

National Transportation Safety Board

Office of Aviation Safety

Washington, DC 20594



WPR23FA188

METEOROLOGY

Specialist's Factual Report

August 31, 2023

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A. ACCIDENT

Location: Albany, Wyoming
Date: May 14, 2023
Time: 1135 mountain daylight time
1735 coordinated universal time (UTC)
Airplane: Cessna T182T; Registration: N665B

B. METEOROLOGY SPECIALIST

Paul Suffern
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 mountain daylight time (MDT) and are based upon the 24-hour clock, where local time is -6 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 41.427436° N, longitude 106.06338° W, at an elevation of about 8,082 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 central Rockies of the United States for 1200 MDT is provided as figure 1 with the location of the accident site within the black circle. The chart depicted a low-pressure system at 1019-hectopascals (hPa) located in west-central Colorado, with a trough² extending northeast of the low across western Colorado through central Wyoming. A high pressure system at 1025-hPa was located over central Utah. The accident site was located immediately east of the trough. Troughs 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 50 to 59 degrees Fahrenheit (°F), dew point temperatures of 42 to 43°F, cloudy to partly cloudy skies, and an east-northeast wind at 10 to 20 knots.

¹ [FAA-H-8083-28](#)

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

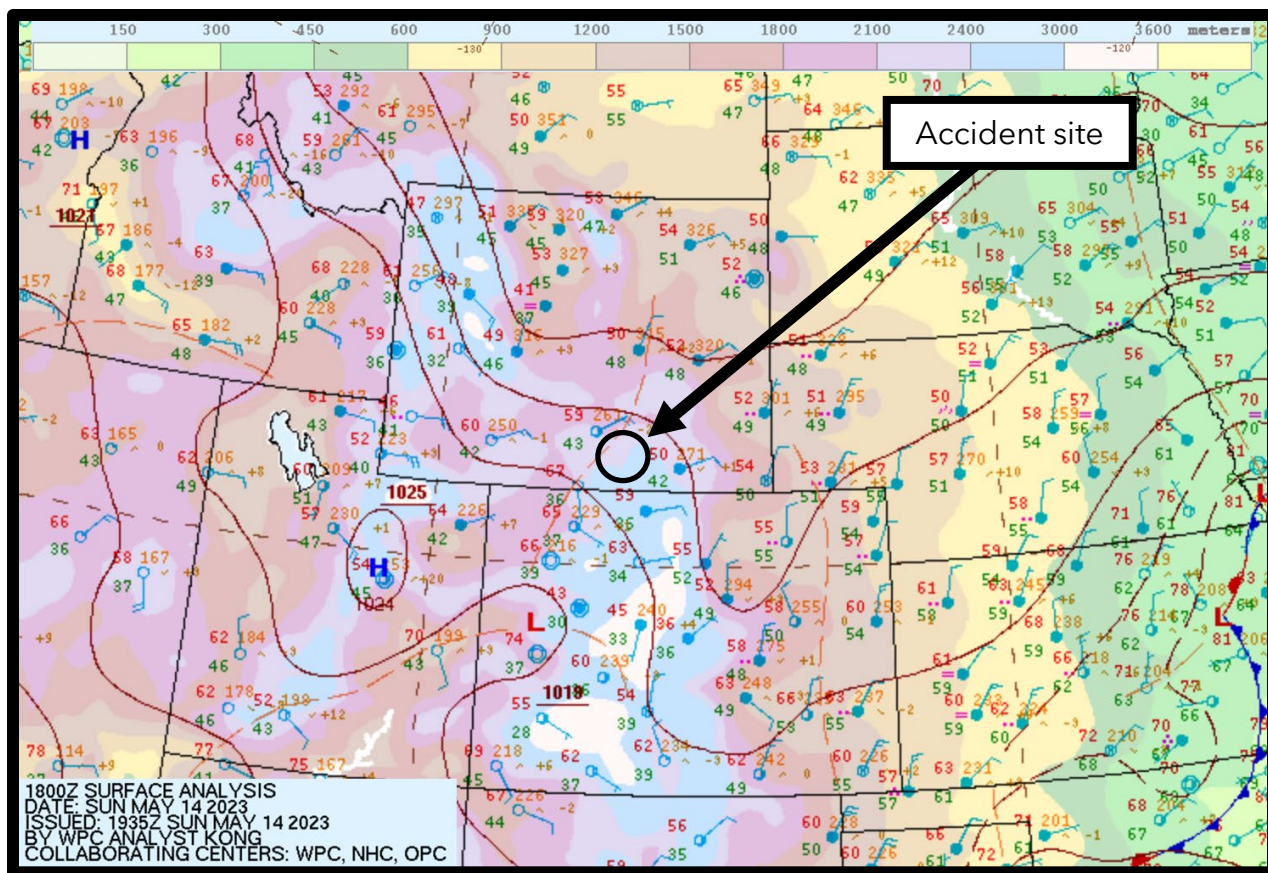


Figure 1. NWS Surface Analysis Chart for 1200 MDT.

1.2 Upper Air Charts

The NWS Storm Prediction Center (SPC) Constant Pressure Charts for 0600 MDT at 700- and 500-hPa are presented in figures 2 and 3. The 850-hPa constant pressure chart depicted an east wind around 15 knots near the accident site (figure 2) with the wind becoming southeasterly at 20 knots by 700-hPa (figure 3). Both charts depicted a general confluent³ flow over the area.

³ Confluent flow - A pattern of wind flow in which air flows inward toward an axis oriented parallel to the general direction of flow. It is the opposite of diffluence. Confluence is not the same as convergence. Winds often accelerate as they enter a confluent zone, resulting in speed divergence which offsets the (apparent) converging effect of the confluent flow.

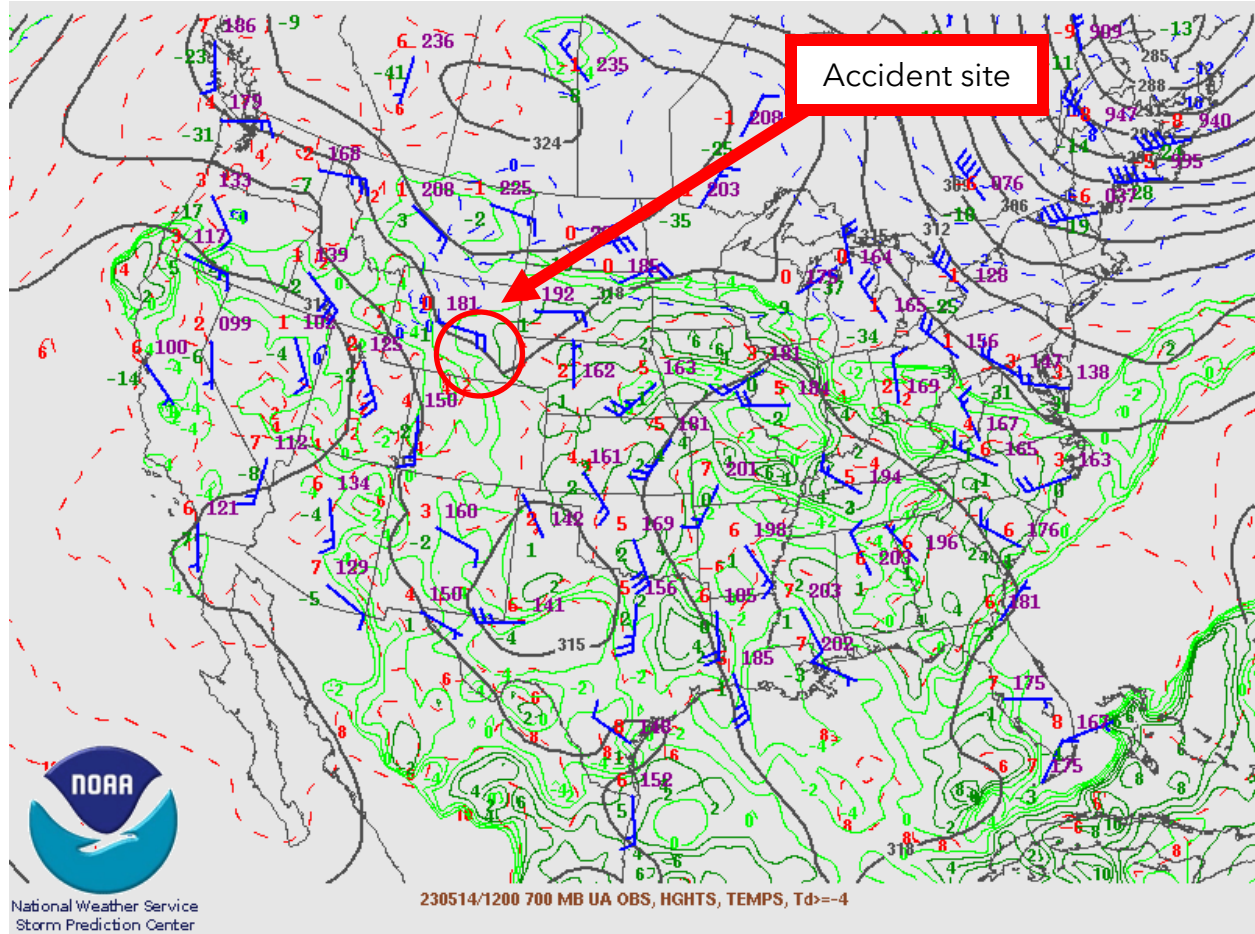


Figure 2. 700-hPa Constant Pressure Chart for 0600 MDT.

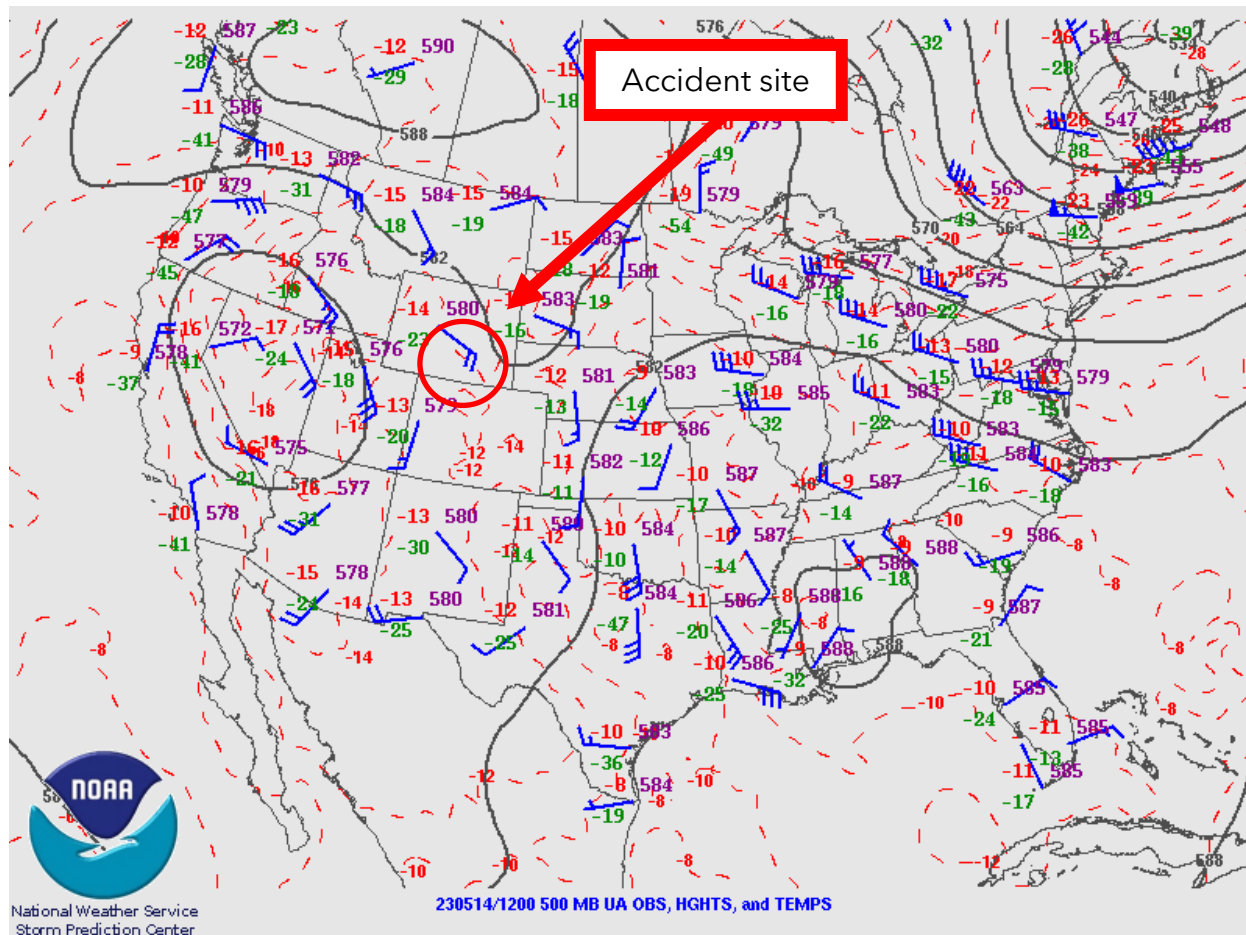


Figure 3. 500-hPa Constant Pressure Chart for 0600 MDT.

2.0 Storm Prediction Center Convective Outlook

The SPC issued the Day 1 Convective Outlook at 1030 MDT (figure 4) with areas of general thunderstorms forecast for the accident site. The SPC defines the “TSTM” area as an area that encloses where a 10% or higher probability of thunderstorms is forecast during the valid period.

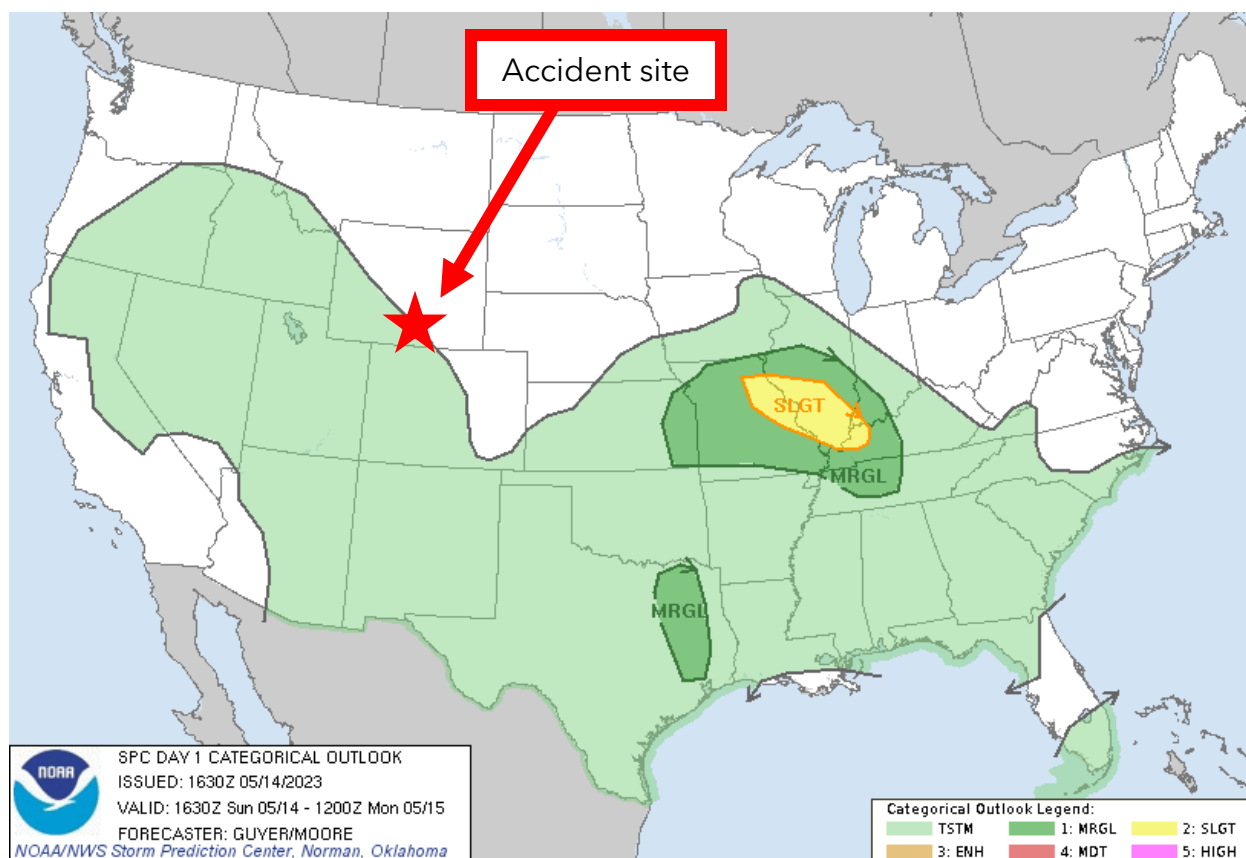


Figure 4. SPC day 1 Convective Outlook valid at the time of the accident.

3.0 Surface Observations

The area surrounding the accident site was documented using official Aviation Routine Weather Reports (METARs) and Special Reports (SPECIs)⁴. The following observations were taken from standard code and are provided in plain language. Figure 5 is a local sectional chart with the accident site and the closest weather reporting location marked. A magnetic variation⁵ of 9° east was indicated over the area.

⁴ 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://www.federalmetbook.com/)

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

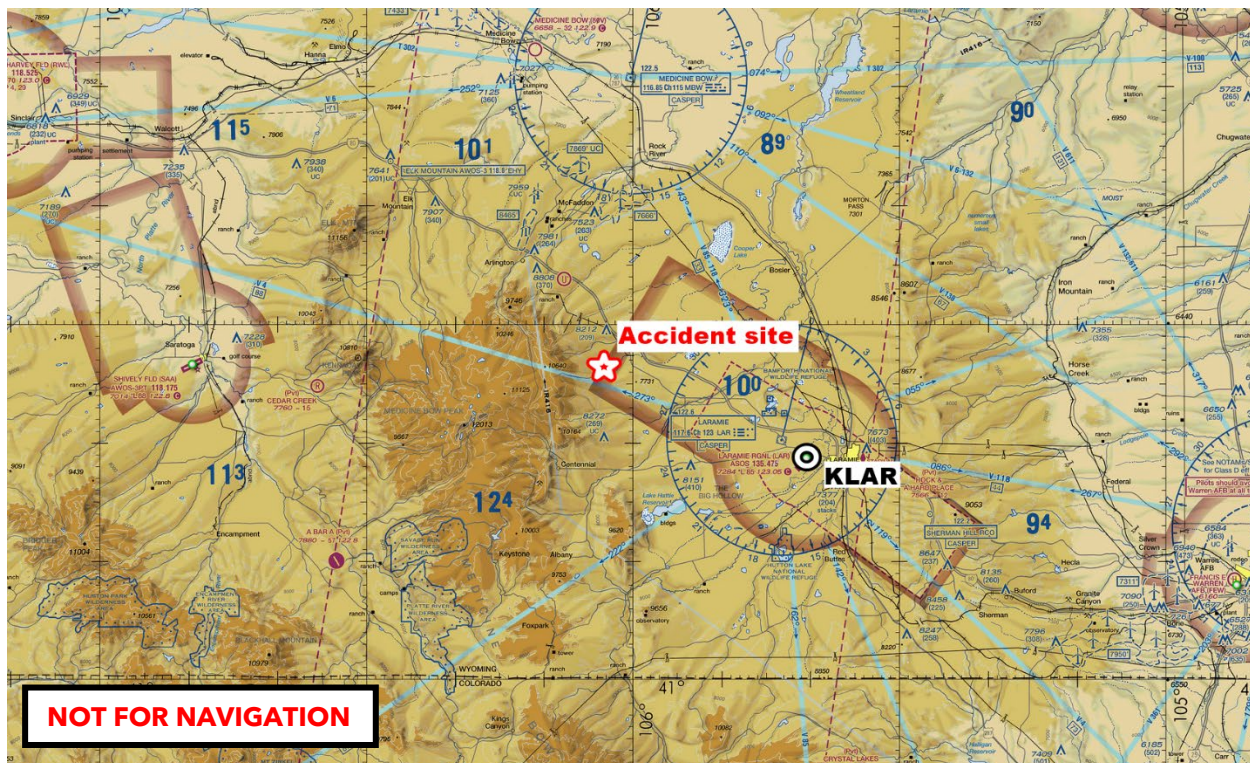


Figure 5. FAA sectional aeronautical chart of the accident area with the location of the accident site and surface observation site noted.

Laramie Regional Airport (KLAR) had the closest official weather station to the accident site. KLAR had an Automated Surface Observing System (ASOS⁶) and its longline⁷ reports were not augmented. The KLAR ASOS was located 19 miles southeast of the accident site (figure 5), at an elevation of 7,284 ft, and issued the following observations surrounding the period of the accident:⁸

⁶ ASOS - Automated Surface Observing System is equipped with meteorological instruments to observe and report wind, visibility, weather phenomena, ceiling, temperature, dewpoint, altimeter, and barometric pressure. ASOS are maintained by the NWS.

⁷ "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.

⁸ 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 between UTC and local times.

[0909 MDT] SPECI KLAR 141509Z AUTO 05006KT 10SM BKN017
OVC044 08/06 A3048 RMK AO2 T00830056=

[0939 MDT] SPECI KLAR 141539Z AUTO 04007KT 10SM OVC014 08/06
A3049 RMK AO2 T00780056=

[0948 MDT] SPECI KLAR 141548Z AUTO 05006KT 10SM BKN016
OVC021 08/06 A3049 RMK AO2=

[0953 MDT] METAR KLAR 141553Z AUTO 04006KT 10SM BKN016
OVC021 08/06 A3049 RMK AO2 SLP275 T00830061=

**[1053 MDT] METAR KLAR 141653Z AUTO 05012KT 10SM BKN017
OVC024 09/06 A3049 RMK AO2 RAB31E48 SLP271 P0000
T00940056=**

ACCIDENT TIME 1135 MDT

**[1153 MDT] METAR KLAR 141753Z AUTO 07012KT 10SM OVC019
10/06 A3049 RMK AO2 SLP271 60000 T01000056 10106 20056
53001=**

[1238 MDT] SPECI KLAR 141838Z AUTO 08009KT 10SM -RA FEW014
SCT023 OVC050 10/07 A3049 RMK AO2 RAB02 P0001 T01000072=

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

KLAR weather at 1053 MDT, automated, wind from 050° at 12 knots, visibility 10 miles or greater, a broken ceiling at 1,700 ft above ground level (agl), overcast clouds at 2,400 ft agl, temperature of 9° Celsius (C), dew point temperature of 6°C, and an altimeter setting of 30.49 inches of mercury (inHg). Remarks, automated station with a precipitation discriminator, rain began at 1031 and ended at 1048 MDT, sea level pressure 1027.1 hPa, a trace of precipitation since 0953 MDT, temperature 9.4°C, dew point temperature 5.6°C.

KLAR weather at 1153 MDT, automated, wind from 070° at 12 knots, visibility 10 miles or greater, overcast ceiling at 1,900 ft agl, temperature of 10°C, dew point temperature of 6°C, and an altimeter setting of 30.49 inHg. Remarks, automated station with a precipitation discriminator, sea level pressure 1027.1 hPa, 6-hourly precipitation of a trace, temperature 10.0°C, dew point temperature 5.6°C, 6-hourly maximum temperature of 10.6°C, 6-hourly minimum temperature of 5.6°C, 3-hourly pressure increase of 0.1 hPa.

The observations from the KLAR ASOS around the accident time identified MVFR⁹ conditions prevailed surrounding the period of the accident.

4.0 Upper Air Sounding

A High-Resolution Rapid Refresh (HRRR)¹⁰ model sounding was created¹¹ for the approximate accident site coordinates for 1200 MDT. The HRRR sounding was plotted on a standard Skew-T Log P diagram¹² from the surface to 500-hPa (or approximately 18,000 ft) using the RAOB¹³ software package and is included as figure 6. The sounding depicted an elevation of 8,038 ft over the grid point with a near surface temperature of 6.1°C, a dew point temperature of 5.3°C, and a relative humidity of 95%. The sounding depicted the lifted condensation level (LCL)¹⁴, and the level of free convection (LFC)¹⁵ at 334 ft agl, and the convective condensation level (CCL)¹⁶ at 1,876 ft agl. The freezing level was located at 11,014 ft. The precipitable water value at 0.53 inches.

⁹ 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.

¹⁰ 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.

¹¹ HRRR sounding was created using NOAA Air Resource Laboratory: [READY Archived Meteorology \(noaa.gov\)](https://ready.noaa.gov/).

¹² 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.

¹³ RAOB – (The complete Rawinsonde Observation program) is an interactive sounding analysis program developed by Esonde Research Services, The Villages, Florida.

¹⁴ LCL – The height at which a parcel of moist air becomes saturated when it is lifted dry adiabatically.

¹⁵ 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.

¹⁶ 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.

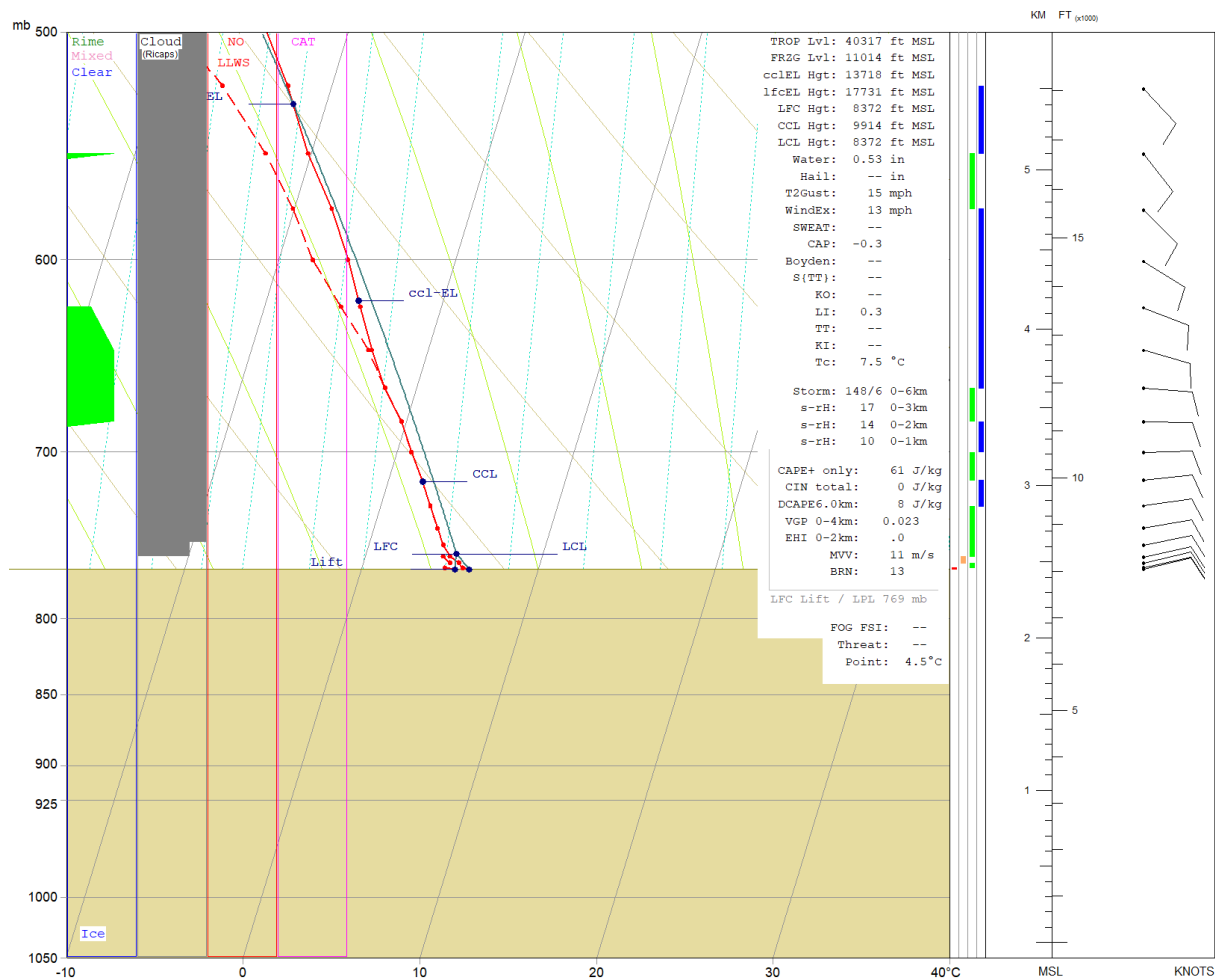


Figure 6. 1200 MDT HRRR sounding.

The 1200 MDT HRRR sounding indicated a conditionally unstable to stable environment from the surface through 18,000 ft. RAOB indicated a cloud layer from 8,300 ft through 18,000 ft. Light to moderate rime icing was indicated by RAOB in a layer between 11,000 ft and 14,000 ft.

The 1200 MDT HRRR sounding wind profile indicated an easterly near surface wind at 10 knots with the wind becoming southeasterly through 18,000 ft. The wind speed remained at or below 10 knots through 28,000 ft (not shown). RAOB did not indicate the possibility of low-level wind shear (LLWS), or clear air turbulence (CAT) for below 18,000 ft. At the airplane's approximate altitude before descent¹⁷ (around 13,150 ft), the temperature was -3.9°C, the dew point temperature was -4.5°C, the relative humidity was 96%, and the wind was from 110° at 9 knots.

¹⁷ Please see track information located in the docket of this accident.

5.0 Satellite Data

Geostationary Operational Environmental Satellite number 16 (GOES-16) visible and infrared data were obtained from an archive at the Space Science Engineering Center at the University of Wisconsin-Madison in Madison, Wisconsin, and processed using the Man-computer Interactive Data Access System software. Visible and infrared imagery (GOES-16 bands 2 and 13) at wavelengths of 0.64 microns (μm) and 10.3 μm , respectively, were retrieved for the period from 0800 MDT through 1400 MDT and reviewed, and the closest images to the time of the accident were documented.

Figure 7 presents the GOES-16 visible image at 1136 MDT at 2X magnification with the accident site highlighted with a red square. The visible imagery indicated cloud cover above the accident site with the cloud cover moving from southeast to northwest (attachment 1). Figure 8 presents the GOES-16 infrared image at 1136 MDT at 6X magnification with the accident site highlighted with a red square. The lower brightness temperatures (green and yellow colors; higher cloud tops) were located northeast through southeast of the accident site at the accident time. The brightness temperature of 267 Kelvin above the accident site would have been near 14,500 ft based on the vertical temperature profile provided by the 1200 MDT HRRR sounding. It should be noted these figures have not been corrected for any parallax error. The "Day Cloud Phase" Red, Green, Blue (RGB) GOES-16 imagery at the accident time indicated the cloud cover above the accident site was made up of water droplets and not glaciating clouds (attachments 2 and 3).

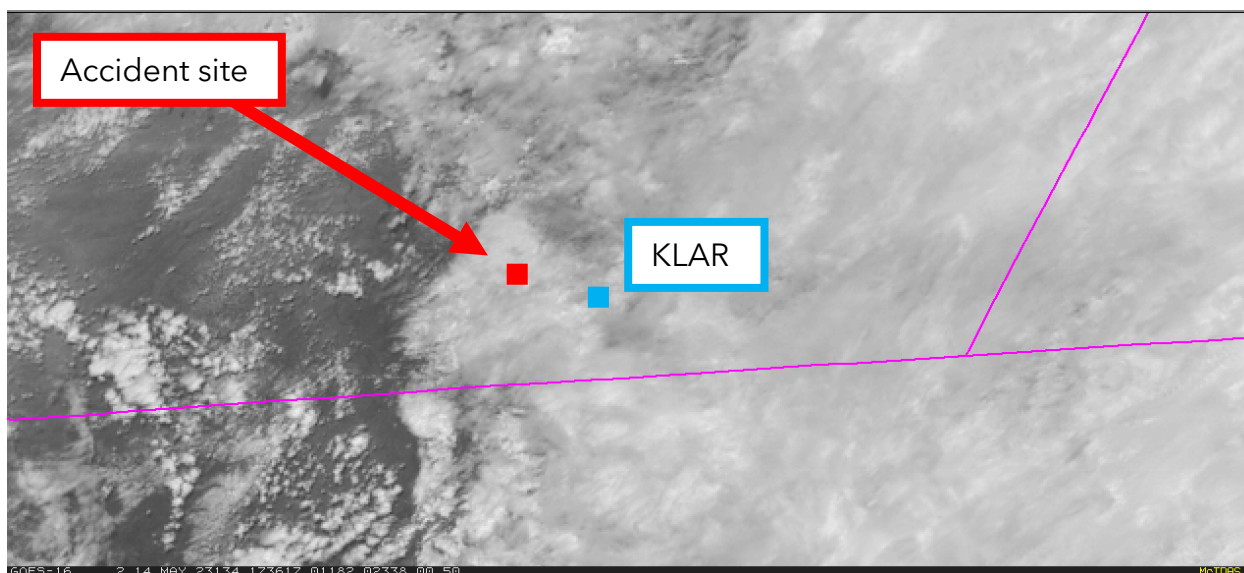


Figure 7. GOES-16 visible image at 1136 MDT.

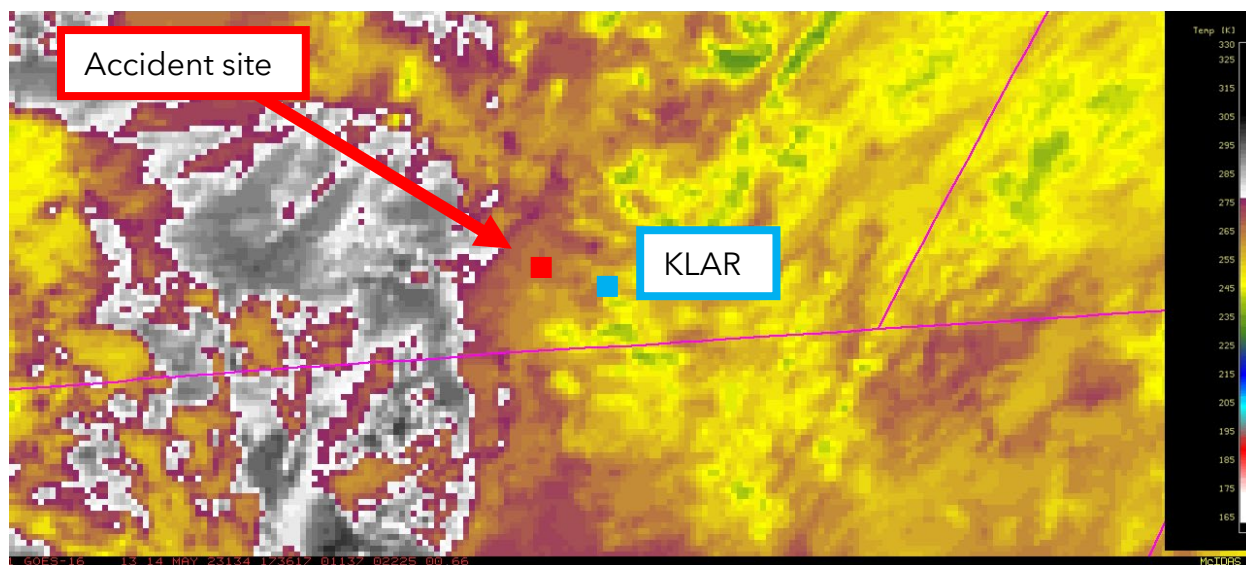


Figure 8. GOES-16 infrared image at 1136 MDT.

6.0 National Radar Imagery

A regional view of the NWS National Reflectivity Mosaic is included as figure 9 for 1135 MDT with the approximate location of the accident site marked by a red circle. No echoes were depicted above the accident site in the mosaic imagery.

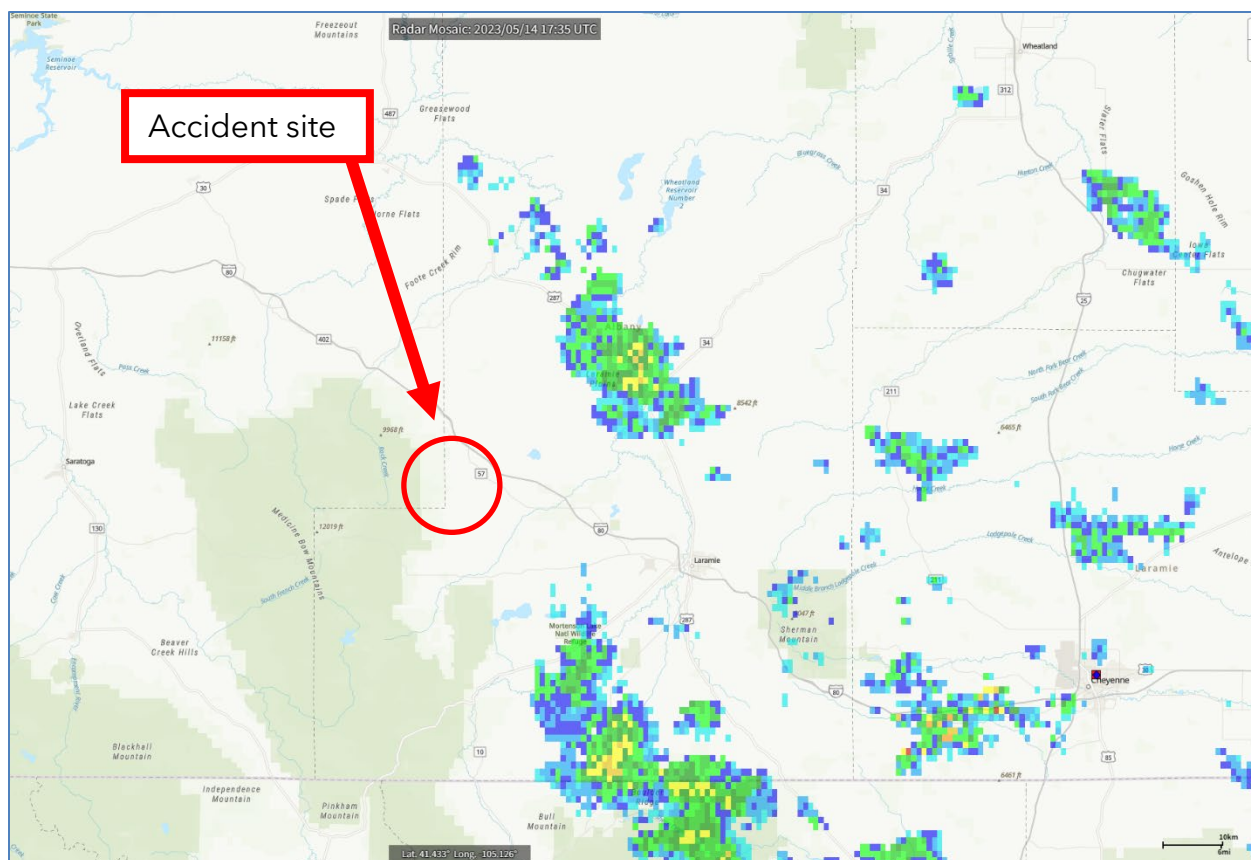


Figure 9. National Reflectivity Mosaic for 1135 MDT.

7.0 Weather Surveillance Radar Imagery

The closest NWS Weather Surveillance Radar-1988, Doppler (WSR-88D)¹⁸ to the accident site was in Cheyenne, Wyoming, (KCYS) located 59 miles east-southeast 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.

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

7.1 Volume Scan Strategy

During the period surrounding the accident, the KCYS WSR-88D radar was operating in the precipitation mode VCP-215¹⁹ (figure 10). 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.

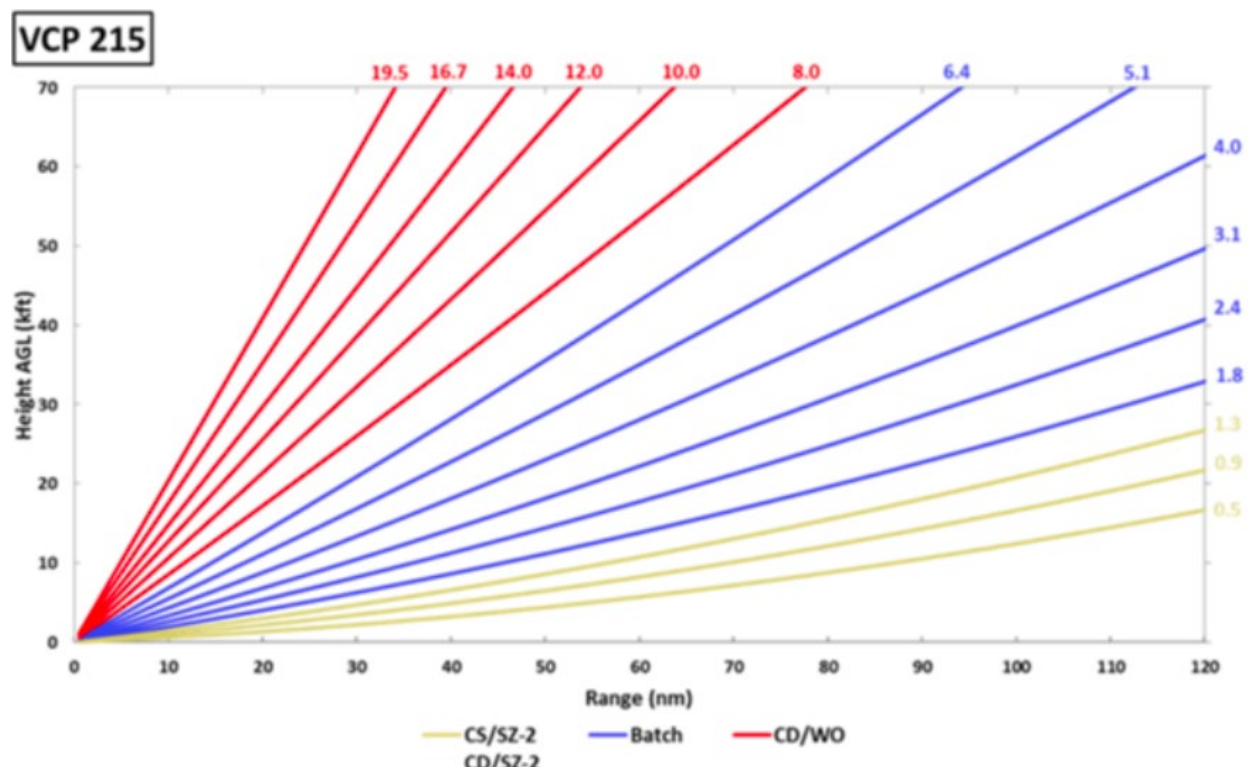


Figure 10. VCP-215 Precipitation Mode Scan Strategy.

¹⁹ Contiguous Surveillance (CS)--The low Pulse Repetition Frequency (PRF) scan of the split cut. Gives a high R_{max} value to determine proper target location and intensity, but a low V_{max} value limits the velocities that can be measured.

Contiguous Doppler (CD)--The high PRF scan of the split cut. Gives a low R_{max} value causing more range folded (multiple trip) echoes, but a high V_{max} value to get higher, more accurate velocity values. Batch Mode - Uses alternating low and high PRFs on each radial for one full rotation at each elevation angle. The two resulting data sets (low PRF and high PRF) are combined to resolve range ambiguity.

Used in the middle elevation angles.

W - With range unfolding (W)

WO - Without range unfolding (WO)

7.2 Beam Height Calculation

Assuming standard refraction²⁰ of the KCYS WSR-88D radar beam with the antenna elevation at 6,192 ft, and considering a beamwidth²¹ of 0.95°, the following table shows the approximate heights for the radar beams' centers, tops, and bases for certain antenna elevations over the accident site. These heights have been rounded to the nearest 10 ft.

ANTENNA ELEVATION	BEAM CENTER	BEAM BASE	BEAM TOP
KCYS 0.48°	11,500 ft	8,530 ft	14,470 ft

Based on the radar height calculations, the elevation scans reviewed from KCYS listed in the above table combined to depict conditions between 8,530 ft and 14,470 ft over the accident site.

7.3 Reflectivity

Reflectivity is the measure of the efficiency of a target in intercepting and returning radio energy. With hydrometeors²² it is a function of the drop size distribution, number of particles per unit volume, physical state (ice or water), shape, and aspect. Reflectivity is normally displayed in dBZ²³ 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."

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

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

²² Hydrometeors are any product of condensation or sublimation of atmospheric water vapor, whether formed in the free atmosphere or at the earth's surface; also, any water particles blown by the wind from the earth's surface. Hydrometeors are classified as; (a) Liquid or solid water particles suspended in the air: cloud, water droplets, mist, or fog. (b) Liquid precipitation: drizzle and rain. (c) Freezing precipitation: freezing drizzle and freezing rain. (d) Solid (frozen) precipitation: ice pellets, hail, snow, snow pellets, and ice crystals. (e) Falling particles that evaporate before reaching the ground: virga. (f) Liquid or solid water particles lifted by the wind from the earth's surface: drifting snow, blowing snow, blowing spray. (g) Liquid or solid deposits on exposed objects: dew, frost, rime, and glazed ice.

²³ 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.

7.4 Base Reflectivity and Lightning Data

Figures 11 and 12 present the KCYS WSR-88D base reflectivity images for the 0.48° elevation scans initiated at 1128:07 and 1132:39 MDT with resolutions of 0.5° X 250 m. These images depicted scattered areas of reflectivity values between -5 and 15 dBZ moving from east to west over the last 12 minutes of the accident flight track (attachment 4).

There were no lightning flashes²⁴ reported within 25 miles of the accident site within 30 minutes before and after the accident time.²⁵

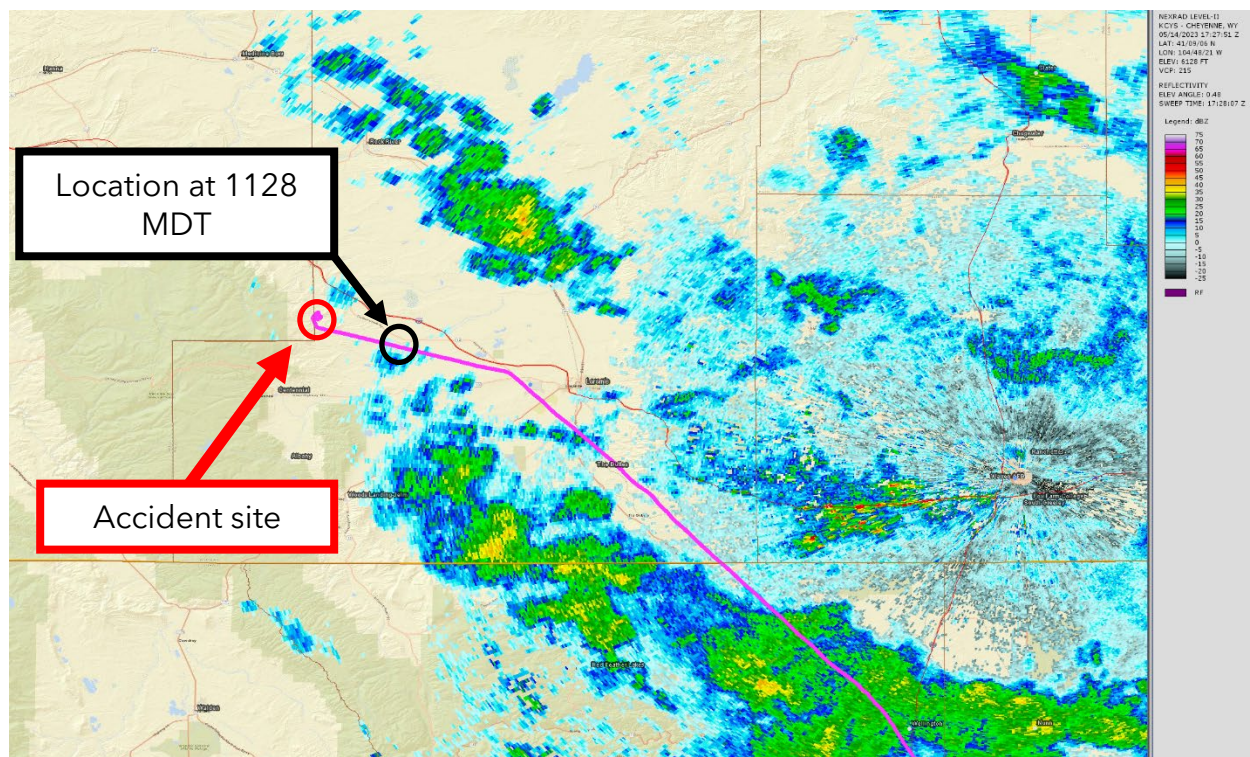


Figure 11. KCYS WSR-88D reflectivity for the 0.48° elevation scan initiated at 1128:07 MDT with the accident site marked with the red circle, the location of the accident aircraft in the black circle, and the accident flight track in pink.

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

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

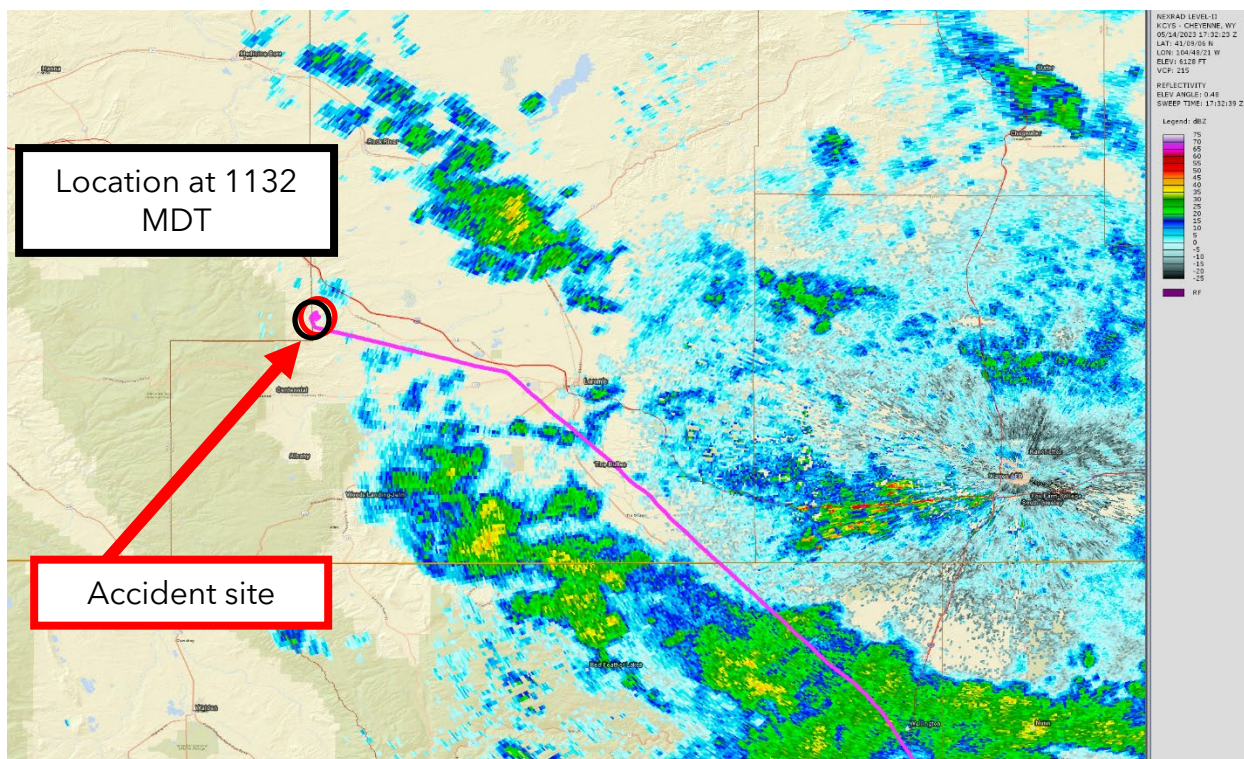


Figure 12. KCYS WSR-88D reflectivity for the 0.48° elevation scan initiated at 1132:39 MDT with the accident site marked with the red circle, the location of the accident aircraft in the black circle, and the accident flight track in pink.

8.0 Pilot Reports

The longline-disseminated pilot reports²⁶ (PIREPs) distributed into the national airspace system (NAS) within two hours before and after the accident time and within 120 miles of the accident site at altitudes below 18,000 ft are shown here. A PIREP of light rime icing was provided by the accident pilot and reported in the NAS at 1116 MDT (highlighted in bold below):

BJC UA /OV BJC/TM 1644/FL006/TP C172/SK OVC006

**LAR UA /OV LAR125013/TM 1716/FL130/TP C82S/TA M02/IC LGT RIME/RM ZDV
FD LGT RIME**

CPR UA /OV CPR028013/TM 1722/FL090/TP PA32/TA 0/IC NEG/RM IMC @ 090 LOTS
OF MOISTURE NEG

DEN UA /OV 50 NW DEN/TM 1805/FL170/TP A320/TA -17/IC LGT RIME

CPR UA /OV CPR230015/TM 1833/FL100/TP C560/SK TOPS082/TB NEG/IC NEG/RM
DURD

²⁶ Only PIREPs with the World Meteorological Organization headers UBWY**, UBCO**, UBSD**, and UBNE** were considered. These do not include pilot reports only broadcast via radio.

9.0 Significant Meteorological Information

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

10.0 Center Weather Service Advisories

The Denver (ZDV) 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.

11.0 Airmen's Meteorological Information

The NWS Aviation Weather Center (AWC) had text Airmen's Meteorological Information (AIRMET) advisory Sierra valid for the accident site at the accident time. The text AIRMET Sierra were issued at 0845 MDT and forecast (1) IFR conditions due to precipitation, mist, and fog and (2) mountain obscuration due to clouds, precipitation, and mist. AIRMET Zulu for moderate icing was valid for the accident flight through a point 20 miles east KLAR, but AIRMET Zulu was not valid for the accident site:

WAUS45 KPCI 141445
WA55
-SLCS WA 141445
AIRMET SIERRA UPDT 4 FOR IFR AND MTN OBSCN VALID UNTIL 142100

.
AIRMET IFR...MT WY CO NM
FROM 40SSE HVR TO 80SW DIK TO 70SW RAP TO GLD TO 50W LBL TO 50NE
RSK TO 40ESE CHE TO 50SSE BOY TO 40E BPI TO JAC TO 40SSE HLN TO
40SSE HVR
CIG BLW 010/VIS BLW 3SM PCPN/BR/FG. CONDS CONTG BYD 21Z THRU 03Z.

.
AIRMET MTN OBSCN...ID NV UT OR
FROM 60SSE LKT TO PIH TO 50ESE MLD TO 50S SLC TO 60SSE BVL TO
40SSE ELY TO 70ENE OAL TO 60NNE LKV TO 80SW BKE TO 60SSE LKT
MTNS OBSC BY CLDS/PCPN/BR. CONDS DVLPNG 15-18Z. CONDS CONTG BYD
21Z THRU 03Z.

.
AIRMET MTN OBSCN...ID MT WY UT CO
FROM 60ESE YXC TO 40SSW YQL TO GTF TO HVR TO SHR TO 40NNW CHE TO
50SSE OCS TO 20WSW HVE TO 40N BCE TO 40NNE DTA TO 60N JAC TO
70WSW HLN TO 60ESE YXC

MTNS OBSC BY CLDS/PCPN/BR. CONDS CONTG BYD 21Z THRU 03Z.

**AIRMET MTN OBSCN...WY CO NM
FROM SHR TO CYS TO TBE TO 60SW TCC TO 40NNE RSK TO 30ESE CHE TO
40NNW CHE TO SHR
MTNS OBSC BY CLDS/PCPN/BR. CONDS CONTG BYD 21Z THRU 03Z.**

12.0 Graphical Forecasts for Aviation

The Graphical Forecasts for Aviation (GFA) products issued by the AWC before the accident flight and valid at 0900 and 1200 MDT are shown in attachment 5. The GFA surface forecasts valid from 0900 and 1200 MDT indicated VFR conditions from the mountain ridge near the accident site westward and IFR to LIFR conditions from the mountain ridge eastward. An east wind at 15 knots with gusts to 25 knots was forecast and a chance (between 30 and 50) of thunderstorms and rain showers. The GFA cloud forecasts applicable to the accident also valid at 0900 and 1200 MDT indicated overcast clouds at the accident site with bases at 9,000 ft with tops between 14,000 ft and 16,000 ft, with cirrus clouds above. The Graphical AIRMETs²⁷ (G-AIRMETs) Sierra and Zulu were overlaid on the GFA cloud forecast products. The only human-generated information reflected in the two GFA products were the G-AIRMETs.

13.0 Terminal Aerodrome Forecast

There were no NWS Terminal Aerodrome Forecast²⁸ (TAF) locations within 15 miles of the accident site.

²⁷ 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.

²⁸ According to NWS Instruction 10-813: "An NWS TAF consists of the expected meteorological conditions significant to aviation at an airport for a specified time period. For the U.S., this is the area within five (5) statute miles (SM) of the center of an airport's runway complex."
www.nws.noaa.gov/directives/sym/pd01008013curr.pdf

14.0 National Weather Service Area Forecast Discussion

The NWS Weather Forecast Office in Cheyenne, Wyoming, (WFO CYS) was responsible for the public forecast in the region of the accident site. WFO CYS issued the following Area Forecast Discussion (AFD) at 0527 MDT, which was the AFD issue closest to the accident time with an aviation section:

FXUS65 KCYS 141127
AFDCYS

Area Forecast Discussion
National Weather Service Cheyenne WY
527 AM MDT Sun May 14 2023

.SHORT TERM...(Today - Monday Night)
Issued at 509 AM MDT Sun May 14 2023

A relatively cool & unsettled weather pattern will persist through the weekend as a well-pronounced Rex Block takes shape in response to a retrograding upper-level low undercutting general upper-level ridging over western North America. As such, there is not really a whole lot to speak of during the short term period, with the dirty ridge taking center stage with persistent clouds and daily chances for scattered/numerous showers across a large part of southeast WY and western NE. Lingering influence from cyclonic flow aloft & the mid-level cold core beneath the upper-level low suggests potential for a bit of a delay in our warming trend as H7 temperatures could only peak at 0 to +1 deg C for most zones through Monday AM. Also, persistent upslope will likely contribute to dense stratus as well as some areas of fog. As such, expect much of the area to struggle to get much warmer than the upper 40s/lower 50s today. Should have better potential for warming on Monday beneath the thermal ridge & having a brief window between vort maxes aloft.

.LONG TERM...(Tuesday - Saturday)
Issued at 509 AM MDT Sun May 14 2023

Models continue to show an unsettled pattern heading into mid to late next week, and continue to be consistent showing the Rex Block trying to reform along the west coast of the United States and Canada. Upper level low pressure will remain nearly stationary near the southern California coastline or near Baja California Tuesday through the end of the week as upper level ridging will remain over the the Pacific NW into British Columbia. Models still indicate the ridge axis will be rather weak earlier in the week, with several vorticity maximums/disturbances aloft moving southeast in weak westerly or northwest flow aloft. These disturbances, along with low level convergence along the Front Range, will be more than enough to initiate daily convection and thunderstorms across most of southeast Wyoming and the far western Nebraska Panhandle. With good run to run consistency, increased POP mainly over southeast Wyoming. The best chance appears to be Wednesday through early Thursday as a cold

front pushes south out of Canada, resulting in additional convergence and forcing along and just ahead of the front. Showers and thunderstorms may actually linger through most of Wednesday night due to some low to midlevel frontogenesis and enhanced OMEGA near the front. Increased POP Wednesday between 45 to 70 percent through the late evening hours.

Tuesday and Wednesday will likely be the warmest days of the week, with highs in the 70s to possibly low 80s over the lower elevations. Can not rule out a few strong to marginally severe thunderstorms across the eastern high plains Tuesday and Wednesday with some 0-6km shear around 25 knots and SBCAPE up to 1200 J/KG.

For later in the week and early next weekend, all models show the Rex Block redeveloping along the west coast with weak northwest flow across eastern Wyoming and western Nebraska. A few disturbances aloft/clipper systems will dive south out of Alberta, which will likely keep nearly a daily threat of precipitation in the forecast. This pattern typically results in mostly cloudy skies each afternoon, scattered showers and thunderstorms lingering into the evening hours, and near normal temperatures for this time of the year. Kept daytime high temperatures near or slightly above average with highs in the mid 60s to mid 70s.

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**.AVIATION...(For the 12Z TAFS through early Monday morning)
Issued at 320 AM MDT Sun May 14 2023**

A blocking pattern will remain in place this weekend with light upslope northeast flow expected to continue through the rest of the weekend. Light showers, drizzle, patchy fog, and overcast skies are expected over the next 24 hours.

HAZARDS/WEATHER TRENDS: Conditions across southeast Wyoming and western Nebraska terminals continue to trend towards prevailing IFR conditions this morning with most sites reporting IFR or LIFR conditions with CIGS below 1000 feet AGL and some limits in VIS between 1 to 3 miles. KLAR and KRWL are the only terminals hanging onto VFR conditions, but expect this to change over the next few hours with lowering CIGS and increasing shower activity. Lower confidence with KRWL as they may stabilize at MVFR with CIGS around 1500 feet AGL through this afternoon.

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.FIRE WEATHER...

Issued at 509 AM MDT Sun May 14 2023

No fire weather concerns w/ recent widespread measurable rainfall, as well as continued seasonably cool temperatures.

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.CYS WATCHES/WARNINGS/ADVISORIES...

WY...None.
NE...None.
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15.0 Winds and Temperature Aloft Forecast

The NWS Winds and Temperature Aloft forecast valid for 0800 MDT for the closest point to the accident site is included below:

FBUS31 KWNO 141400
FD1US1
DATA BASED ON 141200Z
VALID 141800Z FOR USE 1400-2100Z. TEMPS NEG ABV 24000

FT 3000 6000 9000 12000 18000 24000 30000 34000 39000
MBW **0919 1109-01** 1308-14 0706-25 180942 150951 182356

The closest forecast point to the accident site was Medicine Bow, Wyoming, (MBW). The 0800 MDT forecast was for use between 0800 and 1500 MDT. The forecast for 9,000 ft expected a wind from 090° at 19 knots and for 12,000 ft a wind from 110° at 9 knots with a temperature of -1° C.

16.0 Icing Potential

The Current Icing Product (CIP) and Forecast Icing Product (FIP²⁹) imagery provided information on expected icing severity as five categories: none, trace, light, moderate, and heavy. The severity estimates are roughly based on the accretion rate of ice on an airplane, and the levels are determined by the time it would take for an airfoil to accrete 1/4 of an inch of ice: trace = 1 hour; light = 15 minutes to 1 hour; moderate = 5 to 15 minutes; severe = less than 5 minutes. Note that these are general values. Users should always consider the icing susceptibility of their airframe and availability of icing protection provided by their aircraft. Different aircraft and different flight configurations (airspeed, angle of attack, etc.) will experience variations in accretion rate.

The images presented in this report show data from National Center for Atmospheric Research (NCAR)'s prototype CIP and FIP algorithms, generated using NCAR's visualization software. These algorithms differ in various ways from the operational CIP and FIP³⁰ that provided data used to generate the publicly available images accessible through the AWC on the accident day. NCAR's prototype CIP and FIP represent the latest research and development conducted by their team of in-flight icing scientists, and have passed internal validation exercises using voice pilot reports (PIREPs) of icing conditions and scientific airborne research observations of in-flight icing (when available). Through coordination with the FAA and NOAA, NCAR provides the prototype CIP and FIP for an independent validation exercise to determine their suitability for operational use. Pending the outcome of that validation, the operational versions are replaced with the prototype versions. The frequency with which the operational versions are updated is dependent upon the research and development advancements in the prototype versions and available resources to support the operational upgrade.

²⁹ B.C. Bernstein, F. McDonough, M. K. Politovich, B. G. Brown, T. P. Ratvasky, D. R. Miller, C.A. Wolff, and G. Cuning, Current Icing Potential: Algorithm Description and Comparison with Aircraft Observations (Journal of Applied Meteorology, 2005), pp. 969-986.

C.A. Wolff, F. McDonough, M. K. Politovich, B.C. Bernstein, and G. Cuning, FIP Severity Technical Document (Prepared for the Aviation Weather Technology Transfer Technical Review Board), pp. 1-44. <https://arc.aiaa.org/doi/abs/10.2514/6.2009-3531>

Wolff, C. A., D. R. Adriaansen, and M. K. Politovich, 2014: Diagnosing and Forecasting In-Flight Icing Conditions in Alaska. Preprints, 6th AIAA Atmospheric and Space Environments Conference, Atlanta, GA, Amer. Inst. Aero. Astro., 2014-2070, available at: <http://arc.aiaa.org/doi/abs/10.2514/6.2014-2070>.

[Icing Product Alaska \(IPA\) - Experimental | NCAR Research Applications Laboratory | RAL \(ucar.edu\)](http://arc.aiaa.org/doi/abs/10.2514/6.2014-2070)

³⁰ <https://www.aviationweather.gov/icing/fip>

The FIP icing probabilities and icing severity products for the 1-hour forecast valid at 1100 and 1200 MDT at 11,000 through 15,000 ft indicated a 30 to 80% probability of trace to moderate icing above the accident site (attachment 3). The highest probabilities and intensity rates were from 12,000 to 15,000 ft. The CIP products indicated a 30 to 85% probability of light to heavy icing from 10,000 ft through 15,000 ft at 1100 and 1200 MDT above the accident site (attachment 6). The CIP indicated a 20 to 90% probability of Supercooled Large Droplets (SLD)³¹ above the accident site between 11,000 and 14,000 ft at 1100 and 1200 MDT. For more FIP and CIP data and imagery please see attachment 6.

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. The accident pilot did have an account through ForeFlight and filed a flight plan (attachment 7) at 1000 MDT and received a weather briefing package (attachment 8). The weather briefing package generated around 1000 MDT contained all the standard weather information and products including weather products for icing conditions. For more information please see attachments 7 and 8. It is unknown what additional weather information, if any, the accident pilot checked or received during the accident flight.

³¹ [AWC - Icing \(aviationweather.gov\)](https://www.faa.gov/documentLibrary/media/Advisory_Circular/AC_91-92.pdf)

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 obtained for the accident site on May 14, 2023, indicated the following:

SUN

Begin civil twilight	0515 MDT
Sunrise	0546 MDT
Accident time	1135 MDT³³
Sun transit	1300 MDT
Sunset	2016 MDT
End civil twilight	2047 MDT

At the time of the accident the Sun was at an altitude of 60.86° and an azimuth of 134.80°.

E. LIST OF ATTACHMENTS

- Attachment 1 - GOES-16 Visible imagery animation from 1001 to 1201 MDT
- Attachment 2 - GOES-16 Day Cloud Phase RGB animation from 1006 to 1206 MDT
- Attachment 3 - Day Cloud Phase Quick Guide
- Attachment 4 - Animation of KCYS imagery between 1100 and 1145 MDT
- Attachment 5 - GFA information valid at the accident time
- Attachment 6 - CIP and FIP imagery
- Attachment 7 - ForeFlight information
- Attachment 8 - ForeFlight weather information

Submitted by:

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³³ Inserted accident time for reference and context.