NATIONAL TRANSPORTATION SAFETY BOARD

Office of Aviation Safety
Washington, D.C. 20594

March 28, 2018

Weather Study

METEOROLOGY

WPR17LA202

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A. ACCIDENT

Location: Near Roy, Utah
Date: September 12, 2017
Time: 1337 mountain daylight time
1937 Coordinated Universal Time (UTC)
Airplane: Beech A24R, Registration: N9798L

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 the NTSB's Washington D.C. office and from official National Oceanic and Atmospheric Administration (NOAA) National Weather Service (NWS) sources including the National Centers for Environmental Information (NCEI). All times are mountain daylight time (MDT) on September 12, 2017, and are based upon the 24-hour clock, where local time is -6 hours from UTC, and UTC=Z (unless otherwise noted). Directions are referenced to true north and distances in nautical miles. Heights are above mean sea level (msl) unless otherwise noted. Visibility is in statute miles and fractions of statute miles.

The accident site was located at latitude 41.2096° N, longitude 112.0262° W, at an approximate elevation of 4,300 feet (ft).

D. WEATHER INFORMATION

1.0 Synoptic Situation

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

[1] https://www.faa.gov/regulations_policies/advisory_circulars/index.cfm/go/document.information/documentID/1030

1.1 Surface Analysis Chart

The western 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 with the red circle. The chart depicted a surface trough[2] located just west of the accident site stretching from central Utah northwestward into southern Idaho and eastern Oregon. A surface low pressure center with a pressure of 1014-hectopascals (hPa) was located in central Idaho and was connected to the surface trough. Another surface low pressure center was located in southeastern Utah with a pressure of 1013-hPa. Four surface high pressure centers were located near the accident site. One surface high pressure center was located in eastern Nevada with a pressure of 1018-hPa, one surface high pressure center was located northern Arizona with a pressure of 1018-hPa, another surface pressure center was located in western Colorado with a pressure of 1022-hPa, and the final surface high pressure center was located in western Wyoming with a pressure of 1020-hPa. The station models around the accident site depicted air temperatures in the mid 70's to mid 80's degrees Fahrenheit (°F), with temperature-dew point spreads of 23° F or more, a light and variable wind at 5 knots, and clear skies. Surface troughs can act as lifting mechanisms where enhanced lift, gusty winds, clouds, and precipitation can occur if sufficient moisture is present.

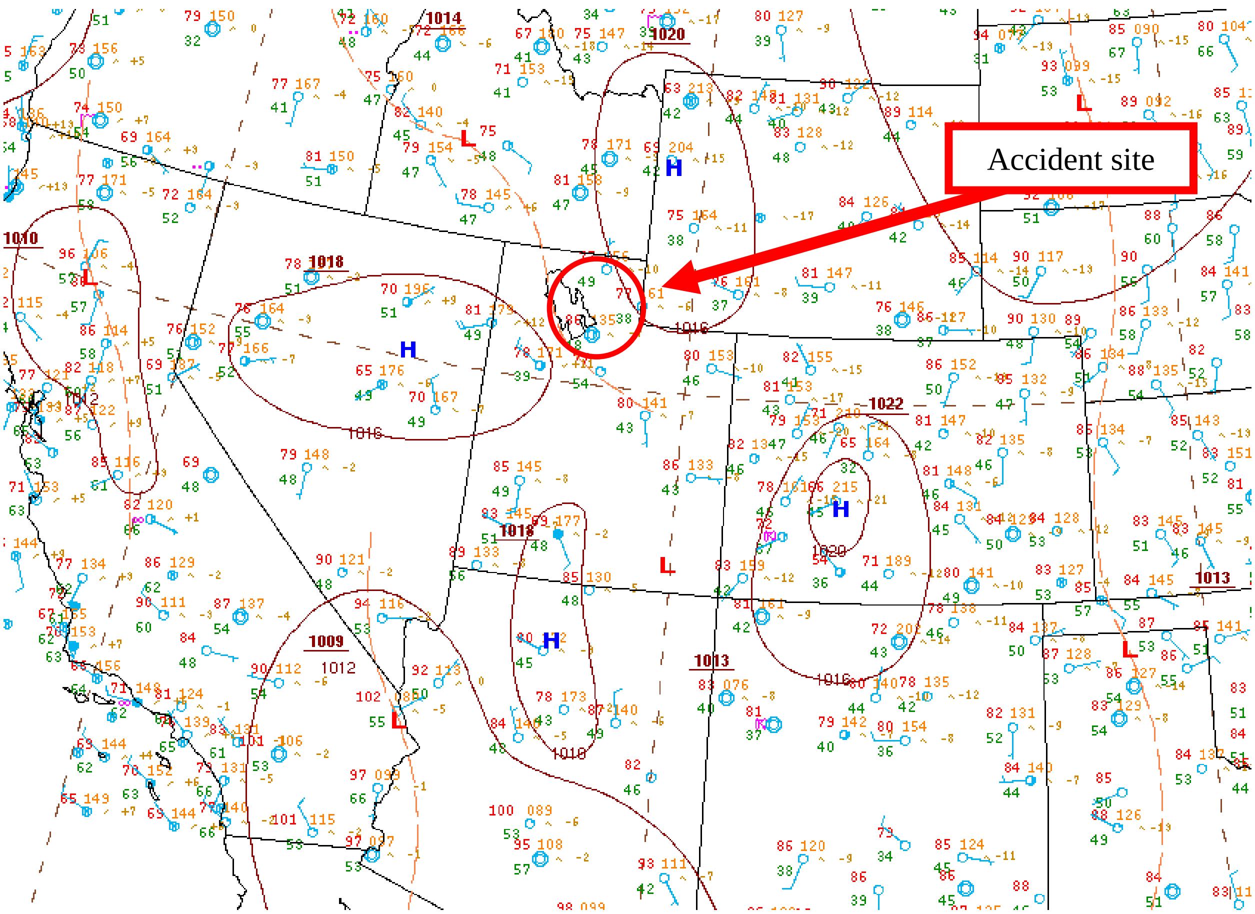

Figure 1 – NWS Surface Analysis Chart for 1200 MDT

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

1.2 Upper Air Charts

The NWS Storm Prediction Center (SPC) Constant Pressure Charts for 1800 MDT at 850-, 700-, 500-, and 300-hPa are presented in figures 2 through 5. The charts did not indicate any consistent mid- or upper-troughs or ridges[3] near the accident site at 1800 MDT. There was a northerly wind of 15 knots at 850-hPa (figure 2) with the wind becoming westerly by 700-hPa (figure 3) with a wind speed of 10 knots. The westerly wind at 700-hPa became southwesterly by 300-hPa with the wind magnitude at 20 knots at 300-hPa (figures 4 and 5).

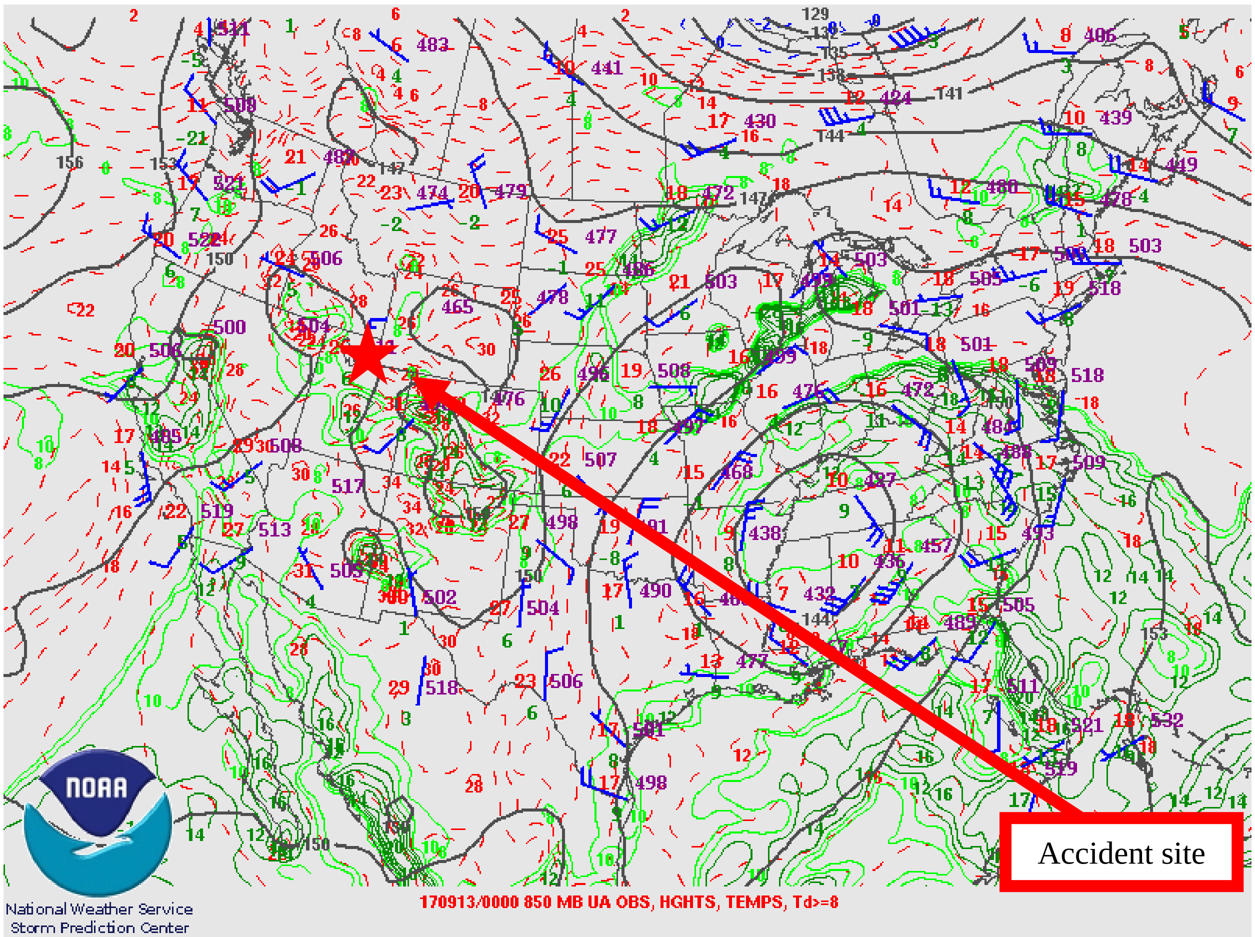

Figure 2 – 850-hPa Constant Pressure Chart for 1800 MDT

[3] Ridge – An elongated area of relatively high atmospheric pressure or heights.

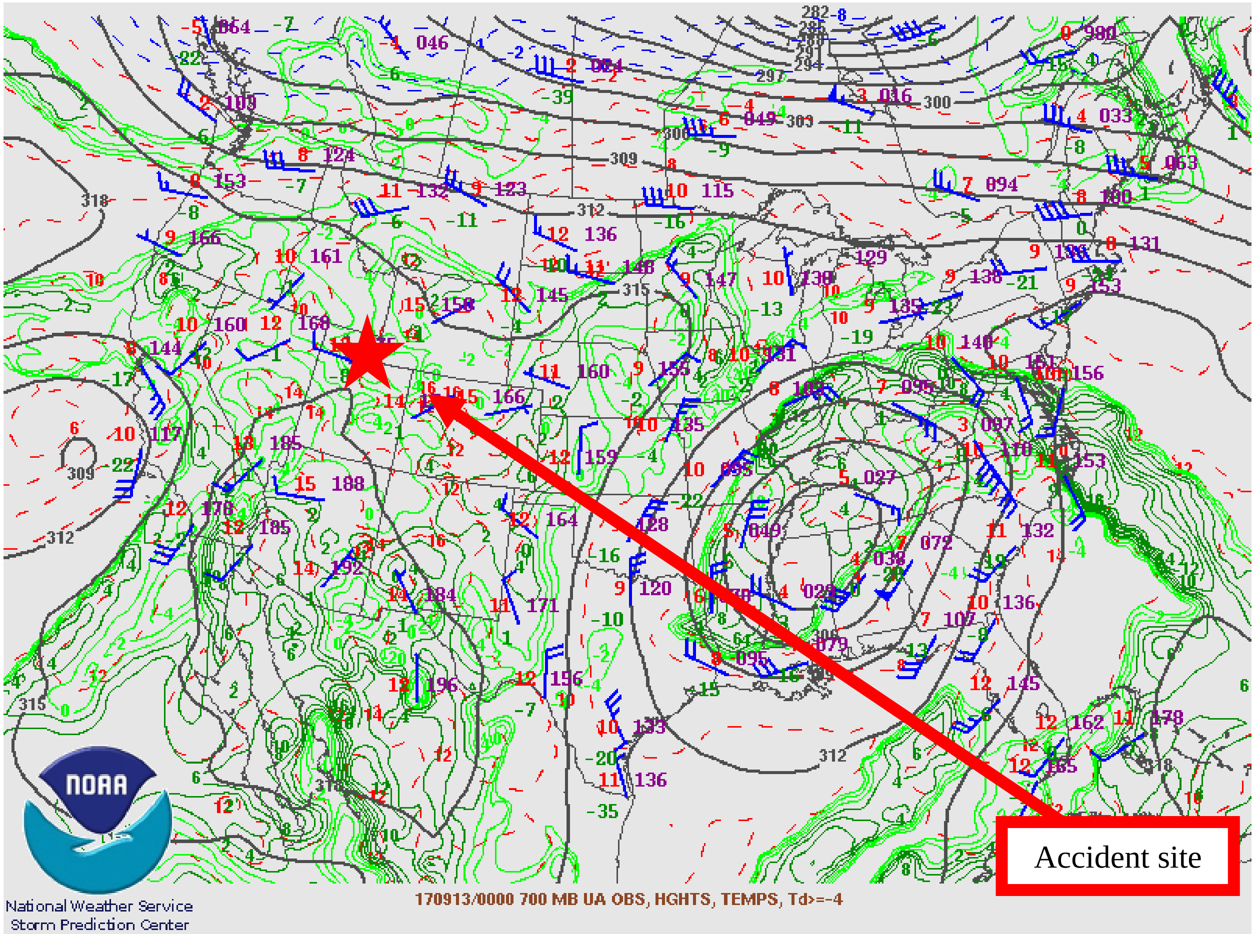

Figure 3 – 700-hPa Constant Pressure Chart for 1800 MDT

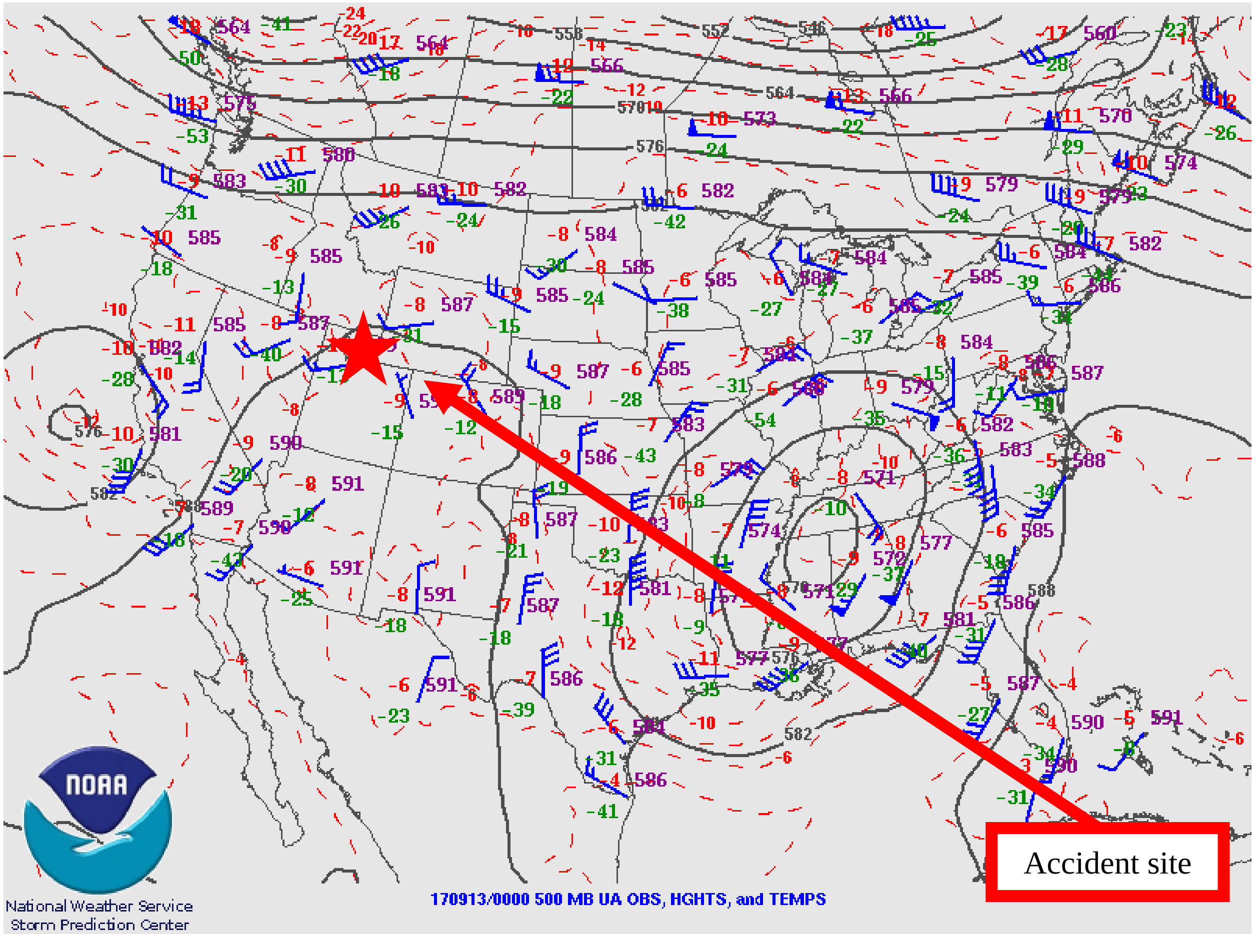

Figure 4 – 500-hPa Constant Pressure Chart for 1800 MDT

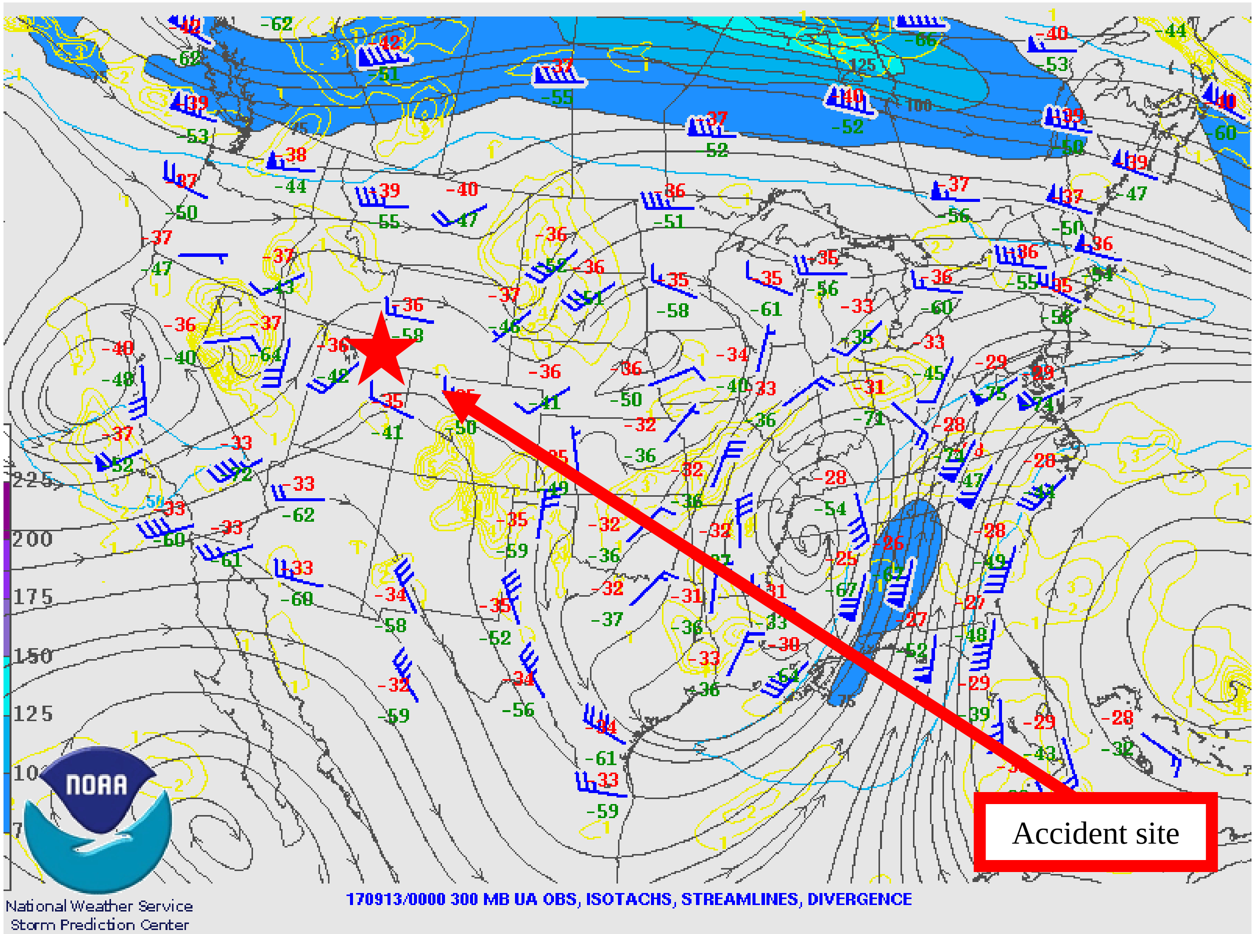

Figure 5 – 300-hPa Constant Pressure Chart for 1800 MDT

2.0 SPC Products

The SPC issued the following Day 1 Convective Outlook at 1018 MDT (figure 6) with areas of general thunderstorms forecast for the accident site during the afternoon hours of September 12. These thunderstorm chances were normal compared to climatology, given that on a normal September day a chance of general thunderstorms would be forecast for the accident area:

SPC AC 121618

Day 1 Convective Outlook
NWS Storm Prediction Center Norman OK
1118 AM CDT Tue Sep 12 2017

Valid 121630Z - 131200Z

...THERE IS A MARGINAL RISK OF SEVERE THUNDERSTORMS OVER PARTS OF CENTRAL CA THIS AFTERNOON AND EVENING...

...SUMMARY...
Isolated damaging gusts are possible from thunderstorms over parts of central California this afternoon and early evening.

...Central CA...
Morning visible satellite imagery shows mostly clear skies across central CA, where dewpoints are in the upper 50s to lower 60s. Strong heating will result in afternoon temperatures in the 90s and steep low-level lapse rates. Forecast soundings suggest rather weak CAPE profiles, but sufficient near favorable terrain for a few afternoon and evening thunderstorms. Relatively strong southerly winds aloft will yield 30-40 knots of effective shear, supporting some rotation in the strongest cells. This will pose some risk of gusty winds or small hail in the strongest cells. Convective coverage is likely to be sparse, but the time period with the greater risk of strong storms would be roughly 23-04z.

...Coastal NC...
A few showers or occasional thunderstorms continue to affect coastal NC today. Local VAD profiles indicate the presence of moderately strong low-level vertical shear in this region, and dewpoints in the low/mid 70s suggest at least some surface-based instability. This suggests that brief rotation in a few cells is possible. However, given the continued weakening wind fields with time and consistent CAM solutions of a lessening threat, the risk of tornadoes is deemed low enough to continue with less than 2% probabilities.

..Hart/Smith/Karstens.. 09/12/2017

CLICK TO GET WUUS01 PTSDY1 PRODUCT

NOTE: THE NEXT DAY 1 OUTLOOK IS SCHEDULED BY 2000Z

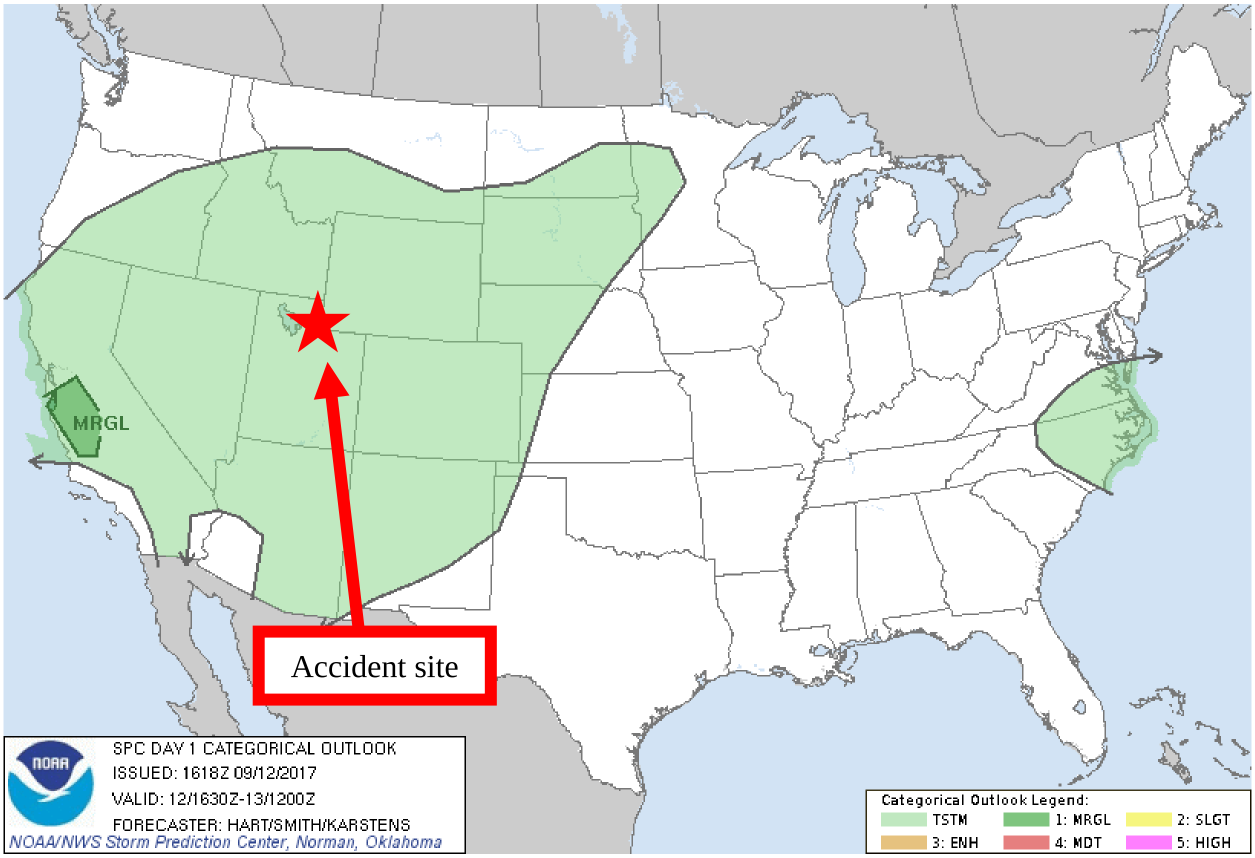

Figure 6 – SPC day 1 Convective Outlook valid at the time of the accident

3.0 Surface Observations

The area surrounding the accident site was documented using official Meteorological Aerodrome Reports (METARs) and Specials (SPECIs). Figure 7 is a sectional map of the region with the accident site and the closest weather reporting locations marked.

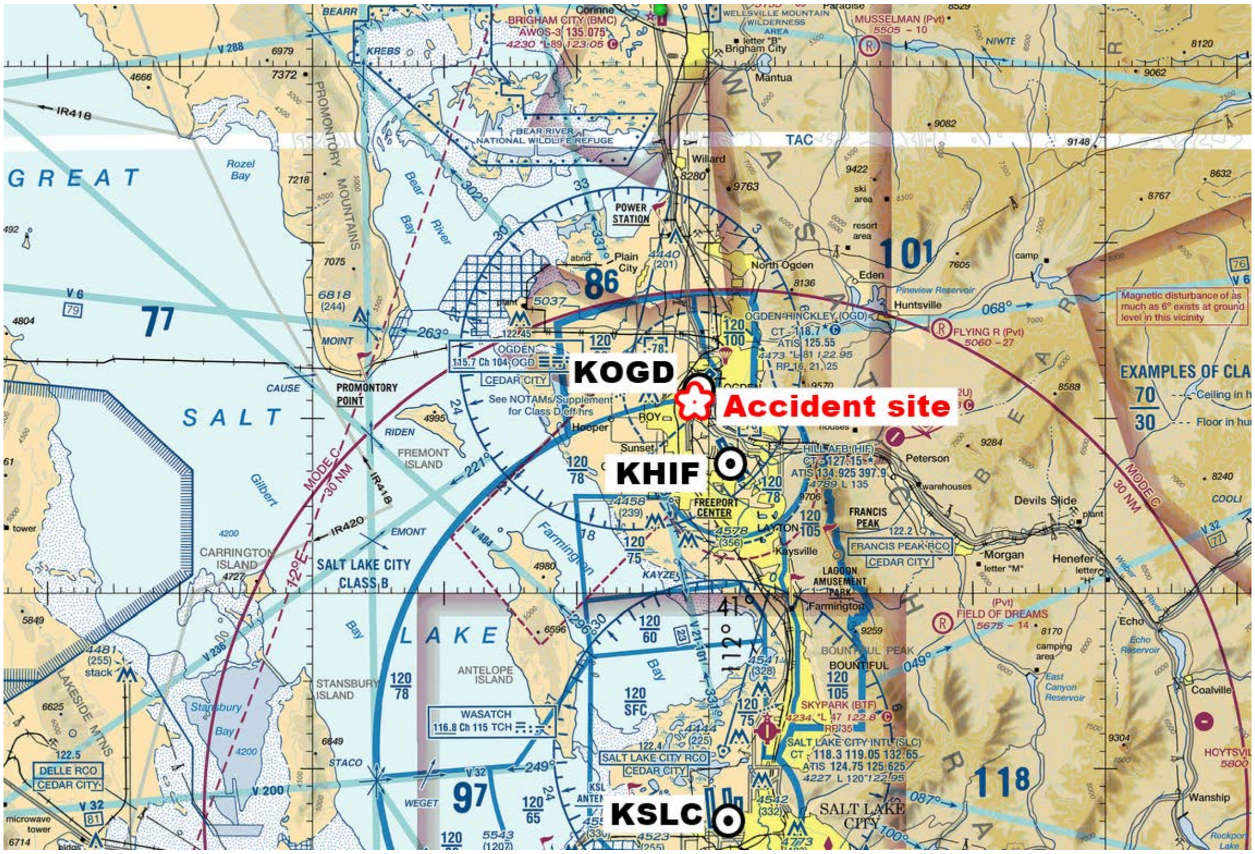

Figure 7 – Sectional Chart with the location of the accident site and surface observation sites

Ogden-Hinckley Airport (KOGD) was the closest airport with official weather observations and was located 3 miles southwest of Ogden, Utah. KOGD had an Automated Surface Observing System (ASOS[4]) whose reports were supplemented by air traffic control (ATC) when ATC was logged on to the system. KOGD air traffic control tower was Limited Aviation Weather Reporting Station (LAWRS) certified. KOGD was located 1 mile southwest of the accident site, at an elevation of 4,473 ft, and had a 14° easterly magnetic variation[5] (figure 7). The following observations were taken and disseminated during the times surrounding the accident:[6]

[0753 MDT] METAR KOGD 121353Z 17008KT 10SM CLR 18/07 A3014 RMK AO2 SLP151 T01780067=

[0853 MDT] METAR KOGD 121453Z 18006KT 10SM CLR 21/07 A3014 RMK AO2 SLP152 T02060072 53003=

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[4] ASOS – Automated Surface Observing Systems are equipped with meteorological instruments to observe and report wind, visibility, ceiling, temperature, dewpoint, altimeter, and barometric pressure.

[5] Magnetic variation – The angle (at a particular location) between magnetic north and true north. 1985, latest measurement taken from http://airnav.com/airport/KOGD

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

[0953 MDT] METAR KOGD 121553Z 00000KT 10SM CLR 24/08 A3014 RMK AO2 SLP150 T02390078=

[1053 MDT] METAR KOGD 121653Z 02008KT 10SM CLR 27/07 A3014 RMK AO2 SLP145 T02720072=

[1153 MDT] METAR KOGD 121753Z VRB04KT 10SM CLR 28/07 A3013 RMK AO2 SLP142 T02830072 10283 20172 58003=

[1253 MDT] METAR KOGD 121853Z VRB03KT 10SM CLR 30/08 A3011 RMK AO2 SLP134 T03000083=

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[1353 MDT] METAR KOGD 121953Z 25014G19KT 10SM CLR 31/09 A3012 RMK AO2 SLP137 T03060089=

[1411 MDT] SPECI KOGD 122011Z 27016G22KT 10SM CLR 29/09 A3013 RMK AO2 T02940094=

[1443 MDT] SPECI KOGD 122043Z 26009KT 10SM CLR 29/07 A3012 RMK AO2 T02940072=

[1453 MDT] METAR KOGD 122053Z 25013G19KT 10SM CLR 28/08 A3012 RMK AO2 SLP142 T02830078 55003=

KOGD weather at 1153 MDT, variable wind at 4 knots, 10 miles visibility or greater, clear skies below 12,000 ft above ground level (agl), temperature of 28° Celsius (C), dew point temperature of 7° C, and an altimeter setting of 30.13 inches of mercury. Remarks: automated station with a precipitation discriminator, sea level pressure 1014.2 hPa, temperature of 28.3° C, dew point temperature of 7.2° C, 6-hourly maximum temperature of 28.3 C, 6-hourly minimum temperature of 17.2 C, 3-hourly pressure decrease of 0.3 hPa.

KOGD weather at 1253 MDT, variable wind at 3 knots, 10 miles visibility or greater, clear skies below 12,000 ft agl, temperature of 30° C, dew point temperature of 8° C, and altimeter setting of 30.11 inches of mercury. Remarks: automated station with a precipitation discriminator, sea level pressure 1013.4 hPa, temperature 30.0° C, dew point temperature 8.3° C.

KOGD weather at 1353 MDT, wind from 250° at 14 knots with gusts to 19 knots, 10 miles visibility or greater, clear skies below 12,000 ft agl, temperature of 31° C, dew point temperature of 9° C, and altimeter setting of 30.12 inches of mercury. Remarks: automated station with a precipitation discriminator, sea level pressure 1013.7 hPa, temperature 30.6° C, dew point temperature 8.9° C.

KOGD weather at 1411 MDT, wind from 270° at 16 knots with gusts to 22 knots, 10 miles visibility or greater, clear skies below 12,000 ft agl, temperature of 29° C, dew point temperature of 9° C, and altimeter setting of 30.13 inches of mercury. Remarks: automated station with a precipitation discriminator, temperature 29.4° C, dew point temperature 9.4° C.

Hill Air Force Base (KHIF) was the next closest airport with official weather observations and was located 6 miles south of Ogden, Utah. KHIF was located 6 miles southeast of the accident site, at an elevation of 4,789 ft, and had a 14° easterly magnetic variation[7] (figure 7). The following observations were taken and disseminated during the times surrounding the accident:

[0658 MDT] METAR KHIF 121258Z AUTO 11013KT 10SM CLR 18/06 A3016 RMK AO2 SLPNO T01750057 $=

[0758 MDT] METAR KHIF 121358Z 11016KT 10SM CLR 17/06 A3016 RMK AO2A SLP158 MIDFLD WND 08013G19KT T01700059=

[0858 MDT] METAR KHIF 121458Z 11016KT 10SM CLR 19/06 A3017 RMK AO2A SLP161 MIDFLD WND 07012KT T01920060 52004=

[0958 MDT] METAR KHIF 121558Z AUTO 11013KT 10SM CLR 22/07 A3016 RMK AO2 SLP155 T02160067=

[1058 MDT] METAR KHIF 121658Z AUTO 07004KT 10SM CLR 25/08 A3017 RMK AO2 SLP156 T02510077=

[1158 MDT] METAR KHIF 121758Z AUTO 00000KT 10SM CLR 27/09 A3016 RMK AO2 SLP153 T02730087 10277 20169 55002=

[1258 MDT] METAR KHIF 121858Z AUTO 28004KT 10SM CLR 29/08 A3014 RMK AO2 RAB53E55 SLP144 P0000 T02930083=

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[1358 MDT] METAR KHIF 121958Z 25015G22KT 10SM FEW050 FEW200 30/08 A3015 RMK AO2A SLP147 MIDFLD WND 24013G23KT T02980082=

[1458 MDT] METAR KHIF 122058Z AUTO 28011G19KT 10SM CLR 29/07 A3015 RMK AO2 PK WND 27028/02 SLP150 60000 T02850071 55003=

[1459 MDT] SPECI KHIF 122059Z AUTO 29014G19KT 10SM CLR 29/07 A3015 RMK AO2 WSHFT 51 SLP150=

[1528 MDT] SPECI KHIF 122128Z 26012KT 10SM CLR 29/07 A3014 RMK AO2A WSHFT 23 SLP146=

[7] Magnetic variation – The angle (at a particular location) between magnetic north and true north. 2000, latest measurement taken from http://airnav.com/airport/KHIF

KHIF weather at 1158 MDT, automated, wind calm, 10 miles visibility or greater, clear skies below 12,000 ft agl, temperature of 27° C, dew point temperature of 9° C, and an altimeter setting of 30.16 inches of mercury. Remarks: automated station with a precipitation discriminator, sea level pressure 1015.3 hPa, temperature 27.3° C, dew point temperature 8.7° C, 6-hourly maximum temperature of 27.7° C, 6-hourly minimum temperature of 16.9° C, 3-hourly pressure decrease of 0.2 hPa.

KHIF weather at 1258 MDT, automated, wind from 280° at 4 knots, 10 miles visibility or greater, clear skies below 12,000 ft agl, temperature of 29° C, dew point temperature of 8° C, and altimeter setting of 30.14 inches of mercury. Remarks: automated station with a precipitation discriminator, rain began at 1253 MDT, rain ended at 1255 MDT, sea level pressure 1014.4 hPa, a trace of precipitation since 1158 MDT, temperature 29.3° C, dew point temperature 8.3° C.

KHIF weather at 1358 MDT, wind from 250° at 15 knots with gusts to 22 knots, 10 miles visibility or greater, few clouds at 5,000 ft agl, few clouds at 20,000 ft agl, temperature of 30° C, dew point temperature of 8° C, and altimeter setting of 30.15 inches of mercury. Remarks: automated station with a precipitation discriminator, sea level pressure 1014.7 hPa, midfield wind from 240° at 13 knots with gusts to 23 knots, temperature 29.8° C, dew point temperature 8.2° C.

KHIF weather at 1458 MDT, automated, wind from 280° at 11 knots with gusts to 19 knots, 10 miles visibility or greater, clear skies below 12,000 ft agl, temperature of 29° C, dew point temperature of 7° C, and altimeter setting of 30.15 inches of mercury. Remarks: automated station with a precipitation discriminator, peak wind from 270° at 28 knots at 1402 MDT, sea level pressure 1015.0 hPa, 6-hourly precipitation of a trace, temperature 28.5° C, dew point temperature 7.1° C, 3-hourly pressure decrease of 0.3 hPa.

Salt Lake City International Airport (KSLC) was located 3 miles west of Salt Lake City, Utah. KSLC had an ASOS whose reports were supplemented by an official weather observer. KSLC was located 25 miles south of the accident site, at an elevation of 4,227 ft, and had a 11° easterly magnetic variation[8] (figure 7). The following observations were taken and disseminated during the times surrounding the accident:

[0754 MDT] METAR KSLC 121354Z 14006KT 10SM FEW140 FEW200 21/11 A3012 RMK AO2 SLP146 T02060106=

[0854 MDT] METAR KSLC 121454Z 13007KT 10SM FEW110 FEW160 FEW210 23/10 A3013 RMK AO2 SLP150 T02280100 53002=

[0954 MDT] METAR KSLC 121554Z 12004KT 10SM FEW100 FEW170 FEW220 25/09 A3012 RMK AO2 SLP143 T02500094=

[1054 MDT] METAR KSLC 121654Z 20006KT 9SM FEW100 FEW170 FEW230 28/10 A3012 RMK AO2 SLP142 VIRGA DSNT SW T02780100=

[8] Magnetic variation – The angle (at a particular location) between magnetic north and true north. 2020, latest measurement taken from http://airnav.com/airport/KSLC

[1154 MDT] METAR KSLC 121754Z 00000KT 10SM FEW090 FEW150 SCT250 30/09 A3011 RMK AO2 SLP135 CB DSNT SW-W TCU DSNT SE AND NW T03000089 10300 20189 58007=

[1254 MDT] METAR KSLC 121854Z VRB04KT 10SM FEW110 SCT150 SCT250 32/08 A3009 RMK AO2 SLP128 VIRGA S AND DSNT SW-W CB DSNT SE AND SW AND NW TCU DSNT S T03170083=

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[1347 MDT] SPECI KSLC 121947Z 27020G30KT 10SM FEW110 31/10 A3010 RMK AO2 PK WND 27030/1939 WSHFT 1927 T03060100=

[1354 MDT] METAR KSLC 121954Z 27024KT 10SM FEW090 SCT110 SCT150 BKN250 31/09 A3010 RMK AO2 PK WND 27030/1939 WSHFT 1927 SLP134 VIRGA SE AND S-SW AND DSNT W CB DSNT SE-SW AND NW TCU DSNT NE AND E T03110094=

[1454 MDT] METAR KSLC 122054Z 30015KT 10SM FEW085 FEW120 SCT150 BKN250 31/07 A3010 RMK AO2 PK WND 28028/1958 SLP133 VIRGA DSNT E AND S CB DSNT SE-S AND SW AND NW TCU DSNT NE-E T03110067 56003=

[1554 MDT] METAR KSLC 122154Z 31013G21KT 10SM FEW085 FEW120 SCT150 BKN250 31/06 A3008 RMK AO2 SLP129 VIRGA CB DSNT N AND SE-S AND SW T03110061=

KSLC weather at 1154 MDT, wind calm, 10 miles visibility or greater, few clouds at 9,000 ft agl, few clouds at 15,000 ft agl, scattered clouds at 25,000 ft agl, temperature of 30° C, dew point temperature of 9° C, and an altimeter setting of 30.11 inches of mercury. Remarks: automated station with a precipitation discriminator, sea level pressure 1013.5 hPa, cumulonimbus clouds distant[9] southwest through west, towering cumulus clouds distant southeast and northwest, temperature of 30.0° C, dew point temperature of 8.9° C, 6-hourly maximum temperature of 30.0 C, 6-hourly minimum temperature of 18.9 C, 3-hourly pressure decrease of 0.7 hPa.

KSLC weather at 1254 MDT, variable wind at 4 knots, 10 miles visibility or greater, few clouds at 11,000 ft agl, scattered clouds at 15,000 ft agl, scattered clouds at 25,000 ft agl, temperature of 32° C, dew point temperature of 8° C, and altimeter setting of 30.09 inches of mercury. Remarks: automated station with a precipitation discriminator, sea level pressure 1012.8 hPa, virga south and distant southwest through west, cumulonimbus clouds distant southeast and southwest, towering cumulous clouds distant south, temperature 31.7° C, dew point temperature 8.3° C.

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

KSLC weather at 1347 MDT, wind from 270° at 20 knots with gusts to 30 knots, 10 miles visibility or greater, few clouds at 11,000 ft agl, temperature of 31° C, dew point temperature of 10° C, and altimeter setting of 30.10 inches of mercury. Remarks: automated station with a precipitation discriminator, peak wind from 270° at 30 knots at 1339 MDT, wind shift at 1327 MDT, temperature 30.6° C, dew point temperature 10.0° C.

KSLC weather at 1354 MDT, wind from 270° at 24 knots, 10 miles visibility or greater, few clouds at 9,000 ft agl, scattered clouds at 11,000 ft agl, scattered clouds at 15,000 ft agl, broken ceiling at 25,000 ft agl, temperature of 31° C, dew point temperature of 9° C, and altimeter setting of 30.10 inches of mercury. Remarks: automated station with a precipitation discriminator, peak wind from 270° at 30 knots at 1339 MDT, wind shift at 1327 MDT, sea level pressure 1013.4 hPa, virga southeast and south through southwest, distant cumulonimbus clouds southeast through southwest and northwest, towering cumulus clouds distant northeast and east, temperature 31.1° C, dew point temperature 9.4° C.

3.1 One Minute Wind Observations

The one-minute KOGD ASOS surface data was provided by the NWS for the time surrounding the accident. One-minute raw wind data was provided with two separate magnitudes and wind directions[10]. The first wind data in table 1 is the two-minute average wind speed, which was updated every 5 seconds and reported once a minute. The second source of one-minute wind data is the five-second maximum wind average, which was updated every five seconds and reported once every minute (table 1). The following table provides the meteorological data in UTC time.

[10] The wind directions are in reference to true north.

Time UTC	Dir of 2 min avg wind	Speed of 2 min avg wind (knots)	Dir of max 5 sec avg wind	Speed of max 5 sec avg wind (knots)
1920	294	6	328	9
1921	310	6	331	9
1922	315	7	305	11
1923	283	9	292	12
1924	263	8	292	9
1925	273	6	286	7
1926	283	7	286	10
1927	279	9	281	10
1928	273	8	258	9
1929	273	7	261	10
1930	267	9	266	14
1931	262	10	262	11
1932	266	8	276	10
1933	274	8	282	12
1934	266	9	298	13
1935	252	10	225	15
1936	244	11	244	12
1937	235	10	233	11
1938	238	9	239	13
1939	250	10	274	14
1940	259	11	265	13
1941	250	12	240	16
1942	242	12	245	15
1943	249	11	246	12
1944	247	8	260	10
1945	245	8	248	14
1946	245	11	240	15
1947	240	12	226	15
1948	237	12	241	15
1949	242	12	240	16
1950	253	12	262	13

Table 1 – One-minute KOGD ASOS data for the time surrounding the accident

At 1336 MDT, KOGD reported the two-minute average wind from 244° at 11 knots, a five-second maximum average wind from 244° at 12 knots.

At 1337 MDT, KOGD reported the two-minute average wind from 235° at 10 knots, a five-second maximum average wind from 233° at 11 knots.

At 1338 MDT, KOGD reported the two-minute average wind from 238° at 9 knots, a five-second maximum average wind from 239° at 13 knots.

The observations from KOGD, KHIF, and KSLC surrounding the accident time indicated VFR[11] conditions with gusty surface winds. The wind gusted as high as 22 knots at KOGD in the 30 minutes on either side of the accident time, the wind gusted as high as 28 knots at KHIF in the 30 minutes on either side of the accident time, and the wind gusted as high as 30 knots at KSLC in the 30 minutes on either side of the accident time. In addition, virga, cumulonimbus clouds, and towering cumulous clouds were observed in the vicinity of KSLC surrounding the accident time.

4.0 Upper Air Data

The closest official upper air sounding to the accident site was from KSLC with a site number 72572. The 1800 MDT sounding was plotted on a standard Skew-T log P diagram[12] with the derived stability parameters included in figure 8 (with data from the surface to 600-hPa, or 14,000 ft msl.) This sounding data was analyzed using the RAOB[13] software package. The sounding depicted the lifted condensation level (LCL)[14] at 13,597 ft msl, a convective condensation level (CCL)[15] of 15,199 ft, and a level of free convection (LFC)[16] at 16,912 ft. The freezing level was 15,496 ft. The precipitable water value was 0.81 inches.

[11] Visual Flight Rules – Refers to the general weather conditions pilots can expect at the surface. VFR criteria means a ceiling greater than 3,000 feet agl and greater than 5 miles visibility.
[12] 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.
[13] RAOB – (The complete Rawinsonde Observation program) is an interactive sounding analysis program developed by Environmental Research Services, Matamopras, Pennsylvania.
[14] Lifting Condensation Level (LCL) - The height at which a parcel of moist air becomes saturated when it is lifted dry adiabatically.
[15] 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.
[16] Level of Free Convection (LFC) – The level at which a parcel of saturated air becomes warmer than the surrounding air and begins to rise freely. This occurs most readily in a conditionally unstable atmosphere.

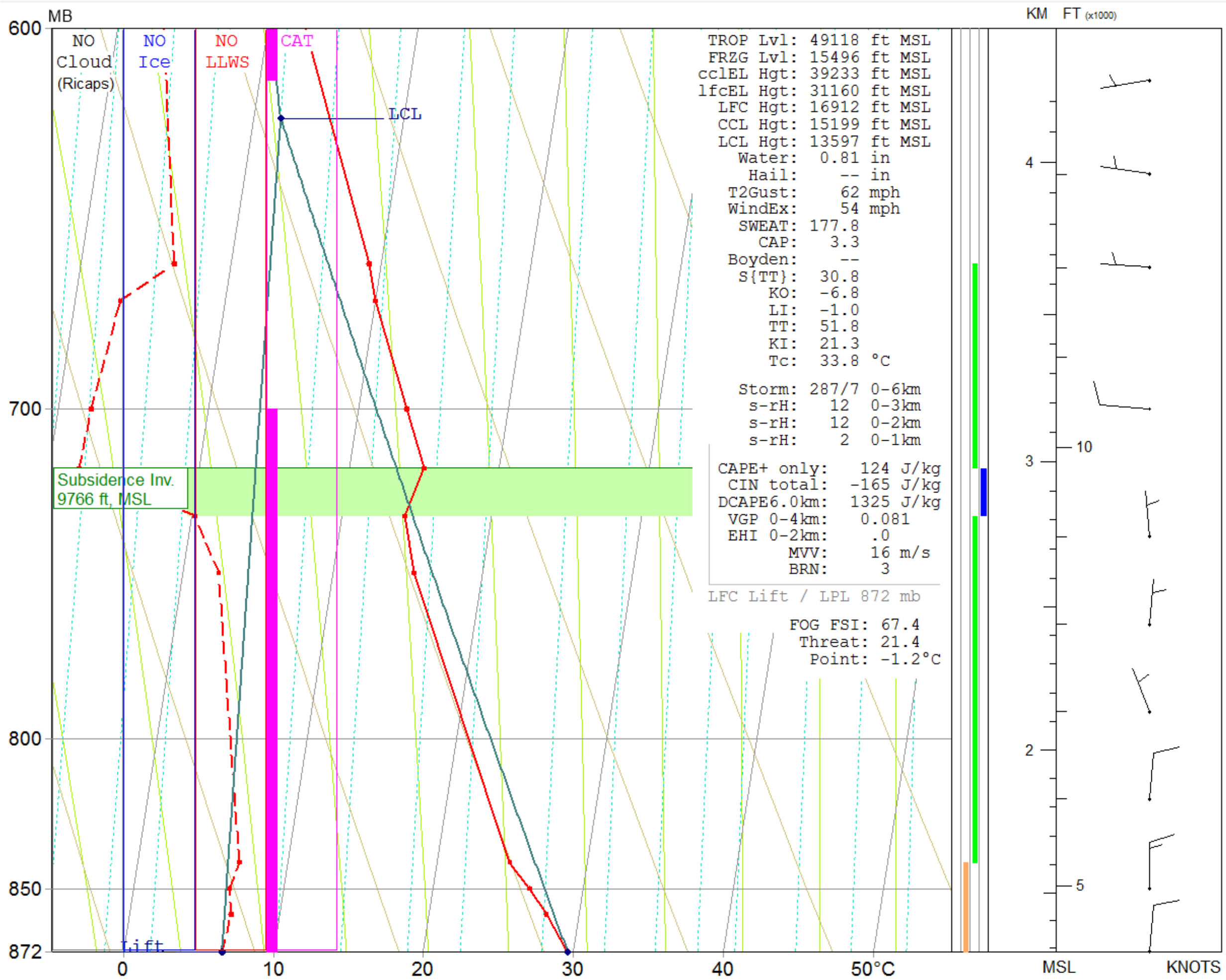

Figure 8 – 1800 MDT KSLC sounding

The 1800 MDT KSLC sounding indicated a mainly conditionally unstable environment from the surface through 14,000 ft with 124 J/kg of CAPE[17] from the surface. This environment would have been supportive of cloud formation and rain showers, if a lifting mechanism was in the area of the accident site at the accident time (sections 1.1 and 1.2). The maximum vertical velocity (MVV) for this atmosphere was calculated as 16 meters/second (about 3,150 ft per minute).[18] Downdraft CAPE (DCAPE; 6 kilometers agl)[19] was measured at 1,325 Joules/kilogram. RAOB did not identified any location for the possibility of clouds below 14,000 ft. No areas of icing were indicated by RAOB for below 14,000 ft. The 1800 MDT KSLC sounding indicated the strongest wind speeds possible with any convective outflow was estimated at 62 mph (54 knots) as indicated by the T2Gust parameter.

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[17] Convective Available Potential Energy (CAPE) – CAPE is a measure of the amount of energy available for convection and is directly related to the maximum potential vertical speed within an updraft.

[18] MVV is not usually considered a realistic estimate for maximum vertical velocity in a storm. Anecdotes suggest considering a value of MVV/2, however it is not well understood when or where such a half-value should be applied.

[19] The DCAPE can be used to estimate the potential strength of rain-cooled downdrafts within thunderstorm convection, and is similar to CAPE. Larger DCAPE values are associated with stronger downdrafts.

The 1800 MDT KTBW sounding wind profile indicated a surface wind from 005° at 11 knots with the wind remaining northerly through 10,000 ft. The wind speed increased to 15 knots at 5,000 ft, but dropped back down to 10 knots by 6,000 ft and remained at or below 10 knots through 14,000 ft. The mean 0 to 6-kilometer (18,000 ft) wind was from 287° at 7 knots. RAOB did not indicate the possibility of low-level wind shear between the surface and 2,000 ft outside of rain shower or thunderstorm activity. RAOB indicated the possibility of clear-air turbulence in two layers between the surface and 14,000 ft.

5.0 Satellite Data

Visible and infrared data from the Geostationary Operational Environmental Satellite number 16 (GOES-16) data was obtained from an archive at the Space Science Engineering Center at the University of Wisconsin-Madison in Madison, Wisconsin, and processed using the Man-computer Interactive Data Access System software. Visible and infrared imagery (GOES-16 bands 2 and 13) at wavelengths of 0.64 microns (µm) and 10.3 µm, respectively, were retrieved for the period. Satellite imagery surrounding the time of the accident, from 1100 MDT through 1500 MDT at approximately 15-minute intervals were reviewed, and the closest images to the time of the accident are documented here.

Figures 9 and 10 present the GOES-16 visible imagery from 1325 and 1345 MDT at 2X magnification with the accident site highlighted with a red square. Inspection of the visible imagery indicated no cloud cover over the accident site at the accident time, however, a cloud boundary is apparent moving past the accident site between 1325 and 1345 MDT (attachment 1) with additional cumulus cloud development east of the accident site across the mountainous terrain by 1357 MDT. The additional cloud cover across the mountainous terrain east of the accident site formed as the outflow boundary/gust front (discussed in sections 17.0 and 18.0) moved eastward into the mountainous terrain inducing additional vertical motion. It should be noted these figures have not been corrected for any parallax error.

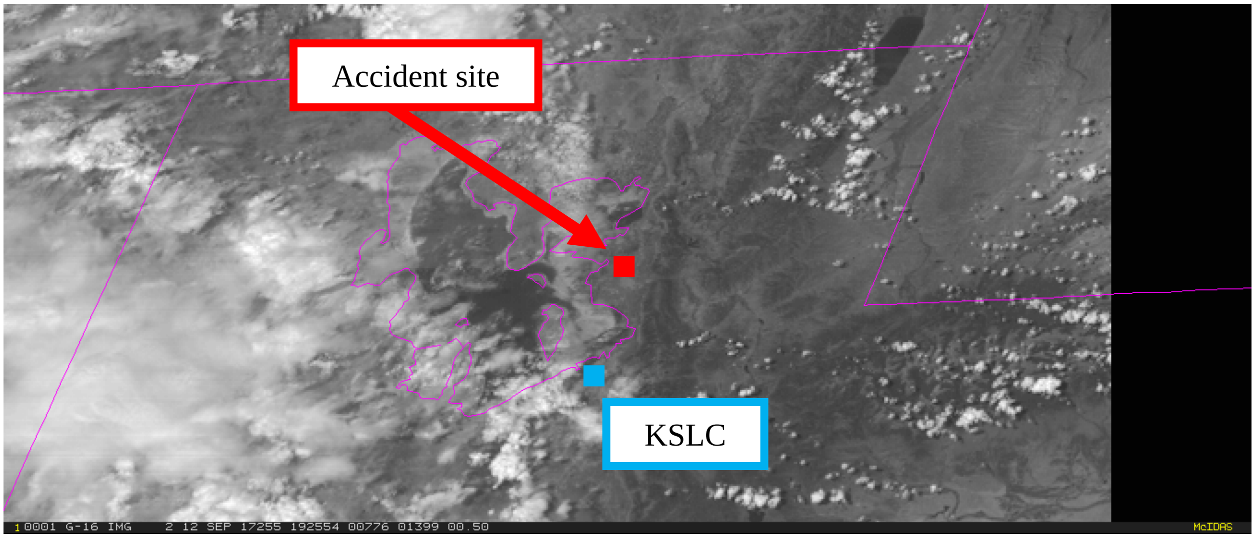


Figure 9 – GOES-16 visible image at 1325 MDT

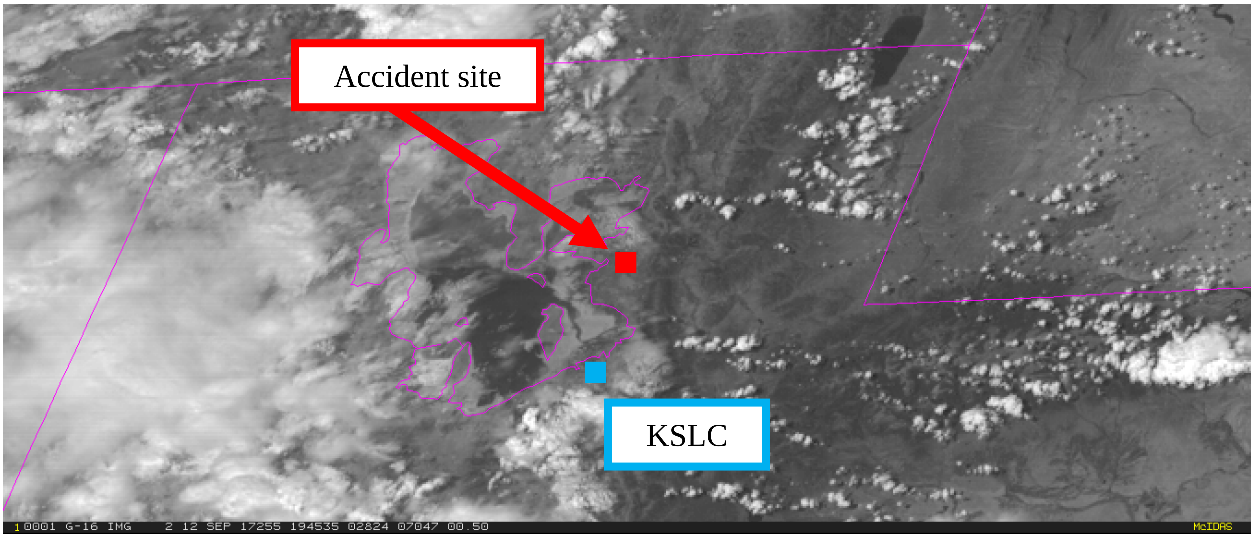


Figure 10 – GOES-16 visible image at 1345 MDT

6.0 Radar Imagery Information

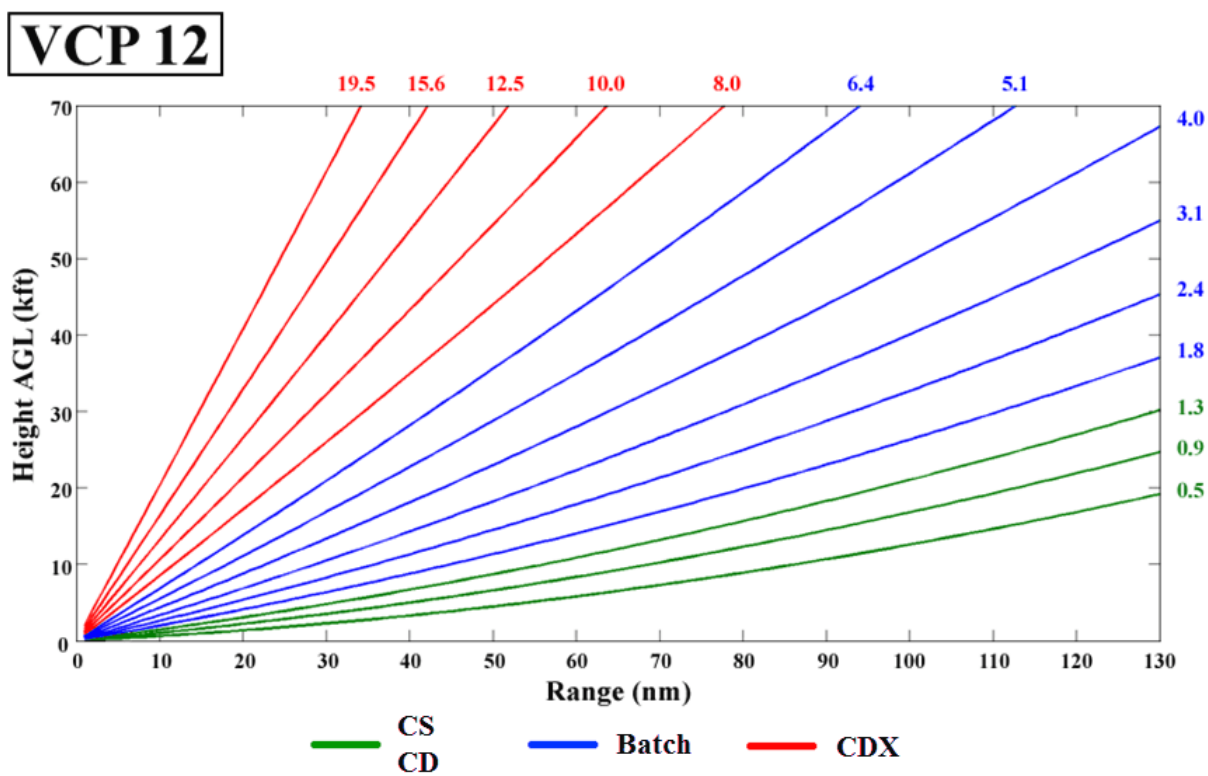
The closest NWS Weather Surveillance Radar-1988, Doppler (WSR-88D)[20] to the accident site was the Salt Lake City, Utah, radar (KMTX), located 19 miles west-northwest of the accident site at 6,460 ft. Level II and III archive radar data were obtained from the NCEI using the NEXRAD Data Inventory Search and displayed using the NOAA's Weather and Climate Toolkit software.

[20] The WSR-88D is an S-band 10-centimeter wavelength radar with a power output of 750,000 watts, and with a 28-foot parabolic antenna that concentrates the energy between a 0.87° and 0.96° beam width. The radar produces three basic types of products: base reflectivity, base radial velocity, and base spectral width.

6.1 Volume Scan Strategy

The WSR-88D is a computer-controlled radar system, which automatically creates a complete series of specific scans in a specific sequence known as a volume scan. Individual elevation scans are immediately available 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 five to ten-minute volume scan.

The WSR-88D operates in several different scanning modes, identified as Mode A and Mode B. Mode A is the precipitation scan and has three common scanning strategies. The most common is where the radar makes 14 elevation scans from 0.5° to 19.5° every four and a half minutes. This particular scanning strategy is documented as volume coverage pattern 12 (VCP-12). 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 KMTX WSR-88D radar was operating in the precipitation mode (Mode A, VCP-12). 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-12 Precipitation Mode Scan Strategy[21]

[21] Contiguous Surveillance (CS)--The low PRF scan of the split cut. Gives a high R_{max} value to determine proper target location and intensity, but a low V_{max} value limits the velocities that can be measured.
Contiguous Doppler (CD)--The high PRF scan of the split cut. Gives a low R_{max} value causing more range folded (multiple trip) echoes, but a high V_{max} value to get higher, more accurate velocity values.
Batch Mode – Uses alternating low and high PRFs on each radial for one full rotation at each elevation angle. The two resulting data sets (low PRF and high PRF) are combined to resolve range ambiguity. Used in the middle elevation angles.

6.2 Beam Height Calculation

Assuming standard refraction[22] of the WSR-88D 0.95° wide radar beam, the following table shows the approximate beam height and width[23] information[24] of the radar display over the site of the accident. The heights have been rounded to the nearest 10 ft.

ANTENNA ELEVATION	BEAM CENTER	BEAM BASE	BEAM TOP	BEAM WIDTH
0.5°	7,730 ft	6,790 ft	8,670 ft	1,880 ft

Based on the radar height calculations, the 0.5° elevation scan depicted the conditions between 6,790 ft and 8,670 ft msl over the accident site and these are the closest altitudes to the accident site before the accident occurred.

6.3 Reflectivity

Reflectivity is the measure of the efficiency of a target in intercepting and returning radio energy. With hydrometeors[25] 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 (dBZ[26]), and is a general measure of echo intensity. FAA Advisory Circular AC 00-24C, "Thunderstorms," dated February 19, 2013, also defines the echo intensity levels and weather radar echo intensity terminology associated with those levels. For dBZ values less than 30 the weather radar echo intensity terminology should be "light." For dBZ values between 30 and 40, the terminology should be "moderate." "Heavy" terminology is used for dBZ values greater than 40 dBZ but less than 50 dBZ, inclusive. Finally, any dBZ values above 50 dBZ shall be described as "extreme." From the NWS, precipitation conditions at the surface can be inferred from VIP Levels described in the chart below:

W – With range unfolding (W)

WO – Without range unfolding (WO)

[22] Standard Refraction in the atmosphere is when the temperature and humidity distributions are approximately average, and values set at the standard atmosphere.

[23] Beam width – A measure of the angular width of a radar beam.

[24] Beamwidth values are shown for legacy resolution products. Super resolution products would an effective beamwidth that would be approximately half these values.

[25] Hydrometeors are any product of condensation or sublimation of atmospheric water vapor, whether formed in the free atmosphere or at the earth's surface; also, any water particles blown by the wind from the earth's surface. Hydrometeors are classified as; (a) Liquid or solid water particles suspended in the air: cloud, water droplets, mist or fog. (b) Liquid precipitation: drizzle and rain. (c) Freezing precipitation: freezing drizzle and freezing rain. (d) Solid (frozen) precipitation: ice pellets, hail, snow, snow pellets, and ice crystals. (e) Falling particles that evaporate before reaching the ground: virga. (f) Liquid or solid water particles lifted by the wind from the earth's surface: drifting snow, blowing snow, blowing spray. (g) Liquid or solid deposits on exposed objects: dew, frost, rime, and glazed ice.

[26] dBZ – A non-dimensional "unit" of radar reflectivity which represents a logarithmic power ratio (in decibels , or dB) with respect to radar reflectivity factor, Z.

- VIP 1 (Level 1, 18-30 dBZ) - Light precipitation
- VIP 2 (Level 2, 30-38 dBZ) - Light to moderate rain.
- VIP 3 (Level 3, 38-44 dBZ) - Moderate to heavy rain.
- VIP 4 (Level 4, 44-50 dBZ) - Heavy rain
- VIP 5 (Level 5, 50-57 dBZ) - Very heavy rain; hail possible.
- VIP 6 (Level 6, >57 dBZ) - Very heavy rain and hail; large hail possible.

6.4 Base Reflectivity and Lightning Data

Figures 11 through 13 present the KMTX WSR-88D base reflectivity images for the 0.5° elevation scans initiated at 1335, 1337, and 1339 MDT with a resolution of 0.5° X 250 m. The KMTX data indicated -5 to 10 dBZ reflectivity values above the accident site between 1335 and 1339 MDT, but those reflectivity values were not precipitation targets, but likely due to dust, insects, or other particles based on the correlation coefficient data (not shown). The outflow or gust front boundary can be seen moving past the accident site on the base velocity data (attachments 2 and 3) after 1344 MDT. It is likely the outflow or gust front boundary moved past the accident site right around the accident time (section 3.0), but since KMTX is looking at targets between 6,790 and 8,670 ft msl above the accident site (section 6.2), KMTX is likely missing the leading edge of the outflow or gust front boundary. There were no lightning strikes around the accident site at the accident time.[27] Terminal Doppler Weather Radar (TDWR) data was retrieved and reviewed from the Salt Lake City area (TSLC) around the accident time. The TSLC data provided similar information about the gust front boundary timing and movement as KMTX (attachments 4, 5, and 6).

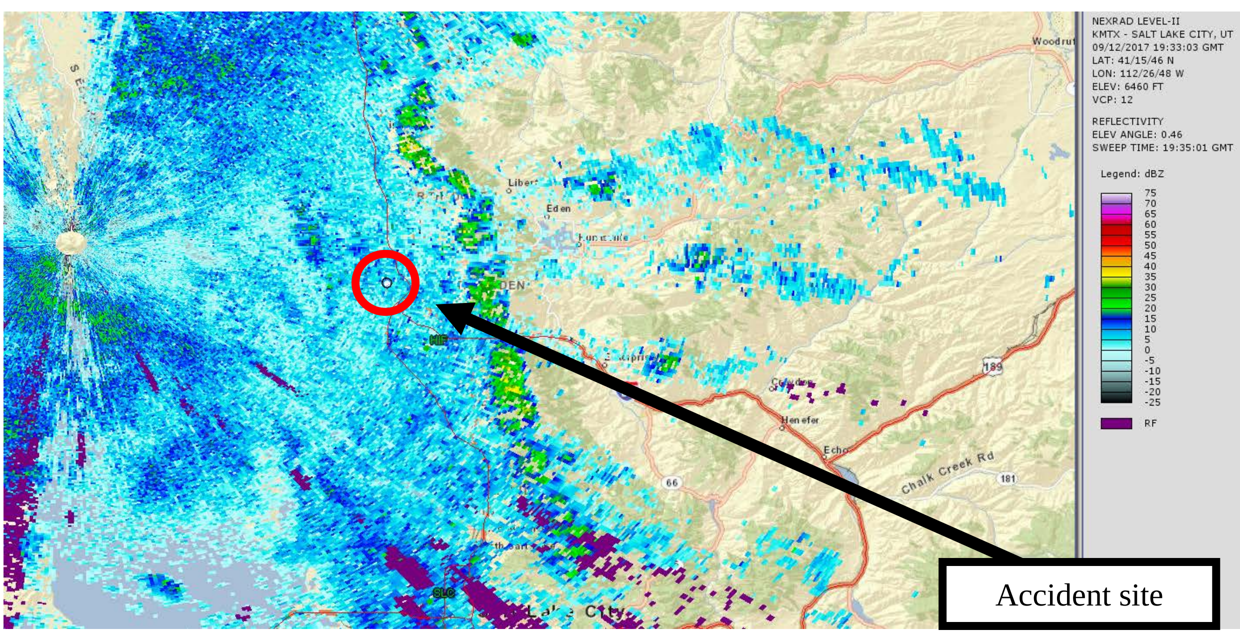


Figure 11 – KMTX WSR-88D reflectivity for the 0.5° elevation scan initiated at 1335 MDT

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

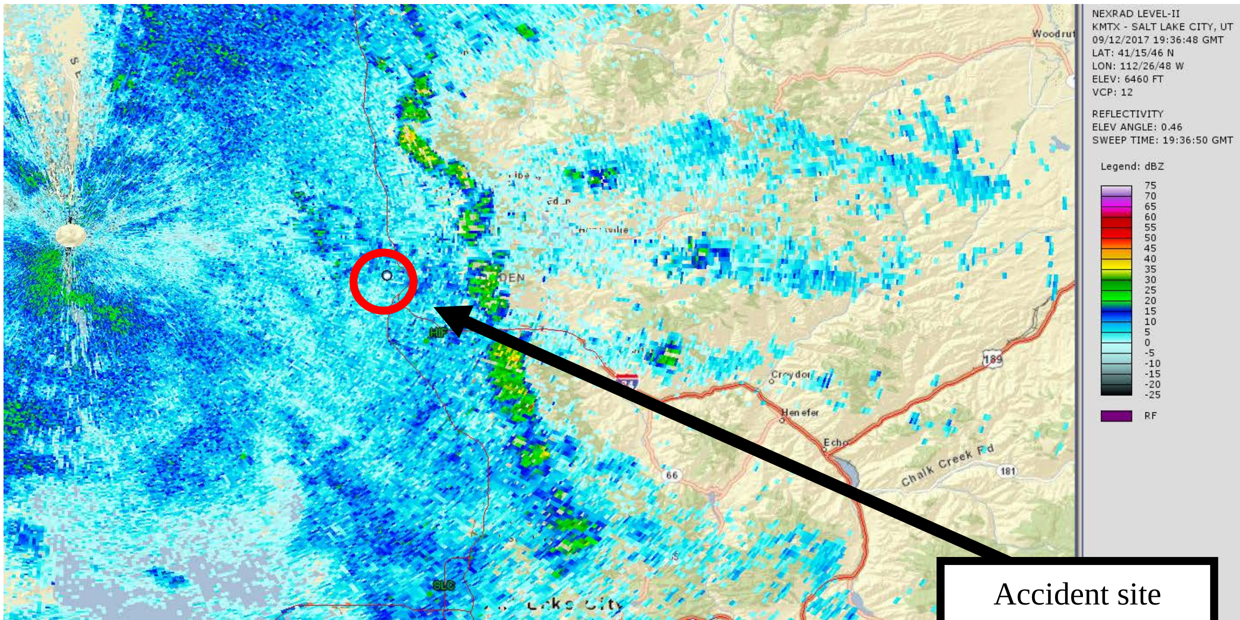


Figure 12 – KMTX WSR-88D reflectivity for the 0.5° elevation scan initiated at 1337 MDT

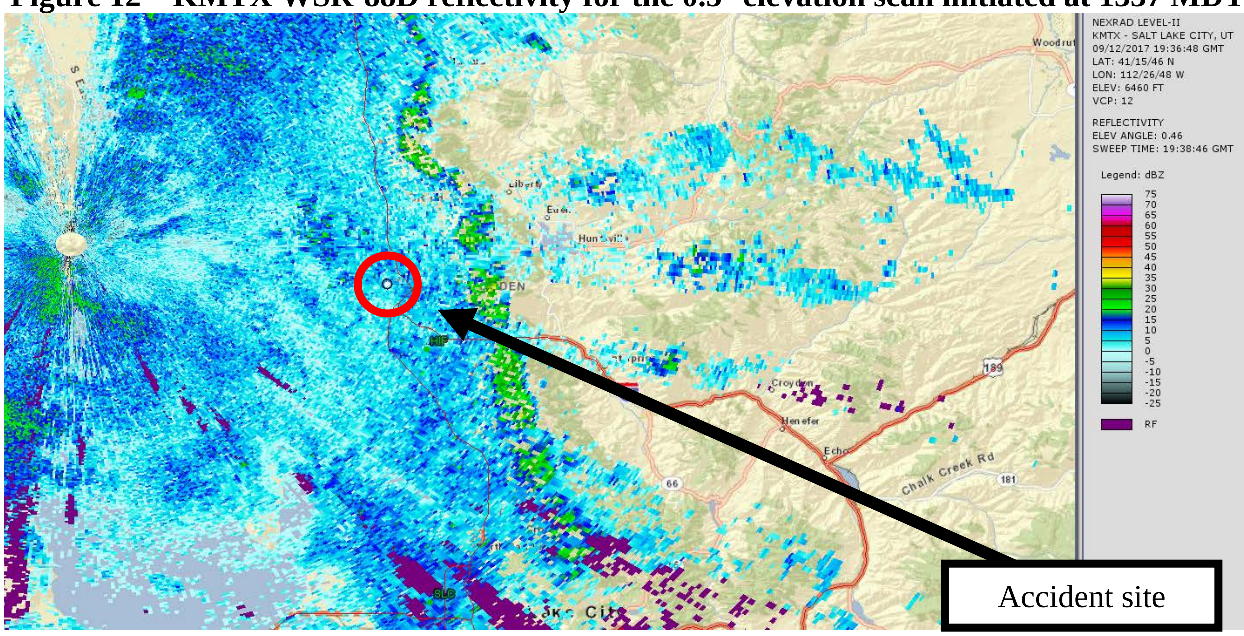


Figure 13 – KMTX WSR-88D reflectivity for the 0.5° elevation scan initiated at 1339 MDT

7.0 Pilot Reports[28]

All pilot reports (PIREPs) within about 200 miles of the accident site from about two hours prior to the accident time to about two hours after the accident time were reviewed. There were no PIREPs issued into the national airspace for altitudes below FL180[29].

[28] Only pilot reports with the WMO header UBUT**, UBID**, and UBWY** identifier were considered.

[29] Flight Level – A Flight Level (FL) is a standard nominal altitude of an aircraft, in hundreds of ft. This altitude is calculated from the International standard pressure datum of 1013.25 hPa (29.92 inHg), the average sea-level pressure, and therefore is not necessarily the same as the aircraft's true altitude either above mean sea level or above ground level.

8.0 SIGMET and CWSU Advisories

There was a Convective Significant Meteorological Information (SIGMET) advisory valid for the area just southwest of the accident site with the area of thunderstorms forecast to move near and over the accident site between 1255 and 1455 MDT. Convective SIGMET 40W was issued at 1255 MDT and warned of an area of thunderstorms with the SIGMET area moving from 190° at 20 knots with thunderstorm tops to FL420 (figure 14):

WSUS33 KKCI 121855
SIGW
-MKCW WST 121855
CONVECTIVE SIGMET 40W
VALID UNTIL 2055Z
UT NV
FROM 30NW BVL-30SW SLC-DTA-ELY-30NW BVL
AREA TS MOV FROM 19020KT. TOPS TO FL420.

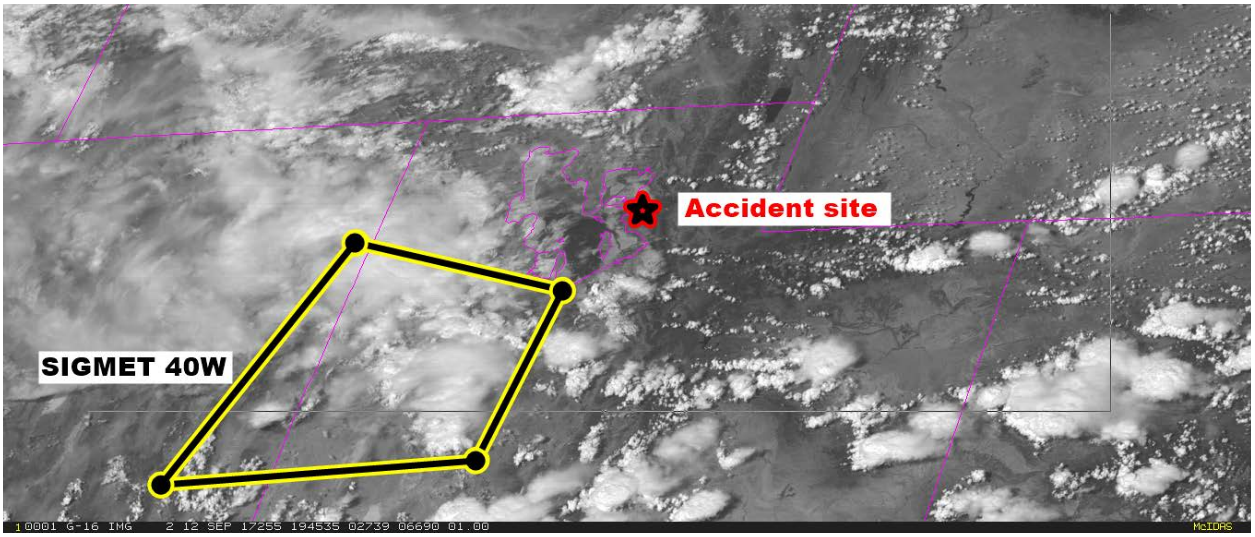


Figure 14 – GOES-16 visible image at 1345 MDT with SIGMET 40W and the accident site marked

There were no non-convective SIGMETs valid at the accident time. There were no Center Weather Service Unit (CWSU) Meteorological Impact Statements (MIS)s or Center Weather Advisories (CWA)s were valid for the accident site at the accident time.

9.0 AIRMETs

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

10.0 Area Forecast

The Area Forecast issued at 0445 MDT, valid at the accident time, forecast clear skies through 1500 MDT. After 1500 MDT scattered clouds at 11,000 ft msl with a broken ceiling at 15,000 ft and tops at FL210 was forecast. In addition, after 1500 MDT widely scattered light rain and thunderstorms were forecast with cumulonimbus tops to FL420:

```
FAUS45 KKCI 121045
FA5W
-SLCC FA 121045
SYNOPSIS AND VFR CLDS/WX
SYNOPSIS VALID UNTIL 130500
CLDS/WX VALID UNTIL 122300...OTLK VALID 122300-130500
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..UPR LOW E CNTRL WY.  RIDGE ELSW. LIGHT W-SWLY
FLOW THRUT. UPR LOW LIFTING NEWD DURG PD. BY 05Z UPR RIDGE THRUT.
SFC..HI PRES ACRS FCST AREA. CDFNT MOVG INTO NRN-MT-NRN ID DURG
PD AND BY 05Z WILL EXTD FROM SERN TO NW MT-NRN ID.
.
ID
NRN...SKC. FU ALF. OTLK...VFR.
CNTRL MTNS...SKC. FU ALF THRUT PD. 22Z SCT150. OTLK...VFR SHRA.
SWRN...SKC. 21Z SCT-BKN130 TOP FL210. WDLY SCT -TSRA. CB TOP
FL380. OTLK...VFR TSRA.
SERN...SKC. 21Z SCT150. ISOL -SHRA. OTLK...VFR SHRA.
.
MT
CONTDVD WWD...SKC. FU ALF. OTLK...VFR.
SWRN MTNS...SKC. FU ALF THRUT PD. 22Z SCT150. OTLK...VFR SHRA.
ERN SLOPES OF CONTDVD...SKC. FU ALF. TIL 15Z VIS 5SM FU HZ TOP
130. OTLK...VFR.
CNTRL...
 N HLF..SKC. FU ALF. OTLK...VFR.
 S HLF...SKC. FU ALF. 21Z SCT140. OTLK...VFR SHRA.
ERN...SKC. FU ALF. OTLK...VFR.
.
WY
PLAINS...SCT CI. 21Z SCT150. ISOL -TSRA. CB TOP FL420.
OTLK...VFR.
MTNS E OF CONTDVD...SKC. OTLK...VFR.
MTNS W OF CONTDVD...SKC. 21Z SCT150. ISOL -SHRA. OTLK...VFR SHRA.
.
NV
NWRN...
 N HLF...BKN150 TOP FL270. SCT -SHRA. WDLY SCT -TSRA. CB TOP
FL430. 16Z SCT-BKN150. ISOL -SHRA. OTLK...VFR TSRA.
 S HLF...BKN150 TOP FL250. SCT -TSRA. CB TOP FL430. 13Z
SCT-BKN150. ISOL -SHRA. 22Z WDLY SCT -TSRA. OTLK...VFR TSRA.
NERN...SCT-BKN150 TOP FL210. WDLY SCT -SHRA. ISOL -TSRA. CB TOP
FL430. 15Z ISOL -SHRA. 21Z WDLY SCT -TSRA. OTLK...VFR TSRA.
```

SRN...SCT130. OTLK...VFR.
.
UT
NW...SKC. 21Z SCT110 SCT-BKN150 TOP FL210. WDLY SCT -TSRA. CB TOP FL420. OTLK...VFR TSRA.
ERN...SKC. 21Z SCT150. ISOL -SHRA. OTLK...VFR SHRA.
SW...SCT-BKN150 TOP FL210. WDLY SCT -SHRA. ISOL -TSRA. CB TOP
FL430. 15Z ISOL -SHRA. 21Z WDLY SCT -TSRA. OTLK...VFR TSRA.
.
CO
PLAINS...
SRN 1/4...SCT CI. 22Z SCT110. WDLY SCT -TSRA. CB TOP FL450.
OTLK...VFR TSRA.
ELSW...SCT CI. OTLK...VFR...01Z WRN PTNS SHRA.
MTNS...SCT150. 19Z BKN150 TOP FL210. SCT -SHRA. WDLY SCT -TSRA.
CB TOP FL420. OTLK...VFR TSRA.
.
AZ
NW...SKC. 20Z SCT130. OTLK...VFR.
NERN...SCT150. 19Z BKN150 TOP FL210. SCT -SHRA. WDLY SCT -TSRA.
CB TOP FL420. OTLK...VFR TSRA.
SWRN...SKC. OTLK...VFR.
SERN...SKC. 21Z SCT100. OTLK...VFR SHRA.
.
NM
PLAINS...
N HLF...SCT CI. 22Z SCT110. WDLY SCT -TSRA. CB TOP FL450.
OTLK...VFR TSRA.
S HLF...SKC. OTLK...VFR.
MTNS...
N 2/3...SCT150. 19Z BKN150 TOP FL210. SCT -SHRA. WDLY SCT -TSRA.
CB TOP FL450. OTLK...VFR TSRA.
S 1/3...SKC. OTLK...VFR.
....

11.0 Terminal Aerodrome Forecast

KOGD was the closest site with a Terminal Aerodrome Forecast (TAF). The TAF issued before the accident time, but valid after the time of the accident was issued at 1336 MDT and was valid for a 22-hour period beginning at 1400 MDT. The TAF for KOGD was as follows:

KOGD 121936Z 1220/1318 **26014G24KT P6SM SCT110**
FM122100 27011KT P6SM VCSH SCT100 BKN160
FM130200 15006KT P6SM SCT100 BKN200
FM130600 17010KT P6SM VCSH SCT100 BKN140=

The 1336 MDT forecast expected after 1400 MDT, a wind from 260° at 14 knots with gusts to 24 knots, greater than 6 statute miles visibility, and scattered clouds at 11,000 ft agl.

The KOGD valid at the accident time was issued at 1134 MDT and was valid for a 24-hour period beginning at 1200 MDT. The 1134 TAF for KOGD was as follows:

KOGD 121734Z 1218/1318 **33006KT P6SM SCT150**
FM130200 15006KT P6SM SCT100 BKN200
FM130600 17010KT P6SM VCSH SCT100 BKN140=

The 1134 MDT forecast expected a wind from 330° at 6 knots, greater than 6 statute miles visibility, and scattered clouds at 15,000 ft agl.

12.0 NWS Area Forecast Discussion

The NWS Office in Salt Lake City, Utah, issued the following Area Forecast Discussion (AFD) at 0940 MDT (closest AFD to the accident time). The aviation section of the AFD discussed that VFR conditions were expected to prevail through the TAF period with a shift in winds from southeast to northwest around 1200 to 1300 MDT. The discussion also indicated a 20 percent chance of gusty and erratic thunderstorm outflow winds to impact TAF sites:

FXUS65 KSLC 121540
AFDSLC

Area Forecast Discussion
National Weather Service Salt Lake City UT
940 AM MDT Tue Sep 12 2017

.SYNOPSIS...High pressure will remain over the area into Wednesday.
A series of storm systems will bring cooler and wetter conditions to
Utah and southwest Wyoming for the latter part of the work week
before drier conditions return for the upcoming weekend.

&&

.DISCUSSION...Another mostly sunny morning is in place across Utah
and southwest Wyoming, as a large ridge dominates the weather over
the Rocky Mountain region. A closed low continues to spin on the
California coast, and on the eastern fringes of this low a couple
of disturbances are moving northward through Nevada, with one of
those brushing by far western Utah and kicking off some isolated
thunderstorms. Otherwise, convection should largely initiate off
the higher terrain this afternoon and move slowly northward in the
increasing southwesterly flow.

This afternoon will be another very warm one, and potentially the
warmest day left in 2017. Salt Lake City is forecast to hit or
exceed 90 for the 80th time this year, but cooling with a pattern
change is expected starting tomorrow. This starts with the closed
low moving across the Great Basin, bringing an increase in
convection Wednesday and Thursday, followed by a larger and colder
trough pushing in from the northwest for the end of the week.

Will continue to monitor the convection over far western Utah to
see if a morning forecast update is needed later on, but otherwise
the forecast looks to be on track. The previous long term
discussion follows.

.LONG TERM (AFTER 12Z THURSDAY)...Confidence continues to grow regarding a significant pattern change during the long term period as an increasingly active northern branch jet amplifies over the western CONUS mid/late week. Global models are all in agreement that amplification of a long wave northern branch trough will dig along the West Coast by Thursday, which will kick the closed low which has been stuck off the CA coast inland. This first trough has the potential for organized convection and localized flash flood potential Thu as it translates overhead (focused across the south), while the trailing/deeper trough associated with the long wave will bring markedly cooler temps coincident with fairly widespread precip Fri/Sat, and a potential for a light dusting of snow for the high country of the north.

As mentioned the persistent closed low off the Cali coast will be the first to impact the area (Thu), this as upstream amplification of the northern branch jet ejects the upper low east while eventually phasing it into the amplifying long wave overhead. Globals continue to depict modest deep layer moisture on the order of .75", ample upper level jet support/divergence aloft, and enough instability across especially the southern half of the area to support organized convective potential midday/afternoon. Shear profiles depict fairly rapid storm motion potential detracting from prolonged heavy rainers, but training potential exists for the Grand Staircase where terrain influences may aid. Have continued to increase PoPs this package (namely of the convective potential).

In wake of the Thu trough passage, the trailing upper low embedded within the northern branch long wave will continue to dig southeast and overhead Fri-Sat, this surging the first notable cold front of the early Fall season into northern/central Utah. Globals have trended towards the more amplified/deeper solution depicted by the EC over the last few days, and have continued to lean in that direction this forecast package. Though details will continue to come to form, frontal passage Fri will bring unseasonably cool temps and widespread precip across the north/west, with snow levels potentially falling to 8-9kft post frontal. Light accums are noted in grids for the high Uintas/Wasatch by Fri night, while the daytime high at KSLC has been lowered to 66F. Have upped PoPs to likely wording coincident with the mid level frontal passage.

The upper low will then lift north/east and eventually downstream later Sat through into early next week. Not overly confident of pattern evolution during this timeframe due to namely run to run discrepancies in globals, but have continued to lean towards short wave ridge influencing drying conditions and gradual warming.

&&

.AVIATION...VFR conditions should prevail at KSLC through the valid TAF period. Southeast winds currently in place are expected to switch to the northwest between 18-19z. A 20% chance exists for gusty/erratic thunderstorm outflow winds to impact the terminal this afternoon.

&&

.FIRE WEATHER...ERCs are in the 70th-89th percentile across most
of northern Utah, closer to 50th percentile across portions of
central Utah and all of southern Utah. Values have been steady or
rising during the past several days.

Cutoff low off the California coast gets swept in across the area
Thursday as a stronger system drops out of the Pacific Northwest.
There could be wind/Rh issues across south central and southeast
Utah ahead of the cold front Thursday but fuels are mainly not
critical at this time there. Cold front will cross the state
Thursday night and Friday.

Precipitation chances, chance of wetting rain, and even high
elevation snowfall will increase through the remainder of the work
week. With low levels still relatively dry, dry microbursts may
affect areas near shower activity with gusty/erratic winds mainly
in the 35-45 mph range. Temperatures are forecast to lower by 20F
from today to Friday many locations, as RH jumps up Thursday and
Friday.

&&

.SLC WATCHES/WARNINGS/ADVISORIES...
UT...None.
WY...None.
&&

$$

13.0 NWS Hazardous Weather Outlook

The NWS Office in Salt Lake City, Utah, issued the following Hazardous Weather Outlook (HWO) at 0422 MDT. The HWO indicated that isolated to scattered showers and thunderstorms might bring locally gusty and erratic winds across Utah and southwestern Wyoming during the day:

FLUS45 KSLC 121143
HWOSLC

Hazardous Weather Outlook
National Weather Service Salt Lake City UT
422 AM MDT Tue Sep 12 2017

UTZ001>016-019>021-517-518-WYZ021-131000-
Cache Valley/Utah Portion-Northern Wasatch Front-
Salt Lake and Tooele Valleys-Southern Wasatch Front-
Great Salt Lake Desert and Mountains-Wasatch Mountain Valleys-
Wasatch Mountains I-80 North-Wasatch Mountains South of I-80-
Western Uinta Mountains-Wasatch Plateau/Book Cliffs-
Western Uinta Basin-Castle Country-San Rafael Swell-
Sanpete/Sevier Valleys-West Central Utah-Southwest Utah-
Utahs Dixie and Zion National Park-South Central Utah-
Glen Canyon Recreation Area/Lake Powell-Central Mountains-
Southern Mountains-Southwest Wyoming-
422 AM MDT Tue Sep 12 2017

This Hazardous Weather Outlook is for the western two thirds of
Utah and southwest Wyoming.

.DAY ONE...Today and Tonight

Isolated to scattered showers and thunderstorms may bring locally
gusty/erratic winds.

.DAYS TWO THROUGH SEVEN...Wednesday through Monday

The potential for organized thunderstorm development exists
Thursday. Isolated severe development is expected across namely
southern portions of the outlook area.

A strong cold front will bring significantly cooler temps to the
outlook area beginning Friday. Widespread precipitation is expected
across the north/west, coupled with temperatures some 10 to 15
degrees below average. Lowering snow levels will have the potential
to allow light accumulations for elevations over 8000 to 9000 feet
across the northern mountains. Hunters, hikers, and others with
outdoors and backcountry plans should be prepared for raw
conditions.

.SPOTTER INFORMATION STATEMENT...

Weather spotters are encouraged to report significant weather
conditions according to standard operating procedures.

$$

Rogowski/Merrill

For more information from NOAA/s National Weather Service visit...
http://weather.gov/saltlakecity

For information on potential road travel impacts visit...
http://www.udottraffic.utah.gov/roadweatherforecast.aspx

14.0 NWS Airport Weather Warning

The NWS Office in Salt Lake City, Utah, issued the following Airport Weather Warning (AWW) for KSLC at 1328 MDT with outflow winds gusting to greater than 26 knots for KSLC. The warning was valid from 1330 to 1440 MDT and warned of a west wind of 20 to 25 mph with gusts to 30 to 35 mph:

WWUS85 KSLC 121928
AWWSLC

UTC035-122045-
Airport Weather Warning for Salt Lake City International Airport
National Weather Service Salt Lake City UT
128 PM MDT Tue Sep 12 2017

Airport Weather Warning for outflow winds gusting to greater than 30 mph/26 kt for the Salt Lake City International Airport.

Valid 130 PM to 240 PM MDT.

West winds 20 to 25 mph with gusts 30 to 35 mph.

$$

For more information from NOAA/s National Weather Service visit...
http://weather.gov/saltlakecity

15.0 Winds and Temperature Aloft Forecast

The NWS 0801 MDT Winds and Temperature Aloft forecast valid for the accident flight are included below:

```
FBUS31 KWNO 121401
FD1US1
-DATA BASED ON 121200Z
VALID 121800Z   FOR USE 1400-2100Z. TEMPS NEG ABV 24000

FT  3000    6000    9000   12000   18000   24000  30000  34000  39000

SLC        9900    2806+16 2907+08 2616-09 2515-21 231436 241945 243156
```

The closest forecast point was Salt Lake City, Utah, (SLC). The 0801 MDT SLC forecast indicated a calm wind at 6,000 ft and a wind at 9,000 ft from 280° at 6 knots with a temperature of 16° C.

16.0 Pilot Weather Briefing and Information

A search of official weather briefing sources, such as Leidos, and Direct User Access Terminal Service (DUATS), revealed that the accident pilot did not contact Leidos, or DUATS. An archive search of ForeFlight data revealed that the accident pilot did not gather weather information from ForeFlight before or during the accident flight. It is unknown if the accident pilot checked or received additional weather information before or during the accident flight.

17.0 ITWS Information

In response to NTSB request 17-266, the FAA provided the screen shots of the Integrated Terminal Weather System (ITWS)[30] Situation Display applicable to the Salt Lake City, Utah, area for the time period surrounding the accident. Images from the ITWS Situation Display for 1300 through 1400 MDT are presented in Attachment 7. The ITWS data indicated a gust front in between KOGD and KSLC at 1335 MDT moving northeastward towards KOGD and the accident site. Gust front conditions were indicated on the ITWS display through 1350 MDT.

[30] Please see: https://www.faa.gov/air_traffic/technology/itws/ for more information.

18.0 Gust Front, Outflow, and Thunderstorm Training Information

The FAA's Advisory Circular AC 00-6B[31] titled "Aviation Weather" issued in August 2016 is the primary basic training guide on many weather hazards, including gust fronts and outflow. In sections 19.6.2, 19.6.4, and 19.6.6, gust front conditions are associated with rain showers and more frequently with thunderstorm activity. Gust fronts create many hazards for aviation and can cause damaging wind at the surface.

The FAA Advisory Circular AC 00-24C[32] titled "Thunderstorms" issued in February 2013 is the primary basic training guide on thunderstorm hazards used for flight training guidance. Figure 15 is a cross section of a squall line thunderstorm from AC 00-24B depicting the shelf cloud, gust front, and its related cold air outflow. The turbulence region of a gust front is identified from the leading edge or "nose", which would be marked by a sudden wind shift and increase in wind speed along with potentially moderate to severe turbulence up to 1,000 and occasionally to 3,000 feet agl. A sudden wind shift and gusty winds associated with a gust front can be seen at KOGD, KHIF, and KSLC (section 3.0), when the gust front moves across those airports at the accident time. Multiple surges of cold dense air are typical results in individual strong gusts. Behind the "head" of the gust front, another area of turbulence is typically found near the "wake." This can cause wave formations with the density discontinuities between the warm and cold air masses resulting again in moderate to severe turbulence. Gust fronts are often observed extending up to 15 miles from the main precipitation core of the thunderstorm and rain shower.

[31] https://www.faa.gov/regulations_policies/advisory_circulars/index.cfm/go/document.information/documentID/1029851

[32] https://www.faa.gov/regulations_policies/advisory_circulars/index.cfm/go/document.information/documentID/1020774

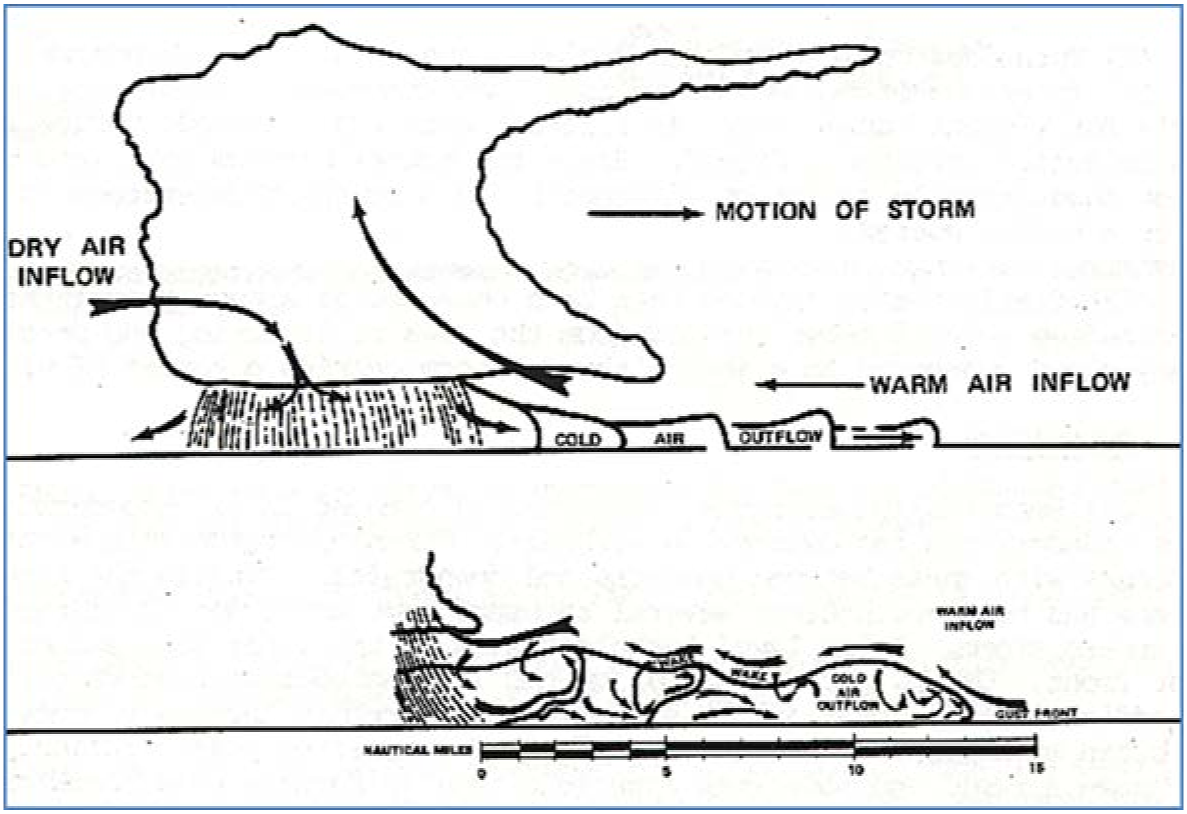


Figure 15 – Cross section of a thunderstorm showing the cold air outflow and gust front

As a result of the hazardous nature of thunderstorms and rain showers and the related gust front and outflow the FAA has published several common practices or do's and don'ts on thunderstorm flying, which are published in AC 00-24C and the Aeronautical Information Manual (AIM) under Chapter 7 Safety of Flight, section 7-1-29. The following avoidance rules are published:

DOS AND DON'TS OF THUNDERSTORM AVOIDANCE.

a. Thunderstorm Avoidance. Never regard any thunderstorm lightly, even when radar observers report the echoes are of light intensity. Avoiding thunderstorms is the best policy. Following are some dos and don'ts of thunderstorm avoidance:

(1) Don't land or takeoff in the face of an approaching thunderstorm. A sudden gust front of low-level turbulence could cause loss of control.

(2) Don't attempt to fly under a thunderstorm even if you can see through to the other side. Turbulence and wind shear under the storm could be hazardous.

(3) Don't attempt to fly under the anvil of a thunderstorm. There is a potential for severe and extreme clear air turbulence.

(4) Don't fly without airborne radar into a cloud mass containing scattered embedded thunderstorms. Scattered thunderstorms not embedded usually can be visually circumnavigated.

(5) Don't trust the visual appearance to be a reliable indicator of the turbulence inside a thunderstorm.

(6) Don't assume that ATC will offer radar navigation guidance or deviations around thunderstorms.

(7) Don't use data-linked weather next generation weather radar (NEXRAD) mosaic imagery as the sole means for negotiating a path through a thunderstorm area (tactical maneuvering).

(8) Do remember that the data-linked NEXRAD mosaic imagery shows where the weather *was*, not where the weather *is*. The weather conditions may be 15 to 20 minutes older than the age indicated on the display.

(9) Do listen to chatter on the ATC frequency for Pilot Weather Reports (PIREP) and other aircraft requesting to deviate or divert.

(10) Do ask ATC for radar navigation guidance or to approve deviations around thunderstorms, if needed.

(11) .Do use data-linked weather NEXRAD mosaic imagery (e.g., Flight Information Service-Broadcast (FIS-B)) for route selection to avoid thunderstorms entirely (strategic maneuvering).

(12) Do advise ATC, when switched to another controller, that you are deviating for thunderstorms before accepting to rejoin the original route.

(13) Do ensure that after an authorized weather deviation, before accepting to rejoin the original route, that the route of flight is clear of thunderstorms.

(14) Do avoid by at least 20 miles any thunderstorm identified as severe or giving an intense radar echo. This is especially true under the anvil of a large cumulonimbus.

(15) Do circumnavigate the entire area if the area has 6/10 thunderstorm coverage.

(16) Do remember that vivid and frequent lightning indicates the probability of a severe thunderstorm.

(17) Do regard as extremely hazardous any thunderstorm with tops 35,000 feet or higher whether the top is visually sighted or determined by radar.

(18) Do give a PIREP for the flight conditions.

(19) Do divert and wait out the thunderstorms on the ground if unable to navigate around an area of thunderstorms.

b. Dos Before Entering a Storm. If unable to avoid penetrating a thunderstorm, the following are some dos *before* entering the storm:

(1) Tighten the safety belt, put on the shoulder harness (if installed), and secure all loose objects.

(2) Plan and hold the course to take the aircraft through the storm in a minimum time.

(3) To avoid the most critical icing, establish a penetration altitude below the freezing level or above the level of -15ºC.

(4) Verify that pitot heat is on and turn on carburetor heat or jet engine anti-ice. Icing can be rapid at any altitude and cause almost instantaneous power failure and/or loss of airspeed indication.

(5) Establish power settings for turbulence penetration airspeed recommended in the aircraft manual.

(6) Turn up cockpit lights to highest intensity to lessen temporary blindness from lightning.

(7) If using automatic pilot, disengage Altitude Hold Mode and Speed Hold Mode. The automatic altitude and speed controls will increase maneuvers of the aircraft thus increasing structural stress.

(8) If using airborne radar, tilt the antenna up and down occasionally. This will permit the detection of other thunderstorm activity at altitudes other than the one being flown.

c. Dos and Don'ts for Thunderstorm Penetration. Following are some dos and don'ts during the thunderstorm penetration:

(1) Do keep your eyes on the flight instruments. Looking outside the cockpit can increase danger of temporary blindness from lightning.

(2) Don't change power settings; maintain settings for the recommended turbulence penetration airspeed.

(3) Do maintain constant attitude. Allow the altitude and airspeed to fluctuate.

(4) Don't turn back once in the thunderstorm. A straight course through the storm most likely will get the aircraft out of the hazards most quickly. In addition, turning maneuvers increase stress on the aircraft.

Figure 16 is a series of images from a research weather computer model simulating the turbulence flow created by the density differences in a gust front and the creation of Kelvin-Helmholtz instability[33] along the boundary of the airmass. The turbulence noted along and in the gust front is a common location of loss of aircraft control. Further information on the hazards of a gust fronts and outflow and the safest courses of action for pilot can be found in the FAA's AC 00-6B, the FAA's AC 00-24C, the FAA's Aeronautical Information Manual change 2 section 7-1-26 published in January 2015, and from the University Corporation for Atmospheric Research (UCAR)[34].

[33] Kelvin-Helmholtz instability – Instability caused by air masses with different densities moving at different speeds that create turbulence and wave-like patterns in the clouds when visible.

[34] UCAR's Collaboration among Education and Training Programs (COMET) Meteorology Education and Training (MetEd) module on Thunderstorm Downdrafts: https://www.meted.ucar.edu/tropical/synoptic/local_storms/navmenu.php?tab=1&page=2.0.0&type=flash

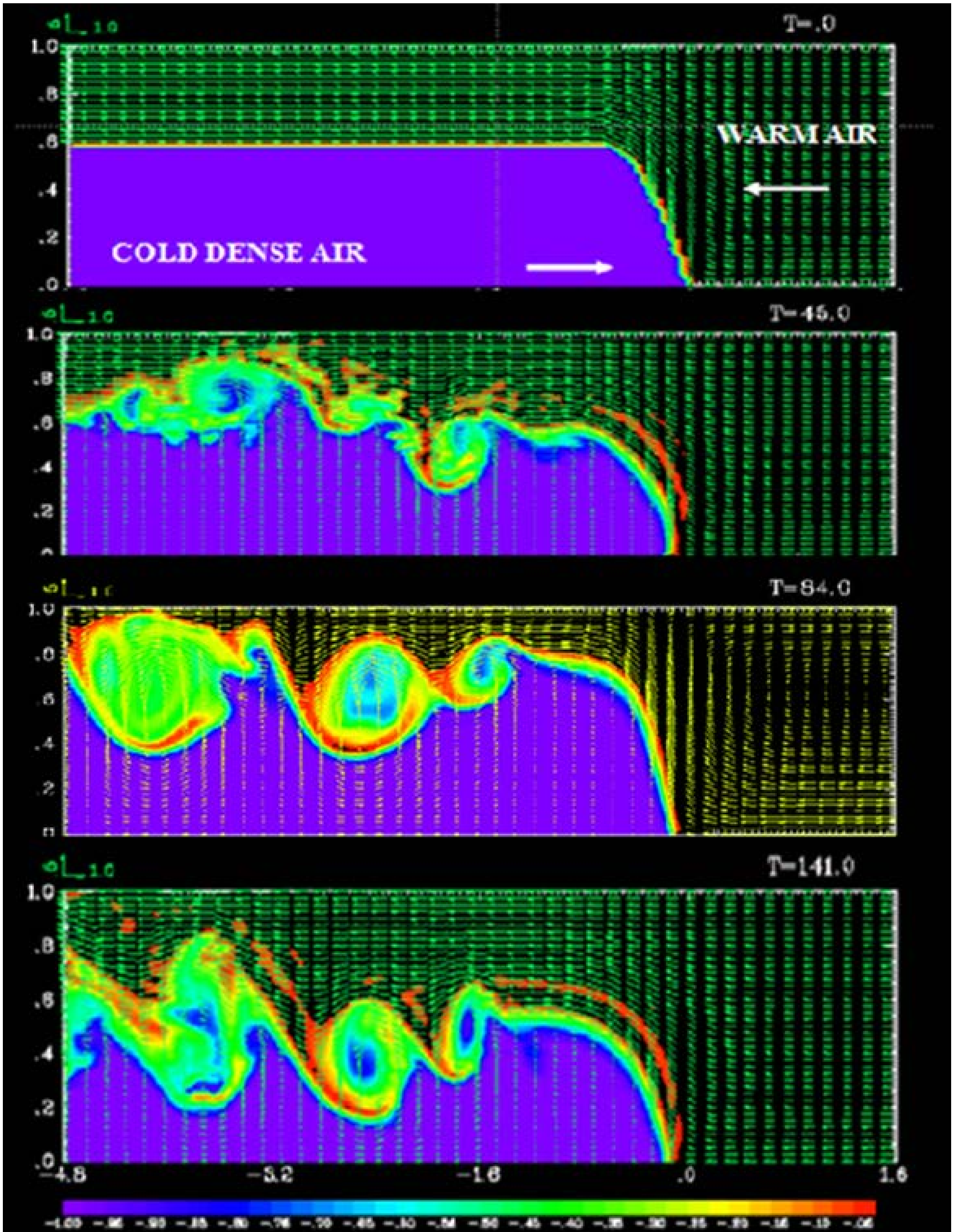


Figure 16 – Computer modeling of the turbulence flow created by the density differences in a gust front

19.0 Astronomical Data

The astronomical data obtained from the United States Naval Observatory for the accident site on September 12, 2017, indicated the following:

SUN	
Begin civil twilight	0638 MDT
Sunrise	0706 MDT
Sun transit	1324 MDT
Sunset	1942 MDT
End civil twilight	2009 MDT

E. LIST OF ATTACHMENTS

Attachment 1 – GOES-16 visible satellite animation from 1257 to 1357 MDT

Attachment 2 – KMTX 0.5° elevation scan base velocity data from 1318 to 1359 MDT

Attachment 3 – KMTX 0.5° elevation scan base reflectivity data from 1318 to 1359 MDT

Attachment 4 – TSLC 0.5° elevation scan base reflectivity data from 1305 to 1410 MDT

Attachment 5 – TSLC 0.5° elevation scan base reflectivity data with another filter from 1310 to 1410 MDT

Attachment 6 – TSLC 0.5° elevation scan base velocity data from 1316 to 1416 MDT

Attachment 7 – ITWS information from Salt Lake City area from 1300 to 1400 MDT

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