National Transportation Safety Board

Office of Aviation Safety

Washington, D.C. 20594-2000

May 3, 2012

METEOROLOGICAL FACTUAL REPORT

WPR11MA454

A. Accident

Location: Reno, Nevada
Date: September 16, 2011
Time: approximately 1626 Pacific daylight time (2326 UTC[1])
Aircraft: North American P-51D, registration: N79111

B. Meteorological Specialist

Paul Suffern
Senior Meteorologist
National Transportation Safety Board
Operational Factors Division, AS-30
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C. Summary

On September 16, 2011, about 1626 Pacific daylight time, an experimental single seat North America P-51D, N79111, collided with the airport ramp in the spectator box seat area following a loss of control while maneuvering during an unlimited class gold heat race at the National Championship Air Races (NCAR) at Reno Stead Airport (RTS), Reno, Nevada. The airplane was registered to Aero-Trans Corp, Ocala, Florida, and operated by the pilot as Race 177, the Galloping Ghost, under the provisions of 14 *Code of Federal Regulations* (CFR) Part 91. The commercial pilot and 10 people on the ground sustained fatal injuries; more than 60 people were treated for minor to serious injuries. The airplane fragmented upon impact with the ramp. Visual meteorological conditions prevailed, and no flight plan had been filed for the local air race flight, which departed RTS about 10 minutes before the accident.

[1] UTC – is an abbreviation for Coordinated Universal Time.

D. Details of Investigation

The National Transportation Safety Board's (NTSB) Meteorologist was not on scene for this investigation and gathered all 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 Climatic Data Center (NCDC). All times are Pacific daylight time (PDT) on September 16, 2011, and are based upon the 24-hour clock, where local time is -7 hours from UTC, and UTC=Z. Directions are referenced to true north and distances in nautical miles. Heights are above mean sea level (msl) unless otherwise noted. Visibility is in statute miles and fractions of statute miles.

The accident site was located at latitude 39.67° N, longitude 119.88° W, elevation: 5,050 feet.

1.0 Synoptic Situation

The synoptic or large scale migratory weather systems influencing the area were documented using standard NWS charts issued by the National Center for Environmental Prediction (NCEP) and the Ocean Prediction Center (OPC) located in Camp Springs, 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-0045G CHG 1.

1.1 Surface Analysis Chart

The NWS Surface Analysis Chart for 1700 PDT is provided as figure 1, with the approximate location of the accident site marked. The chart depicted a trough[2] east of the accident site, stretching from northwestern Nevada southward into northern Mexico. A surface low pressure center was located in central Nevada with a surface pressure of 1007-hectopascals (hPa). The station models to the north and east of the accident site depicted temperatures from the low 70's to low 80's Fahrenheit (F), with temperature-dew point spreads of 30° F or more, a west wind between 5 and 15 knots, and partly cloudy skies. Station models to the south of the accident site had temperatures from the mid 60's to mid 80's F, with temperature-dew point spreads of 30° F or more, a west to southwest wind of 5 to 10 knots, and clear skies. Station models to the west of the accident site and located west of the Sierra Nevada Mountain Range had temperatures in the low to mid 80's F, temperature-dew point spreads of 25° F or more, a south wind of 5 to 15 knots, and partly cloudy skies.

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

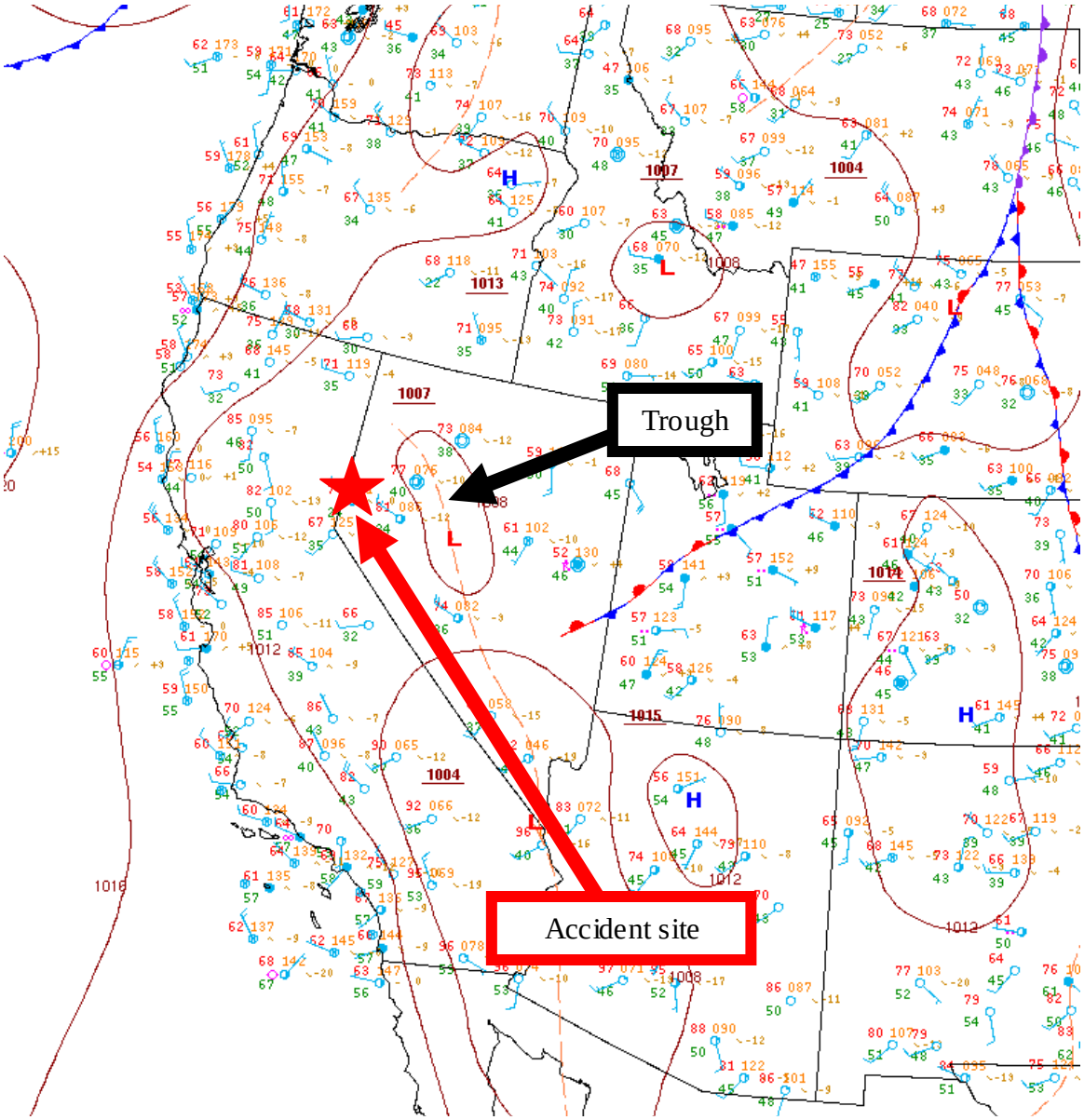

Figure 1 – NWS Surface Analysis Chart for 1700 PDT

1.2 Upper Air Charts

The NWS Storm Prediction Center (SPC) Constant Pressure Charts for 0500 PDT and 1700 PDT are presented for 700-, 500-, and 300-hPa in figures 2 through 5. The 700- and 500-hPa charts depicted a mid-level trough moving eastward across the accident site near the time of the accident. This mid level trough brought a change in the wind direction above the surface from southerly at 0500 PDT to west-northwesterly at 1700 PDT. Winds increased in magnitude with height near the accident site with winds at or above 40 knots at 300-hPa.

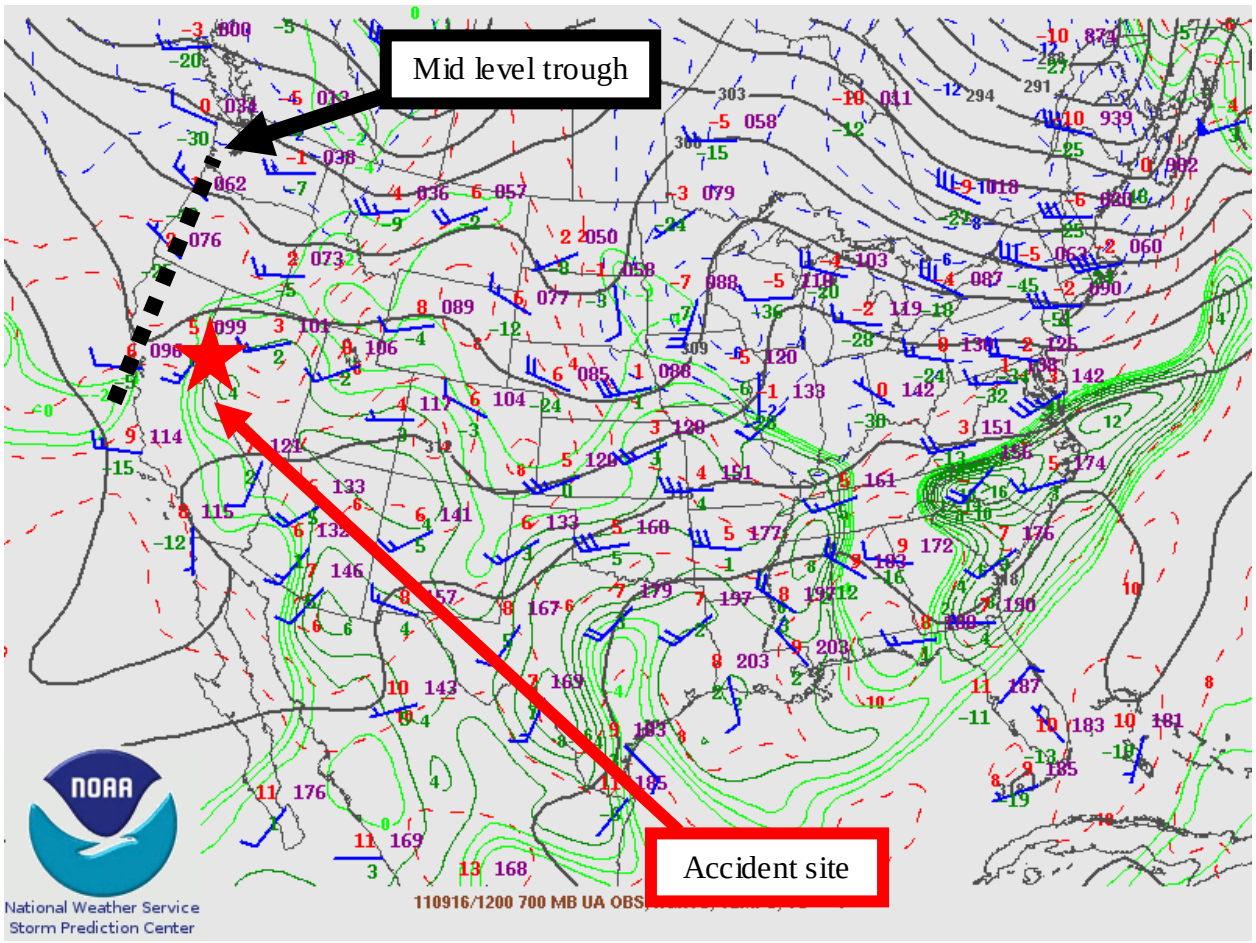

Figure 2 – 700-hPa Constant Pressure Chart for 0500 PDT

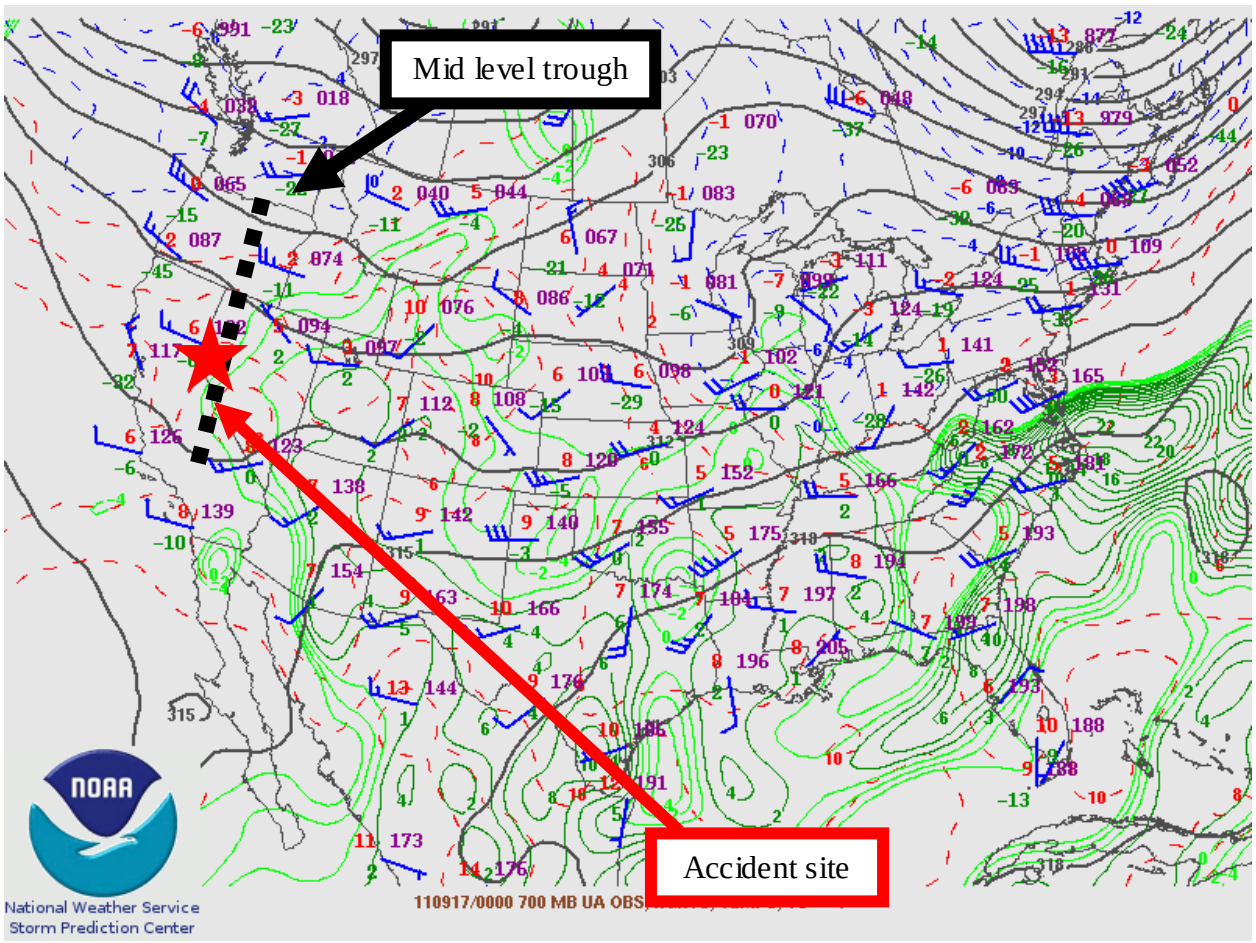

Figure 3 – 700-hPa Constant Pressure Chart for 1700 PDT

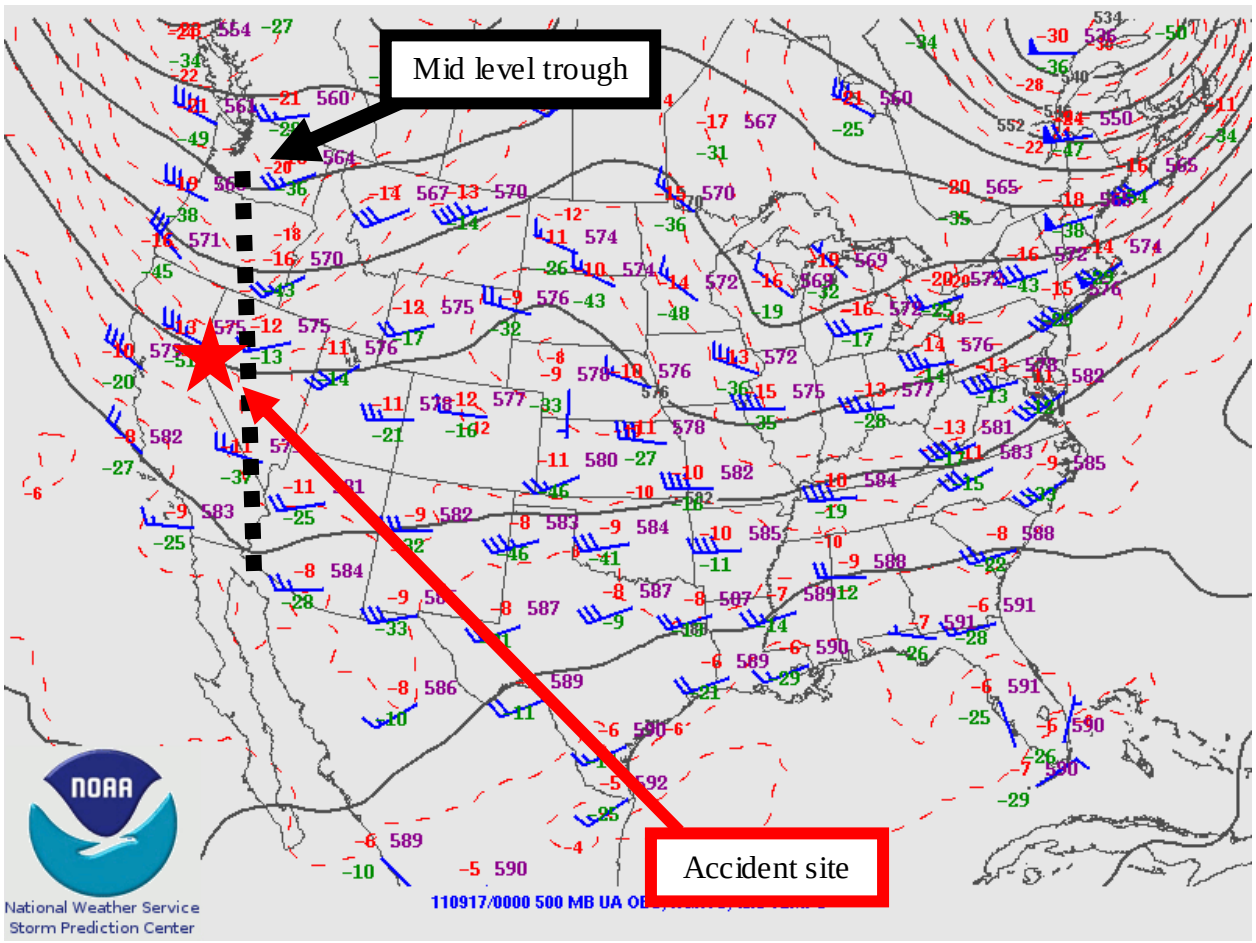

Figure 4 – 500-hPa Constant Pressure Chart for 1700 PDT

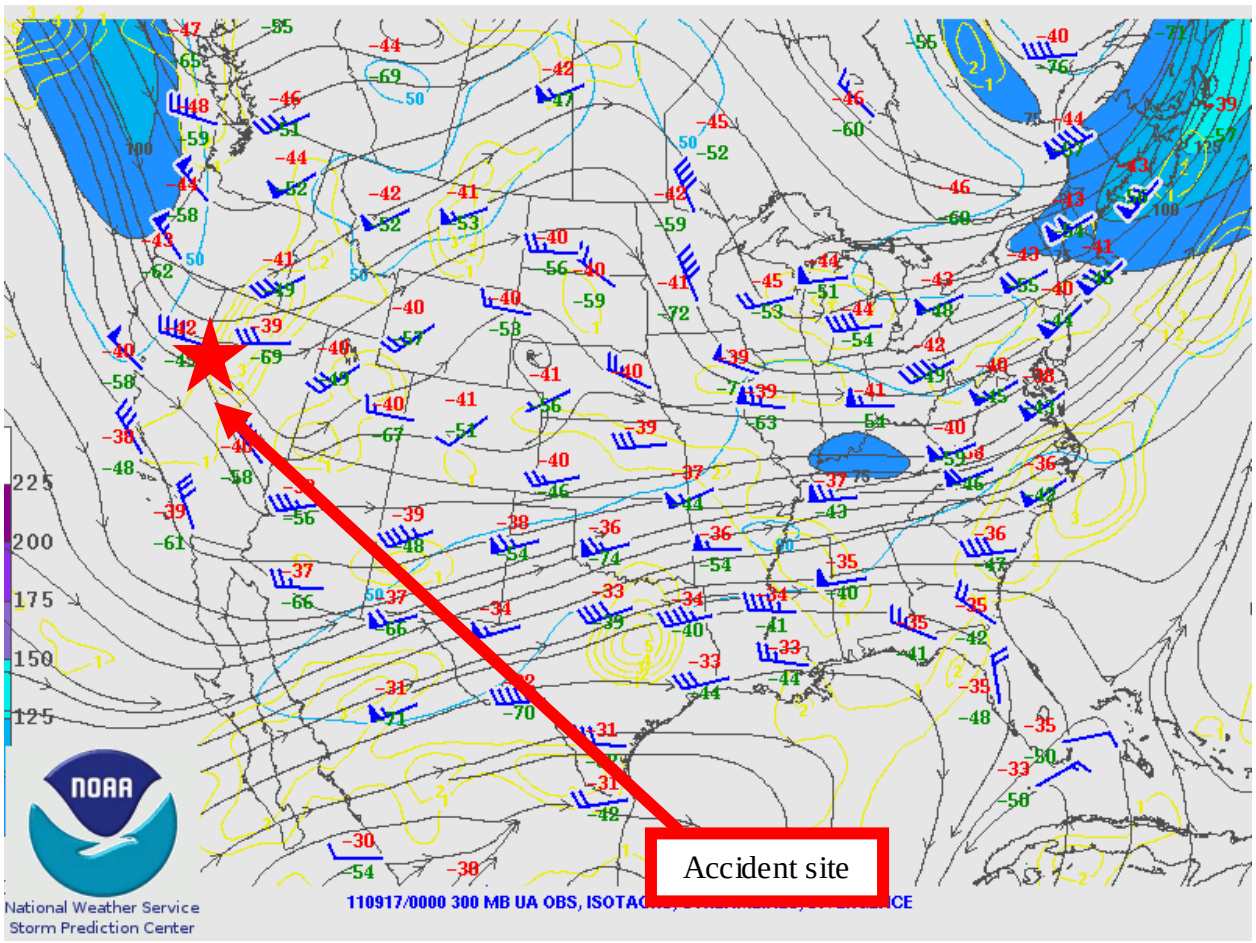

Figure 5 – 300-hPa Constant Pressure Chart for 1700 PDT

2.0 Surface Observations

The area surrounding the accident site was documented utilizing official NWS Meteorological Aerodrome Reports (METARs) and Specials (SPECIs). The following observations were taken from standard code and are provided in plain language.

The closest weather reporting to the accident site was from an Automated Weather Observing System (AWOS[3]) located at Reno/Stead Airport (KRTS) 10 miles northwest of Reno, Nevada (figure 6). These observations were taken from automated equipment and were not supplemented by a human observer. KRTS had an elevation of 5,050 feet, and had a 16° easterly magnetic variation[4]. The following observations were disseminated around the time of the accident:

[3] AWOS – Automated Weather Observing System is equipped with meteorological instruments to observe and report temperature, dewpoint, wind speed and direction, visibility, cloud coverage and ceiling up to twelve thousand feet, and altimeter setting.

[4] Magnetic variation – The angle (at a particular location) between magnetic north and true north.

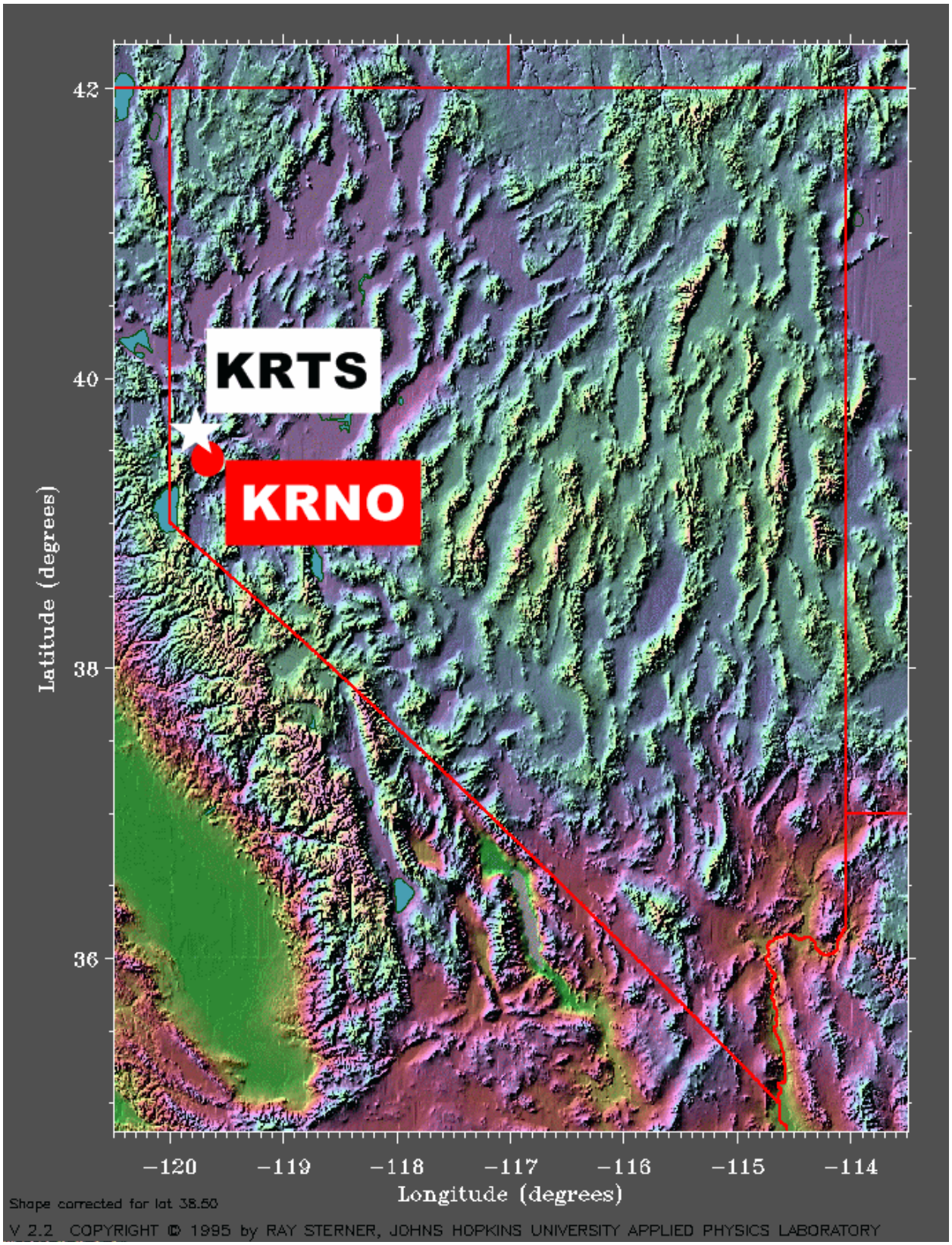

Figure 6 – Map of Nevada with the location of KRTS and KRNO

[1530 PDT] KRTS 162230Z AUTO 26016G22KT 10SM CLR 23/00 A2999

[1540 PDT] KRTS 162240Z AUTO 26017G21KT 10SM CLR 23/00 A2999

[1550 PDT] KRTS 162250Z AUTO 26013G22KT 10SM CLR 23/00 A2999

[1600 PDT] KRTS 162300Z AUTO 26013G20KT 10SM CLR 22/00 A2999

[1610 PDT] KRTS162310Z AUTO 25016G22KT 10SM CLR 22/00 A2999

[1620 PDT] KRTS162320Z AUTO 24015G21KT 10SM CLR 22/00 A2999

ACCIDENT TIME 1626 PDT

[1630 PDT] KRTS162330Z AUTO 26015G20KT 10SM CLR 22/00 A2999

[1640 PDT] KRTS 162340Z AUTO 25015G18KT 10SM 22/00 A2999

[1650 PDT] KRTS 162350Z AUTO 25014KT 10SM 22/M01 A2999

KRTS weather at 1610 PDT, wind from 250° at 16 knots with gusts to 22 knots, 10 miles visibility, clear skies below 12,000 feet above ground level (agl), temperature of 22° Celsius (C), dew point temperature of 0° C, altimeter setting of 29.99 inches of mercury.

KRTS weather at 1620 PDT, wind from 240° at 15 knots with gusts to 21 knots, 10 miles visibility, clear skies below 12,000 feet, temperature of 22° C, dew point temperature of 0° C, altimeter setting of 29.99 inches of mercury.

KRTS weather at 1630 PDT, wind from 260° at 15 knots with gusts to 20 knots, 10 miles visibility, clear skies below 12,000 feet, temperature of 22° C, dew point temperature of 0° C, altimeter setting of 29.99 inches of mercury.

Reno/Tahoe International Airport (KRNO), located 3 miles southeast of Reno, Nevada, had an Automated Surface Observing System (ASOS[5]) (figure 6) whose reports were augmented by the tower. KRNO is located 11 miles southeast of the accident site and KRTS, at an elevation of 4,415 feet, and has a 16° easterly magnetic variation. The following observations were taken and disseminated during the times surrounding the accident:

[1255 PDT] KRNO 161955Z 21004KT 10SM BKN080 BKN100 BKN240 24/03 A2994
RMK AO2 SLP087 T02390033

[1355 PDT] KRNO 162055Z 29013G19KT 10SM SCT085 SCT110 BKN200 26/02 A2992
RMK AO2 WSHFT 2023 SLP077 T02610022 58013

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

[1455 PDT] KRNO 162155Z COR 28019G26KT 10SM SCT085 SCT100 BKN200 26/01 A2992 RMK AO2 PK WND 27026/2150 SLP076 ACSL DSNT S-W NW P0000 T02610011

[1555 PDT] KRNO 162255Z 28017G21KT 10SM SCT085 BKN110 BKN200 25/M02 A2992 RMK AO2 PK WND 27026/2217 SLP080 VIRGA DSNT W ACSL DSNT N-E SE-SW W T02501017

ACCIDENT TIME 1626 PDT

[1655 PDT] KRNO 162355Z 29016KT 10SM SCT085 BKN110 BKN200 23/M04 A2992 RMK AO2 PK WND 28026/2338 SLP081 VIRGA DSNT NW ACSL SW-W NW 60000 T02331044 10261 20222 58000

[1755 PDT] KRNO 170055Z 29013G22KT 10SM FEW085 BKN110 BKN200 23/M03 A2992 RMK AO2 SLP084 ACSL NE SW-W T02331033

[1855 PDT] KRNO 170155Z 28015G26KT 10SM FEW085 SCT110 22/M03 A2994 RMK AO2 PK WND 28026/0150 SLP091 ACSL S-W T02171033

[1955 PDT] KRNO 170255Z 30011KT 10SM FEW110 20/M03 A2997 RMK AO2 SLP104 ACSL SW T02001028 53015

[2055 PDT] KRNO 170355Z 32009KT 10SM CLR 19/M01 A3001 RMK AO2 SLP120 T01891006

KRNO weather at 1455 PDT, wind from 280° at 19 knots with gusts to 26 knots, visibility 10 miles, scattered clouds at 8,500 feet agl, scattered clouds at 10,000 feet, a broken ceiling at 20,000 feet, temperature of 26° C, dew point temperature of 1° C, and an altimeter setting of 29.92 inches of mercury. Remarks: automated station with a precipitation discriminator, peak wind from 270° at 26 knots at 1450 PDT, sea level pressure 1007.6 hPa, altocumulus standing lenticular clouds distant[6] south through west and northwest, 1-hourly precipitation of a trace, temperature 26.1° C, dew point temperature 1.1° C.

KRNO weather at 1555 PDT, wind from 280° at 17 knots with gusts to 21 knots, visibility 10 miles, scattered clouds at 8,500 feet, a broken ceiling at 11,000 feet, broken skies at 20,000 feet, temperature of 25° C, dew point temperature of -2° C, and an altimeter setting of 29.92 inches of mercury. Remarks: automated station with a precipitation discriminator, peak wind from 270° at 26 knots at 1517 PDT, sea level pressure 1008.0 hPa, virga distant west, altocumulus standing lenticular clouds distant north through east, southeast through southwest, and west, temperature 25.0° C, dew point temperature -1.7° C.

[6] Distant means the phenomena was detected by the automated system beyond 10 miles but less than 30 miles from the airport location point.

KRNO weather at 1655 PDT, wind from 290° at 16 knots, visibility 10 miles, scattered clouds at 8,500 feet, a broken ceiling at 11,000 feet, broken skies at 20,000 feet, temperature of 23° C, dew point temperature of -4° C, and an altimeter setting of 29.92 inches of mercury. Remarks: automated station with a precipitation discriminator, peak wind from 280° at 26 knots at 1638 PDT, sea level pressure 1008.1 hPa, virga distant northwest, altocumulus standing lenticular clouds southwest through west and northwest, 6-hourly precipitation of a trace, temperature 23.3° C, dew point temperature -4.4° C, 6-hourly maximum temperature of 26.1° C, 6-hourly minimum temperature of 22.2° C, a 3-hourly increase then decrease in pressure of 0.0 hPa.

2.1 MesoWest Observations

Surface observations were also recovered for several sites near the accident site at the accident time using the MesoWest network of surface observations (figure 7). The Cold Springs surface observation site was located 4 miles west-northwest of the accident site at an elevation of 5,144 feet. The following observations were taken and disseminated during the times surrounding the accident:

Cold Springs weather at 1601 PDT, temperature of 75.0° F, dew point temperature of 31.2° F, and wind from the west at 8 mph with gusts to 21 mph.

Cold Springs weather at 1631 PDT, temperature of 73.0° F, dew point temperature of 31.9° F, and wind from the southwest at 1 mph with gusts to 12 mph.

The Desert Springs surface observation site was located 5 miles east of the accident site at an elevation of 5,280 feet. The following observations were taken and disseminated during the times surrounding the accident:

Desert Springs weather at 1540 PDT, temperature of 75.0° F, dew point temperature of 33.6° F, and wind from the west-northwest at 18 mph with gusts to 29 mph.

Desert Springs weather at 1640 PDT, temperature of 71.0° F, dew point temperature of 31.3° F, and wind from the west at 18 mph with gusts to 27 mph.

The Black Springs surface observation site was located 5 miles south-southeast of the accident site at an elevation of 5,173 feet. The following observations were taken and disseminated during the times surrounding the accident:

Black Springs weather at 1620 PDT, temperature of 70.3° F, dew point temperature of 28.5° F, and wind from the southwest at 13 mph with gusts to 21 mph.

Black Springs weather at 1641 PDT, temperature of 70.0° F, dew point temperature of 29.4° F, and wind from the southwest at 13 mph with gusts to 21 mph.

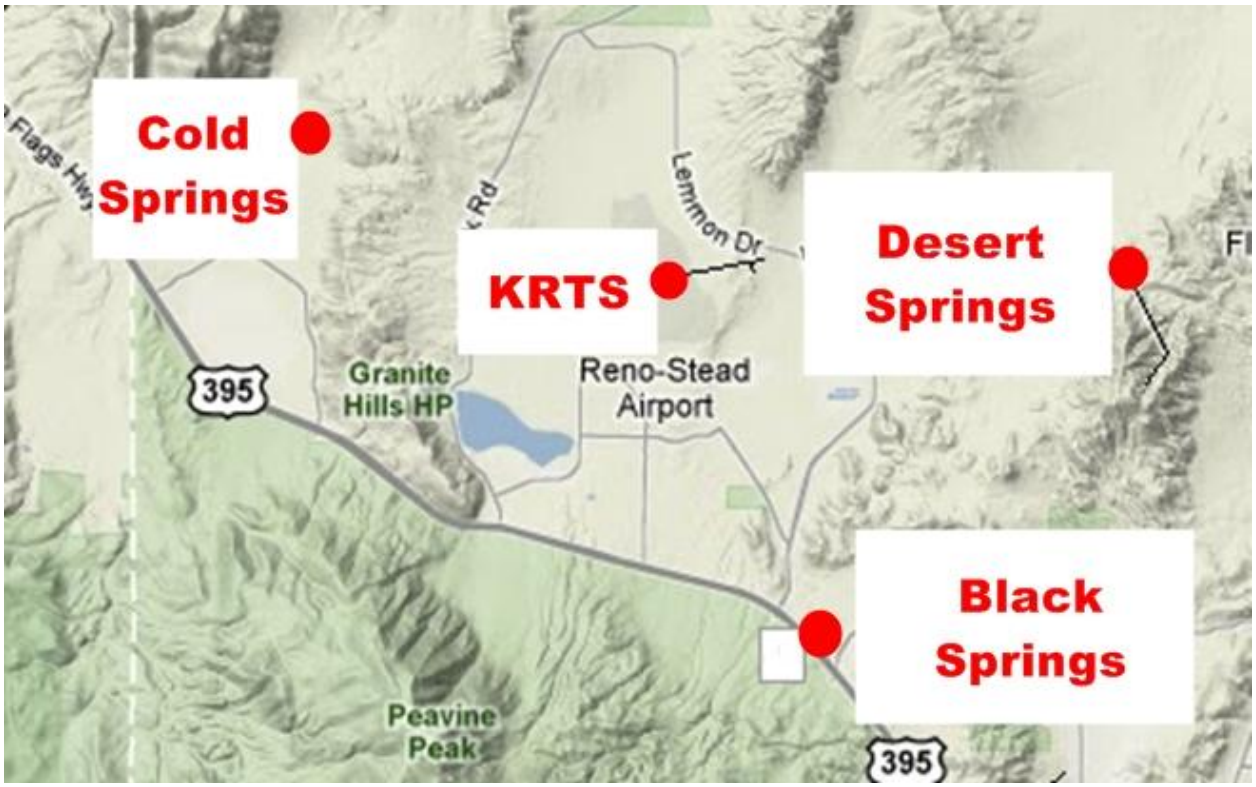

Figure 7 – Map of MesoWest surface observation sites near KRTS

3.0 Upper Air Data

The closest upper air sounding to the accident site was from Reno, Nevada (KREV), which was approximately 7 miles southeast of the accident site, with a site number 72489 and a station elevation of 4,971 feet. The 1700 PDT sounding from KREV was plotted on a standard Skew-T log P diagram[7], which is presented along with the derived stability parameters in figure 8 (with data from the surface to 500-hPa, or approximately 19,000 feet msl). These data were analyzed utilizing the RAOB[8] software package. The sounding depicted a dry vertical environment with the Lifted Condensation Level (LCL)[9] at 13,467 feet, a Convective Condensation Level (CCL)[10] at 16,567 feet, and a Level of Free Convection (LFC)[11] at 13,560 feet. The freezing level was located at 12,292 feet. The tropopause height was identified at 41,375 feet. The precipitable water value was 0.41 inches.

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[7] 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.

[8] RAOB – (The complete Rawinsonde Observation program) is an interactive sounding analysis program developed by Environmental Research Services, Matamopras, Pennsylvania.

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

[10] 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.

[11] 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.

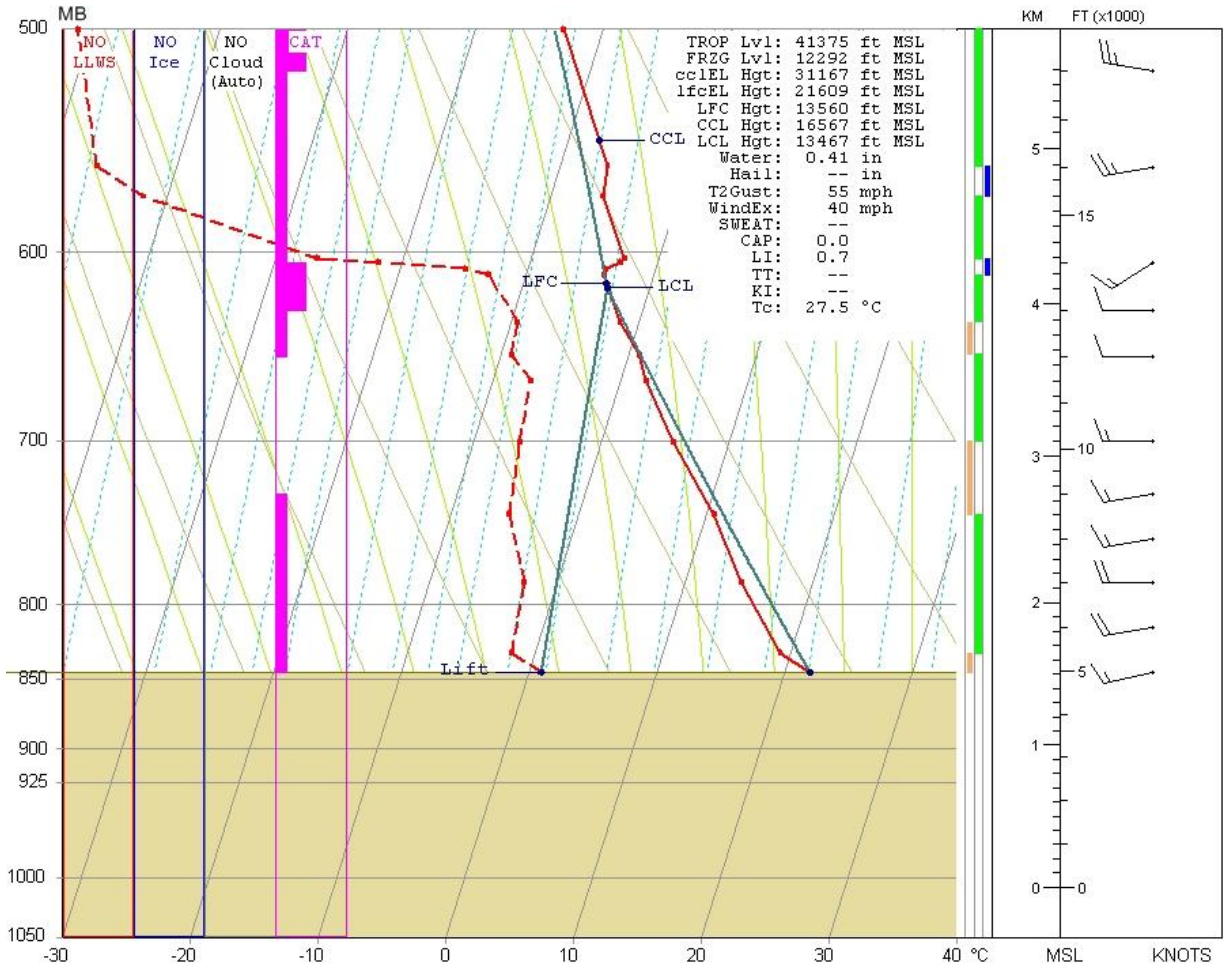


Figure 8 –KREV 1700 PDT sounding

The sounding parameters indicated a dry and conditionally unstable environment from the surface to approximately 14,000 feet. Such conditions are not considered supportive for vertical cloud formation and precipitation, and RAOB did not indicate the potential for the presence of clouds below 19,000 feet. No areas of icing were identified by RAOB.

The sounding wind profile indicated there was a surface wind from 255° at 17 knots and the wind remained out of the west while slowly increasing in speed with height to 25 knots near 18,000 feet. RAOB did not indicate areas of low level wind shear (LLWS), but areas of clear air turbulence were indicated from the surface to 9,000 feet with another area of clear-air turbulence from 12,000 feet through 18,000 feet.

4.0 Satellite Data

Visible and infrared data from the Geostationary Operational Environmental Satellite number 11 (GOES-11) data was obtained from the NCDC and processed with the NTSB's Man-computer Interactive Data Access System (McIDAS) workstation. Visible and infrared imagery (GOES-11 band 1 and 4), at wavelengths of 0.65 microns (μm) and 10.7 μm, respectively, retrieved brightness temperatures for the scene. Satellite imagery surrounding the time of the accident, from 1400 PDT through 1900 PDT 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-11 visible imagery from 1615 and 1630 PDT at 3X magnification with the accident site highlighted with a red square. Inspection of the visible imagery indicated that the cumuliform cloud cover was moving eastward across the accident site at the accident time. Figure 11 presents the GOES-11 infrared imagery from 1630 PDT at 9X magnification with the accident site highlighted with a red square. Based on the brightness temperatures above the accident site and the vertical temperature profile provided by the 1700 PDT KREV sounding (figure 8), the approximate cloud-top heights over the accident site were 19,000 feet.

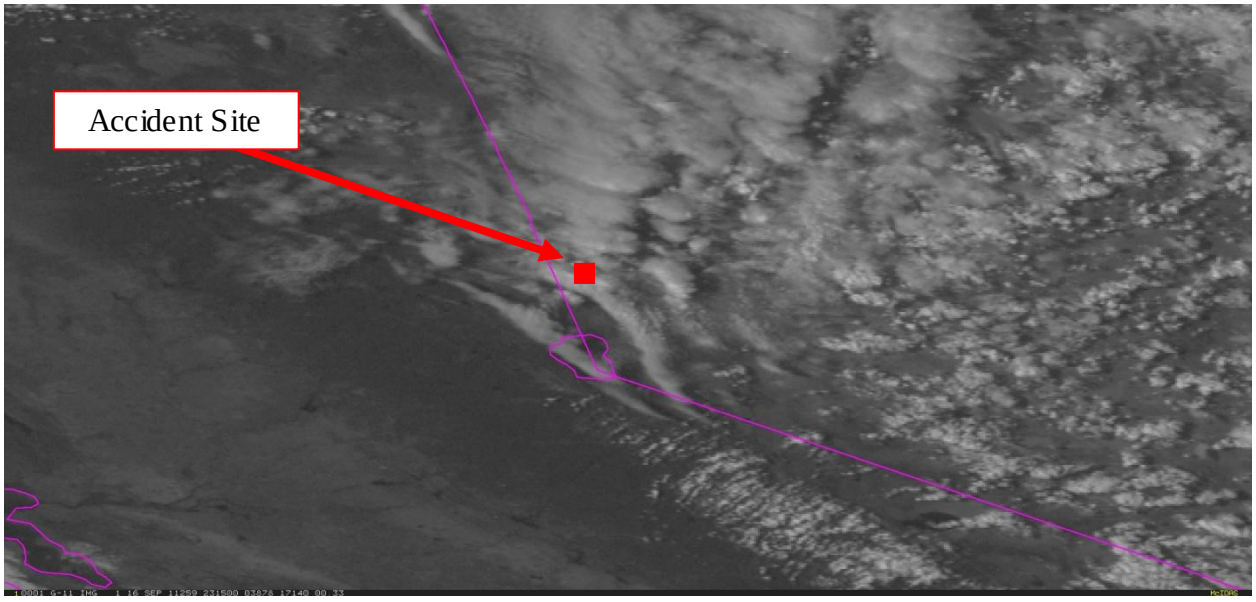


Figure 9 – GOES-11 visible image at 1615 PDT

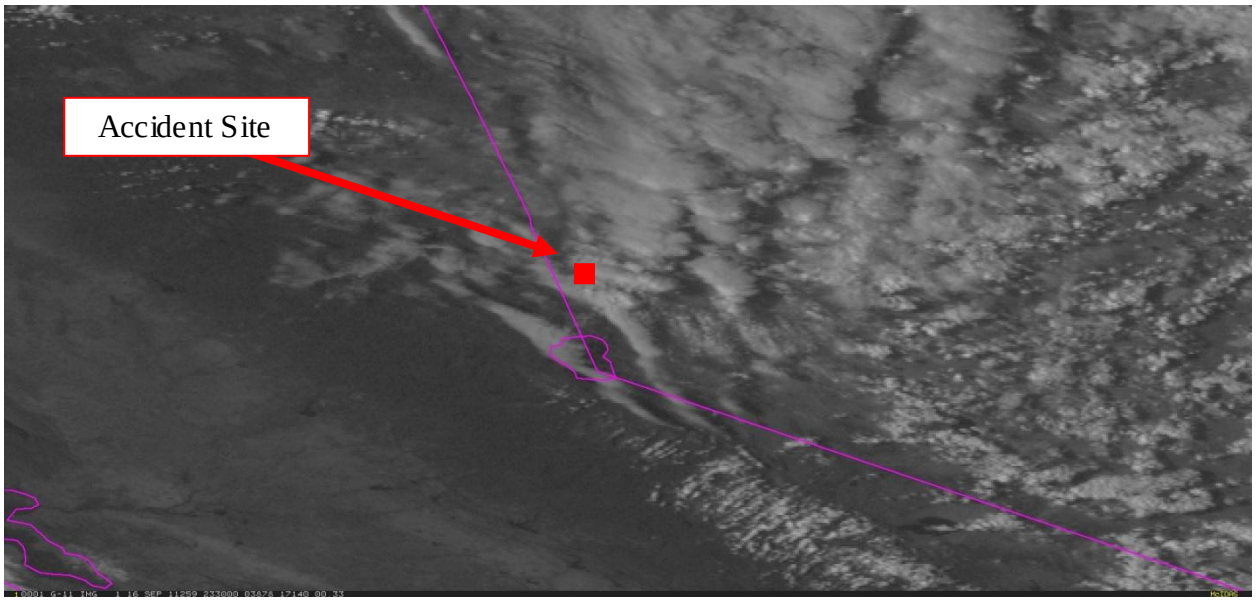


Figure 10 – GOES-11 visible image at 1630 PDT

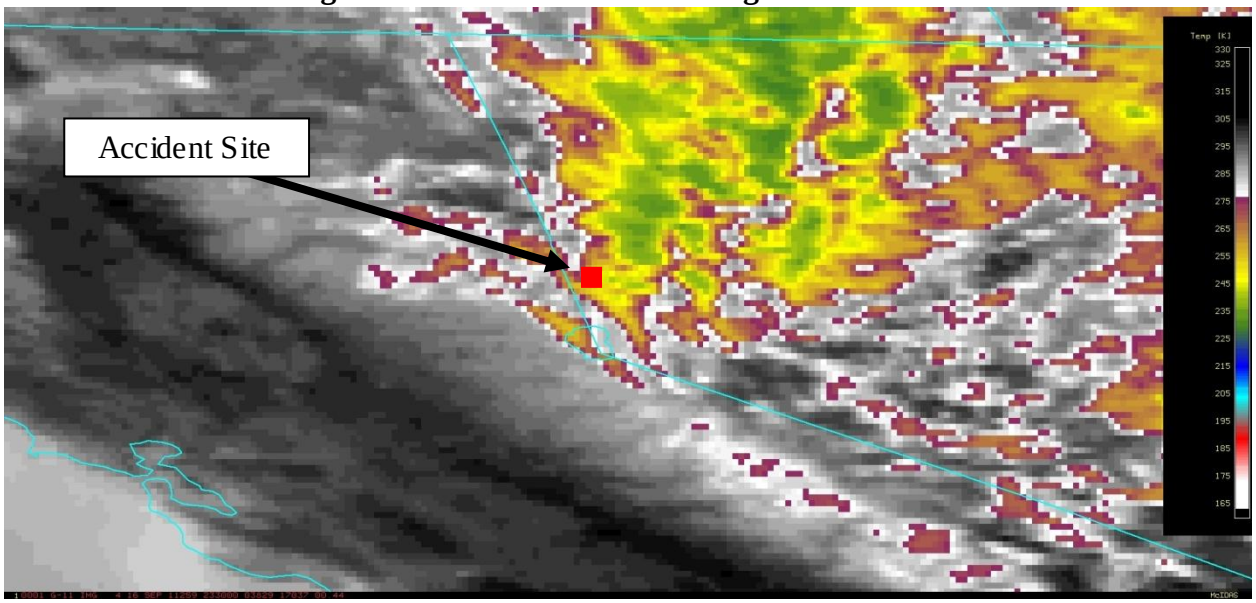


Figure 11 – GOES-11 infrared image at 1630 PDT

5.0 Radar Imagery

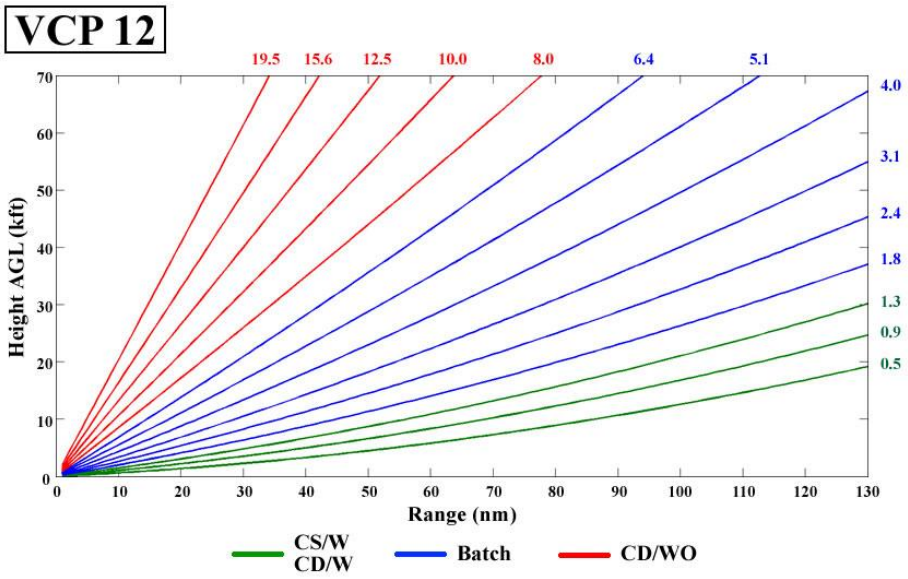
The closest NWS Weather Surveillance Radar-1988, Doppler (WSR-88D) was KRGX located near Reno, Nevada, approximately 20 miles east of the accident site at an elevation of 8,300 feet. Level II archive radar data was obtained from the NCDC utilizing the Hierarchical Data Storage System (HDSS) and displayed using the NWS NEXRAD Interactive Viewer and Data Exporter software.

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 into a 0.95° beam width[12]. The radar produces three basic types of products: base reflectivity, base radial velocity, and base spectral width.

5.1 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 two 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 KRGX WSR-88D radar was operating in the normal 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

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

5.2 Beam Height Calculation

Assuming standard refraction[13] of the WSR-88D 0.95° wide radar beam, the following table shows the approximate beam height and width information of the radar display over the site of the accident. The heights have been rounded to the nearest 10 feet.

ANTENNA ELEVATION	BEAM CENTER	BEAM BASE	BEAM TOP	BEAM WIDTH
0.5°	9,650 feet	8,660 feet	10,640 feet	1,970 feet
6.4°	22,090 feet	21,110 feet	23,070 feet	1,970 feet

Based on the radar height calculations, the 0.5° elevation scan depicted the conditions between 8,660 feet to 10,640 feet msl over the accident site, while the 6.4° elevation scan depicted the conditions between 21,110 feet to 23,070 feet over the accident site.

5.3 Reflectivity

Reflectivity is the measure of the efficiency of a target in intercepting and returning radio energy. With hydrometeors[14] 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[15]), and is a general measure of echo intensity. The chart below relates the NWS video integrator and processor (VIP) intensity levels versus the WSR-88D's display levels, precipitation mode reflectivity in decibels, and rainfall rates.

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

[14] 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.

[15] 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.

NWS VIP/DBZ CONVERSION TABLE

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

5.4 Base Reflectivity

Figures 12 and 13 present the KRGX WSR-88D base reflectivity image for the 0.5° and 6.4° elevation scans initiated at 1625 PDT with a resolution of 0.5° X 250 meters. Figure 12 depicted no echoes over the accident site at the accident time. The lowest elevation scan with echoes over the accident was the 6.4° elevation scan with reflectivity between 10 and 15 dBZ over the accident site at the accident time.

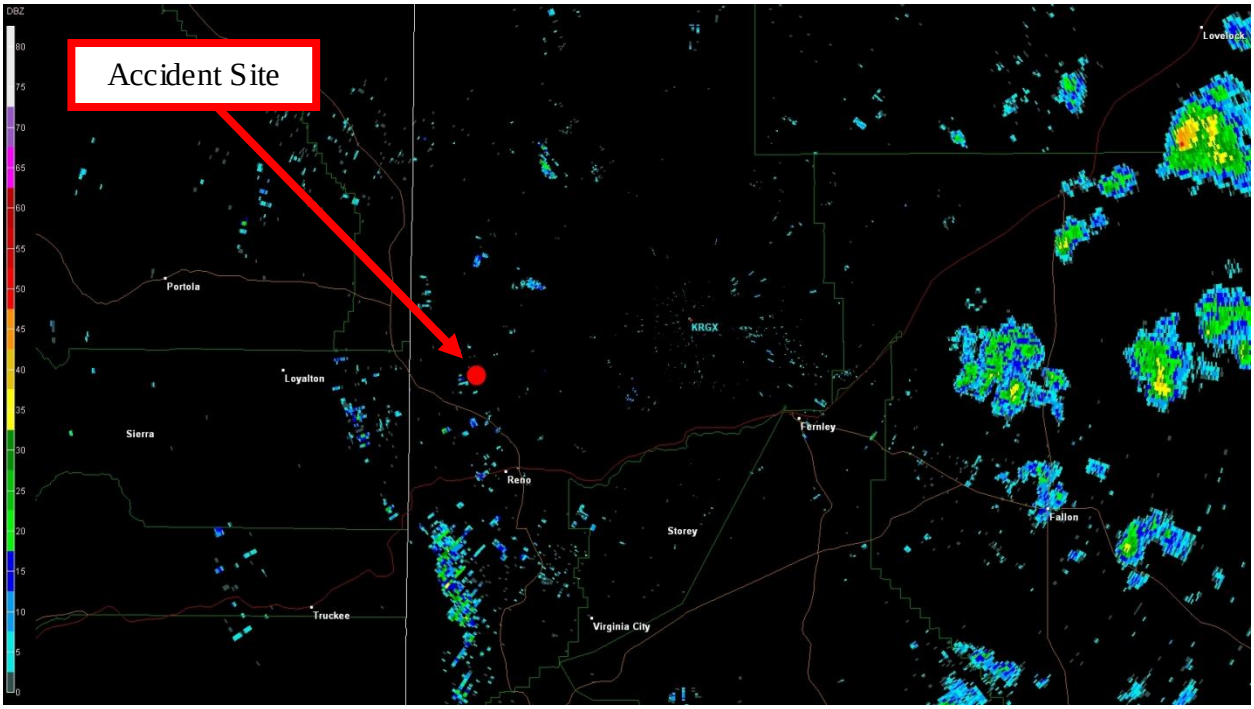


Figure 12 – KRGX WSR-88D 0.5° elevation scan for 1625 PDT

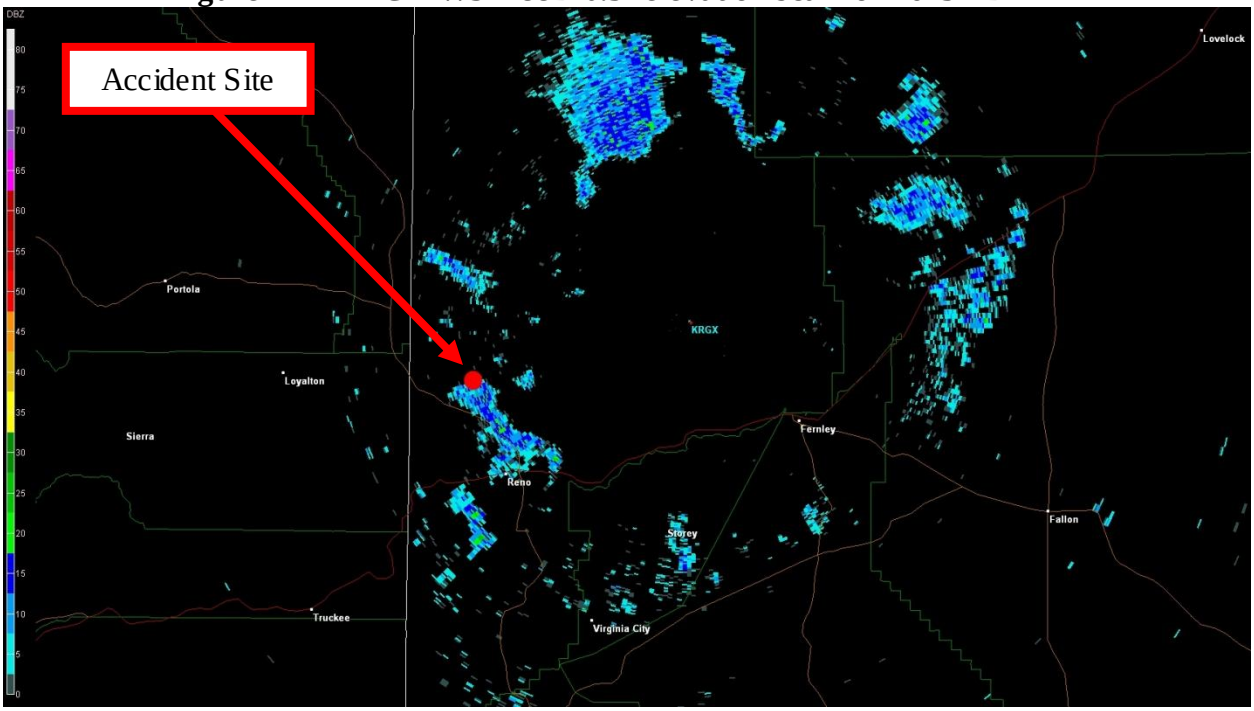


Figure 13 – KRGX WSR-88D 6.4° elevation scan for 1625 PDT

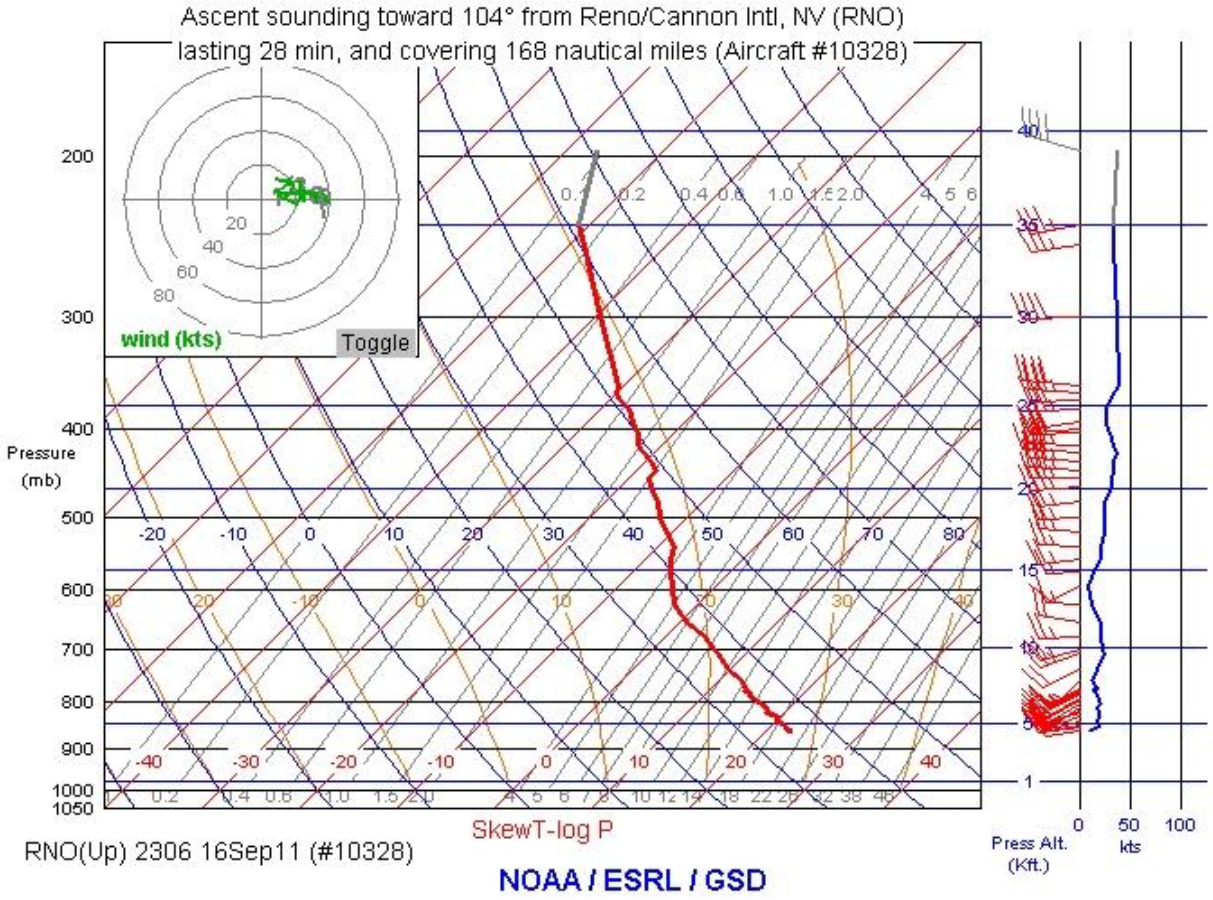
5.5 Lightning

No lightning was detected over the accident site at the accident time.

6.0 AMDAR Data

An aircraft that provided AMDAR data identified as aircraft #10328[16] departed KRNO at 1606 PDT (2306Z) approximately twenty minutes prior to the accident time and retrieved meteorological data on its departure (table 1):

[16] Aircraft #10328 – The aircraft number was determined by the AMDAR data display from the Earth System Research Laboratory's Global Systems Division (ESRL/GSD).



P_alt[17] (ft)	hPa	t/td[18] (°C)	w_dir/w_spd[19] (kts)	Time (UTC)	Lat/Lon[20] (°)
4410	**862**	**22.6/----**	**---°/---**	**2306**	**39.510/-119.755**
4510	**859**	**22.2/----**	**260°/011**	**2306**	**39.510/-119.755**
4750	**851**	**21.6/----**	**260°/020**	**2306**	**39.523/-119.743**
4781	850	21.5/----	260°/020	2306	39.523/-119.743
5090	840	20.2/----	255°/019	2306	39.523/-119.743
5430	830	19.6/----	248°/021	2306	39.523/-119.743

Table 1 – AMDAR meteorological data on a flight departing KRNO twenty minutes prior to the accident time

At 1606 PDT and with a pressure altitude of 4,410 feet, the pressure was 862 hPa, the air temperature was 22.6° C, the latitude was 39.510° N, and the longitude was 119.743° W.

[17] P_alt – Pressure altitude is the indicated altitude when an altimeter is set to an agreed baseline pressure setting. The baseline pressure setting is 1013.25 hPa or 29.92 inches of mercury

[18] t/td – Air temperature and dew point temperature in degrees Celsius.

[19] w_dir/w_spd – Wind direction (reference to true north) and wind speed in knots.

[20] Lat/Lon – Latitude and longitude.

At 1606 PDT and with a pressure altitude of 4,510 feet, the pressure was 859 hPa, the air temperature was 22.2° C, the wind was from 260° at 11 knots, the latitude was 39.510° N, and the longitude was 119.755° W.

At 1606 PDT and with a pressure altitude of 4,750 feet, the pressure was 851 hPa, the air temperature was 21.6° C, the wind was from 260° at 20 knots, the latitude was 39.523° N, and the longitude was 119.743° W.

7.0 Pilot Reports

Pilot reports (PIREPs) were reviewed from one hour prior to the accident time to one hour after the accident time below 20,000 feet and this PIREP was disseminated:

```
RNO UA /OV KRNO/TM 0005/FLUNKN/TP B737/TB OCNL MOD 005/RM DURGD
   LNDING RW 34L WNDS 200/230 20-30KNTS DOWN TO 005. BELOW 005
   HEADWIND AT 10KNOTS AWC-WEB:SWA=
```

Routine pilot report (UA); Over Reno, Nevada; Time – 1705 PDT (0005Z); Flight level[21] – Unknown; Type aircraft – Boeing 737; Turbulence – Occasional moderate at 500 feet; Remarks – During landing runway 34L winds from 200° to 230° at 20 to 30 knots down to 500 feet, below 500 feet headwind at 10 knots.

8.0 SIGMET and CWSU Advisory

No SIGMET was active for the accident site at the accident time.

No CWSU Advisory or Meteorological Impact Statement was active for the accident site at the accident time.

9.0 AIRMETs

No AIRMETs were active for the accident site at the accident time below 30,000 feet.

10.0 Terminal Aerodrome Forecast

KRNO (figure 6) was the closest site with a NWS Terminal Aerodrome Forecast (TAF[22]). The TAF valid at the time of the accident was issued at 1020 PDT and was valid for a 24-hour period beginning at 1100 PDT. The TAF forecast for KRNO was as follows:

---

[21] Flight Level – A Flight Level (FL) is a standard nominal altitude of an aircraft, in hundreds of feet. 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.

[22] Terminal Aerodrome Forecast (TAF) – These forecasts apply to a five statute mile radius from the center of the airport runway complex where the TAF is valid.

KRNO 161720Z 1618/1718 23008KT P6SM SCT080 SCT200
FM162200 27015G25KT P6SM FEW080
FM170300 VRB05KT P6SM SKC=

The forecast expected wind from 270° at 15 knots with gusts to 25 knots, greater than 6 miles visibility, and few clouds at 8,000 feet agl.

Another TAF was issued at 1620 PDT but it was valid after the accident time for a 24-hour period beginning at 1700 PDT:

KRNO 162320Z 1700/1724 **27015G25KT P6SM SCT080 BKN110**
FM170300 VRB05KT P6SM FEW080
FM172000 29008KT P6SM SKC
FM172300 31010G18KT P6SM SKC=

The forecast expected wind from 270° at 15 knots with gusts to 25 knots, greater than 6 miles visibility, scattered clouds at 8,000 feet agl, and a broken ceiling at 11,000 feet agl.

11.0 Area Forecast

The updated Area Forecast issued at 1340 PDT forecasted scattered clouds at 12,000 feet msl with a broken ceiling of cirrus clouds. Isolated thunderstorms in northwestern Nevada, including the accident site, were expected to last until 2100 PDT with cumulonimbus cloud tops forecast to reach FL370:

FAUS45 KKCI 162040 AAA
FA5W
_SLCC FA 162040 AMD
SYNOPSIS AND VFR CLDS/WX
SYNOPSIS VALID UNTIL 171400
CLDS/WX VALID UNTIL 170800...OTLK VALID 170800-171400
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..LGT-MOD WSWLY FLOW AHEAD OF UPR TROF OVR PACNW.
03Z TROF SRN BC-CNTRL WA-CNTRL OR TO NWRN NV. 09Z TROF SERN BC-
SWRN ID-NERN NV. BY 14Z TROF SERN BC-WRN MT-SERN ID-NERN UT.
SFC..STNR FNT ERN MT SWD THRU ERN WY PLAINS-ERN CO PLAINS INTO TX
MOVG EWD. BY 06Z STNR FNT WRN DAKOTAS-NEB PNHDL-ERN CO PLAINS
MOVG LTL RMNDR PD. STNR FNT NERN MT-S CNTRL MT-NERN ID TO NRN NV
MOVG LTL THRU 14Z.
.
ID
NRN...SCT090 BKN CI. OTLK...VFR.
CNTRL MTNS...BKN100 LYRD FL250. WDLY SCT -SHRA. 04Z SCT100 BKN
CI. OTLK...VFR.
SWRN...SCT080 SCT CI. 03Z SCT CI. OTLK...VFR.
SERN...BKN080 LYRD FL250. SCT -SHRA. 03Z SCT100 BKN150 TOP FL250.

ISOL -SHRA. OTLK...VFR.
.
MT
CONTDVD WWD...BKN100 TOP 140. 02Z BKN150 TOP FL220. OTLK...VFR.
SWRN MTNS...BKN100-120 LYRD FL250. WDLY SCT -SHRA/-TSRA. CB TOP FL300. 02Z BKN150 TOP FL220. OTLK...VFR.
ERN SLOPES OF CONTDVD...SCT120 BKN CI. 02Z BKN CI. OTLK...VFR.
CNTRL
E OF CONTDVD...OVC100 LYRD FL250. VIS 5SM -RA. OTLK...VFR.
RMNDR...SCT120 BKN CI. SRN PTNS OCNL BKN120 LYRD FL250. SCT -SHRA. 02Z BKN CI. OTLK...VFR.
ERN
N HLF...SCT-BKN100 TOP 150. 01Z SCT -SHRA. OTLK...VFR.
S HLF...SCT CI. 00Z SCT120 BKN CI. ISOL -SHRA. OTLK...VFR.
.
WY
PLAINS
NRN...SKC. BECMG 0608 BKN CI. OTLK...VFR.
SRN...SCT140. ISOL -TSRA. CB TOP FL320. 04Z SCT CI. OTLK...VFR.
MTNS E OF CONTDVD
NRN
W HLF...BKN110 LYRD FL250. SCT -SHRA/-TSRA. CB TOP FL350. 03Z BKN150 TOP FL250. OTLK...VFR.
E HLF...SCT150. 23Z BKN120 LYRD FL250. TIL 03Z WDLY SCT -TSRA. CB TOP FL360. WND NW G25KT. OTLK...VFR.
SRN...SCT150. ISOL -TSRA. CB TOP FL350. 05Z SCT CI. OTLK...VFR.
MTNS W OF CONTDVD
NRN...OVC120 LYRD FL250. VIS 3SM SCT -TSRA. CB TOP FL400. 02Z BKN120. SCT -SHRA. OTLK...VFR.
SRN...SCT140. 23Z BKN140 LYRD FL250. SCT -SHRA/-TSRA. CB TOP FL390. TIL 02Z WND W G25KT. 05Z BKN120 LYRD FL250. SCT -SHRA. WND SW G25KT. OTLK...VFR WND.
.
NV...UPDT
NWRN...SCT120 BKN CI. TIL 04Z ISOL -TSRA. CB TOP FL370.
OTLK...VFR.
NERN...BKN140 LYRD FL250. SCT -TSRA. CB TOP FL400. 03Z BKN CI. OTLK...VFR.
SRN...SCT140 SCT CI. ISOL -TSRA POSS SEV. CB TOP FL400. TIL 02Z WND S G25KT. OTLK...VFR.
.
UT
NWRN...BKN120 LYRD FL250. SCT -SHRA/-TSRA. CB TOP FL400. 02Z BKN150. ISOL -SHRA. OTLK...VFR.
NERN...SCT120. ISOL -TSRA. CB TOP FL370. 02Z BKN140 LYRD FL250. SCT -SHRA. OTLK...VFR.
SRN HLF...SCT120. OCNL BKN120 TOP FL220. SCT -TSRA. CB TOP FL440. 03Z SCT120 BKN CI. OTLK...VFR.
.
CO
PLAINS
NRN
XTRM E...BKN045 TOP 060. 03Z WDLY SCT -TSRA. CB TOP FL400. OTLK...IFR CIG FG.
RMNDR...SCT120 BKN CI. ISOL -TSRA. CB TOP FL400. 03Z FEW120 SCT CI. OTLK...VFR.

SRN...SCT090. ISOL -TSRA. CB TOP FL400. BECMG 0406 BKN050 TOP
070. OTLK...MVFR CIG.
MTNS E OF CONTDVD...BKN120 TOP FL200. WDLY SCT -SHRA/-TSRA. CB
TOP FL400. 02Z FEW120 SCT CI. OTLK...VFR.
MTNS W OF CONTDVD...BKN140 TOP FL220. TIL 03Z WDLY SCT -TSRA. CB
TOP FL400. OTLK...VFR.
.
AZ
NRN HLF...SCT120. TIL 23Z OCNL BKN120 TOP FL200. VIS 5SM SCT -
TSRA. CB TOP FL400. 03Z BKN CI. OTLK...VFR.
SWRN...SCT120. OTLK...VFR.
SERN...SCT120. TIL 01Z OCNL BKN120 TOP 150. WDLY SCT -TSRA. CB
TOP FL440. OTLK...VFR.
.
NM...UPDT
PLAINS
NRN...SCT100. WND SW G25KT. ISOL -TSRA POSS SEV. CB TOP FL400.
01Z SCT120 BKN CI. OTLK...VFR.
SRN...SCT120. ISOL -TSRA POSS SEV. CB TOP FL400. 02Z SCT CI.
OTLK...VFR.
MTNS
N HLF...BKN120 TOP FL220. WDLY SCT -SHRA/-TSRA. CB TOP FL400. 03Z
BKN CI. OTLK...VFR.
S HLF...SCT100. TIL 00Z OCNL BKN100 TOP 160. VIS 3SM SCT TSRA
POSS SEV. CB TOP FL400. 03Z SCT CI. OTLK...VFR.
....

12.0 National Weather Service Area Forecast Discussion

The National Weather Service Office in Reno, Nevada, issued the following Area Forecast Discussion at 1450 PDT which discussed the breezy surface winds and prevailing VMC[23] conditions:

FXUS65 KREV 162150
AFDREV
AREA FORECAST DISCUSSION
NATIONAL WEATHER SERVICE RENO NV
250 PM PDT FRI SEP 16 2011
.SHORT TERM...
TROF WHICH MOVED THRU THE REGION LAST NIGHT IS PRODUCING CONVECTION
TODAY FROM CNTRL NV TO THE ERN GREAT BASIN...WITH ISOLATED CELLS
EAST OF HWY 95 IN THE W-CNTRL NV BASIN. MEANWHILE...A SECONDARY
SHORTWAVE MOVING ACROSS NRN CA WILL PRODUCE SOME SHOWERS AND
POSSIBLY A FEW TSTMS FOR NERN CA AND NWRN NV THRU LATE AFTN.
THE LAST OF THE CONVECTIVE CELLS SHOULD EXIT W-CNTRL NV BY 03Z AS
THE FORCING ASSOCIATED WITH THE SECOND SHORTWAVE MOVES TO THE EAST
AND DAYTIME HEATING IS LOST. OTHERWISE...AIR MASS WILL BEGIN TO
DRY OUT ACROSS THE REMAINDER OF ERN CA-WRN NV AS WEST WINDS SPREAD
ACROSS THE REGION.
FOR THIS WEEKEND...FLAT RIDGE WILL KEEP DRY AND STABLE AIR MASS

[23] Visual Meteorological Conditions (VMC) – Weather conditions equal to or better than specifications for Visual Flight Rules (VFR). VFR Refers to the general weather conditions pilots can expect at the surface. VFR criteria means a ceiling above 3,000 feet agl and greater than 5 miles visibility.

AND LIGHT WINDS OVER THE REGION. AREAS OF CIRRUS WILL SPREAD
ACROSS THE REGION MAINLY NORTH OF HWY 50 ON SATURDAY...THEN
PUSHING NORTH OF LOVELOCK-SUSANVILLE LINE BY SUNDAY. TEMPS WILL
NUDGE BACK UP ABOVE NORMAL ON SUNDAY AS 700 MB TEMPS AND 500 MB
HEIGHTS RISE.
ON MONDAY...WEAK SHORTWAVE IS EXPECTED TO BRUSH ACROSS THE NWRN
US. THE TRACK OF THIS SYSTEM VARIES BETWEEN THE GFS AND ECMWF WITH
THE ECMWF AND MANY OF THE GFS ENSEMBLE MEMBERS MUCH FARTHER TO
THE NORTH OF THE 12Z GFS. FOR NOW THE FARTHER NORTH TRACK WAS
PREFERRED WHICH WILL RESULT IN CONTINUED LIGHT WINDS. EVEN WITH
LESS MIXING...TEMPS WILL CONTINUE TO INCREASE INTO THE MID-UPR 80S
FOR LOWER ELEVATIONS AS 700 MB TEMPS RISE ABOVE +10 C OVER THE
SIERRA. MJD
.LONG TERM...TUESDAY THROUGH FRIDAY...
MODELS IN GOOD AGREEMENT WITH STRONG RIDGE BUILDING OVER THE WESTERN
US NEXT WEEK. THIS WILL INTRODUCE A WARMING AND DRYING TREND TO THE
REGION WITH AFTERNOON MAX TEMPERATURES 5 TO 10 DEGREES ABOVE NORMAL
BY MIDWEEK. AFTERNOON WINDS WILL REMAIN RELATIVELY LIGHT THROUGH THE
PERIOD AS THERE IS NOW LESS AFTERNOON HEATING TIME TO CREATE A
STRONG ENOUGH THERMAL GRADIENT FOR A ZEPHYR TO DEVELOP WITH ALSO
ALSO VERY LITTLE SUPPORT ALOFT. OVERALL EXPECT CLEAR AND DRY
CONDITIONS THROUGH NEXT WEEK. LABELLE
&&
.AVIATION
**VFR CONDITIONS AT ALL TERMINALS TODAY WITH SOME MID LEVEL MOISTURE
LINGERING OVER THE REGION THROUGH THIS EVENING. AFTERNOON WEST WINDS
WILL INCREASE WITH GUSTS 20-25 KTS AT KRNO...KTRK AND KTVL THROUGH
03Z THIS EVENING.** EXPECT THE TYPICAL SW-W WINDS AT MMH THIS
AFTERNOON WITH GUSTS UP TO 25 KTS THROUGH 03Z FOLLOWED BY
DIRECTION SHIFT TO THE NW AND LIGHT WIND SPEEDS. LABELLE
&&
.REV WATCHES/WARNINGS/ADVISORIES...
NV...NONE.
CA...NONE.
&&
$$
HTTP://WEATHER.GOV/RENO

13.0 Weather Watches

No weather watches were active for Nevada at the time of the accident.

14.0 Storm Prediction Center Products

The Storm Prediction Center issued the following day 1 Convective Outlook at 1250 PDT with thunderstorms forecasted east of the accident site (figure 14):

SPC AC 161950

DAY 1 CONVECTIVE OUTLOOK
NWS STORM PREDICTION CENTER NORMAN OK
0250 PM CDT FRI SEP 16 2011

VALID 162000Z - 171200Z

...NO SVR TSTM AREAS FORECAST...

...SERN AZ...NM THROUGH WRN TX...

DIABATIC HEATING OVER THE HIGHER TERRAIN IS PROMOTING DEVELOPMENT OF SCATTERED THUNDERSTORMS FROM AZ THROUGH NM WITHIN AN ENVIRONMENT CHARACTERIZED BY 500-1000 J/KG MLCAPE AND 25-35 KT DEEP SHEAR. THIS PARAMETER SPACE WILL GENERALLY SUPPORT MULTICELL CONVECTION...BUT A FEW STORMS MAY ATTAIN MARGINAL SUPERCELL STRUCTURES. THE STRONGER STORMS COULD POSE A THREAT FOR ISOLATED MARGINALLY SEVERE HAIL AND LOCALLY STRONG WIND GUSTS THROUGH EARLY EVENING.

..DIAL.. 09/16/2011

.PREV DISCUSSION... /ISSUED 1119 AM CDT FRI SEP 16 2011/

...SYNOPSIS...
PROGRESSIVE PATTERN WILL PREVAIL THROUGH SAT...WITH A WEAK SPLIT IN THE FLOW MOVING SLOWLY E ACROSS THE GRT BASIN/CNTRL RCKYS...DOWNSTREAM FROM BROAD TROUGH OVER THE PACIFIC NW/WRN CANADA. SEVERAL LOW AMPLITUDE DISTURBANCES IN THE SRN STREAM JET WILL ENHANCE TSTM PROBABILITIES...AND THE POTENTIAL FOR STRONG/POSSIBLY SVR ACTIVITY...OVER PARTS OF THE SRN HI PLNS.

AT THE SFC...SHALLOW COOL DOME NOW IN PLACE ALONG THE ERN SLOPES OF THE SRN/CNTRL RCKYS...ASSOCIATED WITH DEPARTING UPR TROUGH IN THE NORTHEAST...WILL BEGIN TO ERODE FROM THE W AND S LATER TODAY AS THE SRN STREAM IMPULSES CONTINUE E/ENEWD.

...SRN RCKYS/SRN HI PLNS...
LEAD SRN STREAM DISTURBANCE NOW OVER S CNTRL CO SHOULD FURTHER WEAKEN AS IT CONTINUES SLOWLY ENEWD. DIMINISHING LOW/MID LVL WAA RELATED TO THIS FEATURE SHOULD MAINTAIN SCTD ELEVATED TSTMS OVER PARTS OF SE OK AND THE ARKLATEX. UPSTREAM DISTURBANCE NOW NEAR THE FOUR CORNERS ALSO SHOULD DEAMPLIFY AS IT MOVES E INTO SRN CO LATER TODAY. TSTMS SHOULD INCREASE OVER THE SRN RCKYS AND THE NM MTNS IN ASSOCIATION WITH THIS SYSTEM AND DAYTIME HEATING. OTHER STORMS LIKELY WILL FORM OVER THE SRN HI PLNS IN RESPONSE TO SFC HEATING AND SELY LOW LVL UPSLOPE FLOW ON BACK SIDE OF RETREATING SFC RIDGE.

LARGE SCALE FORCING FOR ASCENT WILL REMAIN WEAK. BUT COMBINATION OF INCREASINGLY MOIST LOW LVL UPSLOPE FLOW BENEATH FAIRLY STEEP MID LVL LAPSE RATES SHOULD SUPPORT WDLY SCTD STRONGER STORMS BY MID AFTN OVER THE HI PLNS OF ERN NM/FAR W TX. WITH SBCAPE OF 500-1000 J/KG AND 30+ KT WSWLY MID LVL WINDS..SETUP COULD YIELD A FEW MULTICELLS/BRIEF SUPERCELLS WITH SVR HAIL AND LOCALLY DMGG WIND. SOME OF THE STORMS COULD SPREAD E/NE INTO THE TX/OK PANHANDLES AND PERHAPS SW KS THIS EVE AS SHALLOW COOL/STABLE LAYER CONTINUES TO ERODE NEWD...AND AS SLY LLJ DEVELOPS DOWNSTREAM FROM STRONGER SRN STREAM IMPULSE NOW OVER CA/NV.

CLICK TO GET WUUS01 PTSDY1 PRODUCT

NOTE: THE NEXT DAY 1 OUTLOOK IS SCHEDULED BY 0100Z

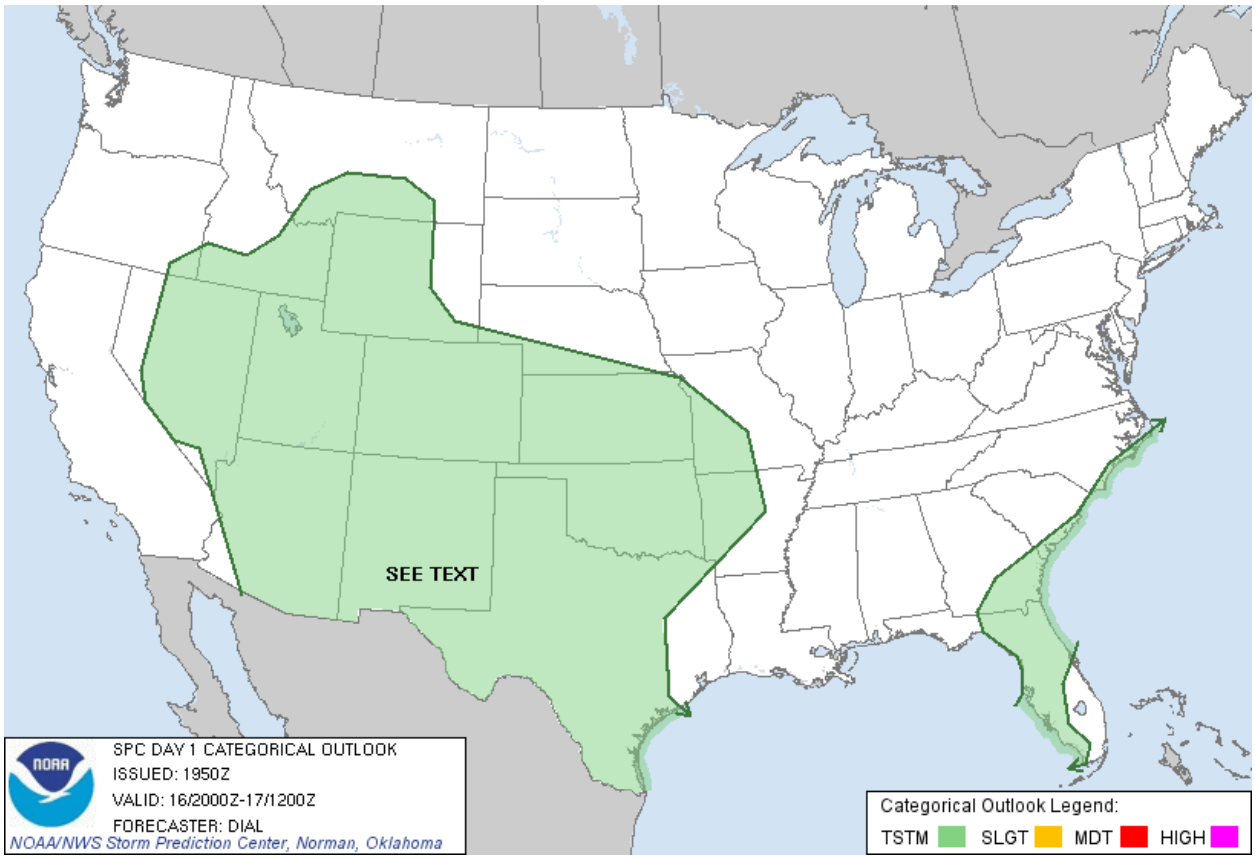


Figure 14 – Storm Prediction Center day 1 Convective Outlook valid at the time of the accident

15.0 Cloud Cover Image

An image captured the cloud cover over the accident site one-minute before the accident time (figure 15). This image was taken 3 miles northwest of the accident site with the image looking southeastward toward KRTS. Runway 14 is the runway looking directly toward the middle of the image. The cloud cover around the accident site around the time of the accident is almost identical to the observations from KRNO. Within the image there are alto-cumulus clouds over and around the accident site with a standing lenticular shaped cloud feature on the right side of the image over the higher terrain.

Figure 15 – Image of the cloud cover looking southeastward toward KRTS and the accident site

16.0 Weather Research and Forecasting Model Simulation

A Weather Research and Forecasting Model (WRF) simulation was run to simulate the weather conditions surrounding the accident site at the accident time. WRF ARW (Advanced Research WRF core) version 3.2.1.5 was run with 3 domains with horizontal grid spacing of 15 km, 5 km, and 1 km over the accident site. Other WRF simulation parameters included: 45 vertical levels, the Kain-Fritsch cumulus parameterization scheme used on the outer domain, a Lin et al. microphysics scheme, a Yonsei University boundary layer scheme, Noah land surface physics, and the Dudhia scheme used for the long and short wave radiation. The WRF 840-hPa (30 m agl) wind over the accident site at 1620 PDT was from 275° at 20 knots (figure 16) and at 1630 PDT the wind was from 275° at 21 knots (figure 17). North-northwest of the accident site and south of the accident there were signatures of the wind changing rapidly within small distances, however, over the Reno-Stead airport the wind conditions above the surface remained laminar. Further above the accident site at 830-hPa (129 m agl) the wind at 1630 PDT was from 280° at 24 knots (figure 18) and at 810-hPa (340 m agl) the wind was from 275° at 23 knots (figure 19).

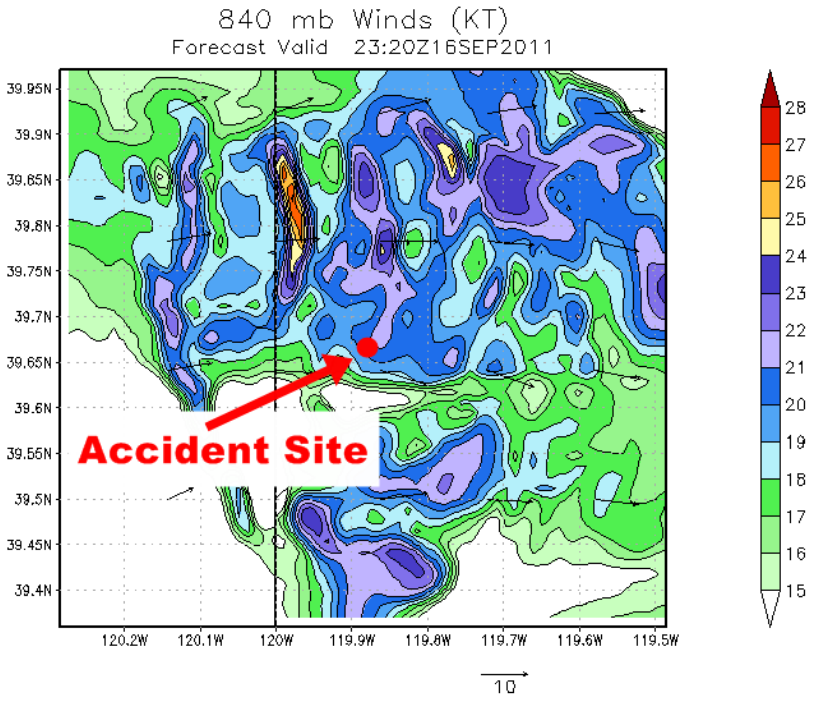


Figure 16 – WRF simulation 840-hPa (30 m agl) wind image from 1620 PDT with the accident site

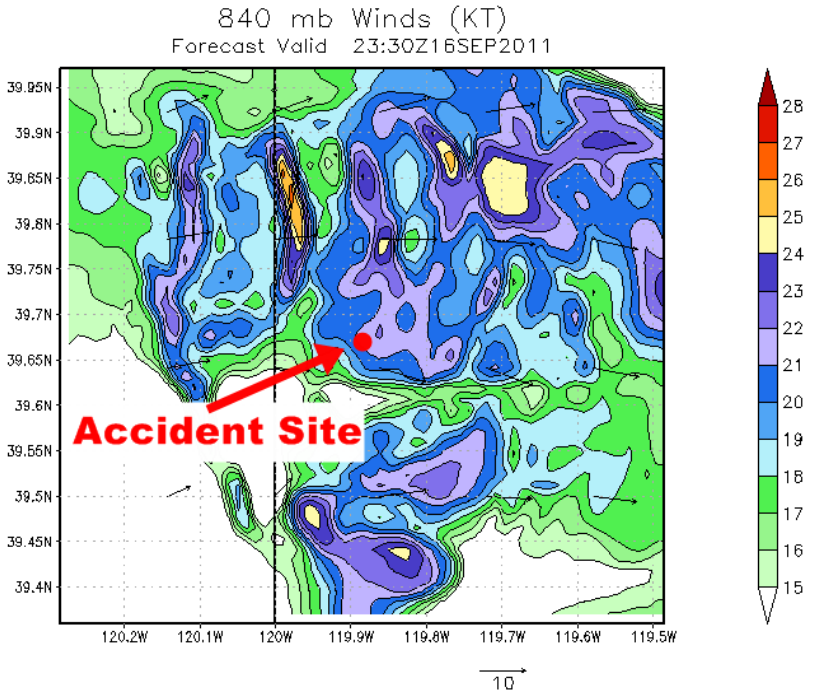


Figure 17 – WRF simulation 840-hPa (30 m agl) wind image from 1630 PDT with the accident site

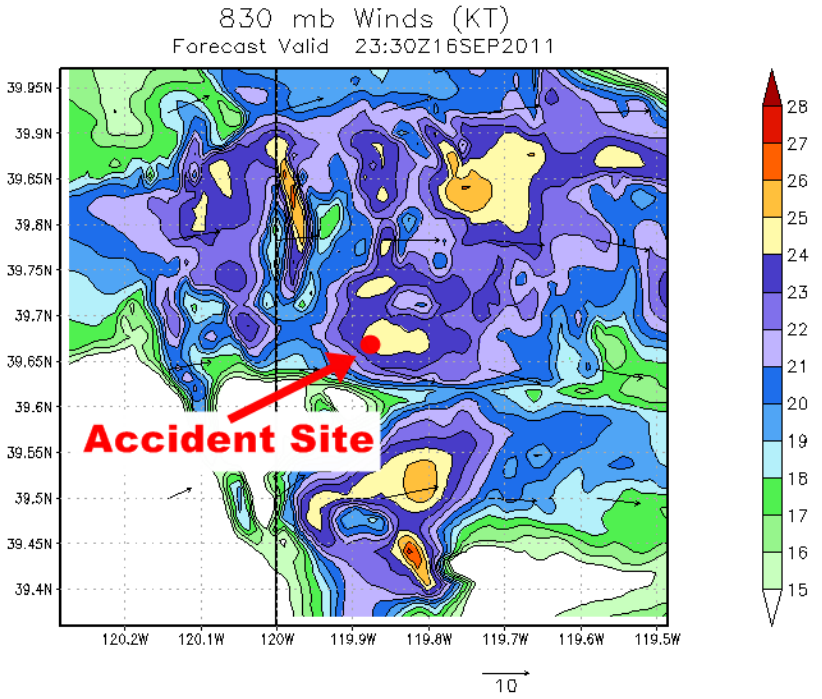


Figure 18 – WRF simulation 830-hPa (129 m agl) wind image from 1630 PDT with the accident site

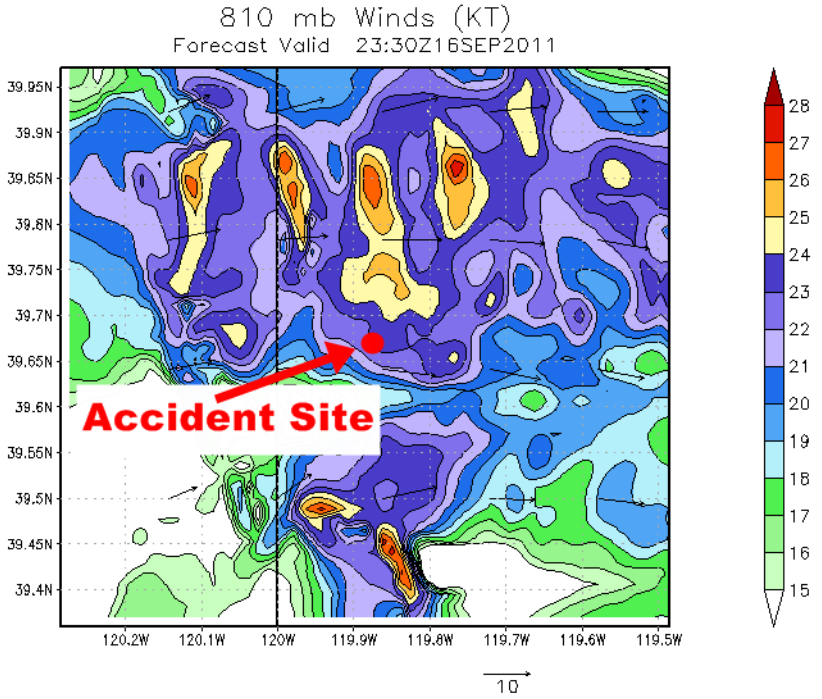


Figure 19 – WRF simulation 810-hPa (340 m agl) wind image from 1630 PDT with the accident site

17.0 Astronomical Data

The astronomical data obtained from the United States Naval Observatory for the accident site on September 16, 2011, indicated the following:

SUN	
Begin civil twilight	0614 PDT
Sunrise	0641 PDT
Sun transit	1254 PDT
Sunset	1907 PDT
End civil twilight	1934 PDT

Paul Suffern
NTSB Senior Meteorologist