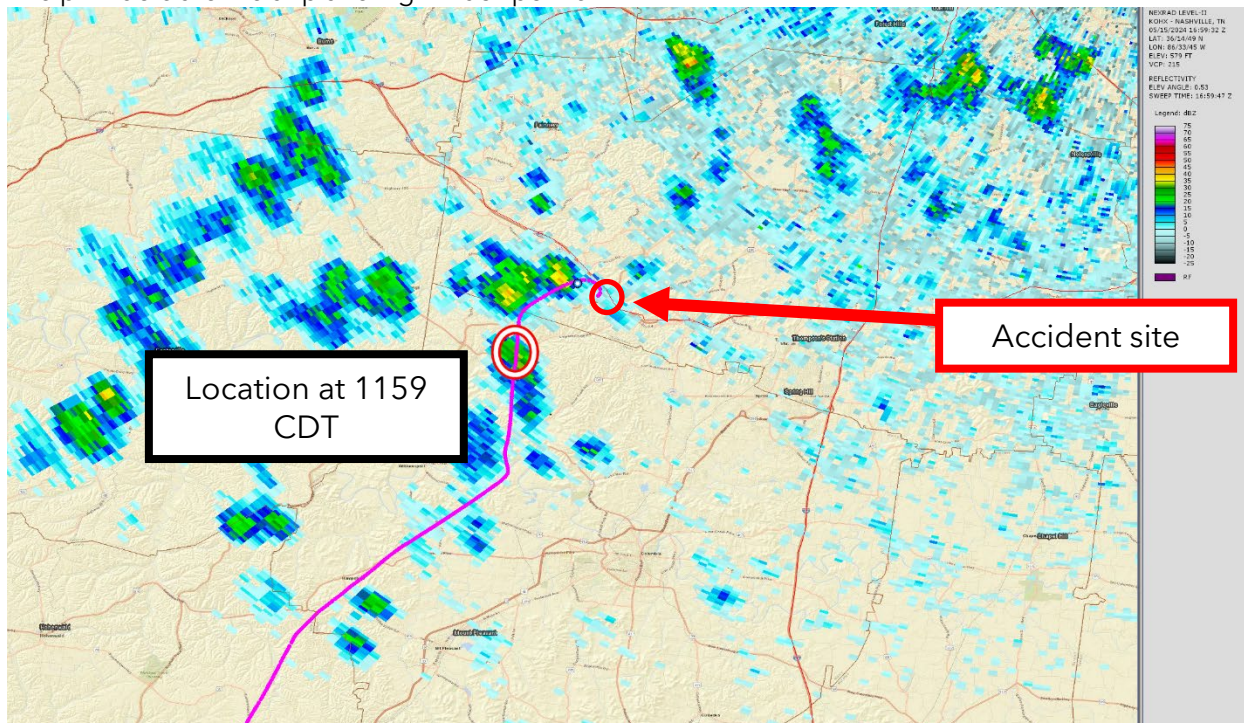


Figure 16. KOHX WSR-88D reflectivity for the 0.53° elevation scan initiated at 1159:47 CDT with the accident site marked with the red circle and the location of the accident aircraft in the red/white circle. The pink dots are the airplane flight track points.

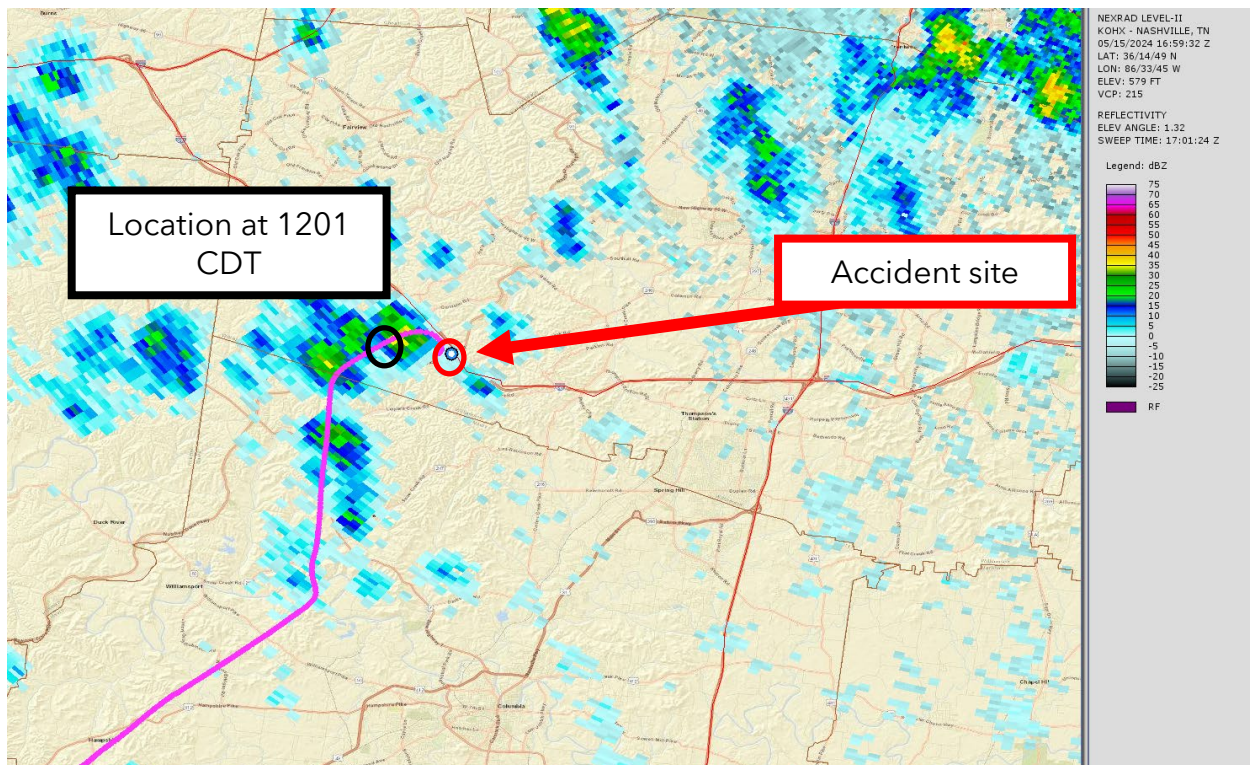


Figure 17. KOHX WSR-88D reflectivity for the 1.32° elevation scan initiated at 1201:24 CDT with the accident site marked with the red circle and the location of the accident aircraft in the black circle. The pink dots are the airplane flight track points.

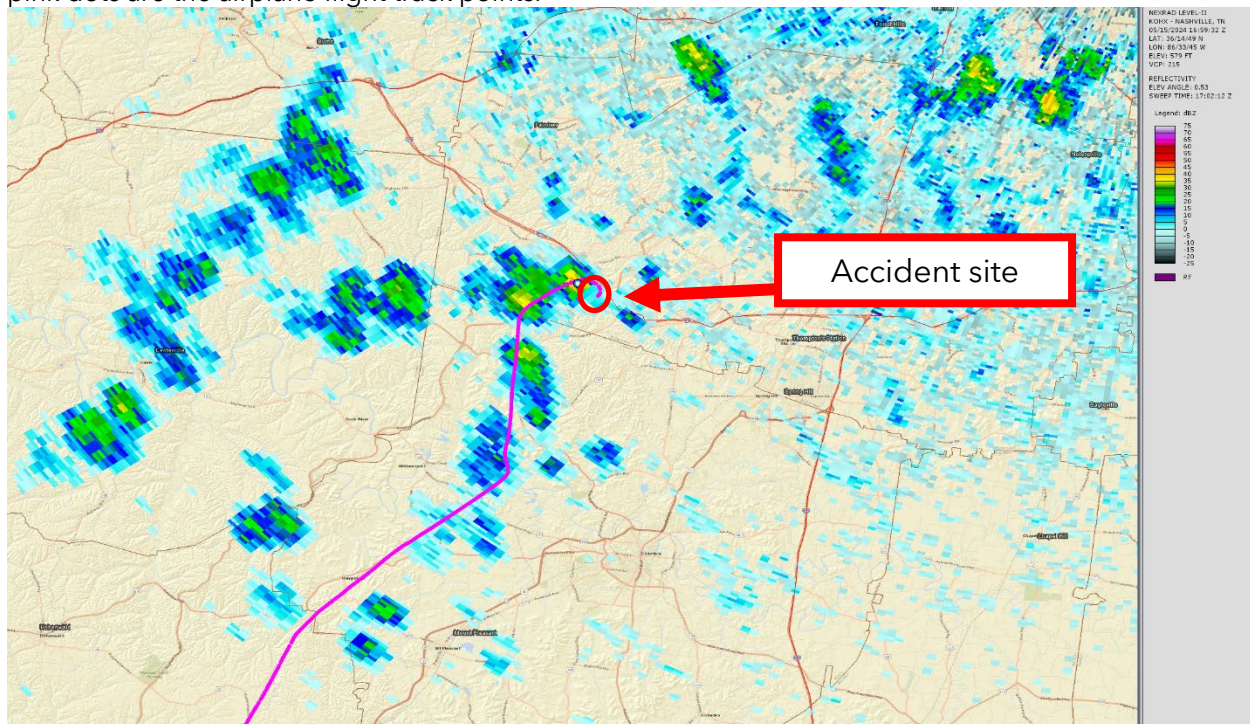


Figure 18. KOHX WSR-88D reflectivity for the 0.5° elevation scan initiated at 1202:12 CDT with the accident site marked with the red circle. The pink dots are the airplane flight track points.

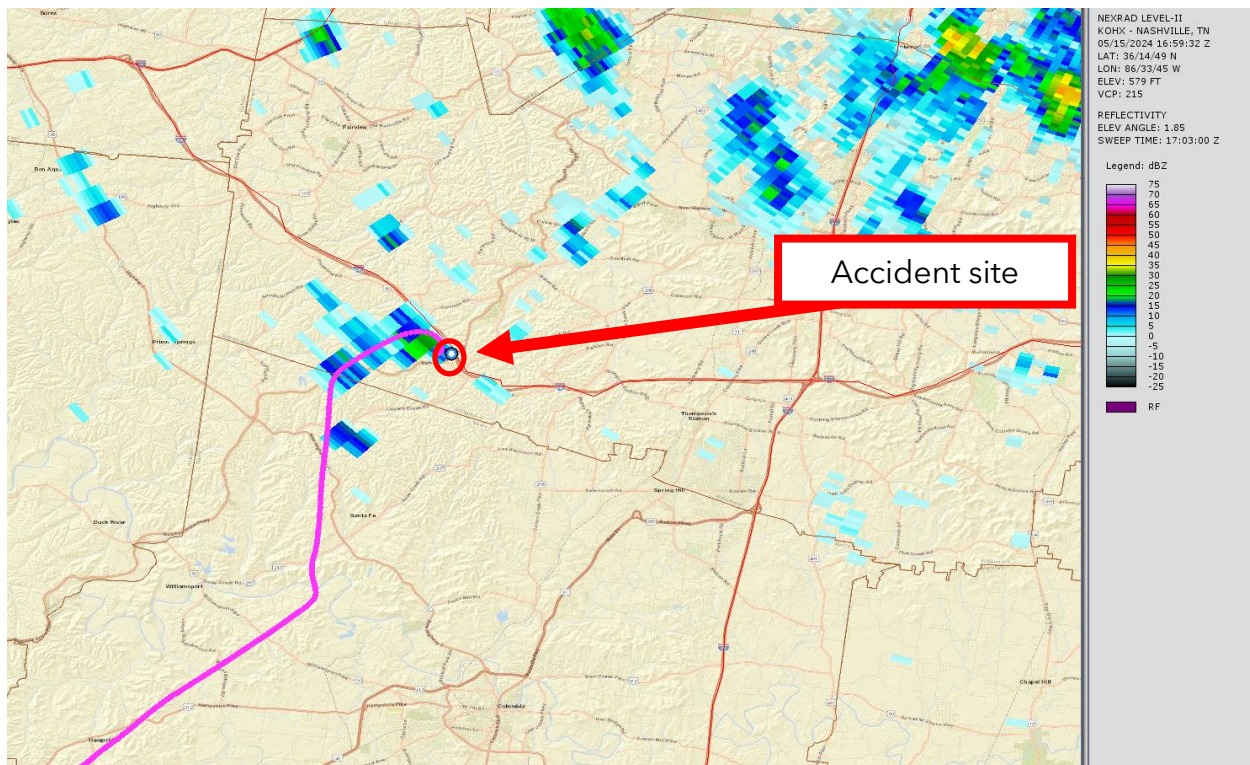


Figure 19. KOHX WSR-88D reflectivity for the 1.85° elevation scan initiated at 1203:00 CDT with the accident site marked with the red circle. The pink dots are the airplane flight track points.

8.0 Pilot Reports

The longline-disseminated pilot reports²⁸ (PIREPs) distributed into the national airspace system (NAS) within 2 hours of the accident time and within 100 miles of the accident site for below 18,000 ft are shown below:

HSV UA /OV KHSV/TM 1700/FLDURGD/TP CRJ7/SK B025

BNA UA /OV BNA290020/TM 1606/FLDURGC/TP E175/SK OVC022

MQY UA /OV MQY/TM 1605/FL020/TP CL35/RM BASES 020

9.0 Significant Meteorological Information

There were no non-convective or convective Significant Meteorological Information (SIGMET) advisories valid for the accident site at the accident time.

²⁸ Only PIREPs with the World Meteorological Organization headers UBTN**, UBKY**, UBAL**, UBMS**, and UBGA** were considered. These do not include pilot reports only broadcast via radio.

10.0 Center Weather Service Advisories and Information

The Memphis (ZME) Air Route Traffic Control Center (ARTCC) Center Weather Service Unit (CWSU) was responsible for the accident region. There was no Center Weather Advisory (CWA) valid for the accident site at the accident time. The ZME CWSU did complete several Pre-Duty Weather Briefings (PDWB) on the day of the accident. For more information please see attachment 2.

11.0 Graphical Forecasts for Aviation

The Graphical Forecasts for Aviation (GFA) products issued by the AWC before the accident flight and valid at 1000 and 1300 CDT and issued around 0800 CDT are shown in figures 20 through 23 (additional GFA forecast products produced after 0800 CDT were not available due to AWC archiving constraints). The GFA surface forecasts applicable at 1000 and 1300 CDT for the accident site indicated VFR conditions with scattered to numerous thunderstorms (between 30 and 100 percent chance) with a west wind of 10 knots and gusts to 15 knots. The GFA cloud forecast applicable to the accident site for 1000 CDT indicated broken to overcast cloud cover at the accident site with scattered clouds at 1,200 ft and broken to overcast clouds at 5,000 to 6,000 ft and cirrus clouds above. The GFA cloud forecast applicable to the accident site for 1300 CDT indicated scattered to broken cloud cover at the accident site with scattered clouds at 2,700 ft broken clouds at 10,000 ft, clouds tops at 12,000 ft, and cirrus clouds above. The Graphical AIRMETs²⁹ (G-AIRMET) valid at 1000 and 1300 CDT are located on figures 20 through 23 and no G-AIRMETs were valid for the accident site. The only human-generated information reflected in the two GFA products were the G-AIRMETs.

²⁹ Graphical AIRMETs found on the Aviation Weather Center webpage at <http://aviationweather.gov>, are graphical forecasts of en-route weather hazards valid at discrete times no more than 3 hours apart for a period of up to 12 hours into the future (for example, 00, 03, 06, 09, and 12 hours). G-AIRMETs are snap shots at discrete time intervals as defined above. The text AIRMET is the result of the production of the G-AIRMET but provided in a time smear for a 6hr valid period.

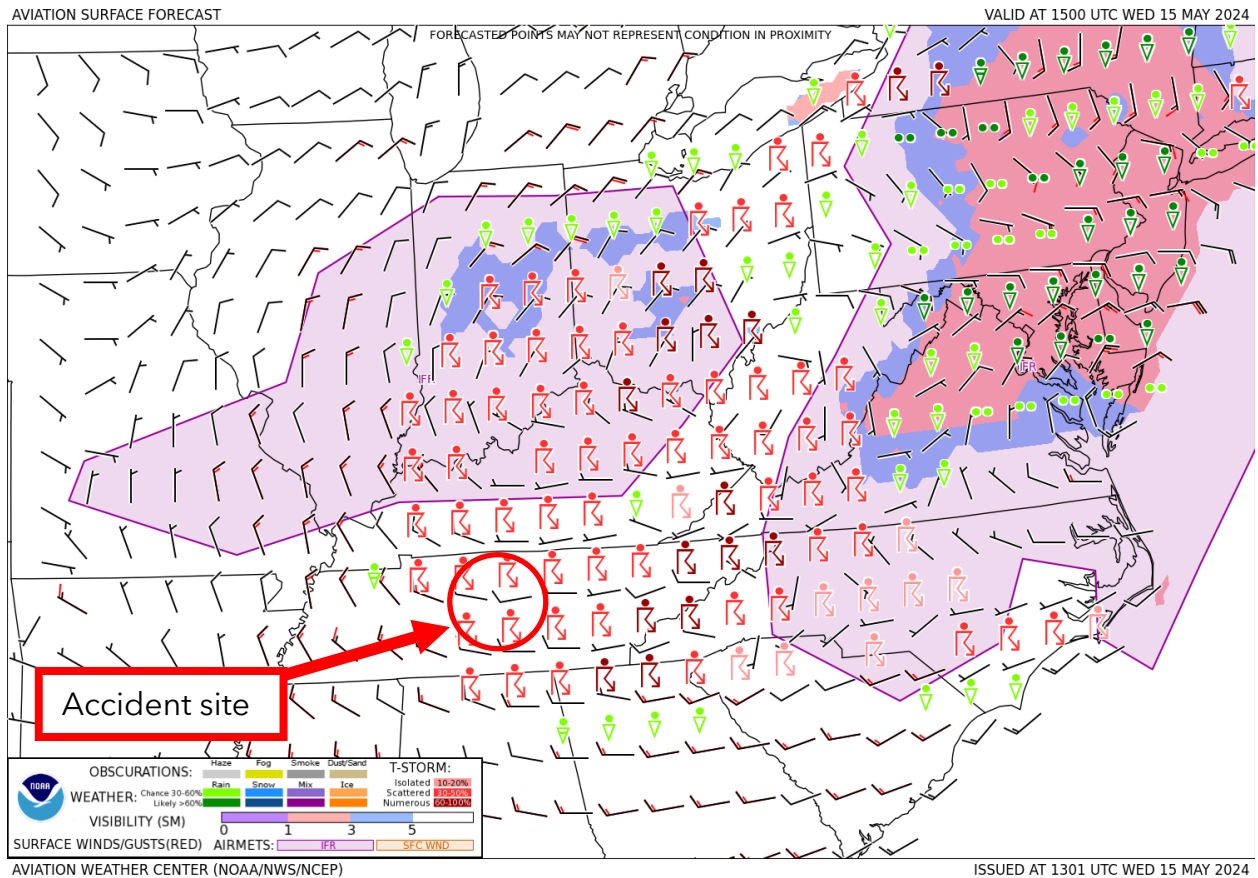


Figure 20. GFA Surface Forecast valid at 1000 CDT with forecast issued at 0801 CDT.

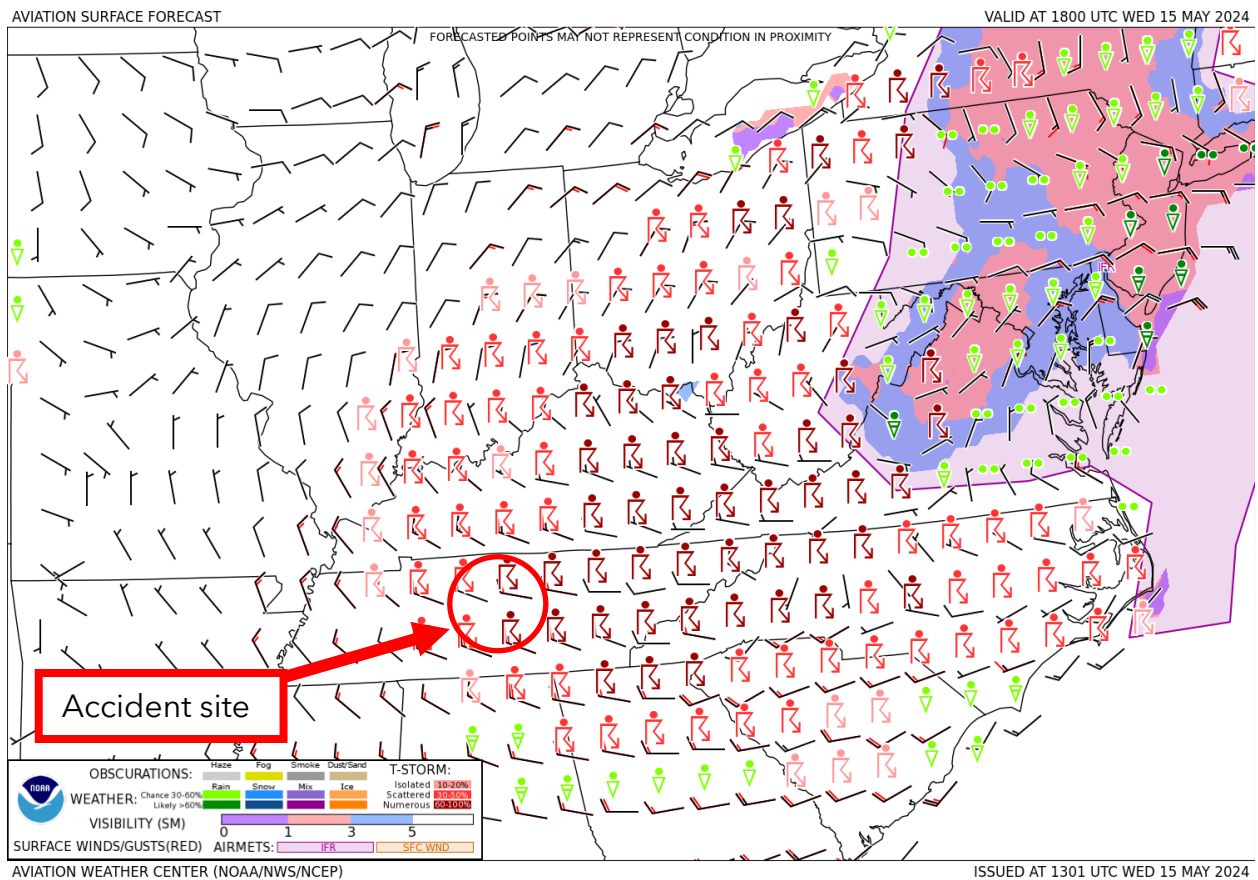


Figure 21. GFA Surface Forecast valid at 1300 CDT with forecast issued at 0801 CDT.

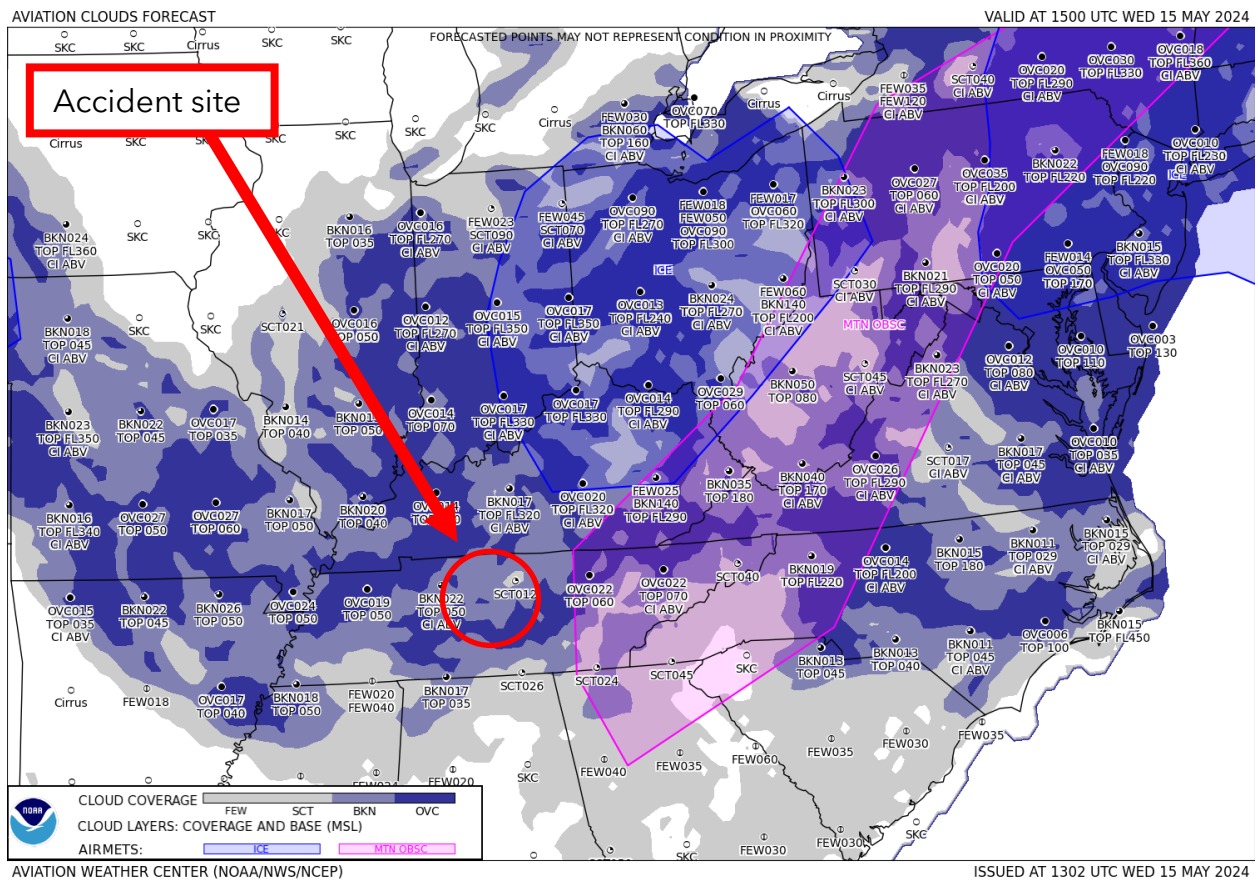


Figure 22. GFA Aviation Clouds Forecast valid at 1000 CDT with forecast issued at 0802 CDT.

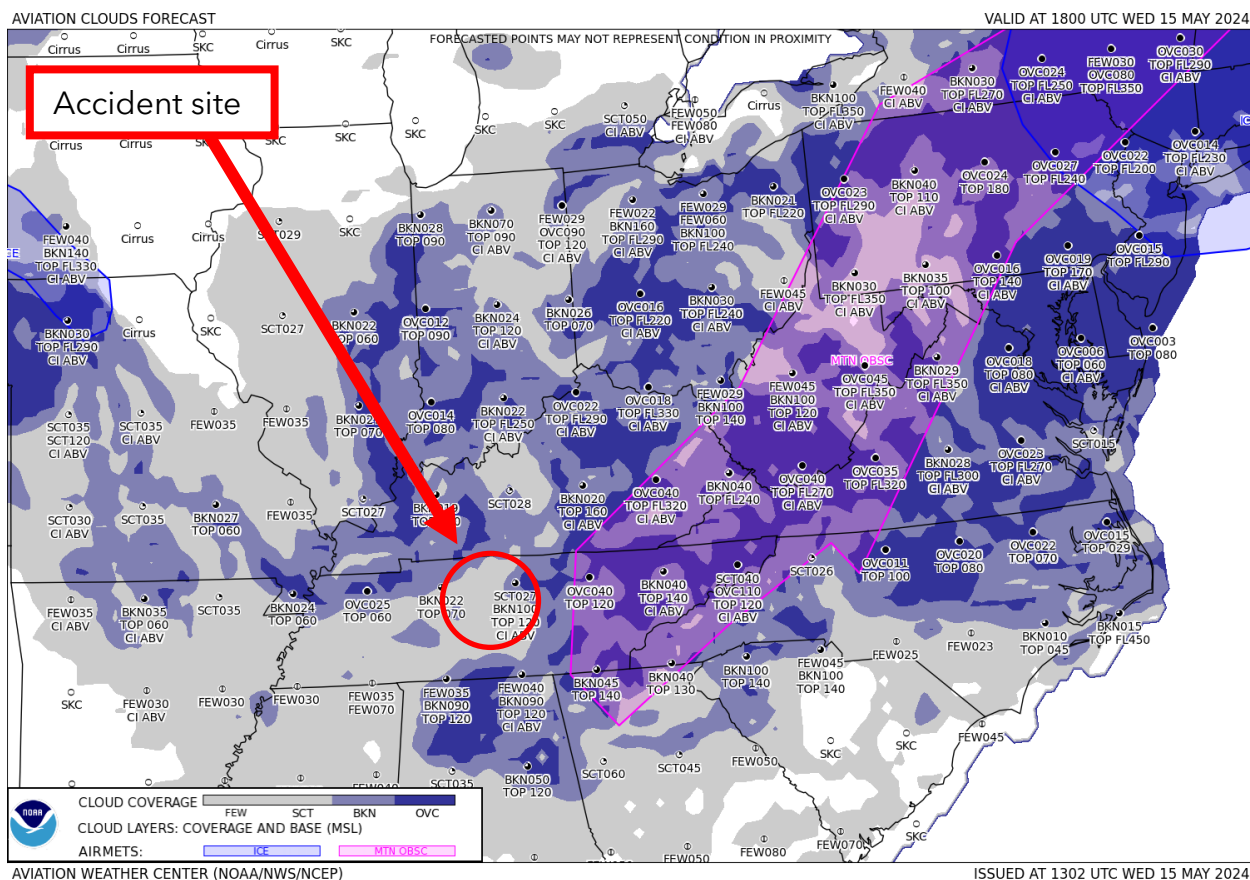


Figure 23. GFA Aviation Clouds Forecast valid at 1300 CDT with forecast issued at 0802 CDT.

12.0 Airmen's Meteorological Information

There were no NWS Aviation Weather Center (AWC) text Airmen's Meteorological Information (AIRMET) advisories valid for the accident site at the accident time.

13.0 Terminal Aerodrome Forecast

There were no airports within 20 miles of the accident site with an NWS Terminal Aerodrome Forecast³⁰ (TAF).

³⁰ According to NWS Instruction 10-813: "An NWS TAF consists of the expected meteorological conditions significant to aviation at an airport for a specified time period. For the U.S., this is the area within five (5) statute miles (SM) of the center of an airport's runway complex."
www.nws.noaa.gov/directives/sym/pd01008013curr.pdf

14.0 National Weather Service Area Forecast Discussion

The NWS weather forecast office in Nashville, Tennessee, (WFO OHX) was responsible for the public surface forecast in the region of the accident site. WFO OHX issued the following Area Forecast Discussion (AFD) at 0639 CDT, which was the AFD issued closest to the accident time with an aviation section.

FXUS64 KOHX 151139
AFDOHX

Area Forecast Discussion
National Weather Service Nashville TN
639 AM CDT Wed May 15 2024

...New AVIATION...

.SHORT TERM...
(Today through Friday)
Issued at 151 AM CDT Wed May 15 2024

A moist/humid but rain free morning appears to be in place. Dewpoint depressions are 0F to 2F area wide with some fog formation noted across the south so far. Numerics indicate 1-3sm vsbys by 12Z for the cwa. Dewpoints are expected to hold steady so will need to watch if any dense pockets emerge.

Today, a weak but stacked system will continue moving eastward across KY. Backside shortwave energy will move southward and provide a continuing chance of showers and a few thunderstorms today. High temperatures today should warm into the mid to upper 70s and aid with the convective development by early afternoon. Cells will move southeastward but no strong or severe thunderstorms are expected. A few showers will hang on into Wednesday evening before moving out.

Upper ridging will return Thursday with perhaps some partial sunshine. On its heels, however, the next system of interest will be developing over the southern Plains. Associated moisture, in the form of showers and thunderstorms, will be moving in Thursday night and especially on Friday. Shear levels will pick up Friday afternoon so perhaps a marginal risk upcoming. Otherwise, rainfall amounts through the short term will be less than one inch.

For the short term temps, the numbers look seasonal for the most part. But, it will be into the 80s on Thursday with the upper ridging in place.

&&

.LONG TERM...
(Friday Night through next Wednesday)
Issued at 151 AM CDT Wed May 15 2024

In the extended forecast, the aforementioned storm system looks as though it will be a rather slow mover, potentially. It also looks as though it will be a weakening stacked system, with the pva feeder being absent. Instabilities still abound but forcing and shear look to be on the weak side when severe phasing is examined. Moreover, spc keeps the area free of any D4-D8 severe potential. Showers and tstms will be moving out by Saturday night. A stacked zone of high pressure will move in on Sunday and start to warm us up. A warm front will lift to our north with showers and tstms along and north of it. For good measure, the NBM wants to input low pops for the tail end of the period.

For the extended temps, seasonal warmth expected for the weekend. Then we will warm up nicely as previously mentioned upper ridging sets in. Highs will warm to well into the 80s early next week. Lows will increase as well and will reach into the mid to upper 60s.

&&

.AVIATION...

(12Z TAFS)

Issued at 634 AM CDT Wed May 15 2024

Upper trough shortwave axis will push to the east of the mid state today. Backside energy will keep clouds and isolated to scattered showers and a few tstms in the forecast. Low IFR cigs will prevail for much of the taf period. VCTS will cover the wx grouping. Otw, light winds will veer from westerly to northwesterly with time.

&&

.PRELIMINARY POINT TEMPS/POPS...

Nashville	78	60	84	65	/	60	10	10	30
Clarksville	75	58	83	64	/	50	10	20	40
Crossville	70	58	78	58	/	80	40	0	10
Columbia	78	58	84	64	/	50	10	10	30
Cookeville	72	59	78	61	/	80	30	0	20
Jamestown	70	58	77	59	/	90	30	0	10
Lawrenceburg	77	58	83	64	/	50	10	0	30
Murfreesboro	78	59	83	63	/	70	20	10	20
Waverly	76	58	84	63	/	50	0	10	40

&&

.OHX WATCHES/WARNINGS/ADVISORIES...

None.

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15.0 Radar Display of STARS Derived Imagery

A STARS³¹ maintenance replay of the accident sequence was viewed and screenshots of the display of weather were obtained. The Departure Radar West Controller (DRW) at BNA TRACON did have settings for level 1 through level 5 precipitation active and available for view:³²

- 1: 18<30 dBZ
- 2: 30<41 dBZ
- 3: 41<46 dBZ
- 4: 46<50 dBZ
- 5: 50<57 dBZ
- 6: 57+ dBZ

Figure 24 provides an exemplar view of what precipitation levels 1 through 6 look like on STARS display of precipitation. Level 1 is described as "light", level 2 is described as "moderate", level 3 and 4 are described as "heavy", and level 5 and 6 are described as "extreme." Figures 25 through 27 show the STARS display of precipitation used and seen by the accident controller at 1159, 1201, and 1202 CDT. The accident aircraft did not encounter any precipitation noted on STARS throughout the last 11 minutes of the accident flight. For more imagery please see attachment 3.

³¹ STARS – Standard Terminal Automation Replacement System – A system that receives radar data and flight plan information and presents the information to air traffic controllers on high resolution, 20" x 20" color displays allowing the controller to monitor, control, accept hand-off of air traffic, and assist with weather avoidance.

³² The FAA provided the following dBZ levels for the Airport Surveillance Radar-9 (ASR-9) radars (which provided info to STARS).

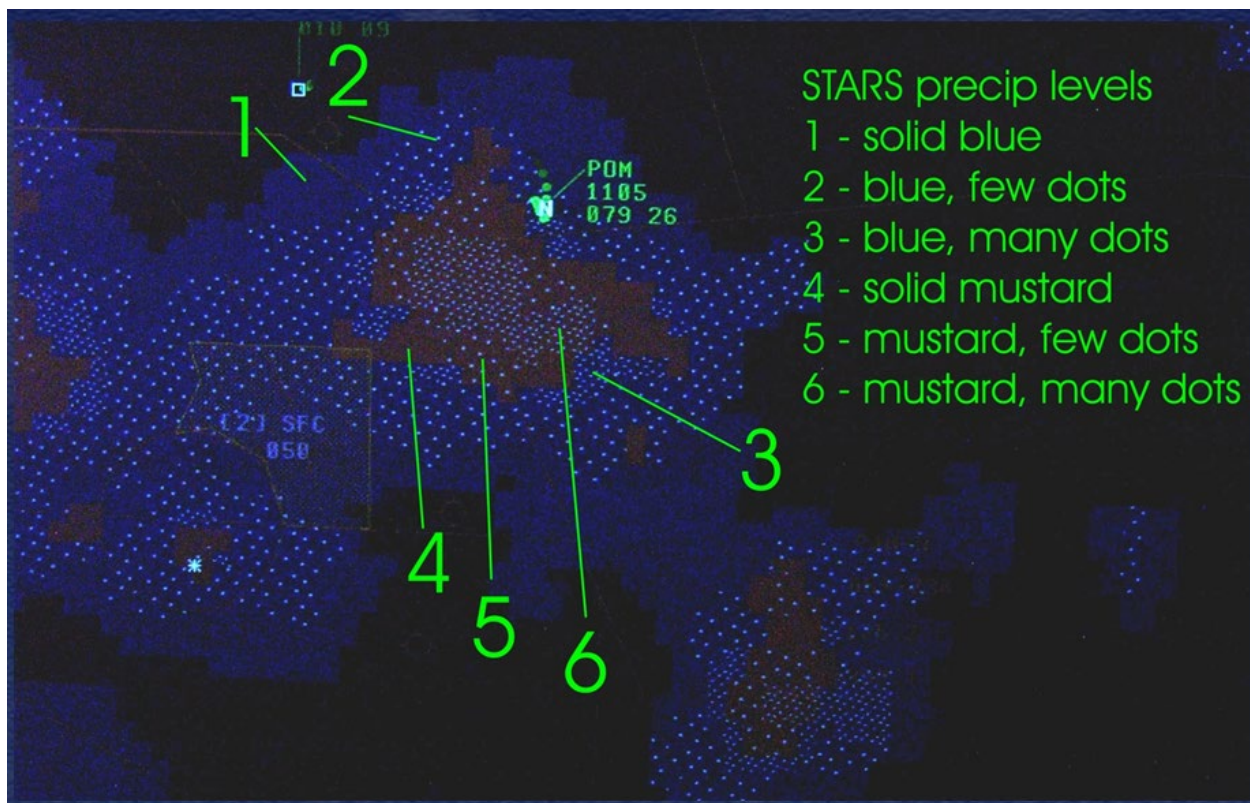


Figure 24. Exemplar display of STARS derived precipitation levels.



Figure 25. Screenshot of the DRW displayed precipitation from 1159:00 CDT.





Figure 27. Screenshot of the DRW displayed precipitation from 1202:00 CDT.

Daily facility logs from BNA TRACON indicated several weather display concerns for STARS to include, "6 level wx works in linear mode and ASR weather intermittent." For more information on these details please see the ATC factual report for this accident and attachment 4.

16.0 Display of ZME R14/R42 ERAM Imagery

The ATC workgroup conducted a review of facility documents and an En Route Automation Modernization (ERAM) replay of the ZME R14/R42 combined sector controller's display. The ERAM system processes flight and surveillance data, provides communications, and generates display data to air traffic controllers. ERAM has increased flexibility in routing around congestion, bad weather and other airspace restrictions. After the accident, the FAA secured the sector R14/R42 ERAM replay showing the sector R14/R42 controller preference settings and intensities.

Figure 28 provides an exemplar display of ERAM-displayed precipitation. Precipitation levels follow the categories in section 6.3. Figures 29 through 32 show the sector R14/R42 ERAM displayed precipitation at 1148, 1154, 1158, and 1200 CDT. For more imagery please see attachment 5.

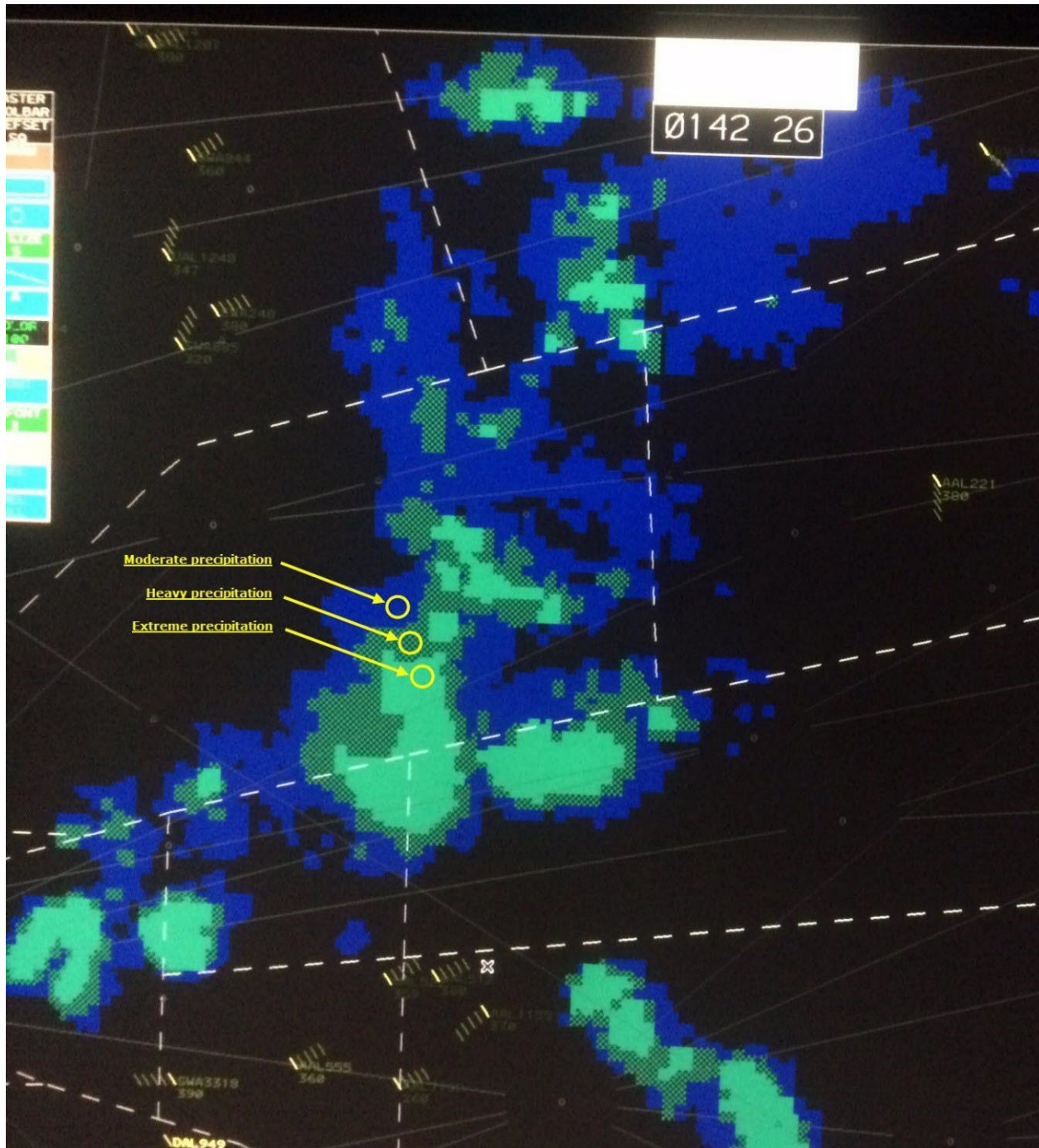


Figure 28. Exemplar display of ERAM derived precipitation levels.

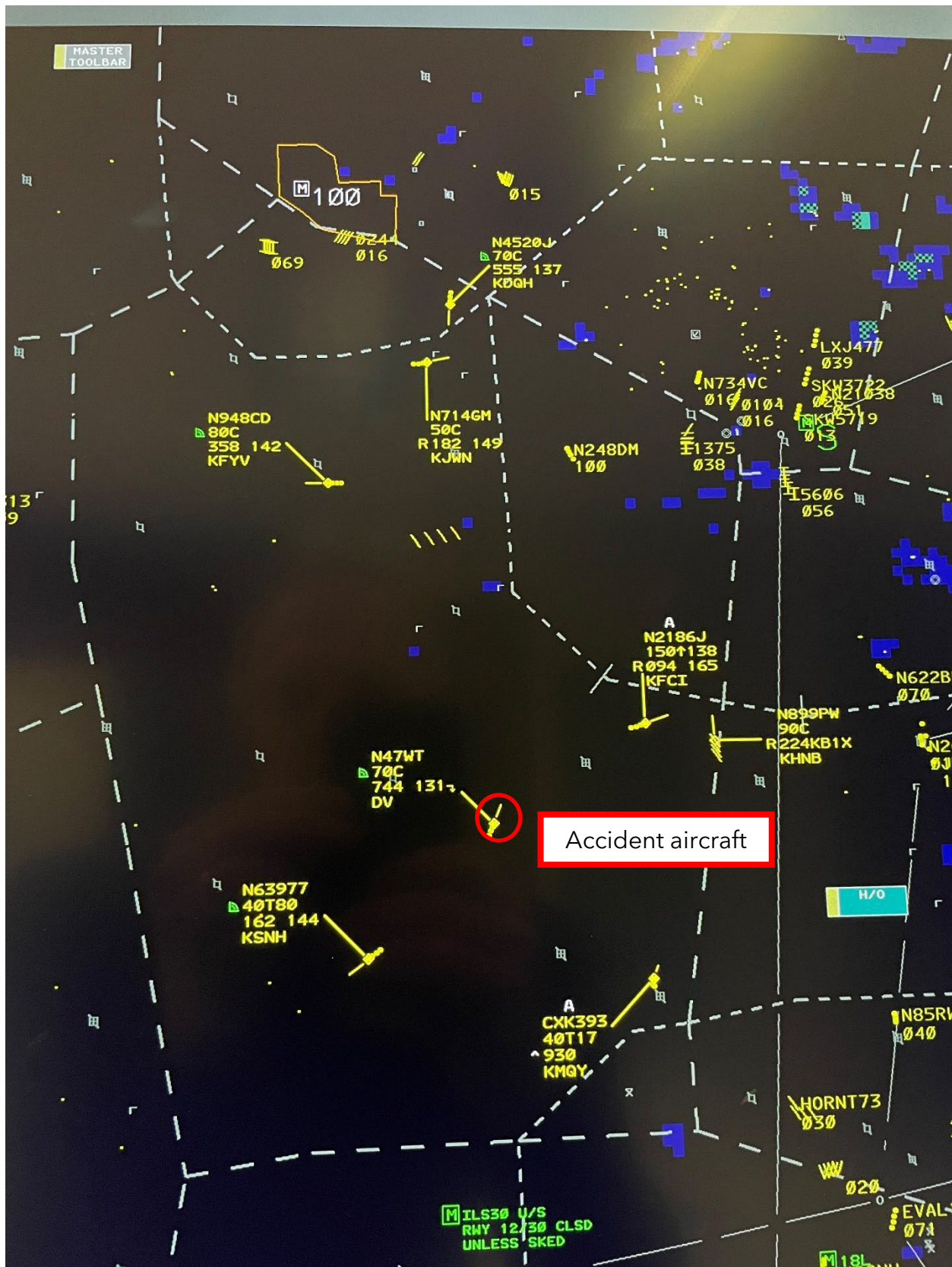


Figure 29. Screenshot of the sector R14/R42 ERAM displayed precipitation from 1148:00 CDT.



Figure 30. Screenshot of the sector R14/R42 ERAM displayed precipitation from 1154:00 CDT.



Figure 31. Screenshot of the sector R14/R42 ERAM displayed precipitation from 1158:00 CDT.



Figure 32. Screenshot of the sector R14/R42 ERAM displayed precipitation from 1200:00 CDT.

17.0 Astronomical Data

The astronomical data obtained for the accident site on May 15, 2024, indicated the following:

SUN

Begin civil twilight	0513 CDT
Sunrise	0542 CDT
Accident time	1202 CDT ³³
Sun transit	1245 CDT
Sunset	1948 CDT
End civil twilight	2016 CDT

At the time of the accident the Sun was at an altitude of 70.81° and azimuth of 147.89°.

18.0 XM Weather Imagery

The XM weather radar imagery from 1102 through 1257 CDT was provided to the investigation and can be found in attachment 6 with the radar imagery zoomed in towards the accident site.

19.0 Pilot Weather Information

Title 14 CFR 91.103 states that “Each pilot in command shall, before beginning a flight, become familiar with all available information concerning that flight.” FAA AC 91-92 “Pilot’s Guide to a Preflight Planning” (dated March 15, 2021) provided pilot guidance on preflight self-briefings, including planning, weather interpretation, and risk identification/mitigation skills. The AC further stated in part:

Pilots adopting these guidelines will be better prepared to interpret and utilize real-time weather information before departure and en route, in the cockpit, via technology like Automatic Dependent Surveillance-Broadcast (ADS-B) and via third-party providers.³⁴

³³ Inserted accident time for reference and context.

³⁴ https://www.faa.gov/documentLibrary/media/Advisory_Circular/AC_91-92.pdf. The AC also listed multiple online FAA resources for aviation flight planning services for adverse weather.

A search of archived information indicated that the accident pilot did not request weather information from Leidos Flight Service. The accident pilot did have an account with ForeFlight and did file their flight plan through ForeFlight and received a weather briefing (attachments 7 and 8). The flight path was created on May 13 around 1328 CDT, but set to be filed around 0900 CDT on May 14, with a planned departure time of 0900 CDT on May 15. The weather briefing information was set to be generated on May 15 and was provided to the pilot via PDF file around 0600 CDT on May 15 (attachment 8). The ForeFlight weather briefing contained the ForeFlight Vertical Cross Section Chart with 9,000 ft as the filed altitude for travel, wind, turbulence, and temperature chart for 9,000 ft, the significant weather chart for FL250 to FL630 for the route of flight, METARs and TAFs along the route of flight, and SIGMETs valid for the central and eastern United States. In addition, the accident pilot viewed several weather imagery pages between 0929 CDT on May 12, and 0634 CDT on May 15. For more information please see attachments 7 and 8.

20.0 Flight Information Services - Broadcast Imagery

Flight Information Services - Broadcast³⁵ imagery was requested by the NTSB from the FAA and the FIS-B datasets can be found in attachment 9.

21.0 Integrated Terminal Weather System Imagery

The archived Integrated Terminal Weather System (ITWS)³⁶ imagery surrounding the accident site and the Nashville region was requested by the NTSB from the FAA. The FAA provided the ITWS imagery from 1158:58 and 1200:03 CDT and those images can be found in attachments 10 and 11.

³⁵ [ADS-B In Pilot Applications | Federal Aviation Administration \(faa.gov\)](#)

³⁶ [Integrated Terminal Weather System \(ITWS\) | Federal Aviation Administration](#)

E. LIST OF ATTACHMENTS

Attachment 1 - GOES-16 visible satellite imagery animation from 1106 to 1241 CDT

Attachment 2 - ZME CWSU PDWB valid on the day of the accident

Attachment 3 - STARS maintenance replay of the displayed of weather from 1151 to 1203 CDT

Attachment 4 - BNA TRACON daily log for May 15

Attachment 5 - Sector R14/R42 ERAM animation from 1140 to 1202 CDT

Attachment 6 - XM weather radar imagery from 1102 to 1257 CDT

Attachment 7 - ForeFlight correspondence

Attachment 8 - ForeFlight dataset

Attachment 9 - FIS-B dataset

Attachment 10 - ITWS imagery from 1158:58 CDT

Attachment 11 - ITWS imagery from 1200:03 CDT

Submitted by:

Paul Suffern
Senior Meteorologist