



NATIONAL TRANSPORTATION SAFETY BOARD

Office of Aviation Safety
Washington, D.C. 20594

August 22, 2018

Weather Study

METEOROLOGY

ERA18LA119

Table Of Contents

A. ACCIDENT	3
B. METEOROLOGIST	3
C. DETAILS OF THE INVESTIGATION	3
D. FACTUAL INFORMATION	3
1.0 Synoptic Situation	3
1.1 Surface Analysis Chart	4
1.2 Upper Air Charts	5
2.0 SPC Products	9
3.0 Surface Observations	11
4.0 Upper Air Data	15
5.0 Satellite Data	17
6.0 Radar Imagery Information	19
6.1 Volume Scan Strategy	19
6.2 Beam Height Calculation	20
6.3 Reflectivity	21
6.4 Base Reflectivity and Lightning Data	22
7.0 Pilot Reports	24
8.0 SIGMET	26
9.0 AIRMETs	26
10.0 CWSU Advisories	26
11.0 Graphical Forecasts for Aviation	26
12.0 Terminal Aerodrome Forecast	26
13.0 NWS Area Forecast Discussion	27
14.0 Winds and Temperature Aloft Forecast	28
15.0 Pilot Weather Briefing	29
16.0 Astronomical Data	29
E. LIST OF ATTACHMENTS	29

A. ACCIDENT

Location: Atlantic Ocean off the coast of Stuart, Florida
Date: March 31, 2018
Time: 1120 eastern daylight time
1520 Coordinated Universal Time (UTC)
Aircraft: Ames LNC2, Registration: N4ZQ

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 daylight time (EDT) on March 31, 2018, and are based upon the 24-hour clock, where local time is -4 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.

The exact accident location was not known; however, it is presumed to be in the vicinity of the debris field which was located at approximate latitude 27.334° N, longitude 79.801° W, at sea level.

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/1030

1.1 Surface Analysis Chart

The Florida section of the NWS Surface Analysis Chart for 1100 EDT is provided as figure 1 with the approximate location of the accident site marked within the red circle. The chart indicated a low-pressure system at 1020-hectopascals (hPa) located off the northeast Florida and north of the Bahamas over the western Atlantic Ocean, with an associated cold frontal boundary stretched southwestward from the low-pressure system across the accident site and southern Florida into the southern Gulf of Mexico.

The station models around the accident site depicted air temperatures in the mid 70's degrees Fahrenheit (°F), dew point temperatures in the mid 60's °F with temperature-dew point spreads of 11° F or less, a variable wind of 5 knots or less, and partly cloudy skies.

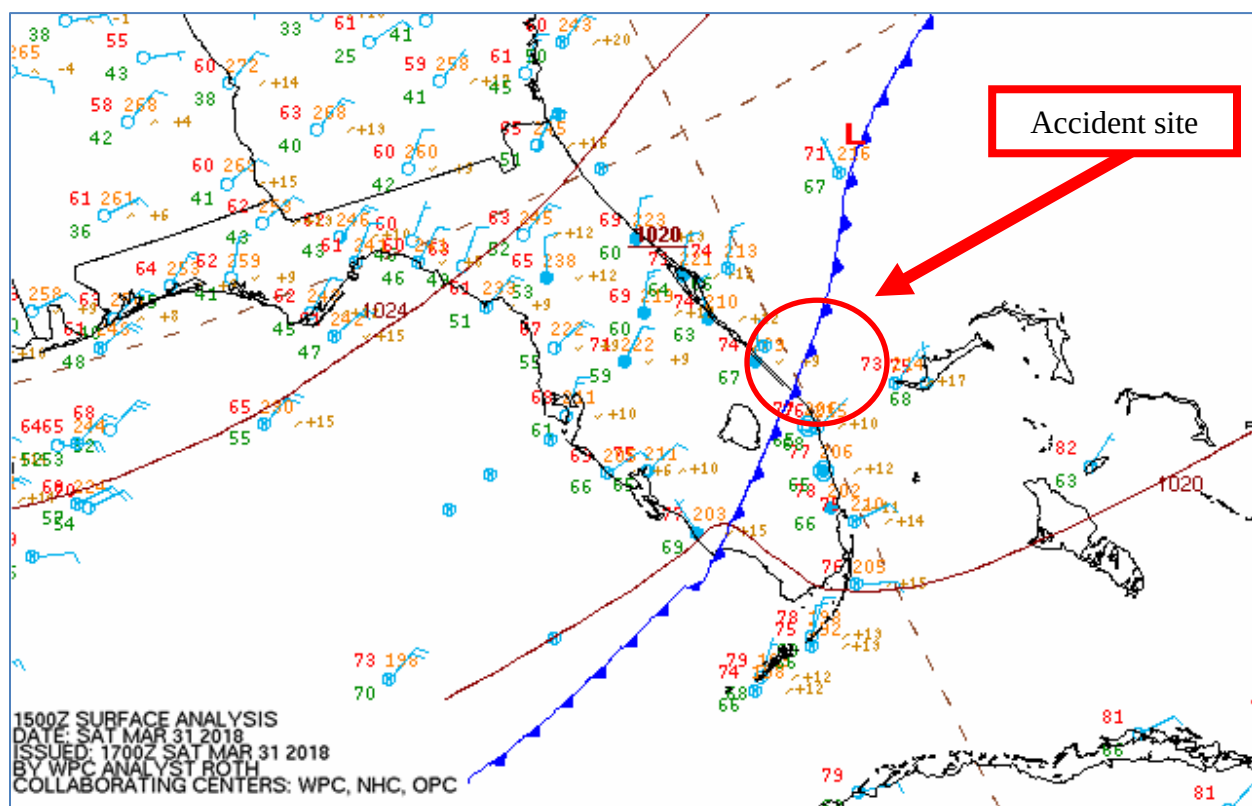


Figure 1 – NWS Surface Analysis Chart for 1100 EDT

1.2 Upper Air Charts

The NWS Storm Prediction Center (SPC) Constant Pressure Charts for 0800 EDT at 925-, 850-, 700-, 500-, and 300-hPa are presented in figures 2 through 6. There was a low-level trough² located over the accident site (figure 2) at 925-hPa. Troughs can act as lifting mechanisms to help produce clouds and precipitation if sufficient moisture is present. There was an east to northeast wind at 10 knots at 925-hPa that became a southwesterly 5 knot wind by 700-hPa (figure 4). By 300-hPa, the wind was from the southwest at 45 knots (figure 6).

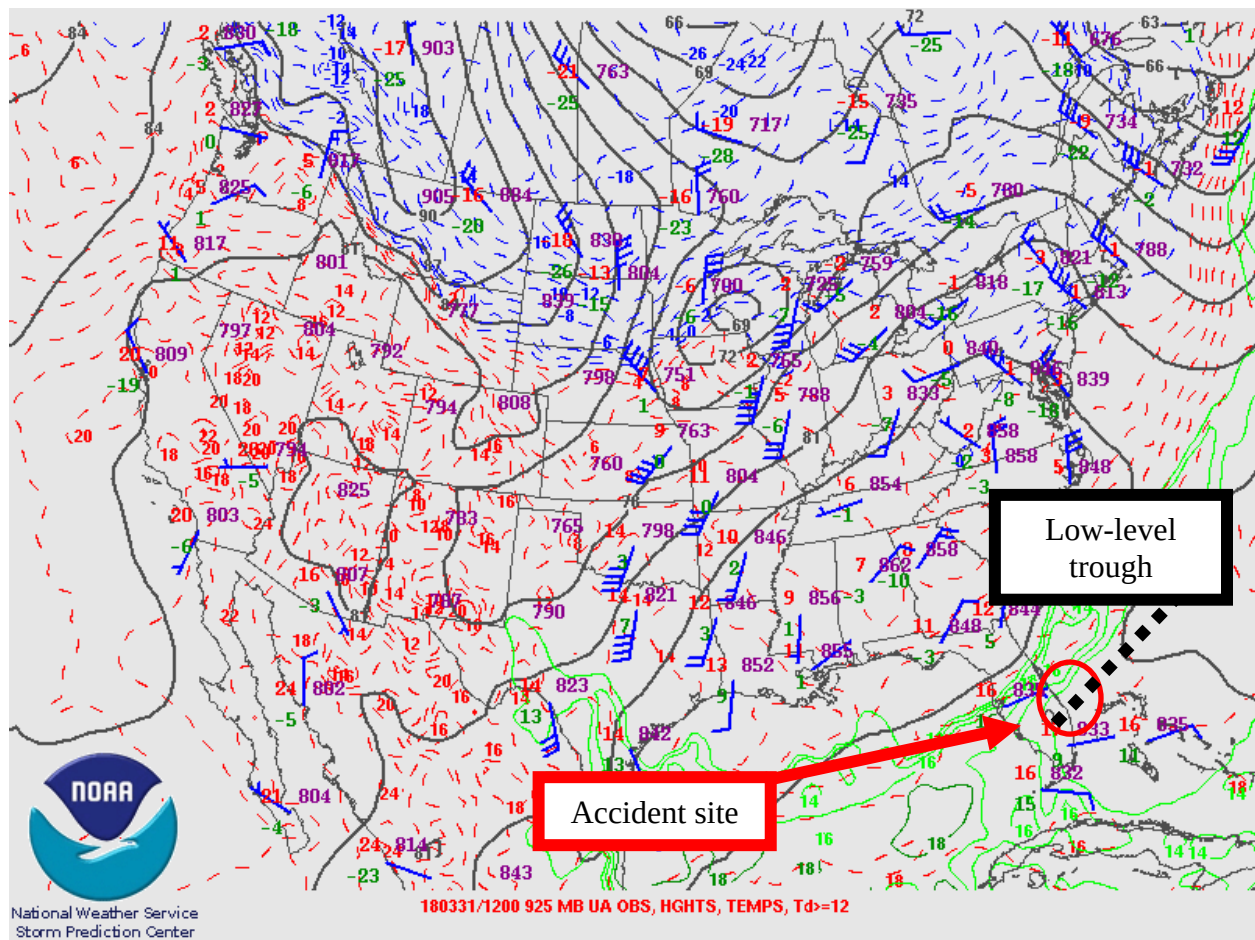


Figure 2 – 925-hPa Constant Pressure Chart for 0800 EDT

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

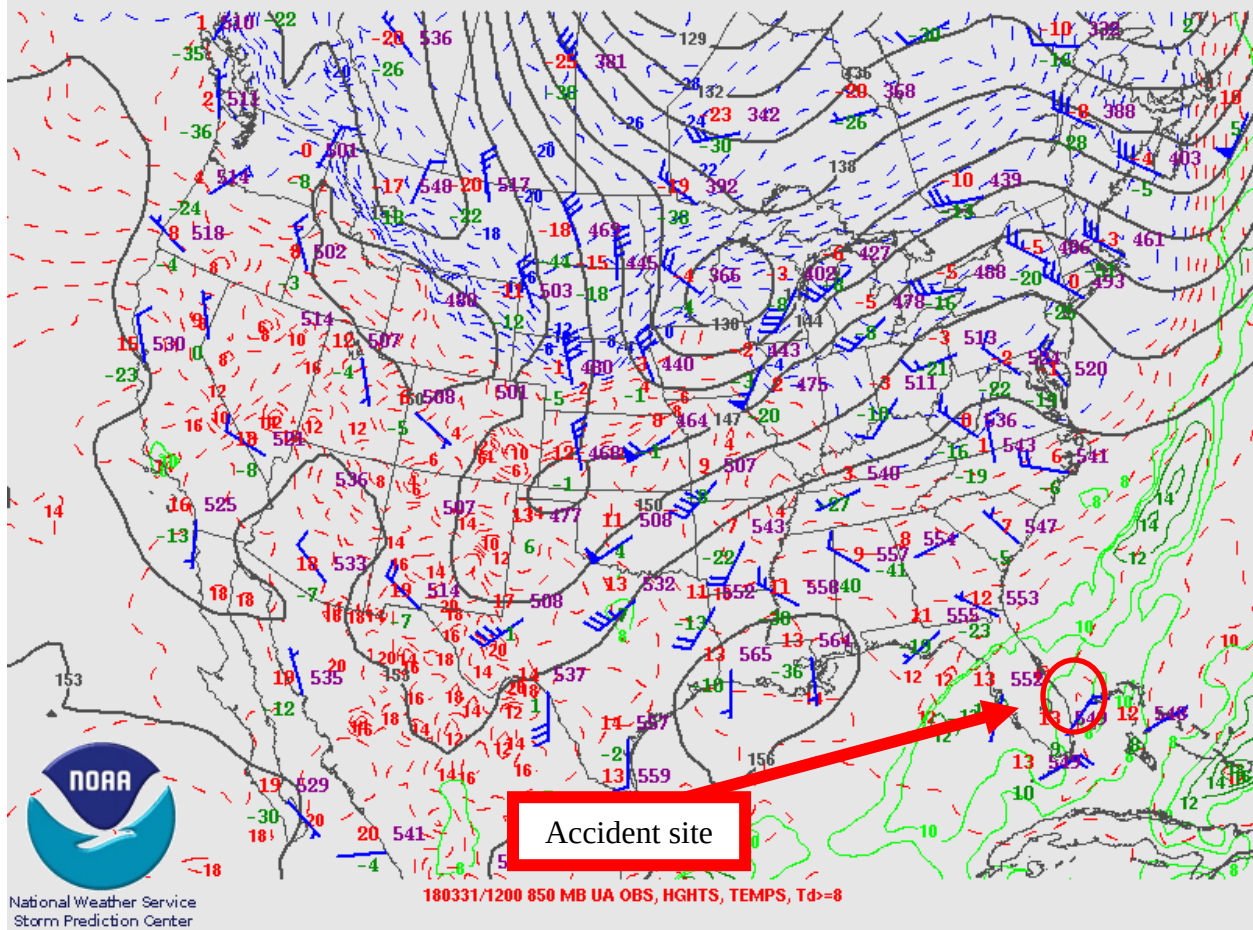


Figure 3 – 850-hPa Constant Pressure Chart for 0800 EDT

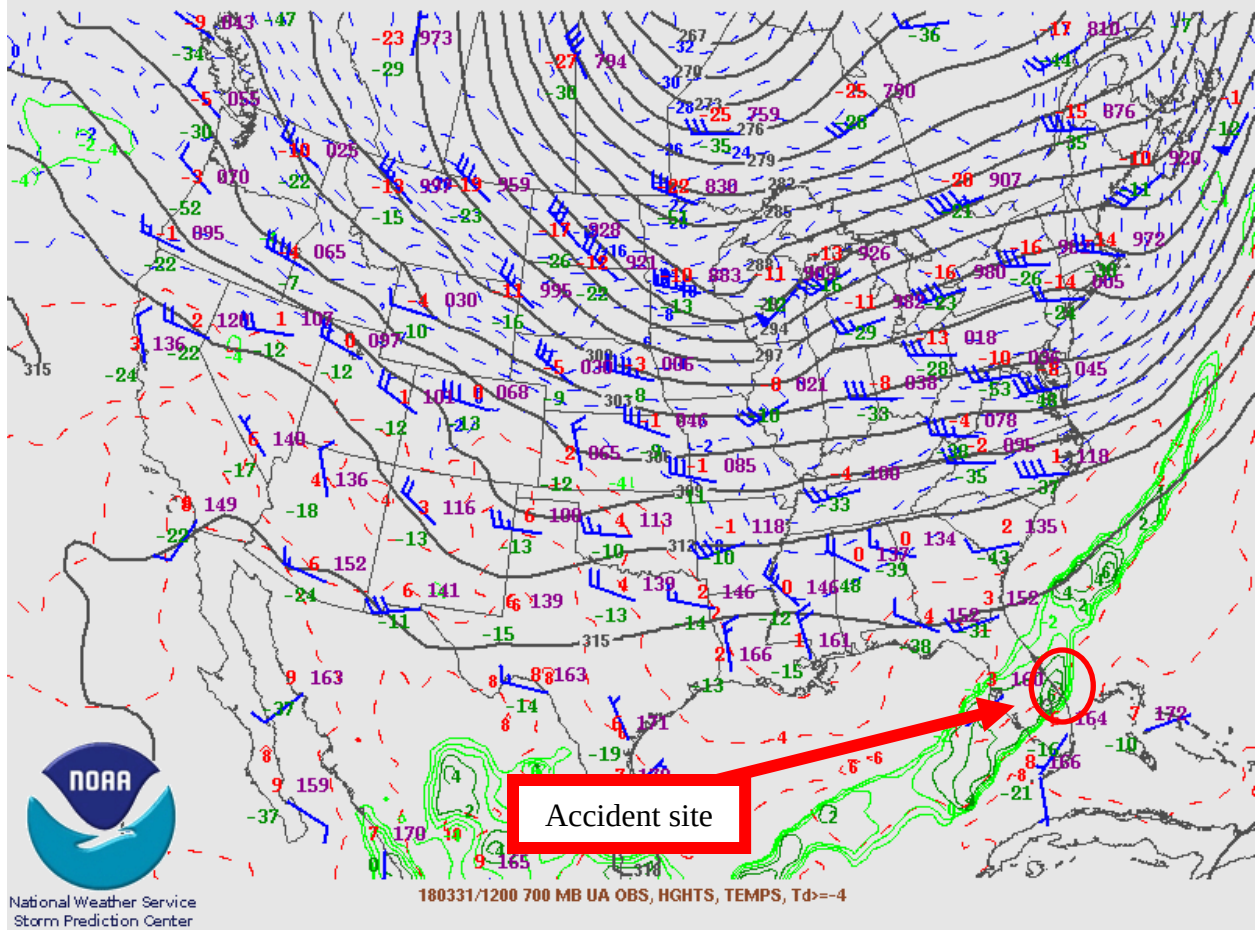


Figure 4 – 700-hPa Constant Pressure Chart for 0800 EDT

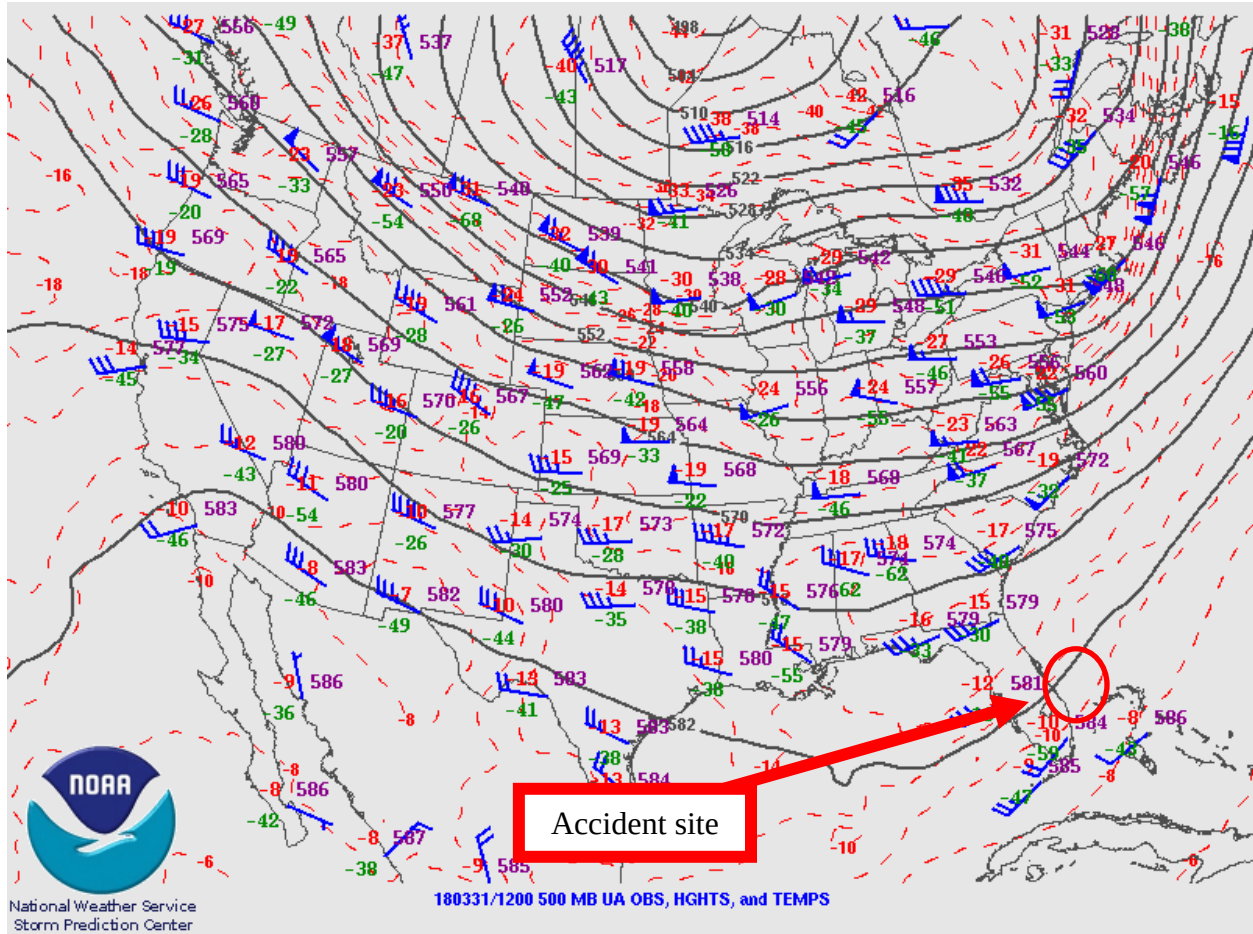


Figure 5 – 500-hPa Constant Pressure Chart for 0800 EDT

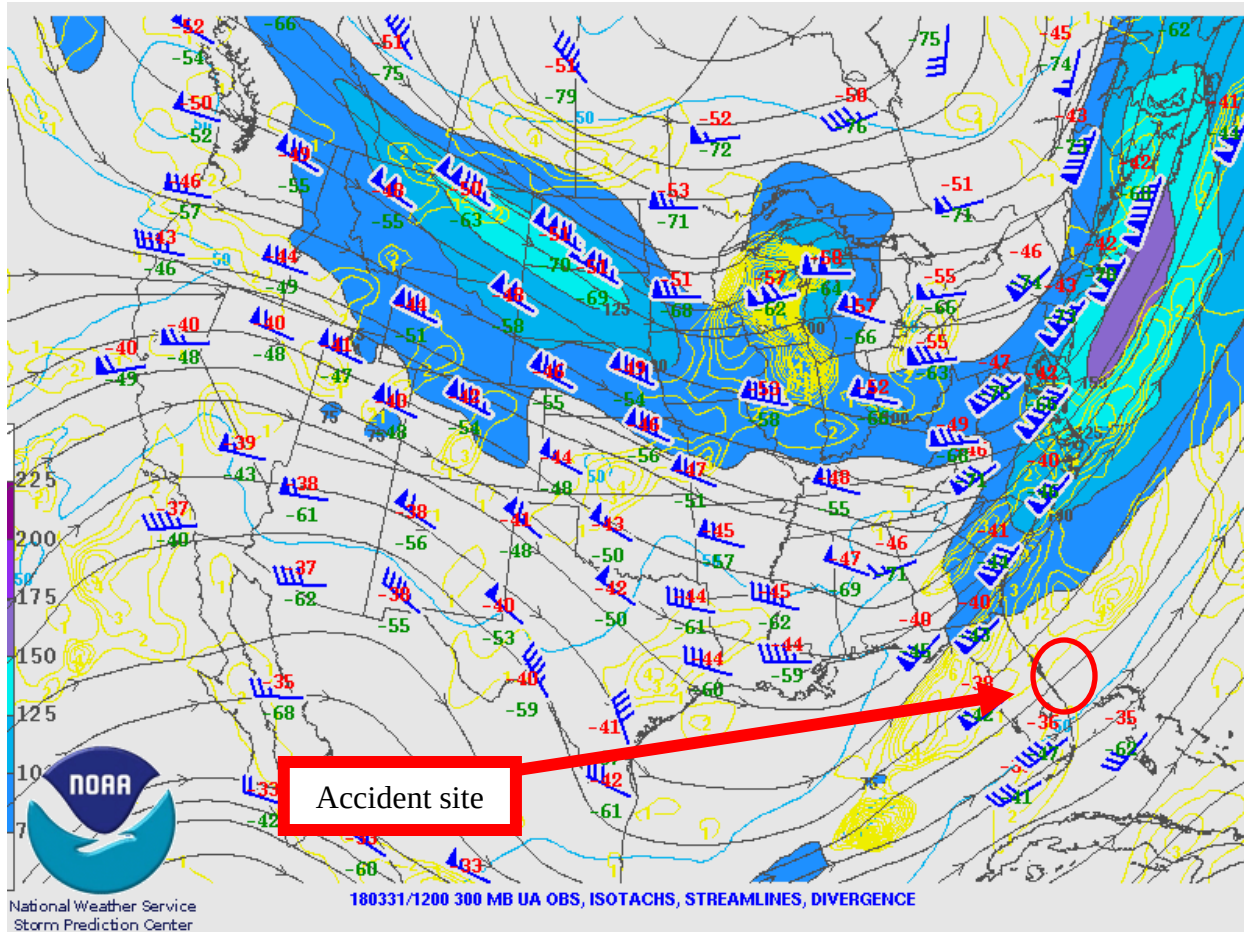


Figure 6 – 300-hPa Constant Pressure Chart for 0800 EDT

2.0 SPC Products

SPC issued the following Day 1 Convective Outlook at 0909 EDT (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 valid before the time of takeoff had general thunderstorms forecast for a similar area, including the accident site:

SPC AC 311309

Day 1 Convective Outlook CORR 1
NWS Storm Prediction Center Norman OK
0809 AM CDT Sat Mar 31 2018

Valid 311300Z - 011200Z

...NO SEVERE THUNDERSTORM AREAS FORECAST...

CORRECTED FOR MISSING THUNDER LINES

...SUMMARY...

Thunderstorms are possible from southern Oklahoma across the Ozarks region and over parts of the Florida Peninsula.

...Synopsis...

Broadly cyclonic mid/upper flow will cover much of the country this period, south of a big cyclone anchored over the Hudson Bay region. The strongest embedded shortwave perturbation -- now apparent in moisture-channel imagery over the upper Mississippi Valley region -- will move quickly eastward across the upper Great Lakes through 00Z, then over southern portions of ON/QC thereafter. A strong shortwave trough and embedded/compact 500-mb cyclone will dig southeastward from the Gulf of Alaska to the BC coast.

At the surface, a cold front was analyzed at 11z from a frontal-wave low over western WI southwestward across western NE and northwestern KS, becoming quasistationary from eastern Co northwestward over southwestern MT. The cyclone -- related to the nearby shortwave trough -- will deepen and eject in a northeastward-curving path across the upper Great Lakes and QC through the period. By 00Z the front should reach northern IN, southern MO and northwest TX. By 12Z the front should extend from northern New England across WV, northwestern TN, southeastern OK, and southeastern NM.

...Southern OK across Ozarks region...

Isolated to widely scattered thunderstorms are expected to occur from this afternoon into overnight hours within a growing, southwest/northeast plume of precip and showers embedded within a low-level warm-advection/moisture-transport plume. Buoyancy will be very limited in this elevated, early-stage return-flow regime, with MUCAPE remaining below 500 J/kg over most of the outlook area, except for portions of southern OK this evening. In that area, a brief/2-3-hour period of surface-based effective-inflow parcels with 50s to low-60s F surface dew points may support MLCAPE approaching 1000 J/kg, as weakening CINH and lift near the front help to generate and sustain convection. Although low-level winds will be modest, limiting overall hodograph size and shear/SRH in the lowest km, 30-40 kt effective-shear vectors may support some storm organization with isolated hail and gusts approaching severe limits. The severe potential still appears too conditional/isolated for a categorical outlook area, but will continue to be monitored for any trends in that direction.

..Edwards.. 03/31/2018

NOTE: THE NEXT DAY 1 OUTLOOK IS SCHEDULED BY 1630Z

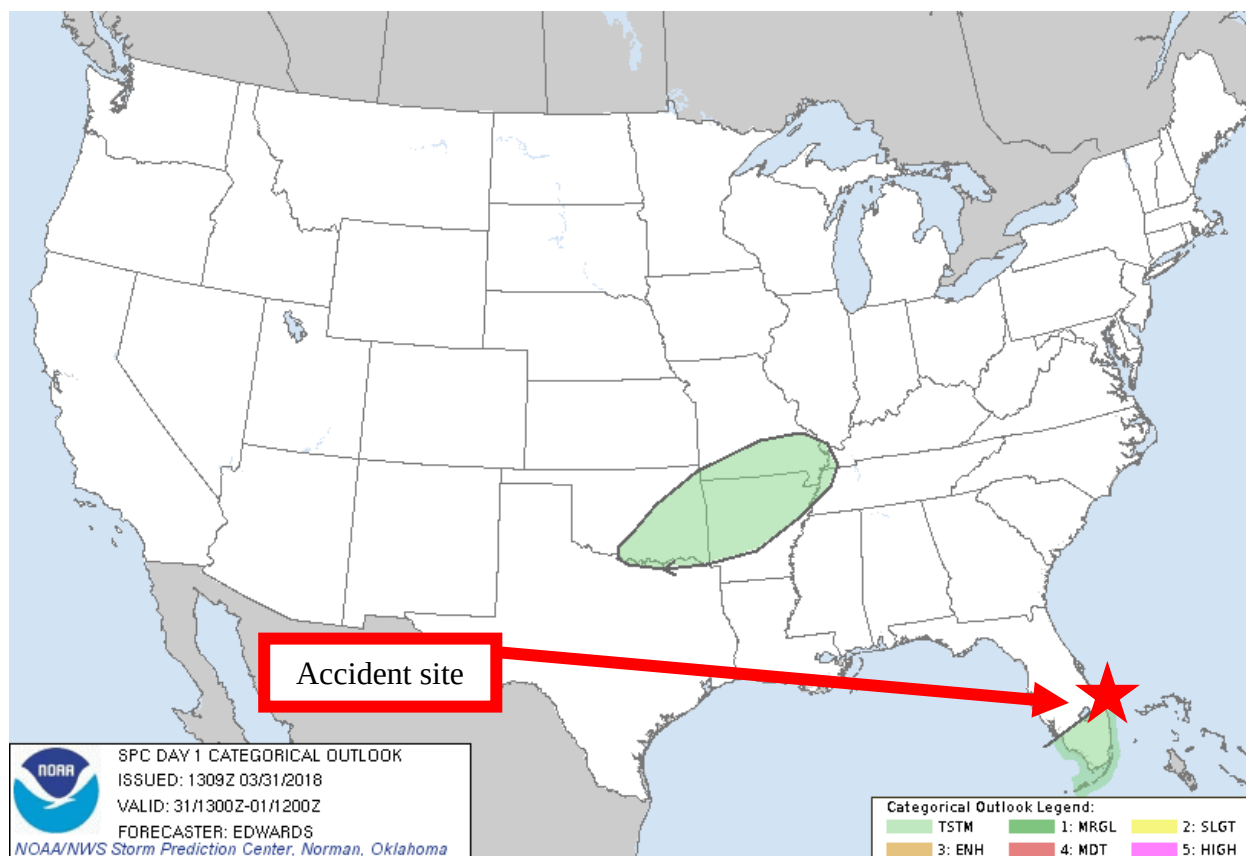


Figure 7 – SPC day 1 Convective Outlook valid at the time of the accident

3.0 Surface Observations

The area surrounding the accident site was documented using official 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 debris field, the closest surface observation sites, and the direct route of flight from departure to intended destination (pink line)

Witham Field Airport (KSUA), Stuart, Florida, was the closest official weather observation point to the debris field. KSUA had an Automated Weather Observing System (AWOS³) whose reports were supplemented by air traffic controllers (ATC) when the KSUA ATC tower was in operation. KSUA was located 24 miles west-southwest of the accident site, at an elevation of 16 feet (ft), and had a 7° westerly magnetic variation⁴ (figure 8). The following raw observations were disseminated during the times surrounding the accident:⁵

[0647 EDT] METAR KSUA 311047Z 00000KT 7SM SCT030 20/18 A3011=

[0747 EDT] METAR KSUA 311147Z 00000KT 7SM BKN050 21/19 A3012=

[0847 EDT] METAR KSUA 311247Z VRB04KT 7SM BKN050 22/19 A3013=

[0947 EDT] METAR KSUA 311347Z VRB04KT 7SM BKN050 23/19 A3015=

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. Latest measurement taken from <http://airnav.com/airport/KSUA>

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

[1047 EDT] METAR KSUA 311447Z VRB04KT 7SM FEW020 BKN050 25/19 A3016=

ACCIDENT TIME 1120 EDT

[1147 EDT] METAR KSUA 311547Z 03008KT 7SM FEW020 BKN050 25/20 A3016=

[1247 EDT] METAR KSUA 311647Z 05010KT 7SM VCSH BKN012 OVC050 24/20 A3016=

[1347 EDT] METAR KSUA 311747Z 03012KT 7SM BKN012 OVC050 24/20 A3015=

[1450 EDT] METAR KSUA 311850Z 10004KT 7SM SCT012 BKN050 25/19 A3012=

The relevant observations in plain language were as follows:

KSUA weather at 0947 EDT, wind variable at 4 knots, 7 miles visibility, broken ceiling at 5,000 ft above ground level (agl), temperature of 23° Celsius (C), dew point temperature of 19° C, and an altimeter setting of 30.15 inches of mercury.

KSUA weather at 1047 EDT, wind variable at 4 knots, 7 miles visibility, few clouds at 2,000 ft agl, broken ceiling at 5,000 ft, temperature of 25° C, dew point temperature of 19° C, and an altimeter setting of 30.16 inches of mercury.

KSUA weather at 1147 EDT, wind from 030° at 8 knots, 7 miles visibility, few clouds at 2,000 ft agl, a broken ceiling at 5,000 ft agl, temperature of 25° C, dew point temperature of 20° C, and an altimeter setting of 30.16 inches of mercury.

KSUA weather at 1247 EDT, wind from 050° at 10 knots, 7 miles visibility, vicinity⁶ showers, a broken ceiling at 1,200 ft agl, overcast skies at 5,000 ft agl, temperature of 24° C, dew point temperature of 20° C, and an altimeter setting of 30.16 inches of mercury.

Treasure Coast International Airport (KFPR), Fort Pierce, Florida, was the next closest airport to the accident site with official weather information. KFPR had an Automated Surface Observing System (ASOS⁷) whose reports were supplemented by ATC when the KFPR ATC tower was in operation. KFPR was located 32 miles west-northwest of the accident site, at an elevation of 23 ft, and had a 7° westerly magnetic variation. The following observations were disseminated during the times surrounding the accident:

***[0939 EDT] SPECI KFPR 311339Z 36006KT 10SM BKN013 23/20 A3014 RMK AO2
T02330200=***

⁶ In the vicinity of the airport is defined as a weather phenomenon within 5-10 miles of the airfield, but not over the airfield.

⁷ ASOS – Automated Surface Observing System is equipped with meteorological instruments to observe and report wind, visibility, ceiling, temperature, dewpoint, altimeter, and barometric pressure.

[0948 EDT] SPECI KFPR 311348Z 02008KT 10SM SCT014 BKN070 23/20 A3013
RMK AO2=

[0953 EDT] METAR KFPR 311353Z 01007KT 10SM BKN014 BKN070 24/20 A3013
RMK AO2 SLP204 T02390200=

[1008 EDT] SPECI KFPR 311408Z 05008KT 10SM SCT014 BKN020 BKN070 23/19
A3014 RMK AO2 T02330194=

[1031 EDT] SPECI KFPR 311431Z 01009KT 10SM SCT015 23/19 A3014 RMK AO2
T02330194=

***[1039 EDT] SPECI KFPR 311439Z 02009KT 10SM BKN015 23/19 A3015 RMK AO2
T02330194=***

***[1053 EDT] METAR KFPR 311453Z 03008KT 10SM OVC017 23/19 A3015 RMK AO2
SLP209 T02330194 53009=***

ACCIDENT TIME 1120 EDT

***[1131 EDT] SPECI KFPR 311531Z 04008KT 10SM FEW024 OVC030 24/19 A3016
RMK AO2 T02390189=***

***[1153 EDT] METAR KFPR 311553Z 03006KT 10SM FEW019 FEW025 OVC034 24/20
A3015 RMK AO2 SLP210 T02390200=***

[1253 EDT] METAR KFPR 311653Z 04007KT 10SM BKN016 BKN030 OVC070 24/21
A3015 RMK AO2 SLP209 T02390206=

[1331 EDT] SPECI KFPR 311731Z 10007KT 10SM SCT012 BKN031 OVC042 23/21
A3014 RMK AO2 RAB1654E10 P0000 T02330211=

KFPR weather at 1039 EDT, wind from 020° at 9 knots, 10 miles visibility or greater, a broken ceiling at 1,500 ft agl, temperature of 23° C, dew point temperature of 19° C, and an altimeter setting of 30.15 inches of mercury. Remarks: automated station with a precipitation discriminator, temperature 23.3° C, dew point temperature 19.4° C.

KFPR weather at 1053 EDT, wind from 030° at 8 knots, 10 miles visibility or greater, an overcast ceiling at 1,700 ft agl, temperature of 23° C, dew point temperature of 19° C, and an altimeter setting of 30.15 inches of mercury. Remarks: automated station with a precipitation discriminator, sea-level pressure 1020.9 hPa, temperature 23.3° C, dew point temperature 19.4° C, 3-hourly pressure increase of 0.9 hPa.

KFPR weather at 1131 EDT, wind from 040° at 8 knots, 10 miles visibility or greater, few clouds at 2,400 ft agl, an overcast ceiling at 3,000 ft agl, temperature of 24° C, dew point temperature of 19° C, and an altimeter setting of 30.16 inches of mercury. Remarks: automated station with a precipitation discriminator, temperature 23.9° C, dew point temperature 18.9° C.

KFPR weather at 1153 EDT, wind from 030° at 6 knots, 10 miles visibility or greater, few clouds at 1,900 ft agl, few clouds at 2,500 ft agl, an overcast ceiling at 3,400 ft agl, temperature of 24° C, dew point temperature of 20° C, and an altimeter setting of 30.15 inches of mercury. Remarks: automated station with a precipitation discriminator, sea-level pressure 1021.0 hPa, temperature 23.9° C, dew point temperature 20.0° C.

The observations from KSUA and KFPR surrounding the accident time indicated mainly VFR⁸ to MVFR⁹ ceiling conditions. Vicinity showers were observed at KSUA at 1247 EDT.

4.0 Upper Air Data

A High-Resolution Rapid Refresh (HRRR)¹⁰ model sounding was created for the accident site for 1100 EDT with station elevation at sea level. The 1100 EDT HRRR sounding was plotted on a standard Skew-T Log P diagram¹¹ 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 RAOB¹² software package. The sounding depicted the lifted condensation level (LCL)¹³ at 1,431 ft agl, the level of free convection (LFC)¹⁴ at 1,558 ft agl, and the convective condensation level (CCL)¹⁵ at 3,016 ft agl. The sounding had a greater than 80% relative humidity from 1,400 ft through 4,500 ft. The freezing level was at 13,394 ft msl. The precipitable water value was 1.31 inches.

⁸ 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 5 miles visibility.

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

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

¹¹ Skew T log P diagram – is a standard meteorological plot using temperature and the logarithmic of pressure as coordinates, used to display winds, temperature, dew point, and various indices used to define the vertical structure of the atmosphere.

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

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

¹⁴ 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.

¹⁵ 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.

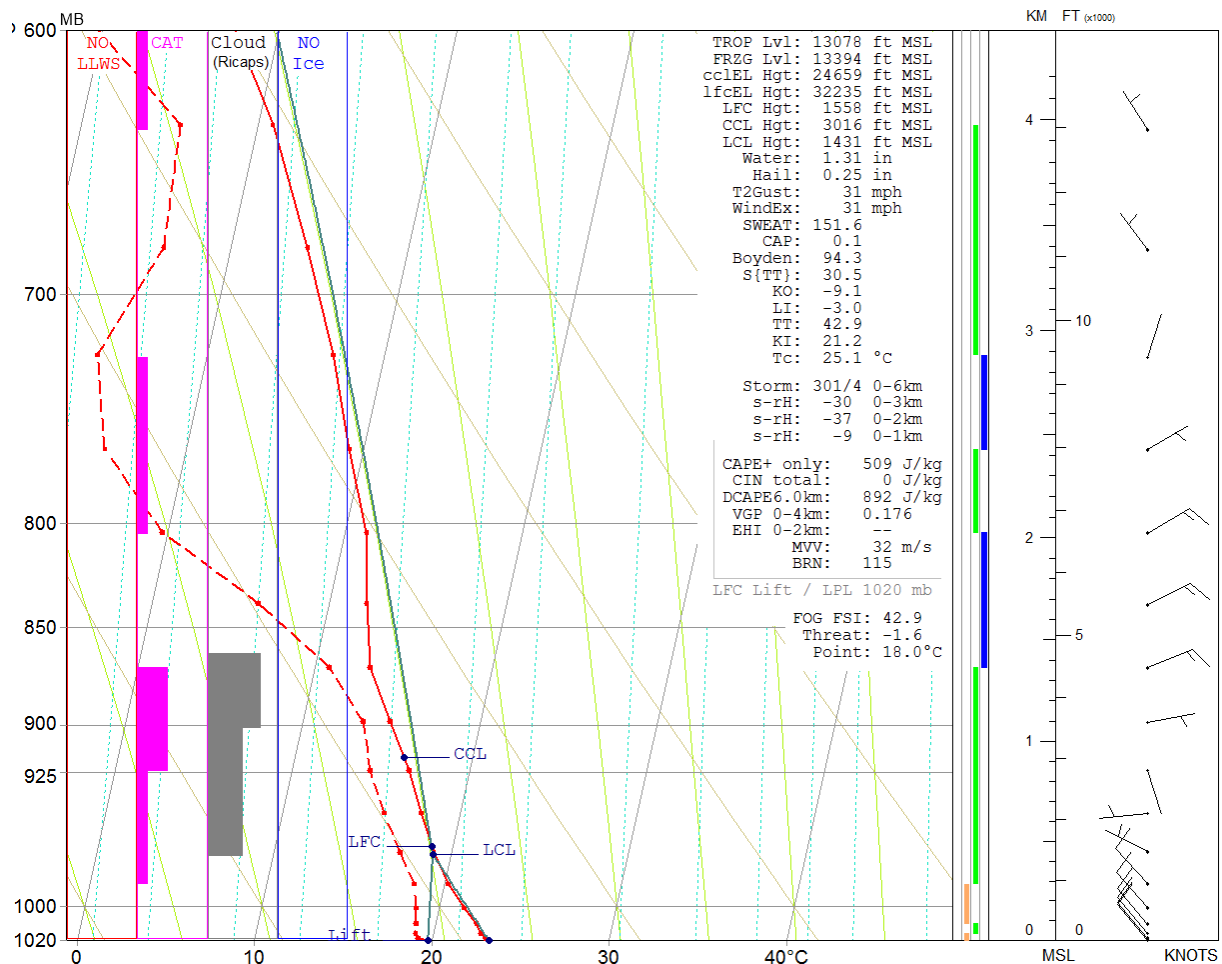


Figure 9 – 1100 EDT HRRR sounding

The 1100 EDT HRRR sounding indicated an alternating unstable and conditionally unstable environment from the surface through 4,500 ft with 509 Joules/kilogram (J/kg) of CAPE¹⁶. The maximum vertical velocity (MVV) for this atmosphere was calculated as 32 meters/second (about 6,299 ft per minute).¹⁷ Downdraft CAPE (DCAPE; 6 kilometers agl)¹⁸ was measured at 892 J/kg. RAOB identified the possibility of clouds between 1,500 ft through 4,500 ft. No areas of icing were indicated by RAOB for below 14,000 ft.

¹⁶ Convective Available Potential Energy (CAPE) – CAPE is a measure of the amount of energy available for convection and is directly related to the maximum potential vertical speed within an updraft.

¹⁷ MVV is not usually considered a realistic estimate for maximum vertical velocity in a storm. Anecdotes suggest considering a value of MVV/2, however it is not well understood when or where such a half-value should be applied.

¹⁸ The DCAPE can be used to estimate the potential strength of rain-cooled downdrafts within thunderstorm convection, and is similar to CAPE. Larger DCAPE values are associated with stronger downdrafts.

The 1100 EDT HRRR sounding wind profile indicated a surface wind from 322° at 10 knots with little variation in direction through 2,000 ft. The wind shifted to the east between 3,000 and 8,000 ft with wind speeds of 15 knots or less. Above 8,000 ft the wind backed¹⁹ to the northwest with wind speeds less than 10 knots.. RAOB indicated no possibility of low-level wind shear outside of convective activity. RAOB indicated the possibility of light clear-air turbulence in several layers between 1,000 ft and 14,000 ft.

5.0 Satellite Data

Visible and infrared 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 imagery (GOES-16 bands 1 and 13) at wavelengths of 0.47 microns (μm) and 10.3 μm , respectively, were retrieved for the period. Satellite imagery surrounding the time of the accident, from 0900 EDT through 1400 EDT at approximately 15-minute intervals were reviewed, and the closest images to the time of the accident are documented here.

Figures 10 and 11 present the GOES-16 visible imagery at 1115 and 1122 EDT at 3X magnification with the accident site highlighted with a red square. Inspection of the visible imagery indicated abundant cloud cover above the accident site at the accident time with the low-level cloud cover moving from northeast to southwest and the mid- and high-level cloud cover moving from southwest to northeast (attachment 1).

Figure 12 present the GOES-16 infrared imagery at 1122 EDT 5X magnification with the accident site highlighted with a red square. Inspection of the infrared imagery indicated cloud cover over the accident site. The lower brightness temperatures (green colors; higher cloud tops) were located around the debris location and in areas across Florida with the lower brightness temperature bands oriented southwest to northeast. Based on the brightness temperatures above the accident site and the vertical temperature profile provided by the 1100 EDT HRRR sounding, the approximate cloud-top heights over the accident site were 27,000 ft at 1122 EDT. It should be noted these figures have not been corrected for any parallax error.

¹⁹ A backing wind is a wind that turns counter-clockwise with height.

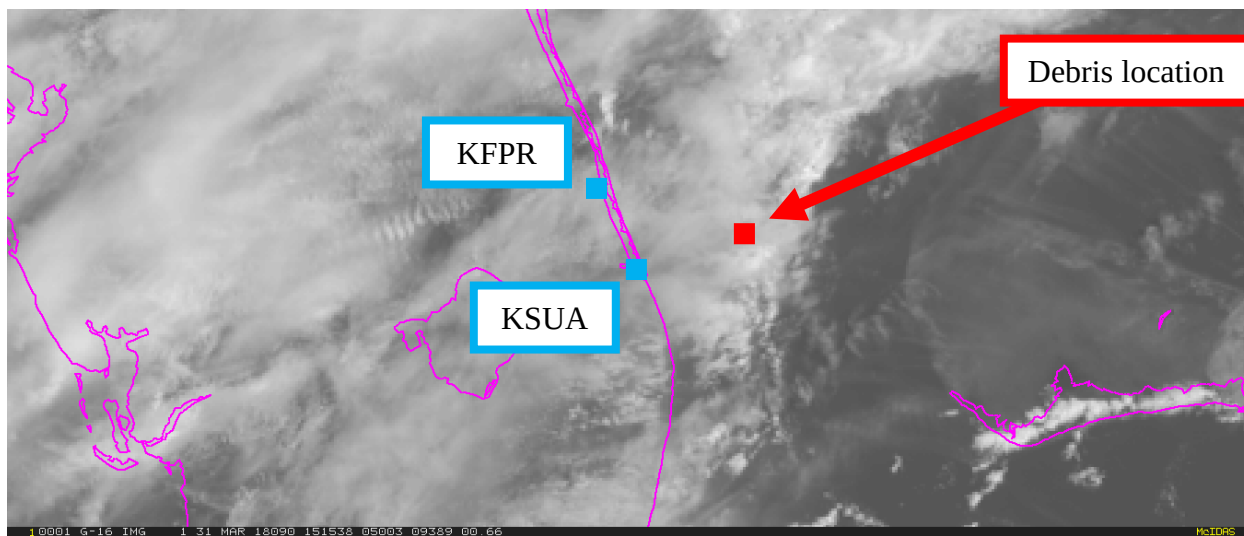


Figure 10 – GOES-16 visible image at 1115 EDT

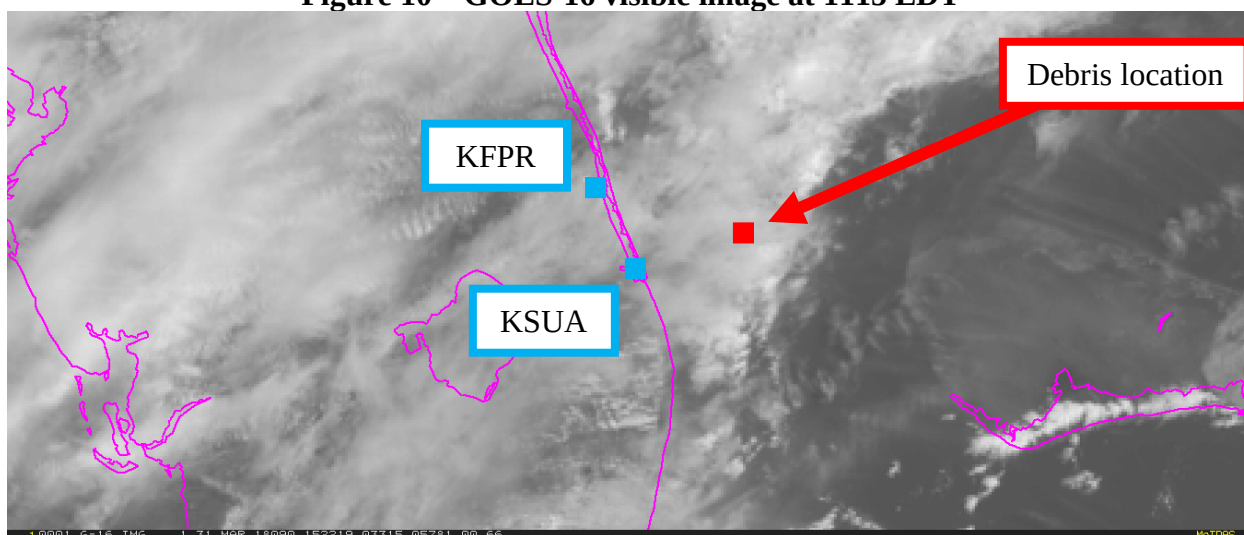


Figure 11 – GOES-16 visible image at 1122 EDT

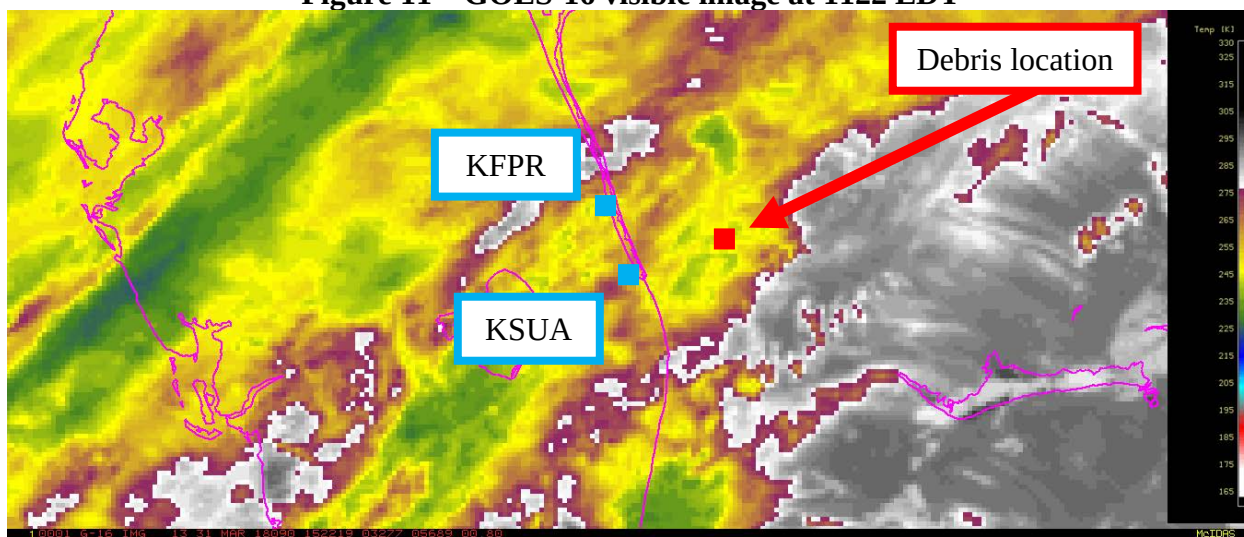


Figure 12 – GOES-16 infrared image at 1122 EDT

6.0 Radar Imagery Information

The closest NWS Weather Surveillance Radar-1988, Doppler (WSR-88D)²⁰ to the accident site was the Melbourne, Florida, radar (KMLB), which was located 72 miles north-northwest of the last ATC target point²¹, and 65 miles north-northwest of the debris location 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.

6.1 Volume Scan Strategy

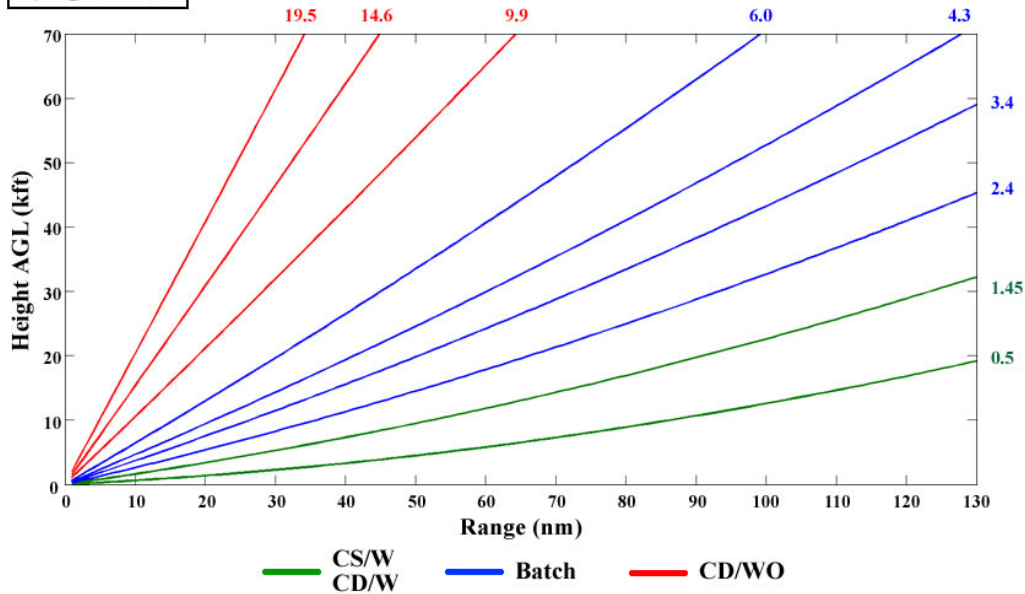
The WSR-88D is a computer-controlled radar system, which automatically creates a complete series of specific scans in a specific sequence known as a volume scan. Individual elevation scans are immediately available. Products that require data from multiple elevation scans are not available until the 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 9 elevation scans from 0.5° to 19.5° around every six minutes. This particular scanning strategy is documented as volume coverage pattern 21 (VCP-21). 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 KMLB WSR-88D radar was operating in the precipitation mode (Mode A, VCP-21). 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.

²⁰ 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.

²¹ For more ATC information please see the docket for this investigation.

VCP 21



VCP-21 Precipitation Mode Scan Strategy²²

6.2 Beam Height Calculation

Assuming standard refraction²³ of the KMLB WSR-88D radar beam, at an elevation of 149 ft and considering a beamwidth²⁴ of 0.95°, the following table shows the approximate heights for the radar beam center, top and base for several antenna elevations over the accident site. These heights have been rounded to the nearest 10 ft.

ANTENNA ELEVATION	BEAM CENTER	BEAM BASE	BEAM TOP
0.5°	7,730 ft	4,180 ft	11,280 ft

Based on the radar height calculations, the 0.5° elevation scan depicted the conditions between 4,180 ft and 11,280 ft msl over the accident site and these scans are the closest altitudes to the accident aircraft's altitude before the accident occurred.

²² 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)

²³ Standard Refraction in the atmosphere is when the temperature and humidity distributions are approximately average, and values set at the standard atmosphere.

²⁴ Beamwidth - the angular separation between the half power points on the antenna radiation pattern, where the gain is one half the maximum value.

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 00-24C²⁷, “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:

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.

²⁷

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.

6.4 Base Reflectivity and Lightning Data

Figures 13, 14, and 15 present the KMLB WSR-88D base reflectivity images for the 0.5° elevation scans initiated at 1110, 1115, and 1121 EDT, respectively, with a resolution of 0.5° X 250 m. The FAA ATC flight track of N4ZQ is also overlaid. Reflectivity values between 30 and 45 dBZ were located in the area of the last ATC target point between 1115 and 1121 EDT, and this would correspond to moderate to heavy rainfall (section 6.3). The reflectivity bands were moving from northeast to southwest between 1100 and 1135 EDT (attachment 2).

ATC provided weather information to N4ZQ at 1112:37 and 1112:45 EDT, indicating “..areas of moderate to heavy precipitation eleven to one o’clock...” and that ATC flight track point is highlighted in figures 13 and 14.²⁸

There were no lightning strikes around the accident site at the accident time.²⁹

²⁸ For more ATC information please see the docket for this investigation.

²⁹ A review of Earth Networks Total Lightning network was done.

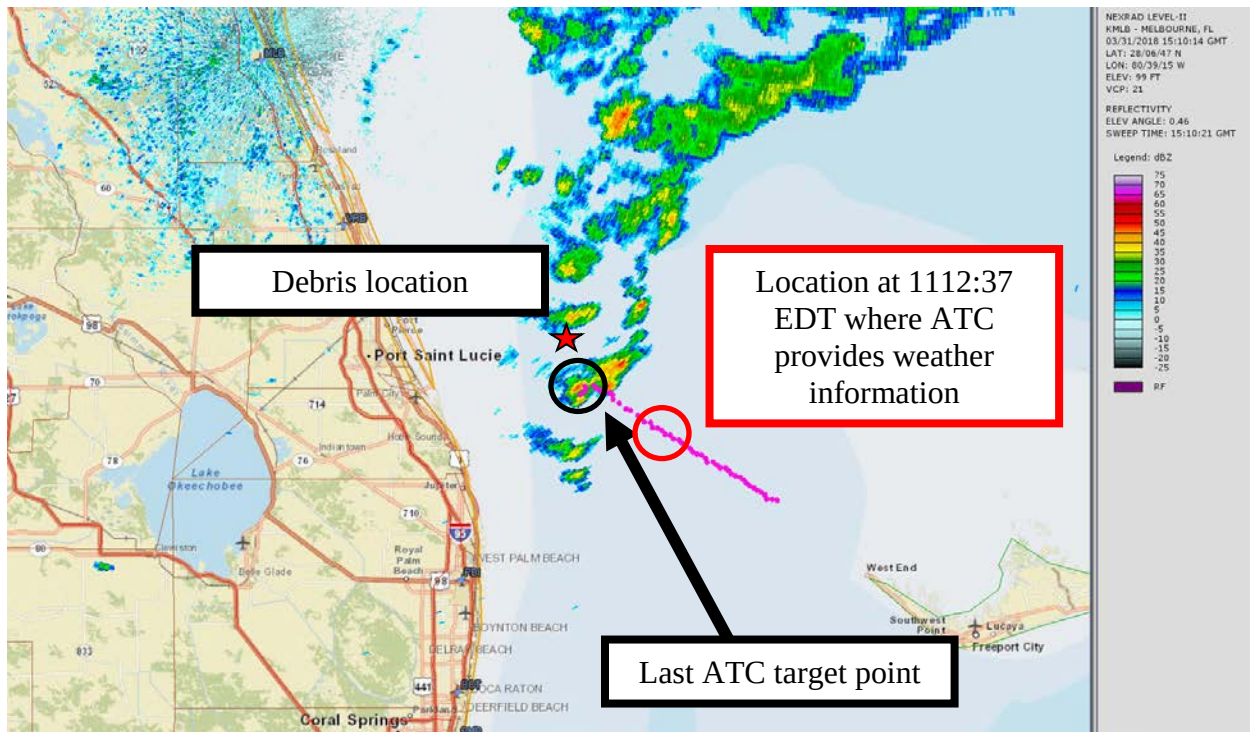


Figure 13 – KMLB WSR-88D reflectivity for the 0.5° elevation scan initiated at 1110 EDT with the last ATC target point marked with black circle and the ATC flight track points in pink

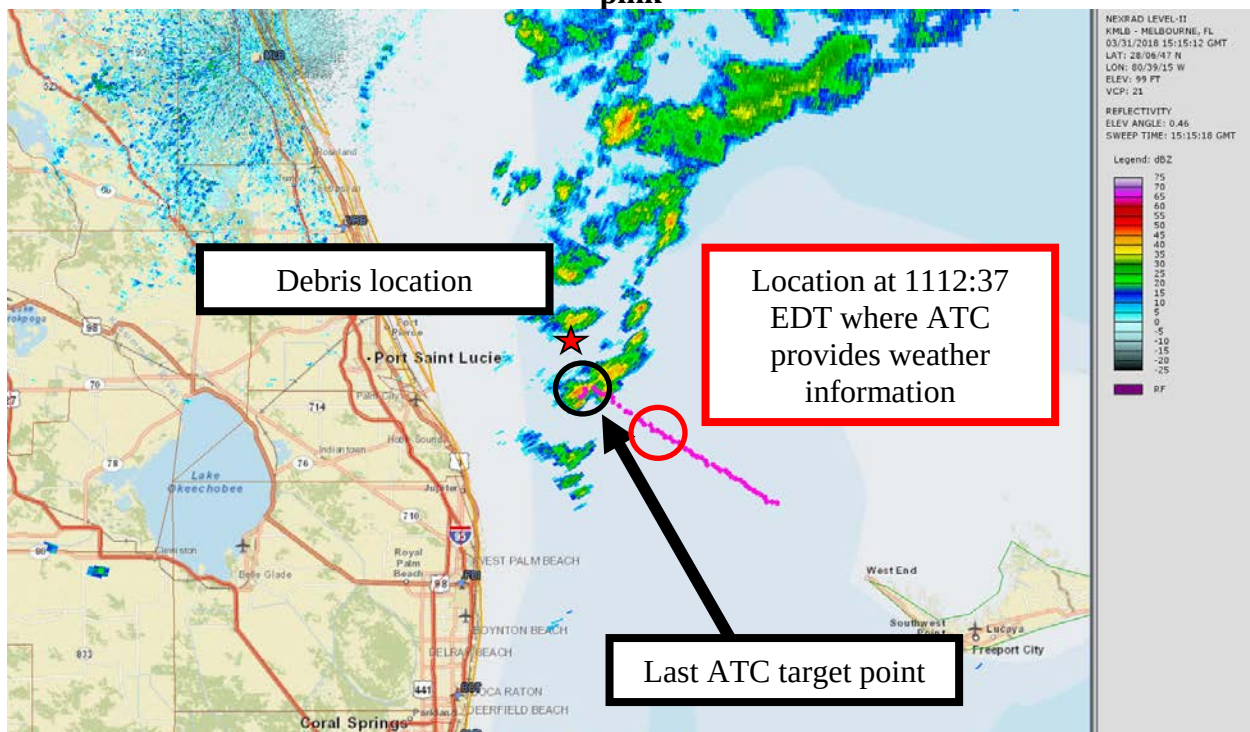


Figure 14 – KMLB WSR-88D reflectivity for the 0.5° elevation scan initiated at 1115 EDT with the last ATC target point marked with black circle and the ATC flight track points in pink

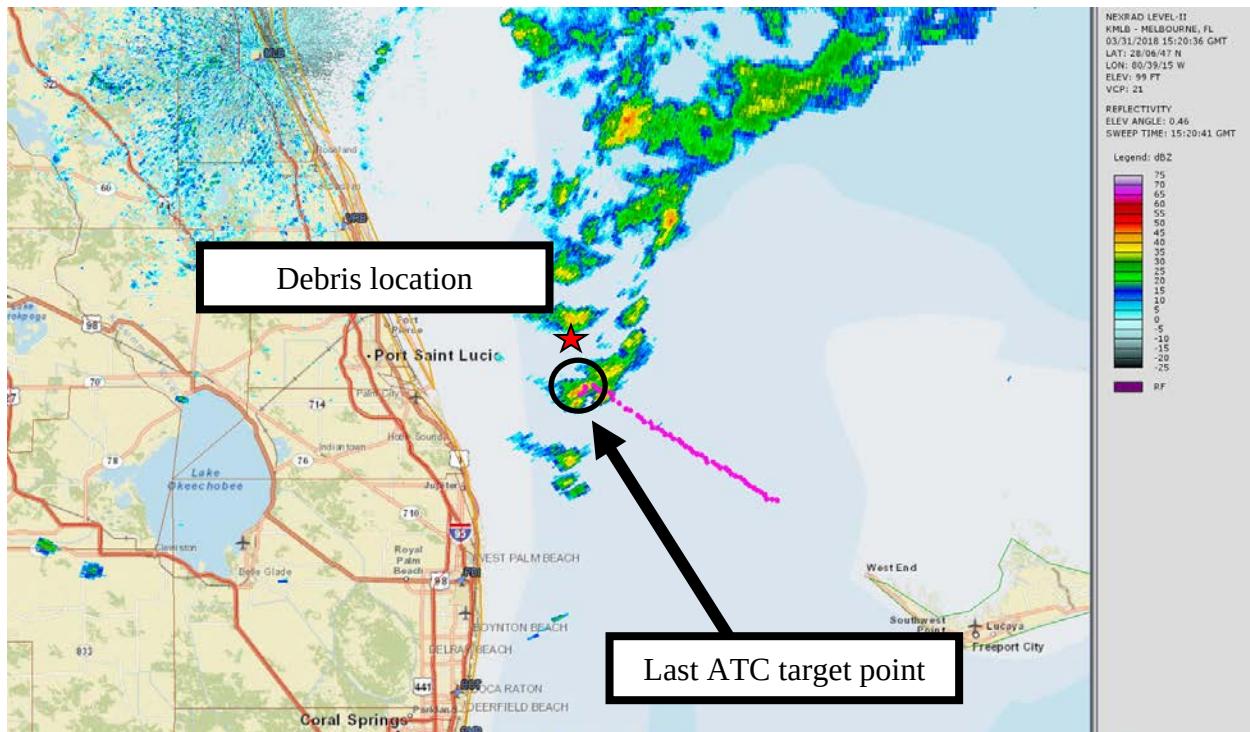


Figure 14 – KMLB WSR-88D reflectivity for the 0.5° elevation scan initiated at 1121 EDT with the last ATC target point marked with black circle and the ATC flight track points in pink

7.0 Pilot Reports³⁰

All pilot reports (PIREPs) within 100 miles of the accident site from about one hour prior to the accident time to about one hour after the accident time were reviewed. Only PIREPs for below FL180³¹ are provided below:

TMB UA /OV 3 EAST/TM 1440/FL020/TP C56X/SK BKN022

COF UA /OV COF/TM 1446/FL020/TP P28A/SK OVC028

ISM UA /OV ISM/TM 1448/FLDURGC/TP C68A/SK SCT020 BKN028

PBI UA /OV PBI/TM 1452/FL040/TP C421/SK BKN046

VRB UA /OV VRB180010/TM 1452/FL020/TP C680/SK OVC019

PBI UA /OV SWOMP/TM 1502/FL080/TP B737/TB CONT LGT CHOP

OBE UA /OV OBE/TM 1513/FL015/TP SR22/SK BKN-OVC020/WV 04006KT/TB NEG/RM DURC WX BREAKS TOWARDS SOUTH

³⁰ Only pilot reports with the WMO header UBFL** identifier were considered.

³¹ 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.

FXE UA /OV 270003/TM 1519/FL010/TP CL60/SK BKN025

TIX UA /OV TIX270003/TM 1526/FL020/TP C172/SK BKN030

VRB UA /OV 1 MILE NW OF VRB/TM 1610/FL012/TP C310/SK BKN014

The decoded PIREPs in plain language from standard code and abbreviation were as follows:

Routine pilot report (UA), Miami Executive Airport, Florida (TMB); Over – 3 miles east; Time – 1040 EDT (1440Z); Altitude – 2,000 ft; Type aircraft – Cessna Citation Excel; Sky – Broken skies at 2,200 ft.

Routine pilot report (UA), Patrick Air Force Base, Florida (COF); Over – COF; Time – 1046 EDT (1446Z); Altitude – 2,000 ft; Type aircraft – Piper PA-28 Cherokee; Sky – Overcast skies at 2,800 ft.

Routine pilot report (UA), Kissimmee Gateway Airport, Florida (ISM); Over – ISM; Time – 1048 EDT (1448Z); Altitude – During climb; Type aircraft – Cessna Citation Latitude; Sky – Scattered clouds at 2,000 ft, broken skies at 2,800 ft.

Routine pilot report (UA), Palm Beach International Airport, Florida (PBI); Over – PBI; Time – 1052 EDT (1452Z); Altitude – 4,000 ft; Type aircraft – Cessna 421; Sky – Broken skies at 4,600 ft.

Routine pilot report (UA), Vero Beach Regional Airport, Florida (VRB); Over – 10 miles from VRB on the 180° radial; Time – 1052 EDT (1452Z); Altitude – 2,000 ft; Type aircraft – Cessna Citation Sovereign; Sky – Overcast skies 1,900 ft.

Routine pilot report (UA), PBI; Over – SWOMP VOR; Time – 1102 EDT (1502Z); Altitude – 8,000 ft; Type aircraft – Boeing B737; Turbulence – Constant light chop.

Routine pilot report (UA), Okeechobee County Airport, Florida (OBE); Over – OBE; Time – 1113 EDT (1513Z); Altitude – 1,500 ft; Type aircraft – Cirrus SR22; Sky – Broken to overcast skies at 2,000 ft; Wind – From 040° at 6 knots; Turbulence – Negative; Remarks – During climb weather breaks towards the south.

Routine pilot report (UA), Fort Lauderdale Executive Airport, Florida (FXE); Over – 3 miles on the 270° radial; Time – 1119 EDT (1519Z); Altitude – 1,000 ft; Type aircraft – Bombardier Challenger 600; Sky – Broken skies at 2,500 ft.

Routine pilot report (UA), Space Coast Regional Airport, Florida (TIX); Over – 3 miles from TIX on the 270° radial; Time – 1126 EDT (1526Z); Altitude – 2,000 ft; Type aircraft – Cessna 172; Sky – Broken skies at 3,000 ft.

Routine pilot report (UA), VRB; Over – One-mile northwest of VRB; Time – 1210 EDT (1610Z); Altitude – 1,200 ft; Type aircraft – Cessna 310; Sky – Broken skies at 1,400 ft.

8.0 SIGMET

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

9.0 AIRMETs

There were no Airmen's Meteorological Information (AIRMET)s valid for the accident site at the accident time for below 10,000 ft.

10.0 CWSU Advisories

There was no Center Weather Service Unit (CWSU) Center Weather Advisory (CWA) or Meteorological Impact Statement (MIS) valid at the accident site at the accident time.

11.0 Graphical Forecasts for Aviation

The Graphical Forecasts for Aviation (GFA) products made available before the accident time and before the accident flight departed, indicated a chance (between 30 to 60 percent) of rain showers across southern Florida and eastward over the western Atlantic Ocean including the accident site after 0800 EDT (attachment 3). The aviation cloud forecast indicated overcast cloud bases around 3,000 ft with clouds top at 5,500 ft and cirrus clouds above (attachment 3).

12.0 Terminal Aerodrome Forecast

KSUA had the closest NWS Terminal Aerodrome Forecast (TAF) and the TAF valid at the accident time was issued at 0725 EDT and was valid for a 24-hour period beginning at 0800 EDT. The 0725 EDT TAF for KSUA was as follows:

TAF KSUA 311125Z 3112/0112 VRB03KT P6SM SCT025 OVC050
FM311400 06006KT P6SM SCT015 BKN035
FM311800 08009KT P6SM SCT025 BKN060
FM010000 10005KT P6SM SCT020 BKN070=

Between 1000 and 1400 EDT the TAF expected a wind from 060° at 6 knots, greater than 6 miles visibility, scattered clouds at 1,500 ft agl, and a broken ceiling at 3,500 ft agl.

The KFPR TAF valid at the accident time was an amended TAF issued at 1108 EDT and was valid for a 21-hour period beginning at 1100 EDT. The 1108 EDT TAF for KFPR was as follows:

TAF AMD KFPR 311508Z 3115/0112 **04010KT P6SM SCT015 OVC050**
TEMPO 3115/3118 OVC015
FM010000 09005KT P6SM SCT020 OVC080
FM010600 VRB02KT P6SM FEW015 BKN100=

Between 1100 and 2000 EDT the TAF expected a wind from 040° at 10 knots, greater than 6 miles visibility, scattered clouds at 1,500 ft agl, and an overcast ceiling at 5,000 ft agl. Temporary conditions between 1100 and 1400 EDT of an overcast ceiling 1,500 ft agl.

The KFPR TAF valid before departure was issued at 0725 EDT and was valid for a 24-hour period beginning at 0800 EDT. The 0725 EDT TAF for KFPR was as follows:

TAF KFPR 311125Z 3112/0112 VRB03KT P6SM FEW015 OVC060
FM311400 36004KT P6SM SCT015 BKN035
FM311600 06008KT P6SM SCT025 BKN060
FM010000 10005KT P6SM SCT020 BKN070=

Between 1000 and 1200 EDT the TAF expected a wind from 360° at 4 knots, greater than 6 miles visibility, scattered clouds at 1,500 ft agl, and a broken ceiling at 3,500 ft agl.

13.0 NWS Area Forecast Discussion

The NWS Office in Melbourne, Florida, issued the following Area Forecast Discussion (AFD) at 1010 EDT (closest AFD to the accident time with an aviation section). The aviation section of the AFD discussed ceilings around 4,000 to 6,000 ft through the afternoon with occasional ceilings around 2,000 to 3,000 ft with light rain showers:

FXUS62 KMLB 311410
AFDMLB

Area Forecast Discussion
National Weather Service Melbourne FL
1010 AM EDT Sat Mar 31 2018

.DISCUSSION...

Frontal bndry has pushed into the Treasure Coast/Lake-O region with precipitation largely confined to the Gulf Stream from Cape Canaveral southward. Mrgng RAOBs depict the boundary quite well... KTBW/KXMR soundings measuring PWat values btwn 1.50"-1.75", decreasing northward to 0.25"-0.50" at KJAX/KTAE and southward to around 1.00" at KMFL/KEYW/MYNN. Lcl wind profilers showing the front is quite shallow with N/NE flow 20-25KTS thru 3KFT, backing to W/SW AOB 10KTS btwn 4-6KFT.

Post frontal sfc ridge draped over the Mid Atlc/Carolina Coasts will maintain a tight sfc/low lvl pgrad acrs central FL today as the stalls in the vcnty of Lake-O/Jupiter Inlet. MOS PoPs in the 50-70pct ahead of the front and 40-50pct behind the front continue too high based on radar trends...esp given the bulk of the mid lvl omega lift has fallen behind the frontal boundary, upr lvl divergence has largely collapsed, and H85-H50 dewpoint depressions btwn 3-5C confined to the region btwn the I-4 corridor and the Ft. Pierce Inlet/NW shore of Lake-O. No sig changes to the 30-40pct spread from Cape Canaveral/Lake-K southward and AOB 20pct to the north.

Mcldy skies and brisk N/NE winds will keep max temps in the L/M70s along and north of I-4...M/U70s to the south.

&&

.AVIATION...Thru 01/12Z.

Sfc Winds: Thru 31/21Z...N of KVRB-KSEF N/NE 8-12KTS ocnl sfc G18-22KTS coastal sites...S of KVRB-KSEF E/NE 6-10KTS. Btwn 31/21Z-31/24Z...bcmg E/NE 5-8KTS. Btwn 01/03Z-01/06Z...N of KVRB-KSEF bcmg N/NW 3-6KTS...S of KVRB-KSEF bcmg vrbl AOB 3KTS.

Vsbys/WX/Cigs: Thru 01/00Z...cigs btwn FL040-060...S of KISM-KTIX ocnl MVFR cigs btwn FL020-030 in -shra. Btwn 01/00Z-01/06Z...N of KISM-KTIX MVFR cigs btwn FL020-030...S of KISM-KTIX cigs btwn FL060-080. Aft 01/06Z...N of KISM-KTIX MVFR cigs btwn FL010-020 areas MVFR vsbys in BR...S of KISM-KTIX cigs btwn FL080-100.

&&

.MARINE...

Weakening frontal boundary just south of Sebastian Inlet will wash out over the Treasure Coast waters today. Gentle to moderate N/NE breeze will prevail behind the frontal boundary, veering to a light to gentle E/NE breeze ahead of it. Seas 2-3FT nearshore and 3-4FT offshore, mainly in a 12sec pd NE swell. Latest sfc obs show sustained winds 15-20KTS with ocnl G20-25KTS...in line with a tight post-frontal pgrad. Winds to continue until the pgrad relaxes...will extend the cautionary statement thru the aftn package and expand it to include nearshore zones down to Sebastian Inlet. Sct shras/isold tsras in the Gulf Stream...brief isold shras over the shelf waters.

&&

.MLB WATCHES/WARNINGS/ADVISORIES...

FL...None.

AM...None.

&&

\$\$

14.0 Winds and Temperature Aloft Forecast

The NWS 1001 EDT Winds and Temperature Aloft forecast valid for the closest point to the accident site is included below:

FBUS31 KWN0 311401

FD1US1

DATA BASED ON 311200Z

VALID 311800Z FOR USE 1400-2100Z. TEMPS NEG ABV 24000

FT 3000 6000 9000 12000 18000 24000 30000 34000 39000

MLB 0517 9900+11 9900+06 3009+01 2522-12 2540-23 246438 247549 249060

The accident site was closest to the Melbourne, Florida, (MLB) forecast point. The 1001 EDT MLB forecast for use between 1000 and 1700 EDT indicated a wind at 3,000 ft from 050° at 17 knots, a calm wind at 6,000 ft with a temperature of 11° C, and a calm wind at 9,000 ft with a temperature of 6° C.

15.0 Pilot Weather Briefing

A search of official weather briefing sources such as contract Automated Flight Service Station (AFSS) provider Leidos weather briefings and the Direct User Access Terminal Service (DUATS) was done and the accident pilot did not request a weather briefing through Leidos or DUATS.

A search of archived data from ForeFlight was done and the accident pilot did request a weather briefing at 0903 EDT on March 30, the day before the accident, the flight planned to depart at 0900 on March 31. The ForeFlight weather briefing contained all the standard weather information valid for March 30 at 0900 EDT. The only weather forecast product that included data valid for 0900 on March 31 was the Winds Aloft forecast (attachment 4). The accident pilot did not request a weather briefing or weather information via ForeFlight on March 31. For more information please see attachment 4. It is unknown if the accident pilot checked or received anymore weather information before or during the accident flight.

16.0 Astronomical Data

The astronomical data obtained from the United States Naval Observatory for the accident site on March 31, 2018, indicated the following:

SUN	
Begin civil twilight	0647 EDT
Sunrise	0711 EDT
Accident	1120 EDT³²
Sun transit	1323 EDT
Sunset	1936 EDT
End civil twilight	2000 EDT

E. LIST OF ATTACHMENTS

Attachment 1 – Animation of GOES-16 visible satellite imagery (band 2, 0.64 μm) from 0907 EDT to 1302 EDT

Attachment 2 – Animation of KMLB WSR-88D reflectivity for the 0.5° elevation scan initiated between 1100 and 1135 EDT

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

Attachment 4 – Correspondence with ForeFlight

³² Inserted accident time for reference and context.

Submitted by:

Paul Suffern
Senior Meteorologist

THIS PAGE INTENTIONALLY BLANK