NATIONAL TRANSPORTATION SAFETY BOARD

Office of Aviation Safety
Washington, D.C. 20594

January 24, 2020

Factual Report

METEOROLOGY

DCA19MA143

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A. ACCIDENT

Location: Jacksonville, Florida
Date: May 3, 2019
Time: 2142 eastern daylight time
0142 Coordinated Universal Time (UTC) May 4, 2019
Aircraft: Boeing 737-81Q, Registration: N732MA

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 launched to Jacksonville, Florida, for this investigation and gathered information, at times, with the NTSB air traffic control (ATC) group. The combined meteorology/ATC group met at Jacksonville Naval Air Station (Jax NAS) on May 4 to 6 to conduct weather observer and various other controller interviews. The group met at the Jacksonville Terminal Radar Approach Control Facility (TRACON) on May 7 to participate in ATC interviews, and at the Jacksonville Air Route Traffic Control Center (ARTCC ZJX) Center Weather Service Unit (CWSU) on May 8 to gather data pertinent to the investigation.

In addition, the NTSB meteorologist gathered 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 daylight time (EDT) on May 3, 2019, and are based upon the 24-hour clock, where local time is -4 hours from UTC, and UTC=Z (unless otherwise noted). Directions are referenced to true north and distances in nautical miles. Heights are above mean sea level (msl) unless otherwise noted. Visibility is in statute miles and fractions of statute miles. NWS airport and station identifiers use the standard International Civil Aviation Organization 4-letter station identifiers versus the International Air Transport Association 3-letter identifiers, which deletes the initial country code designator "K" for U.S. airports.

The accident site was located at latitude 30.231667° N, longitude 81.660278° W, with an approximate elevation of 2 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]

1.1 Surface Analysis Chart

The southeast section of the NWS Surface Analysis Chart for 2300 EDT is provided as figure 1 with the approximate location of the accident site marked within the red circle. The chart identified a surface low pressure center located over southeastern Georgia with a surface pressure of 1014-hectopascals (hPa) with a trough[2] extending westward across southeastern Georgia stretched to the west into southern Alabama. Troughs can act as lifting mechanisms to produce clouds and precipitation if sufficient moisture is present.

The station models around the accident site depicted air temperatures in the low to mid 70's degrees Fahrenheit (°F), dew point temperatures in the low 70's °F with temperature-dew point spreads of 3°F or less, with a variable wind of 10 knots or less indicated, and partly cloudy sky cover.

[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.

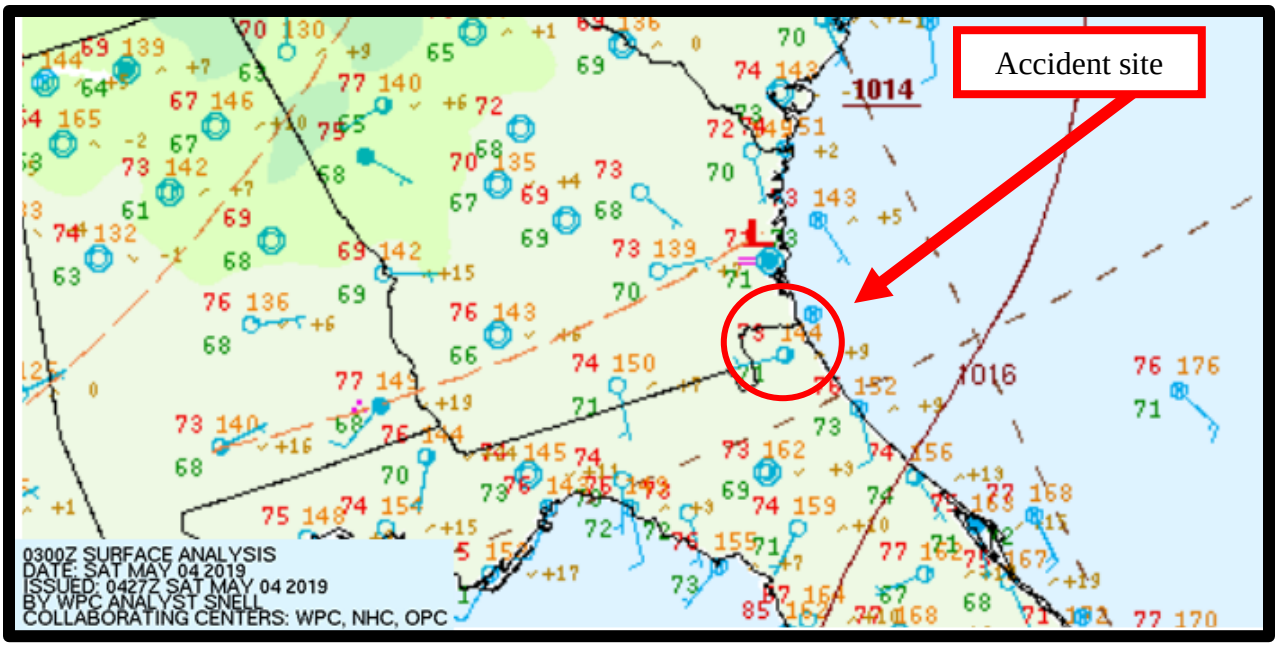


Figure 1 – NWS Surface Analysis Chart for 2300 EDT

1.2 Upper Air Charts

The NWS Storm Prediction Center (SPC) Constant Pressure Charts for 2000 EDT at 925-, 850-, 700-, 500-, and 300-hPa are presented in figures 2 through 6. There were low- and mid-level troughs located above and just northeast of the accident site from 925- through 500-hPa. These low- and mid-level troughs were associated with the surface trough in southern Georgia (figure 1). There was a west wind of 10 knots at 925-hPa above the accident site with the wind becoming northwesterly by 700-hPa (figure 4) with the wind speed at 10 knots. By 300-hPa, the wind above the accident site was from the south and the wind speed increased to 30 knots (figure 6).

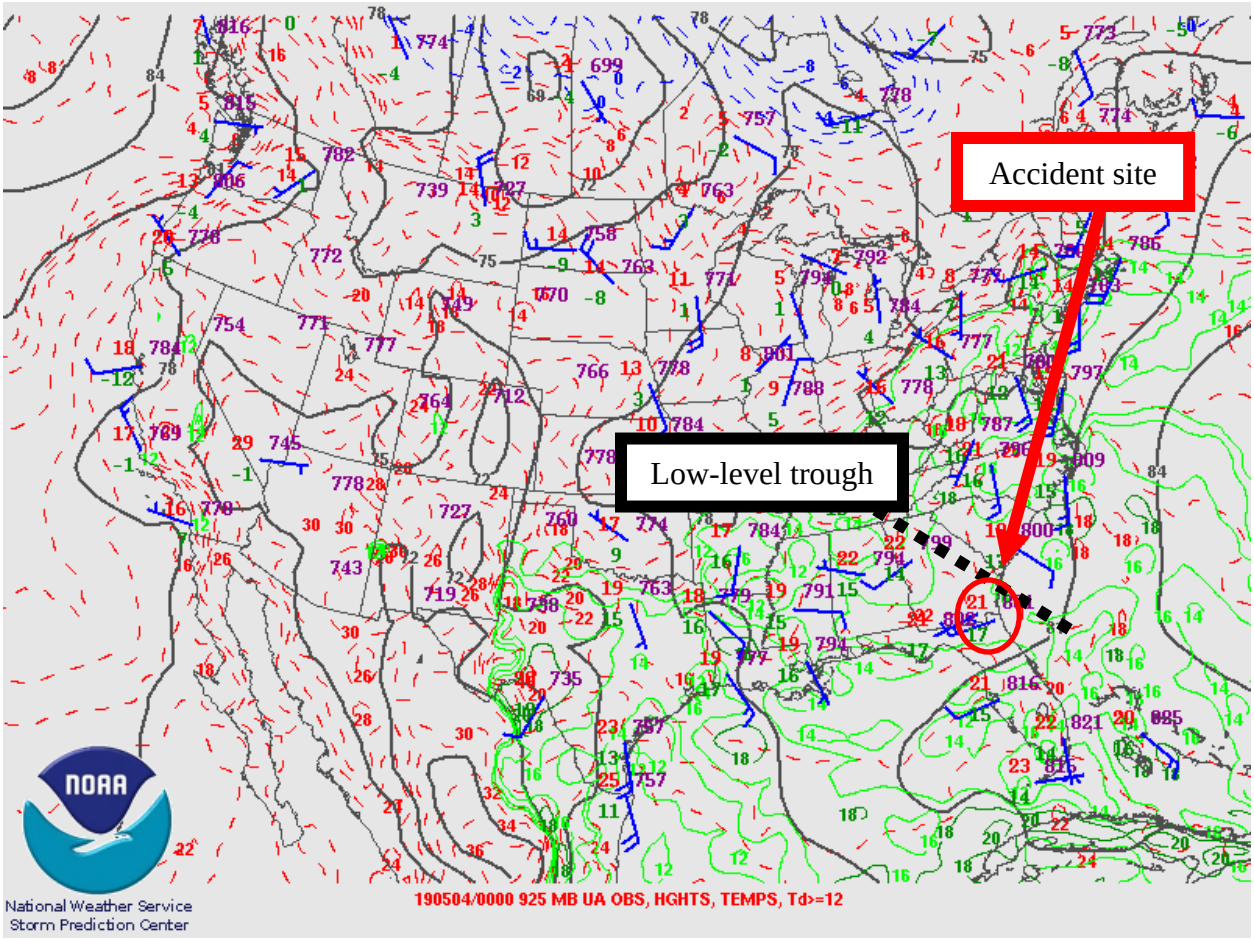


Figure 2 – 925-hPa Constant Pressure Chart for 2000 EDT

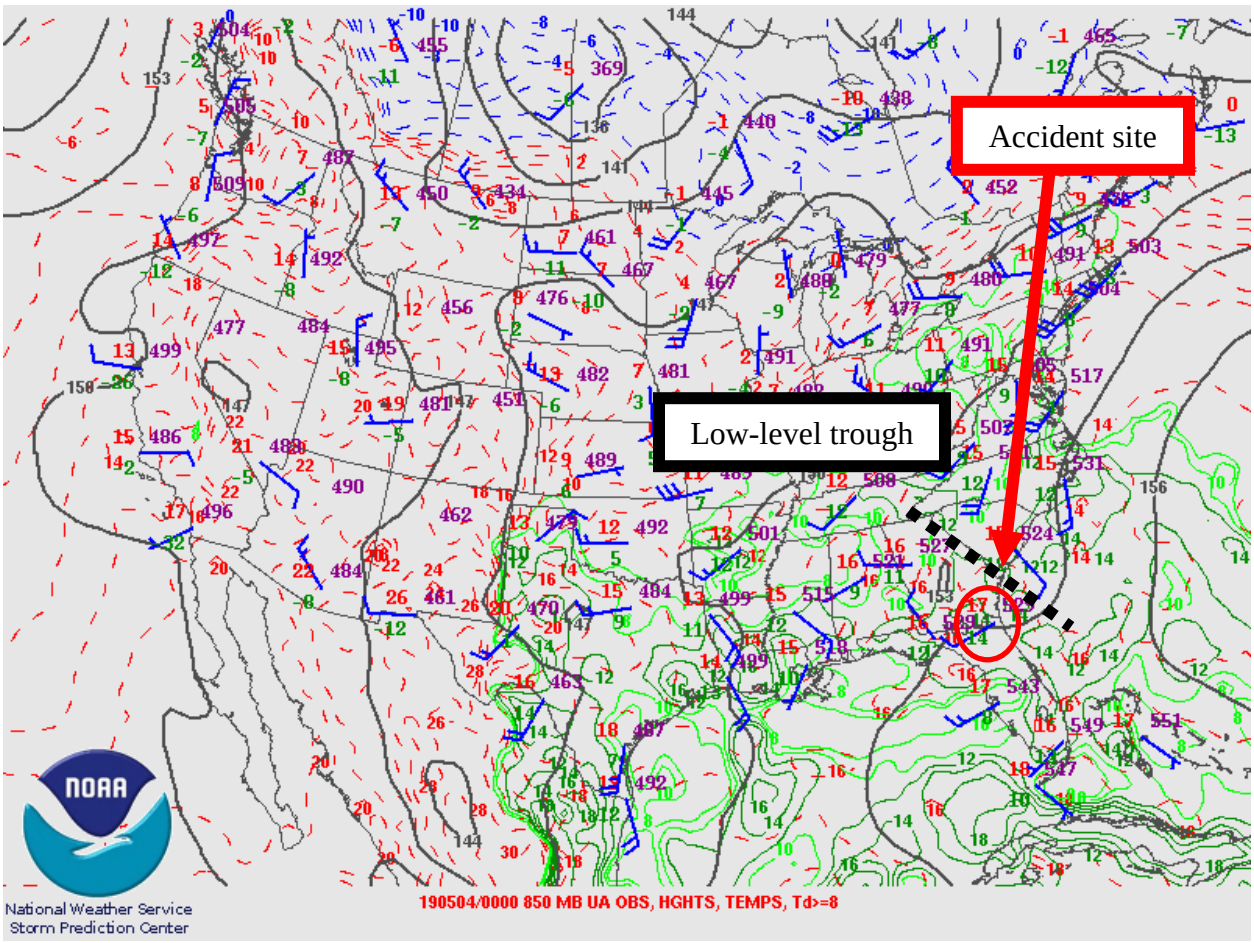


Figure 3 – 850-hPa Constant Pressure Chart for 2000 EDT

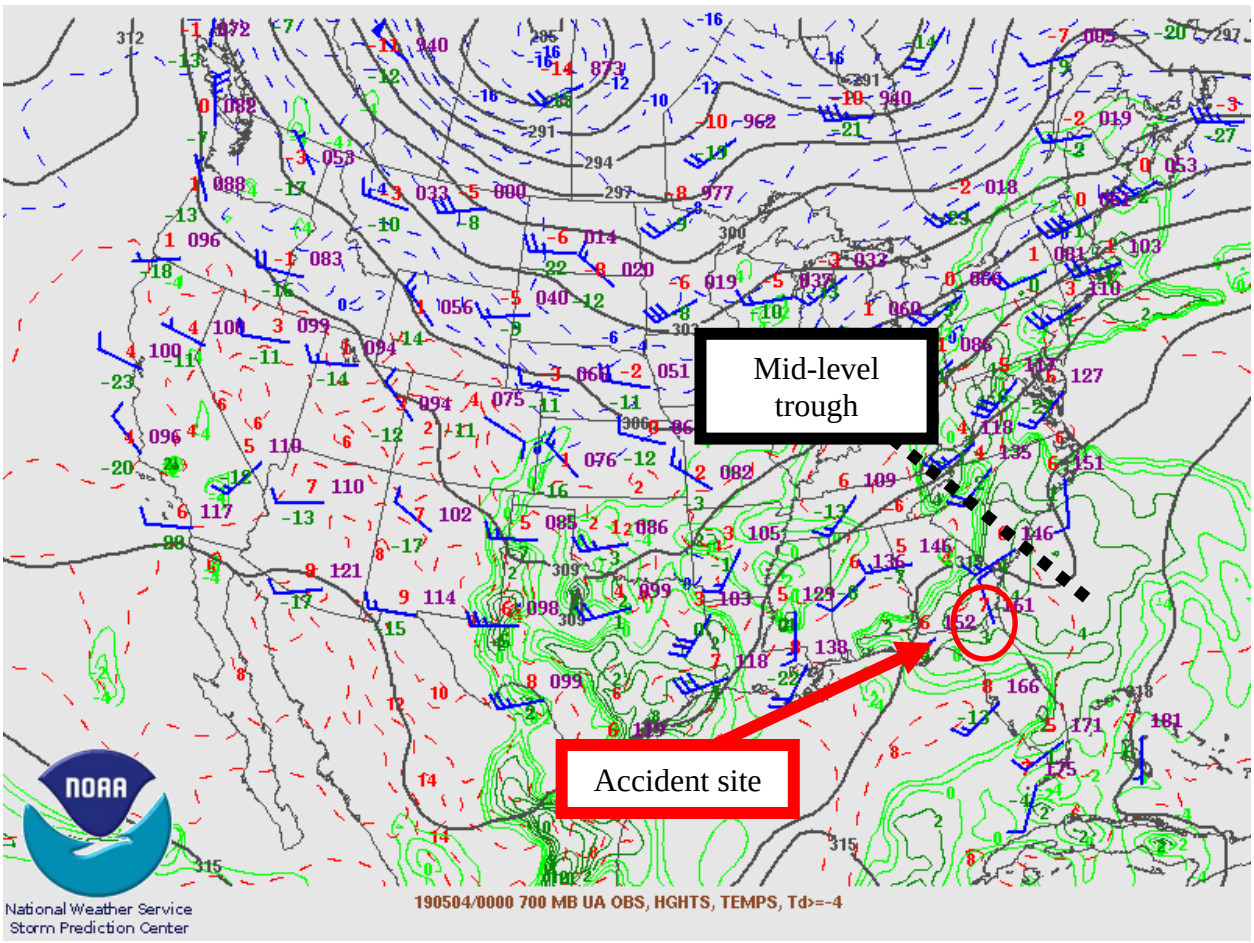


Figure 4 – 700-hPa Constant Pressure Chart for 2000 EDT

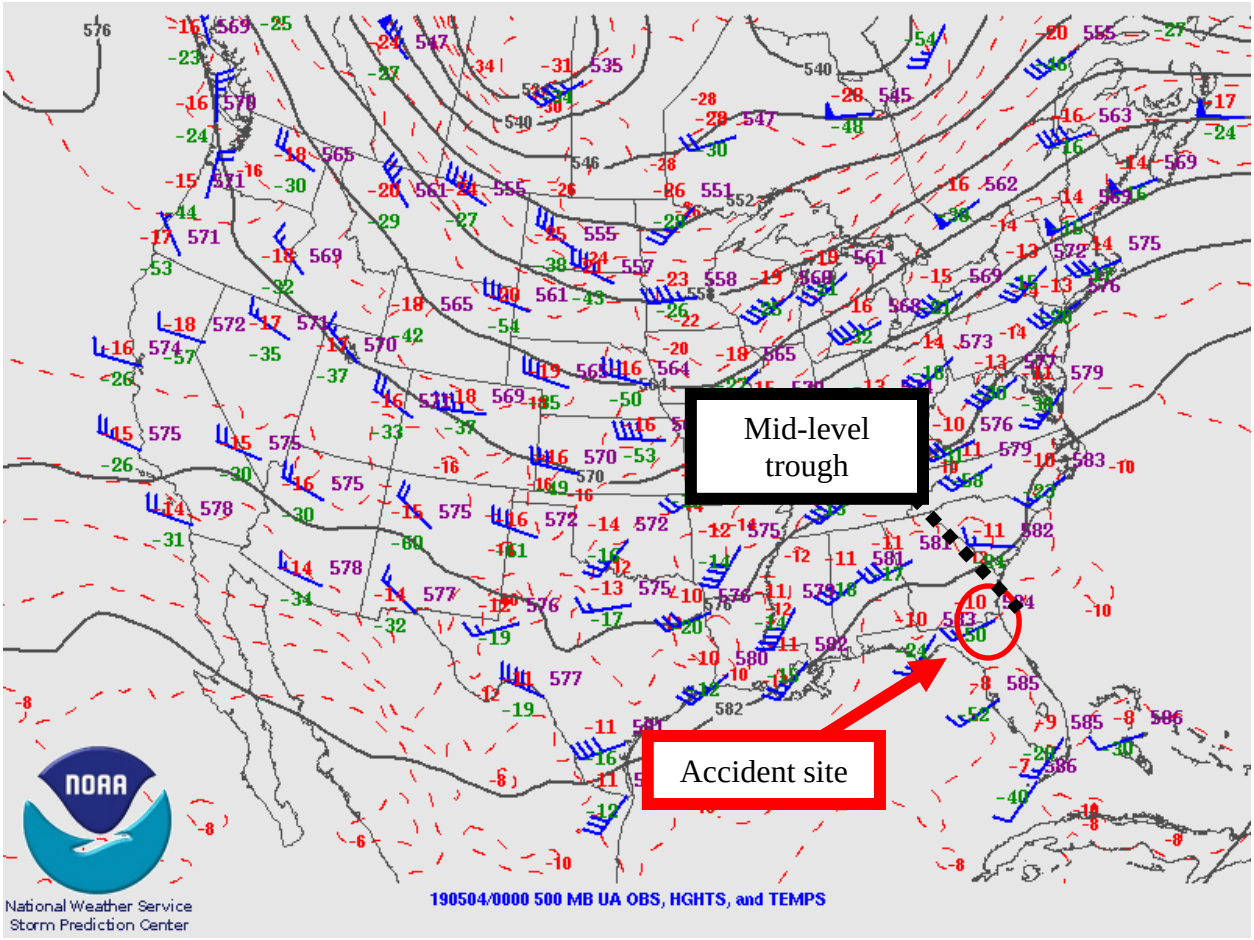


Figure 5 – 500-hPa Constant Pressure Chart for 2000 EDT

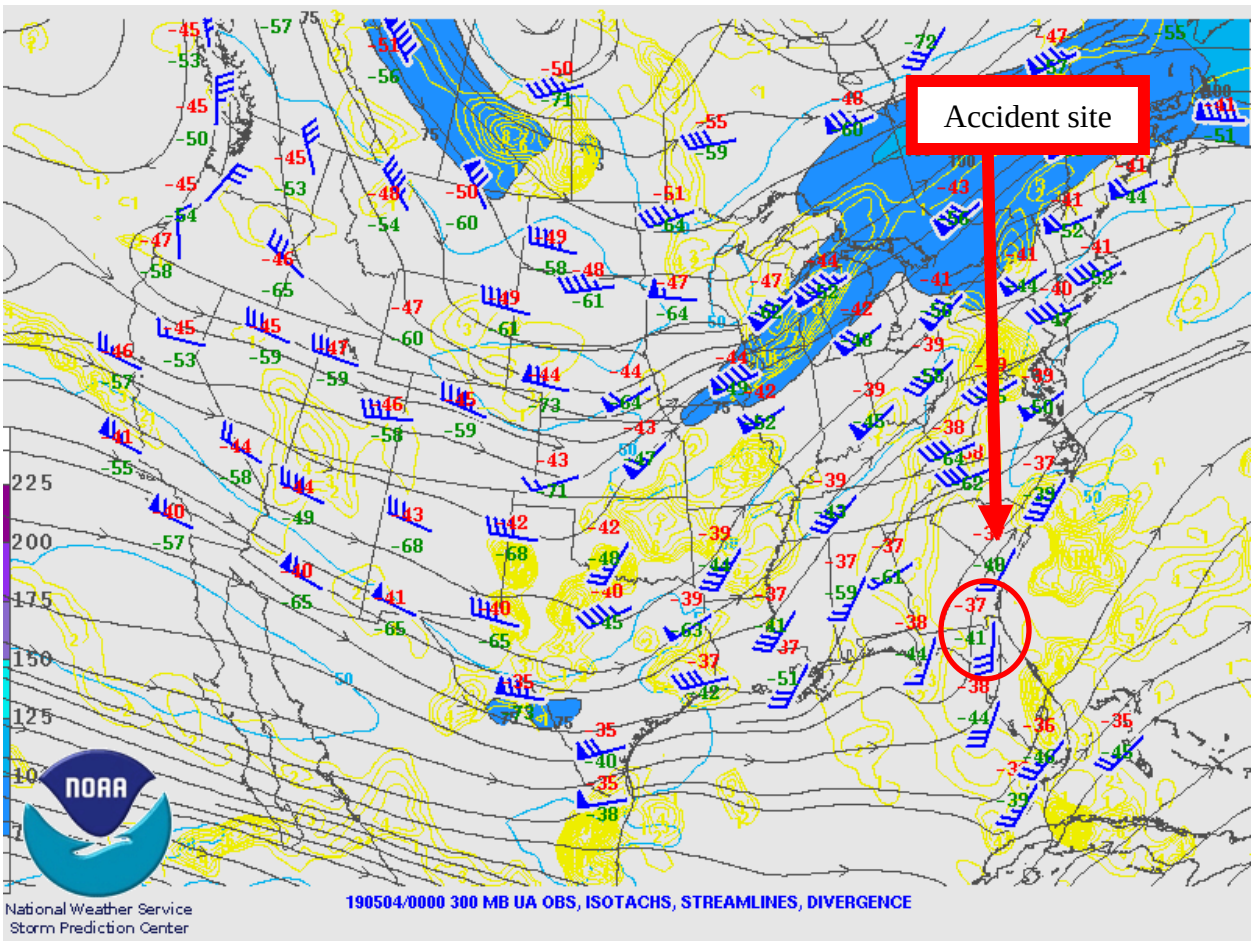


Figure 6 – 300-hPa Constant Pressure Chart for 2000 EDT

2.0 SPC Products

SPC issued the following Day 1 Convective Outlook at 2055 EDT (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:

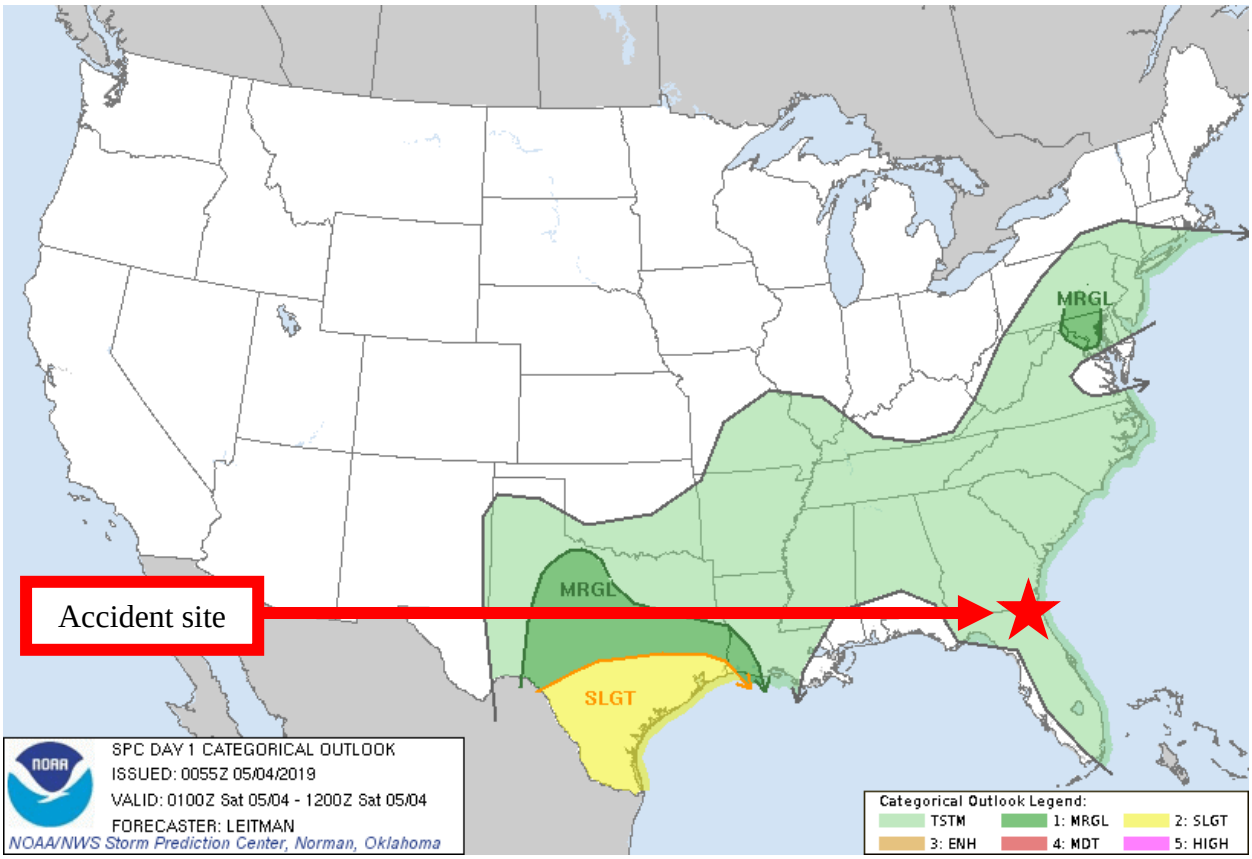


Figure 7 – SPC day 1 Convective Outlook valid at the time of the accident

SPC AC 040055

Day 1 Convective Outlook
NWS Storm Prediction Center Norman OK
0755 PM CDT Fri May 03 2019

Valid 040100Z - 041200Z

...THERE IS A SLIGHT RISK OF SEVERE THUNDERSTORMS ACROSS PORTIONS OF CENTRAL AND SOUTHERN TEXAS...

...SUMMARY...
Severe thunderstorms will continue overnight across parts of central and southern Texas. Hail and damaging wind gusts will be the main concern, though a couple of tornadoes cannot be ruled out.

...Texas...

Scattered thunderstorms across the South Plains vicinity may continue to produce hail for another hour or two this evening before weakening as the boundary layer stabilizes and modest deep layer shear struggles to maintain organized storm structures with diminishing instability. Further south, a line across central Texas is expected to organize and shift south/southeast overnight. This will pose mainly a damaging wind threat, though midlevel lapse rates remain very steep, as is evident in regional 00z RAOBs. This should

continue to support some threat for large hail, though convective mode may temper this somewhat. Low level shear will be sufficient to continue modest tornado probabilities as well, with brief spin-ups in mesovortices along the bowing line segment possible. While convective mode is expected to remain linear, it should be noted that a more conditional threat for tornadoes would exist if any discrete cells develop ahead of the line. Given latest hi-res guidance and 00z observations, have expanded the Slight risk a bit further east across the upper Texas coast.

...Mid-Atlantic Vicinity...

The 00z IAD RAOB indicated modest midlevel lapse rates and strong deep layer shear. This should support a continued risk of hail and locally damaging gusts for a couple more hours this evening. Storms should gradually weaken as the stabilizing boundary layer limits severe potential. Thus, the Slight risk has been removed and have limited the Marginal risk area to ongoing storms over northern VA, southern PA and points downstream into central/northern MD to indicate a diminishing threat over the next couple of hours.

..Leitman.. 05/04/2019

CLICK TO GET WUUS01 PTSDY1 PRODUCT

NOTE: THE NEXT DAY 1 OUTLOOK IS SCHEDULED BY 0600Z

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 locations marked.

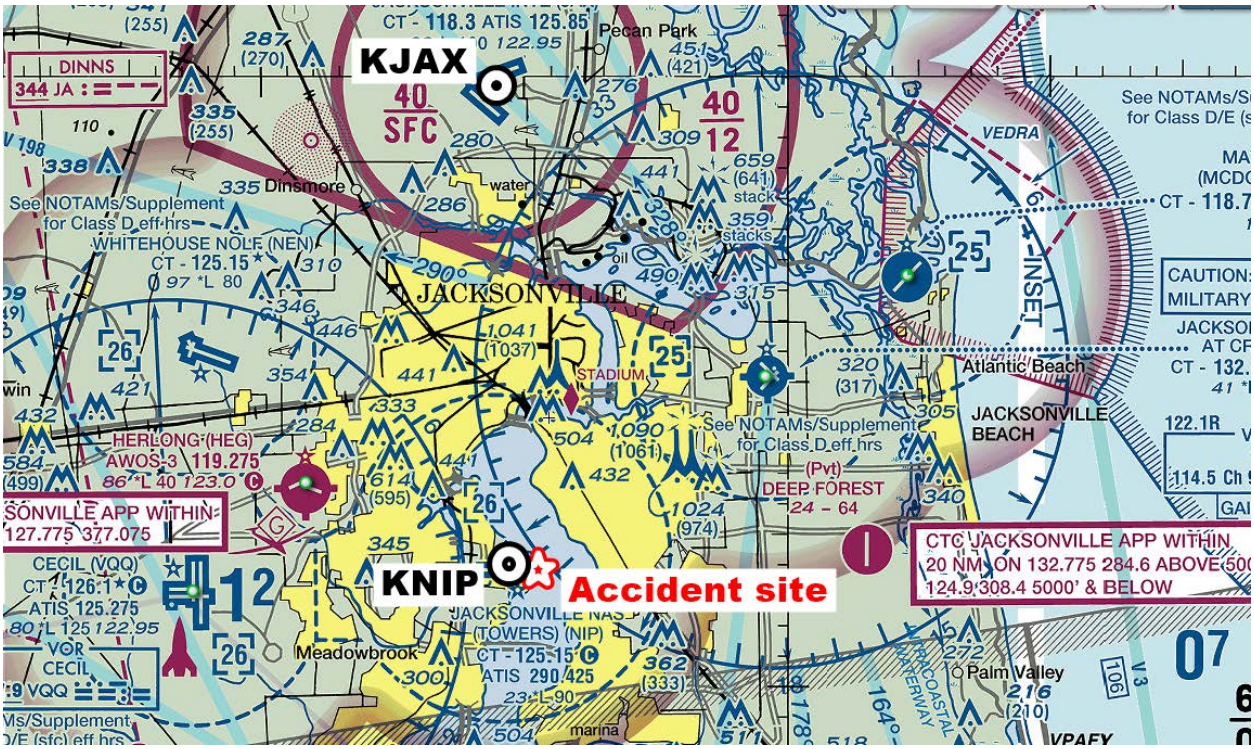


Figure 8 – Sectional map of the Jacksonville area with the location of the accident site and surface observation sites

Jacksonville Naval Station (KNIP) had the closest official weather station to the accident site. KNIP had an Automated Surface Observing System (ASOS[3]) whose reports were supplemented by official certified contract weather observers. KNIP ASOS site was located between both runways at the centerfield location approximate 4,500 ft west-northwest of the accident site, at an elevation of 23 ft, and had a 6° westerly magnetic variation[4] (figure 8). The following observations were taken and disseminated during the times surrounding the accident:[5]

[1853 EDT] METAR KNIP 032253Z 19004KT 10SM FEW020 SCT035 BKN065 BKN250 26/22 A2993 RMK AO2 RAB2154E37 TSE53 SLP130 CB DSNT W-NW T1 SET P0001 T02560222 $=

[1953 EDT] METAR KNIP 032353Z 12004KT 10SM FEW015 SCT030 BKN120 BKN250 26/21 A2994 RMK AO2 SLP133 CB DSNT SW-W T2 SET 60001 T02560206 10289 20256 53001 $=

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

[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.

[2053 EDT] METAR KNIP 040053Z 00000KT 10SM -RA SCT010 BKN030 BKN045 BKN250 25/22 A2997 RMK AO2 RAB52 SLP143 OCNL LTGIC DSNT SW CB DSNT SW T2 SET P0000 T02500222 $=

[2103 EDT] SPECI KNIP 040103Z 06003KT 10SM -RA SCT008 BKN030CB BKN250 25/23 A2997 RMK AO2 OCNL LTGIC DSNT SW CB DSNT SW T2 SET P0000 T02500228 $=

[2105 EDT] SPECI KNIP 040105Z 08003KT 10SM -TSRA SCT008 BKN030CB BKN045 BKN250 25/23 A2997 RMK AO2 TSB04 OCNL LTGIC VC W TS W MOV E T2 SET P0000 T02500228 $=

[2122 EDT] SPECI KNIP 040122Z 35004KT 5SM +TSRA BR SCT008 BKN018CB OVC030 24/22 A2998 RMK AO2 TSB04 FRQ LTGIC OHD TS OHD MOV E T1 SET P0010 T02440222 $=

ACCIDENT TIME 2142 EDT

[2145 EDT] SPECI KNIP 040145Z 29008G16KT 3SM +TSRA BR SCT008 BKN015CB OVC032 24/22 A2999 RMK AO2 TSB04 FRQ LTGIC OHD TS OHD MOV E T1 SET P0063 T02440222 $=

[2153 EDT] METAR KNIP 040153Z 13003KT 2SM +TSRA BR SCT010 BKN021CB OVC03523/21 A2998 RMK AO2 TSB04 SLP149 FRQ LTGIC OHD TS OHD MOV E T1 SET P0074 T02280206 $=

[2217 EDT] SPECI KNIP 040217Z 00000KT 10SM -TSRA SCT025CB BKN080 BKN120 BKN250 24/21 A2997 RMK AO2 OCNL LTGIC VC E TS E MOV E T1 SET P0000 T02390211 $=

[2240 EDT] SPECI KNIP 040240Z 13004KT 10SM FEW015 SCT080 BKN250 24/22 A2997 RMK AO2 RAE23 TSE39 T1 SET P0000 T02390217 $=

KNIP special weather observation at 2122 EDT (last METAR observation before accident time), wind from 350° at 4 knots, 5 miles visibility, heavy rain and thunderstorms, mist, scattered clouds at 800 ft above ground level (agl), broken ceiling of cumulonimbus clouds at 1,800 ft agl, overcast skies at 3,000 ft agl, temperature of 24°Celsius (C), dew point temperature of 22°C, and an altimeter setting of 29.98 inches of mercury (inHg). Remarks: automated station with a precipitation discriminator, thunderstorms began at 2104 EDT, frequent lightning overhead, thunderstorm overhead moving east, thunderstorm conditions are forecasted within 10 miles of KNIP, 0.10 inches of precipitation since 2053 EDT, temperature 24.4°C, dew point temperature 22.2°C, maintenance is needed on the system.

KNIP special weather observation at 2145 EDT (first METAR observation after the accident time), wind from 290° at 8 knots with gusts to 16 knots, 3 miles visibility, heavy rain and thunderstorms, mist, scattered clouds at 800 ft agl, broken ceiling of cumulonimbus clouds at 1,500 ft agl, overcast skies at 3,200 ft agl, temperature of 24°C, dew point temperature of 22°C, and an altimeter setting of 29.99 inHg. Remarks: automated station with a precipitation discriminator, thunderstorms began at 2104 EDT, frequent lightning in cloud and overhead, thunderstorm overhead moving east, thunderstorm conditions are forecasted within 10 miles of KNIP, 0.63 inches of precipitation since 2053 EDT, temperature 24.4°C, dew point temperature 22.2°C, maintenance is needed on the system.

The observations from KNIP surrounding the accident time indicated MVFR[6] conditions with heavy rain and thunderstorms and a gusty west-northwest wind reported after the accident time. 0.53 inches of precipitation fell between 2122 and 2145 EDT. A "T1 SET" thunderstorm warning was issued for KNIP at 2122 EDT (see attachment 6 for more information).

The 1- and 5-minute ASOS data from KNIP was retrieved for the accident timeframe and is provided in attachment 1. The following 5-minute observations for KNIP were:

5-MIN KNIP 040125Z 35003KT 5SM +TSRA BR SCT008 BKN018CB OVC030 24/23 A2998 -30 90 1100 350/03 RMK AO2 TSB04 FRQ LTGIC OHD TS OHD MOV E T1 SET P0020 T02440228 $

5-MIN KNIP 040130Z VRB03KT 3SM +TSRA BR SCT008 BKN018CB OVC030 24/23 A2999 -30 93 1000 VRB/03 RMK AO2 TSB04 FRQ LTGIC OHD TS OHD MOV E T1 SET P0036 T02390228 $

5-MIN KNIP 040135Z VRB05KT 3SM +TSRA BR SCT008 BKN018CB OVC030 24/22 A2999 -30 90 1000 VRB/05 RMK AO2 TSB04 FRQ LTGIC OHD TS OHD MOV E T1 SET P0041 T02390222 $

5-MIN KNIP 040140Z 23010G16KT 3SM +TSRA BR SCT008 BKN018CB OVC030 24/22 A2999 -30 90 1000 230/10G16 RMK AO2 TSB04 FRQ LTGIC OHD TS OHD MOV E T1 SET P0052 T02390222 $

Accident 0142 UTC

[6] As defined by the NWS and the FAA Aeronautical Information Manual (AIM) section 7-1-7 defines the following general flight categories:

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

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

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

5-MIN KNIP 040145Z 29008G16KT 3SM +TSRA BR SCT008 BKN015CB OVC032 24/22 A2999 -30 87 1100 290/08G16 RMK AO2 TSB04 FRQ LTGIC OHD TS OHD MOV E (ACFT MSHP) T1 SET P0063 T02440222 $

5-MIN KNIP 040150Z VRB04KT 3SM +TSRA BR SCT008 BKN015CB OVC032 23/22 A2999 -30 90 1000 VRB/04 RMK AO2 TSB04 SLP150 FRQ LTGIC OHD TS OHD MOV E (ACFT MSHP) T1 SET P0071 T02330217 $

The 1-minute KNIP observations indicated that at 2141 EDT, wind from 240° at 9 knots in the 2 minute wind average (sustained), and wind from 242° at 10 knots in the maximum wind that occurred over the previous minute (5-second average, gusts).

The 1-minute KNIP observations indicated that at 2142 EDT, wind from 248° at 8 knots in the 2 minute wind average (sustained), and wind from 260° at 10 knots in the maximum wind that occurred over the previous minute (5-second average, gusts).

The 1-minute KNIP observations indicated that at 2143 EDT, wind from 261° at 9 knots in the 2 minute wind average (sustained), and wind from 271° at 13 knots in the maximum wind that occurred over the previous minute (5-second average, gusts).

The 1-minute KNIP observations indicated that the wind direction was easterly at 2130 EDT with the wind direction shifting to southerly by 2133 EDT and a southwesterly wind direction by 2135 EDT. For more 1- and 5-minute KNIP observations please see attachments 1, 2, and 3. The KNIP ASOS system log files are contained in attachment 4. The edit log files from around the accident time frame were obtained and are displayed in figures 9, 10, and 11. The edit log files are in eastern standard time (EST).

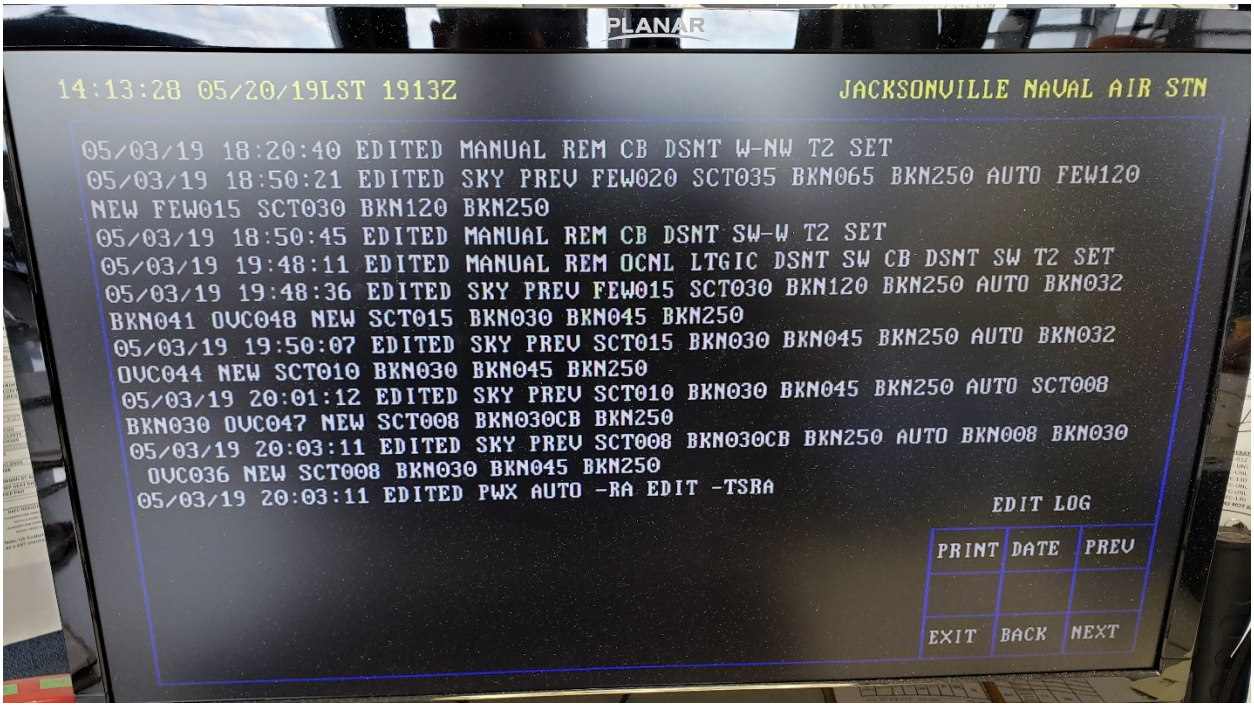


Figure 9 – KNIP edit log files from 1920 to 2103 EDT

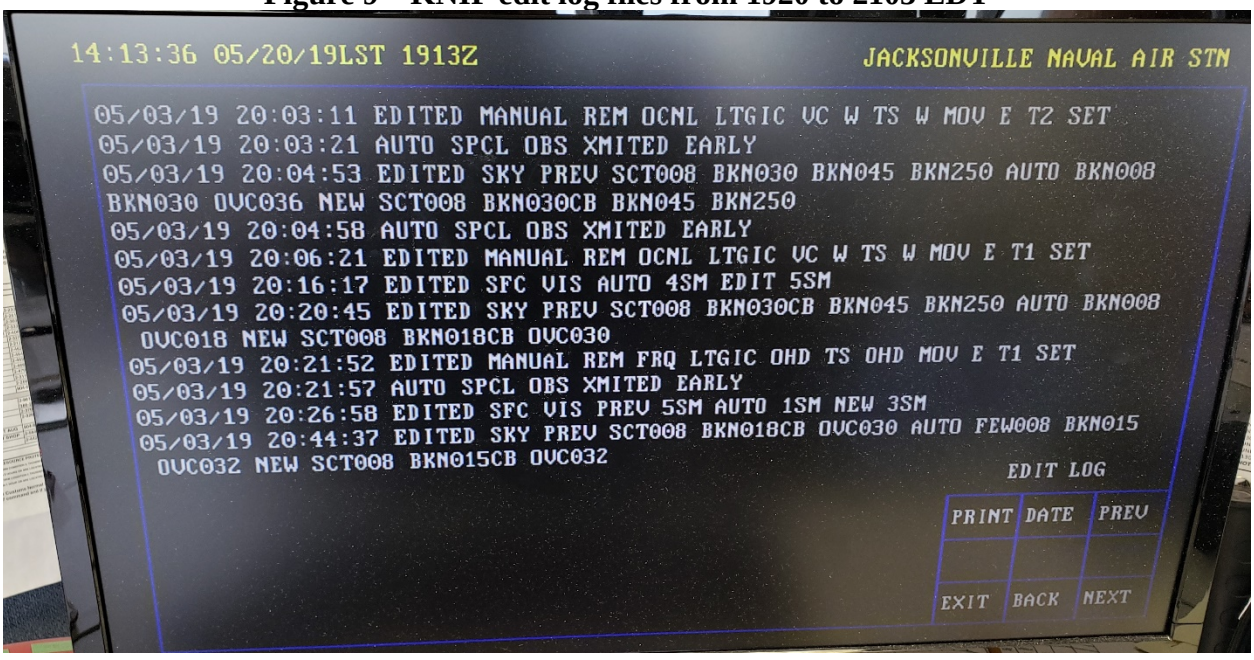


Figure 10 – KNIP edit log files from 2103 to 2145 EDT

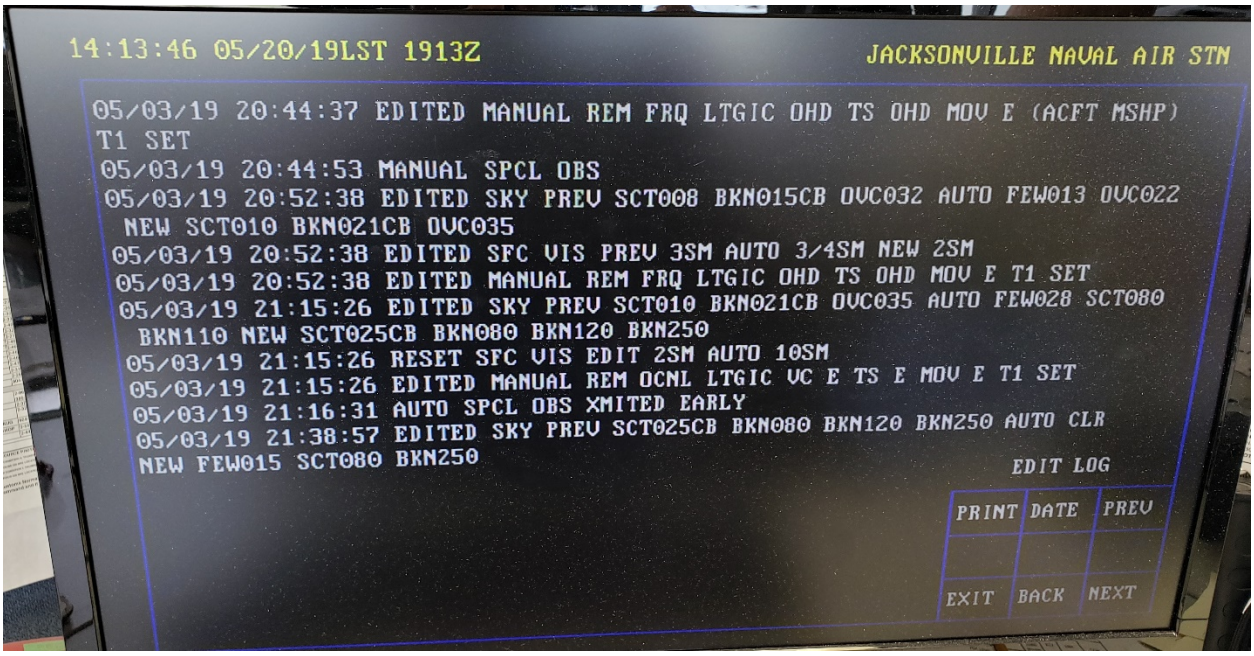


Figure 11 – KNIP edit log files from 2145 to 2239 EDT

3.1 KNIP ASOS Equipment

The KNIP ASOS and back up wind sensor locations were noted relative to the location of the runways and accident site (figures 12 and 13). The KNIP ASOS was located 4,500 ft west-northwest of the accident site and in between the runways. The KNIP back up wind sensor was located 4,000 ft west-northwest of the accident site (in between the runways) and the wind sensor does not provide archived weather information.

Figure 12 – KNIP ASOS equipment with the image facing east-southeast towards the accident site

Figure 13 – KNIP backup wind sensor with the image facing east-southeast towards the accident site

4.0 Upper Air Data

The Jacksonville, Florida, (KJAX) upper air sounding was the closest site with an upper air sounding located 16 miles north of the accident site (figure 8) with a surface elevation of 30 ft (station ID 72206). The 2000 EDT KJAX sounding was plotted on a standard Skew-T Log P diagram[7] with the derived stability parameters included in figure 14 with data from the surface to 600-hPa (or approximately 14,000 ft msl). This data was analyzed using the RAOB[8] software package. The sounding depicted the lifted condensation level (LCL)[9] at 805 ft agl, the level of free convection (LFC)[10] at 1,224 ft agl, and the convective condensation level (CCL)[11] at 3,493 ft agl. The freezing level was located at 13,688 ft msl. The precipitable water value was 1.88 inches. The mean storm motion was from 318° at 6 knots.

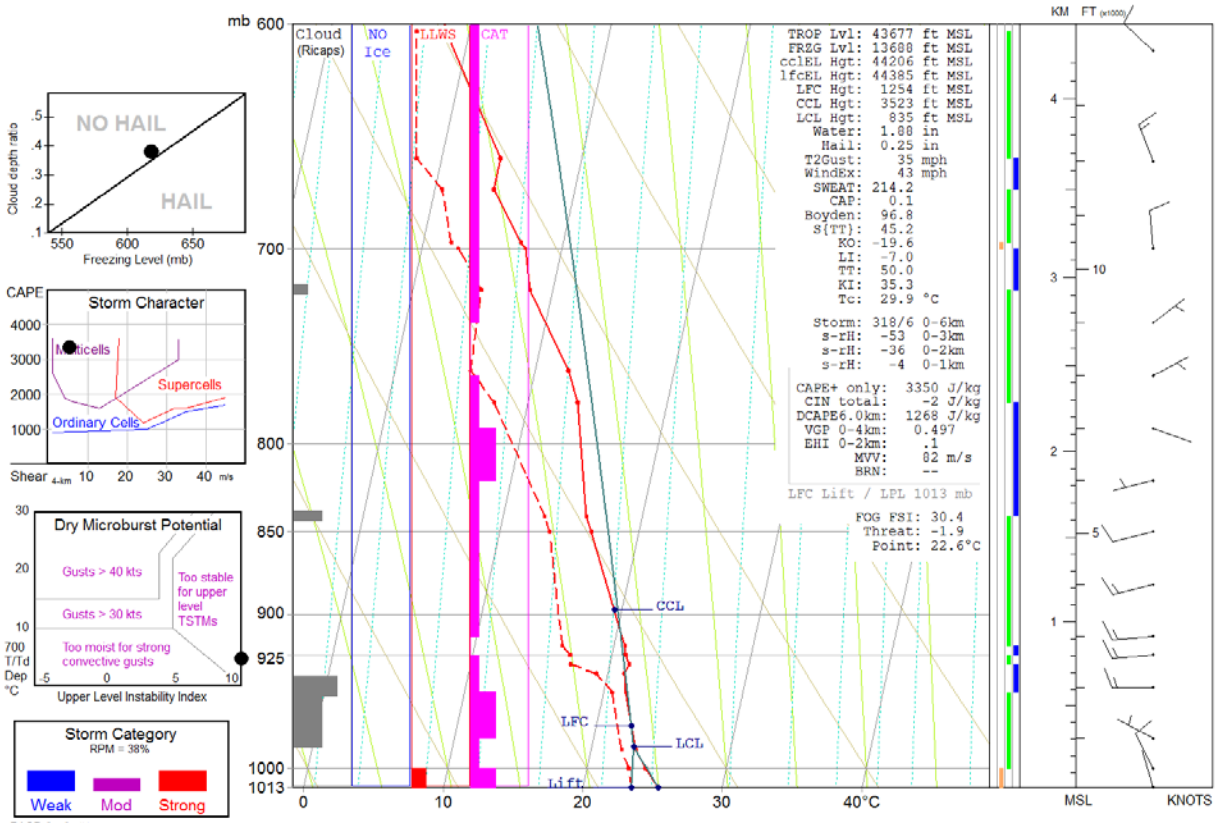


Figure 14 – 2000 EDT KJAX sounding

[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.

The 2000 EDT KJAX sounding indicated a conditionally unstable environment from the surface through 14,000 ft. RAOB identified the possibility of clouds from 1,000 ft msl through 2,000 ft msl. Additional small layers of clouds were identified by RAOB at 6,000 ft and 10,000 ft msl. 3,350 Joules/kilogram (J/kg) of CAPE[12] were indicated on the sounding and the maximum vertical velocity (MVV) for this atmosphere was calculated as 82 meters/second (about 16,142 ft per minute).[13] Given the environment, RAOB indicated a high probability of multicell thunderstorm development was possible with no hail or severe thunderstorm activity (wind, tornadoes, hail, etc…) at the surface. Downdraft CAPE (DCAPE; 6 kilometers agl)[14] was measured at 1,268 J/kg. If rain showers or thunderstorms formed in this environment, the 2000 EDT KJAX sounding indicated that the strongest wind speeds possible at the surface (due to, for example, a microburst, outflow boundary, or gust front) would have been 43 mph (37 knots) according to the WindEx parameter.

The KJAX sounding wind profile indicated a surface wind from 345° at 2 knots with the wind becoming westerly through 2,000 ft. The wind speed increased from 2 knots at the surface to 15 knots at 2,000 ft msl. Between 5,000 and 14,000 ft the wind was variable and at or below 15 knots. RAOB indicated the small possibility of light low-level wind shear (LLWS) and light clear-air turbulence (CAT) outside of rain shower or thunderstorm activity.

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 1700 EDT through 2300 EDT and reviewed, and the closest images to the time of the accident were documented. Due to the loss of sunlight the GOES-16 visible imagery was not available for the accident time.

Figures 15, 16, and 17 present the GOES-16 infrared imagery from 2141 and 2146 EDT at 6X magnification with the accident site highlighted with a red square (red circle in figure 17). Inspection of the infrared imagery indicated cloud cover over the accident site. The lower brightness temperatures (blue and green colors; higher cloud tops) were located above and to the northeast and northwest of the accident site. There was a rapid increase in geostationary lightning mapper (GLM)[15] targets after 2100 EDT above the accident site with GLM indicated lightning flashes at the accident site at the accident time (attachment 5). The cloud cover was continuing to expand with time after 2100 EDT and the higher cloud tops were moving from southwest to northeast (attachment 5). Based on the brightness temperatures above the accident site and the vertical temperature profile provided by the 2000 EDT KJAX sounding, the approximate cloud-

[12] Convective Available Potential Energy (CAPE) – CAPE is a measure of the amount of energy available for convection and is directly related to the maximum potential vertical speed within an updraft.
[13] MVV is not usually considered a realistic estimate for maximum vertical velocity in a storm. Anecdotes suggest considering a value of MVV/2, however it is not well understood when or where such a half-value should be applied.
[14] The DCAPE can be used to estimate the potential strength of rain-cooled downdrafts within thunderstorm convection, and is similar to CAPE. Larger DCAPE values are associated with stronger downdrafts.
[15] https://ghrc.nsstc.nasa.gov/lightning/overview_glm.html

top heights over the accident site were 24,000 ft at 2146 EDT (253º Kelvin). It should be noted these figures have not been corrected for any parallax error.

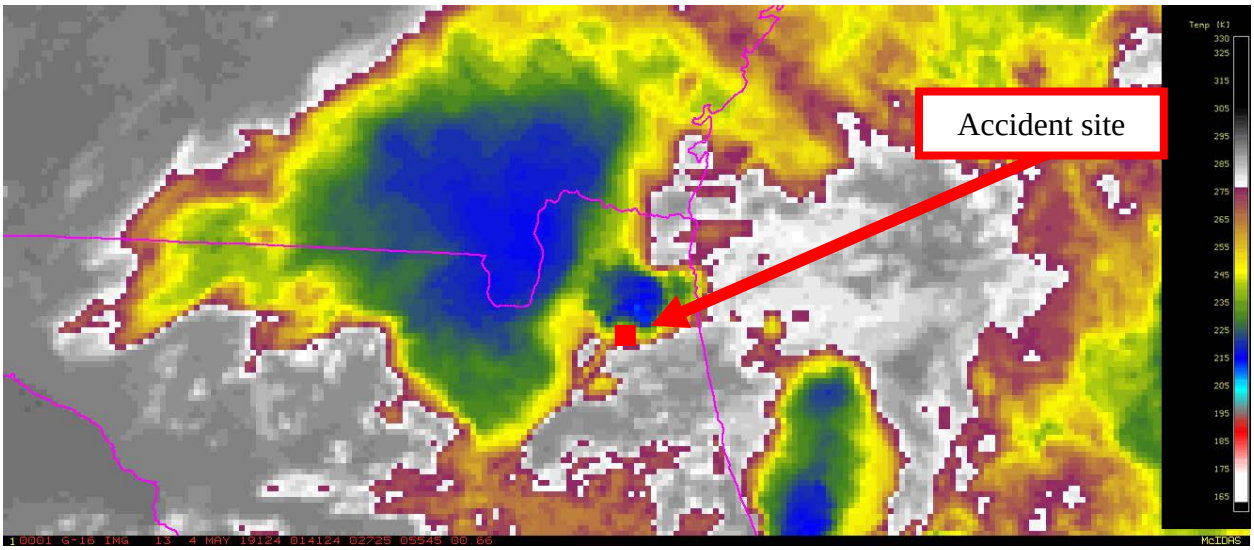


Figure 15 – GOES-16 infrared image at 2141 EDT

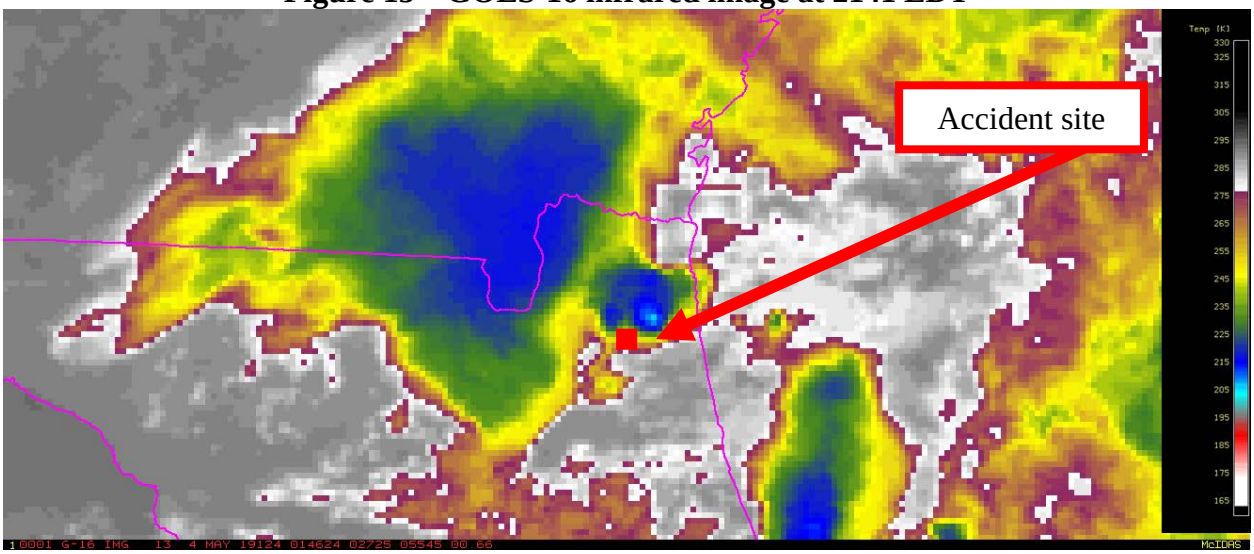


Figure 16 – GOES-16 infrared image at 2146 EDT

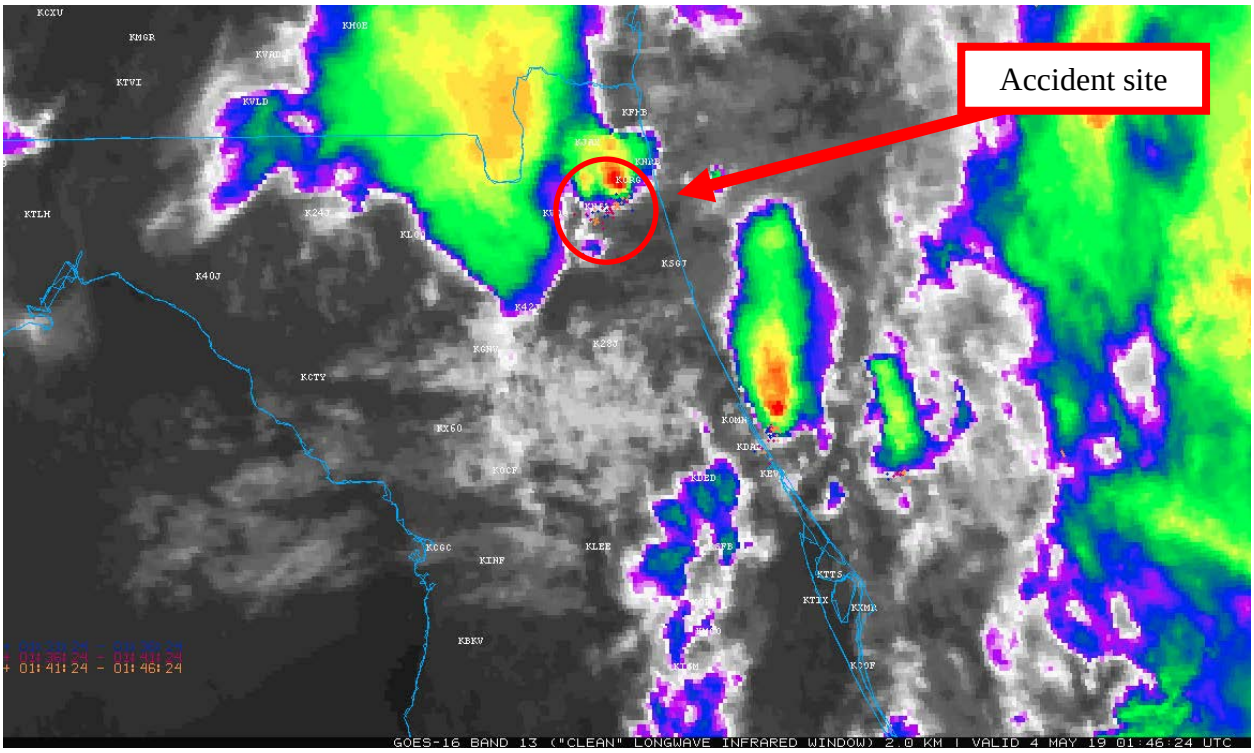


Figure 17 – GOES-16 infrared image at 2146 EDT with GLM data from 2131 to 2146 EDT

6.0 Regional Radar Imagery Information

A regional view of the NWS national composite radar mosaic is included as figure 18 for 2145 EDT with the approximate location of the accident site marked within a white circle. The image depicted an area of echoes extending east-to-west over the Jacksonville area from echoes of 45 to 55 decibels (dBZ[16]) echoes above the accident site.

[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.

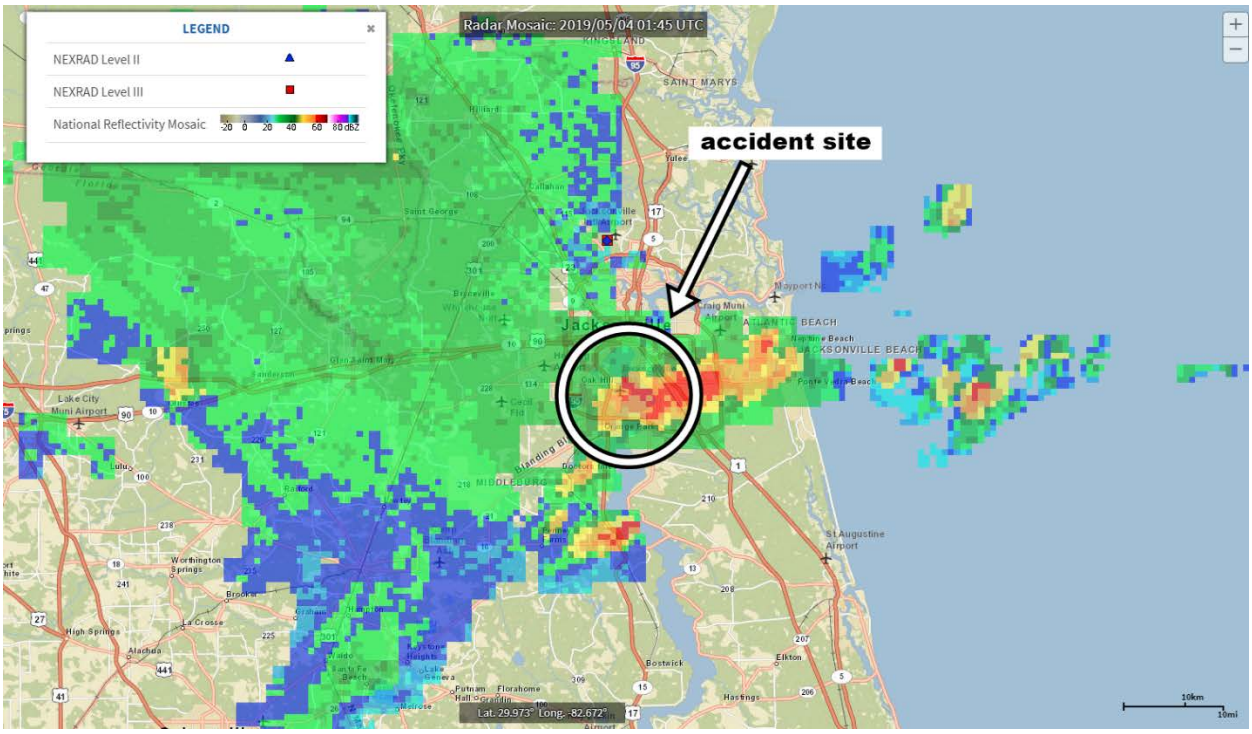


Figure 18 – Regional Composite Reflectivity image for 2145 EDT

7.0 Weather Radar Imagery

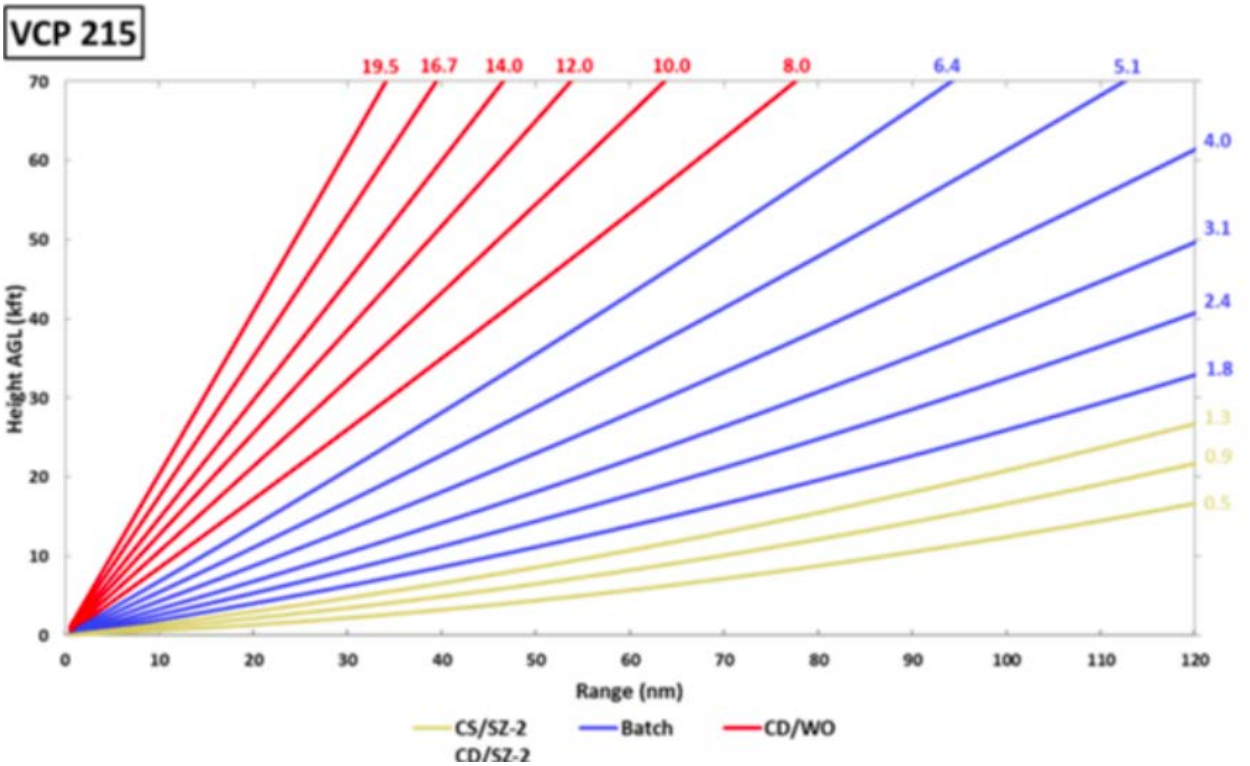
The closest NWS Weather Surveillance Radar-1988, Doppler (WSR-88D)[17] to the accident site was KJAX. Level II archive radar data was obtained from the NCEI utilizing the NEXRAD Data Inventory Search and displayed using the NOAA's Weather and Climate Toolkit software

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 KJAX 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.

[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.



VCP-215 Precipitation Mode Scan Strategy[18]

7.2 Beam Height Calculation

Assuming standard refraction[19] of the WSR-88D radar beam with the antenna elevation at 159 ft (KJAX), and considering a beamwidth[20] 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
KJAX 0.5°	1,120 ft	380 ft	1,860 ft

[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)

[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.

Based on the radar height calculations, the elevation scans from KJAX listed in the above table depicted the conditions between 380 ft and 1,860 ft msl over the accident site and these scans "saw" the closest altitudes to the surface at the accident time.

7.3 Reflectivity

Reflectivity is the measure of the efficiency of a target in intercepting and returning radio energy. With hydrometeors[21] 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[22], "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 list below:

- 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 19, 20, 21, 22, and 23 present the KJAX WSR-88D base reflectivity images for the 0.5° elevation scans initiated at 2119:17, 2125:15, 2131:27, 2137:33, and 2143:17 EDT, respectively, with a resolution of 0.5° X 250 m, with the flight track overlaid. Reflectivity values between 40 and 55 dBZ were located above the accident site at the accident time. Reflectivity values above 40 dBZ were located above KNIP as early as 2055 EDT (attachment 7). The reflectivity bands were moving from west to east (attachments 7). The radial velocity data indicated velocity targets heading away from KJAX and KNIP at the accident time with increasing strength to the east and southeast of KNIP after the accident time (attachment 8).

[21] Hydrometeors are any product of condensation or sublimation of atmospheric water vapor, whether formed in the free atmosphere or at the earth's surface; 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.

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

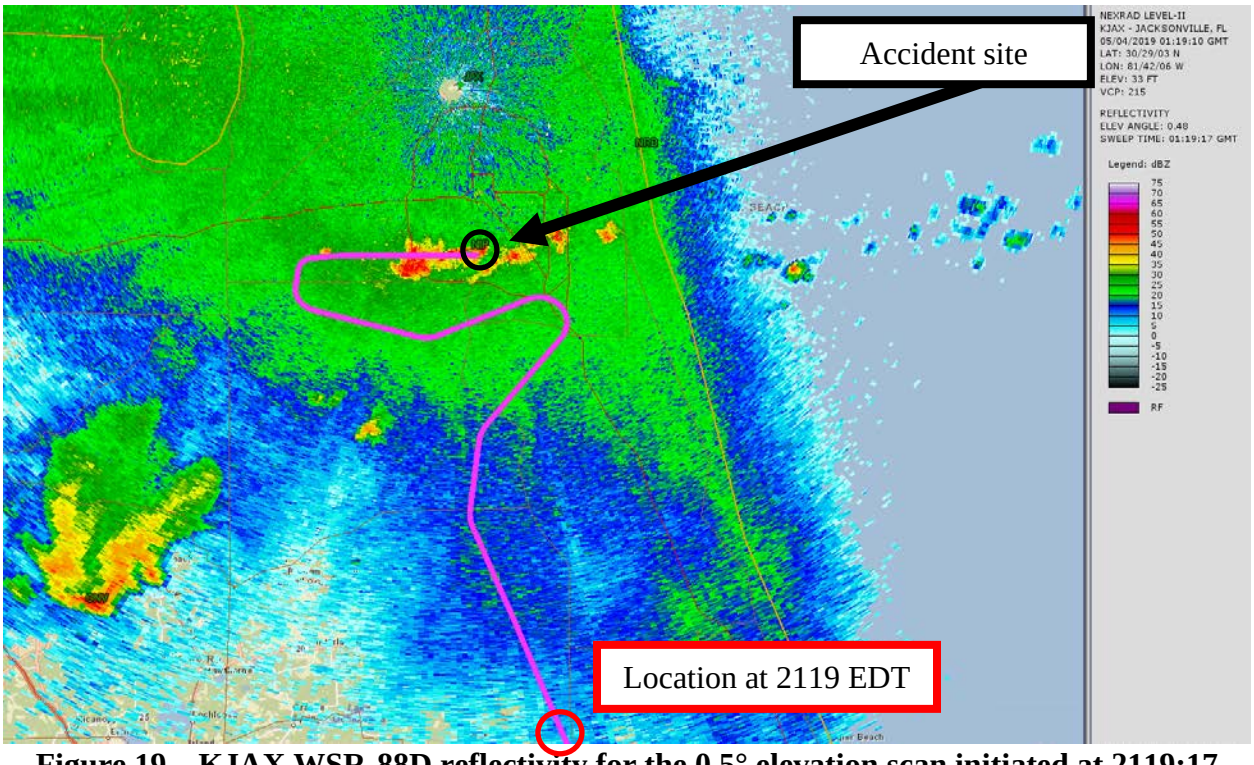


Figure 19 – KJAX WSR-88D reflectivity for the 0.5° elevation scan initiated at 2119:17 EDT with the accident site marked with black circle and the accident flight track in pink

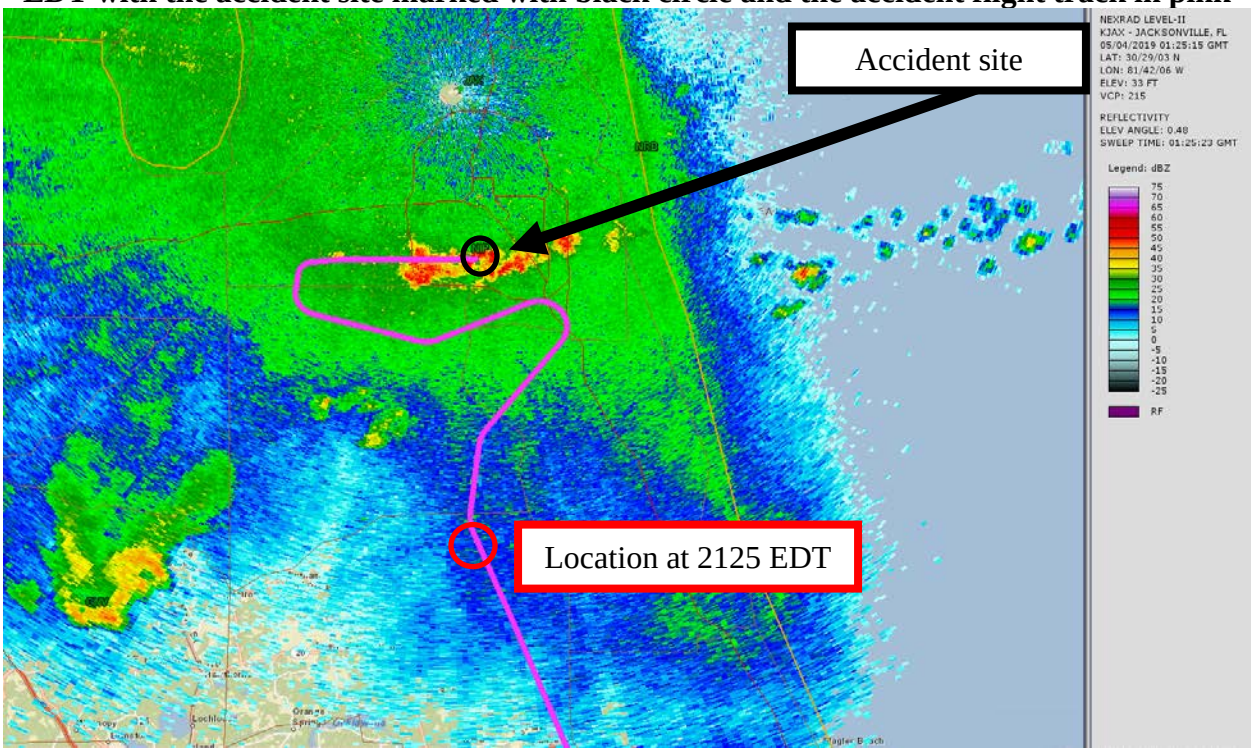


Figure 20 – KJAX WSR-88D reflectivity for the 0.5° elevation scan initiated at 2125:15 EDT with the accident site marked with black circle and the accident flight track in pink

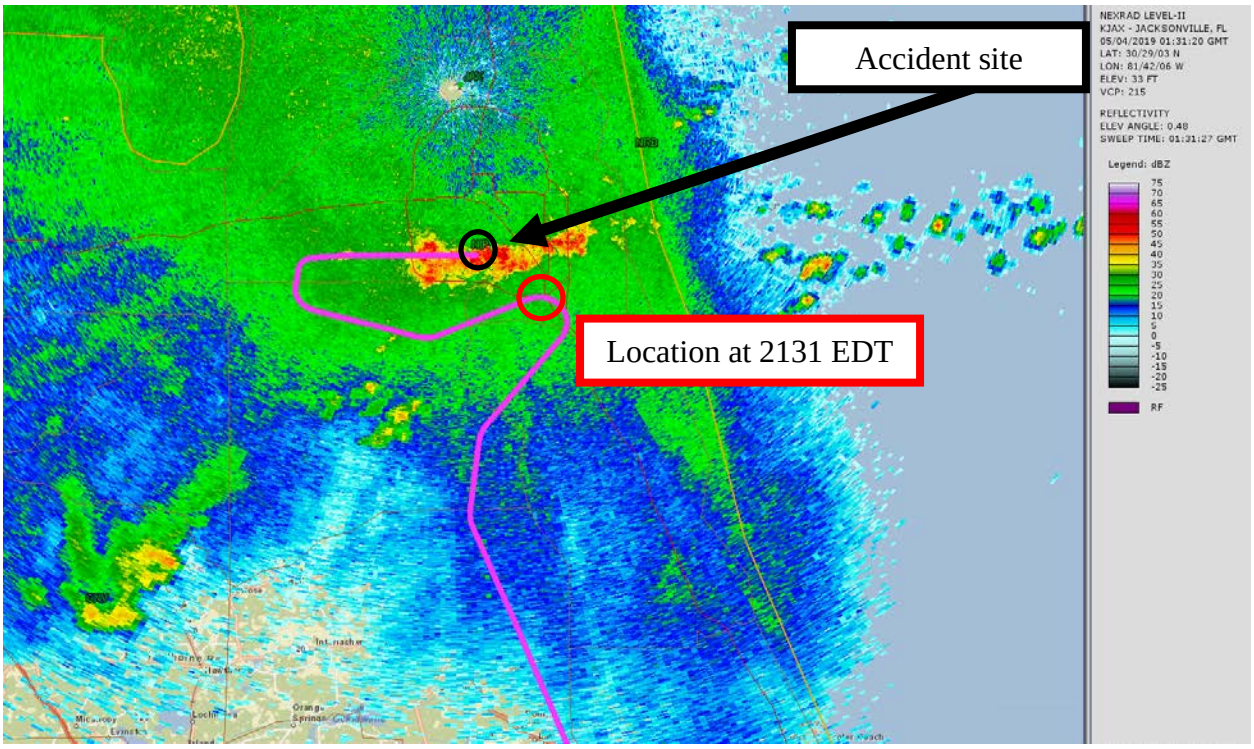


Figure 21 – KJAX WSR-88D reflectivity for the 0.5° elevation scan initiated at 2131:27 EDT with the accident site marked with black circle and the accident flight track in pink

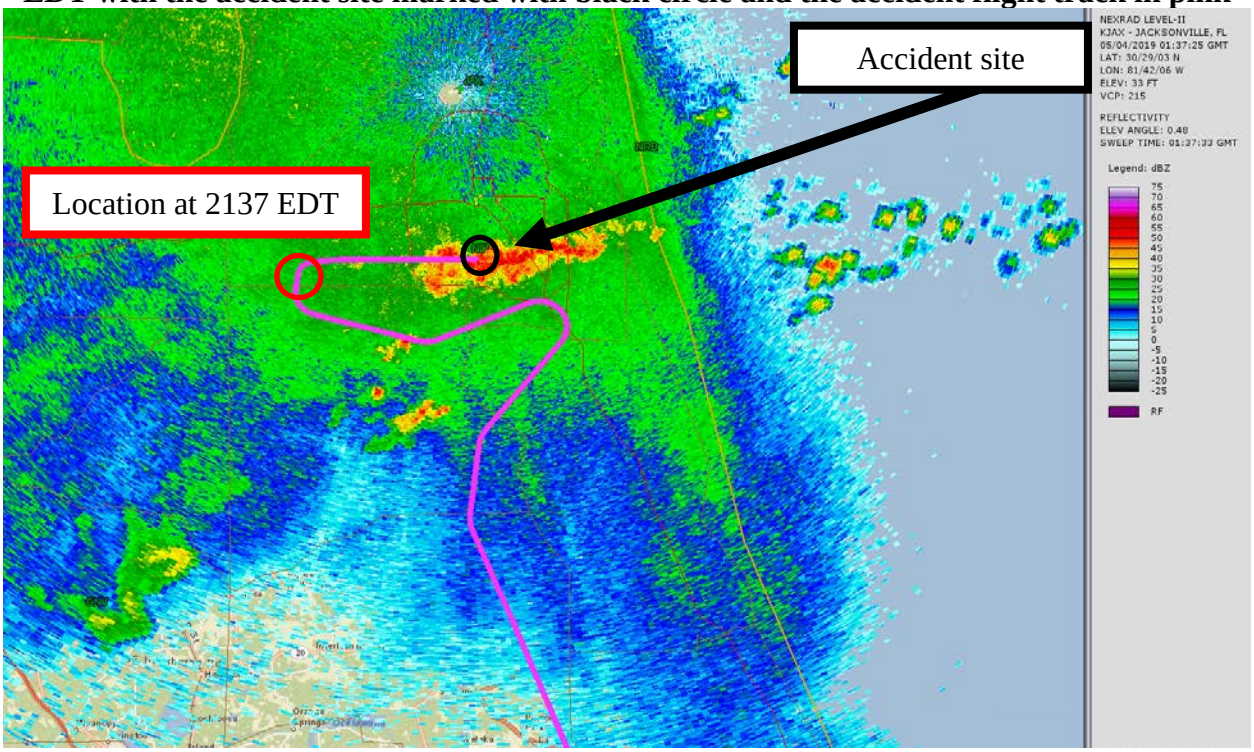


Figure 22 – KJAX WSR-88D reflectivity for the 0.5° elevation scan initiated at 2137:33 EDT with the accident site marked with black circle and the accident flight track in pink

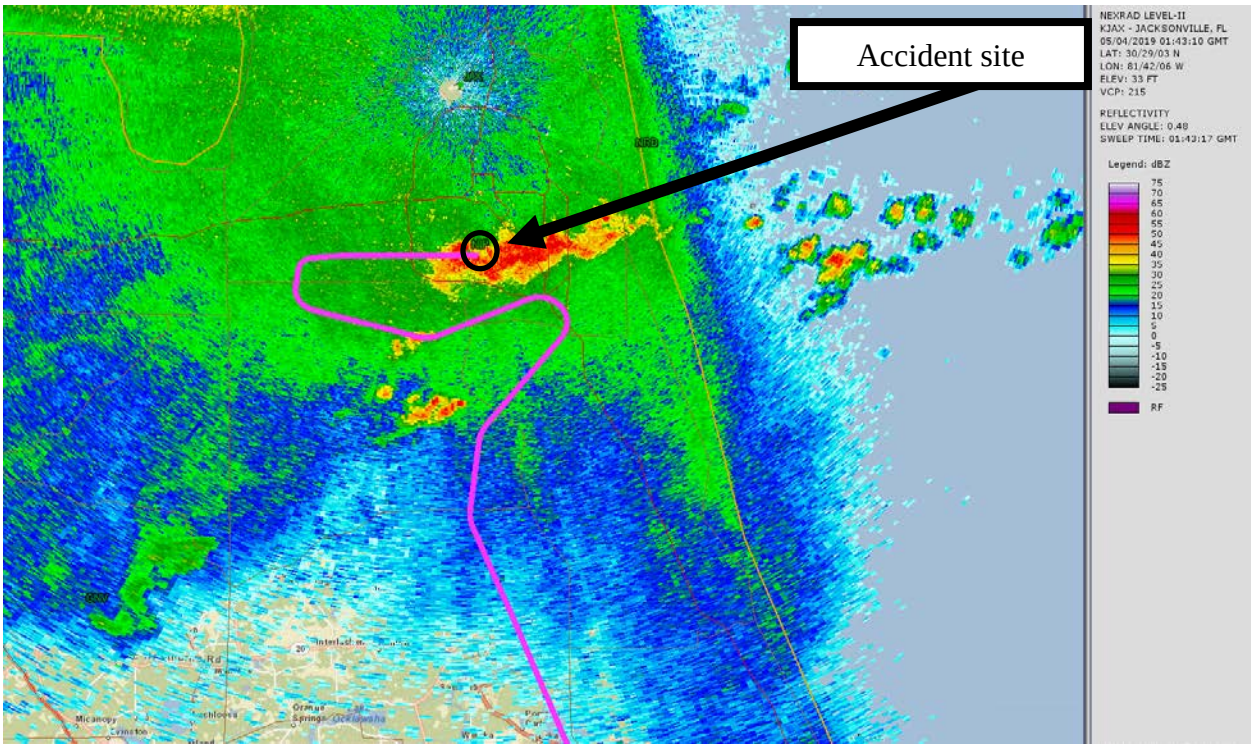


Figure 23 – KJAX WSR-88D reflectivity for the 0.5° elevation scan initiated at 2143:17 EDT with the accident site marked with black circle and the accident flight track in pink

There were 714 lightning flashes[23] between 2125 and 2145 EDT and the lightning flashes are plotted as black dots on figure 24.[24] The closest lightning flash to the accident flight occurred at 2141:17 EDT with the lightning flash located 1,637 ft north of the flight track.

[23] 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.
[24] A review of Earth Networks Total Lightning network was done.

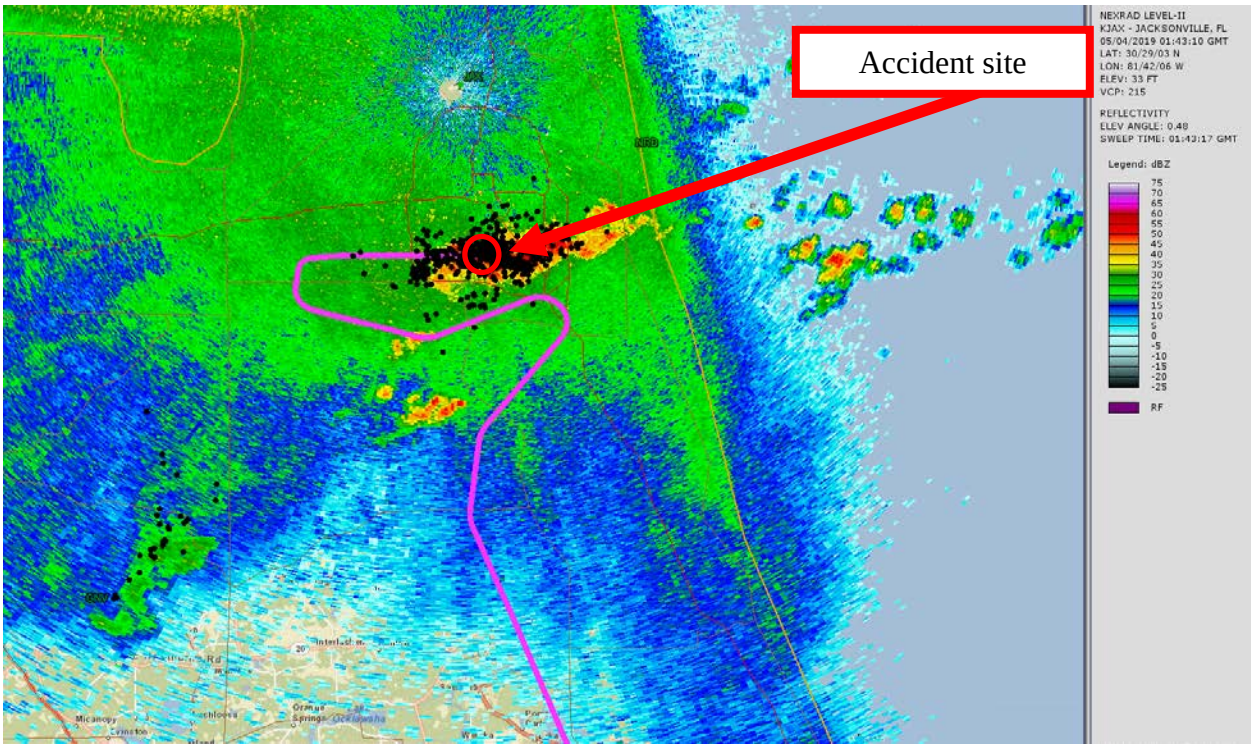


Figure 24 – KJAX WSR-88D reflectivity for the 0.5° elevation scan initiated at 2143:17 EDT with the accident site marked with red circle, the accident flight track in pink, lightning flashes marked as black dots

8.0 Pilot Reports[25]

There were no pilot reports (PIREPs) distributed into the national airspace within 75 miles of the accident site from about two hours prior to the accident time to two hours after the accident time.

[25] Only pilot reports with the World Meteorological Organization headers UBFL** and UBGA** were considered.

9.0 Convective SIGMETs

There were several Convective Significant Meteorological Information (SIGMET) advisories issued surrounding the period of the accident.. Convective SIGMET 25E was issued at 1955 EDT and valid through 2155 EDT and it warned of an area of thunderstorms with tops to FL450 with the area movement from 250° at 10 knots. The advisory was updated by Convective SIGMET 3E at 2055 EDT, which was current at the time of the accident and valid through 2255 EDT and it warned of an area of thunderstorms moving little with tops above FL450 (figure 25).[26]:

WSUS31 KKCI 032355
SIGE
KMKCE WST 032355

CONVECTIVE SIGMET 25E
VALID UNTIL 0155Z
FL GA AND FL CSTL WTRS
FROM 20N CRG-20NW OMN-10WSW CTY-50SSE TLH-20E TLH-20N CRG
AREA TS MOV FROM 25010KT. TOPS ABV FL450.

Updated at 2055 EDT to the following:

WSUS31 KKCI 040055
SIGE
MKCE WST 040055

CONVECTIVE SIGMET 3E
VALID UNTIL 0255Z
FL GA AND FL CSTL WTRS
FROM 50N CTY-10NE CRG-20SSE OMN-10ESE CTY-50N CTY
AREA TS MOV LTL. TOPS ABV FL450.

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

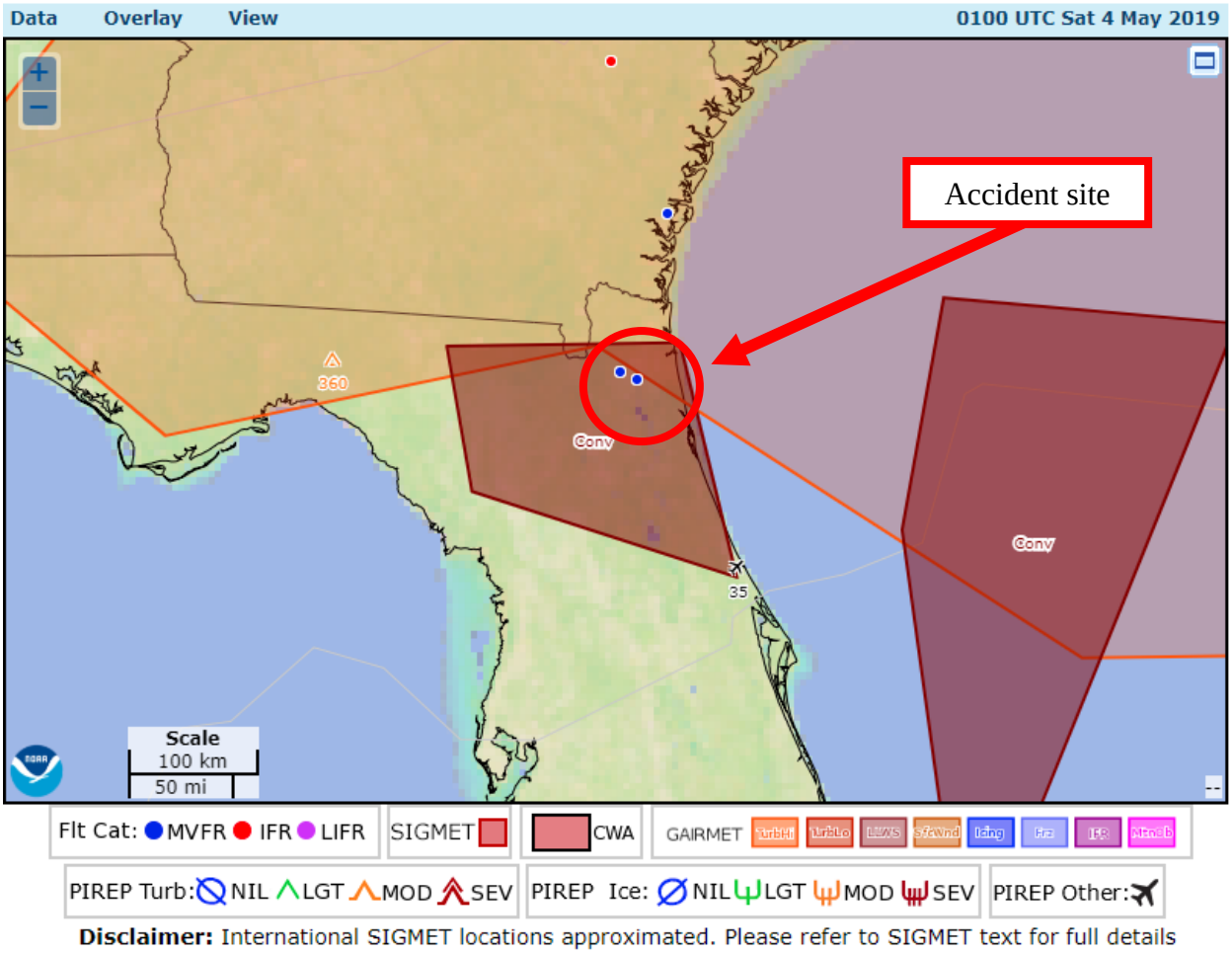


Figure 25 – SIGMETs, AIRMETs, and CWAs valid at 2100 EDT through the accident time

10.0 CWSU Products

The ZJX CWSU was responsible for the region. The ZJX CWSU issued no Meteorological Impact Statements (MIS) for the area prior to the accident nor were any Center Weather Advisories (CWA) valid for the accident site at the accident time. CWSU personnel were not on shift at the time of the accident in accordance with ZJX CWSU normal hours of operation.

11.0 AIRMETs

No Airmen's Meteorological Information (AIRMET) advisories were valid for the accident site at the accident time.

12.0 Graphical Forecasts for Aviation

The Graphical Forecasts for Aviation (GFA) products made available before the accident flight and valid at 1400 EDT are shown in attachment 9. The GFA surface forecast products indicated VFR surface visibilities with a chance (between 30 and 60 percent chance) rain shower activity forecast and variable surface winds at or below 5 knots at the accident site. The GFA cloud forecast valid before departure for around the accident time indicated cloud ceilings around 2,200 ft with clouds top around 18,000 ft. For more information please see attachment 9.

13.0 Terminal Aerodrome Forecast

KNIP was the closest airport Terminal Aerodrome Forecast (TAF). The TAF was issued by the certified weather observers located at KNIP. The KNIP TAF that was valid at the time of the accident was issued at 1900 EDT and was valid for a 24-hour period beginning at 1900 EDT. The TAF for KNIP was as follows:

TAF KNIP 0323/0423 **18004KT 9999 VCTS SCT015 BKN030CB BKN100 BKN250**
532809 533705 QNH2991INS
TEMPO 0323/0404 VRB10G20KT 4800 SHRA BR SCT010 BKN020CB BKN080 BKN250
FM040400 23005KT 9999 SCT015 SCT060 BKN250 522809 523705 QNH2990INS
TEMPO 0407/0413 VRB04KT SCT005 BKN015 BKN250
FM041500 23008KT 9999 FEW020 SCT040 BKN250 500000 QNH2992INS
FM041800 23010KT 9999 VCSH SCT030 BKN060 BKN250 QNH2984INS
T22/0411Z T32/0419Z FN20061=

Between 1900 EDT and 0000 EDT (on May 4, 2019), the forecast expected a wind from 180° at 4 knots, greater than 7 miles visibility, vicinity[27] thunderstorms, scattered clouds at 1,500 ft agl, a broken ceiling of cumulonimbus clouds at 3,000 ft agl, broken clouds at 10,000 ft agl, broken clouds at 25,000 ft agl. The forecast also included a turbulence forecast for frequent moderate turbulence in clear-air from 28,000 ft to 37,000 ft, and frequent moderate turbulence in clear-air from 37,000 ft to 42,000 ft. The forecast minimum altimeter setting of 29.91 inches of mercury. Temporary conditions were forecast between 1900 EDT and 0000 EDT of variable winds of 10 knots with gusts to 20 knots, 3 miles visibility in moderate rain showers and mist, scattered clouds at 1,000 ft agl, a broken ceiling of cumulonimbus clouds at 2,000 ft agl, broken clouds at 8,000 ft agl, and broken clouds at 25,000 ft agl.

14.0 NWS Area Forecast Discussion

The NWS office in Jacksonville, Florida, issued the following Area Forecast Discussion (AFD) at 2121 EDT (closest AFD to the accident time). The aviation section of the AFD discussed isolated thunderstorms continuing to wane over the next few hours, but continued with vicinity thunderstorms in the TAFs till 2300 EDT:

[27] In the vicinity of the airport is defined as a weather phenomenon within 5-10 statute miles of the airfield.

FXUS62 KJAX 040121
AFDJAX

Area Forecast Discussion
National Weather Service Jacksonville FL
921 PM EDT Fri May 3 2019

.UPDATE...Isolated showers and storms continue across Ne Fl due to a trough of low pressure interacting with a moist and unstable airmass over the area (SB Cape on 00z Jax sounding 3661J). This activity will gradually wane next several hours due to loss of daytime heating and trough begins to lift out. As the trough lifts out overnite deep layer ridging and dry air aloft will begin to move in and coupled with adequate low level moisture could lead to areas of low clouds and fog. High-res HRRR continues to show mainly low clouds (with patches of fog) developing near I-75 corridor and moving into much of the area early Sat am. Any patchy fog and low clouds should lift by mid morning.

&&

.AVIATION...Isolated storms will continue to wane the next few hours but have VCTS at GNV and VQQ til around 03Z. High-res HRRR continues to indicate low clouds forming towards the gulf coast and spreading east. Have carried previous fcst of IFR at GNV aft 08Z and MVFR at JAX... VQQ...and CRG aft 09Z-10Z. Conditions improve to VFR by 14Z-15Z Sat.

&&

.MARINE...Weak low pressure will move north of the waters tonight. A few isolated storms possible tonight.

Rip Currents: Moderate risk.

&&

.PRELIMINARY POINT TEMPS/POPS...
AMG 67 88 68 83 / 0 0 30 60
SSI 70 85 70 83 / 0 0 10 50
JAX 68 90 69 87 / 20 0 10 50
SGJ 67 87 69 85 / 20 0 0 50
GNV 66 88 68 86 / 20 0 10 50
OCF 66 89 68 88 / 20 0 10 40

&&

.JAX WATCHES/WARNINGS/ADVISORIES...
FL...None.
GA...None.
AM...None.

&&

$$

15.0 Winds and Temperature Aloft Forecast

The NWS 1600 EDT Winds and Temperature Aloft forecast valid for the closest point to the accident site is included below:

```
FBUS31 KWNO 032000
FD1US1
DATA BASED ON 031800Z
VALID 040000Z   FOR USE 2000-0300Z. TEMPS NEG ABV 24000

FT  3000    6000    9000   12000   18000   24000  30000  34000  39000
JAX 2313 2607+14 2806+10 3309+04 2914-10 2422-21 202337 182448 183061
```

The accident site was located closest to the JAX forecast point. The 1600 EDT JAX forecast valid at 2000 EDT for use between 1600 EDT and 2300 EDT indicated a wind at 3,000 ft from 230° at 13 knots, a wind at 6,000 ft from 260° at 7 knots with a temperature of 14° C, and a wind at 9,000 ft from 280° at 6 knots with a temperature of 10°C.

16.0 Fleet Weather Center Products

At KNIP the contract weather observers (CWO) supplement the ASOS weather information 24 hours a day, and in addition from 0400 to 2000 EDT the CWO also provide weather forecast (including KNIP TAF) to Navy personnel and support personnel at KNIP. The accident time was after 2000 EDT and therefore the Navy's Fleet Weather Center (FWC) was providing the weather forecast for KNIP at the accident time with the CWO monitoring and supplementing ASOS. Attachment 10 contains all the FWC weather information valid at the accident time including the thunderstorm warning issued for KNIP at 2105 EDT valid until 2200 EDT.

17.0 Pilot Weather Briefing

The accident pilot did receive weather briefing information from the company's dispatch and that information will be summarized in the Operations factual report for this accident.

18.0 ZJX CWSU Information

The ZJX CWSU provided a pre-duty weather briefing (attachment 11) at 1908 EDT for the ATC personnel at ZJX and this pre-duty weather briefing was also made available at the TRACONs for the ZJX area (including Jacksonville TRACON). The CWSU pre-duty weather briefing discussed tropical moisture moving northeastward overnight with scattered thunderstorms over the Atlantic routes. The graphical imagery provided at this point in the discussion showed an area of convective weather developing over KNIP after 2000 EDT. The pre-duty weather briefing indicated fog developing after 0400 EDT (May 4, 2019), with AIRMETs valid for high level turbulence and no AIRMET Sierra or Zulu valid at the time of the weather briefing. TAFs were shown on the pre-duty weather briefing for select airports in and near ZJX airspace, but KJAX TAF (nor was KNIP) was not one of the airports shown (attachment 11).

19.0 Consolidated Storm Prediction for Aviation Data

The FAA Air Route traffic Control Centers (ARTCC) managers and CWSU use the Consolidated Storm Prediction for Aviation (CoSPA) to display WSR-88D imagery, with lightning data, echo tops, movement, and growth and decay predictions in one display system. The CoSPA images were retrieved for 2110, 2120, 2130, and 2140 EDT and provided in figures 26 through 29 with the accident site marked. The CoSPA, along with depicting NWS weather radar VIP levels, lightning data, weather satellite, and storm motion, forecast areas of likely rain shower or thunderstorm growth (orange hatched areas) and areas of likely rain shower or thunderstorm dissipation (blue hatched areas). The thunderstorm and rain shower activity was moving from west to east around 5 knots with CoSPA forecast areas of rain shower or thunderstorm growth over the accident site from 2110 EDT onward (orange hatched areas). The accident site located in an area of VIP level values of 4 to 5 (section 7.3) and CoSPA cloud top values indicated to FL420.

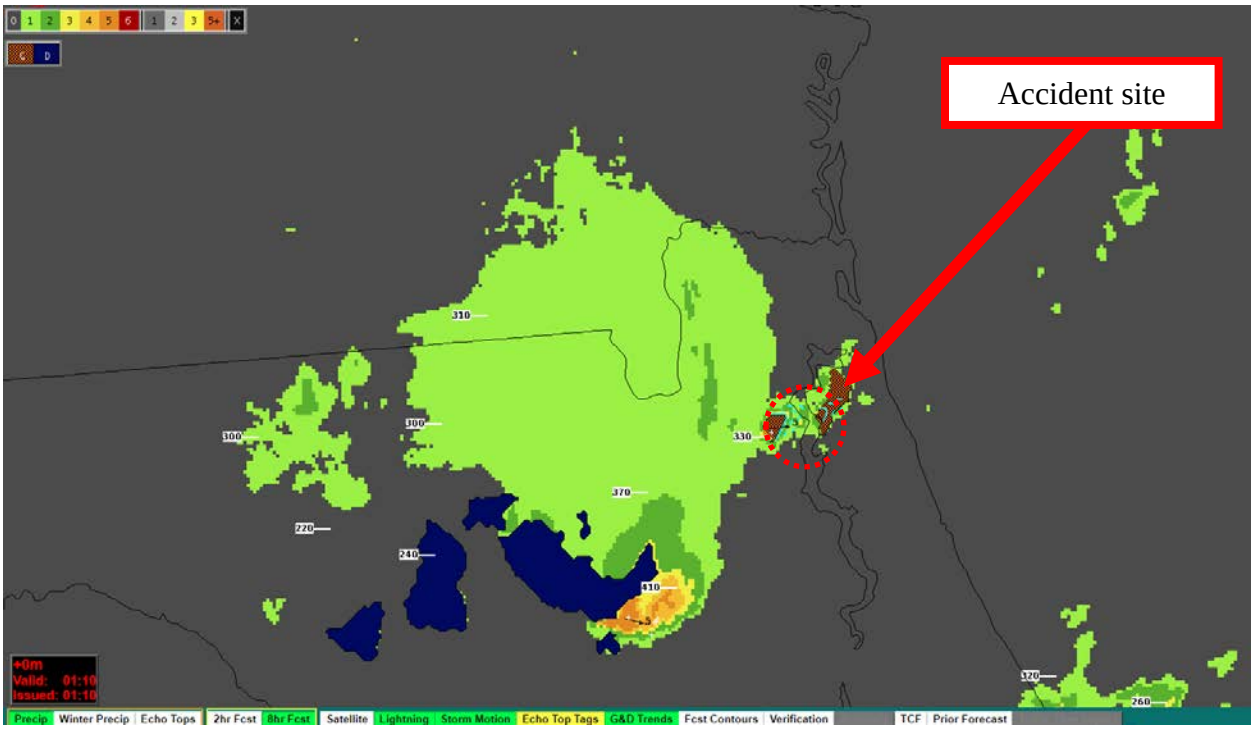


Figure 26 – CoSPA image from 2110 EDT with the accident site marked

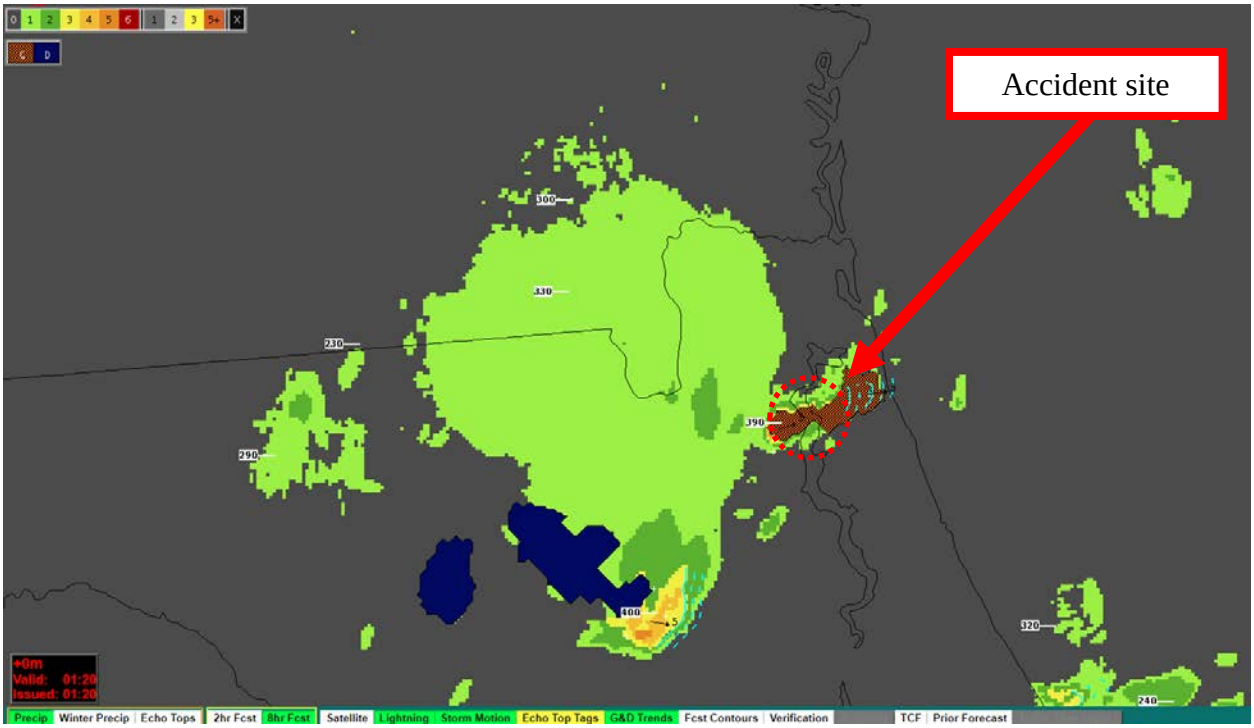


Figure 27 – CoSPA image from 2120 EDT with the accident site marked

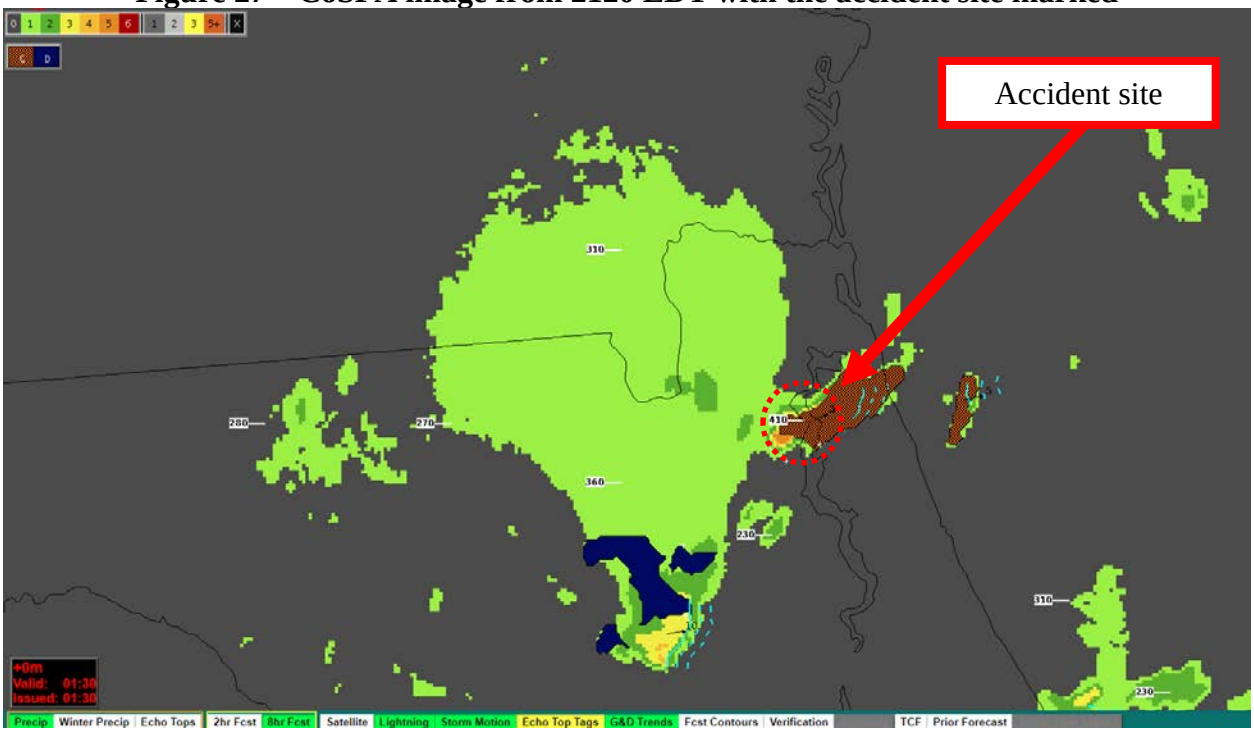


Figure 28 – CoSPA image from 2130 EDT with the accident site marked

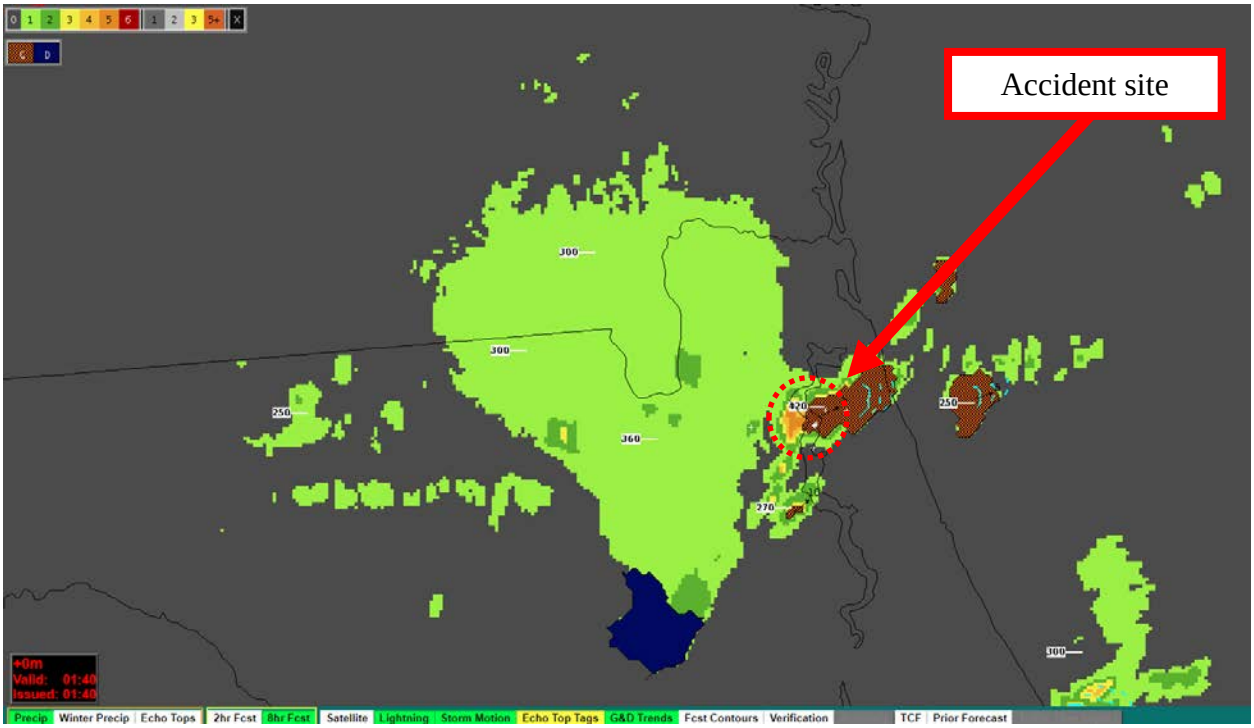


Figure 29 – CoSPA image from 2140 EDT with the accident site marked

20.0 STARS Information

The TRACONs use the Standard Terminal Automation Replacement System (STARS)[28] to display weather, and what was used by ATC at Jacksonville TRACON was obtained and is displayed below in figures 31 to 34 and attachment 12. The Jacksonville TRACON did have settings for level 1 through level 6 precipitation active and available for view:[29]

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

Figure 30 provides an exemplar view of what precipitation levels 1 through 6 look like on STARS display of precipitation. Figures 31 through 34 show the STARS display of precipitation used and seen by Jacksonville TRACON ATC at 2130, 2134, 2138, and 2142 EDT. Between 2130 and 2142 EDT level 3 and 4 precipitation (moderate to heavy precipitation) was indicated over KNIP. For more data please see attachment 12.

[28] https://www.raytheon.com/capabilities/products/stars
[29] The FAA provided the following dBZ levels for the ASR-9 radars (which provided info to STARS). For more information regarding STARS display please see attachment 2 of CEN16FA276.

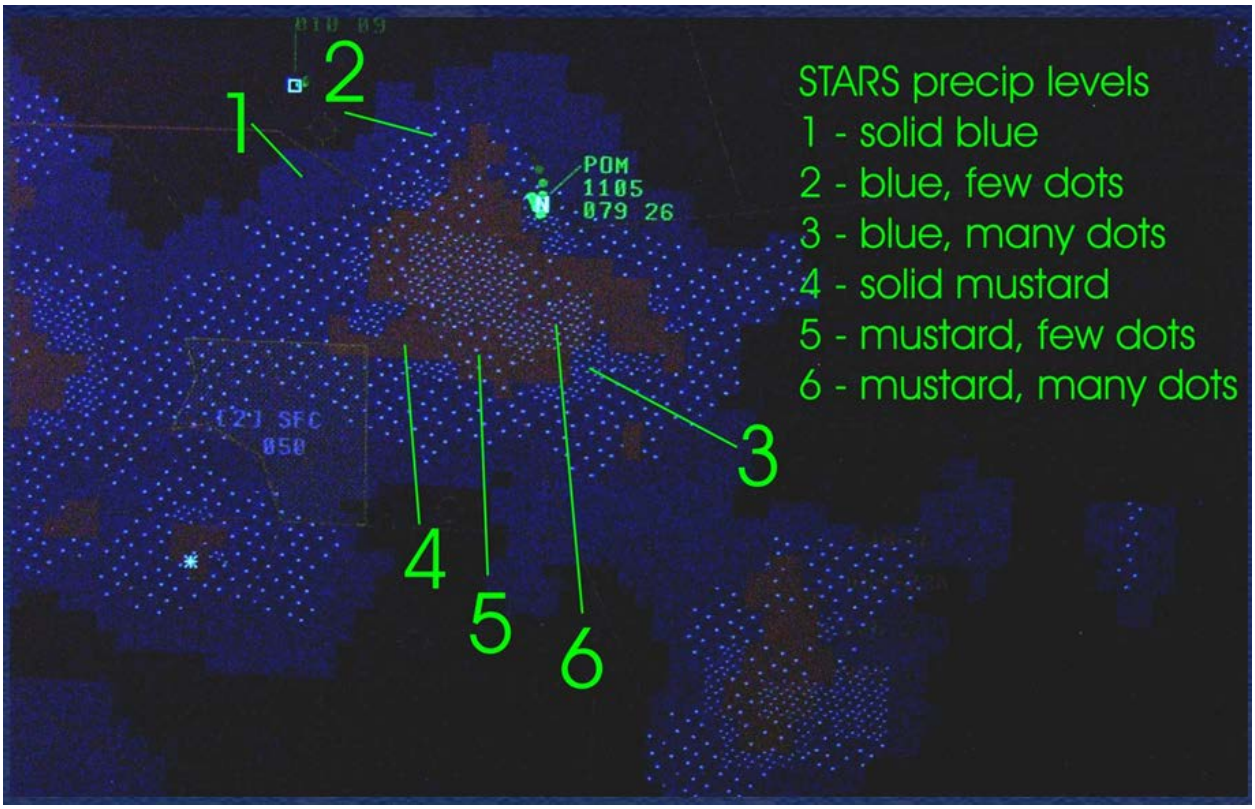


Figure 30 – Exemplar display of STARS precipitation levels 1 through 6

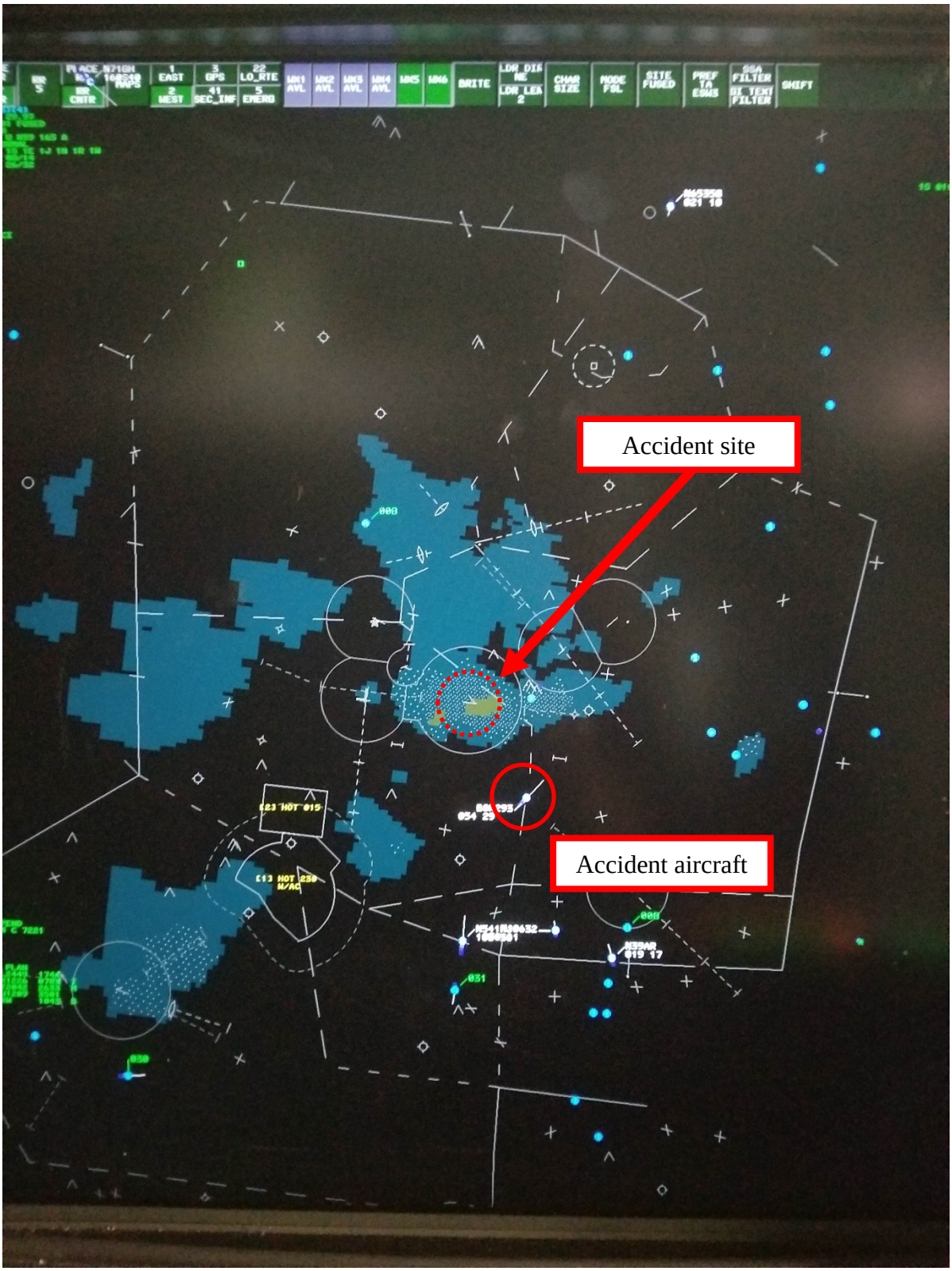


Figure 31 – STARS weather and precipitation level display for 2130 EDT

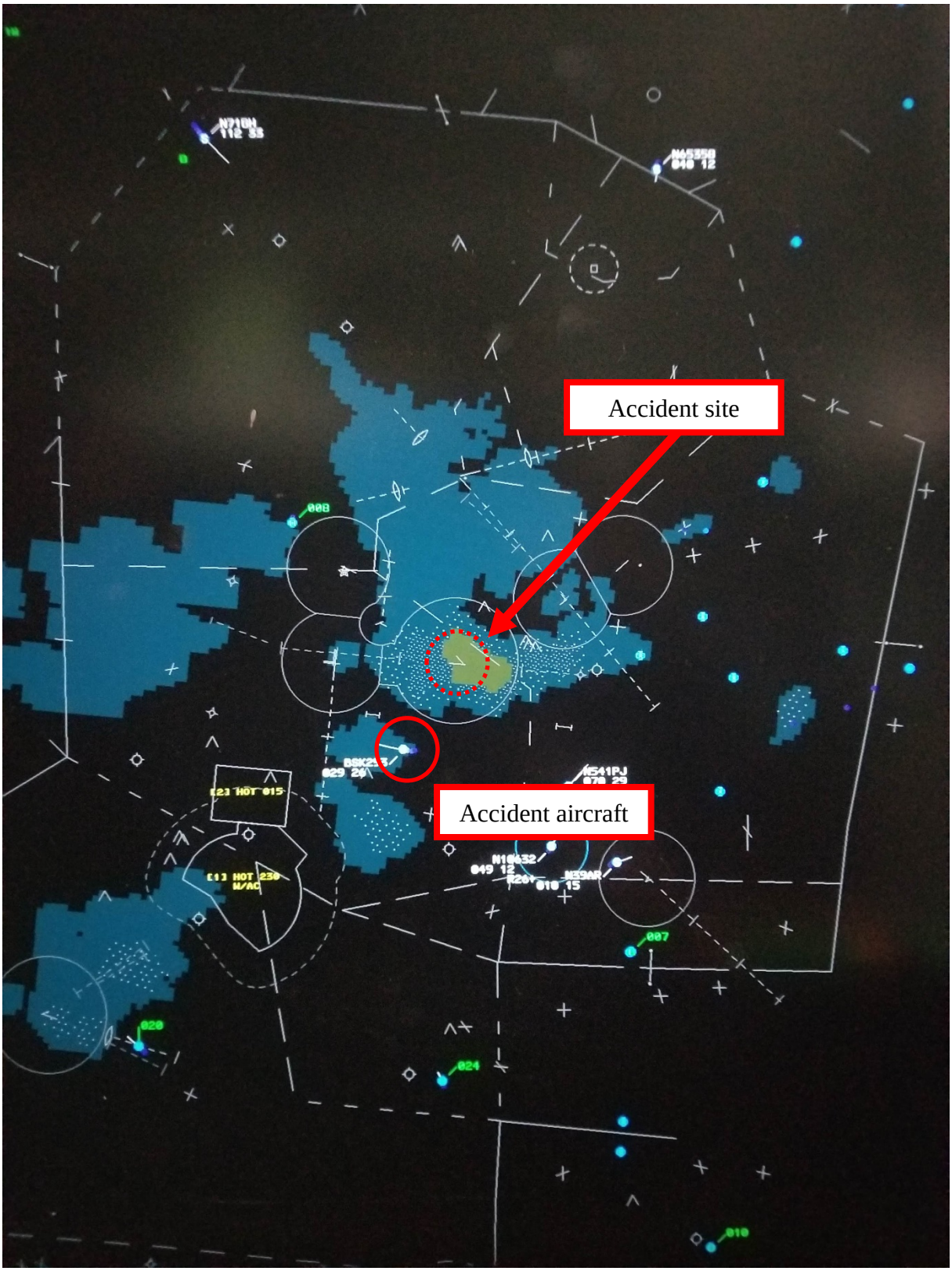


Figure 32 – STARS weather and precipitation level display for 2134 EDT

Figure 33 – STARS weather and precipitation level display for 2138 EDT

Figure 34 – STARS weather and precipitation level display for 2142 EDT

21.0 Radar Display of WARP Derived Imagery

The ZJX ATC's radar display of Weather and Radar Processor (WARP)[30] weather derived imagery, weather radar representation, settings, and aircraft movement of the accident aircraft is provided in figures 36 through 41 with images from 2120, 2124, 2128, 2132, 2138, and 2141:31 EDT, respectively. Each minute screen capture of WARP weather imagery is displayed in attachment 13. An exemplar image of WARP weather derived imagery precipitation levels is provided as figure 35. The ZJX radar display of WARP weather derived imagery indicated heavy to extreme precipitation above KNIP and the accident site at 2120 EDT (figure 36) with the area of extreme precipitation continuing to grow in areal coverage through 2142 EDT (figure 41) and remaining above the accident site and KNIP (attachment 13). For more WARP imagery please see attachment 13. The STARS display of weather and precipitation levels at the accident site did not match the WARP display of weather and precipitation levels, with WARP display of weather and precipitation indicating extreme precipitation above the accident site and KNIP as early as 2120 EDT.

[30] http://www.tc.faa.gov/its/cmd/visitors/data/ACT-300/warp.pdf

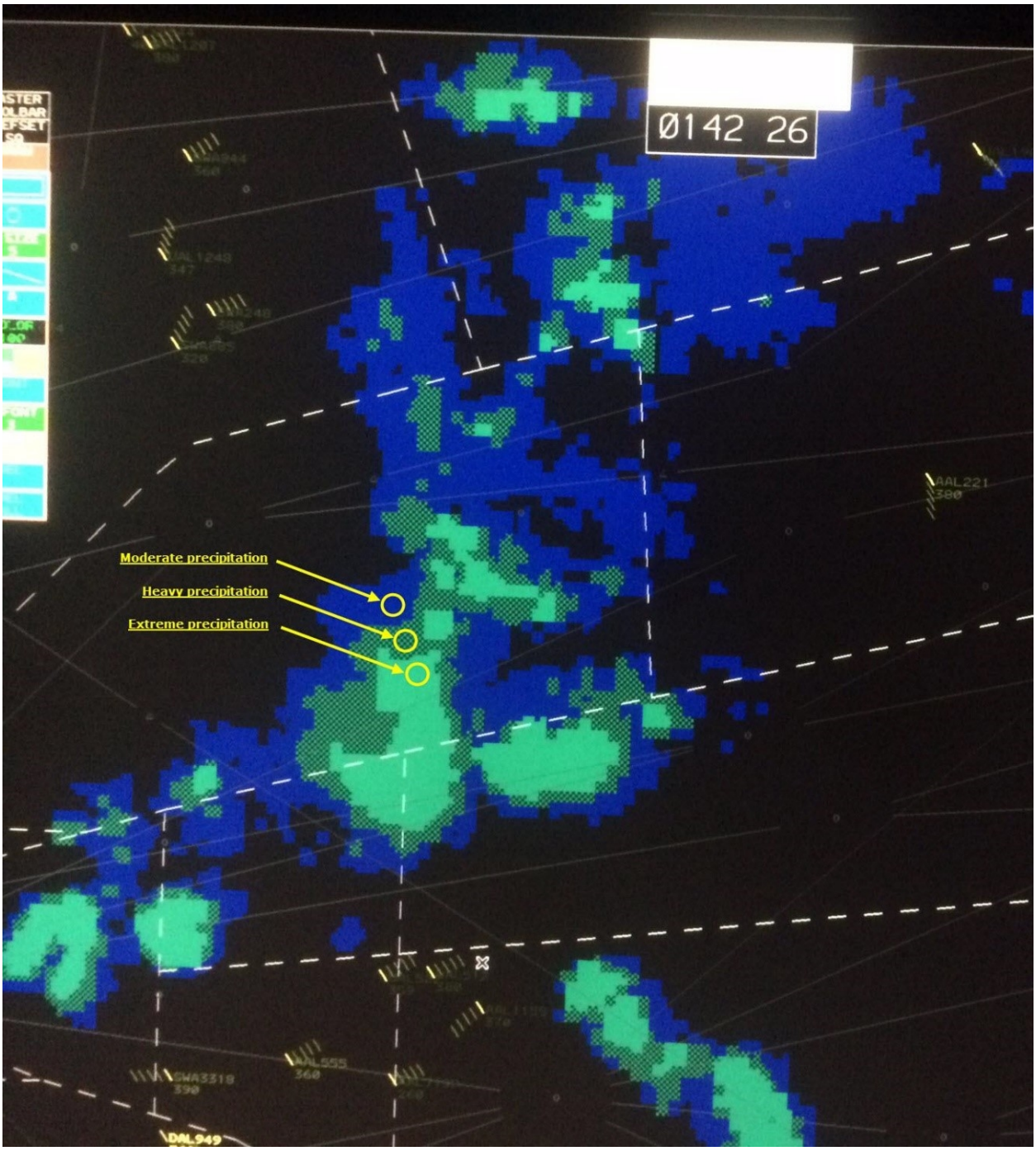


Figure 35 – Exemplar display of WARP derived precipitation levels

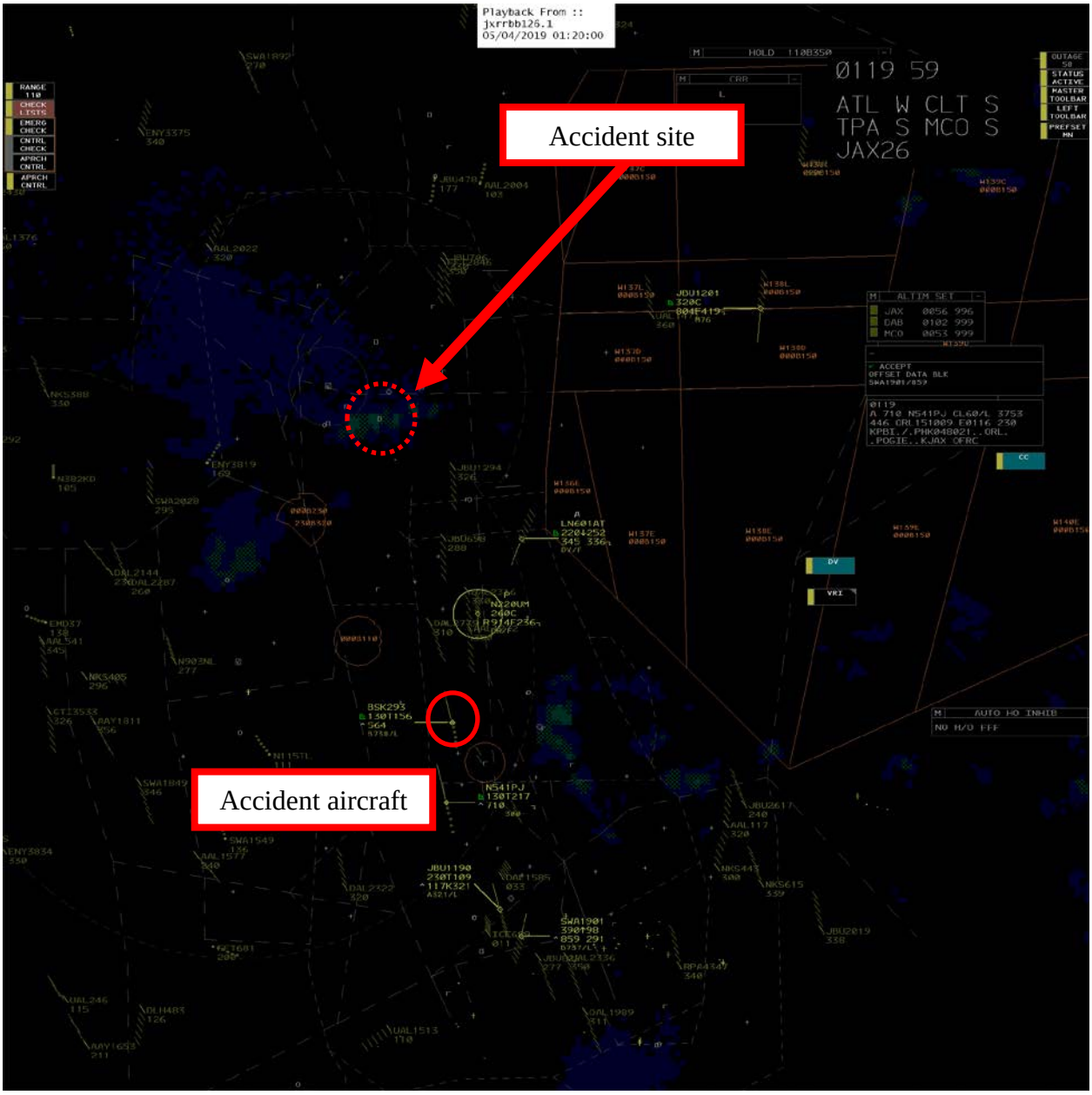


Figure 36 – Screenshot of the ZJX air traffic controller's radar display at 2120 EDT with WARP derived weather displayed

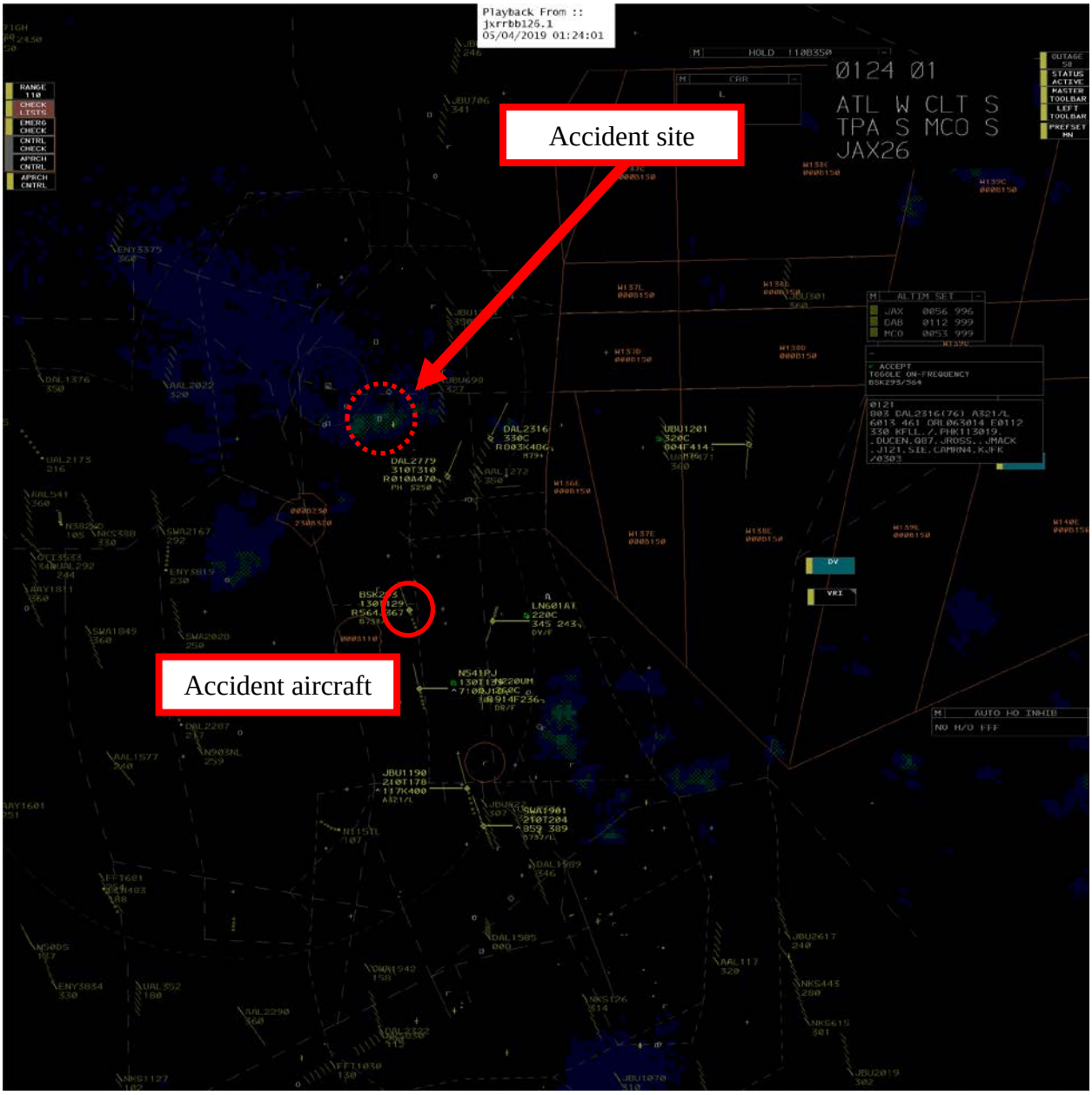


Figure 37 – Screenshot of the ZJX air traffic controller's radar display at 2124 EDT with WARP derived weather displayed

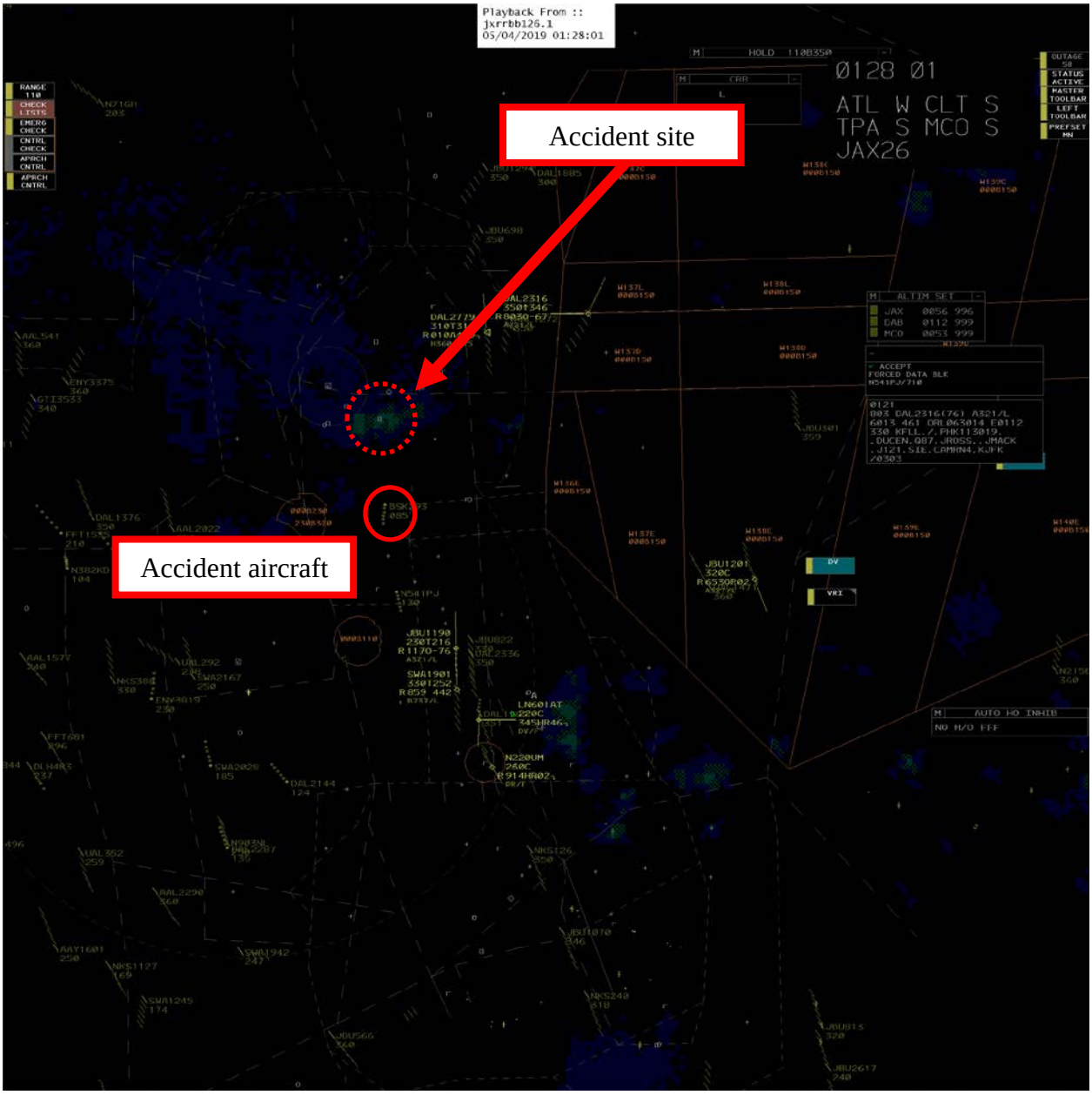


Figure 38 – Screenshot of the ZJX air traffic controller's radar display at 2128 EDT with WARP derived weather displayed

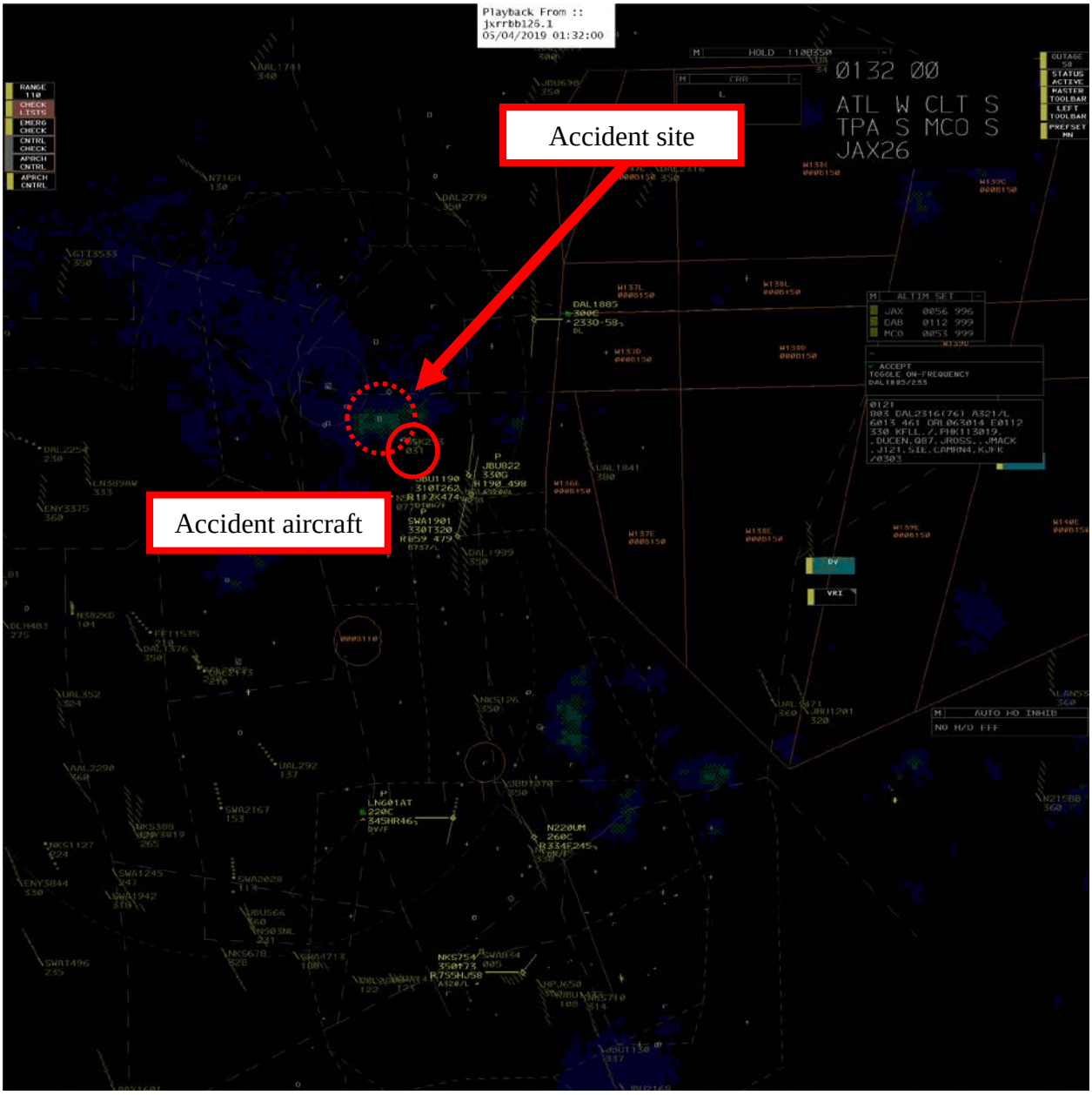


Figure 39 – Screenshot of the ZJX air traffic controller's radar display at 2132 EDT with WARP derived weather displayed

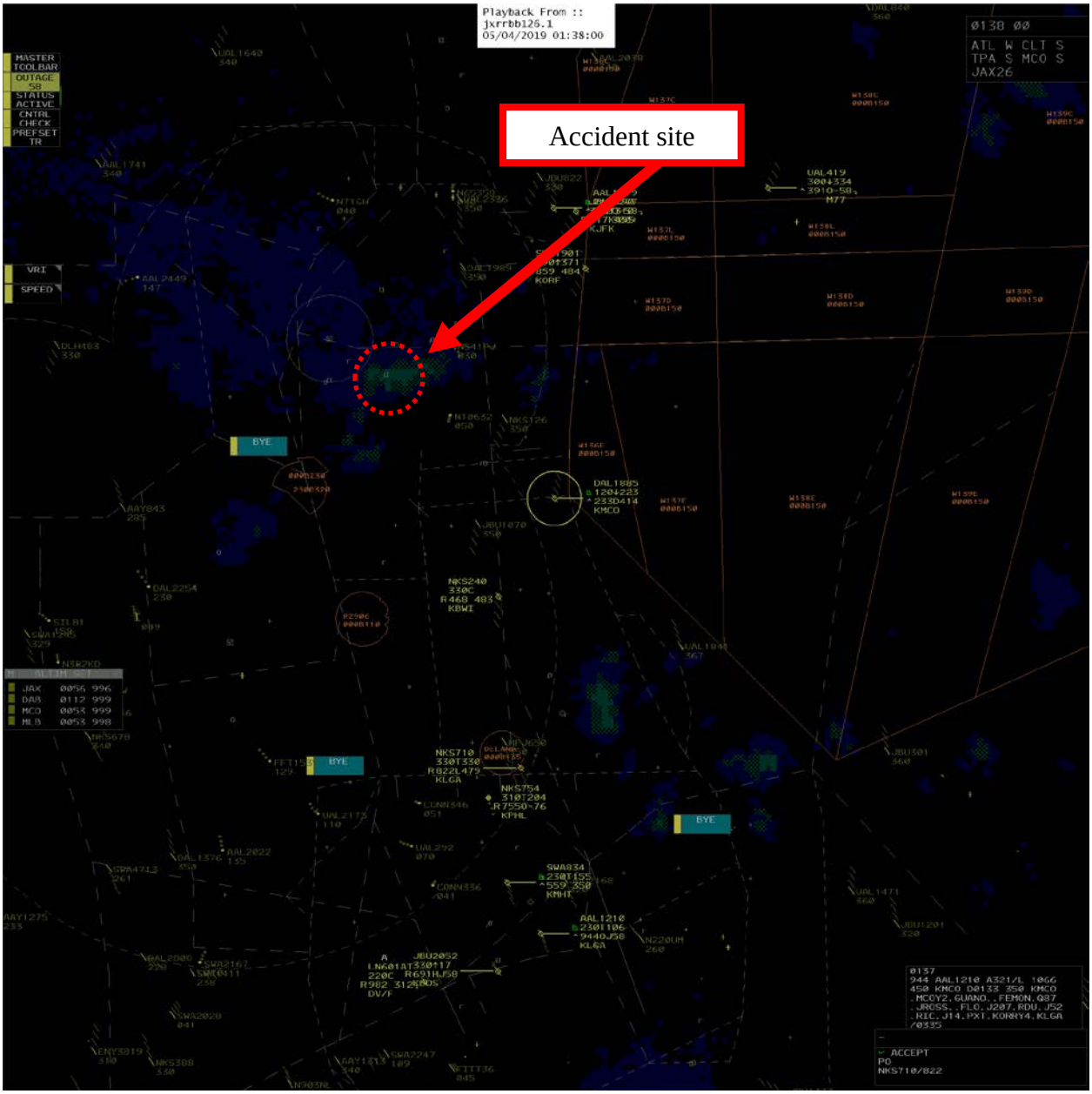


Figure 40 – Screenshot of the ZJX air traffic controller's radar display at 2138 EDT with WARP derived weather displayed

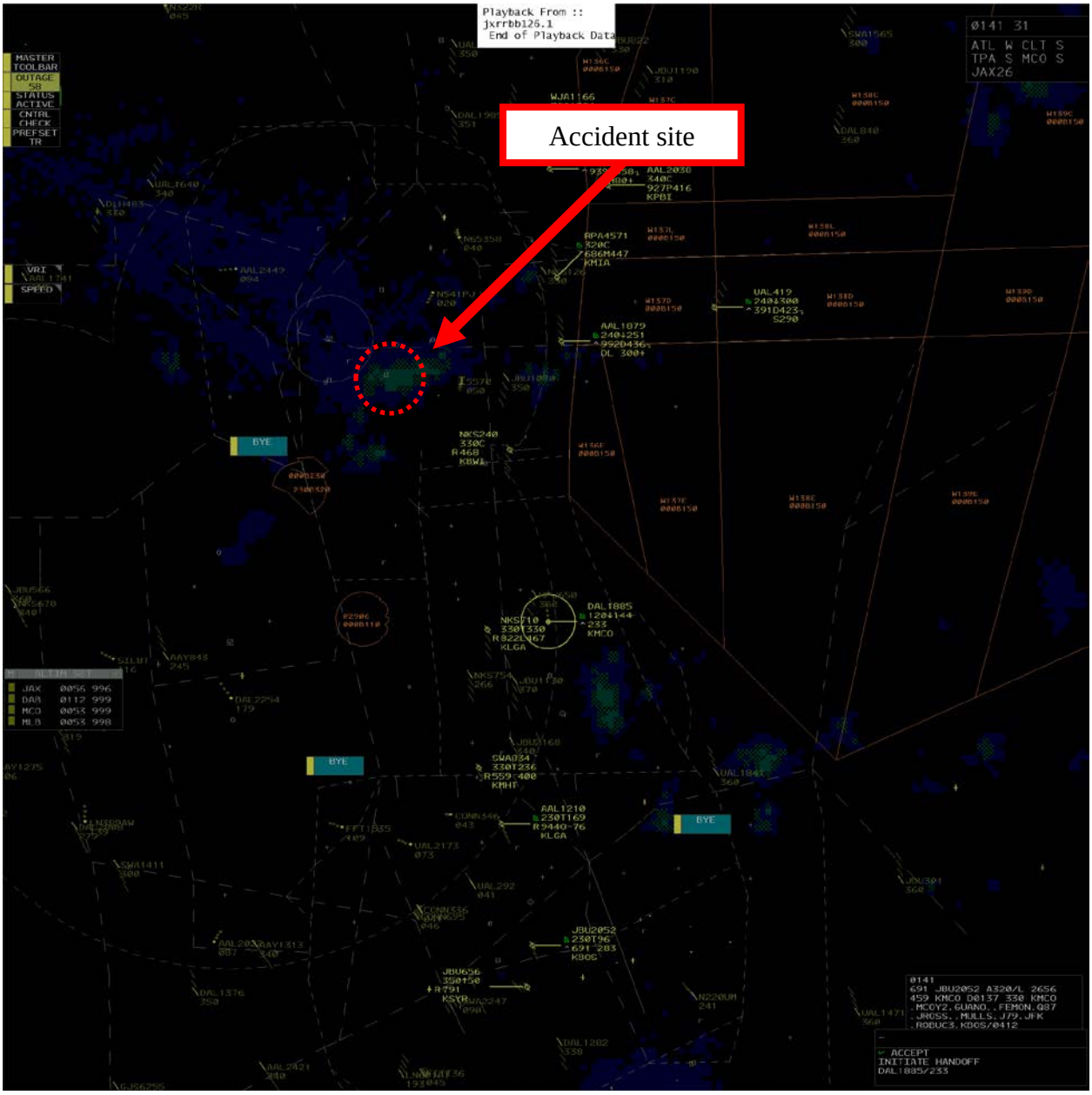


Figure 41 – Screenshot of the ZJX air traffic controller's radar display at 2141:31 EDT with WARP derived weather displayed

22.0 KNIP Contractor Weather Observers

The NTSB weather specialist and ATC group interviewed the off-going and on-coming KNIP CWOs on May 5, 2019. The full interviews are available as attachments 14 and 15. In addition, the visibility markers used by KNIP CWOs are available as attachment 16.

23.0 Astronomical Data

The astronomical data obtained from the United States Naval Observatory for the accident site on May 3, 2019, indicated the following:

SUN	
Begin civil twilight	0616 EDT
Sunrise	0642 EDT
Sun transit	1323 EDT
Sunset	2006 EDT
End civil twilight	2031 EDT
Accident time	**2142 EDT**[31]

The Moon set time was at 1901 EDT and therefore the Moon was below the horizon at the accident time.

24.0 Thunderstorm Training Information

The Federal Aviation Administration's (FAA) Advisory Circular AC 00-24C titled "Thunderstorms" issued in February 2013 is a basic training guide on thunderstorm hazards used for flight training guidance. As a result of the hazardous nature of thunderstorms the FAA has published several common practices or do's and don'ts on thunderstorm flying, which are published in AC 00-24C and the Aeronautical Information Manual (AIM) under Chapter 7 Safety of Flight, section 7-1-29. The following avoidance rules are published:

DOS AND DON'TS OF THUNDERSTORM AVOIDANCE.

a. Thunderstorm Avoidance. Never regard any thunderstorm lightly, even when radar observers report the echoes are of light intensity. Avoiding thunderstorms is the best policy. Following are some dos and don'ts of thunderstorm avoidance:

(1) Don't land or takeoff in the face of an approaching thunderstorm. A sudden gust front of low-level turbulence could cause loss of control.

(2) Don't attempt to fly under a thunderstorm even if you can see through to the other side. Turbulence and wind shear under the storm could be hazardous.

(3) Don't attempt to fly under the anvil of a thunderstorm. There is a potential for severe and extreme clear air turbulence.

(4) Don't fly without airborne radar into a cloud mass containing scattered embedded thunderstorms. Scattered thunderstorms not embedded usually can be visually circumnavigated.

(5) Don't trust the visual appearance to be a reliable indicator of the turbulence inside a thunderstorm.

(6) Don't assume that ATC will offer radar navigation guidance or deviations around thunderstorms.

[31] Inserted accident time for reference and context.

(7) Don't use data-linked weather next generation weather radar (NEXRAD) mosaic imagery as the sole means for negotiating a path through a thunderstorm area (tactical maneuvering).

(8) Do remember that the data-linked NEXRAD mosaic imagery shows where the weather *was*, not where the weather *is*. The weather conditions may be 15 to 20 minutes older than the age indicated on the display.

(9) Do listen to chatter on the ATC frequency for Pilot Weather Reports (PIREP) and other aircraft requesting to deviate or divert.

(10) Do ask ATC for radar navigation guidance or to approve deviations around thunderstorms, if needed.

(11) .Do use data-linked weather NEXRAD mosaic imagery (e.g., Flight Information Service-Broadcast (FIS-B)) for route selection to avoid thunderstorms entirely (strategic maneuvering).

(12) Do advise ATC, when switched to another controller, that you are deviating for thunderstorms before accepting to rejoin the original route.

(13) Do ensure that after an authorized weather deviation, before accepting to rejoin the original route, that the route of flight is clear of thunderstorms.

(14) Do avoid by at least 20 miles any thunderstorm identified as severe or giving an intense radar echo. This is especially true under the anvil of a large cumulonimbus.

(15) Do circumnavigate the entire area if the area has 6/10 thunderstorm coverage.

(16) Do remember that vivid and frequent lightning indicates the probability of a severe thunderstorm.

(17) Do regard as extremely hazardous any thunderstorm with tops 35,000 ft or higher whether the top is visually sighted or determined by radar.

(18) Do give a PIREP for the flight conditions.

(19) Do divert and wait out the thunderstorms on the ground if unable to navigate around an area of thunderstorms.

b. Dos Before Entering a Storm. If unable to avoid penetrating a thunderstorm, the following are some dos *before* entering the storm:

(1) Tighten the safety belt, put on the shoulder harness (if installed), and secure all loose objects.

(2) Plan and hold the course to take the aircraft through the storm in a minimum time.

(3) To avoid the most critical icing, establish a penetration altitude below the freezing level or above the level of -15ºC.

(4) Verify that pitot heat is on and turn on carburetor heat or jet engine anti-ice. Icing can be rapid at any altitude and cause almost instantaneous power failure and/or loss of airspeed indication.

(5) Establish power settings for turbulence penetration airspeed recommended in the aircraft manual.

(6) Turn up cockpit lights to highest intensity to lessen temporary blindness from lightning.

(7) If using automatic pilot, disengage Altitude Hold Mode and Speed Hold Mode. The automatic altitude and speed controls will increase maneuvers of the aircraft thus increasing structural stress.

(8) If using airborne radar, tilt the antenna up and down occasionally. This will permit the detection of other thunderstorm activity at altitudes other than the one being flown.

c. Dos and Don'ts for Thunderstorm Penetration. Following are some dos and don'ts during the thunderstorm penetration:

(1) Do keep your eyes on the flight instruments. Looking outside the cockpit can increase danger of temporary blindness from lightning.

(2) Don't change power settings; maintain settings for the recommended turbulence penetration airspeed.

(3) Do maintain constant attitude. Allow the altitude and airspeed to fluctuate.

(4) Don't turn back once in the thunderstorm. A straight course through the storm most likely will get the aircraft out of the hazards most quickly. In addition, turning maneuvers increase stress on the aircraft.

E. LIST OF ATTACHMENTS

Attachment 1 – 1- and 5-minute KNIP ASOS data

Attachment 2 – ASOS 1-minute coding document

Attachment 3 – ASOS documentation

Attachment 4 – KNIP system log files around the accident time

Attachment 5 – GOES-16 Infrared animation from 2101 to 2231 EDT with GLM lightning data

Attachment 6 – Navy weather definitions

Attachment 7 – KJAX WSR-88D level 2 base reflectivity animation for the 0.5° elevation scans from 2055 to 2200 EDT

Attachment 8 – KJAX WSR-88D radial velocity animation for the 0.5° elevation scans from 2101 to 2155 EDT

Attachment 9 – GFA products valid for the accident flight

Attachment 10 – FWC products

Attachment 11 – ZJX CWSU pre-duty weather briefing

Attachment 12 – STARS displayed weather imagery valid around the accident time

Attachment 13 – WARP displayed weather imagery valid around the accident time

Attachment 14 – Interview of off-going CWO

Attachment 15 – Interview of on-coming CWO

Attachment 16 – KNIP visibility markers

Submitted by:

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Paul Suffern
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