

National Transportation Safety Board

Office of Aviation Safety

Washington, DC 20594



WPR22LA251

METEOROLOGY

Group Chair's Factual Report

January 5, 2023

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A. ACCIDENT

Location: Salt Lake City, Utah
Date: July 13, 2022
Time: 1852 mountain daylight time
0052 coordinated universal time (UTC) on July 14, 2022
Airplane: Cessna 208B; Registration: N877FE

B. METEOROLOGY GROUP

Specialist Paul Suffern
National Transportation Safety Board
Washington, DC

Group Member Scott Birch
National Weather Service
Western Region Headquarters
Salt Lake City, Utah

C. DETAILS OF THE INVESTIGATION

The National Transportation Safety Board's Senior Meteorologist travelled to Salt Lake City, Utah, with the Air Traffic Control (ATC) group for follow up work in this investigation. Additional data for this investigation were collected 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 Factual Report contains the meteorological factors pertinent to the weather surrounding the accident time. All times are mountain daylight time (MDT) and are based upon the 24-hour clock, where local time is -6 hours from UTC. Directions are referenced to true north and distances are in nautical miles. Heights are above mean sea level (msl) unless otherwise noted. Visibility is in statute miles and fractions of statute miles. NWS 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.

The accident site was located approximately at latitude 40.7838° N, Longitude 111.9736° W, and elevation of 4,225 feet (ft).

D. FACTUAL INFORMATION

1.0 Synoptic Situation

The synoptic or large-scale migratory weather systems influencing the area were documented using standard NWS charts issued by the National Center for Environmental Prediction and the WPC, 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 Federal Aviation Administration (FAA) "Aviation Weather Handbook", FAA-H-8083-28.¹

1.1 Surface Analysis Chart

The NWS Surface Analysis Chart centered over Utah for 1800 MDT is provided as figure 1 with the accident site within the black circle. The chart depicted a low-pressure system over southern Idaho at 1006-hectopascals (hPa). High-pressure systems were located in southern Utah, northwestern Wyoming, and central Colorado at 1016-, 1018-, and 1020-hPa, respectively. No surface fronts or troughs² were located near the accident site at 1800 MDT.

The station model closest to the accident site depicted an air temperature of 100 degrees Fahrenheit (°F), dew point temperature of 46°F, a temperature-dew point spread of 54°F, mostly clear skies, and a calm wind.

¹ [FAA-H-8083-28](#)

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

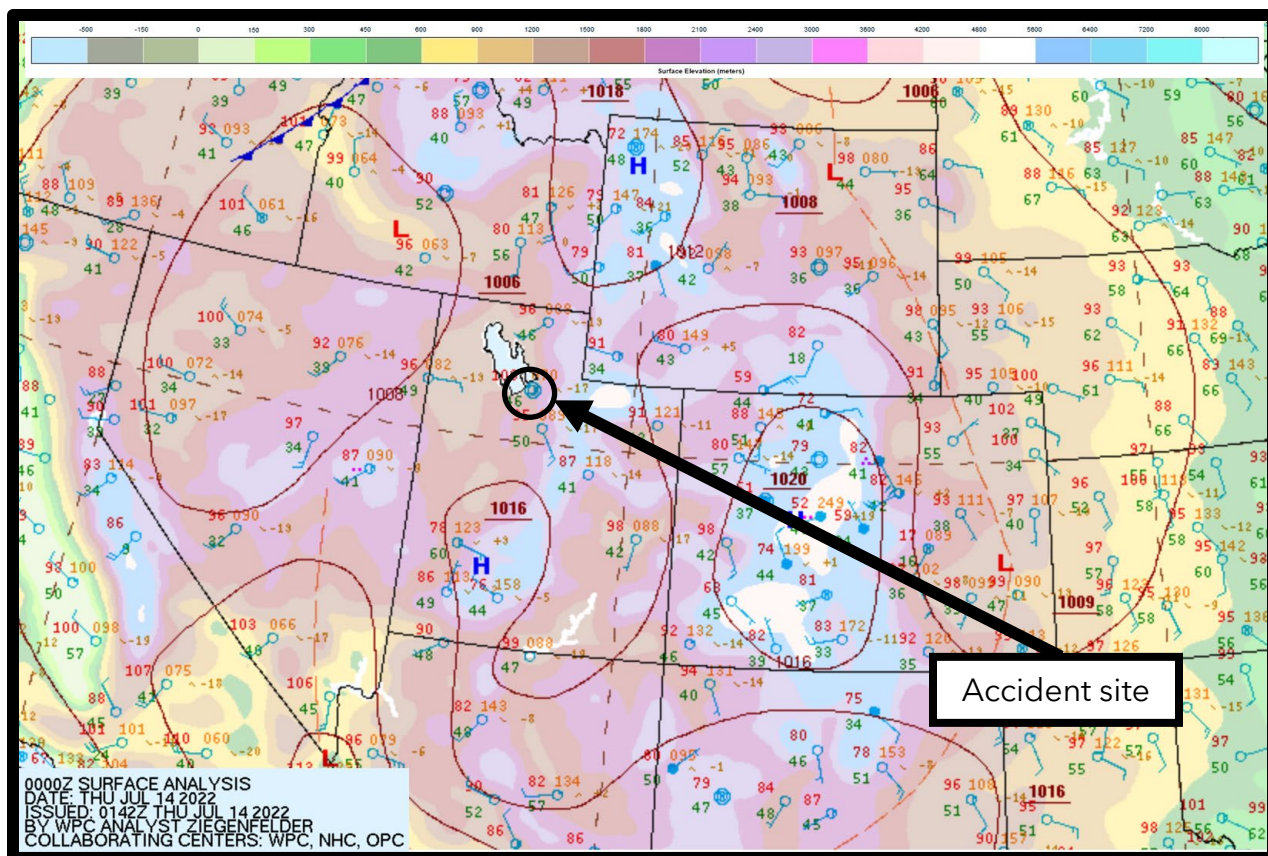


Figure 1. NWS Surface Analysis Chart for 1800 MDT.

1.2 Upper Air Charts

The NWS Storm Prediction Center (SPC) Constant Pressure Charts for 1800 MDT at 700- and 500-hPa are presented in figures 2 and 3, respectively. The accident site was located beneath a mid-level trough. Troughs and fronts can act as lifting mechanisms to help produce clouds and precipitation if sufficient moisture is present. The 700-hPa constant pressure chart depicted a southwest wind of 10 to 15 knots near the accident site with the wind above remaining similar in direction and speed through 500-hPa (figure 3).

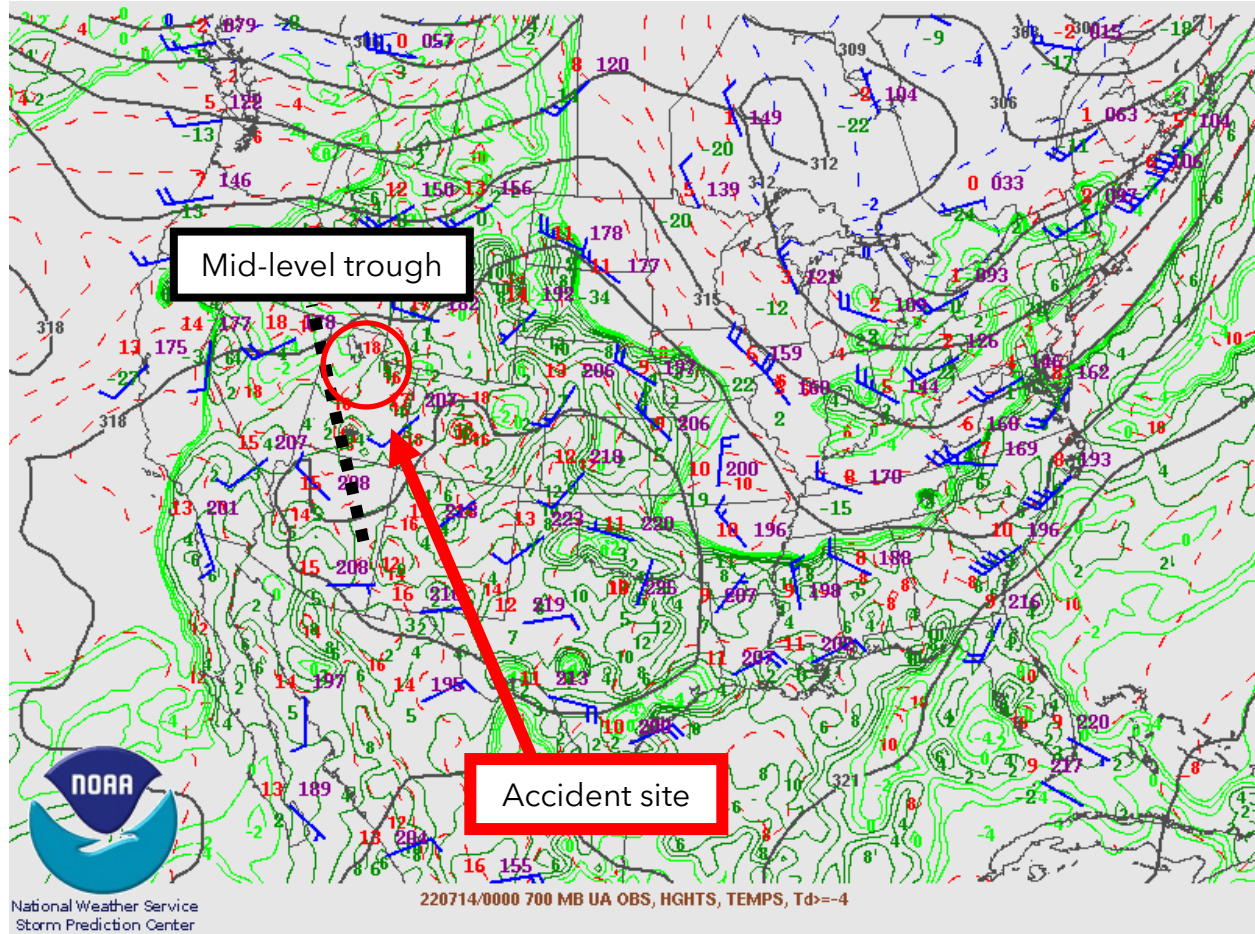


Figure 2. 700-hPa Constant Pressure Chart for 1800 MDT.

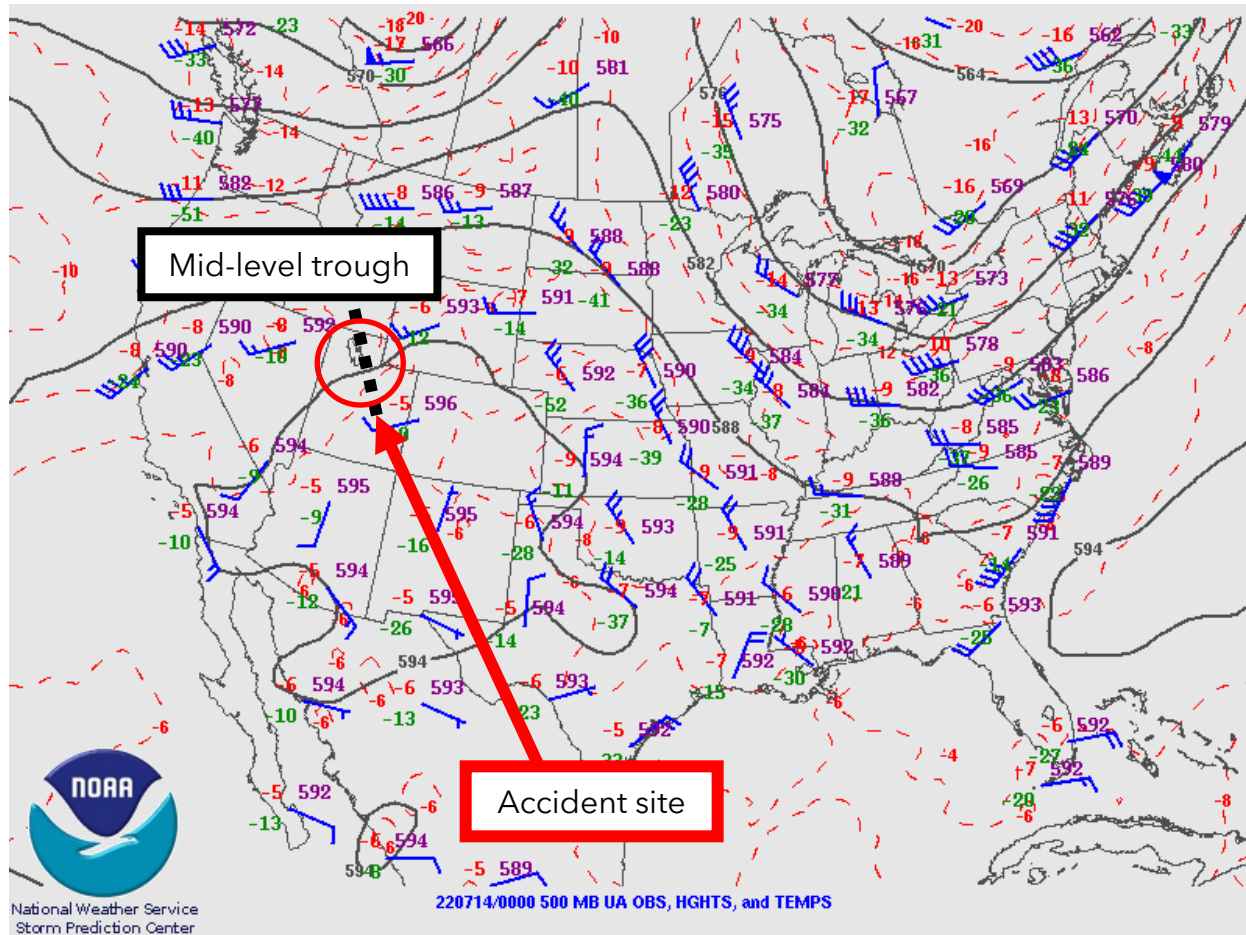


Figure 3. 500-hPa Constant Pressure Chart for 1800 MDT.

2.0 Storm Prediction Center Convective Outlook

SPC issued a Day 1 Convective Outlook at 1354 MDT (figure 4) with areas of general thunderstorms forecast for the accident site. SPC defines the "TSTM" area as an area that encloses where a 10% or higher probability of thunderstorms is forecast during the valid period.

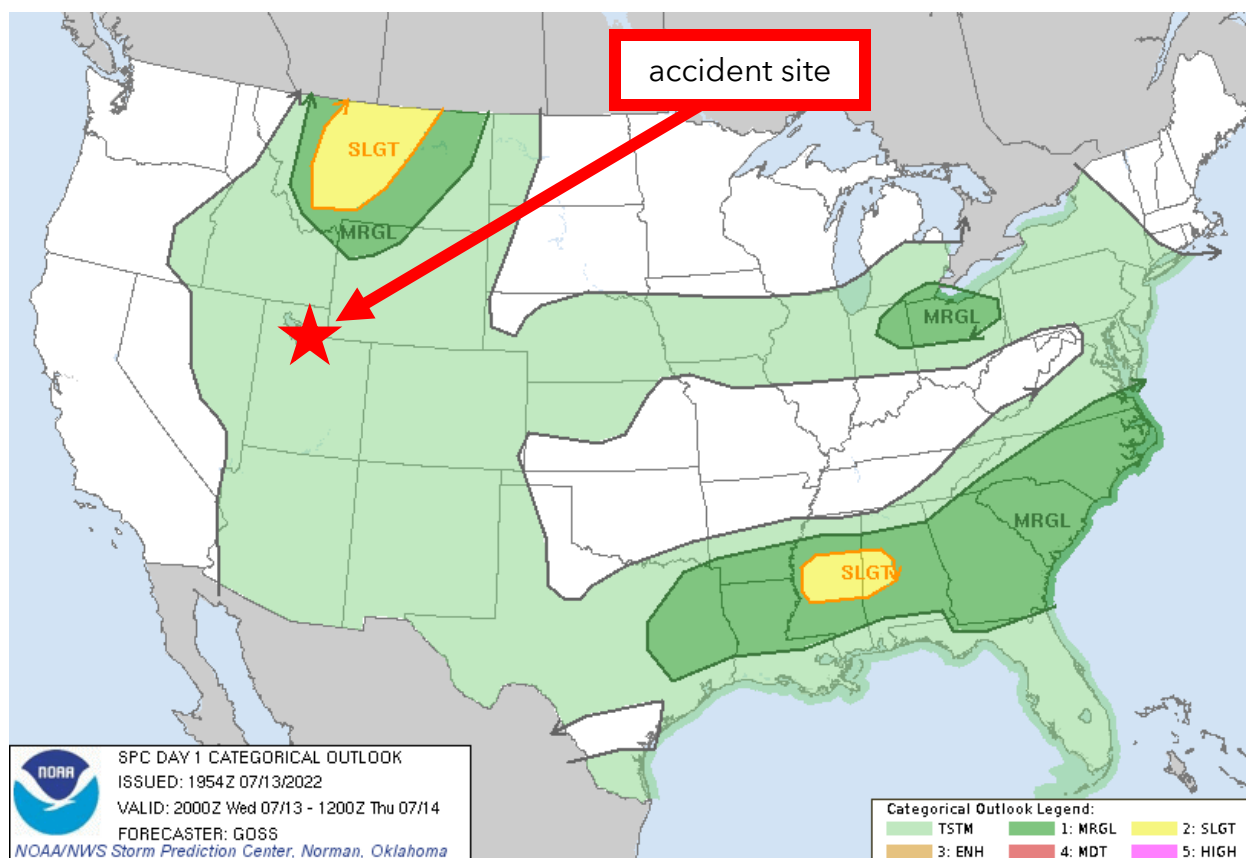


Figure 4. SPC day 1 Convective Outlook valid at the time of the accident.

3.0 Surface Observations

The area surrounding the accident site was documented using official Aviation Routine Weather Reports (METARs) and Special Reports (SPECIs). The following observations were taken from standard code and are provided in plain language. Figure 5 is a local sectional chart with the accident site and the closest weather reporting location marked. The magnetic variation³ was indicated as 11.5° east in the area.

³ Magnetic variation - The angle (at a particular location) between magnetic north and true north. Latest measurement taken from <https://skyvector.com/>

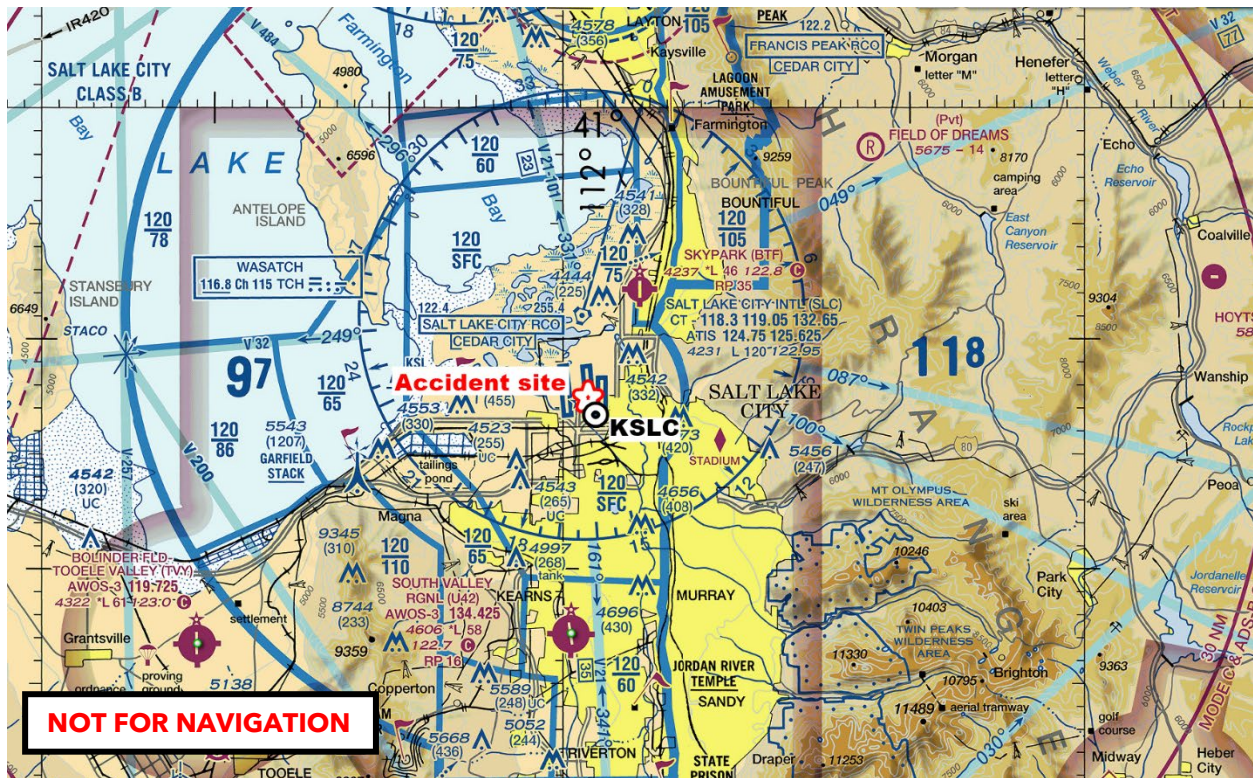


Figure 5. FAA sectional aeronautical chart of the accident area with the location of the accident site and surface observation site.

Salt Lake City International Airport (KSLC) had the closest official weather station to the accident site. KSLC had an Automated Surface Observing System (ASOS⁴) and longline⁵ reports were augmented by a Certified Weather Observer. The KSLC ASOS was located around 5,000 ft south-southeast of the accident site, at an elevation of 4,226 ft, and issued the following observations surrounding the period of the accident:⁶

[1536 MDT] SPECI KSLC 132136Z 31021G29KT 10SM TS SCT110
 BKN160 BKN240 33/12 A3001 RMK AO2 PK WND 31029/2135 WSHFT
 2116 RAB07E27 TSB09 P0000 T03330122

⁴ ASOS - Automated Surface Observing System is equipped with meteorological instruments to observe and report wind, visibility, weather phenomena, ceiling, temperature, dewpoint, altimeter, and barometric pressure. ASOS are maintained by the NWS.

⁵ "Longline" refers to the dissemination of weather observations with the intent that they are available in near-real time to national databases and accessible to the general global public from a large number of vendors. This does not include public accessibility to observations from a reporting station's Very High Frequency (VHF; line-of-site) or telephone broadcast, where applicable. Longline dissemination of weather observations is the primary vehicle through which the weather observations are distributed.

⁶ The bold sections of products in this report are intended to highlight the text that directly reference the weather conditions that affected the accident region around the accident time. The local times in this section next to the METARs are provided for quick reference between UTC and local times.

[1554 MDT] METAR KSLC 132154Z 35009KT 10SM FEW080CB SCT110
SCT160 BKN240 37/09 A3000 RMK AO2 PK WND 31029/2135 WSHFT
2116 RAB07E27 TSB09E50 SLP088 CB VC NE AND CB DSNT W MOV
NE P0000 T03670094

[1654 MDT] METAR KSLC 132254Z VRB05KT 10SM FEW120 SCT150
BKN240 37/08 A2998 RMK AO2 SLP079 T03720083

[1754 MDT] METAR KSLC 132354Z 00000KT 10SM SCT150 BKN240
38/08 A2995 RMK AO2 SLP070 60000 T03780078 10383 20328 58017

**[1833 MDT] SPECI KSLC 140033Z 34016G21KT 10SM TS
FEW110CB SCT150 BKN240 37/08 A2995 RMK AO2 LTG DSNT SW
TSB27 CB VC SW MOV NE T03720083**

ACCIDENT TIME 1852 MDT

**[1854 MDT] METAR KSLC 140054Z 30029G48KT 9SM -TSRA
FEW018 FEW120 BKN140 BKN240 33/13 A2997 RMK AO2 PK
WND 32048/0054 LTG DSNT SW RAB51 TSB27E42B50 SLP081
CB OHD MOV NE P0000 T03280128**

[1915 MDT] SPECI KSLC 140115Z 03015G24KT 9SM -RA FEW035
BKN100 OVC120 31/13 A2998 RMK AO2 PK WND 32039/0055 WSHFT
0058 LTG DSNT S AND SW TSE15 P0003 T03110133

[1922 MDT] SPECI KSLC 140122Z 07005KT 10SM VCTS -RA FEW035CB
BKN095 BKN120 BKN240 31/14 A2998 RMK AO2 PK WND 32039/0055
WSHFT 0058 LTG DSNT SE AND SW TSE15 CB S MOV NE P0003
T03110144

[1945 MDT] SPECI KSLC 140145Z 19021G42KT 10SM -RA FEW055
BKN120 26/15 A3006 RMK AO2 PK WND 19042/0139 WSHFT 0058
LTG DSNT E-S TSE15 PRESRR CB SE MOV NE P0003 T02560150

The bold type observations decoded in plain language were as follows:

KSLC weather at 1833 MDT, wind from 340° at 16 knots with gusts to 21 knots, visibility 10 miles or greater, thunderstorm, few cumulonimbus clouds at 11,000 ft above ground level (agl), scattered clouds at 15,000 ft agl, broken ceiling at 24,000 ft agl, temperature of 37° Celsius (C), dew point temperature 8°C, and an altimeter setting of 29.95 inches of mercury (inHg). Remarks, automated station with a

precipitation discriminator, lightning distant⁷ southwest, thunderstorm began at 1827 MDT, cumulonimbus cloud in the vicinity⁸ southwest moving northeast, temperature 37.2°C, dew point temperature 8.3°C.

KSLC weather at 1854 MDT, wind from 300° at 29 knots with gusts to 48 knots, visibility 9 miles, thunderstorm with light rain, few clouds at 1,800 ft agl, few clouds at 12,000 ft agl, broken ceiling at 14,000 ft agl, broken clouds at 24,000 ft agl, temperature of 33°C, dew point temperature 13°C, and an altimeter setting of 29.97 inHg. Remarks, automated station with a precipitation discriminator, peak wind at 1854 MDT from 320° at 48 knots, lightning distant southwest, rain began at 1851 MDT, thunderstorm began at 1827 MDT and ended at 1842 MDT and thunderstorm began again at 1850 MDT, sea level pressure 1008.1 hPa, cumulonimbus clouds overhead moving northeast, a trace of precipitation since 1754 MDT, temperature 32.8°C, dew point temperature 12.8°C.

The observations from KSLC surrounding the accident time indicated VFR⁹ conditions prevailed with thunderstorms and gusting winds to 48 knots at 1854 MDT. The one- and five-minute KSLC ASOS observations surrounding the accident timeframe can be found in attachment 1. Exemplar KSLC ASOS instrumentation imagery and a chart depicting the ASOS' location on the airport are provided in figures 6 and 7, respectively.

⁷ "Distant" is defined as a weather phenomenon greater than 10 statute miles from the point of observation.

⁸ "In the vicinity" is defined as a weather phenomenon within 5-10 statute miles from the point of observation.

⁹ The NWS and the FAA Aeronautical Information Manual (AIM) section 7-1-7 defines the following general flight categories:

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

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

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



Figure 6. Exemplar image of KSLC ASOS instrumentation.

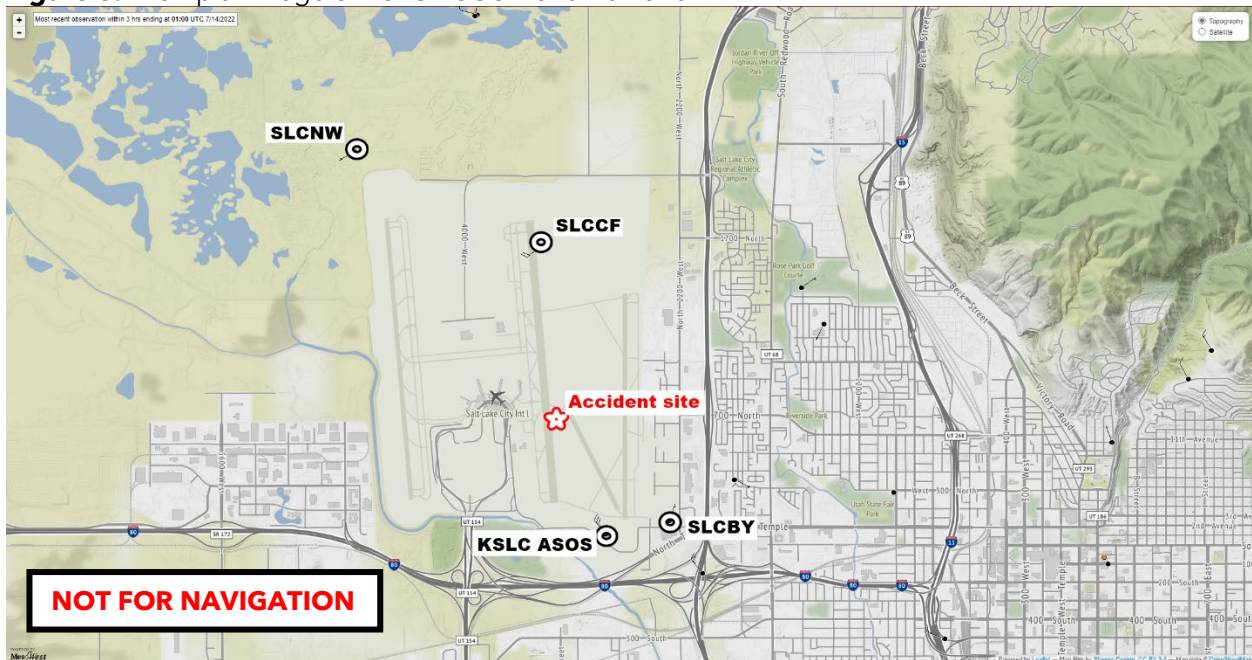


Figure 7. KSLC airport map with additional surface observation sites.

Several unofficial surface observations sites were found close to the accident site using the MesoWest network¹⁰ and their locations are documented in figure 7. The NWS "RSOIS" Site (SLCBY)¹¹, the KSLC Airport ("Center Field") Wind 3 (SLCCF)¹² and the KSLC Airport Wind 2 (SLCNW)¹³ stations were located within 2 miles of the accident site. The data from SLCBY, SLCCF, and SLCNW can be found in attachments 2, 3 and 4¹⁴. Additional wind sensors were requested by SLC ATC in November 2015 (attachment 29), but that request was denied by April 2016 (attachment 30).

4.0 Upper Air Sounding

Salt Lake City, Utah, had an upper air sounding (KSLC sounding) that had a station ID of 72572, with a surface elevation of 4,226 ft. The KSLC sounding launch site was located within a mile of the accident site. The 1800 MDT KSLC sounding was plotted on a standard Skew-T Log P diagram¹⁵ using the RAOB software¹⁶ from the surface to 400-hPa (or approximately 25,000 ft) along with the derived stability parameters and is included as figure 8. The sounding depicted the lifted condensation level (LCL)¹⁷ and the level of free convection (LFC)¹⁸ at 16,367 ft, and the convective condensation level (CCL)¹⁹ at 17,073 ft. The freezing level was located at 16,595 ft with the precipitable water value at 0.95 inches.

¹⁰ [MesoWest Data \(utah.edu\)](http://mesowest.utah.edu)

¹¹ [MESOWEST STATION INTERFACE \(utah.edu\)](http://mesowest-station-interface.utah.edu)

¹² [MESOWEST STATION INTERFACE \(utah.edu\)](http://mesowest-station-interface.utah.edu)

¹³ [MESOWEST STATION INTERFACE \(utah.edu\)](http://mesowest-station-interface.utah.edu)

¹⁴ Maintenance schedule and reliability for these stations is unknown.

¹⁵ 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.

¹⁶ RAOB - (The complete Rawinsonde Observation program) is an interactive sounding analysis program developed by Esonde Research Services, The Villages, Florida.

¹⁷ LCL - The height at which a parcel of moist air becomes saturated when it is lifted dry adiabatically.

¹⁸ 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.

¹⁹ 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.

The 1800 MDT KSLC sounding indicated an unstable to conditionally unstable environment from the surface through 25,000 ft. Clouds were indicated by RAOB between 17,000 and 20,000 ft. No icing was indicated by RAOB below 25,000 ft. A positive CAPE²⁰ value of 499 Joules/kilogram (J/kg) was indicated on the sounding and the maximum vertical velocity (MVV) for this atmosphere was calculated as 32 meters/second (about 6,299 ft per minute).²¹ Downdraft CAPE (DCAPE; 6 kilometers agl)²² was measured at 1,406 J/kg. If rain showers or thunderstorms formed in this environment, the sounding indicated that the strongest wind speeds possible at the surface (due to, for example, a downdraft²³, outflow boundary, or gust front) would have been 75 mph (65 knots) according to the T2 Gust parameter, or 64 mph (56 knots) according to the WindEx parameter.

The 1800 MDT KSLC sounding wind profile indicated a near surface wind from 160° at 2 knots with the wind outside of rain showers and thunderstorms remaining light and variable under 5 knots through 9,000 ft. Above 9,000 ft the wind became southwesterly through 25,000 ft. The wind speed increased to 15 knots by 10,000 ft and the wind speed was up to 35 knots by 23,000 ft. The RAOB analysis program indicated the possibility of light low-level wind shear (LLWS) outside of rain shower and thunderstorm activity, along with several layers of light clear air turbulence (CAT) from the surface through 25,000 ft.

5.0 Satellite Data

The Geostationary Operational Environmental Satellite numbers 16 (GOES-16) and 17 (GOES-17) visible and infrared data were 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-16/17 bands 2 and 13) at wavelengths of 0.64 microns (μm) and 10.3 μm , respectively, were retrieved for the period from 1500 MDT through 2200 MDT and reviewed, and the closest images to the time of the accident were documented.

²⁰ 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.

²¹ 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.

²² 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.

²³ Small-scale downward moving air current in a cumulonimbus or cumulus cloud.

A satellite image showing a coastal area with a red square marking the accident site. A red arrow points from a box labeled "Accident site" to the red square. The image includes a purple outline of a landmass and a purple line indicating a boundary. Metadata at the bottom reads: "GOES-17 2 14 JUL 22195 005617 01213 08502 00.50" and "H010AS".

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PG 17 OF 55

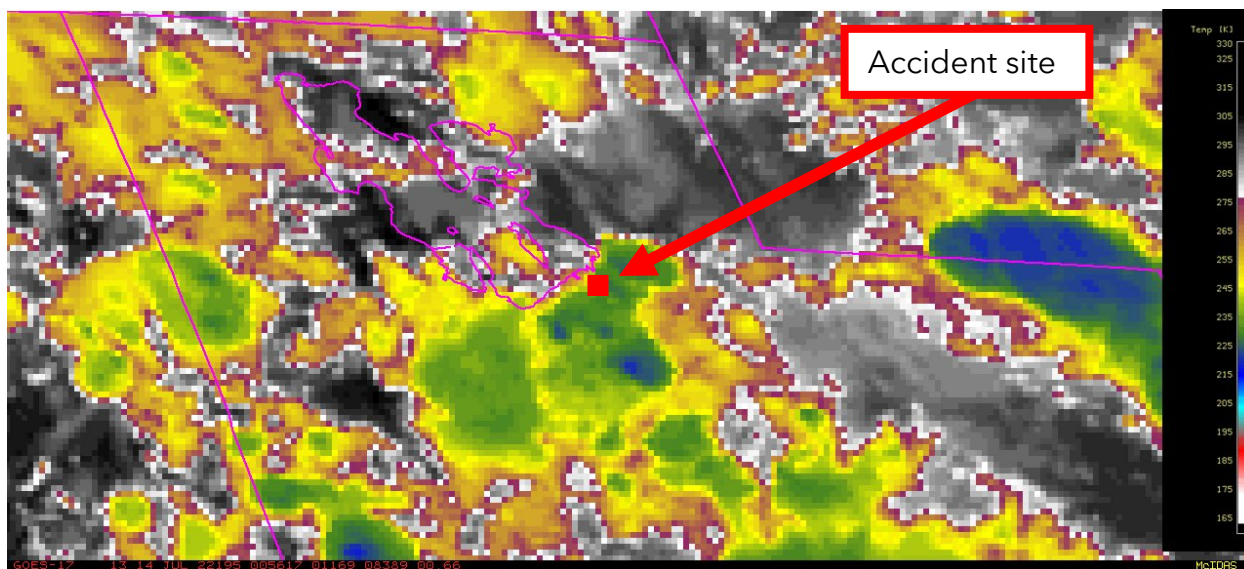


Figure 10. GOES-17 infrared image at 1856 MDT.

6.0 National Radar Imagery

A regional view of the NWS National Reflectivity Mosaic is included as figure 11 for 1855 MDT with the approximate location of the accident site marked by a red circle. The image depicted 15 to 40 dBZ²⁶ echoes above the accident site.

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.

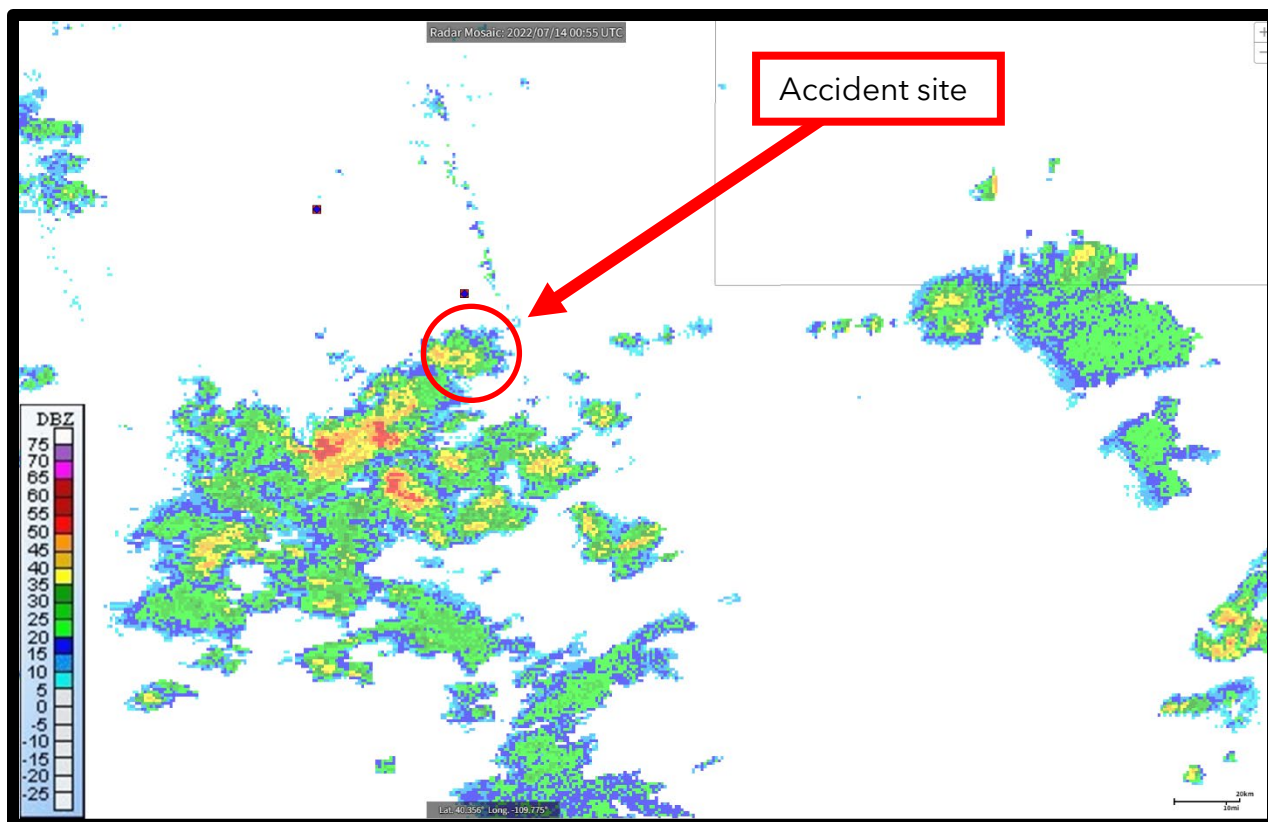


Figure 11. National Reflectivity Mosaic for 1855 MDT.

7.0 Weather Surveillance Radar Imagery

The closest NWS Weather Surveillance Radar-1988, Doppler (WSR-88D)²⁷ to the accident site was Box Elder County, Utah, WSR-88D, (KMTX) located 36 miles northwest of the accident site. The Level II archive radar data were obtained from the NCEI utilizing the NEXRAD Data Inventory Search and displayed using the NOAA's Weather and Climate Toolkit software. In addition, the Terminal Doppler Weather Radar (TDWR)²⁸ data from Salt Lake City (TSLC) was obtained and reviewed. TSLC was located 11 miles north-northeast of the accident site.

²⁷ 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.

²⁸ TDWR is a network of Doppler weather radars operated by the FAA. TDWR uses a carrier wave in the frequency band of 5600-5650 MHz (5 cm wavelength), with a narrow beam and angular resolution of 0.5 degrees, and has a peak power of 250 kW.

7.1 Volume Scan Strategy

During the period surrounding the accident, the KMTX WSR-88D radar was operating in the precipitation mode VCP-212 (figure 12). The following figure 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.

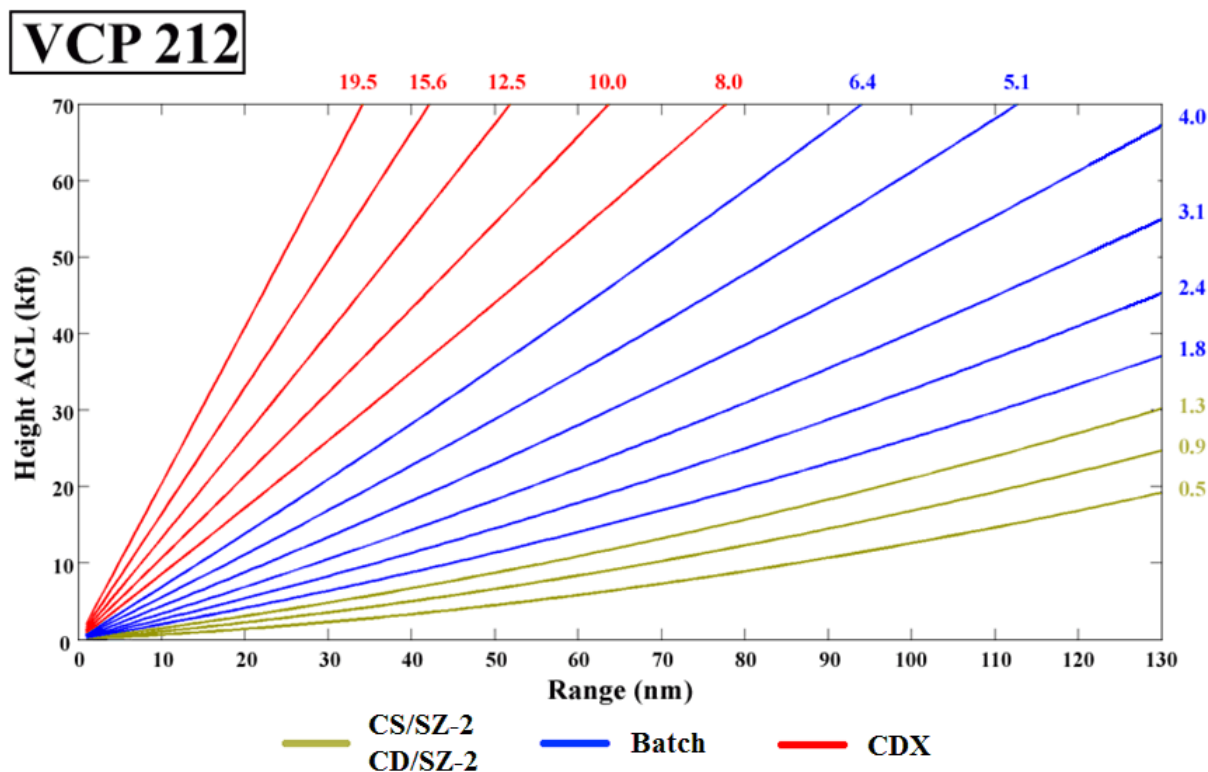


Figure 12. VCP-212 Precipitation Mode Scan Strategy²⁹.

²⁹ Contiguous Surveillance (CS)--The low Pulse Repetition Frequency (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.

W - With range unfolding (W)

WO - Without range unfolding (WO)

7.2 Beam Height Calculation

Assuming standard refraction³⁰ of the KMTX WSR-88D radar beam with the antenna elevation at 6,593 ft, and considering a beamwidth³¹ of 0.95°, and TSLC with the antenna elevation at 4,295 ft, the following table shows the approximate heights for the radar beams' centers, tops and bases for certain antenna elevations over the accident site. These heights have been rounded to the nearest 10 ft.

ANTENNA ELEVATION	BEAM CENTER	BEAM BASE	BEAM TOP
KMTX 0.0°	7,450 ft	5,640 ft	9,260 ft
TSLC 0.5°	4,960 ft	4,670 ft	5,250 ft

Based on the radar height calculations, the elevation scans reviewed from KMTX and TSLC listed in the above table combined to depict conditions between 4,670 ft and 9,260 ft over the accident site which covered the altitudes of the accident flight on descent into the Salt Lake City region.

³⁰ Standard Refraction in the atmosphere is when the temperature and humidity distributions are approximately average, and values set at the standard atmosphere.

³¹ Beamwidth - the angular separation between the half power points on the antenna radiation pattern, where the gain is one half the maximum value.

7.3 Reflectivity

Reflectivity is the measure of the efficiency of a target in intercepting and returning radio energy. With hydrometeors³² 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. FAA Advisory Circular AC 00-24C³³, "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 to 50 dBZ, inclusive. Finally, any dBZ values above 50 dBZ shall be described as "extreme."

7.4 Base Reflectivity and Lightning Data

Figures 13 through 17 present the KMTX WSR-88D and TSLC TDWR base reflectivity images for the 0.0° and 0.5° elevation scans initiated at 1836:37, 1842:35, 1848:24, 1851:24, and 1854:11 MDT with a resolutions of 0.5° X 250 m. The flight track data³⁴ of N877FE has been overlaid in pink for context in figures 13-17. These images depicted reflectivity values between 20 and 40 dBZ moving from southwest to northeast over the accident site at the time of the accident (attachment 7). An increase in wind speed towards the TSLC TDWR can be seen near the accident site at the accident time (attachment 8). In addition, the base reflectivity core can be seen descending towards the accident site at the accident time (attachment 9).

³² 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.

³³

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

³⁴ For more information please see the docket in this accident.

There were 50 lightning flashes³⁵ (black dots on figures 13 to 17) reported within 25 miles of the accident site within 10 minutes prior to and following the accident time with the closest lightning flash occurring at 1850:46 MDT 1 mile west of the flight track.³⁶ Figure 17 highlights the lightning flash locations near the accident site within the circled region.

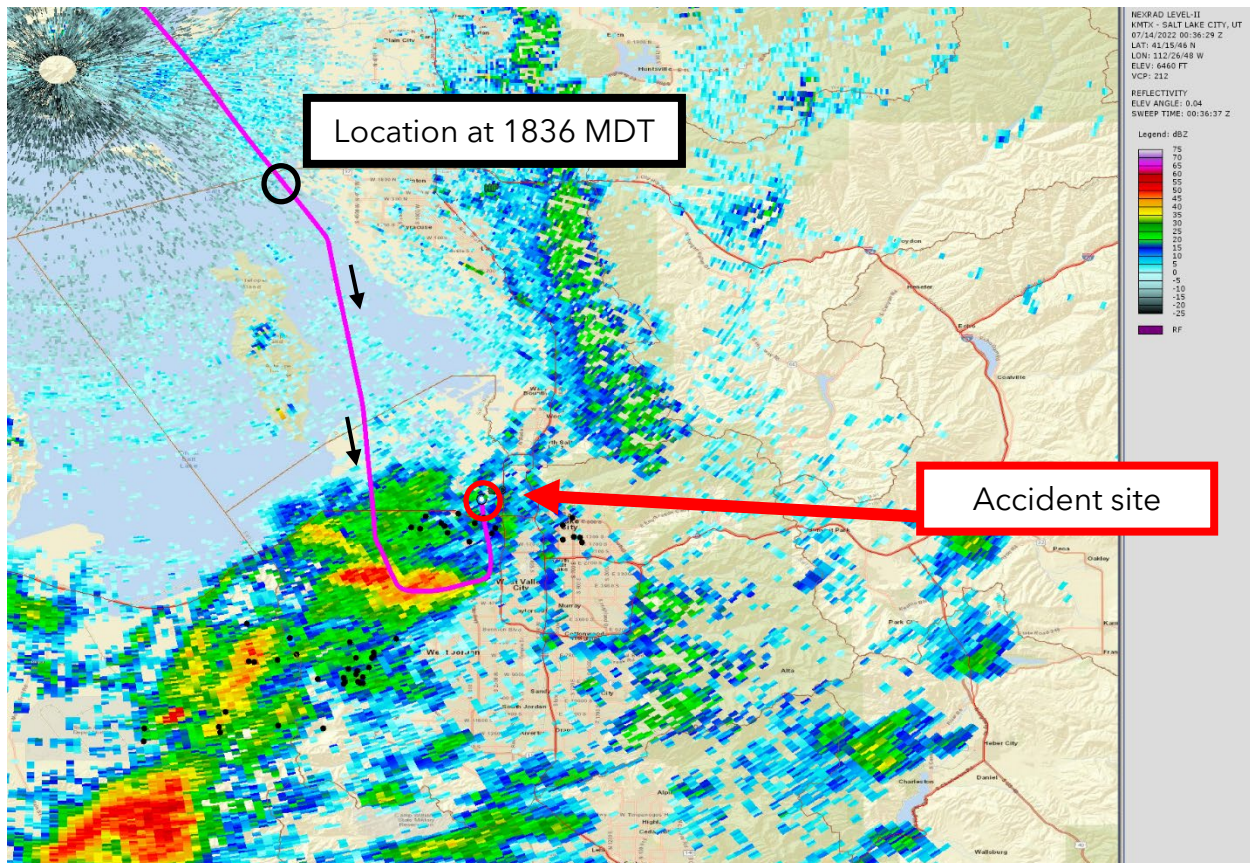


Figure 13. KMTX WSR-88D reflectivity for the 0.0° elevation scan initiated at 1836:37 MDT with the accident site marked with the red circle. The flight track is in pink with arrows pointing in the direction of travel. Lightning flashes are the black dots.

³⁵ Lightning Flash – This is one contiguous conducting channel and all the current strokes/pulses that flow through it. There are two types of flashes: ground flashes and cloud flashes.

³⁶ A review of Earth Networks Total Lightning network and GOES-16 Geostationary Lightning Mapper was done.

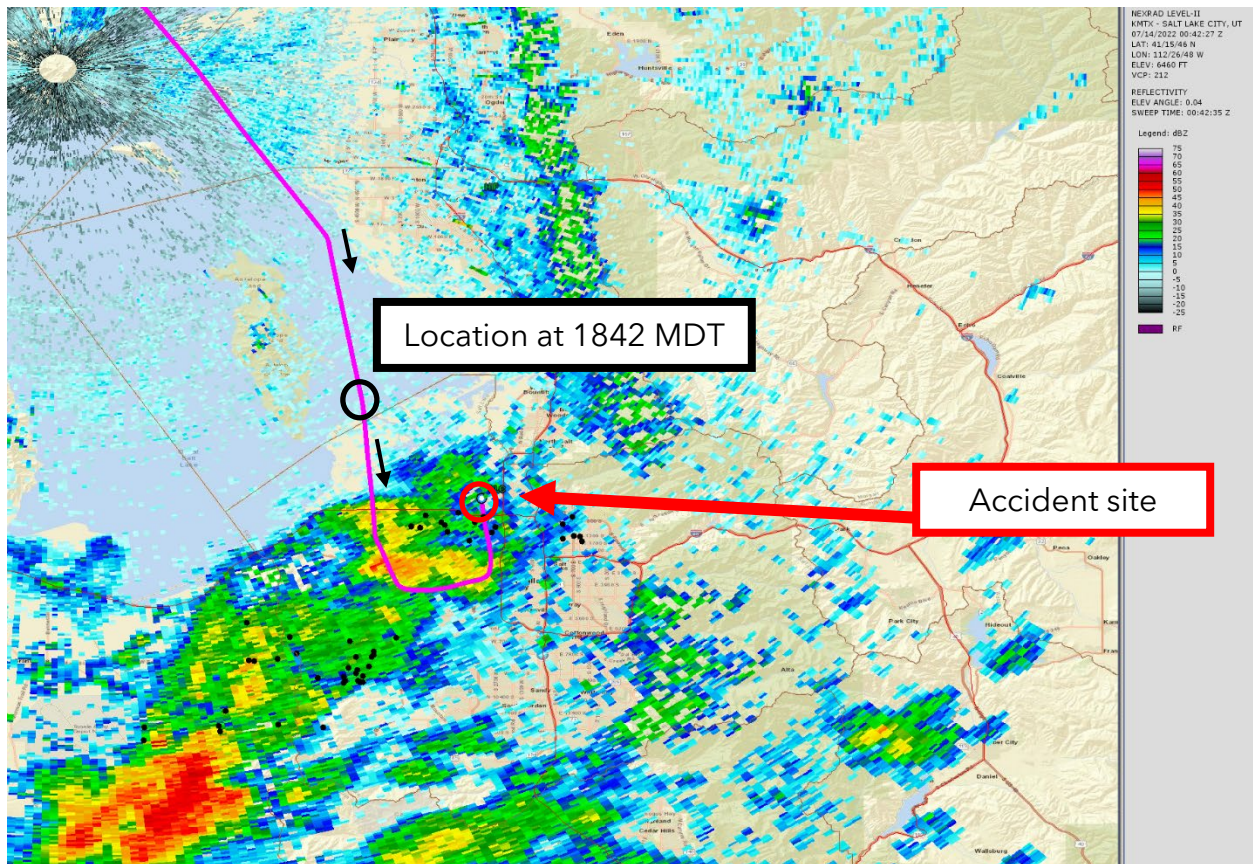


Figure 14. KMTX WSR-88D reflectivity for the 0.0° elevation scan initiated at 1842:35 MDT with the accident site marked with the red circle. The flight track is in pink with arrows pointing in the direction of travel. Lightning flashes are the black dots.

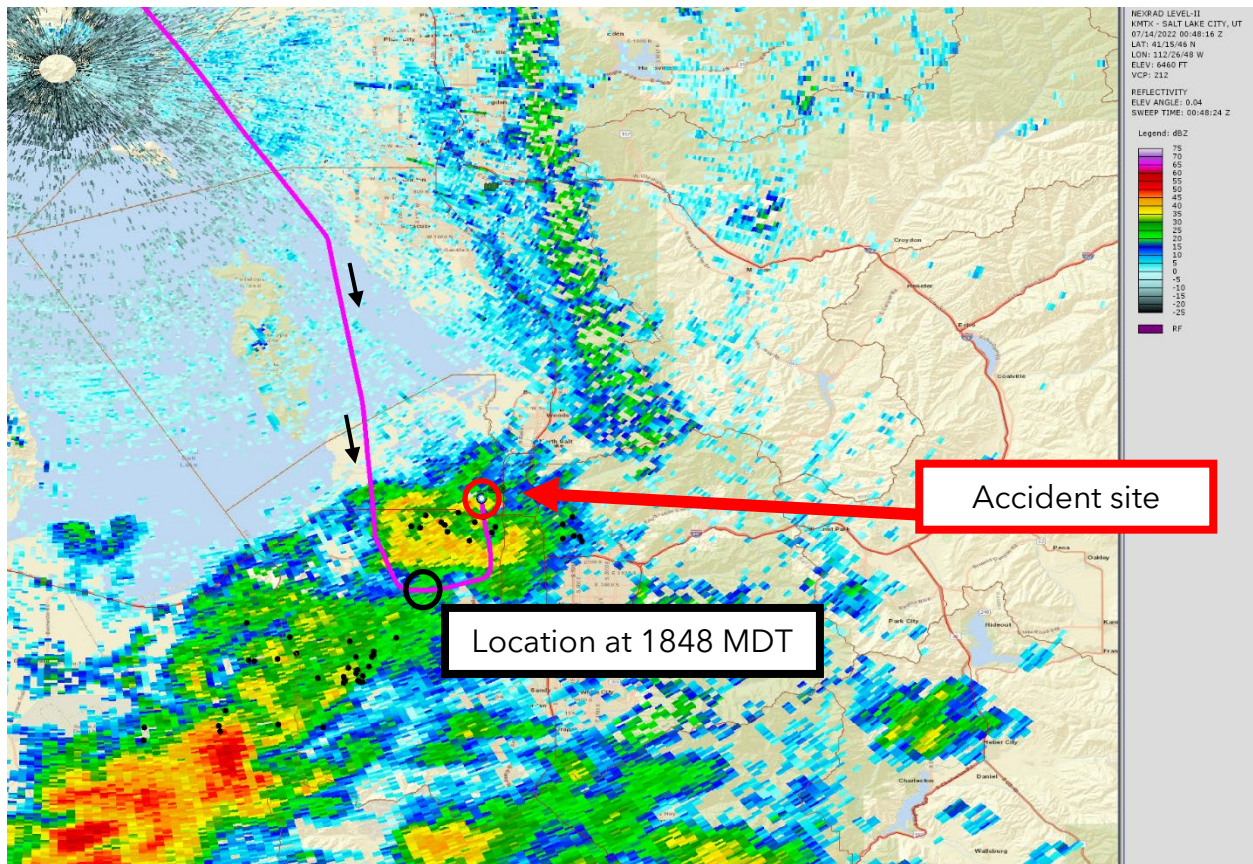


Figure 15. KMTX WSR-88D reflectivity for the 0.0° elevation scan initiated at 1848:24 MDT with the accident site marked with the red circle. The flight track is in pink with arrows pointing in the direction of travel. Lightning flashes are the black dots.

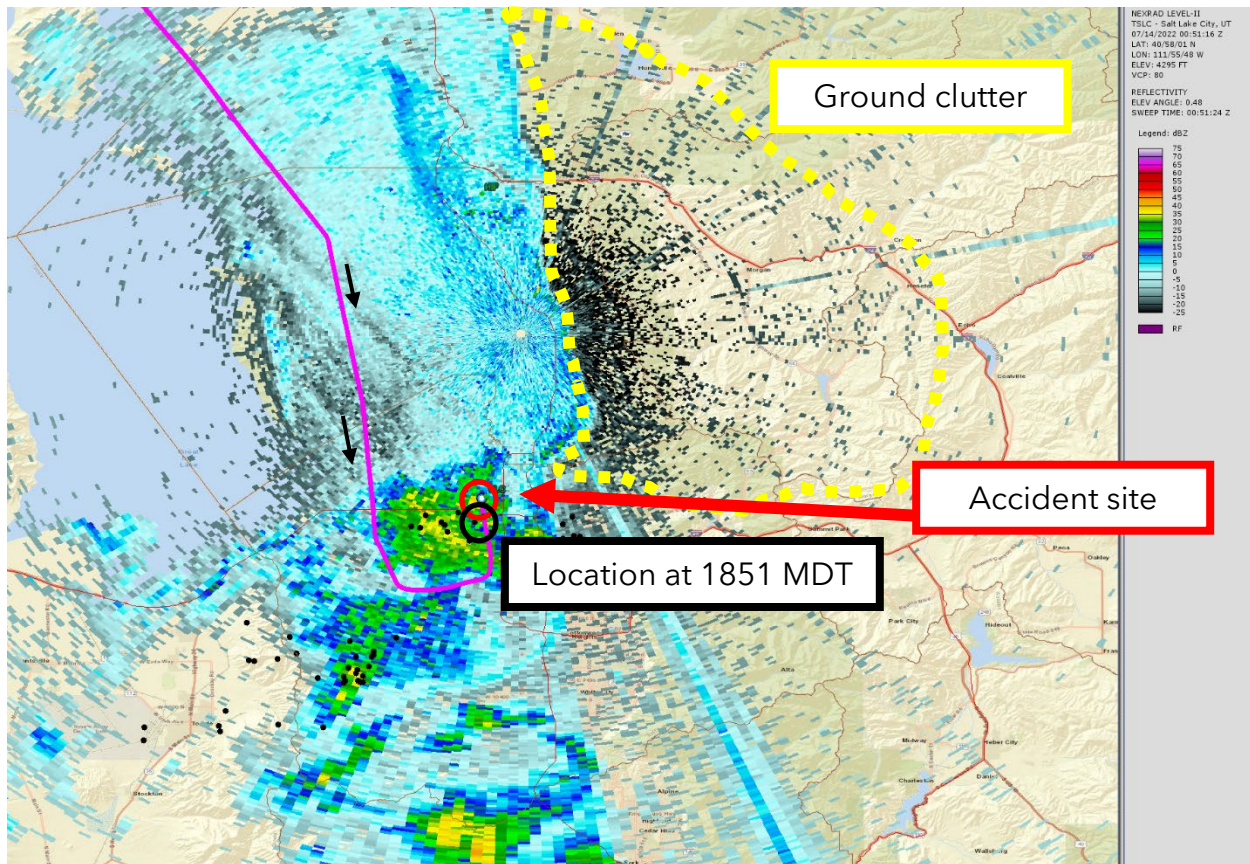


Figure 16. TSLC WSR-88D reflectivity for the 0.5° elevation scan initiated at 1851:24 MDT with the accident site marked with the red circle. The flight track is in pink with arrows pointing in the direction of travel. Lightning flashes are the black dots.

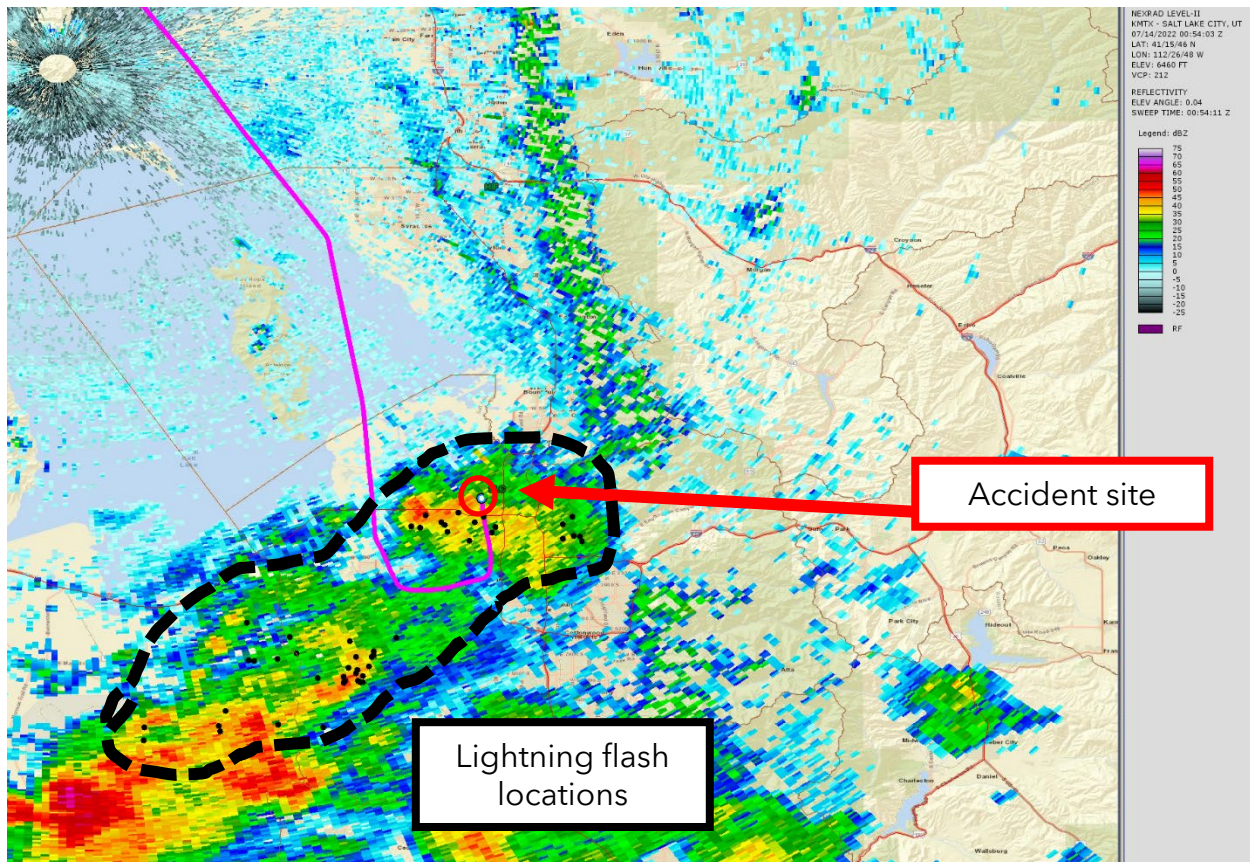


Figure 17. KMTX WSR-88D reflectivity for the 0.0° elevation scan initiated at 1854:11 MDT with the accident site marked with the red circle. The flight track is in pink with arrows pointing in the direction of travel. Lightning flashes are the black dots.

Rain showers and convective clouds can produce downdrafts, outflow boundaries and gust fronts during the mature and decaying stages of their life cycle, which can create an environment favorable for unexpected changes in wind direction and speed at the surface. Figure 18 is a diagram of a downburst (or “microburst”) that has originated from a convective cloud with precipitation. According to the Aeronautical Information Manual (AIM) section 7-1-24³⁷, microbursts are typically relatively small in area and produce less than 1 to 2 ½ miles in diameter of strong divergent winds and downdrafts that can reach 6,000 feet per minute. Microbursts can be found in and beneath convective clouds, usually embedded in heavy rain or in benign-appearing virga. When there is little or no precipitation at the surface accompanying the microburst, a ring of blowing dust may be the only visual clue of its existence.

³⁷ [Meteorology \(faa.gov\)](https://www.faa.gov)
[Microburst - Glossary of Meteorology \(ametsoc.org\)](https://www.ametsoc.org)

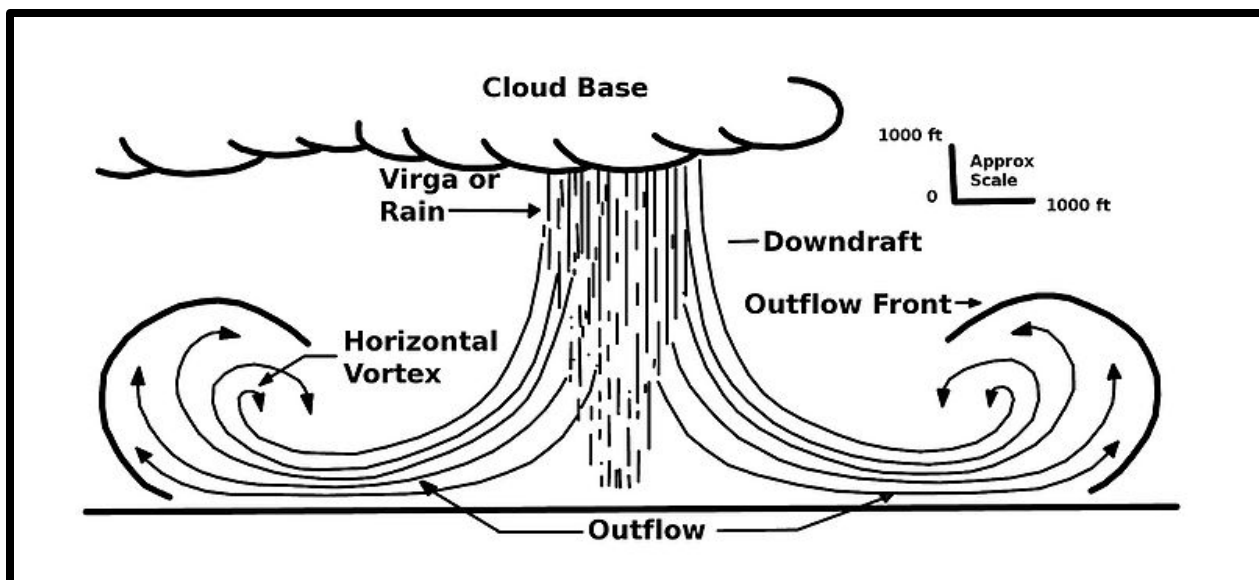


Figure 18. Diagram of a downburst and outflow.

8.0 Pilot Reports

The longline-disseminated pilot reports³⁸ (PIREPs) distributed into the national airspace system (NAS) about two hours on either side of the accident time within 100 miles of the accident site for below 19,000 ft are shown below. The PIREP made at 1856 MDT (in **bold**) was given by the flight approaching KSLC directly after the accident flight:

VEL UA /OV MTU360005/TM 2303/FL180/TP EVOT/TB LGT - MOD CHOP FL180 /ZLC

VEL UA /OV MTU290015/TM 2308/FL160/TP EVOT/TA M09/TB MOD/IC LGT - MOD RIME /ZLC

SLC UA /OV KSLC330010/TM 2351/FL080/TP CRJ9/WX BLDU/TB MOD 070-080/RM DURD BASE TURN ABEAM ANTELOPE ISLAND, DUST STORM OBSERVED

SLC UA /OV 10 NW SLC/TM 0030/FL065/TP C172/WV 700-800 FT PER MINUTE DOWNDRAFTS/RM MODERATE RAIN BEGINNING AT GARFIELD STACK

SLC UUA /OV TCH170012/TM 0047/FL075/TP B752/WV 20 KNOT GAIN /TB MOD TURB/RM 9 MILE FINAL RWY34L

SLC UUA /OV 1 MILE SOUTH SLC/TM 0056/FL060/TP C208/TB SEVERE RWY 35

SLC UA /OV SLC300020/TM 0112/FL140/TP B739/WV 24231KT/TB LGT CHOP 100-140/RM HOLDING NW SLC

SLC UA /OV 2 MILE FINAL RWY 16R/TM 0141/FL047/TP CRJ9/RM GAIN OF 15 KTS

SLC UA /OV UDUZU/TM 0213/FL098/TP BE99/TB MOD TURB WITH ONE SVR JOLT

³⁸ Only pilot reports with the World Meteorological Organization headers UBCO**, UBWY**, UBU***, UBNV**, and UBD** were considered. These do not include pilot reports only broadcast via radio.

SLC UA /OV KSLC/TM 0241/FLDURD/TP KODI/TB LGT - MOD/RM FINAL RWY 17
SLC UA /OV TCH184022/TM 0243/FL120/TP CRJ2/TB CONT LGT OCNL MOD/RM
DURD

9.0 Significant Meteorological Information

Convective Significant Meteorological Information (SIGMET) advisory 66W was issued at 1755 MDT and was valid for the accident site at the accident time (figure 19). Convective SIGMET 66W forecast an area of thunderstorms moving little with cloud tops above FL450³⁹:

WSUS33 KPCI 132355
SIGW
MKCW WST 132355

CONVECTIVE SIGMET 66W
VALID UNTIL 0155Z
WY UT ID NV
FROM 30N JAC-20NNW OCS-50WSW DVC-50N LAS-50S BOI-30N JAC
AREA TS MOV LTL. TOPS ABV FL450.

³⁹ 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 standard 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.

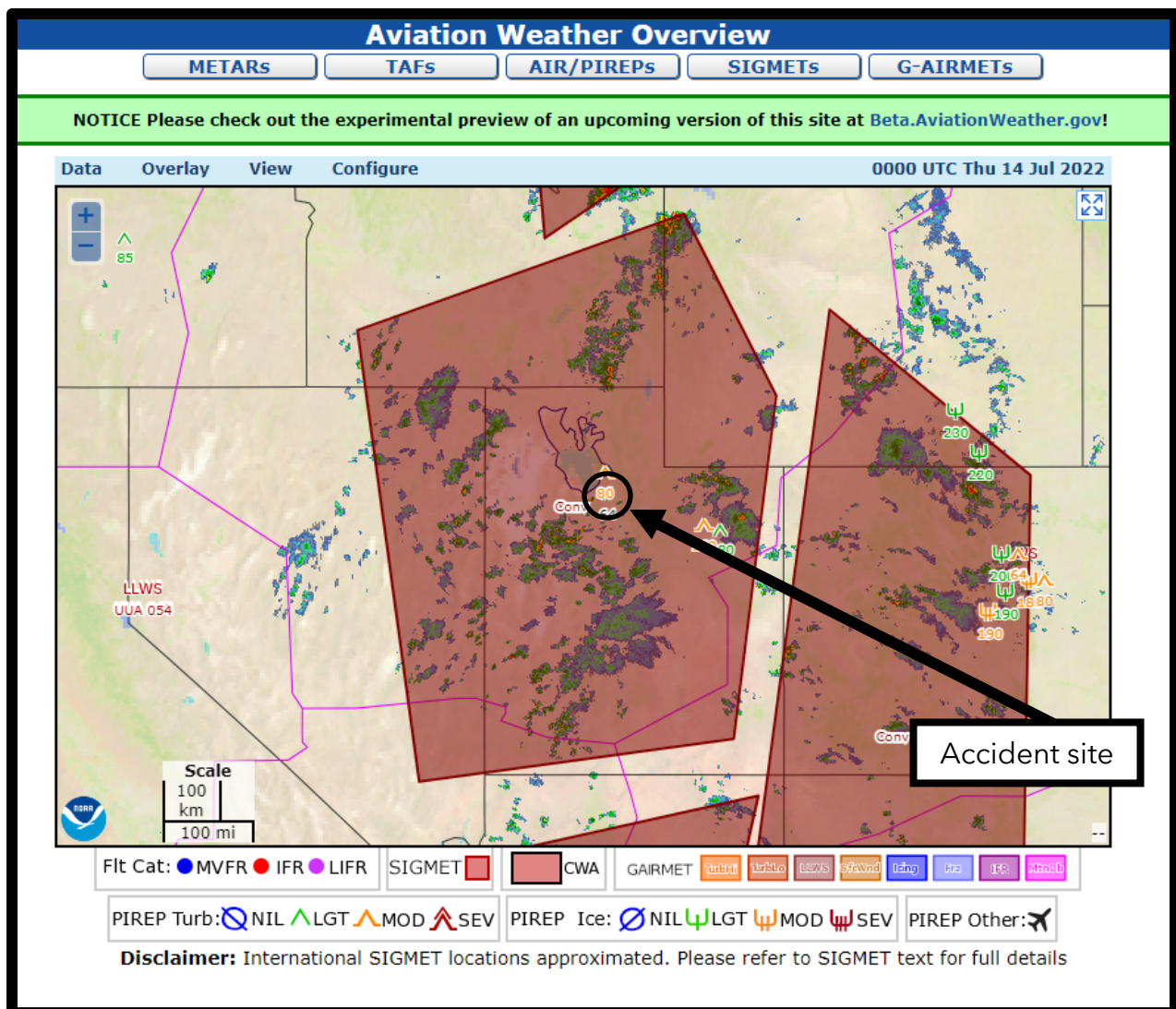


Figure 19. Convective SIGMET valid at the accident time.

10.0 Center Weather Service Advisories

The Salt Lake City (ZLC) Air Route Traffic Control Center (ARTCC) Center Weather Service Unit (CWSU) was responsible for the accident region. There was no Center Weather Advisory (CWA) valid from the ZLC CWSU at the accident time. The ZLC CWSU forecaster on duty at the time of the accident provided a statement located as attachment 12.

11.0 Airmen's Meteorological Information

The NWS Aviation Weather Center had an Airmen's Meteorological Information (AIRMET) advisory Sierra valid for the accident site at the accident time. The text AIRMET Sierra was issued at 1445 MDT and forecast mountain obscuration conditions due to clouds and precipitation:

WAUS45 KPCI 132045

WA5S

-SLCS WA 132045

AIRMET SIERRA UPDT 3 FOR IFR AND MTN OBSCN VALID UNTIL 140300

NO SGFNT IFR EXP OUTSIDE OF CNVTV ACT.

AIRMET MTN OBSCN...NV UT CO AZ NM

FROM 30WNW BCE TO 20E CIM TO 40WNW CME TO 50W CME TO 30ENE SSO
TO 80SW SJN TO 40SSW INW TO 50S PGS TO 30ENE LAS TO 30WNW BCE
MTNS OBSC BY CLDS/PCPN. CONDS DVLPG 21-00Z. CONDS CONTG BYD 03Z
THRU 09Z.

AIRMET MTN OBSCN...ID WY NV UT CO NM

**FROM 30W MLD TO 50SE MLD TO 40NNE MTU TO 70SSW DDY TO 20SE CYS
TO 20ESE DEN TO 20E CIM TO 30WNW BCE TO 40SSW DTA TO 60W BVL TO
40SSE TWF TO 30W MLD
MTNS OBSC BY CLDS/PCPN. CONDS DVLPG 21-00Z. CONDS CONTG BYD 03Z
THRU 09Z.**

AIRMET MTN OBSCN...ID MT WY

FROM 20NNW HVR TO 20NE SHR TO 20S CZI TO 60S BOY TO 20SSE BPI TO
40E MLD TO 30ENE PIH TO 60S LKT TO 40WNW LKT TO 50SE MLP TO 50SE
FCA TO 50S YQL TO 20NNW GTF TO 20NNW HVR
MTNS OBSC BY CLDS/PCPN. CONDS CONTG BYD 03Z ENDG 06-09Z.

OTLK VALID 0300-0900Z...MTN OBSCN ID WY NV UT CO AZ NM

BOUNDED BY 50NE JAC-40NNW BOY-70SSE BOY-20ESE CYS-20ESE DEN-20E
CIM-30SE FTI-50WNW CME-30SE TCS-20ENE SSO-40ESE DRK-50S PGS-
30ENE LAS-30WNW BCE-60SSE BVL-60WSW BVL-30S TWF-30W PIH-50NE JAC
MTNS OBSC BY CLDS/PCPN. CONDS CONTG THRU 09Z.

....

12.0 Graphical Forecasts for Aviation

The Graphical Forecasts for Aviation (GFA) products issued before the accident flight and valid at 1800 MDT are shown in attachment 10. The GFA surface forecast applicable to the accident site that was valid before the accident flight's departure indicated VFR surface visibilities, scattered (between 30 and 50 percent chance) thunderstorms, and a southwest surface wind at 10 knots with gusts to 15 knots. The GFA cloud forecast applicable to the accident site that was valid before departure for times surrounding the accident time indicated cirrus clouds above the accident site. The Graphical AIRMET⁴⁰ (G-AIRMET) Sierra valid for the accident site was valid starting at 2100 MDT with additional G-AIRMETs valid north and south of Utah. The only human-generated information reflected in the two GFA products were the G-AIRMETs. For more information, please see attachment 10.

13.0 Terminal Aerodrome Forecast

KSLC was the closest site with an NWS Terminal Aerodrome Forecast⁴¹ (TAF) current at the time of the accident. The KSLC TAF valid before departure was issued at 1720 MDT and was valid for a 30-hour period beginning at 1800 MDT. The 1720 MDT TAF for KSLC was as follows:

FTUS45 KSLC 132320
TAFSLC
TAF
KSLC 132320Z 1400/1506 18012G22KT P6SM VCTS SCT110CB BKN150
FM140200 18020G30KT P6SM SCT110 BKN150
FM140500 02010KT P6SM VCTS BKN110CB
FM140700 15009KT P6SM FEW110 BKN150
FM141600 18015G25KT P6SM SCT110 BKN150=

Between 1800 and 2000 MDT the forecast expected a wind from 180° at 12 knots with gusts to 22 knots, greater than 6 miles visibility, vicinity thunderstorms, scattered cumulonimbus clouds at 11,000 ft agl, and a broken ceiling at 15,000 ft agl.

⁴⁰ Graphical AIRMETs (G-AIRMETs), found on the Aviation Weather Center webpage at <http://aviationweather.gov>, are graphical forecasts of en-route weather hazards valid at discrete times no more than 3 hours apart for a period of up to 12 hours into the future (for example, 00, 03, 06, 09, and 12 hours). G-AIRMETs are snap shots at discrete time intervals as defined above. The text AIRMET is the result of the production of the G-AIRMET but provided in a time smear for a 6 hour valid period.

⁴¹ According to NWS Instruction 10-813: "An NWS TAF consists of the expected meteorological conditions significant to aviation at an airport for a specified time period. For the U.S., this is the area within five (5) statute miles (SM) of the center of an airport's runway complex."
www.nws.noaa.gov/directives/sym/pd01008013curr.pdf

Additional KSLC TAFs were issued at 1806 and 1824 MDT, and were valid starting at 1800 MDT. The 1806 MDT TAF for KSLC was as follows:

FTUS45 KSLC 140006 AAB
TAFSLC
TAF AMD
KSLC 140006Z 1400/1506 16009G18KT P6SM VCTS SCT110CB BKN150
FM140030 33011G24KT P6SM VCTS SCT110CB BKN150
FM140500 02010KT P6SM VCTS BKN110CB
FM140700 15009KT P6SM FEW110 BKN150
FM141600 18015G25KT P6SM SCT110 BKN150=

Between 1830 and 2300 MDT, the forecast expected a wind from 330° at 11 knots with gusts to 24 knots, greater than 6 miles visibility, vicinity thunderstorms, scattered cumulonimbus clouds at 11,000 ft agl, and a broken ceiling at 15,000 ft agl.

The 1824 MDT TAF for KSLC was as follows:

FTUS45 KSLC 140024 AAA
TAFSLC
TAF AMD
KSLC 140024Z 1400/1506 16009G18KT P6SM VCTS SCT110CB BKN150
FM140030 33011G24KT P6SM VCTS SCT110CB BKN150
FM140400 15009KT P6SM VCSH FEW110 BKN150
FM141600 18015G25KT P6SM SCT110 BKN150=

Between 1830 and 2200 MDT, the forecast expected a wind from 330° at 11 knots with gusts to 24 knots, greater than 6 miles visibility, vicinity thunderstorms, scattered cumulonimbus clouds at 11,000 ft agl, and a broken ceiling at 15,000 ft agl.

14.0 National Weather Service Area Forecast Discussion

The NWS weather forecast office in Salt Lake City, Utah, (WFO SLC) was responsible for the public forecast in the region of the accident site. WFO SLC issued the following Area Forecast Discussion (AFD) at 1600 MDT, the closest AFD to the accident time with an aviation section:

FXUS65 KSLC 132200
AFDSLC

Area Forecast Discussion
National Weather Service Salt Lake City UT
400 PM MDT Wed Jul 13 2022

.SYNOPSIS...Showers and thunderstorms will continue to spread northward today as moisture increases across area. This moisture is expected to remain in place into the early part of next week, bringing daily thunderstorm and flash flooding threats. Meanwhile,

excessive heat continues for northern Utah through at least tomorrow with some lingering heat through early next week.

&&

.SHORT TERM (Through 12Z/06AM Friday)...A textbook monsoon surge pattern for Utah is underway with as satellite imagery depicts a high pressure cell aloft parked over the Four Corners region, advecting in moisture from the southeast along with weak flow aloft and an antecedent warm air mass. This afternoon, SPC mesoanalysis shows 500-1000 J/Kg of MUCAPE, with a bit of a cap on SBCAPE as of yet over Northern Utah though that should erode soon. PWATs are just a tick below an inch for most of the area, highest (a little over 1") in the southwest corner of the state and lowest in the northwest corner (a little under 0.8"). The flow direction is favoring convective initiation along the central spine of mountains in Utah, moving northeastward. Additionally, **recent CAMs are fairly confident in an area of thunderstorms moving off the higher terrain along the NV/UT border and translating across the west deserts to the I-15 corridor and the Wasatch Front this evening. Storms generally east of I-15 and south of I-80 remain a flash flood threat, while storms elsewhere are more of a gusty outflow winds threat.** For info on the fire weather implications of this thunderstorm threat, see the Fire Weather section of this AFD. As is the case for us this time of year, flash flooding is a threat for any slot canyons, recent burn scars, and normally dry washes.

As was the case yesterday, expect isolated lingering convective activity into the overnight hours, bringing continued cloud cover, limiting overnight decoupling, and promoting another warm night. KSLC has only had ~5 nights in its climate record with an overnight low of 80 or higher; the current forecast is 80. Speaking of heat, the HeatRisk tool shows elevated risks of heat illness lingering into tomorrow over northern Utah where the current forecast highs and particularly the lows are abnormal for many consecutive days. A slight moderation in daytime highs is expected for the latter portion of this week, partially related to increased afternoon cloud cover and precip chances, but still remaining elevated. Will allow the next few shifts to reassess if we want to continue heat headlines in the form of a long-lasting advisory. Another record we may approach is the consecutive days of 100+ for SLC; our current forecast combined with yesterday's observed high would easily move into the top 10.

Tomorrow looks to be a near carbon copy of today, with a slight overall uptick in available moisture yet again. One difference is a better chance of wetting storms for far northern and western Utah and a slightly reduced threat of microburst winds.

.LONG TERM (After 12Z/06AM Friday)...The extended forecast period is expected to be an active pattern of weather with monsoonal like conditions returning and statewide hot temperatures remaining. An

upper level ridge pattern over the 4 corners area will keep temperatures across the CWA consistently hot with many areas seeing 100F+ through the entire extended. The ridging pattern aloft also will help transport a sufficient amount of moisture to the CWA that will fuel shower and thunderstorm initiation/development. A NW Pacific trough feature is expected to develop over the extended as well that could bring a flattened pattern to the ridge, bringing drier air back to the CWA but there remains uncertainty in the timing and development of this feature.

Warm temperatures will persist over the CWA through the extended that could meet excessive heat risk thresholds as forecasted afternoon highs span from 98-104F for northern valleys and 100-112F for southern UT while overnight temperatures only fall into the 70s and low 80s. The moisture being lofted into the CWA could change these forecasted temps slightly as enough cloud cover could keep afternoon temperatures cooler from lack of daytime heating but also keep overnight temperatures warmer from lack of surface cooling. Anyone with any heat related health issues should continue to monitor conditions.

Sufficient moisture brought from down south will pool over the CWA and some guidance is forecasting PWAT values that are 100-200% of the climatological norm which when combined with proper forcing from S/SW flow will keep the potential for daily convection to develop over the CWA. Model guidance currently is pointing towards Friday, Saturday and Sunday as the most active days as the potential for a flattened ridge and dry air returning will lessen chances for the start of the next work week. The best chance for precipitation is primarily for areas in central/southern UT that are east of I-15 that will get additional forcing from high terrain areas. Strong S/SW flow will help bring some of this moisture northward leaving chances for areas in and around the Wasatch/Uinta Mountains to spark up storms as well. With expected continuous days of precipitation that will have relatively slow storm motion and potentially moderate rainfall rates, there will be high potential for flash flooding situations in many popular slot canyons, national/state parks and any areas with recent burn scars.

&&

.AVIATION...KSLC...A risk for evening thunderstorms will persist through approximately 07Z though CIG are expected to be high based. Any thunderstorms that pass on station have the potential to reduce visibility temporarily. Meanwhile, southerly wind gusts are forecast to peak between 02 and 05Z before improving through the overnight hours. Tomorrow is expected to bring another round of increasing southerly winds by mid-morning with winds forecast to switch out of the northwest in the early afternoon. VFR conditions are anticipated tomorrow.

.REST OF UTAH AND SOUTHWEST WYOMING...A risk for thunderstorms will continue into the early evening hours before improving overnight.

CIGs are expected to be high based but VIS may temporarily decrease conditions to MVFR or IFR status on station. Look for diurnally driven winds otherwise through tomorrow.

&&

.FIRE WEATHER...

&&

.SLC WATCHES/WARNINGS/ADVISORIES...

UT...Red Flag Warning until midnight MDT tonight for UTZ478-492.

Heat Advisory until midnight MDT Thursday night for UTZ106.

Excessive Heat Warning until midnight MDT Thursday night for UTZ101>105.

WY...None.

&&

\$\$

15.0 Airport Weather Warning

The WFO SLC issued three Airport Weather Warnings (AWW) for the Salt Lake City International Airport between 1800 and 1900 MDT and were as follows:

WWUS85 KSLC 140017

AWWSLC

UTC035-140115-

Airport Weather Warning for the Salt Lake City International Airport

National Weather Service Salt Lake City UT

617 PM MDT Wed Jul 13 2022

Airport Weather Warning for outflow wind gusts of 30 mph/26 kts or greater for the Salt Lake City International Airport.

Valid 617 PM MDT to 715 PM MDT

\$\$

For more information from NOAA's National Weather Service visit...

<http://weather.gov/saltlakecity>

WWUS85 KSLC 140026

AWWSLC

UTC035-140045-

Airport Weather Warning for the Salt Lake City International Airport

National Weather Service Salt Lake City UT
626 PM MDT Wed Jul 13 2022

Airport Weather Warning for lightning within 5 nm of the Salt Lake City International Airport.

Valid 626 PM MDT to 645 PM MDT

\$\$

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

WWUS85 KSLC 140045

AWWSLC

UTC035-140100-

Airport Weather Warning for the Salt Lake City International Airport
National Weather Service Salt Lake City UT
645 PM MDT Wed Jul 13 2022

Airport Weather Warning for lightning within 5 nm of the Salt Lake City International Airport.

Valid 645 PM MDT to 700 PM MDT

\$\$

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

The AWW warned of lightning activity within 5 miles of KSLC and greater than or equal to 26-knot wind gusts expected between 1817 and 1915 MDT. WFO SLC has a letter of agreement (LOA) with the Salt Lake City Department of Airports to provide AWWs for thresholds defined in the LOA (attachment 11).

16.0 National Weather Service Information

The WFO SLC forecaster responsible for the aviation forecast at the time of the accident (Forecaster 1) and the forecaster responsible for the aviation forecast before the accident time (Forecaster 2) were interviewed and transcripts of those interviews are provided in attachments 13 and 14. During the interviews with the WFO SLC forecasters, it was noted that the use of VCTS in the TAF(s) was inconsistent. Each forecaster had a different philosophy when forecasting VCTS based on the aviation training they had received.

A timeline of select weather forecast and observation information was created and is provided below with additional information found in attachment 24:

Weather Timeline – Observations and Forecasts
Times in MDT

12:00: CWSU Pre Duty Weather Briefing (PDWB) completed and was available on the internet by 1207.

15:12: TAFSLC

15:36: SPECI KSLC

15:54: METAR KSLC

16:54: METAR KSLC

16:55: Convective SIGMET 61W valid until 1755

17:20: TAFSLC

17:51: PIREP SLC UA /OV KSLC330010

17:54: METAR KSLC

17:55: Convective SIGMET 66W valid until 1855

18:00: KSLC Upper Air Sounding

18:06: TAFSLC

18:10: The TRACON called the CWSU to ask about the updated TAF and winds.

18:17: AWW issued and valid until 1915

18:24: TAFSLC

18:25: The CWSU called the TRACON to brief on the AWW and to discuss the KSLC TAF.

18:26: AWW issued valid until 1845

18:30: PIREP KSLC UA /OV 10 NW KSLC

18:33: SPECI KSLC

18:45: AWW issued and valid until 1900

18:47: PIREP KSLC UUA /OV TCH170012

18:52: Time of accident

18:52: SLCCF (Center field wind): WNW (290°) 16 mph

18:54: METAR KSLC: 30029G48KT 9SM -TSRA PK WND 32048/0054 LTG DSNT SW CB OHD MOV NE

18:56: PIREP KSLC UUA /OV 1 MILE SOUTH KSLC

19:12: WFO SLC called the CWSU about updating the KSLC TAF.

19:12: PIREP KSLC UA /OV SLC300020

19:15: SPECI KSLC

19:22: SPECI KSLC

19:45: SPECI KSLC

17.0 Winds and Temperature Aloft Forecast

The NWS 1359 MDT Winds and Temperature Aloft forecast valid for the closest point to the accident site is included below:

```
FBUS31 KWNO 131959
FD1US1
DATA BASED ON 131800Z
VALID 140000Z FOR USE 2000-0300Z. TEMPS NEG ABV 24000

FT 3000 6000 9000 12000 18000 24000 30000 34000 39000
SLC 9900 2207+22 2414+13 2526-06 2326-17 252232 252743 263053
```

The closest forecast point to the accident site was Salt Lake City, Utah, (SLC). The 1359 MDT SLC forecast for use between 1400 MDT and 2100 MDT indicated a calm wind at 6,000 ft, a wind at 9,000 ft from 220° at 7 knots with a temperature of +22°C, and a wind at 12,000 ft from 240° at 14 knots with a temperature of +13°C.

18.0 Consolidated Storm Prediction for Aviation Data

The Consolidated Storm Prediction for Aviation (CoSPA)⁴² images were retrieved for 1830, 1835, 1840, 1845, 1850, and 1855 MDT and provided in figures 20 through 25 with the accident site marked. Along with depicting NWS weather radar VIP levels, lightning data, weather satellite, and storm motion, the CoSPA imagery provides forecasts of areas of convective growth (orange hatched areas) and areas of convective decay (blue hatched areas). The rain shower activity was moving from southeast to northwest with time and growing in areal coverage. In addition, the accident site was located in an area of projected convective growth from 1830 through 1845 MDT.

⁴² <https://cospa.wx.ll.mit.edu/>
<https://ral.ucar.edu/projects/CoSPA/index.php>
<https://ral.ucar.edu/solutions/products/consolidated-storm-prediction-aviation-cospa>

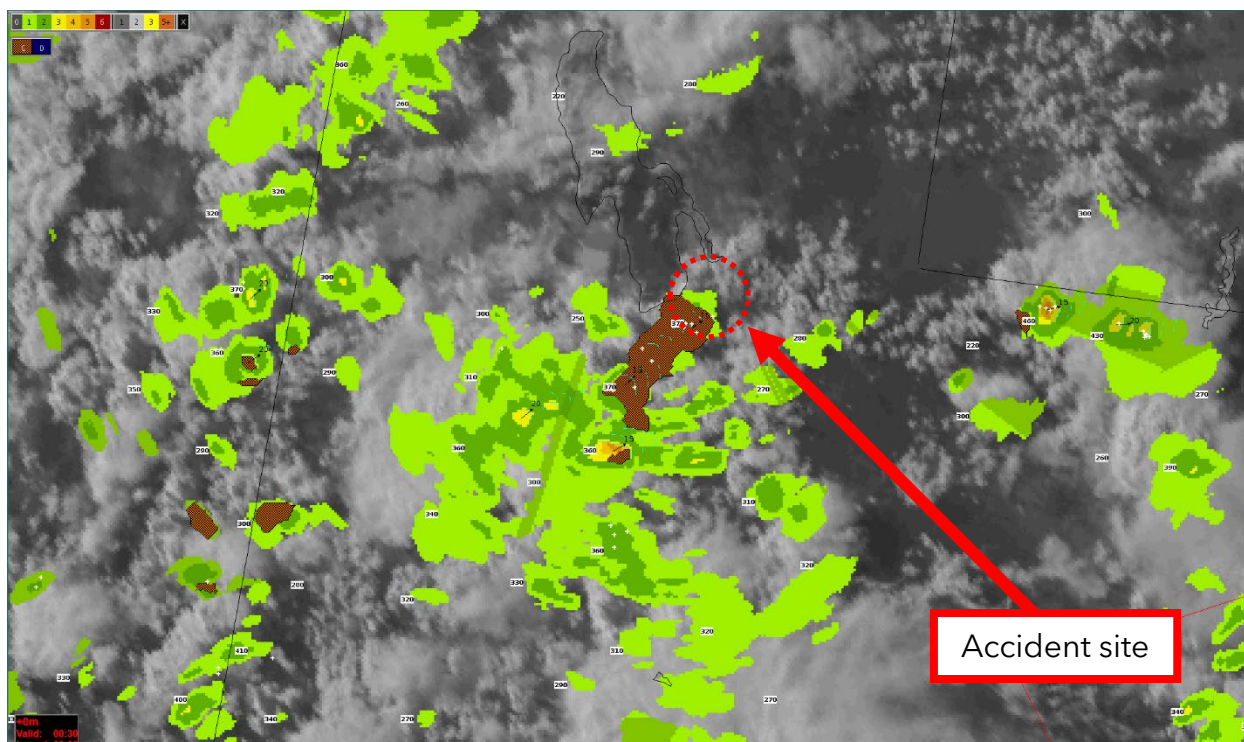


Figure 20. CoSPA image from 1830 MDT with the accident site marked.

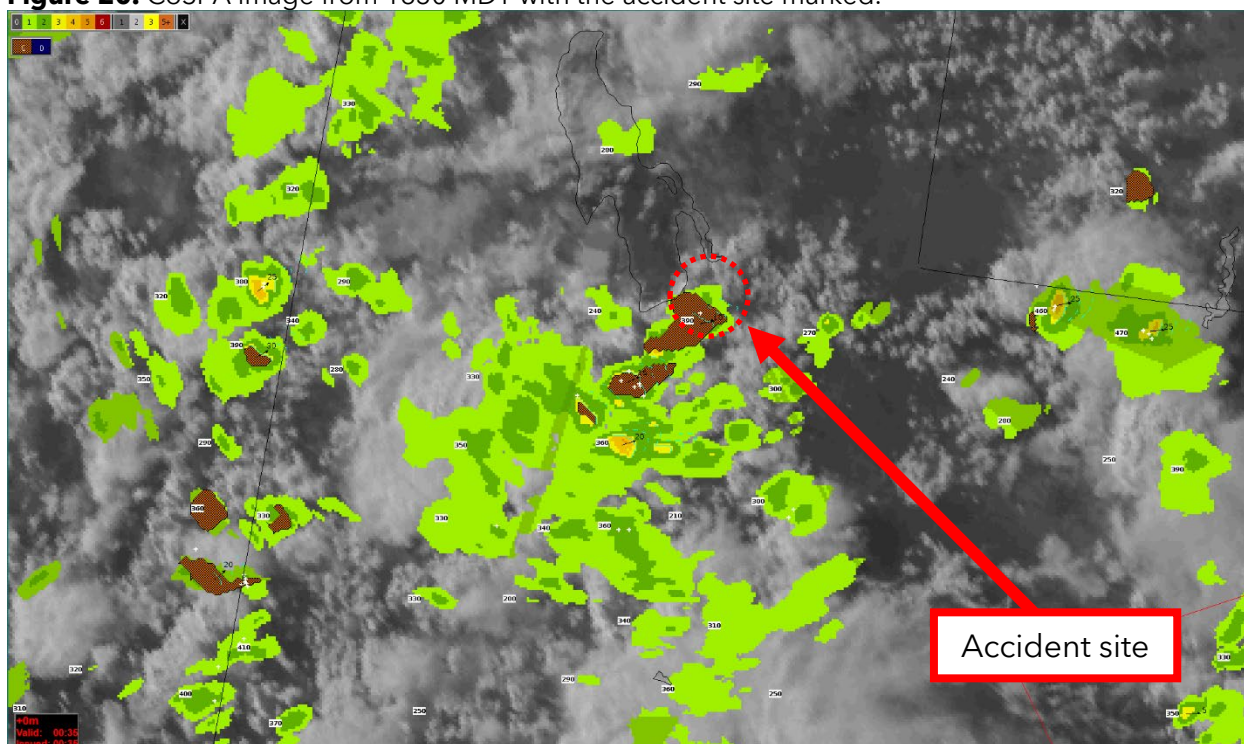


Figure 21. CoSPA image from 1835 MDT with the accident site marked.

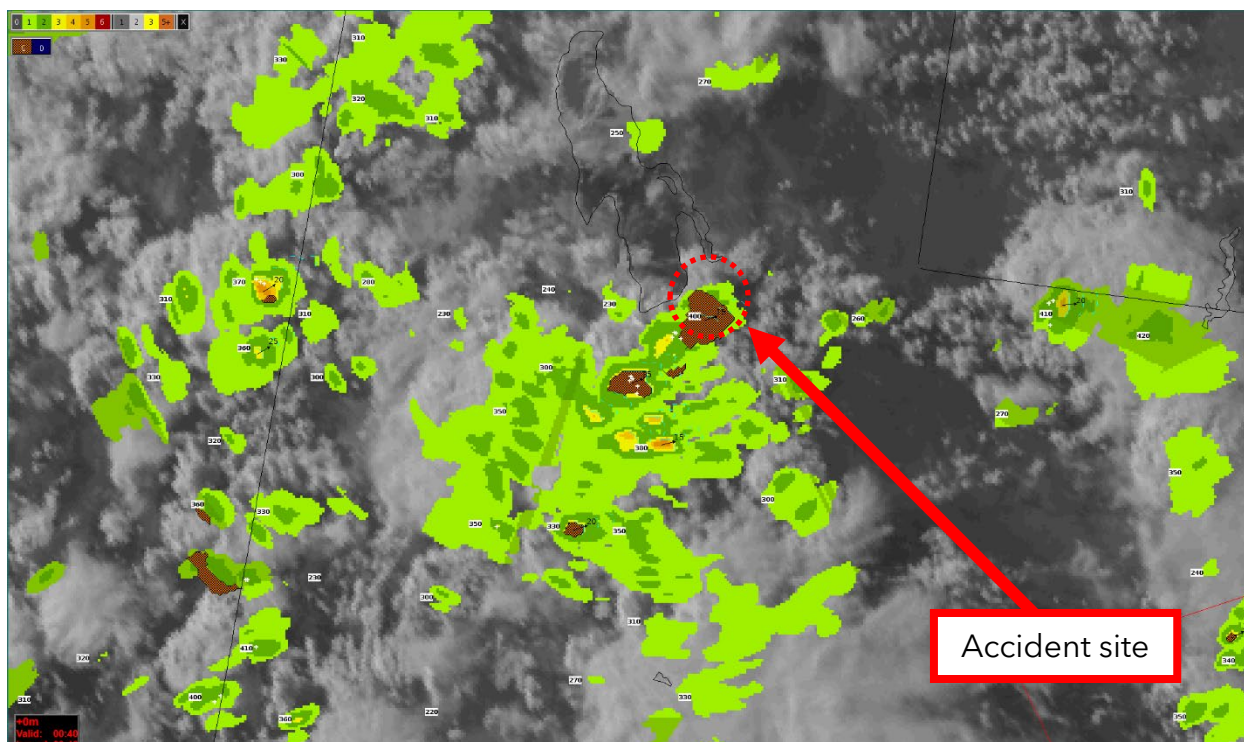


Figure 22. CoSPA image from 1840 MDT with the accident site marked.

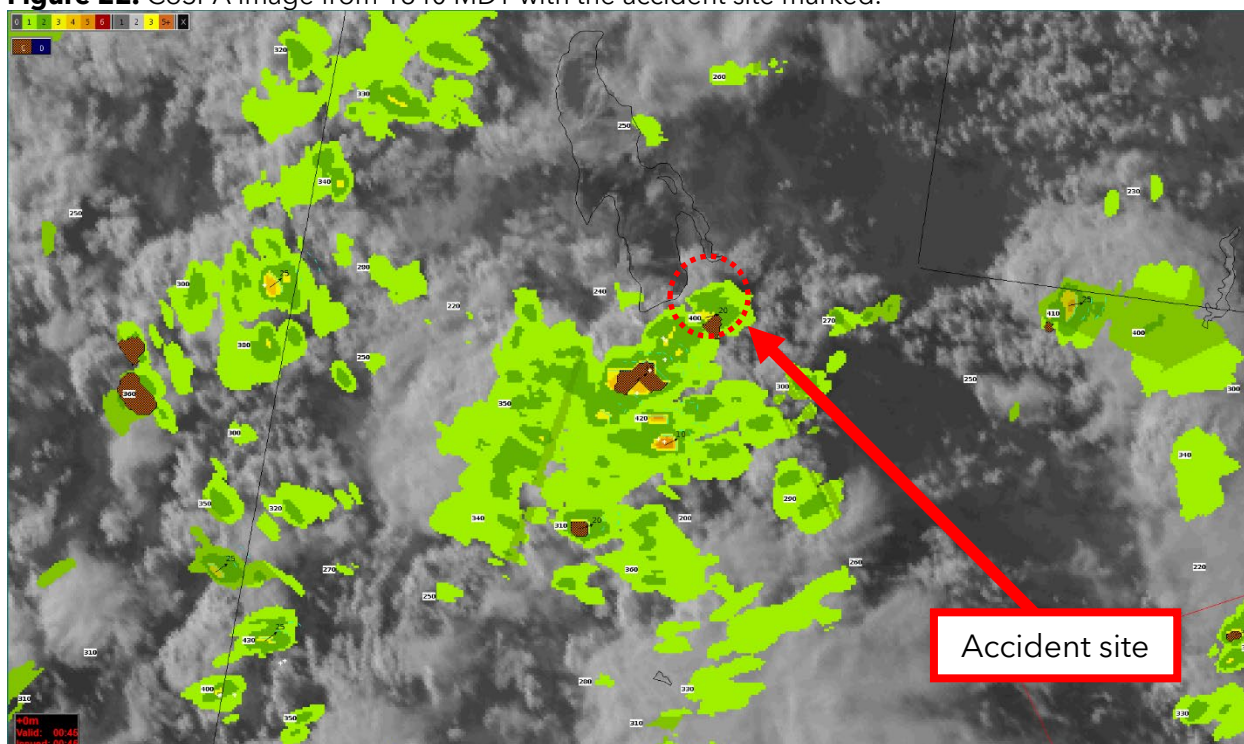


Figure 23. CoSPA image from 1845 MDT with the accident site marked.

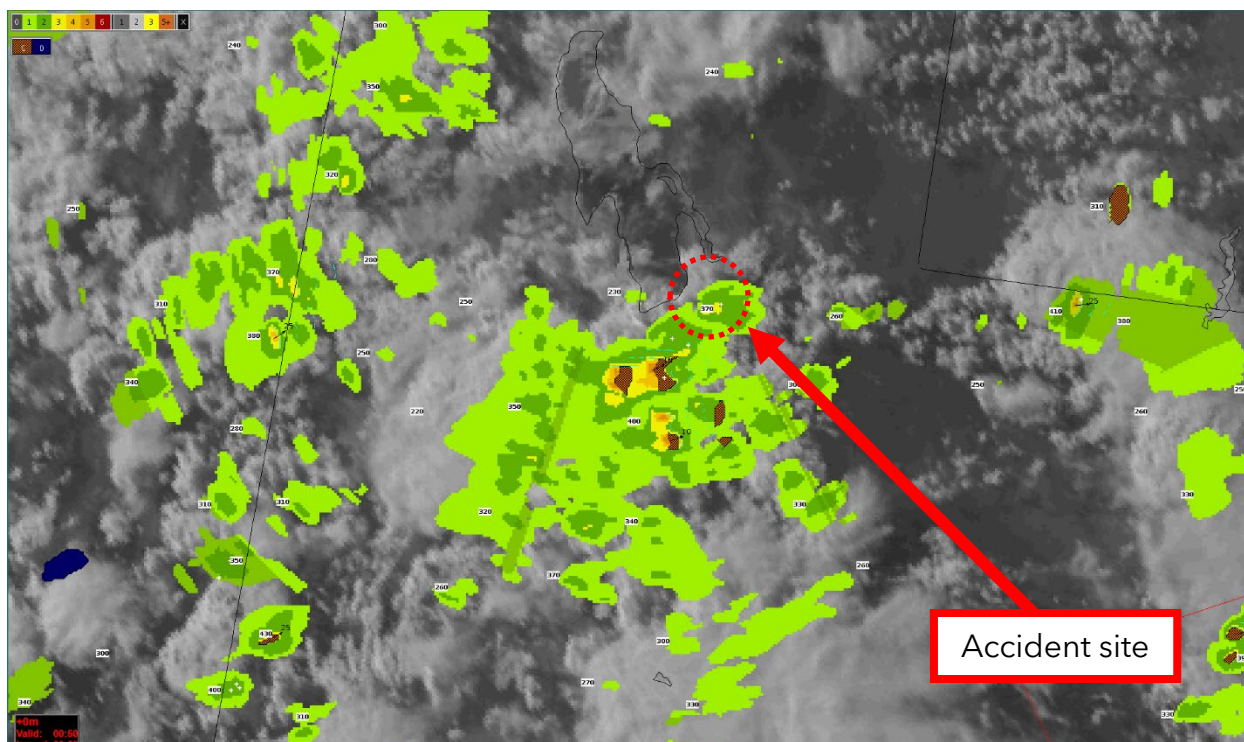


Figure 24. CoSPA image from 1850 MDT with the accident site marked.

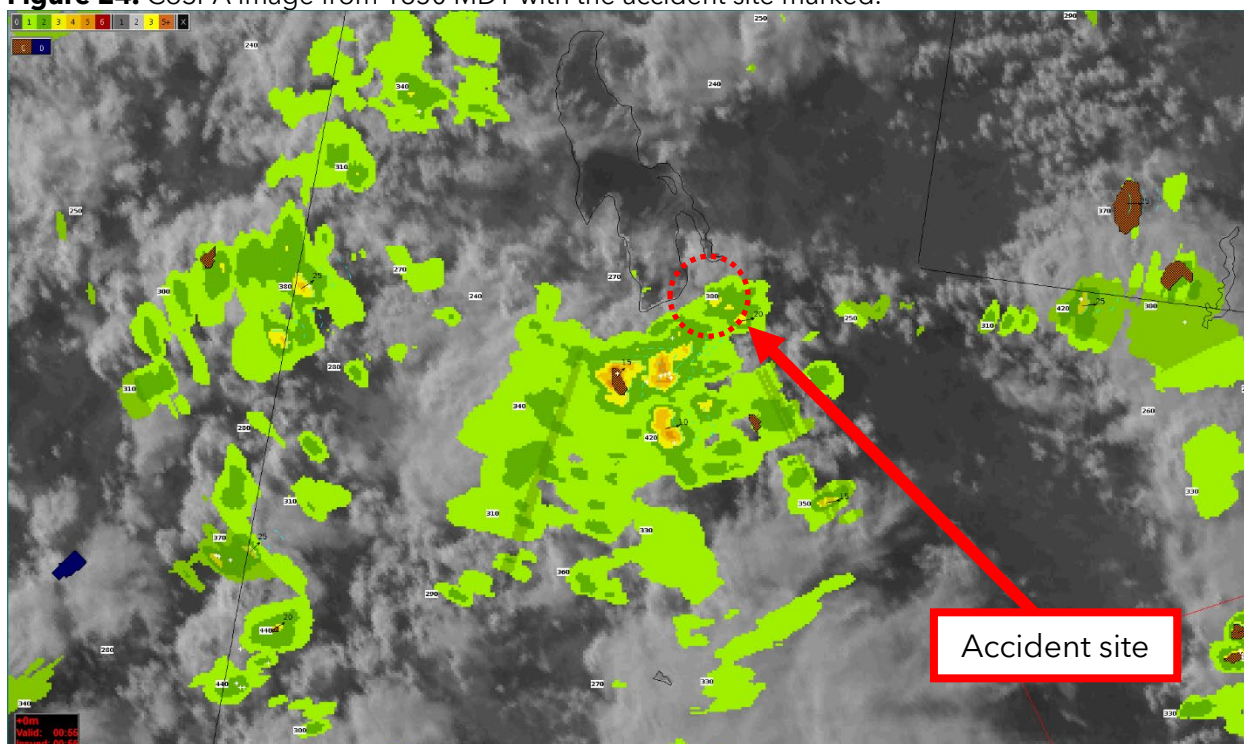


Figure 25. CoSPA image from 1855 MDT with the accident site marked.

19.0 Weather Camera Imagery

Video imagery around the accident time was provided by Salt Lake City International Airport Operations and can be found in attachments 15 through 17 and are located in the docket. Virga can be seen descending towards the accident site starting between 1849 and 1850 MDT and continuing through 1854 MDT (attachment 16), with gusting winds and rainfall at the surface starting between 1850:15 and 1851 MDT (attachment 17).

20.0 Pilot Weather Information

For more information regarding the accident pilot and weather information⁴³ please see the Operational Factors Factual contained in the docket for this investigation.

21.0 FIS-B Regional NEXRAD

Flight Information Services-Broadcast (FIS-B) data were retrieved for this accident. This FIS-B data presents what would have been displayed on the pilot's screen (attachment 18). For more information on the pilot's screen and settings please see the Operational Factors Factual. The FIS-B regional NEXRAD data is updated once every 5 minutes and is based upon composite NEXRAD reflectivity data. For more information please see attachment 18.

22.0 Radar Display of STARS Derived Imagery

A STARS⁴⁴ maintenance replay of the accident sequence was viewed and screenshots of the display of weather were obtained. The actual STARS weather display viewed by the accident air traffic controller from around the accident time are contained in figures 27 through 30 with additional information in attachment 19. The accident air traffic controller did have settings for level 1 through level 6 precipitation active and available for view:⁴⁵

⁴³ https://www.faa.gov/documentLibrary/media/Advisory_Circular/AC_91-92.pdf

⁴⁴ STARS - Standard Terminal Automation Replacement System - A system that receives radar data and flight plan information and presents the information to air traffic controllers on high resolution, 20" x 20" color displays allowing the controller to monitor, control, accept hand-off of air traffic, and assist with weather avoidance.

⁴⁵ The FAA provided the following dBZ levels for the Airport Surveillance Radar-9 (ASR-9) radars (which provided info to STARS).

- 1: 18<30 dBZ
- 2: 30<41 dBZ
- 3: 41<46 dBZ
- 4: 46<50 dBZ
- 5: 50<57 dBZ
- 6: 57+ dBZ

Figure 26 provides an exemplar view of what precipitation levels 1 through 6 look like on a STARS display of precipitation. Figures 27 through 30 show the STARS display of precipitation used and seen by the accident air traffic controller at around 1848, 1849, 1850, and 1851 MDT.

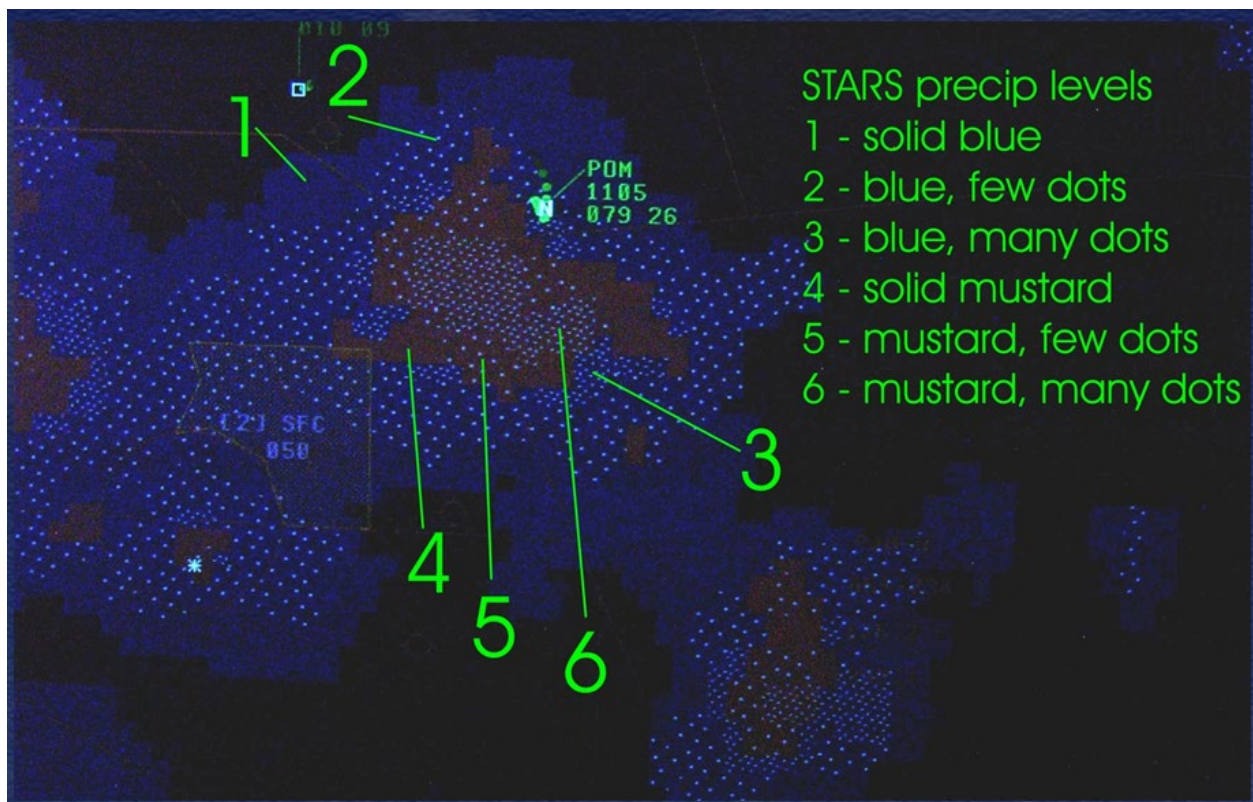


Figure 26. Exemplar display of STARS precipitation levels 1 through 6.





Figure 28. STARS weather and precipitation level display used and seen by the accident air traffic controller from around 1849 MDT.



Figure 29. STARS weather and precipitation level display used and seen by the accident air traffic controller from around 1850 MDT.



Figure 30. STARS weather and precipitation level display used and seen by the accident air traffic controller from 1851 MDT.

23.0 Pre-Duty Weather Briefing

ZLC CWSU completed and posted the PDWB valid at the accident time by 1207 MDT (attachment 20). The briefing covered the afternoon/evening shift until 2019 MDT. The summary of hazards included isolated thunderstorms in the early afternoon becoming scattered thunderstorms throughout the ZLC airspace. Icing, turbulence, and gusty winds were expected to be associated with the thunderstorm activity. The PDWB also highlighted the KSLC TAF with vicinity thunderstorms and gusty winds after 2200 UTC (1600 MDT).

24.0 Integrated Terminal Weather System

Integrated Terminal Weather System (ITWS)⁴⁶ information was not requested in time⁴⁷ to be retrieved for the accident timeframe. Exemplar views of the SLC ATC tower facility and S56 TRACON facility ITWS display locations are provided in figures 31 and 32. The SLC ATC tower facility ITWS display was located in the north end of the tower cab behind the supervisor position. The S56 TRACON facility ITWS display locations were on computer monitors at both the supervisor and traffic manager positions. An exemplar active weather day view of ITWS displayed data from S56 TRACON facility is provided in figure 33. The ITWS reference sheets for both TDWR and non-TDWR locations are provided in attachments 21 and 22. The historical development of the ITWS reference sheet is discussed in attachment 23.

⁴⁶ https://cdm.fly.faa.gov/?page_id=176
<https://ral.ucar.edu/sites/default/files/public/events/2008/friends-and-partners-in-aviation-weather/docs/deans-fpaw-2008.pdf>

⁴⁷ ITWS data is stored for 14 days, then the data is overwritten.



Figure 31. Exemplar view of the ITWS location in the SLC ATC Tower facility.

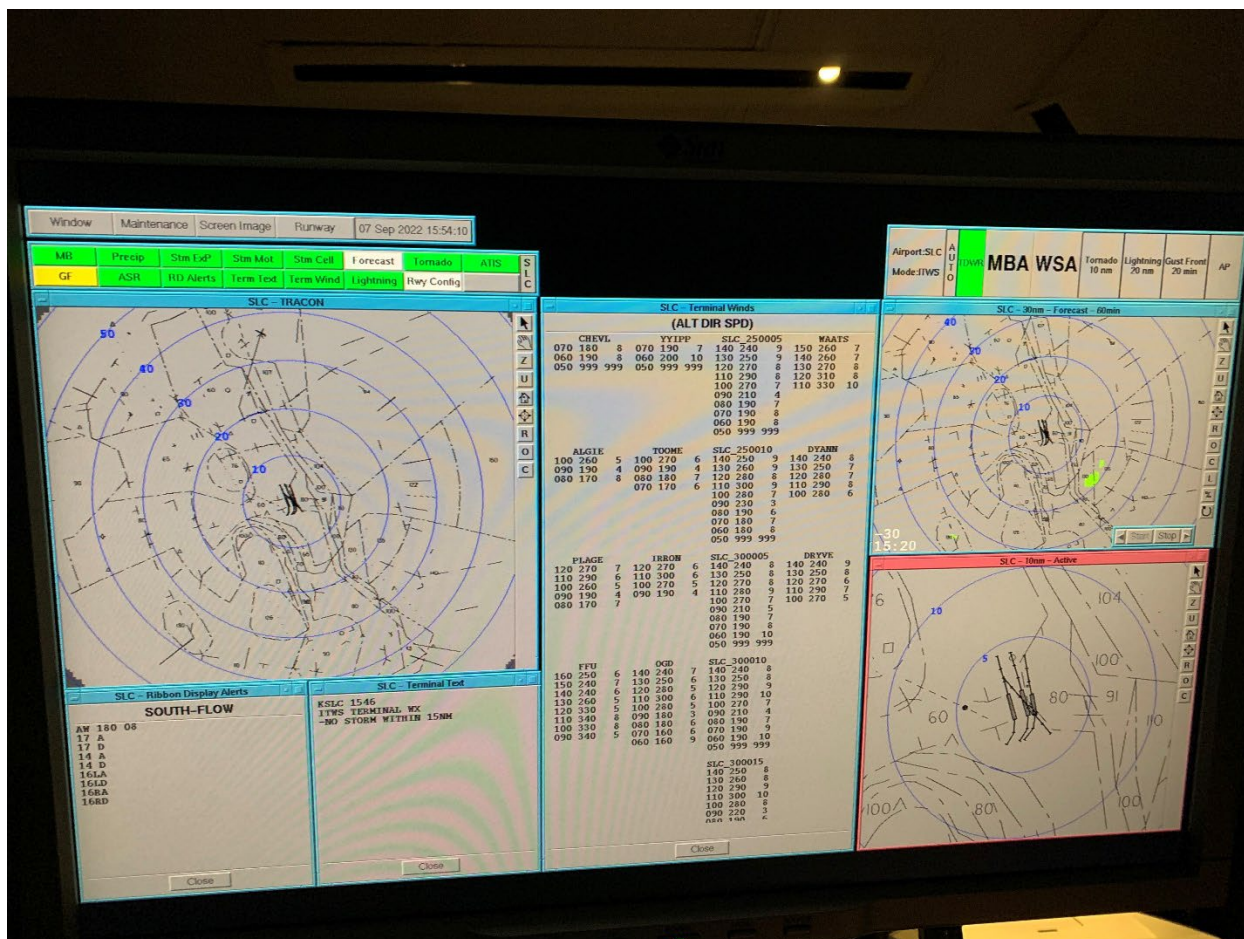


Figure 32. Exemplar view of the ITWS location in the S56 TRACON facility.

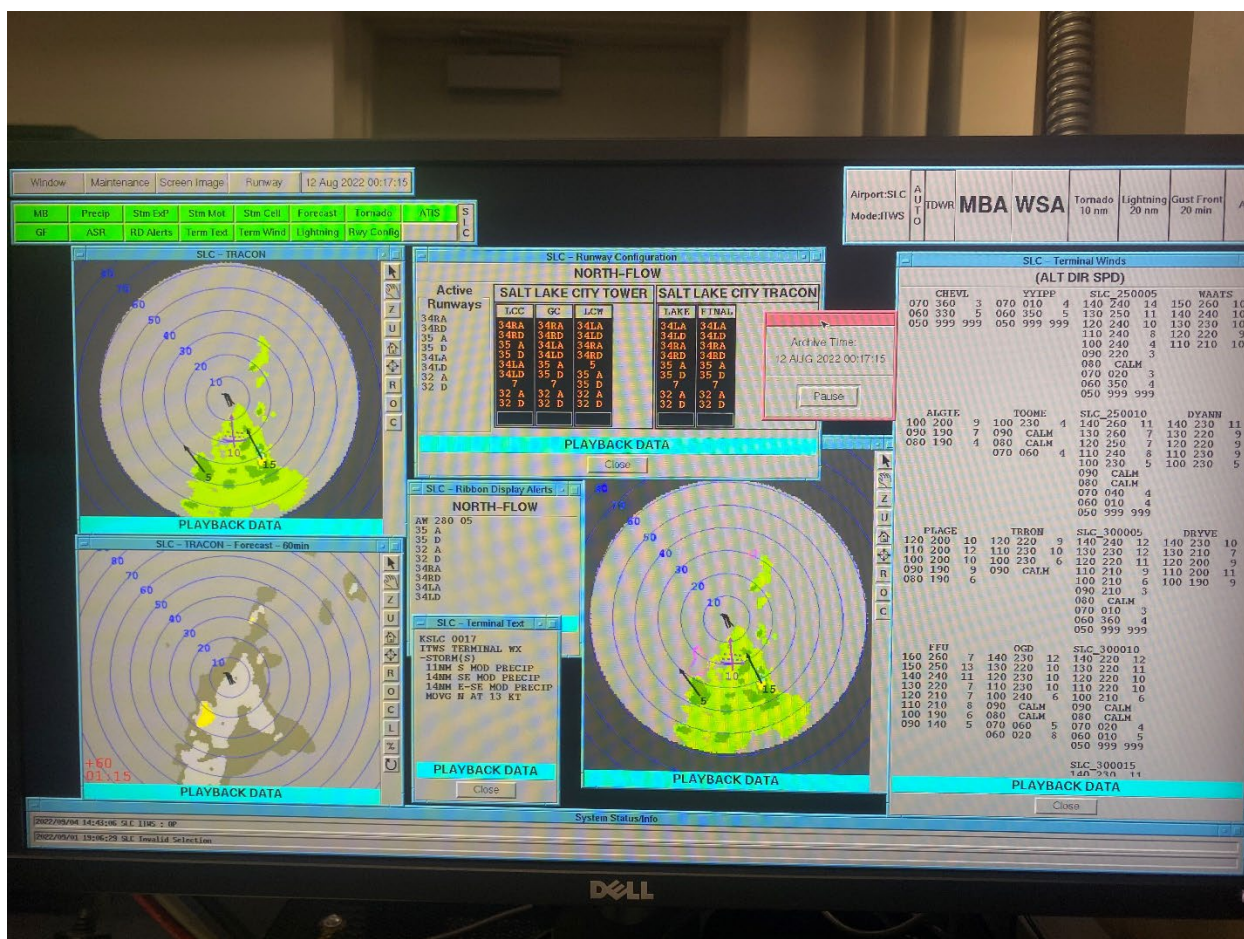


Figure 33. Exemplar view of ITWS data in the S56 TRACON facility from an active weather day.

25.0 Additional FAA Integrated Terminal Weather System Data

While the original ITWS information was not retrieved for the accident timeframe, the FAA was able to reproduce some of the ITWS imagery using TDWR base products. The FAA was able to use the Product Generator (PG) archive weather input data and create a playback of ITWS imagery to include Microburst (MB) shapes, Wind Shear (WS) shapes, and Ribbon Display Terminal (RBDT) alerts. For more information on the methodology used please see attachments 25 through 27 with the Ribbon Display Information box highlighted in figure 34. For the recreated ITWS imagery please see attachment 28.

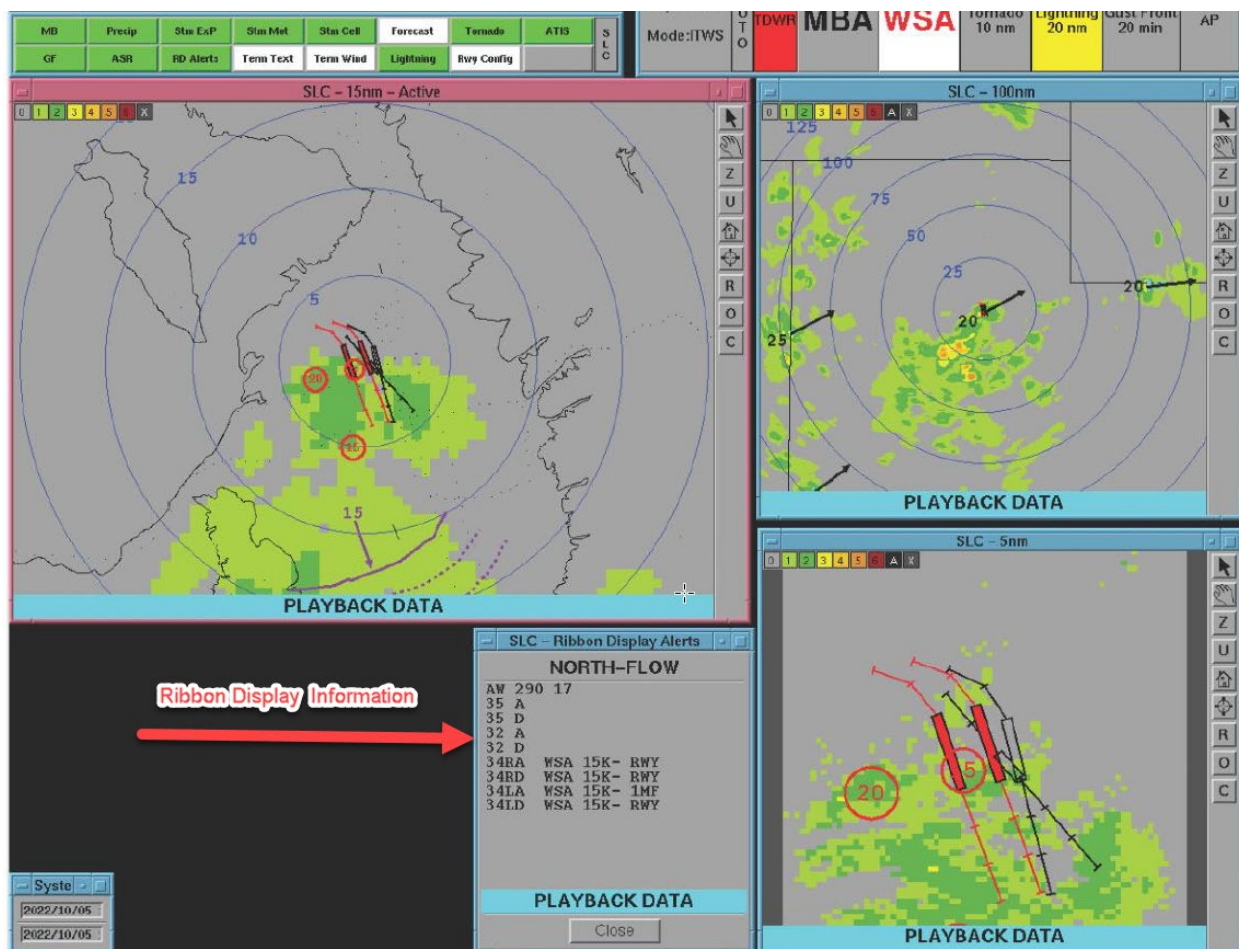


Figure 34. Exemplar view of ITWS data with Ribbon Display Information highlighted.

26.0 Astronomical Data

The astronomical data obtained for the accident site on July 13, 2022, indicated the following:

SUN

Begin civil twilight 0535 MDT

Sunrise 0608 MDT

Sun transit 1334 MDT

Accident time 1852 MDT⁴⁸

Sunset 2059 MDT

End civil twilight 2132 MDT

⁴⁸ Inserted accident time for reference and context.

At the time of the accident the Sun was located at an altitude of 21.70° and azimuth of 280.55°.

E. LIST OF ATTACHMENTS

Attachment 1 - One- and five-minute KSLC ASOS observation surrounding the accident time

Attachment 2 - Observations from SLCBY surrounding the accident time

Attachment 3 - Observations from SLCCF surrounding the accident time

Attachment 4 - Observations from SLCNW surrounding the accident time

Attachment 5 - GOES-16 visible satellite animation from 1801 to 1931 MDT with GLM data overlaid

Attachment 6 - GOES-16 RGB satellite animation from 1801 to 1931 MDT with GLM data overlaid

Attachment 7 - TSLC weather radar imagery animation of the base reflectivity 0.5° elevation scan from 1833 to 1927 MDT

Attachment 8 - TSLC weather radar imagery animation of the radial velocity 0.5° elevation scan from 1833 to 1927 MDT

Attachment 9 - TSLC 3-Dimensional weather radar imagery animation of the base reflectivity above the accident site south facing view from 1830 to 1900 MDT

Attachment 10 - GFA information valid at the accident time

Attachment 11 - LOA between WFO SLC and Salt Lake City Department of Airports

Attachment 12 - ZLC CWSU personnel statement

Attachment 13 - WFO SLC forecaster 1 interview

Attachment 14 - WFO SLC forecaster 2 interview

Attachment 15 - Salt Lake City International Airport video imagery 1

Attachment 16 - Salt Lake City International Airport video imagery 2

Attachment 17 - Salt Lake City International Airport video imagery 3

Attachment 18 - FIS-B weather information around the accident time

Attachment 19 - STARS weather display from 1837 to 1857 MDT

Attachment 20 - PDWB valid at the accident time

Attachment 21 - ITWS reference sheet for TDWR equipped locations
Attachment 22 - ITWS reference sheet for non-TDWR equipped locations
Attachment 23 - ITWS reference sheet history
Attachment 24 - ZLC CWSU accident day log
Attachment 25 - FAA memo for ITWS recreation dataset
Attachment 26 - FAA accident details with TDWR and ITWS imagery
Attachment 27 - FAA description of the ITWS recreation dataset
Attachment 28 - ITWS recreation dataset
Attachment 29 - Additional SLC airport wind sensor information 1
Attachment 30 - Additional SLC airport wind sensor information 2

Submitted by:

Paul Suffern
Senior Meteorologist