NATIONAL TRANSPORTATION SAFETY BOARD

Office of Aviation Safety
Washington, D.C. 20594

November 30, 2021

Group Chairman's Factual Report

METEOROLOGY

CEN21FA198

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A. ACCIDENT

Location: Danville, Arkansas
Date: April 23, 2021
Time: 1701 central daylight time
2201 Coordinated Universal Time (UTC)
Airplane: Piper PA-46-310P; Registration: N461DK

B. METEOROLOGY GROUP

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Senior Meteorologist
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NextGen Aviation Weather Research (ANG-C61)
Federal Aviation Administration

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 and also from the National Centers for Environmental Information (NCEI). In addition, the National Center for Atmospheric Research (NCAR) and the National Aeronautics and Space Administration Langley Research Center (NASA LaRC) provided additional weather data. This Factual Report contains the meteorological factors pertinent to the weather surrounding the accident time. All times are central daylight time (CDT), and are based upon the 24-hour clock, where local time is -5 hours from UTC. Directions are referenced to true north and distances in nautical miles. Heights are above mean sea level (msl) unless otherwise noted. Visibility is in statute miles and fractions of statute miles. NWS station identifiers use the standard International Civil Aviation Organization 4-letter station identifiers versus the International Air Transport Association 3-letter identifiers, which deletes the initial country code designator "K" for U.S. airports.

The accident site was located at latitude 34.9674° N, Longitude 93.6222° W, with an approximate elevation of 940 feet (ft).

D. FACTUAL INFORMATION

1.0 Synoptic Situation

The synoptic or large-scale migratory weather systems influencing the area were documented using standard NWS charts issued by the National Center for Environmental Prediction (NCEP) 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]

1.1 Surface Analysis Chart

The NWS Surface Analysis Chart centered over the southcentral United States for 1600 CDT is provided as figure 1 with the location of the accident site within the red circle. The chart depicted a stationary front from southern Mississippi into southern Oklahoma. A trough[2] was located from eastern Kansas southwestward into the Panhandle of Texas. Troughs can act as lifting mechanisms to help produce clouds and precipitation if sufficient moisture is present. Several low-pressure centers were in eastern New Mexico and the Texas Panhandle with pressures as low as 998-hectopascals (hPa). The accident site was located southeast of the surface trough and north of the stationary front.

The station models around the accident site depicted air temperatures in the mid 50's to mid-60's degrees Fahrenheit (°F), dew point temperatures in the low to mid 50's °F with temperature-dew point spreads of 12°F or less, an east wind between 5 and 15 knots, and mostly cloudy skies. Light rain and thunderstorms were reported from north Texas to central Oklahoma.

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

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

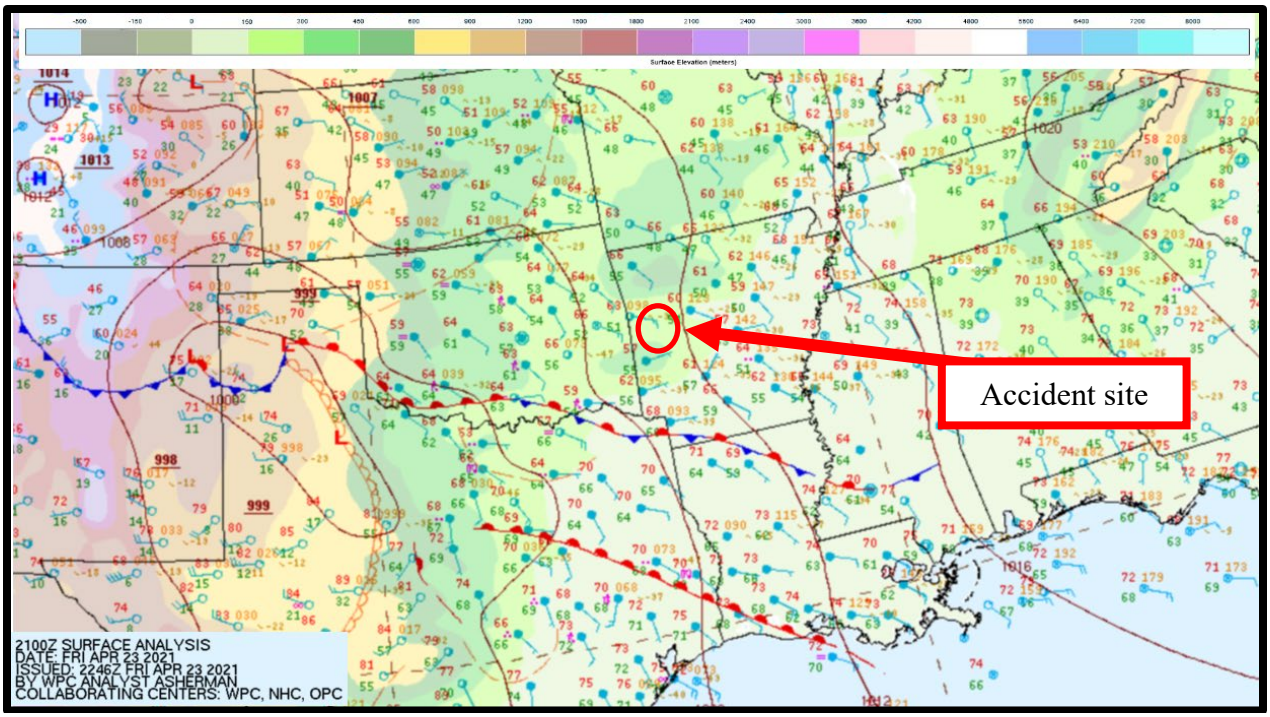


Figure 1 – NWS Surface Analysis Chart for 1600 CDT.

1.2 Upper Air Charts

The NWS Storm Prediction Center (SPC) Constant Pressure Charts for 1900 CDT at 925-, 850-, 700-, 500-, and 300-hPa are presented in figures 2 through 6. The accident site was located in between two low-level troughs at 850-hPa (figure 3) with the 700- and 500-hPa mid-level trough southwest of the accident site. There was a southeast wind at 30 knots at 925-hPa with the wind becoming westerly at 35 knots by 500-hPa, and southwesterly at 85 knots by 300-hPa (figure 6).

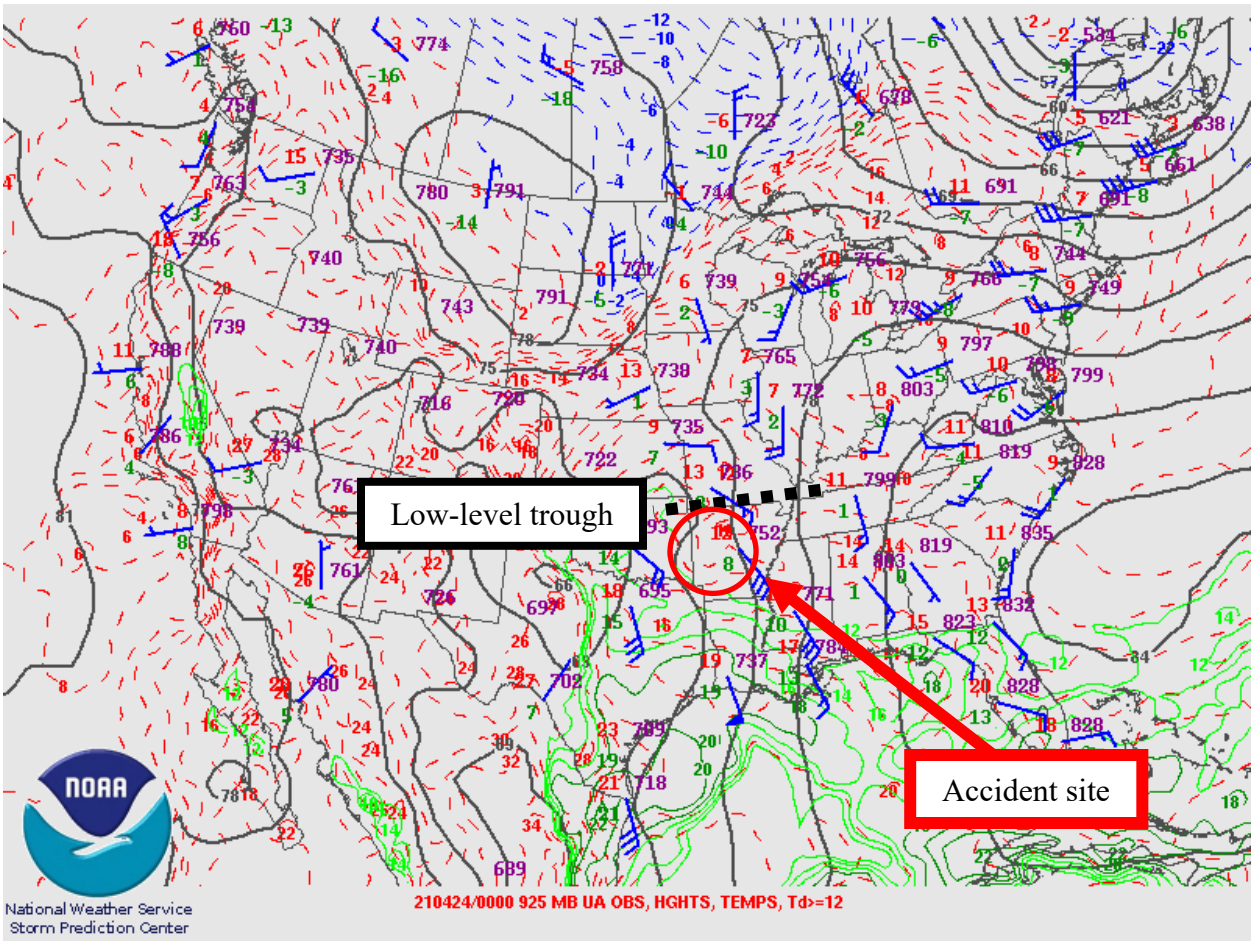


Figure 2 – 925-hPa Constant Pressure Chart for 1900 CDT.

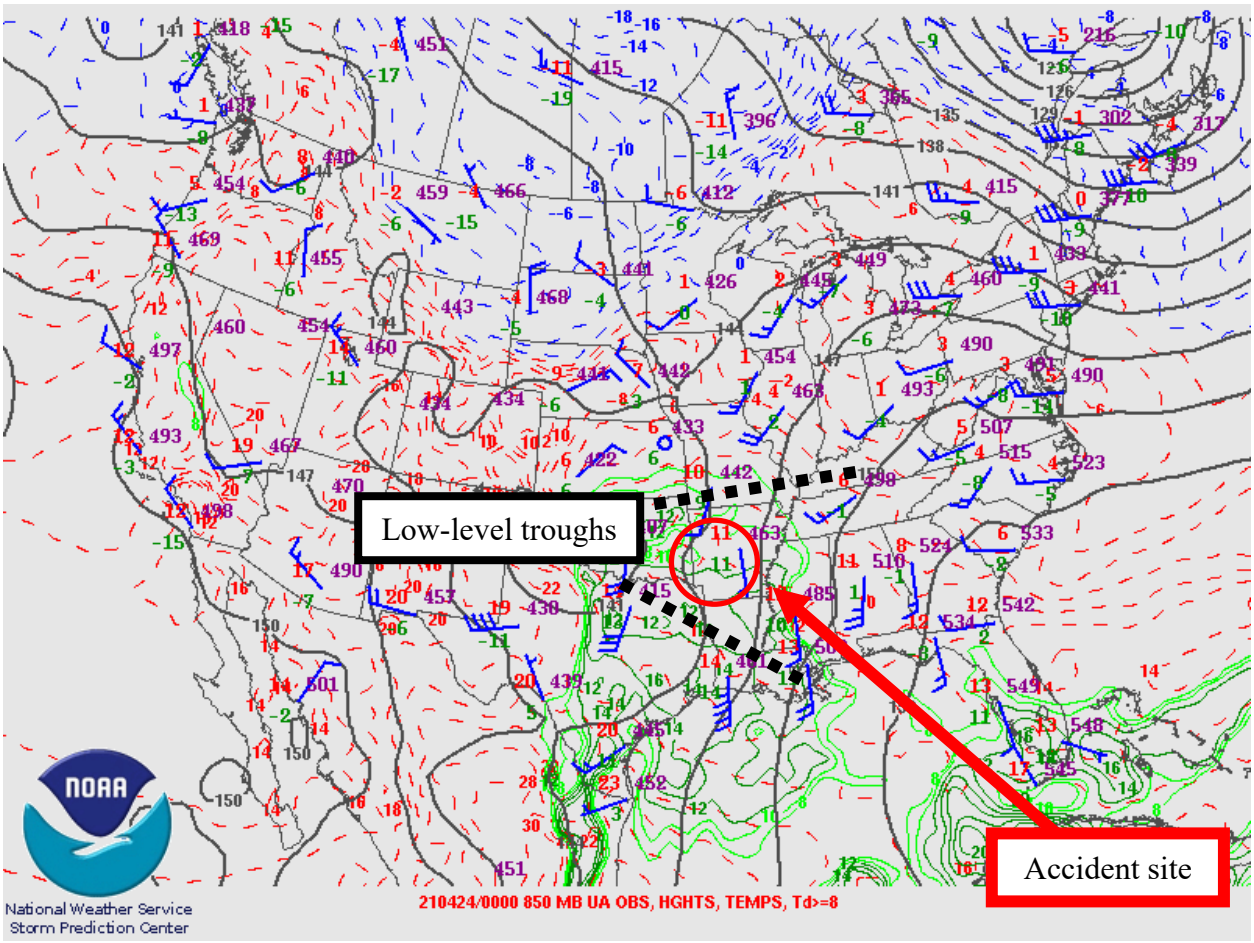


Figure 3 – 850-hPa Constant Pressure Chart for 1900 CDT.

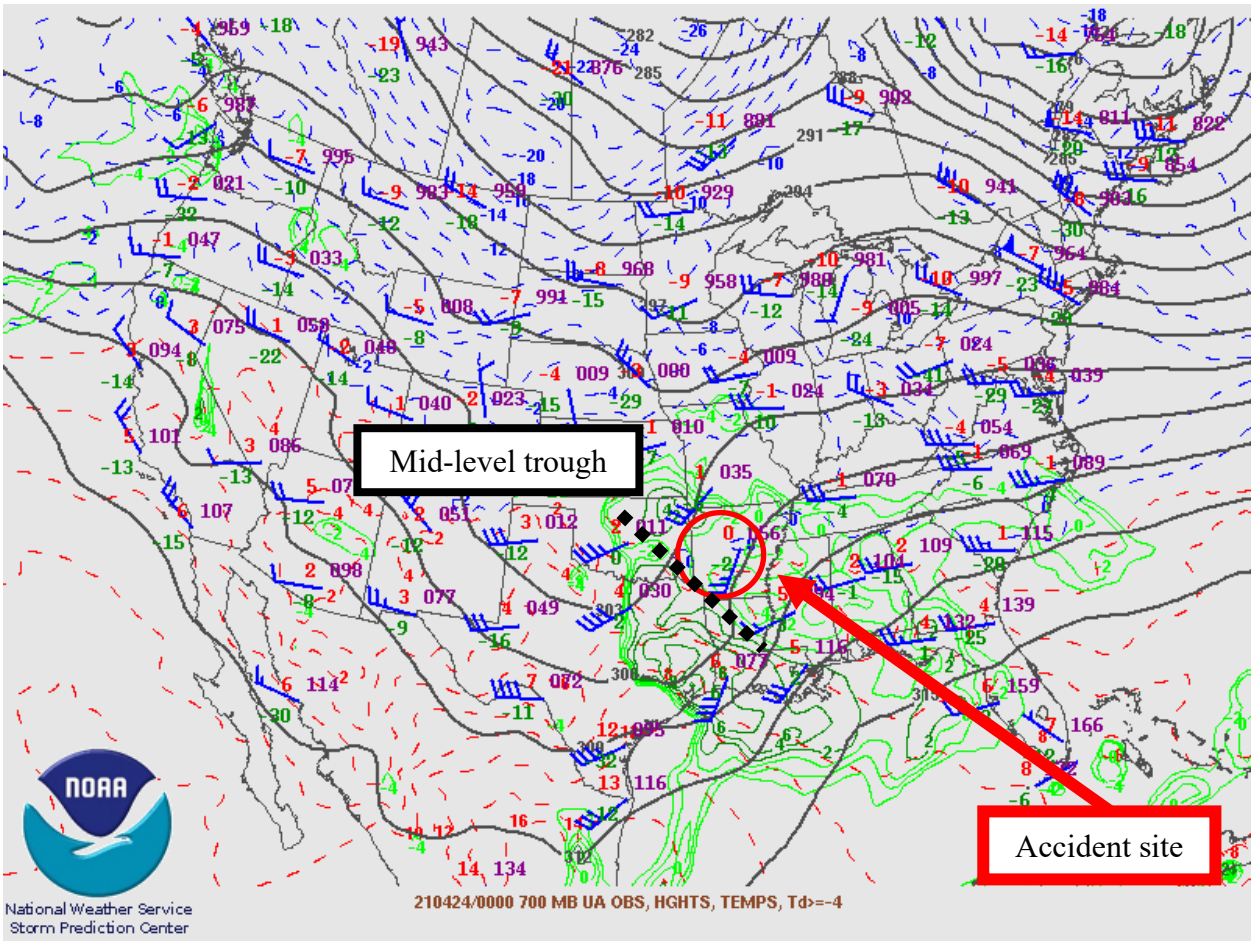


Figure 4 – 700-hPa Constant Pressure Chart for 1900 CDT.

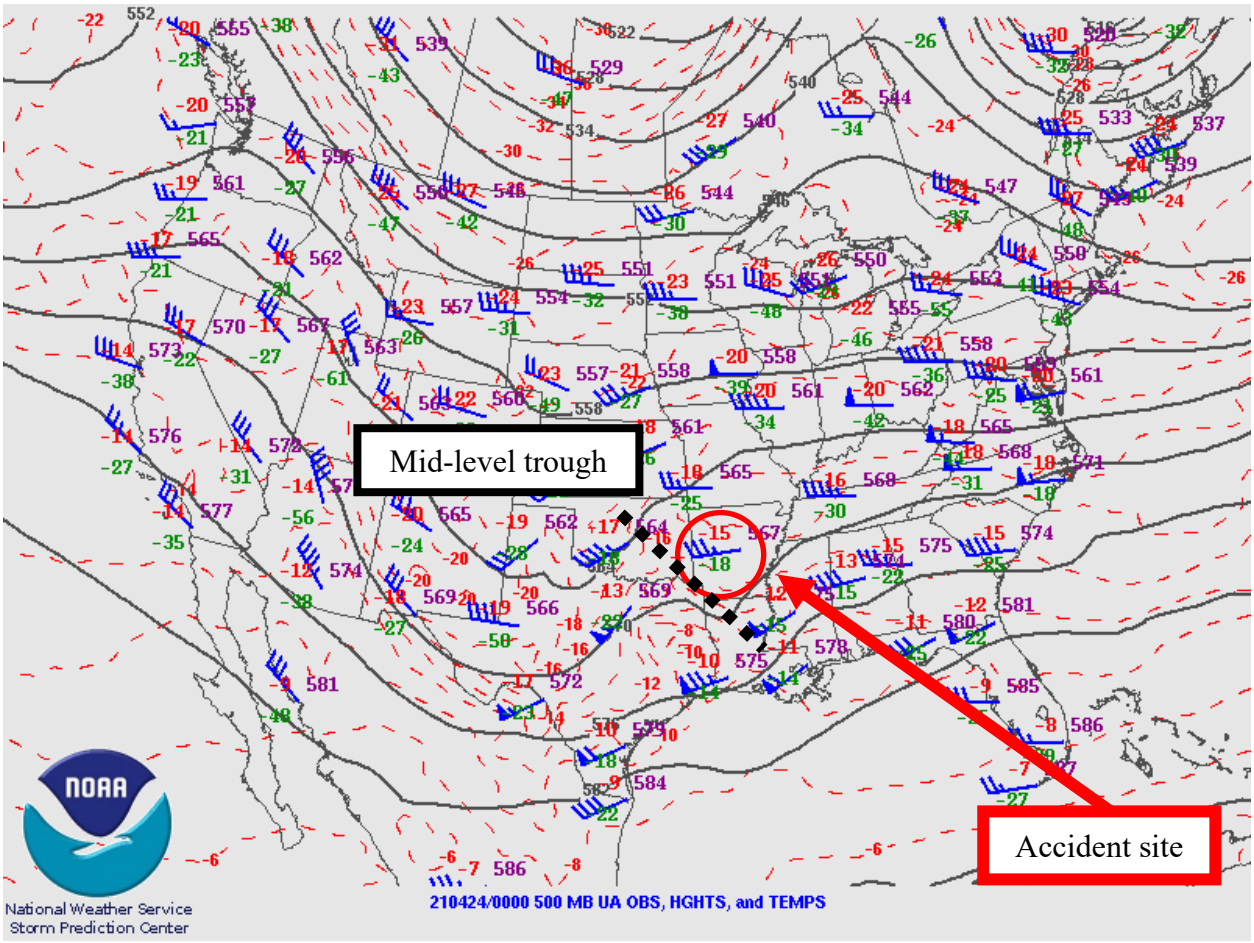


Figure 5 – 500-hPa Constant Pressure Chart for 1900 CDT.

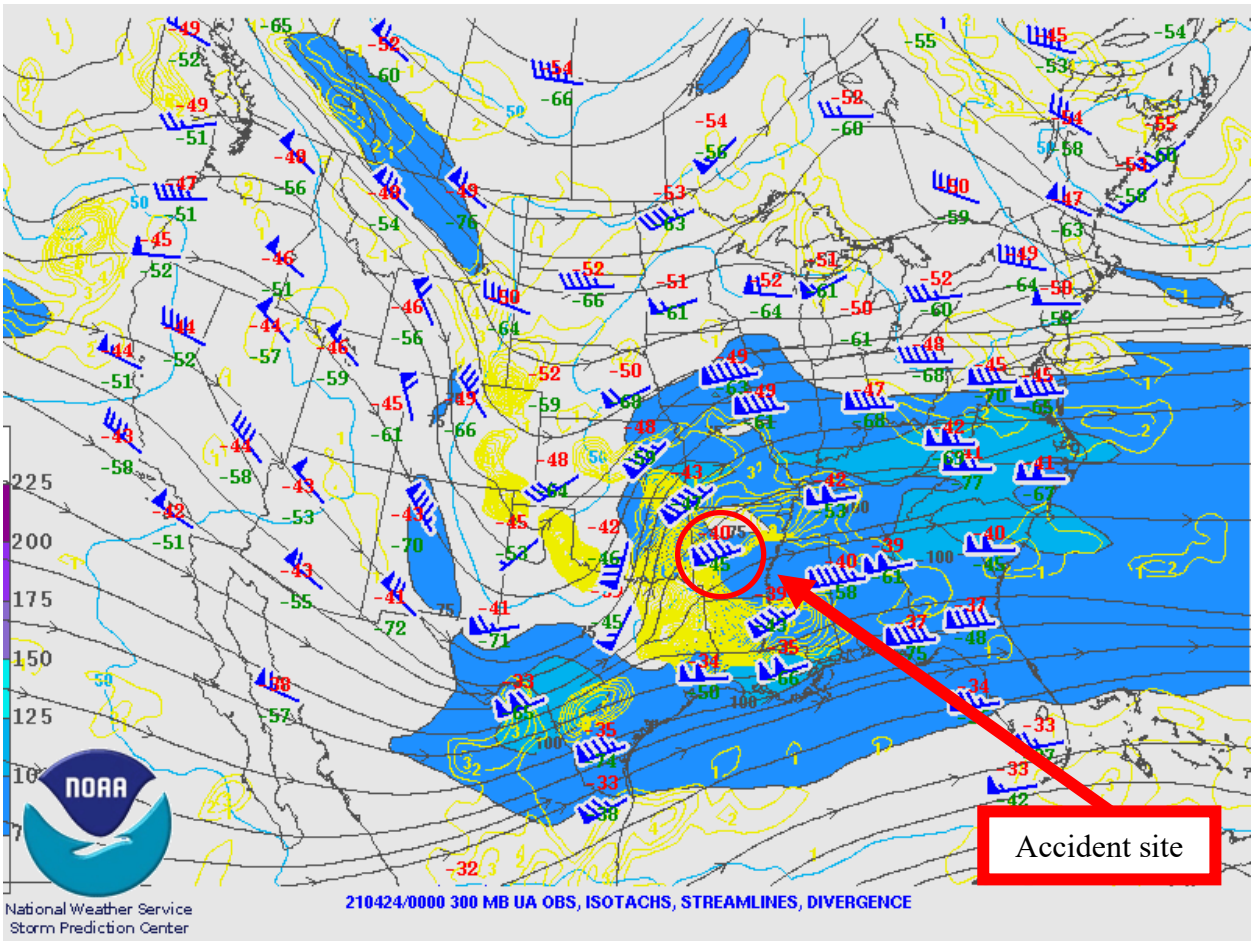


Figure 4 – 300-hPa Constant Pressure Chart for 1900 CDT.

2.0 Storm Prediction Center Convective Outlook

SPC issued the following Day 1 Convective Outlook at 1458 CDT (figure 7) with a slight risk for severe thunderstorms forecast for the area during the period. A slight risk of severe thunderstorms is higher than the background climatology of thunderstorms activity for the month of April. The accident site was in an area where SPC forecasted a 5 percent chance of large hail within 25 miles of a point and a 15 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 text follows figure 9.

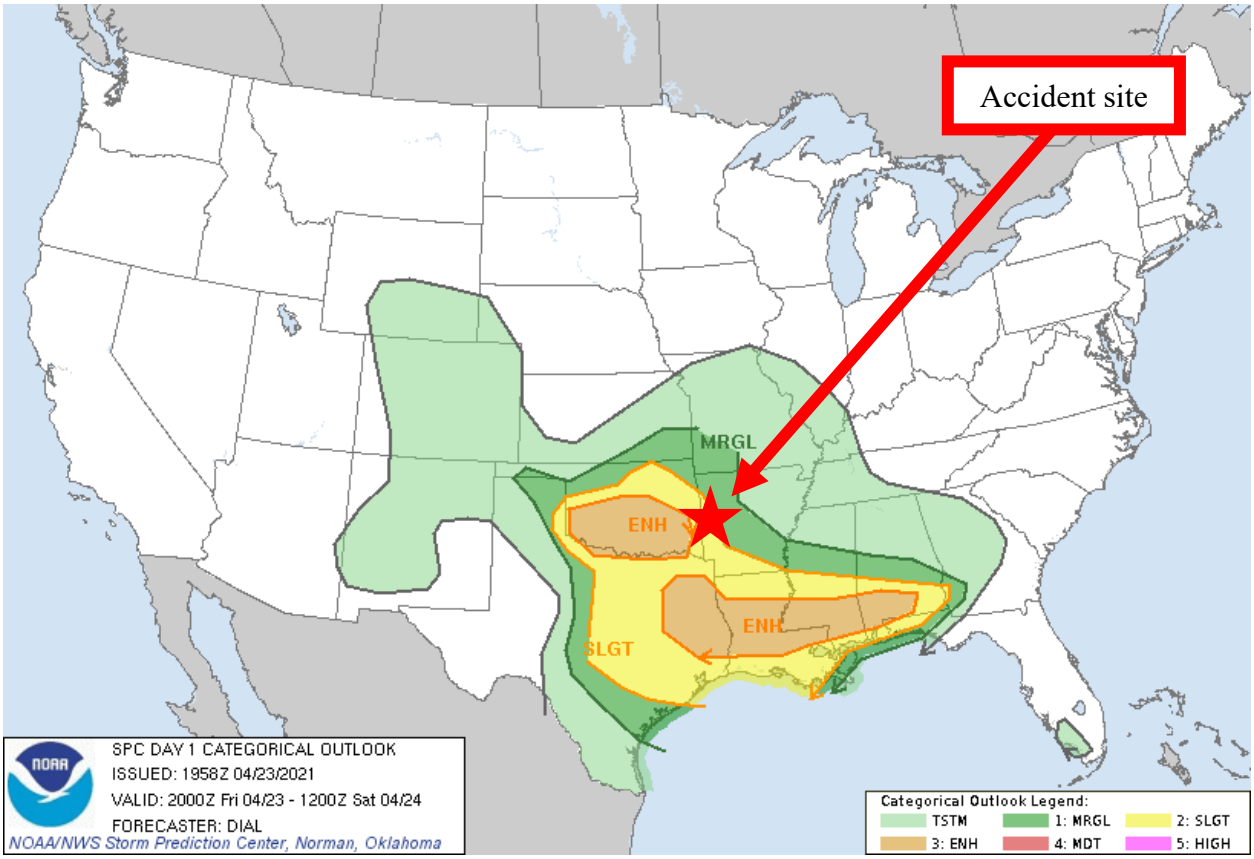


Figure 7 – SPC day 1 Convective Outlook valid at the time of the accident.

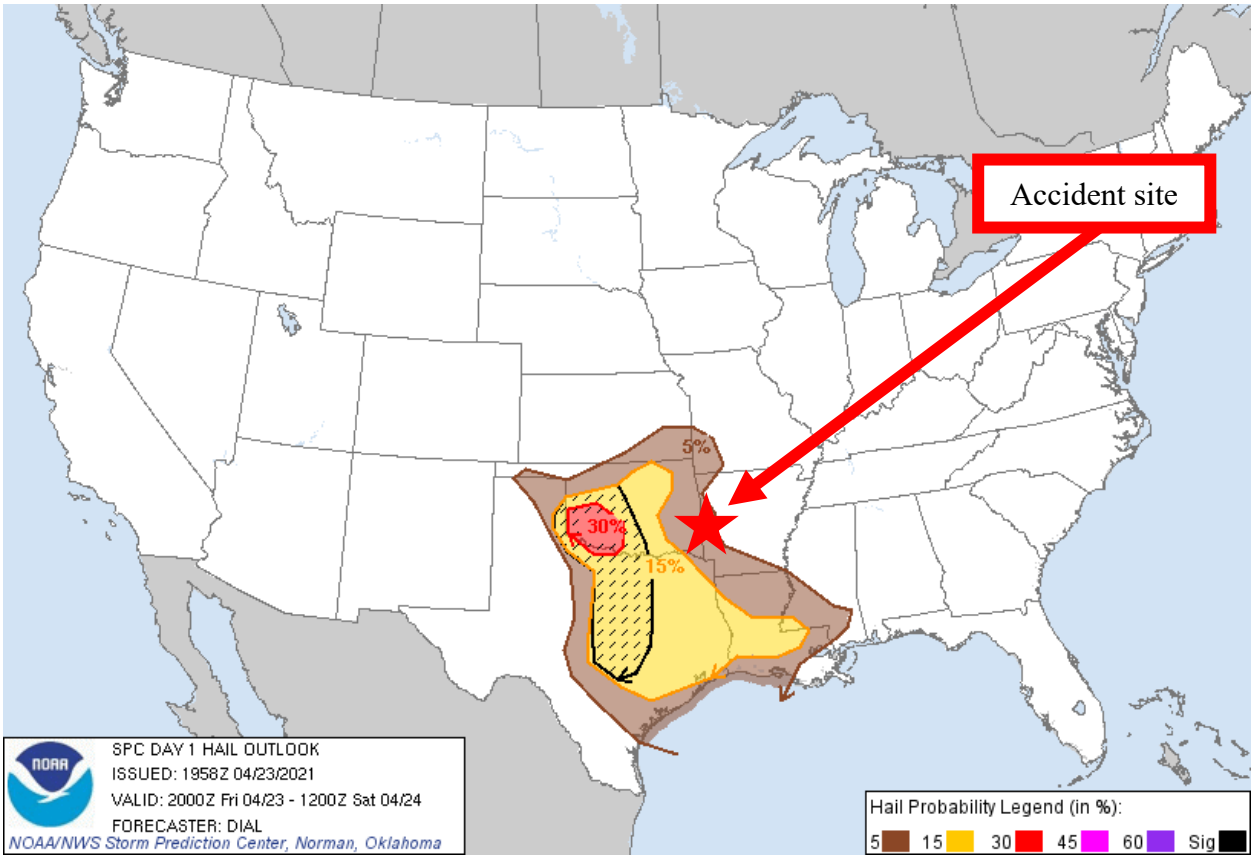


Figure 8 – SPC day 1 Hail Outlook valid at the time of the accident.

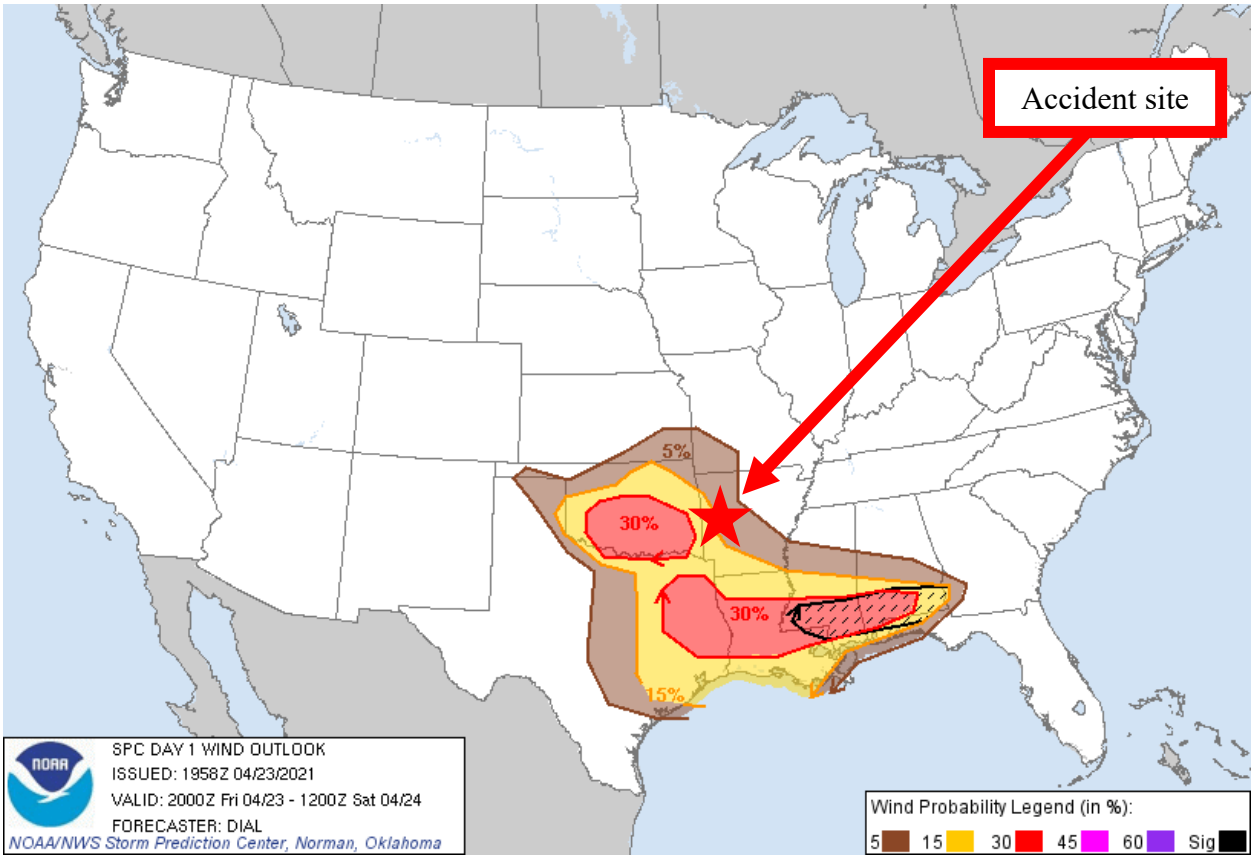


Figure 9 – SPC day 1 Wind Outlook valid at the time of the accident.

SPC AC 231958

Day 1 Convective Outlook
NWS Storm Prediction Center Norman OK
0258 PM CDT Fri Apr 23 2021

Valid 232000Z - 241200Z

...THERE IS AN ENHANCED RISK OF SEVERE THUNDERSTORMS FROM PORTIONS OF THE SOUTHERN PLAINS INTO THE GULF COAST STATES...

...SUMMARY...
Severe wind, large to very large and destructive hail, and a few tornadoes are possible today and tonight across parts of the southern Plains to lower Mississippi Valley.

...Southern portion of Gulf Coast states...

Primary change to previous forecast has been to extend the ENH risk area farther east along southern portions of the Gulf Coast states. Storms that develop over TX this afternoon are expected to evolve into an MCS with likelihood of embedded organized storm structures especially on the southern end near advancing warm front this evening into the overnight. An intense 60 + kt southwesterly low-level jet accompanying the progressive shortwave trough will support large 0-2 km hodographs within a strongly sheared

environment. Bowing segments and embedded supercells capable of damaging wind and a few tornadoes will be the main threats.

..Dial.. 04/23/2021

.PREV DISCUSSION... /ISSUED 1113 AM CDT Fri Apr 23 2021/

...TX early this afternoon...
Morning water vapor loop shows a trough progressing across AZ/NM and northern Mexico into TX. Large-scale lift associated with this trough will begin to overspread an increasingly moist/unstable air mass over central TX by early afternoon - leading to scattered thunderstorm development. Forecast soundings from north-central to south-central TX show steep mid-level lapse rates and sufficient CAPE to pose a risk of hail in the stronger cells. Low and mid level winds are also sufficiently strong for a threat of gusty/damaging winds.

...Southeast TX into LA/MS/AL this evening and tonight...
A strong southerly low-level jet is forecast to develop after dark across far southeast TX and southern LA. This will help to focus lift and shear along precipitation-reinforced boundary that will extend across the region. Most CAM solutions show multiple bow/supercell structures tracking along the boundary through the evening and overnight into parts of southern MS/AL. Present indications are that damaging winds will be the main threat with these storms. However, there is increasing concern for a greater tornado risk as well - both supercellular and QLCS. Will maintain 5% tornado probabilities at this time but may introduce higher probabilities at 20z if confidence of the narrow corridor of threat increases.

...Southeast TX Panhandle into Southern OK...
Southeasterly low-level winds continue to transport increasingly moist/unstable air northward into the eastern TX panhandle and southwest OK. This will lead to the development of scattered intense thunderstorms this afternoon and evening. Forecast soundings show very steep lapse rates and robust CAPE profiles, along with strong deep-layer shear. This should promote supercells capable of very large hail and a tornado or two. Activity is expected to persist through the evening and spread eastward across central/southern OK with an increasingly linear nature, along with the potential of more widespread damaging wind risk.

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 Aviation Routine Weather 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.

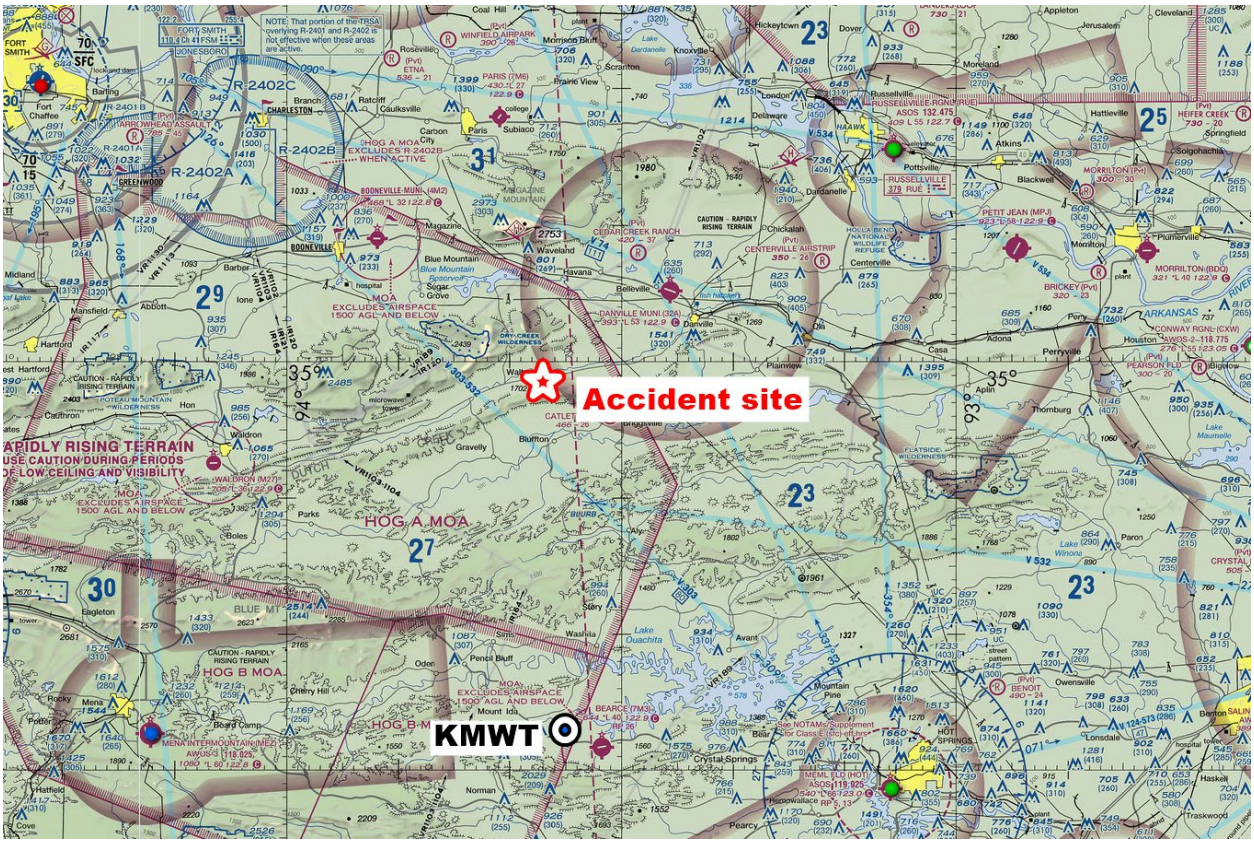


Figure 10 – Sectional map of the accident area with the location of the accident site and surface observation site.

The closest official weather station to the accident site was KMWT located in Mount Ida, Arkansas. KMWT had an Automated Surface Observing System (ASOS[3]) who's longline[4] reports were not supplemented. The KMWT ASOS was located 25 miles south of the accident site, at an elevation of 702 ft, and had a 1° easterly magnetic variation[5] (figure 10). The following automated longline observations were disseminated during the times surrounding the accident:[6]

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

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

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

[6] The bold sections in this NWS product and the rest of the products in this report are intended to highlight the text 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.

[1253 CDT] METAR KMWT 231753Z AUTO VRB04KT 10SM OVC014 14/11 A2996 RMK AO2 SLP143 60001 T01440106 10144 20100 58009=

[1331 CDT] SPECI KMWT 231831Z AUTO 14006KT 10SM OVC015 14/10 A2994 RMK AO2 T01440100=

[1533 CDT] SPECI KMWT 232033Z AUTO VRB04KT 10SM OVC014 14/11 A2988 RMK AO2 T01440111=

[1553 CDT] METAR KMWT 232053Z AUTO VRB05KT 10SM OVC014 14/11 A2986 RMK AO2 SLP110 T01440111 58033=

[1653 CDT] METAR KMWT 232153Z AUTO VRB03KT 10SM OVC009 14/11 A2983 RMK AO2 SLP102 T01390111=

ACCIDENT TIME 1701 CDT

[1815 CDT] SPECI KMWT 232315Z AUTO VRB03KT 2 1/2SM RA BR OVC008 13/12 A2981 RMK AO2 P0005 T01280117=

[1840 CDT] SPECI KMWT 232340Z AUTO 00000KT 1 1/2SM +RA BR OVC007 13/12 A2981 RMK AO2 P0013 T01280117=

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

KMWT weather at 1653 CDT, automated, variable wind at 3 knots, visibility 10 miles or greater, overcast ceiling 900 ft above ground level (agl), temperature of 14° Celsius (C), dew point temperature of 11°C, and an altimeter setting of 29.83 inches of mercury (inHg). Remarks: automated station with a precipitation discriminator, sea level pressure 1010.2 hPa, temperature of 13.9°C, dew point temperature of 11.1°C.

KMWT weather at 1815 CDT, automated, variable wind at 3 knots, visibility 2 and a half miles, moderate rain, mist, overcast ceiling 800 ft agl, temperature of 13°C, dew point temperature of 12°C, and an altimeter setting of 29.81 inHg. Remarks: automated station with a precipitation discriminator, 0.05 inches of precipitation since 1653 CDT, temperature of 12.8°C, dew point temperature of 11.7°C.

The observations from KMWT surrounding the accident time indicated IFR[7] conditions with moderate rain reported.

[7] 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

4.0 Upper Air Sounding

A High-Resolution Rapid Refresh (HRRR)[8] model sounding was created for the accident site for 1700 CDT which provided a surface elevation of 758 ft.[9] The 1700 CDT HRRR sounding was plotted on a standard Skew-T Log P diagram[10] with the derived stability parameters included in figure 11 with data from the surface to 300-hPa (or approximately 30,000 ft msl). These data were analyzed using the RAOB[11] software package. The sounding depicted the lifted condensation level (LCL)[12] at 1,800 ft msl and the convective condensation level (CCL)[13] at 6,706 ft msl. The freezing level was located at 11,145 ft msl. The precipitable water value was 1.21 inches.

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.

[8] 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.
[9] HRRR sounding was created using NOAA Air Resource Laboratory: https://ready.arl.noaa.gov/READYamet.php
[10] 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.
[11] RAOB – (The complete Rawinsonde Observation program) is an interactive sounding analysis program developed by Eosonde Research Services, The Villages, Florida.
[12] LCL - The height at which a parcel of moist air becomes saturated when it is lifted dry adiabatically.
[13] 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.

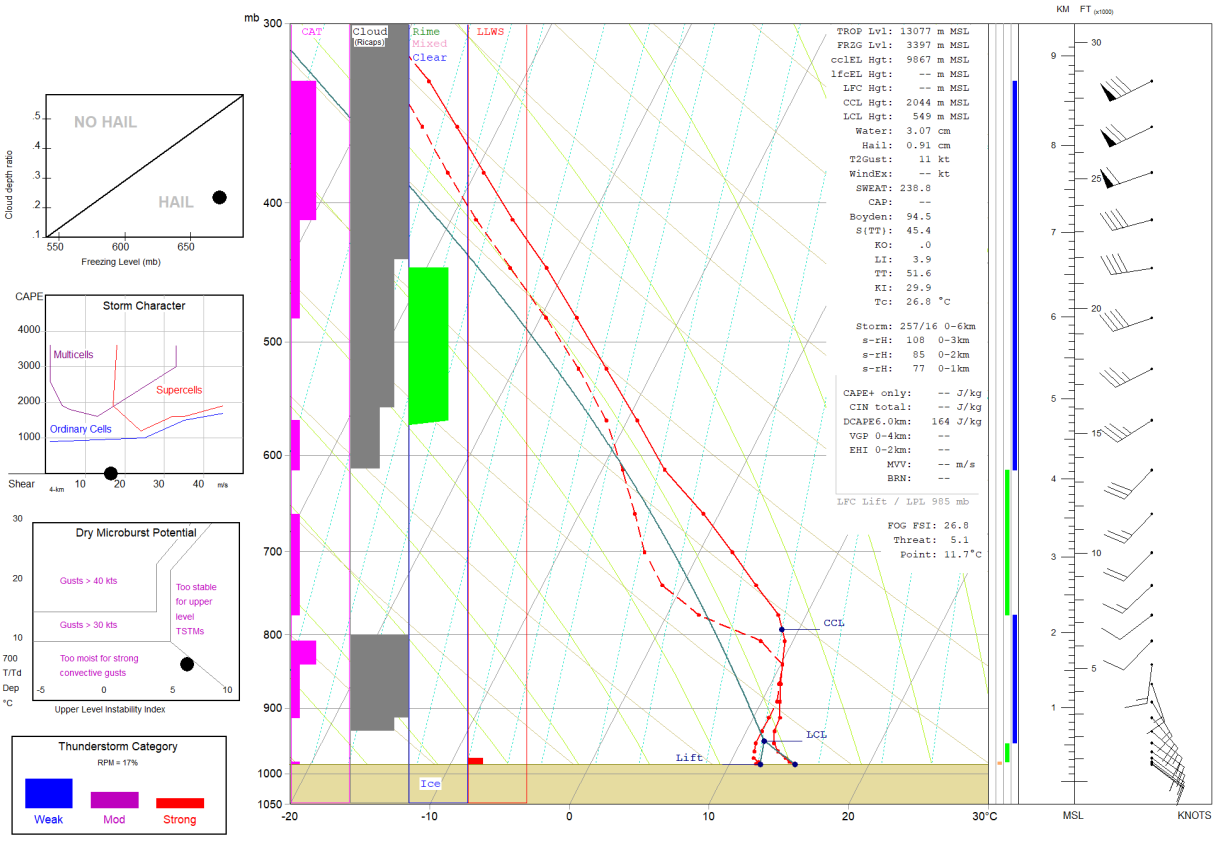


Figure 11 – 1700 CDT HRRR sounding.

The 1700 CDT HRRR sounding for the accident site indicated a conditionally stable environment from 8,000 ft through 30,000 ft. Clouds were indicated by RAOB from 2,000 ft through 7,000 ft with another cloud layer from 14,000 ft through 30,000 ft. RAOB indicated moderate rime from 15,000 ft to 22,000 ft. RAOB indicated that any precipitation would be from rain showers.

The 1700 CDT HRRR sounding wind profile indicated a near surface wind from 129° at 6 knots with the wind veering[14] to the southwest by 6,000 ft. The wind speed increased to 30 knots by 13,000 ft and then to 80 knots by 28,000 ft. RAOB indicated the possibility of light low-level wind shear (LLWS) between the surface and 1,000 ft agl. RAOB indicated the possibility of light to moderate clear-air turbulence in several layers between the surface and 28,000 ft. At the aircraft's altitude[15] near 19,000 ft around 1659 CDT, the wind was from 235° at 40 knots, temperature was -17.4°C and the dew point temperature was -19.7°C with a relative humidity of 82%.

[14] A clockwise turning of the wind with height in the northern hemisphere.
[15] For more information please see air traffic control (ATC) data located in the docket of this accident.

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 1500 CDT through 2200 CDT and reviewed, and the closest images to the time of the accident were documented.

Figures 12 and 13 present the GOES-16 visible imagery from 1700 and 1710 CDT at 2X magnification with the accident site highlighted with a red square. The cloud cover was moving from west to east. Figure 14 presents the GOES-16 infrared imagery from 1700 CDT at 6X magnification with the accident site highlighted with a red square. The lower brightness temperatures (green and blue colors; higher cloud tops) were located above and to the southwest of the accident site. The brightness temperature of about 222 Kelvin above the accident site would have been near 35,000 ft based on the vertical temperature profile provided by the 1700 CDT HRRR sounding. It should be noted these figures have not been corrected for any parallax error.

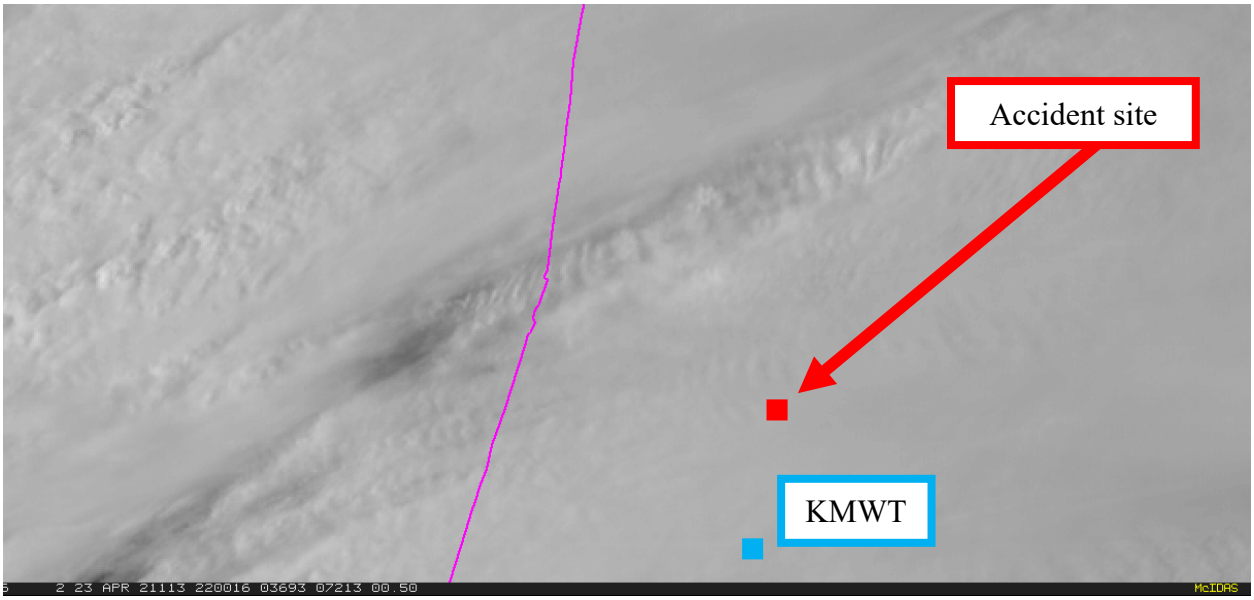


Figure 12 – GOES-16 visible image at 1700 CDT.

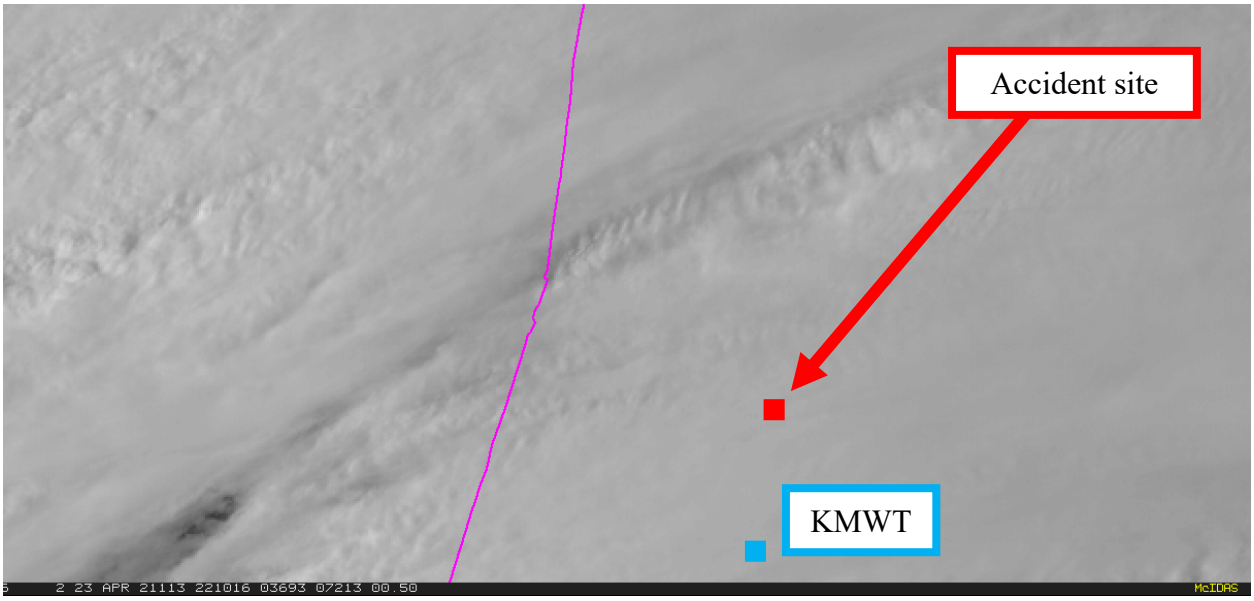


Figure 13 – GOES-16 visible image at 1710 CDT.

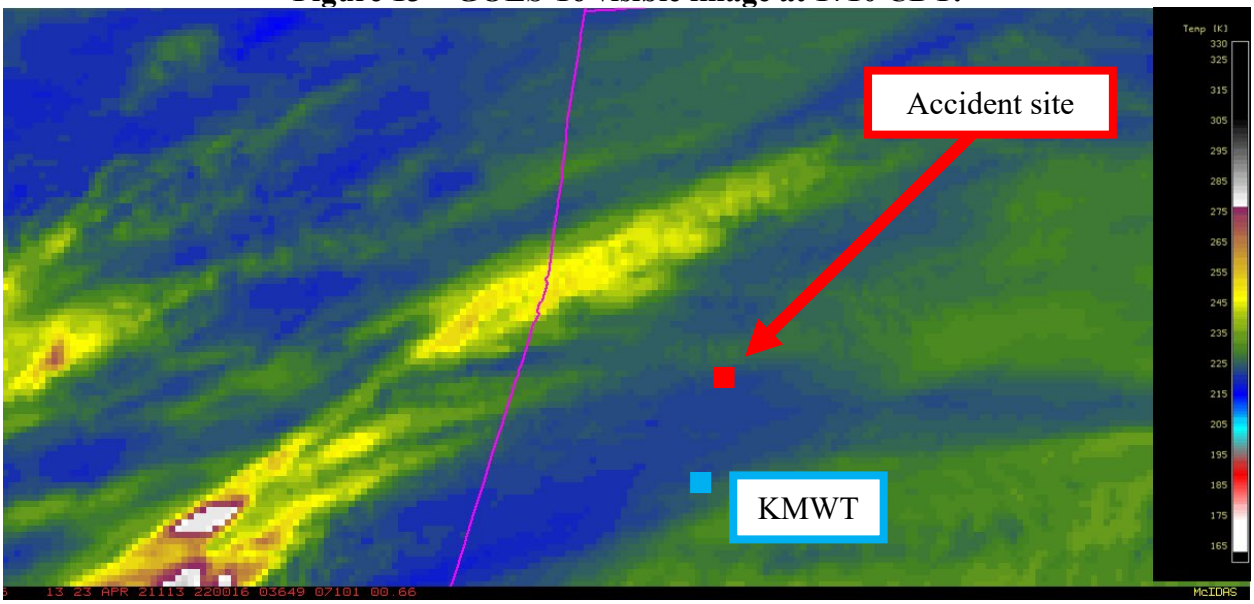


Figure 14 – GOES-16 infrared image at 1700 CDT.

6.0 Regional Radar Imagery Information

A regional view of the NWS National Composite Radar Mosaic from NCEI is included as figure 15 for 1700 CDT with the approximate location of the accident site marked within a red circle. The image depicted echoes from 10 to 30 decibels (dBZ[16]) above the accident site at 1700 CDT.

[16] 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.

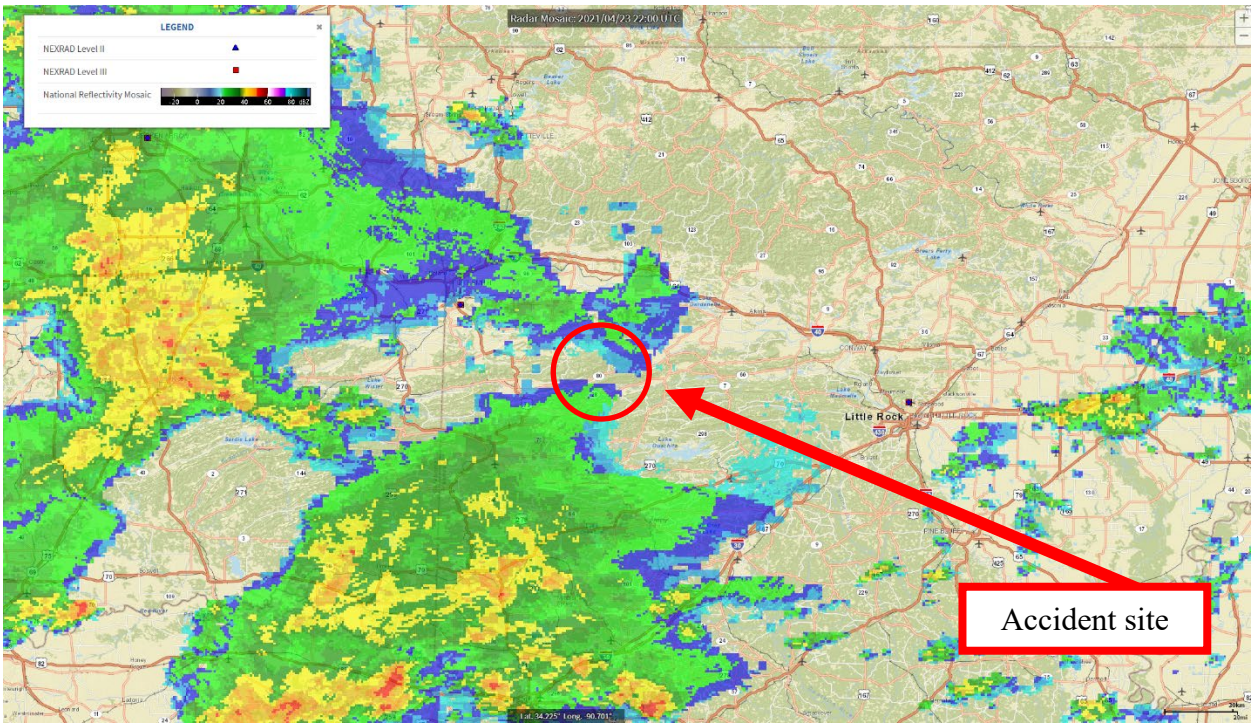


Figure 15 – Regional Composite Reflectivity image for 1700 CDT.

7.0 Radar Imagery Information

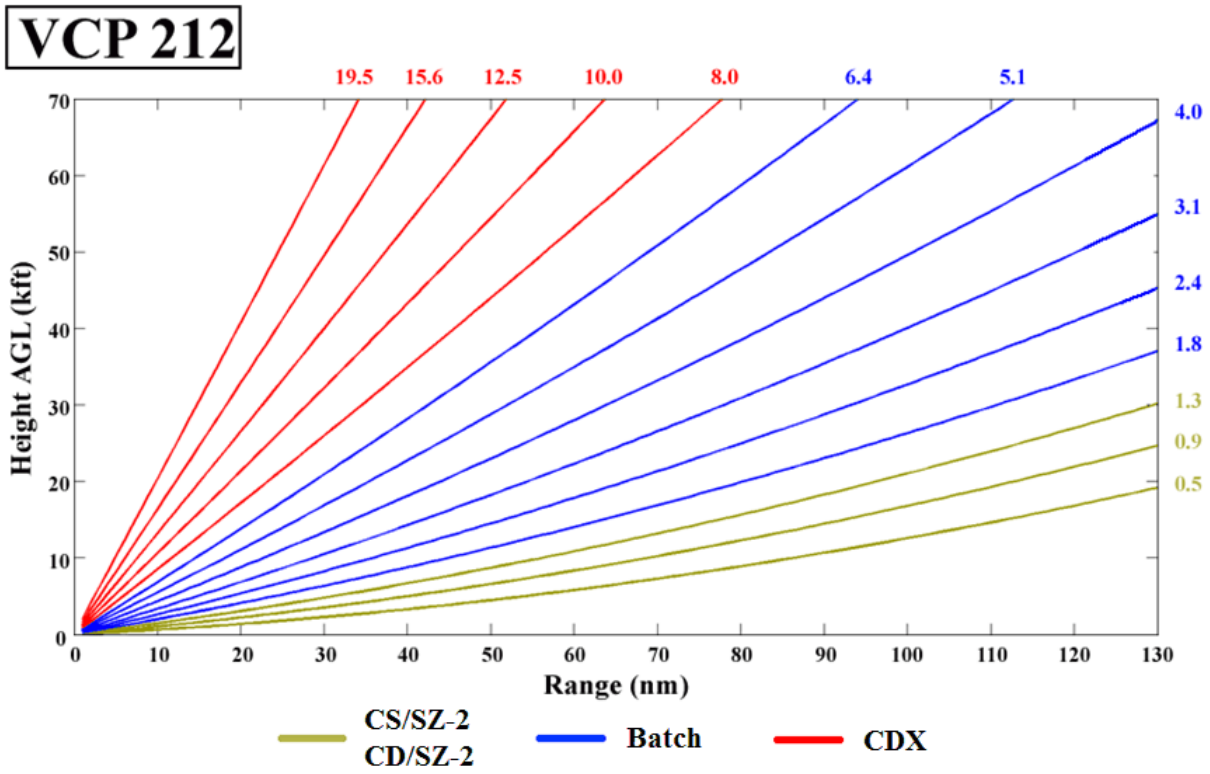
The closest NWS Weather Surveillance Radar-1988, Doppler (WSR-88D)[17] to the accident site was Fort Smith, Arkansas, (KSRX) located 42 miles northwest of the accident site. Level II and III archive radar data were obtained from the NCEI utilizing the NEXRAD Data Inventory Search and displayed using the NOAA's Weather and Climate Toolkit software.

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 four-to-ten-minute volume scan.

[17] 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.

The WSR-88D operates in two main scanning modes, identified as Mode A and Mode B. Mode A is the precipitation scan and has several scanning strategies[18]. The most common is where the radar makes 14 elevation scans from 0.5° to 19.5° every four and a half minutes. This scanning strategy is documented as volume coverage pattern 212 (VCP-212). Mode B is the clear-air mode, where the radar makes 9 elevation scans during a ten-minute period. During the period surrounding the accident, the KSRX 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.



VCP-212 Precipitation Mode Scan Strategy.

[18] 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 refraction[19] of the KSRX WSR-88D radar beam with the antenna elevation at 737 ft, and considering a beamwidth[20] of 0.95°, the following table shows the approximate heights for the radar beam center, base, and top for an antenna elevation over the accident site and for the approximate altitudes of the accident flight[21] at the KSRX WSR-88D display times (section 7.4). These heights have been rounded to the nearest 10 ft.

ANTENNA ELEVATION	BEAM CENTER	BEAM BASE	BEAM TOP
KSRX 4.0°	19,770 ft	17,700 ft	21,840 ft
KSRX 6.4°	18,780 ft	17,510 ft	20,050 ft
KSRX 10.0°	12,400 ft	11,870 ft	12,930 ft

Based on the radar height calculations, the elevation scan from KSRX listed in the above table depicted the conditions between 11,870 ft and 21,840 ft and these scans "saw" the closest altitudes to the aircraft's altitude[22] at the KSRX WSR-88D display times (section 7.4).

7.3 Reflectivity

Reflectivity is the measure of the efficiency of a target in intercepting and returning radio energy. With hydrometeors[23] 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 00-24C[24], "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."

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

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

[21] For more altitude information please see the ATC track data located in the docket of this accident.

[22] For more altitude information please see the information located in the docket of this accident.

[23] 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.

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

7.4 Base Reflectivity and Lightning Data

Figures 16 through 20 present the KSRX WSR-88D base reflectivity images for the 4.0°, 6.4°, and the 10.0° elevation scans initiated at 1639:50, 1646:34, 1652:07, 1658:22, and 1704:48 CDT with a resolution of 0.5° X 250 m. Reflectivity values between 5 and 20 dBZ were located above the accident site at the accident time and along the accident flight track during the accident flight.

There were no lightning flashes[25] near the accident site at the accident time.[26]

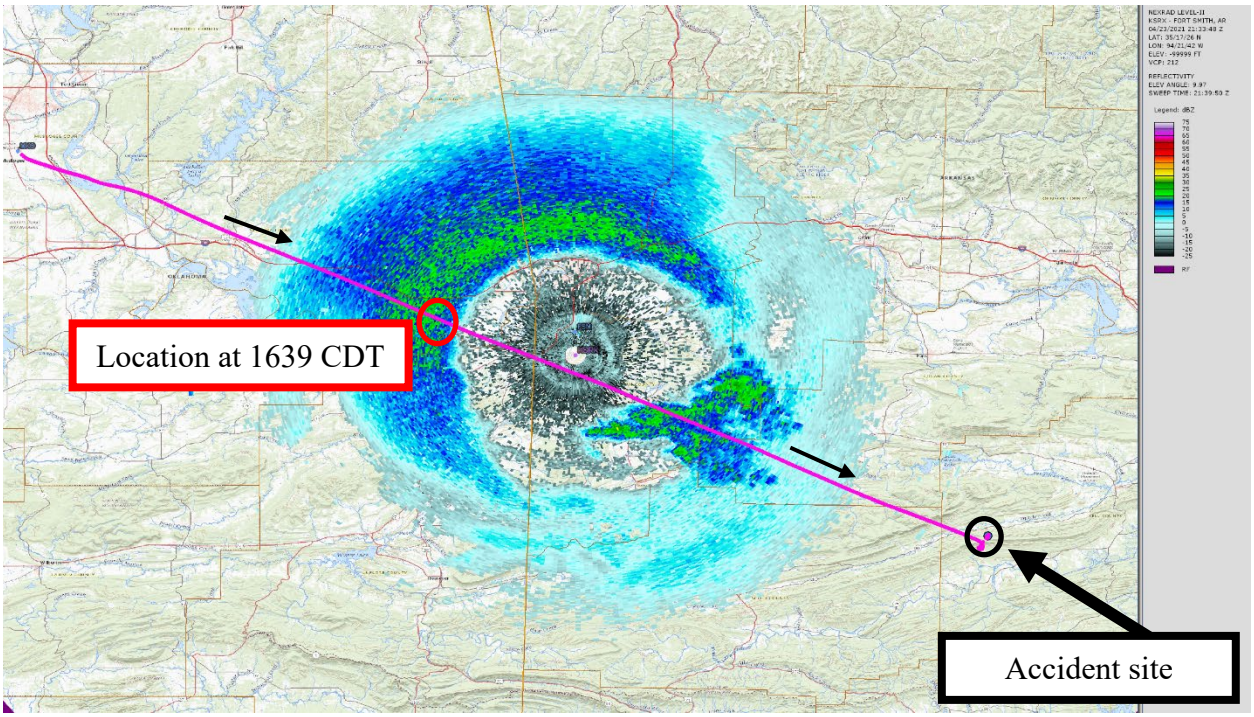

Figure 16 – KSRX WSR-88D reflectivity for the 10.0° elevation scan initiated at 1639:50 CDT with the accident site marked with a black circle and the accident flight track in pink with arrows pointing in the direction of travel.

[25] 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. A review of Earth Networks Total Lightning network was done.
[26] A review of Earth Networks Total Lightning network was done.

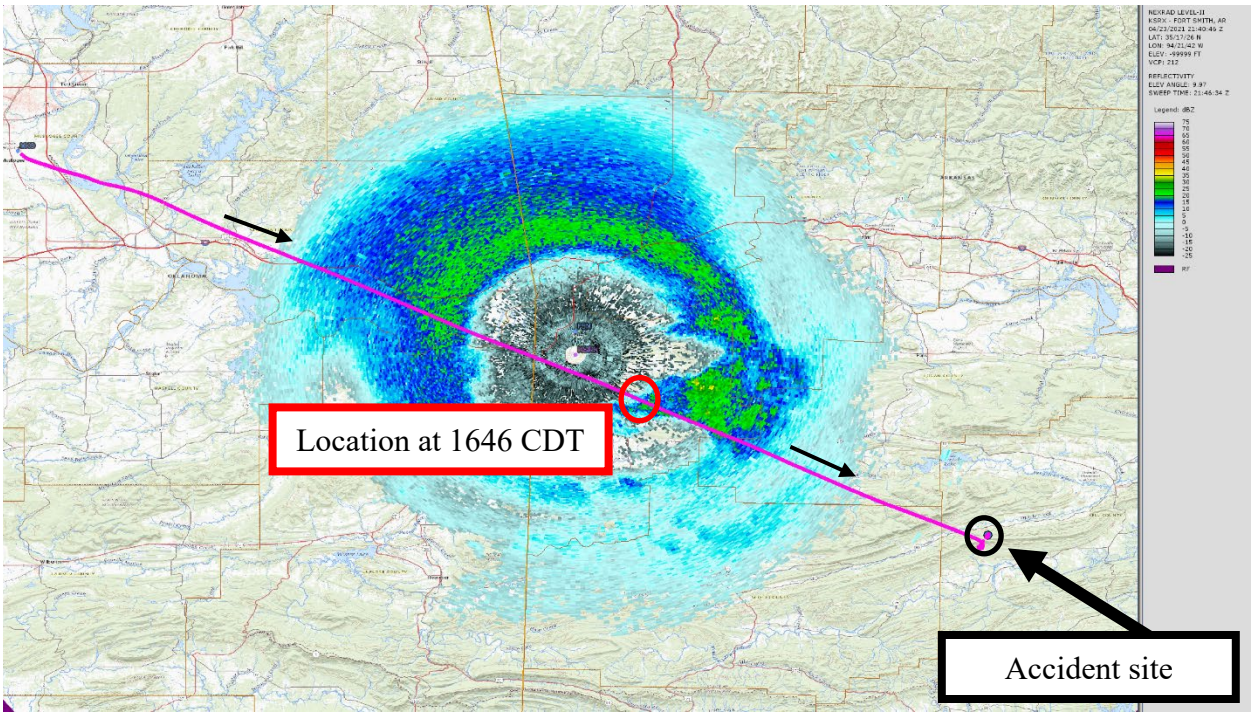

Figure 17 – KSRX WSR-88D reflectivity for the 10.0° elevation scan initiated at 1646:34 CDT with the accident site marked with a black circle and the accident flight track in pink with arrows pointing in the direction of travel.

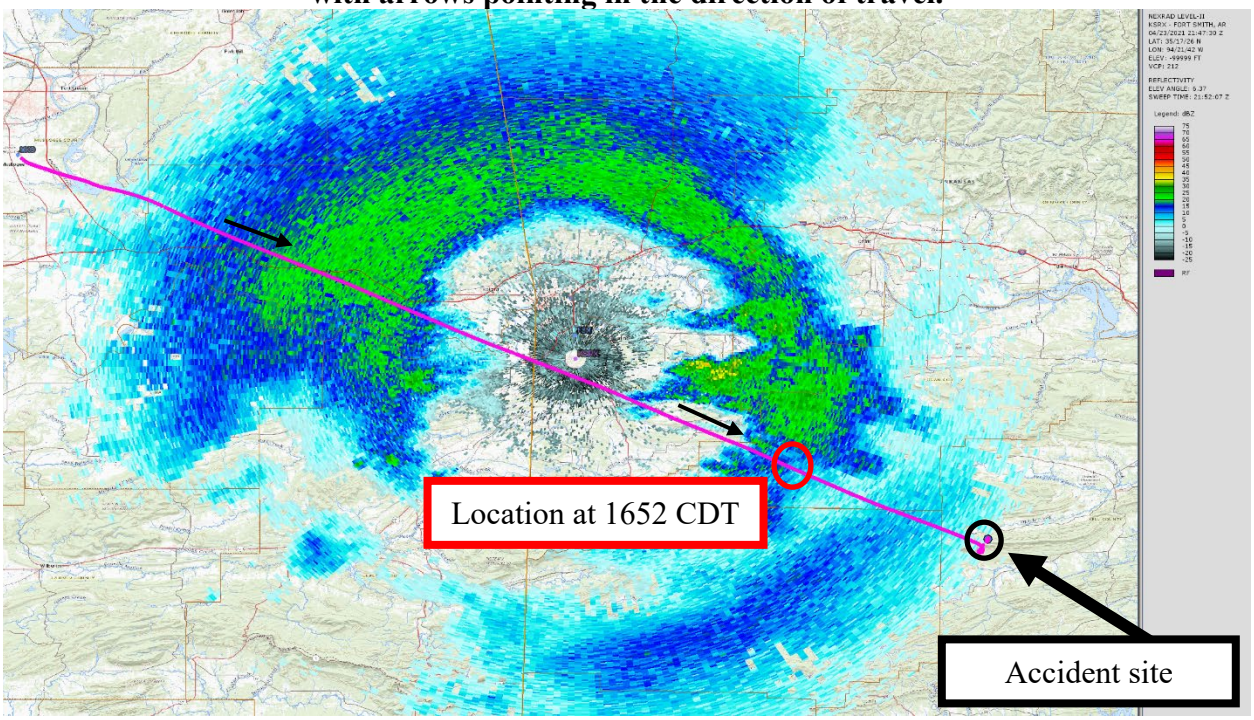

Figure 18 – KSRX WSR-88D reflectivity for the 6.4° elevation scan initiated at 1652:07 CDT with the accident site marked with a black circle and the accident flight track in pink with arrows pointing in the direction of travel.

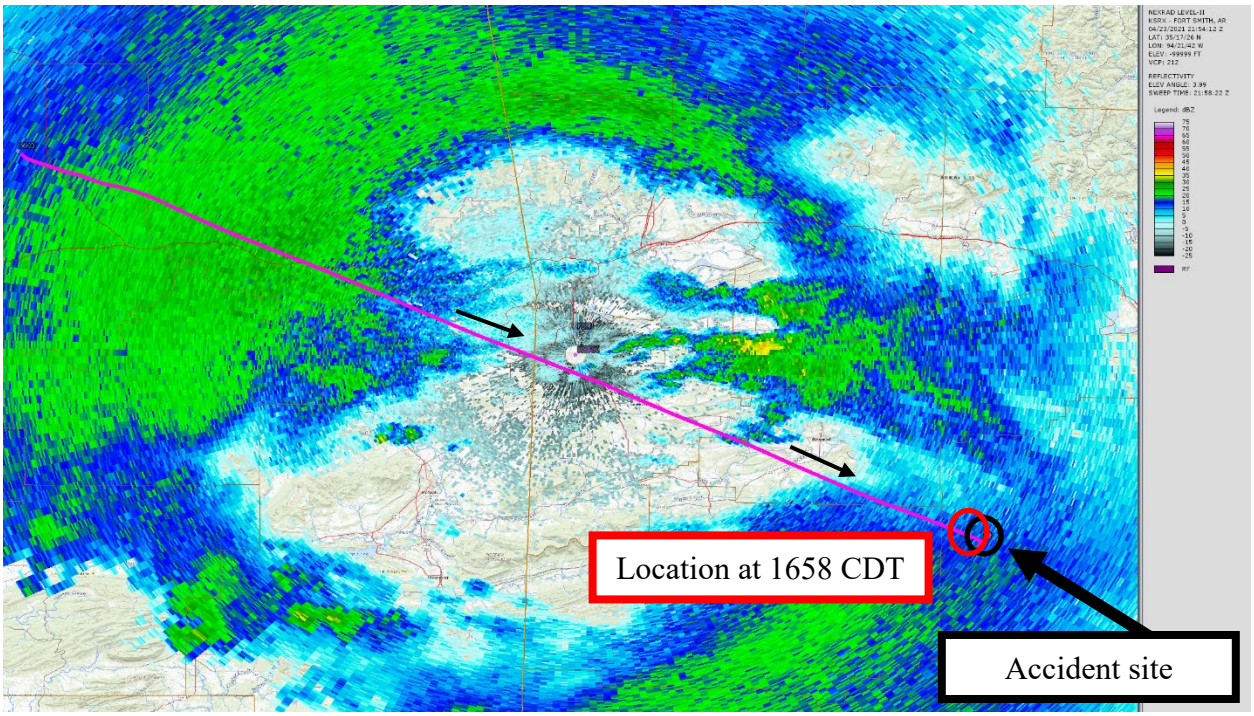

Figure 19 – KSRX WSR-88D reflectivity for the 4.0° elevation scan initiated at 1658:22 CDT with the accident site marked with a black circle and the accident flight track in pink with arrows pointing in the direction of travel.

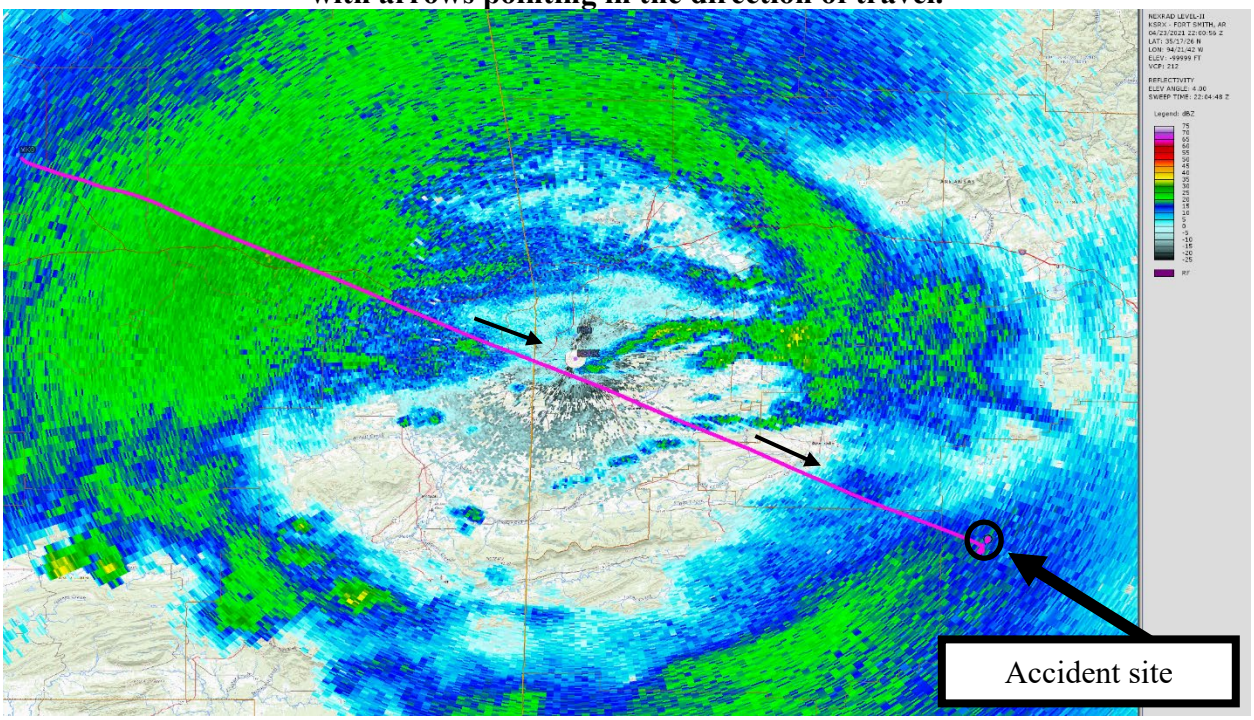

Figure 20 – KSRX WSR-88D reflectivity for the 4.0° elevation scan initiated at 1704:48 CDT with the accident site marked with a black circle and the accident flight track in pink with arrows pointing in the direction of travel.

8.0 Pilot Reports

The longline-disseminated pilot reports[27] (PIREPs) distributed into the national airspace (NAS) were reviewed from about three hours prior to the accident time to three hours after the accident time and only the PIREPs around 100 miles of the accident site below FL300[28] are shown here:

FSM UA /OV FSM2055/TM 2055/FL260/TP H25B/TB CONS MOD 260-250/RM ZME

LIT UA /OV LIT315050/TM 2105/FL260/TP B737/TB CONS MOD CHOP 260-340/RM ZME

TXK UA /OV TXK045040 /TM 2113 /FL300 /TP E170 /TB MOD /RM FL280-300 ZFW AWC-WEB

LIT UA /OV LIT315050/TM 2130/FL270/TP C130/TB CONS MOD CHOP/RM ZME

LIT UA /OV LIT315025/TM 2237/FL200/TP SW4/TA M11/RM IMC NEG ICE

FSM UA /OV FSM135045/TM 2256/FL200/TP SW4/TA M10/IC TRACE RIME/RM ZME

XNA UA /OV XNA135040/TM 2310/FL170/TP E145/IC LGT RIME 170-160/RM ZME

9.0 Significant Meteorological Information

There were no non-convective Significant Meteorological Information (SIGMET) advisories valid for the accident site at the accident time. Convective SIGMET 38C issued at 1655 CDT was valid at the accident time. Convective SIGMET 31C issued at 1555 CDT was valid at the time of departure. Both SIGMETs warned of an area of severe embedded thunderstorms with tops above FL450, hail to 2 inches, and wind gusts to 60 knots possible with the SIGMET polygon moving from 250° at 35 knots:

WSUS32 KKCI 232155
SIGC
MKCC WST 232155
CONVECTIVE SIGMET 38C
VALID UNTIL 2355Z
LA AR TX OK
FROM 10S FSM-20WNW ELD-50N SAT-60SE ABI-10S FSM
AREA SEV EMBD TS MOV FROM 25035KT. TOPS ABV FL450.
HAIL TO 2 IN...WIND GUSTS TO 60KT POSS.

WSUS32 KKCI 232055
SIGC
MKCC WST 232055
CONVECTIVE SIGMET 31C
VALID UNTIL 2255Z
LA AR TX OK
FROM 30SSE FSM-30ENE TXK-20SSE GGG-30NW CWK-10SSE ABI-30SSE FSM

[27] Only pilot reports with the World Meteorological Organization headers UBAR**, UBOK**, UBTX**, UBLA**, and UBMO** were considered. These do not include pilot reports only broadcast via radio.
[28] 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.

AREA SEV EMBD TS MOV FROM 25035KT. TOPS ABV FL450.
HAIL TO 2 IN...WIND GUSTS TO 60KT POSS.

10.0 Center Weather Service Unit Advisories

The Memphis (ZME) Air Route Traffic Control Center (ARTCC) Center Weather Service Unit (CWSU) was responsible for the accident region. There were no Center Weather Advisories (CWA) valid at the accident time.

11.0 Airmen's Meteorological Information

Airmen's Meteorological Information (AIRMET) advisories Sierra and Zulu were valid for the accident site at the accident time (issued around 1545 CDT). The AIRMETs warned of IFR conditions due to precipitation and mist, and moderate icing between the freezing level[29] and FL250:

WAUS44 KKCI 232045
WA4S
-DFWS WA 232045
AIRMET SIERRA UPDT 7 FOR IFR VALID UNTIL 240300
.
AIRMET IFR...OK TX AR LA MS AND CSTL WTRS
FROM OSW TO RZC TO 50NNW ARG TO 50SW MEM TO 30NNW MCB TO 30ESE
LCH TO 60WSW LCH TO 50E BRO TO 20W BRO TO 40ENE JCT TO 60WSW TTT
TO SPS TO 20WSW CDS TO LBL TO OSW
CIG BLW 010/VIS BLW 3SM PCPN/BR. CONDS CONTG BYD 03Z THRU 09Z.
.

WAUS44 KKCI 232045
WA4Z
-DFWZ WA 232045
AIRMET ZULU UPDT 3 FOR ICE AND FRZLVL VALID UNTIL 240300
.
AIRMET ICE...TN KY
FROM 50W HNN TO HNN TO HMV TO GQO TO 50W VXV TO 20ESE LOZ TO
60NNW HMV TO 50W HNN
MOD ICE BTN FRZLVL AND FL180. FRZLVL 050-100. CONDS ENDG BY 00Z.
.
AIRMET ICE...OK AR TN LA MS AL
FROM 20ENE RZC TO 20NNW DYR TO 20SSW GQO TO 30N LGC TO PZD TO
40SE MHZ TO 60SE MLU TO 60SW MEM TO 20WSW FSM TO 20ENE RZC
MOD ICE BTN FRZLVL AND FL250. FRZLVL 110-130. CONDS DVLPG 00-03Z.
CONDS CONTG BYD 03Z THRU 09Z.
.
OTLK VALID 0300-0900Z...ICE OK AR TN LA MS AL
BOUNDED BY 20SW BWG-20SSE VXV-GQO-PZD-40SE MHZ-60SE MLU-40WNW
SQS-50NNW ELD-20WSW FSM-20N RZC-20SW BWG
MOD ICE BTN FRZLVL AND FL250. FRZLVL 090-120. CONDS CONTG THRU
09Z.
.
FRZLVL...RANGING FROM 065-155 ACRS AREA

[29] Freezing level between 11,000 and 13,000 ft msl.

080 ALG 20SSE VXV-40W VXV-30SE BWG
120 ALG 90S MRF-50NW CWK-20WNW TTT-30WSW MEI-40NW MGM-40WNW
PZD
....

12.0 Graphical Forecasts for Aviation

The Graphical Forecasts for Aviation (GFA) products issued before the accident flight and valid at 2000 CDT are shown in attachment 1. The GFA surface forecast valid for departure for around the accident time indicated LIFR surface visibilities with numerous (between 60 to 100 percent) thunderstorms and a surface wind from the southeast at 10 knots. The GFA cloud forecast valid before departure for around the accident time indicated overcast cloud bases at 2,000 ft with cloud tops at FL350 and cirrus clouds above. The Graphical AIRMETs[30] (G-AIRMET) Sierra and Zulu for IFR conditions and icing, respectively, were overlaid on the GFA surface and cloud forecast graphics. The only human-generated information reflected in the two GFA products are the G-AIRMETs and the GFA is "human-over-the-loop." For more information, please see attachment 1.

13.0 Terminal Aerodrome Forecast

There were no NWS Terminal Aerodrome Forecast[31] (TAF) sites located within 30 miles of the accident site.

14.0 NWS Area Forecast Discussion

The NWS office in Little Rock, Arkansas, (WFO LZK) issued the following Area Forecast Discussion (AFD) at 1504 CDT:

FXUS64 KLZK 232004
AFDLZK

Area Forecast Discussion
National Weather Service Little Rock AR
304 PM CDT Fri Apr 23 2021

.DISCUSSION...

Early afternoon regional radar imagery shows scattered rain
showers extending from the Little Rock metro area to the east
generally south of highway 67/167 and north of highway 65. Visible
satellite imagery shows some breaks in the cloud cover and surface
observations confirm that temperatures have climbed into the lower
to mid 60s to the northeast and southwest of central Arkansas.
Persistent light rainfall has kept temperatures down into the mid
to upper 50s this afternoon. We are running out of time and
daylight for temperatures to climb much higher, so this may end up

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

being the high temperature for the day today. Water vapor satellite imagery shows a strong shortwave trough over the Chihuahua province of northern Mexico moving east towards the Rio Grande and west central Texas.

Surface objective analysis showed an axis of higher theta-e air extending from the Texas and Louisiana Gulf Coast northwest over north Texas to approximately the Red River. The strong northern Mexico shortwave trough is expected to swing northeast late this evening and overnight spreading strong large scale forcing for ascent over north Texas this afternoon and then northeast over Arkansas after sunset. This strong forcing for ascent will also result in surface cyclogenesis, resulting in a relatively strong surface low moving east southeast along the Red River from sunset through sunrise Saturday morning.

Cyclogenesis will induce strong low-level warm air advection over Arkansas from this evening through the overnight hours resulting in the development of widespread rain shower and isolated to scattered thunderstorm activity from southwest to northeast across the state. By midnight widespread rain showers and isolated to scattered thunderstorms are expected to encompass the entire state. When the strong forcing for ascent associated with differential positive vorticity advection couples with the strong warm air advection, a line of strong forced convection is expected to develop over eastern Oklahoma and move east-southeast into Arkansas around 1 to 2 AM.

This squall line appears to be strong and well organized according to convective allowing models. However, as the strong squall line/potential linear mesoscale convective system moves east into Arkansas, it will encounter low, low-level theta-e air causing any surface based ingestion of air into the squall line to become elevated or decoupled. This will cause the northern and central portion of the line to weaken substantially as it moves across the state. The southern portion of the line may remain intense as higher theta-e air hugs the Arkansas/Louisiana line.

Depending on the northern extent of the higher theta-e air, the squall line may be capable of bringing some strong to damaging winds down to the surface across portions of southwest and south central Arkansas. Do not expect any widespread wind damage, but pockets of wind damage, likely topping out at 50 to 60 mph, are possible across the southern portion of this squall line. Convective allowing models do indicate that the squall line is strong enough to develop a mesoscale high in the wake of the line of storms indicating that while the line of storms will weaken...it will hold together as it moves east across northern and central Arkansas. Assuming this squall is decoupled, expect that locally heavy rainfall and some gusty winds of 30 to 40 mph may accompany the passage of the line of storms.

The strong upper level shortwave trough is expected to move over Arkansas Saturday morning bringing a dry slot over the southern portion of the state. Moisture wrapped up north of the dry slot will likely result in the continuation of rain showers across

northern and portions of central Arkansas through Saturday morning. Rain showers should clear out from west to east Saturday afternoon as forcing for subsidence and low-level cool and dry air advection build across the state in the wake of the upper trough.

Convection allowing models do indicate some cellular activity in the core of the upper trough. With 700 mb temperatures forecast to be near 0 deg C and 500 mb temperatures forecast to be around -17 to -18 deg C, there may be some isolated thunderstorms that develop within the cold core of the upper trough Saturday morning. Warm air advection appears to continue Saturday morning at the 850 mb level resulting in steep lapse rates in the 850 to 500 mb level. This may be sufficient to allow for the development of some small hail (likely pea-sized) with thunderstorms across the northern portion of the state tomorrow morning. Thunderstorms in cold core upper lows can also sometimes produce cold-air funnels, but the dynamics of these features are not well understood. If cold air funnels are present, they will certainly not be dangerous as low-level air remains very stable.

Sunday through Tuesday...

Upper level ridging is expected to remain in place over Arkansas resulting in mostly sunny skies and southerly winds each day. Temperatures will warm up quite a bit Monday and Tuesday resulting in highs in the lower to mid 80s for most locations across the state. Clouds will build back in over Arkansas late in the day on Tuesday as the next upper level storm system approaches the central United States.

Tuesday night through Thursday...

Medium range guidance continues to struggle with consistency regarding the timing and strength of the mid-week storm system, but all medium range guidance indicates that a strong upper level trough will spread large scale forcing for ascent over Arkansas either indirectly via upstream cyclogenesis and the resultant warm and humid air advection over the state, or directly as the upper trough approaches the state either Wednesday or Thursday. The GFS has been supporting a faster solution while the ECMWF has been 18 to 24 hours slower with the passage of the upper trough. These large scale discrepancies make for a somewhat low-confidence forecast for the mid-week system. However, all model guidance shows some form of large scale forcing for ascent over Arkansas Wednesday and Thursday, so confidence in rainfall over the area is high. Details regarding severe weather chances and exact rainfall totals have the lowest confidence at this time. In general two to three inches of rain are expected across the state in the 48 hour period, but will not speculate on any impacts at this time until guidance comes into better agreement.

Cavanaugh

&&

.PRELIMINARY POINT TEMPS/POPS...

Batesville AR 52 67 46 73 / 100 90 10 0
Camden AR 56 75 49 79 / 100 20 0 0
Harrison AR 51 64 44 72 / 100 80 0 0
Hot Springs AR 53 72 47 76 / 100 40 0 0
Little Rock AR 54 70 48 75 / 100 50 0 0
Monticello AR 56 73 51 76 / 100 30 0 0
Mount Ida AR 52 72 47 77 / 100 40 0 0
Mountain Home AR 52 65 44 72 / 100 90 0 0
Newport AR 54 65 47 72 / 100 90 0 0
Pine Bluff AR 56 72 49 75 / 100 30 0 0
Russellville AR 53 70 46 76 / 100 60 0 0
Searcy AR 52 69 46 74 / 100 70 0 0
Stuttgart AR 56 70 50 74 / 100 50 0 0
&&

.LZK Watches/Warnings/Advisories...NONE.
&&

$$

15.0 Winds and Temperature Aloft Forecast

The NWS 1457 CDT Winds and Temperature Aloft forecast valid for the closest point to the accident site is included below:

```
FBUS31 KWNO 231957
FD1US1
DATA BASED ON 231800Z
VALID 240000Z   FOR USE 2000-0300Z. TEMPS NEG ABV 24000

FT  3000    6000    9000   12000   18000   24000  30000  34000  39000
FSM 1625 2023+10 2123+04 2523-02 2637-16 2454-26 239541 731852 733860
```

The closest forecast point to the accident site was Fort Smith, Arkansas (FSM). The 1457 CDT FSM forecast for use between 1500 CDT and 2200 CDT indicated a wind at 12,000 ft from 250° at 23 knots with a temperature of -2°C, a wind at 18,000 ft from 260° at 37 knots with a temperature of -16°C, and a wind at 24,000 ft from 240° at 54 knots with a temperature of -26°C.

16.0 Pilot Weather Briefing

The accident pilot did receive weather information[32] from Leidos Flight Service. The accident pilot first contacted Leidos around 1554 CDT and had additional discussions with Leidos Flight Service through about 1620 CDT. For more information, please see attachments 2, 3, 4, 5, 6 and 7.

A search of archived ForeFlight information indicated that the accident pilot did request and receive weather information from ForeFlight at 1525 CDT (see attachment 8).

[32] https://www.faa.gov/documentLibrary/media/Advisory_Circular/AC_91-92.pdf

17.0 Icing Potential

Current Icing Product (CIP) and Forecast Icing Product (FIP)[33] are created by NCEP Central Operations (NCO) and displayed at the Aviation Weather Center (AWC) website[34], and are intended to supplement other icing advisories (e.g. AIRMETs and SIGMETs)[35]. Figures 21 through 23 are the FIP icing probabilities and icing severity products and 1-hour forecast valid at 1700 CDT at 14,000, 16,000, and 18,000 ft, and indicated a 30 to 50% probability of icing at 14,000 to 18,000 ft over the area. The FIP also indicated that the icing intensity near the accident site would range from "moderate" to "heavy" categories.[36]

The CIP product indicated a 40 to 60% probability of icing at 14,000, 16,000 and 18,000 ft at 1700 CDT above the accident site (figures 24, 25, and 26). The CIP also indicated that the icing near the accident site would be in the "light" category above 14,000 ft with pockets of "moderate to heavy" category along the flight track prior to the accident. In addition, the CIP indicated an unknown probability of Supercooled Large Droplets (SLD)[37] above 12,000 ft at the accident site at 1700 CDT (attachment 9). For more FIP and CIP data please see attachment 9. For additional icing information please see Federal Aviation Administration (FAA) Advisory Circular "Pilot Guide: Flight in Icing Conditions", AC 91-74B.[38]

[33] B.C. Bernstein, F. McDonough, M. K. Politovich, B. G. Brown, T. P. Ratvasky, D. R. Miller, C.A. Wolff, and G. Cunning, Current Icing Potential: Algorithm Description and Comparison with Aircraft Observations (Journal of Applied Meteorology, 2005), pp. 969-986.
C.A. Wolff, F. McDonough, M. K. Politovich, B.C. Bernstein, and G. Cunning, FIP Severity Technical Document (Prepared for the Aviation Weather Technology Transfer Technical Review Board), pp. 1-44.
https://arc.aiaa.org/doi/abs/10.2514/6.2009-3531
[34] AWC - Icing (aviationweather.gov)
[35] NCAR re-ran the CIP and FIP algorithms to produce the data highlighted in this report.
[36] https://www.aviationweather.gov/icing/fip
[37] AWC - Icing (aviationweather.gov)
[38] AC 91-74B - Pilot Guide: Flight In Icing Conditions – Document Information (faa.gov)

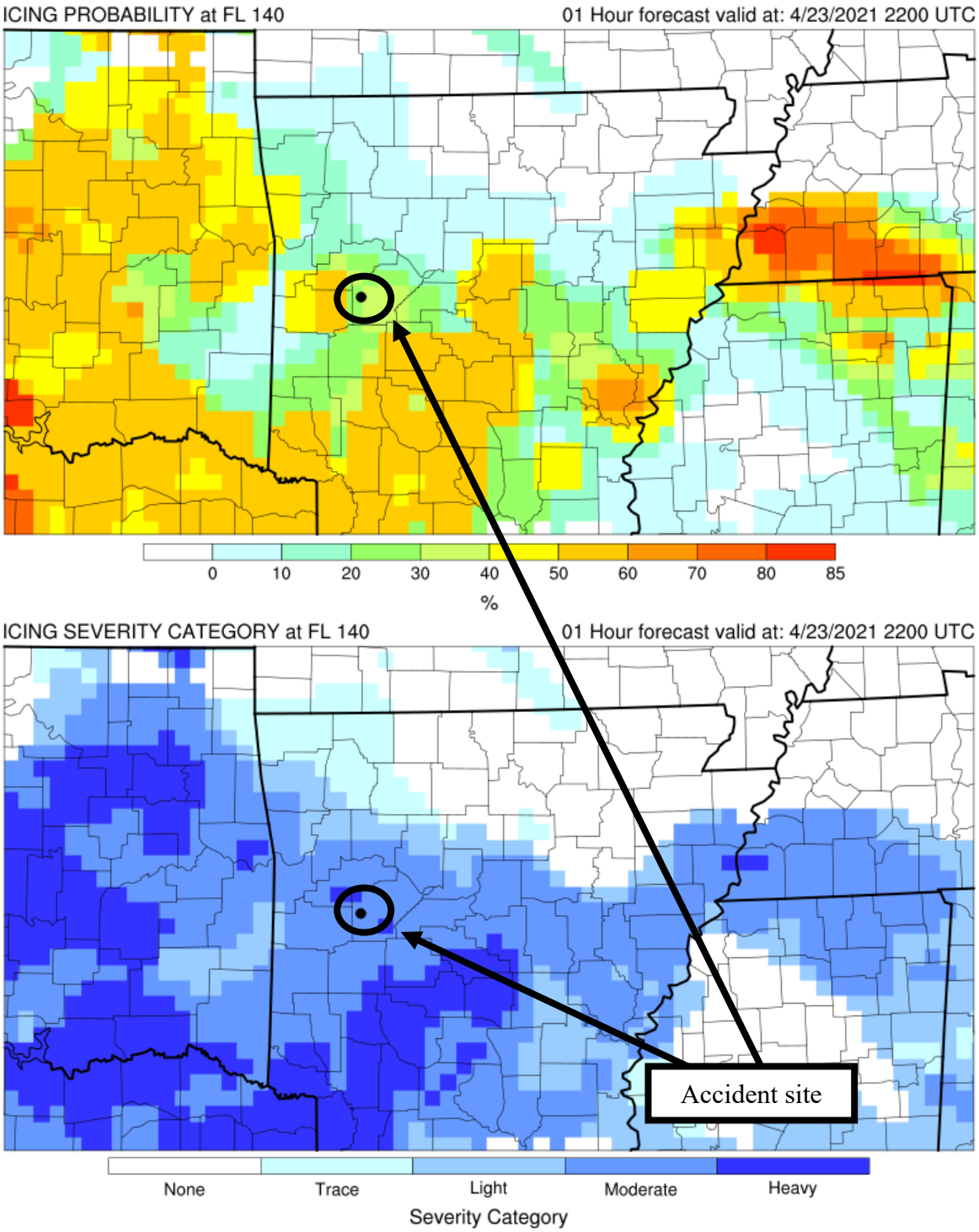

Figure 21 – (top) FIP probability of icing at 14,000 ft above msl and (bottom) FIP severity of icing at 14,000 ft above msl 1-hour forecast valid for 1700 CDT.

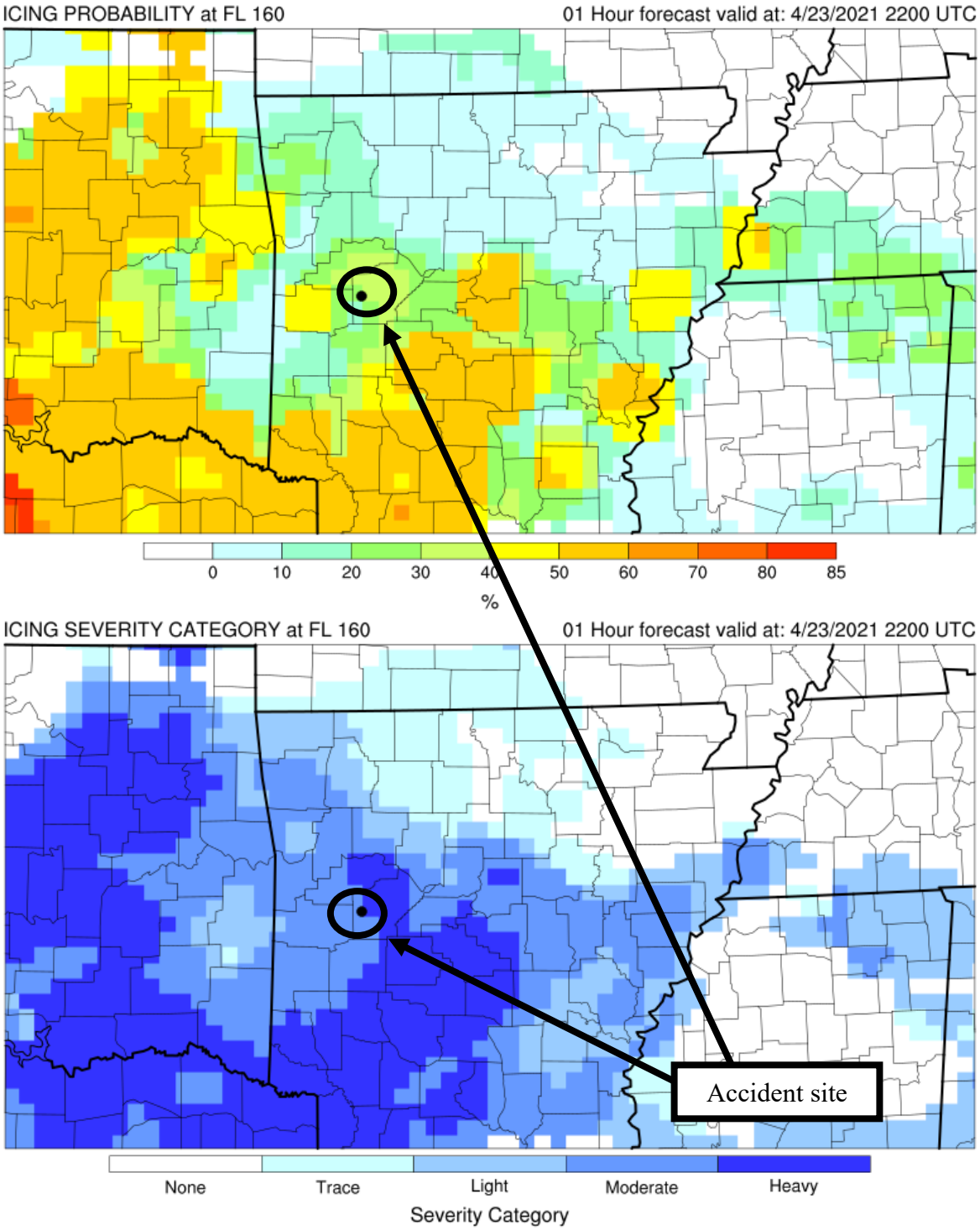

Figure 22 – (top) FIP probability of icing at 16,000 ft above msl and (bottom) FIP severity of icing at 16,000 ft above msl 1-hour forecast valid for 1700 CDT.

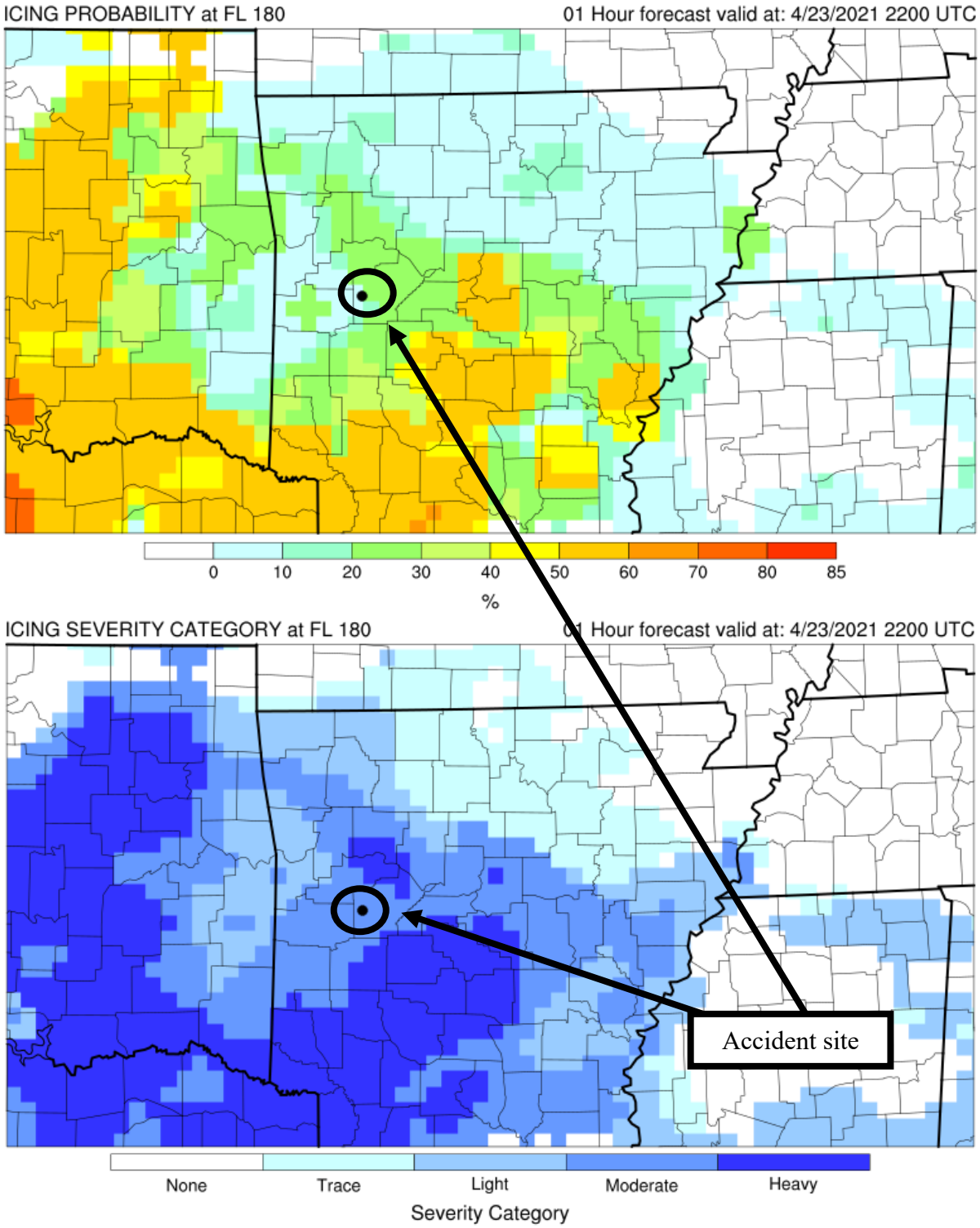

Figure 23 – (top) FIP probability of icing at 18,000 ft above msl and (bottom) FIP severity of icing at 18,000 ft above msl 1-hour forecast valid for 1700 CDT.

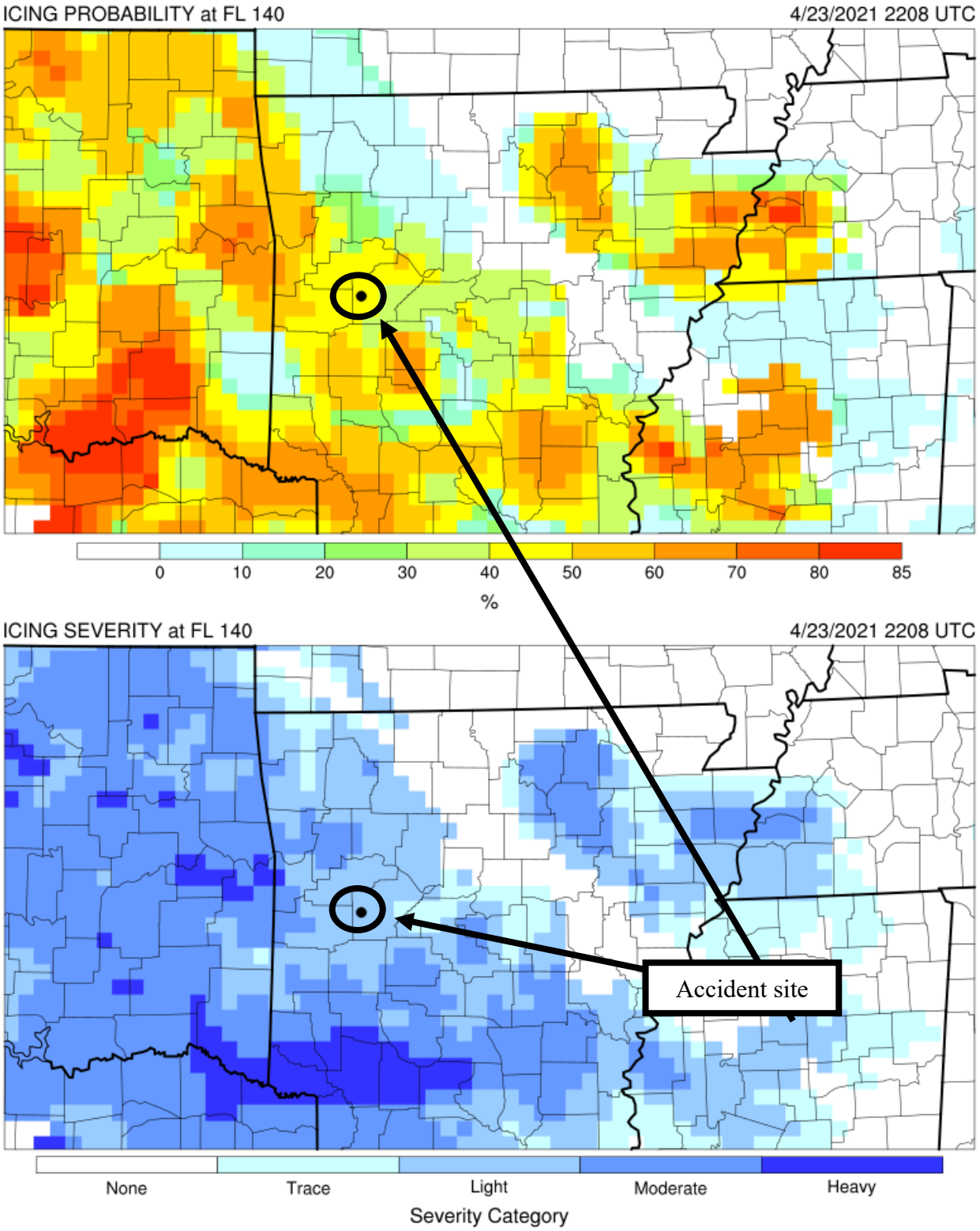

Figure 24 – (top) CIP probability of icing at 14,000 ft above msl and (bottom) CIP severity of icing at 14,000 ft above msl valid for around 1700 CDT.

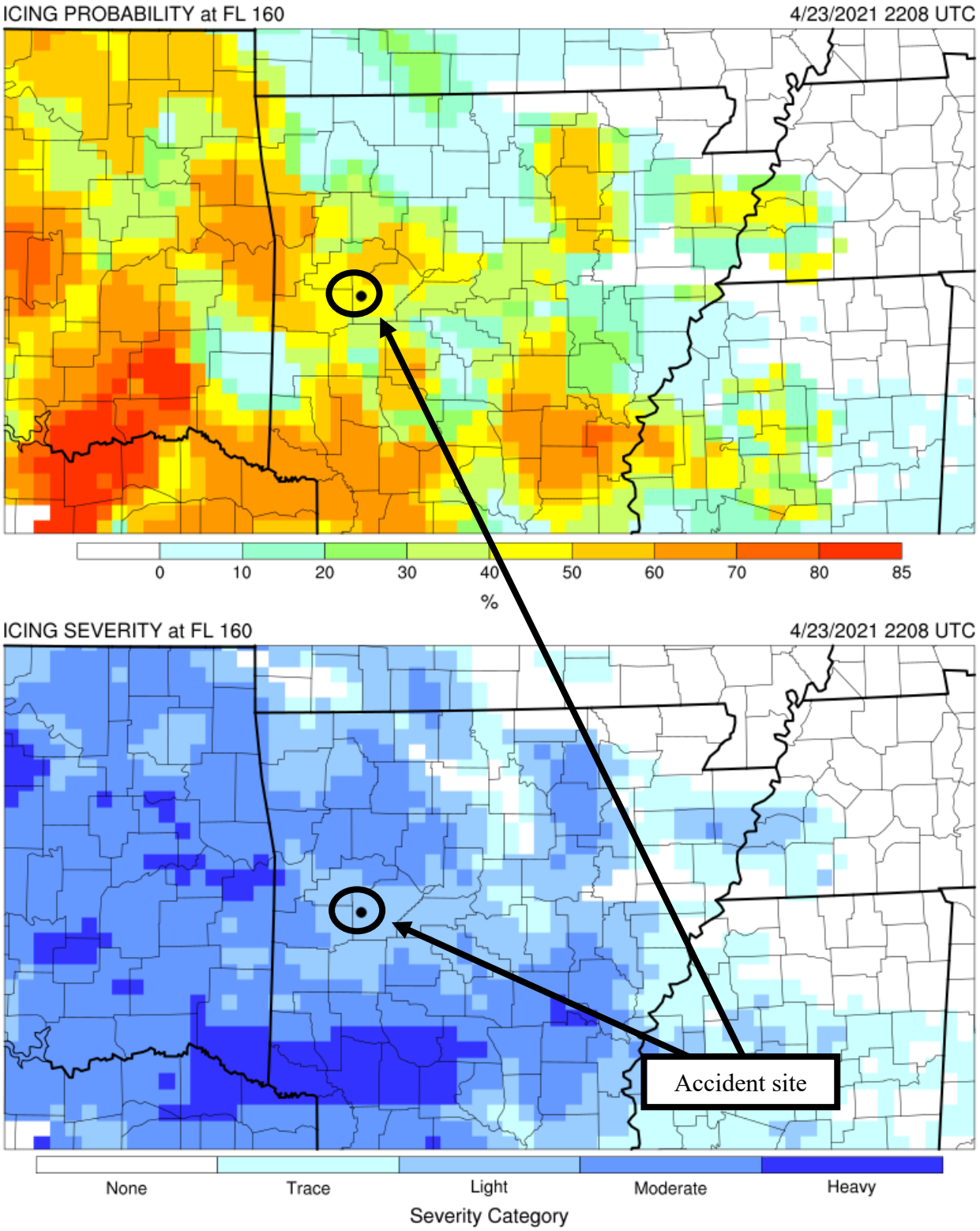

Figure 25 – (top) CIP probability of icing at 16,000 ft above msl and (bottom) CIP severity of icing at 16,000 ft above msl valid for around 1700 CDT.

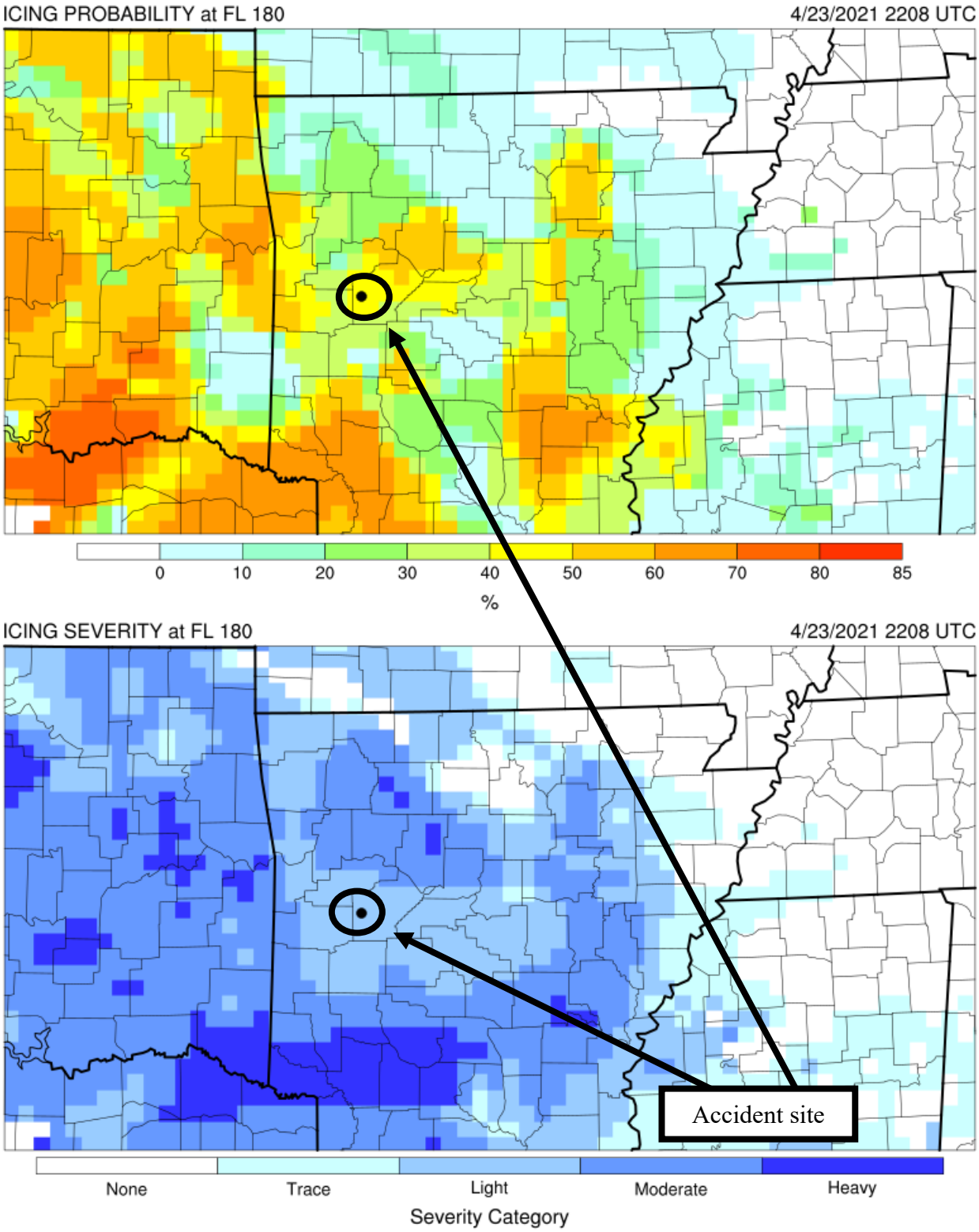

Figure 26 – (top) CIP probability of icing at 18,000 ft above msl and (bottom) CIP severity of icing at 18,000 ft above msl valid for around 1700 CDT.

18.0 Center Weather Service Unit Weather Briefing

The ZME CWSU issued several Pre-Duty Weather Briefings on the accident day with the Pre-Duty Weather Briefing issued at 1200 CDT valid at the accident time. For more information, please see attachment 10.

19.0 National Center for Atmospheric Research Icing Study

The NCAR Inflight Icing Team provided an icing-focused analysis for this accident. The NCAR analysis indicated the potential for icing and the icing severity were increasing over time leading up to the accident time. In addition, NCAR analysis showed the accident flight went through a cell of increased radar reflectivity prior to the accident time. All information contained therein is found in attachments 11 and 12.

20.0 Additional National Aeronautics and Space Administration Satellite Imagery

Additional GOES-16 data was provided by the National Aeronautics and Space Administration (NASA) Langley Research Center Climate Science Branch (LaRC-E302). The LaRC-E302 imagery[39] indicated moderate or greater icing conditions likely for the accident site at the accident time and additional data are found in attachment 13.

21.0 Astronomical Data

The astronomical data obtained for the accident site on April 23, 2021, indicated the following:

SUN	
Begin civil twilight	0606 CDT
Sunrise	0632 CDT
Sun transit	1313 CDT
Accident time	**1701 CDT**[40]
Sunset	1954 CDT
End civil twilight	2020 CDT

At the time of the accident the Sun was located at an altitude of 34.19° and azimuth of 261.55°.

[39] https://satcorps.larc.nasa.gov/cgi-bin/site/showdoc?docid=22&lkdomain=Y&domain=ICNG_CONUS_GEW
[40] Inserted accident time for reference and context.

E. LIST OF ATTACHMENTS

Attachment 1 – GFA valid for the accident site at accident time

Attachment 2 – Leidos contact history and weather document 1

Attachment 3 – Leidos contact history and weather document 2

Attachment 4 – Leidos contact history and weather document 3

Attachment 5 – Leidos Flight Service discussion with accident pilot 1

Attachment 6 – Leidos Flight Service discussion with accident pilot 2

Attachment 7 – Leidos Flight Service discussion with accident pilot 3

Attachment 8 – ForeFlight weather information provided for the accident flight

Attachment 9 – FIP and CIP information valid for the accident site at the accident time

Attachment 10 – ZME CWSU pre-duty weather briefings on the accident day

Attachment 11 – NCAR icing analysis document

Attachment 12 – NCAR icing data

Attachment 13 – LaRC-E302 imagery for the accident timeframe

Submitted by:

_____

Paul Suffern
Senior Meteorologist