



NATIONAL TRANSPORTATION SAFETY BOARD

Office of Aviation Safety
Washington, D.C. 20594

October 18, 2018

Group Chairman's Factual Report

METEOROLOGY

ERA18LA157

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A. ACCIDENT

Location: Amagansett, New York
Date: June 2, 2018
Time: 1433 eastern daylight time
1833 Coordinated Universal Time (UTC)
Airplane: Piper PA-31-350 Navajo; registration: N41173

B. METEOROLOGIST

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

C. SUMMARY

On June 2, 2018 about 1433 eastern daylight time, a Piper PA-31-350, N41173, was destroyed when it impacted the Atlantic Ocean near Indian Wells Beach, Amagansett, New York. The commercial pilot and three passengers were fatally injured. Visual meteorological conditions prevailed, and no flight plan was filed for the flight that originated from Newport State Airport (UUU), Newport, Rhode Island, destined for East Hampton Airport (HTO), East Hampton, New York. The personal flight was conducted under the provisions of Title 14 *Code of Federal Regulations* Part 91.

D. DETAILS OF THE INVESTIGATION

The National Transportation Safety Board's 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 Center for Environmental Information (NCEI). All times are eastern daylight time (EDT) based upon the 24-hour clock, local time is -4 hours from UTC, and UTC=Z. NWS airport and station identifiers use the standard International Civil Aviation Organization 4-letter station identifiers versus the International Air Transport Association 3-letter identifiers, which deletes the initial country code designator "K" for U.S. airports. Directions are referenced to true north and distances in nautical miles. Heights are in feet (ft) above mean sea level (msl) unless otherwise noted. Visibility is in statute miles and fractions of statute miles.

The accident site was located at latitude 40° 57' 19.7" N and longitude 72° 7' 46.9" W at sea level, and was approximately ½ mile off shore from Amagansett, New York.

E. WEATHER 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 (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 00-45H.

1.1 Surface Analysis Chart

The northeast section of the NWS Surface Analysis Chart for 1400 EDT on June 2, 2018 is included as figure 1 with the approximate accident site located within the red circle. The chart depicted a low-pressure system with a central pressure of 1005-hectopascals (hPa)¹ over eastern Long Island along a cold front which extended over the area from off the Massachusetts coast, west-southwestward over Long Island, New York, into New Jersey, southeast Pennsylvania, and into West Virginia. A secondary trough of low pressure was also depicted extending across central New York west-northwest into southern Ontario.

The station models on the surface analysis chart depicted a cyclonic (counterclockwise) wind flow pattern in the vicinity of the accident site associated with the low-pressure system. Over Long Island the surface winds were from the southwest, and over Connecticut and Rhode Island the winds were from the north. Thunderstorms were noted in the immediate vicinity of the accident site, with temperatures in the upper 70’s to low 80’s °F, with dew point temperatures from 69° to 72° F over the region.

¹ Hectopascal (hPa) is the standard term for reporting sea level pressure and is interchangeable with the term millibar (mb) with the same units. The International Standard Atmosphere (ISA) is based on a sea level pressure is 1013.25-hPa with a temperature of 15° Celsius (C) or 59° Fahrenheit (F).

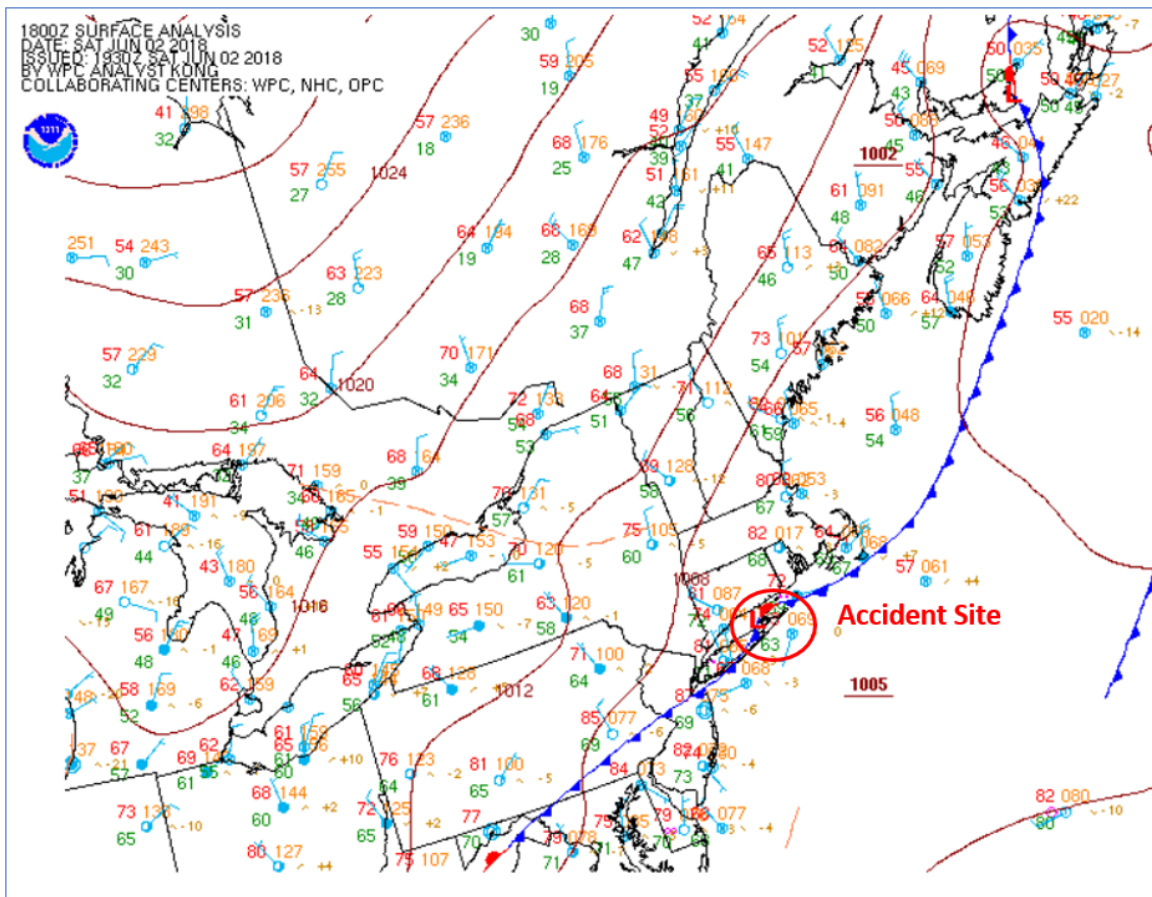


Figure 1 - Northeast Surface Analysis Chart for 1400 EDT

1.2 Convective Outlook

The NWS Storm Prediction Center (SPC) is tasked with providing timely and accurate forecasts and watches for severe thunderstorms and tornadoes over the contiguous United States. One of their primary products highlighting the expected areas of organized thunderstorms is the Convective Outlook (AC), which is used in pilot preflight weather briefings. Figure 2 is the mid-day Convective Outlook issued at 1242 EDT on June 2, 2018 and valid for the period from 1230 through 0800 EDT on June 3, 2018. The chart depicted a general risk of non-severe thunderstorms (light green shading) over most of the eastern half of the country and included the New York and Rhode Island areas. A general risk of thunderstorms implied a greater than 10% probability of thunderstorm development through the period. The focus or greatest risk of storm development was noted in two “slight risk” areas of severe thunderstorms²; the first centered over southern

² A severe thunderstorm is defined as a thunderstorm which has a high potential for producing a tornado, surface hail of an inch or larger in diameter, and/or outflow winds of 50 knots or more. Severe thunderstorms also imply frequent lightning, and to aviation localized instrument meteorological conditions, potential for severe to extreme turbulence, severe icing conditions, low-level wind shear and/or microbursts. A slight risk is defined as an area of organized severe thunderstorms, which was not expected to be widespread in coverage and with varying intensity.

Missouri, Arkansas, western Tennessee, and northwestern Mississippi, and the other area over southern Georgia and northern Florida.

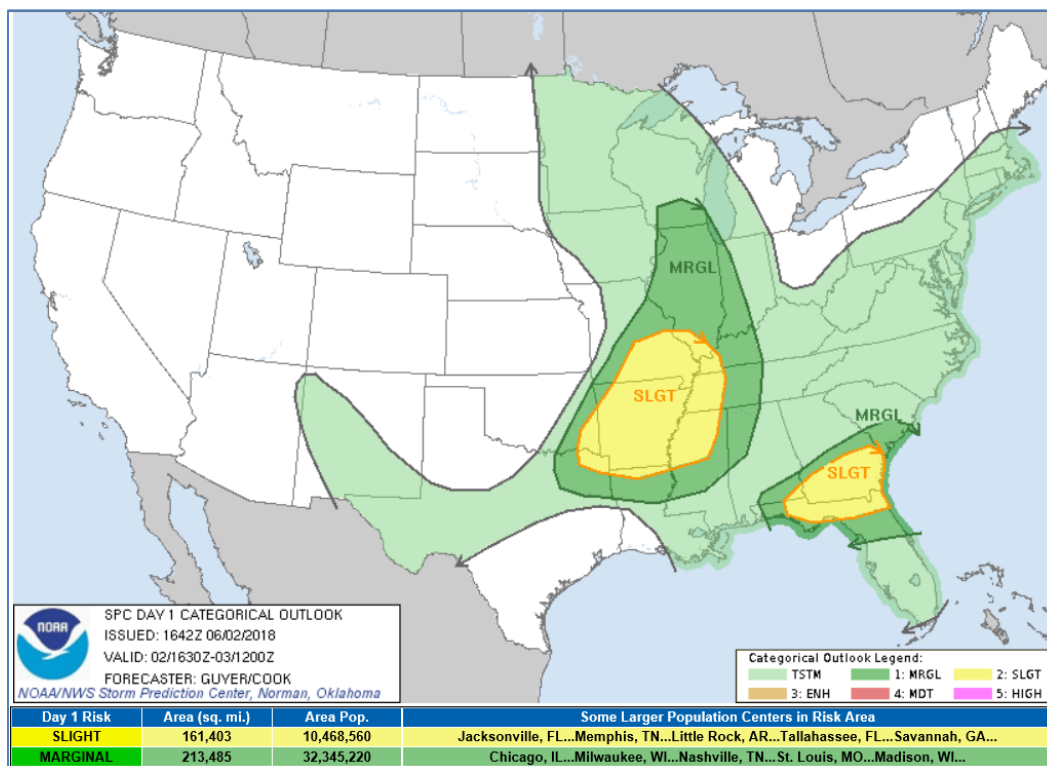


Figure 2 - NWS Convective Outlook issued at 1242 EDT

1.3 Constant Pressure Charts

The NWS SPC forecast upper air constant pressure charts³ for 850-, 700-, 500-, and 250-hPa for 2000 EDT (0000Z on June 3, 2018) are included as figures 3 through 6 respectively, and depict the conditions at approximately 5,000 ft, 10,000 ft, 18,000 ft, and 34,000 ft. The chart has been annotated with the location of defined upper level low's, high's, and troughs for clarity. The charts depict contour lines of equal height, isotherms of equal temperature (red dashed lines), temperature-dew point spreads less than 4° C on the 850- and 700-hPa charts, and isotachs or lines of equal wind speed on the 250-hPa chart to depict the jet stream. Wind flow typically flows parallel to the contour lines on constant pressure charts.

The charts depicted upper level lows extending off the New England coast and another one over Saskatchewan with a long-wave troughs extending into the central United States. A developing cut off upper level low was identified developing over the Mid-Atlantic region with a short-wave trough extending southwestward.

³ The SPC upper air maps are produced by using the available 0000Z rawinsonde observations with a first guess from the 1800Z North American Mesoscale (NAM) numerical model 6-hour forecast of the objective analysis. Errors may result if NAM model data is not available, or if sounding data is late or erroneous.

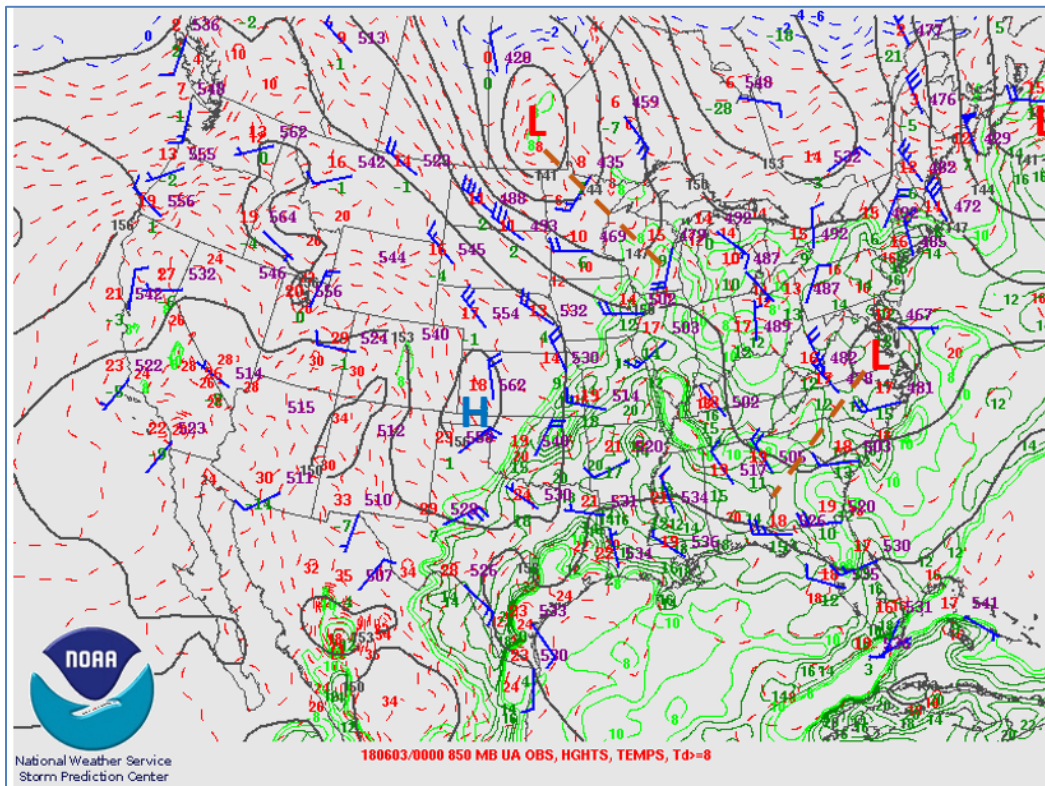


Figure 3 - NWS 850-hPa constant pressure chart for 2000 EDT

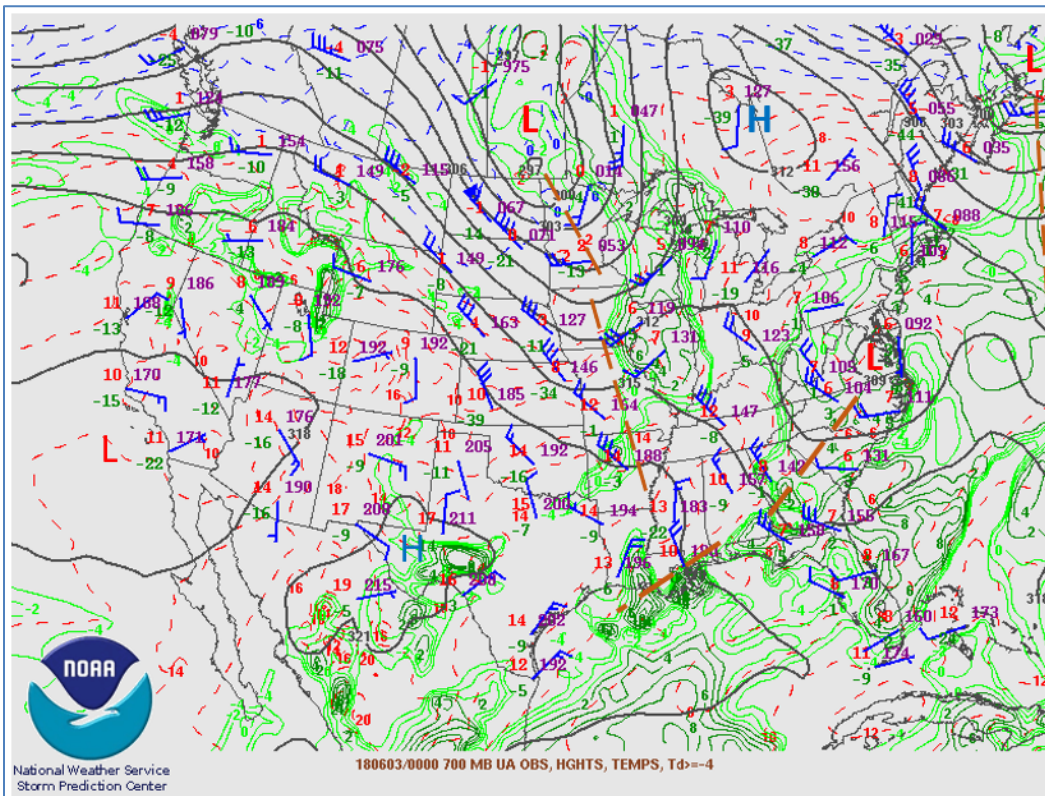


Figure 4 - 700-hPa constant pressure chart for 2000 EDT

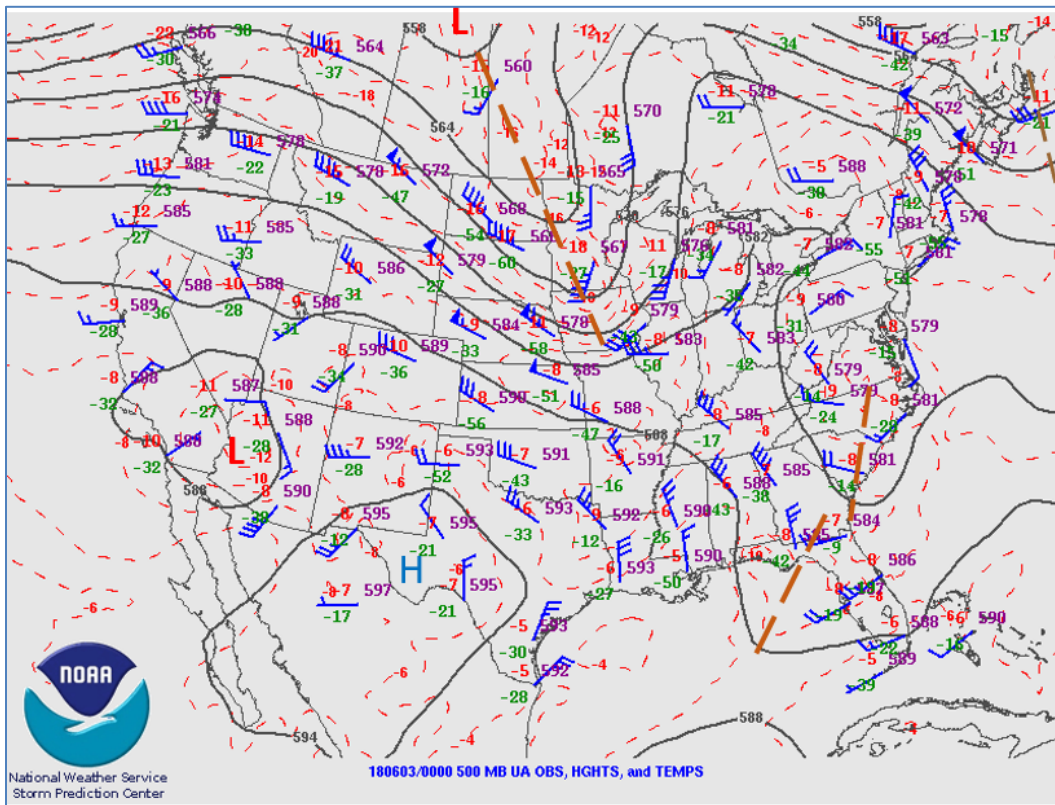


Figure 5 - 500-hPa constant pressure chart for 2000 EDT

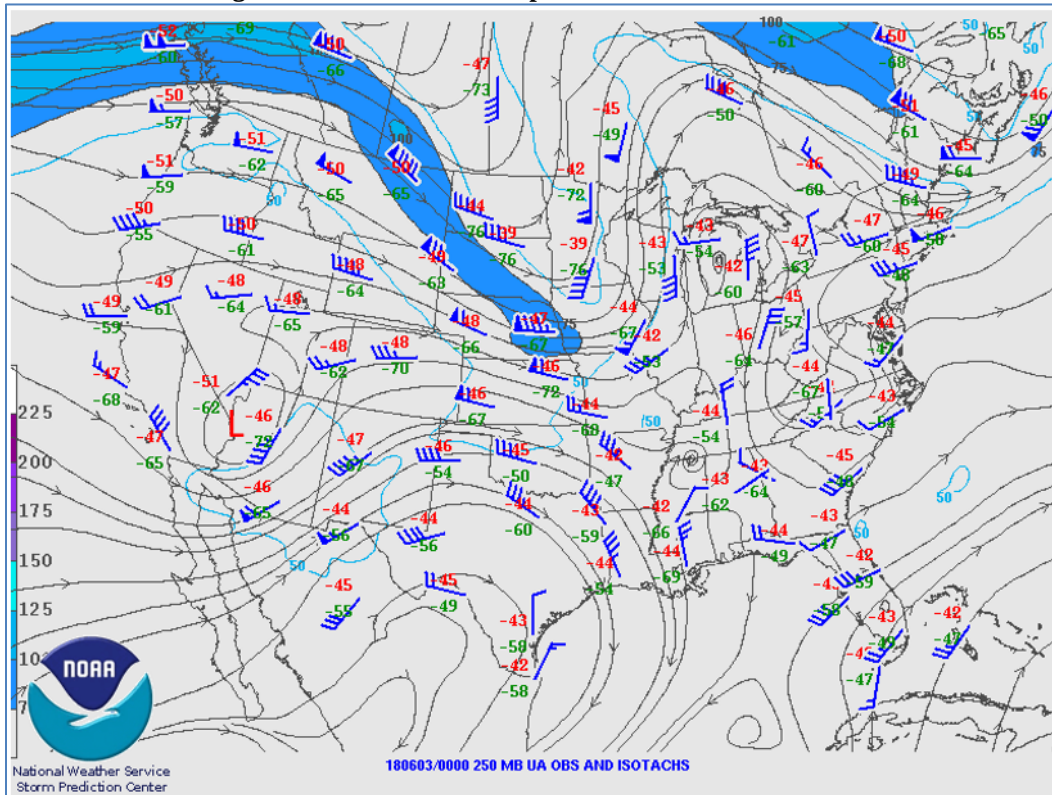


Figure 6 - 250-hPa constant pressure chart for 2000 EDT

1.4 12-hour Prognostic Chart

The NWS 12-hour Surface Prognostic Chart current at the time and valid for 0200 EDT on June 3, 2018 is included in figure 7. The chart depicted a new low-pressure system over eastern Virginia along an associated cold frontal system extending over the Mid-Atlantic region, and no longer referenced the front or low-pressure system over New York. A trough of low-pressure extended north from the low into eastern Pennsylvania into southeast New York. A large band of precipitation in the form of thunderstorms and rain showers were expected in the vicinity of the low-pressure area and north. The 12-hour prognostic chart did not include any forecast precipitation over eastern Long Island during the 12-hour period ending at 0200 EDT on June 3, 2018.

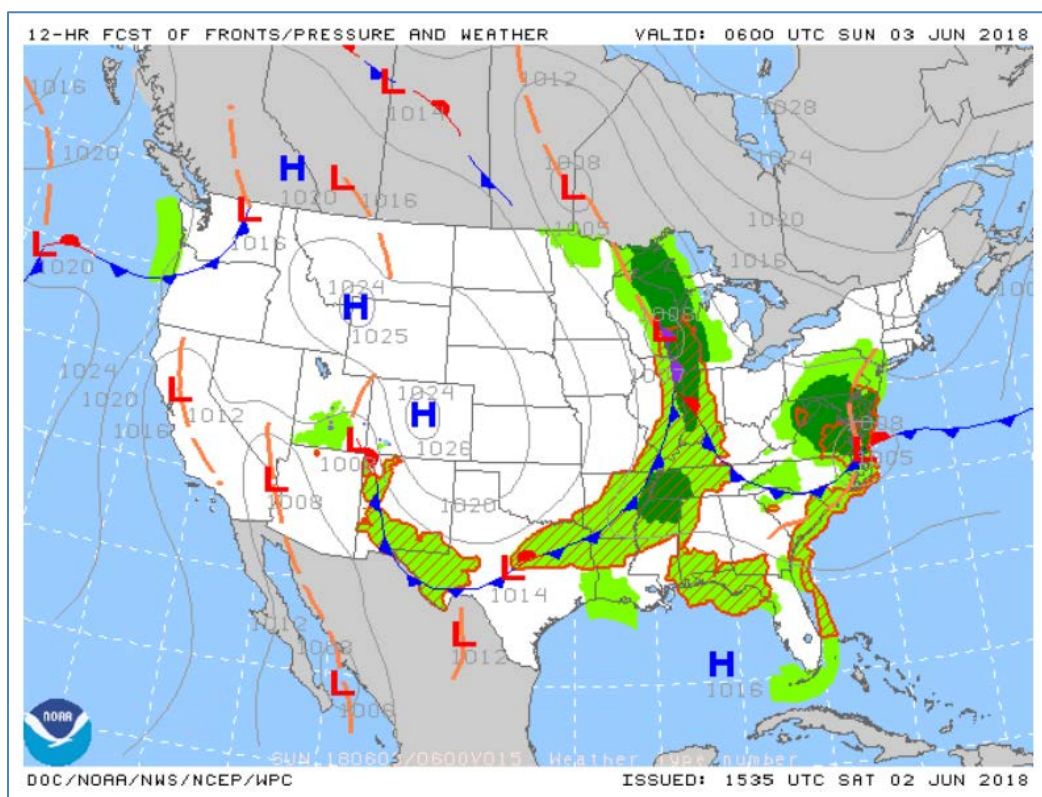


Figure 7 - 12-hour Surface Prognostic Chart valid for 0200 EDT June 3rd

2.0 Observations

The area was documented using the official NWS Meteorological Aerodrome Reports (METAR) and specials (SPECI) issued for the planned destination and departure airports. The cloud heights are reported in height above ground level (agl) in the following section.

2.1 East Hampton, New York

The closest weather reporting location to the accident site was from the planned destination of East Hampton Airport (KHTO), East Hampton, New York, approximately 5 ½ miles west from

the accident site. The airport listed an elevation of 55 ft and a magnetic variation of 14° West. The airport had an Automated Weather Observation System (AWOS) and issued observations every 20-minutes. The following conditions were reported surrounding the time of the accident:

KHTO weather observation at 1415 EDT, automated⁴, wind missing, visibility 10 miles or more, scattered clouds at 1,700 ft, ceiling⁵ broken at 3,100 ft, overcast at 3,800 ft, temperature 24° C, dew point temperature of 20° C, altimeter 29.74 inches of mercury (Hg). Remarks: automated observation system with a precipitation discriminator, lightning distant⁶ north and northeast, temperature 24.0° C, dew point 20.3° C.

KHTO weather observation at 1435 EDT, automated, wind missing, visibility 7 miles in thunderstorm and light rain, scattered clouds at 1,300 ft, scattered clouds at 2,100 ft, ceiling overcast at 2,600 ft, temperature 22° C, dewpoint 20° C, altimeter 29.76 inches of Hg. Remarks: automated observation system with a precipitation discriminator, lightning distant north through southeast, hourly precipitation 0.02 inches, temperature 21.9° C, dew point 20.4° C.

The raw observations in standard code and abbreviations with local time provided in the beginning bracket are included below from 0655 through 1600 EDT. The observations from above and time of the accident are in bold type for reference.

[0655] METAR KHTO 021055Z AUTO 0000KT M1/4SM FG OVC003 18/18 A2970 RMK AO2 T01820181
[0715] METAR KHTO 021115Z AUTO 0000KT 1/4SM FG OVC003 19/19 A2970 RMK AO2 T01900189
[0735] METAR KHTO 021135Z AUTO 0000KT 1/2SM FG OVC003 20/19 A2970 RMK AO2 T01950193
[0755] METAR KHTO 021155Z AUTO 3200KT 4SM BR OVC003 20/20 A2971 RMK AO2 70052 T02000199
10201 20162
[0815] METAR KHTO 021215Z AUTO 3300KT 4SM BR OVC003 20/20 A2971 RMK AO2 T01960195
[0835] METAR KHTO 021235Z AUTO 3400KT 2 1/2SM BR OVC003 20/19 A2971 RMK AO2 VIS 2V5
T01950193
[0855] METAR KHTO 021255Z AUTO 3400KT 7SM OVC003 20/20 A2971 RMK AO2 T02010200
[0915] METAR KHTO 021315Z AUTO 3600KT 10SM BKN003 BKN007 21/21 A2971 RMK AO2 T02140207
[0935] METAR KHTO 021335Z AUTO 0200KT 10SM SCT005 23/21 A2971 RMK AO2 T02260207
[0955] METAR KHTO 021355Z AUTO 3500KT 10SM CLR 24/21 A2971 RMK AO2 T02440211
[1015] METAR KHTO 021415Z AUTO 3600KT 10SM CLR 25/21 A2972 RMK AO2 T02490211
[1035] METAR KHTO 021435Z AUTO 3500KT 10SM BKN120 25/21 A2972 RMK AO2 T02460210
[1055] METAR KHTO 021455Z AUTO 3400KT 10SM OVC120 25/21 A2972 RMK AO2 T02530213
[1115] METAR KHTO 021515Z AUTO 0200KT 10SM OVC120 25/21 A2972 RMK AO2 T02540213
[1135] METAR KHTO 021535Z AUTO 3500KT 10SM SCT120 27/22 A2972 RMK AO2 T02660222
[1155] METAR KHTO 021555Z AUTO 3300KT 10SM CLR 27/22 A2972 RMK AO2 T02710219
[1215] METAR KHTO 021615Z AUTO 3500KT 10SM CLR 27/22 A2973 RMK AO2 T02710217
[1235] METAR KHTO 021635Z AUTO 0100KT 10SM SCT120 28/22 A2973 RMK AO2 T02780215
[1255] METAR KHTO 021655Z AUTO 0900KT 10SM SCT027 BKN120 28/22 A2972 RMK AO2 T02780215
[1315] METAR KHTO 021715Z AUTO 1600KT 10SM SCT027 BKN120 27/21 A2971 RMK AO2 T02660213
[1335] METAR KHTO 021735Z AUTO 1900KT 10SM SCT029 BKN036 26/21 A2972 RMK AO2 T02550209

⁴ Automated – indicates that no human augmentation to the observation was made.

⁵ Ceiling – is defined as the lowest layer of clouds reported as broken, overcast, or the vertical visibility into a surface based obscuration.

⁶ Lightning Distant – refers to detection beyond 10 miles but less than 30 miles from the airport location point (ALP).

[1355] METAR KHTO 021755Z AUTO 18003KT 10SM BKN034 BKN039 25/21 A2972 RMK AO2 LTG DSNT N AND NE T02500207 10281 20194

[1415] **METAR KHTO 021815Z AUTO 10SM SCT017 BKN031 OVC038 24/20 A2974 RMK AO2 LTG DSNT N AND NE T02400203**

[1433] **Accident**

[1435] **METAR KHTO 021835Z AUTO 7SM -TSRA SCT013 SCT021 OVC026 22/20 A2976 RMK AO2 LTG DSNT N THRU SE P0002 T02190204=**

[1455] METAR KHTO 021855Z AUTO 10SM -TSRA SCT015 BKN026 OVC070 22/20 A2976 RMK AO2 LTG DSNT NE THRU S P0002 T02160203=

[1515] METAR KHTO 021915Z AUTO 10SM -TSRA SCT070 OVC095 21/20 A2975 RMK AO2 LTG DSNT NE AND E P0004 T02130204=

[1535] METAR KHTO 021935Z AUTO 10SM RA SCT050 BKN075 OVC095 21/20 A2974 RMK AO2 P0005 T02130201

[1555] METAR KHTO 021955Z AUTO 10SM SCT033 SCT050 SCT065 22/20 A2974 RMK AO2 P0005 T02180201

A review of the observations indicated that low instrument meteorological conditions (LIFR)⁷ were reported between 0655 through 0915 EDT due to low visibility in fog and mist, with ceilings at 300 ft agl. The cloud cover and visibility improved after 0935 EDT to visual flight rule (VFR) conditions prevailing prior to the accident. The high temperature recorded at KHTO was 27.8° C (82° F) at 1255 MDT. Lightning was first reported at 1355 EDT in the distant north and northeast of the airport, with thunderstorms and rain reported at the airport between 1435 through 1535 EDT with a total of 0.07 inches of precipitation recorded. The wind sensor failed or the data was not reported between 1435 and 1615 EDT for unknown reasons.

The AWOS system at KHTO had an Automated Lightning Detection and Ranging System (ALDARS) installed to detect and report thunderstorm activity. The system is used to determine if cloud-to-ground lightning is present in the area, and if so reports thunderstorms in the present weather field of the METAR report. According the Federal Meteorological Handbook (FMH-1) for Surface Weather Observations and Reporting, section 12.7.1; if lightning is detected within 5 nautical miles of the Airport Location Point (ALP), it will be reported as a thunderstorm (TS) in the main body of the METAR report, with no remark. If the lightning is detected between 5 and 10 miles of the ALP, it will be reported as thunderstorm in the vicinity (VCTS) in the body of the report with no remark. Beyond 10 but less than 30 miles of the ALP, it will be reported in the remarks only as lightning distant (LTG DSNT) followed by the direction from the ALP. The “TS” will continue to be reported in the present weather field of the METAR until no cloud-to-ground lightning strikes are observed for a 15-minute period. With location with a human observer, typically in the case with Automated Surface Observation Systems (ASOS) the observation can be overridden and include the frequency, type, and location of the lightning activity.

2.2 Montauk, New York

The next closest weather reporting location to the accident site was from Montauk Airport (KMTP), Montauk, New York, located 11 miles east-northeast of the accident site or 17 miles from KHTO, at an elevation of 7 ft. The airport had an AWOS which did not have a precipitation

⁷ LIFR conditions – are defined as a ceiling less than 500 ft agl and/or visibility less than 1 statute mile.

discriminator, and did not report visibility, any present weather phenomena, or cloud information, and reported hourly. The following conditions were reported during the period:

[0554] METAR KMTP 020954Z AUTO 00000KT 18/18 A2971 RMK AO1 SLP059 T01780178
[0754] METAR KMTP 021154Z AUTO 32003KT 18/18 A2972 RMK AO1 SLP064 70028 T01830183 10189 20167
53006
[0854] METAR KMTP 021254Z AUTO VRB04KT 19/18 A2973 RMK AO1 SLP067 T01890183
[0954] METAR KMTP 021354Z AUTO 34004KT 22/19 A2973 RMK AO1 SLP066 T02220194
[1054] METAR KMTP 021454Z AUTO VRB03KT 23/21 A2973 RMK AO1 SLP068 T02330206 51004
[1154] METAR KMTP 021554Z AUTO VRB04KT 26/22 A2974 RMK AO1 SLP070 T02560217
[1254] METAR KMTP 021654Z AUTO 00000KT 25/21 A2974 RMK AO1 SLP071 T02500211
[1354] METAR KMTP 021754Z AUTO VRB03KT 26/22 A2973 RMK AO1 SLP069 T02610217 10289 20172 50001
[1433] Accident
[1454] METAR KMTP 021854Z AUTO 00000KT 21/21 A2979 RMK AO1 SLP088 P0001 T02110206
[1554] METAR KMTP 021954Z AUTO 07004KT 23/22 A2976 RMK AO1 SLP077 P0001 T02280217

A review of the observations indicated near saturated conditions with temperature-dew point spreads less than 2° C prior to 1154 EDT, then the spread increased and then decreased again immediately after the accident at 1454 EDT. The winds were variable during the period with no strong gusts being reported surrounding the period on June 2, 2018. It should be noted however, that there is no special criteria for wind and the observations provided are the 2-minute average wind and 10-minute gusts prior to the observation. A peak wind would have been recorded if winds were over 25 knots.

2.3 Newport, Rhode Island

The accident airplane departed from Newport State Airport (KUUU), Newport, Rhode Island about 1410 EDT, which was located about 58 miles northeast of KHTO. The airport listed an elevation of 172 ft. The airport had a federally installed and maintained Automated Surface Observation System (ASOS) and reported weather conditions hourly with special observations as needed. The following conditions were reported at the time of departure:

KUUU weather observation at 1353 EDT, automated, wind from 030° at 11 knots, visibility 10 miles or more, a few clouds at 9,500 ft, temperature 27° C, dew point 20° C, altimeter 29.72 inches of Hg. Remarks: automated observation system with a precipitation discriminator, sea level pressure 1006.0-hPa, temperature 26.7° C, dew point 20.0° C, maximum temperature 28.3° C, minimum temperature 20.6° C, 3-hour pressure tendency steady and unchanged.

The raw observations surrounding the period were as follows:

[0653] METAR KUUU 021053Z AUTO 00000KT 1/4SM FG VV002 20/20 A2968 RMK AO2 SLP047
T02000200
[0753] METAR KUUU 021153Z AUTO VRB04KT 1/2SM FG VV002 21/21 A2969 RMK AO2 SLP052 70013
T02060206 10211 20178 51007
[0822] SPECI KUUU 021222Z AUTO 31004KT 2SM BR OVC002 22/22 A2969 RMK AO2 VIS 3/4V4
T02170217
[0829] SPECI KUUU 021229Z AUTO 28004KT 5SM BR OVC002 22/22 A2969 RMK AO2 T02170217
[0849] SPECI KUUU 021249Z AUTO 33006KT 9SM SCT002 22/22 A2969 RMK AO2
[0853] METAR KUUU 021253Z AUTO 34006KT 10SM FEW002 23/22 A2970 RMK AO2 SLP054 T02280217

[0953] METAR KUUU 021353Z AUTO 36009KT 10SM CLR 26/22 A2970 RMK AO2 SLP055 T02560222
 [1053] KUUU 021453Z AUTO 36007KT 10SM FEW017 27/23 A2972 RMK AO2 SLP060 T02720228 53007
 [1153] METAR KUUU 021553Z AUTO 02013KT 10SM FEW022 28/23 A2971 RMK AO2 SLP059 T02830228
 [1253] METAR KUUU 021653Z AUTO 04012KT 10SM CLR 27/21 A2972 RMK AO2 SLP063 T02720211
 [1353] **METAR KUUU 021753Z AUTO 03011KT 10SM FEW095 27/20 A2972 RMK AO2 SLP060
 T02670200 10283 20206 50000**
 [1400] **Departure**
 [1453] METAR KUUU 021853Z AUTO 03007KT 10SM FEW120 26/20 A2973 RMK AO2 SLP066 T02610200
 [1553] METAR KUUU 021953Z AUTO 06006KT 10SM CLR 27/19 A2974 RMK AO2 SLP067 T02670194
 [1653] METAR KUUU 022053Z AUTO 11004KT 10SM FEW100 25/19 A2976 RMK AO2 SLP076 T02500194
 53015

2.4 Display of METAR

A display of the METAR observations from the NWS Aviation Weather Center's (AWC) website surrounding the period were obtained. The AWC METAR display's the observation by a station model and are color coded to display the general flight categories⁸, with an example of the station legion is included as figure 8.

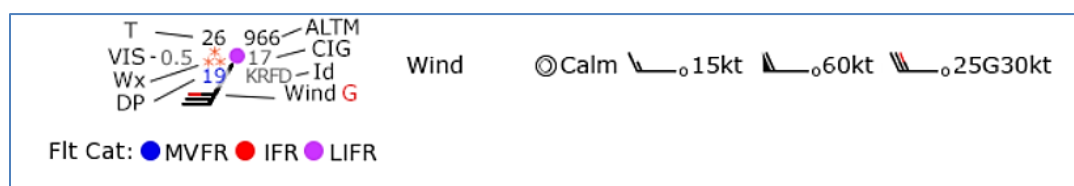


Figure 8 - AWC station decode legion

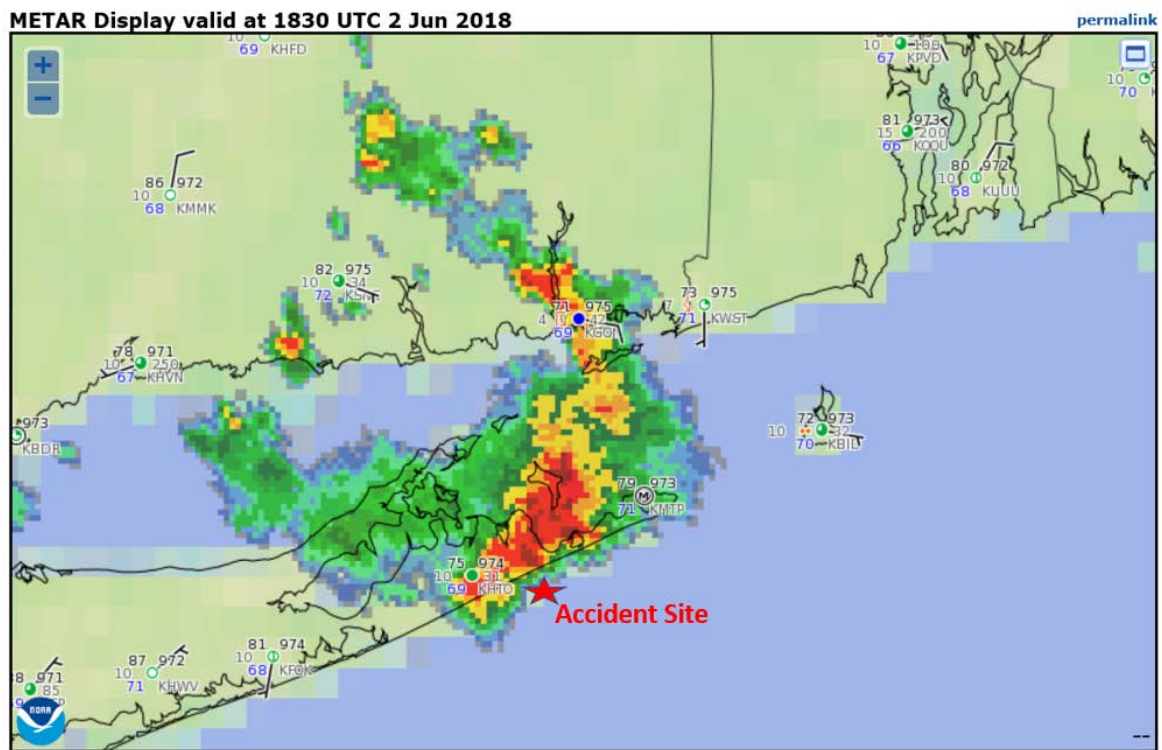
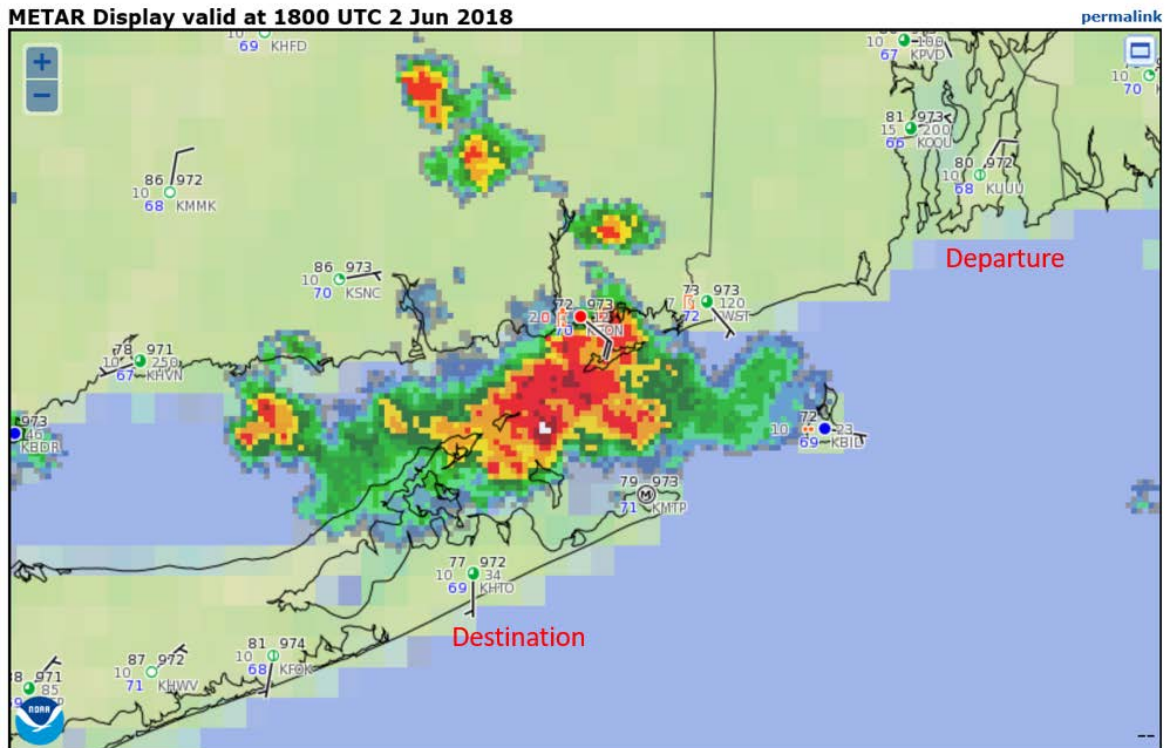
The AWC METAR displays with the National Radar Composite Radar overlaid for 1400, 1430, and 1500 EDT are included as figures 9 through 11, with the approximate accident site marked by a red star. A more detail review of the weather radar information will be included in section 6.0 of this report. The images depict several scattered intense to extreme intensity echoes over southern Connecticut with one large cluster over Long Island and Block island Sound moving southward over eastern Long Island and the accident site during the period.

⁸ As defined by the NWS and the FAA Aeronautical Information Manual (AIM) section 7-1-7 defines the following general flight categories:

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

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

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



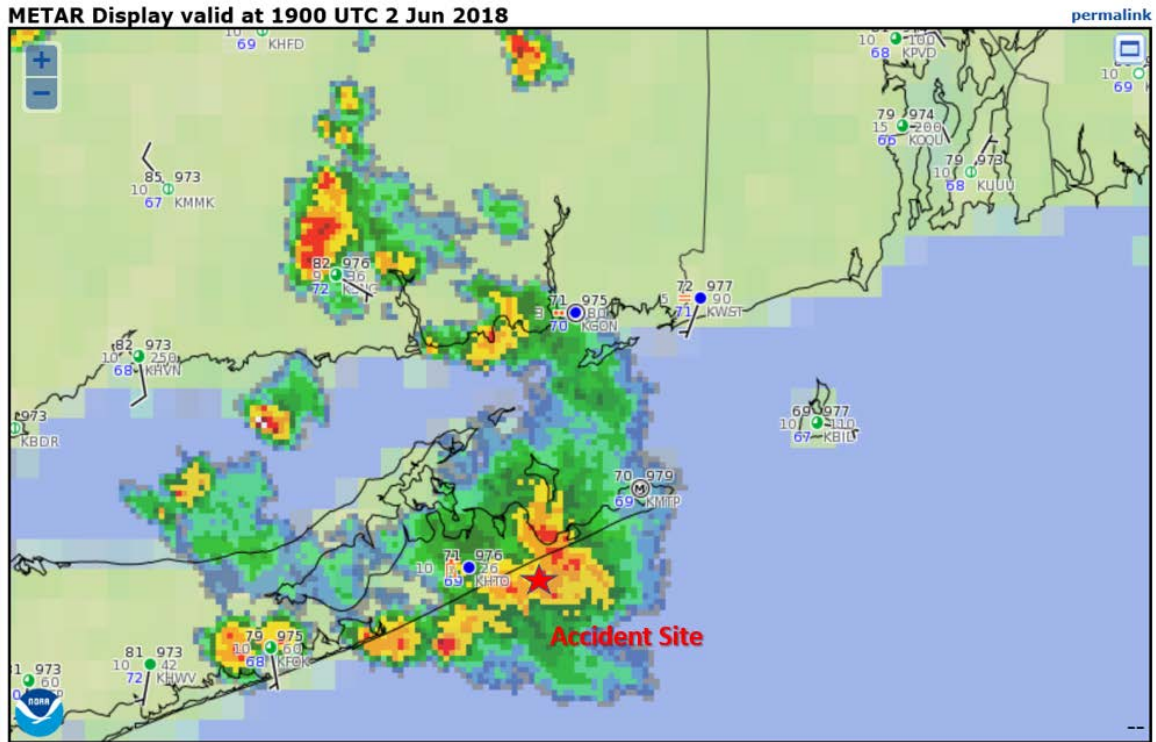


Figure 11 - AWC METAR and radar display at 1500 EDT

3.0 Sounding

To determine the vertical structure and state of the atmosphere over the accident site a High-Resolution Rapid Refresh (HRRR)⁹ numerical model data was retrieved from the NOAA Air Resources Laboratory and plotted on a standard Skew T log P diagram¹⁰ using the complete Rawinsonde Observation RAOB program software¹¹ from the surface to 500-hPa (approximately 18,000 ft). The 1400 EDT HRRR numerical model is included as figure 12 and represents the “pre-storm” environment immediately prior to the accident.

⁹ The HRRR is a National Oceanic and Atmospheric Administration (NOAA) real-time three-kilometer resolution, hourly-updated, cloud-resolving, convection-allowing atmospheric model, initialized by three-kilometer grids with three-kilometer radar assimilation. Radar data is assimilated in the HRRR every 15 minutes over a one-hour period.

¹⁰ 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.

¹¹ RAOB software – The complete RAwinsonde OBservation program is an interactive sounding analysis program developed by Environmental Research Services, Matamoras, Pennsylvania, for plotting and analyzing upper air data.

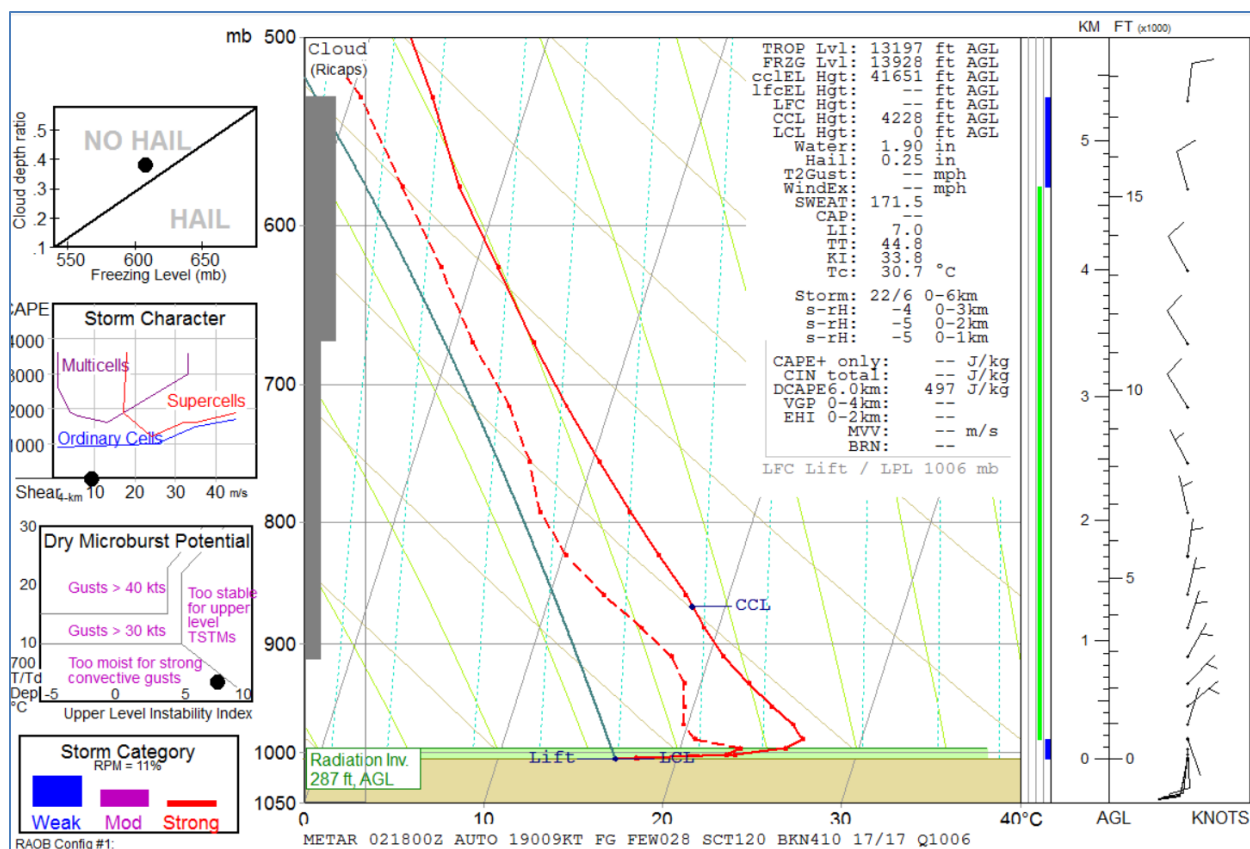


Figure 12 - HRRR model sounding over the accident site for 1400 EDT

The HRRR sounding depicted a surface temperature and dew point of 17° C, with a relative humidity of 100%. The sounding's precipitable water value was 1.90 inches. The freezing level was identified at 13,930 ft. A surface-based temperature inversion was indicated to 287 ft, which contributed in the atmosphere being characterized as being stable with the Lifted Index¹² of +7, and no Convective Available Potential Energy (CAPE)¹³ being calculated on any lifted parcels. As a result, the HRRR sounding storm category supported a weak environment for any strong or severe thunderstorm generation, and only supported ordinary non-severe type storm development which were not considered to be conducive for any strong downdrafts, microbursts, or outflow winds. However; the layer immediately above the surface temperature inversion through 15,000 ft was characterized as conditional unstable¹⁴ based on the lapse rate and was indicated by the

¹² 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.

¹³ 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.

¹⁴ Conditional Unstable - a layer of unsaturated air when its lapse rate of temperature is less than the dry-adiabatic lapse rate but greater than the moist-adiabatic lapse rate. Under such conditions a parcel of air is unstable to upward vertical displacements if it is saturated, but stable to all vertical displacements if it is unsaturated.

green bar on the right side of the sounding (blue – stable, green – conditional unstable, red – unstable). Further, the Most-Unstable (MU) Lifted Index was determined to be -6 with the CAPE of 2,664 J/kg, and indicated a lifted condensation level at 1,351 ft agl, a level of free convection at 2,739 ft agl, with the equilibrium level (EL) at 43,480 ft. Figure 13 is a listing of the significant indices and parameters for the surface based (SB), the most unstable (MU) conditions, and mean layer (ML). Both the most unstable and mean layer conditions indicated an unstable atmosphere favorable for the development of convective type clouds.

Significant Indices & Parameter Comparisons				
Lift type = LFC Virtual correction = no				
	SB SFC-Based 1006 mb	MU Most-Unstable 996 mb	ML Mean-Layer 956 mb	
CAPE Plus(+)	0	2664	1127	J/kg
CAPE 0-3km	0	189	67	J/kg
CIN Total	0	-30	-32	J/kg
NCAPE	0.21	0.21*	0.11*	
LI	7	-6*	-3	
TI	26.8	39.8*	36.8*	
DCI	0	0	0	
BRN	0	265	112	
MVV	0	73	47	m/s
EH1 0-2km	0	0.1	0	
VGP 0-4km	0	0.196	0.127	
Craven 0-6km	-	-	14	
EL(lfc) Hgt	-999	43480	40117	ft,AGL
LFC Hgt	0	2739*	5406*	ft,AGL
LCL Hgt	0	1351	3201	ft,AGL
LFC-LCL	0	423*	672*	m

* indicates that data meets 'high' threshold values,
if they exist in the Severe Weather Parameter Table (F12).

Figure 13 - HRRR Significant Indices and Parameter Comparisons

The wind profile indicated a surface wind from 190° at 9 knots with wind backing to the north with height, with winds speeds of 10 knots or less through 18,000 ft. The mean 0 to 6-kilometer (km) storm motion was from 020° at 6 knots. No strong vertical wind shears were indicated for any significant turbulence outside of any convective activity.

A table of the HRRR model heights, pressure, temperature (T), dew point (Td), relative humidity (RH%), and wind direction and speed, clear air turbulence (CAT), low-level wind shear (LLWS), and icing potential from the surface to 10,000 ft is included below in figure 14.

Height (ft-MSL)	Pres (mb)	T (C)	Td (C)	RH (%)	DD / FF (deg / kts)	CAT (FAA)	LLWS	Icing - Type (AFGWC method)
0	1006	16.6	16.6	100	191 / 9			
28	1005	17.8	17.7	99	191 / 9		LIGHT	
113	1002	23.2	22.7	97	186 / 10		LIGHT	
287	996	25.9	23.4	86	178 / 8	MDT	LIGHT	
551	987	26.7	20.7	70	163 / 1			
966	973	25.9	19.8	69	16 / 1			
1476	956	24.4	19.5	74	48 / 3			
2115	935	22.7	19.1	80	41 / 5			
2858	911	20.8	17.9	83	27 / 5			
3648	886	19.2	15.7	80	15 / 5			
4554	858	17.6	13.0	74	11 / 5			
5618	826	15.4	10.2	71	7 / 5			
6785	792	13.0	8.0	72	348 / 6			
8138	754	10.4	6.5	77	334 / 7			
9585	715	7.6	4.4	80	330 / 8			
11256	672	4.6	1.2	79	330 / 10			

Figure 14 - HRRR sounding data through 11,000 ft

4.0 Satellite Imagery

The Geostationary Operational Environmental Satellite number 16 (GOES-16) data was obtained from an archive at the Space Science Engineering Center at the University of Wisconsin-Madison in Madison, Wisconsin, and processed using the Man-computer Interactive Data Access System (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 13) at a wavelength of 10.3 microns (μm) provided radiative cloud top temperatures with a nominal spatial resolution of 2 km. The visible imagery (band 2) at a wavelength of 0.64 μm provided a nominal spatial resolution of 0.5 km.

Figure 15 is the GOES-16 infrared image at 1432 EDT at 4X magnification with a standard MB temperature enhancement curve applied to highlight the higher and colder cloud tops typically associated with strong convection, and the pressure and frontal position at 1400 EDT. The accident site is marked by a white square and was located on the southern side of an enhanced area of clouds associated with a cluster of cumulonimbus clouds. The radiative cloud top temperature over the accident site was 255° Kelvin (K) or -18.16° C, which corresponded to cloud tops near 24,600 feet based on the HRRR sounding. The maximum cloud tops (yellow area) were identified about 18 miles north of the accident site with a temperature of 214° K or -59.16° C, which corresponded to tops near 43,000 feet.

Figure 16 is the GOES-16 visible image at 4X magnification for 1432 EDT showing the cumulonimbus cloud system's overshooting cloud tops and anvil over Block Island Sound immediately north of the accident site, with the accident site under the leading edge of the lower cloud cover.

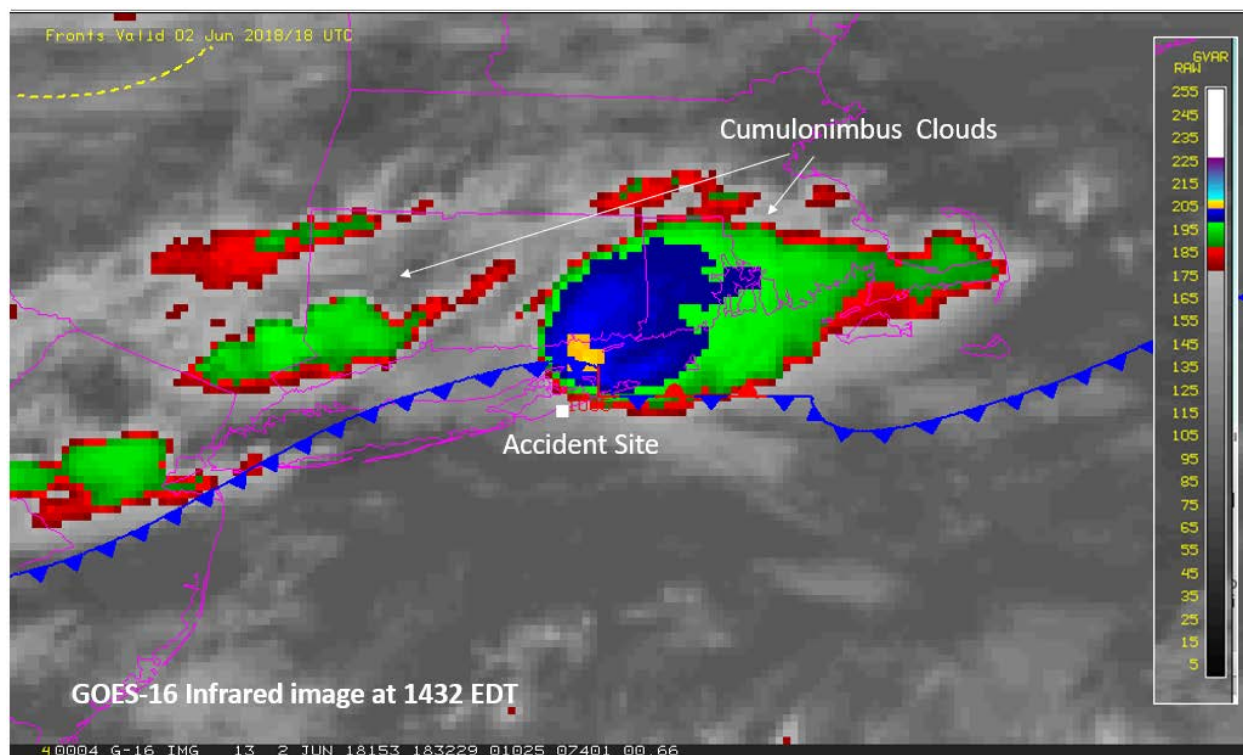


Figure 15 - GOES-16 infrared image at 1432 EDT with frontal positions overlaid

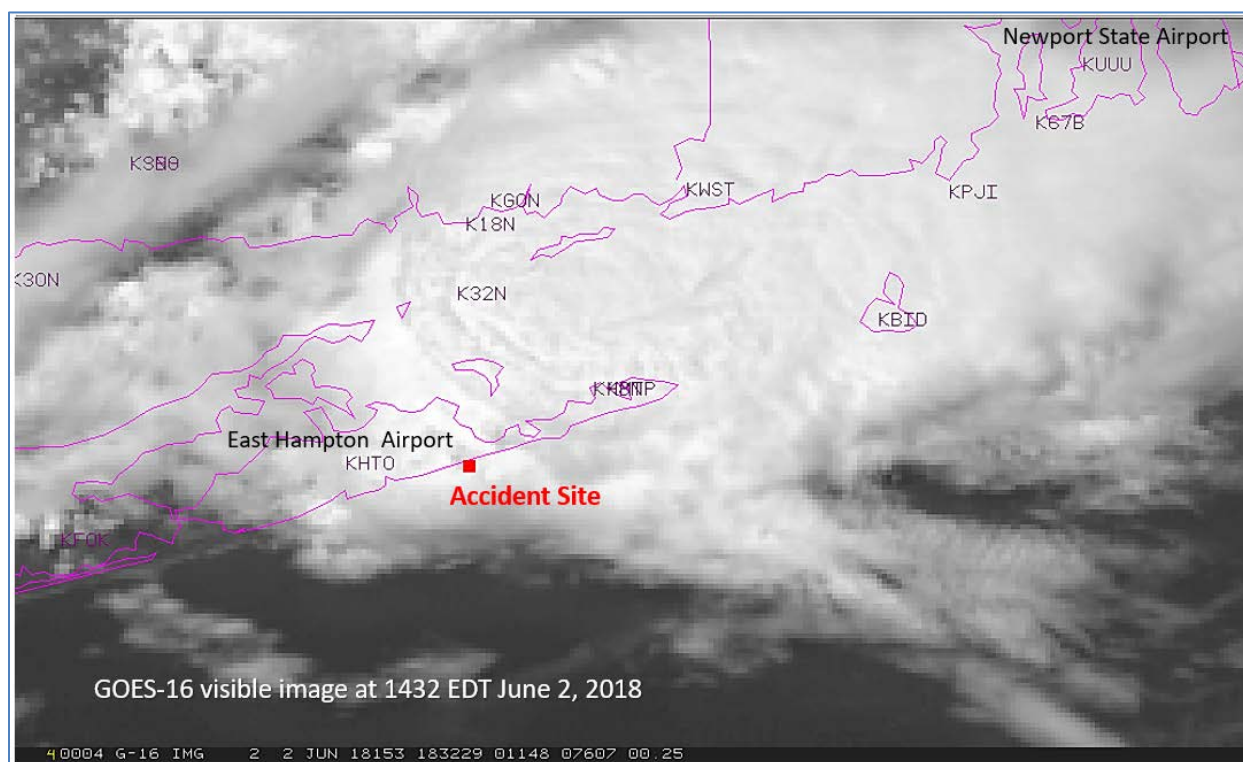


Figure 16 - GOES-16 visible image for 1432 EDT

5.0 Pilot Reports

A search of the NWS database for pilot reports (PIREPs) provided only two reports over the area between 0500 through 2000 EDT. The reports were decoded from standard code and abbreviations and were provided in plain language with time converted to local EDT. The reports were as follows:

Tweed-New Haven Airport (KHVN), New Haven, CT, routine pilot report (UA); Over – HVN; Time – 0510 EDT; Altitude – during climb out; Type aircraft – Canadair Regional Jet (CRJ2) light commuter air carrier jet; Sky cover – overcast clouds bases at 50 ft with tops at 200 ft.

Long Island Mac Arthur Airport (KISP), New York, NY, routine pilot report (UA); Over – ISP; Time – 1429 EDT; Altitude – 300 ft; Type aircraft – Cessna 172 single engine airplane; Remarks – LLWS +/- 10 knots between the surface and 300 ft during descent to runway 06 at ISP.

The above listed PIREPs over HVN and ISP were located about 34 miles northwest and 43 miles west respectively of the accident site.

6.0 Weather Surveillance Radar Imagery

The closest Weather Surveillance Radar-1988, Doppler (WSR-88D) to the accident site was from the NWS Upton (KOKX), New York, Weather Forecast Office (WFO) located 34 miles from the accident site. However, the KOKX radar was down due to a maintenance issue and no data was available from the radar during the period. The next closest WSR-88D was from NWS Boston (KBOX) located 74 miles northeast of the accident site. The level II 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.

6.1 Volume Scan Strategy

The WSR-88D is a computer-controlled radar system, which automatically creates a complete series of specific scans in a specific sequence known as a volume scan. Individual elevation scans are immediately available 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 volume scan, which can range from 4 to 10-minutes depending on the scan being utilized.

The WSR-88D operates in several different scanning modes, identified as Mode A and Mode B. Mode A is the precipitation scan and has multiple scanning strategies, which are used when significant weather echoes are present or severe weather is occurring or is anticipated. 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, which is used when there is no detectable precipitation or when precipitation intensity is light and/or areal extent is small, such as light stratiform precipitation or snow. In the clear air mode the radar makes 5 elevation scans during a ten minute period.

During the period surrounding the accident the KBOX WSR-88D radar was operating in the precipitation mode VCP-215 where the radar makes 15 different elevation scans in 6 minutes. This mode is typically used by the NWS during periods when rapidly evolving wide spread convection is expected and allows for improved low-level vertical resolution of the storms. It has the most vertical resolution of any VCP. Figure 17 is a depiction and elevation scans used in this VCP, and the approximate height and width of the radar beam with distance from the radar site.

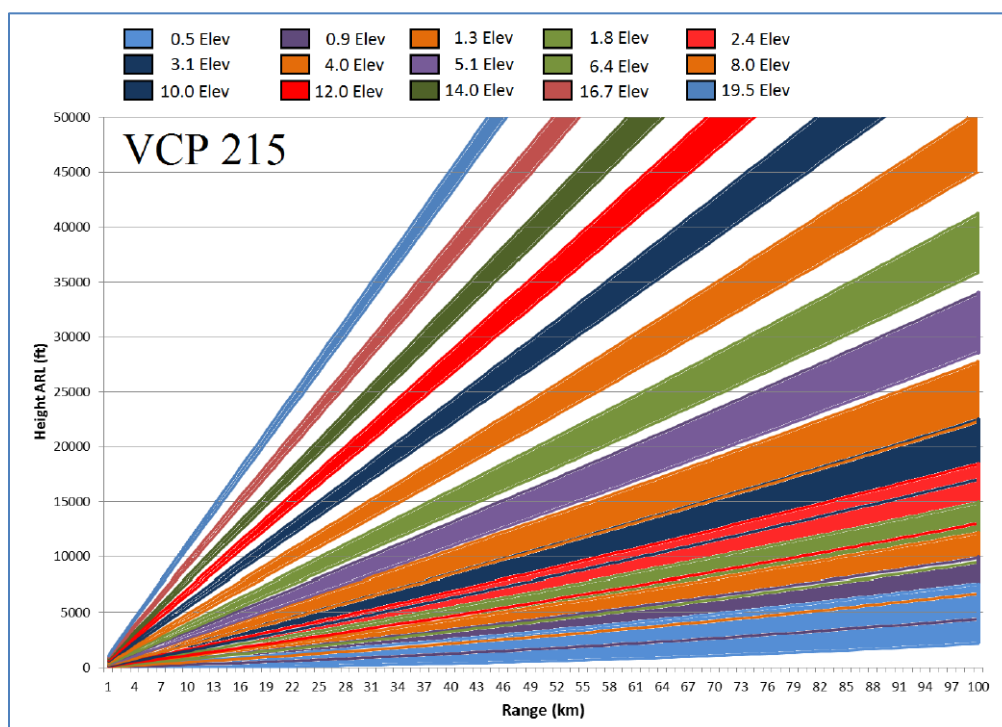


Figure 17 - VCP 215 elevation scans

6.2 Beam Height

Assuming standard refraction¹⁵ of the 0.95° radar beam of the KBOX WSR-88D with an antenna of feeder horn height of 232 feet and a distance of 74 miles 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.

¹⁵ Standard Refraction in the atmosphere is when the temperature and humidity distributions are approximately average, and values set at the standard atmosphere.

Antenna Elevation	Beam Center	Beam base	Beam Top	Beam Width
0.44°	7,310 ft	3,590 ft	11,040 ft	7,450 ft

6.3 Reflectivity

Reflectivity is the measure of the efficiency of a target in intercepting and returning radio energy. With hydrometeors, 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 (dBZ¹⁶) 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 table. 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".

¹⁶ dBZ - 10 log Ze

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

6.4 Base reflectivity Imagery

The KBOX WSR-88D 0.44° base reflectivity image for 1418, 1422, 1428, 1433, and 1438 EDT as figures 18 through 22. Echoes less than 10.0 dBZ have been removed from the images. The FAA flight track data obtained from the NTSB ATC Specialist for the period of the radar scan has also been added. The radar images depict a large multicellular cluster of thunderstorms about 30 miles long and 20 miles wide moving southward at around 10 knots. The accident airplanes flight track is observed approaching the area from the west and southwest, and then enters under the leading edge of the echoes with a maximum of 53.0 dBZ “extreme” intensity echo along the track where echo tops near 48,000 ft. The extreme intensity echoes over 50.0 dBZ extended between the accident site and KHTO by 1438 EDT.



Figure 18 - KBOX WSR-88D 0.44° base reflectivity image at 1418 EDT with flight track

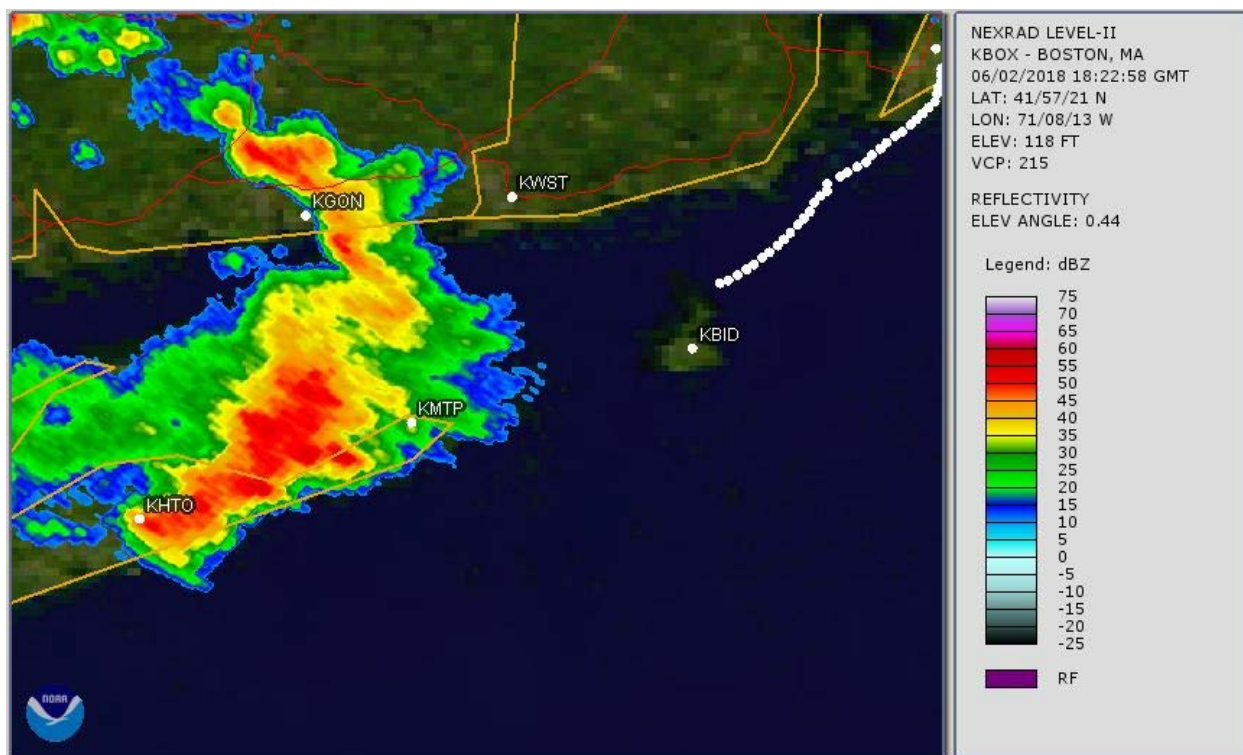


Figure 19 - KBOX WSR-88D 0.44° base reflectivity image at 1422 EDT with flight track

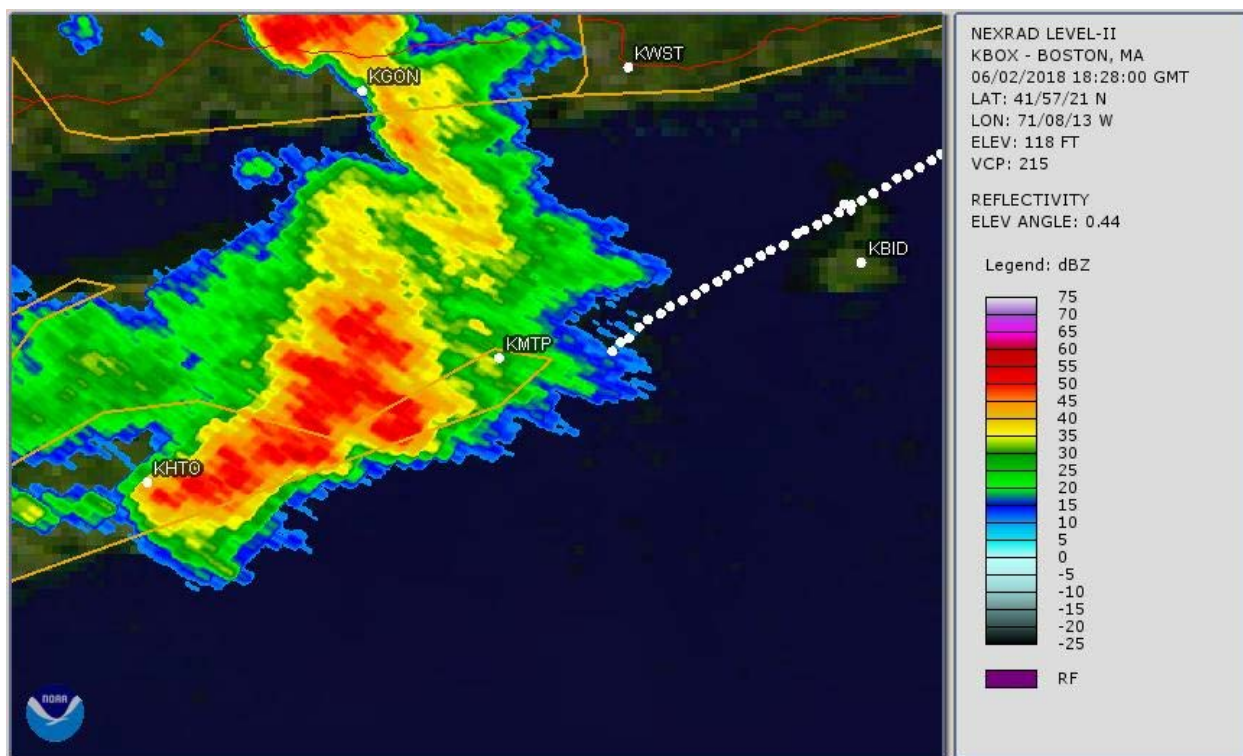


Figure 20 - KBOX WSR-88D 0.44° base reflectivity image at 1428 EDT with flight track



Figure 21 - KBOX WSR-88D 0.44° base reflectivity image at 1433 EDT with flight track

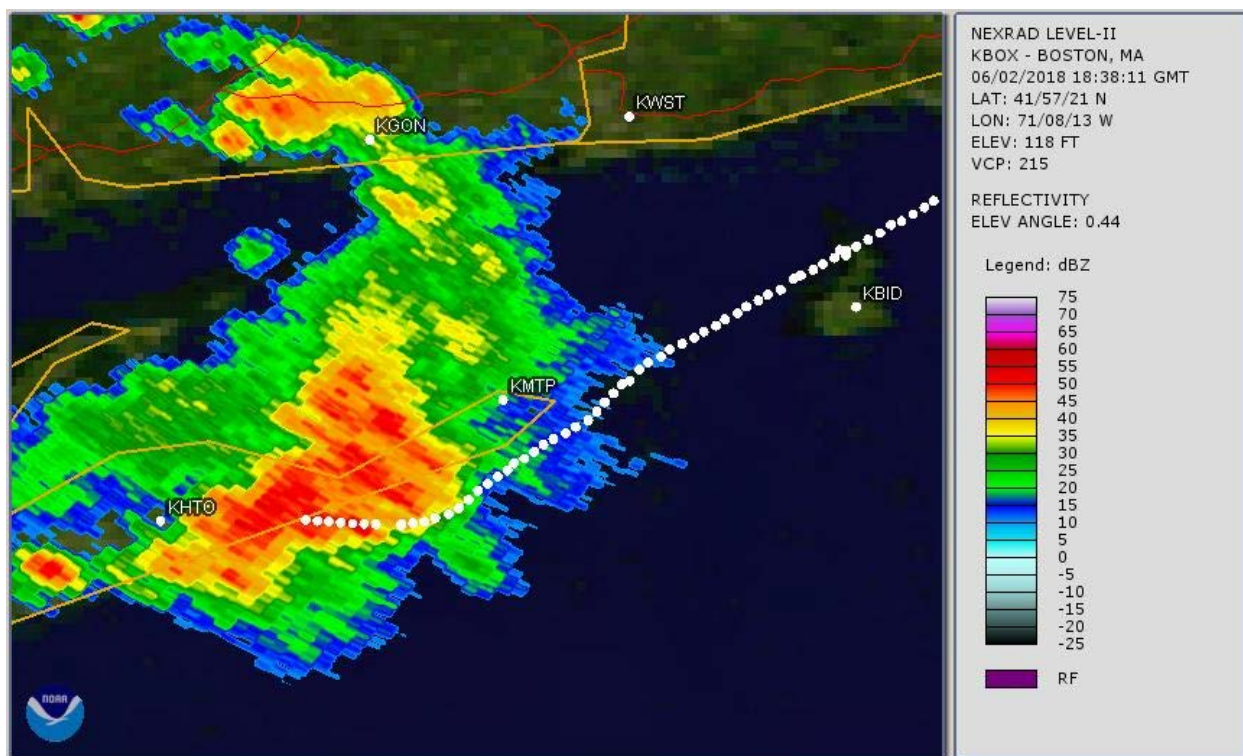


Figure 22 - KBOX WSR-88D 0.44 base reflectivity image at 1438 EDT with flight track

6.5 FAA CoSPA Weather Display

The FAA Consolidated Storm Prediction for Aviation (CoSPA) weather display, which integrates several of the NWS and FAA weather systems into a single display, with lightning and convective initiation and growth into a single display surrounding the period were documented. These images were available to the New York (KZNY) Air Route Traffic Control Center (ARTCC). The CoSPA display is of vertical integrated liquid (VIL) which is the vertical estimation of the mass of water, or liquid water content in a column of air versus reflectivity in section 6.4 above. VIL uses the full volume scan of all the elevation scans and looks similar to reflectivity images. The VIL levels 1 through 6 correspond to the following table (similar to table 6.3 VIP levels):

VIP or VIL Levels	VIL (digital VIL)	VIL (kg/m ²)	Past and Current VIL
1	16	0.15	Level 1
2	74	0.76	Level 2
3	133	3.47	Level 3
4	160	6.92	Level 4
5	181	12.0	Level 5
6	219	31.6	Level 6

The CoSPA images at 15-minute intervals from 1330 through 1415 EDT, then at 5-minute intervals from 1420 through 1440 EDT are included in figures 23 through 32. The intensity of the echoes are marked in VIP or VIL levels 1 through 6 in various colors, similar to reflectivity values. Also included are the echo tops or the highest detection of 18 dBZ in hundreds of feet, cell movement indicated by a black arrow with the speed in knots, and cloud-to-ground lightning strikes with the white “+” symbols from the National Lightning Detection Network (NLDN), and 2-hour storm movement prediction.

The CoSPA images depict a large cluster of convective echoes moving south over Long Island Sound and over eastern Long Island during the period. VIP Level 4 to 5 echoes extending over the accident site at 1430 EDT, with VIP or VIL Level 5 echoes over the site at 1435 and 1440 EDT with lightning activity in the immediate vicinity. The echoes were noted moving southward at 10 knots through the period with echo tops near 46,000 ft.

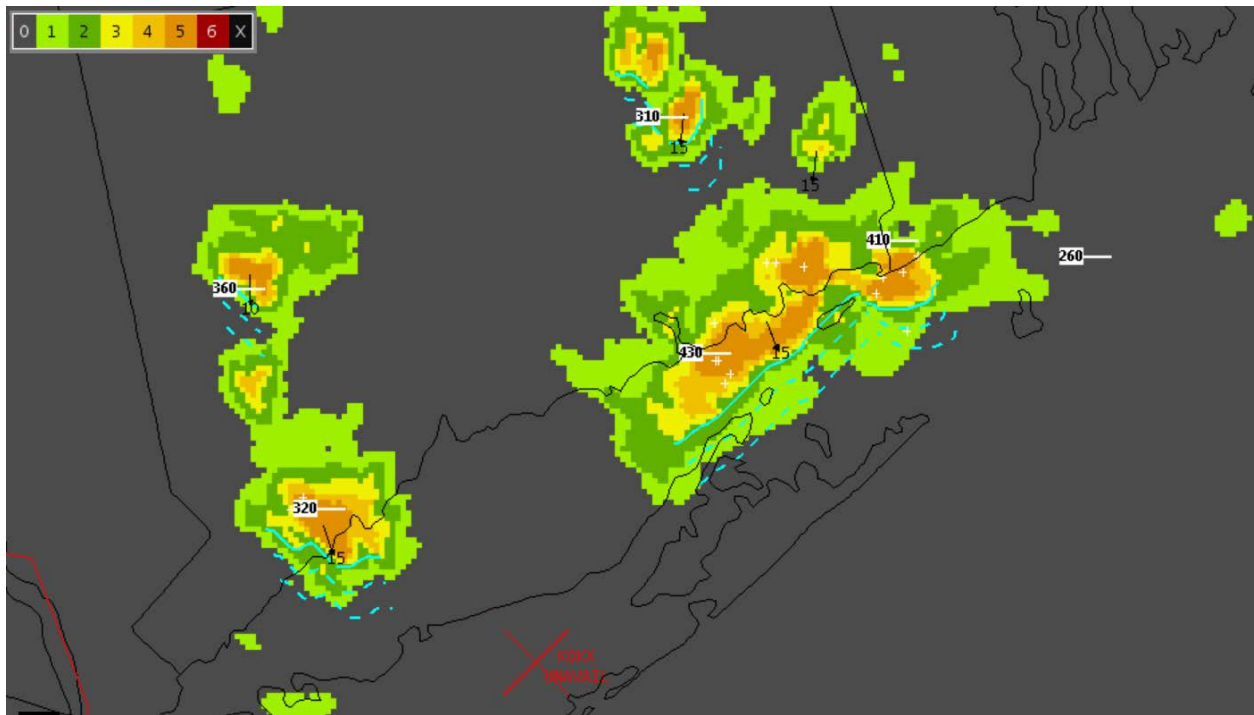


Figure 23 - CoSPA image at 1330 EDT

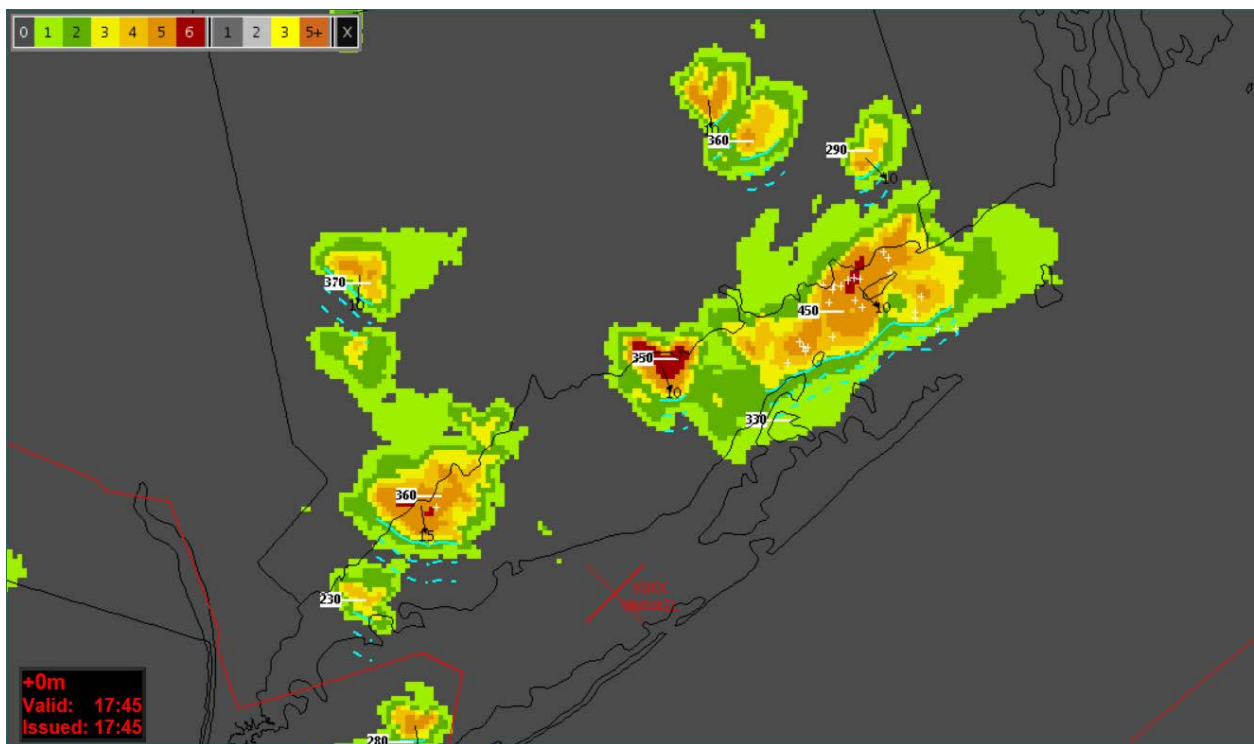


Figure 24 - CoSPA image at 1345 EDT

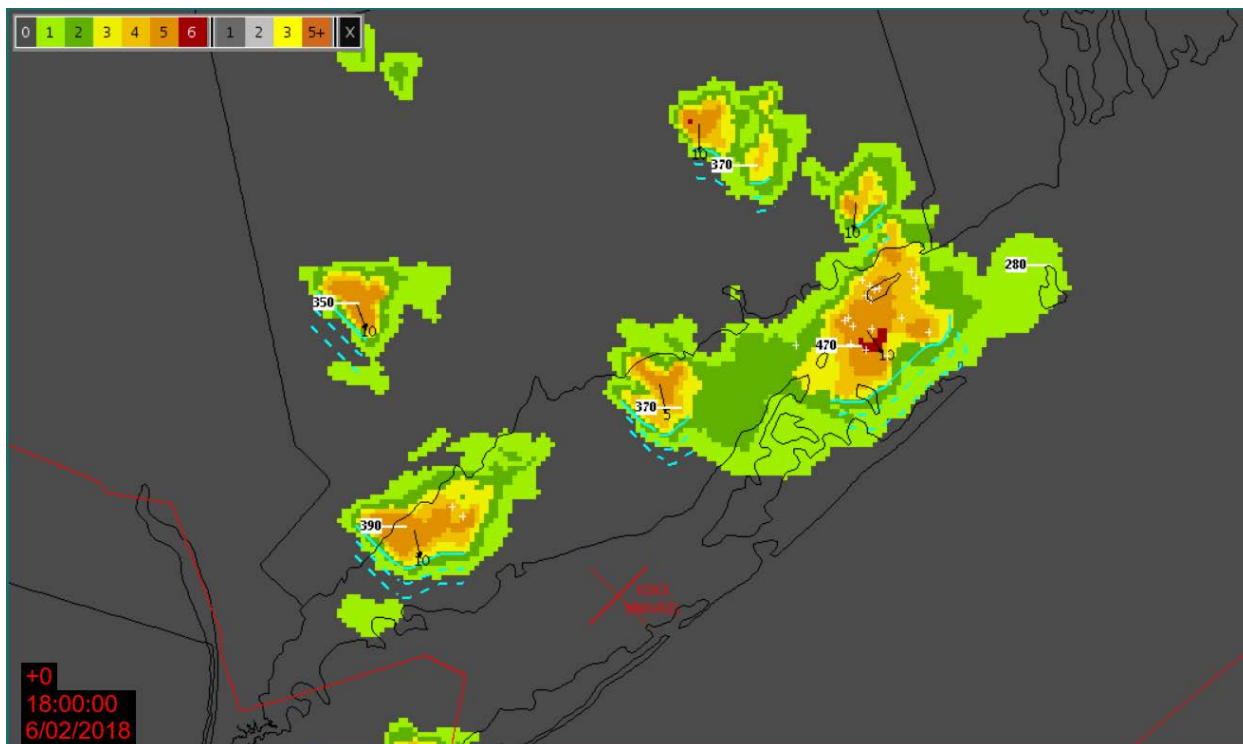


Figure 25 - CoSPA image at 1400 EDT

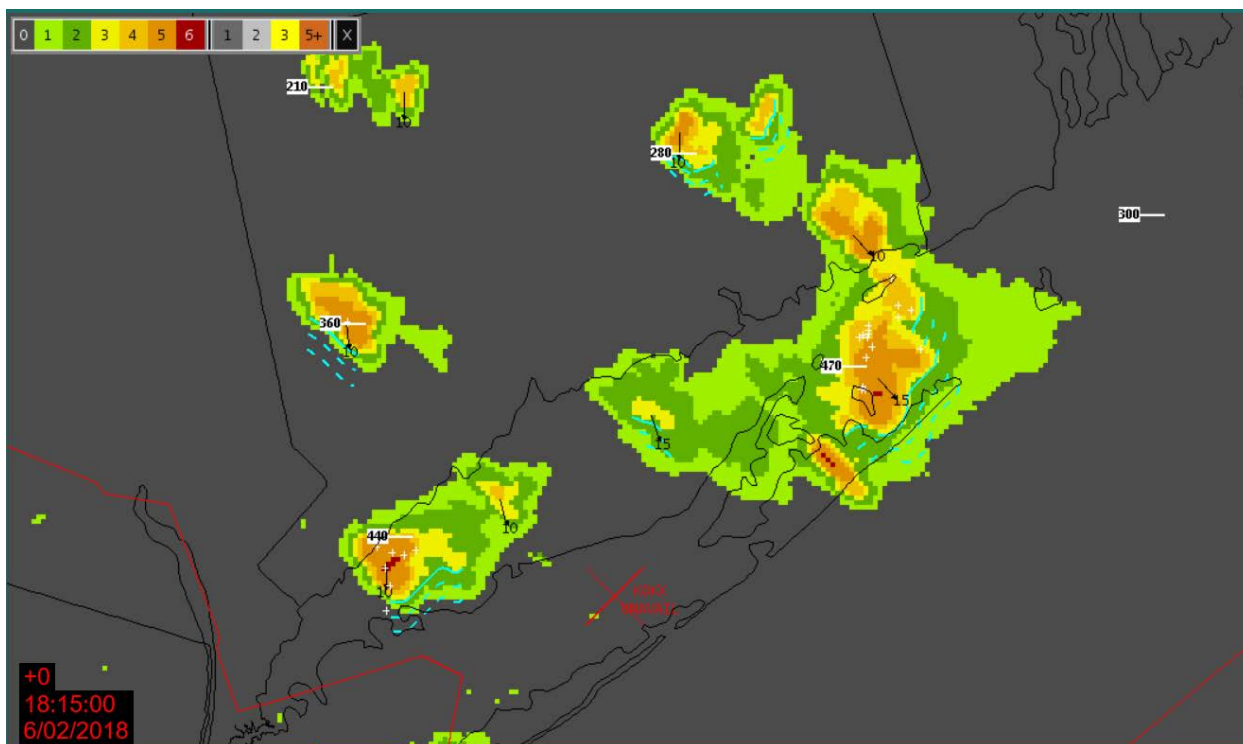


Figure 26 - CoSPA image at 1415 EDT

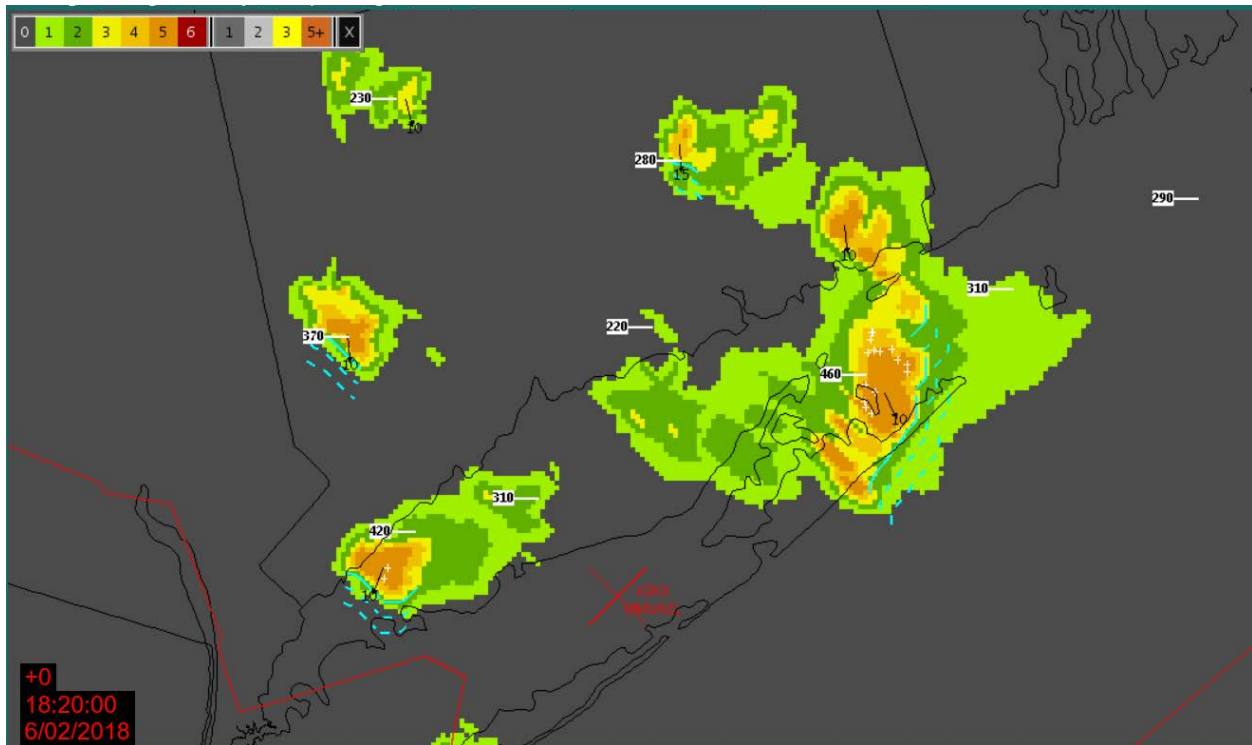


Figure 27 - CoSPA image at 1420 EDT

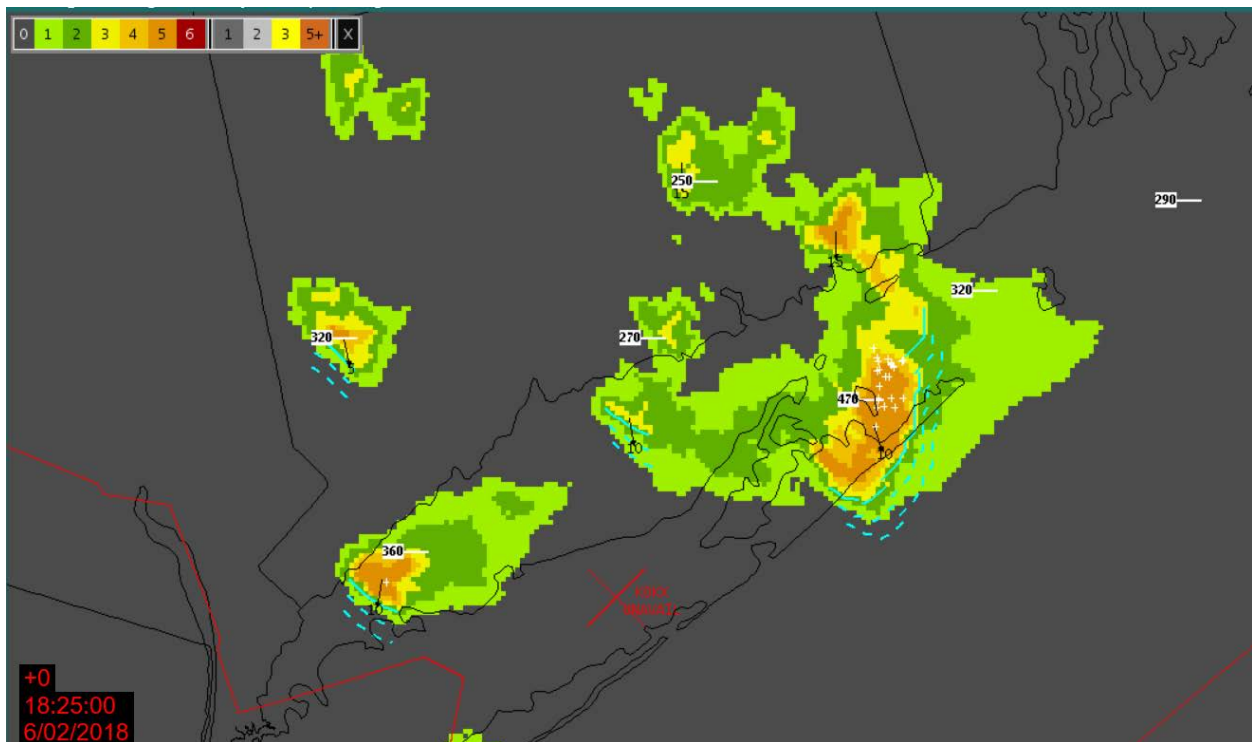


Figure 28 - CoSPA image at 1425 EDT

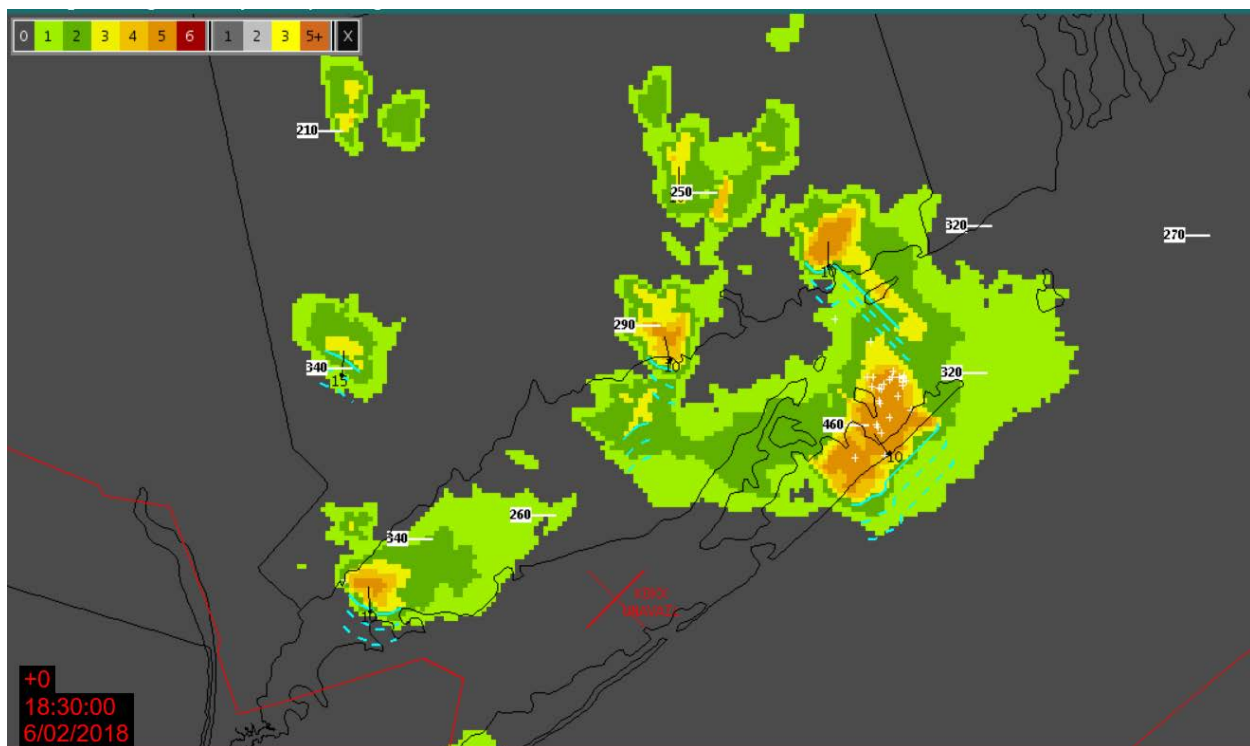


Figure 29 - CoSPA image at 1430 EDT

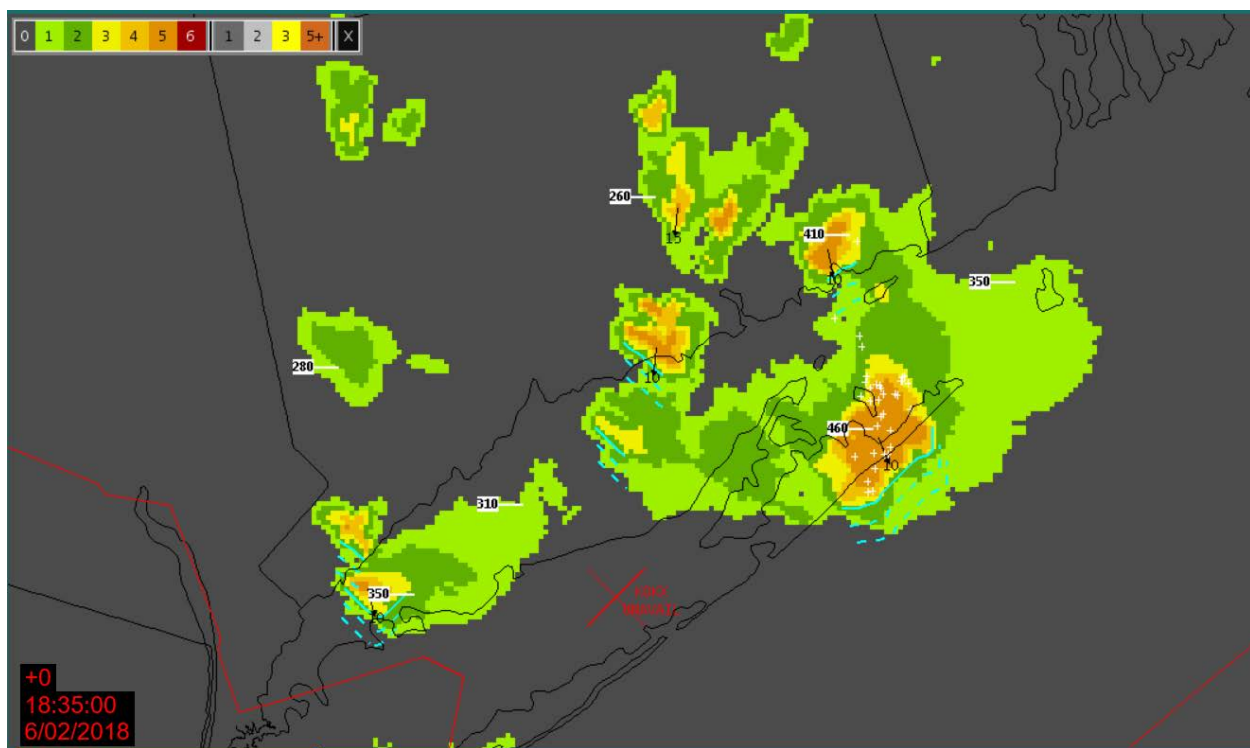


Figure 30 - CoSPA image at 1435 EDT

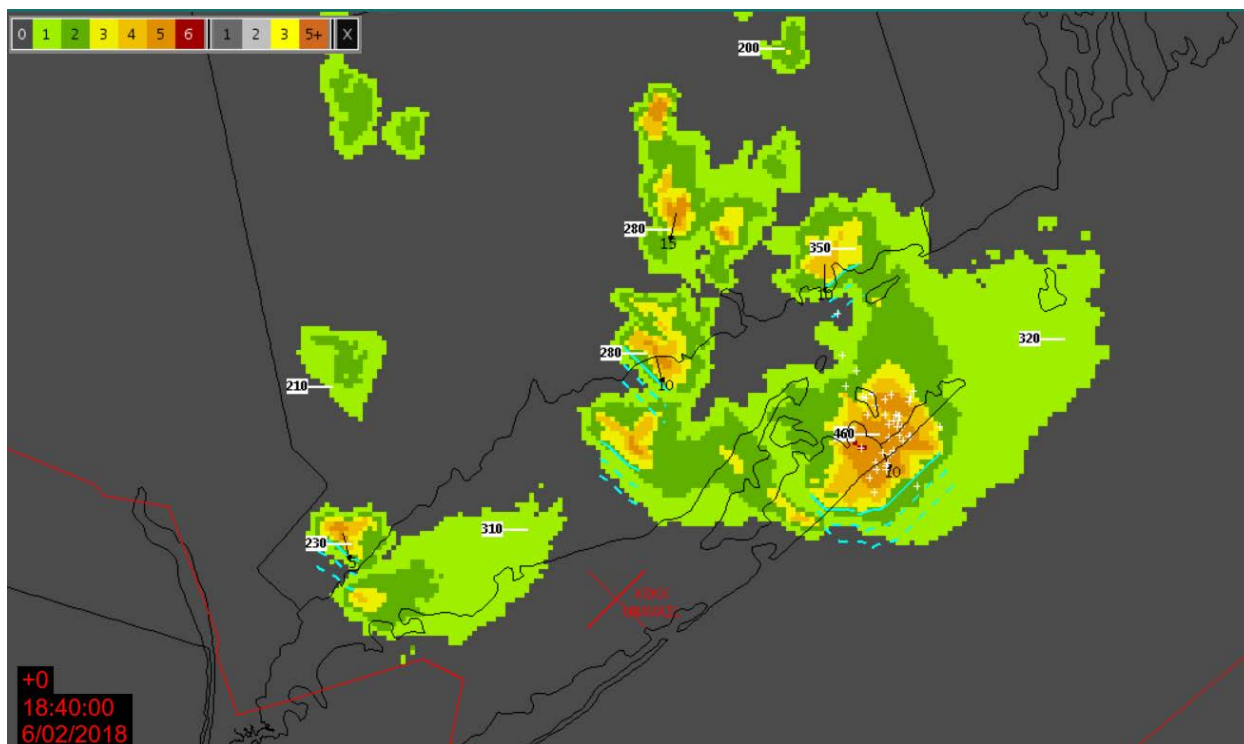


Figure 31 - CoSPA image at 1440 EDT

7.0 Lightning Data

A review of the Earth Networks archive total lightning data indicated a total of 832 lightning flashes between 1400 and 1445 EDT within about a 100 mile radius of the accident site. The vast majority of the lightning were in-cloud flashes.

Figure 32 is the KBOX WSR-88D 0.44° base reflectivity image at the approximate time of the accident with the lightning flashed from 1400 through 1435 EDT overlaid, with in-cloud lightning in white and cloud-to-ground lightning strikes in purple. During this period from 1400 through 1435 EDT, there were 592 in-cloud flashes, and 122 cloud-to-ground strokes, with the closest in-cloud lightning flash located approximately 3 miles north of the accident site. Immediately after the accident, between 1435 and 1445 EDT, another 118 lightning flashed were recorded with multiple flashes in the vicinity of the accident site.

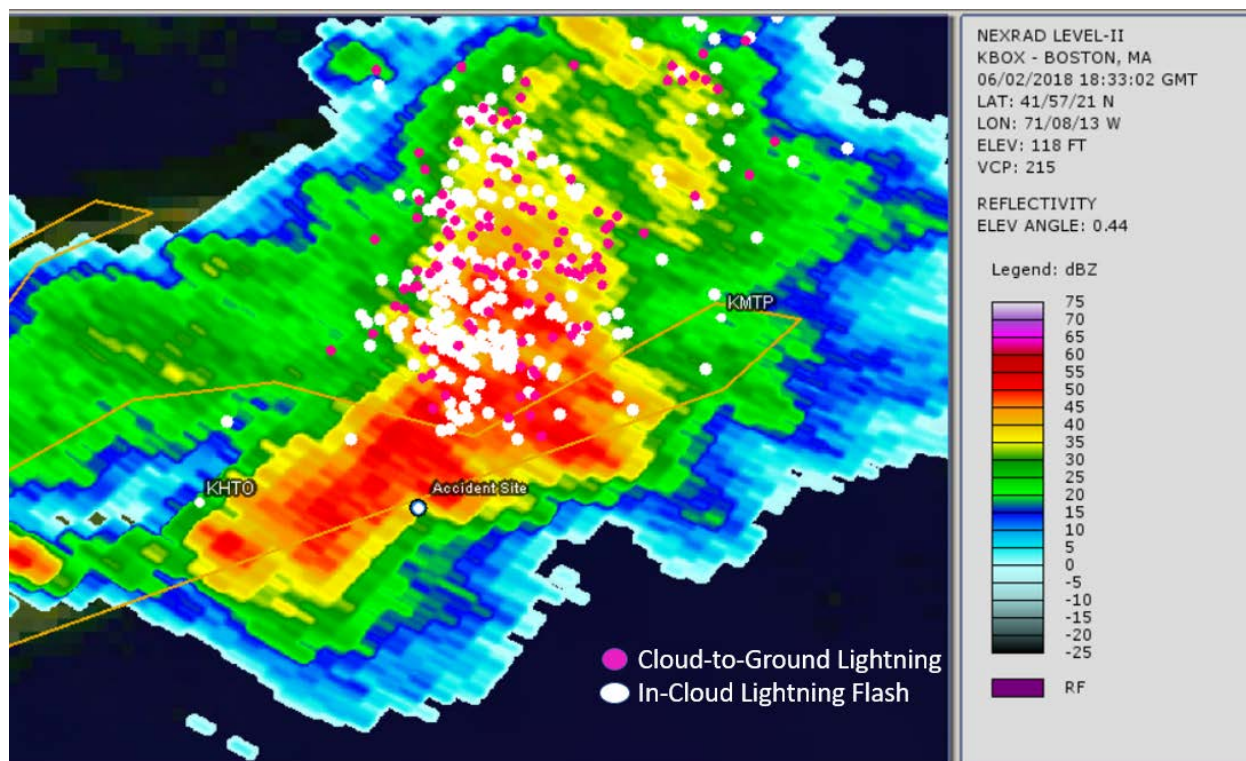


Figure 32 - KBOX WSR-88D 0.5 base reflectivity image with lightning flashes from 1400 to 1435 EDT

8.0 Terminal Aerodrome Forecast

The closest NWS Terminal Aerodrome Forecast (TAF) to the accident site was for KISP located about 43 miles west-southwest of KHTO. While a TAF is only valid for a 5-mile radius of the airport center point, it provides a more time specific forecast of wind direction, speed, gusts, visibility, weather phenomena, cloud coverage and cloud heights than other NWS forecasts. The forecasts issued by the NWS Upton, New York, WFO during the period were as follows.

The forecast current prior to departure was an amended forecast issued at 1154 EDT. The forecast for KISP from 1100 through 1700 EDT expected a wind from 040° at 8 knots, visibility of 6 miles or more, scattered clouds at 4,000 ft agl, and scattered clouds at 15,000 ft. After 1700 through 0200 EDT, thunderstorms were forecast in the vicinity or within 30 miles of the station, with a period of temporary visibility 3 miles in moderate rain showers. The raw forecast was as follows:

TAF AMD KISP 021554Z 0216/0312 02008KT P6SM SCT040 SCT150
 FM022100 04008KT P6SM VCTS BKN040CB
 TEMPO 0221/0224 3SM SHRA BKN025
 FM030000 07009KT P6SM VCTS BKN040CB
 TEMPO 0300/0304 5SM -SHRA BKN020
 FM030600 09010G17KT P6SM BKN040
 FM030900 08012G20KT P6SM BKN050=

The forecast was amended at 1228 EDT and expected from 1400 EDT thunderstorms in the vicinity of the airport with a ceiling broken at 4,000 ft agl in cumulonimbus clouds, with a temporary period between 1400 and 1800 EDT of 3 miles in moderate rain showers with a ceiling broken at 3,000 ft agl. The forecast was as follows:

*TAF AMD KISP 021628Z 0216/0312 03008KT P6SM SCT040 SCT150
FM021800 04008KT P6SM VCTS BKN040CB
TEMPO 0218/0222 3SM SHRA BKN030
FM022200 07009KT P6SM VCTS BKN040CB
TEMPO 0222/0302 5SM -SHRA BKN020
FM030600 09010G17KT P6SM BKN040
FM030900 08012G20KT P6SM BKN050=*

The next scheduled TAF was issued at 1322 EDT and was the forecast current at the time of the accident. The forecast from 1400 EDT expected wind from 040° at 10 knots, visibility 6 miles or more with thunderstorms in the vicinity, ceiling broken at 4,000 ft agl in cumulonimbus clouds, with a temporary period between 1400 and 1800 EDT of 3 miles in moderate rain showers with a ceiling broken at 3,000 ft agl. Thunderstorms and rain showers were expected in the vicinity through 2200 EDT.

*TAF KISP 021722Z 0218/0318 04010KT P6SM VCTS BKN040CB
TEMPO 0218/0222 3SM SHRA BKN030
FM022200 07009KT P6SM VCTS BKN040CB
TEMPO 0222/0302 5SM -SHRA BKN020
FM030200 08010G17KT P6SM BKN025 BKN050
FM030600 09012G19KT P6SM FEW030 BKN040
FM031400 08013G22KT P6SM FEW030 BKN050=*

9.0 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 Information (SIGMET), the Convective SIGMET, the Airmen Meteorological Information (AIRMET), and the Center Weather Advisory (CWA). During the period the only advisory issued applicable to the area were a single Convective SIGMETs and several CWA's which are included below.

9.1 Center Weather Advisories

The New York (KZNY) and Boston (KZBW) Center Weather Service Units (CWSU) located within the Air Route Traffic Control Centers issued the following advisories at between 1200 through 1600 EDT for areas of thunderstorms and heavy rain showers surrounding the period. With the KZBW CWSU was responsible for the region of eastern Long Island and Rhode Island. Of the six advisories issued surrounding the period, only KZBY CWA 102 issued at 1328 EDT

and valid through 1435 EDT impacted the route of flight and was immediately north of the accident site and is included as figure 33 with the GOES-16 satellite image.

<u>Time</u>	<u>Center Weather Advisory</u>
[1211]	<i>FAUS21 KZNY 021611 ZNY1 CWA 021610 ZNY CWA 101 VALID UNTIL 021710 FROM 30NNE SAX-20ENE SAX-10WSW SAX-30NNW SAX-30NNE SAX DVLPG AREA OF SEV TS WITH MOD/HVY RAIN MOV FROM 35010KT. TOPS TO 2FL400. POSS LARGE HAIL AND GSTY SFC WINDS. APRCHG N90 N GATES.</i>
[1226]	<i>FAUS21 KZBW 021626 ZBW1 CWA 021626 ZBW CWA 101 VALID UNTIL 021725 FROM 25WNW BDL-20N PVD-15WNW ACK-15N JFK-25WNW BDL AREA OF DVLPG SHRA/TSRA MOV FM 35015KT. MAX TOPS TO FL340. ASSOCIATED WITH HVY PCPN. IMPACTS TO J75/J121/J174/Q448/Q480. TREND...INCRG.</i>
[1328]	<i>FAUS21 KZBW 021728 ZBW1 CWA 021727 ZBW CWA 102 VALID UNTIL 021825 FROM 25WNW BDL-25NW PVD-35S PVD-15NNE JFK-25WNW BDL AREA OF SHRA/TSRA MOV FM 36015KT. MAX TOPS TO FL410. ASSOCIATED WITH HVY-EXTRM PCPN. IMPACTS TO J75/J121/Q448.</i>
[1336]	<i>FAUS21 KZNY 021736 ZNY1 CWA 021735 ZNY CWA 102 VALID UNTIL 021835 FROM 20WNW SAX-10NNW JFK-25NNE CYN-20NNE ETX-20WNW SAX DVLPG AREA TS WITH MOD/HVY RAIN MOV FROM 01010KT. TOPS TO FL390. POSS SML HAIL. OVR 25-30KT SFC GUSTS. IMPACT TO NY METROS AND J75/J79/J21 EXPCD. CONDS CONTG BYD VALID TIME.</i>
[1407]	<i>FAUS22 KZNY 021807 ZNY2 CWA 021805 ZNY CWA 201 VALID UNTIL 021905 FROM 35NE EMI-45S ETX-30E EMI-10SE EMI-35NE EMI DVLPG AREA TS WITH MOD/HVY RAIN MOV FROM 03010KT. TOPS TO FL440. POSS LRG HAIL AND OVR 25-30KT SFC GUSTS. IMPACT TO J48/J75 EXPCD. CONDS CONTG BYD VALID TIME.</i>
[1508]	<i>FAUS21 KZBW 021908 ZBW1 CWA 021908 ZBW CWA 103 VALID UNTIL 022010 FROM 20E BDL-35ESE HTO-30E JFK-20E BDL AREA OF TS WITH HVY-EXTRM PCPN MOV FM 36010KT. MAX TOPS TO FL380. TREND...INCR. CONTINUING IMPACTS TO J174/J121.</i>
[1558]	<i>FAUS23 KZNY 021958 ZNY3 CWA 021950 ZNY CWA 301 VALID UNTIL 022150 FROM 15SW ETX-25NNE CYN-10SW CYN-30SW ETX-15SW ETX AREA TS INCRG IN COVG WITH HVY/EXTRM RAIN. TS MOV FROM 35012KT.</i>

TOPS TO FL400. AREA EXPECTED TO CONVERGE VCNTY PHL ARND 21Z.

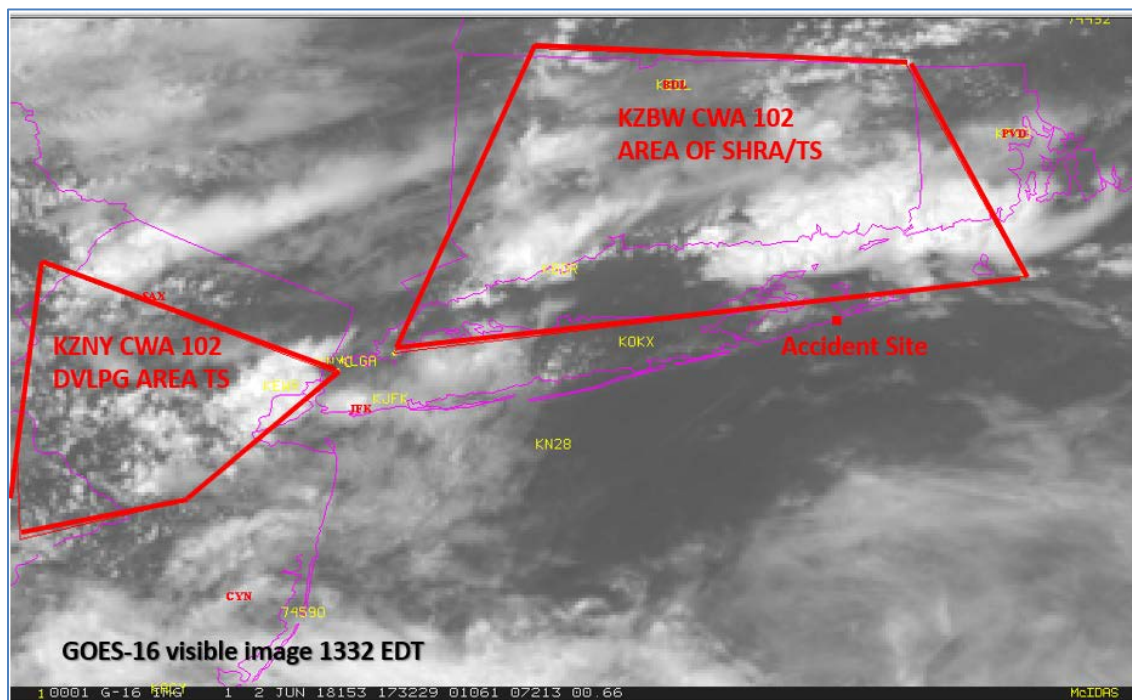
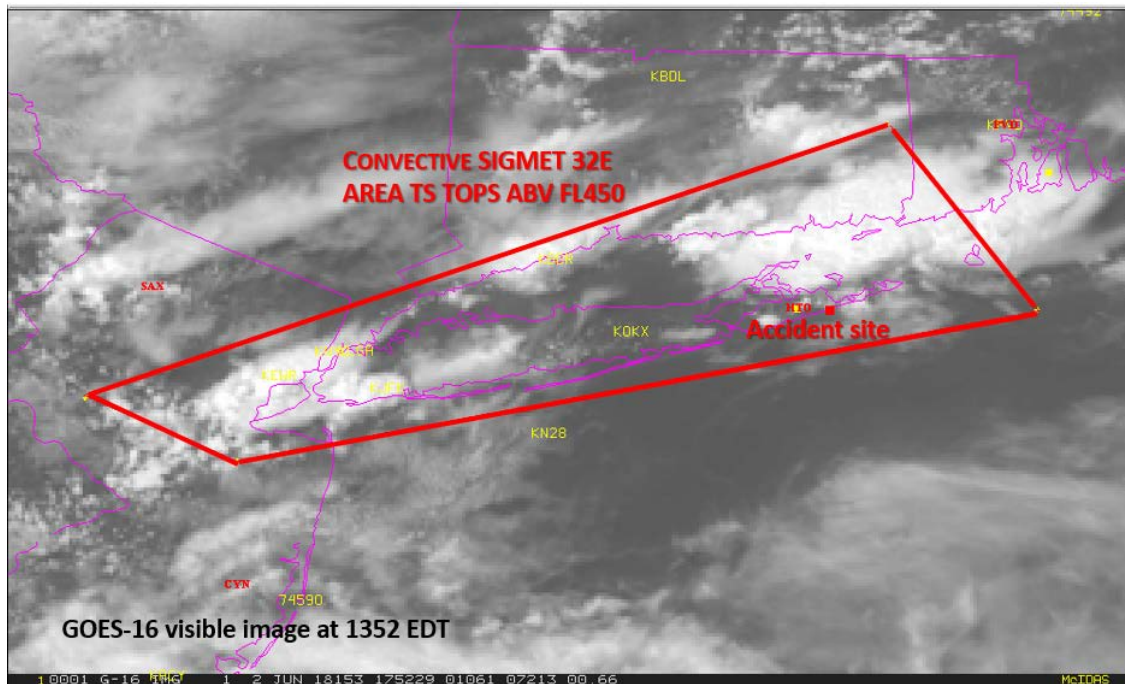


Figure 33 - GOES-16 visible image at 1332 EDT with KZBW and KZNY CWA 102

9.2 Convective SIGMETs

The NWS AWC issued Convective SIGMET 32E at 1355 EDT for an area of thunderstorms extending over Rhode Island, Connecticut, southeast New York, northeast New Jersey, and coastal waters. The area of thunderstorms were moving from 320° at 10 knots, with tops above 45,000 ft. The area enclosed the destination and the accident site and was as follows and is plotted on figure 34. This was the first and only advisory to be issued for the New York area on June 2, 2018.

<u>Time</u>	<u>Convective SIGMET Advisory</u>
[1355]	WSUS31 KPCI 021755
	SIGE
	MKCE WST 021755
	CONVECTIVE SIGMET 32E
	VALID UNTIL 1955Z
	RI CT NY NJ AND CSTL WTRS
	FROM 20W PVD-40E HTO-30N CYN-30SSW SAX-20W PVD
	AREA TS MOV FROM 32010KT. TOPS ABV FL450.



9.3 AIRMET

The NWS AWC issued the following AIRMET Sierra series advisories for IFR conditions over the region during the period.

<u>Time</u>	<u>AIRMET Advisory</u>
0000Z	0000Z
0100Z	0100Z
0200Z	0200Z
0300Z	0300Z
0400Z	0400Z
0500Z	0500Z
0600Z	0600Z
0700Z	0700Z
0800Z	0800Z
0900Z	0900Z
1000Z	1000Z
1100Z	1100Z
1200Z	1200Z
1300Z	1300Z
1400Z	1400Z
1500Z	1500Z
1600Z	1600Z
1700Z	1700Z
1800Z	1800Z
1900Z	1900Z
2000Z	2000Z
2100Z	2100Z
2200Z	2200Z
2300Z	2300Z
2400Z	2400Z

[0713] WAUS41 KKCI 021113 AAB
WA1S

-BOSS WA 021113 AMD

AIRMET SIERRA UPDT 4 FOR IFR AND MTN OBSCN VALID UNTIL 021500

AIRMET IFR...ME NH VT MA RI CT NY NJ PA MD DE VA AND CSTL WTRS
FROM 30SW YSC TO 40WSW YSJ TO 200SE ACK TO 160SE SIE TO 70SSE
SBY TO 50SSW SBY TO 40WSW SIE TO 20W SAX TO ALB TO 30SW YSC
CIG BLW 010/VIS BLW 3SM BR/FG. CONDS CONTG BYD 15Z THRU 21Z.

AIRMET IFR...NY PA OH LE WV MD VA NC SC GA...UPDT
FROM 20ESE SYR TO ALB TO 30W SAX TO 50ESE SLT TO 40S PSB TO 50SW CSN TO
LGC TO GQO TO HMV TO HNN TO 60W HNN TO ERI TO 20NNW JHW TO 20ESE SYR
CIG BLW 010/VIS BLW 3SM BR/FG. CONDS CONTG BYD 15Z ENDG 15-18Z.

[1045] *WAUS41 KKCI 021445*
WA1S

-BOSS WA 021445

AIRMET SIERRA UPDT 5 FOR IFR AND MTN OBSCN VALID UNTIL 022100

AIRMET IFR...PA OH WV MD VA
FROM 20ENE EWC TO 20ESE JST TO 60SE EKN TO 20NNW BKW TO 20SSE

*ROD TO 20ENE EWC
CIG BLW 010/VIS BLW 3SM BR. CONDS ENDG 15-18Z.*

*.
AIRMET IFR...NY PA OH LE
FROM 30ENE SYR TO 30SW ALB TO 30WSW HNK TO 20WNW SLT TO 20ENE
EWC TO 20SSE ROD TO 40SSE CVG TO CVG TO FWA TO 60SW DXO TO 60WSW
CLE TO 20ENE BUF TO 30ENE SYR
CIG BLW 010/VIS BLW 3SM BR. CONDS ENDG 15-18Z.*

*.
AIRMET IFR...ME NH MA RI NY NJ MD DE AND CSTL WTRS
FROM 140SSE BGR TO 190SE ACK TO 150SE SIE TO 70ESE SBY TO 30S
CYN TO 20SE JFK TO 30ESE PVD TO 30E BOS TO 140SSE BGR
CIG BLW 010/VIS BLW 3SM BR/FG. CONDS CONTG BYD 21Z THRU 03Z.*

10.0 Graphic Aviation Forecast

The NWS AWC Graphic Aviation Forecasts (GFA) replaced the Area Forecast in 2017 for pilots to determine the enroute conditions. The GFA visibility, surface winds and precipitation issued at 1200 EDT and valid for 1400 EDT is included as figure 35. The GFA utilizes the LAMP (Local Aviation Model Output Statistics (MOS) Program) flight category for ceiling and visibility with an overlay of the Graphic AIRMET Sierra for IFR conditions. The GFA depicted IFR conditions to the south of the area off Long Island with visibilities less than 3 miles over the route of flight and accident site. The winds showed a cyclonic circulation feature over the region with winds from the east-northeast at 10 knots near the departure area and from the west at 5 knots over Long Island. The chart also depicted thunderstorms and rain showers over the region at less than 30% probability of occurrence.

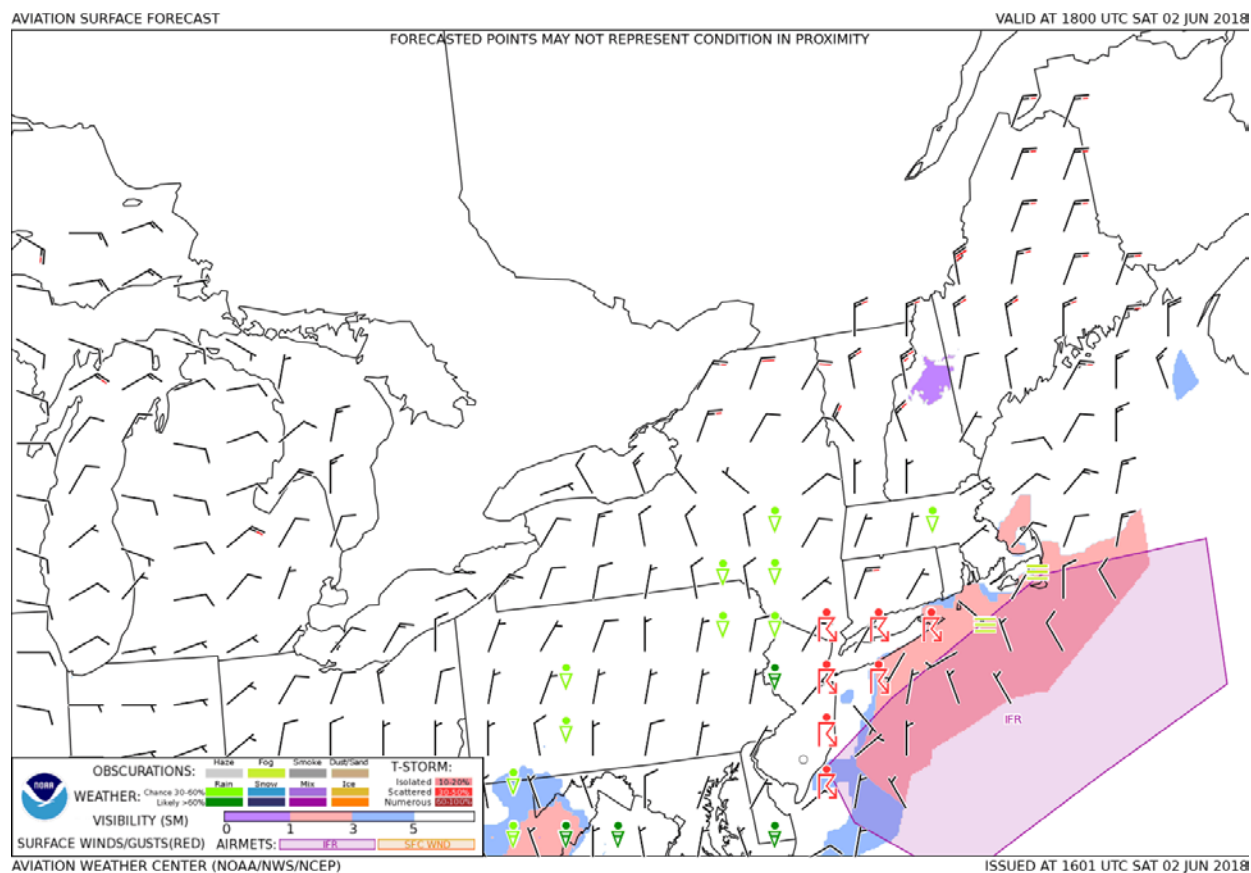


Figure 35 - GFA wind, visibility, weather, and AIRMET for IFR conditions valid for 1400 EDT

The NWS AWC GFA cloud coverage and expected mountain obscuration and icing conditions valid for 1400 EDT is included in figure 36. The cloud cover product are generated at the AWC from the Rapid Refresh Model (RAP) numerical model for cloud coverage (dark blue) and cloud bases and tops, and will overlay Graphic AIRMETs for mountain obscuration (pink) and icing (light blue) expected during the period. Note all cloud heights are MSL in this product. The GFA cloud forecast valid at 1400 EDT depicted overcast clouds with bases at 300 ft with tops at 500 ft over the extreme eastern Long Island near the Montauk area and extending off shore of Long Island and Rhode Island, with clear skies over the inland regions. AIRMET Sierra for mountain obscuration conditions extended over central New York, into Pennsylvania, West Virginia, and western Maryland, which did not impact the route of flight.

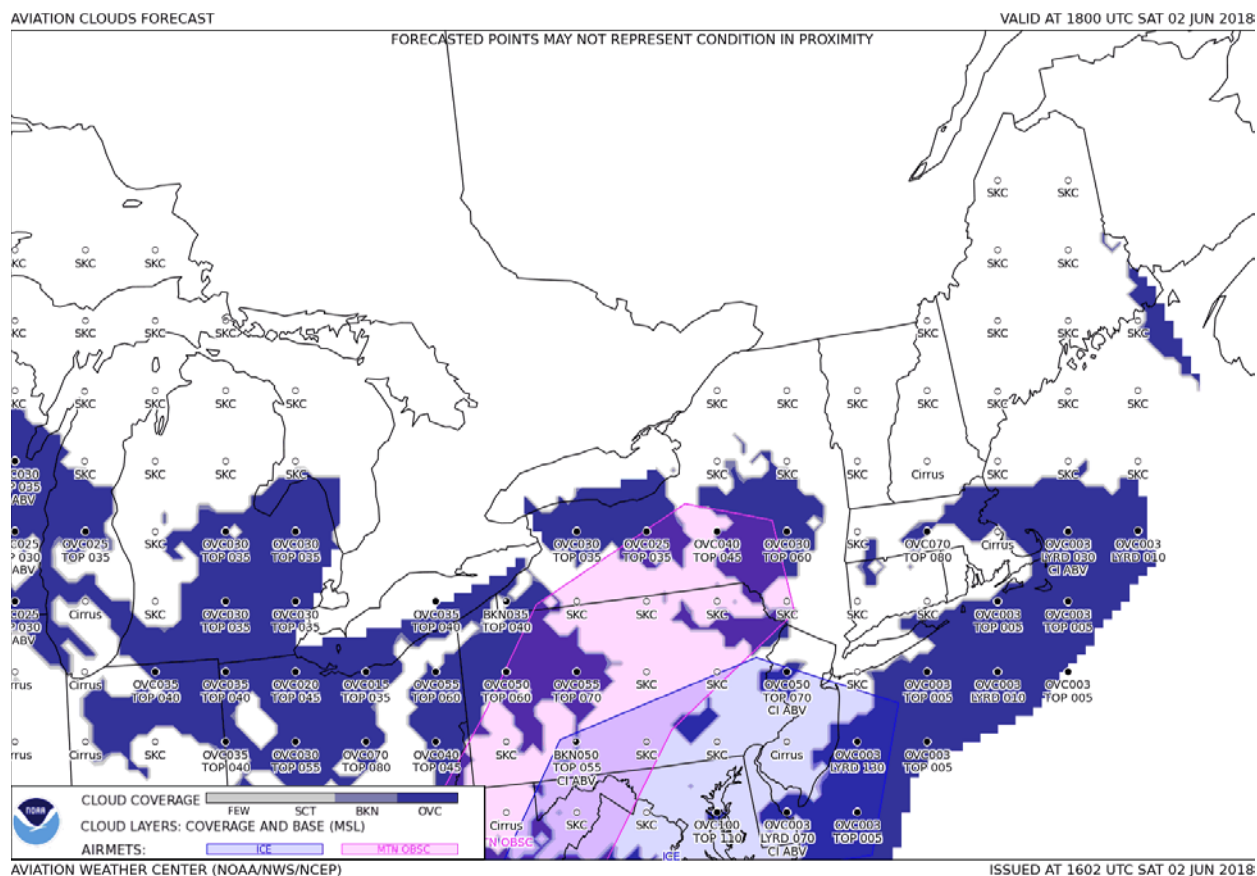


Figure 36 - GFA clouds and AIRMET mountain obscuration and Icing valid at 1400 EDT

11.0 AWC Convective Forecasts

Another Convective weather product available to users at the NWS AWC website is the Traffic Flow Management (TFM) Convective Forecast (TCF) Plot which is a high confidence graphical representation of forecast convection meeting specific criteria¹⁷ for coverage, intensity, and echo tops. The product is a collaborative product issued every 2-hours and valid for a 4-, 6-, and 8-hours after issuance time by meteorologists at the AWC, CWSU, the Air Traffic Control Command Center (ARTCC), various airline, and other authorized participants. The intended purpose of the TCF is to provide air traffic management decision-makers a collaborative forecast and help support convective weather mitigation strategies within the National Airspace System (NAS).

The morning forecasts on June 2, 2018 issued at 0900 EDT did not expected any significant convection developing over eastern Long Island during the period, and expected the area of most concern over Virginia and Maryland at 1500 EDT, and expanding northeastward into New Jersey by 1700 EDT, with sparse coverage of 25-39% and tops to 39,000 ft.

¹⁷ Issuance criteria are for areas or lines of convection contains composite reflectivity echoes of at least 40 dBZ, lines echo tops above 25,000 ft, coverage of at least 25% of the area or for lines a linear coverage of 75% or more over 100 miles, and a forecast confidence of 50%.

The next forecast issued at 1100 EDT is included below in figure 37, which added an additional area of convection developing over Connecticut at 1500 EDT with tops to 34,000 ft, and by 1700 EDT spreading into Rhode Island and Massachusetts. The main area of coverage of the echoes was over Virginia and Maryland. No organized convection was forecasted over Long Island during the period.

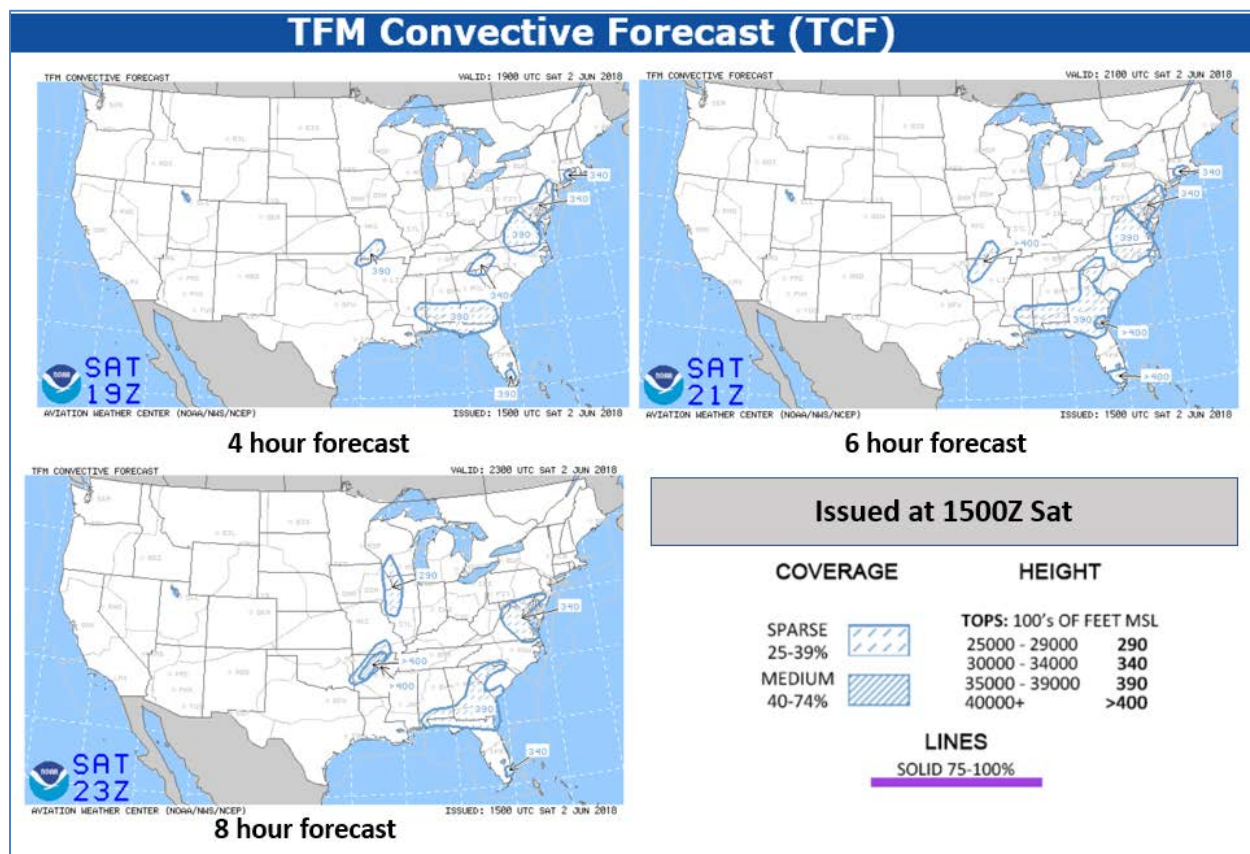


Figure 37 - TFM Convective Forecast (TCF) issued at 1100 EDT for 4-, 6-, and 8-hours

The NWS AWC Extended Convective Forecast Product (ECFP) was also documented, which is a graphical representation of the forecast probability of thunderstorms over the next 72 hours. The automated forecast product is created from the Short-Range Ensemble Forecast (SREF) Calibrated Thunderstorm guidance. Probability of thunderstorm contours are depicted at 40, 60, and 80% probabilities. The morning forecast issued at 0811 EDT and valid for the period after 1400 through 2000 EDT on June 2, 2018 is included as figure 38. An area extended over Connecticut into Long Island with 40 to 59% probability.

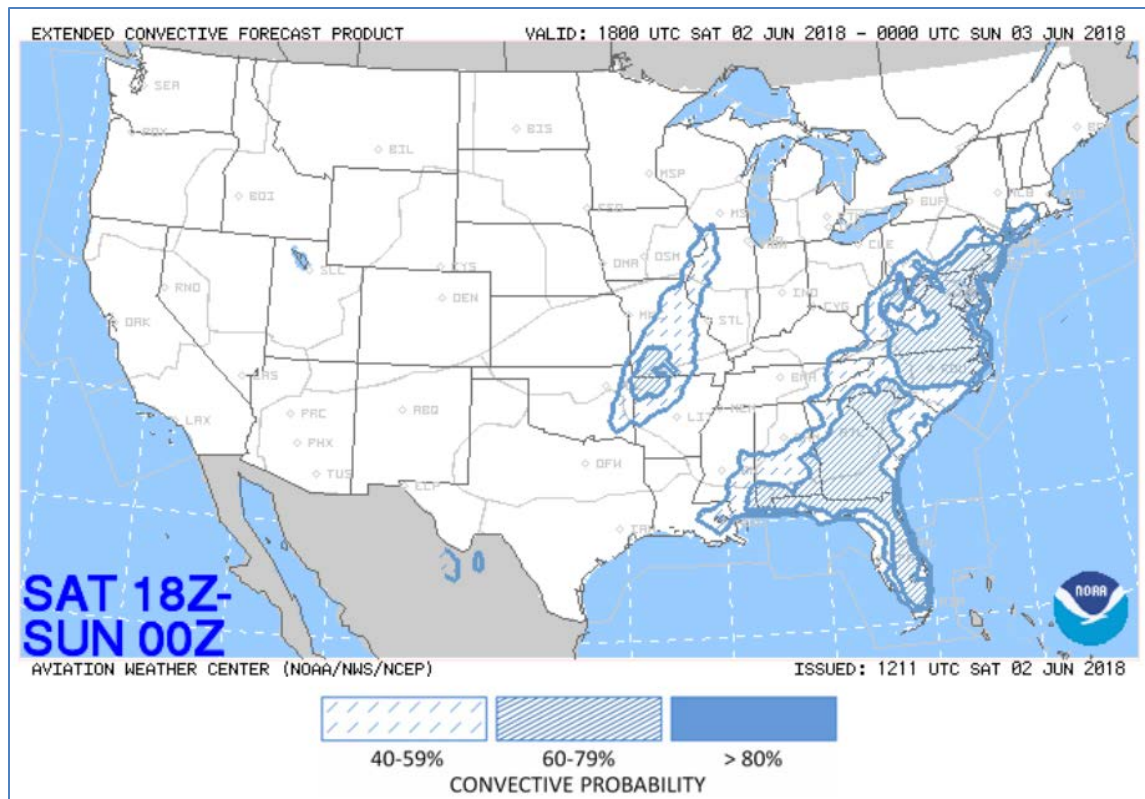


Figure 38 - ECFP Thunderstorm Probability issued at 0811 EDT for the period from 1400 to 2000 EDT

NWS SPC Thunderstorm Watches are also displayed on the AWC site. There were 3 Severe Weather Watches (AWW) issued on June 2, 2018, and none were over the New York area.

12.0 Local Weather Advisories

While the thunderstorms that developed over the region did not meet the NWS SPC criteria for issuance of any weather alerts, the local NWS KOKX WFO issued the following special weather statements to the general public regarding the thunderstorms developing over the area. These weather advisories are not typically disseminated to aviation users, with the exception of airport managers and other ground personnel. Similar marine weather advisories were also issued. The special weather advisories issued at 1321, 1404, 1419, and 1447 EDT were as follows:

TIME ADVISORY
 [1321] WWUS81 KOKX 021721
 SPSOKX
 Special Weather Statement
 National Weather Service New York NY
 121 PM EDT SAT JUN 2 2018

NYZ079-081-021800-
 Southeast Suffolk-Northeast Suffolk-
 121 PM EDT SAT JUN 2 2018

...A LINE OF STRONG THUNDERSTORMS WILL AFFECT EASTERN SUFFOLK COUNTY...

At 121 PM EDT, radar indicated strong thunderstorms were located along a line extending from near Waterford to 6 miles south of Clinton. Movement was south at 10 mph. Winds in excess of 30 mph are possible with these storms.

These storms will be near...Southold and Mattituck around 200 PM EDT.

Torrential rainfall is also occurring with these storms, and may cause localized flooding. Do not drive your vehicle through flooded roadways.

[1404] WWUS81 KOKX 021804
SPSOKX
Special Weather Statement
National Weather Service New York NY
204 PM EDT SAT JUN 2 2018

NYZ081-021845-
Southeast Suffolk-
204 PM EDT SAT JUN 2 2018

...A STRONG THUNDERSTORM WILL AFFECT EAST CENTRAL SUFFOLK COUNTY...

At 203 PM EDT, a strong thunderstorm was located over Gardiners Island, moving south at 20 mph. Winds in excess of 30 mph are possible with this storm, along with heavy rain.

*Locations impacted include...Southampton, Sag Harbor, Bridgehampton, Noyack, East Hampton, Hither Hills State Park, Springs, Montauk, Water Mill, North Haven and **East Hampton Airport.***

[1419] WWUS81 KOKX 021819
SPSOKX
Special Weather Statement
National Weather Service New York NY
219 PM EDT SAT JUN 2 2018

CTZ005-006-NYZ070-021900-
Northern Fairfield-Northern New Haven-Northern Westchester-
219 PM EDT SAT JUN 2 2018

...A STRONG THUNDERSTORM WILL AFFECT CENTRAL FAIRFIELD...WEST CENTRAL NEW HAVEN AND NORTHERN WESTCHESTER COUNTIES...

At 219 PM EDT, a strong thunderstorm was located near Brookfield, or near Newtown, moving southwest at 10 mph. Winds in excess of 30 mph are possible with this storm, along with heavy downpours.

Locations impacted include...Danbury, Southbury, Sherman Newtown, Ridgefield, Monroe, Bethel, Wilton, Brookfield, New Fairfield, Weston, Redding, Georgetown, Oxford and Easton.

[1447] WWUS81 KOKX 021847
SPSOKX
Special Weather Statement
National Weather Service New York NY
247 PM EDT SAT JUN 2 2018

NYZ081-021915-
Southeast Suffolk-
247 PM EDT SAT JUN 2 2018

...A STRONG THUNDERSTORM WILL AFFECT EAST CENTRAL SUFFOLK COUNTY...

At 246 PM EDT, a strong thunderstorm was located near East Hampton, or 8 miles south of Gardiners Island, moving south at 15 mph. Winds in excess of 30 mph are possible with this storm along with heavy downpours.

Locations impacted include...East Hampton, Hither Hills State Park, Springs, Montauk and East Hampton Airport.

13.0 Winds and Temperature Aloft Forecast

The NWS Winds and Temperature Aloft Forecast (FD) current at the time of departure for the route of flight were based on data from 0800 EDT and was valid at 1400 EDT and for use between 1000 through 1700 EDT. The forecast was as follows:

WINDS ALOFT FORECASTS
DATA BASED ON 021200Z
VALID 021800Z FOR USE 1400-2100Z. TEMPS NEG ABV 24000

FT	3000	6000	9000	12000	18000	24000	30000	34000	39000
BOS	0214	3413+13	3316+09	3418+04	3624-08	0230-21	283935	285544	265355
ACK	3618	3615+14	3414+09	3316+03	3316-08	3223-19	283834	273844	263755
BDL	0111	0209+14	3510+08	3612+04	0419-07	0421-20	283835	274545	264455
JFK	3610	0206+14	0305+09	3506+03	3609-08	3012-19	272534	262945	252855

The JFK forecast for 3,000 ft expected wind from 360° at 10 knots, at 6,000 ft wind from 020° at 6 knots with a temperature of 14° C, at 9,000 ft from 350° at 6 knots with a temperature of 9° C. The wind at 18,000 ft or mean wind in a standard atmosphere was from 360° at 9 knots.

14.0 Preflight Weather Briefing

A search of any preflight weather briefings from the FAA contract Automated Flight Service Station (AFSS) Leidos indicated that they had no contact with the pilot on the day of the accident, a search of Foreflight also indicated no contacts. It is therefore unknown what formal weather information the pilot used to familiarize himself before departure on the reported or forecast conditions, and hazardous weather information.

The pilot of the Bonanza accompanying the accident airplane indicated that he and the accident pilot had discussed the weather between the airports and reviewed the weather conditions online through a weather briefing terminal. They planned to fly to the Sandy Point (SEY) VORTAC on Block Island, and then turn west and follow the shoreline into KHTO. The Bonanza pilot departed first with the Navajo pilot following, and he indicated they did not communicate enroute.

15.0 Witness Statements and Photographs

Figure 39 is a Google map image of the accident site, with the East Hampton Airport on the left or western side of the image, and the location of the witness when he started photographing the approaching clouds. The witness photographs were taken less than a mile north-northeast of the accident site, and less than 15 minutes prior to the accident.

The attached photographs (figures 40 through 44) were taken by the witness at 1421 EDT on June 2, 2018 who was on the beach approximately one block east of Atlantic Avenue in Amagansett, as he was heading home due to the approaching storm clouds. The witness stated that when he arrived home around 1530 EDT, he went to check the local NWS weather radar at Upton, NY, to see what was happening and across the top of the radar display it indicated “down for maintenance”. A short time later he received an alert on his phone that a plane had gone down in the area, just off of Indian Wells Beach a short distance away.

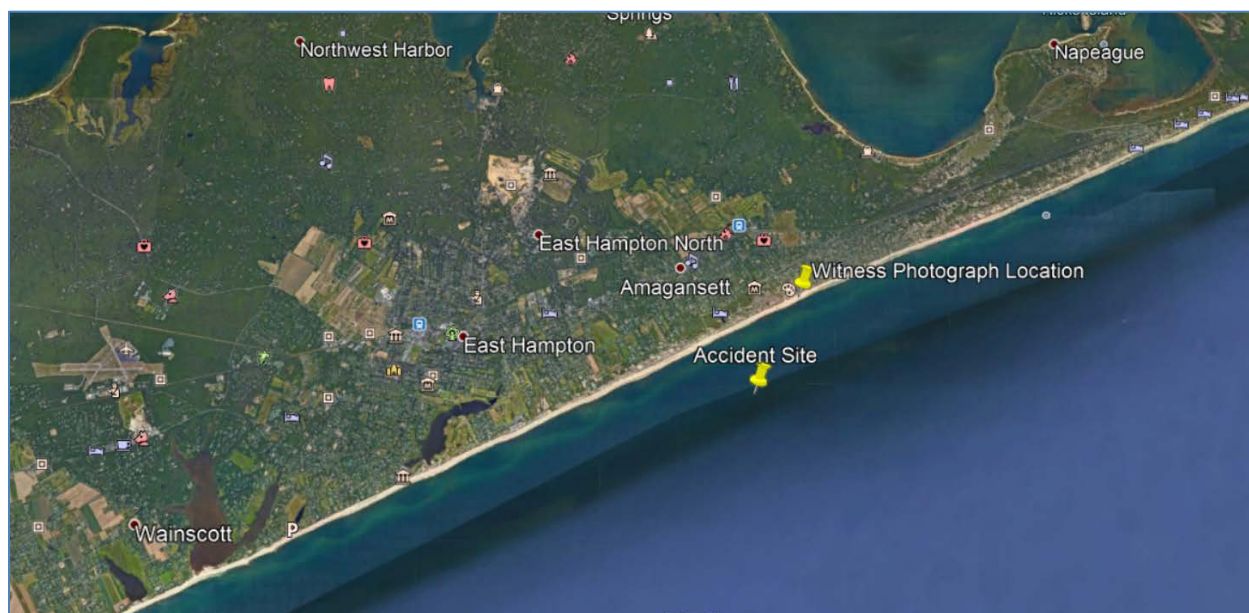


Figure 39 - Location of witness, accident site, and East Hampton Airport



Figure 40 - Witness photograph of storm clouds approaching Amagansett looking north



Figure 41 - Witness photograph of storm clouds looking up the coast to the east-northeast



Figure 42 - Witness photograph again looking north



Figure 43 - Witness photograph looking North at Indian Wells Beach



Figure 44 - Witness photograph looking south to southeast on Indian Wells Beach

16.0 NWS Storm Reports

A review of the NWS SPC Storm Reports from convective storms on June 2, 2018 indicated that the NWS received no reports of any tornadoes, large hail, or damaging winds from any thunderstorm during the period.

17.0 Thunderstorm Reference

Advisory Circular AC 00-24C “Thunderstorms” is one of the general weather knowledge areas listed for flight certificates and indicates that knowledge of thunderstorms and the associated hazards with thunderstorms is critical to the safety of flight. The AC describes development, storm types, storm terminology such as shelf clouds, and gust fronts, and associated hazards. Regarding turbulence in thunderstorms, the AC states the following:

Turbulence

- (1) Potentially hazardous turbulence is present in all thunderstorms, and a severe thunderstorm can destroy an aircraft. Strongest turbulence within the cloud occurs between updrafts and downdrafts. Outside the cloud, shear turbulence is encountered several thousand feet above and up to 20 miles laterally from a severe storm. Additionally, clear air turbulence may be encountered 20 or more miles from the anvil cloud edge.*
- (2) It is almost impossible to hold a constant altitude in a thunderstorm and maneuvering in an attempt to do so greatly increases stress on the aircraft. Stresses are least if the aircraft is held in a constant attitude.*

- (3) A low-level turbulent area is associated with the gust front. Often, a “roll cloud” or “shelf cloud” on the leading edge of the storm marks the top of the extreme turbulence zone. Gust fronts often move far ahead (up to 15 miles) of associated precipitation. The gust front causes a rapid and sometimes drastic change in surface wind ahead of an approaching storm.
- (4) The downward moving column of air in a typical thunderstorm is large. The resultant outflow may produce wind shear, and in some cases the most severe type of wind shear, the microburst. A microburst is a small-scale, intense downdraft that when reaching the surface, spreads outward in all directions from the downdraft center. Virga, streaks of precipitation falling from a thunderstorm cloud but not reaching the ground, may precede a microburst.

The AC also discusses the WSR-88D ground-based weather radar and the precipitation intensity levels, data link of ground radar information to the cockpit, airborne weather radar, and avoidance guidelines. The AC warns that hazardous turbulence may extend to as much as 20 miles from the edge of the radar echo of a thunderstorm. With regards to radar reflectivity intensity the following advice is provided:

Intense or Extreme Echo Avoidance. Avoid heavy or extreme level echoes by a least 20 miles (i.e. echoes should be separated by at least 40 miles before flying between them). Pilots may reduce the distance for avoiding weaker echoes.

AC 00-24C also includes general “Dos and Don’ts of Thunderstorm Avoidance”, which is also emphasized in the Aeronautical Information Manual (AIM), Chapter 7 Safety of Flight in section 7-1-29 Thunderstorm Flying. Regarding flight operations in and near thunderstorms the AIM provided the following advice and recommendations.

Thunderstorm Avoidance. Never regard any thunderstorm lightly, even when radar observers report the echoes are of light intensity. Avoiding thunderstorms is the best policy. Following are some dos and don’ts of thunderstorm avoidance:

- (1) Don’t land or takeoff in the face of an approaching thunderstorm. A sudden gust front of low-level turbulence could cause loss of control.
- (2) Don’t attempt to fly under a thunderstorm even if you can see through to the other side. Turbulence and wind shear under the storm could be hazardous.
- (3) Don’t attempt to fly under the anvil of a thunderstorm. There is a potential for severe and extreme clear air turbulence.
- (4) Don’t fly without airborne radar into a cloud mass containing scattered embedded thunderstorms. Scattered thunderstorms not embedded usually can be visually circumnavigated
- (5) Don’t trust the visual appearance to be a reliable indicator of the turbulence inside a thunderstorm.
- (6) Don’t assume that ATC will offer radar navigation guidance or deviations around thunderstorms.
- (7) Don’t use data-linked weather next generation weather radar (NEXRAD) mosaic imagery as the sole means for negotiating a path through a thunderstorm area (tactical maneuvering).
- (8) Do remember that the data-linked NEXRAD mosaic imagery shows where the weather was, not where the weather is. The weather conditions may be 15 to 20 minutes older than the age indicated on the display.
- (9) Do listen to chatter on the ATC frequency for Pilot Weather Reports (PIREP) and other aircraft requesting to deviate or divert.
- (10) Do ask ATC for radar navigation guidance or to approve deviations around thunderstorms, if needed.
- (11) Do use data-linked weather NEXRAD mosaic imagery (e.g., Flight Information Service-Broadcast (FIS-B)) for route selection to avoid thunderstorms entirely (strategic maneuvering).

- (12) Do advise ATC, when switched to another controller, that you are deviating for thunderstorms before accepting to rejoin the original route.*
- (13) Do ensure that after an authorized weather deviation, before accepting to rejoin the original route, that the route of flight is clear of thunderstorms.*
- (14) Do avoid by at least 20 miles any thunderstorm identified as severe or giving an intense radar echo. This is especially true under the anvil of a large cumulonimbus.*
- (15) Do circumnavigate the entire area if the area has 6/10 thunderstorm coverage.*
- (16) Do remember that vivid and frequent lightning indicates the probability of a severe thunderstorm.*
- (17) Do regard as extremely hazardous any thunderstorm with tops 35,000 feet or higher whether the top is visually sighted or determined by radar.*
- (18) Do give a PIREP for the flight conditions.*
- (19) Do divert and wait out the thunderstorms on the ground if unable to navigate around an area of thunderstorms.*

17.1 Thunderstorm Gust Front

Figure 45 is a schematic of a cross section through a squall line of thunderstorms and shows the gust front or outflow boundary under and propagating outward from the leading edge of the thunderstorm. The leading edge of clouds, which often marked the leading edge of the gust front is known as a shelf cloud¹⁸. The turbulence region of a gust front is identified from the leading edge or “nose”, which would be marked by a sudden wind shift and increase in wind speed along with potentially moderate to severe turbulence up to 1,000 and occasionally to 3,000 feet agl. Multiple surges of cold dense air are typical results in individual strong gusts. Behind the “head” of the gust front, another area of turbulence is typically found near the “wake.” This can cause wave formations with the density discontinuities between the warm and cold air masses resulting again in moderate to severe turbulence. Gust fronts can extend up to 15 miles from the main precipitation core of the thunderstorm.

¹⁸ Shelf cloud – is a low-hanging, well defined, wedge-shaped formation that occurs along the leading edge of a gust front in a thunderstorm. Shelf clouds most often form just ahead of intense lines of thunderstorms.

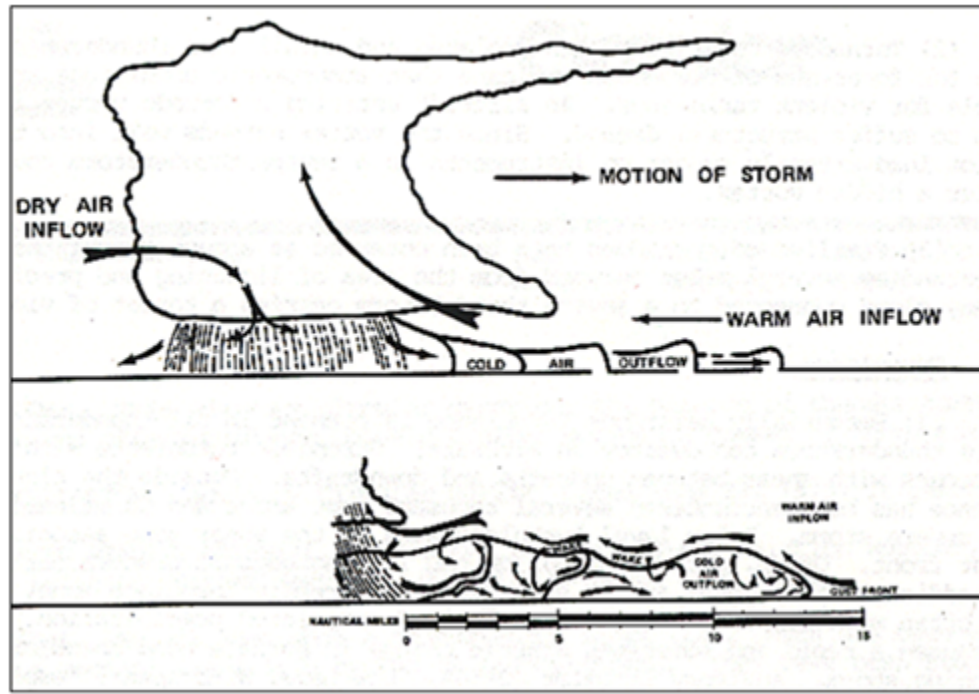


Figure 45 - Cross section of a squall line and the gust front

To further illustrate the turbulent flow in gust fronts, figure 46 is a series of images from a numerical model of a gust front, which depicts the turbulence vortices that can typically develop along the boundary between the cold outflow and warm air.

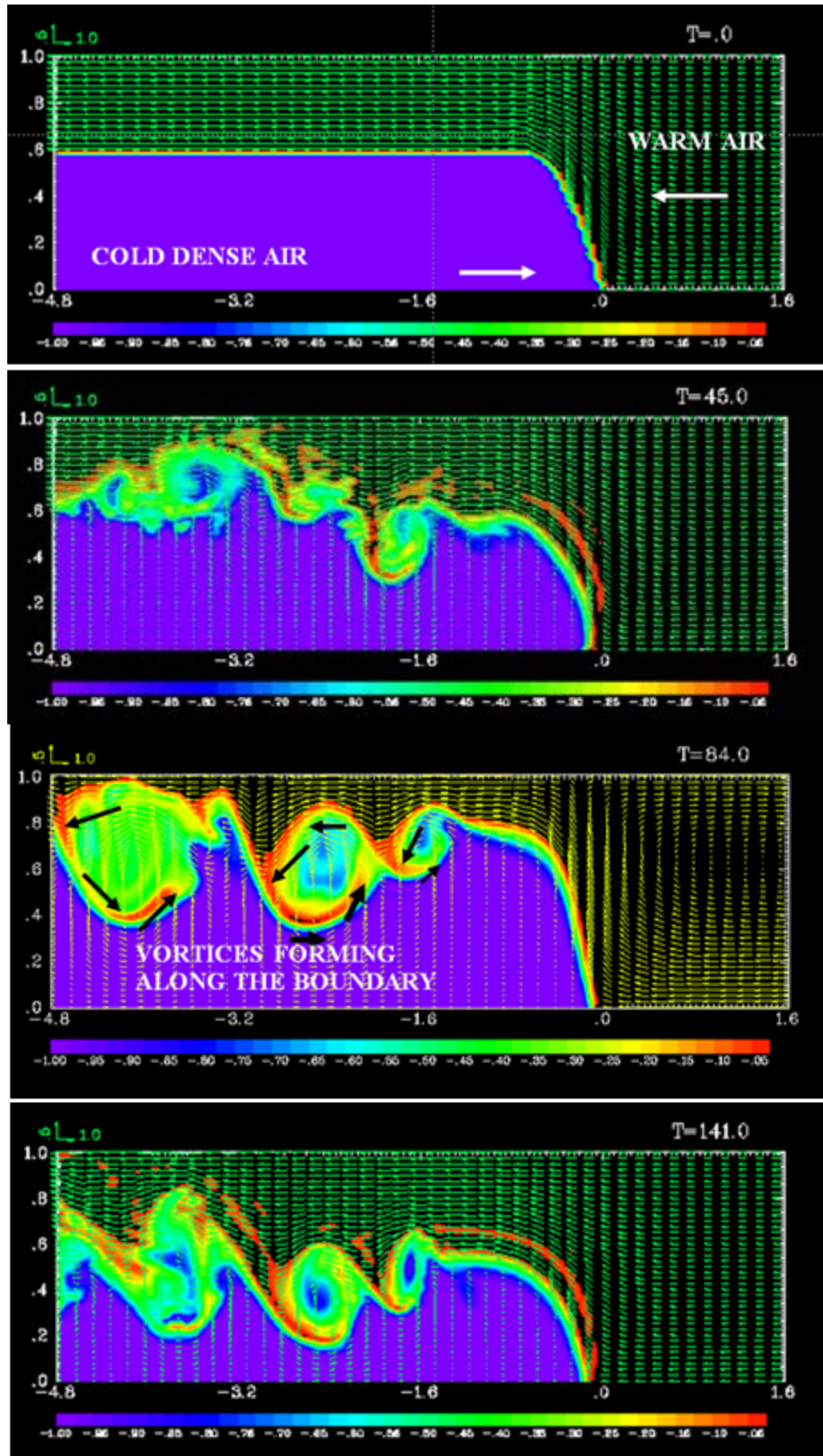


Figure 46 - Numerical model of turbulence in a gust front

18.0 Astronomical Conditions

The United States Naval Observatory's website provided the following astronomical conditions for Amagansett, Suffolk County, New York for June 2, 2018.

SUN	
Beginning civil twilight	0446 EDT
Sunrise	0519 EDT
Sun transit	1247 EDT
Sunset	2015 EDT
End civil twilight	2048 EDT

Submitted by:

Don Eick
Senior Meteorologist

