NATIONAL TRANSPORTATION SAFETY BOARD

Office of Aviation Safety
Washington, D.C. 20594

August 3, 2017

Group Chairman's Factual Report

METEOROLOGY

WPR17FA085

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A. ACCIDENT

Location: Near Harrisburg, Oregon
Date: April 7, 2017
Time: 1048 Pacific daylight time
1748 Coordinated Universal Time (UTC)
Airplane: Piper PA-46-310P, registration: N123SB

B. METEOROLOGIST

Paul Suffern
Senior Meteorologist
Operational Factors Division (AS-30)
National Transportation Safety Board

C. DETAILS OF THE INVESTIGATION

The National Transportation Safety Board's (NTSB) Meteorologist did not travel for this investigation and gathered the weather data for this investigation from the NTSB's Washington D.C. office and from official National Oceanic and Atmospheric Administration (NOAA) National Weather Service (NWS) sources including the National Centers for Environmental Information (NCEI). All times are Pacific daylight time (PDT) on April 7, 2017, and are based upon the 24-hour clock, where local time is -7 hours from UTC, and UTC=Z (unless otherwise noted). Directions are referenced to true north and distances in nautical miles. Heights are above mean sea level (msl) unless otherwise noted. Visibility is in statute miles and fractions of statute miles.

The accident site was located at latitude 44.295° N, longitude 123.183° W, at an approximate elevation of 300 feet (ft).

D. FACTUAL INFORMATION

1.0 Synoptic Situation

The synoptic or large scale migratory weather systems influencing the area were documented using standard NWS charts issued by the National Center for Environmental Prediction and the 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 Surface Analysis Chart

The NWS Surface Analysis Chart for 1100 PDT is provided as figure 1 with the approximate location of the accident site marked within the red circle. The chart indicated that there was a surface low pressure center located in the eastern Pacific Ocean just west of Washington state with a pressure of 972-hectopascals (hPa). A dissipating occluded front stretched eastward from the surface low pressure center in the eastern Pacific Ocean across northern Washington state and into southern Alberta. Another frontal boundary stretched southward from southern Alberta into southern Idaho and southwestward into central California. The station models around the accident site depicted air temperatures in the mid to upper 40's degrees Fahrenheit (°F), dew point temperatures in the low 40's °F with temperature-dew point spreads of 6° F or less, a southwest wind at 15 to 20 knots, cloudy skies, and light to moderate rain.

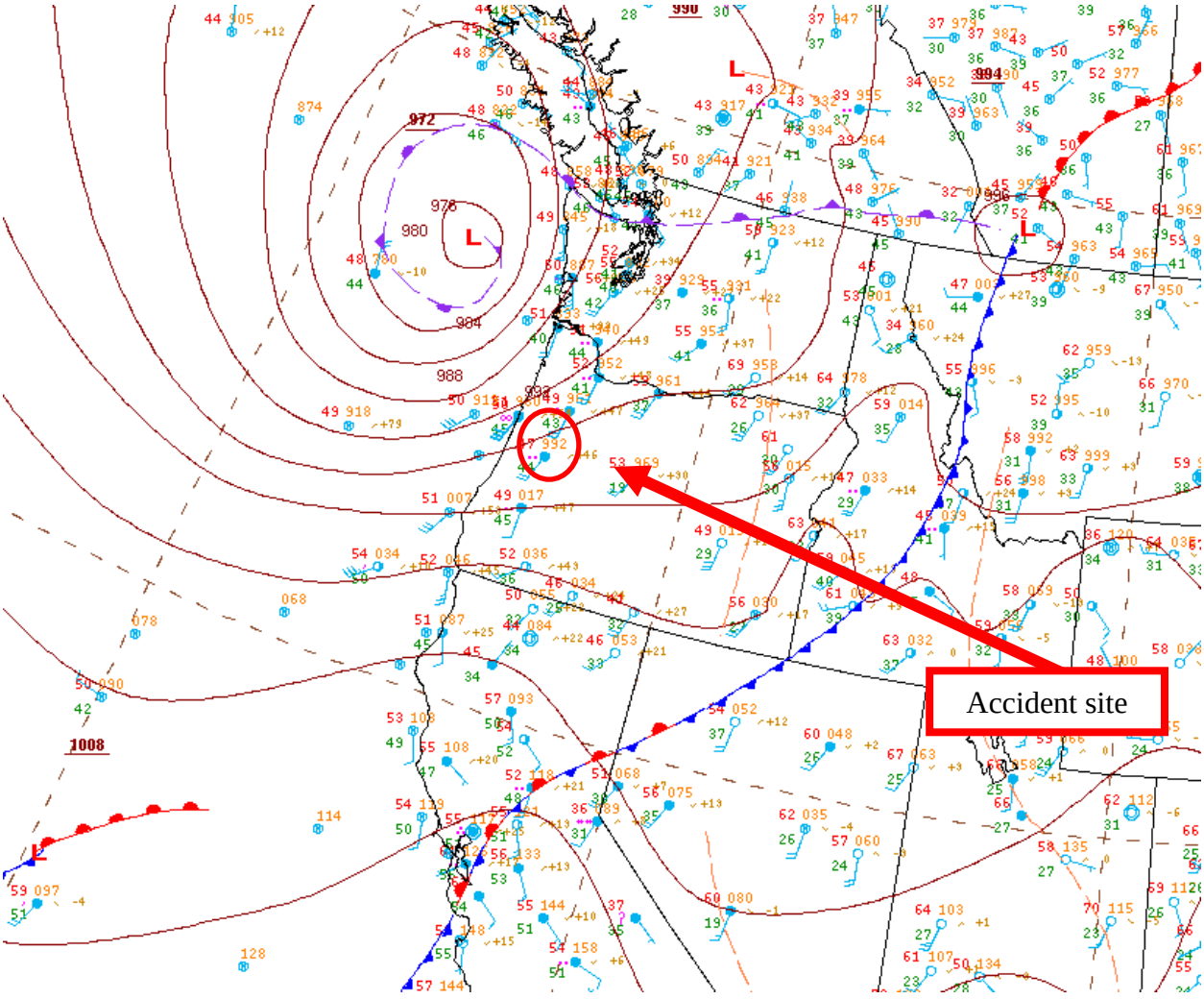

Figure 1 – NWS Surface Analysis Chart for 1100 PDT

1.2 Upper Air Charts

The NWS Storm Prediction Center (SPC) Constant Pressure Charts for 0500 PDT at 925-, 850-, 700-, 500-, and 300-hPa are presented in figures 2 through 6. There was a vertically stacked low pressure system northwest of the accident site located in the eastern Pacific Ocean just west of Washington state. There was a low-level trough[1] located west of the accident site (figure 3) and south of the vertically stacked low pressure center at 850-hPa. Troughs can act as lifting mechanisms to help produce clouds and precipitation if sufficient moisture is present. There was a south wind of 15 to 30 knots at 925-hPa (figure 2) above the accident site. The wind became southwesterly by 700-hPa with a wind speed of 60 knots (figure 4). The 60-knot southwesterly wind at 700-hPa became a 95-knot southwest wind by 300-hPa (figure 6).

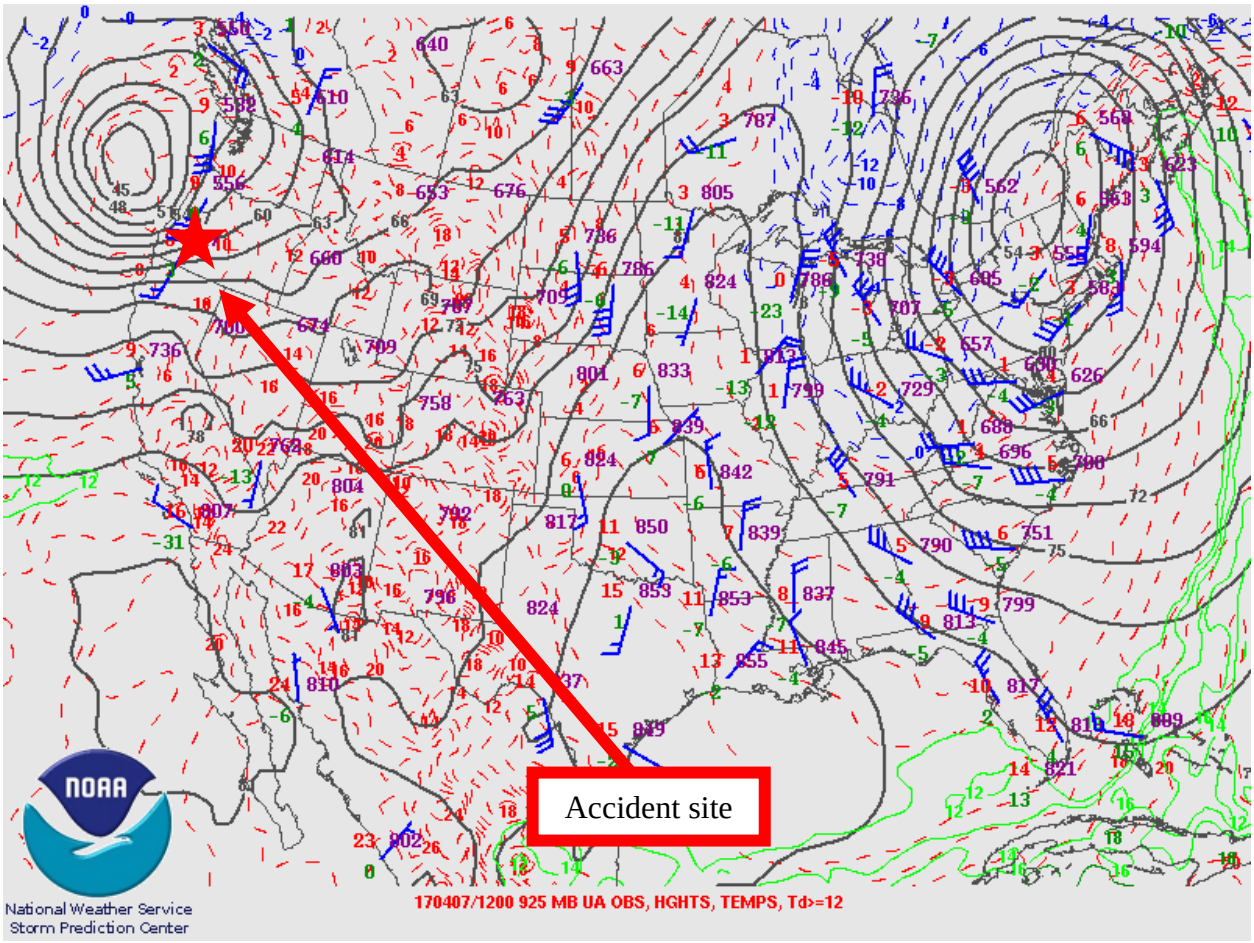

Figure 2 – 925-hPa Constant Pressure Chart for 0500 PDT

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

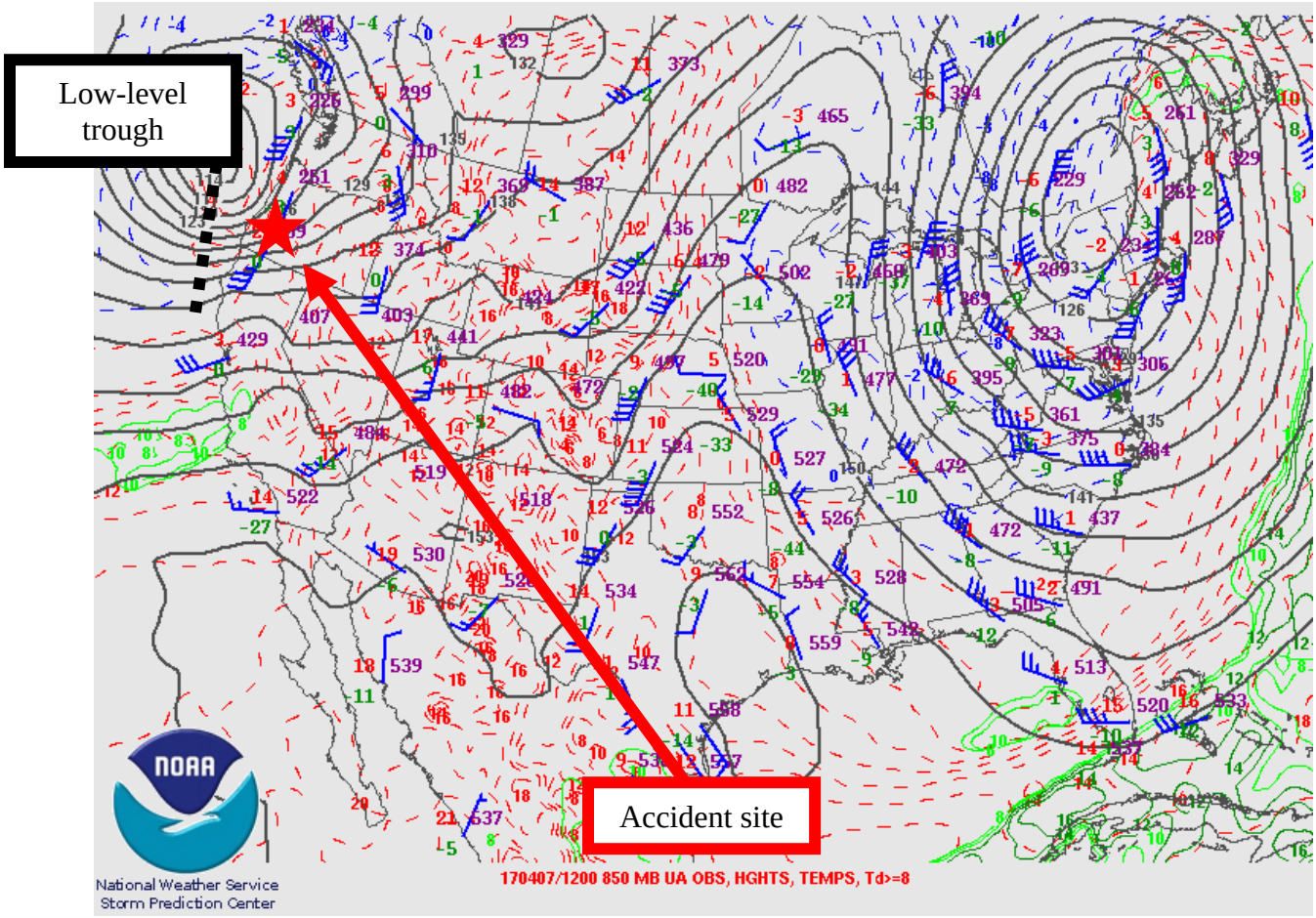

Figure 3 – 850-hPa Constant Pressure Chart for 0500 PDT

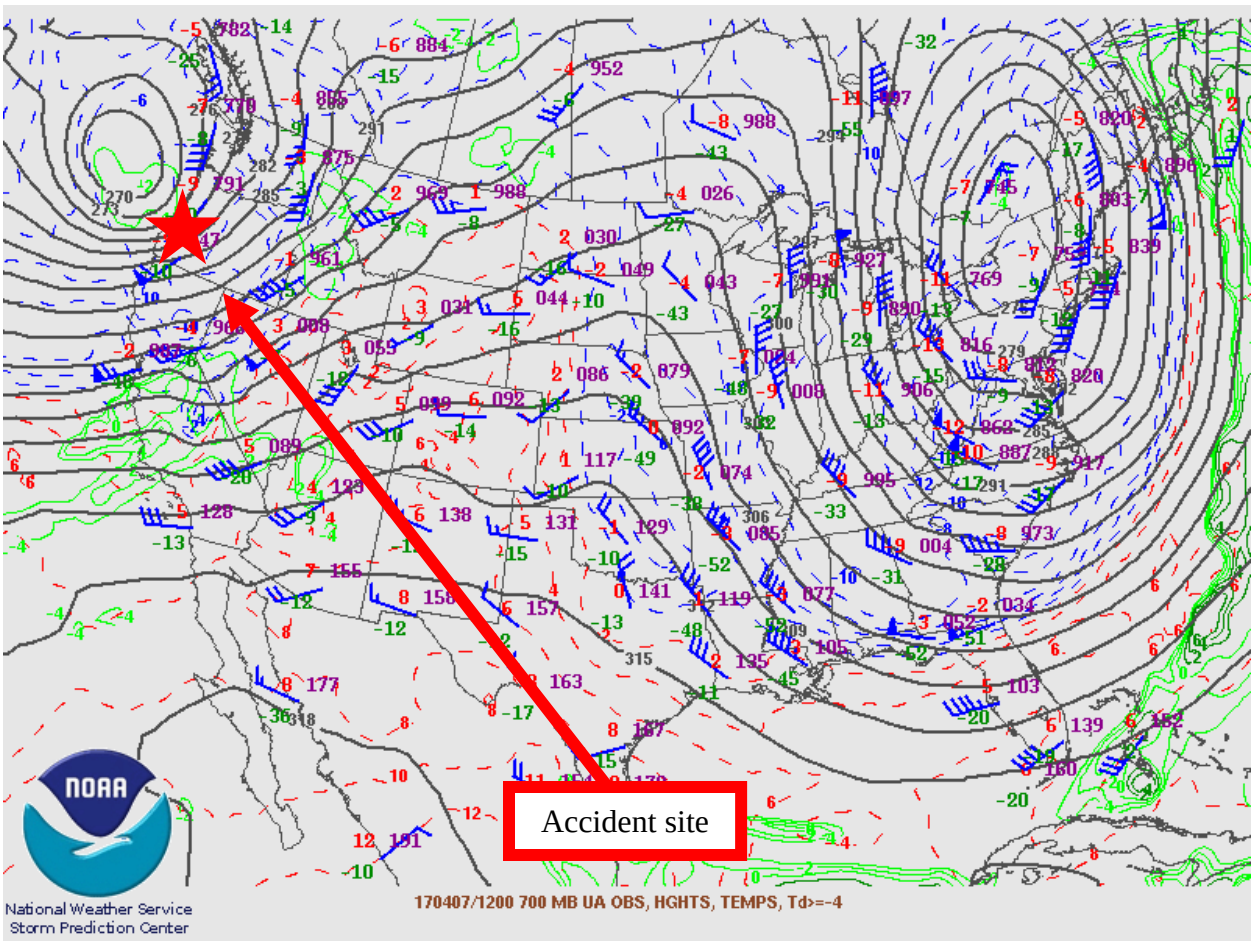

Figure 4 – 700-hPa Constant Pressure Chart for 0500 PDT

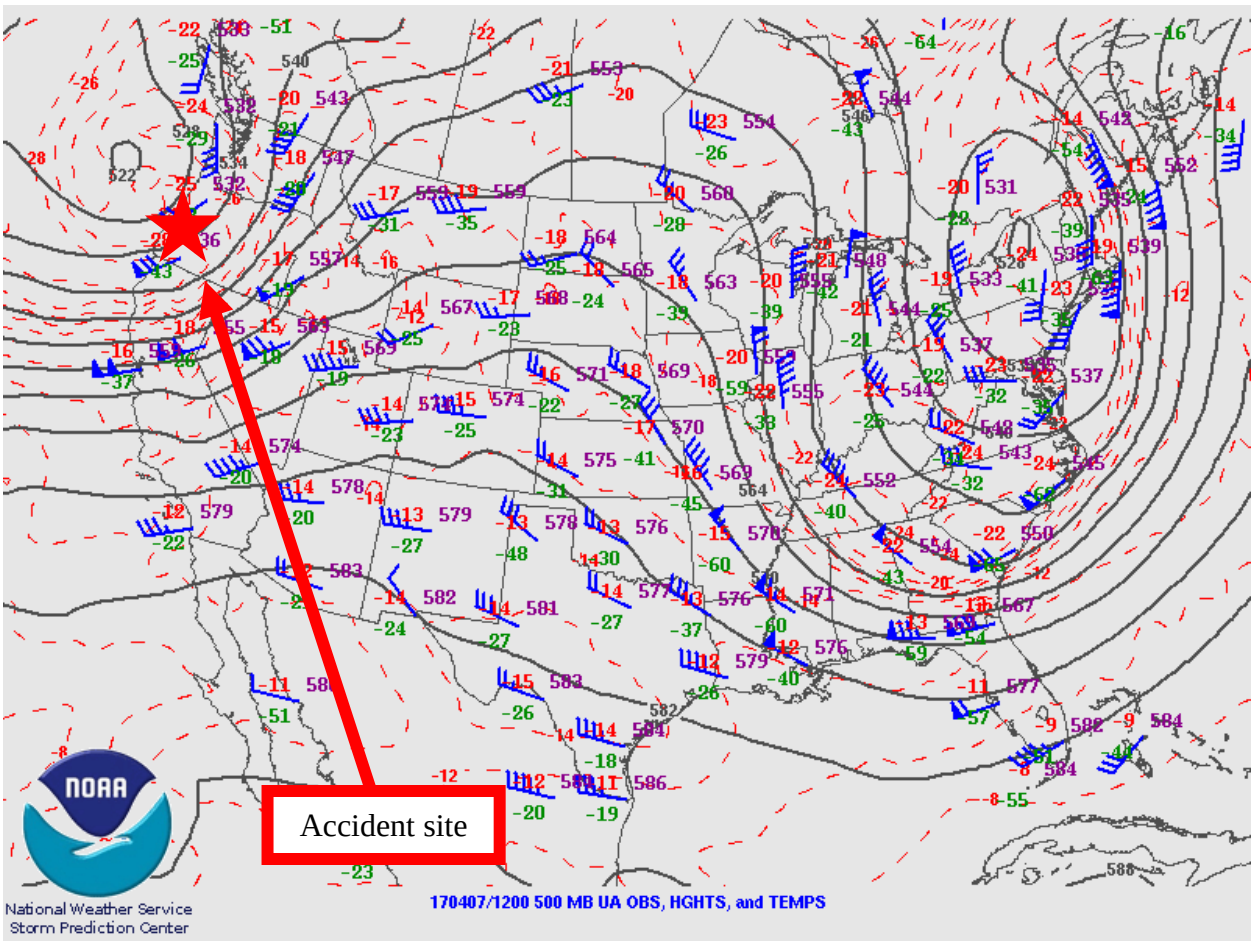

Figure 5 – 500-hPa Constant Pressure Chart for 0500 PDT

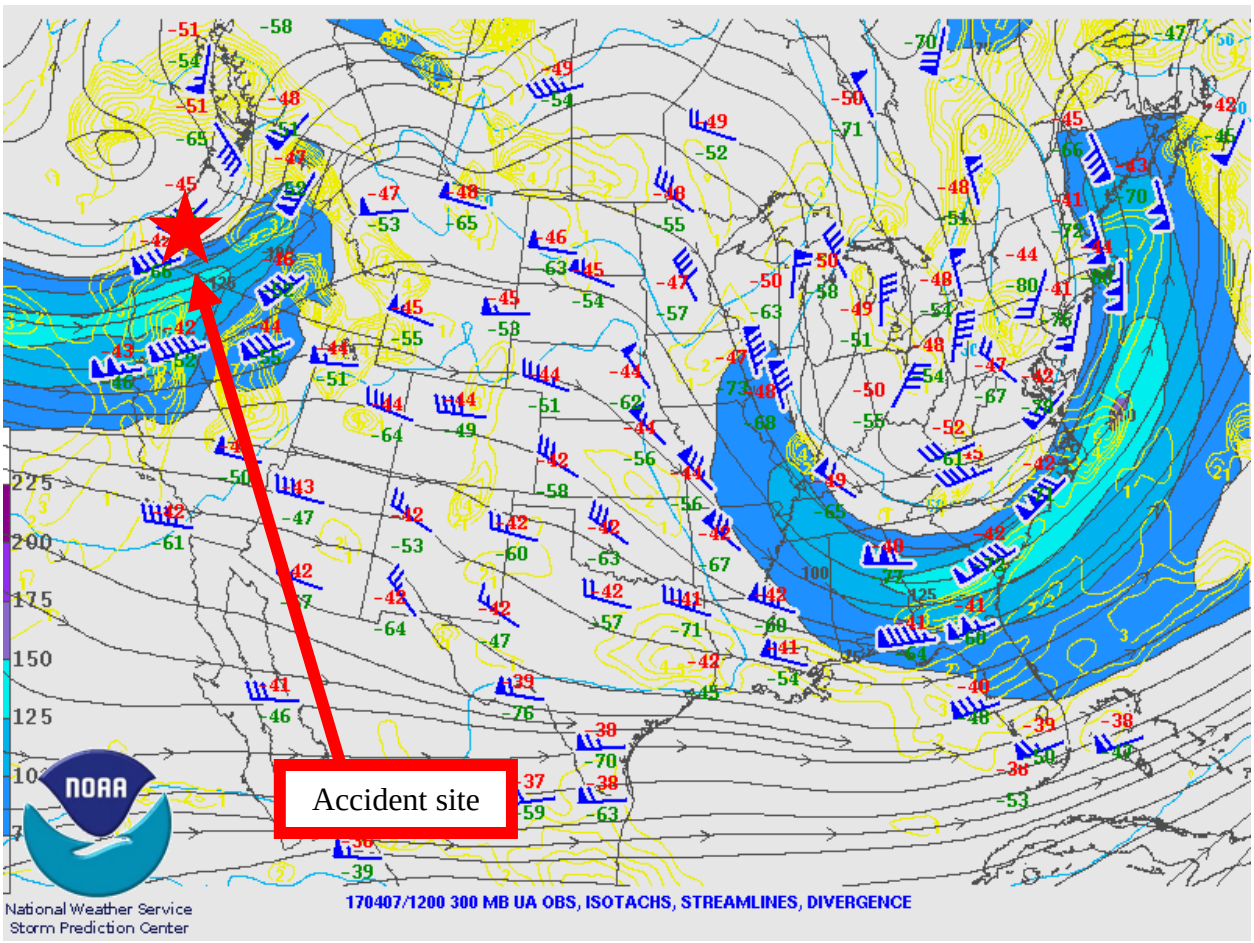

Figure 6 – 300-hPa Constant Pressure Chart for 0500 PDT

2.0 SPC Products

The SPC issued the following Day 1 Convective Outlook at 0917 PDT (figure 7) with areas of general thunderstorms forecast for the accident site during the accident day. These thunderstorm chances were relatively high compared to climatology, given that on a normal April day no chance of general thunderstorms would be forecast for the accident area. The SPC Day 1 Convective Outlook valid before the accident flight departed Van Nuys Airport (KVNY) was identical in the accident area to the SPC Day 1 Convective Outlook below:

SPC AC 071617

Day 1 Convective Outlook
NWS Storm Prediction Center Norman OK
1117 AM CDT Fri Apr 07 2017

Valid 071630Z - 081200Z

...THERE IS A MARGINAL RISK OF SEVERE THUNDERSTORMS OVER PARTS OF
THE NORTHERN INTERMOUNTAIN/NORTHERN ROCKIES REGION...

...SUMMARY...
A few thunderstorms associated with hail and strong wind gusts will be possible across northeast Oregon, extreme eastern Washington, northern Idaho, and northwest Montana through this evening.

...Synopsis...
A high-amplitude flow pattern is forecast to progress slowly eastward across the CONUS during the period as a long-wave trough approaches the Pacific coast tonight.

Within the larger-scale western trough, water vapor imagery shows a series of features that will impact convective potential over the northwest US. First, a short-wave trough is moving rapidly northeastward across the northern intermountain region, downstream from an upper low off the Pacific Northwest coast near 45.9N/126.7W that is lifting toward southern British Columbia. An upstream trough over the eastern Pacific is moving eastward and will approach the northern California coast late tonight.

...Northern Intermountain/Northern Rockies Region...
Ongoing low-topped thunderstorms are associated with the aforementioned lead short-wave trough moving across the area. This activity is expected to continue spreading toward northwest Montana into the afternoon. Additional storms are expected to develop in the wake of the initial convection from parts of northeast Oregon and northern Idaho into northwest Montana, where visible satellite imagery indicates some breaks in the cloud cover developing. This will promote zones of stronger diabatic heating to occur, and when coupled with cooling temperatures aloft, will contribute to steepening surface-500 mb lapse rates of 7.5-8.0 C/km. Although moisture will be limited with PW values of 0.5-0.75 in, MUCAPE will reach 250-400 J/kg in areas where stronger heating occurs.

Dynamic forcing for large-scale ascent associated with the left exit region of a strong southwesterly upper-level jet will overspread the region from southwest to northeast into this evening. Sufficient vertical shear /35-45 kt effective bulk shear/ coupled with steep lapse rates suggest potential for stronger cells to produce marginally severe hail. In addition, drier boundary layer profiles will enhance downdraft intensity through evaporative cooling processes, which may promote a few strong surface wind gusts through this evening.

..Weiss/Cohen.. 04/07/2017

CLICK TO GET WUUS01 PTSDY1 PRODUCT

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

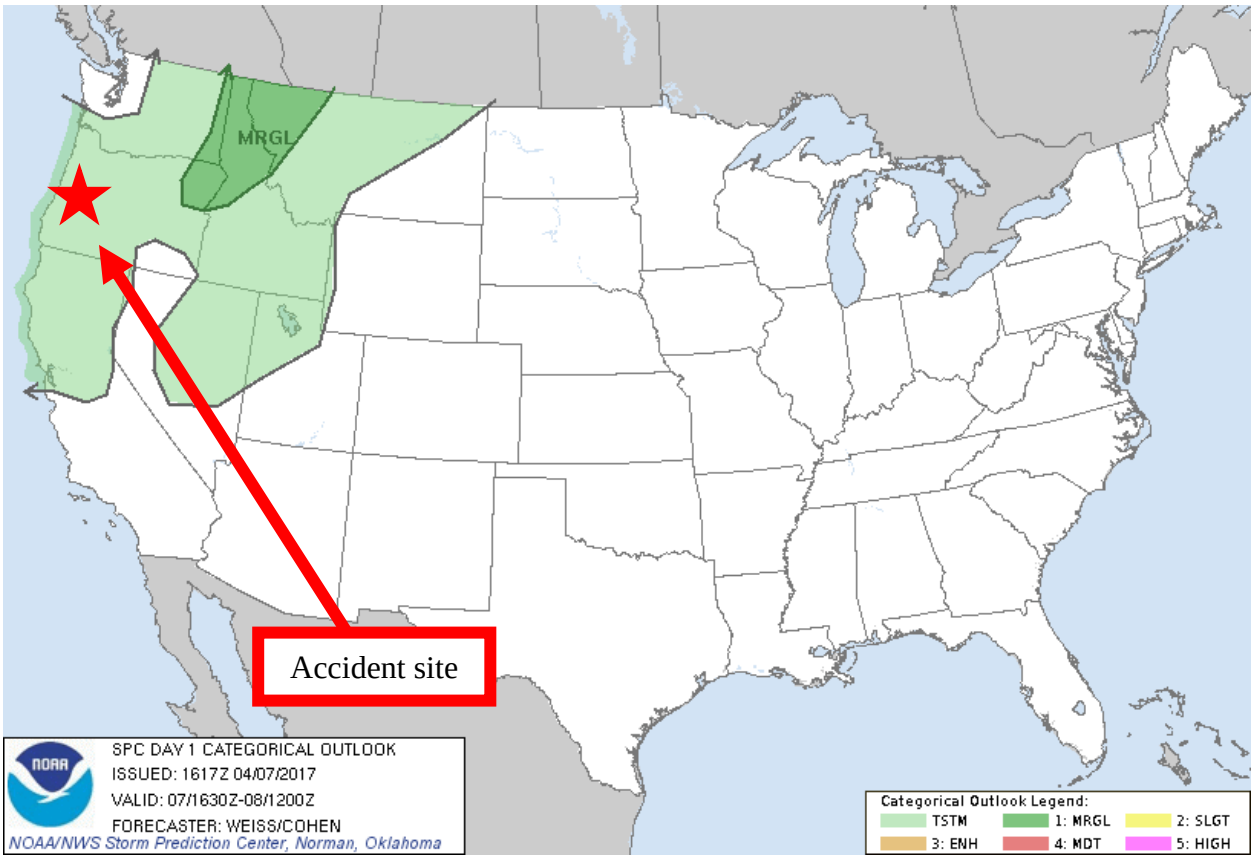

Figure 7 – SPC day 1 Convective Outlook valid at the time of the accident

3.0 Surface Observations

The area surrounding the accident site was documented using official NWS Meteorological Aerodrome Reports (METARs) and Specials (SPECIs). Figure 8 is a sectional chart with the accident site and the closest weather reporting locations to the accident site marked.

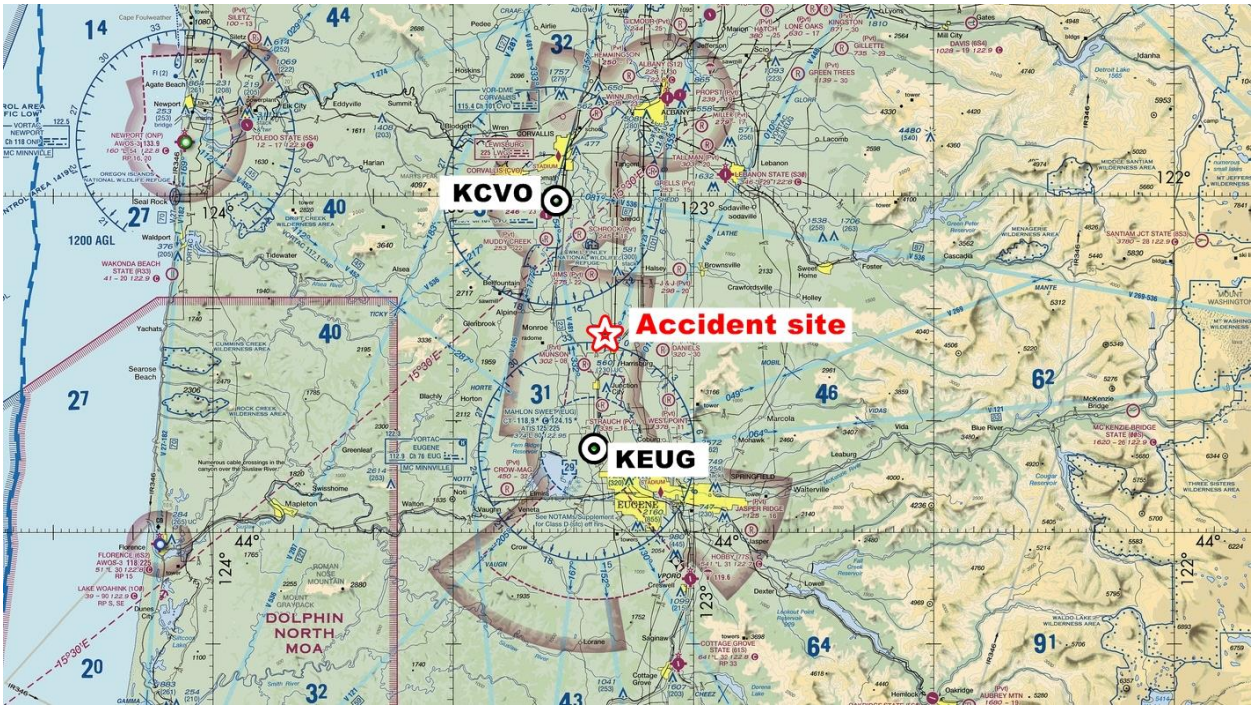

Figure 8 – Sectional chart of accident area with the location of the accident site and surface observation sites

Mahlon Sweet Field Airport (KEUG) was the closest official weather station to the accident site, and was located 7 miles northwest of Eugene, Oregon. KEUG had an Automated Surface Observing System (ASOS[2]) whose reports were supplemented by an official weather observer. KEUG was located 10 miles south of the accident site, at an elevation of 374 ft, and had a 16° easterly magnetic variation[3] (figure 8). The following observations were taken and disseminated during the times surrounding the accident:[4]

[0454 PDT] METAR KEUG 071154Z AUTO 18022G35KT 10SM 11/06 A2921 RMK AO2 PK WND 18035/1146 SLP889 60001 70012 T01060056 10122 20089 56010 CHINO RNW 34 $=

[0554 PDT] METAR KEUG 071254Z 18024G36KT 10SM SCT050 OVC065 11/04 A2922 RMK AO2 PK WND 17036/1246 SLP893 T01110039 $=

[0654 PDT] METAR KEUG 071354Z 17025G35KT 7SM -RA BKN034 BKN048 BKN075 11/04 A2929 RMK AO2 PK WND 18039/1256 RAB47 SLP917 T01110039 PNO $=

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

[3] Magnetic variation – The angle (at a particular location) between magnetic north and true north. 2010, latest measurement taken from http://www.airnav.com/airport/KEUG

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

[0754 PDT] METAR KEUG 071454Z 19015KT 6SM BR BKN032 BKN050 OVC065 10/07 A2937 RMK AO2 RAE50 SLP944 6//// T01000072 53055 PNO $=

[0827 PDT] SPECI KEUG 071527Z 19013KT 6SM -RA BR BKN024 OVC050 10/07 A2940 RMK AO2 RAB17 T01000072 PNO $=

[0854 PDT] METAR KEUG 071554Z 18013KT 7SM -RA BKN021 OVC050 10/06 A2942 RMK AO2 RAB17 SLP961 T01000061 PNO $=

[0954 PDT] METAR KEUG 071654Z 18025G35KT 10SM SCT025 BKN033 OVC041 09/06 A2946 RMK AO2 PK WND 18035/1652 RAE1556B12E35 SLP977 P0000 T00890061=

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[1054 PDT] METAR KEUG 071754Z 20018G26KT 7SM -RA FEW024 OVC035 08/07 A2951 RMK AO2 PK WND 18035/1706 RAB1656 SLP992 P0011 6//// T00830067 51046 $=

[1122 PDT] SPECI KEUG 071822Z 19027G36KT 8SM -RA SCT024 OVC037 09/07 A2953 RMK AO2 PK WND 18036/1820 P0003 T00890067 $=

[1154 PDT] METAR KEUG 071854Z 19022G30KT 10SM SCT024 BKN040 BKN090 10/06 A2955 RMK AO2 PK WND 20038/1832 RAE39 PRESRR SLP006 P0003 T01000061 $=

[1254 PDT] METAR KEUG 071954Z 23012G22KT 8SM -RA SCT025 BKN035 OVC045 09/07 A2958 RMK AO2 PK WND 19035/1921 RAB19E30B48 SLP017 P0000 T00940072=

KEUG weather at 0854 PDT, wind from 180° at 13 knots, 7 miles visibility, light rain, broken ceiling at 2,100 ft above ground level (agl), overcast skies at 5,000 ft agl, temperature of 10° Celsius (C), dew point temperature of 6° C, and an altimeter setting of 29.42 inches of mercury. Remarks, station with a precipitation discriminator, rain began at 0817 PDT, sea level pressure 996.1 hPa, temperature 10.0° C, dew point temperature 6.1° C, tipping bucket rain gauge sensor is not operating, maintenance is needed on the system.

KEUG weather at 0954 PDT, wind from 180° at 25 knots with gusts to 35 knots, 10 miles visibility, scattered clouds at 2,500 ft agl, broken ceiling at 3,300 ft agl, overcast skies at 4,100 ft agl, temperature of 9° C, dew point temperature of 6° C, and an altimeter setting of 29.46 inches of mercury. Remarks, station with a precipitation discriminator, peak wind from 180° at 35 knots at 0952 PDT, rain ended at 0856 PDT, rain began at 0912 PDT, rain ended at 0935 PDT, sea level pressure 997.7 hPa, one-hourly precipitation of a trace, temperature 8.9° C, dew point temperature 6.1° C.

KEUG weather at 1054 PDT, wind from 200° at 18 knots with gusts to 26 knots, 7 miles visibility, light rain, few clouds at 2,400 ft agl, overcast ceiling at 3,500 ft agl, temperature of 8° C, dew point temperature of 7° C, and an altimeter setting of 29.51 inches of mercury. Remarks, station with a precipitation discriminator, peak wind from 180° at 35 knots at 1006 PDT, rain began at 0956 PDT, sea level pressure 999.2 hPa, one-hourly precipitation of 0.11 inches, 6-hourly precipitation unknown, temperature 8.3° C, dew point temperature 6.7° C, 3-hourly pressure increase of 4.6 hPa, maintenance is needed on the system.

KEUG weather at 1122 PDT, wind from 190° at 27 knots with gusts to 36 knots, 8 miles visibility, light rain, scattered clouds at 2,400 ft agl, overcast ceiling at 3,700 ft agl, temperature of 9° C, dew point temperature of 7° C, and an altimeter setting of 29.53 inches of mercury. Remarks, station with a precipitation discriminator, peak wind from 180 at 36 knots at 1120 PDT, one-hourly precipitation of 0.03 inches, temperature 8.9° C, dew point temperature 6.7° C, maintenance is needed on the system.

Corvallis Municipal Airport (KCVO) was located 4 miles southwest of Corvallis, Oregon. KCVO had an Automated Weather Observing System (AWOS[5]) whose reports were not supplemented. KCVO was located 13 miles north-northwest of the accident site, at an elevation of 250 ft, and had a 15° easterly magnetic variation[6] (figure 8). The following observations were taken and disseminated during the times surrounding the accident:[7]

[0835 PDT] METAR KCVO 071535Z 18010KT 9SM FEW020 BKN033 OVC050 09/06 A2935 RMK AO1=

[0855 PDT] METAR KCVO 071555Z 18011KT 10SM FEW031 BKN039 OVC050 09/06 A2937 RMK AO1=

[0915 PDT] METAR KCVO 071615Z 18010KT 9SM FEW029 SCT038 OVC048 09/06 A2938 RMK AO1=

[0935 PDT] METAR KCVO 071635Z 17010KT 5SM FEW032 SCT042 BKN048 09/07 A2939 RMK AO1=

[0955 PDT] METAR KCVO 071655Z 18008KT 5SM FEW019 SCT033 BKN040 09/07 A2941 RMK AO1=

[1015 PDT] METAR KCVO 071715Z 17010KT 9SM SCT018 BKN031 OVC049 09/07 A2944 RMK AO1=

[5] 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.

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

[7] 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 affected the accident location around the accident time. The local times in section 3.0 next to the METARs are provided for quick reference between UTC and local times around the accident time.

[1035 PDT] METAR KCVO 071735Z 18009KT 8SM SCT021 BKN035 OVC055 09/07 A2946 RMK AO1=

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[1055 PDT] METAR KCVO 071755Z 18007KT 7SM FEW015 SCT022 BKN029 09/07 A2947 RMK AO1 10100 20080 52054=

[1115 PDT] METAR KCVO 071815Z 17009KT 9SM FEW022 BKN030 OVC042 09/07 A2948 RMK AO1=

[1135 PDT] METAR KCVO 071835Z 18011KT 10SM FEW029 SCT039 BKN047 10/08 A2949 RMK AO1=

[1155 PDT] METAR KCVO 071855Z 18010KT 7SM FEW030 BKN039 OVC055 09/07 A2950 RMK AO1=

KCVO weather at 1015 PDT, wind from 170° at 10 knots, 9 miles visibility, scattered clouds at 1,800 ft agl, broken ceiling at 3,100 ft agl, overcast skies 4,900 ft agl, temperature of 9° C, dew point temperature of 7° C, and an altimeter setting of 29.44 inches of mercury. Remarks, station without a precipitation discriminator.

KCVO weather at 1035 PDT, wind from 180° at 9 knots, 8 miles visibility, scattered clouds at 2,100 ft agl, broken ceiling at 3,500 ft agl, overcast skies 5,500 ft agl, temperature of 9° C, dew point temperature of 7° C, and an altimeter setting of 29.46 inches of mercury. Remarks, station without a precipitation discriminator.

KCVO weather at 1055 PDT, wind from 180° at 7 knots, 7 miles visibility, few clouds at 1,500 ft agl, scattered clouds at 2,200 ft agl, broken ceiling at 2,900 ft agl, temperature of 9° C, dew point temperature of 7° C, and an altimeter setting of 29.47 inches of mercury. Remarks, station without a precipitation discriminator, 6-hourly maximum temperature of 10.0° C, 6-hourly minimum temperature of 8.0° C, 3-hourly pressure increase of 5.4 hPa.

KCVO weather at 1115 PDT, wind from 170° at 9 knots, 9 miles visibility, few clouds at 2,200 ft agl, broken ceiling at 3,000 ft agl, overcast skies 4,200 ft agl, temperature of 9° C, dew point temperature of 7° C, and an altimeter setting of 29.48 inches of mercury. Remarks, station without a precipitation discriminator.

The observations from KEUG and KCVO surrounding the accident time indicated surface winds gusts to 36 knots with MVFR[8] to VFR[9] ceiling conditions.

[8] Marginal Visual Flight Rules – Refers to the general weather conditions pilots can expect at the surface. MVFR criteria means a ceiling between 1,000 and 3,000 ft agl and/or 3 to 5 miles visibility.
[9] 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.

4.0 Upper Air Data

A High-Resolution Rapid Refresh (HRRR)[10] model sounding was created for the accident site for 1100 PDT. The 1100 PDT sounding was plotted on a standard Skew-T log P diagram[11] with the derived stability parameters included in figure 9 (with data from the surface to 600-hPa, or 14,000 ft msl.) This sounding data was analyzed using the RAOB[12] software package. The sounding depicted the lifted condensation level (LCL)[13] at 1,718 ft msl, a convective condensation level (CCL)[14] of 2,302 ft, and a level of free convection (LFC)[15] at 1,864 ft. The freezing level was 4,241 ft. The precipitable water value was 0.57 inches.

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

[11] 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.

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

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

[14] 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.

[15] 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.

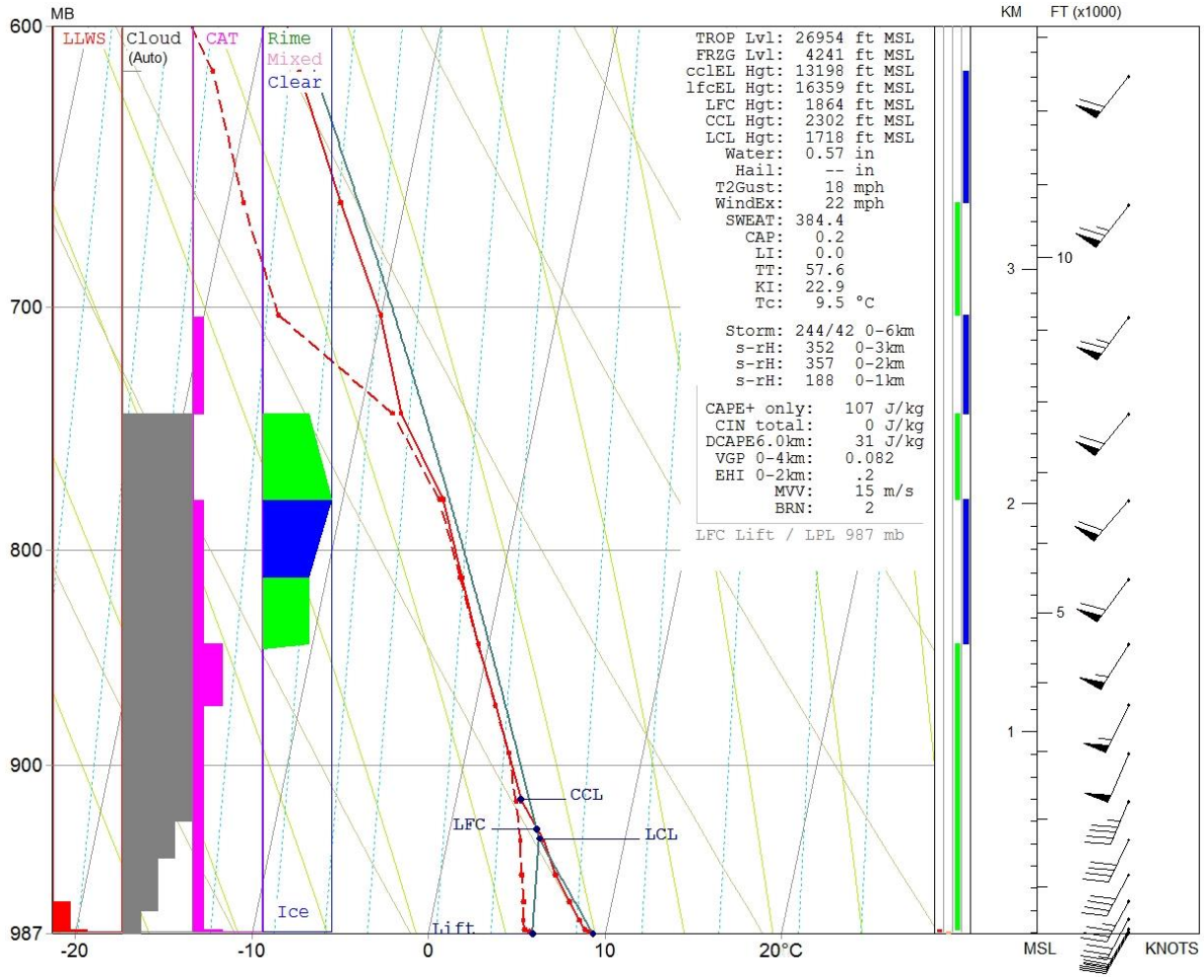


Figure 9 – 1100 PDT HRRR sounding for the accident site

The 1100 PDT HRRR sounding indicated a conditionally unstable environment from the surface through 4,500 ft. There was 107 J/kg of CAPE[16]. The maximum vertical velocity (MVV) for this atmosphere was calculated as 15 meters/second (about 2,953 ft per minute).[17] Downdraft CAPE (DCAPE; 6 kilometers agl)[18] was measured at 31 Joules/kilogram. RAOB identified the possibility of clouds between the surface and 8,000 ft. RAOB identified that moderate or greater icing was likely between 4,500 and 8,000 ft.

The 1100 PDT HRRR sounding wind profile indicated a surface wind from 208° at 20 knots with the wind remaining southwesterly through 14,000 ft. The wind speed increased to 40 by 1,500 ft and 50 knots by 3,000 ft. RAOB indicated the possibility of low-level wind shear (LLWS) between the surface and 1,000 ft. RAOB indicated the possibility of clear-air turbulence in two layers between the surface and 9,000 ft.

[16] Convective Available Potential Energy (CAPE) – CAPE is a measure of the amount of energy available for convection and is directly related to the maximum potential vertical speed within an updraft.
[17] MVV is not usually considered a realistic estimate for maximum vertical velocity in a storm. Anecdotes suggest considering a value of MVV/2, however it is not well understood when or where such a half-value should be applied.
[18] The DCAPE can be used to estimate the potential strength of rain-cooled downdrafts within thunderstorm convection, and is similar to CAPE. Larger DCAPE values are associated with stronger downdrafts.

5.0 Satellite Data

Visible and infrared data from the Geostationary Operational Environmental Satellite number 15 (GOES-15) data was obtained from an archive at the Space Science Engineering Center at the University of Wisconsin-Madison in Madison, Wisconsin, and processed using the Man-computer Interactive Data Access System software. Visible and infrared imagery (GOES-15 bands 1 and 4) at wavelengths of 0.65 microns (μm) and 10.7 μm, respectively, were retrieved for the period. Satellite imagery surrounding the time of the accident, from 0900 PDT through 1300 PDT at approximately 15-minute intervals were reviewed, and the closest images to the time of the accident are documented here.

Figures 10 and 11 present the GOES-15 visible imagery from 1045 and 1052 PDT at 2X magnification with the accident site marked with a red box. The visible imagery indicated cloud cover above the accident site at the accident time with the cloud cover cumuliform in nature moving from southwest to northeast (attachment 1). Figure 12 presents the GOES-15 infrared imagery from 1045 PDT at 6X magnification with the accident site highlighted with a red square. Inspection of the infrared imagery indicated cloud cover over the accident site with that cloud cover moving from southwest to northeast (attachment 2). The lower brightness temperatures (green colors, higher cloud tops) were located above the accident site at the accident time, with the lower brightness temperatures moving northeast of the accident site after the accident time. Based on the brightness temperatures above the accident site and the vertical temperature profile provided by the 1100 PDT HRRR sounding, the approximate cloud-top heights over the accident site were 18,000 ft at 1045 PDT. It should be noted these figures have not been corrected for any parallax error.

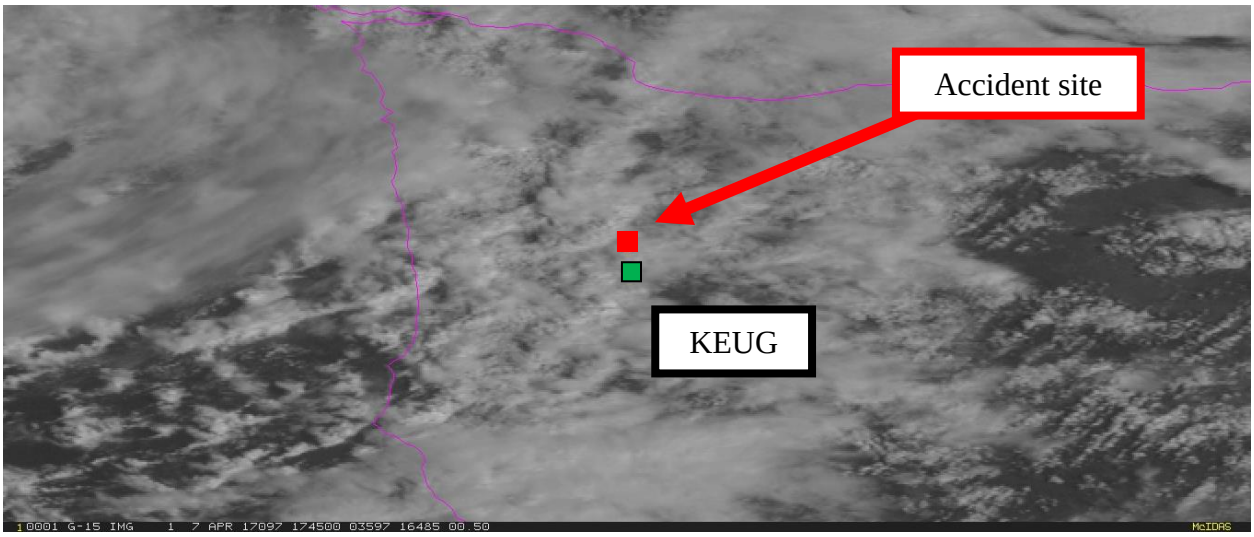


Figure 10 – GOES-15 visible image at 1045 PDT

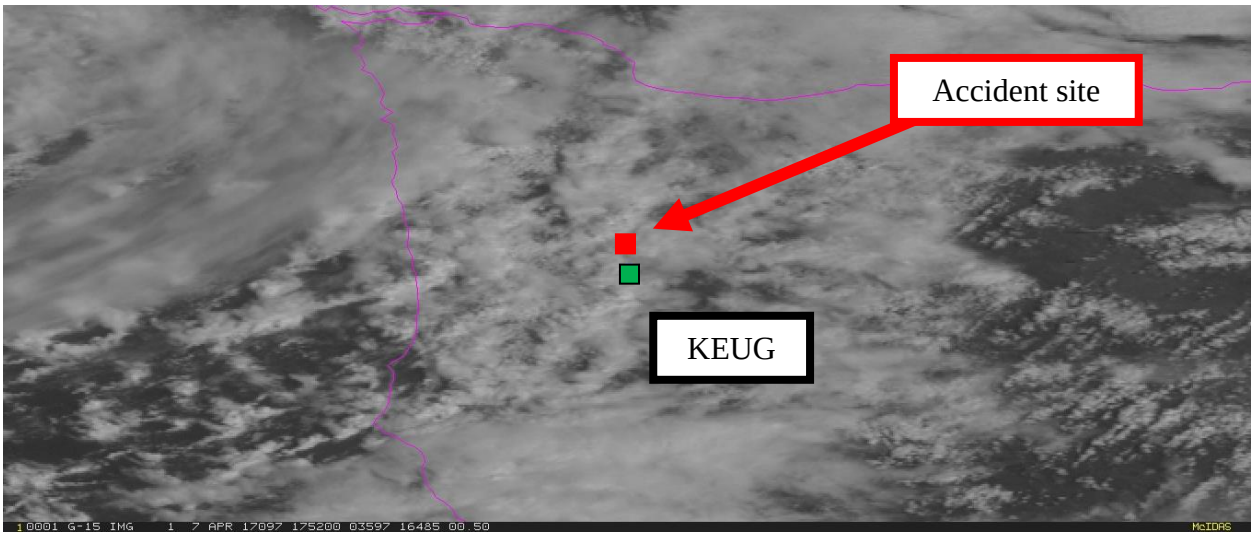


Figure 11 – GOES-15 visible image at 1052 PDT

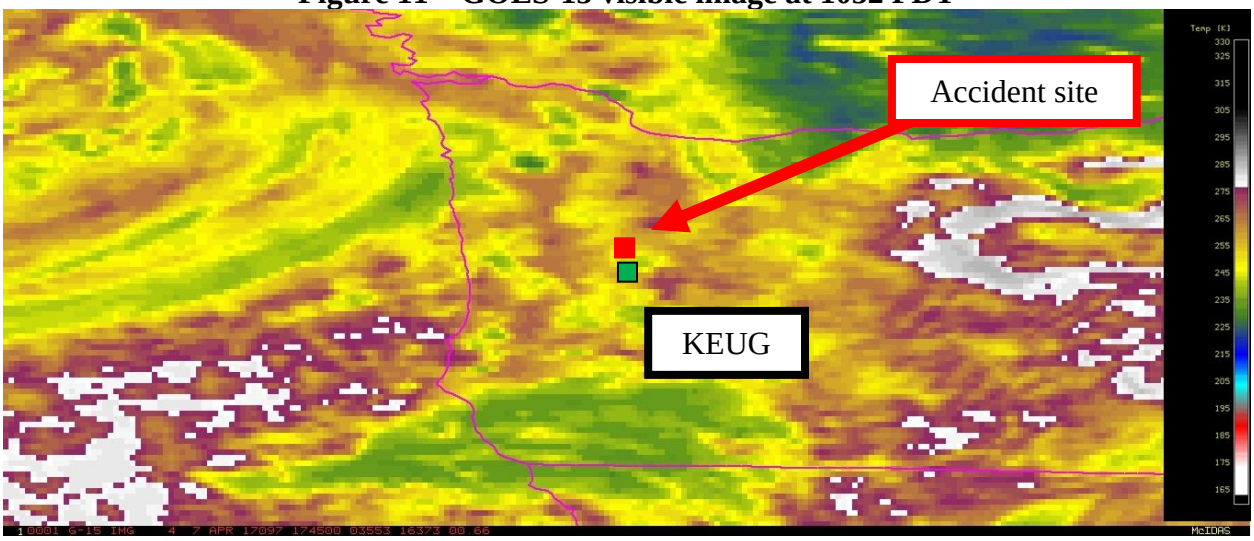


Figure 12 – GOES-15 infrared image at 1045 PDT

6.0 Radar Imagery Information

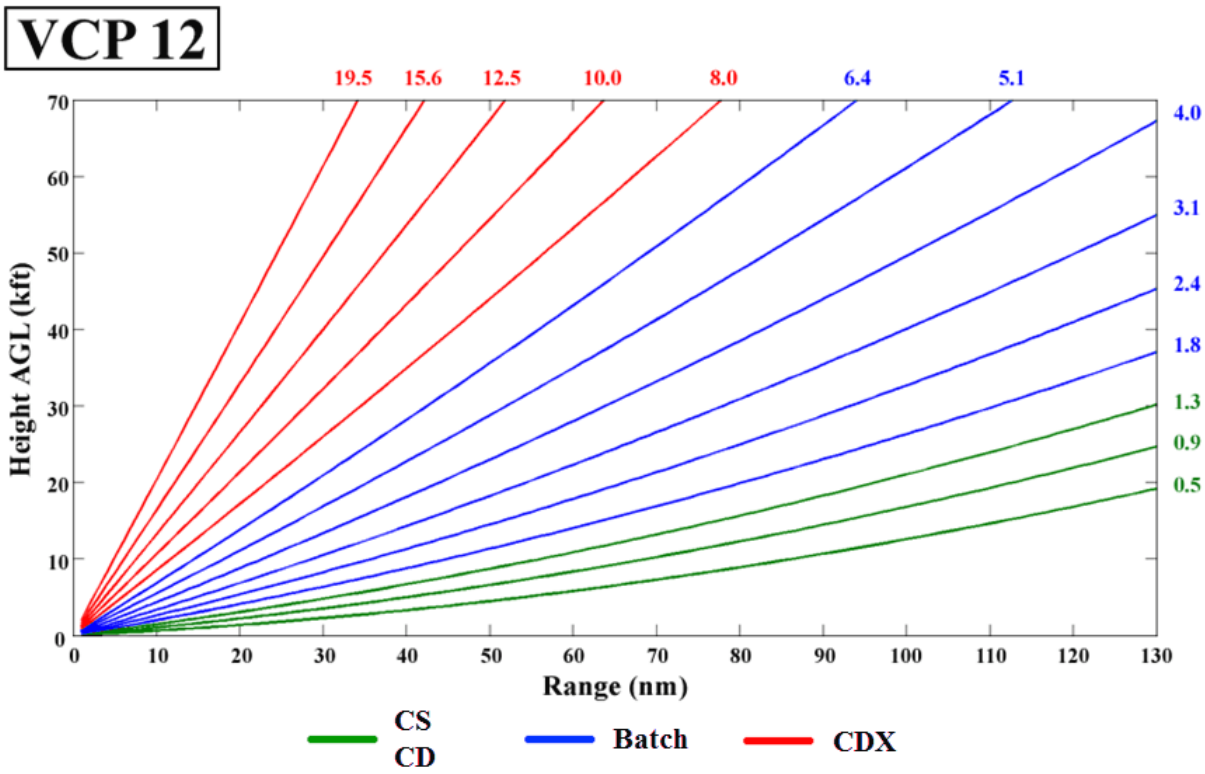
The closest NWS Weather Surveillance Radar-1988, Doppler (WSR-88D)[19] to the accident site was the Portland, Oregon, radar (KRTX), which was located 86 miles north-northeast of the accident site at an elevation of 1,572 ft. Level II and III archive radar data were obtained from the NCEI utilizing the NEXRAD Data Inventory Search and displayed using the NOAA's Weather and Climate Toolkit software.

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

6.1 Volume Scan Strategy

The WSR-88D is a computer-controlled radar system, which automatically creates a complete series of specific scans in a specific sequence known as a volume scan. Individual elevation scans are immediately available on the WSR-88D's Principle Users Processor (PUP). Products that require data from multiple elevation scans are not available until the end of the five to ten minute volume scan.

The WSR-88D operates in several different scanning modes, identified as Mode A and Mode B. Mode A is the precipitation scan and has three common scanning strategies. The most common is where the radar makes 14 elevation scans from 0.5° to 19.5° every four and a half minutes. This particular scanning strategy is documented as volume coverage pattern 12 (VCP-12). Mode B is the clear-air mode, where the radar makes 5 elevation scans during a ten minute period. During the period surrounding the accident, the KRTX WSR-88D radar was operating in the precipitation mode (Mode A, VCP-12). The following chart provides an indication of the different elevation angles in this VCP, and the approximate height and width of the radar beam with distance from the radar site.



VCP-12 Precipitation Mode Scan Strategy[20]

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

6.2 Beam Height Calculation

Assuming standard refraction[21] of the WSR-88D 0.95° wide radar beam, the following table shows the approximate beam height and width[22] information[23] of the radar display over the site of the accident. The heights have been rounded to the nearest 10 ft.

ANTENNA ELEVATION	BEAM CENTER	BEAM BASE	BEAM TOP	BEAM WIDTH
0.5°	11,490 ft	7,250 ft	15,730 ft	8,480 ft

Based on the radar height calculations, the 0.5° elevation scan depicted the conditions between 7,250 ft and 15,730 ft msl over the accident site and these are the closest altitudes to the accident flight level before the accident occurred.[24]

6.3 Reflectivity

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

W – With range unfolding (W)
WO – Without range unfolding (WO)

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

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

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

[24] For more information, please see the air traffic control (ATC) data located in the docket for this accident.

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

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

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

6.4 Base Reflectivity and Lightning Data

Figures 13 through 15 present the KRTX WSR-88D base reflectivity images for the 0.5° elevation scans initiated at 1046, 1048, and 1051 PDT with a resolution of 0.5° X 250 meters. The ATC flight track is also included with the arrows pointing in the direction of travel. The accident flight track indicated that an area of 10 to 20 dBZ reflectivity values was located along and above the route of flight between 1046 and 1051 PDT. KRTX data between 1029 and 1101 PDT (attachment 3) indicated that the reflectivity values were moving from southwest to northeast, with the 10 to 20 dBZ reflectivity values located along and north of KEUG. The WSR-88D reflectivity values above the accident site at the accident time would correspond to light precipitation (section 6.3). There were no lightning flashes[27] and strikes surrounding the accident site around the accident time.[28]

[27] Lightning Flash – This is one contiguous conducting channel and all the current strokes/pulses that flow through it. There are two types of flashes: ground flashes and cloud flashes.
[28] A review of Earth Networks Total Lightning network was done.

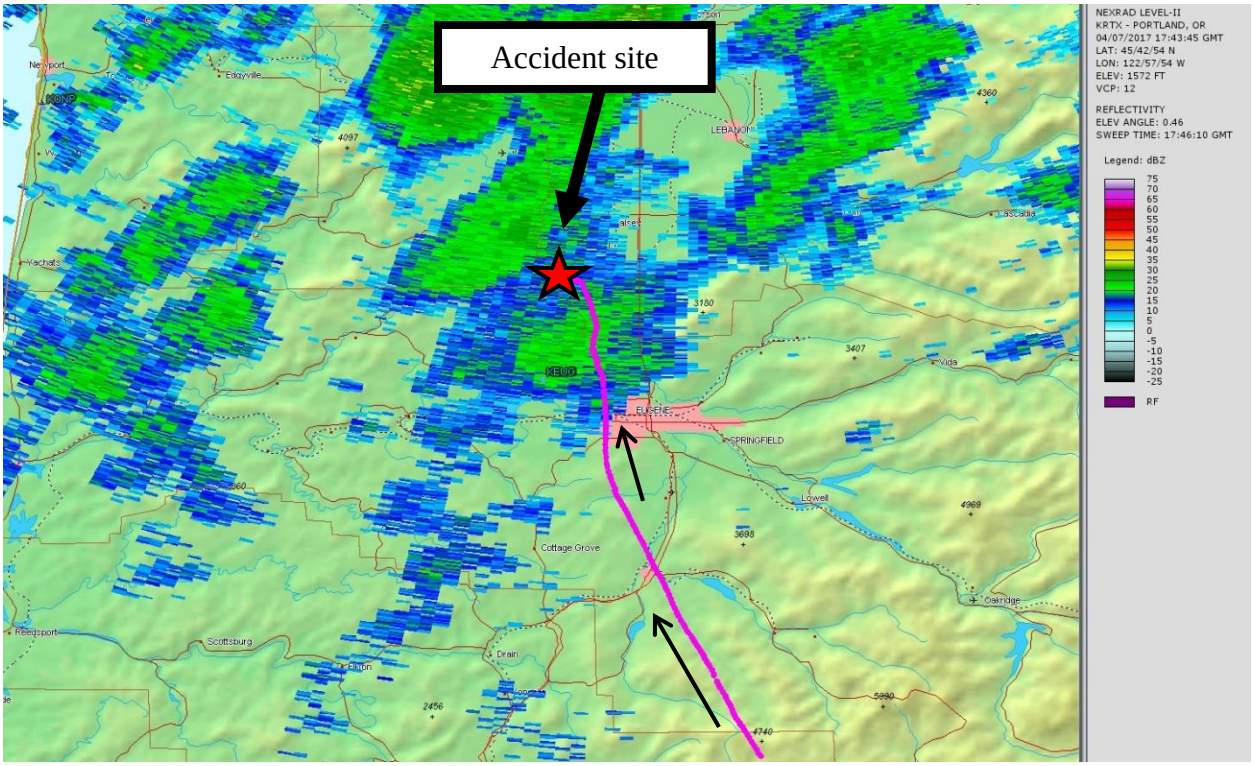


Figure 13 – KRTX WSR-88D reflectivity for the 0.5° elevation scan initiated at 1046 PDT with the ATC flight track (pink dots) and arrows pointing in direction of travel

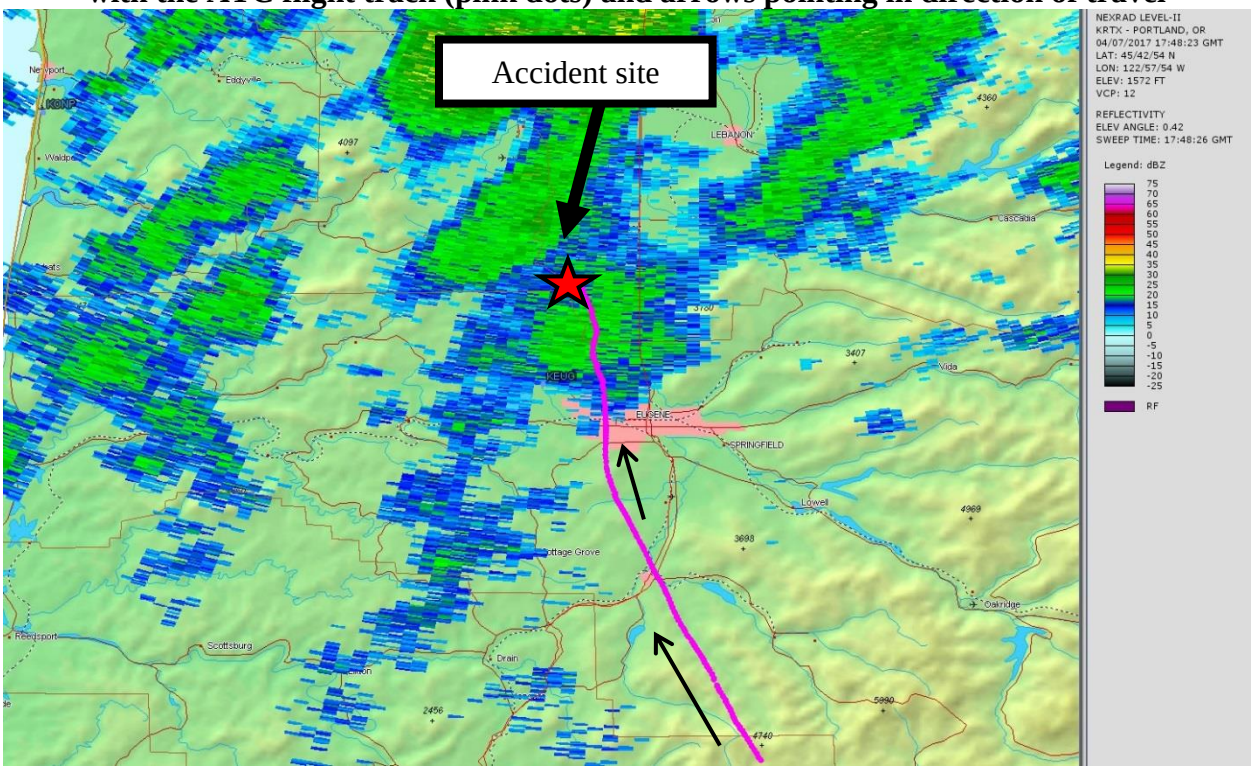


Figure 14 – KRTX WSR-88D reflectivity for the 0.5° elevation scan initiated at 1048 PDT with the ATC flight track (pink dots) and arrows pointing in direction of travel

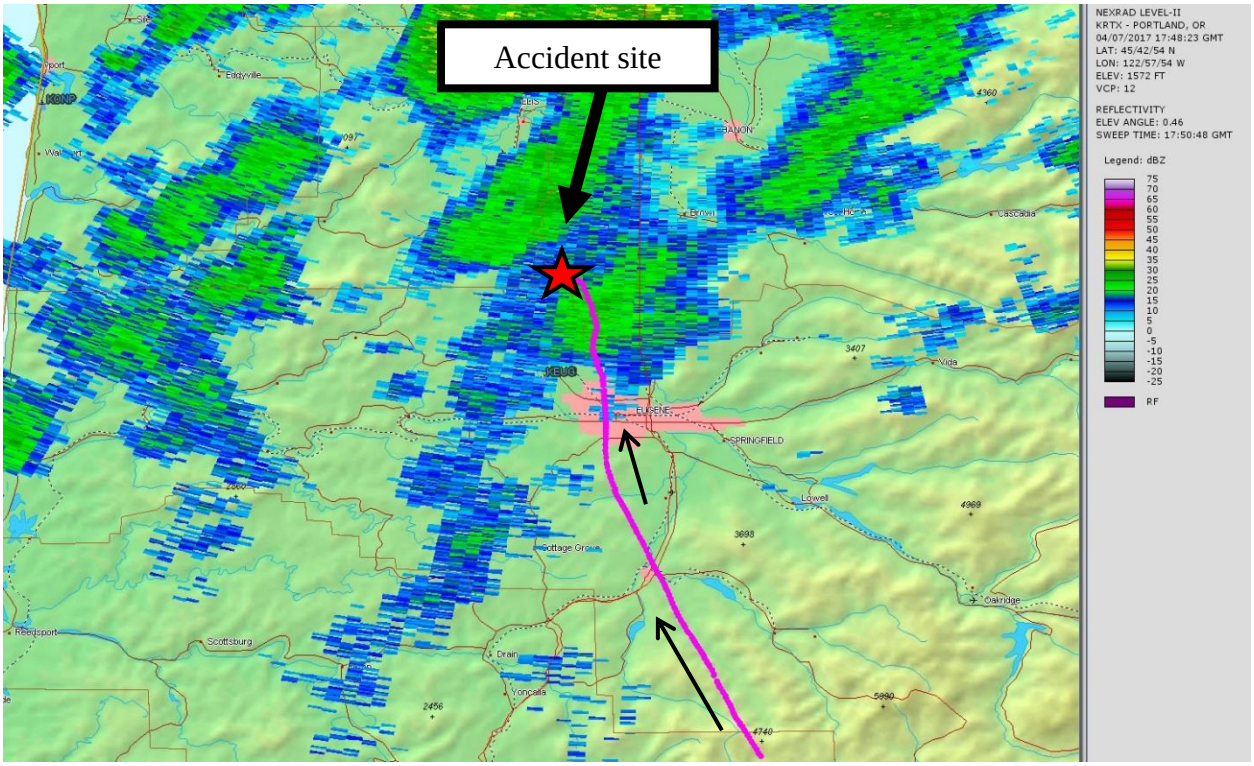


Figure 15 – KRTX WSR-88D reflectivity for the 0.5° elevation scan initiated at 1051 PDT with the ATC flight track (pink dots) and arrows pointing in direction of travel

6.5 ATC STARS Weather Imagery

ATC provided weather information to the accident pilot while on approach to KEUG.[29] ATC had a view of the weather information via the Standard Terminal Automation Replacement System (STARS) , which used the Airport Surveillance Radar-9 (ASR-9) and ASR-11 sites around KEUG to provide a display of the precipitation intensity information for ATC. An exemplar display of the STARS precipitation levels is provided in figure 16 with the corresponding dBZ values below (section 6.3):[30]

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

Figures 17 through 21 showed a view of the STARS display of weather and precipitation from 1044:02, 1046:02, 1048:02, 1048:29, and 1050:06 PDT with the accident flight marked. At

[29] For more information see the ATC data contained in the docket of this accident.
[30] For more information regarding STARS display please see attachment 2 of CEN16FA276 and weather factual data from CEN16LA286.

1044:02 PDT, the accident flight was located in level 2 precipitation with level 4 and 5 precipitation to the west and north of the accident flight (figure 17). By 1046:02 PDT, the accident flight was located in level 3 precipitation with level 4 and 5 precipitation between the accident flight and KEUG (figure 18). The accident flight was located in level 3 and 4 precipitation at 1048:02 PDT (figure 19) with the level 4 precipitation area increasing by 1048:29 PDT to fully cover the accident flight location (figure 20). By 1050:06 PDT, level 4 and 5 precipitation was indicated directly above the accident site (figure 21).

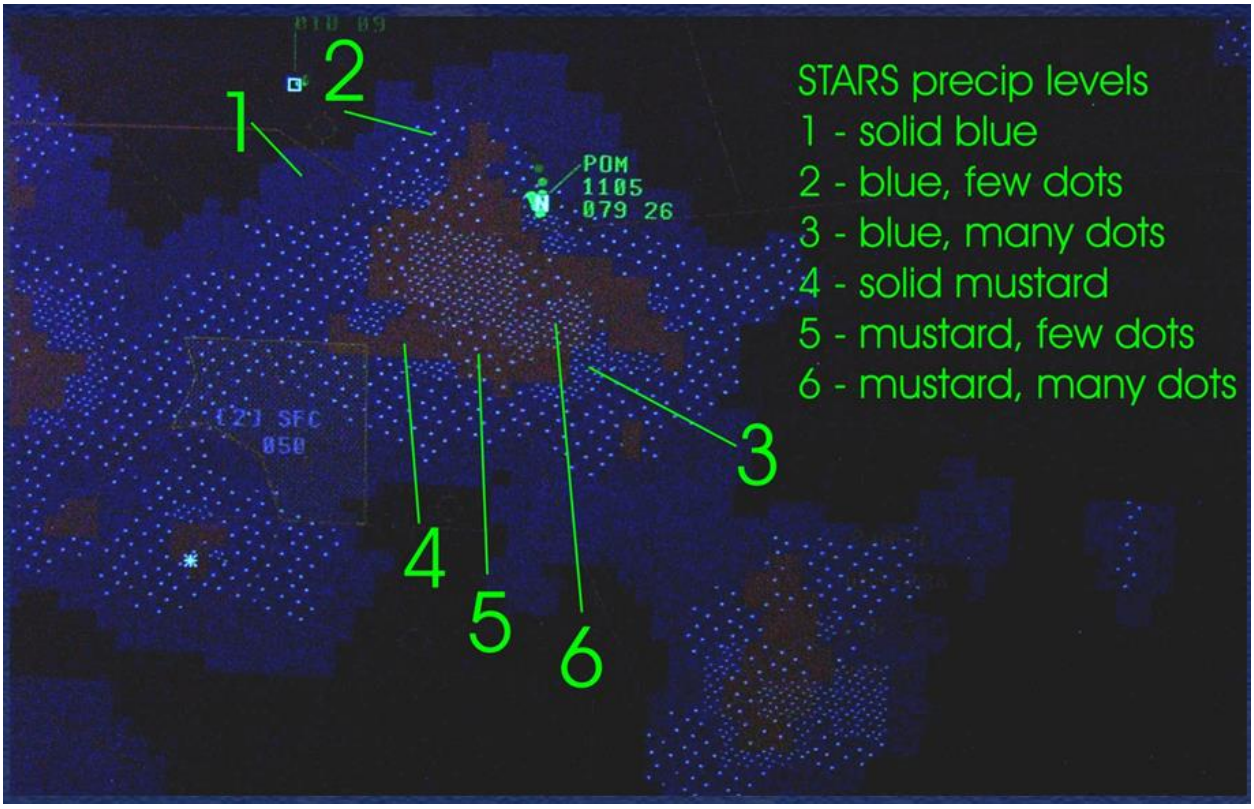


Figure 16 – Exemplar display of STARS precipitation levels 1 through 6

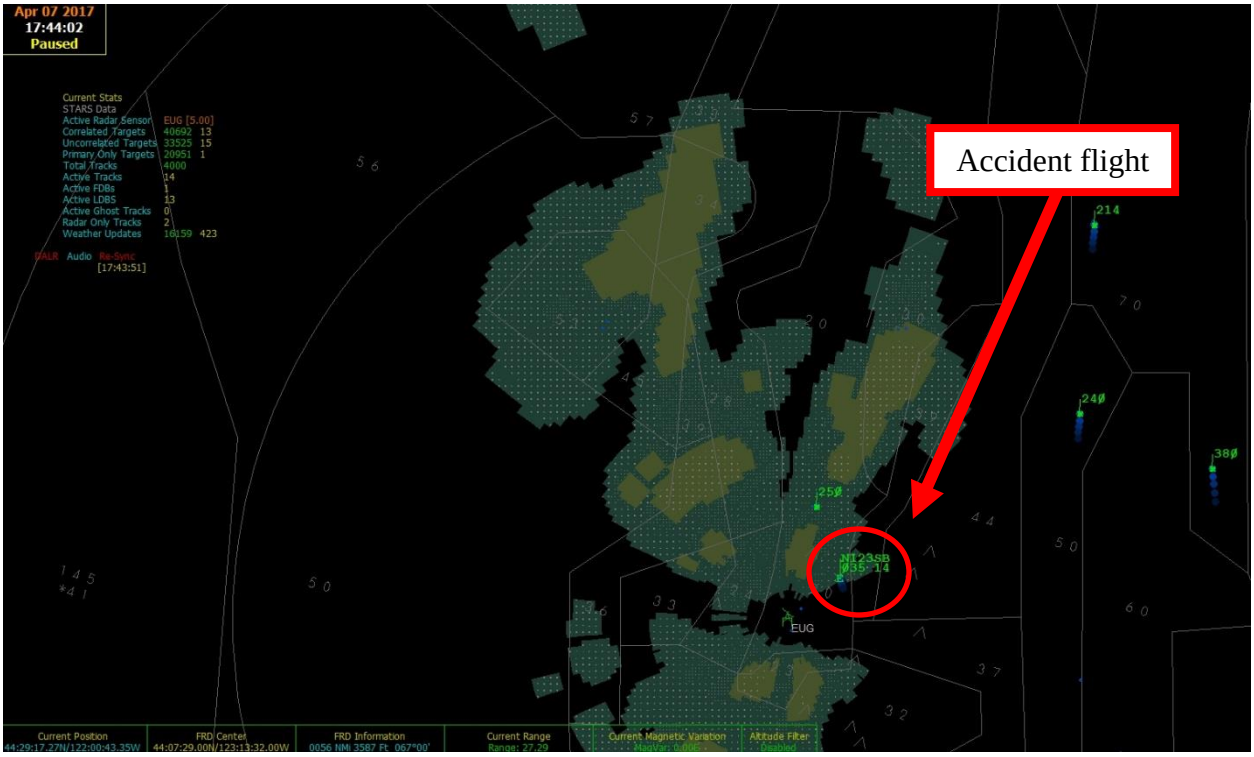


Figure 17 – STARS weather and precipitation level display from 1044:02 PDT

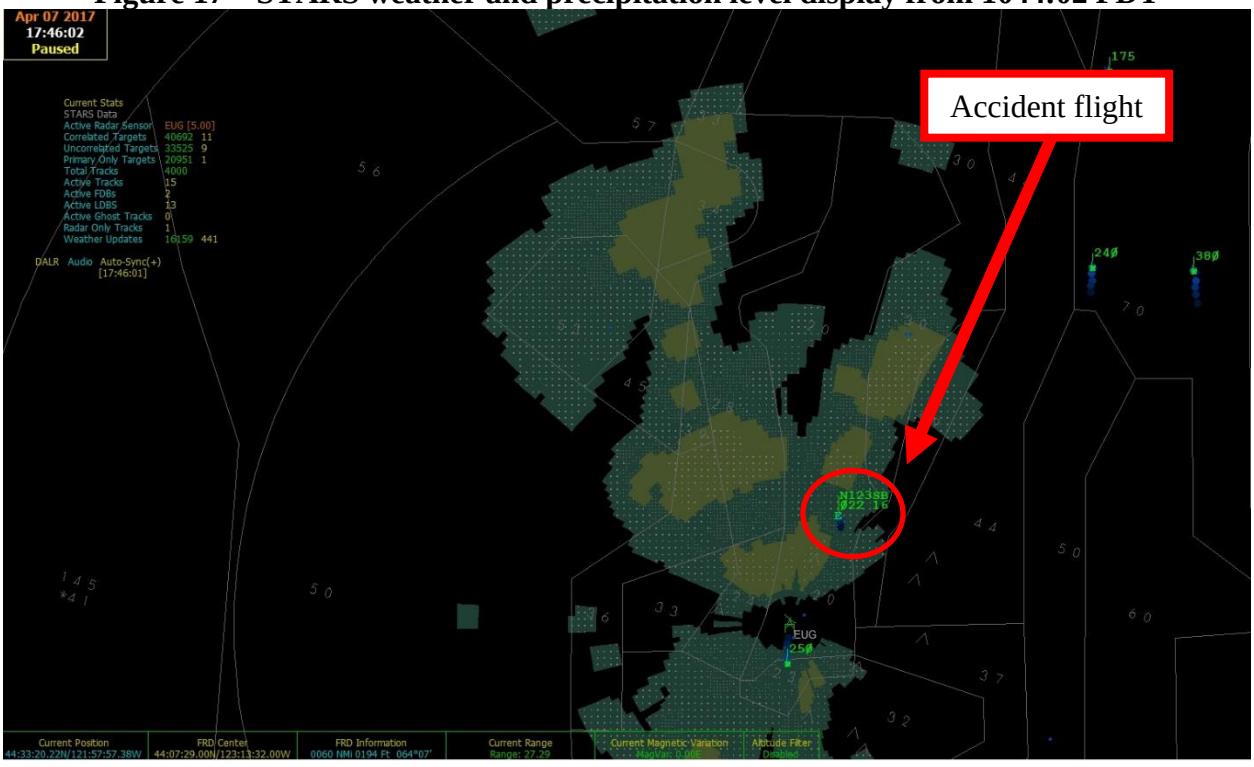


Figure 18 – STARS weather and precipitation level display from 1046:02 PDT

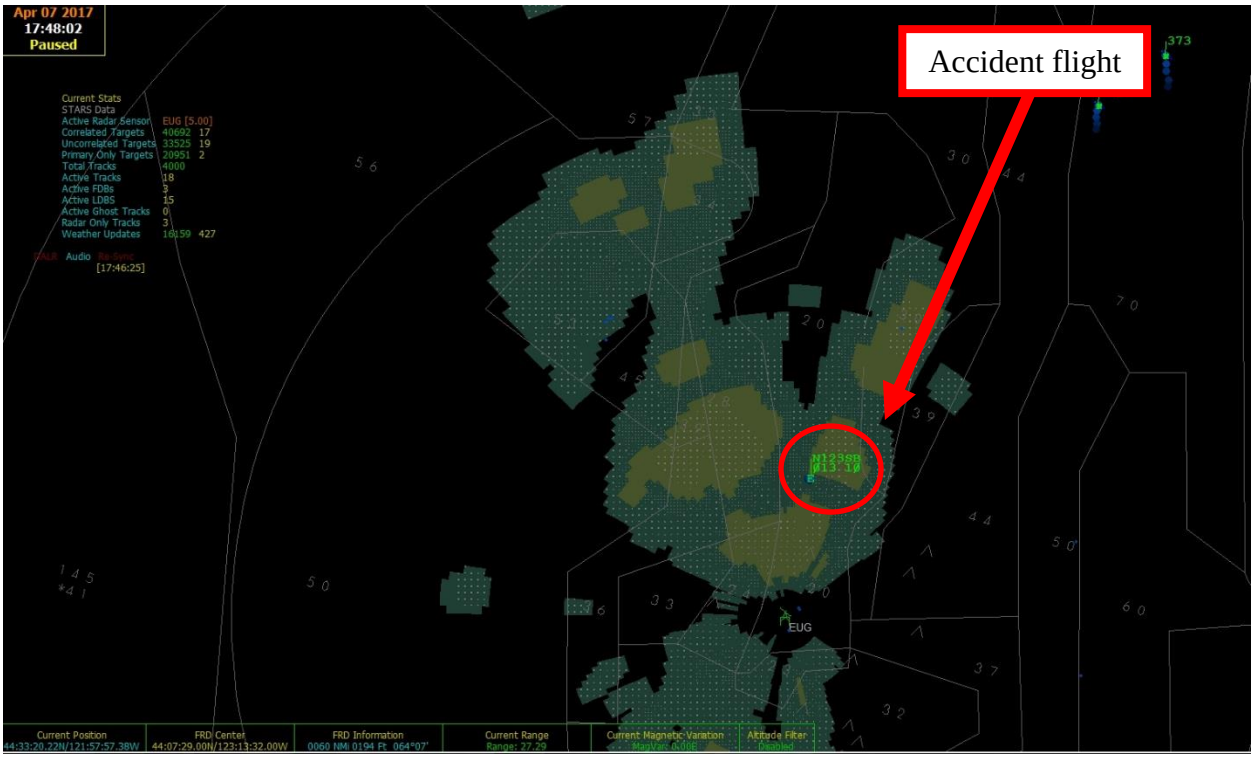


Figure 19 – STARS weather and precipitation level display from 1048:02 PDT

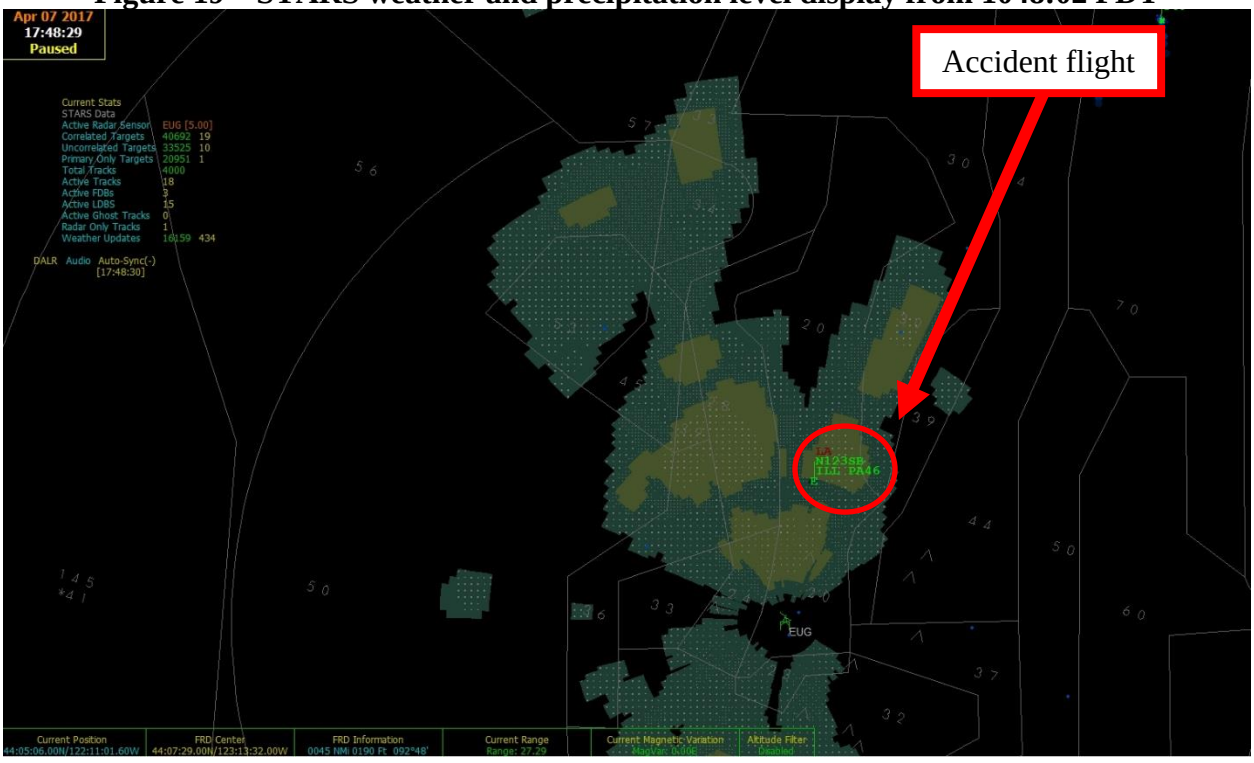


Figure 20 – STARS weather and precipitation level display from 1048:29 PDT

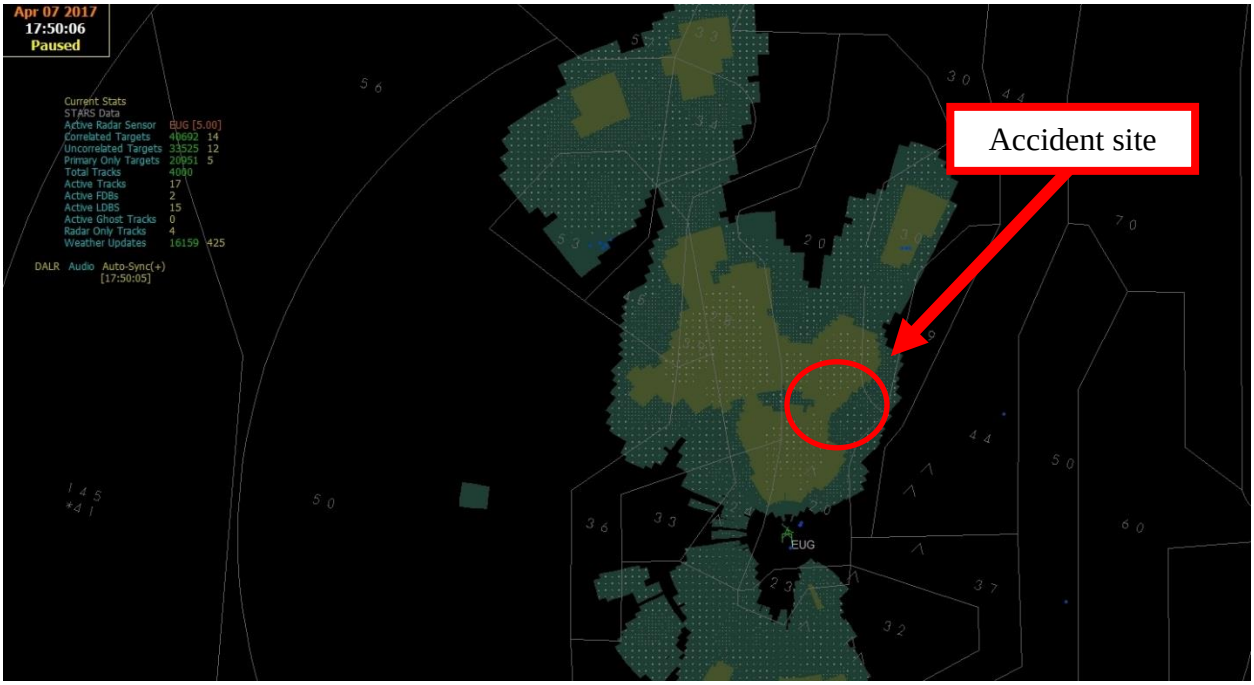


Figure 21 – STARS weather and precipitation level display from 1050:06 PDT

7.0 Pilot Reports[31]

All pilot reports (PIREPs) close to the accident site from about two hours prior to the accident time to about two hours after the accident time were reviewed. Only PIREPs for below FL180[32] are provided below:

RDM UUA /OV RDM/TM 1552/FL032/TP DH8D/TB CNT MDT 130 AND BLO/RM LLWS -15KTS / 100AGL FAP RY 23

OTH UA /OV OTH090010/TM 1606/FL050/TP ASTR/TB MOD/RM -ZSE

KOTH UA /OV KOTH/TM 1608/FL021/TP AST/RM BASES OVC021 WIND SHEAR +/- 08KTS BLW 010

KOTH UA /OV KOTH/TM 1612/FL040/TP C208/RM WIND 209055 TRUE AT 040MSL 10 NE OTH

PDX UA /OV PDX/TM 1619/FL080/TP B739/TB MOD/RM MOD TURBC BELOW FL080 AWC-WEB/

RBG UA /OV RBG/TM 1622/FL045/TP C208/TA UNKN/IC LGT-MOD RIME/RM -ZSE

KEUG UA /OV EUG020018/TM 1643/FL050/TP C525/TB MOD-LGT

ONP UA /OV ONP/TM 1651/FL024/TP C208/SK OVC027/TB LGT CHOP/RM ON FINAL RWY16 -ZSE

KOTH UA /OV KOTH/TM 1714/FL021/TP C208/RM BASES OVC021

[31] Only pilot reports with the WMO header UBOR** identifier were considered.
[32] 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.

RDM UUA /OV KRDM/TM 1745/FL130/TP CRJ2/TA M/TB LGT-MOD/IC LGT MX/RM LLWS +/- 10KTS 300 AGL. DURD FL130-FL090/ -ZSE

KEUG UA /OV EUG250008/TM 1803/FL060/TP C208/TA M03/TB MOD TURB/IC MOD RIME

KRDM UUA /OV LAX-RDM/TM 1819/FL100/TP CRJ7/TB LGT OCNL MDT 100 BLO/IC NEGATIVE/RM LLWS + 15 KTS 036 AND BLO DURGD=

PDX UUA /OV PDX/TM 1830/FL030/TP B737/WV 90 KT CROSSWIND THROUGH 6000, MOD CHOP=

OTH UA /OV KOTH/TM 1842/FLDURC/TP ASTR/TB CONTINUOUS MOD SFC-028=

UAO UA /OV UAO36005/TM 1915/FL005/TP ASTR/TB MOD/RM -20 KTS ON SHORT FINAL RWY 17=

KPDX UA /OV 7 W/TM 1937/FL028/TP A320/SK OVC028=

AST UA /OV AST165020/TM 1939/FL050/TP C208/TB MOD/RM ..ZSE=

UAO UUA /OV KUAO/TM 1940/FL010/TP C340/TB MOD /RM LLWS +/-10 KT ON FINAL DURD RWY17=

Urgent pilot report (UUA); Over Redmond, Oregon; Time – 0852 PDT (1552Z); Altitude – 3,200 ft; Type aircraft – Bombardier Dash 8; Turbulence – Continuous moderate 13,000 ft and below; Remarks – LLWS -15 knots at 100 ft agl on final approach to runway 23.

Routine pilot report (UA); 10 miles from North Bend, Oregon, on the 090° radial; Time – 0906 PDT (1606Z); Altitude – 5,000 ft; Type aircraft – Gulfstream G100; Turbulence – Moderate.

Routine pilot report (UA); Over North Bend, Oregon; Time – 0908 PDT (1608Z); Altitude – 2,100 ft; Type aircraft – Gulfstream G100; Remarks – Bases with an overcast ceiling at 2,100 ft, wind shear of +/- 8 knots below 1,000 ft.

Routine pilot report (UA); Over North Bend, Oregon; Time – 0912 PDT (1612Z); Altitude – 4,000 ft; Type aircraft – Cessna 208; Remarks – Wind from 209° at 55 knots true at 4,000 ft msl 10 miles northeast of North Bend, Oregon.

Routine pilot report (UA); Over Portland, Oregon; Time – 0919 PDT (1619Z); Altitude – 8,000 ft; Type aircraft – Boeing 737-900; Turbulence – Moderate; Remarks – Moderate turbulence below 8,000 ft.

Routine pilot report (UA); Over Roseburg, Oregon; Time – 0922 PDT (1622Z); Altitude – 4,500 ft; Type aircraft – Cessna 208; Temperature – Unknown; Icing – Light to moderate rime.

Routine pilot report (UA); 18 miles from Eugene, Oregon, on the 020° radial; Time – 0943 PDT (1643Z); Altitude – 5,000 ft; Type aircraft – Cessna 525 Citation Jet; Turbulence – Moderate to light.

Routine pilot report (UA); Over Newport, Oregon; Time – 0951 PDT (1651Z); Altitude – 2,400 ft; Type aircraft – Cessna 208; Sky – Overcast at 2,700 ft; Turbulence – Light chop; Remarks – On final on runway 16.

Routine pilot report (UA); Over North Bend, Oregon; Time – 1014 PDT (1714Z); Altitude – 2,100 ft; Type aircraft – Cessna 208; Remarks – Bases with an overcast ceiling at 2,100 ft.

Urgent pilot report (UUA); Over Redmond, Oregon; Time – 1045 PDT (1745Z); Altitude – 13,000 ft; Type aircraft – Bombardier CRJ200; Temperature – Missing; Turbulence – Light to moderate; Icing – Light mixed; Remarks – LLWS +/-10 knots at 300 ft agl. During descent from 13,000 to 9,000 ft.

Routine pilot report (UA); 8 miles from Eugene, Oregon, on the 250° radial; Time – 1103 PDT (1803Z); Altitude – 6,000 ft; Type aircraft – Cessna 208; Temperature – -8° C; Turbulence – Moderate; Icing – Moderate rime.

Urgent pilot report (UUA); Over Los Angeles, California, to Redmond, Oregon; Time – 1119 PDT (1819Z); Altitude – 10,000 ft; Type aircraft – Bombardier CRJ700; Turbulence – Light with occasional moderate below 10,000 ft; Icing – Negative; Remarks – LLWS +15 knots at 3,600 ft and below during descent.

Routine pilot report (UA); Over Portland, Oregon; Time – 1130 PDT (1830Z); Altitude – 3,000 ft; Type aircraft – Boeing 737-700; Wind – 90 knots, crosswind through 6,000 ft with moderate chop.

Routine pilot report (UA); Over North Bend, Oregon; Time – 1142 PDT (1842Z); Altitude – During climb; Type aircraft – Gulfstream G100; Turbulence – Continuous moderate from the surface through 2,800 ft.

Routine pilot report (UA); 5 miles from North Bend, Oregon, on the 360° radial; Time – 1215 PDT (1915Z); Altitude – 500 ft; Type aircraft – Gulfstream G100; Turbulence – Moderate; Remarks – -20 knots on short final into runway 17.

Routine pilot report (UA); 7 miles west of Portland, Oregon; Time – 1237 PDT (1937Z); Altitude – 2,800 ft; Type aircraft – Airbus A320; Sky – Overcast at 2,800 ft.

Routine pilot report (UA); 20 miles from Astoria, Oregon, on the 165° radial; Time – 1239 PDT (1939Z); Altitude – 5,000 ft; Type aircraft – Cessna 208; Turbulence – Moderate.

Urgent pilot report (UUA); Over Aurora, Oregon; Time – 1240 PDT (1940Z); Altitude – 1,000 ft; Type aircraft – Cessna 340; Turbulence – Moderate; Remarks – LLWS +/- 10 knots on final during descent into runway 17.

8.0 SIGMET and CWSU Advisories

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

No Center Weather Service Unit (CWSU) Meteorological Impact Statement (MIS) was valid for the accident site at the accident time. A CWSU Center Weather Advisories (CWA) was valid for the accident site from 6,000 to 14,000 ft warning of occasional severe turbulence (figure 22):

FAUS22 KZSE 071727
ZSE2 CWA 071727
ZSE CWA 202 VALID UNTIL 071927
FROM 25WSW YKM-DSD-EUG-45N PDX-25WSW YKM
AREA OCNL SVR TURB. 060-140. RPRTD BY B738 AND B190 ACFT. ZSE CWSU AD071727Z
=

A similar CWSU CWA had been issued at 0812 PDT warning of areas of occasional severe turbulence through 1012 PDT:

FAUS22 KZSE 071512
ZSE2 CWA 071512
ZSE CWA 201 VALID UNTIL 071712
FROM 25WSW YKM-DSD-EUG-45N PDX-25WSW YKM
AREA OCNL SVR TURB. 060-140. RPRTD BY B738 AND B190 ACFT. ZSE CWSU AD071512Z
=

9.0 AIRMETs

There were Airmen's Meteorological Information (AIRMET) advisories Sierra and Tango that were valid for the accident site at the accident time (figure 22). The accident flight passed through AIRMET Zulu for moderate icing conditions on descent into KEUG. AIRMET Sierra warned of mountain obscuration conditions in clouds and precipitation, while AIRMET Tango warned of both moderate turbulence conditions below 16,000 ft and LLWS conditions (figures 22 through 25):

594
WAUS46 KKCI 071445
WA6S
-SFOS WA 071445
AIRMET SIERRA UPDT 2 FOR IFR AND MTN OBSCN VALID UNTIL 072100
.
AIRMET IFR...CA AND CSTL WTRS
FROM 20SSW LAX TO 20SE MZB TO 220SW MZB TO 180SW RZS TO 20SSW LAX
CIG BLW 010/VIS BLW 3SM PCPN/BR. CONDS ENDG 18-21Z.
.
AIRMET MTN OBSCN...WA OR ID MT WY NV UT
FROM 50SW YQL TO 40E BPI TO BAM TO 20WNW BOI TO 20SW BKE TO
70ENE PDT TO 30WSW EPH TO 40SE YDC TO 50SW YQL
MTNS OBSC BY CLDS/PCPN. CONDS CONTG BYD 21Z THRU 03Z.
.
AIRMET MTN OBSCN...WA OR CA
FROM 20WNW HUH TO 40SE YDC TO 30WSW EPH TO 30ESE LKV TO 30SSE FMG TO 60SW BTY TO 40SW RZS TO 40NW ENI TO 80NNW FOT TO HQM TO 20WNW TOU TO 20WNW HUH
MTNS OBSC BY CLDS/PCPN. CONDS CONTG BYD 21Z THRU 03Z.

.
OTLK VALID 2100-0300Z...MTN OBSCN WA OR CA NV
BOUNDED BY 80WSW YXC-20SSE YKM-80SW REO-40SSE FMG-70SW BTY-20W
LAX-50SW RZS-40NW ENI-80WSW OED-20NNW HQM-20W TOU-HUH-80WSW YXC
MTNS OBSC BY CLDS/PCPN. CONDS CONTG THRU 03Z.
....

812
WAUS46 KKCI 071445
WA6Z
-SFOZ WA 071445
AIRMET ZULU UPDT 3 FOR ICE AND FRZLVL VALID UNTIL 072100
.
AIRMET ICE...WA OR CA ID MT WY NV UT CO AZ AND CSTL WTRS
FROM 40SW YXC TO 60NE GGW TO 20NW DBL TO 40E PGS TO 20W TRM TO
160SW RZS TO 120SW PYE TO 60SSW OAK TO 50NE DNJ TO 40SW YXC
MOD ICE BTN FRZLVL AND FL240. FRZLVL 100-120. CONDS CONTG BYD 21Z
THRU 03Z.
.
AIRMET ICE...WA OR CA ID MT NV AND CSTL WTRS
FROM 20NW HUH TO 50SW YXC TO 50NE DNJ TO 60SSW OAK TO 120SW PYE
TO 140WSW FOT TO 140W TOU TO 20NW HUH
MOD ICE BTN FRZLVL AND FL200. FRZLVL 050-070. CONDS CONTG BYD 21Z
THRU 03Z.
.
OTLK VALID 2100-0300Z...ICE WA OR CA ID MT WY NV UT CO AZ NM AND
CSTL WTRS
BOUNDED BY 70NE GGW-60WNW PUB-50SW RSK-20W TBC-30E PGS-50W
EHF-50SW OAK-50NE DNJ-50SSW YXC-70NE GGW
MOD ICE BTN FRZLVL AND FL240. FRZLVL 100-120. CONDS CONTG THRU
03Z.
.
FRZLVL...RANGING FROM 030-135 ACRS AREA
  040 ALG 150SW FOT-50SW FOT-20NNW ONP-60NNW ONP-140WSW HQM-
    160W HQM
  080 ALG 140WSW SNS-40SW MOD-50S FMG
  120 ALG 150SW RZS-30NNE LAX-40W LAS
....

275
WAUS46 KKCI 071522 AAA
WA6T
-SFOT WA 071522 AMD
AIRMET TANGO UPDT 3 FOR TURB STG WNDS AND LLWS VALID UNTIL 072100
.
AIRMET TURB...WA OR CA ID MT WY NV UT CO AND CSTL WTRS
FROM 40SE YDC TO 50NNW ISN TO 70SW RAP TO 20WSW LAR TO 160SW RZS
TO 140WSW FOT TO 150WNW FOT TO 70SSW YKM TO 40SE YDC
MOD TURB BTN FL180 AND FL400. CONDS CONTG BYD 21Z THRU 03Z.
.
AIRMET TURB...CA AND CSTL WTRS
FROM BTY TO EED TO BZA TO 20S MZB TO 20W LAX TO 50WNW RZS TO BTY
MOD TURB BLW 140. CONDS CONTG BYD 21Z THRU 03Z.
.
AIRMET TURB...WA OR CA ID MT WY NV UT CO AZ NM AND CSTL WTRS
FROM 20NW HUH TO 40SSW YXC TO JNC TO 80SSW RSK TO 50W PHX TO BTY

TO 50WNW RZS TO 140WSW FOT TO 140W TOU TO 20NW HUH
MOD TURB BLW 160. CONDS CONTG BYD 21Z THRU 03Z.
.
AIRMET STG SFC WNDS...WA OR CA AND CSTL WTRS
FROM 30NW TOU TO 20SE HQM TO ONP TO 40S FOT TO 140WSW FOT TO
150WSW TOU TO 30NW TOU
SUSTAINED SURFACE WINDS GTR THAN 30KT EXP. CONDS CONTG BYD 21Z
THRU 03Z.
.
LLWS POTENTIAL...WA OR CA AND CSTL WTRS...UPDT
BOUNDED BY 20N TOU-50W EPH-80SSW LKV-50N FOT-20N TOU
LLWS EXP. CONDS CONTG BYD 21Z THRU 03Z.
....

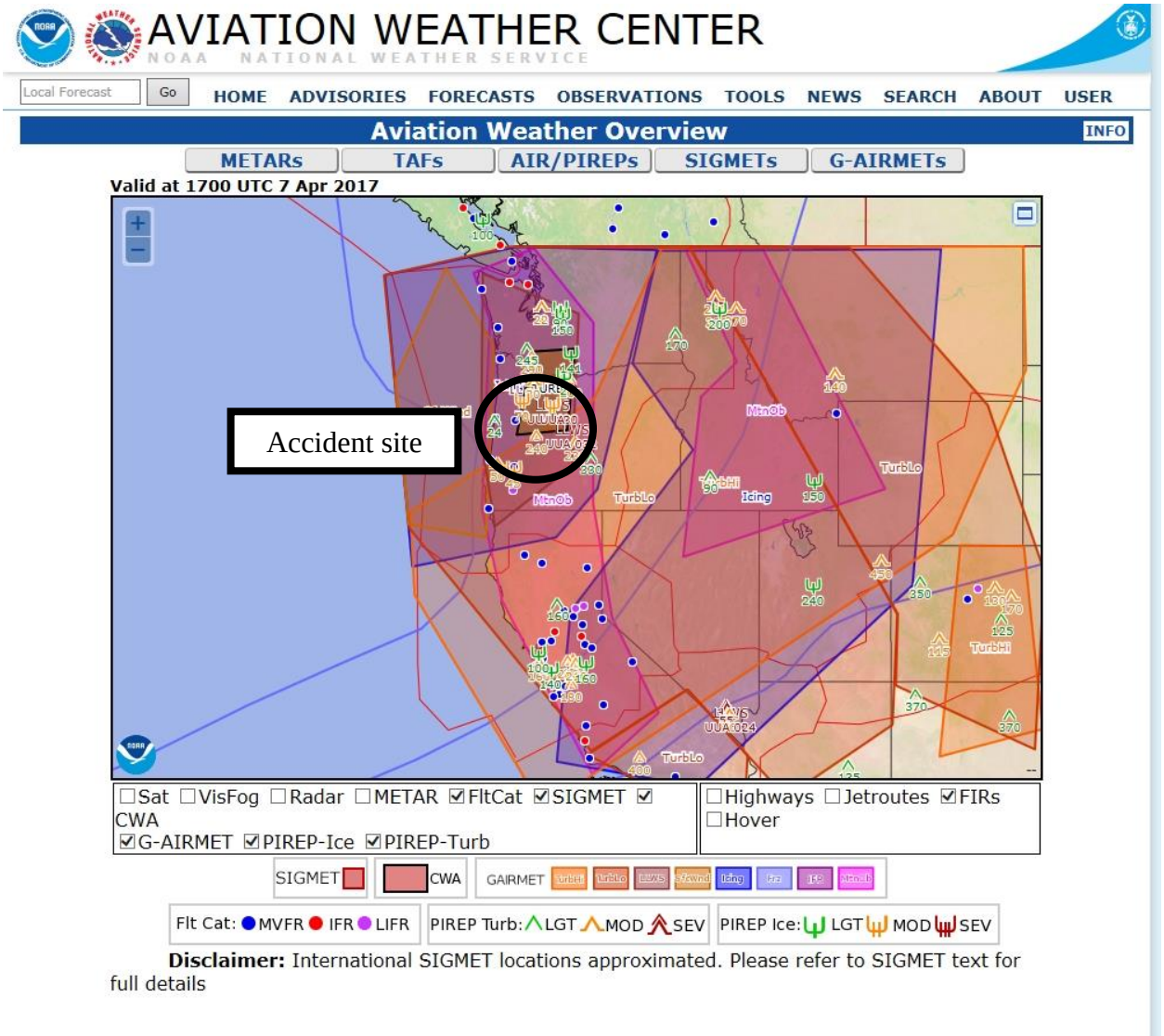


Figure 22 – AIRMETs, SIGMETs and CWAs valid at the accident time (at 1000 PDT)

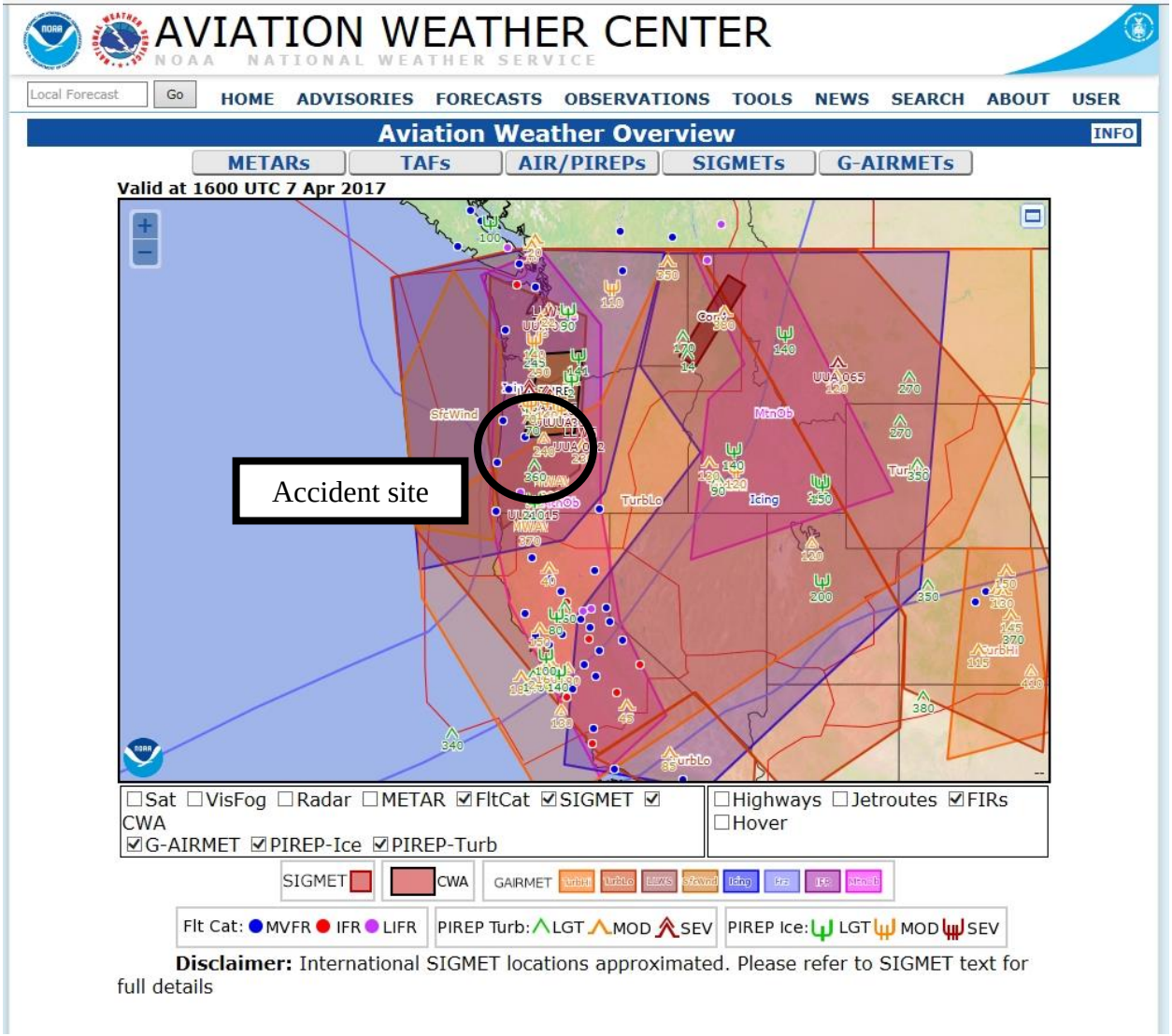


Figure 23 – AIRMETs, SIGMETs and CWAs valid at 0900 PDT

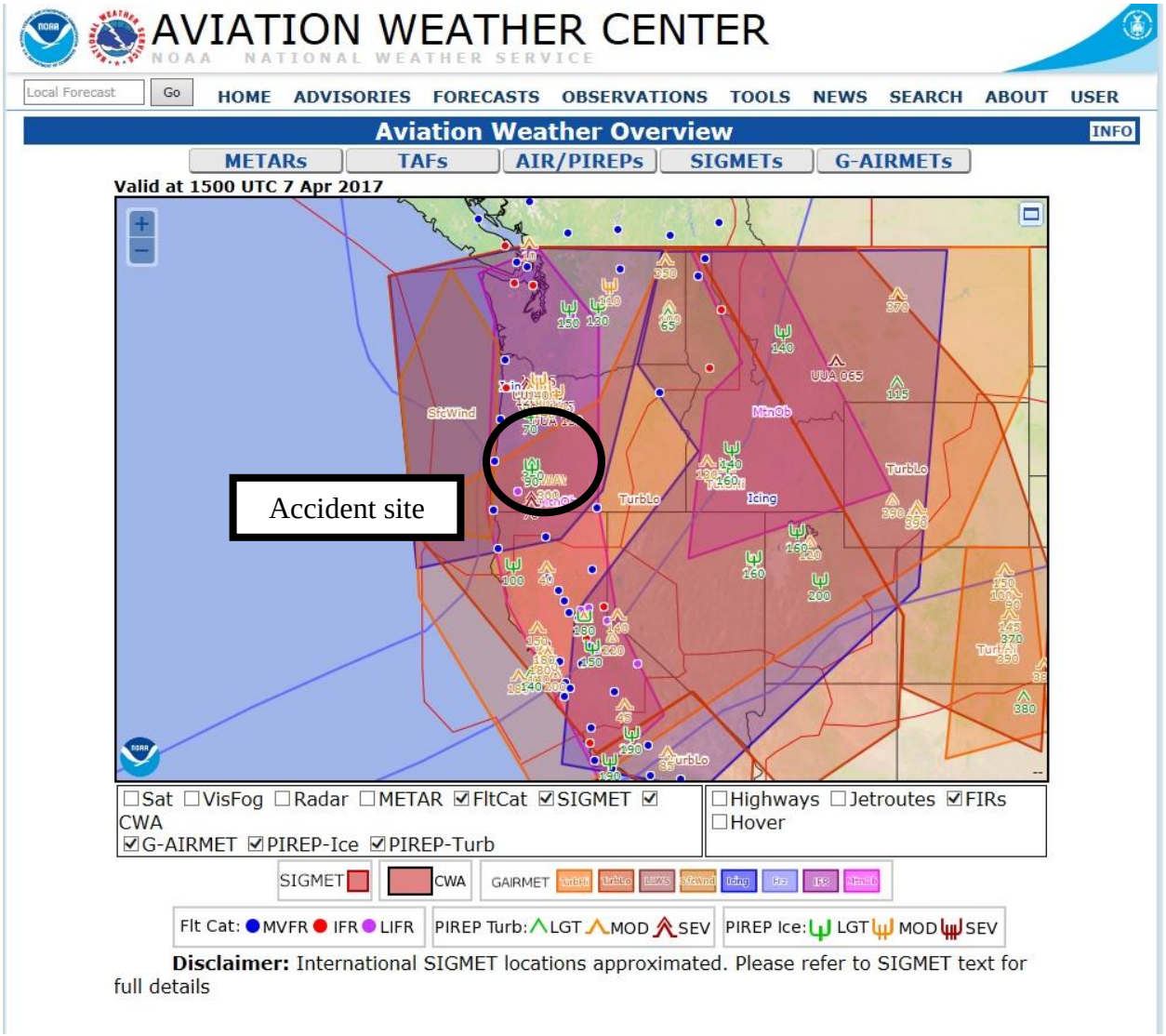


Figure 24 – AIRMETs, SIGMETs, and CWAs valid at 0800 PDT

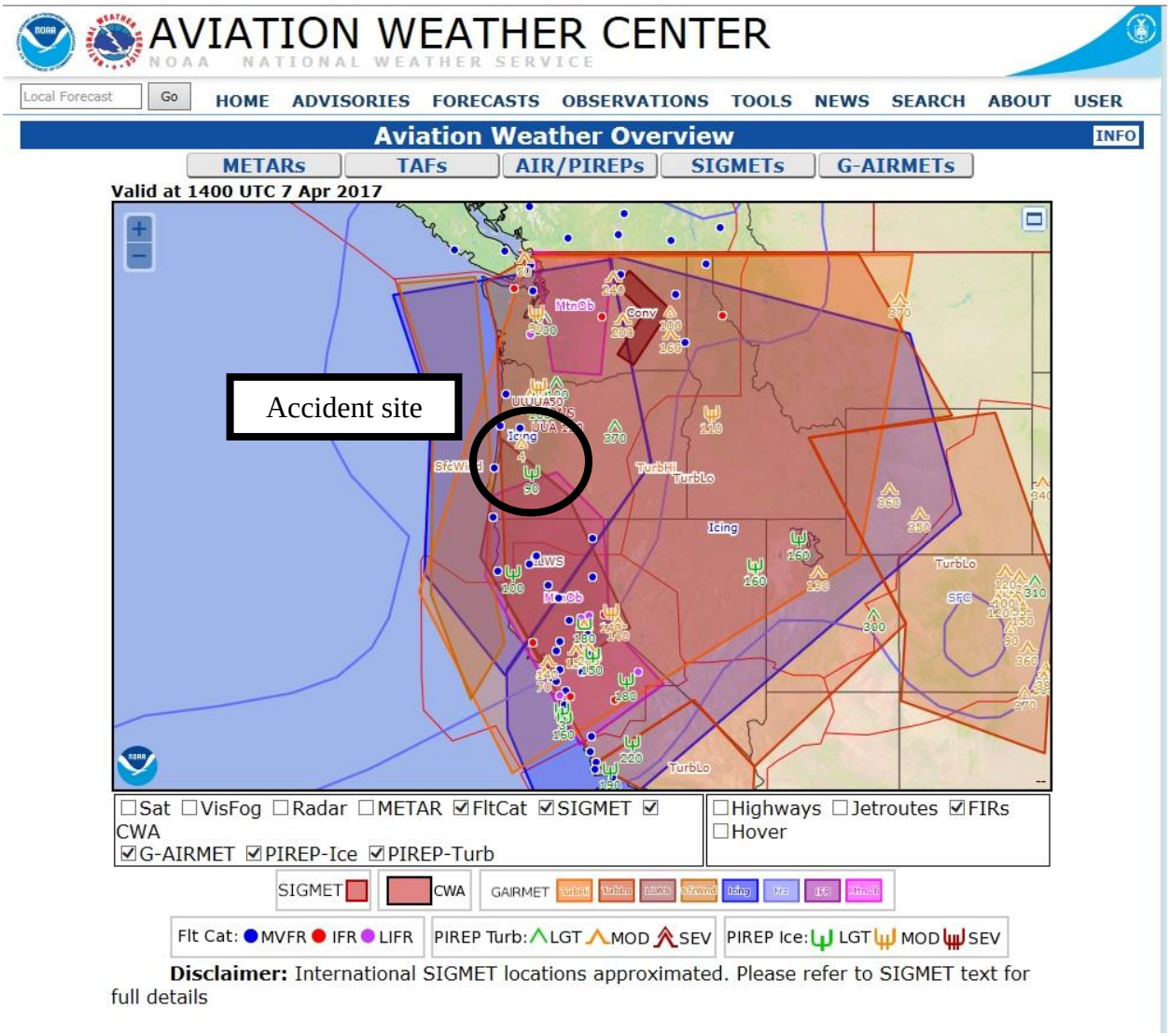


Figure 25 – AIRMETs, SIGMETs, and CWAs at valid 0700 PDT

10.0 Area Forecast

The Area Forecast issued at 0345 PDT, valid at the accident time, forecasted a broken ceiling at 6,000 ft, with layered clouds through FL240, moderate rain, and a south wind gusting to 45 knots:

177
FAUS46 KKCI 071045
FA6W
-SFOC FA 071045
SYNOPSIS AND VFR CLDS/WX
SYNOPSIS VALID UNTIL 080500
CLDS/WX VALID UNTIL 072300...OTLK VALID 072300-080500
WA OR CA AND CSTL WTRS
.
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...NONE.
.
WA CASCDS WWD
CSTL SXNS...OVC050 TOP FL240. RA. 16Z OVC025. VIS 5SM RA BR. WND SE G30KT. OTLK...MVFR CIG RA BR WND.
PUGET SOUND-INTR VLY...OVC100 TOP FL220. TIL 14Z RA. 17Z OVC040. SCT SHRA. WND S G25KT. OTLK...VFR SHRA WND 02Z MVFR CIG SHRA BR WND.
CASCDS...
N HLF...OVC060 TOP FL240. VIS 5SM RA BR. 17Z OVC050 TOP FL260. VIS 3SM BR. SCT SHRA/SHSN ABV 050. OTLK...IFR CIG SHRA SHSN BR.
S HLF...OVC080 TOP FL240. 16Z OVC050. VIS 3SM RA/SN ABV 055 BR. WND S G30KT. OTLK...IFR CIG RA SN BR WND.
.
WA E OF CASCDS
NERN MTNS...OVC070 TOP FL260. 12Z WDLY SCT SHRA/TSRA. CB TOP FL320. OTLK...VFR TIL 01Z SHRA TSRA.
S CNTRL...OVC100 TOP FL240. TIL 15Z RA. 18Z WND SW G35KT. OTLK...VFR TIL 03Z WND.
SE...OVC090 TOP FL260. RA. 16Z BKN CI. 20Z BKN100. OTLK...VFR.
.
OR CASCDS WWD
CSTL SXNS...OVC040 TOP FL240. WDLY SCT SHRA. 12Z WND SW G45-55KT. 18Z SCT SHRA/TSRA. CB TOP FL300. 21Z BKN040. SCT SHRA/TSRA. OTLK...VFR SHRA TIL 02Z TSRA.
WILLAMETTE VLY...BKN060 LYRD FL240. RA. WND S G45KT. 20Z SCT SHRA/WDLY SCT TSRA. CB TOP FL300. WND S G35KT. OTLK...VFR SHRA TIL WND 02Z TSRA.
SWRN INTR...OVC050 TOP 160. SCT SHRA/ISOL TSRA. CB TOP FL260. WND SE G30KT. 18Z SCT SHRA/TSRA. OTLK...VFR SHRA TIL 01Z TSRA.
CASCDS...
N HLF...BKN090 TOP FL240. WND S G30KT. SCT SHRA. 19Z OVC060. SCT SHRA/TSRA. CB TOP FL280. WND SW G45KT. OTLK...MVFR CIG SHRA WND TIL 02Z TSRA.
S HLF...OVC070 TOP FL180. SCT SHRA. WND S 40KT. 18Z OVC050. SCT SHRA/TSRA. CB TOP FL300. WND S G40KT. OTLK...MVFR CIG SHRA WND TIL 02Z TSRA.
.
OR E OF CASCDS
CNTRL...OVC080 TOP FL240. TIL 13Z RA. WND SW G35KT. 16Z BKN100. WND SW G40KT. OTLK...VFR TIL 02Z WND.
NERN...OVC120 TOP FL180. 17Z WND SW 35KT. OTLK...VFR TIL 01Z WND.
SE...OVC140 TOP FL200. 18Z SCT120 BKN CI. WND SW G40KT. OTLK...VFR TIL 03Z WND.
.
NRN CA...STS-SAC-TVL LN NWD
CSTL SXNS...
FOT NWD...OVC040 TOP 120. SCT SHRA/ISOL TSRA. CB TOP FL240. WND SW G35KT. 20Z OVC050 TOP FL200. SCT SHRA/TSRA. CB TOP FL300. OTLK...VFR SHRA TIL 02Z TSRA.
S FOT...OVC040 TOP 120. ISOL SHRA. 21Z BKN035. OTLK...VFR 03Z MVFR CIG RA BR.
SAC VLY...OVC025 TOP 100. WND S G40KT. 20Z SCT SHRA/TSRA. CB TOP

FL320. WND S G30KT. OTLK...MVFR CIG TIL 02Z SHRA TSRA WND.
SHASTA-SISKIYOUS...OVC070-090 TOP 160. RA. WND S G45KT. 18Z WDLY
SCT SHRA/TSRA. CB TOP FL320. OTLK...VFR SHRA TSRA 02Z MVFR CIG.
RMNDR...OVC080 TOP FL260. VIS 5SM RASN BR. WND SW G30KT. 19Z SCT
SHRA/ISOL TSRA. CB TOP FL320. OTLK...MVFR CIG SHRA TSRA 00Z VFR
NERN CA ELSW MVFR CIG.
.
CNTRL CA
CSTL SXNS...
SNS NWD...OVC015 TOP 060. SCT SHRA. 14Z BKN070 TOP 100.
OTLK...VFR 03Z MVFR CIG.
S SNS...BKN025 TOP 100. SCT SHRA. 18Z OVC025 TOP 070. WND S
G30KT. OTLK...MVFR CIG TIL 02Z SHRA.
SAN JOAQUIN VLY...OVC090 TOP FL260. RA. 15Z OVC025. VIS 5SM RA
BR. OTLK...MVFR CIG RA BR 00Z VFR RA.
SRN SIERNEV...OVC110 TOP FL260. VIS 3SM RASN BR. WND SW G40KT.
15Z WND W 40KT. OTLK...MVFR CIG RASN BR WND.
.
SRN CA..VBG-NID-60NNW BIH LN SWD
CSTL SXNS...
LAX NWD...BKN020 BKN120 TOP FL240. 19Z BKN070. RA. OTLK...VFR RA.
S LAX...BKN015 TOP 020. 17Z BKN CI. OTLK...VFR.
INTR MTNS-MOJAVE...BKN CI. 20Z WND W G30KT. OTLK...VFR TIL 03Z
WND.
RMNDR...BKN CI. OTLK...VFR.
.
CSTL WTRS
WA...OVC080 TOP FL240. SCT SHRA. WND SE G30KT. 20Z WND W G45KT.
OTLK...VFR SHRA WND.
OR...OVC070 TOP FL240. SCT SHRA. WND S G50KT. 18Z SCT SHRA/TSRA.
CB TOP FL280. WND SW G40KT. OTLK...VFR SHRA TSRA WND.
CA...
NRN...OVC040 TOP FL180. WDLY SCT SHRA. WND SW G40KT. SCT
SHRA/TSRA. CB TOP FL300. OTLK...VFR SHRA TSRA.
CNTRL...BKN060 TOP FL250. SCT SHRA. OTLK...VFR SHRA.
SRN...BKN120 TOP FL240. OTLK...VFR.
....

11.0 Terminal Aerodrome Forecast

KEUG was the closest site to the accident site with a NWS Terminal Aerodrome Forecast (TAF). The TAF issued immediately prior to the accident and valid for after 1100 PDT was as follows:

TAF KEUG 071720Z 0718/0818 **18025G35KT P6SM -SHRA SCT025 BKN035 OVC040**
FM080300 24018G28KT P6SM -SHRA BKN040
FM080600 19013KT P6SM VCSH BKN040
FM081400 18010KT P6SM BKN050=

The 1020 PDT TAF expected a wind from 180° at 25 knots with gusts to 35 knots, greater than 6 miles visibility, light rain showers, scattered clouds at 2,500 ft agl, broken ceiling at 3,500 ft agl, and overcast skies at 4,000 ft agl.

The 0917 PDT KEUG TAF was valid at the time of the accident and was valid for a 20-hour period beginning at 0900 PDT. The 0917 PDT TAF for KEUG was as follows:

KEUG 071617Z 0716/0812 **18015G25KT P6SM -SHRA BKN020 OVC050**
FM072000 22015G25KT P6SM -SHRA OVC040
FM080100 24015G25KT P6SM -SHRA BKN040
FM080600 17010KT P6SM VCSH SCT040 OVC100=

The 0917 PDT TAF expected a wind from 180° at 15 knots with gusts to 25 knots, greater than 6 miles visibility, light rain showers, broken ceiling at 2,000 ft agl, and overcast skies at 5,000 ft agl.

12.0 NWS Area Forecast Discussion

The NWS Office in Portland, Oregon, issued the following Area Forecast Discussion (AFD) at 0900 PDT (closest AFD to the accident time with an aviation section). The aviation section of the AFD discussed that the strong winds of 40 to 45 knots, and some gusts to 60 knots, would be the main aviation hazard throughout the day with MVFR conditions possible in the stronger rain showers:

217
FXUS66 KPQR 071601 CCB
AFDPQR

Area Forecast Discussion...UPDATE
National Weather Service Portland OR
900 AM PDT Fri Apr 7 2017

UPDATED MARINE AND AVIATION SECTIONS

.SYNOPSIS...An unusually strong early April storm has arrived this morning and is causing tree damage and power outages. The storm will track northward off the coast and produce strong winds today along the coast and in the coastal mountains and very windy conditions in the inland valleys and foothills, plus high seas along the coast. There is a chance of a thunderstorm today. Cooler air and showers will spread in tonight and Saturday with snow levels lowering below the Cascade passes. The next front is expected mainly Sunday night into Monday as snow levels remain mostly below the Cascade passes. The next system is expected the middle of next week.

&&

.SHORT TERM...Today through Sunday...A 976 mb low center about 160 miles west-southwest of Astoria is tracking north toward Vancouver Island. Winds picked up on the central Oregon coast and south inland zones as a front moved into the area a few hours ago. Strong winds have spread to the north Willamette Valley, but is somewhat easing in the southern zones. Wind damage and power outages have been report through most of the interior zones. The strongest winds inland are occurring now through about late morning. Coastal winds still have to spread to the north coast and the threat for high winds are expected to last through the afternoon. Interestingly wind gusts at

the coast so far have been comparable to those inland. The NAM has a low level jet around 50 kts over the western half of the zone (roughly I-5 west). It also shows this jet weakening around midday.

Will keep the current wind warning/advisory as is, but have updated the wind advisory for the interior lowland zones to include gusts to 60 mph for this morning. Also convection is something we'll have to watch today as thunderstorms or stronger showers can easily transport some of the higher momentum winds down to the surface, causing more wind damage. /mh

Previous discussion follows...A strong low pressure system was moving northward off the coast inside 130W early this morning, and is forecast to move onshore near the northern tip of Vancouver Island this evening. This low is forecast to deepen to near 970 mb while off the coast, driven by an unusually strong early April jet stream of nearly 160 kt.

This storm will produce strong winds today along the coast and in parts of the coastal mountains, and very windy conditions in the interior valleys and Cascade foothills. The associated cold front was moving through the forecast area overnight and early this morning with rain and mountain snow. The strongest winds and a good batch of rain will be associated with the bent back occlusion around the low center as it moves onto the coast in the 12z-15z time frame this morning and then across the remainder of the forecast area through the remainder of the morning. There will also be a chance of thunder as this low pressure system moves through today.

Cooler air spreads into southwest Washington and northwest Oregon tonight and Saturday and snow levels in the Cascades will drop below the Cascade passes to around 2500 to 3000 ft by Saturday morning. Amounts will probably stay below snow advisory criteria, but could cause the passes to become snow covered. The models right now suggest the south Washington Cascades will see the greatest accumulations, but the Oregon Cascades could see several inches as well.

Showers will decrease Saturday night as the associated upper trough moves east. Sunday could be rather dry as the next front is still offshore, spreading rain onshore late Sunday and especially Sunday night. Tolleson

.LONG TERM...No Changes. Previous discussion follows...
Sunday night through Thursday...A cool showery weather pattern on Monday looks increasingly likely to take a break Tuesday as weak shortwave ridging tries to build over the Pacific Northwest. Still maintained some PoPs in this portion of the forecast, but seems increasingly likely these can be cut further as confidence grows in a 24 hour dry period developing Tuesday. Models are in general agreement that a closed low pressure system will then move eastward towards California towards the middle of next week. While the bulk of the unsettled weather looks likely to stay to our south, some cooling aloft and south-southwesterly flow should lead to some showers spreading back into the region during the middle part of next week.

&&

.AVIATION...Strong winds are the main aviation hazard today with widespread gusts around 40-45 kt, and some areas with gusts up to 60 kt. Strong winds will decrease this afternoon, but still gust in the 20-30kt range through tonight. Otherwise, mostly VFR conditions with occasional MVFR due to stronger showers. There is a chance for thunderstorms through the early evening. ~TJ

KPDX AND APPROACHES...Strong gusty winds today with gusts mostly 35-45kt. Winds should shift from S to SW between 2 and 5 pm this afternoon. Mostly VFR, with occasional MVFR with heavier showers. Thunderstorms are possible between 18Z and 03Z. ~TJ

&&

.MARINE...A strong low (around 976 mb) is around 150 miles west of the Columbia River Bar this morning. Winds will be strongest south of the low. Storm force winds have been reporting at buoy #46050 (off of Newport) since 4 am this morning with the highest gust measured so far at 54 kt. The seas at this buoy are rapidly building and were at 25 ft at the last observation (8 AM). Surface observations along the coast show that the storm force winds are likely offshore the north Oregon coast now, and the seas at buoy #46248 (30 miles west of Columbia Bar) have risen from 13 ft at 7 am to 18 ft at 8 am.

The storm force winds will continue into the afternoon with seas likely peaking around 28 ft. Expect winds to decrease below 30 kt early this evening, and seas to lower below 20 ft late this evening.

A cold front will approach the waters late Saturday and bring another round of south gales on Sunday. Seas will likely build back into the low to mid teens in response to the winds on Sunday and remain above 10 ft through late Monday. Weak high pres looks to move over the waters early next week and could bring a day or two of winds less than 20 kt and seas below 10 ft. TJ/64

&&

.PQR WATCHES/WARNINGS/ADVISORIES...
OR...Wind Advisory until 5 PM PDT this afternoon for Central Willamette Valley-Greater Portland Metro Area-Lower Columbia-South Willamette Valley.

High Wind Warning until 5 PM PDT this afternoon for Central Coast Range of Western Oregon-North Oregon Coast.

High Surf Advisory until 11 PM PDT this evening for Central Oregon Coast-North Oregon Coast.

High Wind Warning until 8 PM PDT this evening for Coast Range of Northwest Oregon.

High Wind Warning until 2 PM PDT this afternoon for Central

Oregon Coast.

WA...Wind Advisory until 5 PM PDT this afternoon for Greater Vancouver Area-I-5 Corridor in Cowlitz County.

High Wind Warning until 5 PM PDT this afternoon for South Washington Coast.

High Surf Advisory until 11 PM PDT this evening for South Washington Coast.

High Wind Warning until 8 PM PDT this evening for Willapa Hills.

PZ...Storm Warning until 5 PM PDT this afternoon for Coastal Waters from Cape Shoalwater WA to Florence OR out 60 nm.

Small Craft Advisory for Rough Columbia River Bar until 9 AM PDT Saturday.

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www.twitter.com/NWSPortland

This discussion is for Northwest Oregon and Southwest Washington from the Cascade crest to 60 nautical miles offshore. The area is commonly referred to as the forecast area.

13.0 Wind Advisory

The NWS Office in Portland, Oregon, issued the following Wind Advisory at 0727 PDT (valid through 1700 PDT) to warn of a south wind of 25 to 35 mph with gusts as high as 60 mph at the surface. A similar Wind Advisory was issued at 0240 PDT warning of the gusty south winds between 0700 and 1700 PDT for the accident site and surrounding area:

ORZ005>008-WAZ022-039-072300-
/O.CON.KPQR.WI.Y.0007.000000T0000Z-170408T0000Z/
Lower Columbia-Greater Portland Metro Area-
Central Willamette Valley-South Willamette Valley-I-5 Corridor in Cowlitz County-Greater Vancouver Area-
Including the cities of St. Helens, Clatskanie, Hillsboro, Portland, Wilsonville, Oregon City, Gresham, Troutdale, Salem, McMinnville, Woodburn, Stayton, Dallas, Eugene, Springfield, Corvallis, Albany, Lebanon, Longview, Kelso, Castle Rock, Vancouver, Battle Ground, Ridgefield, Washougal, Yacolt, and Amboy
727 AM PDT Fri Apr 7 2017

...WIND ADVISORY REMAINS IN EFFECT UNTIL 5 PM PDT THIS AFTERNOON...

* UPDATE...Gusty winds have arrived in the Willamette Valley this morning and will continue to spread north this morning.

* WINDS...South wind 25 to 35 mph with gusts 35 to 50 mph. Local gusts to 60 mph.

* TIMING...This morning through this afternoon. Strongest winds expected through about midday.

* IMPACTS...Tree damage and power outages. High profile vehicles may also experience difficulties in the gusty winds.

PRECAUTIONARY/PREPAREDNESS ACTIONS...

A Wind Advisory is issued when sustained winds are forecast to be 31 to 39 mph or gusts will range between 45 and 57 mph. Winds of these magnitudes may cause minor property damage without extra precautions. Motorists in high profile vehicles should use caution until the winds subside.

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14.0 Winds and Temperature Aloft Forecast

The NWS 0701 PDT Winds and Temperature Aloft forecast valid for the closest point to the accident site is included below:

```
483
FBUS31 KWNO 071401
FD1US1
-DATA BASED ON 071200Z
VALID 071800Z   FOR USE 1400-2100Z. TEMPS NEG ABV 24000

FT  3000    6000    9000   12000   18000   24000  30000  34000  39000

OTH 2158 2256-04 2256-09 2256-15 2257-30 2340-41 224847 225247 224947
```

The accident site was closest to the OTH (North Bend, Oregon) forecast point. The 0701 PDT OTH forecast indicated a wind at 3,000 ft from 210° at 58 knots, a wind at 6,000 ft from 220° at 56 knots with a temperature of -4° C, and a wind at 9,000 ft from 220° at 56 knots with a temperature of -9° C.

15.0 Pilot Weather Briefing

A search of official weather briefing sources, such as Lockheed Martin Flight Service (LMFS), Leidos weather briefings, and Direct User Access Terminal Service (DUATS) was done. The accident pilot did not receive an official DUATS weather briefing, or voice LMFS or Leidos weather briefings, but did receive ForeFlight and Leidos text and graphical weather briefings at 0416 and 0417 PDT (attachments 4 through 8). In the ForeFlight graphical and text weather briefing (attachments 4 and 5), the accident pilot received AIRMETs Sierra, Zulu, and Tango all valid along the route or at the intended destination (including AIRMET Tango for LLWS), the METARs and TAFs valid at 0417 PDT, the Area Forecast, the SPC Day 1 Convective Outlook, the Winds Aloft forecast, and that there were no urgent PIREPs along the route of flight from before 0417 PDT. Attachments 6 and 7 are the Leidos text version of the ForeFlight weather briefing request at 0416 and 0417 PDT. It is unknown if the accident pilot checked or received additional weather information before or during the accident flight.

16.0 Accident Scene Images

The NTSB investigator-in-charge took some images of the accident scene and discovered that an area of tall grass had been blown over the day of the accident (figures 26 and 27). The area of blown over tall grass was located 450 ft southwest of the accident site. These images were provided to the NWS and the NWS estimated that it would take greater than 35 knot winds to lay over tall grass as the images indicated (attachment 9). The NWS indicated that a microburst or bow echo type of outflow event could not be ruled out (attachment 9).

Figure 26 – Image from the accident scene looking northeastward with the accident wreckage marked (red circle)

Figure 27 – Image from the accident scene looking northward with the accident wreckage marked (red circle)

17.0 Astronomical Data

The astronomical data obtained from the United States Naval Observatory for the accident site on April 7, 2017, indicated the following:

SUN	
Begin civil twilight	0613 PDT
Sunrise	0642 PDT
Sun transit	1315 PDT
Sunset	1948 PDT
End civil twilight	2018 PDT

18.0 Downburst and Microburst Information

The FAA's Advisory Circular AC 00-6B titled "Aviation Weather" issued in August 2016 is a basic training guide on many weather hazards, including downbursts and microbursts. In section 19.6.3, downburst and microburst are associated with rain showers and more frequently with thunderstorm activity. Downbursts create many hazard for aviation and often cause damaging wind at the surface. An exemplar diagram of a downburst from a rain shower or thunderstorm cloud base is shown in figure 28. Further information on the hazards of a downburst and microburst and the safest courses of action for pilot can be found in the FAA's AC 00-6B, the FAA's AC 00-24C, the FAA's Aeronautical Information Manual change 2 section 7-1-26 published in January 2015, and from the University Corporation for Atmospheric Research (UCAR)[33].

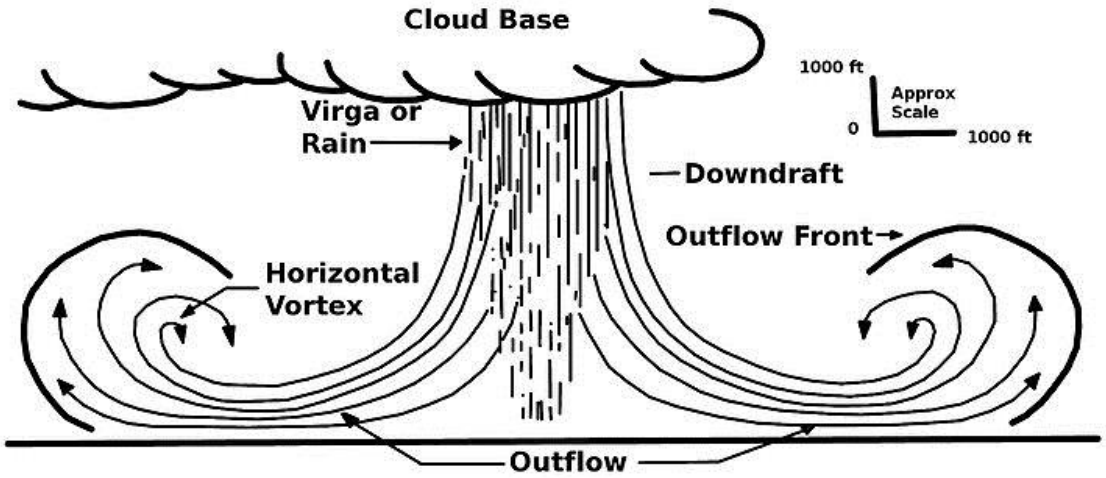

Figure 28 – Exemplar diagram of a downburst and outflow

E. LIST OF ATTACHMENTS

Attachment 1 – GOES-15 visible satellite imagery from 0900 to 1200 PDT

Attachment 2 – GOES-15 infrared satellite imagery from 1000 to 1200 PDT

Attachment 3 – KRTX base reflectivity from 1029 and 1101 PDT

Attachment 4 – ForeFlight graphical imagery from weather briefing at 0417 PDT

Attachment 5 – Correspondence with ForeFlight

Attachment 6 – Leidos standard weather briefing package text from 0416 PDT

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

Attachment 7 – Leidos standard weather briefing package text from 0417 PDT

Attachment 8 – LMFS contact history with N123SB

Attachment 9 – Correspondence with the National Weather Service

Submitted by:

_____

Paul Suffern
Senior Meteorologist

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