



NATIONAL TRANSPORTATION SAFETY BOARD

Office of Aviation Safety
Washington, D.C. 20594

September 19, 2019

Weather Study

METEOROLOGY

CEN19FA247

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A. ACCIDENT

Location: Ontonagan, Michigan
Date: August 3, 2019
Time: 1143 eastern daylight time
1543 Coordinated Universal Time (UTC)
Aircraft: Piper PA-28-180; Registration: N5167L

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 including the National Centers for Environmental Information (NCEI). All times are eastern daylight time (EDT) on August 3, 2019, and are based upon the 24-hour clock, where local time is -4 hours from UTC, and UTC=Z (unless otherwise noted). Directions are referenced to true north and distances in nautical miles. Heights are above mean sea level (msl) unless otherwise noted. Visibility is in statute miles and fractions of 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 46.6991° N, longitude 89.4727° W at an approximate elevation of 1,480 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

1.1 Surface Analysis Chart

The northcentral United States section of the NWS Surface Analysis Chart for 1400 EDT is provided as figure 1 with the location of the accident site marked within the red circle. The chart identified a low pressure system over Upper Michigan and near the accident site with a minimum pressure of 1016-hectopascals (hPa). A cold front stretched from the low pressure center in Upper Michigan westward into northern Minnesota and a stationary frontal boundary stretched from the low pressure center in Upper Michigan eastward over Lake Michigan, Lake Huron, and into southern Canada. A high pressure system was located over eastern Minnesota with a pressure of 1021-hPa. The accident site was located directly below the cold frontal boundary.

The station models around the accident site depicted air temperatures in the mid 60's to mid 70's degrees Fahrenheit (°F) and dew point temperatures in the mid 60's °F with a temperature-dew point spread of 3° or more. A north wind of 5 knots was indicated behind the cold front, a west wind of 5 knots ahead of the cold front, with clear skies ahead of the cold front, partly cloudy to overcast skies behind the cold front, and rain showers reported behind the cold front.

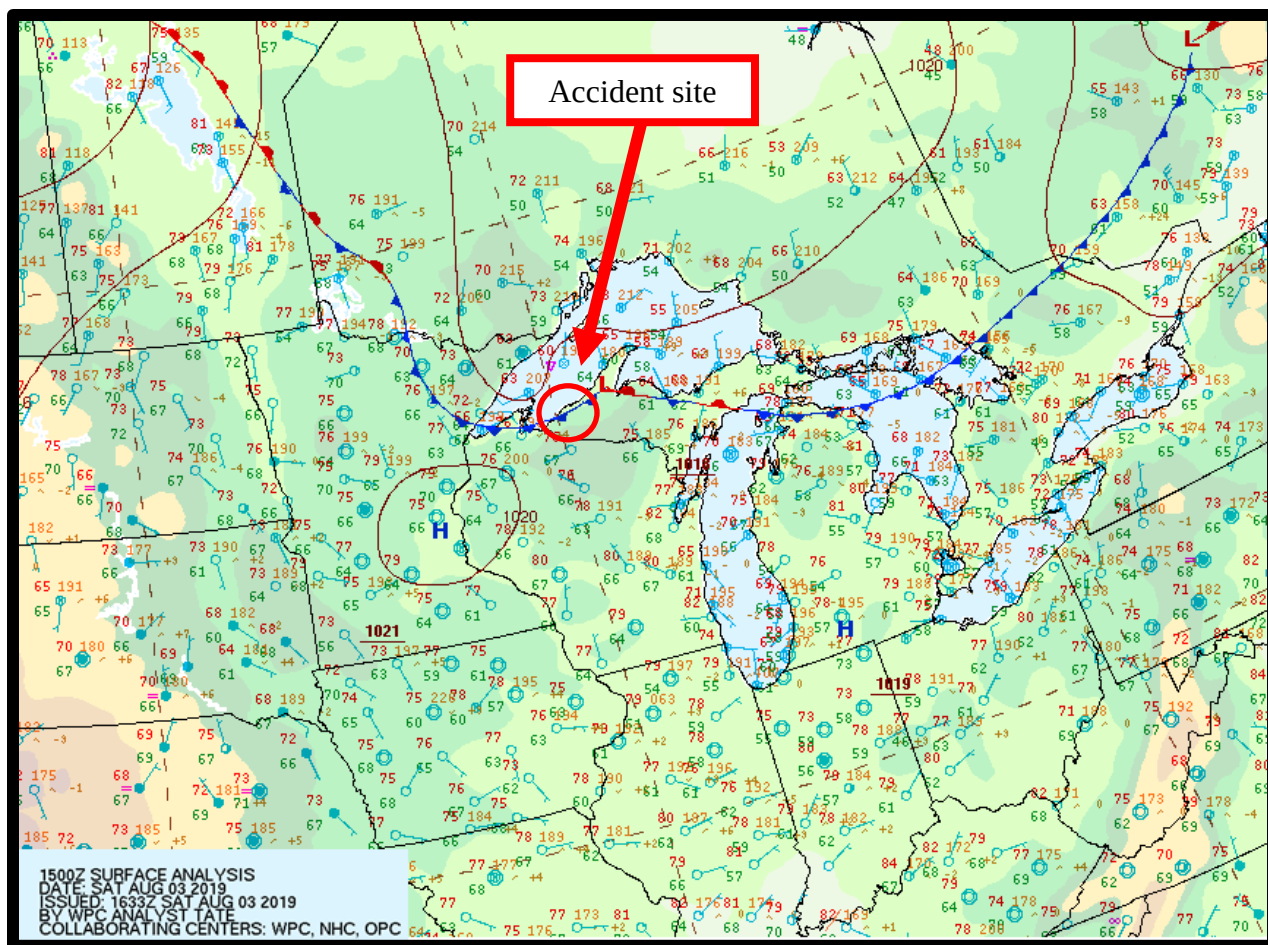


Figure 1 – NWS Surface Analysis Chart for 1100 EDT

1.2 Upper Air Charts

The NWS Storm Prediction Center (SPC) Constant Pressure Charts for 0800 EDT at 925-, 850-, 700-, 500-, and 300-hPa are presented in figures 2 through 6. There was a trough² at low- and mid-levels located above the accident site at 925- through 500-hPa. Troughs can act as lifting mechanisms to help produce clouds and precipitation if sufficient moisture is present and there is upper level support for surface fronts. The wind was from the northwest at 15 knots at 925-hPa with the wind remaining from the northwest at 10 to 15 knots through 300-hPa (figure 6).

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

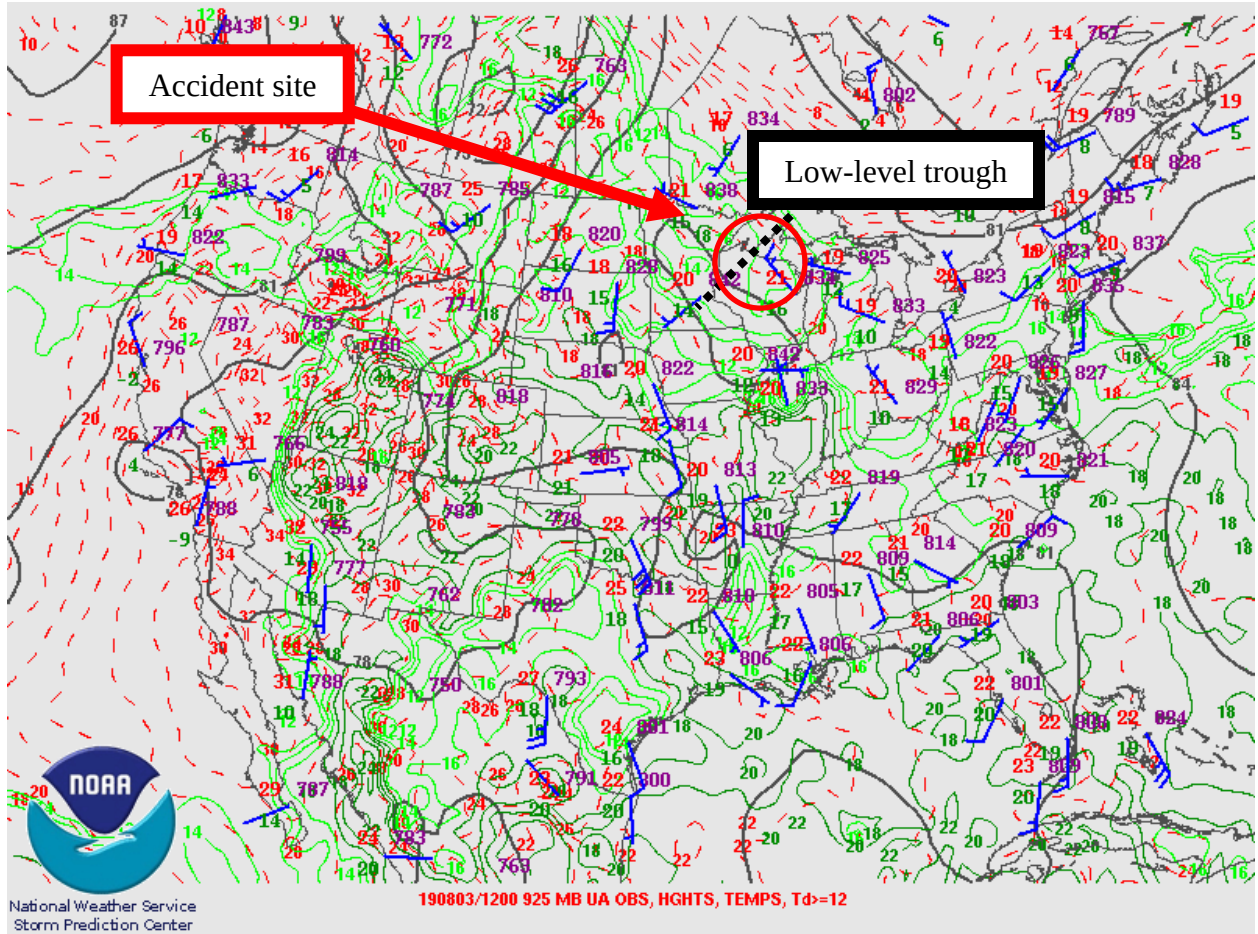


Figure 2 – 925-hPa Constant Pressure Chart for 0800 EDT

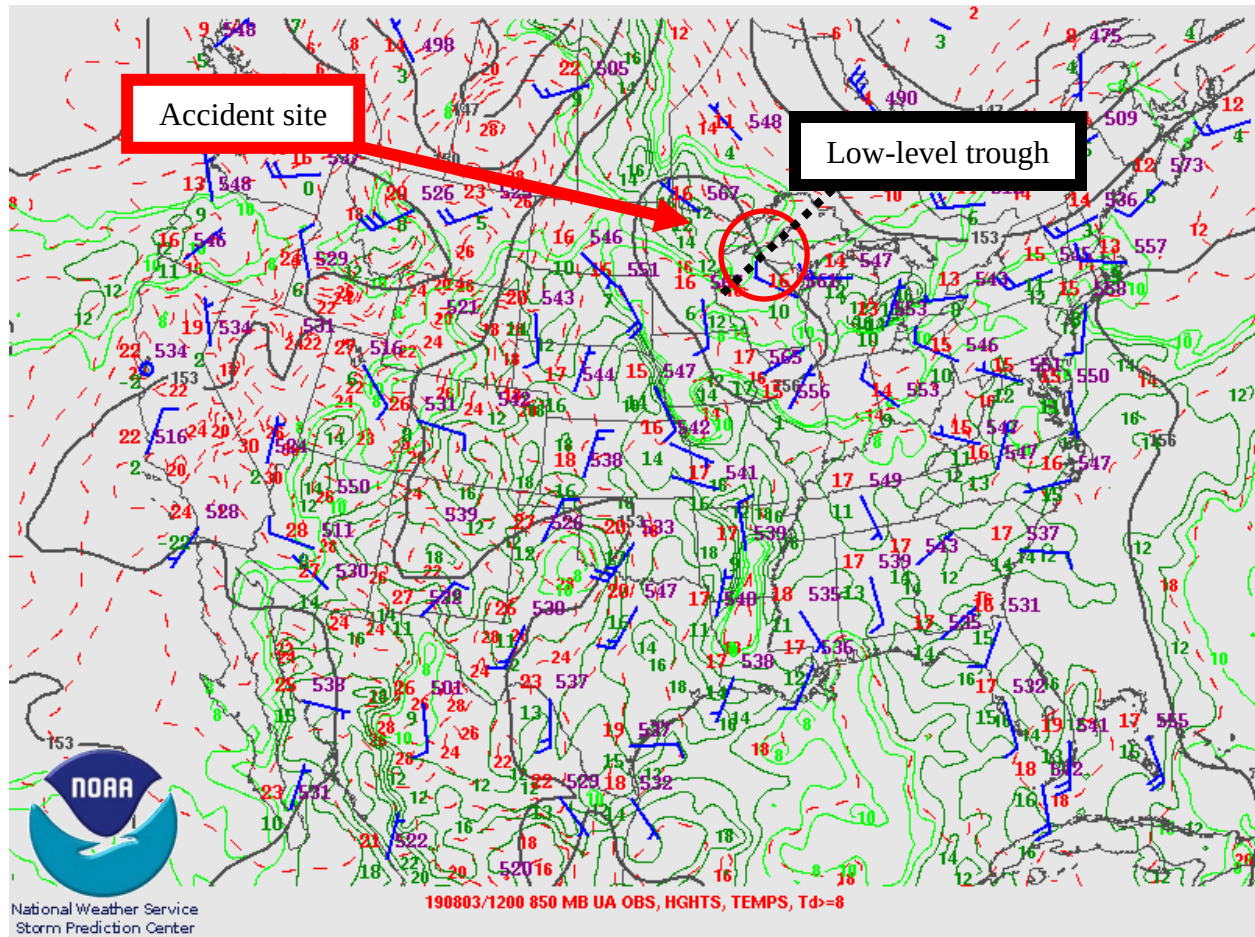


Figure 3 – 850-hPa Constant Pressure Chart for 0800 EDT

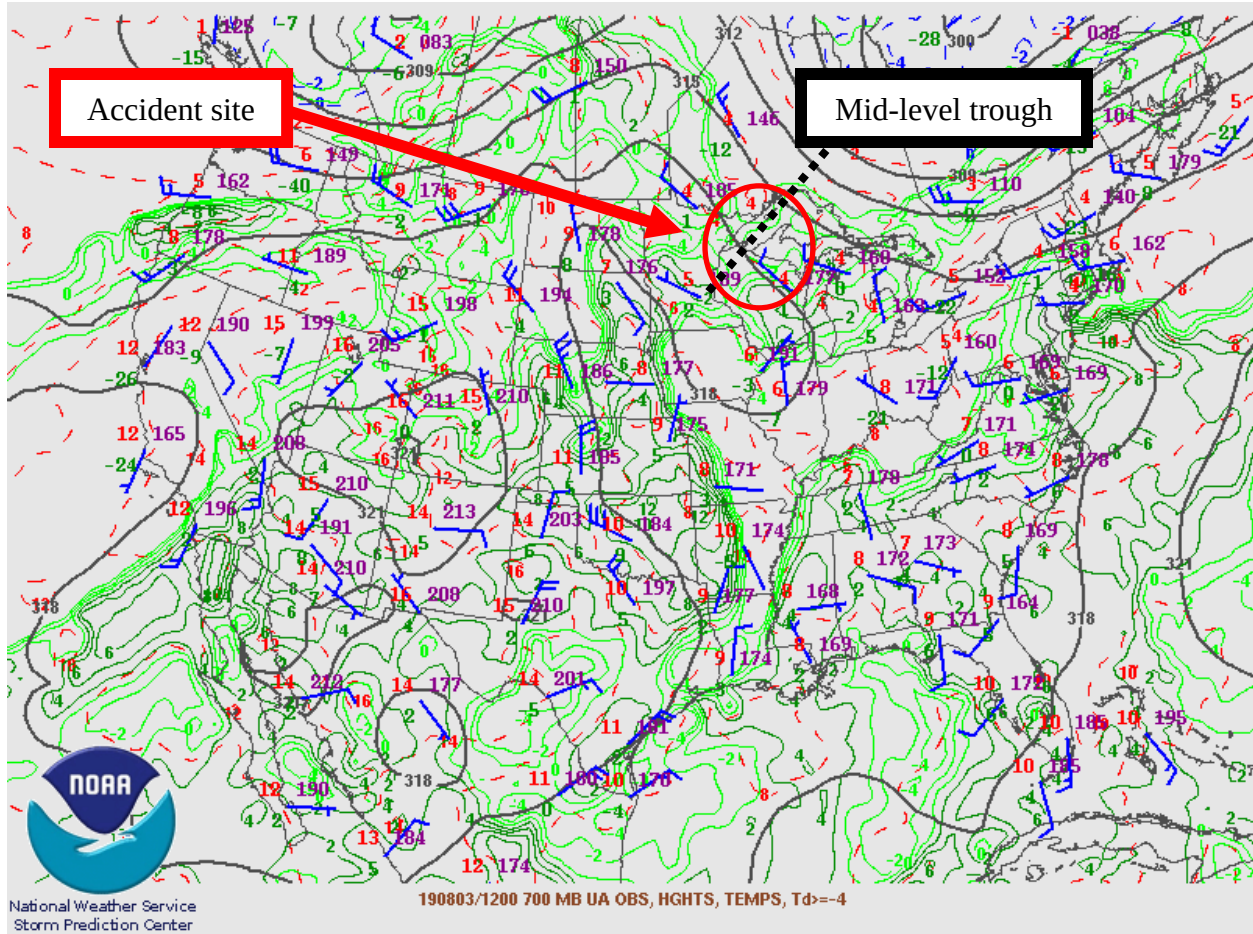


Figure 4 – 700-hPa Constant Pressure Chart for 0800 EDT

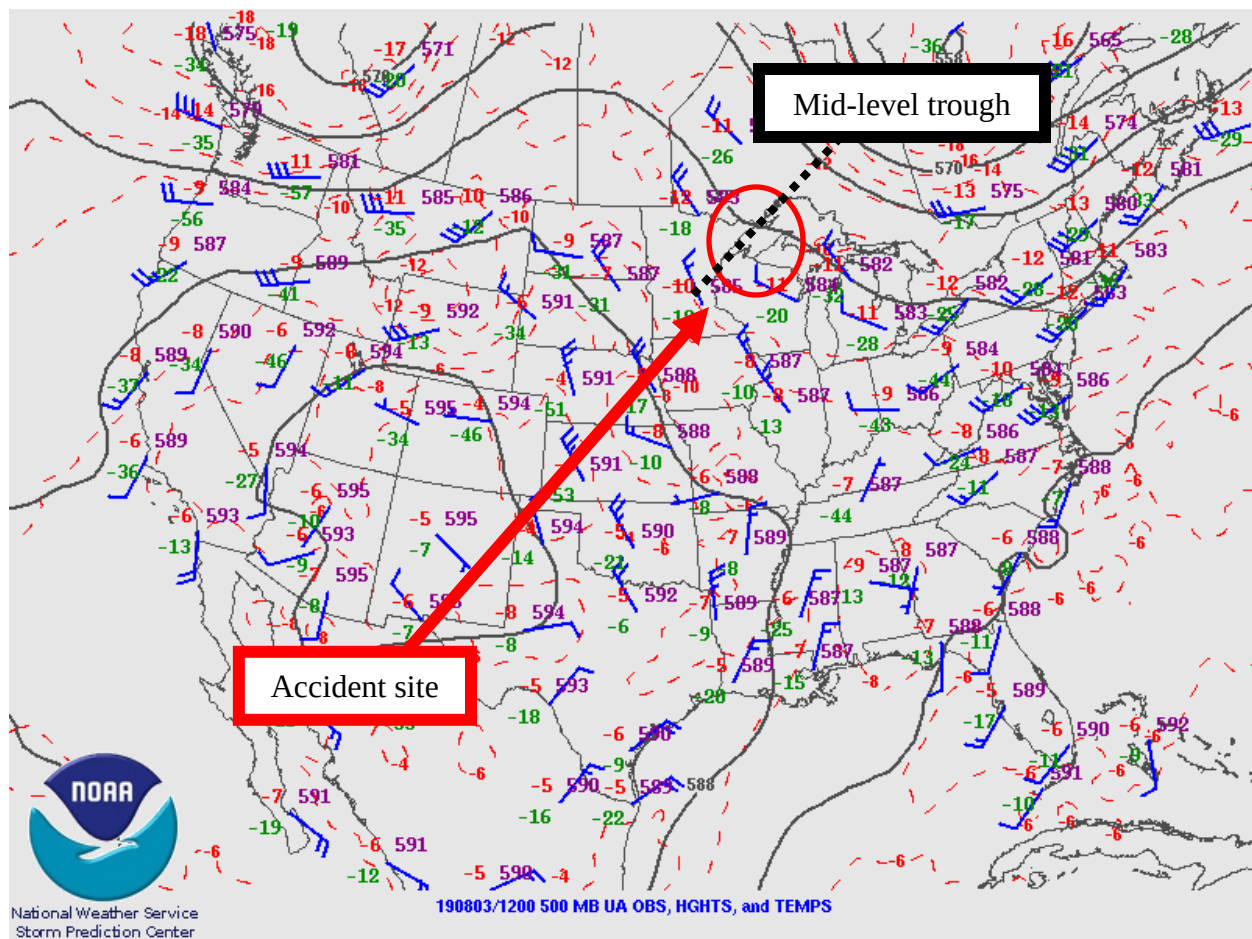


Figure 5 – 500-hPa Constant Pressure Chart for 0800 EDT

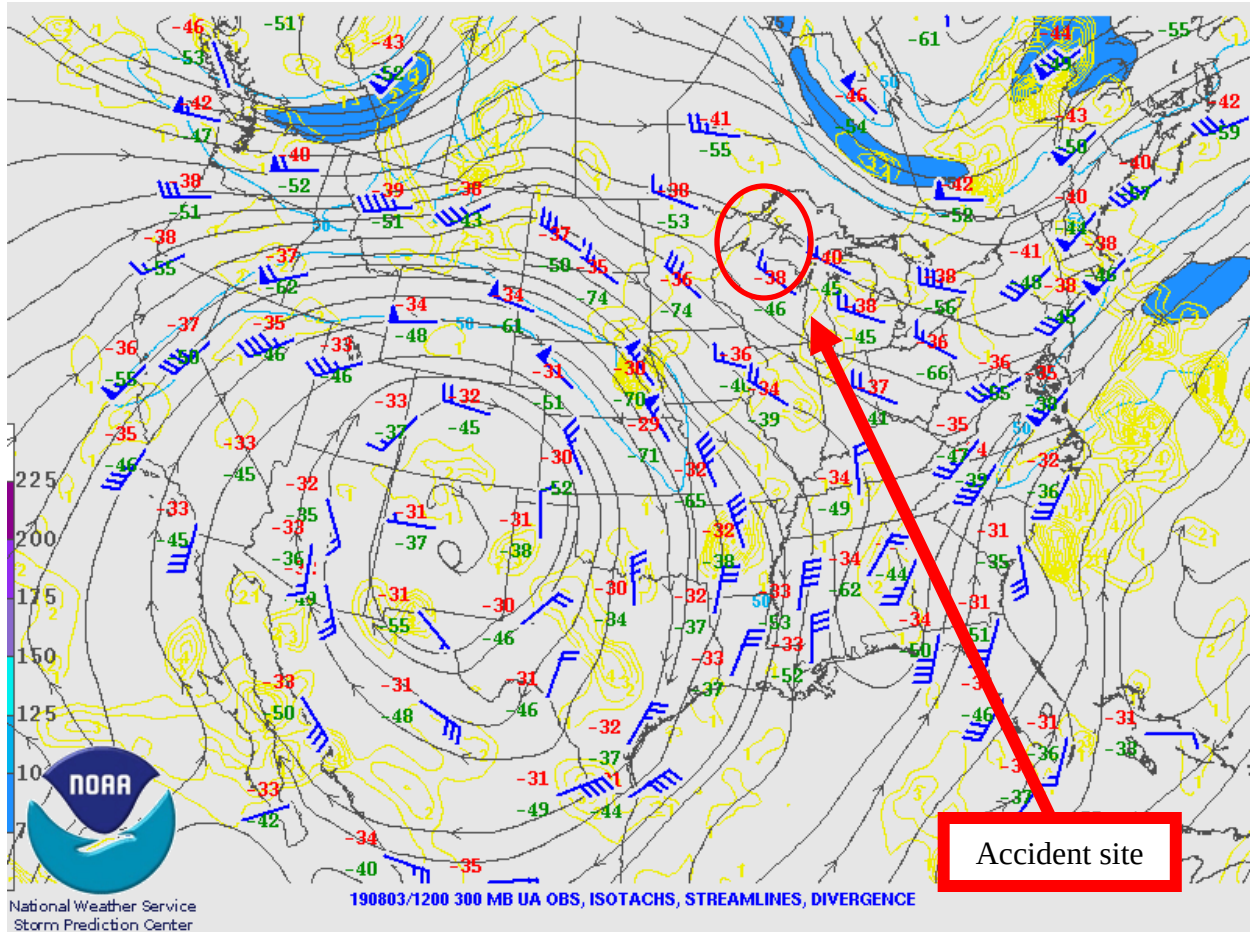


Figure 6 – 300-hPa Constant Pressure Chart for 0800 EDT

2.0 SPC Convective Outlook

SPC issued the following Day 1 Convective Outlook at 0854 EDT (figure 7) with areas of general thunderstorms forecast for the accident site³. SPC defines the “TSTM” area as an area that encloses where a 10% or higher probability of thunderstorms is forecast during the valid period. The SPC Day 1 Convective Outlook text follows figure 7:

³ The 0900 and 0800 EDT SPC Day 1 Convective Outlook forecast similar conditions and had similar graphics.

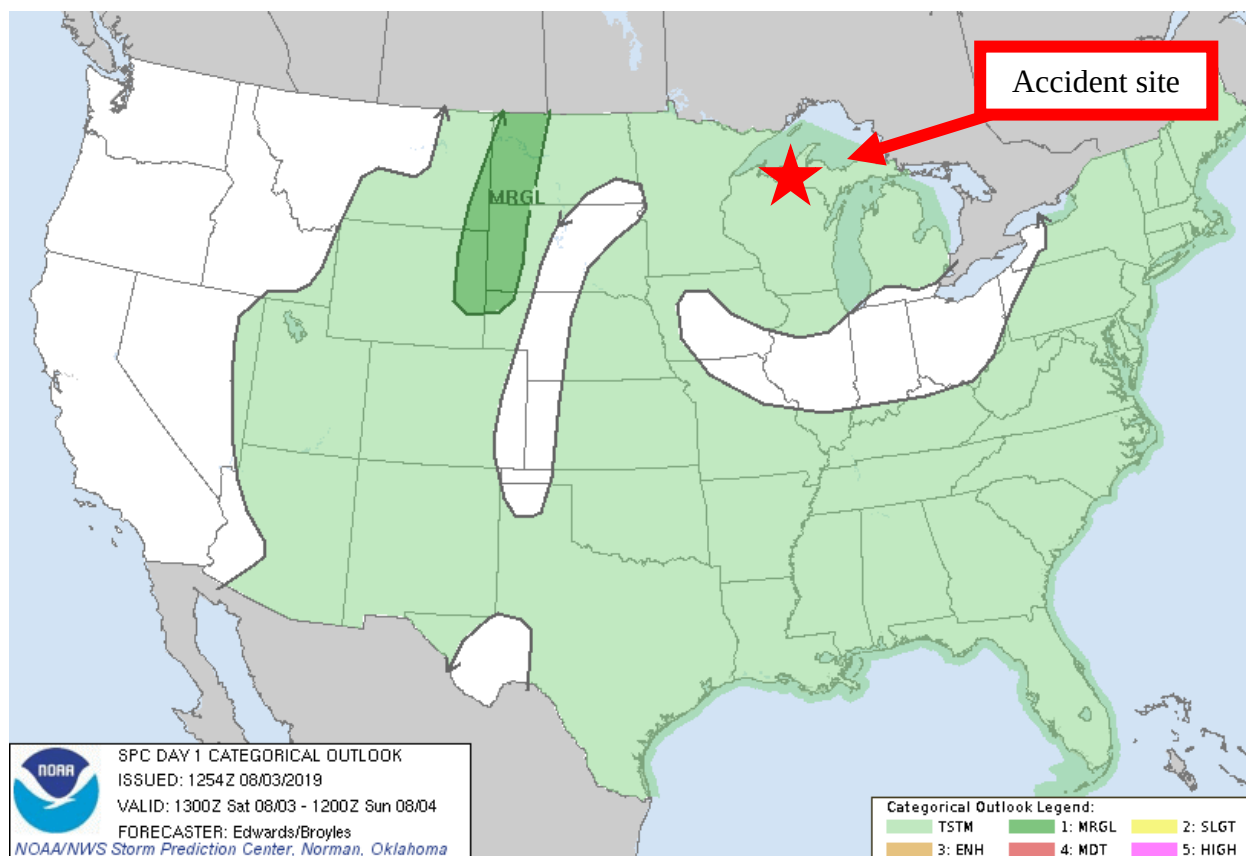


Figure 7 – SPC day 1 Convective Outlook valid at the time of the accident

SPC AC 031254

Day 1 Convective Outlook
NWS Storm Prediction Center Norman OK
0754 AM CDT Sat Aug 03 2019

Valid 031300Z - 041200Z

...THERE IS A MARGINAL RISK OF SEVERE THUNDERSTORMS OVER PARTS OF THE NORTHERN PLAINS...

...SUMMARY...

Isolated strong to severe thunderstorms are possible this afternoon over the northern High Plains.

...Synopsis...

The upper-air pattern will continue to feature a stout anticyclone centered over the southern Rockies, with ridging northward across the central Rockies and northern High Plains. A strong shortwave trough -- apparent in moisture-channel imagery over the Canadian Rockies -- should move eastward across much of SK by the end of the period. A lesser perturbation -- initially over central/eastern MT -- will move eastward through the mean ridge to central ND by 00Z.

At the surface, 11Z analysis showed a quasistationary frontal zone from south-central New England across central PA, becoming diffuse

over much of the Ohio Valley, then better-defined again from the Ozarks to the central Dakotas. A moist axis was drawn just to the west of the boundary across the central/northern Plains. This boundary should remain near its present locations except where overtaken tonight by a cold front moving southward from QC across NY and New England.

...Northern Plains...

Isolated to widely scattered thunderstorms are expected to develop this afternoon near the ND/MT line and south-southwestward over northeastern WY, in a zone of favorably strong surface heating, and near a surface trough located west of the moist axis. Activity should move eastward to southeastward into stronger moisture for a few hours, with isolated large hail or strong-severe gusts possible.

The minor perturbation and associated cloud cover should pass over the area before peak afternoon destabilization. This will render two somewhat counterbalancing effects:

1. Relatively unimpeded, strong surface diabatic heating, producing steep low-level lapse rates in an environment of at least marginally favorable low-level moisture, with MLCINH essentially eliminated in some spots.
2. Weak large-scale subsidence, or at best, near-neutral vertical-motion fields in midlevels by late afternoon. Height falls related to the peripheral influence of the Canadian trough should wait until tonight, and will be subtle.

These factors call into question the coverage of convection, through buoyancy should be favorable, with surface dew points 60s F contributing to a narrow corridor of MLCAPE in the 1000-2000 J/kg range (locally/briefly higher). Effective-shear magnitudes 30-35 kt are forecast with nearly straight hodographs, indicating a blend of multicellular and splitting/brief supercell modes possible. Convection should diminish markedly after dark as appreciable large-scale forcing for ascent, preceding the major shortwave trough, remains north of the international border.

...Southern OK to central TX...

Isolated hail briefly near severe levels cannot be ruled out in the next couple hours from a core or two within a lengthy plume of convection training southward across southern KS and eastern/southern OK into north TX, until the supportive warm-advection regime weakens diurnally. The potential appears too isolated/conditional for an outlook area.

Isolated to widely scattered thunderstorms may develop this afternoon across southern OK and north TX, a few of which may produce strong gusts. The most favorable instability is expected south and west of the early cloud cover over parts of central TX, as strong surface heating weakens MLCINH and deepens/mixes the boundary layer. However, low-level forcing and convective coverage in that regime appears questionable. Meanwhile, extensive cloud cover is evident in satellite imagery and should linger over much of the area of greatest deep-layer support. As such, an unconditional outlook is not being re-introduced at this time due to lingering concerns over convective coverage/organization, as well as the lack of more-

substantial vertical shear. However, the well-mixed boundary layer will offer some cause for concern if enough storm coverage can accumulate to organize cold pools. Mesoscale trends will be monitored for a better-organized, stronger wind threat than currently evident.

...Eastern PA to southern New England...

Widely scattered thunderstorms are possible this afternoon in a west-southwest/east-northeast corridor along and south of the front. This area will reside within the northern rim of a corridor of favorable low-level moisture and diurnal heating south of the boundary. Surface dew points commonly in the mid/upper 60s F in lower elevations, and MLCAPE near 1500 J/kg may support a few strong multicells with downdrafts approaching severe levels. However, weak low/middle-level winds will substantially limit vertical shear. While minor damage cannot be ruled out in the most intense cores, the potential for severe/50+ kt wind appears too small and conditional for a categorical area at this time.

..Edwards/Broyles.. 08/03/2019

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NOTE: THE NEXT DAY 1 OUTLOOK IS SCHEDULED BY 1630Z

3.0 Surface Observations

The area surrounding the accident site was documented using official Meteorological Aerodrome Reports (METARs) and Specials (SPECIs). Figure 8 is a sectional chart with the accident site and the closest weather reporting location to the accident site marked.

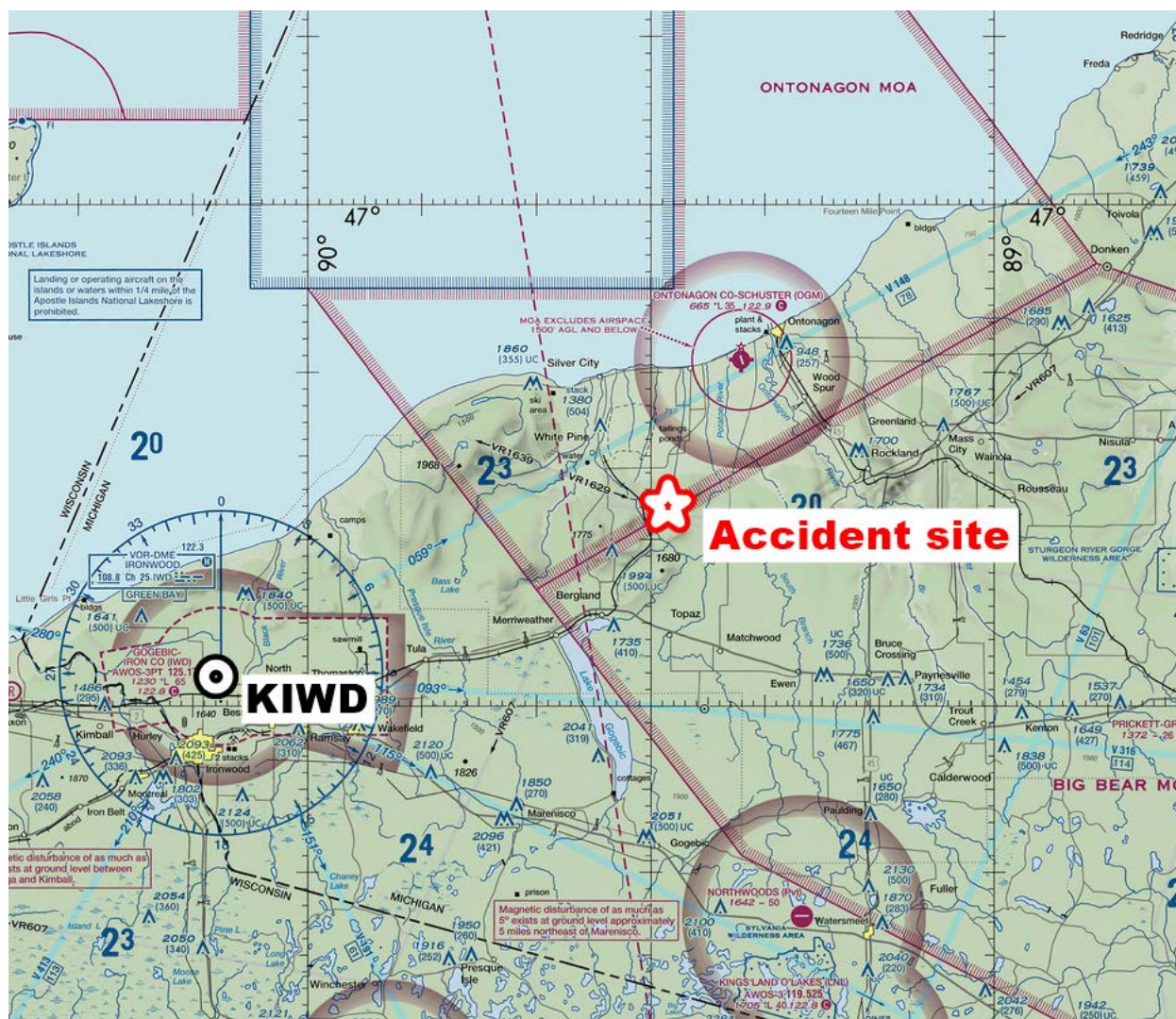


Figure 8 – Sectional chart of accident area with the location of the accident site and the closest surface observation site

The closest official weather reporting facility to the accident site was from Gogebic-Iron County Airport, Michigan, (KIWD) equipment at an elevation of 1,230 ft and was 29 miles west-southwest of the accident site. KIWD had an Automated Weather Observing System (AWOS⁴) whose reports were not supplemented and KIWD had a 3° westerly magnetic variation⁵ (figure 8). The following observations were taken and disseminated during the times surrounding the accident:⁶

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 twelve thousand 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 Bolded sections in this report highlight information that directly reference the weather conditions that affected the accident location around the accident time.

[0749 EDT] SPECI KIWD 031149Z AUTO 00000KT 4SM BR BKN003 14/14 A3012
RMK AO2=

[0756 EDT] METAR KIWD 031156Z AUTO 00000KT 9SM FEW003 16/15 A3012 RMK
AO2 SLP198 T01560150 10167 20133 52004=

[0856 EDT] METAR KIWD 031256Z AUTO 26007KT 10SM CLR 19/18 A3012 RMK
AO2 SLP196 T01940183=

[0956 EDT] METAR KIWD 031356Z AUTO 28006KT 10SM CLR 21/19 A3013 RMK
AO2 SLP199 T02110189=

**[1056 EDT] METAR KIWD 031456Z AUTO 34005KT 10SM FEW013 SCT110 23/19
A3013 RMK AO2 SLP201 T02280194 53004=**

**[1128 EDT] SPECI KIWD 031528Z AUTO 33009KT 10SM BKN014 BKN100 22/19
A3015 RMK AO2=**

ACCIDENT TIME 1143 EDT

**[1156 EDT] METAR KIWD 031556Z AUTO 01008KT 10SM BKN010 21/18 A3015 RMK
AO2 CIG 008V012 SLP207 T02110183=**

**[1206 EDT] SPECI KIWD 031606Z AUTO 06004KT 10SM SCT008 BKN110 21/18
A3015 RMK AO2=**

[1256 EDT] METAR KIWD 031656Z AUTO 09007KT 10SM FEW070 24/18 A3012 RMK
AO2 LTG DSNT SE SLP196 T02440183=

KIWD weather at 1056 EDT, automated, wind from 340° at 5 knots, 10 miles visibility or greater, few clouds at 1,300 ft above ground level (agl), scattered clouds at 11,000 ft agl, temperature of 23° Celsius (C), dew point temperature of 19°C, and an altimeter setting of 30.13 inches of mercury (inHg). Remarks, station with a precipitation discriminator, sea level pressure 1020.1 hPa, temperature 22.8°C, dew point temperature 19.4°C, 3-hourly pressure increase of 0.4 hPa.

KIWD weather at 1128 EDT, automated, wind from 330° at 9 knots, 10 miles visibility or greater, broken ceiling at 1,400 ft agl, broken clouds at 10,000 ft agl, temperature of 22°C, dew point temperature of 19°C, and an altimeter setting of 30.15 inHg. Remarks, station with a precipitation discriminator.

KIWD weather at 1156 EDT, automated, wind from 010° at 8 knots, 10 miles visibility or greater, broken ceiling at 1,000 ft agl, temperature of 21°C, dew point temperature of 18°C, and an altimeter setting of 30.15 inHg. Remarks, station with a precipitation discriminator, ceiling varying between 800 and 1,200 ft agl, sea level pressure 1020.7 hPa, temperature 21.1°C, dew point temperature 18.3°C.

KIWD weather at 1206 EDT, automated, wind from 060° at 4 knots, 10 miles visibility or greater, scattered clouds at 800 ft agl, broken ceiling at 11,000 ft agl, temperature of 21°C, dew point temperature of 18°C, and an altimeter setting of 30.15 inHg. Remarks, station with a precipitation discriminator.

Observations from KIWD surrounding the accident time indicated VFR⁷ conditions with a surface wind from the northwest to northeast between 4 and 9 knots. Sections 6.0 and 7.4 will further illustrate the convective weather conditions near the accident site at the accident time.

4.0 Upper Air Data

A High-Resolution Rapid Refresh (HRRR)⁸ model sounding was created for the accident site for 1200 EDT with a station elevation of 1,394 ft.⁹ The 1200 EDT HRRR sounding was plotted on a standard Skew-T Log P diagram¹⁰ with the derived stability parameters included in figure 9 with data from the surface to 600-hPa (or approximately 14,000 ft msl). This data was analyzed using the RAOB¹¹ software package. The sounding depicted the lifted condensation level (LCL)¹² and the level of free convection (LFC)¹³ at 1,050 ft agl (2,444 ft msl), and the convective condensation level (CCL)¹⁴ at 2,849 ft agl (4,243 ft msl). The freezing level was located at 12,768 ft msl. The precipitable water value was 1.54 inches.

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

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

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

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

⁸ The HRRR is a NOAA real-time three-kilometer resolution, hourly-updated, cloud-resolving, convection-allowing atmospheric model, initialized by three-kilometer grids with three-kilometer radar assimilation. Radar data is assimilated in the HRRR every 15 minutes over a one hour period.

⁹ HRRR sounding was created using NOAA Air Resource Laboratory: <https://ready.arl.noaa.gov/READYamet.php>

¹⁰ Skew T log P diagram – is a standard meteorological plot using temperature and the logarithmic of pressure as coordinates, used to display winds, temperature, dew point, and various indices used to define the vertical structure of the atmosphere.

¹¹ RAOB – (The complete Rawinsonde Observation program) is an interactive sounding analysis program developed by Environmental Research Services, Matamoras, Pennsylvania.

¹² LCL - The height at which a parcel of moist air becomes saturated when it is lifted dry adiabatically.

¹³ 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.

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.

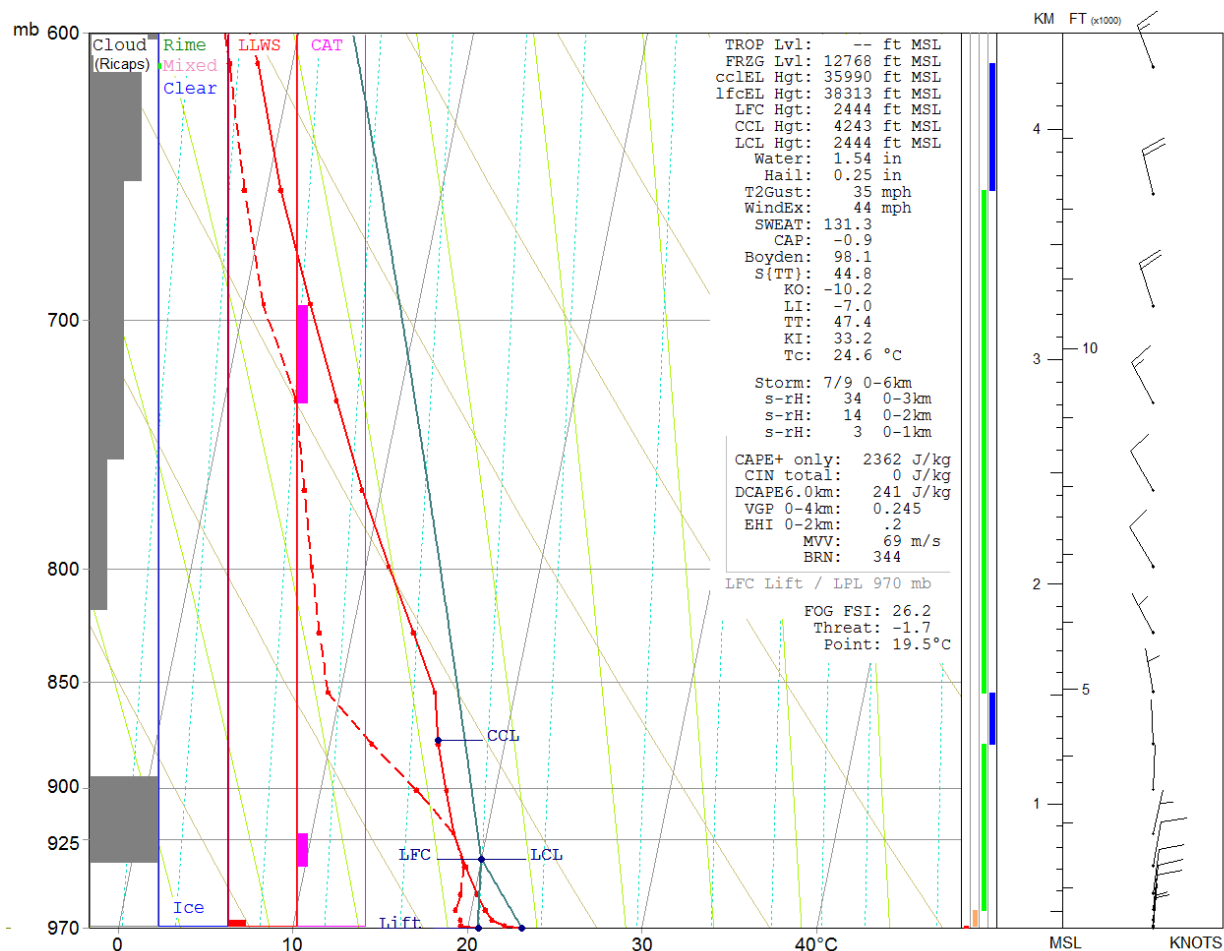


Figure 9 – 1200 EDT HRRR sounding for the accident site

The 1200 EDT HRRR sounding for the accident site indicated a mostly conditionally unstable environment from the surface through 12,000 ft, with a Lifted Index of -7. RAOB identified the possibility of clouds in several layers from ~1,000 ft agl (2,500 ft msl) through 14,000 ft msl. A positive CAPE¹⁵ value of 2,362 Joules/kilogram (J/kg) was indicated on the sounding and the maximum vertical velocity (MVV) for this atmosphere was calculated as 69 meters/second (about 13,583 ft per minute).¹⁶ Downdraft CAPE (DCAPE; 6 kilometers agl)¹⁷ was measured at 241 J/kg. If rain showers or thunderstorms formed in this environment, the 1200 EDT HRRR sounding indicated that the strongest wind speeds possible at the surface (due to, for example, a microburst, outflow boundary, or gust front) would have been 35 mph (30 knots) according to the T2 Gust parameter, or 44 mph (38 knots) according to the WindEx parameter.

¹⁵ Convective Available Potential Energy (CAPE) – CAPE is a measure of the amount of energy available for convection and is directly related to the maximum potential vertical speed within an updraft.

¹⁶ MVV is not usually considered a realistic estimate for maximum vertical velocity in a storm. Anecdotes suggest considering a value of MVV/2, however it is not well understood when or where such a half-value should be applied.

¹⁷ The DCAPE can be used to estimate the potential strength of rain-cooled downdrafts within thunderstorm convection and is similar to CAPE. Larger DCAPE values are associated with stronger downdrafts.

The 1200 EDT HRRR sounding wind profile indicated a surface wind from 005° at 7 knots with the wind remaining northerly through 14,000 ft msl. The wind speed increased to 10 knots by 7,000 ft. RAOB indicated light low-level wind shear (LLWS) between the surface and ~2,000 ft agl. RAOB indicated light clear-air turbulence (CAT) existed in two layers between 2,500 ft msl and 10,000 ft msl. The mean 0 to 6-kilometer wind and storm motion were from 007° at 9 knots.

5.0 Satellite Data

Data from the Geostationary Operational Environmental Satellite number 16 (GOES-16) data was 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 (band 2) and infrared (bands 13) imagery at wavelengths of 0.64 microns (μm) and 10.3 μm , respectively, were retrieved for the period. Satellite imagery surrounding the time of the accident, from 0900 EDT through 1400 EDT at approximately 5-minute intervals were reviewed, and the closest images to the time of the accident are documented here.

Figures 10, 11, and 12 present the GOES-16 visible imagery from 1130, 1140, and 1150 EDT at 2X magnification with the accident site highlighted with a red square. The GOES-16 imagery indicated overcast cloud cover above the accident site at the accident time. The cloud cover was cumuliform in nature and spreading southeastward. Ahead of the main cumulonimbus cloud line, the white arrows on figures 10 and 11 highlight an outflow boundary moving southeastward across the accident site at the accident time. The cloud cover was moving from northwest to southeast with multiple outflow boundaries present moving southward ahead of the main cumulonimbus cloud area (attachment 1).

Figure 13 presents the GOES-16 infrared imagery from 1140 EDT at 5X magnification and with a temperature enhancement curve applied with the accident site highlighted with a red square. Inspection of the infrared imagery indicated abundant cloud cover over the accident site at the accident time with the lowest brightness temperatures (green and yellow colors, higher clouds) located north of the accident site over Lake Superior. Based on the brightness temperatures above the accident site (268 Kelvin) and the vertical temperature profile provided by the 1200 EDT HRRR sounding, the approximate cloud-top heights over the accident site were 15,000 ft at 1140 EDT. It should be noted these figures have not been corrected for any parallax error.

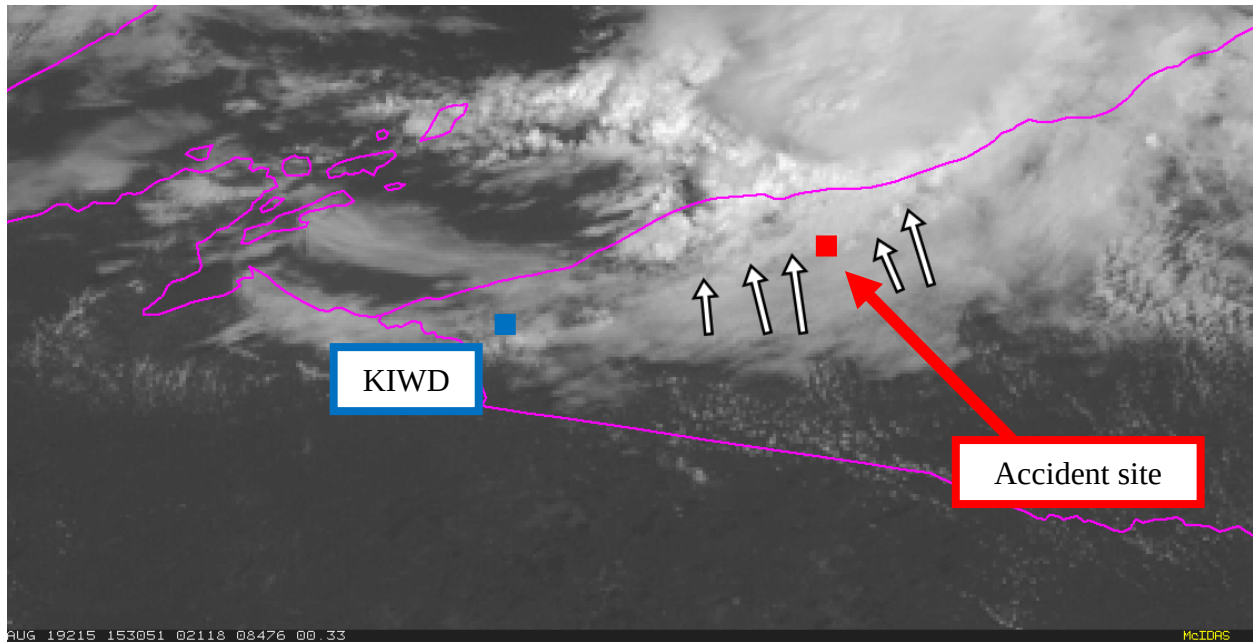


Figure 10 – GOES-16 visible image at 1130 EDT

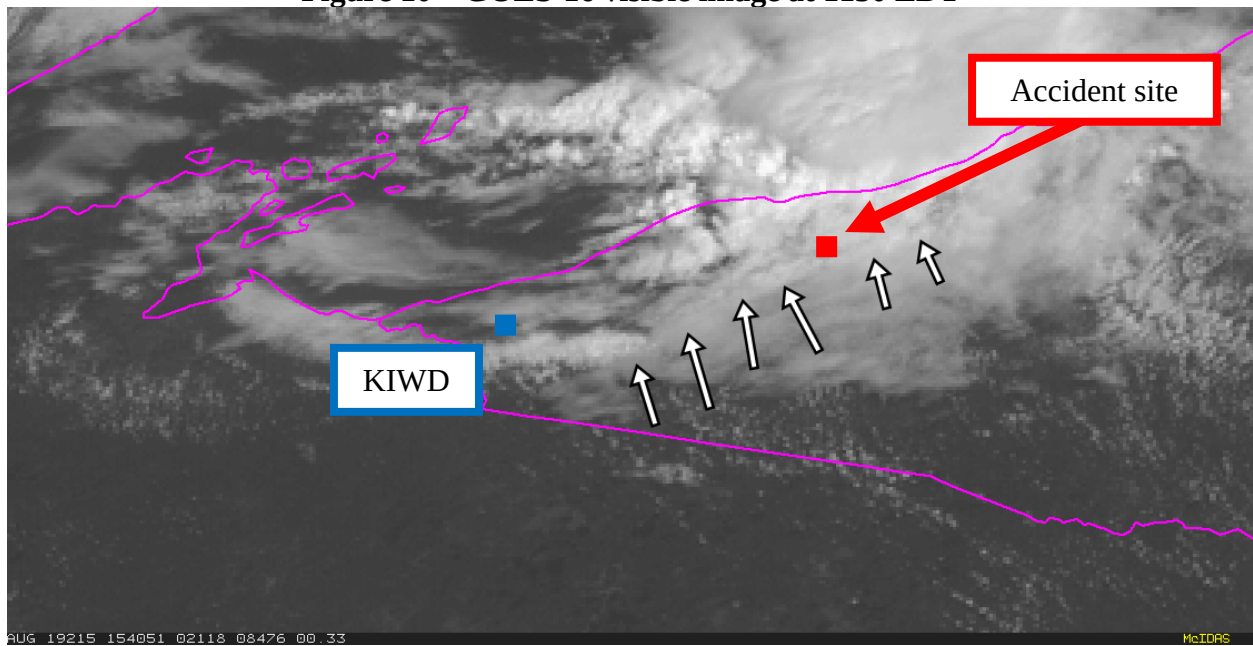


Figure 11 – GOES-16 visible image at 1140 EDT

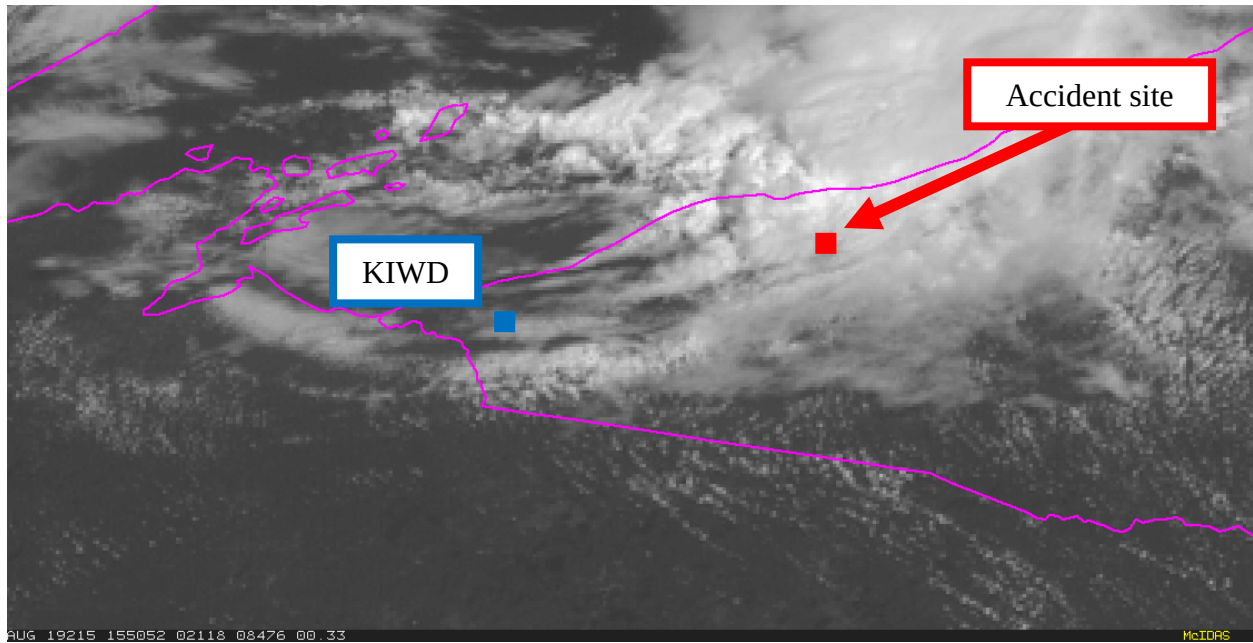


Figure 12 – GOES-16 visible image at 1150 EDT

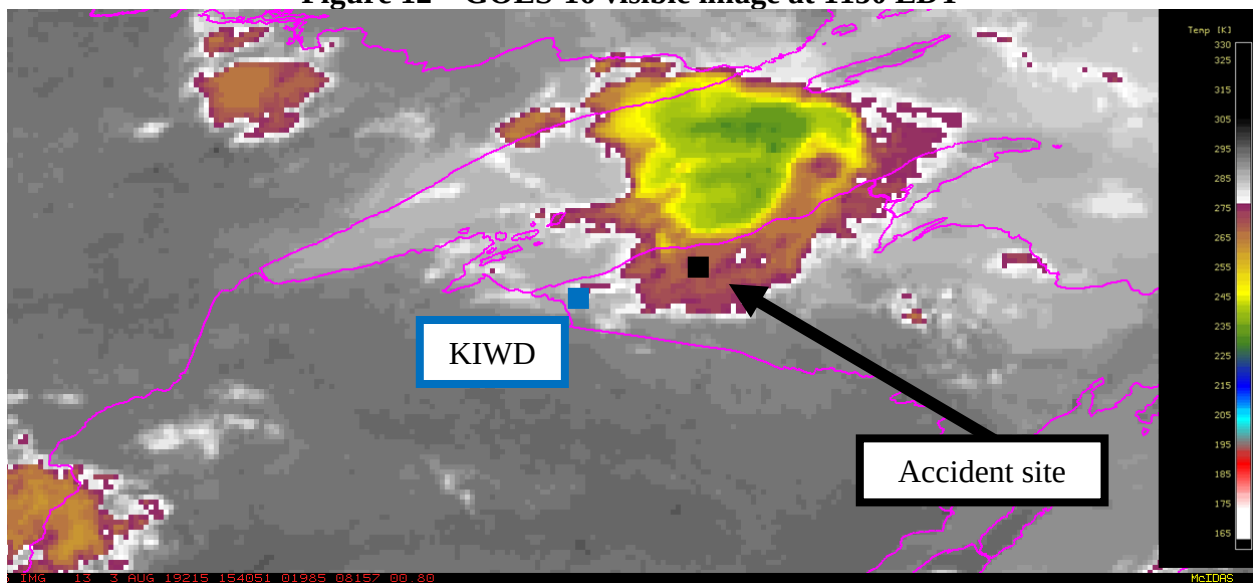


Figure 13 – GOES-16 infrared image at 1140 EDT

6.0 Regional Radar Imagery Information

A regional view of the NWS National Composite Radar Mosaic is included as figure 14 for 1145 EDT. The image depicted echoes from 20 to 35 decibels (dBZ¹⁸) to the northwest and in the vicinity of the accident site.

¹⁸ 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.

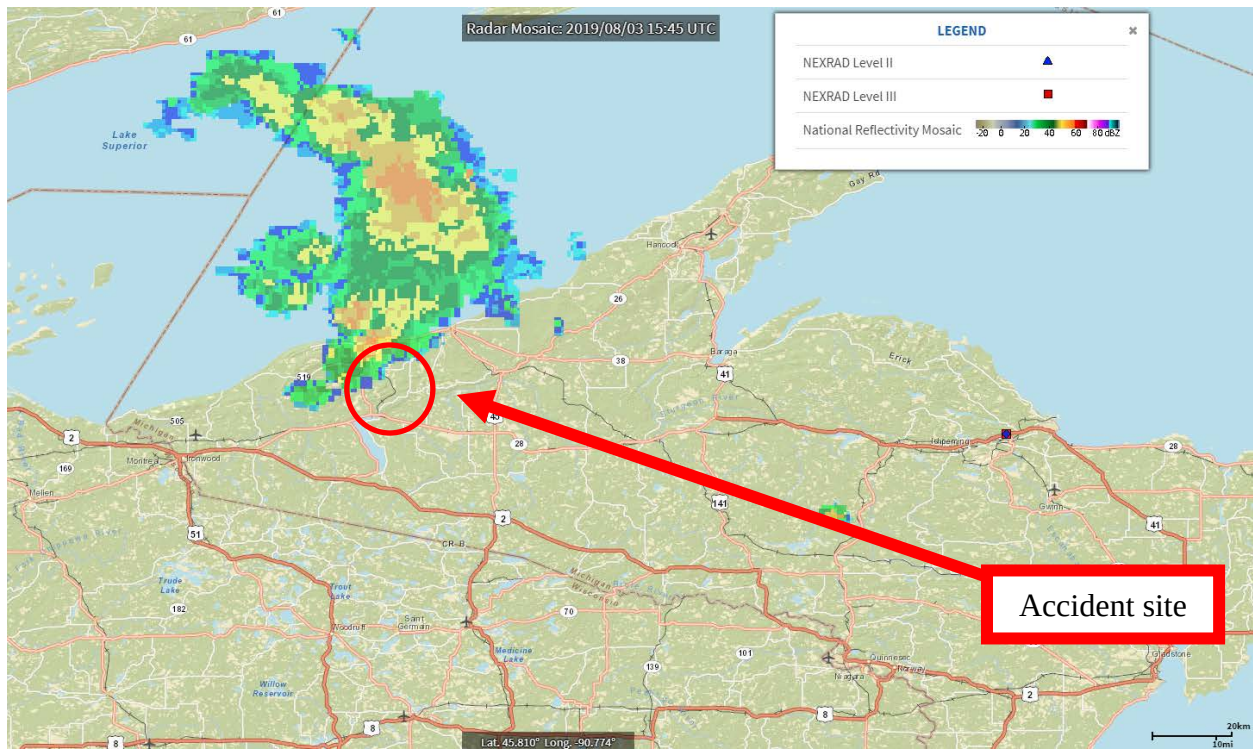


Figure 14 – Regional Composite Reflectivity image for 1145 EDT

7.0 Radar Imagery Information

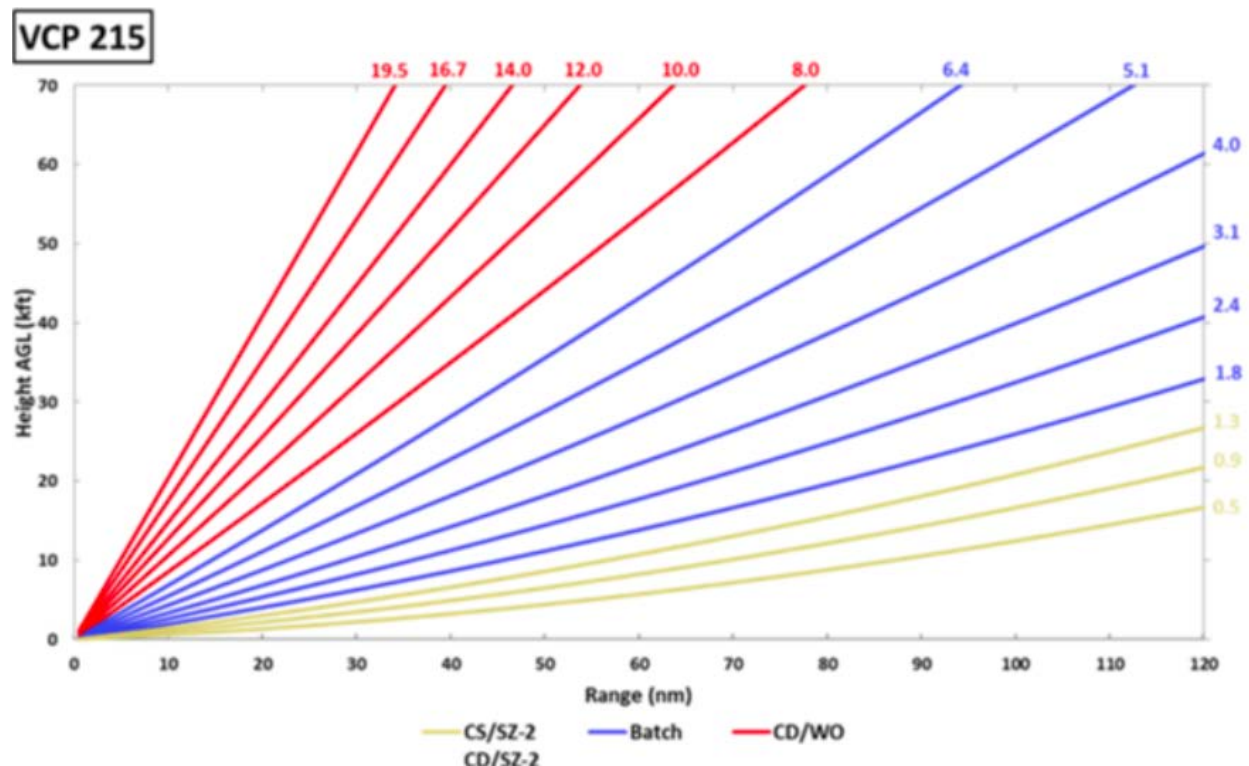
The closest NWS Weather Surveillance Radar-1988, Doppler (WSR-88D)¹⁹ to the accident site was Marquette, Michigan, (KMQT), with antenna elevation of 1,525 ft located 80 miles east of the accident site. Level II archive radar data was obtained from the NCEI utilizing the NEXRAD Data Inventory Search and displayed using the NOAA's Weather and Climate Toolkit software.

7.1 Volume Scan Strategy

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

¹⁹ 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 several different scanning modes, identified as Mode A and Mode B. Mode A is the precipitation scan and has three common scanning strategies. The most common is where the radar makes 15 elevation scans from 0.5° to 19.5° every six minutes. This particular scanning strategy is documented as volume coverage pattern 215 (VCP-215). Mode B is the clear-air mode, where the radar makes 5 elevation scans during a ten-minute period. During the period surrounding the accident, the KMQT 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 Strategy²⁰

²⁰ 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 refraction²¹ of the WSR-88D radar beam with the antenna elevation at 1,525 ft, and considering a beamwidth²² 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
KMQT 0.5°	10,410 ft	6,470 ft	14,350 ft

Based on the radar height calculations, the elevation scan from KMQT listed in the above table depicted the conditions between 6,470 ft and 14,350 ft over the accident site and “saw” the closest altitudes to the ground and the accident aircraft’s flight level before the accident.²³

7.3 Reflectivity

Reflectivity is the measure of the efficiency of a target in intercepting and returning radio energy. With hydrometeors²⁴ 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 00-24C²⁵, “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:

²¹ Standard Refraction in the atmosphere is when the temperature and humidity distributions are approximately average, and values set at the standard atmosphere.

²² Beamwidth - the angular separation between the half power points on the antenna radiation pattern, where the gain is one half the maximum value.

²³ Flight Level – A Flight Level (FL) is a standard nominal altitude of an aircraft, in hundreds of ft. This altitude is calculated from the International standard pressure datum of 1013.25 hPa (29.92 inHg), the standard sea-level pressure, and therefore is not necessarily the same as the aircraft’s true altitude either above mean sea level or above ground level.

²⁴ 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.

²⁵

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

7.4 Base Reflectivity and Lightning Data

Figures 15 through 19 present the KMQT WSR-88D base reflectivity images for the 0.5° elevation scans initiated at 1127:46, 1132:05, 1136:25, 1140:44 and 1145:03 EDT, respectively, with a resolution of 0.5° X 250 m. The accident flight track is included on the figures as a pink line for context with the departure airport (IWD) and intended destination airport (OGM) marked.²⁶ The accident flight flew in between precipitation targets between 1127 and 1132 EDT (figures 15 and 16), but then flew through reflectivity values between 20 and 40 dBZ between 1132 and 1136 EDT (figures 16 and 17). After 1136 EDT the accident flight remained ahead (southeast) of the reflectivity values through the accident time with the reflectivity values from KMQT WSR-88D only able to depict targets as low as ~6,000 ft msl (section 7.2). The reflectivity bands were moving from northwest to southeast (attachment 2).

There were no lightning flashes²⁷ around the accident site at the accident time.²⁸

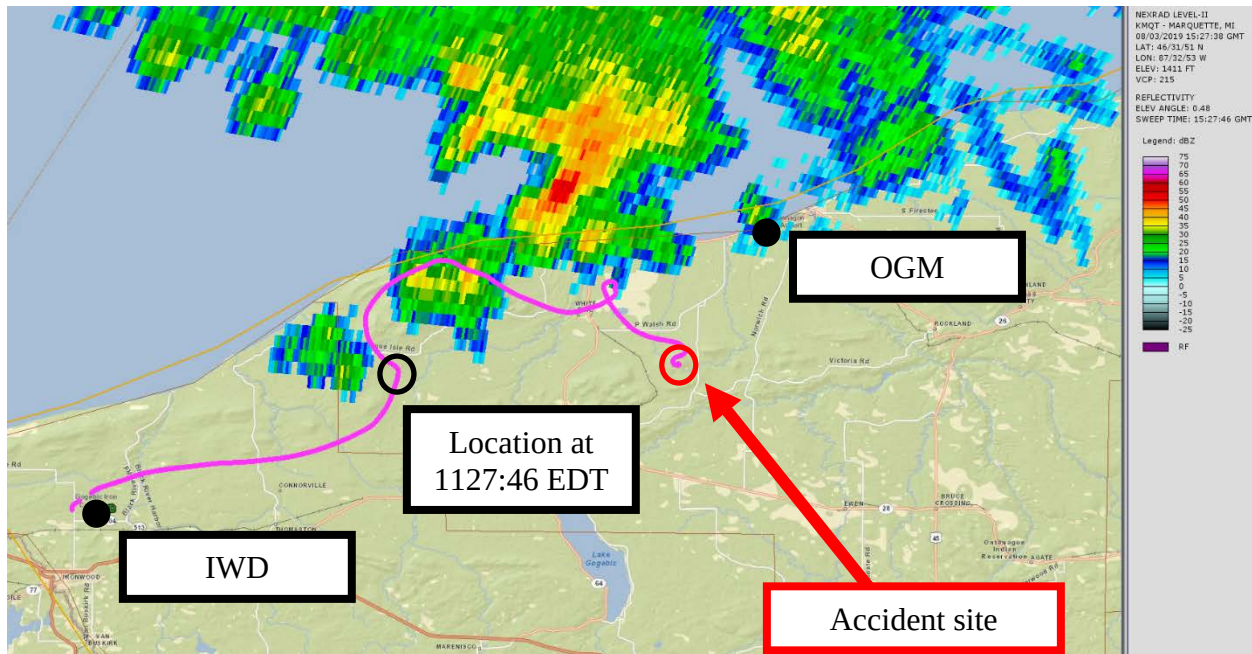


Figure 15 – KMQT WSR-88D reflectivity for the 0.5° elevation scan initiated at 1127:46 EDT with the accident site marked with a red circle and the flight track in pink

²⁶ For more information about the accident flight track please see the data located in the docket for this accident.

²⁷ 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.

²⁸ A review of Earth Networks Total Lightning network was done.

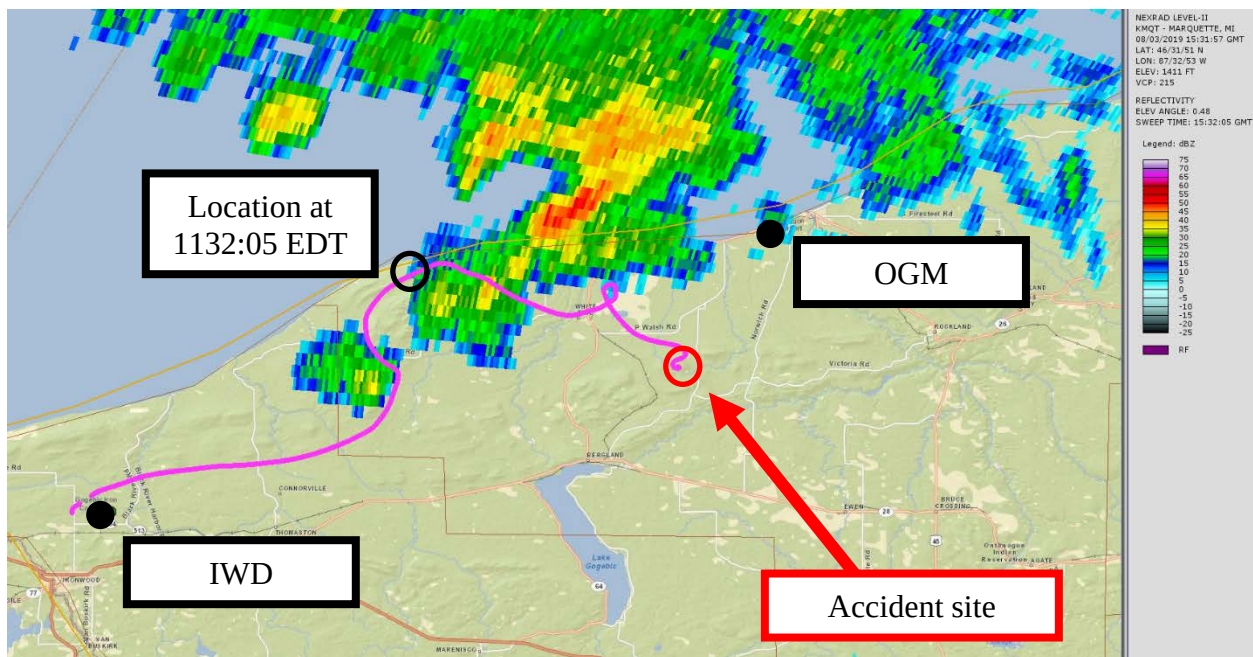


Figure 16 – KMQT WSR-88D reflectivity for the 0.5° elevation scan initiated at 1132:05 EDT with the accident site marked with a red circle and the flight track in pink

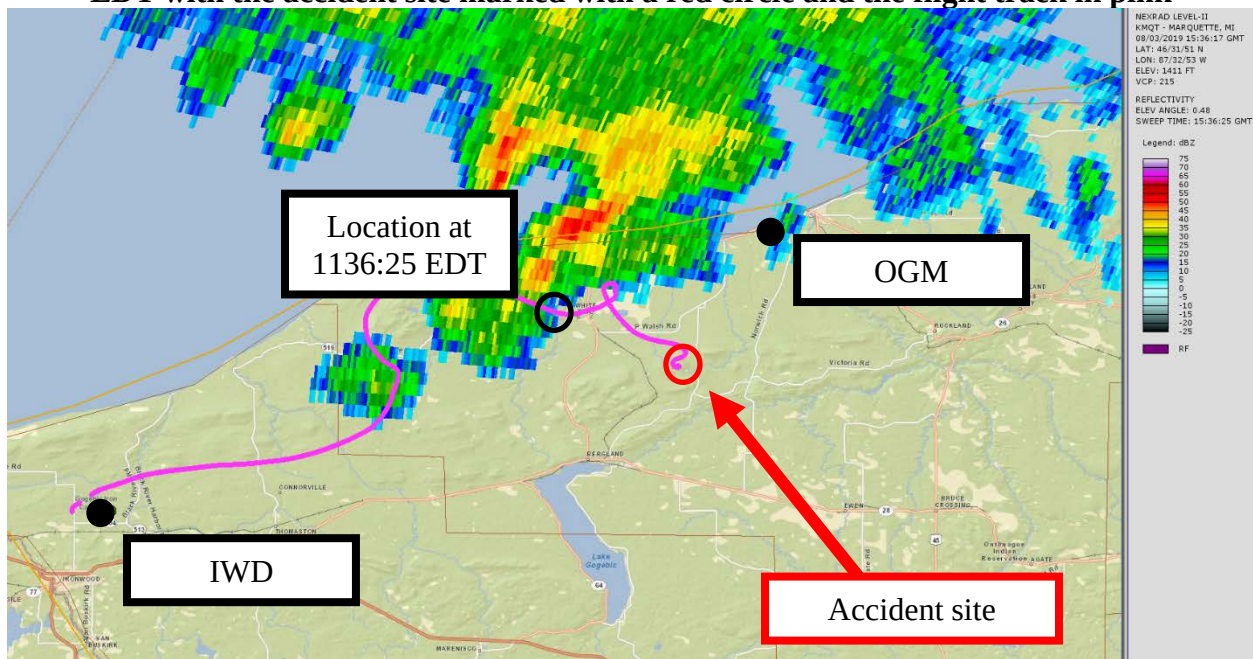


Figure 17 – KMQT WSR-88D reflectivity for the 0.5° elevation scan initiated at 1136:25 EDT with the accident site marked with a red circle and the flight track in pink

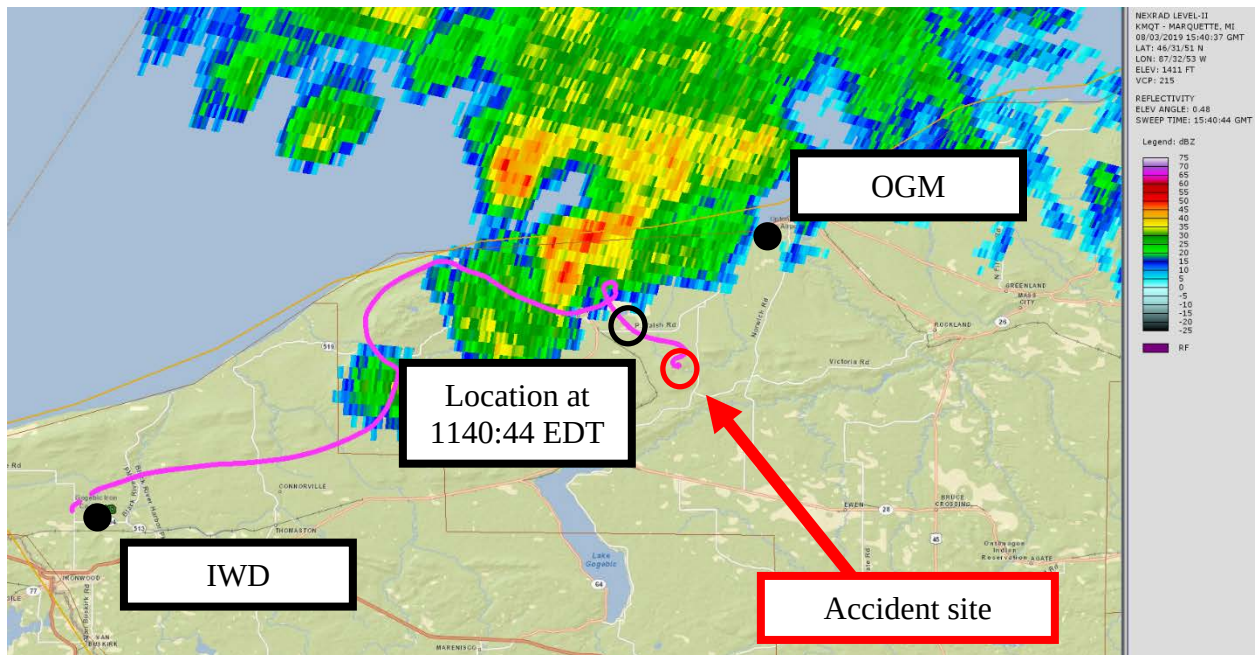


Figure 18 – KMQT WSR-88D reflectivity for the 0.5° elevation scan initiated at 1140:44 EDT with the accident site marked with a red circle and the flight track in pink

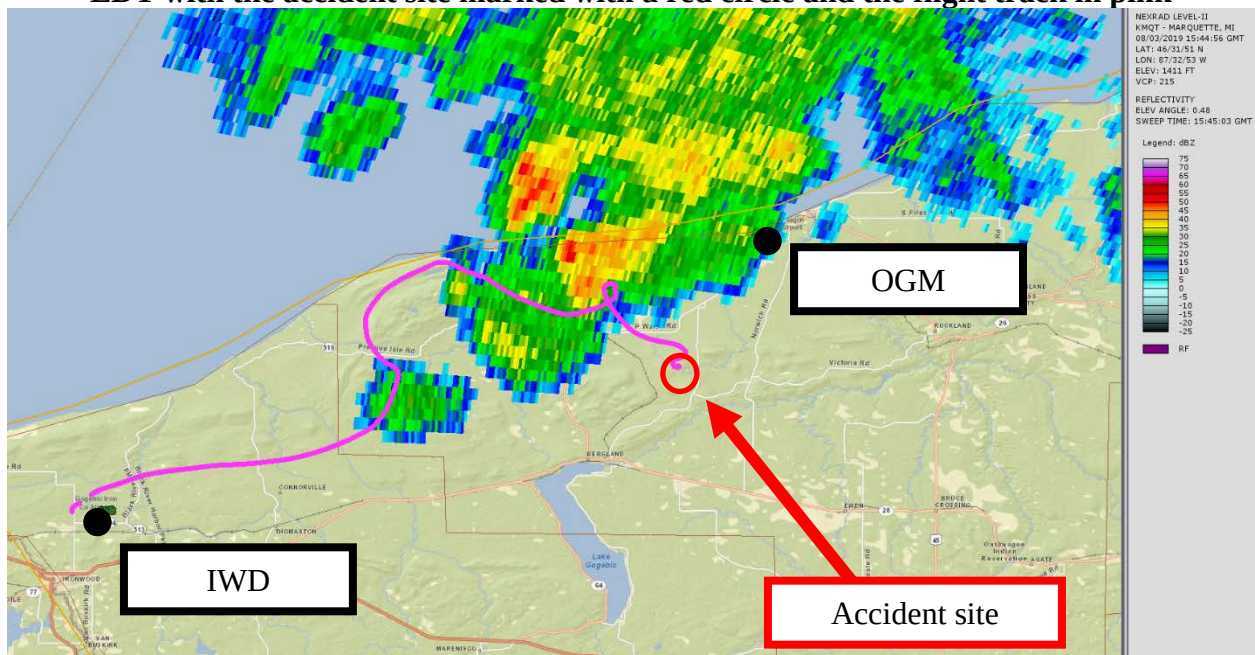


Figure 19 – KMQT WSR-88D reflectivity for the 0.5° elevation scan initiated at 1145:03 EDT with the accident site marked with a red circle and the flight track in pink

8.0 Pilot Reports²⁹

There were no pilot reports (PIREPs) within 80 miles of the accident site from about three hours prior to the accident time to about three hours after the accident time reported into the national airspace.

9.0 SIGMETs

There were convective Significant Meteorological Information (SIGMET) advisories issued by the Aviation Weather Center (AWC) valid for the accident site at the accident time. Figures 20 through 22 include the valid SIGMETs and graphical-Airmen's Meteorological Information (G-AIRMET) valid at 1000, 1100, and 1200 EDT. SIGMET 75C issued at 0955 EDT and valid through 1155 EDT warned of an area of embedded thunderstorms with the SIGMET 75C box movement from 310° at 15 knots with thunderstorm tops to FL410. SIGMET 78C issued at 1055 EDT and valid through 1255 EDT warned of an area of embedded thunderstorms with the SIGMET 78C box movement from 310° at 15 knots with thunderstorm tops to FL380:

WSUS32 KKKCI 031355

SIGC

-MKCC WST 031355

CONVECTIVE SIGMET 75C

VALID UNTIL 1555Z

MI MN LS

FROM 60WSW YQT-40S YQT-70N RHI-70ENE DLH-60WSW YQT

AREA EMBD TS MOV FROM 31015KT. TOPS TO FL410.

WSUS32 KKKCI 031455

SIGC

-MKCC WST 031455

CONVECTIVE SIGMET 78C

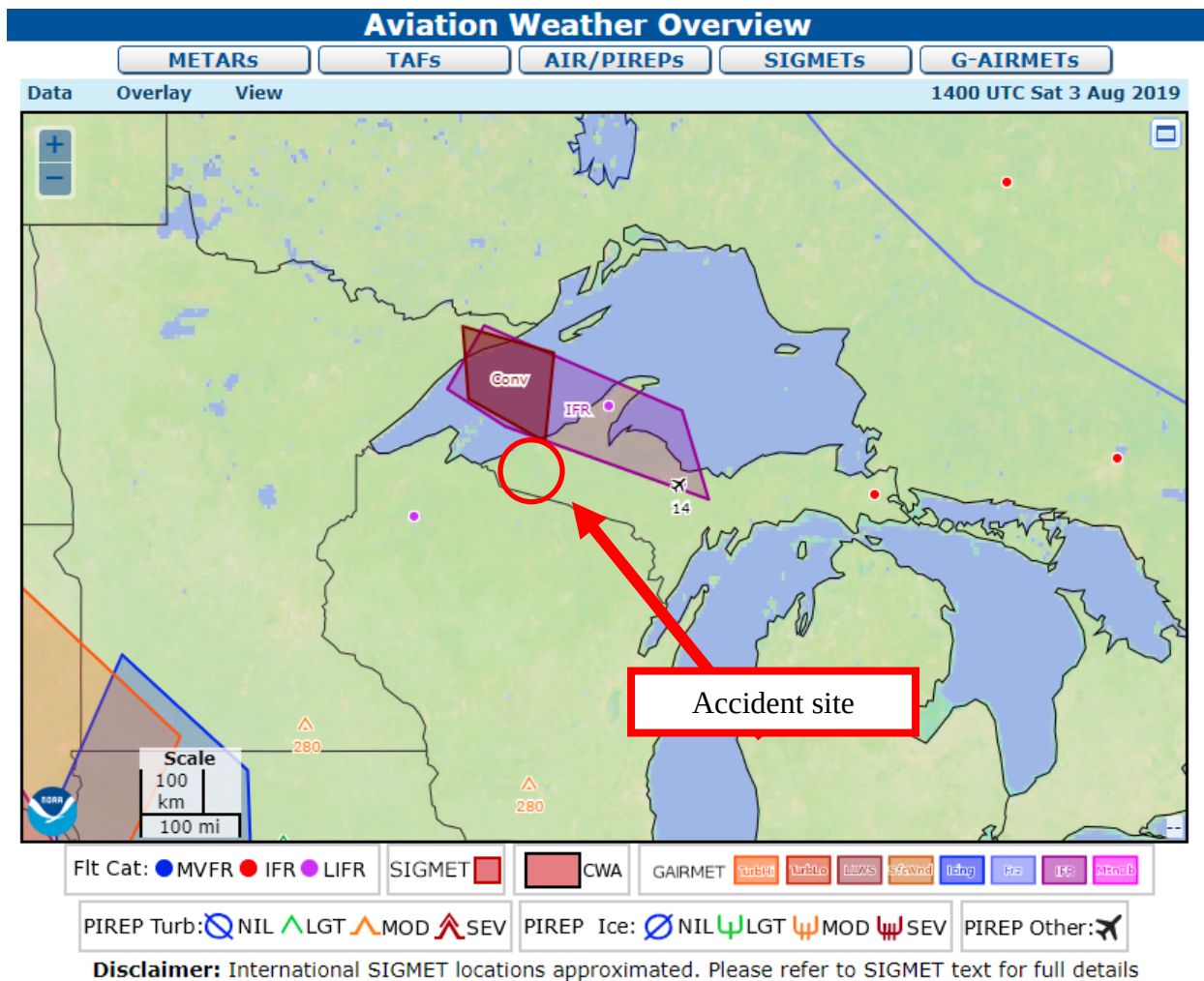
VALID UNTIL 1655Z

MI WI MN LS

FROM 50WSW YQT-40SSE YQT-60N RHI-60ENE DLH-50WSW YQT

AREA EMBD TS MOV FROM 31015KT. TOPS TO FL380.

²⁹ Only pilot reports with the World Meteorological Organization (WMO) header UBMI** and UBWI** identifier were considered.



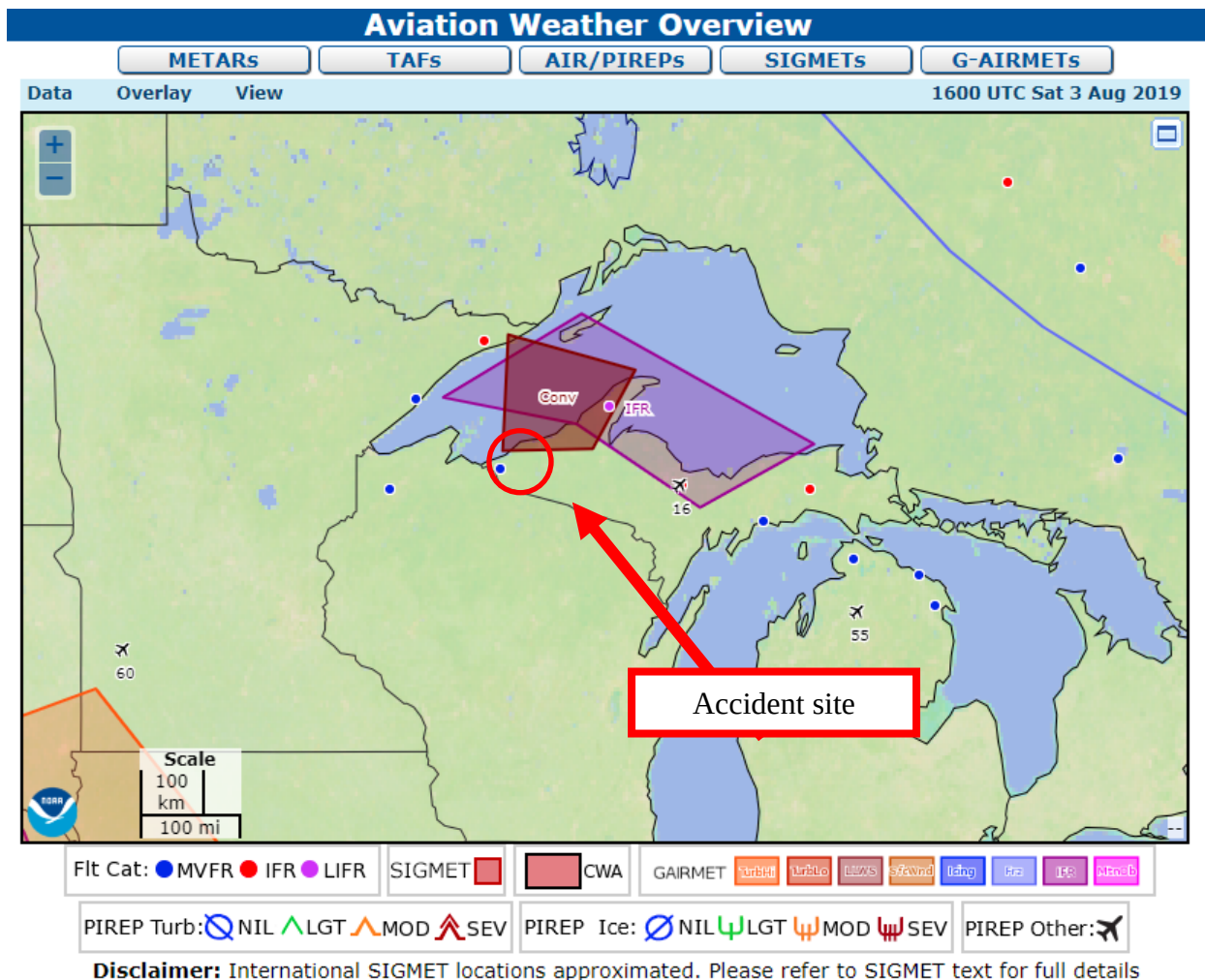


Figure 22 – AWC SIGMETs and G-AIRMETs valid at 1200 EDT

10.0 CWSU Advisories

There were no Center Weather Service Unit (CWSU) Center Weather Advisories (CWA) or Meteorological Impact Statement (MIS) valid for the accident site at the accident time.

11.0 AIRMETs

There was AIRMET Sierra valid for the accident site at the accident time for below 10,000 ft. AIRMET Sierra warned of IFR conditions due to mist:

WAUS43 KKC 031445
 WA3S
 CHIS WA 031445
 AIRMET SIERRA UPDT 5 FOR IFR AND MTN OBSCN VALID UNTIL 032100

AIRMET IFR...MN WI LS MI
 FROM 30ESE YQT TO 40NW SSM TO 30SE SAW TO 60E DLH TO 50NNE DLH
 TO 60SW YQT TO 30ESE YQT

CIG BLW 010/VIS BLW 3SM BR. CONDS ENDG BY 21Z.

.
AIRMET IFR...KY TN

FROM 40SSE IIU TO 40NNE HNV TO HNV TO 30SSW VXV TO 40SSE IIU
CIG BLW 010/VIS BLW 3SM BR/FG. CONDS ENDG 15-18Z.

.
AIRMET IFR...KS MO OK TX AR

FROM 20WSW SLN TO 60ESE SLN TO 30NNE RZC TO 50W LIT TO 30NNW GGG
TO 20NE ADM TO 20WNW OKC TO 30W MMB TO 40WNW LBL TO 60NNE MMB TO
40W ICT TO 20WSW SLN
CIG BLW 010/VIS BLW 3SM PCPN/BR/FG. CONDS CONTG BYD 21Z THRU 03Z.

.
AIRMET IFR...ND SD NE KS MN

FROM 60SSE YWG TO 70WSW GFK TO 60SSW ABR TO 30SSW FSD TO 40NW
PWE TO 30NE SLN TO 50ESE MCK TO 50WSW LBF TO 40S ANW TO 80SE RAP
TO 30NNW DPR TO 20WSW BIS TO 70ESE MOT TO 80ENE MOT TO 60SSE YWG
CIG BLW 010/VIS BLW 3SM PCPN/BR. CONDS ENDG 18-21Z.

.
AIRMET MTN OBSCN...KY TN

FROM 20N LOZ TO HNV TO 40SSW VXV TO 50WSW LOZ TO 20N LOZ
MTNS OBSC BY CLDS/BR. CONDS ENDG BY 18Z.

.
OTLK VALID 2100-0300Z...MTN OBSCN KY TN

BOUNDED BY 30SSE HNN-HMV-GQO-60W VXV-30SSE HNN
MTNS OBSC BY CLDS/PCPN/BR. CONDS DVLPG 21-00Z. CONDS CONTG THRU
03Z.

....

12.0 Graphical Forecasts for Aviation

The Graphical Forecasts for Aviation (GFA) products made available before the accident flight are shown in attachment 3. The GFA surface forecast products indicated VFR conditions would prevail with isolated thunderstorms (between 10 to 20 percent chance) forecast for 1100 EDT in the 0901 EDT GFA surface forecast. The GFA cloud forecast products indicated clear skies were forecast at 1100 EDT above the accident site with an overcast cloud ceiling at 600 ft msl with cloud tops at 3,500 ft msl forecast north of OGM and over Lake Superior. For more information please see attachment 3.

13.0 Terminal Aerodrome Forecast

KIWD was the closest site with an NWS Terminal Aerodrome Forecast (TAF) and the KIWD TAF valid at the accident time was issued at 0720 EDT and was valid for a 24-hour period beginning at 0800 EDT. The 0720 EDT TAF for KIWD was as follows:

TAF KIWD 031120Z 0312/0412 00000KT P6SM SCT003
FM031400 00000KT P6SM VCSH SCT150
FM031800 36005KT P6SM VCSH SCT150
FM032100 36006KT P6SM SCT180=

Between 1000 and 1400 EDT, the TAF expected a calm wind, greater than 6 miles visibility, vicinity³⁰ showers, and scattered clouds at 15,000 ft agl.

14.0 NWS Area Forecast Discussion

The NWS Office in Marquette, Michigan, issued the following Area Forecast Discussion (AFD) at 0731 EDT (closest AFD to the accident time with an aviation section). The aviation section of the AFD discussed LIFR conditions during the morning becoming VFR by noon:

FXUS63 KMQT 031131
AFDMQT

Area Forecast Discussion
National Weather Service Marquette MI
731 AM EDT Sat Aug 3 2019

.SHORT TERM...(Today and tonight)
Issued at 425 AM EDT SAT AUG 3 2019

Water vapor imagery and RAP analysis reveals a subtle shortwave over the MN/Ontario border moving se. This shortwave is helping to sustain a small cluster of t-storms north of the MN arrowhead into Ontario early this morning. Based on warming cloud tops on IR satellite imagery and decreasing lightning activity, it would appear this cluster of storms is weakening in the past hour, so not so sure if these storms will hold together long enough to get into northern Lake Superior or Isle Royale in the next couple hours. Lingering moist dewpoints in the upper 50s to lower 60s and near calm winds have also resulted in patchy fog this morning across portions of the U.P. although expect this patchy fog to burn off pretty quickly after sunrise.

Light northeast winds ahead of advancing sfc high pressure from Ontario will keep conditions cooler and more stable over the northern tier counties today, especially near Lake Superior, where highs are expected in the lower to mid 70s for the most part, though farther inland most spots should climb to the upper 70s with even low 80s possible across the southern tier. There could be some isolated showers/t-storms along the Wisconsin border by this afternoon where HRRR, RAP and NAM soundings indicate MLCAPes rising into the 500-1000 j/kg range. Models also indicate that the presence of an inverted sfc trough could provide a focus for convection, so have kept slight chc pops in for along the WI border this afternoon.

Any lingering convection should die out early evening along WI border with loss of daytime instability. With clear skies and sfc high pressure becoming centered over the central counties later tonight, min temps could lower into the mid to upper 40s over the typical cold spots of the interior east half while readings in the lower 50s will be more common over the interior west half. Look for min temps in the upper 50s to around 60s near the Great Lakes shorelines. Patchy fog is possible again later tonight beneath sfc

³⁰ In the vicinity of the airport is defined as a weather phenomenon within 5-10 statute miles of the airfield.

high pressure as temps radiate through daytime dew points.

.LONG TERM...(Sunday through Friday)
Issued at 349 AM EDT SAT AUG 3 2019

The large-scale pattern starting Sunday will continue to be characterized by strong ridging over the Southwestern U.S. and NW flow on its eastern periphery over the Great Lakes. As warmer air advects in aloft on Sunday, we should get well into the 80s for highs with perhaps an isolated 90 degree reading, most likely over the interior west.

A fairly significant upper low is progged to move through the northern Canadian Prairies Sunday and then dip into northern Ontario Monday. At the surface, a cold front will approach western Lake Superior Sunday night and then gradually push across Upper Michigan on Monday. There are some differences in timing among the models right now but there is a decent consensus for at least mid 60s dew points ahead of the front leading to upwards of 2000 J/kg CAPE and 30 to 40 knots of 0-6 km shear. The slower NAM is even more potent with the CAPE/shear combo but not worth putting too much stock into that solution yet. Regardless, looks like a few strong to severe storms will be possible across the U.P. Monday. Capped POPs at high-end chance rather than likely to account for lingering uncertainty in FROPA timing but regardless of exact timing, showers and storms seem like a good bet for most and the next forecast cycle will probably warrant likely POPs.

Tuesday looks quite pleasant behind the front with highs only in the mid 70s and less humidity, though with cyclonic curvature remaining overhead and cooler air aloft an isolated weak shower or two is not out of the question, mainly west. Cool NW flow looks to persist Wednesday and Thursday as the aforementioned closed upper low settles in over Hudson Bay, though a weaker front may clip the region Wednesday and spark off more showers. The GFS and EC both then advertise a potent short wave rotating around the low and dropping through the Upper Great Lakes somewhere around Thursday night or Friday. This would be our next good chance of rain. At the moment it looks like we do not destabilize enough ahead of the wave for thunderstorms, but the progged 850 mb temps of 5 C behind the wave (even as low as 2 C in the GFS) mean next weekend looks seasonably cool and breezy at this point.
&&

.AVIATION...(For the 12Z TAFS through 12Z Sunday morning)
Issued at 728 AM EDT SAT AUG 3 2019

Abundant low level moisture lingering over the region will support fog/low stratus into the late morning hours with LIFR to VLIFR possible at KCMX and KSAW. By midday, heating will bring quick improvement with VFR conditions expected at all sites by 16Z.
&&

.MARINE...(For the 4 AM Lake Superior forecast issuance)
Issued at 425 AM EDT SAT AUG 3 2019

Weak pressure gradient across Lake Superior will keep prevailing winds less than 20 knots through the forecast period. Moist dew points in place should allow patchy fog to linger over the lake through this morning.
&&

.MQT WATCHES/WARNINGS/ADVISORIES...

Upper Michigan...

None.

Lake Superior...

None.

Lake Michigan...

None.

&&

\$\$

15.0 Winds and Temperature Aloft Forecast

The NWS 1000 EDT Winds and Temperature Aloft forecast valid for 1400 EDT for the closest point to the accident site is included below:

FBUS31 KWN0 031400

FD1US1

DATA BASED ON 031200Z

VALID 031800Z FOR USE 1400-2100Z. TEMPS NEG ABV 24000

FT 3000 6000 9000 12000 18000 24000 30000 34000 39000

MQT 0609 0109+12 3414+06 3413+03 3109-11 3010-22 301639 312947 314552

The accident site was closest to the Marquette, Michigan, (MQT) forecast point. The MQT forecast for use between 1000 EDT and 1700 EDT indicated a wind at 3,000 ft from 060° at 9 knots and at 6,000 ft a wind from 010° at 9 knots with a temperature of 12°C.

16.0 Consolidated Storm Prediction for Aviation Data

The Consolidated Storm Prediction for Aviation (CoSPA)³¹ images were retrieved for 1120, 1125, 1130, 1135, 1140, and 1145 EDT and provided in figures 23 through 28 with the accident site marked. The CoSPA, along with depicting NWS weather radar VIP levels, lightning data, weather satellite, and storm motion, forecast areas of likely rain shower or thunderstorm growth (orange hatched areas) and areas of likely rain shower or thunderstorm dissipation (blue hatched areas) and areas where outflow boundaries or wind shear would likely be present (light blue solid and dashed lines). Through 1145 EDT the accident site remained free of precipitation VIP level 1 and higher, however the CoSPA depicted outflow boundary and wind shear (blue solid and dashed lines) line moved southeastward into the accident site area by 1145 EDT.

³¹ For more information please see <https://ral.ucar.edu/solutions/products/consolidated-storm-prediction-aviation-cospa> and <https://cospa.wx.ll.mit.edu/login.jsf>

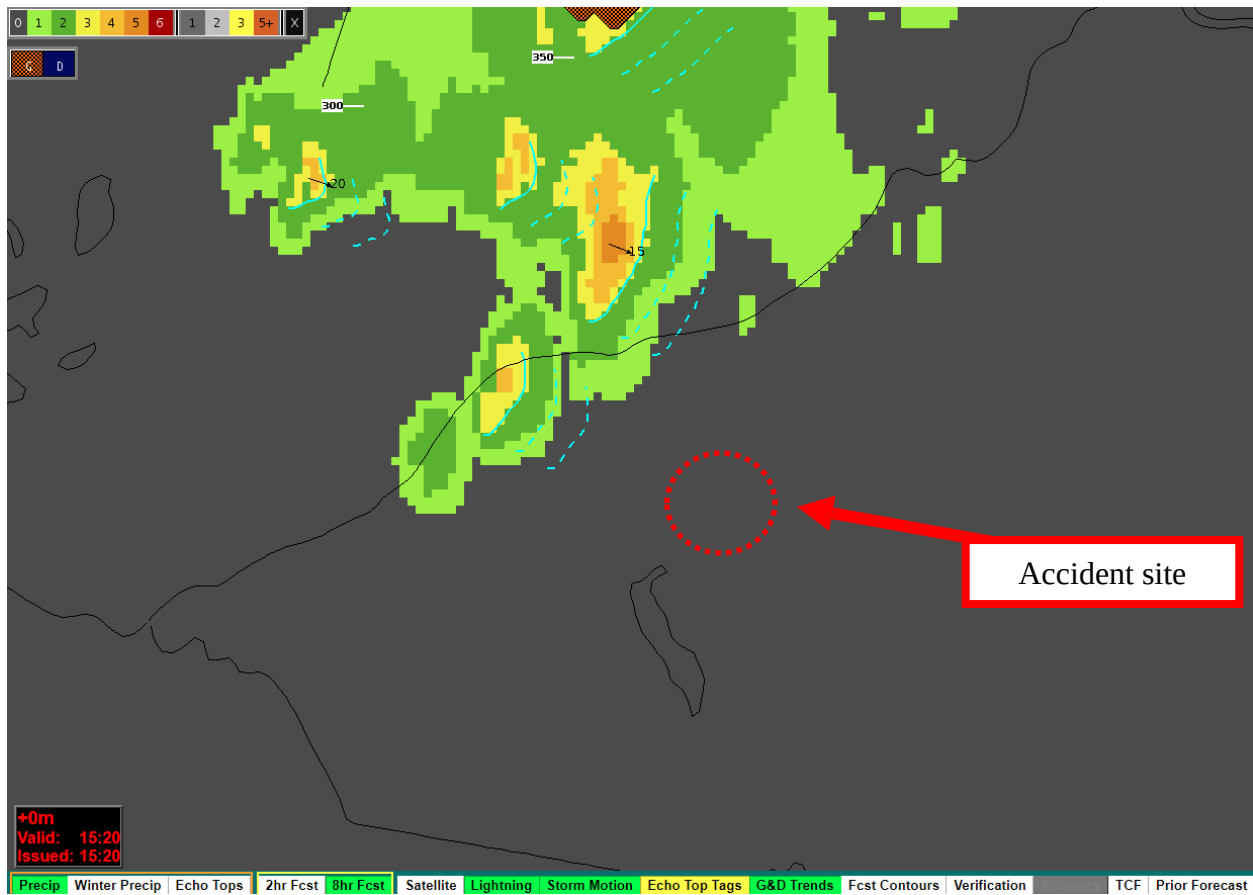


Figure 23 – CoSPA image from 1120 EDT with the accident site marked

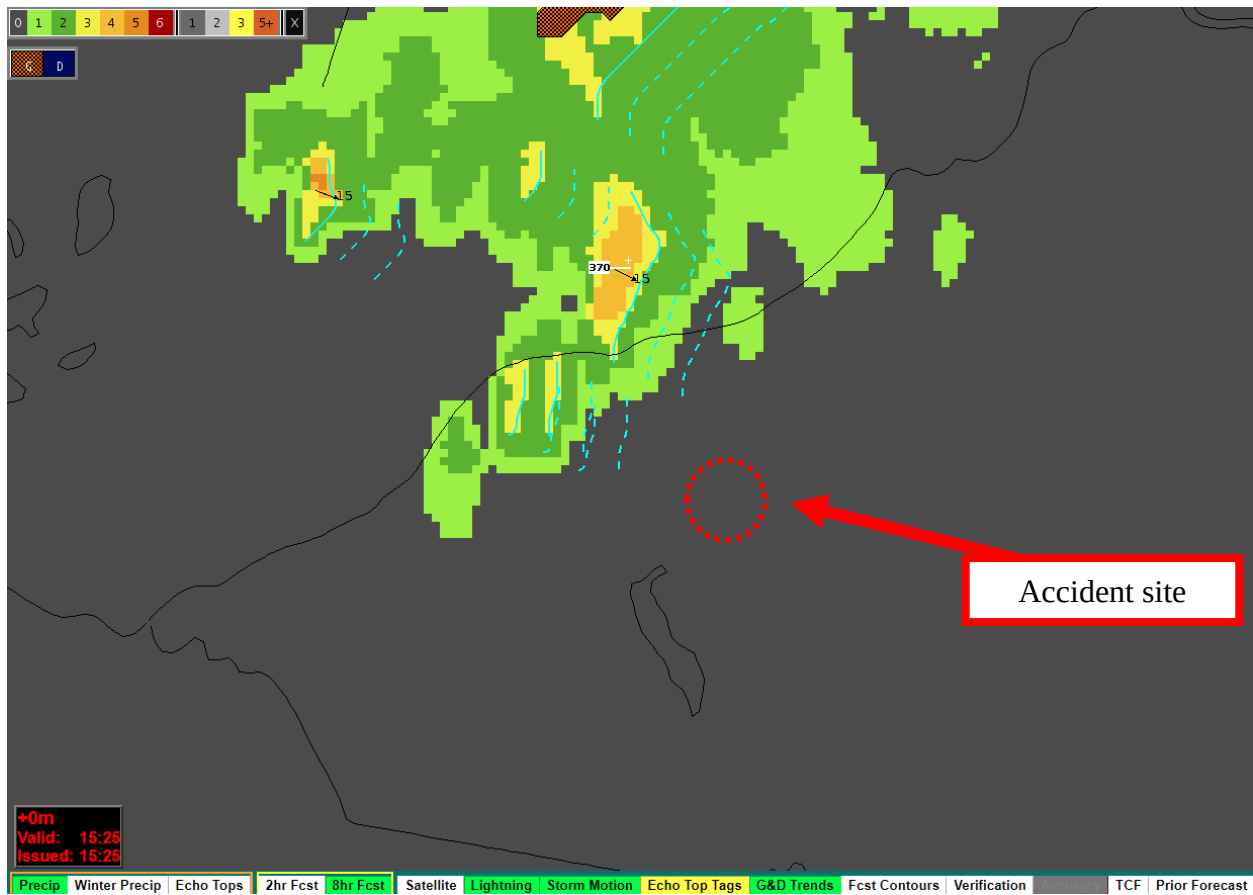


Figure 24 – CoSPA image from 1125 EDT with the accident site marked

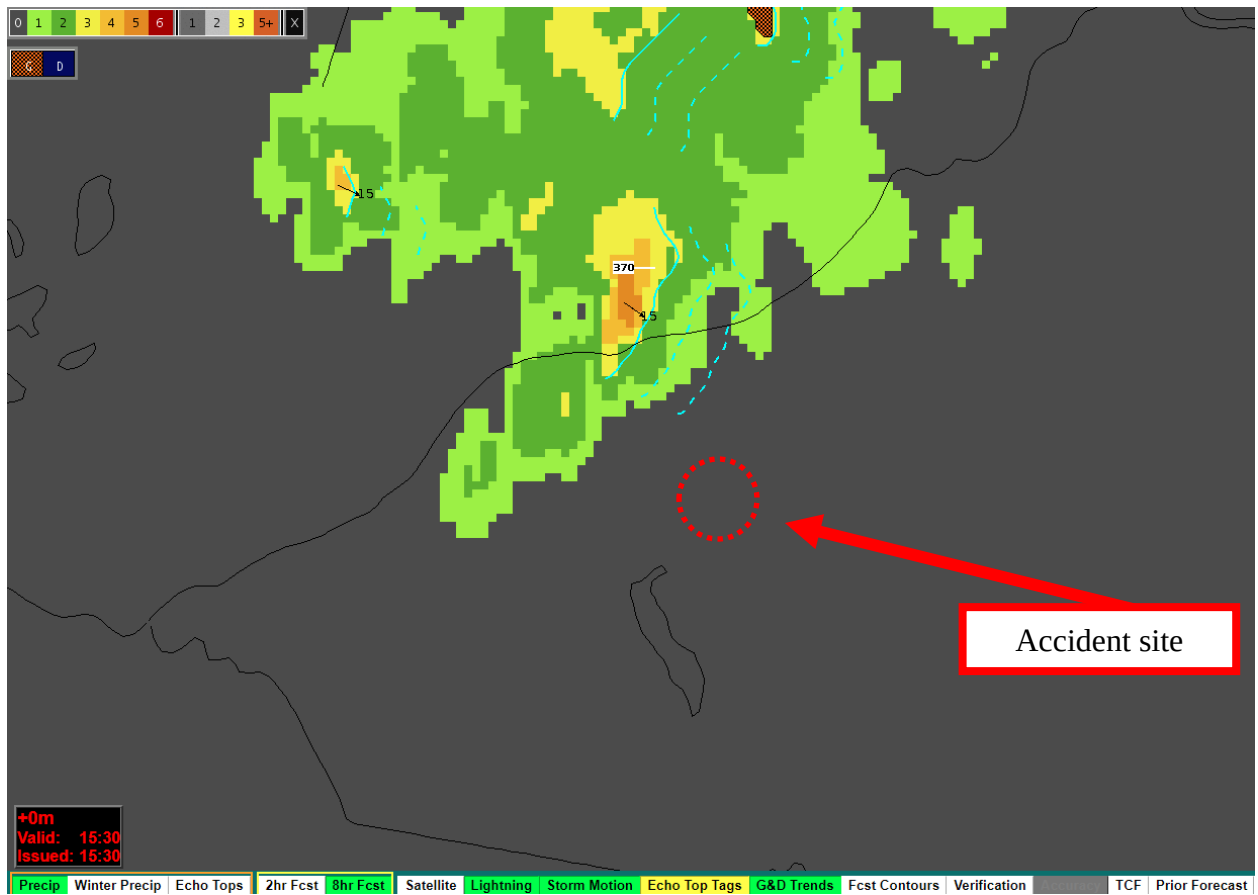


Figure 25 – CoSPA image from 1130 EDT with the accident site marked

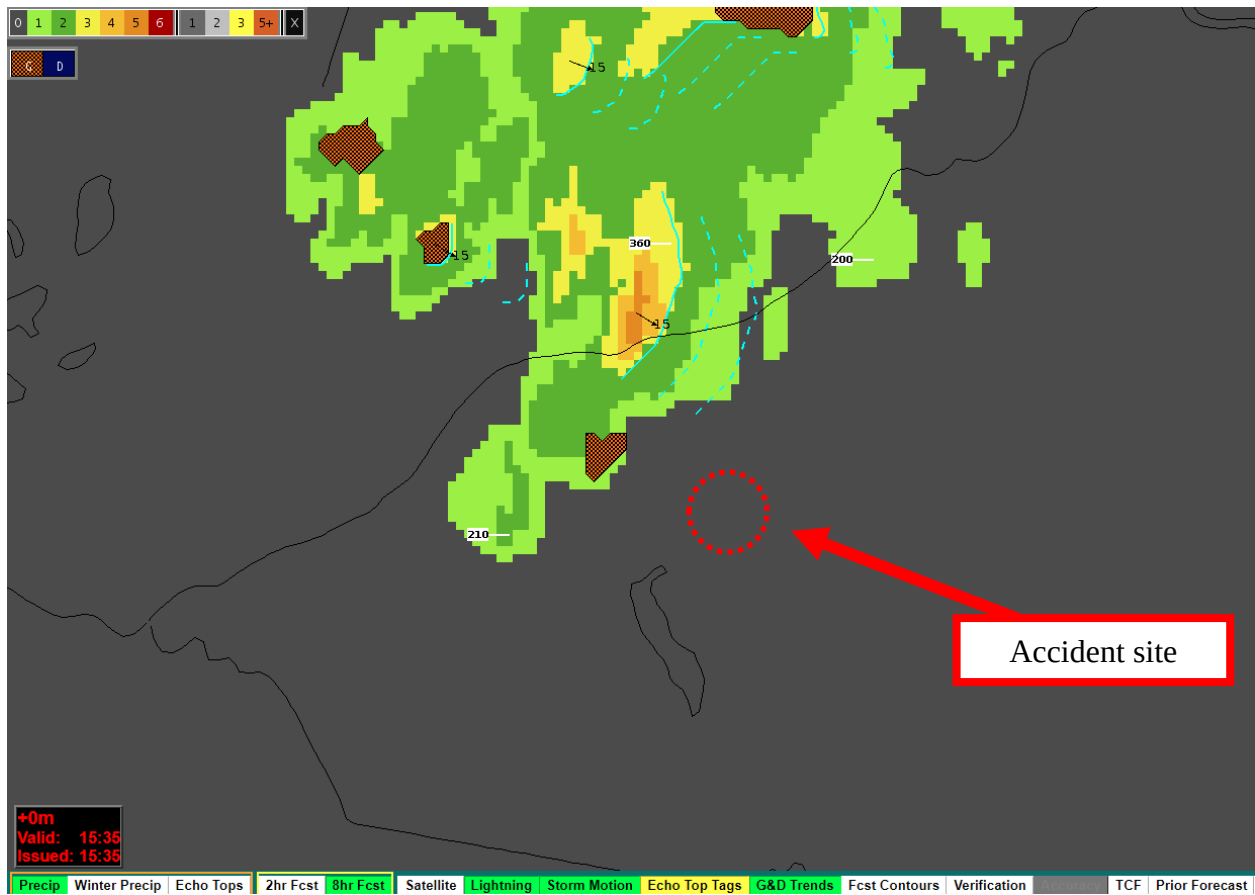


Figure 26 – CoSPA image from 1135 EDT with the accident site marked

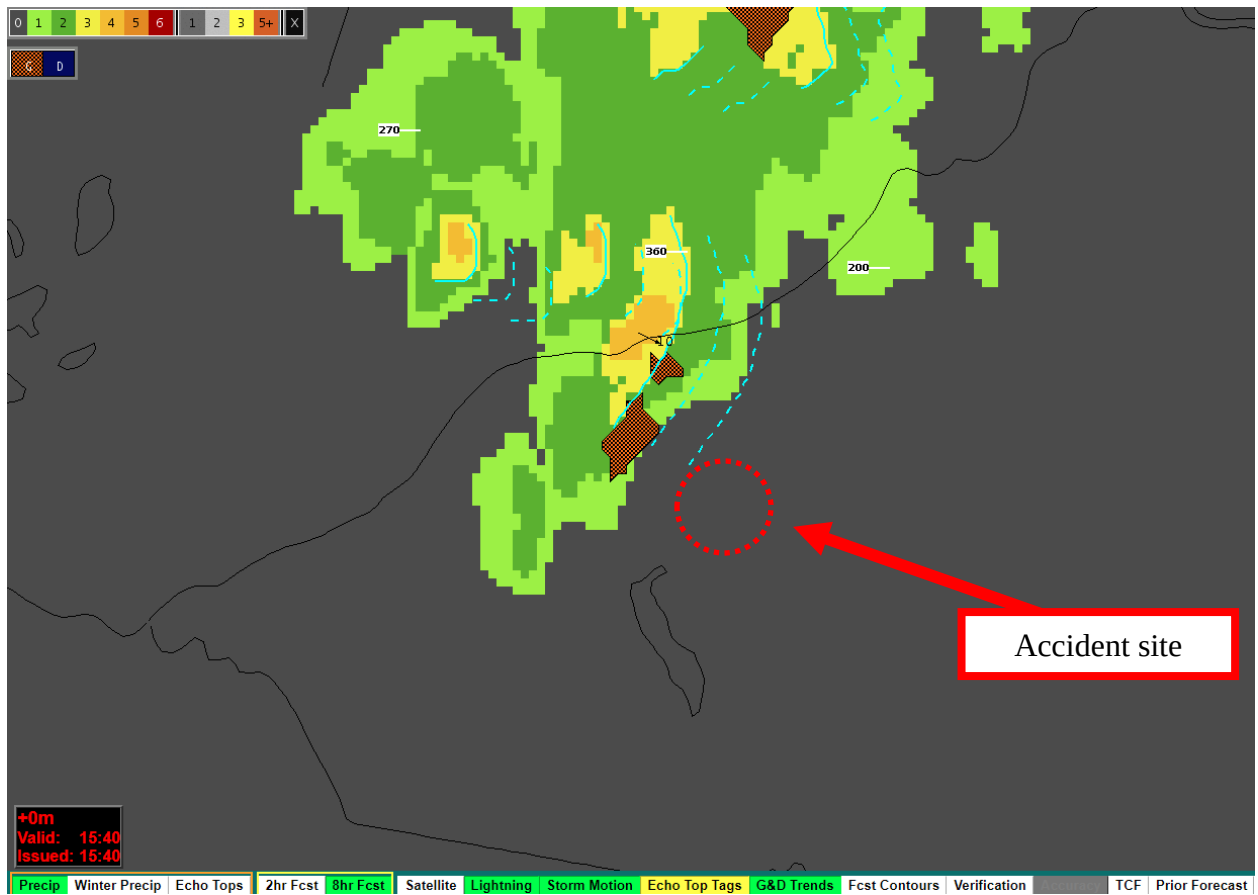


Figure 27 – CoSPA image from 1140 EDT with the accident site marked

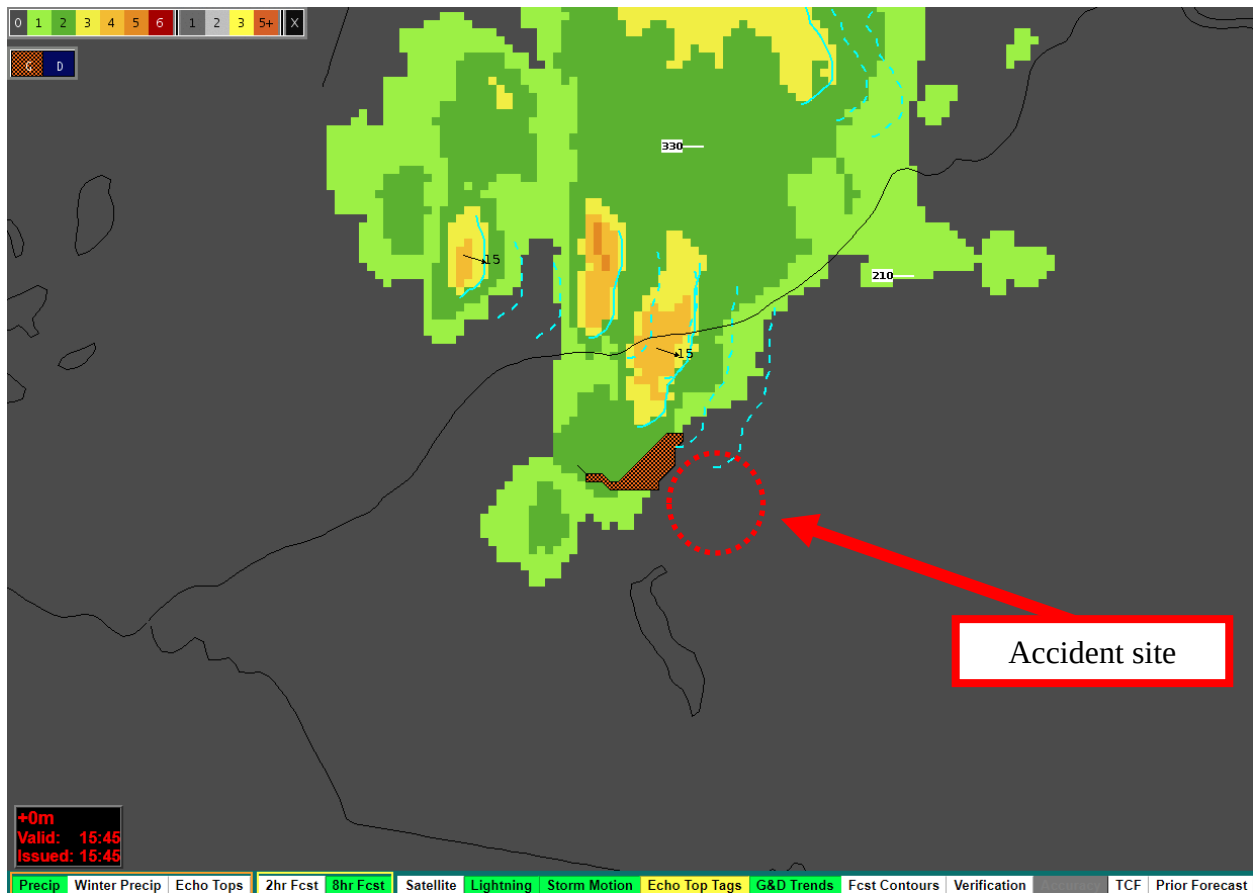


Figure 28 – CoSPA image from 1145 EDT with the accident site marked

17.0 Pilot Weather Briefing

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

A check of ForeFlight was done and revealed that the accident pilot did not request a weather briefing through ForeFlight. The accident pilot did access airport information via ForeFlight as late as 1121 EDT (attachment 4) when the accident pilot checked the airport information for John F. Kennedy Memorial Airport, Ashland, Wisconsin (KASX). With no internet access while in flight, ForeFlight is still able to access weather information directly from the FAA, but it leaves no record of such remote access. It is unknown if the accident pilot checked or received any additional weather information before or during the accident flight.

18.0 Astronomical Data

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

SUN	
Begin civil twilight	0605 EDT
Sunrise	0640 EDT
Accident	1143 EDT³²
Sun transit	1404 EDT
Sunset	2127 EDT
End civil twilight	2202 EDT

E. LIST OF ATTACHMENTS

Attachment 1 – GOES-16 visible animation from 1001 to 1201 EDT

Attachment 2 – KMQT WSR-88D base reflectivity images for the 0.5° elevation scans animation from 1101 to 1153 EDT

Attachment 3 – GFA products available before the accident flight for around the accident time

Attachment 4 – Accident flight information via ForeFlight

Submitted by:

Paul Suffern
Senior Meteorologist

³² Inserted accident time for reference and context.

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