



NATIONAL TRANSPORTATION SAFETY BOARD

**Office of Aviation Safety
Washington, D.C. 20594**

December 7, 2015

Group Chairman's Factual Report

METEOROLOGICAL FACTUAL REPORT

DCA15LA173

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A. ACCIDENT

Location: Charlotte, North Carolina

Date: August 15, 2015

Time: About 1837 eastern daylight time (2237 UTC¹)

Airplane: American Airlines flight 1851, Airbus A321; registration N564UW

B. METEOROLOGY GROUP

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National Transportation Safety Board

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Washington, D.C. 20594-2000

No Meteorological group was formed with this accident.

C. SUMMARY

On August 15, 2015, about 1837 eastern daylight time, American Airlines flight 1851, an Airbus A321, N564UW, reportedly encountered wind shear while on final approach to the Charlotte Douglas International Airport (CLT), Charlotte, North Carolina. The airplane touched down short of the runway in the paved overrun area and performed a go-around before circling back and successfully landing. There were no injuries to the 6 crew members and 153 passengers onboard. The airplane was substantially damaged when it struck several runway end lights and experienced a tail strike during the go around. The flight was operating under the provisions of 14 Code of Federal Regulations Part 121, as a scheduled domestic passenger flight and originated from Hartsfield - Jackson Atlanta International Airport (ATL), Atlanta, Georgia.

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 and the National Climatic Data Center (NCDC). All times are eastern daylight time (EDT) based upon the 24 hour clock, local time +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. NWS airport and station identifiers use standard International Civil Aviation Organization (ICAO) 4-letter station identifiers versus International Air Transport Association (IATA) 3-letter identifiers which deletes the initial country code designator "K" for U.S. airports. Both codes are both used intermittently in this report.

¹ UTC – is an abbreviation for Coordinated Universal Time.

E. 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 (NCEP) located in College Park, 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 00-45G.

1.1 Surface Analysis Chart

A section of the NWS Surface Analysis Chart for 1700 EDT (2100Z) on August 15, 2015 centered over the area is included in figure 1. The chart depicted a high pressure system at 1023-hectopascals (hPa)² over the northern Mississippi and Alabama border and a stationary front off the east coast, which resulted in a weak pressure gradient over the southeastern United States. No significant frontal or any outflow boundaries were identified over the route of flight or in the immediate area of Charlotte, North Carolina, which is enclosed in a red circle on the chart. The station model for Charlotte depicted a calm wind, partly cloudy skies, temperature of 89° Fahrenheit (F), a dew point temperature of 60° F, and a sea level pressure of 1018.6-hPa. Except for the station model for Mt. Airy, North Carolina, that reported light continuous rain, there were no other reports of significant weather along the route of flight or in the immediate vicinity of Charlotte, NC.

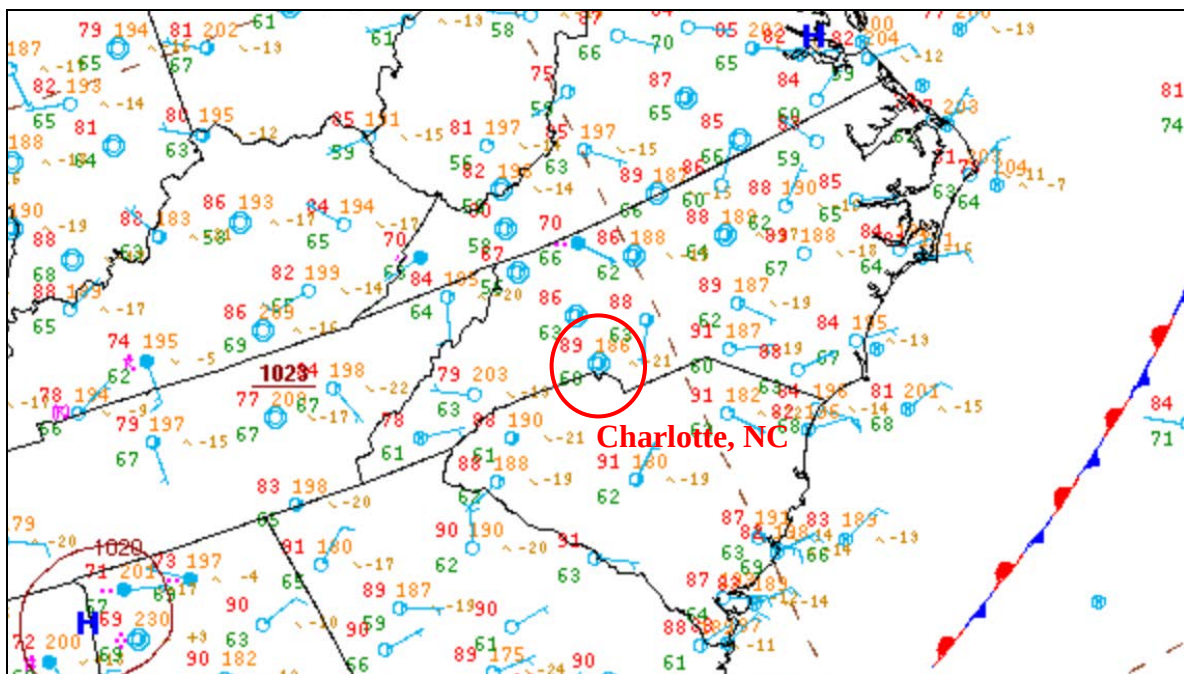


Figure 1 - NWS Surface Analysis Chart for 1700 EDT

² Hectopascals (hPa) is the new NWS standard for reporting pressure and is interchangeable with millibars (mb) as used in reporting sea level pressure and upper level pressure levels.

1.2 Weather Radar Mosaic

The NWS National Center for Environment Information³ National radar mosaic for 1835 EDT (2235Z) centered over the Charlotte area is included as figure 2. The image depicted a band of echoes extending from Greenville, South Carolina east-northeastward to Spenser, North Carolina to the northeast of Charlotte, with several small echoes in the vicinity and south of the Charlotte International Airport. These two small areas of echoes near the airport ranged in the 45 to 50 dBZ range. Stronger more intense echoes were identified northeast of Charlotte near 60 dBZ.

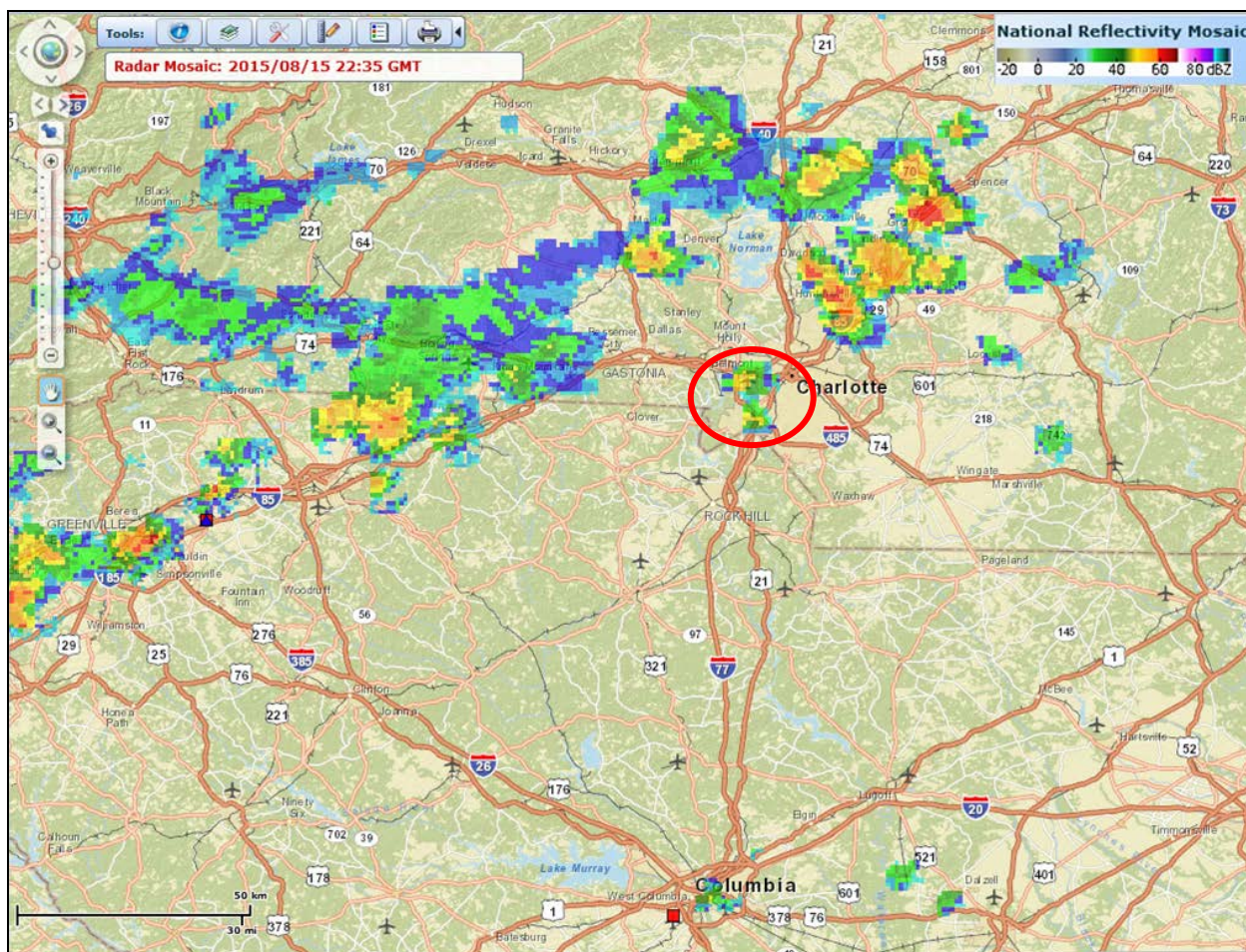


Figure 2 - NCDC National radar mosaic for 1835 EDT

As a result of identifying echoes in the vicinity of the airport, the closest NWS weather radar will be further documented in detail in section 5.0 of this report.

1.3 Convective Outlook

The NWS Storm Prediction Center's (SPC) graphic Convective Outlook issued at 1559 EDT and current for the period on August 15, 2015 to highlight where the center was expecting organized severe thunderstorm activity during the next 24 hours is included as figure 3. The

³ Formerly called the National Climatic Data Center (NCDC)

chart depicted a slight risk of organized severe thunderstorm⁴ activity was expected over the northern Plains over Minnesota, and the Dakota's as indicated by the yellow shaded area, with a marginal risk surrounding the area. Over North Carolina a risk of general airmass type convection⁵ was possible over the region shaded in light green, with no organized severe thunderstorms expected for the east coast or along the general route of flight.

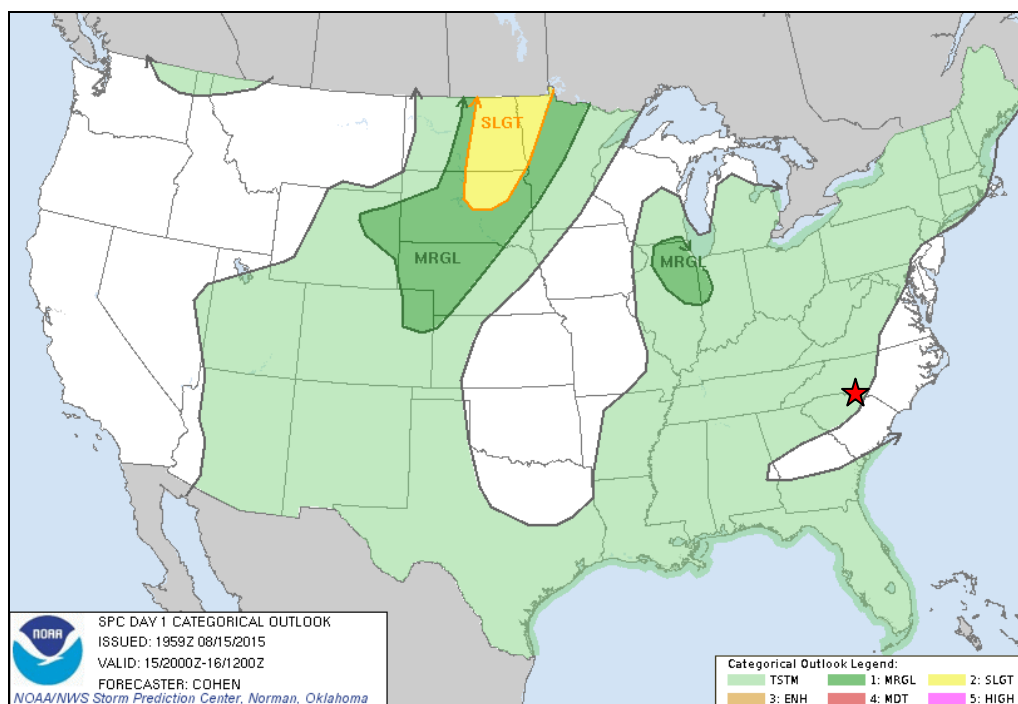


Figure 3 – NWS Convective Outlook issued at 1559 EDT

1.4 Constant Pressure Charts

The NWS Constant Pressure Charts for 850-, 700-, 500-, and 300-hPa at 2000 EDT (0000Z on August 15, 2015) are included as figures 4-7 and depicted the general upper level conditions over the country immediately after the accident.

The 850-hPa chart depicted the approximate conditions at 5,000 feet, while the 700-hPa chart depicted the conditions at approximately 10,000 feet. Both charts depicted high pressure dominating over the region with winds of 10 knots or less over the Charlotte region, with a low pressure system depicted over eastern North Carolina. The 500-hPa chart depicted the conditions of the mean atmosphere at approximately 18,000 feet and depicted upper level low pressure systems over northern Kentucky and Louisiana, with a defined trough of low pressure between the two lows, which supported rising motion ahead of the low over eastern

⁴ A severe thunderstorm is defined as capable of producing a tornado, strong outflow winds of 50 knots or greater, and/or large hail over 1 inch in diameter. Severe thunderstorms also imply severe to extreme turbulence, severe icing, heavy rain, and a threat of low-level windshear. Severe thunderstorms also have a longer duration and greater size than ordinary thunderstorms.

⁵ An airmass type thunderstorm is one of short duration in the mature stage, and generally does not produce a tornado, large hail, or strong outflow winds; however, all thunderstorm implies the potential for severe turbulence.

Kentucky and into western North Carolina. Another separate upper level low pressure system at 500-hPa was depicted over western central Florida, well to the south of the accident site. The resultant pressure gradient resulted in southwest to westerly winds of 10 knots over North Carolina. The 300-hPa chart depicting the conditions at approximately 30,000 feet continued to depict the upper level lows over the Kentucky/Indiana border and the other one over the Louisiana/Mississippi border, the resultant wind flow over North Carolina was from the west at 30 to 45 knots. A weak jet stream was depicted over the Pacific northwest into Montana with maximum winds of 80 knots. No strong jet stream winds were identified over the east coast during the period.

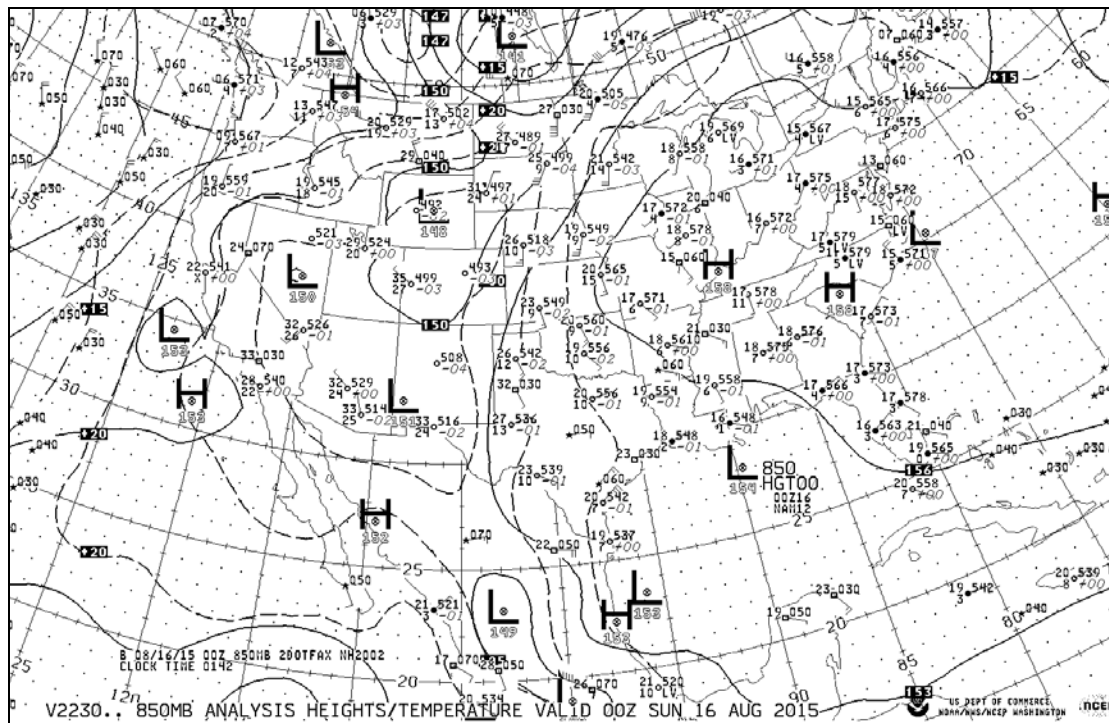


Figure 4 - 850-hPa Constant Pressure Chart for 2000 EDT

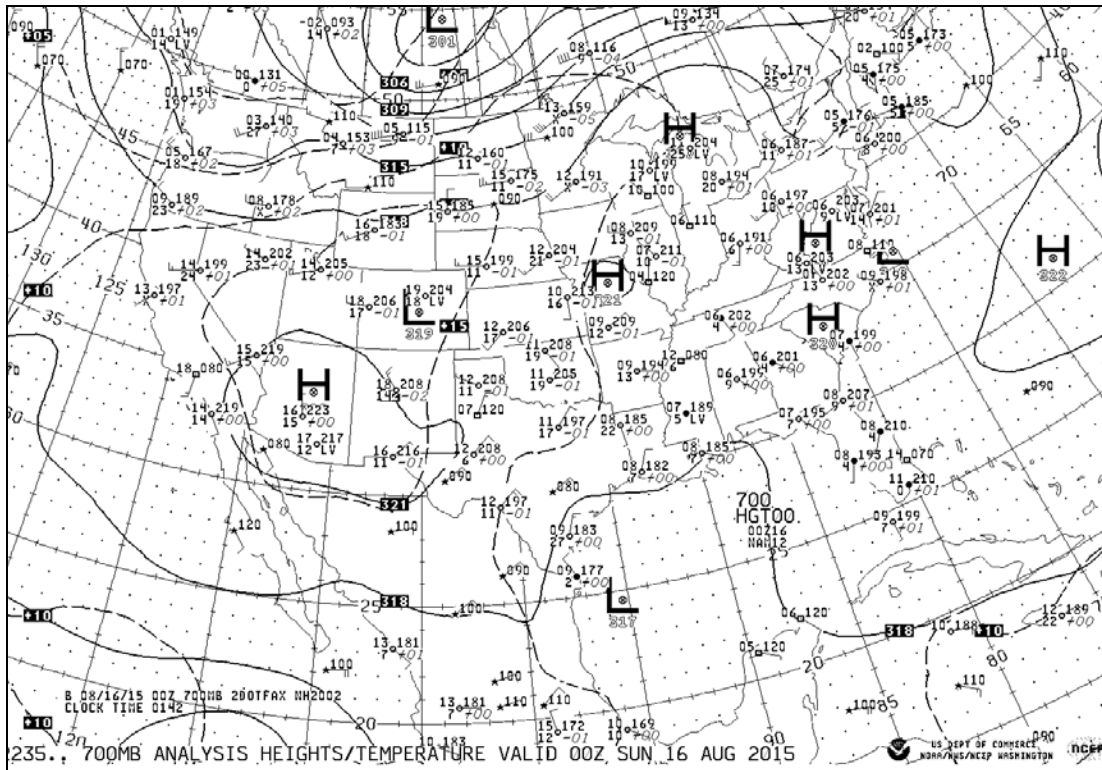


Figure 5 - 700-hPa Constant Pressure Chart for 2000 EDT

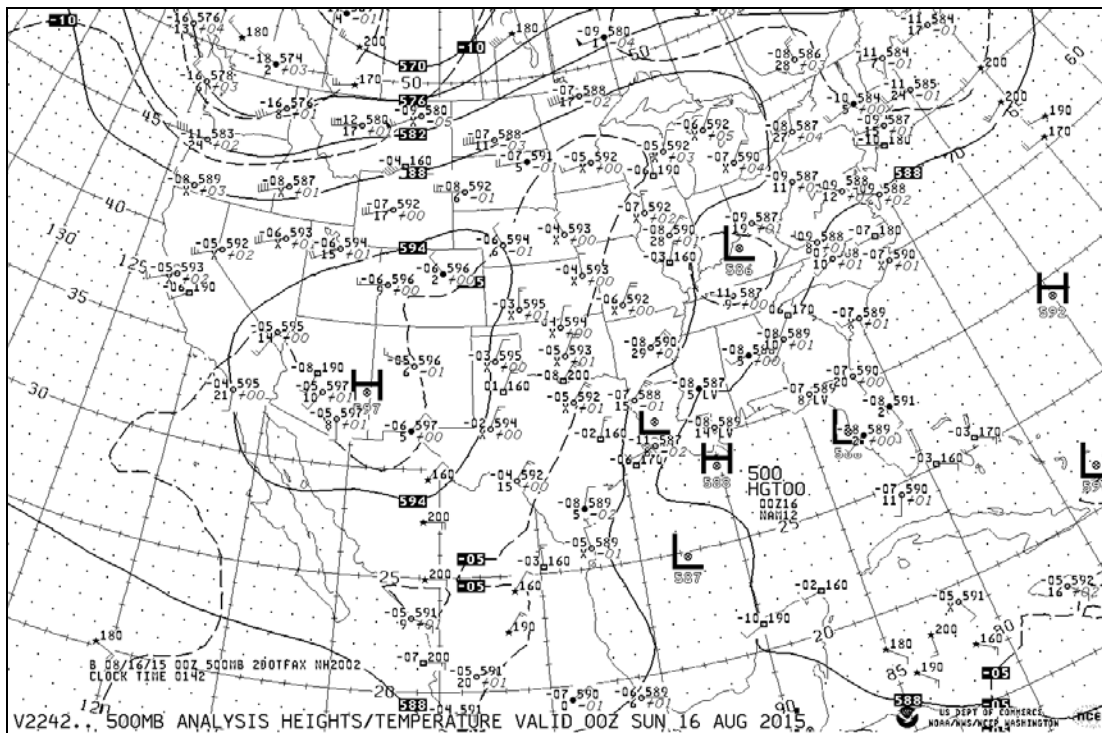


Figure 6 - NWS 500-hPa Constant Pressure Chart for 2000 EDT

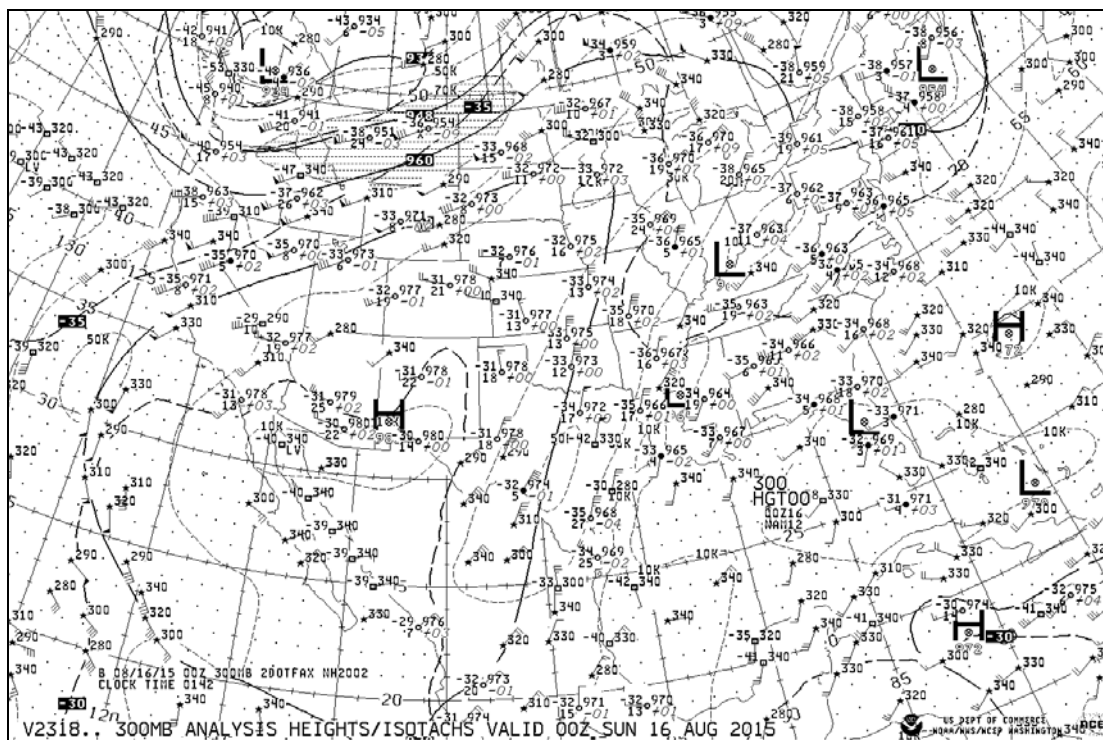


Figure 7 - 300-hPa Constant Pressure Chart for 2000 EDT

2.0 Charlotte Surface Weather Observations

The official NWS Meteorological Aerodrome Reports (METARs) and special reports (SPECIs) surrounding the period were documented for Charlotte/Douglas International Airport (KCLT), Charlotte, North Carolina. The airport had an Automated Surface Observation System (ASOS) and was augmented by a NWS certified weather observer. The airport lists an elevation of 748 feet and a magnetic variation of 7° West. The following weather conditions were reported surrounding the time of the accident, with cloud heights reported above ground level (agl):

Charlotte/Douglas International Airport weather observation at 1752 EDT (2152Z), wind calm, visibility unrestricted at 10 statute miles, scattered clouds at 6,000 feet agl with towering cumulus clouds, scattered clouds at 25,000 feet, temperature 32° Celsius (C), dew point temperature 16° C, altimeter 30.10 inches of mercury (Hg). Remarks: automated surface observation system, sea level pressure 1018.4-hPa, towering cumulus clouds northeast and northwest, temperature 32.2° C, dew point 15.6° C.

Charlotte/Douglas International Airport weather observation at 1852 EDT (2252Z), wind from 180° at 7 knots, visibility 10 miles in light rain, scattered clouds at 6,500 feet agl with towering cumulus clouds, ceiling broken at 10,000 feet, and broken at 25,000 feet, temperature 28° C, dew point temperature 16° C, altimeter 30.10 inches of Hg. Remarks: automated surface observation system, rain began at 1811 EDT, sea level pressure 1018.4-hPa, towering cumulus clouds northeast and southwest through northwest, hourly precipitation 0.15 inches, temperature 28.3° C, dew point 16.1° C.

A review of the NWS reporting criteria for a special observation were reviewed (see section 19.0 of this report) and no weather conditions were detected between 1752 and 1852 EDT that met the requirements for issuance of a special report, even with moderate to heavy rain being reported during the period as visibility did not deteriorate below the required reporting values. The first requirement for a special report, was made when a thunderstorm was first reported as beginning at 1903 EDT (2303Z) by the detection of lightning activity followed by deteriorating conditions in heavy rain, reduced visibility and instrument flight rule (IFR) conditions by 1948 EDT (2348Z), and a peak wind gusts of 26 knots. The raw observations surrounding the period with the general flight categories⁶ were as follows:

VFR METAR KCLT 152052Z 00000KT 10SM SCT060 BKN250 32/16 A3011 RMK AO2 SLP186 T03170156 58021=

VFR METAR KCLT 152152Z 00000KT 10SM SCT060TCU SCT250 32/16 A3010 RMK AO2 SLP184 TCU NE AND NW T03220156=

Accident 2237Z

VFR METAR KCLT 152252Z 18007KT 10SM -RA SCT065TCU BKN100 BKN250 28/16 A3010 RMK AO2 RAB11 SLP184 TCU NE AND SW-NW P0015 T02830161=

VFR SPECI KCLT 152304Z 18005KT 10SM TS SCT065CB BKN110 BKN250 27/18 A3010 RMK AO2 TSB03RAE04 OCNL LTGICCG TS S STNRY P0000=

VFR SPECI KCLT 152329Z 27008KT 10SM SCT060 BKN130 BKN250 26/18 A3012 RMK AO2 TSB03E27RAE04 PRESRR TS DSPTD P0000=

VFR SPECI KCLT 152337Z 23009KT 10SM -TSRA SCT060CB BKN130 BKN250 25/19 A3012 RMK AO2 TSB03E27B36RAE04B34 OCNL LTGICCG W TS W STNRY TS DSPTD P0000=

IFR SPECI KCLT 152348Z 20018G26KT 2 1/2SM R18C/4500VP6000FT +TSRA BKN060CB OVC130 23/19 A3015 RMK AO2 PK WND 21026/2346 TSB03E27B36RAE04B34 PRESRR FRQ LTGICCG W TS SW-W MOV E TS DSPTD P0007=

IFR SPECI KCLT 160002Z 13012KT 2 1/2SM R18C/3500VP6000FT +TSRA FEW022 BKN047 OVC060CB 23/19 A3014 RMK AO2 WSHFT 2345 OCNL LTGICCG E TS E-S MOV E P0032=

⁶ As defined by the NWS and the FAA Aeronautical Information Manual (AIM) section 7-1-7 defines the following general flight categories:

- Low Instrument Flight Rules (LIFR*) – ceiling or lowest layer of clouds reported as broken, overcast or the vertical visibility into a surface based obscuration below 500 feet agl and/or visibility less than 1 statute mile.
- Instrument Flight Rules (IFR) – ceiling between 500 to below 1,000 feet agl and/or visibility 1 to less than 3 miles.
- Marginal Visual Flight Rules (MVFR**) – ceiling from 1,000 to 3,000 feet agl and/or visibility 3 to 5 miles.
- Visual Flight Rules (VFR) – ceiling greater 3,000 feet agl and visibility greater than 5 miles.

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

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

MVFR SPECI KCLT 160009Z 12008KT 4SM TSRA SCT038 BKN060CB BKN130 OVC250 23/19 A3014 RMK AO2 WSHFT 2345 FRQ LTGICCG E-S TS E-S MOV E P0034=

VFR SPECI KCLT 160042Z 23005KT 10SM SCT060 BKN130 BKN250 23/19 A3014 RMK AO2 WSHFT 2345 TSE36RAE40 TS MOV E P0036=

VFR METAR KCLT 160052Z 00000KT 10SM -RA SCT060 BKN130 BKN250 23/19 A3014 RMK AO2 WSHFT 2345 TSE36 SLP199 TS MOV E P0036 T02280194=

2.1 Charlotte ASOS Location

The physical location of the ASOS sensors on Charlotte/Douglas International Airport are indicated in figure 8, or approximately 1,700 feet south of the touchdown zone on runway 18C and 750 feet west of the runway 18C/36C. The coordinates were latitude 35.2225° N and longitude -80.95431° W. With respect to the accident, the ASOS was located approximately 8,700 feet north-northeast or 1.4 miles from the accident site.



Figure 8 - ASOS location and accident site

2.2 Charlotte ASOS High Resolution Data

A review of the 5-minute ASOS data from Charlotte/Douglas International Airport indicated that at the time of American Airlines flight 1851 was on approach to 36L and at the time of the accident, the following weather conditions were being reported by the ASOS:

Charlotte/Douglas International Airport weather at 1835 EDT (2235Z), wind from 220° at 6 knots, visibility 6 miles in moderate rain, ceiling broken at 6,000 feet agl, broken at 8,000 feet, overcast at 10,000 feet, temperature 27° C, dew point temperature 18° C, altimeter 30.10 inches of Hg, pressure altitude 580 feet, relative humidity 58%, density altitude 2,200 feet, magnetic winds from 230° at 6 knots. Remarks: automated surface observation system, rain began at 1811 EDT, hourly precipitation 0.13 inches.

The high resolution 5-minute observation data for Charlotte/Douglas International Airport indicated that moderate to heavy rain was reported from 2211Z to 2245Z, then light rain thru 2305Z, when a thunderstorm was reported. Wind speeds began to increase immediately prior to the event at 2225Z with gusts to 16 knots, decreased again, and pickup when the main thunderstorm moved over the field with peak winds of 26 knots. The raw observations surrounding the period were as follows:

5-MIN KCLT 152155Z 05003KT 10SM SCT065 33/16 A3010 580 35 2800 060/03 RMK AO2

5-MIN KCLT 152200Z VRB03KT 10SM BKN060 32/16 A3010 580 36 2700 VRB/03 RMK AO2

5-MIN KCLT 152205Z VRB03KT 10SM BKN060 32/16 A3010 590 36 2700 VRB/03 RMK AO2

5-MIN KCLT 152210Z 00000KT 10SM BKN060 31/15 A3010 590 37 2600 000/00 RMK AO2

5-MIN KCLT 152215Z 16009KT 8SM RA BKN060 30/17 A3010 590 45 2500 170/09 RMK AO2 RAB11 P0001

5-MIN KCLT 152220Z 16007KT 5SM +RA OVC060 29/18 A3010 580 50 2300 170/07 RMK AO2 RAB11 P0004

5-MIN KCLT 152225Z 22012G16KT 4SM RA OVC060 28/18 A3010 580 54 2200 230/12G16 RMK AO2 RAB11 P0006

5-MIN KCLT 152230Z 23007G16KT 190V280 6SM +RA BKN060 OVC100 27/19 A3010 580 62 2100 240/07G16 200V290 RMK AO2 RAB11 P0011

5-MIN KCLT 152235Z 22006KT 6SM RA BKN060 BKN080 OVC100 27/18 A3010 580 58 2200 230/06 RMK AO2 RAB11 P0013

Accident 2237Z

5-MIN KCLT 152240Z 21010KT 6SM RA SCT060 SCT070 OVC100 27/18 A3010 580 58 2200 220/10 RMK AO2 RAB11 P0014

5-MIN KCLT 152245Z 20010KT 6SM -RA FEW060 OVC100 26/19 A3010 590 64 2000 210/10 RMK AO2 RAB11 P0015

5-MIN KCLT 152250Z 18009KT 6SM -RA FEW060 OVC100 28/17 A3010 590 50 2200 190/09 RMK AO2 RAB11 SLP184 P0015 T02780167

5-MIN KCLT 152255Z 19007KT 10SM -RA FEW070 BKN090 OVC110 28/17 A3010 590 50 2200 190/07 RMK
AO2 P0000

5-MIN KCLT 152300Z 18005KT 10SM -RA FEW065 BKN090 BKN110 27/18 A3010 590 57 2100 180/05 RMK
AO2 P0000

5-MIN KCLT 152305Z 18004KT 10SM TS SCT065CB BKN110 BKN250 27/18 A3010 590 58 2200 190/04 RMK
AO2 TSB03RAE04 OCNL LTGICCG TS S STNRY P0000

5-MIN KCLT 152310Z 18004KT 10SM TS SCT065CB BKN110 BKN250 28/18 A3010 590 54 2200 180/04 RMK
AO2 TSB03RAE04 OCNL LTGICCG TS S STNRY P0000

5-MIN KCLT 152315Z 20003KT 10SM TS SCT065CB BKN110 BKN250 28/18 A3010 590 52 2300 210/03 RMK
AO2 TSB03RAE04 OCNL LTGICCG TS S STNRY P0000

5-MIN KCLT 152320Z 18006KT 10SM TS SCT065CB BKN110 BKN250 28/17 A3010 580 50 2300 180/06 RMK
AO2 TSB03RAE04 OCNL LTGICCG TS S STNRY P0000

5-MIN KCLT 152325Z VRB06KT 10SM TS SCT065CB BKN110 BKN250 26/18 A3011 570 59 2000 VRB/06 RMK
AO2 TSB03RAE04 OCNL LTGICCG TS S STNRY P0000

5-MIN KCLT 152330Z 28009KT 10SM SCT060 BKN130 BKN250 26/19 A3012 570 64 2000 280/09 RMK AO2
TSB03E27RAE04 PRESRR TS DSPTD P0000

5-MIN KCLT 152335Z 24007KT 10SM -RA SCT060 BKN130 BKN250 25/19 A3012 570 68 1900 250/07 RMK AO2
TSB03E27RAE04B34 TS DSPTD P0000

5-MIN KCLT 152340Z 24009KT 10SM -TSRA SCT060CB BKN130 BKN250 25/19 A3013 560 68 1900 250/09 RMK
AO2 TSB03E27B36RAE04B34 OCNL LTGICCG W TS W STNRY TS DSPTD P0000

5-MIN KCLT 152345Z 22011G22KT 3SM -TSRA BKN060CB BKN130 BKN250 24/19 A3014 550 76 1700
230/11G22 RMK AO2 TSB03E27B36RAE04B34 PRESRR FRQ LTGICCG W TS SW-W STNRY TS DSPTD
P0001

5-MIN KCLT 152350Z 17013G26KT 2SM R18C/4000VP6000FT +TSRA BKN060CB OVC130 23/19 A3016 530 78
1700 180/13G26 RMK AO2 PK WND 21026/2346 TSB03E27B36RAE04B34 PRESRR SLP204 OCNL
LTGICCG OHD TS OHD MOV E TS DSPTD P0015 60030 T02330194 10333

5-MIN KCLT 152355Z 13015G26KT 1 1/4SM R18C/3500VP6000FT +TSRA SCT022 BKN047 OVC060CB 23/19
A3015 540 78 1700 140/15G26 RMK AO2 OCNL LTGICCG OHD TD OHD MOV E P0017

The KCLT ASOS 1-minute data was also documented. The following table is the ASOS running 2-minute average wind data through the period, which is the average 5-second wind measurements during the past 2-minute period, updated every minute. The maximum wind data is the highest 5-second wind speed and direction during the past minute. The following ASOS wind data was reported between 1820 and 1900 EDT, with the accident occurring at 1837 EDT.

Time (EDT)	2-minute average wind (°true/KT)	Maximum wind (°true/KT)
1820	158° 07	175° 09
1821	171° 07	180° 09
1822	184° 08	214° 09
1823	205° 09	224° 12
1824	222° 12	224° 16
1825	220° 12	221° 15
1826	215° 10	209° 11
1827	223° 10	241° 12
1828	244° 10	268° 13
1829	260° 10	275° 13
1830	234° 07	199° 09
1831	212° 06	215° 08
1832	222° 05	235° 05
1833	221° 04	217° 05
1834	216° 05	221° 06
1835	219° 06	228° 08
1836	222° 06	218° 07
1837	217° 06	213° 08
1838	213° 07	215° 10
1839	215° 09	211° 10
1840	212° 10	204° 11
1841	205° 11	197° 12
1842	197° 11	202° 14
1843	191° 10	200° 11
1844	194° 10	201° 12
1845	199° 10	198° 10
1846	191° 08	175° 10
1847	185° 08	190° 10
1848	185° 08	181° 09
1849	184° 08	187° 10
1850	183° 09	184° 10
1851	180° 08	186° 10
1852	182° 07	179° 08
1853	186° 06	191° 08
1854	189° 06	186° 07
1855	187° 07	186° 08
1856	182° 07	172° 07
1857	178° 06	176° 07
1858	177° 06	176° 06
1859	179° 05	175° 06
1900	176° 05	174° 07

A plot of the wind direction from the 1-minute ASOS 2-minute average wind and peak wind direction from 1820 through 1900 EDT is included in figure 9. Wind speeds varied from 4 to 14 knots at the ASOS location during the period with winds from the southeast veering or changing clockwise to the south then west, and then backing to the southwest and south during the period.

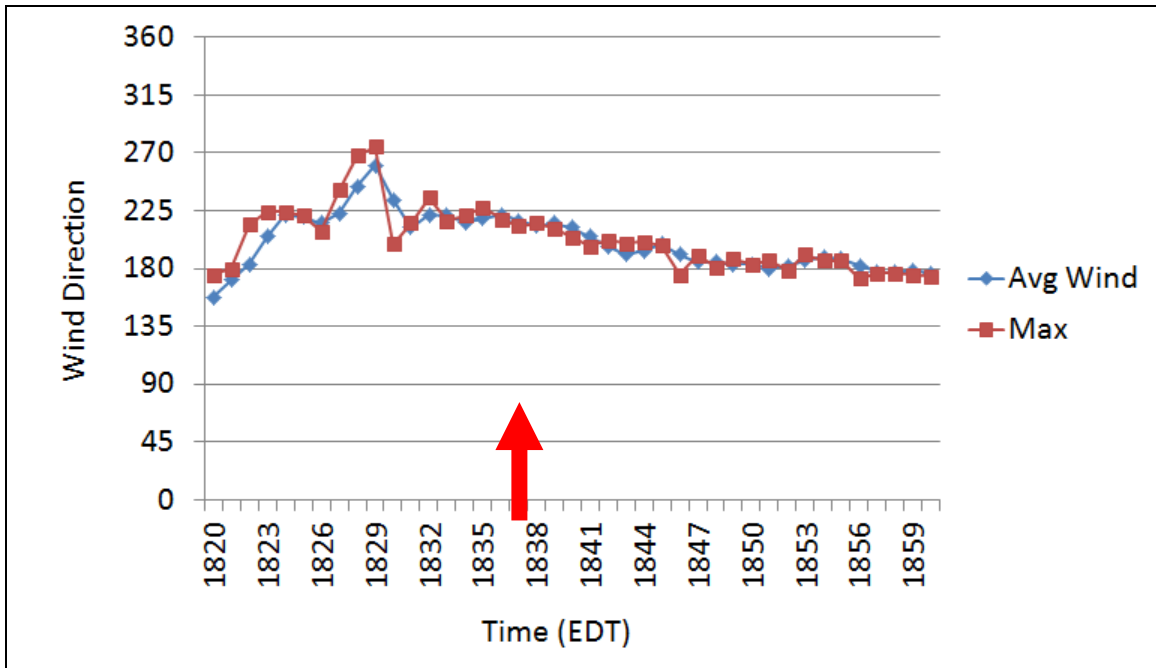


Figure 9 - Plot of wind direction

2.3 NWS METAR Display

The NWS Aviation Weather Center (AWC) website display of hourly observations at 1840 EDT is included as figure 10, with the radar overlaid. The charts depicted the general flight categories by the color coded station models, where blue indicated MVFR, red IFR, pink LIFR conditions, and no shading indicating VFR conditions. The chart depicted an area of echoes in the vicinity of Charlotte with the station reporting VFR conditions, with wind calm, visibility 10 statute miles, broken clouds, a temperature of 90° F, and a dew point of 60° F. Several stations to the west through north-northwest reported rain showers, with Lincolnton-Lincoln County Airport (KIPJ), Lincolnton, NC, located 19 miles north-northwest reporting MVFR conditions with 4 miles in heavy rain.

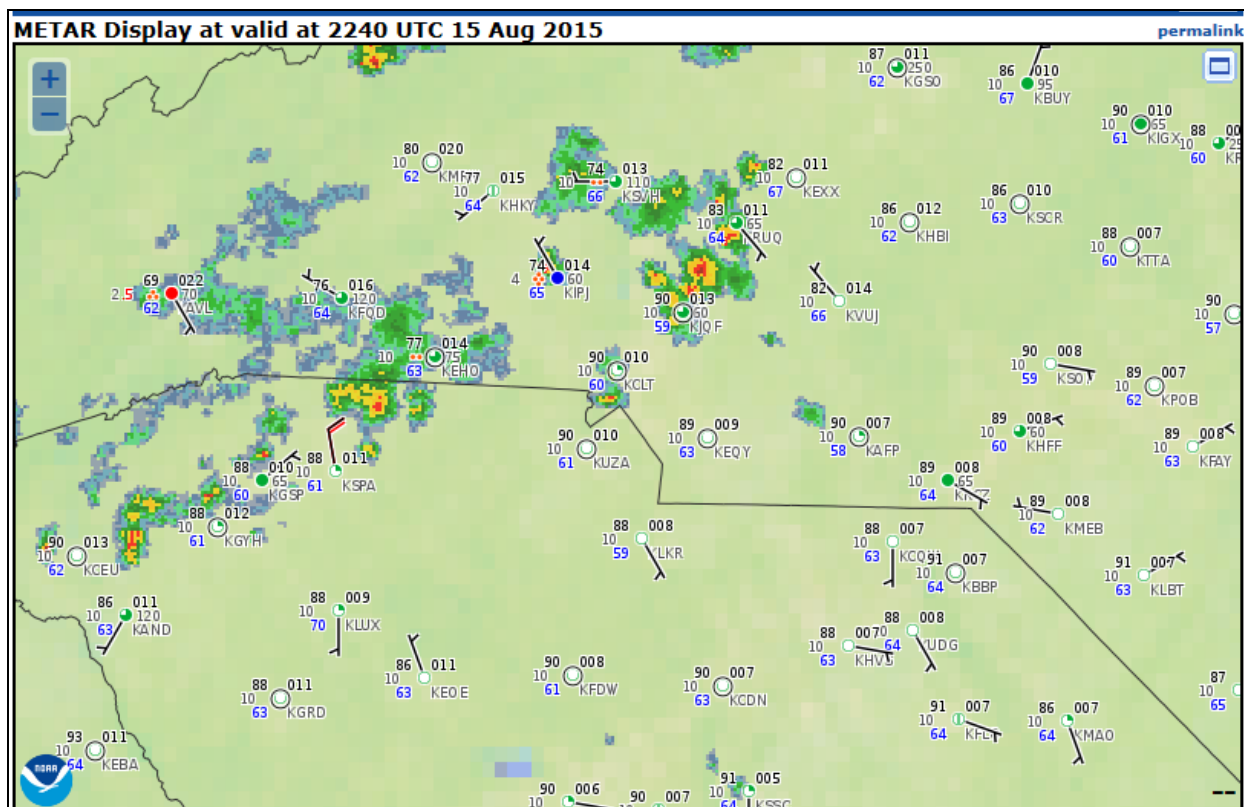


Figure 10 - NWS METAR display at 1845 EDT

3.0 Upper Air Data

The upper air conditions and stability indices of the atmosphere were documented with official NWS rawinsonde data, numerical weather prediction model data, and in-situ measurement from meteorological sensors installed on aircraft operating in the vicinity near the time of the accident.

3.1 NWS Rawinsonde Observation – Greensboro, NC

The closest upper air sounding or rawinsonde observation (RAOB) was from the NWS Greensboro (KGSO), North Carolina, site number 72317, located approximately 72 miles north-northeast of the accident site at an elevation of 886 feet. The 2000 EDT (0000Z on August 16, 2015) sounding was plotted on a standard Skew-T log P diagram⁷ utilizing RAOB⁸ software is included as figure 11 from the surface to 500-hPa or 18,000 feet.

⁷ 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.

⁸ RAOB – (The complete Rawinsonde Observation program) is an interactive sounding analysis program developed by Environmental Research Services, Matamoras, Pennsylvania.

The Greensboro sounding depicted a relatively warm and dry low-level environment with a surface temperature of 28.6° C and a relative humidity of 48%. The lifted condensation level (LCL)⁹ was identified at 828-hPa or at 5,005 feet agl, the convective condensation level (CCL)¹⁰ at 783-hPa or at 6,551 feet, and the level of free convection (LFC)¹¹ at 777-hPa or 6,782 feet agl. The equilibrium level (EL)¹² or expected top of convective clouds was at 36,428 feet with the tropopause at identified at approximately 40,000 feet. The freezing level was identified at approximately 14,180 feet.

The stability parameters indicated a Lifted Index (LI)¹³ of -2.0, a Total-Totals Index of 47.2, and a K-Index¹⁴ of 25.1 or near a 40% probability of isolated to scattered convection. The Convective Available Potential Energy (CAPE)¹⁵ was 407 Joules/kilogram (J/kg), which indicated a weak potential for severe thunderstorms. The overall storm classification favored the development for ordinary type thunderstorms to isolated pulse storms¹⁶. The maximum vertical velocity of the potential updrafts was 29 meters/second (m/s) or 58 knots. The sounding also

⁹ Lifting Condensation Level (LCL) - The height at which a parcel of moist air becomes saturated when it is lifted dry adiabatically.

¹⁰ 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.

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 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.

¹³ Lifted Index (LI) - A common measure of atmospheric instability. Its value is obtained by computing the temperature that air near the ground would have if it were lifted to 500-hPa or approximately 18,000 feet and comparing that temperature to the actual temperature at that level. Negative values indicate instability - the more negative, the more unstable the air is, and the stronger the updrafts are likely to be with any developing thunderstorms.

¹⁴ K-Index - The measure of thunderstorm potential based on the vertical temperature lapse rate, the moisture content of the lower atmosphere and the vertical extent of the moist layer. The higher the K-Index, the greater the probability of air mass type thunderstorms development.

¹⁵ 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.

¹⁶ Pulse thunderstorm - A pulse storm is a single cell thunderstorm that is usually not very strong; when it is of substantial intensity, it only produces severe weather for short periods of time. Such a storm weakens and then generates another short burst, hence "pulse." Pulse storms ordinarily form in environments with low wind shear and moderate instability, with the low wind shear contributing a short average lifespan of less than an hour. Severe weather in a pulse storm will most often occur during a momentarily forceful updraft, taking the form of hail or particularly damaging winds brought about by downbursts.

supported the likelihood for surface hail to 0.34 inch in diameter and indicated a precipitable water value of 1.36 inches. The microburst index or WINDEX indicated potential outflow of 51 knots. A comparison of the sounding stability and severe weather indices from the sounding are included as appendices 1 and 2 respectively.

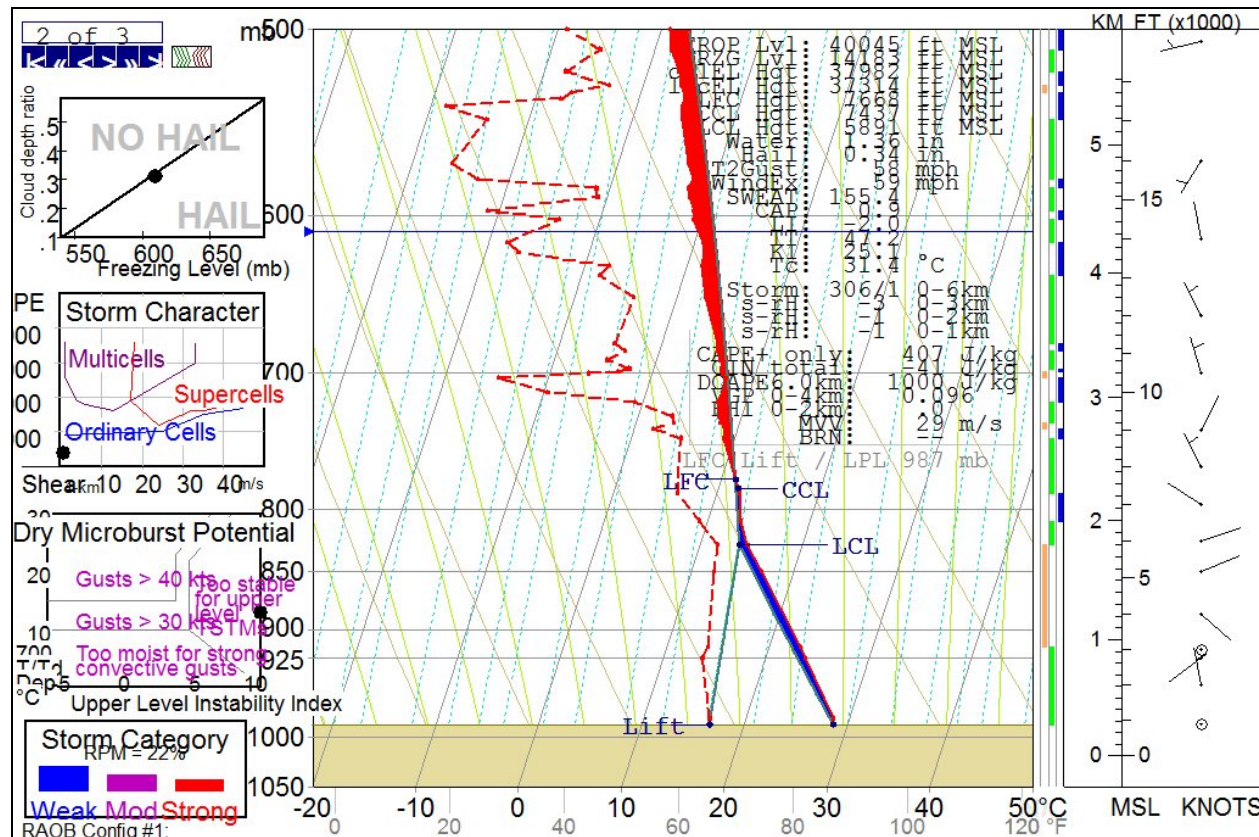


Figure 11 – NWS Greensboro, NC sounding at 2000 EDT

The wind profile indicated calm surface wind, with light and variable winds through 18,000 feet with wind speeds less than 10 knots. The mean 0 to 6 kilometer or 18,000 feet wind was from 276° at 2 knots.

3.2 North American Mesoscale Model Sounding – Charlotte, NC

A North American Mesoscale (NAM) forecast system numerical model sounding was also plotted from data obtained from the NOAA Air Resource Laboratory (ARL) archive data over the Charlotte area and plotted using the RAOB software. Figure 12 is the NAM model sounding for 1700 EDT (2100Z) on August 15, 2015. The NAM sounding was similar to the observed Greensboro observed sounding with respect to cloud heights with a CCL at 5,686 feet agl, and the LCC and LFC at 6,009 feet agl, with expected tops of convective clouds to 40,000 feet. The model sounding indicated a slightly more unstable atmosphere with a Lifted Index of -4, a Total-Totals Index of 50.5, and a K-index of 38.7, and continued to supported ordinary single cell and pulse type storms more numerous in coverage with an 80% probability. The Total-Totals Index value supported the development of a few severe thunderstorms or a moderate risk of strong to

severe thunderstorms and the CAPE values increased to 1,354 (J/kg). The sounding WINDEX index support microbursts with winds of 64 knots.

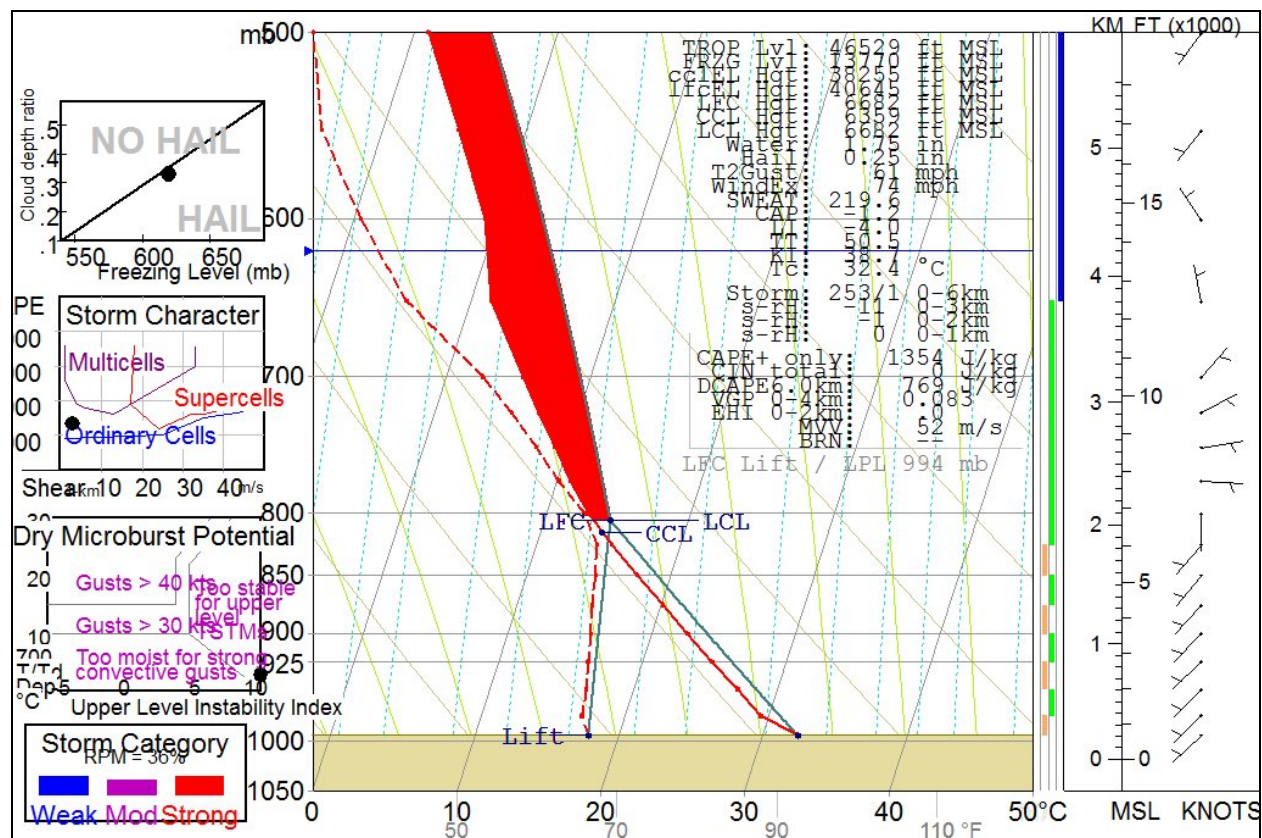


Figure 12 – KCLT NAM model sounding for 1700 EDT

The NAM wind profile indicated a surface wind from 225 at 3 knots with winds from the southwest through 6,000 feet. The wind profile remained weak with altitude with wind speeds less than 10 knots through 18,000 feet.

3.3 Aircraft Sounding – Charlotte, NC

A search of the NOAA Earth System Research Laboratory/Global Systems Division (ESRL/GSD) website (<http://amdar.noaa.gov/>) for Aircraft Meteorological Data Reports (AMDAR) provided upper air data closer to the time of the accident from aircraft. An aircraft identified as #10544 made a descent sounding into Charlotte/Douglas International Airport at 1748 EDT or approximately an hour prior to the accident and is included as figure 13. The sounding depicted a similar structure of the NWS Greensboro and NAM soundings with a LCL at 770-hPa or 7,410 feet msl (6,550 feet agl) with a Lifted Index of -1 and a K-index of 37. The AMDAR sounding wind profile also depicted a relative light and variable winds below 18,000 feet of 10 knots or less.

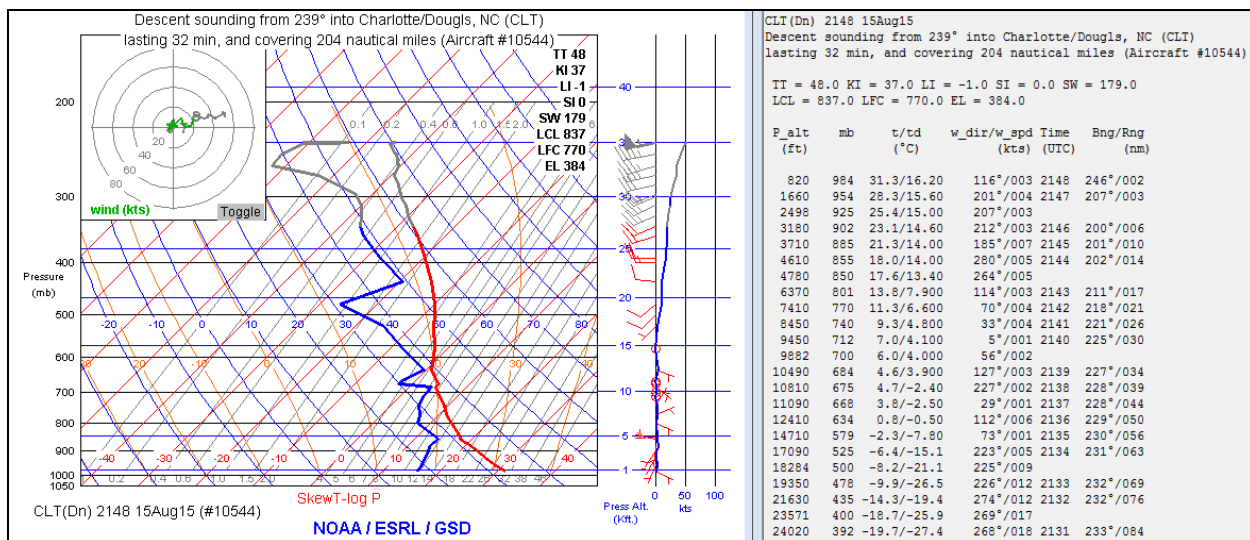


Figure 13 - Aircraft descent sounding into KCLT at 1748 EDT

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 (SSEC) at the University of Wisconsin-Madison (UW) in Madison, Wisconsin, and processed using the Safety Board's Man-computer Interactive Data Access 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 14 is the GOES-13 infrared image at 6X magnification and with a standard MB temperature enhancement curve applied to highlight the higher and colder cloud tops associated with deep convection for 1837 EDT. The image depicted a band of enhanced clouds extending northeast to southwest across central North Carolina immediately west of Greensboro (KGSO) and Charlotte (KCLT) associated with cumulonimbus clouds, and associated with temperature enhancement area. Over the Charlotte area an area of towering cumulus clouds or cumulus congestus type clouds are observed with a radiative cloud top temperature of 268° Kelvin or -5.16° C, which corresponded to cloud tops near 17,000 feet based on the Greensboro sounding. Relatively clear skies were observed over most of eastern North Carolina and South Carolina.

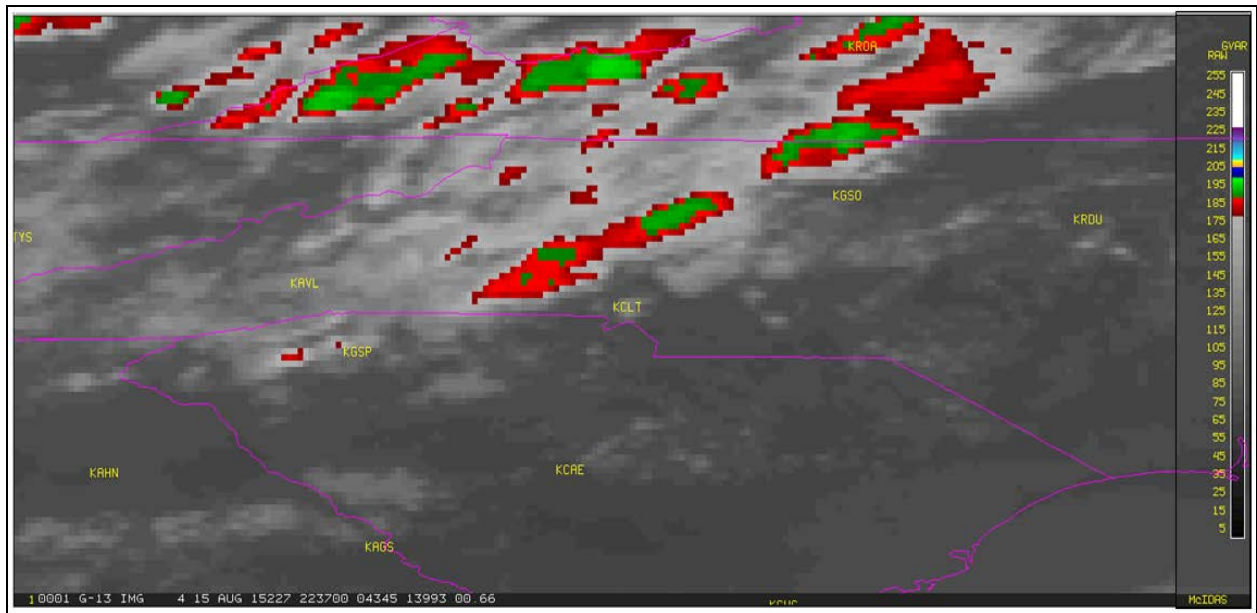


Figure 14 - GOES-13 infrared image at 6X magnification for 1837 EDT

Figure 15 is a composite image of the GOES-13 visible imagery at 1830, 1837, and 1845 EDT at 4X magnification, which depicted an area of cumulus congestus or towering cumulus clouds over the Charlotte area, with a broken line of cumulonimbus clouds running northeast to southwest across North Carolina to the west of the area. The cumulus congestus clouds in the vicinity of Charlotte did not display any classic high cirriform anvil blow-off identified with classic cumulonimbus clouds and were likely associated with growing cumulonimbus clouds, which had not reached the mature stage or dissipating stage, where anvil blow-off is common.

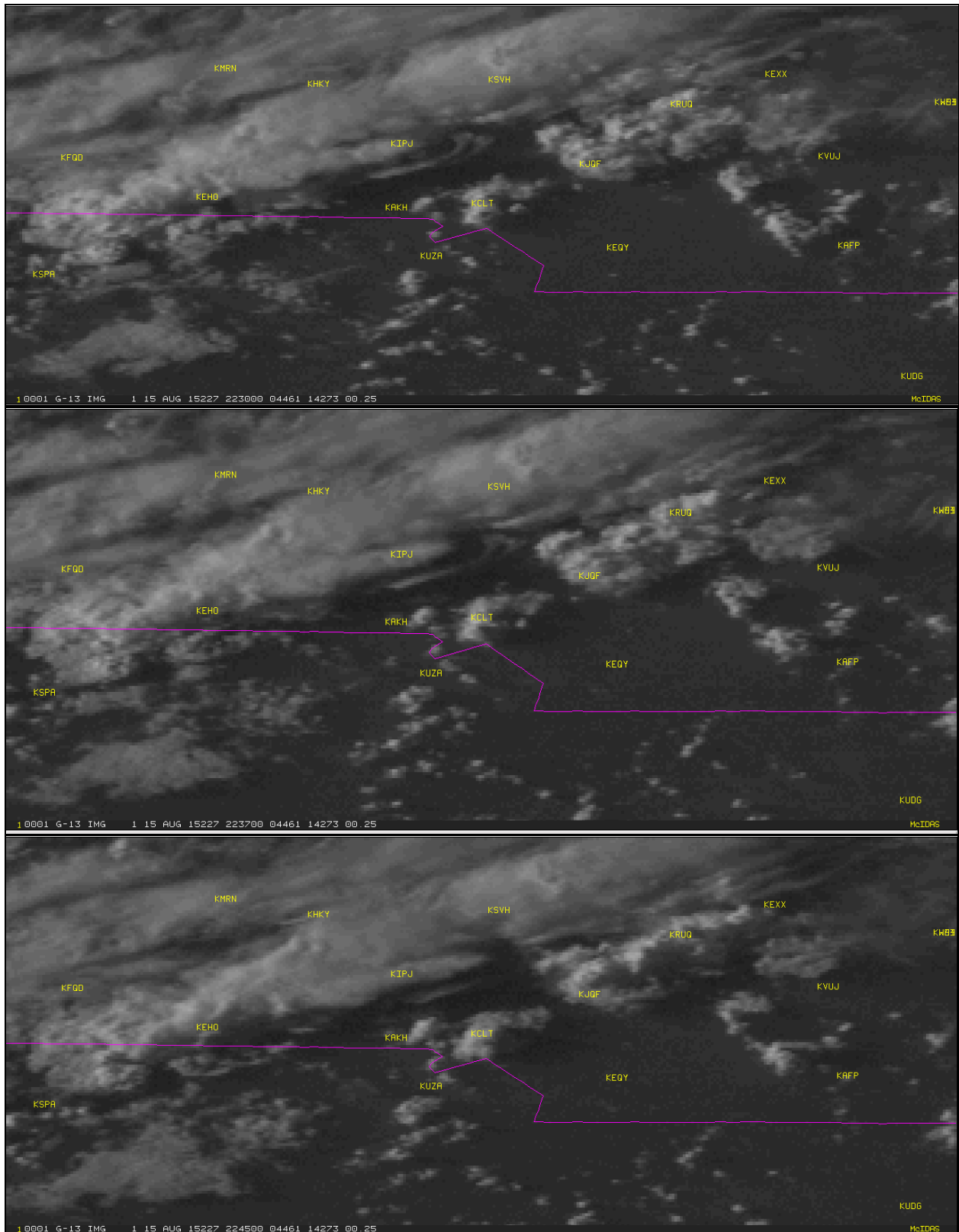


Figure 15 - GOES-13 visible images at 1830 EDT (top), 1837 EDT (center), and at 1845 EDT (bottom) at 4X magnification

5.0 Weather Radar Information

The closest Weather Surveillance Radar-1988, Doppler (WSR-88D) to the accident site was from the NWS Greer (KGSP), SC forecast office located approximately 64 miles southwest of the accident site, located at the Greenville Spartanburg International Airport. The level II and III archive data was obtained from the National Center for Environmental Information (NCEI) utilizing the Hierarchical Data Storage System (HDSS) 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 (PUP). Products that require data from multiple elevation scans are not available until the end of the six 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 the non-severe convective mode where the radar makes 9 elevation scans from 0.50° to 19.5° 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 KGSP WSR-88D radar was operating in the precipitation mode VCP-12 where the radar makes 14 different elevation scans in 4 ½ minutes. This mode is typically used by the NWS during periods when rapidly evolving severe convection is expected, and allows for improved low-level vertical resolution of the storms. Figure 16 is a depiction of this volume scan and the different elevation angles, beam height with distance from the radar site.

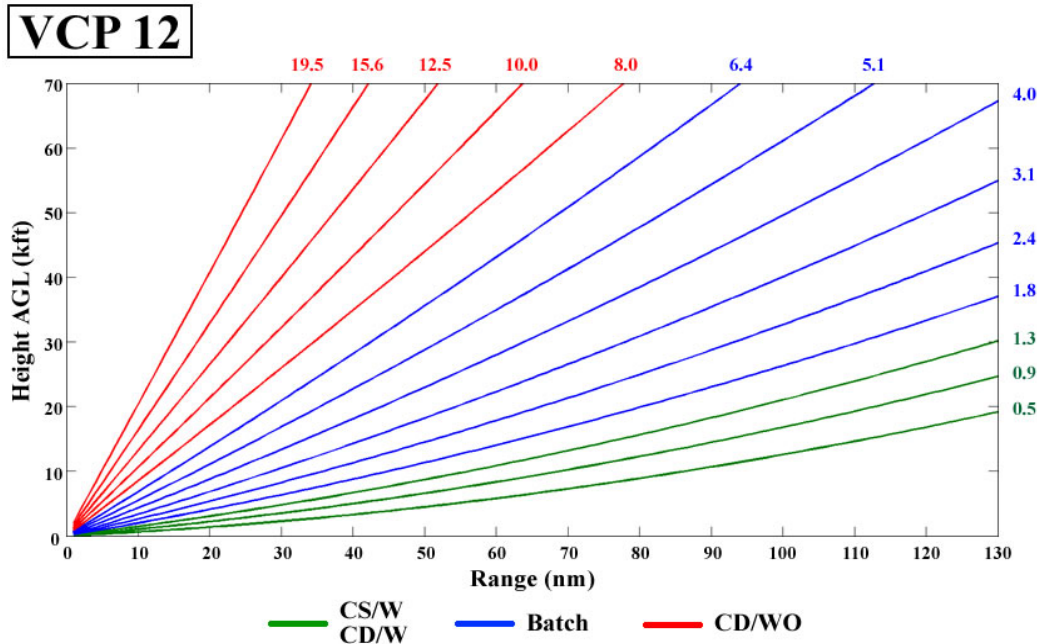


Figure 16- VCP-12 scanning mode

5.2 Beam Height Calculation

Assuming standard refraction¹⁷ of the 0.95° radar beam of the KGSP WSR-88D with an antenna height of 1,069 feet and a distance of 64 miles and an azimuth of 74° from the radar, the following table shows the approximate beam height and width information of the radar display over the site of the accident. The heights have been rounded to the nearest 10 feet.

ANTENNA ELEVATION	BEAM CENTER	BEAM BASE	BEAM TOP	BEAM WIDTH
0.5°	7,180 feet	3,950 feet	10,400 feet	6,450 feet

Based on the radar height calculations, the 0.5° elevation scan depicts the conditions encompassing the altitude between 3,950 and 10,400 feet over the accident site at KCLT. The conditions depicted are echoes above the flight path and not necessarily echoes the aircraft was operating through at the time.

5.3 Reflectivity

Reflectivity is the measure of the efficiency of a target in intercepting and returning radio energy. With hydrometeors¹⁸ it is a function of the drop size distribution, number of particles per

¹⁷ Standard Refraction in the atmosphere is when the temperature and humidity distributions are approximately average, and values set at the standard atmosphere.

¹⁸ 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

unit volume, physical state (ice or water), shape, and aspect. Reflectivity is normally displayed in decibels (dBZ¹⁹), 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 Very Light	3	15 to 19	.01 in/hr
	4	20 to 24	.02 in/hr
	5	25 to 29	.04 in/hr
2 Light to Moderate	6	30 to 34	.09 in/hr
	7	35 to 39	.21 in/hr
3 Strong	8	40 to 44	.48 in/hr
4 Very Strong	9	45 to 49	1.10 in/hr
5 Intense	10	50 to 54	2.49 in/hr
6 Extreme	11	55 to 59	>5.67 in/hr
	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 pilots based on the following scale:

- (a) "Light" (< 30 dBZ, NWS VIP level 1 – not displayed)
- (b) "Moderate" (30 to 40 dBZ, NWS VIP level 2)
- (c) "Heavy" (> 40 to 50 dBZ, NWS VIP level 3 and 4)
- (d) "Extreme" (> 50 dBZ, NWS VIP level 5 and 6)

(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.

¹⁹ dBZ - 10 log Ze

5.4 Base Reflectivity

The NWS Greer, SC (KGSP) WSR-88D 0.5° base reflectivity images for 1829, 1834, and 1838 EDT are included as figures 17-19 with the flight track for the period overlaid. The images show several small single cell echoes over and immediately south of the Charlotte/Douglas International Airport, with several other defined cells west through north and northeast of the Charlotte area. Figures 18 and 19 show the flight track of American Airlines flight 1851 on approach to 36L and directly under one defined cell on final approach, which has intensified to approximately 55 dBZ at 1838 EDT or at the approximate time of the accident.

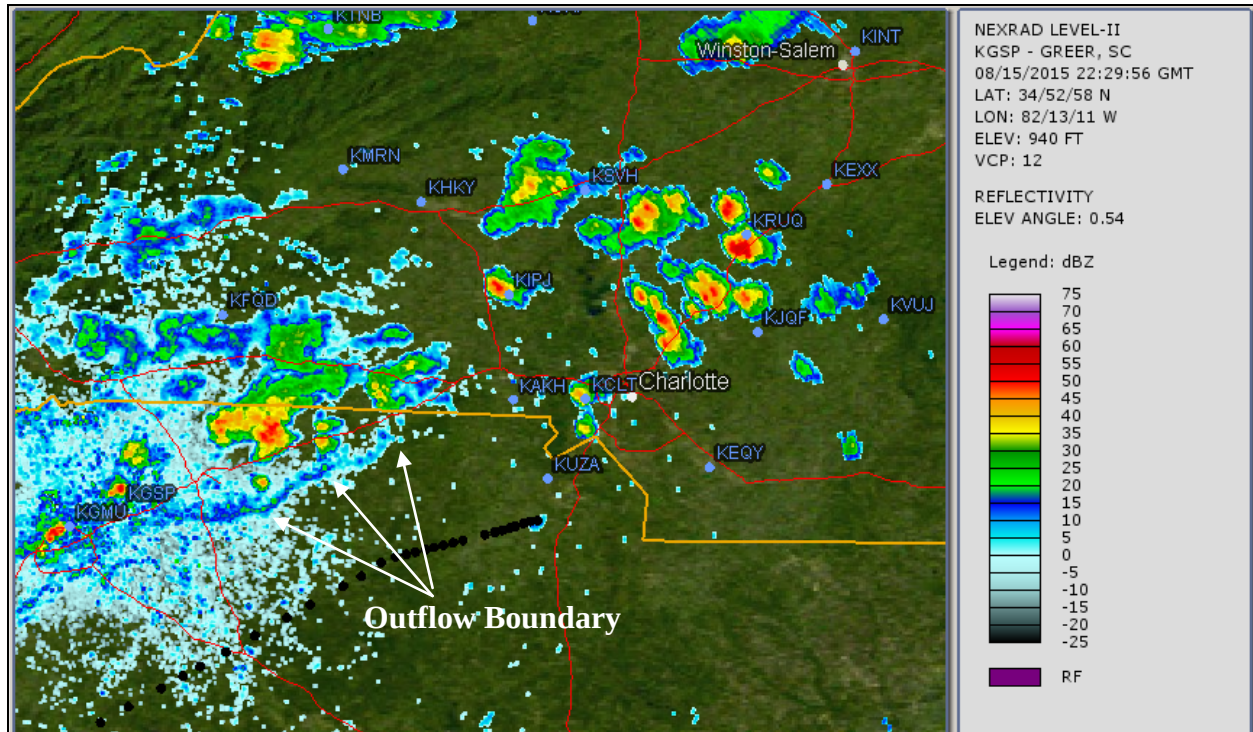


Figure 17 - KGSP WSR-88D 0.5° base reflectivity image at 1829 EDT

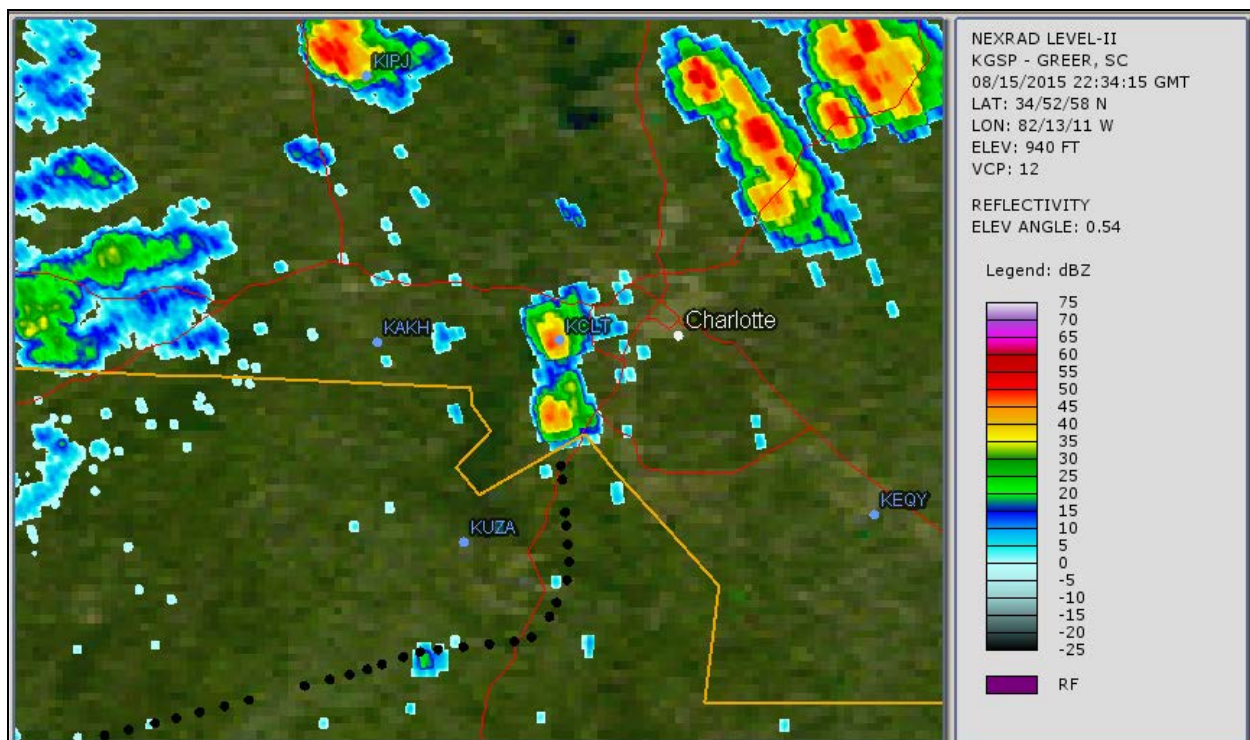


Figure 18 - KGSP WSR-88D 0.5° base reflectivity image at 1834 EDT

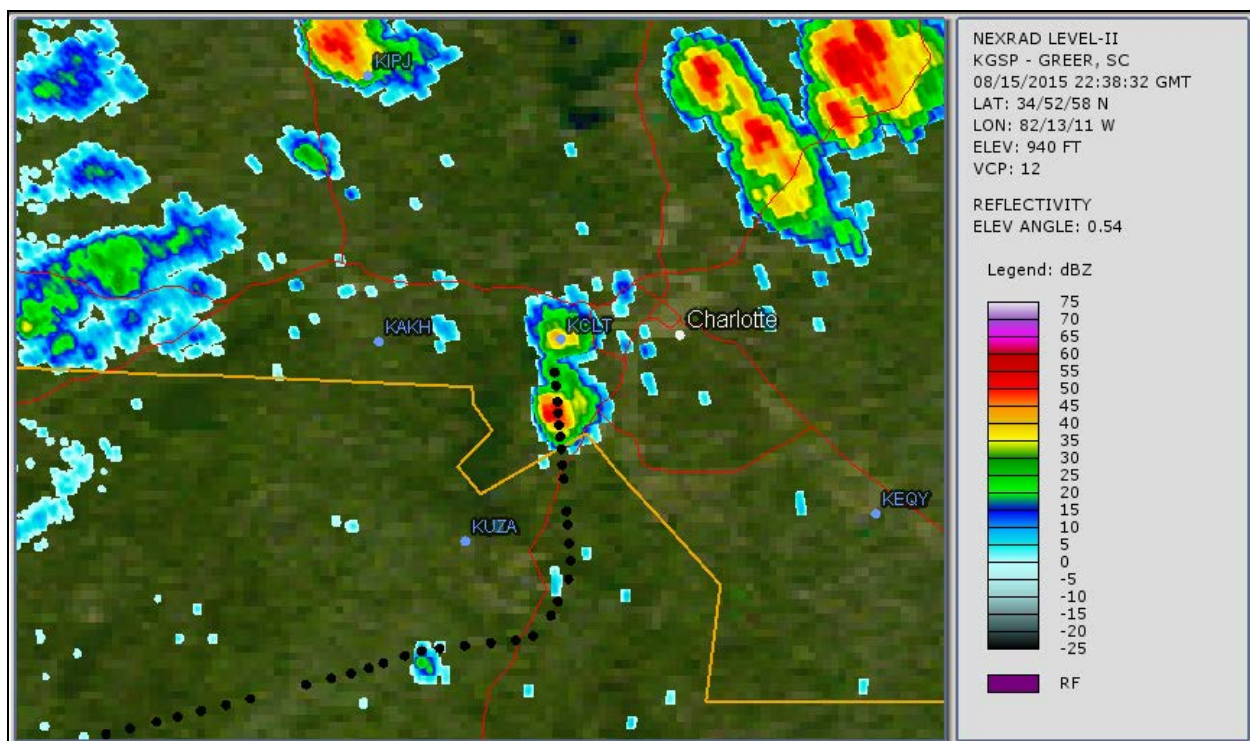


Figure 19 - KGSP WSR-88D 0.5 base reflectivity image at 1838 EDT

Figure 20 is a close up of the KGSP WSR-88D 0.5° base reflectivity images at 1829 through 1851 EDT over the Charlotte/Douglas International Airport showing the rapid development of two defined cells over the approach course and the airport during the period, finally merging into one larger cell or multicellular system by 1851 EDT.

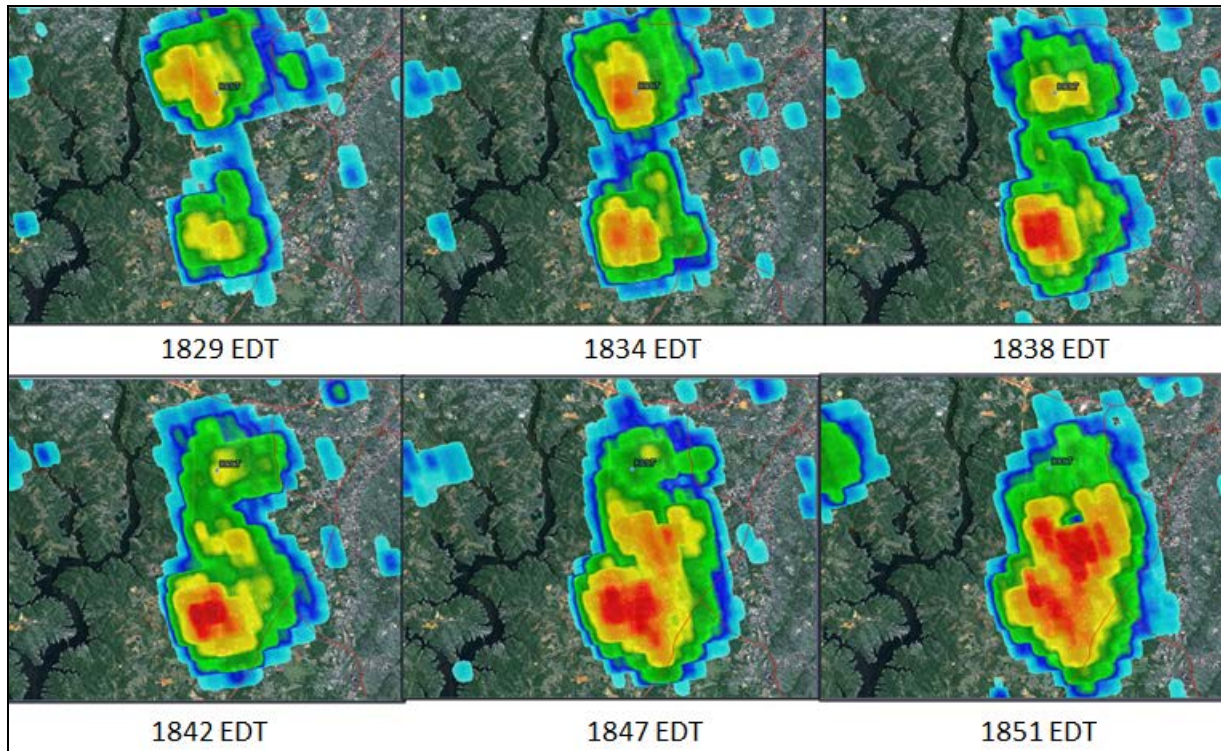


Figure 20 – Close up of the KGSP WSR-88D 0.5° base reflectivity from 1829 through 1851 EDT

The Level II data from KGSP WSR-88D was also analyzed utilizing the Gibson Ridge Software, specifically “GRLevel2” (GR2). Figure 21 is a three-dimensional display of the echoes along the flight path and over the airport at 1838 EDT. Note the echoes begin near 6,000 feet along the general center of the radar beam over the area and extend to approximately 15,000 feet.

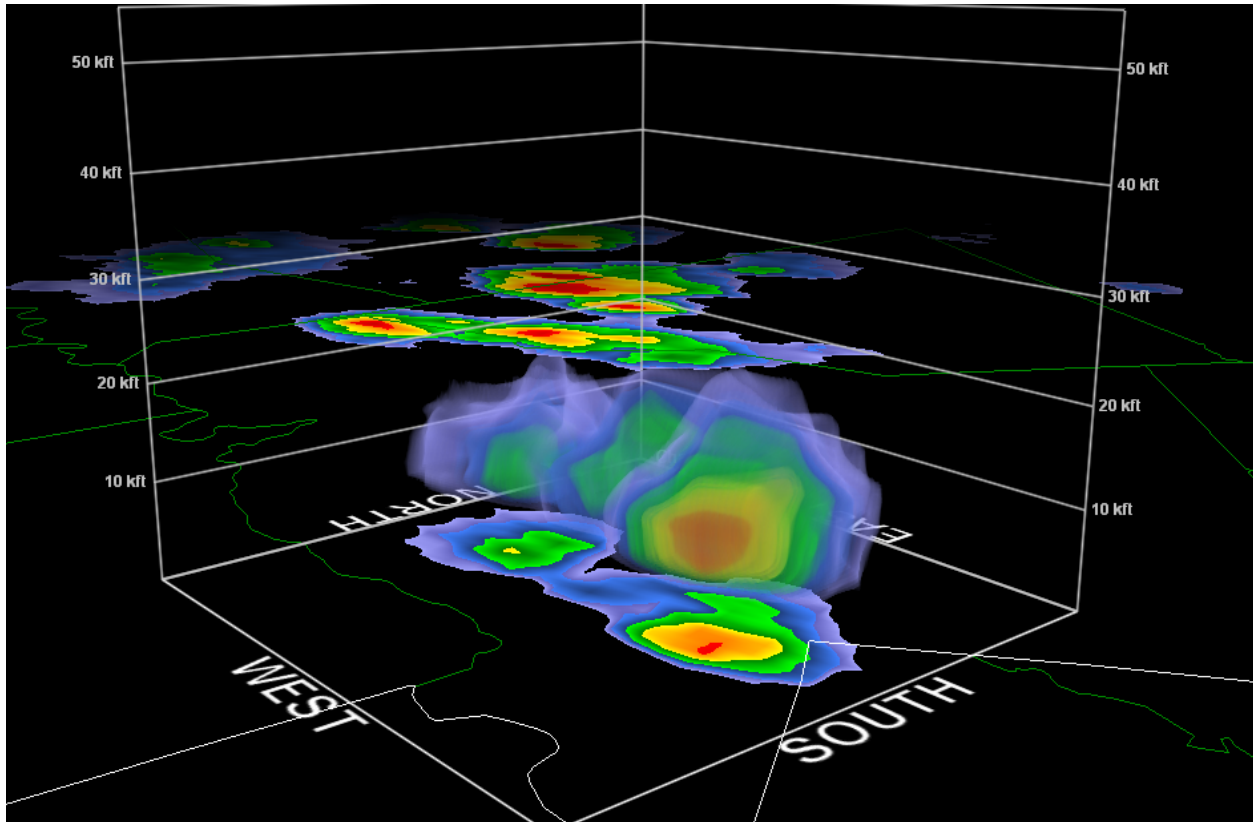


Figure 21 - KGSP WSR-88D cross section of echoes along approach course at 1838 EDT

5.5 Charlotte Terminal Doppler Weather Radar

Charlotte/Douglas International Airport is one of 45 airports that have a Terminal Doppler Weather Radar (TDWR) system installed to help provide air traffic controllers real-time wind shear detection. Several of the TDWR products were downloaded surrounding the period to help display the radar information available during the period. The CLT TDWR was located approximately 9 miles north of the accident site.

The TDWR is a C-band 5.3 centimeter wavelength radar with a power of 5.3 centimeters with a power output of 250,000 watts, with a 24-foot parabolic antenna concentrating the energy into a 0.55° beam width, and with a 1 to 5 minute update rate. The normal range is 90 kilometers or 56 miles, versus the WSR-88D of 240 km or 150 mile range. The TDWR has the advantage of better resolution with respect to reflectivity over the WSR-88D, but is subject to precipitation attenuation.

Based on the TDWR location 9 miles north of the accident site, and an antenna height of approximately 871 feet, the 0.20° lowest base reflectivity image was scanning the airspace approximately 850 to 1,380 feet over the accident site, with the center of the beam at 1,120 feet.

5.6 Charlotte TDWR Base Reflectivity

Figures 22 through 24 are the CLT TDWR 0.20° base reflectivity images at 1835, 1837, and 1839 EDT respectively with the flight track overlaid and approximate conditions the aircraft penetrated on the approach. The images depict very light intensity echoes of 25 dBZ or less along the final approach and touchdown areas.

The CLT radial velocity imagery were also reviewed but not documented due to the limited amount of information provided from the images. No clear divergent couplets were identifiable on the images.

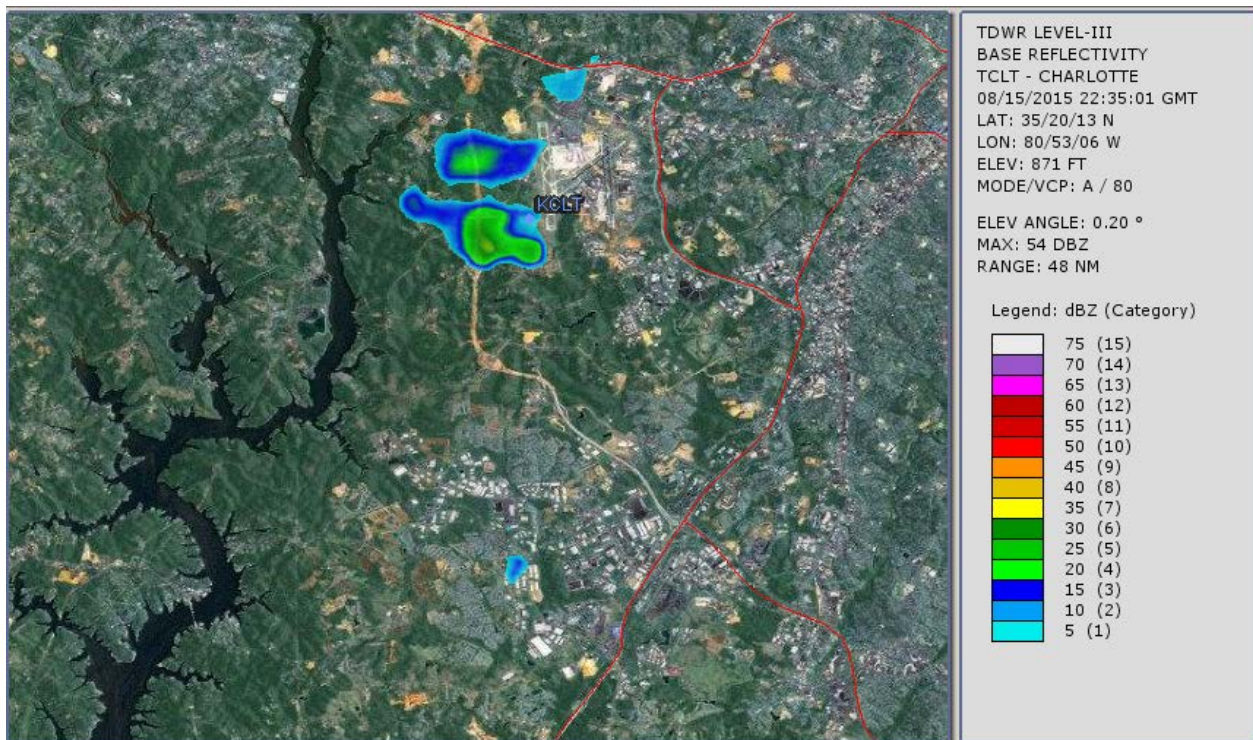


Figure 22 - CLT TDWR 0.20° base reflectivity image at 1835 EDT

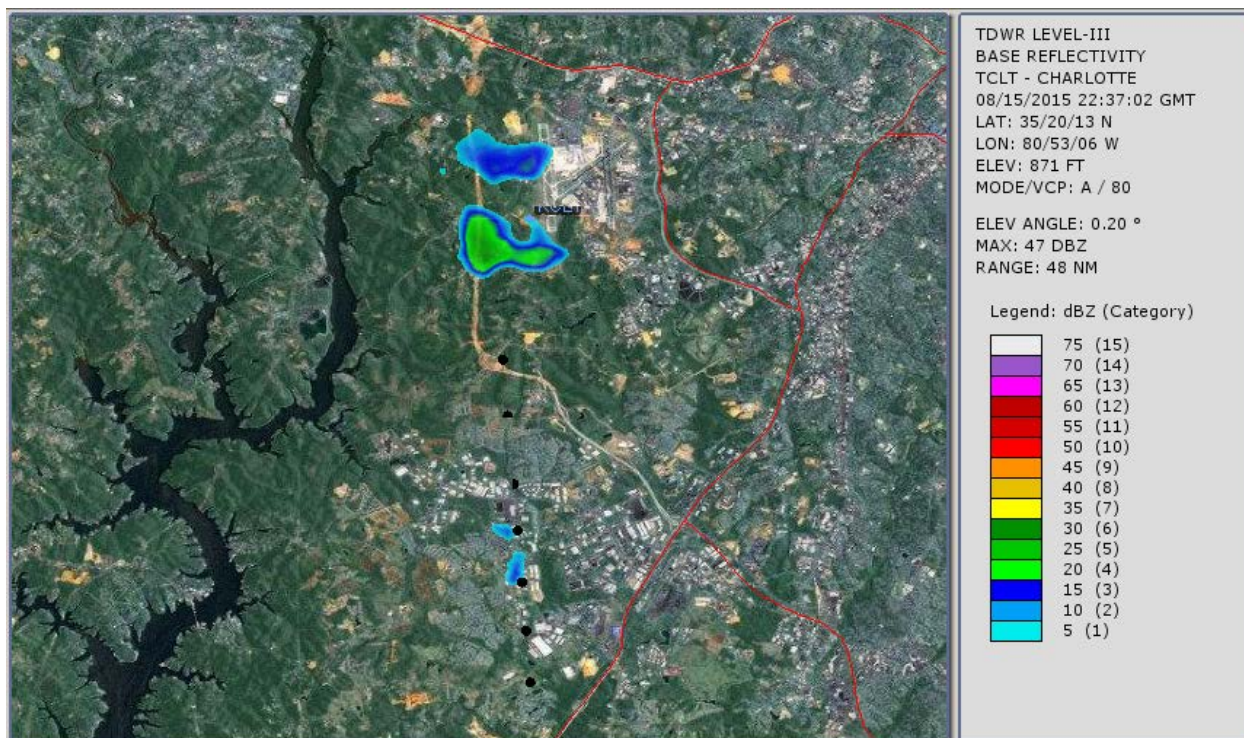


Figure 23 - CLT TDWR 0.20° base reflectivity image at 1837 EDT

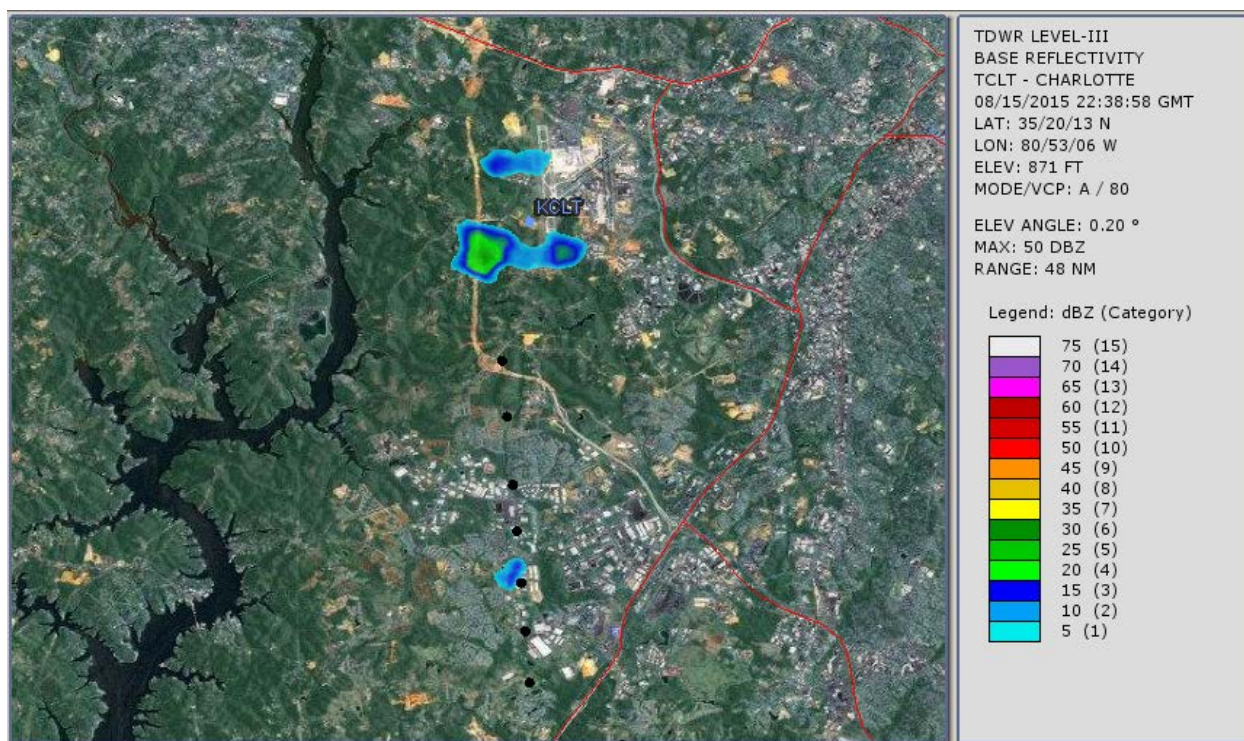


Figure 24 - CLT TDWR 0.20° base reflectivity image at 1839 EDT

Figures 25 and 26 are the CLT TDWR 0.60° base reflectivity images extending from 1,235 to 1,760 feet over the accident site. The images depicted stronger echoes aloft with cores near 45 to 50 dBZ along and over the touchdown area of runway 36L.

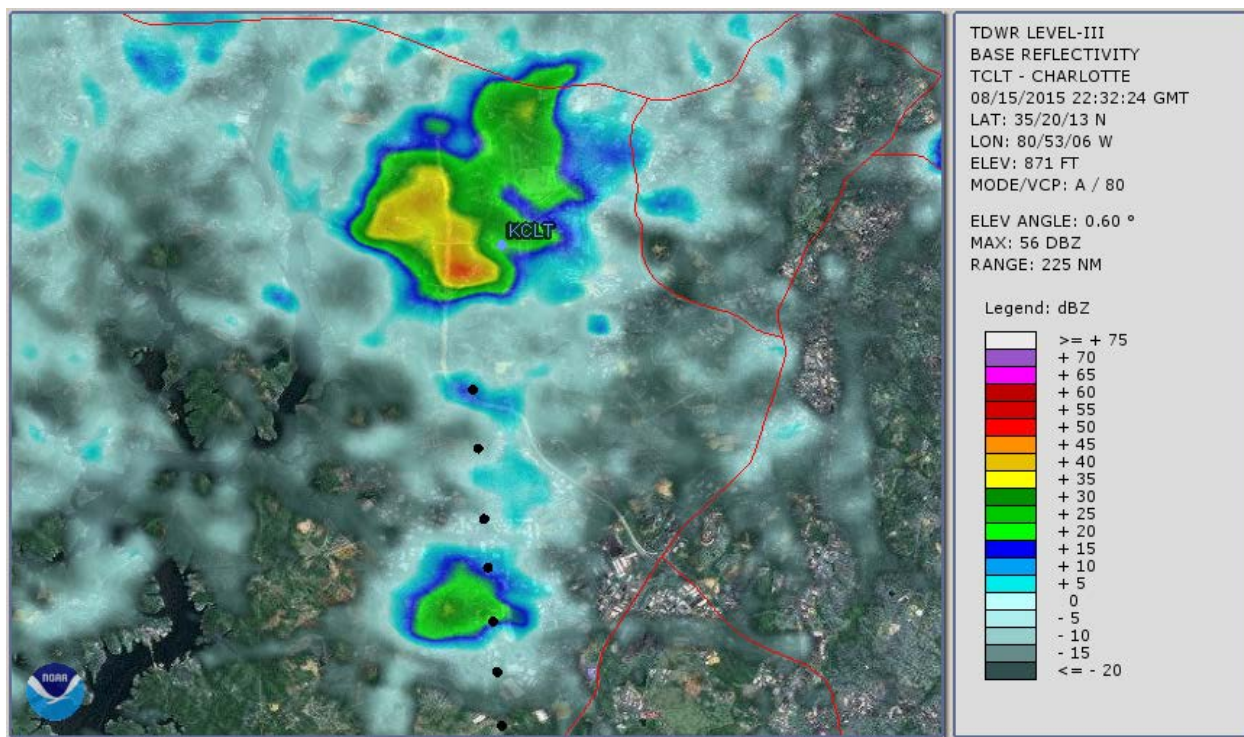


Figure 25 - CLT TDWR 0.6° base reflectivity image for 1832 EDT

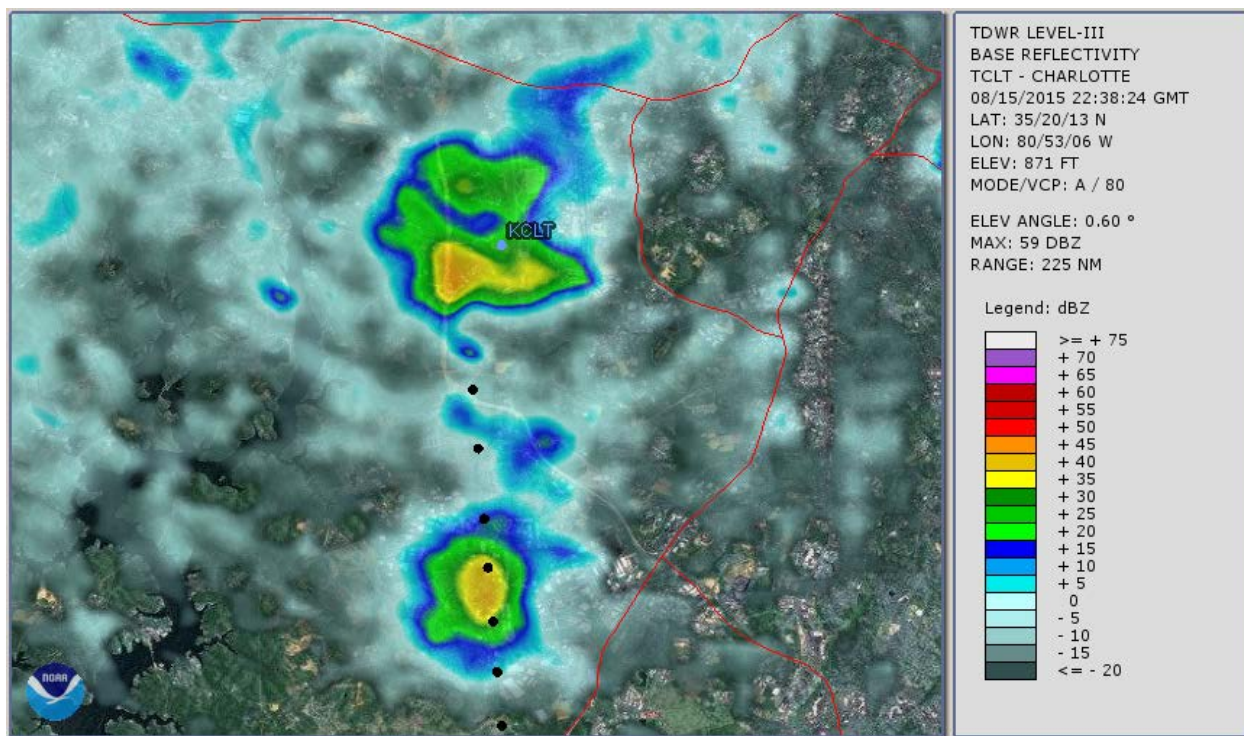


Figure 26 - CLT TDWR 0.6° base reflectivity image at 1838 EDT

5.7 Charlotte TDWR Composite Reflectivity

The WSR-88D and TDWR composite reflectivity images are completed at the end of the VCP scan and depicts the maximum reflectivity in dBZ of each of the different elevation scans. Composite reflectivity images show the highest reflectivity value retrieved for a column from the individual radar sweeps for a single volume scan. Composite reflectivity provides a plan view of the most intense portions of thunderstorms, and can be compared with the lowest elevation scan base reflectivity image to help determine the 3-dimensional structure of a thunderstorm. Figures 27 through 31 are the CLT TDWR composite reflectivity images at approximately 1832, 1836, 1838, 1842, and 1844 EDT with the flight track overlaid. The composite images show two distinct high reflectivity cores over the flight path and near the touchdown zone near 55 dBZ during the period.

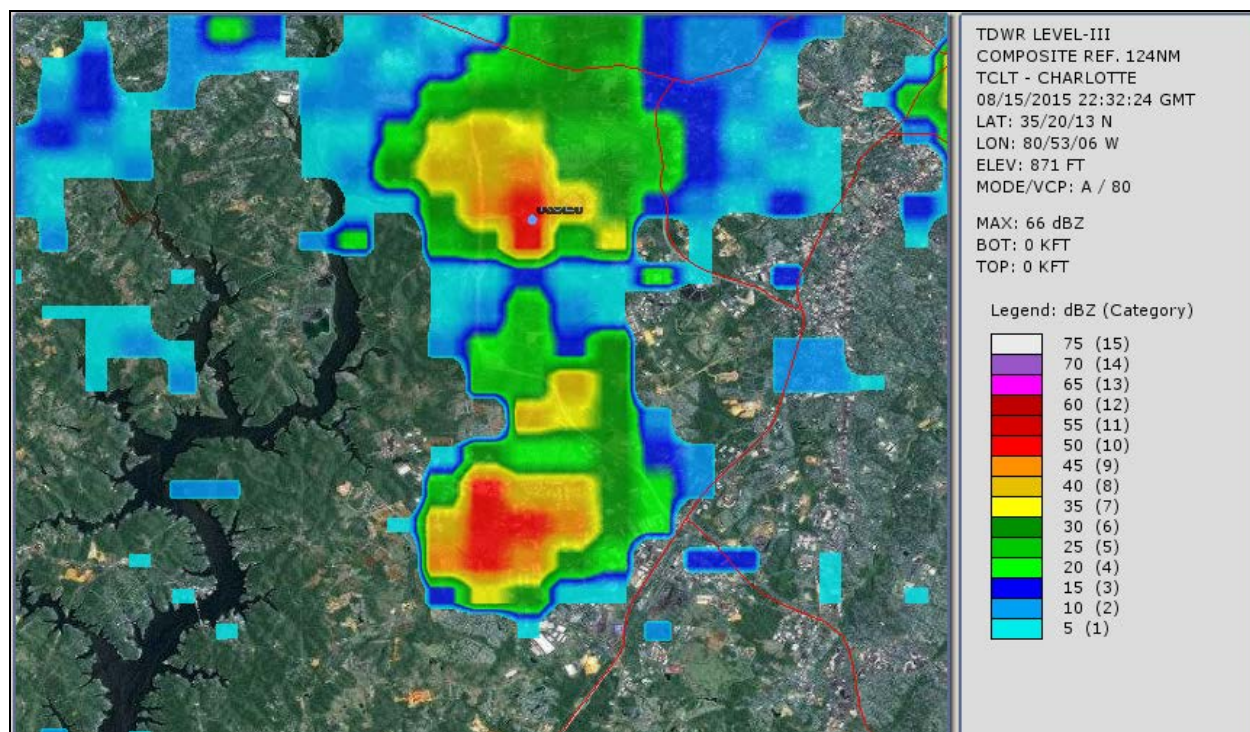


Figure 27 - CLT TDWR composite reflectivity image at 1832 EDT

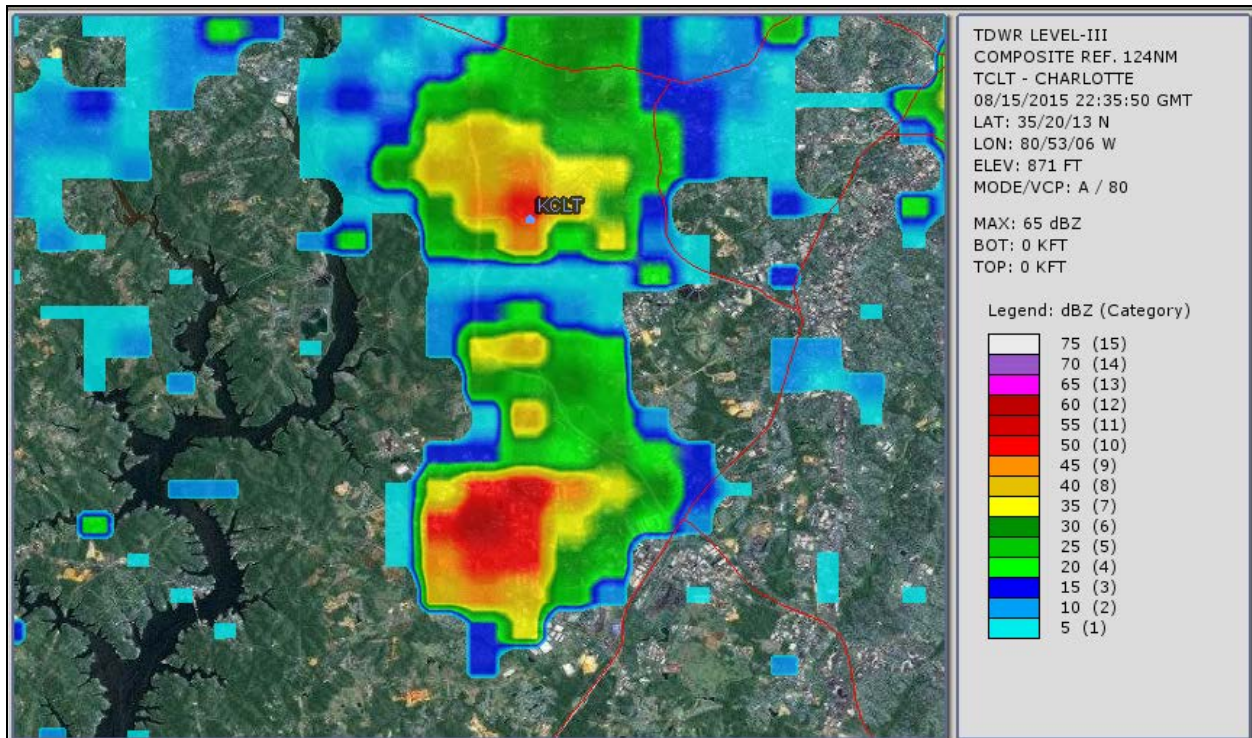


Figure 28 - CLT TDWR composite reflectivity image at 1835:50 EDT

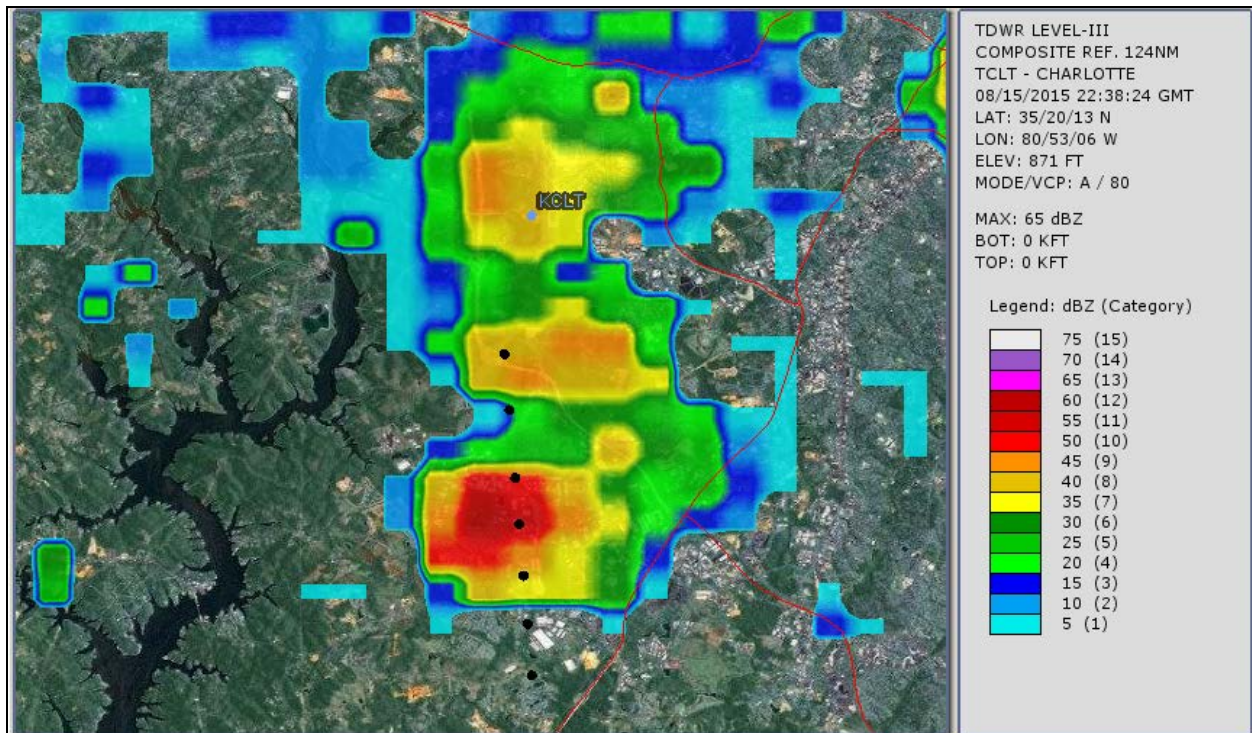


Figure 29 - CLT TDWR composite reflectivity image at 1838:24 EDT

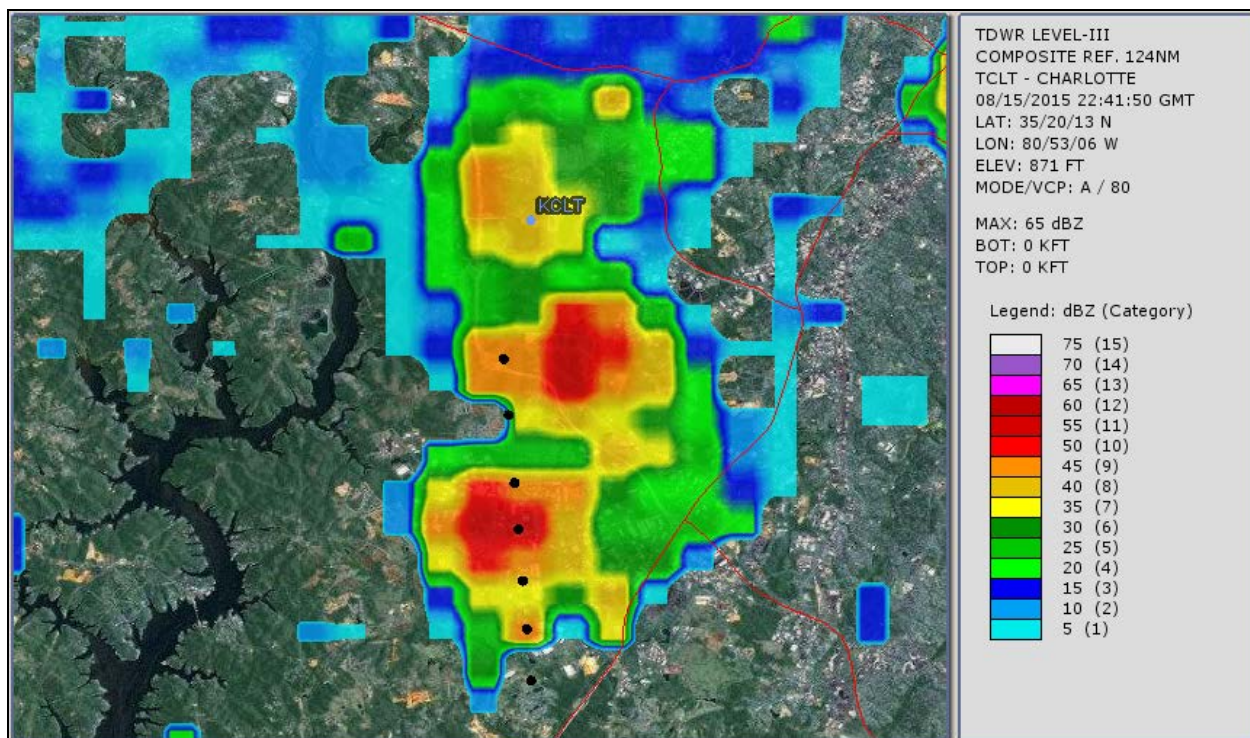


Figure 30 - CLT TDWR composite reflectivity at 1841:50 EDT

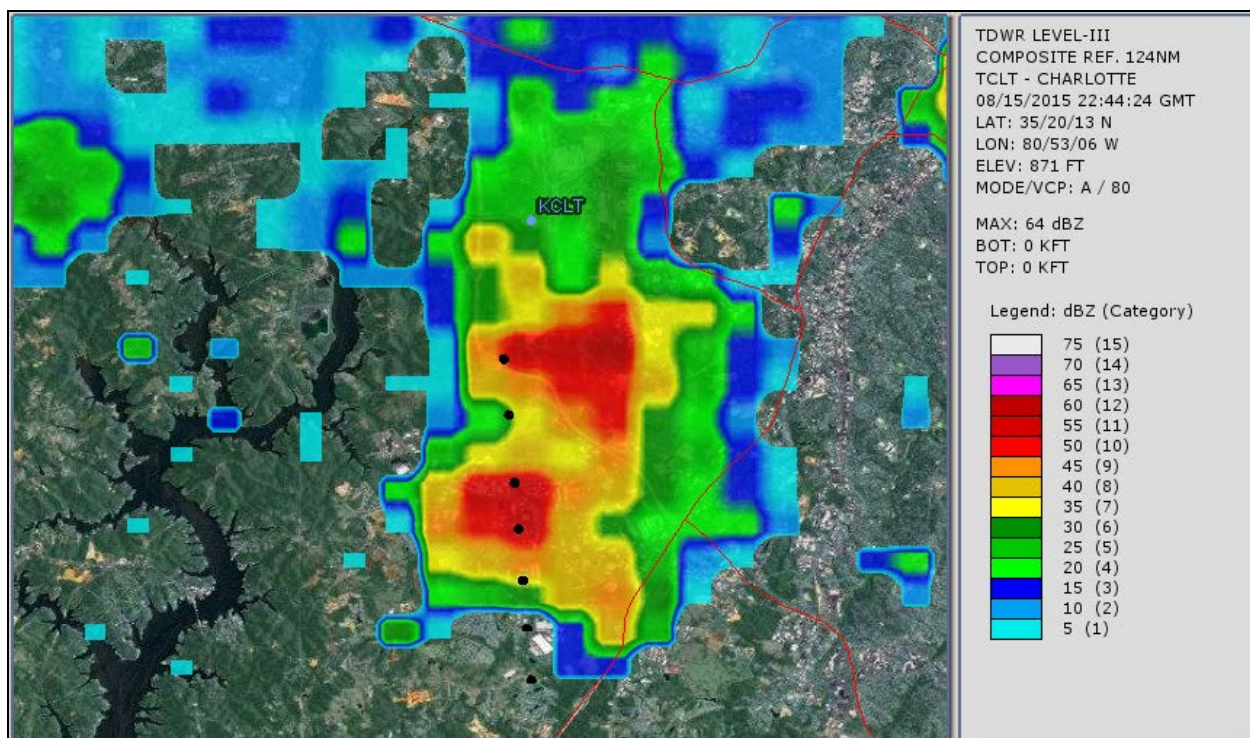


Figure 31 - CLT TDWR composite reflectivity at 1844:24 EDT

6.0 Lightning Data

A review of the Earth Networks lightning data base for the period from 1800 to 1845 EDT detected approximately 65 total lightning strokes over the area during the period. Figure 32 is a depiction of the Greer, SC, WSR-88D base reflectivity image at 1838 EDT with the flight track overlaid up to the time of the accident, and total lightning strokes. There were 55 in-cloud lightning strokes observed and are indicated in dark purple, and 10 cloud-to-ground strikes are indicated in light purple. No cloud-to-ground lightning strike detected within 5 miles of the airport to trigger an alert of thunderstorms by the ASOS lightning detection system.

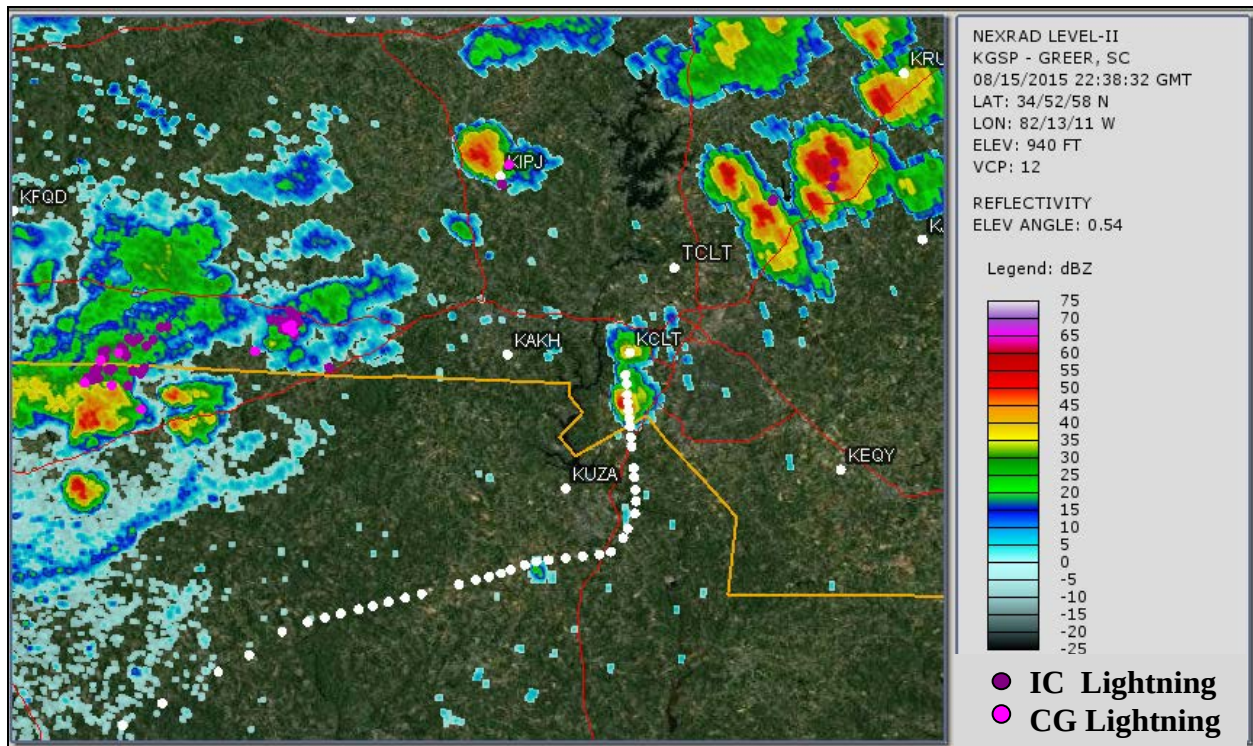


Figure 32 - Lightning strikes from 1800 to 1845 EDT

Another lightning display was obtained from VAISALA which operates a large detection network across the continental United States is included as figure 33. The image is color coded to display the total lightning strikes during the period with the dark red the most recent strikes near the time of the wind shear encounter. The VAISALA data indicated 191 lightning events within 50 miles of the accident site during the period from 1800 to 1845 EDT, with the closest strike 17.3 miles north-northeast of the accident site.

Figure 34 is the VAISALA lightning display within 25 miles of the accident site with the time of the in-cloud (C) and cloud-to-ground (G) strike noted. The display indicated 8 lightning events during the same period from 1800 to 1845 EDT, with the closest cloud-to-ground lightning strike (17.3NM) to the north-northeast at 1843:19 EDT.

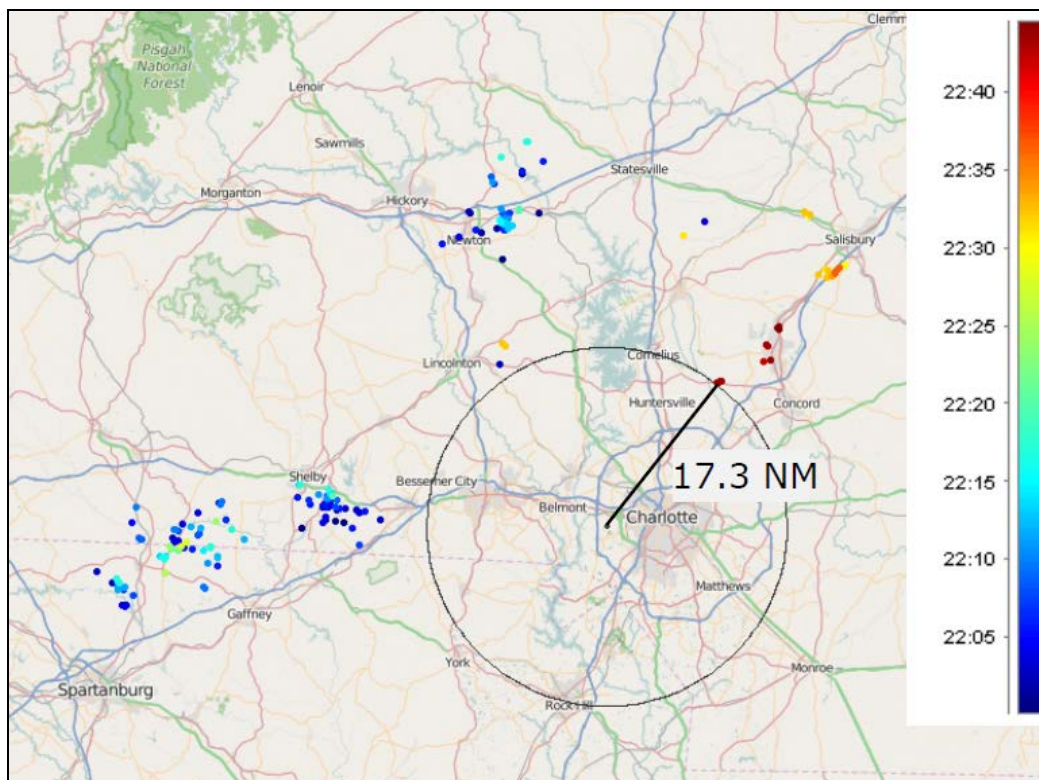


Figure 33 - VAISALA Lightning display between 1800 (2200Z) and 1845 EDT (2245Z)

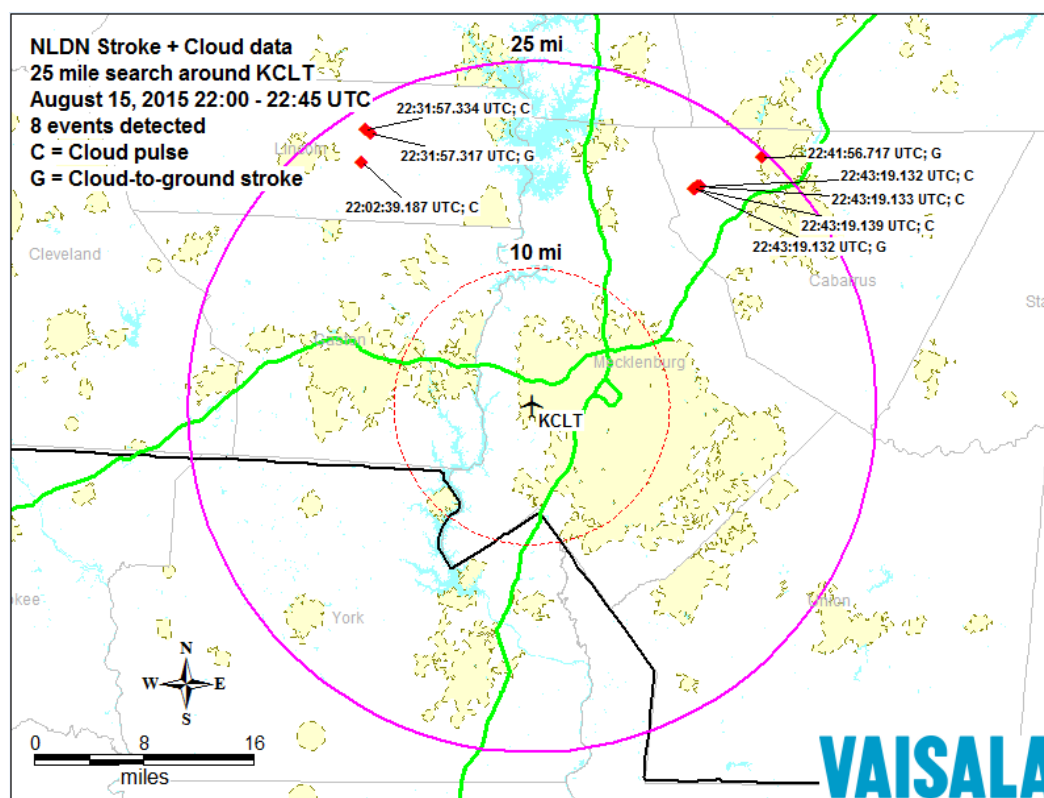


Figure 34 - VAISALA Lightning strikes within 25 miles between 1800 and 1845 EDT

7.0 Pilot Reports

The following pilot report (PIREPs) was recorded over the route of flight during the period.

GVL UA /OV CNI090010 /TM 1645 /FL045 /TP P28A /SK BKN110 /TA 20 /TB NEG

*EXX UA /OV JQF-RUQ360020/TM 1657/FL095/TP M7/SK SCT/WX FV20SM/WV 00000KT/TB NEG/RM /WX
FV05SM 090-BLO FV20-30SM 090-ABV*

CLT UA /OV CLT225040/TM 1904/FL110/TP A321/TB MOD CHOP/RM ZTL

EOE UA /OV EOE230001/TM 1931/FL080/TP P28A/SK SCT055/TB NEG

GVL UA /OV CNI090010/TM 1938/FL036/TP P28A/SK SCT060/TA 23

SPA UA /OV SPA270008/TM 2034/FL030/TP P28A/TA 25/TB LGT CHOP/RM DURD

There were no official pilot reports entered into the NWS database reporting wind shear conditions in the Charlotte area during the period. The Air Traffic Control Specialist report will document several pilot reports of aircraft on approach into Charlotte who advise the controller of conditions encountered by several aircraft including the incident flight's report of encountering windshear during the period.

8.0 NWS Terminal Aerodrome Forecast

The NWS Greenville-Spartanburg (KGSP) Weather Forecast Office (WFO), located in Greer, SC, had the responsibility for the Terminal Aerodrome Forecast (TAF) issuance for Charlotte. The normally scheduled forecast issued at 1321 EDT and two following amended forecasts issued were as follows:

TAF KCLT 151721Z 1518/1618 26005KT P6SM SCT070

FM152000 26004KT P6SM VCSH BKN060

FM160100 21003KT P6SM BKN060

FM161700 25004KT P6SM BKN070=

TAF AMD KCLT 152058Z 1521/1618 26004KT P6SM VCSH SCT060 BKN250

FM160100 21003KT P6SM BKN060

FM161700 25004KT P6SM BKN070=

TAF AMD KCLT 152207Z 1522/1618 26004KT P6SM VCSH SCT060 BKN250

TEMPO 1522/1524 VRB10G18KT TSRA BKN050CB

FM160100 21003KT P6SM BKN060

FM161700 25004KT P6SM BKN070=

The initial forecast for KCLT issued at 1321 EDT, expected prevailing wind from the west or 260° at 4 knots, visibility better than 6 miles, with rain showers in the vicinity or within 10 miles of the station, with a ceiling broken at 6,000 feet agl. The forecast was amended at 1658 EDT, and continued to expected rain showers in the vicinity of the airport with only a scattered layer of clouds at 6,000 feet. A second amendment was issued after the aircraft was airborne at 1807 EDT, and expected a temporary period of variable winds gusting to 18 knots, with thunderstorms and moderate rain, with a ceiling broken at 5,000 feet agl in cumulonimbus clouds.

The American Airlines weather document issued to the flight included the TAFs issued at 1321 EDT (1721Z) and the amended forecast at 1658 EDT (2058Z) above.

9.0 NWS Aviation Forecast Discussion

The NWS Greer, SC, WFO issued the following Aviation Weather Discussion to provide the meteorological reasoning behind the issuance of the Charlotte TAF and their general forecast for the area.

*FXUS62 KGSP 152103
AFDGSP*

*AREA FORECAST DISCUSSION
NATIONAL WEATHER SERVICE GREENVILLE-SPARTANBURG SC
503 PM EDT SAT AUG 15 2015*

.SYNOPSIS...

WEAK HIGH PRESSURE WILL LINGER ATOP THE REGION FOR THE REST OF THE WEEKEND BEFORE A WEAK COLD FRONT APPROACHES FROM THE NORTHWEST EARLY NEXT WEEK. THIS FRONT WILL WASH OUT ACROSS THE AREA ON TUESDAY. ANOTHER COLD FRONT IS EXPECTED TO APPROACH BY THURSDAY AND BRING INCREASED CHANCES OF WIDESPREAD SHOWERS AND THUNDERSTORMS.

.AVIATION /21Z SATURDAY THROUGH THURSDAY/...

AT KCLT...VFR EXPECTED THRU THE PERIOD. FOR TODAY...EXPECT SCT TO BKN MOSTLY HIGH BASED STRATOCU. CANNOT RULE OUT A FEW SHOWERS/STORMS AROUND THIS AFTERNOON. ONE OF THE CONVECTION ALLOWING MODELS HAS SOME DEVELOPMENT IN THE LATE AFTERNOON...SO A VCSH WAS INTRODUCED AT 21Z. WIND DIRECTION WILL BE PROBLEMATIC. SPEED SHOULD BE 5KT OR LESS...AND POSSIBLY CALM FOR SEVERAL STRETCHES...UNLESS A THUNDERSTORM DEVELOPS NEARBY...IN WHICH CASE DIRECTION WILL BE DOMINATED BY OUTFLOWS. SW SHOWS UP THE MOST IN THE GUIDANCE...SO THAT WAS CHOSEN FOR THE BALANCE OF THE DAY. TONIGHT SHOULD HAVE MID/HIGH CONVECTIVE DEBRIS CLOUDS WITH A LIGHT/VARIABLE WIND.

ELSEWHERE...VALLEY FOG AROUND KAVL SHOULD BURN OFF/DISSIPATE BY 13Z OR SO. FOR THE DAY...SIMILAR TO KCLT...SO EXPECT SCT/BKN VFR LEVEL CLOUDS. SHOWER/TSTM ACTIVITY WILL BE A BIT MORE PLENTIFUL THIS AFTERNOON SO A PROB30 WAS ALSO INCLUDED AT KHKY...IN ADDITION TO KAVL. NOT CONFIDENT ENUF TO INCLUDE AT THE UPSTATE TAF SITES FOR NOW. THE CONVECTION SHOULD SLOWLY DIMINISH WITH LOSS OF HEATING. WIND DIRECTION WILL DEPEND ON THUNDERSTORM OUTFLOWS...BUT WILL OTHERWISE BE VARIABLE WITH SPEED UNDER 5 KT.

The discussion was update immediately after the accident, to the following:

*FXUS62 KGSP 152337
AFDGSP*

*AREA FORECAST DISCUSSION
NATIONAL WEATHER SERVICE GREENVILLE-SPARTANBURG SC
737 PM EDT SAT AUG 15 2015*

.SYNOPSIS...

WEAK HIGH PRESSURE WILL LINGER ATOP THE REGION FOR THE REST OF THE WEEKEND BEFORE A WEAK COLD FRONT APPROACHES FROM THE NORTHWEST EARLY NEXT WEEK. THIS FRONT WILL WASH OUT ACROSS THE AREA ON TUESDAY. ANOTHER COLD FRONT IS EXPECTED TO APPROACH BY THURSDAY AND BRING INCREASED CHANCES OF WIDESPREAD SHOWERS AND THUNDERSTORMS.

.
AVIATION /00Z SUNDAY THROUGH THURSDAY/...

AT KCLT...A COUPLE OF TSTMS IN VICINITY OF THE TERMINAL AT TIME OF TAF ISSUANCE...BUT SHUD DRIFT SOUTH AWAY FROM THE TERMINAL...BUT WILL KEEP A TEMPO IN FOR FIRST HOUR. AN ADDITIONAL SHRA OR TSRA MAY DEVELOP BEFORE THE ATMOS STABILIZES WITHIN A COUPLE HOURS AFTER SUNSET. THERE WILL BE A FAIR AMOUNT OF CONVECTIVE DEBRIS MID AND HIGH CLOUDS AGAIN TONIGHT...WHICH SHUD KEEP KCLT VFR. WINDS WILL BE LIGHT. ON SUNDAY...GUIDANCE SHOWS STEERING FLOW TURNING MORE OUT OF THE SOUTHWEST AND PERHAPS LESS INSTBY ACRS THE PIEDMONT. SO WILL NOT HAVE ANY CONVECTION MENTIONED IN THE LATTER PART OF THE TAF. WINDS SHUD FAVOR A SW DIRECTION SUNDAY AFTN.

10.0 In-Flight Weather Advisories

The NWS issues in-flight weather advisories designated as Severe Weather Forecast Alerts (AWW's), Convective SIGMET's (WST's), SIGMET's (WS's), Center Weather Advisories (CWA's), and AIRMET's (WA's). In-flight advisories serve to notify en route pilots of the possibility of encountering hazardous flying conditions, which may not have been forecast at the time of the preflight briefing. Whether or not the condition described is potentially hazardous to a particular flight is for the pilot to evaluate on the basis of experience and the operational limits of the aircraft.

The following Convective SIGMET was issued prior to the accident for extreme northern Georgia, western South and North Carolina, eastern Tennessee and Kentucky, and southwestern Virginia for an area of thunderstorms, with little expected movement. The area did not extend over the Charlotte area and generally was located west of the route of flight. Figure 35 is a depiction of the advisories in effect at 1713 EDT.

MKCE WST 152155
CONVECTIVE SIGMET 61E
VALID UNTIL 2355Z
VA NC WV SC TN KY
FROM 30ENE PSK-20SSE GSO-30E ODF-30ENE LOZ-30ENE PSK
AREA TS MOV LTL. TOPS ABV FL450.

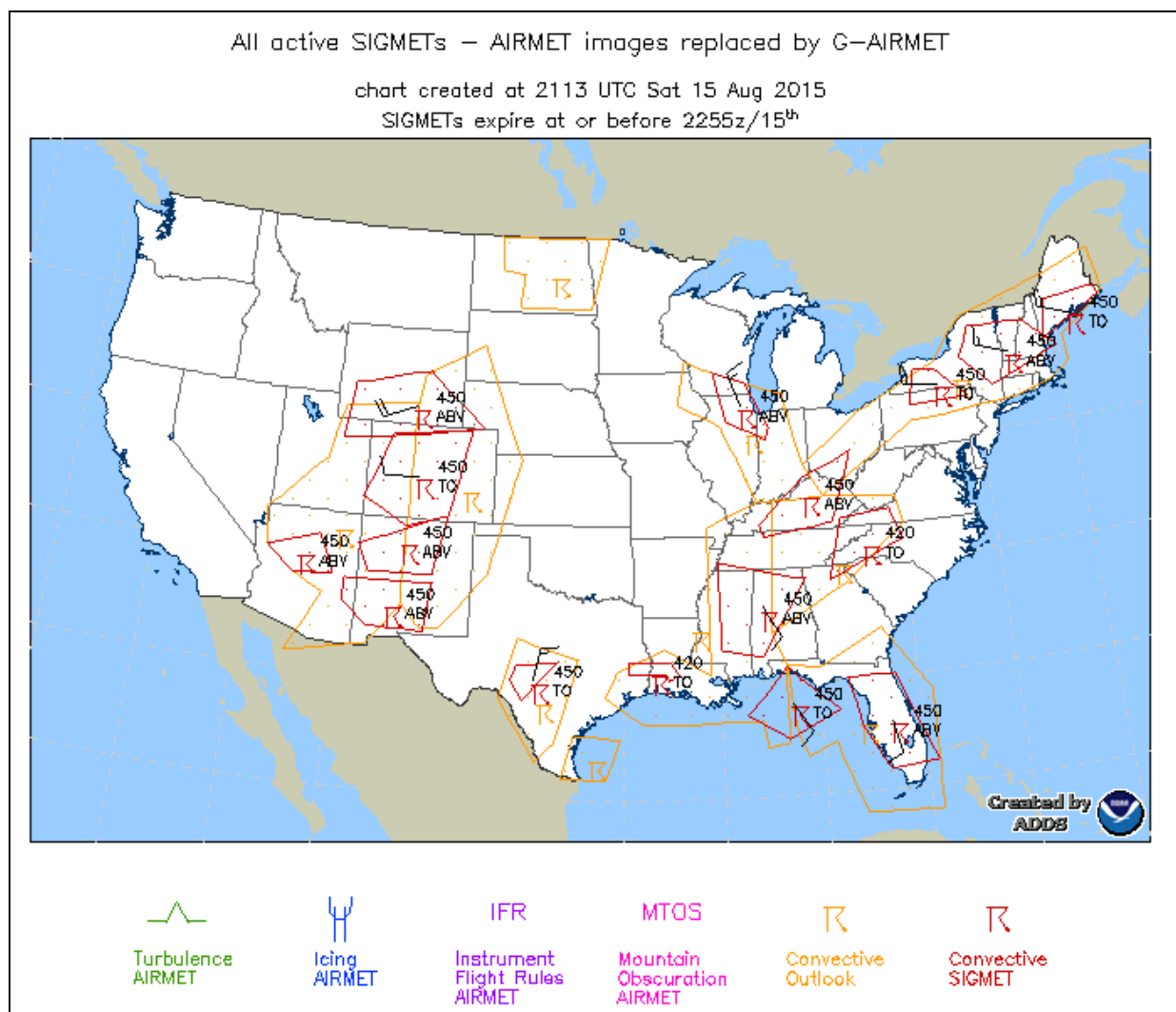


Figure 35 – NWS Convective SIGMETs current at the time

11.0 Center Weather Service Unit Products

The Atlanta Center Weather Service Unit issued a Center Weather Advisories (CWA) prior to the accident at 1603 EDT, which was valid until 1700 EDT for an area of heavy to extreme precipitation in scattered rain showers and thunderstorms, with little movement extending from Alabama northeastward into southwestern Virginia. The area did not extend over the Charlotte area but extended over western North Carolina. The advisory was as follows:

FAUS21 KZTL 152003 2015227 2003
 ZTL1 CWA 152000
 ZTL CWA 104 VALID UNTIL 152100
 FROM VUZ-25SE PSK
 AREA 50NM WIDE HVY-EXTRM PCPN IN SCTD SHRA AND TSRA MOVG LTL. MAX
 TOPS NR FL350. EXP LTL CHNG IN CVRG/INTSTY THRU PD.

12.0 Convective Products

The NWS AWC Collaborative Convective Forecast Product (CCFP) issued at 1500 EDT and valid for the next 2-hours or for 1700 EDT (2100Z) is attached as figure 36. The image depicted no significant convective activity over the Charlotte area. The closest area of convection was for an area over Tennessee into extreme northwest Georgia, northern and western Alabama, and into Mississippi, where a low confidence or a 25 to 49% of storms were expected to form with tops to 34,000 feet. A higher confidence area of 50 to 100% was located within that area over Mississippi with tops to 39,000 feet.

The 4-hour CCFP valid for 1900 EDT (2300Z) is included as figure 37. The chart continued to depict no significant areas of convective activity over the Charlotte area, the closest activity was a high confidence area over Tennessee and Mississippi with tops to 34,000 feet. No significant convection was expected along the route of flight.

The next issuance of the CCFP at 1700 EDT 2-hour forecast valid at 1900 EDT (2300Z) immediately after the accident is included as figure 38, and continued to depict no significant convective activity along the route of flight or in the vicinity of Charlotte.

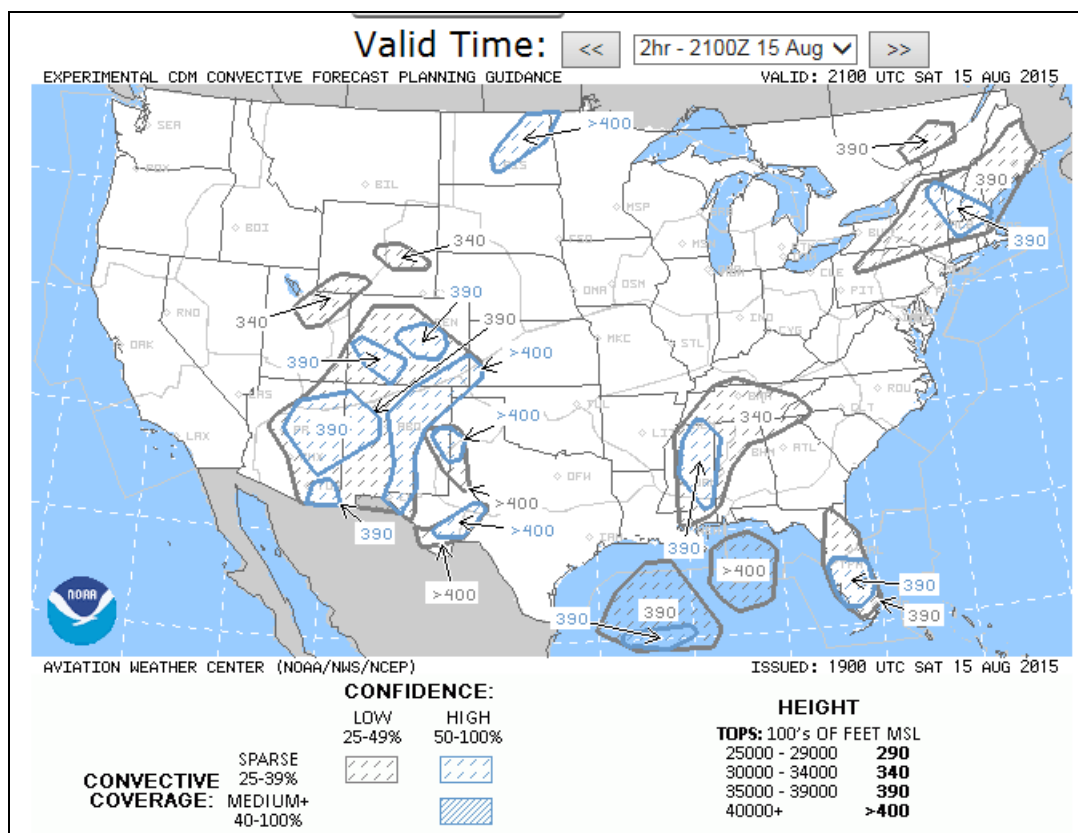


Figure 35 - CCFP 2-hour forecast issued at 1500 and valid for 1700 EDT

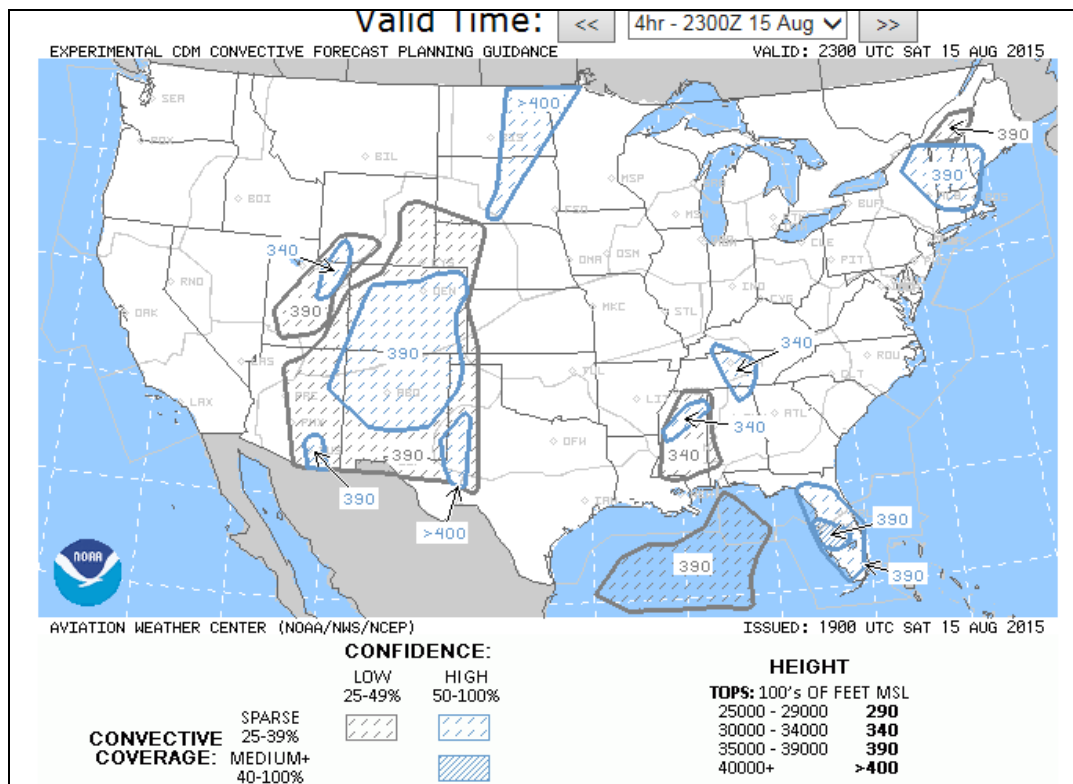


Figure 36 - CCFP 4-hour forecast issued at 1500 and valid for 1900 EDT

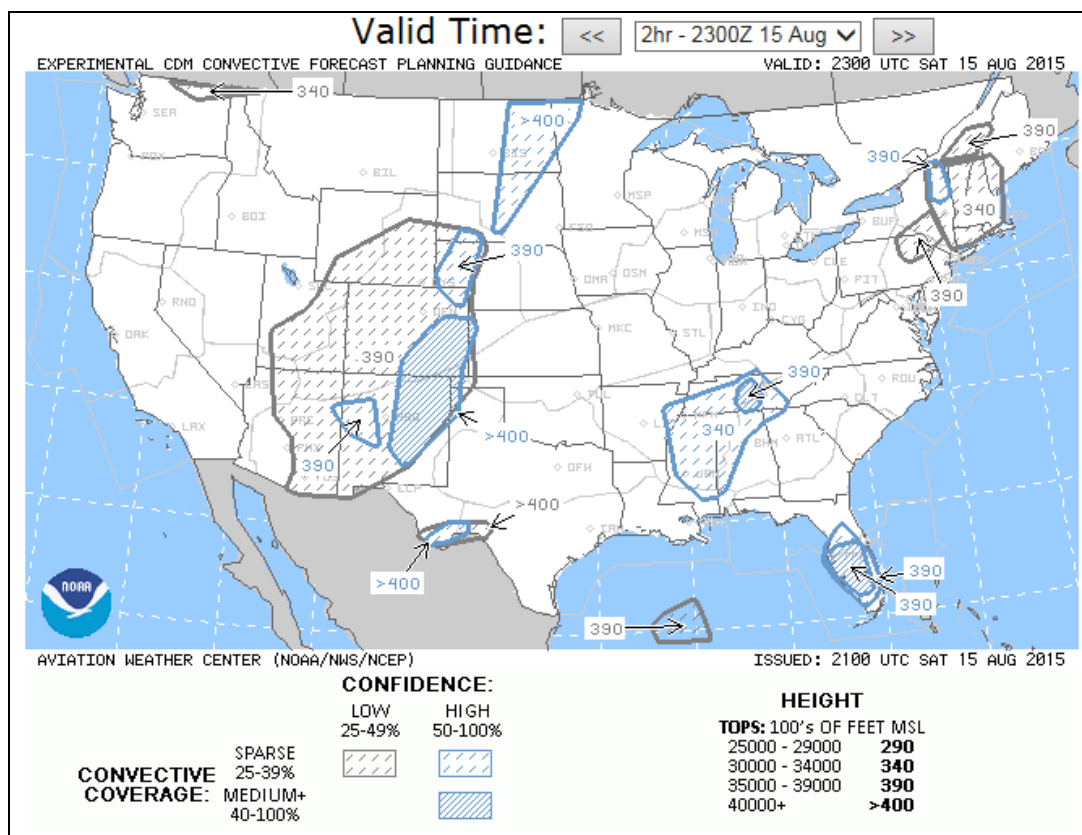


Figure 37 - CCFP 2-hour forecast issued 1700 and valid for 1900 EDT

13.0 ATC Weather Displays

The FAA various weather support systems to provide weather data to the air traffic centers, approach, and towers were documented.

13.1 Consolidated Storm Prediction for Aviation

The Consolidated Storm Prediction for Aviation (CoSPA)²⁰ developed by the Massachusetts Institute of Technology's Lincoln Laboratory (MIT/LL) provided a 1 kilometer resolution image of the vertical integrated liquid (VIL), echo tops, lightning, and expected growth and decay trend during the period were obtained and documented for the period. Figures 39 through 43 are the CoSPA images from 1800 to 1900 EDT at 15-minute intervals.

At 1815 EDT an area of echoes with echo tops near 24,000 feet and little or no motion was identified over the Charlotte area. By 1845 EDT the area had increased to 26,000 feet. Little to no lightning was identified with the echo, and stronger more pronounced echoes were scattered over the area west through north and northeast of the Charlotte area.

²⁰ Consolidated Storm Prediction for Aviation (CoSPA) Program was established by the Federal Aviation Administration's (FAA's) Aviation Weather Research Program (AWRP) in order to integrate several experimental systems into one high-quality expert system. The system integrated several prototype products such as the Corridor Integrated Weather System (CIWS), Integrated Terminal Weather System (ITWS), Collaborative Convective Forecast Product (CCFP), Convective SIGMETs, Numerical Weather Prediction (NWP), AutoNowcaster, and National Convective Weather Forecast (NCWF).

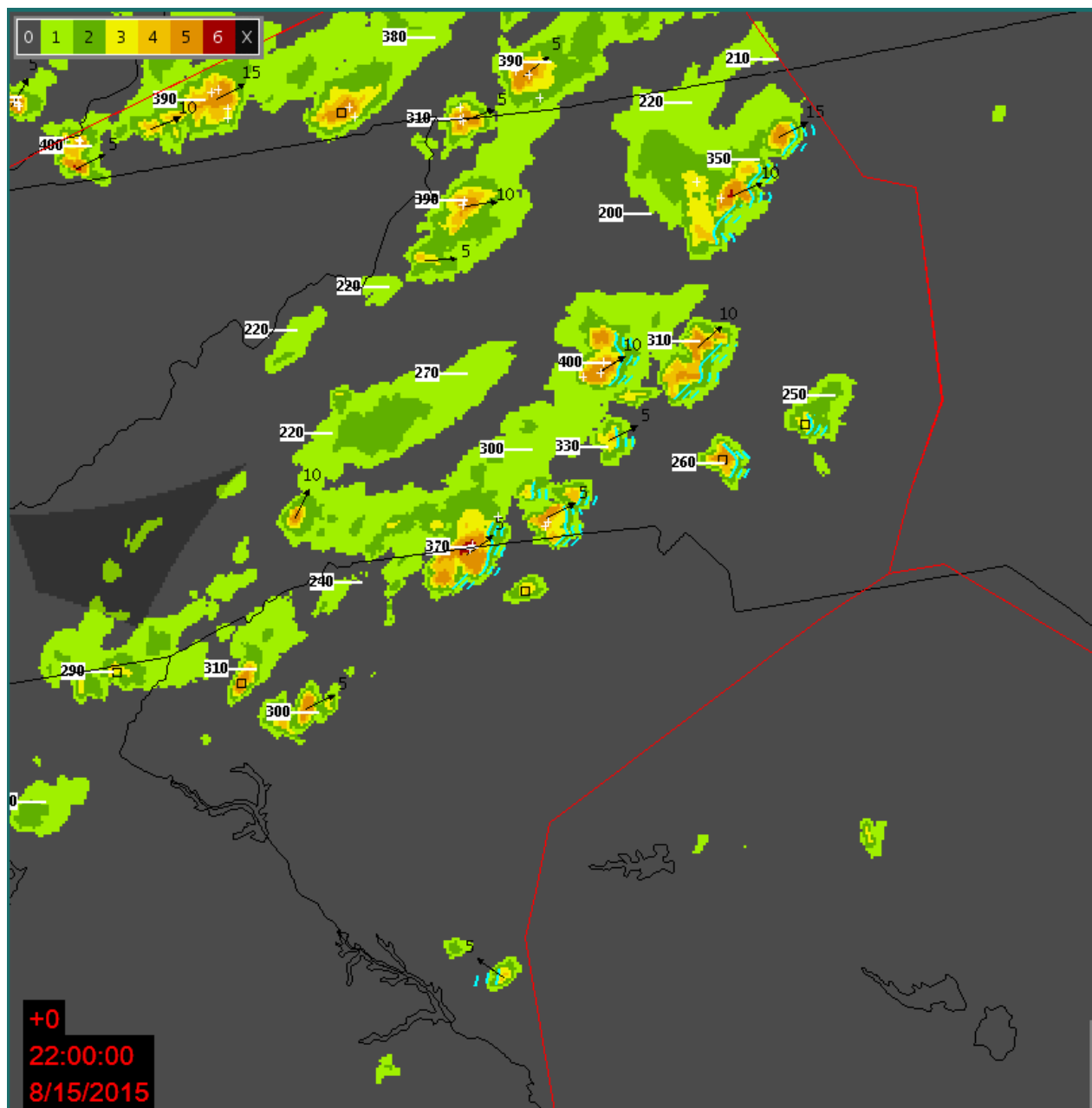


Figure 38 - CoSPA image at 1800 EDT (2200Z)

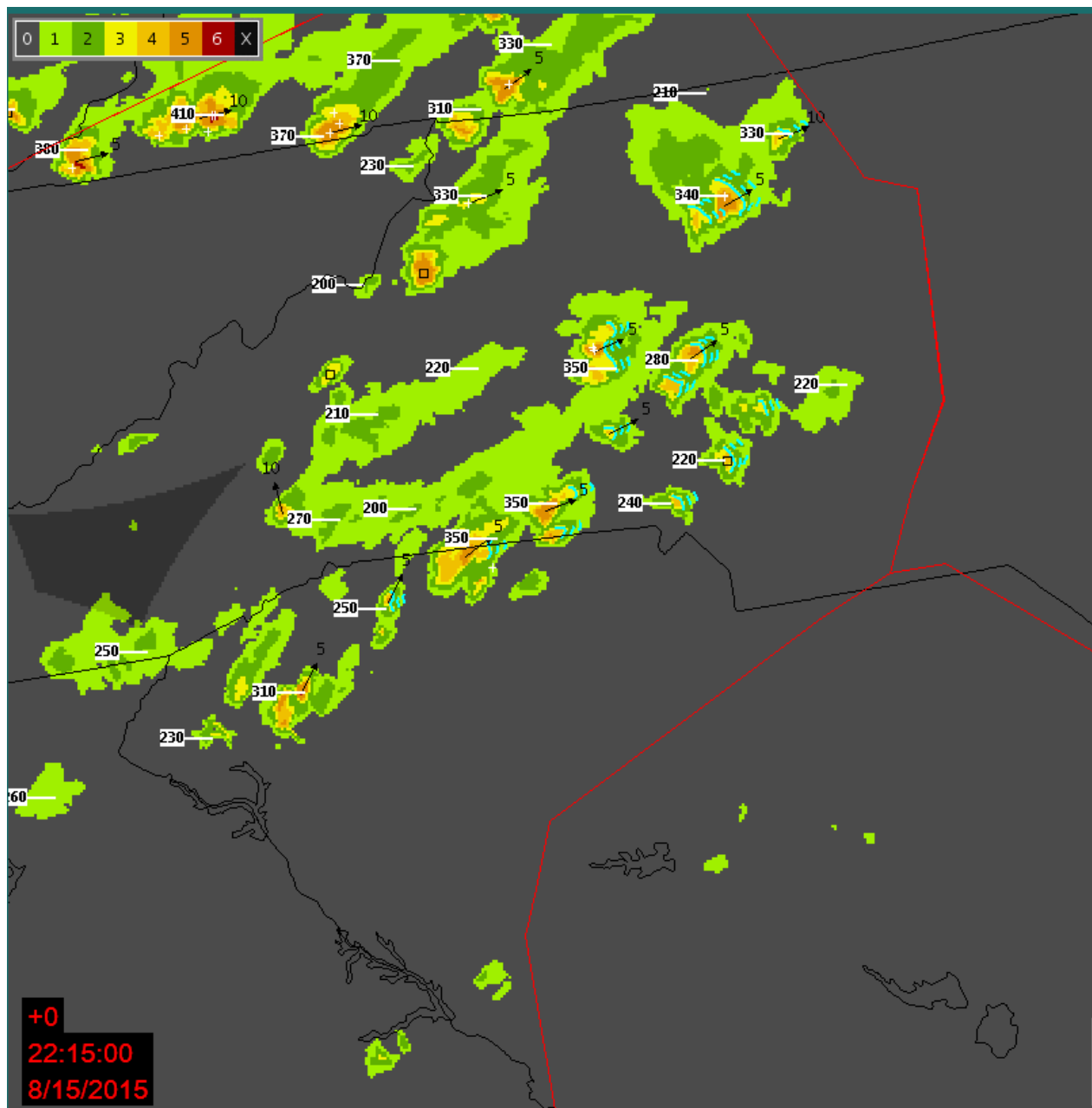


Figure 40 - CoSPA image at 1815 EDT (2215Z)

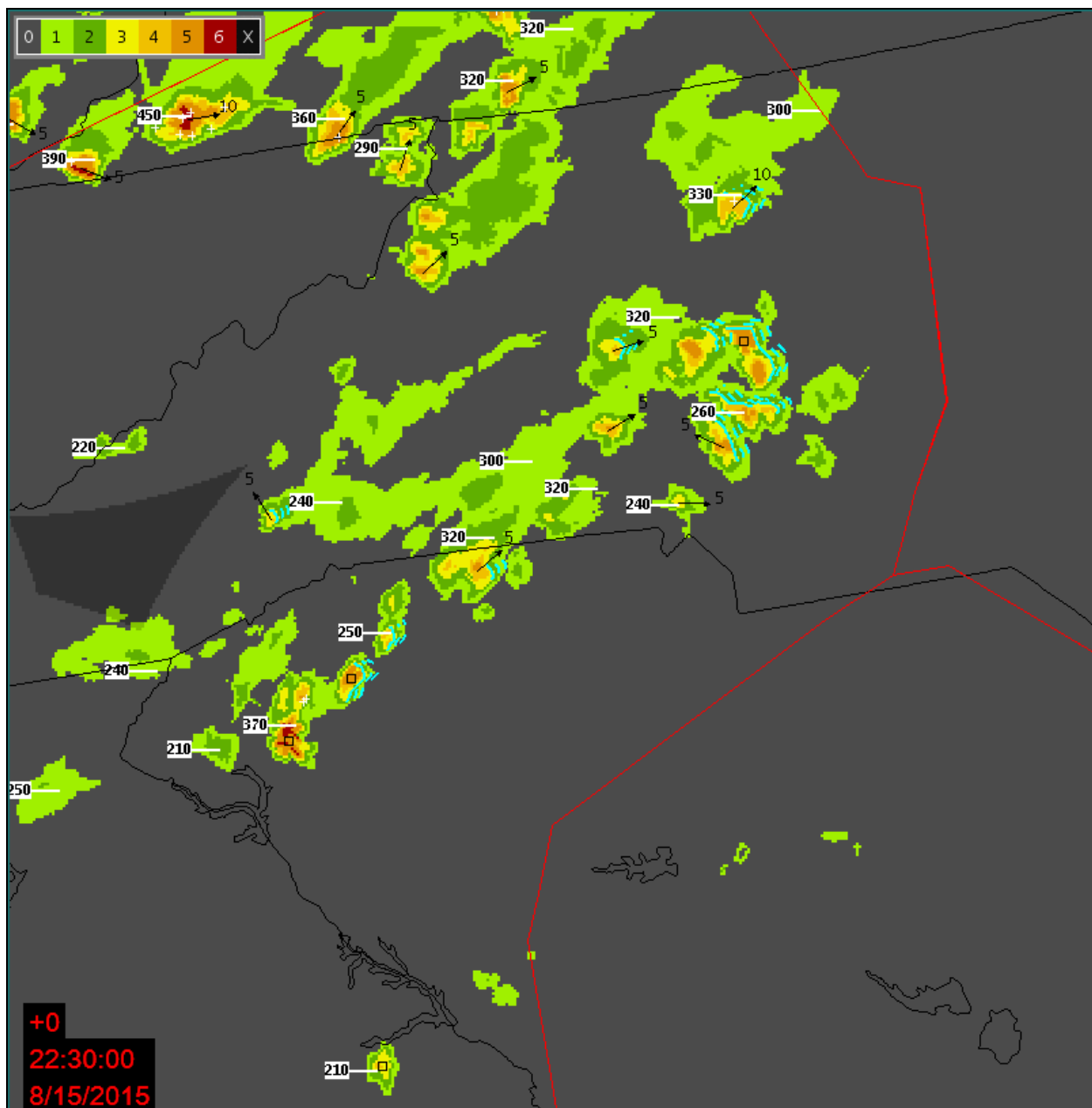


Figure 39 - CoSPA image at 1830 EDT (2230Z)

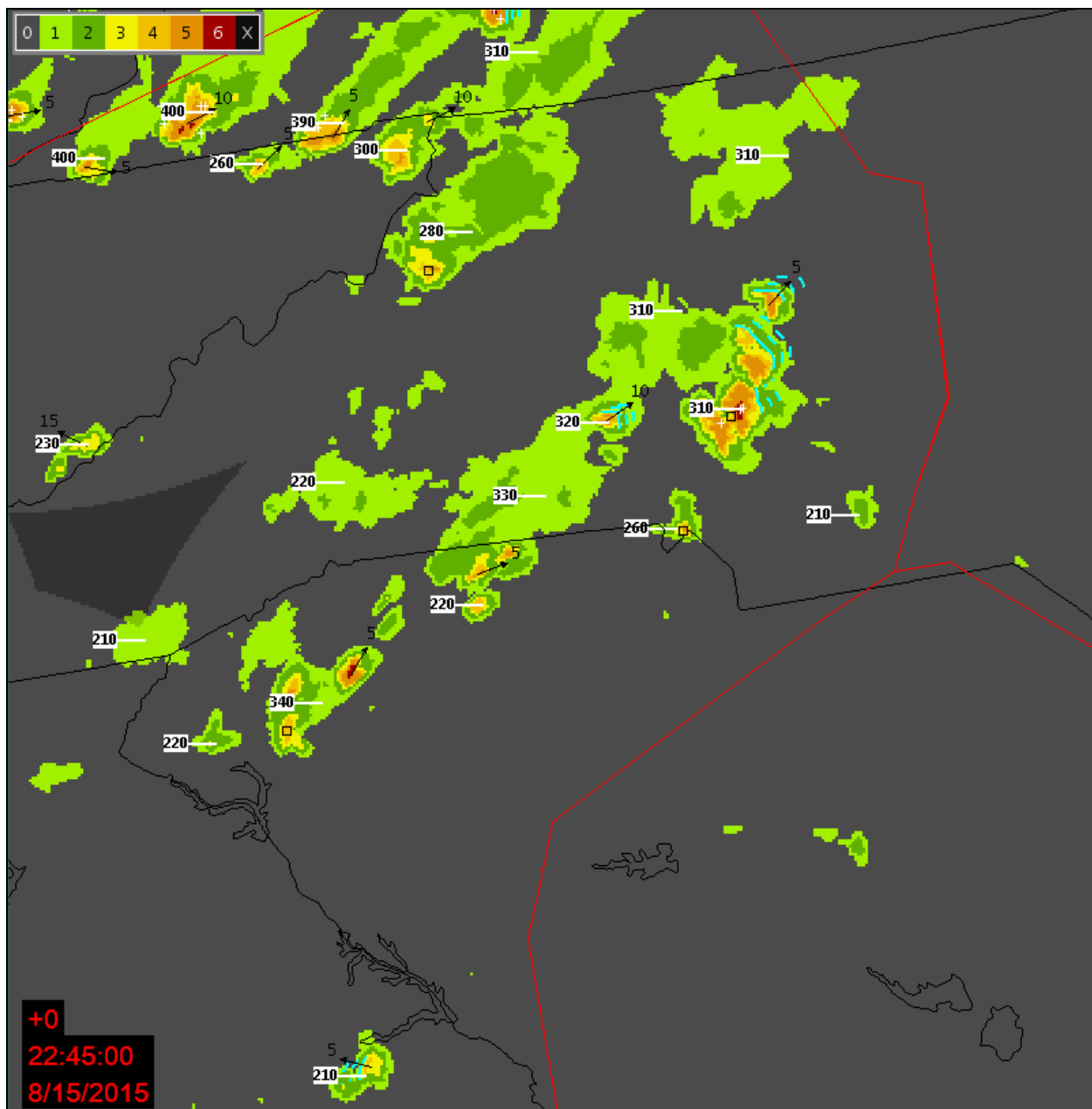


Figure 42 - CoSPA image at 1845 EDT (2245Z)

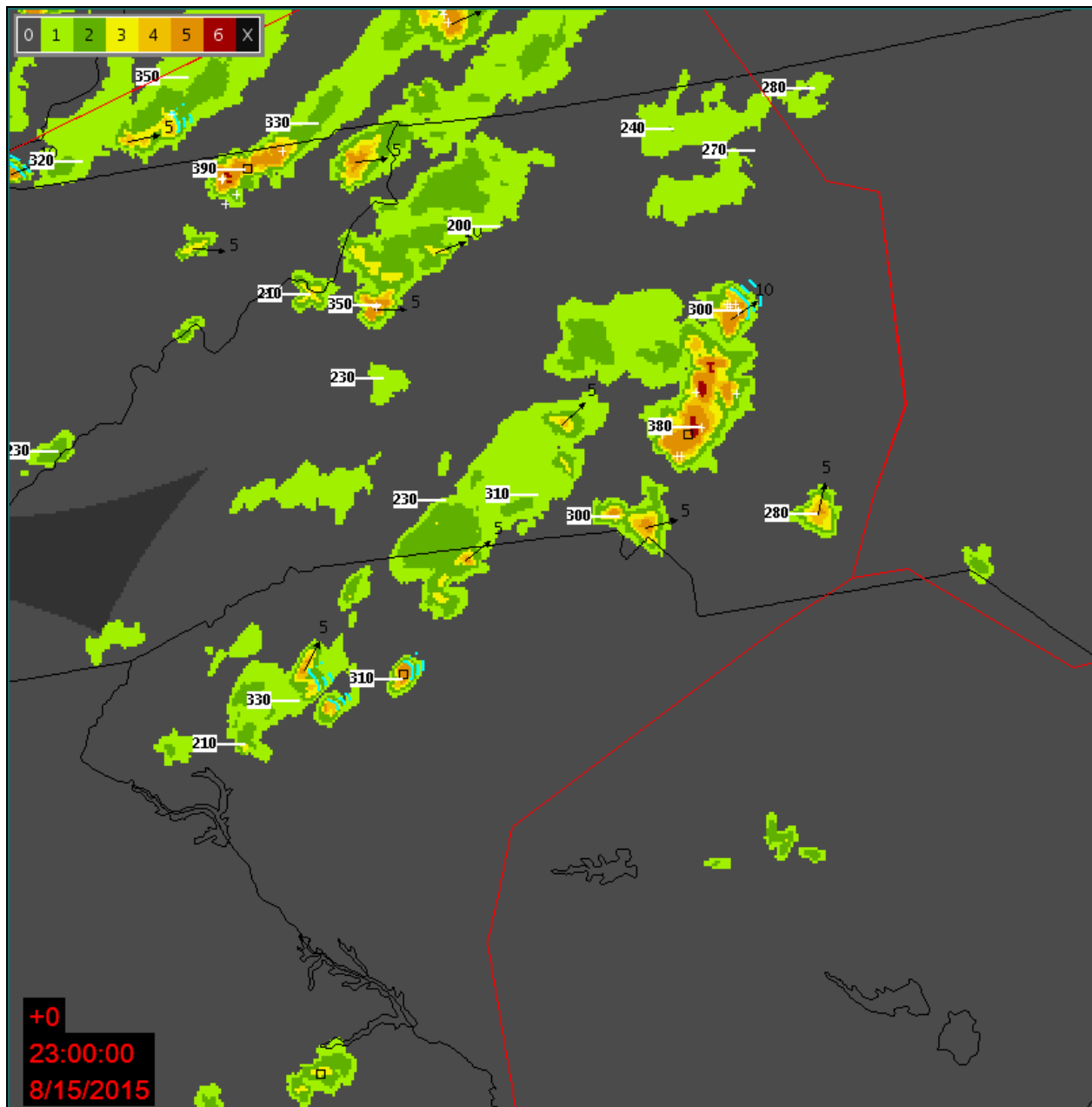


Figure 40 - CoSPA image at 1900 EDT (2300Z)

13.2 Integrated Terminal Weather System (ITWS)

The FAA Integrated Terminal Weather System (ITWS) developed by MIT/LL displays from 1820 through 1855 EDT were documented, at approximately every 2-minutes or the equivalent update rate of the TDWR. The ITWS display provides a regional radar mosaic of precipitation levels or VIP levels 1-6 based on VIL with any significant storm motion of VIP levels of 3 or higher in the top left section of the display out to 200 miles, and a close up view of the radar or VIL displays from levels 1-6 on the top right with any detected microbursts, a runway and radar view within 5 miles on the bottom left hand portion of the image, the Charlotte Ribbon Display

of the Airport Wind (AW)²¹ and any runway specific alerts on the bottom center, and playback text of the information being provided to the air traffic controller on the bottom right. Other features includes a Microburst Alert (MBA) when a divergent couplet or opposing winds from the convective cell is detected the top header bar will be highlighted in red and if a Wind Shear Alert (WSA) is identified with a significant change in wind direction or speed will be highlighted in white in the upper header of the ITWS as indicated in figure 44, along with any indication of a tornado within 10 miles, lightning within 20 miles, and any gust fronts within 20 miles of the station center point.

The ITWS displays from 1821 through 1839 EDT provided at 2 minute intervals are included as figures 44 through 53. A short narrative is included below each image describing some of the display features and alerts for each period.

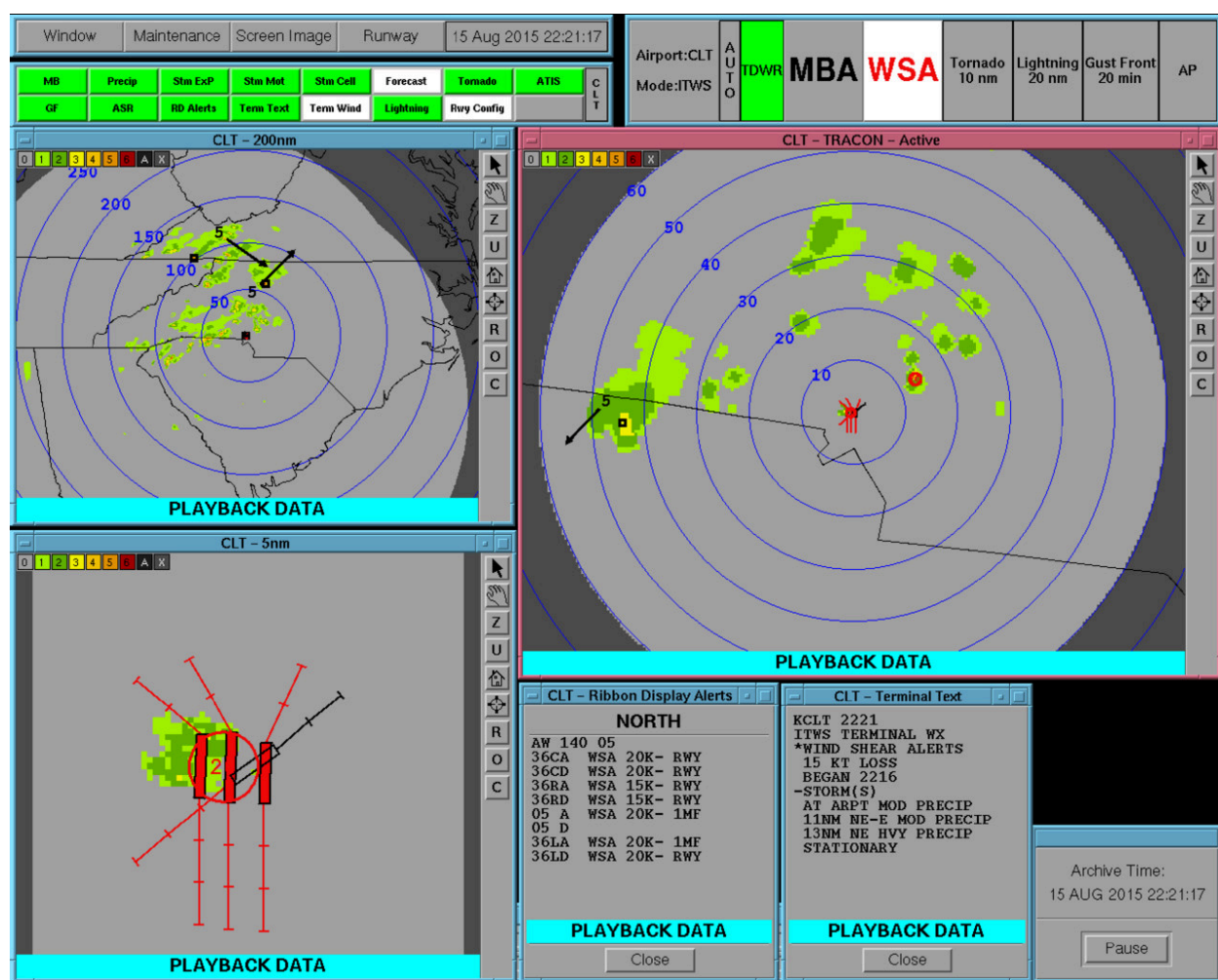


Figure 41 - ITWS display at 1821 EDT

ITWS display at 1821 EDT (2221Z) with a windshear alert (WSA) is active for 3 of the primary north/south runways. The ribbon display indicated an airport wind from 140° magnetic at 5 knots with a windshear alert the 36L approach for a 20 knot loss of wind speed at 1 mile

²¹ The Airport Wind sensor is located on the approach light system to runway 5.

final is indicated with moderate rain being reported at the airport. The wind shear alerts began at 1816 EDT.

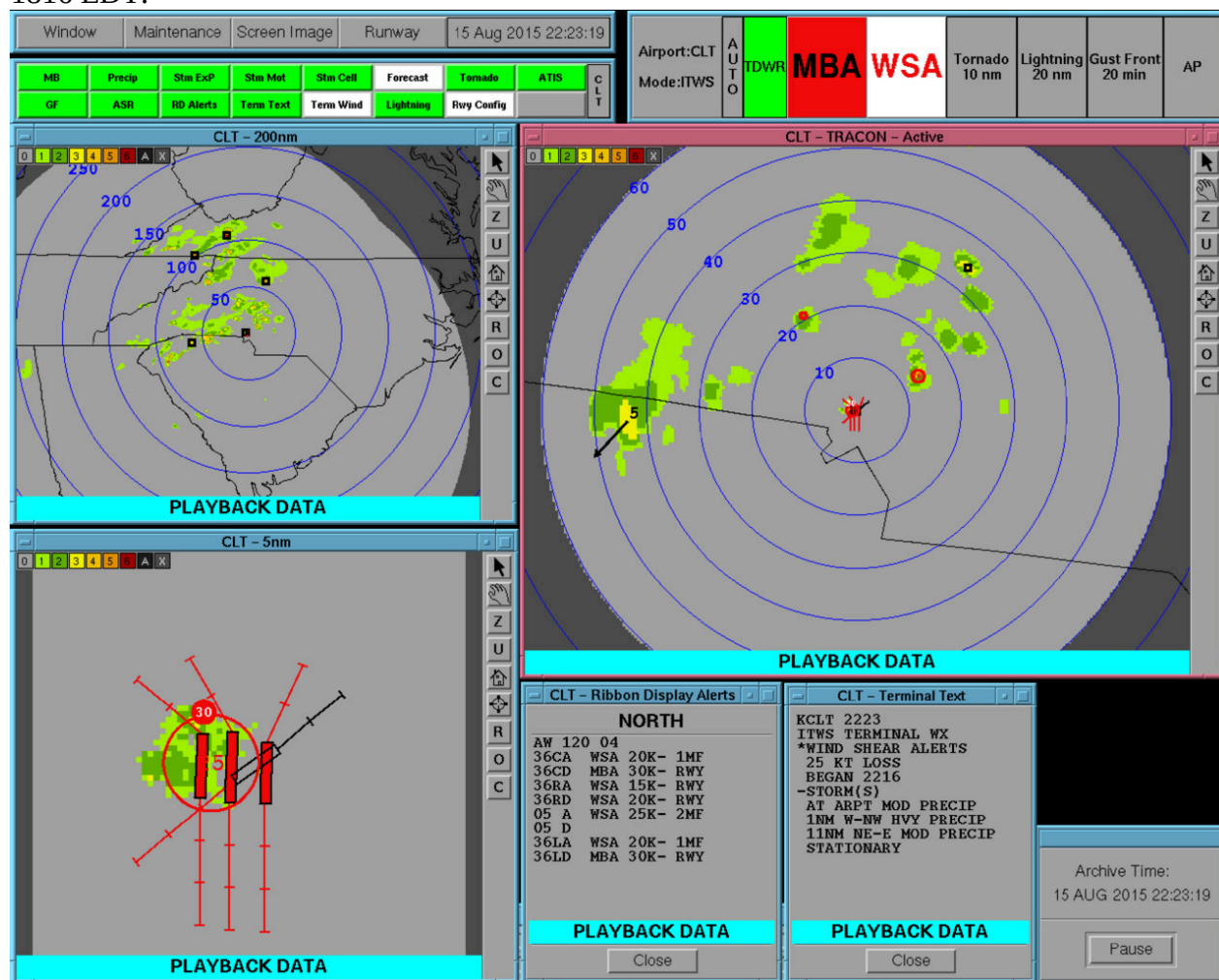


Figure 42 - ITWS display at 1823 EDT

ITWS display at 1823 EDT (2228Z) indicated a microburst and windshear alerts were active for the 3 primary north/south runways. Airport wind from 120° magnetic at 4 knots with an alert for 36L arrivals was a windshear alert for a 20 knot loss 1 mile final. A microburst symbol is indicated on the departure end of runway 36L immediately north of the airport. Moderate rain was at the airport with heavy precipitation west and northwest of the airport.

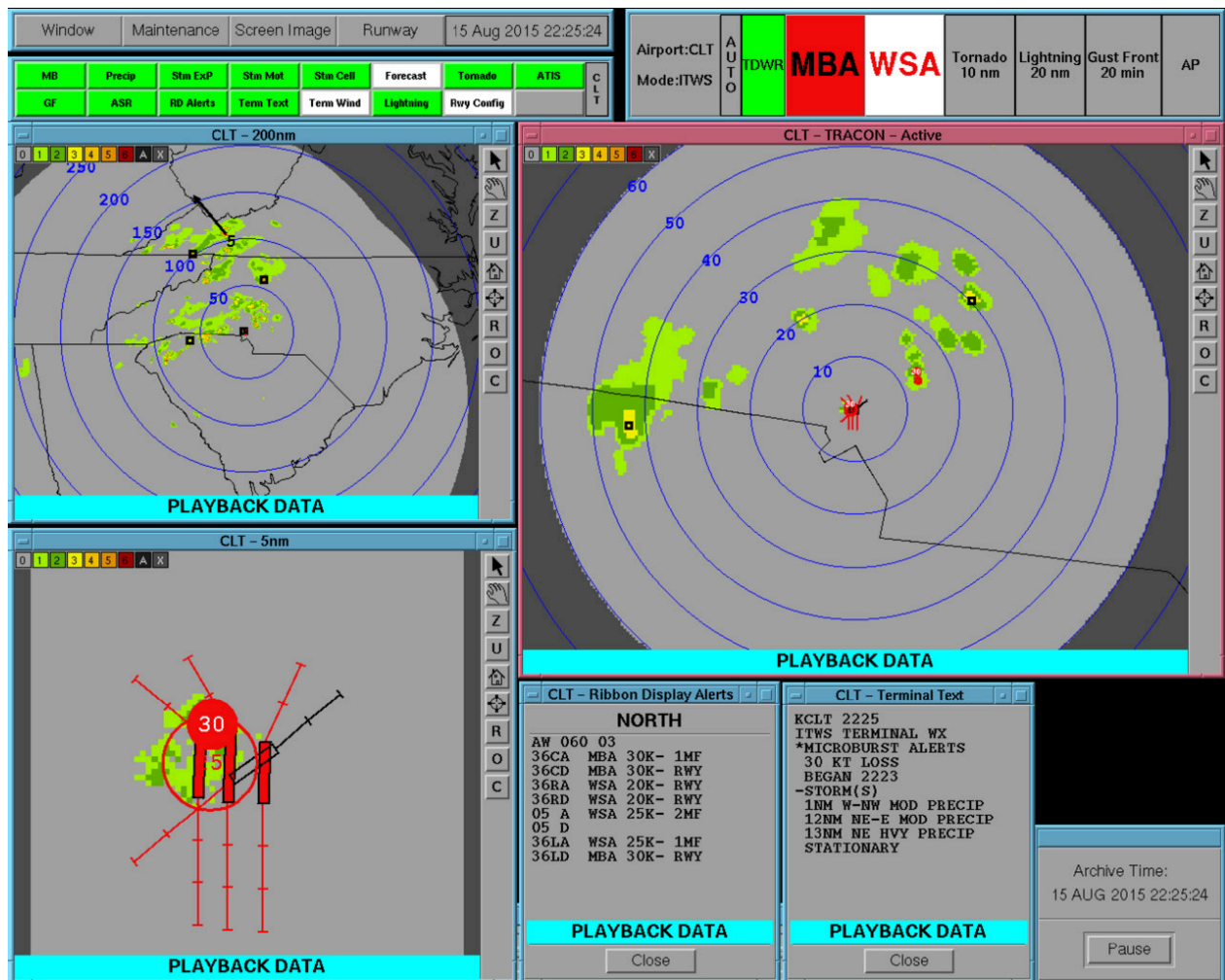


Figure 43 - ITWS display at 1825 EDT

ITWS display for 1825 EDT (2225Z) with microburst and windshear alerts active for the airport. The CLT 5 mile radar display showed a 30 knot microburst over 36L and 36C. The ribbon display indicated an airport wind from 060° at 3 knots and for 36L arrivals a windshear alert of a 25 knot loss at 1 mile final was expected. Microburst alerts began at 1823.

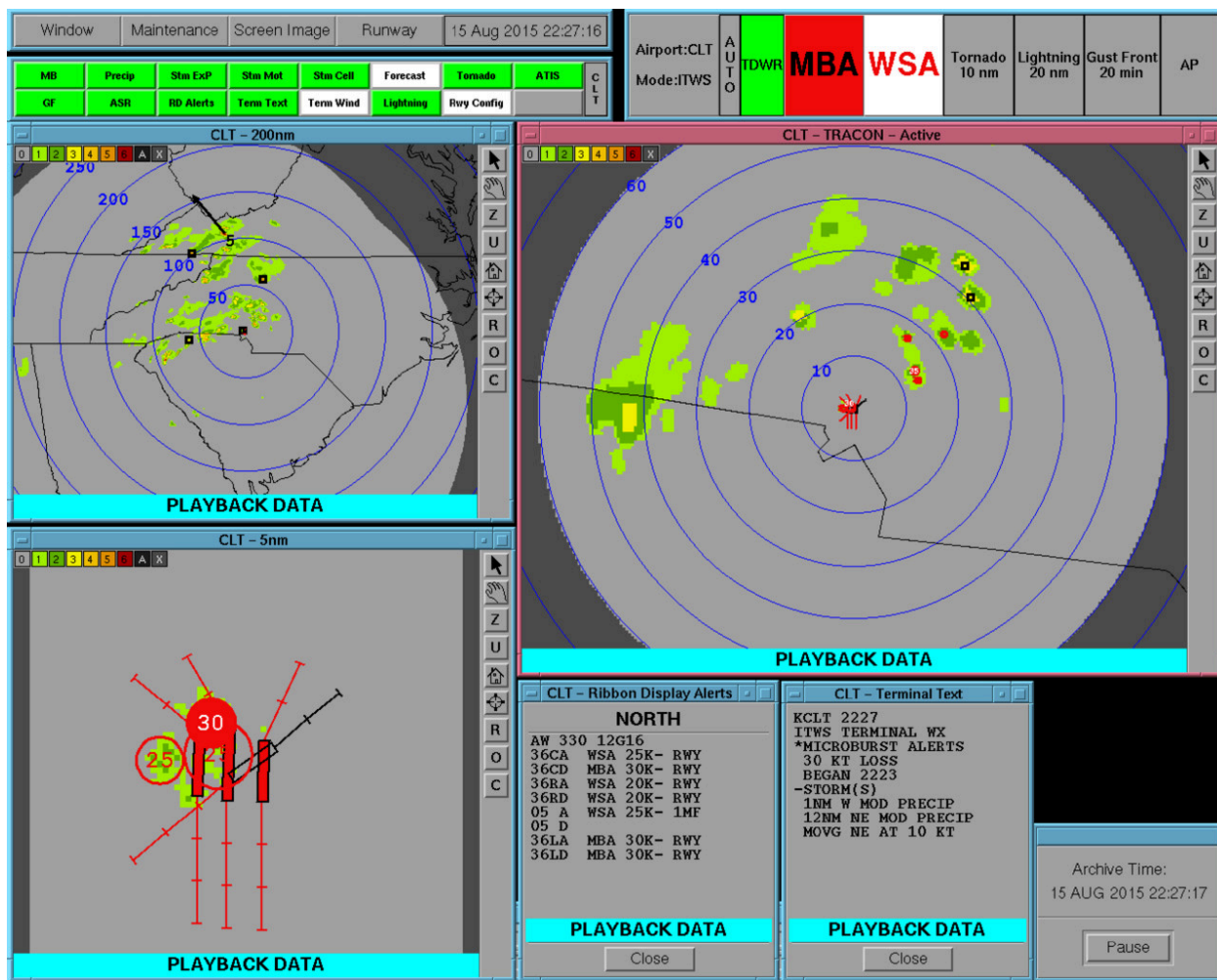


Figure 44 - ITWS display at 1827 EDT

ITWS display at 1827 EDT (2227Z) with microburst and windshear alerts active. A microburst continued to be depicted over the northern portions of runways 36L and 36C. Advisories for 36L approach was a microburst alert expected 30 knot loss over the runway. Moderate precipitation was located 1 mile west of the airport, the microburst alerts began at 1823 EDT for a 30 knot loss. The airport wind was from 330° magnetic at 12 knots gusting to 16 knots.

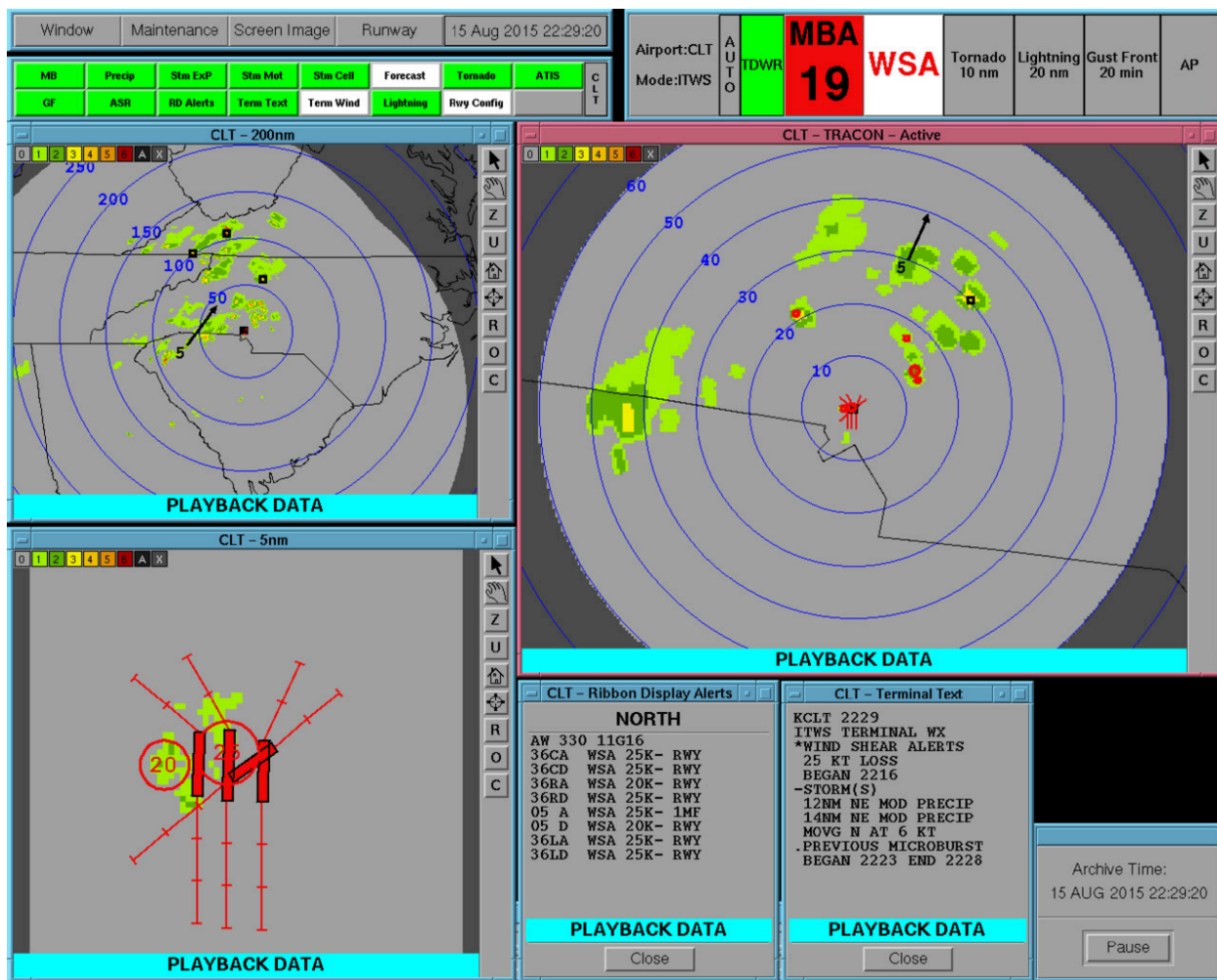


Figure 45 - ITWS display at 1829 EDT

ITWS display at 1829 EDT (2229Z) with microburst and windshear alerts in effect for all runways. The ribbon display indicated an airport wind from 330° magnetic at 11 knots gusting to 16 knots, with a windshear alert for 36L arrivals for a 25 knot loss on the runway. The previous microburst began at 1823 and ended at 1828 EDT.

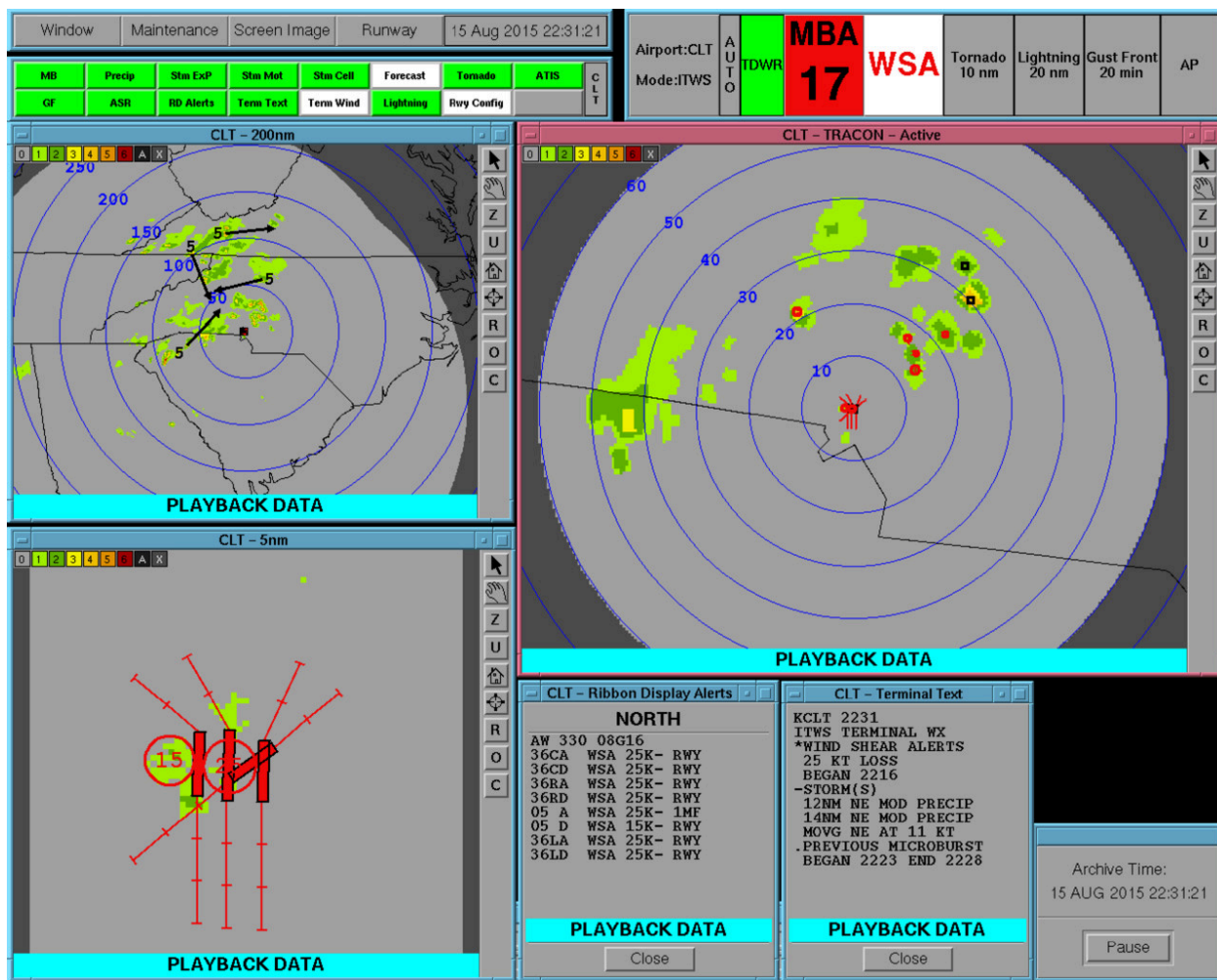


Figure 46 - ITWS display at 1831 EDT

ITWS display at 1831 EDT (2231Z) with microburst and windshear alerts active for all runways. The primary microburst was located 17 miles northeast of the airport. The ribbon display indicated an airport wind from 330° magnetic at 8 knots gusting to 16 knots, and a windshear alert for 36L approach for a 25 knot loss over the runway.

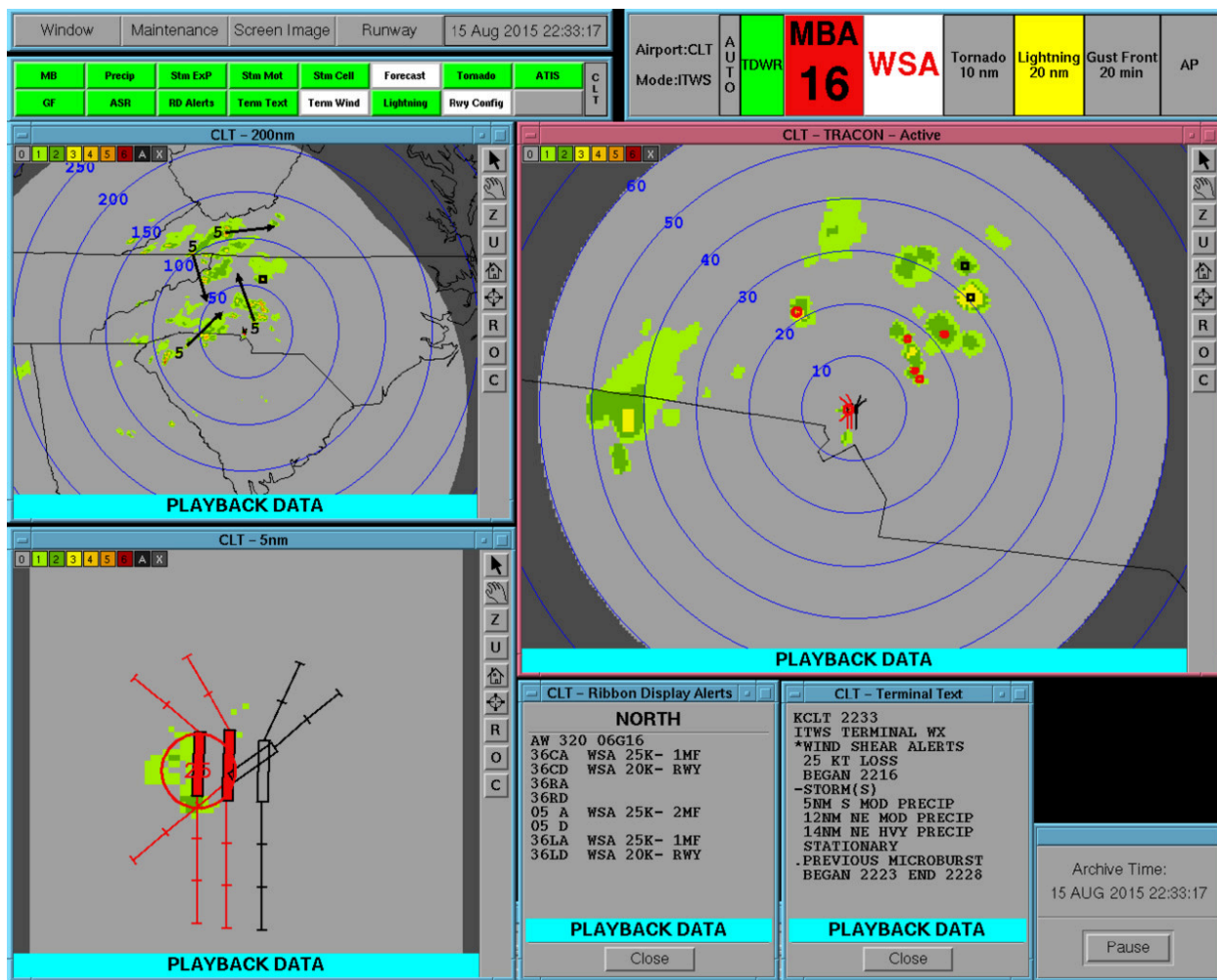


Figure 47 - ITWS display at 1833 EDT

ITWS display at 1833 EDT (2233Z) with microburst and wind shear alerts active for the terminal area, and for lightning within 20 miles of the station. The primary microburst was located 16 miles northeast of the airport, and an area of moderate precipitation located 5 miles south of the airport. Windshear advisories were active for runways 36L and 36C. The ribbon display indicated for 36L arrivals a windshear alert for a 25 knot loss 1 mile final. The airport wind was from 320° magnetic at 6 knots gusting to 16 knots.

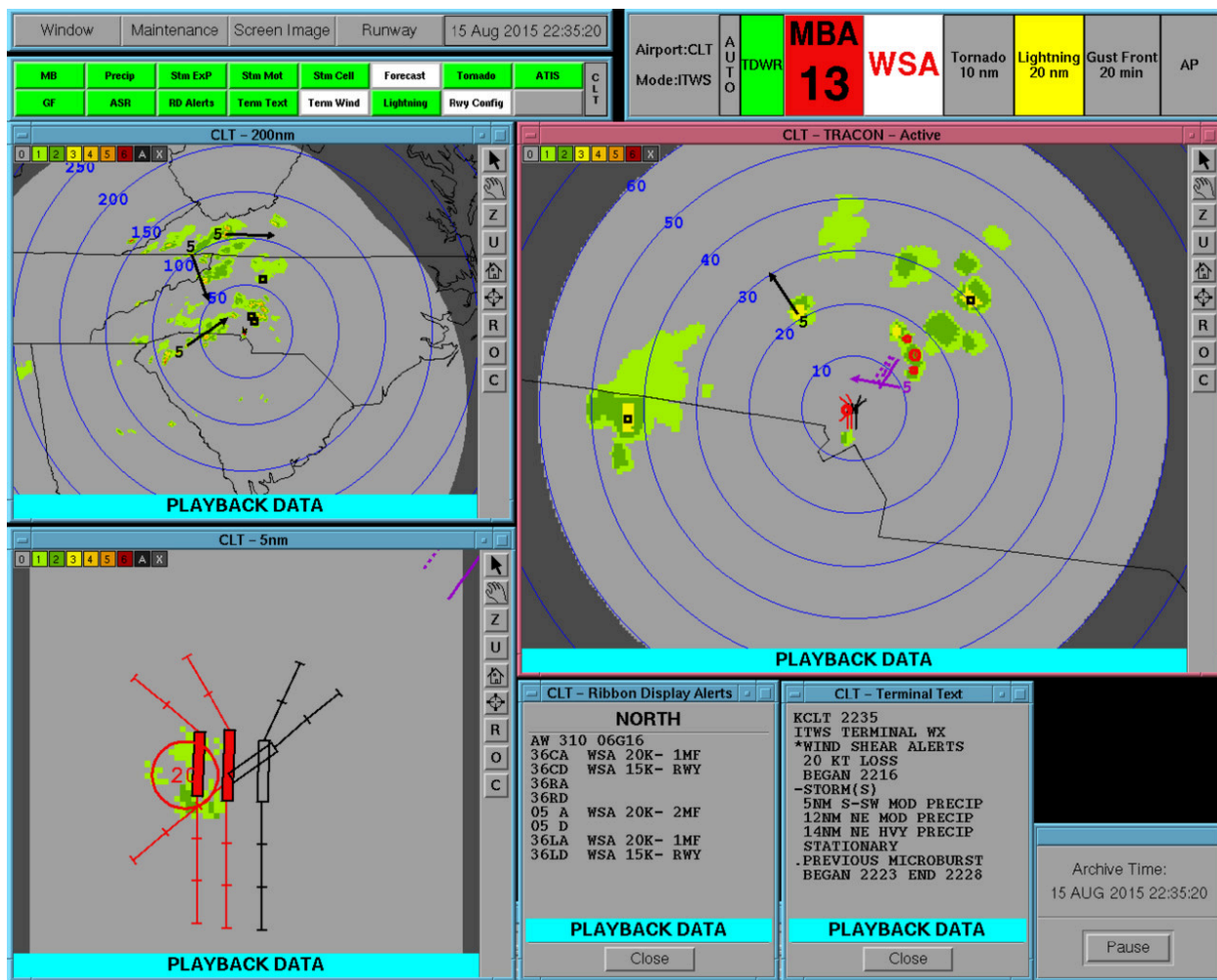


Figure 51 - ITWS display at 1835 EDT

ITWS display at 1835 EDT (2235Z) with microburst and windshear alerts active for the terminal area, and lightning activity within 20 miles of the airport. The lower section of the display indicated that windshear advisories were current for runways 36L and 36C, with moderate precipitation identified 5 miles south through southwest of the airport. The airport wind was from 310° magnetic at 6 knots gusting to 16 knots. The display also depicted a gust front approximately 5 miles to the northeast moving westward at 5 knots.

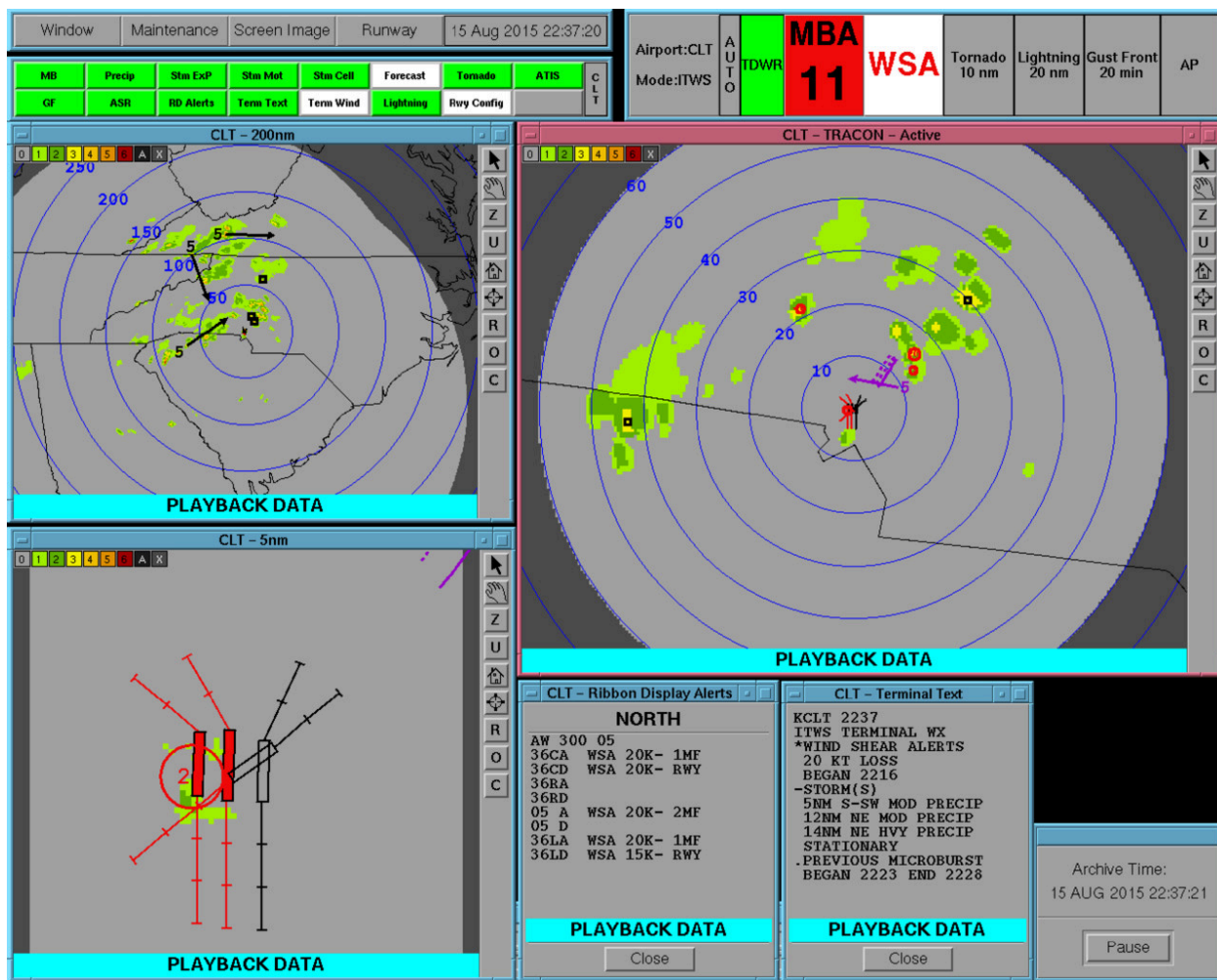


Figure 48 - ITWS display at 1837 EDT

ITWS display at 1837 EDT (2237Z) or the approximate time of the accident. The header indicated a microburst located 11 miles northeast of the airport, with windshear advisories current for runways 36L and 36C. The terminal display indicated that moderate precipitation was located 5 miles south through southwest of the airport, 12 miles northeast of the airport, with heavy precipitation 14 miles to the northeast. The previous microburst alert began at 1823 and ended at 1828 EDT. The advisory for 36L arrivals was for a windshear alert of a loss of 20 knots 1 mile final. No microbursts alerts were active for any runways at the time of the accident. The airport wind was from 300° magnetic at 5 knots at the time.

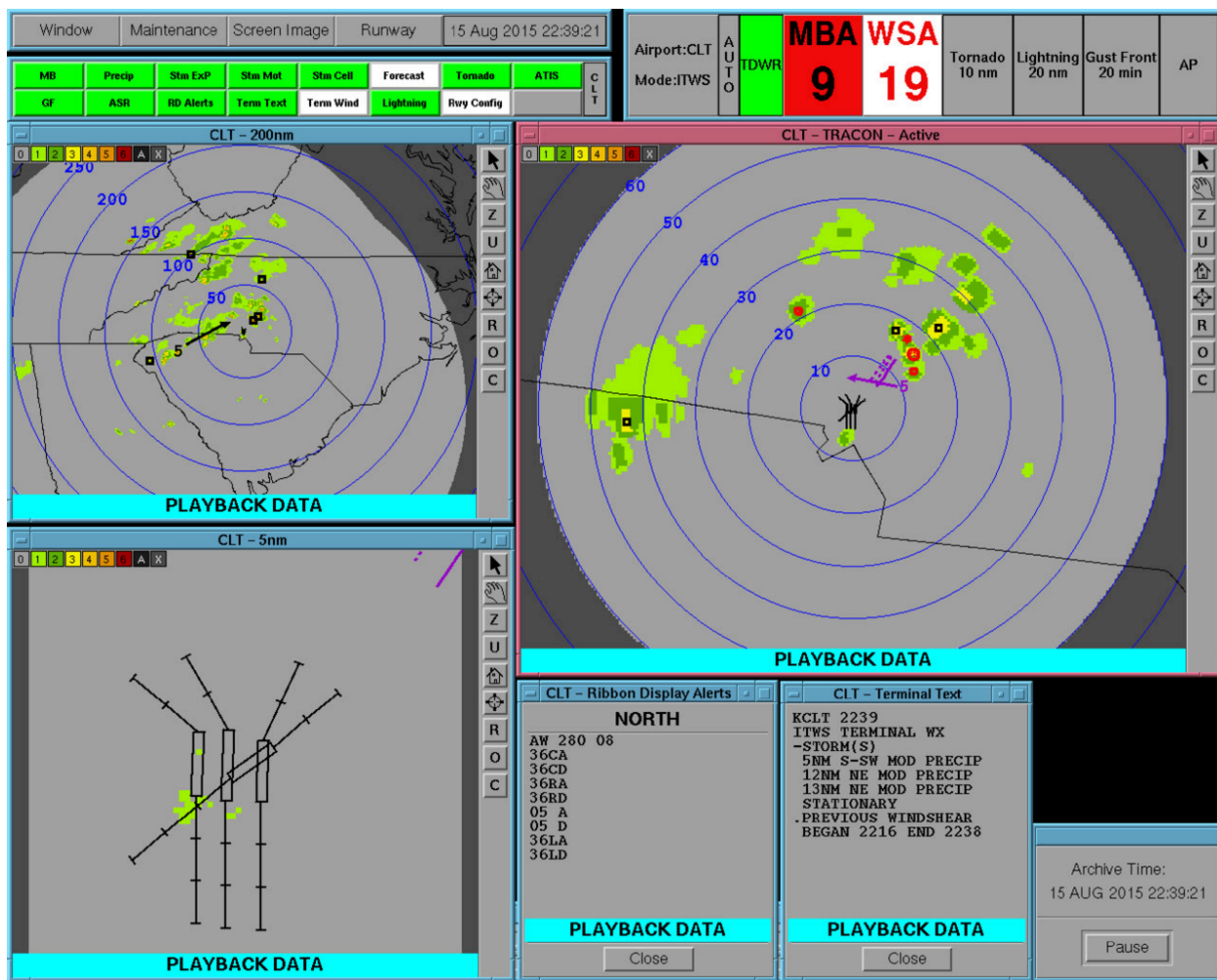


Figure 49 - ITWS display at 1839 EDT

ITWS display at 1839 EDT (2239Z) immediately after the accident with the microburst and windshear advisories headers illuminated for activity off the airport. The lower 5 mile TDWR scan showed echoes over the approach paths to runways 36L and 36C with no active alerts over the airport. The airport wind was from 280° magnetic at 8 knots.

14.0 Winds and Temperature Aloft Forecast

The NWS winds and temperature aloft forecast current during the period was as follows:

WINDS ALOFT FORECASTS
 DATA BASED ON 151800Z
 VALID 160000Z FOR USE 2000-0300Z. TEMPS NEG ABV 24000
 FT 3000 6000 9000 12000 18000 24000 30000 34000 39000
 ATL 0705 0805+16 1310+08 1712+02 2212-08 2513-19 271634 262544 264054
 CSG 0810 0811+15 1411+09 1705+03 2109-08 2410-19 263033 254044 264454
 GSP 3106 2407+15 2008+09 9900+02 2316-09 2618-19 271535 271446 253554
 CAE 1605 9900+15 9900+08 9900+02 2410-08 2517-18 242234 262744 263455
 TRI 2813+15 9900+09 9900+03 9900-10 2517-19 242535 232446 262156
 FLO 2012 2807+15 3611+09 3206+03 2409-08 2518-18 252534 242544 252756

15.0 Dispatch and Preflight Weather Briefing

The dispatcher responsible for the planning and release provided a statement regarding the event and indicated that he planned the flight with a destination alternate airport of Raleigh-Durham International Airport (KRDU), and included 45 minutes of holding fuel for potential use over the destination. He indicated that he made the flight crew aware of the Convective SIGMET issued for the route and had planned for extra fuel for possible deviation for weather and possible altitude deviations for turbulence.

The American Airlines weather document issued to flight 1851 was reviewed and is included in the Operations Factual Report attachments. The dispatch release included a destination alternate airport of KRDU, and included extra fuel for possible deviations enroute. The release was based on the NWS forecast issued in section 8.0 at 1321 EDT, and the release updated with the amended forecast at 1807 EDT with no significant changes to the forecast. The latest Convective SIGMETs 47E and 61E were also noted. None impacted the route of flight, but were current to the west of the area. There was no American Airlines weather advisories current for thunderstorms, turbulence, or icing hazards for the departure, destination or the route of flight.

16.0 Astronomical Data

Data from the United States Naval Observatory indicated the following for Charlotte, Mecklenburg County, North Carolina on August 15, 2015.

Beginning civil twilight	0616 EDT
Sunrise	0643 EDT
Sunset	2012 EDT
Event	2037 EDT
End of civil twilight	2039 EDT

At the time of the accident the Sun was 5° degrees below the horizon at an azimuth of 291°, and officially 2 minutes prior to official nighttime.

17.0 NWS Storm Reports

A review of the NWS Storm Reports registered one noted high wind event at approximately 1900 EDT in Kannapolis, Cabarrus County, North Carolina immediately north of Charlotte, at coordinates 35.49 N and 80.62 W, that law enforcement reported a large tree down on Barr Road and Trinity Church Road, in Kannapolis, NC. The report was logged by the NWS Greer, SC forecast office. Figure 54 is the NWS Storm Reports reported for the day.

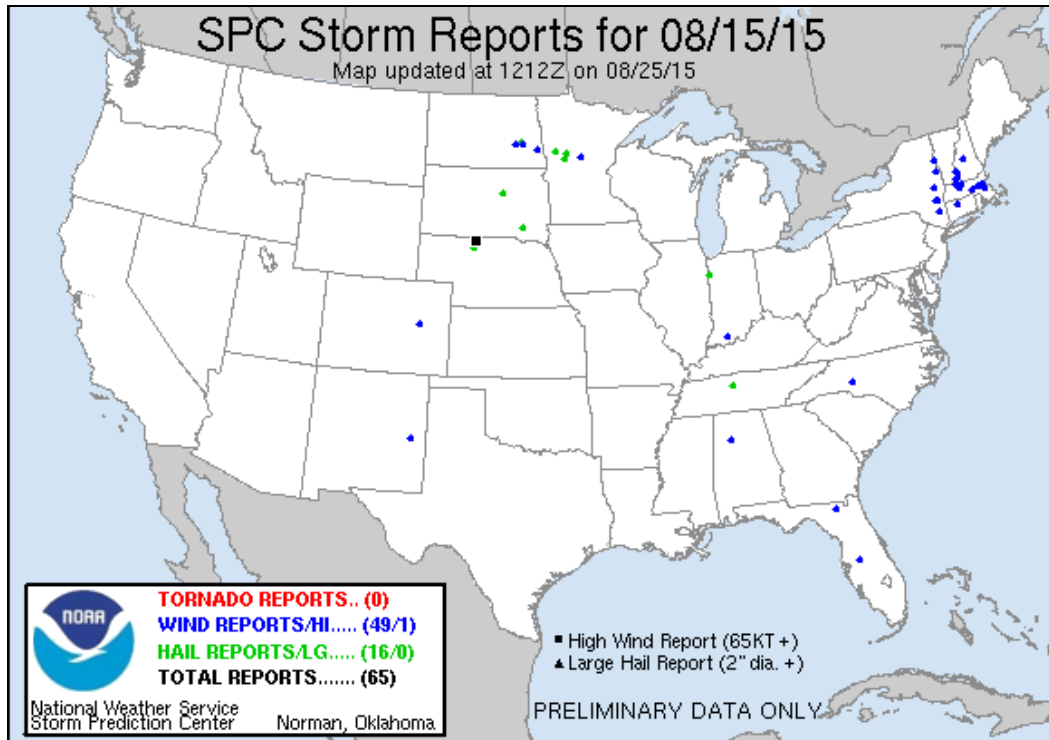


Figure 50 - NWS Storm Reports on August 15, 2015

18.0 NWS Weather Reporting Criteria

Weather observing and reporting procedures are defined in the Federal Meteorological Handbook Number 1 (FMH-1). Section 2.5.2a defines when a special weather observation is required. The primary criteria for the issuance of a special observation or SPECI are defined as the following:

1. **Wind shift** - wind direction changes 45° or more in 15 minutes or less, with wind speeds of 10 knots or more.
2. **Visibility** – if surface visibility in the main body of the report decreases to less than, or if below, increases to or exceeds: 3 miles, 2 miles, 1 mile, or the lowest instrument approach procedure minimum, or ½ mile in none.
3. **Runway Visual Range (RVR)** – the highest values from the designated RVR runway decreases to less than, or if below, increases or exceeds 2,400 feet during the preceding 10 minutes.
4. **Tornado, funnel cloud, or water spout** – is observed, disappears from sight, or ends.
5. **Thunderstorm** – begins or ends.
6. **Precipitation** – report any hail, freezing precipitation, or ice pellet occurrence or change in intensity.
7. **Squalls** – a sudden increase of wind or squall occurs.
8. **Ceiling** – when a ceiling forms or dissipates below, decreases to less than, or if below, increases to equal or exceeds: 3000 feet, 1500 feet, 1000 feet, 500 feet, or the lowest approach procedure minimum specified or 200 feet if none.

9. **Sky condition** – if a layer of clouds or obscuring phenomena form below 1,000 feet when not reported in the previous report
10. **Volcanic eruption**
11. **Aircraft Mishap** – upon notification of an aircraft mishap, unless an intervening observation has already been made.
12. **Miscellaneous** – any meteorological situation identified by the responsible agency, or in the option of the observer, is critical for safety.

FMH-1 section 8.4 is the present weather observation standards and covers reporting intensity and proximity of weather conditions. Tables 8-1 and 8-2 of that section on the reporting of the intensity of rain by rainfall rate and estimating the intensity are included below.

Table 8-1 Intensity of Rain on Rainfall Rate

Intensity	Criteria
Light	Up to 0.10 inch per hour; maximum 0.01 inch in 6 minutes
Moderate	0.11 to 0.30 inch per hour; more than 0.01 to 0.03 inch in 6 minutes
Heavy	More than 0.30 inch per hour; more than 0.03 inch in 6 minutes

Table 8-2 Estimating Intensity of Rain

Intensity	Criteria
Light	From scattered drops that, regardless of duration, do not completely wet an exposed surface up to a conditions where individual drops are easily seen.
Moderate	Individual drops are not clearly identifiable; spray is observed just above pavement and other hard surfaces.
Heavy	Rain seemingly falls in sheets; individual drops are not identifiable; heavy spray to heights of several inches is observed over hard surfaces.

In addition, FAA Order 7110.65T – “Air Traffic Control” section 2-9-3 provides the following guidance regarding the issuance of weather in Automated Terminal Information System (ATIS) broadcasts in the terminal area:

a. Airport/facility name, phonetic letter code, time of weather sequence (UTC). Weather information consisting of wind direction and velocity, visibility, obstructions to vision, present weather, sky condition, temperature, dew point, altimeter, a density altitude advisory when appropriate and other pertinent remarks included in the official weather observation. Wind direction, velocity, and altimeter shall be reported from certified direct reading instruments. Temperature and dew point should be reported from certified direct reading sensors when available. Always include weather observation remarks of lightning, cumulonimbus, and towering cumulus clouds.

19.0 Microburst References

The Aeronautical Information manual (AIM) chapter 7 – Safety of Flight, section 7-1-26 provides the following information on microbursts.

Parent clouds producing microburst activity can be any of the low or middle layer convective cloud types. Microburst commonly occur within the heavy rain portion of thunderstorms, and in much weaker, benign appearing convective cells that have little or no precipitation reaching the ground.

Common characteristics of microbursts include:

1. **Size.** The microburst downdraft is typically less than 1 mile in diameter as it descends from the cloud base to about 1,000 to 3,000 feet agl. In the transition zone near the ground, the downdraft changes to a horizontal outflow that can extend to approximately 2 ½ miles in diameter.
2. **Intensity.** The downdrafts can be as strong as 6,000 feet per minute. Horizontal winds near the surface can be as strong as 45 knots resulting in a 90 knot shear (headwind to tailwind change for a traversing aircraft) across the microburst. These strong horizontal winds occur within a few hundred feet of the ground.
3. **Visual Signs.** Microbursts can be found almost anywhere that there is convective activity. They may be embedded in heavy rain associated with a thunderstorm or in light rain in benign appearing virga. When there is little or no precipitation at the surface accompanying the microburst, a ring of blowing dust may be the only visual clue of its existence.
4. **Duration.** An individual microburst will seldom last longer than 15 minutes from the time it strikes the ground until dissipation. The horizontal winds continue to increase during the first 5 minutes with the maximum intensity winds lasting approximately 2-4 minutes. Sometimes microbursts are concentrated into a line structure, and under these conditions, activity may continue for as long as an hour. Once microburst activity starts, multiple microbursts in the same general area are not uncommon and should be expected.

Microburst wind shear may create a severe hazard for aircraft within 1,000 feet of the ground, particularly during the approach to landing and landing and take-off phases. The impact of a microburst on aircraft is illustrated in figure 55. The aircraft may encounter a headwind (performance increasing) followed by a downdraft and tailwind (both performance decreasing), possibly resulting in terrain impact.

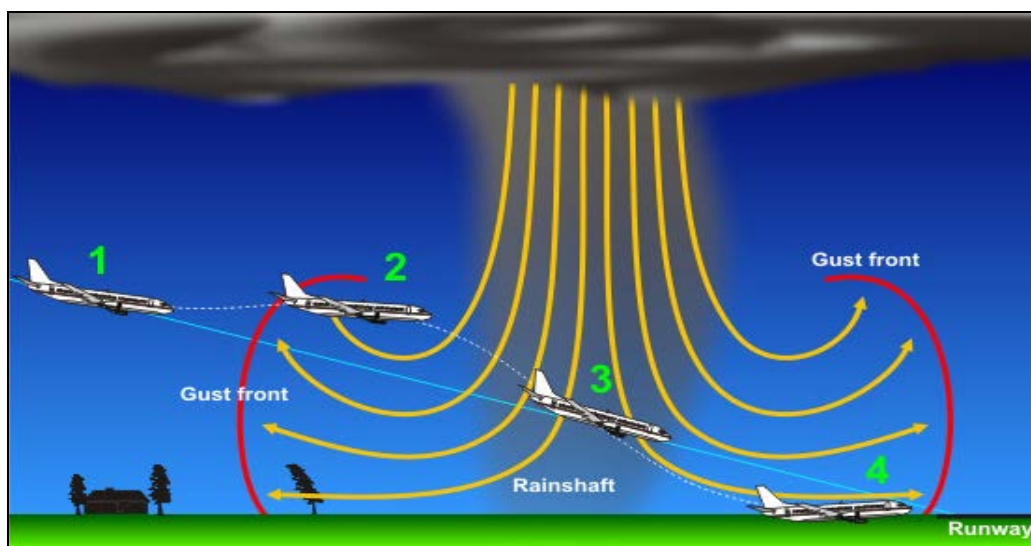


Figure 51 - Microburst encounter on landing

F. LIST OF APPENDICES

Appendix 1: NWS Greensboro, NC sounding stability indices

Appendix 2: NWS Greensboro, NC, severe weather sounding parameters

Submitted by:

Donald Eick

NTSB Senior Meteorologist

Appendix 1 – NWS Greensboro sounding stability indices comparison

The Surface based (SB), most unstable (MU), and mean layer (ML) Convective Available Potential Energy (CAPE), Convective Inhibition (CIN), Lifted Index (LI),

	SB SFC-Based 987 mb	MU Most-Unstable 981 mb	ML Mean-Layer 937 mb	
=====				
CAPE Plus(+)	407	431	132	J/kg
CAPE 0-3km	22	23	6	J/kg
CIN Total	-41	-24	-31	J/kg
NCAPE	0.05	0.05	0.02	
LI	-2	-2	-1	
TI	27.1	27.1	26.1	
DCI	0	0	0	
BRN	0	0	0	
MVV	29	29	16	m/s
EH1 0-2km	0	0	0	
VGP 0-4km	0.096	0.099	0.055	
Craven 0-6km	-	-	1	
EL(lfc) Hgt	37314	37469	32011	ft,MSL
LFC Hgt	7668*	7614*	8438*	ft,MSL
LCL Hgt	5891	6063	6584	ft,MSL
LFC-LCL	542*	473*	565*	m
* indicates that data meets 'high' threshold values, if they exist in the Severe Weather Parameter Table				

Appendix 2 – NWS Greensboro, NC, sounding severe weather indices

Parameter	Weak	Moderate	Strong
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200 mb Wind Speed (kt)	35		
500 mb Wind Speed (kt)	5		
700 mb Wind Speed (kt)	6		
700 mb Dewpoint Depression (C)			13.0
850 mb Wind Speed (kt)	2		
850 mb Dewpoint (C)			12.2
700 - 500 mb lapse rate (C/km)	-5.9		
Boyden Index		98.0	
BRN - Bulk Richardson No.			
BRN Shear (m ² /s ²)			
CAP Strength			0.9
CAPE 0-3 km, AGL	22		
CAPE Total	367		
Craven SigSvr Parameter (mixed-layer lift)	1		
CT - Cross Totals		21.3	
DCAPE 6.0 km, AGL		1000	
Delta Theta-e (ePT)			23.8
EH1 - Energy Helicity Index	0.0		
GOES HMI (Hybrid Microburst Index)	2		
Hail (inches)		0.34	
HI - Humidity Index			27.6
JI - Jefferson Index		26	
K Index		25.1	
KO Index			-13.7
LFC-LCL height (m)			542
LFC - Level of Free Convection (mb)			777
LI - Lifted Index	-2.0		
MDPI - Microburst Day Potential Index		0.7	
NCAPE (Normalized CAPE)	0.05		
S Index	34.2		
SCP - Supercell Composite Parameter			
Severity - Thunderstorm Severity Index	4.5		
SHIP - Significant Hail Parameter	0.0		
SI - Showalter Index		-0.3	
srH - storm-relative Helicity (0-3 km)	-3		
STP - Significant Tornado Parameter	0.0		
Surface Dewpoint (C)		16.6	
SWEAT Index	155.4		
T2 Gust (kt)		50	
TI - Thompson Index	27		
TQ Index			17
TT - Total Totals		47.2	
VGP - Vorticity Generation Parameter	0.096		
VT - Vertical Totals		25.9	
Waterspout Index	40		
WBZ - WetBulb Zero Hgt (ft,AGL)		9146	
Windex (kt)			51
WMSI - Wet Microburst Severity Index		10	
	====	=====	=====
Weighted Category Totals:	21	14	10
			RPM = 22%