



NATIONAL TRANSPORTATION SAFETY BOARD

Office of Aviation Safety
Washington, D.C. 20594

May 16, 2018

Group Chairman's Factual Report

METEOROLOGY

CEN17FA354

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A. ACCIDENT

Location: Near Glenwood Springs, CO
Date: September 15, 2017
Time: 2010 mountain daylight time
0210 Coordinated Universal Time (UTC), September 16, 2017
Airplane: Cirrus SR22, Registration: N462SR

B. METEOROLOGY GROUP

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

Jennifer Stark
NWS Meteorologist on detail to the NTSB
Meteorologist in Charge
WFO Pueblo

C. DETAILS OF THE INVESTIGATION

The National Transportation Safety Board's (NTSB) Meteorologist did not travel for this investigation and gathered the weather data from official National Oceanic and Atmospheric Administration (NOAA) National Weather Service (NWS) sources including the National Centers for Environmental Information (NCEI). All times are mountain daylight time (MDT) on September 15, 2017, and are based upon the 24-hour clock, where local time is -6 hours from UTC, and UTC=Z (unless otherwise noted). Directions are referenced to true north and distances in nautical miles. Heights are above mean sea level (msl) unless otherwise noted. Visibility is in statute miles and fractions of statute miles.

The accident site was located at approximately latitude 39.6976° N, longitude 107.3609° W, and an elevation of 10,800 feet (ft).

D. WEATHER INFORMATION

1.0 Synoptic Situation

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

¹

https://www.faa.gov/regulations_policies/advisory_circulars/index.cfm/go/document.information/documentID/1030235

1.1 Surface Analysis Chart

The NWS Surface Analysis Chart for 1800 MDT is provided as figure 1 with the approximate location of the accident site marked within the red circle. The chart depicted a surface low pressure system over eastern Colorado with a pressure of 1001-hectopascals (hPa). A cold front extended southwest from the 1001-hPa surface low pressure center pressure through southwest Colorado and into southern Utah. The station models around the accident site depicted air temperatures in the upper 60's degrees Fahrenheit (°F), dew point temperatures in the lower 30's °F, a southwest wind between 10 and 20 knots, and clear skies with no precipitation.

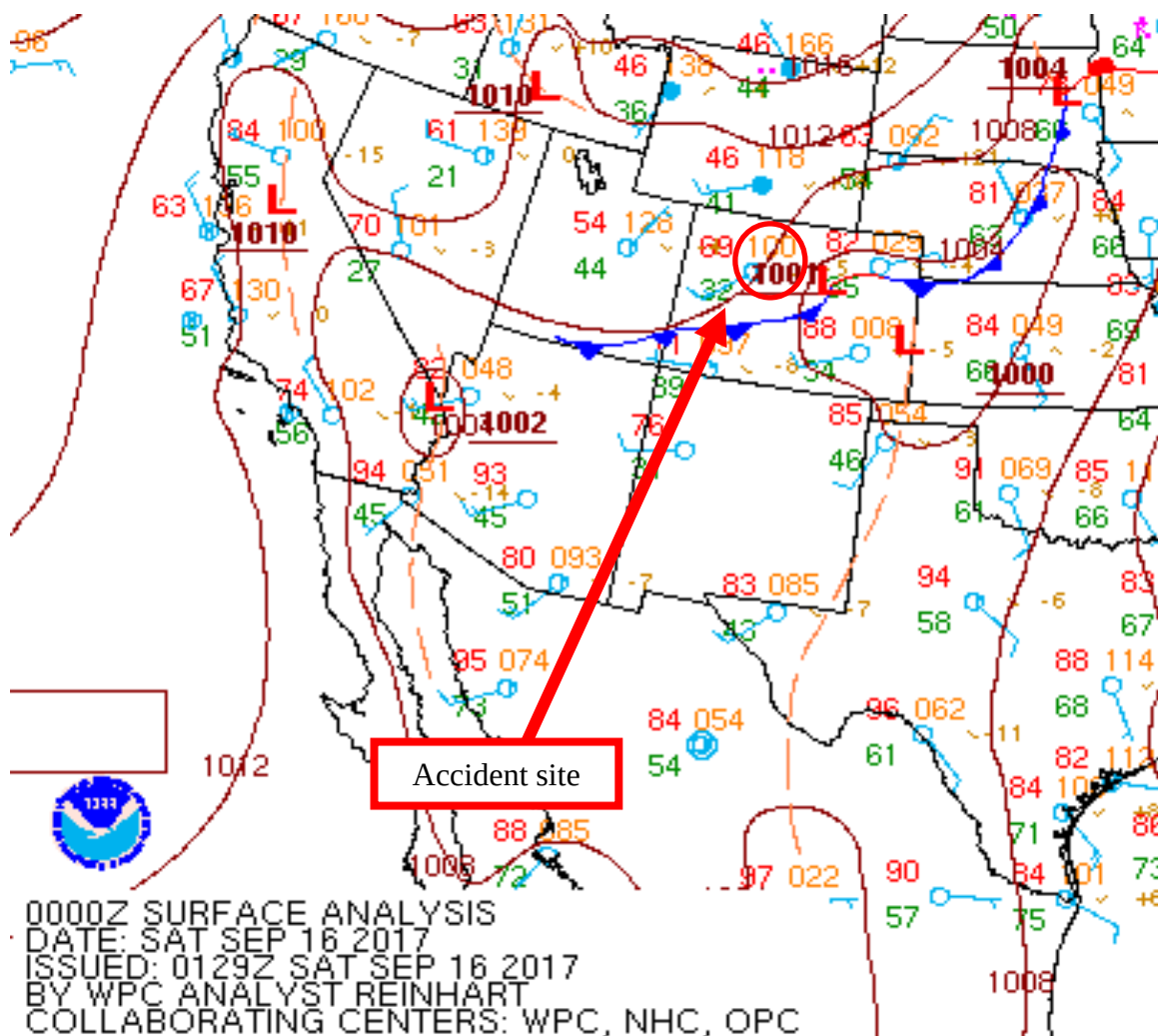


Figure 1 – NWS Surface Analysis Chart for 1800 MDT

1.2 Upper Air Charts

The NWS Storm Prediction Center (SPC) Constant Pressure Charts for 1800 MDT at 700-, 500-, and 250-hPa are presented in figures 2 through 4. The accident site was located between two low-level troughs². There was a southwest wind of 20 knots at 700-hPa above the accident site (figure 2). The mid-level trough axis was located west of the accident site. The wind was southwesterly at 500-hPa and the wind speed increased to 30 knots above the accident site (figure 3). At 250-hPa, the upper level trough was located west of the accident site. The wind was west-southwesterly and the wind speed increased to 55 knots above the accident (figure 4).

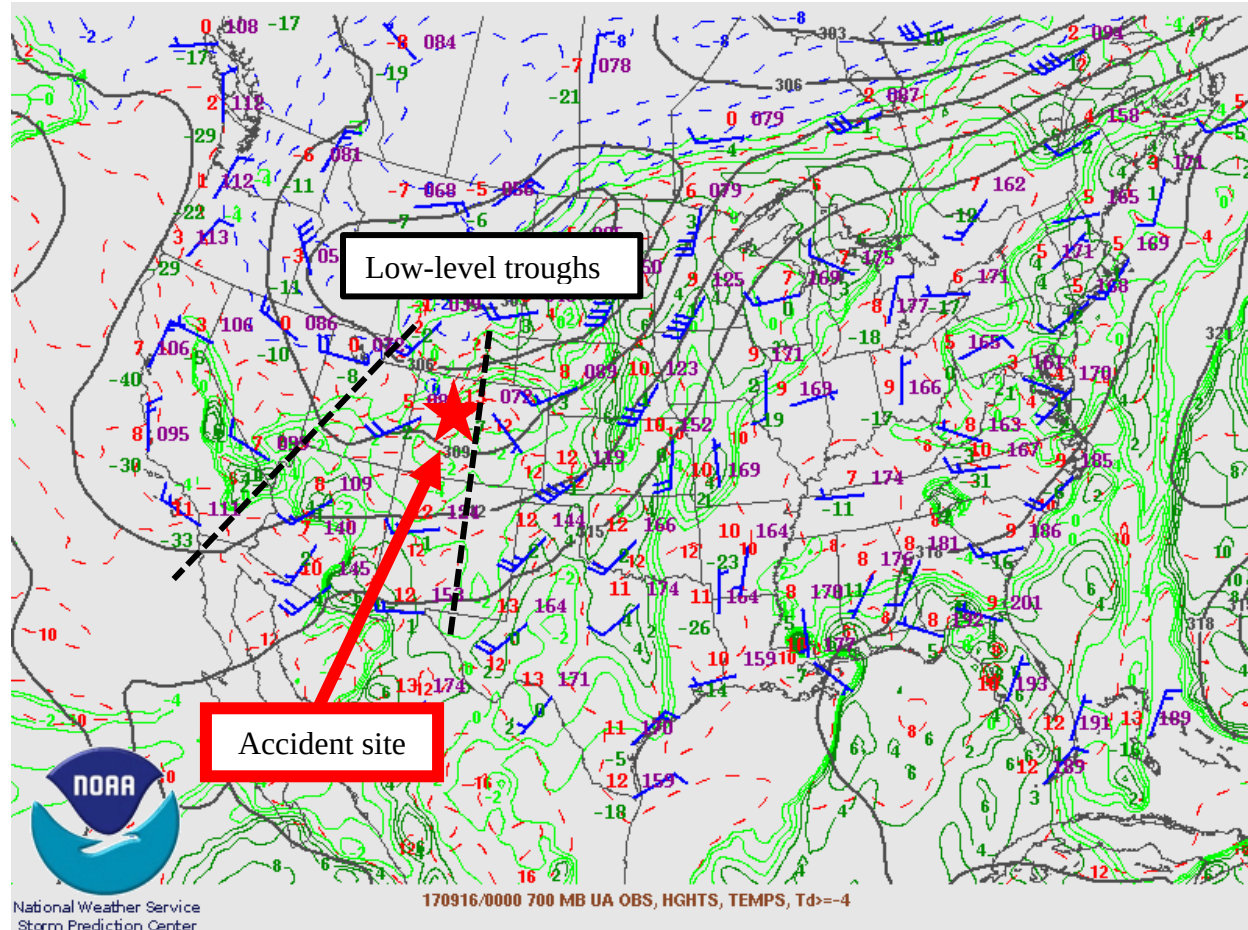


Figure 2 – 700-hPa Constant Pressure Chart for 1800 MDT

² Trough – An elongated area of relatively low atmospheric pressure or heights. Areas near troughs are favored locations for enhanced vertical motion, clouds, and precipitation

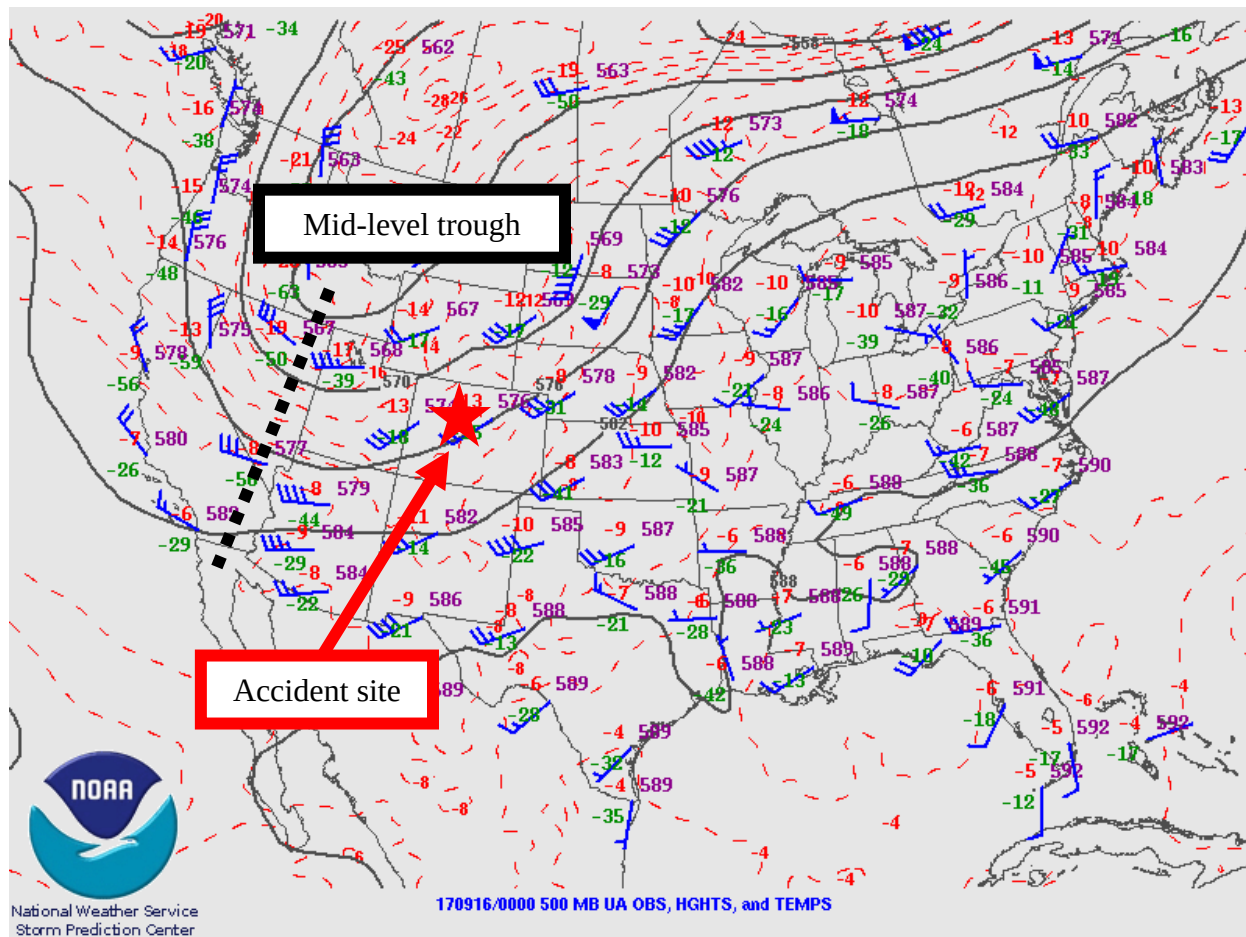


Figure 3 – 500-hPa Constant Pressure Chart for 1800 MDT

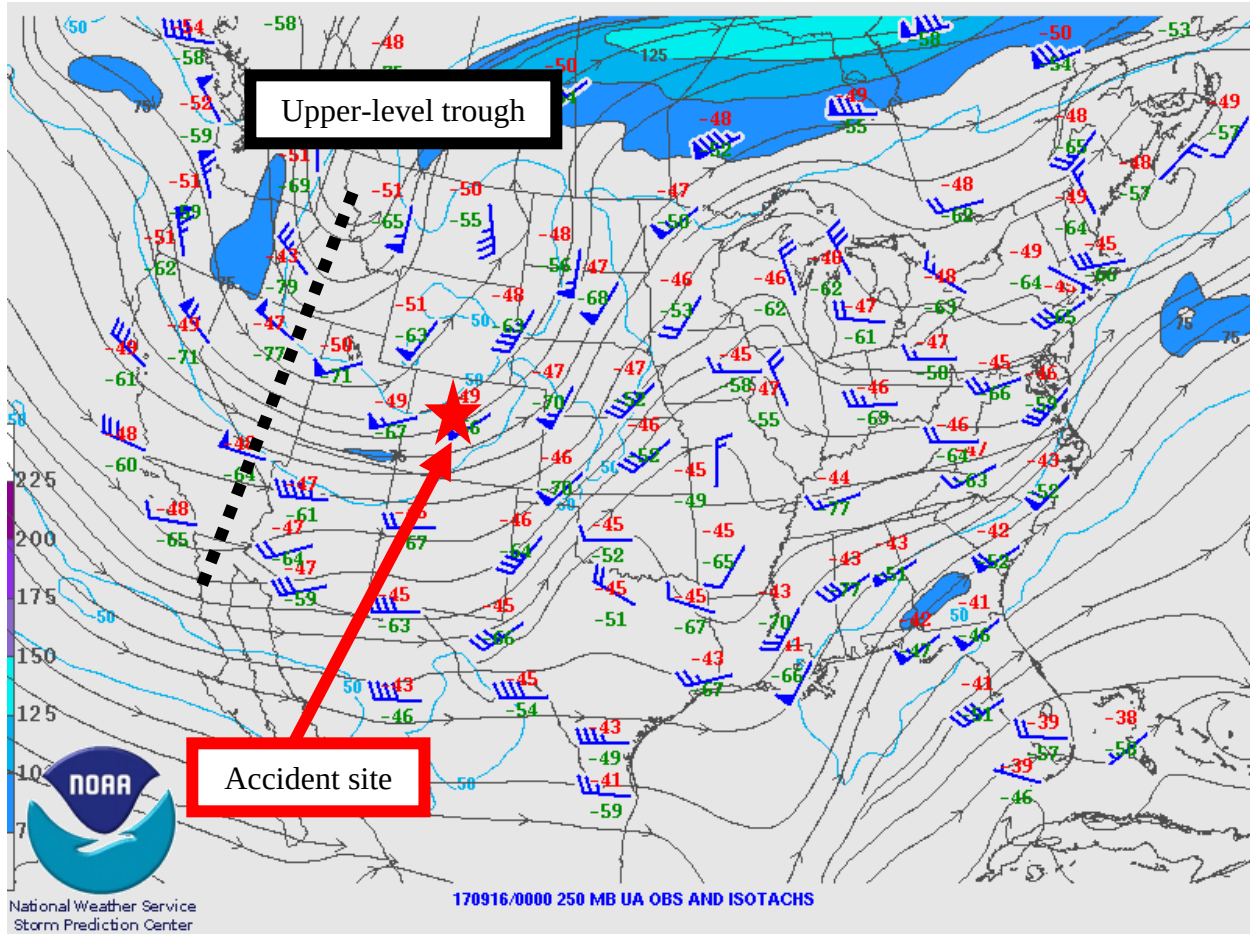


Figure 4 – 250-hPa Constant Pressure Chart for 1800 MDT

2.0 SPC Products

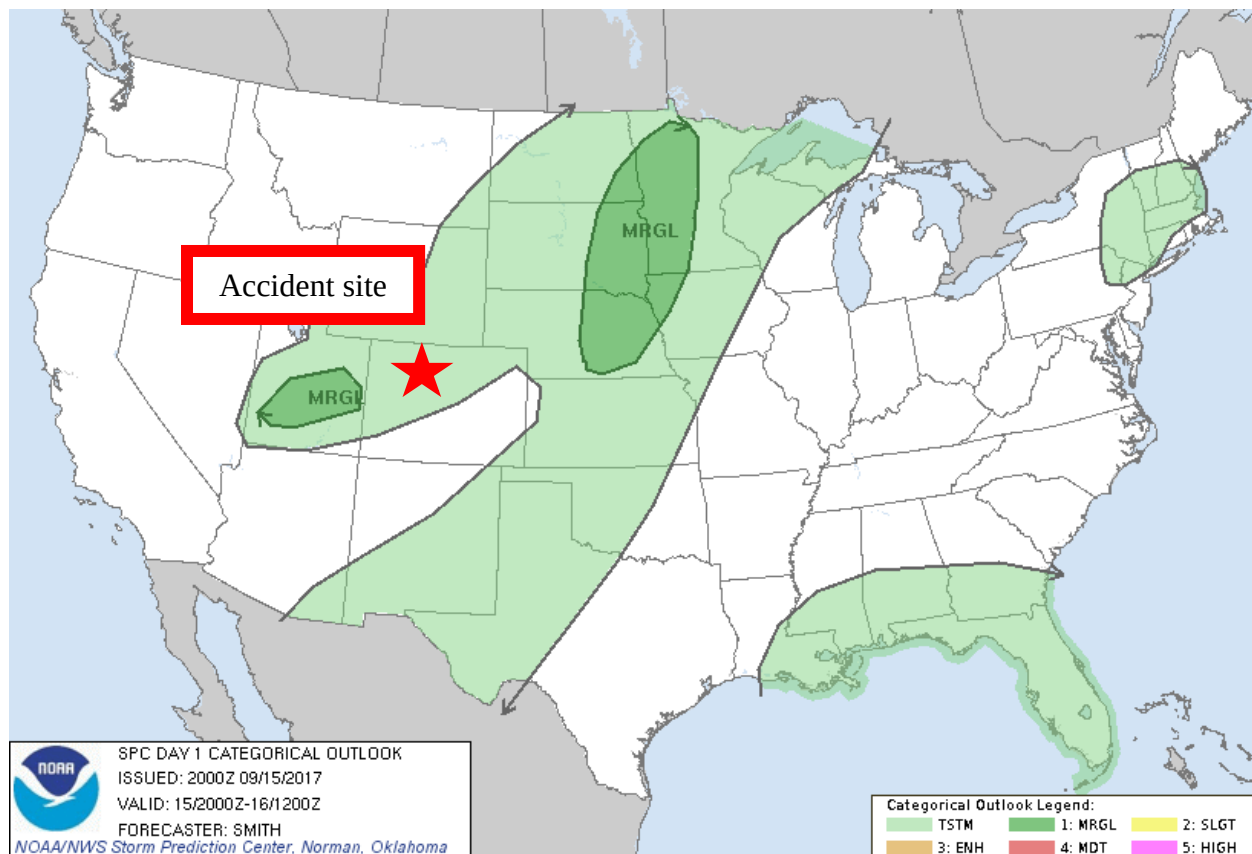


Figure 5 – Day One Convective Outlook issued by SPC at 1400 MDT

The Day One convective outlook issued by the SPC at 1400 MDT was valid for 1400 MDT through 0600 MDT on September 16, 2017 (Figure 5). The accident site was included in a “TSTM” area. 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.

3.0 Surface Observations

The area surrounding the accident site was documented using official Meteorological Aerodrome Reports (METARs) and Specials (SPECIs). The following observations were taken from standard code and are provided in plain language with visibility reported in statute miles for this section. Figure 6 is a sectional chart with the accident site and the closest weather reporting locations marked.

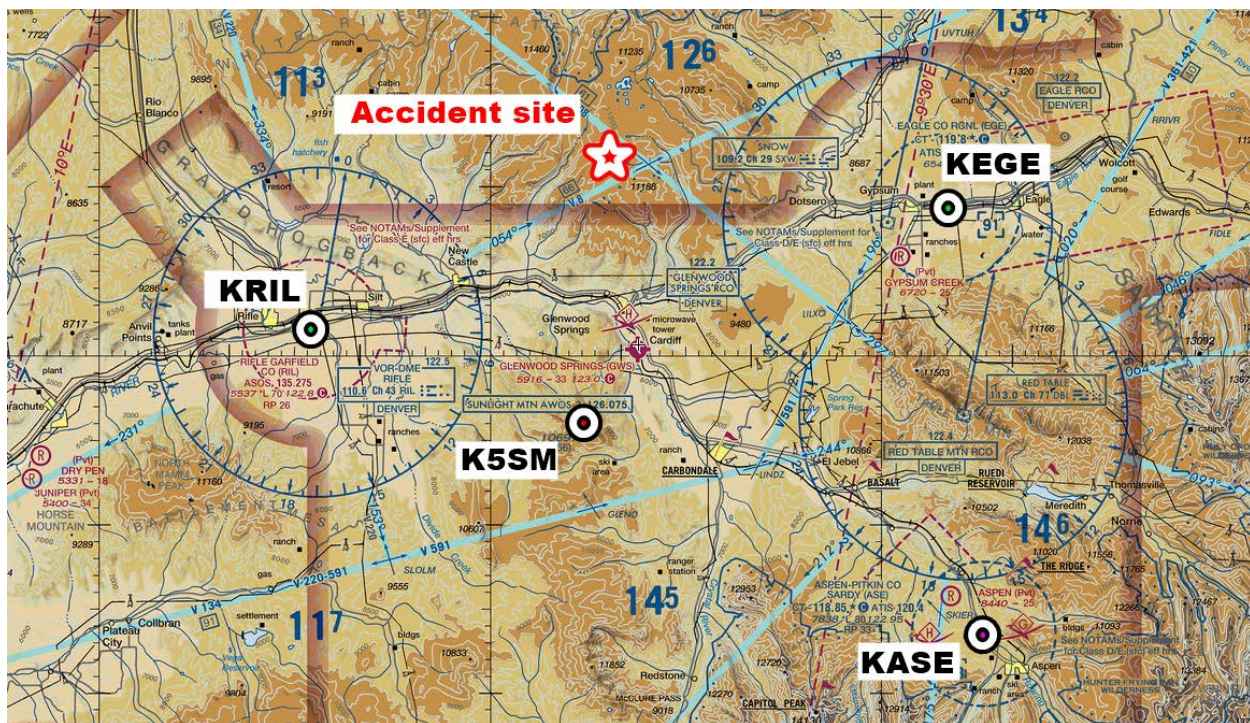


Figure 6 – Sectional chart of accident area with the location of the accident site and surface observation sites

Rifle Garfield County Airport (KRIL) was the closest official weather station to the accident site, located 20 miles southwest of the accident site, at an elevation of 5,537 ft, and was equipped with an Automated Surface Observing System (ASOS³). Observations from KRIL were automated and were not augmented by a human observer. KRIL had a 10° easterly magnetic variation⁴ (figure 6). The following observations were taken and disseminated during the times surrounding the accident:⁵

[1729 MDT] SPECI KRIL 152329Z AUTO 32026G37KT 10SM BKN090 OVC110 17/07
A2992 RMK AO2 PK WND 32037/2326 WSHFT 2309 LTG
DSNT NW PRESRR T01670067=

[1753 MDT] METAR KRIL 152353Z AUTO 33020G30KT 10SM VCTS BKN095 BKN110
16/07 A2994 RMK AO2 PK WND 33038/2339 WSHFT 2309
LTG DSNT NE AND SW AND W SLP095 T01560067 10233
20156 53016=

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

⁴ Magnetic variation – The angle (at a particular location) between magnetic north and true north. Latest measurement taken from <http://airnav.com/airport/KRIL>

⁵ The bold sections in this NWS product and the rest of products in this report are intended to highlight the sections that directly reference the weather conditions that affected the accident location around the accident time. The local times in section 3.0 next to the METARs are provided for quick reference between UTC and local times around the accident time.

[1835 MDT] SPECI KRIL 160035Z AUTO 29016G26KT 10SM TSRA BKN070 BKN085
OVC110 14/08 A2997 RMK AO2 PK WND 33032/0000 LTG
DSNT ALQDS RAB25 TSB34 P0001 T01390078=

[1853 MDT] METAR KRIL 160053Z AUTO 27023G36KT 10SM -TSRA BKN070 OVC080
13/09 A2999 RMK AO2 PK WND 26036/0050 LTG DSNT
NE-SE RAB25 TSB34 SLP119 P0002 T01280094=

**[1911 MDT] SPECI KRIL 160111Z AUTO 28016G22KT 10SM -RA SCT065 OVC080
12/09 A3002 RMK AO2 LTG DSNT N-SE TSE05 PRESRR
P0002 T01170089=**

**[1953 MDT] METAR KRIL 160153Z AUTO 30005KT 10SM BKN075 OVC095 12/08
A3004 RMK AO2 LTG DSNT S RAE48 TSE05 SLP139 P0002
T01220083=**

ACCIDENT TIME 2010 MDT

**[2053 MDT] METAR KRIL 160253Z AUTO VRB03KT 10SM BKN060 OVC080 12/08
A3007 RMK AO2 SLP145 60004 T01220083 51039=**

[2153 MDT] METAR KRIL 160353Z AUTO 19003KT 10SM FEW044 OVC055 12/09
A3007 RMK AO2 RAB0256E11 SLP140 P0000 T01170094=

KRIL weather at 1911 MDT, automated, wind from 280° at 16 knots with gusts to 22 knots, 10 miles visibility or greater, light rain, scattered clouds at 6,500 ft above ground level (agl), overcast ceiling at 8,000 ft agl, temperature 12° Celsius (C), dew point temperature of 9° C, and an altimeter setting of 30.02 inches of mercury. Remarks, station with a precipitation discriminator, lightning distant⁶ north through southeast, thunderstorm ended 1905 MDT, pressure rising rapidly, precipitation of 0.02 inches since 1853 MDT, temperature 11.7° C, dew point temperature 8.9° C.

KRIL weather at 1953 MDT, automated, wind from 300° at 5 knots, 10 miles visibility or greater, broken ceiling at 7,500 ft agl, overcast skies at 9,500 ft agl, temperature 12° C, dew point temperature of 8° C, and an altimeter setting of 30.04 inches of mercury. Remarks, station with a precipitation discriminator, lightning distant south, rain ended 1948 MDT, thunderstorm ended 1905 MDT, sea level pressure 1013.9 hPa, precipitation of 0.02 inches since 1853 MDT, temperature 12.2° C, dew point temperature 8.3° C.

KRIL weather at 2053 MDT, automated, variable wind direction at 3 knots, 10 miles visibility or greater, broken ceiling at 6,000 ft agl, overcast skies at 8,000 ft agl, temperature 12° C, dew point temperature of 8° C, and an altimeter setting of 30.07 inches of mercury. Remarks, station with a precipitation discriminator, sea level pressure 1014.5 hPa, six hourly precipitation of 0.04 inches, temperature 12.2° C, dew point temperature 8.3° C, 3-hourly pressure increase of 3.9 hPa.

⁶ Distant indicated that the lightning was beyond 10 miles but less than 30 miles from the center of the airport (or airport location point, [ALP]).

Sunlight Peak (K5SM) was equipped with an Automated Weather Observing System (AWOS⁷) whose reports were not supplemented. K5SM was located 16 miles south of the accident site (figure 6) at an elevation of 10,604 ft, and K5SM observations around the accident time are listed below:

[1829 MDT] METAR K5SM 160029Z AUTO 26007G20KT 230V030 10SM -TSRA BKN006 BKN047 OVC095 03/01 A3022 RMK AO2 LTG DSNT SW THRU N=

[1849 MDT] METAR K5SM 160049Z AUTO 26012G21KT 190V320 1 3/4SM -TSRA OVC002 03/02 A3022 RMK AO2 LTG DSNT W THRU NE=

[1910 MDT] METAR K5SM 160110Z AUTO 27014G25KT 230V310 1/4SM -RA OVC002 01/01 A3023 RMK AO2 LTG DSNT NW THRU NE=

[1929 MDT] METAR K5SM 160129Z AUTO 24010G28KT 170V290 1/4SM -RA OVC002 01/01 A3023 RMK AO2 LTG DSNT NE=

[1950 MDT] METAR K5SM 160150Z AUTO 24011G23KT 210V280 1/4SM -VCTSRA OVC002 01/01 A3023 RMK AO2 LTG DSNT NE E AND W=

[2008 MDT] METAR K5SM 160208Z AUTO 24011G23KT 210V280 1/2SM FG OVC002 02/01 A3024 RMK AO2=

ACCIDENT TIME 2010 MDT

[2031 MDT] METAR K5SM 160231Z AUTO 24012G24KT 180V300 1 1/4SM -RA OVC002 02/01 A3024 RMK AO2 LTG DSNT E=

[2049 MDT] METAR K5SM 160249Z AUTO 23011G22KT 1 1/4SM BR OVC002 02/01 A3026 RMK AO2=

[2110 MDT] METAR K5SM 160310Z AUTO 23008G15KT 1SM VCTS BR OVC002 02/01 A3028 RMK AO2 LTG DSNT SE=

K5SM weather at 1950 MDT, automated, wind from 240° at 11 knots with gusts to 23 knots, wind direction variable from 210° to 280°, a quarter mile visibility, thunderstorm with light rain in the vicinity⁸, overcast ceiling at 200 ft agl, temperature of 1° C, dew point temperature of 1° C, and an altimeter setting of 30.23 inches of mercury. Remarks, station with a precipitation discriminator, lightning distant northeast, east and west.

⁷ AWOS – Automated Weather Observing System is equipped with meteorological instruments to observe and report temperature, dewpoint, wind speed and direction, visibility, cloud coverage and ceiling up to twelve thousand feet, and altimeter setting.

⁸ In the vicinity of the airport is defined as a weather phenomenon within 5-10 miles of the airfield, but not over the airfield.

K5SM weather at 2008 MDT, automated, wind from 240° at 11 knots with gusts to 23 knots, wind direction variable from 210° to 280°, a half mile visibility, fog, overcast ceiling at 200 ft agl, temperature of 2° C, dew point temperature of 1° C, and an altimeter setting of 30.24 inches of mercury. Remarks, station with a precipitation discriminator.

K5SM weather at 2031 MDT, automated, wind from 240° at 12 knots with gusts to 24 knots, wind direction variable from 180° to 300°, one and a quarter miles visibility, light rain, overcast ceiling at 200 ft agl, temperature of 2° C, dew point temperature of 1° C, and an altimeter setting of 30.24 inches of mercury. Remarks, station with a precipitation discriminator, lightning distant east.

K5SM weather at 2049 MDT, automated, wind from 230° at 11 knots with gusts to 22 knots, one and a quarter miles visibility, mist, overcast ceiling at 200 ft agl, temperature of 2° C, dew point temperature of 1° C, and an altimeter setting of 30.26 inches of mercury. Remarks, station with a precipitation discriminator.

Eagle County Regional Airport (KEGE) was the next closest official weather station to the accident site, located 21 miles east-southeast of the accident site, at an elevation of 6,547 ft, and had a 13° easterly magnetic variation⁹ (figure 6). KEGE was equipped with an ASOS whose observations were automated and were not augmented by a human observer. The following observations were taken and disseminated during the times surrounding the accident:

[1756 MDT] METAR KEGE 152356Z 23015G20KT 10SM SCT085 21/00 A2994 RMK AO2 LTG DSNT W AND NW SLP100 T02060000 10217 20189 56005 \$=

[1856 MDT] METAR KEGE 160056Z 30011KT 10SM FEW090 18/03 A2998 RMK AO2 LTG DSNT SW AND W SLP117 T01830033 \$=

[1956 MDT] METAR KEGE 160156Z AUTO 32012G23KT 10SM BKN055 BKN085 OVC110 13/03 A3006 RMK AO2 LTG DSNT N AND SE PRESRR SLP155 T01330033 \$=

ACCIDENT TIME 2010 MDT

[2056 MDT] METAR KEGE 160256Z AUTO 25004KT 10SM FEW037 OVC060 13/04 A3011 RMK AO2 SLP170 T01330039 53047 \$=

KEGE weather at 1956 MDT, automated, wind from 320° at 12 knots with gusts to 23 knots, 10 miles visibility or greater, ceiling broken at 5,500 ft agl, broken clouds at 8,500 ft agl, overcast clouds at 11,000 ft agl, temperature of 13° C, dew point temperature of 3° C, and an altimeter setting of 30.06 inches of mercury. Remarks, station with a precipitation discriminator, lightning distant north and southeast, pressure rising rapidly, sea level pressure 1015.5 hPa, temperature 13.3° C, dew point temperature 3.3° C, maintenance is needed on the system.

⁹ Magnetic variation – The angle (at a particular location) between magnetic north and true north. Latest measurement taken from <http://airnav.com/airport/KEGE>

KEGE weather at 2056 MDT, automated, wind from 250° at 4 knots, 10 miles visibility or greater, few clouds at 3,700 ft agl, overcast ceiling at 6,000 ft agl, temperature of 13° C, dew point temperature of 4° C, and an altimeter setting of 30.11 inches of mercury. Remarks, station with a precipitation discriminator, sea level pressure 1017.0 hPa, temperature 13.3° C, dew point temperature 3.9° C, 3-hourly pressure increase of 4.7 hPa., maintenance is needed on the system.

Aspen-Pitkin County Airport / Sardy Field (KASE) was the next closest official weather station to the accident site, was located 37 miles southeast of the accident site at an elevation of 7,838 ft, and had a 9° easterly magnetic variation¹⁰ (figure 6). KASE was equipped with an ASOS whose observations were augmented by air traffic control (ATC) when the ATC tower was open. The following observations were taken and disseminated during the times surrounding the accident:

[1753 MDT] METAR KASE 152353Z 22006KT 10SM BKN090 BKN110 19/M01 A3000
RMK AO2 SLP056 T01891006 10206 20172 55002=

[1853 MDT] METAR KASE 160053Z 25006KT 10SM BKN085 OVC110 17/M01 A3001
RMK AO2 LTG DSNT NW SLP060 T01721006=

[1921 MDT] SPECI KASE 160121Z 20007KT 10SM -RA FEW016 SCT070 BKN085
12/06 A3006 RMK AO2 PK WND 20028/0108 WSHFT 0101 RAB05
P0000 T01170056=

**[1953 MDT] METAR KASE 160153Z AUTO 34013KT 10SM FEW042 BKN080 OVC100
12/05 A3009 RMK AO2 PK WND 20028/0108 WSHFT 0101 LTG
DSNT NE RAB05E34 SLP106 P0000 T01170050=**

ACCIDENT TIME 2010 MDT

**[2053 MDT] METAR KASE 160253Z AUTO 34006KT 10SM SCT023 BKN033 BKN085
09/05 A3014 RMK AO2 RAB0159E11 SLP121 P0000 60000 T00940050 53040=**

KASE weather at 1953 MDT, automated, wind from 340° at 13 knots, 10 miles visibility or greater, few clouds at 4,200 ft agl, ceiling broken at 8,000 ft agl, overcast skies at 10,000 ft agl, temperature 12° C, dew point temperature of 5° C, and an altimeter setting of 30.09 inches of mercury. Remarks, station with a precipitation discriminator, peak wind from 200° at 28 knots at 1908 MDT, wind shift at 1901 MDT, lightning distant northeast, rain began 1905 MDT rain ended 1934 MDT, sea level pressure 1010.6 hPa, trace of precipitation in the past hour, temperature 11.7° C, dew point temperature 5.0° C.

¹⁰ Magnetic variation – The angle (at a particular location) between magnetic north and true north. 2015, latest measurement taken from <http://airnav.com/airport/KASE>

KASE weather at 2053 MDT, automated, wind from 340° at 6 knots, 10 miles visibility or greater, scattered clouds at 2,300 ft agl, ceiling broken at 3,300 ft agl, broken skies at 8,500 ft agl, temperature 9° C, dew point temperature of 5° C, and an altimeter setting of 30.14 inches of mercury. Remarks, station with a precipitation discriminator, rain began at 1959 MDT and rain ended 2011 MDT, sea level pressure 1012.1 hPa, trace of precipitation in the past hour, 6-hourly precipitation of a trace, temperature 9.4° C, dew point temperature 5.0° C, 3-hourly pressure increase of 4.0 hPa.

The observations from K5SM (elevation of about 10,600 feet) indicated LIFR¹¹ conditions with gusty winds, light rain, distant lightning, and thunderstorms in the vicinity. At KRIL, KEGE, and KASE (elevations between 5,500 and 7,800 ft), VFR¹² conditions were reported with gusty surface winds, light rain, and distant lightning.

4.0 Upper Air Data

A High-Resolution Rapid Refresh (HRRR)¹³ model sounding was created for the accident site for both 2000 and 2200 MDT with a surface elevation of 10,548 ft. The soundings were plotted on a standard Skew-T log P diagram¹⁴ with the derived stability parameters included in figures 7 and 8 (with data from the surface to 500-hPa, or approximately 18,000 ft msl.) This data was analyzed utilizing the RAOB¹⁵ software package. The 2000 MDT sounding depicted the lifted condensation level (LCL)¹⁶ at 10,589 ft msl (41 ft agl), a convective condensation level (CCL)¹⁷ of 13,827 ft msl (3,279 ft agl), and a level of free convection (LFC)¹⁸ at 10,589 ft msl (41 ft agl). The 2000 MDT sounding indicated the freezing level was at 12,147 ft with a precipitable water value of 0.36 inches. The 2200 MDT sounding depicted the LCL at 10,878 ft msl (330 ft agl), a CCL of 13,532 ft msl (2,984 ft agl), and a LFC at 15,073 ft msl (4,525 ft agl). The 2200 MDT sounding indicated the freezing level was at 12,217 ft with a precipitable water value of 0.40 inches.

¹¹ Low Instrument Flight Rules (LIFR) – Refers to the general weather conditions pilots can expect at the surface. LIFR criteria means a ceiling below 500 ft agl and/or less than 1 mile visibility.

¹² Visual Flight Rules – Refers to the general weather conditions pilots can expect at the surface. VFR criteria means a ceiling greater than 3,000 feet agl and greater than 5 miles visibility.

¹³ 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.

¹⁴ 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.

¹⁵ RAOB – (The complete Rawinsonde Observation program) is an interactive sounding analysis program developed by Environmental Research Services, Matamoras, Pennsylvania.

¹⁶ Lifting Condensation Level (LCL) - The height at which a parcel of moist air becomes saturated when it is lifted dry adiabatically.

¹⁷ 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.

¹⁸ Level of Free Convection (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.

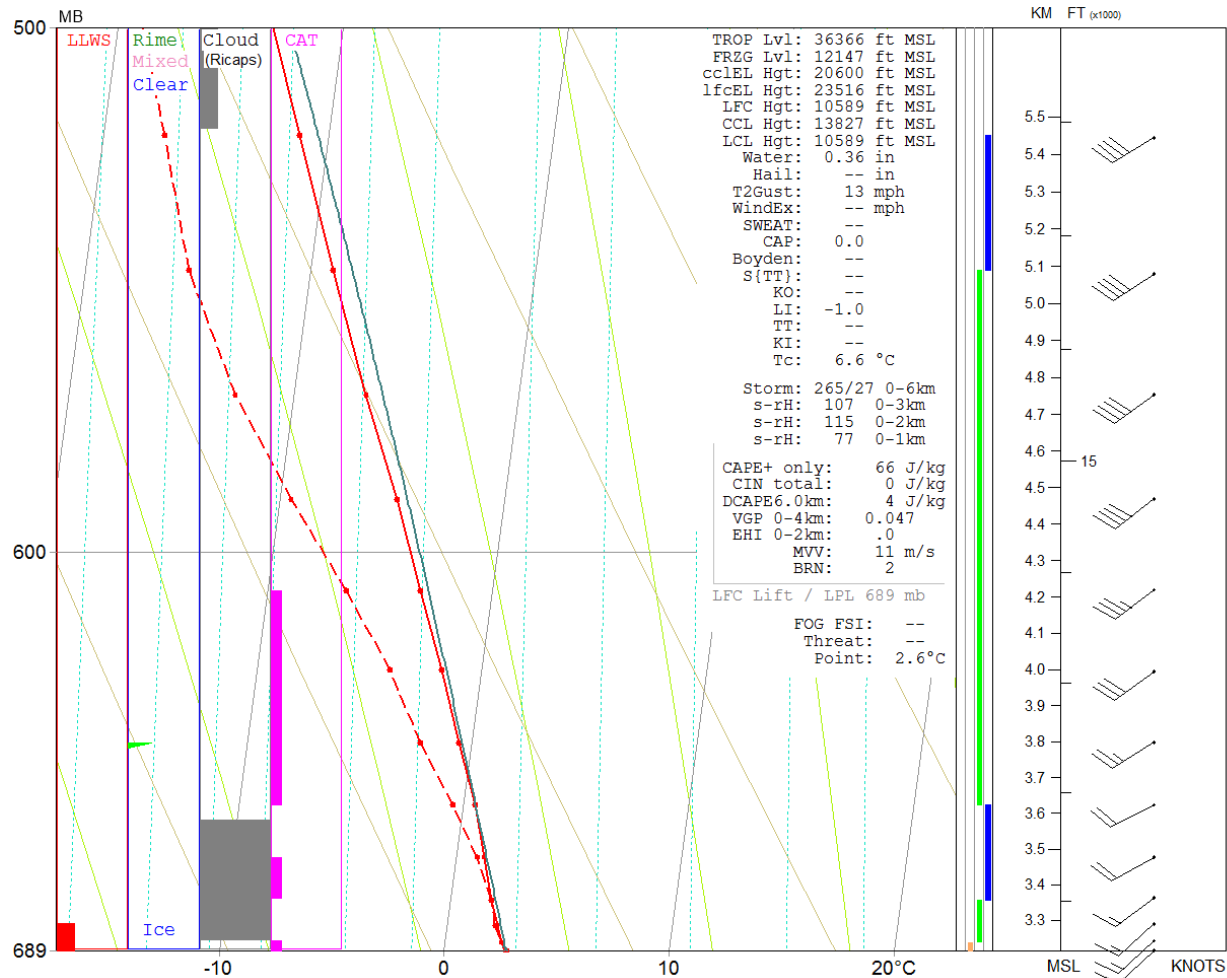


Figure 7 – 2000 MDT HRRR sounding for the accident site

The 2000 MDT HRRR sounding indicated a mostly conditionally unstable layer between the surface (10,548 ft) and 18,000 ft (figure 7). RAOB indicated that clouds were likely from near the surface through 12,000 ft. A small layer of rime icing conditions was indicated by RAOB around 12,500 ft.

The 2000 MDT HRRR sounding wind profile indicated that the wind at 11,000 ft was from the southwest at 15 knots with the wind increasing in speed to 40 knots by 14,000 ft. RAOB indicated the possibility of light low-level wind shear (LLWS) between the surface and 11,000 ft. Light clear-air turbulence was indicated by RAOB in several layers between 11,000 ft and 14,000 ft.

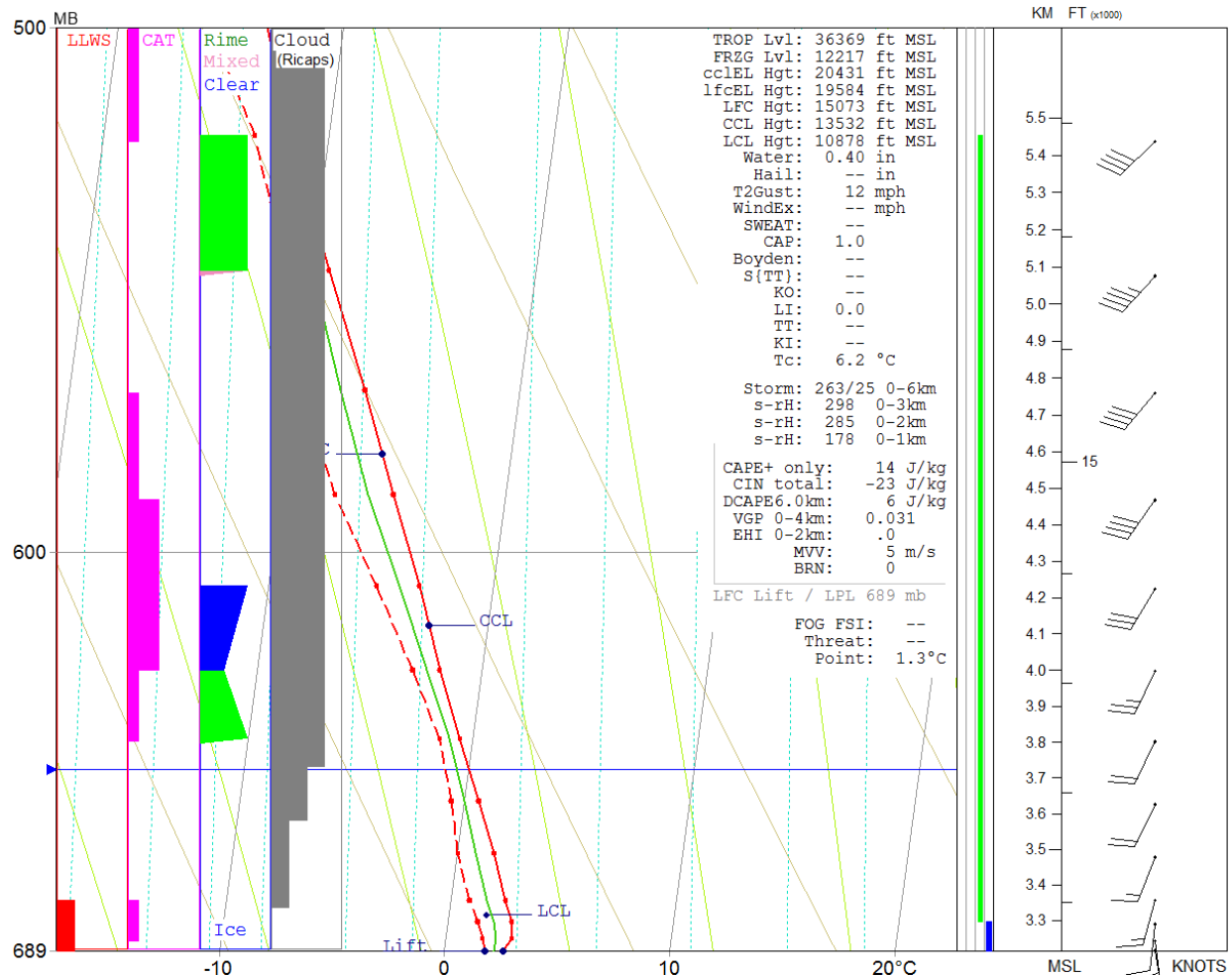


Figure 8 – 2200 MDT HRRR sounding for the accident site

The 2200 MDT HRRR sounding indicated a conditionally unstable layer between the surface and 18,000 ft (figure 8). RAOB indicated that clouds were likely from near the surface through 18,000 ft. Moderate or greater clear, mixed, and rime icing conditions were indicated by RAOB between 12,500 and 14,000 ft and then again above 16,500 ft. Relative humidity was above 80 percent in the dendritic growth zone between -10° C and -20° C.¹⁹

¹⁹ S.G. Cober, G. A. Isaac, and J. W. Strapp, Characterizations of Aircraft Icing Environments that Include Supercooled Large Drops (Journal of Applied Meteorology, 2001), pp. 1984-2002.
B.C Bernstein, C.A. Wolff, and F. McDonough, An Inferred Climatology of Icing Conditions Aloft, Including Supercooled Large Drops. Part I: Canada and the Continental United States (Journal of Applied Meteorology and Climatology, 2007), pp. 1857-1878.
Williams, E.R., D.J. Smalley, M.F. Donovan, R.G. Hallowell, K.T. Hood, B.J. Bennett, R. Evaristo, A. Stepanek, T. Bals-Elsholz, J. Cobb, J. Ritzman, A. Korolev, M. Wolde, Measurements of Differential Reflectivity in Snowstorms in Warm Season Stratiform Systems (Journal of Applied Meteorology and Climatology, 2015), pp 573-595.

The 2200 MDT HRRR sounding wind profile indicated that the wind at 11,000 ft was from 185° at 15 knots with the wind becoming southwesterly through 14,000 ft. The wind increased in speed to 40 knots by 14,000 ft. RAOB indicated the possibility of light LLWS between the surface and 11,000 ft. Light to moderate clear-air turbulence was indicated by RAOB in several layers between 11,000 ft and 18,000 ft.

5.0 Satellite Data

Infrared data from the Geostationary Operational Environmental Satellite number 16 (GOES-16) was obtained from an archive at the Space Science Engineering Center at the University of Wisconsin-Madison in Madison, Wisconsin, and processed using the Man-computer Interactive Data Access System software. Infrared imagery (GOES-16 band 13) at wavelengths of 10.3 microns (μm), was retrieved for the period. Satellite imagery surrounding the time of the accident, from 1800 MDT through 2200 MDT at approximately 15-minute intervals were reviewed, and the closest images to the time of the accident are documented here.

Figures 9, 10, and 11 present the GOES-16 infrared imagery from 2000, 2015, and 2300 MDT at 5X magnification with the accident site highlighted with a red square. Inspection of the infrared imagery indicated cloud cover over the accident site with the cloud cover moving from southwest to northeast (attachment 1). The lower brightness temperatures (green color; higher cloud tops) were located west, north, and northeast of the accident site. Based on the brightness temperatures above the accident site and the vertical temperature profile provided by the 2000 and 2200 MDT HRRR soundings, the approximate cloud-top heights over the accident site were 22,000 ft at 2015 MDT. It should be noted these figures have not been corrected for any parallax error.

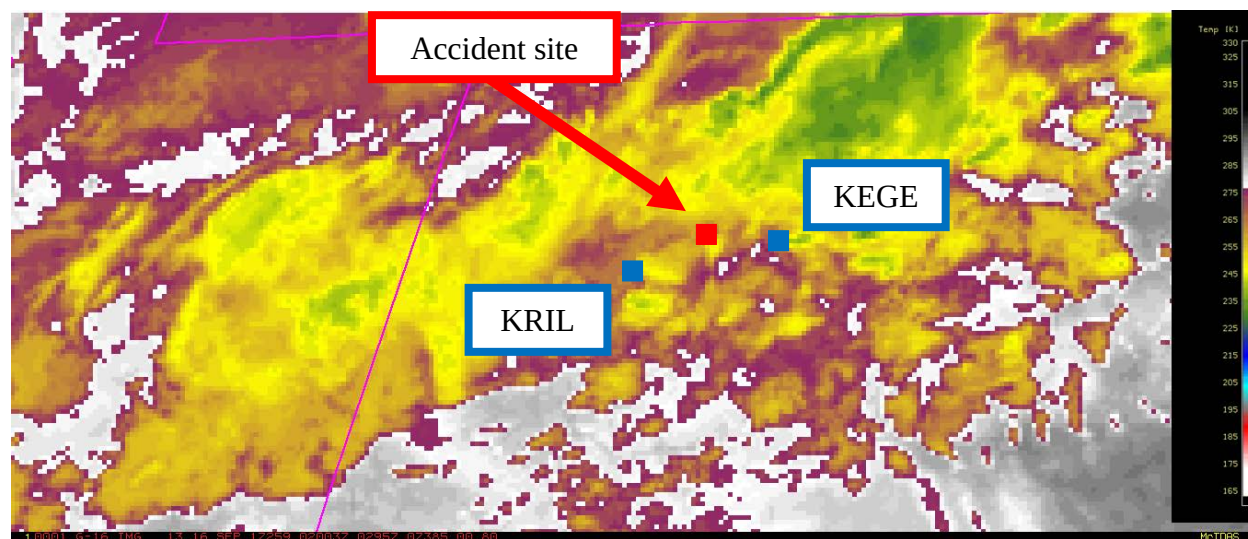


Figure 9 – GOES-16 infrared image at 2000 MDT

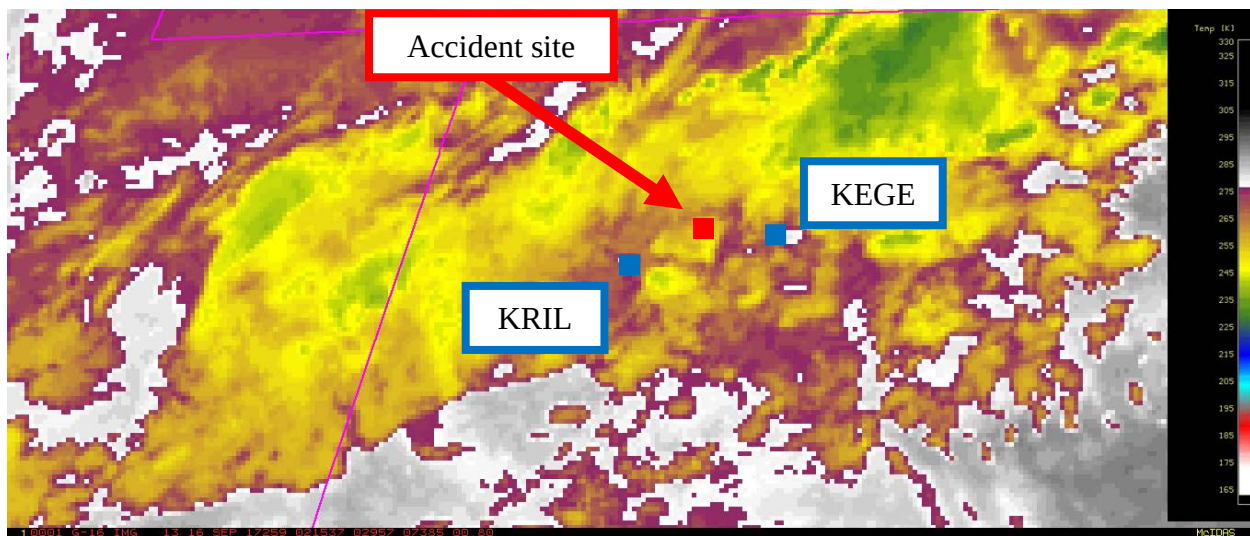


Figure 10 – GOES-16 infrared image at 2015 MDT

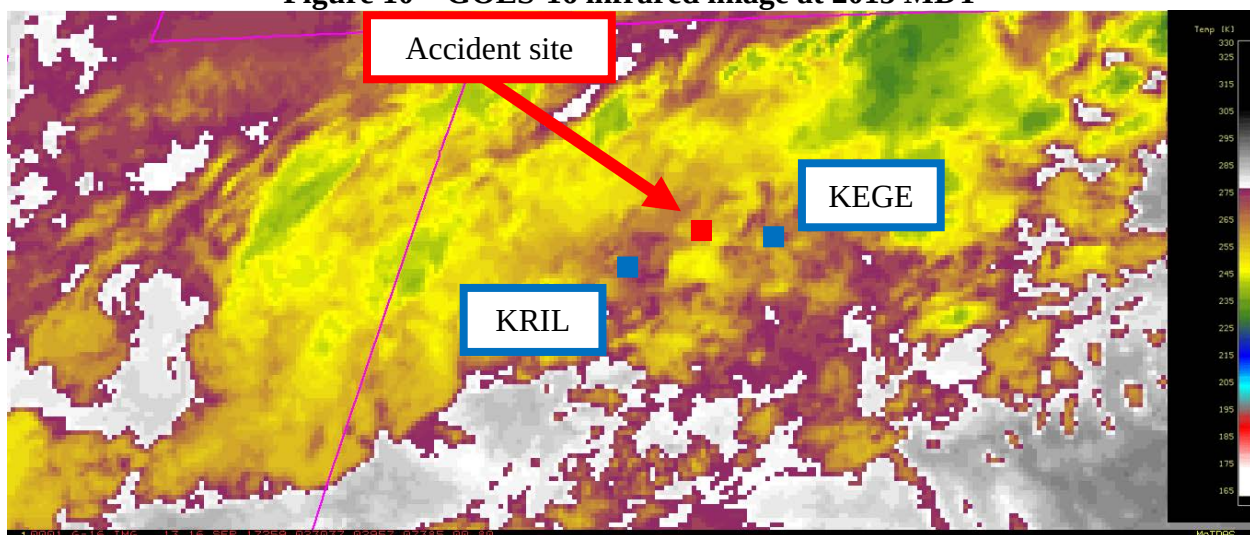


Figure 11 – GOES-16 infrared image at 2030 MDT

6.0 Radar Imagery Information

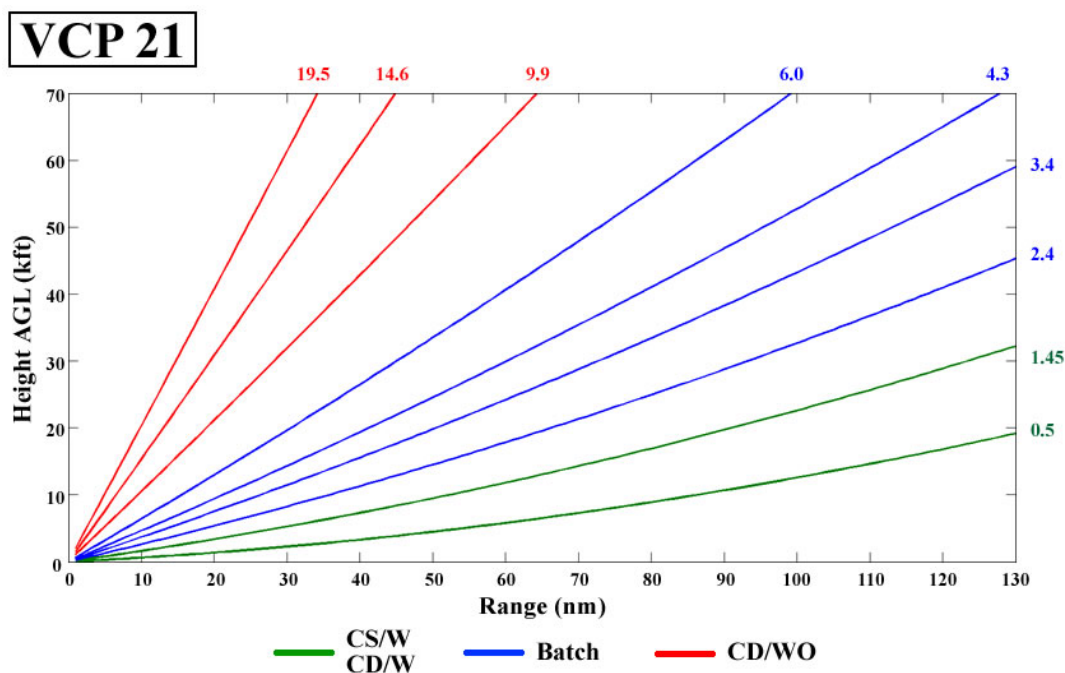
The closest NWS Weather Surveillance Radar-1988, Doppler (WSR-88D)²⁰ to the accident site was the Grand Junction, Colorado, radar (KGJX), which was located 55 miles southwest of the accident site at an elevation of 9,992 ft. Level II and III archive radar data were obtained from the NCEI utilizing the NEXRAD Data Inventory Search and displayed using the NOAA's Weather and Climate Toolkit software.

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.

6.1 Volume Scan Strategy

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

The WSR-88D operates in several different scanning modes, identified as Mode A and Mode B. Mode A is the precipitation scan and has three common scanning strategies. The most common is where the radar makes 9 elevation scans from 0.5° to 19.5° every six minutes. This particular scanning strategy is documented as volume coverage pattern 21 (VCP-21). Mode B is the clear-air mode, where the radar makes 5 elevation scans during a ten-minute period. During the period surrounding the accident, the KGJX WSR-88D radar was operating in the precipitation mode (Mode A, VCP-21). The following chart provides an indication of the different elevation angles in this VCP, and the approximate height and width of the radar beam with distance from the radar site.



VCP-21 Precipitation Mode Scan Strategy²¹

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)

6.2 Beam Height Calculation

Assuming standard refraction²² of the WSR-88D radar beam, and considering a beamwidth²³ of 0.95°, the following table shows the approximate heights for the radar beam center, top and base for several antenna elevations over the accident site. These heights have been rounded to the nearest 10 feet.

ANTENNA ELEVATION	BEAM CENTER	BEAM BASE	BEAM TOP
0.5°	15,100 ft	12,390 ft	17,810 ft

Based on the radar height calculations, the 0.5° elevation scan depicted the conditions between 12,390 ft and 17,810 ft msl over the accident site and these scans are the closest altitudes to the accident site before the accident occurred.²⁴

6.3 Reflectivity

Reflectivity is the measure of the efficiency of a target in intercepting and returning radio energy. With hydrometeors²⁵ 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 (dBZ²⁶), and is a general measure of echo intensity. FAA Advisory Circular AC 00-24C, “Thunderstorms,” dated February 19, 2013, also defines the echo intensity levels and weather radar echo intensity terminology associated with those levels. For dBZ values less than 30 the weather radar echo intensity terminology should be “light.” For dBZ values between 30 and 40, the terminology should be “moderate.” “Heavy” terminology is used for dBZ values greater than 40 dBZ but less than 50 dBZ, inclusive. Finally, any dBZ values above 50 dBZ shall be described as “extreme.” From the NWS, precipitation conditions at the surface can be inferred from VIP Levels described in the chart below:

- VIP 1 (Level 1, 18-30 dBZ) - Light precipitation
- VIP 2 (Level 2, 30-38 dBZ) - Light to moderate rain.
- VIP 3 (Level 3, 38-44 dBZ) - Moderate to heavy rain.
- VIP 4 (Level 4, 44-50 dBZ) - Heavy rain

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 For more information, please see the ATC data located in the docket for this accident.

²⁵ 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.

²⁶ 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.

- VIP 5 (Level 5, 50-57 dBZ) - Very heavy rain; hail possible.
- VIP 6 (Level 6, >57 dBZ) - Very heavy rain and hail; large hail possible.

6.4 Base Reflectivity and Lightning Data

Figures 12 through 15 present the KGJX WSR-88D base reflectivity images for the 0.5° elevation scans initiated at 1949, 2002, 2007, and 2012 MDT with a resolution of 0.5° X 250 m. The ATC observed flight track is also included with the arrows pointing in the direction of travel. The accident flight track and base reflectivity values indicated that the accident site was located in areas of 20 to 30 dBZ reflectivity values between 2007 and 2012 MDT (figures 14 and 15). The reflectivity values above the accident site at the accident time corresponded to light precipitation (section 6.3).

There were no lightning strikes around the accident site at the accident time.²⁷ A review of the dual-polarization level II and III data was done.

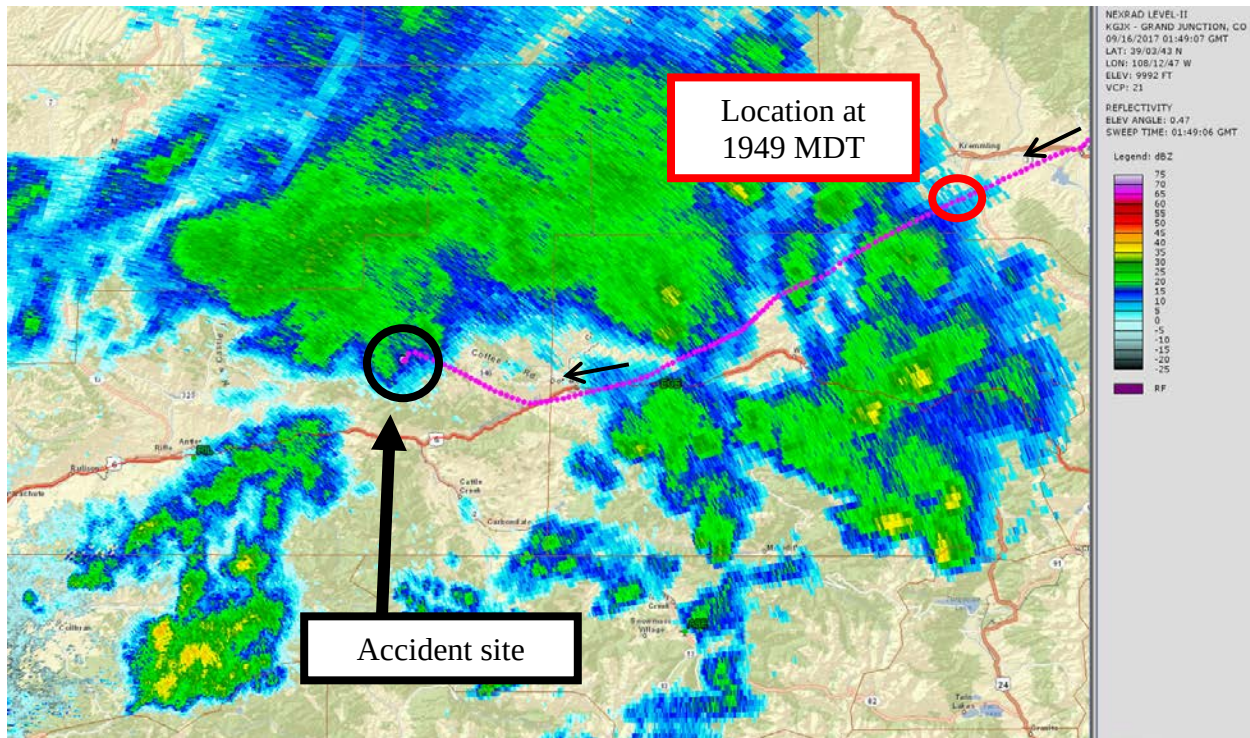


Figure 12 – KGJX WSR-88D reflectivity for the 0.5° elevation scan initiated at 1949 MDT with the ATC flight track (pink dots) and arrows pointing in direction of travel

²⁷ A review of Earth Networks Total Lightning network was done.

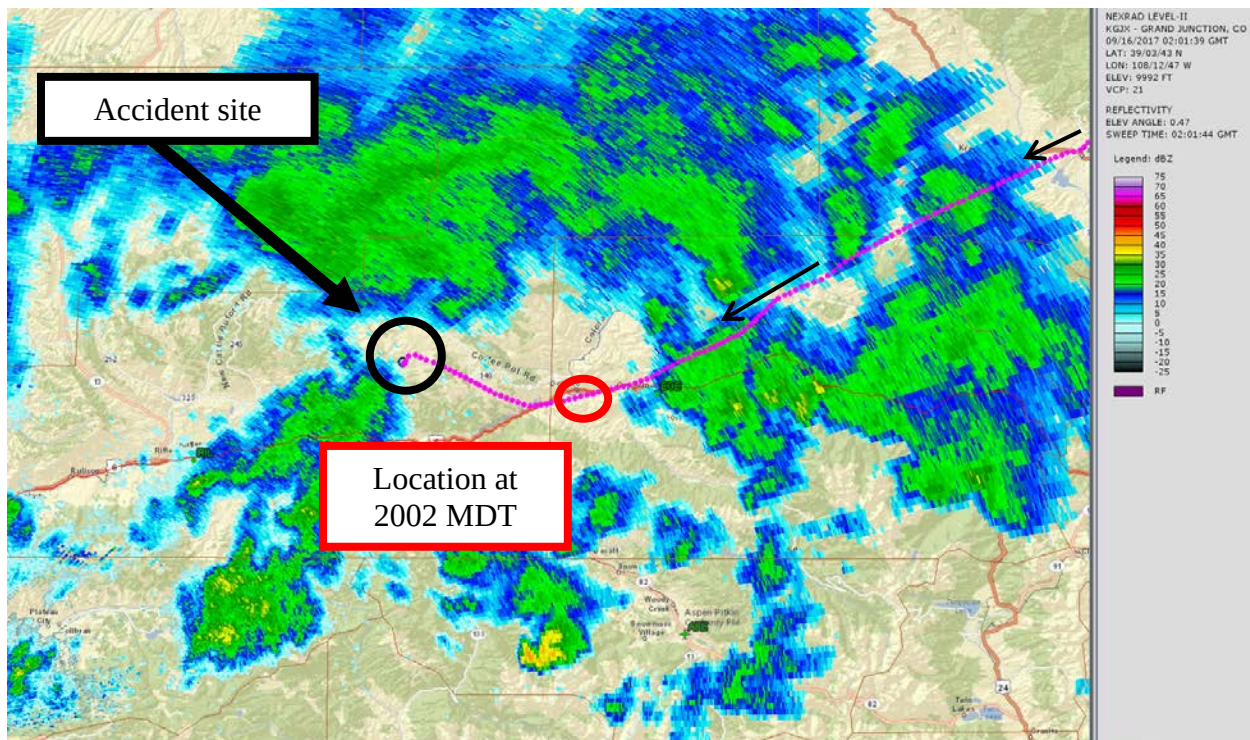


Figure 13 – KGJX WSR-88D reflectivity for the 0.5° elevation scan initiated at 2002 MDT with the ATC flight track (pink dots) and arrows pointing in direction of travel

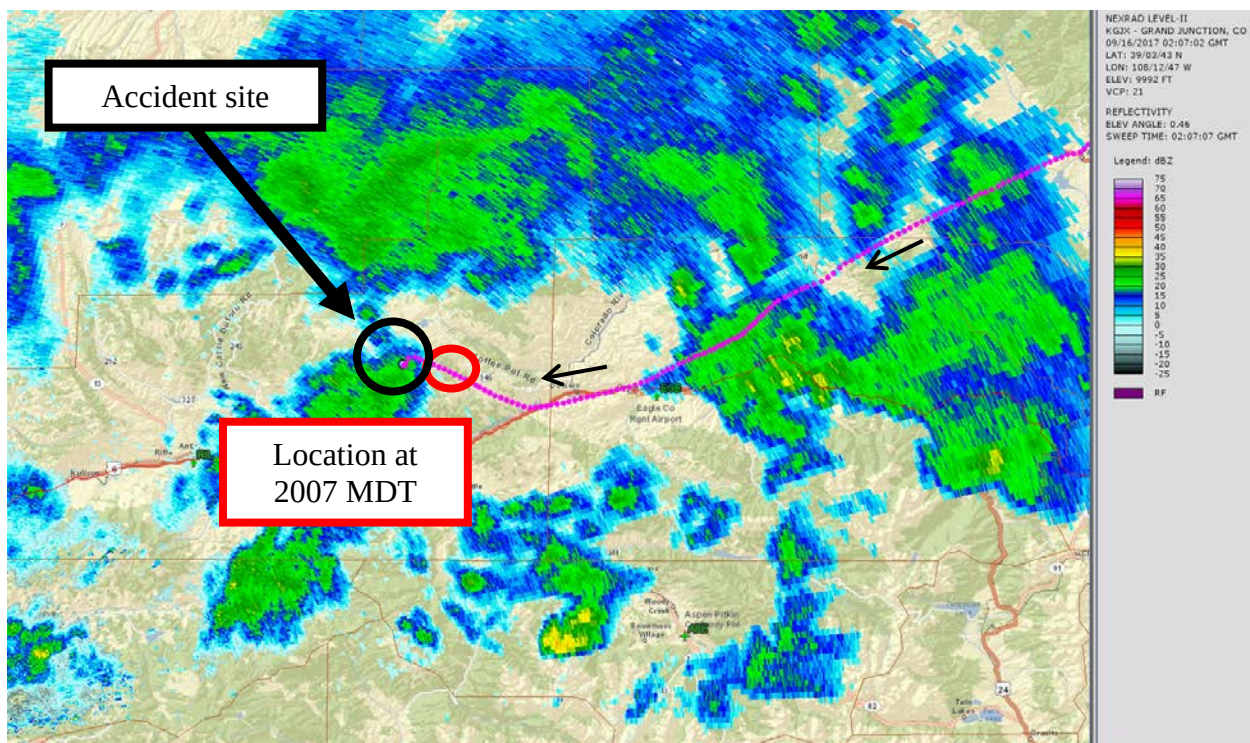


Figure 14 – KGJX WSR-88D reflectivity for the 0.5° elevation scan initiated at 2007 MDT with the ATC flight track (pink dots) and arrows pointing in direction of travel

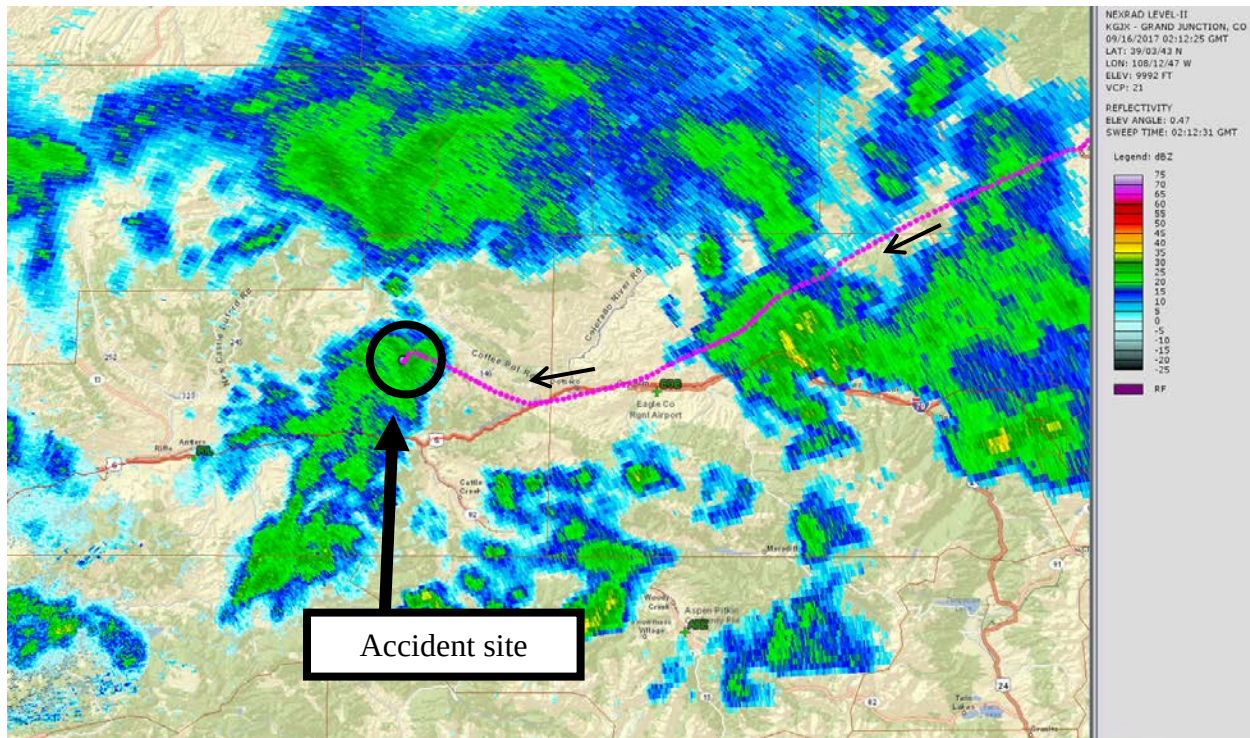


Figure 15 – KGJX WSR-88D reflectivity for the 0.5° elevation scan initiated at 2012 MDT with the ATC flight track (pink dots) and arrows pointing in direction of travel

7.0 Pilot Reports²⁸

All pilot reports (PIREPs) within 150 miles of the accident site from three hours prior to the accident time to two hours after the accident time were reviewed. Only PIREPs below FL250²⁹ are provided below:

GJT UA /OV JNC100020/TM 2340/FL130/TP CRJ2/TB MOD/RM DURC FL130-180 /ZDV

BJC UUA /OV DEP END R30L /TM 0001/FL059/TP C172/RM +/- 10 KTS LLWAS

GUC UA /OV HBU040030/TM 0009/FL215/TP C2/TA M05/IC MOD RIME/RM ZDV

BJC UUA /OV BJC360005/TM 0100/FL064/TP PA32/RM 1500 FPM DDFT

DEN UA /OV DEN225020/TM 0249/FL075/TP DA40/TB MOD TURB 075-085 DURC

²⁸ Only pilot reports with the WMO header UBCO** identifier were considered.

²⁹ 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 average 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.

Routine pilot report (UA) Grand Junction, Colorado, (GJT); Over – 20 miles from Grand Junction VOR (JNC) on a 100° radial; Time – 1740 MDT (2340Z); Altitude – 13,000 ft; Type aircraft – Bombardier CRJ-200; Turbulence – Moderate; Remarks – During climb between 13,000 ft and FL180; Denver Air Route Traffic Control Center (ZDV).

Urgent pilot report (UUA) Rocky Mountain Metropolitan Airport (BJC); Over – Departure end of Runway 30L; Time – 1801 MDT (0001Z); Altitude – 5,900 ft; Type aircraft – Cessna 172; Remarks – Plus or minus 10 knots of LLWS.

Routine pilot report (UA) Gunnison-Crested Butte Regional Airport (GUC); Over – 30 miles from Blue Mesa VOR (HBU), on a 040° radial; Time – 1809 MDT (0009Z); Altitude – 21,500 ft; Type aircraft – Grumman C-2; Temperature – -5° C; Icing – Moderate rime; Remarks –ZDV.

Urgent pilot report (UUA) BJC; Over – 5 miles from BJC on a 005° radial; Time – 1900 MDT (0100Z); Altitude – 6,400 ft; Type aircraft – Piper PA-32; Remarks – 1,500 ft per minute downdraft.

Routine pilot report (UA) Denver, Colorado (DEN); Over – 20 miles from DEN VOR on a 225° radial; Time – 2049 MDT (0249Z); Altitude – 7,500 ft; Type aircraft – Diamond DA40; Turbulence – Moderate turbulence between 7,500 and 8,500 ft during climb.

8.0 SIGMETs and CWSU Advisories

Convective Significant Meteorological Information (SIGMET) advisory 1W was valid for the accident site from 1855 to 2055 MDT and warned of an area of thunderstorms with tops to FL350 with the SIGMET area moving from 250° at 25 knots. Convective SIGMET 10C was valid for the accident site from 1955 to 2155 MDT and warned of an area of thunderstorms with tops to FL370 with the SIGMET area moving from 230° at 20 knots:

WSUS33 KPCI 160055
SIGW
-MKCW WST 160055

CONVECTIVE SIGMET 1W
VALID UNTIL 0255Z
CO UT
FROM 30ESE CHE-40E HBU-30SSE HVE-60SW MTU-30ESE CHE
AREA TS MOV FROM 25025KT. TOPS TO FL350.

CONVECTIVE SIGMET 2W
VALID UNTIL 0255Z
NM AZ
FROM 50NE TUS-50NW DMN-30WSW DMN-60SSE SSO-50S TUS-50NE TUS
DMSHG AREA TS MOV FROM 24015KT. TOPS TO FL420.

WSUS32 KPCI 160155
SIGC
-MKCC WST 160155
CONVECTIVE SIGMET 6C
VALID UNTIL 0355Z

MN ND
FROM 90NW GFK-30SE INL-40W BRD-60N ABR-70E BIS-90NW GFK
AREA EMBD TS MOV FROM 23025KT. TOPS TO FL440.

CONVECTIVE SIGMET 7C
VALID UNTIL 0355Z
MN SD ND
FROM 60N ABR-30SSE FAR-40N FSD-60SSE ABR-60N ABR
AREA TS MOV FROM 21030KT. TOPS TO FL450.

CONVECTIVE SIGMET 8C
VALID UNTIL 0355Z
KS NE SD
FROM 10N FSD-80NE HLC-30WNW HLC-40W FSD-10N FSD
AREA SEV TS MOV FROM 24030KT. TOPS ABV FL450.
HAIL TO 1 IN...WIND GUSTS TO 50KT POSS.

CONVECTIVE SIGMET 9C
VALID UNTIL 0355Z
TX
FROM 60W INK-40S MAF-70SSE MRF-40SSW MRF-60SE ELP-60W INK
AREA TS MOV FROM 24030KT. TOPS ABV FL450.

CONVECTIVE SIGMET 10C
VALID UNTIL 0355Z
NE CO WY
FROM 30N BFF-30NNW SNY-40E JNC-20SW CHE-30N BFF
AREA TS MOV FROM 23020KT. TOPS TO FL370.

CONVECTIVE SIGMET 11C
VALID UNTIL 0355Z
TX NM
FROM 40SSW LBL-30ESE AMA-30ENE CME-30NW TXO-40SSW LBL
DVLPG AREA TS MOV FROM 25020KT. TOPS TO FL440.

CONVECTIVE SIGMET 12C
VALID UNTIL 0355Z
NM
FROM 20WSW CIM-10N FTI-30NNE ABQ-60N ABQ-20WSW CIM
AREA TS MOV FROM 25020KT. TOPS TO FL310.

OUTLOOK VALID 160355-160755
AREA 1...FROM 60SSE YWG-60ENE SAW-BDF-IRK-30NNE SPS-30SW
AMA-40WSW LBF-CYS-50S MLS-60SSE YWG
WST ISSUANCES POSS. REFER TO MOST RECENT ACUS01 KWNS FROM STORM
PREDICTION CENTER FOR SYNOPSIS AND METEOROLOGICAL DETAILS.

AREA 2...FROM 30SW AMA-30NNE SPS-SJT-90SSE MRF-50SSW MRF-50WNW
MRF-ELP-30S DMN-30N TCS-30SW AMA
WST ISSUANCES EXPD. REFER TO MOST RECENT ACUS01 KWNS FROM STORM
PREDICTION CENTER FOR SYNOPSIS AND METEOROLOGICAL DETAILS.

No non-convective SIGMETs, Center Weather Service Unit (CWSU) Center Weather Advisories (CWA)s, or CWSU meteorological impact statements (MIS)s were valid for the accident site at the accident time.

9.0 AIRMETs

Airmen's Meteorological Information (AIRMET) advisory Tango was issued at 1445 MDT and valid at the accident time for the accident site. The AIRMET forecasted moderate turbulence below 18,000 ft:

WAUS45 KPCI 152045
WA5T
-SLCT WA 152045
AIRMET TANGO UPDT 3 FOR TURB VALID UNTIL 160300

.
AIRMET TURB...ID MT WY UT WA OR
FROM 50WSW YXC TO 40NW HVR TO 60NW ISN TO 50NW RAP TO DDY TO
40NNE OCS TO 60ENE SLC TO 50S MLD TO 30WSW BKE TO 50WSW YXC
MOD TURB BTN FL240 AND FL410. CONDS CONTG BYD 03Z THRU 09Z.

.
AIRMET TURB...WY UT CO AZ NM
FROM 30E CZI TO 70SW RAP TO 30S TBE TO 70SW TCC TO 60S ABQ TO
30S SJN TO 60SSE INW TO 50ESE DRK TO 40NE MTU TO 50NE OCS TO 30E
CZI
MOD TURB BLW FL180. CONDS CONTG BYD 03Z THRU 09Z.

.
OTLK VALID 0300-0900Z...TURB WY NV UT CO AZ NM
BOUNDED BY 40E SHR-70NW RAP-70SW RAP-20SSW TBE-40WSW TCC-40WSW
SJN-50ESE DRK-20ENE TBC-60SE BCE-40SSW ILC-30WNW BVL-50S BPI-40E
SHR
MOD TURB BLW FL180. CONDS CONTG THRU 09Z.

....

10.0 Area Forecast

The Area Forecast issued at 1345 MDT, and valid at the accident time, forecasted a broken ceiling at 9,000 ft with tops FL230, isolated thunderstorms with light rain, thunderstorms tops at FL360. Between 1800 MDT and 2100 MDT, conditions were forecast to become: ceiling broken at 8,000 ft with tops at FL270 and isolated thunderstorms with light rain:

FAUS45 KPCI 151945
FA5W
-SLCC FA 151945
SYNOPSIS AND VFR CLDS/WX
SYNOPSIS VALID UNTIL 161400
CLDS/WX VALID UNTIL 160800...OTLK VALID 160800-161400
ID MT WY NV UT CO AZ NM

.
SEE AIRMET SIERRA FOR IFR CONDS AND MTN OBSCN.
TS IMPLY SEV OR GTR TURB SEV ICE LLWS AND IFR CONDS.
NON MSL HGTS DENOTED BY AGL OR CIG.

.

SYNOPSIS...ALF..TROF FM NWRN MT SWD THRU SRN NV. LT SWLY WND OVR
UT/CO/NRN AZ/NM. 08Z TROF FM N CNTRL MT SWD THRU SWRN AZ. LT SWLY
WND OVR WY/UT/CO/NERN AZ/NRN NM. LT NWLY WND OVER NRN NV. 14Z
TROF FM N CNTRL MT SWD THRU SWRN AZ. LT SWLY WND OVR SRN
WY/CO/NRN NM. LT NWLY WND OVR UT. SFC..CDFNT OVR SRN UT EWD THRU
NERN CO. 08Z CDFNT FM SRN UT EWD THRU SERN CO THRU RMNDR FORECAST
PD.

..
ID

NRN...BKN070 TOPS 130. BECMG 0003 SCT070. 06Z SKC. OCNL SCT070.
OTLK...VFR.
CNTRL MTNS...
WRN HLF...BKN090 TOPS 120. BECMG 0003 SCT100. OTLK...VFR.
ERN HLF...OVC070 TOPS FL280. VIS 3-5SM -RA BR. OTLK...MVFR CIG
RA BR.
SWRN...SCT100. WND NW 20G30KT. BECMG 0003 SKC. OCNL SCT100.
OTLK...VFR.
SERN...SCT070 BKN090 TOPS 150. ISOL -SHRA. 03Z SCT020 BKN090
TOPS FL190. ISOL -SHRA. OTLK...VFR SHRA.

..
MT

CONTDVD WWD...
NRN HLF...BKN060 TOPS 160. 06Z BKN070 TOPS 100. 08Z SCT070.
OTLK...VFR.
SRN HLF...OVC060 TOPS FL270. VIS 3-5SM SCT -SHRA BR.
OTLK...MVFR CIG SHRA SHSN BR.
SWRN MTNS...OVC070 TOPS FL240. VIS 3-5SM -RASN BR. OTLK...MVFR
CIG RASN BR.
ERN SLOPES OF CONTDVD...OVC070 TOPS FL270. -RA. OTLK...MVFR CIG
RA BR.
CNTRL...OVC050 TOPS FL300. VIS 3-5SM -RA BR. BECMG 0608 OVC050
TOPS FL230. VIS 3-5SM -RA BR. OTLK...IFR CIG RA BR.
ERN...OVC050 TOPS FL300. VIS 3-5SM -RA BR. BECMG 0306 OVC050
TOPS FL180. -RA. OTLK...IFR CIG RA BR.

..
WY

PLAINS...
NRN HLF...OVC060 TOPS FL260. VIS 3-5SM ISOL -SHRA BR. BECMG
0003 OVC060 TOPS 140. VIS 3-5SM ISOL -SHRA BR. OTLK...IFR
CIG SHRA BR.
SRN HLF...BKN120 TOPS 170. BECMG 0003 OVC090 TOPS FL220. -RA.
WND NW G25KT. BECMG 0608 BKN090 LYRD FL190. OTLK...MVFR CIG.
MTNS E OF CONTDVD...BKN090 TOPS FL200. -RA/ISOL -TSRA. CB TOPS
FL380. BECMG 0003 OVC090 TOPS 150. VIS 3-5SM -RA/ISOL -TSRA
BR. OTLK...MVFR CIG SHRA BR.
MTNS W OF CONTDVD...BKN100 LYRD FL290. ISOL -SHRA/ISOL -TSRA. CB
TOPS FL380. 00Z BKN100 TOPS 130. ISOL -SHRA/ISOL -TSRA.
OTLK...VFR.

..
NV

NWRN...SCT110. BECMG 0003 SKC. OTLK...VFR.
NERN...SCT110. 06Z SKC. OTLK...VFR.
SRN...SKC. OCNL SCT130. BECMG 0306 SCT130. OTLK...VFR.

..
UT

NRN HLF...BKN090 TOPS 130. ISOL -TSRA. CB TOPS FL360. BECMG 0003

SCT120. BECMG 0608 BKN110 TOPS 140. OTLK...VFR.
 SRN HLF...BKN130 TOPS 170. ISOL -TSRA. CB TOPS FL380. BECMG 0003
 BKN120 TOPS 160. ISOL -TSRA. 06Z BKN100 TOPS 150. OTLK...VFR.
 .
 CO
 PLAINS...SKC. OTLK...VFR.
 MTNS E OF CONTDVD...SKC. OCNL SCT120. BECMG 0003 BKN150 TOPS
 170. BECMG 0608 SCT080 SCT140. OTLK...VFR.
MTNS W OF CONTDVD...
NRN HLF...BKN090 TOPS FL230. ISOL -TSRA. CB TOPS FL360. BECMG
0003 BKN080 TOPS FL270. ISOL -TSRA. BECMG 0608 SCT070 BKN140
TOPS FL190. OTLK...VFR.
 SRN HLF...SCT090. BECMG 0003 SCT120. 08Z SCT090. OTLK...VFR.
 .
 AZ
 NRN HLF...SKC. OCNL SCT100. OTLK...VFR.
 SWRN...SKC. OTLK...VFR.
 SERN...SCT080. 06Z SKC. OCNL SCT060. OTLK...VFR.
 .
 NM
 PLAINS...SCT100. ISOL -TSRA. CB TOPS FL390. BECMG 0003 BKN140
 TOPS 170. ISOL -TSRA. OTLK...MVFR TSRA.
 MTNS E OF CONTDVD...SCT150. BECMG 0608 SKC. OTLK...VFR.
 MTNS W OF CONTDVD...SCT150. 03Z SKC. OTLK...VFR.

11.0 Terminal Aerodrome Forecast

KRIL and KEGE were the closest sites to the accident site with a NWS Terminal Aerodrome Forecast (TAF). The KEGE TAF valid at the time of the accident was issued at 2009 MDT and was valid for a 22-hour period beginning at 2000 MDT. The TAF for KEGE was as follows:

FTUS45 KGJT 160209 AAA
 TAFEKE
 TAF AMD
 KEGE 160209Z 1602/1624 **32012G23KT P6SM VCSH BKN050 BKN090 OVC110**
TEMPO 1602/1604 -RA OVC050
 FM160400 22007KT P6SM FEW045 SCT070
 FM160700 15006KT P6SM FEW050 SCT070
 FM161600 25006KT P6SM FEW050 SCT110
 FM162100 24016G26KT P6SM FEW100 FEW250
 AMD LTD TO CLD VIS AND WIND TIL 161300=

The forecast expected a wind from 320° at 12 knots with gusts to 23 knots, greater than 6 miles visibility, showers in the vicinity, broken ceiling at 5,000 ft agl, broken clouds at 9,000 ft agl, and overcast clouds at 11,000 ft agl. Temporary conditions were forecast between 2000 and 2200 MDT of light rain and an overcast ceiling at 5,000 ft agl.

The KEGE TAF issued at 2009 MDT was an amendment to the previous TAF for KEGE which was issued at 1722 MDT valid at 1800 MDT:

606

FTUS45 KGJT 152322
TAFEGE
TAF
KEGE 152322Z 1600/1624 25015KT P6SM FEW080 SCT120
TEMPO 1600/1602 VRB20G35KT -TSRA SCT060CB BKN080
FM160200 25013G22KT P6SM VCSH FEW060 SCT090
FM160400 22007KT P6SM FEW045 SCT070
FM160700 15006KT P6SM FEW050 SCT070
FM161600 25006KT P6SM FEW050 SCT110
FM162100 24016G26KT P6SM FEW100 FEW250
AMD LTD TO CLD VIS AND WIND 1601/1613=

At 2000 MDT the 1722 MDT KEGE TAF expected a wind from 250° at 13 knot with gusts to 22 knots, greater than 6 miles visibility, showers in the vicinity, few clouds at 6,000 ft, scattered clouds at 9,000 ft.

The KRIL TAF valid at the time of the accident was issued at 2006 MDT and was valid for a 22-hour period beginning at 2000 MDT. The TAF for KRIL was as follows:

KRIL 160206Z 1602/1624 **30005KT P6SM VCTS BKN070CB OVC100**
TEMPO 1602/1604 VRB20G35KT -TSRA SCT060CB BKN080
FM160400 28009KT P6SM SCT050 BKN070
FM160600 27007KT P6SM FEW060 SCT070
FM161400 28006KT P6SM FEW060 SCT090=

The forecast expected a wind from 300° at 5 knots, greater than 6 miles visibility, thunderstorms in the vicinity, broken ceiling of cumulonimbus clouds at 7,000 ft, overcast skies at 10,000 ft. Temporary conditions of variable winds of 20 knots gusting to 35 knots, thunderstorms with light rain, scattered cumulonimbus clouds at 6,000 ft, and a broken ceiling of 8,000 ft were forecast between 2000 and 2200 MDT.

The TAF issued at 2006 MDT was an amendment to the previous TAF for KRIL which was issued at 1839 MDT valid at 1900 MDT:

630
FTUS45 KGJT 160039 AAB
TAFRIL
TAF AMD
KRIL 160039Z 1601/1624 **32015G25KT P6SM VCTS BKN090CB OVC110**
TEMPO 1601/1603 VRB20G35KT -TSRA SCT060CB BKN080
FM160300 28010KT P6SM VCSH SCT050 BKN070
FM160400 28009KT P6SM SCT050 BKN070
FM160600 27007KT P6SM FEW060 SCT070
FM161400 28006KT P6SM FEW060 SCT090=

The 1839 MDT KRIL TAF expected a wind from 320° at 15 knots with gusts to 25 knots, greater than 6 miles visibility, thunderstorms in the vicinity, broken ceiling of cumulonimbus clouds at 9,000 ft, overcast skies at 11,000 ft. Temporary conditions of variable winds of 20 knots gusting to 35 knots, thunderstorms with light rain, scattered cumulonimbus clouds at 6,000 ft, and a broken ceiling of 8,000 ft were forecast between 1900 and 2100 MDT.

The TAF issued at 1839 MDT was an amendment to the previous TAF for KRIL which was issued at 1733 MDT valid at 1800 MDT:

516
FTUS45 KGJT 152333 AAA
TAFRIL
TAF AMD
KRIL 152333Z 1600/1624 **32015G25KT P6SM VCSH BKN090 OVC110**
TEMPO 1601/1603 VRB20G35KT -TSRA SCT060CB BKN080
FM160300 28010KT P6SM VCSH SCT050 BKN070
FM160400 28009KT P6SM SCT050 BKN070
FM160600 27007KT P6SM FEW060 SCT070
FM161400 28006KT P6SM FEW060 SCT090=

The 1733 MDT KRIL TAF expected a wind from 320° at 15 knots with gusts to 25 knots, greater than 6 miles visibility, showers in the vicinity, broken ceiling at 9,000 ft, and an overcast ceiling at 11,000 ft agl. Temporary conditions were forecast between 1900 and 2100 MDT of variable winds at 20 knots with gusts to 35 knots, thunderstorms with light rain, scattered cumulonimbus clouds at 6,000 ft, and a broken ceiling at 8,000 ft.

12.0 NWS Area Forecast Discussion

The NWS Office in Grand Junction, Colorado, issued the following Area Forecast Discussion (AFD) at 1753 MDT (closest AFD to the accident time with an aviation section). The aviation section discussed showers and thunderstorms with heavy rain, gusty winds, and hail possible with reduced ceiling conditions for a temporary period at surrounding airports:

FXUS65 KGJT 152353
AFDGJT

Area Forecast Discussion
National Weather Service GRAND JUNCTION CO
553 PM MDT Fri Sep 15 2017

.SHORT TERM...(Tonight through Saturday night)
Issued at 130 PM MDT Fri Sep 15 2017

GOES Water Vapor imagery reveals a distinct moisture axis sweeping through central Utah as of 2pm Friday afternoon. This axis is located along the leading edge of a trough which will pivot through eastern Utah and western Colorado overnight into Saturday. Precipitation along this trough has been limited to mainly light showers from Vernal eastward through Hayden as cloud cover has curtailed instability values over the north so far today. A bit farther south along the Roan and Tavaputs up to the Flat Top range, some sunshine has resulted in SB CAPE values in the 250-750 range per SPC Mesoanalysis. This corridor would be the most likely area to see thunder today. Areas south of I-70 will likely remain too dry in the mid levels to support any substantial convection, and shower activity will remain confined to the higher terrain of the San Juans and Continental Divide.

Westerly winds will increase, especially north of I-70, on

Saturday as the trough passes through around noon. Expect a quiet afternoon as a dry continental airmass moves in behind the trough. A chilly night is expected on Saturday evening into Sunday morning with mostly clear skies, dry air and diminishing winds over much of the central Rockies.

.LONG TERM...(Sunday through Friday)
Issued at 130 PM MDT Fri Sep 15 2017

Not much change in the long term forecast in this afternoon's model cycles, and any changes from the previous forecast have been minor. Warm air advection will resume over the Four Corners on Sunday as west to southwesterly flow develops over the Four Corners. Any isolated convection will be limited to the higher terrain with plenty of dry air in place. As has been the case over the past few days, the major story in the long range forecast will center around our upcoming trough moving in to the west coast. The strong jet that will move in along the PACNW coast has been modeled slightly slower and a bit weaker today, however the broad synoptic setup remains the same. A large longwave trough will dive southward into the central Rockies on Monday evening, which will remain over the western CONUS through the end of the week and through the weekend. GEFS and EPS ensemble guidance remain in good agreement with 500mb height anomalies in the -2 sigma range during this time period. If anything, the GEFS has pushed those anomalous even farther southward into the central Rockies.

The resultant weather for the central Rockies will be temperatures running well below normal. 10 to 15 degrees below normal seems to be a pretty confident forecast area-wide. ECMWF and MEX MOS guidance has come into better agreement on the temperature forecast today. Tuesday evening appears to be the first shot at seeing some shower activity as a shortwave trough passes to the north. The ECMWF is stronger with this trough and indicates shower activity remaining locked in to the central and northern zones through Thursday, while the GFS takes a more piecemeal approach with one trough on Tuesday and then a second and stronger system on Friday. Regardless of the outcome with the mid and late-week systems, fall-like weather will be the headline for next week.

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.AVIATION...(For the 00Z TAFS through 00Z Saturday evening)
Issued at 547 PM MDT Fri Sep 15 2017

A cold front is moving through the forecast area this evening bringing rainfall, gusty winds, heavy rain and some hail to the region. Several airports are being affected by these storms and for those that aren't, are expected to in the next few hours. Conditions have stayed in the VFR range with ILS breakpoints also not being met. A few of the mountain sites may see brief MVFR as the front rolls through but they shouldn't last very long. Isolated showers will likely continue overnight but look to favor northern areas so shouldn't be any concerns for TAF sites. A few

orographic showers are possible over the northern mountains for tomorrow but no concerns for our TAF sites.

&&

.GJT WATCHES/WARNINGS/ADVISORIES...

CO...None.

UT...None.

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13.0 Winds and Temperature Aloft Forecast

The NWS 2004 MDT Winds and Temperature Aloft forecast valid for the accident flight are included below:

FBUS31 KWN0 160204

FD1US1

DATA BASED ON 160000Z

VALID 160600Z FOR USE 0200-0900Z. TEMPS NEG ABV 24000

FT	3000	6000	9000	12000	18000	24000	30000	34000	39000
GJT		2710+06	2524+00	2440-15	2447-23	255740	257348	246653	

The accident site was closest to the Grand Junction, Colorado, (GJT) forecast point. The 0000 MDT (September 16) GJT forecast for use between 2000 MDT (September 15) and 0300 MDT (September 16) indicated a wind at 9,000 ft from 270° at 10 knots with a temperature of 6° C, a wind at 12,000 ft from 250° at 24 knots with a temperature of 0° C, and a wind at 18,000 ft from 240° at 40 knots with a temperature of -15° C.

The NWS 1401 MDT Winds and Temperature Aloft forecast valid for the accident flight and issued before the accident flight departed are included below:

FBUS31 KWN0 152001

FD1US1

DATA BASED ON 151800Z

VALID 160000Z FOR USE 2000-0300Z. TEMPS NEG ABV 24000

FT	3000	6000	9000	12000	18000	24000	30000	34000	39000
GJT		2619+08	2329+02	2234-13	2335-25	244540	244948	245351	

The 1800 MDT GJT forecast for use between 1400 MDT and 2100 MDT indicated a wind at 9,000 ft from 260° at 19 knots with a temperature of 8° C, a wind at 12,000 ft from 230° at 29 knots with a temperature of 2° C, and a wind at 18,000 ft from 220° at 34 knots with a temperature of -13° C.

14.0 Pilot Weather Briefing

A search of official weather briefing sources, such as Leidos Flight Service and Direct User Access Terminal Service (DUATS), revealed that the accident pilot did not contact Leidos or DUATS. A search of archived ForeFlight information indicated that ForeFlight did not have any record of the accident pilot accessing weather information. However, with no internet access while in flight, ForeFlight is able to access weather information directly from the FAA, leaving no remote record of such access. Therefore, it is possible that the accident pilot was receiving weather updates during the flight. There is no record of the accident pilot receiving or retrieving any other weather information before the accident flight.

According to a conversation with one of the accident pilot's flight instructors, the accident pilot mentioned that for the planned flight on the accident day, the accident pilot said he would use ForeFlight to obtain weather and flight plan information. The accident pilot's aircraft did also have NEXRAD/XM information. For more information please see attachment 2.

According to a record of conversation with the NTSB investigator in charge, the mother of one of the passengers on the accident airplane shared text messages that she received from her daughter, while the accident airplane was en route to Moab, Utah. One of the text messages received at 2008 MDT, said, "Taking the long way around, lots of weather, keep you posted." For more information please see attachment 3.

15.0 Icing Potential³⁰

Current Icing Potential (CIP) and Forecast Icing Potential (FIP) products are created by the NWS' Aviation Weather Center (AWC) and are intended to be supplemental to other icing advisories (e.g. AIRMETs and SIGMETs). Figures 16 through 18 were the FIP icing probabilities and icing severity products, 1-hour forecast valid at 2000 MDT at 11,000, 12,000, 13,000 ft msl (similar values in the FIP are seen in the 2-hour forecast valid at both 2000 and 2100 MDT, attachment 7). The FIP indicated between a 40 to 60 percent probability of icing at 13,000 ft at 2000 MDT at the accident site. No icing was indicated for 12,000 and 11,000 ft because the accident site elevation was modeled at or below the surface at these two levels. The FIP indicated that the icing near the accident site would likely be at trace to moderate levels at 2000 MDT (figure 18). The FIP did not indicate any Supercooled Large Droplet (SLD) potential over the accident area around the accident time (attachment 7). This FIP information would have been available on the NWS AWC website³¹ before the accident flight departed Fort Collins (KFNL).

³⁰ 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>

³¹ <https://www.aviationweather.gov/icing/fip>

The CIP product indicated between a 20 to 40 percent probability of icing at 13,000 ft at 2000 MDT at the accident site. The CIP also indicated that the icing near the accident site would likely be trace to light intensity (figure 21). Similarly, to the FIP, no icing was indicated for 12,000 and 11,000 ft in the CIP because the accident site elevation was modeled at or below the surface at these two levels. The CIP also indicated a 10 to 40 percent chance of SLD near the accident site around the accident time (attachment 7). For more FIP and CIP information and altitudes please see attachment 7.

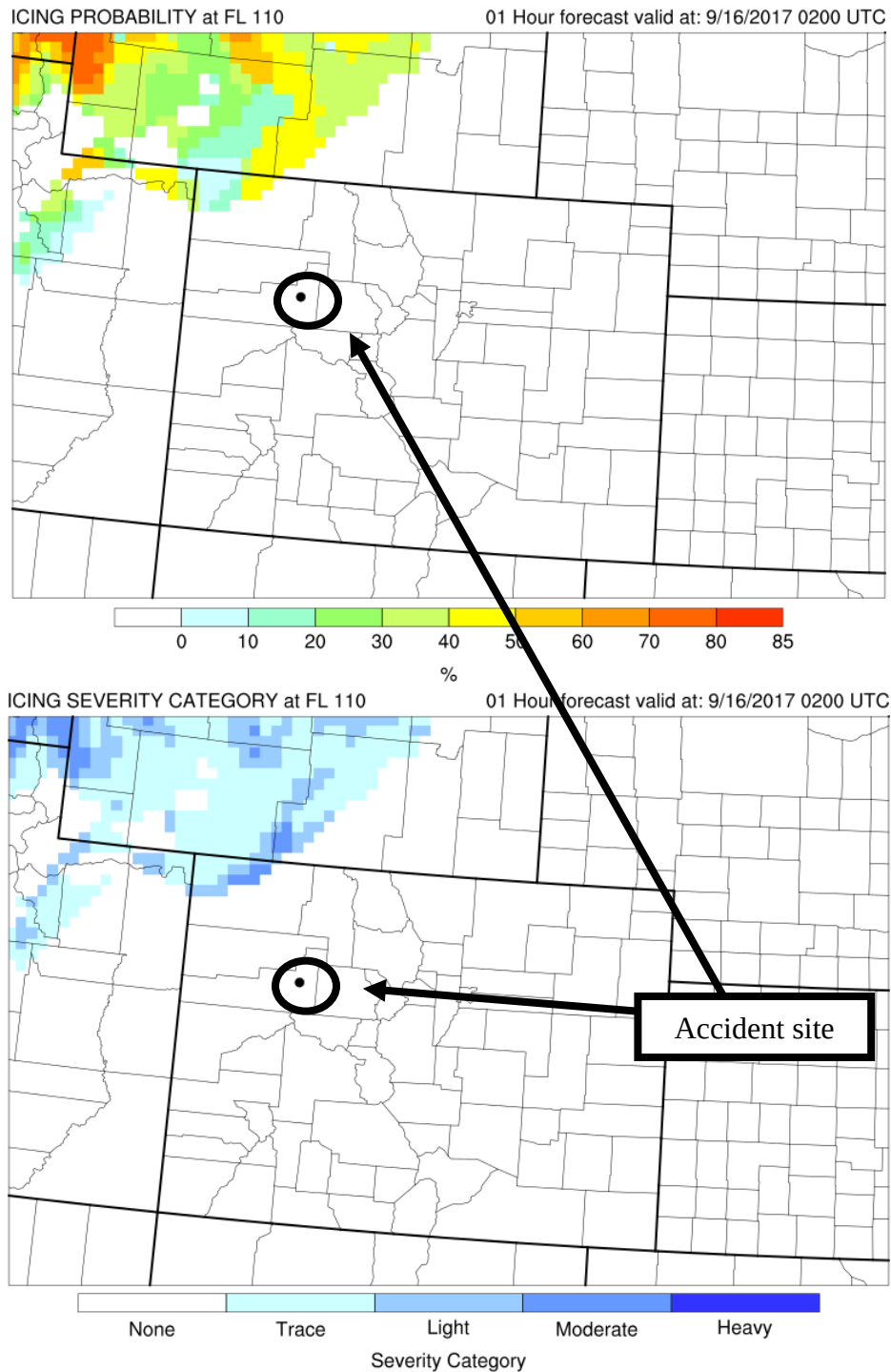


Figure 16 – (top) FIP probability of icing at 11,000 ft msl and (bottom) FIP severity of icing at 11,000 ft msl 1-hour forecast valid for 2000 MDT

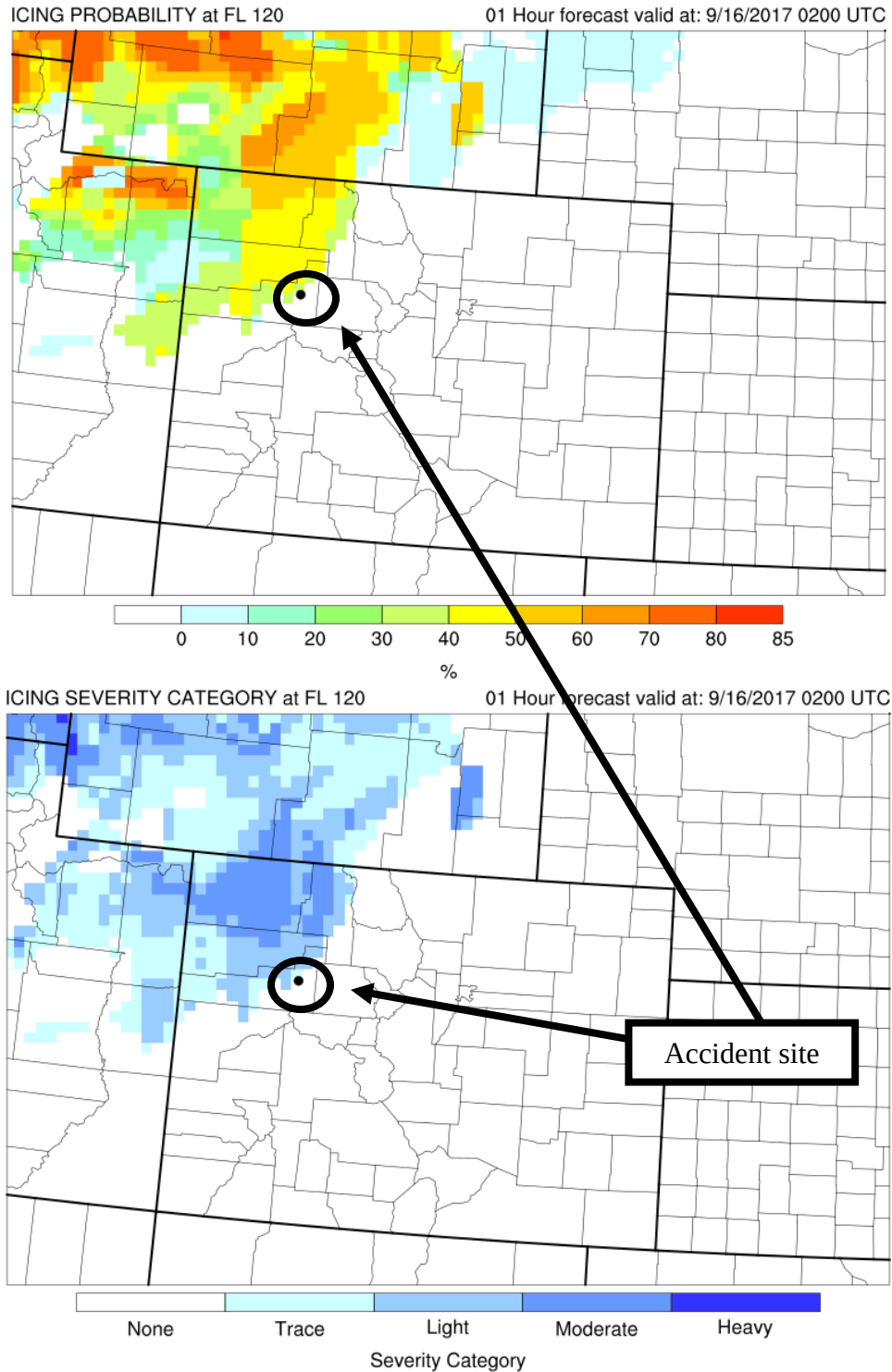


Figure 17 – (top) FIP probability of icing at 12,000 ft msl and (bottom) FIP severity of icing at 12,000 ft msl 1-hour forecast valid for 2000 MDT

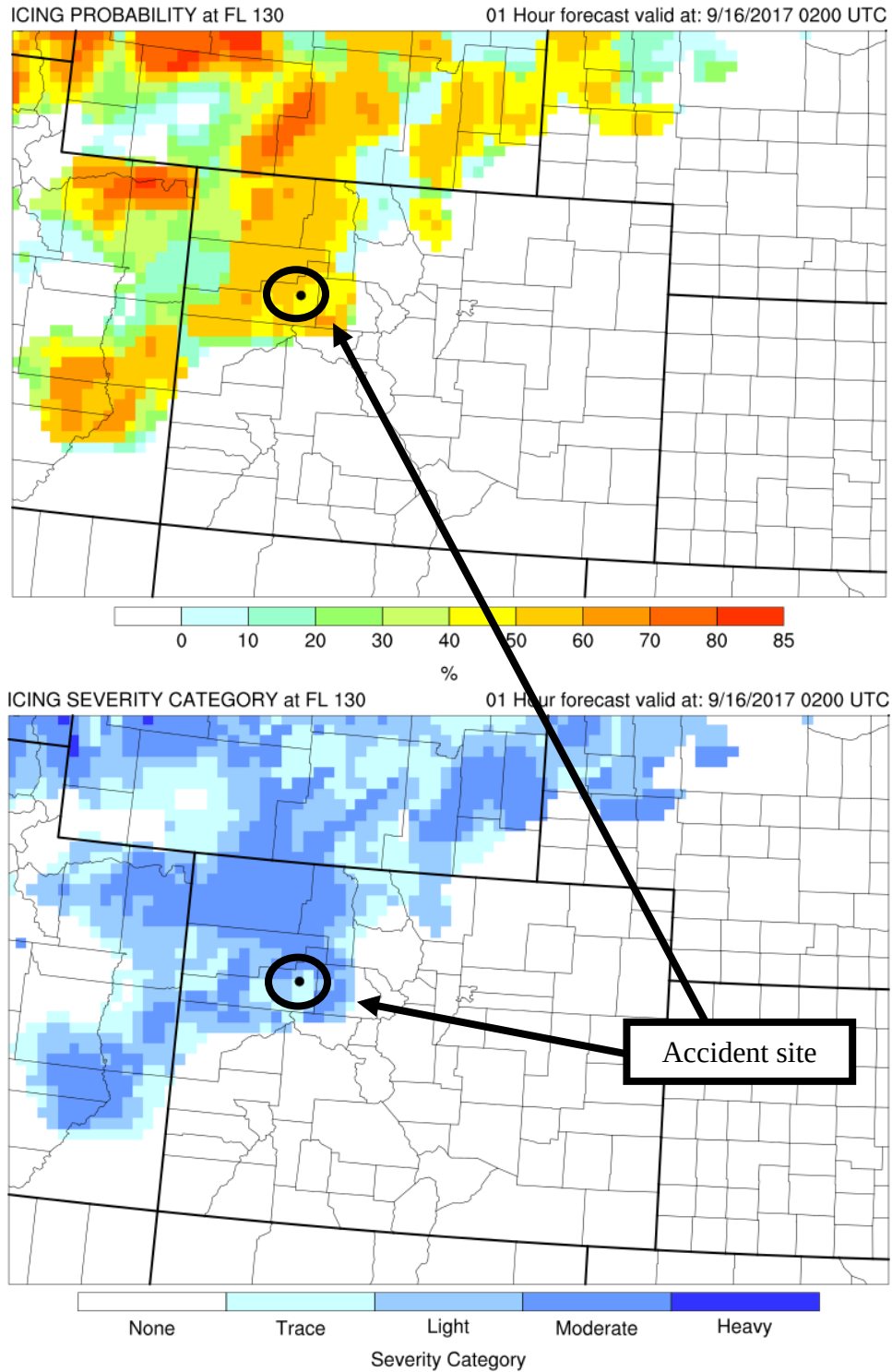


Figure 18 – (top) FIP probability of icing at 13,000 ft msl and (bottom) FIP severity of icing at 13,000 ft msl 1-hour forecast valid for 2000 MDT

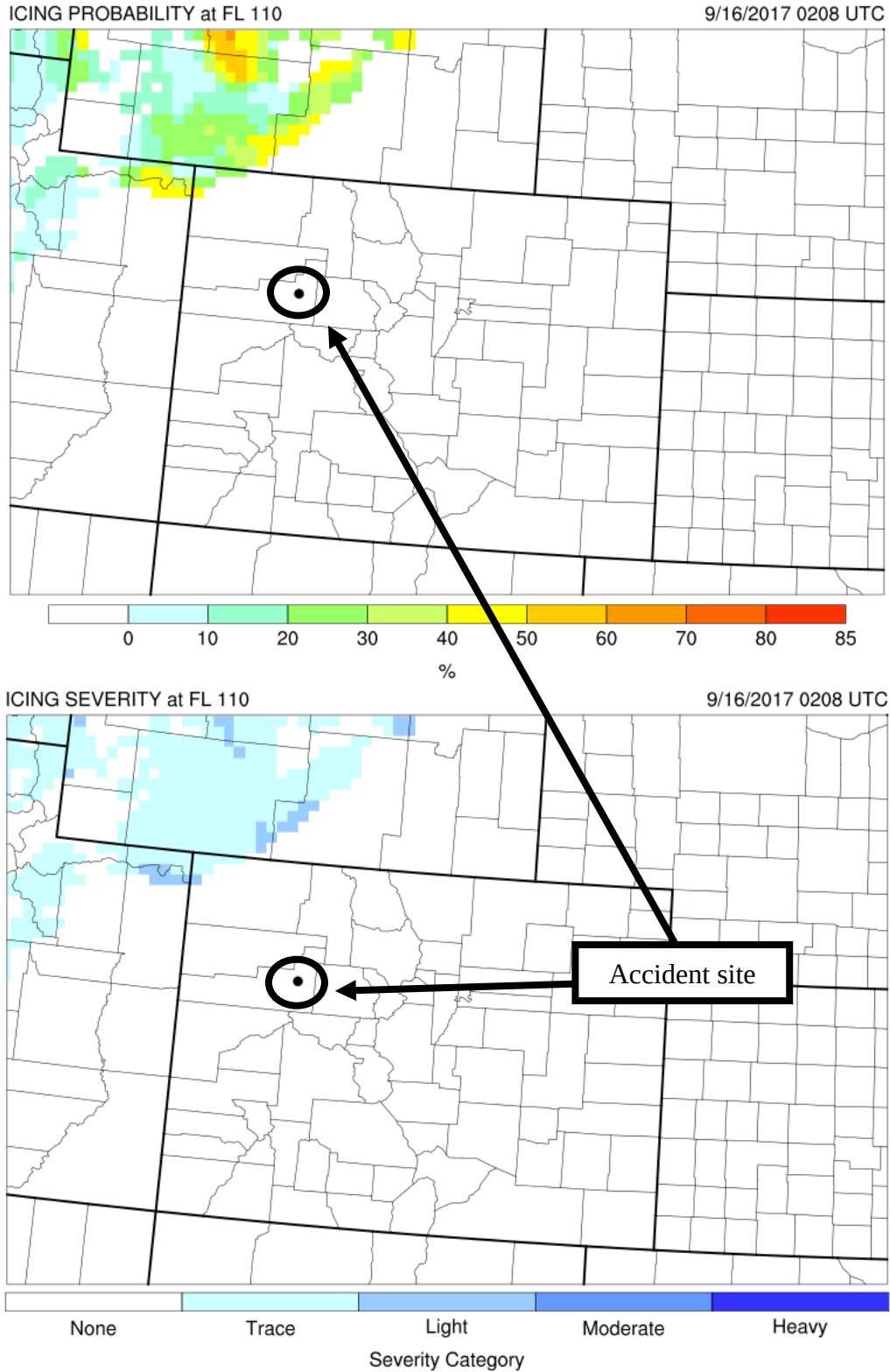


Figure 19 – (top) CIP probability of icing at 11,000 ft msl and (bottom) CIP severity of icing at 11,000 ft msl valid for 2000 MDT

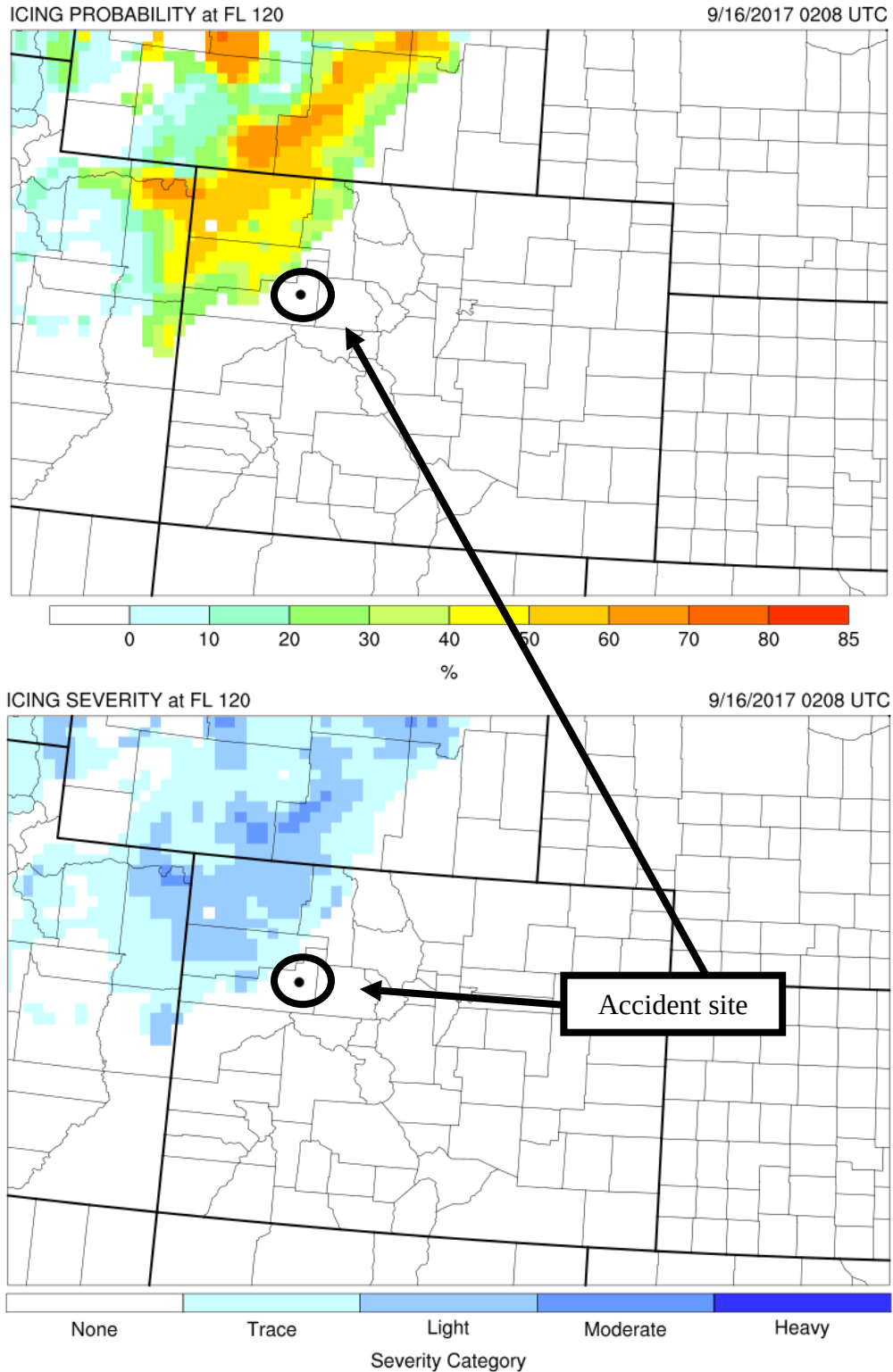


Figure 20 – (top) CIP probability of icing at 12,000 ft msl and (bottom) CIP severity of icing at 12,000 ft msl valid for 2000 MDT

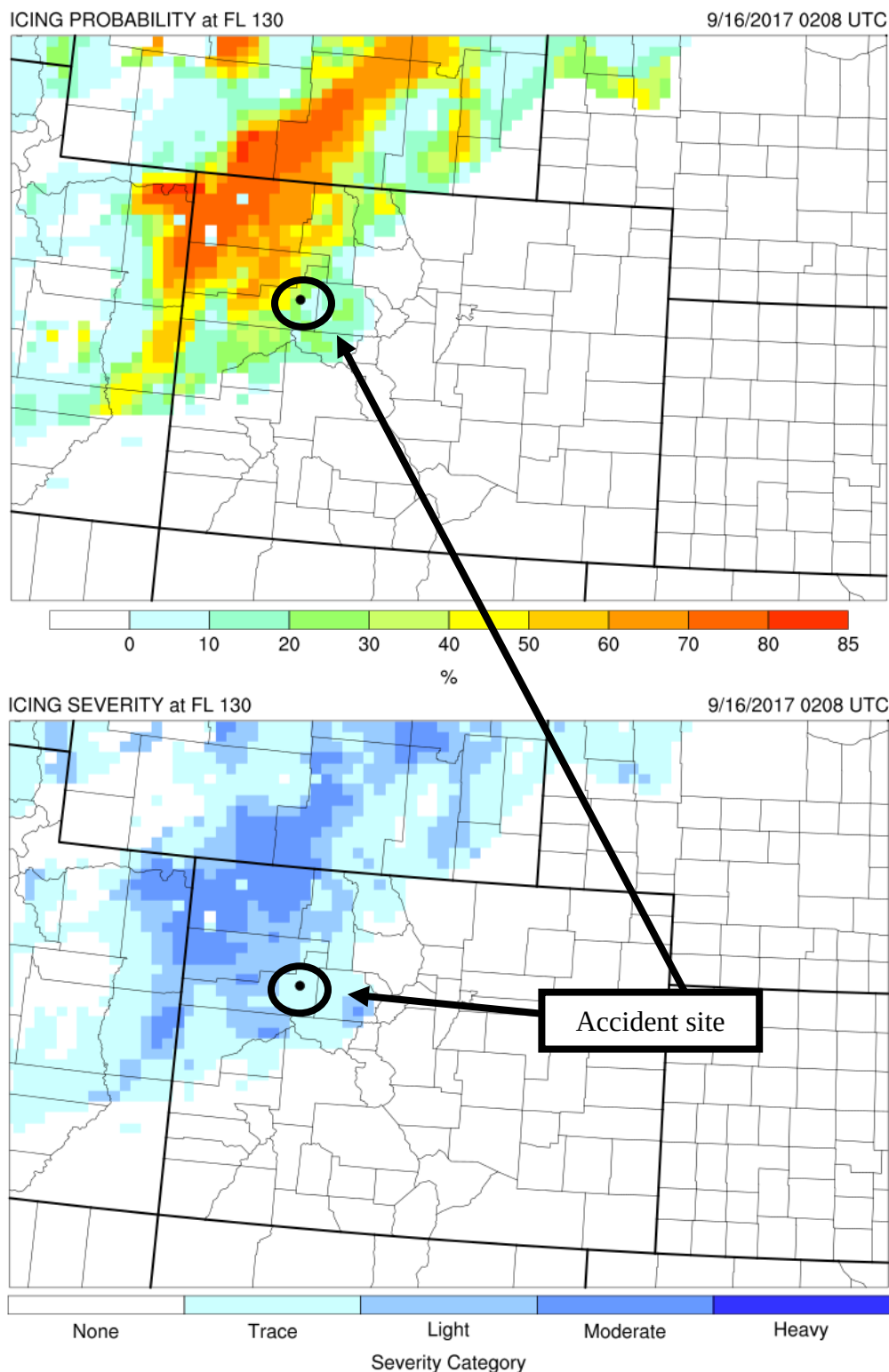


Figure 21 – (top) CIP probability of icing at 13,000 ft msl and (bottom) CIP severity of icing at 13,000 ft msl valid for 2000 MDT

16.0 Additional CWSU Products

The CWSU at ZDV issued two video weather briefings for ATC at ZDV at 1215 MDT and 2002 MDT (attachments 4 and 5), which provided weather forecast updates valid at those times and provided weather situational awareness for ATC at ZDV and surrounding ATC facilities. In addition, during the afternoon stand up meeting at ZDV at 1545 MDT, the CWSU briefed the need for PIREPs, and that the weather in most ZDV sectors would require the solicitation of PIREPs (see attachment 6).

17.0 Astronomical Data

The astronomical data obtained from the United States Naval Observatory for the accident site on September 15, 2017, indicated the following:

SUN

Begin civil twilight	0624 MDT
Sunrise	0651 MDT
Sun transit	1304 MDT
Sunset	1917 MDT
End civil twilight	1944 MDT
Accident	2010 MDT

MOON

Moonrise	0150 MDT
Moon transit	0913 MDT
Moonset	1632 MDT
Accident	2010 MDT

The Moon was set around the accident site at the accident time.

E. LIST OF ATTACHMENTS

Attachment 1 – Animation of GOES-16 infrared imagery from 1902 MDT to 2107 MDT

Attachment 2 – Record of conversation with one of the accident pilot's flight instructors

Attachment 3 – Record of conversation from investigator in charge

Attachment 4 – CWSU ZDV video weather briefing from 1215 MDT

Attachment 5 – CWSU ZDV video weather briefing from 2002 MDT

Attachment 6 – CWSU ZDV PIREP solicitation graphic from 1545 MDT

Attachment 7 – CIP/FIP data for 2000 and 2100 MDT around the accident site

Submitted by:

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