



NATIONAL TRANSPORTATION SAFETY BOARD

Office of Aviation Safety
Washington, D.C. 20594

November 25, 2020

Specialist's Factual Report

METEOROLOGY

CEN20LA374

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A. ACCIDENT

Location: Walker, Minnesota
Date: September 1, 2020
Time: About 2007 central daylight time
0107 Coordinated Universal Time (UTC) on September 2, 2020
Airplane: Piper PA-28-235; Registration: N8957W

B. SENIOR METEOROLOGIST

Donald Eick
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National Transportation Safety Board

C. SUMMARY

On September 1, 2020, about 2007 central daylight time (CDT), a Piper PA-28-235 airplane, N8957W, was destroyed when it was involved in an accident in Walker, Minnesota. The pilot was fatally injured. The airplane was operated as a Title 14 *Code of Federal Regulations* (CFR) Part 91 personal flight. The flight originated at Hardy-Anders Field Natchez-Adams County Airport (HEZ), Natchez, Mississippi, about 0912 CDT, and landed at Kirksville Regional Airport (IRK), Kirksville, Missouri about 1303 CDT, where the pilot purchased fuel. The airplane departed IRK about 1436 with an intended destination of Bemidji Regional Airport (BJI), Bemidji, Minnesota.

D. DETAILS OF THE INVESTIGATION

The National Transportation Safety Board's (NTSB) Senior Meteorologist was not on scene for this investigation and conducted the meteorology phase of the investigation from the Washington D.C. office, collecting data from official National Weather Service (NWS) sources including the Weather Prediction Center (WPC) and the National Center for Environmental Information (NCEI). All times are CDT based upon the 24 hour clock, local time is +5 hours to UTC, and UTC=Z. Directions are referenced to true north and distances in nautical miles. Heights are in feet (ft) above mean sea level (msl) unless otherwise noted. Visibility is in statute miles and fractions of statute miles.

The accident site was located at latitude 47.207845° N and longitude 94.381777° W, at an elevation of approximately 1,295 ft.

E. FACTUAL INFORMATION

1.0 Synoptic Conditions

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

1.1 Surface Analysis Chart

The northcentral section of the NWS Surface Analysis Chart for 1900 CDT (0000Z on September 2, 2020) is included as figure 1 with the approximate accident site marked by a red star. The chart depicted a low-pressure system over Manitoba, Canada, at 989-hectopascals (hPa)¹ along an occluded front with a cold front extending from the triple point² near the Manitoba and Ontario boarder southward into northwestern Minnesota and into South Dakota. A warm front also extended southeastward from the triple point across southwest Ontario, Canada, into northeastern Minnesota and Wisconsin. The accident site was located in the warm air sector between the approaching cold front to the west and the warm front to the east. Further to the south in Iowa another low-pressure system at 1007-hPa was identified along a stationary front that stretched across northwest Missouri, into central Iowa, and eastward into northern Illinois. The accident flight had flown across this stationary front after refueling in Missouri, which was located south of the front.

The station models in the vicinity of the accident site indicated surface winds from the south at 10 to 15 knots, with scattered to broken sky cover, temperatures in the 60's °F and dew point temperatures near 50° F. Thunderstorms were depicted along the cold front to the northwest of the accident site.

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

² Triple point is where the occluded front, cold front and warm front all intersect. It also represents the intersection point between boundaries of different air masses, and often is associated with significant lifting and often a focus for potential severe weather.

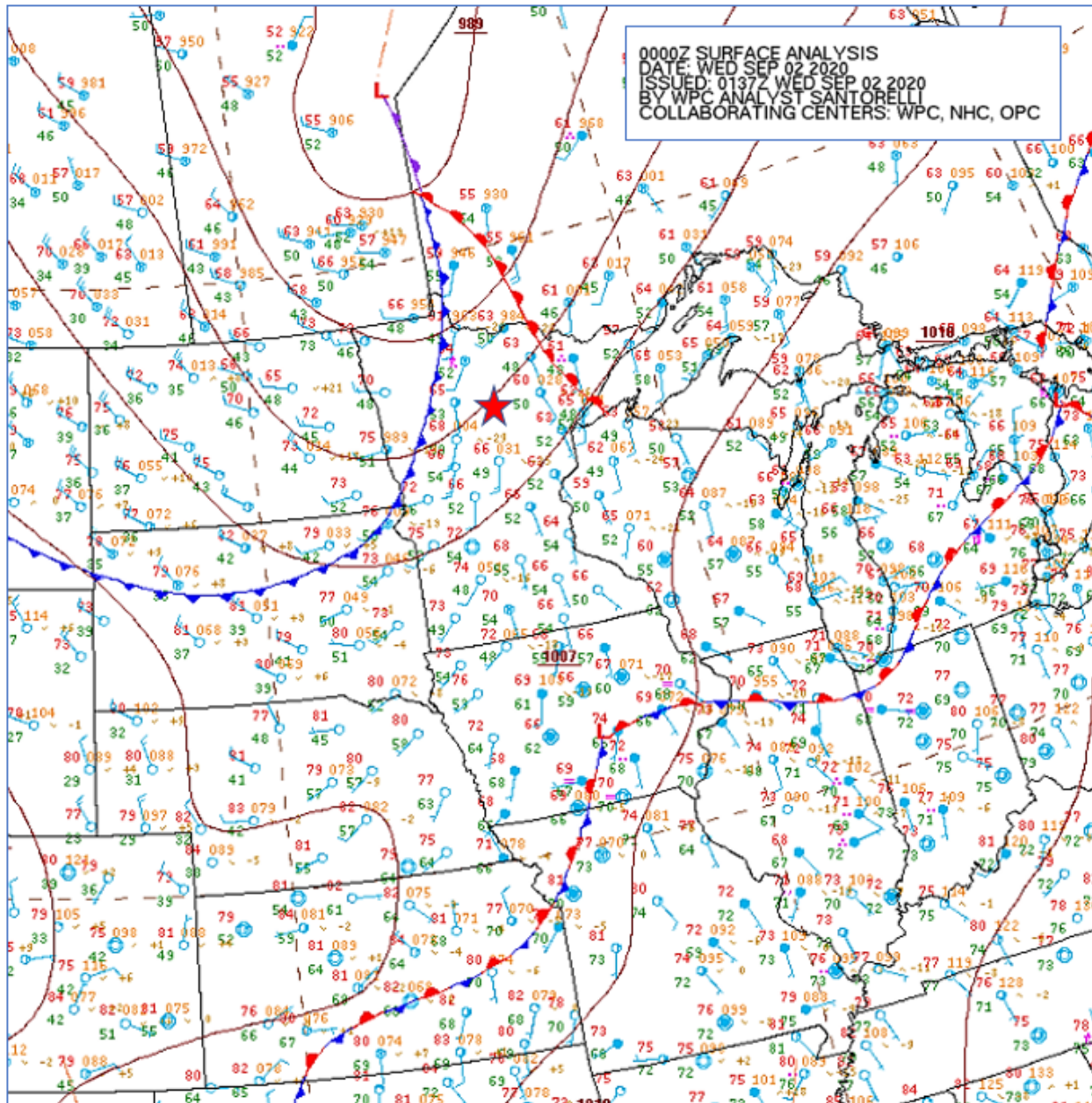


Figure 1 - northcentral section of the NWS Surface Analysis chart for 1900 CDT with accident site marked

1.2 National Composite Radar Mosaic

The NWS NCEI National Composite Radar Mosaic for 2010 CDT is included as figure 2 with the approximate accident site marked by the red star. The image depicted a line of precipitation which extended from Lake George east-northeastward to Spring Lake, Minnesota, and into the Mine Centre, Ontario, Canada, area. The accident site was located under the leading edge of the area of precipitation with areas of extreme intensity echoes extending west through northeast of the accident site.

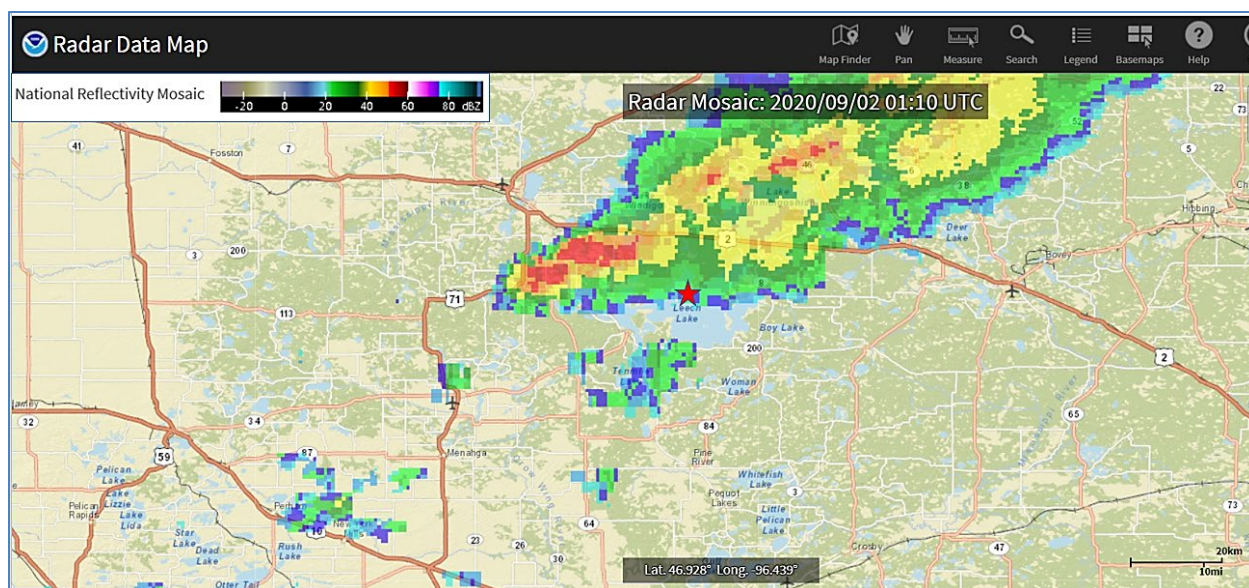


Figure 2 - National Composite Radar Mosaic for 2010 CDT with accident site marked

To further review any potential impact from the line of echoes, the closest weather surveillance radar will be documented in section 5.0 of this report.

1.3 Convective Outlook

The NWS Storm Prediction Center (SPC) is tasked with providing timely and accurate forecasts and watches for severe thunderstorms and tornadoes over the contiguous United States. One of their primary products highlighting the expected areas of organized thunderstorms is the Convective Outlook (AC) graphic and bulletin. The intent of the chart is to identify to users where the NWS SPC expects organized thunderstorms and severe thunderstorms³ to form, and the general weather threat expected. The SPC Convective Outlook issued at approximately 1440 CDT and valid for the period of the accident is included as figure 3 with the approximate accident marked by the red star. The chart depicted a slight risk of severe thunderstorms over Arkansas and extreme western Tennessee, surrounded by a marginal risk over Mississippi, and a general risk over Missouri and Iowa, with another general risk of airmass type thunderstorms over northern Minnesota during the period.

³ A severe thunderstorm is defined as one that produces a tornado, large hail over 1.0 inch in diameter or more, or outflow winds of 50 knots or more. While all thunderstorms imply the likelihood of lightning and severe turbulence, a severe thunderstorm implies a likelihood of severe to extreme turbulence, low-level wind shear, and a high probability of encountering damaging hail.

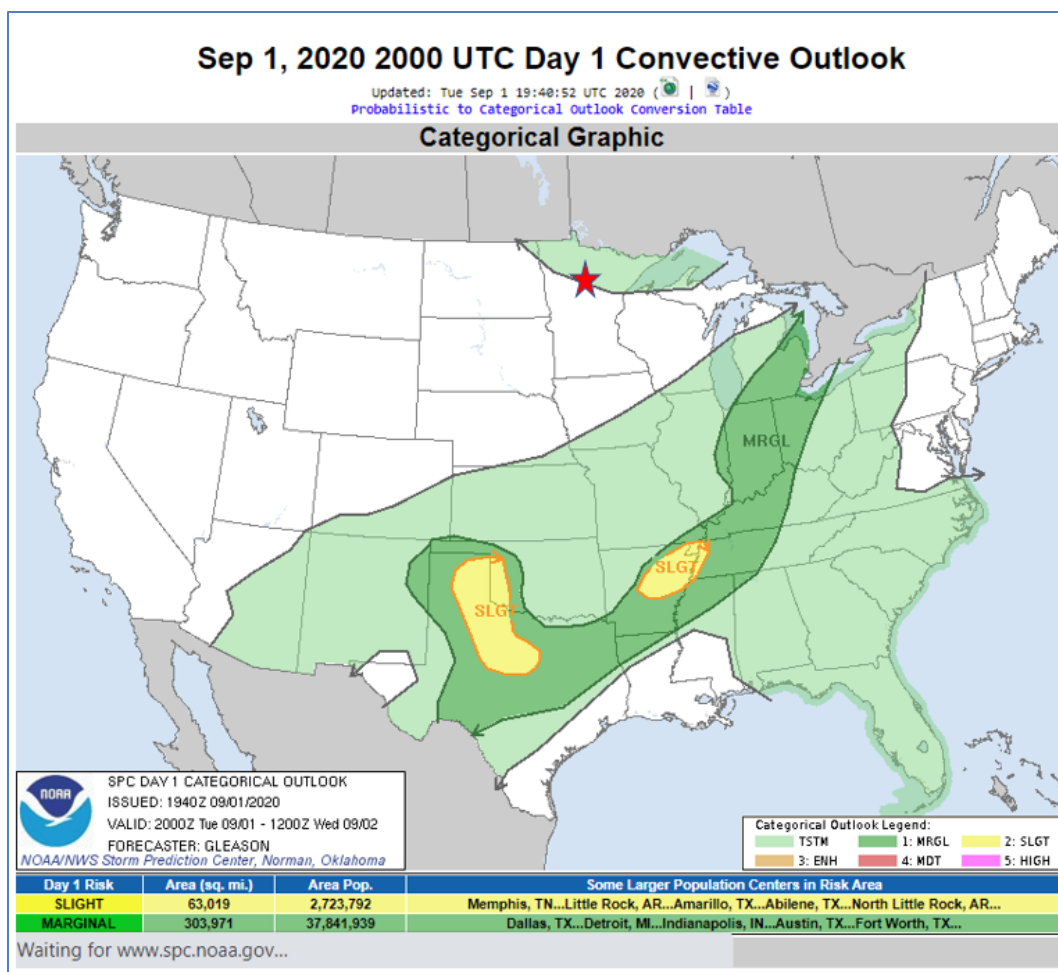


Figure 3 - Convective Outlook issued at 1440 CDT for thunderstorms

The narrative to the Convective Outlook was as follows.

*SPC AC 011940
 Day 1 Convective Outlook
 NWS Storm Prediction Center Norman OK
 0240 PM CDT Tue Sep 01 2020*

Valid 012000Z - 021200Z

...THERE IS A SLIGHT RISK OF SEVERE THUNDERSTORMS ACROSS PARTS OF THE SOUTHERN PLAINS AND MID-SOUTH...

...SUMMARY...

Severe thunderstorms capable of large hail, damaging winds, and a tornado or two are most likely to occur between 4 PM and 12 AM CDT in parts of western Oklahoma and northwest Texas from the Panhandle to the Big Country. Other severe storms may produce isolated damaging winds and perhaps a few tornadoes across parts of the Mid-South through this evening.

...20Z Update...

Severe probabilities for damaging winds and isolated tornadoes have been increased across parts of central/eastern AR into the MO Bootheel and far western TN. Convection that has recently increased in intensity across central AR along an outflow boundary has shown persistent signs of low-level rotation.

Current expectations are for ongoing storms to spread northeastward across the Mid-South through the remainder of the afternoon into the early evening along/south of a strong low-level instability gradient. A small-scale shortwave trough moving over this region is supporting 30-35 kt of effective bulk shear, which should be sufficient for continued storm organization. Low-level winds from recent KLZK VWP's also show a strengthening/veering profile, and the potential for a few tornadoes with low-topped supercells and cells embedded within the larger line remains apparent. For more information on the near-term severe risk across this area, see Mesoscale Discussion 1662.

Severe hail/wind probabilities have also been expanded eastward into parts of western OK, where storms may develop along a stalled front later this afternoon. The airmass is becoming at least moderately unstable across this area, and deep-layer shear will support supercells. There is also some potential for strong to severe convection to spread eastward from the TX Panhandle into western OK later this evening. For more information on the short-term severe threat across this region, see Mesoscale Discussion 1663.

..Gleason.. 09/01/2020

A review of the NWS SPC Storm Reports indicated a single report of large hail of 1 inch in diameter was reported at 1948 CDT approximately 7 miles south of Bemidji, in Hubbard County, Minnesota approximately 15 miles west-northwest of the accident site. There were also 14 reports of tornadoes across Arkansas, Missouri, and western Tennessee in the slight risk area between about 1400 and 1730 CDT after the accident airplane had traversed the area.

1.4 12-hour Surface Prognostic Chart

The NWS 12-hour Surface Prognostic Chart valid for 0100 CDT on September 2, 2020, is included as figure 4. The forecast chart depicted the cold front moving southward into central Minnesota by the valid time of the chart with no significant precipitation over the region at that time. Further south the stationary front over Iowa had dropped into central Missouri with a high probability of rain and thunderstorms over southern Missouri and Arkansas.

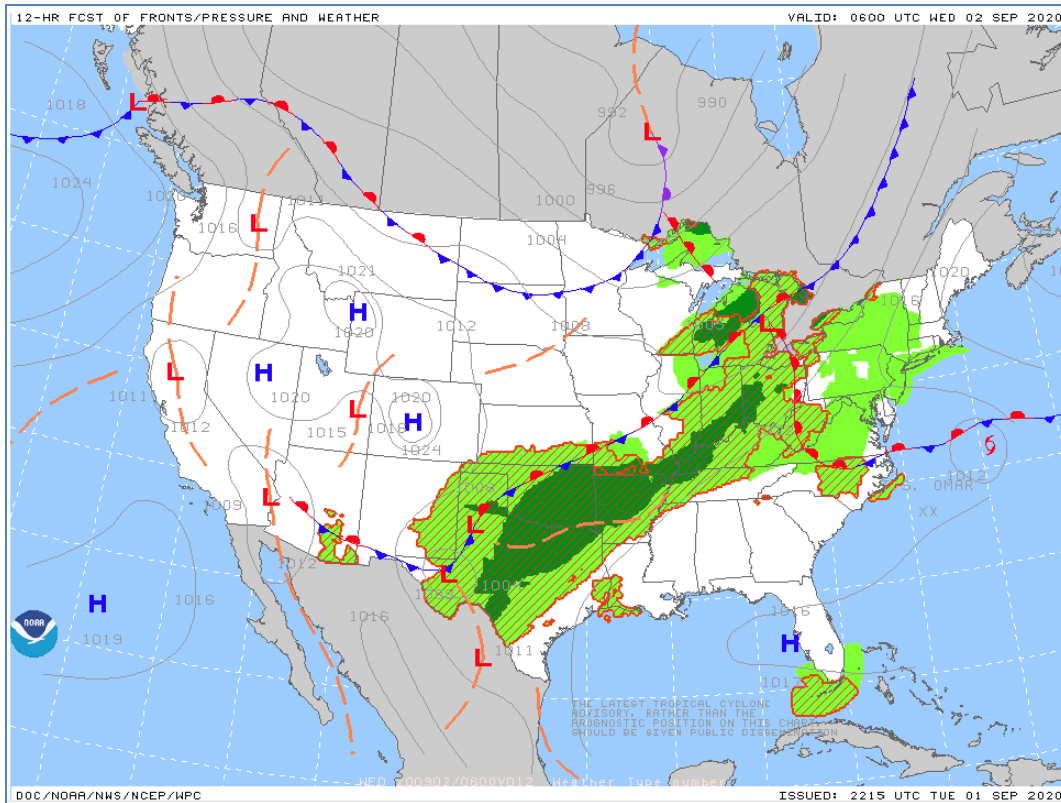


Figure 4 - 12-hour Surface Prognostic Chart valid for 0100 CDT September 2, 2020

2.0 Surface Observations

The official NWS Meteorological Aerodrome Reports (METARs) and special reports (SPECIs) surrounding the period were documented for the area. The cloud heights are reported above ground level (agl), and the magnetic variation over the region was estimated as 1° E based on the sectional chart for the area.

2.1 Walker, Minnesota

The closest weather reporting site to the accident site was from Walker Municipal Airport (KY49), Walker, Minnesota, located approximately 12 miles west of the accident site at an elevation of 1,348 ft. The airport had an Automated Weather Observation System (AWOS), which was not augmented and issued observations every 20 minutes. The following conditions were reported surrounding the time of the accident.

Weather observation for KY49 at 1955 CDT, automated, wind from 190° at 14 knots gusting to 20 knots, visibility 10 miles or more, ceiling broken at 9,000 ft agl, overcast at 11,000 ft, temperature 18° C, dew point 12° C, altimeter 29.49 inches of mercury ("Hg). Remarks: automated station with a precipitation discriminator, lightning distant north and northwest, temperature 17.8° C, dew point 11.5° C.

Weather observation for KY49 at 2015 CDT, automated, wind from 200° at 14 knots gusting to 28 knots, visibility 10 miles in thunderstorm and light rain, scattered clouds at

6,500 ft agl, ceiling broken at 7,500 ft, overcast at 10,000 ft, temperature 18° C, dew point 12° C, altimeter 29.48 "Hg. Remarks: automated station with a precipitation discriminator, lightning distant northwest through northeast, temperature 18.0° C, dew point 11.6° C.

The general flight categories⁴ and raw observations from 1815 through 2115 CDT were as follows, with the observations in bold type provided above in plain language with the time of the accident.

VFR METAR KY49 012315Z AUTO 19013G21KT 10SM CLR 18/11 A2954 RMK AO2 LTG DSNT N AND NW T01820114=

VFR METAR KY49 012335Z AUTO 19012G20KT 10SM VCTS CLR 18/12 A2953 RMK AO2 LTG DSNT N AND NW T01820115=

VFR METAR KY49 012355Z AUTO 18016G19KT 10SM CLR 18/12 A2951 RMK AO2 LTG DSNT N AND NW T01800116 10190 20165=

VFR METAR KY49 020015Z AUTO 19011G17KT 10SM SCT095 SCT120 18/12 A2950 RMK AO2 LTG DSNT N AND NW T01790117=

VFR METAR KY49 020035Z AUTO 19014G18KT 10SM SCT080 BKN100 BKN120 18/12 A2949 RMK AO2 LTG DSNT N AND NW T01800116=

VFR METAR KY49 020055Z AUTO 19014G20KT 10SM BKN090 OVC110 18/12 A2949 RMK AO2 LTG DSNT N AND NW T01780115=

Accident 0107Z

VFR METAR KY49 020115Z AUTO 20014G28KT 10SM -TSRA SCT065 BKN075 OVC100 18/12 A2948 RMK AO2 LTG DSNT NW THRU NE T01800116=

VFR METAR KY49 020135Z AUTO 28010G21KT 10SM -VCTSRA SCT040 BKN050 OVC075 18/12 A2954 RMK AO2 LTG DSNT ALQS T01750122=

VFR METAR KY49 020155Z AUTO 25007G14KT 10SM SCT040 SCT050 BKN090 18/12 A2954 RMK AO2 LTG DSNT NE AND E T01750122=

VFR METAR KY49 020215Z AUTO 24007KT 10SM CLR 17/12 A2954 RMK AO2 LTG DSNT E T01700121=

⁴ As defined by the NWS and the FAA Aeronautical Information Manual (AIM) section 7-1-7 defines the following general flight categories based on weather conditions reported:

- Low Instrument Flight Rules (LIFR*) – ceiling below 500 ft above ground level (agl) and/or visibility less than 1 statute mile.

- Instrument Flight Rules (IFR) – ceiling between 500 to below 1,000 feet agl and/or visibility 1 to less than 3 miles.

- Marginal Visual Flight Rules (MVFR**) – ceiling from 1,000 to 3,000 ft agl and/or visibility 3 to 5 miles.

- Visual Flight Rules (VFR) – ceiling greater 3,000 ft agl and visibility greater than 5 miles.

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

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

2.2 Longview, Minnesota

The next closest reporting station was located approximately 18 miles south-southeast of the accident site at Longview municipal Airport (KXVG), Longville, Minnesota, at an elevation of 1,337 ft. The airport also had an AWOS and issued observations every 20-minutes. The following conditions were reported immediately after the accident.

Weather observation for KXVG at 2013 CDT, automated, wind from 180° at 10 knots gusting to 20 knots, visibility 10 miles, thunderstorms in the vicinity, scattered clouds at 10,000 ft agl, temperature 18° C, dew point 11° C, altimeter 29.52 "Hg. Remarks: automated station with a precipitation discriminator, lightning distant northwest.

The general flight conditions and raw observations surrounding the period from 1753 through 2213 CDT were as follows.

VFR METAR KXVG 012253Z AUTO 17012G15KT 134V194 10SM VCTS SCT100 19/11 A2959 RMK AO2 LTG DSNT NW=

VFR METAR KXVG 012313Z AUTO 18010G17KT 10SM CLR 19/11 A2958 RMK AO2 LTG DSNT NW=

VFR METAR KXVG 012333Z AUTO 17010G20KT 10SM VCTS CLR 19/11 A2957 RMK AO2 LTG DSNT NW=

VFR METAR KXVG 012353Z AUTO 17011G18KT 10SM VCTS CLR 18/11 A2956 RMK AO2 LTG DSNT NW=

VFR METAR KXVG 020013Z AUTO 18011G17KT 10SM VCTS CLR 18/11 A2955 RMK AO2 LTG DSNT NW=

VFR METAR KXVG 020033Z AUTO 18013G20KT 10SM CLR 18/11 A2953 RMK AO2 LTG DSNT NW=

VFR METAR KXVG 020053Z AUTO 18010G18KT 10SM VCTS CLR 18/11 A2952 RMK AO2 LTG DSNT NW=

Accident 0107Z

VFR METAR KXVG 020113Z AUTO 18010G20KT 10SM VCTS SCT100 18/11 A2952 RMK AO2 LTG DSNT NW=

VFR METAR KXVG 020133Z AUTO 17008G16KT 10SM -VCTSRA SCT075 BKN100 17/11 A2951 RMK AO2 LTG DSNT NE AND NW=

VFR METAR KXVG 020153Z AUTO 22010G16KT 10SM VCTS SCT075 BKN080 OVC110 18/11 A2952 RMK AO2 LTG DSNT NE AND NW=

VFR METAR KXVG 020213Z AUTO 23008G18KT 204V264 10SM VCTS SCT075 SCT080 OVC110 18/12 A2955 RMK AO2 LTG DSNT NE=

VFR METAR KXVG 020233Z AUTO 00000KT 10SM VCTS SCT070 BKN095 OVC110 18/12 A2956 RMK AO2 LTG DSNT NE=

VFR METAR KXVG 020253Z AUTO 23007KT 10SM VCTS SCT095 18/12 A2956 RMK AO2 LTG DSNT NE AND SE=

VFR METAR KXVG 020313Z AUTO 00000KT 10SM VCTS CLR 18/12 A2957 RMK AO2 LTG DSNT SE=

2.3 Bemidji, Minnesota

KBJI was the planned destination and was located approximately 32 miles northwest of the accident site at an elevation of 1,391 ft. The airport had an AWOS and reported the following conditions surrounding the period.

Weather observation for KBJI at 1955 CDT, automated, wind from 250° at 7 knots gusting to 10 knots, visibility 10 miles or more, thunderstorms in the vicinity, scattered clouds at 2,800 ft agl, scattered clouds at 4,800 ft, ceiling broken 6,000 ft, temperature 16° C, dew point 14° C, altimeter 29.51 "Hg. Remarks: automated station with a precipitation discriminator, lightning distant all quadrants, hourly precipitation 0.13 inches, temperature 15.5° C, dew point 13.6° C.

Accident 0107Z

Weather observation for KBJI at 2015 CDT, automated, wind from 200° at 4 knot, visibility 10 miles or more, scattered clouds at 9,000 ft agl, scattered clouds at 12,000 ft, temperature 15° C, dew point 14° C, altimeter 29.51 "Hg. Remarks: automated station with a precipitation discriminator, lightning distant east through south, temperature 14.7° C, dew point 13.7° C.

The general flight categories and raw observations surrounding the time of the accident were as follows.

VFR METAR KBJI 012315Z AUTO 19011G20KT 10SM SCT120 19/11 A2951 RMK AO2 LTG DSNT N AND NW T01860112=

VFR METAR KBJI 012335Z AUTO 19017G20KT 10SM VCTS SCT100 SCT120 19/12 A2949 RMK AO2 LTG DSNT N AND NW T01860115=

VFR METAR KBJI 012355Z AUTO 18013G20KT 10SM VCTS SCT090 BKN110 19/12 A2946 RMK AO2 LTG DSNT N AND W T01850116 10200 20158=

VFR METAR KBJI 020015Z AUTO 20017G25KT 10SM BKN090 BKN110 19/12 A2946 RMK AO2 LTG DSNT NW THRU NE T01860115=

VFR METAR KBJI 020035Z AUTO 31015KT 10SM VCTSRA BKN055 OVC090 17/13 A2951 RMK AO2 LTG DSNT ALQS P0001 T01690128=

VFR METAR KBJI 020055Z AUTO 25007G10KT 10SM VCTS SCT028 SCT048 BKN060 16/14 A2951 RMK AO2 LTG DSNT ALQS P0013 T01550136=

Accident 0107Z

VFR METAR KBJI 020115Z AUTO 20004KT 10SM SCT090 SCT120 15/14 A2951 RMK AO2 LTG DSNT E THRU S T01470137=

VFR METAR KBJI 020135Z AUTO 22006KT 10SM CLR 15/13 A2951 RMK AO2 T01460131=

VFR METAR KBJI 020155Z AUTO 23008KT 10SM CLR 15/13 A2952 RMK AO2 T01510127=

2.4 METAR Display

The NWS Aviation Weather Center's (AWC) display of METARs for 2010 CDT from their website⁵ is included as figure 5 with the approximate accident site marked by the red star and the weather radar overlaid. The temperatures and dew point temperatures are in °F and the ceiling heights are in 100's ft agl. The accident site was noted on the southern edge of the precipitation with the stations reporting southerly winds immediately west, south, and east of the accident site with distant lightning indicated.

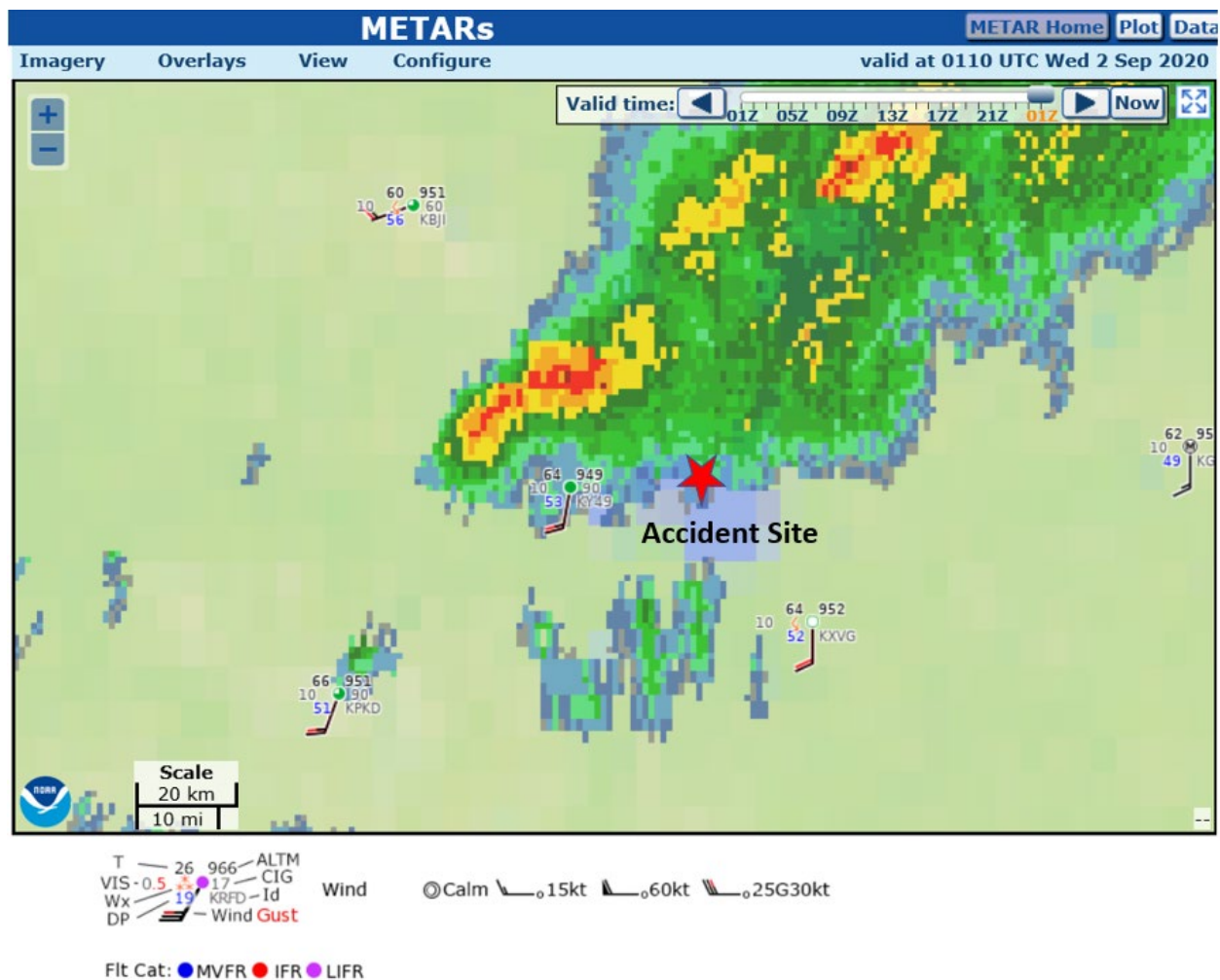


Figure 5 - NWS Aviation Weather Center's METAR display for 2010 CDT

3.0 Upper Air Sounding

To determine the vertical structure and state of the atmosphere over the accident site a High-Resolution Rapid Refresh (HRRR)⁶ numerical model data was retrieved from the NOAA Air

⁵ <https://aviationweather.gov/>

⁶ The HRRR is a National Oceanic and Atmospheric Administration (NOAA) real-time three-kilometer resolution, hourly-updated, cloud-resolving, convection-allowing atmospheric model, initialized by three-kilometer grids with three-kilometer radar assimilation. Radar data is assimilated in the HRRR every 15 minutes over a one-hour period.

Resources Laboratory and plotted on a standard Skew T log P diagram⁷ using the complete Rawinsonde Observation RAOB program software⁸. Figure 6 is the HRRR numerical model sounding for 2000 CDT over the approximate accident site from the surface to 400-hPa or 24,000 ft.

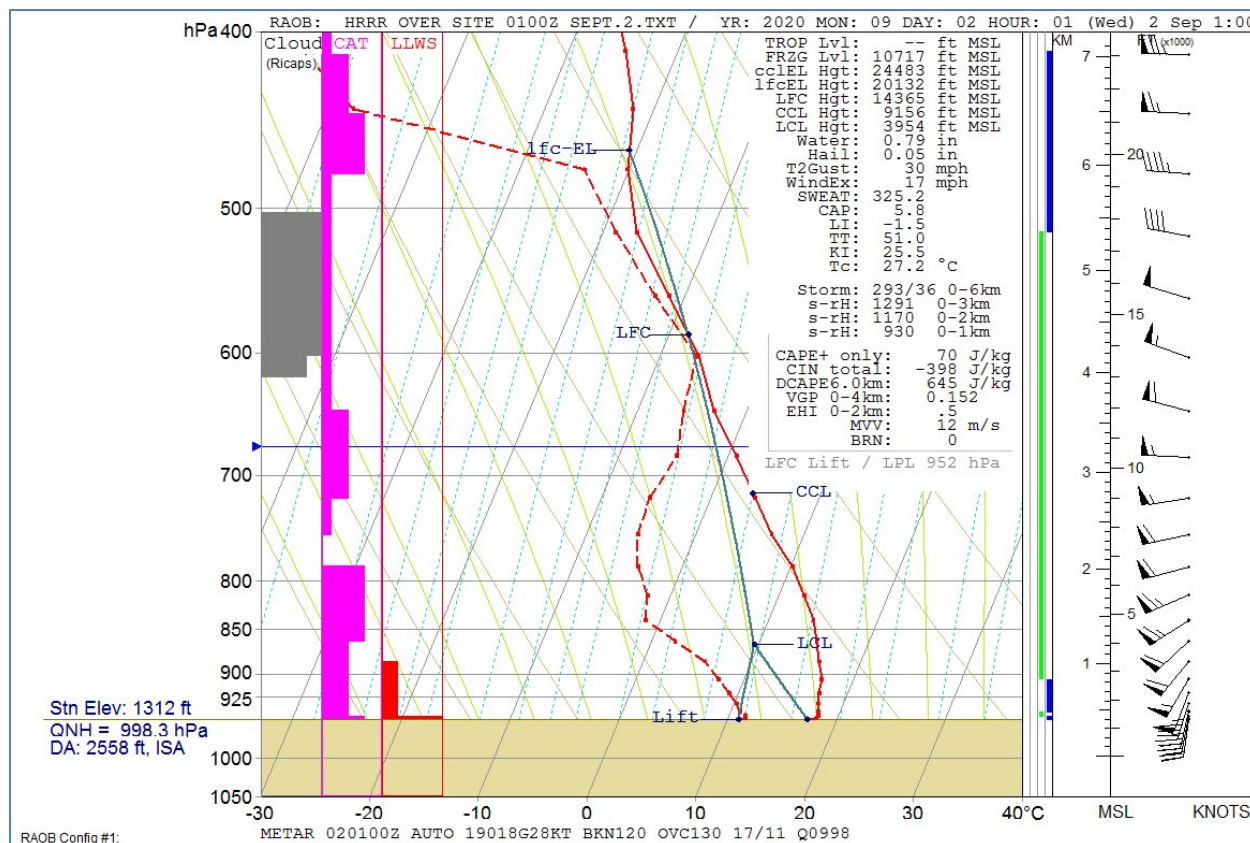


Figure 6 - High-Resolution Rapid Refresh (HRRR) sounding for 2000 CDT over the accident site

The HRRR numerical model sounding depicted the elevation of 1,312 ft over the coordinates with a near surface temperature of 17° C, a dew point of 11° C, with the relative humidity of 67%. The lifted condensation level (LCL)⁹ was identified at 2,642 ft agl (3,954 ft msl), the convective condensation level (CCL)¹⁰ at 9,155 ft msl, and the level of free convection (LFC)¹¹ at 14,365 ft. The freezing level was identified at 10,717 ft and is indicated by a blue horizontal line across the sounding diagram, and implied icing in-clouds possible above this level. The precipitable water¹²

⁷ Skew T log P diagram – is a standard meteorological plot or thermodynamic diagram using temperature and the logarithmic of pressure as coordinates, used to display winds, temperature, dew point, and various indices used to define the vertical structure of the atmosphere.

⁸ RAOB – (The complete Rawinsonde Observation program) is an interactive sounding analysis program developed by Environmental Research Services, Matamoras, Pennsylvania.

⁹ Lifting Condensation Level (LCL) - the level at which a lifted parcel becomes saturated. The LCL height corresponds to cloud base height for forced ascent.

¹⁰ Convective Condensation Level (CCL) - The level in the atmosphere to which an air parcel, if heated from below, will rise dry adiabatically, without becoming colder than its environment just before the parcel becomes saturated.

¹¹ Level of Free Convection (LFC) - the last level where a parcel becomes buoyant, or "warmer" than the environmental temperature at the same level. The LFC represents the bottom of the layer containing CAPE.

¹² Precipitable Water (PW) - The total amount of (condensed) water available within the lowest 400 mb of the

content was 0.79 inches, which is considered low moisture content for severe thunderstorms. The RAOB sounding algorithm depicted a broken to overcast layer from 12,000 ft through 18,000 ft where the relative humidity was greater than 80%. The atmosphere was characterized as conditional unstable with a Lifted Index¹³ of -1.5, with the Convective Available Potential Energy (CAPE)¹⁴ value of 70 Joules/kilogram (J/kg). The RAOB algorithm indicated the potential outflow winds from the thunderstorm (T2Gust) was 26 knots (30 mph).

The HRRR wind profile and RAOB algorithm indicated a surface wind from 190° at 18 knots with gusts to 28 knots, with winds veering to the west with height with increasing wind speeds of 50 knots or more above 1,000 ft agl. The 0 to 6 kilometer (or 18,000 ft) storm motion was from about 290° at 36 knots. The strong low-level winds and RAOB algorithm indicated a risk of moderate turbulence below 6,000 ft and is indicated by the purple bars on the left side of the diagram labelled as Clear Air Turbulence (CAT).

4.0 Satellite Imagery

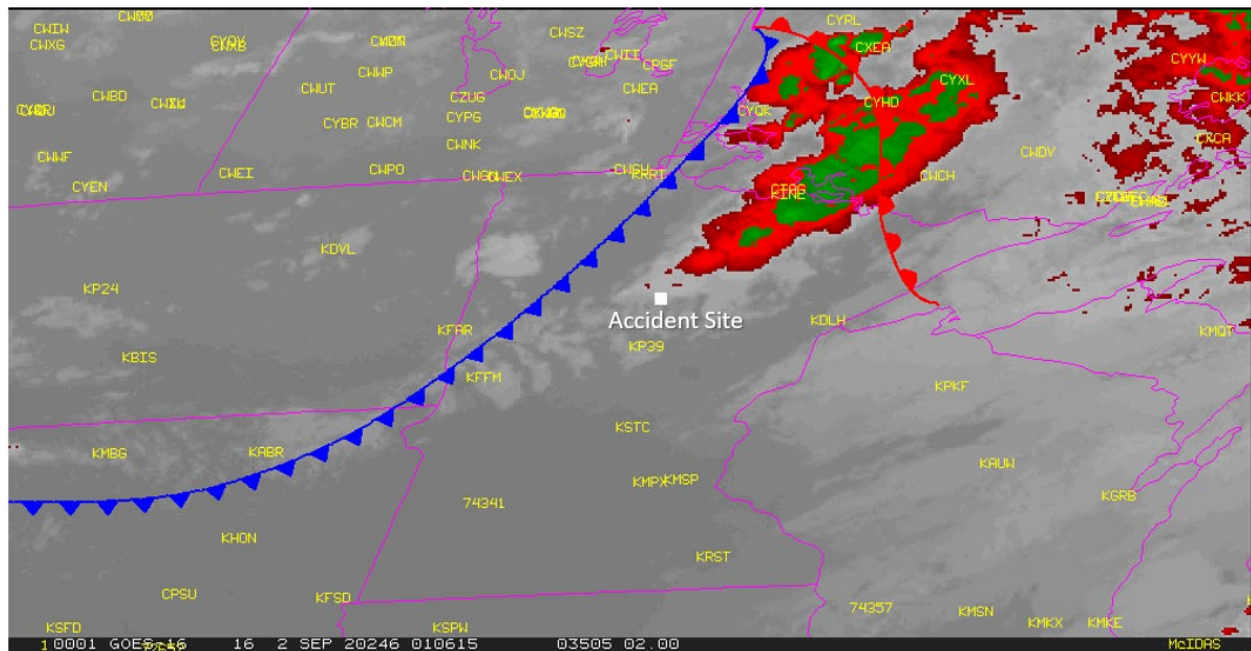
The Geostationary Operational Environmental Satellite number 16 (GOES-16) data was obtained from an archive at the Space Science Engineering Center (SSEC) at the University of Wisconsin-Madison in Madison, Wisconsin, and processed using the Man-computer Interactive Data Access System (McIDAS) software. The infrared long wave band 13 imagery at a wavelength of 10.3 microns (μm) and a resolution of 2 km, along with the visible (band 2) at a wavelength of 0.64 μm with a resolution of 0.5 km were obtained surrounding the time of the accident.. The infrared imagery provided a standard satellite image with radiative cloud top or brightness temperatures. The low Sun angle prevented documentation of the visible image at the time of the accident, thus imagery prior to the accident time were documented.

Figure 7 is the GOES-16 infrared image at 2006 CDT at 2X magnification with a standard MB temperature enhancement curve applied to highlight the higher and colder cloud tops typically associated with deep convection. The pressure and frontal systems from the synoptic period of 1900 CDT are also overlaid on the image. The image depicted a band of cumulonimbus clouds from Canada southwestward into northern Minnesota and immediately north of the accident site, which was located under the southern edge of the line of the cumulonimbus cloud, and under a mid-level cloud band of altocumulus to altostratus clouds.

sounding.

¹³ Lifted Index (LI) – is an index to access low-level parcel (in)stability of the troposphere. the difference between the lifted parcel temperature at 500 hPa and the 500 hPa temperature in the sounding. Negative values denote parcels that are warmer than the background 500 hPa temperatures and are thus buoyant or "unstable".

¹⁴ Convective Available Potential Energy (CAPE) - the integrated "positive area" in J/kg (from the LFC to EL) for the lifted parcel. Thunderstorm updraft strength is related to CAPE.



Another view of the GOES-16 infrared image at 2001 CDT with the Geostationary Lightning Mapper Group Density display overlaid was obtained and is included as figure 8. According to the NASA researchers the Geostationary Lightning Mapper (GLM) maps the extent of the cloud illuminated by individual lightning flashes and the flash rates are most closely tied to updraft and storm evolution. The image depicts significant lightning flashes from the cumulonimbus cloud immediately bordering west through north and northeast of the accident site.

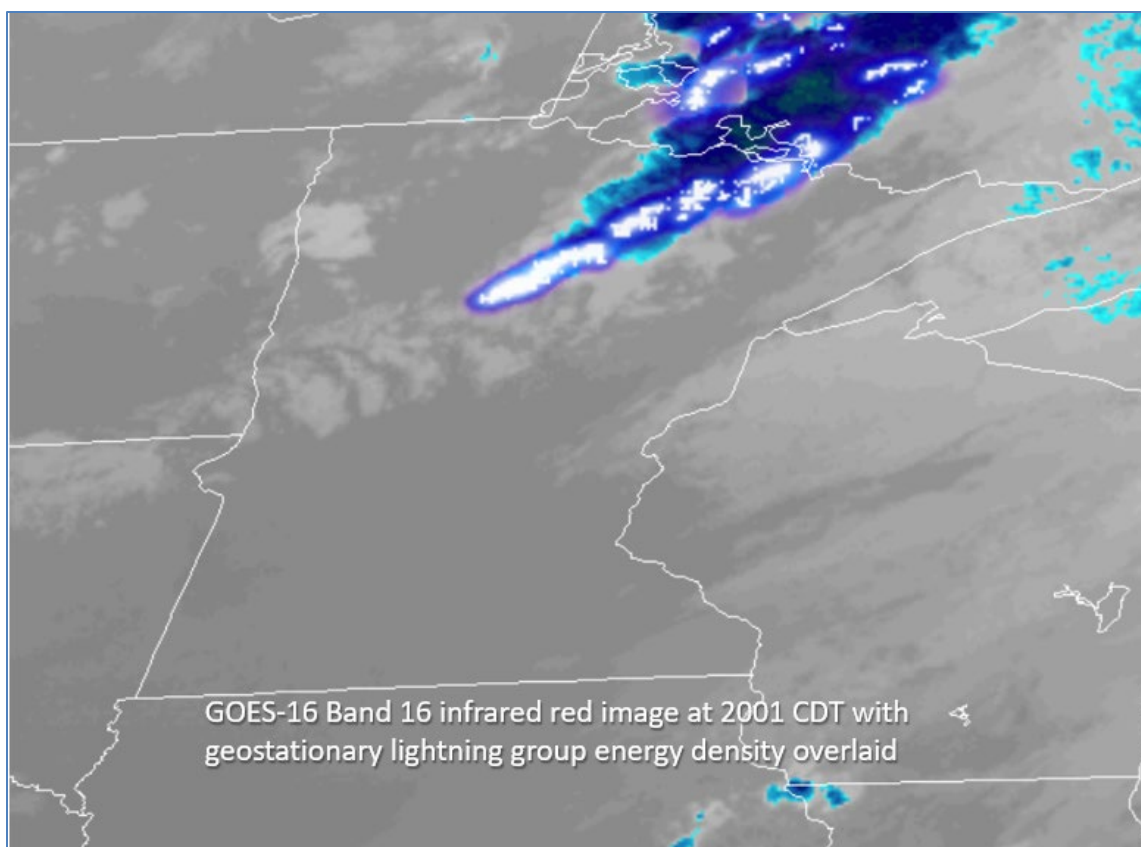


Figure 8 - GOES-16 infrared image for 2001 CDT with lightning density overlaid

Figure 9 is the GOES-16 visible image at 2X magnification for 1946 CDT or approximately 20 minutes prior to the accident with the image enhanced to show the lower altocumulus clouds over the area ahead of the line of cumulonimbus clouds, which are depicted extending west through northeast of the accident site. The local landmarks are overlaid in purple along with the official reporting locations across the region.

5.1 Reflectivity

Reflectivity is the measure of the efficiency of a target in intercepting and returning radio energy. With hydrometeors¹⁷, it is a function of the drop size distribution, number of particles per unit volume, physical state (ice or water), shape, and aspect. Reflectivity is normally displayed in decibels (dBZ¹⁸) and is a general measure of echo intensity. Figure 10 is a chart that relates the NWS video integrator and processor (VIP) intensity levels versus the WSR-88D's display levels, precipitation mode reflectivity in decibels, and rainfall rates. Note echoes of 15 dBZ and greater are typically associated with precipitation reaching the surface.

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

Figure 10 - WSR-88D reflectivity levels, dBZ, and rainfall rates

The Advisory Circular AC 00-24C – “Thunderstorms” had standardized the radar intensity level terminology to four basic levels for aviation which are defined in figure 11. Air traffic control weather processors are also programmed to display these levels, with the controller instructed¹⁹ to describe the intensity to pilots based on the intensity levels.

¹⁷ 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 glaze ice.

¹⁸ dBZ - $10 \log Z_e$

¹⁹ FAA Joint Order 7110.65W - Air Traffic Control, section 2-6-4 “Weather and Chaff Services”.

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

Figure 11 - Weather radar intensity level terminology

5.2 Composite Reflectivity Imagery

Composite reflectivity images utilize all elevation scans during each volume scan to create the image. It is composed of the greatest echo intensity (reflectivity) from any elevation angle seen from the radar, and it is used to reveal the highest reflectivity value in the column. Composite reflectivity image is one of the last radar image views, necessitated by the need for all elevation scans to be completed before this image can be produced. The short range composite reflectivity product (NCR) provides a resolution of 1 km x 1 km (0.54 nm x 0.54 nm) to 124 miles radius. Figure 12 is the KDLH WSR-88D composite reflectivity image for 2007 CDT with the flight track overlaid. The image depicted the flight path of N8957W as it approached KY49 then flew east-southeastward for approximately 40 miles before turning back to the northwest and westward, when it descended under the leading edge of the storm complex, and disappeared from air traffic control radar.

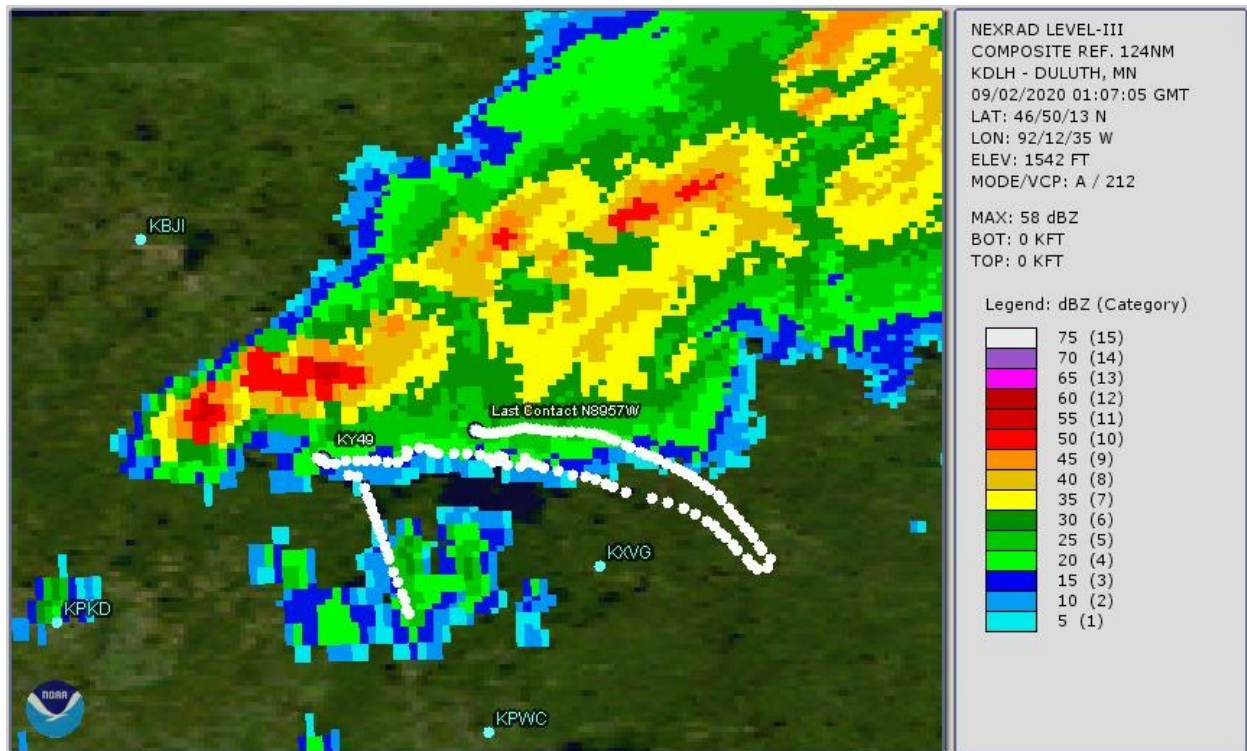


Figure 12 - KDLH WSR-88D composite reflectivity image for 2007 CDT with the flight track overlaid

5.3 Base Reflectivity Imagery

The WSR-88D base reflectivity images are the individual elevation scan images for the VCP being operated with a resolution of 0.25 km (0.13 nm) x 0.5°. Assuming a standard refraction²⁰ of the KDLH WSR-88D 0.95° radar beam with an antenna height of 1,541 ft, the lowest 0.44° antenna elevation was scanning the altitudes between approximately 7,390 ft to 16,660 ft, with the center of the beam near 12,030 ft over the accident site. Figure 13 is the KDLH WSR-88D 0.44° elevation scan base reflectivity image for the period ending at 2007 CDT with the flight track overlaid. The image depicted a line of thunderstorms with several intense to extreme echoes of 60 dBZ extending immediately west through northeast of the accident site, with the radar indicated hail to 0.71 inches²¹ in the extreme western echo noted by the green triangle and with echo tops or the highest altitude of echoes of 18.5 dBZ, at about 28,000 ft. Echoes over the flight track and accident site ranged from 15 to 29 dBZ (or light intensity reflectivity).

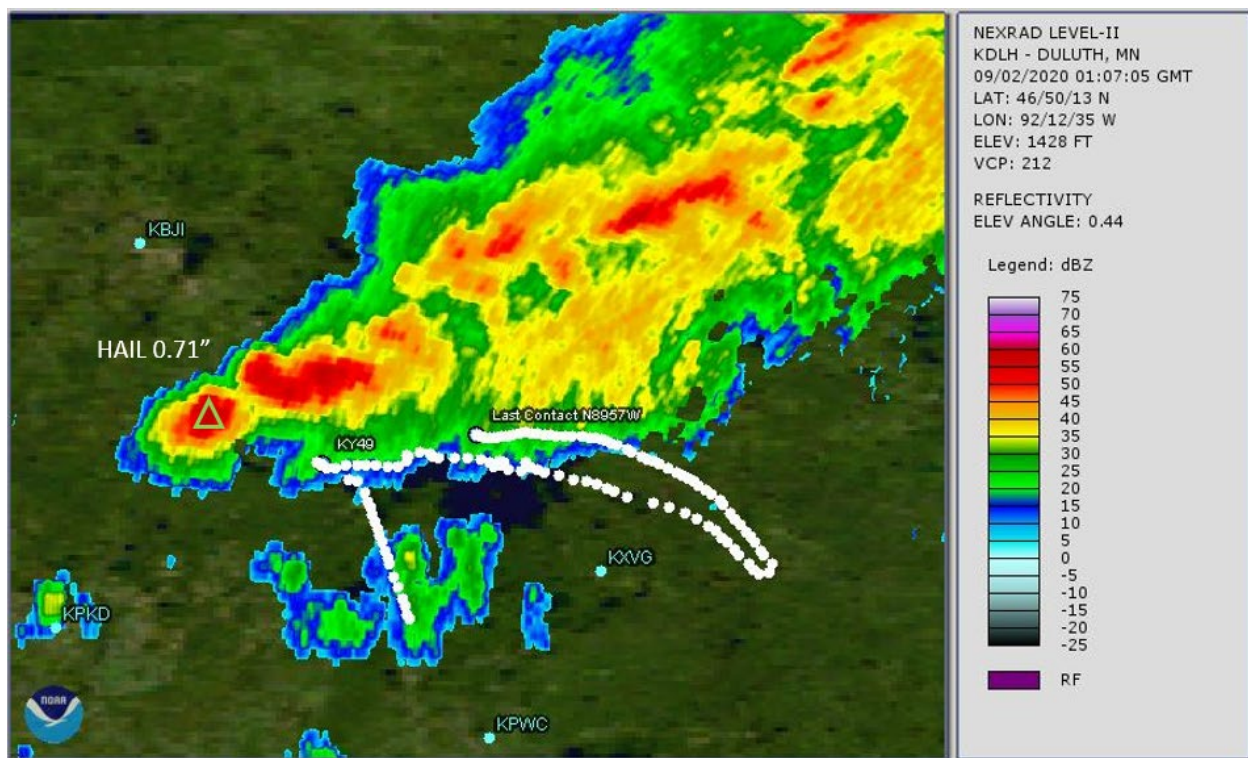


Figure 13 - KDLH WSR-88D 0.44 base reflectivity image issued at 2007 CDT with the flight track overlaid

5.4 Radial Velocity Imagery

The WSR-88D base velocity data displayed the tangential components of the wind that were moving towards the radar in cool values (green/blue) and away from the radar in warm colors (red/orange). The KDLH WSR-88D 0.44° base velocity image for 2007 CDT is included as figure 14. Due to the height of the radar beam the radial velocity product could not determine the

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

²¹ Corresponded to the NWS Storm Prediction Center's report of large hail 7 miles south of Bemidji, MN.

boundary layer conditions or outflow regions over the accident site at the time. The winds were from the west at 50 knots near 12,000 ft. A potential mesocyclone²² (red area) was coincident with the intense area of echoes located immediately north of Walker (KY49) near Wilkinson and Laporte, Wisconsin, or west of the accident site with easterly winds near 65 knots immediately next to westerly winds of 50 knots (or an approximately 115 knot wind shear).

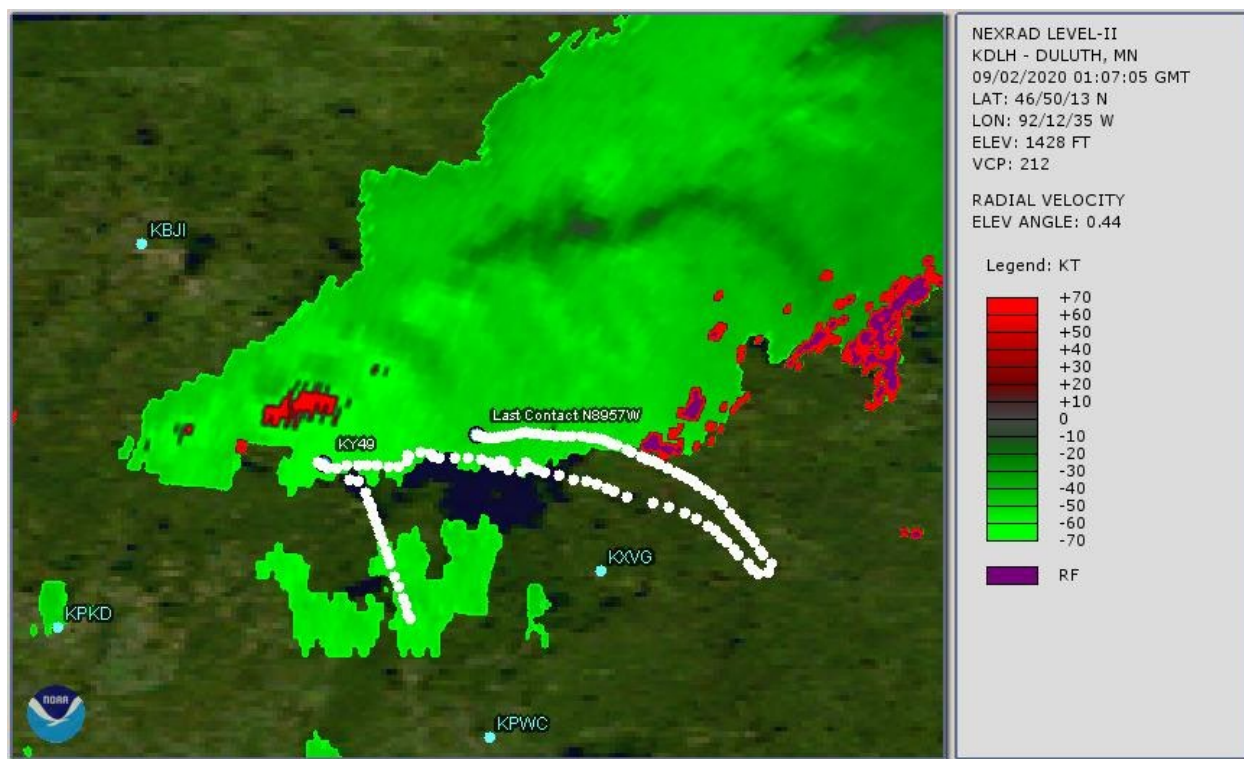


Figure 14 - KDLH WSR-88D 0.44° base velocity image at 2007 CDT

6.0 Lightning Data

Lightning data was obtained from the Earth Networks Total Lightning network for an approximately 30 miles radius of the accident site for the 30-minute period between 1940 and 2010 CDT and are displayed in figure 15. During the 30-minute period a total of 353 lightning flashes²³ were recorded, with approximately 49 cloud-to-ground strikes, with all but one stroke being negatively charged. The lightning flashes were clustered around the flight track and located along the leading edge of the storm complex.

²² A mesocyclone is storm-scale region of rotation (vortex), typically around 2 to 6 nm in diameter, within a thunderstorm.

²³ Lightning Flash – This is one contiguous conducting channel and all the current strokes/pulses that flow through it. There are two types of flashes: ground flashes and cloud flashes.

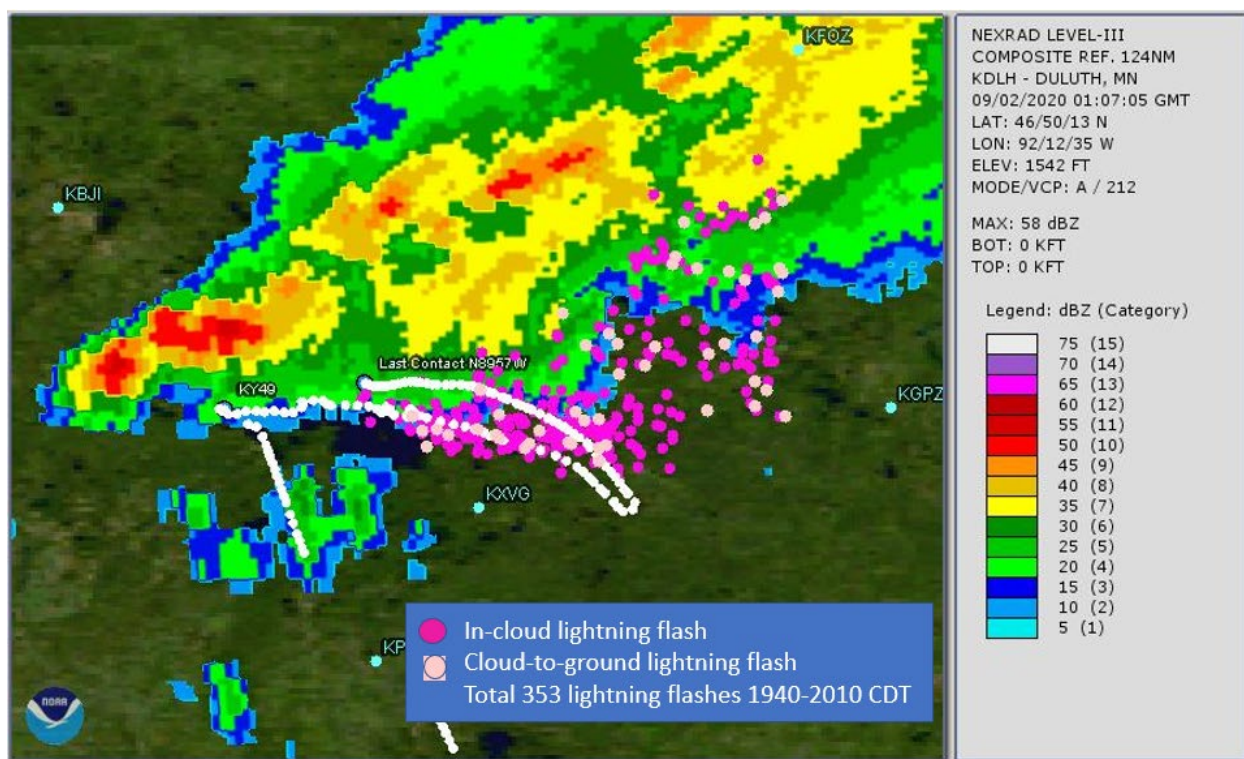


Figure 15 - Earth Networks Lightning Flashes between 1940 through 2010 CDT

According to the NWS Federal Meteorological Handbook (FMH-1) the frequency, type of lightning, and location shall be reported according to the following to the following chart in figure 16.

Type of Lightning		
Type	Contraction	Definition
Cloud-ground	CG	Lightning occurring between cloud and ground.
In-cloud	IC	Lightning which takes place within the cloud.
Cloud-cloud	CC	Streaks of lightning reaching from one cloud to another.
Cloud-air	CA	Streaks of lightning which pass from a cloud to the air, but do not strike the ground.
Frequency of Lightning		
Frequency	Contraction	Definition
Occasional	OCNL	Less than 1 flash/minute.
Frequent	FRQ	About 1 to 6 flashes/minute.
Continuous	CONS	More than 6 flashes/minute.

Figure 16 - FMH-1 Table 12-5. Type and Frequency of Lightning

7.0 Pilot Reports

A search of pilot reports or PIREPs three hours prior to and after the accident over northern Minnesota resulted in no issued reports during the period.

8.0 NWS Forecasts and Advisories

8.1 Terminal Aerodrome Forecast

The closest Terminal Aerodrome Forecast (TAF) to the accident site was for KBJI. While a TAF is valid for a 5-mile radius of the airport, it provides a time specific break down of expected winds, weather, and clouds for an approximately 24-hour period. The forecasts issued prior to departure and the time of the accident were as follows. The initial forecast for KBJI was an amended TAF issued at 1515 CDT and valid from 1600 CDT through 1500 CDT on September 2, 2020.

*AMD TAF KBJI 012015Z 0120/0218 20014G22KT P6SM VCSH BKN090
FM012100 21016G25KT P6SM VCTS BKN120CB
FM020200 24009KT P6SM SCT120 WS020/29040KT=*

The forecast expected from 1600 through 2100 CDT of wind from 210° at 16 knots gusting to 25 knots, visibility 6 miles or more, with thunderstorms in the vicinity of the airport, ceiling broken at 12,000 ft in cumulonimbus clouds. After 2100 CDT, the wind was expected to be from 240° at 9 knots, visibility 6 miles or more, with scattered clouds at 12,000 ft, the forecast also included wind shear at 2,000 ft with wind from 290° at 40 knots.

The next scheduled TAF was issued at 1821 CDT and was as follows.

*TAF KBJI 012321Z 0200/0224 20015G22KT P6SM VCTS BKN080CB
TEMPO 0200/0201 -TSRA
FM020200 27008KT P6SM SCT150 WS020/29040KT
FM020500 27008KT P6SM FEW250
FM021800 25012KT P6SM SCT150=*

The forecast for KBJI from 1900 CDT expected surface wind from 200° at 15 knots gusting to 22 knots, visibility 6 miles or more, with thunderstorms in the vicinity, ceiling broken at 8,000 ft agl in cumulonimbus clouds, with a period of temporary conditions between 1900 and 2000 CDT of thunderstorms and light rain. After 2100 CDT the forecast included the wind shear at 2,000 ft from 290° at 40 knots.

8.2 Winds Aloft Forecast

The NWS Winds and Temperature Aloft bulletin current for the period was valid for 1900 CDT and was for use between 1500 through 2200 CDT. The winds above 39,000 ft have been excluded.

WINDS ALOFT FORECASTS

DATA BASED ON 011800Z

VALID 020000Z FOR USE 2000-0300Z. TEMPS NEG ABV 24000

<i>FT</i>	<i>3000</i>	<i>6000</i>	<i>9000</i>	<i>12000</i>	<i>18000</i>	<i>24000</i>	<i>30000</i>	<i>34000</i>	<i>39000</i>
<i>MSP</i>	2026	2534+12	2638+04	2640-02	2762-10	2770-20	298735	298744	266751
<i>AXN</i>	2332	2439+11	2543+03	2842-03	2768-11	2883-21	790234	790144	287650
<i>DLH</i>	2028	2341+09	2442+02	2545-03	2649-15	2677-24	279038	780043	278347
<i>INL</i>	2136	2354+07	2447+00	2542-05	2646-18	2746-31	276041	276842	287244
<i>GFK</i>	2937	2939+09	3037+01	3038-05	2843-19	2966-27	790035	801141	299447

The forecast for Duluth (DLH) for 3,000 ft expected wind from 200° at 28 knots, at 6,000 ft from 230° at 41 knots with a temperature of 9° C, and at 9,000 ft from 240° at 42 knots with a temperature of 2° C.

8.3 Inflight Weather Advisories

Inflight Aviation Weather Advisories are forecasts to advise en route aircraft of the development of potentially hazardous weather. Inflight aviation weather advisories in the conterminous U.S. are issued by the NWS AWC, as well as from the Center Weather Service Units (CWSU) associated with FAA Air Route Traffic Control Centers (ARTCCs). There are four basic types of inflight aviation weather advisories: the Significant Meteorological Information (SIGMET), the Convective SIGMET, the Airman's Meteorological Information (AIRMET), and the Center Weather Advisory (CWA). At the time and location of the accident the NWS had issued a Convective SIGMET for thunderstorms and an AIRMET Tango for the potential for moderate turbulence below 6,000 ft and low-level wind shear (LLWS), which are depicted below.

Figure 17 is a depiction of the graphic and text Convective SIGMET 8C which was issued for a line of thunderstorms with the approximate accident site marked.

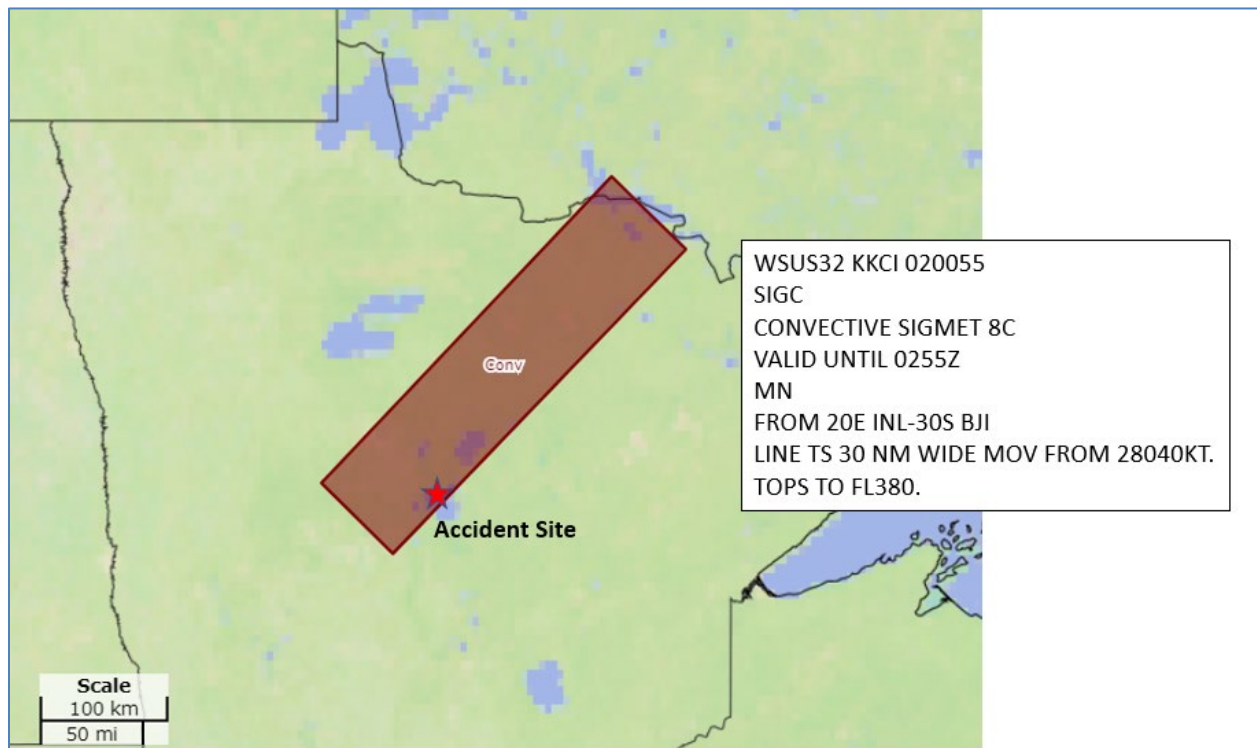


Figure 17 - Graphic and text of Convective SIGMET 8C issued at 1955 CDT

The advisory warned of a line of thunderstorms 30 miles wide moving eastward at 40 knots, with tops to 38,000 ft. The advisory implied the possibility of severe and greater turbulence, low-level winds shear, and possible instrument meteorological conditions with the storms.

An earlier advisory Convective SIGMET 56C was issued at 1855 CDT for an area of thunderstorms which also included the destination airport and the accident site. This advisory was subsequently replaced by Convective SIGMET 8C.

*WSUS32 KPCI 012355
SIGC
MKCC WST 012355
CONVECTIVE SIGMET 56C
VALID UNTIL 0155Z
MN
FROM 50WNW INL-20E INL-30S BJI-40NE FAR-50WNW INL
AREA TS MOV FROM 28040KT. TOPS TO FL360.*

Figure 18 is a depiction of AIRMET Tango update 6 issued at 1545 CDT for a new area of moderate turbulence below 6,000 ft and low-level wind shear (LLWS)²⁴, followed by the text bulletins below.

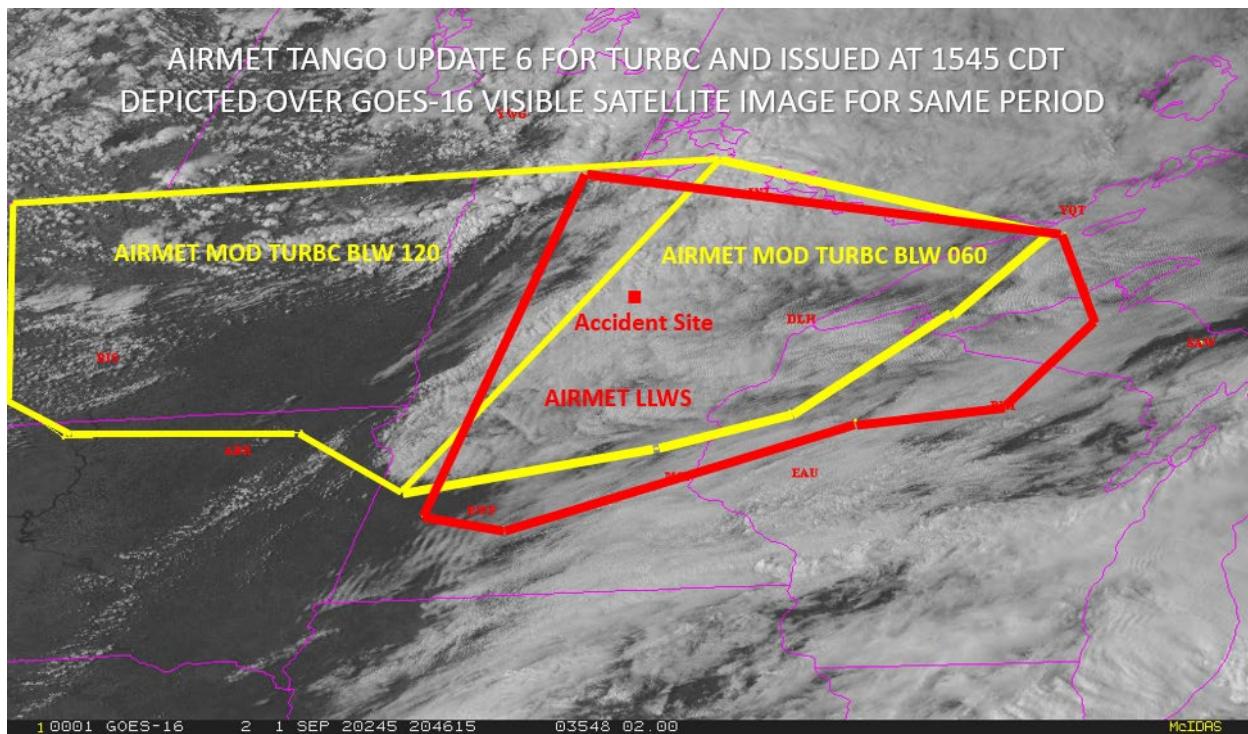


Figure 18 - AIRMET Tango update 6 issued for turbulence and low-level wind shear at 1545 CDT

*WAUS43 KPCI 012045
WA3T
CHIT WA 012045
AIRMET TANGO UPDT 6 FOR TURB AND LLWS VALID UNTIL 020300
.
AIRMET TURB...SD NE KS MN IA MO WI LM MI LH IL IN OK TX
FROM 50SE SSM TO 60WNW YVV TO 40S ECK TO FWA TO 40SSE FWA TO*

²⁴ AIRMET Tango update 5 issued at 1410 CDT included the new AIRMET for LLWS, no significant turbulence was expected below 25,000 ft for the area at that time.

30NNE COU TO 20ESE ICT TO 30SSW TXO TO 30ESE TBE TO 50W LBL TO
GLD TO 30SE SNY TO 60SSW FSD TO 50SE SSM
MOD TURB BTN FL220 AND FL430. CONDS CONTG BYD 03Z THRU 09Z.

AIRMET TURB...ND SD NE MN IA WI LM LS MI LH
FROM 50NNW ISN TO 60WNW INL TO 30ESE YQT TO 50SE SSM TO 60SSW
FSD TO 40E ABR TO 50NNW ISN
MOD TURB BTN FL200 AND FL380. CONDS CONTG BYD 03Z THRU 09Z.

AIRMET TURB...ND SD MN WI LS
FROM 40NW INL TO 20SSW YQT TO 70E DLH TO 50NNW EAU TO 30NW MSP
TO 50WNW RWF TO 40NW INL
MOD TURB BLW 060. CONDS ENDG 00-03Z.

AIRMET TURB...ND SD MN
FROM 40NW INL TO 50WNW RWF TO 30ENE ABR TO 60S BIS TO 40S DIK TO
70SSW ISN TO 50NNW ISN TO 40NW INL
MOD TURB BLW 120. CONDS ENDG 00-03Z.

LLWS POTENTIAL...MN WI LS MI
BOUNDED BY 80SE YWG-20S YQT-60WNW SAW-RHI-40NNE EAU-20SE RWF-30W
RWF-80SE YWG
LLWS EXP. CONDS DVLPG 21-00Z. CONDS CONTG BYD 03Z THRU 09Z.

9.0 Astronomical Conditions

The United States Naval Observatory Multiyear Interactive Computer Almanac (MICA) software was used to provide the following astronomical data over the approximate accident site in Walker, Minnesota, on September 1, 2020. The time of the accident has been added in italic bold type for reference.

Sunset	1957 CDT
<i>Accident</i>	<i>2007 CDT</i>
End civil twilight	2028 CDT
 Moonrise	 2015 CDT
Moon culmination	0041 CDT

At the time of the accident the Sun had just set with civil twilight ending at 2028 CDT and nighttime²⁵ beginning. At the time of the accident the Sun was 1.76° below the horizon at an azimuth of 284°.

²⁵ Night as defined in 14 *Code of Federal Regulations* 1.1 – General Definitions. Defines night as the time between the end of civil twilight and the beginning of morning civil twilight, as published in the Air Almanac, converted to local time.

10.0 Weather Briefing

A search of the FAA contract Automated Flight Service Station (AFSS) provider Leidos indicated that they had no contact from the pilot for any weather briefing services, flight plans, or any in-flight contacts. A search of third party weather vendors indicated that the pilot of N8957W had an account with ForeFlight, and that the pilot had accessed their site to view a static radar composite image and viewed the NWS Lower Mississippi Valley region radar loop prior to departure. The pilot did not request a standard weather briefing or file any flight plans through ForeFlight. It is unknown what the pilot may have reviewed on other sources prior to departure.

Submitted by:

Don Eick
Senior Meteorologist