



NATIONAL TRANSPORTATION SAFETY BOARD

Office of Aviation Safety
Washington, D.C. 20594

May 14, 2019

Weather Study

METEOROLOGY

ERA19LA093

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A. ACCIDENT

Location: Atlantic Ocean
Date: February 1, 2019
Time: 1315 eastern standard time
1815 Coordinated Universal Time (UTC)
Aircraft: Piper PA32RT, Registration: N3016L

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 eastern standard time (EST) on February 1, 2019, and are based upon the 24-hour clock, where local time is -5 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 miles.

The approximate location of the accident site was located at latitude 26.6914° N, longitude 79.7206° W.

D. FACTUAL INFORMATION

1.0 Synoptic Situation

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

¹

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

1.1 Surface Analysis Chart

The southeastern United States section of the NWS Surface Analysis Chart for 1300 EST is provided as figure 1 with the location of the accident site marked within the red circle. The chart indicated a surface trough² located across Florida oriented south to north from the Florida Keys northward to near Jacksonville, Florida. Troughs can act as lifting mechanisms to help produce clouds and precipitation if sufficient moisture is present.

The station models around the accident site depicted air temperatures in the low 70's degrees Fahrenheit (°F), dew point temperatures in the mid to upper 60's °F with a temperature-dew point spread of 6° or less, a south to southeast wind between 5 and 15 knots, mostly cloudy skies and light rain.

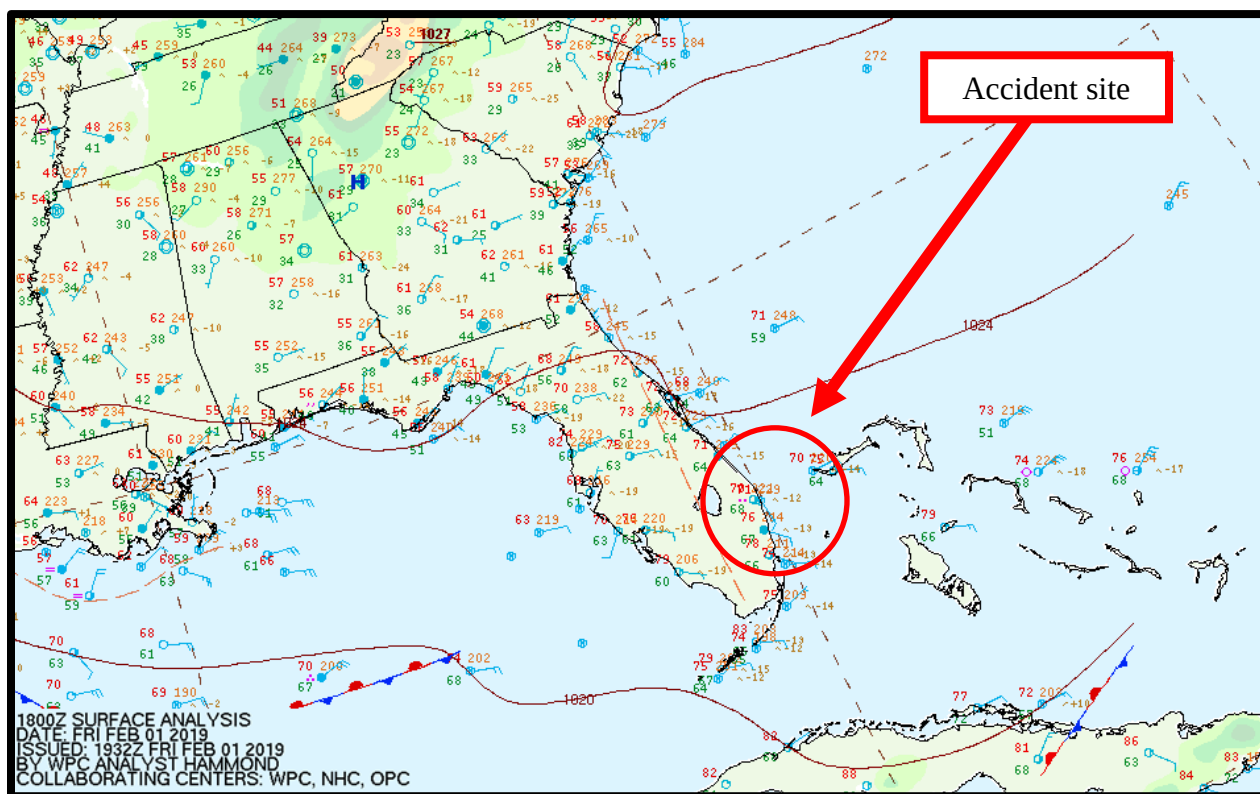


Figure 1 – NWS Surface Analysis Chart for 1300 EST

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

1.2 Upper Air Charts

The NWS Storm Prediction Center (SPC) Constant Pressure Charts for 0700 EST at 925-, 850-, 700-, 500-, and 300-hectopascals (hPa) are presented in figures 2 through 6. There was a low-level trough directly to the west of the accident site at 925- and 850-hPa (figure 2 and 3). The wind was from the east to southeast at 10 to 15 knots at 925- and 850-hPa with the wind becoming westerly at 35 knots by 500-hPa (figure 5). At 300-hPa, the wind was from the west-southwest at 70 knots (figure 6).

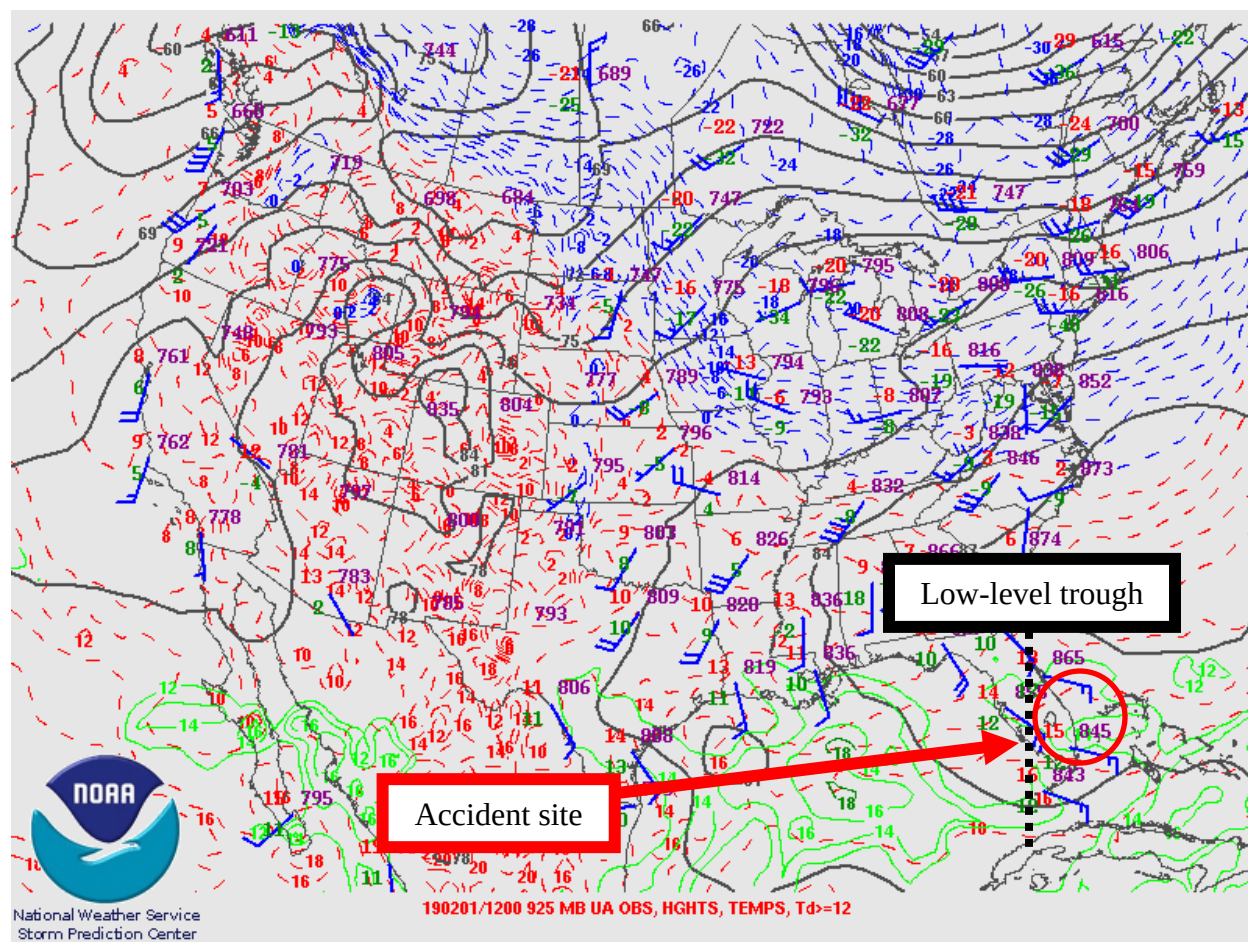


Figure 2 – 925-hPa Constant Pressure Chart for 0700 EST

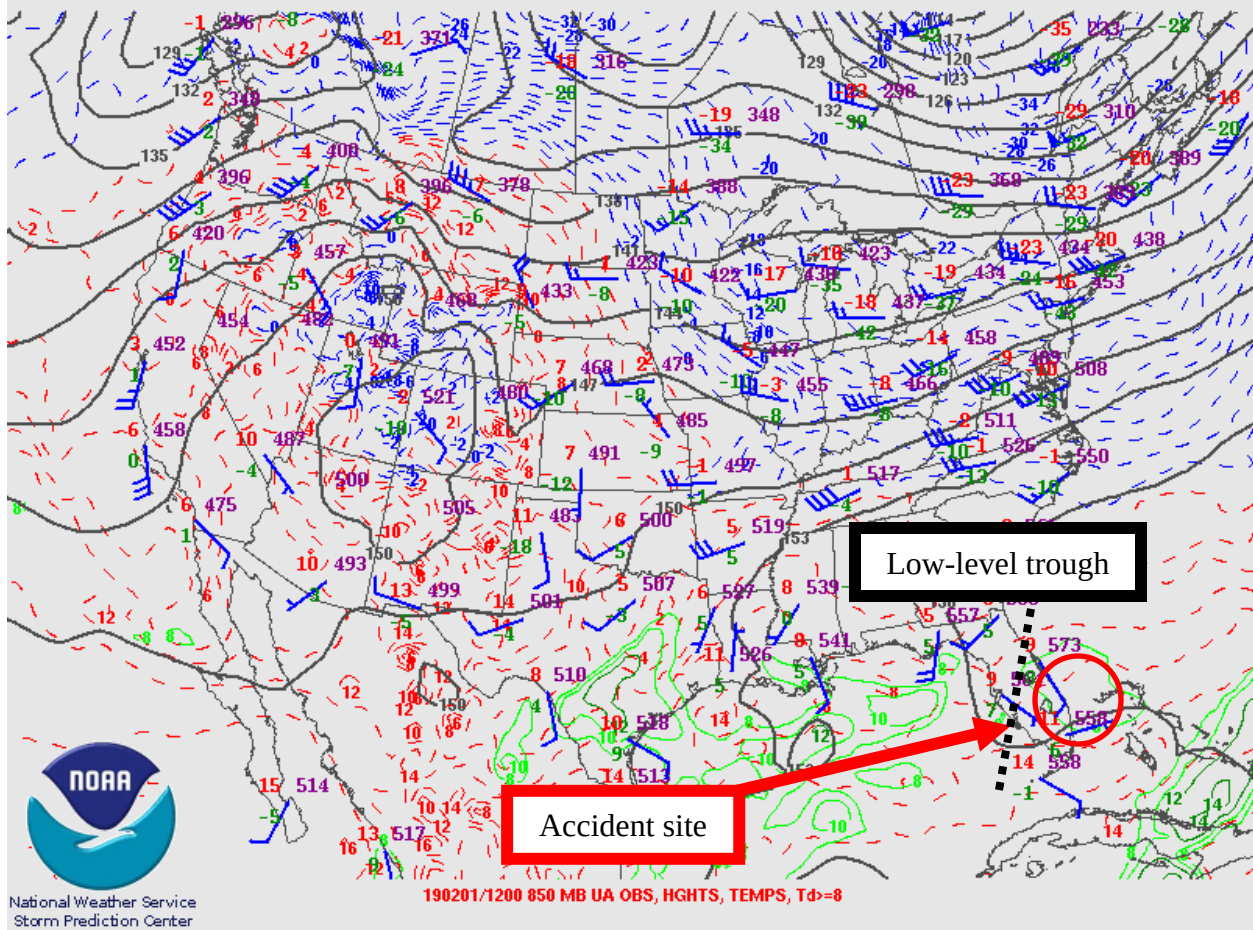


Figure 3 – 850-hPa Constant Pressure Chart for 0700 EST

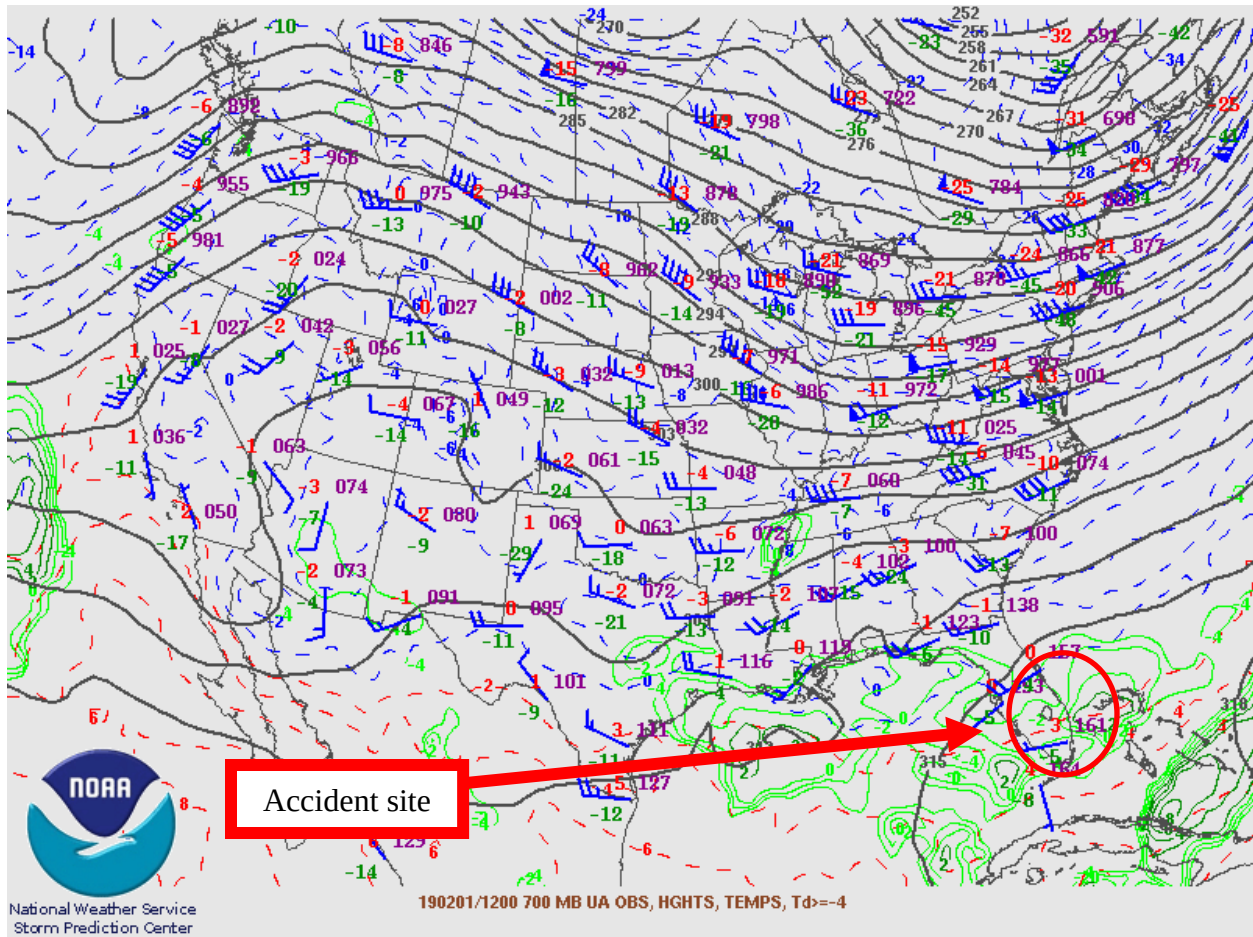


Figure 4 – 700-hPa Constant Pressure Chart for 0700 EST

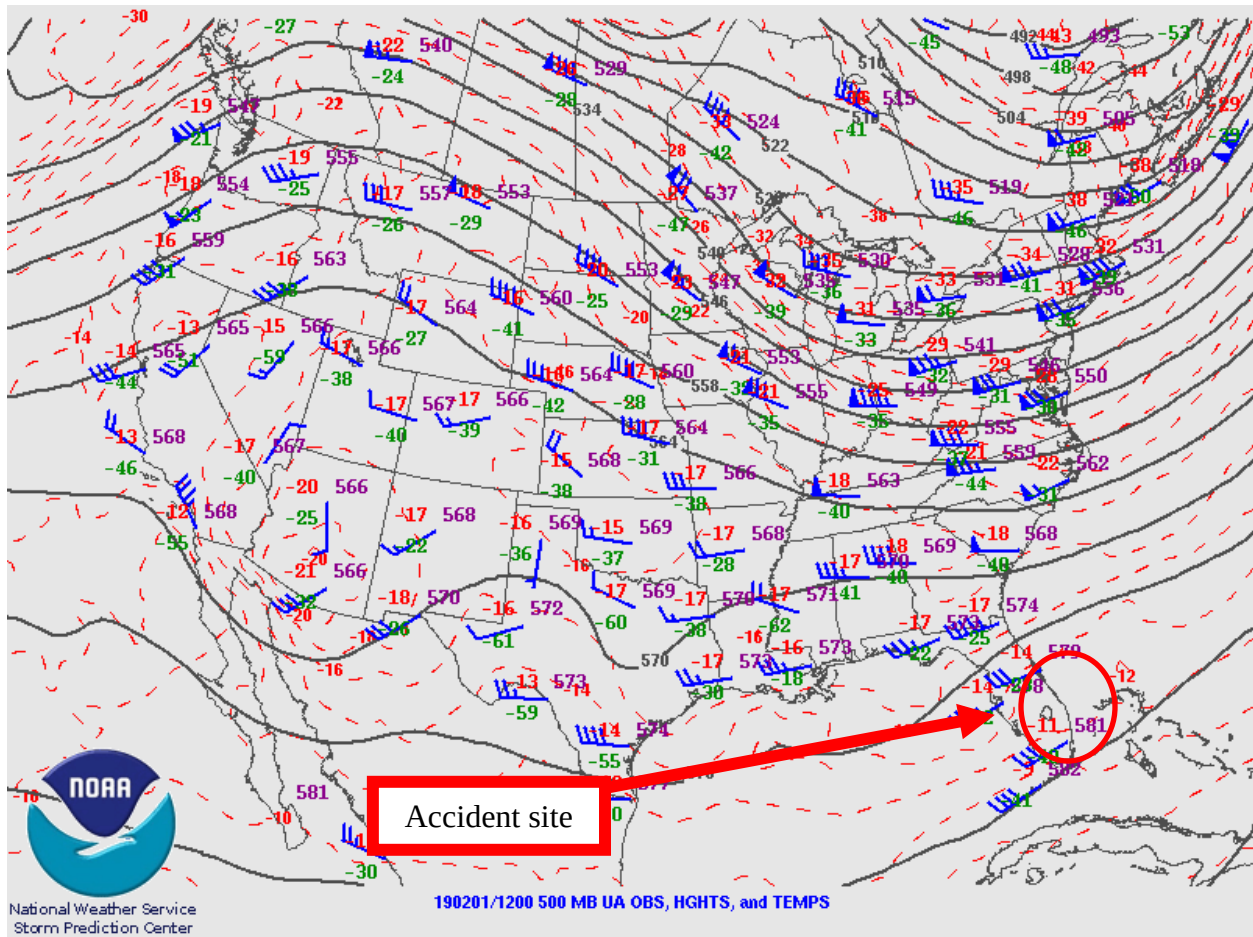


Figure 5 – 500-hPa Constant Pressure Chart for 0700 EST

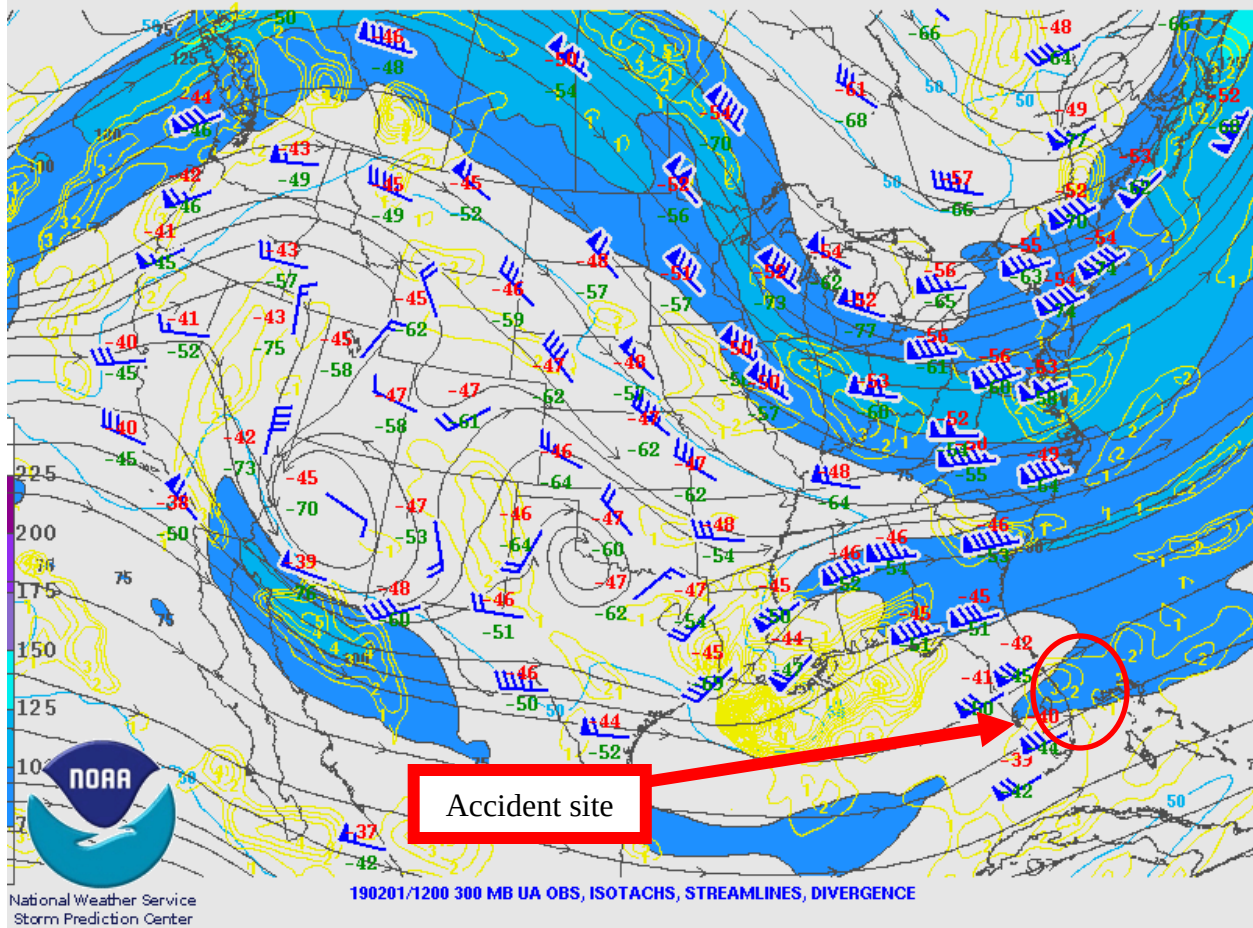


Figure 6 – 300-hPa Constant Pressure Chart for 0700 EST

2.0 SPC Products

SPC issued the following Day 1 Convective Outlook at 0927 EST (figure 7) with areas of general thunderstorms forecast for the accident site. SPC defines the “TSTM” area as an area that encloses where a 10% or higher probability of thunderstorms is forecast during the valid period. The SPC Day 1 Convective Outlook text follows figure 7:

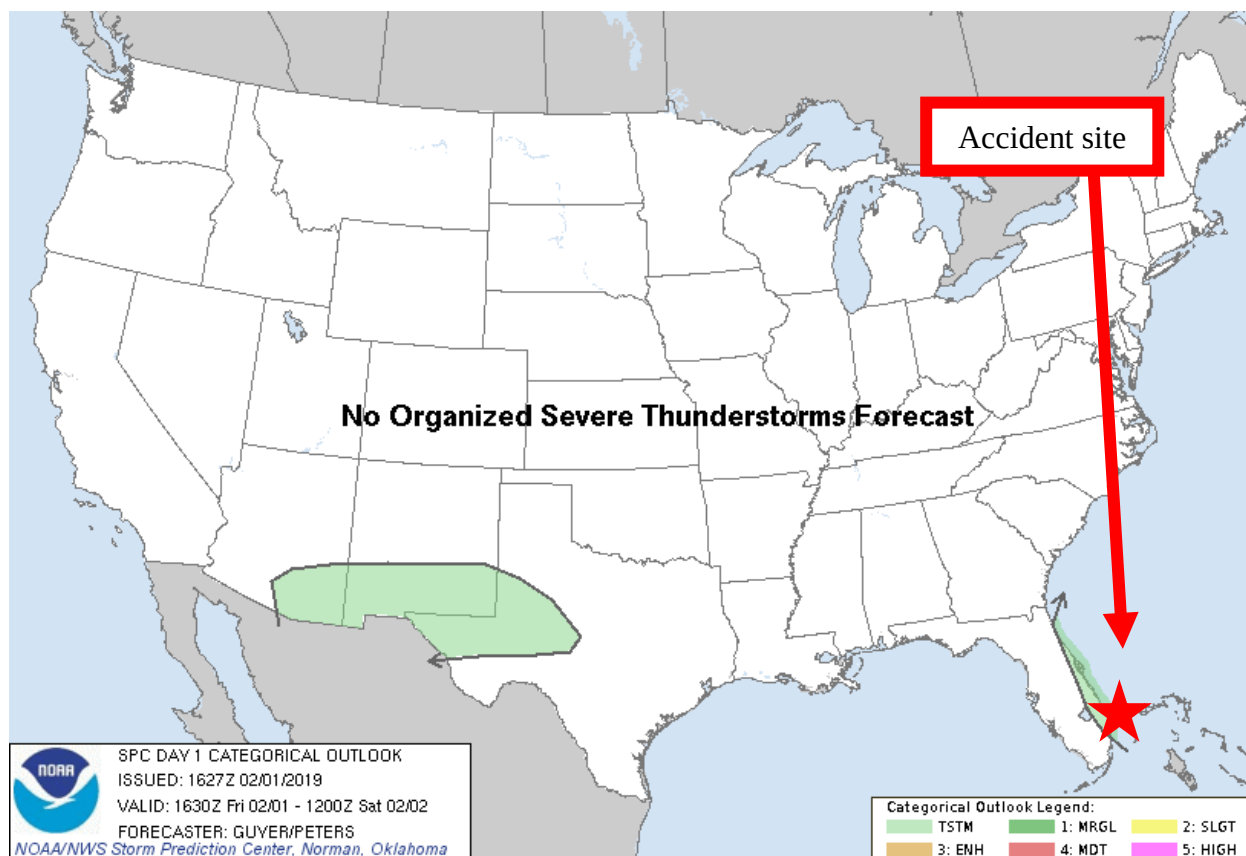


Figure 7 – SPC day 1 Convective Outlook valid at the time of the accident

SPC AC 011627

Day 1 Convective Outlook
NWS Storm Prediction Center Norman OK
1027 AM CST Fri Feb 01 2019

Valid 011630Z - 021200Z

...NO SEVERE THUNDERSTORM AREAS FORECAST...

...SUMMARY...

Severe thunderstorms are not expected over the contiguous U.S. today.

...Southeast Arizona to west/central Texas...

A low-amplitude shortwave trough along the AZ/Sonora border will continue eastward and reach west TX tonight. Orographic ascent coupled with the pocket of cold mid-level temperatures may support redevelopment of isolated thunderstorms this afternoon centered on southern NM. As the system continues eastward, isolated thunderstorms could occur across parts of West TX this evening, and as far east as west-central TX late tonight.

...Florida Peninsula...

Scattered showers will persist mostly along the east coast of the FL Peninsula today, with a marginally supportive thermodynamic

environment potentially allowing for a few thunderstorms over inland areas as well as offshore. As a weak shortwave trough over the north-central Gulf of Mexico at midday approaches the Peninsula this evening, additional showers are expected especially across the north-central Peninsula tonight. A few lightning strikes cannot be entirely ruled out, but the overall potential/coverage should remain low tonight within a marginally unstable environment.

..Guyer/Peters.. 02/01/2019

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

3.0 Surface Observations

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

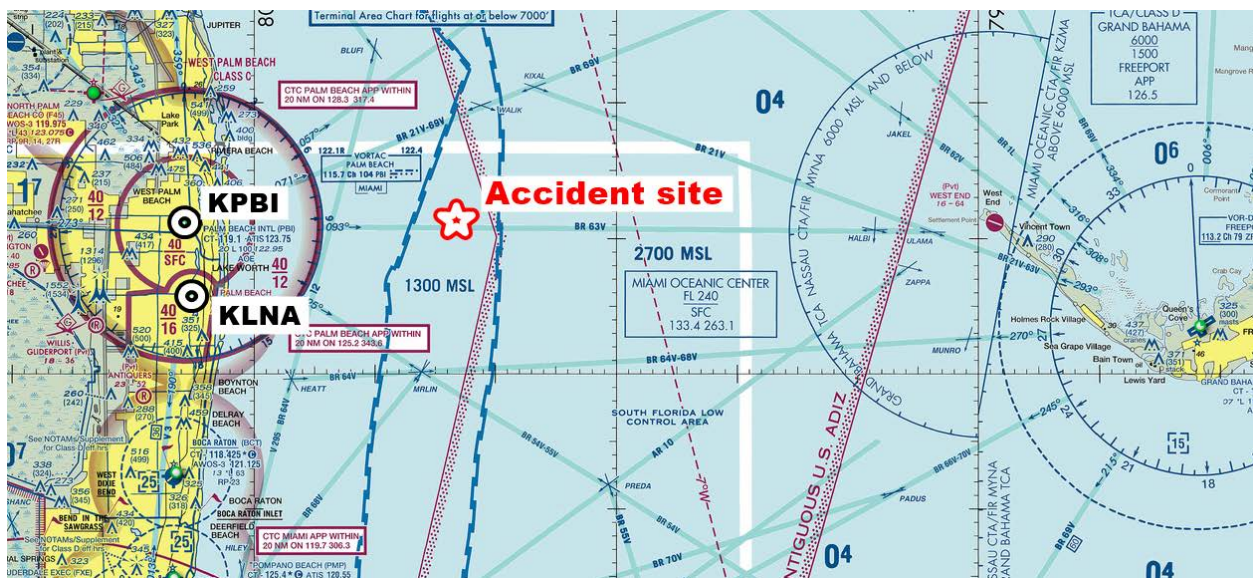


Figure 8 – Sectional chart of accident area with the location of the accident site and the closest surface observation sites

The closest official weather reporting facility to the accident site was from Palm Beach International Airport (KPBI), West Palm Beach, Florida, at an elevation of 20 ft, and was 20 miles west of the accident site. KPBI had an Automated Surface Observing System (ASOS³) whose reports were supplemented by official weather observers and KPBI had a 7° westerly magnetic variation⁴ (figure 8). The following observations were taken and disseminated during the times surrounding the accident:⁵

[1046 EST] SPECI KPBI 011546Z 13011KT 3SM -RA BR SCT011 BKN018CB BKN032
20/19 A3023 RMK AO2 CB SE MOV N CB DSNT N SE P0012 T02000194 \$=

[1053 EST] METAR KPBI 011553Z 12011KT 3SM R10L/5500VP6000FT -RA BR
BKN028CB BKN050 BKN065 20/19 A3023 RMK AO2 SLP236 CB SE
MOV N CB DSNT N SE P0013 T02000194 \$=

[1153 EST] METAR KPBI 011653Z 12003KT 9SM BKN029CB BKN045 BKN060 21/20
A3021 RMK AO2 RAE40 SLP229 CB E-SE MOV N CB DSNT S
P0001 T02060200 \$=

[1253 EST] METAR KPBI 011753Z VRB05KT 5SM -RA BR BKN015 BKN020CB BKN046
21/20 A3019 RMK AO2 RAB43 SLP221 CB OHD-ALQDS MOV N CB
DSNT SE-S P0000 60043 T02110200 10222 20189 58012 \$=

**[1300 EST] SPECI KPBI 011800Z 17004KT 5SM -RA BR BKN012 BKN018CB BKN046
21/19 A3018 RMK AO2 CB OHD-ALQDS MOV N CB DSNT SE-S
P0001 T02110194 \$=**

**[1309 EST] SPECI KPBI 011809Z 00000KT 2 1/2SM RA BR BKN012 BKN021CB
BKN036 21/19 A3018 RMK AO2 CB OHD-ALQDS MOV N CB
DSNT SE-S P0001 T02060194 \$=**

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**[1322 EST] SPECI KPBI 011822Z 00000KT 3SM RA BR SCT012 BKN027CB BKN041
21/20 A3017 RMK AO2 CB OHD-NE-E MOV N CB DSNT NE SE
P0006 T02110200=**

**[1338 EST] SPECI KPBI 011838Z 20003KT 7SM RA BKN017CB BKN029 BKN041
22/20 A3016 RMK AO2 CB OHD-NE-E MOV N CB DSNT NE SE
P0006 T02170200=**

³ ASOS – Automated Surface Observing System is equipped with meteorological instruments to observe and report wind, visibility, ceiling, temperature, dewpoint, altimeter, and barometric pressure.

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

⁵ Bolded sections in this report highlight information that directly reference the weather conditions that affected the accident location around the accident time.

[1353 EST] METAR KPBI 011853Z 00000KT 10SM SCT015 BKN020CB BKN041 22/21
A3015 RMK AO2 RAE39 SLP209 CB NE-SE MOV N CB DSNT NE SE
P0006 T02220206 \$=

KPBI weather at 1300 EST, wind from 170° at 4 knots, 5 miles visibility, light rain, mist, broken ceiling at 1,200 ft above ground level (agl), broken clouds of cumulonimbus clouds at 1,800 ft agl, broken clouds at 4,600 ft agl, temperature of 21 °Celsius (C), dew point temperature of 19 °C, and an altimeter setting of 30.18 inches of mercury (inHg). Remarks: automated station with a precipitation discriminator, cumulonimbus clouds overhead and all quadrants moving north, cumulonimbus clouds distant⁶ southeast through south, 0.01 inches of precipitation since 1253 EST, temperature 21.1 °C, dew point temperature 19.4 °C, maintenance is needed on the system.

KPBI weather at 1309 EST, wind calm, 2 and a half miles visibility, moderate rain, mist, broken ceiling at 1,200 ft agl, broken clouds of cumulonimbus clouds at 2,100 ft agl, broken clouds at 3,600 ft agl, temperature of 21 °C, dew point temperature of 19 °C, and an altimeter setting of 30.18 inHg. Remarks: automated station with a precipitation discriminator, cumulonimbus clouds overhead and all quadrants moving north, cumulonimbus clouds distant southeast through south, 0.01 inches of precipitation since 1253 EST, temperature 20.6 °C, dew point temperature 19.4 °C, maintenance is needed on the system.

KPBI weather at 1322 EST, wind calm, 3 miles visibility, moderate rain, mist, scattered clouds 1,200 ft agl, broken cloud ceiling of cumulonimbus clouds at 2,700 ft agl, broken clouds at 4,100 ft agl, temperature of 21 °C, dew point temperature of 20 °C, and an altimeter setting of 30.17 inHg. Remarks: automated station with a precipitation discriminator, cumulonimbus clouds overhead and northeast through east moving north, cumulonimbus clouds distant northeast and southeast, 0.06 inches of precipitation since 1253 EST, temperature 21.1 °C, dew point temperature 20.0 °C.

KPBI weather at 1338 EST, wind from 200° at 3 knots, 7 miles visibility, moderate rain, broken cloud ceiling of cumulonimbus clouds at 1,700 ft agl, broken clouds at 2,900 ft agl, broken clouds at 4,100 ft agl, temperature of 22 °C, dew point temperature of 20 °C, and an altimeter setting of 30.16 inHg. Remarks: automated station with a precipitation discriminator, cumulonimbus clouds overhead and northeast through east moving north, cumulonimbus clouds distant northeast and southeast, 0.06 inches of precipitation since 1253 EST, temperature 21.7 °C, dew point temperature 20.0 °C.

Palm Beach County Park Airport (KLNA), was the departure airport located at an elevation of 14 ft, and was 20 miles west-southwest of the accident site (figure 8). Departure time was around 1300 EST. KLNA had an Automated Weather Observing System (AWOS⁷) whose reports were not supplemented. The following observations were taken and disseminated during the times surrounding the accident:

⁶ Distant indicated that the lightning was beyond 10 miles but less than 30 miles from the center of the airport (or airport location point, [ALP]).

⁷ 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.

[1135 EST] METAR KLNA 011635Z AUTO 10003KT 20/19 A3023 RMK AO2 T02020189 PWINO=

[1155 EST] METAR KLNA 011655Z AUTO 05005KT 10SM -RA SCT010 BKN016 OVC026 21/19 A3022 RMK AO2 T02050193=

[1215 EST] METAR KLNA 011715Z AUTO 00000KT 7SM -DZ SCT012 BKN020 OVC040 21/19 A3021 RMK AO2 T02050190=

[1235 EST] METAR KLNA 011735Z AUTO 00000KT 7SM RA BKN012 BKN017 OVC037 21/19 A3020 RMK AO2 T02050192=

[1255 EST] METAR KLNA 011755Z AUTO 15003KT 20/19 A3019 RMK AO2 6//// T02030192 PWINO=

[1315 EST] METAR KLNA 011815Z AUTO 17003KT BKN014 BKN023 OVC033 21/19 A3018 RMK AO2 T02060192 PWINO=

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[1335 EST] METAR KLNA 011835Z AUTO 21003KT BKN014 BKN027 OVC085 21/20 A3017 RMK AO2 T02080195 PWINO=

[1355 EST] METAR KLNA 011855Z AUTO 00000KT 10SM SCT012 SCT028 OVC120 21/20 A3016 RMK AO2 T02110200 PWINO=

[1415 EST] METAR KLNA 011915Z AUTO 16003KT 10SM BKN014 BKN024 OVC120 21/20 A3015 RMK AO2 T02140195=

KLNA weather at 1255 EST, automated, wind from 150° at 3 knots, temperature of 20 °C, dew point temperature of 19 °C, and an altimeter setting of 30.19 inHg. Remarks: automated station with a precipitation discriminator, 6-hourly precipitation unknown, temperature 20.3 °C, dew point temperature 19.2 °C, precipitation identifier information not available..⁸

KLNA weather at 1315 EST, automated, wind from 170° at 3 knots, broken ceiling at 1,400 ft agl, broken clouds at 2,300 ft agl, overcast clouds at 3,300 ft agl, temperature of 21 °C, dew point temperature of 19 °C, and an altimeter setting of 30.18 inHg. Remarks: automated station with a precipitation discriminator, temperature 20.6 °C, dew point temperature 19.2 °C, precipitation identifier information not available.

⁸ Visibility and cloud ceiling missing from the METAR for an unknown reason. Visibility is missing in the 1315 and 1335 EST observations as well.

KLNA weather at 1335 EST, automated, wind from 210° at 3 knots, broken ceiling at 1,400 ft agl, broken clouds at 2,700 ft agl, overcast clouds at 8,500 ft agl, temperature of 21 °C, dew point temperature of 20 °C, and an altimeter setting of 30.17 inHg. Remarks: automated station with a precipitation discriminator, temperature 20.8 °C, dew point temperature 19.5 °C, precipitation identifier information not available.

KLNA weather at 1355 EST, automated, wind calm, visibility 10 miles or greater, scattered clouds at 1,200 ft agl, scattered clouds at 2,800 ft agl, overcast ceiling at 12,000 ft agl, temperature of 21 °C, dew point temperature of 20 °C, and an altimeter setting of 30.16 inHg. Remarks: automated station with a precipitation discriminator, temperature 21.1 °C, dew point temperature 20.0 °C, precipitation identifier information not available.

The observations from KPBI and KLNA surrounding the accident time indicated predominately MVFR⁹ conditions with visibility conditions dropping into the IFR¹⁰ category. Light to moderate rain was reported at KPBI with the precipitation identifier sensor and visibility sensor not working at KLNA at the accident time or time of departure.¹¹ The surface wind remained variable under 5 knots with cumulonimbus clouds surrounding the airports and overhead.

4.0 Upper Air Data

A High-Resolution Rapid Refresh (HRRR)¹² model sounding was created for the accident site for 1200 EST¹³ with station elevation of 0 ft.¹⁴ The 1200 EST HRRR 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 approximately 14,000 ft msl). This data was analyzed using the RAOB¹⁶ software package. The sounding depicted the lifted condensation level (LCL)¹⁷ at 632 ft agl, the level of free convection (LFC)¹⁸ at 632 ft agl, and the convective condensation level (CCL)¹⁹ at 1,888 ft agl. The sounding had a greater than 90% relative humidity from the surface through 20,000 ft msl. The freezing level was located at 11,956 ft msl. The precipitable water value was 1.75 inches.

⁹ Marginal Visual Flight Rules – Refers to the general weather conditions pilots can expect at the surface. MVFR criteria, which is a sub-category of VFR conditions, are a ceiling 1,000 to 3,000 ft agl and/or 3 to 5 miles visibility.

¹⁰ Instrument Flight Rules (IFR) – Refers to the general weather conditions pilots can expect at the surface. IFR criteria means a ceiling below 1,000 ft agl and/or less than 3 miles visibility.

¹¹ AWOS maintenance records were not able to be retrieved for KLNA.

¹² 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.

¹³ Closest time available due to archiving issues related to the government shutdown.

¹⁴ HRRR sounding was created using NOAA Air Resource Laboratory: <https://ready.arl.noaa.gov/READYamet.php>

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

¹⁸ 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.

¹⁹ 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.

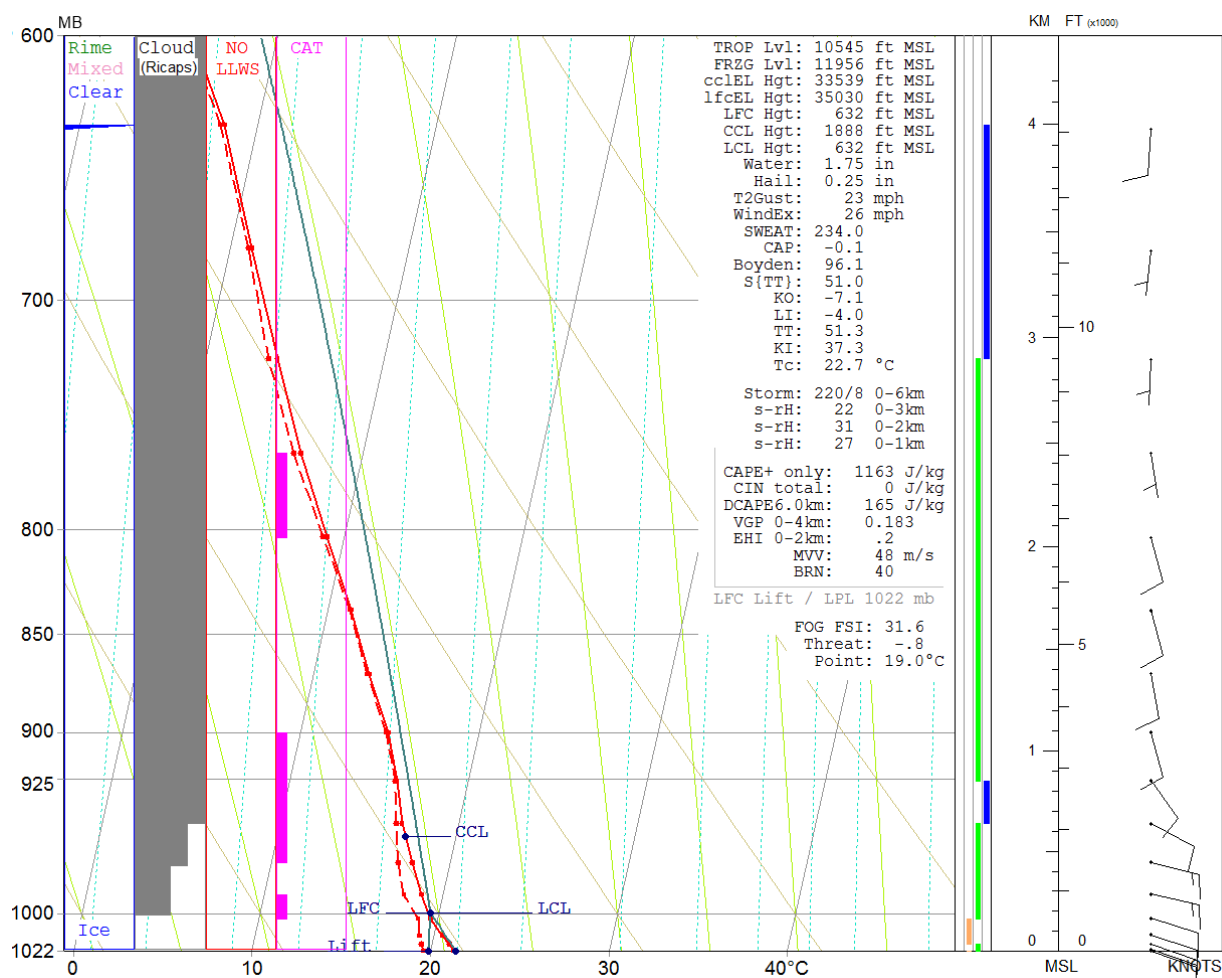


Figure 9 – 1200 EST HRRR sounding for the accident site

The 1200 EST HRRR sounding for the accident site indicated an unstable to conditionally unstable environment from the surface through 9,500 ft, with a very small stable layer between 2,250 and 2,750 ft. RAOB identified the possibility of clouds from 500 ft agl through 14,000 ft msl. 1,163 Joules/kilogram (J/kg) of CAPE²⁰ were indicated on the sounding and the maximum vertical velocity (MVV) for this atmosphere was calculated as 48 meters/second (about 9,450 ft per minute).²¹ Downdraft CAPE (DCAPE; 6 kilometers agl)²² was measured at 165 J/kg. If rain showers or thunderstorms formed in this environment, the 1200 EST HRRR sounding indicated that the strongest wind speeds possible at the surface (due to, for example, a microburst, outflow boundary, or gust front) would have been 23 mph (20 knots) according to the T2 Gust parameter, or 26 mph (23 knots) according to the WindEx parameter.

²⁰ 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.

²¹ 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.

²² 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.

The 1200 EST HRRR sounding wind profile indicated a surface wind from 111° at 9 knots with the wind remaining from the east through 2,000 ft. The wind veered²³ to the south by 5,000 ft and the wind speed remained between 5 and 10 knots through 14,000 ft. RAOB did not indicate the possibility of low-level wind shear (LLWS) outside of rain shower or thunderstorm activity. RAOB indicated a small chance of light clear-air turbulence existed in several layers between 1,000 ft and 7,000 ft. The mean storm motion vector was from 220° at 8 knots.

5.0 Satellite Data

Data from the Geostationary Operational Environmental Satellite number 16 (GOES-16) 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 1100 EST through 1700 EST at approximately 5-minute intervals were reviewed, and the closest images to the time of the accident are documented here.

Figures 10 and 11 present the GOES-16 visible imagery from 1300 and 1315 EST at 3X magnification with the accident site highlighted with a red square. The GOES-16 imagery indicated overcast cloud cover above the accident site at the accident time with the low-level cloud cover moving from east to west and the mid- and upper-level cloud cover moving from west to east (attachment 1). The visible satellite imagery indicated a band of cumuliform clouds located above the accident site at the accident time.

Figure 12 presents the GOES-16 infrared imagery from 1315 EST at 6X 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 (green colors, higher clouds) located to the east of the accident site. Based on the brightness temperatures above the accident site (266° Kelvin) and the vertical temperature profile provided by the 1200 EST HRRR sounding, the approximate cloud-top heights over the accident site were 16,000 ft at 1315 EST. It should be noted these figures have not been corrected for any parallax error.

²³ A clockwise turning of the wind with height in the northern hemisphere.

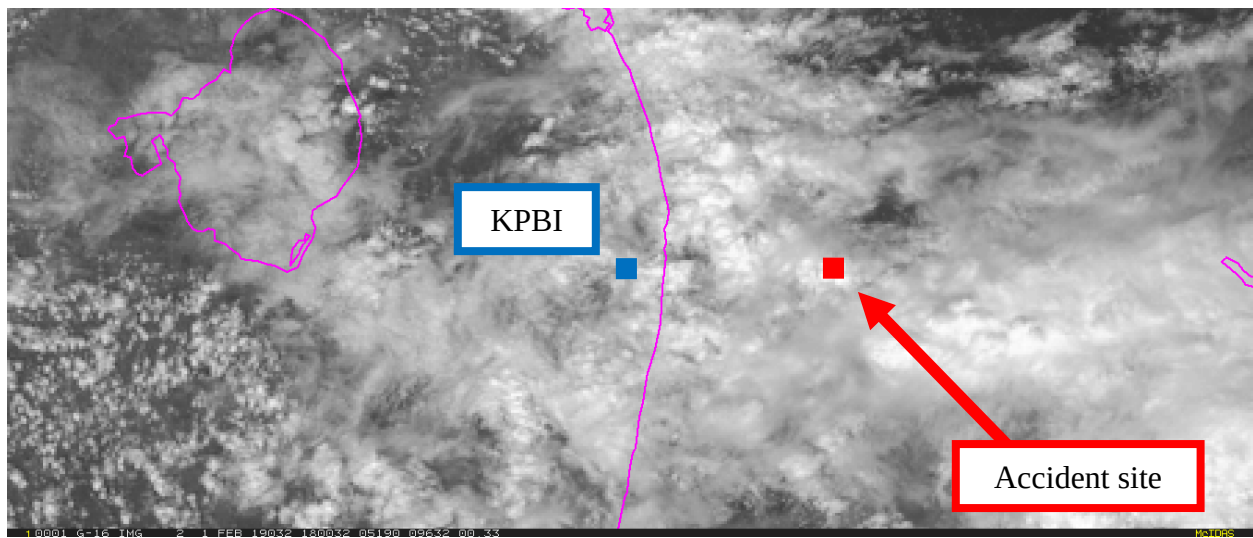


Figure 10 – GOES-16 visible image at 1300 EST

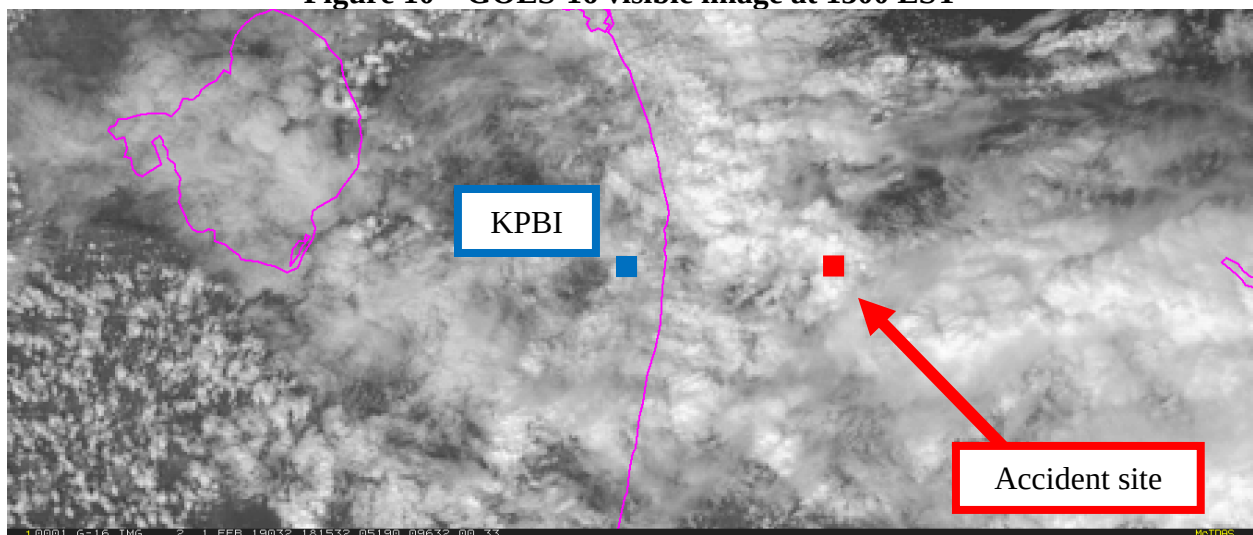


Figure 11 – GOES-16 visible image at 1315 EST

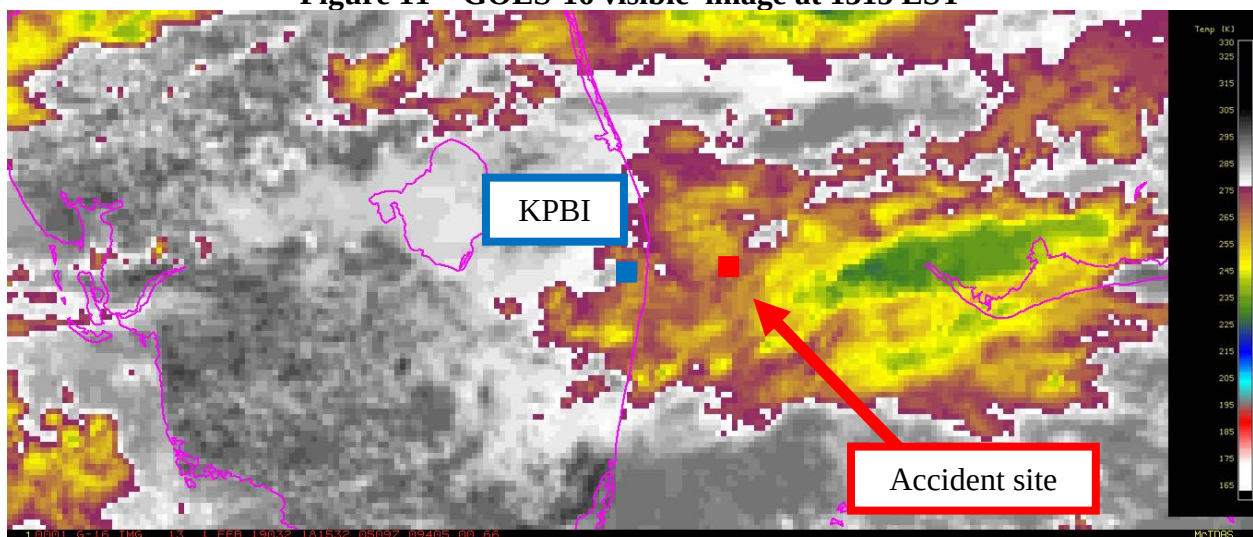


Figure 12 – GOES-16 infrared image at 1315 EST

6.0 Regional Radar Imagery Information

A regional view of the NWS National Composite Radar Mosaic is included as figure 13 for 1315 EST with the approximate location of the accident site marked by a red circle. The image depicted 35 to 55 decibels (dBZ²⁴) echoes above the accident site.

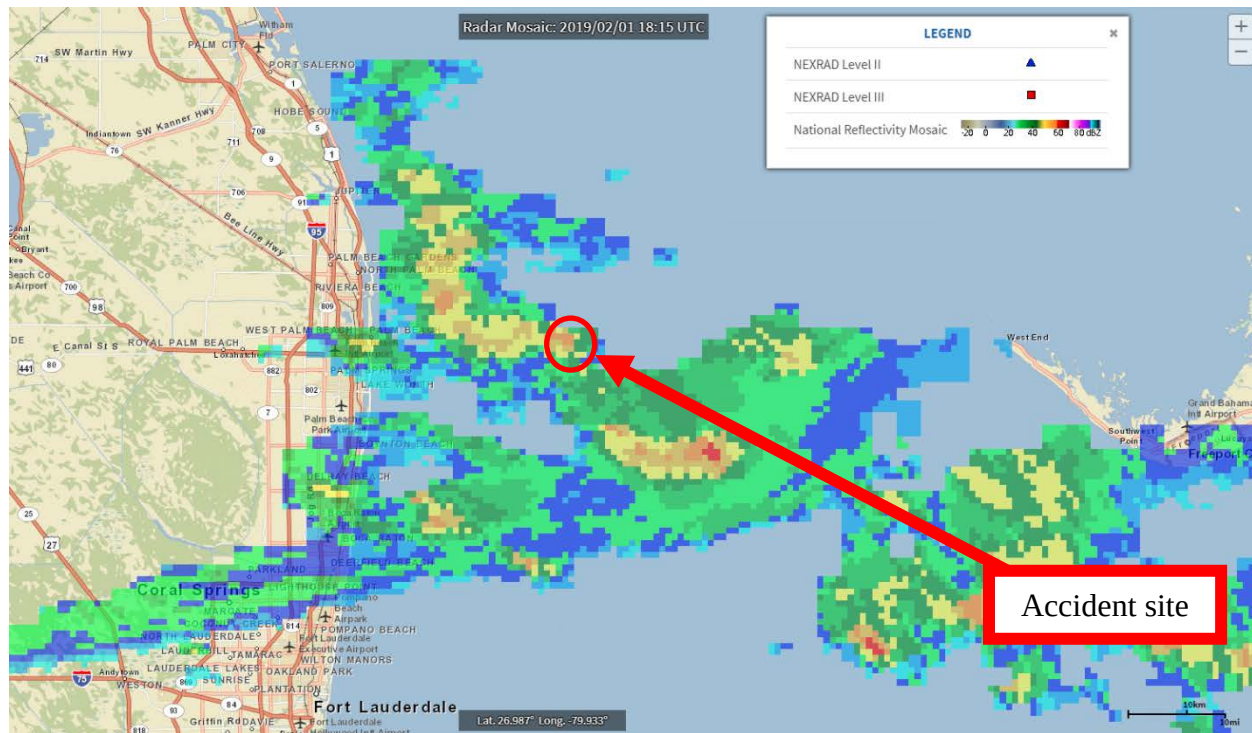


Figure 13 – Regional Composite Reflectivity image for 1315 EST

7.0 Radar Imagery Information

The closest NWS Weather Surveillance Radar-1988, Doppler (WSR-88D)²⁵ to the accident site was Miami, Florida, (KAMX) located 75 miles south-southwest 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.

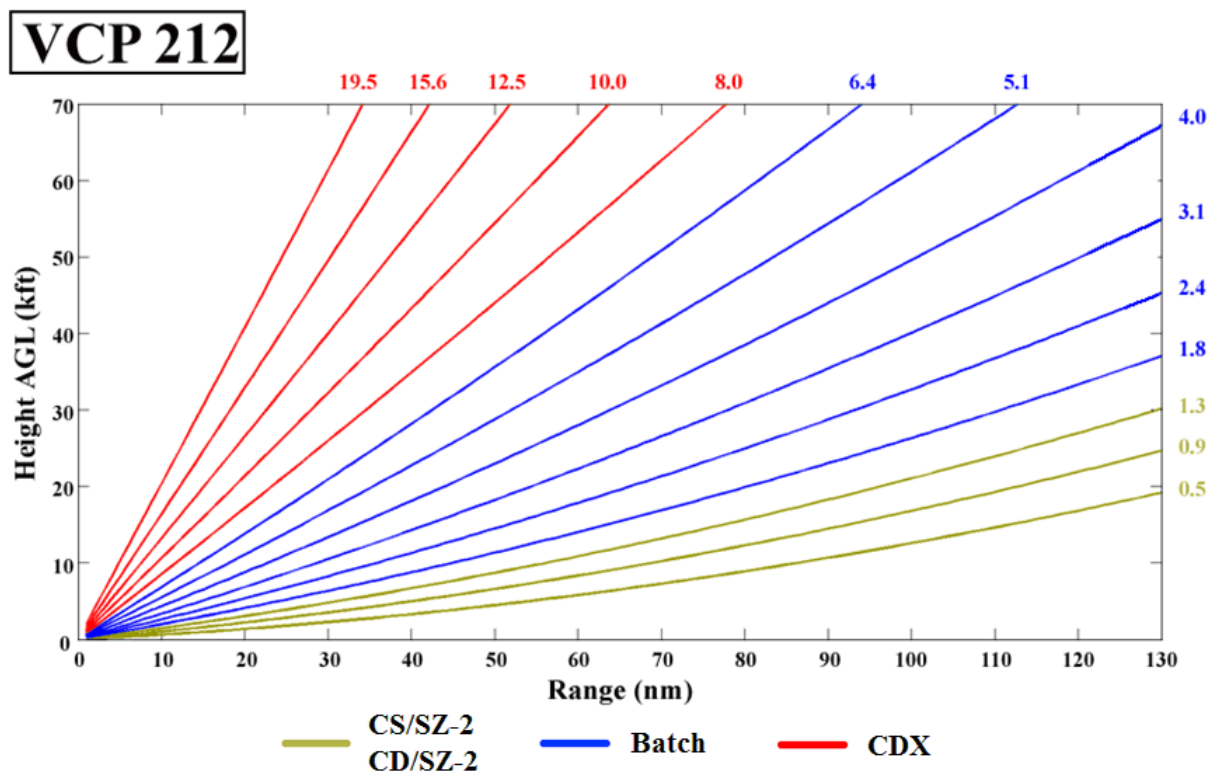
²⁴ dBZ – A non-dimensional “unit” of radar reflectivity which represents a logarithmic power ratio (in decibels , or dB) with respect to radar reflectivity factor, Z.

²⁵ 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.

7.1 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 KAMX 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.



VCP-212 Precipitation Mode Scan Strategy²⁶

²⁶ 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)

7.2 Beam Height Calculation

Assuming standard refraction²⁷ of the WSR-88D radar beam with the antenna elevation at 111 ft (KAMX), and considering a beamwidth²⁸ 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
KAMX 0.5°	8,160 ft	4,460 ft	11,860 ft

Based on the radar height calculations, the elevation scan listed in the above table depicted the conditions between 4,460 ft and 11,860 ft msl over the accident site and these scans “saw” the closest altitudes to the ground and the accident aircraft’s flight level.²⁹

7.3 Reflectivity

Reflectivity is the measure of the efficiency of a target in intercepting and returning radio energy. With hydrometeors³⁰ 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 00-24C³¹, “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:

²⁷ Standard Refraction in the atmosphere is when the temperature and humidity distributions are approximately average, and values set at the standard atmosphere.

²⁸ Beamwidth - the angular separation between the half power points on the antenna radiation pattern, where the gain is one half the maximum value.

²⁹ For more information please see Air Traffic Control data located in the docket of this accident.

³⁰ 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.

³¹

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

- 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

7.4 Base Reflectivity and Lightning Data

Figures 14, 15, 16, and 17 present the KAMX WSR-88D base reflectivity images for the 0.5° elevation scans initiated at 1303:29, 1309:27, 1311:34, and 1315:26 EST, respectively, with a resolution of 0.5° X 250 m. The accident aircraft first entered precipitation between 1303 and 1309 EST (figures 14 and 15, attachment 2). Reflectivity values between 30 and 50 dBZ or moderate to heavy rain intensity echoes (section 7.3) were located above the accident site at the accident time. The reflectivity bands were moving from south to north (attachment 2).

There were no lightning strikes near the accident site at the accident time.³²

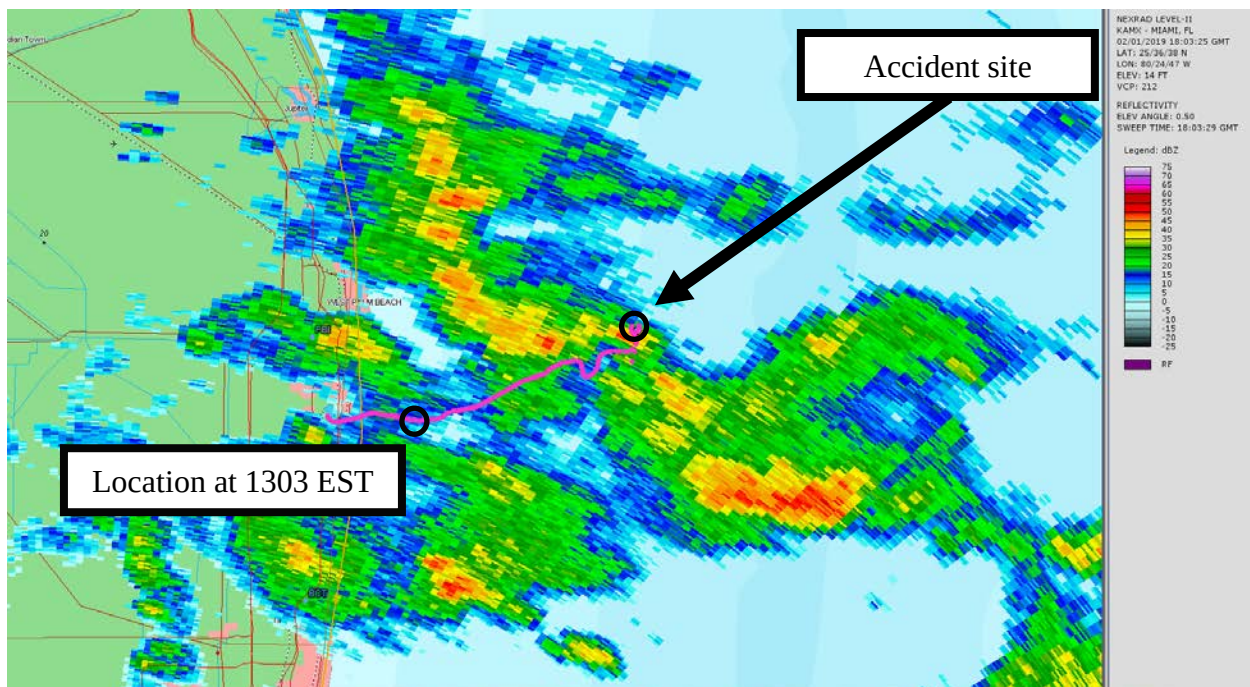


Figure 14 – KAMX WSR-88D reflectivity for the 0.5° elevation scan initiated at 1303:29 EST with the accident site marked with black circle, the accident flight track in pink

³² A review of Earth Networks Total Lightning network was done.

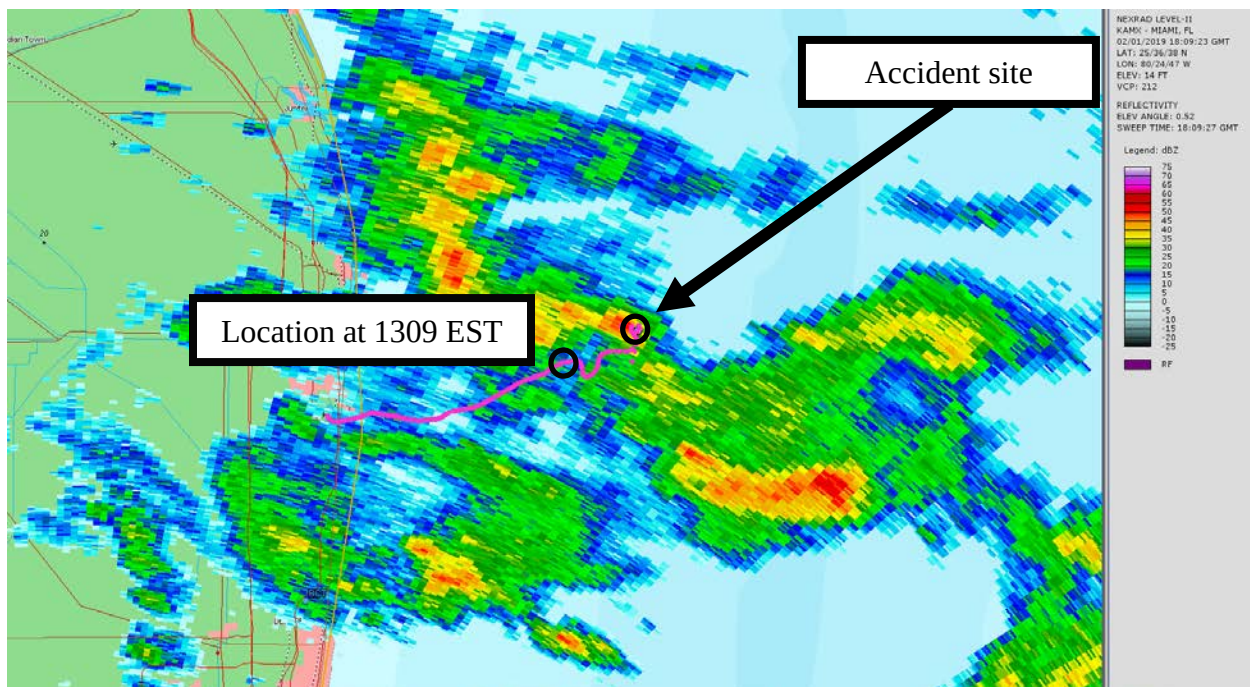


Figure 15 – KAMX WSR-88D reflectivity for the 0.5° elevation scan initiated at 1309:27 EST with the accident site marked with black circle, the accident flight track in pink

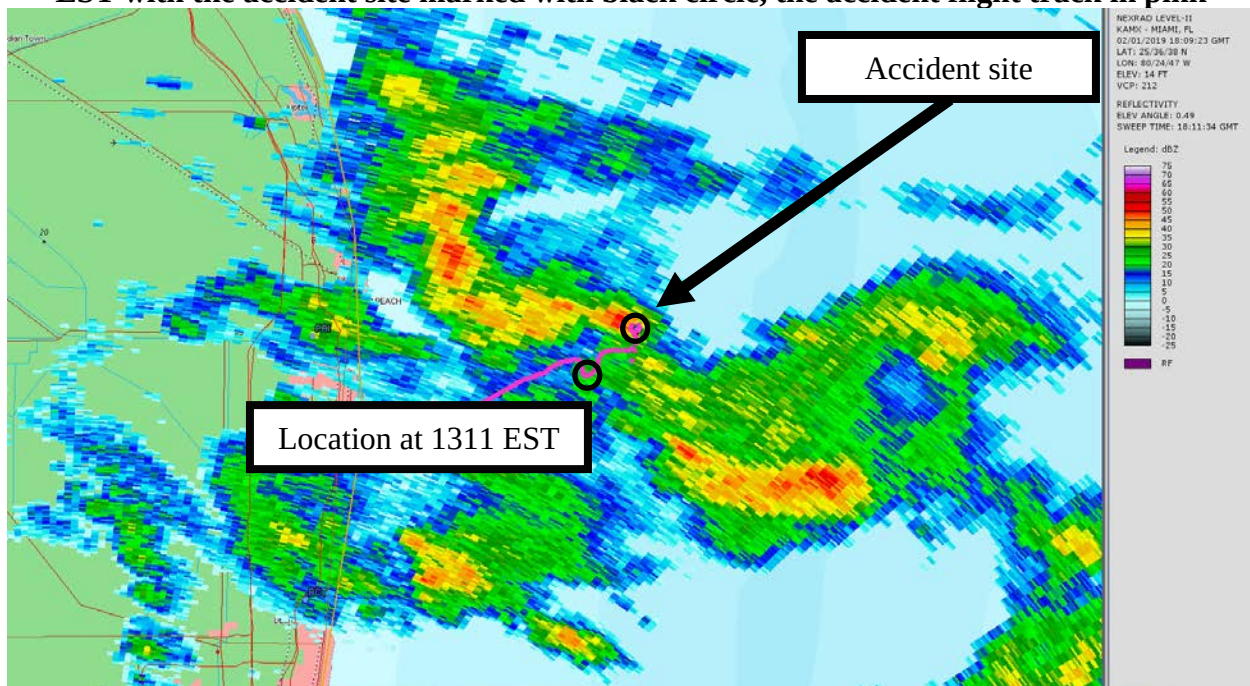


Figure 16 – KAMX WSR-88D reflectivity for the 0.5° elevation scan initiated at 1311:34 EST with the accident site marked with black circle, the accident flight track in pink

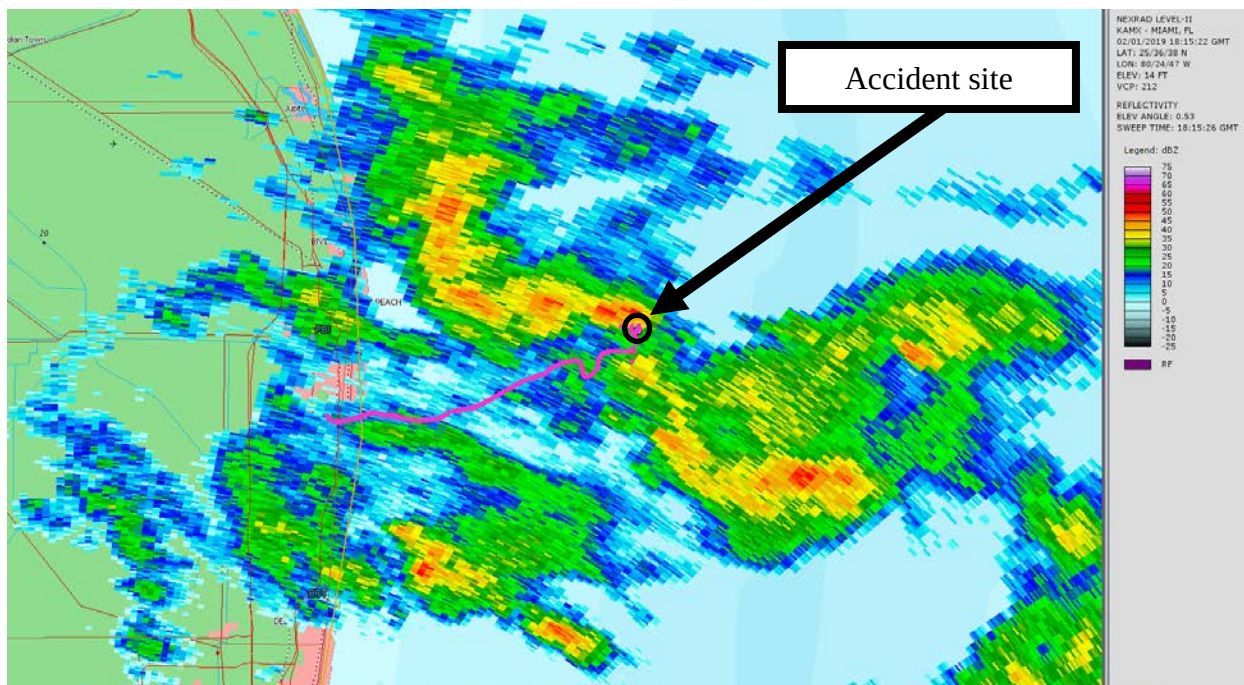


Figure 17 – KAMX WSR-88D reflectivity for the 0.5° elevation scan initiated at 1315:26 EST with the accident site marked with black circle, the accident flight track in pink

8.0 Pilot Reports³³

All pilot reports (PIREPs) within 80 miles of the accident site from about an hour and a half hours prior to the accident time to about one hour after the accident time for below FL200³⁴ are provided below:

PBI UA /OV PBI045005/TM 1635/FL060/TP GLF5/WX LIGHT RAIN/TB LGT

PBI UA /OV PBI077040/TM 1638/FL140/TP C414/TA 03/IC LGT

VRB UA /OV TRV100004/TM 1703/FL006/TP P28A/SK BKN008

PBI UA /OV PBI090010/TM 1705/FL040/TP C206/WX MODERATE RAIN

VRB UA /OV KVRB/TM 1709/FL008/TP P82A/SK BKN008/RM DURD RWY 12R

TMB UA /OV TMB270005/TM 1710/FL020/TP C560/SK SCT025/WX FV10SM

VRB UA /OV KFPR045010/TM 1724/FL018/TP PA31/TB NEG/RM DURD

PBI UA /OV PBI100010/TM 1800/FL100/TP A320/SK IMC/TB LGT-MOD CHOP/RM FISEL ARVL NO GOOD

PBI UA /OV PBI270004/TM 1805/FL012/TP A320/SK BKN012

³³ Only pilot reports with the World Meteorological Organization (WMO) header UBFL** identifier were considered.

³⁴ Flight Level – A Flight Level (FL) is a standard nominal altitude of an aircraft, in hundreds of ft. This altitude is calculated from the International standard pressure datum of 1013.25-hPa (29.92 inHg), the average sea-level pressure, and therefore is not necessarily the same as the aircraft's true altitude either above mean sea level or above ground level.

VRB UA /OV KVRB/TM 1825/FL007/TP E55P/SK BKN007/RM DURD RWY12R

PBI UA /OV MYAM/TM 1830/FL040/TP PA32/SK SCT045/WX FV99SM

VRB UA /OV KVRB/TM 1906/FL007/TP B350/SK BKN007/RM DURD RWY12R

MYGF UA /OV ZFP270010/TM 1907/FL150/TP SF34/TA M04/TB LGT CHOP/IC LGT RIME

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

Routine pilot report (UA) PBI; Over – 5 miles from PBI on the 045° radial; Time – 1135 EST (1635Z); Altitude – 6,000 ft; Type aircraft – Gulfstream V; Weather – Light rain; Turbulence – Light.

Routine pilot report (UA) PBI; Over – 40 miles from PBI on the 077° radial; Time – 1138 EST (1638Z); Altitude – 14,000 ft; Type aircraft – Cessna 414; Temperature – 3 °C; Icing - Light.

Routine pilot report (UA) Vero Beach Regional Airport (VRB); Over – 4 miles from Vero Beach VORTAC (TRV) on the 100° radial; Time – 1203 EST (1703Z); Altitude – 600 ft; Type aircraft – Piper PA-28 Cherokee; Sky – Broken clouds at 800 ft.

Routine pilot report (UA) PBI; Over – 10 miles from PBI on the 090° radial; Time – 1205 EST (1705Z); Altitude – 4,000 ft; Type aircraft – Cessna 206; Weather – Moderate rain.

Routine pilot report (UA) VRB; Over – VRB; Time – 1209 EST (1709Z); Altitude – 800 ft; Type aircraft – Piper PA-28 Cherokee (mis coded as “P82A”); Sky – Broken clouds at 800 ft; Remarks – During descent into runway 12R.

Routine pilot report (UA) Miami Executive Airport (TMB); Over – 5 miles from TMB on the 270° radial; Time – 1210 EST (1710Z); Altitude – 2,000 ft; Type aircraft – Cessna Citation V; Sky – Scattered clouds at 2,500 ft; Weather – Flight visibility 10 statute miles.

Routine pilot report (UA) VRB; Over – 10 miles from Treasure Coast International Airport (FPR) on the 045° radial; Time – 1224 EST (1724Z); Altitude – 1,800 ft; Type aircraft – Piper PA-31 Navajo; Turbulence – Negative; Remarks – During descent.

Routine pilot report (UA) PBI; Over – 10 miles from PBI on the 100° radial; Time – 1300 EST (1800Z); Altitude – 10,000 ft; Type aircraft – Airbus A320; Sky – Instrument meteorological conditions (IMC); Turbulence – Light to moderate chop; Remarks – FISEL arrival no good.

Routine pilot report (UA) PBI; Over – 4 miles from PBI on the 270° radial; Time – 1305 EST (1805Z); Altitude – 1,200 ft; Type aircraft – Airbus A320; Sky – Broken clouds at 1,200 ft.

Routine pilot report (UA) VRB; Over – VRB; Time – 1325 EST (1825Z); Altitude – 700 ft; Type aircraft – Embraer Phenom 300; Sky – Broken clouds at 700 ft; Remarks – During descent into runway 12R.

Routine pilot report (UA) PBI; Over – Leonard M Thompson International Airport, Bahamas, (MYAM); Time – 1330 EST (1830Z); Altitude – 4,000 ft; Type aircraft – Piper PA-32; Sky – Scattered clouds at 4,500 ft; Weather – Flight visibility unlimited.

Routine pilot report (UA) VRB; Over – VRB; Time – 1406 EST (1906Z); Altitude – 700 ft; Type aircraft – Beechcraft Super King Air; Sky – Broken clouds at 700 ft; Remarks – During descent into runway 12R.

Routine pilot report (UA) Grand Bahama International Airport, Bahamas (MYGF); Over – 10 miles from Freeport, Bahamas, VORTAC (ZFP) on the 270° radial; Time – 1407 EST (1907Z); Altitude – 15,000 ft; Type aircraft – Saab 340; Temperature – -4 °C; Turbulence – Light chop; Icing – Light rime.

9.0 SIGMET

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

10.0 CWSU Advisories

The Center Weather Service Unit (CWSU) at the Air Route Traffic Control Center in Miami, Florida, (ZMA) issued Center Weather Advisory (CWA) 103 which was valid for the accident site at the accident time. CWA103 was issued at 1145 EST and valid until 1345 EST and warned of areas of moderate rain showers and isolated thunderstorms with heavy precipitation with tops to FL280 (figure 18). The movement of the CWA box was from 170° at 10 knots and little change in weather was expected through the period. No Meteorological Impact Statements (MIS) were valid for the accident site at the accident time.

FAUS21 KZMA 011645

ZMA1 CWA 011645

ZMA CWA 103 VALID UNTIL 011845

FROM 150N ZFP-45SE ZFP-30S PBI-50N TRV-150N ZFP

AREA OF SHRA AND ISOLD TS WITH HVY PCPN MOV FM 17010KT. MAX TOPS TO

FL280. EXP LTL CHG THRU PD.

MS

=

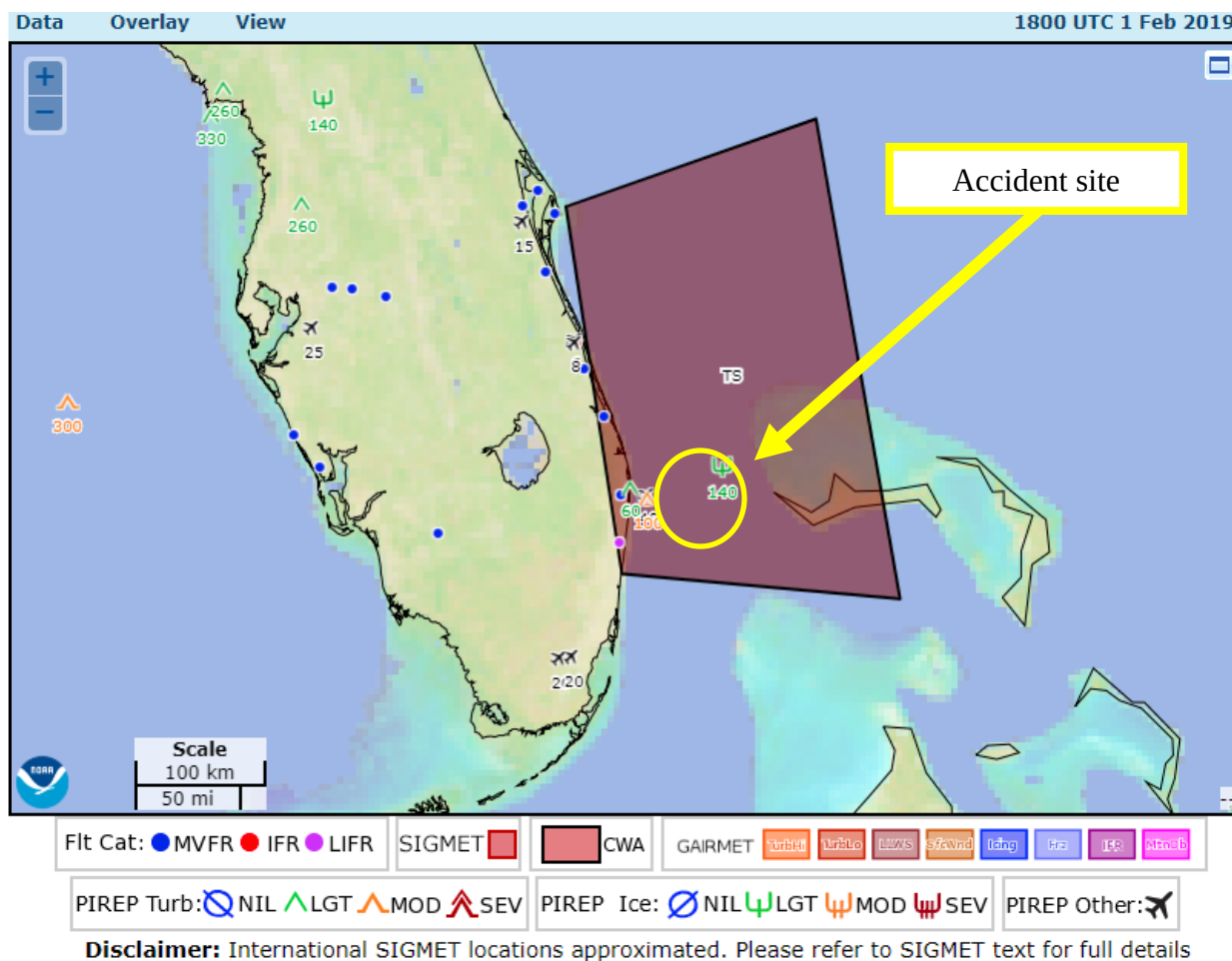


Figure 18 – SIGMETs, CWAs, and PIREPs valid at 1300 EST

11.0 AIRMETs

There were no Airmen's Meteorological Information (AIRMET) advisories valid for the accident site at the accident time for below FL200.

12.0 Graphical Forecasts for Aviation

The Graphical Forecasts for Aviation (GFA) products made available before the accident flight are shown in attachment 3. The GFA surface forecast products indicated VFR³⁵ conditions would be likely with a chance of rain shower activity (30 to 60 percent chance) for 1300 EST with a surface wind from the east at 5 knots. The GFA cloud forecast products indicated a cloud ceiling at 2,200 ft msl with cloud tops to 10,000 ft msl. For more information please see attachment 3.

³⁵ Visual Flight Rules – Refers to the general weather conditions pilots can expect at the surface. VFR criteria means a ceiling greater than 3,000 feet agl and greater than 6 miles visibility.

13.0 Terminal Aerodrome Forecast

KPBI was the closest site with a NWS Terminal Aerodrome Forecast (TAF). The KPBI TAF valid at the accident time was issued at 1239 EST and was valid for a 24-hour period beginning at 1300 EST. The 1239 EST TAF for KPBI was as follows:

TAF KPBI 011739Z 0118/0218 **10011KT 6SM SHRA SCT025 BKN050**
TEMPO 0118/0121 VRB15G25KT 4SM SHRA SCT010 BKN025
FM012200 10008KT P6SM VCSH SCT020 BKN035 BKN050
FM020400 11010KT P6SM SCT015 BKN050 BKN070
FM021200 13011KT P6SM VCSH FEW015 SCT025 BKN050=

The TAF expected a wind from 100° at 11 knots, 6 miles visibility, moderate rain showers, scattered clouds at 2,500 ft agl, and a broken ceiling at 5,000 ft agl. Temporary conditions³⁶ of a variable wind at 15 knots with gusts to 25 knots, 4 miles visibility, moderate rain showers, scattered clouds at 1,000 ft agl, and a broken ceiling at 2,500 ft agl were forecast between 1300 and 1600 EST.

14.0 NWS Area Forecast Discussion

The NWS Office in Miami, Florida, issued the following Area Forecast Discussion (AFD) at 1246 EST (closest AFD to the accident time with an aviation section). The aviation section of the AFD discussed “sub-VFR” conditions continuing over the next day or so with IFR conditions possible due to convection during the daylight hours and low clouds and fog during the overnight period:

FXUS62 KMFL 011746
AFDMFL

Area Forecast Discussion
National Weather Service Miami FL
1246 PM EST Fri Feb 1 2019

.AVIATION...

Convection associated with a weak frontal boundary meandering across South Florida's Atlantic waters will continue to create periods of sub-VFR conditions over the next day or so. PBI is the terminal most likely to be impacted this afternoon with MVFR or brief bouts of IFR/LIFR conditions possible. Low cigs/fog is possible overnight, mainly in SW Florida and over the interior, which will possible affect APF into Saturday morning. Additional convection on Saturday could again create sub-VFR conditions mainly along the east coast.

&&

.PREV DISCUSSION... /issued 1016 AM EST Fri Feb 1 2019/

UPDATE...

³⁶ From NWSI 10-813: TEMPO - temporary fluctuations to forecast conditions which are expected to last less than one hour in each instance and, in the aggregate, to cover less than half of the indicated period.

Persistent scattered showers can be seen on radar this morning lingering over the Atlantic waters. Easterly winds along the coast have allowed for several of these showers to make their way inland over the Palm Beach and Broward metro areas before dissipating. Given the fair amount of low-level moisture and upper level divergence, a few stronger, isolated storms cannot be ruled out as the day progresses. Otherwise, the rest of the forecast looks good and no major changes are anticipated.

PREV DISCUSSION... /issued 330 AM EST Fri Feb 1 2019/

DISCUSSION...

SHORT TERM: Showers have continued to persist overnight over the Atlantic waters and have been drifting west over the east coast with northeasterly to easterly flow. No drainage flow tonight has allowed showers to move onshore. The lack of drainage flow developing will continue to allow showers to affect the east coast metro.

High pressure across the region today but enough low-level moisture and easterly flow will continue to allow the east coast to see showers. A weak shortwave will be moving across the Gulf towards Florida as we move throughout the day today into tomorrow. It looks though the surface feature will keep most of the moisture and dynamic forcing to our north. While most of the forcing stays north the shortwave will be in close enough proximity to increase shower chances across the region into Saturday. Highest rain chances will be across northern portions, around the Lake region and Palm Beach. This region and the Atlantic waters also could see an isolated thunderstorm Saturday.

LONG TERM: As we move into Sunday a lingering shower is possible but upper level ridging will begin to build across the region with high pressure dominating the weather pattern for next week. A pleasant week in store for South Florida with mostly dry conditions and temperatures around normal or just above average for this time of year.

MARINE...

Breezy easterly flow across South Florida waters. Scattered showers with an isolated thunderstorm will be possible over the Atlantic waters the next couple of days. Seas in Atlantic waters will be generally 3 to 4 feet with a few areas around 5 feet offshore Palm Beach in the Gulf Stream. Seas in the Gulf will be generally 2 feet or less.

BEACH FORECAST...

There is a high risk of rip currents at Palm Beach County beaches today. There is a moderate risk of rip currents at the remainder of the east coast beaches. An enhanced risk of rip currents is possible through the weekend.

&&

.PRELIMINARY POINT TEMPS/POPS...

West Palm Beach 66 77 65 78 / 40 40 30 20

Fort Lauderdale 67 78 68 79 / 30 40 30 20
Miami 67 79 67 80 / 30 40 30 20
Naples 63 78 63 78 / 10 20 10 10

&&

.MFL WATCHES/WARNINGS/ADVISORIES...

FL...High Rip Current Risk until 7 PM EST this evening for FLZ168.

AM...None.

GM...None.

&&

15.0 Winds and Temperature Aloft Forecast

The NWS 0858 EST Winds and Temperature Aloft forecast valid for 1300 EST for the closest point to the accident site is included below:

FBUS31 KWN0 011358

FD1US1

DATA BASED ON 011200Z

VALID 011800Z FOR USE 1400-2100Z. TEMPS NEG ABV 24000

FT	3000	6000	9000	12000	18000	24000	30000	34000	39000
MIA	1408	9900+10	2410+06	2313+00	2630-12	2655-24	257440	269148	752152

The accident site was closest to the Miami, Florida, (MIA) forecast point. The MIA forecast for use between 0900 EST and 1600 EST indicated a wind at 3,000 ft from 140° at 8 knots, at 6,000 ft a calm wind with a temperature of 10 °C, and at 9,000 ft a wind from 240° at 10 knots with a temperature of 6 °C.

16.0 Pilot Weather Briefing

The accident pilot received a weather briefing through Leidos at 1200 EST (attachments 4,5, and 6). During the briefing the weather briefer provided the SPC convective outlook, CWA 103, METARs, and winds aloft. The accident pilot asked about the line of weather and if it was moving north and he would fly south of it and the briefer responded saying the line of weather was just sitting there. The accident pilot told the briefer he “saw that one little red blob out there.” For more information please see attachments 4, 5, and 6.

In addition, a check of ForeFlight was done and the accident pilot did not request any weather information from ForeFlight. It is unknown if the accident pilot checked or received any weather information before or during the accident flight.

17.0 Astronomical Data

The astronomical data obtained from the United States Naval Observatory for the accident site on February 1, 2019, indicated the following:

SUN	
Begin civil twilight	0640 EST
Sunrise	0704 EST
Sun transit	1232 EST
Accident	1315 EST³⁷
Sunset	1801 EST
End civil twilight	1825 EST

E. LIST OF ATTACHMENTS

Attachment 1 – GOES-16 visible animation from 1232 through 1342 EST

Attachment 2 – KAMX WSR-88D base reflectivity animation from 1245 to 1338 EST

Attachment 3 – GFA products available before the accident flight for around the accident time

Attachment 4 – Leidos text weather briefing information provided at 1200 EST

Attachment 5 – Leidos audio weather briefing information provided at 1200 EST

Attachment 6 – GFA products provided by Leidos to the accident pilot during the weather briefing package from 1200 EST

Submitted by:

Paul Suffern
Senior Meteorologist

³⁷ Inserted accident time for reference and context.

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