



## **NATIONAL TRANSPORTATION SAFETY BOARD**

Office of Aviation Safety  
Washington, D.C. 20594

November 27, 2019

### **Weather Study**

# **METEOROLOGY**

DCA19CA206

## Table Of Contents

|                                                 |    |
|-------------------------------------------------|----|
| A. ACCIDENT .....                               | 3  |
| B. METEOROLOGIST .....                          | 3  |
| C. DETAILS OF THE INVESTIGATION .....           | 3  |
| D. FACTUAL INFORMATION .....                    | 4  |
| 1.0 Synoptic Situation .....                    | 4  |
| 1.1 Surface Analysis Chart .....                | 4  |
| 1.2 Upper Air Charts .....                      | 5  |
| 2.0 SPC Convective Outlook .....                | 8  |
| 3.0 Surface Observations .....                  | 8  |
| 4.0 Upper Air Data .....                        | 10 |
| 5.0 Satellite Data .....                        | 12 |
| 6.0 Regional Radar Imagery .....                | 14 |
| 7.0 Pilot Reports .....                         | 15 |
| 8.0 SIGMET .....                                | 16 |
| 9.0 CWSU Advisories .....                       | 16 |
| 10.0 AIRMETs .....                              | 16 |
| 11.0 Graphical Forecasts for Aviation .....     | 16 |
| 12.0 Winds and Temperature Aloft Forecast ..... | 16 |
| 13.0 Pilot Weather Briefing .....               | 16 |
| 14.0 GTG information .....                      | 17 |
| 15.0 Astronomical Data .....                    | 17 |
| E. LIST OF ATTACHMENTS .....                    | 17 |

## **A. ACCIDENT**

Location: 20 miles northeast of Denver, Colorado  
Date: August 27, 2019  
Time: about 0650 mountain daylight time  
1250 Coordinated Universal Time (UTC)  
Aircraft: Frontier Airlines flight 461, Airbus A320, Registration: N328FR

## **B. METEOROLOGIST**

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

## **C. DETAILS OF THE INVESTIGATION**

The National Transportation Safety Board's (NTSB) Meteorologist did not travel for this investigation and gathered the weather data for this investigation from official National Oceanic and Atmospheric Administration (NOAA) National Weather Service (NWS) sources including the National Centers for Environmental Information (NCEI). All times are mountain daylight time (MDT) on August 27, 2019, 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 miles. NWS airport and station identifiers use the standard International Civil Aviation Organization 4-letter station identifiers versus the International Air Transport Association 3-letter identifiers, which deletes the initial country code designator "K" for U.S. airports.

According to the Captain's statement<sup>1</sup>, the accident occurred while descending through 15,000 feet (ft) about 20 miles northeast of Denver International Airport (KDEN), which gives an approximate latitude of 40.043° N and longitude of 104.3178° W.

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<sup>1</sup> For more information please see the docket for this accident.

## **D. FACTUAL INFORMATION**

### **1.0 Synoptic Situation**

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

#### **1.1 Surface Analysis Chart**

The central United States section of the NWS Surface Analysis Chart for 0600 MDT is provided as figure 1 with the approximate location of the accident site marked with the red star. The chart indicated a low pressure system at 1014-hectopascals (hPa) over southeastern Wyoming, with a trough<sup>3</sup> extending north and south of the low from central Montana, Wyoming, into central Colorado east of the Front Range. Two high pressure systems at 1024- and 1020-hPa were located over western Wyoming and Colorado respectively. . The accident site was located east of the surface trough and Front Range.

The station models around the accident site depicted air temperatures in the upper 50’s to 60’s degrees Fahrenheit (°F), dew point temperatures in the mid 40’s to mid 50’s °F, with a temperature-dew point spread of 10° or more, a southeast to east wind to 5 knots, and overcast cloud cover.

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<sup>2</sup>

[https://www.faa.gov/regulations\\_policies/advisory\\_circulars/index.cfm/go/document.information/documentID/1030235](https://www.faa.gov/regulations_policies/advisory_circulars/index.cfm/go/document.information/documentID/1030235)

<sup>3</sup> Trough – An elongated area of relatively low atmospheric pressure or heights.

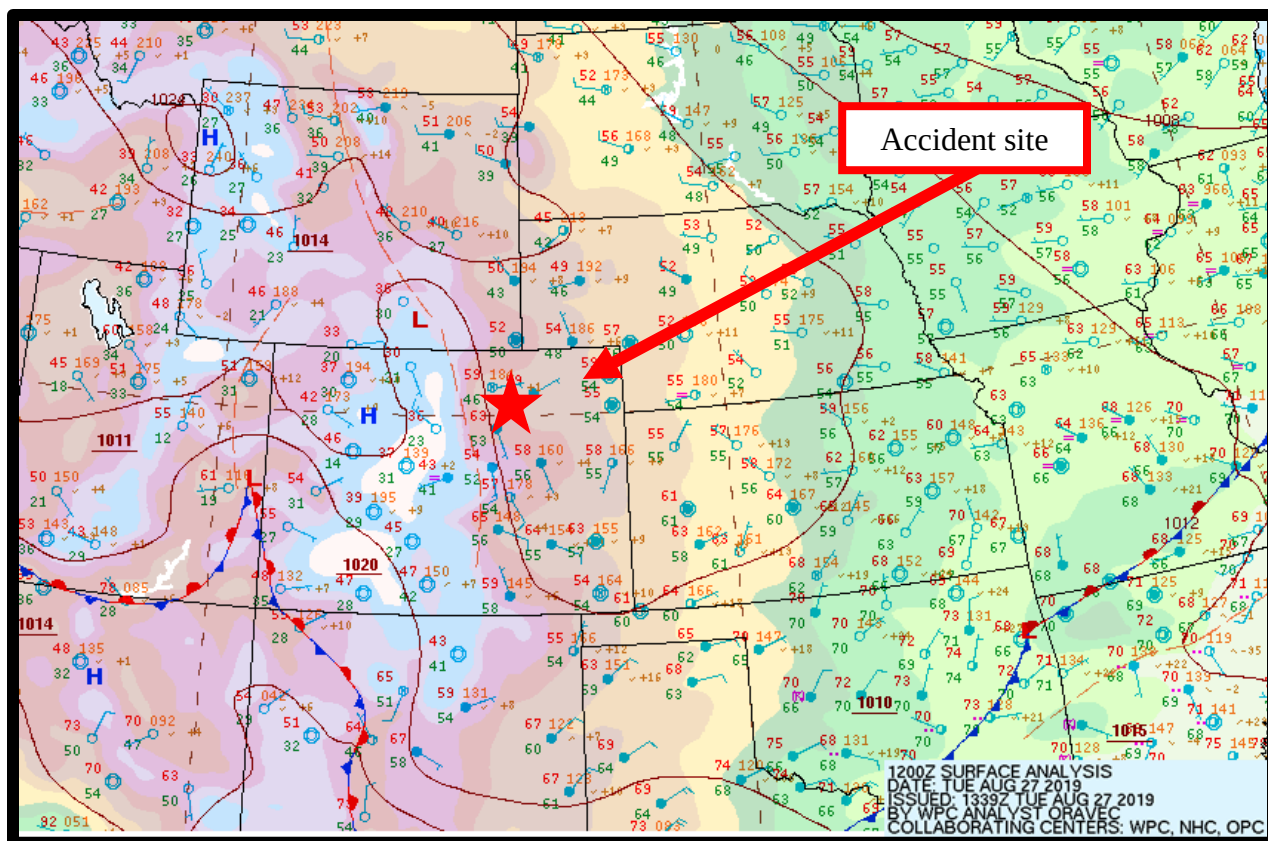
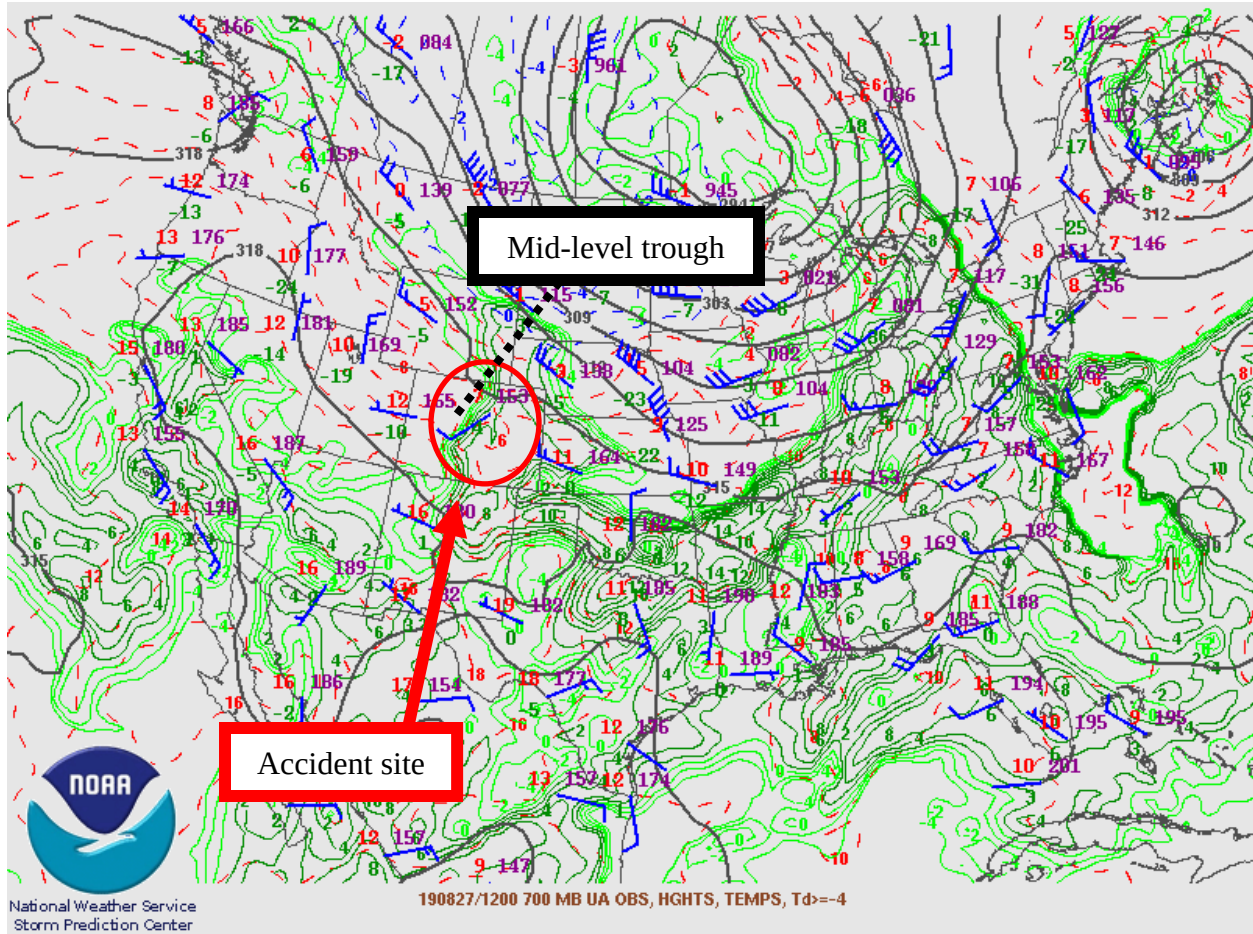


Figure 1 – NWS Surface Analysis Chart for 0600 MDT

## 1.2 Upper Air Charts

The NWS Storm Prediction Center (SPC) Constant Pressure Charts for 0600 MDT at 700-, 500-, and 300-hPa are presented in figures 2 through 3. There was a mid-level trough located above the accident site at 700-hPa (figure 2). Troughs can act as lifting mechanisms to help produce clouds and precipitation if sufficient moisture is present. The wind was from the southwest at 10 knots at 700-hPa with the wind becoming west-northwesterly at 30 knots by 500-hPa (figure 3). The wind speed continued to increase through 300-hPa with the 300-hPa wind was from the west-northwest at 50 knots (figure 4).



**Figure 2 – 700-hPa Constant Pressure Chart for 0600 MDT**

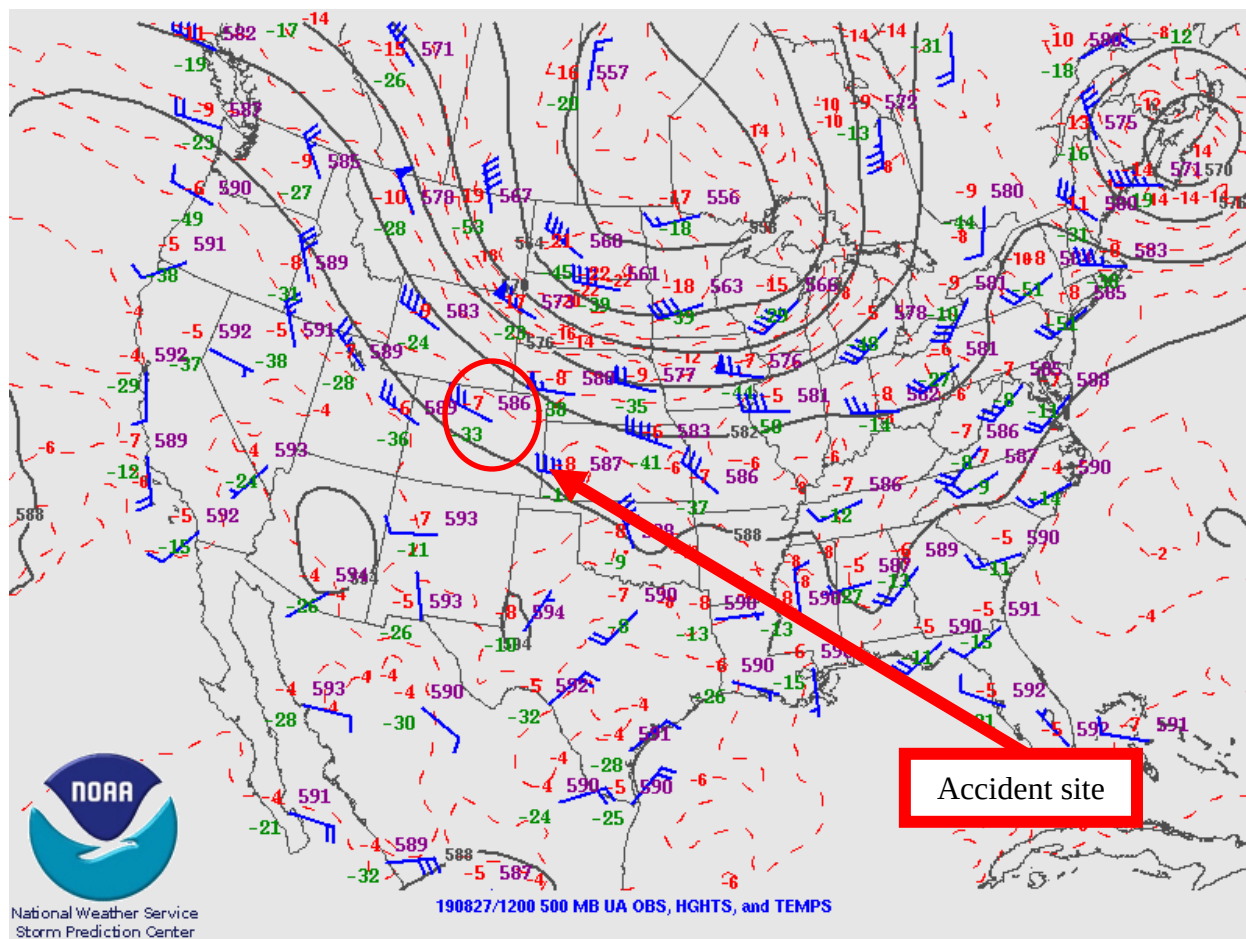
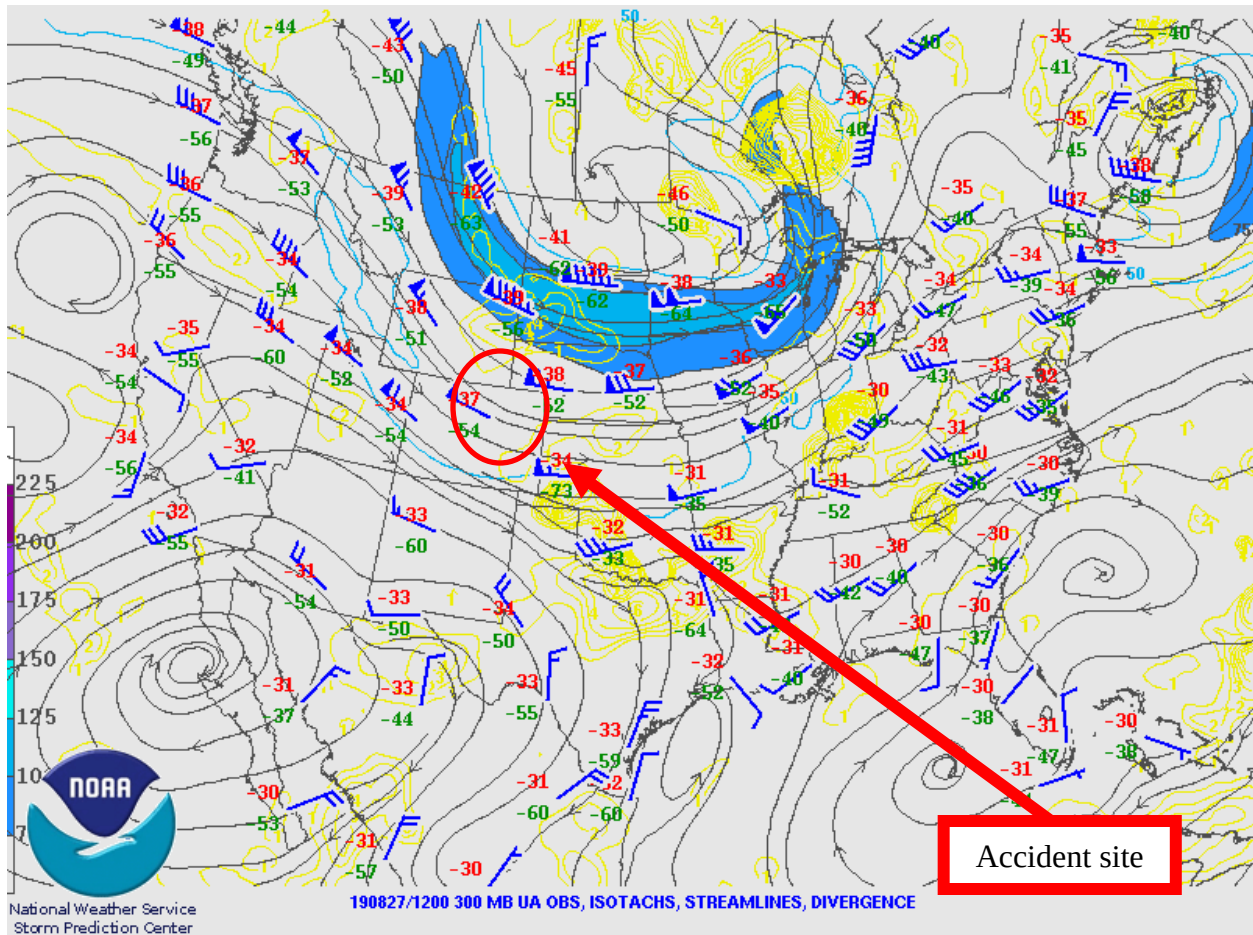


Figure 3 – 500-hPa Constant Pressure Chart for 0600 MDT



**Figure 4 – 300-hPa Constant Pressure Chart for 0600 MDT**

## 2.0 SPC Convective Outlook

No thunderstorms were forecast by SPC over Colorado during the period.

## 3.0 Surface Observations

The area surrounding the accident site was documented using official Meteorological Aerodrome Reports (METARs) and Specials (SPECIs).

Denver International Airport (KDEN), Denver, Colorado, was the destination airport located at an elevation of 5,434 ft, and located approximately 20 miles southwest of the accident site. KDEN had an Automated Surface Observing System (ASOS<sup>4</sup>) whose reports were supplemented by official weather observers and KDEN had a 8° easterly magnetic variation<sup>5</sup>. The following observations were taken and disseminated during the times surrounding the accident:<sup>6</sup>

<sup>4</sup> ASOS – Automated Surface Observing System is equipped with meteorological instruments to observe and report wind, visibility, present weather, cloud cover, temperature, dewpoint, altimeter, and barometric pressure.

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

<sup>6</sup> Bolded sections in this report highlight information that directly reference the weather conditions that affected the

[0053 MDT] METAR KDEN 270653Z 08006KT 10SM SCT075 BKN220 16/09 A3019  
RMK AO2 SLP155 T01610089 402670139=

[0153 MDT] METAR KDEN 270753Z 08004KT 10SM FEW060 BKN080 16/09 A3018  
RMK AO2 SLP148 T01610089=

[0253 MDT] METAR KDEN 270853Z 10007KT 10SM SCT050 BKN070 16/09 A3016  
RMK AO2 SLP142 T01610094 58009=

[0353 MDT] METAR KDEN 270953Z 10006KT 10SM BKN047 16/09 A3016 RMK AO2  
SLP141 T01560094=

[0453 MDT] METAR KDEN 271053Z 13006KT 10SM FEW047 SCT220 14/09 A3017  
RMK AO2 SLP145 T01390094=

***[0553 MDT] METAR KDEN 271153Z 20005KT 10SM BKN050 15/10 A3018 RMK AO2  
SLP148 T01500100 10167 20139 53004=***

**ACCIDENT TIME 0650 MDT**

***[0653 MDT] METAR KDEN 271253Z 26008KT 10SM SCT050 SCT220 13/09 A3020  
RMK AO2 SLP160 T01330094=***

[0753 MDT] METAR KDEN 271353Z 27009KT 10SM FEW050 SCT130 SCT220 15/09  
A3023 RMK AO2 SLP171 T01500089=

[0853 MDT] METAR KDEN 271453Z 28009KT 10SM FEW050 SCT130 SCT220 17/09  
A3024 RMK AO2 SLP178 T01670094 51018=

KDEN weather at 0553 MDT, wind from 200° at 5 knots, 10 miles visibility or greater, a broken ceiling at 5,000 ft above ground level (agl), temperature of 15°Celsius (C), dew point temperature of 10°C, and an altimeter setting of 30.18 inches of mercury (inHg). Remarks: automated station with a precipitation discriminator, sea level pressure 1014.8 hPa, temperature 15.0°C, dew point temperature 10.0°C, 6-hourly maximum temperature of 16.7°C, 6-hourly minimum temperature of 13.9°C, 3-hourly pressure increase of 0.4 hPa.

KDEN weather at 0653 MDT, wind from 260° at 8 knots, 10 miles visibility or greater, scattered clouds at 5,000 ft agl, scattered clouds at 22,000 ft agl, temperature of 13°C, dew point temperature of 9°C, and an altimeter setting of 30.20 inHg. Remarks: automated station with a precipitation discriminator, sea level pressure 1016.0 hPa, temperature 13.3°C, dew point temperature 9.4°C.

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accident location around the accident time.

The observations from KDEN surrounding the accident time indicated VFR<sup>7</sup> conditions, with cloud bases at 5,000 ft agl (~10,000 ft msl), and the surface wind from the southwest to west between 5 to 8 knots.

#### 4.0 Upper Air Data

The Denver, Colorado, (KDNR) upper air sounding was the closest site with an upper air sounding located 31 miles southwest of the accident site with a surface elevation of 5,331 ft (station ID 72469). The 0600 MDT KDNR sounding was plotted on a standard Skew-T Log P diagram<sup>8</sup> with the derived stability parameters included in figure 5 with data from the surface to 400-hPa (or approximately 24,000 ft msl). This data was analyzed using the RAOB<sup>9</sup> software package. The sounding depicted the lifted condensation level (LCL)<sup>10</sup> at 7,334 ft msl and the convective condensation level (CCL)<sup>11</sup> at 10,992 ft msl. The freezing level was located at 15,588 ft msl. The precipitable water value was 0.71 inches.

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

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

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

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

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

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

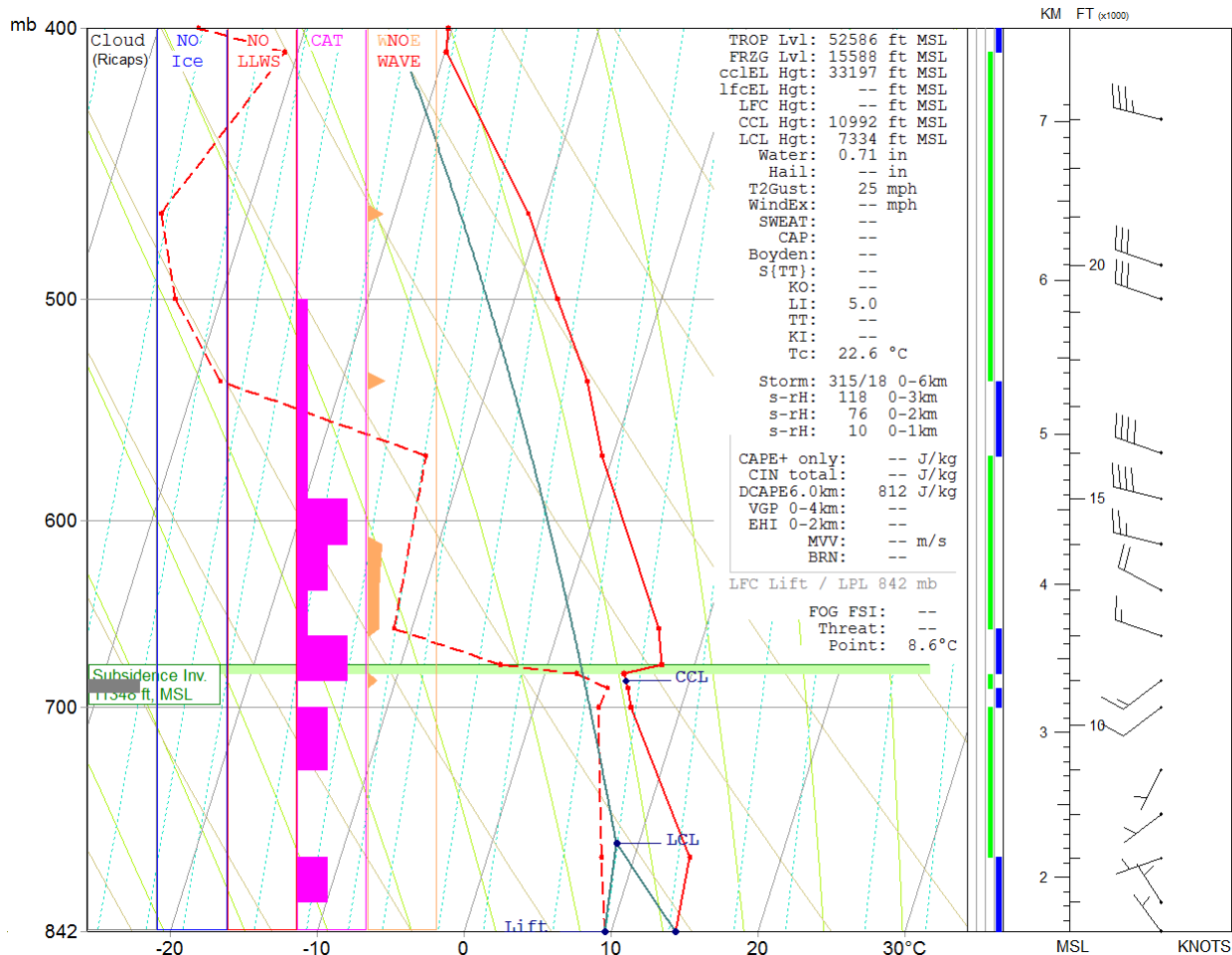
\*\*By definition, VFR is a ceiling greater than or equal to 3,000 ft agl and visibility greater than 5 miles while MVFR is a sub-category of VFR.

<sup>8</sup> 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.

<sup>9</sup> RAOB – (The complete Rawinsonde Observation program) is an interactive sounding analysis program developed by Environmental Research Services, Matamoras, Pennsylvania.

<sup>10</sup> LCL - The height at which a parcel of moist air becomes saturated when it is lifted dry adiabatically.

<sup>11</sup> 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 5 – 0600 MDT KDNR sounding**

The 0600 MDT KDNR sounding indicated alternating layers of conditional instability and a stable environment from the surface through 24,000 ft msl. RAOB identified the possibility of clouds between 11,000 and 12,000 msl. No icing conditions were indicated by RAOB for below 24,000 ft msl. RAOB indicated a subsidence inversion<sup>12</sup> was in place at 11,348 ft msl with clouds indicated below that inversion layer (figure 5).

The 0600 MDT KDNR sounding wind profile indicated a surface wind from 325° at 5 knots with the wind remaining southwesterly to westerly through 24,000 ft msl. The wind speed increased to 40 knots by 15,000 ft msl. At 15,000 ft msl the approximate environmental conditions had the wind from 285° at 39 knots with a temperature of 1°C. RAOB indicated a potential for light to severe clear-air turbulence (CAT) the surface and 24,000 ft msl with the highest potential for CAT located between 11,000 and 15,000 ft msl. Figure 6 summarizes the text KDNR information and strength of the potential for mountain conditions and turbulence therein with light mountain wave conditions indicated by RAOB between 11,000 and 14,000 ft msl.

<sup>12</sup> Inversion – A departure from the usual decrease of the value of an atmospheric property with increasing altitude; also, the layer through which this departure occurs (the "inversion layer"), or the lowest altitude at which the departure is found (the "base of the inversion").

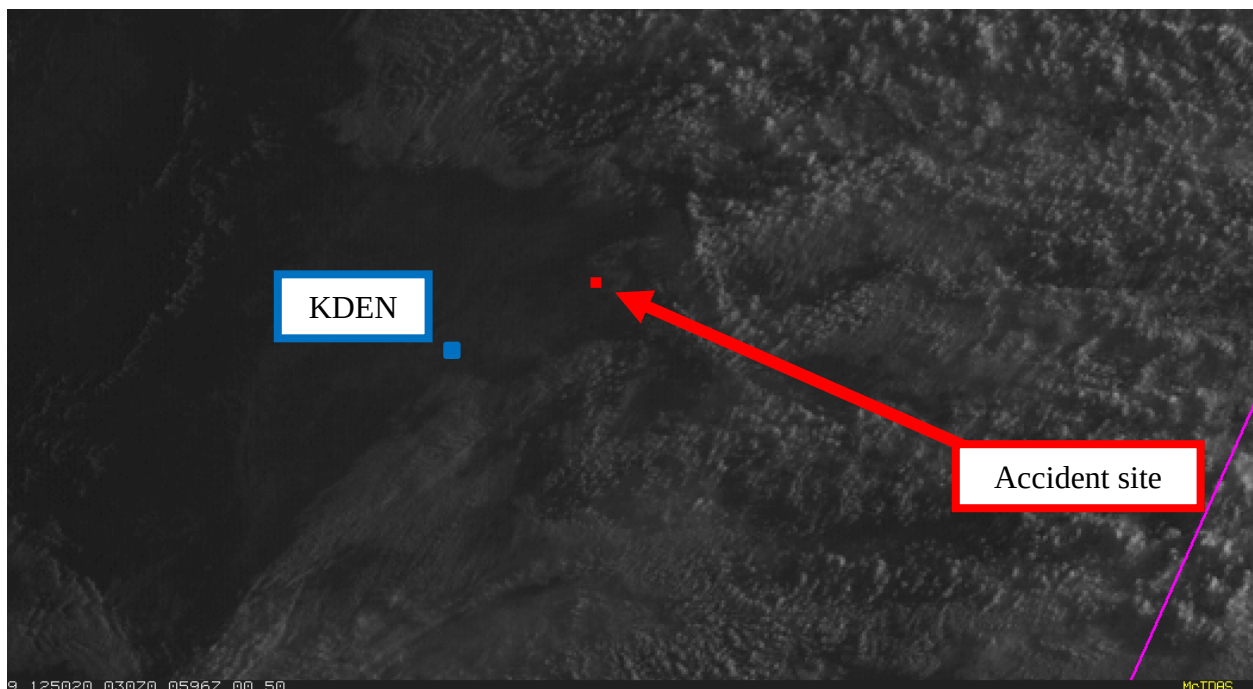
| Level | Height<br>(ft-MSL) | Pres<br>(mb) | T<br>(C) | Td<br>(C) | RH<br>(%) | DD / FF<br>(deg / kts) | CAT<br>(FAA) | LLWS | Icing - Type<br>(AFGWC method) | Wave/x---w---Turb<br>nm fpm max |
|-------|--------------------|--------------|----------|-----------|-----------|------------------------|--------------|------|--------------------------------|---------------------------------|
| 1     | 5331               | 842          | 14.4     | 9.6       | 73        | 325 / 5                |              |      |                                |                                 |
| 2     | 6000               | 822          |          |           |           | 330 / 7                | MDT          |      |                                |                                 |
| 3     | 7030               | 792          | 13.8     | 7.8       | 67        | 250 / 6                |              |      |                                |                                 |
| 4     | 8000               | 764          |          |           |           | 230 / 5                |              |      |                                |                                 |
| 5     | 9000               | 737          |          |           |           | 205 / 4                | MDT          |      |                                |                                 |
| 6     | 10408              | 700          | 6.6      | 4.4       | 86        | 230 / 12               |              |      |                                |                                 |
| 7     | 10835              | 689          | 6.0      | 4.6       | 91        |                        |              |      |                                |                                 |
| 8     | 11000              | 685          |          |           |           | 230 / 13               |              |      |                                | 2.15 231 LIGHT                  |
| 9     | 11149              | 681          | 5.4      | 2.2       | 80        |                        |              |      |                                |                                 |
| 10    | 11348              | 676          | 7.8      | -3.2      | 46        |                        | SVR          |      |                                |                                 |
| 11    | 12000              | 660          |          |           |           | 290 / 16               |              |      |                                |                                 |
| 12    | 12159              | 656          | 6.8      | -11.2     | 26        |                        | LGT          |      |                                | 2.55 287 LIGHT                  |
| 13    | 13000              | 636          |          |           |           | 300 / 21               | MDT          |      |                                | 3.48 347 LIGHT                  |
| 14    | 14000              | 612          |          |           |           | 285 / 27               | SVR          |      |                                | 4.79 471 LIGHT                  |
| 15    | 15000              | 590          |          |           |           | 285 / 39               | LGT          |      |                                |                                 |
| 16    | 15941              | 569          | -0.7     | -12.7     | 40        | 290 / 40               |              |      |                                |                                 |
| 17    | 17548              | 535          | -3.3     | -28.3     | 12        |                        | LGT          |      |                                | 5.80 618 LT-MD                  |
| 18    | 19291              | 500          | -7.1     | -33.1     | 11        | 290 / 30               |              |      |                                |                                 |
| 19    | 20000              | 486          |          |           |           | 290 / 31               |              |      |                                |                                 |
| 20    | 21079              | 466          | -10.9    | -35.9     | 11        |                        |              |      |                                | 6.83 564 LIGHT                  |
| 21    | 23000              | 431          |          |           |           | 285 / 33               |              |      |                                |                                 |
| 22    | 24372              | 408          | -19.9    | -30.9     | 37        |                        |              |      |                                |                                 |
| 23    | 24854              | 400          | -20.3    | -37.3     | 20        | 285 / 37               |              |      |                                | 3.97 305 LIGHT                  |
| 24    | 25000              | 398          |          |           |           | 285 / 38               |              |      |                                |                                 |
| 25    | 25530              | 389          | -21.3    | -42.3     | 13        |                        | LGT          |      |                                | 11.22 1150 LT-MD                |
| 26    | 27000              | 366          |          |           |           | 275 / 40               |              |      |                                |                                 |
| 27    | 28663              | 341          | -29.9    | -48.9     | 14        |                        | LGT          |      |                                |                                 |
| 28    | 29998              | 322          | -31.9    | -55.9     | 7         | 290 / 52               |              |      |                                | 14.54 1426 MD-SV                |

**Figure 6 – 0600 MDT KDNR sounding text information**

## 5.0 Satellite Data

Data from the Geostationary Operational Environmental Satellite number 16 (GOES-16) data was obtained from an archive at the Space Science Engineering Center at the University of Wisconsin-Madison in Madison, Wisconsin, and processed using the Man-computer Interactive Data Access System software. Visible (band 2) and infrared (bands 13) imagery at wavelengths of 0.64 microns ( $\mu\text{m}$ ) and 10.3  $\mu\text{m}$ , respectively, were retrieved for the period. Satellite imagery surrounding the time of the accident, from 0400 MDT through 1100 MDT at approximately 5-minute intervals were reviewed, and the closest images to the time of the accident are documented here.

Figures 7 and 8 present the GOES-16 visible imagery from 0650 and 0700 MDT at 2X magnification with the accident site highlighted with a red square. Inspection of the visible imagery indicated the accident site was located on a boundary where there was no cloud cover over the accident site and points westward and abundant cloud cover at points eastward. The cloud cover was forming over the accident site location and moving eastward with time (attachment 1). Figure 9 present the GOES-16 infrared imagery from 0650 MDT at 4X magnification and with a temperature enhancement curve applied with the accident site highlighted with a red square. Inspection of the infrared imagery indicated abundant cloud cover to the northeast through southeast of the accident site with the lowest brightness temperatures (yellow and orange blue colors, higher clouds) located east of the accident site. Animation of the infrared imagery indicated the cloud cover moving eastward with stationary west to east oriented wave or bandlike features located within the cloud cover in eastern Colorado, western Kansas, and western Nebraska (attachment 2). Based on the brightness temperatures above the accident site (283 Kelvin) and the vertical temperature profile provided by the 0600 MDT KDNR sounding, there were no clouds above the accident site. However, the cloud cover located within the accident site area (and points eastward) had a brightness temperature of 273 Kelvin, which would yield the approximate cloud-top heights of 15,000 ft at 0650 MDT. It should be noted these figures have not been corrected for any parallax error.



**Figure 7 – GOES-16 visible image at 0650 MDT**

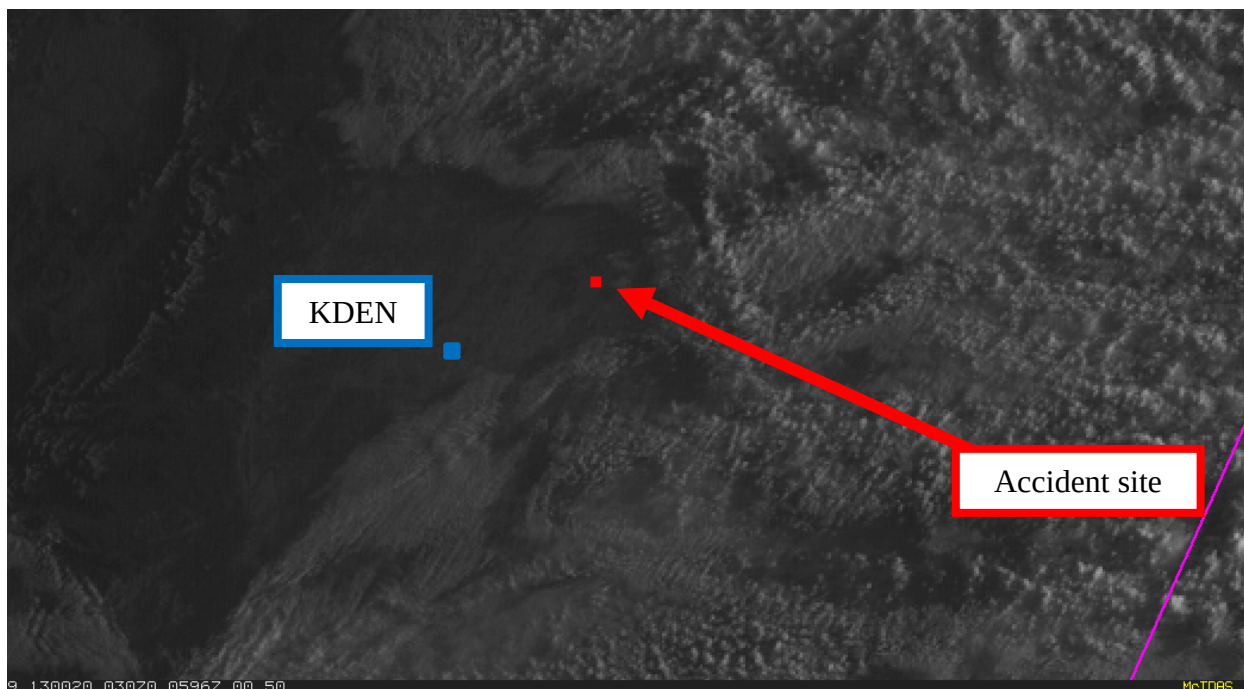


Figure 8 – GOES-16 visible image at 0700 MDT

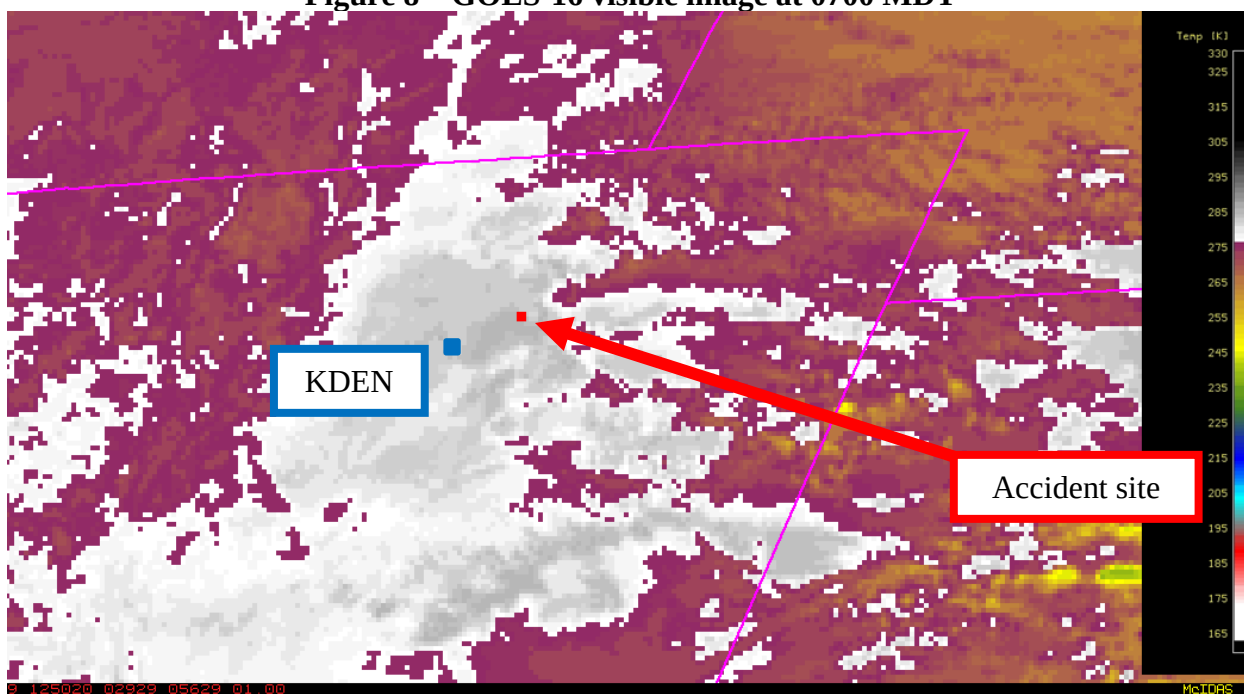
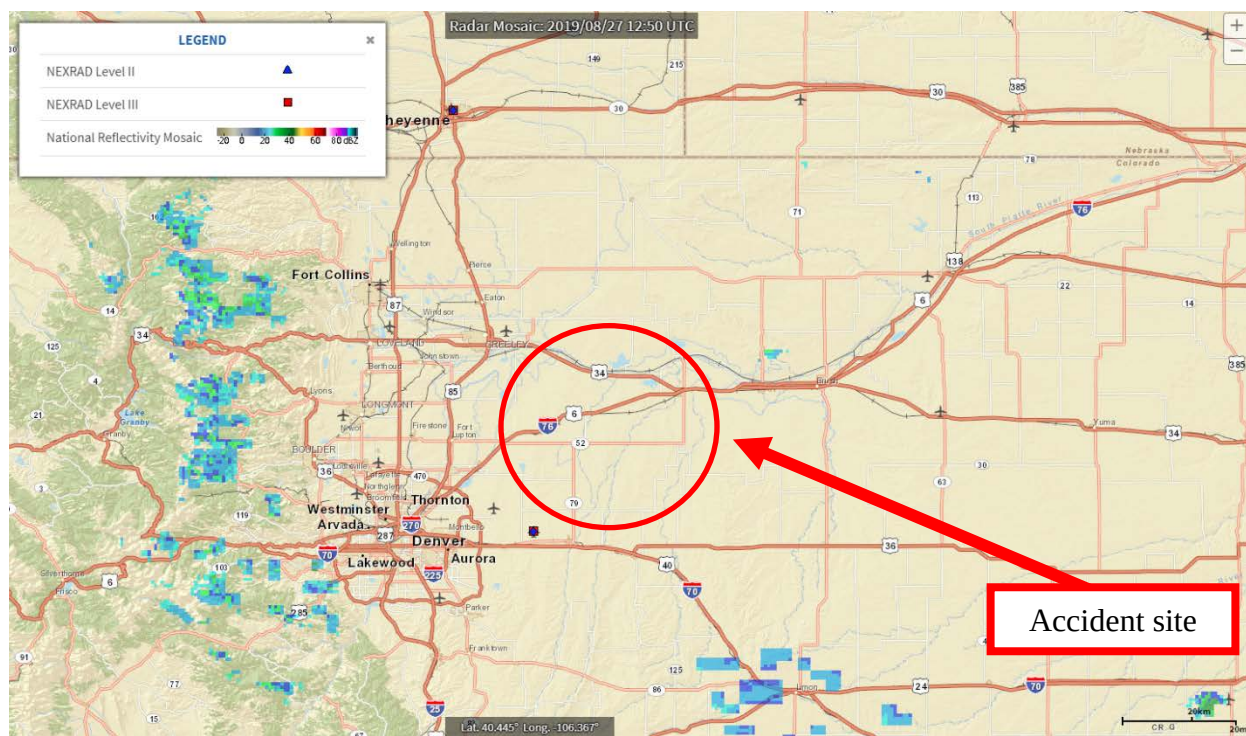


Figure 9 – GOES-16 infrared image at 0650 MDT

## 6.0 Regional Radar Imagery

A regional view of the NWS National Composite Radar Mosaic is included as figure 10 for 0650 MDT. The image depicted no precipitation targets or echoes in the immediate vicinity of the accident site at the accident time.



**Figure 10 – Regional Composite Reflectivity image for 0650 MDT**

In addition, the FAA Consolidated Storm Prediction for Aviation (CoSPA) radar images were retrieved and reviewed around the accident time and the CoSPA imagery indicated no precipitation, and lightning activity over the area surrounding the period of the accident.

## 7.0 Pilot Reports

All pilot reports (PIREPs)<sup>13</sup> within 100 miles of the accident site from about 2 hours prior to the accident time to about 2 hours after the accident time were reviewed for below FL250<sup>14</sup> and there was only one PIREP distributed into the national airspace which is provided below:

AKO UA /OV FTG-AKO /TM 1437 /FL070 /TP C185 /SK OVC075 /TB NEG /RM SMTH

The reports in plain language taken from standard code and abbreviations, with cloud heights in msl:

Colorado Plains Regional Airport, Colorado, (AKO) routine pilot report (UA); Over – between Front Range Airport (FTG) and AKO; Time – 0837 MDT (1437Z); Altitude – 7,000 ft; Type aircraft – Cessna 185; Sky – Overcast skies at 7,500 ft; Turbulence – Negative; Remarks – Smooth.

<sup>13</sup> Only pilot reports with the World Meteorological Organization (WMO) header UBCO\*\* identifier were considered.

<sup>14</sup> 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.

## 8.0 SIGMET

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

## 9.0 CWSU Advisories

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

## 10.0 AIRMETs

There were no Airmen's Meteorological Information (AIRMET) advisories valid for the accident site at the accident time.

## 11.0 Graphical Forecasts for Aviation

The Graphical Forecasts for Aviation (GFA) products made available before the accident flight are shown in attachment 3. The GFA surface forecast products indicated surface VFR conditions would prevail with a surface wind from the east at 5 knots. The GFA cloud forecast products indicated an overcast cloud ceiling at 10,000 ft msl with cloud tops at 12,000 ft msl. For more information please see attachment 3.

## 12.0 Winds and Temperature Aloft Forecast

The NWS Winds and Temperature Aloft forecast issued at 0152 MDT and valid for 0600 MDT for the closest point to the accident site is included below:

```
FBUS31 KWN0 270752
FD1US1
DATA BASED ON 270600Z
VALID 271200Z   FOR USE 0800-1500Z. TEMPS NEG ABV 24000

FT  3000    6000    9000   12000   18000   24000   30000   34000   39000
DEN                2212+10 2714+06 2831-07 2838-21 295036 305743 296153
```

The accident site was closest to the DEN forecast point. The DEN forecast for use between 0200 MDT and 0900 MDT indicated a wind at 9,000 ft from 220° at 12 knots with a temperature of 10°C, a wind at 12,000 ft from 270° at 14 knots with a temperature of 6°C, and a wind at 18,000 ft from 280° at 31 knots with a temperature of -7°C.

## 13.0 Pilot Weather Briefing

The accident pre-flight weather information is further discussed in the Operations Report located in the docket for this accident.

## 14.0 GTG information

The NWS Aviation Weather Center (AWC) provided Graphical Turbulence Guidance (GTG) plots that indicated turbulence at the accident time and at the flight level. For more information please see attachment 4.<sup>15</sup>

## 15.0 Astronomical Data

The astronomical data obtained for the accident site on August 27, 2019, indicated the following:

|                      |                              |
|----------------------|------------------------------|
| <b>SUN</b>           |                              |
| Begin civil twilight | 0553 MDT                     |
| Sunrise              | 0622 MDT                     |
| <b>Accident</b>      | <b>0650 MDT<sup>16</sup></b> |
| Sun transit          | 1300 MDT                     |
| Sunset               | 1938 MDT                     |
| End civil twilight   | 2006 MDT                     |

## E. LIST OF ATTACHMENTS

Attachment 1 – GOES-16 visible animation from 0706 MDT to 1106 MDT

Attachment 2 – GOES-16 infrared animation from 0706 to 1106 MDT

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

Attachment 4 – AWC GTG forecast and imagery

Submitted by:

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Paul Suffern  
Senior Meteorologist

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<sup>15</sup> For more information on GTG please see: <https://aviationweather.gov/turbulence>

<sup>16</sup> Inserted accident time for reference and context.

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