



NATIONAL TRANSPORTATION SAFETY BOARD

Office of Aviation Safety
Washington, D.C. 20594

March 12, 2021

Factual Report

METEOROLOGY

ERA20FA118

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A. ACCIDENT

Location: Bishop, Georgia
Date: March 3, 2020
Time: 1634 eastern standard time
2134 Coordinated Universal Time (UTC)
Aircraft: Piper PA-46-310P; Registration: N43368

B. METEOROLOGIST

Paul Suffern
Senior Meteorologist
Operational Factors Division (AS-30)
National Transportation Safety Board

C. DETAILS OF THE INVESTIGATION

The National Transportation Safety Board's (NTSB) Meteorologist participated with the NTSB air traffic control (ATC) group¹ at the Atlanta TRACON (A80) for this investigation. In addition, information was gathered for this investigation from official National Oceanic and Atmospheric Administration (NOAA) National Weather Service (NWS) sources including the National Centers for Environmental Information (NCEI). All times are eastern standard time (EST) on March 3, 2020, and are based upon the 24-hour clock, where local time is -5 hours from UTC, and UTC=Z (unless otherwise noted). Directions are referenced to true north and distances in nautical miles. Heights are above mean sea level (msl) unless otherwise noted. Visibility is in statute miles and fractions of statute miles. NWS airport and station identifiers use 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 location used was at latitude 33.8567° N, longitude 83.4864° W, with an approximate elevation of 810 feet (ft).

¹ For more Information about the NTSB ATC information gathered please see the ATC factual and attachments located in the accident docket.

D. WEATHER 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 Weather Prediction Center, 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 joint NWS and Federal Aviation Administration (FAA) Advisory Circular “Aviation Weather Services”, AC 00-45H.²

1.1 Surface Analysis Chart

The mid-Atlantic section of the NWS Surface Analysis Chart for 1600 EST is provided as figure 1 with the approximate location of the accident site marked within the red circle. The chart depicted a cold front extending from West Virginia southwestward across eastern Tennessee into northern Alabama, Mississippi, Louisiana, into southeast Texas. A high pressure system was located over eastern Arkansas with a pressure of 1012-hectopascals (hPa), behind the cold front. The accident site was located in the warm air sector to the southeast of the cold front.

The station models around the accident site depicted air temperatures in the upper 60’s degrees Fahrenheit (°F), dew point temperatures in the low to mid 60’s °F with temperature-dew point spreads of 8°F or less, winds from the northwest to southwest wind at 10 knots, and mostly cloudy sky cover with light rain.

²

https://www.faa.gov/regulations_policies/advisory_circulars/index.cfm/go/document.information/documentID/1030235

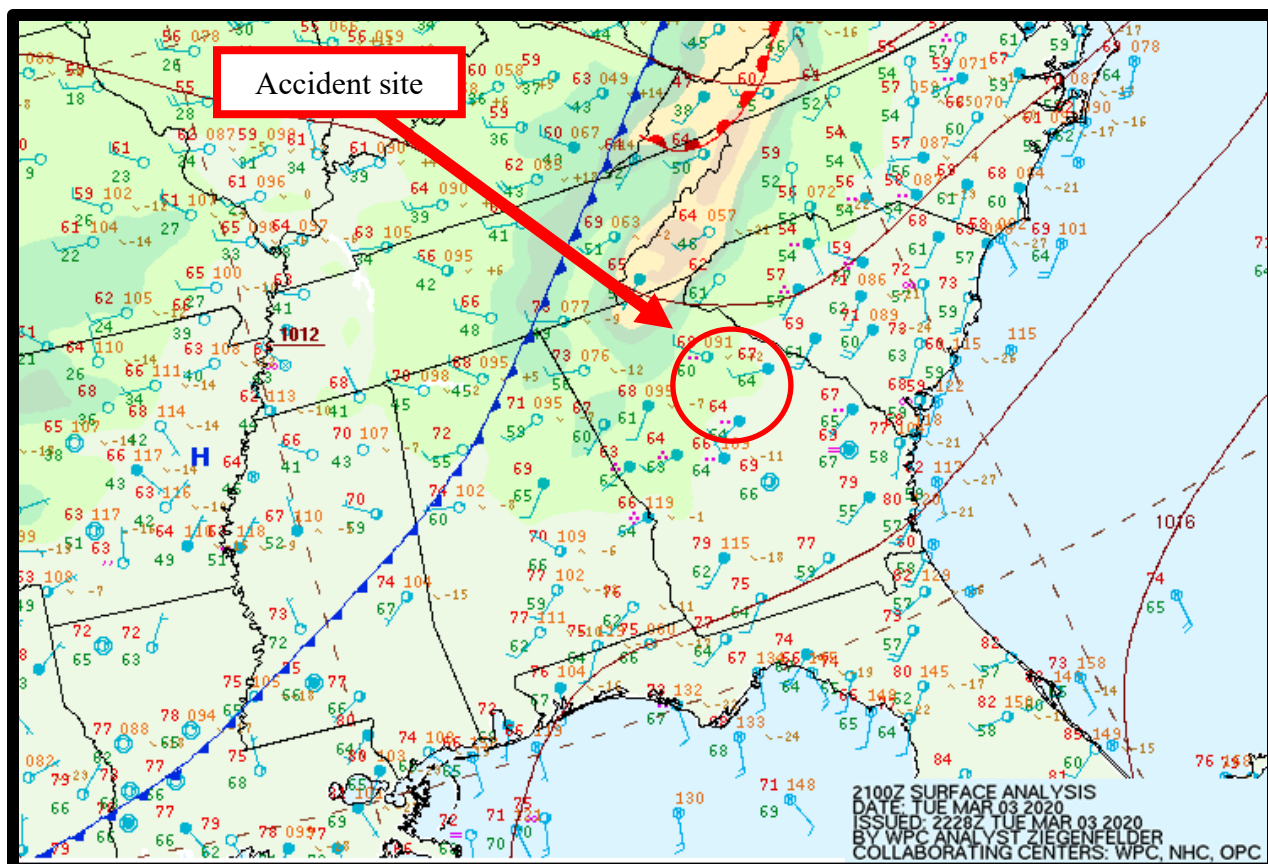


Figure 1 – NWS Surface Analysis Chart for 1600 EST

1.2 Upper Air Charts

The NWS Storm Prediction Center (SPC) Constant Pressure Charts for 1900 EST at 925-, 850-, 700-, 500-, and 300-hPa are presented in figures 2 through 6. There was a low- and mid-level trough³ depicted immediately east of the accident site, having moved across the accident region hours previously, from 925- through 700-hPa. Troughs can act as lifting mechanisms to help produce clouds and precipitation if sufficient moisture is present. There was a west wind of 20 knots at 925-hPa above the accident site with the wind remaining westerly through 300-hPa (figure 6). The wind speed increased to 55 knots by 700-hPa (figure 4) with a wind speed to 105 knots at 300-hPa (figure 6).

³ Trough – An elongated area of relatively low atmospheric pressure or heights.

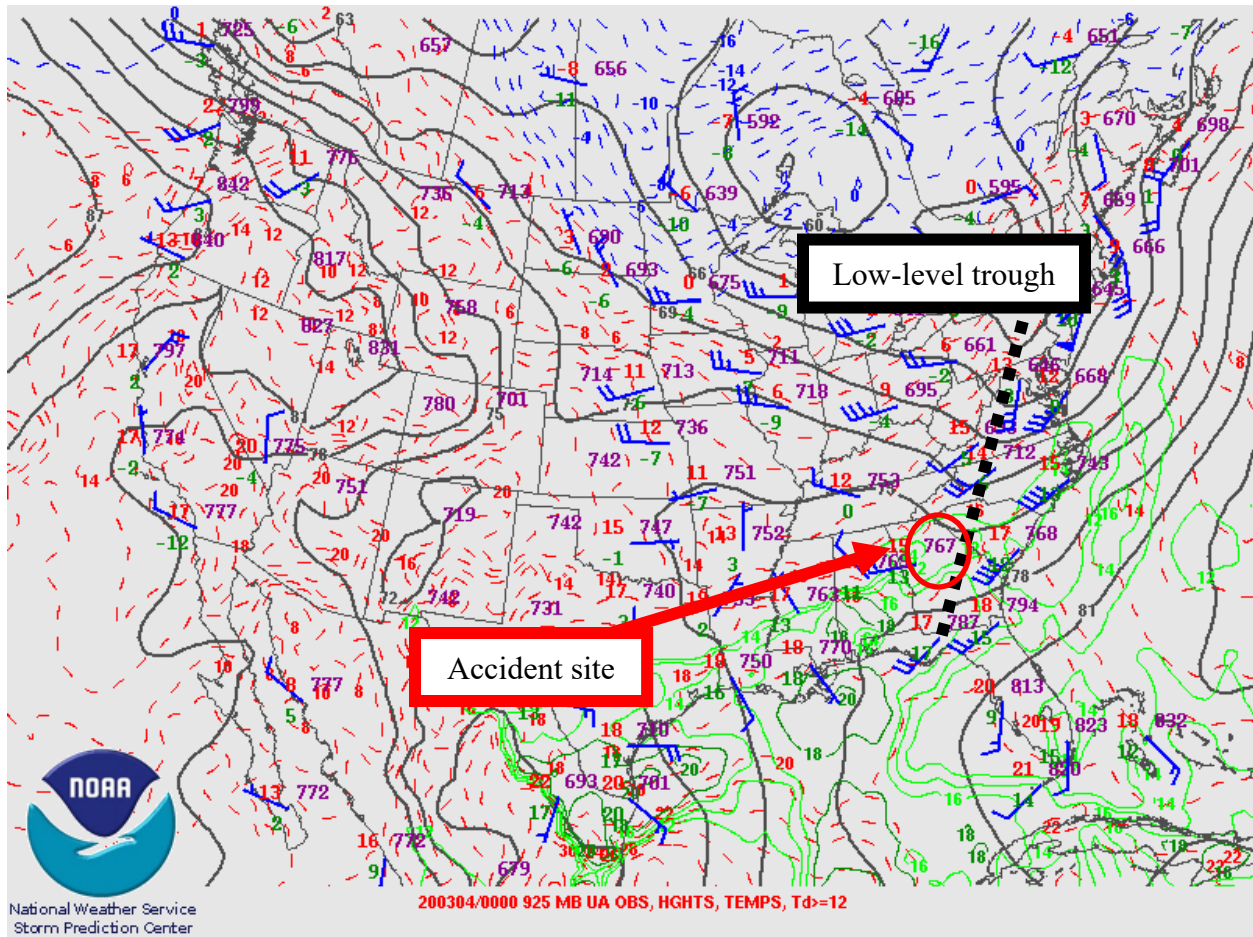


Figure 2 – 925-hPa Constant Pressure Chart for 1900 EST

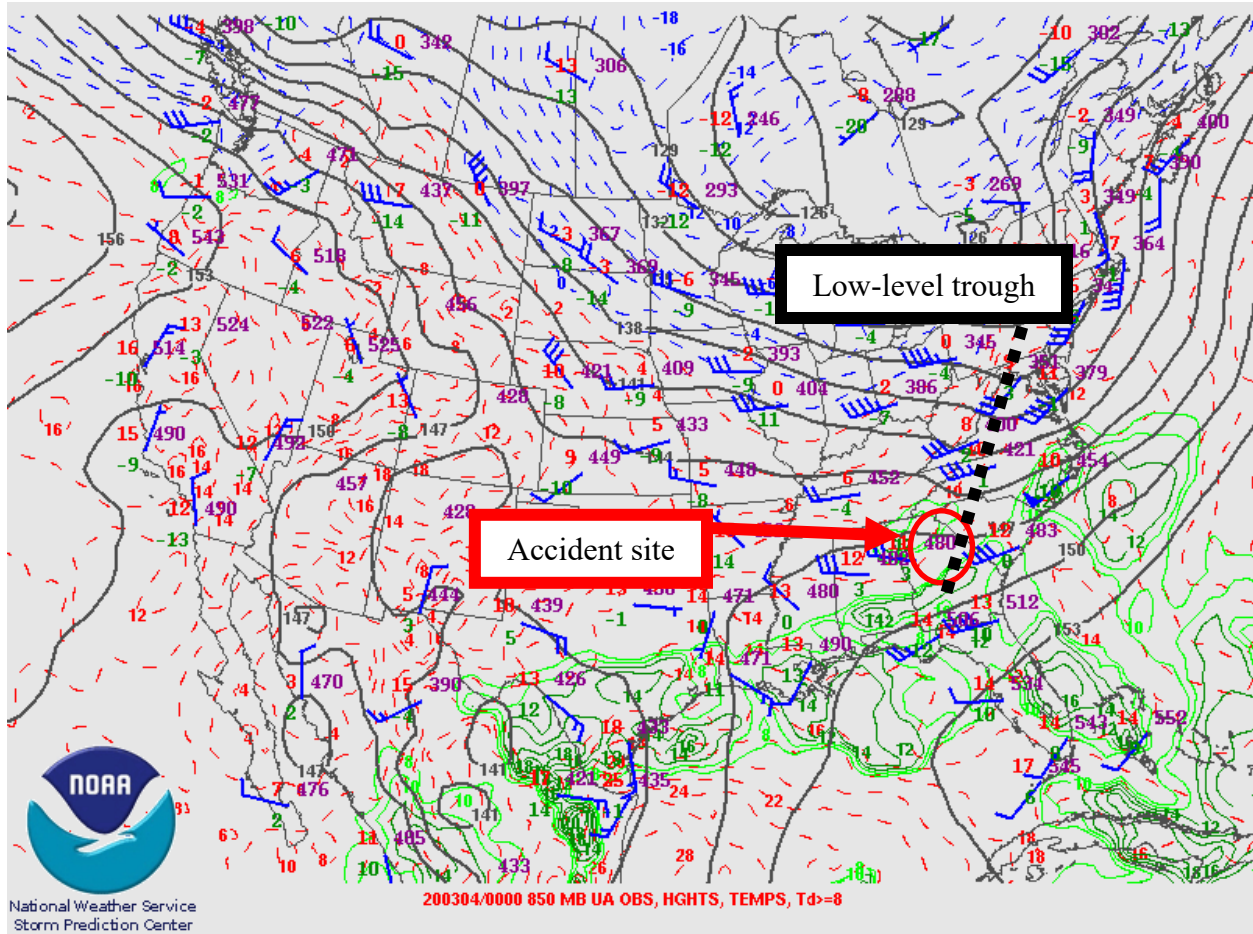


Figure 3 – 850-hPa Constant Pressure Chart for 1900 EST

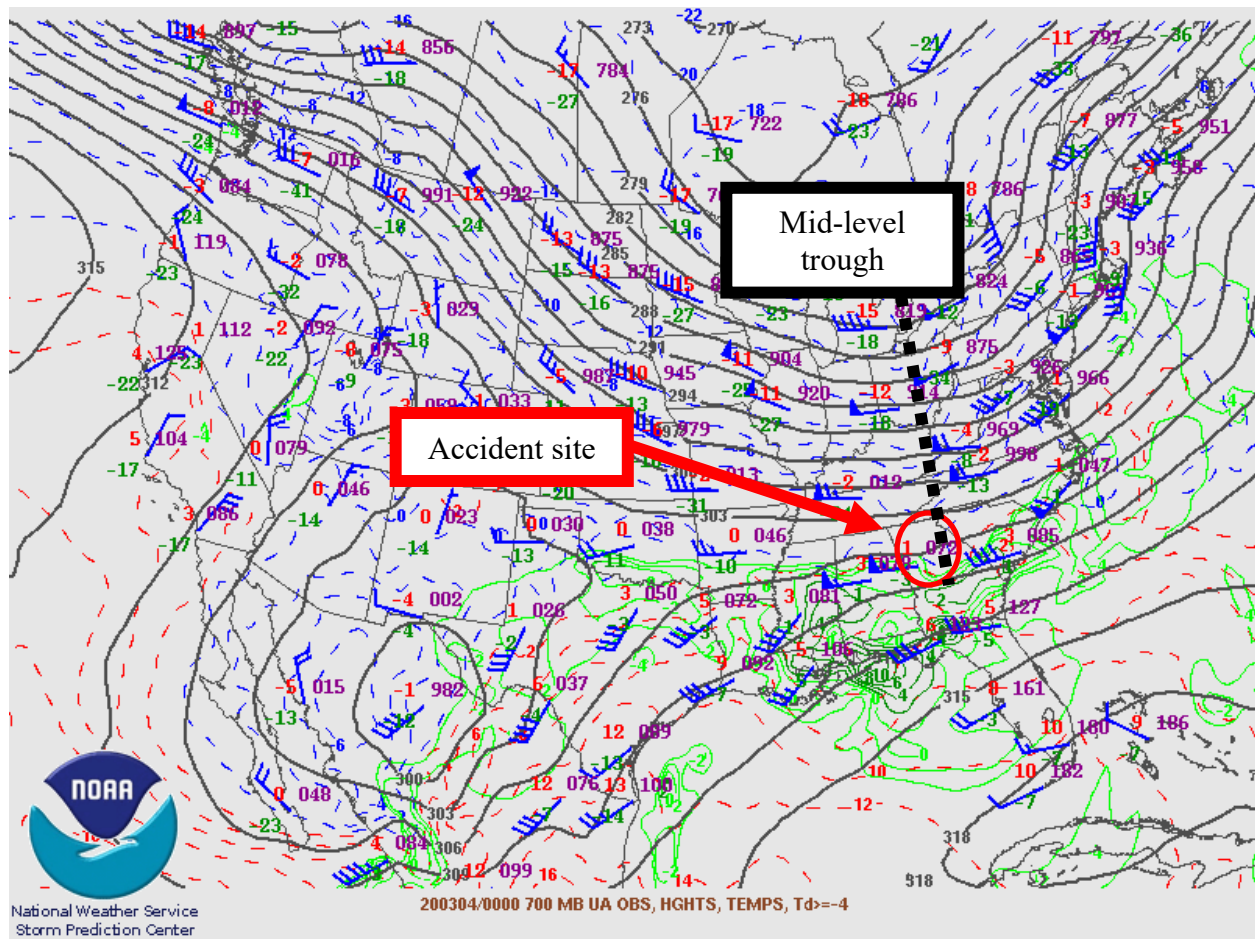


Figure 4 – 700-hPa Constant Pressure Chart for 1900 EST

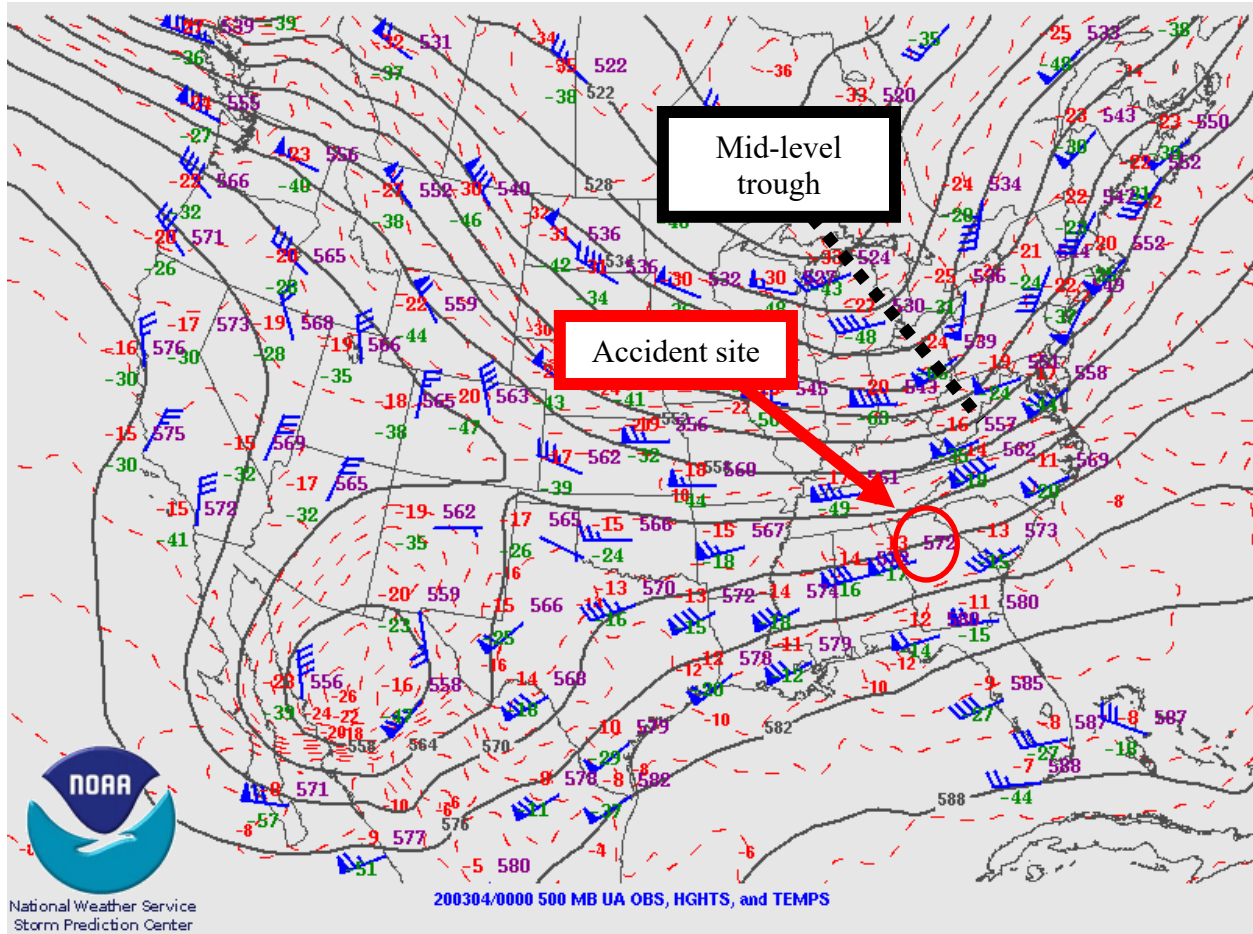


Figure 5 – 500-hPa Constant Pressure Chart for 1900 EST

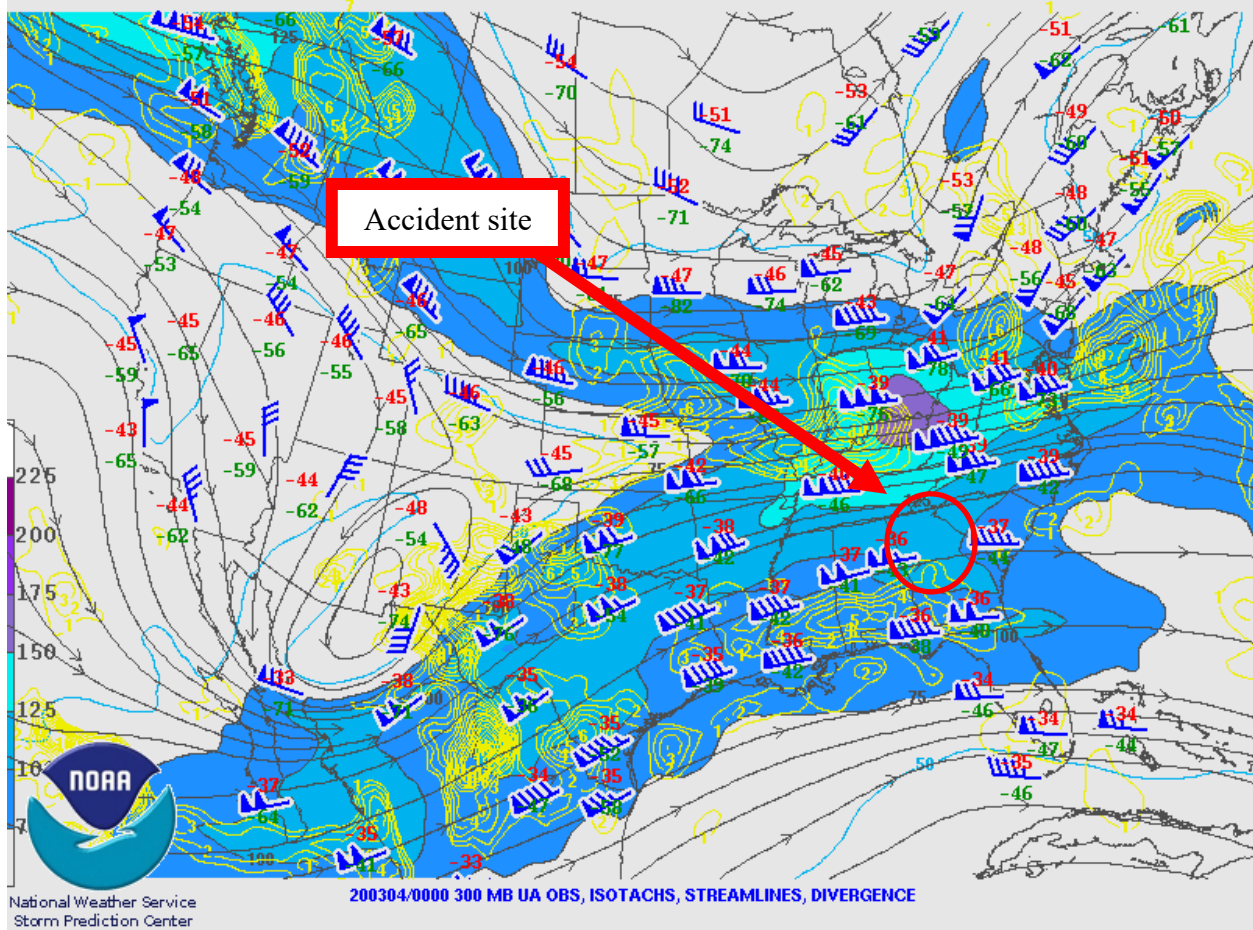


Figure 6 – 300-hPa Constant Pressure Chart for 1900 EST

2.0 SPC Convective Outlook

SPC issued the following Day 1 Convective Outlook at 1456 EST (figure 7) with a marginal risk for severe thunderstorms forecast for the area during the period. A marginal risk of severe thunderstorms is higher than the background climatology of thunderstorms activity for Georgia and Alabama during the early March timeframe. The accident site was located in an area where SPC forecasted a 2 percent chance of a tornado within 25 miles of a point and a 5 percent chance of damaging thunderstorm winds or wind gusts 50 knots or greater within 25 miles of a point (figures 8 and 9). The SPC Day 1 Convective Outlook issued at 1111 EST (valid before the accident flight departed) had a similar forecast for the accident site. The SPC Day 1 Convective Outlook text follows figure 9.

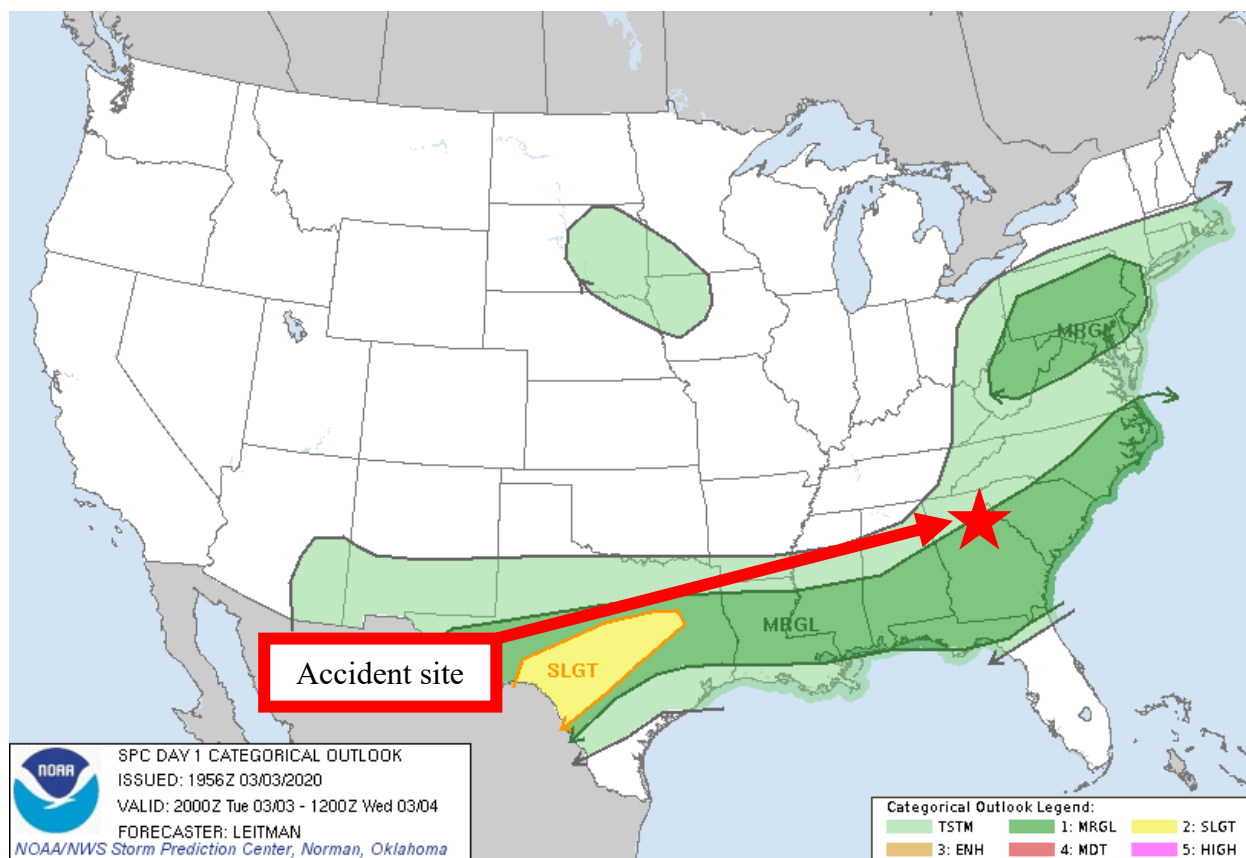


Figure 7 – SPC day 1 Convective Outlook valid at the time of the accident

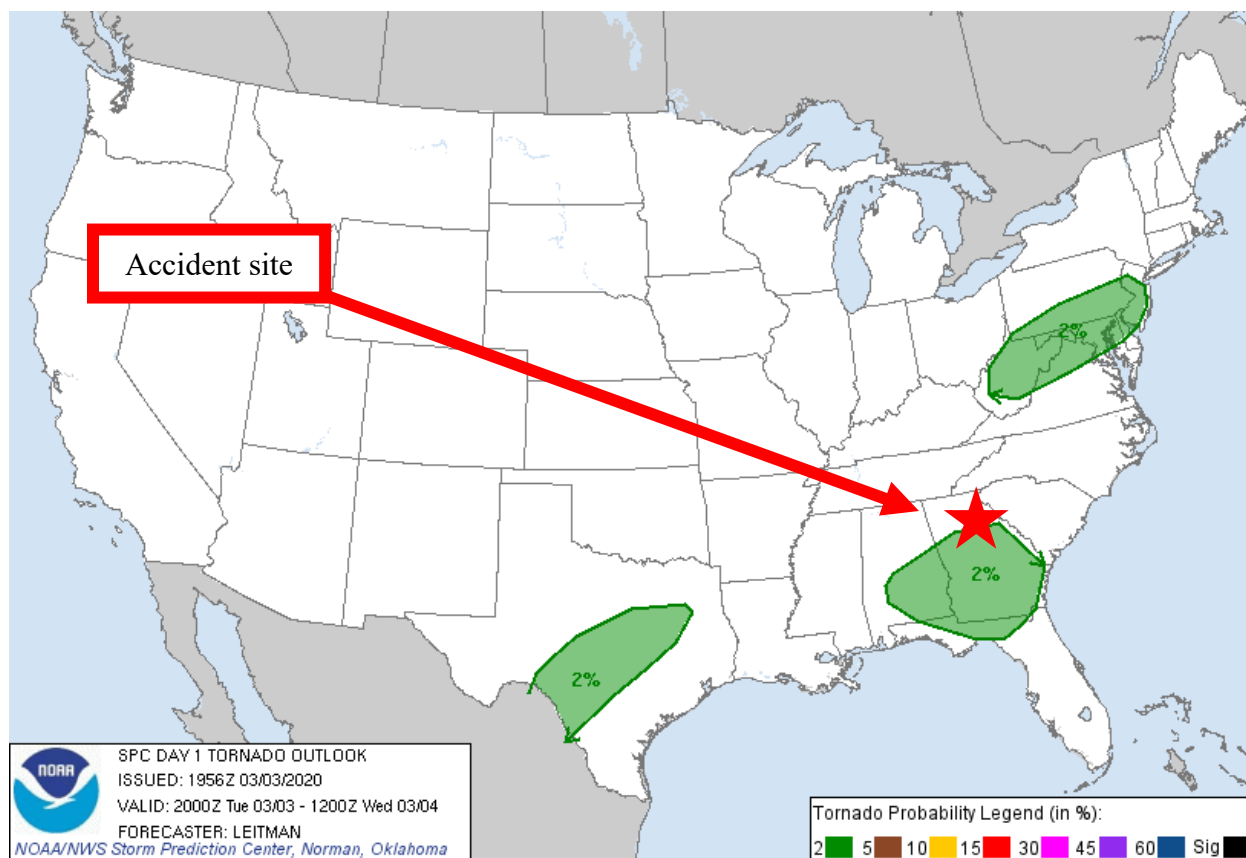


Figure 8 – SPC day 1 Tornado Outlook valid at the time of the accident

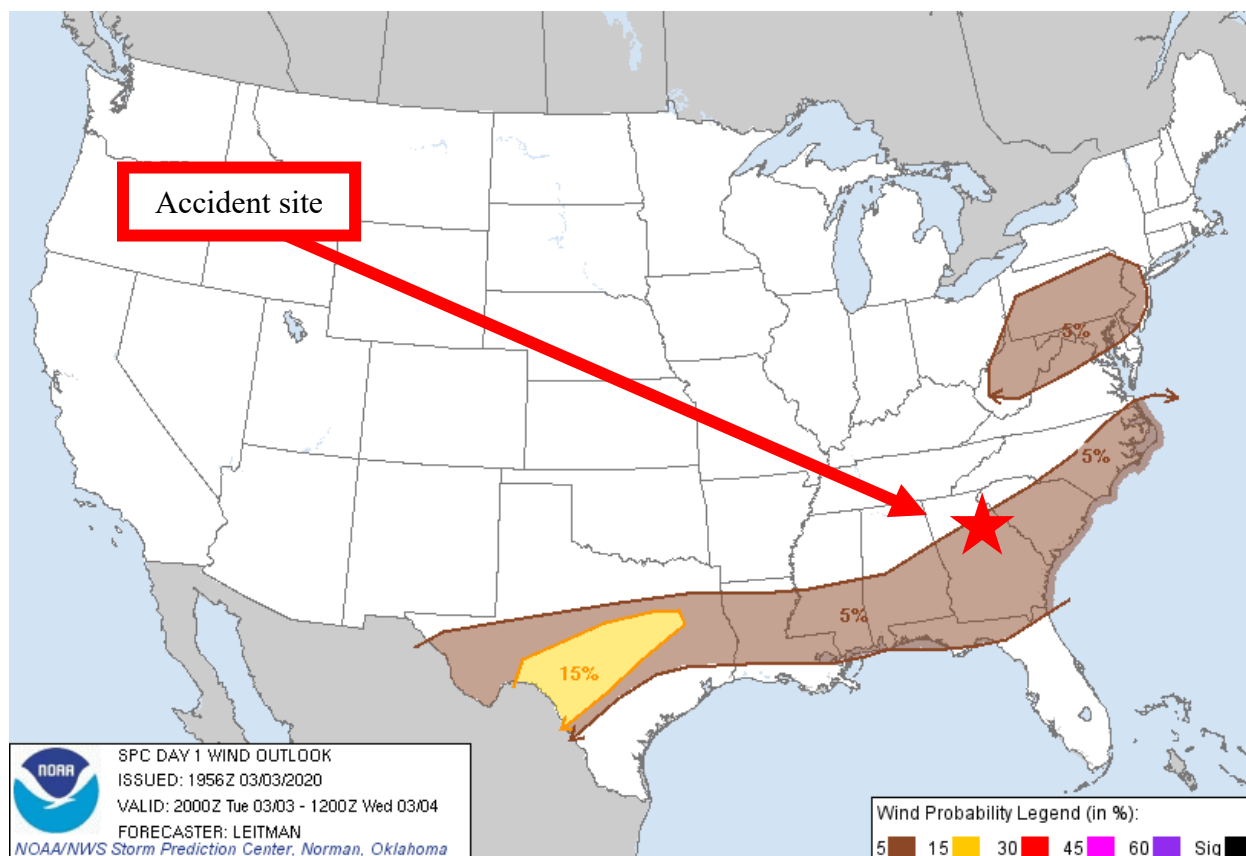


Figure 9 – SPC day 1 Wind Outlook valid at the time of the accident

SPC AC 031956

Day 1 Convective Outlook
 NWS Storm Prediction Center Norman OK
 0156 PM CST Tue Mar 03 2020

Valid 032000Z - 041200Z

...THERE IS A SLIGHT RISK OF SEVERE THUNDERSTORMS ACROSS PARTS OF
 SOUTHWEST AND CENTRAL TX...

...SUMMARY...

Thunderstorms with locally damaging winds will be possible today in
 corridors from West Virginia to New Jersey and in North Carolina.
 Additional severe storms with large hail and damaging winds are
 expected tonight, mainly across central Texas.

...20z Update...

...Southeast States...

Only minor adjustments have been made to the previous outlook. The
 Marginal risk area has been trimmed across parts of northern GA into
 Upstate SC/central NC based on latest surface observations of the
 effective wedge front and/or rain-cooled boundary layer. Further
 south, portions of the FL Peninsula/far northern FL and the GA/SC
 coast have been added to the Marginal risk area based on latest

hi-res guidance. CAMs, along with the 18z RAP indicate storms developing near a warm front over the Gulf, offshore from the eastern FL Panhandle and developing east/northeast along the boundary late in the period. These storms could produce hail. Additionally, if they are able to interact with the boundary and become surface-based, a tornado cannot be ruled out.

Otherwise, the remainder of the forecast is on track.

..Leitman.. 03/03/2020

.PREV DISCUSSION... /ISSUED 1011 AM CST Tue Mar 03 2020/

A complex convective day is forecast across the nation, with several areas having at least a low risk of damaging wind gusts. A more substantial and organized risk of severe storms will materialize after dark across central and southwest TX.

...TX...

A relatively deep upper low is moving across northwest Mexico. Increasingly strong southeasterly low-level winds will help to transport Gulf moisture into southwest TX, with MLCAPE values around 1000 J/kg after 00z. Large-scale lift ahead of this feature will help to initiate scattered thunderstorms after dark across southwest TX, with activity spreading eastward into central TX overnight. Model guidance suggests a mix of cellular and linear modes will occur, capable of large hail and damaging winds. This threat may persist through much of the night.

...WV into NJ...

Water vapor imagery shows a fast-moving shortwave trough over KY. This feature will track eastward across the Mid-Atlantic region through the day. Considerable cloud cover and dewpoints only in the 40s to lower 50s will greatly limit the amount of destabilization in this area, with afternoon MLCAPE values below 500 J/kg. Nevertheless, strong forcing will likely result in a cluster of fast-moving showers and thunderstorms. Given the weak thermodynamics and presentation in 12z CAMs, will maintain only MRGL risk but re-evaluate area at 20z update.

...NC/SC...

The tail end of the aforementioned trough moving through the Mid-Atlantic region will affect the Carolinas later today. As the leading edge of the forcing overspreads a more moist and unstable air mass over eastern NC, a majority of models suggest that a line of thunderstorms will form. A few of these storms may sufficiently intensify to produce gusty/damaging wind gusts.

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NOTE: THE NEXT DAY 1 OUTLOOK IS SCHEDULED BY 0100Z

3.0 Surface Observations

The area surrounding the accident site was documented using official Meteorological Aerodrome Reports (METARs) and Specials (SPECIs). The following observations were taken from standard code and are provided in plain language. Figure 10 is a local sectional chart with the accident site and the closest weather reporting location marked.



Figure 10 – Sectional map of the accident area with the location of the accident site and surface observation site

Athens/Ben Epps Airport (KAHN), Athens, Georgia, had the closest official weather station to the accident site. KAHN had an Automated Surface Observing System (ASOS⁴) whose reports were supplemented by ATC when the tower was in operation⁵. KAHN ASOS site was located 10 miles northeast of the accident site, at an elevation of 813 ft, and had a 5° westerly magnetic variation⁶. The following observations were taken and disseminated during the times surrounding the accident:⁷

[1551 EST] METAR KAHN 032051Z 31012G20KT 4SM -RA SCT025 BKN031 BKN037
20/16 A2981 RMK AO2 RAB48 SLP091 P0000 60000 T02000156 53002=

[1553 EST] SPECI KAHN 032053Z 29010G20KT 1 3/4SM +RA SCT023 BKN029 BKN037
19/15 A2980 RMK AO2 P0001 T01890150=

⁴ ASOS – Automated Surface Observing System is equipped with meteorological instruments to observe and report wind, visibility, ceiling, temperature, dewpoint, altimeter, and barometric pressure.

⁵ Between 0800 and 2000 local time.

⁶ Magnetic variation – The angle (at a particular location) between magnetic north and true north. Latest measurement taken from <https://skyvector.com/>

⁷ The bold sections in this NWS product and the rest of the products in this report are intended to highlight the sections that directly reference the weather conditions that affected the accident location around the accident time. The local times in this section next to the METARs are provided for quick reference between UTC and local times around the accident time.

[1556 EST] SPECI KAHN 032056Z 28007G20KT 1 1/4SM +RA SCT023 BKN032 BKN060
18/15 A2979 RMK AO2 P0011 T01780150=

[1602 EST] SPECI KAHN 032102Z 26004KT 2 1/2SM -RA FEW023 BKN032 BKN060
18/15 A2978 RMK AO2 P0011 T01830150=

***[1606 EST] SPECI KAHN 032106Z 30008KT 10SM BKN025 BKN032 OVC060 18/15
A2979 RMK AO2 RAE05 P0011 T01830150=***

ACCIDENT TIME 1634 EST

***[1643 EST] SPECI KAHN 032143Z 25004KT 10SM FEW029 SCT120 19/16 A2980
RMK AO2 RAE05B15E25 P0011 T01890156=***

[1651 EST] METAR KAHN 032151Z 00000KT 10SM FEW029 BKN120 19/16 A2980
RMK AO2 RAE05B15E25 SLP090 P0011 T01890156=

KAHN weather at 1606 EST, wind from 300° at 8 knots, 10 miles visibility or greater, broken ceiling at 2,500 ft above ground level (agl), broken clouds at 3,200 ft agl, overcast skies at 6,000 ft agl, temperature of 18°Celsius (C), dew point temperature of 15°C, and an altimeter setting of 29.79 inches of mercury. Remarks: automated station with a precipitation discriminator, rain ended at 1605 EST, 0.11 inches of precipitation since 1553 EST, temperature 18.3°C, dew point temperature 15.0°C.

KAHN weather at 1643 EST, wind from 250° at 4 knots, 10 miles visibility or greater, few clouds at 2,900 ft agl, scattered clouds at 12,000 ft agl, temperature of 19°C, dew point temperature of 16°C, and an altimeter setting of 29.80 inches of mercury. Remarks: automated station with a precipitation discriminator, rain ended at 1605 EST, rain began at 1615 EST, rain ended at 1625 EST, 0.11 inches of precipitation since 1553 EST, temperature 18.9°C, dew point temperature 15.6°C.

A review of the raw observations from KAHN prior to the accident indicated IFR⁸ conditions due to visibility with heavy rain, but reported VFR conditions at the time of the accident.

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

* By definition, IFR is a ceiling less than 1,000 ft agl and/or visibility less than 3 miles while LIFR is a sub-category of IFR.

**By definition, VFR is a ceiling greater than or equal to 3,000 ft agl and visibility greater than 5 miles while MVFR is a sub-category of VFR.

4.0 Upper Air Data

A High-Resolution Rapid Refresh (HRRR)⁹ model sounding was created for the accident site for 1700 EST with station elevation of 787 ft.¹⁰ The 1700 EST HRRR sounding was plotted on a standard Skew-T Log P diagram¹¹ with the derived stability parameters included in figure 11 with data from the surface to 600-hPa (or approximately 14,000 ft msl). These data were analyzed using the RAOB¹² software package. The sounding depicted the lifted condensation level (LCL)¹³ at 1,299 ft agl, the level of free convection (LFC)¹⁴ at 1,466 ft agl, and the convective condensation level (CCL)¹⁵ at 2,658 ft agl. The freezing level was located at 10,797 ft msl. The precipitable water value was 1.10 inches. The mean storm motion was from 298° at 44 knots.

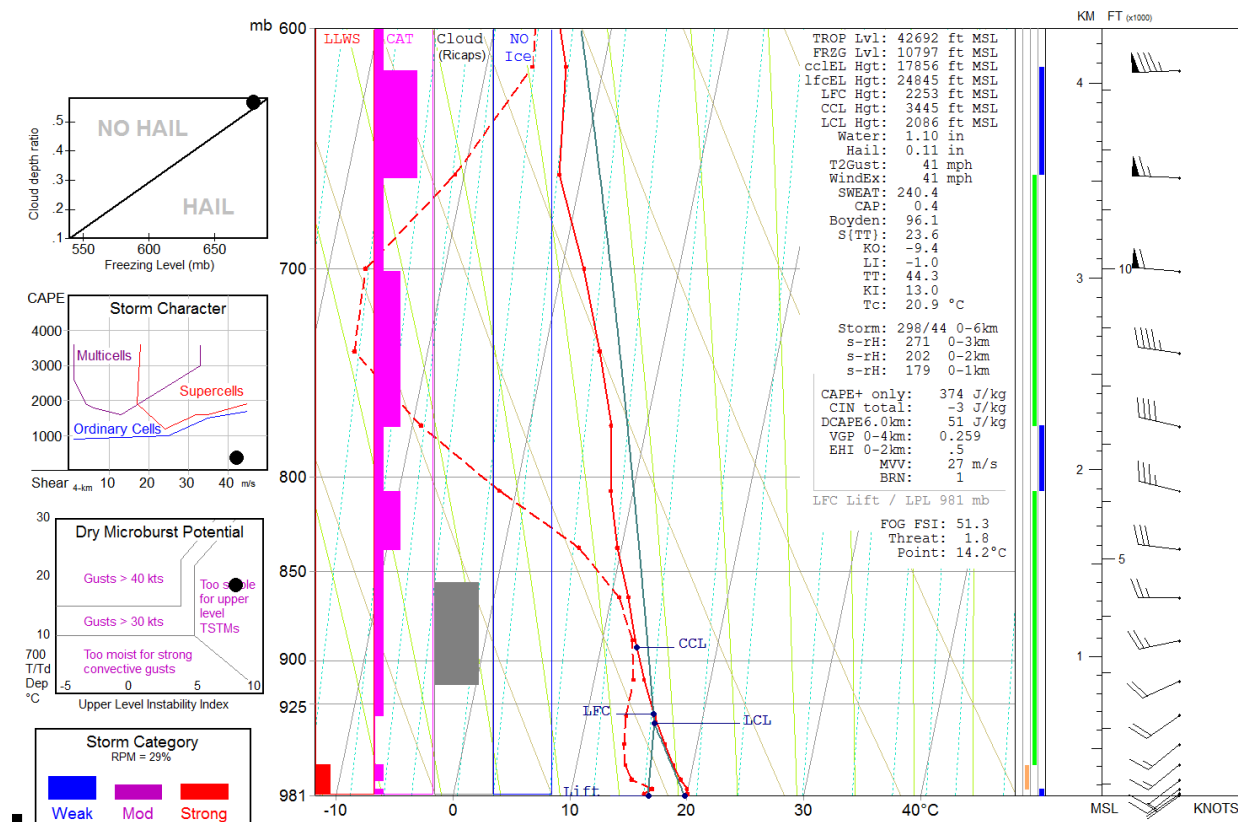


Figure 11 – 1700 EST HRRR sounding

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: <https://ready.arl.noaa.gov/READYamet.php>

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 Environmental Research Services, Matamoras, Pennsylvania.

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.

The 1700 EST HRRR sounding indicated a conditionally unstable environment. The sounding provided 374 Joules/kilogram (J/kg) of CAPE¹⁶ were indicated on the sounding and the maximum vertical velocity (MVV) for this atmosphere was calculated as 27 meters/second (about 5,315 ft per minute).¹⁷ Given the environment, RAOB indicated that ordinary rain shower cells development was possible with no hail or severe thunderstorm activity (wind, tornadoes, hail, etc...) likely. Downdraft CAPE (DCAPE; 6 kilometers agl)¹⁸ was measured at 51 J/kg. If rain showers or thunderstorms formed in this environment, the 1700 EST HRRR sounding indicated that the strongest wind speeds possible at the surface (due to, for example, a microburst, outflow boundary, or gust front) would have been 41 mph (30 knots) according to the WindEx and T2Gust parameters.

The 1700 EST HRRR sounding wind profile indicated a surface wind from 232° at 5 knots with the wind veering¹⁹ to the west through 14,000 ft. The wind speed increased to 30 knots by 5,000 ft msl and 85 knots by 13,500 ft. RAOB indicated the possibility of light low-level wind shear (LLWS) outside of a rain shower or thunderstorm activity between the surface and 1,500 ft msl. At the accident airplane's altitude of approximately 6,000 ft the sounding indicated a west wind at 34 knots with a temperature of 8.1°C and a relative humidity of 51%.

5.0 Satellite Data

The 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) at wavelengths of 0.64 microns (μm) and 10.3 μm, respectively, were retrieved for the period from 1200 EST through 1900 EST and reviewed, and the closest images to the time of the accident were documented.

Figures 12 and 13 present the GOES-16 visible imagery at 1630 and 1640 EST at 2X magnification with the accident site highlighted with a red square. The visible imagery indicated an extensive layer of cloud cover with cumuliform cloud cover closest to the ground and cirriform cloud cover above. The cloud cover moving from west to east (attachment 1) with the cumuliform cloud cover growing and expanding in areal extent through the period. There were no Geostationary Lightning Mapper (GLM)²⁰ lightning flashes near the accident site at the accident time (attachment 1).

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.

¹⁸ The DCAPE can be used to estimate the potential strength of rain-cooled downdrafts within thunderstorm convection, and is similar to CAPE. Larger DCAPE values are associated with stronger downdrafts.

¹⁹ A clockwise turning of the wind with height in the northern hemisphere.

²⁰ <https://weather.msfc.nasa.gov/cgi-bin/sportPublishData.pl?dataset=goeseastglm&product=group&loc=conus> and <https://nasasporttraining.wordpress.com/total-lightning-training/>

Figure 14 presents the GOES-16 infrared imagery from 1640 EST at 4X magnification with the accident site highlighted with a red square. Inspection of the infrared imagery indicated cloud cover over the accident site. The lower brightness temperatures (blue and green colors; higher cloud tops) were located above and to the southwest through east of the accident site. Based on the brightness temperatures above the accident site and the vertical temperature profile provided by the 1700 EST HRRR sounding, the approximate cloud-top heights over the accident site were 22,000 ft at 1640 EST (254 Kelvin). It should be noted these figures have not been corrected for any parallax error.

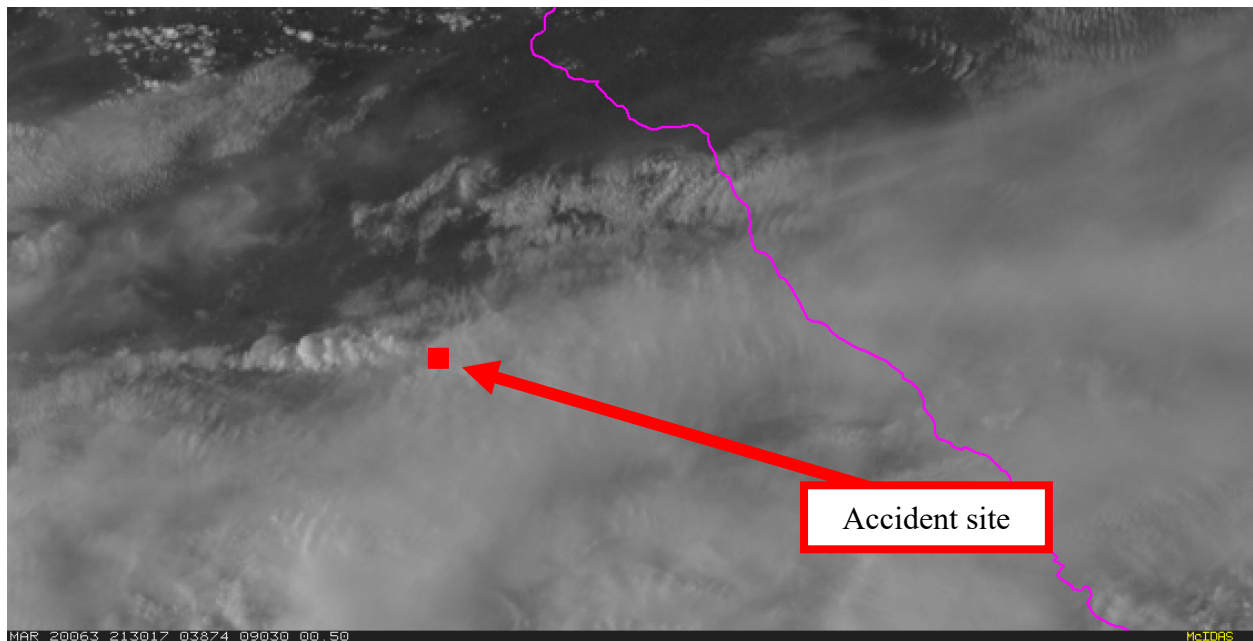


Figure 12 – GOES-16 visible image at 1630 EST

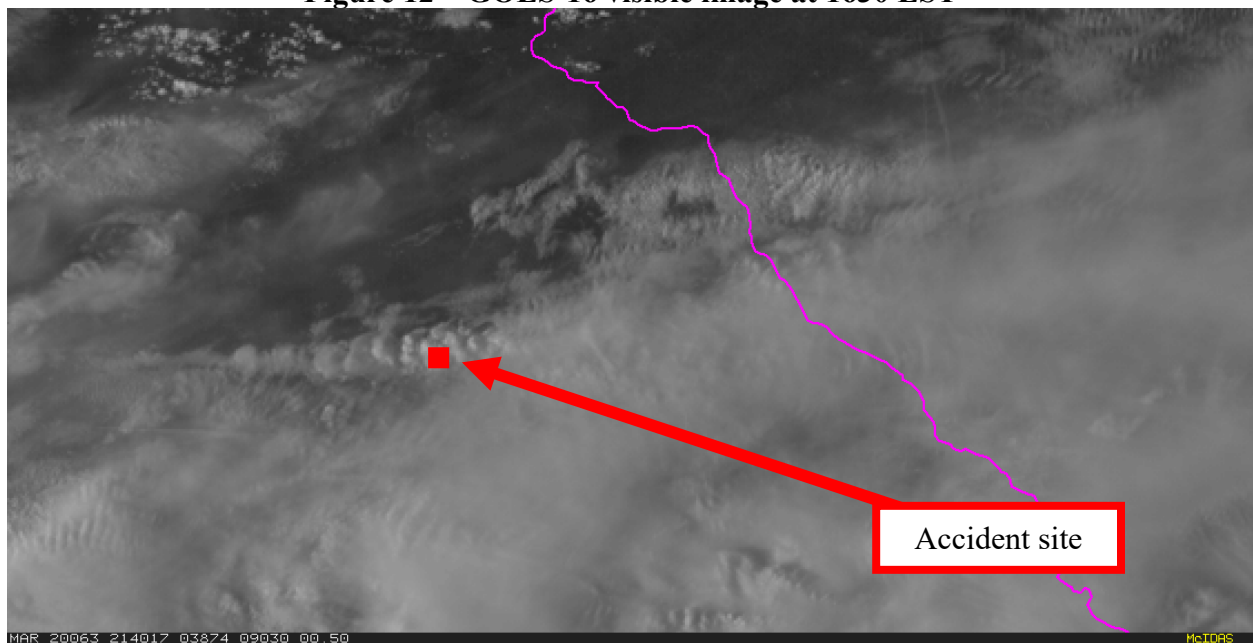


Figure 13 – GOES-16 visible image at 1640 EST

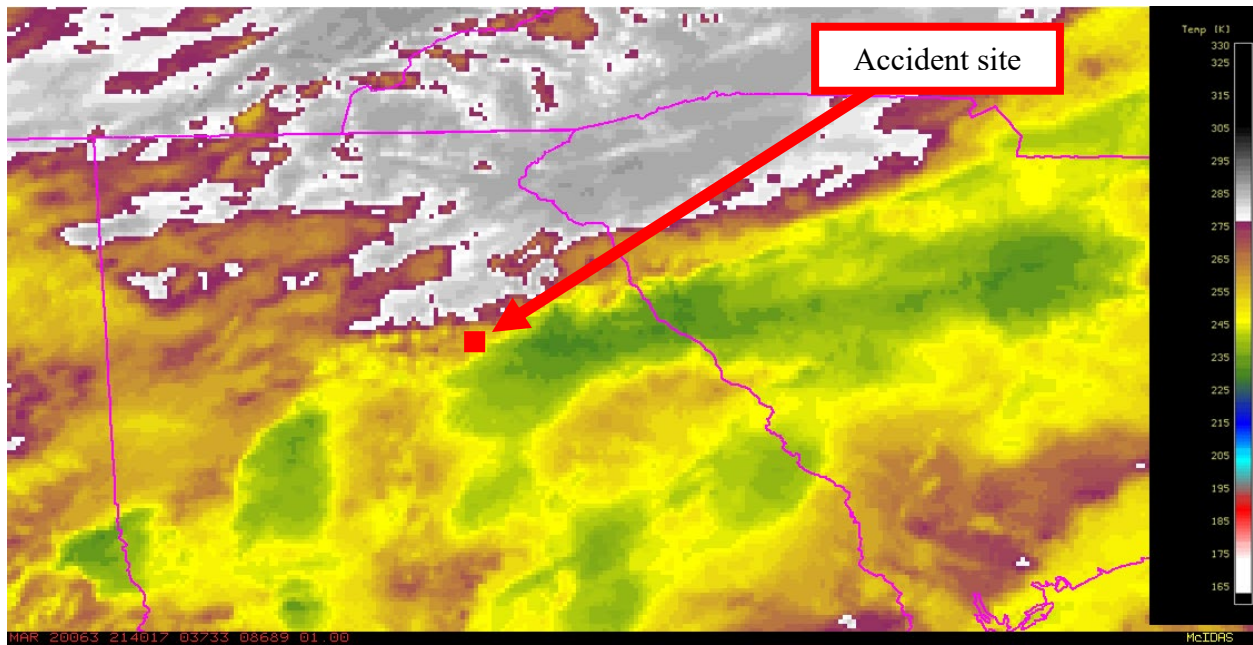


Figure 14 – GOES-16 infrared image at 1640 EST

6.0 Regional Radar Imagery Information

A regional view of the NWS National Composite Radar Mosaic is included as figure 15 for 1635 EST with the approximate location of the accident site marked within a red circle. The image depicted an east-to west band of echoes east of Atlanta and extending south of Athens, to near Columbia, South Carolina. The image depicted echoes from 40 to 55 decibels (dBZ²¹) in the line and in the vicinity of the accident site.

²¹ 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.

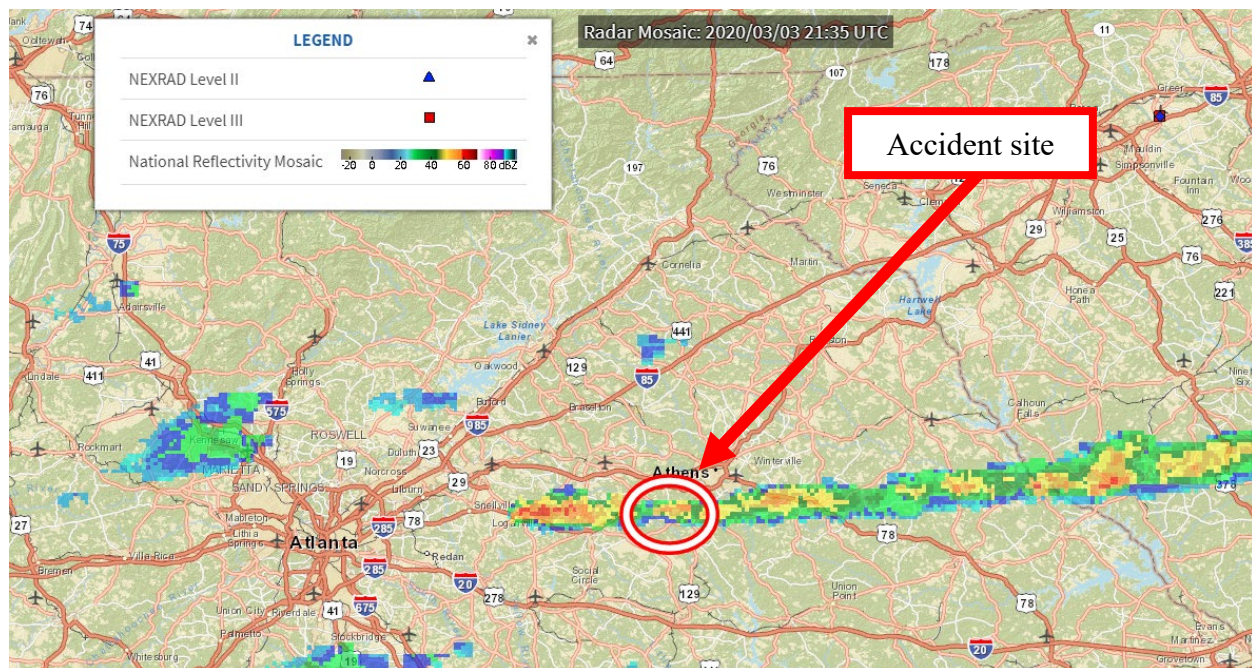


Figure 15 – Regional Composite Reflectivity image for 1635 EST

7.0 Radar Imagery Information

The closest NWS Weather Surveillance Radar-1988, Doppler (WSR-88D)²² to the accident site was Atlanta, Georgia (KFFC) located 62 miles southwest of the accident site. Level II and level III archive radar data was obtained from the NCEI utilizing the NEXRAD Data Inventory Search and displayed using the NOAA's Weather and Climate Toolkit software.

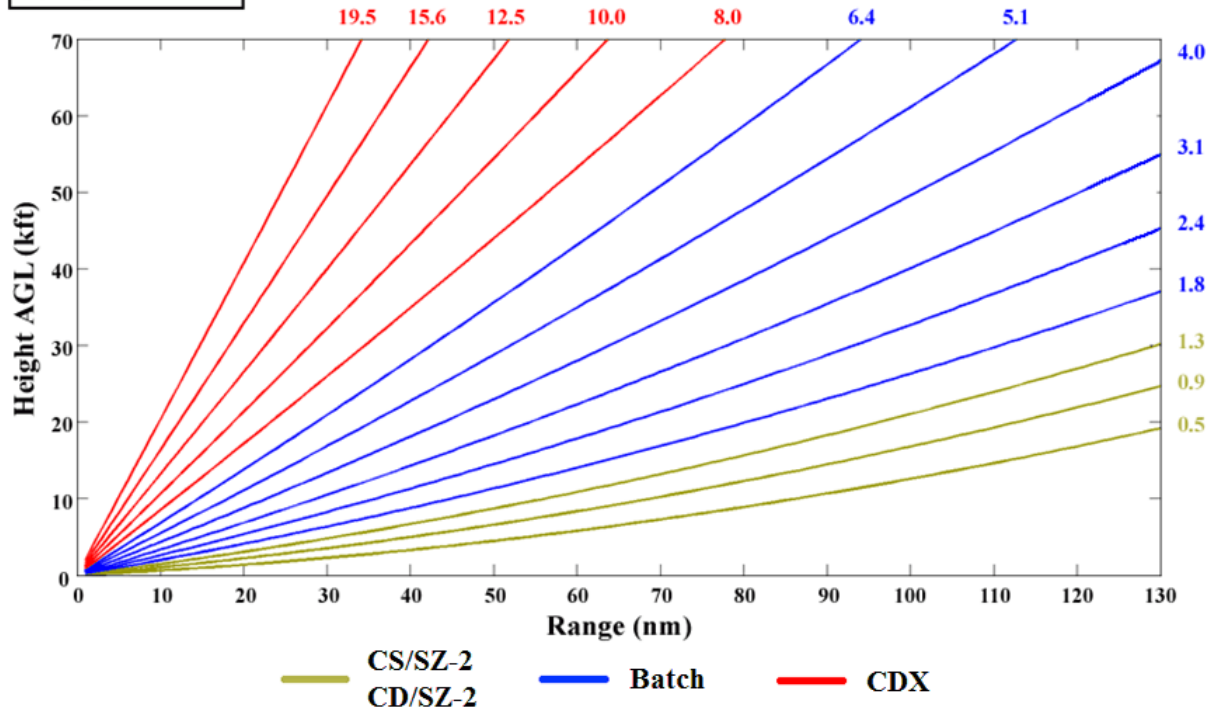
7.1 Volume Scan Strategy

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. Products that require data from multiple elevation scans are not available until the end of the five to ten minute volume scan.

The WSR-88D operates in several different scanning modes, identified as Mode A and Mode B. Mode A is the precipitation scan and has three common scanning strategies. The most common is where the radar makes 14 elevation scans from 0.5° to 19.5° every four and a half minutes. This particular scanning strategy is documented as volume coverage pattern 212 (VCP-212). Mode B is the clear-air mode, where the radar makes 5 elevation scans during a ten-minute period. During the period surrounding the accident, the KFFC WSR-88D radar was operating in the precipitation mode VCP-212. 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.

²² 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.

VCP 212



VCP-212 Precipitation Mode Scan Strategy²³

7.2 Beam Height Calculation

Assuming standard refraction²⁴ of the KFFC WSR-88D radar beam with the antenna elevation at 972 ft, and considering a beamwidth²⁵ of 0.95°, the following table shows the approximate heights for the radar beam center, base and top for antenna elevations over the accident site. These heights have been rounded to the nearest 10 ft.

ANTENNA ELEVATION	BEAM CENTER	BEAM BASE	BEAM TOP
KFFC 0.5°	7,040 ft	3,980 ft	10,100 ft

²³ 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)

²⁴ Standard Refraction in the atmosphere is when the temperature and humidity distributions are approximately average, and values set at the standard atmosphere.

²⁵ Beamwidth - the angular separation between the half power points on the antenna radiation pattern, where the gain is one half the maximum value.

Based on the radar height calculations, the elevation scans from KFFC listed in the above table depicted the conditions between 3,980 ft and 10,100 ft msl over the accident site and these scans “saw” the closest altitudes to the accident aircraft’s flight level before the descent in altitude.^{26,27}

7.3 Reflectivity

Reflectivity is the measure of the efficiency of a target in intercepting and returning radio energy. With hydrometeors²⁸ 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. FAA Advisory Circular AC 00-24C²⁹, “Thunderstorms,” dated February 19, 2013, 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 but less than 50 dBZ, inclusive. Finally, any dBZ values above 50 dBZ shall be described as “extreme.”

7.4 Base Reflectivity and Lightning Data

Figures 16 through 21 present the KFFC WSR-88D base reflectivity images for the 0.5° elevation scans initiated at 1614:35, 1620:09, 1625:42, 1628:20, 1631:15, and 1633:53 EST, respectively, with a resolution of 0.5° X 250 m. Reflectivity values between 45 and 55 dBZ were located above the accident site at the accident time and indicative of heavy to very heavy rainfall (section 7.3). The band of rain showers was moving southeastward with time and the “gaps” in the rain shower band were filling as more rain showers developed between 1614 and 1634 EST (attachment 2).

There were no lightning flashes³⁰ near the accident site at the accident time.³¹

²⁶ Flight Level – A Flight Level (FL) is a standard nominal altitude of an aircraft, in hundreds of ft. This altitude is calculated from the International standard pressure datum of 1013.25 hPa (29.92 inHg), the standard sea-level pressure, and therefore is not necessarily the same as the aircraft's true altitude either above mean sea level or above ground level.

²⁷ For more information please see air traffic control (ATC) data located in the docket of this accident.

²⁸ 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.

²⁹

https://www.faa.gov/regulations_policies/advisory_circulars/index.cfm/go/document.information/documentID/1020774

³⁰ 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.

³¹ A review of Earth Networks Total Lightning network was done.

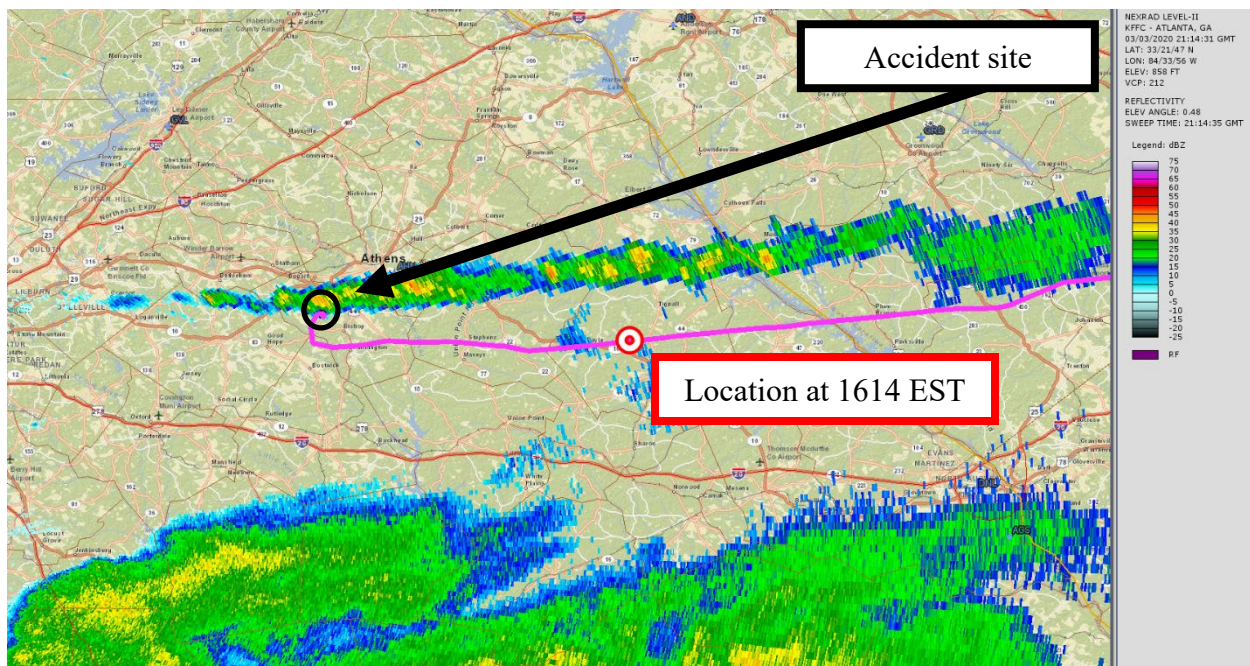


Figure 16 – KFFC WSR-88D reflectivity for the 0.5° elevation scan initiated at 1614:35 EST with the accident site marked with black circle and the accident flight track in pink

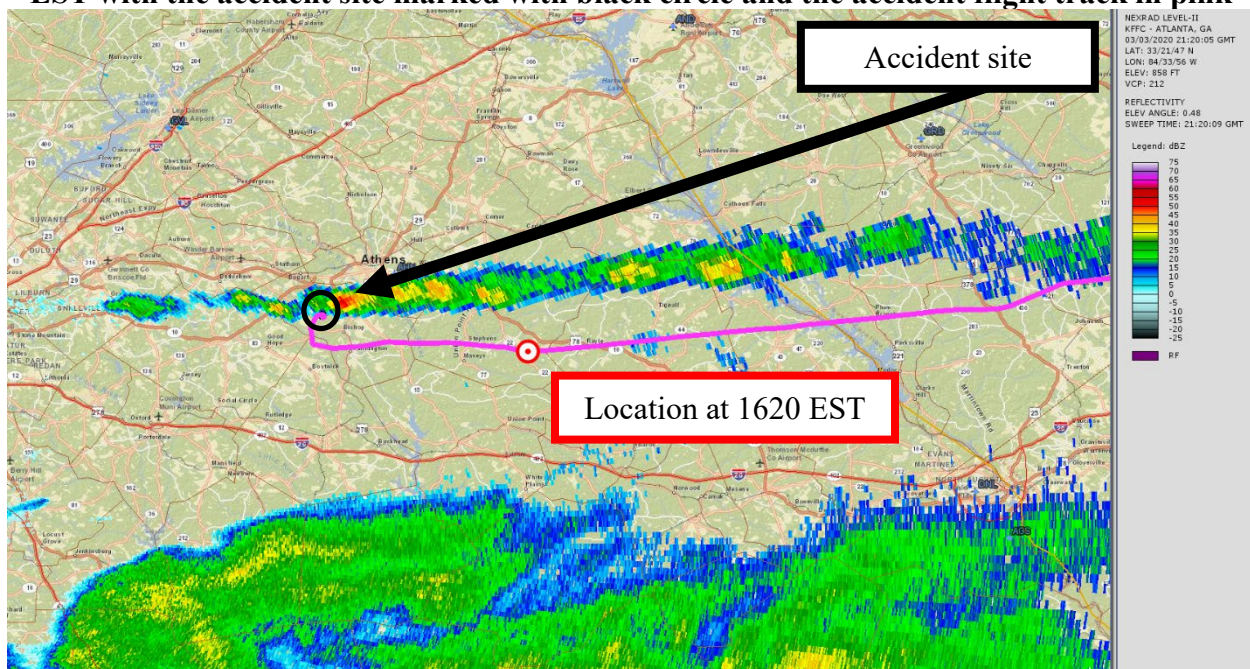


Figure 17 – KFFC WSR-88D reflectivity for the 0.5° elevation scan initiated at 1620:09 EST with the accident site marked with black circle and the accident flight track in pink

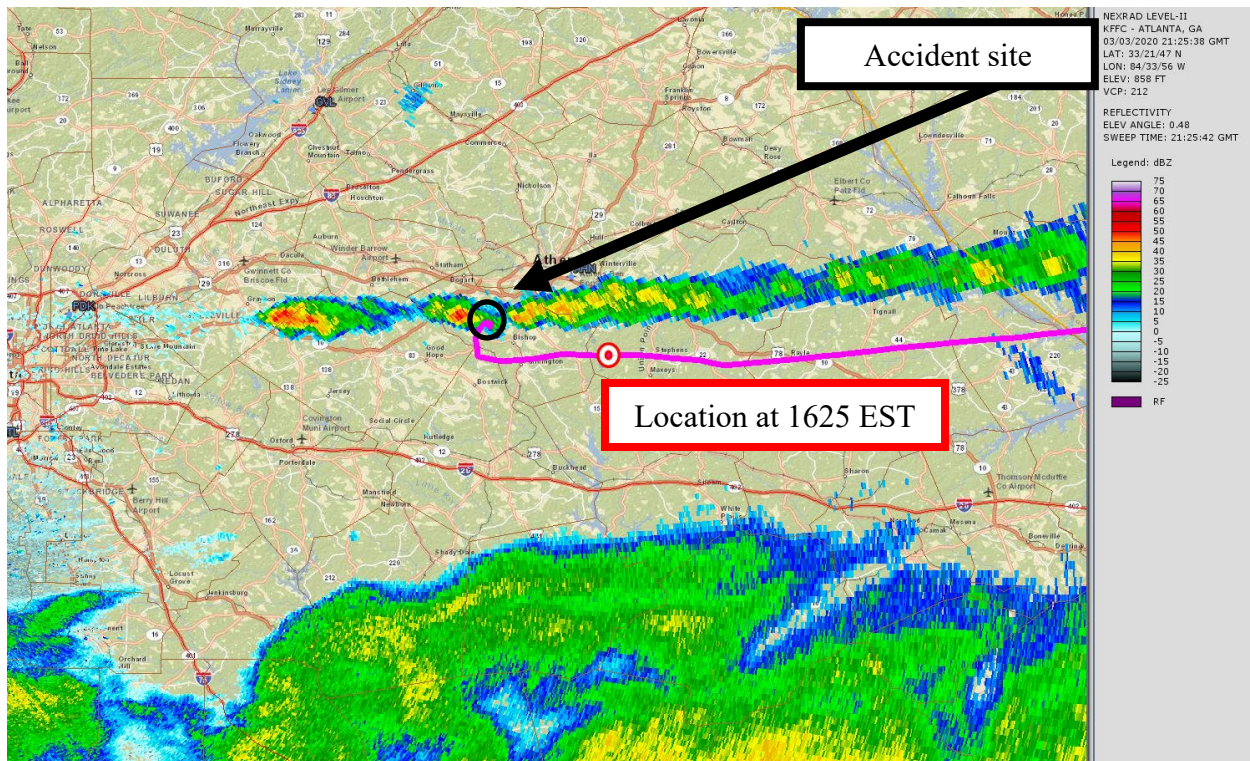


Figure 18 – KFFC WSR-88D reflectivity for the 0.5° elevation scan initiated at 1625:42 EST with the accident site marked with black circle and the accident flight track in pink

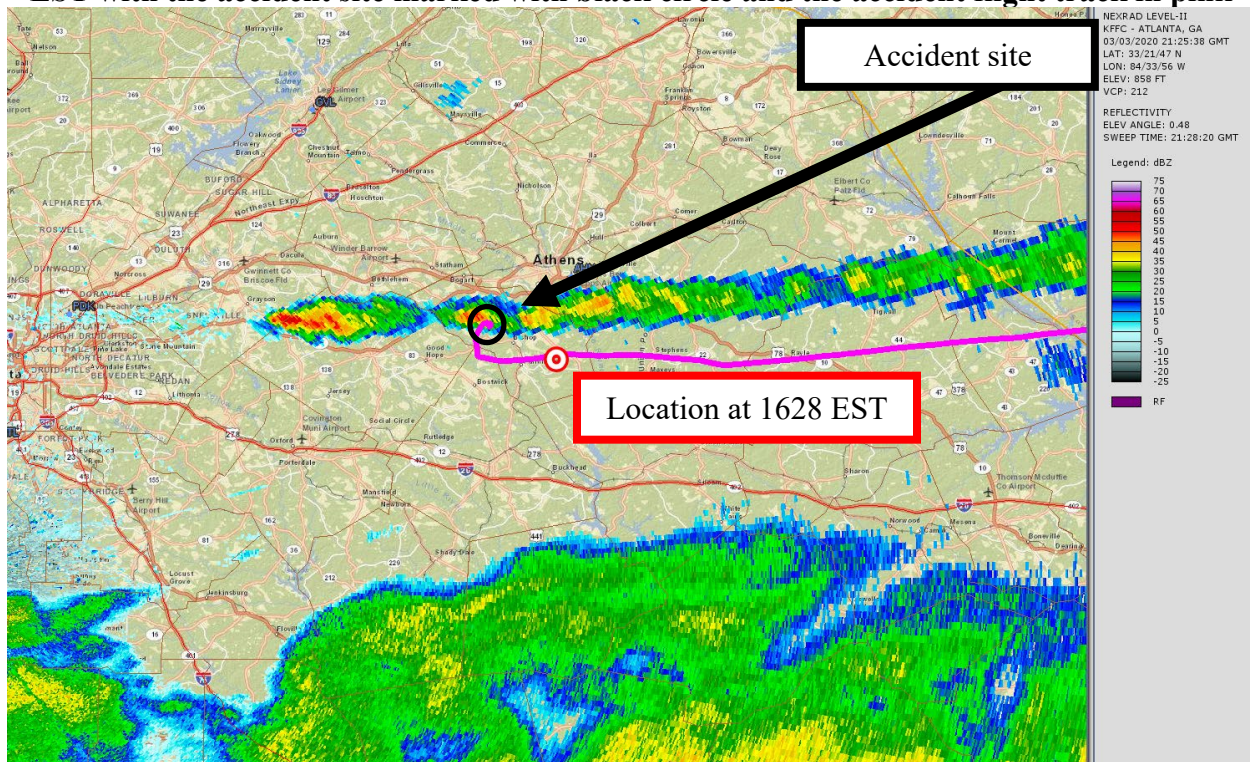


Figure 19 – KFFC WSR-88D reflectivity for the 0.5° elevation scan initiated at 1628:20 EST with the accident site marked with black circle and the accident flight track in pink

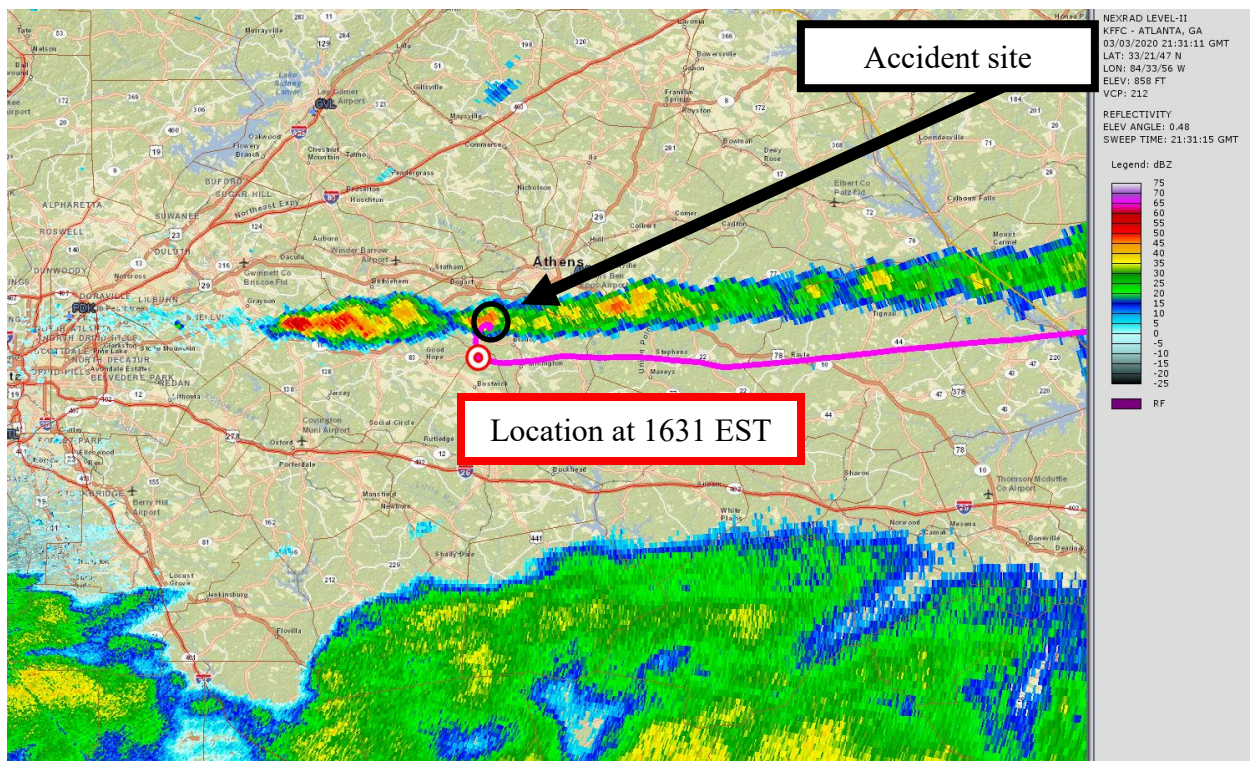


Figure 20 – KFFC WSR-88D reflectivity for the 0.5° elevation scan initiated at 1631:15 EST with the accident site marked with black circle and the accident flight track in pink

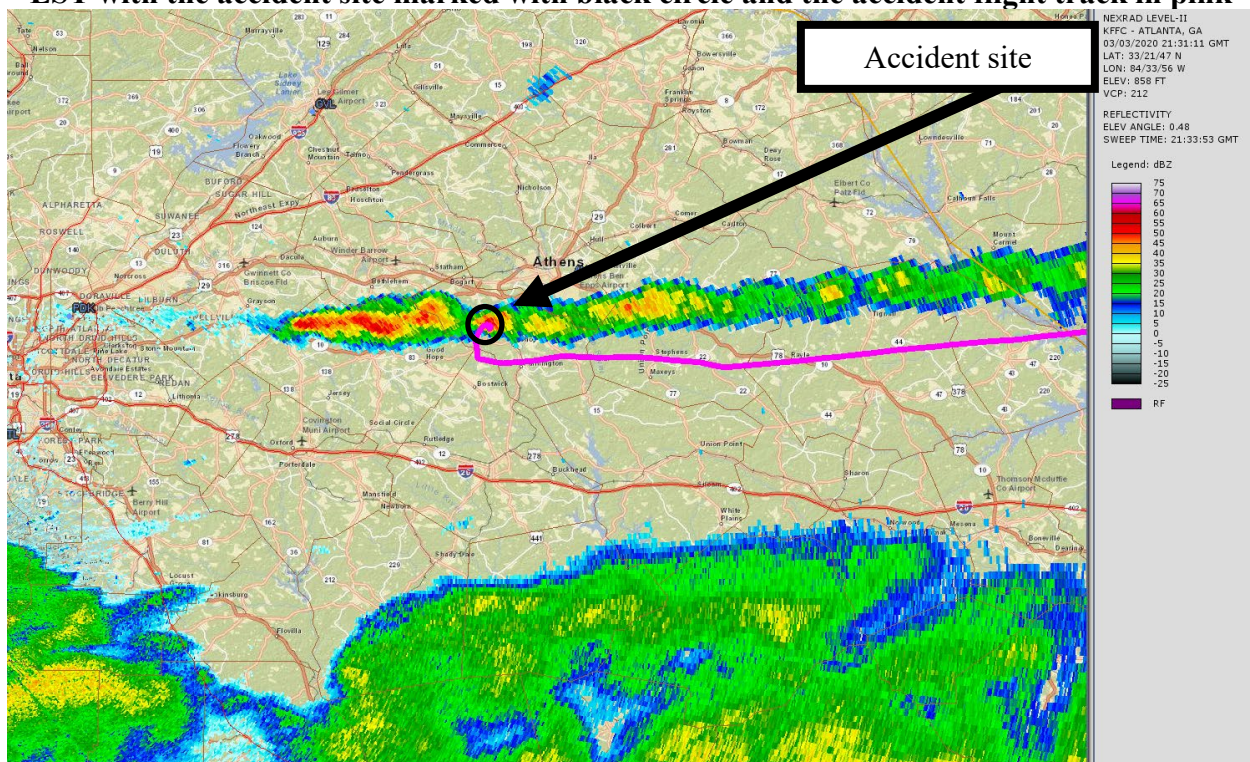


Figure 21 – KFFC WSR-88D reflectivity for the 0.5° elevation scan initiated at 1633:53 EST with the accident site marked with black circle and the accident flight track in pink

8.0 Pilot Reports³²

There were numerous pilot reports (PIREPs) distributed into the national airspace within 75 miles of the accident site from about one hour prior to the accident time to one hour after the accident time and they are reported below for below 18,000 ft msl. The ATC personnel in contact with the accident aircraft requested and received two PIREPs (or ride reports) from other aircraft that had gone in between the rain shower line preceding the accident aircraft³³, however, those PIREPs were not distributed into the national airspace (NAS). Nine additional PIREPs were recorded by A80 but not distributed into the NAS and are included in attachments 3 and 8.

ATL UA /OV ATL135050/TM 2023/FL120/TP B757/TA 27/TB LIGHT CHOP

ATL UA /OV ATL315030/TM 2105/FL130/TP MD88/WV 27003

GYH UA /OV KGYH050004/TM 2124/FL017/TP FA90/SK BKN008-TOP021/WX 10/TA 17/WV 22006

GSP UA /OV GRD135010/TM 2132/FL080/TP SR22/TB MOD

CAE UA /OV 8 S CHATT/TM 2133/FL080/TP SR22/TB MOD TURB

MCN UA /OV MCN/TM 2140/FLDURGD/TP E135/TA 09/IC LGT RIME 110-130

ATL UA /OV ATL045020/TM 2143/FLDURGD/TP CRJ7/TB MOD

SPA UA /OV SPA/TM 2149/FL160/TP E145/TB CONS LGT CHOP/RM ZTLFD

SPA UA /OV SPA/TM 2154/FL150/TP A319/TB CONS LGT OCNL MOD 150-180/RM ZTLFD

ATL UA /OV ATL/TM 2202/FLDURGC/TP B737/SK BASE SCT035

WRB UA /OV MCN320035/TM 2226/FL280/TP B350/TB NEG/RM SMOOTH RIDE ZTLFD

MCN UA /OV MCN/TM 2229/FLDURGD/TP B737/SK BKN060

ATL UUA /OV VPC/TM 2233/FLDURGD/TP BE36/TB MOD-SEV TB/RM NEG INJ OR DAMAGE

9.0 SIGMET

The NWS had Convective Significant Meteorological Information (SIGMET) advisory 66E valid for the accident site at the accident time. SIGMET 66E was issued at 1555 EST and was valid through 1755 EST and warned of an area of thunderstorms with the forecast box moving from 250° at 50 knots with thunderstorm tops to FL280 (figure 22). Previously, SIGMET 62E was issued at 1455 EST valid for the accident site and it warned of an area of thunderstorms with the forecast box moving from 250° at 50 knots with thunderstorm tops to FL330 (figure 23):

³² Only pilot reports with the World Meteorological Organization headers UBSC**, UBTN**, UBNC**, UBAL**, and UBGA** were considered.

³³ For more information please see the ATC factual located in the docket for this accident.

CONVECTIVE SIGMET 66E

VALID UNTIL 2255Z

NC SC GA

FROM 50SW RDU-30NE FLO-10WSW FLO-30ENE ATL-20SSW SPA-50SW RDU

AREA TS MOV FROM 25050KT. TOPS TO FL280.

WSUS31 KPCI 031955

SIGE

MKCE WST 031955

CONVECTIVE SIGMET 62E

VALID UNTIL 2155Z

NC SC GA

FROM 20S GSO-30SSW RDU-FLO-20NE ATL-ODF-20S GSO

AREA TS MOV FROM 25050KT. TOPS TO FL330.

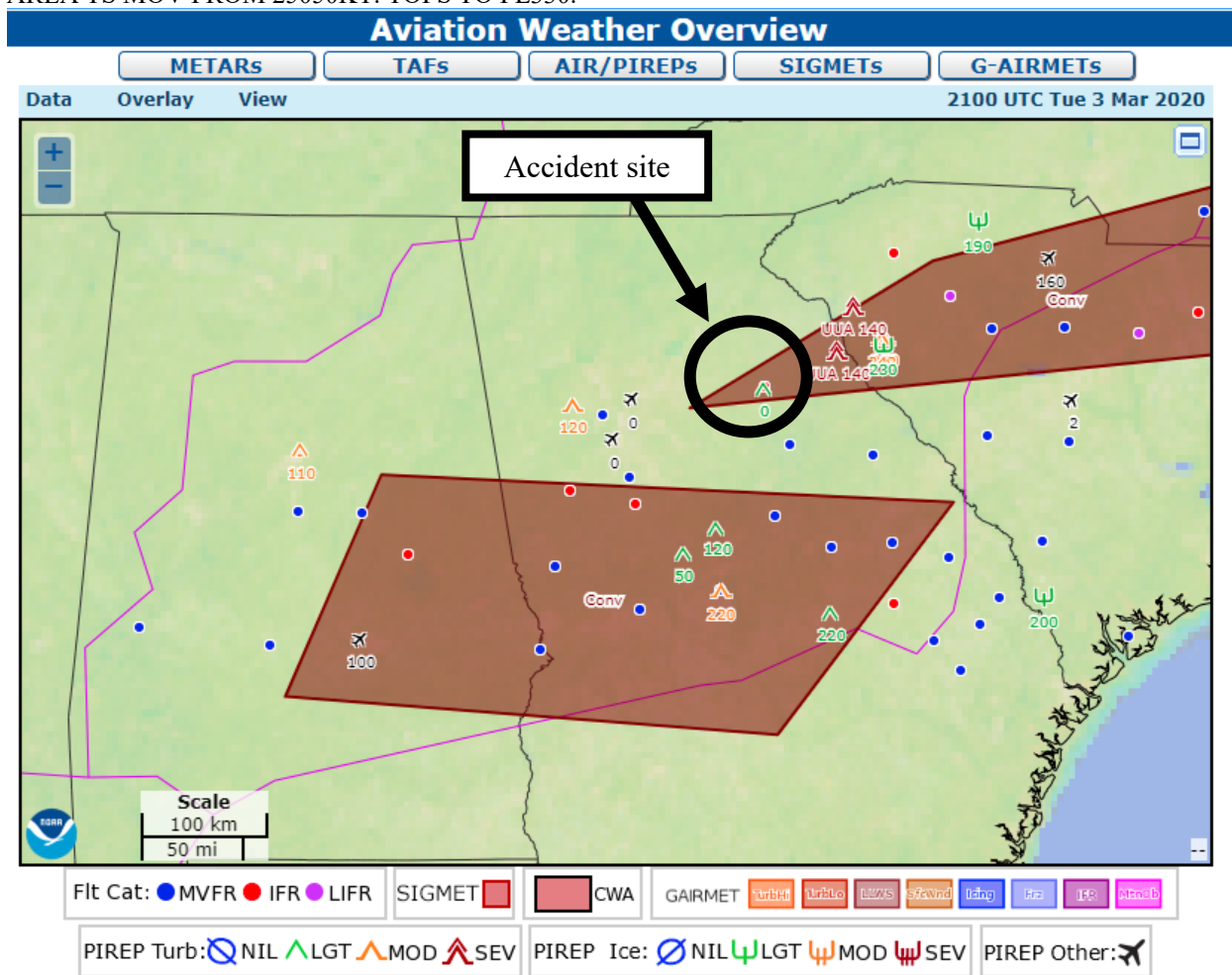


Figure 22 – SIGMETs, PIREPs, and CWAs valid at 1600 EST through the accident time

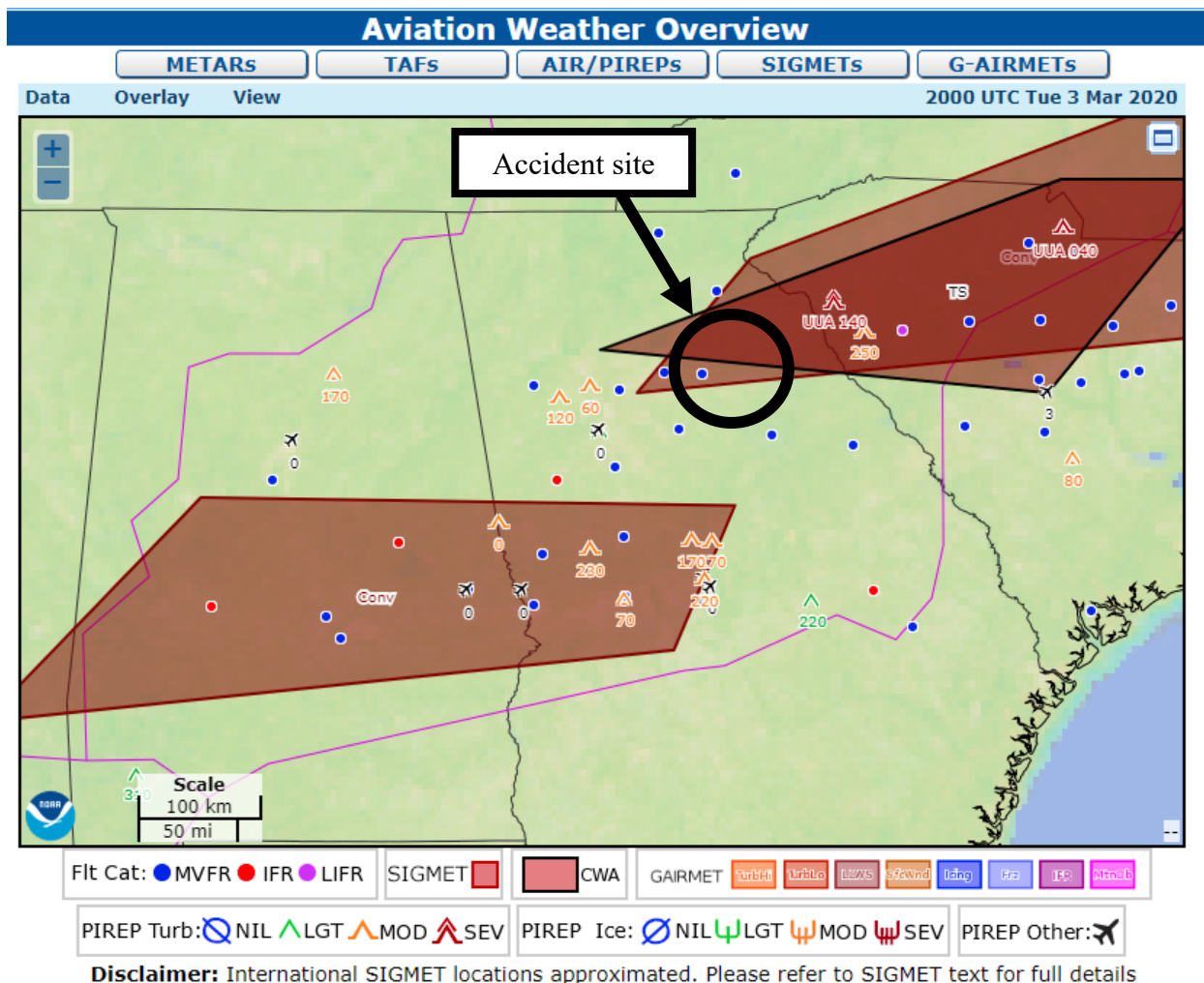


Figure 23 – SIGMETs, PIREPs, and CWAs valid at 1500 EST through 1600 EST

10.0 CWSU Advisories

The Air Route Traffic Control Center Atlanta, Georgia, (ZTL) Center Weather Service Unit (CWSU) was responsible for the region. The ZTL CWSU issued no Meteorological Impact Statements (MIS) for the area prior to the accident. ZTL CWSU issued Center Weather Advisory (CWA) 201 at 1404 EST (before the accident aircraft departed) and was valid until 1510 EST for the accident area (figure 23). The advisory warned of an area of rain showers and thunderstorms with heavy to extreme precipitation and max tops to FL310. The forecast box was expected to move from 260° at 45 knots:

FAUS22 KZTL 031904
 ZTL2 CWA 031905
 ZTL CWA 201 VALID UNTIL 032010
 FROM CLT-60E CLT-CAE-30N ATL-CLT
**AREA SHRA/TS WITH HVY-EXTRM PCPN. MAX TOPS NR FL310. MOVG FM
 26045KT. EXP LTL CHNG IN COVRG/INTST THRU PD.**
 =

11.0 AIRMETs

Airmen's Meteorological Information (AIRMET) advisories Sierra, Tango, and Zulu were valid for the accident site at the accident time. The AIRMETs warned of mountain obscuration by clouds, precipitation, and mist, moderate turbulence below 16,000 ft, and moderate icing between the freezing level³⁴ and FL220:

WAUS42 KPCI 032045

WA2S

-MIAS WA 032045

AIRMET SIERRA UPDT 5 FOR IFR AND MTN OBSCN VALID UNTIL 040300

.
AIRMET IFR...GA FL AND CSTL WTRS
FROM 40WNW PZD TO 40WSW AMG TO 50S TLH TO 130W PIE TO 130ESE LEV
TO 40W CEW TO 50SW PZD TO 40WNW PZD
CIG BLW 010/VIS BLW 3SM PCPN/BR. CONDS DVLPG AFT 21Z. CONDS
CONTG BYD 03Z THRU 09Z.

.
AIRMET IFR...NC SC GA
FROM 20SSW ORF TO 50S ECG TO 20W ILM TO 20E CHS TO 40SE IRQ TO
20SE ODF TO 20ENE CLT TO 40S LYH TO 20SSW ORF
CIG BLW 010/VIS BLW 3SM PCPN/BR. CONDS CONTG BYD 03Z THRU 09Z.

.
AIRMET MTN OBSCN...NC SC GA ME NH VT MA NY PA WV MD VA
FROM 60ESE YQB TO 30W BGR TO CON TO HAR TO CLT TO ATL TO GQO TO
HMV TO 40S HNN TO 30ESE HNN TO 30SW EWC TO JHW TO SYR TO MSS TO
20SSE YSC TO 60ESE YQB
MTNS OBSC BY CLDS/PCPN/BR. CONDS CONTG BYD 03Z THRU 09Z.

.
OTLK VALID 0300-0900Z...IFR SC GA FL AND CSTL WTRS
BOUNDED BY 20SE IRQ-20ENE SAV-40S SAV-30W CRG-CTY-90WSW PIE-210S
CEW-130ESE LEV-40W CEW-50SW PZD-20E LGC-20SE IRQ
CIG BLW 010/VIS BLW 3SM PCPN/BR. CONDS CONTG THRU 09Z.

....

WAUS42 KPCI 032045

WA2T

-MIAT WA 032045

AIRMET TANGO UPDT 4 FOR TURB STG WNDZ AND LLWS VALID UNTIL 040300

.
AIRMET TURB...NC SC GA ME NH VT MA RI CT NY LO NJ PA OH LE WV MD
DC DE VA AND CSTL WTRS
FROM 70NE YYZ TO 110ESE ENE TO 170SE ACK TO 200S ACK TO 160SE
SIE TO 190ESE ECG TO 150SSE ILM TO 40W PZD TO GQO TO HMV TO HNN
TO CVG TO FWA TO 30SE ECK TO 70NE YYZ
MOD TURB BTN 160 AND FL390. CONDS CONTG BYD 03Z THRU 09Z.

.
AIRMET TURB...NC SC GA ME NH VT MA RI CT NY LO NJ PA OH LE WV MD
DC DE VA AND CSTL WTRS
FROM YSC TO 80ENE ACK TO 140ESE SIE TO 110E ILM TO 80SE SAV TO
30NNW PZD TO GQO TO HMV TO HNN TO CVG TO 40NNE ERI TO YOW TO YSC
MOD TURB BLW 160. CONDS CONTG BYD 03Z THRU 09Z.

³⁴ Freezing level between 6,000 and 13,000 ft msl.

AIRMET STG SFC WND...NC SC MA RI NY NJ MD DE VA AND CSTL WTRS
FROM 30SSW HTO TO 190SE ACK TO 160SE SIE TO 190ESE ECG TO 140SSE
ILM TO 90S ILM TO 70E ECG TO 30SSW HTO
SUSTAINED SURFACE WINDS GTR THAN 30KT EXP. CONDS CONTG BYD 03Z
THRU 09Z.

.
LLWS POTENTIAL...NC SC VT MA CT NY LO NJ PA WV MD DC DE VA AND
CSTL WTRS
BOUNDED BY 20WSW MSS-20NNW MPV-70S HTO-90SE ECG-30W ILM-30N ODF-
HNV-20ENE EWC-20WSW MSS
LLWS EXP. CONDS DVLPG 00-03Z. CONDS CONTG BYD 03Z ENDG 06-09Z.

.
OTLK VALID 0300-0900Z
AREA 1...TURB NC SC GA ME NH VT MA RI CT NY LO NJ PA OH LE WV MD
DC DE VA AND CSTL WTRS
BOUNDED BY 90WSW YOW-100SSE BGR-180SE ACK-160SE SIE-190ESE ECG-
130SSE ILM-40SSE LGC-GQO-HMV-HNN-CVG-FWA-30SE ECK-90WSW YOW
MOD TURB BTN 160 AND FL390. CONDS CONTG THRU 09Z.

.
AREA 2...TURB NC SC GA ME NH VT MA RI CT NY LO NJ PA WV MD DC DE
VA AND CSTL WTRS
BOUNDED BY YSC-60ESE BGR-100ESE ACK-160SE SIE-190ESE ECG-130SSE
ILM-80SE SAV-20SE LGC-30ENE HNV-40W PSB-YOW-YSC
MOD TURB BLW 160. CONDS CONTG THRU 09Z.

.
AREA 3...STG SFC WND...NC ME NH MA RI NY NJ MD DE VA AND CSTL WTRS
BOUNDED BY 110SE BGR-200SE ACK-160SE SIE-190ESE ECG-140ESE ILM-
60SE SBY-40SSE HTO-20SW ACK-110SE BGR
SUSTAINED SURFACE WINDS GTR THAN 30KT EXP. CONDS CONTG THRU 09Z.

....

WAUS42 KKCI 032045
WA2Z
-MIAZ WA 032045
AIRMET ZULU UPDT 5 FOR ICE AND FRZLVL VALID UNTIL 040300

.
**AIRMET ICE...NC SC GA MA RI CT NY NJ MD DE VA AND CSTL WTRS
FROM 40E ACK TO 140E ACK TO 200SE ACK TO 160SE SIE TO 190ESE ECG
TO 130SSE ILM TO 110SE CHS TO 40WNW PZD TO GQO TO SPA TO 40SSE
CSN TO SBY TO 40E ACK
MOD ICE BTN FRZLVL AND FL220. FRZLVL 060-130. CONDS CONTG BYD 03Z
THRU 09Z.**

.
FRZLVL...RANGING FROM 075-150 ACRS AREA
080 ALG 40E VXV-30NNE GSO
120 ALG 50S LGC-30SSW CHS-90SE CHS-170SSE ILM

....

12.0 Graphical Forecasts for Aviation

The Graphical Forecasts for Aviation (GFA) products made available before the accident flight and valid at 1400 EST are shown in attachment 4. The GFA surface forecast products indicated VFR surface visibilities with likely (greater than 60 percent chance) rain shower activity and a surface wind from the southwest at 10 to 15 knots. The GFA cloud forecast valid before departure

for around the accident time indicated scattered to broken ceilings at 2,100 to 2,800 ft msl, overcast skies around 12,000 ft msl with layered clouds through the cloud top altitude at FL420. The Graphical AIRMET (G-AIRMET) Zulu valid for the accident site was overlaid on the GFA cloud forecast graphics. For more information please see attachment 4.

13.0 Terminal Aerodrome Forecast

KAHN was the closest airport to the accident site with a NWS Terminal Aerodrome Forecast (TAF). The KAHN TAF valid at the time of the accident was an amended issued at 1456 EST and was valid for a 22-hour period beginning at 1500 EST. The TAF for KAHN was as follows:

AMD TAF KAHN 031956Z 0320/0418 **24012KT P6SM SCT020 OVC035**
TEMPO 0320/0322 22014G25KT 3SM -SHRA BR BKN015
FM032200 26011KT P6SM BKN040
FM040400 29007KT P6SM BKN150
FM041700 30008KT 6SM BR BKN025=

Between 1500 and 1700 EST, the forecast expected a wind from 240° at 12 knots, greater than 6 miles visibility, scattered clouds at 2,000 ft agl, an overcast ceiling at 3,500 ft agl. Temporary conditions³⁵ of a wind from 220° at 14 knots with gusts to 25 knots, 3 miles visibility, light rain showers, mist, and a broken ceiling at 1,500 ft agl were forecast between 1500 and 1700 EST.

14.0 NWS Area Forecast Discussion

The NWS office in Peachtree City, Georgia, issued the following Area Forecast Discussion (AFD) at 1500 EST (closest AFD to the accident time). The aviation section of the AFD discussed ceilings in the MVFR to VFR range with showers across the area expected to move southward:

FXUS62 KFFC 032000
AFDFFC

Area Forecast Discussion
National Weather Service Peachtree City GA
300 PM EST Tue Mar 3 2020

.SHORT TERM /Tonight through Wednesday Night/...
Current radar loop shows two lines of storms moving west to east across the area. The first line is across N GA and should be exiting the state over the next few hours. The second line is moving across central GA. This second line is moving slightly southward also but it is expected to diminish some overnight before moving back northward Wednesday. Continued southwesterly flow is keeping things warm and moist but this flow will transition to slightly more westerly tonight. Even with the flow becoming a bit more westerly we keep deep layer moisture moving across the area through Thursday. Precipitable water values remain in the 1 to 1.5 inch range

³⁵ The TEMPO group is used for any conditions in wind, visibility, weather, or sky condition which are expected to last for generally less than an hour at a time (occasional), and are expected to occur during less than half the time period.

through the period.

Will see a short break in the precipitation tonight and into Wednesday morning with precip pushing back in Wed. A weak wave moves NE out of the Gulf tonight and helps reinforce the frontal boundary as it also moves back northward Wed morning/afternoon. Likely to categorical PoPs will spread northward first into central Georgia and then into north Georgia Wednesday. This will bring an additional 1 to 1.5 inches of rainfall to central Georgia, and a quarter of an inch across N GA. With the cumulative rainfall today and the additional rainfall expected Wednesday, this has prompted us to issue a Flash Flood Watch for portions of North and central GA beginning Wednesday morning continuing through Thursday afternoon. Please see the FFAFFC (Flash Flood Watch) for more information.

Low temperatures tonight and Wednesday night expected to be in the 40s and 50s with highs Wednesday in the 50s and 60s.

01

.LONG TERM /Thursday through Tuesday/...

Although dreary conditions are expected at the start of the long term, there's light at the end of the tunnel (week)!

A Flash Flood Watch for heavy rainfall continues from the short term into the extended period, with heavy rain still a threat Thursday morning. Strong isentropic lift as shortwave approaches will promote good precipitation shield over middle beginning Wednesday night, and lifting northward and focusing over north Georgia through Thursday morning. As main upper low pressure system shifts east of the area during the day, expect rainfall to end from west to east in the afternoon.

Behind the exiting system, high pressure will prevail, with sunny skies. Breezy conditions are expected Friday as tight pressure gradient remains in place, but lighter winds are anticipated Saturday and Sunday.

Moisture return is anticipated early next week as southerly flow sets up ahead of the next system. Another wet work week is expected as rain chances return late Monday through Tuesday, and let's just hope the ECMWF solution wins out in the end since it ends the rain nearly two days earlier than the GFS!

31

&&

.Hydrology...

A Flash Flood Watch has been issued for 12Z Wednesday through 18Z Thursday to highlight the greatest threat of flash flooding. The Watch area includes counties along and south of I-20 where rainfall amounts of 2 to 3.5 inches are expected over the area. The highest amounts are focused over middle Georgia. Streamflows

remain above average (with some rivers still in flood over central Georgia) and soils are already saturated. Runoff from the additional rain will lead to a greater threat of flash flooding over this time.

&&

.AVIATION...

18Z Update...

Ceilings hovering in the MVFR range but will lift into the VFR range just before sunset. Will see MVFR ceilings move back in Tuesday a precip moves back in. Showers across the area are diminishing as the line moves a bit further south. should see a few more showers at the TAF sites this afternoon then taper off just before sunset. Rain moves back in Tuesday afternoon. Wind will stay out of the W to NW. Wind speeds are in the 10-20kt range and will diminish to 10kt or less overnight and stay there through the period.

//ATL Confidence...18Z Update...

Confidence high on all elements.

01

&&

.PRELIMINARY POINT TEMPS/POPS...

Athens	52	60	47	51	/	20	80	90	100
Atlanta	52	58	47	52	/	20	90	100	90
Blairsville	44	57	42	50	/	20	70	80	90
Cartersville	50	58	46	53	/	30	80	90	90
Columbus	57	62	50	60	/	50	90	100	90
Gainesville	50	58	46	50	/	20	80	90	90
Macon	56	62	50	56	/	40	80	100	100
Rome	50	59	46	54	/	30	80	90	90
Peachtree City	53	59	48	54	/	30	90	100	90
Vidalia	61	66	53	59	/	60	80	80	100

&&

.FFC WATCHES/WARNINGS/ADVISORIES...

Flash Flood Watch from Wednesday morning through Thursday afternoon for the following zones: Baldwin...Barrow...Bibb...Bleckley...Butts...Carroll...Chattahoochee...Clayton...Cobb...Coweta...Crawford...Crisp...DeKalb...Dodge...Dooly...Douglas...Emanuel...Fayette...Glascok...Greene...Gwinnett...Hancock...Haralson...Harris...Heard...Henry...Houston...Jasper...Jefferson...Johnson...Jones...Lamar...Laurens...Macon...Marion...Meriwether...Monroe...Montgomery...Morgan...Muscogee...Newton...North Fulton...Oconee...Paulding...Peach...Pike...Pulaski...Putnam...Rockdale...Schley...South Fulton...Spalding...Stewart...Sumter...Talbot...Taliaferro...Taylor...Telfair...Toombs...Trentlen...Troup...Twiggs...Upson...Walton...Warren...Washington...Webster...Wheeler...Wilcox...Wilkinson.

&&

\$\$

15.0 Winds and Temperature Aloft Forecast

The NWS 1455 EST Winds and Temperature Aloft forecast valid for the closest point to the accident site is included below:

```
FBUS31 KWN0 031955
FD1US1
DATA BASED ON 031800Z
VALID 040000Z   FOR USE 2000-0300Z. TEMPS NEG ABV 24000

FT  3000    6000    9000   12000   18000   24000   30000   34000   39000
ATL 2825 2932+08 2945+01 2666-01 2783-13 2775-24 770237 772247 763758
```

The accident site was located closest to the Atlanta, Georgia, (ATL) forecast point. The 1455 EST ATL forecast for use between 1500 EST and 2200 EST indicated a wind at 3,000 ft from 280° at 25 knots, a wind at 6,000 ft from 290° at 32 knots with a temperature of 8°C, and a wind at 9,000 ft from 290° at 45 knots with a temperature of 1°C.

16.0 Pilot Weather Briefing

The accident pilot did not request a weather briefing from the FAA contract Flight Service Station provider Leidos.

A search of archived ForeFlight information indicated that the accident pilot did request weather information for flights at both FL200 and 6,000 ft via ForeFlight Mobile (attachments 5 and 6) at 1445 EST with a planned departure of 1515 EST and an actual departure time around 1529 EST³⁶. The 1445 EST weather briefing information contained all the standard weather information valid at 1445 EST, including Convective SIGMET information valid along the route of flight, AIRMETs, CWA, a surface analysis chart, current METARs valid along the route of flight, PIREPs, a GFA forecast, TAFs, turbulence cross section information, and the winds aloft information. The accident pilot did not access any weather imagery via ForeFlight mobile prior to the accident flight on the accident day but could have accessed text information. For more information please see attachments 5 and 6. There is no record of the accident pilot receiving or retrieving any other weather information before or during the accident flight.

17.0 ZTL CWSU Information

ZTL CWSU provided a pre-duty weather briefing at 0540 EST the day of the accident for ATC working at A80 with the weather briefing containing all the standard weather information (attachment 7). The ZTL CWSU weather briefing sheet produced at 1245 EST for A80 was archived and is available as attachment 9.

³⁶ See ATC information located in the docket of this accident.

18.0 XM Weather images

The airplane was equipped with a Garmin³⁷, which was fitted to be able to display XM Weather information (attachment 11) with a subscription.³⁸ If the accident pilot had XM Weather composite radar information up during the accident flight he would have seen something similar to the recreated XM Weather information in figures 24 through 29 (time in figures in CST). The top right portion of figures 24 through 29 are the time stamp generated for the image. This imagery is similar to the XM Weather composite radar information available around and before the accident time. The scale used in the XM Weather composite radar information is located in figure 30. The time in the bottom left portion of figures 24 through 29 are the times at which the XM Weather composite radar information would have been available for viewing in the cockpit for the pilot (attachment 10).

Comparison imagery was made between the level III KFFC WSR-88D composite reflectivity imagery and the XM weather radar composite imagery around the accident time and are included as figures 31 to 34.³⁹ The XM Weather composite radar images displayed 30 to 40 dBZ values above the accident site at the accident time. For additional information regarding the XM Weather composite radar data please see attachment 12.

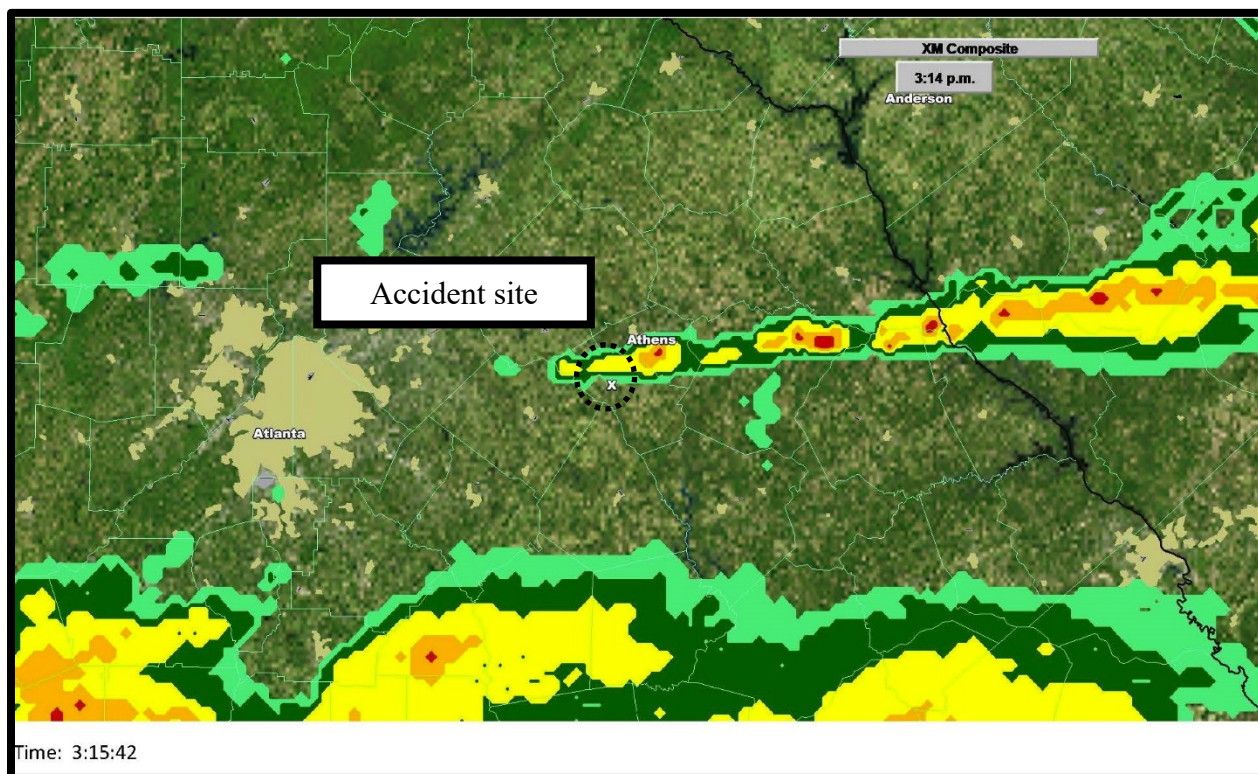


Figure 24 –XM Weather Radar from 1614 EST

³⁷ For more information on the electronic equipment located on the accident aircraft please see the docket information for this accident.

³⁸ It is unknown if the pilot had a subscription to display XM Weather information.

³⁹ See: https://nts.gov/safety/safety-alerts/Documents/SA_017.pdf

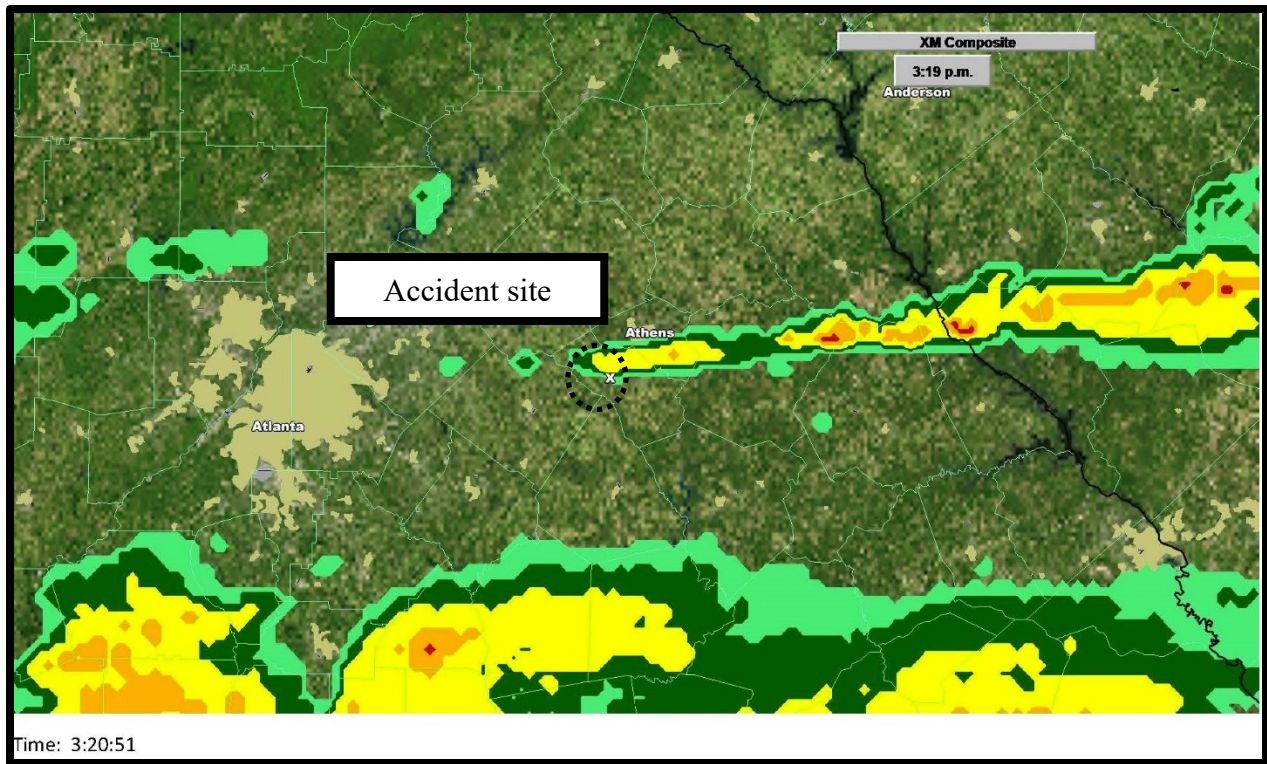


Figure 25 – XM Weather Radar from 1619 EST

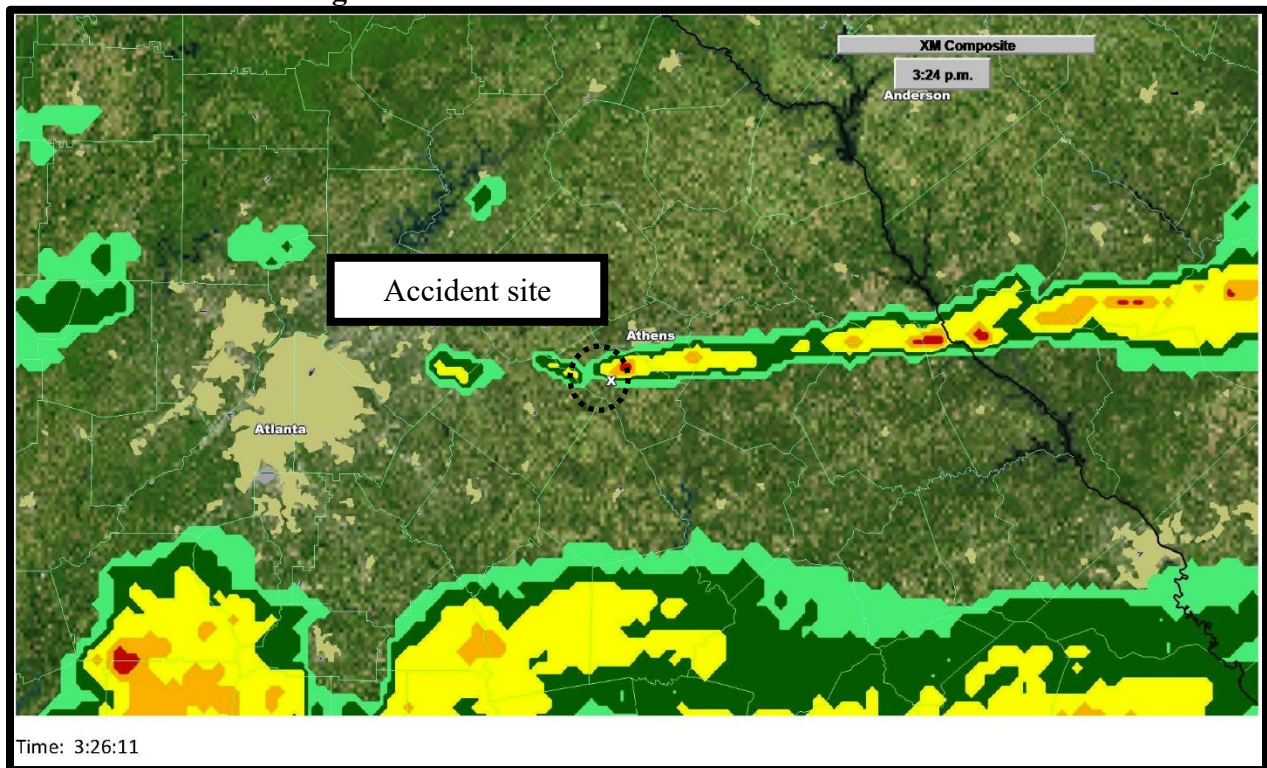


Figure 26 – XM Weather Radar from 1624 EST

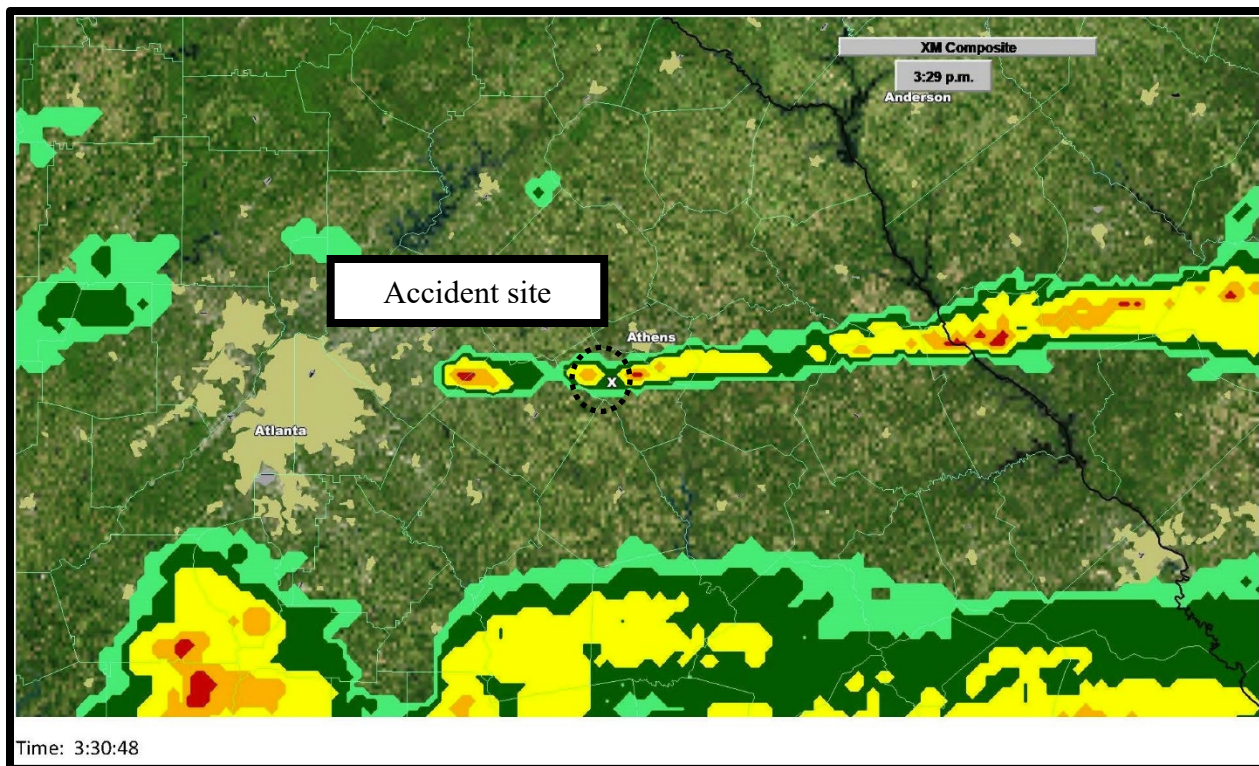


Figure 27 – XM Weather Radar from 1629 EST

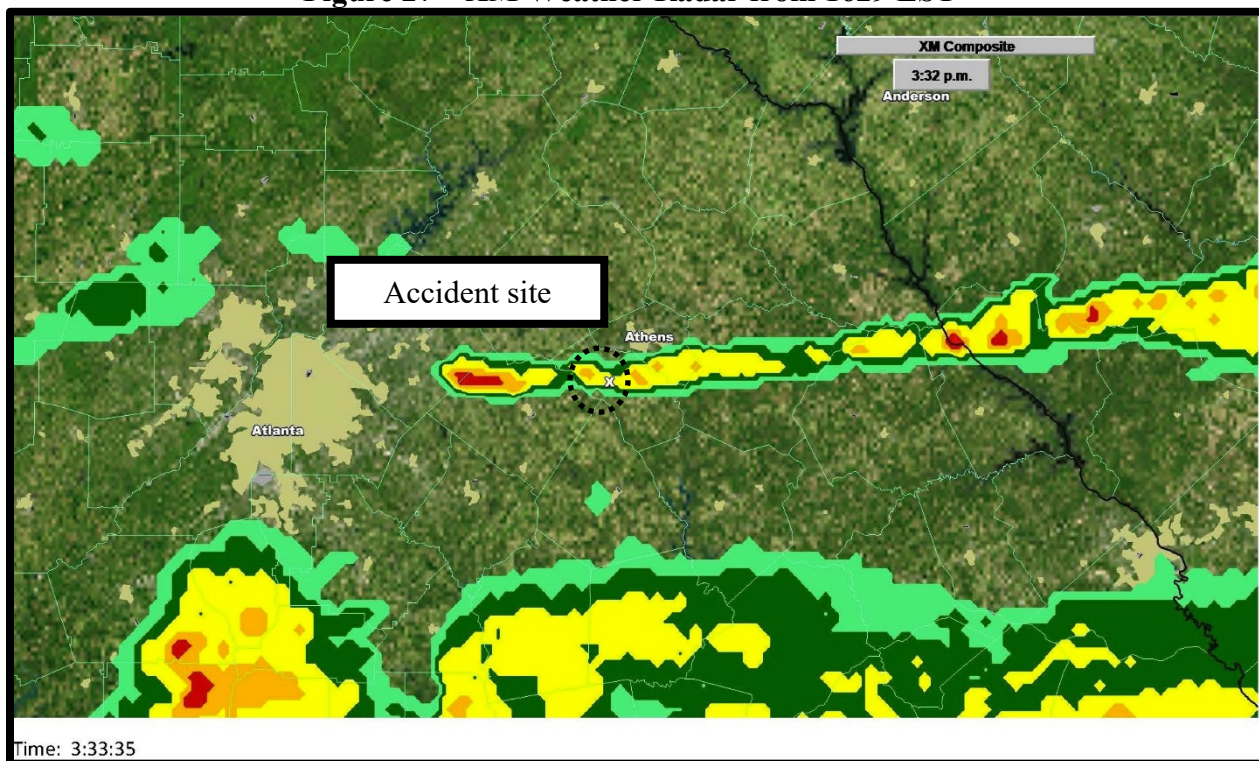


Figure 28 – XM Weather Radar from 1632 EST

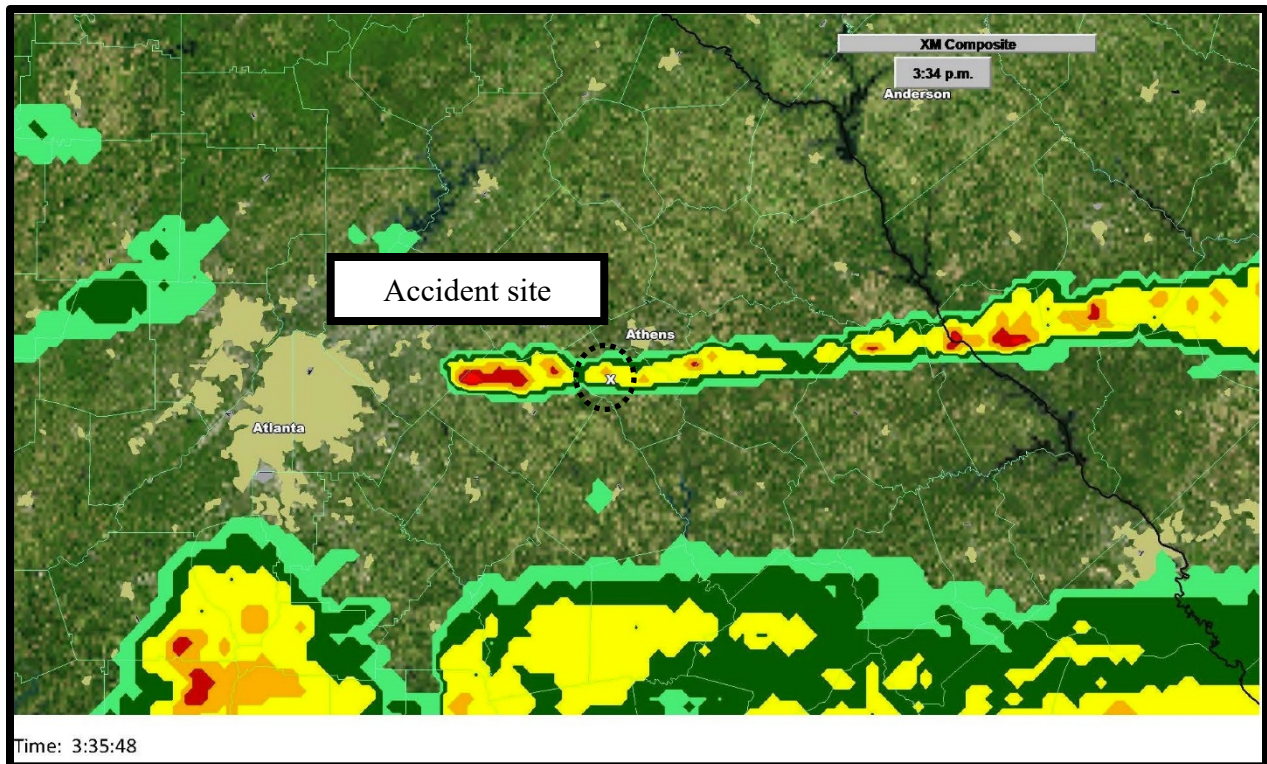


Figure 29 – XM Weather Radar from 1634 EST

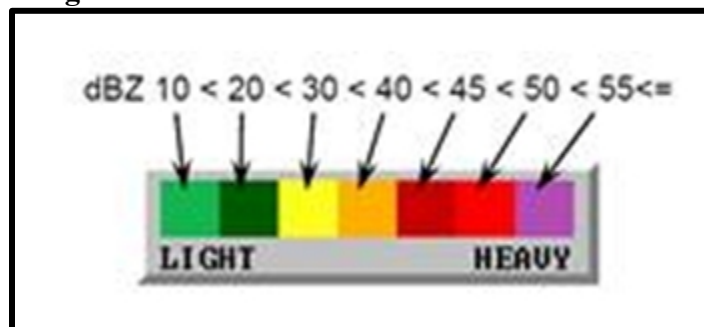
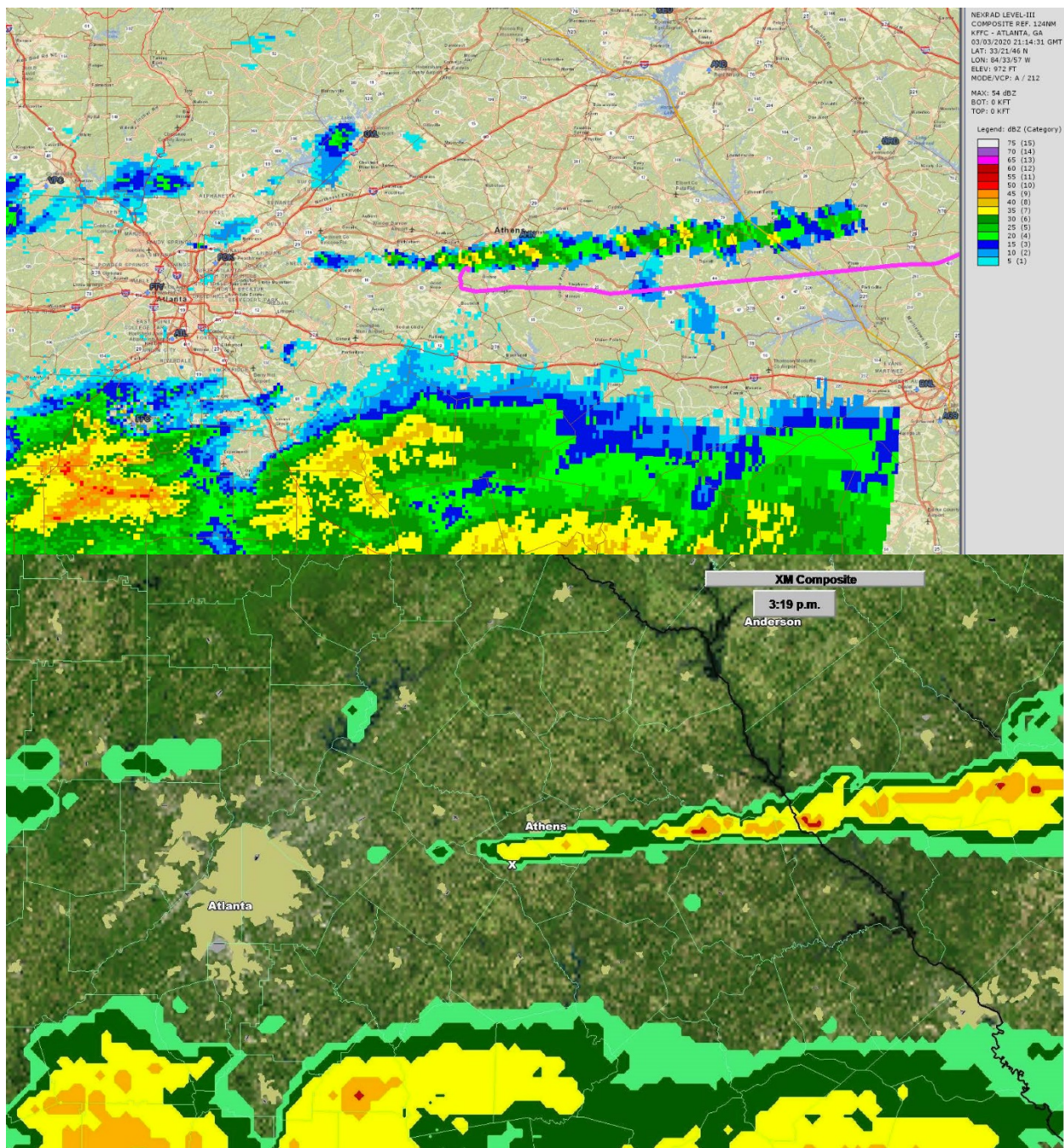
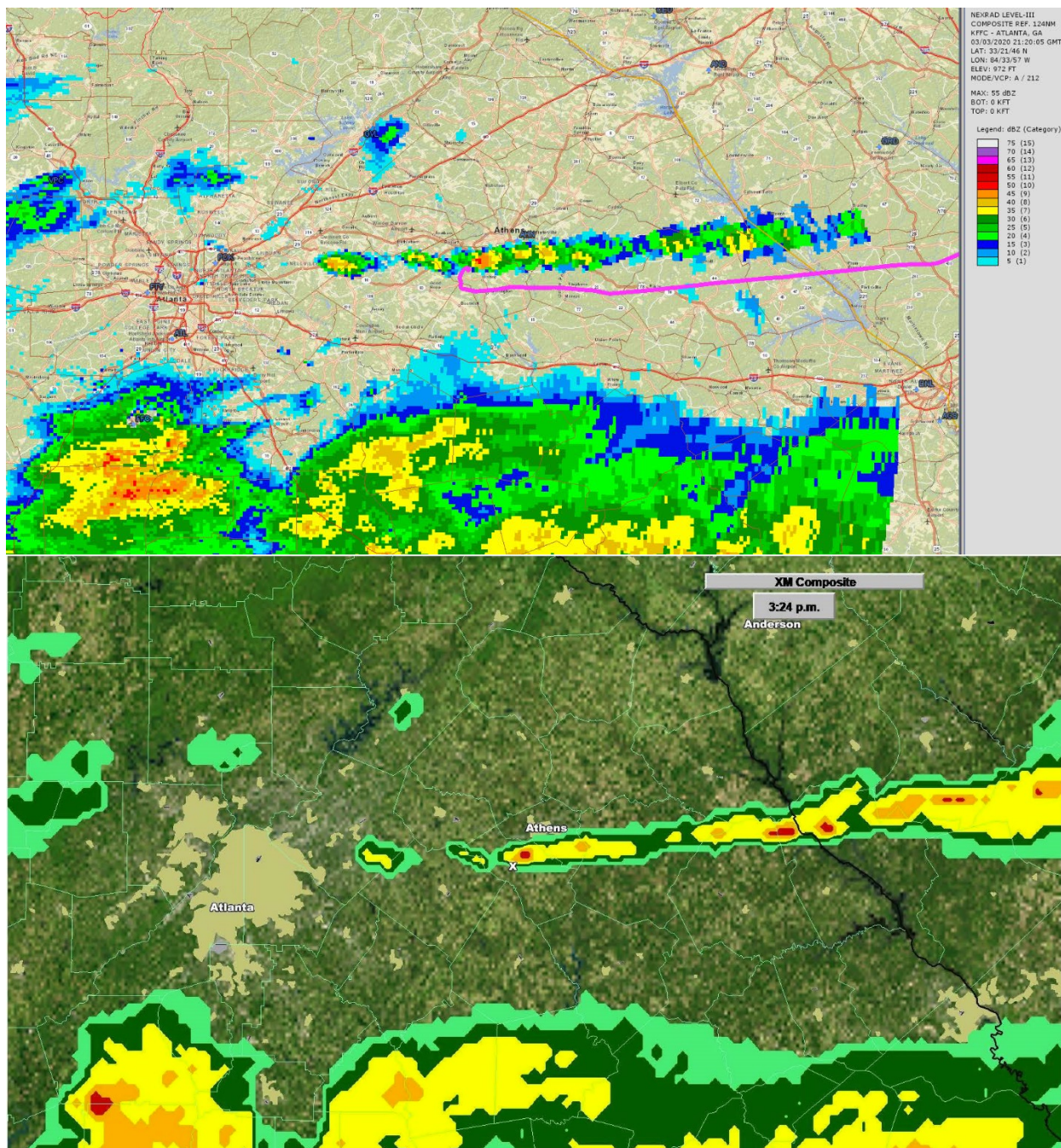


Figure 30 – XM Weather Radar scale for figures 24 through 29



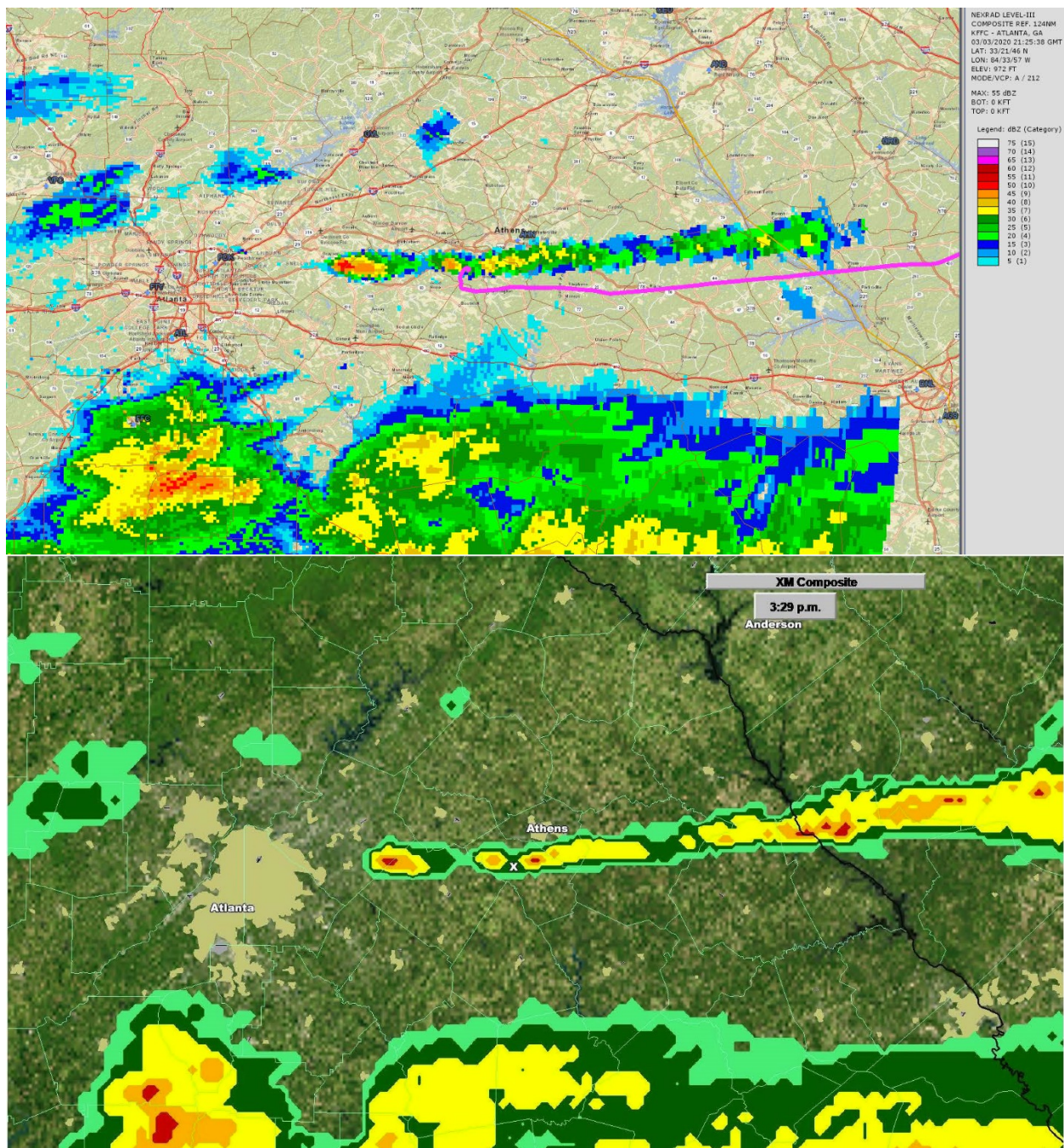
Time: 3:20:51

Figure 31 – Comparison of KFFC WSR-88D composite reflectivity from 1614:31 EST and XM Weather Radar from 1619 EST



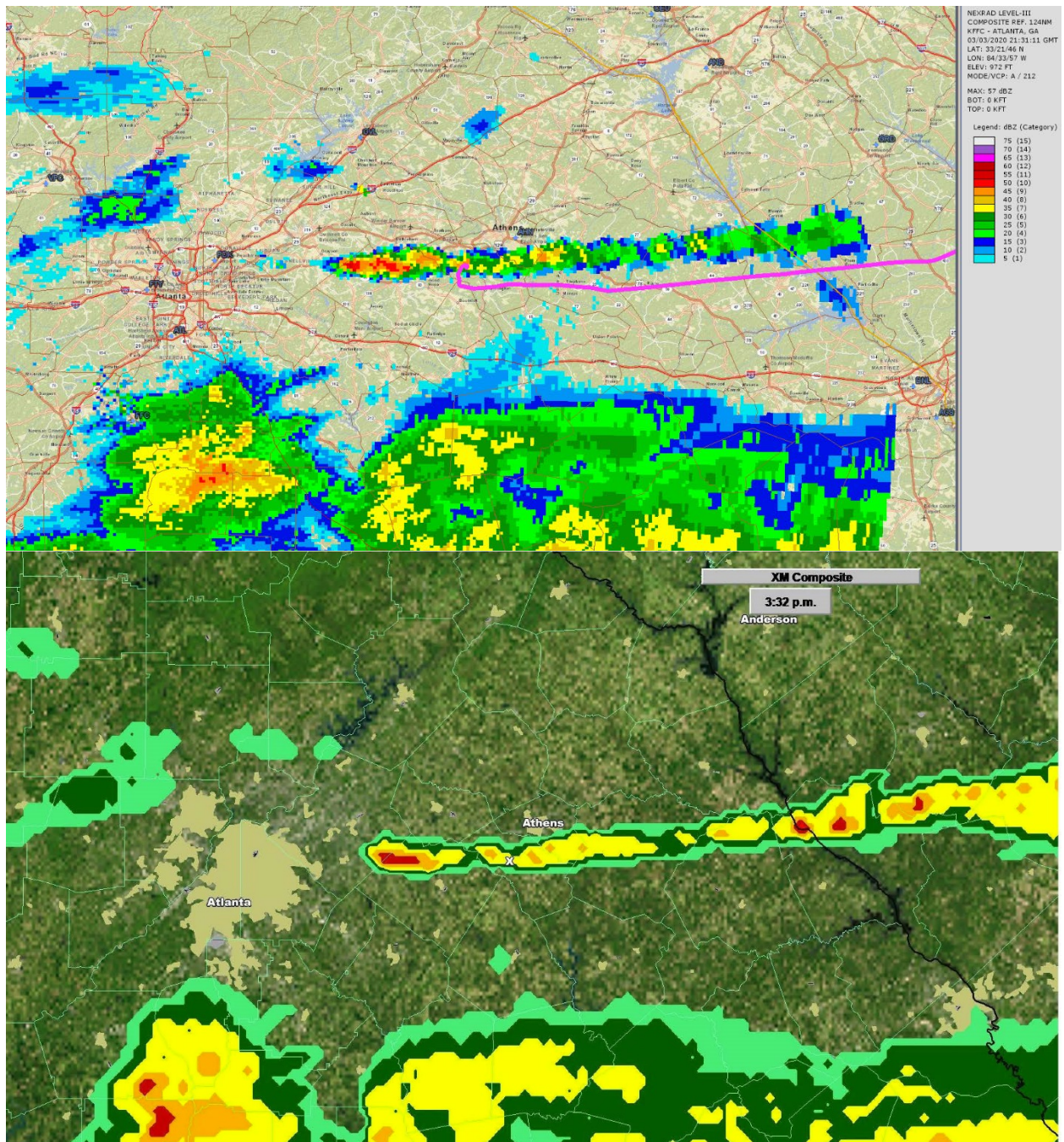
Time: 3:26:11

Figure 32 – Comparison of KFFC WSR-88D composite reflectivity from 1620:05 EST and XM Weather Radar from 1624 EST



Time: 3:30:48

Figure 33 – Comparison of KFFC WSR-88D composite reflectivity from 1625:38 EST and XM Weather Radar from 1629 EST



Time: 3:33:35

Figure 34 – Comparison of KFFC WSR-88D composite reflectivity from 1631:11 EST and XM Weather Radar from 1632 EST

19.0 FIS-B Regional NEXRAD with Flight Path

Flight Information Services–Broadcast (FIS-B) data was retrieved for this accident. If the accident pilot had the regional NEXRAD weather radar screen selected on their electronic equipment⁴⁰ then the FIS-B regional NEXRAD weather radar data provided in attachment 13 would have been the imagery being viewed. The FIS-B regional NEXRAD data is updated once every 5 minutes and is based upon composite NEXRAD reflectivity data. For more information please see attachment 13.

20.0 Consolidated Storm Prediction for Aviation Data

The Consolidated Storm Prediction for Aviation (CoSPA)⁴¹ images were retrieved for 1620, 1625, 1630, and 1635 EST and provided in figures 35 through 38 with the accident site marked. The CoSPA, along with depicting NWS weather radar VIP levels, lightning data, weather satellite, and storm motion, forecast areas of likely rain shower or thunderstorm growth (orange hatched areas) and areas of likely rain shower or thunderstorm dissipation (blue hatched areas). The rain shower activity was moving from west to east with time and growing in areal coverage. In addition, the accident site located in an of projected rain shower or thunderstorm growth from 1630 onward (orange hatched area). Cloud tops were indicated to FL280 and storm motion from 280° at 25 knots (figures 37 and 38).

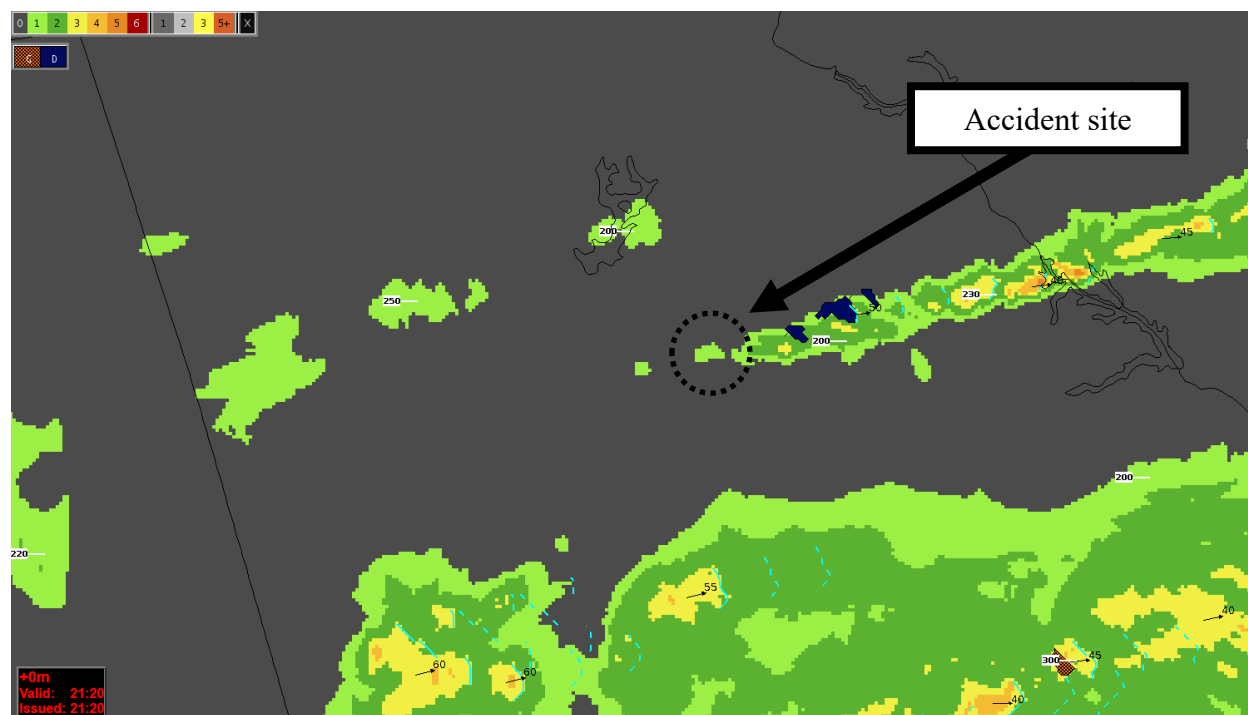
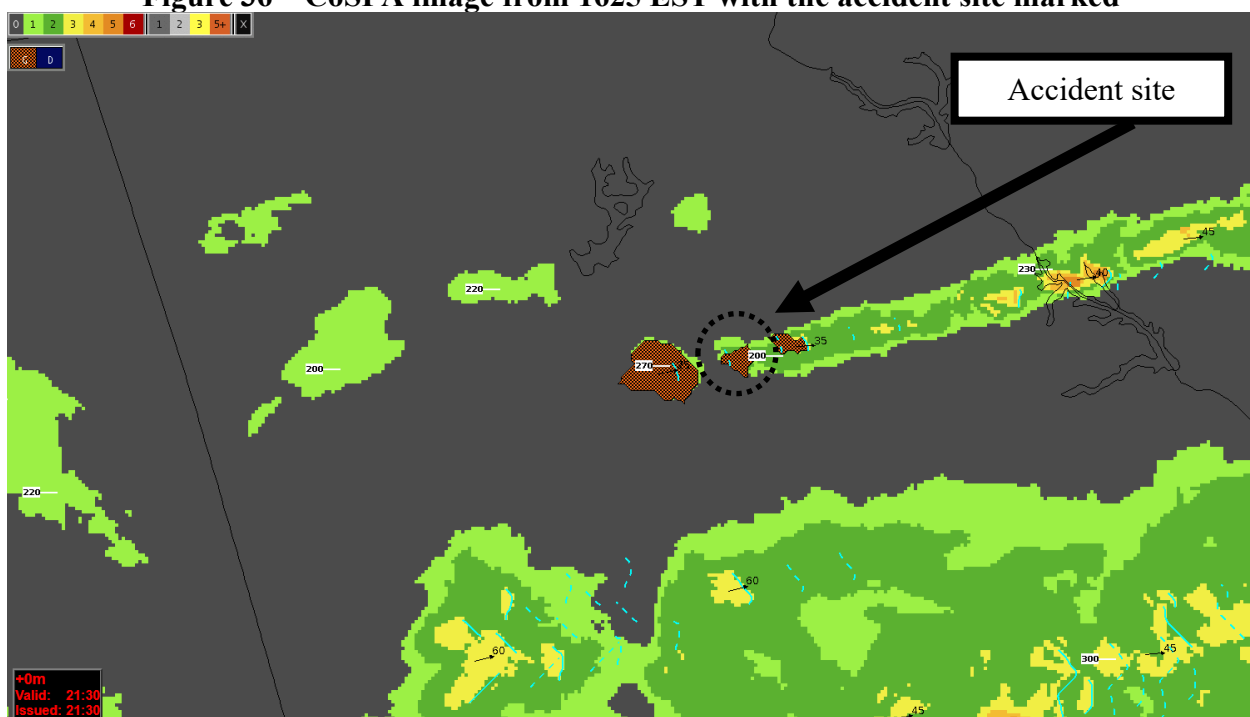
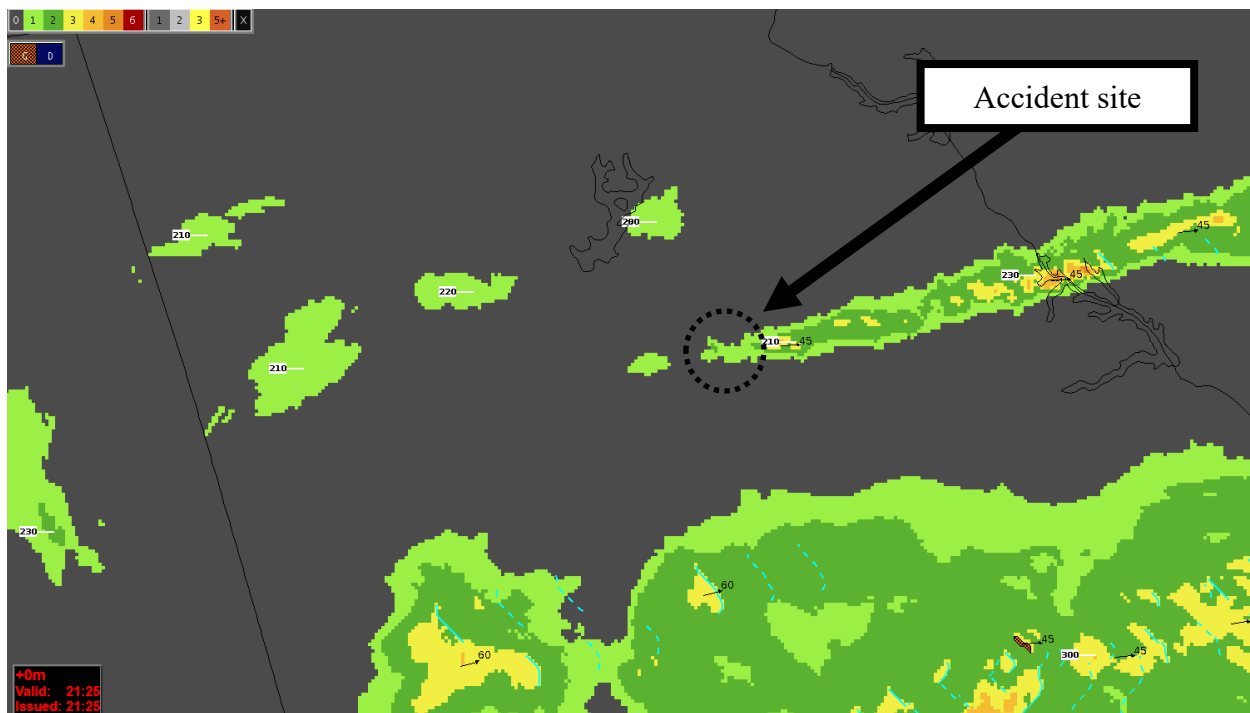


Figure 35 – CoSPA image from 1620 EST with the accident site marked

⁴⁰ For more information on the electronic equipment located on the accident aircraft please see the docket information for this accident.

⁴¹ <https://cospa.wx.ll.mit.edu/>
<https://ral.ucar.edu/projects/CoSPA/index.php>
<https://ral.ucar.edu/solutions/products/consolidated-storm-prediction-aviation-cospa>



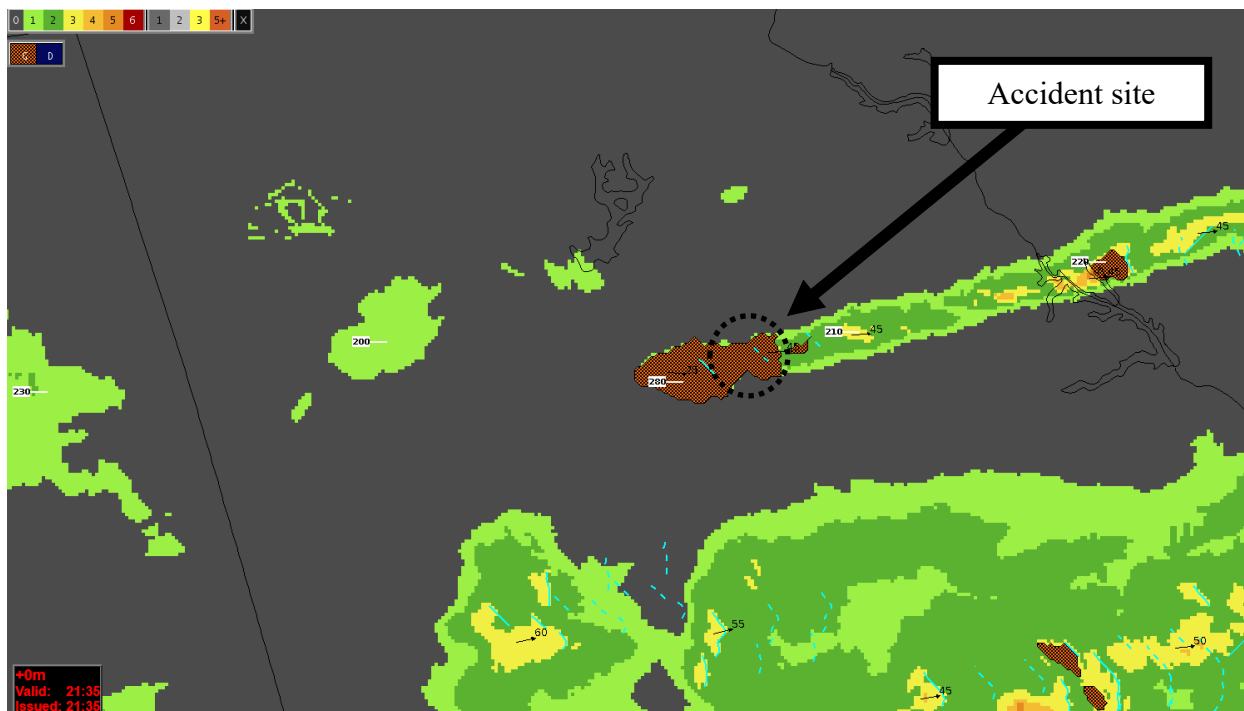


Figure 38 – CoSPA image from 1635 EST with the accident site marked

21.0 Radar Display of STARS Derived Imagery

A STARS⁴² maintenance replay of the accident sequence was viewed and screenshots of the display of weather were obtained. The actual STARS weather display viewed by the A80 ATC from around the accident time are contained in figures 40 through 44 with additional information in attachment 14. The A80 air traffic controller did have settings for level 1 through level 6 precipitation active and available for view:⁴³

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

Figure 39 provides an exemplar view of what precipitation levels 1 through 6 look like on STARS display of precipitation. Figures 40 through 46 show the STARS display of precipitation used and seen by the accident controllers at 1624, 1626, 1628, 1630, 1632, 1633, and 1634 EST.

⁴² 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.

⁴³ The FAA provided the following dBZ levels for the Airport Surveillance Radar-9 (ASR-9) radars (which provided info to STARS). For more information regarding STARS display please see attachment 2 of CEN16FA276.

The accident aircraft remained south of the depicted precipitation until between 1632 and 1633 EST. The accident aircraft remained in level 1 to 3 depicted precipitation between 1633 and 1634 EST.

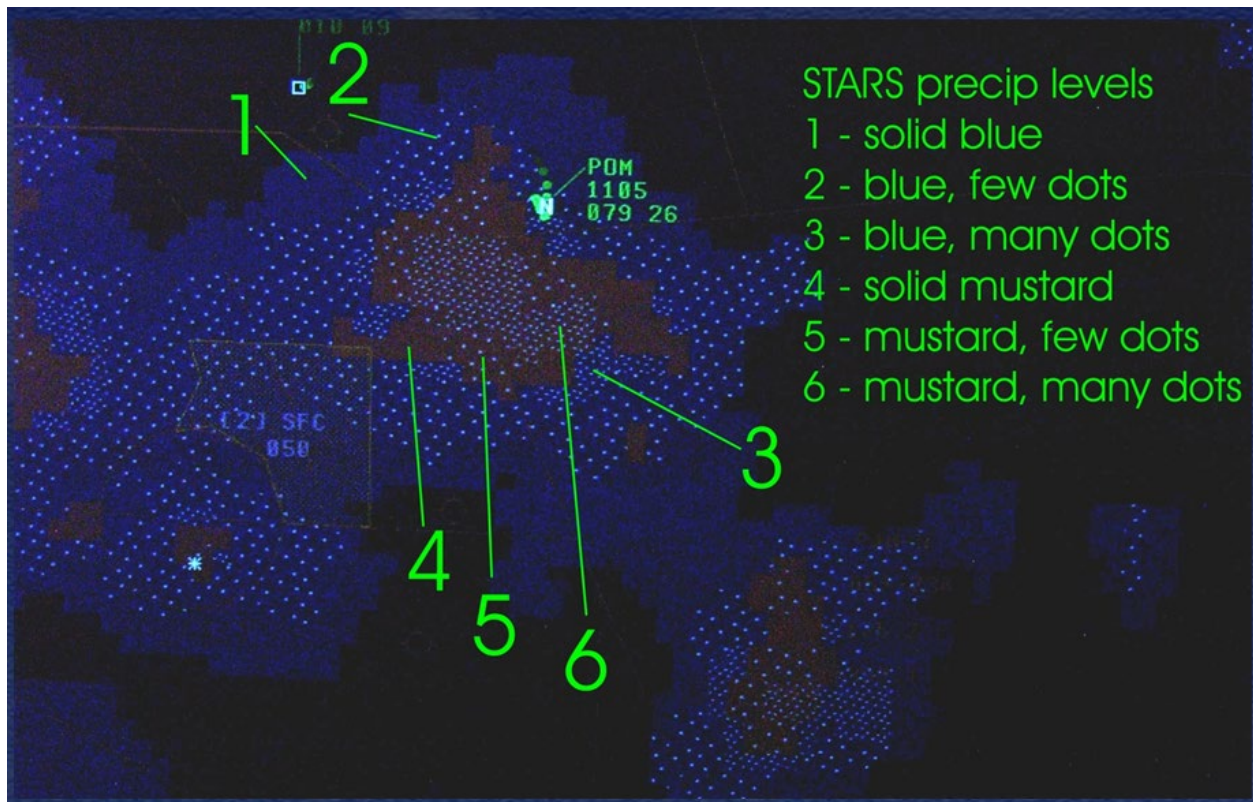


Figure 39 – Exemplar display of STARS precipitation levels 1 through 6



Figure 40 – STARS weather and precipitation level display used and seen by accident controller from 1624 EST



Figure 41 – STARS weather and precipitation level display used and seen by accident controller from 1626 EST



Figure 42 – STARS weather and precipitation level display used and seen by accident controller from 1628 EST



Figure 43 – STARS weather and precipitation level display used and seen by accident controller from 1630 EST





Figure 45 – STARS weather and precipitation level display used and seen by accident controller from 1633 EST

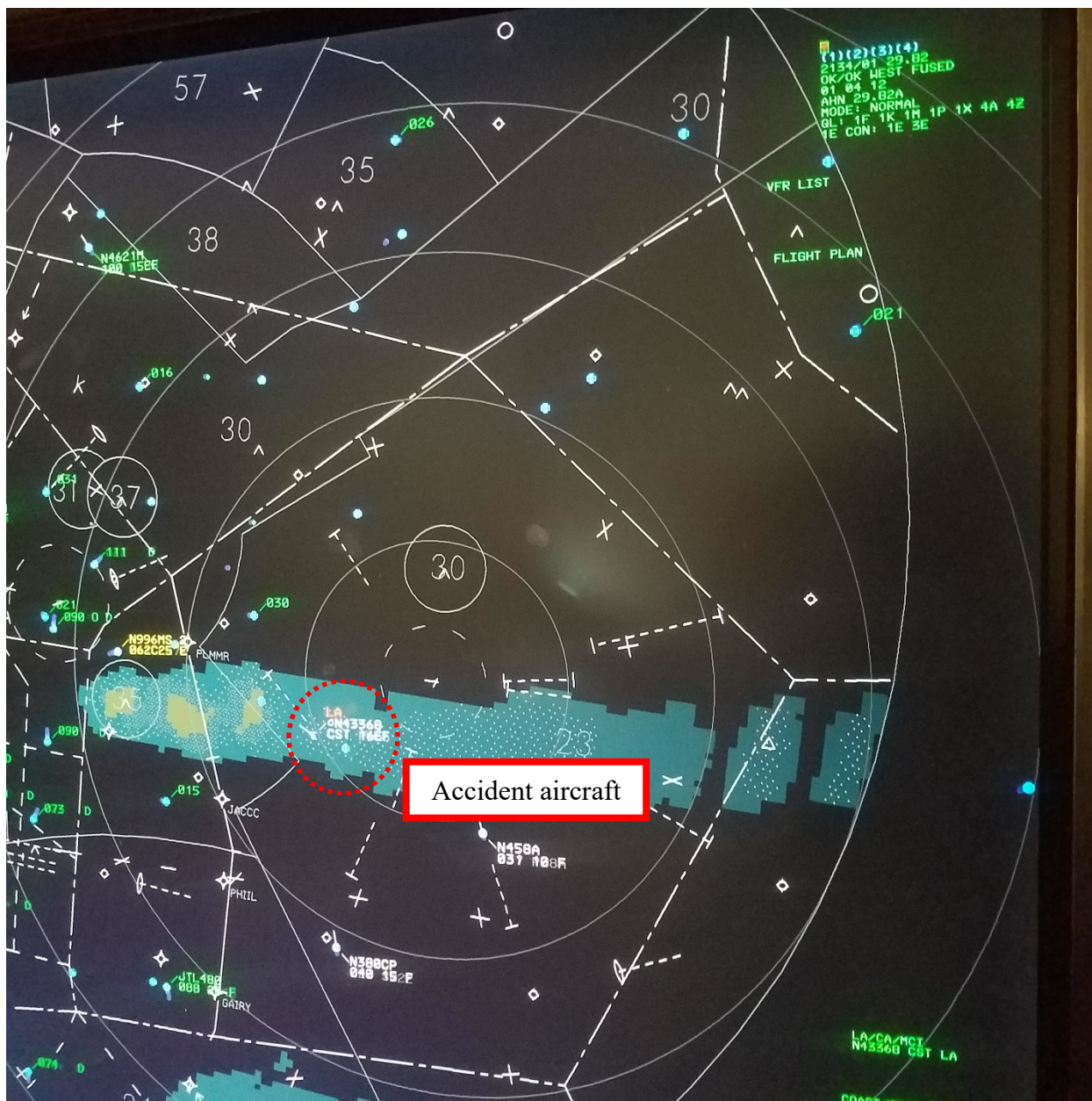


Figure 46 – STARS weather and precipitation level display used and seen by accident controller from 1634 EST

22.0 Weather Reference Information

Integrated Terminal Weather System (ITWS)⁴⁴ information was retrieved for the accident timeframe and is provided in attachment 15. In addition, A80 had an ITWS reference sheet (attachment 16). The historical development of the ITWS reference sheet is discussed in attachment 20 along with the non-Terminal Doppler Weather Radar (TDWR) ITWS reference sheet information contained in attachment 19.

A similar reference sheet was developed for CoSPA and Corridor Integrated Weather System (CIWS) information⁴⁵ in March 2018 and the CoSPA/CIWS reference sheet can be found in attachment 22.

23.0 Witness Information

Witness information was retrieved from around the accident timeframe and their locations are located in figure 47 approximately 0.4 miles north of the accident site and approximately 0.7 miles north-northeast of the accident site, respectively. The witness located 0.4 miles north of the accident site stated that after the accident sequence that he had “never seen it rain harder than it was right after the accident.” The witness located 0.7 miles north-northeast of the accident site stated around the accident timeframe there were scattered rain showers in the area with cloud bases about 2,500 to 3,000 ft agl and no lightning or thunder with visibility of about 20 miles. For more information please see attachments 17 and 18.

⁴⁴ https://cdm.fly.faa.gov/?page_id=176
<https://ral.ucar.edu/sites/default/files/public/events/2008/friends-and-partners-in-aviation-weather/docs/deans-fpaw-2008.pdf>

⁴⁵ <http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.163.142&rep=rep1&type=pdf>



Figure 47 – Witness locations compared to accident flight track (red line)

24.0 Additional Flights Weather Information

Additional flight information was obtained for N513JM, N4621M, N362SH, and N43368 (accident flight) from 1547:11 EST through 1631:15 EST. The WSR-88D base reflectivity data from KFFC around the accident timeframe was overlaid with the flight tracks and figures are labeled with the flight locations at the valid times of the KFFC imagery (figures 48 through 56).

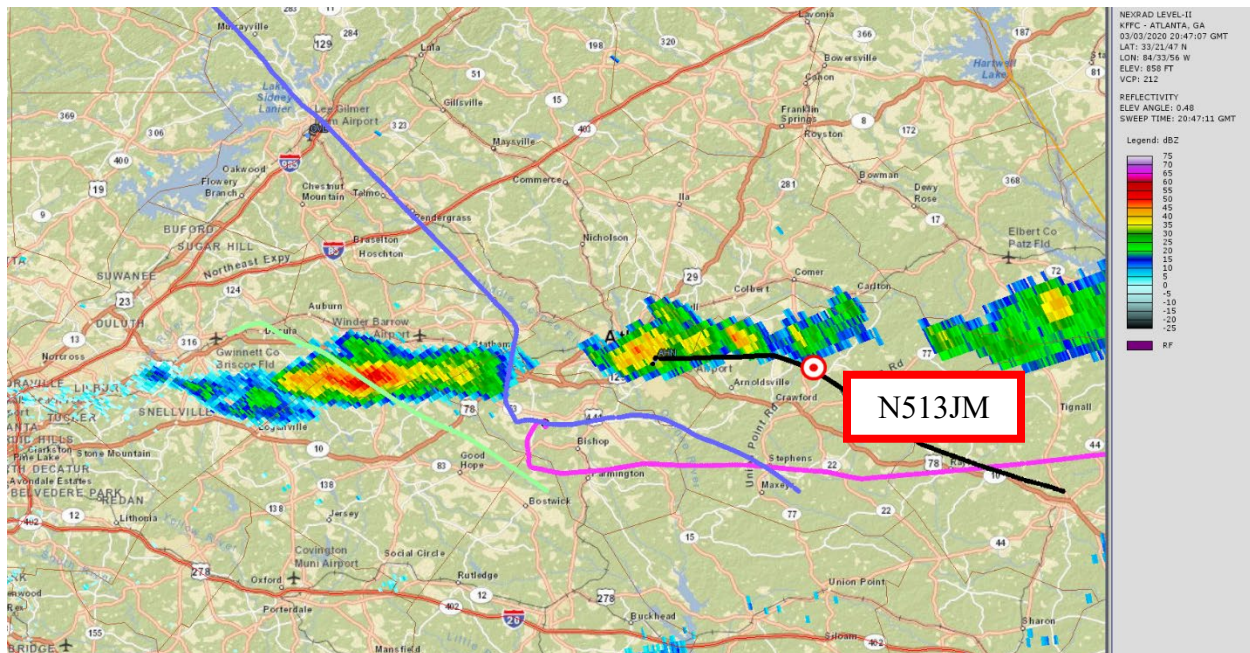


Figure 48 – KFFC WSR-88D reflectivity for the 0.5° elevation scan initiated at 1547:11 EST with additional flight tracks in black, pink, blue, and green

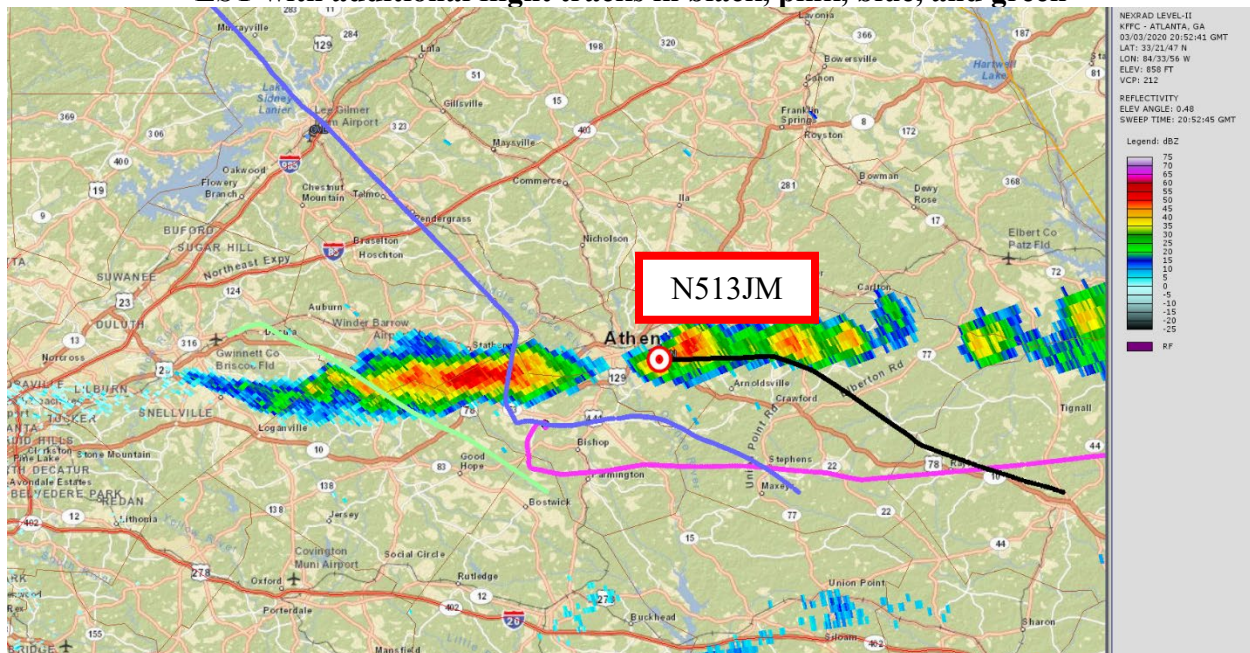


Figure 49 – KFFC WSR-88D reflectivity for the 0.5° elevation scan initiated at 1552:45 EST with additional flight tracks in black, pink, blue, and green

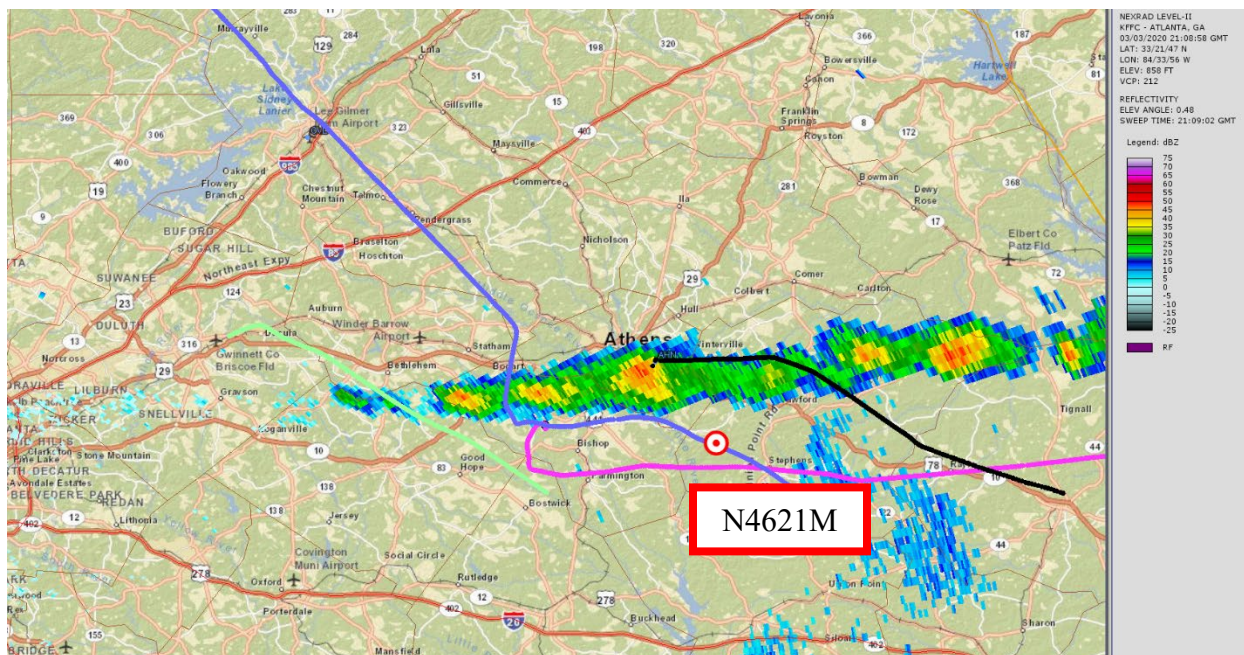


Figure 50 – KFFC WSR-88D reflectivity for the 0.5° elevation scan initiated at 1609:02 EST with additional flight tracks in black, pink, blue, and green

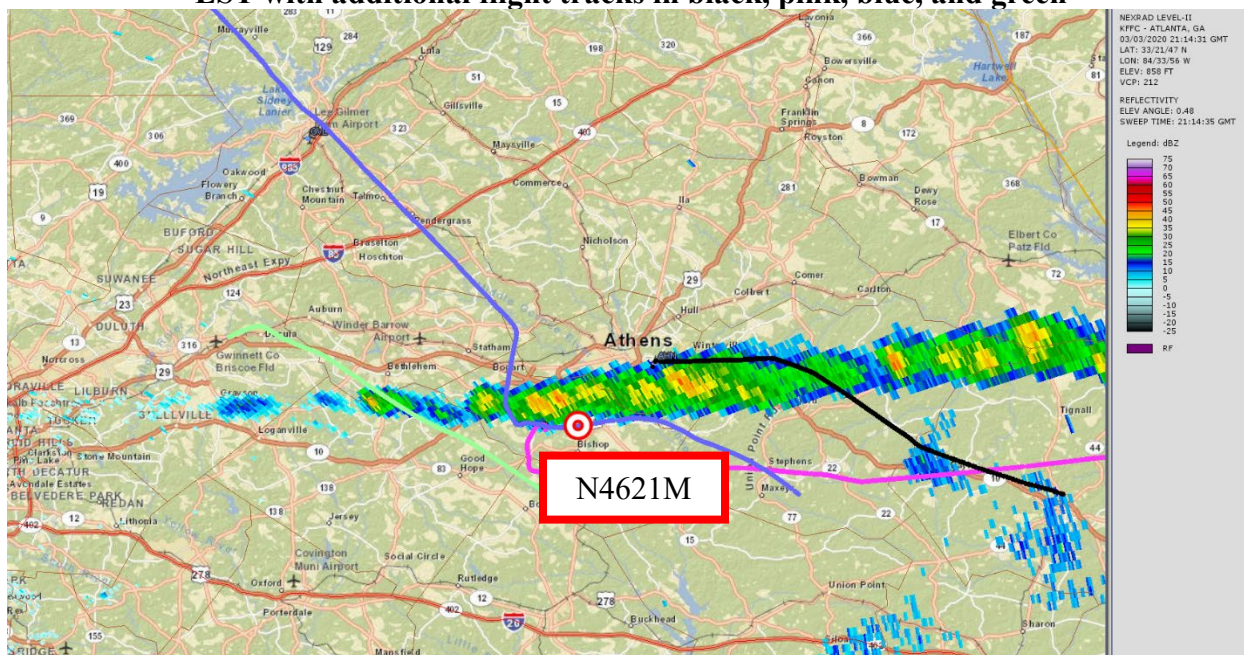


Figure 51 – KFFC WSR-88D reflectivity for the 0.5° elevation scan initiated at 1614:35 EST with additional flight tracks in black, pink, blue, and green

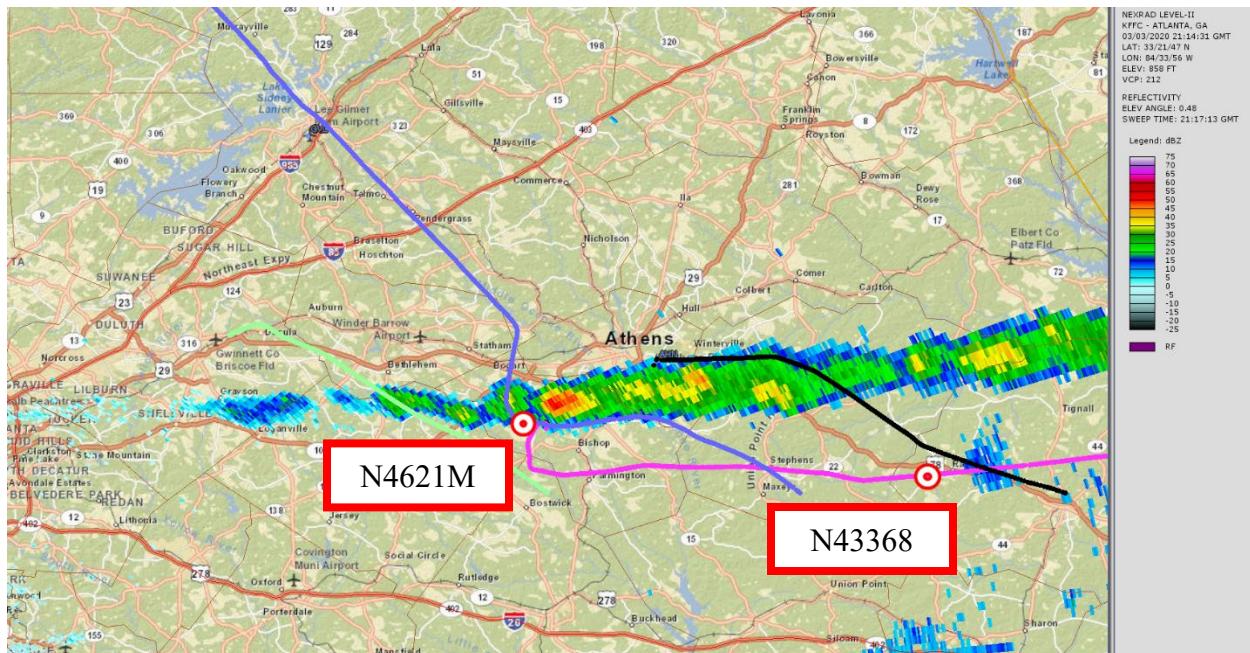


Figure 52 – KFFC WSR-88D reflectivity for the 0.5° elevation scan initiated at 1617:13 EST with additional flight tracks in black, pink, blue, and green

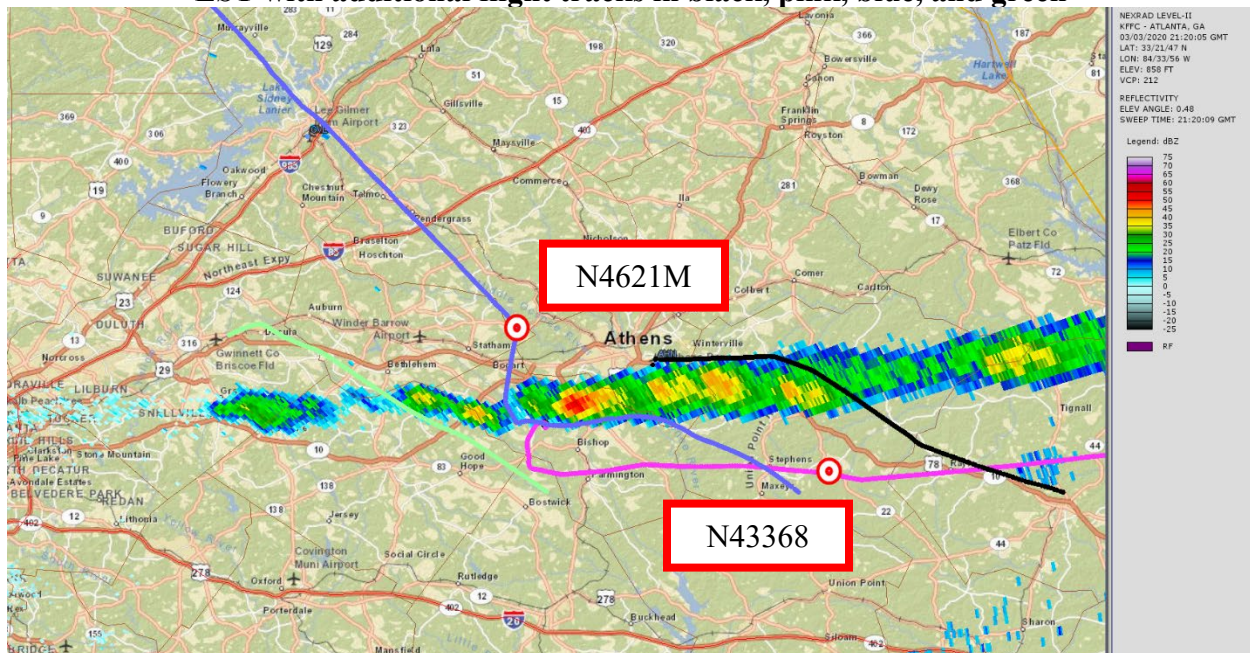


Figure 53 – KFFC WSR-88D reflectivity for the 0.5° elevation scan initiated at 1620:09 EST with additional flight tracks in black, pink, blue, and green

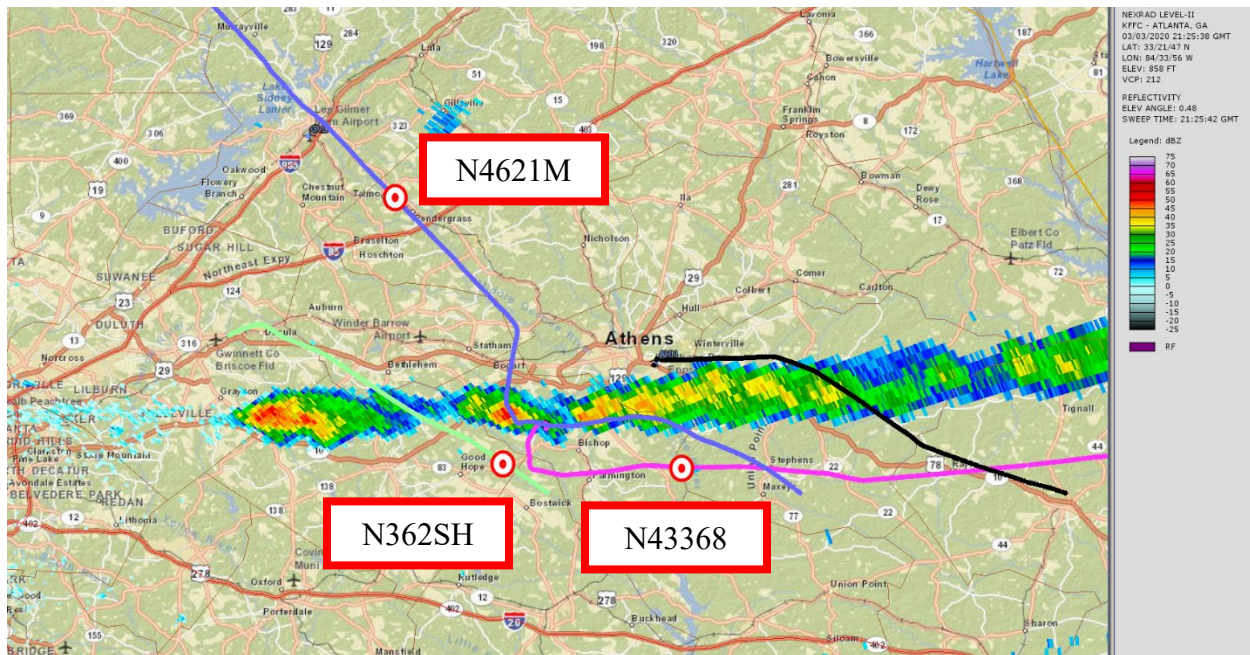


Figure 54 – KFFC WSR-88D reflectivity for the 0.5° elevation scan initiated at 1625:42 EST with additional flight tracks in black, pink, blue, and green

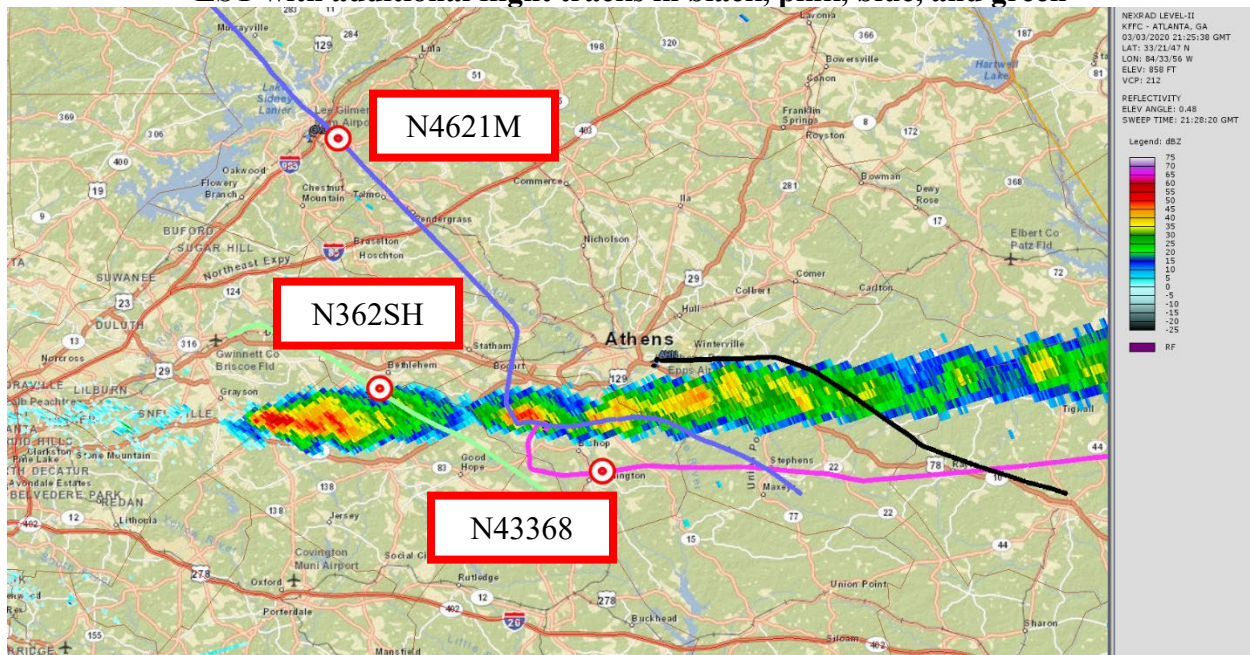


Figure 55 – KFFC WSR-88D reflectivity for the 0.5° elevation scan initiated at 1628:20 EST with additional flight tracks in black, pink, blue, and green

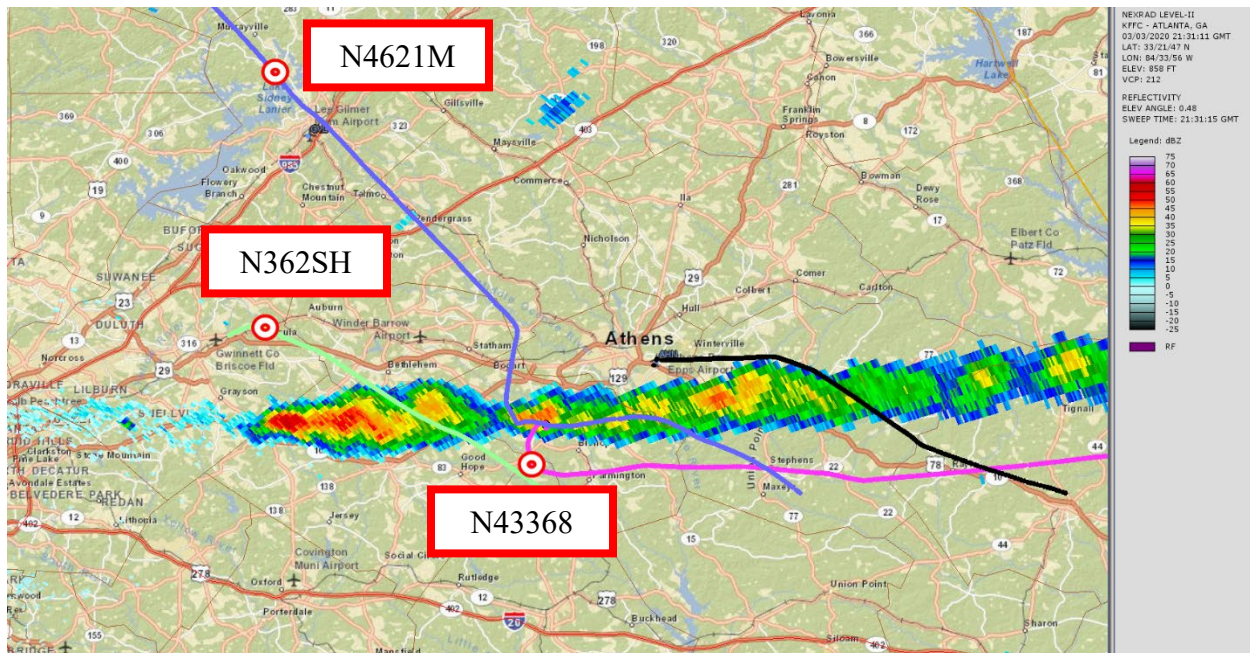


Figure 56 – KFFC WSR-88D reflectivity for the 0.5° elevation scan initiated at 1631:15 EST with additional flight tracks in black, pink, blue, and green

25.0 Article on Aviation Weather Information Displays

A research article was published in *Aerospace Medicine and Human Performance* in April 2020 highlighting the results of a study of general aviation pilots and misinterpretation of weather information. For more information please see attachment 21.

26.0 Astronomical Data

The astronomical data obtained for the accident site on March 3, 2020, indicated the following:

SUN	
Begin civil twilight	0634 EST
Sunrise	0659 EST
Sun transit	1246 EST
Accident time	1634 EST⁴⁶
Sunset	1833 EST
End civil twilight	1858 EST

E. LIST OF ATTACHMENTS

Attachment 1 – GOES-16 Visible animation from 1521 to 1721 EST

⁴⁶ Inserted accident time for reference and context.

Attachment 2 – KFFC WSR-88D level 2 base reflectivity animation for the 0.5° elevation scans from 1558 to 1657 EST

Attachment 3 – Additional PIREP information part 1

Attachment 4 – GFA products valid for the accident flight

Attachment 5 – ForeFlight correspondence

Attachment 6 – Additional ForeFlight correspondence

Attachment 7 – ZTL CWSU pre-duty weather briefing from 0540 EST

Attachment 8 – Additional PIREP information part 2

Attachment 9 – A80 pre-duty weather briefing sheet from 1245 EST

Attachment 10 – Correspondence on XM weather information

Attachment 11 – Correspondence on accident aircraft equipment

Attachment 12 – XM weather composite weather radar imagery from around accident time

Attachment 13 – FIS-B accident data imagery and package

Attachment 14 – STARS imagery from accident flight

Attachment 15 – ITWS data from accident timeframe

Attachment 16 – A80 ITWS reference sheet

Attachment 17 – Witness Information 1

Attachment 18 – Witness Information 2

Attachment 19 – Additional ITWS reference sheet

Attachment 20 – ITWS reference sheet history

Attachment 21 – Research article from Aerospace Medicine and Human Performance

Attachment 22 – CIWS/CoSPA reference sheet

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