

National Transportation Safety Board

Office of Aviation Safety

Washington, DC 20594



CEN24FA326

METEOROLOGY

Specialist's Factual Report

October 15, 2024

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A. ACCIDENT

Location: Crofton, Nebraska
Date: August 26, 2024
Time: 0841 central daylight time
1341 coordinated universal time (UTC)
Airplane: Rans S-19; Registration: N519JR

B. METEOROLOGY SPECIALIST

Paul Suffern
Senior Meteorologist
National Transportation Safety Board
Washington, DC

C. DETAILS OF THE INVESTIGATION

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

The accident site was located at approximate latitude 42.696098° N, longitude 97.550794° W, at an elevation of 1,700 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 WPC, 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 Federal Aviation Administration (FAA) "Aviation Weather Handbook", FAA-H-8083-28.¹

1.1 Surface Analysis Chart

The NWS Surface Analysis Chart centered over the northcentral United States for 1000 CDT is provided as figure 1 with the location of the accident site within the black circle. The chart depicted a low-pressure center over northwestern Iowa with another low-pressure center over north central Iowa with pressures at 1017- and 1015-hectopascals (hPa), respectively. A frontal system stretched southwestward from the 1017-hPa low-pressure center above the accident site then westward into Wyoming. The frontal boundary also stretched northeastward from the 1017-hPa low-pressure center through central Minnesota and into southern Canada. Fronts can act as lifting mechanisms to help produce clouds and precipitation if sufficient moisture is present.

The station models closest to the accident site depicted air temperatures of 75 to 76°F, dew point temperatures of 73 and 74°F, overcast sky cover, and a northwest wind of 10 knots.

¹ [FAA-H-8083-28](#)

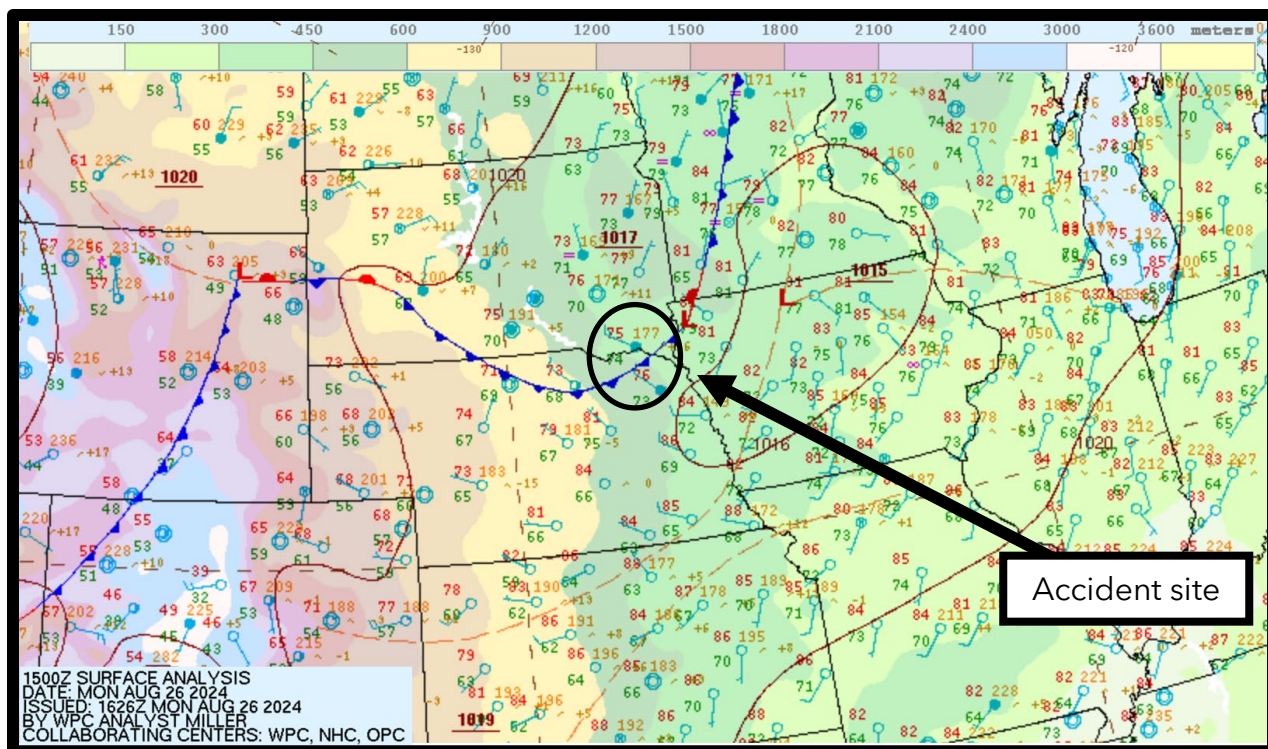


Figure 1. NWS Surface Analysis Chart for 1000 CDT.

1.2 Upper Air Charts

The NWS Storm Prediction Center (SPC) Constant Pressure Charts for 0700 CDT at 925-, 850-, and 700-hPa are presented in figures 2 through 4. The charts indicated low- and mid-level troughs² at 925- through 700-hPa (figures 2 through 4) northeast and southwest of the accident site. The 925-hPa constant pressure chart depicted a westerly wind around 20 knots (figure 2) becoming southwesterly at 20 knots by 700-hPa (figure 4).

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

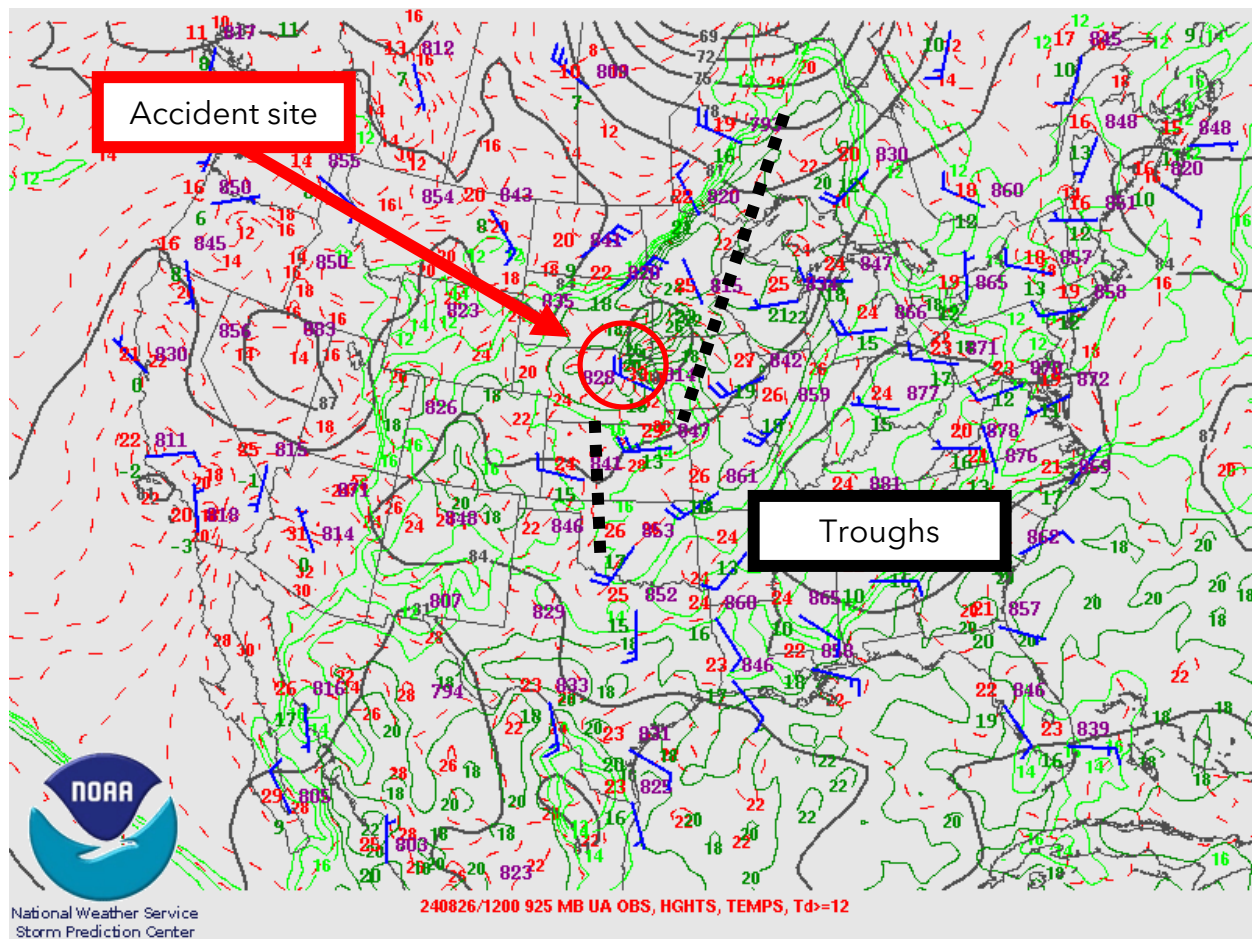


Figure 2. 925-hPa Constant Pressure Chart for 0700 CDT.

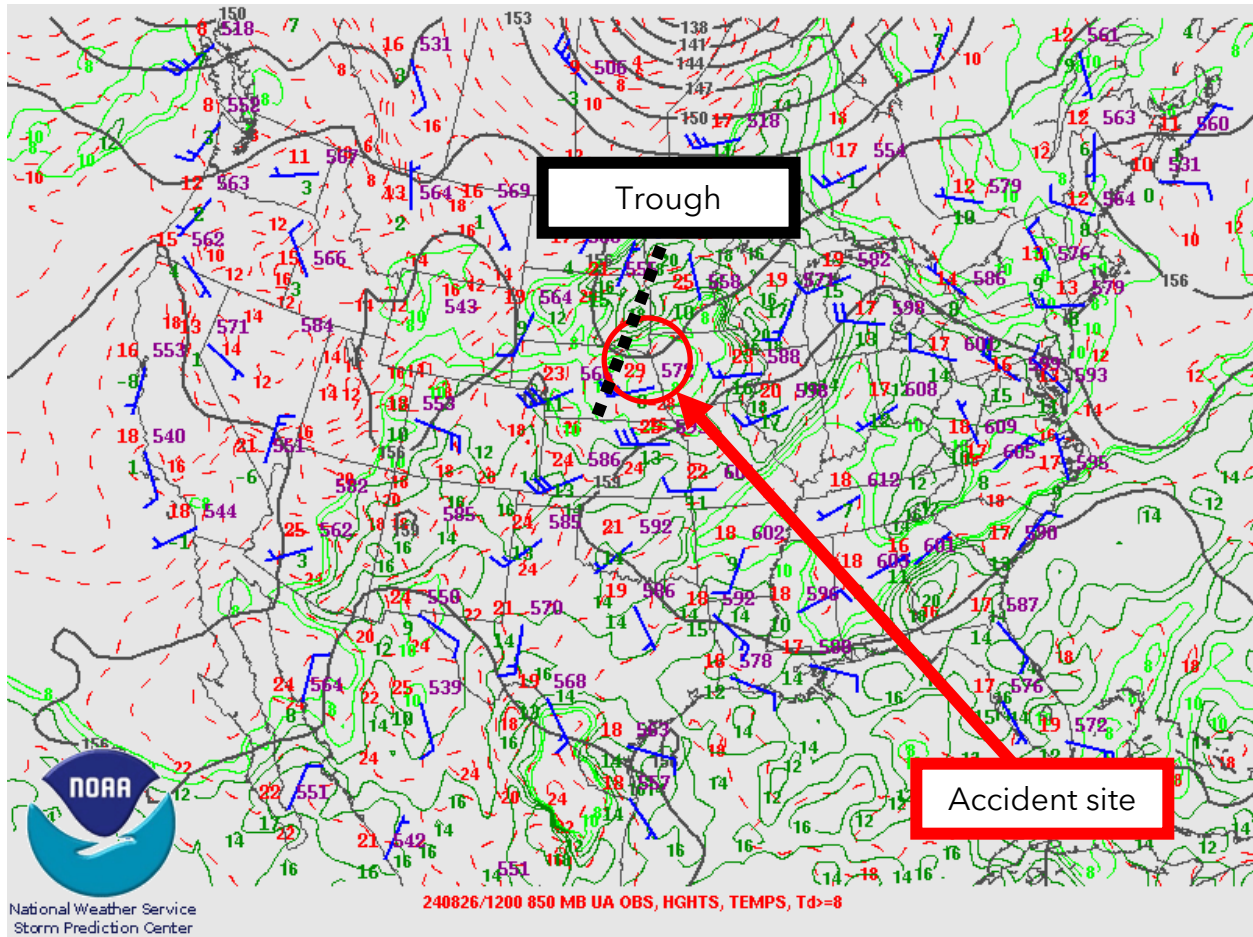


Figure 3. 850-hPa Constant Pressure Chart for 0700 CDT.

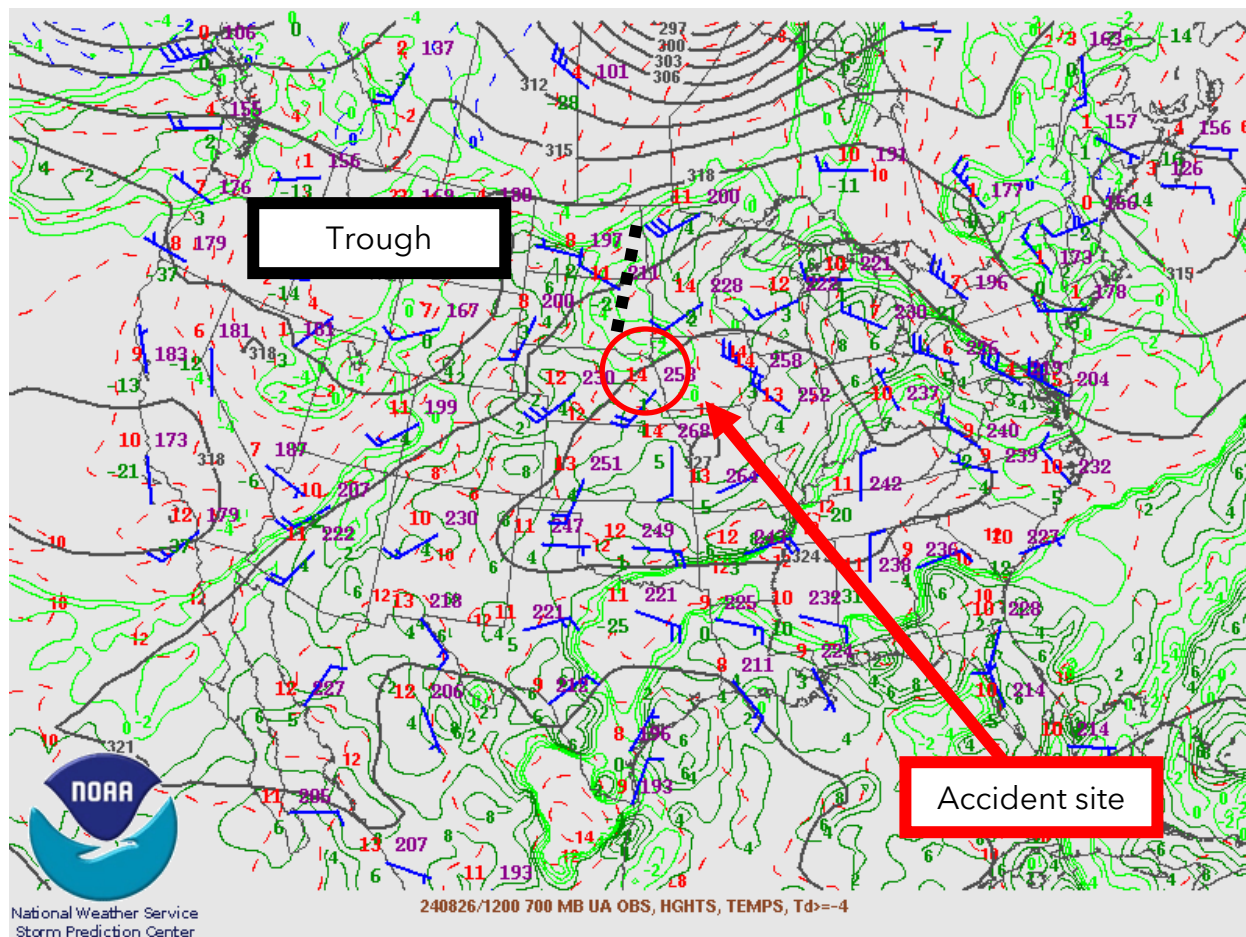


Figure 4. 700-hPa Constant Pressure Chart for 0700 CDT.

2.0 Storm Prediction Center Convective Outlook

SPC issued a Day 1 Convective Outlook at 0758 CDT (figure 5) with the accident site located in an area where a “slight” risk for severe thunderstorms was expected (or a level 2 out of 5 risk). In addition, the accident location was located in a 2% probability of a tornado within 25 miles of a point (figure 6), a 15% probability of one inch diameter hail or larger within 25 miles of a point (figure 7), and a 15% probability of damaging thunderstorms winds or wind gusts of 50 knots or higher within 25 miles of a point (figure 8). The text of the SPC Day 1 Convective Outlook follows figure 8.

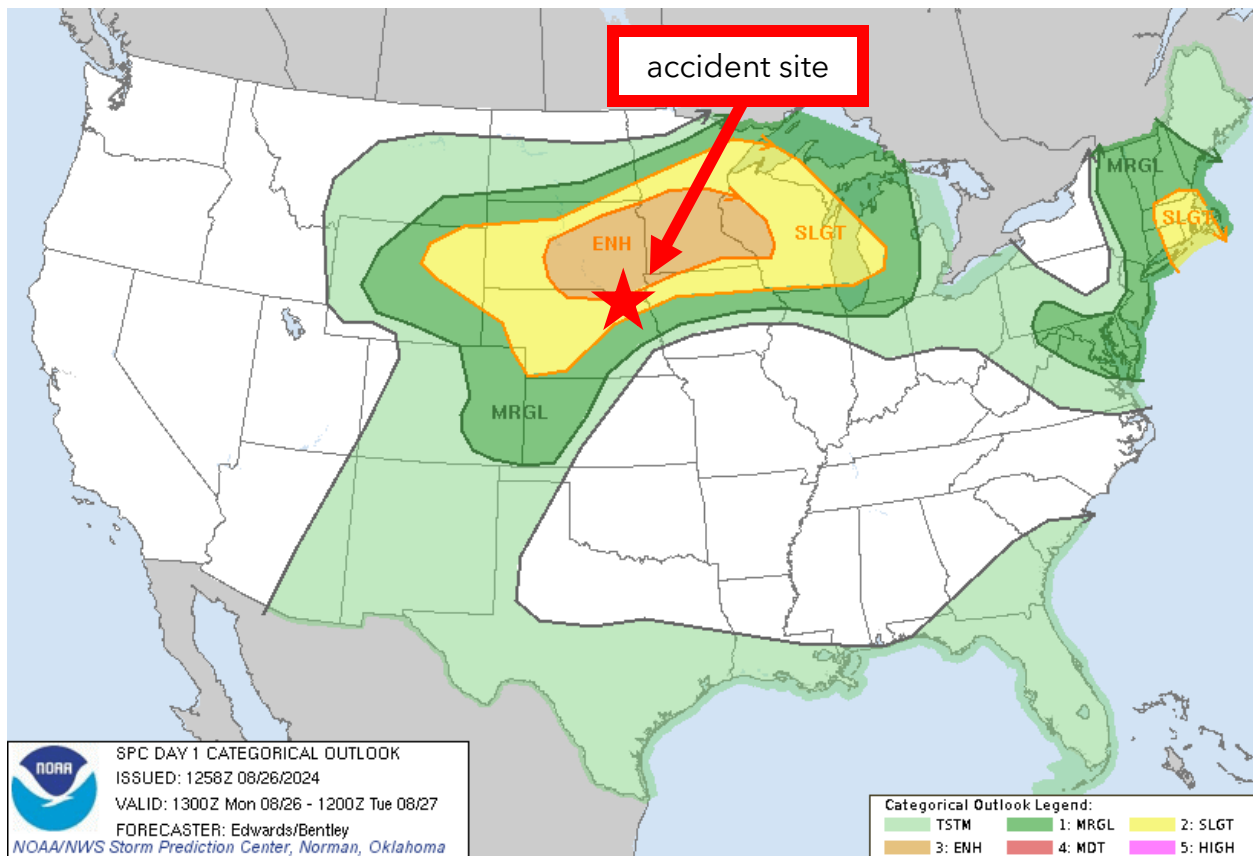


Figure 5. SPC day 1 Convective Outlook valid at the time of the accident.

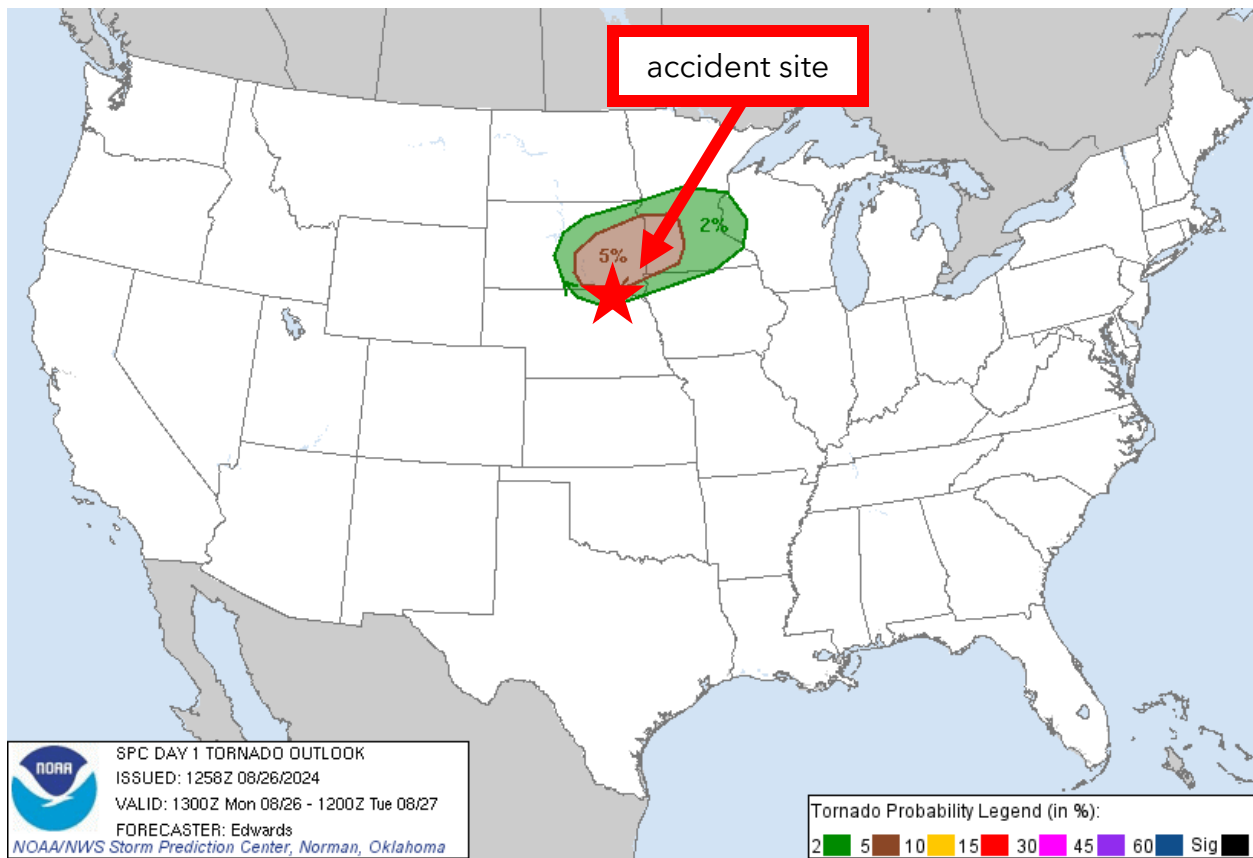


Figure 6. SPC day 1 Tornado Outlook valid at the time of the accident.

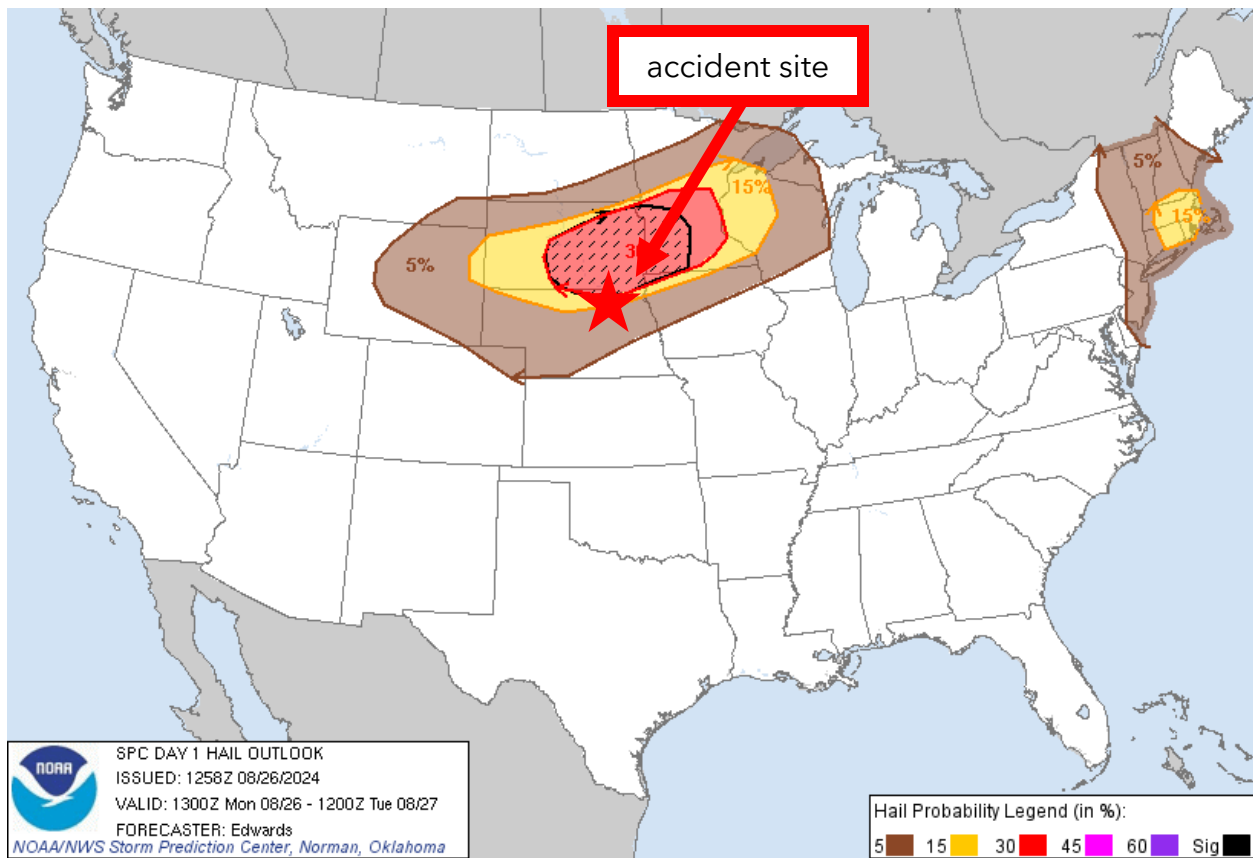


Figure 7. SPC day 1 Hail Outlook valid at the time of the accident.

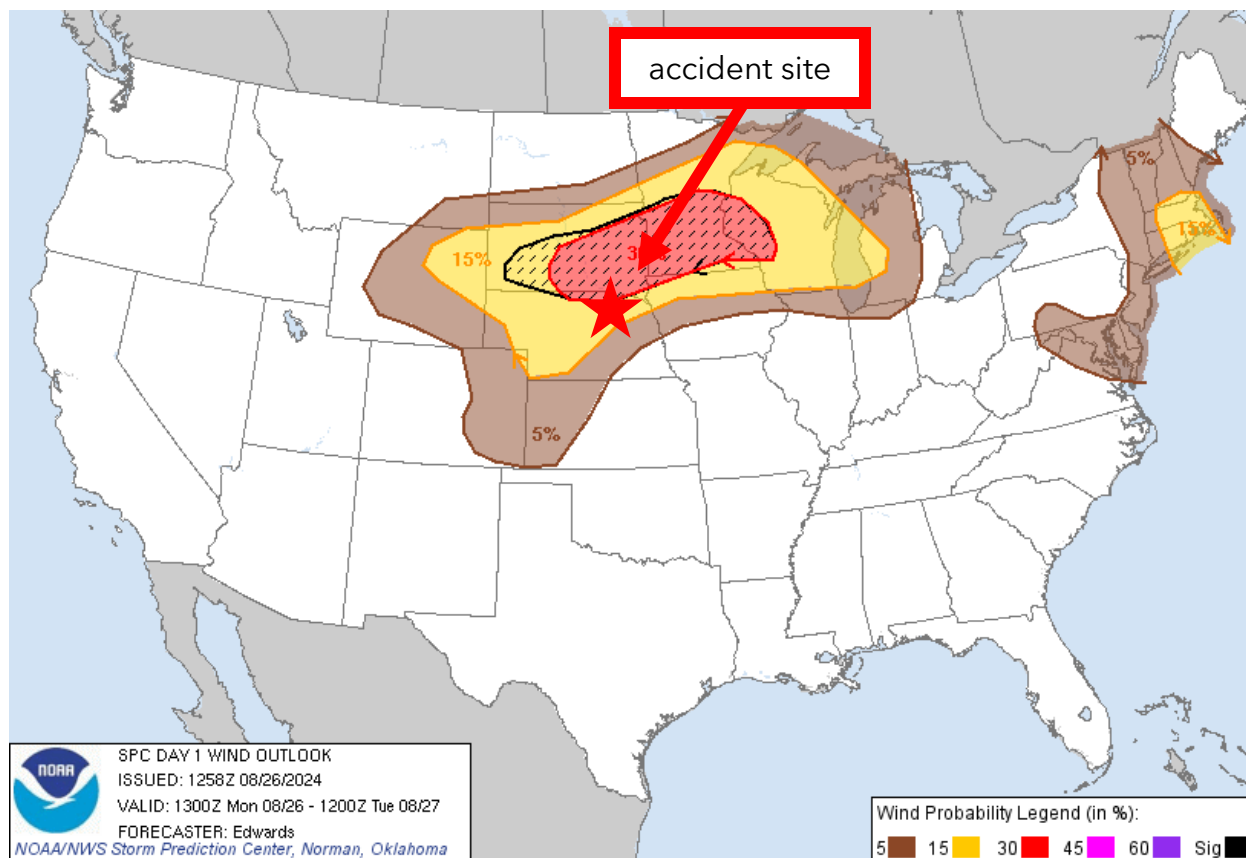


Figure 8. SPC day 1 Wind Outlook valid at the time of the accident.

SPC AC 261258

Day 1 Convective Outlook
NWS Storm Prediction Center Norman OK
0758 AM CDT Mon Aug 26 2024

Valid 261300Z - 271200Z

...THERE IS AN ENHANCED RISK OF SEVERE THUNDERSTORMS ACROSS PARTS OF SOUTH DAKOTA...EXTREME NORTHERN NEBRASKA...MINNESOTA...AND WISCONSIN...

...THERE IS A SLIGHT RISK OF SEVERE THUNDERSTORMS SURROUNDING THE ENHANCED RISK...AND ACROSS PORTIONS OF NEW ENGLAND...

...SUMMARY...

Severe thunderstorm gusts, large to very large hail and a few tornadoes are possible today and tonight across parts of South Dakota, extreme northern Nebraska, Minnesota, and Wisconsin.

...Synopsis...

In mid/upper levels, a persistent and large anticyclone has shifted its center across the southern Plains to the lower Missouri Valley, with ridging northeastward across the Lake Superior and James Bay regions. The ridge will shift eastward across the Upper Great Lakes

and southern QC through the period. This will occur in response to these developments on either side:

1. A broad but not very intense cyclone -- initially centered near the western ME/QC border -- will pivot roughly eastward to the adjoining parts and the Canadian Maritimes through the period. As this occurs, a shortwave trough/vorticity lobe -- now in the western semicircle of the cyclone over the St. Lawrence Valley -- should dig southward across eastern NY and extreme western New England today, then weaken and move offshore from the southern New England Coast tonight.
2. A strong shortwave trough -- initially over western MT, southeastern ID and northern UT -- should move to eastern MT and central WY by 00Z, then to the western Dakotas within 12 more hours. This will foster the northeastward ejection of two weak perturbations, now apparent in moisture-channel imagery over the western NE Panhandle/southeastern WY region into southwestern SD, the other over central/eastern CO. By 00Z, these features should reach eastern ND and eastern/southern SD, respectively.

At the surface, 11Z analysis showed a low near FSD, with cold front arching southwestward across the NE Sandhills then northwestward to another low over east-central WY near CPR. A quasistationary frontal zone was drawn from the low northeastward over western/northern MN. The low should move slowly eastward today while the poleward frontal extension moves little, and the cold front moves southeastward into northwestern IA and eastern/central NE. The western segment of that front should hang up over northwestern NE and east-central WY amid mass response to the approaching shortwave trough, which also should induce a surface trough and perhaps secondary/reinforcing baroclinic zone across the lee of the north-central Rockies over eastern WY and into southeastern MT.

...North-central Plains to Upper Midwest...

Two main rounds of severe-thunderstorm potential are apparent today, each crossing portions of the main risk area, which represents an aggregated severe potential from both complexes. From east to west:

1. Strong-severe thunderstorms should develop over eastern SD near or north/northwest of the surface low this afternoon -- perhaps arising as early and far west as central SD during midday. This activity will be related to maximized low-level lift associated with the low, and a plume of large-scale ascent preceding the weaker shortwave troughs, and already supporting convection at this time over western SD. Whether the ongoing convection will be continuous with later activity is uncertain. In either event, this eastern complex should intensify substantially over the southeastern SD/southwestern MN/northwestern IA vicinity as it crosses the low-level baroclinic zone and encounters a strongly unstable, richly moist boundary layer, with upper 60s to mid 70s surface dewpoints. Beneath steep lower-middle-level lapse rates, this should contribute to a corridor of 3500-5000 J/kg MLCAPE near I-90 from the FSD area to near the Mississippi River, decreasing to a still-favorable 2000-4000 J/kg in central MN. Supercells with destructive hail,

potentially significant-severe gusts, and a few tornadoes are possible, though so is fairly quick upscale expansion.

2. An area of convection may develop as early as late morning to midday well behind the surface cold front, in higher terrain of northern/central WY, initially with a marginal severe threat. This convection should be supported by at least modest low/middle-level moisture, and strong cooling/destabilization aloft, related to the swath of strong large-scale DCVA/ascent immediately preceding the northern Rockies shortwave trough. This activity may be an outgrowth or extension of nonsevere thunderstorms now over extreme western WY near the Star and Hams Fork Valleys and adjacent ranges. These thunderstorms should organize into an MCS and expand/intensify as activity proceeds into greater moisture, instability and storm-relative/post-frontal low-level flow to the east, on the High Plains and near the Black Hills.

Northeasterly to easterly flow behind the front and near the trough, beneath strengthening southwest flow aloft, will support 45-60 kt effective-shear magnitudes. Buoyancy will increase eastward as the convection -- which may already have evolved into an outflow-dominant arc by the time it gets into greater moisture east of the Black Hills -- further intensifies into the northern part of a corridor of 1500-2000 J/kg MLCAPE and still-favorable storm-relative boundary-layer flow. Some of this convection may be supercellular to the extent it can remain at least somewhat discrete, with severe wind and large to very large hail possible. With time, wind will dominate as the main threat. This activity should encounter the outflow from the other complex somewhere over southeastern SD or southern MN tonight.

Mesoscale uncertainty over the positioning and strength of the outflow (and thus threat of severe to its poleward side) preclude greater unconditional probabilities at this time. Still, a focused corridor of destructive winds remains a possibility across southern parts of SD/MN, some of it potentially affecting areas struck by the first complex.

...Northeastern CONUS...

Widely scattered to scattered thunderstorms should develop over portions of eastern NY and New England, as well as parts of western/central PA and northwestern MD -- each moving southward to southeastward through a favorable airmass for organized convection. Strong to locally severe gusts are possible, along with severe hail.

Over the New England part of the outlook, cold air aloft, overlying low-level moisture represented by mid/upper 50s F surface dewpoints, should combine with limited diurnal heating to remove MLCINH, and support peak/preconvective MLCAPE in the 1000-1500 J/kg range. Though low-level flow will be modest, relatively straight/lengthy hodographs will support some hail potential. Further southwest, greater low-level moisture (dewpoints mostly mid/upper 60s to near 70 F at lower elevations) but weaker mid/upper-level lapse rates

will be present, yielding similar CAPE values but with different vertical distribution of buoyancy (more skewed to low levels). Still, enough deep/speed shear will be present to support organized multicells and at least transient/isolated supercells.

..Edwards/Bentley.. 08/26/2024

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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 Aviation Routine Weather Reports (METARs) and Special Reports (SPECIs)³. The following observations were taken from standard code and are provided in plain language. Figure 9 is a local sectional chart with the accident site and the closest weather reporting location marked. A magnetic variation⁴ of 3.5° east was indicated over the area.

³ Latest criteria for SPECIs can be found in the Federal Meteorological Handbook: [Federal Meteorological Handbook Number 1, Surface Weather Observations and Reports \(icams-portal.gov\)](https://icams-portal.gov/fmh1/)

⁴ Magnetic variation - The angle (at a particular location) between magnetic north and true north. Latest measurement taken from <https://skyvector.com/>

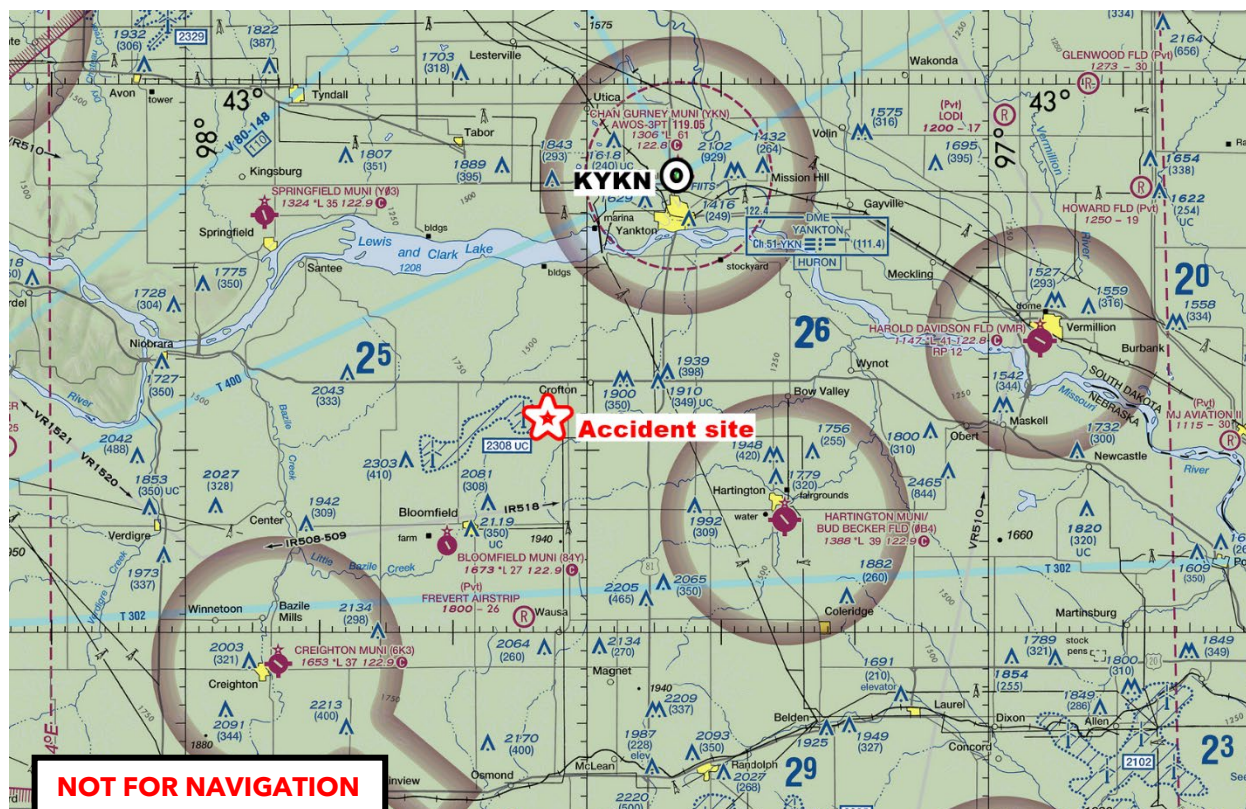


Figure 9. FAA sectional aeronautical chart of the accident area with the locations of the accident site and surface observation site noted.

The closest official weather reporting site was from Chan Gurney Municipal Airport (KYKN), Yankton, South Dakota, located 15 miles north-northeast of the accident site (figure 9) at an elevation of 1,306 ft. KYKN had an Automated Weather Observing System (AWOS⁵) and its longline reports⁶ were not augmented. The following observations were reported surrounding the accident time:⁷

[0616 CDT] SPECI KYKN 261116Z AUTO 30006KT M1/4SM FG BKN002
OVC018 24/24 A2999 RMK AO2 \$

⁵ AWOS - Automated Weather Observing System is equipped with meteorological instruments to typically observe and report temperature, dewpoint, wind speed and direction, visibility, cloud coverage and ceiling up to 12,000 feet, and altimeter setting. AWOS are maintained by the FAA. Certain AWOS may have different reporting or observational equipment.

⁶ "Longline" refers to the dissemination of weather observations with the intent that they are available in near-real time to national databases and accessible to the general global public from a large number of vendors. This does not include public accessibility to observations from a reporting station's Very High Frequency (VHF; line-of-site) or telephone broadcast, where applicable. Longline dissemination of weather observations is the primary vehicle through which the weather observations are distributed.

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

[0631 CDT] SPECI KYKN 261131Z AUTO 30003KT 1/4SM -RA FG
BKN002 OVC018 24/24 A3000 RMK AO2 RAB19 P0000 \$

[0656 CDT] METAR KYKN 261156Z AUTO 31005KT 1/4SM FG BKN002
OVC021 24/24 A3000 RMK AO2 RAB19E32 SLP158 P0000 60000
T02440244 10244 20228 53013 \$

[0714 CDT] SPECI KYKN 261214Z AUTO 31005KT 3/4SM BR BKN002
OVC021 24/24 A3001 RMK AO2 \$

[0740 CDT] SPECI KYKN 261240Z AUTO 29008KT 1/4SM FG BKN002
OVC019 24/24 A3002 RMK AO2 \$

[0756 CDT] METAR KYKN 261256Z AUTO 29006KT 1/4SM FG BKN002
OVC019 24/24 A3002 RMK AO2 SLP164 T02390239 \$

[0818 CDT] SPECI KYKN 261318Z AUTO 31006KT M1/4SM -RA FG
BKN002 OVC019 24/24 A3002 RMK AO2 RAB17 P0000 \$

**[0825 CDT] SPECI KYKN 261325Z AUTO 30005KT 1/4SM -RA FG
BKN002 OVC019 24/24 A3002 RMK AO2 RAB17 P0000 \$**

ACCIDENT TIME 0841 CDT

**[0856 CDT] METAR KYKN 261356Z AUTO 29009KT 1/4SM FG
BKN002 OVC019 24/24 A3004 RMK AO2 RAB17E26 SLP173
P0000 T02440244 \$**

[0903 CDT] SPECI KYKN 261403Z AUTO 24013KT 3/4SM BR BKN002
OVC019 24/24 A3008 RMK AO2 PRESRR \$

[0907 CDT] SPECI KYKN 261407Z AUTO 22012G17KT 2SM BR BKN002
OVC019 24/24 A3009 RMK AO2 PRESRR \$

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

KYKN weather at 0825 CDT, automated, wind from 300° at 5 knots, visibility ¼ mile, light rain, fog, broken ceiling at 200 ft above ground level (agl), overcast skies at 1,900 ft agl, temperature of 24°C, dew point temperature of 24°C, and an altimeter setting of 30.02 inches of mercury (inHg). Remarks, automated station with a precipitation discriminator, rain began at 0817 CDT, a trace of precipitation since 0756 CDT, maintenance indicator on.

KYKN weather at 0856 CDT, automated, wind from 290° at 9 knots, visibility ¼ mile, fog, broken ceiling at 200 ft agl, overcast skies at 1,900 ft agl, temperature of 24°C, dew point temperature of 24°C, and an altimeter setting of 30.04 inHg. Remarks, automated station with a precipitation discriminator, rain began at 0817 and ended at 0826 CDT, sea level pressure 1017.3 hPa, a trace of precipitation since 0756 CDT, temperature 24.4°C, dew point temperature 24.4°C, maintenance indicator on.

The observations from the KYKN reported LIFR⁸ conditions prevailing from 0600 through the time of the accident.

4.0 Meteorological Tower Information

Weather information from a meteorological tower located around a 200 ft from the accident site was retrieved and its information can be found in figure 10 below and attachment 1. The tower had a surface elevation of 1,670 ft with the wind speed sensor located at 260 ft agl, the pressure sensor at 246 ft agl, the temperature and humidity sensors at 247 ft agl. Around the accident time, the wind speed ranged from 7 to 16 knots (3.8 to 8.1 m/s) from the west to northwest direction, the temperature was around 24.8°C, and the humidity was 100%. Starting at 0340 CDT through 1140 CDT the humidity was indicated as 100%.

⁸ 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.

PCTimeStamp	Met1_Avg. Wind dir. (Deg)	Met1_Avg. Wind speed (m/s)	Met1_Avg. Pressure (mBar)	Met1_HumiditySens1_Avg (%)	Met1_TempAvg (deg C)
8/26/2024 2:40	295	7.2	943	90	27.3
8/26/2024 2:50	294	7.3	943	95	27.2
8/26/2024 3:00	292	8.8	943	77	27
8/26/2024 3:10	294	8.8	943	68	26.6
8/26/2024 3:20	309	8.6	943	90	26.3
8/26/2024 3:30	311	8	943	99	26.1
8/26/2024 3:40	302	5.4	944	100	25.8
8/26/2024 3:50	293	4.5	944	100	25.7
8/26/2024 4:00	309	6.2	944	100	25.6
8/26/2024 4:10	313	5.7	944	100	25.5
8/26/2024 4:20	302	5.3	944	100	25.4
8/26/2024 4:30	303	6.2	944	100	25.2
8/26/2024 4:40	301	5.9	944	100	25.1
8/26/2024 4:50	317	6.5	944	100	25
8/26/2024 5:00	320	6.2	944	100	24.9
8/26/2024 5:10	321	6.5	944	100	24.9
8/26/2024 5:20	324	6.7	944	100	24.8
8/26/2024 5:30	327	6.4	944	100	24.8
8/26/2024 5:40	325	6.5	944	100	24.7
8/26/2024 5:50	327	5.5	944	100	24.7
8/26/2024 6:00	326	5	945	100	24.8
8/26/2024 6:10	313	5.2	945	100	24.8
8/26/2024 6:20	309	5.6	945	100	24.8
8/26/2024 6:30	315	5.9	945	100	24.8
8/26/2024 6:40	319	6.2	945	100	24.8
8/26/2024 6:50	321	6.4	945	100	24.9
8/26/2024 7:00	325	6.5	945	100	24.9
8/26/2024 7:10	330	6.6	945	100	24.9
8/26/2024 7:20	330	5.9	945	100	24.9
8/26/2024 7:30	336	5.9	945	100	25
8/26/2024 7:40	335	6.1	945	100	25.1
8/26/2024 7:50	319	5.9	945	100	25.2
8/26/2024 8:00	252	11	947	100	25.3
8/26/2024 8:10	282	6.8	947	100	25.2
8/26/2024 8:20	273	6.3	947	100	25
8/26/2024 8:30	275	3.8	947	100	24.9
8/26/2024 8:40	290	6	946	100	24.8
8/26/2024 8:50	300	8.1	946	100	24.8
8/26/2024 9:00	296	7.1	946	100	24.8
8/26/2024 9:10	299	6.5	946	100	24.9
8/26/2024 9:20	325	5.7	946	100	25
8/26/2024 9:30	320	7	946	100	25.2
8/26/2024 9:40	322	5.7	946	100	25.4
8/26/2024 9:50	333	4.7	946	100	25.6

Figure 10. Weather information from the meteorological tower with time in CDT.

5.0 Upper Air Sounding

A High-Resolution Rapid Refresh (HRRR)⁹ model sounding was created¹⁰ for the approximate accident site coordinates for 0900 CDT. The HRRR sounding was plotted on a standard Skew-T Log P diagram¹¹ from the surface to 600-hPa (or approximately 14,000 ft) using the RAOB¹² software package and is included as figure 11. The sounding depicted an elevation of 1,598 ft over the grid point with a near surface temperature of 25.4°C, a dew point temperature of 24.0°C, with a relative humidity of 92%. The lifted condensation level (LCL)¹³ and the level of free convection (LFC)¹⁴ were identified at 597 ft agl (2,195 ft msl), and the convective condensation level (CCL)¹⁵ at 8,156 ft msl. The freezing level was located at 15,667 ft. The precipitable water value was 1.71 inches.

⁹ The HRRR is a NOAA real-time three-kilometer resolution, hourly-updated, cloud-resolving, convection-allowing atmospheric model, initialized by three-kilometer grids with three-kilometer radar assimilation. Radar data is assimilated in the HRRR every 15 minutes over a one-hour period.

¹⁰ HRRR sounding was created using NOAA Air Resource Laboratory: [READY Archived Meteorology \(noaa.gov\)](https://ready.arl.noaa.gov/).

¹¹ Skew T log P diagram - is a standard meteorological plot using temperature and the logarithmic of pressure as coordinates, used to display winds, temperature, dew point, and various indices used to define the vertical structure of the atmosphere.

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

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

¹⁴ 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.

¹⁵ 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.

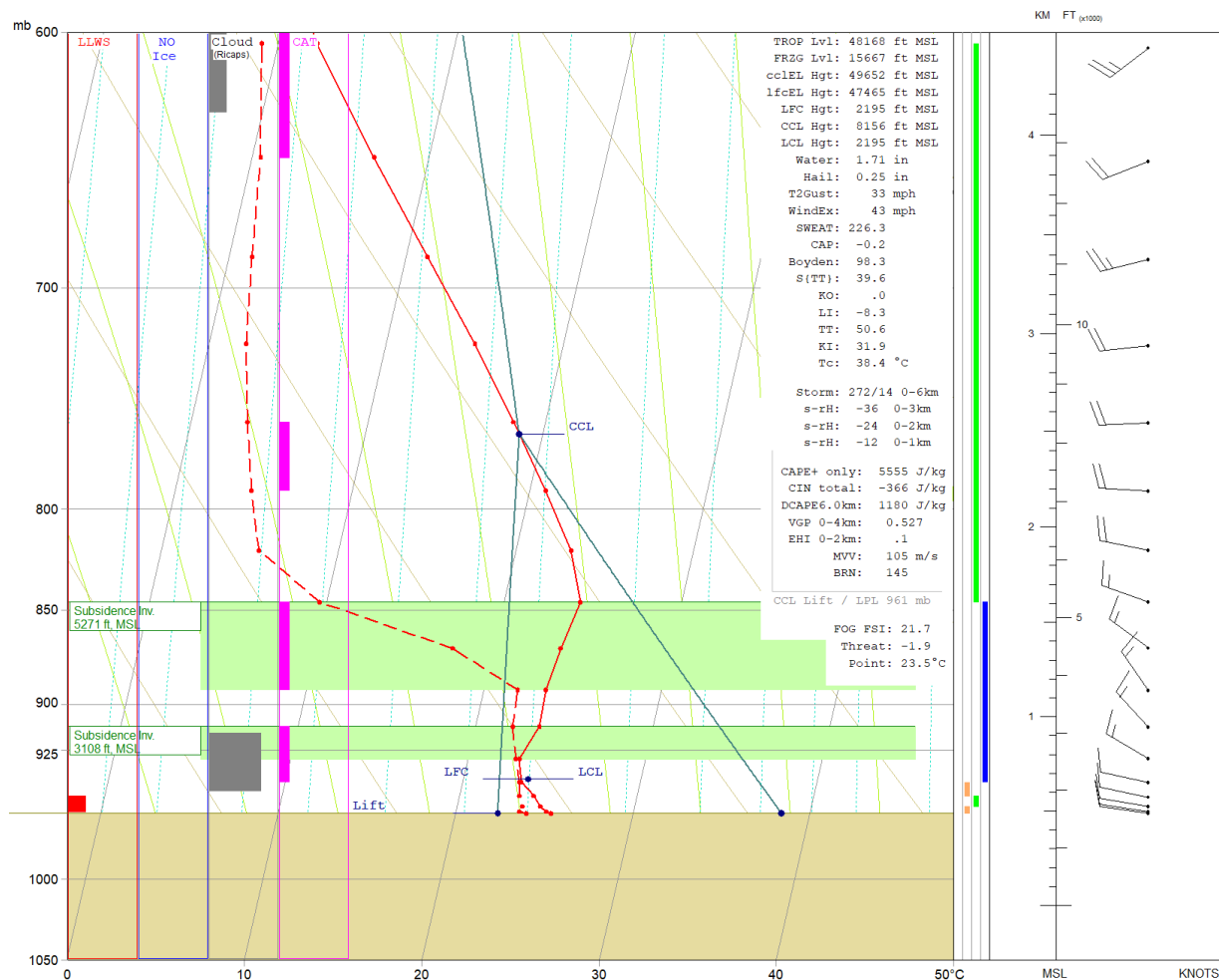


Figure 11. 0900 CDT HRRR sounding.

The 0900 CDT HRRR sounding identified an unstable and conditionally unstable environment from the surface through 500 ft, then a stable layer between 500 ft and 5,250 ft. RAOB indicated a cloud layer (gray bar on left axis) between 400 ft agl through 1,400 ft agl with another cloud layer starting at 13,000 ft. No icing was noted below 12,000 ft. The top of subsidence inversions¹⁶ were indicated at 3,108 ft and 5,271 ft.

The 0900 CDT HRRR sounding wind profile indicated a near-surface wind from 280° at 9 knots with the wind remaining from the west to northwest through 14,000 ft. The wind speed increased to 15 knots by 2,500 ft at to 25 knots by 14,000 ft. Light low-level wind shear (LLWS) was noted by RAOB below 500 ft. Very light clear air turbulence (CAT) was noted by RAOB in several layers between 500 ft agl through 14,000 ft.

¹⁶ Inversion - A departure from the usual decrease of the value of an atmospheric property with increasing altitude; also, the layer through which this departure occurs (the "inversion layer"), or the lowest altitude at which the departure is found (the "base of the inversion").

6.0 Satellite Data

Geostationary Operational Environmental Satellite number 16 (GOES-16) visible and infrared data were obtained from an archive at the Space Science Engineering Center at the University of Wisconsin-Madison in Madison, Wisconsin, and processed using the Man-computer Interactive Data Access System software. Visible and infrared imagery (GOES-16 bands 2 and 13, respectively) at wavelengths of 0.64 microns (μm) and 10.3 μm , respectively, were retrieved for the period from 0600 CDT through 1400 CDT and reviewed, and the closest images to the time of the accident were documented.

Figure 12 presents the GOES-16 visible image at 0841 CDT at 2X magnification with the accident site highlighted with a red square. Cloud cover was indicated above the accident site with the low-level cloud cover moving southward across the accident site at the accident time and the mid- and upper-level cloud cover moving from southwest to northeast (attachment 2). Figure 13 presents the GOES-16 infrared image at 0841 CDT at 6X magnification with the accident site highlighted with a red square. Cloud cover was indicated above the accident site with lower brightness temperatures (blue and green colors; higher cloud tops) located southwest through northwest of the accident site. The brightness temperature above the accident site was 254 Kelvin¹⁷ which would have been near 26,000 ft (not shown) based on the vertical temperature profile provided by the 0900 CDT HRRR sounding. It should be noted these figures have not been corrected for any parallax error. While the accident occurred after sunrise, the lower level cloud cover could be seen moving southward before sunrise. The Nighttime Microphysics Red, Green, Blue (RGB) imagery¹⁸ indicated there were two different levels of cloud cover above the accident site with a combination of low-level water clouds and another layer of high cirriform clouds composed of ice crystals (attachment 3). The low-level water clouds moved over and remained in place above the accident site after 0501 CDT with the higher ice clouds spreading across the accident site close to sunrise.

¹⁷ around -19°C

¹⁸ https://weather.msfc.nasa.gov/sport/training/quickGuides/rgb/QuickGuide_NtMicro_GOESR_NASA_SPoRT_20191206.pdf

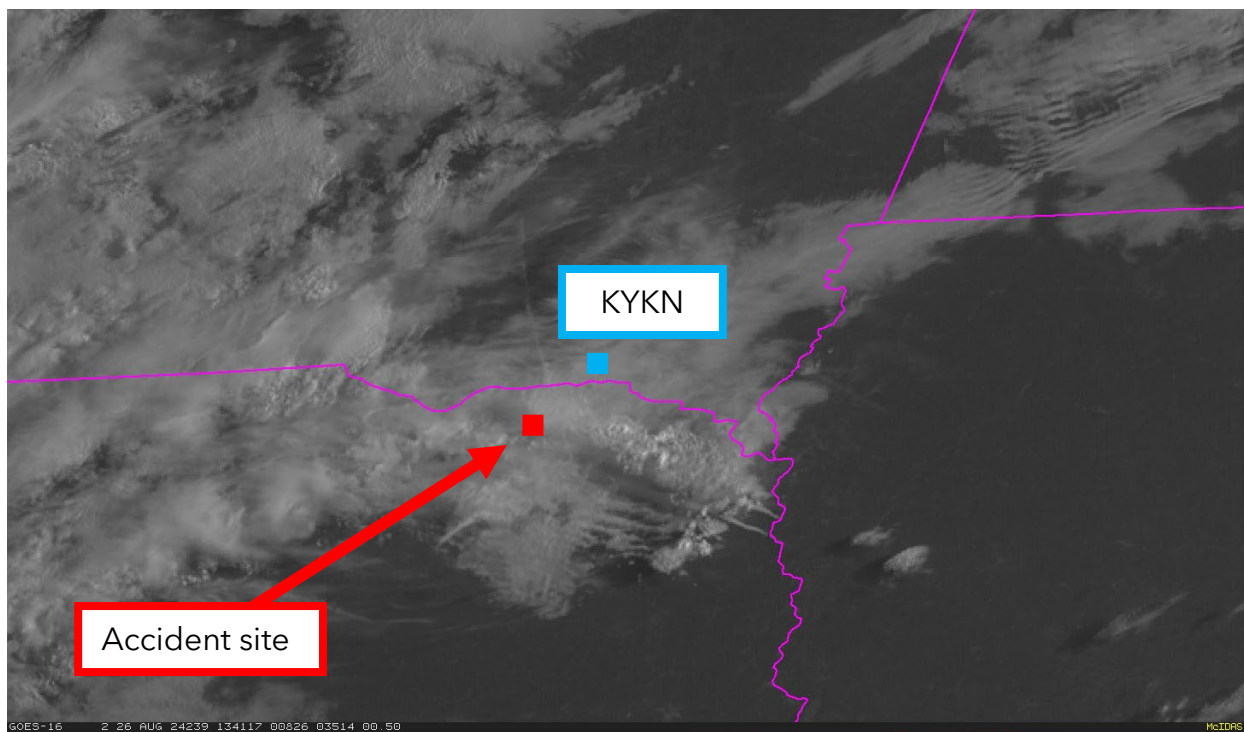


Figure 12. GOES-16 visible image at 0841 CDT.

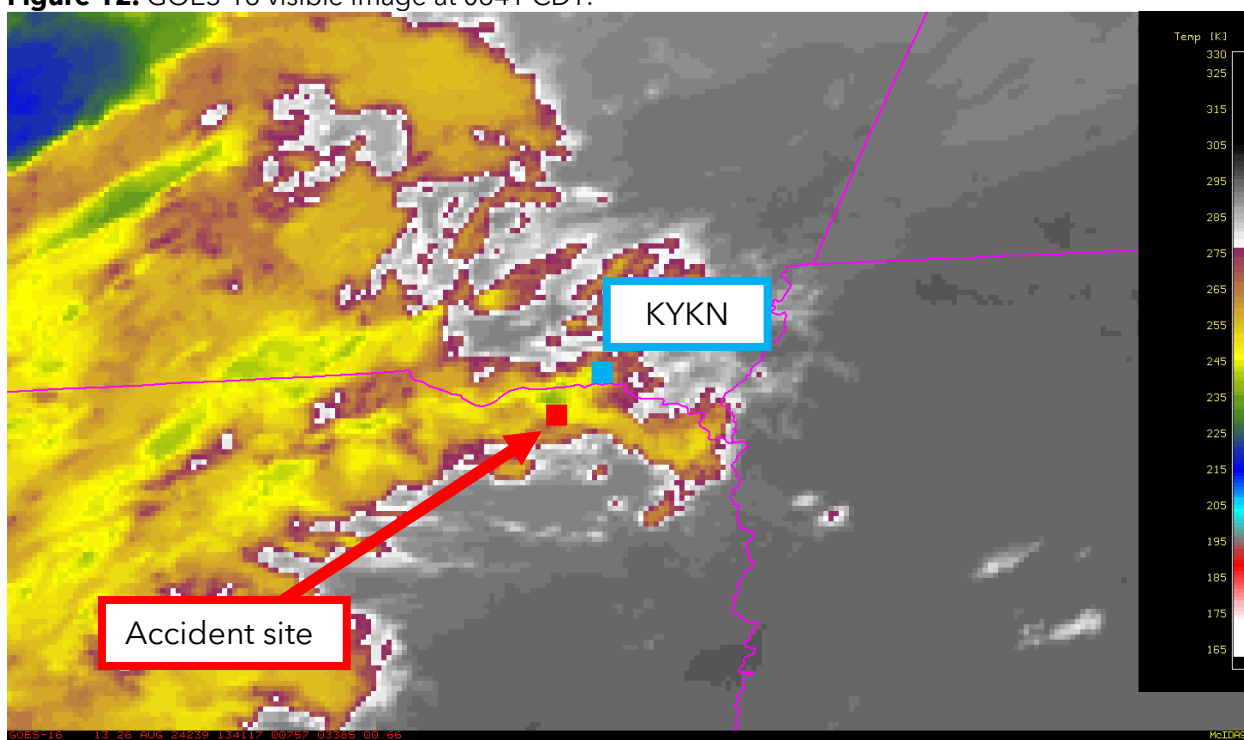


Figure 13. GOES-16 infrared image at 0841 CDT.

7.0 National Radar Imagery

A regional view of the NWS National Reflectivity Mosaic is included as figure 14 for 0840 CDT with the approximate location of the accident site marked by a red circle. The mosaic imagery depicted echoes of 20 to 40 dBZ¹⁹ above the accident site.

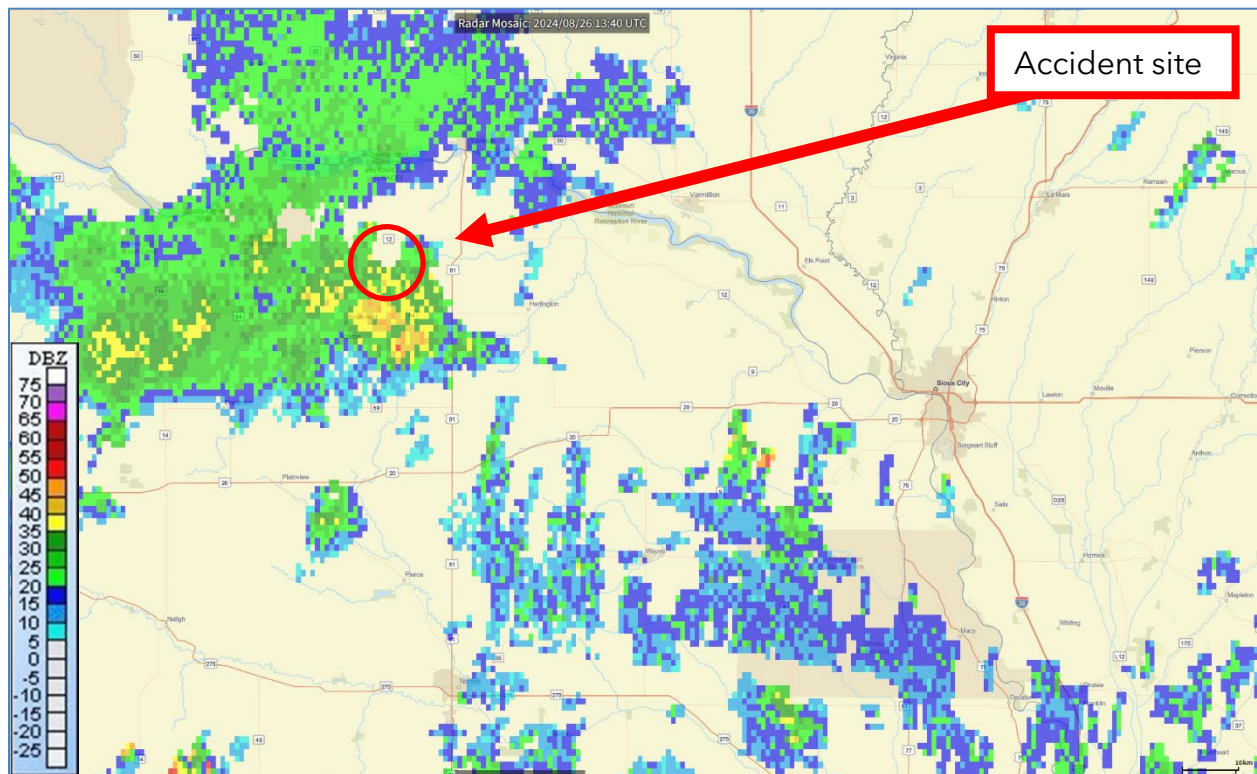


Figure 14. National Reflectivity Mosaic for 0840 CDT.

8.0 Weather Surveillance Radar Imagery

The closest NWS Weather Surveillance Radar-1988 Doppler (WSR-88D)²⁰ to the accident site was from Sioux Falls (KFSD), South Dakota, located 64 miles northeast of the accident site. The Level II archive radar data were obtained from the NCEI utilizing the NEXRAD Data Inventory Search and displayed using the NOAA's Weather and Climate Toolkit software.

¹⁹ 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.

²⁰ 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.

8.1 Volume Scan Strategy

During the period surrounding the accident, the KFSD WSR-88D radar was operating in the precipitation mode VCP-215²¹ (figure 15). The following figure 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.

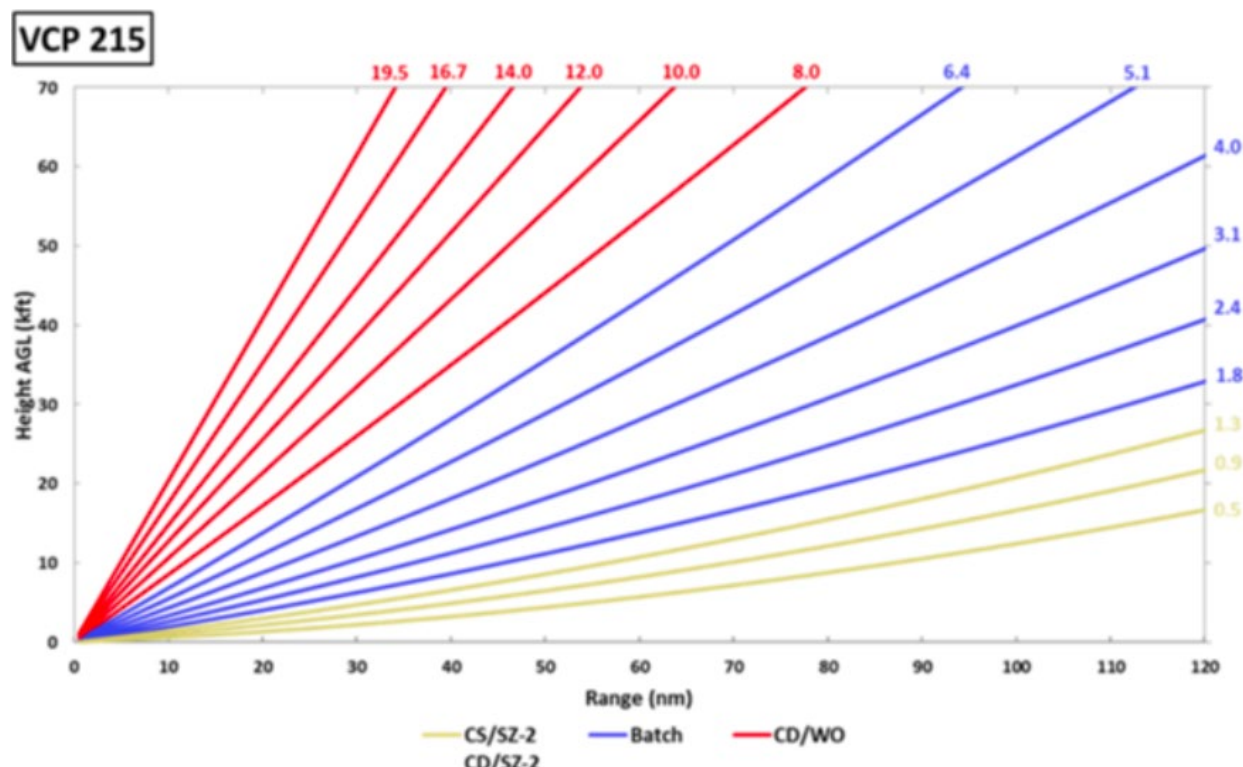


Figure 15. VCP-215 precipitation Mode Scan Strategy.

²¹ 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)

8.2 Beam Height Calculation

Assuming standard refraction²² of the KFSD WSR-88D radar beam with the antenna elevation at 1,495 ft, and considering a beamwidth²³ of 0.95°, the following table shows the approximate heights for the 0.44° radar beam's centers, tops and bases over the accident site. These heights have been rounded to the nearest 10 ft.

ANTENNA ELEVATION	BEAM CENTER	BEAM BASE	BEAM TOP
KFSD 0.44°	7,200 ft	3,970 ft	10,420 ft

Based on the radar height calculations, the elevation scans reviewed from KFSD listed in the above table combined to depict conditions between 3,970 ft and 10,420 ft over the accident site.

8.3 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. The FAA Aviation Weather Handbook 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 to 50 dBZ, inclusive. Finally, any dBZ values above 50 dBZ shall be described as "extreme."

²² Standard Refraction in the atmosphere is when the temperature and humidity distributions are approximately average, and values set at the standard atmosphere.

²³ Beamwidth - the angular separation between the half power points on the antenna radiation pattern, where the gain is one half the maximum value.

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.

8.4 Base Reflectivity Data and Lightning Data

Figures 16-18 present the KFSD WSR-88D base reflectivity images for the 0.44° elevation scans initiated at times between 0836:47 and 0846:36 CDT with resolutions of 0.5° X 250 m. These images depicted portions of reflectivity values between 15 and 35 dBZ moving northeast across the accident site between 0841 and 0846 CDT.

There were no lightning flashes²⁵ reported within 30 miles of the accident site within 15 minutes of the accident time.²⁶

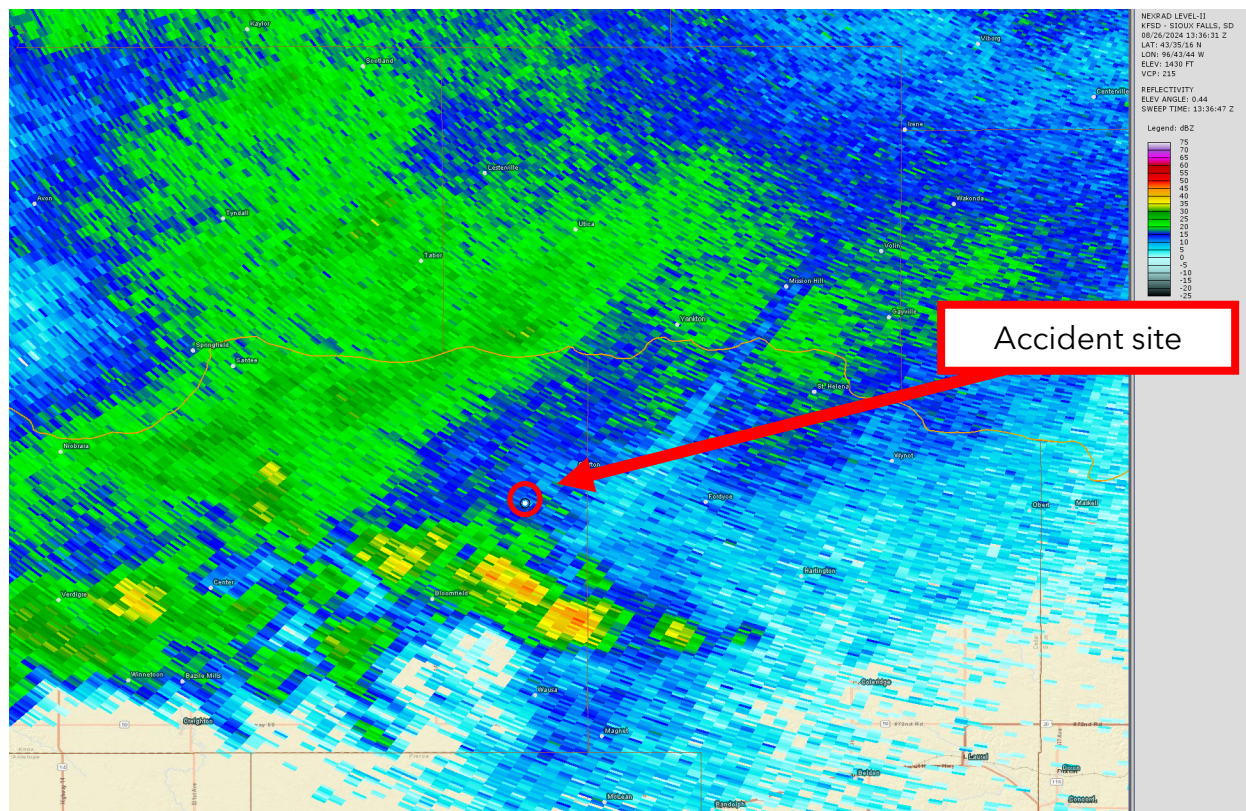


Figure 16. KFSD WSR-88D reflectivity for the 0.44° elevation scan initiated at 0836:47 CDT with the accident site marked with the red circle.

²⁵ 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.

²⁶ A review of Earth Networks Total Lightning network and GOES-16 Geostationary Lightning Mapper (GLM) was done.

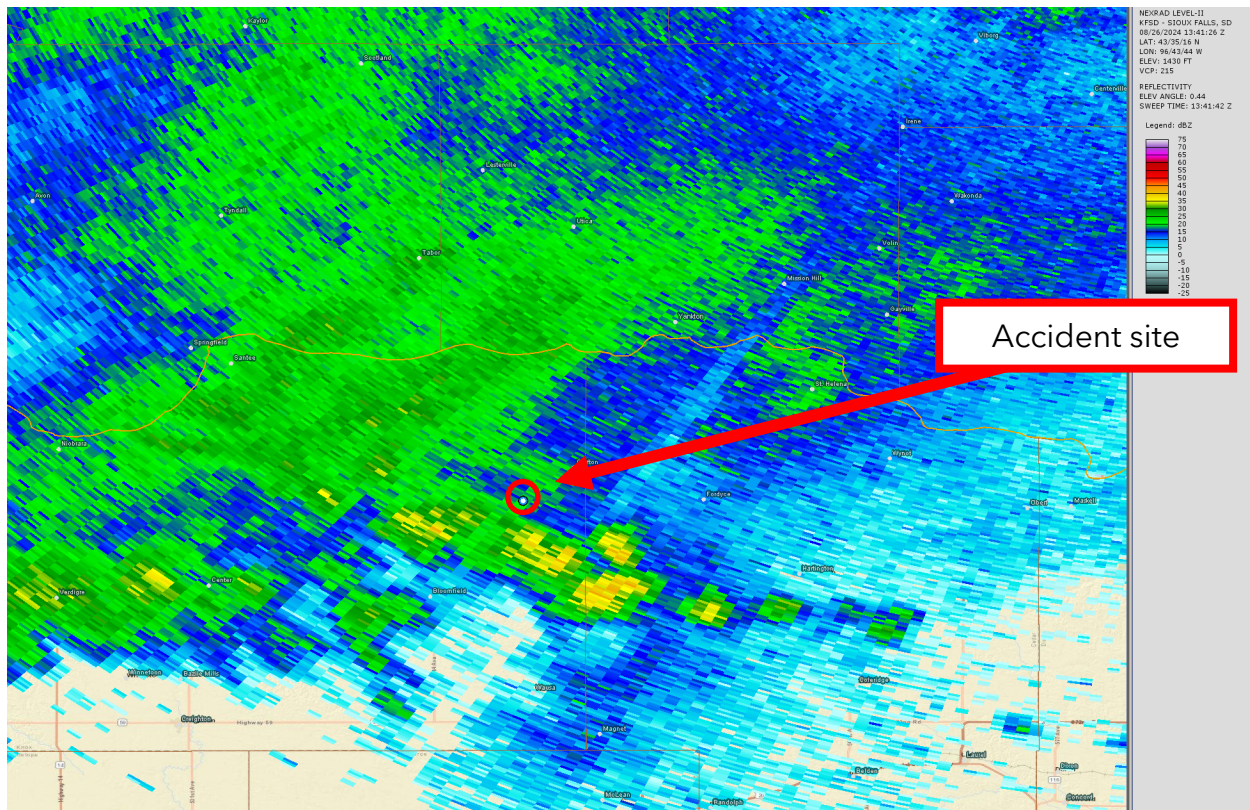


Figure 17. KFSD WSR-88D reflectivity for the 0.44° elevation scan initiated at 0841:42 CDT with the accident site marked with the red circle.

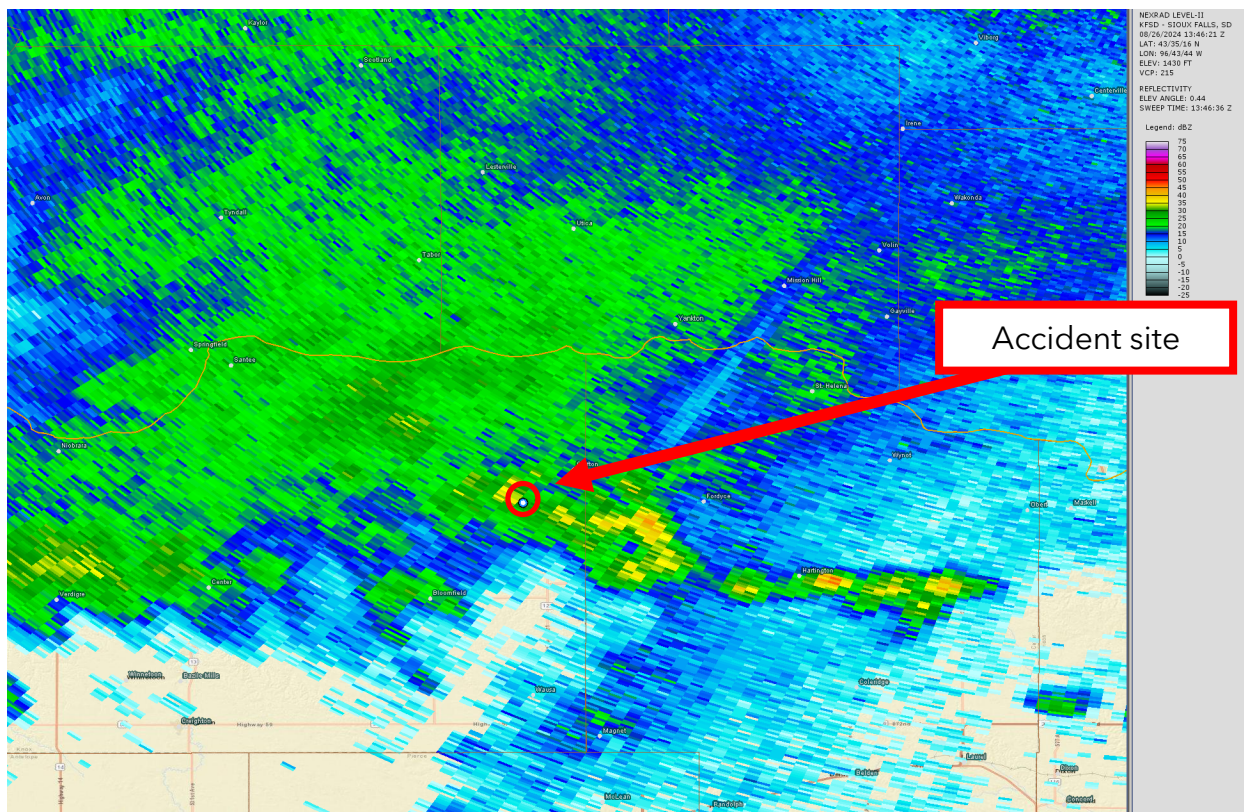


Figure 18. KFSD WSR-88D reflectivity for the 0.44° elevation scan initiated at 0846:36 CDT with the accident site marked with the red circle.

9.0 Pilot Reports

The longline-disseminated pilot reports²⁷ (PIREPs) distributed into the national airspace system (NAS) within 2 hours of the accident time and within 100 miles of the accident site for below 18,000 ft are shown here:

FSD UA /OV FSD180007/TM 1341/FLDURGD/TP M20P/SK OVC022-TOP026

OFK UA /OV OFK/TM 1305/FL110/TP C441/SK BASE022-TOP035

FSD UA /OV FSD120004/TM 1209/FLDURGC/TP A320/SK OVC022-TOP025

ONL UA /OV ONL180016/TM 1204/FL150/TP PC24/SK BASE150-TOPUNKN

10.0 Significant Meteorological Information

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

²⁷ Only PIREPs with the World Meteorological Organization headers UBNE**, UBSD**, UBMN**, and UBIA** were considered. These do not include pilot reports only broadcast via radio.

11.0 Center Weather Service Unit Advisories

The Minneapolis (ZMP) Air Route Traffic Control Center (ARTCC) Center Weather Service Unit (CWSU) was responsible for the accident region. There was no Center Weather Advisory (CWA) valid for the accident site at the accident time.

12.0 Graphical Forecasts for Aviation

The Graphical Forecasts for Aviation (GFA) products issued by the NWS Aviation Weather Center (AWC) around 0500 CDT and valid at both 0700 and 1000 CDT are shown in figures 19 through 22. The GFA surface forecasts applicable at 0700 CDT for the accident site indicated LIFR conditions with no chance of precipitation and a west wind of 5 knots. By 1000 CDT, the GFA surface forecasts indicated VFR surface visibilities and a northwest wind of 5 knots. A Graphical AIRMET²⁸ (G-AIRMET) Sierra for IFR conditions was depicted extending over North Dakota and Minnesota north and northeast of the accident site. The GFA cloud forecast applicable to the accident site for 0700 CDT indicated few to scattered cloud cover at the accident site with cloud bases around 2,100 ft. The 1000 CDT GFA cloud forecast indicated a broken ceiling at 2,300 ft with cirrus clouds above. The accident site was on the border of G-AIRMET Zulu valid for 1000 CDT (figure 22). The only human-generated information reflected in the two GFA products were the G-AIRMETs.

²⁸ Graphical AIRMETs (G-AIRMETs), found on the Aviation Weather Center webpage at <http://aviationweather.gov>, are graphical forecasts of en-route weather hazards valid at discrete times no more than 3 hours apart for a period of up to 12 hours into the future (for example, 00, 03, 06, 09, and 12 hours). G-AIRMETs are snap shots at discrete time intervals as defined above. The text AIRMET is the result of the production of the G-AIRMET but provided in a time smear for a 6hr valid period.

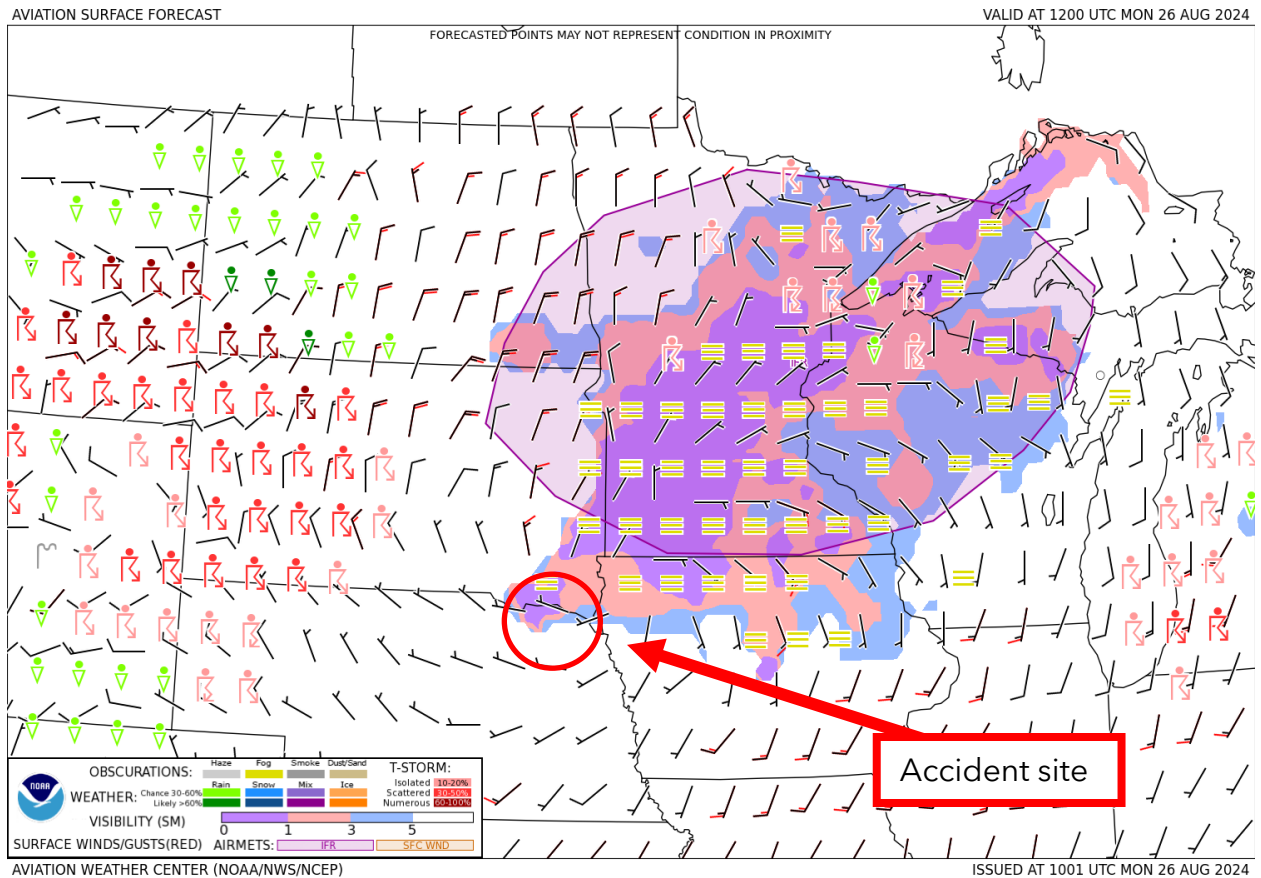


Figure 19. GFA Surface Forecast valid at 0700 CDT with forecast issued at 0501 CDT.

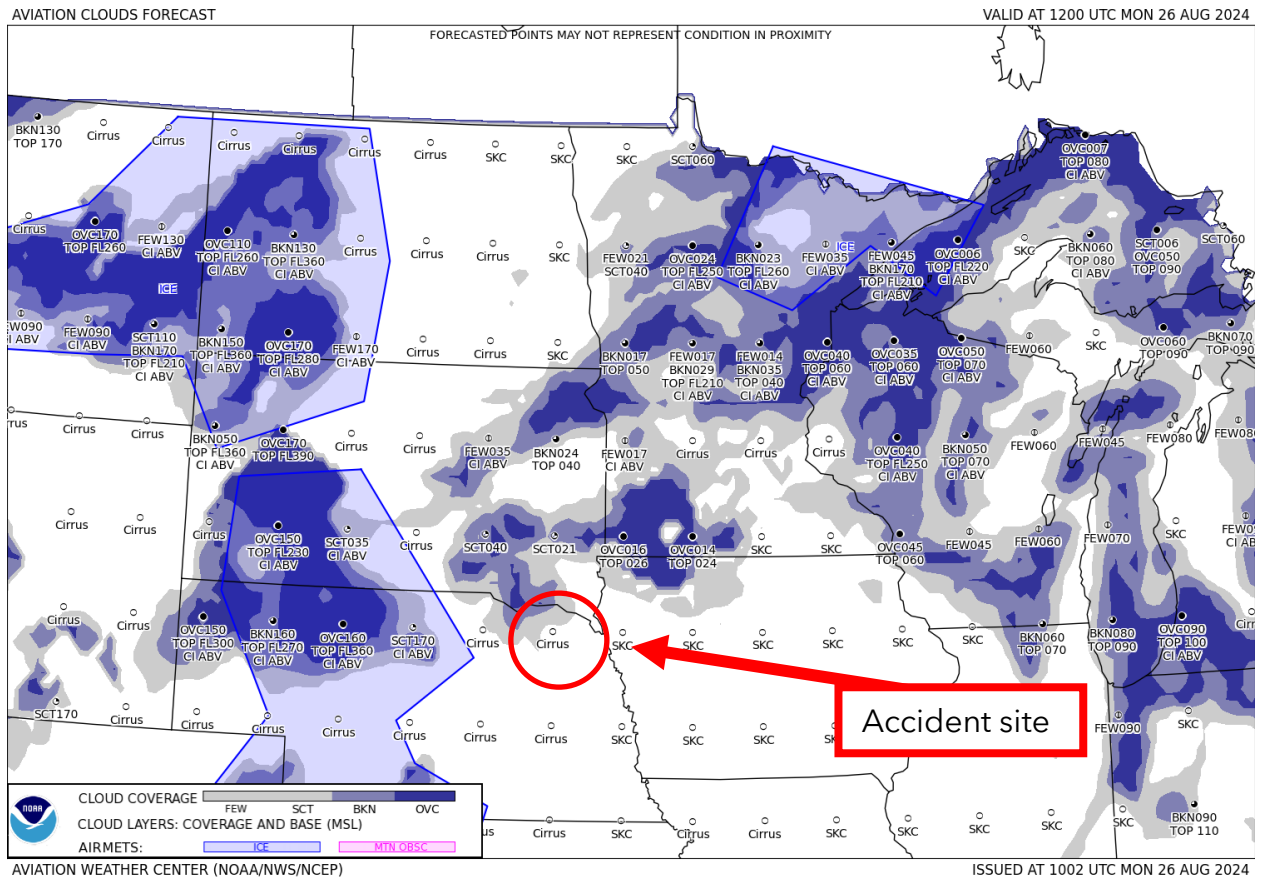


Figure 20. GFA Aviation Clouds Forecast valid at 0700 CDT with forecast issued at 0502 CDT.

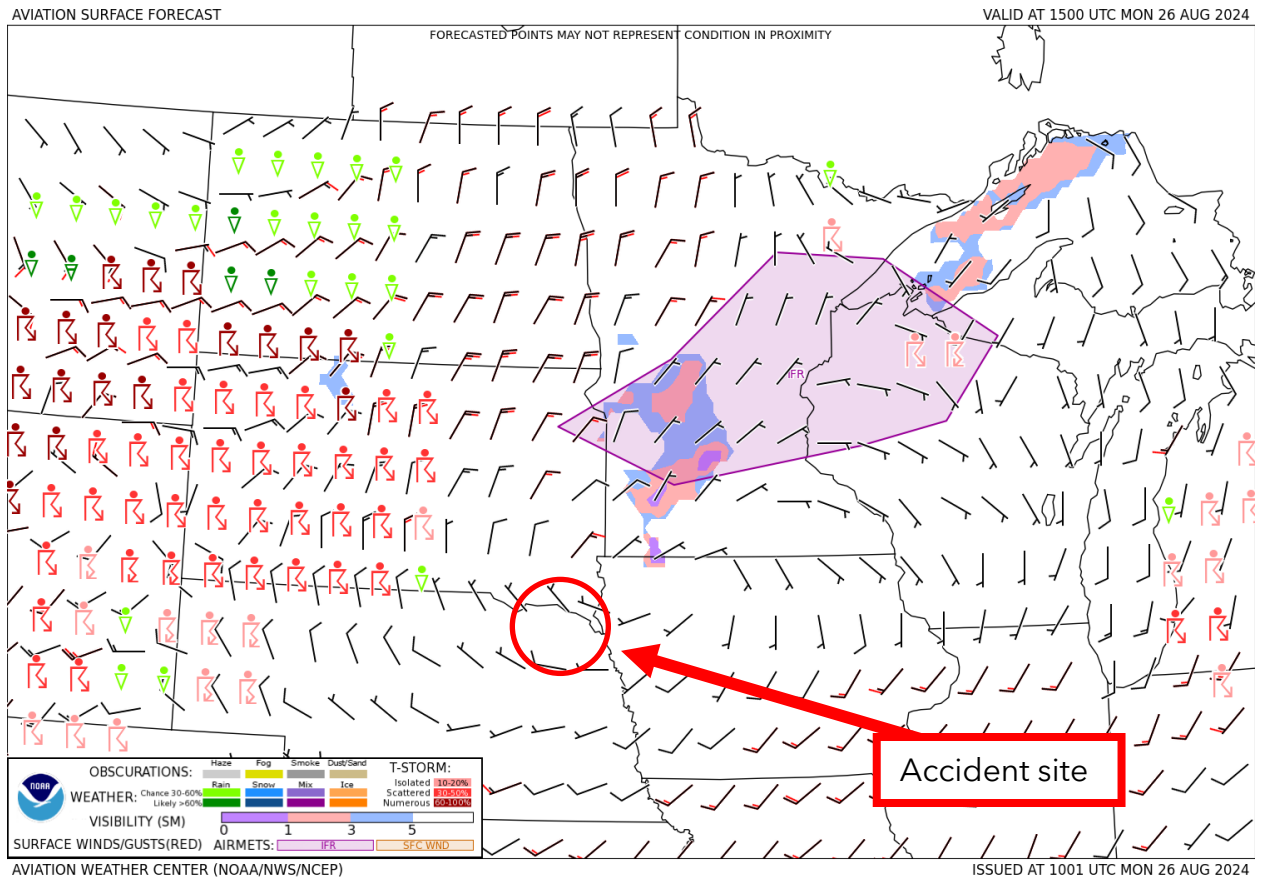


Figure 21. GFA Surface Forecast valid at 1000 CDT with forecast issued at 0501 CDT.

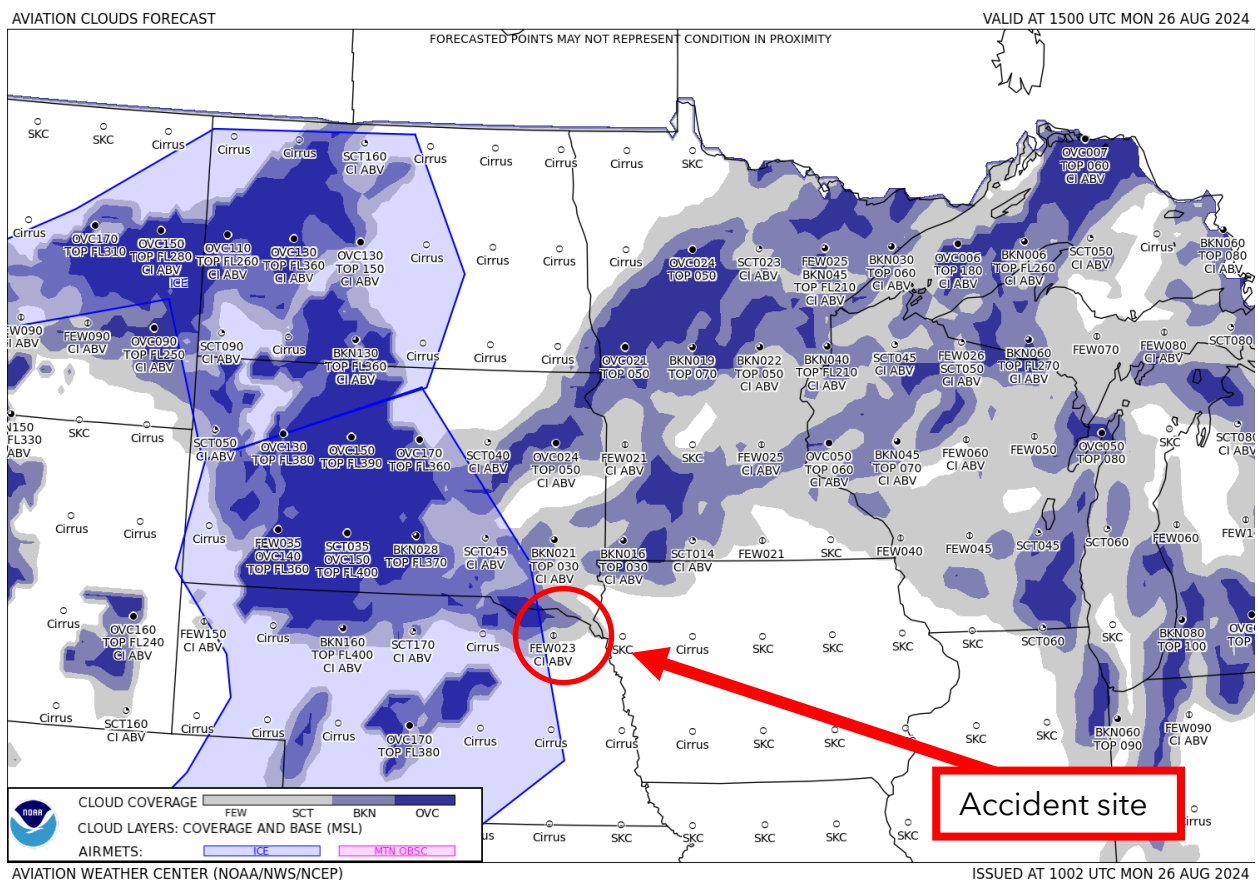


Figure 22. GFA Aviation Clouds Forecast valid at 1000 CDT with forecast issued at 0502 CDT.

13.0 Text Airmen's Meteorological Information

The AWC had text Airmen's Meteorological Information (AIRMET) advisory Zulu valid for the accident site at the accident time. The text AIRMET was issued at 0345 CDT and forecast moderate icing conditions between the freezing level²⁹ and FL250³⁰:

WAUS43 KKI 260845
 WA3Z
 -CHIZ WA 260845
 AIRMET ZULU UPDT 1 FOR ICE AND FRZLVL VALID UNTIL 261500
 .
 AIRMET ICE...ND SD
 FROM 60NE MOT TO 70ENE BIS TO 50WNW ABR TO 70NW RAP TO 50NNW ISN
 TO 50NW MOT TO 60NE MOT

²⁹ Freezing level between 14,000 and 16,000 ft.

³⁰ 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.

MOD ICE BTN FRZLVL AND FL250. FRZLVL 120-140. CONDS CONTG BYD 15Z
THRU 21Z.

.
AIRMET ICE...SD NE KS
FROM 50WNW ABR TO 40WSW FSD TO 50NW PWE TO 70WSW SLN TO 40ENE
LAA
TO GLD TO 70SW RAP TO 70NW RAP TO 50WNW ABR
MOD ICE BTN FRZLVL AND FL250. FRZLVL 140-160. CONDS CONTG BYD 15Z
ENDG 18-21Z.

.
AIRMET ICE...ND MN WI LS
FROM 40NW INL TO 20SSE YQT TO 80E DLH TO 40SSW BRD TO 30SW GFK TO
70NE GFK TO 40NW INL
MOD ICE BTN 150 AND FL220. CONDS ENDG 12-15Z.

.
OTLK VALID 1500-2100Z...ICE ND SD MN
BOUNDED BY 50NNW ISN-40N MOT-60WNW INL-40NE ABR-50WNW RAP-50NNW
ISN
MOD ICE BTN FRZLVL AND FL250. FRZLVL 120-140. CONDS CONTG THRU
21Z.

.
FRZLVL...RANGING FROM 120-165 ACRS AREA
160 BOUNDED BY 20S RHI-40N GRB-20ENE MKG-20E GIJ-30ESE BVT-
40SSW TTH-30NW AXC-40SSW IOW-20NE DSM-60S RWF-20SW RWF-
40WSW MSP-30SSW EAU-20S RHI
160 ALG 20NE ARG-40SSW TTH-40WSW IIU-40SW VXV
....

14.0 Terminal Aerodrome Forecast

There were no NWS Terminal Aerodrome Forecast³¹ (TAF) within 30 miles of the accident.

15.0 National Weather Service Area Forecast Discussion

The NWS weather forecast office in Omaha/Valley, Nebraska, (WFO OAX) was responsible for the public forecast in the region of the accident site. WFO OAX issued the following Area Forecast Discussion (AFD) at 0634 CDT. This was the AFD issued closest to the accident time with an aviation section:

³¹ According to NWS Instruction 10-813: "An NWS TAF consists of the expected meteorological conditions significant to aviation at an airport for a specified time period. For the U.S., this is the area within five (5) statute miles (SM) of the center of an airport's runway complex."
www.nws.noaa.gov/directives/sym/pd01008013curr.pdf

FXUS63 KOAX 261134
AFDOAX

Area Forecast Discussion
National Weather Service Omaha/Valley NE
634 AM CDT Mon Aug 26 2024

.KEY MESSAGES...

- One more hot day with heat index values of 102 to 112 this afternoon.
- A cold front Monday evening will begin to bring some relief from the heat, along with an enhanced risk of severe storms near the SD border, and a slight risk for the remainder of northeast Nebraska.
- Periodic thunderstorms chances continue throughout the upcoming work week.

&&

.DISCUSSION...

Issued at 320 AM CDT Mon Aug 26 2024

One more hot day is forecast today with high temperatures again forecast into the upper 90s to lower 100s. As with the last couple of days, MAV/GFS looks to be running 4-5 degrees too warm. Dewpoints today are forecast to be slightly cooler by a couple of degrees versus Sunday, nevertheless, it will still be uncomfortably hot this afternoon with heat index values from 102 to 112. The existing heat advisory will remain intact, and we did upgrade southwest IA to another excessive heat warning where heat index values could be as high as 112.

There is a weak frontal boundary that remains stalled across extreme northern NE, and this will be reinforced by a short wave moving out of the Rockies this afternoon and evening. Scattered thunderstorms may develop across portions of central NE and SD by early evening, with thunderstorm becoming likely in northeast NE by mid to late evening. SPC has maintained the severe risk levels, with an enhanced risk along the SD border, buffered by a slight risk for the remainder of northeast NE. The chances of storms will be in the forecast tonight for area north of Interstate 80, with areas to the south likely remaining dry.

For Tuesday, there could be spotty lingering showers in northeast NE Tuesday morning, but chances are only 20%. It very well could be dry by then. And with the frontal boundary still in the area Tuesday afternoon, have introduced a 20% chance for the southern half of our coverage area. High temperatures Tuesday will be a little cooler, still above normal in the middle 80s to lower 90s, but cool enough to not need another day

of excessive heat headlines.

The front could trigger additional isolated thunderstorms along/south of I80 Tuesday night. As a result, SPC has placed much of the area in a marginal risk for severe storms on their new day 2 outlook.

Wednesday looks dry, with the frontal boundary washing out or lifting back north. As a result, it will still be hot with above normal temperatures and highs in the lower 90s.

The models do push a renewed front back into the area, but the 00z models are not in agreement on the timing. ECMWF is about 12 hours sooner with the arrival of the front than the GFS, so the confidence in the timing in the details remains low at this time. With the model blends averaging out the timing, NBM places pops in the Wednesday night through Thursday night period at 20-60%. I am confident that we'll see increasing precipitation chances, during the mid week time frame, it's just the exact timing this far that remains in question.

Cooler temperatures are coming behind the front though, highs forecast in the upper 70s in northeast NE Thursday, but still in the upper 80s to the south.

And then dry conditions and near normal temperatures are expected to through most of the upcoming Labor Day weekend with highs in the upper 70s to lower 80s.

&&

.AVIATION /12Z TAFS THROUGH 12Z TUESDAY/...
Issued at 616 AM CDT Mon Aug 26 2024

Patchy fog has developed in NE Nebraska but believe that it will not push south to OFK before dissipating by 15Z.

The winds are generally out of the south at 5-10 knots, and will be turning westerly over the course of the day, becoming northwest later tonight.

Strong or severe thunderstorms developing in central Nebraska later this evening may clip OFK as they push northeast after dark. Confidence isn't great (50%), but have added categorical -TSRA from 07Z to 09Z Tuesday at OFK. Watch for timing changes with the 18Z TAFs issued later today.

&&

.OAX WATCHES/WARNINGS/ADVISORIES...
NE...Heat Advisory from 1 PM this afternoon to 8 PM CDT this evening for NEZ011-012-015-018-032>034-042>045-050>053-065>068-078-088>093.

IA...Heat Advisory from 1 PM this afternoon to 8 PM CDT this evening for IAZ043-055-056-069-079.
Excessive Heat Warning from 1 PM this afternoon to 8 PM CDT this evening for IAZ080-090-091.

&&

\$\$

16.0 Winds and Temperature Aloft Forecast

The NWS 0257 CDT Winds and Temperature Aloft Forecast, which was intended for use between 0300 and 1000 CDT and was valid for the closest points to the accident site, are included below:

FBUS31 KWNO 260757
FD1US1
DATA BASED ON 260600Z
VALID 261200Z FOR USE 0800-1500Z. TEMPS NEG ABV 24000

FT	3000	6000	9000	12000	18000	24000	30000	34000	39000
FSD	9900	2317+25	2422+18	2431+11	2431-07	2425-17	222634	253343	211953
ONL		2512+24	2323+18	2225+10	2125-08	2219-18	223034	234343	222552

17.0 Pilot Weather Information

Title 14 CFR 91.103 states that “Each pilot in command shall, before beginning a flight, become familiar with all available information concerning that flight.” FAA AC 91-92 “Pilot’s Guide to a Preflight Planning” (dated March 15, 2021) provided pilot guidance on preflight self-briefings, including planning, weather interpretation, and risk identification/mitigation skills. The AC further stated in part:

Pilots adopting these guidelines will be better prepared to interpret and utilize real-time weather information before departure and en route, in the cockpit, via technology like Automatic Dependent Surveillance-Broadcast (ADS-B) and via third-party providers.³²

A search of archived information indicated that the accident pilot did not request weather information from Leidos Flight Service or have an account with ForeFlight. It is unknown what, if any, weather information the pilot checked before the flight.

³² https://www.faa.gov/documentLibrary/media/Advisory_Circular/AC_91-92.pdf. The AC also listed multiple online FAA resources for aviation flight planning services for adverse weather.

18.0 Astronomical Data

The astronomical data obtained³³ for the accident site on August 26, 2024, indicated the following:

SUN

Begin civil twilight 0620 CDT

Sunrise 0649 CDT

Accident time 0841 CDT³⁴

Sun transit 1332 CDT

Sunset 2014 CDT

End civil twilight 2043 CDT

At the time of the accident the Sun was above the horizon at an altitude of 19.56° and an azimuth of 94.22°.

E. LIST OF ATTACHMENTS

Attachment 1 - Meteorological tower information

Attachment 2 - GOES-16 visible imagery animation from 0716 to 0911 CDT

Attachment 3 - GOES-16 Nighttime Microphysics RGB animation from 0501 to 0736 PDT

Submitted by:

Paul Suffern

Senior Meteorologist

³³ <https://www.suncalc.org/> and <https://www.mooncalc.org/>

³⁴ Inserted accident time for reference and context.