



National Transportation Safety Board

Office of Aviation Safety
Washington, D.C. 20594-2000
June 9, 2009

METEOROLOGY FACTUAL REPORT

WPR09MA159

A. ACCIDENT

Location: Butte, Montana
Date: March 22, 2009
Time: 1430 Mountain Daylight Time (2030 UTC¹)
Aircraft: Pilatus PC-12/45; registration: N128CM

B. METEOROLOGICAL SPECIALIST

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C. SUMMARY

On March 22, 2009, at 1430 mountain daylight time, a Pilatus PC-12/45, N128CM, descended to ground impact near the approach end of runway 33 at the Bert Mooney Airport, Butte, Montana. The airplane was owned and operated by Eagle Capital Leasing, of Enterprise, Oregon, as a personal transportation flight under the provisions of 14 Code of Federal Regulations Part 91. The airplane was destroyed in the collision sequence and post crash fire. All 14 persons onboard the airplane were killed in the accident and there were no reported ground injuries. The flight departed Oroville, California, at 1210 Pacific daylight time on an instrument flight rules (IFR) flight plan and clearance destined for Gallatin Field, Bozeman, Montana. The airplane was diverting to Butte at the time of the accident. Visual meteorological conditions prevailed at both the Bozeman and Butte airports.

¹ UTC – is an abbreviation for Coordinated Universal Time.

C. DETAILS OF INVESTIGATION

The National Transportation Safety Board's (NTSB) meteorologist specialist was not on scene for this investigation and gathered all the weather data for this investigation from the Washington D.C. office from official National Weather Service (NWS) sources including the National Climatic Data Center (NCDC). All times used in this report are based upon the 24 hour clock. Local time of mountain daylight time (MDT) is +6 hours to Coordinated Universal Time (UTC), and UTC=Z. 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.

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 (NCEP) located in Camp Springs, Maryland. These are the base products used in describing weather features and in the creation of forecasts and warnings. Reference to these charts and other aviation weather products can be found in the joint NWS and Federal Aviation Administration (FAA) Advisory Circular "Aviation Weather Services", AC 00-45.

1.0.1 Surface Analysis Chart

The NWS Surface Analysis Chart for 1500 MDT (2100Z) is included as figure 1 with the approximate location of the accident site enclosed in a red circle. The chart depicted the conditions prior to the accident. The chart depicted two low pressure systems with a central pressure of 993-hectopascals (hPa) over northern Wyoming associated with and along a cold front that extended across western Wyoming and then southwestward into Utah. Another low pressure system at 995-hPa was located just off the eastern side of the map over northeastern Montana with a cold front extending south-southwest over the eastern portion of the Montana and then westward and northwestward across the state and became stationary over Alberta, Canada. This cold front was approaching the Butte and Bozeman area from the north and the main influence to the weather in the region of the accident site.

The station model for Butte, Montana, indicated winds from the northwest at 10 knots, broken sky conditions, temperature of 44° Fahrenheit (F), dew point 26° F, and a sea level pressure of 1000.9-hPa.

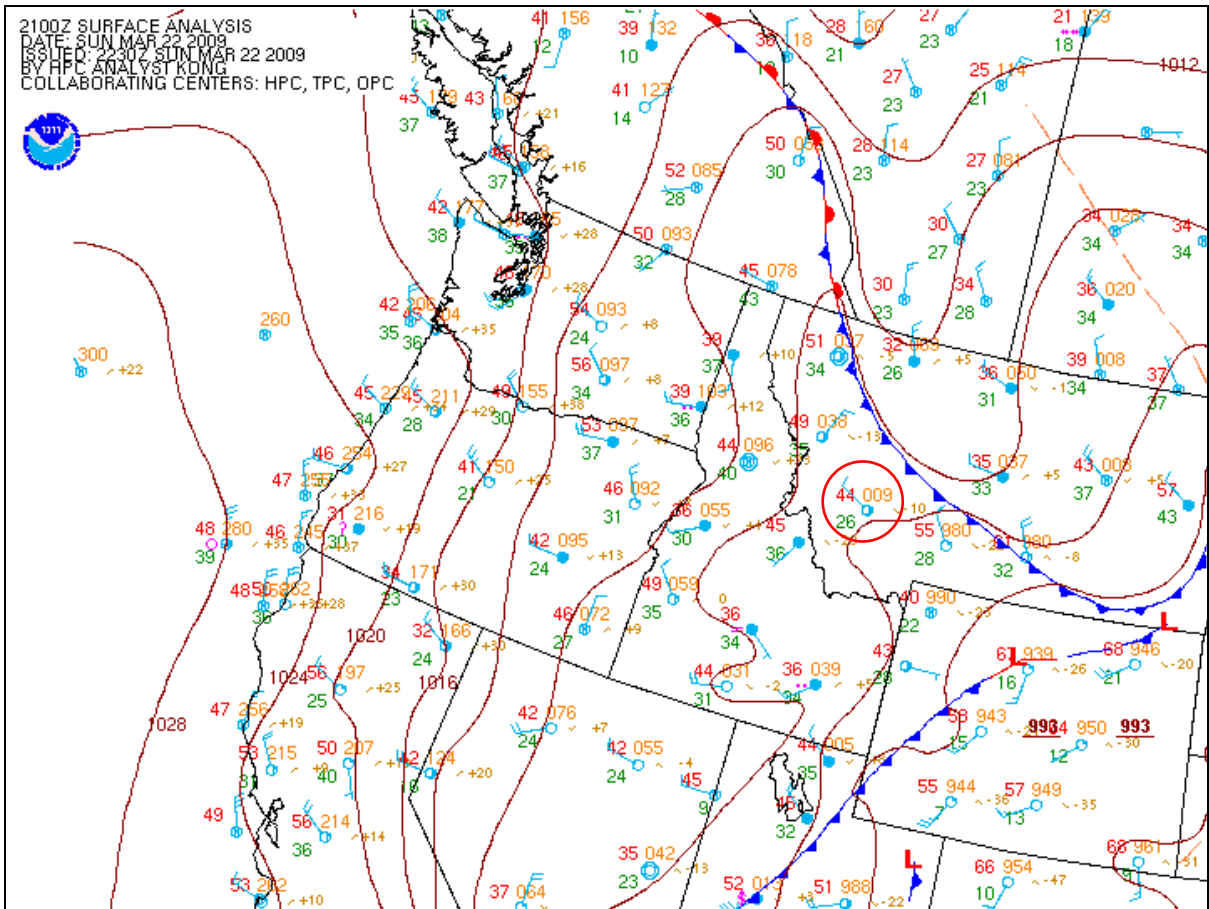


Figure 1 – NWS Surface Analysis Chart for 1500 MDT

1.0.2 Weather Depiction Chart

The NWS Weather Depiction Charts for 1300 and 1600 MDT are included as figure 2A and 2B respectively. The chart depicted an area of instrument flight rule (IFR) conditions² over northern and southern Idaho, western and central Montana, and Alberta and Saskatchewan, Canada, by a shaded contour line. Surrounding that area was an area of marginal visual flight rules (MVFR) conditions³ indicated by an unshaded contour. Visual flight rule (VFR) conditions⁴ were depicted over southern Montana and the accident site at 1300 MDT without any contour. On the 1600 MDT chart MVFR conditions were reported in the Dillon area with visibility 4 miles in light continuous snow, and an overcast ceiling at

² IFR conditions – are defined as a ceiling or lowest layer of clouds reported as broken or overcast, or the vertical visibility into a surface based obscuration of less than 1,000 feet above ground level (agl) and/or visibility less than 3 statute miles.

³ MVFR conditions – are defined as a ceiling between 1,000 and 3,000 feet agl inclusive and/or visibility 3 to 5 miles inclusive.

⁴ VFR conditions – are defined as no ceiling or a ceiling greater than 3,000 feet agl and visibility greater than 5 miles.

1,700 feet agl. Along the route of flight across Idaho and extreme southwest Montana, the charts depicted an area of IFR to MVFR conditions due to low overcast ceilings and visibility in snow and rain.

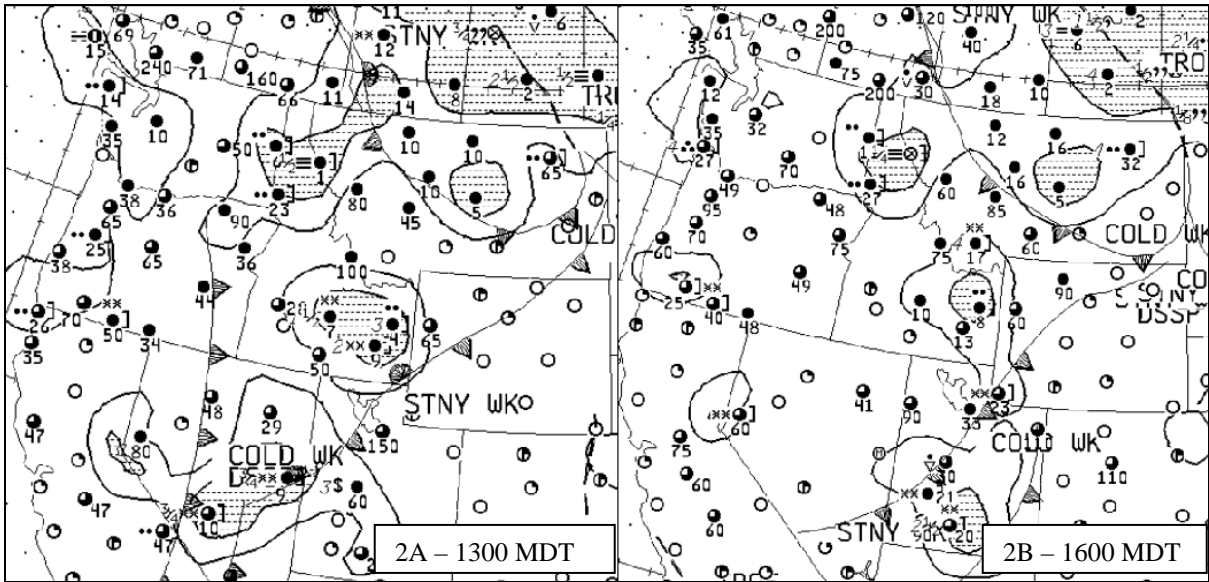


Figure 2 – NWS Weather Depiction Charts for 1300 and 1600 MDT

1.0.3 Upper Air Analysis

The NWS Constant Pressure Chart for 700- and 500-hPa is included as figures 3A and 3B respectively for 1800 MDT (0000Z March 23, 2009), depicting conditions at approximately 10,000 and 18,000 feet. The 700-hPa chart (3A) depicted an upper level low pressure system over Idaho with a trough of low pressure extending south-southwestward into southern California. At 500-hPa the low was located over western Oregon.

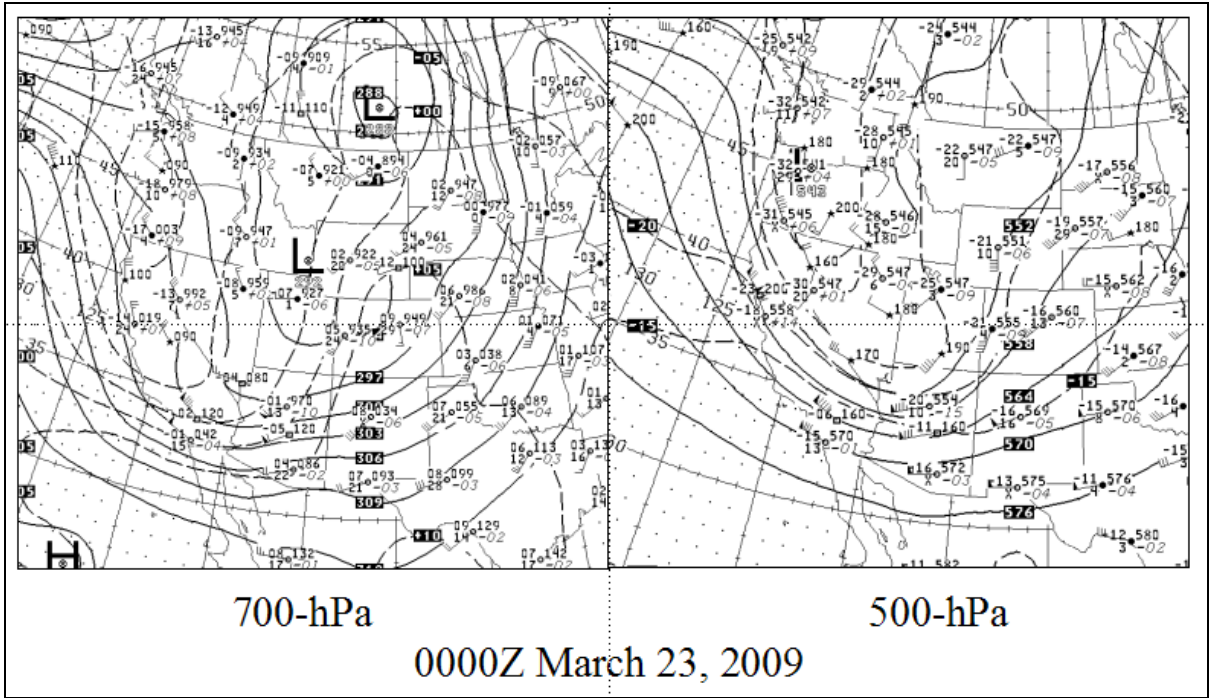


Figure 3 – NWS 700- and 500-hPa Constant Pressure Chart for 1800 MDT

1.0.4 NWS Low-level Significant Weather Prognostic Chart

The NWS 12-hour Low-level Significant Weather Prognostic Chart current at the time of the accident is included as figure 4. The chart was issued at approximately 1120 MDT (1720Z) and was valid for 1800 MDT (0000Z). The chart depicted a 994-hPa low pressure system over Wyoming to the southeast of the accident site, with an occluded front extending south-southwestward to another low pressure system at 995-hPa over eastern Utah with a cold front continuing south-southwestward into Arizona. Another low pressure system at 999-hPa was located over Canada with an occluded front extending south-southeastward into North Dakota to the triple point where the front split into a stationary front to the southeast and a cold front to the west-southwest dipping into Wyoming and then northwestward into Montana to the east of the accident site.

Along the route of flight an area of light continuous snow and snow showers was expected across the eastern portions of northern California, Nevada, Idaho, and Montana.

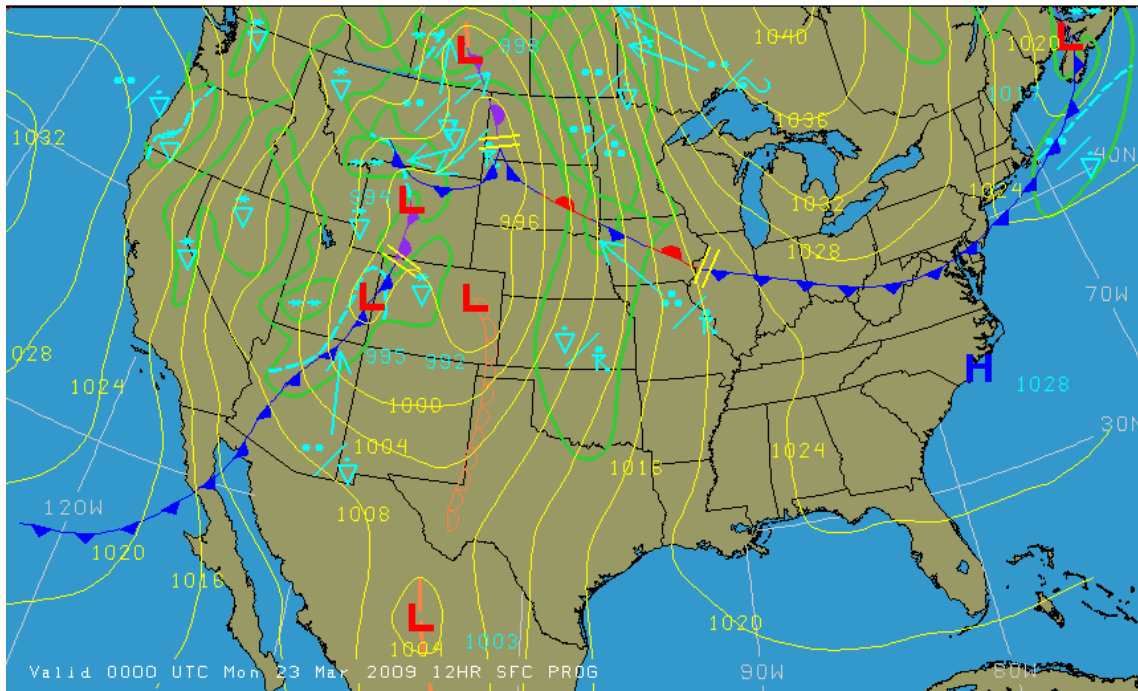


Figure 4 – Significant Weather Prognostic Chart for 1800 MDT

2.0 Surface Observations

The surrounding area was documented utilizing official NWS Meteorological Aerodrome Reports (METARs) and Specials (SPECIs). The following observations are taken from standard code provided in plain language, with cloud heights reported in agl.

2.0.1 Bert Mooney Airport (KBTM), Butte, Montana

The Bert Mooney Airport (KBTM) at an elevation of 5,550 feet msl had an Automated Weather Observation System (AWOS-3) installed and reported the following conditions surrounding the period:

KBTM weather observation at 1353 MDT (1953Z), automated observation, wind from 320° at 10 knots, visibility 10 miles, a few clouds at 4,400 feet, ceiling⁵ overcast at 8,000 feet, temperature 7° Celsius (C), dew point temperature -3° C, altimeter setting 29.57 inches of Mercury (Hg). Remarks: automated observation system, sea level pressure 1001.2-hPa, temperature 6.7° C, dew point -2.8° C.

⁵ Ceiling – is defined as the lowest layer of clouds reported as broken or overcast, or the vertical visibility into a surface based obscuration.

KBTM weather observation at 1453 MDT (2053Z), automated observation, wind from 300° at 8 knots, visibility 10 miles, ceiling broken at 6,500 feet, temperature 7° C, dew point temperature -3° C, altimeter setting 29.56 inches of Hg. Remarks: automated observation system, sea level pressure 1000.9-hPa, temperature 6.7° C, dew point -3.3° C, 3-hour pressure tendency fallen 1.0-hPa.

2.0.3 Gallatin Field Airport (KBZM), Bozeman, Montana

The planned destination was Gallatin Field Airport (KBZN), Bozeman, Montana, located approximately 57 miles east from the accident site at an elevation of 4,473 feet msl. The airport had a federally installed and maintained Automated Surface Observation System (ASOS), which reported the following conditions surrounding the period:

KBZN weather observation at 1356 MDT (1956Z), wind from 290° at 7 knots, wind 240° variable 320°, visibility 10 miles, sky clear below 12,000 feet, temperature 14° C, dew point -1° C, altimeter 29.54 inches of Hg. Remarks: automated observation system, sea level pressure 998.8-hPa, temperature 13.9° C, dew point -1.1° C.

KBZN weather observation at 1456 MDT (2056Z), wind from 350° at 8 knots, visibility 10 miles, ceiling broken at 5,500 feet, temperature 14° C, dew point -1° C, altimeter 29.52 inches of Hg. Remarks: automated observation system, sea level pressure 998.2-hPa, temperature 13.9° C, dew point -0.6° C, 3-hour pressure tendency fallen 2.2-hPa.

KBZN weather observation at 1556 MDT (2156Z), wind from 360° at 11 knots, visibility 10 miles, scattered clouds at 7,000 feet, temperature 13° C, dew point 0° C, altimeter 29.51 inches of Hg. Remarks: automated observation system, sea level pressure 998.0-hPa, temperature 13.3° C, dew point 0° C.

KBZN weather observation at 1656 MDT (2256Z), wind from 010° at 9 knots gusting to 19 knots, wind 320° variable 040°, visibility 10 miles in light rain, ceiling broken at 3,700 feet, overcast at 6,000 feet, temperature 12° C, dew point 0° C, altimeter 29.52 inches of Hg. Remarks: automated observation system, rain began at 52 minutes past the hour, sea level pressure 998.6-hPa, hourly precipitation less than 0.01 inches (trace), temperature 11.7° C, dew point 0° C.

KBZN special weather observation at 1749 MDT (2349Z), wind from 180° at 17 knots gusting to 29 knots, visibility 2 1/2 miles in moderate rain, a few clouds at 3,600 feet, ceiling broken at 4,700 feet, overcast at 6,000 feet, temperature 7° C, dew point 2° C, altimeter 29.60 inches of Hg. Remarks: automated observation system, peak wind from 160 at 29 knots occurred at 1745 MDT (2345Z), wind shift occurred at 1733 MDT (2333Z), rain ended at 1704 and began 1749 MDT, hourly precipitation 0.02 inches.

2.0.4 Dillon Airport (KDLN), Dillon, Montana

Dillon Airport (KDLN) was located approximately 43 miles south of the accident site and along the route of flight, at an elevation of 5,241 feet msl. The airport had an ASOS and reported the following conditions:

KDLN weather observation at 1353 MDT (1953Z), automated observation system, wind from 350° at 5 knots, visibility 10 miles, a few clouds at 6,000 feet, temperature 8° C, dew point -1° C, altimeter 29.53 inches of Hg. Remarks: automated observation system, sea level pressure 998.3-hPa, temperature 8.3° C, dew point -1.1° C.

KDLN weather observation at 1453 MDT (2053Z), automated observation system, wind from 230° at 15 knots, visibility 10 miles, scattered clouds at 4,100 feet, ceiling overcast at 5,000 feet, temperature 4° C, dew point 1° C, altimeter 29.52 inches of Hg. Remarks: automated observation system, wind shift occurred at 1436 MDT (2036Z), sea level pressure 998.9-hPa, hourly precipitation 0.01 inches, 6-hour precipitation 0.01 inches, temperature 4.4° C, dew point 0.6° C, 3-hour pressure tendency fallen 1.6-hPa.

KDLN weather observation at 1500 MDT (2100Z), automated observation system, wind from 230° at 16 knots, visibility 10 miles, ceiling broken at 4,300 feet, overcast at 5,000 feet, temperature 4° C, dew point 1° C, altimeter 29.52 inches of Hg. Remarks: automated observation system, wind shift occurred at 1440 MDT (2040Z).

KDLN weather observation at 1527 MDT (2127Z), automated observation system, wind from 200° at 10 knots, visibility 2 1/2 miles in heavy rain and mist, ceiling broken at 1,300 feet, overcast at 4,000 feet, temperature 2° C, dew point 0° C, altimeter 29.55 inches of Hg. Remarks: automated observation system, wind shift occurred at 1440 MDT (2040Z), rain began at 17 minutes after the hour, hourly precipitation 0.04 inches.

MVFR conditions with a mixture of rain, snow, and unknown precipitation continued to be reported through 1700 MDT (2300Z) at Dillon.

3.0 Upper Air Data

The closest upper air sounding or rawinsonde observation (RAOB) was from the NWS Great Falls (KTFX), Montana, site number 72776, located approximately 100 miles northeast of the accident site at an elevation of 3,707 feet msl. The 1800 MDT sounding on March 22, 2009, from KTFX plotted on a standard Skew-T log P diagram⁶ with the observed and derived stability parameters and is included as figure 5 from the surface to 350-hPa or 26,000 feet.

⁶ 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.

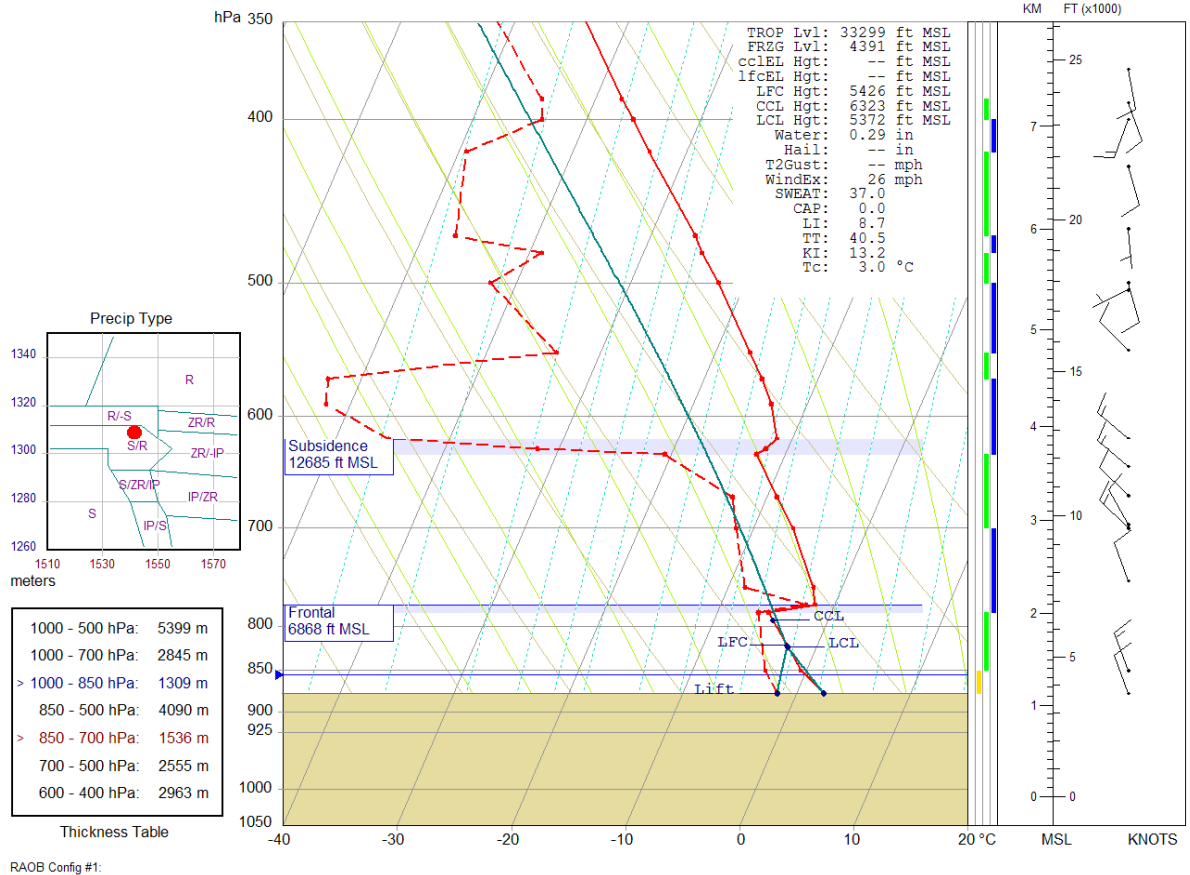


Figure 5 –KTFX sounding for 1800 MDT

The KTFX sounding depicted the freezing level or 0° C at 855-hPa or 684 feet agl (4,391 feet msl) with temperatures remaining freezing above this level. The significant levels on the sounding were a lifted condensation level (LCL)⁷ at 823-hPa or at 1,665 feet agl, a convective condensation level (CCL)⁸ at 794-hPa or 2,616 feet agl, and a level of free convection (LFC)⁹ at 821-hPa or 1,719 feet agl, with no defined equilibrium level (EL)¹⁰. A

⁷ Lifting Condensation Level (LCL) - The height at which a parcel of moist air becomes saturated when it is lifted dry adiabatically.

⁸ Convective Condensation Level (CCL) - The height to which a parcel of air, if heated sufficiently from below, will rise adiabatically until condensation starts. This is typically used to identify the base of cumuliform clouds, which are normally produced from surface heating and thermal convection.

⁹ 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.

¹⁰ Equilibrium Level (EL) - On a sounding, the level above the level of free convection (LFC) at which the temperature of a rising air parcel again equals the temperature of the environment. The height of the EL is the height at which thunderstorm updrafts no longer accelerate upward. Thus, to a close approximation, it represents the height of expected (or ongoing) thunderstorm tops. However, strong updrafts will continue to rise past the EL before stopping, resulting in storm tops that are higher than the EL. This process sometimes can be seen visually as an overshooting tops or anvil dome. The EL typically is higher than the tropopause, and is a more accurate reference for storm tops.

frontal inversion was identified at 777-hPa or 3,161 feet agl or 6,868 feet msl, with temperatures remaining below freezing in the layer. Another inversion associated with subsidence was identified at 619-hPa or 12,685 feet msl. The tropopause height was identified at 33,299 feet. With moisture profile indicated a relative humidity of 75 percent or more from just above the surface to 7,000 feet. The stability parameters indicated a Lifted Index (LI)¹¹ of 8.7 indicating a stable atmosphere, and a K-Index¹² of 13.2, limiting convective activity. Stability is also displayed on the right hand portion of the chart with yellow indicating an unstable layer, green indicating conditionally unstable, and blue indicating stable layers. The sounding favored a mixture of snow and rain, with a precipitable water content of 0.29 inches.

The table 1 below is the observed height, pressure, temperature, dew point temperature, relative humidity (RH) in percent, wind direction and speed, with the derived clear air turbulence (CAT) potential, icing, and mountain wave activity for the 1800 MDT sounding.

Level	Height (ft-MSL)	Pres (hPa)	T (C)	Td (C)	RH (%)	DD / FF (deg / kts)	CAT (FAA)	LLWS	Icing - Type (AF @ 75% RH)	Wave/X-W-Turb nm fpm max
1	3707	877.0	2.4	-1.7	74	340 / 10	LGT		Base:855 mb	
2	4533	850.0	-0.5	-3.6	80	340 / 13			TRC Clear	
3	6602	785.0	-5.5	-6.4	93				LGT Rime	
4	6868	777.0	-1.7	-2.5	94				LGT Rime	
5	7480	759.0	-2.5	-8.5	63					
6	7707	752.4				340 / 11	LGT			2.01 589 LT-MD
7	9572	700.0	-6.5	-11.5	68	315 / 17	MDT			3.56 154 LIGHT
8	9707	696.3				330 / 12				
9	10652	671.0	-9.1	-13.0	73		LGT			
10	10707	669.5				315 / 11				2.07 229 LIGHT
11	11707	643.5				310 / 13				2.44 261 LIGHT
12	12123	633.0	-12.5	-20.5	51					
13	12322	628.0	-11.9	-31.9	17					
14	12685	619.0	-11.3	-45.3	4		LGT			
15	12707	618.5				310 / 16				
16	13888	590.0	-13.1	-52.1	2					2.08 315 LIGHT
17	14747	570.0	-14.9	-52.9	2					2.25 146 LIGHT
18	15630	550.0	-16.9	-33.9	21					
19	15707	548.3				315 / 11	LGT			
20	17707	505.1				245 / 6	SVR			3.39 479 LIGHT
21	17953	500.0	-22.3	-42.3	14	165 / 11				
22	18932	480.0	-24.9	-38.9	26					
23	19484	469.0	-26.1	-47.1	12					
24	19707	464.6				175 / 7				2.12 316 LIGHT
25	21707	426.5				165 / 11				6.06 482 LIGHT
26	22178	418.0	-33.3	-49.3	19		LGT			
27	23187	400.0	-35.9	-43.9	44	200 / 15	MDT			
28	23707	390.9				160 / 10				
29	23820	389.0	-37.7	-44.7	48					
30	24707	373.6				170 / 11	LGT			
31	26707	341.0				200 / 15				
32	28707	311.3				200 / 19	MDT			9.76 1000 LT-MD
33	29514	300.0	-52.5	-61.5	33	175 / 15	LGT			

Table 1 – Sounding data

¹¹ Lifted Index (LI) - A common measure of atmospheric instability. The lifted index is obtained by lifting a parcel of air from near the surface to 500-hPa or 18,000 feet, and comparing the lifted parcels temperature to the environmental temperature at that level. Negative values indicate instability - the more negative, the more unstable the air is, and the stronger the updrafts are likely to be with any developing thunderstorms.

¹² K-Index - The measure of thunderstorm potential based on the vertical temperature lapse rate, the moisture content of the lower atmosphere and the vertical extent of the moist layer. The higher the K-Index, the greater the probability of air mass type thunderstorms development.

The sounding wind profile indicated surface wind from 340° at 10 knots with little variation in height through 16,500 feet, with an abrupt change in direction to the south above this level. As a result of the wind shift the sounding indicated a high probability of turbulence between 15,700 and 25,000 feet. The turbulence analysis program of the RAOB sounding indicated a 100 percent probability of severe turbulence at 17,700 feet with a vertical wind shear of 11.6 knots per 1,000 feet. The level of maximum wind was identified above the tropopause at 65,000 feet from 245° at 52 knots. The mean 0 to 6 kilometer wind was from 304° at 6 knots.

4.0 Model Sounding

The NOAA Air Research Laboratory (ARL) archive model data was reviewed and a model sounding for 1500 MDT (2100Z) on March 22, 2009 was generated utilizing the North American Model at 12-kilometer resolution. Figure 6 is the NAM12 model data for the approximate time of the accident plotted on a Skew-T log P diagram for Butte, Montana. The sounding indicated a freezing level near 7,200 feet, or approximately 1,650 feet agl.

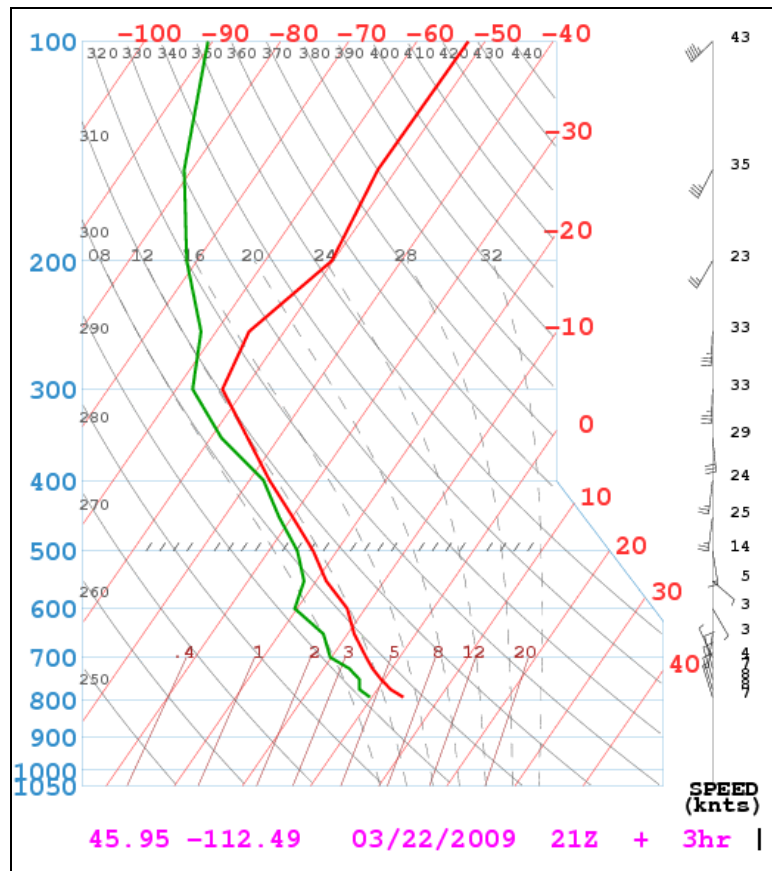


Figure 6 – Forecast sounding at 1500 MDT at Butte

The wind profile depicted northwesterly winds from the surface through 10,000 feet, with an abrupt change to the southeast and then southwest above 30,000 feet. The highest

likelihood for turbulence was between 9,000 and 11,500 feet with this wind shift or critical layer, and again between 15,600 and 20,500 feet with another change in wind direction and speed.

The following table is the forecast pressure, height rounded to the nearest 10 feet, temperature, dew point, and wind direction and speed.

Pressure (hPa)	Height (ft msl)	Temp (°C)	Dewpoint (°C)	Wind (dir/kt)
794	6,260	4.6	-0.3	340° 8
775	6,900	2.0	-2.6	340° 10
750	7,760	-0.5	-3.7	340° 10
725	8,650	-2.9	-6.3	340° 8
700	9,550	-4.9	-10.2	330° 4
650	11,450	-9.0	-13.6	190° 4
600	13,470	-12.6	-20.3	140° 3
550	15,620	-18.5	-21.8	120° 6
500	17,930	-23.5	-25.8	170° 15
450	20,430	-29.8	-31.9	190° 26
400	23,130	-37.1	-38.0	190° 26
350	26,110	-44.6	-48.4	170° 31
300	29,430	-53.2	-57.6	180° 34

5.0 Satellite Data

The Geostationary Operations Environmental Satellite number 11 (GOES-11) data was obtained from the National Climatic Data Center (NCDC) and displayed on the National Transportation Safety Board’s Man-computer Interactive Data Access System (McIDAS) workstation. Both visible and infrared imagery was obtained surrounding the time of the accident. The infrared imagery (band 4) at a wavelength of 10.7 microns (μm) provided a 4-kilometer (km) resolution with radiative cloud top temperatures. The visible imagery (band 1) at a wavelength of 0.65 μm provided a resolution of 1 km.

Figure 7 is the GOES-11 infrared band 4 image at 1415 MDT (2015Z) at 4X magnification with a standard MB temperature enhancement curve applied to highlight the higher and colder cloud tops associated with deep convection. The image depicted an extensive area of clouds over the route of flight with an enhanced area of mid- to high-level clouds over Idaho and southwestern Montana, which extended over the accident site. The radiative cloud top temperature over the accident site was observed at 228.30° Kelvin (K) or -44.86°C , which according to the KFTX and the model sounding indicated cloud tops in the range of 26,500 feet.

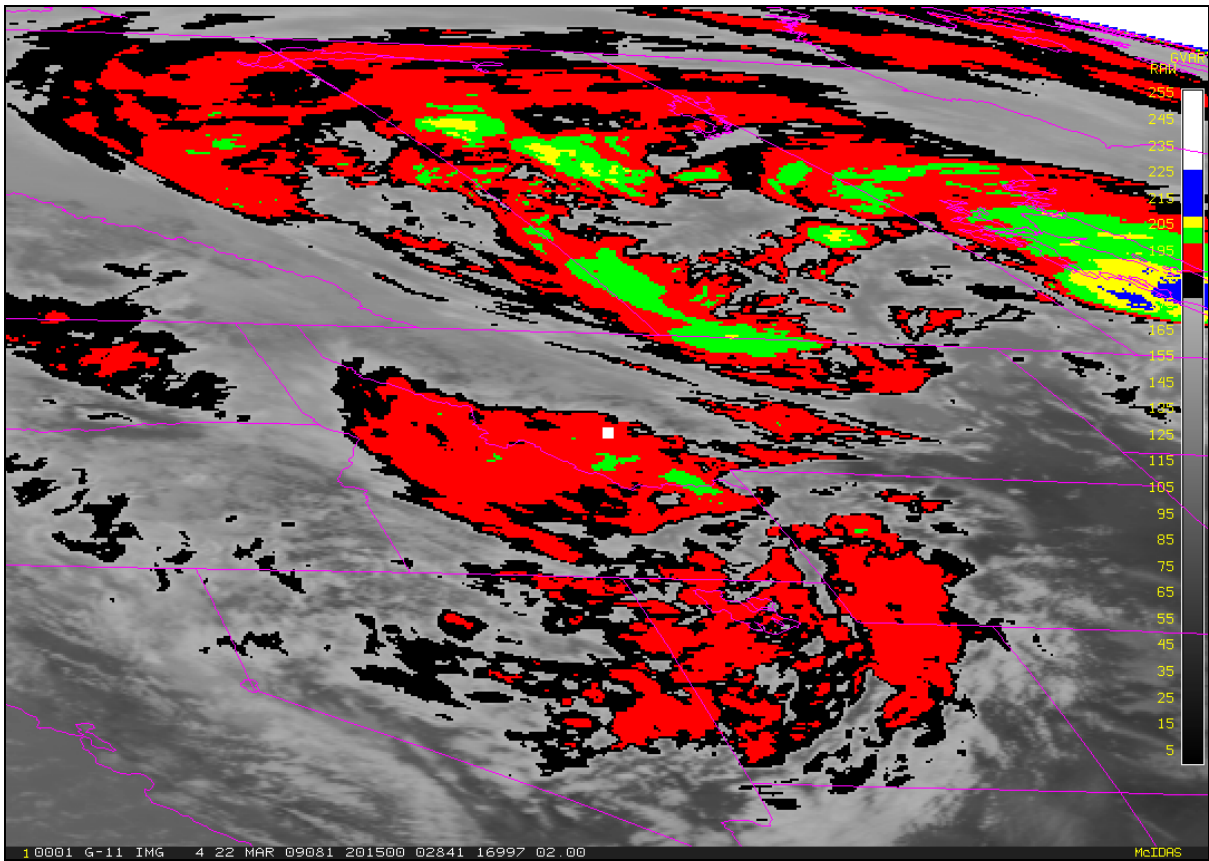


Figure 7 – GOES-11 infrared image at 1415 MDT

Figure 8 is the GOES-11 visible image for 1430 MDT at 2X magnification. The image depicted an extensive area of cirrostratus clouds over the route of flight and accident site with some embedded cumulus congestus clouds to the south and southwest near Dillon, Montana.

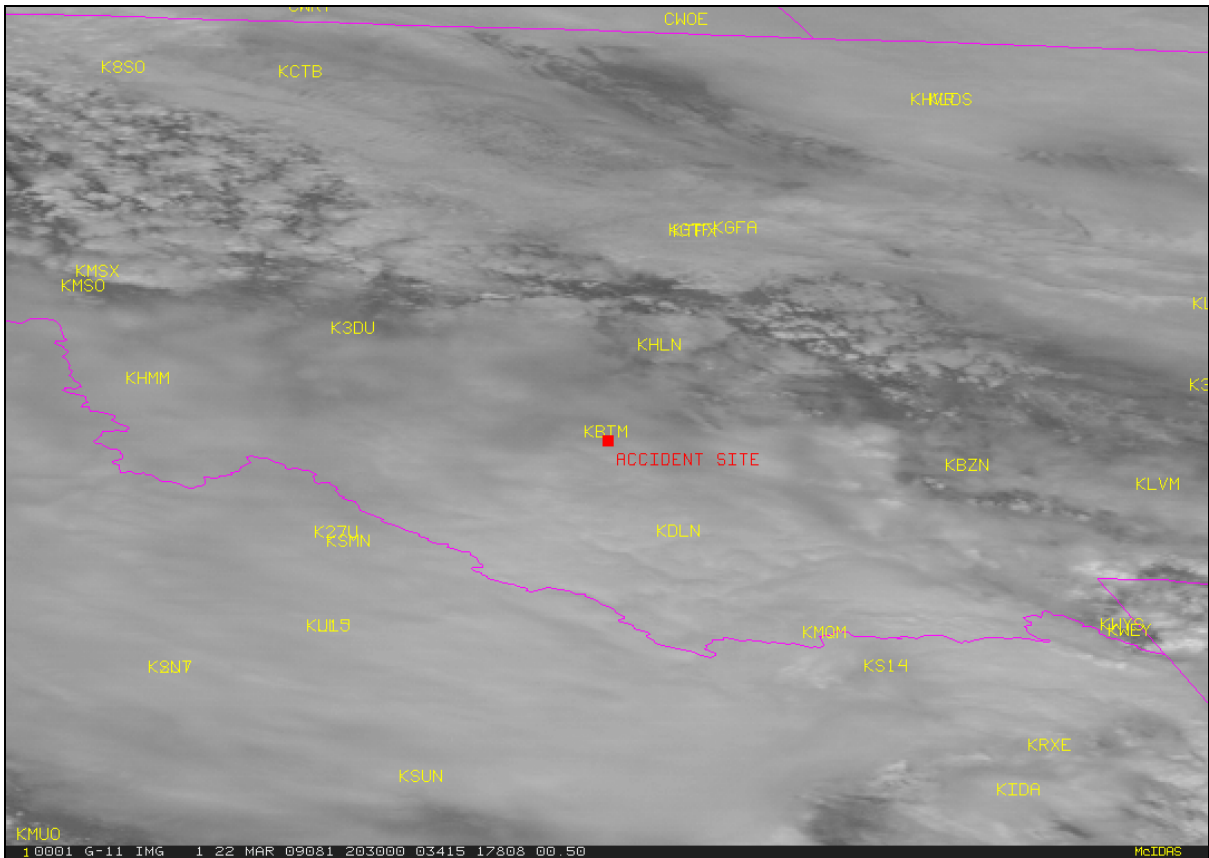


Figure 8 – GOES-11 visible image at 1430 MDT

5.0 Weather Radar Information

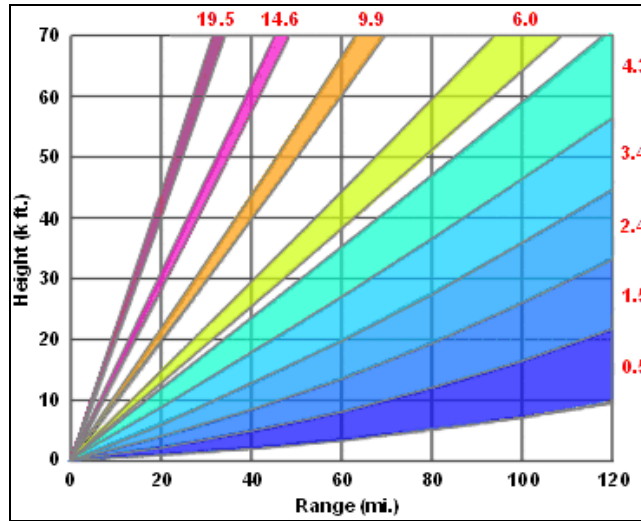
The closest NWS Weather Surveillance Radar-1988, Doppler (WSR-88D) was located at Missoula (KMSX) approximately 60 miles east of the accident site. The Level II radar data was obtained online from the Safety Board’s Man-computer Interactive Display and Archive System (McIDAS), with the flight track overlaid.

The WSR-88D is an S-band 10 centimeter wavelength radar with a power output of 750,000 watts, with a 28-foot parabolic antenna concentrating the energy into a 0.95-degree beam width. The radar produces three basic types of products reflectivity, radial velocity, and spectral width.

5.0.1 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 on the WSR-88D’s Principle Users Processor (PUP). Products that require data from multiple elevation scans are not available until the end of the six 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 two common scanning strategies. The most common is where the radar makes 9 elevation scans from 0.50 degrees to 19.5 degrees 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 KMSX WSR-88D radar was operating in the normal 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 Strategy

5.0.2 Reflectivity

Reflectivity is the measure of the efficiency of a target in intercepting and returning radio energy. With hydrometeors¹³ 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 (dBZ¹⁴), and is a general measure of echo intensity. The chart below relates the NWS video integrator and processor (VIP) intensity levels versus the WSR-88D's display levels, precipitation mode reflectivity in decibels, and rainfall rates.

¹³ 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 glaze ice.

¹⁴ dBZ - $10 \log Z_e$

NWS VIP/DBZ CONVERSION TABLE

NWS VIP	WSR-88D LEVEL	PREC MODE DBZ	RAINFALL
0	0	< 5	
	1	5 to 9	
	2	10 to 14	
1 Very Light	3	15 to 19	.01 in/hr
	4	20 to 24	.02 in/hr
	5	25 to 29	.04 in/hr
2 Light to Moderate	6	30 to 34	.09 in/hr
	7	35 to 39	.21 in/hr
3 Strong	8	40 to 44	.48 in/hr
4 Very Strong	9	45 to 49	1.10 in/hr
5 Intense	10	50 to 54	2.49 in/hr
6 Extreme	11	55 to 59	>5.67 in/hr
	12	60 to 64	
	13	65 to 69	
	14	70 to 74	
	15	> 75	

The Federal Aviation Administration (FAA) Advisory Circular AC 00-24B titled “Thunderstorms” dated January 2, 1983, also defines the echo intensity levels and potential weather phenomena associated with those levels. If the maximum VIP Level is 1 “weak” and 2 “moderate”, then light to moderate turbulence is possible with lightning. VIP Level 3 is “strong” and severe turbulence is possible with lightning. VIP Level 4 is “very heavy” and severe turbulence is likely with lightning. VIP Level 5 is “intense” with severe turbulence, lightning, hail likely, and organized surface wind gusts. VIP Level 6 is “extreme” with severe turbulence, lightning, large hail, extensive surface wind gusts and turbulence.

Air traffic control (ATC) weather display systems also use radar weather processors with the ability to determine precipitation intensity, with controllers instructed to describe the intensity to pilots based on the following scale:

- (a) "Light" (< 30 dBZ)
- (b) "Moderate" (30 to 40 dBZ)
- (c) "Heavy" (> 40 to 50 dBZ)
- (d) "Extreme" (> 50 dBZ)

5.0.3 Base Reflectivity

Figures 9 and 10 are the KMSX WSR-88D base reflectivity image for the 0.5 degree elevation scan completed at 1420 MDT (2020Z) and 1432 MDT (1432Z) provided at 4X magnification and with a resolution of 1° X 1 kilometers. The radar image depicts numerous

Billings, MT (BIL) routine pilot report (UA); Over – Billings; Time – 1141 MDT (1741Z); Flight level – 37,000 feet; Type aircraft – Boeing 737 air carrier jet; Temperature – minus 53° C; Wind – 198° at 43 knots; Turbulence – negative; Remarks – moderate mountain wave with mostly smooth ride at 37,000 feet; Remarks – entered from NWS AWC website.

Miles City, MT (MLS) routine pilot report (UA); Over – 30 miles west of Miles City; Time – 1208 MDT (1808Z); Flight level – 36,000 feet; Type aircraft – Embraer EMB-170 (E170) regional air carrier jet; Temperature – minus 55° C; Turbulence – light to occasional moderate turbulence; Remarks – smoothed out west of Miles City.

Helena, MT (HLN) routine pilot report (UA); Over – Helena; Time – 1504 MDT (2104Z); Flight level – 37,000 feet; Type aircraft – Boeing 737 air carrier jet; Temperature – minus 52° C; Wind – 183° at 34 knots; Turbulence – negative; Remarks – good ride between Seattle (SEA) to present position; Remarks – entered from NWS AWC website.

Bozeman, MT (BZN) routine pilot report (UA); Over – 20 miles southwest of Bozeman; Time – 1521 MDT (2121Z); Flight level – 15,000 feet; Type aircraft – Cessna Citation (C560) business jet; Temperature – minus 1° C; Icing – light rime icing between 15,000 and 12,300 feet; Remarks – entered by Salt Lake City (ZLC) CWSU.

Lewiston, MT (LWT) routine pilot report (UA); Over – 20 miles south of Lewiston; Time – 1541 MDT (2141Z); Flight level – 5,000 feet; Type aircraft – Beechcraft Musketeer (BE24) single engine airplane; Sky cover – overcast bases at 4,500 feet; Weather – flight visibility 2 miles in light rain; Wind – 300° at 15 knots; Turbulence – none.

Billings, MT (BIL) routine pilot report (UA); Over – Billings; Time – 1628 MDT (2228Z); Flight level – 38,000 feet; Type aircraft – Boeing 737 air carrier jet; Turbulence – moderate; Remarks – entered by Salt Lake City (ZLC) CWSU.

Idaho Pilot Reports

Pocatello, ID (PIH) routine pilot report (UA); Over – 10 miles south-southeast of Pocatello; Time – 0933 MDT (1533Z); Flight level – 9,000 feet; Type aircraft – Embraer EMB-120 (E120) regional air carrier jet; Temperature – 0° C; Icing – light rime icing between 9,000 and 19,000 feet; Remarks – entered by Salt lake City (ZLC) CWSU.

Boise, ID (BOI) routine pilot report (UA); Over – 30 miles west of Boise; Time – 1034 MDT (1634Z); Flight level – 31,000 feet; Type aircraft – McDonald Douglas (MD-83) air carrier jet; Turbulence – moderate chop; Remarks – entered by Salt Lake City (ZLC) CWSU.

Pocatello, ID (PIH) routine pilot report (UA); Over – Pocatello; Time – 1100 MDT (1700Z); Flight level – 27,000 feet; Type aircraft – Beechcraft King Air (BE20) turboprop; Sky cover – thin layer of clouds; Weather - flight visibility 2 to 3 miles; Turbulence – light; Remarks – entered by Salt lake City (ZLC) CWSU.

Boise, ID (BOI) routine pilot report (UA); Over – 30 miles northwest of Boise; Time – 1308 MDT (1908Z); Flight level – 29,000 feet; Type aircraft – McDonald Douglas (MD-83) air carrier jet; Turbulence – moderate chop; Remarks – entered by Salt Lake City (ZLC) CWSU.

Coeur d’Alene, ID (COE) routine pilot report (UA); Over – 15 miles southeast of Coeur d’Alene; Time – 1318 MDT (1918Z); Flight level – 11,500 feet; Type aircraft – McDonald Douglas (MD-81) air carrier jet; Turbulence – moderate; Remarks – during climb.

Lewiston, ID (LWS) routine pilot report (UA); Over – 30 miles east-southeast of Lewiston; Time – 1338 MDT (1938Z); Flight level – 8,000 feet; Type aircraft – Rockwell Commander (AC90) turboprop business aircraft; Temperature – minus 8° C; Icing – light rime icing between 9,500 and 8,000 feet; Remarks – during descent from Settle Center (ZSE).

Idaho Falls, ID (IDA) routine pilot report (UA); Over – Idaho Falls; Time – 1348 MDT (1948Z); Flight level – 12,000 feet; Type aircraft – Canadair Regional Jet (CRJ2); Temperature – minus 1° C; Icing – light rime icing; Remarks – during descent from Salt Lake City (ZLC).

Idaho Falls, ID (IDA) routine pilot report (UA); Over – Idaho Falls; Time – 1404 MDT (2004Z); Flight level – 7,000 feet; Type aircraft – Canadair Regional Jet (CRJ2); Sky cover – overcast bases at 400 feet; Temperature – minus 1° C; Icing – light rime icing below 8,000 feet.

Idaho Falls, ID (IDA) routine pilot report (UA); Over – 10 miles north of Idaho Falls; Time – 1445 MDT (2045Z); Flight level – 20,000 feet; Type aircraft – Lancair 4 (LNC4) high performance airplane; Remarks – moderate updraft +500 feet from Salt Lake City (ZLC).

Idaho Falls, ID (IDA) routine pilot report (UA); Over – Idaho Falls; Time – 1508 MDT (2108Z); Flight level – unknown; Type aircraft – DeHavilland Dash-8 (DH8D) regional air carrier turboprop; Sky cover – overcast clouds bases unknown with tops at 7,900 feet; Icing – negative; Remarks – temperature unknown, bases of clouds at 700 feet agl.

Boise, ID (BOI) routine pilot report (UA); Over – 30 miles northwest of Boise; Time – 1615 MDT (2215Z); Flight level – 13,000 feet; Type aircraft – Piper Seneca (PA43) multiengine turboprop; Temperature – minus 8° C; Icing – light rime icing; Remarks – entered by Salt Lake City (ZLC) CWSU.

Pullman, ID (PUW) routine pilot report (UA); Over – 25 miles north of Pullman; Time – 1642 MDT (2242Z); Flight level – 11,000 feet; Type aircraft – DeHavilland Dash-8 (DH8D) regional air carrier turboprop; Temperature – minus 9° C; Icing – moderate rime icing; Remarks – entered by Salt Lake City (ZLC) CWSU.

McCall, ID (MYL) routine pilot report (UA); Over – McCall; Time – 1659 MDT (2259Z), Flight level – 22,000 feet; Type aircraft – Piper Turbo Saratoga (PA31) single engine airplane; Sky cover – sky clear; Weather – flight visibility 10 miles; Temperature – minus 30° C; Turbulence – light to occasional moderate turbulence.

Idaho Falls, ID (IDA) routine pilot report (UA); Over – Idaho Falls; Time – 1709 MDT (2309Z); Flight level – 8,000 feet; Type aircraft – Pilatus PC-12 single engine turboprop; Temperature – minus 12 C; Icing – moderate mixed icing between 10,000 and 8,000 feet encountered during descent.

7.0 Area Forecast

The Area Forecast (FA) is a forecast of visual flight rules (VFR) clouds and weather conditions over an area as large as the size of several states. It must be used in conjunction with the AIRMET Sierra (IFR) bulletin for the same area in order to get a complete picture of the weather. The area forecast together with the AIRMET Sierra bulletin are used to determine forecast enroute weather and to interpolate conditions at airports which do not have a terminal forecast (TAF) issued. The region that covers Montana is under the Salt Lake City (KSLC) regional forecast. The forecast valid for this accident was issued at 1345 MDT (1945Z) and was valid until 0200 MDT (0800Z) on March 23, 2009. The forecast is as follows:

FAUS45 KKCI 221945

FA5W

_SLCC FA 221945

SYNOPSIS AND VFR CLDS/WX

SYNOPSIS VALID UNTIL 231400

CLDS/WX VALID UNTIL 230800...OTLK VALID 230800-231400

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..AT 20Z DEEP TROF ERN WA-SRN NV-SWRN AZ. STG W WND

OVR AZ..MOD W/SW OVER SERN UT/CO/NM/ERN WY. BY 14Z LOW NERN CO

TROF SWRN UT-SRN CA. STG W WND AZ/NM.

SFC...AT 20Z DEEP LOW OVR NERN MT WITH CDFNT TO S CNTRL MT-NWRN

MT. STNR FNT NWRN WY-SWRN WY-W CNTRL NV-SRN NV..BECMG CDFNT SRN

NV AND CONTG SWD. DRYLINE FAR ERN CO-FAR ERN NM. BY 14Z DEEP LOW

SWRN NEB WITH OCFNT TO SWRN KS..BECMG CDFNT SWRN KS-E CNTRL NM-

ELP. ANOTHER CDFNT NWRN MT-NWRN WY-SERN WY.

.

ID

NRN...BKN-OVC050 TOP 120 BKN CI. -SHRA. 05Z SCT100 BKN150 LYRD FL250. OTLK...VFR.

CNTRL MTNS...BKN-OVC080 TOP 150 BKN CI. -SHRASN. ISOL -TSRASN. CB TOP FL280. 03Z SCT-

BKN080 BKN120 LYRD FL250. -SHRASN.

SWRN...BKN100 OVC140 LYRD FL250. -SHRA. WND NW G25KT. 04Z BKN150. OTLK...VFR.

SERN...BKN-OVC070 TOP FL250. -SHRASN. ISOL -TSRASN. CB TOP FL280. WND SW G25KT. 05Z

OVC060 TOP 120. -SHRASN. OTLK...IFR CIG SHRASN.

.
MT

CONTDVD WWD...BKN100 LYRD FL250. -SHRA. 03Z BKN-OVC080. -SHRA. OTLK...VFR SHRA.
SWRN MTNS...BKN090 LYRD FL250. -SHRASN. 02Z BKN070. VIS 4-5SM -RASN BR. OTLK...MVFR
CIG SN BR.
ERN SLOPES OF CONTDVD...BKN080 OVC120 TOP FL250. -SHRASN. OTLK...VFR SHRASN.
CNTRL...BKN060 OVC100 TOP FL250. -SHRA. 04Z BKN-OVC060. -RASN. OTLK...MVFR CIG RASN.
NERN...OVC030 LYRD FL250. 04Z BKN060. OTLK...VFR.
SERN...SCT100 BKN-OVC CI. OTLK...VFR SHRA.

The forecast for Idaho was for broken to overcast clouds at 8,000 feet msl with tops to 15,000 feet, with broken cirrus clouds above, with light rain and snow showers and isolated thunderstorms and light rain and snow, with cumulonimbus cloud tops to 28,000 feet.

The forecast for southwestern Montana was for broken clouds at 9,000 feet msl layered to 25,000 feet, with light rain and snow showers.

8.0 In-Flight Weather Advisories

The NWS issues in-flight weather advisories designated as Severe Weather Forecast Alerts (AWW's), Convective SIGMET's (WST's), SIGMET's (WS's), Center Weather Advisories (CWA's), and AIRMET's (WA's). In-flight advisories serve to notify en route pilots of the possibility of encountering hazardous flying conditions, which may not have been forecast at the time of the preflight briefing. Whether or not the condition described is potentially hazardous to a particular flight is for the pilot to evaluate on the basis of experience and the operational limits of the aircraft.

Figure 11 is a plot of the AIRMETs¹⁵ current at the time of the accident, with the text of the advisories below:

WAUS45 KKCI 221445
WA5S
_SLCS WA 221445
AIRMET SIERRA UPDT 4 FOR IFR AND MTN OBSCN VALID UNTIL 222100

.
AIRMET IFR...ID MT
FROM 60SSW YYN TO LKT TO 40SE BKE TO 60SW YXC TO 60SSW YYN
CIG BLW 010/VIS BLW 3SM PCPN/BR. CONDS ENDG 18-21Z.

.
AIRMET MTN OBSCN...ID MT WY NV UT
FROM 50WSW YXC - 40NNE HVR - BPI - 60SSE SLC - 60S BVL - ILC - 40SSW FMG - 40SE LKV - 50SE
REO - 50WSW YXC
MTNS OBSC BY CLDS/PCPN/BR. CONDS CONTG BYD 21Z THRU 03Z.

¹⁵ Airman's Meteorological Information - AIRMET (WAs) are advisories of significant weather phenomena but describe conditions at intensities lower than those, which require the issuance of SIGMETs. AIRMETs are intended for dissemination to all pilots in the preflight and en route phase of flight to enhance safety. AIRMET Bulletins are issued on a scheduled basis every 6 hours beginning at 0145Z during Central Daylight Time and at 0245Z during Central Standard Time. Unscheduled updates and corrections are issued as necessary.

.
OTLK VALID 2100-0300Z
AREA 1...IFR UT AZ
BOUNDED BY 30SSW HVE-20NNW INW-PGS-50SE ILC-30SSW HVE
CIG BLW 010/VIS BLW 3SM PCPN. CONDS DVLPG 21-00Z. CONDS CONTG THRU 03Z.

.
AREA 2...MTN OBSCN ID MT WY NV UT
BOUNDED BY 50NNE HVR-BOY-30NNE BPI-50WSW MTU-30SSW FMG-40SE LKV-60SE REO-50SW
YXC-50NNE HVR
MTNS OBSC BY CLDS/PCPN/BR. CONDS CONTG THRU 03Z.

WAUS45 KPCI 221445
WA5T
_SLCT WA 221445
AIRMET TANGO UPDT 4 FOR TURB AND STG SFC WINDS VALID UNTIL 222100

.
...SEE SIGMET NOVEMBER SERIES...

.
...SEE SIGMET YANKEE SERIES...

.
AIRMET TURB...ID WY NV UT CO AZ NM
FROM 40WNW RAP - 30ESE CYS - 40ESE SNY - 50W LBL - 30ESE TBE - INK - ELP - 50S TUS - BZA -
EED - 40SSW FMG - 60SSE LKV - 40WNW RAP
MOD TURB BTN FL180 AND FL400. CONDS CONTG BYD 21Z THRU 03Z.

.
AIRMET TURB...ID MT WY NV UT CO AZ NM WA OR CA AND CSTL WTRS
FROM YKM - TWF - SHR - 60NW RAP - 50SSW BFF - 40E SNY - 50W LBL - 30ESE TBE - INK - ELP -
50S TUS - BZA - 20S MZB - 130SW MZB - 90SW FOT - YKM
MOD TURB BLW FL180. CONDS CONTG BYD 21Z THRU 03Z.

.
AIRMET STG SFC WINDS...NV AZ NM CA
FROM 50W RSK - SJN - 30WSW TRM - EHF - 50W RSK
SUSTAINED SURFACE WINDS GTR THAN 30KT EXP. CONDS DVLPG 15-18Z. CONDS CONTG BYD
21Z THRU 03Z.

.
OTLK VALID 2100-0300Z
AREA 1...TURB ID MT WY NV UT CO AZ NM WA OR CA AND CSTL WTRS
BOUNDED BY 70ESE YDC-TWF-30WNW RAP-50SSW BFF-50E SNY-50W LBL-30ESE TBE-INK-ELP-
50S TUS-BZA-20S MZB-220SW MZB-140WSW FOT-
110WNW ONP-140W TOU-70ESE YDC
MOD TURB BTN FL180 AND FL400. CONDS CONTG THRU 03Z.

.
AREA 2...TURB ID MT WY NV UT CO AZ NM WA OR CA AND CSTL WTRS
BOUNDED BY 20NNE YKM-TWF-80NW RAP-30ESE CYS-40E SNY-50W LBL-30ESE TBE-INK-ELP-
50S TUS-BZA-20S MZB-210SW MZB-90WSW FOT-20NNE-YKM
MOD TURB BLW FL180. CONDS CONTG THRU 03Z.

.
AREA 3...STG SFC WINDS NV AZ NM CA
BOUNDED BY 50W RSK-50NNE SSO-50ESE LAX-EHF-50W RSK
SUSTAINED SURFACE WINDS GTR THAN 30KT EXP. CONDS CONTG THRU 03Z.

WAUS45 KPCI 221445
WA5Z
_SLCZ WA 221445

AIRMET ZULU UPDT 2 FOR ICE AND FRZLVL VALID UNTIL 222100

AIRMET ICE...ID MT WY NV UT WA OR

FROM 50WSW YXC - 50NE GGW - BIL - 20E BCE - 60N OAL - 70W BAM - BKE - 50NNE BKE - 50WSW YXC

MOD ICE BTN FRZLVL AND FL180. FRZLVL 070-100. CONDS CONTG BYD 21Z THRU 03Z.

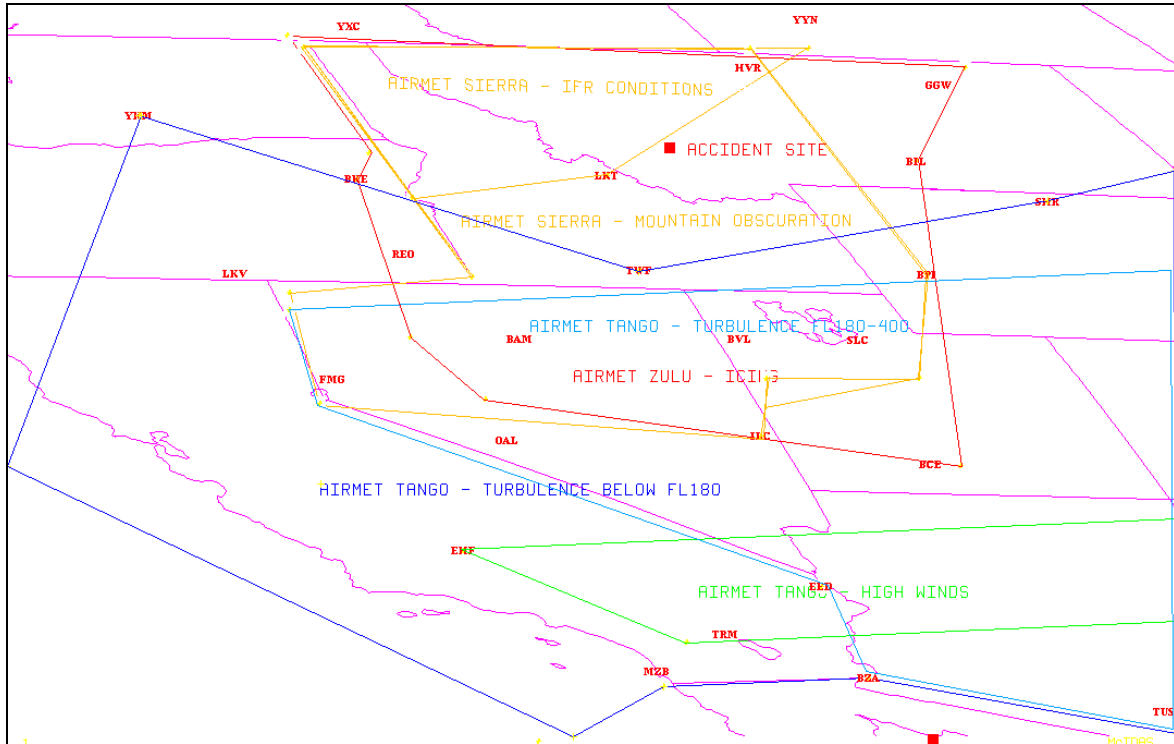


Figure 11 – AIRMETs current during the period

The NWS also had the following SIGMETs¹⁶ and Convective SIGMETs current during the period; however, none extended over the route of flight or the accident site. The Convective SIGMETs outlook extended over extreme southern Montana and eastern Idaho, east of the route of flight and immediately south of the Bozeman area.

WSUS05 KPCI 221845

-SLCY WS 221845

SIGMET YANKEE 3 VALID UNTIL 222245

CO NM

FROM CHE TO 40N DEN TO PUB TO FTI TO 30NW ABQ TO CHE

OCNL SEV TURB BTN FL300 AND FL390. RPRTD BY ACFT. CONDS CONTG BYD 2245Z.

....

WSUS05 KPCI 221720

-SLCN WS 221720

¹⁶ Significant Meteorological Information (SIGMET) - is a weather advisory that contains meteorological information concerning the safety of all aircraft. There are two types of SIGMETs, convective and non-convective. The criteria for a non-convective SIGMET is severe or greater turbulence or icing, or instrument meteorological conditions due to dust, sand, or volcanic ash that extends over a 3,000-square-mile area.

*SIGMET NOVEMBER 2 VALID UNTIL 222120
AZ CA
FROM PGS TO 40S DRK TO 30E MZB TO 40NE LAX TO PGS
OCNL SEV TURB BLW 140. RPRTD BY ACFT. CONDS CONTG BYD 2120Z.*

*MKCW WST 221955
CONVECTIVE SIGMET...NONE
OUTLOOK VALID 222155-230155.
FROM 60E DLN-40WNW BOY-50W JNC-50W TBC-EED-30S
BTY-ELY-PIH-DBS-60E DLN
WST ISSUANCES POSS. REFER TO MOST RECENT ACUS01 KWNS
FROM STORM PREDICTION CENTER FOR SYNOPSIS AND METEOROLOGICAL
DETAILS.*

9.0 Terminal Aerodrome Forecast (TAF)

The Terminal Aerodrome Forecast (TAF) current for KBTM at the time of the accident was issued at 1133 MDT and is as follows:

*TAF KBTM 221733Z 2218/2318 VRB05KT P6SM VCSH BKN090
FM230200 33010KT P6SM VCSH OVC050
FM230600 33010KT 4SM -SN OVC030
FM231700 33015KT P6SM VCSH BKN030=*

The forecast expected from 1200 through 2000 MDT winds variable at 5 knots, visibility better than 6 miles with showers in the vicinity, and a ceiling broken at 9,000 feet agl

10.0 Icing Potential

The NWS Current Icing Product (CIP) is a supplementary weather product that provides a graphical view of the current icing environment. Input from weather sensors is provided to software models to produce this automatically generated graphical weather product. The CIP is updated hourly by the NWS Aviation Weather Center (AWC), and provides current information via icing severity graphics and icing probability graphics. CIP products are not forecasts, but presentations of current conditions at the time of the analysis.

Figures 12 through 14 are the NWS CIP icing diagnostic chart for 1400 MDT at 7,000, 9,000, and 12,000 feet.

40 Km U.S. Icing Products
20 UTC Sun March 22, 2009

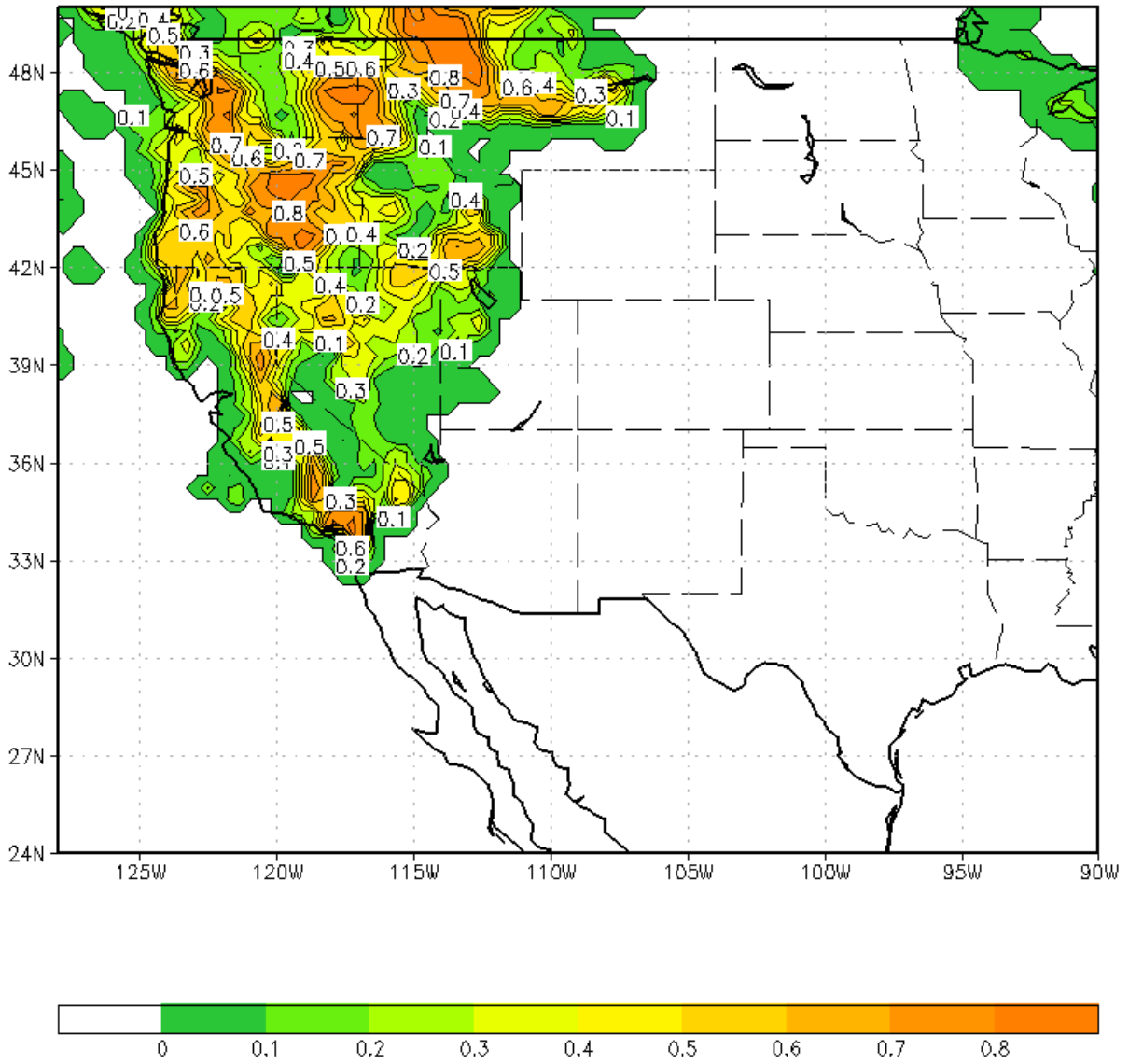


Figure 12 – CIP for 7,000 feet

40 Km U.S. Icing Products
20 UTC Sun March 22, 2009

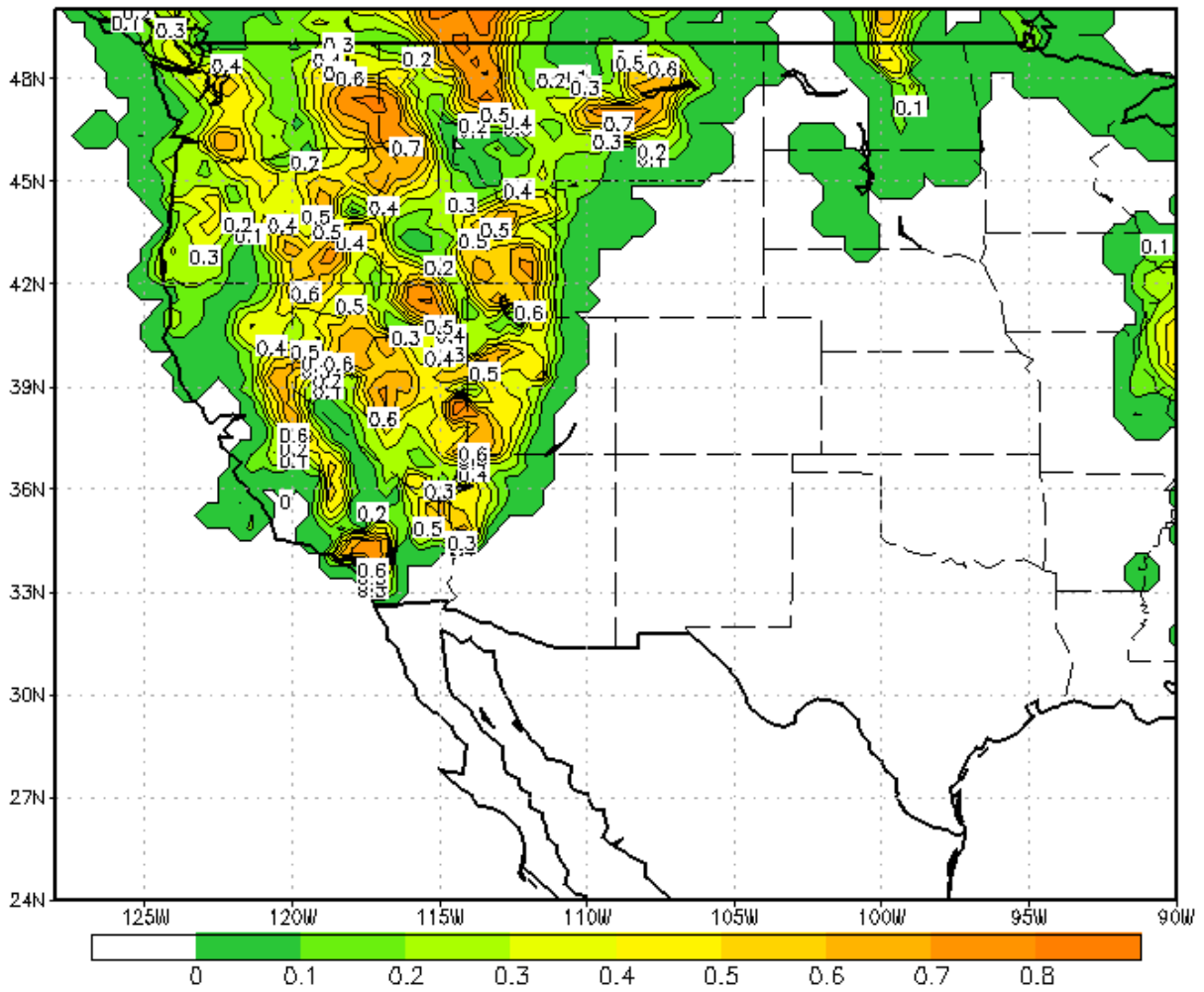


Figure 13 – CIP for 9,000 feet

40 Km U.S. Icing Products
20 UTC Sun March 22, 2009

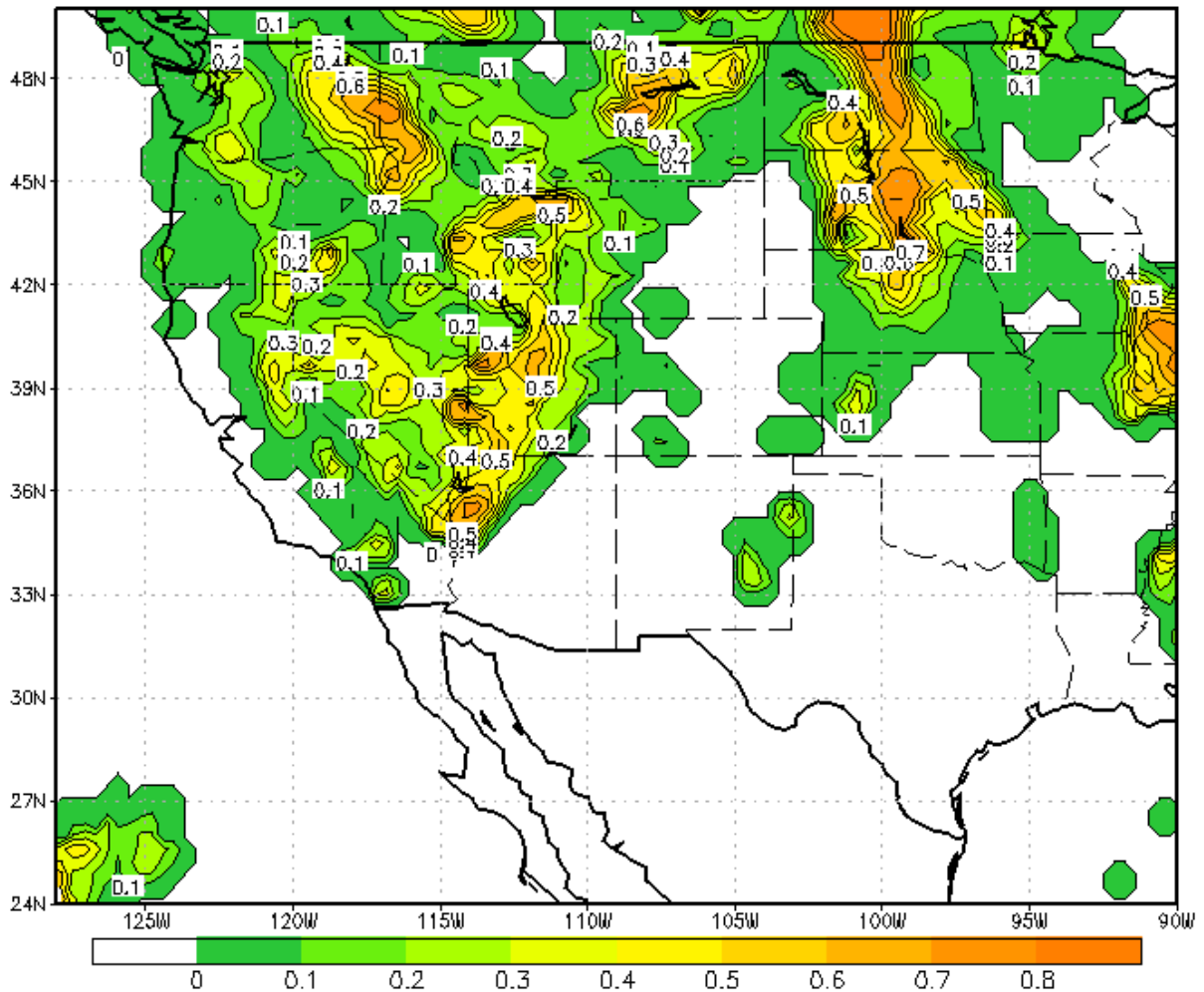


Figure 14 – CIP for 12,000 feet

11.0 Statements

A Beechcraft King Air, N791DC, at 1433 MDT (2033Z) approximately 17 miles southeast of Butte at 14,000 feet provided a pilot report, that they were picking up ice and requested deviations around the weather. They provided a statement regarding their flight conditions and indicated that the cloud bases were at 8,000 to 9,000 feet with cloud tops at 24,000 feet, with precipitation in the form of rain and snow. They further characterized the clouds as cumulus, and did not depict any significant echoes on their weather radar. They encountered light to moderate mixed ice from 17,000 to 8,000 feet on descent, with an accumulation of 1/4 inch per hour. The total time in icing conditions was estimated to be 5-minutes, with temperatures ranging from -8° to -15° C. No significant splattering of droplets or any ice beyond their pneumatic boot protection along the leading edge of the wing was detected to

imply any supercooled large droplets (SLD). Some residual rime ice was observed on the aircraft spinners on the ground upon landing. The pilots of the airplane were aware of the icing forecast and provided a pilot report of their encounter, and described the conditions as “typical spring weather in the mountains”.

12.0 Astronomical Data

The following astronomical data was obtained from the United States Naval Observatory website for Butte, Silver Bow County, Montana:

Beginning of civil twilight	0659 MDT
Sunrise	0729 MDT
Elevation of Sun at 1428 MDT	43° above the horizon
Azimuth of Sun at 1428 MDT	200°
Sunset	1946 MDT
End of civil twilight	2016 MDT

Donald E. Eick
NTSB Senior Meteorologist