**NATIONAL TRANSPORTATION SAFETY BOARD**

Office of Aviation Safety
Washington, D.C. 20594

June 7, 2017

## Group Chairman's Factual Report

# METEOROLOGY

ERA16FA309

## Table Of Contents

## A. AIRCRAFT ACCIDENT

Location: Hollywood, Florida
Date: September 3, 2016
Time: 0952 Eastern Daylight Time
1352 universal coordinated time (UTC)
Airplane: Cessna 172; Registration: N6091E

## B. METEOROLOGIST

Don Eick
Meteorologist Specialist
Operational Factors Division (AS-30)
National Transportation Safety Board

## C. SUMMARY

On September 3, 2016 about 0952 eastern daylight time, a Cessna 172N, N6091E, was destroyed when it impacted the Atlantic Ocean, while maneuvering near Hollywood, Florida. The private pilot and pilot rated passenger were fatally injured. The airplane departed from Pompano Beach Airpark (PMP), Pompano Beach, Florida, and was destined for Ocean Reef Club Airport (07FA), Key Largo, Florida. The airplane was owned by Volux Aviation LLC, and operated by a private individual. Visual meteorological conditions prevailed and no flight plan was filed for the personal flight conducted under the provisions of 14 *Code of Federal Regulations* Part 91.

## D. DETAILS OF THE INVESTIGATION

The National Transportation Safety Board's (NTSB) Senior Meteorologist was not on scene for this investigation and conducted the meteorology phase of the investigation from the Washington D.C. office, collecting data from official National Weather Service (NWS) sources including the Weather Prediction Center (WPC) and the National Center for Environmental Information (NCEI). All times are eastern daylight time (EDT) based upon the 24 hour clock, local time is +4 hours to 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 accident site was based on the coordinates of latitude 26.046667° N, and longitude 80.061944° W.

## E. FACTUAL INFORMATION

### 1.0 Synoptic Conditions

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 located in Camp Springs, Maryland. These are the base products used in describing weather features and in the creation of forecasts and warnings. Reference to these charts can be found in the joint NWS and Federal Aviation Administration (FAA) Advisory Circular "Aviation Weather Services", AC 00-45H.

### 1.1 Surface Analysis Chart

The southeast section of the NWS Surface Analysis Chart for 0800 EDT (1200Z) on September 3, 2016 is included as figure 1 below with the approximate accident site marked by a red star. The chart depicted the Azores-Bermuda high pressure ridge extending over south Florida with a developing cold frontal system and dissipating stationary front over northern Florida. A trough of low pressure was also identified over the northwest Florida coastal area merging into the frontal region. A relative weak pressure gradient dominated south Florida. A warning block was noted on the chart for Tropical Storm Hermine and indicated that the position of the storm was at 35.6° N and 75.6°W or over the outer banks of North Carolina at the time and was not influencing Florida's weather on the day of the accident.

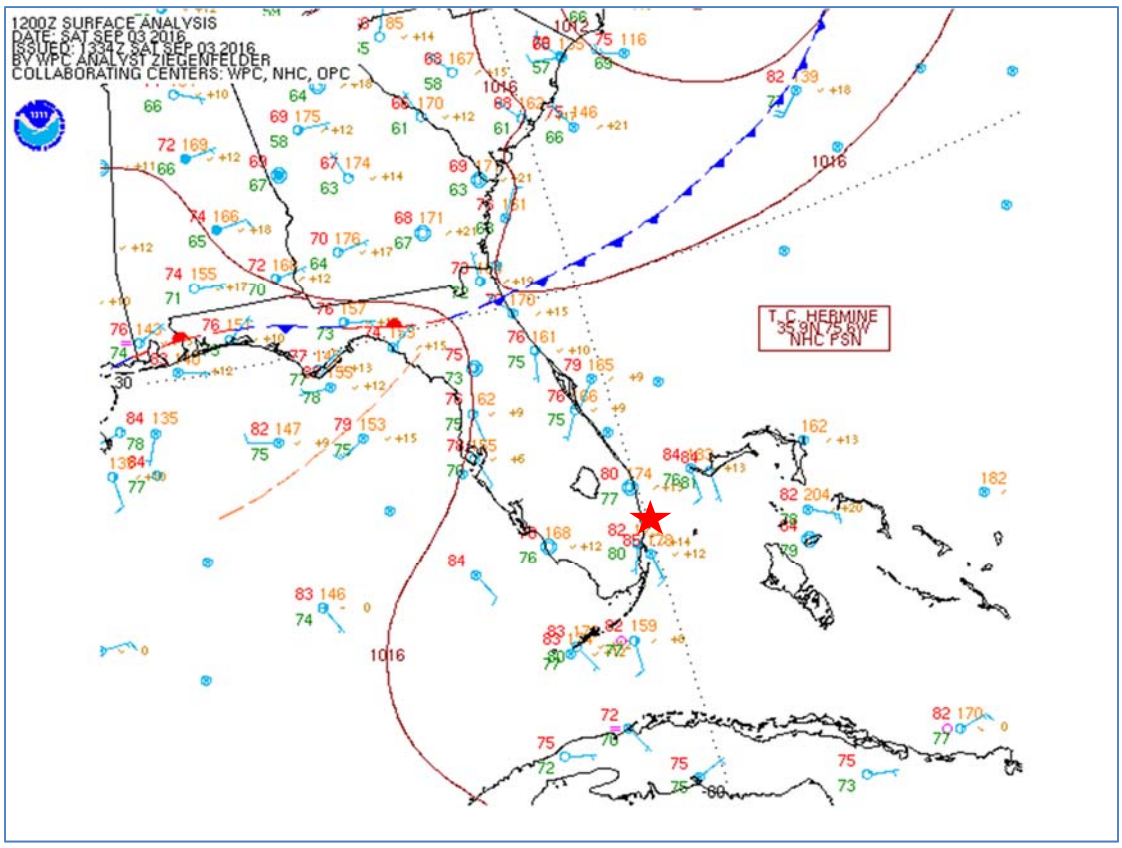


**Figure 1 - NWS southeast section of the surface analysis chart for 0800 EDT**

The station models surrounding the accident site depicted a light pressure gradient over the region with a general anticyclonic or clockwise wind flow over the region with light southerly winds. The station model for Miami immediately south of the accident site depicted a southerly wind of 5 knots, broken sky cover, temperature of 82° Fahrenheit (F), and a dew point temperature 80° F.

## 1.2 Regional Radar Mosaic

The regional weather radar mosaic for 1000 EDT (1400Z) is included as figure 2 below and depicted a broken line of scattered echoes extending off the southeast Florida coast into southern Florida near the Fort Lauderdale and Miami areas, with another larger area of echoes over northwestern Florida from the Tampa area northeastward to the St. Augustine, Florida area.

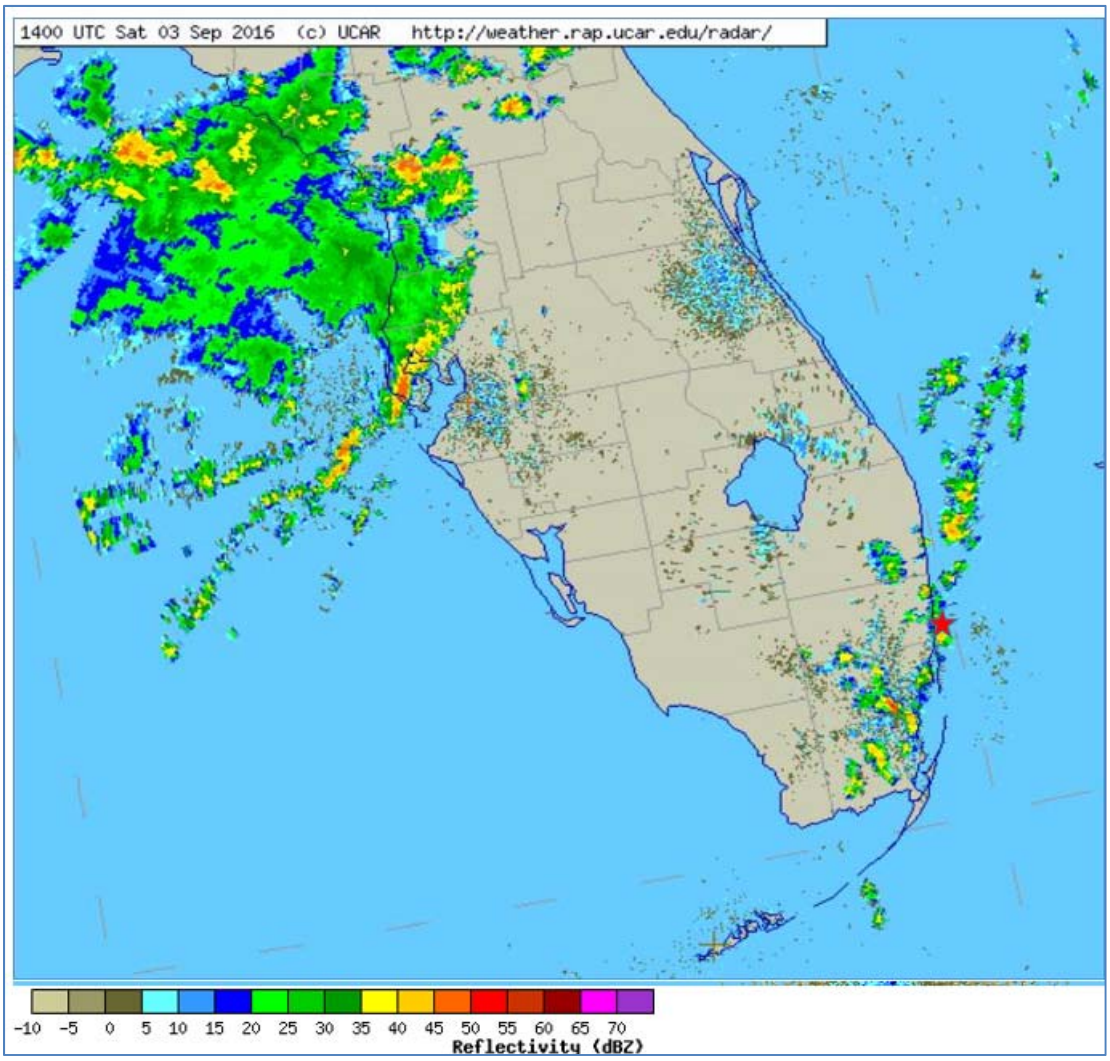


**Figure 2 - Regional radar mosaic for 1000 EDT**

Since echoes were identified in the vicinity of the accident site, the closest NWS weather surveillance radar will be further documented in section 5.0 of this report.

## 1.3 Significant Weather Prognostic Chart

The NWS WPC 12-hour Significant Weather Prognostic Chart valid at the time the flight departed was valid for 1400 EDT on Saturday September 3, 2016 is included as figure 3. The primary features noted was Tropical Storm Hermine moving into the North Carolina and Virginia coasts with high winds and rain. A stationary front was depicted east of the tropical storm stretching along the east coast into northern Florida westward along the Gulf of Mexico coastal states into Texas. A large area of precipitation was expected along the front, and all of Florida was expected to be impacted by rain showers and thunderstorms during the period. Greater than 50% coverage of precipitation was expected across central and northern Florida. Over southeast Florida, less than 50% coverage of scattered rain showers and thunderstorms were expected.

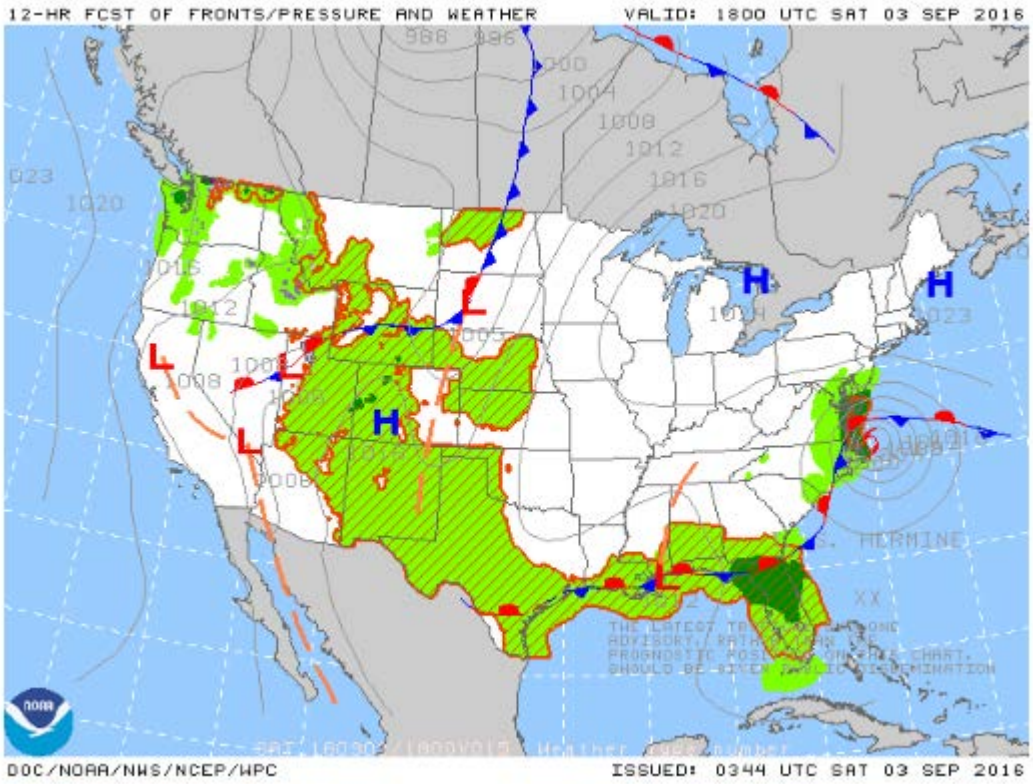


**Figure 3 - NWS 12-Hour Significant Weather prognostic Chart**

## 1.4 Convective Outlook

The NWS Storm Prediction Center's (SPC) Day 1 Convective Outlook issued at 0610 EDT on September 3, 2016 is included as figure 4. The chart depicted a general risk of air mass type thunderstorms over the southeast United States, with no organized areas of severe thunderstorms expected over the southeast during the period.

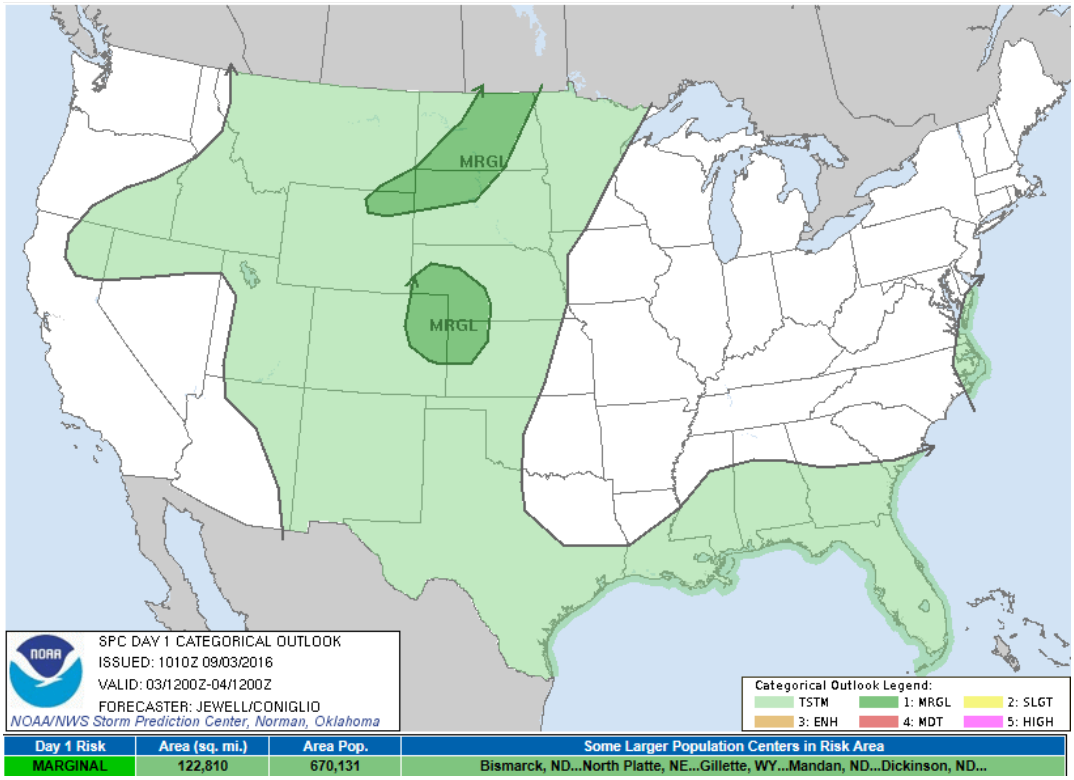


**Figure 4 - NWS SPC Convective Outlook**

## 2.0 Surface Observations

The official NWS Meteorological Aerodrome Reports (METARs) and special reports (SPECIs) sites surrounding the period were documented for the area. The cloud heights are reported above ground level (agl). The local sectional chart for the area depicted the isogonic line or magnetic variation of 6° West over the region.

## 2.1 Fort Lauderdale/Hollywood International Airport

The closest weather reporting location to the accident site was from Fort Lauderdale/Hollywood International Airport (KFLL) at an elevation of 65 feet (ft). The airport had an Automated Surface Observation System (ASOS) that was augmented by NWS certified observers. The following conditions were reported about the time of the accident:

KFLL weather observation at 0853 EDT (1253Z), wind from 230° at 5knots, visibility 10 statute miles, scattered clouds at 2,000 ft agl in cumulonimbus clouds (CB), scattered at 9,000 ft, ceiling[1] broken at 25,000 ft, temperature 29° Celsius (C) (84° F), dew point temperature 26° C (79° F), and an altimeter of 30.04 inches of mercury (Hg). Remarks: automated observation system with a precipitation discriminator, sea level pressure 1017.1-hPa, cumulonimbus cloud northeast moving north and distant or more than 10 miles south through southwest moving north, temperature 28.9° C, dew point 26.1° C.

[1] A ceiling is defined as the lowest layer of clouds reported as broken or overcast, or the vertical visibility into a surface based obscuration.

KFLL weather observation at 0953 EDT (1353Z), wind from 150° at 10 knots, visibility 10 statute miles in light rain, scattered clouds at 1,500 ft agl in cumulonimbus clouds, scattered at 6,000 ft and ceiling broken at 10,000 ft, and broken at 25,000 ft, temperature 27° C (80° F), dew point temperature 23° C (73° F), and altimeter of 30.06 inches of Hg. Remarks: automated observation system, rain began at 0952 EDT, sea level pressure 1017.1-hPa, cumulonimbus clouds overhead through north and from the west to northwest moving northeast, hourly precipitation less than 0.01 inches or a trace, temperature 26.7° C, dew point 23.3° C.

A thunderstorm was reported at the airport at 0956 EDT with occasional lightning in-cloud to the north, with no appreciable change in winds, visibility, or sky cover over the airport. Visual flight rule (VFR) conditions[2] prevailed during the period with no significant change in prevailing visibility or ceiling height surrounding the period.

The following observations in raw format and code reported surrounding the period were as follows:

*METAR KFLL 031053Z 25003KT 10SM FEW030 SCT095 SCT250 27/26 A3002 RMK AO2 SLP165 T02720256=*

*METAR KFLL 031153Z 00000KT 10SM FEW020 SCT030 BKN043 BKN250 28/26 A3003 RMK AO2 SLP168 T02780261 10278 20272 51013=*

*METAR KFLL 031253Z 23005KT 10SM SCT020CB SCT090 BKN250 29/26 A3004 RMK AO2 SLP171 CB NE MOV N AND DSNT S-SW MOV N T02890261=*

*Accident 1352Z*

*METAR KFLL 031353Z 15010KT 10SM -RA SCT015CB SCT060 BKN100 BKN250 27/23 A3006 RMK AO2 RAB52 SLP179 CB OHD-N AND W-NW MOV NE P0000 T02670233=*

*SPECI KFLL 031356Z 15008KT 10SM -TSRA FEW017CB SCT024 BKN060 27/23 A3006 RMK AO2 TSB56 OCNL LTGIC N TS N MOV NE P0000 T02670233=*

*SPECI KFLL 031424Z 13007KT 10SM SCT025CB SCT060 BKN090 27/24 A3006 RMK AO2 RAE23 TSB1356E23 CB DSNT NE AND SE AND NW MOV NE P0000 T02670239=*

*METAR KFLL 031453Z 16006KT 10SM SCT029 BKN120 BKN250 29/24 A3006 RMK AO2 RAE23 TSB1356E23 SLP178 TCU DSNT W AND NW P0000 60000 T02890244 50010=*

## 2.2 Pompano Beach Airpark

The accident airplane departed from Pompano Beach Airport (KPMP) about 0943 EDT. The airport was located about 11 miles north of the accident site at an elevation of 19 feet. The airport had an ASOS installed and reported the following conditions at the time of departure and the accident.

[2] VFR conditions are defined as no ceiling or a ceiling above 1,000 ft agl and visibility greater than 3 miles.

KPMP weather observation at 0853 EDT, wind from 250° at 3 knots, visibility 9 miles, scattered clouds at 2,000 ft agl, temperature 28° C (82° F), dewpoint 26° C (79° F), altimeter 30.05 inches of Hg. Remarks: automated observation system with a precipitation discriminator, lightning distant[3] northeast and south, sea level pressure 1017.5-hPa.

KPMP weather observation at 0953 EDT, wind from 150° at 4 knots, visibility 9 miles, scattered clouds at 3,200 ft agl, temperature 29° C (84° F), dewpoint 26° C (79° F), altimeter 30.06 inches of Hg. Remarks: automated observation system with a precipitation discriminator, lightning distant northeast and south, sea level pressure 1017.9-hPa.

Instrument flight rule (IFR) conditions[4] were reported between 1001 and 1027 EDT due to thunderstorms and rain showers. The raw observations in standard format surrounding the period were as follows:

*METAR KPMP 031053Z 00000KT 8SM FEW016 SCT090 27/26 A3002 RMK AO2 SLP167 T02720256*

*METAR KPMP 031153Z 26003KT 9SM CLR 28/26 A3004 RMK AO2 SLP173 T02780256 10283 20272 51015*

*METAR KPMP 031253Z 25003KT 9SM SCT020 28/26 A3005 RMK AO2 LTG DSNT NE SLP175*

*Accident 1352Z*

*METAR KPMP 031353Z 15004KT 9SM SCT032 29/26 A3006 RMK AO2 LTG DSNT NE AND S SLP179 T02940256*

*SPECI KPMP 031401Z VRB03KT 1 3/4SM -RA SCT018 BKN026 29/26 A3006 RMK AO2 LTG DSNT NE AND S RAB01 P0002 T02940256*

*SPECI KPMP 031409Z 07009KT 4SM +RA SCT010 BKN018 BKN025 28/25 A3007 RMK AO2 LTG DSNT NE AND S RAB01 P0006 T02780250*

*SPECI KPMP 031413Z 11008KT 2 1/2SM +RA SCT008 BKN018 OVC025 27/24 A3007 RMK AO2 LTG DSNT NE AND S RAB01 P0007 T02720244*

*SPECI KPMP 031417Z 07014G23KT 2SM +TSRA BR BKN012 BKN018 OVC025 26/24 A3007 RMK AO2 LTG DSNT NE RAB01 TSB16 P0008 T02610239*

*SPECI KPMP 031422Z VRB04G23KT 1/2SM +TSRA BKN015 OVC025 26/23 A3007 RMK AO2 VIS 1/4V5 LTG DSNT NE RAB01 TSB16 P0009 T02610228*

*SPECI KPMP 031424Z VRB03G23KT 1SM -TSRA BKN015 BKN025 27/23 A3006 RMK AO2 VIS 1/4V5 LTG DSNT NE RAB01 TSB16 P0010 T02670233*

*SPECI KPMP 031427Z VRB06KT 6SM -TSRA BKN015 BKN025 27/24 A3006 RMK AO2 LTG DSNT NE RAB01 TSB16 P0011 T02720239*

*SPECI KPMP 031435Z 17006KT 6SM HZ SCT013 28/24 A3006 RMK AO2 LTG DSNT W RAB01E32 TSB16E35 P0013 T02780244*

[3] Distant with regards to lightning means beyond 10 miles but less than 30 nautical miles of the airport location point (ALP).

[4] IFR conditions – are defined a ceiling less than 1,000 ft agl and/or visibility less than 3 statute miles visibility.

*METAR KPMP 031453Z 17004KT 6SM VCTS HZ CLR 28/24 A3006 RMK AO2 LTG DSNT SW AND W RAB01E32 TSB16E35 SLP181 P0017 60017 T02830239 52008*

*SPECI KPMP 031519Z 17004KT 10SM SCT020 30/24 A3007 RMK AO2 LTG DSNT SW AND W P0006 T03000244*

*METAR KPMP 031553Z 17005KT 10SM VCTS SCT020 31/24 A3006 RMK AO2 LTG DSNT W SLP181 P0008 T03110244*

## 3.0 Upper Air Sounding

The closest NWS upper air station or rawinsonde observation (RAOB) was from the NWS Miami (KMFL) Weather Forecast Office (WFO), site number 72202, located about 18 miles south of the accident site at an elevation of 13 feet. The 0800 EDT (1200Z) observation was plotted on a standard Skew-T log P diagram[5] from the surface to 500-hPa or 18,000 ft utilizing RAOB software[6] and is included as figure 5.

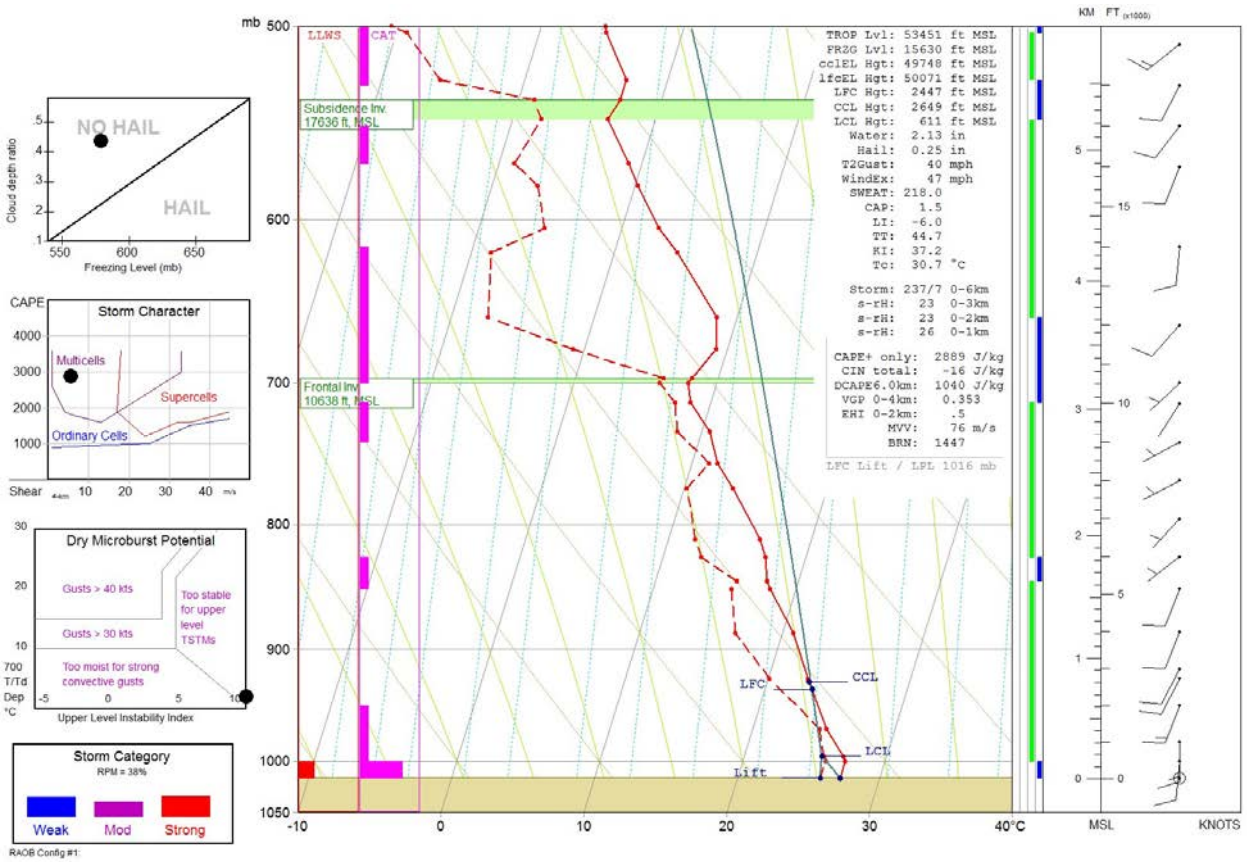


**Figure 5 - Miami 0800 EDT upper air observation**

[5] Skew T log P diagram – is a standard meteorological plot or thermodynamic diagram 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.

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

The KMFL upper air sounding at 0800 EDT (1200Z) depicted a warm moist low-level environment with a surface relative humidity 92% and a conditional unstable atmosphere supporting multicellular type thunderstorms with a Lifted Index (LI) of -6 and the most unstable LI of -7, with a K-index of 37.2 which indicated an approximate 80% chance of storms. The Convective Available Potential Energy (CAPE)[7] value was high at 2,889 Joules/Kilogram (J/kg), with the most unstable CAPE at 3,559 J/kg. Due to the extremely unstable atmosphere, the potential updraft strength or maximum vertical velocity (MVV)[8] was calculated at 76 meters/second or 147 knots, or assuming a half value would have implied potential updrafts of over 6,000 feet/minute. The downdraft potential was also determined to be strong with a DCAPE[9] value of 1,040 J/kg. The T2 Gust and Windex or microburst wind estimates were at approximately 40 knots. The lifted condensation level (LCL)[10] was at about 600 ft agl, the level of free convection (LFC)[11] at 2,430 ft agl, and the convective condensation level (CCL)[12] at 2,640 ft agl, with the equilibrium level (EL)[13] or expected convective cloud tops at 50,000 ft. The freezing level was at 15,630 ft. The mean 0 to 6 kilometer or 18,000 feet wind was from the south or from 210° at 9 knots, and the expected storm motion was 240° or towards the northeast at 7 knots. The relative humidity was greater than 90% from the surface through 2,000 feet, with a density altitude of 1,739 feet based at the surface and a temperature of 27.2° C or 81° F. The threat of carburetor icing was light below 2,500 feet, and increased to moderate above 2,700 feet through 10,000 feet.

## 4.0 Satellite Imagery

The Geostationary Operational Environmental Satellite number 13 (GOES-13) 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

---

[7] Convective Available Potential Energy (CAPE) – is a measure of the amount of energy available for convection. CAPE is directly related to the maximum potential vertical speed within an updraft; thus, higher values indicate greater potential for severe weather.

[8] MVV is often an overestimate in storms and MVV/2 is often considered a more realist estimate of the updrafts.

[9] DCAPE – Downdraft CAPE 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 and DCAPE values over 1,000 J/kg have been associated with strong thunderstorm downdrafts and damaging outflow winds.

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

[11] Level of Free Convection (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.

[12] Convective Condensation Level (CCL) - The height to which a parcel of air, if heated sufficiently from below, will rise adiabatically until condensation starts. This is typically used to identify the base of cumuliform clouds, which are normally produced from surface heating and thermal convection.

[13] Equilibrium Level (EL) - On a sounding, the level above the level of free convection (LFC) at which the temperature of a rising air parcel again equals the temperature of the environment. The height of the EL is the height at which thunderstorm updrafts no longer accelerate upward. Thus, to a close approximation, it represents the height of expected (or ongoing) thunderstorm tops. However, strong updrafts will continue to rise past the EL before stopping, resulting in storm tops that are higher than the EL. This process sometimes can be seen visually as an overshooting tops or anvil dome. The EL typically is higher than the tropopause, and is a more accurate reference for storm tops.

System (McIDAS) software. Both the infrared long wave and visible band imagery were obtained surrounding the time of the accident. The infrared long wave imagery (band 4) at a wavelength of 10.7 microns (μm) provided standard satellite image with radiative cloud top temperatures with a resolution of 4 km. The visible imagery (band 1) at a wavelength of 0.65 μm provided a resolution of 1 km.

Figure 6 is the GOES-13 infrared image for 0955 EDT at 4X magnification with a standard MB temperature enhancement curve applied to highlight the higher and colder cloud tops associated with deep convection and/or high cirriform type clouds. The image depicted several scattered areas of cumulus congestus to cumulonimbus type clouds with enhanced cloud tops over southeast Florida, with one extending over the accident site. The radiative cloud top temperature over the KFLL area indicated by the red enhancement was 234° Kelvin or -39° C, which corresponded to cloud tops near 36,000 feet based on the Miami sounding. Several other larger cumulonimbus cloud with enhancement were noted to the northwest of the Tampa area (KTPA) with tops estimated near 46,000 feet, and north of the Cross City area (KCTY). It should be noted these figures have not been corrected for any parallax error.

The GOES-13 visible images at 0945, 0955, and 1000 EDT are included as figures 6 through 9 at 3X magnification. The images depict a short band of cumulus congestus to cumulonimbus type clouds over the southeast Florida coast and over the accident site.

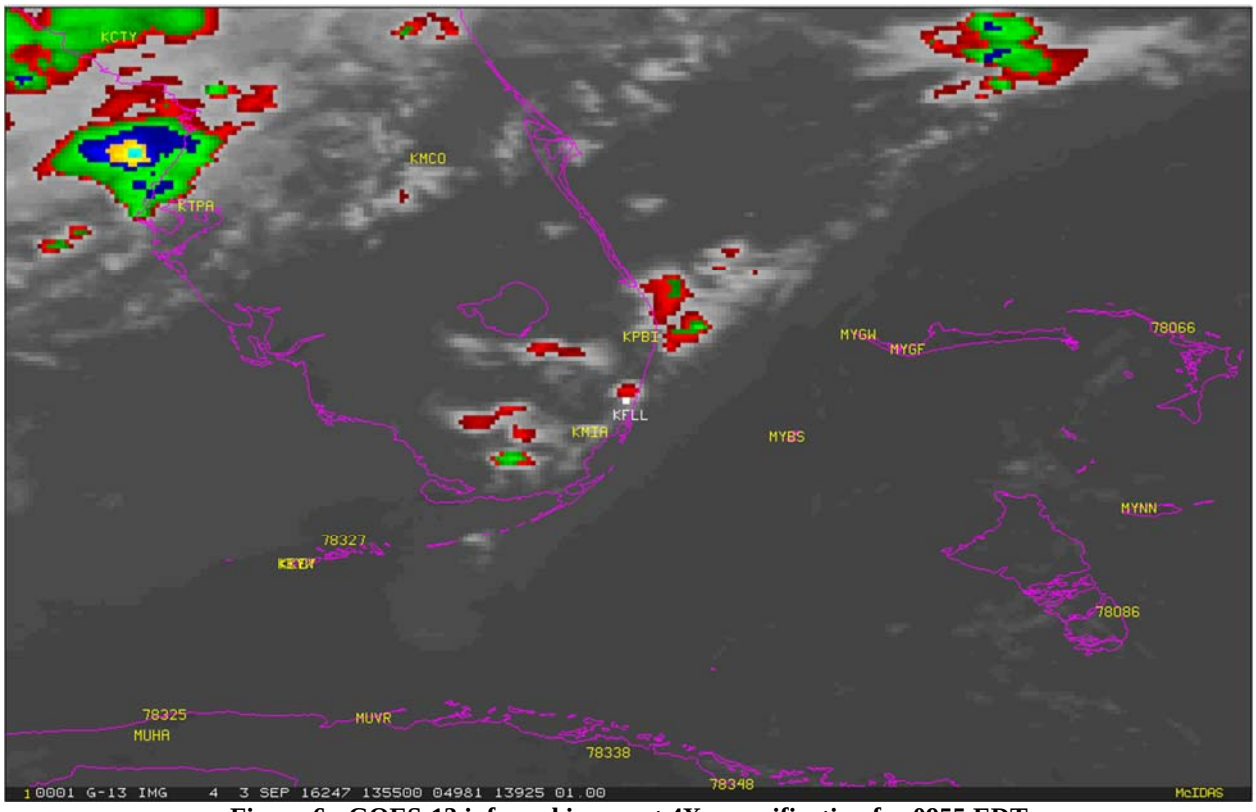


**Figure 6 - GOES-13 infrared image at 4X magnification for 0955 EDT**

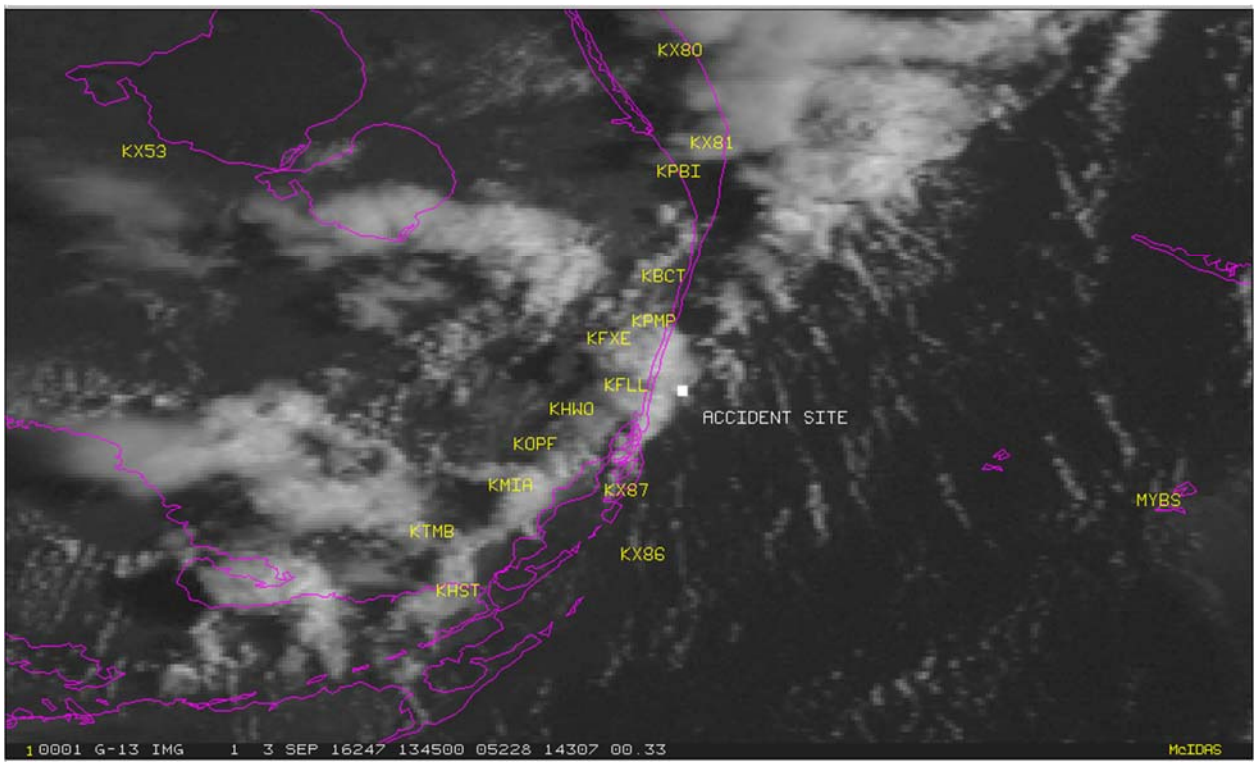


**Figure 7 - GOES-13 visible image at 0945 EDT at 3X magnification**

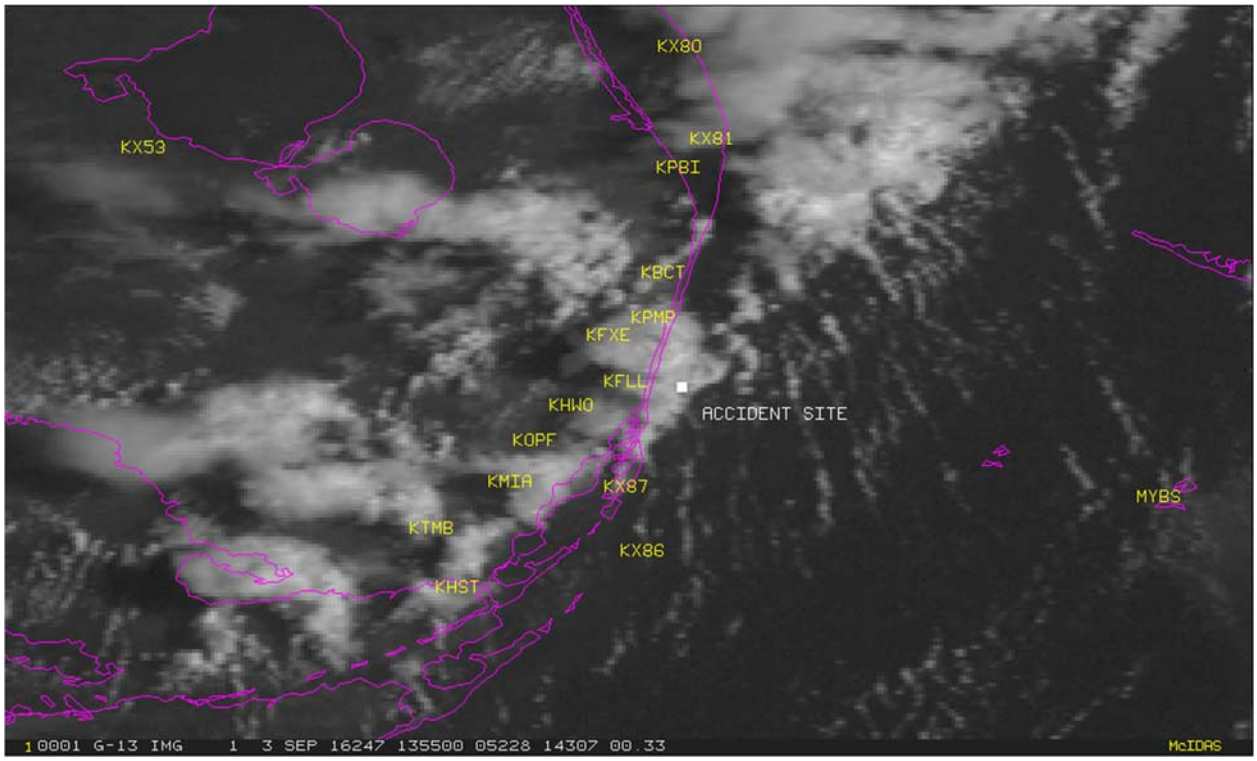


**Figure 8 - GOES-13 visible image at 0955 EDT at 3X magnification**

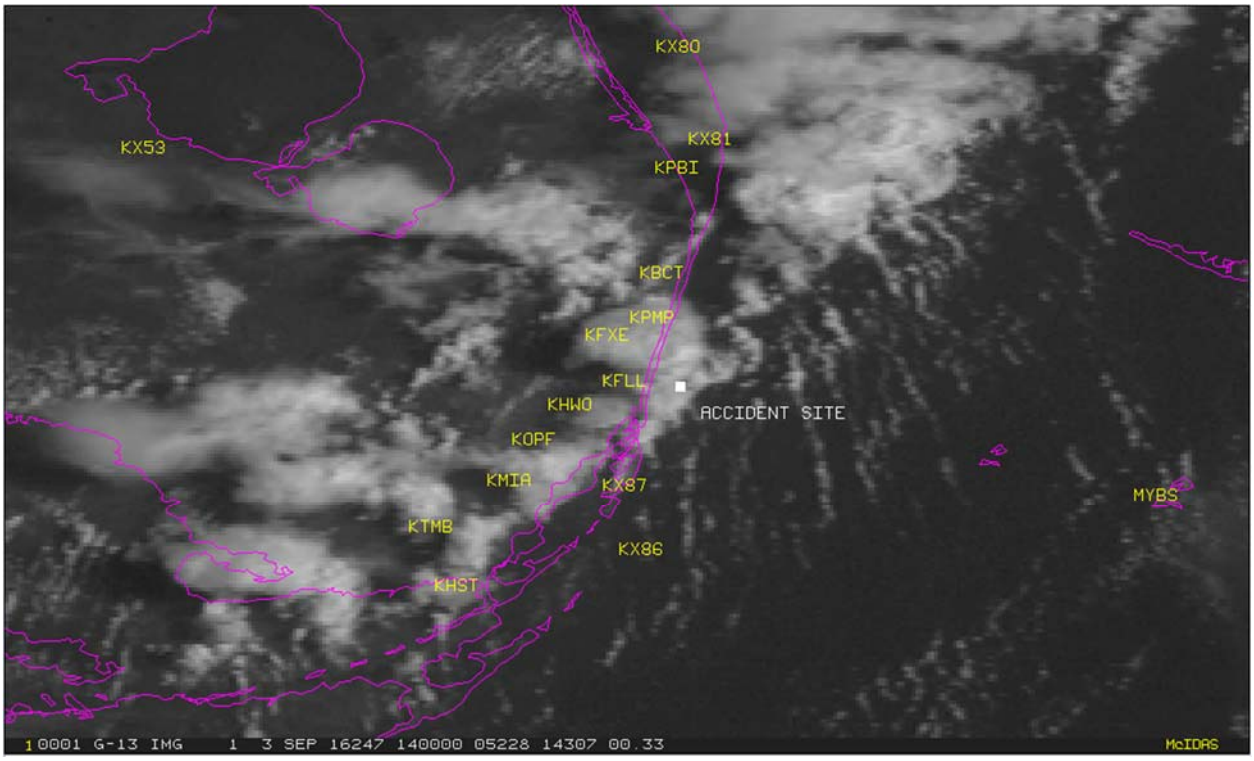


**Figure 9 - GOES-13 visible image at 1000 EDT at 3X magnification**

## 5.0 Weather Surveillance Radar

The closest Weather Surveillance Radar-1988, Doppler (WSR-88D) to the accident site was the NWS Miami (KAMX) site location about 32 miles south-southwest of the accident site, and about 10 miles south of the KMFL WFO. The level II and III archive data was obtained from the NCEI using the Hierarchical Data Storage System and displayed using the NWS NEXRAD Interactive Viewer and Data Exporter software.

The WSR-88D is a S-band 10 centimeter wavelength radar with a power output of 750,000 watts, with a 28-foot parabolic antenna concentrating the energy into a 0.95° beam width. The radar produces three basic types of products reflectivity, radial velocity, and spectral width.

## 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 on the WSR-88D's Principle Users Processor. Products that require data from multiple elevation scans are not available until the end of the five to ten minute volume scan.

The WSR-88D operates in several different scanning modes, identified as Mode A and Mode B. Mode A is the precipitation scan and has three common scanning strategies. The most common is where the radar makes 14 elevation scans from 0.5° to 19.5° every four minutes. This particular scanning strategy is documented as volume coverage pattern 12 (VCP-12). Mode B is the clear-

air mode, where the radar makes 5 elevation scans during a ten minute period. During the period surrounding the accident, the KAMX WSR-88D radar was operating in the precipitation mode (Mode A, VCP-12).

## 5.2 Reflectivity

Reflectivity is the measure of the efficiency of a target in intercepting and returning radio energy. With hydrometeors[14], it is a function of the drop size distribution, number of particles per unit volume, physical state (ice or water), shape, and aspect. Reflectivity is normally displayed in decibels (dBZ[15]), and is a general measure of echo intensity. The chart below relates the NWS video integrator and processor (VIP) intensity levels versus the WSR-88D's display levels, precipitation mode reflectivity in decibels, and rainfall rates.

**NWS VIP/DBZ CONVERSION TABLE**

| NWS VIP | WSR-88D Level | PREC MODE dBZ | RAINFALL |
|---|---|---|---|
| 0 | 0 | < 5 | |
| | 1 | 5 to 9 | |
| | 2 | 10 to 14 | |
| 1 | 3 | 15 to 19 | .01 in/hr |
| Very Light | 4 | 20 to 24 | .02 in/hr |
| | 5 | 25 to 29 | .04 in/hr |
| 2 | 6 | 30 to 34 | .09 in/hr |
| Light to | 7 | 35 to 39 | .21 in/hr |
| Moderate | | | |
| 3 | 8 | 40 to 44 | .48 in/hr |
| Strong | | | |
| 4 | 9 | 45 to 49 | 1.10 in/hr |
| Very Strong | | | |
| 5 | 10 | 50 to 54 | 2.49 in/hr |
| Intense | | | |
| 6 | 11 | 55 to 59 | >5.67 in/hr |
| Extreme | 12 | 60 to 64 | |
| | 13 | 65 to 69 | |
| | 14 | 70 to 74 | |
| | 15 | > 75 | |

Air traffic control (ATC) weather display systems also use radar weather processors with the ability to determine precipitation intensity, with controllers instructed to describe the intensity to

[14] Hydrometeors are any product of condensation or sublimation of atmospheric water vapor, whether formed in the free atmosphere or at 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 glaze ice.

[15] dBZ - 10 log Ze

pilots based on the following table[16]. One exception is that the centers weather and radar processor system does not display light intensity echoes below 30 dBZ. This table is also referenced for pilots in Advisory Circular AC 00-24C - "Thunderstorm".

| Reflectivity (dBZ) Ranges | Weather Radar Echo Intensity Terminology |
|---|---|
| **< 30 dBZ** | Light |
| **30 – 40 dBZ** | Moderate |
| **>40 – 50 dBZ** | Heavy |
| **>50 dBZ** | Extreme |

## 5.3 Beam Calculations

Based on the accident site being 32 miles from the KAMX radar antenna, which had an antenna height of 111 ft, the center of the 0.5° elevation scan beam was at about 2,490 ft with the beam base near 870 ft and the top of the beam near 3,220 ft.

## 5.4 Composite Reflectivity Imagery

Composite reflectivity images use all the elevation scans during the volume scan to create the image, and is composed of the highest reflectivity value from any elevation angle scan of a volume scan by the radar. As such, it provides a synopsis of the most important reflectivity features in the entire coverage area, and can help determine some storm structural features and intensity trends in storms when compared to base products. Composite images are not available until the end of the volume scan period and are also used by inflight weather in the cockpit displays, and in the generation of some ATC weather displays.

Figures 10 through 13 are the KAMX WSR-88D composite reflectivity images at 0938, 0943, 0948, and 0953 EDT with the accident site noted. The images depict a band of heavy to extreme intensity echoes along the southeast Florida coast and immediately east of KFLL during the period, with the echoes in the immediate vicinity of the accident site reaching maximum intensity and then decreasing in intensity with time and moving north-northeastward. Attachment 1 is an animation of the composite radar imagery from 0903 through 1004 EDT (1304Z-14004Z), which shows the rapid development and dissipation of multiple cells over the area. One cell develops rapidly over the departure airport very quickly and reaches 50 dBZ intensity within 10 minutes near the end of the sequence.

[16] FAA Joint Order 7110.65W - Air Traffic Control, section 2-6-4 "Weather and Chaff Services".

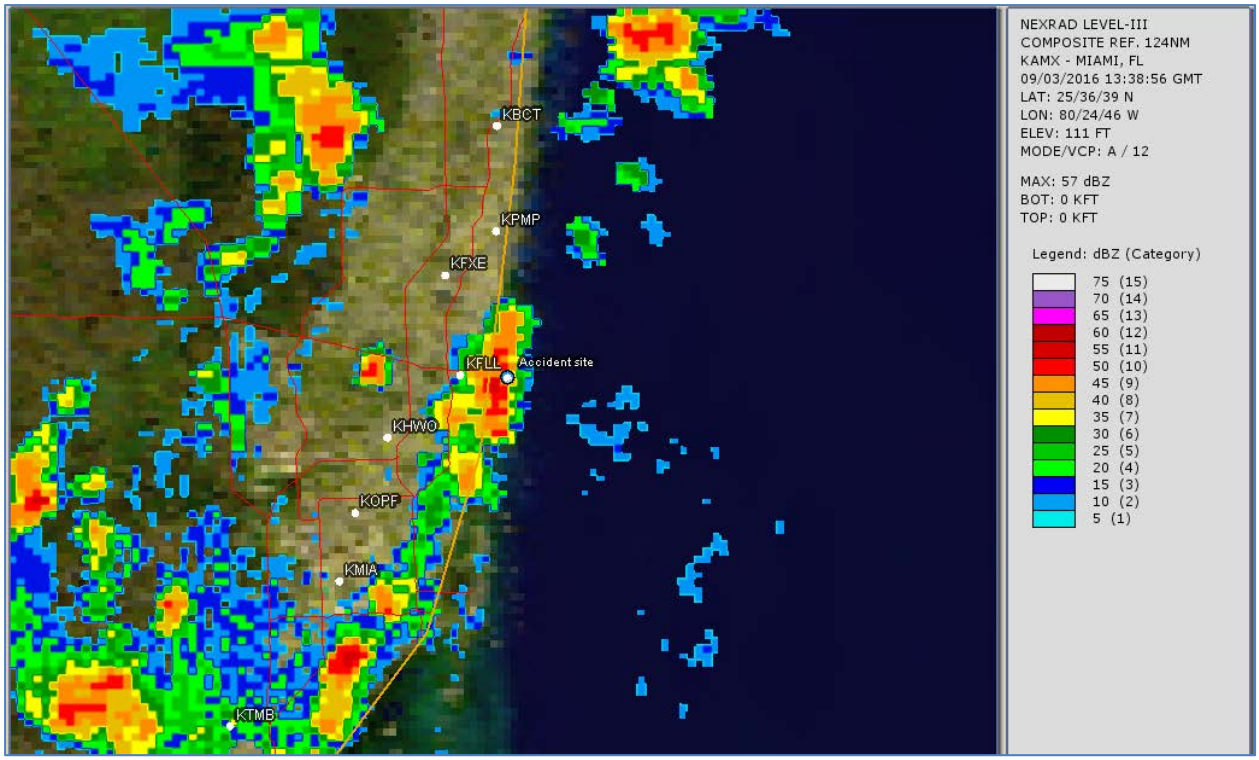


**Figure 10 - KAMX WSR-88D composite reflectivity image at 0938 EDT**

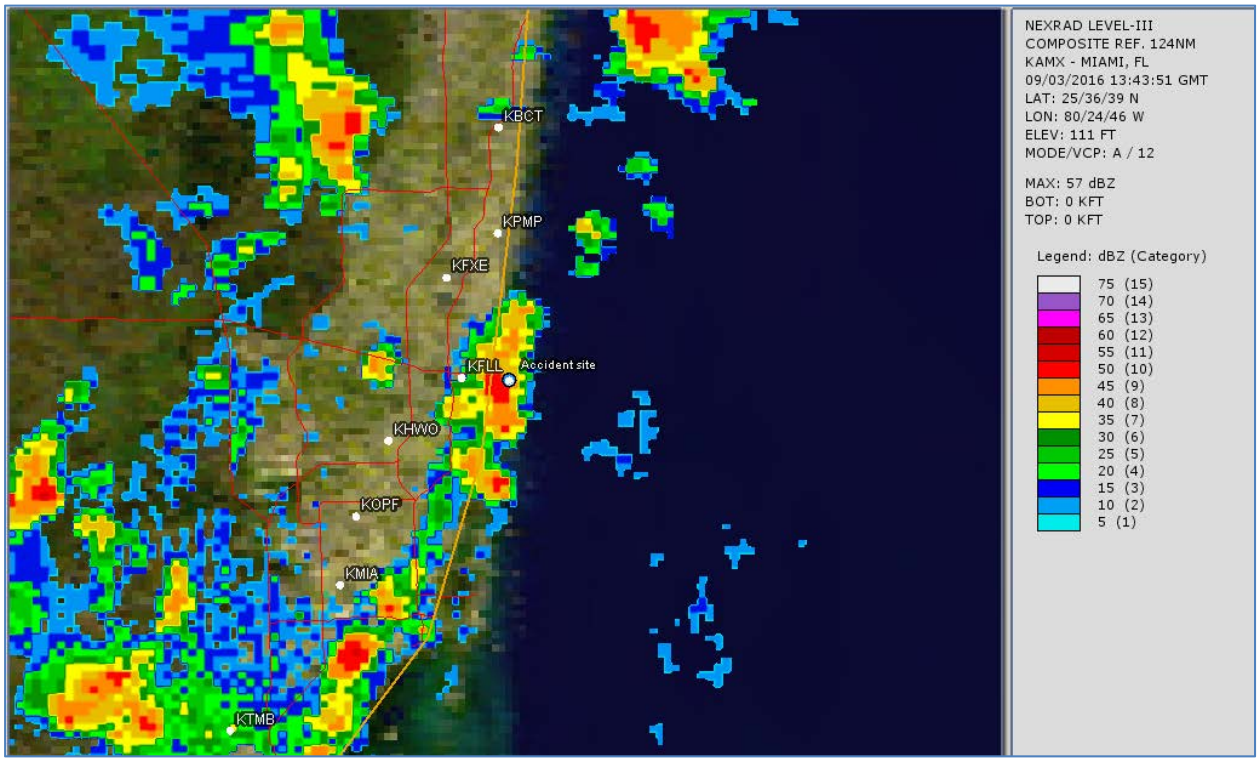


**Figure 11 - KAMX WSR-88D composite reflectivity image at 0943 EDT**

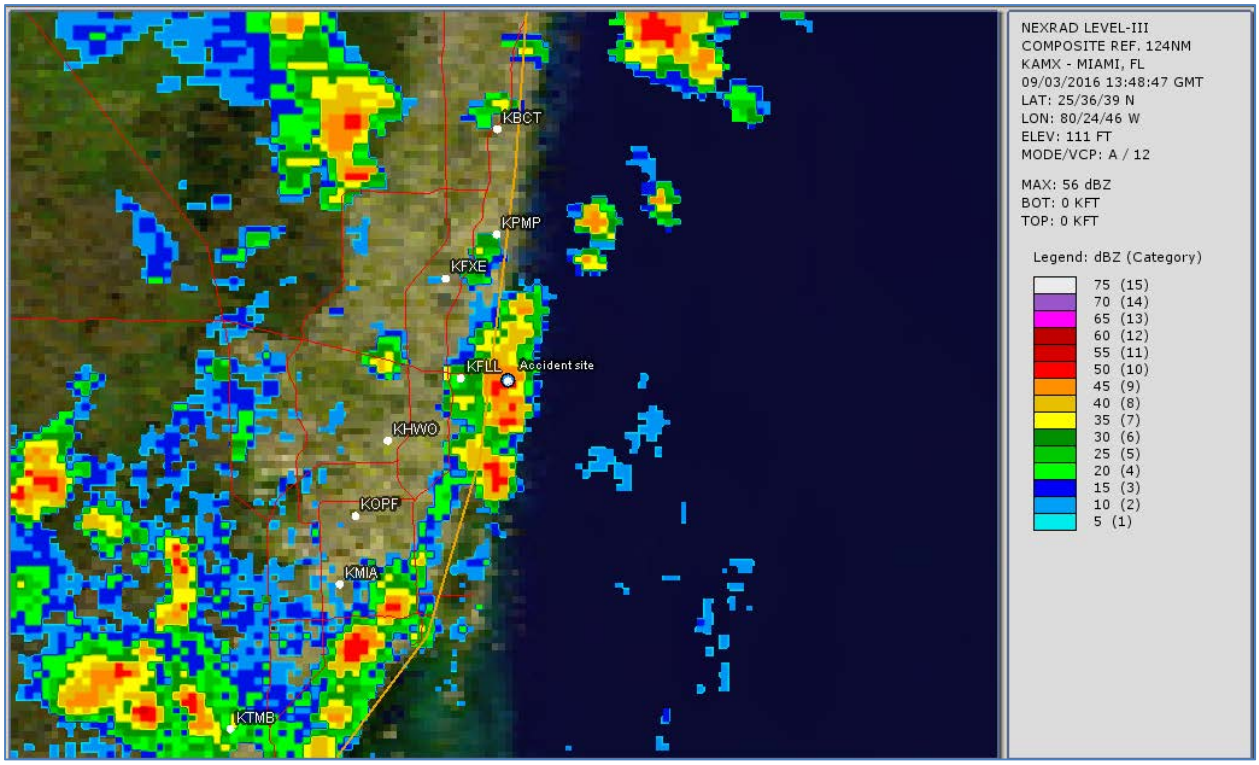


**Figure 12 - KAMX WSR-88D composite reflectivity image at 0948 EDT**

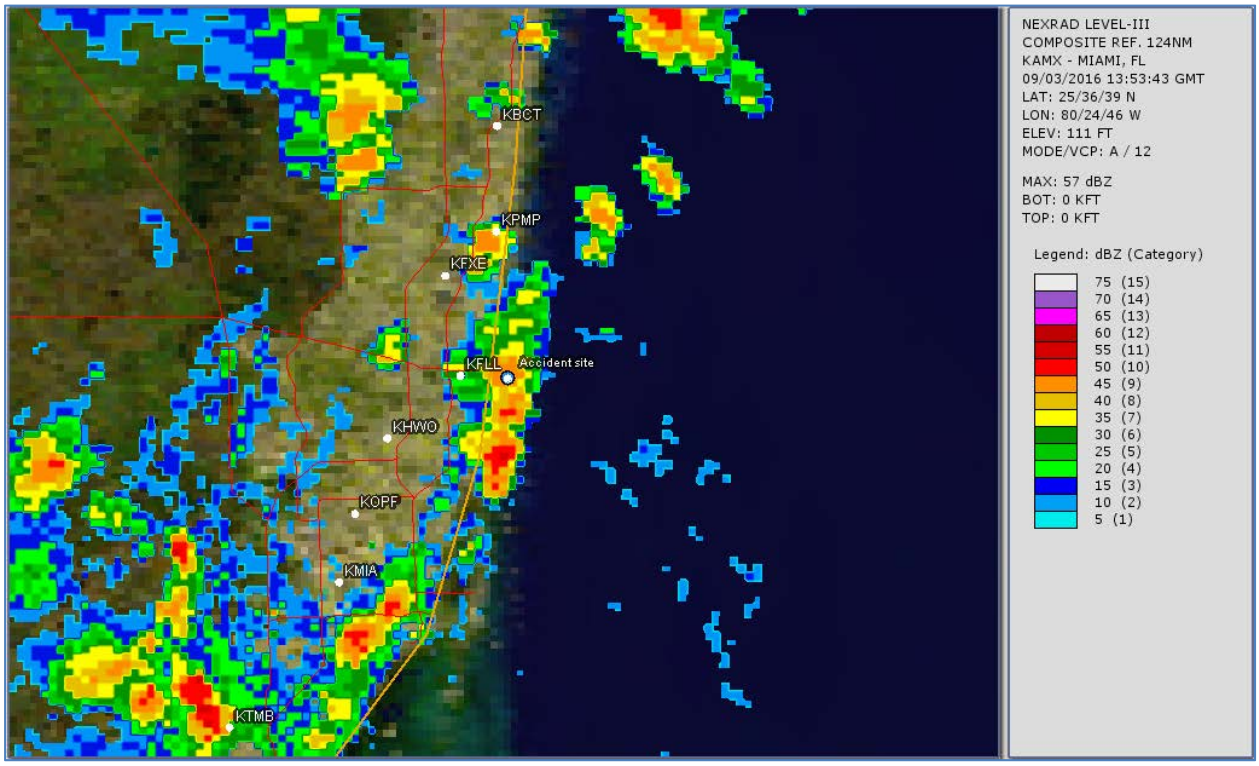


**Figure 13 - KAMX WSR-88D composite reflectivity image at 0953 EDT**

## 5.5 Base Reflectivity Imagery

The KAMX WSR-88D 0.5° base reflectivity image at 0953 EDT sampling the lowest section of the weather with the flight path departing KPMP obtained from the accident airplanes GPS data and the final accident site is included as figures 14 and 15. Figure 15 has a 50% transparency applied to show the surface features and the location of the KFLL airport. The accident site was located under a small but intense reflectivity core of 51 dBZ or "extreme" intensity. Attachment 2 is an animation of the base reflectivity images surrounding the period, showing the echoes near the surface and several of the intense cells develop over the area. An area of very light intensity echoes of 0 to 10 dBZ is noted moving eastward and away from the cluster over the accident site evident of an outflow boundary or gust front. While not evident in the radial velocity images a shallow outflow boundary appears in the area east of the main precipitation area moving outward.

Figure 16 presents the air traffic control weather display at the approximate time of the accident. Please see the ATC Specialist Report for further details on the Standard Terminal Automated Replacement System (STARS) radar display.

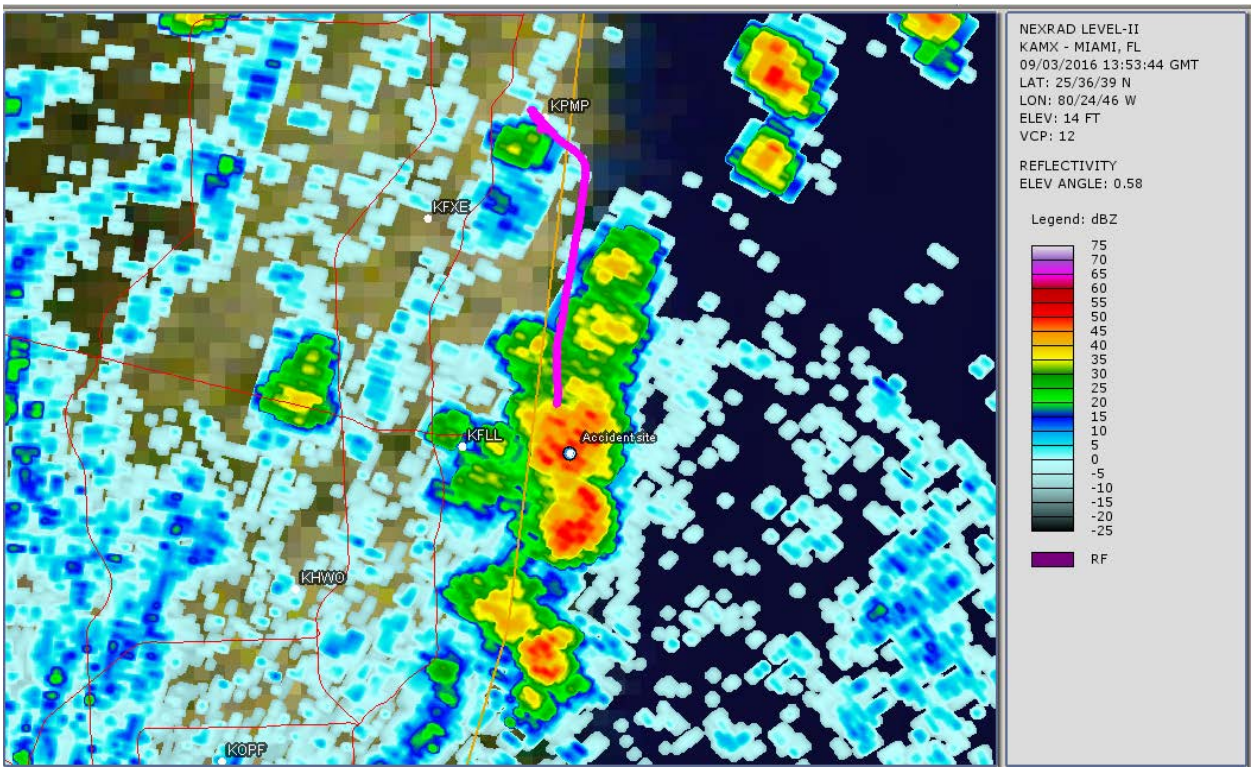


**Figure 14 - KAMX WSR-8D 0.5° base reflectivity image at 0953 EDT**

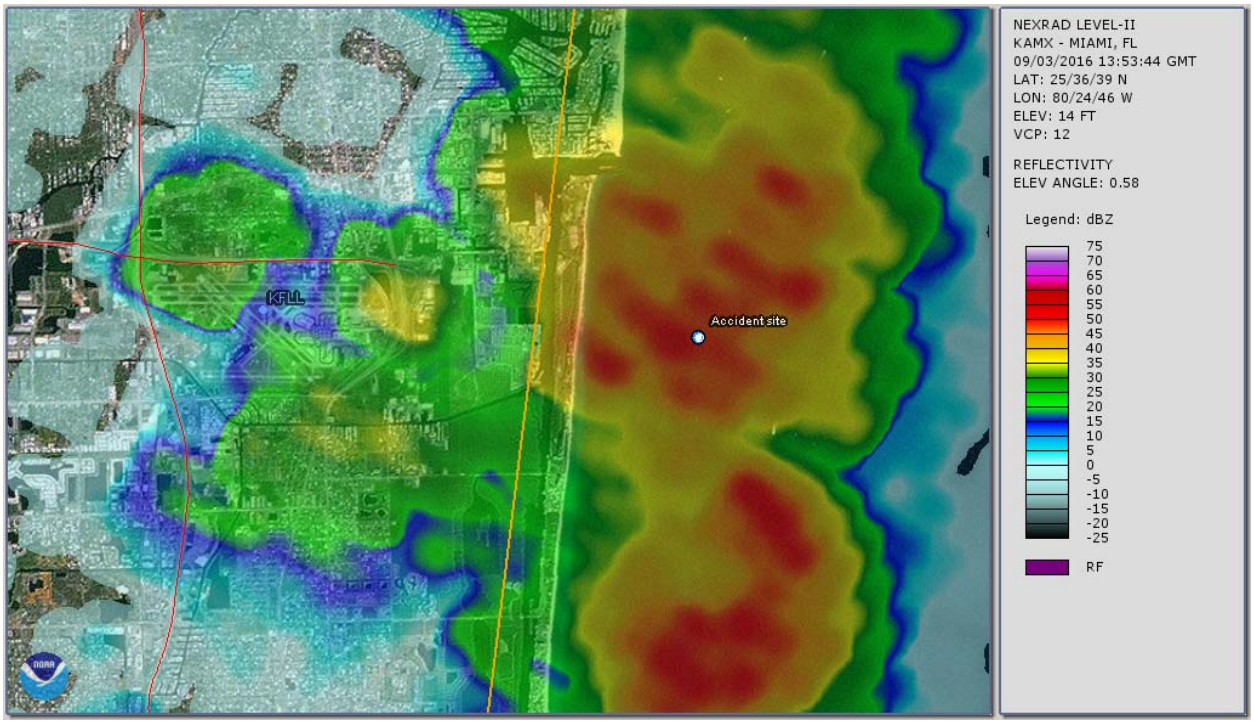


**Figure 15 - KAMX WSR-88D 0.5° base reflectivity image at 0953 EDT and KFLL airport location**

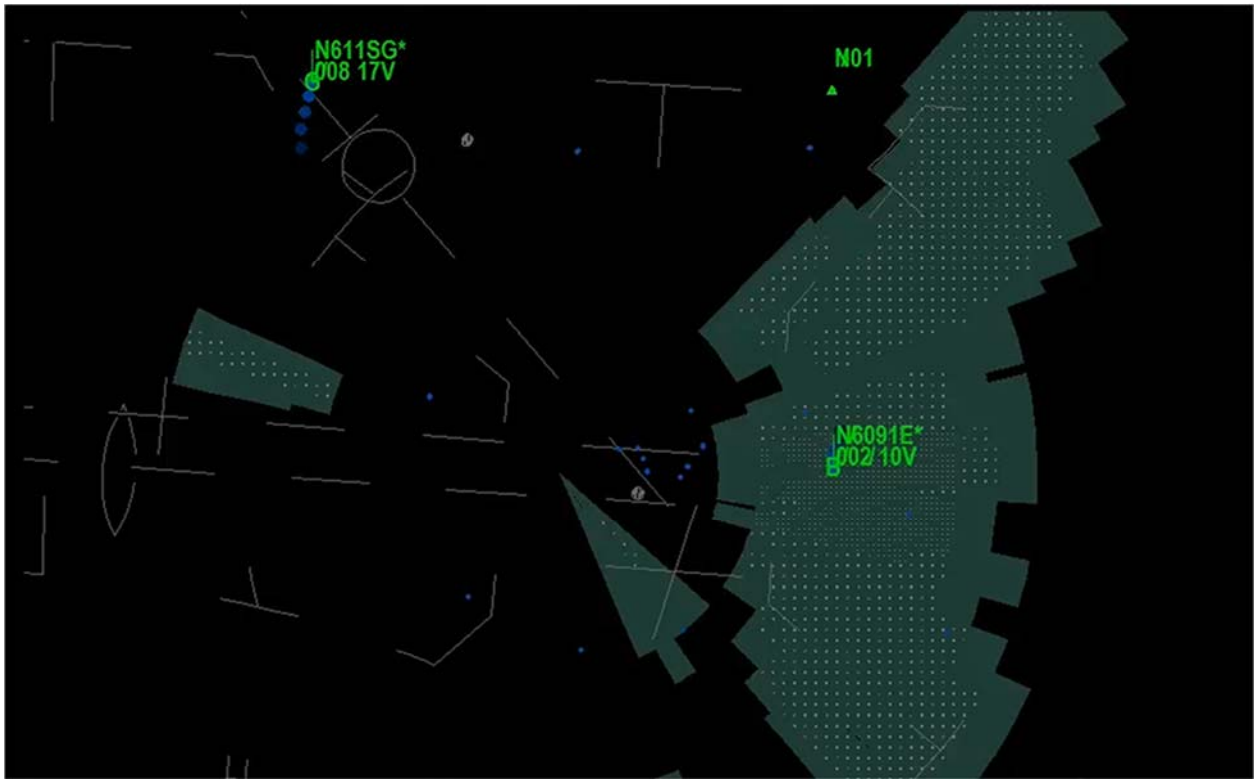


**Figure 16 - Air Traffic Control STAR weather display at about 0952 EDT**

Figure 17 is the KAMX WSR-88D vertical cross section north-to-south along the general flight track for the base reflectivity data at 0943, 0948, and 0953 EDT utilizing GR2Analyst radar software[17]. The composite image shows the change in the echoes with time and the vertical collapse of the main echo core during the period. The image shows an area of echoes reaching 53 to 56 dBZ reaching near 12,000 ft and then collapse to the surface during the period. The image on the right or at 0953 EDT still depicts an echo of 51 dBZ near the base of the scan, and at 0948 EDT at 52 dBZ, and at 0953 EDT at 51 dBZ. The main echo core of 40 dBZ and greater reaches a height of 21,000 ft at 0943 EDT, then collapses to 15,000 ft at 0948 EDT, and to 12,000 ft at 0953 EDT. The maximum echo tops over the accident site reached up to 44,000 feet at 0948 EDT and were just below 40,000 ft at the time of the accident.

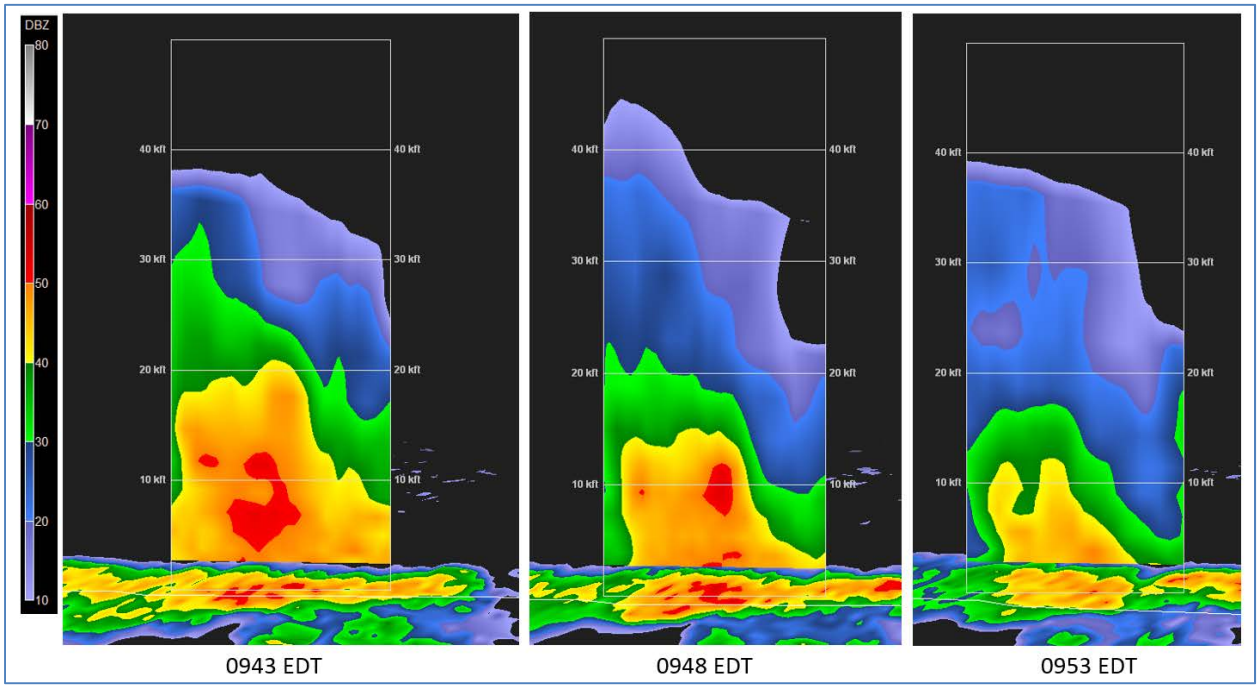


**Figure 17 - Cross section of the KAMX WSR-88D base reflectivity data at 0943, 0948 and 0953 EDT**

## 6.0 Pilot Reports

The following pilot reports or PIREPs were recorded over southeast Florida between 0800 through 1300 EDT, the reports are taken from standard code and abbreviations, and reproduced in plain language with the time converted from UTC to EDT. The reports are as follows:

Palm Beach International Airport (PBI) routine pilot report (UA); Over – 15 miles east of PBI; Time – 0835 EDT; Flight Level – 9,000 ft; Type aircraft – Saab 340 regional commuter multiengine turboprop; Sky cover – broken clouds at 6,500 ft; Weather – heavy rain with towering cumulus clouds (TCU) development.

[17] GR2Analyst software was created by Gibson Ridge Software, LLC and is a computer program that allows analysis and viewing of Level II radar data.

Fort Lauderdale/Hollywood International Airport (FLL) routine pilot report (UA); Over – 020° azimuth and 15 miles from FLL VORTAC; Time – 0843 EDT; Flight Level – 5,000 ft; Type aircraft – Boeing 737 air carrier jet; Sky cover – broken clouds at 5,000 ft.

Melbourne International Airport (MLB) routine pilot report (UA); Over – MLB; Time – 0851 EDT; Flight Level – 3,500 ft; Type aircraft – Piper Warrior single engine airplane; Remarks – high cirriform clouds visual meteorological conditions.

Palm Beach International Airport (PBI) urgent pilot report (UUA); Over – 090° azimuth and 10 miles east of PBI VORTAC; Time – 0900 EDT; Flight Level – 600 ft; Type aircraft – Piper Warrior single engine airplane; Weather – well defined waterspout.

Palm Beach International Airport (PBI) routine pilot report (UA); Over – 15 miles southeast of PBI; Time – 0919 EDT; Flight Level – 4,000 ft; Type aircraft – Gulfstream G-V executive business jet; Sky cover – broken clouds at 4,500 ft; Weather – light rain.

Fort Lauderdale/Hollywood International Airport (FLL) routine pilot report (UA); Over – 1 miles west of FLL; Time – 0921 EDT; Flight Level – 100 ft; Type aircraft – Saab 340 regional commuter multiengine turboprop; Remarks – smooth ride.

Palm Beach International Airport (PBI) routine pilot report (UA); Over – 20 miles southeast of PBI; Time – 0922 EDT; Flight Level – 3,00 ft; Type aircraft – Cessna Skyhawk single engine airplane; Sky cover – Overcast clouds; Weather – instrument flight rule conditions.

Fort Lauderdale/Hollywood International Airport (FLL) routine pilot report (UA); Over – 1 miles east of FLL; Flight Level – 100 ft; Type aircraft – Airbus A319 air carrier jet; Remarks – smooth ride.

Miami International; Airport (MIA) routine pilot report (UA); Over – 3 miles northeast of MIA; Time – 0945 EDT; Flight Level – 1,000 ft; Type aircraft - Airbus A319 air carrier jet; Weather – moderate rain; Turbulence - light chop.

Palm Beach International Airport (PBI) routine pilot report (UA); Over – 27 miles southeast of PBI; Time – 1026 EDT; Flight Level – 2,600 ft; Type aircraft – Piper Aztec multiengine airplane; Sky cover – scattered clouds at 3,000 ft and broken at 4,000 ft; Weather – light rain.

Miami International; Airport (MIA) routine pilot report (UA); Over – 7 miles northwest of Opa-Locka Executive Airport (OPF); Time – 1038 EDT; Flight Level – 2,000 ft; Type aircraft – Cessna Citation executive corporate jet; Weather – light rain; Turbulence – None.

Miami International; Airport (MIA) routine pilot report (UA); Over – 8 miles northeast of OPF; Time – 1046 EDT; Flight Level – 1,500 ft; Type aircraft – Cessna Skyhawk single engine airplane; Weather – light to moderate rain; Turbulence – light to moderate.

Palm Beach International Airport (PBI) routine pilot report (UA); Over – 280° azimuth and 10 miles from PBI VORTAC; Time – 1200 EDT; Flight Level – 2,000 ft; Type aircraft – Lear jet

Longhorn executive corporate jet; Sky cover – scattered clouds at 2,200 ft; Weather – visibility 10 miles.

Orlando Executive Airport (ORL) routine pilot report (UA); Over – the airport; Time – 1234 EDT; Flight Level – 2,200 ft; Type aircraft – Airbus A319 air carrier jet; Weather – heavy rain.

Orlando Executive Airport (ORL) routine pilot report (UA); Over – the airport; Time – 1237 EDT; Flight Level – 2,200 ft; Type aircraft – Boeing 737 air carrier jet; Remarks – low-level wind shear with +/- 20 knots of airspeed.

Orlando International Airport (MCO) routine pilot report (UA); Over – runway 18L descent; Time – 1238 EDT; Flight Level – 1,500 ft; Type aircraft – Airbus A321 air carrier jet; Turbulence – low-level wind shear increase of 5 knots of airspeed on final; Remarks – heavy rain on rollout with a smooth ride.

The raw PIREPs in their original form were as follows:

*PBI UA /OV 15 E PBI/TM 1235/FL90/TP SF34/SK BKN065/WX +RA WITH TCU DEVELOPMENT=*
*FLL UA /OV FLL020015/TM 1243/FL050/TP B737/SK BKN 050=*
*MLB UA /OV MLB /TM 1251 /FL035 /TP P28A /RM HI CI VMC=*
***PBI UUA /OV PBI090010 /TM 1300 /FL006 /TP P28A /WX +FC /RM WATERSPOUT=***
*PBI UA /OV 15 SE PBI/TM 1319/FL40/TP G5/SK BKN045/WX -RA=*
*FLL UA /OV FLL275001/TM 1321/FL001/TP SF34/RM SMOOTHE RIDE=*
*PBI UA /OV 20 SE PBI/TM 1322/FL30/TP C172/SK OVC/WX IFR=*
*FLL UA /OV FLL095001/TM 1331/FL001/TP A319/RM SMOOTHE RIDE=*
*MIA UA /OV 3 NE/TM 1345/FL010/TP A319/WX RAIN/TB LIGHT CHOP=*
*PBI UA /OV 27 SE PBI/TM 1426/FL026/TP PA23/SK SCT 030 KBN 40/WX -RA=*
*MIA UA /OV 8 NE OPF/TM 1438/FL020/TP C750/WX LGT RN/TB NONE=*
*MIA UA /OV 7 NW OPF/TM 1446/FL015/TP C172/WX LGT TO MDT RN/TB LGT TO MDT=*
*PBI UA /OV PBI 28010/TM 1600/FL020/TP LJ55/SK SCT022/WX 10SM=*
*ORL UA /OV 000000/TM 1634/FL022/TP A321/WX +RA=*
*ORL UA /OV 000000/TM 1637/FL022/TP B738/WV +/-20KTS=*
*MCO UA /OV RWY 18L DESCENT/TM 1638/FL015/TP A321/TB +5 KTS ON FINAL/RM HEAVY RAIN ON ROLLOUT SMOOTH RIDE=*

## 7.0 Area Forecast

The Area Forecast (FA) is a forecast of VFR clouds and weather conditions over an area as large as the size of several states. It must be used in conjunction with the Airman's Meteorological Information (AIRMET) Sierra bulletin for the same area in order to get a complete picture of the weather. The area forecast together with the AIRMET Sierra bulletin are used to determine forecast enroute weather and to interpolate conditions at airports which do not have a terminal forecast (TAF) issued. The NWS Aviation Weather Center (AWC) located in Kansas City, Missouri, issues the FA at regular intervals and issues specials reports as necessary usually in the form of an AIRMET. The forecasts current at the time of the accident was issued at 0445 EDT and valid until 1700 EDT, and was as follows:

*FAUS42 KKCI 030845*
*FA2W*
*MIAC FA 030845*

*SYNOPSIS AND VFR CLDS/WX*
*SYNOPSIS VALID UNTIL 040300*
*CLDS/WX VALID UNTIL 032100...OTLK VALID 032100-040300*
*NC SC GA FL AND CSTL WTRS E OF 85W*
*.*
*SEE AIRMET SIERRA FOR IFR CONDS AND MTN OBSCN.*
*TS IMPLY SEV OR GTR TURB SEV ICE LLWS AND IFR CONDS.*
*NON MSL HGTS DENOTED BY AGL OR CIG.*
*.*
*SYNOPSIS...SEE LATEST TPC ADVISORIES FOR TC HERMINE LOCATED OVR ERN NC...MOV NEWD. 09Z STNR FNT ALG A 180E ECG-ECG-30SE CHS-30N*
*CRG-TLH-SJI LN. 03Z STNR FNT ALG A 200S ACK-30SE SBY-ECG-60SE CHS-30N CRG-GLH-SJI LN.*
*.*
*FL*
*PNHDL...*
*W HLF...SCT030 SCT CI. 16Z SCT-BKN040 TOPS 080. WDLY SCT -TSRA. CB TOPS FL400. OTLK...VFR TSRA.*
*E HLF...BKN010 TOPS 100. VIS 5SM BR. 14Z SCT030. 19Z WDLY SCT -TSRA. CB TOPS FL400. OTLK...VFR TSRA. 01Z VFR.*
*NRN PEN...SCT015-025 OVC035 TOPS 150. WDLY SCT -SHRA/-TSRA. CB TOPS FL400. 14Z BKN025. WDLY SCT -SHRA. 17Z BKN035. WDLY SCT-TSRA. OTLK...VFR TSRA.*
*CNTRL PEN...SCT030 SCT-BKN100 TOPS 150. WDLY SCT -SHRA. BECMG 1518 SCT035 BKN050. SCT -TSRA. CB TOPS FL400. OTLK...VFR TSRA.*
*SRN PEN...SCT035 SCT150 SCT CI. BECMG 1518 SCT035 SCT-BKN100 TOPS 150. WDLY SCT -TSRA. CB TOPS FL400. OTLK...VFR TSRA 01Z VFR.*

The forecast for southern Florida expected scattered clouds at 3,500 ft, with scattered to broken clouds at 10,000 ft with tops to 15,000 feet, with widely scattered thunderstorms and light rain showers. Cumulonimbus cloud tops to 40,000 ft.

## 8.0 Inflight Weather Advisories

Inflight Aviation Weather Advisories are forecasts to advise en route aircraft of development of potentially hazardous weather. Inflight aviation weather advisories in the conterminous U.S. are issued by the NWS AWC, as well as from the Center Weather Service Units (CWSU) associated with FAA Air Route Traffic Control Center's (ARTCCs).

There are four basic types of inflight aviation weather advisories: the Significant Meteorological Advisory (SIGMET), the Convective SIGMET, AIRMET, and the Center Weather Advisory (CWA). The following advisories were issued chronologically surrounding the period:

### Period prior to accident

The Miami ARTCCs NWS CWSU issued CWA number 101 at 0810 EDT and was valid until 1010 EDT for area of thunderstorms and rain shower with heavy precipitation moving from 210 at 10 knots, with cumulonimbus cloud tops to 45,000 ft. The area was expected to change little through the period and extended over the route of flight and bordered the accident site.

The NWS AWC issued Convective SIGMET 34E for northwestern Florida and the coastal waters of the Gulf of Mexico at 0855 EDT and was valid until 1055 EDT for an area of thunderstorms with tops above 45,000 ft. This advisory did not impact the route of flight. Both

of these advisories are depicted in figure 18 over the GOES-13 visible satellite image at 0825 EDT, with the accident site marked by a yellow square. The text of the advisories were as follows:

*FAUS21 KZMA 031210*
*ZMA1 CWA 031210*
*ZMA CWA 101 VALID UNTIL 031410*
*FROM 70E TRV-30SE PBI-40SW MIA-35W PBI-70E TRV*
*AREA OF TS AND SHRA WITH HVY PCPN MOV FM 21010KT. TS TOPS TO FL450.*
*EXP LTL CHG THRU 1410Z.*
*JO*

*MKCE WST 031255*
*CONVECTIVE SIGMET 34E*
*VALID UNTIL 1455Z*
*FL AL AND CSTL WTRS*
*FROM 30SE SJI-40NNW CTY-40NE PIE-50W SRQ-130SSE SJI-30SE SJI*
*AREA TS MOV LTL. TOPS ABV FL450.*
*REF INTL SIGMET GOLF SERIES.*

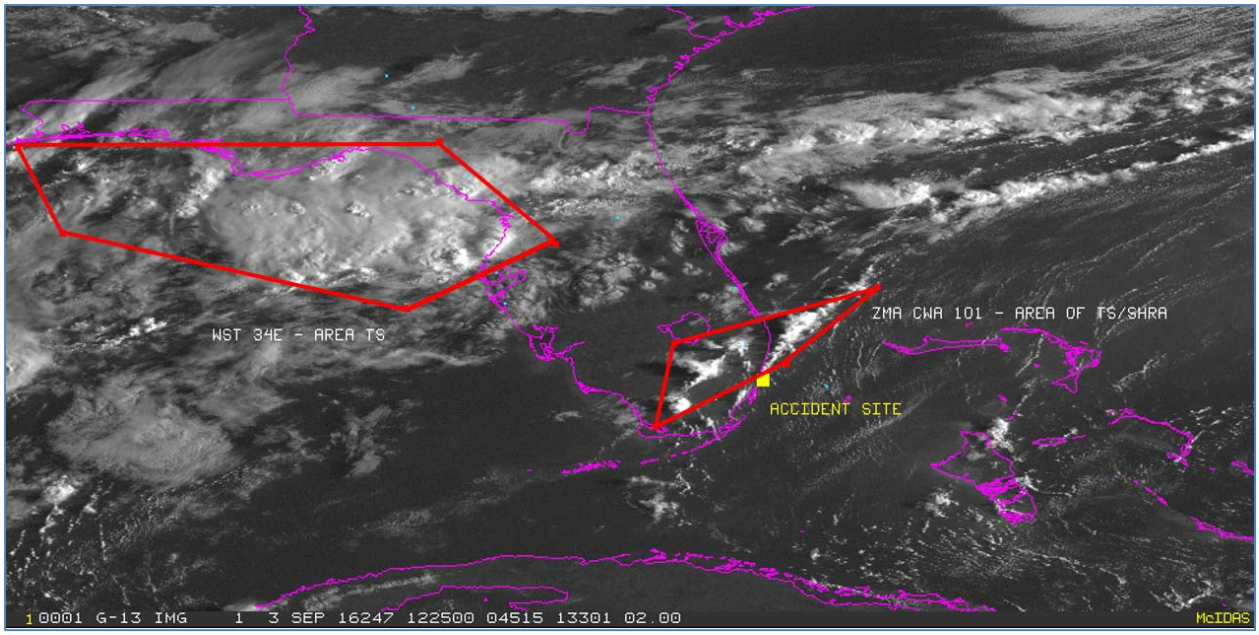


**Figure 18 - NWS weather advisories issued between 0800-0950 EDT**

## Period immediately after the accident

The NWS AWC continue issuing an advisory for northwestern Florida and the coastal waters with Convective SIGMET 36E for an area of thunderstorms with tops above 45,000 ft and issued a new advisory 37E over southeast Florida which included the accident site for an area of thunderstorms with tops to 43,000 ft. In addition, at 1032 EDT the Miami CWSU issued a CWA for another area of thunderstorms south of Convective SIGMET 36E. The plot of these advisories is included as figure 19 followed by the text of the advisories.

*MKCE WST 031355*
*CONVECTIVE SIGMET 36E*

*VALID UNTIL 1555Z*
*FL AND FL AL CSTL WTRS*
*FROM 20S CEW-20SSW CRG-10NNE OMN-50WSW SRQ-100SSE SJI-20S CEW*
*AREA TS MOV LTL. TOPS ABV FL450.*
*REF INTL SIGMET GOLF SERIES.*

*CONVECTIVE SIGMET 37E*
*VALID UNTIL 1555Z*
*FL AND CSTL WTRS*
*FROM 40ESE TRV-90ENE PBI-50SSW MIA-50WSW MIA-40ESE TRV*
*AREA TS MOV FROM 21010KT. TOPS TO FL430.*

*FAUS22 KZMA 031432*
*ZMA2 CWA 031435*
*ZMA CWA 201 VALID UNTIL 031635*
*FROM 105W SRQ-225SSW TLH*
*AREA OF TS...25 NM WIDE...MOV FM 25010KT. TOPS EST TO FL420. EXP*
*INCRG COVG THRU 1635Z.*
*JO*

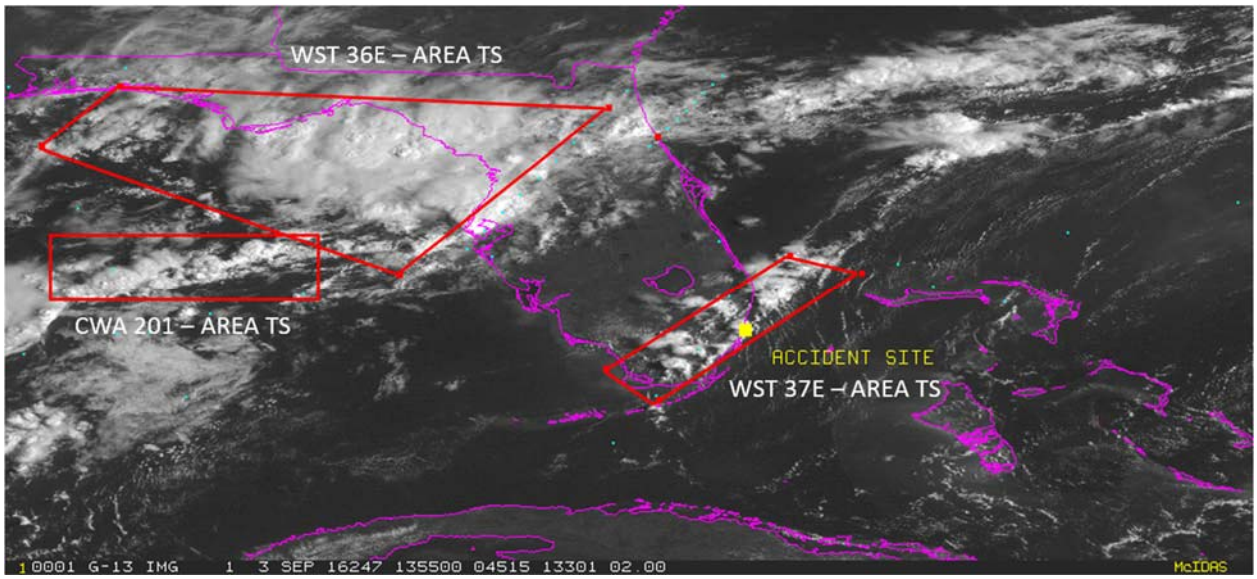


**Figure 19 - NWS weather advisories issued between 0955-1040 EDT**

## 9.0 Terminal Aerodrome Forecast

The NWS Miami WFO issued the Terminal Aerodrome Forecast or TAF for KFLL at 0720 EDT for a 24-hour period. The forecast was as follows:

*TAF KFLL 031120Z 0312/0412 VRB03KT P6SM VCSH FEW020 SCT030 BKN250*
*FM031400 15010KT P6SM SCT030 SCT060*
*FM040000 VRB05KT P6SM FEW025 SCT250=*

The forecast expected basic VFR conditions to prevail with light and variable winds at 3 knots, visibility better than 6 miles with rain showers in the vicinity or between 5 to 10 miles from the airport, a few clouds at 2,000 ft agl, scattered clouds at 3,000 ft, and ceiling broken at 25,000 ft.

After 1000 EDT, continued VFR conditions were expected with no mention of convective activity afterwards through 0800 EDT on September 4, 2016.

### 10.0 Preflight Weather

There was no record of any preflight weather briefing; what information the pilot may have used to familiarize himself of the atmospheric conditions is therefore unknown.

## F. Attachments

1. NWS Miami NWS WSR-88D composite reflectivity animation

2. NWS Miami WSR-88D base reflectivity animation

Submitted by:

_____

Don Eick
Senior Meteorologist

**THIS PAGE INTENTIONALLY BLANK**