



NATIONAL TRANSPORTATION SAFETY BOARD

Office of Aviation Safety
Washington, D.C. 20594

September 20, 2018

Group Chairman's Factual Report

METEOROLOGY

WPR18FA073

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A. ACCIDENT

Location: Near Elko, Nevada
Date: January 11, 2018
Time: 1802 Pacific standard time
0202 Coordinated Universal Time (UTC) on January 12, 2018
Aircraft: PA-23-250, Registration: N54857

B. METEOROLOGY GROUP

Paul Suffern
Group Chairman
Operational Factors Division (AS-30)
National Transportation Safety Board

Scott Birch
National Weather Service
Regional Aviation Meteorologist
NWS Western Region Headquarters

C. DETAILS OF THE INVESTIGATION

The National Transportation Safety Board's Meteorologist did not travel for this investigation and gathered the weather data for this investigation from official National Oceanic and Atmospheric Administration (NOAA) National Weather Service (NWS) sources including the National Centers for Environmental Information (NCEI). All times are Pacific standard time (PST) on January 11, 2018, and are based upon the 24-hour clock, where local time is -8 hours from UTC, and UTC=Z (unless otherwise noted). Directions are referenced to true north and distances in nautical miles. Heights are above mean sea level (msl) unless otherwise noted. Visibility is in statute miles and fractions of statute miles.

The approximate location of the accident site was at latitude 40.2311° N, longitude 115.5333° W, with an approximate elevation of 10,000 feet (ft).

D. WEATHER INFORMATION

1.0 Synoptic Situation

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

1.1 Surface Analysis Chart

The western section of the NWS Surface Analysis Chart for 1900 PST is provided as figure 1 with the approximate location of the accident site marked with the red circle. The chart indicated a frontal boundary extending from southwestern Oregon northeastward into central Washington. Another frontal boundary stretched from central Washington eastward into western Montana then southeastward into central Colorado. A surface high pressure center with a pressure of 1027-hectopascals (hPa) was located in eastern California. Other surface low and high pressure centers were located along and near the frontal boundaries well north, east, and southeast of the accident site. There were no surface pressure systems or frontal boundaries near the accident site at the accident time.

The station observations around the accident site depicted air temperatures in the low 30’s to low 40’s degrees Fahrenheit (°F), dew point temperatures in the mid 20’s to low 30’s °F with temperature-dew point spreads of 9° F or more, a variable surface wind of 5 knots, and overcast sky cover.

¹

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

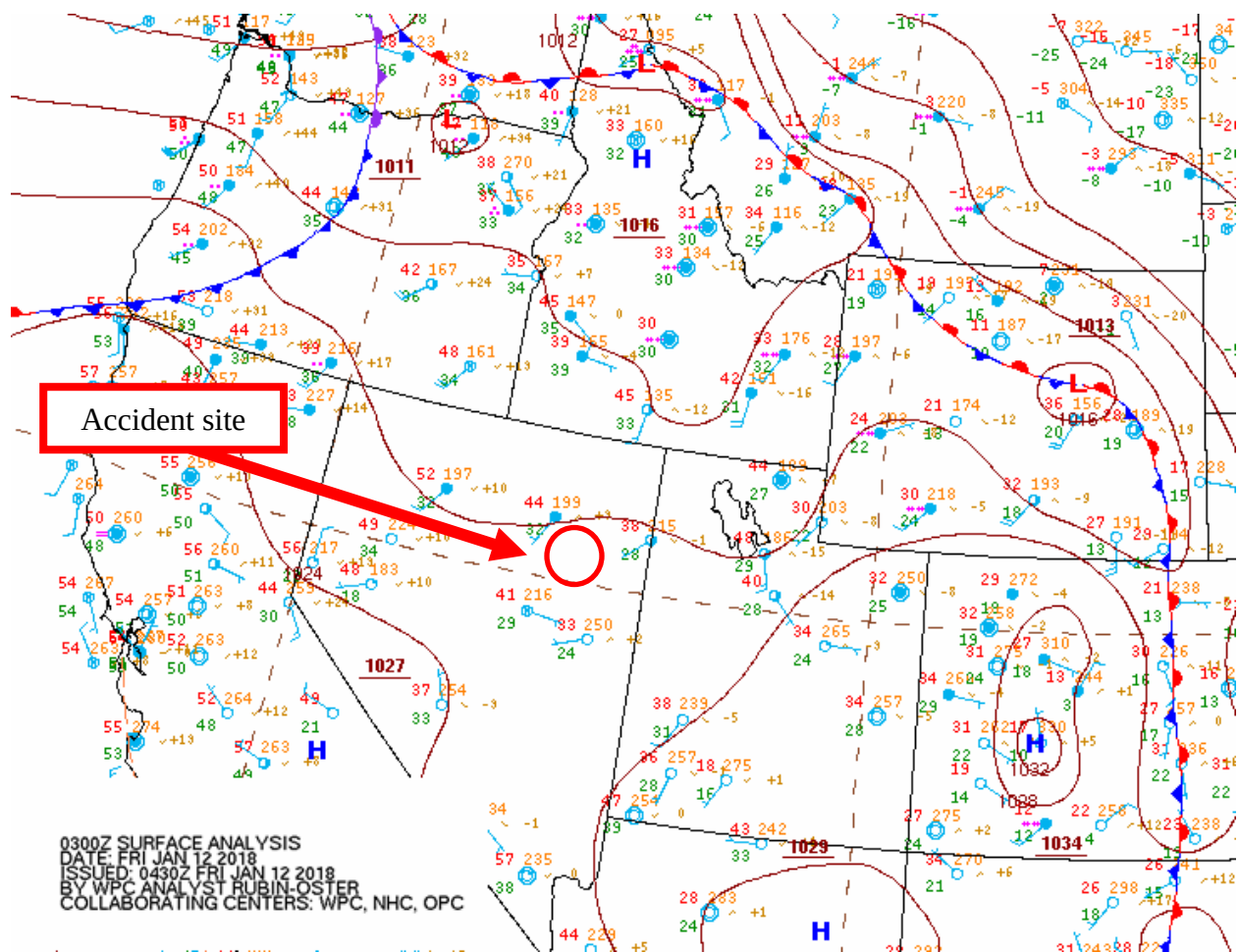


Figure 1 – NWS Surface Analysis Chart for 1900 PST

1.2 Upper Air Charts

The NWS Storm Prediction Center (SPC) Constant Pressure Charts for 1600 PST at 700-, 500-, and 300-hPa are presented in figures 2 through 4. There was a mid-level trough² located west of the accident site over central Oregon and Washington at 1600 PST. Troughs can act as lifting mechanisms to help produce clouds and precipitation if sufficient moisture is present. There was a west wind of 40 knots at 700-hPa (figure 2) with the wind increasing in speed to 70 knots by 500-hPa. By 300-hPa, the wind was from the west at 100 knots (figure 4).

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

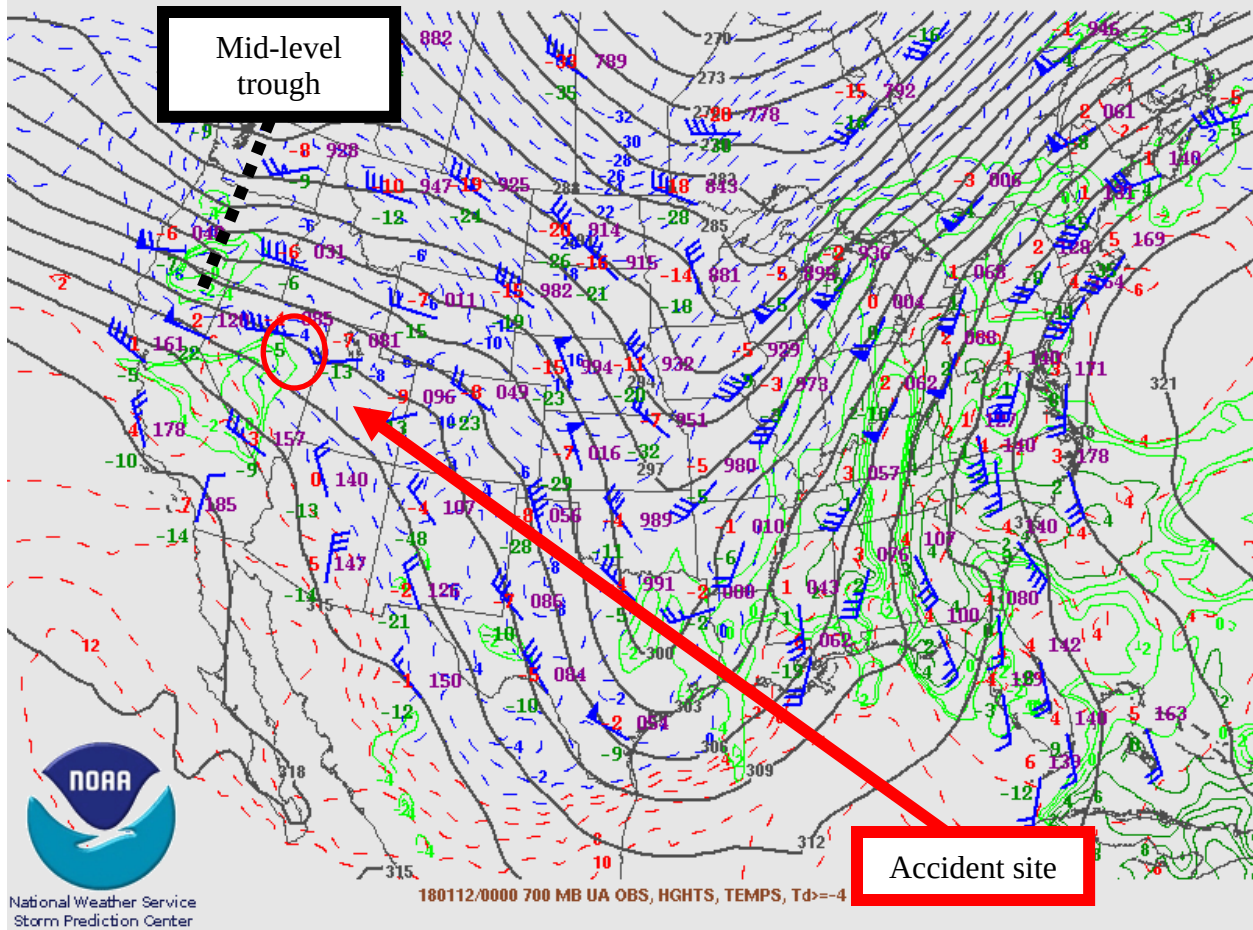


Figure 2 – 700-hPa Constant Pressure Chart for 1600 PST

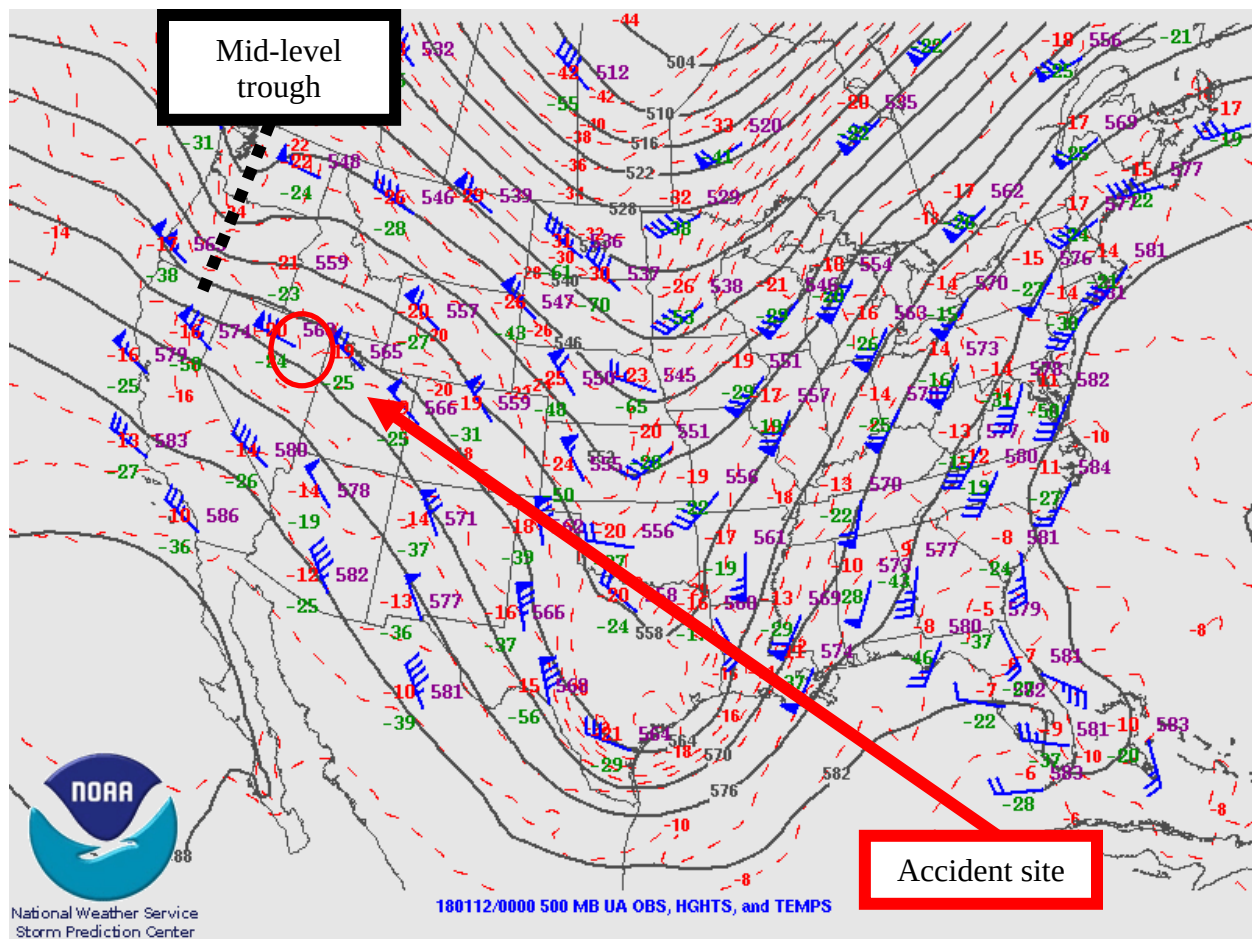


Figure 3 – 500-hPa Constant Pressure Chart for 1600 PST

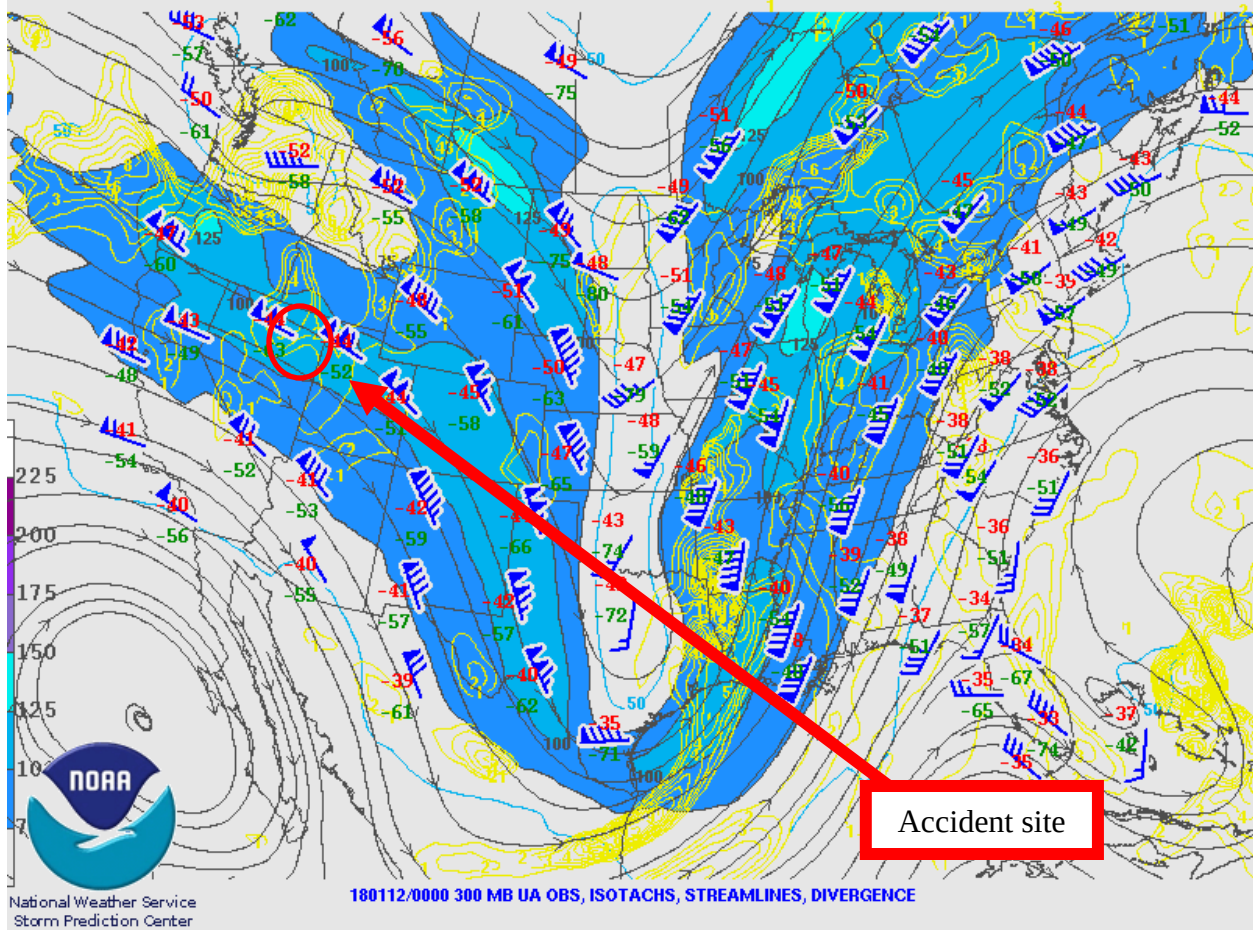


Figure 4 – 300-hPa Constant Pressure Chart for 1600 PST

2.0 SPC Products

No thunderstorms were forecast by SPC for the accident site on the accident day.

3.0 Surface Observations

The area surrounding the accident site was documented using official Meteorological Aerodrome Reports (METARs) and Specials (SPECIs). The following observations were taken from standard code and are provided in plain language with visibility reported in statute miles for this section. Figure 5 is a local sectional chart with the accident site and the closest weather reporting locations marked.

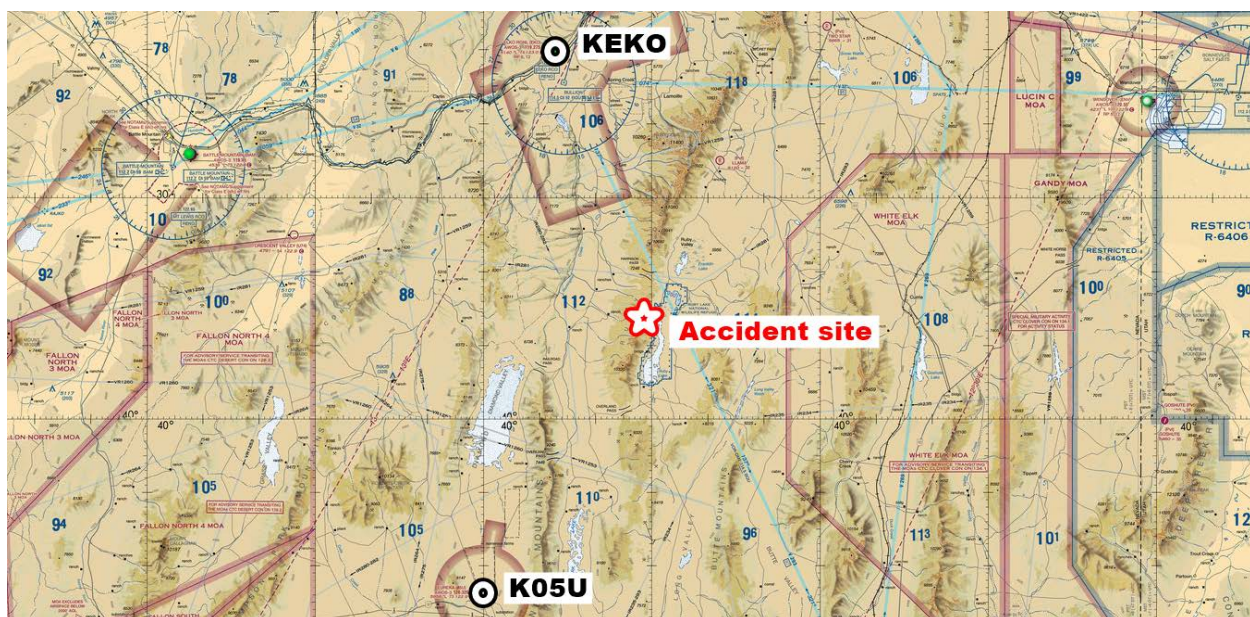


Figure 5 – Sectional map of the accident area with the location of the accident site and surface observation sites

Elko Regional Airport (KEKO) had the closest official weather station to the accident site and was located 1 mile from Elko, Nevada. KEKO had an Automated Weather Observing System (AWOS³) whose reports were not supplemented. KEKO was located 38 miles north-northwest of the accident site, at an elevation of 5,140 ft, and had a 12° easterly magnetic variation⁴ (figure 5). The following observations were taken and disseminated during the times surrounding the accident:⁵

- [1056 PST] METAR KEKO 111856Z AUTO 20011KT 10SM OVC075 07/00 A3022 RMK
AO2 SLP233 T00720000=

- [1156 PST] METAR KEKO 111956Z AUTO 23012KT 10SM BKN075 09/M02 A3018
RMK AO2 SLP219 T00891017=

- [1256 PST] METAR KEKO 112056Z AUTO 25013KT 10SM SCT080 09/M02 A3016
RMK AO2 SLP212 T00891022 58019=

- [1356 PST] METAR KEKO 112156Z AUTO 20007KT 10SM OVC050 09/M02 A3013
RMK AO2 SLP202 T00891017=

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 ft, and altimeter setting.

⁴ Magnetic variation – The angle (at a particular location) between magnetic north and true north. Latest measurement taken from <http://airnav.com/airport/KEKO>

⁵ The bold sections in this NWS product and the rest of products in this report are intended to highlight the sections that directly reference the weather conditions that effected the accident location around the accident time. The local times in this section next to the METARs are provided for quick reference between UTC and local times around the accident time.

[1456 PST] METAR KEKO 112256Z AUTO 22018G23KT 10SM SCT120 11/M03 A3010
RMK AO2 PK WND 22029/2244 SLP188 T01111028=

[1556 PST] METAR KEKO 112356Z AUTO 23009KT 10SM CLR 10/M02 A3010 RMK
AO2 SLP190 T01001017 10111 20061 56017=

**[1656 PST] METAR KEKO 120056Z AUTO 00000KT 10SM SCT110 06/M01 A3012
RMK AO2 SLP204 T00611006=**

**[1756 PST] METAR KEKO 120156Z AUTO 03003KT 10SM FEW090 05/M01 A3012
RMK AO2 SLP203 T00501006=**

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**[1856 PST] METAR KEKO 120256Z AUTO 21004KT 10SM OVC085 07/00 A3011 RMK
AO2 SLP199 T00670000 50003=**

**[1956 PST] METAR KEKO 120356Z AUTO 00000KT 10SM OVC075 04/00 A3013 RMK
AO2 SLP207 T00440000=**

[2056 PST] METAR KEKO 120456Z AUTO 25006KT 10SM FEW070 03/M01 A3013
RMK AO2 SLP208 T00281006=

[2156 PST] METAR KEKO 120556Z AUTO 00000KT 10SM FEW060 03/M01 A3016
RMK AO2 SLP214 T00281006 10094 20022 53014=

KEKO weather at 1656 PST, automated, wind calm, 10 miles visibility or greater, scattered clouds at 11,000 ft above ground level (agl), temperature of 6° Celsius (C), dew point temperature of -1° C, and an altimeter setting of 30.12 inches of mercury. Remarks: automated station with a precipitation discriminator, sea level pressure 1020.4 hPa, temperature 6.1° C, dew point temperature -0.6° C.

KEKO weather at 1756 PST, automated, wind from 030° at 3 knots, 10 miles visibility or greater, few clouds at 9,000 ft agl, temperature of 5° C, dew point temperature of -1° C, and an altimeter setting of 30.12 inches of mercury. Remarks: automated station with a precipitation discriminator, sea level pressure 1020.3 hPa, temperature 5.0° C, dew point temperature -0.6° C.

KEKO weather at 1856 PST, automated, wind from 210° at 4 knots, 10 miles visibility or greater, an overcast ceiling at 8,500 ft agl, temperature of 7° C, dew point temperature of 0° C, and an altimeter setting of 30.11 inches of mercury. Remarks: automated station with a precipitation discriminator, sea level pressure 1019.9 hPa, temperature 6.7° C, dew point temperature 0.0° C, 3-hourly pressure decrease of 0.3 hPa.

KEKO weather at 1956 PST, automated, wind calm, 10 miles visibility or greater, an overcast ceiling at 7,500 ft agl, temperature of 4° C, dew point temperature of 0° C, and an altimeter setting of 30.13 inches of mercury. Remarks: automated station with a precipitation discriminator, sea level pressure 1020.7 hPa, temperature 4.4° C, dew point temperature 0.0° C.

Eureka Airport (K05U) had the next closest official weather station to the accident site located 6 miles northwest of Eureka, Nevada. K05U had an AWOS whose reports were not supplemented. K05U was located 43 miles south-southwest of the accident site, at an elevation of 5,958 ft, and had a 13° easterly magnetic variation⁶ (figure 5). The following observations were taken and disseminated during the times surrounding the accident:

[1555 PST] METAR K05U 112355Z AUTO 25011G18KT 10SM CLR 11/M02 A3020
RMK A01=

[1615 PST] METAR K05U 120015Z AUTO 23008KT 10SM CLR 10/M02 A3019 RMK
A01=

[1635 PST] METAR K05U 120035Z AUTO 22006G11KT 10SM CLR 08/M02 A3018
RMK A01=

[1655 PST] METAR K05U 120055Z AUTO 13006KT 10SM CLR 06/M02 A3018 RMK
A01=

[1715 PST] METAR K05U 120115Z AUTO 13008KT 10SM CLR 04/M01 A3018 RMK
A01=

***[1735 PST] METAR K05U 120135Z AUTO 12009KT 10SM CLR 04/M01 A3019 RMK
A01=***

***[1755 PST] METAR K05U 120155Z AUTO 13011KT 10SM CLR 05/M01 A3019 RMK
A01=***

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***[1815 PST] METAR K05U 120215Z AUTO 14009KT 10SM CLR 05/M01 A3018 RMK
A01=***

***[1835 PST] METAR K05U 120235Z AUTO 13009KT 10SM CLR 04/M02 A3019 RMK
A01=***

[1855 PST] METAR K05U 120255Z AUTO 11005G11KT 10SM SCT070 05/M02 A3020
RMK A01=

⁶ Magnetic variation – The angle (at a particular location) between magnetic north and true north. Latest measurement taken from <http://airnav.com/airport/05U>

[1915 PST] METAR K05U 120315Z AUTO 00000KT 10SM OVC070 06/M02 A3021
RMK A01=

K05U weather at 1735 PST, automated, wind from 120° at 9 knots, 10 miles visibility or greater, clear skies below 12,000 ft agl, temperature of 4° C, dew point temperature of -1° C, and an altimeter setting of 30.19 inches of mercury. Remarks: automated station without a precipitation discriminator.

K05U weather at 1755 PST, automated, wind from 130° at 11 knots, 10 miles visibility or greater, clear skies below 12,000 ft agl, temperature of 5° C, dew point temperature of -1° C, and an altimeter setting of 30.19 inches of mercury. Remarks: automated station without a precipitation discriminator.

K05U weather at 1815 PST, automated, wind from 140° at 9 knots, 10 miles visibility or greater, clear skies below 12,000 ft agl, temperature of 5° C, dew point temperature of -1° C, and an altimeter setting of 30.18 inches of mercury. Remarks: automated station without a precipitation discriminator.

K05U weather at 1835 PST, automated, wind from 130° at 9 knots, 10 miles visibility or greater, clear skies below 12,000 ft agl, temperature of 4° C, dew point temperature of -2° C, and an altimeter setting of 30.19 inches of mercury. Remarks: automated station without a precipitation discriminator.

The observations from KEKO and K05U surrounding the accident time indicated VFR⁷ ceiling and visibility conditions. Clouds were present above KEKO with cloud bases around 13,000 to 14,000 ft msl (~9,000 ft agl).

4.0 Upper Air Data

The closest official upper air sounding to the accident site was from KEKO with a site number 72582 with the weather balloon release elevation of 5,226 ft. The 1600 PST KEKO sounding was plotted on a standard Skew-T Log P diagram⁸ with the derived stability parameters included in figure 6 (with data from the surface to 500-hPa, or around 18,000 ft msl.) This data was analyzed using the RAOB⁹ software package. The sounding depicted the lifted condensation level (LCL)¹⁰ at 9,760 ft msl (4,534 ft agl) and the convective condensation level (CCL)¹¹ at 13,298 ft msl (8,072 ft agl). The freezing level was at 7,880 ft msl. The precipitable water value was 0.28 inches.

⁷ Visual Flight Rules – Refers to the general weather conditions pilots can expect at the surface. VFR criteria means a ceiling greater than 3,000 ft agl and greater than 5 miles visibility.

⁸ 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.

⁹ RAOB – (The complete Rawinsonde Observation program) is an interactive sounding analysis program developed by Environmental Research Services, Matamoras, Pennsylvania.

¹⁰ LCL - The height at which a parcel of moist air becomes saturated when it is lifted dry adiabatically.

¹¹ 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.

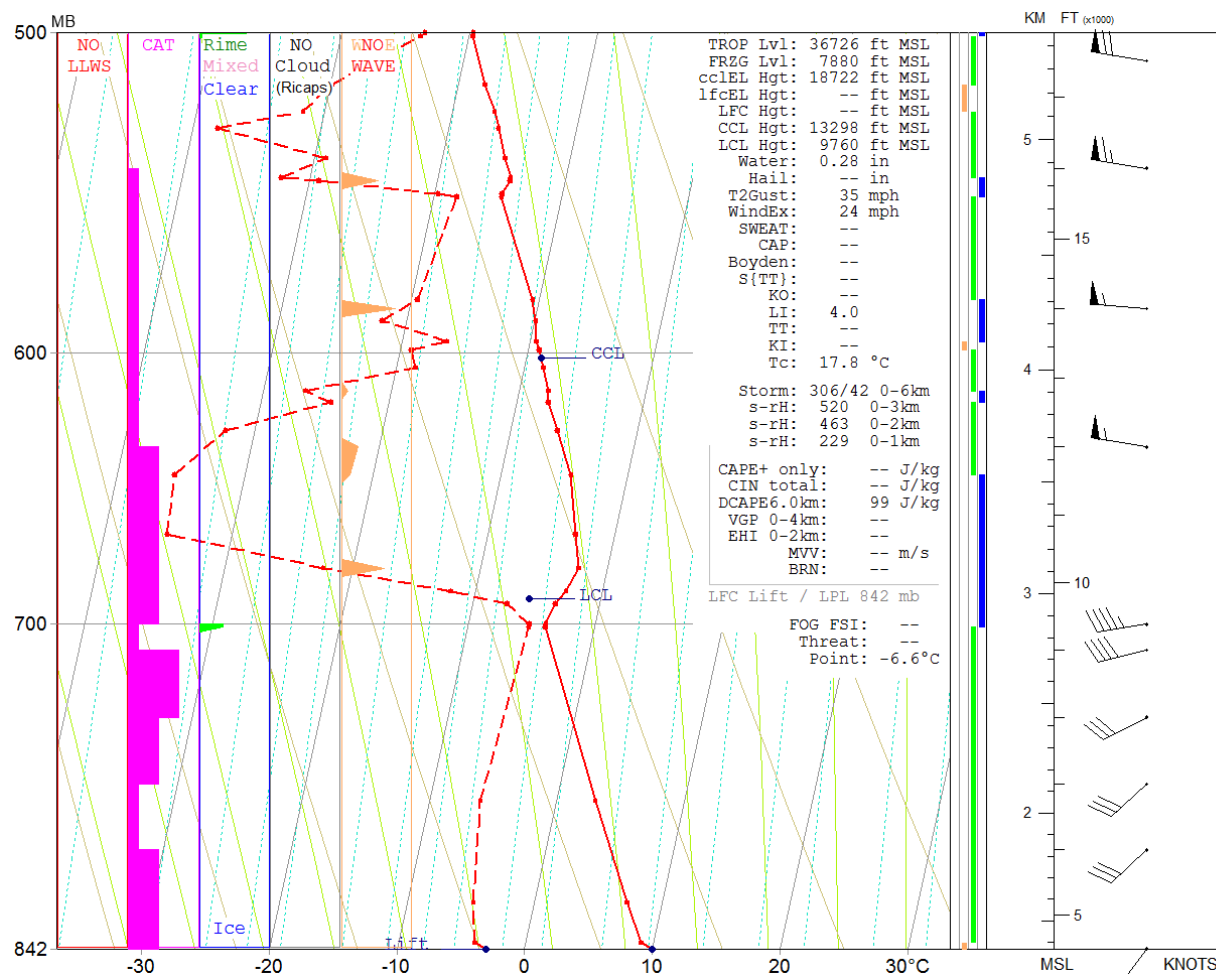


Figure 6 – 1600 PST KEO sounding

The 1600 PST KEO sounding indicated a conditionally unstable environment from the surface through 9,250 ft followed by a stable environment from 9,250 ft through 11,500 ft. Above 11,500 ft through 19,000 ft there were several alternating layers of conditionally unstable and stable layers. Trace rime icing was indicated by RAOB around 9,500 ft.¹² Icing potential will be further discussed in section 20.0, and cloud cover will be discussed in sections 5.0 and 21.0.

¹² S.G. Cober, G. A. Isaac, and J. W. Strapp, Characterizations of Aircraft Icing Environments that Include Supercooled Large Drops (Journal of Applied Meteorology, 2001), pp. 1984-2002.

B.C Bernstein, C.A. Wolff, and F. McDonough, An Inferred Climatology of Icing Conditions Aloft, Including Supercooled Large Drops. Part I: Canada and the Continental United States (Journal of Applied Meteorology and Climatology, 2007), pp. 1857-1878.

Williams, E.R., D.J. Smalley, M.F. Donovan, R.G. Hallowell, K.T. Hood, B.J. Bennett, R. Evaristo, A. Stepanek, T. Bals-Elsholz, J. Cobb, J. Ritzman, A. Korolev, M. Wolde, Measurements of Differential Reflectivity in Snowstorms in Warm Season Stratiform Systems (Journal of Applied Meteorology and Climatology, in press).

The 1600 PST KEKO sounding wind profile indicated a surface wind from 215° at 16 knots with the wind increasing in speed to 30 knots from the southwest by 6,000 ft. By 10,000 ft the wind turned westerly and increased in speed to 45 knots. The wind continued to increase in speed through 19,000 ft where the wind speed was near 70 knots. RAOB did not indicate the possibility of low-level wind shear (LLWS) between the surface and 7,000 ft. RAOB indicated a high probability of light to severe clear-air turbulence in several layers between the surface and 16,000 ft, with the most severe clear-air turbulence layer identified by RAOB at 8,000 ft. RAOB also indicated the possibility of light to severe mountain wave conditions¹³ in between 10,000 and 16,000 ft with updraft and downdraft speeds as high as 2,400 ft per minute (figure 7). Mountain wave conditions will be further discussed in section 21.0.

Level	Height (ft-MSL)	Pres (mb)	T (C)	Td (C)	RH (%)	DD / FF (deg / kts)	CAT (FAA)	LLWS	Icing - Type (AFGWC method)	Wave/x---W---Turb nm fpm max
1	4485	842	10.0	-3.0	40	215 / 16				
2	4582	839	9.0	-4.0	40					
3	5202	820	7.2	-4.8	42		MDT			
4	6000	796				225 / 28				
5	6749	774	3.0	-6.0	52		LGT			
6	7000	767				225 / 32	MDT			
7	8000	738				240 / 32	SVR			
8	9000	710				255 / 39				
9	9350	701	-3.9	-5.2	91		LGT		TRC Rime	
10	9387	700	-3.9	-5.2	91	260 / 43			TRC Rime	
11	9685	692	-3.5	-7.3	75					
12	9873	687	-2.9	-11.9	50					
13	10216	678	-2.3	-22.3	20					3.49 1176 MD-SV
14	10719	665	-3.1	-35.1	6					
15	11590	643	-4.5	-35.5	7		MDT			4.64 283 LIGHT
16	12000	633				280 / 53				6.17 587 LIGHT
17	12238	627	-6.3	-32.3	11					
18	12650	617	-7.5	-24.5	24					
19	12816	613	-7.7	-26.7	20					5.69 243 LIGHT
20	13151	605	-8.5	-18.5	44					
21	13404	599	-9.1	-19.1	44					
22	13531	596	-9.5	-16.5	57					
23	13830	589	-9.9	-21.9	37		LGT			
24	14000	585				275 / 57				8.80 2424 SEVERE
25	14132	582	-10.5	-19.5	48					
26	15595	549	-14.7	-18.2	75					
27	15640	548	-14.7	-19.7	66					
28	15822	544	-14.3	-29.3	27					5.95 1149 MD-SV
29	15868	543	-14.3	-32.3	20		LGT			
30	16000	540				280 / 66				
31	16144	537	-15.1	-29.1	29					
32	16562	528	-16.1	-38.1	13					
33	16797	523	-16.7	-31.7	26					

Figure 7 – 1600 PST KEKO sounding text data

¹³ Default RAOB mountain range parameters were used.

5.0 Satellite Data

Visible and infrared data from the Geostationary Operational Environmental Satellite number 16 (GOES-16) data were obtained from an archive at the Space Science Engineering Center (SSEC) at the University of Wisconsin-Madison in Madison, Wisconsin, and processed using the Man-computer Interactive Data Access System software (McIDAS). Visible and infrared imagery (GOES-16 bands 2 and 13) at wavelengths of 0.64 microns (μm) and 10.3 μm , respectively, were retrieved for the period. Satellite imagery surrounding the time of the accident, from 1500 PST through 2200 PST at approximately 15-minute intervals were reviewed, and the closest images to the time of the accident are documented here. Due to the low light conditions at the time of the accident, only the infrared imagery is documented below.

Figures 8, 9, and 10 present the GOES-16 infrared imagery from 1745, 1800, and 1815 PST, respectively, at 4X magnification with the accident site highlighted with a red square. Inspection of the infrared imagery indicated cloud cover over the accident site with the cloud cover moving from northwest to southeast. The lower brightness temperatures (green and yellow colors; higher cloud tops) were located northwest and northeast of the accident site. In addition, wave-like features are seen from Reno, Nevada, eastward into Utah and northward over Oregon and Idaho at the accident time in the satellite animation data (attachments 1 and 2). Based on the brightness temperatures above the accident site and the vertical temperature profile provided by the 1600 PST KEO sounding, the approximate cloud-top heights over the accident site were 15,500 ft at 1800 PST. It should be noted these figures have not been corrected for any parallax error.

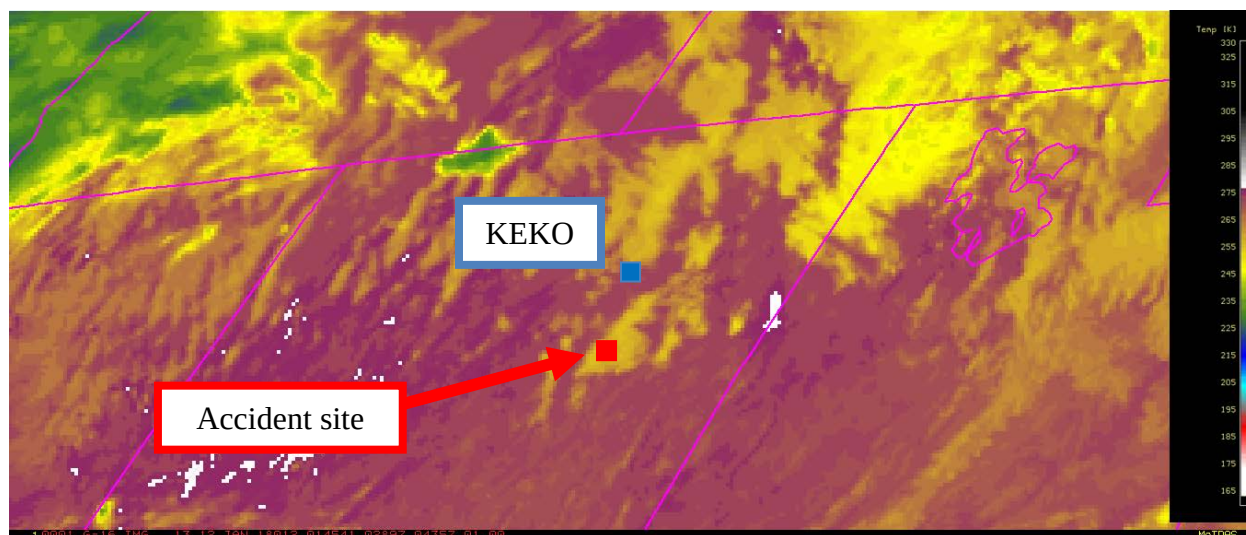


Figure 8 – GOES-16 infrared image at 1745 PST

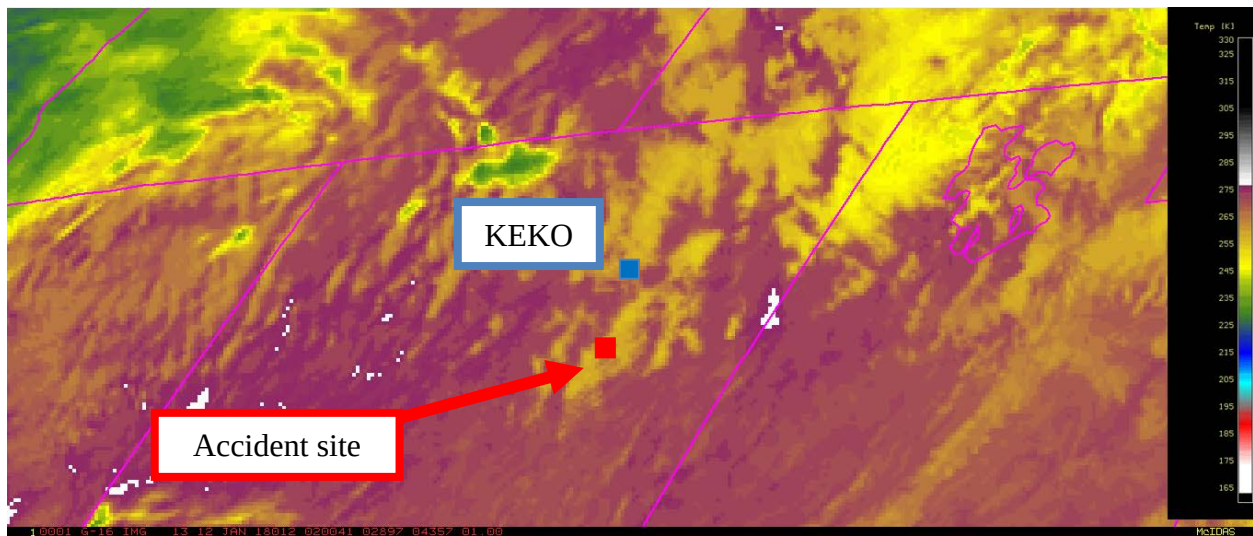


Figure 9 – GOES-16 infrared image at 1800 PST

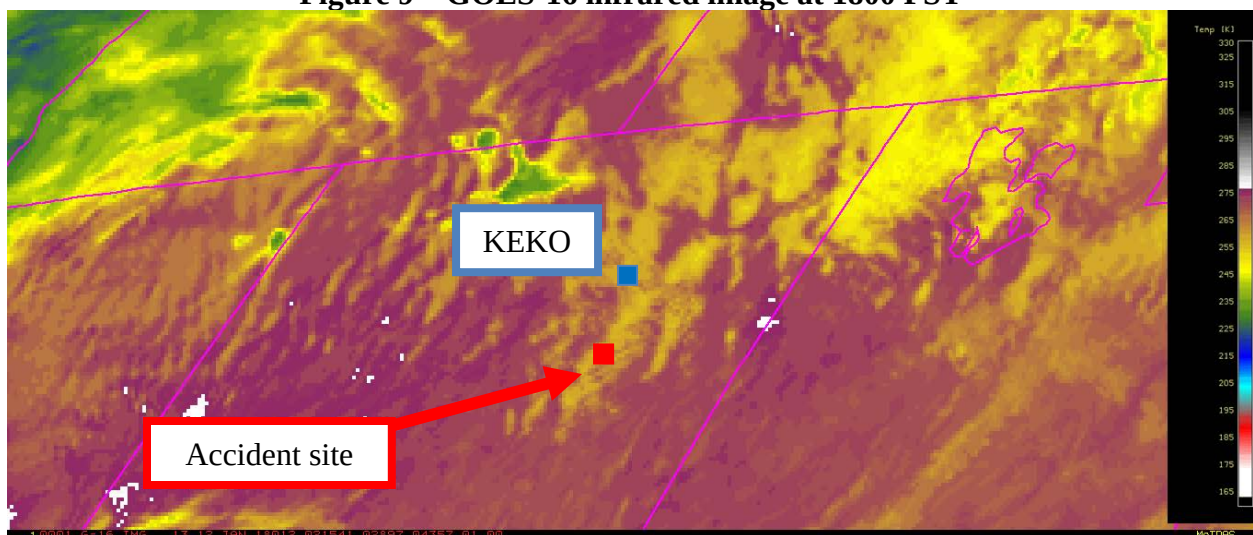


Figure 10 – GOES-16 infrared image at 1815 PST

Additional data from GOES-16 was obtained from the SSEC and a band differencing technique was applied on GOES-16 wavelengths of 3.9 μm , 10.4 μm , and 12.4 μm that was consistent with the Nighttime Microphysics RGB (red green blue) imagery described in attachment 3.

Figures 11, 12, 13, and 14 present the GOES-16 Nighttime Microphysics RGB imagery from 1730, 1745, 1800, and 1815 PST, respectively, at 4X magnification with the accident site highlighted in a green circle. Inspection of the Nighttime Microphysics RGB imagery indicated green to tan colors associated with the clouds located above the accident site around the accident time. These green to tan colors on the Nighttime Microphysics RGB imagery indicate mid-level water clouds and thick mid-level water or ice clouds (attachment 3). The mid-level cloud coverage increased above the mountainous terrain throughout northern Nevada between 1612 and 1702 PST with the cloud cover remaining above the mountainous terrain from 1702 PST through 2017 PST (attachment 4). For more information on the Nighttime Microphysics RGB please see attachment 3.¹⁴

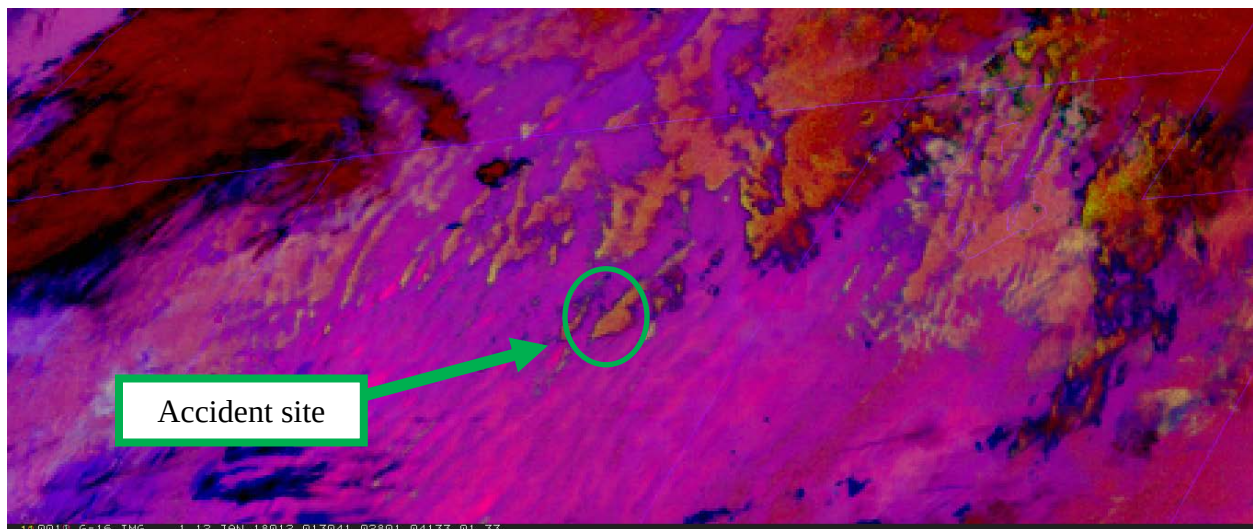


Figure 11 – GOES-16 Nighttime Microphysics RGB image at 1730 PST

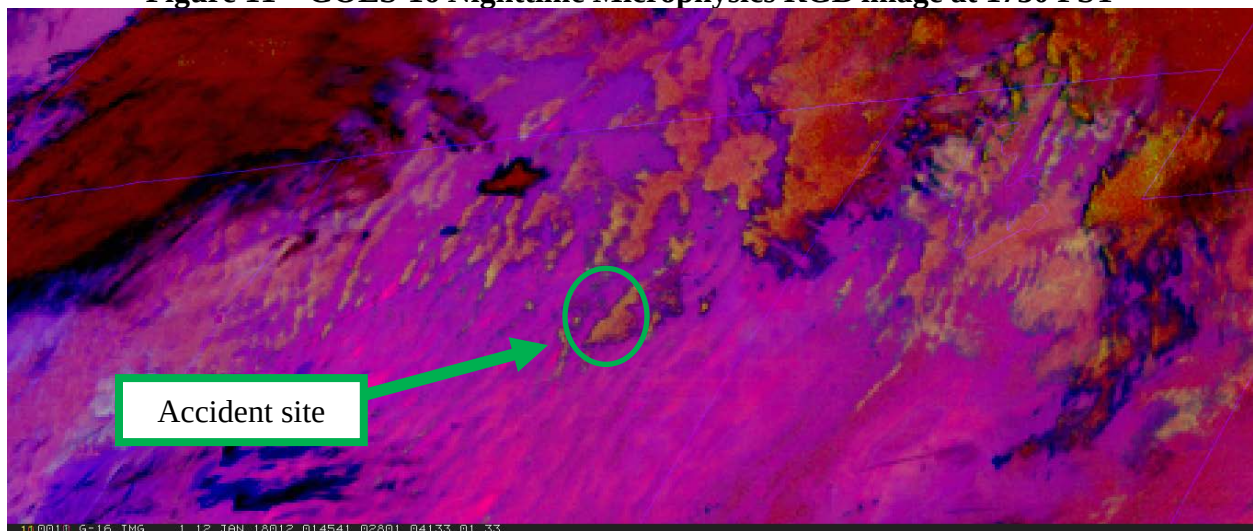


Figure 12 – GOES-16 Nighttime Microphysics RGB image at 1745 PST

¹⁴ Also see: <https://nasasporttraining.wordpress.com/2017/02/23/nighttime-microphysics-rgb-application-aviation-module-2/>

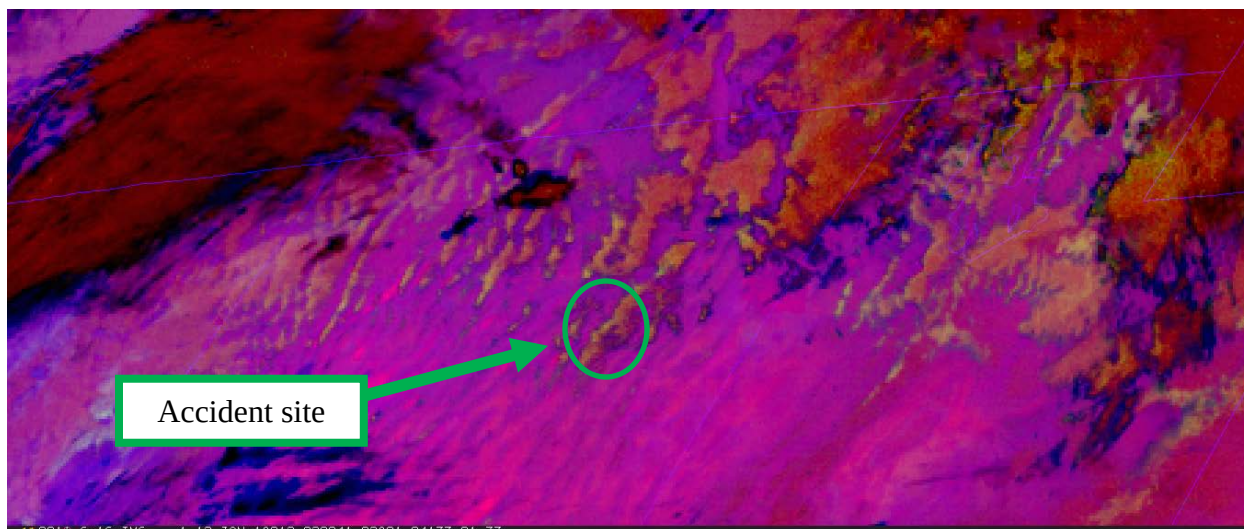


Figure 13 – GOES-16 Nighttime Microphysics RGB image at 1800 PST

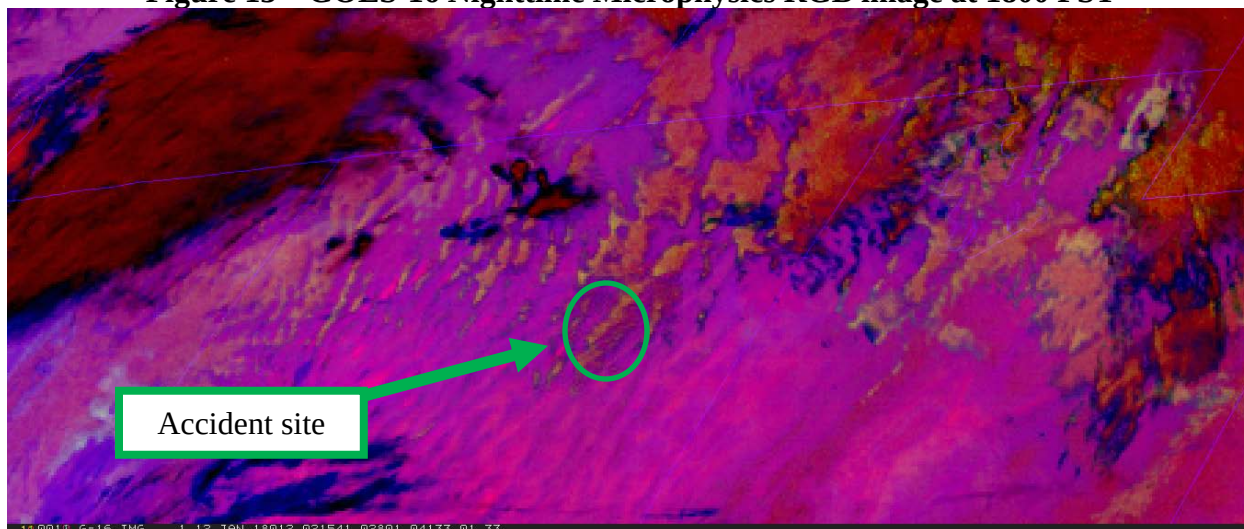


Figure 14 – GOES-16 Nighttime Microphysics RGB image at 1815 PST

Additional GOES-16 data was provided by the National Aeronautics and Space Administration (NASA) Langley Research Center Climate Science Branch (LARC-E302). Figures 15 and 16 present the GOES-16 icing index and icing top imagery from 1800 PST with the accident site highlighted in a red circle. The imagery from 1800 PST for the accident site suggested possible icing in the 10,000 to 20,000 ft msl range. For additional information and satellite imagery please see attachments 5 and 6.¹⁵

¹⁵ Smith, W. L., P. Minnis, C. Fleeger, D. Spangenberg, R. Palikonda, L. Nguyen, 2012: Determining the Flight Icing Threat to Aircraft with Single-Layer Cloud Parameters Derived from Operational Satellite Data. J. Appl. Meteor. Climatol., 51, 1794–1810.

Smith, W. L., Jr, 2014: 4-D cloud properties from passive satellite data and applications to resolve the flight icing threat to aircraft. PhD Dissertation, University of Wisconsin-Madison, 165 pp.

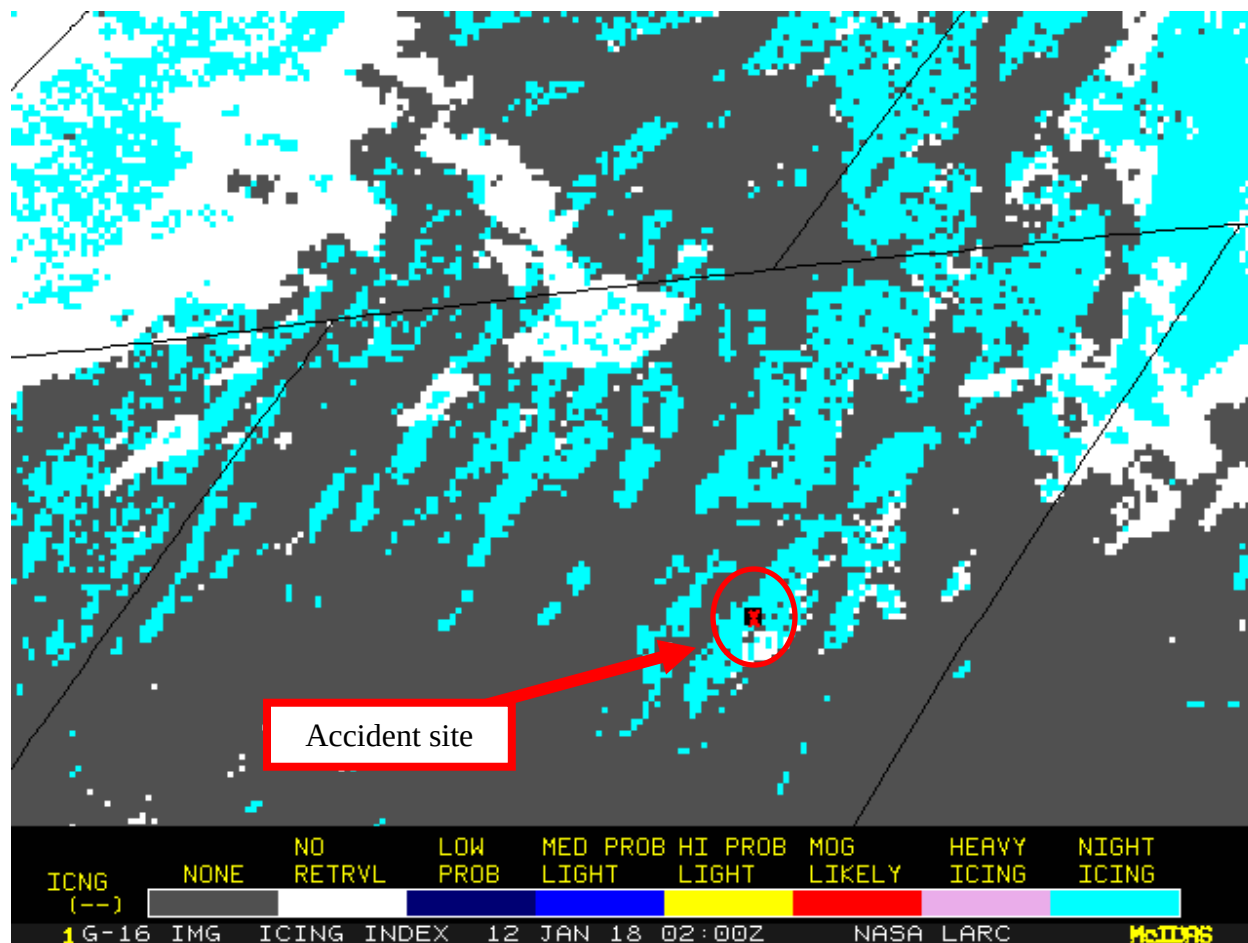


Figure 15 – NASA LARC-E302 GOES-16 icing index image at 1800 PST

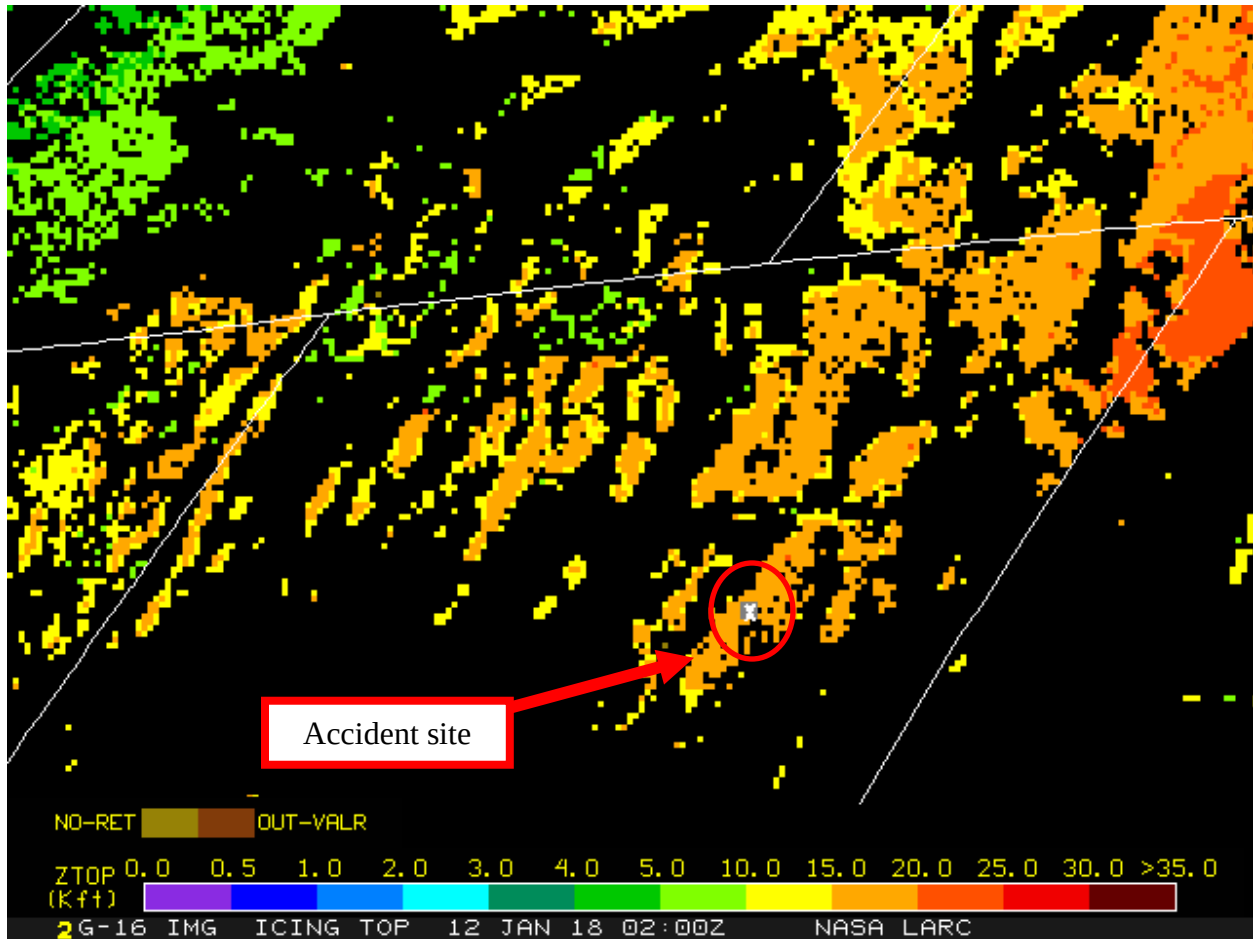


Figure 16 – NASA LARC-E302 GOES-16 icing top image at 1800 PST

6.0 Radar Imagery Information

The closest NWS Weather Surveillance Radar-1988, Doppler (WSR-88D)¹⁶ to the accident site was the Elko/Lander, Nevada, radar (KLRX), which was located 65 miles west-northwest of the accident site at an elevation of 6,895 ft. 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. No precipitation targets were located above the accident site at the accident time. There were no lightning strikes around the accident site at the accident time.¹⁷

¹⁶ 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.

¹⁷ A review of data from the Earth Networks Total Lightning Network was performed.

7.0 Pilot Reports¹⁸

All publicly disseminated pilot reports (PIREPs) within 150 miles of the accident site from about two hours prior to the accident time to about two hours after the accident time for below FL250¹⁹ are provided below:

ELY UA /OV ELY290060/TM 0014/FL115/TP BE99/TB MOD/RM ZLC

EKO UA /OV BQU077045/TM 0242/FL150/TP PC12/TA M15/TB MOD/IC MOD RIME/RM ZLC

Routine pilot report (UA) Ely, Nevada, (ELY); Over – 60 miles from ELY, on the 290° radial; Time – 1614 PST (0014Z); Altitude – 11,500 ft; Type aircraft – Beechcraft Model 99; Turbulence – Moderate; Remarks – Salt Lake City Air Route Traffic Control Center (ZLC).

Routine pilot report (UA) Elko, Nevada, (EKO); Over – 45 miles from Bullion VOR, on the 077° radial; Time – 1842 PST (0242Z); Altitude – 15,000 ft; Type aircraft – Pilatus PC-12; Temperature – -15° C; Turbulence – Moderate; Icing – Moderate rime; Remarks – ZLC.

8.0 SIGMET

There were no convective or non-convective Significant Meteorological Information (SIGMET) advisories valid for the accident site at the accident time.

9.0 CWSU Advisories

There were no Center Weather Service Unit (CWSU) Advisories (CWA) that were valid for the accident site at the accident time. A Meteorological Impact Statement (MIS) issued by the ZLC CWSU was valid for the accident site at the accident time. The MIS warned of rain and snow spreading mainly across the northern and central parts of ZLC airspace with increasing winds, areas of blowing snow, areas of IFR²⁰ with mountain obscuration, icing, LLWS, and mountain waves. Pilots, especially general aviation pilots, were urged to get a detailed weather briefing and to monitor the ZLC CWSU website and the aviationweather.gov website for weather updates:

FAUS20 KZLC 111446

ZLC MIS 01 VALID 111445-120400

...FOR ATC PLANNING PURPOSES ONLY...

RAIN AND SNOW WILL SPREAD ACROSS NORTHERN AND CENTRAL ZLC AIRSPACE THROUGH FRIDAY. INCREASING WINDS THIS AFTERNOON AND EVENING WILL PRODUCE AREAS OF LOW VISIBILITY IN BLOWING SNOW. WIDESPREAD LOW CLOUDS WITH IFR CONDITIONS AND MOUNTAINS OBSCURED ARE EXPECTED WITH INCREASED ICING...TURBULENCE AND AREAS OF LLWS WITH POSS MTN WAVES. PILOTS, ESPECIALLY GENERAL AVIATION AND THOSE UNFAMILIAR WITH LOCAL

¹⁸ Only pilot reports with the WMO header UBNV**, UBOR**, UBTU**, and UBID** identifier were considered.

¹⁹ Flight Level – A Flight Level (FL) is a standard nominal altitude of an aircraft, in hundreds of ft. This altitude is calculated from the International standard pressure datum of 1013.25 hPa (29.92 inHg), the average sea-level pressure, and therefore is not necessarily the same as the aircraft's true altitude either above mean sea level or above ground level.

²⁰ Instrument Flight Rules – Refers to the general weather conditions pilots can expect at the surface. IFR criteria means a ceiling below 1,000 ft agl and/or less than 3 miles visibility.

TERRAIN, SHOULD GET A DETAILED BRIEFING. MONITOR WEATHER.GOV/ZLC AND AVIATIONWEATHER.GOV FOR UPDATES FOR CHANGING CONDITIONS.

=

10.0 AIRMETS

There were Airmen's Meteorological Information (AIRMET) Zulu and Tango advisories that were valid for the accident site at the accident time. The AIRMET Zulu warned of moderate icing conditions between the freezing level and FL200 and identified the freezing level as between the surface and 9,000 ft. The AIRMET Tango warned of moderate turbulence below FL180. The advisories were as follows:

WAUS45 KPCI 112045

WA5Z

-SLCZ WA 112045

AIRMET ZULU UPDT 3 FOR ICE AND FRZLVL VALID UNTIL 120300

.

AIRMET ICE...NV CA

FROM 20NNW FMG TO 60SSW BAM TO 20ENE OAL TO 20SE MOD TO 20NNW PYE
TO 20NNW FMG

MOD ICE BTN FRZLVL AND 150. FRZLVL 060-100. CONDS ENDG 21-00Z.

.

AIRMET ICE...ID MT WY NV UT CO WA OR CA AND CSTL WTRS

**FROM YDC TO 50WSW YXC TO 30ESE YXC TO 30SSE YQL TO 40SSW HVR TO
40W MLS TO 50ENE DBL TO 40NNE JNC TO 40SSW SLC TO 40WNW DTA TO
90S LKV TO 60S OED TO 50SW OED TO 160W ONP TO 140W TOU TO YDC
MOD ICE BTN FRZLVL AND FL200. FRZLVL SFC-090. CONDS CONTG BYD 03Z
THRU 09Z.**

.

OTLK VALID 0300-0900Z...ICE ID MT WY NV UT CO WA OR CA AND CSTL
WTRS

BOUNDED BY YDC-50WSW YXC-30SW YQL-60ESE MLS-70SW RAP-GLD-50SSE
HBU-20ESE DTA-80SW TWF-OED-20WSW ONP-60WNW TOU-40WNW HUH-YDC
MOD ICE BTN FRZLVL AND FL200. FRZLVL SFC-080. CONDS CONTG THRU
09Z.

.

FRZLVL...RANGING FROM SFC-140 ACRS AREA

MULT FRZLVL BLW 090 BOUNDED BY 30NW INW-30ENE INW-30SW ABQ-
60E ELP-20SE ELP-60SE SSO-20WNW SSO-20ESE DRK-30NW INW

MULT FRZLVL 070-100 BOUNDED BY 60WSW REO-20NW BAM-40SSW FMG-
20N ENI-60SSW FOT-30NW FOT-60WSW REO

SFC ALG 30ESE GEG-40SW MLP-60SSW LKT-MLD-30NW HVE-60WSW ABQ-
40NE TCC

080 ALG 60NNW FMG-70W BVL-40SSW BVL-70ENE TBC-40NE SJN-50ENE
TCS-30E ELP

120 ALG EED-20W SSO-50S SSO

....

WAUS45 KPCI 112045

WA5T

-SLCT WA 112045

AIRMET TANGO UPDT 3 FOR TURB AND LLWS VALID UNTIL 120300

.

AIRMET TURB...ID MT WY NV UT CO AZ NM WA OR CA AND CSTL WTRS

FROM 20WSW YDC TO 50WSW YQL TO 50NNW ISN TO 70SW RAP TO GLD TO
50W LBL TO 30ESE TBE TO 60WSW LBB TO 30W DVC TO 20ESE ELY TO 30S
LKV TO 30NW FOT TO 130WSW ONP TO 20WNW TOU TO 20WSW YDC
MOD TURB BTN FL180 AND FL410. CONDS CONTG BYD 03Z THRU 09Z.

.
**AIRMET TURB...ID MT WY NV UT CO AZ NM WA OR CA AND CSTL WTRS
FROM 30WSW YDC TO 40E FCA TO 20N SHR TO 70SW RAP TO 30WNW TBE TO
30S ABQ TO 60NE INW TO 40ENE HVE TO 40WNW HEC TO 40ESE RZS TO
30SSW CZQ TO 30SSW FOT TO 110WSW ONP TO TOU TO 30WSW YDC
MOD TURB BLW FL180. CONDS CONTG BYD 03Z THRU 09Z.**

.
LLWS POTENTIAL...ID MT WY NV UT CO WA OR CA AND CSTL WTRS
BOUNDED BY 50S YDC-20SW FCA-60WSW RAP-40SW DEN-60SE REO-80SSW
LKV-30SE OED-60WSW OED-20NW ONP-50SSE HQM-20SW SEA-40S HUH-50S
YDC
LLWS EXP. CONDS CONTG BYD 03Z THRU 09Z.

.
OTLK VALID 0300-0900Z...TURB ID MT WY NV UT CO AZ NM WA OR CA
AND CSTL WTRS
BOUNDED BY 30WSW YDC-40NW FCA-30E FCA-70E SHR-70W RAP-30SW RAP-
GLD-50W LBL-50S TBE-50NW CME-50S ABQ-40NNW LAX-40NNW SAC-30NNW
ENI-130WSW ONP-70W HQM-40S TOU-30WSW YDC
MOD TURB BLW FL180. CONDS CONTG THRU 09Z.

....

11.0 Graphical Forecasts for Aviation

The Graphical Forecasts for Aviation (GFA) products made available before the accident time and before the accident flight departed Sacramento, California, (KMCC), and were issued around 1500 PST indicated no cloud cover along the accident flight route with no restrictions to visibility and a surface wind from the southwest at 10 to 20 knots at 1600 and 1900 PST (attachment 7). The reason for the differences between the GFA surface forecast and the GFA cloud forecast is the two are computed automatically by two different weather models (attachment 8). The Rapid Refresh (RAP) weather model is used for the aviation cloud forecast and the Localized Aviation MOS²¹ Program (LAMP) weather model is used for the surface forecast charts, and both forecasts are issued with no human intervention (attachment 8). The only human-generated information reflected in the two GFA products are the AIRMETs. The final GFA product creation process is human-over-the-loop.²²

12.0 Terminal Aerodrome Forecast

KEKO was the closest site to the accident site with a NWS Terminal Aerodrome Forecast (TAF). The TAF valid at the time of the accident was issued at 1520 PST and was valid for a 24-hour period beginning at 1600 PST. The TAF for KEKO was as follows:

²¹ Model Output Statistics: https://www.weather.gov/mdl/mos_home

²² HOTL is defined as a model that does not require human interaction. It is done completely by computation and automation. In this type of simulation a human is not always part of the simulation and consequently does not always influence the outcome of the weather product.

TAF KEKO 112320Z 1200/1224 24012G22KT P6SM BKN150
FM120200 23010G17KT P6SM SCT150
FM120800 24006KT P6SM SCT150=

After 1800 PST, the forecast expected a wind from 230° at 10 knots with gusts to 17 knots, greater than 6 miles visibility, and scattered clouds at 15,000 ft agl.

13.0 NWS Area Forecast Discussion

The NWS office in Elko, Nevada, issued the following Area Forecast Discussion (AFD) at 1358 PST (closest AFD to the accident time). The aviation section of the AFD discussed likely lowering ceiling and visibility conditions at KEKO after 2200 PST due to snow:

FXUS65 KLKN 112158
AFDLKN

Area Forecast Discussion
National Weather Service Elko NV
158 PM PST Sun Feb 11 2018

.SYNOPSIS...A winter weather system will bring needed moisture in the form of snow to the state beginning this evening. The main impacts will be across Lander, Eureka and southwest Elko County through Monday. The system will be slow to exit and areas south of highway 50 could see snow showers through Tuesday night. Another system will begin to move into northern Nevada on Wednesday.

&&

.SHORT TERM...Tonight through Wednesday. Expecting some breezy conditions around the area today...winds at Ely began gusting over 30 mph before noon from the south as the next low pressure area approaches. This next system will begin affecting the LKN CWFA by late this afternoon and will impact northern and central Nevada through Tuesday night. On its heels...another system will move into northern Nevada on Wednesday.

Tonight through Monday night. A cold trough will envelop the state and a cold front will slowly drag through. In general, a few inches of valley snow is expected and about a half-foot for the mountains. But residence time is important to the amounts. The models continue to show a twin low center on the initial entry into Nevada. The first low center will move in this evening followed by the re-enforcing second low center early Monday morning. The energy introduced by this second feature will assist the low in its future retrograde motion but could also slow down the frontal passage and help set up a healthy precipitation band along a line from the northern Nye border with Eureka County through the Ruby Mountains. The GFS model has more of a focused QPF track than the the other models and the current Winter Weather Advisory for Lander, Eureka and southwest Elko County will stand unchanged for this entire period. It is possible that the amounts could change upward depending on the stretching of the trough and the timing of when the low center moves offshore. Low temperatures

will range from the teens to the 20s. High temperatures will range from the 30s to around 40 degrees.

Tuesday Through Tuesday night. The positive-tilted low pressure trough will be straddling the LKN CWFA and stretching as central low pressure retrogrades from central California to re-position off the California coast. Precipitation will linger across areas south of highway 50. This will also be the small window of opportunity for some heavy snowfall across northeast Nye County and southern White Pine County as a southerly fetch of moisture gets pumped up from the south. High temperatures will range from the mid 30s to the mid 40s. Low temperatures will be in the teens and 20s.

Wednesday. Mean low pressure within the trough over the west will be moving back onshore in southern California. Another low pressure wave will be diving into the trough and precipitation will be spreading into northern Nevada. High temperatures will generally be in the 40s.

.LONG TERM...Wednesday night through next Sunday.

Both the GFS and the EC are digging a trof extremely deeper into Nevada than they were 24 hours ago. If this were to occur then both northern and central Nevada would receive another good shot of snow and reinforcing cold air on Wednesday evening through Thursday morning. Continued the trend of the previous forecast in raising pops and expanding the area but not quite yet as much as the models would suggest due to the model flip flopping that has been occurring lately.

Also trended the temperatures cooler, especially on Wednesday night through Friday, but again, not as much as guidance would suggest. Can continue to drop once better run to run consistency is achieved by the models.

After Thursday, a dry northerly flow should be on tap for at least a couple of days.

The next system is due either late next weekend or early the following week, depending on the model.

&&

.AVIATION...Snow showers develop for KWMC this evening and persist through the night. Light runway accumulations are possible with MVFR likely and brief IFR possible. **KEKO will see a substantially better chance at seeing MVFR and IFR. Runway accumulations around an inch or two will also be possible. Start time for KEKO should be around 06Z and persist through Monday morning. KELY should see lesser amounts of snow starting Monday morning along with MVFR conditions and tempo IFR possible.** KTPH has a lower chance for snow showers on Monday, with MVFR conditions at times and no accumulations expected.

&&

.LKN WATCHES/WARNINGS/ADVISORIES...

Winter Weather Advisory from 4 PM this afternoon to 4 PM PST
Monday for Northern Lander County and Northern Eureka County-
Ruby Mountains/East Humboldt Range-Southern Lander County and
Southern Eureka County-Southwestern Elko County.

&&

\$\$

14.0 Winds and Temperature Aloft Forecast

The NWS 1202 PST Winds and Temperature Aloft forecast valid for the closest point to the accident site is included below:

FBUS31 KWN0 112002

FD1US1

DATA BASED ON 111800Z

VALID 120000Z FOR USE 2000-0300Z. TEMPS NEG ABV 24000

FT	3000	6000	9000	12000	18000	24000	30000	34000	39000
BAM			2523-06	2432-12	2542-23	2449-34	237149	256954	285952

The accident site was closest to the Battle Mountain, Nevada, (BAM) forecast point. The 1202 PST BAM forecast for use between 1200 PST and 1900 PST indicated a wind at 9,000 ft from 250° at 23 knots with a temperature of -6° C, a wind at 12,000 ft from 240° at 32 knots with a temperature of -12° C, and a wind at 18,000 ft from 250° at 42 knots with a temperature of -23° C.

15.0 Pilot Weather Briefing and Witness Information

A search of official weather briefing sources, such as Leidos Flight Service and Direct User Access Terminal Service (DUATS), revealed that the accident pilot did not request a weather briefing from Leidos or DUATS.

A search of archived ForeFlight information indicated that ForeFlight did not have any record of the accident pilot accessing weather information. With no internet access while in flight, ForeFlight is still able to access weather information directly from the FAA, but leaving no remote record of such access. The accident flight received portions of the 1756 PST KEKO METAR from ZLC ATC at 1800 PST. There is no record of the accident pilot receiving or retrieving any other weather information before or during the accident flight.

16.0 CWSU Information

ZLC CWSU issued several weather products as supplemental aviation information on the day of the accident. At 1043 PST, ZLC CWSU posted information on Facebook and Twitter that described the winter weather conditions around ZLC airspace and suggested that pilots, especially general aviation pilots, get a detailed weather briefing (Facebook post on figure 17). At 1230 PST, the ZLC CWSU produced a video weather briefing for ZLC ATC, which described the weather conditions across ZLC airspace and the movement of weather systems and weather forecasts therein (attachment 9). ZLC CWSU produced a weather package at the request of ZLC ATC after the accident time and this weather package is provided in attachment 10. Due to the east position of GOES-16 and bandwidth limitations with the internet and the Advanced Weather Interactive Processing System (AWIPS), ZLC CWSU did not have access to the full GOES-16 satellite data imagery. This means ZLC CWSU would not have had access to the GOES-16 imagery including the Nighttime Microphysics RGB imagery discussed in section 5.0.



See more of US National Weather Service Salt Lake City Center Weather Service Unit on Facebook

Figure 17 – ZLC CWSU Facebook weather post at 1043 PST

17.0 CWSU Forecaster Interviews²³

The CWSU forecaster on duty at the time of the accident stated that he worked a regular schedule leading up to the accident day and worked between 1330 and 2130 MST on the accident day. The CWSU forecaster on duty at the time of the accident stated that his criteria for issuing a MIS at ZLC is that the weather event has to be long duration and it is left up to the meteorologist on duty to determine that, but has to be longer than 2 hours, and things such as severe icing, mountain waves, prolonged fog, and strong LLWS could all trigger an MIS. The CWSU forecaster stated that MISs²⁴ are strictly for the FAA ATC at ZLC, they are meant for them and to educate them and made for their awareness.

The CWSU forecaster on duty before the accident time worked between 0620 and 1430 MST on the accident day. She stated that there is no criteria for issuing a MIS and it is very much up to forecaster discretion as to when to issue one. She stated that ZLC has been much more proactive to issue MISs for mountain wave conditions in the last few years. The wording, “PILOTS, ESPECIALLY GENERAL AVIATION AND THOSE UNFAMILIAR WITH LOCAL TERRAIN, SHOULD GET A DETAILED BRIEFING”, (see section 9.0) phraseology was brought into the MIS at ZLC this season and she could not remember which forecaster first used the phraseology, but wanted to use it since the weather pattern this winter had been more benign weather stretches in between active weather days. She stated the phraseology is used fairly often at ZLC, as forecasters can use templates when they issue a MIS and there are 2 to 3 people at ZLC CWSU that use the phraseology. She stated that she sees the audience of ZLC CWSU weather products as primarily ATC, and she tries to “gear” the information toward both ATC and pilots because pilots can see the information too. She tries to reach out to pilots, because if pilots know the conditions they won’t go up in them and then get into a weather situation where they need lots of help from ATC. The social media posts (that ZLC CWSU issues) are for aviation and the general public as she would rather get the information out there. She stated that general aviation is part of audience for MISs and she wants general aviation pilots to watch out for weather conditions as well. For further information on the CWSU interviews please see attachment 11.

²³ The factual information contained in this section was taken from the CWSU forecaster interviews conducted on February 9 and 22, 2018, and for more information please see attachment 11.

²⁴ <http://www.nws.noaa.gov/directives/sym/pd01008003curr.pdf>

18.0 NWS Aviation Satellite Training Information

During correspondence with NWS it was established that the AWC weather forecasters were required to go through the same training on GOES-16 imagery as the rest of the NWS forecasters did. This training included the satellite foundation course for GOES-R²⁵ (GOES-16), but this training did not include any specific GOES-16 or other satellite imagery examples on aviation icing conditions (attachments 16 and 18). The same satellite training for GOES-R (GOES-16) was required for CWSU forecasters (attachment 19). Additional in-house training has been done at the AWC (attachment 16) and provided by the Cooperative Program for Operational Meteorology, Education, and Training (COMET)²⁶, but none of these training courses focused on GOES-16 imagery and aviation icing conditions. The NWS directive 10-815 state that there were 4 required training items for aviation forecasters, but none of those training items included GOES-16 imagery with aviation icing conditions (attachment 17). As of July 9, 2018, the NWS was in the process of working with COMET to update the old satellite information/imagery for these required aviation training courses (attachments 17 and 20).

19.0 Investigative Trip in Boulder

On July 9, 2018, the meteorology group had a meeting with 2 individuals from COMET, based in Boulder, Colorado. These two individuals are in charge of developing aviation-related training courses for COMET and COMET is one of the main training resources for the NWS. During the meetings, it was discussed that COMET, through NWS funding, is currently updating old aviation weather training. COMET is updating the “Forecasting Mountain Wave Course” and the “Volcanic Ash Course”. It is anticipated that COMET will receive funding to update the Distance Learning Aviation Course (DLAC) this upcoming year (FY19), and with that funding, COMET plans to update the DLAC material to include GOES-16 cases and datasets. Some of the aviation courses anticipated to be updated over the next year include aviation courses on clear-air turbulence, enroute icing, and mountain wave turbulence. As discussed during the meeting on July 9, the NWS uses an aviation professional development series (PDS)²⁷ to keep the NWS forecasters (including the AWC and CWSU forecasters) updated and trained on the latest aviation weather technological and educational advances. The NWS keeps the aviation PDS organized into many professional competency units (PCU)s which allow for specific instruction on different aviation topics.²⁸ The aviation related PCUs are currently in a simplification and review process. No current COMET or NWS related training with GOES-16 data includes material on enroute icing.²⁹ For more information please see attachment 20.

²⁵ http://rammb.cira.colostate.edu/training/visit/training_sessions/satfc-g.asp

²⁶ https://www.meted.ucar.edu/training_module.php?id=1374#.W03y8NJKiUk
https://www.meted.ucar.edu/training_detail.php?topicSorting=12&languageSorting=1&module_sorting=publishDataDesc

²⁷ <https://training.weather.gov/aviationPDS.php>

²⁸ <https://training.weather.gov/aviationPDS.php>

²⁹ COMET MetEd and NWS course material reviewed through July 2018

20.0 Icing Potential³⁰

Current Icing Potential (CIP) and Forecast Icing Potential (FIP) products are available at the NWS Aviation Weather Center (AWC) and are intended to be supplemental to other icing advisories (e.g. AIRMETs and SIGMETs). Figures 18 through 20 were the FIP icing probabilities and icing severity products, 1-hour forecast valid at 1800 PST at 10,000, 11,000, and 12,000 ft msl (similar values in the FIP are seen in the 2-hour forecast valid at both 1800 and 1900 PST, attachment 12). The FIP images indicated between a 20 to 60 percent probability of icing at 10,000 and 11,000 ft at 1800 PST over the accident site (figures 18 and 19). The FIP also indicated that the icing near the accident site would likely be of trace to light severities (figures 18 and 19). The FIP indicated no potential for any Supercooled Large Droplet (SLD) over the accident area around the accident time (attachment 12). This FIP information would have been available on the NWS AWC website.³¹

The CIP product indicated no probability of icing at 10,000, 11,000, and 12,000 ft at 1800 PST at the accident site (figures 21 through 23). At 1900 PST, the CIP product indicated up to a 30 percent probability of icing at 12,000 ft (attachment 12). The CIP also indicated an unknown chance of SLD near the accident site around the accident time (attachment 12). For more FIP and CIP information see attachment 12.

³⁰ B.C. Bernstein, F. McDonough, M. K. Politovich, B. G. Brown, T. P. Ratvasky, D. R. Miller, C.A. Wolff, and G. Cunning, Current Icing Potential: Algorithm Description and Comparison with Aircraft Observations (Journal of Applied Meteorology, 2005), pp. 969-986.

C.A. Wolff, F. McDonough, M. K. Politovich, B.C. Bernstein, and G. Cunning, FIP Severity Technical Document (Prepared for the Aviation Weather Technology Transfer Technical Review Board), pp. 1-44.

<https://arc.aiaa.org/doi/abs/10.2514/6.2009-3531>

³¹ <https://www.aviationweather.gov/icing/fip>

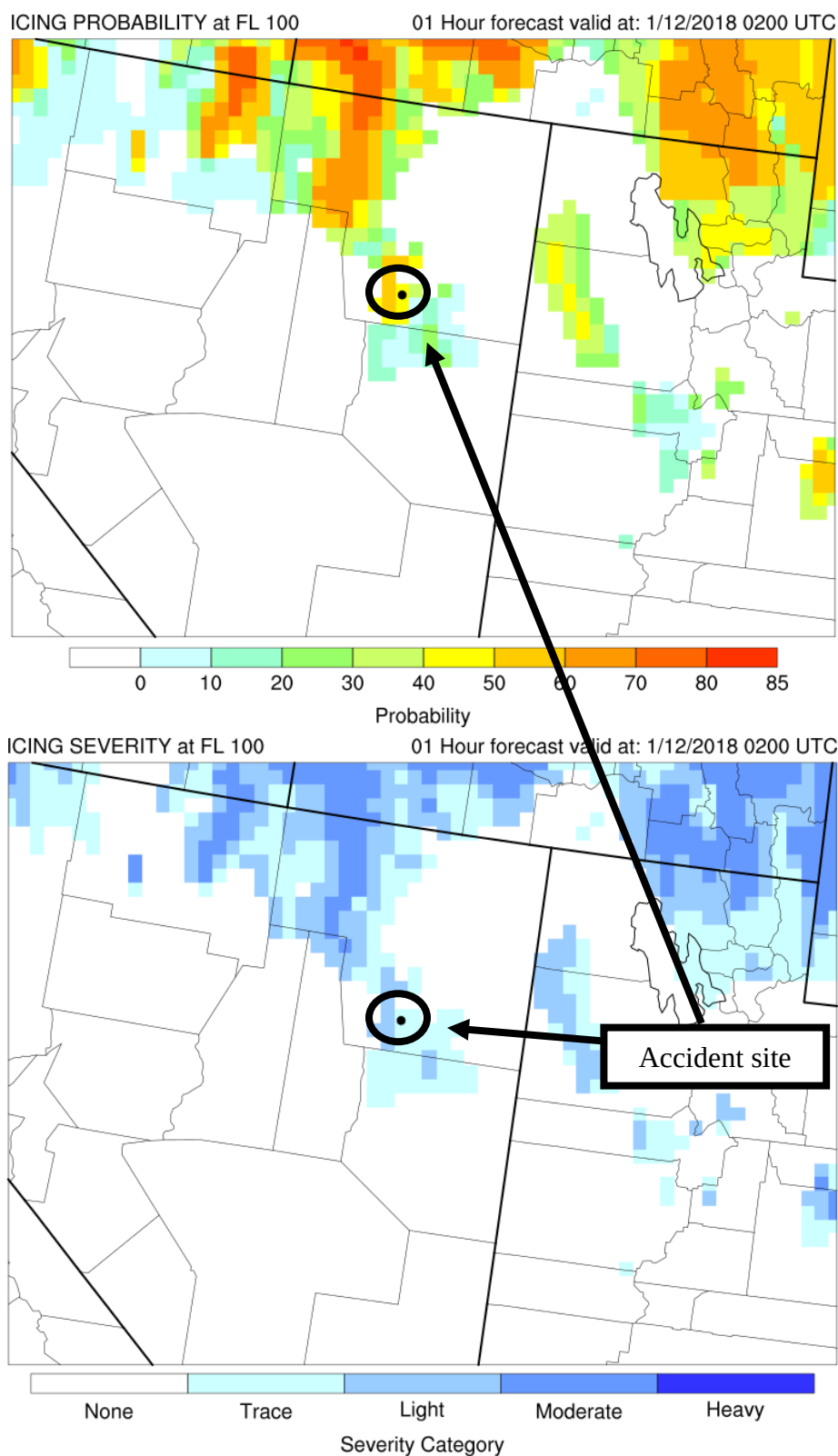
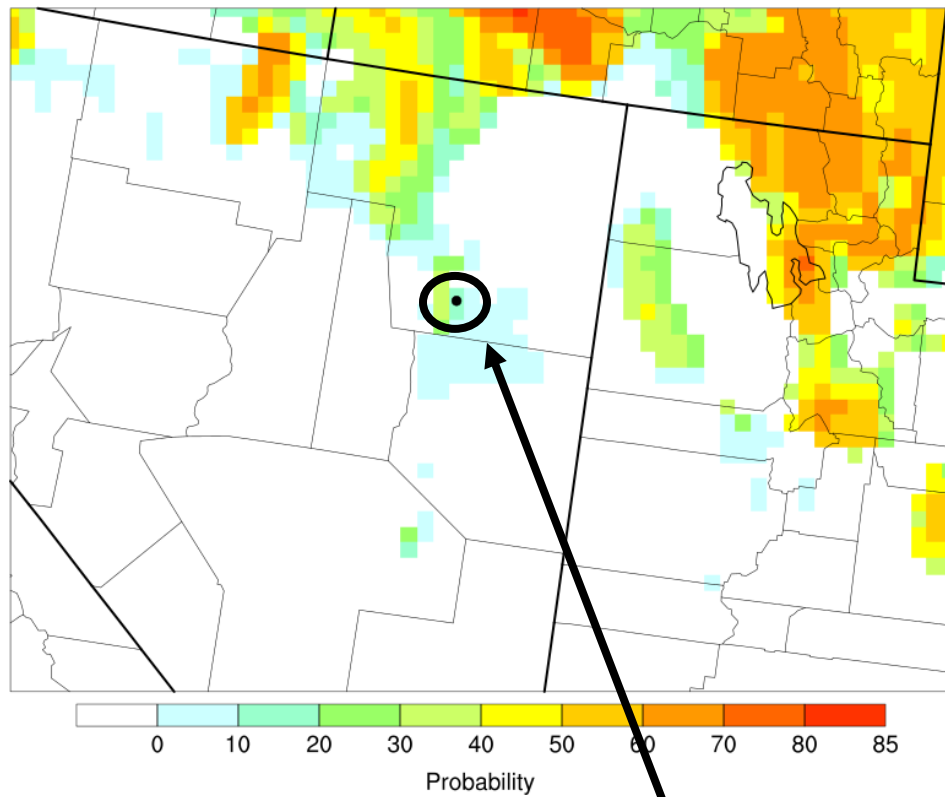


Figure 18 – (top) FIP probability of icing at 10,000 ft msl and (bottom) FIP severity of icing at 10,000 ft msl 1-hour forecast valid for 1800 PST

ICING PROBABILITY at FL 110 01 Hour forecast valid at: 1/12/2018 0200 UTC



ICING SEVERITY at FL 110 01 Hour forecast valid at: 1/12/2018 0200 UTC

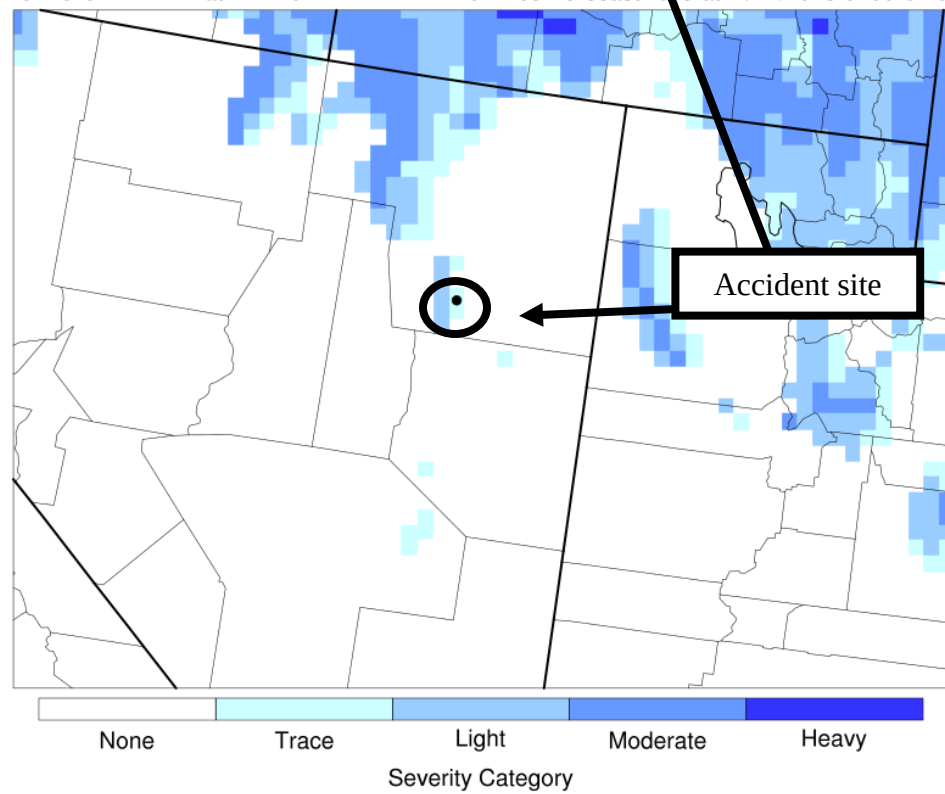


Figure 19 – (top) FIP probability of icing at 11,000 ft msl and (bottom) FIP severity of icing at 11,000 ft msl 1-hour forecast valid for 1800 PST

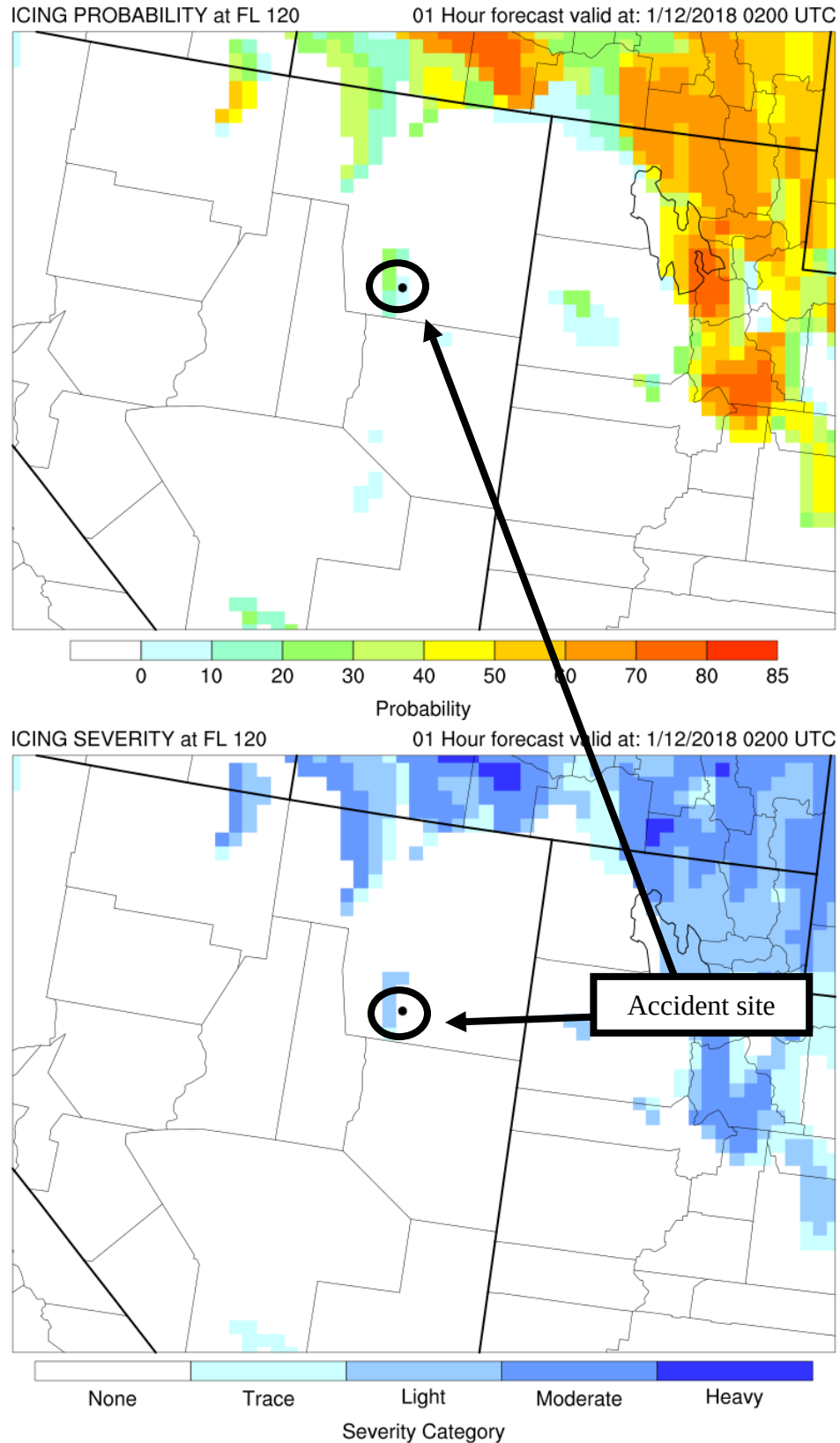


Figure 20 – (top) FIP probability of icing at 12,000 ft msl and (bottom) FIP severity of icing at 12,000 ft msl 1-hour forecast valid for 1800 PST

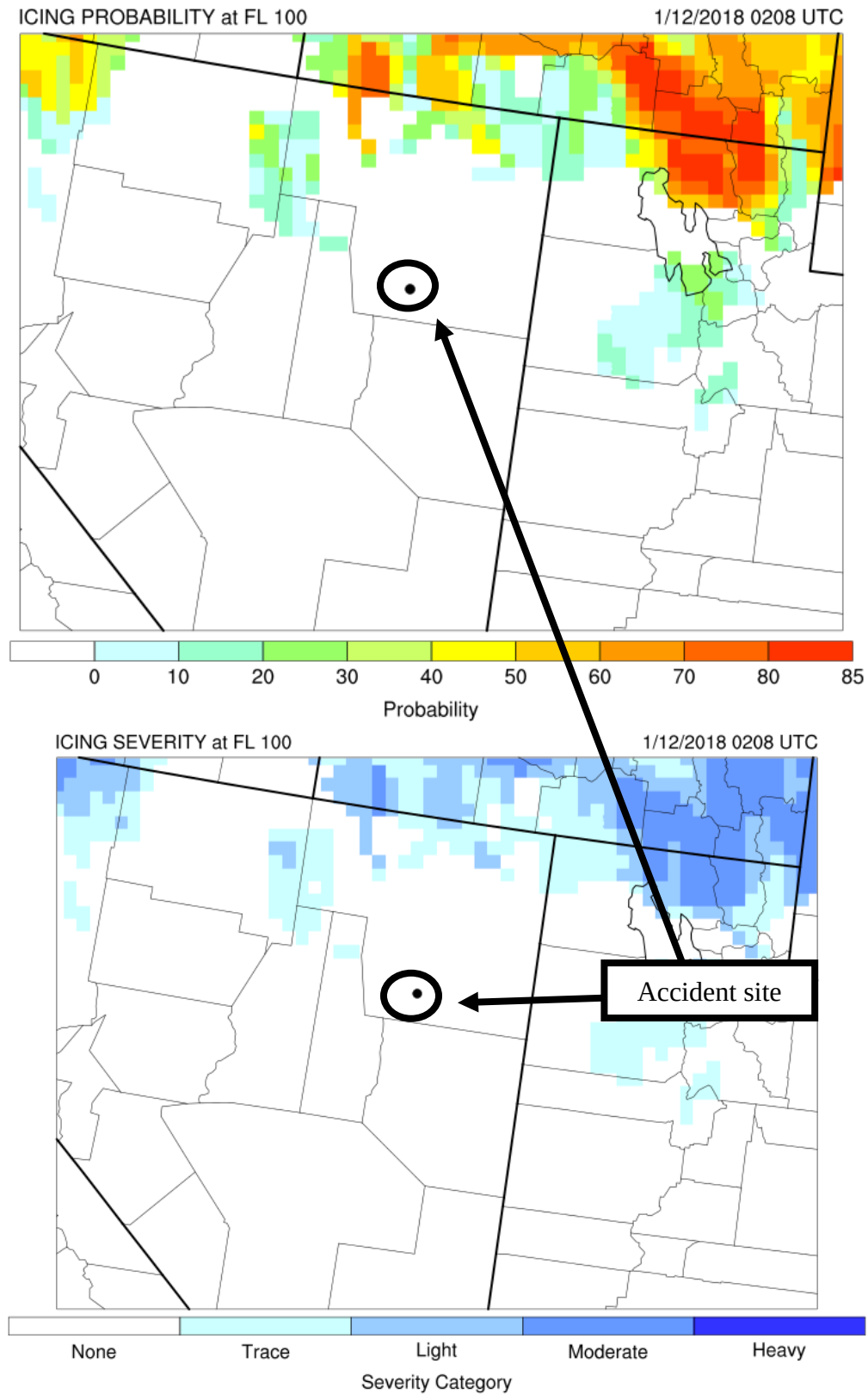


Figure 21 – (top) CIP probability of icing at 10,000 ft msl and (bottom) CIP severity of icing at 10,000 ft msl valid for 1800 PST

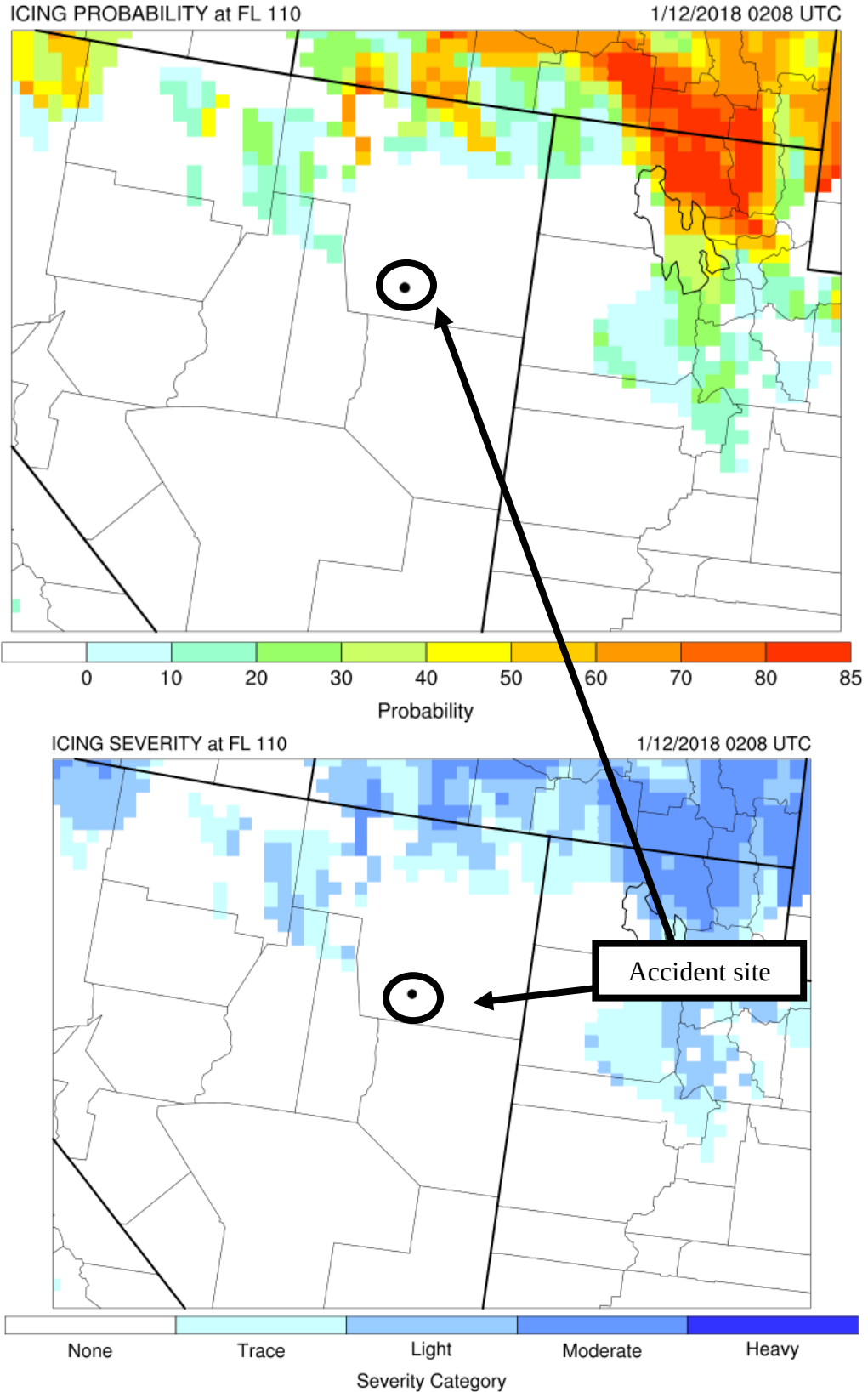


Figure 22 – (top) CIP probability of icing at 11,000 ft msl and (bottom) CIP severity of icing at 11,000 ft msl valid for 1800 PST

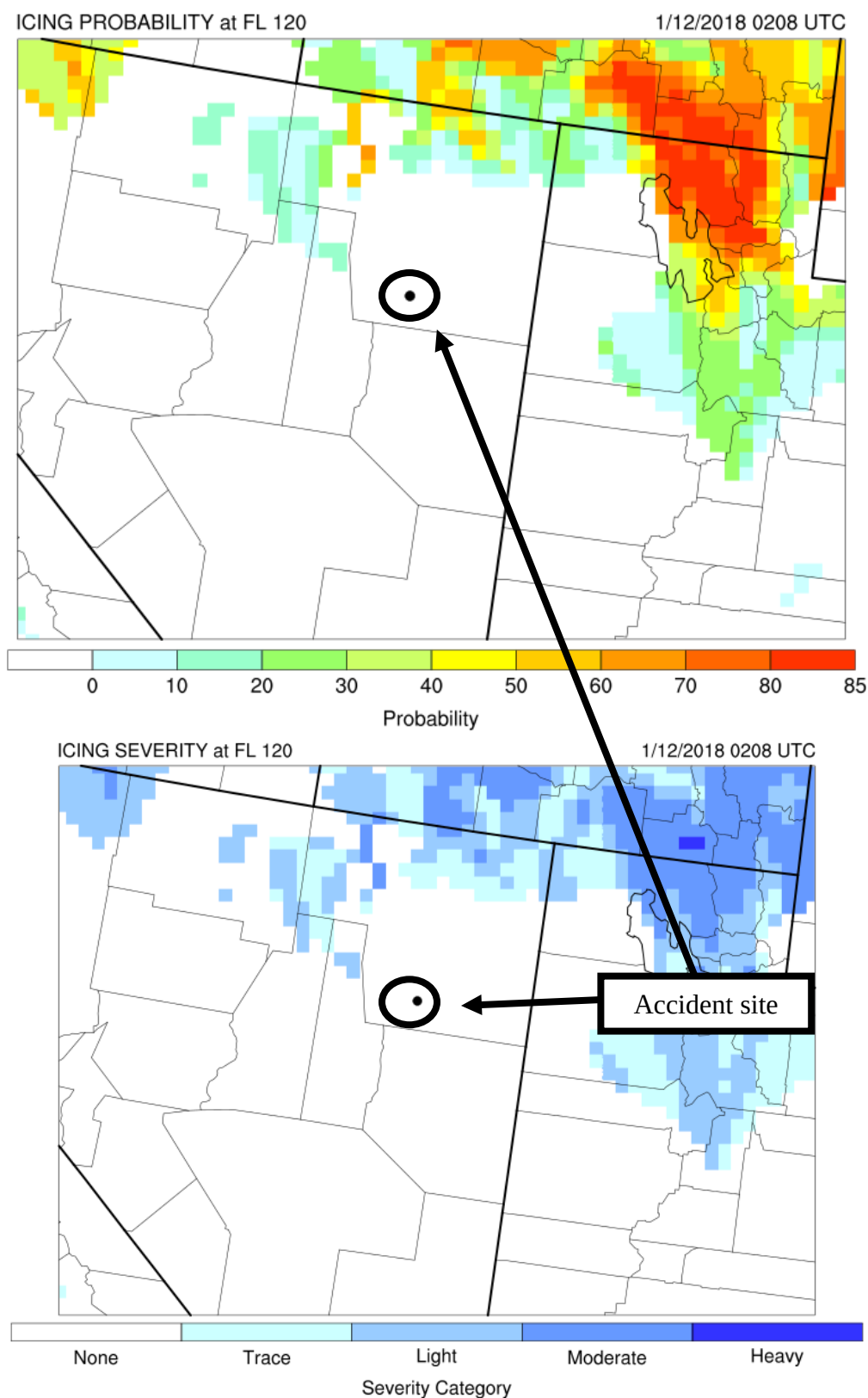


Figure 23 – (top) CIP probability of icing at 12,000 ft msl and (bottom) CIP severity of icing at 12,000 ft msl valid for 1800 PST

21.0 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 8 km, 1.6 km, and 320 m over the accident site. Other WRF simulation parameters included: 60 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 terrain (in feet) used in domain 2 is shown in figure 24 along with the location of the cross sections used figures 25 through 27 (along with attachments 13 through 15) with the location of the accident site marked. Figures 25 and 26 depict the potential temperature³² in degrees Kelvin (solid lines) and the vertical velocity in feet per minute (color fill) at 1800 PST along a west to east cross section (figure 25) and north to south cross section (figure 26). The vertical velocity data indicated that at the flight level³³ the accident flight was travelling at before the encounter with terrain the accident flight was in an area of downdrafts with a magnitude between 800 and 1,200 feet per minute (figures 25 and 26) with increasing downdraft magnitude near the terrain and east of the terrain (attachments 13 and 14). West of the terrain features (figure 25 and attachment 13) the accident flight would have been in an area of updrafts with magnitudes of 300 to 600 feet per minute. Figure 27 depicts the potential temperature in degrees Kelvin (solid lines) and relative humidity in percent (color fill) at 1800 PST along a west to east cross section with the accident site marked. Near the higher terrain and above the accident site were areas of greater than 90 percent relative humidity at 1800 PST between 9,000 and 15,000 ft msl. Areas with equal to or greater than 90 percent relative humidity are generally areas where cloud cover is expected. The areas with relative humidity remaining at or above 90 percent increased in coverage and vertical extent between 1600 PST on January 11 and 0000 PST on January 12 (attachment 15). Areas of greater than 90 percent relative humidity at the flight level the accident flight was travelling at before the encounter with terrain were located above the accident site as early as 1700 PST with the upper boundary of 90 percent relative humidity between 13,000 and 15,000 ft msl between 1700 PST and 2300 PST (attachment 15). Upper air soundings were produced for the accident site from the WRF simulations for 1600, 1700, and 1800 PST (figures 28 through 30). The WRF soundings indicated an increase in relative humidity between the surface and 15,000 ft msl between 1600 and 1800 PST.

³² Potential temperature of a parcel of fluid at pressure P is the temperature that the parcel would acquire if adiabatically brought to a standard reference pressure P_0 , usually 1000 hPa.

³³ For more information please see the ATC data contained in the docket of this accident.

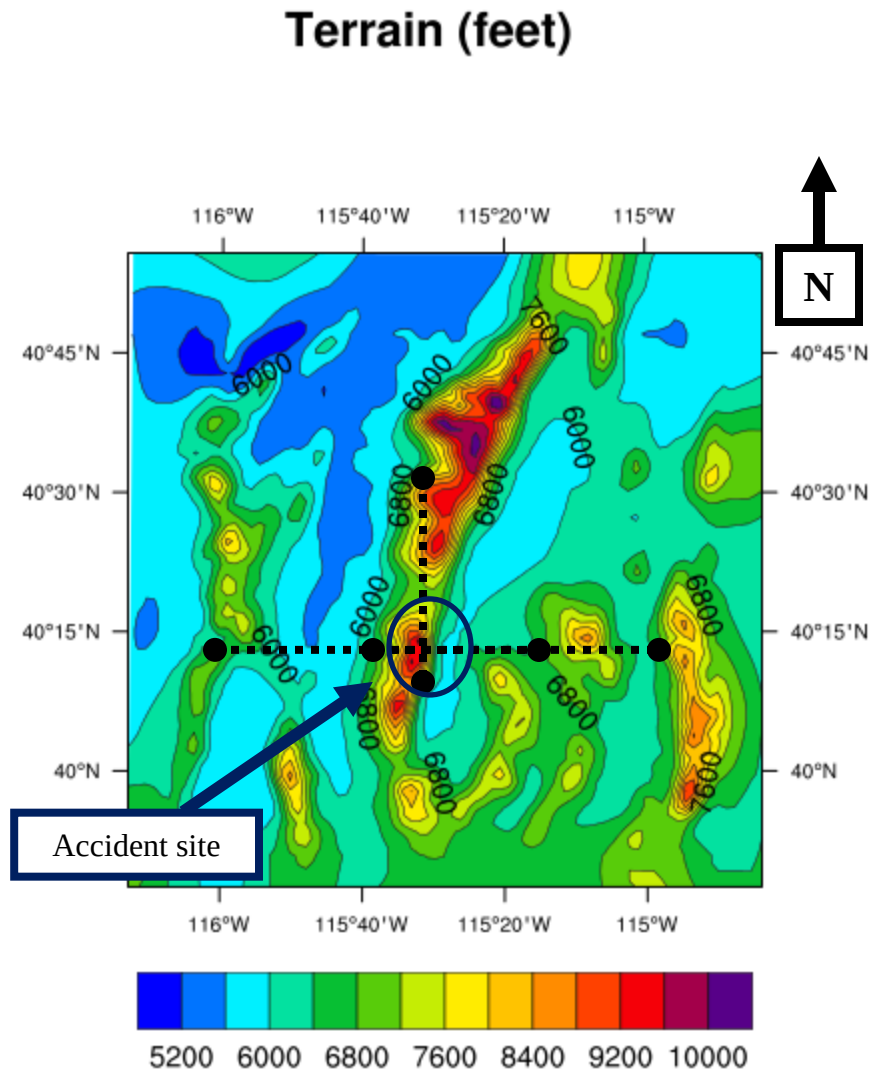


Figure 24 – WRF simulation terrain in feet with the accident site marked and the locations of the cross sections in the following figures (black dashed lines)

W

E

Vertical Velocity 2018-01-12_02:00:00

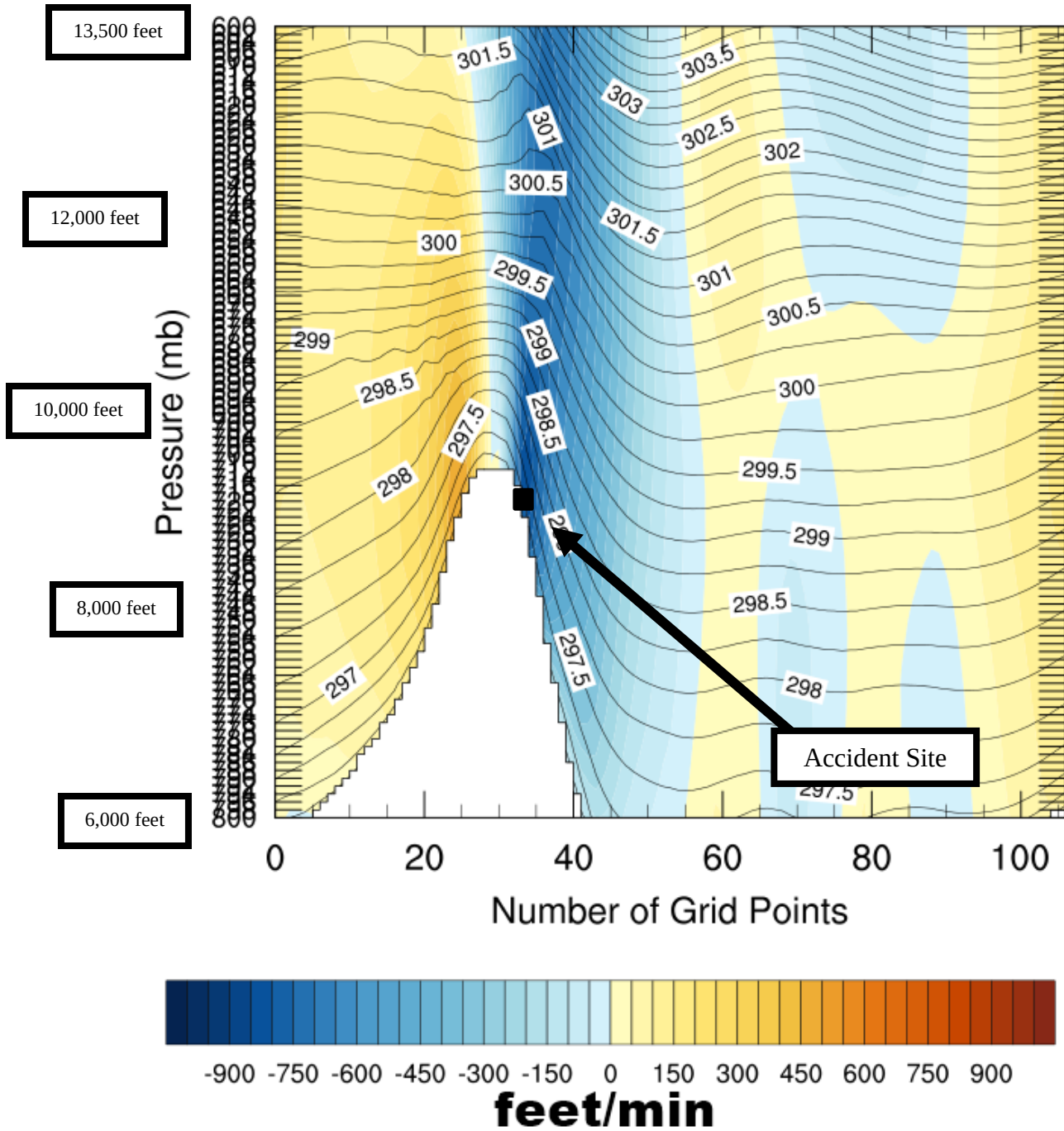


Figure 25 – WRF cross section from 1800 PST of vertical velocity in feet per minute (color fill) and potential temperature in kelvin (black lines) from west to east across the terrain with the approximate accident site marked

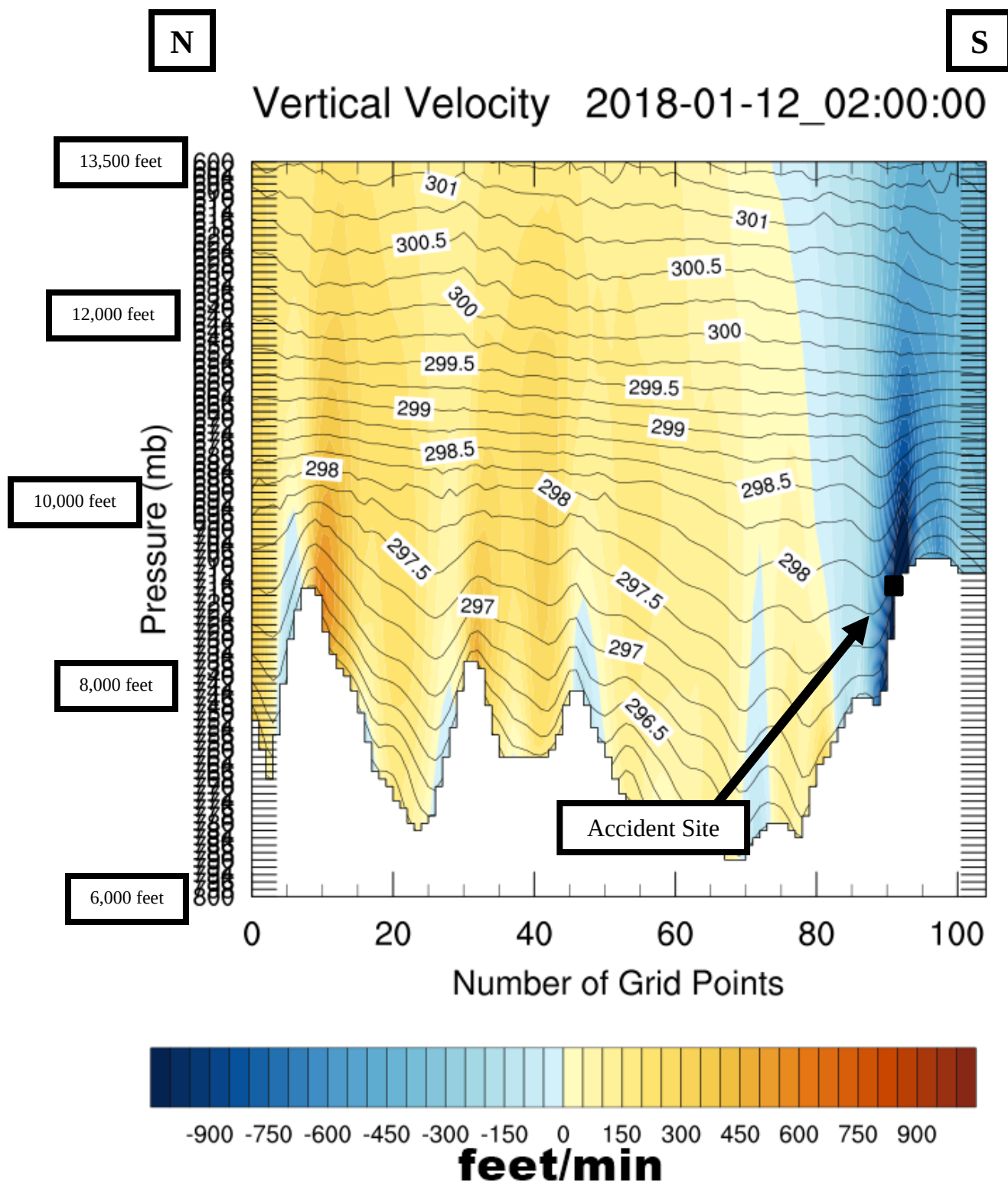


Figure 26 – WRF cross section from 1800 PST of vertical velocity in feet per minute (color fill) and potential temperature in kelvin (black lines) from north to south across the terrain with the approximate accident site marked

W

E

Relative Humidity 2018-01-12_02:00:00

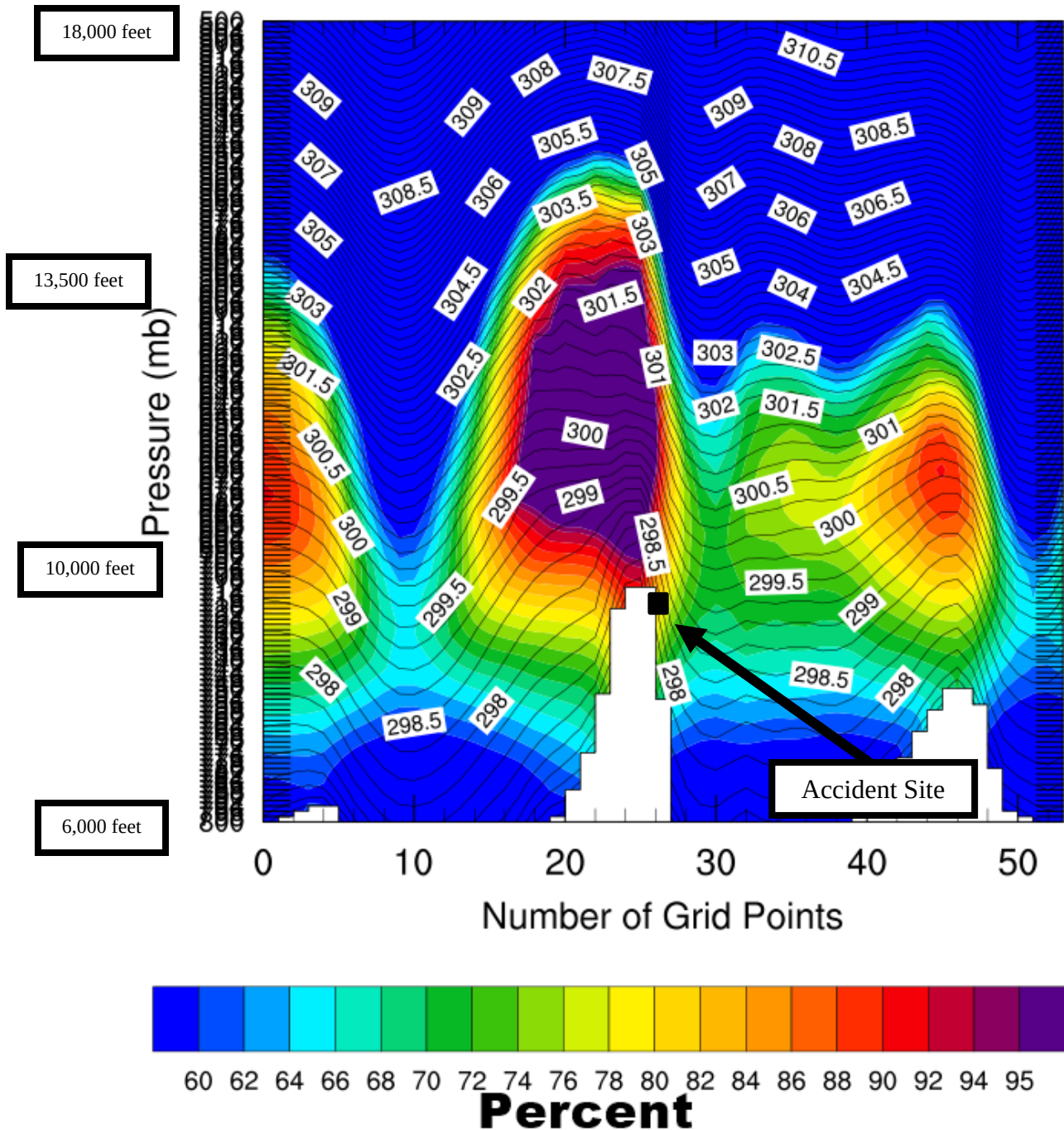


Figure 27 – WRF cross section from 1800 PST of relatively humidity in percent (color fill) and potential temperature in kelvin (black lines) from west to east across the terrain with the approximate accident site marked

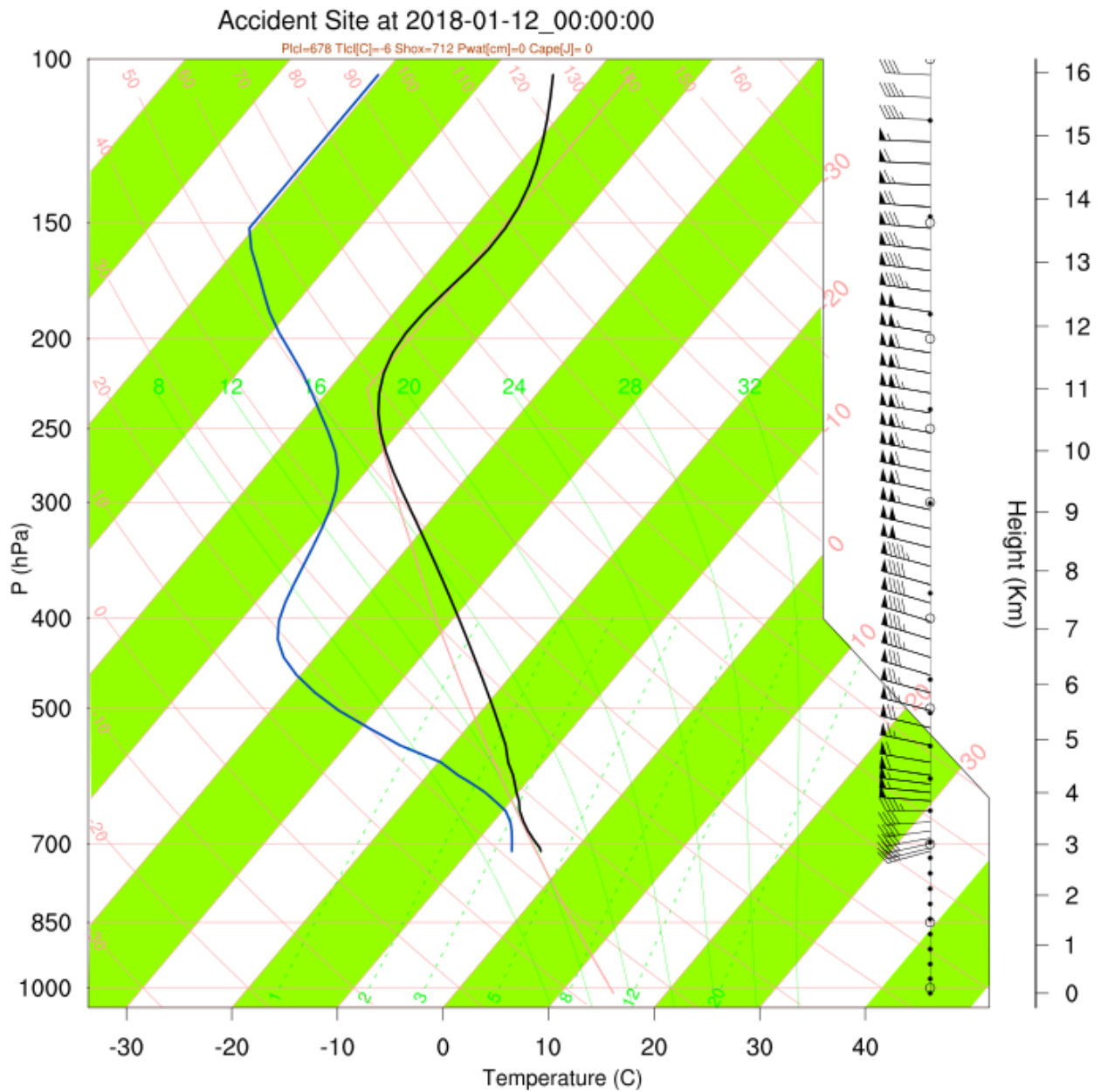


Figure 28 – WRF sounding from 1600 PST for the accident site

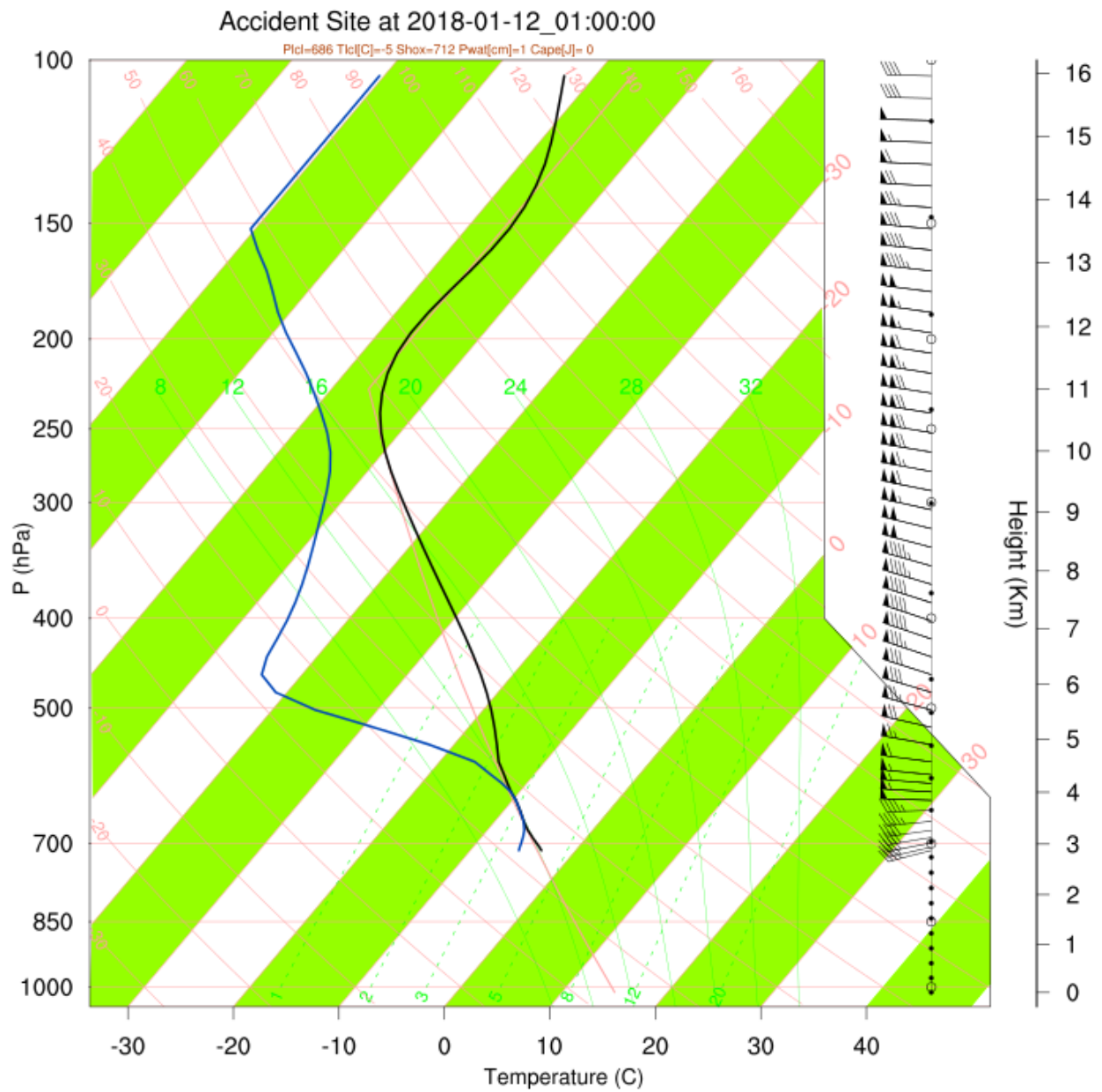


Figure 29 – WRF sounding from 1700 PST for the accident site

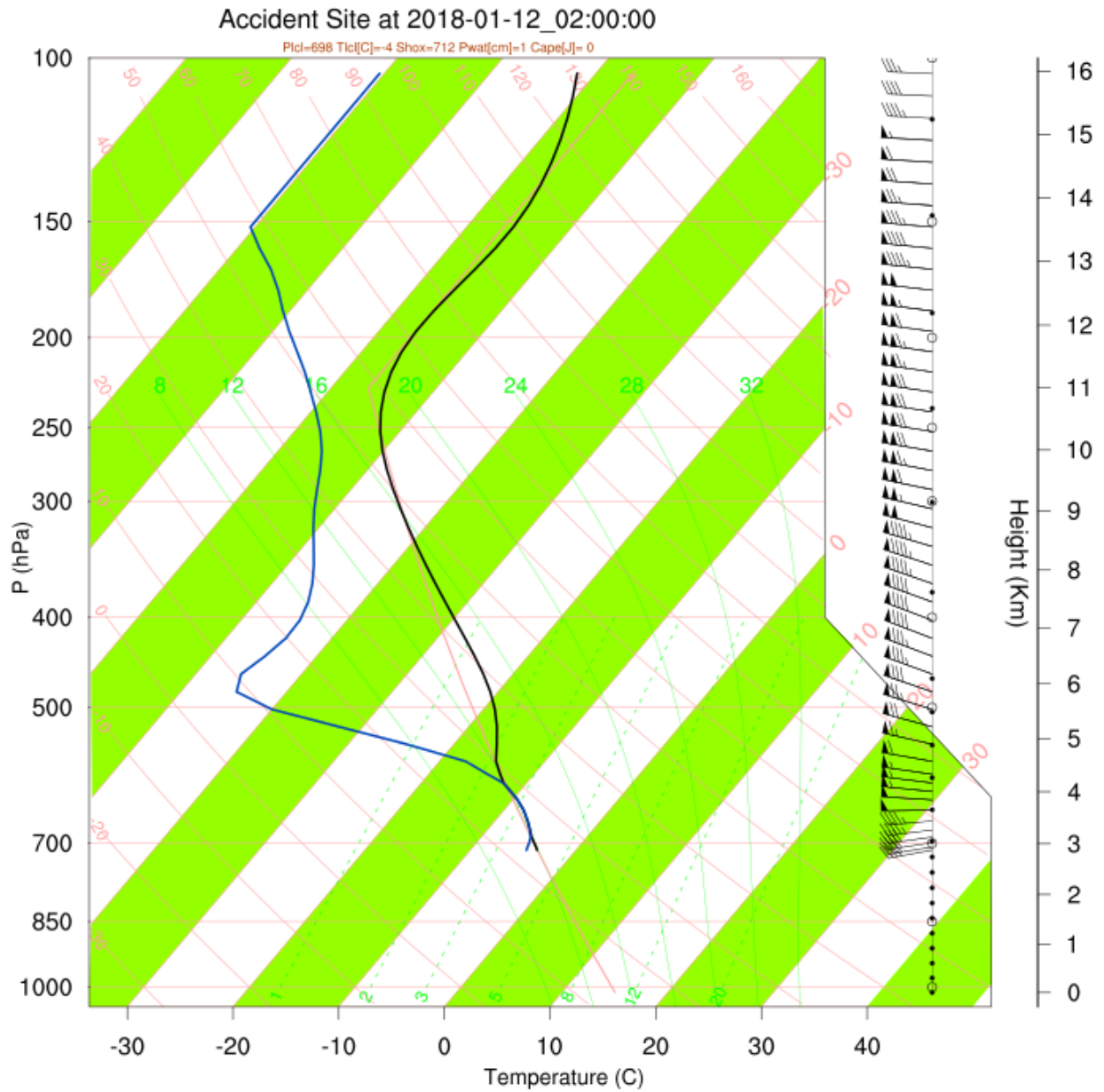


Figure 30 – WRF sounding from 1800 PST for the accident site

22.0 Astronomical Data

The astronomical data obtained from the United States Naval Observatory for the accident site on January 11, 2018, indicated the following:

SUN

Begin civil twilight	0634 PST
Sunrise	0704 PST
Sun transit	1150 PST
Sunset	1637 PST
End civil twilight	1707 PST
Accident time	1802 PST³⁴

MOON

Moonrise	0217 PST
Moon transit	0743 PST
Moonset	1303 PST
Accident time	1802 PST

E. LIST OF ATTACHMENTS

Attachment 1 – Western United States view GOES-16 Band 10 lower-level water vapor infrared satellite animation from 1617 to 2012 PST

Attachment 2 – Northern Nevada view GOES-16 Band 10 lower-level water vapor infrared satellite animation from 1617 to 2022 PST

Attachment 3 – NASA SPoRT Nighttime Microphysics RGB quick guide

Attachment 4 – Northern Nevada view GOES-16 Nighttime Microphysics RGB satellite animation from 1612 to 2017 PST

Attachment 5 – Email correspondence with NASA LARC-E302

Attachment 6 – GOES-16 satellite imagery animation provided by NASA LARC-E302

Attachment 7 – GFA products valid for the accident site around the accident time and before the accident flight departed MCC

Attachment 8 – Correspondence with the Aviation Weather Center regarding GFA products

Attachment 9 – ZLC CWSU video weather briefing issued at 1230 PST

Attachment 10 – ZLC CWSU weather package produced for ZLC ATC after the accident time

³⁴ Inserted accident time for reference and context.

Attachment 11 – ZLC CWSU Interview Summaries

Attachment 12 – CIP and FIP products valid at 1800 and 1900 PST for the accident flight

Attachment 13 – Animation of a west to east WRF cross section of vertical velocity and potential temperature from 1700 to 1900 PST

Attachment 14 – Animation of a north to south WRF cross section of vertical velocity and potential temperature from 1700 to 1900 PST

Attachment 15 – Animation of a west to east WRF cross section of relative humidity and potential temperature from 1600 PST on January 11 to 0000 PST on January 12

Attachment 16 – AWC required GOES-16 satellite training correspondence

Attachment 17 – NWS required satellite training correspondence

Attachment 18 – NWS required GOES-R satellite training official email

Attachment 19 – CWSU required GOES-16 satellite training correspondence

Attachment 20 – Trip summary of investigative trip to Boulder in July 2018

Submitted by:

Paul Suffern
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