



NATIONAL TRANSPORTATION SAFETY BOARD

Office of Aviation Safety
Washington, D.C. 20594

March 21, 2019

Factual Report

METEOROLOGY

CEN19FA022

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A. ACCIDENT

Location: Broomfield, Colorado
Date: November 2, 2018
Time: 1151 mountain daylight time
1751 Coordinated Universal Time (UTC)
Aircraft: Mustang II, Registration: N287BM

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 November 2, 2018, 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 final wreckage location was estimated at latitude 39.9975° N, longitude 105.0458° W at an approximate elevation of 5,170 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 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 central United States section of the NWS Surface Analysis Chart for 1200 MDT is provided as figure 1 with the approximate location of the accident site marked within the red circle. The chart indicated a stationary front located across northeastern Colorado. The stationary front stretched from southern Montana southeastward into Kansas, where the boundary became a cold front which stretched from Kansas, through Oklahoma and into Arkansas. A low pressure center was located in southern Iowa with a pressure of 1009-hectopascals (hPa).

The station models around the accident site depicted air temperatures in the mid 40's to mid 50's degrees Fahrenheit (°F), dew point temperatures in the low 30's °F with temperature-dew point spreads of 16° F or more, a west wind of 10 knots reported in Denver, Colorado, with clear skies.

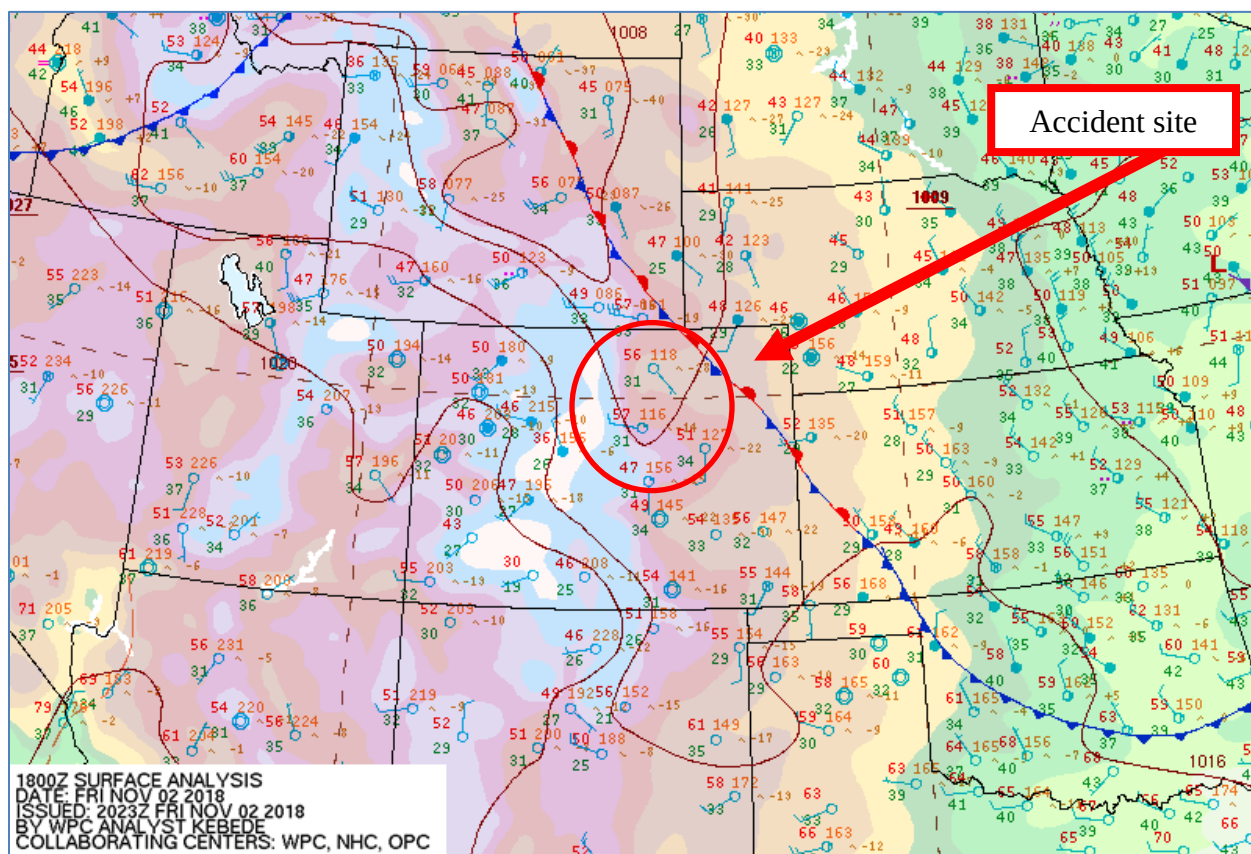


Figure 1 – NWS Surface Analysis Chart for 1200 MDT

1.2 Upper Air Charts

The NWS Storm Prediction Center (SPC) Constant Pressure Charts for 0600 MDT at 700-, 500-, and 300-hPa are presented in figures 2 through 4. There was a mid-level trough² located northwest of the accident site located from Wyoming southwestward into northern Utah. Troughs can act as lifting mechanisms to help produce clouds and precipitation if sufficient moisture is present. The wind was from the northwest at 40 knots at 700-hPa with the wind veering³ to the north-northwest through 300-hPa. At 300-hPa, the wind was from the north-northwest at 75 knots (figure 4).

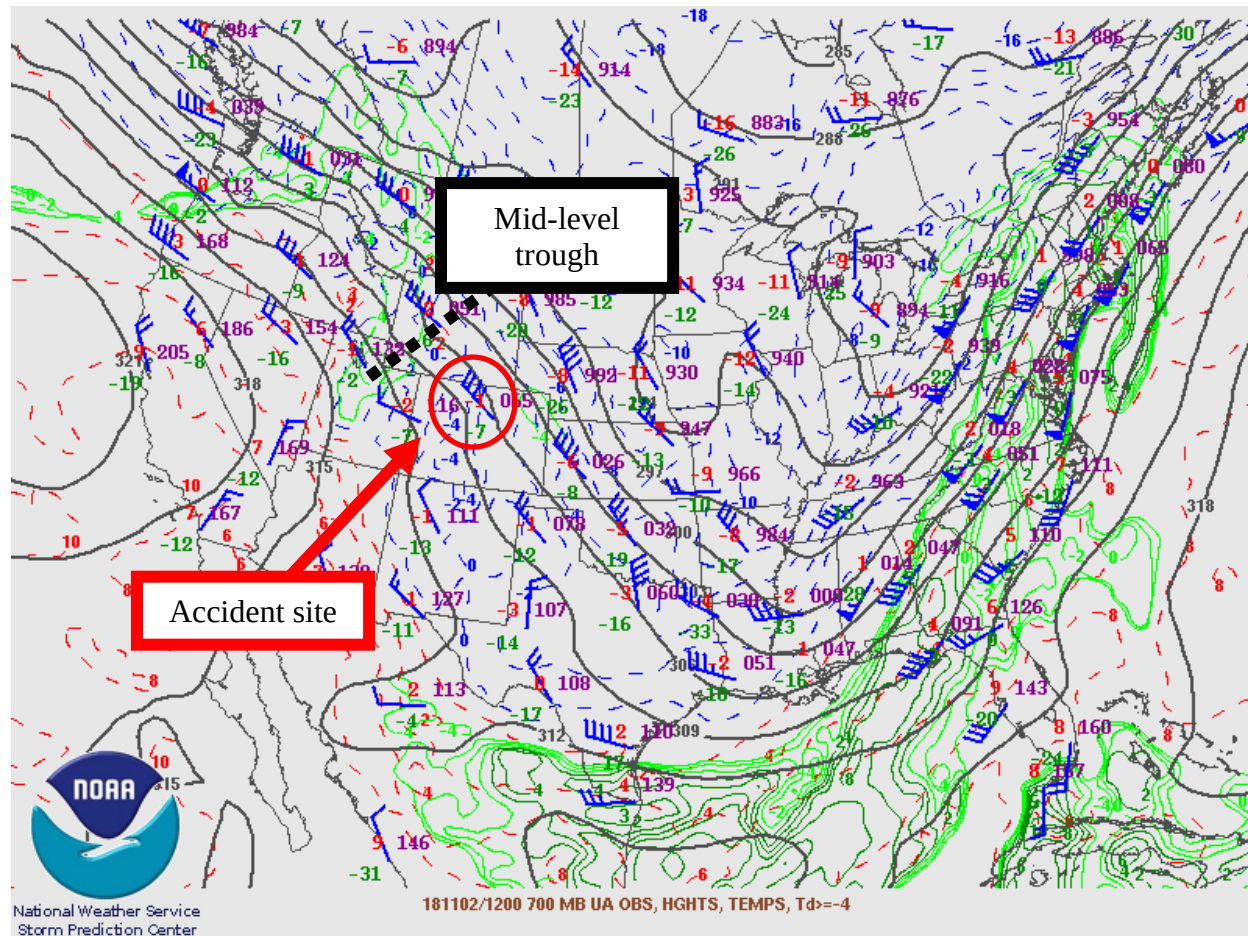


Figure 2 – 700-hPa Constant Pressure Chart for 0600 MDT

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

³ A change in wind direction with height in a clockwise sense in the Northern Hemisphere

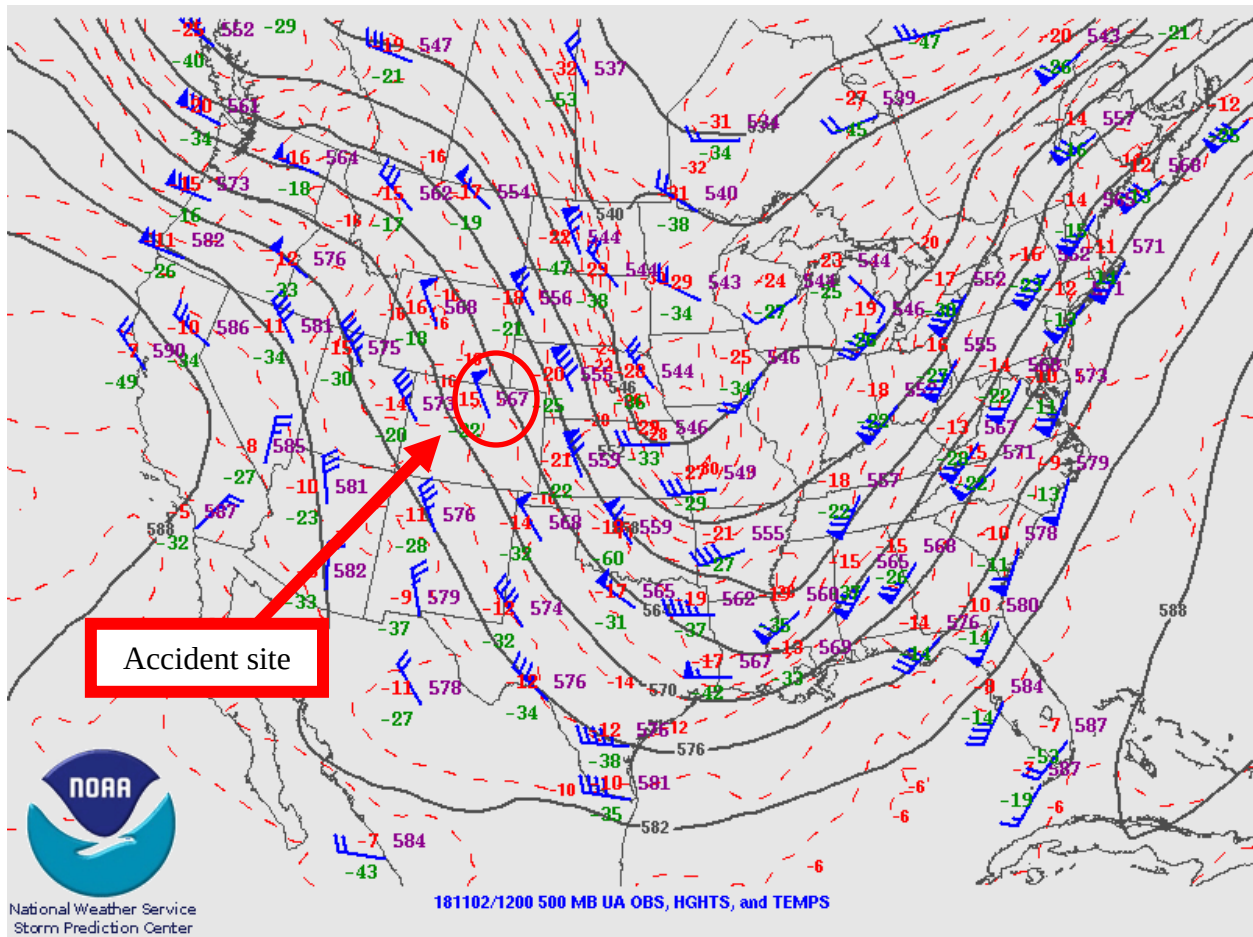


Figure 3 – 500-hPa Constant Pressure Chart for 0600 MDT

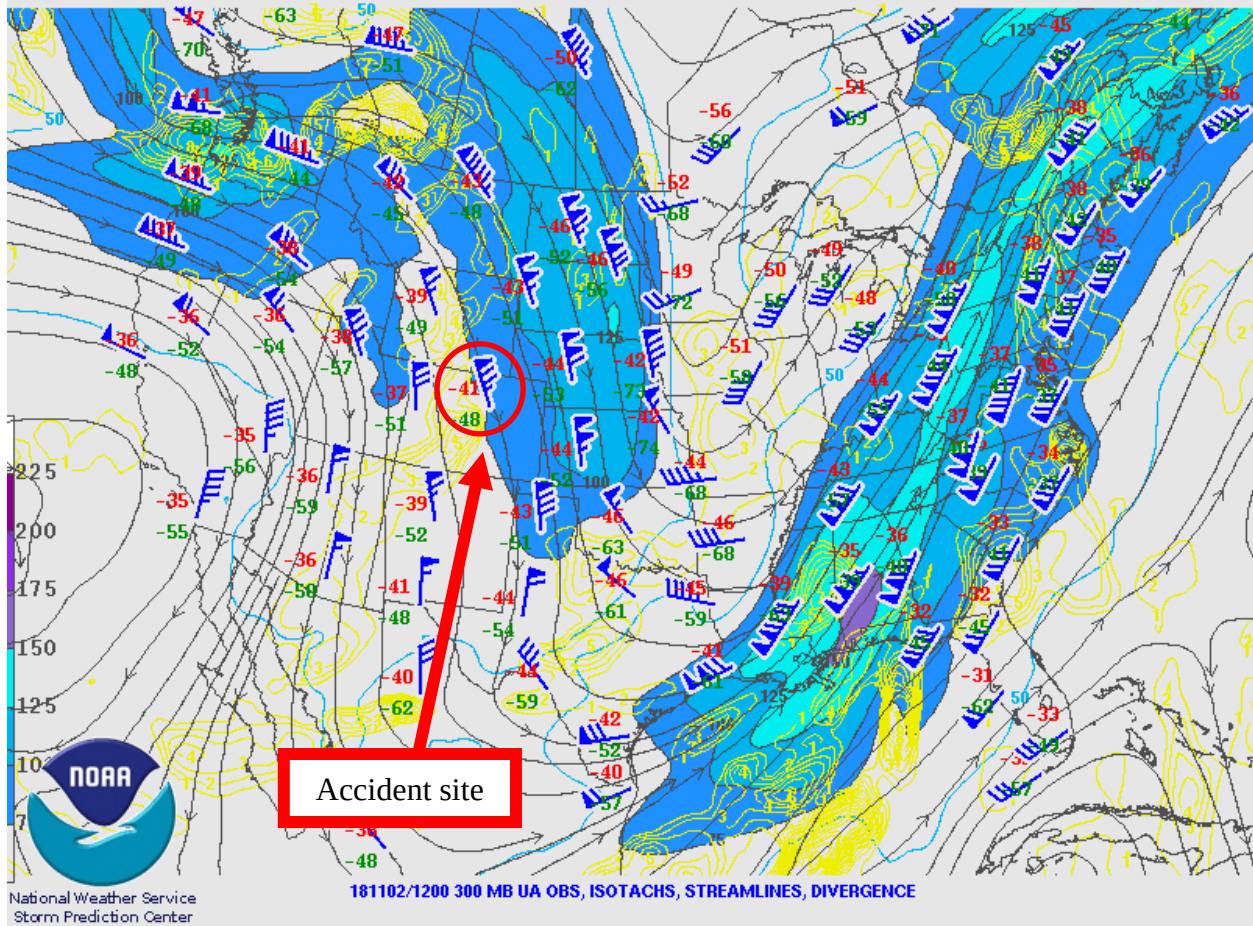


Figure 4– 300-hPa Constant Pressure Chart for 0600 MDT

2.0 SPC Products

SPC did not forecast any thunderstorms to impact the accident site at the accident time.

3.0 Surface Observations

The area surrounding the accident site was documented using official Meteorological Aerodrome Reports (METARs) and Specials (SPECIs). Figure 5 is a sectional chart with the accident site and the closest weather reporting locations to the accident site marked.

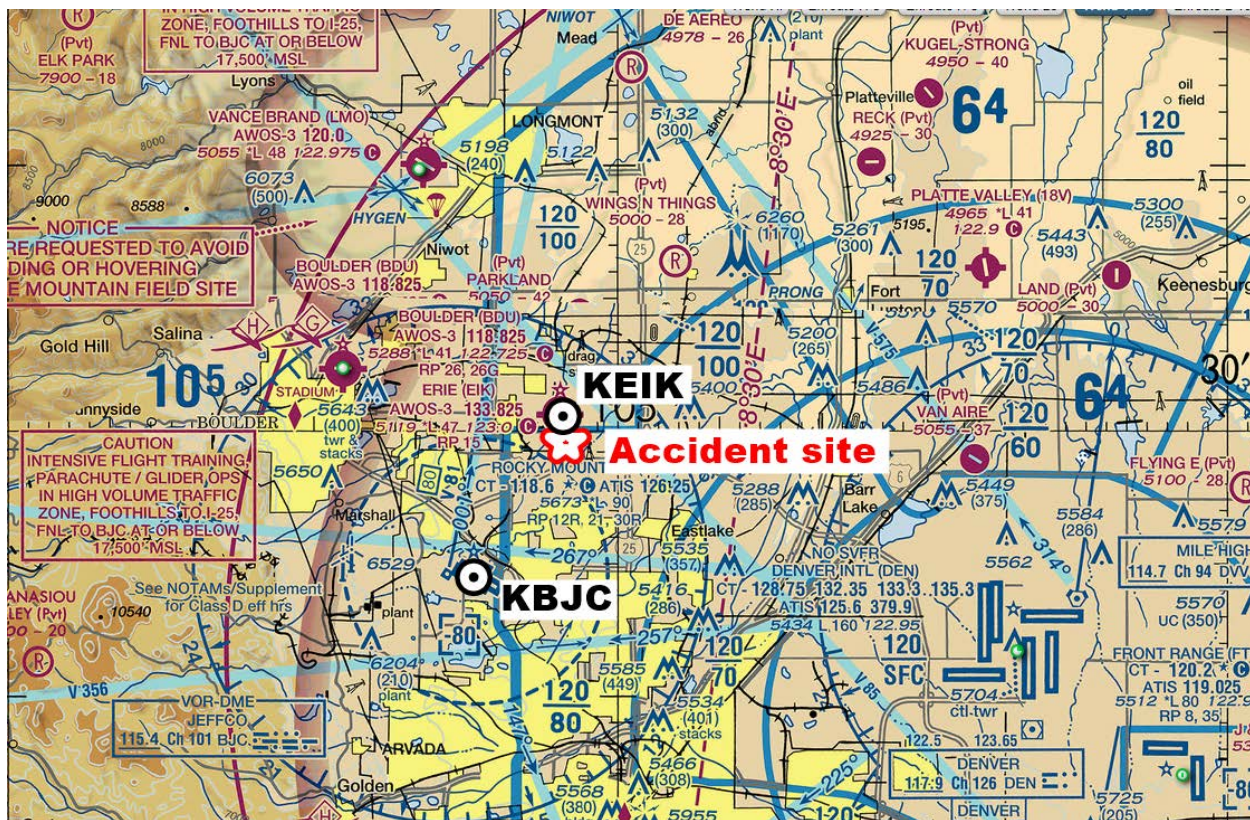


Figure 5 – Sectional chart of accident area with the location of the accident site and the closest surface observation sites

Erie Municipal Airport (KEIK) had the closest official weather observation point, and was the intended destination of the accident flight, and was located 3 miles south of Erie, Colorado. KEIK had an Automated Weather Observing System (AWOS⁴) whose reports were not supplemented. KEIK was located a mile north of the accident site, at an elevation of 5,119 ft, and had a 8° easterly magnetic variation⁵ (figure 5). The following observations were taken and disseminated during the times surrounding the accident:⁶

[0954 MDT] METAR KEIK 021554Z AUTO 00000KT 10SM CLR 07/00 A3001 RMK AO2 T00681001=

[1012 MDT] METAR KEIK 021612Z AUTO 19003KT 10SM CLR 08/00 A2999 RMK AO2 T00821004=

[1036 MDT] METAR KEIK 021636Z AUTO 18003KT 10SM CLR 11/00 A2998 RMK AO2 T01081001=

⁴ 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.

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

⁶ Bolded sections in this report highlight information that directly reference the weather conditions that affected the accident location around the accident time.

[1054 MDT] METAR KEIK 021654Z AUTO 00000KT 10SM CLR 13/M01 A2997 RMK
AO2 T01271010=

**[1112 MDT] METAR KEIK 021712Z AUTO 32003KT 10SM CLR 13/M02 A2995 RMK
AO2 T01341016=**

**[1136 MDT] METAR KEIK 021736Z AUTO 33004KT 10SM CLR 15/M02 A2995 RMK
AO2 T01521020=**

ACCIDENT TIME 1151 MDT

**[1154 MDT] METAR KEIK 021754Z AUTO 30007KT 10SM CLR 16/M02 A2994 RMK
AO2 T01571016=**

**[1212 MDT] METAR KEIK 021812Z AUTO 31010G15KT 10SM CLR 17/M01 A2993
RMK AO2 T01701014=**

[1236 MDT] METAR KEIK 021836Z AUTO 30021G28KT 10SM CLR 18/M02 A2991
RMK AO2 T01791022=

[1254 MDT] METAR KEIK 021854Z AUTO 29018G31KT 10SM CLR 18/M02 A2990
RMK AO2 T01801021=

KEIK weather at 1112 MDT, automated, wind from 320° at 3 knots, 10 miles visibility or greater, clear skies below 12,000 ft above ground level (agl), temperature of 13° Celsius (C), dew point temperature of -2° C, and an altimeter setting of 29.95 inches of mercury. Remarks: automated station with a precipitation discriminator, temperature 13.4° C, dew point temperature -1.6° C.

KEIK weather at 1136 MDT, automated, wind from 330° at 4 knots, 10 miles visibility or greater, clear skies below 12,000 ft agl, temperature of 15° C, dew point temperature of -2° C, and an altimeter setting of 29.95 inches of mercury. Remarks: automated station with a precipitation discriminator, temperature 15.2° C, dew point temperature -2.0° C.

KEIK weather at 1154 MDT, automated, wind from 300° at 7 knots, 10 miles visibility or greater, clear skies below 12,000 ft agl, temperature of 16° C, dew point temperature of -2° C, and an altimeter setting of 29.94 inches of mercury. Remarks: automated station with a precipitation discriminator, temperature 15.7° C, dew point temperature -1.6° C.

KEIK weather at 1212 MDT, automated, wind from 310° at 10 knots with gusts to 15 knots, 10 miles visibility or greater, clear skies below 12,000 ft agl, temperature of 17° C, dew point temperature of -1° C, and an altimeter setting of 29.93 inches of mercury. Remarks: automated station with a precipitation discriminator, temperature 17.0° C, dew point temperature -1.4° C.

Rocky Mountain Metropolitan Airport (KBJC) was the next closest official weather observation point to the accident site. KBJC had an AWOS whose reports were supplemented by air traffic control (ATC) between the hours of 0600 to 2200 local. KBJC was located 6 miles south-southwest of the accident site at an elevation of 5,673 ft (figure 5). The following observations were taken and disseminated during the times surrounding the accident:

[0750 MDT] METAR KBJC 021350Z VRB03KT 10SM FEW080 BKN160 02/M02 A2997=

[0850 MDT] METAR KBJC 021450Z 00000KT 10SM FEW080 FEW200 04/M02 A2998=

[0946 MDT] METAR KBJC 021546Z 00000KT 10SM FEW080 FEW200 09/M01 A2997=

[1011 MDT] SPECI KBJC 021611Z 28012G17KT 50SM FEW080 FEW200 13/M01 A2995=

[1055 MDT] SPECI KBJC 021655Z 30015G22KT 50SM FEW080 FEW200 15/M01 A2992=

[1150 MDT] METAR KBJC 021750Z 27026G35KT 50SM FEW080 FEW200 17/M01 A2992=

ACCIDENT TIME 1151 MDT

[1250 MDT] METAR KBJC 021850Z 27021G34KT 50SM FEW080 FEW200 17/M01 A2988=

[1456 MDT] METAR KBJC 022056Z 26017G23KT 50SM FEW080 SCT200 15/M02 A2984=

[1555 MDT] METAR KBJC 022155Z 27002KT 50SM FEW080 SCT150 SCT2002 15/M03 A2983=

[1610 MDT] SPECI KBJC 022210Z 27002KT 50SM FEW080 SCT150 SCT2002 15/M03 A2983=

KBJC weather at 1055 MDT, wind from 300° at 15 knots with gusts to 22 knots, 50 miles visibility, few clouds at 8,000 ft agl, few clouds at 20,000 ft agl, temperature of 15° C, dew point temperature of -1° C, and an altimeter setting of 29.92 inches of mercury.

KBJC weather at 1150 MDT, wind from 270° at 26 knots with gusts to 35 knots, 50 miles visibility, few clouds at 8,000 ft agl, few clouds at 20,000 ft agl, temperature of 17° C, dew point temperature of -1° C, and an altimeter setting of 29.92 inches of mercury..

KBJC weather at 1250 MDT, wind from 270° at 21 knots with gusts to 34 knots, 50 miles visibility, few clouds at 8,000 ft agl, few clouds at 20,000 ft agl, temperature of 17° C, dew point temperature of -1° C, and an altimeter setting of 29.88 inches of mercury..

KBJC weather at 1456 MDT, wind from 260° at 17 knots with gusts to 23 knots, 50 miles visibility, few clouds at 8,000 ft agl, scattered clouds at 20,000 ft agl, temperature of 15° C, dew point temperature of -2° C, and an altimeter setting of 29.84 inches of mercury.

The observations from KEIK and KBJC surrounding the accident time indicated VFR⁷ conditions. Gusty wind conditions were observed at KBJC by 1011 MDT with gusts to 35 knots around the accident time. Gusty wind conditions were observed at KEIK at 1212 MDT with gusts reaching 31 knots by 1252 MDT.

4.0 Upper Air Data

A High-Resolution Rapid Refresh (HRRR)⁸ model sounding was created for the accident site for 1200 MDT with a station elevation of 5,115 ft,⁹ plotted on a standard Skew-T Log P diagram,¹⁰ and is included in figure 6 (with data from the surface to 600-hPa (or approximately 14,000 ft msl). This data was analyzed using the RAOB¹¹ software package. The sounding depicted the lifted condensation level (LCL)¹² at 6,729 ft agl (11,844 ft msl), and the convective condensation level (CCL)¹³ at 8,228 ft agl (13,343 ft msl). The sounding had a less than 60 percent relative humidity from the surface through 13,000 ft. The freezing level was located at 11,076 ft msl. The precipitable water value was 0.48 inches.

⁷ 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 6 miles visibility.

⁸ 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.

⁹ HRRR sounding was created using NOAA Air Resource Laboratory: <https://ready.arl.noaa.gov/READYamet.php>

¹⁰ 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.

¹¹ RAOB – (The complete Rawinsonde Observation program) is an interactive sounding analysis program developed by Environmental Research Services, Matamoras, Pennsylvania.

¹² LCL - The height at which a parcel of moist air becomes saturated when it is lifted dry adiabatically.

¹³ 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.

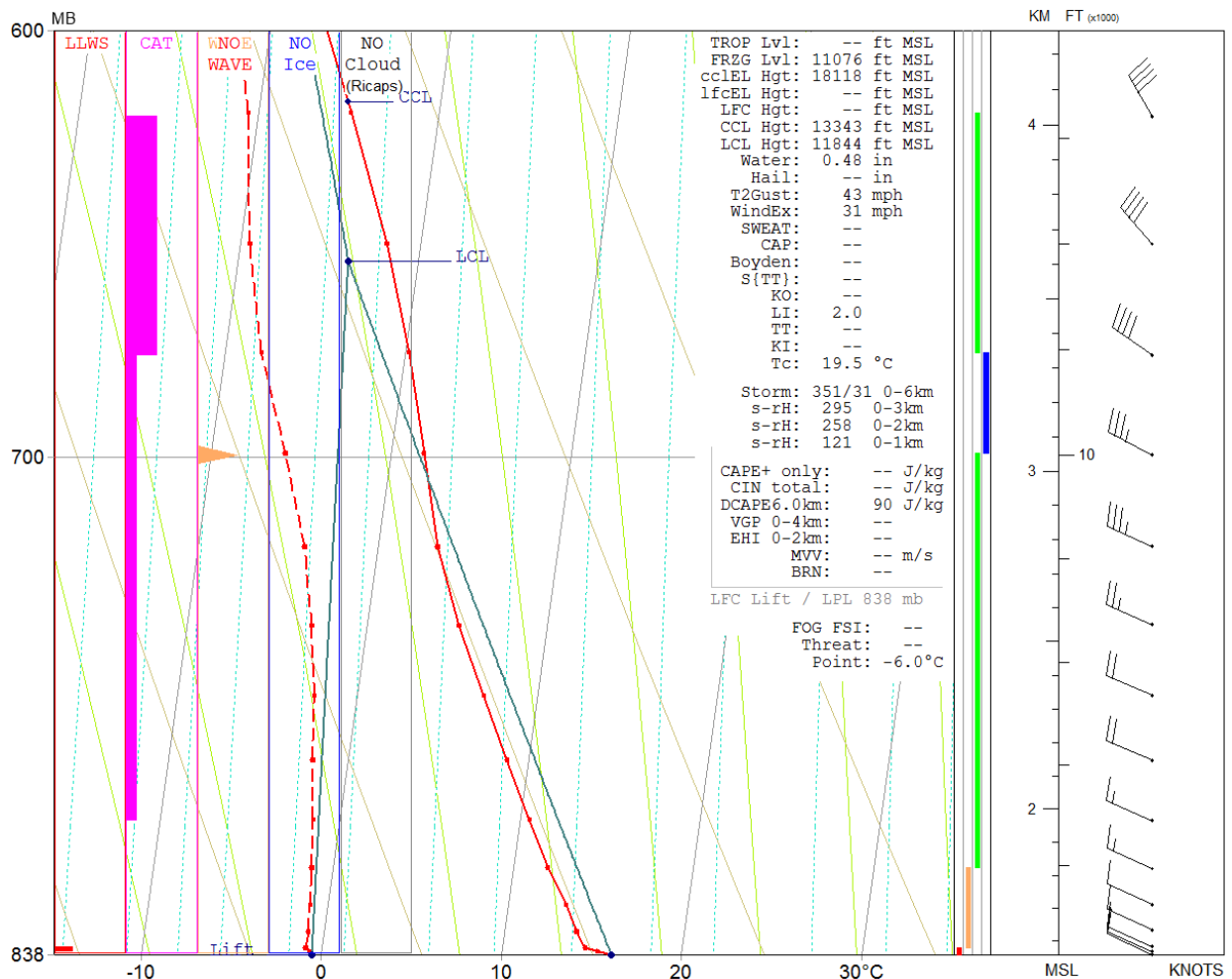


Figure 6 – 1200 MDT HRRR sounding for the accident site

The 1200 MDT HRRR sounding for the accident site indicated an unstable environment from the surface through 6,000 ft msl, with a conditionally unstable environment from 6,000 ft msl through 10,000 ft msl. RAOB did not identify the possibility of clouds for below 14,000 ft msl. No icing was indicated by RAOB below 14,000 ft msl.

The 1200 MDT HRRR sounding wind profile indicated a surface wind from 297° at 10 knots with the wind increasing in speed to 37 knots from the northwest by 10,000 ft. RAOB indicated the possibility of light low-level wind shear (LLWS) between the surface and 5,500 ft. RAOB indicated the possibility of light to moderate clear-air turbulence above 6,500 ft msl. RAOB also indicated the possibility of moderate to severe mountain wave conditions¹⁴ in between 9,000 and 11,000 ft with updraft and downdraft speeds as high as 1,214 ft per minute (figure 7). Mountain wave conditions will be further discussed in sections 16.0 and 17.0.

¹⁴ Default RAOB mountain range parameters were used.

Level	Height (ft-MSL)	Pres (mb)	T (C)	Td (C)	RH (%)	DD / FF (deg / kts)	CAT (FAA)	LLWS	Icing - Type (AFGWC method)	Wave/x---W---Turb nm fpm max
1	5115	838	16.1	-0.5	32	297 / 10				
2	5148	837	15.3	-0.7	33	296 / 10				
3	5181	836	14.6	-0.9	34			LIGHT		
4	5197	836				296 / 11				
5	5347	831	14.0	-0.9	36					
6	5364	830				296 / 11				
7	5614	823	13.2	-1.0	37	296 / 12				
8	5971	812				296 / 13				
9	5984	812	11.9	-1.2	40					
10	6460	798	10.5	-1.5	43	295 / 14	LGT			
11	7047	781	8.8	-2.0	47	295 / 18	LGT			
12	7678	763	7.0	-2.4	51	295 / 22				
13	8356	744	5.1	-3.1	55		LGT			
14	8366	744				295 / 27	LGT			
15	9121	723	3.3	-4.1	58	296 / 33	LGT			
16	10000	699				299 / 37				5.69 1214 MD-SV
17	10017	699	1.8	-5.9	57		LGT			
18	10951	675				307 / 39				
19	10978	674	0.2	-8.0	54		MDT			
20	12009	648	-1.9	-9.5	56	321 / 39	MDT			
21	13202	619				332 / 39				
22	13240	618	-4.9	-10.6	64					
23	14501	588				334 / 39				6.68 1593 MD-SV
24	14517	588	-8.2	-12.6	71		LGT			
25	15951	556				330 / 44				
26	15981	555	-11.3	-15.4	72		LGT			
27	17598	520				326 / 48				
28	17661	519	-14.1	-18.9	67					
29	19301	486				325 / 52				
30	19392	484	-16.7	-23.0	58					
31	20981	454				326 / 54				6.84 167 LIGHT
32	21071	452	-19.1	-26.8	51					
33	22592	425				326 / 56				

Figure 7 – 1200 MDT HRRR sounding text data

5.0 Satellite Data

The Geostationary Operational Environmental Satellite number 16 (GOES-16) imagery 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 and infrared (bands 2 and 13) imagery at a wavelength of 0.64 microns (μm) and 10.3 μm were retrieved for the period. Satellite imagery surrounding the time of the accident, from 0900 MDT through 1400 MDT at approximately 5-minute intervals were reviewed, and the closest images to the time of the accident are documented here.

Figure 8 presents the GOES-16 visible imagery from 1152 MDT at 2X magnification with the accident site highlighted with a red square. The cloud cover remained relatively stationary and west of the accident site along the Front Range of the Rocky Mountains between 0907 and 1307 MDT (attachment 1), with no clouds over the accident site. Figure 9 presents the GOES-16 infrared imagery from 1152 MDT 4X magnification with the accident site highlighted with a red square. Inspection of the infrared imagery also indicated brightness temperatures consistent with no cloud cover over the accident site. The lower brightness temperatures (bright yellow and green colors; higher cloud tops) were located to the west of the accident site over the Rocky Mountains. Wave-like cloud features and drier air were noted west of the accident site in the low-level water vapor imagery between 0917 and 1317 MDT (attachment 2). It should be noted these figures have not been corrected for any parallax error.

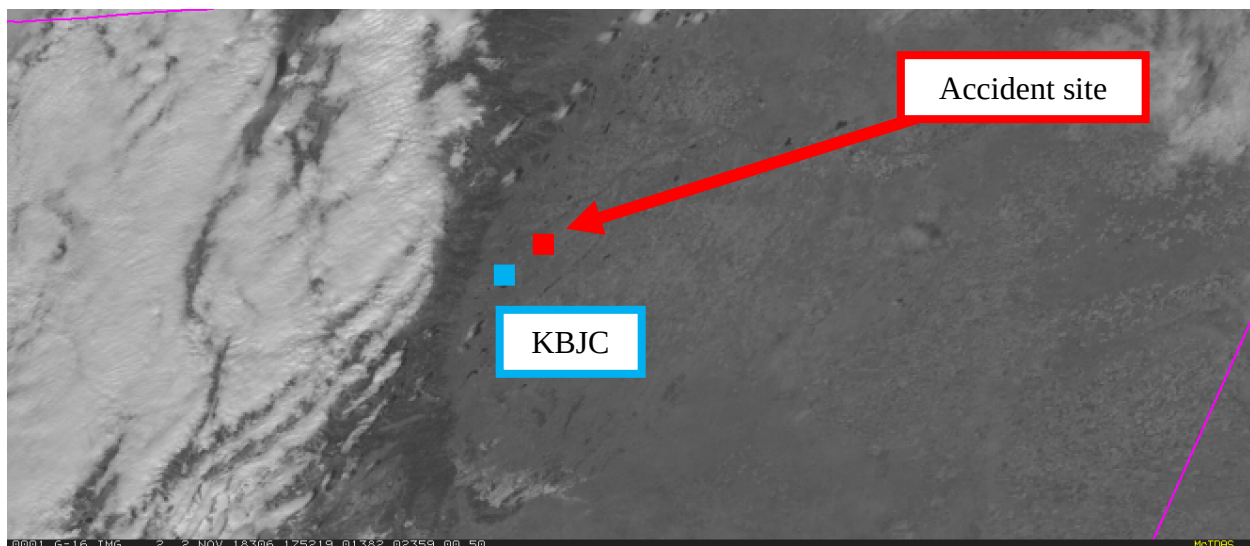


Figure 8 – GOES-16 visible image at 1152 MDT

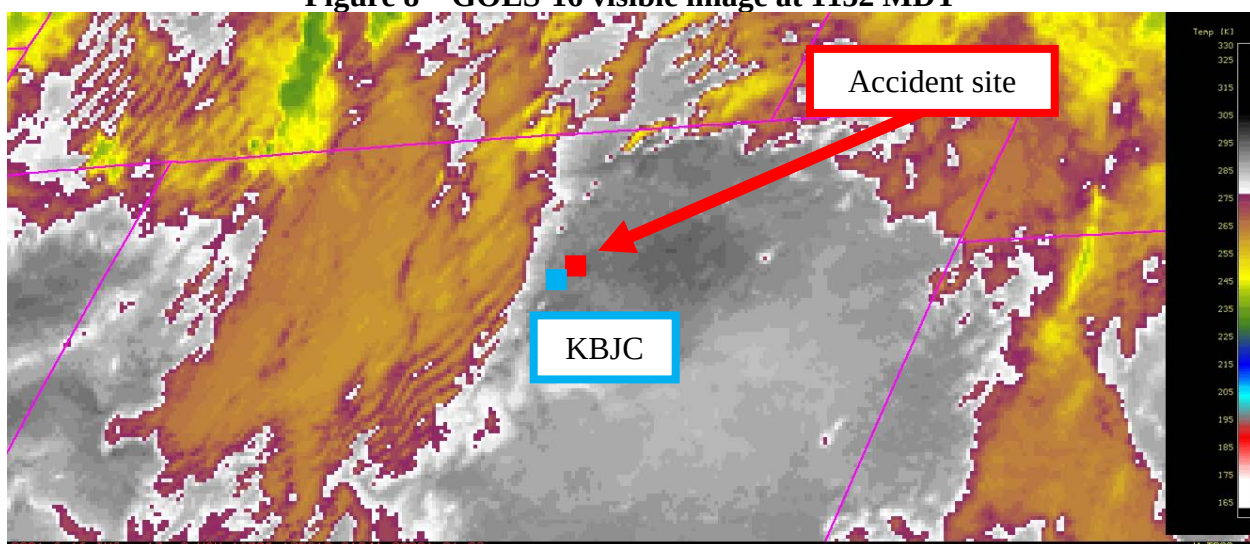


Figure 9 – GOES-16 infrared image at 1152 MDT

7.0 Pilot Reports¹⁶

All pilot reports (PIREPs) within 80 miles of the accident site from about four hours prior to the accident time to about two hours after the accident time were reviewed. Only PIREPs for below FL200¹⁷ are provided below:

BJC UUA /OV BJC22004/TM 1420/FL066/TP BE35/TB MOD-SEV

DEN UUA /OV BJC24005/TM 1430/FL067/TP BE33/TB SEVERE

DEN UA /OV DEN230040/TM 1440/FL135/TP C210/TB MOD/RM 135-125

BJC UA /OV BJC12005/TM 1458/FL64/TP BE20/TB LGT 064-080/RM WEST OF I-25 APA-BJC

MNH UA /OV APA180015/TM 1500/FL085/TP C172/SK SKC/WX FV50SM/TA 03/WV 27008KT/TB LGT

KAFF UA /OV KAFF/TM 1543/FL080/TP TG16/TB MOD

AKO UA /OV AKO225007/TM 1552/FL070/TP C172/SK SCT-BKN110/WX FV10SM/TA 04/WV 27015KT/TB NEG/IC NEG/RM SMOOTH

BJC UA /OV FA R30R/TM 1609/FL062/TP C172/TB LGT-MOD

KAFF UA /OV KAFF270005/TM 1610/FL080-100/TP TG16/TB MOD

ARP UAL2385 3948N 10439W 1616 F090 TB CONT LGT TURB RM B739 OV DEN 090-140 EMMYS6

FTG UA /OV FTG045010/TM 1621/FL065/TP C172/WX FV99SM/TB NEG

DEN UA /OV DEN220040/TM 1652/FL170/TP B737/TB MOD DURGD 230-170

DEN UA /OV DEN220040/TM 1855/FL180/TP B737/TB MOD/RM FL180-140

DEN UA /OV DEN200044/TM 1900/FL170/TP C525/TB MOD

KAFF UA /OV KAFF/TM 1907/FL066-095/TP TG16/TB LGT OCNL MOD/RM WEST PATTERN

FTG UA /OV FTG045010 /TM 1926 /FL060 /TP C172 /WV 27030KT /TB LGT /RM WV 27020G30

DEN UA /OV DEN230045/TM 1930/FLDURD/TP B757/TB MOD TURB 170-140

The decoded PIREPs in plain language from standard code and abbreviation were as follows:

Urgent pilot report (UUA), BJC¹⁸; Over – 4 miles from BJC or Jeffco VOR/DME on the 220° radial; Time – 0820 MDT (1420Z); Altitude – 6,600 ft; Type aircraft – Beechcraft 35 Bonanza; Turbulence – Moderate to severe.

¹⁶ Only pilot reports distributed into the National Airspace (NAS) with the World Meteorological Organization (WMO) headers UBCO**, UBWY**, UBKS**, and UBNE** identifier were considered.

¹⁷ 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.

¹⁸ Similar location as KBJC.

Urgent pilot report (UUA), Denver International Airport, Colorado (DEN); Over – 5 miles from BJC on the 240° radial; Time – 0830 MDT (1430Z); Altitude – 6,700 ft; Type aircraft – Beechcraft 33 Bonanza; Turbulence – Severe.

Routine pilot report (UA), DEN; Over – 40 miles from DEN VOR/DME on the 230° radial; Time – 0840 MDT (1440Z); Altitude – 13,500 ft; Type aircraft – Cessna 210; Turbulence – Moderate; Remarks – Between 13,500 and 12,500 ft.

Routine pilot report (UA), BJC; Over – 5 miles from BJC on the 120° radial; Time – 0858 MDT (1458Z); Altitude – 6,400 ft; Type aircraft – Beechcraft Super King Air; Turbulence – Light between 6,400 and 8,000 ft; Remarks – West of Interstate 25 between Centennial Airport, Colorado, (APA), and BJC.

Routine pilot report (UA), MNH; Over – 15 miles from APA on the 180° radial; Time – 0900 MDT (1500Z); Altitude – 8,500 ft; Type aircraft – Cessna 172; Sky – Clear skies; Weather – Forward visibility 50 statute miles; Temperature – 3° C; Wind – From 270° at 8 knots; Turbulence – Light.

Routine pilot report (UA), USAF Academy Airfield, Colorado, (AFF); Over – AFF; Time – 0943 MDT (1543Z); Altitude – 8,000 ft; Type aircraft – “TG16”; Turbulence – Moderate.

Routine pilot report (UA), Colorado Plains Regional Airport, Colorado, (AKO); Over – 7 miles from AKO on the 225° radial; Time – 0952 MDT (1552Z); Altitude – 7,000 ft; Type aircraft – Cessna 172; Sky – Scattered to broken clouds at 11,000 ft; Weather – Flight visibility 10 statute miles; Temperature – 4° C; Wind – From 270° at 15 knots; Turbulence – Negative; Icing – Negative; Remarks – Smooth.

Routine pilot report (UA), BJC; Over – Final approach into runway 30R (BJC); Time – 1009 MDT (1609Z); Altitude – 6,200 ft; Type aircraft – Cessna 172; Turbulence – Light to moderate.

Routine pilot report (UA), AFF; Over – 5 miles from AFF on the 270° radial; Time – 1010 MDT (1610Z); Altitude – 8,000 ft to 10,000 ft; Type aircraft – “TG16”; Turbulence – Moderate.

Airplane pilot report (ARP) from United Airlines flight 2385 located at 39:48° N, 104:39° W; Time – 1016 MDT (1616Z); Altitude – 9,000 ft; Turbulence – Continuous light turbulence; Type aircraft – Boeing 737-900; Remarks – Over DEN between 9,000 and 14,000 ft on EMMYS6 departure.

Routine pilot report (UA), Front Range Airport, Colorado, (FTG); Over – 10 miles from FTG on the 045° radial; Time – 1021 MDT (1621Z); Altitude – 6,500 ft; Type aircraft – Cessna 172; Weather – Flight visibility unlimited; Turbulence – Negative.

Routine pilot report (UA), DEN; Over – 40 miles from DEN on the 220° radial; Time – 1052 MDT (1652Z); Altitude – 17,000 ft; Type aircraft – Boeing 737-700; Turbulence – Moderate during descent between FL230 and 17,000 ft.

Routine pilot report (UA), DEN; Over – 40 miles from DEN on the 220° radial; Time – 1255 MDT (1855Z); Altitude – FL180; Type aircraft – Boeing 737-700; Turbulence – Moderate; Remarks – Between FL180 and 14,000 ft.

Routine pilot report (UA), DEN; Over – 44 miles from DEN on the 200° radial; Time – 1300 MDT (1900Z); Altitude – 17,000 ft; Type aircraft – Cessna 525 Citation Jet; Turbulence – Moderate.

Routine pilot report (UA), AFF; Over – AFF; Time – 1307 MDT (1907Z); Altitude – 6,600 ft to 9,500 ft; Type aircraft – “TG16”; Turbulence – Light with occasional moderate; Remarks – In the west pattern.

Routine pilot report (UA), FTG; Over – 10 miles from FTG on the 045° radial; Time – 1326 MDT (1926Z); Altitude – 6,000 ft; Type aircraft – Cessna 172; Wind – From 270° at 30 knots; Turbulence – Light; Remarks – Wind from 270° at 20 knots with gusts to 30 knots.

Routine pilot report (UA), DEN; Over – 45 miles from DEN on the 230° radial; Time – 1330 MDT (1930Z); Altitude – During descent; Type aircraft – Boeing 757; Turbulence – Moderate turbulence between 17,000 and 14,000 ft.

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

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

10.0 AIRMETs

There were Airmen’s Meteorological Information (AIRMET) advisories Tango and Zulu that were valid for the accident site at the accident time. The 0845 MDT AIRMETs warned of moderate turbulence conditions below FL180, LLWS conditions, and warned of moderate icing conditions between the freezing level¹⁹ and FL220:

WAUS45 KKCI 021445

WA5T

-SLCT WA 021445

AIRMET TANGO UPDT 3 FOR TURB STG WNDG AND LLWS VALID UNTIL 022100

.

AIRMET TURB...ID MT WA OR AND CSTL WTRS

FROM 50ESE YXC TO 40NW DNJ TO BOI TO 60S BOI TO 20SW REO TO

30SSE LKV TO OED TO 70WNW OED TO 30NNW HQM TO 40NNW TOU TO 20NNE

¹⁹ Freezing level between the 2,000 ft and 10,000 ft.

HUH TO 50ESE YXC
MOD TURB BLW 120. CONDS CONTG BYD 21Z THRU 03Z.

.
AIRMET TURB...MT
FROM 30SSE YQL TO 50NNW GGW TO 60NE MLS TO 70ESE MLS TO 70SSE
MLS TO 30SSE YQL
MOD TURB BLW 080. CONDS CONTG BYD 21Z THRU 03Z.

.
AIRMET TURB...ID MT WY UT CO NM
FROM 50ESE YXC TO 30SSE YQL TO 70SSE MLS TO 60WNW BFF TO 40SE
TBE TO 40SSE CIM TO 60SSW HBU TO 30E JNC TO 40NNW HVE TO 30SSE
TWF TO 60S BOI TO BOI TO 40NW DNJ TO 50ESE YXC
MOD TURB BLW FL180. CONDS CONTG BYD 21Z THRU 03Z.

.
AIRMET TURB...ID MT WY NV UT CO NM WA OR CA AND CSTL WTRS
FROM 50NNW ISN TO 70SW RAP TO BFF TO GLD TO 50W LBL TO 30ESE TBE
TO INK TO ELP TO 20SSW DMN TO 40ESE DVC TO 50SSW BVL TO 40E ENI
TO 150SW FOT TO 150WSW FOT TO 110WNW ONP TO 150W TOU TO 50NNW ISN
MOD TURB BTN FL180 AND FL430. CONDS CONTG BYD 21Z THRU 03Z.

.
AIRMET STG SFC WINDS...ID
FROM DBS TO 50ESE PIH TO 20WNW MLD TO 60NNE TWF TO DBS
SUSTAINED SURFACE WINDS GTR THAN 30KT EXP. CONDS DVLPG 18-21Z.
CONDS CONTG BYD 21Z ENDG 00-03Z.

.
AIRMET STG SFC WINDS...MT
FROM 20SE LWT TO 30SW BIL TO 80E DLN TO 40ESE HLN TO 20SE LWT
SUSTAINED SURFACE WINDS GTR THAN 30KT EXP. CONDS DVLPG 18-21Z.
CONDS CONTG BYD 21Z ENDG 00-03Z.

.
AIRMET STG SFC WINDS...WY
FROM 40SE BOY TO 70SE DDY TO 20SSW CYS TO 50SSW OCS TO 40SE BPI
TO 60S BOY TO 40SE BOY
SUSTAINED SURFACE WINDS GTR THAN 30KT EXP. CONDS CONTG BYD 21Z
THRU 03Z.

.
LLWS POTENTIAL...WY CO
BOUNDED BY 70SW RAP-30WSW AKO-PUB-20E HBU-40SSE LAR-40SSE DDY-
70SW RAP
LLWS EXP. CONDS ENDG 15-18Z.

.
LLWS POTENTIAL...ID MT WY
BOUNDED BY 60SE YXH-40SW DDY-30SE BPI-40ENE MLD-40ENE DBS-20NW
DBS-LKT-50NE DNJ-20SSE MLP-50SE YXC-60SE YXH
LLWS EXP. CONDS CONTG BYD 21Z THRU 03Z.

.
OTLK VALID 2100-0300Z...TURB ID MT WY NV UT CO NM
BOUNDED BY 20SSE YQL-50SW HVR-50S MLS-30E CYS-40SW LAA-70SSE TBE-
50NNW CME-60E TCS-60WSW ALS-20ENE DVC-40E BCE-20ENE BTY-60SE FMG-
40ESE BOI-40NW DNJ-60SSE MLP-40SE YXC-20SSE YQL
MOD TURB BLW FL180. CONDS CONTG THRU 03Z.

....

WAUS45 KPCI 021445
WA5Z
-SLCZ WA 021445

AIRMET ZULU UPDT 2 FOR ICE AND FRZLVL VALID UNTIL 022100

.
AIRMET ICE...ID MT WY NV UT CO WA OR
FROM 90E YDC TO 30SSE YQL TO 70SSW LWT TO 20SW BOY TO 20W OCS TO
40E MTU TO 50ESE SLC TO 20SW PIH TO 50N BAM TO 20SE LKV TO 20W
OED TO 30SW EUG TO 50SSE EPH TO 90E YDC
MOD ICE BTN FRZLVL AND FL200. FRZLVL 060-110. CONDS CONTG BYD 21Z
ENDG 21-00Z.

.
AIRMET ICE...MT WY UT CO
FROM 30SSE YQL TO 30NNE HVR TO 70SW RAP TO BFF TO GLD TO 60S GLD
TO 40ENE PUB TO 40SSW DEN TO 40SSE HBU TO 30NE DVC TO 20WNW JNC
TO 20WSW OCS TO 20WSW BOY TO 30SSE YQL
MOD ICE BTN FRZLVL AND FL220. FRZLVL 020-100. CONDS CONTG BYD 21Z
THRU 03Z.

.
AIRMET ICE...ID MT WY
FROM 40NNE HVR TO 50NNW ISN TO 60NNW BFF TO 40NNE HVR
MOD ICE BTN FRZLVL AND FL200. FRZLVL SFC-060. CONDS CONTG BYD 21Z
THRU 03Z.

.
OTLK VALID 2100-0300Z
AREA 1...ICE ID MT WY
BOUNDED BY 50WSW YXC-50NNW ISN-70SW RAP-30NNE DBS-90SSE GEG-50WSW
YXC
MOD ICE BTN FRZLVL AND FL200. FRZLVL SFC-060. CONDS CONTG THRU
03Z.

.
AREA 2...ICE ID MT WY NV UT CO
BOUNDED BY 80SSE GEG-40SSE DLN-70SW RAP-BFF-GLD-40ENE LAA-30ESE
HBU-60S HBU-50W JNC-30ESE DTA-60ESE REO-50SW DNJ-80SSE GEG
MOD ICE BTN FRZLVL AND FL220. FRZLVL 020-100. CONDS CONTG THRU
03Z.

.
FRZLVL...RANGING FROM SFC-155 ACRS AREA
MULT FRZLVL 120-140 BOUNDED BY 70ENE TCS-70E ELP-ELP-20NW TCS-
70ENE TCS
MULT FRZLVL 080-110 BOUNDED BY 20NNW GTF-20SW LWT-30NNW JAC-
30ESE BOI-20ESE DNJ-LKT-60N LKT-20NNW GTF
MULT FRZLVL 040-090 BOUNDED BY 30NNE HVR-50NNE GGW-70SSW ISN-
70SW RAP-BFF-20NW GLD-50SE DEN-30NNE HVR
040 ALG 70S YYN-60ESE MLS-80SW DIK
080 ALG 30ESE BKE-20W LKT-40SSE GTF-30SW LWT-50ESE BIL-50NE
PUB-40E LAA
120 ALG 90SSE LKV-70S BAM-60SW DTA-20WSW ABQ-60SSE ABQ-60E ELP

....

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 VFR conditions with a west wind of 10 knots with gusts to 15 knots. The GFA cloud forecast products indicated clear skies east of the Rocky Mountains (including the accident site) with AIRMET Zulu valid for the accident time. For more information please see attachment 3.

The GFA forecast products use two different weather models and are computed automatically. The Rapid Refresh (RAP) weather model is used for the cloud forecast and the Localized Aviation MOS²⁰ Program (LAMP) weather model is used for the surface forecast charts, and both forecasts are issued with no human intervention. The only human-generated information reflected in the two GFA products are the AIRMETs. The GFA is “human-over-the-loop.”

12.0 Terminal Aerodrome Forecast

KBJC was the closest site with a NWS Terminal Aerodrome Forecast (TAF). The KBJC TAF valid at the accident time was the TAF issued at 0521 MDT and was valid for a 24-hour period beginning at 0600 MDT. The 0521 MDT TAF for KBJC was as follows:

```
TAF KBJC 021121Z 0212/0312 VRB05KT P6SM SCT100
FM021400 24006KT P6SM SCT150
FM021700 29015G25KT P6SM SCT200
FM022000 29024G36KT P6SM SCT080 SCT150
FM030100 26015KT P6SM SCT100 BKN150
FM030400 25012KT P6SM SCT060 BKN100
PROB30 0304/0308 -SHRA BKN060=
```

Between 1100 and 1400 MDT, the TAF expected a wind from 290° at 15 knots with gusts to 25 knots, greater than 6 miles visibility, and scattered clouds at 20,000 ft agl.

13.0 NWS Area Forecast Discussion

The NWS Office in Boulder, Colorado, issued the following Area Forecast Discussion (AFD) at 0933 MDT (closest AFD to the accident time with an aviation section). The aviation section of the AFD discussed an increase in wind speed to between 15 and 20 knots with gusts around 30 knots through the afternoon:

FXUS65 KBOU 021533
AFDBOU

Area Forecast Discussion
National Weather Service Denver/Boulder CO
933 AM MDT Fri Nov 2 2018

.UPDATE...
Issued at 934 AM MDT Fri Nov 2 2018

Shallow moisture trapped in the mountains is keeping some light snow in place. However, moisture is quite shallow so there has also been some drizzle in lower elevations and even a bit of freezing drizzle across a few of the mountain passes per latest CDOT cams. Road temperatures will be warming this afternoon so impacts from the freezing drizzle should be minimized through most of the afternoon.

²⁰ Model Output Statistics: https://www.weather.govmdl/mos_home

Otherwise, our focus will remain on the next round of heavier snow reaching the mountains this evening. We still expect a sharp increase in snow intensity by 5-6 PM in the Rabbit Ears Pass area and 8-10 PM along the I-70 Mountain Corridor. This rapid increase can be expected with the onset of cold advection and arrival of the left exit region of the upper level jet. A quick burst of 1-2 inch per hour snowfall possible, followed by lighter snow overnight into Saturday. The forecast for the snow and winds is on track. Main message is to complete I-70 Mountain Corridor travel by early this evening as travel conditions through the Colorado high country will deteriorate quickly from north to south this evening. Forecast confidence is high.

&&

.SHORT TERM...(Today and tonight)
Issued at 149 AM MDT Fri Nov 2 2018

For today, NW flow aloft will gradually increase thru the aftn with varying amounts of moisture embedded in the flow. Overall warm air advection is still shown thru much of the day so despite favorable orographics believe snow amounts will stay on the light side in the mtns. Meanwhile, sfc low pres will intensify from sern WY into ern CO thru the day which will lead to a decent low lvl pres gradient by aftn. As a result will see gusty winds eventually spread from the higher terrain across the plains by early aftn. As for temps, with downslope winds in place, this will lead to even warmer highs across nern CO with readings generally in the lower to mid 60s. Finally can't completely rule out a few aftn showers near the WY-NE border area due to favorable lapse rates.

By tonight an upper level trough embedded in the NW flow aloft will track across the area. As this feature moves across expect increasing snow in the mtns as cold air advection occurs along with increasing instability. In addition there will be a good shot of mid level qg ascent and nrn CO will be in the favored left front quadrant of an upper level jet. Meanwhile gusty winds will produce widespread blowing snow over the higher passes.

Across nern CO as the main part of the upper level trough passes over there will be a good chc of showers over the plains. Closer to the foothills with downslope northwest low lvl flow this will probably limit shower development. However, a band of showers will probably come off the higher terrain associated with the upper level jet around midnight. At this point not exactly sure where this band will be but latest data suggests it would end up over srm areas of the front range urban corridor. Meanwhile with increasing flow aloft expect mixing from higher based showers will continue to produce gusty winds over the foothills and plains overnight. A few gusts in the foothills may reach the 60 to 70 mph range but for the most part winds should stay below high wind criteria.

.LONG TERM...(Saturday through Thursday)

Issued at 149 AM MDT Fri Nov 2 2018

Colorado will remain under a persistent and strong northwest flow aloft through next week. The main impacts will be snow and windy conditions in the mountains, especially Saturday morning and again late Sunday and into Monday. Across lower elevations, generally dry and mild but potential for strong winds on Saturday and again on Monday afternoon along with a chance of showers.

On Saturday, exiting upper level disturbance into Kansas with increasing QG descent over northern Colorado. Moisture depth will be decreasing during the day in the mountains with still some light accumulations, mainly in the morning. Local snow model yielding an additional 1-4 inches of snow. Current winter weather advisory goes out through the day on Saturday but conditions should be improving during the afternoon. Across lower elevations main concern revolves around potential for strong winds on Saturday. Moderate QG decent and good mixing could see wind gusts up to 50 mph during the afternoon over the far plains. For now will not issue a high wind watch but speeds might be getting close. Have increased winds in this period for the upcoming forecast.

A brief respite in the weather for Saturday night and early Sunday with flat ridging and warm advection period with just some light scattered snow showers in the mountains. Next system will rapidly influence Northern Colorado weather late Sunday through Monday with another slug of moisture for the mountains. Will most likely see another potential for 6-12 inches in the mountains and locally higher amounts so winter weather advisories or low end warnings will probably be needed for this event as well. Will not issue anything for now as to not convolute the current advisories ongoing. Across lower elevations may also see scattered rain and snow showers develop on the plains as well due to decent QG upward ascent through Monday morning.

A bit drier for Tuesday and Wednesday but there will be enough moisture in the northwest flow for continued slight chance of snow showers. Temperatures on the plains will continue at just below seasonal normals for this time of year.

&&

.AVIATION...(For the 18Z TAFS through 18Z Saturday afternoon)
Issued at 934 AM MDT Fri Nov 2 2018

Winds will become more west/northwest toward 18Z and increase with speeds of 15-20 knots with gusts around 30 knots through 01Z. Then winds should subside by early evening. However, as some high based showers move off the higher terrain decent mixing could lead to sporadic gusty west to southwest winds 04Z-08Z. As far as ceilings they may drop down to 8000-10000 feet tonight as higher based showers move across.

On Saturday, gusty north winds will develop with speeds at KDEN increasing to 20-25 knots with gusts around 35 knots.

&&

.BOU WATCHES/WARNINGS/ADVISORIES...
Winter Weather Advisory from 6 PM this evening to 6 PM MDT
Saturday for COZ031-033-034.

&&

\$\$

14.0 Winds and Temperature Aloft Forecast

The NWS 0757 MDT Winds and Temperature Aloft forecast valid for the closest point to the accident site is included below:

```
FBUS31 KWN0 021357
FD1US1
DATA BASED ON 021200Z
VALID 021800Z    FOR USE 1400-2100Z. TEMPS NEG ABV 24000

FT  3000    6000    9000    12000    18000    24000    30000    34000    39000
DEN                                3139+05 3227-02 3345-15 3252-25 315438 339548 329857
```

The accident site was closest to the DEN forecast point. The DEN forecast valid for 1200 MDT and for use between 0800 and 1500 MDT indicated a wind at 9,000 ft from 310° at 39 knots with a temperature of 5° C, a wind at 12,000 ft from 320° at 27 knots with a temperature of -2° C, and a wind at 18,000 ft from 330° at 45 knots with a temperature of -15° C.

15.0 Pilot Weather Briefing

The accident pilot did not request a weather briefing through Leidos.

A search of archived ForeFlight information indicated that the accident pilot did not review or request any weather information from ForeFlight. It is unknown if the accident pilot checked or received additional weather information before or during the accident flight. Please see attachment 14 for more information regarding what the accident pilot typically checked for aviation weather information.

16.0 Mountain Waves and Hazardous Mountain Winds

In FAA Advisory Circular (AC) 00-6B²¹ published on August 23, 2016, section 17.2.2.1 describes mountain wave conditions and the associated aviation hazards therein (figure 11). Additional information on the hazardous weather and wind conditions in mountainous terrain is published in the FAA's Advisory Circular 00-57 (AC-00-57)²² published on September 10, 1997.

²¹

https://www.faa.gov/documentLibrary/media/Advisory_Circular/AC_00-6B.pdf

²²

https://www.faa.gov/documentLibrary/media/Advisory_Circular/00-57.pdf

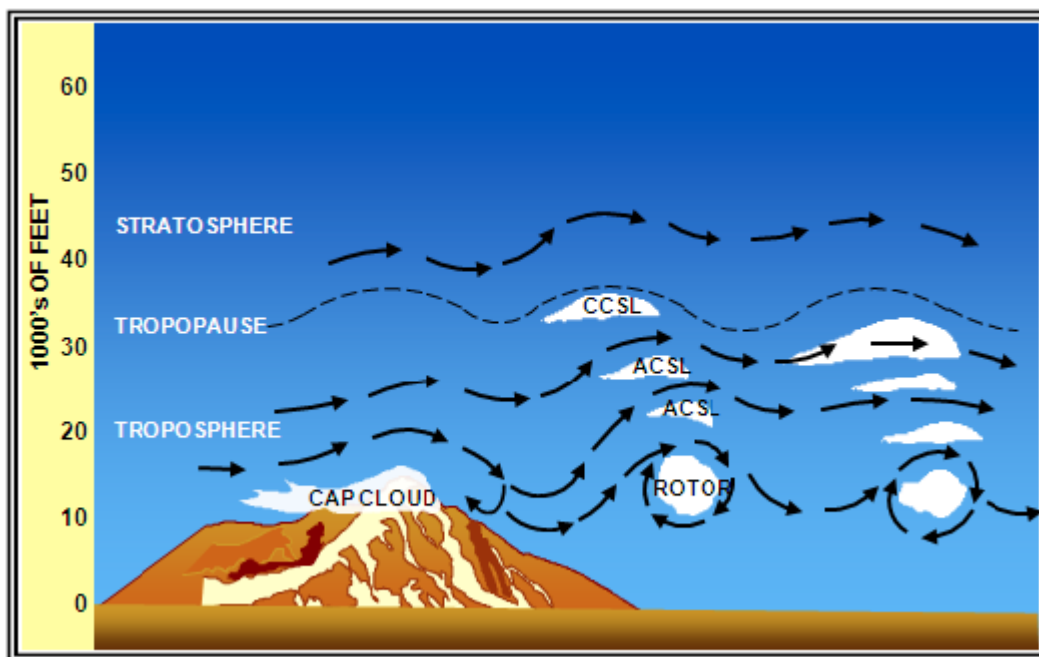


Figure 11 – AC 00-06B mountain wave conditions

17.0 Weather Research and Forecasting Model Simulation

A Weather Research and Forecasting Model (WRF) simulation was run to simulate the weather conditions surrounding the time of the accident. WRF ARW (Advanced Research WRF core) version 3.2.1.5 was run with 3 domains with horizontal grid spacing of 8 km, 1.6 km, and 320 m over the accident site. Other WRF simulation parameters included: 60 vertical levels, the Kain-Fritsch cumulus parameterization scheme used on the outer domain, a Lin et al. microphysics scheme, a Yonsei University boundary layer scheme, Noah land surface physics, and the Dudhia scheme used for the long and short wave radiation. The terrain (in ft) used in domain 2 and domain 3 are shown in figures 12 and 13 along with the location of the cross sections used figures 20 and 21 (along with attachments 10 through 12) with the location of the accident site marked.

Figures 14 through 18 depicted the winds²³ at 840 hPa (approximately 5,100 ft) in knots at 1100, 1130, and 1200 MDT for domains 2 and 3. The winds near the accident site (upper right hand black dot) changed from a south to southeast wind between 4 to 8 knots at 1100 and 1130 MDT (figures 14, 15, 17, and 18) to a west wind between 20 to 25 knots at 1200 MDT (figures 16 and 19). Attachments 4 and 5 show the wind speed rapidly increasing near the surface at BJC around 1030 to 1040 MDT and the wind speed rapidly increasing at the accident site right around the accident time (1140 to 1200 MDT). Above 7,000 ft, the wind speed remained above 20 knots at both BJC and the accident site as early as 0400 MDT (attachments 5 through 10)²⁴ with the wind

²³ All wind magnitudes are in knots and are sustained wind speeds.

²⁴ The approximate altitudes of the pressure levels for this dataset were 830-hPa around 5,350 ft, 820-hPa around 5,650 ft, 810-hPa around 6,000 ft, 800-hPa around 6,500 ft, 780-hPa, around 7,000 ft, and 750-hPa around 8,000 ft.

speed increasing to between 30 and 50 knots at 7,000 ft by 1020 MDT above BJC and by 1100 MDT above the accident site (attachments 5 through 10).

Figure 19 depicted the potential temperature²⁵ in degrees Kelvin (solid lines) and the vertical velocity (color fill) in ft per minute (fpm) at 1150 MDT along a west-to-east cross-section. The vertical velocity data indicated that before the encounter with terrain the accident flight was in an area of downdrafts with a magnitude between 200 and 1,000 fpm and updrafts between 300 and 1,500 fpm (attachments 10 and 12) at 1150 MDT with the downdrafts and updrafts increasing in magnitude between 1030 and 1230 MDT.

Figure 20 depicted the potential temperature (solid lines) and the horizontal wind speed in knots (color fill) at 1150 MDT along a west-to-east cross-section. The horizontal wind data indicated that before the encounter with terrain the accident flight was in an area horizontal wind magnitudes between 20 and 30 knots (attachments 10 and 11) at 1150 MDT. The wind magnitude increased from below 10 knots before 1130 MDT to above 20 knots by 1140 MDT.

An upper air sounding was made for the accident site and BJC from the WRF simulation (domain 3 dataset) and the upper air soundings indicated an inversion²⁶ was in place above the accident site until 0900 MDT and in place above BJC until 1030 MDT (attachment 10). An additional inversion was in place between the surface and 7,000 ft above the accident site between 1030 and 1130 MDT.

²⁵ Potential temperature of a parcel of fluid at pressure P is the temperature that the parcel would acquire if adiabatically brought to a standard reference pressure P_0 , usually 1000 hPa.

²⁶ Inversion – An increase of temperature with height.

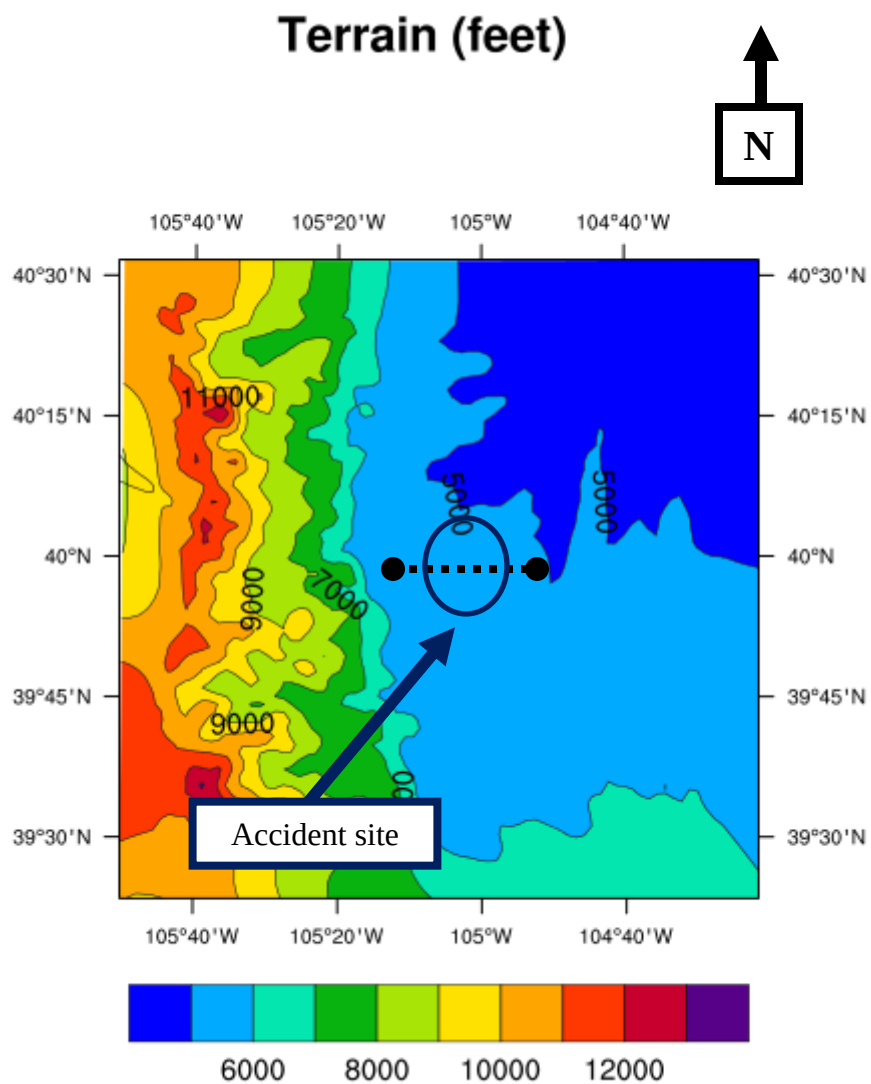


Figure 12 – WRF simulation terrain for domain 2 in ft with the accident site marked and the locations of the cross sections (black dashed lines)

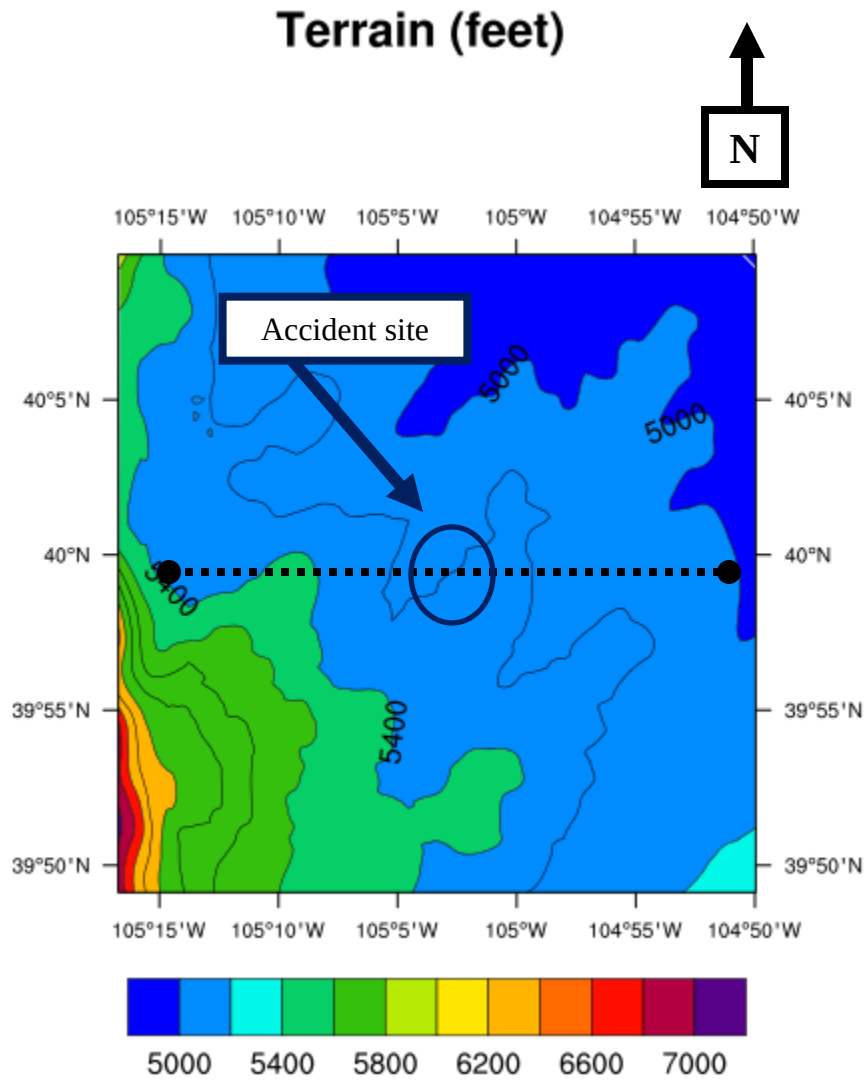


Figure 13 – WRF simulation terrain for domain 3 in ft with the accident site marked and the locations of the cross sections (black dashed lines)

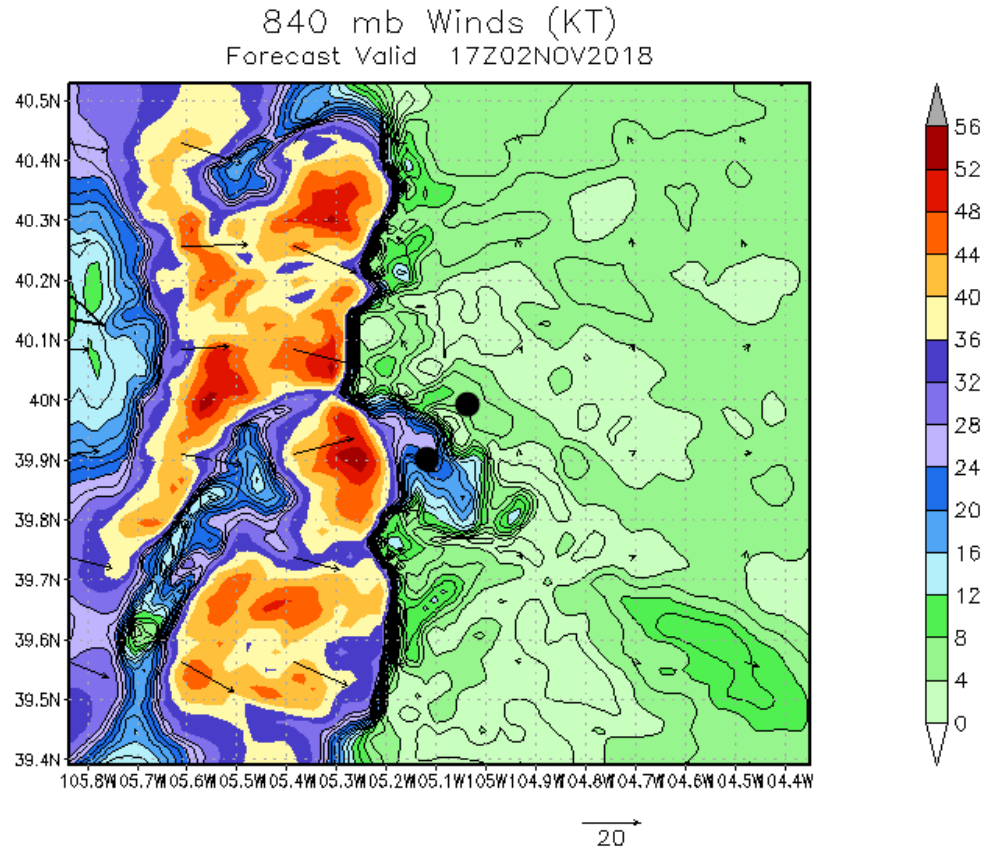


Figure 14 – WRF domain 2 wind in knots at 840 hPa from 1100 MDT with the approximate accident site marked (upper right black dot) and location of BJC (lower left black dot)

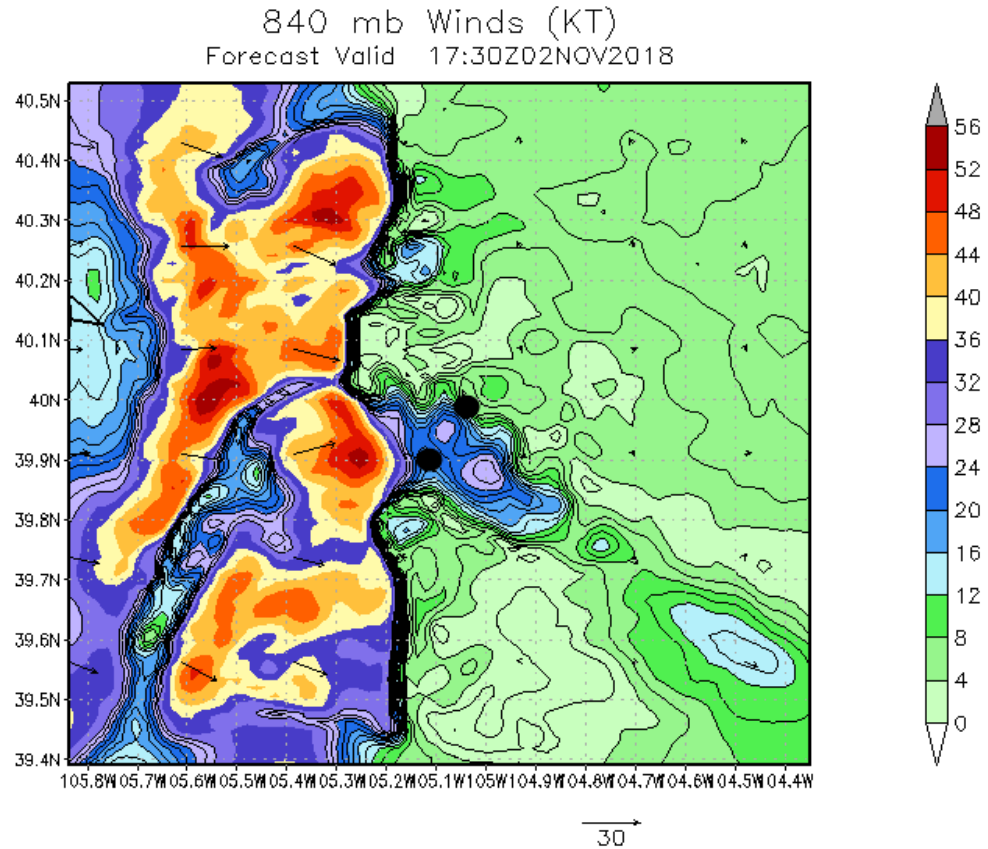


Figure 15 – WRF domain 2 wind in knots at 840 hPa from 1130 MDT with the approximate accident site marked (upper right black dot) and location of BJC (lower left black dot)

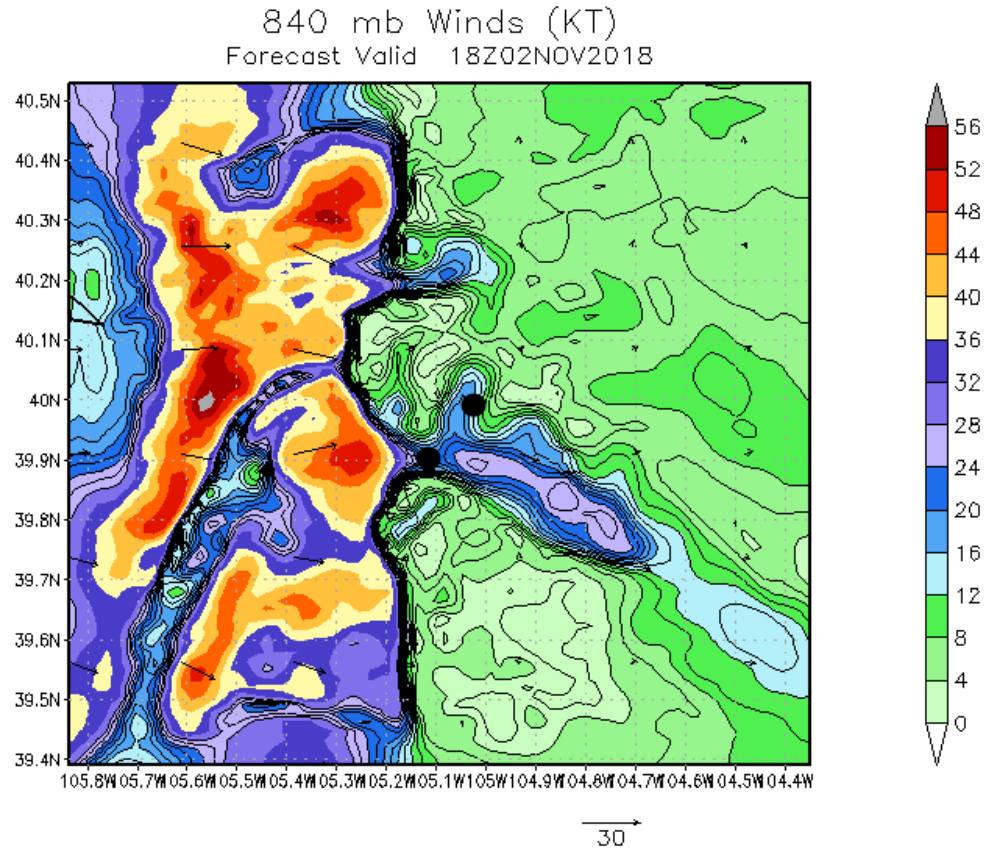


Figure 16 – WRF domain 2 wind in knots at 840 hPa from 1200 MDT with the approximate accident site marked (upper right black dot) and location of BJC (lower left black dot)

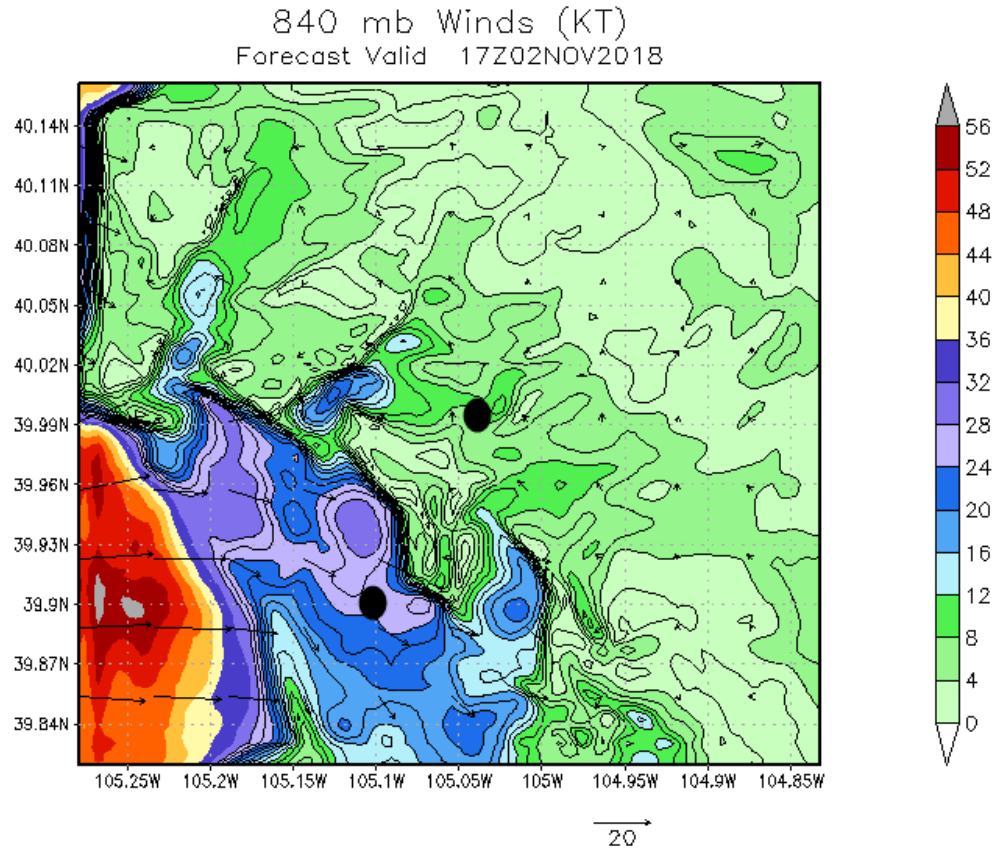


Figure 17 – WRF domain 3 wind in knots at 840 hPa from 1100 MDT with the approximate accident site marked (upper right black dot) and location of BJC (lower left black dot)

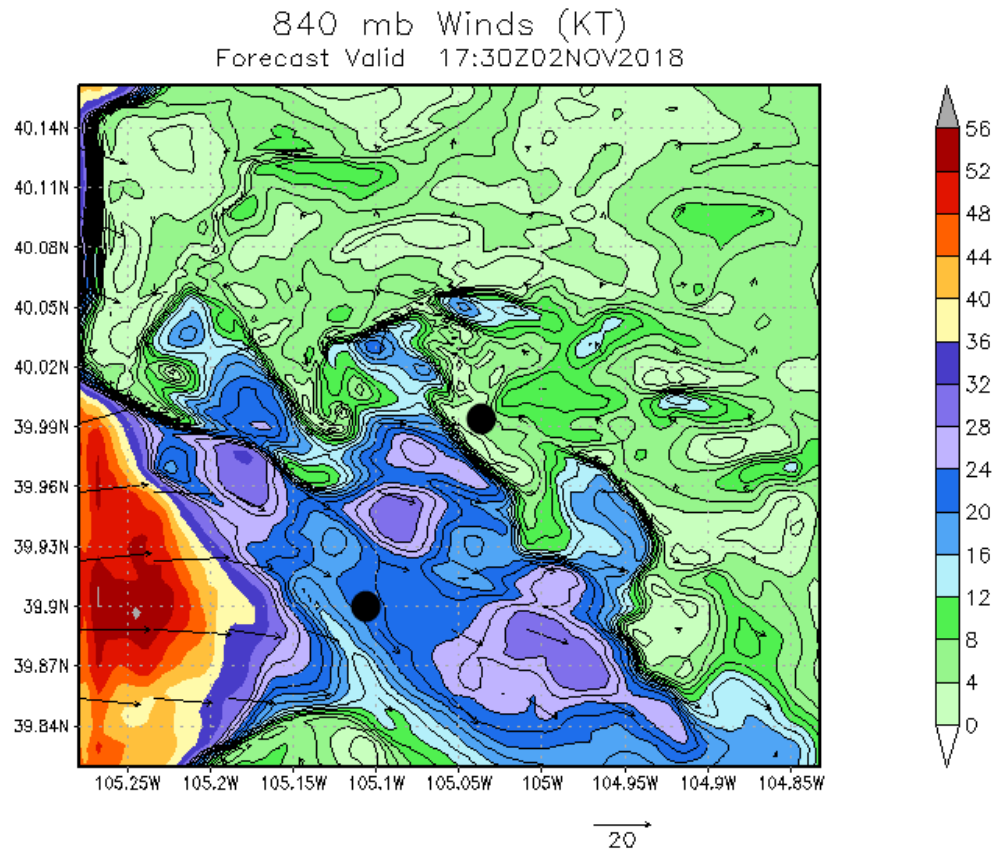


Figure 18 – WRF domain 3 wind in knots at 840 hPa from 1130 MDT with the approximate accident site marked (upper right black dot) and approximate location of BJC (lower left black dot)

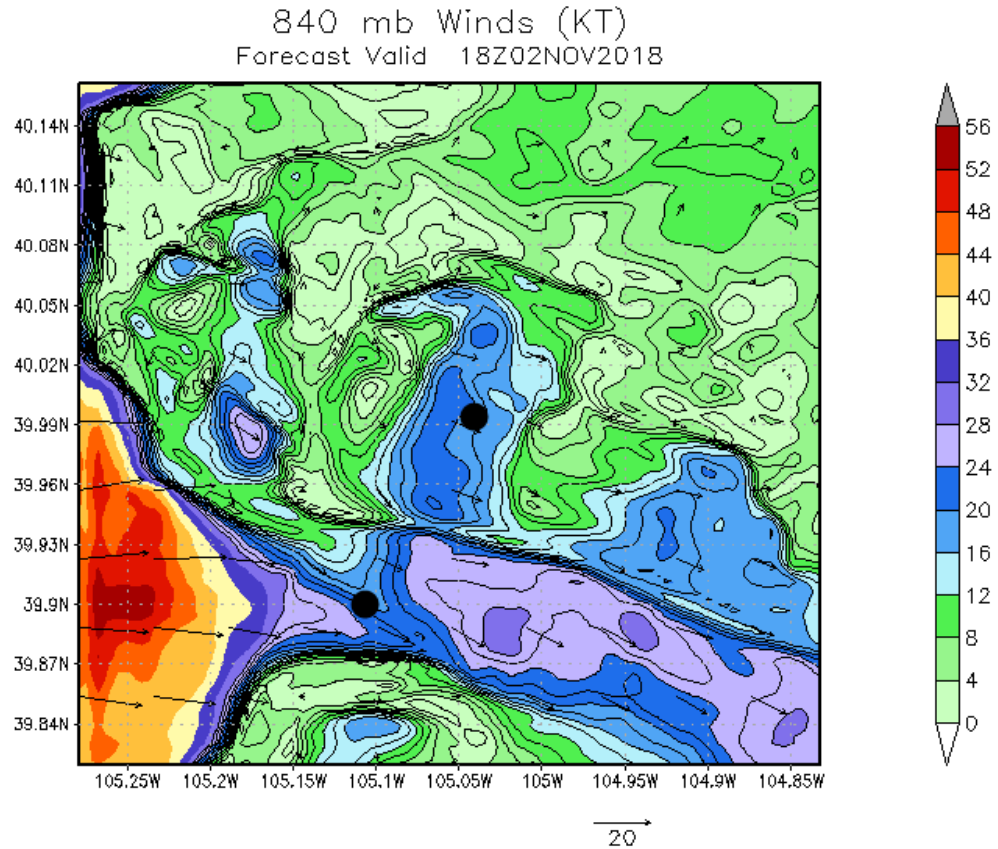


Figure 19 – WRF domain 3 wind in knots at 840 hPa from 1200 MDT with the approximate accident site marked (upper right black dot) and location of BJC (lower left black dot)

W

Vertical Velocity 2018-11-02_17:50:00

E

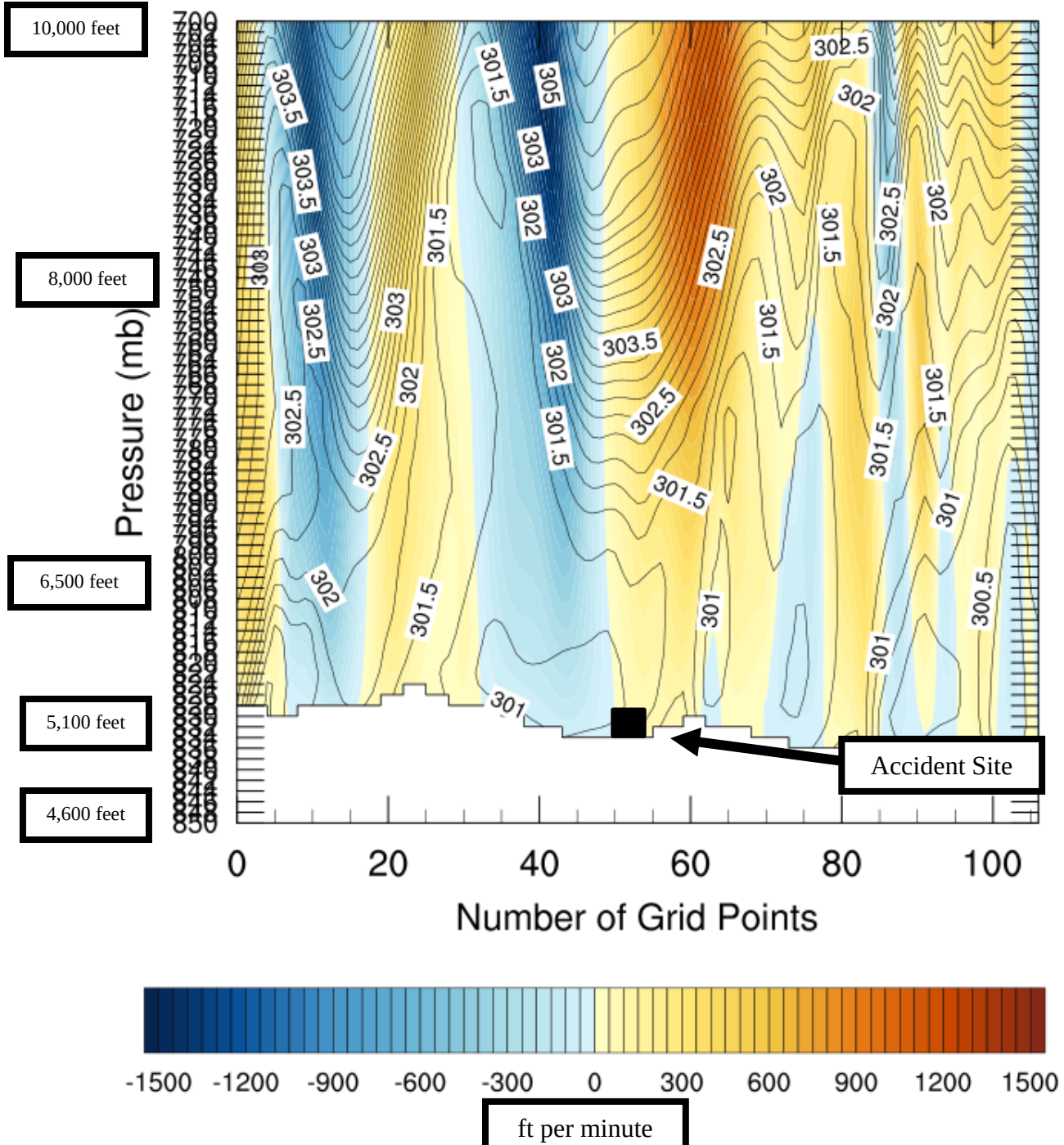


Figure 20 – WRF cross section from 1150 MDT of vertical velocity in fpm (color fill) and potential temperature in kelvin (black lines) from west to east across the terrain with the approximate accident site marked

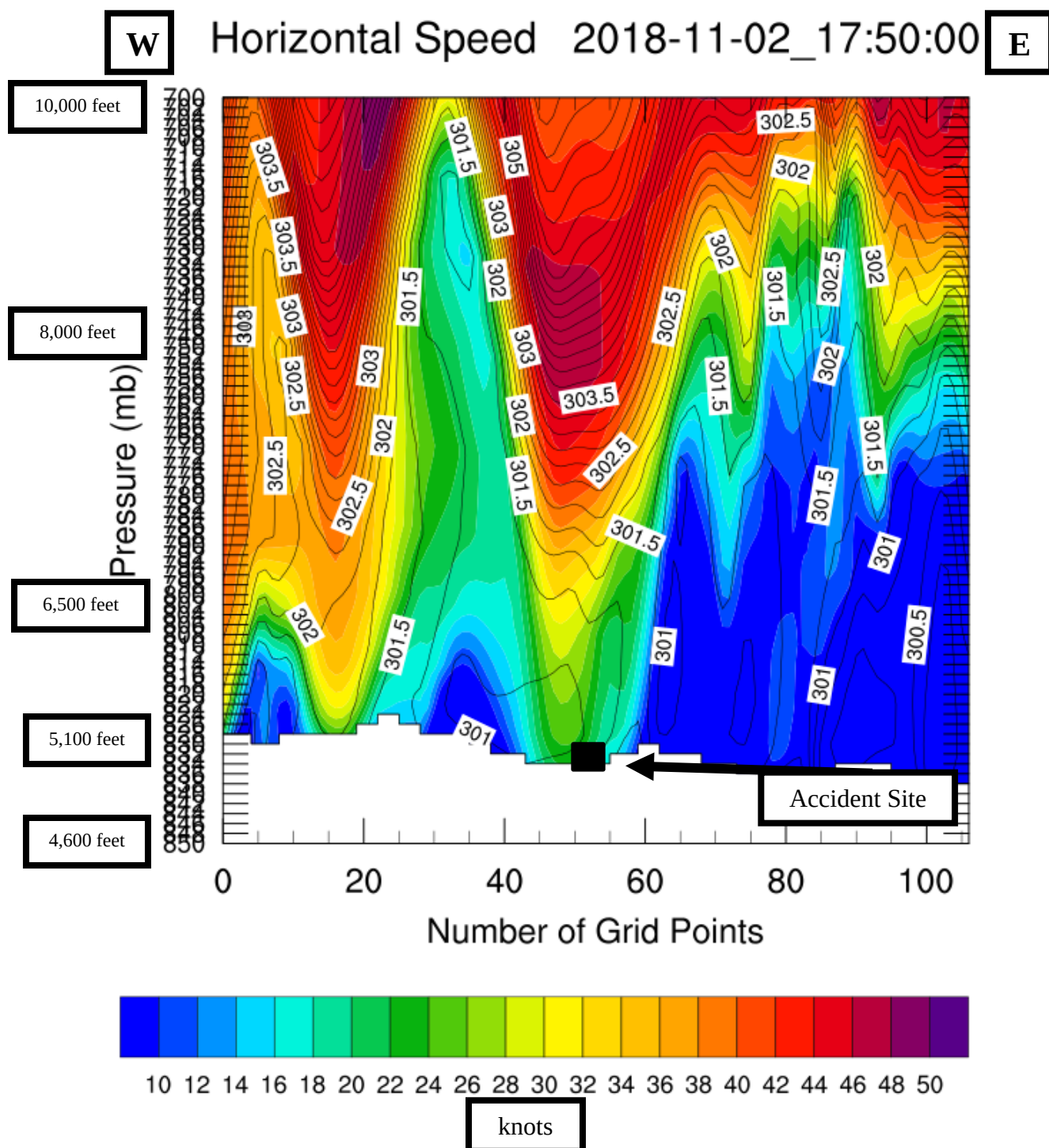


Figure 21 – WRF cross section from 1150 MDT of horizontal wind speed in knots (color fill) and potential temperature in kelvin (black lines) from west to east across the terrain with the approximate accident site marked

18.0 Graphic Turbulence Guidance

The NWS Aviation Weather Center (AWC) provided the Graphical Turbulence Guidance

(GTG) products that were available before the accident flight departed and would have been available as a supplemental turbulence forecast for the accident pilot.²⁷ The AWC GTG clear air and mountain wave turbulence forecast both indicated moderate or greater turbulence east of the mountainous terrain in Colorado and over the accident site from 0900 MDT through 1500 MDT between 5,000 and 10,000 ft (figures 22, 23, and attachment 13). For more information and images please see attachment 13.

GTG Clear Air Turbulence at FL070

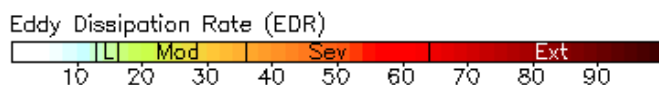
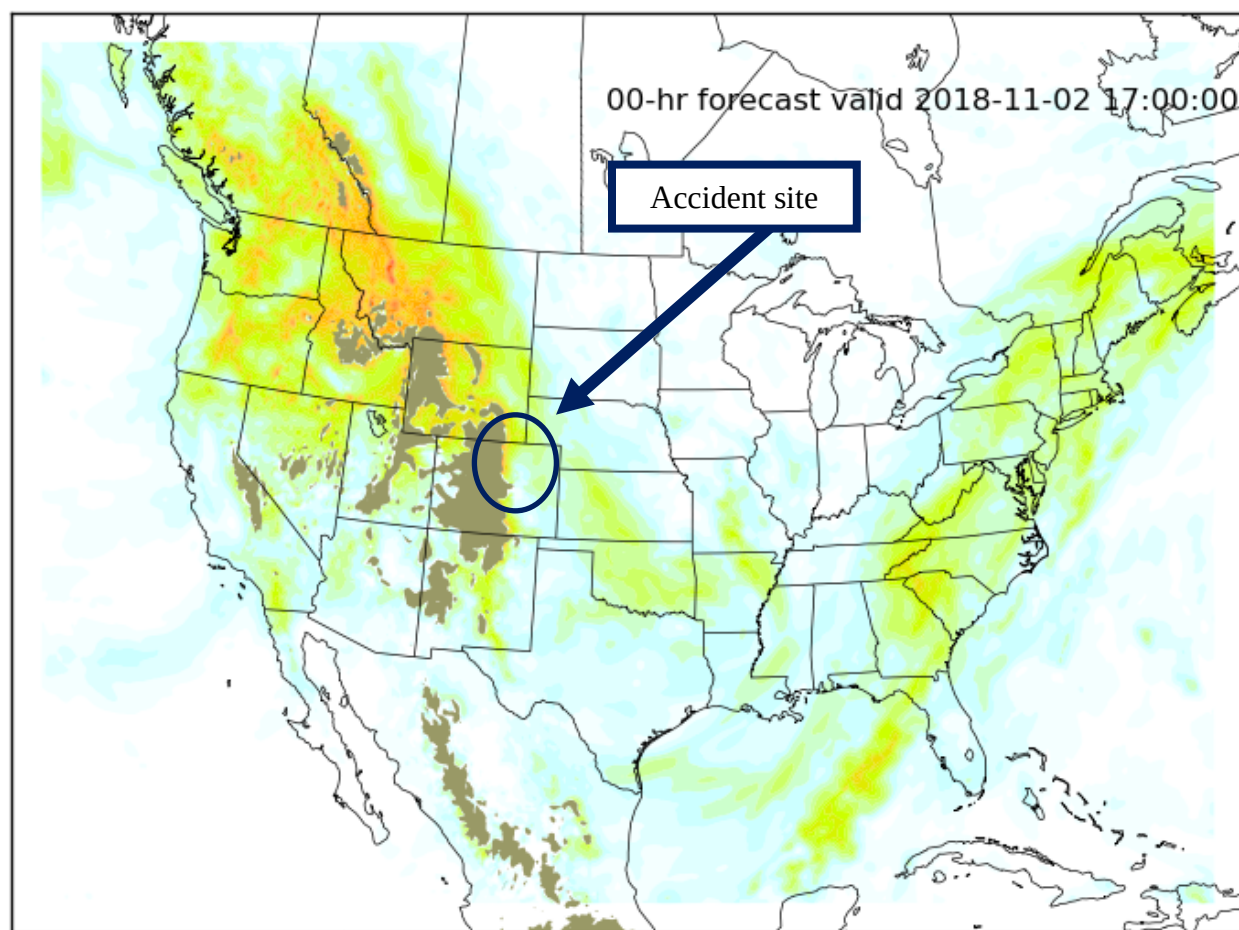


Figure 22 – GTG clear air turbulence forecast from 1100 MDT valid at 1100 MDT for 7,000 ft

²⁷ <https://aviationweather.gov/turbulence/gtg>

GTG Mountain Wave Turbulence at FL070

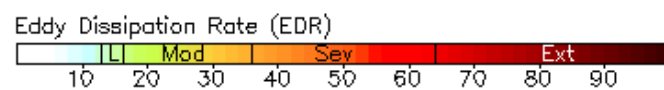
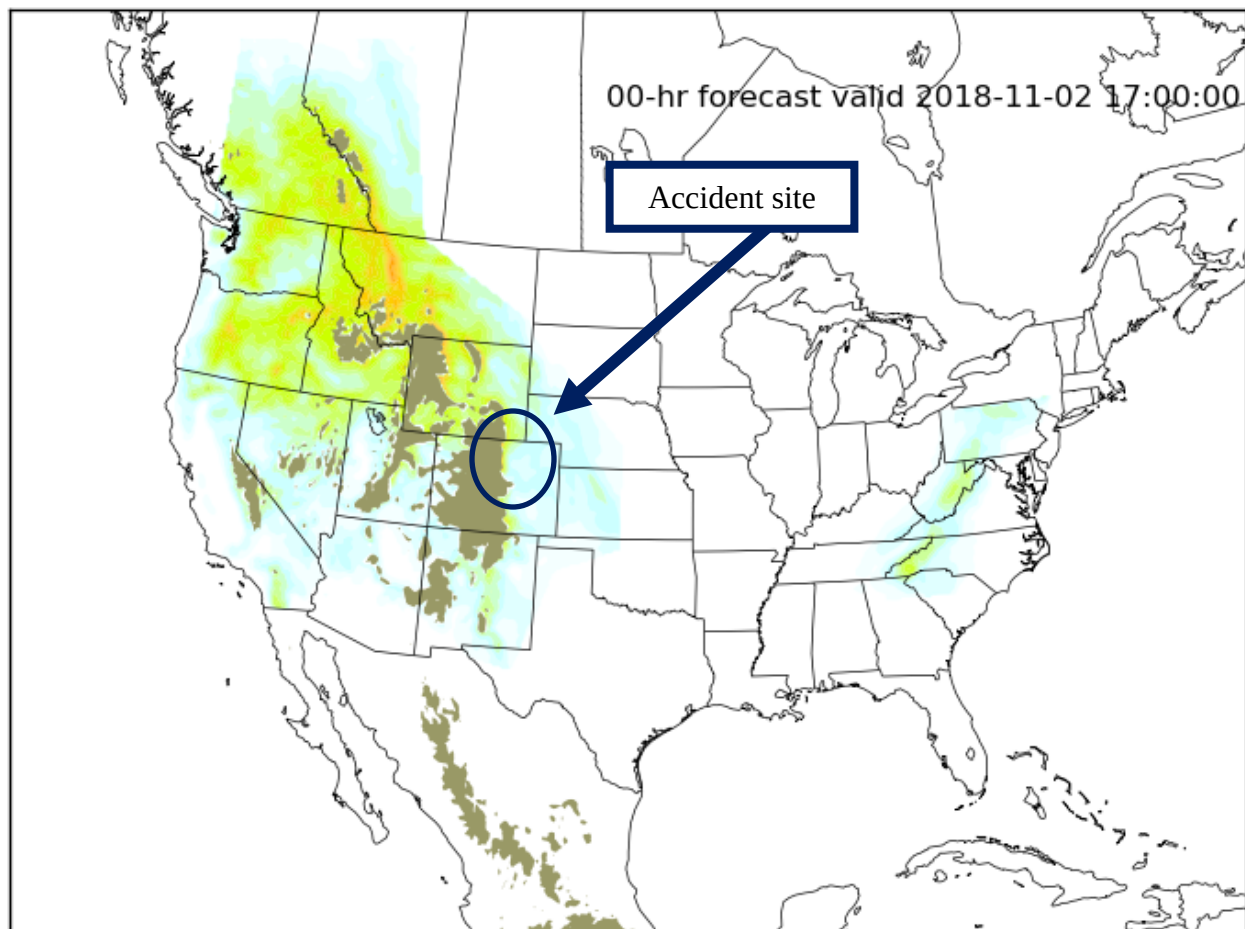


Figure 23 – GTG mountain wave turbulence forecast from 1100 MDT valid at 1100 MDT for 7,000 ft

19.0 Astronomical Data

The astronomical data obtained from the United States Naval Observatory for the accident site on November 2, 2018, indicated the following:

SUN	
Begin civil twilight	0702 MDT
Sunrise	0731 MDT
Accident	1151 MDT²⁸
Sun transit	1244 MDT
Sunset	1757 MDT
End civil twilight	1825 MDT

E. LIST OF ATTACHMENTS

Attachment 1 – GOES-16 visible imagery animation from 0907 to 1307 MDT

Attachment 2 – GOES-16 low-level water vapor imagery animation from 0917 to 1317 MDT

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

Attachment 4 – WRF domain 2 wind at 840-hPa animation from 0230 to 1500 MDT

Attachment 5 – WRF domain 3 wind at 840-hPa animation from 0000 to 1500 MDT

Attachment 6 – WRF domain 2 wind at 810-hPa animation from 0230 to 1500 MDT

Attachment 7 – WRF domain 3 wind at 810-hPa animation from 0000 to 1500 MDT

Attachment 8 – WRF domain 2 wind at 780-hPa animation from 0230 to 1500 MDT

Attachment 9 – WRF domain 3 wind at 780-hPa animation from 0000 to 1500 MDT

Attachment 10 – Additional WRF imagery and animations from 0000 through 1500 MDT

Attachment 11 – WRF cross section from 1030 MDT to 1230 MDT of horizontal wind speed in knots (color fill) and potential temperature in kelvin (black lines)

Attachment 12 – WRF cross section from 1030 MDT to 1230 MDT of vertical velocity in fpm (color fill) and potential temperature in kelvin (black lines)

Attachment 13 – NWS AWC GTG forecast and images from 0900 MDT through 1500 MDT for 5,000 through 10,000 ft

²⁸ Inserted accident time for reference and context.

Attachment 14 – Witness information regarding accident pilot's aviation weather sources

Submitted by:

Paul Suffern
Senior Meteorologist

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