



NATIONAL TRANSPORTATION SAFETY BOARD

Office of Aviation Safety
Washington, D.C. 20594

May 17, 2022

Specialist's Factual Report

METEOROLOGY

CEN22FA080

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A. ACCIDENT

Location: Bloomington, Indiana
Date: December 17, 2021
Time: 2008 eastern standard time
0108 Coordinated Universal Time (UTC) on December 18, 2021
Aircraft: Piper PA-32R-300; Registration: N5677V

B. METEOROLOGIST

Paul Suffern
Senior Meteorologist
Operational Factors Division (AS-30)
National Transportation Safety Board

C. DETAILS OF THE INVESTIGATION

The National Transportation Safety Board's (NTSB) Meteorologist did not travel for this investigation and gathered the weather data for this investigation from official National Oceanic and Atmospheric Administration (NOAA) National Weather Service (NWS) sources and also from the National Centers for Environmental Information (NCEI). This Specialist's Factual Report contains the meteorological factors pertinent to the weather surrounding the accident time. All times are eastern standard time (EST) and are based upon the 24-hour clock, where local time is - 5 hours from UTC. Directions are referenced to true north and distances are in nautical miles. Heights are above mean sea level (msl) unless otherwise noted. Visibility is in statute miles and fractions of statute miles. NWS station identifiers use the standard International Civil Aviation Organization 4-letter station identifiers versus the International Air Transport Association 3-letter identifiers, which deletes the initial country code designator "K" for U.S. airports.

The accident site was located at latitude 39.10886° N, Longitude 86.60448° W, at an approximate elevation of 950 feet (ft).

D. FACTUAL INFORMATION

1.0 Synoptic Situation

The synoptic or large-scale migratory weather systems influencing the area were documented using standard NWS charts issued by the National Center for Environmental Prediction and the Weather Prediction Center, located in College Park, Maryland. These are the base products used in describing synoptic weather features and in the creation of forecasts and warnings for the NWS. Reference to these charts can be found in the joint NWS and Federal Aviation Administration (FAA) Advisory Circular "Aviation Weather Services", AC 00-45H.¹

¹

https://www.faa.gov/regulations_policies/advisory_circulars/index.cfm/go/document.information/documentID/1030

1.1 Surface Analysis Chart

The NWS Surface Analysis Chart centered over the Ohio River Valley for 1900 EST is provided as figure 1 with the location of the accident site within the red circle. The chart depicted a stationary frontal boundary from central Oklahoma eastward to West Virginia. A high-pressure system with pressure of 1023-hectopascals (hPa) was in western South Carolina with several low-pressure systems in northern Nebraska, southwestern Missouri, and central Oklahoma with pressures of 1019-, 1011-, and 1009-hPa, respectively. The accident site was located north of the stationary frontal boundary on the cool side of the front.

The station models around the accident site depicted air temperatures in the upper 30's degrees Fahrenheit (°F), dew point temperatures in the mid 30's °F with temperature-dew point spreads of 3°F or less, cloudy skies, and light rain.

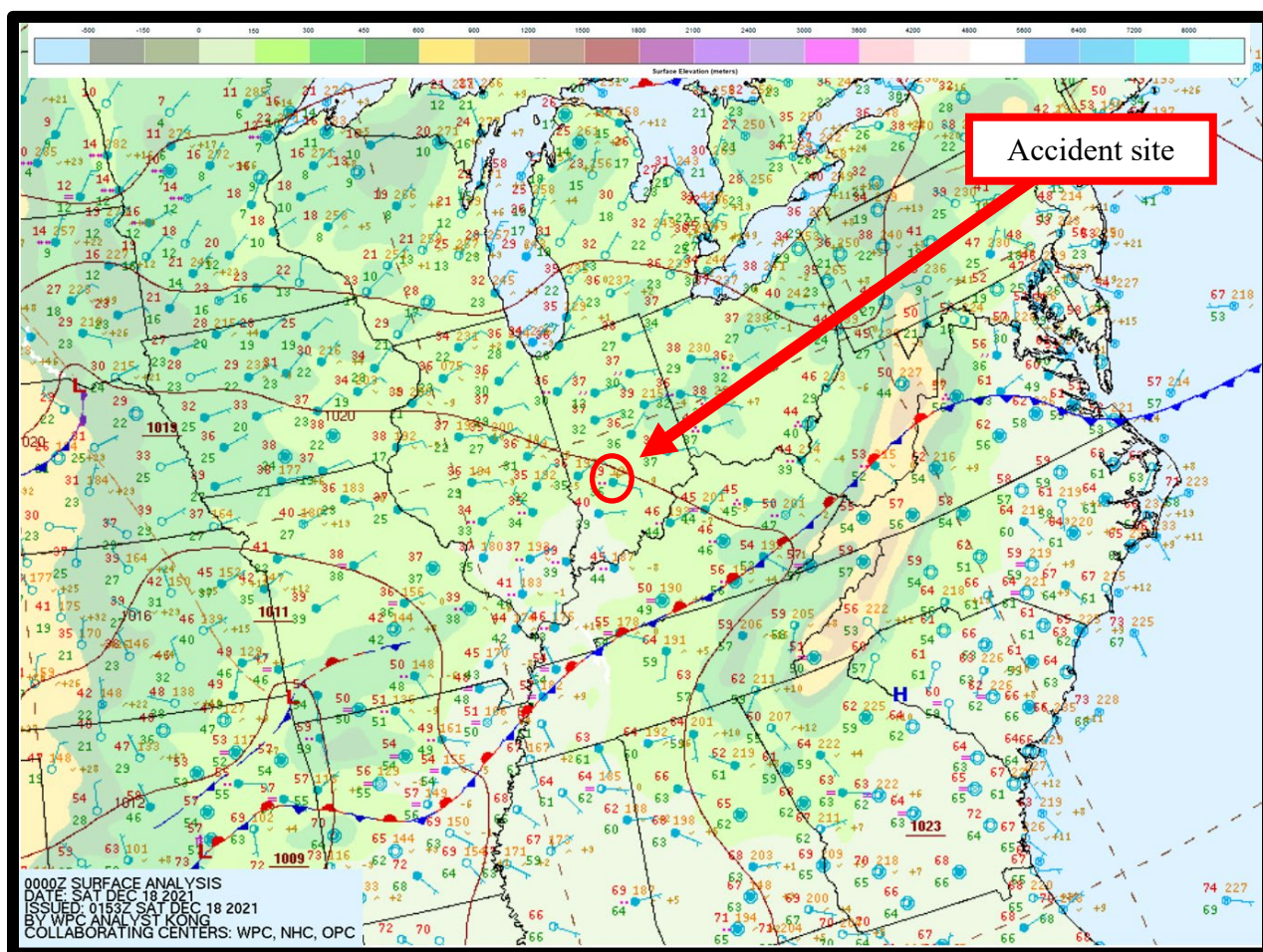


Figure 1 – NWS Surface Analysis Chart for 1900 EST.

1.2 Upper Air Charts

The NWS Storm Prediction Center (SPC) Constant Pressure Charts for 1900 EST at 925-, 850- and 700-hPa are presented in figures 2 through 4. The accident site was in the vicinity of a low-level trough² (figures 2 and 3). Troughs can act as lifting mechanisms to help produce clouds and precipitation if sufficient moisture is present. There was an east wind at 15 knots at 925-hPa with the wind becoming southwesterly through 700-hPa. The wind speed increased to 30 knots by 700-hPa.

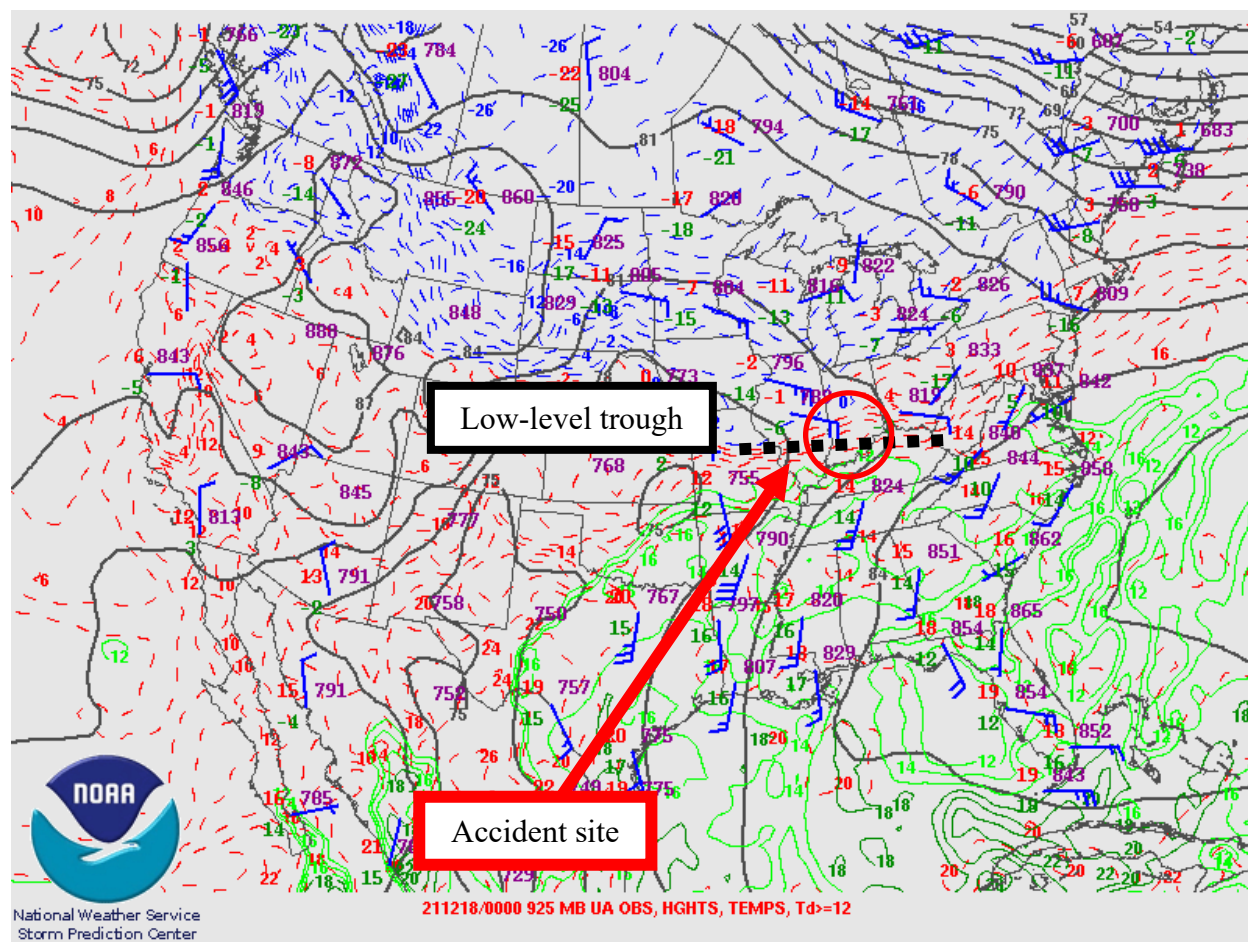


Figure 2 – 925-hPa Constant Pressure Chart for 1900 EST.

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

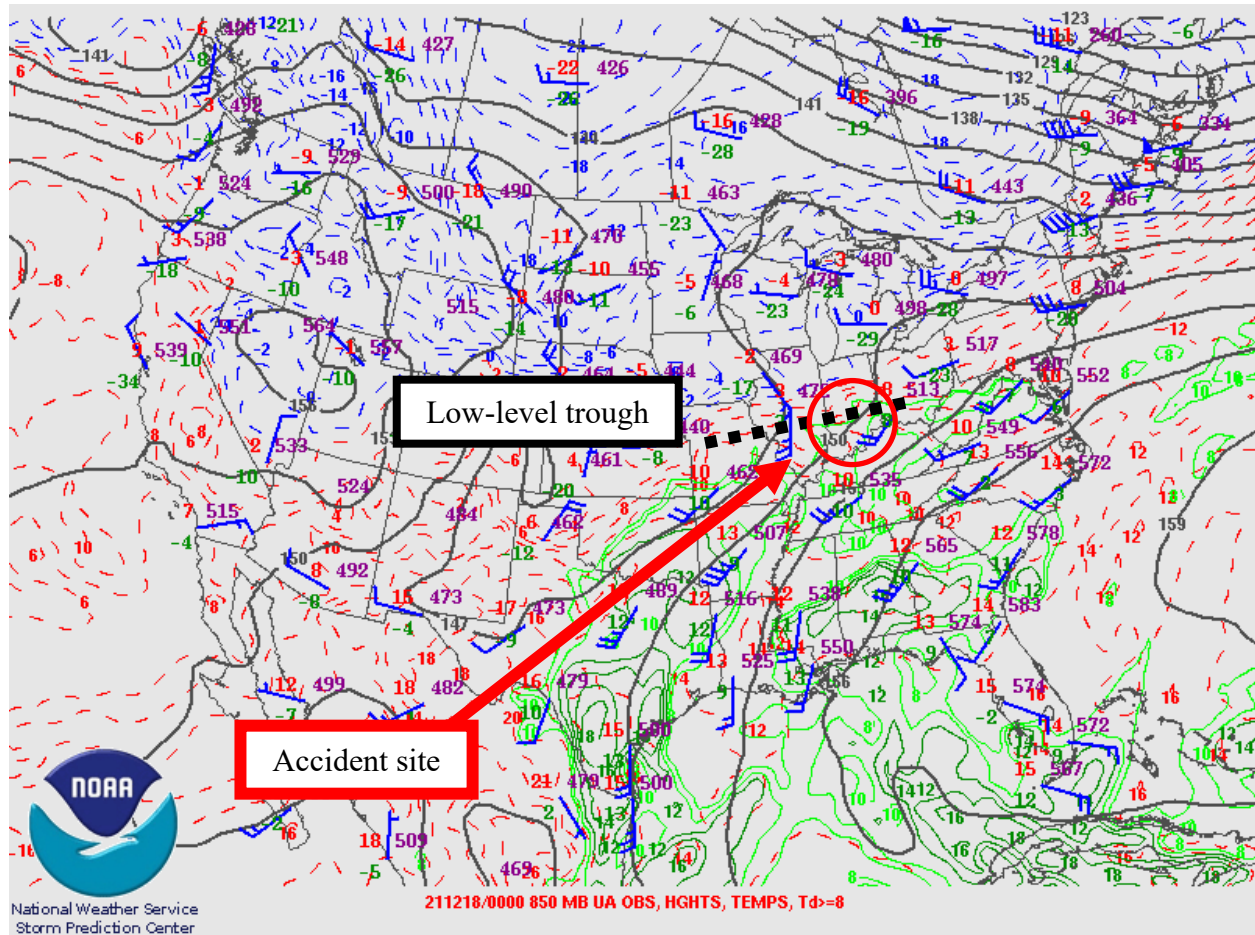


Figure 3 – 850-hPa Constant Pressure Chart for 1900 EST.

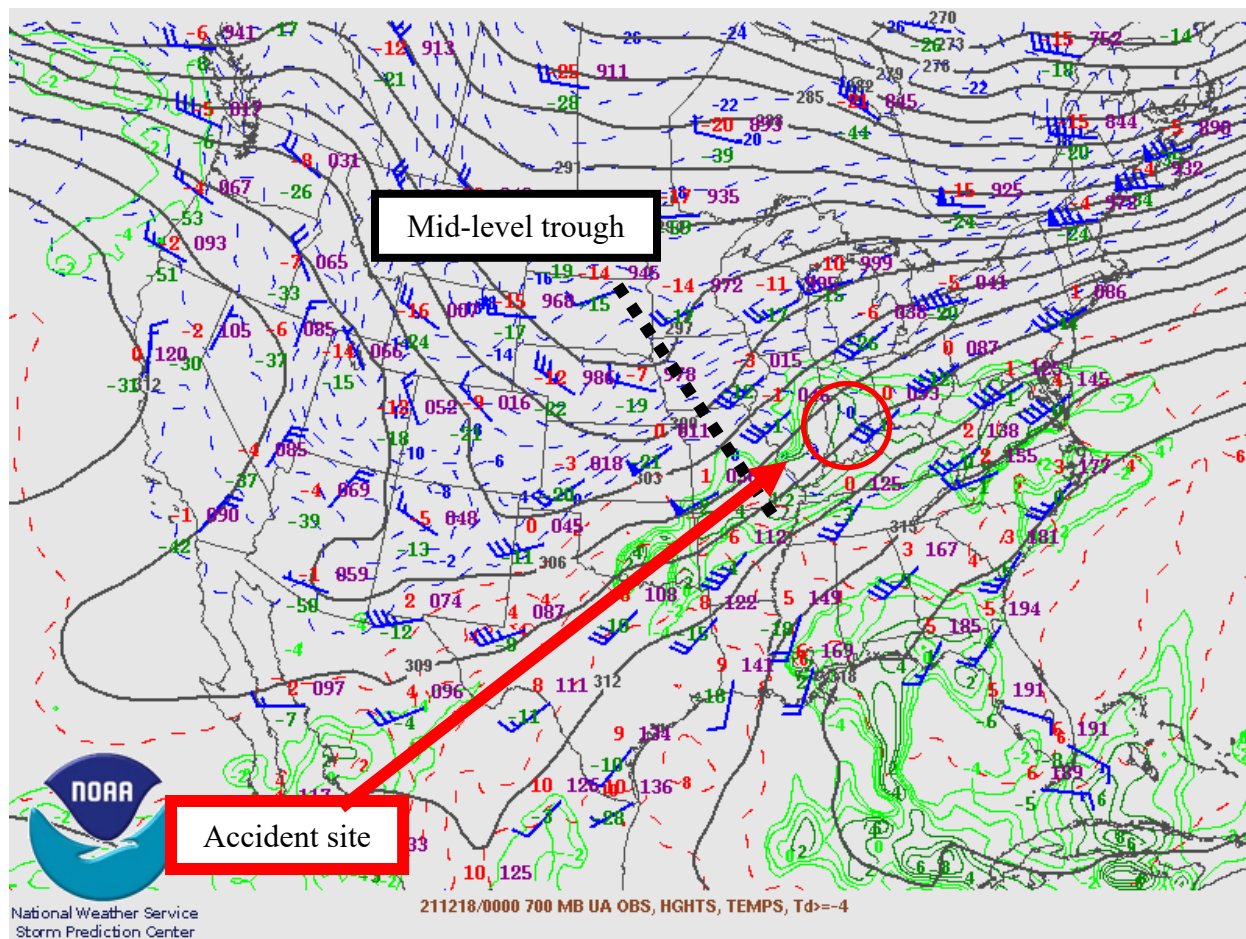


Figure 4 – 700-hPa Constant Pressure Chart for 1900 EST.

2.0 SPC Convective Outlook

The SPC issued the following Day 1 Convective Outlook at 2002 EST (figure 5) with areas of general thunderstorms forecast for the accident site. SPC defines the “TSTM” area as an area where a 10% or higher probability of thunderstorms is forecast during the valid period. The SPC Day 1 Convective Outlook text follows figure 5.

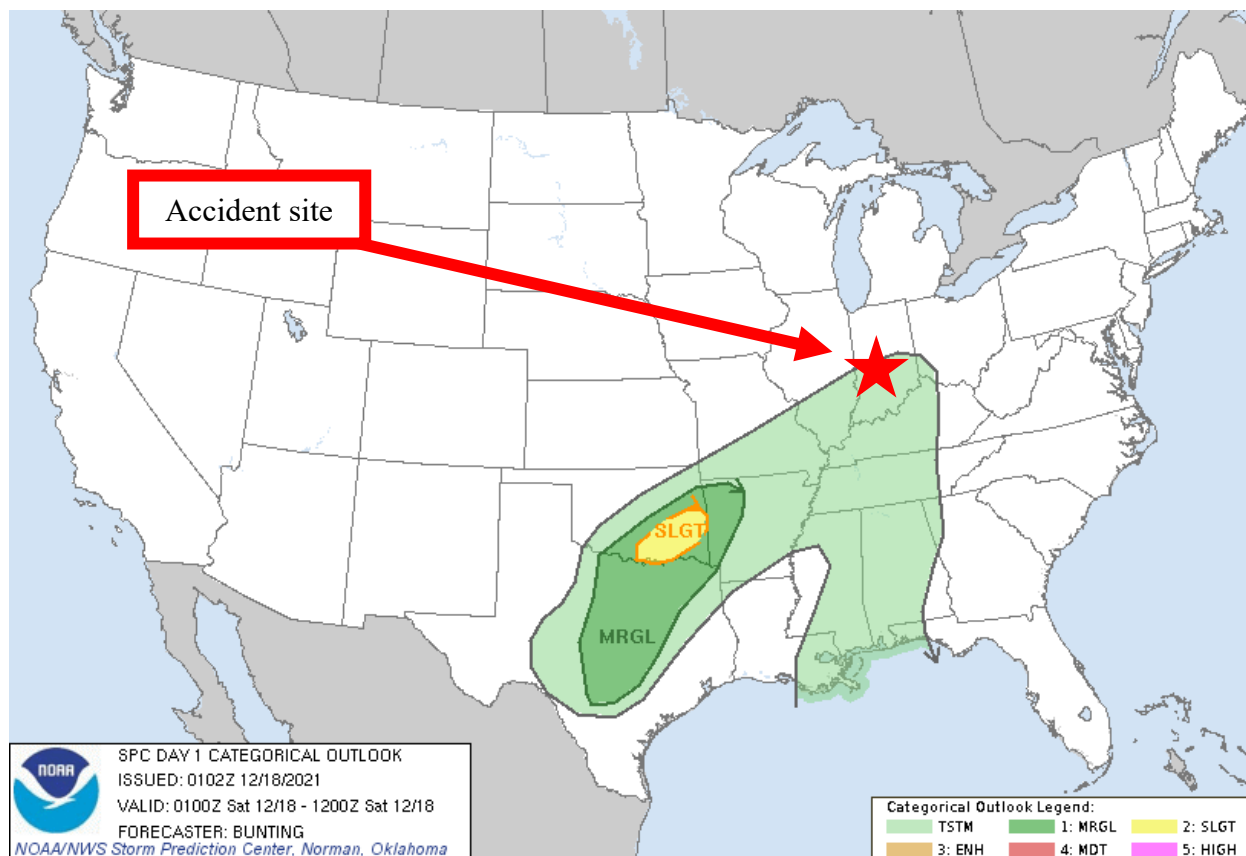


Figure 5 – SPC day 1 Convective Outlook valid at the time of the accident

SPC AC 180102

Day 1 Convective Outlook
NWS Storm Prediction Center Norman OK
0702 PM CST Fri Dec 17 2021

Valid 180100Z - 181200Z

...THERE IS A SLIGHT RISK OF SEVERE THUNDERSTORMS OVER PORTIONS OF SOUTHEAST OKLAHOMA...

...SUMMARY...

Isolated severe thunderstorms are possible tonight across parts of the southern Great Plains.

Only minor adjustments were made to the thunder area and the northern portion of the Marginal Risk area. Please refer to MCD 2043 for the latest short-term thinking across the Slight Risk area. Otherwise, latest observational data and numerical guidance continues to suggest an isolated severe risk into the overnight hours across northern/central TX as the front continues to move southeast in the presence of modest instability and around 35-40 kts of effective shear.

..Bunting.. 12/18/2021

CLICK TO GET WUUS01 PTSDY1 PRODUCT

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

3.0 Surface Observations

The surface conditions near the accident site were documented using official Aviation Routine Weather Reports (METARs) and Specials (SPECIs). The following observations were taken from standard code and are provided in plain language. Figure 6 is a local sectional chart with the accident site and the closest weather reporting location marked.

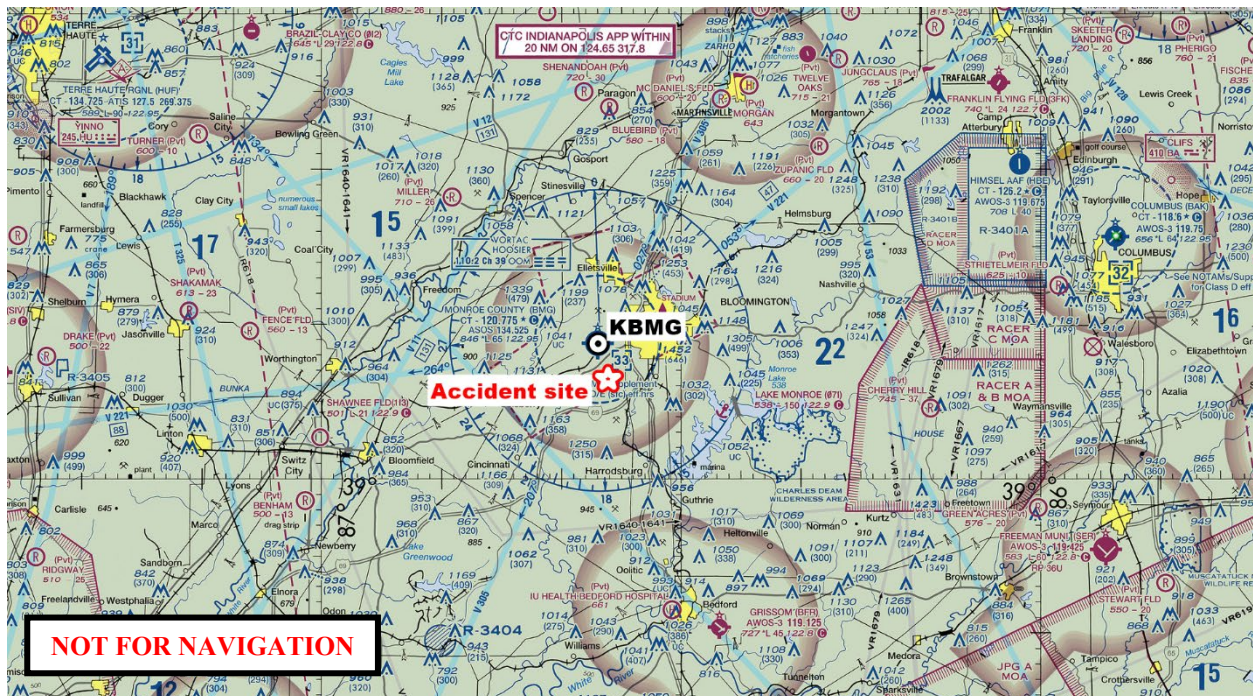


Figure 6 – Sectional map of the accident area with the location of the accident site and surface observation site.

Monroe County Airport (KBMG) had the closest official weather station to the accident site. KBMG had an Automated Surface Observing System (ASOS³) whose longline⁴ reports were augmented by air traffic control when the tower was in operation⁵. The KBMG ASOS was located 2 miles north-northwest of the accident site, at an elevation of 846 ft, and had a 4° westerly magnetic variation⁶ (figure 6). KBMG AWOS observations surrounding the accident time are shown below:⁷

[1753 EST] METAR KBMG 172253Z 10006KT 7SM -RA OVC005 03/02 A3010 RMK AO2 SLP197 P0003 T00330022

[1845 EST] SPECI KBMG 172345Z 11008KT 2SM -RA BR OVC005 03/03 A3009 RMK AO2 P0001 T00330028

[1853 EST] METAR KBMG 172353Z 12008KT 2 1/2SM -RA BR OVC004 04/02 A3009 RMK AO2 SLP194 P0001 60038 T00390022 10044 20022 56009

[1902 EST] SPECI KBMG 180002Z 11009KT 5SM -RA BR OVC004 04/02 A3008 RMK AO2 P0000 T00390022

[1953 EST] METAR KBMG 180053Z 11008KT 7SM -RA OVC004 04/03 A3008 RMK AO2 RAE03B29 SLP192 P0000 T00390028

ACCIDENT TIME 2008 EST

[2011 EST] SPECI KBMG 180111Z 13008KT 4SM -RA BR OVC005 04/03 A3006 RMK AO2 P0000 T00390028

[2037 EST] SPECI KBMG 180137Z 09006KT 3SM -RA BR OVC004 04/03 A3006 RMK AO2 P0000 T00390033

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

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

⁴ “Longline” refers to the dissemination of weather observations with the intent that they are available in near-real time to national databases and accessible to the general global public from a large number of vendors. This does not include public accessibility to observations from a reporting station’s Very High Frequency (VHF; line-of-site) or telephone broadcast, where applicable. Longline dissemination of weather observations is the primary vehicle through which the weather observations are distributed.

⁵ ATC hours of operation 0630 to 2130 local.

⁶ Magnetic variation – The angle (at a particular location) between magnetic north and true north. Latest measurement taken from <https://skyvector.com/>

⁷ The bold sections in this NWS product and the rest of the products in this report are intended to highlight the text that directly reference the weather conditions that affected the accident location around the accident time. The local times in this section next to the METARs are provided for quick reference between UTC and local times around the accident time.

KBMG weather at 1953 EST, wind from 110° at 8 knots, visibility 7 miles, light rain, overcast ceiling at 400 ft above ground level (agl), temperature of 4° Celsius (C), dew point temperature 3°C, and an altimeter setting of 30.08 inches of mercury (inHg). Remarks, station with a precipitation discriminator, rain ended at 1903 EST, rain began at 1929 EST, sea level pressure 1019.2 hPa, a trace of precipitation since 1853 EST, temperature 3.9°C, dew point temperature 2.8°C.

KBMG weather at 2011 EST, wind from 130° at 8 knots, visibility 4 miles, light rain and mist, overcast ceiling at 500 ft agl, temperature of 4°C, dew point temperature 3°C, and an altimeter setting of 30.06 inHg. Remarks, station with a precipitation discriminator, a trace of precipitation since 1953 EST, temperature 3.9°C, dew point temperature 2.8°C.

The observations from KBMG surrounding the accident time indicated LIFR⁸ conditions in light rain and mist.

4.0 Upper Air Sounding

A High-Resolution Rapid Refresh (HRRR)⁹ model sounding was created for the accident site for 2000 EST with a surface elevation of 840 ft msl.¹⁰ The 2000 EST HRRR sounding was plotted on a standard Skew-T Log P diagram¹¹ with the derived stability parameters included in figure 7 with data from the surface to 600-hPa (or approximately 14,000 ft above msl). These data were analyzed using the RAOB¹² software package. The sounding depicted the lifted condensation level (LCL)¹³ 209 ft agl and the convective condensation level (CCL)¹⁴ at 8,027 ft. The freezing level was located at 10,044 ft. The precipitable water value was 1.08 inches.

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 The HRRR is a NOAA real-time three-kilometer resolution, hourly-updated, cloud-resolving, convection-allowing atmospheric model, initialized by three-kilometer grids with three-kilometer radar assimilation. Radar data is assimilated in the HRRR every 15 minutes over a one-hour period.

¹⁰ HRRR sounding was created using NOAA Air Resource Laboratory: <https://ready.arl.noaa.gov/READYamet.php>

¹¹ 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.

¹² RAOB – (The complete Rawinsonde Observation program) is an interactive sounding analysis program developed by Eosonde Research Services, The Villages, Florida.

¹³ LCL - The height at which a parcel of moist air becomes saturated when it is lifted dry adiabatically.

¹⁴ 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.

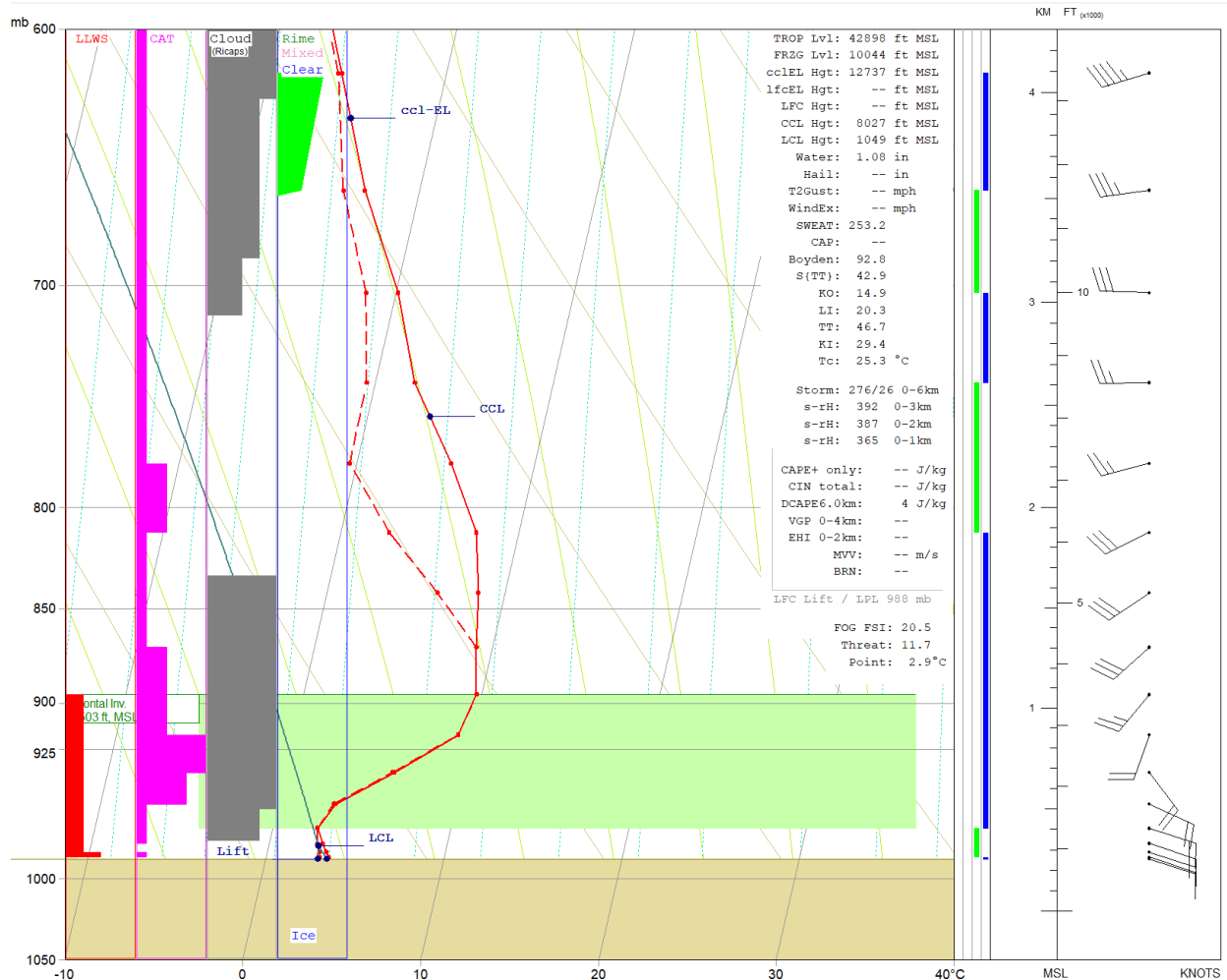


Figure 7 – 2000 EST HRRR sounding.

The 2000 EST HRRR sounding for the accident site indicated a conditionally unstable environment from the surface through 500 ft agl, with a stable layer between 500 ft agl and 6,000 ft. Clouds were indicated by RAOB to be present from 300 ft agl through 5,500 ft with clouds present again above 10,000 ft. The top of a frontal inversion¹⁵ was noted at 3,503 ft. No icing potential was indicated by RAOB below 10,000 ft.

The 2000 EST HRRR sounding wind profile indicated a near surface wind from 109° at 9 knots with the wind remaining easterly through 2,000 ft. Above 2,000 ft the wind veered¹⁶ and became southwesterly to westerly through 14,000 ft. The wind speed was between 10 to 20 knots between the surface and ~1,200 ft agl. The wind speed continued to increase with height to 30 knots by 4,000 ft. RAOB indicated the possibility of light to moderate low-level wind shear (LLWS) below 2,000 ft agl, and moderate or greater clear air turbulence below 7,000 ft.

¹⁵ Inversion – A departure from the usual decrease of the value of an atmospheric property with increasing altitude; also, the layer through which this departure occurs (the "inversion layer"), or the lowest altitude at which the departure is found (the "base of the inversion").

¹⁶ A clockwise turning of the wind with height in the northern hemisphere.

5.0 Satellite Data

Geostationary Operational Environmental Satellite number 16 (GOES-16) visible and infrared data were obtained from an archive at the Space Science Engineering Center at the University of Wisconsin-Madison in Madison, Wisconsin, and processed using the Man-computer Interactive Data Access System software. Visible and infrared imagery (GOES-16 bands 2 and 13) at wavelengths of 0.64 microns (μm) and 10.3 μm , respectively, were retrieved for the period from 1600 EST through 2300 EST and reviewed, and the closest images to the time of the accident were documented. Given the sun angle, the visible imagery (band 2) did not provide useful information.

Figure 8 presents the GOES-16 infrared imagery from 2010 EST at 3X magnification with the accident site highlighted with a red square. The lower brightness temperatures (green and blue colors; higher cloud tops) were located to the southwest to north to east of the accident site. The cloud cover was moving from southwest to northeast (attachment 1). The brightness temperature of about 251 Kelvin above the accident site would have been near 22,000 ft based on the vertical temperature profile provided by the 2000 EST HRRR sounding. It should be noted these figures have not been corrected for any parallax error.

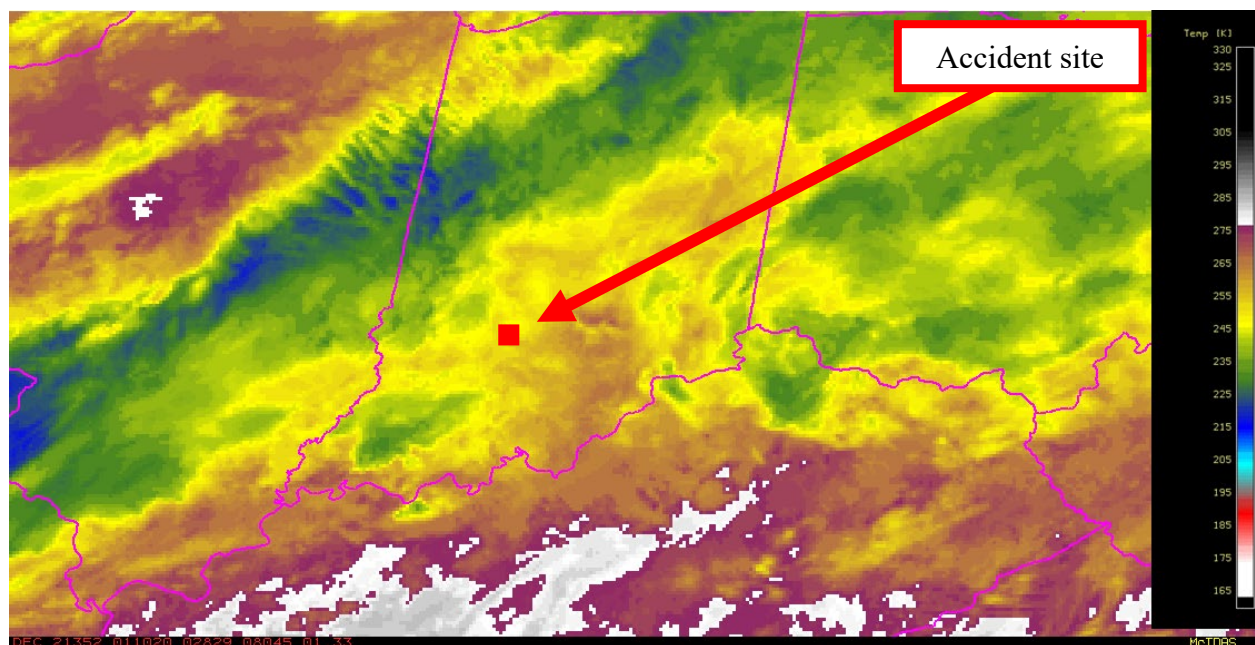


Figure 8 – GOES-16 infrared image at 2010 EST.

6.0 Regional Radar Imagery Information

A regional view of the NWS National Reflectivity Mosaic is included as figure 9 for 2010 EST with the approximate location of the accident site marked by a red circle. The image depicted echoes from 15 to 35 decibels (dBZ¹⁷) above the accident site.

¹⁷ dBZ – A non-dimensional “unit” of radar reflectivity which represents a logarithmic power ratio (in decibels or dB) with respect to radar reflectivity factor, Z.

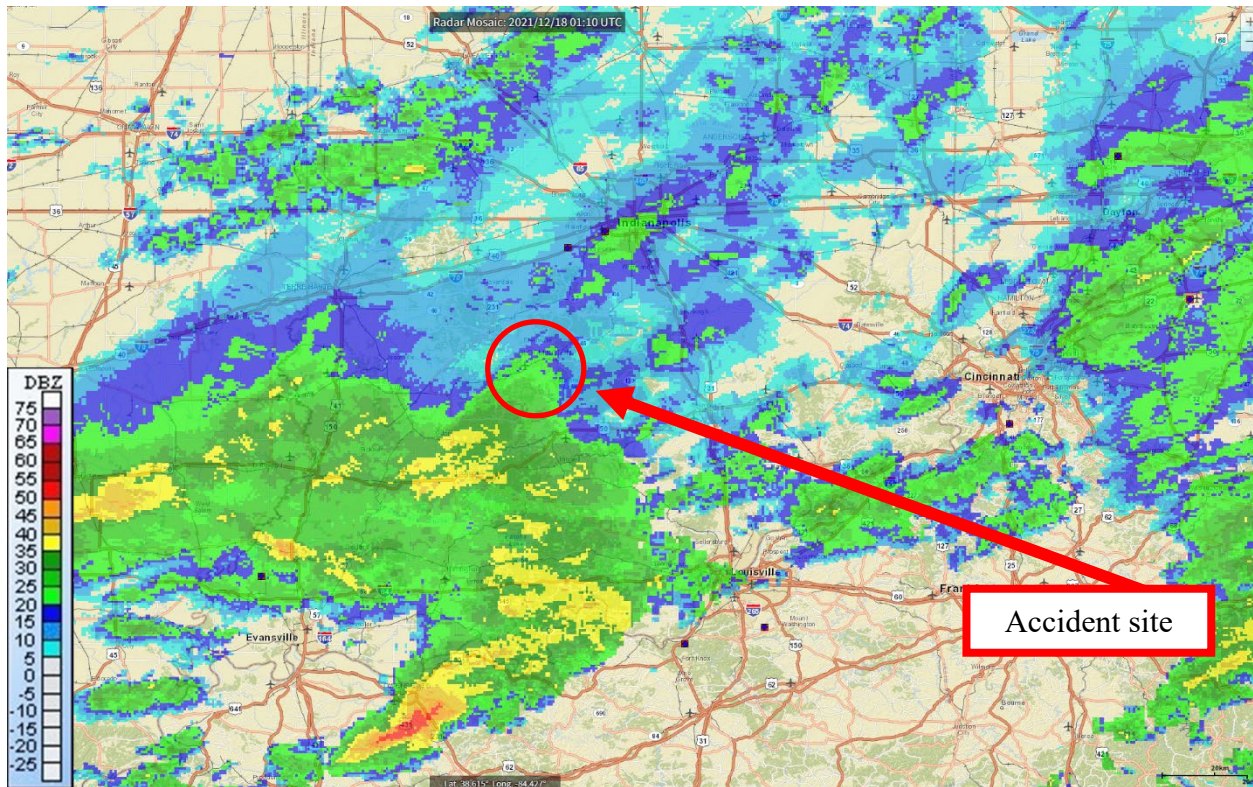


Figure 9 – National Reflectivity Mosaic for 2010 EST.

7.0 Radar Imagery Information

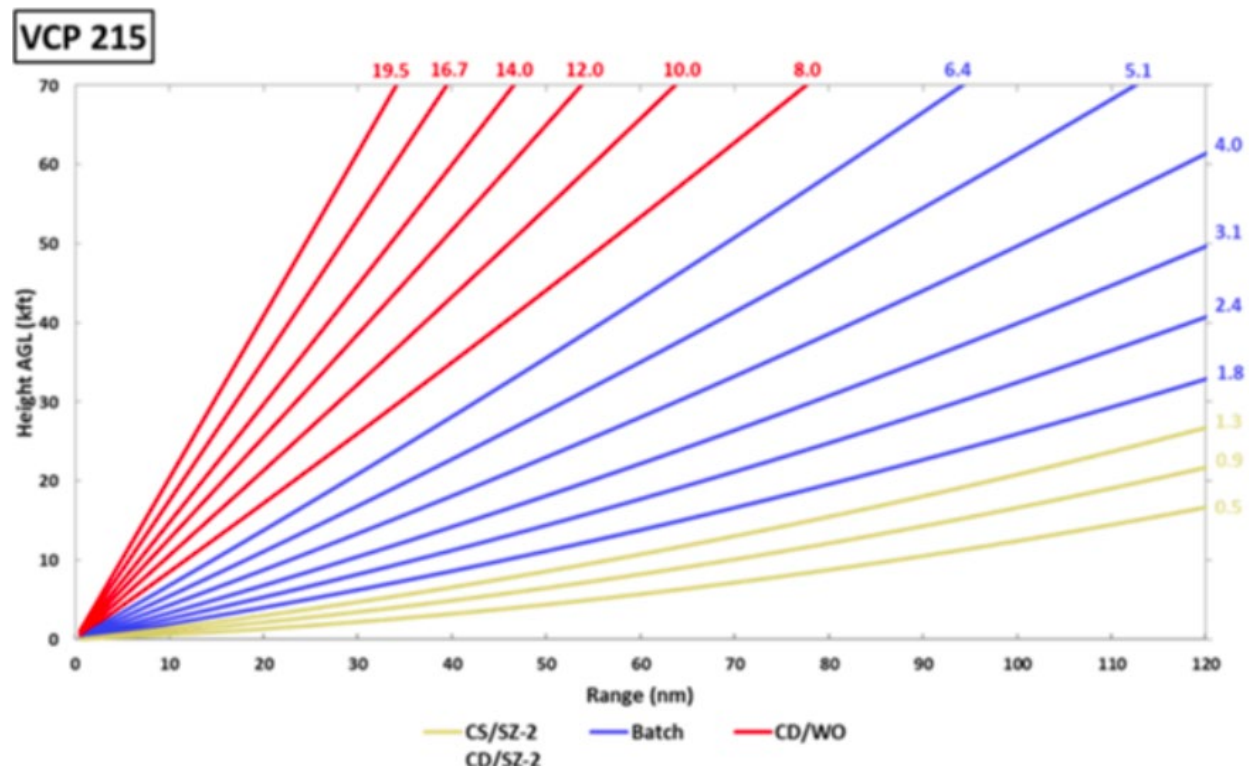
The closest NWS Weather Surveillance Radar-1988, Doppler (WSR-88D)¹⁸ to the accident site was Indianapolis, Indiana (KIND) located 39 miles north-northeast of the accident site. Level II archive radar data were obtained from the NCEI utilizing the NEXRAD Data Inventory Search and displayed using the NOAA’s Weather and Climate Toolkit software.

7.1 Volume Scan Strategy

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

¹⁸ The WSR-88D is an S-band 10-centimeter wavelength radar with a power output of 750,000 watts, and with a 28-foot parabolic antenna that concentrates the energy between a 0.87° and 0.96° beam width. The radar produces three basic types of products: base reflectivity, base radial velocity, and base spectral width.

The WSR-88D operates in two main different scanning modes, identified as Mode A and Mode B. Mode A is the precipitation scan where the radar makes 15 elevation scans from 0.5° to 19.5° every six minutes. This particular scanning strategy is documented as volume coverage pattern 215 (VCP-215). Mode B is the clear-air mode, where the radar makes 5 elevation scans during a ten-minute period. During the period surrounding the accident, the KIND 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 Strategy¹⁹

¹⁹ Contiguous Surveillance (CS)--The low Pulse Repetition Frequency (PRF) scan of the split cut. Gives a high $R_{\max}$ value to determine proper target location and intensity, but a low $V_{\max}$ value limits the velocities that can be measured. Contiguous Doppler (CD)--The high PRF scan of the split cut. Gives a low $R_{\max}$ value causing more range folded (multiple trip) echoes, but a high $V_{\max}$ value to get higher, more accurate velocity values.

Batch Mode – Uses alternating low and high PRFs on each radial for one full rotation at each elevation angle. The two resulting data sets (low PRF and high PRF) are combined to resolve range ambiguity. Used in the middle elevation angles.

W – With range unfolding (W)

WO – Without range unfolding (WO)

7.2 Beam Height Calculation

Assuming standard refraction²⁰ of the KIND WSR-88D radar beam with the antenna elevation at 887 ft, and considering a beamwidth²¹ of 0.95°, the following table shows the approximate heights for the radar beam center, top and base for antenna elevations over the accident site. These heights have been rounded to the nearest 10 ft.

ANTENNA ELEVATION	BEAM CENTER	BEAM BASE	BEAM TOP
KIND 0.5°	4,060 ft	2,140 ft	5,980 ft

Based on the radar height calculations, the elevation scans from KIND listed in the above table depicted the conditions between 2,140 ft and 5,980 ft over the accident site and these scans “saw” the closest altitudes to the ground.

7.3 Reflectivity

Reflectivity is the measure of the efficiency of a target in intercepting and returning radio energy. With hydrometeors²² it is a function of the drop size distribution, number of particles per unit volume, physical state (ice or water), shape, and aspect. Reflectivity is normally displayed in dBZ and is a general measure of echo intensity. FAA Advisory Circular AC 00-24C²³, “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.”

²⁰ Standard Refraction in the atmosphere is when the temperature and humidity distributions are approximately average, and values set at the standard atmosphere.

²¹ Beamwidth - the angular separation between the half power points on the antenna radiation pattern, where the gain is one half the maximum value.

²² 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.

²³

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

7.4 Base Reflectivity and Lightning Data

Figures 10 through 12 present the KIND WSR-88D base reflectivity images for the 0.5° elevation scans initiated at 1954:17, 2001:13, and 2008:15 EST, respectively, with a resolution of 0.5° X 250 m. Reflectivity values between 10 and 25 dBZ were located above the accident site at the accident time and indicative of very light to light precipitation (section 7.3). The band of precipitation was moving from southwest to northeast with time (attachment 2).

There were no lightning flashes²⁴ with 50 miles of the accident site within 30 minutes prior to or following the accident time.²⁵

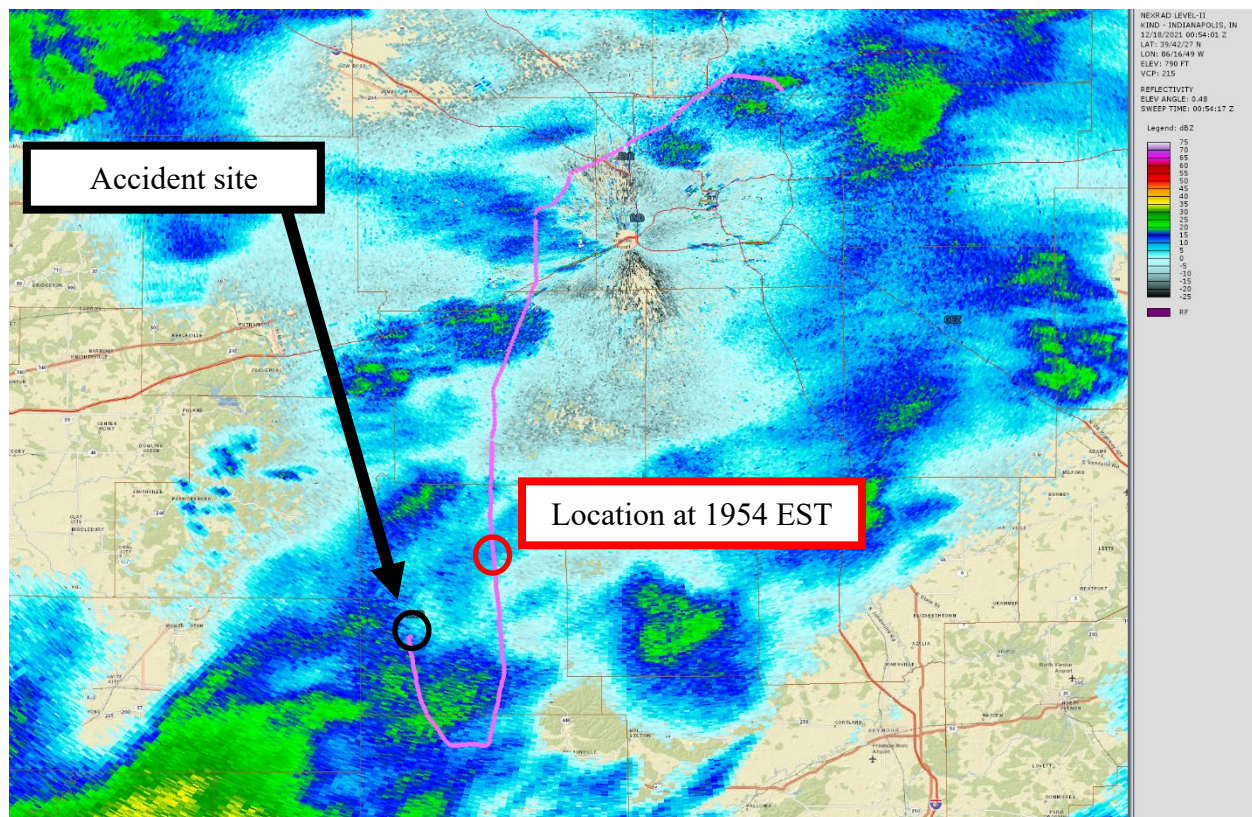


Figure 10 – KIND WSR-88D reflectivity for the 0.5° elevation scan initiated at 1954:17 EST with the accident site marked with black circle and the accident flight track in pink.

²⁴ Lightning Flash – This is one contiguous conducting channel and all the current strokes/pulses that flow through it. There are two types of flashes: ground flashes and cloud flashes.

²⁵ A review of Earth Networks Total Lightning network and GOES-16 Geostationary Lightning Mapper was done.

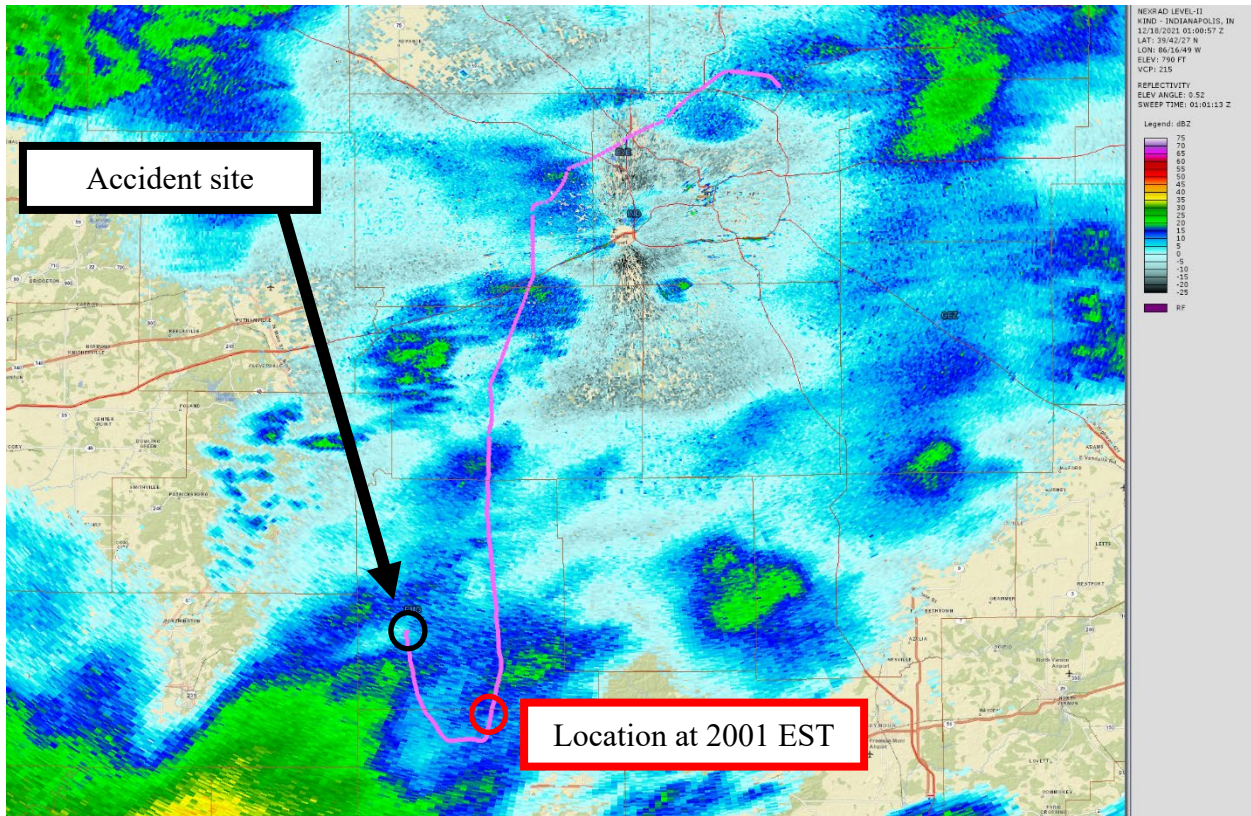


Figure 11 – KIND WSR-88D reflectivity for the 0.5° elevation scan initiated at 2001:13 EST with the accident site marked with black circle and the accident flight track in pink.

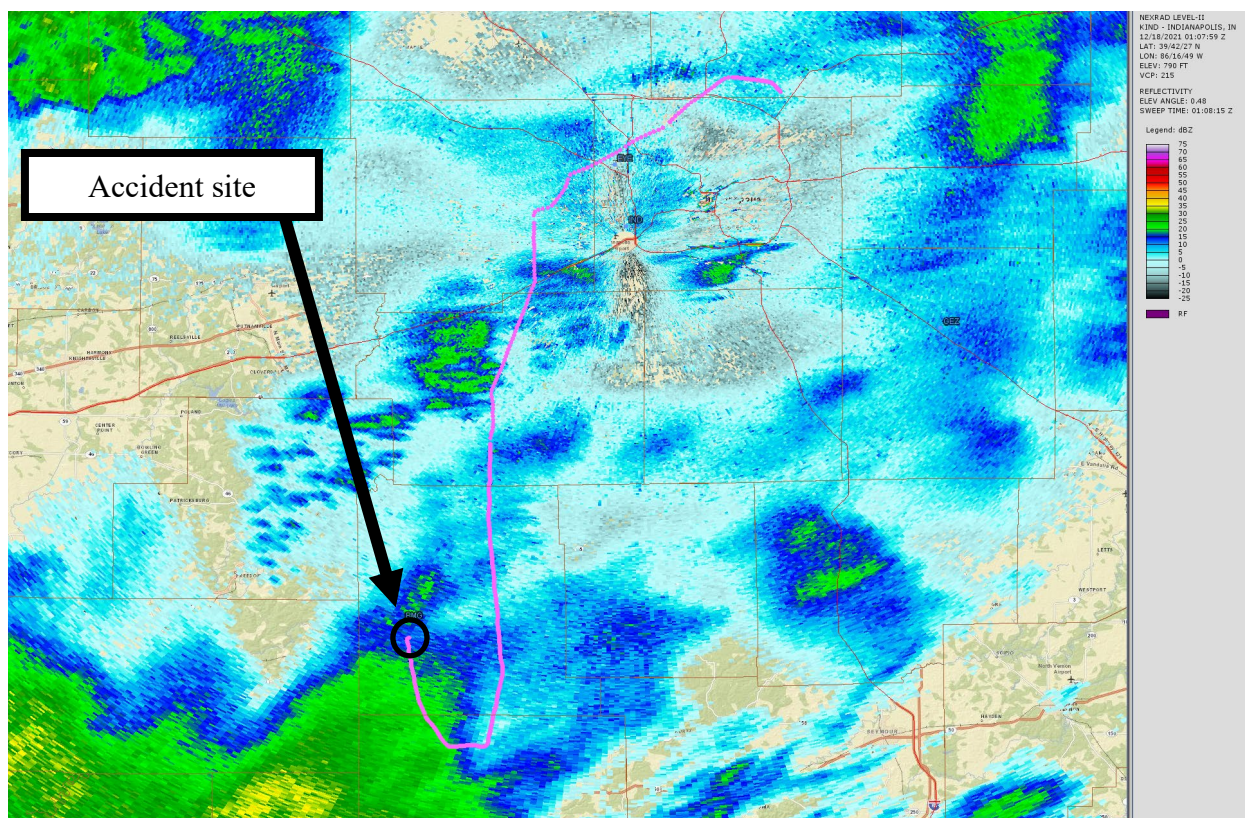


Figure 12 – KIND WSR-88D reflectivity for the 0.5° elevation scan initiated at 2008:15 EST with the accident site marked with black circle and the accident flight track in pink.

8.0 Pilot Reports

The longline-disseminated pilot reports²⁶ (PIREPs) distributed into the national airspace (NAS) were reviewed from about two hours prior to the accident time to two hours after the accident time and the PIREPs within 100 miles of the accident site below 18,000 ft are shown below:

SDF UA /OV JVV/TM 2317/FLDURGD/TP H25B/WX RA/TB NEG/RM FINAL RWY 18 JVV

LOU UA /OV LOU/TM 2322/FL013/TP C56X/SK BKN013/WX FV03SM/RM DURD

CMI UA /OV CMI/TM 2323/FL085/TP LJ45/SK OVC060/BTWN LYRS 085/RM DURC/MULTIPLE LYRS/N BOUND

OKK UA /OV OKK/TM 0012/FL150/TP HA4T/TB OCNL MOD CHOP

SDF UA /OV SDF/TM 0014/FLDURGC/TP B744/SK BKN012

EVV UA /OV EVV/TM 0015/FLDURGD/TP E145/RM BASES 007

LOU UA /OV LOU/TM 0033/FL011/TP BE30/SK OVC011/RM DURD

LEX UA /OV KLEX270020/TM 0104/FL070/TP SR22/TB LGT CHOP

²⁶ Only pilot reports with the World Meteorological Organization headers UBIN*, UBIL**, UBKY** and UBOH** were considered. These do not include pilot reports only broadcast via radio.

SDF UA /OV SDF/TM 0105/FLDURGC/TP B737/SK BKN009-TOP030

LAF UA /OV BVT145030/TM 0140/FL140/TP F2TH/TB LGT-MOD

IND UA /OV IND/TM 0156/FL030/TP E75S/SK 005BKN UNKN

SDF UA /OV SDF/TM 0211/FL060/TP CRJ9/WX RA/TB NEG

IND UA /OV MIE/TM 0215/FL130/TP E75S/TB MOD 150-110/RM DURD

IND UA /OV AID/TM 0307/FL110/TP CRJ9/TB LT TO MOD/RM LT TO MOD TURB 160 TO 120 THEN LT OUT OF 120 DURGD

9.0 Significant Meteorological Information

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

10.0 Center Weather Service Advisories

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

11.0 Airmen's Meteorological Information

There was an Airmen's Meteorological Information (AIRMET) advisory Sierra valid for the accident site at the accident time. The AIRMET Sierra issued at 1545 EST forecast IFR conditions in precipitation and mist through 2200 EST. In addition, an AIRMET Zulu was valid for the accident site for moderate icing above the freezing level (section 4.0):

WAUS43 KKCI 172045

WA3S

-CHIS WA 172045

AIRMET SIERRA UPDT 4 FOR IFR AND MTN OBSCN VALID UNTIL 180300

.

**AIRMET IFR...KS MO IL IN KY OK AR TN MS AL
FROM 20SW BVT TO 40S FWA TO CVG TO HNN TO HMV TO GQO TO IGB TO
30S OKC TO 50WSW TUL TO 50W OSW TO 30ESE MCI TO 20SW BVT
CIG BLW 010/VIS BLW 3SM PCPN/BR. CONDS CONTG BYD 03Z THRU 09Z.**

.

AIRMET IFR...ND SD MN
FROM 50SSE YWG TO BJI TO 30SSE MSP TO 20NNE RWF TO 40NW FSD TO
30W ABR TO 40W RAP TO 50NNW ISN TO 50SSE YWG
CIG BLW 010/VIS BLW 3SM PCPN/BR. CONDS CONTG BYD 03Z ENDG 06-09Z.

.

AIRMET MTN OBSCN...KY TN
FROM HNN TO HMV TO GQO TO 50WSW LOZ TO HNN
MTNS OBSC BY CLDS/PCPN/BR. CONDS CONTG BYD 03Z THRU 09Z.

.

OTLK VALID 0300-0900Z...IFR KS IA MO LM MI LH IL IN KY OK TX AR

TN MS AL
BOUNDED BY 20ESE ECK-FWA-CVG-HNN-HMV-GQO-40SSE MSL-IGB-TXK-20SW
MLC-20N OSW-20NNE IRK-20W JOT-20ESE ECK
CIG BLW 010/VIS BLW 3SM PCPN/BR. CONDS CONTG THRU 09Z.
....

12.0 Graphical Forecasts for Aviation

The Graphical Forecasts for Aviation (GFA) products issued before the accident flight and valid at 1900 EST are shown in attachment 3. The GFA surface forecast applicable to the accident region that was valid before the accident flight's departure for times surrounding the accident time indicated MVFR to IFR surface visibilities, an east surface wind at 5 knots with gusts to 15 knots, and a chance (between 30 and 60 percent) of rain showers. The GFA cloud forecast applicable to the accident region that was valid before departure for times surrounding the accident time indicated overcast cloud coverage with ceilings between 1,000 and 1,200 ft and cloud tops to FL370²⁷. The Graphical AIRMETs²⁸ (G-AIRMET) Sierra and Zulu for IFR conditions and moderate icing were overlaid on the GFA surface and clouds forecast imagery. The only human-generated information reflected in the two GFA products were the G-AIRMETs. For more information, please see attachment 3.

13.0 Terminal Aerodrome Forecast

KBMG was the closest airport to the accident site with an NWS Terminal Aerodrome Forecast²⁹ (TAF). The KBMG TAF valid at the time of the accident was issued at 1821 EST and was valid for a 24-hour period beginning at 1900 EST. The 1821 EST TAF for KBMG was as follows:

FTUS43 KIND 172321
TAFBMG
TAF
KBMG 172321Z 1800/1824 **10006KT P6SM -RADZ OVC005**
FM180300 11005KT 3SM -RA BR OVC004
FM180700 12004KT 1SM RA BR OVC002
FM181500 29007KT 2SM BR VCSH OVC002
FM181700 31008KT 5SM BR OVC006
FM182000 32010G18KT P6SM OVC011
AMD LTD TO CLD VIS AND WIND 1802/1814=

Between 1900 and 2200 EST the forecast expected a wind from 100° at 6 knots, greater than 6 miles visibility, light rain and drizzle, and an overcast ceiling at 500 ft agl.

²⁷ Flight Level – A Flight Level (FL) is a standard nominal altitude of an aircraft, in hundreds of ft. This altitude is calculated from the International standard pressure datum of 1013.25 hPa (29.92 inHg), the standard sea-level pressure, and therefore is not necessarily the same as the aircraft's true altitude either above msl or agl.

²⁸ <https://aviationweather.gov/gairmet>

²⁹ According to NWS Instruction 10-813: "An NWS TAF consists of the expected meteorological conditions significant to aviation at an airport for a specified time period. For the U.S., this is the area within five (5) statute miles (SM) of the center of an airport's runway complex." www.nws.noaa.gov/directives/sym/pd01008013curr.pdf

14.0 NWS Area Forecast Discussion

The NWS office in Indianapolis, Indiana, (WFO IND) was responsible for the public forecast and TAFs in the region of the accident site. WFO IND issued the following Area Forecast Discussion at 1831 EST that identified rain overspreading the region and areas of drizzle expected with uncertainty with the exact onset of LIFR conditions:

FXUS63 KIND 172331
AFDIND

Area Forecast Discussion
National Weather Service Indianapolis IN
631 PM EST Fri Dec 17 2021

...Updated Aviation Discussion...

.Forecast Update...
Issued at 549 PM EST Fri Dec 17 2021

We sent a quick forecast update to adjust a few fields based on observational trends. We added resolution to the precipitation probability fields, "extremizing" to 100 percent at locations where it is now raining. There may be a period of modest midlevel drying into early evening which will lessen radar echos, but low-level saturation depth is still sufficient for collision coalescence and persistent drizzle during this relative lull. The warm advection/isentropic ascent pattern continues through the night and hi-res guidance plus upstream observations suggest rainfall rates will again increase later in the night. This will push much of southern Indiana over one inch storm total through tomorrow morning, with over one half inch elsewhere. This falls well below flash flood guidance but some main stem river levels may be elevated this weekend.

One additional note, low-level warm/moist advection has been enough to preclude wet bulbing effect into a more critical level with regards to precipitation type. A couple of obs have briefly shown snow, but we have high confidence this is an erroneous given the thermal profile featuring a significant warm layer just above the surface. Dew points are high enough to preclude wet bulbing to near freezing.

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.Short Term...(This evening through Saturday night)
Issued at 138 PM EST Fri Dec 17 2021

Tonight.

As of early this afternoon, rain has begun to fall across the southwestern counties ahead of the approaching surface low and along the fairly diffuse warm front along the Ohio River. The heaviest of the rain will arrive after midnight as the surface low pushes into southern Indiana and a 40-50kt LLJ advects copious amounts of moisture into the frontal region with strong isentropic lift

expected along the boundary. Rain amounts look to exceed an inch across the southern counties which will likely create pockets of flooding and lead to elevated river levels through the rest of the weekend and into next week. Updrafts may be just strong enough to create a few strikes of lightning in the strongest of showers, but with little to no surface or elevated instability, elected to keep thunder out of the forecast for now. Will monitor the lightning trends upstream and may need to reintroduce into the forecast later this evening.

Thick cloud cover will keep temperatures relatively mild overnight with lows in the mid to upper 30s with some pockets of 40-42 across the far southern counties. There will likely be pockets of fog between the periods of rain overnight, but winds look to remain strong enough to limit the overall coverage and density of fog cover.

Saturday and Saturday Night.

During the morning hours on Saturday the surface low will push off to the northwest with surface and low level flow shifting to the northwest and leading to an end to the low level moisture advection and isentropic lift that will have been the primary catalyst for precipitation overnight. Expect that by the late morning hours that precipitation will have ended for all but the far eastern counties. Model sounding show that even with the loss of moisture advection, the low levels remain saturated or mostly saturated through the daytime hours which will lead to a cloudy day with relatively mild temperatures in the morning with a slow dropoff during the day as weak CAA and cloudy skies combine to create the non-diurnal temperature curve.

Drier air will slowly erode the cloud deck during the overnight hours with quiet weather expected through the night as high pressure begins to build across the area. Temperatures look to drop into the mid 20s to low 30s with lowest temperatures across the west which will experience the most effective radiational cooling.

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.Long Term...(Sunday through Friday)
Issued at 138 PM EST Fri Dec 17 2021

Throughout much of the long term period, central Indiana will remain on the periphery of the northern stream aloft. A few upper troughs will move through the northern stream, but forcing will remain north of the area. Moisture will be confined to the southern stream, well to the south.

Thus, only expect only a couple of dry cold frontal passages through much of the week leading up to Christmas Eve. Temperatures will bounce around normal as the cold fronts bring periodic pushes of some cooler air.

Uncertainty ramps up for Christmas Eve though, as models do not agree on the development of the upper pattern. There is a potential for some precipitation Thursday night into Christmas Eve depending

on the pattern evolution. However, with the very low confidence, will only have some slight chance PoPs then.

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.Aviation...(00Z TAF Issuance)
Issued at 631 PM EST Fri Dec 17 2021

IMPACTS:

--Lowest ceilings (including LIFR potential) after approximately 05z.

--Winds will shift from the east to northwest around 15-17z.

--Some lower visibility from light fog may occur late tonight.

Discussion:

Rain has overspread most of the area early this evening. There will be enough low-level saturation for at least drizzle, with waves of light/moderate rain lasting through the morning hours, then gradual improving conditions. Around 05z to 15z should be when the worst of the conditions occur, including LIFR ceilings. Check the specific TAF for timing, although some uncertainty with the exact onset of LIFR conditions exists and amendments may be needed based on observational trends.

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.IND WATCHES/WARNINGS/ADVISORIES...

None.

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15.0 Winds and Temperature Aloft Forecast

The NWS 1459 EST Winds and Temperature Aloft forecast valid for the closest point to the accident site is included below:

FBUS31 KWNO 171959

FD1US1

DATA BASED ON 171800Z

VALID 180000Z FOR USE 2000-0300Z. TEMPS NEG ABV 24000

FT	3000	6000	9000	12000	18000	24000	30000	34000	39000
IND	1316	2324+07	2333+02	2435-03	2654-16	2359-26	237842	248454	259963

The closest forecast point to the accident site was Indianapolis, Indiana (IND). The 1459 EST IND forecast for use between 1500 EST and 2200 EST indicated a wind at 3,000 ft from 130° at 16 knots, a wind at 6,000 ft from 230° at 24 knots with a temperature of 7°C, and a wind at 9,000 ft from 230° at 33 knots with a temperature of 2°C.

16.0 Pilot Weather Briefing

The accident pilot did not request weather information³⁰ from Leidos Flight Service.

A search of archived ForeFlight information indicated that the accident pilot requested and received weather information from ForeFlight at 1613:36, 1908:19, and 1918:55 EST with a planned departure from Indianapolis Metro Airport (KUMP) between 1920 and 1930 EST. The weather information provided by ForeFlight contained all the standard weather forecast information, including the valid AIRMETs, PIREPs, GFA, TAFs, and METARs. For more information including full weather briefing information and graphics please see attachment 4.

17.0 Astronomical Data

The astronomical data obtained for the accident site on December 17, 2021, indicated the following:

SUN

Begin civil twilight	0730 EST
Sunrise	0800 EST
Sun transit	1243 EST
Sunset	1726 EST
End civil twilight	1756 EST
Accident time	2008 EST³¹

MOON

Moonrise	1620 EST
Accident time	2008 EST³²
Moon transit	2356 EST
Moonset	0640 EST on December 18, 2021

At the time of the accident the Moon was located at an altitude of 40.51° and azimuth of 91.49°, and the phase was Waxing Gibbous at 98.8 percent illumination.

E. LIST OF ATTACHMENTS

Attachment 1 – GOES-16 infrared satellite animation between 1901 and 2101 EST

Attachment 2 – KIND WSR-88D base reflectivity animation from 1919 to 2015 EST

Attachment 3 – GFA valid for the accident site at accident time

Attachment 4 – ForeFlight correspondence

³⁰ https://www.faa.gov/documentLibrary/media/Advisory_Circular/AC_91-92.pdf

³¹ Inserted accident time for reference and context.

³² Inserted accident time for reference and context.

Submitted by:

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