



NATIONAL TRANSPORTATION SAFETY BOARD

Office of Aviation Safety
Washington, D.C. 20594

May 14, 2019

Factual Report

METEOROLOGY

ERA19FA113

Table Of Contents

A.	ACCIDENT	3
B.	METEOROLOGIST	3
C.	DETAILS OF THE INVESTIGATION	3
D.	WEATHER INFORMATION	3
1.0	Synoptic Situation	3
1.1	Surface Analysis Chart	4
1.2	Upper Air Charts	5
2.0	SPC Products	9
3.0	Surface Observations	11
4.0	Upper Air Data	14
5.0	Satellite Data	16
6.0	Regional Radar Imagery Information	17
7.0	Radar Imagery Information	18
7.1	Volume Scan Strategy	19
7.2	Beam Height Calculation	20
7.3	Reflectivity	20
7.4	Base Reflectivity and Lightning Data	21
8.0	Pilot Reports	23
9.0	SIGMET	25
10.0	CWSU Products	25
11.0	AIRMETs	25
12.0	Graphical Forecasts for Aviation	27
13.0	Terminal Aerodrome Forecast	27
14.0	NWS Area Forecast Discussion	27
15.0	Winds and Temperature Aloft Forecast	30
16.0	Pilot Weather Briefing	30
17.0	XM Weather images	31
18.0	Weather Information From Additional N26617 Flights	35
19.0	Astronomical Data	35
E.	LIST OF ATTACHMENTS	35

A. ACCIDENT

Location: Near Louisburg, North Carolina
Date: March 1, 2019
Time: 1921 eastern standard time
0021 Coordinated Universal Time (UTC) March 2, 2019
Aircraft: Cessna 182S, Registration: N26617

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 did not travel for this investigation and gathered the weather data 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 1, 2019, 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.

The accident site was located at latitude 36.0019° N, longitude 78.3547° W, with an approximate elevation of 270 feet (ft).

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.¹

¹

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

1.1 Surface Analysis Chart

The eastern section of the NWS Surface Analysis Chart for 1900 EST is provided as figure 1 with the approximate location of the accident site marked within the red circle. The chart identified surface low pressure centers located over southwestern Virginia and in the western Atlantic Ocean with surface pressures of 1013- and 1018-hectopascals (hPa), respectively. A stationary front stretched from southwest Virginia southward into southern North Carolina, south of the accident site and the stationary front becoming a warm front in southeastern North Carolina with the warm front stretching into the western Atlantic Ocean. A cold front stretched southward from southwestern Virginia into southern Alabama. A north-to-south oriented surface trough² was located from southwestern Virginia into western Pennsylvania. Another surface trough was located in the western Atlantic Ocean associated with the 1018-hPa surface low pressure system. The accident site was located in the cool air sector north of the warm frontal boundary.

The station models around the accident site depicted air temperatures in the low to mid 40's degrees Fahrenheit (°F), dew point temperatures in the low to mid 40's °F with temperature-dew point spreads of 1° F or less, with a north to northeast winds of 5 to 10 knots, overcast sky cover, with light to moderate continuous rain.

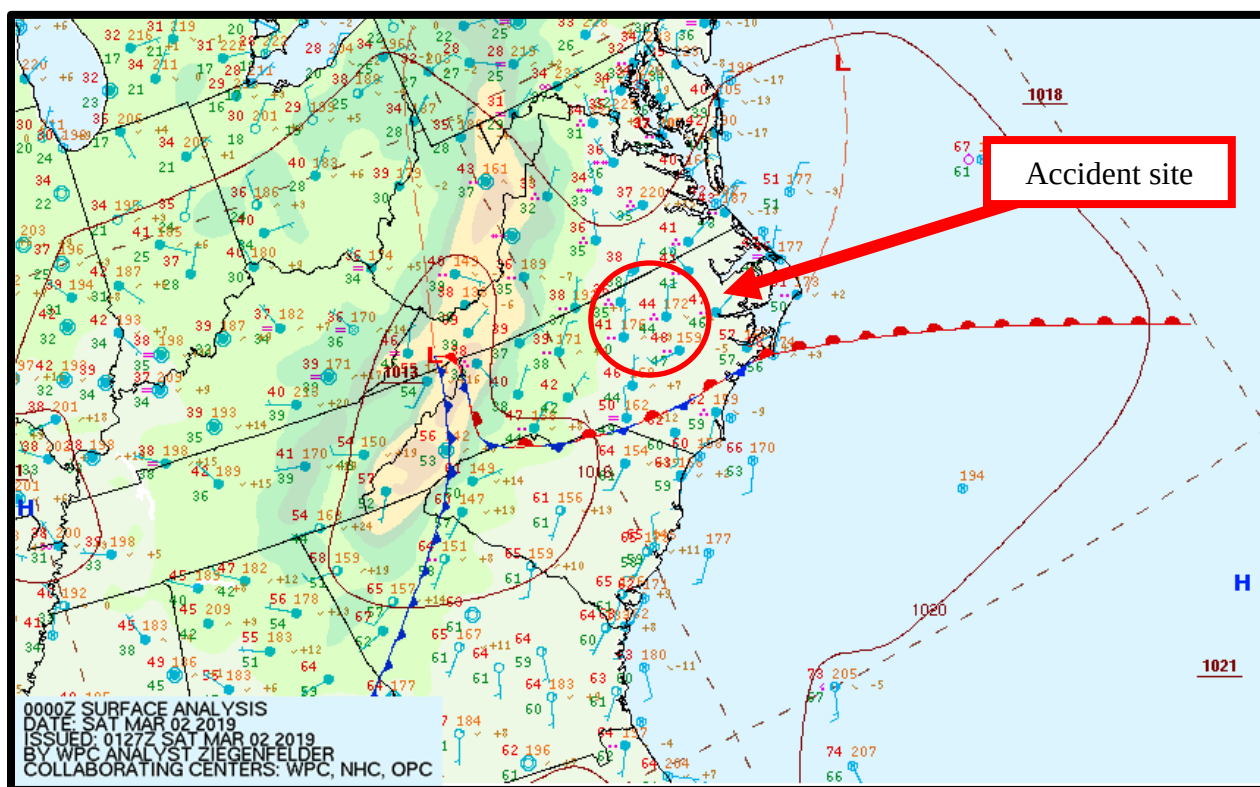


Figure 1 – NWS Surface Analysis Chart for 1900 EST

² Trough – An elongated area of relatively low atmospheric pressure or heights.

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 were low-level troughs located north and south of the accident site at 925-hPa (figure 2) with a low-level trough located over and just south of the accident site at 850-hPa (figure 3). Troughs can act as lifting mechanisms to help produce clouds and precipitation if sufficient moisture is present. There was also a mid-level trough located southwest of the accident site over the Tennessee Valley at 700- and 500-hPa (figures 4 and 5). There was a south to southeast wind of 10 to 20 knots at 925-hPa above the accident site with the wind becoming southwesterly by 700-hPa (figure 4) at 35 knots. By 300-hPa, the wind above the accident site was from the southwest and the wind speed increased 80 knots (figure 6).

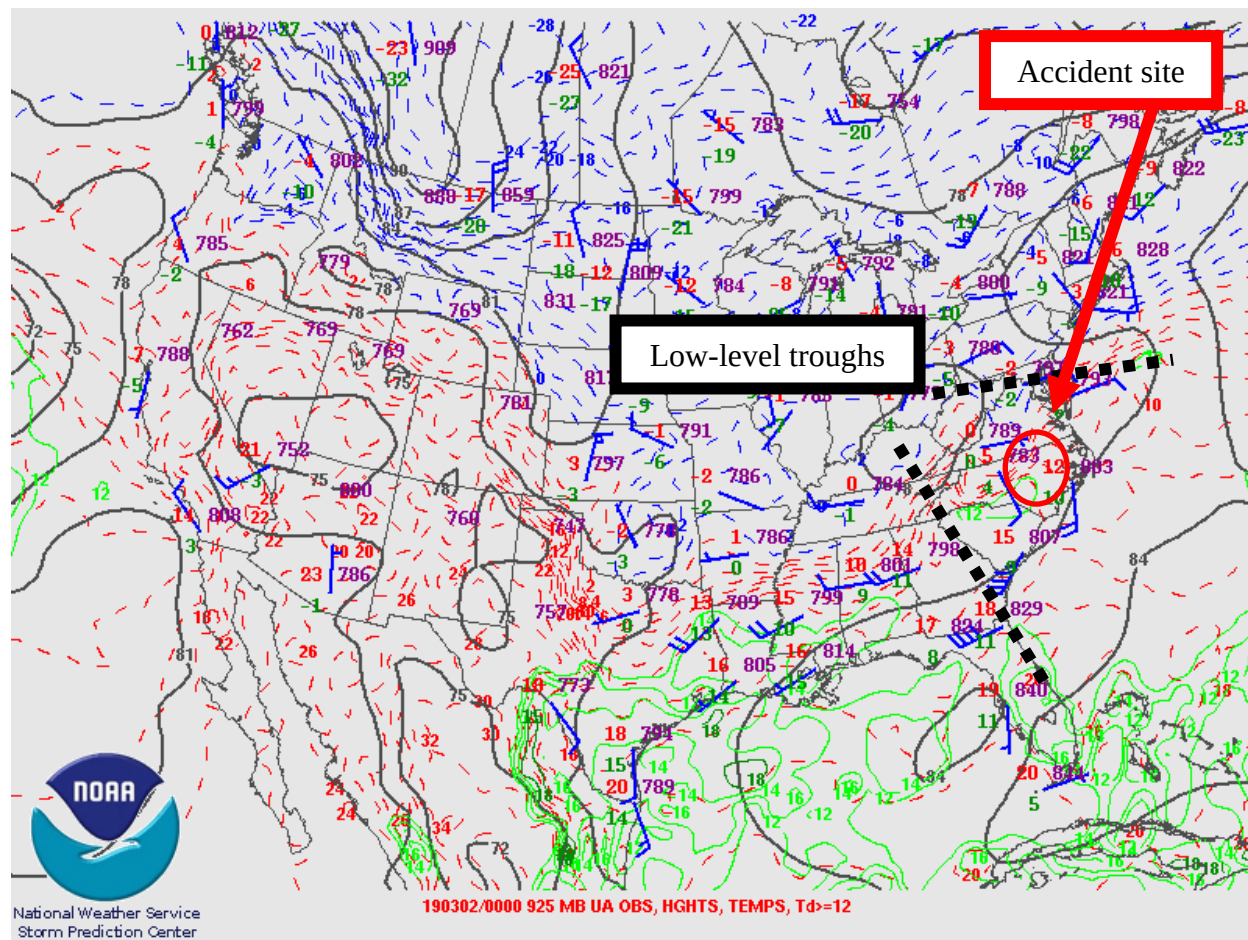


Figure 2 – 925-hPa Constant Pressure Chart for 1900 EST

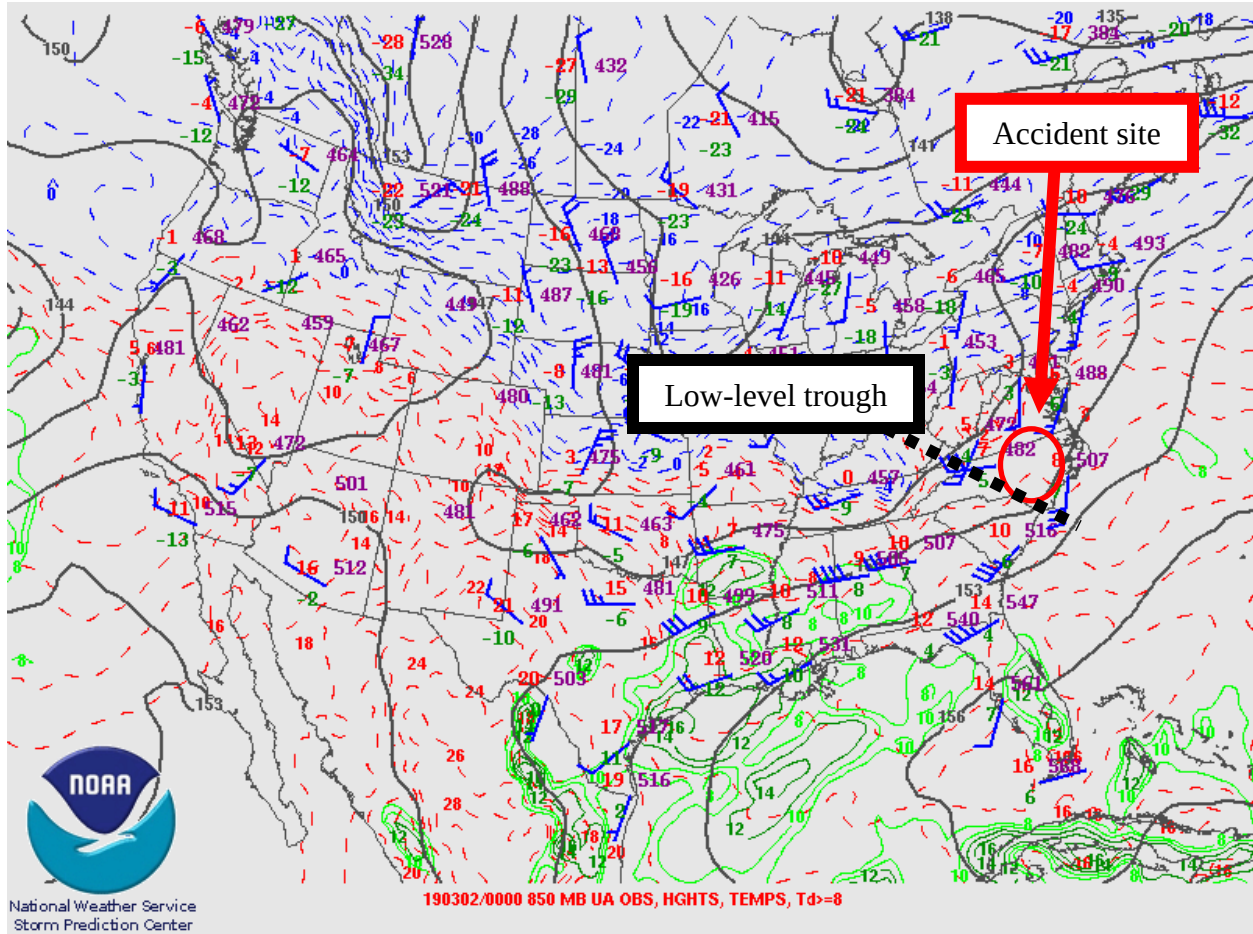


Figure 3 – 850-hPa Constant Pressure Chart for 1900 EST

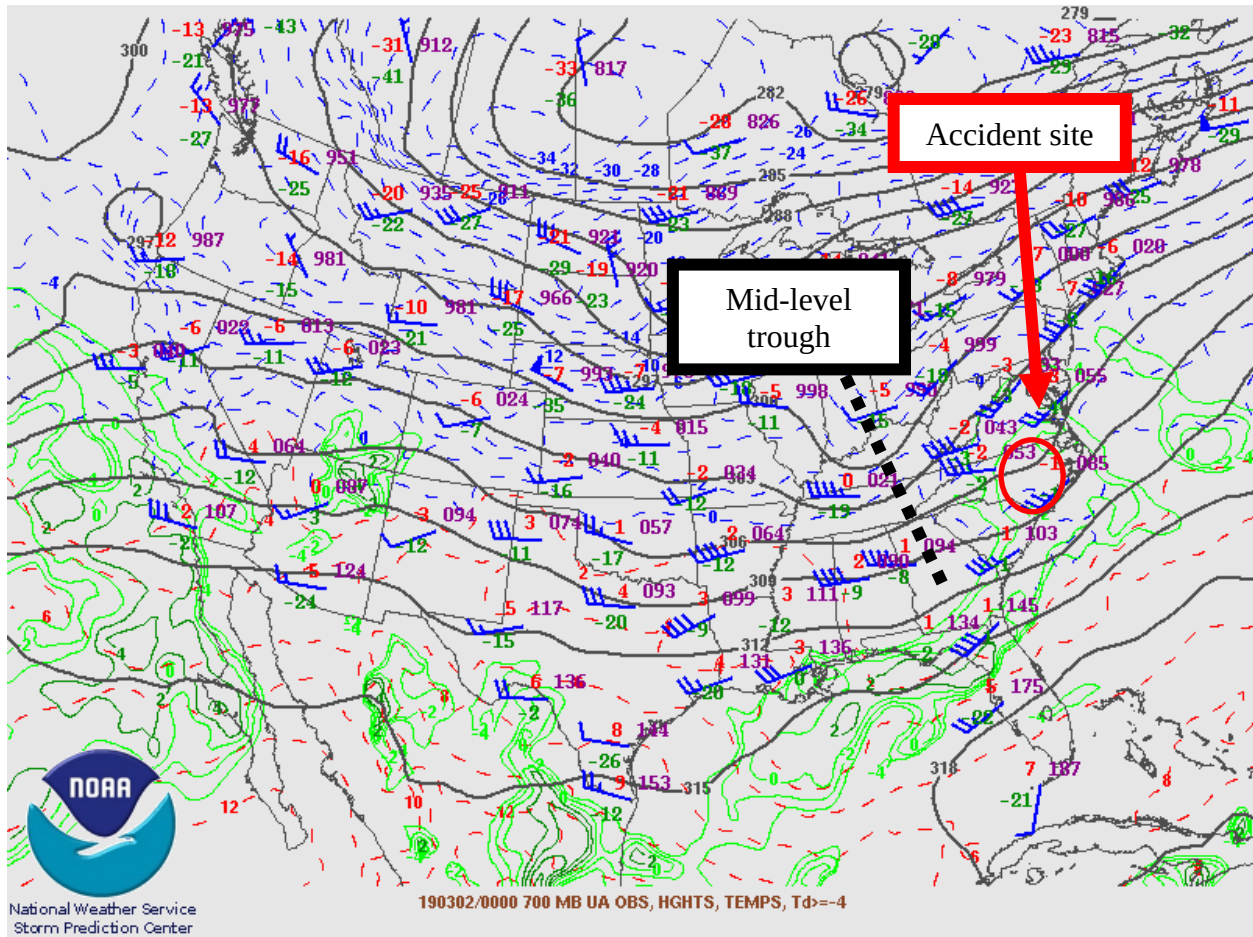


Figure 4 – 700-hPa Constant Pressure Chart for 1900 EST

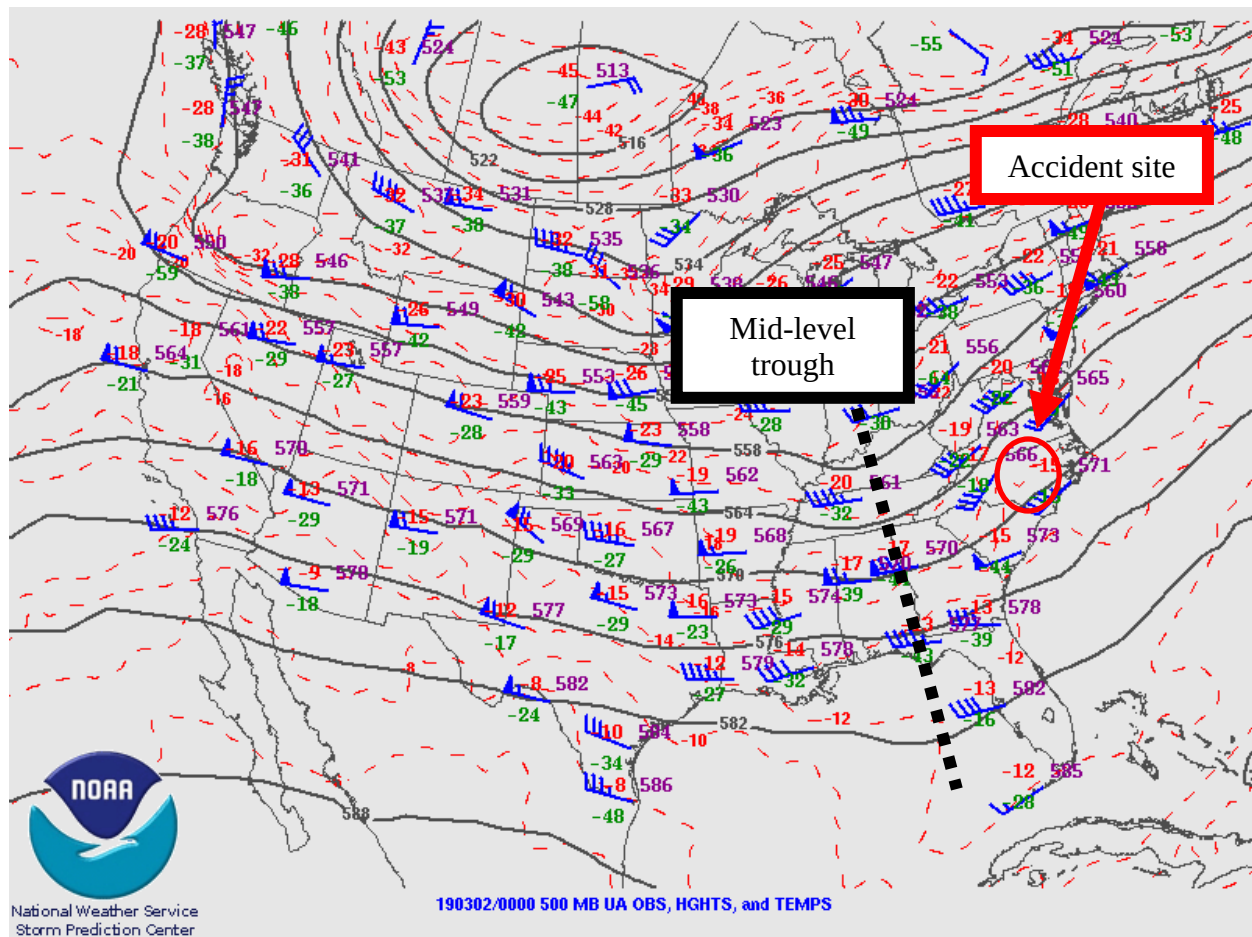


Figure 5 – 500-hPa Constant Pressure Chart for 1900 EST

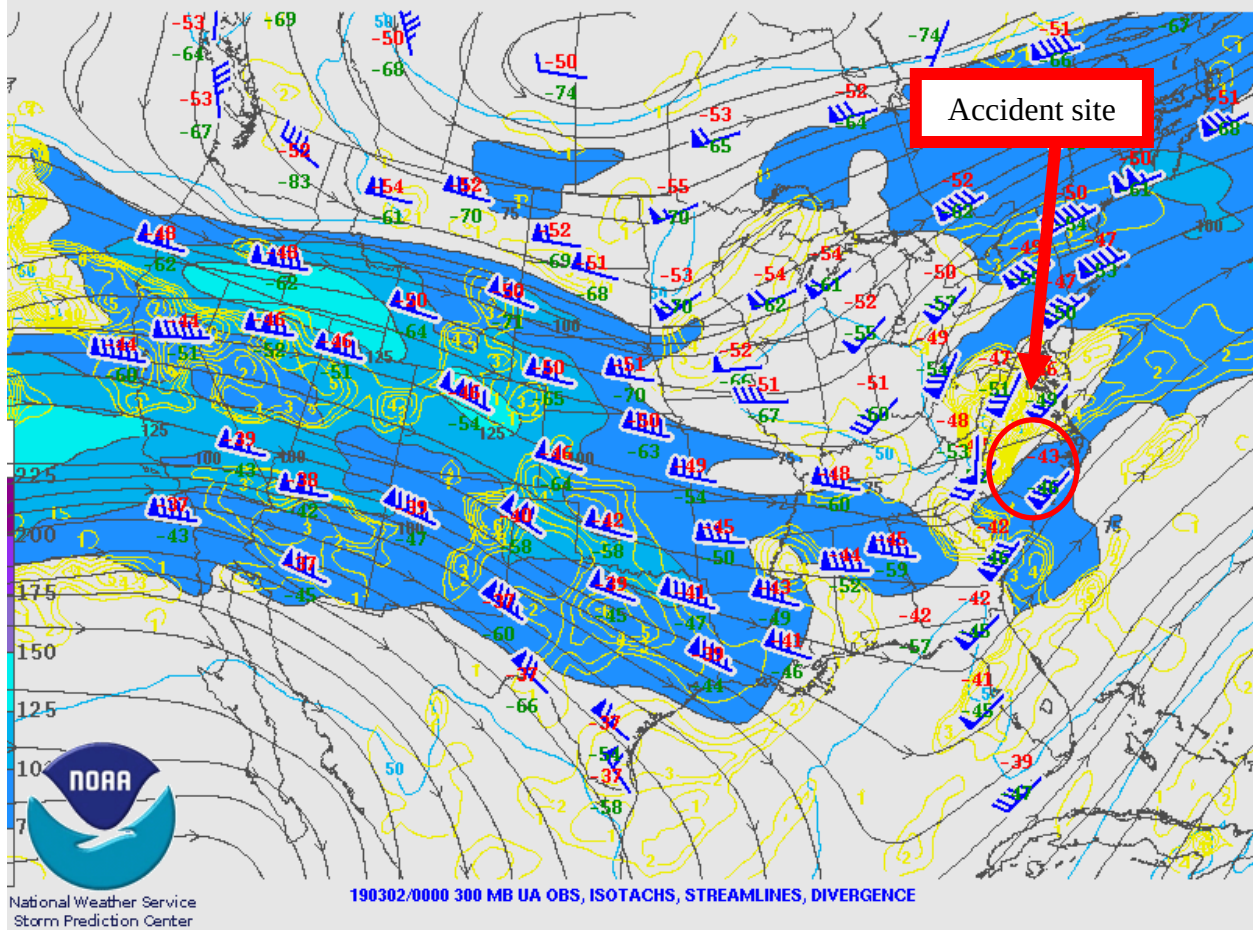


Figure 6 – 300-hPa Constant Pressure Chart for 1900 EST

2.0 SPC Products

SPC issued the following Day 1 Convective Outlook at 1440 EST (figure 7) with areas of general thunderstorms forecast for the accident site. SPC defines the “TSTM” area as an area that encloses where a 10% or higher probability of thunderstorms is forecast during the valid period. The SPC Day 1 Convective Outlook text follows figure 7:

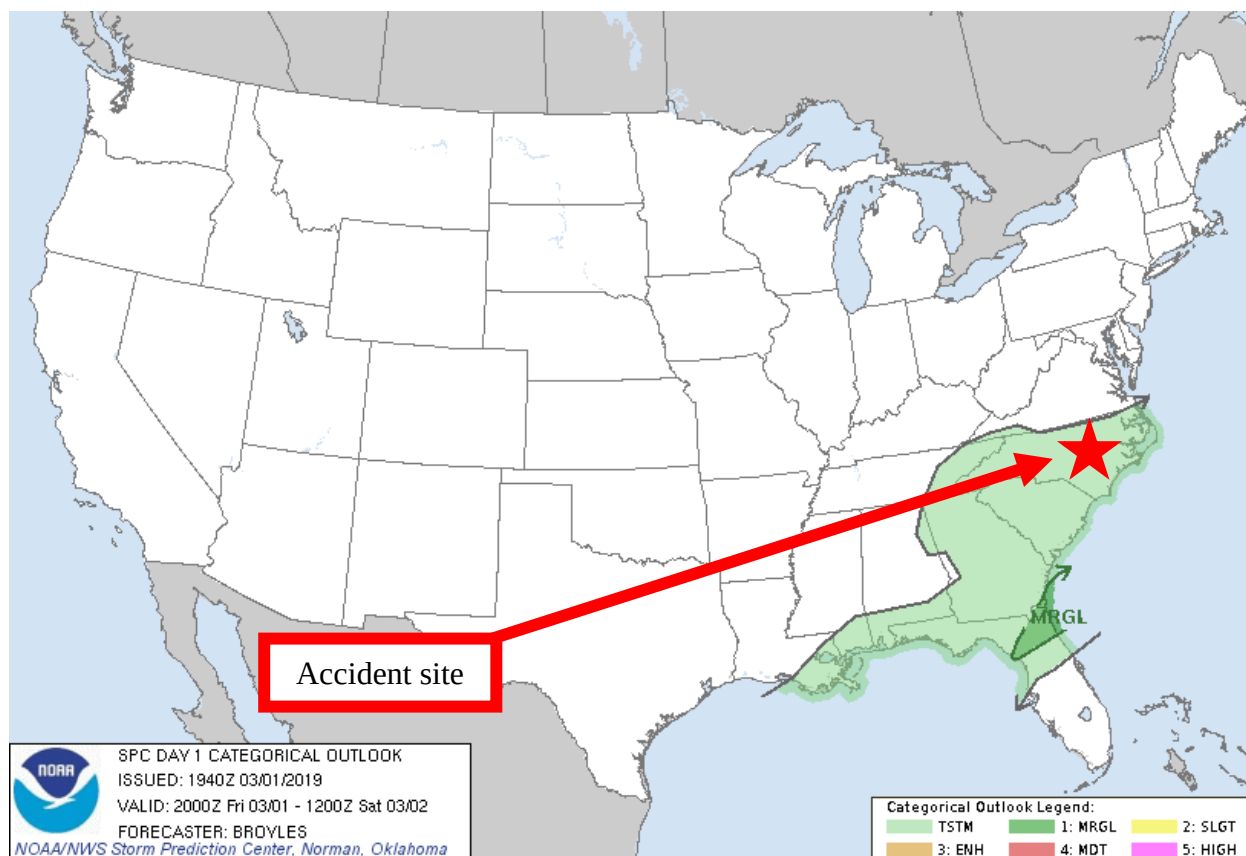


Figure 7 – SPC day 1 Convective Outlook valid at the time of the accident

SPC AC 011940

Day 1 Convective Outlook
NWS Storm Prediction Center Norman OK
0140 PM CST Fri Mar 01 2019

Valid 012000Z - 021200Z

...THERE IS A MARGINAL RISK OF SEVERE THUNDERSTORMS ACROSS PARTS OF FAR SOUTHEAST GEORGIA AND NORTHERN FLORIDA...

...SUMMARY...

Thunderstorms are possible across much of the Southeast. A few strong storms may affect parts of far southeast Georgia and northern Florida this afternoon.

...DISCUSSION...

The only change to the outlook for this issuance is to remove the marginal risk from areas behind the line that is currently in northern Florida. The marginal risk for strong wind gusts continues ahead of the line where MLCAPE values are around 1000 J/kg and 0-6 Km shear is near 50 kt according the RAP.

..Broyles.. 03/01/2019

.PREV DISCUSSION... /ISSUED 1011 AM CST Fri Mar 01 2019/

...GA/FL...

A progressive shortwave trough is moving across the central Gulf Coast region. This system has resulted in a line of thunderstorms extending from southwest GA and the central FL peninsula into the northeast Gulf of Mexico. Clearing is occurring ahead of the line, resulting in weak destabilization and steepening of low level lapse rates over southeast GA and north FL. This area may see a few strong storms capable of gusty winds through the afternoon. Therefore have added a Marginal risk to this region. Please refer to Mesoscale Discussion #135 for further details.

Farther north, widespread clouds continue to inhibit surface heating and destabilization in an otherwise favorably sheared environment. While an isolated strong storm cannot be ruled out over parts of north GA into the western Carolinas this afternoon, the risk appears too low to warrant severe probabilities at this time.

[CLICK TO GET WUUS01 PTSDY1 PRODUCT](#)

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 8 is a local sectional chart with the accident site and the closest weather reporting location marked.

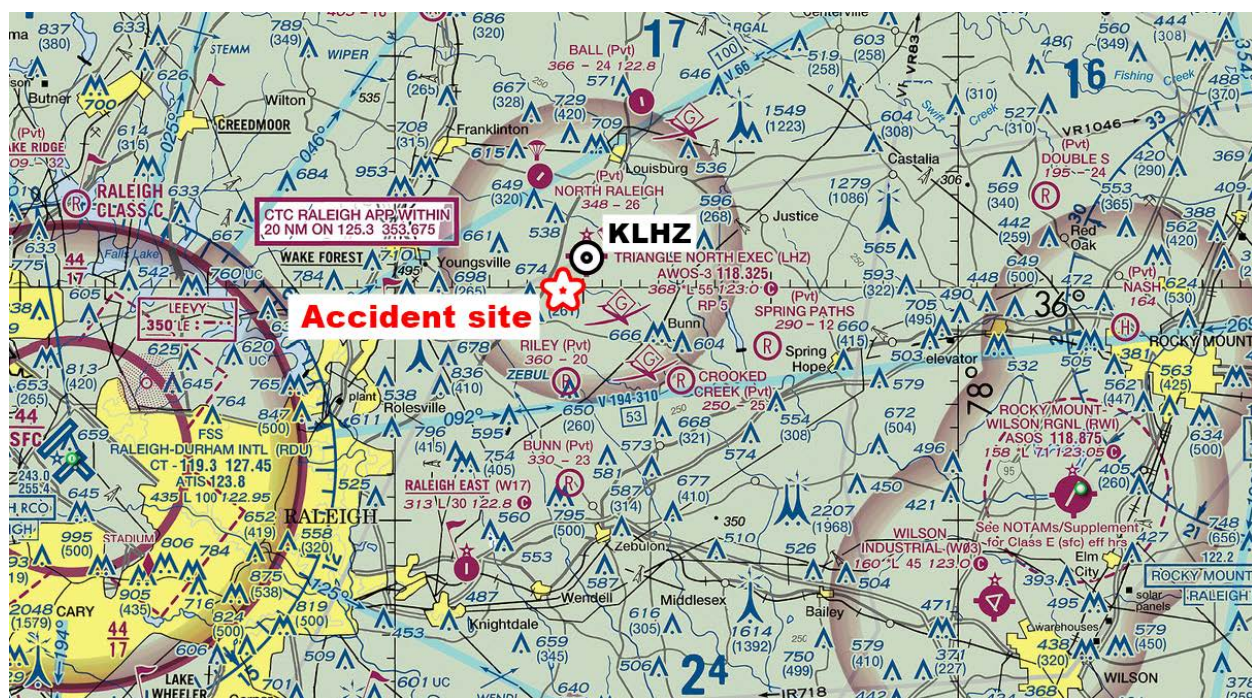


Figure 8 – Sectional map of the accident area with the location of the accident site and surface observation site

Triangle North Executive Airport (KLHZ), had the closest official weather station to the accident site (and was also the departure airport). KLHZ had an Automated Weather Observing System (AWOS³) whose reports were not supplemented. KLHZ was located 2 miles northeast of the accident site, at an elevation of 368 ft, and had a 9° westerly magnetic variation⁴ (figure 8). The following observations were taken and disseminated during the times surrounding the accident:⁵

[1700 EST] METAR KLHZ 012200Z AUTO 01005KT 3SM +RA BKN004 OVC009 05/05
A3008 RMK AO2=

[1720 EST] METAR KLHZ 012220Z AUTO 03005KT 3SM +RA OVC004 05/05 A3008
RMK AO2 P0009=

[1740 EST] METAR KLHZ 012240Z AUTO 01005KT 4SM RA OVC004 05/05 A3007
RMK AO2 P0015=

[1800 EST] METAR KLHZ 012300Z AUTO 03005KT 5SM RA OVC006 04/04 A3008
RMK AO2=

[1820 EST] METAR KLHZ 012320Z AUTO 01005KT 5SM +RA BKN004 OVC008 04/04
A3007 RMK AO2 P0008=

[1840 EST] METAR KLHZ 012340Z AUTO 34003KT 1 3/4SM -SN OVC006 04/04
A3008 RMK AO2 VIS 1 1/2V3 P0025=

**[1900 EST] METAR KLHZ 020000Z AUTO 33003KT 2SM UP OVC006 04/04 A3009
RMK AO2 VIS 1 1/2V3 P0001=**

**[1920 EST] METAR KLHZ 020020Z AUTO 02004KT 5SM RA SCT003 BKN006 OVC011
04/04 A3008 RMK AO2 P0007=**

ACCIDENT TIME 1921 EST

**[1940 EST] METAR KLHZ 020040Z AUTO 36003KT 7SM -RA OVC006 04/04 A3008
RMK AO2 P0009=**

³ AWOS – Automated Weather Observing System is equipped with meteorological instruments to observe and report temperature, dewpoint, wind speed and direction, visibility, cloud coverage and ceiling up to twelve thousand feet, and altimeter setting.

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

⁵ 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.

**[2000 EST] METAR KLHZ 020100Z AUTO 32007KT 4SM +RA OVC006 04/04 A3012
RMK AO2 P0001=**

[2020 EST] METAR KLHZ 020120Z AUTO 04007KT 5SM RA BKN004 OVC010 04/04
A3007 RMK AO2 P0007=

[2040 EST] METAR KLHZ 020140Z AUTO 02006KT 7SM RA OVC006 03/03 A3009
RMK AO2 P0009=

KLHZ weather at 1900 EST, automated, wind from 330° at 3 knots, 2 miles visibility, unknown precipitation, an overcast ceiling at 600 ft above ground level (agl), temperature of 4 °Celsius (C), dew point temperature of 4 °C, and an altimeter setting of 30.09 inches of mercury (inHg). Remarks: automated station with a precipitation discriminator, visibility varying between 1 and a half miles and 3 miles, 0.01 inches of precipitation since 1900 EST.

KLHZ weather at 1920 EST, automated, wind from 020° at 4 knots, 5 miles visibility, moderate rain, scattered clouds at 300 ft agl, broken ceiling at 600 ft agl, overcast clouds at 1,100 ft agl, temperature of 4 °C, dew point temperature of 4 °C, and an altimeter setting of 30.08 inHg. Remarks: automated station with a precipitation discriminator, 0.07 inches of precipitation since 1900 EST.

KLHZ weather at 1940 EST, automated, wind from 360° at 3 knots, 7 miles visibility, light rain, overcast ceiling at 600 ft agl, temperature of 4 °C, dew point temperature of 4 °C, and an altimeter setting of 30.08 inHg. Remarks: automated station with a precipitation discriminator, 0.09 inches of precipitation since 1900 EST.

KLHZ weather at 2000 EST, automated, wind from 320° at 7 knots, 4 miles visibility, heavy rain, overcast ceiling at 600 ft agl, temperature of 4 °C, dew point temperature of 4 °C, and an altimeter setting of 30.12 inHg. Remarks: automated station with a precipitation discriminator, 0.01 inches of precipitation since 2000 EST.

The observations from KLHZ surrounding the accident time indicated IFR⁶ conditions with light to heavy rain and a northwest to northeast surface wind between 3 to 7 knots.

⁶ Instrument Flight Rules (IFR) – Refers to the general weather conditions pilots can expect at the surface. IFR criteria means a ceiling below 1,000 ft agl and/or less than 3 miles visibility.

4.0 Upper Air Data

The closest official upper air sounding to the accident site was from Greensboro, North Carolina, KGSO, located 78 miles west of the accident site, with a site number 72317, with an elevation of 886 ft. The 1900 EST KGSO sounding was plotted on a standard Skew-T Log P diagram⁷ with the derived stability parameters included in figure 9 (with data from the surface to 400-hPa, or around 24,000 ft msl.) This data was analyzed using the RAOB⁸ software package. The sounding depicted the lifted condensation level (LCL)⁹ and the level of free convection (LFC)¹⁰ at the surface (886 ft msl), and the convective condensation level (CCL)¹¹ at 6,995 ft agl (7,881 ft msl). The sounding had a greater than 85% relative humidity from the surface through 20,000 ft msl. The freezing level was at 8,644 ft msl. The precipitable water value was 0.96 inches. A frontal inversion was noted between 1,000 through 4,000 ft, where temperature increased with altitude.

⁷ 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.

⁸ RAOB – (The complete Rawinsonde Observation program) is an interactive sounding analysis program developed by Environmental Research Services, Matamoras, Pennsylvania.

⁹ LCL - The height at which a parcel of moist air becomes saturated when it is lifted dry adiabatically.

¹⁰ 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.

¹¹ 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.

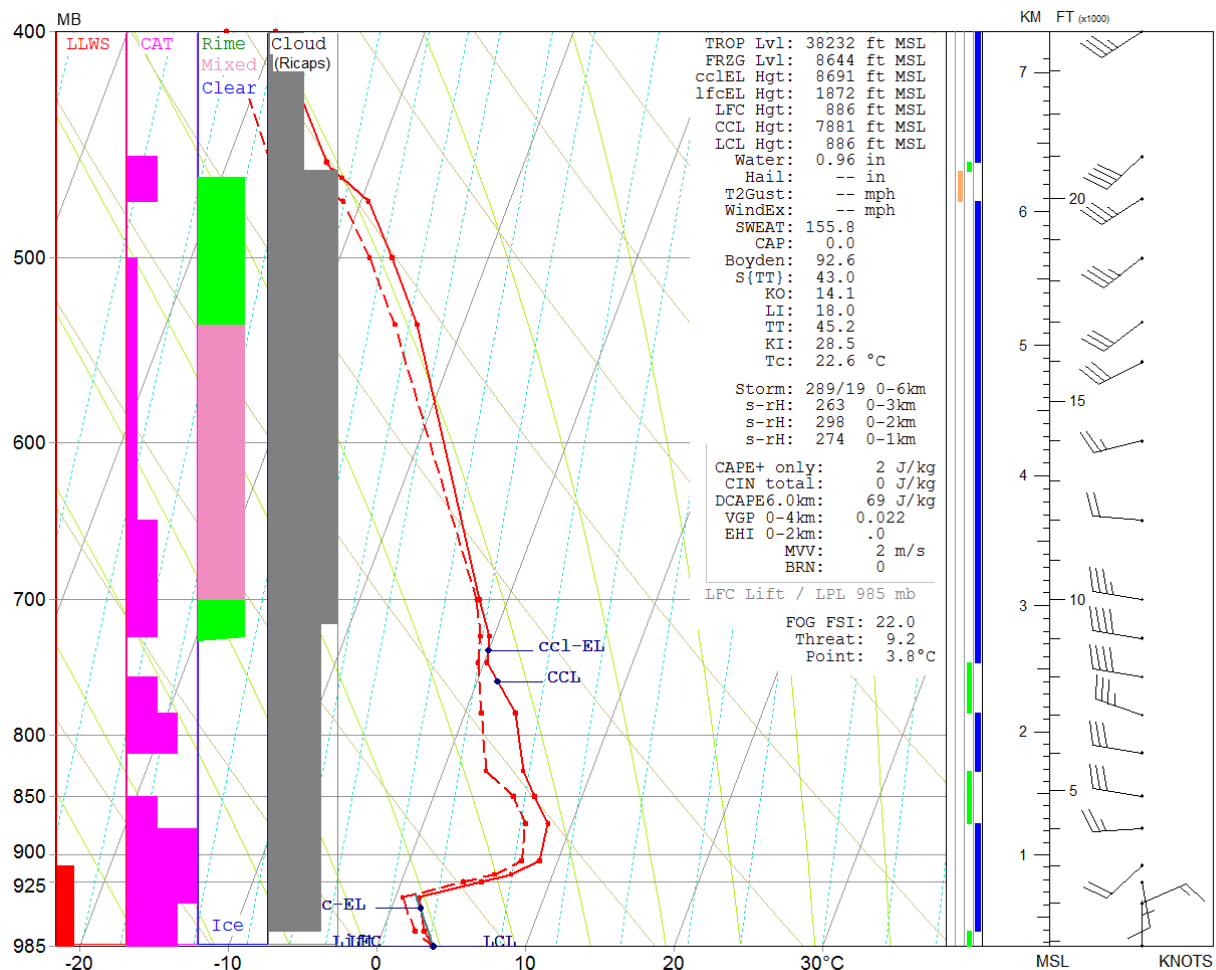


Figure 9 – 1900 EST KGSO sounding

The 1900 EST KGSO sounding indicated alternating layers of conditional instability and a stable environment from the surface through 20,000 ft msl. RAOB identified the possibility of clouds between 1,000 ft msl through 24,000 ft. Moderate rime and mixed icing was indicated by RAOB between 9,000 ft msl and 20,000 ft msl.

The 1900 EST KGSO sounding wind profile indicated a surface wind from 360° at 5 knots with the wind veering¹² to the south by 2,500 ft msl. The wind increased in speed to 20 knots by 3,000 ft msl. The wind continued to veer to the west by 4,000 ft with increasing wind speed to 30 knots. The wind remained from the west to southwest above 4,000 ft through 24,000 ft with the wind speed between 30 to 45 knots. RAOB indicated a high probability of moderate or greater clear-air turbulence between the surface and 12,000 ft msl. Light to moderate low-level wind shear (LLWS) was indicated by RAOB from the surface through 3,000 ft msl.

¹² A change in wind direction with height in a clockwise sense in the Northern Hemisphere

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 $10.3 \mu\text{m}$, respectively, were retrieved for the period from 1600 EST through 2200 EST and reviewed, and the closest images to the time of the accident were documented. Due to the solar angle and time of day the visible imagery was not beneficial around the accident time.

Figures 10, 11, and 12 present the GOES-16 infrared imagery from 1900, 1915, and 1930 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 to the west, north, and east of the accident site with the cloud cover moving from west to east. Based on the brightness temperatures above the accident site and the vertical temperature profile provided by the 1900 EST KGSO sounding, the approximate cloud-top heights over the accident site were estimated at 18,000 ft at 1915 EST (258° Kelvin). It should be noted these figures have not been corrected for any parallax error.

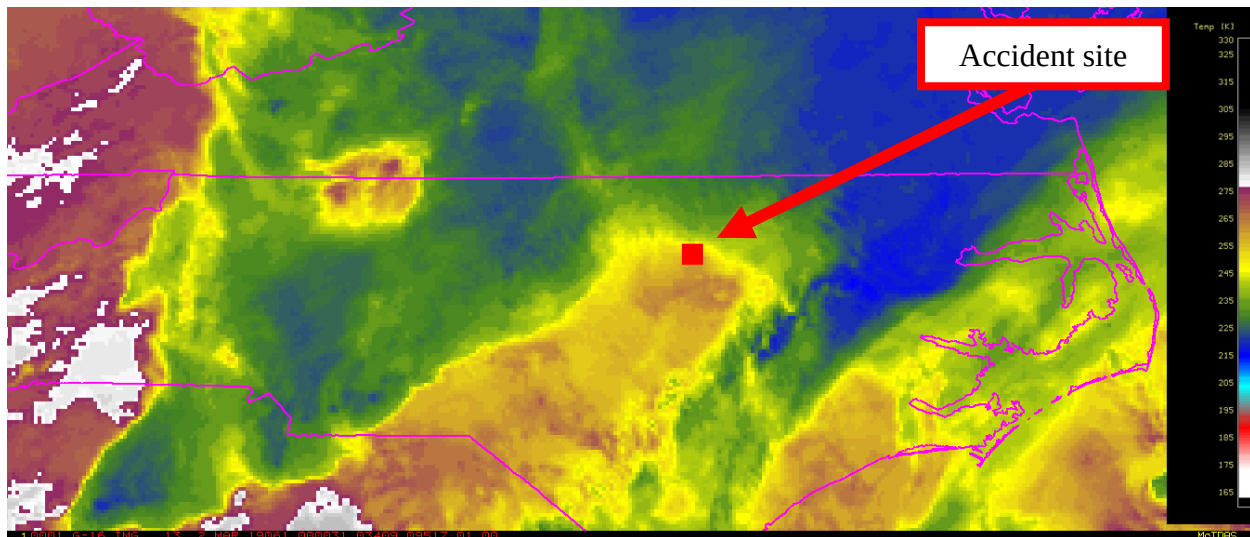


Figure 10 – GOES-16 infrared image at 1900 EST

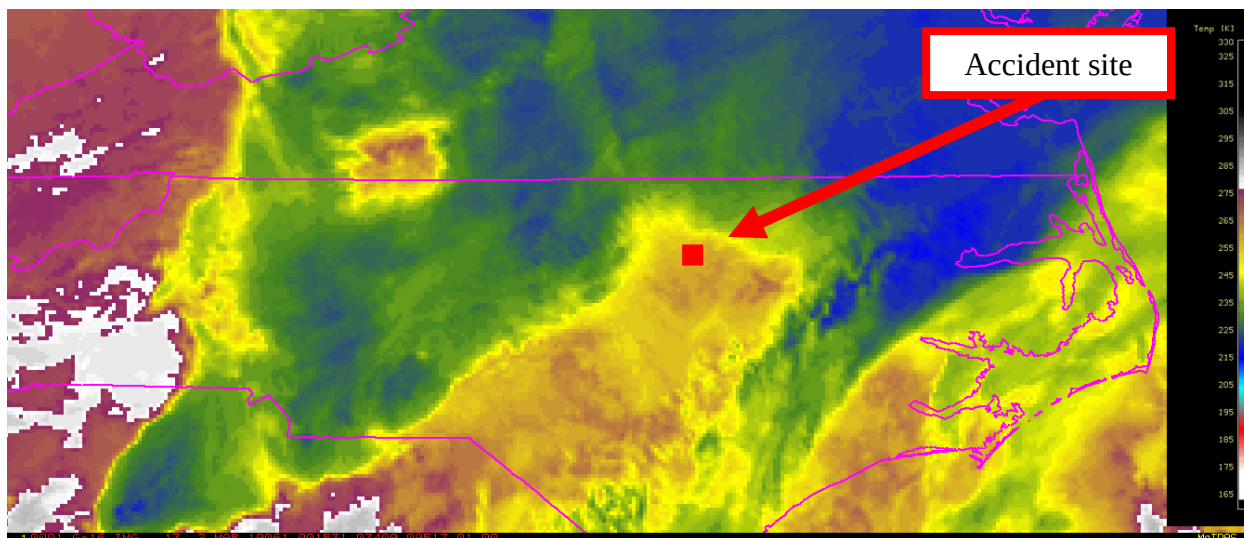


Figure 11 – GOES-16 infrared image at 1915 EST

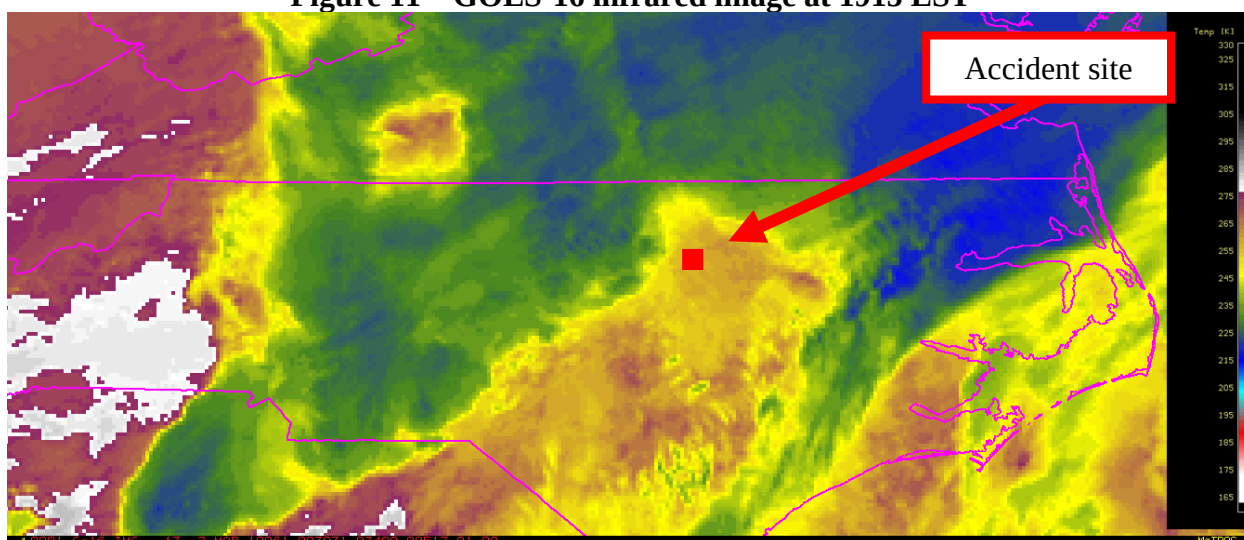


Figure 12 – GOES-16 infrared image at 1930 EST

6.0 Regional Radar Imagery Information

A regional view of the NWS national composite radar mosaic is included as figure 13 for 1920 EST with the approximate location of the accident site marked by a red circle. The image depicted echoes from 30 to 45 decibels (dBZ¹³) echoes over the accident area at the accident time.

¹³ 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.

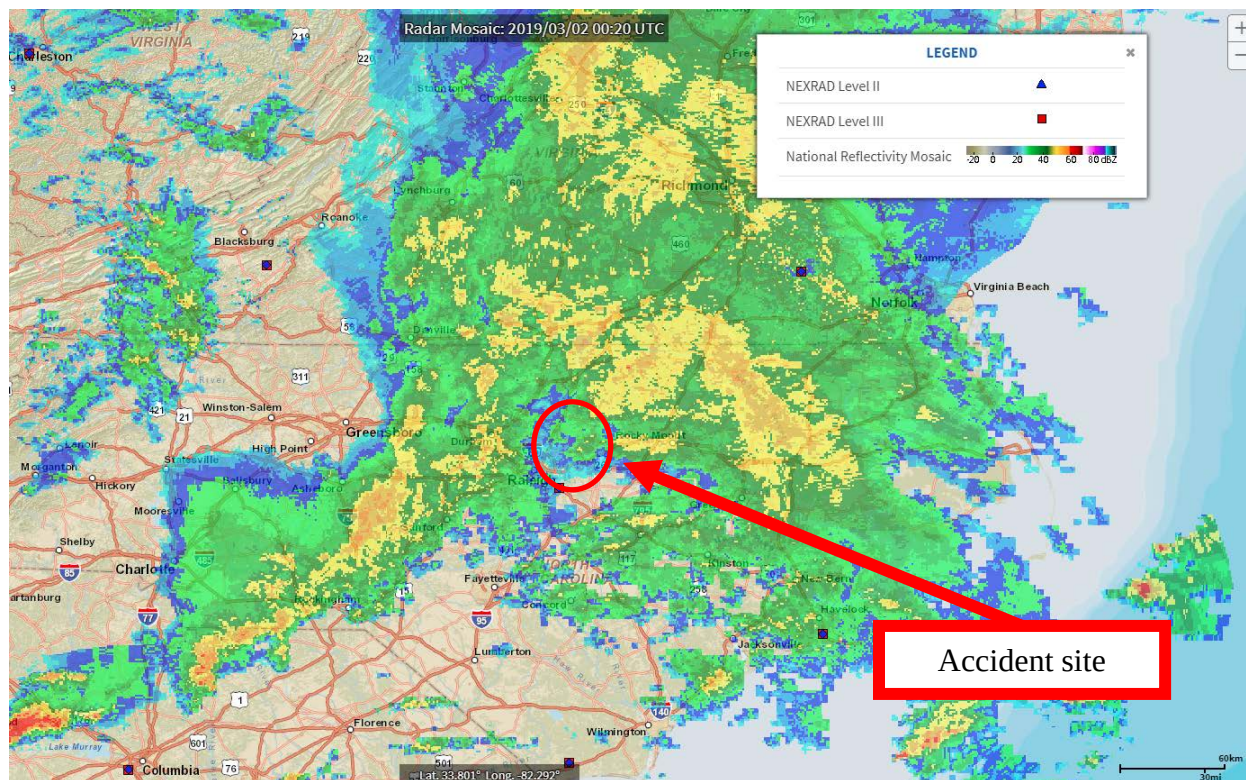


Figure 13 – Regional Composite Reflectivity image for 1920 EST

7.0 Radar Imagery Information

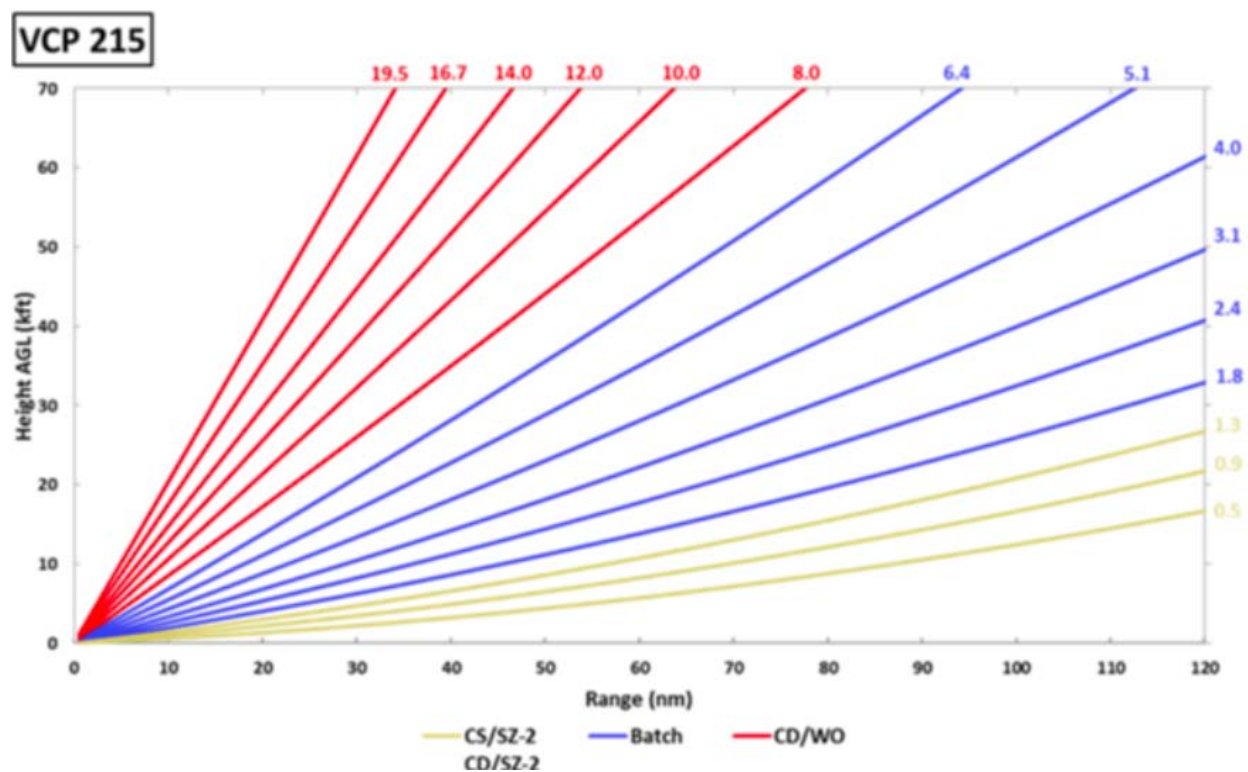
The closest NWS Weather Surveillance Radar-1988, Doppler (WSR-88D)¹⁴ to the accident site was Raleigh/Durham, North Carolina, (KRAX) and was located 21 miles south-southwest of the accident site. Level II archive radar data was obtained from the NCEI utilizing the NEXRAD Data Inventory Search and displayed using the NOAA’s Weather and Climate Toolkit software.

¹⁴ 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

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 15 elevation scans from 0.5° to 19.5° every six minutes. This particular scanning strategy is documented as volume coverage pattern 215 (VCP-215). 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 KRAX WSR-88D radar was operating in the precipitation mode VCP-215. 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.



VCP-215 Precipitation Mode Scan Strategy¹⁵

¹⁵ 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 refraction¹⁶ of the WSR-88D radar beam with the antenna elevation at 461 ft (KRAX), and considering a beamwidth¹⁷ of 0.95°, the following table shows the approximate heights for the radar beam center, top and base 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
KRAX 0.5°	1,060 ft	570 ft	1,550 ft

Based on the radar height calculations, the elevation scan listed in the above table depicted the conditions between 570 ft and 1,550 ft msl over the accident site and these scans “saw” the closest altitudes to the ground.

7.3 Reflectivity

Reflectivity is the measure of the efficiency of a target in intercepting and returning radio energy. With hydrometeors¹⁸ 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 00-24C¹⁹, “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.” From the NWS, precipitation conditions at the surface can be inferred from VIP Levels described in the chart below:

¹⁶ Standard Refraction in the atmosphere is when the temperature and humidity distributions are approximately average, and values set at the standard atmosphere.

¹⁷ Beamwidth - the angular separation between the half power points on the antenna radiation pattern, where the gain is one half the maximum value.

¹⁸ 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.

¹⁹

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

- VIP 1 (Level 1, 18-30 dBZ) - Light precipitation
- VIP 2 (Level 2, 30-38 dBZ) - Light to moderate rain
- VIP 3 (Level 3, 38-44 dBZ) - Moderate to heavy rain
- VIP 4 (Level 4, 44-50 dBZ) - Heavy rain
- VIP 5 (Level 5, 50-57 dBZ) - Very heavy rain; hail possible
- VIP 6 (Level 6, >57 dBZ) - Very heavy rain and hail; large hail possible

7.4 Base Reflectivity and Lightning Data

Figures 14, 15, 16, and 17 present the KRAK WSR-88D base reflectivity images for the 0.5° elevation scans initiated at 1914:00, 1917:29, 1920:47, and 1924:11 EST, respectively, with a resolution of 0.5° X 250 m. Reflectivity values between 20 and 35 dBZ were located over KLHZ and above the accident site during the period. The reflectivity bands were moving from west to east (attachment 1).

There were no lightning strikes around the accident site at the accident time.²⁰

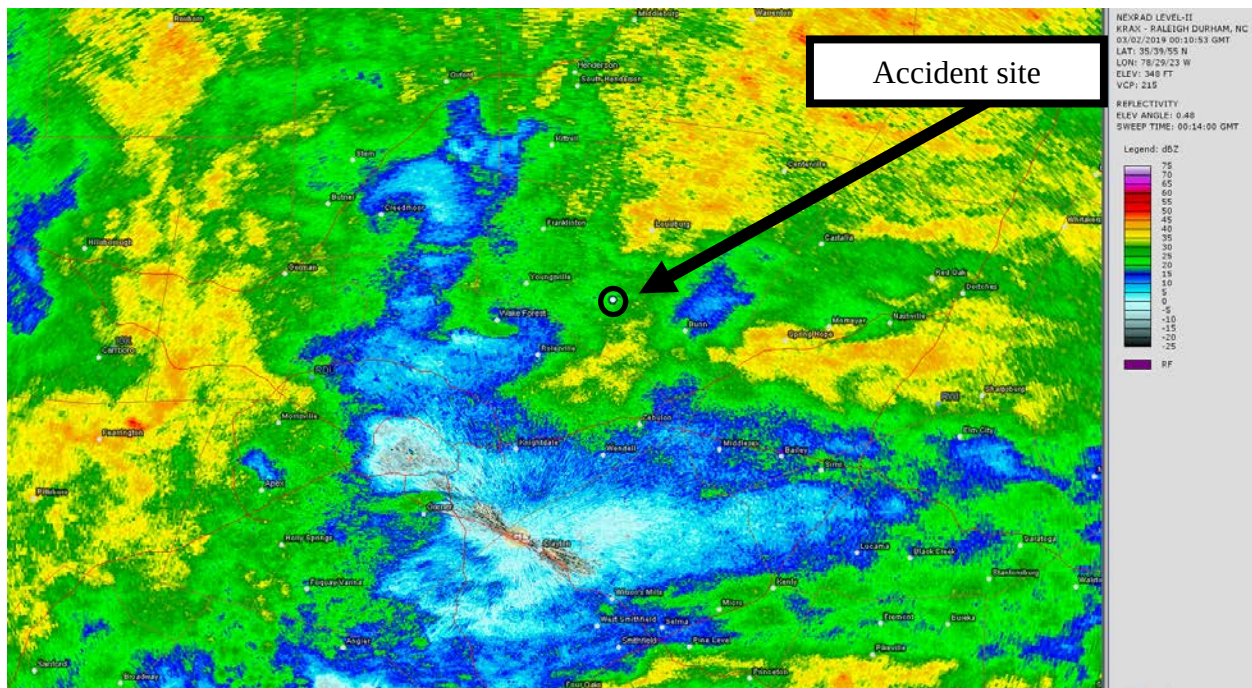


Figure 14 – KRAK WSR-88D reflectivity for the 0.5° elevation scan initiated at 1914:00 EST with the accident site marked with black circle

²⁰ A review of Earth Networks Total Lightning network was done.

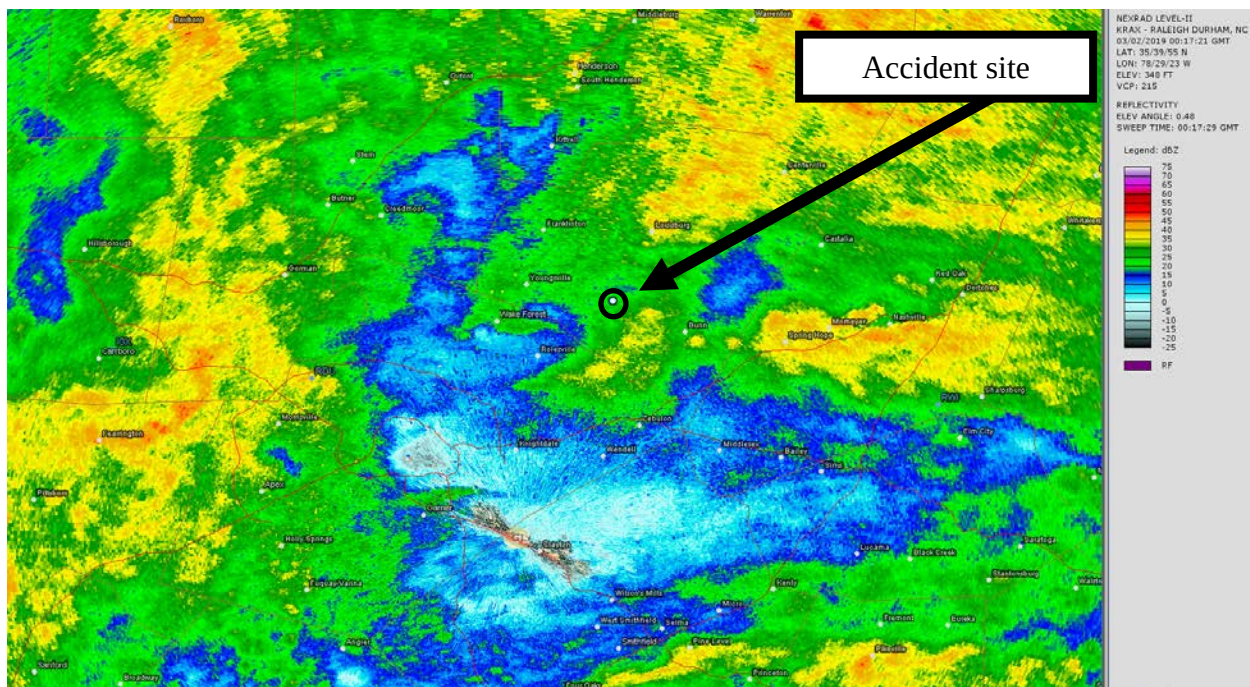


Figure 15 – KRAP WSR-88D reflectivity for the 0.5° elevation scan initiated at 1917:29 EST with the accident site marked with black circle

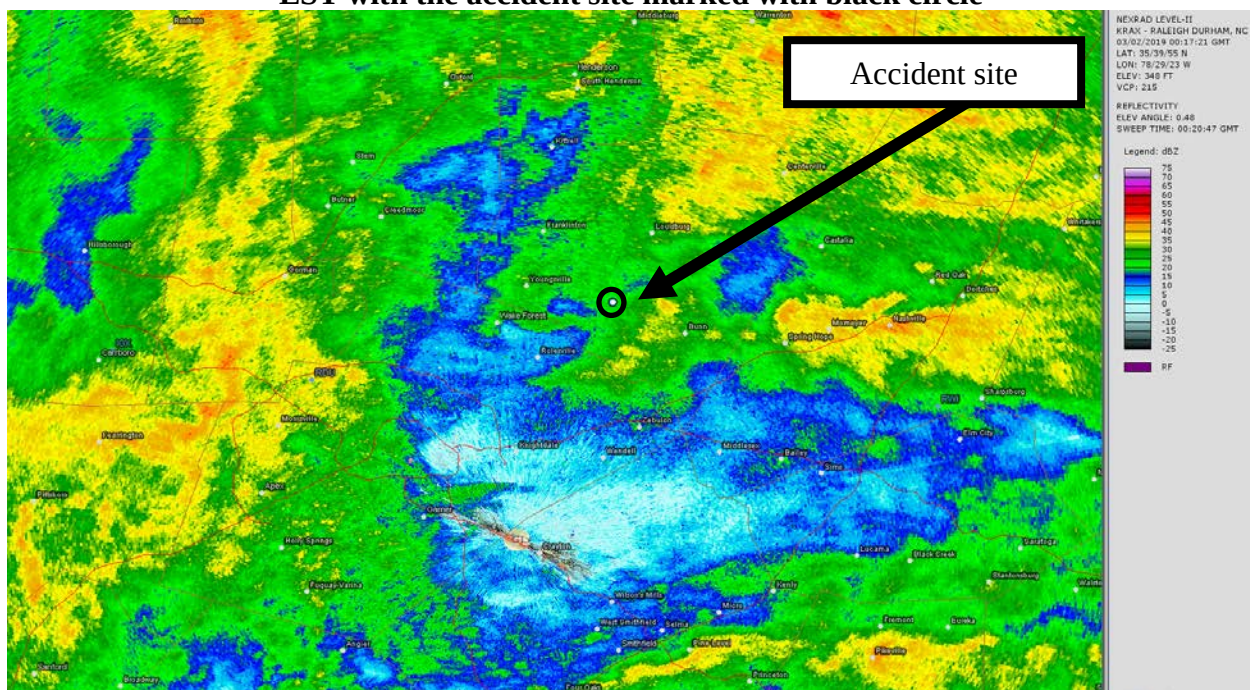


Figure 16 – KRAP WSR-88D reflectivity for the 0.5° elevation scan initiated at 1920:47 EST with the accident site marked with black circle

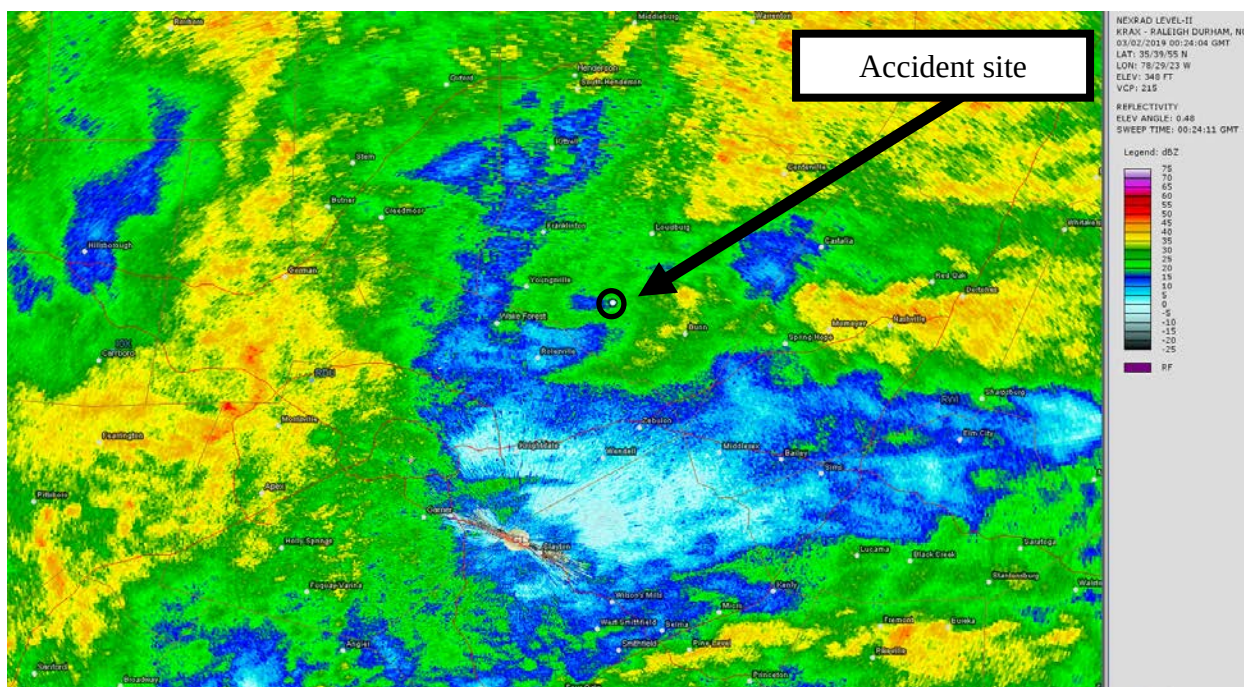


Figure 17 – KRAP WSR-88D reflectivity for the 0.5° elevation scan initiated at 1924:11 EST with the accident site marked with black circle

8.0 Pilot Reports²¹

All pilot reports (PIREPs) within 80 miles of the accident site from about two hours prior to two hours after the accident time for below FL190²² are provided below:

RDU UA /OV RDU135015/TM 2225/FL040/TP PA32/WX MOD RAIN/TB LT CHOP

RDU UA /OV RDU/TM 2235/FLDURGD/TP GLF4/SK OVC009

FAY UA /OV FAY090022/TM 2244/FL050/TP BE58/TB SEVERE TURBULENCE BETWEEN 050-060

FAY UA /OV FAY/TM 2258/FL003/TP CRJ2/SK CEILING BKN 003

RDU UA /OV RDU240040/TM 2300/FL170/TP CRJ7/TA M11/IC LGT RIME

FAY UA /OV SDZ/TM 2301/FL170/TP B737/TA M11/IC LGT RIME

GSO UA /OV GSO230001/TM 2314/FL014/TP E145/SK OVC015/WX LT RA/TB SMOOTH/RM DURD

RDU UA /OV RDU/TM 2347/FLDURGD/TP B737/SK OVC009

FAY UA /OV SDZ200015/TM 0019/FL190/TP CRJ7/TB MOD/RM 170-190

²¹ Only pilot reports with the World Meteorological Organization headers UBNC** and UBVA** were considered.

²² 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.

GSO UA /OV GSO230001/TM 0026/FL014/TP E175/SK OVC015/RM DURD

RDU UA /OV RDU045003/TM 0029/FL020/TP B737/SK BKN015

FAY UA /OV FAY/TM 0103/FL170/TP CRJ9/TB MOD OCNL CONT

BUY UA /OV BUY/TM 0120/FL014/TP PC12/SK OVC014

GSO UA /OV GSO230001/TM 0133/FLDURD/TP CRJ2/SK OVC015

AVC UA /OV LVL180025/TM 0138/FL160/TP A320/TA M09/IC LGT RIME/RM 160-140

The reports in plain language taken from standard code and abbreviations, with time converted to local were as follows:

Routine pilot report (UA) Raleigh-Durham International Airport, North Carolina (RDU); Over -15 miles from RDU VORTAC on the 135° radial; Time – 1725 EST (2225Z); Altitude – 4,000 ft; Type aircraft – Piper PA-32; Weather – Moderate rain; Turbulence – Light chop.

Routine pilot report (UA) RDU; Over - RDU; Time – 1735 EST (2235Z); Altitude – During descent; Type aircraft – Gulfstream IV; Sky – Overcast clouds at 900 ft.

Routine pilot report (UA) Fayetteville Regional Airport, North Carolina (FAY); Over - 22 miles from FAY on the 090° radial; Time – 1744 EST (2244Z); Altitude – 5,000 ft; Type aircraft – Beechcraft Baron; Turbulence – Severe turbulence between 5,000 and 6,000 ft.

Routine pilot report (UA) FAY; Over - FAY; Time – 1758 EST (2258Z); Altitude – 300 ft; Type aircraft – Bombardier CRJ-200; Sky – Ceiling broken at 300 ft.

Routine pilot report (UA) RDU; Over - 40 miles from RDU VORTAC on the 240° radial; Time – 1800 EST (2300Z); Altitude – 17,000 ft; Type aircraft – Bombardier CRJ-700; Temperature – -11 °C; Icing – Light rime.

Routine pilot report (UA) FAY; Over Southern Pines, North Carolina (SDZ) VORTAC; Time – 1801 EST (2301Z); Altitude – 17,000 ft; Type aircraft – Boeing B737-700; Temperature – -11 °C; Icing – Light rime.

Routine pilot report (UA) Piedmont Triad International Airport, North Carolina (GSO); Over - 1 mile from GSO on the 230° radial; Time – 1814 EST (2314Z); Altitude – 1,400 ft; Type aircraft – Embraer ERJ145; Sky – Overcast clouds at 1,500 ft; Weather – Light rain; Turbulence – Smooth; Remarks – During descent.

Routine pilot report (UA) RDU; Over - RDU; Time – 1847 EST (2347Z); Altitude – During descent; Type aircraft – Boeing B737-700; Sky – Overcast clouds at 900 ft.

Routine pilot report (UA) FAY; Over - 15 miles from SDZ on the 200° radial; Time – 1919 EST (0019Z); Altitude – 19,000 ft; Type aircraft – Bombardier CRJ-700; Turbulence – Moderate; Remarks – Between 17,000 and 19,000 ft.

Routine pilot report (UA) GSO; Over - 1 mile from GSO on the 230° radial; Time – 1926 EST (0026Z); Altitude – 1,400 ft; Type aircraft – Embraer ERJ175; Sky – Overcast clouds at 1,500 ft; Remarks – During descent.

Routine pilot report (UA) RDU; Over - 3 miles from RDU VORTAC on the 045° radial; Time – 1929 EST (0029Z); Altitude – 2,000 ft; Type aircraft – Boeing B737-700; Sky – Broken clouds at 1,500 ft.

Routine pilot report (UA) FAY; Over - FAY; Time – 2003 EST (0103Z); Altitude – 17,000 ft; Type aircraft – Bombardier CRJ-900; Turbulence – Moderate occasional continuous.

Routine pilot report (UA) Burlington-Alamance Regional Airport, North Carolina (BUY); Over - BUY; Time – 2020 EST (0120Z); Altitude – 1,400 ft; Type aircraft – Pilatus PC-12; Sky – Overcast clouds at 1,400 ft.

Routine pilot report (UA) GSO; Over - 1 mile from GSO on the 230° radial; Time – 2033 EST (0133Z); Altitude – During descent; Type aircraft – Bombardier CRJ-200; Sky – Overcast clouds at 1,500 ft.

Routine pilot report (UA) Mecklenburg-Brunswick Regional Airport, Virginia (AVC); Over - 25 miles from Lawrenceville, Virginia (LVL) VORTAC on the 180° radial; Time – 2038 EST (0138Z); Altitude – 16,000 ft; Type aircraft – Airbus A320; Temperature – -9 °C; Icing – Light rime; Remarks – Between 16,000 and 14,000 ft.

9.0 SIGMET

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

10.0 CWSU Products

There were no Center Weather Service Unit (CWSU) Meteorological Impact Statements (MIS) or Center Weather Advisories (CWA) valid for the accident site at the accident time.

11.0 AIRMETs

Airmen's Meteorological Information (AIRMET) advisories Sierra, Tango, and Zulu were valid for the accident flight's track and accident site at the accident time. The AIRMETs warned of IFR conditions due to precipitation, mist, and fog, moderate icing between the freezing level²³ and FL250, LLWS expected:

WAUS42 KPCI 020008 AAC
WA2T
-MIAT WA 020008 AMD
AIRMET TANGO UPDT 7 FOR TURB AND LLWS VALID UNTIL 020300

²³ Freezing level between 8,000 and 12,000 ft.

.
AIRMET TURB...NC SC GA FL AND CSTL WTRS...UPDT
FROM 160SE SIE TO 190ESE ECG TO 130SSE ILM TO 220ENE TRV TO
90WSW PIE TO 170SE LEV TO 40W CEW TO 50SW PZD TO GQO TO HMV TO
20NE ECG TO 160SE SIE
MOD TURB BTN FL220 AND FL390. CONDS CONTG BYD 03Z THRU 09Z.

.
LLWS POTENTIAL...NC SC GA AND CSTL WTRS
BOUNDED BY 20ESE GSO-30SW ECG-110E ILM-30SW SAV-30WNW ODF-20ESE
GSO
LLWS EXP. CONDS DVLPG 21-00Z. CONDS CONTG BYD 03Z THRU 09Z.
....

WAUS42 KKCI 012246 AAB
WA2S
-MIAS WA 012246 AMD
AIRMET SIERRA UPDT 8 FOR IFR AND MTN OBSCN VALID UNTIL 020300

.
AIRMET IFR...NC SC GA MA RI NY NJ PA OH WV MD DC DE VA AND CSTL
WTRS...UPDT
FROM 40SSE JHW TO 30W ETX TO 30SSW SAX TO 180SSE ACK TO 160SE
SIE TO 190ESE ECG TO 170SE ECG TO 60E CHS TO 20SE IRQ TO 20SSE
VXV TO HMV TO 30N HNN TO 50ESE AIR TO 40SSE JHW
CIG BLW 010/VIS BLW 3SM PCPN/BR/FG. CONDS CONTG BYD 03Z THRU 09Z.

.
AIRMET MTN OBSCN...NC SC GA NY PA WV MD VA
FROM MSS TO 50E MSS TO ALB TO 40SSE PSK TO CLT TO ATL TO GQO TO
HMV TO HNN TO JHW TO SYR TO MSS
MTNS OBSC BY CLDS/PCPN/BR. CONDS CONTG BYD 03Z THRU 09Z.

.
OTLK VALID 0300-0900Z...IFR NC SC GA FL AND CSTL WTRS...UPDT
BOUNDED BY 160SE SIE-190ESE ECG-130SSE ILM-100E CRG-20WSW ORL-
40SSW RSW-90WSW PIE-170SE LEV-130ESE LEV-40W CEW-50SW PZD-LGC-
20ESE VXV-HMV-20NE ECG-160SE SIE
CIG BLW 010/VIS BLW 3SM PCPN/BR/FG. CONDS CONTG THRU 09Z.
....

WAUS42 KKCI 012045
WA2Z
-MIAZ WA 012045
AIRMET ZULU UPDT 3 FOR ICE AND FRZLVL VALID UNTIL 020300

.
AIRMET ICE...NC SC GA AND CSTL WTRS
FROM 180SE SIE TO 190ESE ECG TO 130SSE ILM TO 50W IRQ TO 20ESE
VXV TO HMV TO ECG TO 180SE SIE
MOD ICE BTN FRZLVL AND FL250. FRZLVL 080-120. CONDS CONTG BYD 03Z
ENDG 06-09Z.

.
AIRMET ICE...SC GA FL AND CSTL WTRS
FROM 50W IRQ TO 130SSE ILM TO 220SE CHS TO 80ENE OMN TO 90WSW PIE
TO 190SE LEV TO 80SW TLH TO 30W PZD TO 50W IRQ
MOD ICE BTN FRZLVL AND FL250. FRZLVL 080-120. CONDS CONTG BYD 03Z
ENDG 06-09Z.

.
FRZLVL...RANGING FROM 040-140 ACRS AREA
MULT FRZLVL 040-110 BOUNDED BY 30NE BKW-60SSW CSN-50SW RIC-

20SE GQO-HMV-50WSW BKW-30NE BKW
080 ALG GQO-30S HMV-30ESE GSO-60S RIC
120 ALG 130ESE LEV-40W ORL-220SE CHS

....

12.0 Graphical Forecasts for Aviation

The Graphical Forecasts for Aviation (GFA) products made available before the accident flight are shown in attachment 2. The GFA surface forecast products indicated IFR to MVFR²⁴ surface visibilities at the accident site and along the intended flight path with likely (greater than 60 percent chance) rain shower activity and a northeasterly surface wind at 5 knots. The GFA cloud forecast valid before departure for around the accident time indicated an overcast ceiling 800 ft msl with clouds top between FL380 and FL400. AIRMETs Sierra and Zulu were also located on the figures. For more information please see attachment 2.

13.0 Terminal Aerodrome Forecast

RDU/KRDU was the closest airport to the accident site with a NWS Terminal Aerodrome Forecast (TAF) located 22 miles west-southwest of the accident site. TAFs are only valid for a 5-mile radius around the airport. The KRDU TAF valid at the time of the accident was issued at 1826 EST and was valid for a 24-hour period beginning at 1900 EST. The TAF for KRDU was as follows:

KRDU 012326Z 0200/0224 **05006KT 3SM -SHRA BR BKN006 OVC015**
TEMPO 0200/0203 2SM BR OVC003
FM020300 05006KT 3SM -SHRA OVC010
TEMPO 0203/0206 2SM BR OVC006
FM021300 VRB04KT 5SM BR SCT030 BKN250
FM021500 VRB05KT P6SM SCT250=

Between 1900 and 2200 EST, the forecast expected a wind from 050° at 6 knots, 3 miles visibility, light rain showers and mist, a broken ceiling at 600 ft agl, and overcast clouds at 1,500 ft agl. Temporary conditions were forecast between 1900 and 2200 EST of 2 miles visibility, mist, and an overcast ceiling at 300 ft agl.

14.0 NWS Area Forecast Discussion

The NWS office in Raleigh, North Carolina, issued the following Area Forecast Discussion (AFD) at 1835 EST (closest AFD to the accident time). The aviation section of the AFD discussed MVFR to IFR conditions continuing over the next several hours with rain moving across central North Carolina:

FXUS62 KRAH 012335
AFDRAH

Area Forecast Discussion

²⁴ Marginal Visual Flight Rules – Refers to the general weather conditions pilots can expect at the surface. MVFR criteria means a ceiling 1,000 to 3,000 ft agl and/or 3 to 5 miles visibility.

National Weather Service Raleigh NC
635 PM EST Fri Mar 1 2019

.SYNOPSIS...

Low pressure will track along a stationary front, bringing another round of rain this evening to central NC. A cold front will cross central NC overnight, followed by a narrow ridge of high pressure on Saturday. Another low pressure system will cross the area on Sunday night before colder and drier conditions prevail for early next week.

&&

.NEAR TERM /THROUGH TONIGHT/...

As of 620 PM Friday...

Recently updated the near term forecast to reflect the cooler temperatures being observed across the region. Temperatures will not fluctuate all that much this evening into the overnight, holding pretty much in the 30s to around 40 across the north, and in the low-mid 40s across the south.

The enhanced area of rain associated with a mid level wave crossing the SE U.S. will exit our region by late evening. This will initiate a decreasing trend in precip coverage SW-NE across central NC. Anticipate the rain to be spotty and light overnight as a sfc cold front crosses the region. Skies will remain overcast through the night. AS the low level flow becomes NW towards daybreak, expect partial clearing to initially occur over the northwest-western Piedmont.

&&

.SHORT TERM /SATURDAY AND SATURDAY NIGHT/...

As of 210 PM Friday...

As the cold front moves out to the east expect a drier airmass to move into place with clearing skies from northwest to southeast. Expect much more insolation than this afternoon and as a result, thickness values should allow temperatures to reach the upper 50s in the northeast to middle 60s across the southwest Piedmont.

The return to sunshine will be fairly short lived however as clouds will again begin to increase from the west as another low pressure system in the southern stream flow moves into the area. While precipitation will likely hold off until Sunday morning, there is a slight chance it could begin prior to sunrise. Lows Saturday night in the upper 30s across the northeast to mid 40s in the southwest Piedmont.

&&

.LONG TERM /SUNDAY THROUGH FRIDAY/...

As of 220 PM Friday...

Sun/Sun night: Showers remain a near certainty, peaking Sun

afternoon and evening, with a few storms possible across S and E sections and a risk of locally heavy rain. As surface ridging noses further into the region from the NW, the surface frontal zone will settle just to our south and strengthen, resulting in an increasing NE surface flow into central NC. This low level stability will be further enhanced by evaporative cooling effects as precipitation spreads in from the west, prompted by the approach of a mid level shortwave trough that will subsequently cross the Carolinas late Sun through Sun night. This will be accompanied by strong upper divergence in the right entrance region of a jet over the Northeast states, along with strengthening SW 850 mb flow (to 40-60 kts) into NC. This deep lift and strong kinematics in a moist environment will support high pops and substantial QPF (at least 1-1.5"). Latest model runs favor a surface low track through the heart of central NC, although important subtle track differences will determine which areas get into the warm sector and which do not. (And there may be more than one low, with models hinting at a possible Miller B progression.) The expected thermal structure still indicates an all-liquid event for central NC. Regarding the thunder threat, MLCAPE is expected to be just a few hundred J/kg at most over the SE CWA Sun afternoon and evening, but with such strong kinematics and dynamics late Sun into Sun night, will keep a mention of thunder there in the afternoon and evening. Rain/showers will end W to E overnight as the low and trailing front move through and to our E. Expect highs Sun in the upper 40s to mid 50s NW and upper 50s to mid 60s SE. Lows from the upper 30s NW to near 50 SE.

Mon-Fri: Expect generally dry weather with below normal temps, reaching a nadir Wed when thicknesses will approach 70 m below normal. The storm system and accompanying cold front will be exiting early Mon, yielding a clearing trend, although cloudiness and perhaps light precip will linger in SE sections in the morning. Temps and dewpoints will drop post-front, although the initial CAA will be muted with the mountains delaying the most dense air. Expect highs in the upper 40s to mid 50s. Quick passage of a broad wave and enhanced moisture in the mid levels through the Carolinas Tue will likely bring some cloudiness but little else, given the lack of low level moisture. Highs in the 40s. Polar stream troughing will then dig over the St Lawrence Valley and Northeast, pushing a dry secondary reinforcing cold front through NC Tue night. Behind this front, temps will reach their low point Wed within peak CAA, providing the coldest day of this stretch (highs in the upper 30s to lower 40s) , bookended by the coldest nights (lows in the 20s). Some recovery begins Thu as the surface ridge moves overhead then offshore, inducing moisture return starting late Thu and continuing through Fri. Moisture may become sufficiently deep for good rain chances Fri ahead of another mid level shortwave trough, although increasing model differences with the overall pattern necessitate a conservative approach, and will keep lower chance pops for now. Highs in the upper 40s to lower 50s Thu and in the 50s Fri. -GIH

&&

.AVIATION /00Z SATURDAY THROUGH THURSDAY/...
As of 635 PM Friday...

24 hour TAF period: Generally IFR/MVFR cigs with a wide range in visibilities are expected through the next several hours as the rain continues to push through central NC. These conditions will persist through at least 06Z, possibly through daybreak before dry air filters in and conditions improve to VFR Saturday morning. Low confidence on exact timing resulting in the variability throughout the aviation forecast for each terminal. There may be some additional light rain to move through late overnight, otherwise expect drying from west to east overnight. Winds will be northerly in the 6-12 kt range, becoming light and variable late tonight through Saturday. -KC

Looking ahead: With VFR conditions mainly expected on Saturday, attention will turn to the next system which will approach Sunday afternoon through Monday morning, bringing another chance for rain and sub-VFR conditions. High pressure begins to build in from the west later on Monday and VFR conditions are then expected for the majority of the work week. -Ellis

&&

.RAH WATCHES/WARNINGS/ADVISORIES...
None.

&&

\$\$

15.0 Winds and Temperature Aloft Forecast

The NWS 1458 EST Winds and Temperature Aloft forecast valid for the closest point to the accident site is included below:

FBUS31 KWN0 011958
FD1US1
DATA BASED ON 011800Z
VALID 020000Z FOR USE 2000-0300Z. TEMPS NEG ABV 24000

FT	3000	6000	9000	12000	18000	24000	30000	34000	39000
RDU	1626	2035+07	2433+01	2433-04	2537-16	2639-30	246544	239752	259758

The accident site was located closest to the RDU forecast point. The 1458 EST RDU forecast for use between 1500 EST and 2200 EST indicated a wind at 3,000 ft from 160° at 26 knots, a wind at 6,000 ft from 200° at 35 knots with a temperature of 7° C, and a wind at 9,000 ft from 240° at 33 knots with a temperature of 1° C.

16.0 Pilot Weather Briefing

The accident pilot did not request a weather briefing from Leidos, however, Leidos did archive the ForeFlight documents the accident pilot requested at 1819 EST including the text weather briefing information and flight plan information (attachments 3 and 4).

A search of archived ForeFlight information indicated that the accident pilot did request weather information and filed a flight plan via ForeFlight (attachment 5) at 1819 EST. The weather briefing information contained all the standard weather information valid at 1819 EST, including a convective SIGMET “outlook” area valid along the route of flight, AIRMETs, surface analysis chart, current METARs valid along the route of flight, PIREPs (including the severe turbulence PIREP, section 8.0), GFA forecast, TAFs, and winds aloft. Prior to departure the accident pilot had not looked at any Weather Imagery in the ForeFlight app (attachment 5). There is no record of the accident pilot receiving or retrieving any other weather information before or during the accident flight.

17.0 XM Weather images

The airplane was equipped with a glass cockpit²⁵ (exemplar image in figure 18), which could be optionally fitted to be able to display XM Weather information with a subscription. If the accident pilot had been viewing XM Weather composite radar information he would have had a chance to view something similar to figures 19 through 22 (time in figures in CST), which was 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 23. There was an unknown time delay of the XM weather composite images made available to the accident pilot in the cockpit.²⁶ The XM Weather composite radar images from 1914 through 1929 EST displayed 20 to 30 dBZ values above the accident site. For additional information regarding the XM Weather composite radar data please see attachment 6.

²⁵ For more information on the electronic equipment located on the accident aircraft please see the docket information for this accident to include, Aspen Evolution System (EFD 500, PFD 1000 Pro, MFD 1000).

²⁶ See: https://ntsb.gov/safety/safety-alerts/Documents/SA_017.pdf



Figure 18 – Exemplar cockpit image of the accident aircraft

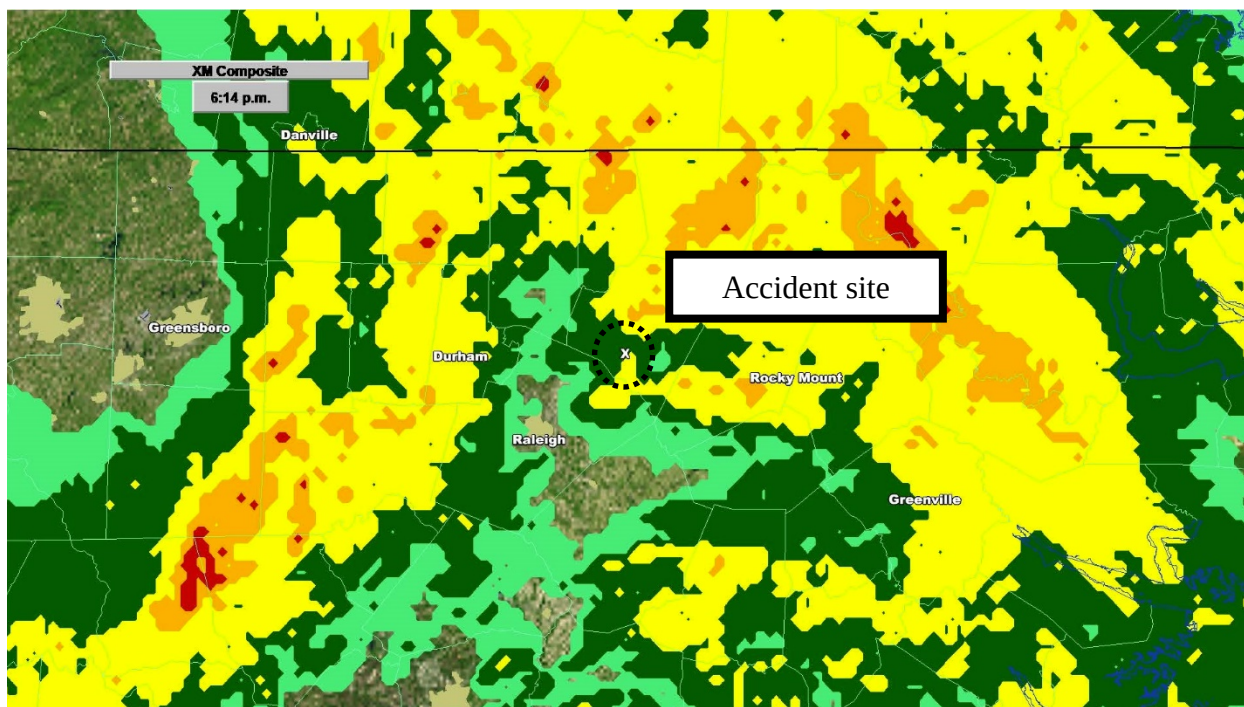


Figure 19 – XM Weather Radar from 1914 EST

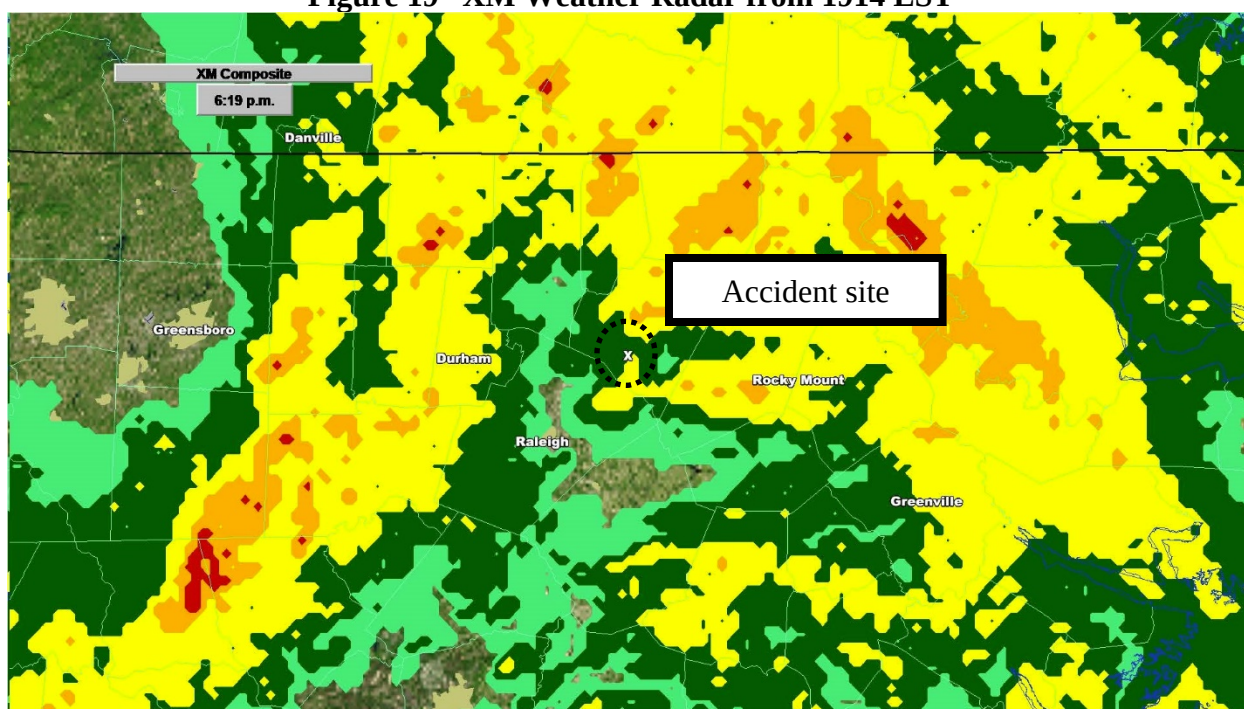


Figure 20 – XM Weather Radar from 1919 EST

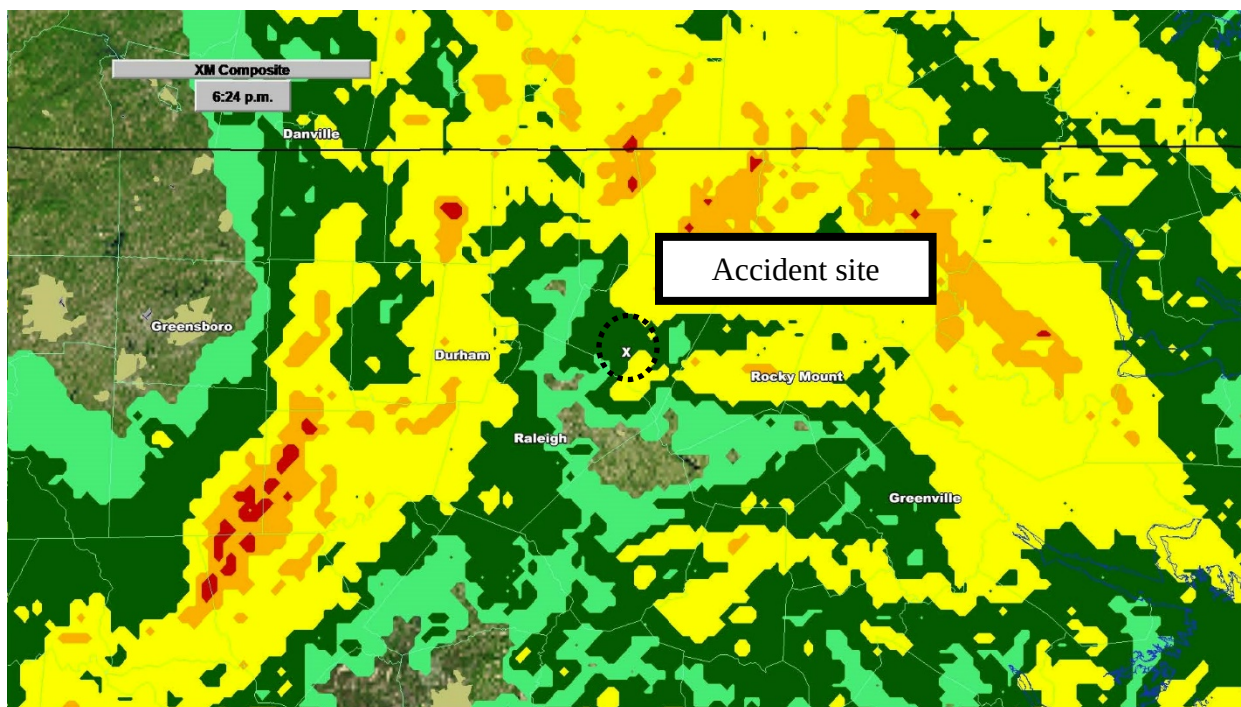


Figure 21 – XM Weather Radar from 1924 EST

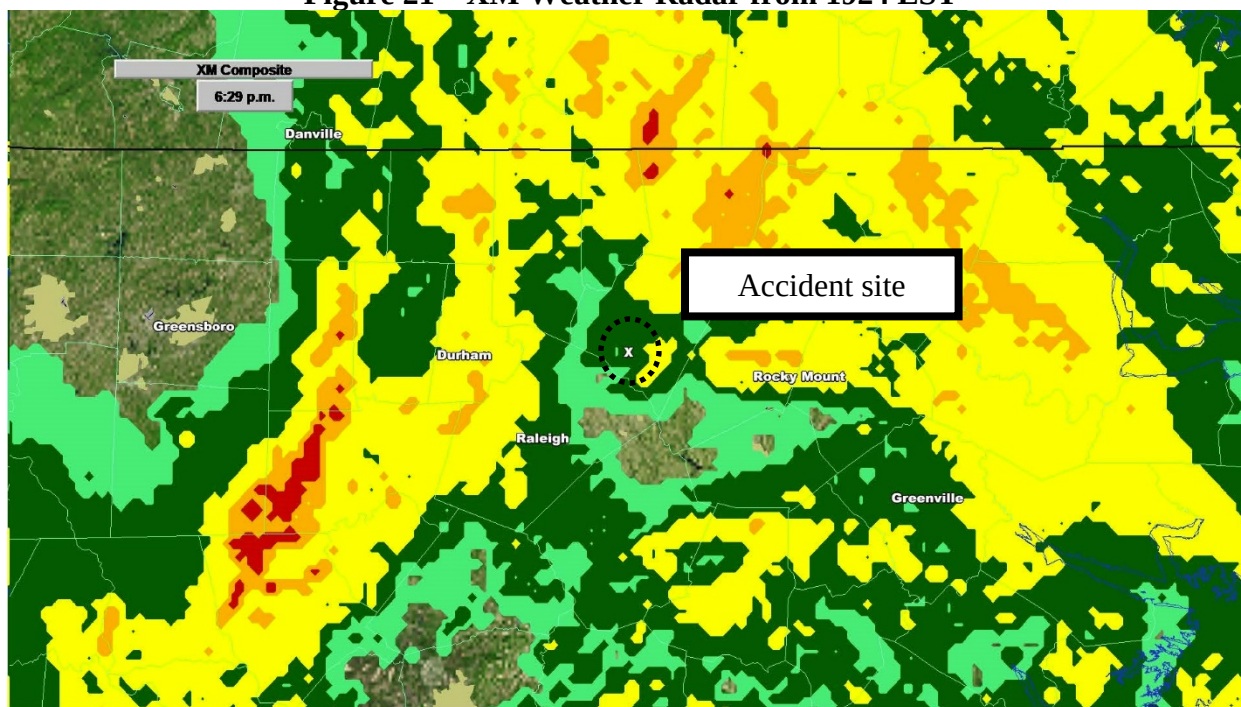


Figure 22 – XM Weather Radar from 1929 EST

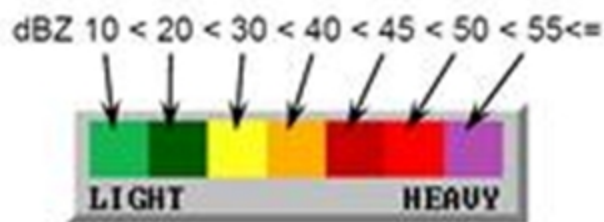


Figure 23 – XM Weather Radar scale for figures 19 through 22

18.0 Weather Information From Additional N26617 Flights

Additional weather information was reviewed for N26617 flights taken between January and March 2019. For more information please see attachments 7 and 8.

19.0 Astronomical Data

The astronomical data obtained from the United States Naval Observatory for the accident site on March 1, 2019, indicated the following:

SUN

Begin civil twilight	0618 EST
Sunrise	0644 EST
Sun transit	1226 EST
Sunset	1808 EST
End civil twilight	1834 EST
Accident time	1921 EST²⁷

MOON

Moonrise	0341 EST
Moon transit	0844 EST
Moonset	1347 EST
Accident time	1921 EST²⁸

The phase of the Moon was Waning Crescent with 20% of the Moon's visible disk illuminated.

E. LIST OF ATTACHMENTS

Attachment 1 – KRAX WSR-88D level 2 base reflectivity animation for the 0.5° elevation scans from 1846 to 1937 EST

Attachment 2 – GFA products valid for the accident flight

²⁷ Inserted accident time for reference and context.

²⁸ Inserted accident time for reference and context.

Attachment 3 – Leidos documentation of ForeFlight weather briefing from 1819 EST

Attachment 4 – Leidos documentation of ForeFlight weather briefing from 1819 EST second copy

Attachment 5 – ForeFlight weather briefing information requested by accident pilot at 1819 EST

Attachment 6 – XM weather composite weather radar imagery from around accident time

Attachment 7 – Additional weather information from previous flights

Attachment 8 – N26617 previous flights' information

Submitted by:

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