



NATIONAL TRANSPORTATION SAFETY BOARD

Office of Aviation Safety
Washington, D.C. 20594

August 19, 2020

Factual Report

METEOROLOGY

ERA20LA206

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A. ACCIDENT

Location: near Eatonton, Georgia
Date: June 5, 2020
Time: 1520 eastern daylight time
1920 Universal Coordinated Time (UTC)
Aircraft: Piper PA-31T; Registration: N135VE

B. METEOROLOGIST

Donald Eick
Meteorology Specialist
Operational Factors Division (AS-30)
National Transportation Safety Board

C. SUMMARY

On June 5, 2020, about 1520 eastern daylight time, a Piper PA-31T, N135VE, was destroyed when it was involved in an accident near Eatonton, Georgia. The accident airplane had departed from Williston Municipal Airport (X60), Williston, Florida, and was on a northerly heading en route to New Castle Henry Marlatt Field (UWL), New Castle, Indiana, at an altitude of 25,000 ft. The two pilots and the three passengers were fatally injured. The airplane was operated as a Title 14 *Code of Federal Regulations* Part 91 personal flight.

D. DETAILS OF THE INVESTIGATION

The National Transportation Safety Board's Senior Meteorologist was not on scene for this investigation and conducted the meteorology phase of the investigation from the Washington D.C. office, collecting data from official National Weather Service (NWS) sources including the Weather Prediction Center (WPC) and the National Center for Environmental Information (NCEI). All times are eastern daylight time (EDT) based upon the 24-hour clock, local time is -4 hours from UTC, and UTC=Z. 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. Directions are referenced to true north and distances in nautical miles. Heights are in feet (ft) above mean sea level (msl) unless otherwise noted. Visibility is in statute miles and fractions of statute miles.

The main wreckage site was located at latitude 33.3813° N and longitude 83.3289° W, at an elevation of approximately 520 ft.

E. WEATHER INFORMATION

1.0 Synoptic Conditions

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 (WPC) located in College Park, Maryland. These are the base products used in describing weather features and in the creation of forecasts and warnings. Reference to these charts can be found in the joint NWS and Federal Aviation Administration (FAA) Advisory Circular “Aviation Weather Services”, AC 00-45H change 2.

1.1 Surface Analysis Chart

The southeast section of the NWS Surface Analysis Chart for 1400 EDT on June 5, 2020 is included as figure 1 with the approximate accident site marked by a red star. The chart depicted a high pressure system over West Virginia at 1013-hectopascals (hPa)¹ with a ridge of high pressure extending southwestward across eastern Tennessee and northern Georgia. To the west-northwest over western Tennessee into northern Mississippi and Arkansas an outflow boundary associated with thunderstorms was noted, which was moving southeastward. No boundaries were identified over Georgia or along the general route of flight.

¹ Hectopascals is the new NWS reference for reporting sea level pressure and is interchangeable with the former term millibar (mb) with the same units. Standard sea-level pressure is 1013.25-hPa at 59° Fahrenheit (F) or 15° Celsius (C).

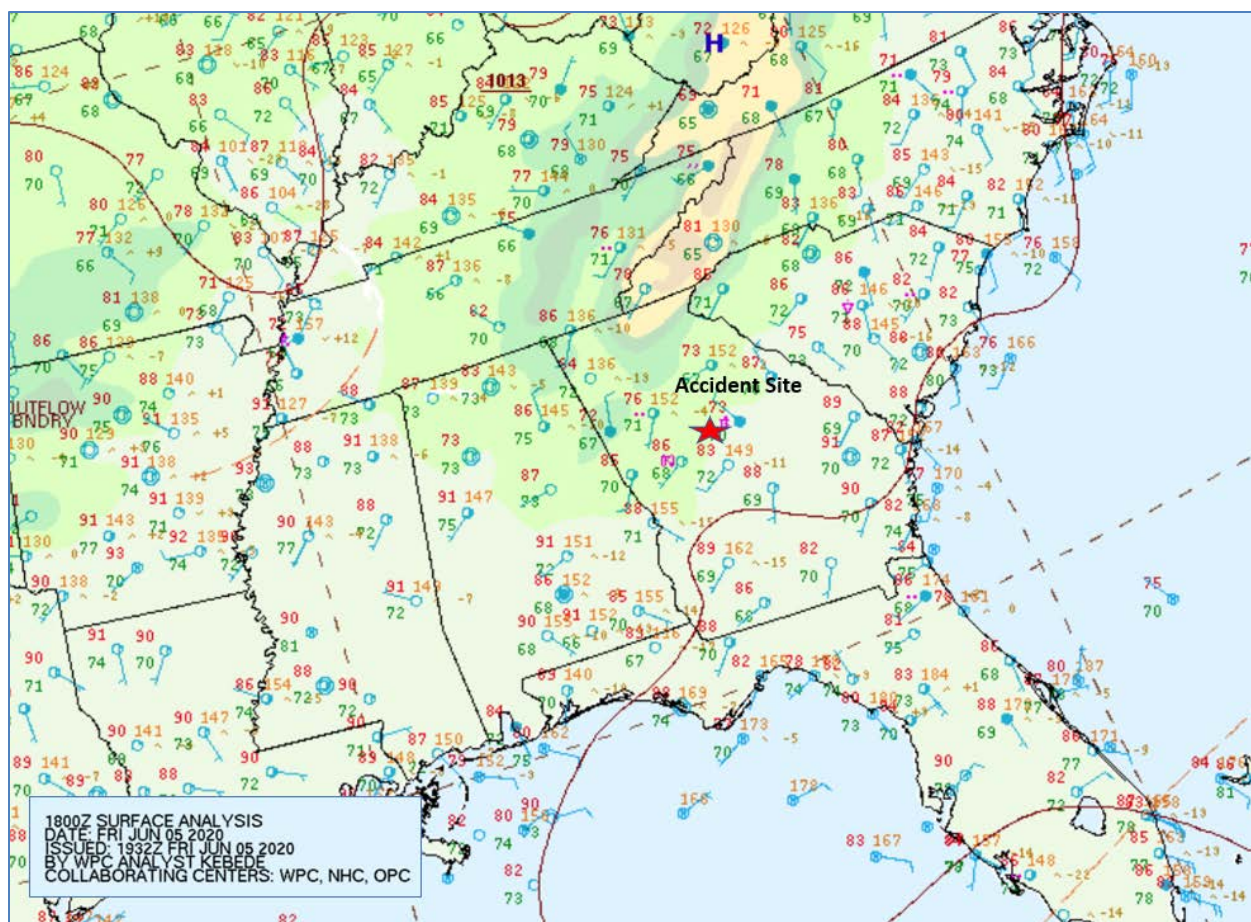


Figure 1 - southeast section of the NWS Surface Analysis Chart for 1400 EDT

The station models in central and northern Georgia indicated variable winds of 10 knots or less over the area with variable broken to overcast cloud cover, with temperatures in the 80's to mid-70's F, with dew point temperatures near 70's F. Several station models depicted thunderstorms and rain showers in the vicinity of the accident site.

1.2 National Composite Radar Mosaic

The southeast section of the National Composite Radar Mosaic² for 1520 EDT is included as figure 2 with an approximate flight track and accident site marked by a red star. The image depicted a broken band of echoes across central Georgia, with several intense echoes located southeast and southwest of the accident site. Light intensity echoes extended over the accident site from one of the stronger cells near Macon, Georgia. Based on the existence of echoes over the flight track the closest NWS weather surveillance radar will be further documented in section 5.0 of this report.

² Composite reflectivity images utilize all elevation scans during each volume scan to create the image. It is composed of the greatest echo intensity (reflectivity) from any elevation angle seen from the radar. It is used to reveal the highest reflectivity in all echoes.

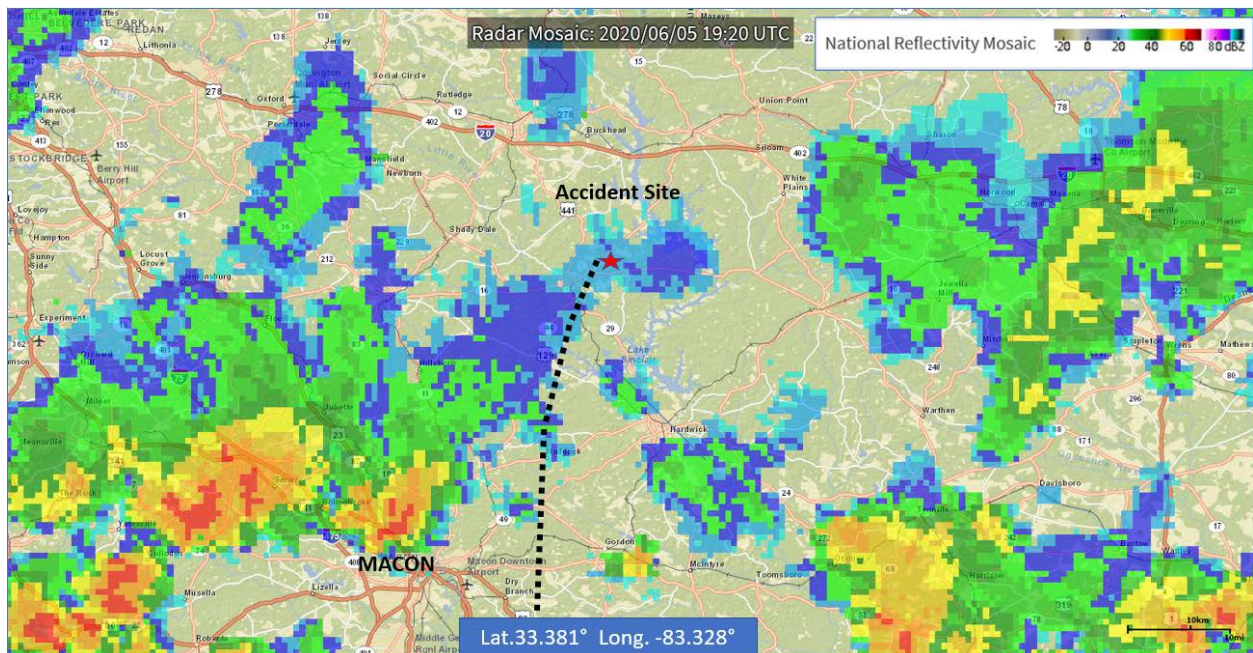


Figure 2 - NWS National Composite Radar Mosaic for 1420 EDT

1.3 Upper Air Charts

The NWS Storm Prediction Center (SPC) 500-hPa and 300-hPa Constant Pressure Charts for 0800 EDT are included as figures 3 and 4, respectively. The approximate accident site has been added as well as the pressure systems and longwave troughs. The 500-hPa chart represents the conditions of the mean atmosphere at approximately 18,000 ft, and the 300-hPa chart the conditions at approximately 30,000 ft with streamlines and isotachs color coded to depict the location and strength of the jetstream at that level.

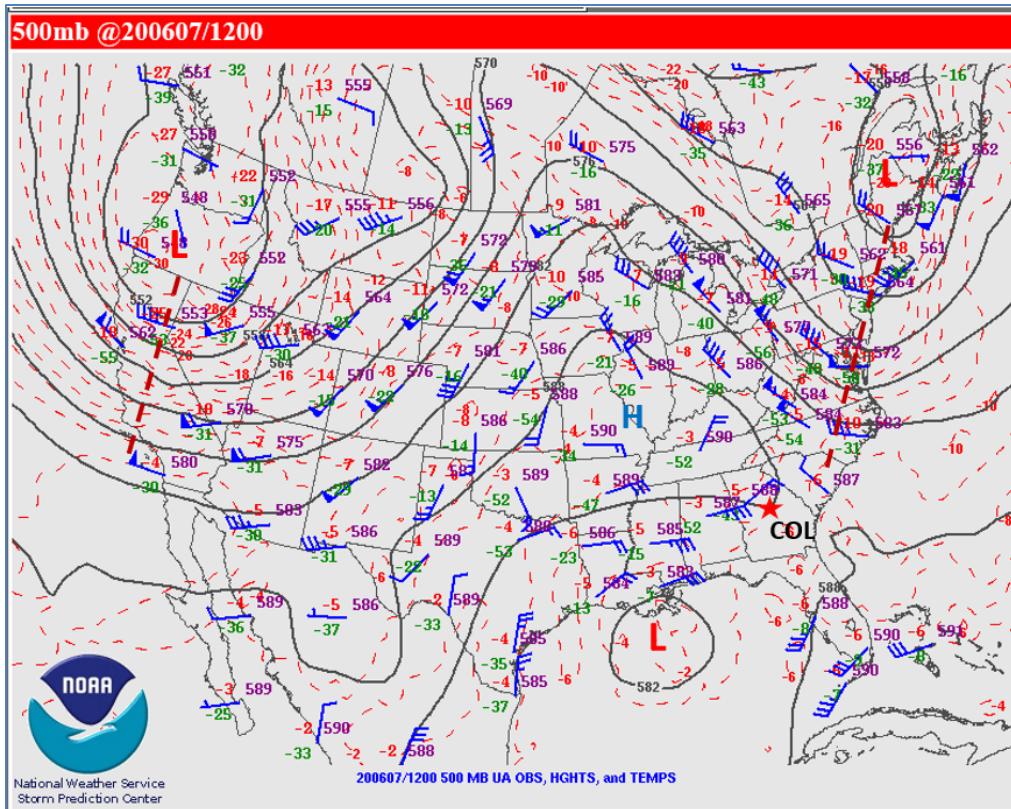


Figure 3 - NWS 500-hPa constant pressure chart for 0800 EDT

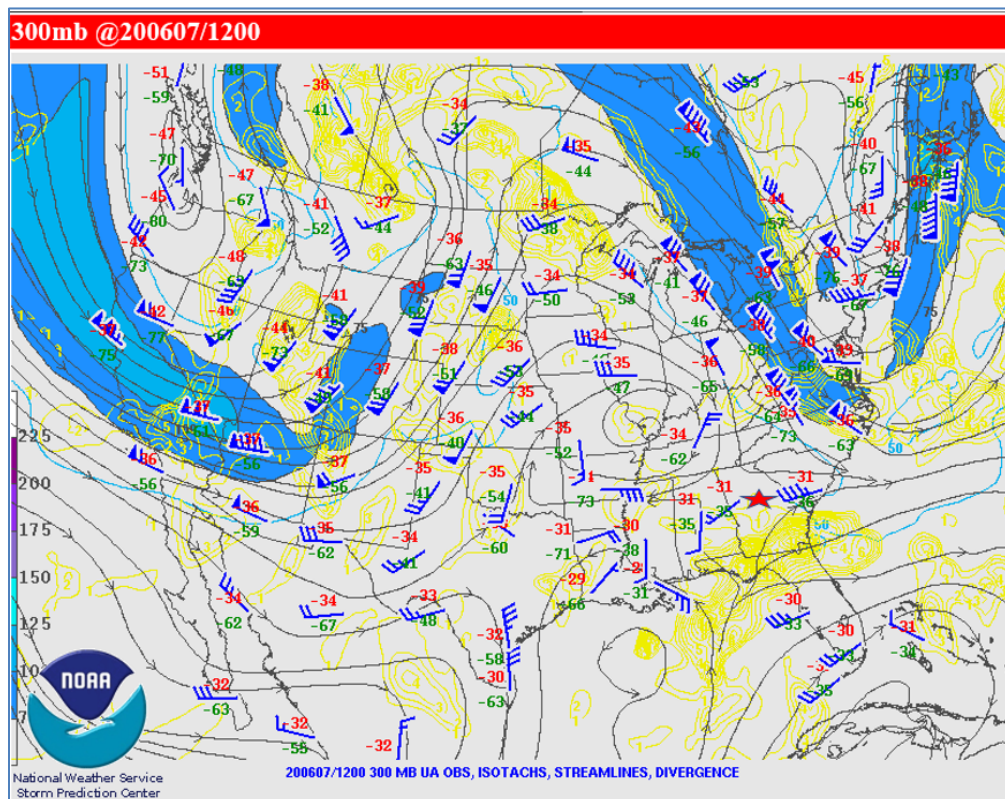


Figure 4 – NWS 300-hPa Constant Pressure Chart for 0800 EDT

A review of the 500- and 300-hPa charts depicted an upper level high pressure center over Missouri with a ridge extending southeastward into northern Georgia with a col³ or neutral point in the pressure field over central Georgia. The resulting pressure pattern resulted in generally light winds which were from the southwest over northern Florida shifting to the east over northern Georgia at 500-hPa, and winds at 300-hPa from the west at 10 to 30 knots.

1.4 Convective Outlook

The NWS SPC is tasked with providing timely and accurate forecasts and watches for severe thunderstorms and tornadoes over the contiguous United States. One of their primary products highlighting the expected areas of organized thunderstorms is the Convective Outlook (AC). The intent of the chart is to identify to users like NWS forecasters, emergency managers, media, and pilots where the SPC expects organized thunderstorms and severe thunderstorms⁴ to form. The SPC mid-day Convective Outlook issued prior to the accident airplanes departure is included as figure 5 followed by the text bulletin issued with the graphic.

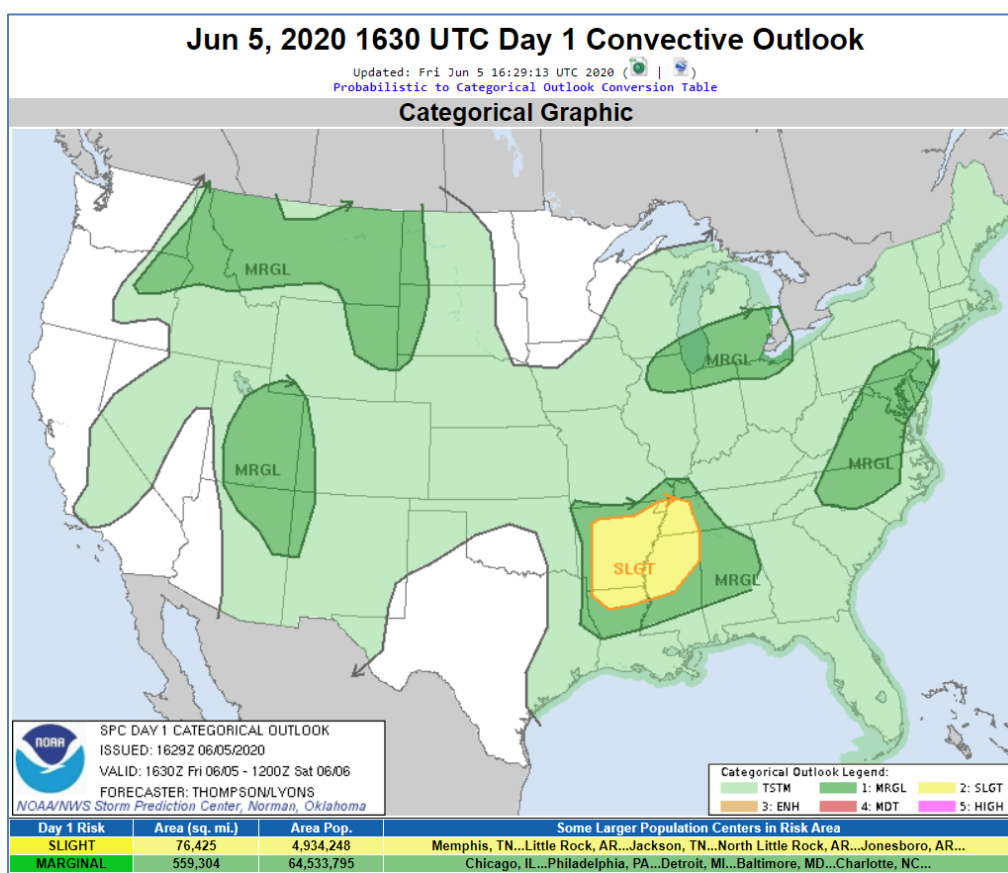


Figure 5 - NWS Day 1 Convective Outlook

³ Col – (also called a saddle point or neutral point) the point of intersection of a trough and a ridge in the pressure pattern on a weather map.

⁴ A severe thunderstorm is one that produces a tornado, large hail over 1.0 inch in diameter, or outflow winds greater than 50 knots. While all thunderstorms imply the likelihood of severe turbulence, a severe thunderstorm implies a high likelihood of severe to extreme turbulence, wind shear, and a high probability of encountering hail.

The convective outlook issued at approximately 1230 EDT depicted a slight risk of severe thunderstorms over Arkansas, western Tennessee, northern Mississippi, and northern Louisiana, surrounded by a marginal risk into Alabama. A general risk of air-mass thunderstorms was also expected over all the eastern half of the United States and included the proposed route of flight and the accident site. The text bulletin issued with the chart is included below with the Northern High Plains and Northern Rockies marginal risk area sections excluded.

SPC AC 051629
Day 1 Convective Outlook
NWS Storm Prediction Center Norman OK
1129 AM CDT Fri Jun 05 2020

Valid 051630Z - 061200Z

...THERE IS A SLIGHT RISK OF SEVERE THUNDERSTORMS THIS AFTERNOON INTO EARLY TONIGHT FOR THE MID-SOUTH AREA...

...SUMMARY...

Severe thunderstorms are possible today into tonight across the Ozarks/Mid-South and Middle/Lower Mississippi Valley. Other strong to severe thunderstorms may occur over the Northern Rockies and adjacent High Plains, the Mid-Atlantic States, as well as the Four Corners area.

...Mid-South area through early tonight...

A remnant MCS (with an MCV) and surface outflow continue to move south-southeastward over the MO Bootheel as of mid-late morning. The storms are expected to develop southeastward along a diffuse boundary toward western TN this afternoon, as well as southward into the unstable warm sector across AR. Strong surface heating south of the ongoing convection and along the outflow boundary will contribute to large buoyancy this afternoon from AR into northern MS and western TN, where MLCAPE will likely reach 3000-4000 J/kg. Though vertical shear will remain relatively weak over this area, the large buoyancy and strong downdraft potential (DCAPE in excess of 1200 J/kg) will favor multicell clusters capable of producing occasional damaging gusts.

...

...NC to the Mid-Atlantic this afternoon/evening...

A weak midlevel trough is moving eastward over the central/southern Appalachians as of midday. Convergence along a weak associated surface trough near the Blue Ridge, in combination with daytime heating and boundary-layer dewpoints in the upper 60s, will support thunderstorm development through early-mid afternoon both along the trough/higher terrain, and in the moist axis farther southeast. Regional 12z soundings revealed rather poor lapse rates which will tend to limit buoyancy somewhat, and also the potential for strong downdrafts. Still, there should be enough steepening of low-level lapse rates to support a low-end downburst threat with multicell clusters spreading eastward this afternoon/evening.

...OH Valley/Great Lakes area this afternoon/evening...

A few thunderstorms will be possible along a surface cold front and in advance of a midlevel trough crossing the upper Great Lakes. Destabilization in advance of the front may be sufficient for a few strong storms with marginally severe wind/hail as far east as southeast Lower MI later this afternoon. Buoyancy will be larger to the west, but forcing for ascent becomes more nebulous with westward extent, from northern IL westward, which will likely limit storm coverage.

..Thompson/Lyons.. 06/05/2020

1.5 12-hour Surface Prognostic Chart

The NWS WPC 12-hour Surface Prognostic Chart current prior to departure was valid for 1400 EDT and is included as figure 6. The chart depicted a chance of thunderstorms and rain showers over the entire eastern United States and included a 30% to 50% probability of thunderstorms over central Georgia. A likely area of thunderstorms and rain showers or greater than 50% probability was indicated over northern Georgia into western North Carolina.

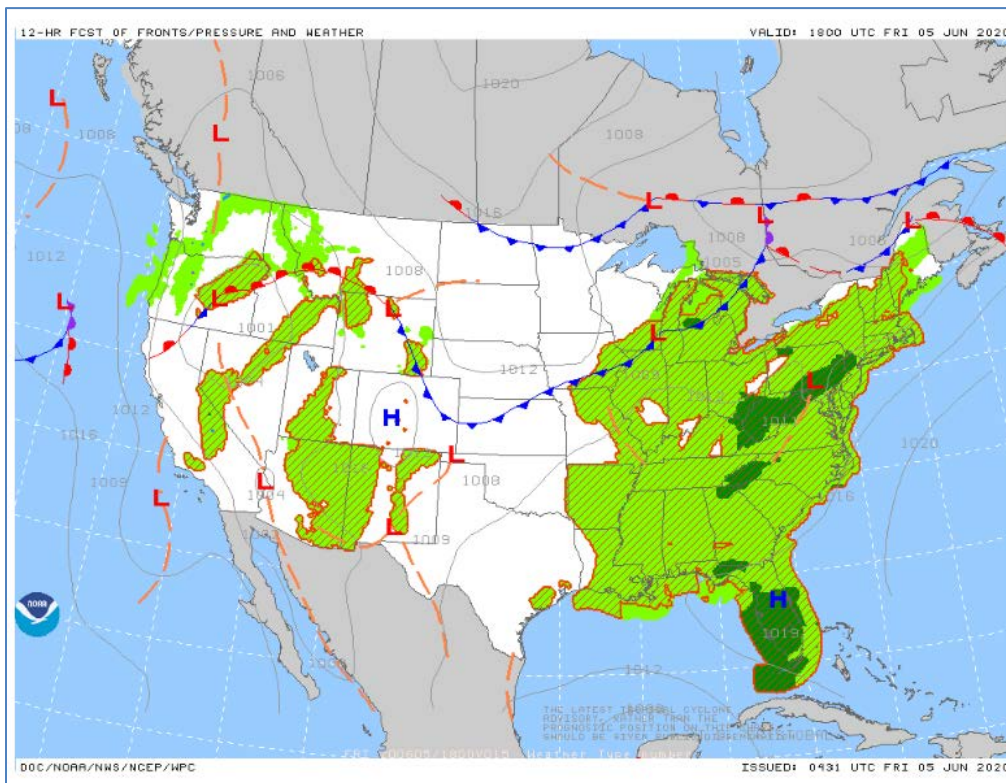


Figure 6 - 12-hour Surface Prognostic Chart valid for 1400 EDT

2.0 Surface Observations

The official observations issued surrounding the accident site were documented using standard meteorological aerodrome reports (METARs) and specials (SPECI). Cloud heights are reported above ground level (agl) in the following section, and the magnetic variation was estimated at 6° west based on the latest sectional chart for the area. Figure 7 is a map of the area with the closest weather reporting sites indicated and the flight track overlaid.

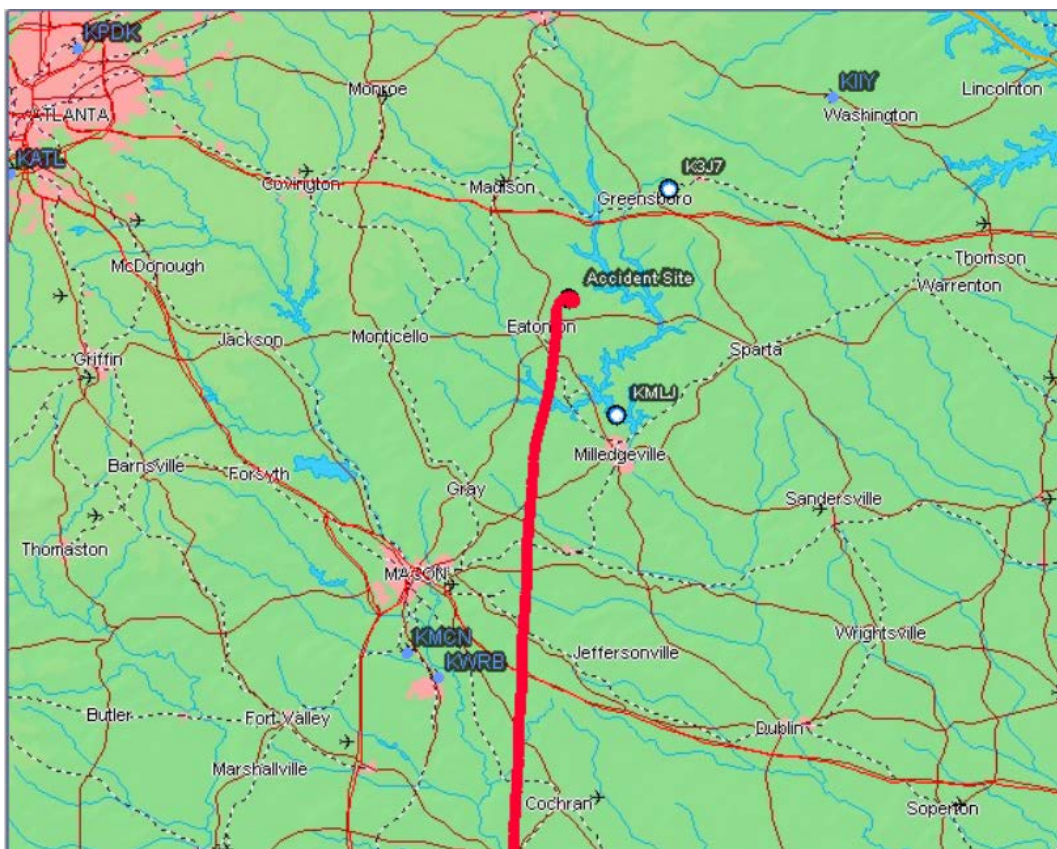


Figure 7 - Map with closest airports indicated with the flight track

2.1 Milledgeville, Georgia

The closest weather reporting station to the accident site was Baldwin County Regional Airport (KMLJ), Milledgeville, Georgia, located about 17 miles south-southeast at an elevation of 385 ft. The airport had an Automated Weather Observation System (AWOS), which issued observations every 20-minutes. The following conditions were reported surrounding the period.

Weather observation for KMLJ at 1515 EDT, automated⁵, wind calm, visibility 10 miles, thunderstorm, scattered clouds at 700 ft agl, scattered at 4,400 ft, temperature 25° C, dew point 22° C, altimeter 29.98 inches of mercury (Hg). Remarks: automated observation system with a precipitation discriminator, lightning distant⁶ east through west.

Weather observation for KMLJ at 1535 EDT, automated, wind calm, visibility 10 miles, scattered clouds at 700 ft agl, scattered at 2,400 ft, and scattered at 3,400 ft, temperature 25° C, dew point 23° C, altimeter 29.99 inches of Hg. Remarks: automated observation system with a precipitation discriminator, lightning distant southeast and west.

⁵ Automated (AUTO) indicates that there is no human augmentation to the observation.

⁶ Distant refers to more than 10 statute miles from the site.

The general flight categories⁷ and raw observations from approximately 1215 through 1635 EDT were as follows:

VFR METAR KMLJ 051615Z AUTO 31008KT 10SM SCT039 SCT050 SCT060 30/22 A3001 RMK AO2 LTG DSNT N SE AND NW=

VFR METAR KMLJ 051635Z AUTO 17005KT 10SM SCT039 SCT050 SCT060 30/22 A3000 RMK AO2 LTG DSNT N AND NW=

VFR METAR KMLJ 051655Z AUTO 00000KT 10SM SCT039 SCT044 BKN095 30/23 A3000 RMK AO2 LTG DSNT NW THRU NE=

VFR METAR KMLJ 051715Z AUTO 00000KT 10SM VCTS SCT039 SCT047 SCT055 30/23 A3000 RMK AO2 LTG DSNT NW THRU NE=

VFR METAR KMLJ 051735Z AUTO 01008KT 330V070 10SM SCT048 SCT060 30/21 A3000 RMK AO2 LTG DSNT E AND NW=

MVFR METAR KMLJ 051755Z AUTO 33009KT 5SM +TSRA SCT031 BKN036 OVC060 23/21 A3004 RMK AO2 LTG DSNT ALQS=

IFR METAR KMLJ 051815Z AUTO 00000KT 2 1/2SM -TSRA SCT013 BKN037 OVC100 23/22 A3000 RMK AO2 LTG DSNT NW THRU E=

VFR METAR KMLJ 051835Z AUTO 00000KT 7SM -RA SCT013 SCT031 BKN041 23/22 A2999 RMK AO2 LTG DSNT ALQS=

VFR METAR KMLJ 051855Z AUTO 00000KT 10SM VCTS SCT033 SCT041 24/22 A2999 RMK AO2 LTG DSNT SE AND W=

VFR METAR KMLJ 051915Z AUTO 00000KT 10SM TS SCT007 SCT044 25/22 A2998 RMK AO2 LTG DSNT E THRU W=

Accident 1922Z

VFR METAR KMLJ 051935Z AUTO 00000KT 10SM SCT007 SCT024 SCT034 25/23 A2999 RMK AO2 LTG DSNT SE AND W=

VFR METAR KMLJ 051955Z AUTO 00000KT 10SM CLR 25/23 A2999 RMK AO2 LTG DSNT W=

VFR METAR KMLJ 052015Z AUTO 00000KT 10SM CLR 25/24 A2997 RMK AO2 LTG DSNT SE W AND NW=

VFR METAR KMLJ 052035Z AUTO 00000KT 10SM CLR 26/24 A2996 RMK AO2 LTG DSNT SE THRU W=

⁷ As defined by the NWS and the FAA Aeronautical Information Manual (AIM) section 7-1-7 defines the following general flight categories based on weather conditions reported:

- 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.

VFR METAR KMLJ 052055Z AUTO 00000KT 10SM CLR 26/24 A2996 RMK AO2 LTG DSNT S AND SW=
VFR METAR KMLJ 052115Z AUTO 00000KT 10SM -RA SCT030 SCT037 SCT045 26/24 A2995 RMK AO2=
VFR METAR KMLJ 052135Z AUTO 00000KT 10SM SCT030 SCT037 SCT045 26/25 A2995 RMK AO2=
VFR METAR KMLJ 052155Z AUTO 00000KT 10SM -RA SCT031 SCT037 SCT049 26/24 A2995 RMK AO2
LTG DSNT S AND W=

The observations from KMLJ from 1215 through 1755 EDT reported lightning activity in the distant surrounding the station and reported thunderstorms and rain showers with temporary MVFR to IFR conditions between 1355 through 1435 EDT.

2.2 Greensboro, Georgia

The next closest weather reporting station to the accident site was Greene County Regional Airport (K3J7), Greensboro, Georgia, located approximately 19 miles northeast of the accident site at an elevation of 689 ft. The airport had an AWOS and issued observations every 20-minutes. The following conditions were reported surrounding the time of the accident.

Weather observation for K3J7 at 1515 EDT, automated, wind from 150° at 6 knots, visibility 10 miles or more, sky clear below 12,000 ft agl, temperature 25° C, dew point 22° C, altimeter 29.98 inches of Hg. Remarks: automated observation system with a precipitation discriminator, lightning distant east through southwest.

Weather observation for K3J7 at 1535 EDT, automated, wind from 180° at 5 knots, visibility 10 miles or more, scattered clouds at 900 ft agl, temperature 25° C, dew point 22° C, altimeter 29.98 inches of Hg. Remarks: automated observation system with a precipitation discriminator, lightning distant southeast and southwest.

The general flight categories and raw observations from approximately 1335 through 1635 EDT were as follows:

VFR METAR K3J7 051735Z AUTO 28003KT 10SM VCTSRA SCT070 BKN100 OVC120 22/21 A3001 RMK AO2
LTG DSNT ALQS=
VFR METAR K3J7 051755Z AUTO 00000KT 10SM SCT055 BKN100 OVC120 22/21 A2999 RMK AO2 LTG
DSNT SE THRU W=
VFR METAR K3J7 051815Z AUTO 00000KT 10SM -VCTSRA SCT075 OVC100 23/21 A2999 RMK AO2 LTG
DSNT E THRU SW=
VFR METAR K3J7 051835Z AUTO 22003KT 10SM -RA SCT033 SCT050 OVC100 23/21 A2999 RMK AO2 LTG
DSNT SE AND W=
VFR METAR K3J7 051855Z AUTO 22003KT 10SM SCT030 SCT042 SCT060 25/21 A2998 RMK AO2=
VFR METAR K3J7 051915Z AUTO 15006KT 10SM CLR 25/22 A2998 RMK AO2 LTG DSNT E THRU SW=

Accident 1922Z

VFR METAR K3J7 051935Z AUTO 18005KT 10SM SCT009 25/22 A2998 RMK AO2 LTG DSNT SE AND SW

VFR METAR K3J7 051955Z AUTO 21004KT 10SM CLR 25/22 A2998 RMK AO2 LTG DSNT SW=

VFR METAR K3J7 052015Z AUTO 16004KT 10SM CLR 25/22 A2998 RMK AO2 LTG DSNT SE AND W=

VFR METAR K3J7 052035Z AUTO 17003KT 10SM CLR 25/22 A2997 RMK AO2=

A review of the observations from K3J7 indicated that thunderstorms were reported in the vicinity of the airport between 1335 through 1435 EDT, with lightning being reported in the distant east through southwest at the time of the accident through 1555 EDT.

3.0 Sounding

To determine the vertical structure and state of the atmosphere over the accident site a High-Resolution Rapid Refresh (HRRR)⁸ numerical model data was retrieved from the NOAA Air Resources Laboratory and plotted on a standard Skew T log P diagram⁹ using the complete Rawinsonde Observation RAOB program software¹⁰. Figure 8 is the HRRR sounding for 1500 EDT from the surface to 250-hPa or approximately 34,000 ft.

The HRRR sounding estimated the surface elevation as 577 ft with a near surface temperature of 24° C (75° F), a dew point temperature of 22° C (72° F), with a relative humidity of 89%, and a density altitude of 2,038 ft. The lifted condensation level (LCL)¹¹ was at 1,424 ft, with the convective condensation level (CCL)¹² at 4,672 ft, and the level of free convection (LFC)¹³ at 4,815 ft. The precipitable water¹⁴ content was 1.86 inches and the atmosphere was characterized as conditionally unstable with a Lifted Index (LI)¹⁵ of -3 and a Convective Available Potential Energy (CAPE) of 1,327 Joules/kilogram. The freezing level was identified at 15,068 ft.

⁸ The HRRR is a National Oceanic and Atmospheric Administration (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 Skew T log P diagram – is a standard meteorological plot or thermodynamic diagram 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.

¹⁰ RAOB software – The complete RAwinsonde OBservation program is an interactive sounding analysis program developed by Environmental Research Services, Matamoras, Pennsylvania, for plotting and analyzing upper air data.

¹¹ Lifted Condensation Level (LCL) - the level at which a lifted parcel becomes saturated. The LCL height corresponds to cloud base height for forced ascent.

¹² Convective Condensation Level (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.

¹³ Level of Free Convection (LFC) - the last level where a parcel becomes buoyant, or "warmer" than the environmental temperature at the same level. The LFC represents the bottom of the layer containing CAPE.

¹⁴ Precipitable Water (PW) is a measure of the depth of liquid water at the surface that would result after precipitating all of the water vapor in a vertical column over a given location, usually extending from the surface to 300 mb.

¹⁵ Lifted Index (LI) - the difference between the lifted parcel temperature at 500 hPa and the 500 hPa temperature in the sounding. Negative values denote parcels that are warmer than the background 500 hPa temperatures and are thus buoyant or "unstable".

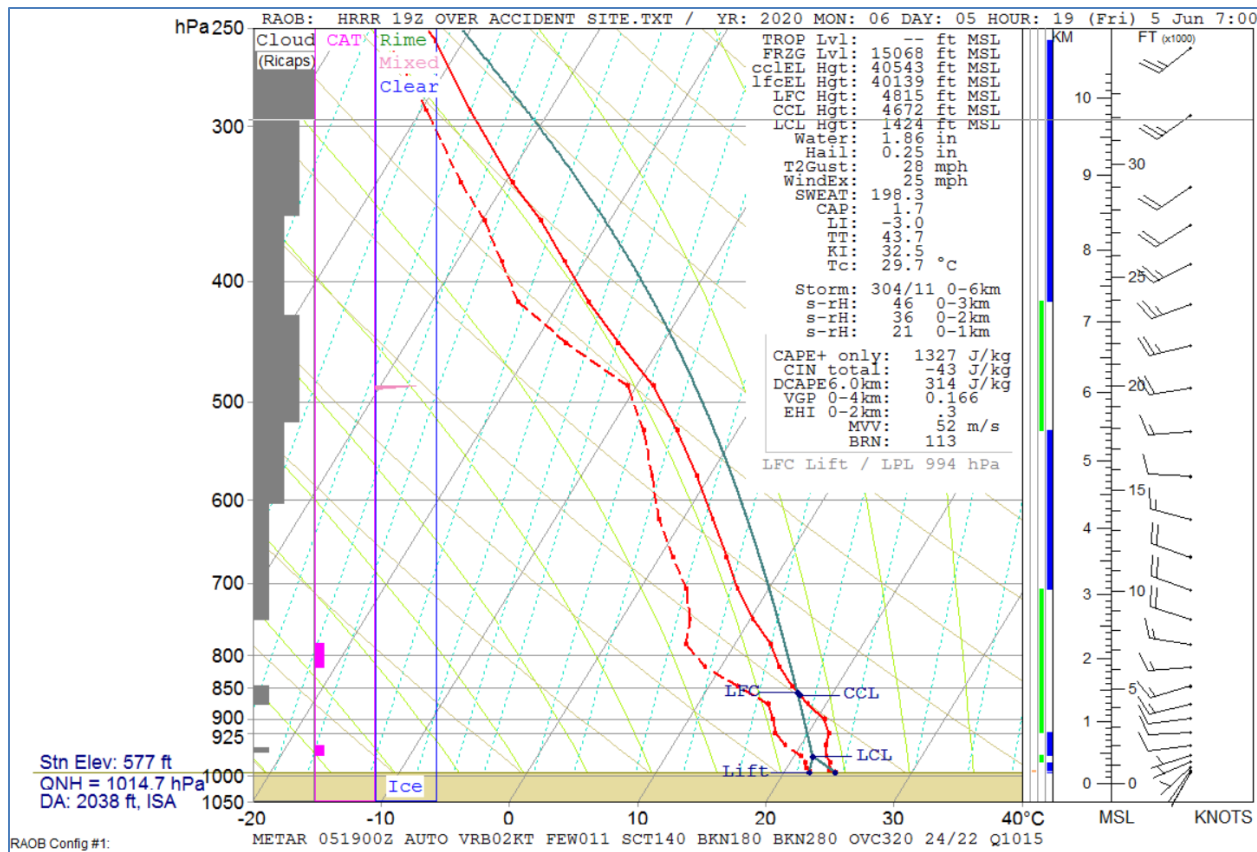


Figure 8 - HRRR numerical model sounding over the accident site for 1500 EDT

The HRRR 1500 EDT wind profile indicated light and variable surface wind, with winds from the south immediately above the surface veering to the west above 2,000 ft and then backing to the southwest at higher altitudes. The wind at 25,000 ft was from about 260° at 25 knots with a temperature of -20° C. The RAOB algorithm did not depict any strong vertical wind shears indicating any organized layers associated with clear air turbulence (CAT). The RAOB algorithm does not consider convectively induced turbulence (CIT), section 7.5 of this report will document the potential for CIT.

4.0 Satellite Imagery

The Geostationary Operational Environmental Satellite number 16 (GOES-16) imagery 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 (McIDAS) software. The infrared long wave and visible imagery were obtained for times surrounding the time of the accident, with the images closest to the time of the accident documented below. The infrared long wave imagery (band 13) at a wavelength of 10.3 microns (μm) provided radiative cloud top temperatures with a nominal spatial resolution of 2 km. The visible (band 2) at a wavelength of 0.64 μm provided images at a resolution of 0.5 km.

Figure 9 is the GOES-16 infrared at 2X magnification with a standard MB temperature enhancement curve applied to highlight the higher and colder cloud tops typically associated with deep convection. The accident site and several of the more defined cumulonimbus clouds are identified, and the surface features from 1500 EDT are also overlaid on the image. The infrared image depicted an area of high clouds associated with cumulonimbus anvil clouds over the accident site with a radiative cloud top temperature of -20°C , which for a saturated parcel would indicate cloud tops near 32,000 ft.

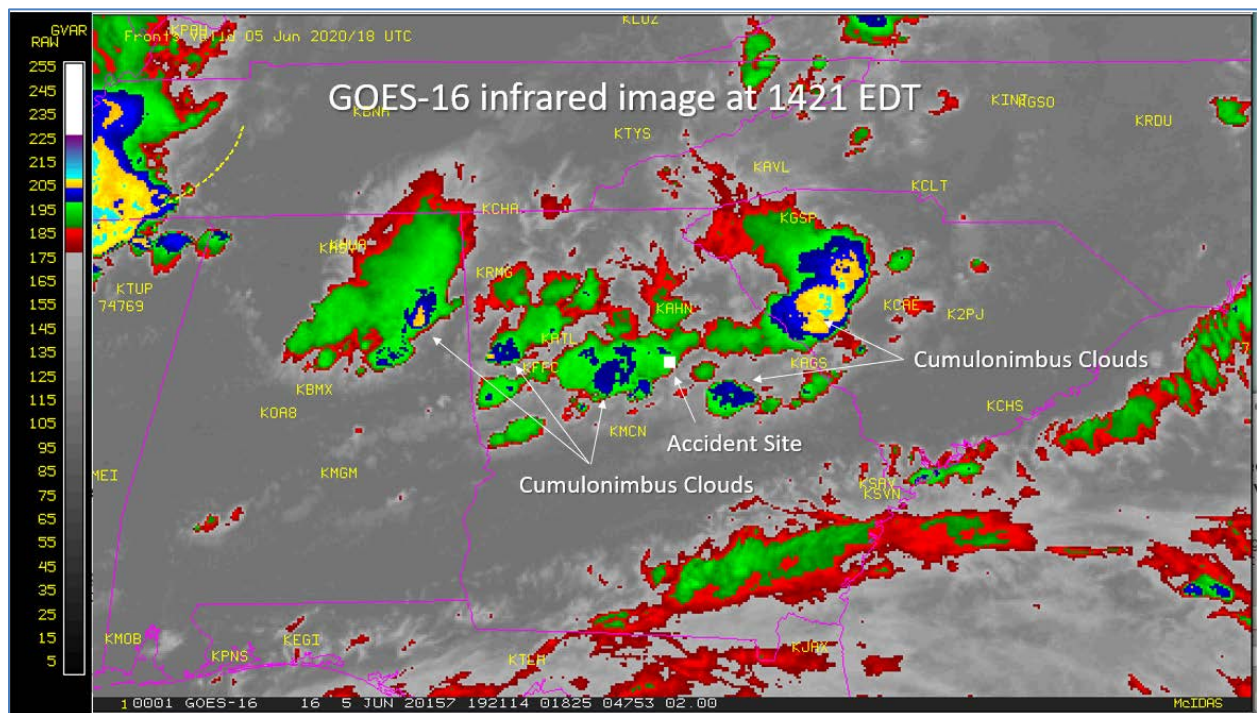


Figure 9 - GOES-16 infrared image at 1521 EDT with a MB temperature enhancement curve

Figure 10 is the GOES-16 visible image at 1521 EDT at 2X magnification at the higher resolution and depicts the main core of the cumulonimbus cloud immediately southwest in the vicinity of Macon, Georgia, with the cumulonimbus anvil extending over the accident site.

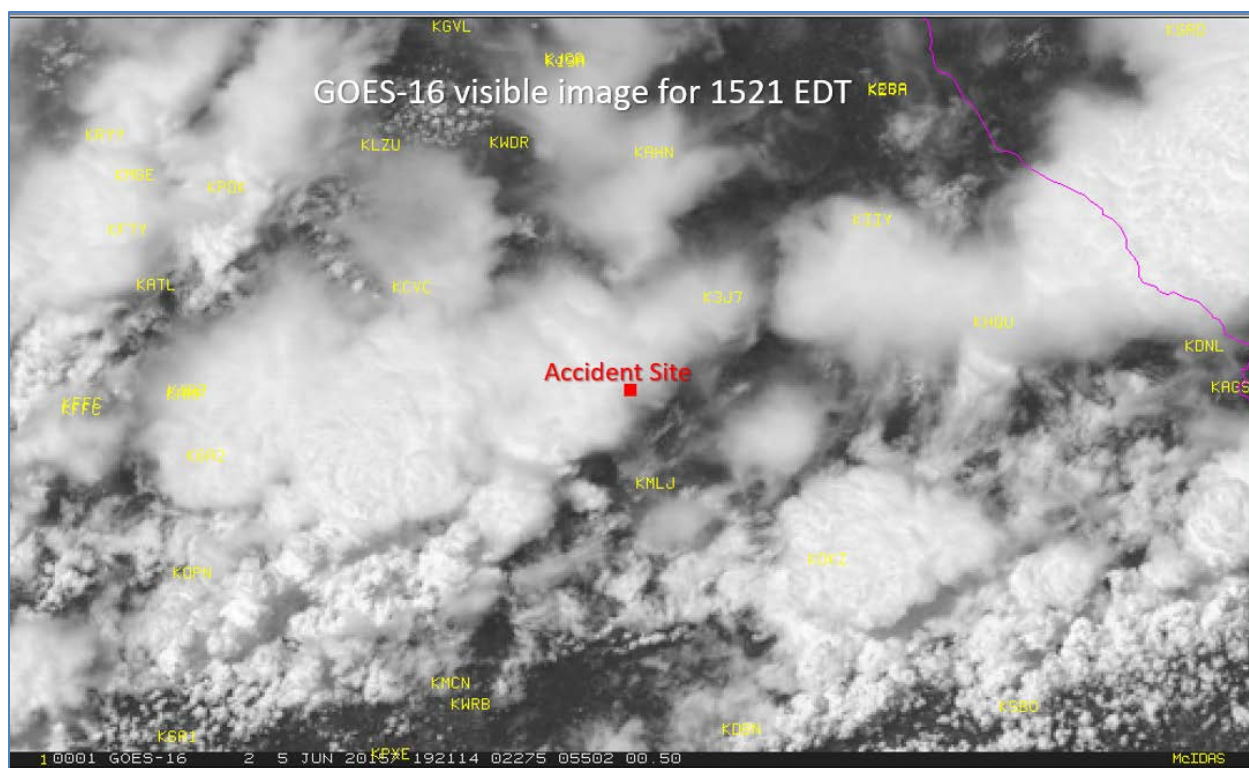


Figure 10 - GOES-16 visible image at 1521 EDT at 2X magnification

5.0 Weather Surveillance Radar Imagery

The NWS Atlanta-Peachtree City (KFFC), Georgia, Weather Surveillance Radar 1988 Doppler (WSR-88D)¹⁶ was located approximately 62 miles west of the accident site. The level II and III archive data were obtained from the NCEI using the Hierarchical Data Storage System and displayed using the NWS NEXRAD Interactive Viewer and Data Exporter software.

5.1 Volume Scanning Strategies

During the period, the KFFC WSR-88D was operating in the precipitation mode volume scan pattern 215 (VCP-215), where the radar makes 15 different elevation scans in 6 minutes. This is one of the most common scanning strategies and offers good low-level coverage and the most upper-level vertical sampling of the atmosphere of all the other scanning strategies. Figure 11 is a depiction of the VCP-215 scanning strategy.

¹⁶ The WSR-88D is a S-band 10-centimeter wavelength radar with a power output of 750,000 watts, with a 28-ft parabolic antenna concentrating the energy into a 0.95° beam width.

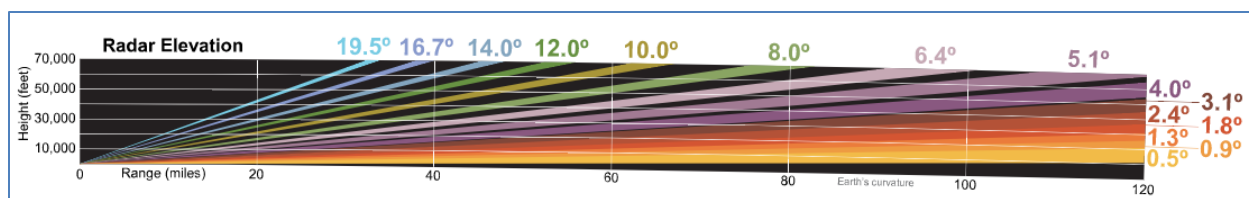


Figure 11 – Depiction of the VCP-215 scanning strategy by distance and height

Assuming a standard refraction¹⁷ of the KFCC WSR-88D radar beam at a distance of 62 miles from the accident site with an antenna height of 972 ft, based on calculations the 0.5° elevation scan was sampling the airspace between approximately 3,680 to 9,930 ft, with the center of the beam at 6,810 ft. While the KFCC WSR-88D 3.12° elevation scan depicted the conditions at the accident airplanes cruising level and sampled the airspace between 20,890 to 27,140 ft, with the center of the beam at 24,020 ft.

5.1 Reflectivity

Reflectivity is the measure of the efficiency of a target in intercepting and returning radio energy. With hydrometeors¹⁸, it is a function of the drop size distribution, number of particles per unit volume, physical state (ice or water), shape, and aspect. Reflectivity is normally displayed in decibels (dBZ¹⁹) and is a general measure of echo intensity. Figure 12 relates the NWS former video integrator and processor (VIP) intensity levels (1-6) versus the WSR-88D's display levels (0-15), precipitation mode levels by reflectivity in decibels (DBZ), and rainfall rates. Generally, reflectivity values over 15 dBZ result in precipitation reaching the surface.

¹⁷ Standard Refraction in the atmosphere is when the temperature and humidity distributions are approximately average, and values set at the standard atmosphere.

¹⁸ Hydrometeors are any product of condensation or sublimation of atmospheric water vapor, whether formed in the free atmosphere or at the earth's surface. 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 glaze ice.

¹⁹ dBZ - $10 \log Z_e$

NWS VIP/DBZ CONVERSION TABLE

NWS VIP	WSR-88D LEVEL	PREC MODE DBZ	RAINFALL
0	0	< 5	
	1	5 to 9	
	2	10 to 14	
1 Very Light	3	15 to 19	.01 in/hr
	4	20 to 24	.02 in/hr
	5	25 to 29	.04 in/hr
2 Light to Moderate	6	30 to 34	.09 in/hr
	7	35 to 39	.21 in/hr
3 Strong	8	40 to 44	.48 in/hr
4 Very Strong	9	45 to 49	1.10 in/hr
5 Intense	10	50 to 54	2.49 in/hr
6 Extreme	11	55 to 59	>5.67 in/hr
	12	60 to 64	
	13	65 to 69	
	14	70 to 74	
	15	> 75	

Figure 12 - NWS VIP levels, WSR-88D levels, reflectivity, and rainfall rates

The FAA has taken the NWS previous VIP levels 1 to 6 intensity levels and has redefined the intensity levels for pilots in Advisory Circular AC 00-24C - “Thunderstorm”. That AC further defines echoes less than 30 dBZ as “light” in intensity, “moderate” echoes 30-40 dBZ, “heavy” with echoes of >40-50 dBZ, and “extreme” intensity with echoes above >50 dBZ. These are the new standard radio phraseology terms used by air traffic controllers to describe weather conditions to pilots as shown in figure 13. With the exception that air route traffic control centers (ARTCC) primary weather display systems do not display light echoes less than 30 dBZ.

Reflectivity (dBZ) Ranges	Weather Radar Echo Intensity Terminology
< 30 dBZ	Light
30 – 40 dBZ	Moderate
>40 – 50 dBZ	Heavy
>50 dBZ	Extreme

Figure 13 – FAA reflectivity ranges and weather intensity terminology

5.2 Composite Reflectivity

The NWS KFFC WSR-88D composite reflectivity image at 1520:55 EDT is included as figure 14 with the flight track overlaid and the accident site. The image depicts the flight deviating between several heavy to extreme intensity echoes east and west of the flight track with light intensity echoes of 25 dBZ or less over the accident site. The individual elevation scans are shown in section 5.3.

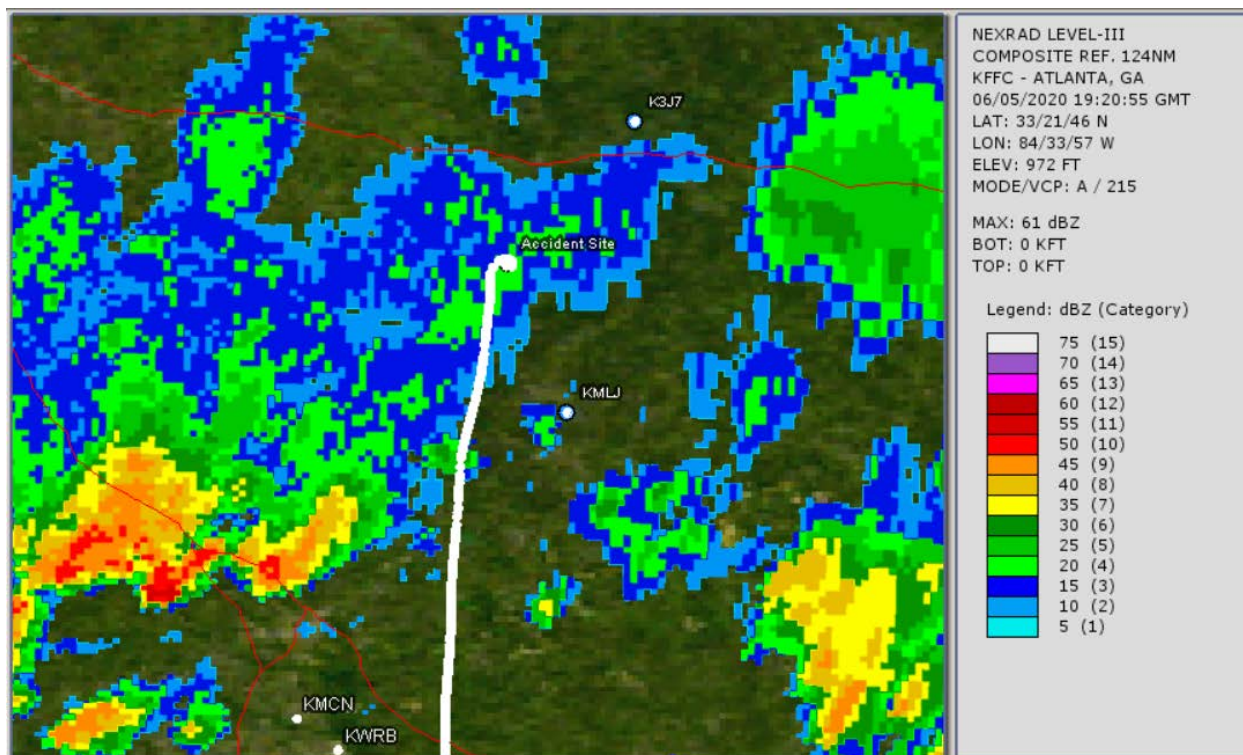


Figure 14 - KFFC WSR-88D Composite Radar image at 1520:55 EDT with the flight track overlaid

5.3 Base Reflectivity Images

The NWS WSR-88D base reflectivity images are the individual elevation scan images for the VCP being operated. The lowest 0.5° base reflectivity elevation scan is often the one radar product distributed by vendors and also available on NWS sites, unless the user has the analysis software to open and view all the VCP scanning strategy for storm structure and to identify other features. Figures 15 and 16 are the KFFC WSR-88D 0.5° and 3.12° base reflectivity images for 1520:55 EDT with the flight track overlaid.

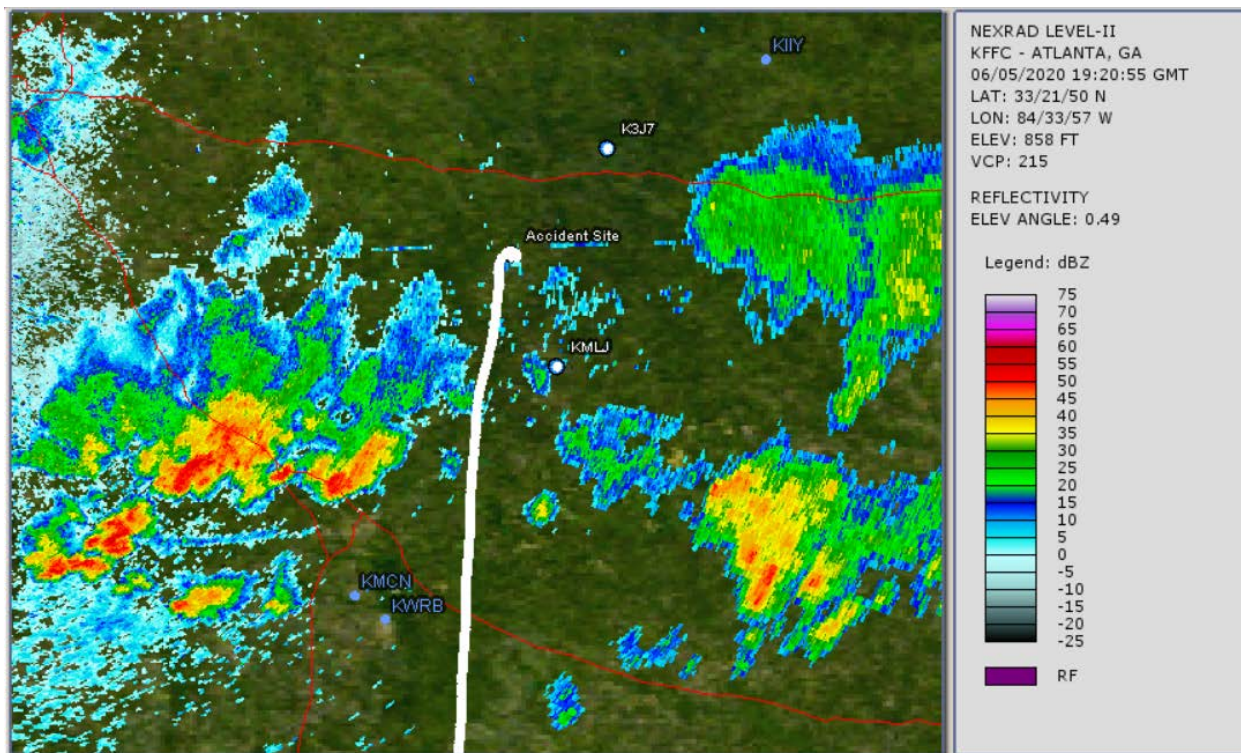


Figure 15 - KFCC WSR-88D 0.5° base reflectivity image at 1520:55 EDT with the flight track overlaid



Figure 16 - KFCC WSR-88D 3.12° base reflectivity image at 1520:55 EDT with the flight track overlaid

The KFCC 0.5° base reflectivity image for 1520:55 EDT (figure 15) depicted several extreme intensity echoes east and west of the flight track and echoes of 10 to 25 dBZ generally under the flight track. The flight track passed approximately 6 miles east and west of echoes over 30 dBZ as it was flying northward. Animation of the images indicate the echoes were moving eastward at 10 to 15 knots.

The KFCC WSR-88D 3.12° base reflectivity image for 1520:55 EDT (figure 16) depicted the accident airplane entering the trailing stratified portion of the complex into very light intensity echoes of 10 to 25 dBZ between 1517 through 1520 EDT, when the accident airplane is observed in a right descending spiral.

5.4 Echo Tops Image

The KFCC WSR-88D High Resolution Echo Tops (EET) product was also obtained, which provides the echo top information with a resolution of 0.54 miles X 1° in 1,000 ft intervals in the vertical. The height values provided are the highest sample volume of 18.5 dBZ. Echo top heights can differ significantly from visual cloud top heights, which can be thousands of feet higher than the echo tops.

Figure 17 is the KFCC WSR-88D Enhanced Echo Tops product for 1520:55 EDT with the flight track overlaid. The image depicted several echo tops in excess of 35,000 ft southeast and southwest of the flight track, with echo tops between 27,000 and 30,000 ft over the flight track during the last few minutes of flight and the accident site.

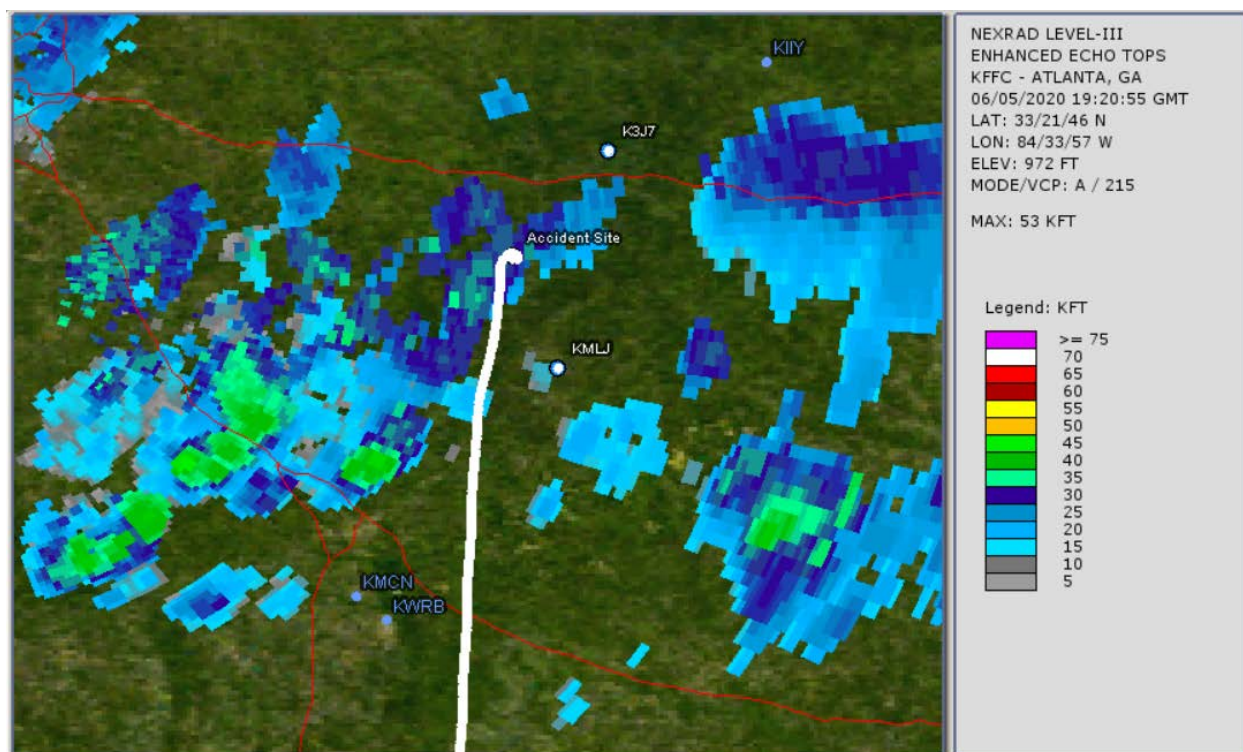


Figure 17 - KFCC WSR-88D Enhanced Echo Tops product for 1520:55 EDT with the flight track overlaid

5.5 Dual Polarization Products

The KFFC WSR-88D dual polarization products²⁰ were also reviewed for additional information regarding the type and characteristics of the hydrometeors over the flight track and accident site. Figure 18 is a combination of the KFFC WSR-88D 3.12° elevation scan of the base reflectivity (BR), differential phase (PHI)²¹, differential reflectivity (ZDR)²², and correlation coefficient (CC)²³ images at 1420:55 EDT with the flight track overlaid.

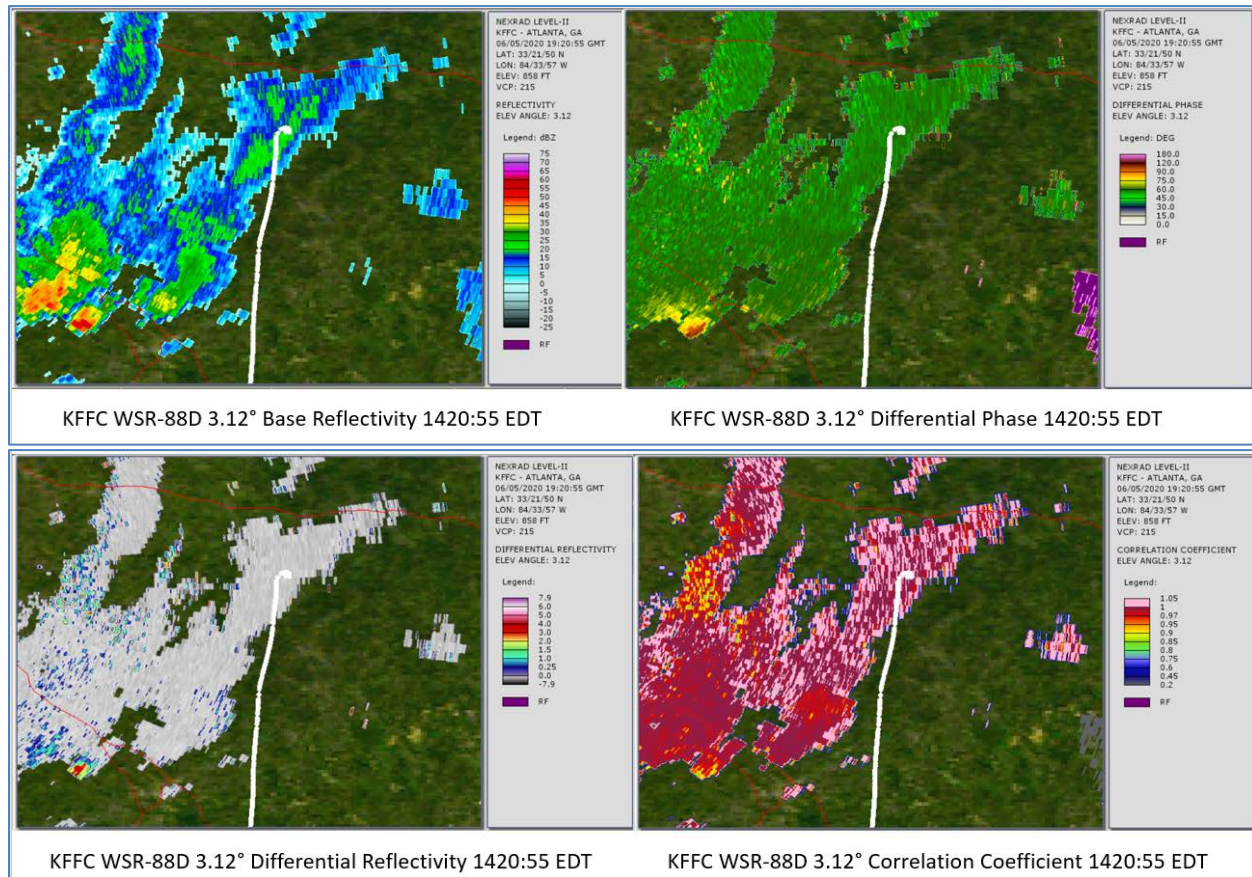


Figure 18 - KFFC WSR-88D 3.12° Base Reflectivity, Differential Phase, Differential Reflectivity, and Correlation Coefficient images for 1420:55 EDT with the flight track overlaid

²⁰ Dual polarization products include: Specific Differential Phase (KDP), Differential Reflectivity (ZDR), and Correlation Coefficient (CC).

²¹ Differential Phase (KDP) is a measure of the difference in 2-way attenuation for the horizontal and vertical pulses in a pulse volume. The differential phase provides information about the shape and concentration of radar targets.

²² Differential Reflectivity (ZDR) is the logarithm ratio of the horizontal power return to the vertical power return. Positive ZDR indicates that the dominant hydrometeors within the volume are larger in the horizontal than the vertical or large rain droplets. Negative values indicate dominant hydrometeors are larger in the vertical than the horizontal. Values near zero indicate that hydrometeors are similar in size in the vertical and horizontal and are an indication of hail or spherical rain droplets.

²³ Correlation Coefficient (CC) is a measure of how similar the horizontal and vertical returned pulse characteristics are among the all pulses in the sample WSR-88D volume. CC provides information about the diversity of hydrometeors within the volume and the values range from 0 to 1, with meteorological echoes tend to have CC values greater than 0.80.

A review of the KFFC WSR-88D dual polarization products for the 3.12° elevation scan supported that the echoes observed along the flight track were associated with hydrometeors associated with small spherical particles of liquid water droplets and ice crystals. Typically associated with stratified cloud regions with cumulonimbus clouds. The droplets based on the below freezing temperatures at that level whereby definition identified as supercooled liquid droplets. However, the lack of any large Zdr values implied low water mass in the returns, or not a lot of precipitation, or exceeding large droplet sizes. A NWS Meteorologist from the NEXRAD Radar Operations Center also reviewed the WSR-88D radar products and provided insight on the dual polarization products on July 23, 2020 in a teleconference. Their review of the KFFC WSR-88D products could not confirm or rule out the possibility of icing or SLD conditions, based on the radar data alone.

5.6 NWS FIS-B Composite Radar Mosaic

The NWS composite radar product used for the FAA Flight Information System Broadcast (FIS-B) for the period is included as figure 19, and also depicted light intensity echoes of 30 dBZ or less along the flight track. The radar data is from the NWS multi-radar/multi-sensor (MRMS) composite mosaic used by the NWS website distribution.

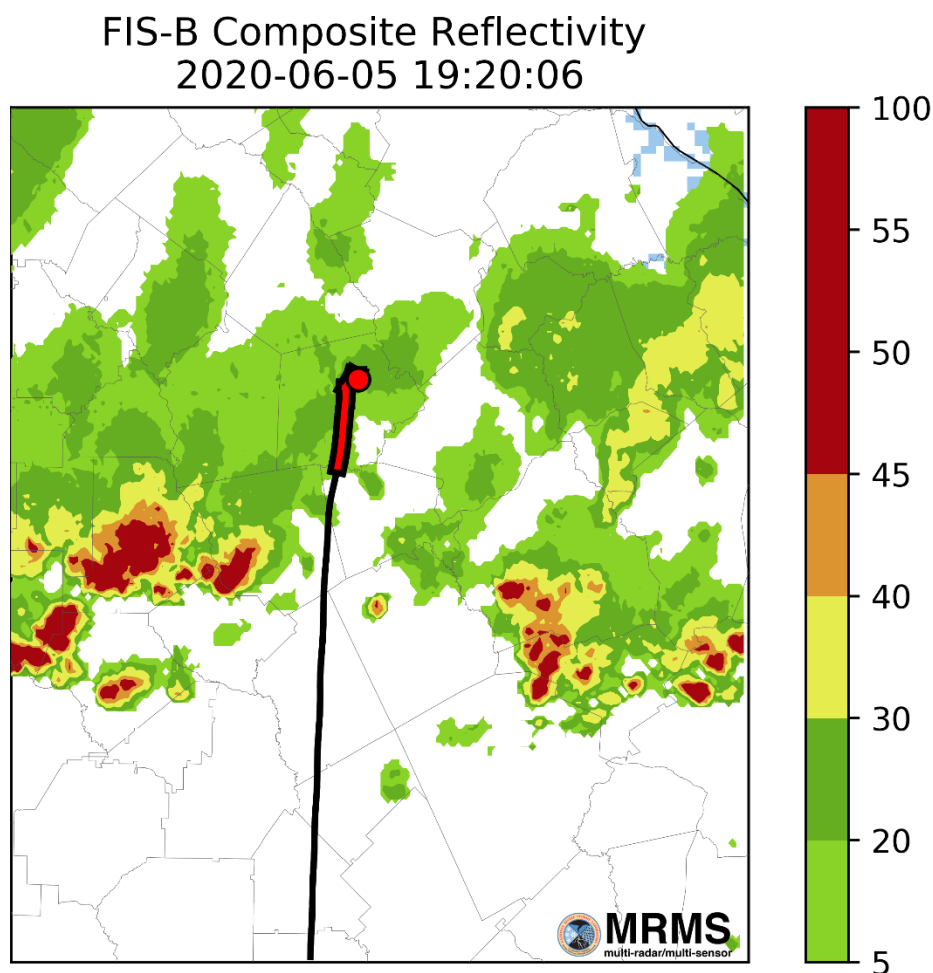


Figure 19 - NWS Composite Radar image at 1420 EDT used in the FIS-B

6.0 Lightning Data

A search of Earth Networks archive site for lightning information indicated that within a 30 mile radius of the accident site between 1445 through 1530 EDT there were no in-cloud or cloud-to-ground lightning strikes recorded. Beyond 30 miles, several of the intense cells southwest, southeast, and east of the accident site were noted of producing lightning flashes. The NWS also confirmed no light strikes in the immediate vicinity of the accident site in their review of the radar data.

7.0 Pilot Reports

The following pilot reports or PIREPs were recorded within 3 hours prior to and after the accident and within 150 miles of the accident site. The reports are provided in original format with abbreviations with time referenced to UTC, followed by a decoded report with detail of the aircraft type. All heights are in ft msl unless otherwise noted. The reports were as follows.

ATL UA /OV AHN045010/TM 1605/FL030/TP PAY2/SK BASES 030 CLR BELOW

Hartsfield-Jackson Atlanta International Airport (ATL), Atlanta, Georgia routine pilot report; Over – 045° azimuth and 10 miles from the Athens VORTAC²⁴ (AHN); Time – 1205 EDT; Altitude – 3,000 ft; Type aircraft – Piper Cheyenne; Sky cover – bases at 3,000 ft and clear below.

LGC UA /OV LGC360005/TM 1621/FL025/TP P28A/SK BKN035/WX FV07SM/TA 20/WV 28015KT/TB NEG/RM +RA 10NM NORTH AND WEST OF KLGC -RA 10NM NORTHEAST OF KLGC

LaGrange-Callaway Airport (LGC), Lagrange, Georgia routine pilot report; Over - Lagrange VORTAC (LGC); Time – 1221 EDT; Altitude – 2,500 ft; Type aircraft – Piper Cherokee; Sky cover – broken clouds at 3,500 ft; Weather – visibility 7 statute miles; Temperature – 20° C; Turbulence – negative; Remarks – heavy rain 10 miles north and west of KLGC, light rain 10 miles northeast of KLGC.

LZU UA /OV 3 MILE FINAL/TM 1812/FL015 /TP PA44

Gwinnett County Airport-Briscoe Field (LZU), Lawrenceville, Georgia routine pilot report; Over – 3 mile final from airport; Time – 1412 EDT; Altitude – 1,500 ft; Type aircraft – Piper Seminole.

JZP UA /OV KCNI/TM 1945/FL055/TP C172/TB NEG

Pickens County Airport (JZP), Jasper, Georgia routine pilot report; Over – Cherokee County Airport (CNI) Canton, Georgia; Time – 1545 EDT; Altitude – 5,500 ft; Type aircraft – Cessna Skyhawk; Turbulence – negative.

ATL UA /OV ATL145040/TM 2000/FL260/TP PC12/TB LGT - MOD CHOP/RM ZTLFD

ATL routine pilot report; Over – 145° azimuth and 40 miles from ATL VORTAC; Time – 1600 EDT; Flight Level²⁵ – 260; Type aircraft - Pilatus PC-12; Turbulence – light to moderate chop; Remarks – entered by Atlanta Center Flight Data (ZTLFD).

²⁴ A VORTAC is a radio-based navigational aid for aircraft pilots consisting of a co-located VHF omnidirectional range (VOR) beacon for azimuth data and a tactical air navigation system (TACAN) beacon for distance. Unless otherwise noted the name of the facility is collocated with the airport/city identifier.

²⁵ Flight Level - Level of surface of constant atmospheric pressure assuming a datum of 29.92 inches Hg., expressed in hundreds of feet; thus, if the actual atmospheric pressure is 29.92 inches Hg., FL220 indicates exactly 22,000 feet. If the actual atmospheric pressure is greater (or less) than 29.92 inches Hg., FL220 will be at an altitude correspondingly higher (or lower).

ATL UA /OV ATL160070/TM 2021/FL250/TP BE20/TB NEG/RM ZTLFD

ATL routine pilot report; Over – 160° azimuth and 70 miles from ATL VORTAC; Time – 1621 EDT; Flight Level – 250; Type aircraft – Beechcraft Super King Air; Turbulence – negative; Remarks – entered by ZTLFD.

SAV UA /OV SAV090040/TM 2055/FL360/TP B737/TB CONS LGT-MOD 360-375

Savannah/Hilton Head International Airport (SAV), Savannah, Georgia routine pilot report; Over – 090° azimuth and 40 miles from SAV VORTAC; Time – 1655 EDT; Flight Level – 360; Type aircraft – Boeing 737; Turbulence – continuous light to moderate turbulence between 36,000 to 37,500 ft.

ATL UA /OV ATL290017/TM 2223/FL090/TP B712/TB NEG/RM ZTLFD

ATL routine pilot report; Over – 290° azimuth and 17 miles from ATL VORTAC; Time – 1823 EDT; Altitude – 9,000 ft; Type aircraft – Boeing 717; Turbulence – negative; Remarks – entered by ZTLFD.

8.0 NWS Forecasts

8.1 Terminal Aerodrome Forecasts

The NWS Atlanta – Peachtree City (KFCC), Georgia Weather Forecast Office (WFO) was responsible for the issuance of the Terminal Aerodrome Forecast (TAF) and other local weather alerts for Eatonton, Putnam County, Georgia. The closest TAF was issued for Athens – Ben Epps Field (KAHN), Athens, Georgia located approximately 38 miles north of the accident site. A TAF is a concise statement of the expected meteorological conditions at an airport during a specified period (usually 24 hours). TAFs are valid for a 5 mile radius around an airport's center point. The forecast current at the time of the accident was issued at 1320 EDT and was as follows.

***TAF KAHN 051720Z 0518/0618 25008KT P6SM VCSH SCT040 BKN250
TEMPO 0519/0523 VRB15G25KT 4SM TSRA BKN030CB
FM060200 24003KT P6SM FEW040 SCT250
FM061000 27004KT P6SM SCT025 SCT250
FM061500 00000KT P6SM SCT035=***

The forecast current for KAHN from 1400 through 2200 EDT expected a wind from 250° at 8 knots, visibility 6 miles or more with rain showers in the vicinity, scattered clouds at 4,000 ft agl and ceiling broken at 25,000 ft, with a temporary period between 1500 and 1900 EDT of winds variable at 15 knots gusting to 25 knots, 4 miles visibility in thunderstorm and moderate rain, with a ceiling broken at 3,000 ft agl in cumulonimbus clouds.

8.2 Area Forecast Discussion

The NWS Area Forecast Discussions (AFD) are issued by each WFO to describe the short term weather conditions within their region with an aviation section that includes the general conditions as it relates to the creation of the TAF. These are useful for additional aviation-related issues that cannot be encoded into the TAF. The discussion also gives some reasoning behind the forecast. These are generated roughly every 6 hours and correspond to the release of the latest TAFs for that office. The long term and marine sections have been excluded. The forecast discussion issued at 1344 EDT was as follows.

FXUS62 KFFC 051744
AFDFFC
Area Forecast Discussion
National Weather Service Peachtree City GA
144 PM EDT Fri Jun 5 2020

...18Z Aviation Forecast Discussion...

.PREV DISCUSSION... /Issued 1047 AM EDT Fri Jun 5 2020/

UPDATE...

An area of initially weakening showers and thunderstorms associated with a shortwave swinging toward the Appalachians has recently begun intensifying as instability has begun to build. PoPs were adjusted upward as this activity moves through the Atlanta metro. Additional showers and thunderstorms are expected to develop through the afternoon as instability increases further.

RW

PREV DISCUSSION... /Issued 759 AM EDT Fri Jun 5 2020/

UPDATE...

Updated for the 12Z Aviation Discussion.

PREV DISCUSSION... /Issued 342 AM EDT Fri Jun 5 2020/

SHORT TERM /Today through Saturday/...

Ongoing and developing showers are the rule this morning across the northern tier as shortwave energy moves out of the Ohio Valley and into the Tennessee Valley. Highest pops will be there initially but as frontal boundary and aforementioned shortwave sags southward, likely pops will spread across the Atlanta metro through the afternoon hours.

Convergence along the front will allow for good mechanical lift and this will be combined with increased instability with CAPE values increasing to around 2000 J/KG. Some impressive DCAPE values to emerge this afternoon as well and would not be surprised to see some increased downburst potential with storms that develop later today.

Front sags south of the area for Saturday leading to quite a reduction in pops area wide. Warmer temps aloft will also allow for decreased instability and will only carry low end chance pops for much of the area although some mid range pops necessary for far southern zones as tropical moisture begins to increase.

Deese

.AVIATION...

18Z Update...

Scattered showers and thunderstorms will remain possible at TAF sites through 00z before coverage begins to diminish. Outside of shra/tsra, generally VFR cigs are expected with reductions in cigs/vsbys in and near convection. While VFR cigs are generally expected to prevail overnight, patchy fog and some potential for patchy low clouds cannot be ruled out. Winds will remain W at 5-10kts through the evening. Winds will become light and vrb by Saturday morning and into the day Saturday.

//ATL Confidence...18Z Update...Medium confidence on all elements.

RW

.PRELIMINARY POINT TEMPS/POPS...

Athens 85 69 89 69 / 70 50 30 10

Atlanta	85 70 88 69 / 60 40 30 20
Blairsville	79 64 85 64 / 60 40 30 20
Cartersville	86 67 90 68 / 60 30 20 20
Columbus	89 71 88 70 / 50 40 40 20
Gainesville	83 69 87 69 / 60 40 30 20
Macon	89 70 87 69 / 50 40 40 20
Rome	87 67 91 69 / 50 30 20 10
Peachtree City	86 68 88 68 / 60 40 30 20
Vidalia	90 73 88 71 / 50 40 40 20

.FFC WATCHES/WARNINGS/ADVISORIES...
NONE.

The discussion warned of possible rain showers and thunderstorms forming over the area during the afternoon with general VFR conditions expected to prevail at the airports, with a chance of rain showers and/or thunderstorms prior to 2000 EDT. No hazardous weather outside of normal air mass convection was expected and no advisories were current for the area. The high temperature for Athens was expected to be 85° F with a 70% probability of precipitation.

8.3 Graphic Forecast for Aviation

The NWS Graphic Forecast for Aviation (GFA) product replaced the Area Forecast and provides a graphical depiction of surface wind, weather, color coded general flight categories, and cloud cover bases and tops, with the Graphic-Airmen's Meteorological Information (G-AIRMET) for IFR conditions, mountain obscuration, icing conditions, and strong surface wind overlaid. The GFA is available at the NWS AWC website and through other weather briefing services. The GFA charts available prior to departure and valid during the period of the accident are included below.

Figure 20 is the GFA Surface Forecast issued at 1201 EDT and valid for 1400 through 1700 EDT. The chart depicted the expected surface wind, visibility, flight category, precipitation and weather from data output from the NWS Localized Aviation MOS²⁶ Product (LAMP), with any G-AIRMETs for IFR conditions expected for the period. The chart indicated westerly winds of 5 knots, with general unrestricted visibility with a greater than 50% chance of thunderstorms across Georgia. No G-AIRMETS for IFR or strong wind conditions were expected over the region during the period.

Figure 21 is the GFA Clouds Forecast issued at 1202 EDT and valid for the period between 1400 and 1700 EDT. The primary data are derived from the NWS Rapid Refresh (RAP) continental-scale NOAA hourly-updated assimilation modeling system run operational at NCEP to produce cloud layers, bases and tops. The forecast expected generally scattered clouds at 5,000 ft msl. A G-AIRMET for mountain obscuration was expected for northern Georgia into eastern Tennessee to the north of the accident site.

²⁶ Model Output Statistics (MOS) guidance.

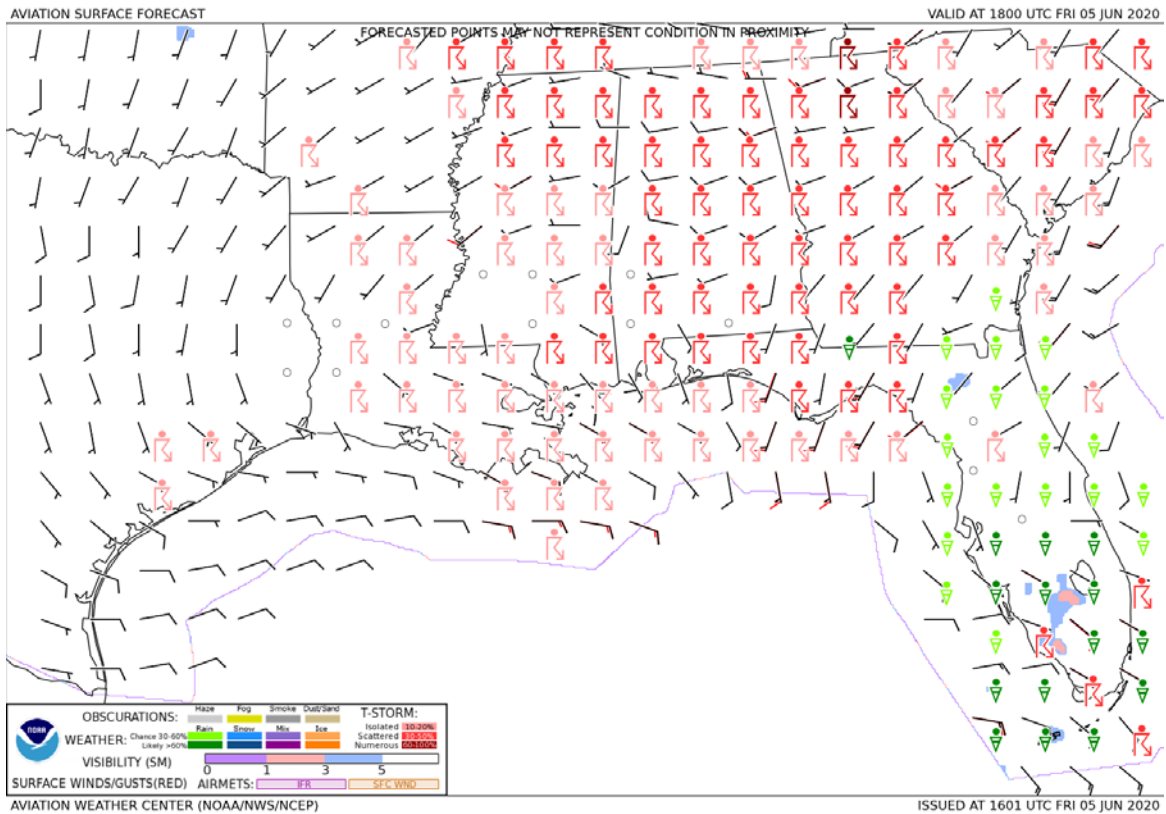


Figure 20 - Graphic Forecast for Aviation Surface Forecast issued at 1201 EDT and valid for 1400 EDT

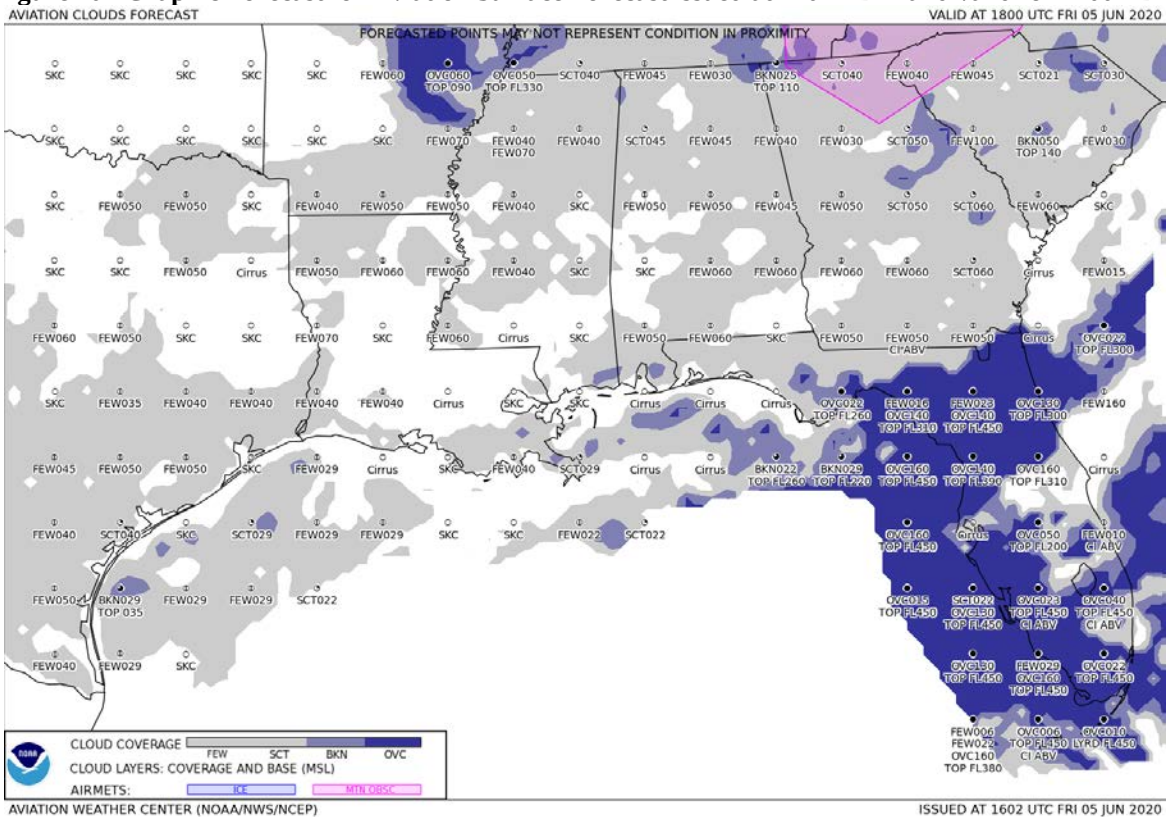


Figure 21 - Graphic Forecast for Aviation Cloud Forecast issued at 1202 EDT and valid for 1400 EDT

8.4 Current Icing Product

The Current Icing Product (CIP) and Forecast Icing Product (FIP) imagery are computer generated three dimensional analysis of information related to the likelihood of encountering icing conditions. Three primary products are generated by the NOAA NCEP and available for display on the NWS AWC website: icing probability, icing severity, and the probability of encountering supercooled large droplets (SLD). The CIP/FIP products graphics are automatically generated with no-human modifications. Information of icing is determined from observational data including WSR-88D radar, satellite, pilot reports, surface observations, lightning, and computer model output. The CIP represents the latest analysis of potential icing regions. The CIP/FIP are intended for flight planning purposes and situational awareness through graphical depiction of current and forecast icing conditions across an area or along a route of flight, and should always be used in combination with icing information from all available sources including AIRMETs, SIGMETs, and PIREPS.

The CIP/FIP icing severity provides information on expected icing severity as five categories: none, trace, light, moderate, and heavy (severe). According to the NCAR and AWC reference notes²⁷, the severity estimations are roughly based on the accretion rate of ice on an airplane, and the levels are determined by the time it would take for an airfoil to accrete 1/4 of an inch of ice: trace = 1 hour; light = 15 minutes to 1 hour; moderate = 5 to 15 minutes; severe = less than 5 minutes. The rates are estimated from the amount of supercooled liquid water expected with a nominal drop diameter of 15 μm , and are further tuned by nearby pilot reports of encountered severity. These are relative values and the use of which should take into account the airframe and the level of icing protection provided by the aircraft. Different aircraft and different flight configurations (airspeed, angle of attack, etc.) will experience variations in accretion rate, and these rates have been simulated for a range of aircraft and are a "broad brush" approach to severity prediction.

The NWS AWC CIP images were captured at the full continental scale depiction. NCAR was requested to re-run the CIP/FIP products over the region to gain a better insight on the potential icing conditions over the accident site. Figures 22-25 are the NCAR CIP images the general icing probability composite, and the specific icing products for FL250 valid on 1508 EDT on June 5, 2020 with the accident site noted by the black circle. The images depicted a general east-to-west band of icing conditions across central and northern Georgia with a 40-60% probability of encountering icing conditions at FL250, with a moderate to heavy severity, with a 40-50% probability of encountering SLD conditions.

²⁷ <https://www.aviationweather.gov/icing/help>

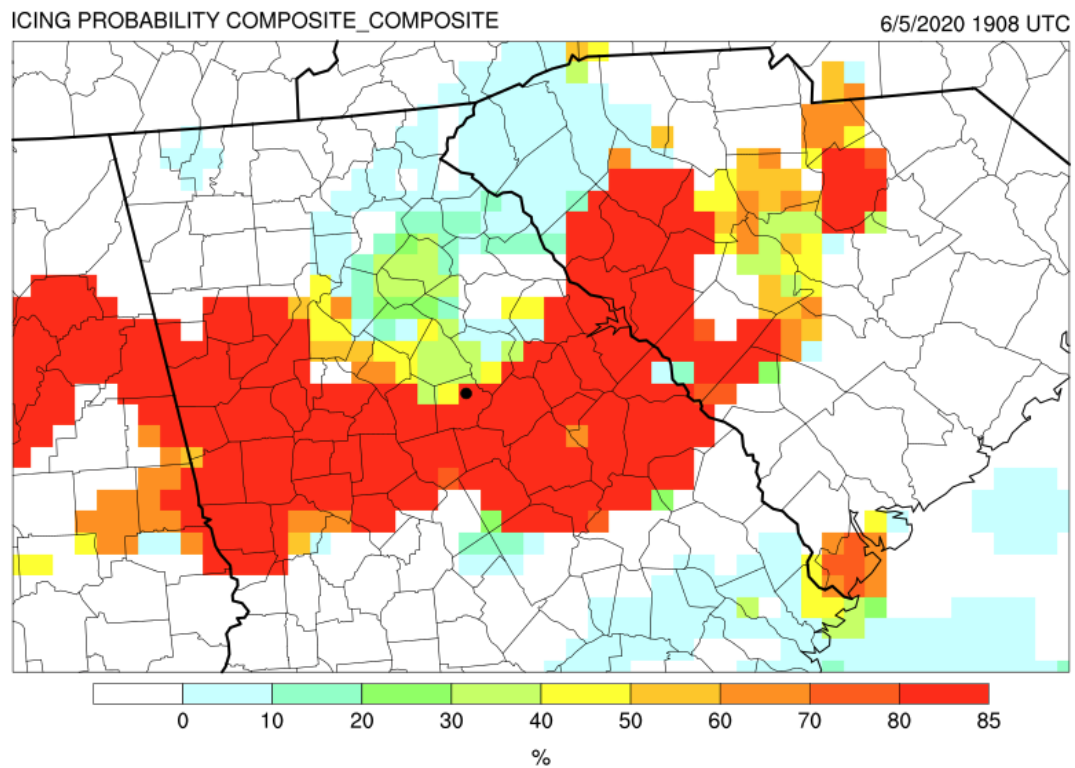


Figure 22 - NCAR Current Icing Product (CIP) icing probability composite for 1508 MST

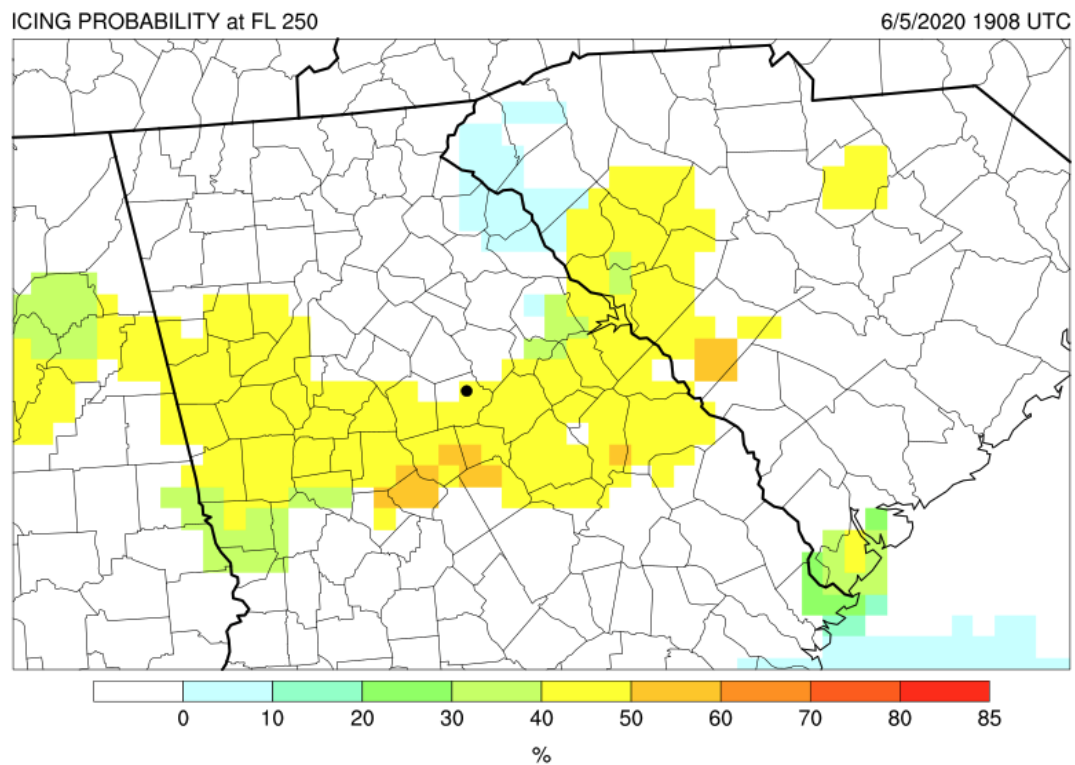


Figure 23 - Current Icing Product for 25,000 ft valid for 1508 EDT

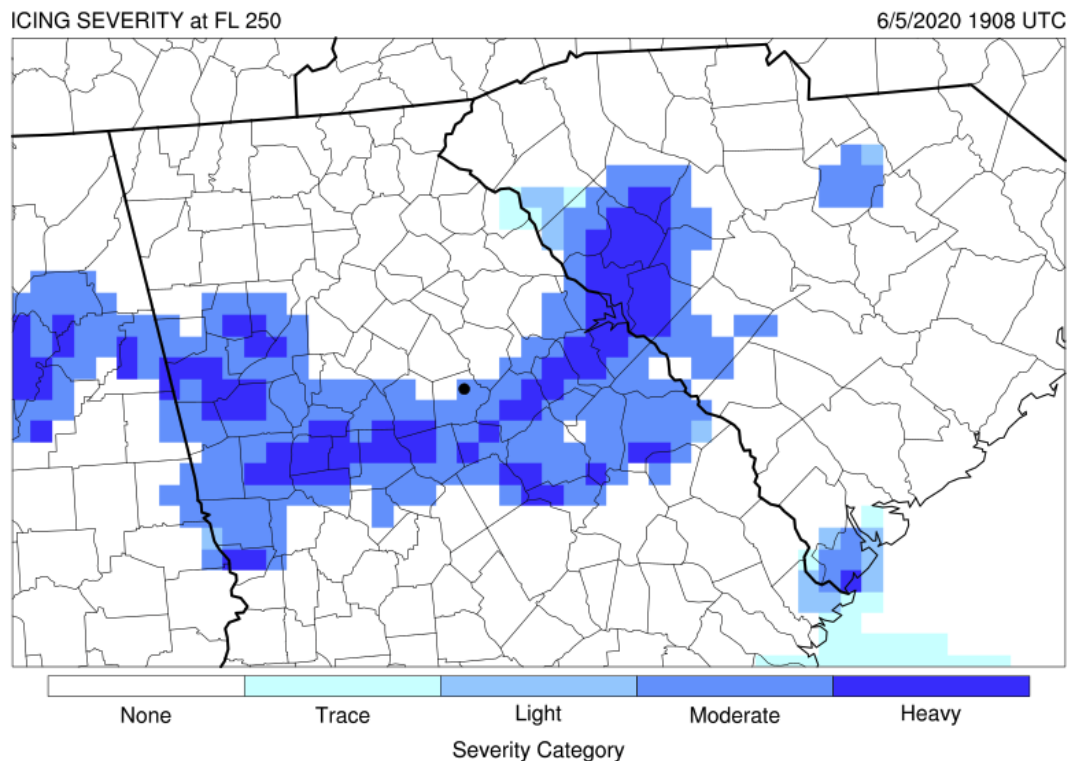


Figure 24 - CIP Severity product for 25,000 ft valid for 1508 EDT

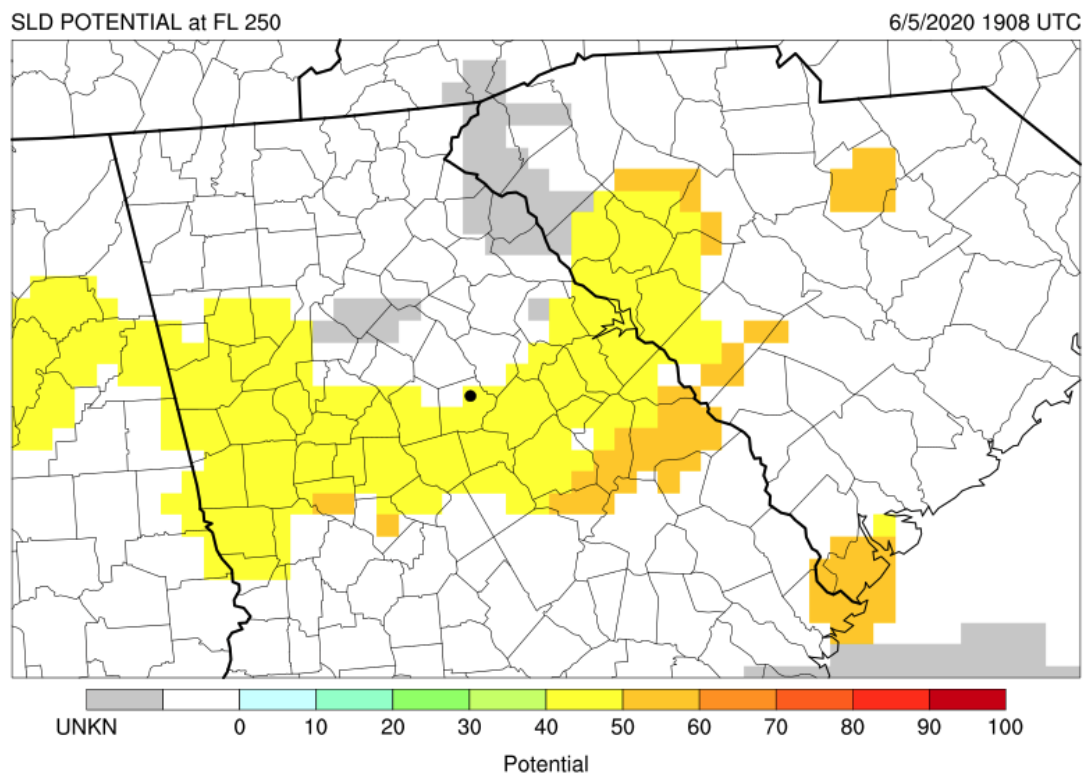


Figure 25 - CIP Super Large Droplet Probability for 24,000 ft valid for 1508 EDT

8.5 Graphic Turbulence Guidance

The Graphic Turbulence Guidance (GTG) was developed by the National Center for Atmospheric Research (NCAR) and is now run operationally at NOAA NCEP and is available to users on the AWC website from the surface to 45,000 ft. The current GTG version 3.0 model is generated from the NOAA Rapid Refresh (RAP) numerical model with a horizontal spacing of 13.5 kilometers with 50 vertical levels, and provides a computer-generated four-dimensional forecast related to the expected intensity of atmospheric turbulence provided in eddy dissipation rate (EDR). EDR ($\text{m}^{2/3} \text{s}^{-1}$) is aircraft independent and is the International Civil Aviation Organization (ICAO) standard for turbulence reporting. EDR varies from close to 0, “smooth”, to near 100 (1), “extreme” for most aircraft types. NCAR defines the following EDR values to various aircraft weight classes and turbulence intensities and is included as figure 24, the Piper Cheyenne fits the light-weight class category²⁸.

AC weight class	Estimated EDR Threshold * 100			
	Light	Moderate	Severe	Extreme
Light	13	16	36	64
Medium (Large)	15	20	44	79
Heavy	17	24	54	96

Figure 26 - Aircraft weight class and eddy dissipation rate (EDR) thresholds

While the current GTG model does not consider Convectively Induced Turbulence (CIT) associated with cumulus type clouds, a new version of the GTGN for “Nowcast” model uses a higher HRRR grid resolution which resolves convection better, adds convective induced turbulence (CIT) parameterization, includes in situ observations of EDR from aircraft, utilizes the WSR-88D reflectivity, spectrum width, and NEXRAD/NCAR Turbulence Detection Algorithm (NTDA), and produces a 3-dimensional mosaic of EDR with an update rate of 5-minutes, with a 2 km horizontal 3,000 ft vertical resolution. This new GTGN version 4 is being run at AWC in a demonstration and evaluation phase and plans to transition to operations in late 2020 to operational use and specifically addresses convectively induced turbulence.

The NCAR was contacted and requested to re-run the GTGN models for this case. The output is referenced to EDR values, which are further defined for a light category aircraft with the turbulence intensity in figure 25 which depicts values on a scale of 0 to 100. NCAR researchers have documented that moderate turbulence encounters are typically associated with EDR values between 18 and 36, severe between 37 and 64, and extreme with values over 65.

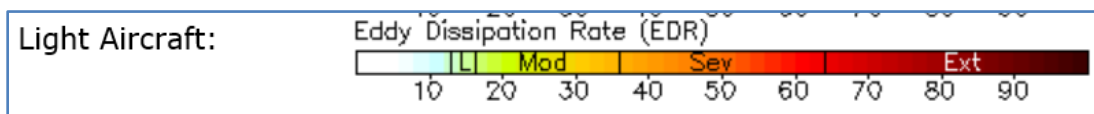


Figure 27 - Light Weight category EDR Thresholds for turbulence

²⁸ Light category aircraft – is defined as an aircraft with a maximum takeoff weight less than 15,500 pounds (examples include Cessna 320, Piper Cub, Learjet 23).

Figure 28 is the NCAR GTG-N model run for 1515 (left image) and 1530 EDT (right image) for 25,000 ft with the accident airplanes flight track overlaid. The images depicted EDR values of 10 to 30 along the flight track²⁹, which would be typically associated with light to moderate intensity turbulence.

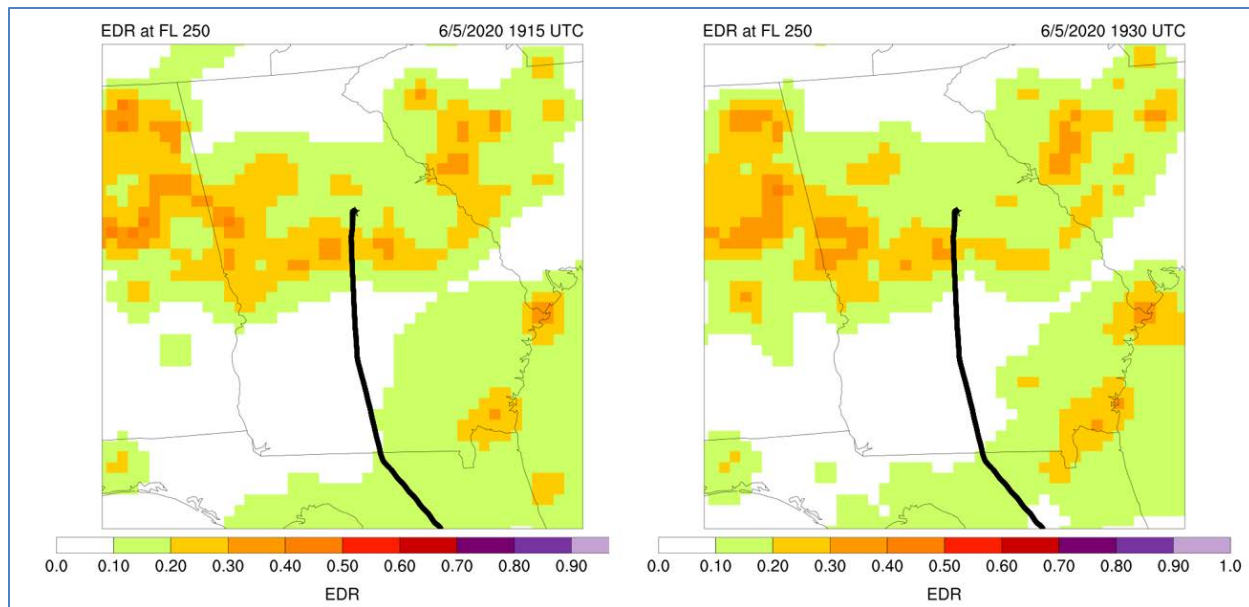


Figure 28 – NCAR GTG-N for 1515 and 1530 EDT for 25,000 ft with flight track overlaid

8.6 Winds and Temperature Aloft Forecast

The Winds and Temperature Aloft Forecast³⁰ (FD) current for the route of flight from Florida through Indiana from 3,000 ft through 39,000 ft valid for 1400 EDT and for use between 1000 and 1500 EDT were as follows. The forecast for 45,000 and 53,000 ft has been excluded.

WINDS ALOFT FORECASTS

DATA BASED ON 051200Z

VALID 051800Z FOR USE 1400-2100Z. TEMPS NEG ABV 24000

FT	3000	6000	9000	12000	18000	24000	30000	34000	39000
JAX	2613	2613+15	2514+10	2414+04	2214-06	2120-17	242532	265541	269053
TLH	2107	9900+15	3105+10	2806+05	2415-07	2320-17	252733	257040	248953
CSG	2308	2911+15	3013+09	2915+04	2711-07	2618-19	252534	242543	252952
ATL	2608	2814+15	2919+09	2824+05	2717-08	2520-19	242634	232644	242853
TYS	2514	2917+14	3018+10	2920+05	2823-07	2516-18	232634	223045	223556
TRI		2418+14	2619+09	2721+05	2624-07	2417-18	242334	222744	233156
LOU	9900	3414+16	3420+10	3420+05	2921-08	2922-20	281335	310845	340856
CVG	9900	3411+15	3416+10	3420+05	2816-08	2720-19	271335	281345	301256
IND	2405	3010+16	3114+10	3221+04	3023-09	2822-19	272236	292346	272457
FWA	2506	3010+14	3016+09	3021+03	2919-09	2720-20	262936	262746	284058

²⁹ EDR values in this display range from 0 to 1.0 previously multiplied by 100.

³⁰ Derived from FBUS31 KWN0 winds aloft bulletin.

The Atlanta (ATL) forecast location was the closest station to the accident site. The forecast for ATL for 24,000 ft expected a wind from 250° at 20 knots with a temperature of -19° C.

9.0 NWS Inflight Weather Advisories

Inflight Aviation Weather Advisories are forecasts to advise en route aircraft of development of potentially hazardous weather. Inflight aviation weather advisories in the conterminous U.S. are issued by the NWS AWC, as well as from the Center Weather Service Units (CWSU) associated with FAA ARTCCs. There are four basic types of inflight aviation weather advisories: the Significant Meteorological Information (SIGMET), the Convective SIGMET, the Airmen Meteorological Information (AIRMET), and the Center Weather Advisory (CWA). Inflight advisories serve to notify en route pilots of the possibility of encountering hazardous flying conditions which may not have been forecast at the time of the preflight briefing. Whether or not the condition described is potentially hazardous to a particular flight is for the pilot to evaluate on the basis of experience and the operational limits of the aircraft. The following advisories were current during the period.

During the period, the NWS AWC had a Convective SIGMET for thunderstorms and an AIRMET Tango for moderate turbulence over the area. There were no Atlanta CWA's or Meteorological Impact Statements (MIS) issued surrounding the period of the accident. The advisories were as follows.

9.1 Convective SIGMET

The NWS AWC issued Convective SIGMET 78E at 1455 EDT for an area of thunderstorms with tops above FL450, which was valid for a 2 hour period. The Convective SIGMET area was expected to move from 250° at 15 knots. The accident site was located within the boundaries of the advisory. The advisory implied the potential for severe to extreme turbulence, and severe icing associated with the thunderstorm activity. The advisory plotted over a GOES-16 visible satellite image with the accident site marked is included as figure 29 followed by the advisory in text form.

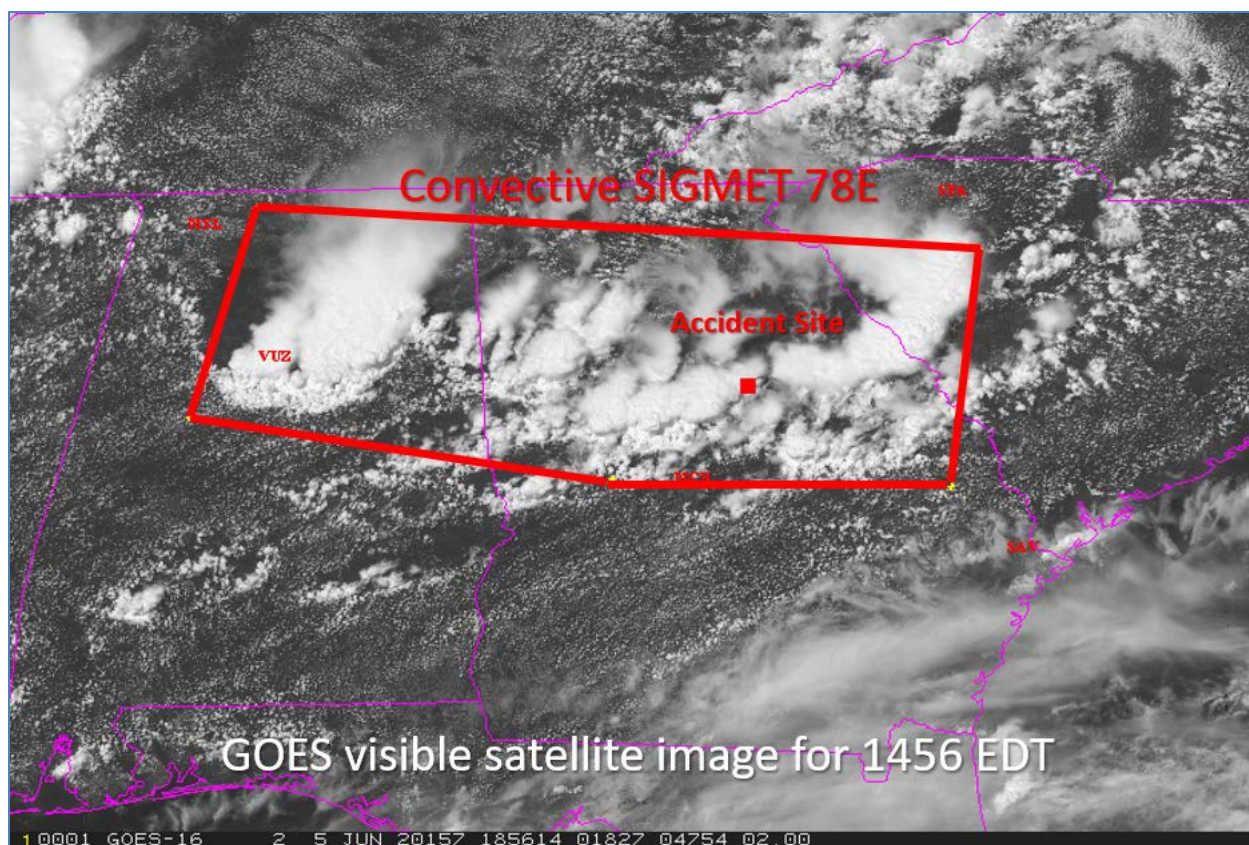
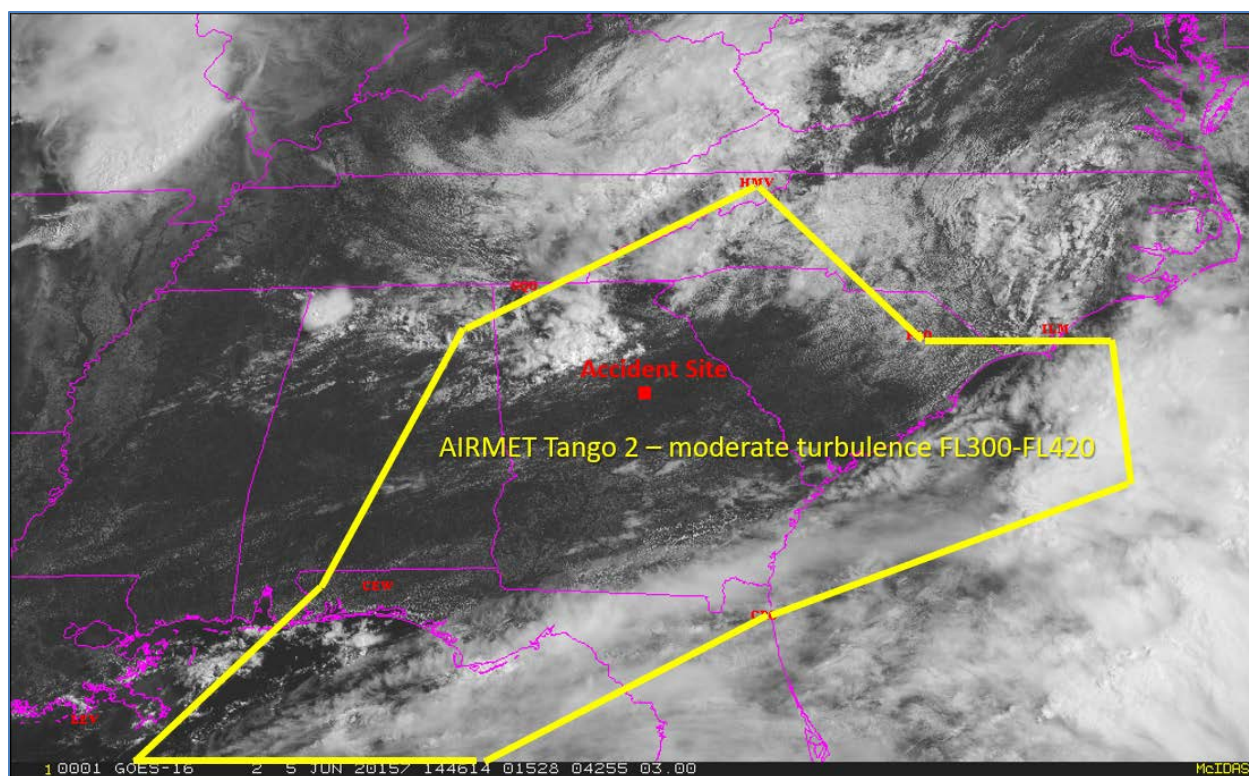


Figure 29 - GOES-16 visible image at 1456 EDT with Convective SIGMET 78E overlaid

WSUS31 KPCI 051855
 SIGE
 MKCE WST 051855
 CONVECTIVE SIGMET 78E
 VALID UNTIL 2055Z
 SC GA AL
 FROM 20ENE MSL-30SSE SPA-40NW SAV-30W MCN-40SW VUZ-20ENE MSL
 AREA TS MOV FROM 25015KT. TOPS ABV FL450.
 WRN PTN MOV FROM 29025KT.

9.2 AIRMETs

Figure 30 is a plot of AIRMET Tango update 2 over the GOES-16 visible satellite image at 1046 EDT at the approximate time of issuance of the advisory. The advisory warned of moderate turbulence between FL300 to FL420. The advisory was current through 1700 EDT and the conditions were expected to continue beyond 1700 through 2300 EDT.



AUS42 KKCI 051445
WA2T
MIAT WA 051445
AIRMET TANGO UPDT 2 FOR TURB VALID UNTIL 052100
.
AIRMET TURB...NC SC GA FL AND CSTL WTRS
FROM HMV TO FLO TO 40ESE ILM TO 140SSE ILM TO CRG TO 210S CEW TO
170SE LEV TO 130ESE LEV TO 40W CEW TO 50SW PZD TO GQO TO HMV
MOD TURB BTN FL300 AND FL420. CONDS CONTG BYD 21Z THRU 03Z.
....

AIRMET Zulu current during the period indicated that no icing conditions were forecast outside of convective activity.

WAUS42 KKCI 051445
WA2Z
MIAZ WA 051445
AIRMET ZULU UPDT 2 FOR ICE AND FRZLVL VALID UNTIL 052100
.
NO SGFNT ICE EXP OUTSIDE OF CNVTV ACT.
.
FRZLVL...RANGING FROM 135-155 ACRS AREA
....

10.0 Preflight Weather Briefing

The FAA Automated Flight Service Station (AFSS) contract provider Leidos had no contact with the pilot of the accident airplane for any services. A search of Foreflight indicated that the pilot did access their system for a route weather briefing (Attachment 1) with graphic images pulled and to file an IFR flight plan. The IFR flight plan was filed from Williston Municipal Airport (X60), Williston, Florida, to New Castle Henry County Airport/Marlatt Field (KUWL), New Castle, Indiana, with no alternate airport designated. The estimated time of departure was 1400 EDT, with an estimated time enroute of 2:36, at a planned cruising altitude of FL180. The fuel on board was provided as 5:20.

The weather briefing included the current Convective SIGMET 65E and 69E, with advisory 65E extending over central and northern Georgia, AIRMET Sierra for IFR conditions over northern Georgia, and AIRMET Tango for turbulence. The briefing also included the synoptic conditions with a surface analysis chart, METARs and TAFs along the proposed route of flight, the GFA Surface and Cloud forecast valid for 1100 EDT and 1700 EDT, wind forecast, and notice to airmen (NOTAM) for the route and selected airports. A radar summary type chart was not included in the briefing; but a real time radar layer that could be overlaid on the map page was available at times when the pilot had an active connection to the internet, or to a compatible ADS-B³¹ (or XM Weather) in-flight weather receiver.

The accident pilot also viewed several other static images such as the Convective Outlook, Surface Prognostic Charts, and Winds Aloft Charts.

11.0 Astronomical Conditions

The astronomical conditions for Eatonton, Putnam County, Georgia, were obtained from the United States Naval Observatory's Multiyear Interactive Computer Almanac (MICA) software. The time of the accident has been added for reference in *italic bold type*.

<u>Sun</u>	
Begin of civil twilight	0558 EDT
Sunrise	0627 EDT
Sun transition	1333 EDT
<i>Accident</i>	<i>1522 EDT</i>
Sunset	2040 EDT
End civil twilight	2108 EDT

At the time of the accident the Sun was at an elevation or altitude of 63.57° above the horizon at an azimuth of 253°.

³¹ ADS-B stands for Automatic Dependent Surveillance-Broadcast that provides pilots the ability to display weather, traffic, and other data on cockpit displays, or wireless on a tablet.

12.0 Weather References

FAA advisory circular AC 00-6B “Aviation Weather” is one of the primary pilot references and is listed as required knowledge in FAA airmen test guides. Chapter 18 covers icing and discusses supercooled large droplets (SLD) and clear icing. Section 18.3.6 states the following:

Icing in Cumuliform Clouds. *The icing layer in cumuliform clouds is smaller horizontally, but greater vertically than in stratiform clouds. Icing is more variable in cumuliform clouds because many of the factors conducive to icing depend on the particular cloud’s stage of development. Icing intensities may range from a trace in small cumulus to severe in a large towering cumulus or cumulonimbus. Although icing occurs at all levels above the freezing level in a building cumuliform cloud, it is most intense in the upper portion of the cloud where the updraft is concentrated and SLDs are plentiful. Icing can extend to great heights in towering cumulus and cumulonimbus where strong updrafts allow SLDs to exist at temperatures as cold as -40 °C. Icing in a cumuliform cloud is usually clear or mixed with rime in the upper levels.*

AC 00-06B Chapter 19 discusses thunderstorms development and hazards. Section 19.6.5 on the hazard of thunderstorm with regards to icing, which states the following:

Icing. *Thunderstorms produce abundant supercooled liquid water above the freezing level. When temperature in the upward current cools to about -15 °C, much of the remaining water vapor sublimates as ice crystals; and above this level, the amount of supercooled water decreases. However, supercooled water can exist at temperatures as cold as -40 °C in the presence of vigorous upward vertical motion, such as in a thunderstorm updraft.*

Supercooled water freezes on impact with an aircraft. Clear icing can occur at any altitude above the freezing level, but at high levels, icing may be rime or mixed rime and clear. The abundance of supercooled water makes clear icing very rapid between 0 °C and -15 °C, and encounters can be frequent in a cluster of cells. Thunderstorm icing can be extremely hazardous.

This hazard is also repeated in FAA advisory circular AC 00-45C “Thunderstorms” notes that severe icing is implied in all thunderstorms, and warns of the hazard of supercooled large water droplets between 0° to -15° C, which can lead to hazardous clear icing conditions.

F. LIST OF ATTACHMENTS

Attachment 1 – Foreflight Weather Document and graphics accessed prior to flight

Submitted by:

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