



NATIONAL TRANSPORTATION SAFETY BOARD

Office of Aviation Safety
Washington, D.C. 20594

March 3, 2017

Weather Study

METEOROLOGY

WPR17FA044

Table Of Contents

A.	ACCIDENT	3
B.	METEOROLOGIST	3
C.	SUMMARY	3
D.	DETAILS OF THE INVESTIGATION	3
E.	WEATHER INFORMATION	4
1.0	Synoptic Situation	4
1.1	Surface Analysis Chart	4
1.2	Upper Air Charts	6
2.0	SPC Products	11
3.0	Surface Observations	11
4.0	Upper Air Data	20
5.0	Satellite Data	21
6.0	Radar Imagery Information	22
6.1	Volume Scan Strategy	23
6.2	Beam Height Calculation	24
6.3	Reflectivity	24
6.4	Base Reflectivity and Lightning Data	25
7.0	Pilot Reports	28
8.0	SIGMET and CWSU Advisory	29
9.0	AIRMETs	29
10.0	Area Forecast	35
11.0	Terminal Aerodrome Forecast	37
12.0	NWS Area Forecast Discussion	38
13.0	Winds and Temperature Aloft Forecast	41
14.0	Pilot Weather Briefing	41
15.0	Puget Sound Convergence Zone	42
16.0	Astronomical Data	42
F.	LIST OF ATTACHMENTS	43

A. ACCIDENT

Location: Near Dabob, Washington
Date: December 29, 2016
Time: 1844 Pacific standard time
0244 Coordinated Universal Time (UTC) on December 30
Airplane: Cessna 182P, N52388

B. METEOROLOGIST

Paul Suffern
Group Chairman
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National Transportation Safety Board

C. SUMMARY

On December 29, 2016, about 1844 Pacific standard time, a Cessna 182P, N52388, collided with terrain near Dabob, Washington. The private pilot and three passengers were fatally injured. The airplane was substantially damaged. The airplane was registered to and operated by the pilot as a personal flight under the provisions of Title 14 *Code of Federal Regulations* Part 91. Visual and instrument meteorological conditions prevailed in the vicinity of the accident site during dark nighttime. A flight plan was not filed for the cross-country flight. The flight originated from Boeing Field International Airport, Seattle, Washington at 1816 with a planned destination of William R. Fairchild International Airport, Port Angeles, Washington.

D. 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 standard time (PST) on December 29, 2016, 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 accident site was located at latitude 47.824° N, longitude 122.790° W, at an approximate elevation of 470 feet.

E. 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 Surface Analysis Chart

The NWS Surface Analysis Chart for 1600 and 1900 PST are provided as figures 1 and 2 with the approximate location of the accident site marked within the red circle. The charts depicted a cold front moving southeastward from near Seattle at 1600 PST to central Washington by 1900 PST. The frontal boundary stretched southwestward into northern Oregon and northward towards British Columbia, where in British Columbia, the frontal boundary became an occluded front. There was a surface low pressure center located in central British Columbia with a pressure of 1010-hectopascals (hPa). The station models around the accident site at both 1600 and 1900 PST depicted air temperatures in the upper 30’s to upper 40’s degrees Fahrenheit (°F), with temperature-dew point spreads of 4° F or less, a southwest to northwest surface wind up to 10 knots, cloudy skies and light rain. With the cold front acting as a lifting mechanism in the mountainous terrain and relatively moist surface conditions, clouds and precipitation would be expected.

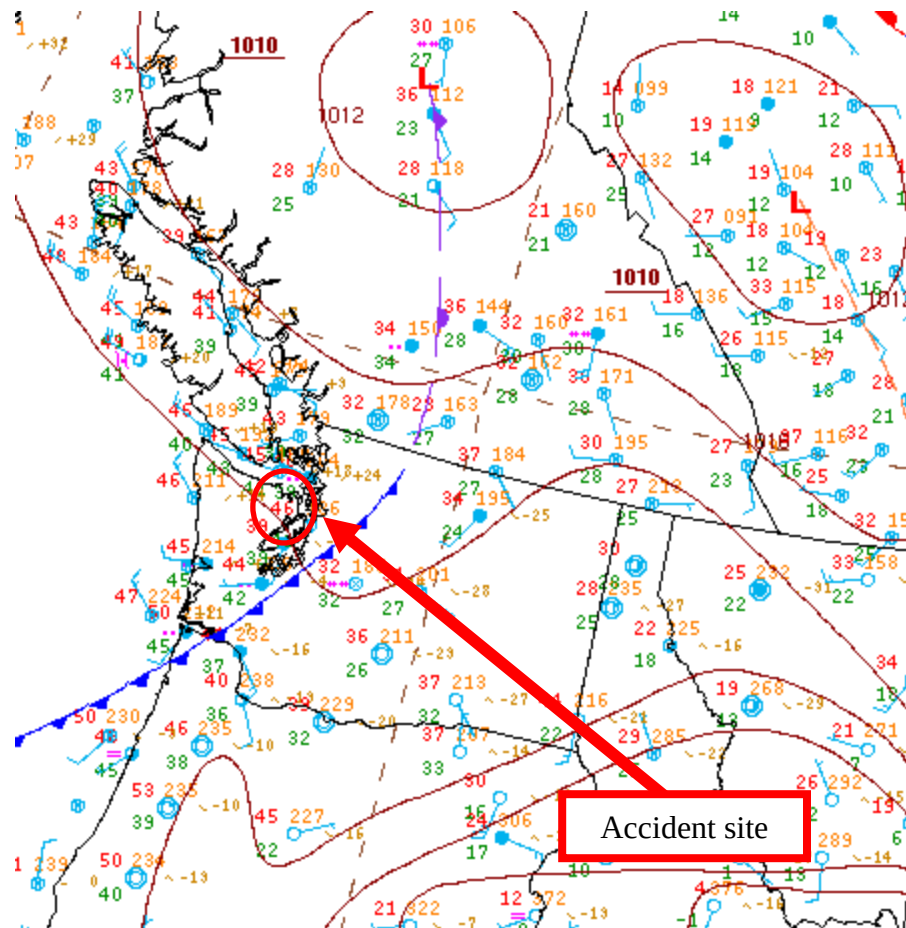


Figure 1 – NWS Surface Analysis Chart for 1600 PST

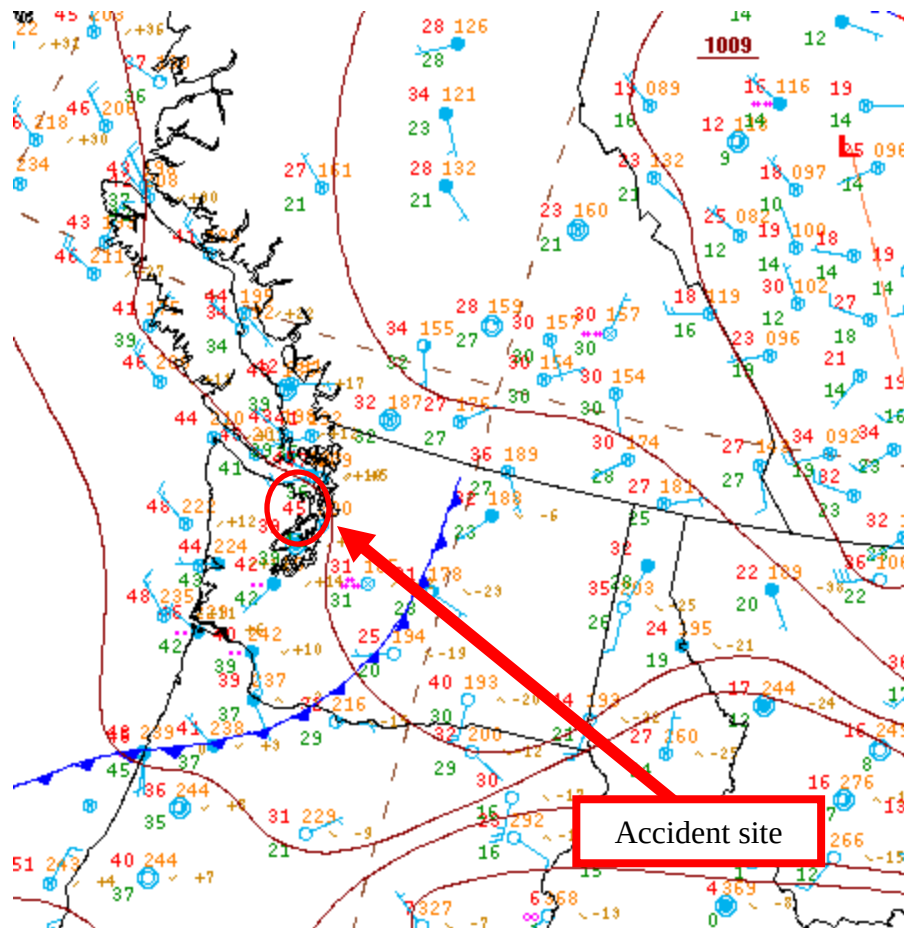


Figure 2 – NWS Surface Analysis Chart for 1900 PST

1.2 Upper Air Charts

The NWS Storm Prediction Center (SPC) Constant Pressure Charts for 1600 PST at 925-, 850-, 700-, 500-, and 300-hectopascals (hPa) are presented in figures 3 through 7. Low- and mid-level troughs¹ were located directly over the accident site around the accident time (figures 3 through 6). These troughs would have acted as lifting mechanisms to help produce clouds and precipitation, especially in mountainous terrain. In addition, the accident site was located in the right entrance region² of the upper-level jet streak (figure 7), which is a location favorable for increased upward vertical motion and therefore favorable for clouds and precipitation given sufficient moisture. There was a west wind of 20 knots at 925-hPa (figure 3) with the wind becoming west-southwesterly by 850- and 700-hPa with the wind increasing in speed to between 25 and 50 knots (figures 4 and 5). The 50-knot west-southwesterly wind at 700-hPa became an 125-knot west wind by 300-hPa (figure 7).

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

² Entrance Region – The region of confluence at the upwind extremity of a jet stream; the opposite of exit region.

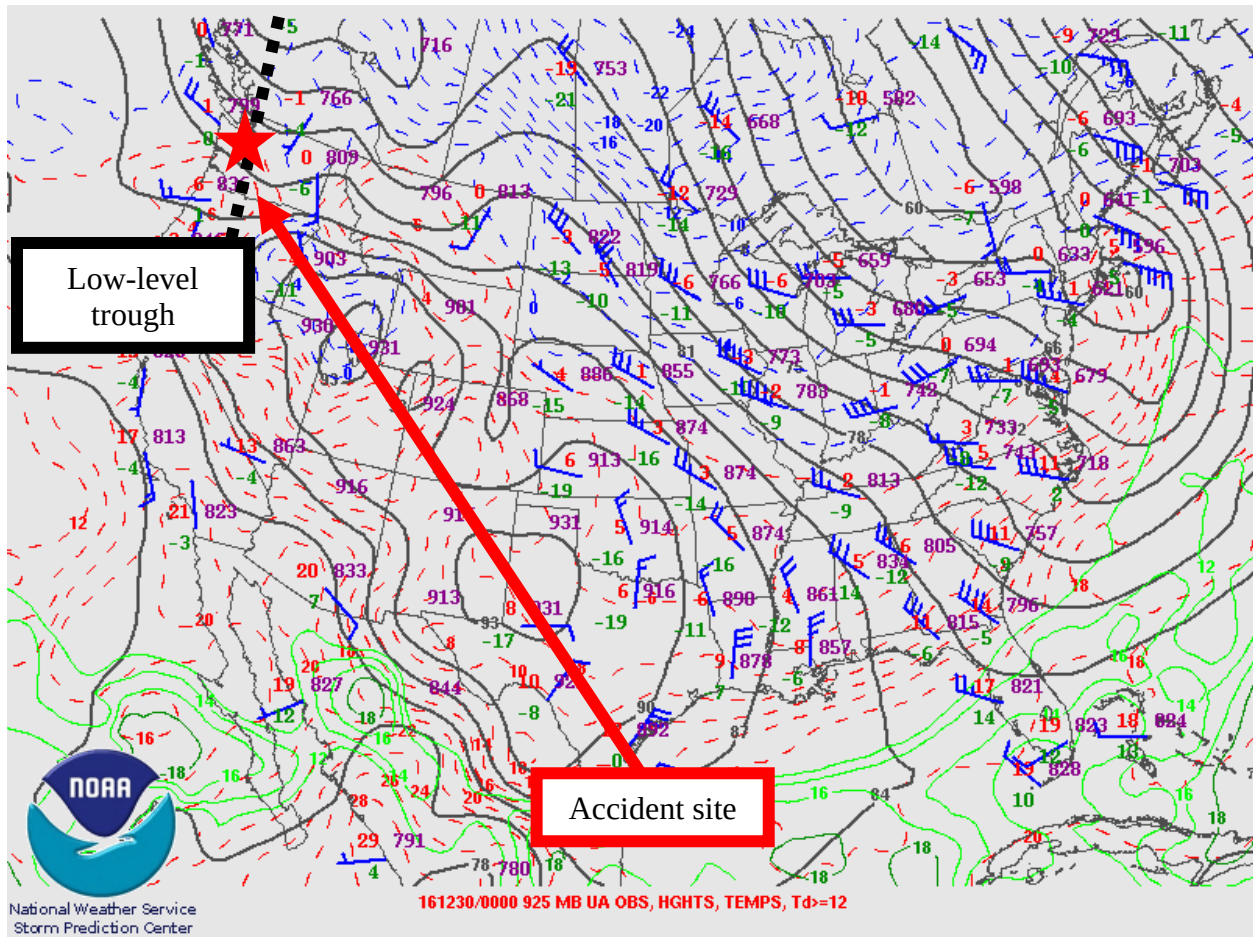


Figure 3 – 925-hPa Constant Pressure Chart for 1600 PST

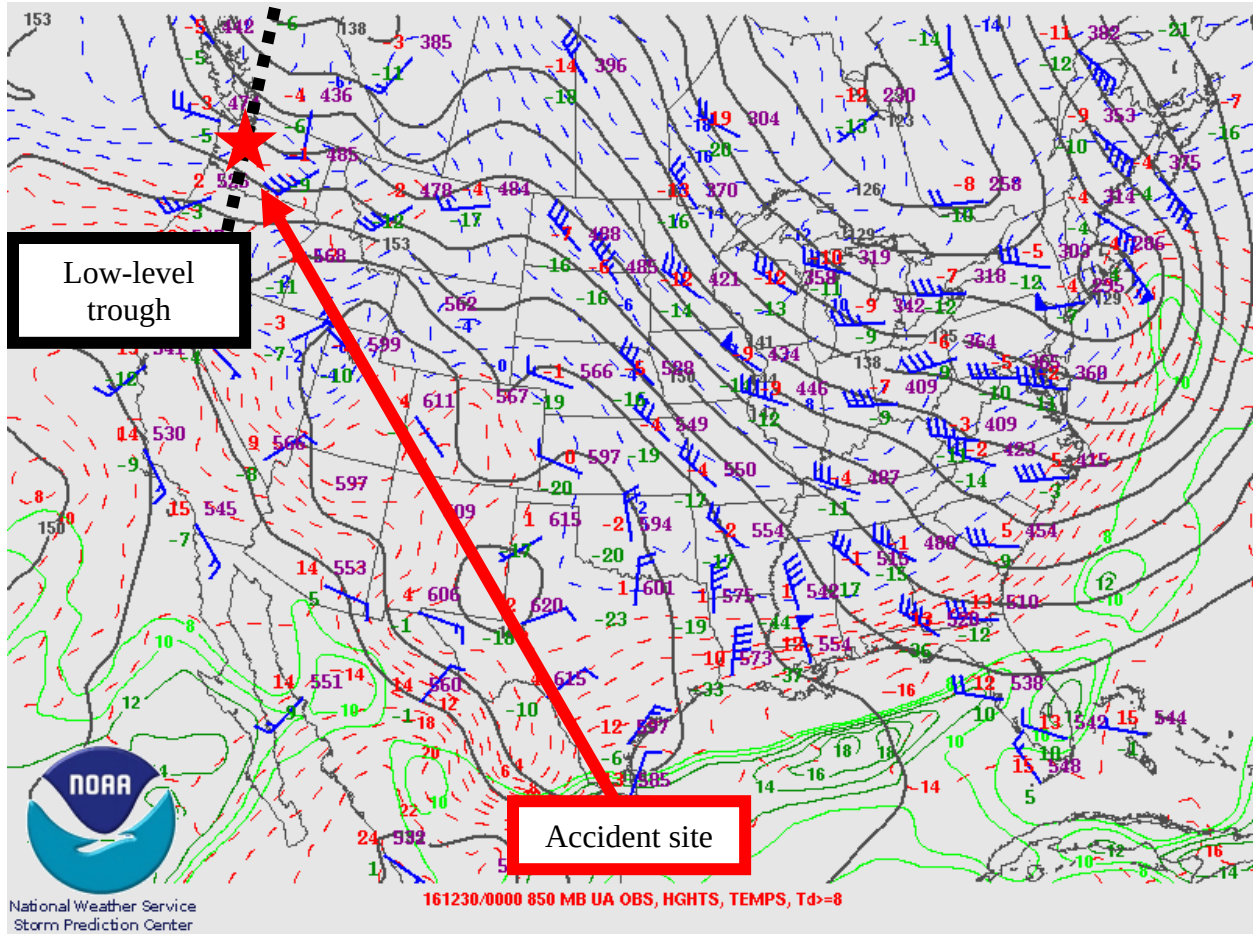


Figure 4 – 850-hPa Constant Pressure Chart for 1600 PST

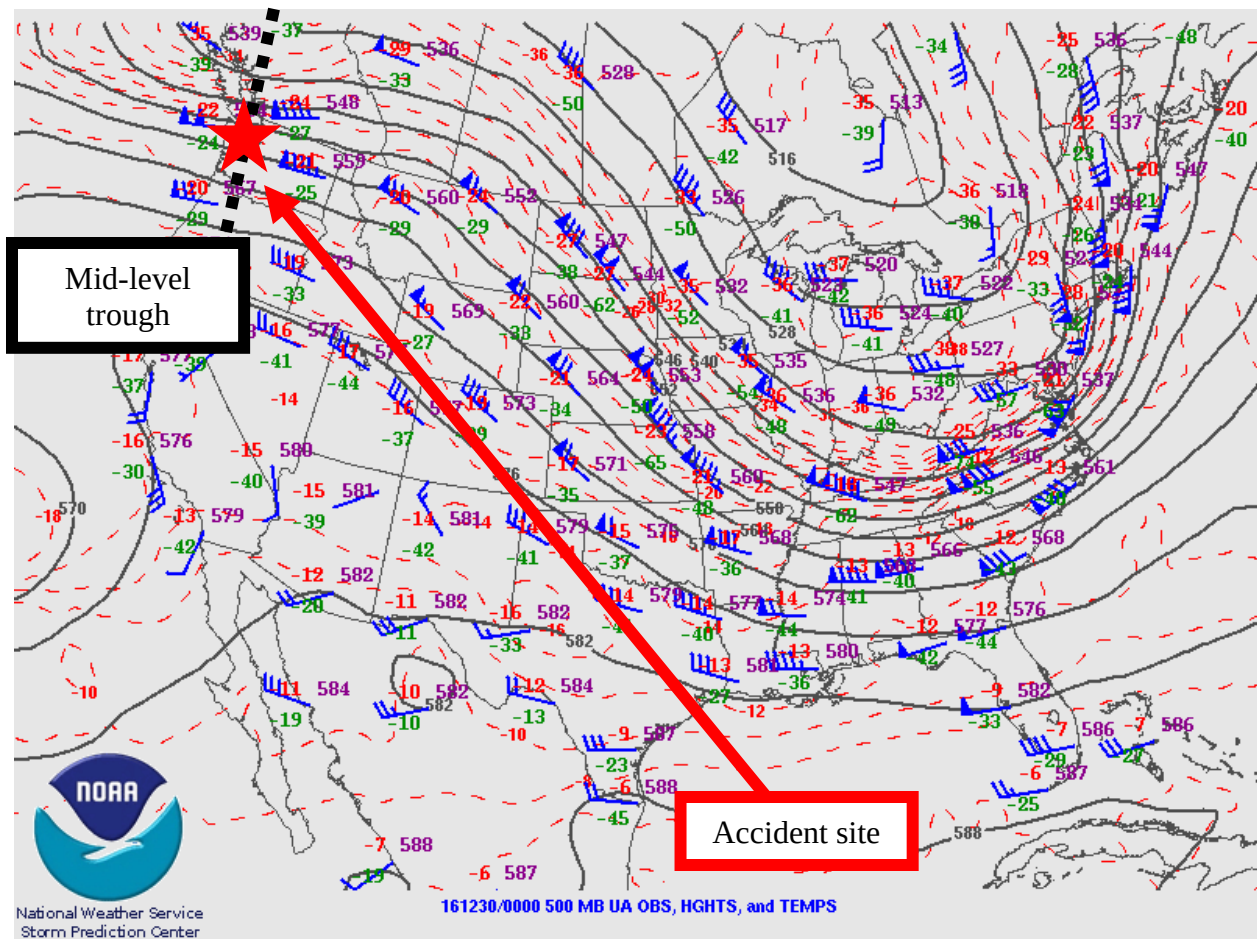


Figure 6 – 500-hPa Constant Pressure Chart for 1600 PST

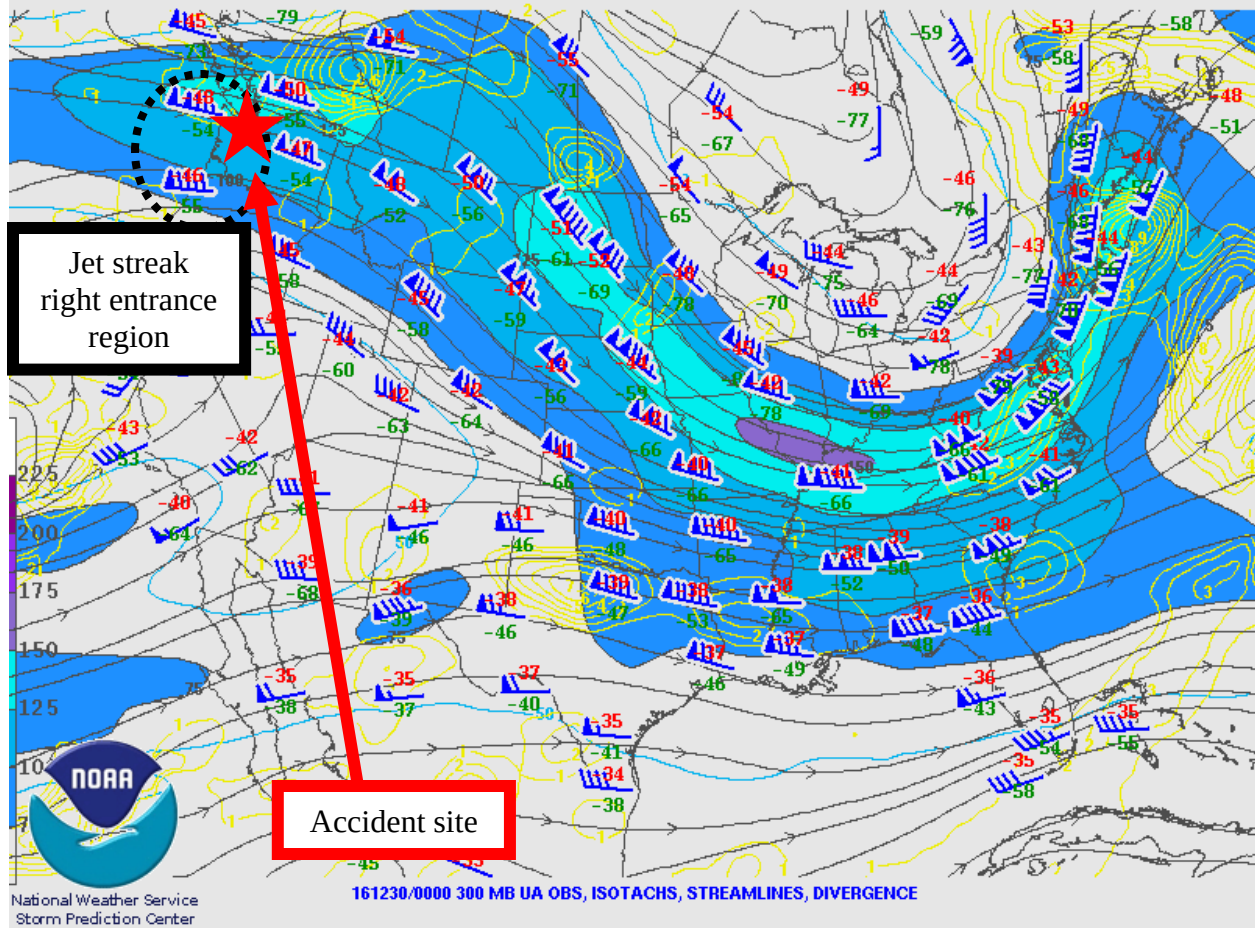


Figure 7 – 300-hPa Constant Pressure Chart for 1600 PST

2.0 SPC Products

There were no thunderstorms forecast for the accident site at the accident time.

3.0 Surface Observations

The area surrounding the accident site was documented utilizing official Meteorological Aerodrome Reports (METARs) and Specials (SPECIs). The following observations were taken from standard code and are provided in plain language with visibility in statute miles for this section. Figure 8 is a sectional chart with the accident site, the closest weather reporting locations marked, and a line between the departure airport and the intended destination airport.



Figure 8 – Sectional chart of accident area with the location of the accident site, surface observation sites, and a line between the departure airport and the intended destination airport

Jefferson County International Airport (KOS9) was the closest official weather station to the accident site, located 6 miles southwest of Port Townsend, Washington. KOS9 had an Automated Weather Observing System (AWOS³) whose reports were not supplemented. KOS9 was located 14 miles north of the accident site, at an elevation of 110 feet, and had a 16° easterly magnetic variation⁴ (figure 8). The following observations were taken and disseminated during the times surrounding the accident:⁵

[1635 PST] METAR KOS9 300035Z AUTO 00000KT 9SM OVC014 06/06 A3012 RMK AO2=

[1655 PST] METAR KOS9 300055Z AUTO 00000KT 9SM BKN014 BKN020 OVC025 06/06 A3012 RMK AO2 P0002=

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

⁴ Magnetic variation – The angle (at a particular location) between magnetic north and true north. 2015, latest measurement taken from <http://www.airnav.com/airport/OS9>

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 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.

[1715 PST] METAR K0S9 300115Z AUTO 00000KT 7SM OVC012 06/06 A3012 RMK AO2=

[1735 PST] METAR K0S9 300135Z AUTO 29005KT 10SM BKN012 BKN016 OVC028 06/06 A3012 RMK AO2=

[1755 PST] METAR K0S9 300155Z AUTO RMK AO2 P0001 PWINO=

[1815 PST] METAR K0S9 300215Z AUTO 10SM RMK AO2 PNO PWINO=

[1835 PST] METAR K0S9 300235Z AUTO 27006KT 10SM 06/05 A3013 RMK AO2=

ACCIDENT TIME 1844 PST

[1855 PST] METAR K0S9 300255Z AUTO 28007KT 10SM 06/04 A3013 RMK AO2=

[1915 PST] METAR K0S9 300315Z AUTO 28010KT 10SM 06/04 A3014 RMK AO2=

[1935 PST] METAR K0S9 300335Z AUTO 30009G15KT 10SM 06/03 A3014 RMK AO2=

[1955 PST] METAR K0S9 300355Z AUTO 29010G16KT 10SM 06/03 A3014 RMK AO2=

K0S9 weather at 1815 PST, 10 miles visibility⁶. Remarks, tipping bucket rain gauge sensor is not operating, present weather identifier sensor is not operating.

K0S9 weather at 1835 PST, wind from 270° at 6 knots, 10 miles visibility, clouds missing, temperature of 6° Celsius (C), dew point temperature of 5° C, and an altimeter setting of 30.13 inches of mercury. Remarks, station with a precipitation discriminator.

K0S9 weather at 1855 PST, wind from 280° at 7 knots, 10 miles visibility, clouds missing, temperature of 6° C, dew point temperature of 4° C, and an altimeter setting of 30.13 inches of mercury. Remarks, station with a precipitation discriminator.

K0S9 weather at 1915 PST, wind from 280° at 10 knots, 10 miles visibility, clouds missing, temperature of 6° C, dew point temperature of 4° C, and an altimeter setting of 30.14 inches of mercury. Remarks, station with a precipitation discriminator.

Bremerton National Airport (KPWT) was the next closest official weather station to the accident site, located 7 miles southwest of Bremerton, Washington. KPWT had an AWOS whose reports were not supplemented. KPWT was located 20 miles south of the accident site, at an elevation of 444 feet, and had a 16° easterly magnetic variation⁷ (figure 8). The following observations were taken and disseminated during the times surrounding the accident:

⁶ Other parameters should have been included in the METAR, but were missing including: wind, clouds, temperature, dew point temperature, and altimeter setting.

⁷ Magnetic variation – The angle (at a particular location) between magnetic north and true north. 2015, latest measurement taken from <http://www.airnav.com/airport/KPWT>

[1635 PST] METAR KPWT 300035Z 20010KT 10SM OVC004 06/05 A3011 RMK AO1=
 [1655 PST] METAR KPWT 300055Z 22007KT 10SM OVC005 06/05 A3012 RMK AO1=
 [1715 PST] METAR KPWT 300115Z 00000KT 10SM OVC004 05/04 A3013 RMK AO1=
 [1735 PST] METAR KPWT 300135Z 00000KT 10SM OVC004 05/04 A3014 RMK AO1=
 [1755 PST] METAR KPWT 300155Z 20005KT 10SM OVC006 05/04 A3014 RMK AO1=
[1815 PST] METAR KPWT 300215Z 22003KT 10SM OVC006 05/04 A3014 RMK AO1=
[1835 PST] METAR KPWT 300235Z 00000KT 10SM OVC006 05/04 A3015 RMK AO1=

ACCIDENT TIME 1844 PST

[1855 PST] METAR KPWT 300255Z 00000KT 10SM OVC008 04/04 A3015 RMK AO1 52014=
[1915 PST] METAR KPWT 300315Z 16003KT 10SM BKN010 OVC018 04/04 A3015 RMK AO1=
 [1935 PST] METAR KPWT 300335Z 00000KT 10SM BKN010 OVC018 05/04 A3017 RMK AO1=
 [1955 PST] METAR KPWT 300355Z 00000KT 9SM OVC008 05/04 A3016 RMK AO1=

KPWT weather at 1815 PST, wind from 220° at 3 knots, 10 miles visibility, overcast ceiling at 600 feet above ground level (agl), temperature of 5° C, dew point temperature of 4° C, and an altimeter setting of 30.14 inches of mercury. Remarks, station without a precipitation discriminator.

KPWT weather at 1835 PST, wind calm, 10 miles visibility, overcast ceiling at 600 feet agl, temperature of 5° C, dew point temperature of 4° C, and an altimeter setting of 30.15 inches of mercury. Remarks, station without a precipitation discriminator.

KPWT weather at 1855 PST, wind calm, 10 miles visibility, overcast ceiling at 800 feet agl, temperature of 4° C, dew point temperature of 4° C, and an altimeter setting of 30.15 inches of mercury. Remarks, station without a precipitation discriminator, 3-hourly pressure increase of 1.4 hPa.

KPWT weather at 1915 PST, wind from 160° at 3 knots, 10 miles visibility, broken ceiling at 1,000 feet agl, overcast skies at 1,800 feet agl, temperature of 4° C, dew point temperature of 4° C, and an altimeter setting of 30.15 inches of mercury. Remarks, station without a precipitation discriminator.

Snohomish County Airport (KPAE) was the next closest official weather station to the accident site, located 6 miles southwest of Everett, Washington. KPAE had Automated Surface Observing System (ASOS⁸) whose reports were supplemented by air traffic control. KPAE was located 21 miles east-northeast of the accident site, at an elevation of 608 feet, and had a 17° easterly magnetic variation⁹ (figure 8). The following observations were taken and disseminated during the times surrounding the accident:

[1453 PST] METAR KPAE 292253Z 16015KT 10SM BKN018 BKN027 OVC055 07/03
A3007 RMK AO2 PK WND 15028/2208 SLP186 T00670028=
[1553 PST] METAR KPAE 292353Z 25006KT 3SM -RA BR BKN009 OVC013 06/04
A3010 RMK AO2 RAB15 SLP198 P0002 60002 T00560044 10067 20050 53008=
[1556 PST] SPECI KPAE 292356Z 24006KT 2 1/2SM -RA BR OVC009 06/04 A3010
RMK AO2 P0001 T00560044=
[1653 PST] METAR KPAE 300053Z 28005KT 2 1/2SM -RA BR BKN009 OVC016 06/05
A3011 RMK AO2 SLP201 P0008 T00560050=
[1655 PST] SPECI KPAE 300055Z 29003KT 3SM -RA BR BKN005 OVC011 06/05
A3011 RMK AO2 CIG 003V009 P0000 T00560050=
***[1726 PST] SPECI KPAE 300126Z 33003KT 5SM -RA BR SCT005 BKN029 OVC034
05/05 A3012 RMK AO2 P0003 T00500050=***
***[1753 PST] METAR KPAE 300153Z 01003KT 5SM -RA BR SCT005 BKN029 OVC034
06/05 A3012 RMK AO2 SLP204 P0004 T00560050=***

ACCIDENT TIME 1844 PST

***[1853 PST] METAR KPAE 300253Z 33006KT 10SM -RA SCT016 SCT022 OVC029
05/04 A3012 RMK AO2 SLP205 P0003 60015 T00500039 51007=***
***[1904 PST] SPECI KPAE 300304Z 32006KT 10SM -RA FEW016 OVC031 05/04 A3013
RMK AO2 P0001 T00500039=***
[1948 PST] SPECI KPAE 300348Z 32003KT 10SM BKN021 BKN036 OVC047 05/04
A3014 RMK AO2 RAE23 P0001=
[1953 PST] METAR KPAE 300353Z 32003KT 10SM BKN021 OVC047 05/04 A3014
RMK AO2 RAE23 SLP212 P0001 T00500039=

⁸ ASOS – Automated Surface Observing System is equipped with meteorological instruments to observe and report wind, visibility, ceiling, temperature, dewpoint, altimeter, and barometric pressure.

⁹ Magnetic variation – The angle (at a particular location) between magnetic north and true north. 2010, latest measurement taken from <http://www.airnav.com/airport/KPAE>

KPAE weather at 1726 PST, wind from 330° at 3 knots, 5 miles visibility, light rain, mist, scattered clouds at 500 feet agl, broken ceiling at 2,900 feet agl, overcast skies at 3,400 feet agl, temperature of 5° C, dew point temperature of 5° C, and an altimeter setting of 30.12 inches of mercury. Remarks, station with a precipitation discriminator, one-hourly precipitation of 0.03 inches, temperature 5.0° C, dew point temperature 5.0° C.

KPAE weather at 1753 PST, wind from 010° at 3 knots, 5 miles visibility, light rain, mist, scattered clouds at 500 feet agl, broken ceiling at 2,900 feet agl, overcast skies at 3,400 feet agl, temperature of 6° C, dew point temperature of 5° C, and an altimeter setting of 30.12 inches of mercury. Remarks, station with a precipitation discriminator, sea-level pressure 1020.4 hPa, one-hourly precipitation of 0.04 inches, temperature 5.6° C, dew point temperature 5.0° C.

KPAE weather at 1853 PST, wind from 330° at 6 knots, 10 miles visibility, light rain, scattered clouds at 1,600 feet agl, scattered clouds at 2,200 feet agl, an overcast ceiling at 2,900 feet agl, temperature of 5° C, dew point temperature of 4° C, and an altimeter setting of 30.12 inches of mercury. Remarks, station with a precipitation discriminator, sea-level pressure 1020.5 hPa, one-hourly precipitation of 0.03 inches, 6-hourly precipitation 0.15 inches, temperature 5.0° C, dew point temperature 3.9° C, 3-hourly pressure increase of 0.7 hPa.

KPAE weather at 1904 PST, wind from 320° at 6 knots, 10 miles visibility, light rain, few clouds at 1,600 feet agl, an overcast ceiling at 3,100 feet agl, temperature of 5° C, dew point temperature of 4° C, and an altimeter setting of 30.13 inches of mercury. Remarks, station with a precipitation discriminator, one-hourly precipitation of 0.01 inches, temperature 5.0° C, dew point temperature 3.9° C.

Boeing Field/King County International Airport (KBFI) was the departure airport, located 4 miles south of Seattle, Washington. KBFI had ASOS whose reports were supplemented by air traffic control. KBFI was located 26 miles southeast of the accident site, at an elevation of 21 feet, and had a 15° easterly magnetic variation¹⁰ (figure 8). The following observations were taken and disseminated during the times surrounding the accident:

[1153 PST] METAR KBFI 291953Z 15009KT 10SM -RA OVC034 06/03 A3016 RMK
AO2 RAB21 SLP211 P0000 T00610028=

[1253 PST] METAR KBFI 292053Z 15008KT 10SM -RA OVC030 06/04 A3013 RMK
AO2 SLP201 P0001 60001 T00610039 58021=

[1353 PST] METAR KBFI 292153Z 17008KT 10SM -RA OVC030 07/06 A3011 RMK
AO2 SLP195 P0001 T00720056=

[1453 PST] METAR KBFI 292253Z 14009KT 10SM -RA BKN032 BKN047 OVC070
07/04 A3009 RMK AO2 SLP190 P0001 T00670044=

¹⁰ Magnetic variation – The angle (at a particular location) between magnetic north and true north. 2020, latest measurement taken from <http://www.airnav.com/airport/KBFI>

[1553 PST] METAR KBFI 292353Z VRB04KT 10SM OVC028 07/06 A3011 RMK AO2
RAE36 SLP195 P0000 60003 T00720056 10072 20056 55007=

**[1653 PST] METAR KBFI 300053Z 19014G19KT 10SM SCT018 BKN028 OVC060 08/06
A3010 RMK AO2 SLP191 T00830061=**

**[1753 PST] METAR KBFI 300153Z VRB06KT 10SM -RA BKN018 OVC030 08/06 A3013
RMK AO2 RAB31 SLP202 P0001 T00780061=**

ACCIDENT TIME 1844 PST

**[1853 PST] METAR KBFI 300253Z 25007KT 10SM -RA SCT012 BKN018 OVC023
07/07 A3015 RMK AO2 SLP208 P0001 60002 T00720072 53013=**

**[1953 PST] METAR KBFI 300353Z 04003KT 10SM OVC017 07/07 A3016 RMK AO2
RAE0257B23E32 SLP212 P0000 T00720072 \$=**

[2053 PST] METAR KBFI 300453Z 09009KT 3SM -RA BR OVC016 06/06 A3018
RMK AO2 RAB01 SLP221 P0003 T00560056 \$=

[2153 PST] METAR KBFI 300553Z 12007KT 8SM OVC022 06/06 A3019 RMK AO2
RAE25 SLP222 P0001 60006 T00560056 10089 20056 51014 \$=

KBFI weather at 1653 PST, wind from 190° at 14 knots with gusts to 19 knots, 10 miles visibility, scattered clouds at 1,800 feet agl, broken ceiling at 2,800 feet agl, overcast skies at 6,000 feet agl, temperature of 8° C, dew point temperature of 6° C, and an altimeter setting of 30.10 inches of mercury. Remarks, station with a precipitation discriminator, sea-level pressure 1019.1 hPa, temperature 8.3° C, dew point temperature 6.1° C.

KBFI weather at 1753 PST, variable wind at 6 knots, 10 miles visibility, light rain, broken ceiling at 1,800 feet agl, overcast skies at 3,000 feet agl, temperature of 8° C, dew point temperature of 6° C, and an altimeter setting of 30.13 inches of mercury. Remarks, station with a precipitation discriminator, rain began at 1731 PST, sea-level pressure 1020.2 hPa, one-hourly precipitation of 0.01 inches, temperature 7.8° C, dew point temperature 6.1° C.

KBFI weather at 1853 PST, wind from 250° at 7 knots, 10 miles visibility, light rain, scattered clouds at 1,200 feet agl, broken ceiling at 1,800 feet agl, overcast skies at 2,300 feet agl, temperature of 7° C, dew point temperature of 7° C, and an altimeter setting of 30.15 inches of mercury. Remarks, station with a precipitation discriminator, sea-level pressure 1020.8 hPa, one-hourly precipitation of 0.01 inches, 6-hourly precipitation 0.02 inches, temperature 7.2° C, dew point temperature 7.2° C, 3-hourly pressure increase of 1.3 hPa.

KBFI weather at 1953 PST, wind from 040° at 3 knots, 10 miles visibility, an overcast ceiling at 1,700 feet agl, temperature of 7° C, dew point temperature of 7° C, and an altimeter setting of 30.16 inches of mercury. Remarks, station with a precipitation discriminator, rain ended at 1857 PST, rain began at 1923 PST, rain ended at 1932 PST, sea-level pressure 1021.2 hPa, one-hourly precipitation of a trace, temperature 7.2° C, dew point temperature 7.2° C, maintenance is needed on the system.

William R. Fairchild International Airport (KCLM) was the intended destination airport, located 3 miles northwest of Port Angeles, Washington. KCLM had ASOS whose reports were not supplemented. KCLM was located 34 miles northwest of the accident site, at an elevation of 291 feet, and had a 16° easterly magnetic variation¹¹ (figure 8). The following observations were taken and disseminated during the times surrounding the accident:

[1406 PST] SPECI KCLM 292206Z AUTO 30015G22KT 4SM -RA BR BKN007 OVC013
06/06 A3007 RMK AO2 P0003 T00610056=

[1421 PST] SPECI KCLM 292221Z AUTO 30011G18KT 4SM -RA BR SCT007 BKN011
OVC034 06/06 A3008 RMK AO2 P0004 T00610056=

[1428 PST] SPECI KCLM 292228Z AUTO 29011G18KT 4SM -RA BR FEW007 SCT011
OVC032 06/06 A3008 RMK AO2 P0004 T00610056=

[1453 PST] METAR KCLM 292253Z AUTO 26009KT 6SM -RA BR FEW007 OVC036
06/06 A3009 RMK AO2 SLP190 P0006 T00560056=

[1553 PST] METAR KCLM 292353Z AUTO 27008KT 10SM -RA OVC065 06/04 A3009
RMK AO2 SLP193 P0002 60019 T00560044 10072 20056 51017=

**[1653 PST] METAR KCLM 300053Z AUTO 27006KT 10SM -RA FEW044 BKN060
OVC080 06/04 A3012 RMK AO2 RAE25B45 SLP201 P0002 T00560044=**

**[1753 PST] METAR KCLM 300153Z AUTO 28017G22KT 9SM -RA SCT038 BKN045
OVC070 05/03 A3013 RMK AO2 SLP206 P0002 T00500033=**

ACCIDENT TIME 1844 PST

**[1853 PST] METAR KCLM 300253Z AUTO 26010KT 9SM -RA OVC036 05/02 A3014
RMK AO2 SLP208 P0004 60008 T00500022 51016=**

**[1953 PST] METAR KCLM 300353Z AUTO 25010KT 10SM CLR 05/03 A3015 RMK
AO2 RAE0256 SLP212 P0000 T00500028=**

[2053 PST] METAR KCLM 300453Z AUTO 25009KT 10SM CLR 04/02 A3016 RMK
AO2 SLP214 T00440022=

¹¹ Magnetic variation – The angle (at a particular location) between magnetic north and true north. 2020, latest measurement taken from <http://www.airnav.com/airport/KCLM>

[2153 PST] METAR KCLM 300553Z AUTO 26012KT 10SM CLR 04/02 A3015 RMK
AO2 SLP212 60008 T00390017 10056 20033 50004=

KCLM weather at 1653 PST, wind from 270° at 6 knots, 10 miles visibility, light rain, few clouds at 4,400 feet agl, broken ceiling at 6,000 feet agl, overcast skies at 8,000 feet agl, temperature of 6° C, dew point temperature of 4° C, and an altimeter setting of 30.12 inches of mercury. Remarks, station with a precipitation discriminator, rain ended at 1625 PST, rain began at 1645 PST, sea-level pressure 1020.1 hPa, one-hourly precipitation of 0.02 inches, temperature 5.6° C, dew point temperature 4.4° C.

KCLM weather at 1753 PST, wind from 280° at 17 knots with gusts to 22 knots, 9 miles visibility, light rain, scattered clouds at 3,800 feet agl, broken ceiling at 4,500 feet agl, overcast skies at 7,000 feet agl, temperature of 5° C, dew point temperature of 3° C, and an altimeter setting of 30.13 inches of mercury. Remarks, station with a precipitation discriminator, sea-level pressure 1020.6 hPa, one-hourly precipitation of 0.02 inches, temperature 5.0° C, dew point temperature 3.3° C.

KCLM weather at 1853 PST, wind from 260° at 10 knots, 9 miles visibility, light rain, an overcast ceiling at 3,600 feet agl, temperature of 5° C, dew point temperature of 2° C, and an altimeter setting of 30.14 inches of mercury. Remarks, station with a precipitation discriminator, sea-level pressure 1020.8 hPa, one-hourly precipitation of 0.04 inches, 6-hourly precipitation 0.08 inches, temperature 5.0° C, dew point temperature 2.2° C, 3-hourly pressure increase of 1.6 hPa.

KCLM weather at 1953 PST, wind from 250° at 6 knots, 10 miles visibility, clear skies below 12,000 feet agl, temperature of 5° C, dew point temperature of 3° C, and an altimeter setting of 30.15 inches of mercury. Remarks, station with a precipitation discriminator, rain ended at 1856 PST, sea-level pressure 1021.2 hPa, one-hourly precipitation of a trace, temperature 5.0° C, dew point temperature 2.8° C.

The observations from KPWT and KPAE surrounding the accident time indicated IFR¹² to MVFR¹³ conditions around the accident site at the accident time with the lowest cloud cover around 600 feet agl in the 2 hours surrounding the accident time. Unfortunately, KOS9 was having equipment issues around the accident time and that prevented observations of visibility and cloud ceiling conditions. Light rain was also falling across most of Puget Sound and the accident flight route (section 6.4). MVFR conditions were present at KBFI before takeoff, while KCLM experienced IFR conditions when the cold front and rain conditions moved eastward through their area a few hours before the accident time.

¹² Instrument Flight Rules – Refers to the general weather conditions pilots can expect at the surface. IFR criteria means a ceiling below 1,000 feet agl and/or less than 3 miles visibility.

¹³ 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 feet agl (inclusive) and/or 3 to 5 miles visibility.

4.0 Upper Air Data

A High-Resolution Rapid Refresh (HRRR)¹⁴ model sounding was created for the accident site for 1900 PST. The 1900 PST sounding was plotted on a standard Skew-T log P diagram¹⁵ with the derived stability parameters included in figure 9 (with data from the surface to 600-hPa, or 14,000 feet msl.) This data was analyzed utilizing the RAOB¹⁶ software package. The sounding depicted the lifted condensation level (LCL)¹⁷ at 653 feet msl and a convective condensation level (CCL)¹⁸ of 2,152 feet. The freezing level was 3,824 feet. The precipitable water value was 0.64 inches.

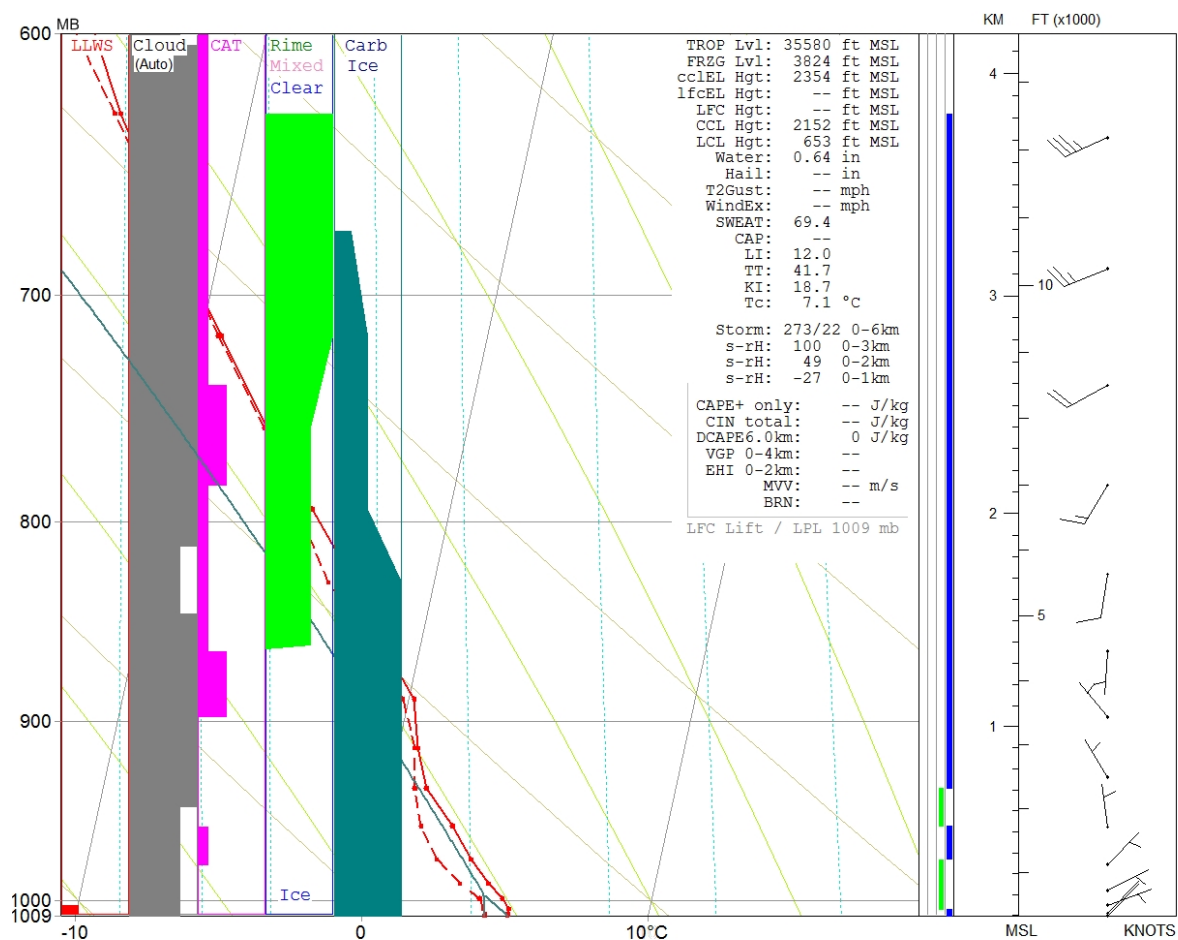


Figure 9 – 1900 PST HRRR sounding for the accident site

¹⁴ 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.

¹⁵ Skew T log P diagram – is a standard meteorological plot using temperature and the logarithmic of pressure as coordinates, used to display winds, temperature, dew point, and various indices used to define the vertical structure of the atmosphere.

¹⁶ RAOB – (The complete Rawinsonde Observation program) is an interactive sounding analysis program developed by Environmental Research Services, Matamoras, Pennsylvania.

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

¹⁸ Convective Condensation Level (CCL) – The level in the atmosphere to which an air parcel, if heated from below, will rise dry adiabatically, without becoming colder than its environment just before the parcel becomes saturated.

The 1900 PST HRRR sounding identified two conditionally unstable layer between the surface and 2,500 feet with stable layers right near the surface, between 1,250 feet and 1,750 feet, and above 2,500 feet. A weak inversion or near-neutral layer was located between the surface and 600 feet and this inversion would have allowed for any clouds that formed below the inversion to remain in place. With the relatively moist atmosphere between the surface and 14,000 feet, RAOB indicated that clouds were likely from the surface through 14,000 feet. Icing conditions were indicated by RAOB but only above 5,000 feet. Given the abundant moisture from the surface to 14,000 feet, the surface frontal boundary (section 1.1), and the low- and mid-level troughs acting as lifting mechanism (section 1.2), clouds and precipitation would be expected near the accident site at the accident time.

The 1900 PST HRRR sounding wind profile indicated a surface wind from 043° at 1 knot with the wind remaining variable and under 10 knots through 6,000 feet. Above 6,000 feet the wind became southwesterly and remained southwesterly through 14,000 feet. The wind speed increased to 15 knots by 7,000 feet, and increased again to 45 knots at 14,500 feet. RAOB indicated the possibility of low-level wind shear (LLWS) between the surface and 500 feet with clear-air turbulence possible in two layers between 1,300 feet and 14,000 feet. Given the relatively light wind magnitudes, neither LLWS nor clear-air turbulence were present outside of precipitation or rain shower activity.

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 1500 PST through 2100 PST at approximately 15-minute intervals were reviewed, and the closest images to the time of the accident are documented here.

Figures 11 and 12 present the GOES-15 infrared imagery from 1845 and 1900 PST at 6X magnification with the accident site highlighted with a red square. Inspection of the infrared imagery indicated abundant clouds over the accident site at the accident time. The clouds were moving from west to east with time (attachment 1). The lower brightness temperatures (yellows and greens, higher cloud tops) were in a band oriented west to east over the accident site around the accident time. Based on the brightness temperatures above the accident site and the vertical temperature profile provided by the 1900 PST HRRR sounding, the approximate cloud-top heights over the accident site were 20,000 feet at 1845 PST. It should be noted these figures have not been corrected for any parallax error. Based on the 1900 PST HRRR sounding data (section 4.0), infrared satellite imagery, surface observation data (section 3.0), and precipitation (section 6.4); lowering ceilings and instrument meteorological conditions (IMC) were present northwestward across Puget Sound.

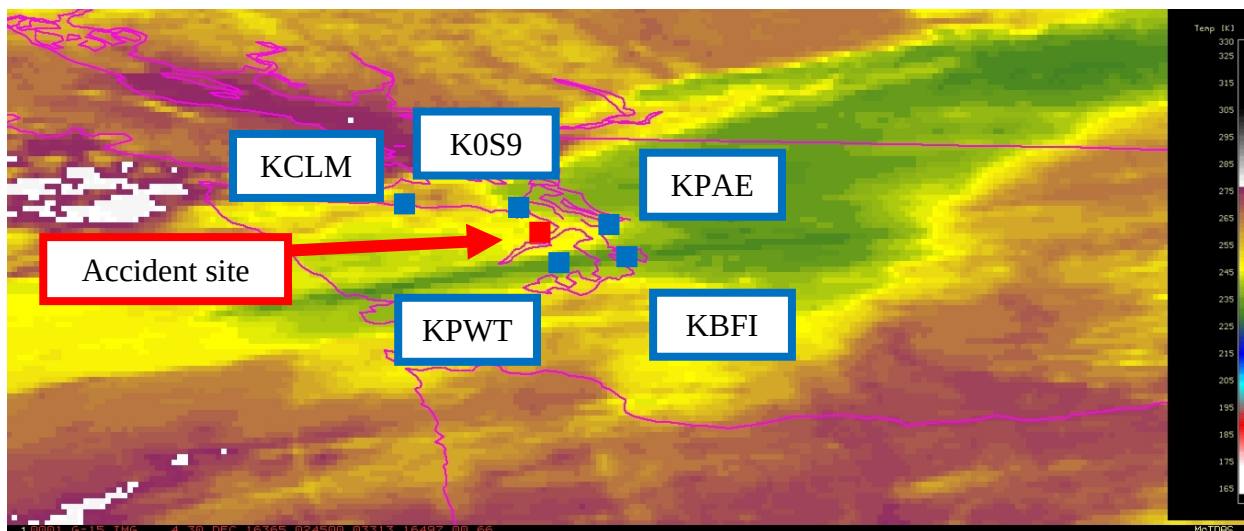


Figure 10 – GOES-15 infrared image at 1845 PST

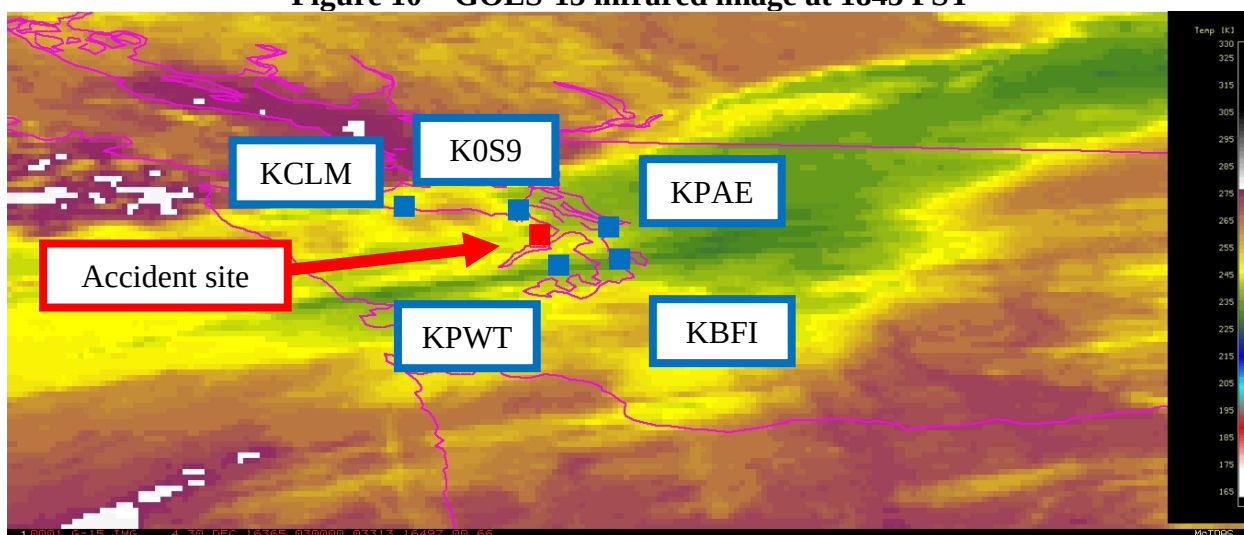


Figure 11 – GOES-15 infrared image at 1900 PST

6.0 Radar Imagery Information

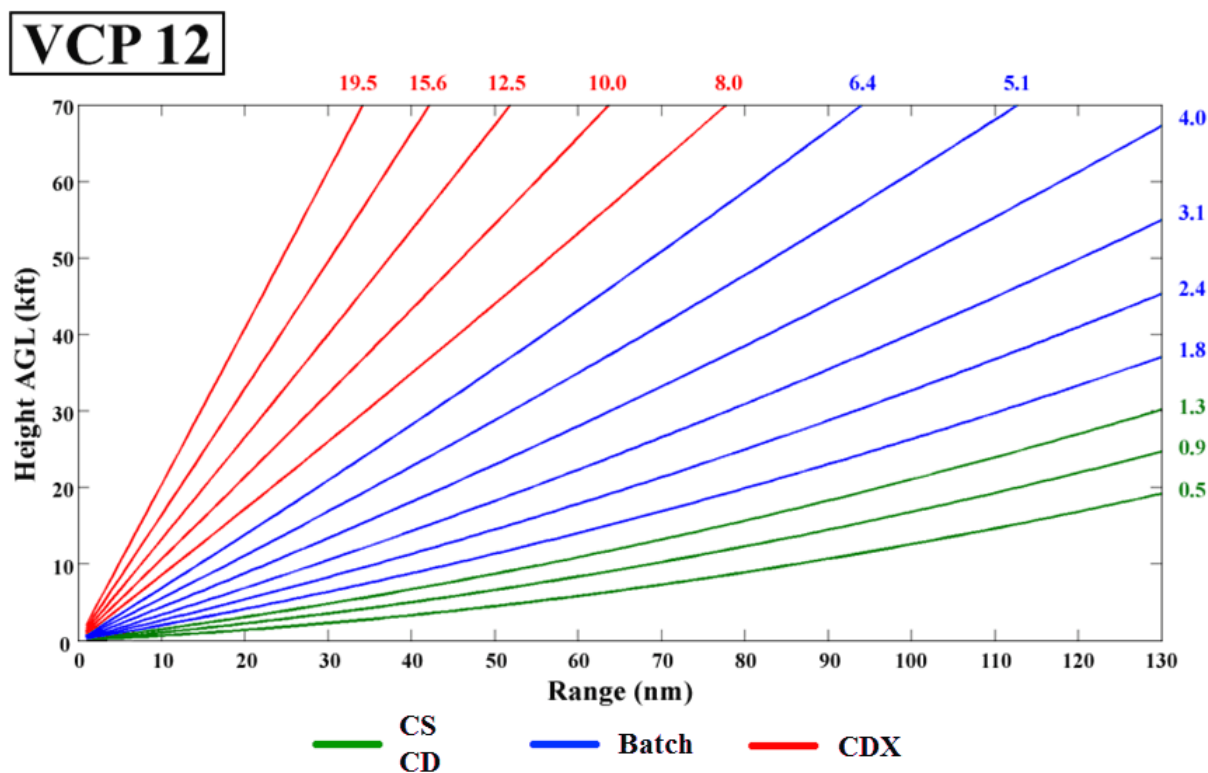
The closest NWS Weather Surveillance Radar-1988, Doppler (WSR-88D)¹⁹ to the accident site was the Seattle, Washington, radar (KATX), which was located 25 miles northeast of the accident site at an elevation of 494 feet. Level II and III archive radar data were obtained from the NCEI utilizing the NEXRAD 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. 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 KATX 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 Strategy²⁰

²⁰ Contiguous Surveillance (CS)--The low Pulse Repetition Frequency (PRF) scan of the split cut. Gives a high $R_{\max}$ value to determine proper target location and intensity, but a low $V_{\max}$ value limits the velocities that can be measured.

Contiguous Doppler (CD)--The high PRF scan of the split cut. Gives a low $R_{\max}$ value causing more range folded (multiple trip) echoes, but a high $V_{\max}$ value to get higher, more accurate velocity values.

Batch Mode – Uses alternating low and high PRFs on each radial for one full rotation at each elevation angle. The two resulting data sets (low PRF and high PRF) are combined to resolve range ambiguity. Used in the middle

6.2 Beam Height Calculation

Assuming standard refraction²¹ of the WSR-88D 0.95° wide radar beam, the following table shows the approximate beam height and width²² information²³ of the radar display over the site of the accident. The heights have been rounded to the nearest 10 feet.

ANTENNA ELEVATION	BEAM CENTER	BEAM BASE	BEAM TOP	BEAM WIDTH
0.5°	2,270 feet	1,040 feet	3,500 feet	2,460 feet

Based on the radar height calculations, the 0.5° elevation scans depicted the conditions between 1,040 feet and 3,500 feet msl over the accident site and these are the closest altitudes to the accident site and accident flight altitude²⁴ before the accident occurred.

6.3 Reflectivity

Reflectivity is the measure of the efficiency of a target in intercepting and returning radio energy. With hydrometeors²⁵ 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 (dBZ²⁶), 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:

elevation angles.

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 see the air traffic control (ATC) data contained 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 12 through 16 present the KATX WSR-88D base reflectivity images for the 0.5° elevation scans initiated at 1836, 1839, 1841, 1843, and 1846 PST with a resolution of 0.5° X 250 m. Base reflectivity values between 10 to 30 dBZ were located above the accident site around the accident time with these reflectivity values indicative of light to moderate rain conditions given the upper air sounding (section 4.0) and surface observations (section 3.0). The accident aircraft likely first encountered precipitation shortly after takeoff with a brief break in precipitation between 1830 and 1836 PST²⁷ (attachment 2), then encountering another area of precipitation around 1836 PST. This second encounter with precipitation is when the accident flight track became erratic with several loops in the flight track between 1836 and 1844 PST. The rain was moving east-southeastward with time (attachment 2). There were no lightning strikes around the accident site at the accident time.²⁸

²⁷ For more information see the ATC data contained in the docket for this accident.

²⁸ A review of Earth Networks Total Lightning network was done.

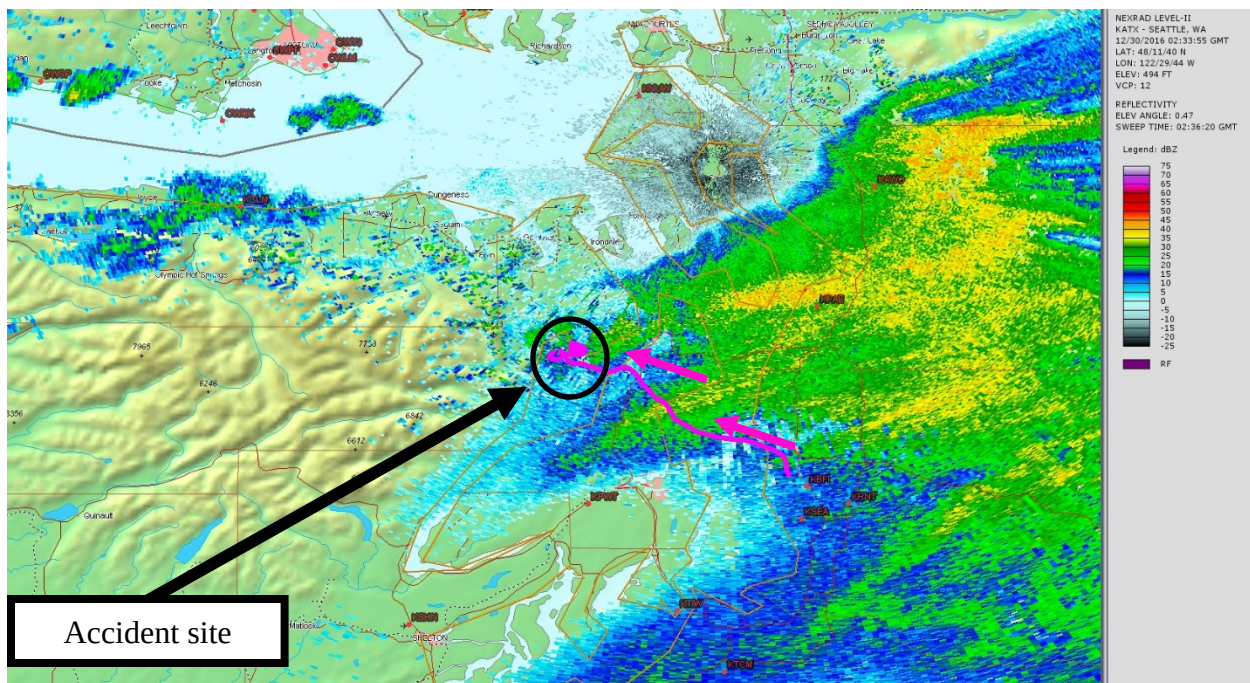


Figure 12 – KATX WSR-88D reflectivity for the 0.5° elevation scan initiated at 1836 PST with the accident site marked with black circle and the accident flight track marked with pink line (arrows in direction of travel)

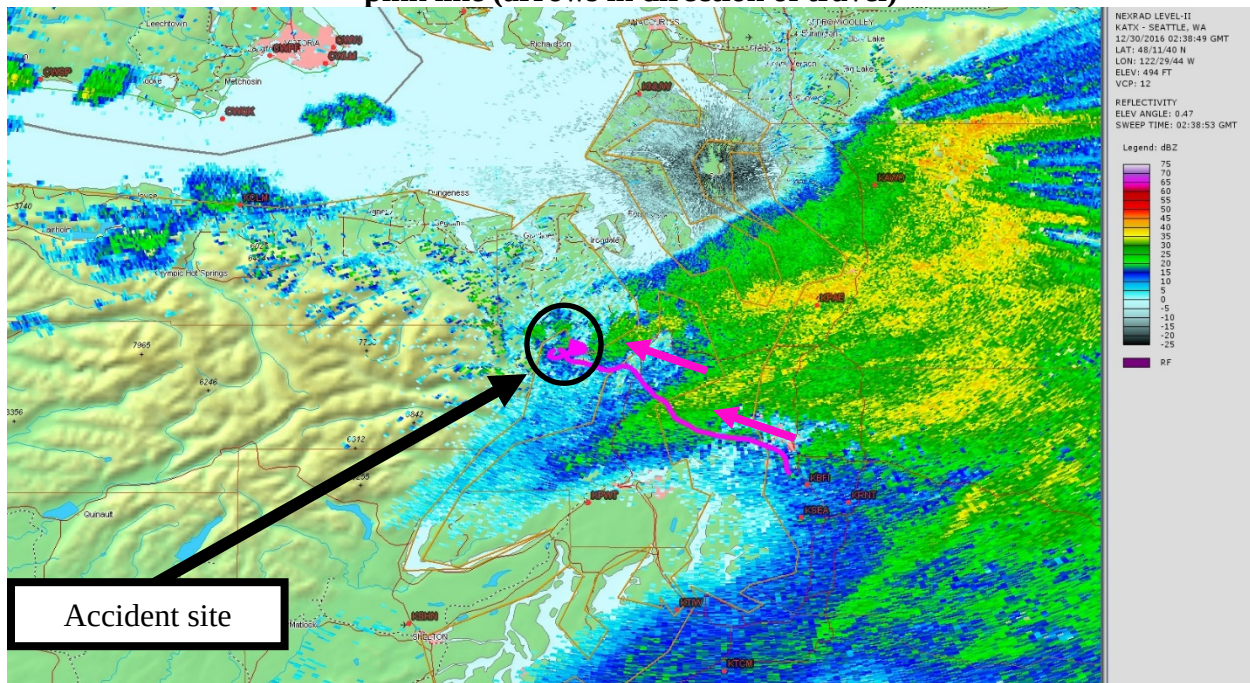


Figure 13 – KATX WSR-88D reflectivity for the 0.5° elevation scan initiated at 1839 PST with the accident site marked with black circle and the accident flight track marked with pink line (arrows in direction of travel)

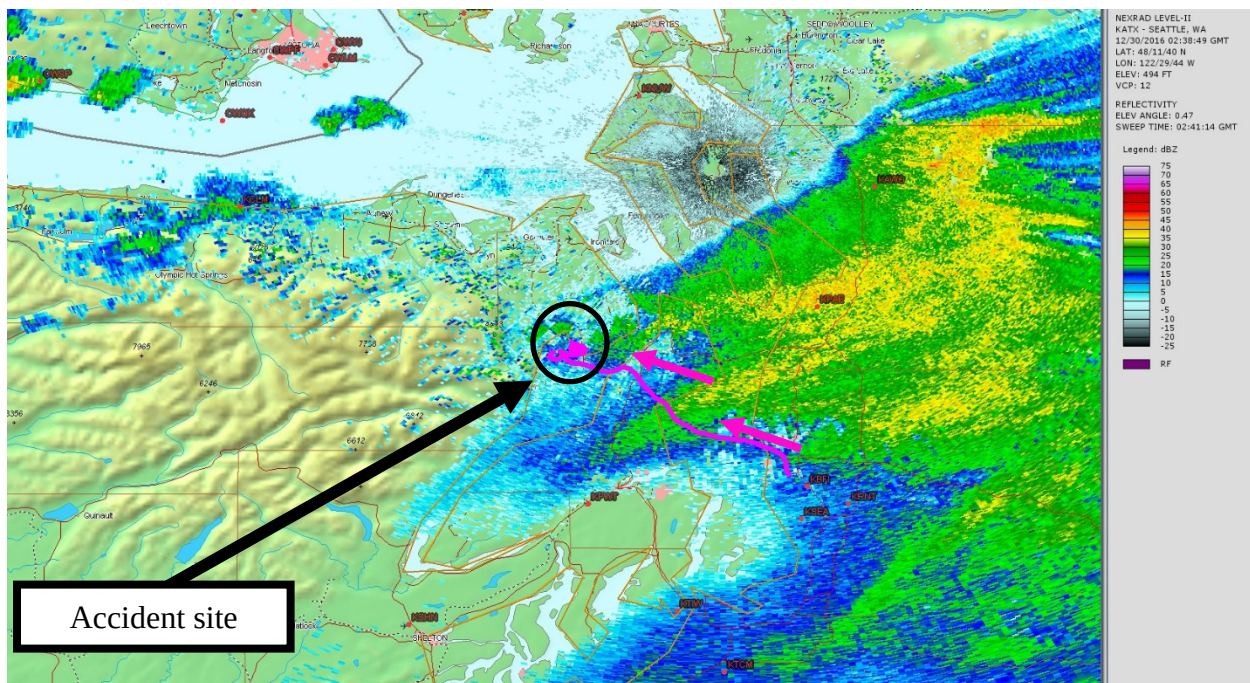


Figure 14 – KATX WSR-88D reflectivity for the 0.5° elevation scan initiated at 1841 PST with the accident site marked with black circle and the accident flight track marked with pink line (arrows in direction of travel)

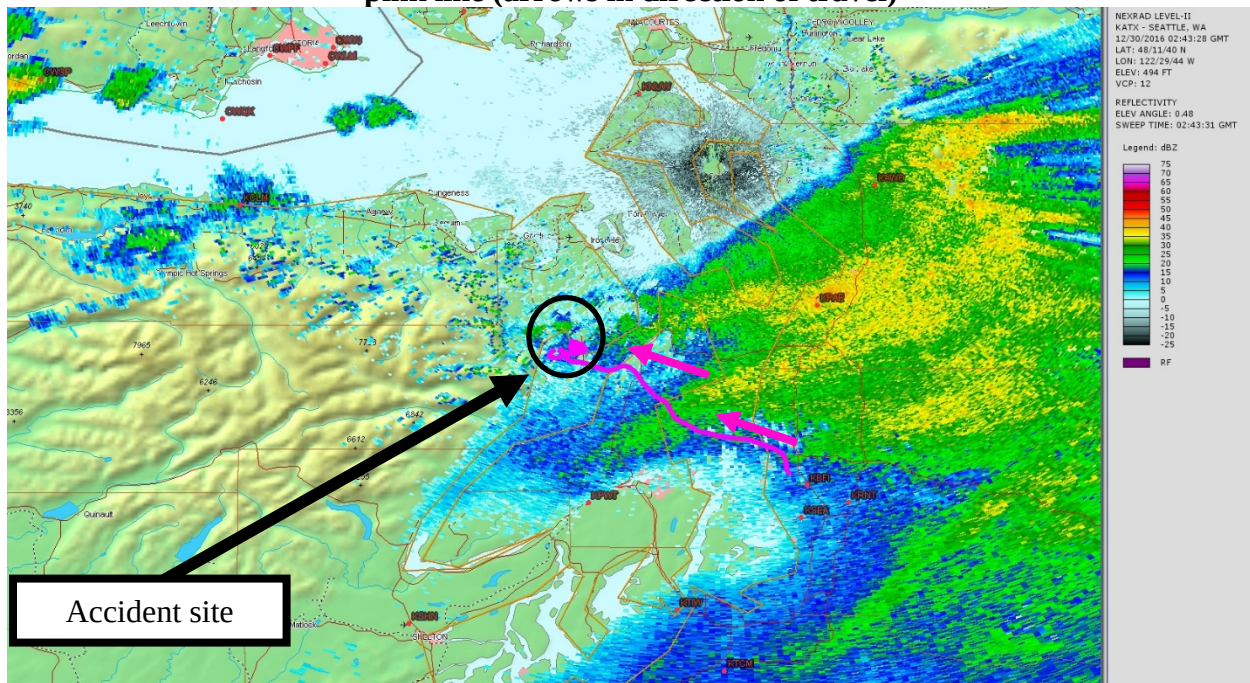


Figure 15 – KATX WSR-88D reflectivity for the 0.5° elevation scan initiated at 1843 PST with the accident site marked with black circle and the accident flight track marked with pink line (arrows in direction of travel)

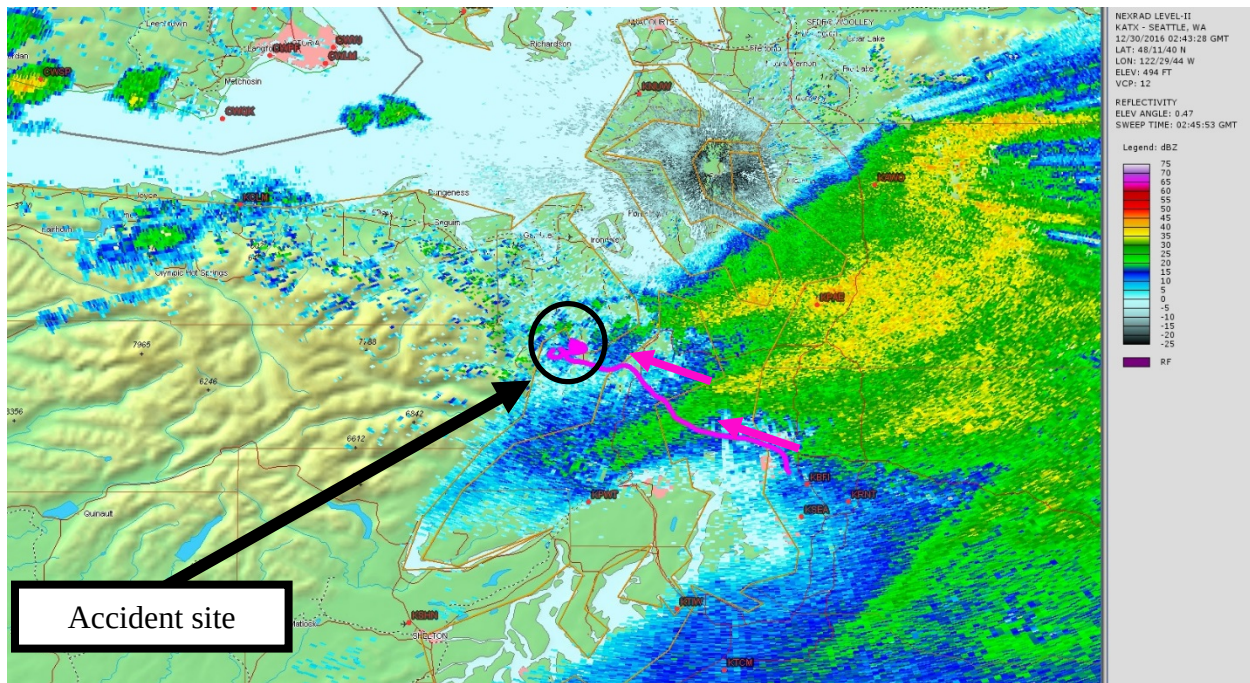


Figure 16 – KATX WSR-88D reflectivity for the 0.5° elevation scan initiated at 1846 PST with the accident site marked with black circle and the accident flight track marked with pink line (arrows in direction of travel)

7.0 Pilot Reports²⁹

All pilot reports (PIREPs) close to the accident site from about two hours prior to the accident time to about three hours after the accident time were reviewed. Only PIREPs for below FL150³⁰ are provided below:

OLM UA /OV OLM/TM 0056/FL017/TP M20/RM BASES 019=

SEA UA /OV SEA040047/TM 0057/FL140/TP B738/TA M14/IC MOD MIX/RM DURD GLASR1 ARR 140-100
..ZSE=

VR UA /OV CYCD /TM 0207 /FLDURD /TP PA31 /TB LGT - MDT 008-015 /RM ON APCH R16

SEA UA /OV SEA00020/TM 0240/FL090/TP PA31/TA -8/IC LIGHT MIXED

SEA UA /OV SEA090010/TM 0320/FL060/TP DH8D/TA M09/IC LGT RIME/RM DURC 060-115

SEA UA /OV SEA109026/TM 0429/FL160/TP B739/TA M02/TB MOD TURB/IC MOD RIME/RM MOD RIME
DURD 120-80/ MOD TURB DURD 160-140

KSEA UUA /OV SEA/TM 0512/FL010/TP B737/RM LLWS +15KT

²⁹ Only pilot reports with the WMO header UBWA** identifier were considered.

³⁰ Flight Level – A Flight Level (FL) is a standard nominal altitude of an aircraft, in hundreds of feet. This altitude is calculated from the International standard pressure datum of 1013.25 hPa (29.92 inHg), the average sea-level pressure, and therefore is not necessarily the same as the aircraft's true altitude either above mean sea level or above ground level.

Routine pilot report (UA); Over Olympia, Washington; Time – 1656 PST (0056Z); Altitude – 1,700 feet; Type aircraft – Mooney M20; Remarks – Bases at 1,900 feet.

Routine pilot report (UA); 47 miles from Seattle, Washington, on the 040° radial; Time – 1657 PST (0057Z); Altitude – 14,000 feet; Type aircraft – Boeing 737-800; Temperature – -14° C; Icing – Moderate mixed; Remarks – During descent for arrival between 14,000 and 10,000 feet.

Routine pilot report (UA); Over Nanaimo, British Columbia, Canada; Time – 1807 PST (0207Z); Altitude – During descent; Type aircraft – Piper PA-31 Navajo; Turbulence – Light to moderate between 800 and 1,500 feet; Remarks – On approach to runway 16.

Routine pilot report (UA); 20 miles from Seattle, Washington, on the 000° radial; Time – 1840 PST (0240Z); Altitude – 9,000 feet; Type aircraft – Piper PA-31 Navajo; Temperature – -8° C; Icing – Light mixed.

Routine pilot report (UA); 10 miles from Seattle, Washington, on the 090° radial; Time – 1920 PST (0320Z); Altitude – 6,000 feet; Type aircraft – Bombardier Dash 8; Temperature – -9° C; Icing – Light rime; Remarks – During climb between 6,000 and 11,500 feet.

Routine pilot report (UA); 26 miles from Seattle, Washington, on the 109° radial; Time – 2029 PST (0429Z); Altitude – 16,000 feet; Type aircraft – Boeing 737-900; Temperature – -2° C; Turbulence – Moderate; Icing – Moderate rime; Remarks – Moderate rime during descent between 12,000 and 8,000 feet with moderate turbulence during descent between 16,000 and 14,000 feet.

Urgent pilot report (UUA); Over Seattle, Washington; Time – 2112 PST (0512Z); Altitude – 1,000 feet; Type aircraft – Boeing 737-700; Remarks – LLWS plus 15 knots.

8.0 SIGMET and CWSU Advisory

There were no SIGMETs valid for the accident site at the accident time.

No Center Weather Service Unit (CWSU) Center Weather Advisories (CWA)s were valid for the accident site at the accident time. No CWSU Meteorological Impact Statements (MIS)s were valid for the accident site at the accident time.

9.0 AIRMETs

AIRMETs Tango, Sierra, and Zulu were issued at 1245 PST and valid at the accident time for the accident site (figures 17 through 20). The AIRMETs forecasted mountain obscuration conditions due to clouds, precipitation, and mist, moderate turbulence below 14,000 feet, and moderate icing conditions between 17,000 feet and the freezing level (freezing level between surface and 3,000 feet):

051
WAUS46 KKCI 292045
WA6T

-SFOT WA 292045

AIRMET TANGO UPDT 3 FOR TURB VALID UNTIL 300300

.

AIRMET TURB...WA AND CSTL WTRS

FROM 20WNW HUH TO 50SW YXC TO 50NE GEG TO 130WSW HQM TO 140W TOU
TO 20WNW HUH

MOD TURB BTN 150 AND FL390. CONDS DVLPG 00-03Z. CONDS CONTG BYD
03Z THRU 09Z.

.

AIRMET TURB...CA AND CSTL WTRS

FROM 30NNW EHF TO 60SSE TRM TO 20S MZB TO 220SW MZB TO 130SW SNS
TO 30NNW EHF

MOD TURB BTN FL200 AND FL370. CONDS DVLPG 21-00Z. CONDS CONTG
BYD 03Z THRU 09Z.

.

AIRMET TURB...WA OR ID MT WY AND CSTL WTRS

**FROM 50ESE YXC TO 60W HLN TO 20NE JAC TO 20WSW DSD TO ONP TO
20SSW HQM TO 20N TOU TO 20ENE HUH TO 50ESE YXC**

MOD TURB BLW 140. CONDS CONTG BYD 03Z THRU 09Z.

.

OTLK VALID 0300-0900Z

AREA 1...TURB WA OR AND CSTL WTRS

BOUNDED BY 20NE HUH-50SW YXC-50NE GEG-30ESE GEG-110W ONP-130WSW
HQM-140W TOU-20NE HUH

MOD TURB BTN 150 AND FL390. CONDS CONTG THRU 09Z.

.

AREA 2...TURB CA AND CSTL WTRS

BOUNDED BY 40W OAL-20SE BTY-EED-BZA-20S MZB-220SW MZB-150WSW SNS-
40W OAL

MOD TURB BTN FL200 AND FL370. CONDS CONTG THRU 09Z.

....

018

WAUS46 KKCI 292045

WA6S

-SFOS WA 292045

AIRMET SIERRA UPDT 3 FOR IFR AND MTN OBSCN VALID UNTIL 300300

.

AIRMET IFR...WA OR AND CSTL WTRS

FROM HQM TO 40NNW BTG TO 40SE BTG TO EUG TO ONP TO HQM
CIG BLW 010/VIS BLW 3SM BR. CONDS CONTG BYD 03Z THRU 09Z.

.

AIRMET MTN OBSCN...WA OR ID MT

**FROM 50SW YQL TO 20ENE HLN TO 60WSW HLN TO 30NW MLP TO 20S EPH
TO 70SW PDT TO 50S ONP TO 20SSE HQM TO TOU TO HUH TO 50SW YQL
MTNS OBSC BY CLDS/PCPN/BR. CONDS CONTG BYD 03Z THRU 09Z.**

.

OTLK VALID 0300-0900Z

AREA 1...IFR WA ID MT

BOUNDED BY 40SSW YQL-70SE FCA-50SSE MLP-70S GEG-20NW GEG-90WSW
YXC-40SSW YQL

CIG BLW 010/VIS BLW 3SM PCPN/BR. CONDS DVLPG 03-06Z. CONDS CONTG
THRU 09Z.

.

AREA 2...MTN OBSCN WA OR ID MT

BOUNDED BY 60WSW YXC-40SW YQL-20NW HLN-90SE MLP-40W BOI-20SE OED-

80NNW FOT-80SW EUG-20WSW TOU-20NE HUH-60WSW YXC
MTNS OBSC BY CLDS/PCPN/BR. CONDS CONTG THRU 09Z.

....

308

WAUS46 KPCI 292045

WA6Z

-SFOZ WA 292045

AIRMET ZULU UPDT 3 FOR ICE AND FRZLVL VALID UNTIL 300300

.

**AIRMET ICE...WA OR ID MT AND CSTL WTRS
FROM 50SE YQL TO 30NNW GTF TO 40SSE FCA TO 50SE SEA TO 30NNW BTG
TO 160W ONP TO 140W TOU TO HUH TO 50SE YQL
MOD ICE BTN FRZLVL AND 170. FRZLVL SFC-030. CONDS CONTG BYD 03Z
THRU 09Z.**

.

AIRMET ICE...CA AND CSTL WTRS
FROM 140SSW SNS TO 30SSE LAX TO 130SW MZB TO 210SW MZB TO 140SSW
SNS
MOD ICE BTN 110 AND FL220. CONDS DVLPG 00-03Z. CONDS CONTG BYD
03Z THRU 09Z.

.

OTLK VALID 0300-0900Z
AREA 1...ICE WA OR ID MT AND CSTL WTRS
BOUNDED BY 30SSW YQL-30WNW HLN-70NNE DNJ-30NNE ONP-90SW
HQM-150WSW HQM-140W TOU-HUH-30SSW YQL
MOD ICE BTN FRZLVL AND 170. FRZLVL SFC-030. CONDS CONTG THRU 09Z.

.

AREA 2...ICE CA AND CSTL WTRS
BOUNDED BY SNS-50S BTY-40ESE HEC-40NW MZB-100SW MZB-220SW
MZB-140WSW SNS-SNS
MOD ICE BTN 100 AND FL220. CONDS CONTG THRU 09Z.

.

FRZLVL...RANGING FROM SFC-120 ACRS AREA
MULT FRZLVL BLW 110 BOUNDED BY 40W EPH-40SW MLP-30NNE LKT-
50SSW JAC-20N OCS-30S JNC-40ENE DTA-50W BCE-40ESE BAM-40NE
FMG-20SE DSD-70SW PDT-40W EPH
SFC ALG 20NNE HUH-70SE HUH-20NW YKM-50W LKV-80SSW LKV-40NNW
FMG
040 ALG 150W ONP-110WNW ONP-60S HQM-20NNW BTG-30N DSD
080 ALG 170WSW ONP-50SSW EUG-60E RBL-20W FMG

....

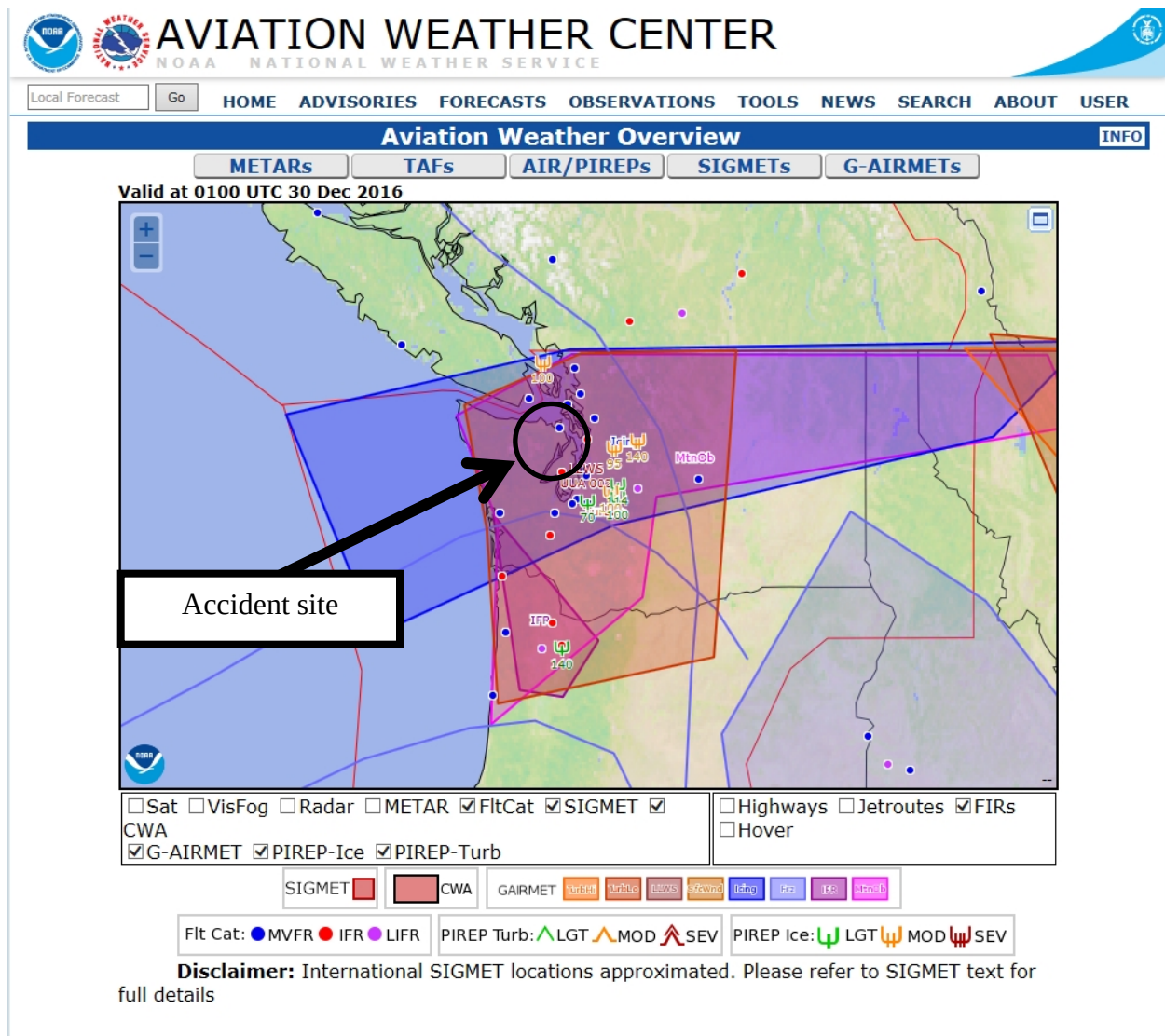


Figure 17 – SIGMETs, AIRMETs, CWAs, and PIREPs valid for the accident area at 1700 PST

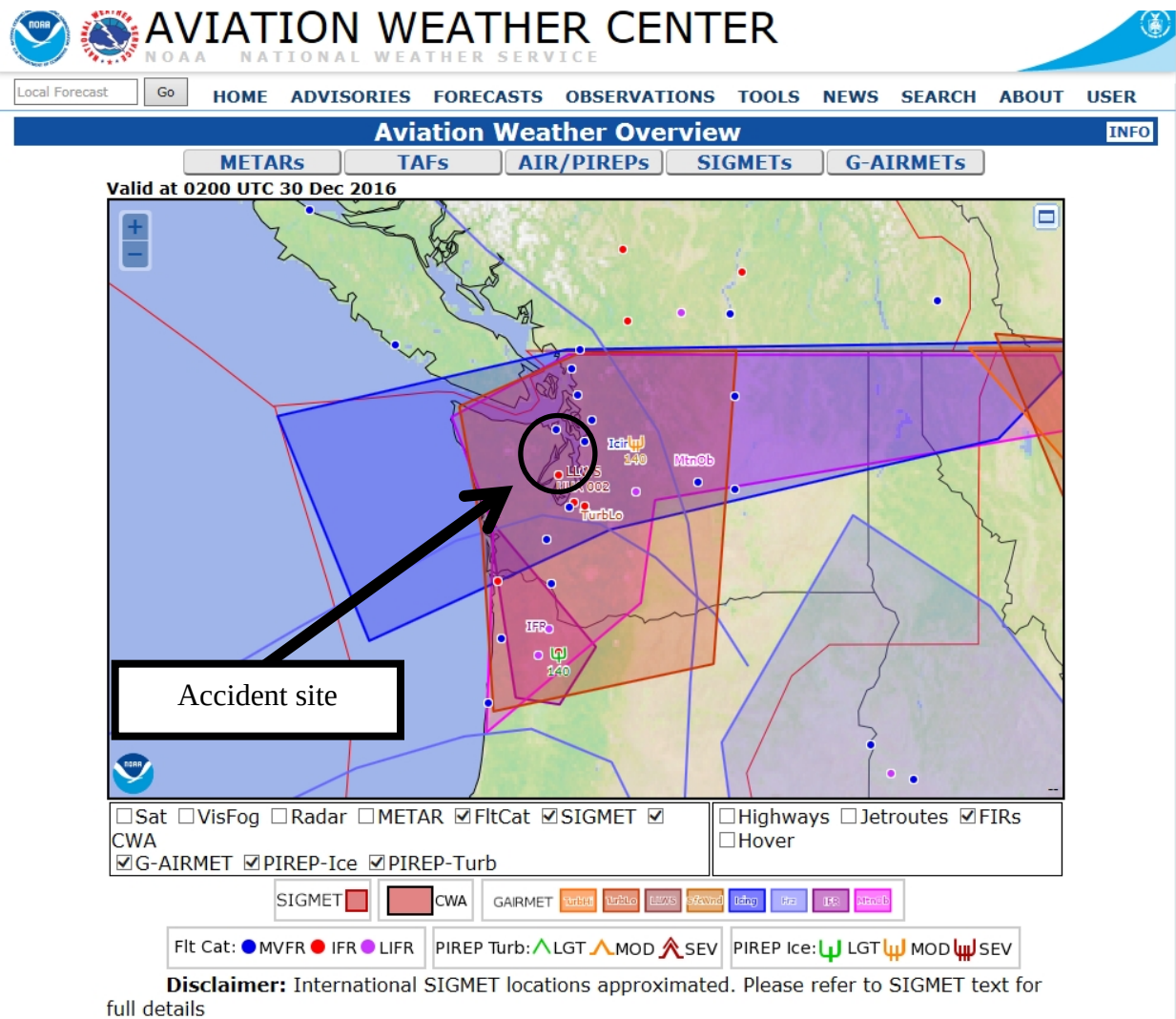


Figure 18 – SIGMETs, AIRMETs, CWAs, and PIREPs valid for the accident area at 1800 PST

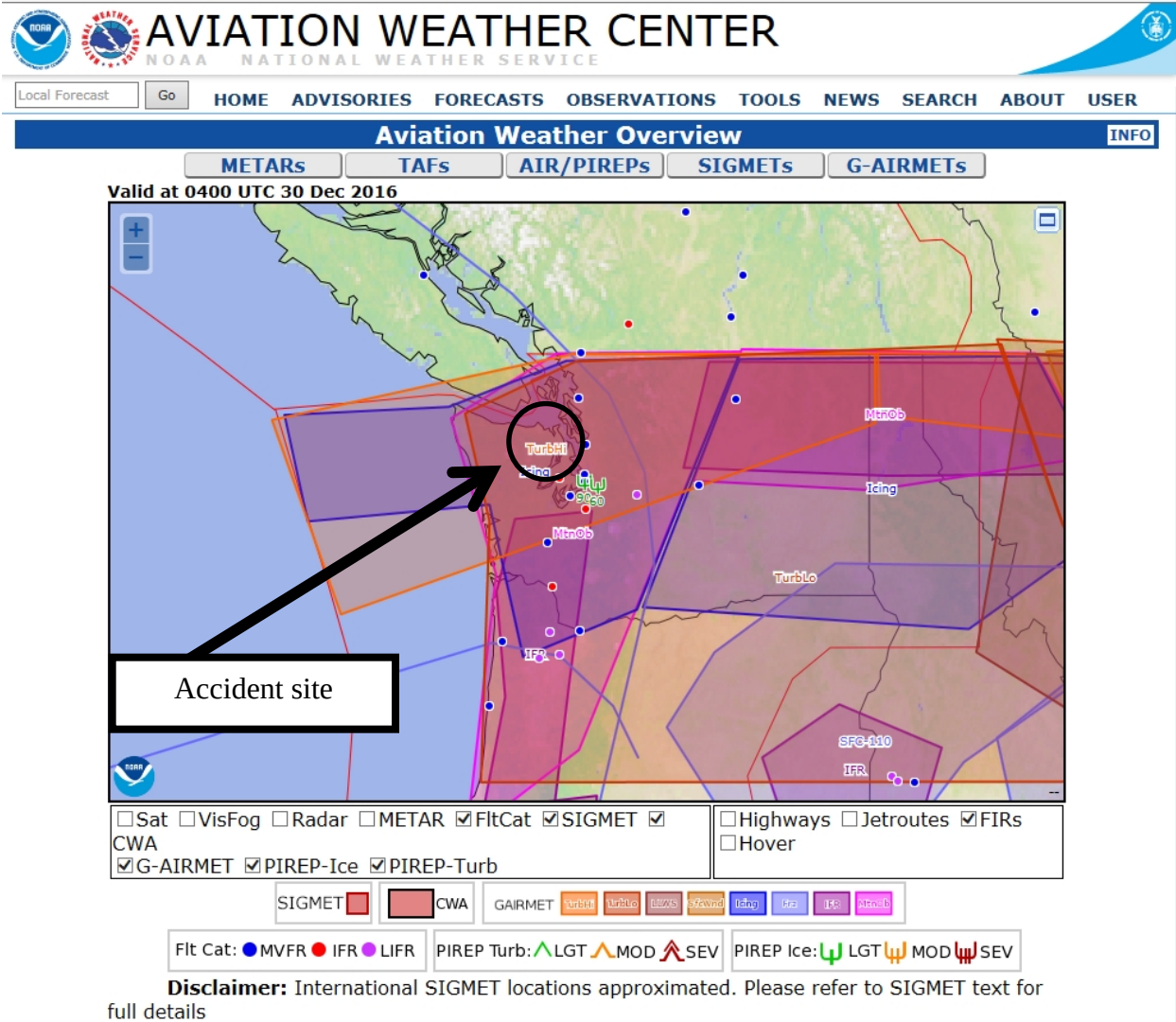


Figure 20 – SIGMETs, AIRMETs, CWAs, and PIREPs valid for the accident area at 2000 PST

10.0 Area Forecast

The Area Forecast issued at 1245 PST, valid at the accident time, forecasted a broken ceiling at 2,500 feet with overcast skies at 4,000 feet and scattered light rain showers for the accident site:

530
FAUS46 KPCI 292045
FA6W
-SFOC FA 292045
SYNOPSIS AND VFR CLDS/WX
SYNOPSIS VALID UNTIL 301500
CLDS/WX VALID UNTIL 300900...OTLK VALID 300900-301500
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...ALF...21Z STG WLY WND FLOW ACRS WA AND ADJACENT CSTL
WTRS...WKNG LATE IN THE PD. BROAD UPR RDG OVR THE SOUTHWESTERN
U.S. 15Z UPR TROF FM S CNTRL B.C. ACRS NW WA AND THE SW WA CSTL
WTRS. AT THE SFC...21Z CDFNT EXTDG SW FM SERN VRISL. 15Z CDFNT
ALG A DNJ-40S DSD-130W FOT LN.

.
WA CASCDS WWD
CSTLN...BKN020 OVC035 LYRD FL250. VIS 5SM IN SCT -SHRA. 01Z
BKN025 BKN035 TOPS 100. SCT -SHRA. OTLK...VFR SHRA 12Z VFR.
RMNDR...OVC030 LYRD FL250. VIS 3-5SM -RA BR. BECMG 0104 BKN025
OVC040. SCT -SHRA. OTLK...MVFR CIG SHRA BR.

.
WA E OF CASCDS
N HLF...BKN035 OVC060 LYRD FL220 OVC CI. WDLY SCT -SHSN.
OTLK...MVFR CIG SHSN THRUT EXC IFR CIG SHSN ERN SXNS.
S HLF...BKN-SCT090-100 TOPS 170. BECMG 0407 SCT025 OVC050. OCNL
-RASN. OTLK...MVFR CIG RA SN BR.

.
OR CASCDS WWD
CSTLN...
N THIRD...BKN020 OVC035 TOPS 070. VIS 5SM -RA BR. 02Z BKN025
OVC040. SCT -SHRA. OTLK...MVFR CIG SHRA.
CNTRL THIRD...SCT015 BKN025 OVC040 TOPS 070. BECMG 0003 OVC015
TOPS 080. VIS 3SM -RADZ BR. OTLK...MVFR CIG SHRA BR.
S THIRD...SCT040. 03Z SCT015 OVC040 TOPS 070. 07Z BKN015-025
TOPS 090. OTLK...IFR CIG BR.
SWRN INTR...SCT020. 08Z OVC020 TOPS 045. OTLK...IFR CIG.
RMNDR...BKN015 TOPS 030. BECMG 0406 BKN015 OVC030 TOPS 090. VIS
5SM -RA BR. OTLK...IFR CIG RA BR.

.
OR E OF CASCDS
COLUMBIA BASIN...SCT-BKN100 TOPS 140. BECMG 0306 OVC045. OCNL
-RASN. OTLK...VFR RA SN.
RMNDR N HLF...SCT100 SCT CI. OTLK...VFR SHSN.
S HLF...SCT CI. OTLK...VFR.

.
NRN CA...STS-SAC-TVL LN NWD
CSTL SXNS...
CSTLN...SKC. 03Z SCT CI. OTLK...VFR.
INLAND...SKC. OTLK...VFR.
SAC VLY...
N HLF...SKC. OTLK...VFR.
S HLF...SKC. 06Z BKN015 TOPS 025. VIS 3SM BR. OTLK...IFR CIG
BR FG.
MTNS...SKC. BECMG 0407 SCT060. VIS 3-5SM IN VLYS. OTLK...VFR
THRUT EXC IFR CIG BR FG IN VLYS.

.
CNTRL CA
CSTL SXNS...
N HLF...SKC. OCNL SCT CI. OTLK...VFR.
S HLF...BKN-SCT CI. BECMG 0204 BKN130 TOPS 150 BKN CI.
OTLK...VFR SHRA 13Z MVFR CIG RA BR.

SAN JOAQUIN VLY...
 N HLF...SKC. BECMG 0507 SCT010. VIS 3-5SM BR. OTLK...MVFR BR
 THRUT 12Z IFR CIG BR FG NRN SXNS.
 S HLF...SKC. BECMG 0306 VIS 5SM HZ SRN SXNS. OTLK...MVFR BR
 12Z SHRA BR.
 MTNS...SKC. 03Z SCT-BKN CI. OTLK...VFR.
 .
 SRN CA..VBG-NID-60NNW BIH LN SWD
 CSTL SXNS...
 CSTLN...
 N HLF...BKN-SCT CI. BECMG 0204 BKN150 TOPS FL250. BECMG 0708
 SCT-BKN060 BKN120. WDLY SCT -SHRA. OTLK...VFR SHRA THRUT
 11Z MVFR CIG RA BR NRN SXNS.
 S HLF...SCT CI. BECMG 0103 SCT100 SCT-BKN150 TOPS FL200.
 OTLK...VFR 12Z SHRA NRN SXNS.
 INLAND...
 INTR MTNS/DESERTS...SKC. OCNL SCT CI. 01Z SCT100 OVC CI.
 OTLK...VFR 14Z MVFR CIG TSRA.
 .
 CSTL WTRS
 WA...BKN020-030 TOPS FL200 OVC CI. VIS 3SM -RA BR. BECMG 0306
 BKN030 TOPS 100. WDLY SCT -SHRA. OTLK...VFR SHRA.
 NRN OR...BKN020-030 TOPS 070. OCNL -RA. OTLK...MVFR CIG SHRA.
 SRN OR...BKN025 TOPS 050. BECMG 0407 BKN025 TOPS 070. OCNL -RA.
 OTLK...MVFR CIG SHRA.
 N HLF CA...SKC. OCNL SCT020. OTLK...VFR.
 S HLF CA...SCT100 SCT-BKN150 TOPS FL200 BKN CI. WDLY SCT -SHRA.
 BECMG 2302 SCT-BKN060 BKN100 LYRD FL250. WDLY SCT -SHRA. BECMG
 0407 BKN025 BKN050. OCNL VIS 4SM -RA. ISOL -TSRA. CB TOPS FL300.
 OTLK...MVFR CIG SHRA.

11.0 Terminal Aerodrome Forecast

KPAE 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 1530 PST and was valid for a 24-hour period beginning at 1600 PST. The TAF for KPAE was as follows:

TAF KPAE 292330Z 3000/3024 **16015G25KT P6SM -RA BKN018 BKN027 OVC060**
 FM300300 20008KT P6SM -SHRA BKN015 BKN040
 FM300800 19006KT 5SM BR OVC012
 FM301800 17005KT P6SM BKN025 BKN040
 FM302100 35006KT P6SM SCT045 BKN250=

The forecast expected a wind from 160° at 15 knots with gusts to 25 knots, greater than 6 miles visibility, light rain, a broken ceiling at 1,800 feet agl, broken skies at 2,700 feet agl, and overcast skies at 6,000 feet agl.

KBFI was the departure airport. The TAF valid at the time of the accident was issued at 1530 PST and was valid for a 24-hour period beginning at 1600 PST. The TAF for KBFI was as follows:

TAF KBFI 292330Z 3000/3024 **14010G18KT P6SM -RA OVC030**
FM300300 17010KT P6SM -SHRA BKN020 OVC035
FM300800 16005KT P6SM VCSH OVC018
FM301800 VRB03KT P6SM BKN025 BKN040
FM302100 02005KT P6SM SCT045 BKN250=

The forecast expected a wind from 140° at 10 knots with gusts to 18 knots, greater than 6 miles visibility, light rain, an overcast ceiling at 3,000 feet agl.

KCLM was the intended destination airport. The TAF valid at the time of the accident was issued at 1530 PST and was valid for a 24-hour period beginning at 1600 PST. The TAF for KCLM was as follows:

TAF KCLM 292330Z 3000/3024 **27016G24KT P6SM -SHRA SCT025 BKN040**
FM300700 26008KT P6SM VCSH SCT020 BKN040
FM301200 26011KT P6SM OVC020
FM302000 33006KT P6SM SCT020 BKN250=

The forecast expected a wind from 270° at 16 knots with gusts to 24 knots, greater than 6 miles visibility, light rain showers, scattered clouds at 2,500 feet agl and a broken ceiling at 4,000 feet agl.

12.0 NWS Area Forecast Discussion

The NWS Office in Seattle, Washington, issued the following Area Forecast Discussion (AFD) at 1510 PST (closest AFD to the accident time with an aviation section). The aviation section of the AFD discussed that MVFR to local IFR conditions and light rain would persist through the overnight hours and into early the next day. Local visibilities of 3 miles, moderate rain, mist, and ceilings around 1,000 feet agl were being observed:

030
FXUS66 KSEW 292310
AFDSEW

Area Forecast Discussion
National Weather Service Seattle WA
310 PM PST Thu Dec 29 2016

.SYNOPSIS...A cold front will move through the area tonight with rain changing to showers. An upper ridge on Friday will bring precipitation to an end. Colder air with the potential for lowland snow will arrive late New Years Eve or Saturday night. Dry and cold weather will prevail for much of next week.

&&

.SHORT TERM...A frontal system will move onshore tonight with rain changing to showers. Snow in the mountains will taper tonight. A few showers will linger into Friday morning, mainly over the mountains. Otherwise, northerly flow aloft will bring a dry day with perhaps some sunshine by afternoon. Dry weather will continue Friday night and most of Saturday morning.

An upper trough and cold front will move into the area from the northwest Saturday afternoon with increasing rain. Rain could mix with snow, especially over the north but onshore flow should preclude any lowland accumulations except maybe over the highest hills.

Snow levels will drop to near sea level Saturday night for the possibility of lowland snow accumulations. In addition, a modified arctic front will drop south through the area early Sunday morning. Local accumulations are possible, either as the air cools overnight, or with the arctic front early Sunday morning. As always, there are questions about how much precipitation there will be when it is cold enough for snow to stick. For now, it looks like at least some locations could pick up an inch or two by Sunday morning.

Drier offshore flow will prevail later Sunday, largely ending any precipitation threat. There will also be some gusty northeast winds for the northwest interior. Schneider

.LONG TERM...Dry northerly flow aloft will prevail Monday through Wednesday with modified arctic air in place. Highs will be mostly in the lower to mid 30s and low will be mostly in the 20s.

A weak upper trough could bring some showers Thursday and Friday but precipitation looks light and spotty. It would probably be cold enough for another threat of lowland snow but accumulations do not look likely for now. Schneider

&&

.AVIATION...Strong westerly flow aloft this afternoon will become weak northwest tonight, as the front over Western Washington moves east of the Cascades. Light northerly flow aloft will prevail Friday. The air mass is moist, but it will gradually dry at upper and mid levels later tonight and Friday.

The front was over the interior lowlands of Western Washington at 2 pm, bringing MVFR to local IFR conditions in light rain. Sky conditions were roughly BKN-OVC025 OVC040 with local visibility AOB 3SM RA BR and ceilings aob BKN010. The front will move east of the Cascades this evening, but moist onshore flow will probably maintain widespread MVFR and local IFR conditions tonight and Friday morning. There should be some improvement Friday late morning and afternoon.

KSEA...South to southwest wind 10-16 gusting 24 kt during the next few hours as the front moves through the Western Washington interior lowlands. At 230 PM the front appeared to be over Puget Sound just west of KSEA, with frontal passage likely around 4 pm. Wind should become southerly 6-12 kt later this evening and tonight. Moist onshore flow following the front will probably keep the terminal MVFR with ceilings mainly 010-020 through Friday morning. McDonnal

&&

.MARINE...A front over the Western Washington interior lowlands this afternoon will move east of the Cascades this evening. Small craft advisory southerlies will give way to onshore flow, with gale force westerlies in the central Strait and east entrance Strait this evening. Onshore flow will ease tonight and turn northerly on Friday.

Westerly winds will rise Saturday, then veer to northwest late Saturday and Saturday night as a strong front and roughly 1008 mb low move across Western Washington from the northwest. Gale west to northwest winds are a good possibility over the coastal waters and through the Strait of Juan de Fuca, with small craft advisory winds elsewhere. Strong north to northeast flow will develop behind the front Sunday, with gale force Fraser outflow winds possible over the northern inland waters and through the Strait of Juan De Fuca Sunday and Sunday night. Northeast flow will probably ease later Monday, but offshore flow will continue for several days. McDonnal

&&

.HYDROLOGY...No river flooding is expected for the next 7 days.

&&

.SEW WATCHES/WARNINGS/ADVISORIES...

WA...Winter Weather Advisory until 4 AM PST Friday for Cascades of Snohomish and King Counties-Cascades of Whatcom and Skagit Counties.

Winter Weather Advisory until 4 PM PST this afternoon for Olympics.

PZ...Small Craft Advisory for rough bar until 3 PM PST Friday for Grays Harbor Bar.

Small Craft Advisory until 3 PM PST Friday for Coastal Waters From Cape Flattery To James Island 10 To 60 Nm-Coastal Waters From Cape Flattery To James Island Out 10 Nm-Coastal Waters From James Island To Point Grenville 10 To 60 Nm-Coastal Waters From James Island To Point Grenville Out 10 Nm-Coastal Waters From Point Grenville To Cape Shoalwater 10 To 60 Nm-Coastal Waters From Point Grenville To Cape Shoalwater Out 10 Nm.

Small Craft Advisory until midnight PST tonight for Admiralty Inlet-Northern Inland Waters Including The San Juan Islands.

Gale Warning until midnight PST tonight for Central U.S. Waters Strait Of Juan De Fuca-East Entrance U.S. Waters Strait Of Juan De Fuca.

Small Craft Advisory until 3 AM PST Friday for West Entrance U.S. Waters Strait Of Juan De Fuca.

Small Craft Advisory until 9 PM PST this evening for Puget Sound and Hood Canal.

&&

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www.weather.gov/seattle

You can see an illustrated version of this discussion at www.weather.gov/seattle/gafd/latest_webafd.html

13.0 Winds and Temperature Aloft Forecast

The NWS 1756 PST Winds and Temperature Aloft forecast valid for the accident flight is included below:

259
FBUS31 KWN0 300156
FD1US1
-DATA BASED ON 300000Z
VALID 300600Z FOR USE 0200-0900Z. TEMPS NEG ABV 24000

FT 3000 6000 9000 12000 18000 24000 30000 34000 39000

SEA 9900 2807-06 2631-11 2655-14 2693-22 7609-34 753347 762653 269054

The accident site was closest to the SEA (Seattle) forecast point. The 1756 PST SEA forecast indicated a calm wind at 3,000 feet and a wind at 6,000 feet from 280° at 7 knots with a temperature of -6° C.

14.0 Pilot Weather Briefing

A search of official weather briefing sources, such as Lockheed Martin Flight Service and Direct User Access Terminal Service was done and the accident pilot did not receive an official weather briefing from those sources. A search of ForeFlight weather information revealed that the accident pilot did not request a weather briefing using ForeFlight Mobile prior to his flight. It is unknown if the accident pilot checked or received any other weather information before or during the accident flight.

15.0 Puget Sound Convergence Zone³¹

When flying in the area of Puget Sound, a relatively common weather phenomenon occurs called the Puget Sound Convergence Zone (PSCZ). The PSCZ is caused by flow around the mountainous terrain of the Olympic Mountains (figure 21) and can result in localized poor weather over western Washington. The PSCZ was first discussed back in the early 1980s (attachment 3) and since then the PSCZ is discussed quite frequently in the weather forecast in Washington (attachment 4) and the FAA has even provided training on the PSCZ for pilots (attachment 5).

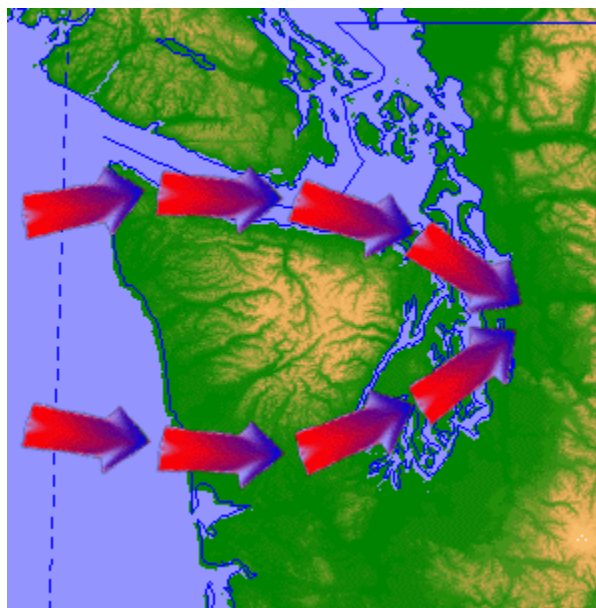


Figure 21 – Puget Sound Convergence Zone wind flow graphic

The weather radar signature near the accident site and accident flight route (figures 12 through 16 and attachment 2) is indicative of precipitation being enhanced by the PSCZ with the west-southwest to east-northeast oriented precipitation band. The PSCZ enhanced precipitation rates in the area of the accident site around the accident time, which led to lower ceiling conditions, reduced visibilities, and IMC.

16.0 Astronomical Data

The astronomical data obtained from the United States Naval Observatory for the accident site on December 29, 2016, indicated the following:

SUN	
Begin civil twilight	0724 PST
Sunrise	0800 PST
Sun transit	1214 PST
Sunset	1627 PST
End civil twilight	1703 PST

³¹ NWS education on PSCZ: <http://www.wrh.noaa.gov/sew/PugetSoundConvZone/player.html>

MOON

Moonrise	0800 PST
Moon transit	1240 PST
Moonset	1721 PST

The Moon was set before the accident flight departed and remained below the horizon during the rest of the accident day.

F. LIST OF ATTACHMENTS

Attachment 1 – GOES-15 infrared imagery animation from 1800 to 1945 PST

Attachment 2 – KATX WSR-88D reflectivity for the 0.5° elevation scan animation from 1802 to 1900 PST with the ATC flight track (pink line)

Attachment 3 – Mass, Clifford. 1981. “Topographically Force Convergence in Western Washington State,” *Monthly Weather Review* 109 (June): 1335-47.

Attachment 4 – McDonnal, Doug and Brad Colman. 2003. “An Investigation of the Puget Sound Convergence Zone Using WES,” *NWS Western Region Technical Attachment Lites* 2003: 03-44. http://www.wrh.noaa.gov/media/wrh/online_publications/talite/talite03.php

Attachment 5 – Document of FAA Safety Team Training in Bellingham, Washington, on January 8, 2015.

Submitted by:

Paul Suffern
Senior Meteorologist

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