

National Transportation Safety Board

Office of Aviation Safety

Washington, DC 20594



WPR22FA253

METEOROLOGY

Specialist's Factual Report

August 30, 2022

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A. ACCIDENT

Location: Buffalo, Wyoming
Date: July 14, 2022
Time: 1231 mountain daylight time (MDT)
1831 coordinated universal time (UTC)
Airplane: Cessna P210N; Registration: N731BJ

B. METEOROLOGY SPECIALIST

Specialist Donald Eick
National Transportation Safety Board
Washington, D.C.

C. SUMMARY

On July 14, 2022, about 1231 mountain daylight time, a Cessna P210N, N731BJ, was destroyed when it was involved in an accident near Buffalo, Wyoming. The pilot and passenger were fatally injured. The airplane was operated as a Title 14 Code of Federal Regulations Part 91 personal flight.

D. DETAILS OF THE INVESTIGATION

The National Transportation Safety Board's Senior Meteorologist was not on scene for this investigation and conducted the meteorology phase of the investigation remotely, collecting data from official National Oceanic and Atmospheric Administration (NOAA) National Weather Service (NWS) sources including the Weather Prediction Center (WPC) and the National Center for Environmental Information (NCEI). This report documents the general weather products and forecasts over the region during the period and the pertinent meteorological parameters related to the accident. All times are reported as mountain daylight time (MDT) based upon the 24-hour clock, local time is -6 hours from UTC, and UTC=Z. NWS airport and station identifiers use the standard International Civil Aviation Organization 4-letter station identifiers versus the International Air Transport Association 3-letter identifiers, which deletes the initial country code designator "K" for U.S. airports. Directions are referenced to true north and distances in nautical miles. Heights are in feet (ft) above mean sea level (msl) unless otherwise noted. Visibility is in statute miles and fractions of statute miles.

The accident site is based on the location at latitude 44.43509° N and longitude 106.95072° W, at an elevation of about 7,400 ft.

E. FACTUAL INFORMATION

1.0 Synoptic Conditions

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) and the WPC located in College Park, Maryland. These are the base products used in describing weather features and in the creation of forecasts and warnings. Reference to these charts can be found in the joint NWS and Federal Aviation Administration (FAA) Advisory Circular "Aviation Weather Services", AC 00-45H change 2¹.

1.1 Surface Analysis Chart

The north-central section of the NWS Surface Analysis Chart for 1200 MDT with the general color-coded topography is included as figure 1 with the approximate accident site marked by a red star. The chart depicted a low-pressure system at 1009-hPa over western South Dakota, with troughs² extending north and south from the low. Another low-pressure system at 1011-hPa was located over North Dakota associated with a warm front, which extended east-southeastward over North Dakota into Minnesota. A high-pressure system at 1023-hPa was located over northwest Wyoming. The accident site was located between the high and the low-pressure system over South Dakota, with a weak pressure gradient over the area. The chart also depicted the accident site eastern or the lee side of high terrain.

¹ https://www.faa.gov/regulations_policies/advisory_circulars/index.cfm/go/document.information/documentID/1030235

² Trough is an elongated area of low-pressure and like fronts, if moisture is available supporting lifting and general clouds and precipitation formation.

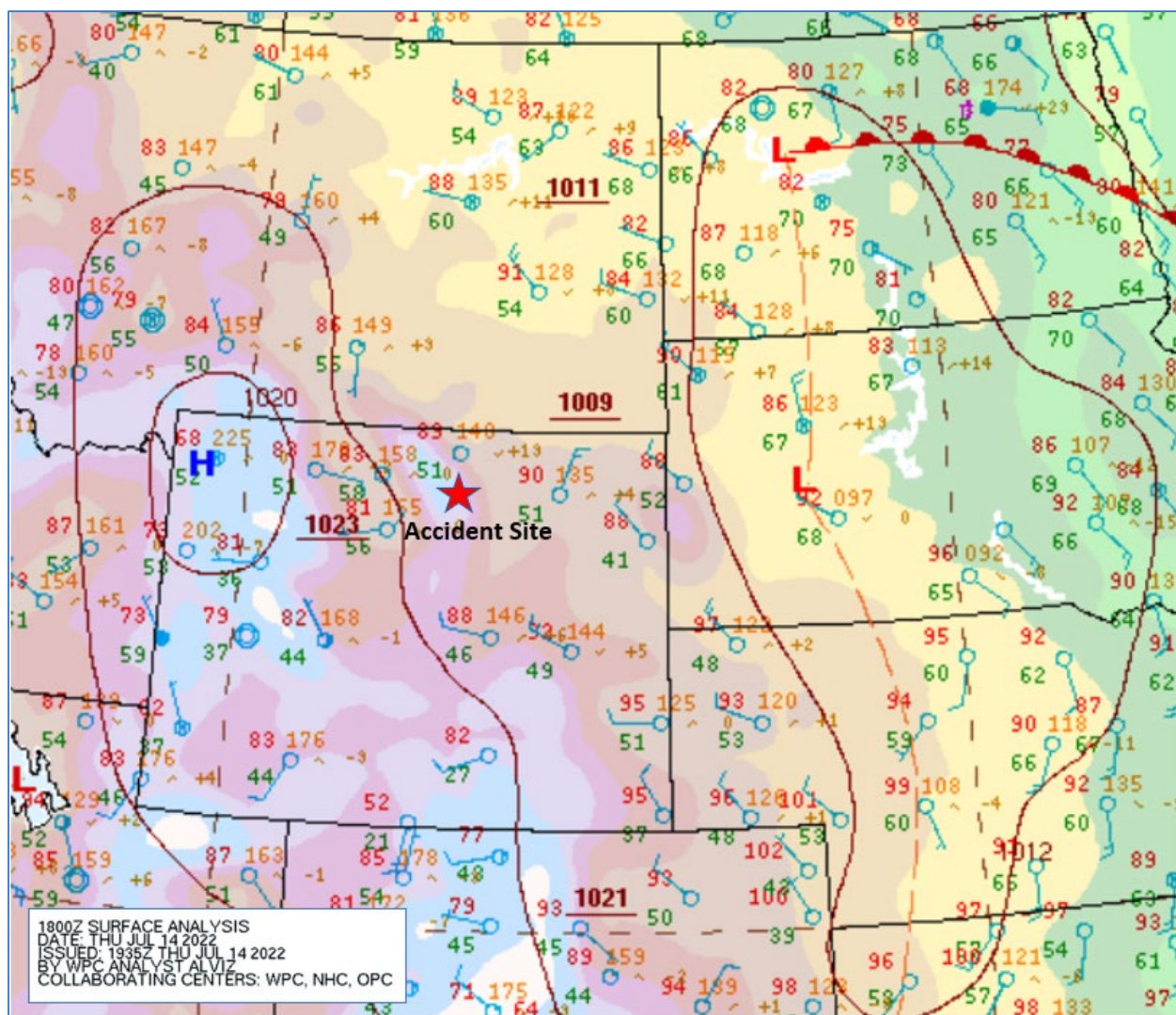


Figure 1 - NWS Surface Analysis Chart for 1200 MDT with accident site marked by red star.

1.2 Regional Reflectivity Mosaic

The NWS Multi-Radar Multi-Sensor (MRMS) national composite reflectivity image for 1230 MDT was obtained for the period and is included as figure 2. The radar image depicted no echoes over the general route of flight or the accident site which is marked by the red star, but did detect an area of echoes of 5 to 30 decibels (dBZ)³ to the west-southwest of the accident site. The closest weather surveillance radar will be further documented in section 5.0 of this report.

³ dBZ stands for decibels relative to Z and is mathematically defined as $10 \log Z_e$, which is the logarithmic dimensional unit.

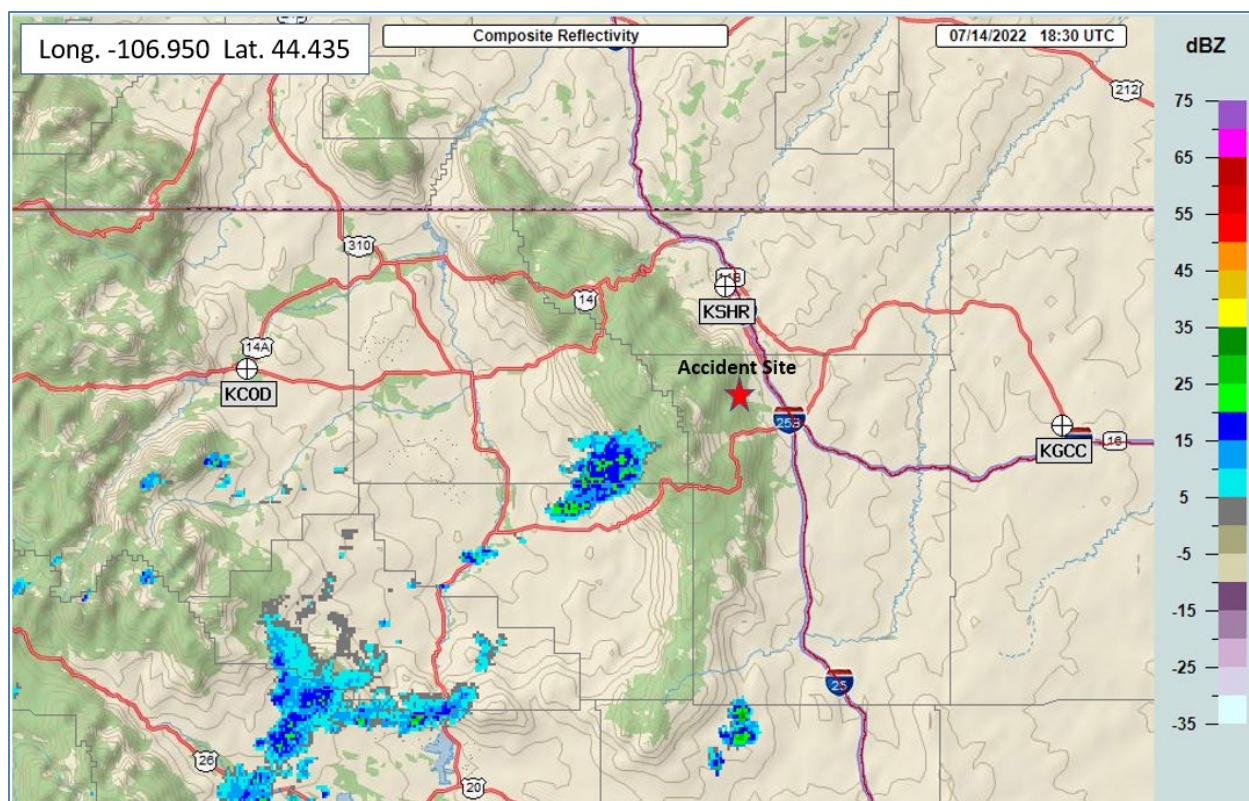


Figure 2 - MRMS Composite Radar Reflectivity image for 1230 MDT with accident site marked.

1.3 Short Range Forecast

The NWS WPC Short Term Forecast Chart valid for 1800 MDT is included as figure 3. The chart continued to depict the low-pressure system over South Dakota moving eastward with a warm front and the high-pressure system over northwestern Wyoming moving little. The chart depicted a chance of rain and thunderstorms likely over the region, with a chance of precipitation.

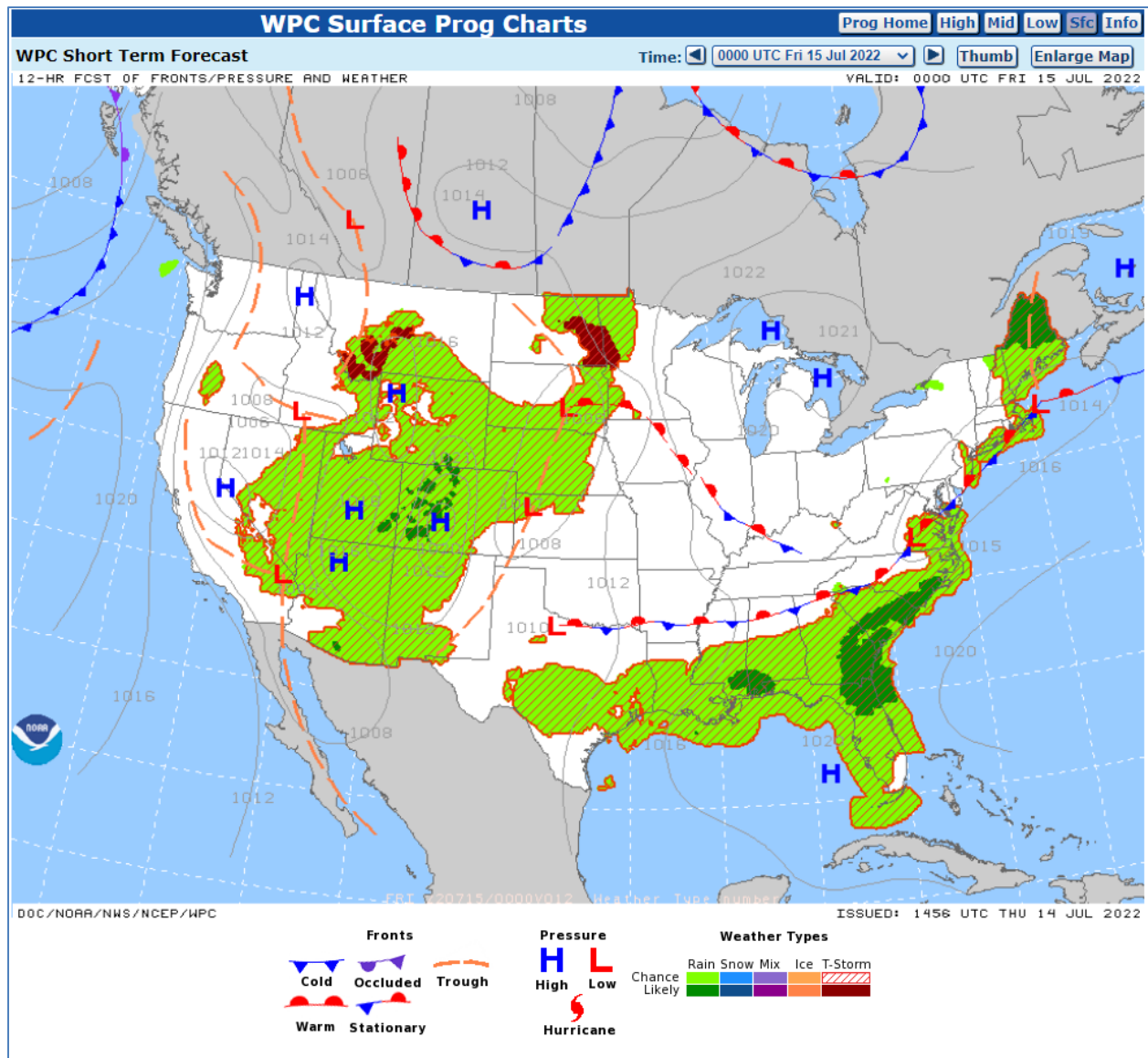


Figure 3 - NWS Short Term Forecast Chart valid for 1800 MDT.

1.4 Convective Outlook

The NWS Storm Prediction Center's (SPC) Convective Outlook issued at 1103 MDT is included as figure 4 and depicted where the NWS expected organized strong to severe thunderstorms⁴ development across the continental United States. The region of southern Montana and northern Wyoming were in an area of a marginal risk⁵ of severe thunderstorms which was described in the narrative below.

⁴ A severe thunderstorm is defined as a cumulonimbus cloud that produces a tornado, large hail of 1-inch or more, and/or wind gusts of 50 knots or greater. Severe thunderstorms also imply the potential for severe to extreme turbulence, severe icing, and potential microbursts.

⁵ A marginal risk is defined as an area of potential severe storms of either limited organization and

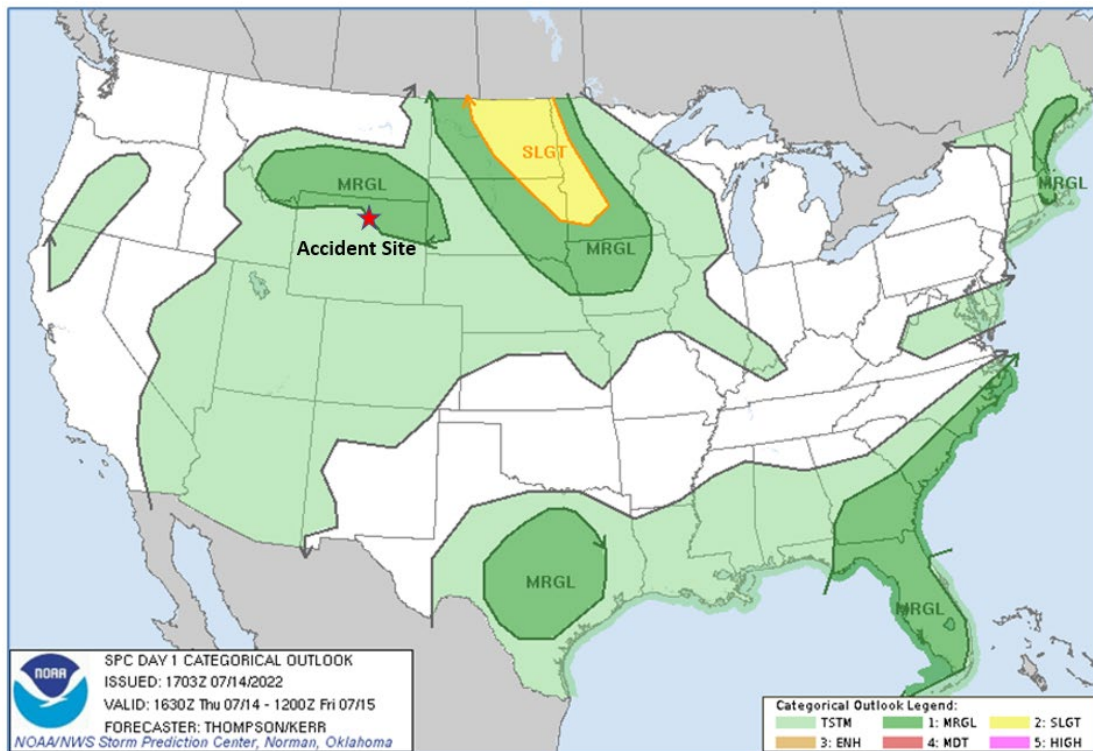


Figure 4 - Day 1 Convective Outlook issued at 1103 MDT for thunderstorms.

SPC AC 141703

Day 1 Convective Outlook CORR 2
NWS Storm Prediction Center Norman OK
1203 PM CDT Thu Jul 14 2022

Valid 141630Z - 151200Z

...THERE IS A SLIGHT RISK OF SEVERE THUNDERSTORMS THIS AFTERNOON
INTO TONIGHT FOR PARTS OF THE DAKOTAS AND WESTERN MN...

CORRECTED FOR OUTLOOK GRAPHICS (GEN TSTM LINE/SEVERE WIND PROBS)

...SUMMARY...

The greatest conditional severe-weather concern is across parts of the Dakotas and western Minnesota, where large hail and damaging gusts are possible from late afternoon through tonight.

...Northern Plains this afternoon into tonight...

A midlevel shortwave trough over southern SK/MB is cresting the midlevel ridge and will begin to move southeastward toward MN this evening into tonight. Some elevated convection is ongoing as of late morning over northeast ND, in a zone of weak warm advection near a northwest-southeast oriented warm front. The potential for diurnal, surface-based convection is

longevity, or very low coverage and marginal intensity.

in question along the front, given that surface temperatures will need to warm to 90F or above to remove convective inhibition across east/southeast ND, and clouds are upstream from this area now. If storms manage to form, the environment will conditionally favor supercells capable of producing large hail/damaging winds, and perhaps a tornado. However, the more probable scenario will be for slightly elevated storms/clusters to form along the immediate cool side of the front tonight, and spread southeastward toward western MN, with an attendant threat for large hail/damaging winds.

...Southern MT vicinity this afternoon through tonight...

Daytime heating and local terrain circulations are expected to initiate at least widely scattered thunderstorms this afternoon across southern MT, in conjunction with subtle speed maxima within the monsoonal moisture plume around the northern periphery of the Four Corners high aloft. Westerly midlevel flow with relatively long/straight hodographs, deep mixing/inverted-v profiles, and modest buoyancy will support the potential for isolated severe outflow gusts and marginally severe hail with small clusters and high-based supercells from southern MT this afternoon into northeastern WY this evening.

2.0 Surface Observations

The official NWS observations issued surrounding the accident site were documented using Aviation Routine Weather Reports (METAR)⁶ and Aviation Select Special Weather Reports (SPECI). Cloud heights are reported above ground level (agl) in the following section, and the magnetic variation was estimated at 9.5° east based on the latest sectional chart for the area.

2.1 Buffalo, WY

The closest official weather reporting site to the accident site was from Johnson County Airport (KBYG), Buffalo, WY, located approximately 12 miles east of the accident site at an elevation of 4,970 ft. The airport had an Automated Surface Observation System (ASOS), whose reports were not augmented by any human observers. At the approximate time of the accident the following conditions were reported.

Weather observation for KBYG at 1153 MDT, automated, wind from 080° at 6 knots, visibility 10 miles or more, sky clear below 12,000 ft agl, temperature 32° Celsius (C), dew point temperature 9° C, altimeter setting 30.18 inches of mercury (inHg). Remarks; automated station with a precipitation discriminator, sea-level pressure 1014.5-hPa, temperature 31.7° C, dew point temperature 8.9° C, 6-hour maximum temperature 32.2° C, 6-hour minimum temperature 18.3° C, 3-hour pressure tendency risen 0.6-hPa.

⁶ Abbreviation for Meteorological Aerodrome Report (METAR), the international observation format.

The observation at 1153 MDT indicated a density altitude of 7,866 ft, based on a temperature of 90° F (32° C), and a relative humidity of 22%. The general flight categories⁷ and raw observations surrounding the period from 1053 through 1653 MDT in standard METAR format were as follows. The observation transcribed above, and the time of the accident are in bold type for reference.

VFR METAR KBYG 141653Z AUTO 14005KT 10SM CLR 29/09 A3017 RMK AO2 SLP141 T02940094=

VFR **METAR KBYG 141753Z AUTO 08006KT 10SM CLR 32/09 A3018 RMK AO2 SLP145
T03170089 2210322 20183 51006=**

Accident 1831Z

VFR METAR KBYG 141853Z AUTO VRB06KT 10SM CLR 32/08 A3018 RMK AO2 SLP145 T03170078=

VFR SPECI KBYG 141950Z AUTO 10SM VCTS CLR 32/08 A3018 RMK AO2 LTG DSNT S=

VFR METAR KBYG 141953Z AUTO 00000KT 10SM VCTS CLR 32/08 A3018 RMK AO2 LTG DSNT S
SLP146 T03220083=

VFR SPECI KBYG 142019Z AUTO 35008KT 10SM CLR 33/08 A3017 RMK AO2 T03280083=

VFR METAR KBYG 142053Z AUTO 01008KT 10SM CLR 33/09 A3016 RMK AO2 SLP138 T03330094
58006=

VFR METAR KBYG 142153Z AUTO 35008KT 10SM FEW095 33/09 A3016 RMK AO2 SLP139
T03280094=

VFR METAR KBYG 142253Z AUTO 28009KT 10SM FEW095 32/10 A3015 RMK AO2 LTG DSNT NW
SLP141 T03170100=

A review of the observations indicated that easterly winds were reported at the time of the accident with thunderstorms in the vicinity or between 5 and 10 statute miles of the airport about 80 minutes after the accident with the main area of lightning reported south of the airport. The winds shifted to the north during that period, with clouds at 9,500 ft agl reported after 1553 MDT.

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

- Low Instrument Flight Rules (LIFR*) - ceiling below 500 ft above ground level (agl) and/or visibility less than 1 statute mile.
- Instrument Flight Rules (IFR) - ceiling between 500 to below 1,000 feet agl and/or visibility 1 to less than 3 miles.
- Marginal Visual Flight Rules (MVFR**) - ceiling from 1,000 to 3,000 ft agl and/or visibility 3 to 5 miles.
- Visual Flight Rules (VFR) - ceiling greater 3,000 ft agl and visibility greater than 5 miles.

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

2.2 Sheridan, WY

The next closest weather reporting station to the accident site was from Sheridan County Airport (KSHR), Sheridan, WY, located about 20 miles north of the accident site at an elevation of 4,021 ft. The airport had an ASOS and reported the following conditions at the time of the accident.

Weather observation for KSHR for 1153 MDT, automated, wind variable at 4 knots, visibility 10 miles or more, sky clear below 12,000 ft, temperature 32° C, dew point temperature 11° C, altimeter 30.11 inHg. Remarks; automated system with a precipitation discriminator, sea level pressure 1014.8-hPa, temperature 31.7° C, dew point temperature 10.6° C, 6-hour maximum temperature 32.2° C, 6-hour minimum temperature 15.0° C, 3-hour pressure tendency risen 0.13-hPa.

The general flight categories and raw observations surrounding the period from 1053 through 1353 MDT were as follows.

VFR METAR KSHR 141653Z AUTO VRB03KT 10SM CLR 32/12 A3009 RMK AO2 SLP139 T03170117=

VFR **METAR KSHR 141753Z AUTO VRB04KT 10SM CLR 32/11 A3011 RMK AO2 SLP148 T03170106 10322 20150 53013=**

Accident 1831Z

VFR METAR KSHR 141853Z AUTO 04005KT 10SM CLR 33/12 A3010 RMK AO2 SLP143 T03330117=

VFR METAR KSHR 141953Z AUTO 00000KT 10SM CLR 34/12 A3009 RMK AO2 SLP139 T03440117=

A review of the conditions at KSHR indicated VFR conditions prevailing during the period with no reported thunderstorms within 30 miles of the station surrounding the period. Thunderstorms were reported between 1650 through 2240 MDT in the vicinity of the station well after the accident.

2.3 Map of Observations

The NWS Aviation Weather Center (AWC) METAR display for 1245 MDT from the Helicopter Emergency Medical Services (HEMS) Tool⁸ is included as figure 5 with the approximate accident site marked by the red star and the general topography. The image depicted general VFR conditions being reported over Wyoming with clear skies below 12,000 ft, visibility unrestricted, and variable winds, with temperatures ranging from 82° F to 90° F.

⁸ <https://www.aviationweather.gov/hemst>

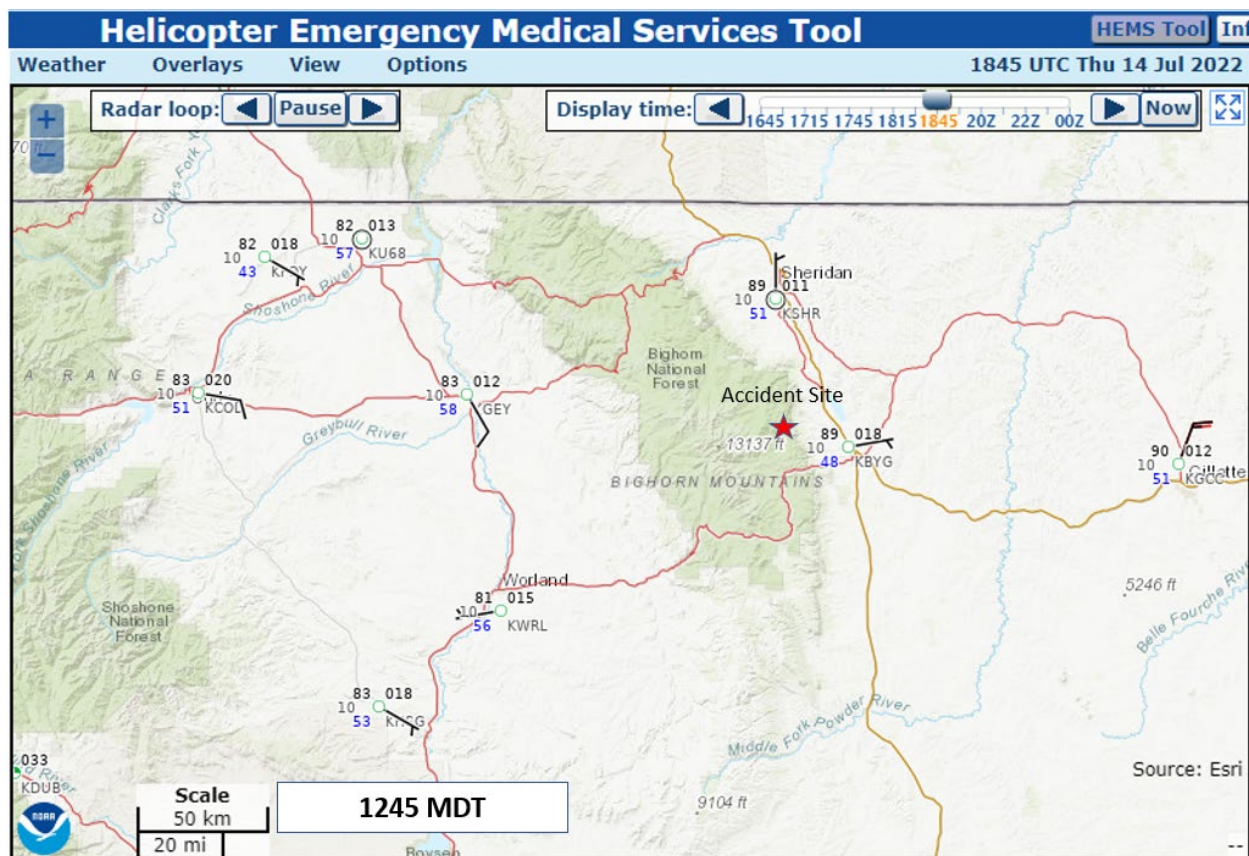


Figure 5 - NWS Aviation Weather Center's METAR display for 1245 MDT.

2.4 Remote Automated Weather Stations

A search of the University of Utah's MesoWest website⁹ of NWS observations and Remote Automated Weather Stations (RAWS) operated by the United States Forestry Service and other land management organizations for monitoring air quality, fire danger, and for research applications was also conducted. One RAWS site identified as School House (SPKW4) was located 7.8 miles south of the accident site (190° azimuth) at an elevation of 8,604 ft. This location was about 12 miles west-southwest of KBYG and along route 391 and heading towards Mather Peak at 12,420 ft. At 1240 MDT SPKW4 reported the following conditions, with wind rounded to the nearest 5°.

SPKW4	Temperature	77° F (25° C)
1240 MDT	Dew Point Temperature	35° F (2° C)
	Relative Humidity	22%
	Wind	275° 10 kt
	Peak Wind	275° 23 kt

⁹ <https://mesowest.utah.edu/>

There were no other RAWS sites located within 25 miles of the accident site.

3.0 Atmospheric Sounding

To determine the vertical structure and state of the atmosphere over the accident site a High-Resolution Rapid Refresh (HRRR)¹⁰ numerical model data were retrieved from the NOAA Air Resources Laboratory using the model grid point¹¹ nearest the accident site for 1300 MDT. The data was then plotted on a standard Skew T log P diagram¹² using RAOB - The Universal RAWinsonde OBservation program¹³ from the surface to 400-hPa or approximately 24,000 ft and is included as figure 6.

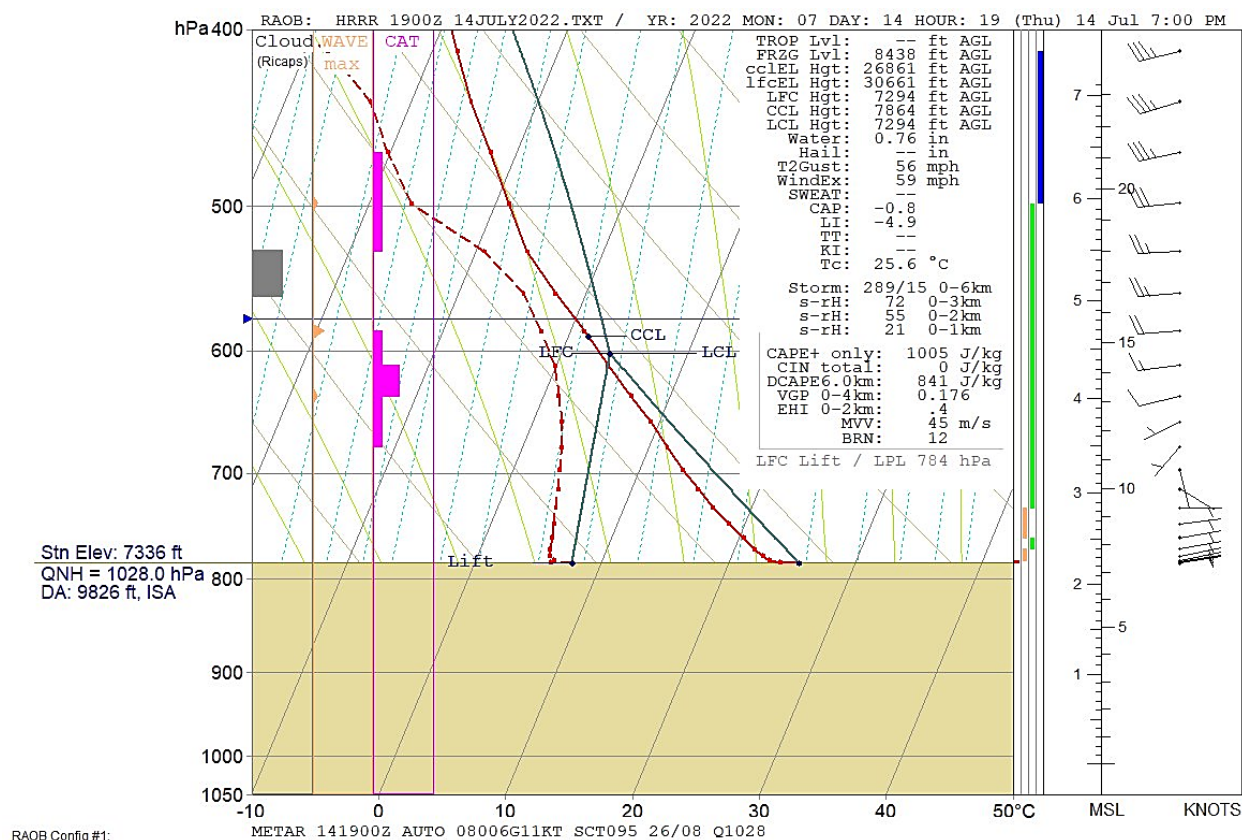


Figure 6 - HRRR numerical model sounding over the accident site for 1300 MDT.

¹⁰ The HRRR is a NOAA real-time three-kilometer resolution, hourly-updated, cloud-resolving, convection-allowing atmospheric model, initialized by three-kilometer grids with three-kilometer radar assimilation. Radar data is assimilated in the HRRR every 15 minutes over a one-hour period.

¹¹ Nearest grid point was at 44.44° N and -106.95° W.

¹² Skew T log P diagram - is a standard meteorological plot or thermodynamic diagram using temperature and the logarithmic of pressure as coordinates, used to display winds, temperature, dew point, and various indices used to define the vertical structure of the atmosphere.

¹³ RAOB -The Complete RAWinsonde OBservation program is an interactive sounding analysis program developed by Eosonde Research Services (ERS) previously known as Environmental Research Services, The Villages, Florida.

The HRRR sounding depicted an elevation of 7,336 ft over the grid point, with a near surface temperature of 25.6° C (78° F), a dew point temperature of 7.7° C (46° F), with a density altitude near 9,826 ft. The sounding depicted the lifted condensation level (LCL)¹⁴ and level of free convection (LFC)¹⁵ at 7,294 ft agl, with the convective condensation level (CCL)¹⁶ at 7,864 ft agl. The freezing level was at 8,438 ft agl (15,774 ft msl). The equilibrium height (based on CCL-EL) or expected cloud tops were estimated to 34,150 ft msl. The atmosphere was characterized as unstable with the Lifted Index (LI)¹⁷ of -4.9, and the Convective Available Potential Energy¹⁸ of 1,005 Joules/kilogram (J/kg), with the downdraft CAPE (DCAPE) of 841 J/kg, which supported the development of thunderstorms with potential outflow winds to about 50 knots and the threat of dry type microbursts¹⁹ due to dry low-level conditions. The sounding derived maximum vertical velocities (MVV) in potential convective updrafts was 45 meters/second or 90 knots. The sounding also supported strong thermals to approximately 18,000 ft with the estimated maximum lift of 757 feet per minute (fpm). The precipitable water content was 0.76 inches. The RAOB analysis program depicted the potential for scattered alto-cumulus clouds at 9,500 ft agl (16,625 ft msl), near the accident airplane cruising level.

The wind profile depicted an easterly wind from 080° at 6 knots from the surface through 8,000 ft, with winds veering to the west above 10,000 ft with increasing wind speeds. The wind at the accident airplane's cruising level of 18,500 ft was from 265° at 28 knots with a temperature of -7° C. The mean 0 to 6 kilometer (approximately 18,000 ft) wind was from 260° at 20 knots.

¹⁴ Lifted Condensation Level (LCL) - the level at which a lifted parcel becomes saturated. The LCL height corresponds to cloud base height for forced ascent.

¹⁵ Level of Free Convection (LFC) - the level where a parcel becomes buoyant, or "warmer" than the environmental temperature at the same level. The LFC represents the bottom of the layer containing CAPE.

¹⁶ Convective Condensation Level (CCL) - the level in the atmosphere to which an air parcel, if heated from below, will rise dry adiabatically, without becoming colder than its environment just before the parcel becomes saturated.

¹⁷ Lifted Index (LI) - A common measure of atmospheric instability. Its value is obtained by computing the temperature that air near the ground would have if it were lifted to 500-hPa or approximately 18,000 feet and comparing that temperature to the actual 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.

¹⁸ Convective Available Potential Energy (CAPE) - the integrated "positive area" in J/kg from the LFC to EL for the lifted parcel and is a measure of the amount of energy available for convection. CAPE is directly related to the maximum potential vertical speed within an updraft; thus, higher values indicate greater potential for severe weather.

¹⁹ Dry type microbursts arise from high based cumulus type clouds with a temperature-dew point spread of 20° C or more and occur with little to no precipitation reaching the surface, and often virga being observed aloft.

The HRRR parameters of height, pressure (Pres), temperature (T), dew point temperature (Td), relative humidity (RH), wind direction and speed, Clear Air Turbulence (CAT) intensity, Low-Level Wind Shear (LLWS) based on the vertical wind shear, icing, and mountain wave (Wave) potential below 25,000 ft was as follows. According to the flight track data during the last 29-seconds of flight the accident airplane descended from 17,450 ft to 14,500 ft by 1231:30 MDT.

Height (ft-msl)	Pres (hPa)	T (°C)	Td (°C)	RH (%)	Wind (deg/kts)	CAT (FAA)	LLWS (FAA)	Icing (AFGW)	Wave/x-W-Turb (nm fpm max)
7336	784	25.6	7.7	32	080/ 6				
7373	783	24.1	6.0	31	079/ 6				
7446	781	23.2	6.2	33	078/ 6				
7593	777	22.5	5.7	34	078/ 6				
7851	770	21.6	5.5	35	079/ 6				
8260	759	20.4	5.3	37	080/ 6				
8748	746	18.8	5.0	40	082/ 5				
9319	731	17.0	4.6	44	090/ 4				
9976	714	15.2	4.2	48	124/ 2				
10645	697	13.4	3.7	52	168/ 2				
11447	677	11.4	3.1	57	218/ 3	LGT			
12309	656	9.3	2.3	62	242/ 6	LGT			
13192	635	6.9	1.2	67	255/ 11	MDT			3.26 149 LIGHT
14228	611	4.1	-0.1	74	262/ 17	LGT			
15384	585	1.1	-2.3	78	265/ 22				7.30 488 LIGHT
16625	558	-2.4	-4.9	83	265/ 23				
18008	529	-6.0	-9.4	77	266/ 26	LGT			
19552	498	-9.0	-16.7	54	264/ 31	LGT			4.92 185 LIGHT
21176	467	-12.1	-20.2	51	257/ 34				
22776	438	-15.3	-23.2	51	252/ 34				
24345	411	-18.0	-28.2	40	255/ 34				

The RAOB analysis program indicated a 63% probability of light turbulence between the accident airplane's altitude range, with a 54% potential for light mountain wave conditions with a wavelength of 7.5 miles and with potential updrafts and downdrafts of 488 feet per minute (fpm) based on the RAOB's worst case scenario for mountain wave conditions.

A cross section over the general route of flight was created based on HRRR data from 1200 and 1300 MDT using the following points of Powel (KPOW), Greybull (KGEY), the accident site, and Buffalo (KBYG), WY, and is included as figure 7. The accident airplane's estimated flight profile has also been added with the enroute cruising altitude of 18,500 ft and descent to 13,475 ft at 1231 MDT. The profile depicted few to scattered clouds developing at the accident airplane's planned cruising altitude and descent to a lower altitude immediately prior to the accident.

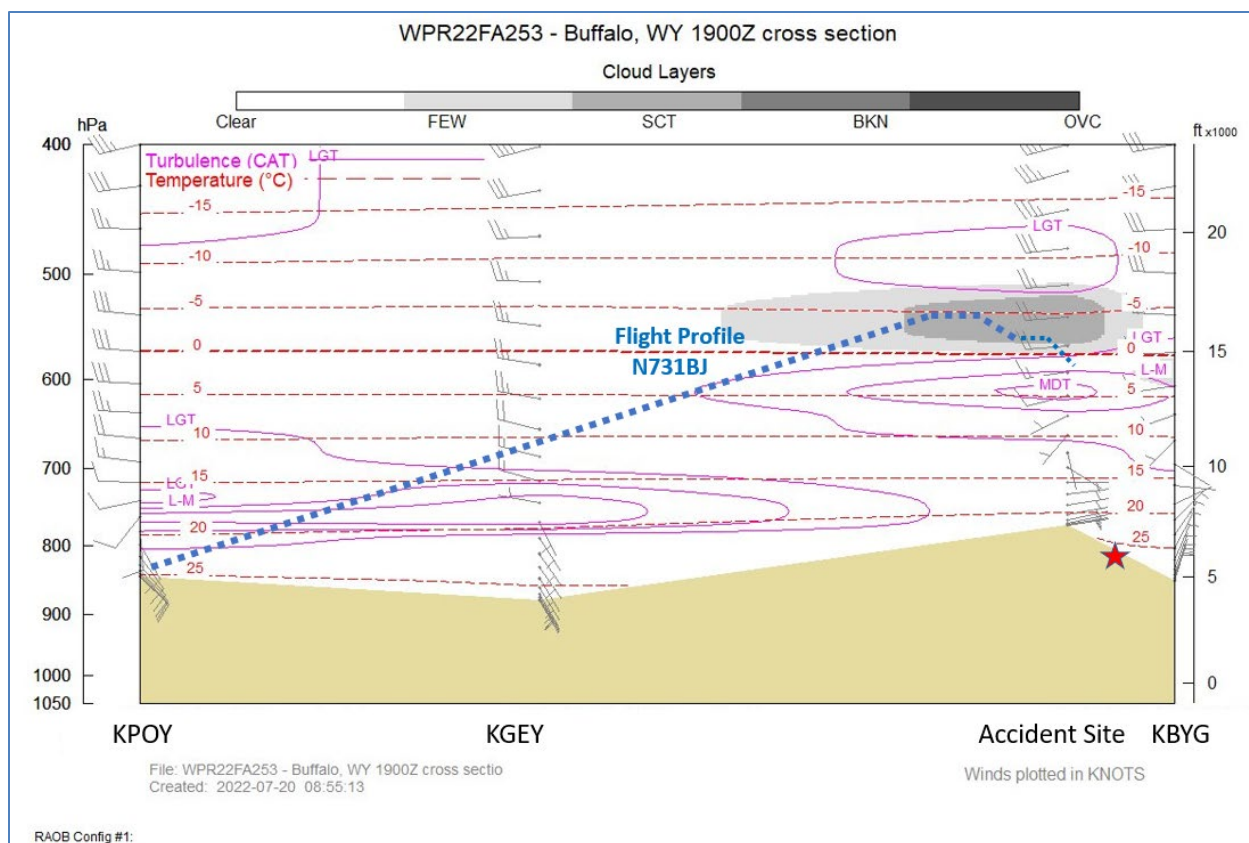


Figure 7 - Cross section along the general route of flight of N731BJ.

4.0 Satellite Imagery

The Geostationary Operational Environmental Satellite number 16 (GOES-16) imagery were obtained from an archive at the Space Science Engineering Center (SSEC) at the University of Wisconsin-Madison in Madison, Wisconsin, and processed using the Man-computer Interactive Data Access System (McIDAS) software. The infrared, water vapor, and visible imagery were reviewed surrounding the period, and the closest images to the accident time documented. The infrared long wave imagery (band 13) at a wavelength of 10.3 microns (μm) provided radiative cloud top temperatures with a nominal spatial resolution of 2 km. The visible (band 2) at a wavelength of 0.64 μm provided images at a resolution of 0.5 km.

Attachment 1 and 2 are the GOES-16 infrared and visible image animations between 1200 and 1300 MDT over Wyoming. Figures 8 and 9 are the GOES-16 infrared and visible imagery at 1231 MDT at 4X magnification which depicted an area of cumulus clouds over the eastern slopes of the Big Horn Mountains and in the vicinity of the accident site. The radiative cloud top temperatures in the vicinity of the accident site ranged to 253 Kelvin or -20°C , which corresponded to cloud tops near 26,000 ft based on the HRRR sounding. The clouds were moving to the east and did not remain

stationary (see attachment 1 and 2 for animation). The satellite imagery has not been corrected for any parallax error.

Figure 10 is a composite image of the GOES-16 visible imagery at 1221, 1226, and 1231 MDT at 4X magnification showing the development of the area of clouds in the immediate vicinity of the accident site. The image depicts clouds over the general route of flight during the last 5-minutes of flight, with the position at 1226 MDT immediately west of the cloud band.

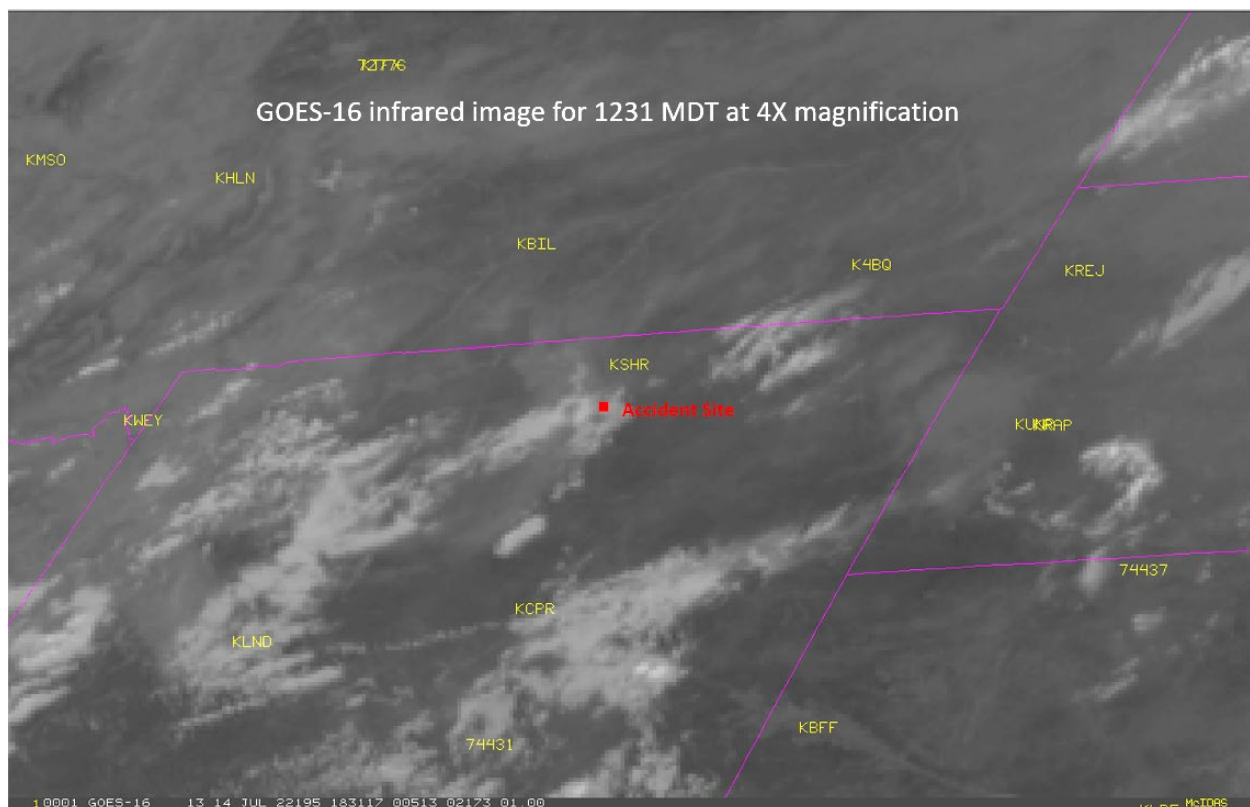


Figure 8 - GOES-16 infrared image for 1231 MDT at 4X magnification.

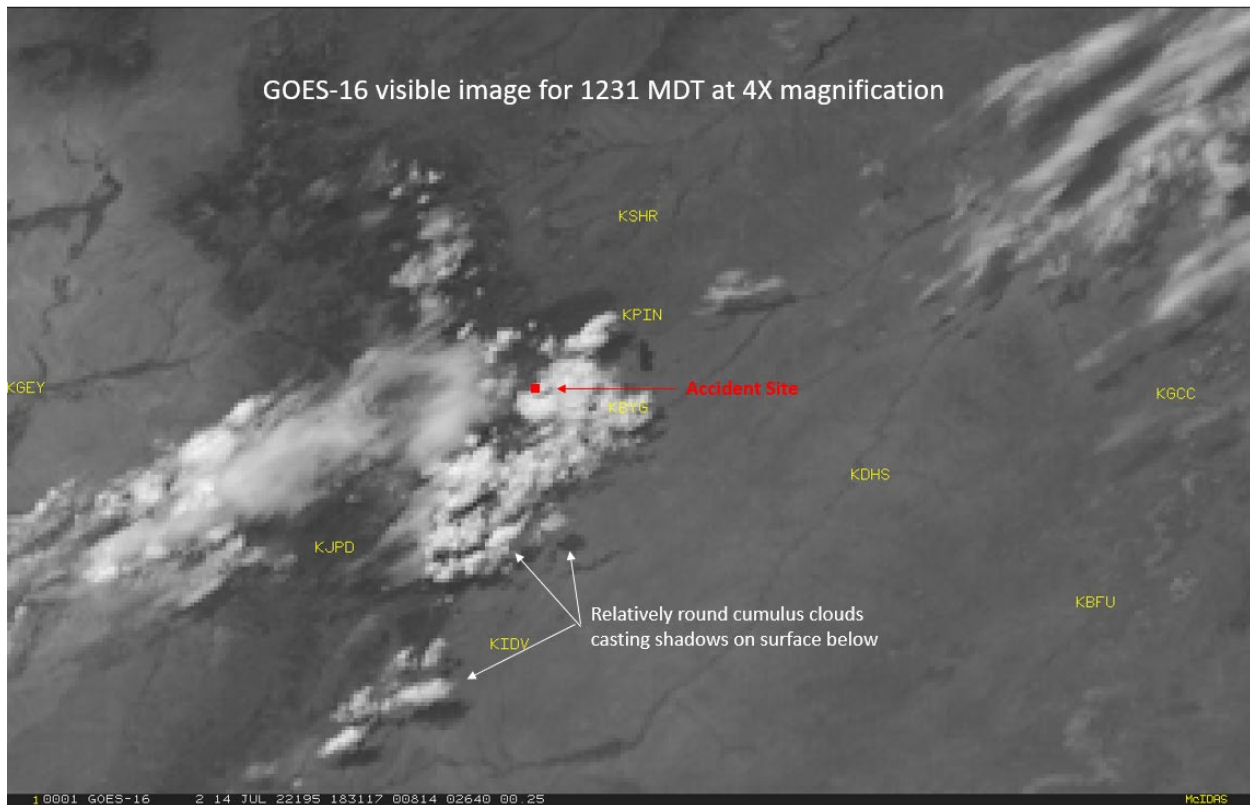


Figure 9 - GOES-16 visible image for 1231 MDT at 4X magnification.

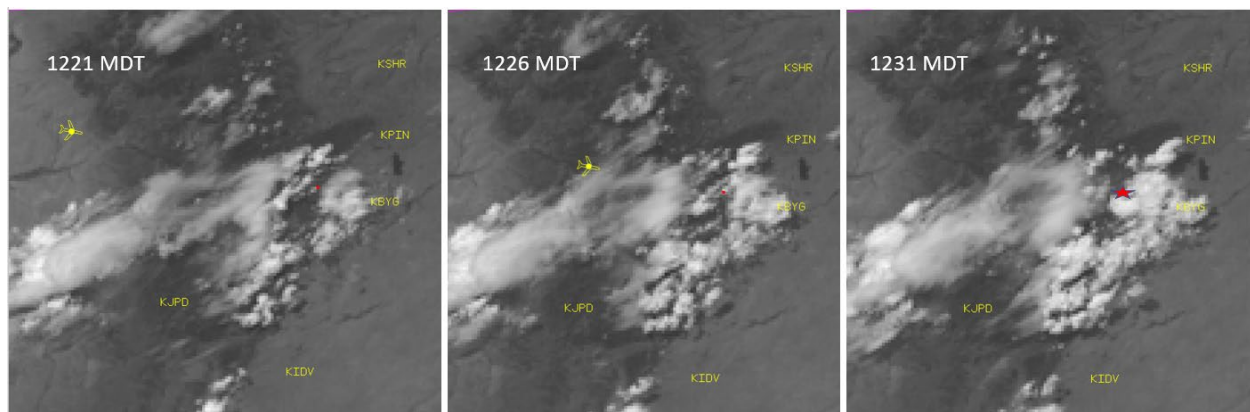


Figure 10 - GOES-16 visible images at 4X for 1221 (left), 1226 (middle), and 1231 MDT (right).

5.0 Weather Surveillance Radar

The closest NWS Weather Surveillance Radar 1988 Doppler (WSR-88D)²⁰ was from the Billings, MT (KBYX), Weather Forecast Office (WFO) located approximately 110

²⁰ The WSR-88D is a 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° beam width. The radar produces

miles northwest of the accident site. The level II archive data were obtained from the NCEI using the Hierarchical Data Storage System and displayed using the NWS NEXRAD Interactive Viewer and Data Exporter software. During the period the KBYX WSR-88D was operating in the standard clear air mode volume scanning pattern 35 (VCP-35) where the radar makes 9 different elevation scans during an 8 minute scan. Assuming standard refraction²¹ of the radar beam with the antenna height of 3,702 ft, the lowest 0.53° elevation scan was sampling the atmosphere between 12,360 through 23,440 ft, with the center of the beam near 17,900 ft over the accident site.

Reflectivity is the measure of the efficiency of a target in intercepting and returning radio energy. With hydrometeors²², it is a function of the drop size distribution, number of particles per unit volume, physical state (ice or water), shape, and aspect. Reflectivity is normally displayed in dBZ and is a general measure of echo intensity. The FAA Advisory Circular AC 00-24C - "Thunderstorm" defines echoes less than 30 dBZ as "light" in intensity, "moderate" echoes 30-40 dBZ, "heavy" with echoes of >40-50 dBZ, and "extreme" intensity with echoes above >50 dBZ. These are the new standard radio phraseology terms used by air traffic controllers to describe weather conditions to pilots as shown in figure 11.

Reflectivity (dBZ) Ranges	Weather Radar Echo Intensity Terminology
< 30 dBZ	Light
30-40 dBZ	Moderate
>40-50 dBZ	Heavy
>50 dBZ	Extreme

Figure 11 - Reflectivity and weather echo intensity terminology.

Figure 12 is the KBLX WSR-88D 0.53° base reflectivity image for 1232 MDT with a resolution of 0.5° x 0.25 km (0.13nm) over the area. The image depicted no significant echoes over the flight track, with an area of echoes of 5 to 35 dBZ or light to moderate intensity echoes approximately 10 miles south of the flight track. A separate search of lightning data from the FAA's Consolidated Storm Prediction for Aviation (CoSPA) display indicated that there were no cloud-to-ground lightning flashes recorded between 1130 through 1255 MDT with this area of echoes²³. The CoSPA imagery

three basic types of products reflectivity, radial velocity, and spectral width.

²¹ Standard refraction implies a standard atmosphere with no ducting or bending of the radar beam due to any inversions or isothermal layers.

²² Hydrometeors are any product of condensation or sublimation of atmospheric water vapor, whether formed in the free atmosphere or at the earth's surface. 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.

²³ Lightning was detected between 1345 and 1410 MDT in the vicinity of KBYG as the echoes moved eastward and developed into a cumulonimbus cloud.

depicted the maximum echo tops near 29,000 ft on the southwest portion of the echo at 1230 MDT.

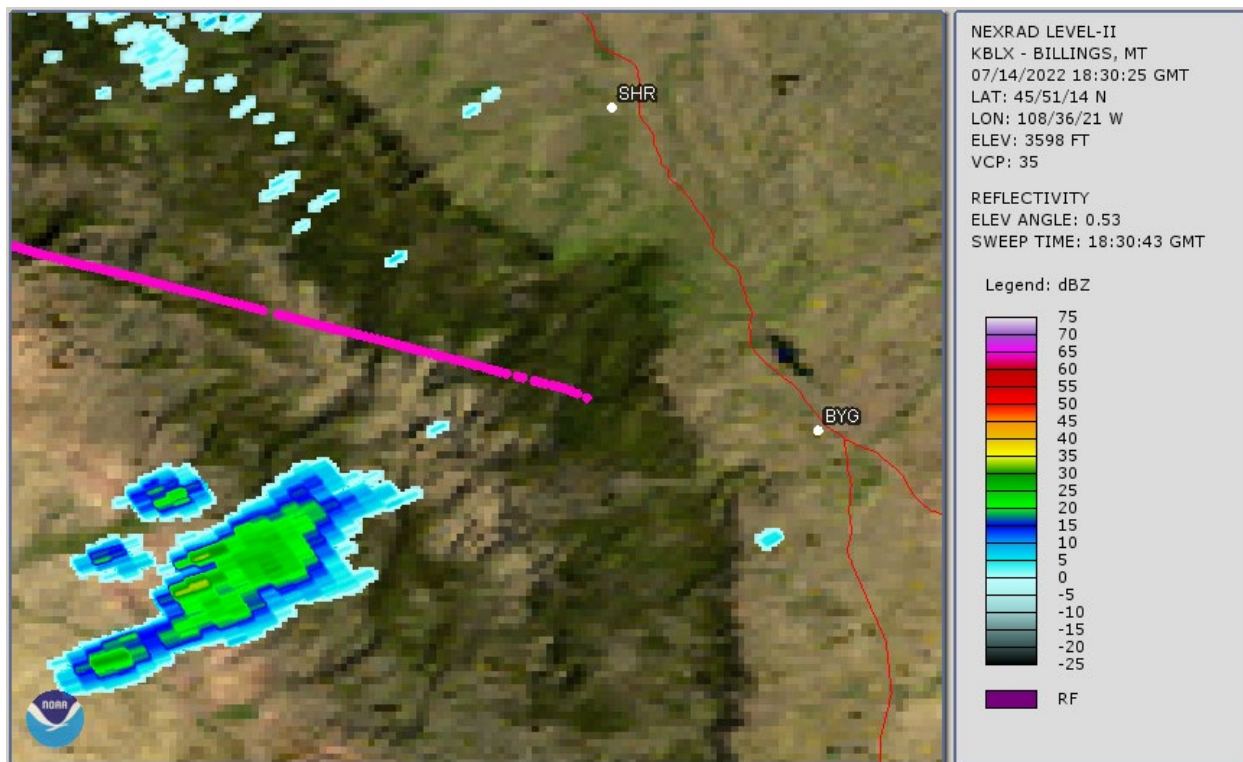


Figure 12 - KBLX WSR-88D 0.53° base reflectivity image for 1230 MDT with the flight track of N731BJ overlaid in magenta.

6.0 Pilot Reports

A search of pilot reports or PIREPs between 0900 through 1600 MDT resulted in no recorded reports in the national database within 120 miles of the accident site.

7.0 NWS Forecasts

The NWS Riverton, WY (KRIW) Weather Forecast Office (WFO) was responsible for issuing Terminal Aerodrome Forecasts (TAFs), local weather advisories and warnings for the area, while the NWS AWC and WPC were responsible for the aviation products and advisories. The following advisories were issued surrounding the period.

7.1 Terminal Aerodrome Forecast

The closest TAF to the accident site was issued for KSHR. While a TAF is only valid for a 5-mile radius around the airport center point, it often provides a breakdown in

wind, visibility, weather, and clouds than other forecasts, and is often used by pilots for a route analysis of weather along the general route of flight. The forecast issued at 1124 MDT and valid for a 24-hour period was as follows, with the bold section highlighting the forecast relevant at the time of the accident.

TAF KSHR 141724Z 1418/1518 08004KT P6SM FEW150

FM142200 36023G35KT P6SM VCTS FEW090CB SCT120

FM150100 19007KT P6SM FEW100

FM151500 09005KT P6SM FEW120=

The forecast for KSHR expected from 1200 through 1600 MDT, wind from 080° at 4 knots, visibility better than 6 miles, a few clouds at 15,000 ft agl. From 1600 through 1900 MDT wind from 360° at 23 knots gusting to 35 knots, visibility better than 6 miles with thunderstorms in the vicinity, a few cumulonimbus clouds at 9,000 ft agl, scattered clouds at 12,000 ft agl.

7.2 Area Forecast Discussion

The NWS Area Forecast Discussions (AFD) are issued by each WFO to describe the short-term weather conditions within their region with an aviation section that includes the general conditions as it relates to the creation of the TAF. These are useful for additional aviation-related issues that cannot be encoded into the TAF and provide some reasoning behind the forecast. These are generated roughly every 6 hours and corresponds to the release of the latest TAFs for that office. The NWS KRIW issued the AFD at 1123 MDT and was as follows. The long term and fire weather forecast sections have been excluded in this case review.

FXUS65 KRIW 141723

AFDRIW

Area Forecast Discussion

National Weather Service Riverton WY

1123 AM MDT Thu Jul 14, 2022

.SHORT TERM...(Today through Friday)

Issued at 258 AM MDT Thu Jul 14, 2022

Moisture continues to stream into Wyoming from Utah and Idaho this morning, with a handful of showers lingering across the area. This activity will increase by early afternoon as the next weak shortwave arrives. Scattered showers and thunderstorms are likely across the area, with the best chances for stronger storms across the west and north where better instability and lift will set up. With a warm and dry surface, the primary threat with convection today will again be gusty outflow winds. This activity will last through the evening, decreasing around midnight. Similar conditions are expected Friday, although models have been showing an early round of showers pushing into southern Wyoming before noon. PWAT values will be higher Friday, which may translate to slightly more of the area seeing a wetting rain. Once again though, the more widespread impact

from this activity will likely be gusty winds. Temperatures will continue to peak above normal for most locations, or generally in the 90s or warmer east and upper 80s west.

*.AVIATION...18Z/Wednesday Issuance
Issued at 1123 AM MDT Thu Jul 14, 2022.*

Another round of convection again this afternoon and evening. All terminals to be VFR with the primary hazard 30-40kt outflow wind. The strongest storms could produce a brief period of MVFR visibility between 21Z/Thursday and 01Z/Friday. Convection continues an eastward trek early in the evening with KCPR seeing the best chance for impacts after 00Z/Friday. Moisture fetch rotating north around a Four Corners high keeps light showers ongoing across the south overnight. A shortwave within this flow is likely to initiate convection over far southern Wyoming just prior to 18Z/Friday.

Please see the Aviation Weather Center and/or CWSU ZDV and ZLC for the latest information on icing and turbulence forecasts.

*.RIW WATCHES/WARNINGS/ADVISORIES...
NONE.*

*SHORT TERM...Myers
AVIATION...CNJ*

7.3 Graphic Forecast for Aviation

The NWS Graphic Forecast for Aviation (GFA) a graphical depiction of surface wind, thunderstorms, precipitation, color coded general flight categories, and cloud cover bases and tops, from graphical output from the NWS's National Digital Forecast Data (NDFD) with the Graphic-Airmen's Meteorological Information (G-AIRMET) for IFR conditions, mountain obscuration, icing conditions, and strong surface wind overlaid for the enroute phase of flight. The GFA is available at the NWS AWC website and through other weather briefing services (Leidos and ForeFlight). The 3-hour GFA static image charts issued around 1000 MDT for the northwestern United States and valid for 1200 MDT are included as figures 13 and 14 with the approximate accident site marked by the red star.

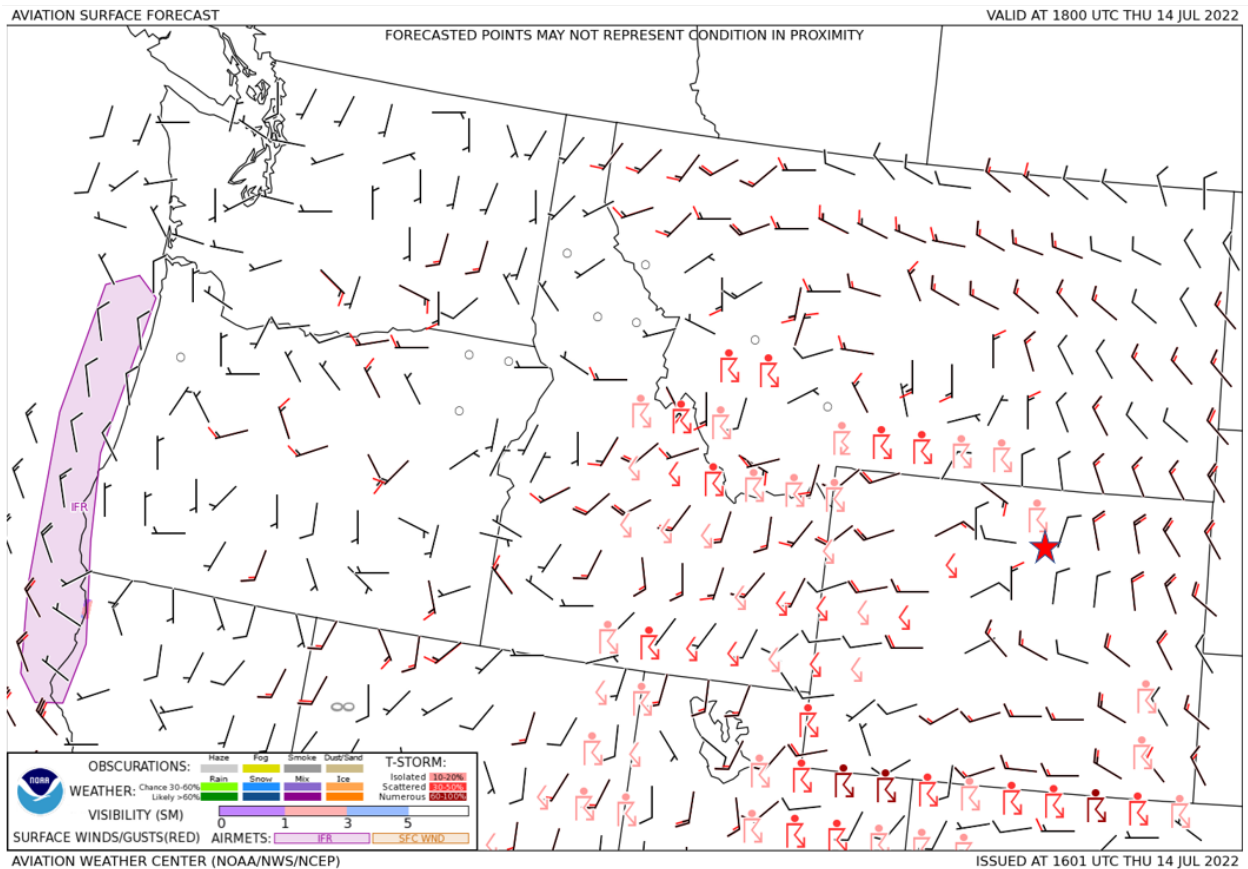


Figure 13 - Graphic Forecast for Aviation Surface Forecast valid for 1200 MDT.

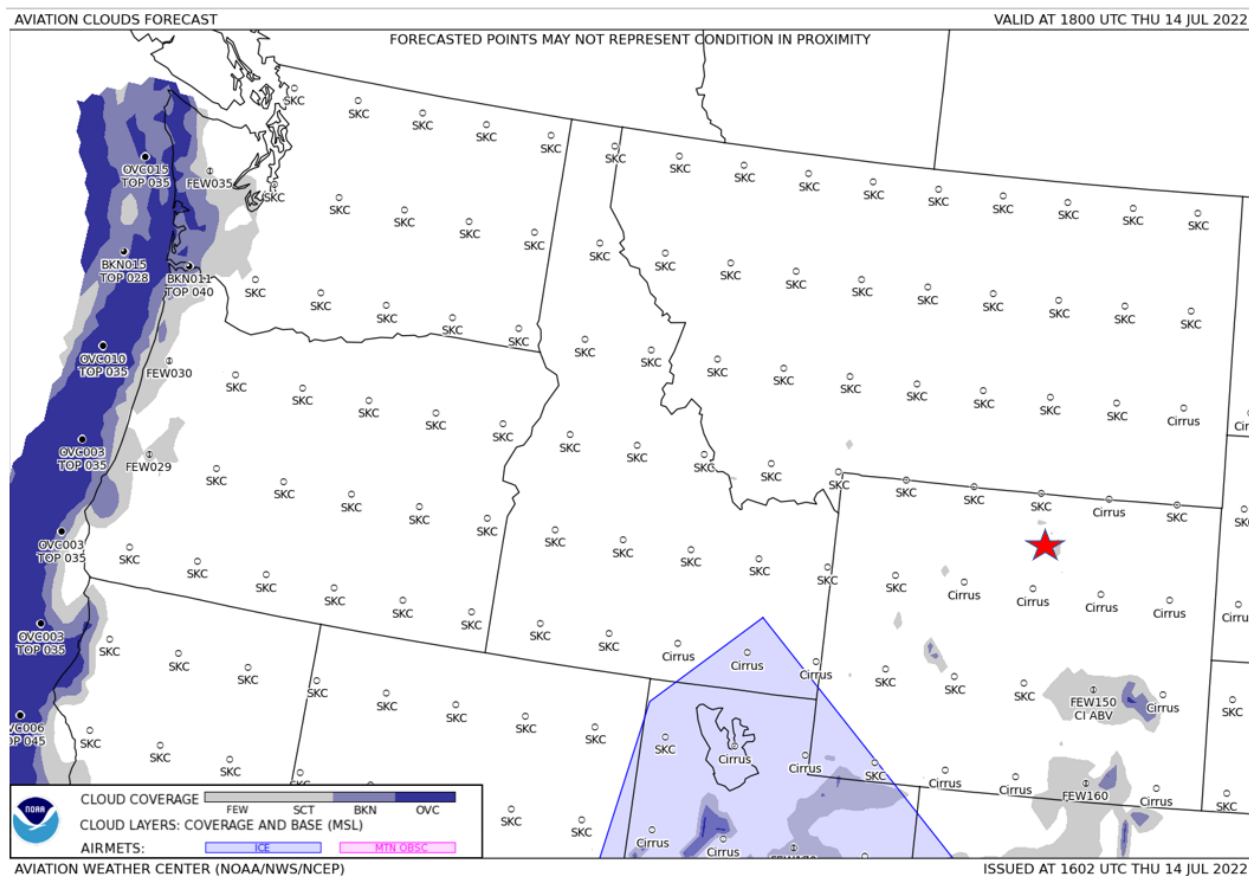


Figure 14 - Graphic Forecast for Aviation Cloud Forecast valid for 1200 MDT.

The GFA surface forecast expected winds from the north at 10 knots, visibility unrestricted with a chance of thunderstorms. While the GFA cloud forecast expected a few to general clear skies over the general route of flight. No G-AIRMETs extended over the general route of flight for IFR, mountain obscuration, strong surface winds or icing conditions.

7.4 Winds and Temperature Aloft Forecast

The Winds and Temperature Aloft Forecast (FD)²⁴ issued at 0800 MDT and for use between 0800 and 1500 MDT were as follows.

FBUS31 KWN0 141400

FD1US1

-DATA BASED ON 141200Z

VALID 141800Z FOR USE 1400-2100Z. TEMPS NEG ABV 24000

FT	3000	6000	9000	12000	18000	24000	30000	34000	39000
-DLH	1311	1912+12	2408+09	3114+06	3324-09	3242-20	324636	335846	346355

²⁴ Based on the FBUS33 KWN0 forecast bulletin.

-BIL	9900	2611+17 2623+09 2633-09 2639-21 255636 256943 256750
-CZI		0109+18 3208+11 2515-08 2428-20 264033 264642 264752
-RAP	3422+22	3215+17 2714+10 2626-07 2719-18 273834 284143 284252

The closest station to the accident site was from Crazy Women VORTAC²⁵, WY. The first forecast level was for 9,000 ft which expected a wind from 010° at 9 knots with a temperature of 18° C, at 12,000 ft the wind was from 320° at 8 knots with a temperature of 11° C, and at 18,000 ft from 250° at 15 knots with a temperature of -8° C.

8.0 NWS Inflight Weather Advisories

Inflight Aviation Weather Advisories are forecasts to advise en route aircraft of development of potentially hazardous weather. Inflight aviation weather advisories in the conterminous U.S. are issued by the NWS AWC, as well as from the Center Weather Service Units (CWSU) associated with FAA air route traffic control centers (ARTCCs). There are four basic types of inflight aviation weather advisories: the Significant Meteorological Information (SIGMET), the Convective SIGMET, the Airmen's Meteorological Information (AIRMET), and the Center Weather Advisory (CWA). Inflight 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.

A review of the NWS database indicated that there were no Convective SIGMETs, SIGMETs, CWA, or AIRMETs current over the route of flight or over the accident site surrounding the period.

9.0 Preflight Weather Briefing

The FAA contract Automated Flight Service Station provider Leidos indicated that they and no 3rd party vendors utilizing the Lockheed Flight Service System had any contact with the N731BJ on the day of the accident. A separate search of ForeFlight indicated that the pilot of N731BJ had an active account and his app was in use prior to the accident, but no weather briefings or other weather graphics were generated on the day of the accident. Prior to the flight the following routes were entered into the app.

²⁵ VORTAC - is a VHF Omni-directional Range and Tactical Air Navigation that provides azimuth and range information.

<u>Date</u>	<u>Time (UTC)</u>	<u>Flight Routes</u>
7/14/2022	16:04:14	Red Lodge (KRED), MT to Lincoln (KLNK), NE
7/14/2022	13:04:49	Powell (POY), WY to KLNK to Mount Vernon (KMVN) IL to Cannon (18A), GA
7/14/2022	13:04:25	POY to KLNK to 18A
7/14/2022	13:04:12	POY to 18A
7/14/2022	1:13:48	KRED to Denver (KDEN), CO

The route strings created do not generate a weather briefing, but may provide some airport data, METAR, TAF, and notice to airmen information. It also does not provide the synoptic conditions, enroute forecast and advisories necessary for a typical weather briefing. Therefore, it is unknown what weather information the pilot may have used to familiarize himself for the flight.

10.0 Witnesses

There were no witnesses to the accident sequence. The aircraft's burned wreckage was found by fire crews about 1400 MDT, who had received calls about a possible wildfire within the rugged mountain terrain.

11.0 Astronomical Conditions

The astronomical conditions were obtained from the United States Naval Observatory's website for the accident site coordinates. The time of the accident has been added for reference in **italic bold** type.

<u>Sun</u>	<u>Time (MDT)</u>
Begin civil twilight	0501
Sunrise	0537
<i>Accident</i>	<i>1231</i>
Culmination	1314
Sunset	2050
End civil twilight	2126

At the approximate time of the accident the sun was about 65° above the horizon at an azimuth of 155°.

F. LIST OF ATTACHMENTS

Attachment 1 - Animation of GOES-16 infrared satellite imagery

Attachment 2 - Animation of GOES-16 visible satellite imagery

Submitted by:

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