NATIONAL TRANSPORTATION SAFETY BOARD

Office of Aviation Safety
Washington, D.C. 20594

October 3, 2019

Factual Report

METEOROLOGY

WPR19FA123

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A. ACCIDENT

Location: Kailua, Hawaii
Date: April 29, 2019
Time: About 0911 Hawaii-Aleutian standard time
About 1911 Coordinated Universal Time (UTC)
Aircraft: Robinson R44; Registration: N808NV

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 official National Oceanic and Atmospheric Administration (NOAA) National Weather Service (NWS) sources including the National Centers for Environmental Information (NCEI). All times are Hawaii-Aleutian standard time (HST) on April 29, 2019, and are based upon the 24-hour clock, where local time is -10 hours from UTC, and UTC=Z. Directions are referenced to true north and distances in nautical miles. Heights are above mean sea level (msl) unless otherwise noted. Visibility is in statute miles and fractions of statute miles. NWS airport and station identifiers use the standard International Civil Aviation Organization 4-letter station identifiers versus the International Air Transport Association 3-letter identifiers, which deletes the initial country code designator "K" for U.S. airports and "P" for OCONUS airports.

The accident site was located at latitude 21.4033° N, longitude 157.7644° W, at an approximate elevation of 10 feet (ft).

D. WEATHER INFORMATION

1.0 Synoptic Situation

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

[1] https://www.faa.gov/regulations_policies/advisory_circulars/index.cfm/go/document.information/documentID/1030

1.1 Surface Analysis Chart

The Pacific surface analysis for 0800 HST is provided as figure 1 with the approximate location of the accident site marked within the red circle. The chart identified a Gale strength surface low pressure center located in the northern Pacific Ocean with cold front extending southward to just northwest of the Hawaiian Islands. A surface trough[2] was located extending ahead of the cold front over the northern Hawaiian Islands and influencing the area in the immediate vicinity of the accident site. Troughs can act as lifting mechanisms to help produce clouds and precipitation if sufficient moisture is present. A stationary and dissipating surface low pressure center with a surface pressure of 1015-hectopascals (hPa) was located west of the Hawaiian Islands near longitude 170° W. The station model near the accident site depicted an east wind of 20 knots.

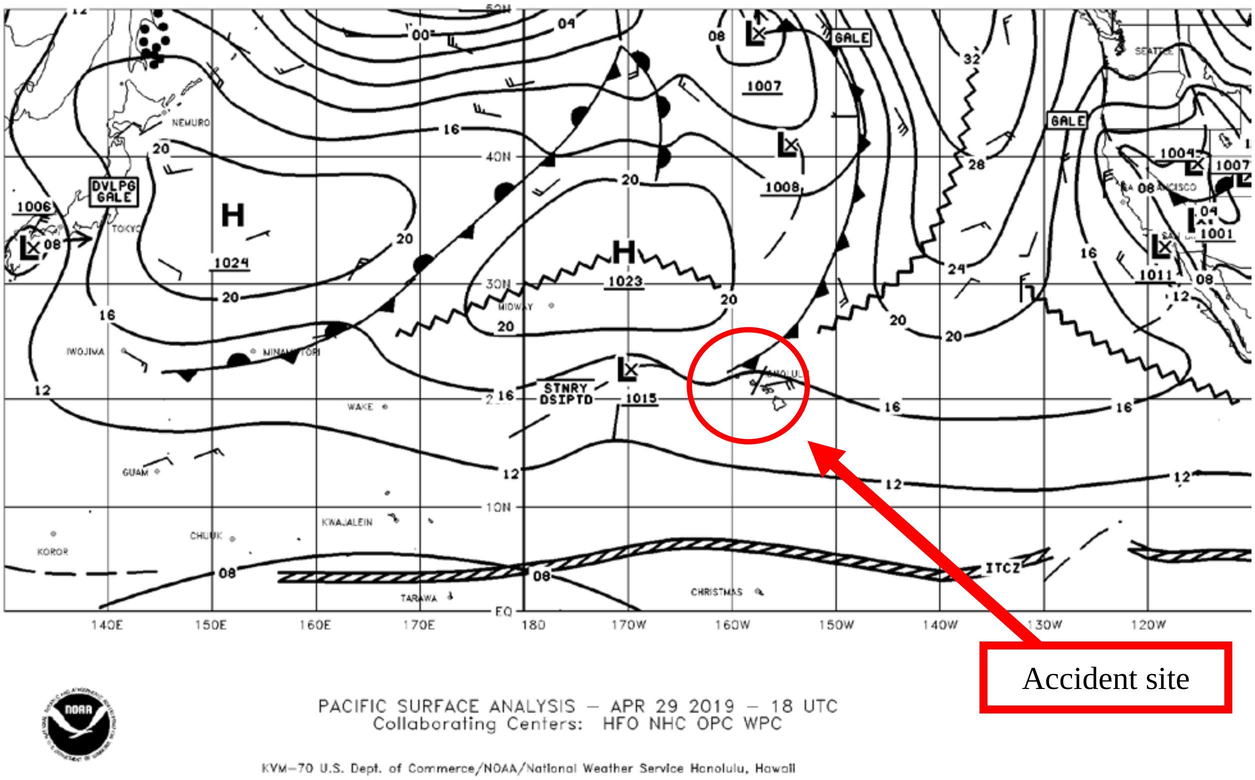

Figure 1 – Pacific Surface Analysis Chart for 0800 HST

2.0 Surface Observations

The area surrounding the accident site was documented using official Meteorological Aerodrome Reports (METARs) and Specials (SPECIs). The following observations were taken from standard code and are provided in plain language. Figure 2 is a local sectional chart with the accident site and the closest weather reporting locations marked.

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

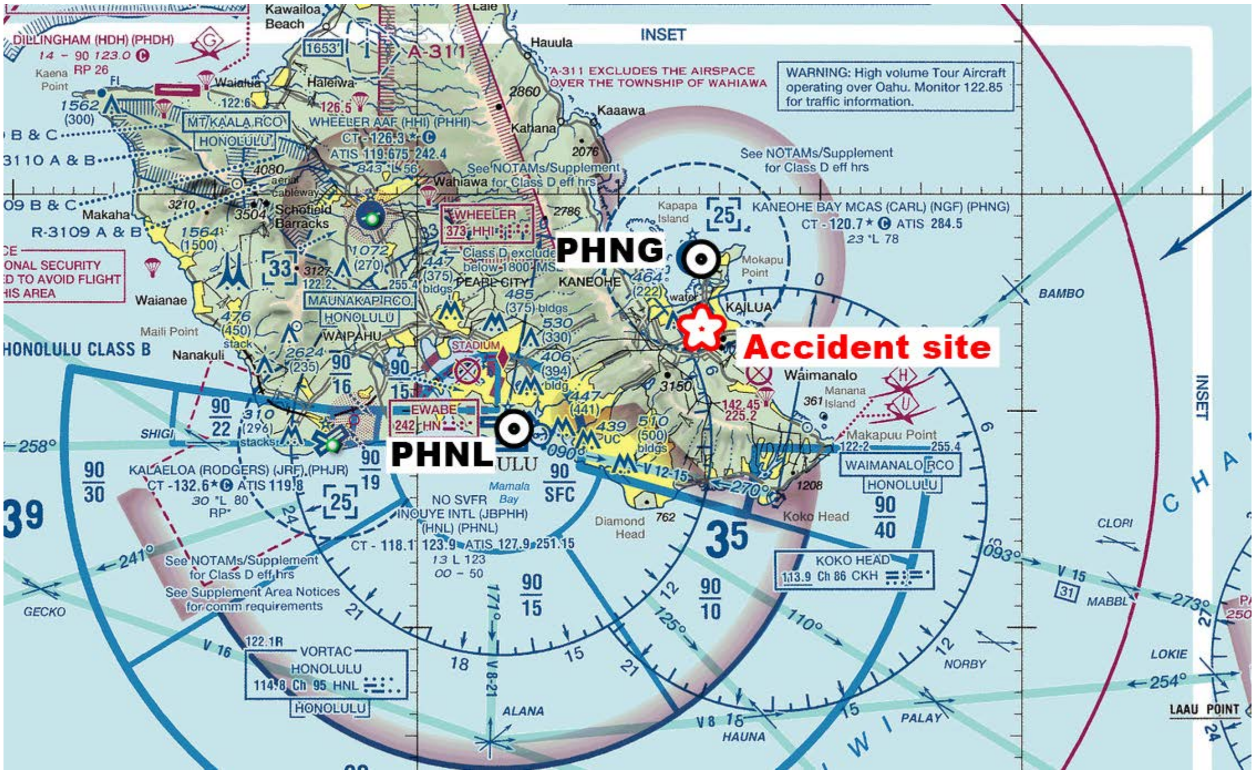

Figure 2 – Sectional map of the accident area with the location of the accident site and surface observation sites

Kaneohe Bay Marine Corps Air Station (PHNG) had the closest official weather station to the accident site and was located 2 miles southwest of Kaneohe, Hawaii. PHNG had official observations who were supplemented by official observers. PHNG was located 3 miles north of the accident site, at an elevation of 23 ft, and had a 9.5° easterly magnetic variation[3] (figure 2). The following observations were taken and disseminated during the times surrounding the accident:[4]

[0657 HST] METAR PHNG 291657Z 00000KT 10SM BKN025 OVC040 23/20 A2995 RMK AO2 SLP138 T02330200 $=

[0704 HST] SPECI PHNG 291704Z 00000KT 9SM FEW029 SCT038 BKN047 23/20 A2996 RMK AO2 T02330200 $=

[0736 HST] SPECI PHNG 291736Z AUTO 26005KT 10SM -RA SCT021 BKN028 OVC047 24/20 A2997 RMK AO2 RAB05 P0000 T02390200 TSNO $=

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

[4] The bold sections in this NWS product and the rest of the 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 this section next to the METARs are provided for quick reference between UTC and local times around the accident time.

[0757 HST] METAR PHNG 291757Z AUTO 28005KT 10SM SCT021 SCT029 BKN048 24/21 A2997 RMK AO2 RAB05E40 SLP144 P0000 60000 T02440206 10244 20228 51012 TSNO $=

[0808 HST] SPECI PHNG 291808Z AUTO 27005KT 10SM SCT019 BKN029 24/21 A2997 RMK AO2 T02440206 TSNO $=

[0832 HST] SPECI PHNG 291832Z AUTO 28003KT 10SM FEW017 SCT026 BKN030 24/20 A2998 RMK AO2 T02440200 TSNO $=

[0844 HST] SPECI PHNG 291844Z AUTO 33003KT 10SM SCT020 BKN026 BKN034 25/19 A2998 RMK AO2 T02500194 TSNO $=

[0857 HST] METAR PHNG 291857Z AUTO 03008KT 4SM -RA BKN018 BKN028 OVC039 24/20 A2999 RMK AO2 RAB54 SLP149 P0001 T02440200 TSNO $=

ACCIDENT TIME 0911 HST

[0924 HST] SPECI PHNG 291924Z 34004KT 3SM RA BR FEW017 BKN033 OVC045 24/22 A2999 RMK AO2 P0006 T02390217 $=

[0950 HST] SPECI PHNG 291950Z 35006KT 4SM BR BKN015 OVC045 25/23 A2999 RMK AO2 RAE44 P0006 T02500228 $=

[0957 HST] METAR PHNG 291957Z 31004KT 4SM BR BKN015 OVC045 26/23 A2999 RMK AO2 RAE44 SLP151 P0006 T02560228 $=

[1057 HST] METAR PHNG 292057Z 30007KT 10SM BKN019 BKN023 BKN075 26/23 A2998 RMK AO2 SLP148 60007 T02610228 50003 $=

PHNG weather at 0844 HST, automated, wind from 330° at 3 knots, 10 miles or greater visibility, scattered clouds at 2,000 ft above ground level (agl), broken ceiling at 2,600 ft agl, broken skies at 3,400 ft agl, temperature of 25 °Celsius (C), dew point temperature of 19 °C, and an altimeter setting of 29.98 inches of mercury (inHg). Remarks: automated station with a precipitation discriminator, temperature 25.0 °C, dew point temperature 19.4 °C, thunderstorm information not available, maintenance is needed on the system.

PHNG weather at 0857 HST, automated, wind from 030° at 8 knots, 4 miles visibility, light rain, broken ceiling at 1,800 ft agl, broken skies at 2,800 ft agl, overcast skies at 3,900 ft agl, temperature of 24 °C, dew point temperature of 20 °C, and an altimeter setting of 29.99 inHg. Remarks: automated station with a precipitation discriminator, rain began at 0854 HST, sea level pressure 1014.9 hPa, 0.01 inches of precipitation since 0757 HST, temperature 24.4 °C, dew point temperature 20.0 °C, thunderstorm information not available, maintenance is needed on the system.

PHNG weather at 0924 HST, wind from 340° at 4 knots, 3 miles visibility, moderate rain, mist, few clouds at 1,700 ft agl, broken ceiling at 3,300 ft agl, overcast skies at 4,500 ft agl, temperature of 24 °C, dew point temperature of 22 °C, and an altimeter setting of 29.99 inHg. Remarks: automated station with a precipitation discriminator, 0.06 inches of precipitation since 0857 HST, temperature 23.9 °C, dew point temperature 21.7 °C, maintenance is needed on the system.

PHNG weather at 0950 HST, wind from 350° at 6 knots, 4 miles visibility, mist, broken ceiling at 1,500 ft agl, overcast skies at 4,500 ft agl, temperature of 25 °C, dew point temperature of 23 °C, and an altimeter setting of 29.99 inHg. Remarks: automated station with a precipitation discriminator, rain ended at 0944 HST, 0.06 inches of precipitation since 0857 HST, temperature 25.0 °C, dew point temperature 22.8 °C, maintenance is needed on the system.

Daniel K Inouye International Airport (PHNL) was the departure airport located 3 miles northwest of Honolulu, Hawaii. PHNL had Automated Surface Observing System (ASOS[5]) whose reports were supplemented by an official observer. PHNL was located 10 miles southwest of the accident site at an elevation of 13 ft (figure 2). The following observations were taken and disseminated during the times surrounding the accident:

[0353 HST] METAR PHNL 291353Z 35004KT 10SM FEW025 FEW070 SCT100 19/19 A2992 RMK AO2 SLP132 T01940194 $=

[0453 HST] METAR PHNL 291453Z 34004KT 10SM FEW100 19/19 A2993 RMK AO2 SLP136 T01940189 55001 $=

[0553 HST] METAR PHNL 291553Z 34004KT 10SM FEW027 SCT100 19/19 A2995 RMK AO2 SLP141 T01890189 $=

[0653 HST] METAR PHNL 291653Z 33004KT 10SM FEW025 FEW045 SCT100 20/19 A2997 RMK AO2 SLP148 T02000194=

[0753 HST] METAR PHNL 291753Z 32006KT 10SM FEW025 FEW050 SCT100 22/19 A2999 RMK AO2 SLP154 T02170189 10217 20189 53019=

[0853 HST] METAR PHNL 291853Z 05007KT 010V080 10SM FEW025 SCT045 24/19 A2999 RMK AO2 SLP156 T02440194=

ACCIDENT TIME 0911 HST

[0953 HST] METAR PHNL 291953Z 08009KT 050V110 10SM FEW025 SCT035 SCT050 26/19 A3000 RMK AO2 SLP158 VCSH NE T02560189=

[1025 HST] SPECI PHNL 292025Z 03011KT 10SM FEW024 SCT047 26/19 A3000 RMK AO2 WSHFT 2005 T02560189=

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5 ASOS – Automated Surface Observing System is equipped with meteorological instruments to observe and report wind, visibility, present weather, cloud coverage and ceiling, temperature, dewpoint, altimeter, barometric pressure, lightning (thunderstorm, and other supplemental information).

[1053 HST] METAR PHNL 292053Z 06011KT 10SM FEW025 SCT040 BKN110 26/18 A3000 RMK AO2 WSHFT 2005 SLP158 T02610183 51003=

[1153 HST] METAR PHNL 292153Z 10008KT 10SM FEW024 SCT050 BKN065 27/18 A2998 RMK AO2 SLP151 T02670183=

PHNL weather at 0853 HST, wind from 050° at 7 knots, wind varying between 010 and 080°, 10 miles visibility or greater, few clouds at 2,500 ft agl, scattered clouds at 4,500 ft agl, temperature of 24 °C, dew point temperature of 19 °C, and an altimeter setting of 29.99 inHg. Remarks: automated station with a precipitation discriminator, sea level pressure 1015.6 hPa, temperature 24.4 °C, dew point temperature 19.4 °C.

PHNL weather at 0953 HST, wind from 080° at 9 knots, wind varying between 050 and 110°, 10 miles visibility or greater, few clouds at 2,500 ft agl, scattered clouds at 3,500 ft agl, scattered clouds at 5,000 ft agl, temperature of 26 °C, dew point temperature of 19 °C, and an altimeter setting of 30.00 inHg. Remarks: automated station with a precipitation discriminator, sea level pressure 1015.8 hPa, vicinity[6] showers northeast, temperature 25.6 °C, dew point temperature 18.9 °C.

The observations from PHNG surrounding the accident time indicated VFR[7] to MVFR conditions with moderate rain reported at the accident time. While VFR conditions prevailed at PHNL during the period.

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[6] In the vicinity of the airport is defined as a weather phenomenon within 5-10 statute miles of the airfield.

[7] As defined by the NWS and the FAA Aeronautical Information Manual (AIM) section 7-1-7 defines the following general flight categories:

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

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

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

3.0 Upper Air Data

A Global Data Assimilation System (GDAS) model sounding was created for the accident site for 0800 HST with a station elevation of 26 ft.[8] The GDAS sounding was plotted on a standard Skew-T Log P diagram[9] with the derived stability parameters included in figure 3 from the surface to 600-hPa (or approximately 14,000 ft msl). This data was analyzed using the RAOB[10] software package. The 0800 HST GDAS sounding depicted the lifted condensation level (LCL)[11] at 1,809 ft agl (1,835 ft msl), the level of free convection (LFC)[12] at 3,084 ft agl (3,110 ft msl), and the convective condensation level (CCL)[13] at 3,787 ft agl (3,813 ft msl). The freezing level was located at 12,521 ft msl. The precipitable water value was 1.51 inches.

[8] GDAS sounding was created using NOAA Air Resource Laboratory: https://ready.arl.noaa.gov/READYamet.php
[9] 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.
[10] RAOB – (The complete Rawinsonde Observation program) is an interactive sounding analysis program developed by Environmental Research Services, Matamoras, Pennsylvania.
[11] LCL - The height at which a parcel of moist air becomes saturated when it is lifted dry adiabatically.
[12] 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.
[13] CCL – The level in the atmosphere to which an air parcel, if heated from below, will rise dry adiabatically, without becoming colder than its environment just before the parcel becomes saturated.

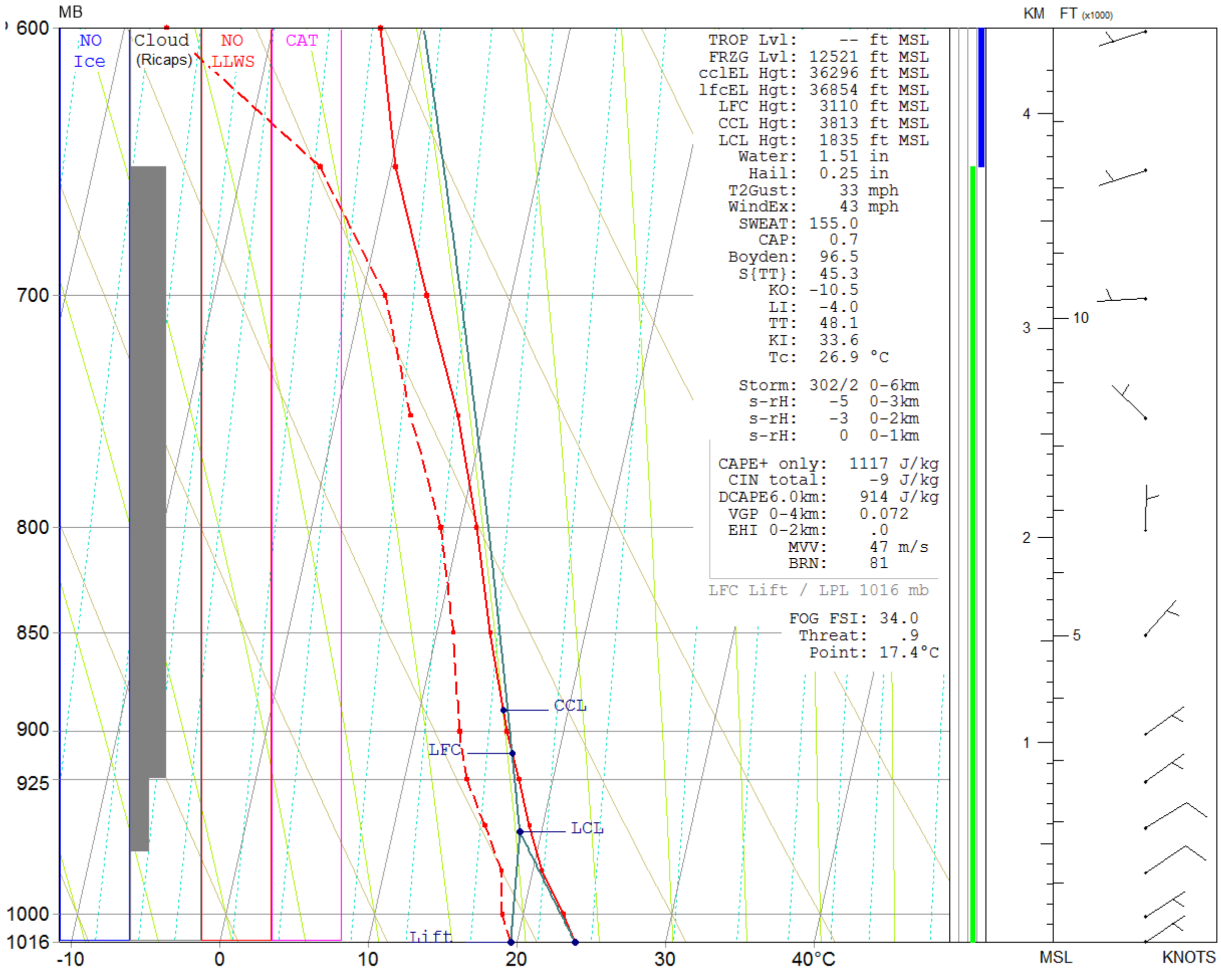


Figure 3 – 0800 HST GDAS sounding

The 0800 HST GDAS sounding stability indices indicated a conditionally unstable environment from the surface through 12,000 ft, with a Lifted Index of -4. RAOB identified the possibility of clouds from 2,000 ft msl through 12,500 ft msl. A positive CAPE[14] value of 1,117 Joules/kilogram (J/kg) was indicated on the sounding and the maximum vertical velocity (MVV) for this atmosphere was calculated as 47 meters/second (about 9,252 ft per minute).[15] Downdraft CAPE (DCAPE; 6 kilometers agl)[16] was measured at 914 J/kg. If rain showers or thunderstorms formed in this environment, the 0800 HST GDAS sounding indicated that the strongest wind speeds possible at the surface (due to, for example, a downdraft[17], outflow boundary, or gust front) would have been 33 mph (29 knots) according to the T2 Gust parameter, or 43 mph (37 knots) according to the WindEx parameter.

[14] 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.
[15] 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.
[16] 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.
[17] Small-scale downward moving air current in a cumulonimbus or cumulus cloud.

The 0800 HST GDAS sounding wind profile indicated a surface wind from 054° at 7 knots with the wind remaining from the east-northeast through 5,000 ft, and then backing[18] to the west by 14,000 ft. Wind speeds remained between 5 and 10 knots through 14,000 ft. RAOB did not indicate low-level wind shear (LLWS) or clear-air turbulence (CAT) outside of rain shower or thunderstorm activity from the surface through 14,000 ft. The mean storm motion vector was from 302° at 2 knots.

4.0 Satellite Data

Data from the Geostationary Operational Environmental Satellite number 17 (GOES-17) 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 (bands 2 and 13) imagery at wavelengths of 0.64 microns (μm) and 10.3 μm were retrieved for the period. Satellite imagery surrounding the time of the accident, from 0700 HST through 1200 HST at approximately 5-minute intervals were reviewed, and the closest images to the time of the accident are documented here.

Figures 4 and 5 present the GOES-17 visible imagery from 0900 and 0910 HST at 2X magnification with the accident site highlighted with a red square. The GOES-17 imagery indicated a band of cumuliform clouds located above the accident site at the accident time. The cloud cover and cumuliform bands were moving from east to west.

Figure 6 presents the GOES-17 infrared imagery from 0910 HST at 4X magnification and with a temperature enhancement curve applied with the accident site highlighted with a red square. Inspection of the infrared imagery indicated abundant cloud cover over the accident site at the accident time with the lowest brightness temperatures (yellow and green colors, higher clouds) located over and northwest and southwest of the accident site. Based on the brightness temperatures above the accident site (249° Kelvin) and the vertical temperature profile provided by the 0800 HST GDAS sounding, the approximate cloud-top heights over the accident site were 25,000 ft at 0910 HST. It should be noted these figures have not been corrected for any parallax error.

[18] A counter-clockwise turning of the wind with height in the northern hemisphere.

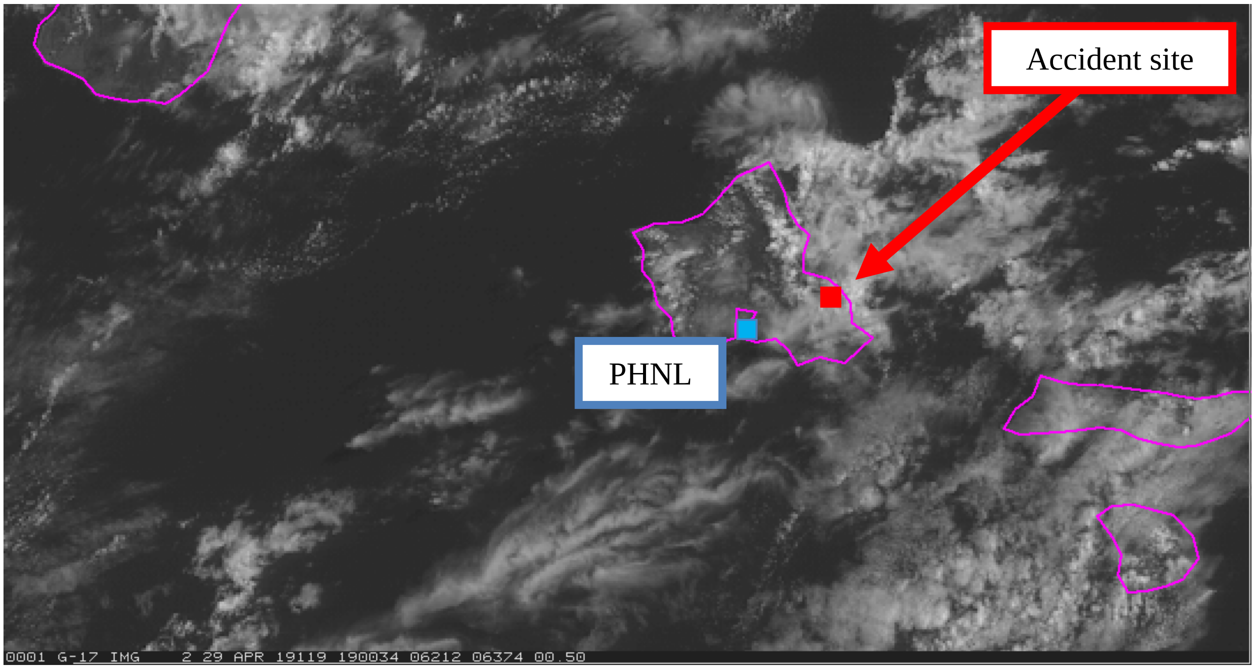


Figure 4 – GOES-17 visible image at 0900 HST

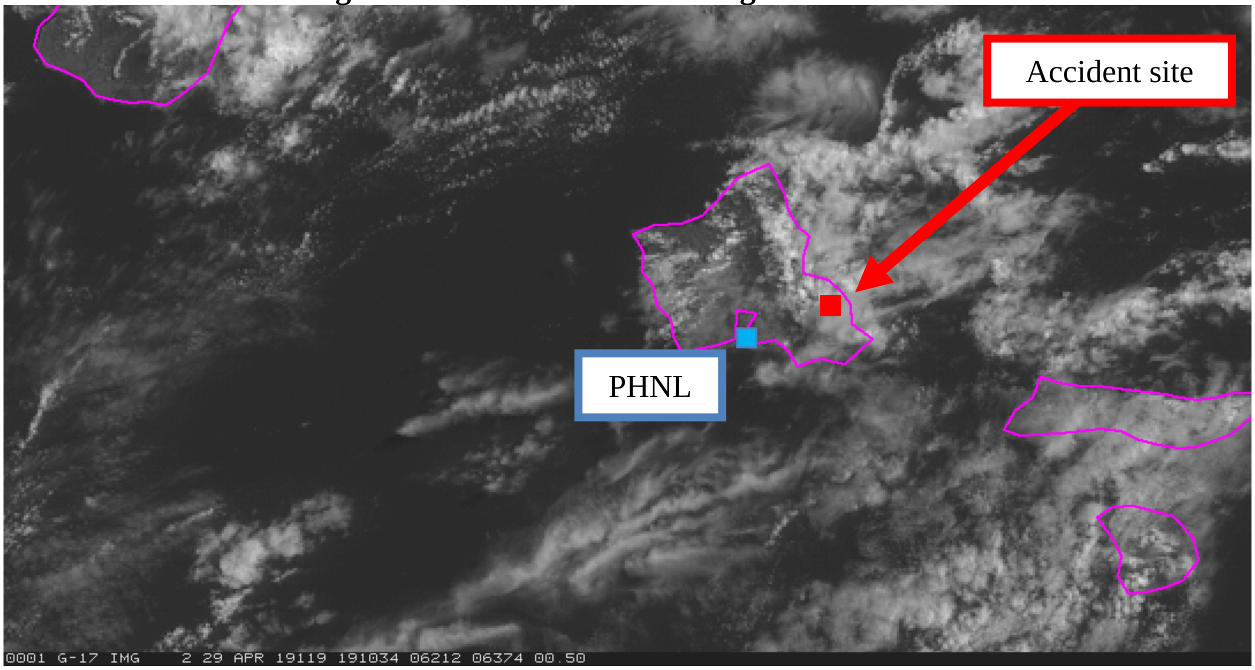


Figure 5 – GOES-17 visible image at 0910 HST

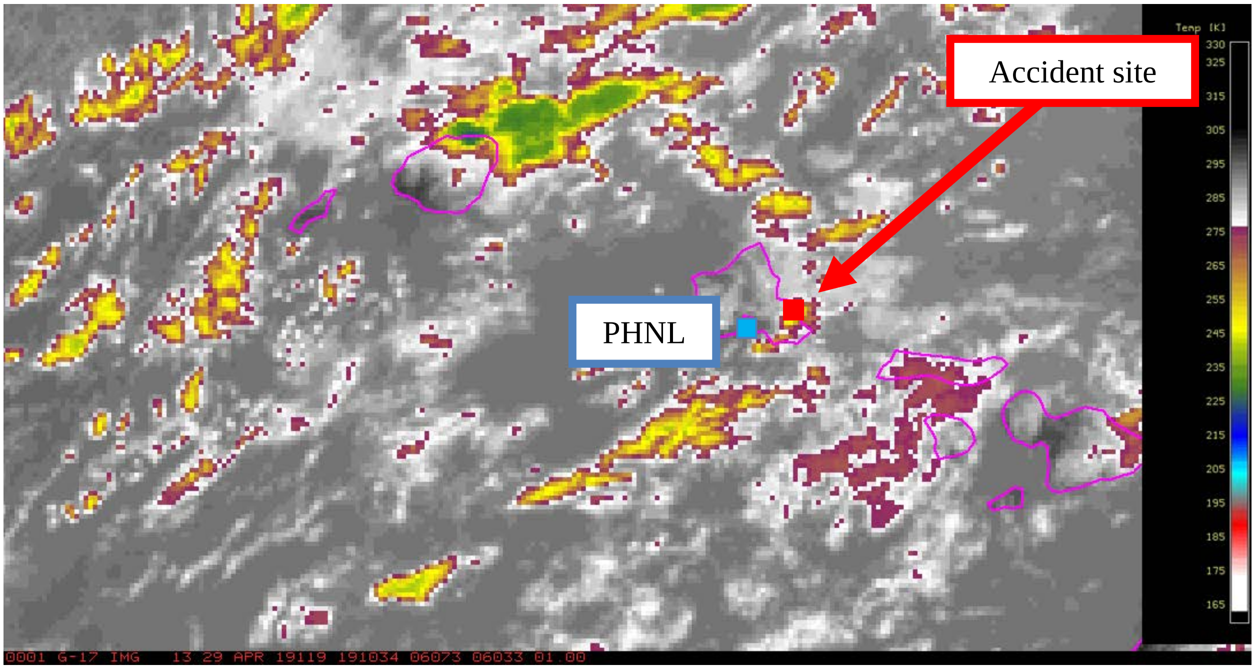


Figure 6 – GOES-17 infrared image at 0910 HST

5.0 Radar Imagery Information

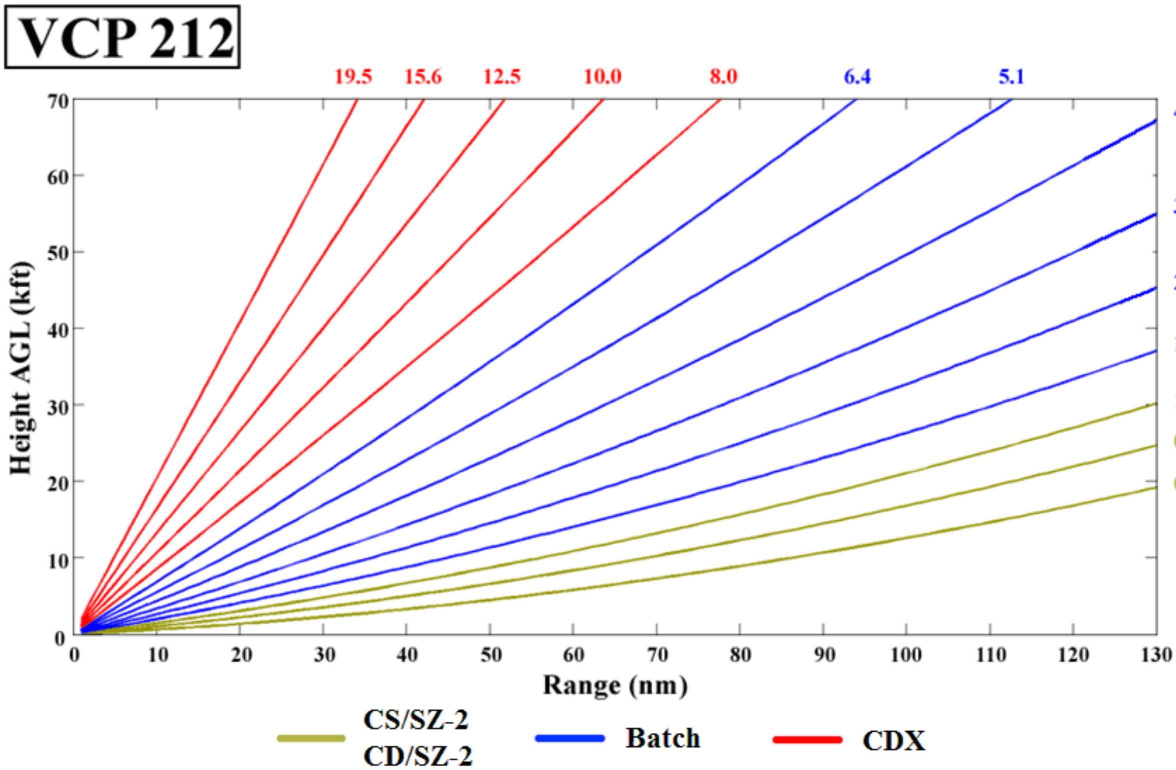
The closest NWS Weather Surveillance Radar-1988, Doppler (WSR-88D)[19] to the accident site was Molokai, Hawaii, (PHMO) and was located 36 miles east-southeast of the accident site. Level II archive radar data was obtained from the NCEI utilizing the NEXRAD Data Inventory Search and displayed using the NOAA's Weather and Climate Toolkit software.

5.1 Volume Scan Strategy

The WSR-88D is a computer-controlled radar system, which automatically creates a complete series of specific scans in a specific sequence known as a volume scan. Individual elevation scans are immediately available. 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 212 (VCP-212). 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 PHMO WSR-88D radar was operating in the precipitation mode VCP-212. 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.

[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.



VCP-212 Precipitation Mode Scan Strategy[20]

5.2 Beam Height Calculation

Assuming standard refraction[21] of the WSR-88D radar beam with the antenna elevation at 1,444 ft (PHMO), and considering a beamwidth[22] of 0.95°, the following table shows the approximate heights for the radar beam center, top and base for antenna elevations over the accident site. These heights have been rounded to the nearest 10 ft.

ANTENNA ELEVATION	BEAM CENTER	BEAM BASE	BEAM TOP
PHMO 0.5°	4,290 ft	2,510 ft	6,070 ft

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

Based on the radar height calculations, the elevation scan listed in the above table depicted the conditions between 2,510 ft and 6,070 ft msl over the accident site and these scans "saw" the closest altitudes to the ground.

5.3 Reflectivity

Reflectivity is the measure of the efficiency of a target in intercepting and returning radio energy. With hydrometeors[23] it is a function of the drop size distribution, number of particles per unit volume, physical state (ice or water), shape, and aspect. Reflectivity is normally displayed in dBZ, and is a general measure of echo intensity. FAA Advisory Circular AC 00-24C[24], "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:

[23] 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.

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

- VIP 1 (Level 1, 15-30 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

5.4 Base Reflectivity Imagery and Lightning Data

Figures 7, 8, 9, 10, and 11 present the PHMO WSR-88D base reflectivity images for the 0.5° elevation scans initiated at 0903:51, 0907:40, 0909:24, 0911:29, and 0915:19 HST, respectively, with a resolution of 0.5° X 250 m. The accident flight track (N808NV, pink dots) and the flight track for N806NV (red dots) were obtained through 0913 HST and are shown on the figures for context.[25] Reflectivity values between 25 and 35 dBZ or light to moderate intensity echoes (section 5.3) were located above the accident site at the time of the accident. The reflectivity bands were moving from northeast to southwest (attachment 1) and expanding in areal coverage with time.

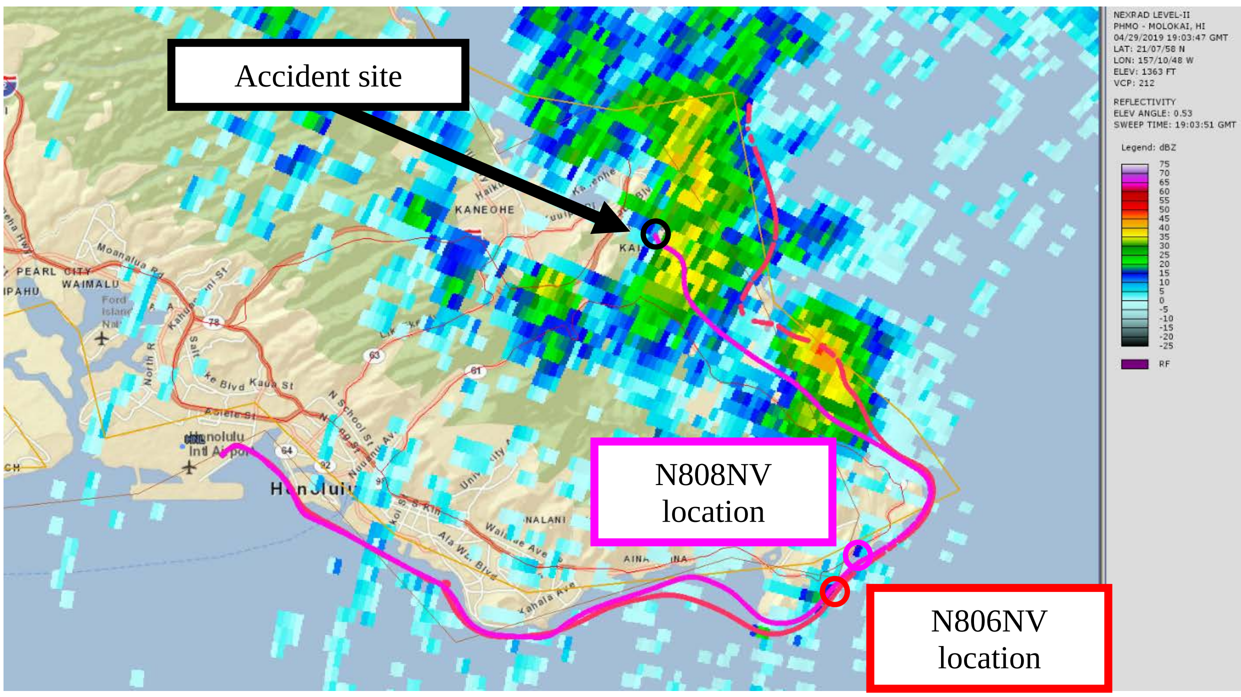


Figure 7 – PHMO WSR-88D reflectivity for the 0.5° elevation scan initiated at 0903:51 HST with the accident site marked with black circle, the accident flight track in pink, and the N806NV flight track in red

[25] For more information please see the factual information from the docket of this accident.

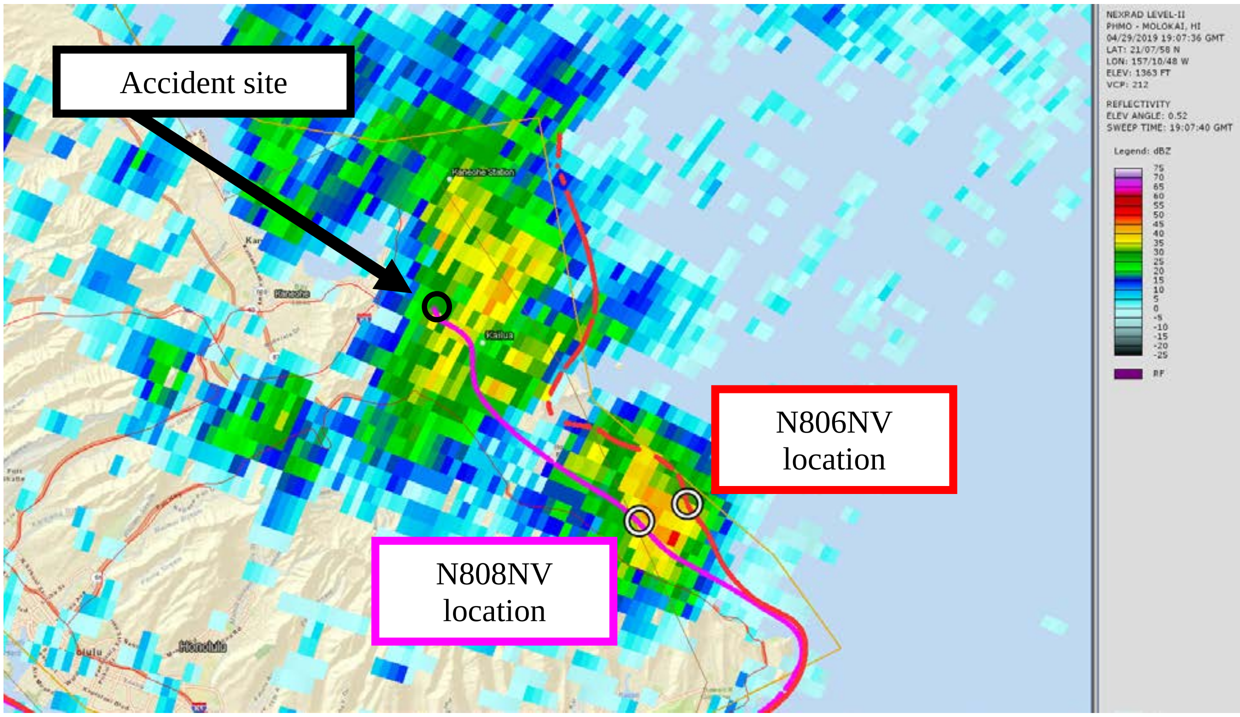


Figure 8 – PHMO WSR-88D reflectivity for the 0.5° elevation scan initiated at 0907:40 HST with the accident site marked with black circle, the accident flight track in pink, and the N806NV flight track in red

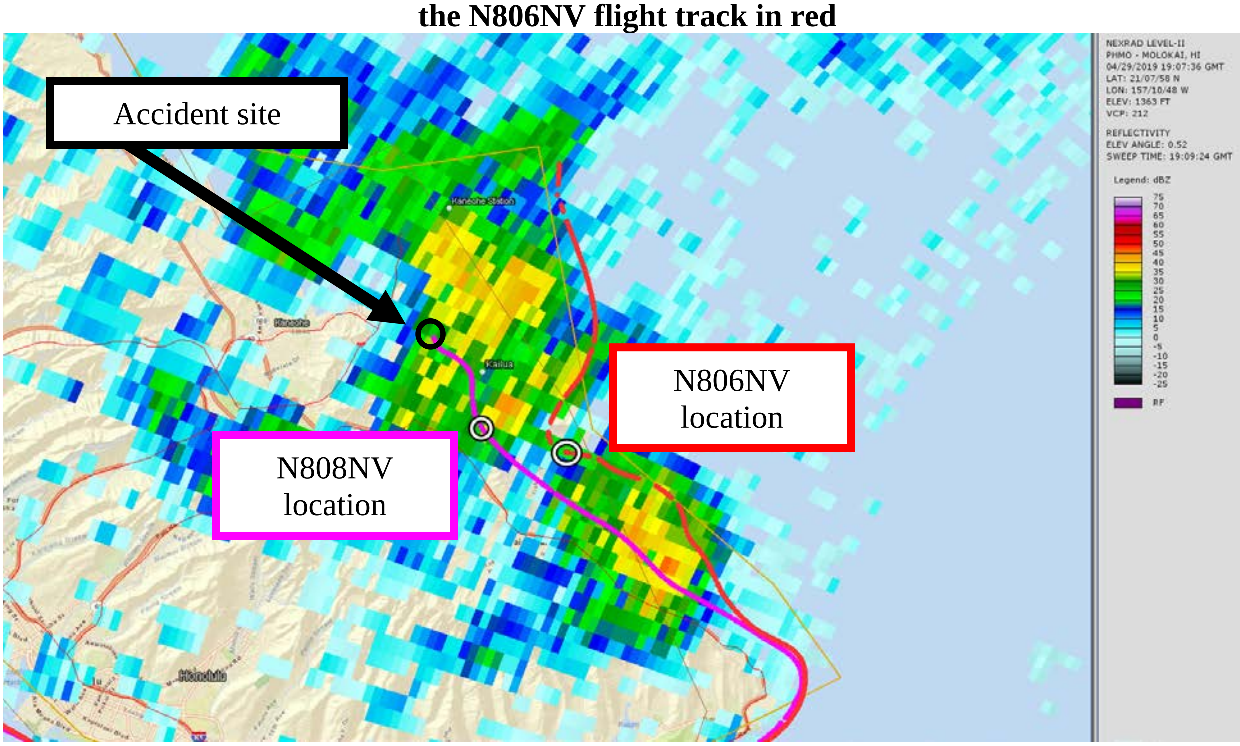


Figure 9 – PHMO WSR-88D reflectivity for the 0.5° elevation scan initiated at 0909:24 HST with the accident site marked with black circle, the accident flight track in pink, and the N806NV flight track in red

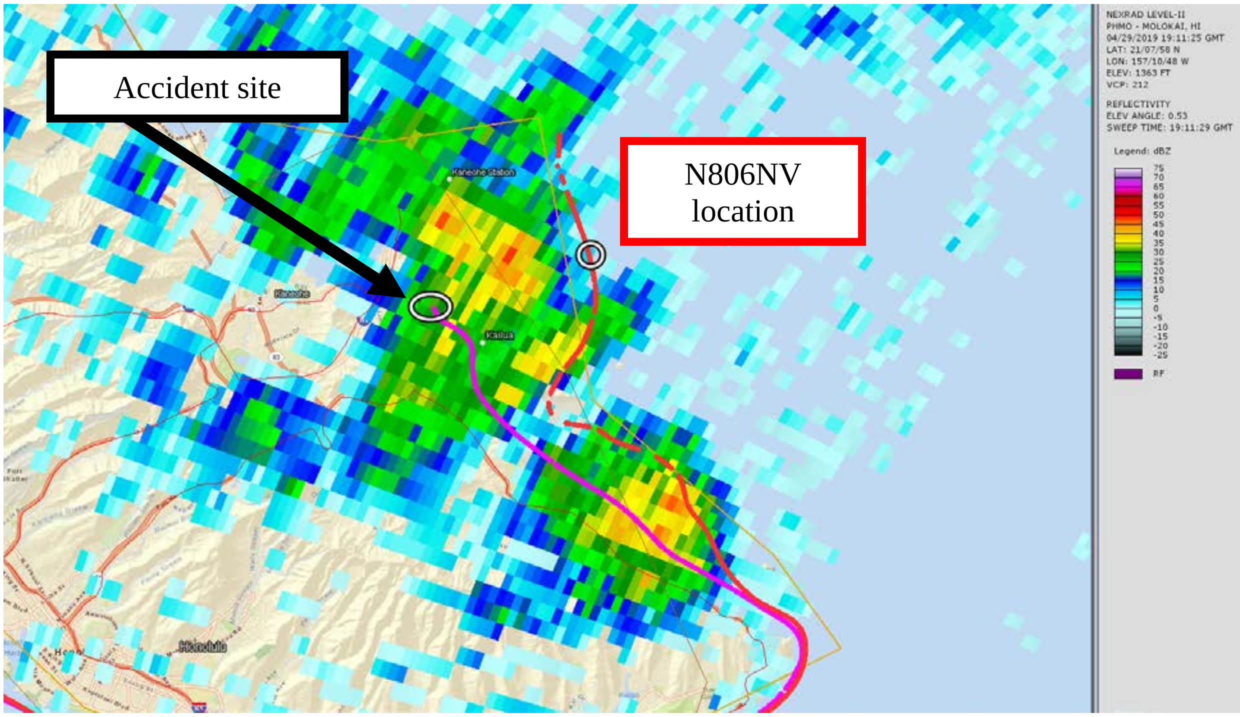


Figure 10 – PHMO WSR-88D reflectivity for the 0.5° elevation scan initiated at 0911:29 HST with the accident site marked with black circle, the accident flight track in pink, and the N806NV flight track in red

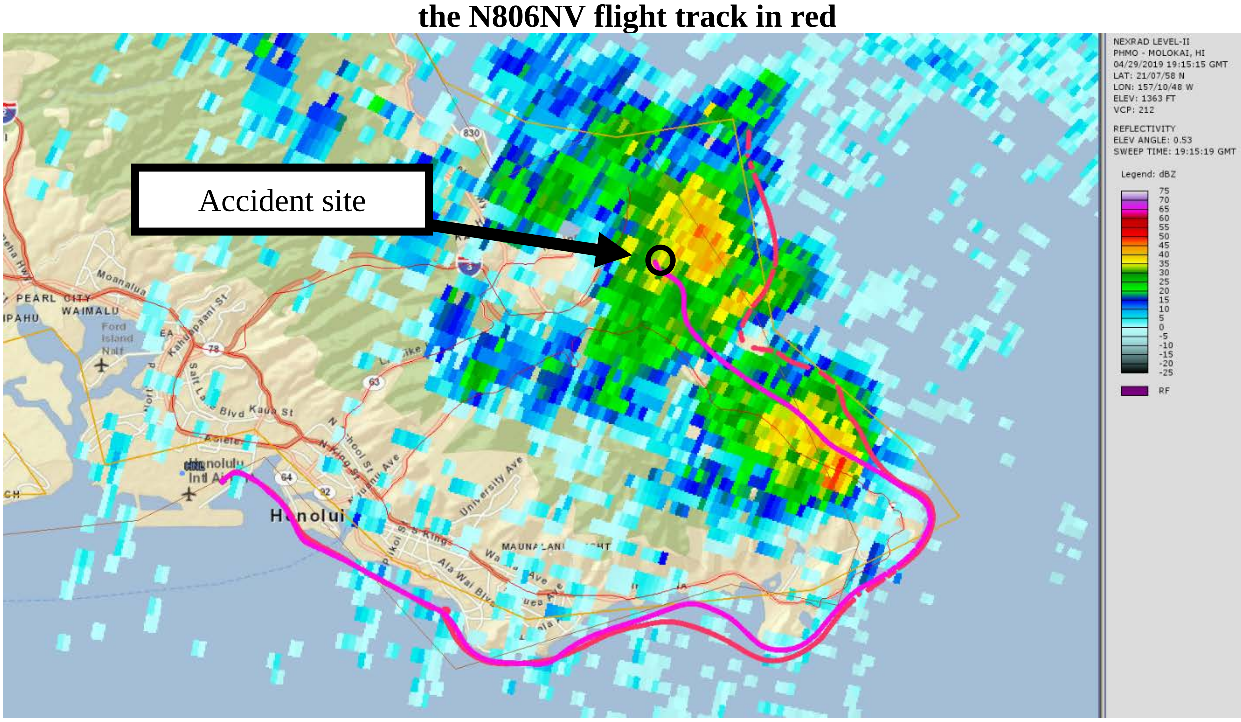


Figure 11 – PHMO WSR-88D reflectivity for the 0.5° elevation scan initiated at 0915:19 HST with the accident site marked with black circle, the accident flight track in pink, and the N806NV flight track in red

A cross section of PHMO base reflectivity from south-southwest to north-northeast through the accident site (middle point on attachment 2) was taken from between 0859 and 0922 HST with reflectivity values from the surface through 50,000 ft msl. The reflectivity values indicated a descending core of 20 to 30 dBZ values descending towards the surface between 0907 and 0915 HST from above the accident site (attachment 2). The radial velocity data did not show a divergent couplet.

Rain showers and convective clouds can produce downdrafts, outflow boundaries and gust fronts during the mature stage of their life cycle. A downdraft, outflow boundary, or gust front can create an environment favorable for unexpected changes in wind direction and speed (figure 12).

A separate review of lightning data indicated that there were no lightning strikes recorded around the accident site at the accident time.[26] This indicated that the echoes were associated with heavy rain showers and not classified as being a thunderstorm.

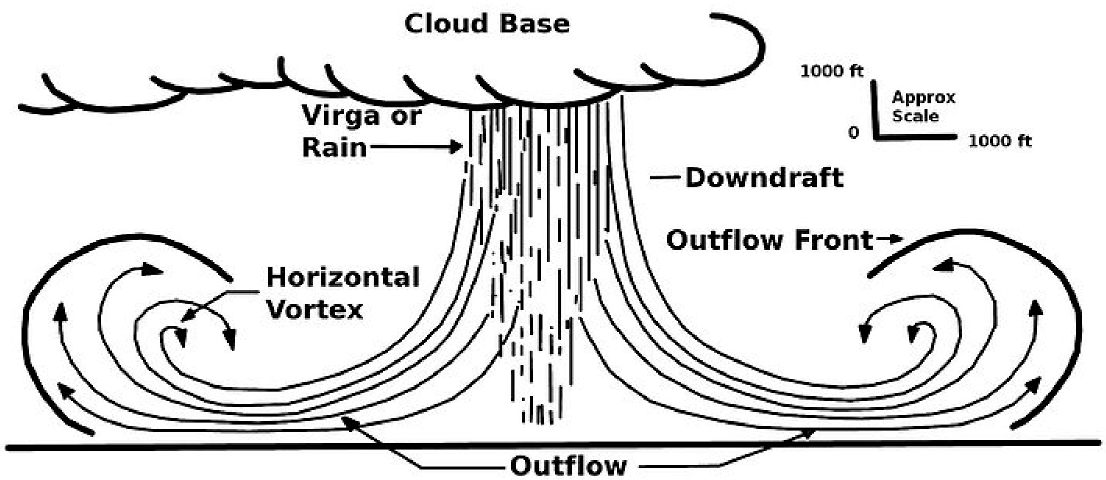


Figure 12 – Exemplar diagram of a downburst and outflow

6.0 Pilot Reports[27]

Pilot reports (PIREPs)s reported in the national airspace within 85 miles of the accident site from about two hours prior to the accident time to about three hours after the accident time for below FL180[28] are provided below:

LIH UA /OV LIH030005/TM 1800/FL010/TP B712/SK SCT015/WX -RA/TB LGT

MKK UA /OV MKK/TM 2215/FL030/TP BE9L/SK BKN025-TOPUNKN/TB NEG/RM NORTH SHORE SCT030

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[26] A review of data from the Earth Networks Total Lightning Network was performed.
[27] Only pilot reports with the World Meteorological Organization headers UBHI** were considered.
[28] Flight Level – A Flight Level (FL) is a standard nominal altitude of an aircraft, in hundreds of ft. This altitude is calculated from the International standard pressure datum of 1013.25 hPa (29.92 inHg), the standard sea-level pressure, and therefore is not necessarily the same as the aircraft's true altitude either above mean sea level or above ground level.

LIH UA /OV LIH090010/TM 2224/FL070/TP B712/SK OVC020-TOP120/WX +RA/RM CB

The report in plain language taken from standard code and abbreviations, with time converted to local were as follows:

Lihue Airport, Hawaii (LIH) routine pilot report (UA); Over – 5 miles from LIH VORTAC on the 030° radial; Time – 0800 HST (1800Z); Altitude – 1,000 ft; Type aircraft – Boeing 717-200; Sky – Scattered clouds at 1,500 ft; Weather – Light rain; Turbulence – Light.

Molokai Airport, Hawaii (MKK) routine pilot report (UA); Over – MKK VORTAC; Time – 1215 HST (2215Z); Altitude – 3,000 ft; Type aircraft – Beech 90 King Air; Sky – Broken clouds at 2,500 ft with tops unknown; Turbulence – Negative; Remarks – North shore scattered clouds 3,000 ft.

LIH routine pilot report (UA); Over – 10 miles from LIH VORTAC on the 090° radial; Time – 1224 HST (2224Z); Altitude – 7,000 ft; Type aircraft – Boeing 717-200; Sky – Overcast clouds at 2,000 ft with tops at 12,000 ft; Weather – Heavy rain; Remarks – Cumulonimbus clouds.

7.0 SIGMET

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

8.0 CWSU Products

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

9.0 AIRMETs

No Airmen's Meteorological Information (AIRMET) advisories were valid for the accident site at the accident time.

10.0 Area Forecast

The NWS office in Honolulu, Hawaii, issued the following Area Forecast for the Hawaiian Islands which warned of brief heavy rain showers remaining possible mainly over the island interiors through day and into the nighttime with isolated MVFR conditions, however, conditions would mainly be few to scattered clouds at 3,500 to 4,500 ft with scattered to broken clouds at 6,000 to 9,000 ft with tops above:

FAHW31 PHFO 291529
FA0HI

HNLC FA 291535
SYNOPSIS AND VFR CLD/WX

SYNOPSIS VALID UNTIL 301000
CLD/WX VALID UNTIL 300400...OUTLOOK VALID 300400-301000
.
SEE AIRMET SIERRA FOR IFR CLD AND MTN OBSC.
TS IMPLY SEV OR GREATER TURB SEV ICE LOW LEVEL WS AND IFR COND.
NON MSL HGT INDICATED BY AGL OR CEILING.
.
SYNOPSIS...UPPER LEVEL TROUGH PASSING OVER THE AREA WILL KEEP THE
AIR MASS UNSTABLE STATEWIDE. ISOLATED THUNDERSTORMS AND LOCALLY HEAVY
SHOWERS DEVELOPING OVER ISLAND WATERS THIS MORNING AND ISLAND
INTERIORS THIS AFTERNOON. LIGHT TRADE WINDS RETURNING THIS EVENING.
.
ALL AREAS.
TEMPO SEPD LYRS FL200 TO FL400. LOWER CLD AND WX FOLLOWS.
.
BIG ISLAND INTERIOR ABV 120.
SKC. 22Z SCT-BKN120 TOPS 160 ISOL CB MAX TOPS FL250 VIS 3-5SM
TSRASN/SHSN BR.
OUTLOOK...IFR SHRA TSRA.
.
BIG ISLAND LOWER SLOPES AND COAST.
FEW035-045 SCT-BKN060-090 TOPS 120 ISOL SCT025 BKN045 -SHRA.
22Z SCT025 SCT045 BKN060-090 TOPS 120-160 TEMPO -SHRA...ISOL BKN020
OVC035 CB MAX TOPS FL350 VIS 3-5SM SHRA/TSRA AFT 00Z.
OUTLOOK...VFR SHRA TSRA.
.
BIG ISLAND ADJ WATERS.
FEW025 SCT045 SCT-BKN060-090 TOPS 090-120 ISOL BKN020 OVC035 -SHRA...
ISOL CB TOPS FL250 VIS 3-5SM SHRA/TSRA AFT 20Z.
OUTLOOK...VFR TSRA.
.
MAUI MOLOKAI LANAI OAHU KAUAI.
FEW-SCT035-045 SCT-BKN060-090 TOPS

BRIEF HEAVY RAIN SHOWES REMAIN POSSIBLE
THROUGHOUT THE NIGHT. LIGHT WIND FLOW AT THE SURFACE WILL ALLOW
SHOWERS TO REMAIN ACTIVE OVER ISLAND INTERIORS. 120 ISOL SCT020 BKN035 -SHRA.
20Z SCT025 SCT045 BKN060-090 TOPS 120-160 TEMPO -SHRA ISOL VIS 3-5SM
SHRA BR..ISOL CB TOPS FL450 VIS AOB 2SM +SHRA/TSRA AFT 22Z.
OUTLOOK...VFR SHRA TSRA.
.
REST OF AREA.
FEW025 SCT045 SCT-BKN060-090 TOPS 090-120 ISOL BKN020 OVC035 -SHRA...
ISOL CB TOPS FL350 VIS 3-5SM TSRA AFT 18Z.
OUTLOOK...VFR TSRA.

11.0 Terminal Aerodrome Forecast

PHNG was the closest airport to the accident site with a Terminal Aerodrome Forecast (TAF). The PHNG TAF valid at the time of the accident was issued at 0503 HST and was valid for a 24-hour period beginning at 0500 HST. The TAF for PHNG was as follows:

TAF PHNG 2915/3015 **35005KT 9999 SCT020 BKN045 QNH2992INS**
TEMPO 2915/2919 8000 -SHRA BKN025
FM292000 06010KT 8000 -SHRA BKN030 BKN045 QNH2990INS
TEMPO 2920/3002 4000 +SHRA BKN020 T25/2921Z T22/3012Z=

Between 0500 and 1000 HST, the forecast expected a wind from 350° at 5 knots, greater than 10 kilometer visibility (greater than 7 miles), scattered clouds at 2,000 ft agl, a broken ceiling at 4,500 ft agl, and a minimum altimeter setting of 29.92 inHg. Temporary conditions were forecast between 0500 and 0900 HST for 8000 meters visibility (5 miles) in light rain showers, and a broken ceiling at 2,500 ft agl.

12.0 NWS Area Forecast Discussion

The NWS office in Honolulu, Hawaii, issued the following Area Forecast Discussion (AFD) at 0340 HST (closest AFD to the accident time). The aviation section of the AFD discussed ample moisture across the islands would help produce moderate to locally intense showers:

FXHW60 PHFO 291340
AFDHFO

Area Forecast Discussion
National Weather Service Honolulu HI
340 AM HST Mon Apr 29 2019

.SYNOPSIS...
A trough of low pressure will remain nearly stationary over the state today, keeping a land and sea breeze pattern in place, with the potential for locally heavy rainfall and thunderstorms during the afternoon and evening. Moderate trade winds will return tonight and continue through Thursday, with showers favoring windward and mauka areas, with a stray shower reaching leeward sections from time to time. A cold front will approach from the northwest on Friday, and move into the island chain over the weekend, bringing an unsettled and potentially wet weather pattern to the state.

&&

.DISCUSSION...
Currently at the surface, a south-southwest to north-northeast oriented trough of low pressure runs through the islands in the vicinity of Oahu. Meanwhile, a 1023 mb high is centered around 1050 miles northwest of Kauai, and a 1034 mb high is centered around 2500 miles north-northeast of Hilo. This is keeping a light wind regime in place across the island chain, with overnight land breezes dominant. Infrared satellite imagery shows variably cloudy skies across the state, with a bit more cloud cover over the southern tip of the Big Island where jet stream cirrus remains rather thick. Radar imagery shows scattered showers mainly over the coastal waters, although some showers are managing to move into land areas near the coast. Main short term concerns revolve around the potential for heavy rainfall and thunderstorms through this evening.

Model solutions remain in good agreement with the large scale synoptic pattern through the work week, with some significant differences noted next weekend. The trough of low pressure will remain nearly stationary in the vicinity of Oahu today, before dissipating this evening as high pressure builds northwest of the state. High pressure will then shift eastward well to the north of the islands through the remainder of the work week. A cold front will then approach from the northwest on Friday, then move into the islands next weekend.

As for sensible weather details, a land breeze and sea breeze pattern will continue into this evening, with showers favoring interior and mountain areas during the afternoon and evening, and the coastal waters and locations near the coast at night into the early morning. An upper level trough will approach from the west today and move through the islands tonight, bringing a core of cold air aloft with H5 temperatures dropping as low as -12 to -13C. This cold air aloft combined with decently steep mid-level lapse rates around 6.5 C/KM, 0-6 KM bulk shear values of 25 to 30 knots, and surface based CAPE values of around 1500 J/KG may be enough to produce a strong thunderstorms or two this afternoon and evening, with some gusty winds and hail not out of the question.

A more typical trade wind pattern will return later tonight, with moderate trades expected Tuesday through Thursday. Showers will favor windward and mauka areas, with a stray shower reaching leeward areas from time to time. The trades will then ease Thursday night and Friday, with a return to more of a convective pattern featuring interior and mauka shower activity expected for Friday afternoon/evening. Forecast confidence remains low over the weekend due to differences in the handling of a closed upper level low diving southward toward Hawaii between the operational models. The GFS features a showery progressive frontal passage through the islands, while the ECMWF shows a slower frontal progression and wetter more unstable pattern. Will hold off on making any significant changes to the forecast over the weekend given the low predictability of upper low positions this far out in the forecast period, and wait until the models converge and details become more clear.

&&

.AVIATION...
An upper level trough passing over the islands has destabilized the local air mass, especially over the smaller islands. This, combined with ample moisture, will produce moderate to locally intense showers. Isolated thunderstorms are expected to develop across the water this morning and interior areas this afternoon.

Weak flow at the surface is allowing land breezes to predominate during the late night and morning hours and sea breezes to prevail in the afternoon and evening hours. The most intense shower activity can be expected to occur in the afternoon and early evening hours and to be focused over island interiors.

Mountain obscuration may become an issue once again this
afternoon.

&&

.MARINE...
A weak surface trough in the vicinity of Oahu is maintaining
light and variable winds across the coastal waters early this
morning. This light background flow will likely persist through
this afternoon. In addition, an upper-level trough moving across
the area from west to east will destabilize the atmosphere. This
will result in locally heavy downpours and a chance of
thunderstorms through this evening.

The surface trough will eventually dissipate later today as a new
surface high pressure system builds far northwest of the area.
This will allow moderate to locally breezy trade winds to develop
across the area from tonight through mid-week. The latest
forecast indicates winds will likely reach the Small Craft
Advisory criteria over the typically windier waters adjacent to
the islands of Maui County and the Big Island from Tuesday through
Wednesday night. The background flow will begin to weaken again
from Thursday through Friday as a new front approaches from the
northwest.

The current moderate northwest swell is expected to peak today,
then gradually subside from tonight through mid-week. A small
reinforcing northwest swell arriving late Wednesday will persist
into next weekend.

A series of small south and southwest swells will maintain small
to moderate surf along south facing shores through the weekend.
Surf may briefly increase along east facing shores around mid-
week as the trade winds strengthen. Otherwise, expect small surf
along east facing shores into early next week.

&&

.HFO WATCHES/WARNINGS/ADVISORIES...
None.

&&

$$

13.0 Winds and Temperature Aloft Forecast

The NWS 0359 HST Winds and Temperature Aloft forecast valid for the closest point to the accident site is included below:

```
FBHW31 KWNO 291359
FD1HW1
DATA BASED ON 291200Z
VALID 291800Z   FOR USE 1400-2100Z. TEMPS NEG ABV 24000

FT  1000 1500 2000 3000    6000    9000   12000   15000   18000   24000
HNL 0506 0507 0506 9900 9900+12 2507+07 2511+01 2509-05 2512-12 2529-24
```

The accident site was located closest to the Honolulu, Hawaii, (HNL) forecast point. The 0359 HST HNL forecast for use between 0400 HST and 1100 HST indicated a wind at 1,000 ft from 050° at 6 knots, a wind at 1,500 ft from 050° at 7 knots, a wind at 2,000 ft from 050° at 6 knots, at 3,000 ft light and variable winds less than 5 knots, and at 6,000 ft light and variable winds less than 5 knots and a temperature of 12 °C.

14.0 Pilot Weather Briefing

The accident pilot did not request a weather briefing from the FAA contract Automated Flight Service Station provider Leidos. A search of archived ForeFlight information indicated that the accident pilot did not request weather information through ForeFlight. There is no record, at this time, of the accident pilot receiving or retrieving any other weather information before or during the accident flight.

15.0 Astronomical Data

The astronomical data obtained from the United States Naval Observatory for the accident site on April 29, 2019, indicated the following:

SUN	
Begin civil twilight	0538 HST
Sunrise	0601 HST
Accident time	**0911 HST**[29]
Sun transit	1228 HST
Sunset	1856 HST
End civil twilight	1919 HST

[29] Inserted accident time for reference and context.

E. LIST OF ATTACHMENTS

Attachment 1 – Animation of PHMO WSR-88D base reflectivity images for the 0.5° elevation scans between 0859 and 0930 HST

Attachment 2 – Cross section animation of PHMO WSR-88D base reflectivity images for elevation scans between 0859 and 0922 HST

Submitted by:

Paul Suffern
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