NATIONAL TRANSPORTATION SAFETY BOARD

Office of Aviation Safety
Washington, D.C. 20594

November 7, 2019

Factual Report

METEOROLOGY

CEN19FA072

Table Of Contents

A. ACCIDENT

Location: Zaleski, Ohio
Date: January 29, 2019
Time: 0651 eastern standard time
1151 Coordinated Universal Time (UTC)
Aircraft: Bell 407; Registration: N191SF

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 traveled to Arkansas to gather factual evidence from Viking Aviation[1] doing business as Survival Flight (SF) for this investigation and also 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 standard time (EST) on January 29, 2019, and are based upon the 24-hour clock, where local time is -5 hours from UTC, and UTC=Z (unless otherwise noted). Directions are referenced to true north and distances in nautical miles. Heights are above mean sea level (msl) unless otherwise noted. Visibility is in statute miles and fractions of statute miles. 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 39.3242° N, longitude 82.3095° W, with an approximate elevation of 940 feet (ft).

[1] For the remainder of the report the operator will be referred to as Survival Flight (SF).

D. WEATHER INFORMATION

1.0 Synoptic Situation

The synoptic or large scale migratory weather systems influencing the area were documented using standard NWS charts issued by the National Center for Environmental Prediction and the Weather Prediction Center, located in College Park, Maryland. These are the base products used in describing synoptic weather features and in the creation of forecasts and warnings for the NWS. Reference to these charts can be found in the joint NWS and Federal Aviation Administration (FAA) Advisory Circular "Aviation Weather Services", AC 00-45H.[2]

1.1 Surface Analysis Chart

The Ohio Valley section of the NWS Surface Analysis Chart for 0700 EST is provided as figure 1 with the location of the accident site located within the red circle. The chart identified two surface low pressure centers located over Ontario, Canada, and Upper Michigan with sea-level pressures of 999- and 1004-hectopascals (hPa), associated with occluded frontal systems. A cold front associated with the low over Ontario, Canada, extended south-southwestward from Lake Erie into New York, Pennsylvania, West Virginia, into western Virginia and North Carolina. The accident site was located on the cold air side behind the front.

The station models around the accident site depicted air temperatures in the range of 18 to 23 degrees Fahrenheit (°F), dew point temperatures around 10 °F with temperature-dew point spreads of 10° F, a west wind of 10 to 15 knots, overcast cloud cover, and light snow reported at Columbus, Ohio, to the west of the accident site.

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

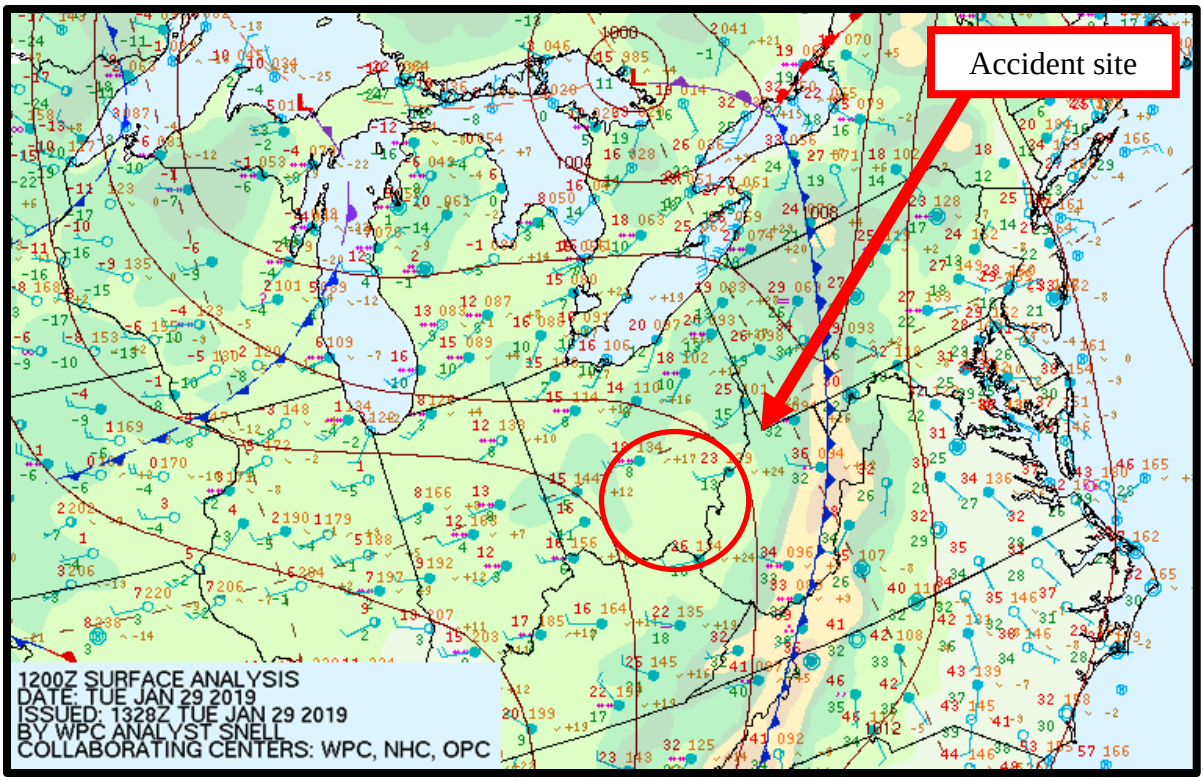

Figure 1 – NWS Surface Analysis Chart for 0700 EST

1.2 Upper Air Charts

The NWS Storm Prediction Center (SPC) Constant Pressure Charts for 0700 EST at 925-, 850-, 700-, 500-, and 300-hPa are presented in figures 2 through 6. There was a low-level trough[3] located over and eastern of the accident site (figures 2 and 3) at 925- and 850-hPa. Troughs can act as lifting mechanisms to help produce clouds and precipitation if sufficient moisture is present. There were also mid-level troughs located west and northeast of the accident site at 700-hPa (figure 4). There was a west wind to 20 knots at 925-hPa above the accident site with the wind becoming southwesterly by 700-hPa (figure 4) and a wind speed of 50 knots. By 300-hPa, the wind above the accident site was from the south-southwest and the wind speed increased to between 90 to 120 knots (figure 6).

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

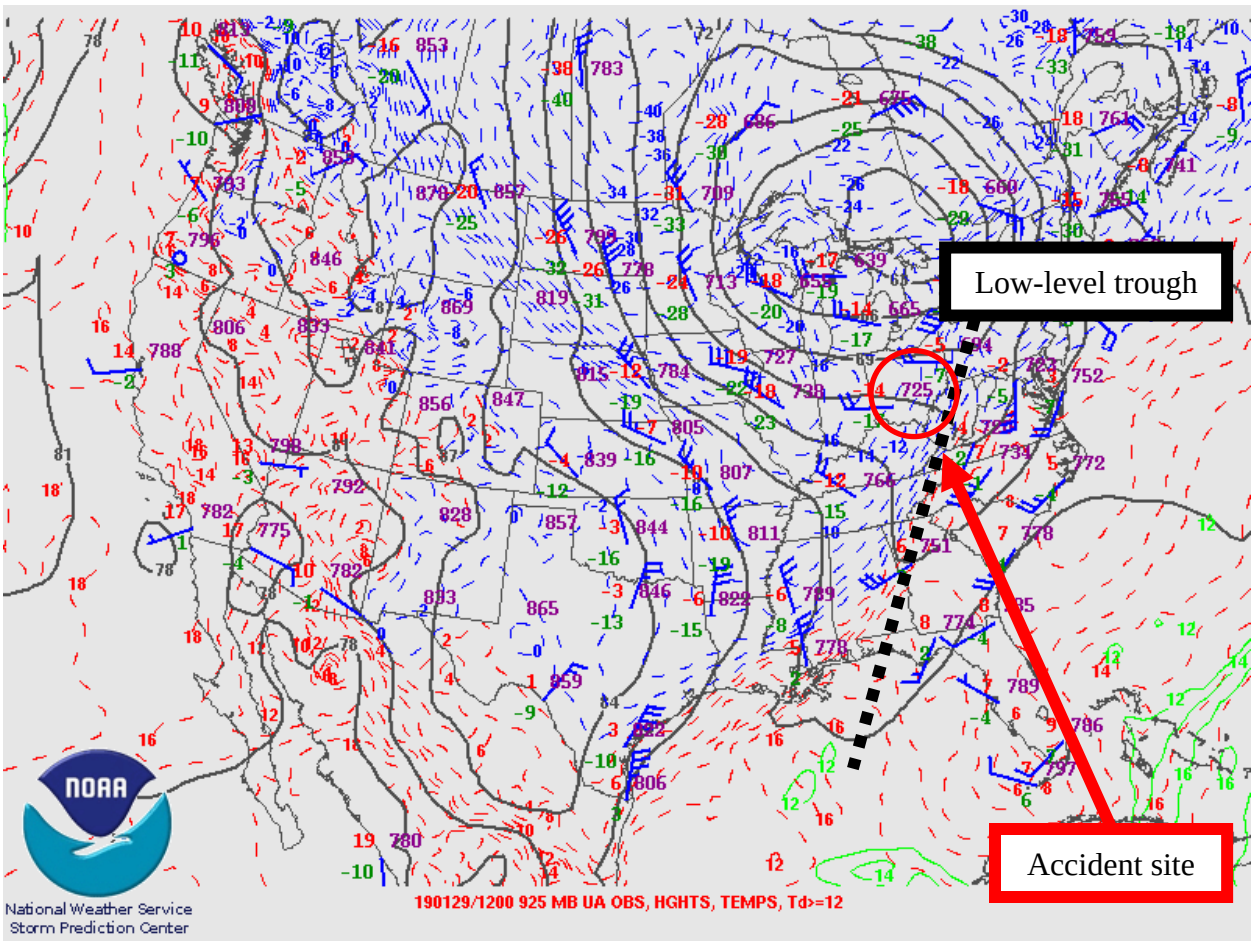

Figure 2 – 925-hPa Constant Pressure Chart for 0700 EST

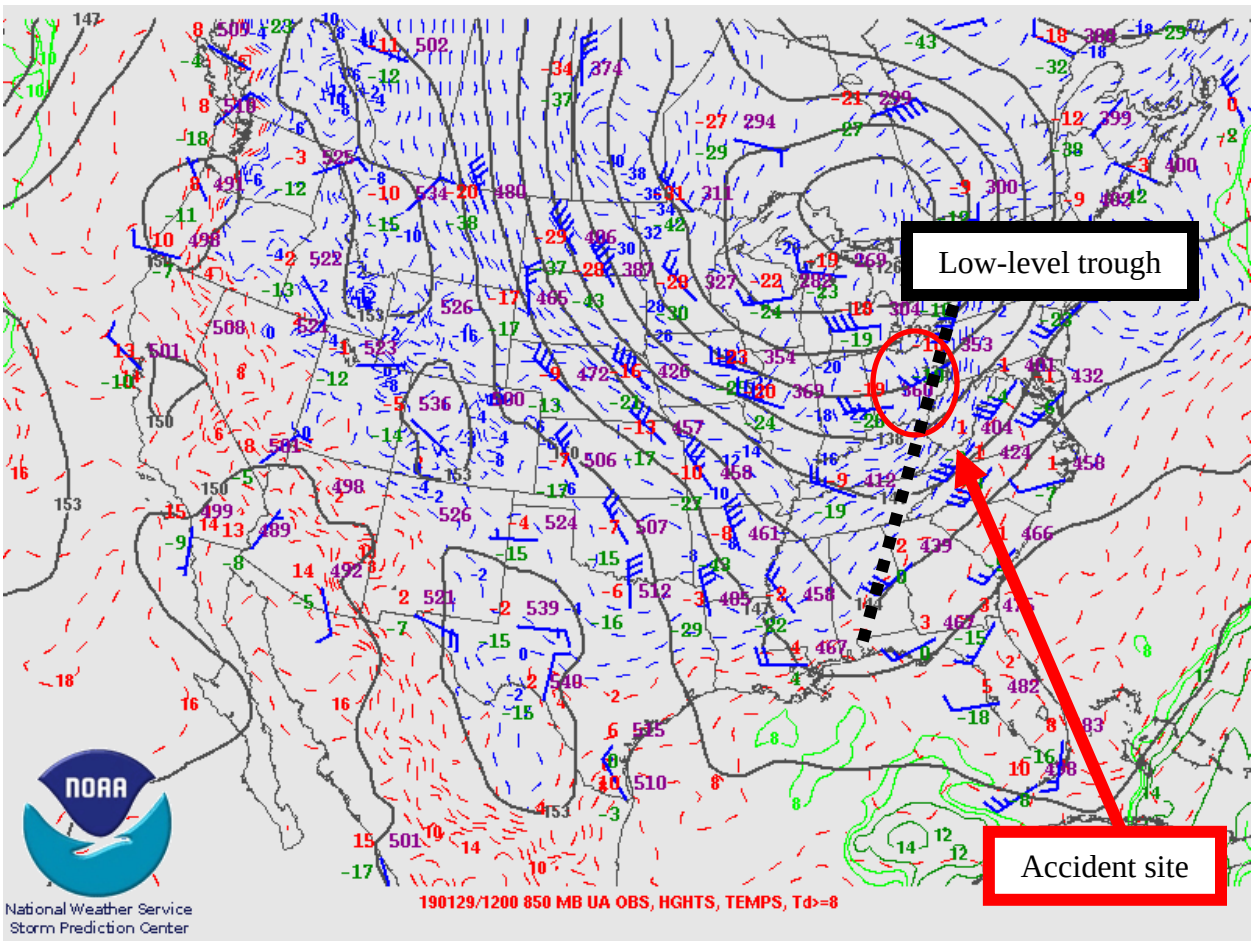

Figure 3 – 850-hPa Constant Pressure Chart for 0700 EST

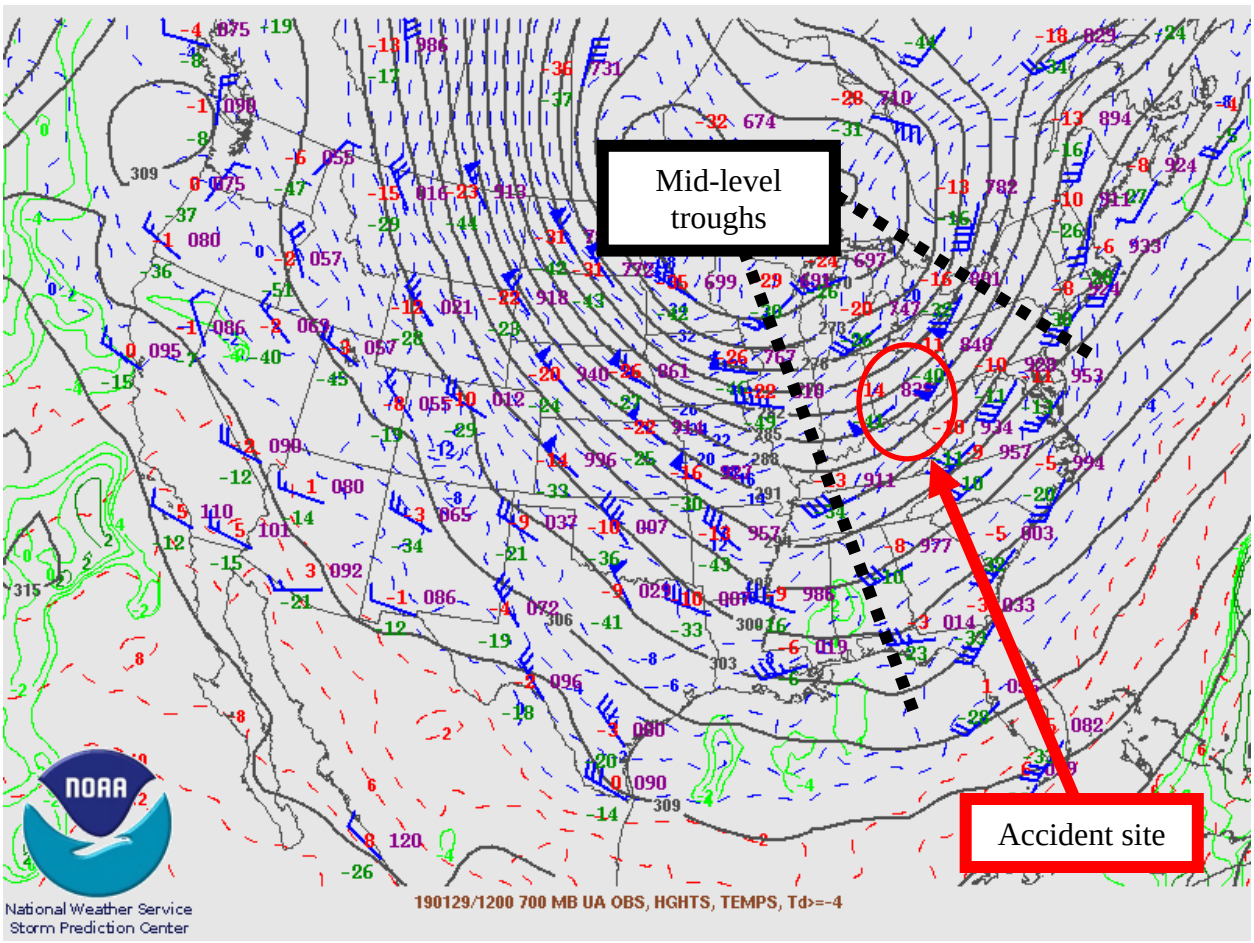

Figure 4 – 700-hPa Constant Pressure Chart for 0700 EST

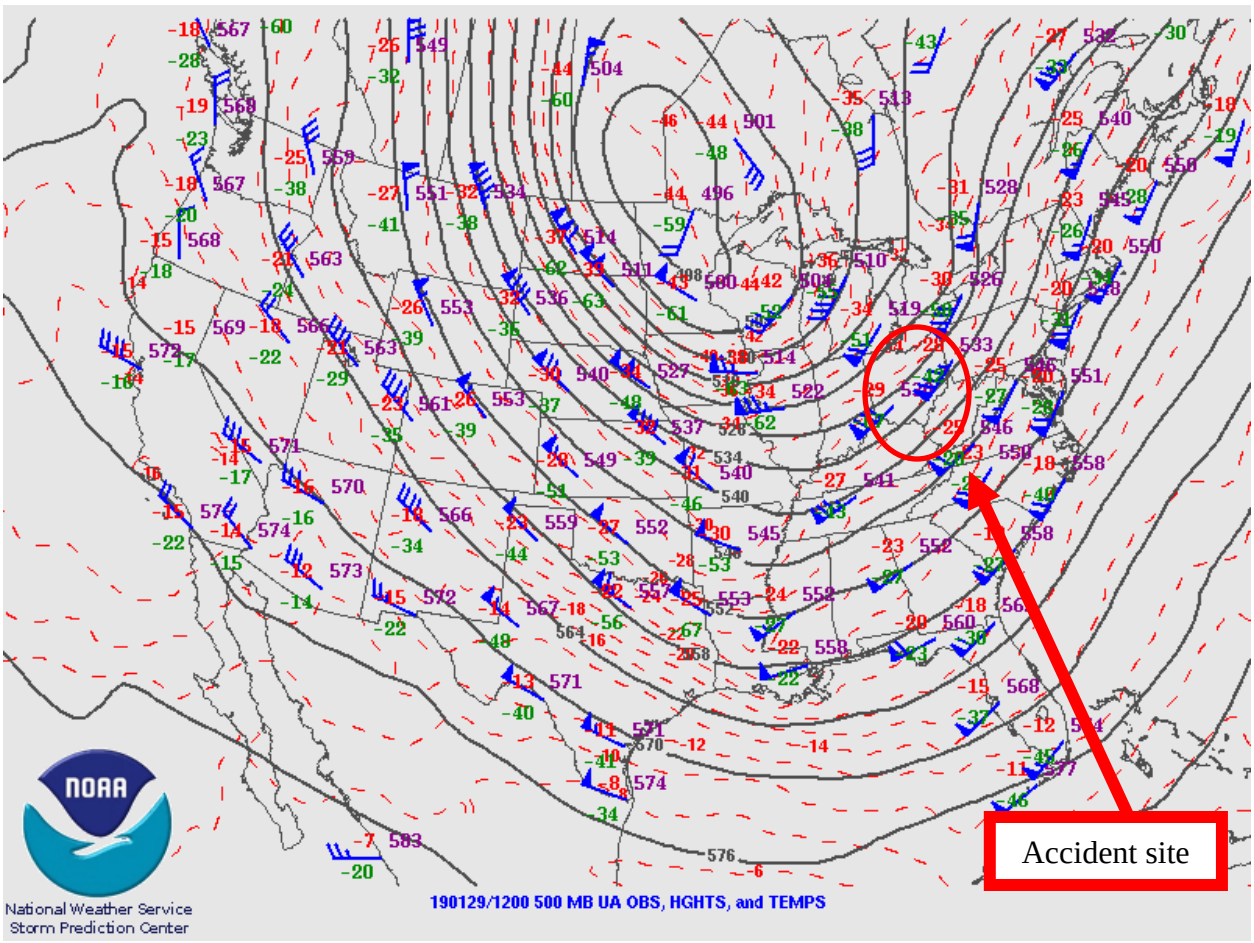

Figure 5 – 500-hPa Constant Pressure Chart for 0700 EST

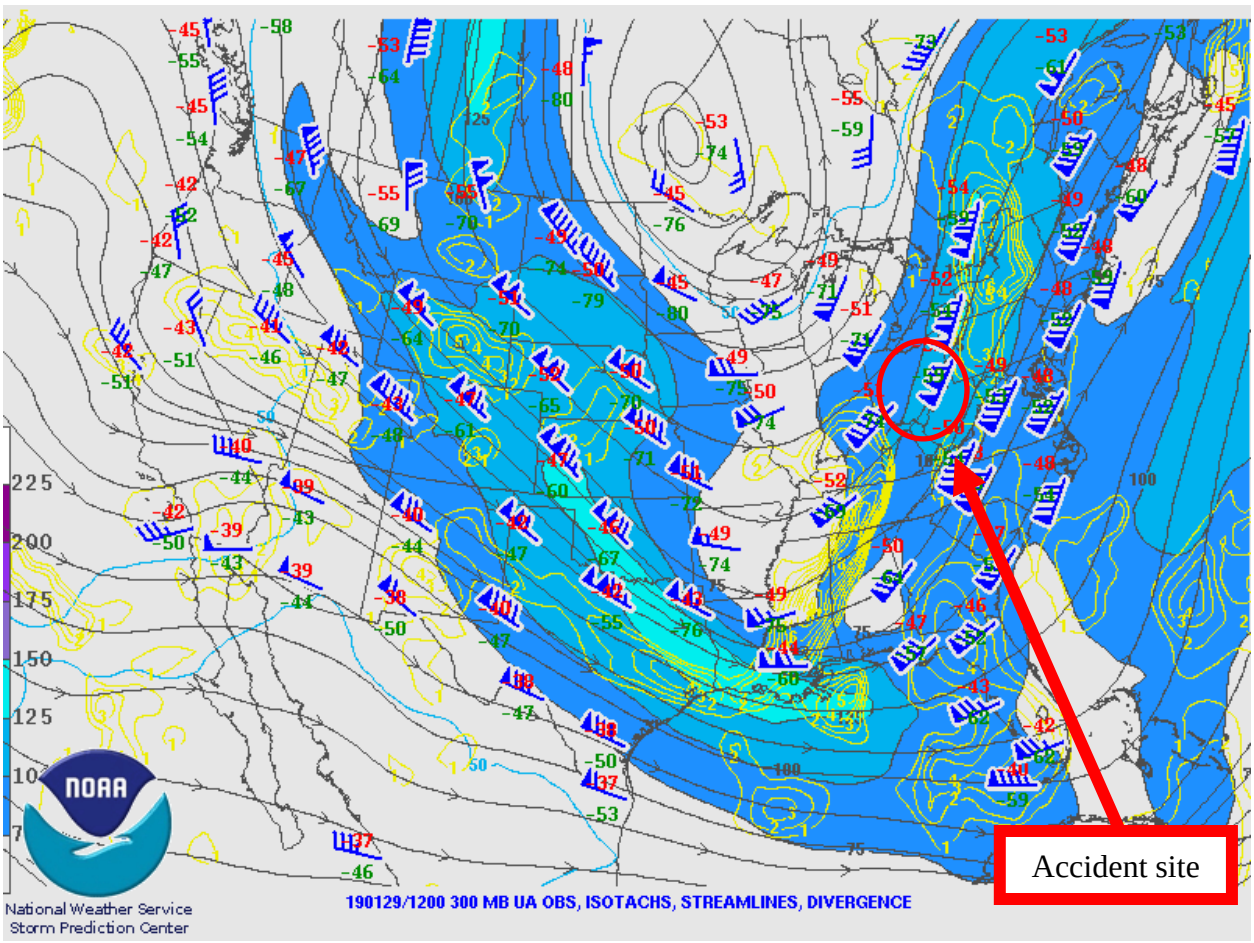

Figure 6 – 300-hPa Constant Pressure Chart for 0700 EST

2.0 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 7 is a local sectional chart with the accident site and the closest weather reporting locations marked.

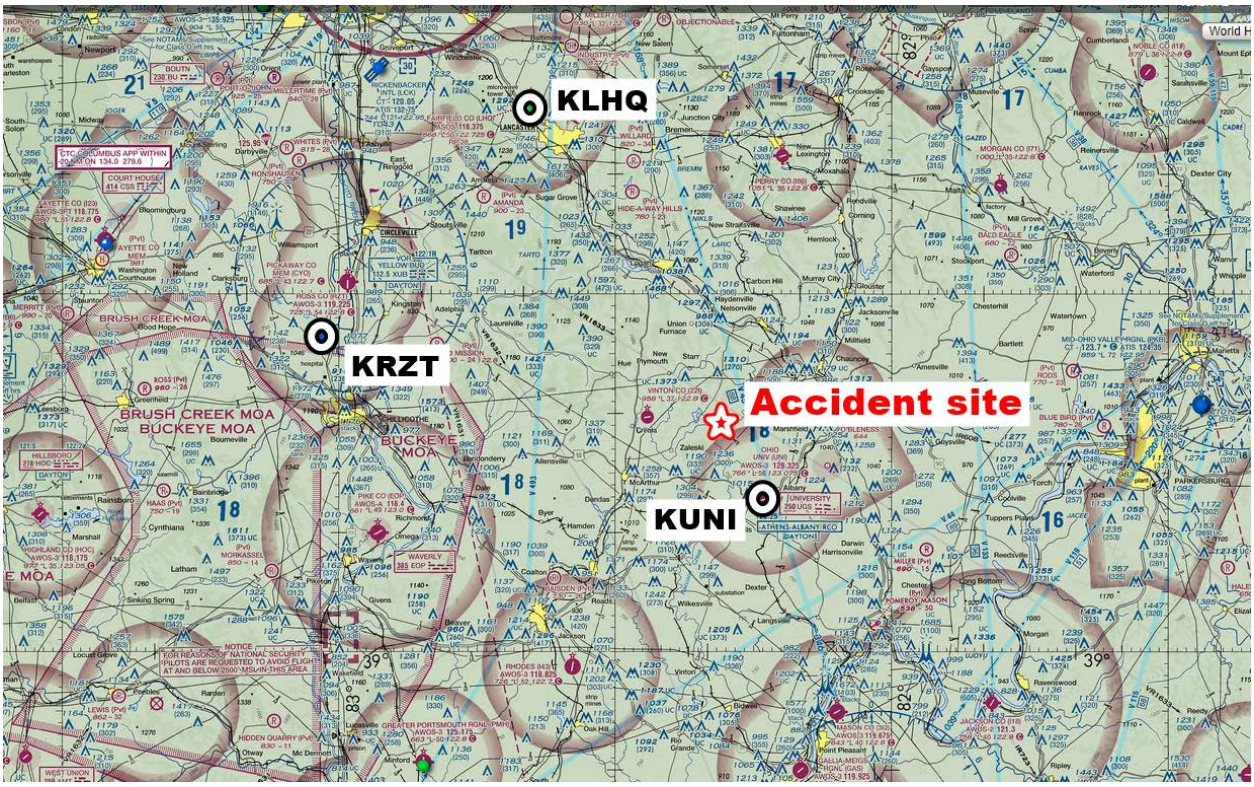

Figure 7 – Sectional map of the accident area with the location of the accident site and surface observation sites

Ohio University Airport (KUNI) had the closest official weather station to the accident site. KUNI had an Automated Weather Observing System (AWOS[4]) whose reports were not supplemented. KUNI was located 8 miles southeast of the accident site, at an elevation of 766 ft, and had a 7° westerly magnetic variation[5] (figure 7). The following observations were taken and disseminated during the times surrounding the accident:[6]

[0415 EST] METAR KUNI 290915Z AUTO 29010G15KT 10SM OVC019 M03/M06 A2985 RMK AO2 T10301060

[0435 EST] METAR KUNI 290935Z AUTO 27011G18KT 10SM OVC021 M03/M06 A2985 RMK AO2 T10331065

[0455 EST] METAR KUNI 290955Z AUTO 28011G15KT 10SM OVC021 M04/M07 A2986 RMK AO2 T10381071

[4] AWOS – Automated Weather Observing System is equipped with meteorological instruments to observe and report temperature, dewpoint, wind speed and direction, visibility, cloud coverage and ceiling up to 12,000 feet, and altimeter setting.

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

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

[0515 EST] METAR KUNI 291015Z AUTO 29009G17KT 10SM OVC023 M05/M08 A2988 RMK AO2 T10461079

[0535 EST] METAR KUNI 291035Z AUTO 27012G17KT 10SM OVC025 M05/M08 A2989 RMK AO2 T10501085

[0555 EST] METAR KUNI 291055Z AUTO 27010KT 10SM OVC025 M05/M09 A2989 RMK AO2 T10551090

[0615 EST] METAR KUNI 291115Z AUTO 29011G19KT 10SM OVC023 M06/M10 A2990 RMK AO2 T10611100

[0635 EST] METAR KUNI 291135Z AUTO 29008G15KT 10SM OVC025 M06/M11 A2991 RMK AO2 T10651106

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[0655 EST] METAR KUNI 291155Z AUTO 28007KT 10SM OVC027 M06/M10 A2992 RMK AO2 T10651104 10045 21065

[0715 EST] METAR KUNI 291215Z AUTO 28010G15KT 10SM OVC027 M07/M10 A2993 RMK AO2 T10661105

[0735 EST] METAR KUNI 291235Z AUTO 29007G14KT 10SM OVC027 M07/M11 A2994 RMK AO2 T10681109

[0755 EST] METAR KUNI 291255Z AUTO 28010G14KT 10SM OVC027 M07/M11 A2994 RMK AO2 T10701111

KUNI weather at 0615 EST, automated, wind from 290° at 11 knots with gusts to 19 knots, 10 miles visibility or greater, overcast ceiling at 2,300 ft above ground level (agl), temperature of -6 °Celsius (C), dew point temperature of -10 °C, and an altimeter setting of 29.90 inches of mercury (inHg). Remarks: automated station with a precipitation discriminator, temperature -6.1 °C, dew point temperature -10.0 °C.

KUNI weather at 0635 EST, automated, wind from 290° at 8 knots with gusts to 15 knots, 10 miles visibility or greater, overcast ceiling at 2,500 ft agl, temperature of -6 °C, dew point temperature of -11 °C, and an altimeter setting of 29.91 inHg. Remarks: automated station with a precipitation discriminator, temperature -6.5 °C, dew point temperature -10.6 °C.

KUNI weather at 0655 EST, automated, wind from 280° at 7 knots, 10 miles visibility or greater, overcast ceiling at 2,700 ft agl, temperature of -6 °C, dew point temperature of -10 °C, and an altimeter setting of 29.92 inHg. Remarks: automated station with a precipitation discriminator, temperature -6.5 °C, dew point temperature -10.4 °C, 6-hourly maximum temperature of 4.5 °C, 6-hourly minimum temperature of -6.5 °C.

KUNI weather at 0715 EST, automated, wind from 280° at 10 knots with gusts to 15 knots, 10 miles visibility or greater, overcast ceiling at 2,700 ft agl, temperature of -7 °C, dew point temperature of -10 °C, and an altimeter setting of 29.93 inHg. Remarks: automated station with a precipitation discriminator, temperature -6.6 °C, dew point temperature -10.5 °C.

Ross County Airport (KRZT) had the next closest official weather station located 34 miles west of the accident site at an elevation of 725 ft (figure 7). KRZT had an AWOS whose reports were not supplemented. The following observations were taken and disseminated during the times surrounding the accident:

[0455 EST] METAR KRZT 290955Z AUTO 30014G19KT 10SM OVC025 M07/M11 A2992 RMK AO2=

[0515 EST] METAR KRZT 291015Z AUTO 29013G20KT 10SM OVC025 M07/M12 A2992 RMK AO2=

[0516 EST] METAR KRZT 291016Z AUTO 30011KT 10SM OVC025 M07/M12 A2992 RMK AO2=

[0535 EST] METAR KRZT 291035Z AUTO 30012G17KT 10SM OVC025 M07/M11 A2993 RMK AO2=

[0555 EST] METAR KRZT 291055Z AUTO 30012G17KT 10SM OVC025 M07/M11 A2993 RMK AO2=

[0615 EST] METAR KRZT 291115Z AUTO 29009G16KT 10SM OVC027 M07/M12 A2993 RMK AO2=

[0616 EST] METAR KRZT 291116Z AUTO 29009G16KT 10SM OVC027 M07/M12 A2994 RMK AO2=

[0635 EST] METAR KRZT 291135Z AUTO 28012G16KT 10SM BKN024 OVC030 M07/M11 A2994 RMK AO2=

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[0655 EST] METAR KRZT 291155Z AUTO 27010KT 10SM BKN024 OVC030 M07/M12 A2995 RMK AO2=

[0656 EST] METAR KRZT 291156Z AUTO 28011G15KT 10SM BKN024 OVC030 M07/M12 A2995 RMK AO2=

[0715 EST] METAR KRZT 291215Z AUTO 28012KT 10SM OVC030 M08/M12 A2996 RMK AO2=

[0716 EST] METAR KRZT 291216Z AUTO 27013KT 10SM OVC030 M08/M12 A2996 RMK AO2=

KRZT weather at 0616 EST, automated, wind from 290° at 9 knots with gusts to 16 knots, 10 miles visibility or greater, overcast ceiling at 2,700 ft agl, temperature of -7 °C, dew point temperature of -12 °C, and an altimeter setting of 29.94 inHg. Remarks: automated station with a precipitation discriminator.

KRZT weather at 0635 EST, automated, wind from 280° at 12 knots with gusts to 16 knots, 10 miles visibility or greater, broken ceiling at 2,400 ft agl, overcast clouds at 3,000 ft agl, temperature of -7 °C, dew point temperature of -11 °C, and an altimeter setting of 29.94 inHg. Remarks: automated station with a precipitation discriminator.

KRZT weather at 0655 EST, automated, wind from 270° at 10 knots, 10 miles visibility or greater, broken ceiling at 2,400 ft agl, overcast clouds at 3,000 ft agl, temperature of -7 °C, dew point temperature of -12 °C, and an altimeter setting of 29.95 inHg. Remarks: automated station with a precipitation discriminator.

KRZT weather at 0656 EST, automated, wind from 280° at 11 knots with gusts to 15 knots, 10 miles visibility or greater, broken ceiling at 2,400 ft agl, overcast clouds at 3,000 ft agl, temperature of -7 °C, dew point temperature of -12 °C, and an altimeter setting of 29.95 inHg. Remarks: automated station with a precipitation discriminator.

Fairfield County Airport (KLHQ) was located about 30 miles northwest of the accident site at an elevation 868 ft (figure 7). KLHQ had an Automated Surface Observing System (ASOS[7]) whose reports were not supplemented. The following observations were taken and disseminated during the times surrounding the accident:

[0105 EST] SPECI KLHQ 290605Z AUTO 27019G26KT 10SM OVC016 M01/M03 A2979 RMK AO2 PK WND 26026/0604 T10111033=

[0153 EST] METAR KLHQ 290653Z AUTO 26018G28KT 10SM BKN021 OVC028 M03/M07 A2981 RMK AO2 PK WND 26029/0606 SLP101 T10281072=

[0208 EST] SPECI KLHQ 290708Z AUTO 27013G24KT 10SM FEW017 SCT023 SCT030 M04/M07 A2982 RMK AO2 T10391072=

[0234 EST] SPECI KLHQ 290734Z AUTO 26016G22KT 9SM BKN023 M04/M08 A2983 RMK AO2 T10441078=

[0253 EST] METAR KLHQ 290753Z AUTO 26011G24KT 10SM BKN023 M05/M09 A2984 RMK AO2 SLP110 T10501089=

[0353 EST] METAR KLHQ 290853Z AUTO 28012G22KT 9SM -SN OVC025 M06/M10

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

A2985 RMK AO2 PK WND 27026/0806 SNB50 SLP116 P0000
60000 T10611100 51022=

[0453 EST] METAR KLHQ 290953Z AUTO 28012G21KT 8SM -SN FEW021 OVC027 M07/M11 A2988 RMK AO2 SNE01B28 SLP125 P0000 T10721111=

[0553 EST] METAR KLHQ 291053Z AUTO 26014KT 5SM -SN OVC024 M08/M12 A2990 RMK AO2 SNE02B30 SLP131 P0000 T10781117=

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[0653 EST] METAR KLHQ 291153Z AUTO 28011KT 10SM OVC026 M08/M12 A2992 RMK AO2 SNE05 SLP138 P0000 60000 70006 T10781122 11006 21078 51021=

[0753 EST] METAR KLHQ 291253Z AUTO 26013KT 9SM -SN OVC028 M08/M13 A2993 RMK AO2 SNB18 SLP143 P0000 T10831128=

[0851 EST] SPECI KLHQ 291351Z AUTO 27012KT 3SM -SN FEW018 FEW024 OVC031 M08/M12 A2995 RMK AO2 P0000=

[0853 EST] METAR KLHQ 291353Z AUTO 27012KT 4SM -SN FEW018 FEW024 OVC033 M08/M12 A2995 RMK AO2 SLP152 P0000 T10831122=

KLHQ weather at 0453 EST, automated, wind from 280° at 12 knots with gusts to 21 knots, 8 miles visibility, light snow, few clouds at 2,100 ft agl, overcast ceiling at 2,700 ft agl, temperature of -7 °C, dew point temperature of -11 °C, and an altimeter setting of 29.88 inHg. Remarks: automated station with a precipitation discriminator, snow ended at 0401 EST and began at 0428 EST, sea level pressure 1012.5 hPa, a trace of precipitation since 0353 EST, temperature -7.2 °C, dew point temperature -11.1 °C.

KLHQ weather at 0553 EST, automated, wind from 260° at 14 knots, 5 miles visibility, light snow, overcast ceiling at 2,400 ft agl, temperature of -8 °C, dew point temperature of -12 °C, and an altimeter setting of 29.90 inHg. Remarks: automated station with a precipitation discriminator, snow ended at 0502 EST, snow began at 0530 EST, sea level pressure 1013.1 hPa, a trace of precipitation since 0453 EST, temperature -7.8 °C, dew point temperature -11.7 °C.

KLHQ weather at 0653 EST, automated, wind from 280° at 11 knots, 10 miles visibility or greater, overcast ceiling at 2,600 ft agl, temperature of -8 °C, dew point temperature of -12 °C, and an altimeter setting of 29.92 inHg. Remarks: automated station with a precipitation discriminator, snow ended at 0605 EST, sea level pressure 1013.8 hPa, a trace of precipitation since 0553 EST, 6-hourly precipitation of a trace, 24-hour precipitation of 0.06 inches, temperature -7.8 °C, dew point temperature -12.2 °C, 6-hourly maximum temperature of -0.6 °C, 6-hourly minimum temperature of -7.8 °C, 3-hourly pressure increase of 2.1 hPa.

KLHQ weather at 0753 EST, automated, wind from 260° at 13 knots, 9 miles visibility, light snow, overcast ceiling at 2,800 ft agl, temperature of -8 °C, dew point temperature of -13 °C, and an altimeter setting of 29.93 inHg. Remarks: automated station with a precipitation discriminator, snow began at 0718 EST, sea level pressure 1014.3 hPa, a trace of precipitation since 0653 EST, temperature -8.3 °C, dew point temperature -12.8 °C.

The observations from KUNI, KRZT, and KLHQ surrounding the accident time indicated MVFR[8] conditions with gusty surface winds from the west between 10 to 20 knots. Visibilities were reported as low as 3 miles at the surface in the light snow conditions at KLHQ.

3.0 Upper Air Data

The Wilmington, Ohio, (KILN) upper air sounding was the closest site with an upper air sounding located 69 miles west of the accident site with a surface elevation of 1,005 ft (station ID 72426). The 0700 EST sounding was plotted on a standard Skew-T Log P diagram[9] with the derived stability parameters included in figure 8 with data from the surface to 600-hPa (or approximately 14,000 ft msl). This data was analyzed using the RAOB[10] software package. The sounding depicted the lifted condensation level (LCL)[11] and the level of free convection (LFC)[12] at 1,252 ft agl (2,257 ft msl), and the convective condensation level (CCL)[13] at 2,609 ft agl (3,614 ft msl). The sounding had a greater than 85% relative humidity from 3,000 ft msl through 5,000 ft msl. The freezing level was at the surface, with the entire depth of the sounding below freezing. The precipitable water value was 0.11 inches. The mean storm motion vector was from 275° at 39 knots.

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

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

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

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

[9] 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.

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

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

[12] 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.

[13] CCL – The level in the atmosphere to which an air parcel, if heated from below, will rise dry adiabatically, without becoming colder than its environment just before the parcel becomes saturated.

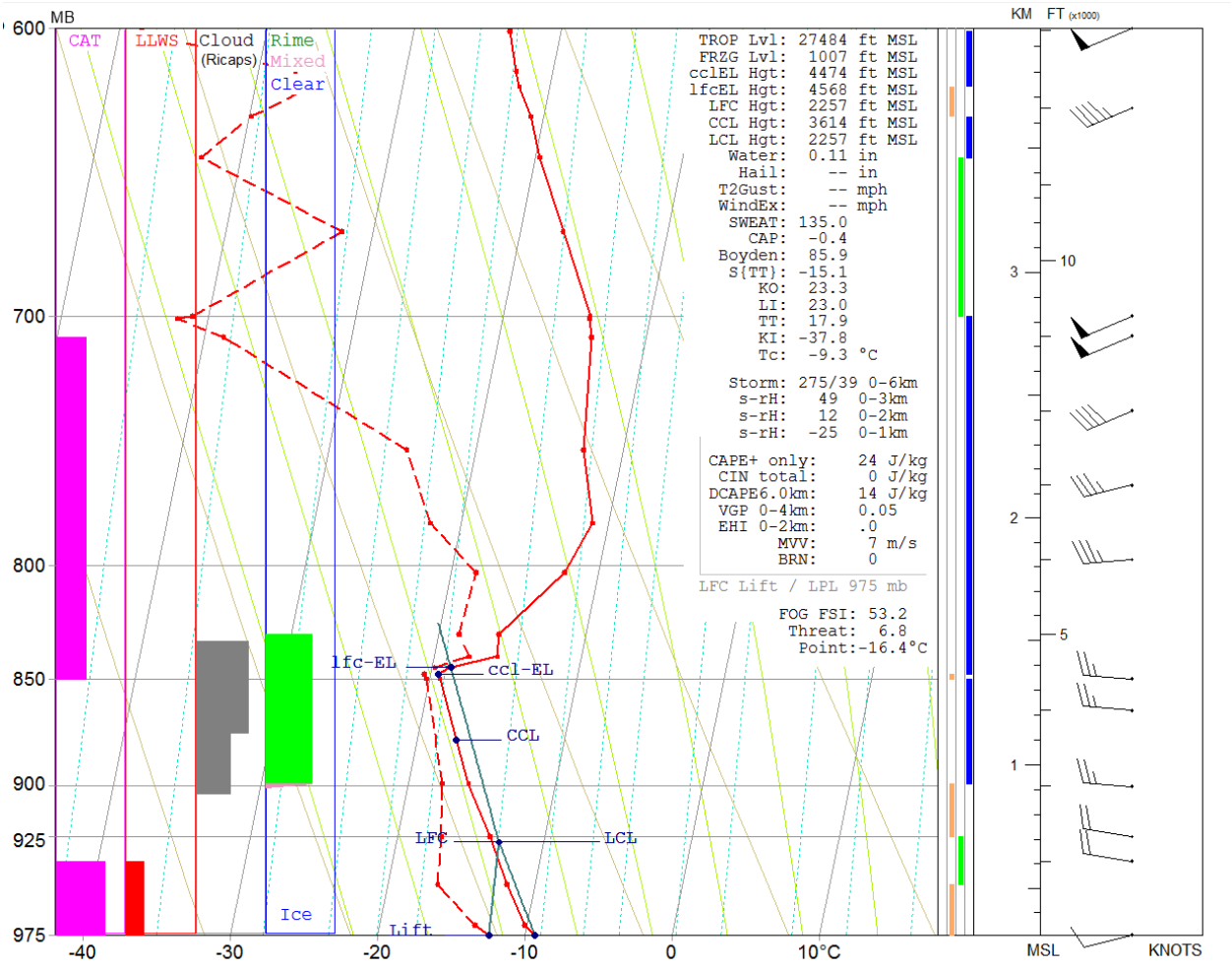


Figure 8 – 0700 EST KILN sounding

The 0700 EST KILN sounding indicated layers of conditional instability and instability between the surface and 3,000 ft msl with a stable environment from 3,000 ft through 9,000 ft msl. RAOB identified the possibility of clouds between 3,000 ft msl through 5,000 ft. Moderate rime icing was indicated by RAOB between 3,000 ft msl and 5,000 ft msl, with potential light rime icing in the layer (Icing potential will be further discussed in section 17.0).[14]

[14] S.G. Cober, G. A. Isaac, and J. W. Strapp, Characterizations of Aircraft Icing Environments that Include Supercooled Large Drops (Journal of Applied Meteorology, 2001), pp. 1984-2002.
B.C Bernstein, C.A. Wolff, and F. McDonough, An Inferred Climatology of Icing Conditions Aloft, Including Supercooled Large Drops. Part I: Canada and the Continental United States (Journal of Applied Meteorology and Climatology, 2007), pp. 1857-1878.
Williams, E.R., D.J. Smalley, M.F. Donovan, R.G. Hallowell, K.T. Hood, B.J. Bennett, R. Evaristo, A. Stepanek, T. Bals-Elsholz, J. Cobb, J. Ritzman, A. Korolev, M. Wolde, Measurements of Differential Reflectivity in Snowstorms in Warm Season Stratiform Systems (Journal of Applied Meteorology and Climatology, 2015), pp. 573-595.

The KILN sounding wind profile indicated a surface wind from 255° at 11 knots with little variation in direction through 6,000 ft msl. The wind increased in speed to 20 knots by 2,000 ft msl. By 9,000 ft msl the wind was from the west-southwest at 50 knots. RAOB indicated the possibility of light low-level wind shear (LLWS) between the surface and 2,000 ft msl. RAOB indicated a high probability of moderate or greater clear-air turbulence between the surface and 2,000 ft msl and RAOB indicated a chance of moderate clear-air turbulence between 4,500 and 9,000 ft msl.

4.0 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. The GOES-16 visible (band 2) and infrared (band 13) imagery at wavelengths of 0.64 microns (μm) and 10.3 μm, respectively, were retrieved for the period from 0200 EST through 1000 EST and reviewed. The closest images to the time of the accident are documented here. Due to low light conditions the GOES-16 visible imagery was too dark to provide imagery at the accident time.

Figures 9 and 10 present the GOES-16 infrared imagery from 0645 and 0700 EST at 4X magnification with the accident site highlighted with a red square. Inspection of the infrared imagery indicated overcast cloud cover over the accident site. The lower brightness temperatures (green colors; higher cloud tops) were located above the accident site stretching to the southwest into northeastern Kentucky. The cloud cover was moving from southwest to northeast. Based on the brightness temperatures above the accident site and the vertical temperature profile provided by the KILN sounding, the approximate cloud-top heights over the accident site were 18,000 ft at 0700 EST (at temperature of 244º Kelvin). The approximate cloud-top heights above KRZT and KLHQ were 11,000 ft at 0700 EST (at temperature of 254º Kelvin). It should be noted these figures have not been corrected for any parallax error.

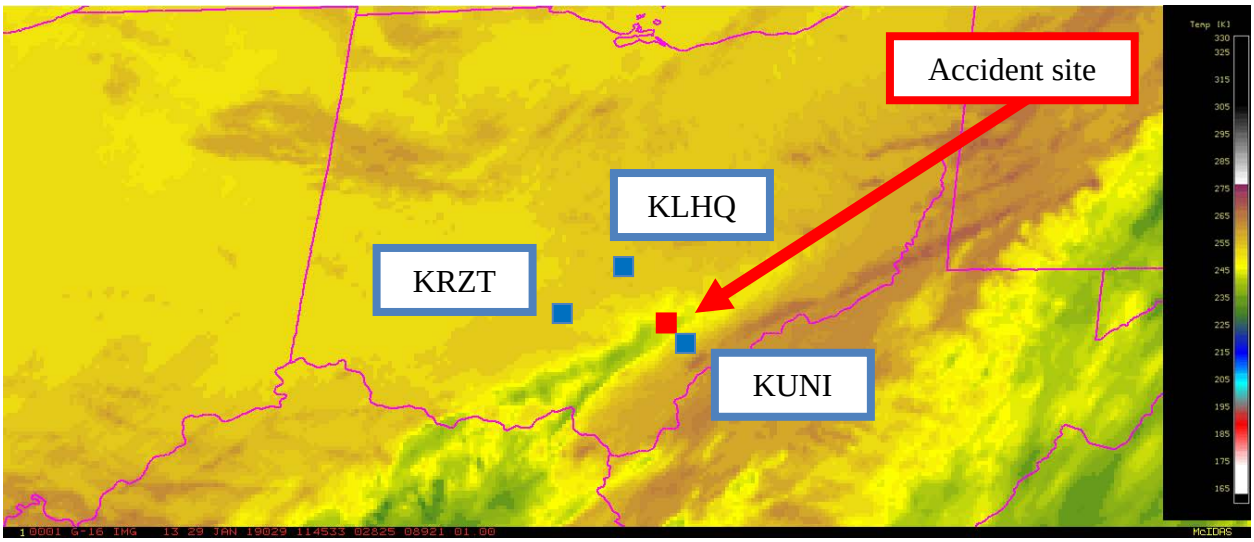


Figure 9 – GOES-16 infrared image at 0645 EST

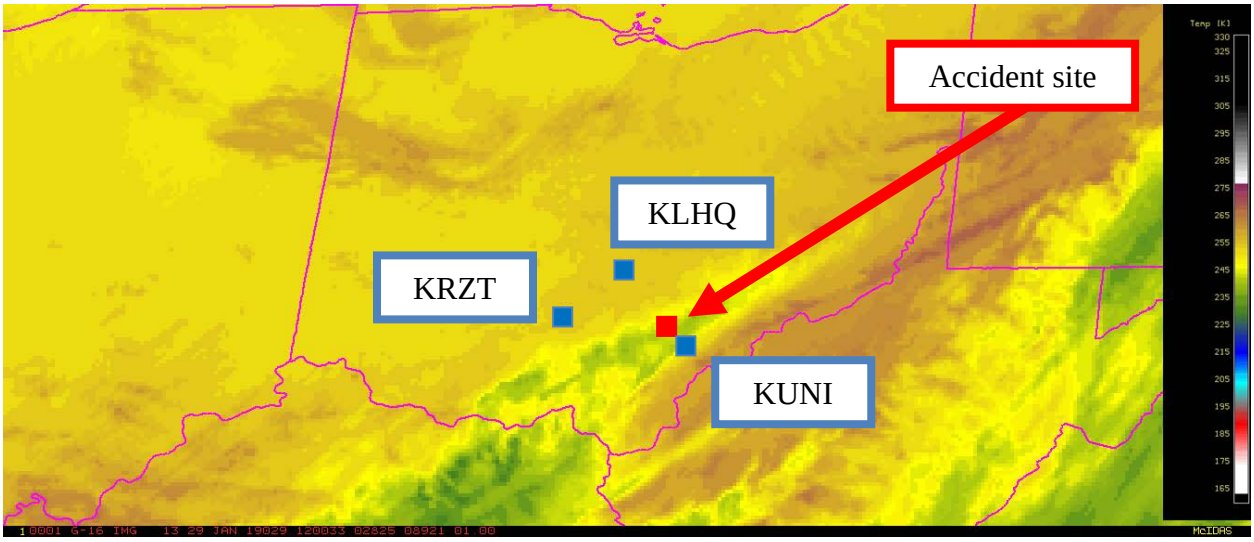


Figure 10 – GOES-16 infrared image at 0700 EST

Figures 11, 12, and 13 present the GOES-16 Nighttime Microphysics RGB (red green blue) imagery from 0647, 0652, and 0657 EST, respectively, with the accident site highlighted in a blue circle. Inspection of the Nighttime Microphysics RGB imagery indicated 2 levels of cloud cover above the accident site at the accident time (attachment 3). The lower-level cloud cover was moving from west to east (attachment 3) and was indicated by the green colors. The higher-level cloud cover was moving from southwest to northeast and was indicated by the dark red colors (attachment 3). The green colors on the Nighttime Microphysics RGB imagery indicate low-level cool water clouds (attachment 2). The dark red colors on the Nighttime Microphysics RGB imagery indicate high thick ice clouds. For more information on the Nighttime Microphysics RGB please see attachment 2.[15]

[15] Also see: https://nasasporttraining.wordpress.com/2017/02/23/nighttime-microphysics-rgb-application-aviation-module-2/

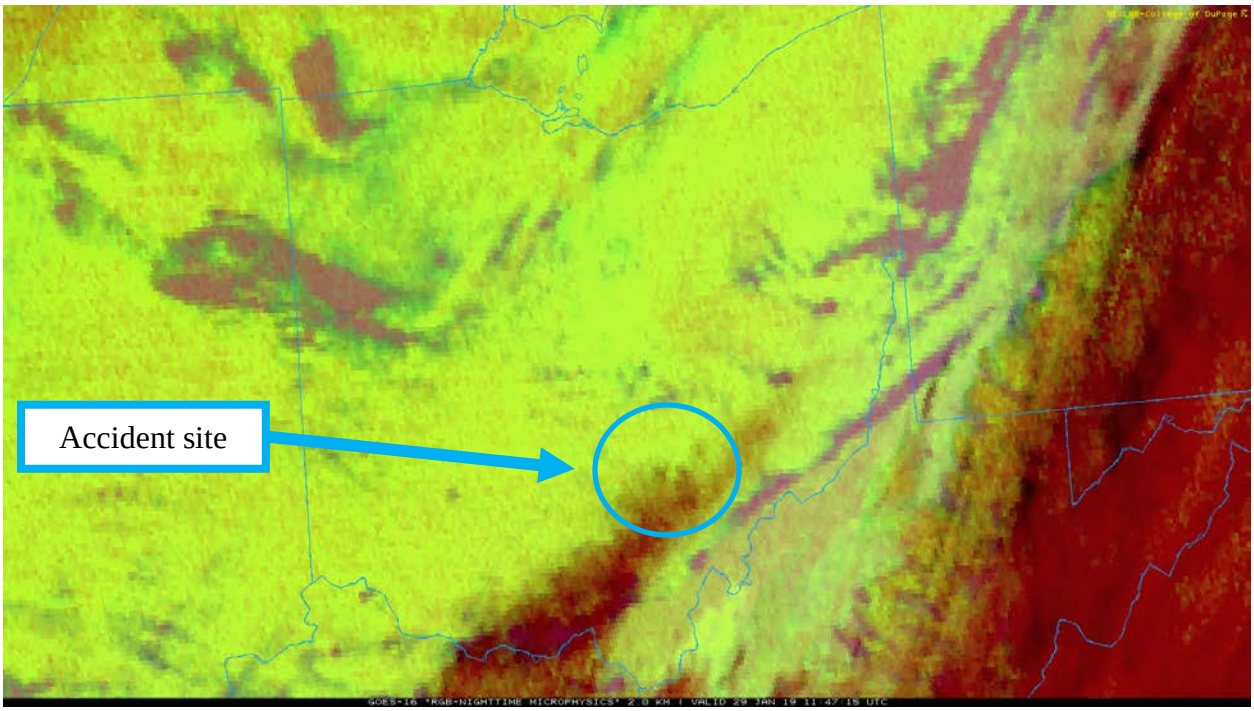


Figure 11 – GOES-16 Nighttime Microphysics RGB image at 0647 EST

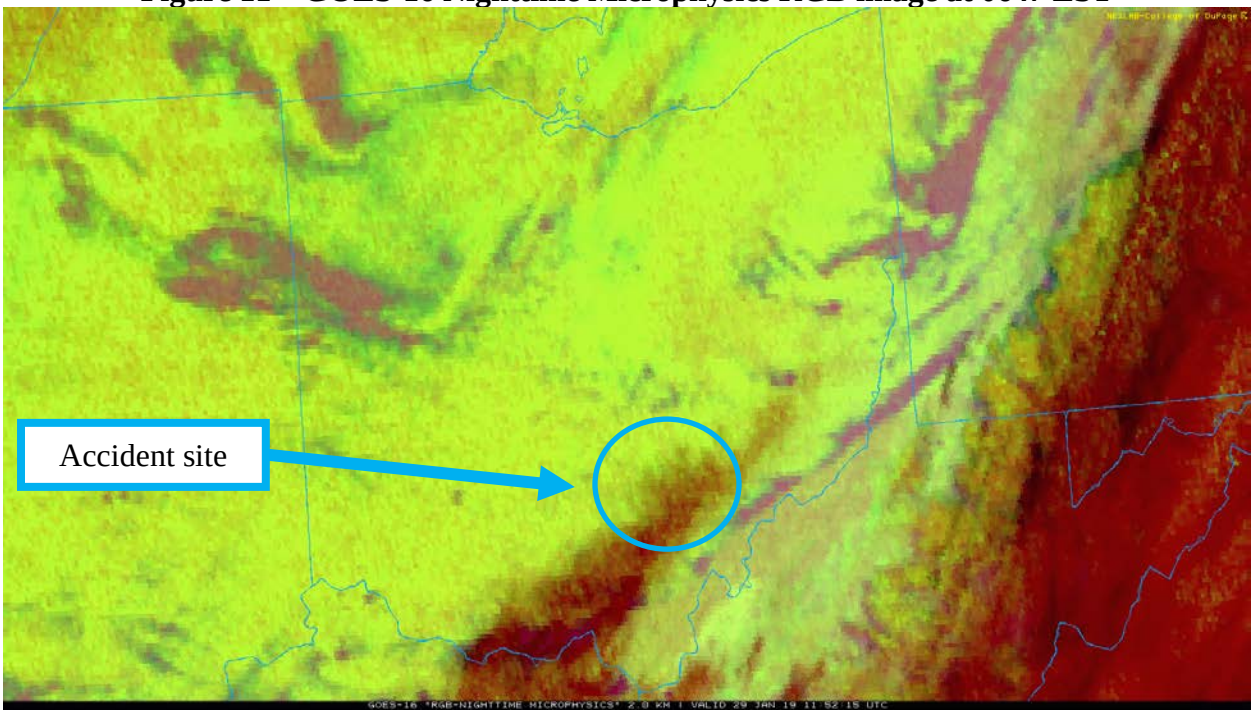


Figure 12 – GOES-16 Nighttime Microphysics RGB image at 0652 EST

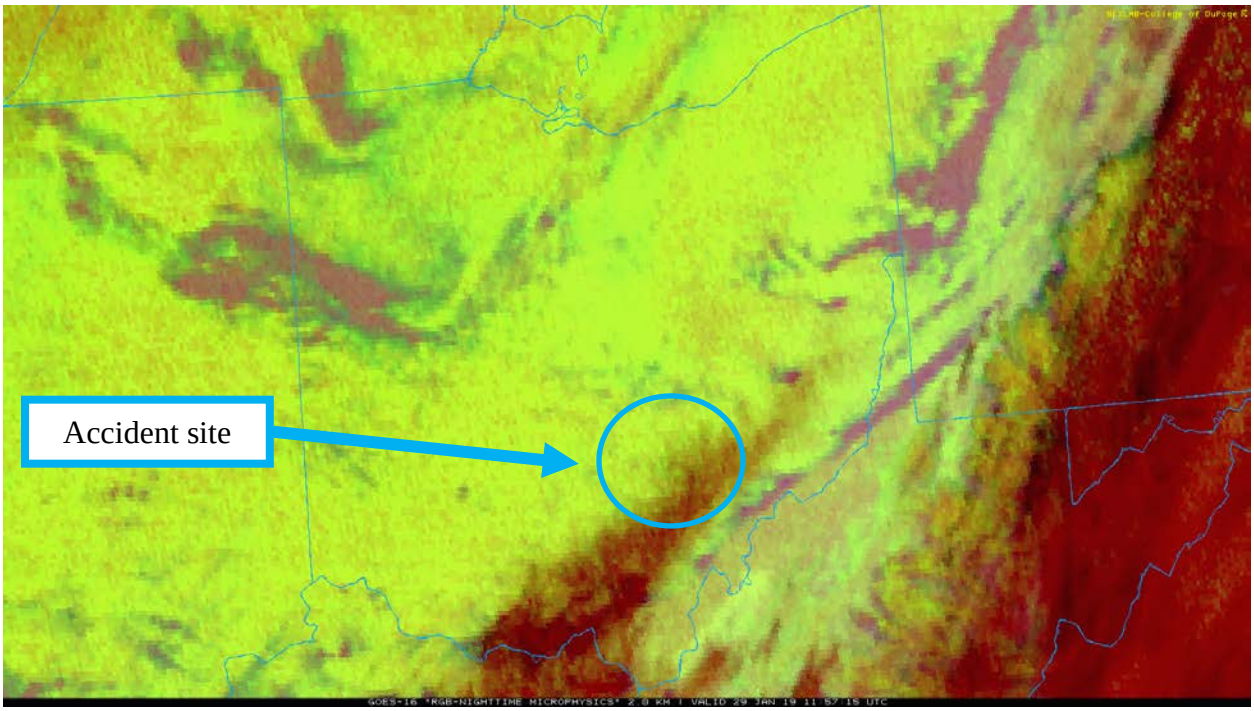


Figure 13 – GOES-16 Nighttime Microphysics RGB image at 0657 EST

5.0 Regional Radar Imagery Information

A regional view of the NWS National Composite Radar Mosaic is included as figure 14 for 0650 EST with the approximate location of the accident site marked by a red circle. The image depicted no precipitation targets above the accident site at the accident time.

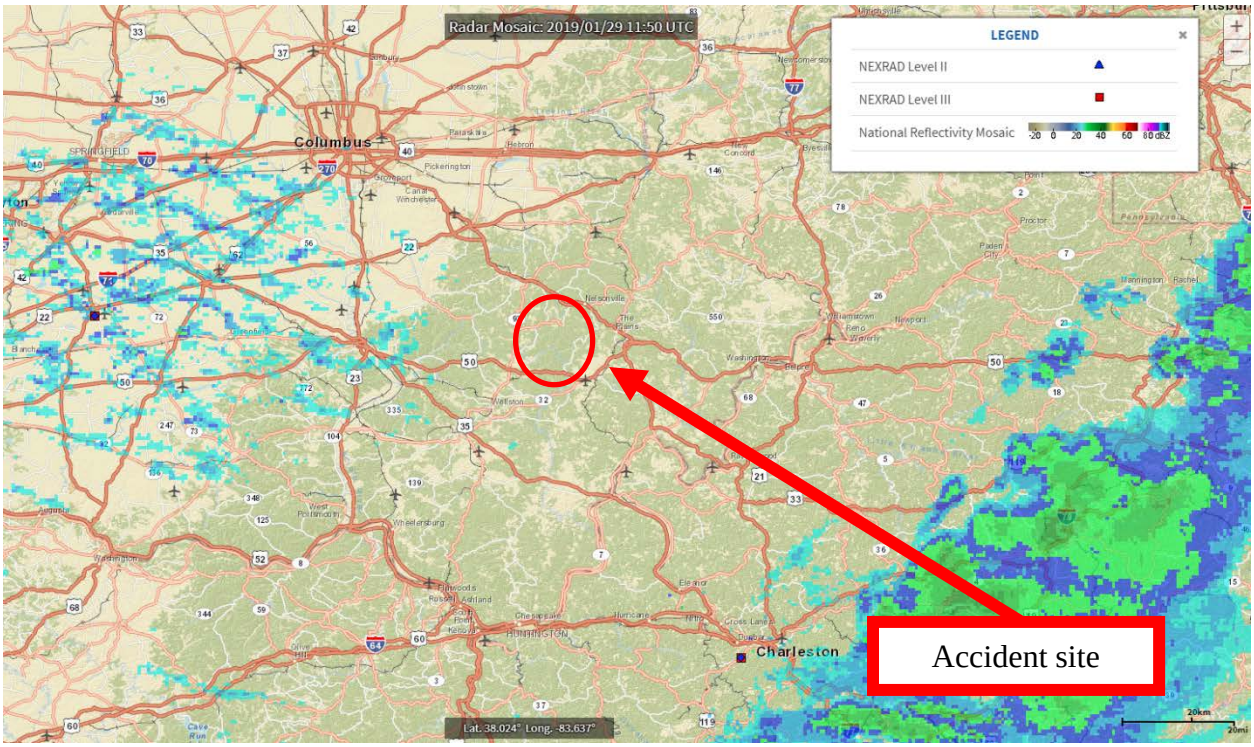


Figure 14 – Regional Composite Reflectivity image for 0650 EST

6.0 Radar Imagery Information

The closest NWS Weather Surveillance Radar-1988, Doppler (WSR-88D)[16] to the accident site was KILN.[17] Level II and level III archive radar data was obtained from the NCEI utilizing the NEXRAD Data Inventory Search and displayed using the NOAA's Weather and Climate Toolkit software. In addition, the weather radar data from the Terminal Doppler Weather Radar (TDWR) located in Columbus, Ohio, (TCMH) was reviewed and displayed with TCMH located 45 miles northwest of the accident site.

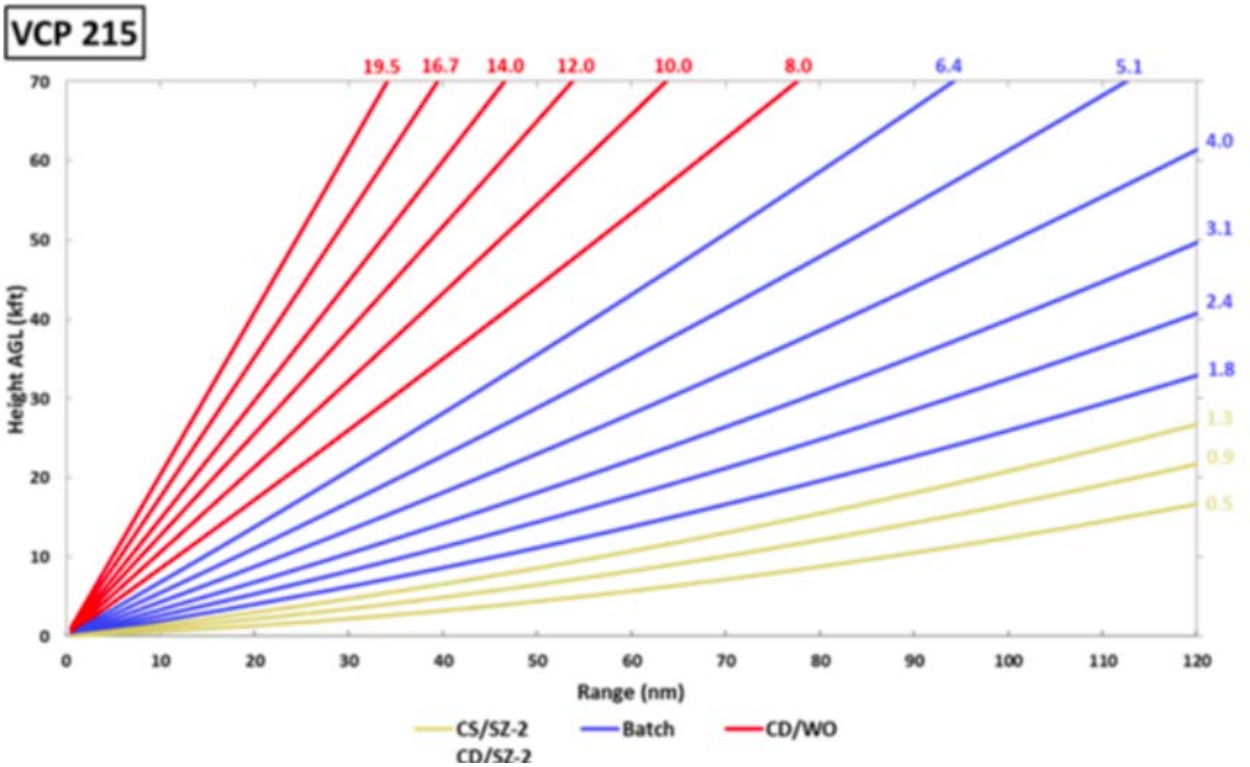
6.1 Volume Scan Strategy

The WSR-88D is a computer-controlled radar system, which automatically creates a complete series of specific scans in a specific sequence known as a volume scan. Individual elevation scans are immediately available. Products that require data from multiple elevation scans are not available until the end of the five to ten-minute volume scan.

The WSR-88D operates in several different scanning modes, identified as Mode A and Mode B. Mode A is the precipitation scan and has three common scanning strategies. The most common is where the radar makes 14 elevation scans from 0.5° to 19.5° every six minutes. This particular

[16] 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.
[17] The WSR-88D in Charleston, West Virginia, (KRLX) was 2 miles closer to the accident site, but KRLX, due to the mountainous terrain surrounding the site, experienced beam blockage in the direction of the accident site.

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 KILN WSR-88D radar was operating in the precipitation mode VCP-215. The following chart provides an indication of the different elevation angles in this VCP, and the approximate height and width of the radar beam with distance from the radar site.



VCP-215 Precipitation Mode Scan Strategy[18]

[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)

6.2 Beam Height Calculation

Assuming standard refraction[19] of the WSR-88D radar beam with the antenna elevation at 1,170 ft, a distance of 69 miles, and considering a beam width[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. The TCMH antenna elevation was located at 1,148 ft, and a distance 45 miles from the accident site.

ANTENNA ELEVATION	BEAM CENTER	BEAM BASE	BEAM TOP
KILN 0.5°	8,430 ft	4,980 ft	11,880 ft
TCMH 0.1°	3,500 ft	2,040 ft	4,960 ft

Based on the radar height calculations, the elevation scans listed in the above table the KILN base reflectivity images from the 0.5° elevation scans depicted the conditions between 4,980 ft and 11,880 ft msl over the accident site, while the TCMH base reflectivity images from the 0.1° elevations scans depicted the conditions between 2,040 ft and 4,960 ft msl and these scans "saw" the closest altitudes to the surface.

6.3 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 decibel (dBZ[22]), and is a general measure of echo intensity. FAA Advisory Circular AC 00-24C[23], "Thunderstorms," dated February 19, 2013, also defines the echo intensity levels and weather radar echo intensity terminology associated with those levels. For dBZ values less than 30 the weather radar echo intensity terminology should be "light." For dBZ values between 30 and 40, the terminology should be "moderate." "Heavy" terminology is used for dBZ values greater than 40 dBZ but less than 50 dBZ, inclusive. Finally, any dBZ values above 50 dBZ shall be described as "extreme." From the NWS, precipitation conditions at the surface can be inferred from VIP Levels described in the chart below:

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

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

[21] 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] 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.

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

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

6.4 Base Reflectivity and Lightning Data

Figures 15 and 16 present the KILN WSR-88D base reflectivity images for the 0.5° elevation scans initiated at 0647:09 and 0651:50 EST, respectively, with a resolution of 0.5° X 250 m. The image depicted scattered echoes of 5 to 15 dBZ along the flight track (attachment 1) as the accident flight departed southeastward from Columbus, with no significant echoes over the accident site.

Figures 17, 18, and 19 present the TCMH TDWR base reflectivity images for the 0.1° elevation scans initiated at 0638:36, 0645:30, and 0651:30 EST, respectively. Reflectivity values between 5 and 15 dBZ were located along the accident flight's location at 0645 EST (figure 18) and above the accident site at the accident time (figure 19). The reflectivity bands were moving from west to east (attachment 4). The reflectivity values between 5 and 15 dBZ were located along the southern third portion of the flight track since 0502 EST (attachment 4).

There were no lightning strikes around the accident site at the accident time.[24]

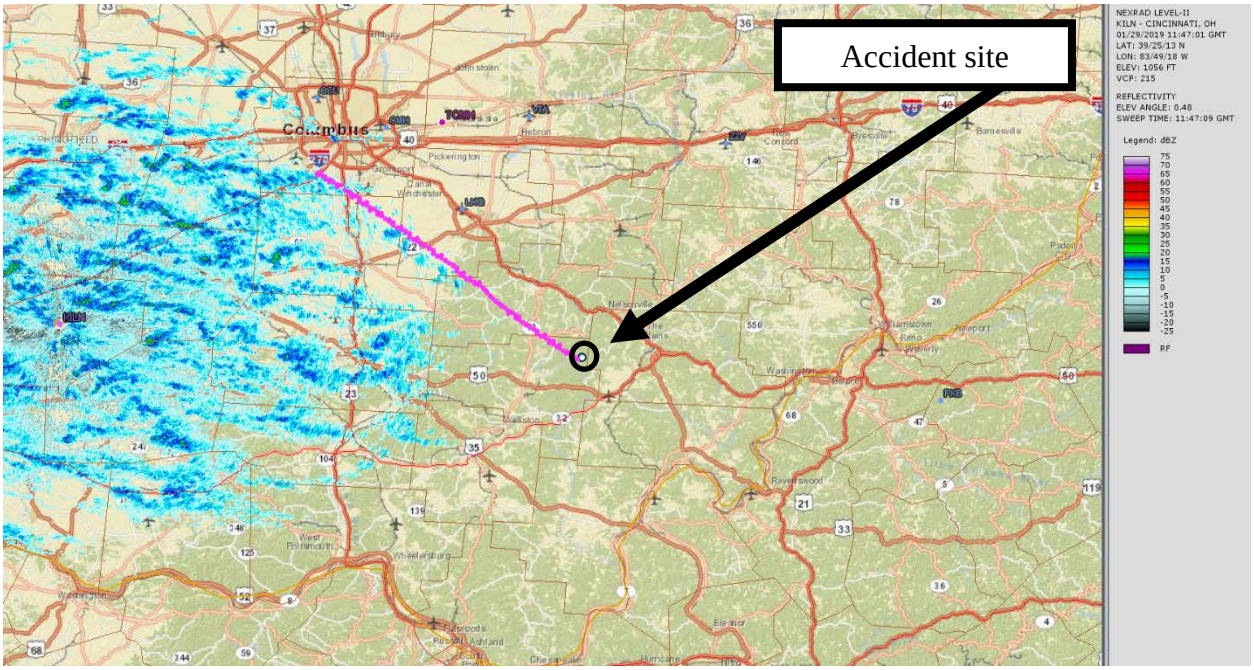


Figure 15 – KILN WSR-88D reflectivity for the 0.5° elevation scan initiated at 0647:09 EST with the accident site marked with black circle, and the accident flight track in pink

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

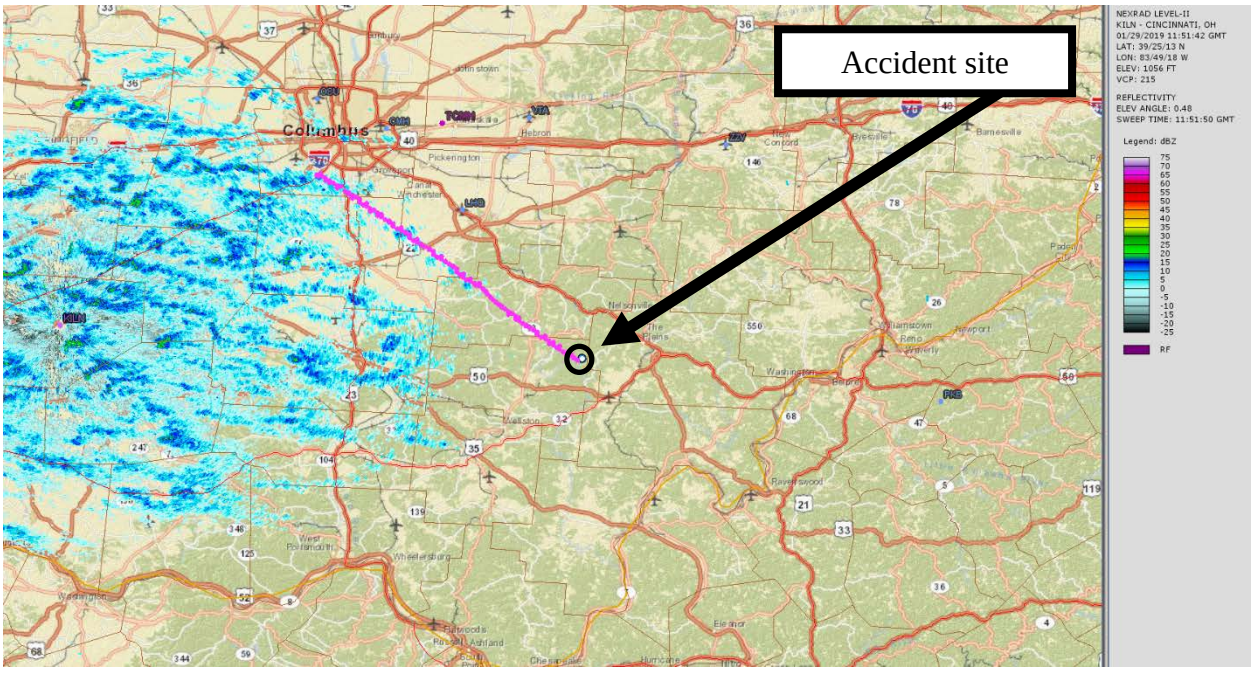


Figure 16 – KILN WSR-88D reflectivity for the 0.5° elevation scan initiated at 0651:50 EST with the accident site marked with black circle, and the accident flight track in pink

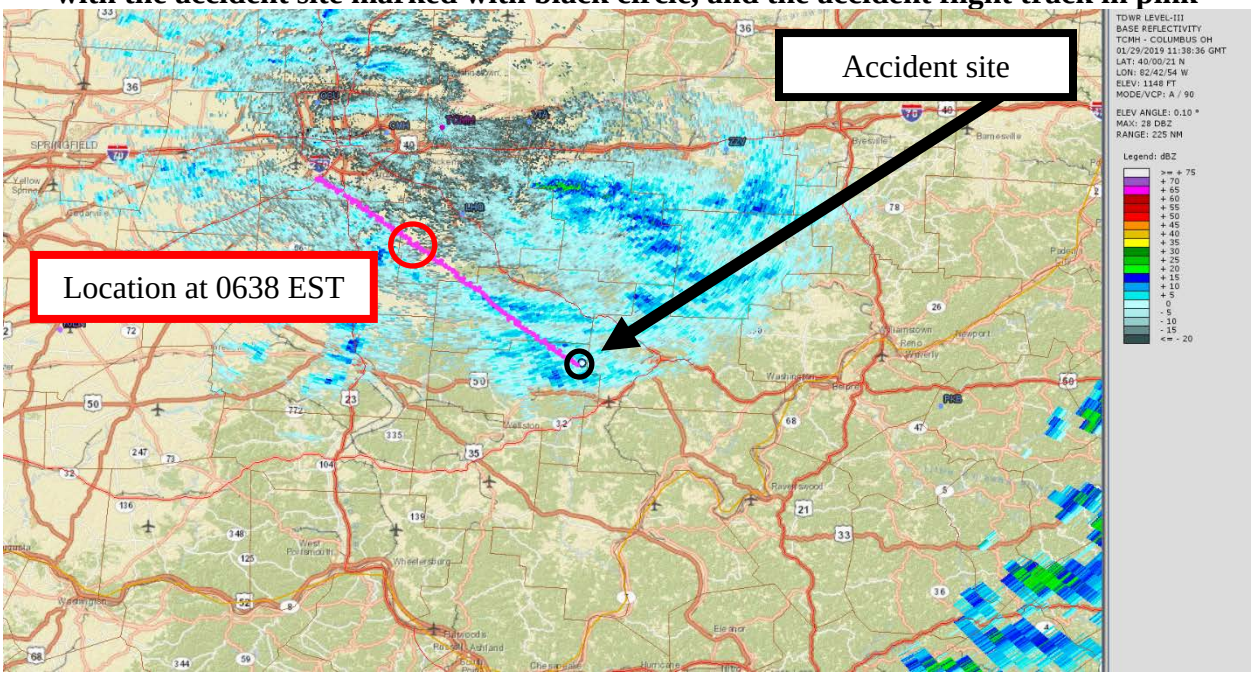


Figure 17 – TCMH TDWR reflectivity for the 0.1° elevation scan initiated at 0638:36 EST with the accident site marked with black circle, and the accident flight track in pink

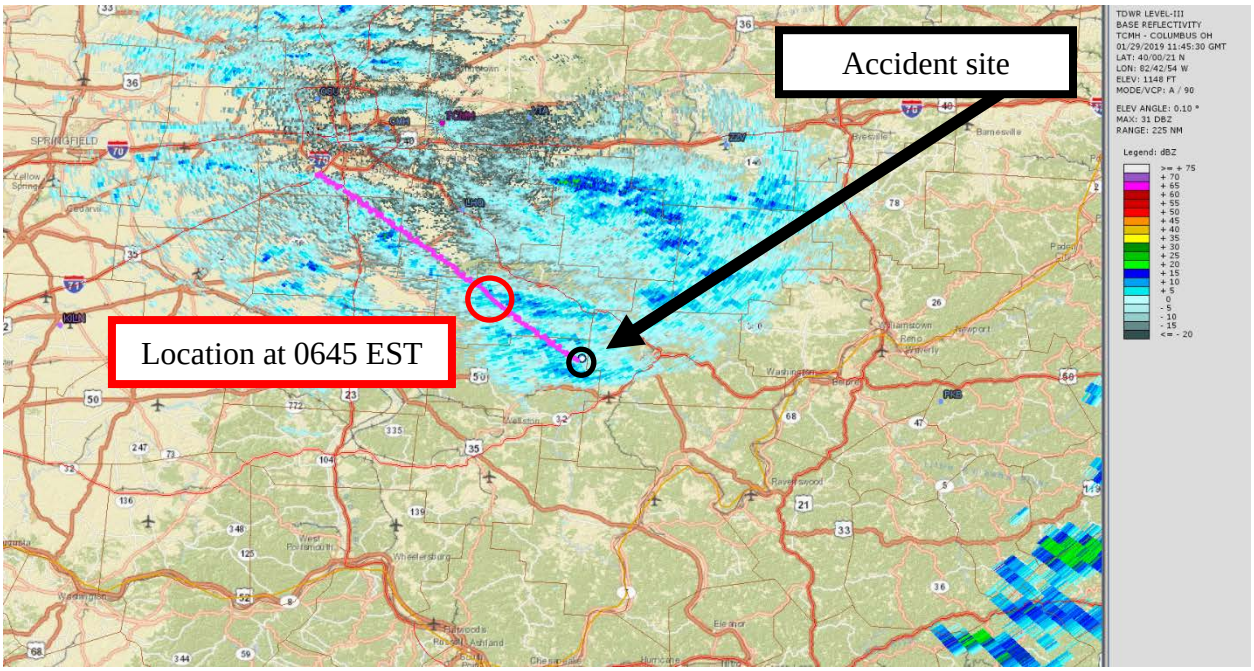


Figure 18 – TCMH TDWR reflectivity for the 0.1° elevation scan initiated at 0645:30 EST with the accident site marked with black circle, and the accident flight track in pink

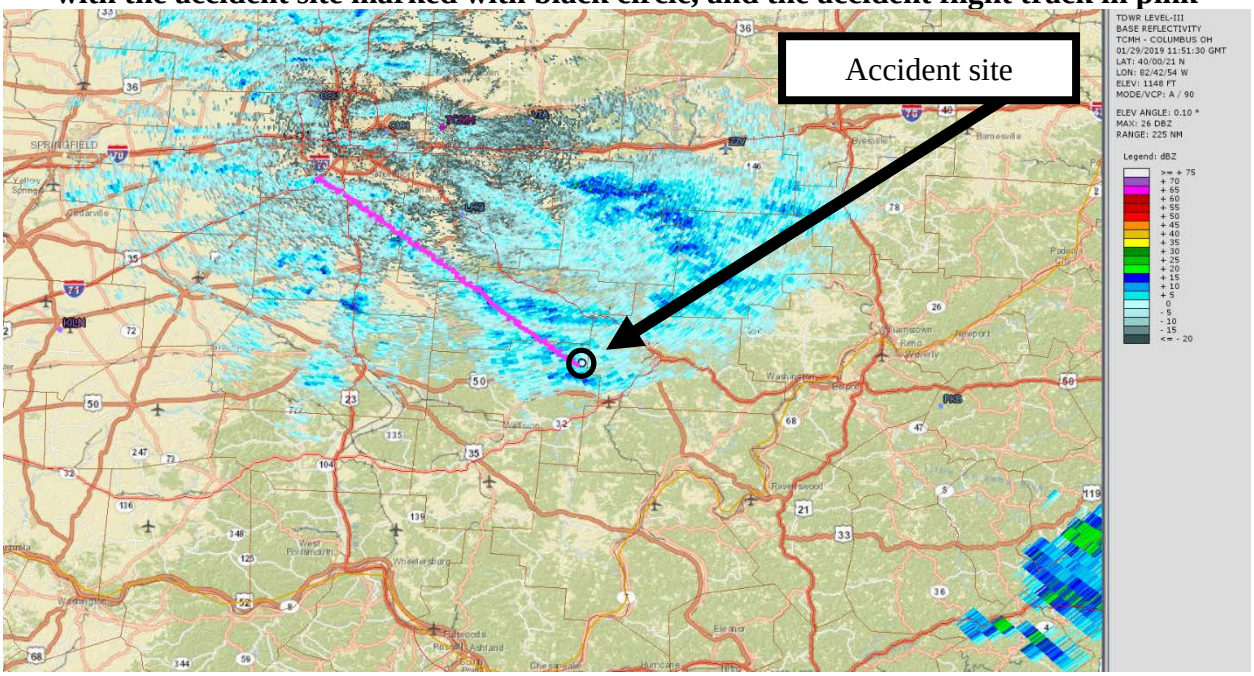


Figure 19 – TCMH TDWR reflectivity for the 0.1° elevation scan initiated at 0651:30 EST with the accident site marked with black circle, and the accident flight track in pink

7.0 Pilot Reports[25]

All pilot reports (PIREPs) within 100 miles of the accident site from about two hours prior to the accident time to about two hours after the accident time for below FL200[26] are provided below:

CRW UA /OV HVQ120025/TM 1002/FL100/TP PC12/TA M07/IC MOD MX

CMH UA /OV DAY/TM 1049/FLDURGC/TP CRJ2/SK OVC025 TOP050 CLR ABV/IC NEG

CMH UA /OV LCK270010/TM 1053/FL040/TP BE58/SK OVC033-TOP045/TA M15/IC LGT RIME

CMH UA /OV DAY/TM 1128/FLDURC/TP MD88/SK BASES 040 TOPS 054/IC NEG

CMH UA /OV CMH270010/TM 1149/FL030/TP A320/SK TOPS 055 BASES 030/TB NEG/IC NEG

CRW UA /OV CRW270010/TM 1235/FL050/TP B737/IC LGT RIME

CMH UA /OV AXV180005/TM 1237/FLDURGC/TP GLF5/SK TOP055/IC NEG

CMH UA /OV CMH/TM 1254/FLDURGC/TP A320/SK BASES 033 TOPS 051/IC NEG

TZR UA /OV TZR/TM 1259/FL015/TP P32A/WX FV02SM -SN/TA M04/IC LGT RIME/RM DURD RWY 04 RNAV LIGHT RIME ICING BETWEEN 040-050/ VIS 2SM -SN/ B018

CMH UA /OV MGY/TM 1308/FLDURGC/TP C25B/SK OVC-TOP050/IC LGT RIME IC

CRW UA /OV 15 N OF BKW/TM 1325/FL100/TP BE58/TA M06/IC TRACE ICE

CRW UA /OV CRW/TM 1330/FL040/TP CRJ2/TA M01/IC LGT RIME

CMH UA /OV OSU/TM 1336/FLDURGC/TP SR22/SK OVC042-TOP051/TA M05/IC NEG

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

Routine pilot report (UA) Yeager Airport, West Virginia (CRW); Over 25 miles from Charleston, West Virginia, VORTAC (HVQ) on the 120° radial; Time – 0502 EST (1002Z); Altitude – 10,000 ft; Type aircraft – Pilatus PC-12; Temperature – minus 7 °C; Icing – Moderate mixed.

Routine pilot report (UA) John Glenn Columbus International Airport, Ohio (CMH); Over Dayton, Ohio(DAY); Time – 0549 EST (1049Z); Altitude – During climb; Type aircraft – Bombardier CRJ-200; Sky – Overcast cloud cover at 2,500 ft with tops at 5,000 ft and clear above; Icing – Negative.

[25] Only pilot reports with the World Meteorological Organization headers UBOH**, UBKY**, and UBWV** were considered.

[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 average 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.

Routine pilot report (UA) CMH; Over 10 miles from Rickenbacker International Airport, Ohio (LCK) on the 270° radial; Time – 0553 EST (1053Z); Altitude – 4,000 ft; Type aircraft – Beechcraft Baron; Sky – Overcast clouds at 3,300 ft with tops at 4,500 ft; Temperature – minus 15 °C; Icing – Light rime.

Routine pilot report (UA) CMH; Over DAY; Time – 0628 EST (1128Z); Altitude – During Climb; Type aircraft – McDonnell Douglas MD-88; Sky – Bases at 4,000 ft with tops at 5,400 ft; Icing – Negative.

Routine pilot report (UA) CMH; Over 10 miles from CMH on the 270° radial; Time – 0649 EST (1149Z); Altitude – 3,000 ft; Type aircraft – Airbus A320; Sky – Tops at 5,500 ft with bases at 3,000 ft; Turbulence – Negative; Icing – Negative.

Routine pilot report (UA) CRW; Over 10 miles from CRW on the 270° radial; Time – 0735 EST (1235Z); Altitude – 5,000 ft; Type aircraft – Boeing 737-700; Icing – Light rime.

Routine pilot report (UA) CMH; Over 5 miles from Neil Armstrong Airport, Ohio (AXV) on the 180° radial; Time – 0737 EST (1237Z); Altitude – During climb; Type aircraft – Gulfstream V; Sky – Tops at 5,500 ft; Icing – Negative.

Routine pilot report (UA) CMH; Over CMH; Time – 0754 EST (1254Z); Altitude – During climb; Type aircraft – Airbus A320; Sky – Bases at 3,300 ft with tops at 5,100 ft; Icing – Negative.

Routine pilot report (UA) Bolton Field Airport, Ohio (TZR); Over TZR; Time – 0759 EST (1259Z); Altitude – 1,500 ft; Type aircraft – Piper PA-32; Weather – Flight visibility 2 statute miles in light snow; Temperature – minus 4 °C; Icing – Light rime; Remarks – During descent into runway 04 RNAV light rime icing between 4,000 and 5,000 ft, visibility 2 miles in light snow, bases at 1,800 ft.

Routine pilot report (UA) CMH; Over Dayton-Wright Brothers Airport, Ohio (MGY); Time – 0808 EST (1308Z); Altitude – During climb; Type aircraft – Cessna Citation Jet/M2; Sky – Overcast clouds with tops at 5,000 ft; Icing – Light rime icing.

Routine pilot report (UA) CRW; Over 15 miles north of Raleigh County Memorial Airport, West Virginia (BKW); Time – 0825 EST (1325Z); Altitude – 10,000 ft; Type aircraft – Beechcraft Baron; Temperature – minus 6 °C; Icing – Trace icing.

Routine pilot report (UA) CRW; Over CRW; Time – 0830 EST (1330Z); Altitude – 4,000 ft; Type aircraft – Bombardier CRJ-200; Temperature – minus 1 °C; Icing – Light rime.

Routine pilot report (UA) CMH; Over Ohio State University Airport, Ohio (OSU); Time – 0836 EST (1336Z); Altitude – During climb; Type aircraft – Cirrus SR22; Sky – Overcast clouds at 4,200 ft with tops at 5,100 ft; Temperature – minus 5 °C; Icing – Negative.

8.0 SIGMET

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

9.0 CWSU Products

There were no Center Weather Service Unit (CWSU) Center Weather Advisories (CWA) valid for the accident site at the accident time. There was CWSU Meteorological Impact Statement (MIS) valid for the accident site at the accident time. MIS 01 was issued by the CWSU at the Indianapolis Air Route Traffic Control Center (ZID ARTCC) at 2115 EST on January 28, 2019, valid through 0700 EST on January 29, 2019. The MIS forecast gusty west winds behind the surface cold front moving eastward overnight with moderate turbulence and moderate mixed icing conditions between 2,000 ft and FL200:[27]

FAUS20 KZID 290215
ZID MIS 01 VALID 290215-291200
FOR ATC PLANNING PURPOSES ONLY
OVER W HALF ZID SFC WIND 28017G26KT BEHIND SFC CDFNT. CONDS SPREAD
EWD ACRS ZID OVRNGT. MOD TURB ACRS ZID OVRNGT. OVER W HALF ZID MOD
MXD ICG 010-060. **OVER E HALF MOD MXD ICG 020-FL200. CONDS SHIFT EWD**
AS FNT MOVS EWD. LAST. =

10.0 AIRMETs

Airmen's Meteorological Information (AIRMET) advisories Tango and Zulu were issued at 0345 EST valid for the accident site at the accident time. AIRMET Tango and Zulu warned of moderate turbulence below 10,000 ft and moderate icing conditions below 8,000 ft:

WAUS41 KKCI 290845
WA1T
-BOST WA 290845
AIRMET TANGO UPDT 1 FOR TURB STG WNDS AND LLWS VALID UNTIL 291500
.
AIRMET TURB...VT NY LO PA OH LE WV MD VA NC SC GA FL
FROM 30ESE YOW TO 50WSW YSC TO 20W CSN TO 50SW PZD TO GQO TO HMV
TO HNN TO CVG TO FWA TO 30SE ECK TO 30ESE YOW
MOD TURB BTN FL180 AND FL280. CONDS CONTG BYD 15Z THRU 21Z.
.
AIRMET TURB...ME NH VT MA RI CT NY LO NJ PA OH LE WV MD DC DE VA
NC SC GA AND CSTL WTRS
FROM 40E YSC TO 20SW BOS TO 40ENE RIC TO 20SSE GSO TO 30ENE ATL
TO GQO TO HMV TO HNN TO CVG TO FWA TO 30SE DXO TO MSS TO 40E YSC
MOD TURB BLW 100. CONDS CONTG BYD 15Z THRU 21Z.
.
AIRMET STG SFC WNDS...NY LO
FROM 50NNW SYR TO 40NE SYR TO 20W BUF TO 20SSW YYZ TO 40ENE YYZ
TO 50NNW SYR

[27] The term "LAST" issued by the ZID CWSU was there to let the reader know that this MIS would be the "last" MIS statement during the overnight period as the ZID CWSU was closed during the overnight period.

SUSTAINED SURFACE WINDS GTR THAN 30KT EXP. CONDS DVLPG 09-12Z.
CONDS CONTG BYD 15Z ENDG 15-18Z.
.
AIRMET STG SFC WNDS...NY PA OH LE
FROM 60SSW YYZ TO 30SW BUF TO 20SW CLE TO 30SE DXO TO 70SE ECK
TO 60SSW YYZ
SUSTAINED SURFACE WINDS GTR THAN 30KT EXP. CONDS ENDG 12-15Z.
.
LLWS POTENTIAL...NH VT MA CT NY LO NJ PA OH LE WV MD DC DE VA NC
SC AND CSTL WTRS
BOUNDED BY 30ESE YOW-30SE YSC-20SSE BDL-20E ECG-40SSE CLT-50S
APE-30NNE APE-40S YYZ-30ESE YOW
LLWS EXP. CONDS CONTG BYD 15Z ENDG 18-21Z.
.
OTLK VALID 1500-2100Z
AREA 1...TURB ME NH VT MA NY LO NJ PA OH LE WV MD DC VA NC SC GA
BOUNDED BY 70NW PQI-30NNE PQI-40ESE EMI-40N ILM-20SW CHS-GQO-HMV-
HNN-20NE CVG-40N CLE-30ESE YOW-20S YSC-70NW PQI
MOD TURB BTN FL180 AND FL280. CONDS CONTG THRU 21Z.
.
AREA 2...TURB ME NH VT MA RI CT NY LO NJ PA OH LE WV MD DC DE VA
NC SC GA AND CSTL WTRS
BOUNDED BY 40NE PQI-40E BOS-90S ILM-20ESE VXV-HMV-HNN-CVG-40S
DXO-30SE YOW-40E YSC-50WNW PQI-40NE PQI
MOD TURB BLW 100. CONDS CONTG THRU 21Z.
...

WAUS41 KKCI 290845
WA1S
-BOSS WA 290845
AIRMET SIERRA UPDT 1 FOR IFR AND MTN OBSCN VALID UNTIL 291500
.
AIRMET IFR...WV VA NC SC GA FL AND CSTL WTRS
FROM 40W EKN TO 20W CSN TO 30N GSO TO 20N SPA TO 30W IRQ TO 20SE
MCN TO 40SW PZD TO 60SW TLH TO 60SE SJI TO 40W CEW TO 50SW PZD
TO GQO TO HMV TO 30SW HNN TO 40W EKN
CIG BLW 010/VIS BLW 3SM PCPN/BR. CONDS DVLPG AFT 09Z. CONDS
CONTG BYD 15Z ENDG 18-21Z.
.
AIRMET IFR...VT MA CT NY LO NJ PA OH LE WV MD DC DE VA
FROM 20ESE YOW TO 60WSW YSC TO 20N BDL TO 20NNE JFK TO 20SSW SAX
TO 20SSW DCA TO 40W EKN TO 40SE EWC TO 40SE CLE TO 20NNW ERI TO
20WSW BUF TO 30ESE YYZ TO 40NW SYR TO 20ESE YOW
CIG BLW 010/VIS BLW 3SM PCPN/BR. CONDS CONTG BYD 15Z THRU 21Z.
.
AIRMET MTN OBSCN...NH VT MA NY PA WV MD VA NC SC GA
FROM 20SSW YSC TO 50E MPV TO CON TO 20N SAX TO 30SSW HAR TO 30N
GSO TO 30W SPA TO ATL TO GQO TO HMV TO HNN TO EWC TO 20NW JHW TO
20NNE SYR TO MSS TO 20SSW YSC
MTNS OBSC BY CLDS/PCPN/BR. CONDS CONTG BYD 15Z THRU 21Z.
.
OTLK VALID 1500-2100Z
AREA 1...IFR ME NH VT MA CT NY LO NJ PA LE WV MD DC DE VA AND
CSTL WTRS
BOUNDED BY 20SE YSC-30S ENE-20SSW BDL-20NNE JFK-40N ORF-20ESE
CSN-20W EKN-30SSW PSB-30SW SYR-20WSW BUF-20E YYZ-40NW SYR-20SE

YOW-50WSW YSC-20SE YSC
CIG BLW 010/VIS BLW 3SM PCPN/BR. CONDS CONTG THRU 21Z.
.
AREA 2...IFR WV VA NC SC GA FL AND CSTL WTRS
BOUNDED BY 20WSW EKN-20WSW CSN-30N GSO-20NNW SPA-40NE MCN-60E
TLH-80SW TLH-50SSE SJI-40W CEW-50SW PZD-GQO-HMV-40WSW BKW-20WSW
EKN
CIG BLW 010/VIS BLW 3SM PCPN/BR. CONDS ENDG 18-21Z.
.
AREA 3...MTN OBSCN ME NH VT MA NY PA WV MD VA NC SC GA
BOUNDED BY 70ESE YQB-CON-20NNW SAX-HAR-40SE PSK-ATL-GQO-HMV-HNN-
EWC-JHW-SYR-20NE MSS-20ESE YSC-70ESE YQB
MTNS OBSC BY CLDS/PCPN/BR. CONDS CONTG THRU 21Z.
....

WAUS41 KKCI 290845
WA1Z
-BOSZ WA 290845
AIRMET ZULU UPDT 2 FOR ICE AND FRZLVL VALID UNTIL 291500
.
AIRMET ICE...NY PA OH LE WV
FROM 30SE ECK TO 30WNW CLE TO 20WNW ERI TO 20WSW BUF TO 20NNE AIR
TO HNN TO CVG TO FWA TO 30SE ECK
MOD ICE BLW 080. CONDS CONTG BYD 15Z THRU 21Z.
.
AIRMET ICE...NH VT MA RI CT NY LO NJ PA OH LE WV MD DC DE VA AND
CSTL WTRS
FROM 20SSE YSC TO 20SE BOS TO 60ESE CYN TO 20NE ECG TO 30NE GSO
TO HMV TO HNN TO 20NNE AIR TO 20WSW BUF TO 20ESE YYZ TO 20SE YOW
TO 20SSE YSC
MOD ICE BTN FRZLVL AND 150. FRZLVL SFC-050. CONDS CONTG BYD 15Z
THRU 21Z.
.
OTLK VALID 1500-2100Z
AREA 1...ICE NY LO PA OH LE WV MD VA
BOUNDED BY 60NE YYZ-50N SYR-20SSE SLT-60S JST-HMV-HNN-CVG-50S
FWA-20NE ROD-40S DXO-30SE ECK-60NE YYZ
MOD ICE BLW 070. CONDS CONTG THRU 21Z.
.
AREA 2...ICE ME NH VT MA RI CT NY LO NJ PA WV MD DC DE VA AND
CSTL WTRS
BOUNDED BY 70WNW PQI-40W YSJ-ACK-120E ORF-50ESE ORF-HMV-60S
JST-50N SYR-20ESE YOW-YSC-70WNW PQI
MOD ICE BTN FRZLVL AND 150. FRZLVL SFC-050. CONDS CONTG THRU 21Z.
.
FRZLVL...RANGING FROM SFC-050 ACRS AREA
  MULT FRZLVL BLW 050 BOUNDED BY JST-20WNW EMI-30NNW CYN-60SE
    JFK-110SE SIE-70SE SBY-40SW SBY-40WSW ORF-50NE RDU-50SW
    CSN-50S EKN-JST
  SFC ALG HMV-40WSW CSN-30SE DCA-20SSW HTO-140ENE ACK
  040 ALG 20NNW GSO-20SSE LYH-60SSW RIC
  040 ALG 80E ORF-120SE SBY-150SE ACK-160ESE ACK
....

11.0 Graphical Forecasts for Aviation

The Graphical Forecasts for Aviation (GFA) products available before the accident flight are shown in attachment 5. The GFA surface forecast products indicated VFR surface visibilities at the accident site for 0400 and 0700 EST with G-AIRMET[28] Zulu forecast for the accident site by 0400 EST. There was a chance (between 30 and 60 percent) of light snow or snow shower activity forecast with a westerly surface wind of 10 to 15 knots. The GFA cloud forecast valid before departure (issued at 0202 and 0502 EST) for 0400 and 0700 EST indicated MVFR ceilings conditions at the accident site with an overcast cloud ceiling at 2,200 to 2,800 ft msl and clouds tops between 5,000 and 7,000 ft msl. For more information please see attachment 5.

The reason for the differences between the GFA surface forecast and the GFA cloud forecast is the two are computed automatically by two different weather models. In this case, the cloud forecast indicated a lower flight category condition than was forecast in the surface forecast product. The Rapid Refresh (RAP) weather model is used for the cloud forecast and the Localized Aviation MOS[29] Program (LAMP) weather model is used for the surface forecast charts, and both forecasts are issued with no human intervention. The only human-generated information reflected in the two GFA products are the AIRMETs and the GFA is "human-over-the-loop."

12.0 Terminal Aerodrome Forecast

Mid-Ohio Valley Regional Airport, West Virginia, (KPKB) was the closest airport to the accident site with a NWS Terminal Aerodrome Forecast (TAF) located 40 miles east of the accident site. The KPKB TAF valid at the time of the accident was issued at 0410 EST and was valid for a 21-hour period beginning at 0400 EST. The 0410 EST TAF for KPKB was as follows:

KPKB 290910Z 2909/3006 **29011G19KT P6SM OVC018**
FM291200 25010G19KT P6SM OVC022
FM292000 25012G21KT P6SM BKN035=

Between 0400 and 0700 EST, the forecast expected a wind from 290° at 11 knots with gusts to 19 knots, greater than 6 miles visibility, and an overcast ceiling at 1,800 ft agl.

13.0 NWS Area Forecast Discussion

The NWS office in Charleston, West Virginia, issued the following Area Forecast Discussion (AFD) at 0640 EST (closest AFD to the accident time). The aviation section of the AFD discussed a transition from rain to snow in the mountains with IFR conditions possible in the snow with winds between 10 to 20 knots and gusts to 20 to 30 knots out of the west:

FXUS61 KRLX 291140
AFDRLX

AREA FORECAST DISCUSSION
National Weather Service Charleston WV
640 AM EST Tue Jan 29 2019

[28] G-AIRMET, graphical AIRMETs. May different in space from text AIRMET product.
[29] Model Output Statistics: https://www.weather.gov/mdl/mos_home

.SYNOPSIS...
Sharply colder today. Arctic cold front crosses late Tuesday night/Wednesday. Brutally cold through Thursday night. System brings light snow friday, then dry and milder for the weekend.

&&

.NEAR TERM /THROUGH TONIGHT/...
As of 630 AM Tuesday...

Made some timing adjustments with the temperatures again, but they were actually doing fairly well. POPs in decent shape as well, and still betting on the surface wave along the front pushing the shield of light snow back into the I79 corridor for a few hours later this morning. As mentioned, it will also serve to slow the exit of the moisture in the mountains as well.

Temperatures likely in the teens in a few of the southeastern Ohio codeine's.

As of 255 AM Tuesday...

As of the issuance of this near term, southeastern Ohio counties now falling below freezing into the 20s, and expect this eastward trend to continue through the early morning hours. Cold front appears to be around the I-79 corridor and should be east of the mountains by 12Z this morning. Both the RAP and HRRR indicate a wave developing along the front at this time which would slow the exit of the moisture through the mountains, largely the reason for the 1 to 3 inch snow accumulations there as precipitation will persist a couple/few more hours. In the end, the changes to the near term forecast are minimal for the most part, and concentrated on the timing of the falling temperatures today and tonight. Will continue to highlight flash freeze potential in the advisory as lowland snow on top of this should be less than an inch. Will be watching the wind gusts this morning as well, with 20-30kt gusts currently along the front and in rain onset. Will see if these relax slightly in the wake of the front. Tonight, gusts ramp up again, and with the falling temperatures, wind chill will start to become an issue in southeastern Ohio and in the higher ridges.

&&

.SHORT TERM /WEDNESDAY THROUGH FRIDAY NIGHT/...
As of 550 AM Tuesday...

What may prove to be the coldest arctic outbreak of the season charges in early Wednesday morning, with temperatures going nowhere Wednesday. Its arrival is timed such that most of the cold advection occurs by dawn, or shortly thereafter. Driven by a large, deep upper level low, as low as 486 dm at 500 mb, sailing across southeastern Canada Wednesday and Wednesday night, the air mas feature 850 mb temperatures of 30 C below zero approaching the middle Ohio Valley Thursday morning, and

ranging from the lower 20s below zero south to the upper 20s below zero north Wednesday. A wave along the front will bring a light fluffy snow, mainly in and near the mountains, Wednesday morning.

The arctic high crosses Thursday, with lows in the morning reflective more of the air mass, with minimal help from radiation. As such, stayed away from the low MET, which paints 5 to 7 degrees below zero across much of the lowlands. The forecast is closer to central guidance and consensus, but still below the higher raw guidance, and close to or a bit below the previous forecast, and below zero across all but far southern portions of the forecast area.

After falling initially Thursday night, temperatures rise on warm advection overnight, as a wave tracking south of the area may bring light snow accumulations overnight Thursday night into Friday. A bit of rain is even possible southern portions of the forecast area Friday, as temperatures climb above freezing.

High pressure rebuilds Friday night, but with no new supply of cold air.

Went a little lower than central guidance temperatures Thursday and Thursday night, and then followed closely through Friday night.

Strong wind gusts to 30 to 35 mph across the lowlands, and 40 to 45 mph along the higher ridges, will follow the arctic cold front on Wednesday. This warranted wind chill warnings across far northwest portion of the forecast area, and the higher terrain of the northern WV mountains, by Wednesday morning, although it may take until late morning for warning criteria to be reached across the latter. By overnight Wednesday night, wind chill advisories go into affect throughout much of the forecast area. The wind chill warnings may be able to be lowered to advisories Wednesday afternoon for far northwest portions of the forecast area, and Thursday afternoon across the higher mountainous terrain.

Wind chill advisories go until late morning to early afternoon Thursday across the lowlands, and into Thursday night across the higher mountainous terrain.

&&

.LONG TERM /SATURDAY THROUGH MONDAY/...
As of 550 AM Tuesday...

This period features a stout warm up, as heights rise and zonal flow ensues. High pressure will bring dry weather for most of the weekend, to go with the moderating temperatures. The next system may bring the next chance for rain to start the new work week.

Central guidance reflects highs in the mid 40s on Saturday, mid

50s on Sunday, and then up to the lower 60s for Monday.
Nighttime lows straddle the freezing mark Saturday night, and
then straddle the 40 degree mark Sunday night, and then up in
the 40s for Monday night.

&&

.AVIATION /11Z TUESDAY THROUGH SATURDAY/...
As of 630 AM Tuesday...

Cold front now through all terminals. Rain to change to snow in the mountains over the next hour or two. Light snow has ended for the front end of the forecast for the PKB/HTS line.

Line of precipitation will make only slow eastward progress over the next 5 through the mountains. CRW expected to see a brief break in snow over the next couple of hours, but has it back in the forecast after 1330Z. Keep snow in CKB/BKW/EKN through roughly 18Z with IFR possible in snow a good bet.

Winds 10-20kts and gusts 20-30kts can be expected at all terminals, generally out of the west.

FORECAST CONFIDENCE AND ALTERNATE SCENARIOS THROUGH 12Z WEDNESDAY...

FORECAST CONFIDENCE: Medium.

ALTERNATE SCENARIOS: Observations in snow expected to fluctuate.
Timing of exit may vary from forecast. May need to increase
winds.

EXPERIMENTAL TABLE OF FLIGHT CATEGORY OBJECTIVELY SHOWS CONSISTENCY
OF WFO FORECAST TO AVAILABLE MODEL INFORMATION:
H = HIGH: TAF CONSISTENT WITH ALL MODELS OR ALL BUT ONE MODEL.
M = MEDIUM: TAF HAS VARYING LEVEL OF CONSISTENCY WITH MODELS.
L = LOW: TAF INCONSISTENT WITH ALL MODELS OR ALL BUT ONE MODEL.

DATE	TUE 01/29/19											
UTC 1HRLY	10	11	12	13	14	15	16	17	18	19	20	21
EST 1HRLY	05	06	07	08	09	10	11	12	13	14	15	16
CRW CONSISTENCY	M	M	H	H	H	H	H	M	H	H	H	H
HTS CONSISTENCY	H	H	H	H	H	H	H	L	H	H	H	H
BKW CONSISTENCY	M	M	H	H	M	H	H	M	H	H	H	M
EKN CONSISTENCY	H	H	L	H	H	M	M	M	H	H	M	M
PKB CONSISTENCY	H	H	H	H	H	H	H	H	M	M	H	M
CKB CONSISTENCY	M	H	M	M	H	H	H	H	M	H	H	M

AFTER 12Z WEDNESDAY...
IFR possible in snow Thursday night/Friday.

&&

.RLX WATCHES/WARNINGS/ADVISORIES...
WV...Winter Weather Advisory until 4 PM EST this afternoon for
WVZ032>034-039-040-515>526.
Wind Chill Advisory from 9 AM Wednesday to 1 PM EST Thursday

for WVZ518-520>522-524-525.
Winter Weather Advisory until noon EST today for WVZ005>011-013>020-024>031.
Wind Chill Advisory from 2 AM to 10 AM EST Thursday for WVZ006>008-014>016-018-026-027.
Wind Chill Warning from 7 PM this evening to 10 PM EST Thursday for WVZ523-526.
Wind Chill Advisory from noon Wednesday to 1 PM EST Thursday for WVZ009-017-019-020-028>032-039-040-515>517-519.
Wind Chill Advisory from 6 AM Wednesday to 1 PM EST Thursday for WVZ010-011.
OH...Winter Weather Advisory until noon EST today for OHZ066-067-075-076-083>087.
Wind Chill Advisory from 2 AM to 10 AM EST Thursday for OHZ086-087.
Wind Chill Advisory from noon Wednesday to 1 PM EST Thursday for OHZ085.
Wind Chill Advisory from 6 AM Wednesday to 1 PM EST Thursday for OHZ067-075-076-083-084.
Wind Chill Warning from 4 AM Wednesday to 1 PM EST Thursday for OHZ066.
KY...Winter Weather Advisory until noon EST today for KYZ101>103-105.
Wind Chill Advisory from 2 AM to 10 AM EST Thursday for KYZ101.
VA...Winter Weather Advisory until 4 PM EST this afternoon for VAZ003-004.

&&

$$

14.0 NWS Winter Weather Advisory

The NWS office in Charleston, West Virginia, issued the following winter weather advisory at 0504 EST. The winter weather advisory warned of rapidly falling temperatures, flash freeze conditions, scattered snow showers, and up to an inch of snow accumulation possible through 1300 EST on January 31:

OHZ067-075-076-083-084-291815-
/O.NEW.KRLX.WC.Y.0003.190130T1100Z-190131T1800Z/
/O.CON.KRLX.WW.Y.0007.000000T0000Z-190129T1700Z/
Morgan-Athens-Washington-Jackson OH-Vinton-
Including the cities of McConnelsville, Stockport, Athens, Marietta, Belpre, Jackson, Wellston, Oak Hill, McArthur, and Hamden
504 AM EST Tue Jan 29 2019

...WINTER WEATHER ADVISORY REMAINS IN EFFECT UNTIL NOON EST TODAY...
...WIND CHILL ADVISORY IN EFFECT FROM 6 AM WEDNESDAY TO 1 PM EST THURSDAY...

* WHAT...Rapidly falling temperatures may create flash freeze conditions from earlier rain. Scatttered snow showers will bring

snow accumulations of less than one inch expected. Very cold wind chills expected. Wind chills as low as 20 below zero expected.

* WHERE...Morgan, Athens, Washington, Jackson OH and Vinton Counties.

* WHEN...For the Winter Weather Advisory, until noon EST today. For the Wind Chill Advisory, from 6 AM Wednesday to 1 PM EST Thursday.

* ADDITIONAL DETAILS...Plan on slippery road conditions. The hazardous conditions could impact the morning or evening commute. The cold wind chills could cause frostbite on exposed skin in as little as 30 minutes.

PRECAUTIONARY/PREPAREDNESS ACTIONS...

A Winter Weather Advisory for snow means periods of snow will cause primarily travel difficulties. Expect snow covered roads and limited visibilities, and use caution while driving.

A Wind Chill Advisory means that cold air and the wind will combine to create low wind chills. Frostbite and hypothermia can occur if precautions are not taken. Make sure you wear a hat and gloves.

Additional information can be found at https://www.weather.gov/rlx as well as on our Facebook and Twitter pages.

&&

$$

15.0 Winds and Temperature Aloft Forecast

The NWS 0257 EST Winds and Temperature Aloft forecast valid for the closest point to the accident site is included below:

```
FBUS31 KWNO 290757
FD1US1
DATA BASED ON 290600Z
VALID 291200Z   FOR USE 0800-1500Z. TEMPS NEG ABV 24000

FT  3000    6000    9000   12000   18000   24000  30000  34000  39000
CMH 2720 2629-14 2451-14 2355-20 2380-29 2399-41 239350 238652 247850
```

The accident site was located closest to the CMH forecast point. The 0257 EST CMH forecast for use between 0300 EST and 1000 EST indicated a wind at 3,000 ft from 270° at 20 knots, a wind at 6,000 ft from 260° at 29 knots with a temperature of -14 °C, and a wind at 9,000 ft from 240° at 51 knots with a temperature of -14 °C.

16.0 Icing Potential[30]

Current Icing Potential (CIP) and Forecast Icing Potential (FIP) products are created by the NWS Aviation Weather Center (AWC) and are intended to be supplemental to other icing advisories (e.g. AIRMETs and SIGMETs). Figures 20 through 22 are the FIP icing probabilities and icing severity products, 1-hour forecast valid at 0700 EST at 1,000, 2,000, and 3,000 ft msl. Higher FIP icing probabilities and severities values are seen in the 2-hour forecast valid at both 0600 and 0700 EST (and the 1-hour forecast valid at 0600 EST) between 1,000 and 3,000 ft (attachment 6). The FIP images in figures 20 through 22 indicated between a 20 to 50% probability of icing at 1,000 to 3,000 ft at 0700 EST above the accident site. The FIP also indicated that the icing near the accident site would likely be in the trace category (figures 20, 21, and 22). The FIP indicated an unknown category of Supercooled Large Droplets (SLD) over the accident site at both 0600 and 0700 EST (attachment 6).[31]

The CIP product indicated between a 0 to 50% probability of icing at 1,000 to 3,000 ft at 0700 EST at the accident site (figures 23, 24, and 25). The CIP also indicated that the icing near the accident site would be in the trace category 1,000 and 3,000 ft (figures 23, 24, and 25). The CIP also indicated an unknown probability of SLD near the accident site at 0600 and 0700 EST (attachment 6). For more FIP and CIP data please see attachment 6.

[30] B.C. Bernstein, F. McDonough, M. K. Politovich, B. G. Brown, T. P. Ratvasky, D. R. Miller, C.A. Wolff, and G. Cunning, Current Icing Potential: Algorithm Description and Comparison with Aircraft Observations (Journal of Applied Meteorology, 2005), pp. 969-986.
C.A. Wolff, F. McDonough, M. K. Politovich, B.C. Bernstein, and G. Cunning, FIP Severity Technical Document (Prepared for the Aviation Weather Technology Transfer Technical Review Board), pp. 1-44.
https://arc.aiaa.org/doi/abs/10.2514/6.2009-3531

[31] https://www.aviationweather.gov/icing/fip

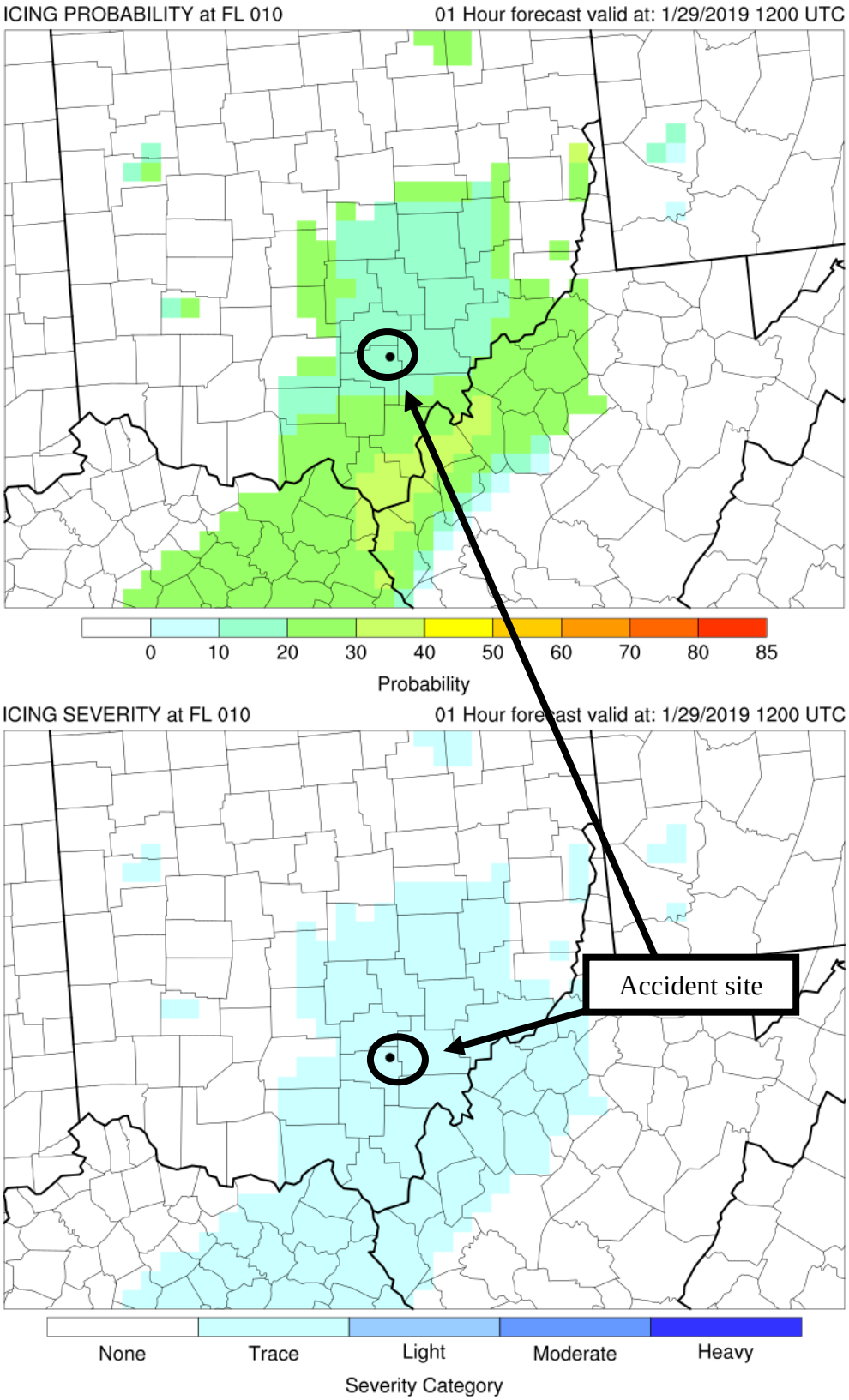


Figure 20 – (top) FIP probability of icing at 1,000 ft msl and (bottom) FIP severity of icing at 1,000 ft msl 1-hour forecast valid for 0700 EST

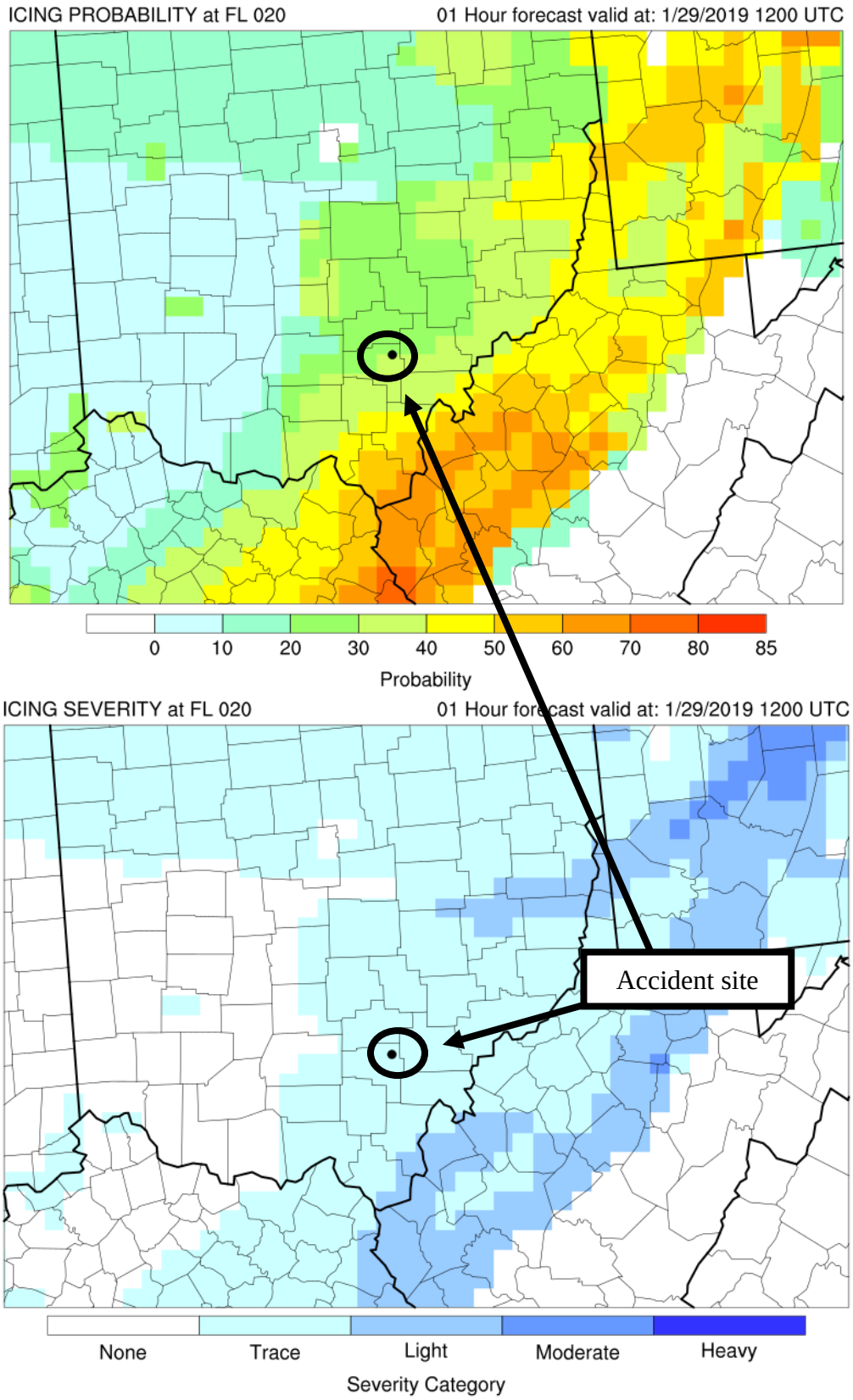


Figure 21 – (top) FIP probability of icing at 2,000 ft msl and (bottom) FIP severity of icing at 2,000 ft msl 1-hour forecast valid for 0700 EST

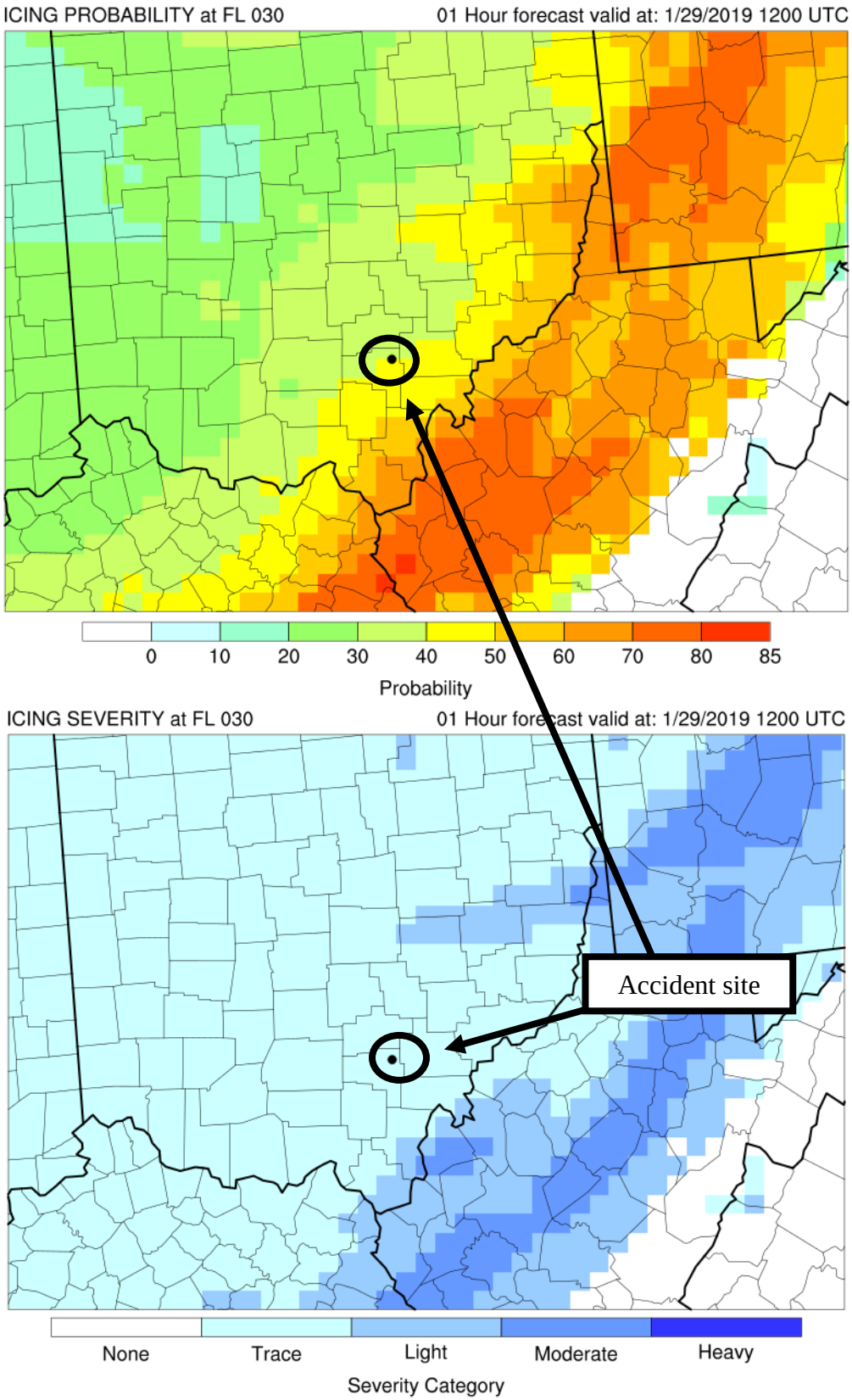


Figure 22 – (top) FIP probability of icing at 3,000 ft msl and (bottom) FIP severity of icing at 3,000 ft msl 1-hour forecast valid for 0700 EST

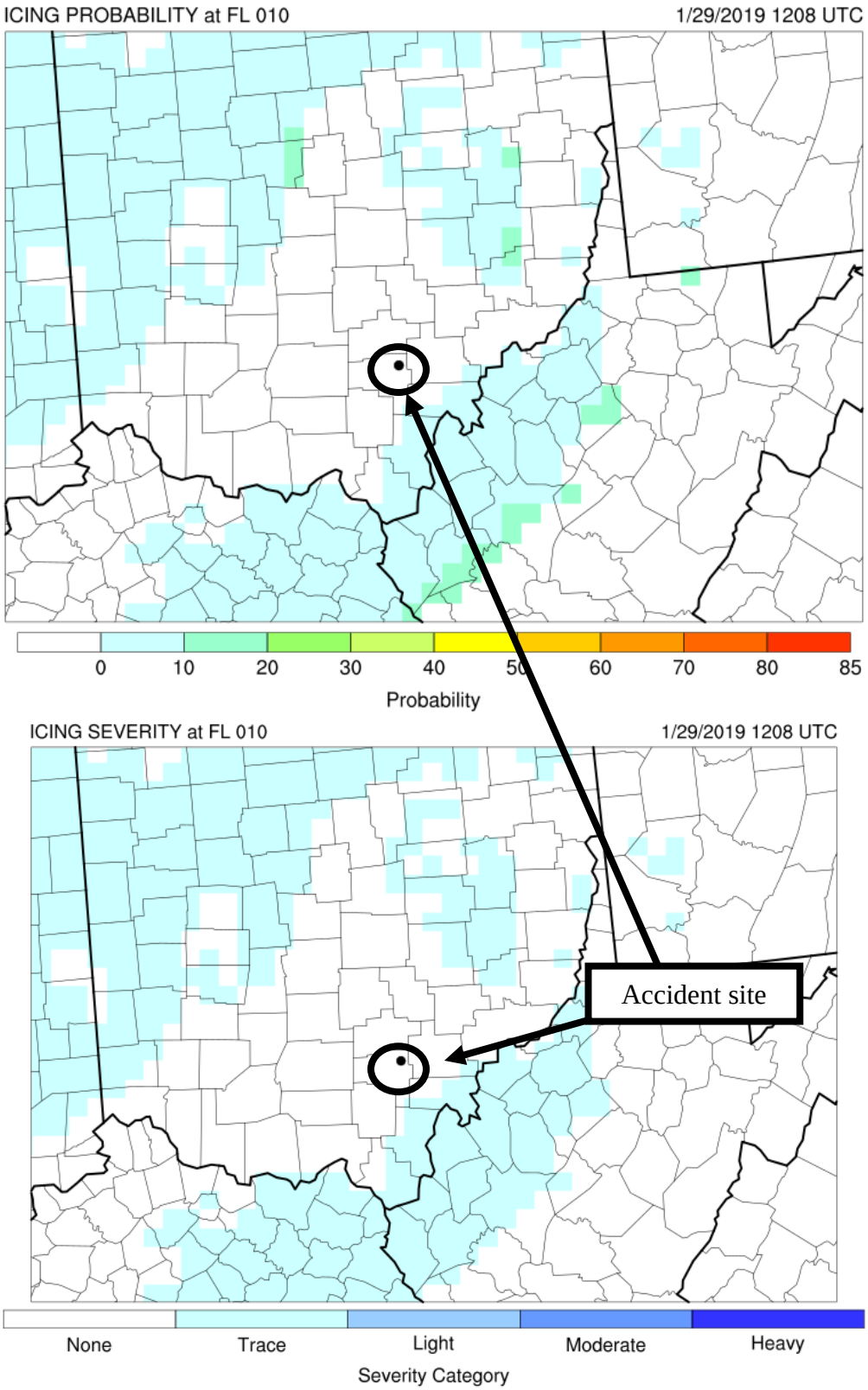


Figure 23 – (top) CIP probability of icing at 1,000 ft msl and (bottom) CIP severity of icing at 1,000 ft msl valid for 0700 EST

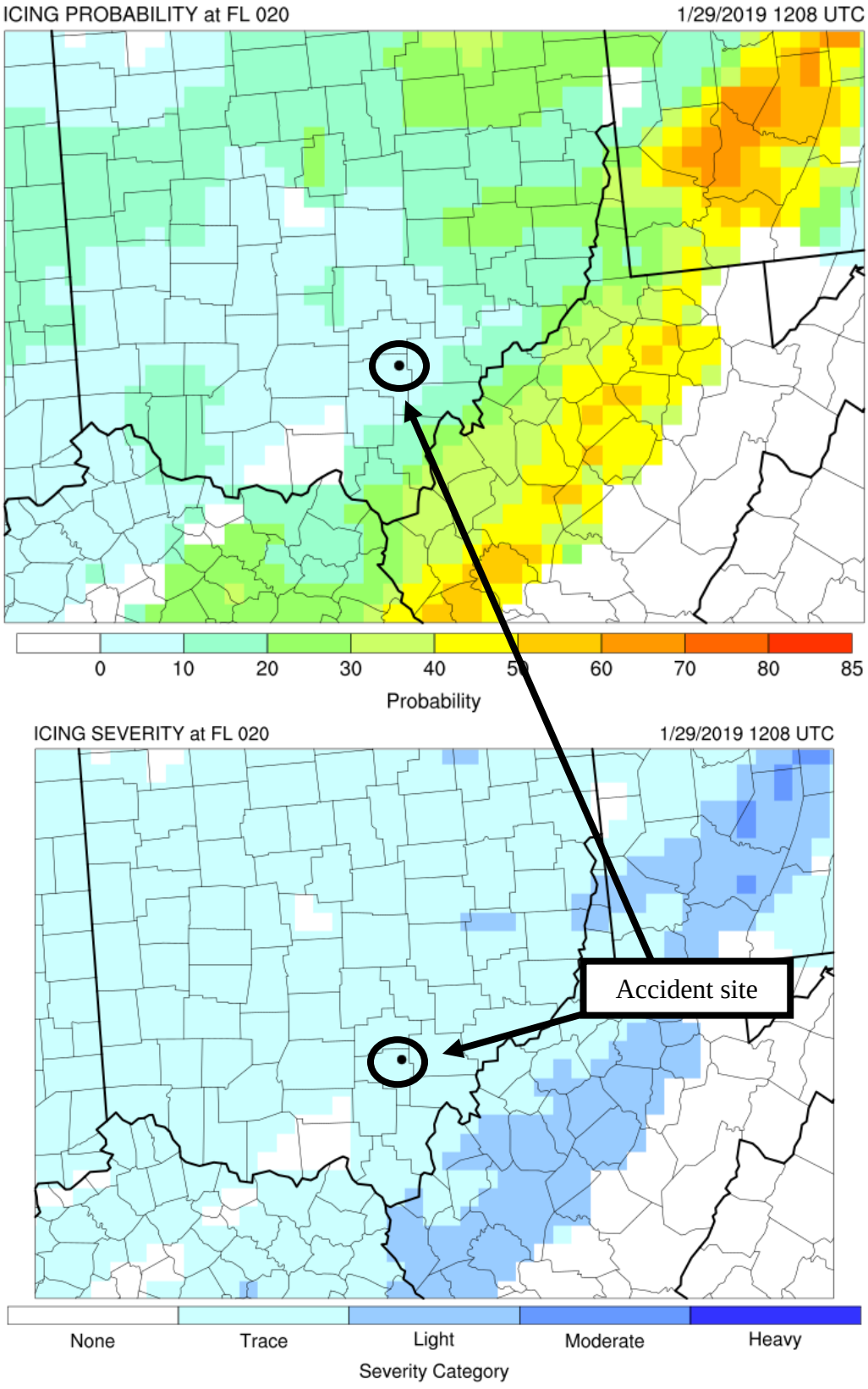


Figure 24 – (top) CIP probability of icing at 2,000 ft msl and (bottom) CIP severity of icing at 2,000 ft msl valid for 0700 EST

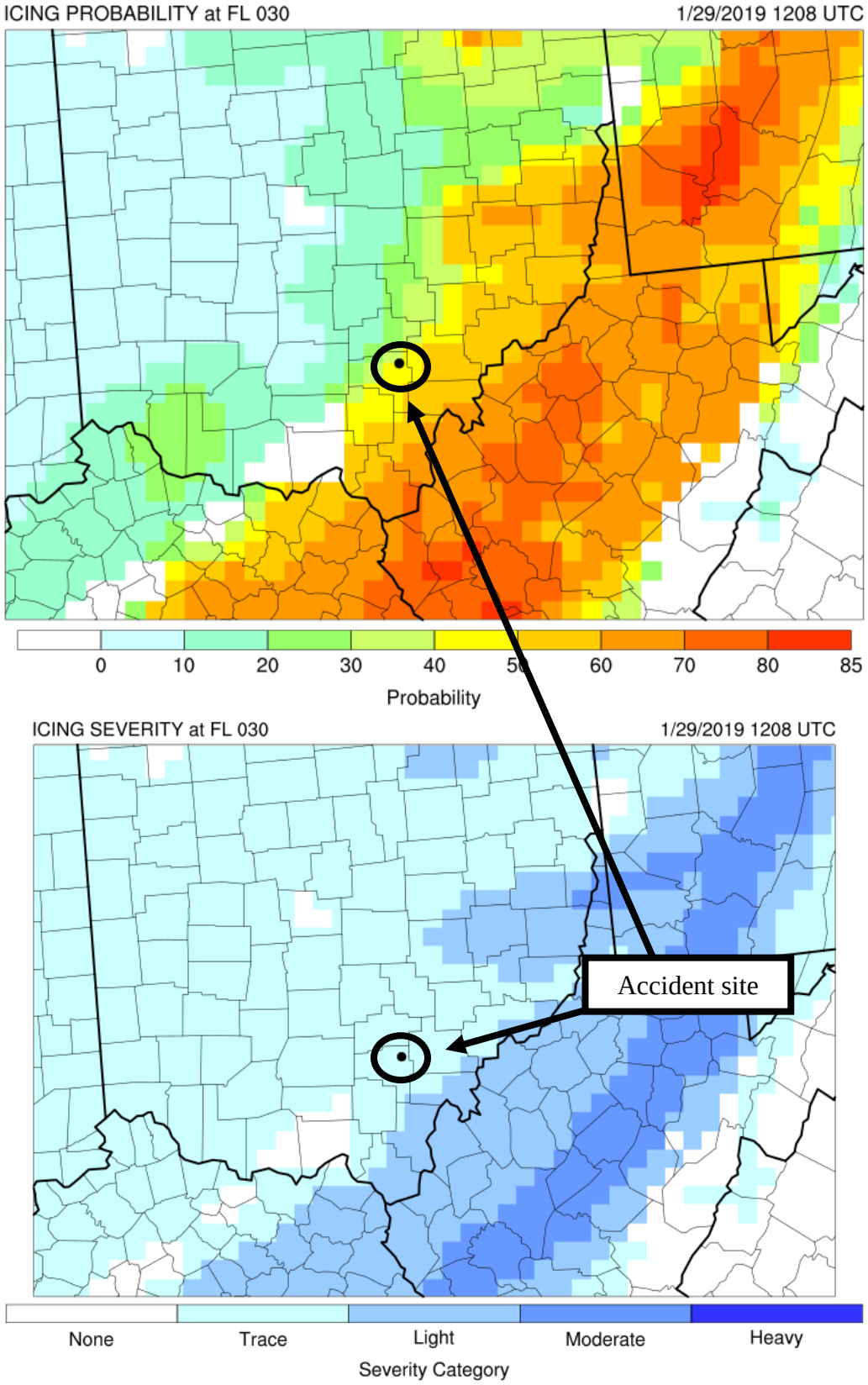


Figure 25 – (top) CIP probability of icing at 3,000 ft msl and (bottom) CIP severity of icing at 3,000 ft msl valid for 0700 EST

17.0 Pilot Weather Briefing

The accident pilot did not request nor receive a weather briefing from Leidos.

A search of archived ForeFlight information indicated that the accident pilot did not request weather information or file a flight plan via ForeFlight. The accident pilot did enter a route into the ForeFlight app at 0632 EST to the user waypoint "HOLZERPOMEROY." The route entered was from 39.787N/0823.966W to 39.055N/082.014W (HOLZERPOMROY). No weather imagery was recently viewed inside the ForeFlight app. For more information please see attachment 7. There is no record of the accident pilot receiving or retrieving any other weather information before or during the accident flight. For more information regarding the risk assessment and processes therein please see the Operations and Human Factors factual located in the docket for this accident.

18.0 HEMS Weather Tool

The Helicopter Emergency Medical Services (HEMS) Tool[32] was developed to support the demanding environment of HEMS operations (attachment 8). The HEMS Tool can overlay multiple fields of interest including many weather related ones and station or map layers. The HEMS Tool began as an experimental product and became operational on May 4, 2015 and is displayed on the AWC website for use (attachment 9). The default HEMS Tool overlay is to layer flight category, PIREPs, SIGMETs, and Multi-Radar/Multi-Sensor System (MRMS)[33] weather radar information on the default mapping projection. MRMS weather radar information does not take into account TDWR information (attachment 11). The HEMS Tool information for 0600 and 0700 EST on the day of the accident is displayed in figures 26 and 27, but due to the late request of information the flight category and MRMS information was not available or displayed (attachment 10). For more information please see attachments 8 through 10.

At the Friends and Partners in Aviation Weather (FPAW) meeting on April 17, 2019, a discussion was held on the "Next Generation of HEMS Weather Tool." There was discussion on the historical background of the HEMS Weather Tool, where technology currently stands for updates, and some ideas of the future HEMS Weather Tool.[34] During the question and answer portion of the session, a question was asked if the HEMS Weather Tool could incorporate or overlay the TDWR information. The AWC responded that they did not think there would be any issues preventing adding TDWR overlay to the HEMS Weather Tool and would take it as an action item to see if feasible and on what time scale it could be added or accomplished. For more information please see attachment 12. More information was requested of the background of the HEMS Weather Tool and requirements therein from the FAA. The HEMS Weather Tool background information provided by the FAA is included in attachments 16 to 19 which includes the HEMS Safety Risk Management Document (SRMD) (attachments 16 and 17), FAA notice N 8000.333 from November 2006 (attachment 18), and FAA correspondence regarding historical context for the HEMS Weather Tool requirements (attachment 19).

[32] https://aviationweather.gov/hemst
[33] https://www.nssl.noaa.gov/news/factsheets/MRMS_2015.March.16.pdf
[34] https://ral.ucar.edu/events/2019/friends-and-partners-in-aviation-weather

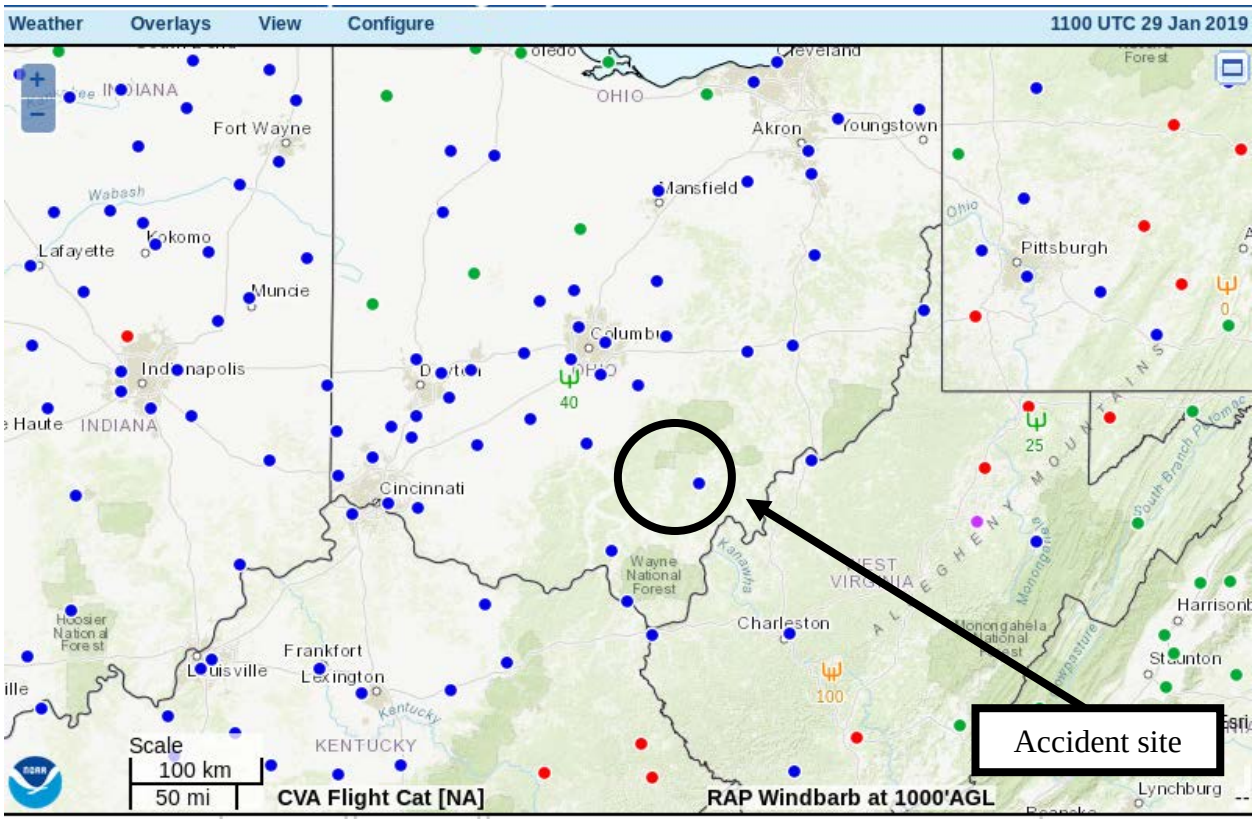


Figure 26 – HEMS Tool valid at 0600 EST

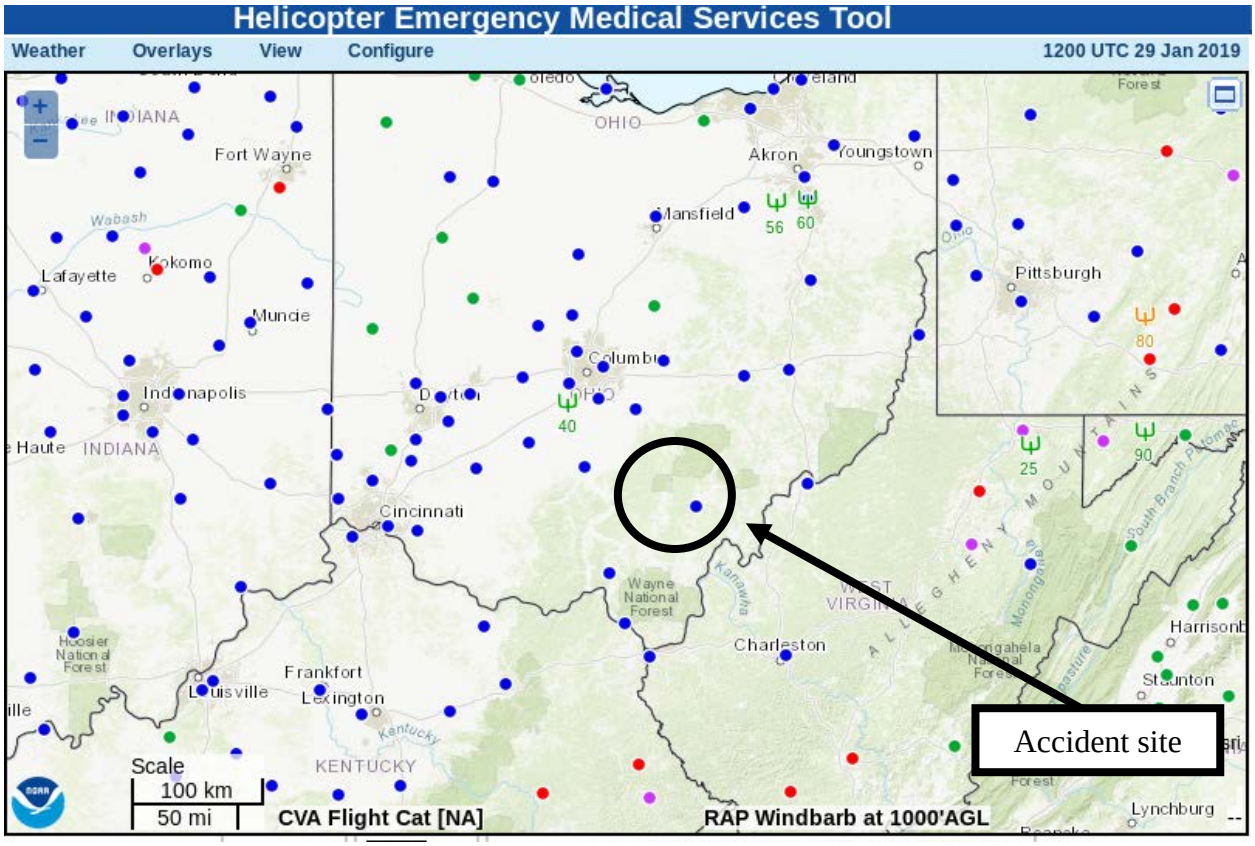


Figure 27 – HEMS Tool valid at 0700 EST

19.0 Survival Flight Operations Control Center[35]

SF Operations Control Center (OCC) personnel on duty at the time of the accident were interviewed. The Operations Control Specialist (OCS) on duty at the time of the accident indicated that he began his shift at 0200 CST on the day of the accident and was in day 3 of 4 night shift work periods. Before the accident flight the OCS received a call from Holzer Meigs Emergency Room in Pomeroy, Ohio, requesting a weather check for a potential flight to Columbus, Ohio. The OCS began flight planning via the computer-aided dispatch consul and called the pilot on duty for a weather check for the proposed flight. The OCS had the HEMS Weather Tool up checking the weather as an added measure. The OCS recalled the weather the night and morning of the accident as marginal with 1,500 ft or higher ceilings with some light snow reporting at the METAR sites, but nothing "seemed" alarming. The weather radar returns to the west showed little patch of snow, but the composite radar on the HEMS Tool didn't necessarily show "always what's on the ground." The OCS recalled some light snow reported between Columbus and Pomeroy, but nothing that would stand out to them, recalling the visibilities at 5 miles and above. The OCS on duty at the time of the accident normal HEMS Weather Tool configuration was to have the flight category overlay with radar, METAR, and TAFs, and if other situations warranted they would overlay additional weather products. The OCS did not recall if they had AIRMETs overlaid on their HEMS Weather Tool display, and did not recalled any significant weather or AIRMETs out for Ohio during the night and morning of the accident. The OCS was not concerned about icing as it was pretty dry and didn't recall seeing anything that was calling for icing.

The OCS on duty at the time of the accident typically used METARs and TAFs as the go/no-go decision point for weather minimums and stayed updated on the weather conditions during their shift by viewing aviation discussion, TAF updates, Prog charts, and mainly the HEMS Weather Tool. They would occasionally use weather resources from the College of DuPage or WeatherTAP. The OCS stated that southeastern Ohio was not the best place for (weather) radar coverage, and believed there is an area there where they can only get (weather) radar coverage down to 6,000 to 4,000 ft but there were other experts in the OCC more familiar on the exact details therein.

The OCS recalled a recent flight that had to turn around due to weather in Oklahoma where there was an icing concern and after accepting the flight and 2 minutes in the pilot turned around due to actual icing buildup on the windshield. The pilot had stated before the flight that icing may be a concern, but they (SF) had another aircraft flying in Oklahoma City at the time and that flight stated they had no icing. According to the SF OCC shift change checklist the weather was indicated as "amber" for the shift before the accident flight.[36]

[35] For more information please see the interviews located in the docket for this accident.
[36] For more information please see the attachments from the Operations and Human Factors factual for this accident.

The OCS who began their shift after the accident time stated they didn't see anything weather wise that would warrant not taking the accident flight. The METARs indicated MVFR conditions and weather radar showed no precipitation and satellite information was not helpful for seeing fog information with the higher cloud cover above. They stated that when viewing weather information they would pass along the weather information that they had, but then it was up to pilot's discretion on how they (the pilots) use that weather information. The HEMS Weather Tool display was one of their main weather sources for watching and monitor weather information and trends. They had not seen any gaps in the coverage of weather radar information where their bases were as the weather radars cover a good amount of the area. They stated it is up to pilot's discretion as to what altitude the flights are taken and that pilots will typically provide PIREPs when they fly into unforecast weather and they (OCS) input the PIREP on the SF OCC shift change checklist form. According to the SF OCC shift change checklist the weather was indicated as "green" for the accident flight.[37]

The SF OCC room was setup with 2 computer workstations with several computer monitors. Figure 28 shows an exemplar image of a typical SF OCC computer workstation setup.

Figure 28 – SF OCC exemplar workstation setup

[37] For more information please see the attachments from the Operations and Human Factors factual for this accident.

20.0 SF Weather training

Before beginning work in the SF OCC, the OCS went through two weeks of classroom and hands on training. On the job training continued for the next 1 to 2 months before working independently in the SF OCC. The Director of safety and training at SF described the training for working at the OCC as 70 to 80 percent weather with several of the OCS holding degrees in meteorology. Weather training for a position in the OCC was comprised of general background on weather, fronts and the aviation environment typically associated, severe weather issues, winter weather issues, "real-world" scenarios, etc… The "weather" training portion provided in OCC training and the weather training provided to pilots is found in attachments 13, 14, and 15.[38]

21.0 FAA Documentation on Flight in Snow and Correspondence of "known ice" Conditions

Several FAA publications discuss flight in winter precipitation conditions, including AC 00-06B, AC 00-45H, the Aeronautical Information Manual (AIM), and AC 91-74B. Information such as, "In flight, dry snow is unlikely to pose a hazard with respect to icing; however, wet snow may begin to adhere to aircraft surfaces. If wet snow does begin to stick, it should then be treated as an icing encounter because ice may begin to form under this accumulation of snow. No aircraft is evaluated in the icing-certification process for this rare situation. If it occurs, the aircraft should exit the conditions as quickly as possible and declare an emergency or contact air traffic control (ATC) as necessary. Be aware that freezing drizzle can coexist with snow. If you are flying into or over areas reporting snow, it is important to understand that the presence of snow does not necessarily mean that icing conditions are not present" is included. For more information regarding "known ice/icing" and the FAA interpretation of such, please see the Operations and Human Factors factual for this accident.

22.0 Additional Flight and Weather Information[39]

Data were obtained for additional flights conducted by SF on January 14, 2019, January 24, 2019, and December 6, 2018, and below is weather information surrounding those flights. The flight on January 14, 2019, departed a Cleveland, Ohio, hospital around 1716 EST and landed at a hospital near Grove City, Ohio, at about 1903 EST. Figure 29 shows the flight track (white dots and red line) with the location of official surface observation sites along the route of flight.

[38] For more information please see the attachments from the Operations and Human Factors factual for this accident.
[39] For more flight track information on these flights please see the docket for this accident.

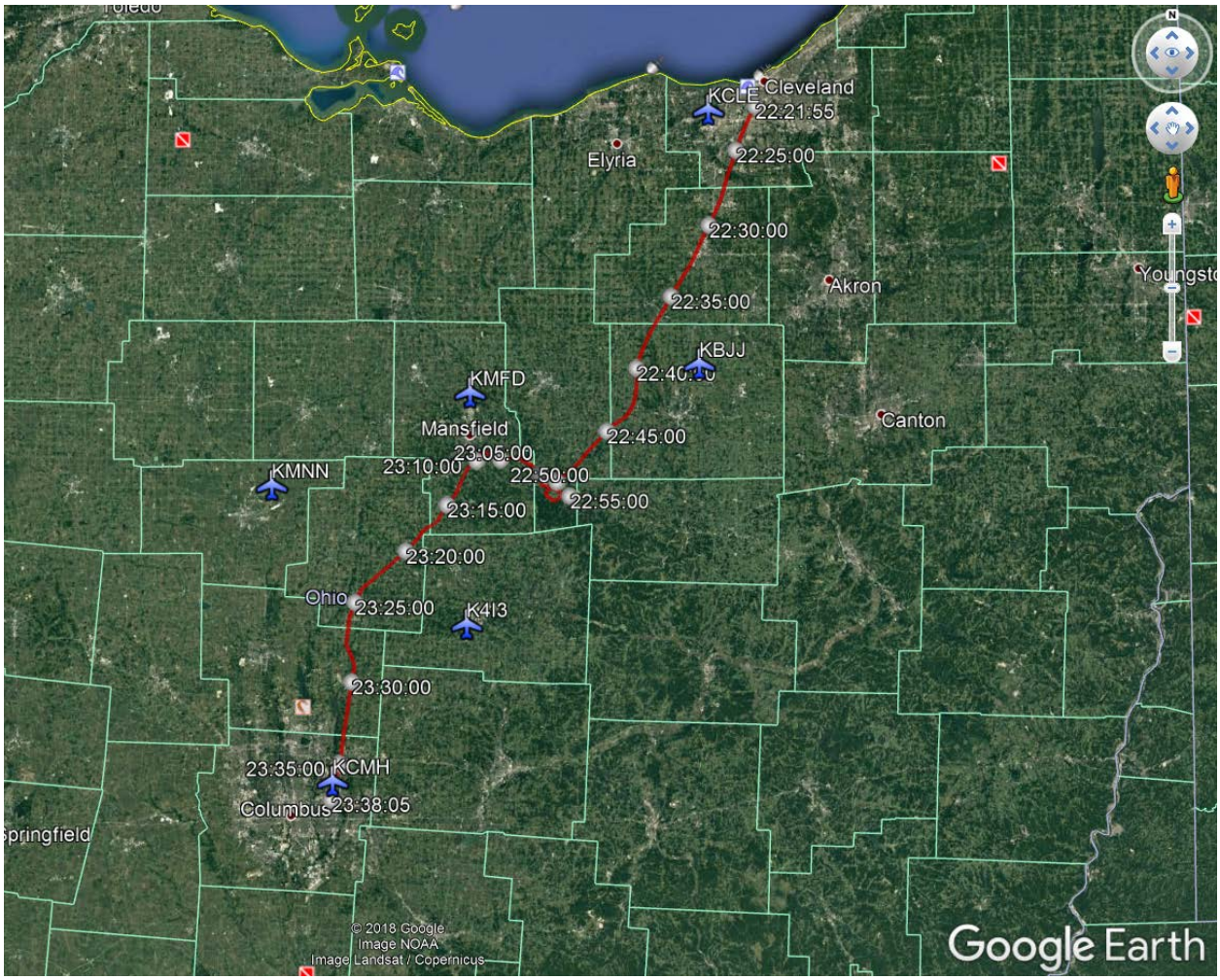


Figure 29 – Google Earth map with the location of surface observation sites for the January 14, 2019 SF flight and the flight track (white dots and red line)

Around the approximate departure time from Cleveland, Ohio, the Cleveland-Hopkins International Airport (KCLE), reported a ceiling at 2,000 ft agl with visibility of 10 miles or greater in the 1651 EST METAR. Mansfield Lahm Regional Airport (KMFD) reported a ceiling at 400 ft agl, visibility of 3 miles, temperature of -4°C, and dew point temperature of -5°C at 1652 EST. Wayne County Airport (KBJJ) reported a ceiling at 1,100 ft agl and visibility of 10 miles or greater at 1656 EST. Marion Municipal Airport (KMNN) reported clear skies below 12,000 ft agl and a visibility of 8 miles at 1653 EST. Knox County Airport (K4I3) reported a ceiling at 1,600 ft agl and a visibility of 10 miles or greater at 1656 EST. John Glenn Columbus International Airport (KCMH) reported a ceiling at 1,100 ft agl and a visibility of 7 miles at 1651 EST.

The KMFD TAF valid before 1716 EST on January 14, 2019, was issued at 1521 EST and valid for a 22-hour period beginning at 1500 EST. The 1521 EST TAF for KMFD (on January 14, 2019) was as follows:

TAF KMFD 142021Z 1420/1518 VRB04KT P6SM OVC006
FM142200 VRB03KT P6SM SCT008 OVC012
FM150000 25004KT P6SM SCT015 OVC025
FM150100 25005KT P6SM FEW030 SCT045
FM150800 26006KT P6SM BKN015=

Between 1521 and 1700 EST on January 14, 2019, the forecast expected a variable wind at 4 knots, greater than 6 miles visibility, and an overcast ceiling at 600 ft agl. Between 1700 EST and 1900 EST on January 14, 2019, the forecast expected a variable wind at 3 knots, greater than 6 miles visibility, scattered clouds at 800 ft agl, and an overcast ceiling at 1,200 ft agl. The KMFD TAF was updated again at 1733 EST for the continued IFR visibility and ceiling conditions present at KMFD (attachment 20).

The KCMH TAF valid before 1716 EST on January 14, 2019, was issued at 1241 EST and valid for a 24-hour period beginning at 1300 EST. The 1241 EST TAF for KCMH (on January 14, 2019) was as follows:

TAF KCMH 141741Z 1418/1518 32006KT P6SM OVC015
FM142300 29004KT P6SM SCT015
FM150800 25004KT P6SM BKN015=

Between 1300 and 1800 EST on January 14, 2019, the forecast expected a wind from 320° at 6 knots, greater than 6 miles visibility, and an overcast ceiling at 1,500 ft agl. After 1800 EST on January 14, 2019, the forecast expected a wind from 290° at 4 knots, greater than 6 miles visibility, and scattered clouds at 1,500 ft agl. KMFD and KCMH were the only 2 TAF sites along the route of flight for the January 14, 2019 flight outside of the Cleveland, Ohio, area. For more information on METAR and TAFs for the January 14, 2019, flight please see attachment 20.

The GOES-16 imagery between 1630 and 1845 EST (attachment 21) indicated a west to east movement of the cloud cover with cloud cover present along the intended flight for the January 14, 2019 flight. Figure 30 shows the GOES-16 infrared imagery (band 13, section 4.0) from 1745 EST on January 14, 2019 with cloud cover present across all METAR sites marked (on figure 30) except for KMNN. No precipitation targets from TDWR or WSR-88D data were noted along the flight path during the flight time.

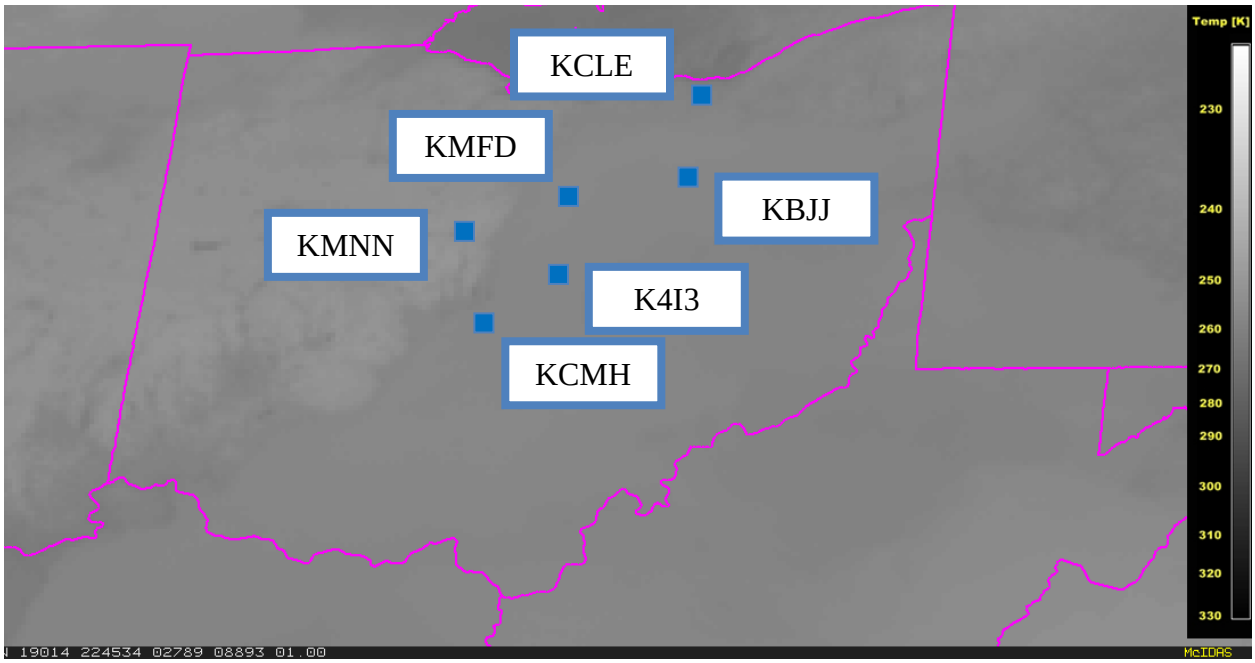


Figure 30 – GOES-16 infrared image at 1745 EST on January 14, 2019

For the January 24, 2019, SF flight, it departed the Columbus, Ohio, region around 1720 EST on January 24, 2019 for the Jackson, Ohio, area. The flight then returned to the Columbus, Ohio, region between approximately 1840 and 1909 EST on January 24, 2019. Below, figure 31 shows the flight track (white dots and red line) with the location of official surface observation sites along the route of flight and the general weather conditions and observations for the Columbus to Jackson, Ohio, region follow figure 31.

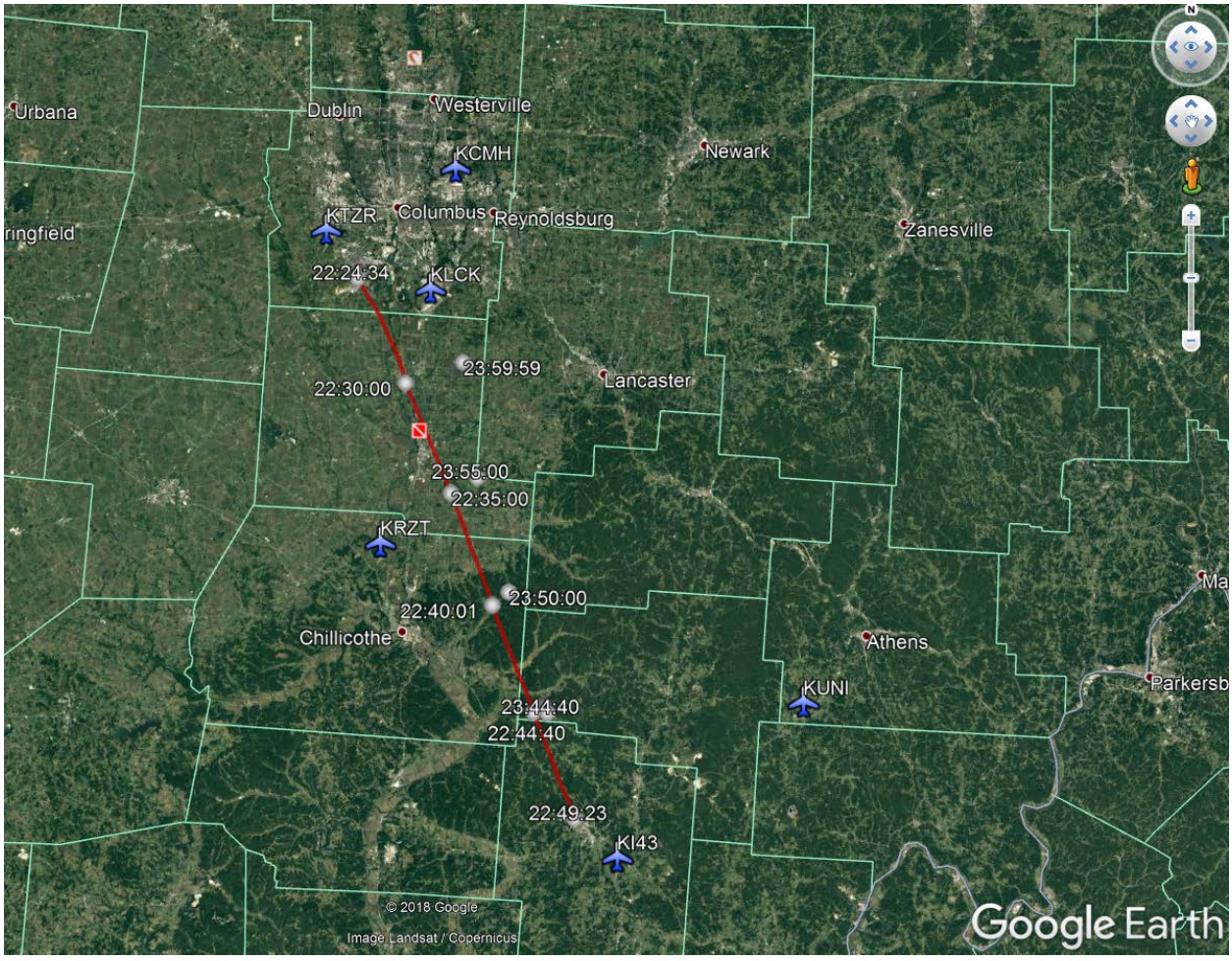


Figure 31 – Google Earth map with the location of surface observation sites for the January 24, 2019 SF flight and the flight track (white dots and red line[40])

Around the approximate departure time from Columbus, Ohio, the Bolton Field Airport (KTZR), reported a wind from 260° at 12 knots with gusts to 16 knots, ceiling at 1,800 ft agl, visibility of 10 miles or greater, temperature of -4°C, and dew point temperature of -7°C in the 1645 EST METAR. KRZT reported a wind from 320° at 10 knots with gusts to 15 knots, ceiling at 2,200 ft agl, and visibility of 10 miles or greater at 1715 EST. James A. Rhodes Airport (KI43) did not report observations on January 23, 24, or 25, 2019. KUNI reported a wind from 260° at 11 knots with gusts to 16 knots, ceiling at 2,500 ft agl, and visibility of 10 miles or greater at 1715 EST. Greater Portsmouth Regional Airport (KPMH) reported a wind from 250° at 3 knots, ceiling at 2,300 ft agl, and visibility of 10 miles or greater at 1716 EST. Rickenbacker International Airport (KLCK) reported a wind from 250° at 12 knots with gusts to 17 knots, ceiling at 2,000 ft agl, and visibility of 10 miles or greater at 1715 EST. KCMH reported a wind from 240° at 11 knots with gusts to 20 knots, ceiling at 2,100 ft agl, and visibility of 10 miles or greater at 1651 EST. In addition, KLCK reported a wind from 240° at 9 knots, ceiling at 2,200 ft agl, and visibility of 10 miles or greater at 1855 EST and KCMH reported a wind from 220° at 8 knots, ceiling at 2,200 ft agl, and visibility of 9 miles with light snow at 1851 EST.

[40] During the return portion of the flight, the red line on the Google Earth imagery was not able to be projected.

The KLCK TAF valid before 1720 EST on January 24, 2019, was issued at 1537 EST and valid for a 21-hour period beginning at 1600 EST. The 1537 EST TAF for KLCK (on January 24, 2019) was as follows:

KLCK 242037Z 2421/2518 26012G18KT P6SM BKN022
FM250100 24012G18KT P6SM BKN025
TEMPO 2502/2504 4SM -SHSN
FM250400 28016G26KT P6SM OVC015
FM251300 27014G22KT P6SM OVC025
FM251700 26012G18KT P6SM SCT035=

Between 1537 and 2000 EST on January 24, 2019, the forecast expected a wind from 260° at 12 knots with gusts to 18 knots, greater than 6 miles visibility, and a broken ceiling at 2,200 ft agl. The KCMH TAF was valid and updated at the same time as the KLCK and the 1537 EST January 24, 2019, KCMH TAF contained the same forecast as the KLCK TAF. For more information on METAR and TAFs for the January 24, 2019, SF flight please see attachment 22. No precipitation targets from TDWR or WSR-88D data were noted along the flight path during the flight time.

For the December 6, 2018, SF flight, the flight departed the Grove City, Ohio, region around 2227 EST on December 6, 2018, approached the KRZT area between 2240 and 2250 EST, and returned to KTZR by 2314 EST on December 6, 2018. Below, figure 32 shows flight track (white dots and red line) with the location of official surface observation sites along the route of flight and the general weather conditions and observations for the Columbus, Ohio, to KRZT region follow figure 32.

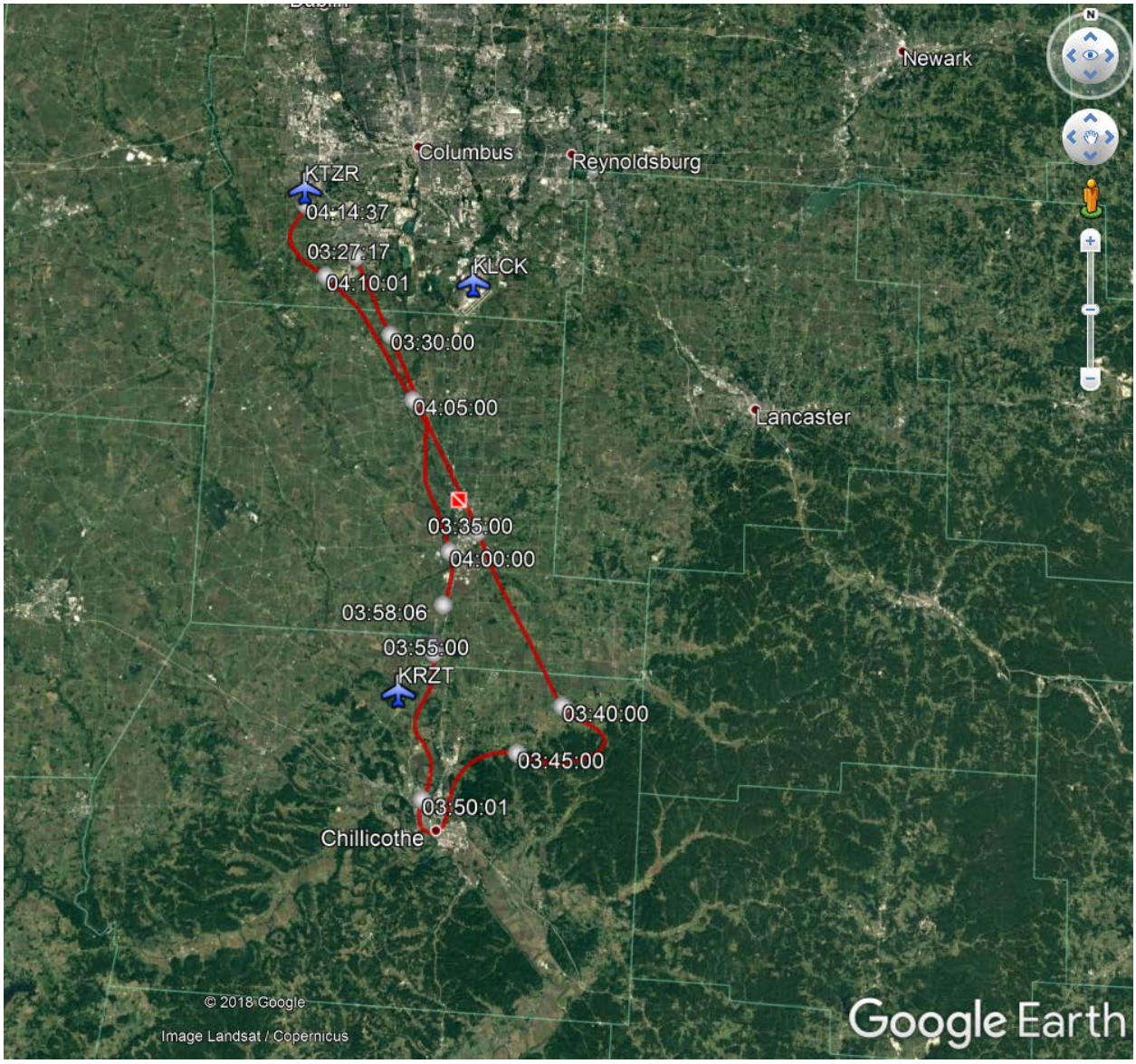


Figure 32 – Google Earth map with the location of surface observation sites for the December 6, 2018 SF flight and the flight track (white dots and red line)

Around the approximate departure time from Grove City, Ohio, KLCK reported a wind from 350° at 9 knots, ceiling at 3,000 ft agl, visibility of 10 miles or greater, temperature of 0°C, and dew point temperature of -3°C in the 2215 EST METAR. KLCK reported ceilings as low as 600 ft agl and visibilities down to 2 miles with light snow when the snow band moved southward through the area (attachments 23 and 24). KRZT reported a wind from 320° at 4 knots, ceiling at 4,800 ft agl, and visibility of 10 miles or greater with light rain at 2215 EST. KTZR reported a wind from 360° at 9 knots, ceiling at 2,800 ft agl, and visibility of 10 miles or greater at 2215 EST. KTZR reported ceilings as low as 500 ft agl and visibilities down to 1 mile with light snow when the snow band moved southward through the area before the flight (attachments 23 and 24).

The KLCK TAF valid before 2227 EST on December 6, 2018, was issued at 2200 EST and valid for a 21-hour period beginning at 2200 EST. The 2200 EST December 6, 2018, TAF for KLCK was as follows:

KLCK 070300Z 0703/0724 **32008KT P6SM SCT030 OVC070**
FM070400 32006KT P6SM SCT035
FM071200 25005KT P6SM SCT012
FM072300 00000KT P6SM FEW050=

Between 2200 and 2300 EST on December 6, 2018, the forecast expected a wind from 320° at 8 knots, greater than 6 miles visibility, scattered clouds at 3,000 ft agl, and an overcast ceiling at 7,000 ft agl. For more information on METAR and TAFs for the December 6, 2018, SF flight please see attachment 23.

Figures 33 through 37 present the KILN WSR-88D base reflectivity images for the 0.5° elevation scans initiated at 2224:04, 2232:49, 2241:33, 2250:20, and 2259:05 EST on December 6, 2018, respectively, with a resolution of 0.5° X 250 m. The image depicted an east to west oriented band of precipitation echoes of 5 to 15 dBZ moving southeastward with time (attachment 24). The December 6, 2018, SF flight entered the precipitation band between 2232 and 2241 EST as the flight continued southward and the flight went north of the precipitation band between 2250 and 2259 EST. For more information on the precipitation band movement and timing please see attachment 24. At the time of departure on the December 6, 2018, SF flight AIRMET Zulu was current for the flight area warning of moderate icing below 8,000 ft. There were no SIGMETs or CWAs valid for the December 6, 2018 flight path.

The GFA surface forecast products indicated MVFR surface visibilities for 2200 EST December 6, 2018, with a chance (between 30 and 60 percent) of light snow or snow shower activity forecast with a westerly surface wind of 5 knots (figure 38). By 0100 EST on December 7, 2018, the GFA surface forecast product indicated no precipitation and VFR conditions (figure 39). The GFA cloud forecast valid before departure on the December 6, 2018, SF flight for 2200 EST on December 6, 2018, and 0100 EST on December 7, 2018, indicated ceilings at 3,000 ft msl with cloud tops at 3,500 ft msl and those cloud conditions moving southward into southern Ohio by 0100 EST on December 7, 2018 (figures 40 and 41).

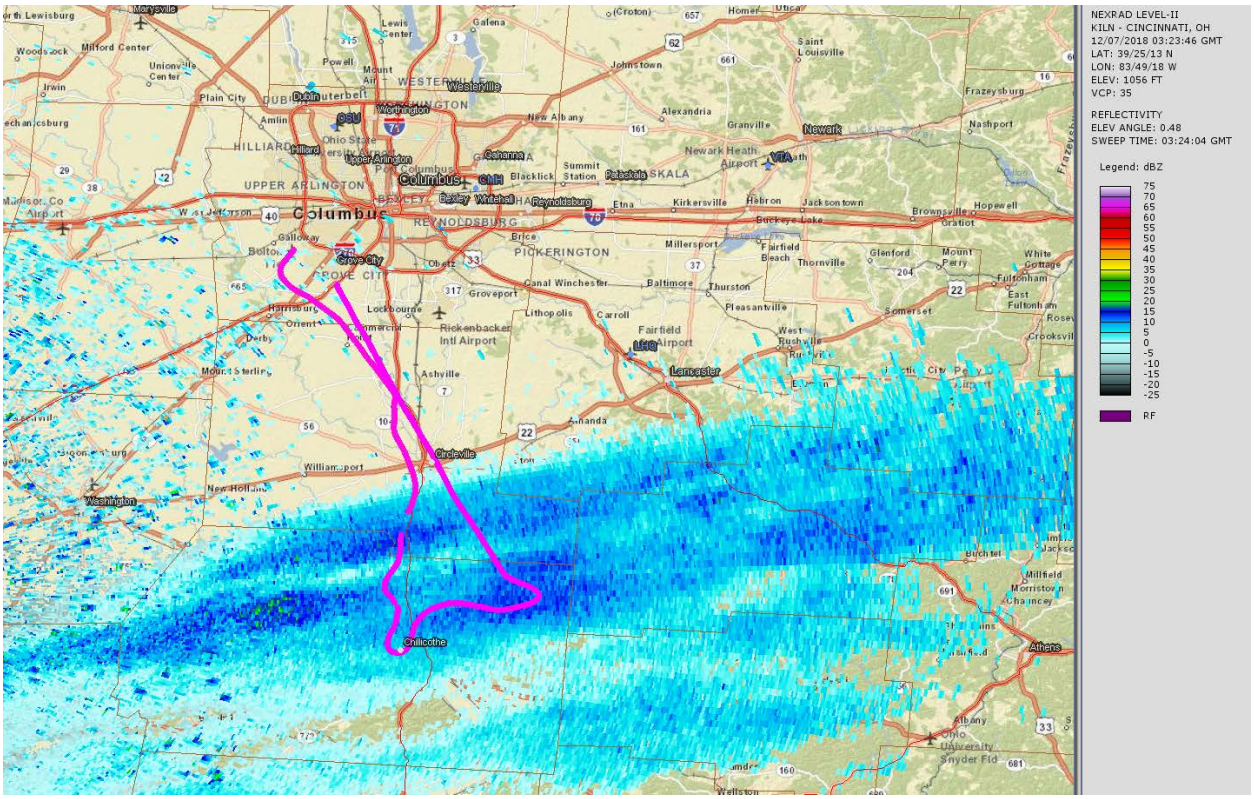


Figure 33 – KILN WSR-88D reflectivity for the 0.5° elevation scan initiated at 2224:04 EST with the December 6, 2018, SF flight track in pink

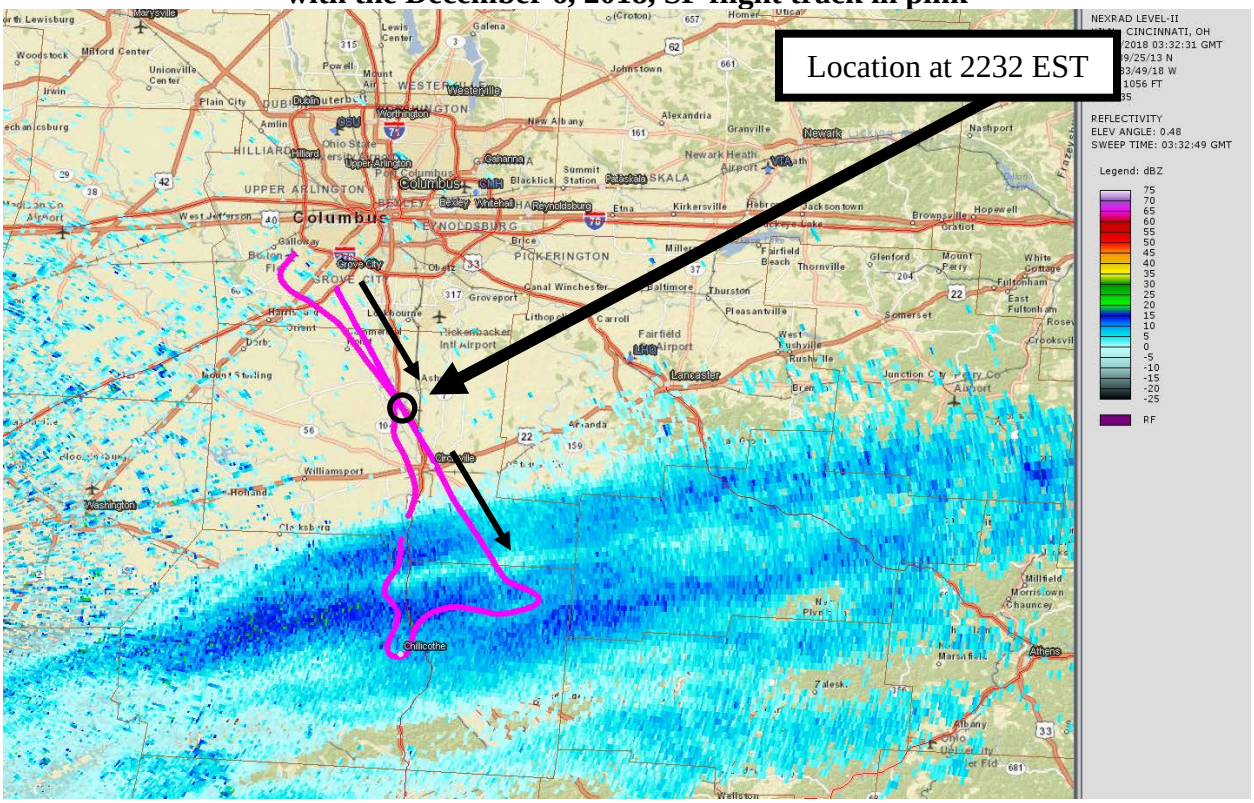


Figure 34 – KILN WSR-88D reflectivity for the 0.5° elevation scan initiated at 2232:49 EST with the December 6, 2018, SF flight track in pink, and location at 2232 EST in black circle

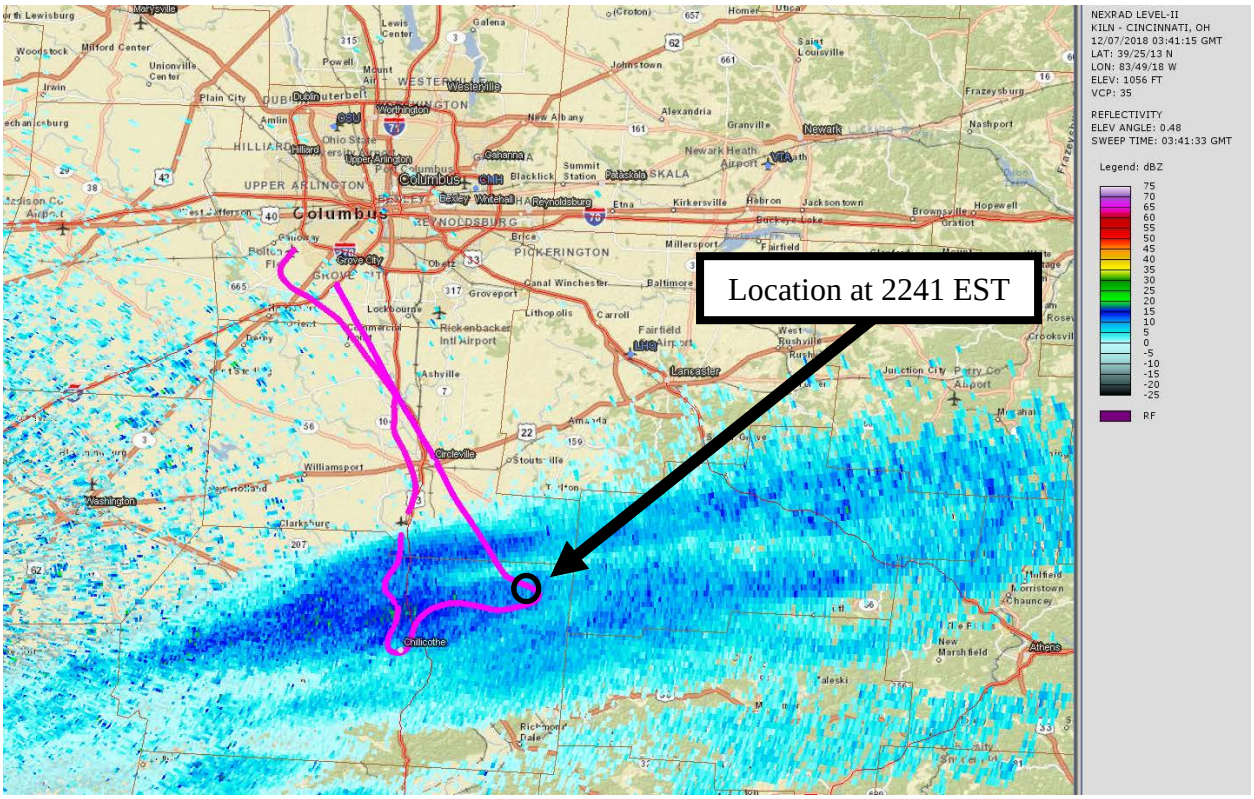


Figure 35 – KILN WSR-88D reflectivity for the 0.5° elevation scan initiated at 2241:33 EST with the December 6, 2018, SF flight track in pink, and location at 2241 EST in black circle

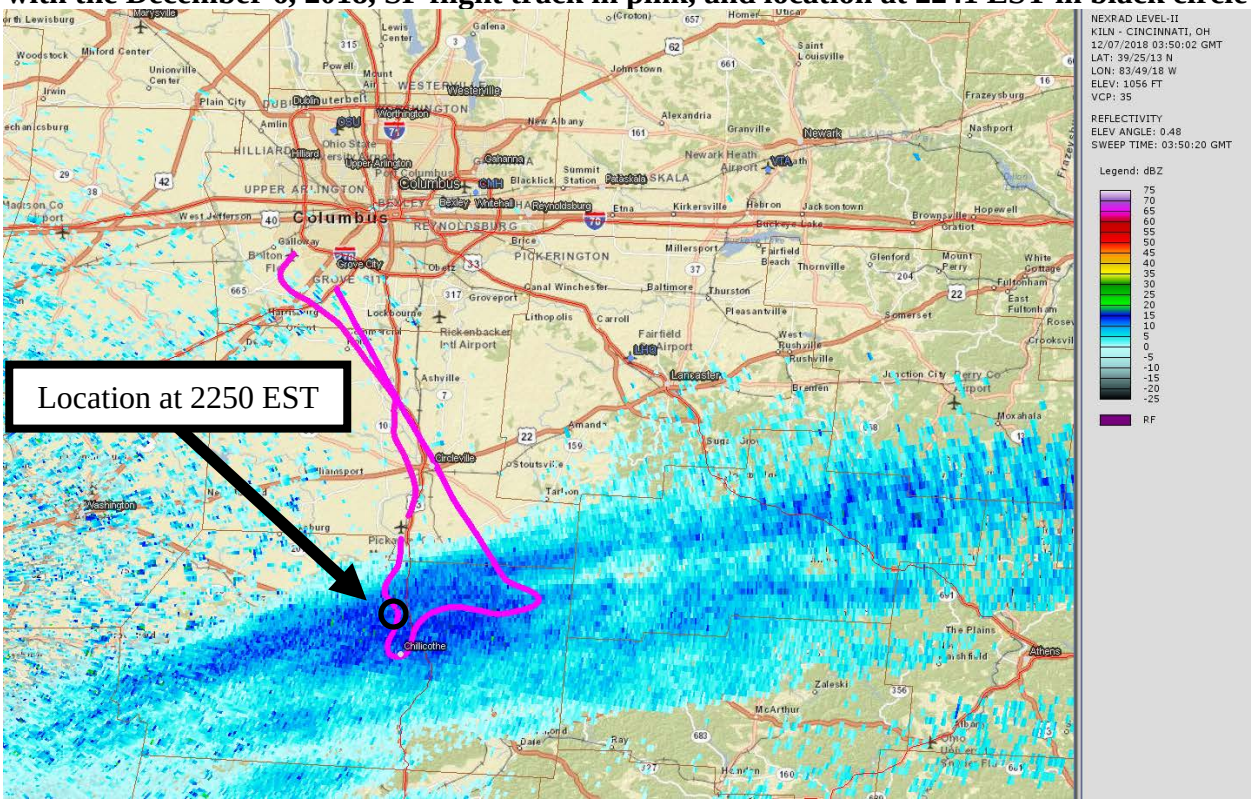


Figure 36 – KILN WSR-88D reflectivity for the 0.5° elevation scan initiated at 2250:20 EST with the December 6, 2018, SF flight track in pink, and location at 2250 EST in black circle

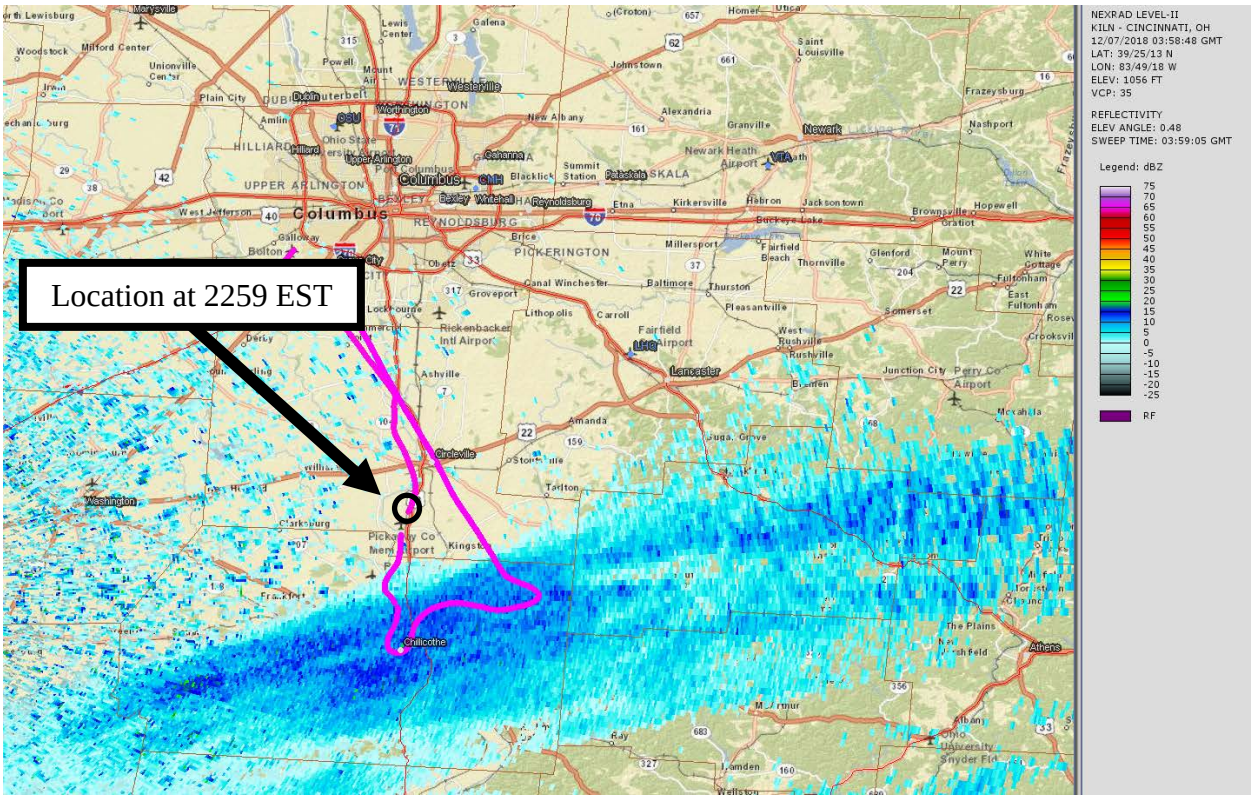


Figure 37 – KILN WSR-88D reflectivity for the 0.5° elevation scan initiated at 2259:05 EST with the December 6, 2018, SF flight track in pink, and location at 2259 EST in black circle

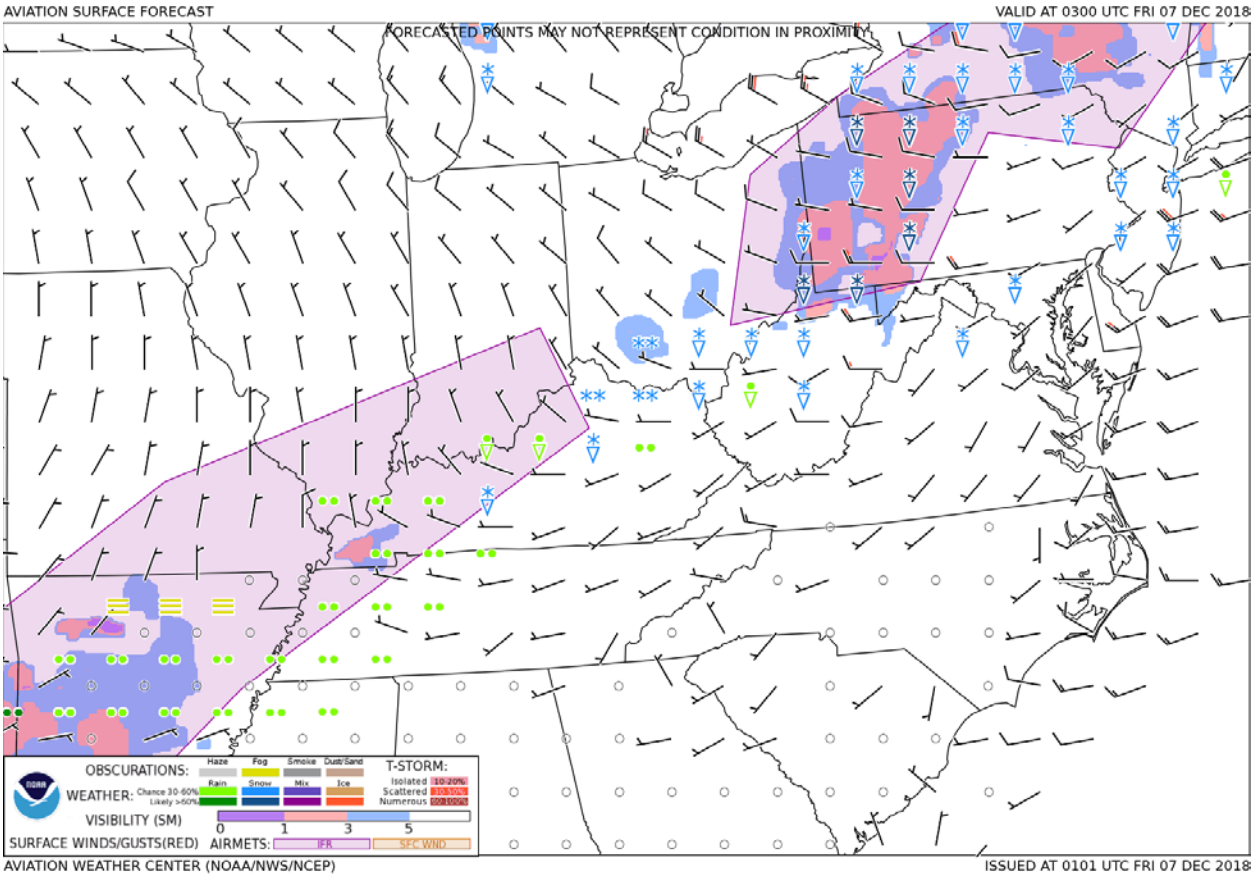


Figure 38 – GFA Surface Forecast valid at 2200 EST on December 6, 2018, with forecast issued at 2001 EST on December 6, 2018

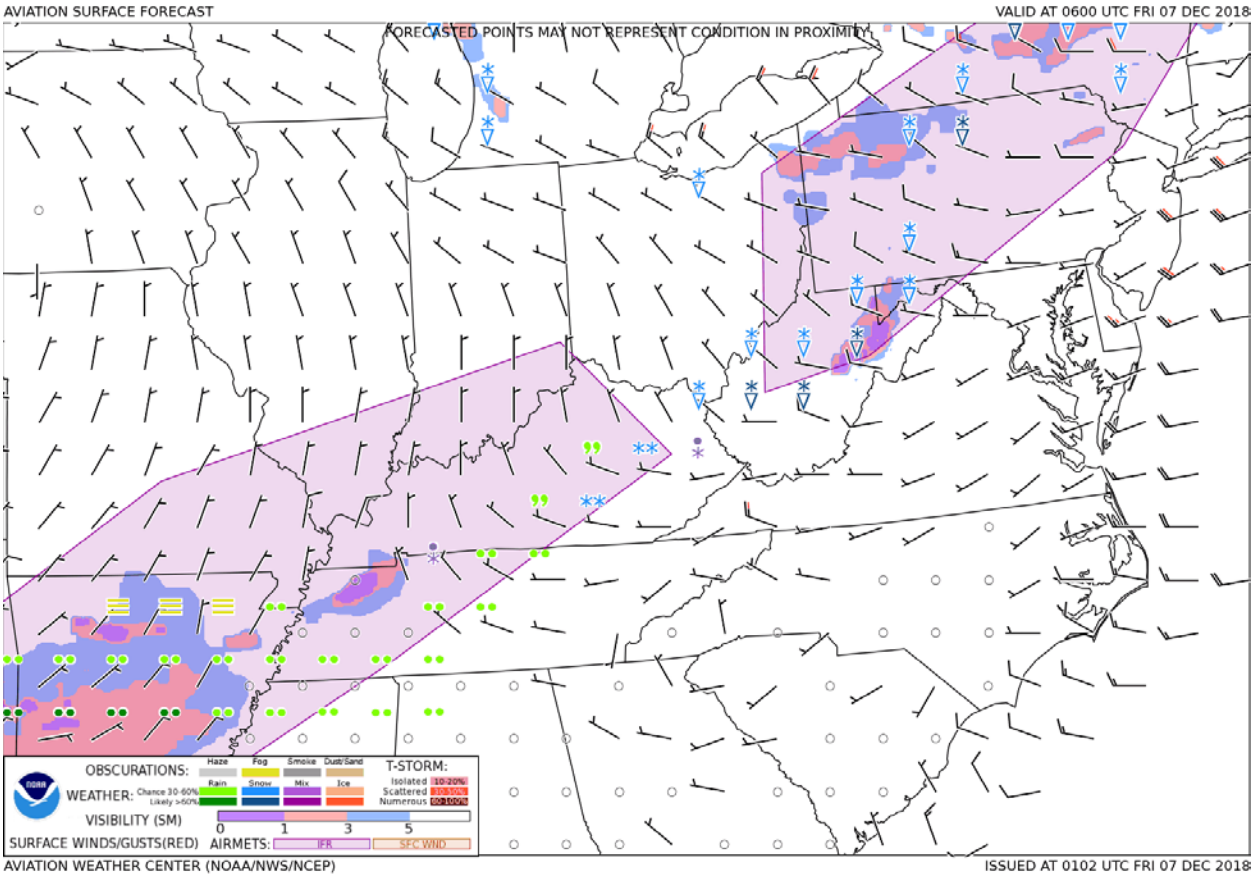


Figure 39 – GFA Surface Forecast valid at 0100 EST on December 7, 2018, with forecast issued at 2002 EST on December 6, 2018

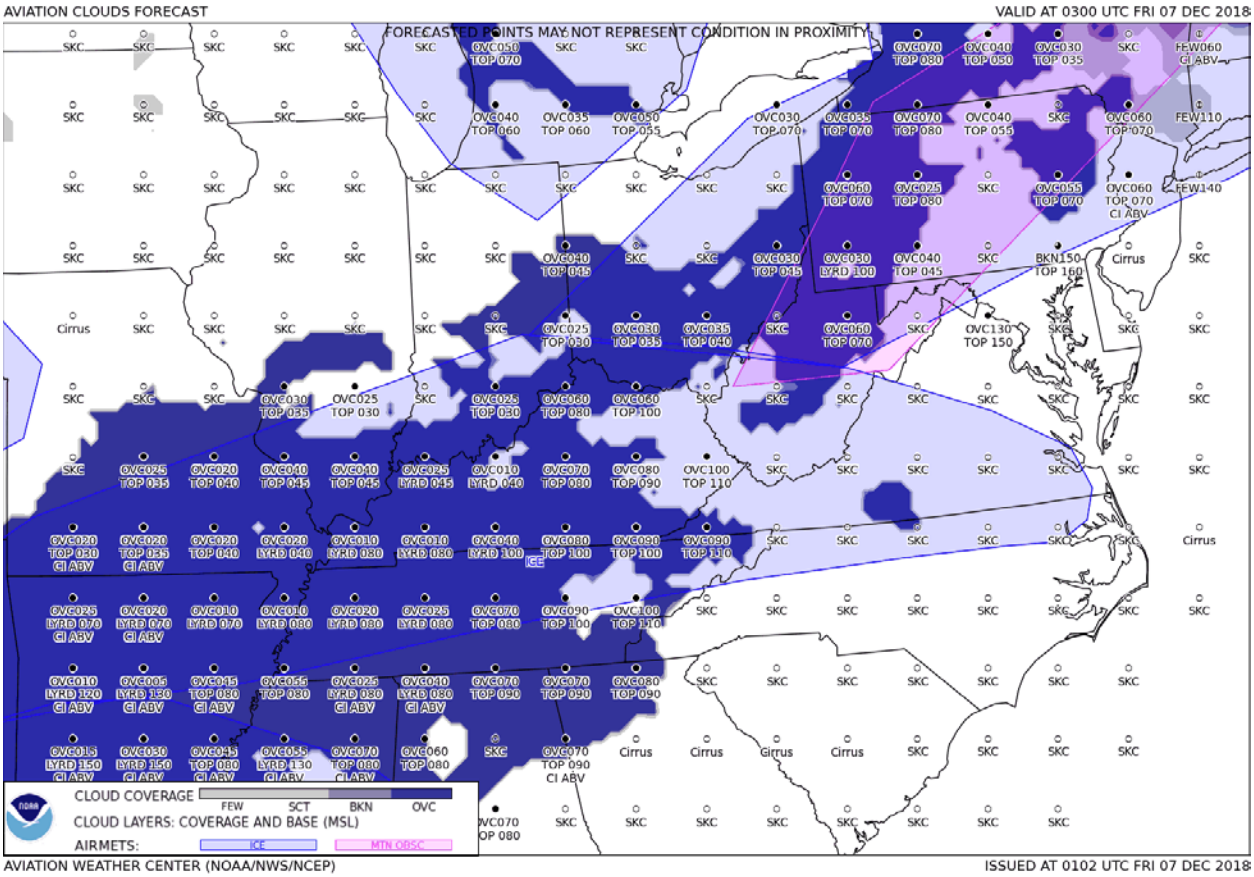


Figure 40 – GFA Cloud Forecast valid at 2200 EST on December 6, 2018, with forecast issued at 2002 EST on December 6, 2018

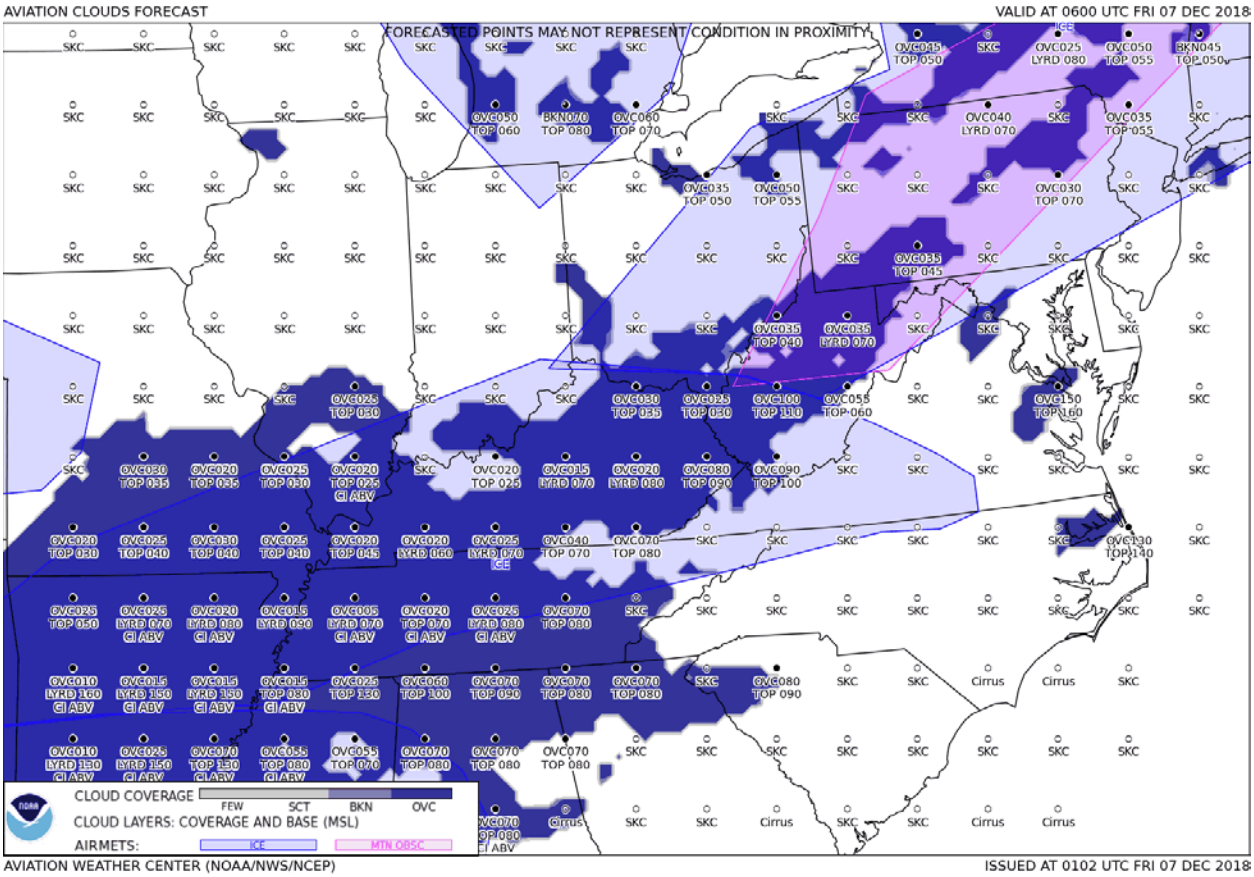


Figure 41 – GFA Cloud Forecast valid at 0100 EST on December 7, 2018, with forecast issued at 2002 EST on December 6, 2018

23.0 Astronomical Data

The astronomical data obtained from the United States Naval Observatory for the accident site on January 29, 2019, indicated the following:

SUN	
Accident time	**0651 EST**[41]
Begin civil twilight	0711 EST
Sunrise	0739 EST
Sun transit	1242 EST
Sunset	1746 EST
End civil twilight	1815 EST

[41] Inserted accident time for reference and context.

MOON	
Moonrise	0227 EST
Accident time	**0651 EST**[42]
Moon transit	0747 EST
Moonset	1301 EST

On the day of the accident the Moon phase was Waning Crescent with 32% of the Moon's visible disk illuminated.

E. LIST OF ATTACHMENTS

Attachment 1 – 10-second flight track dataset

Attachment 2 – NASA SPoRT Nighttime Microphysics RGB quick guide

Attachment 3 – GOES-16 Nighttime Microphysics RGB satellite animation from 0532 to 0732 EST

Attachment 4 – TCMH TDWR base reflectivity animation for the 0.1° elevation scans from 0502 to 0709 EST

Attachment 5 – GFA products valid for the accident flight

Attachment 6 – Additional FIP and CIP information for the accident flight

Attachment 7 – Correspondence with ForeFlight

Attachment 8 – HEMS documentation

Attachment 9 – HEMS Service Change Notice

Attachment 10 – NWS correspondence regarding archived HEMS Tool information

Attachment 11 – MRMS correspondence regarding TDWR information

Attachment 12 – Record of Conversation from FPAW meeting in April 2019

Attachment 13 – SF general weather training

Attachment 14 – SF radar and satellite weather training

Attachment 15 – SF aviation weather training

Attachment 16 – HEMS SRMD document color

[42] Inserted accident time for reference and context.

Attachment 17 – HEMS SRMD document non-color and signed

Attachment 18 – FAA notice N 8000.333

Attachment 19 – FAA correspondence regarding history of HEMS Weather Tool

Attachment 20 – Additional METAR and TAF data for January 14, 2019 SF flight

Attachment 21 – GOES-16 Infrared satellite animation from 1630 to 1845 EST on January 14, 2019

Attachment 22 – Additional METAR and TAF data for January 24, 2019 SF flight

Attachment 23 – Additional METAR and TAF data for December 6, 2018 SF flight

Attachment 24 – KILN base reflectivity animation for the 0.5° elevation scans from 2206 to 2316 EST on December 6, 2018

Submitted by:

_____

Paul Suffern
Senior Meteorologist

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