



NATIONAL TRANSPORTATION SAFETY BOARD

Office of Aviation Safety
Washington, D.C. 20594

May 24, 2019

Factual Report

METEOROLOGY

CEN19FA078

Table Of Contents

A. ACCIDENT	3
B. METEOROLOGIST	3
C. DETAILS OF THE INVESTIGATION	3
D. WEATHER INFORMATION	3
1.0 Synoptic Situation	3
1.1 Surface Analysis Chart	4
1.2 Upper Air Charts	5
2.0 SPC Products	9
3.0 Surface Observations	11
4.0 Upper Air Data	15
5.0 Satellite Data	17
6.0 Regional Radar Imagery Information	18
7.0 Radar Imagery Information	19
7.1 Volume Scan Strategy	19
7.2 Beam Height Calculation	20
7.3 Reflectivity	21
7.4 Base Reflectivity and Lightning Data	21
8.0 Pilot Reports	24
9.0 SIGMET	26
10.0 CWSU Products	26
11.0 AIRMETs	27
12.0 Graphical Forecasts for Aviation	28
13.0 Terminal Aerodrome Forecast	28
14.0 NWS Area Forecast Discussion	29
15.0 Winds and Temperature Aloft Forecast	31
16.0 Pilot Weather Briefing	31
17.0 CWSU Weather Briefing for ATC	31
18.0 Astronomical Data	32
E. LIST OF ATTACHMENTS	32

A. ACCIDENT

Location: Katy, Texas
Date: January 31, 2019
Time: 1610 central standard time
2210 Coordinated Universal Time (UTC)
Aircraft: Mooney M20K, Registration: N56359

B. METEOROLOGIST

Paul Suffern
Senior Meteorologist
Operational Factors Division (AS-30)
National Transportation Safety Board

C. DETAILS OF THE INVESTIGATION

The National Transportation Safety Board's (NTSB) Meteorologist did not travel for this investigation and gathered the weather data for this investigation from official National Oceanic and Atmospheric Administration (NOAA) National Weather Service (NWS) sources including the National Centers for Environmental Information (NCEI). All times are central standard time (CST) on January 31, 2019, and are based upon the 24-hour clock, where local time is -6 hours from UTC, and UTC=Z (unless otherwise noted). Directions are referenced to true north and distances in nautical miles. Heights are above mean sea level (msl) unless otherwise noted. Visibility is in statute miles and fractions of statute miles.

The accident site was located at latitude 29.8485° N, longitude 95.7386° W, with an approximate elevation of 140 feet (ft).

D. WEATHER INFORMATION

1.0 Synoptic Situation

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

¹

https://www.faa.gov/regulations_policies/advisory_circulars/index.cfm/go/document.information/documentID/1030

1.1 Surface Analysis Chart

The southern United States section of the NWS Surface Analysis Chart for 1500 CST is provided as figure 1 with the approximate location of the accident site marked with the red circle. The chart identified surface low pressure centers located over central Oklahoma and western Texas with surface pressures of 1014- and 1010-hectopascals (hPa). A warm front stretched from central Oklahoma eastward into Arkansas. A surface trough² was located just west of the accident site in southern Texas with the surface trough stretching southward into the western Gulf of Mexico.

The station models around the accident site depicted air temperatures in the mid to upper 50's degrees Fahrenheit (°F), dew point temperatures in the mid 50's °F with temperature-dew point spreads of 3° F or less, an east wind of 5 to 10 knots, overcast sky cover, mist, light rain, with heavy rain reported along the coast southwest of Galveston, Texas.

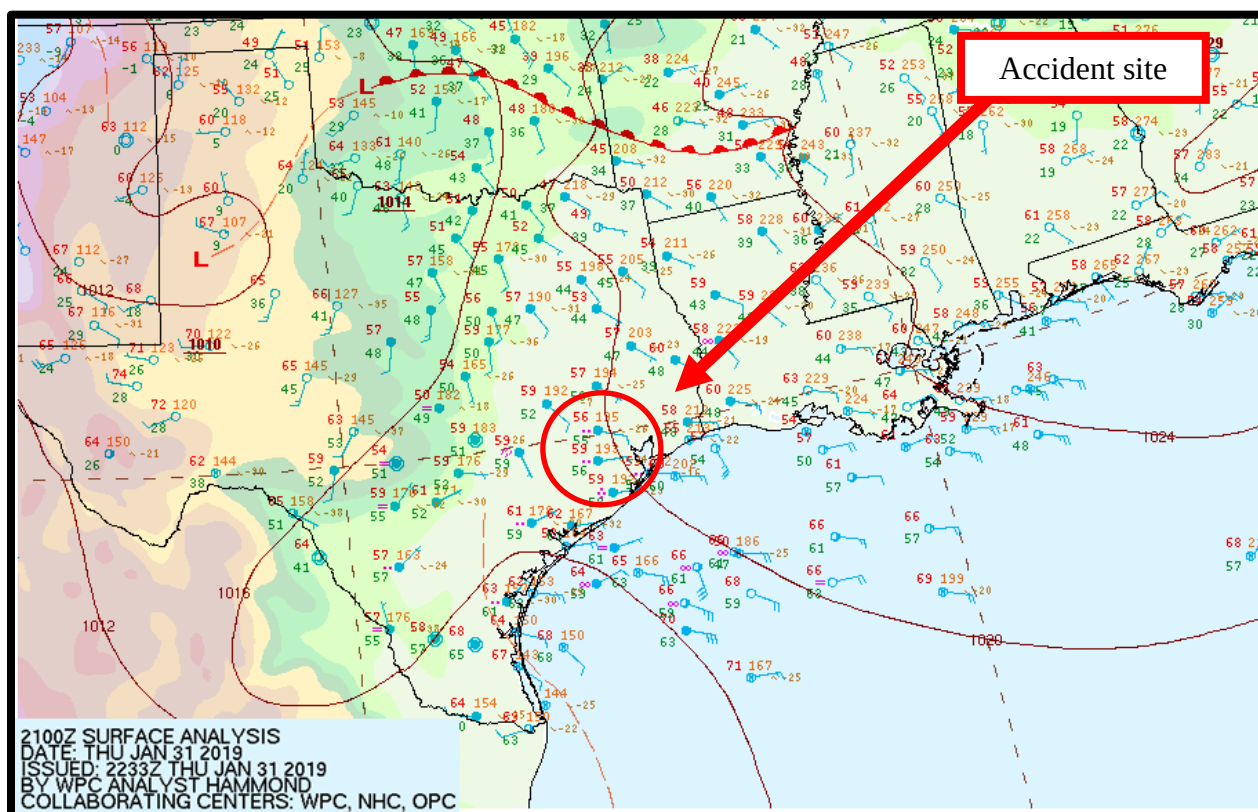


Figure 1 – NWS Surface Analysis Chart for 1500 CST

[235](#)

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

1.2 Upper Air Charts

The NWS Storm Prediction Center (SPC) Constant Pressure Charts for 1800 CST at 925-, 850-, 700-, 500-, and 300-hPa are presented in figures 2 through 6. There was a low-level trough located south of the accident site in the western Gulf of Mexico (figures 2 and 3) at 925- and 850-hPa. Troughs can act as lifting mechanisms to help produce clouds and precipitation if sufficient moisture is present. There was also a mid-level trough located west of the accident site in central and western Texas at 700- and 500-hPa (figures 4 and 5). There was a southeast wind between 10 to 20 knots at 925-hPa above the accident site with the wind becoming westerly by 700-hPa (figure 4) at 30 knots. By 300-hPa, the wind above the accident site was from the southwest and the wind speed increased to between 50 to 70 knots (figure 6).

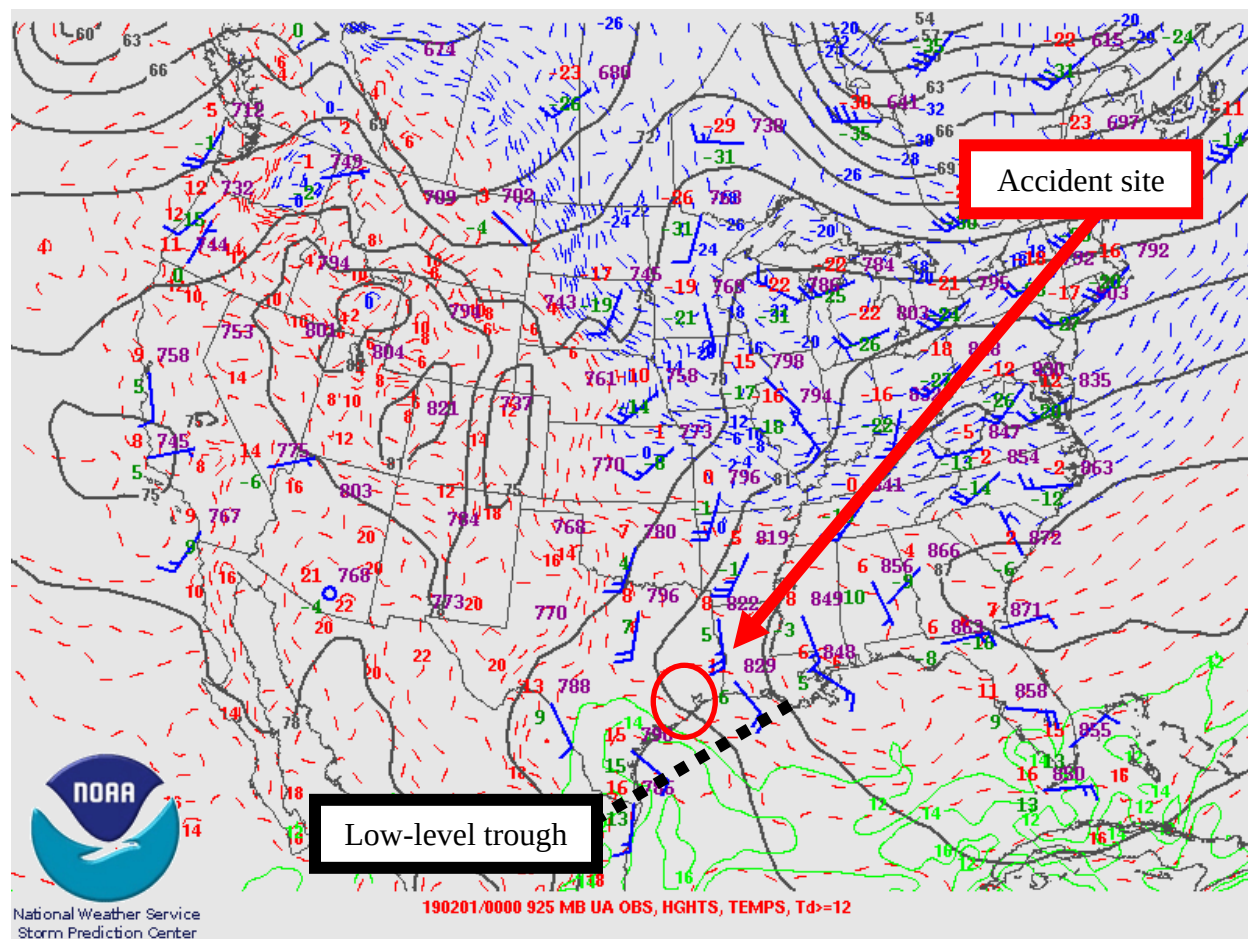


Figure 2 – 925-hPa Constant Pressure Chart for 1800 CST

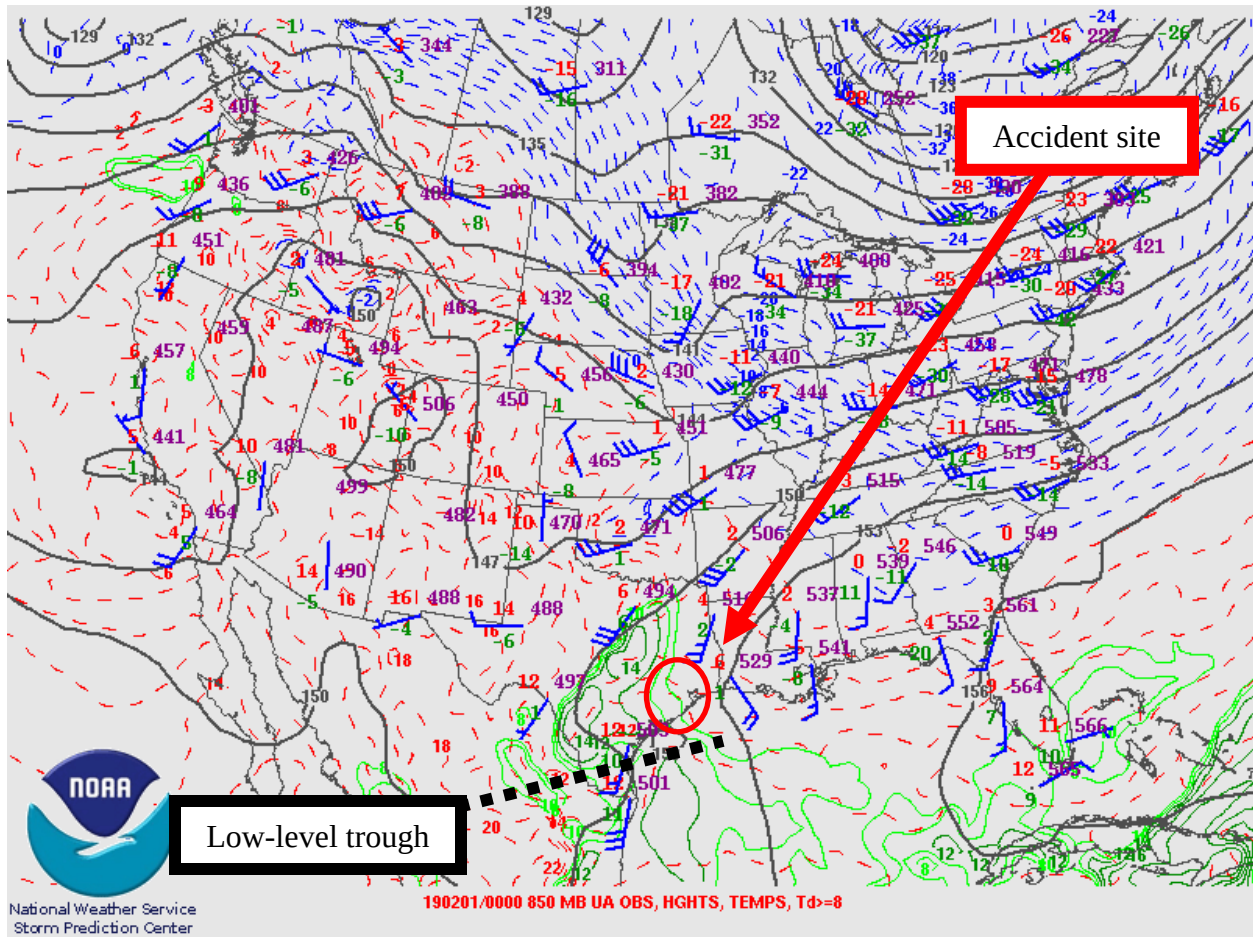


Figure 3 – 850-hPa Constant Pressure Chart for 1800 CST

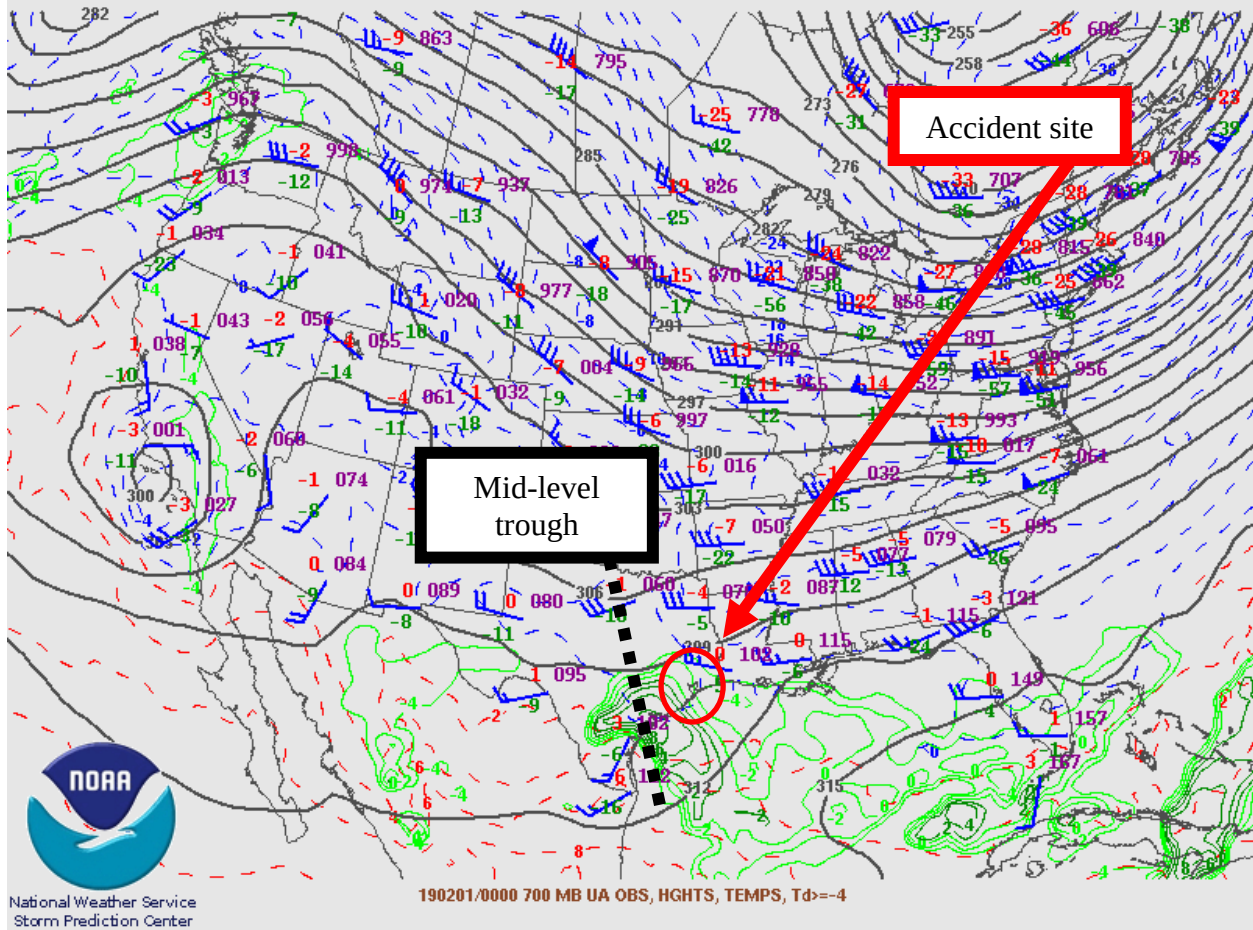


Figure 4 – 700-hPa Constant Pressure Chart for 1800 CST

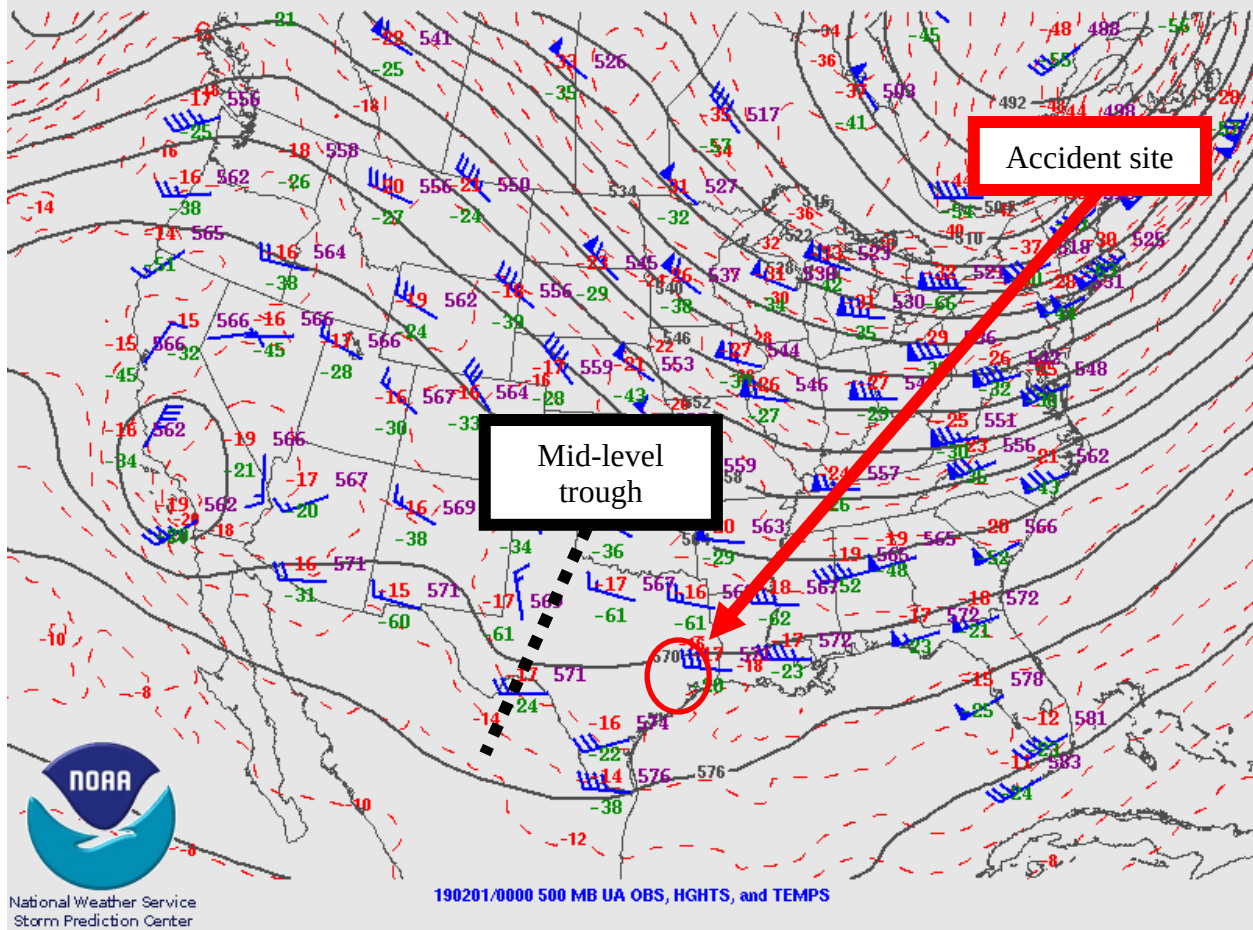


Figure 5 – 500-hPa Constant Pressure Chart for 1800 CST

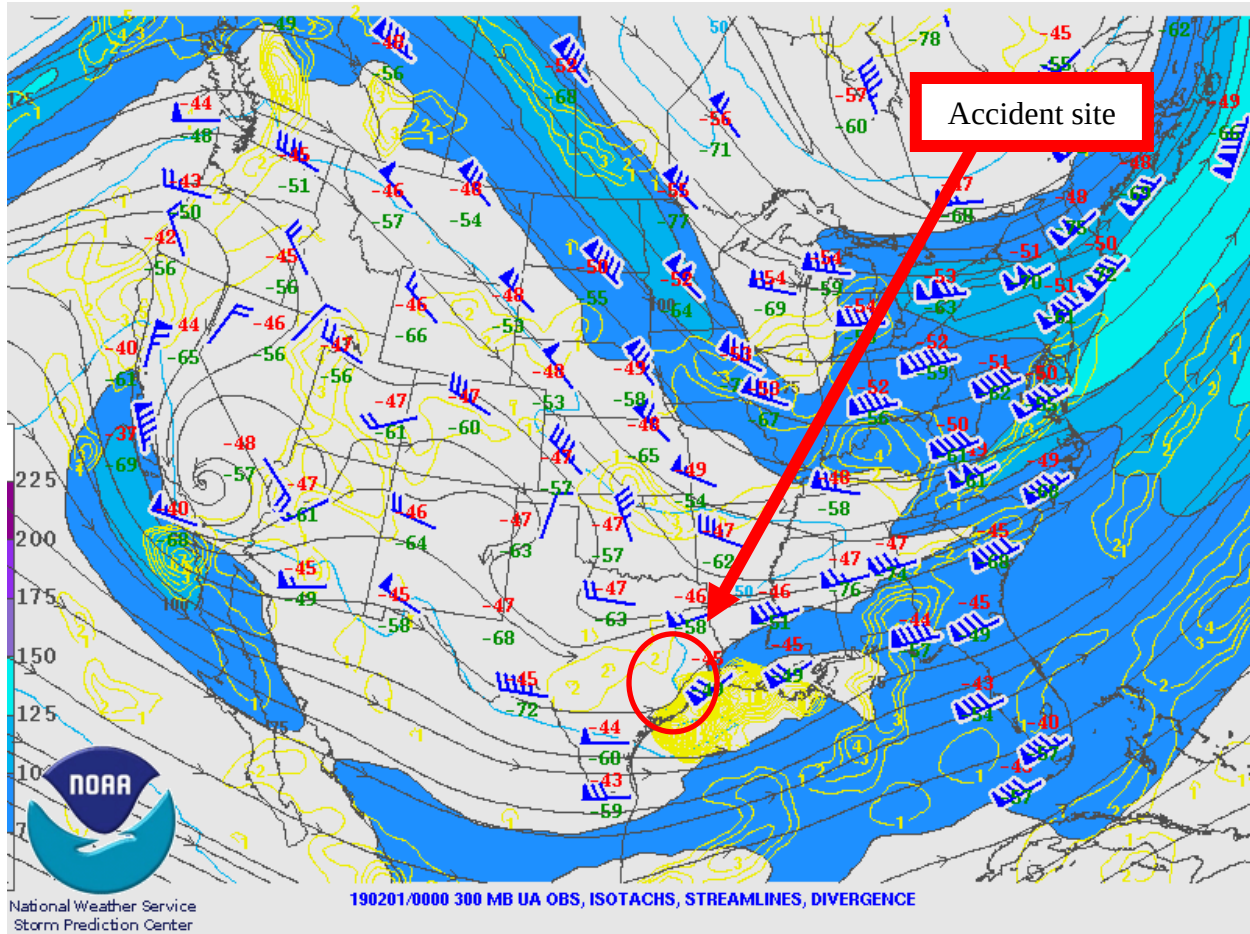


Figure 6 – 300-hPa Constant Pressure Chart for 1800 CST

2.0 SPC Products

SPC issued the following Day 1 Convective Outlook at 1137 CST (figure 7) with areas of general thunderstorms forecast for the accident site. SPC defines the “TSTM” area as an area that encloses where a 10% or higher probability of thunderstorms is forecast during the valid period. The SPC Day 1 Convective Outlook text follows figure 7.

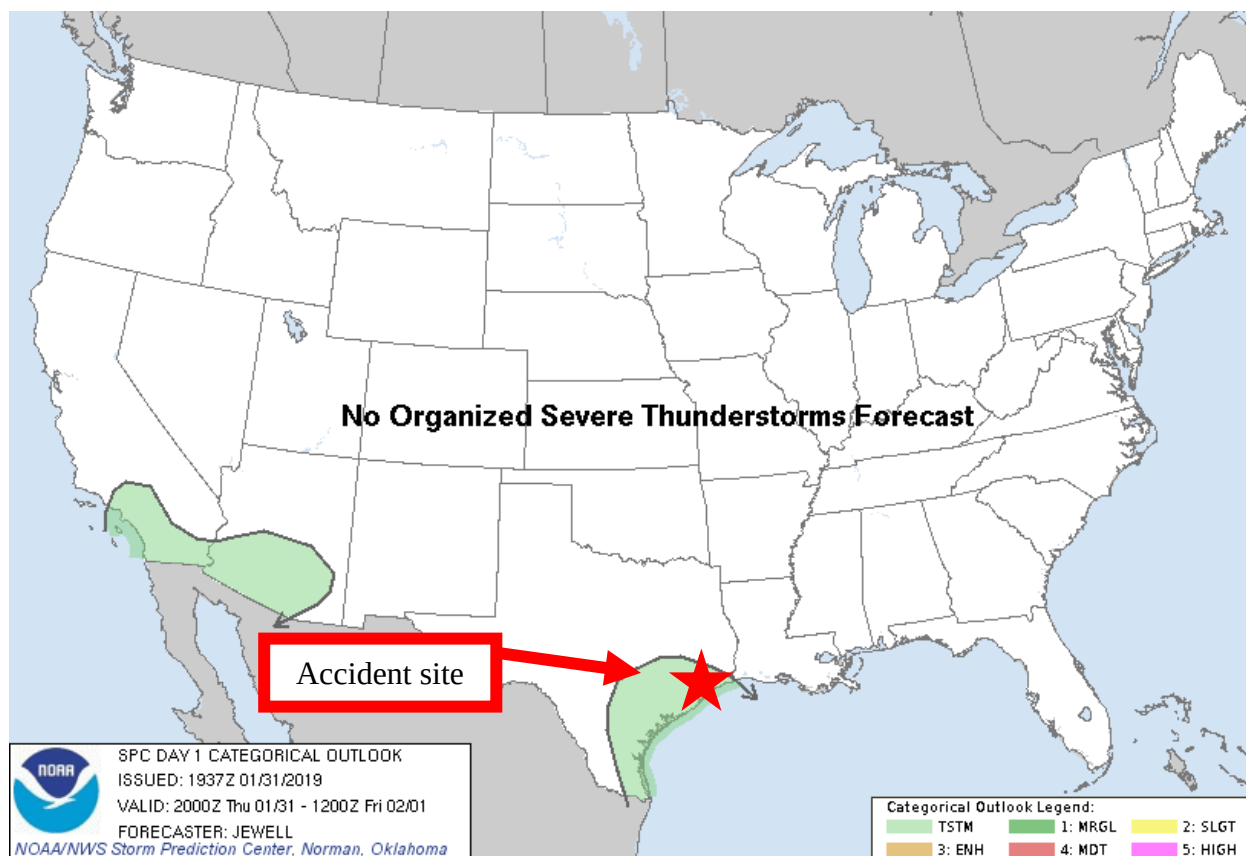


Figure 7 – SPC day 1 Convective Outlook valid at the time of the accident

SPC AC 311937

Day 1 Convective Outlook
NWS Storm Prediction Center Norman OK
0137 PM CST Thu Jan 31 2019

Valid 312000Z - 011200Z

...NO SEVERE THUNDERSTORM AREAS FORECAST...

...SUMMARY...

Isolated thunderstorms are possible across the southwestern U.S. and portions of south Texas.

No changes were required to the existing outlook this update cycle.

..Jewell.. 01/31/2019

.PREV DISCUSSION... /ISSUED 1023 AM CST Thu Jan 31 2019/

Only minor changes have been made to the ongoing forecast. Cool and stable conditions are prevalent across the US today, with the exception of parts of the southwest states and parts of south Texas.

...Southern CA...

An upper low just off the coast of southern CA will continue to track southeastward and weaken through the afternoon, posing a risk of showers and a few thunderstorms over the LA Basin. This threat should end this evening. No severe storms are anticipated with this activity.

...AZ...

Late tonight, lift ahead of the upper low off the CA coast will overspread AZ. This will result in increasing coverage of showers, along with a few thunderstorms.

...South TX...

Scattered thunderstorms have been occurring along and off the coast of south TX. This scenario will continue through the forecast period, with some threat of elevated deep convection spreading inland this afternoon and tonight.

[CLICK TO GET WUUS01 PTSDY1 PRODUCT](#)

NOTE: THE NEXT DAY 1 OUTLOOK IS SCHEDULED BY 0100Z

3.0 Surface Observations

The area surrounding the accident site was documented using official Meteorological Aerodrome Reports (METARs) and Specials (SPECIs). The following observations were taken from standard code and are provided in plain language. Figure 8 is a local sectional chart with the accident site and the closest weather reporting locations marked.

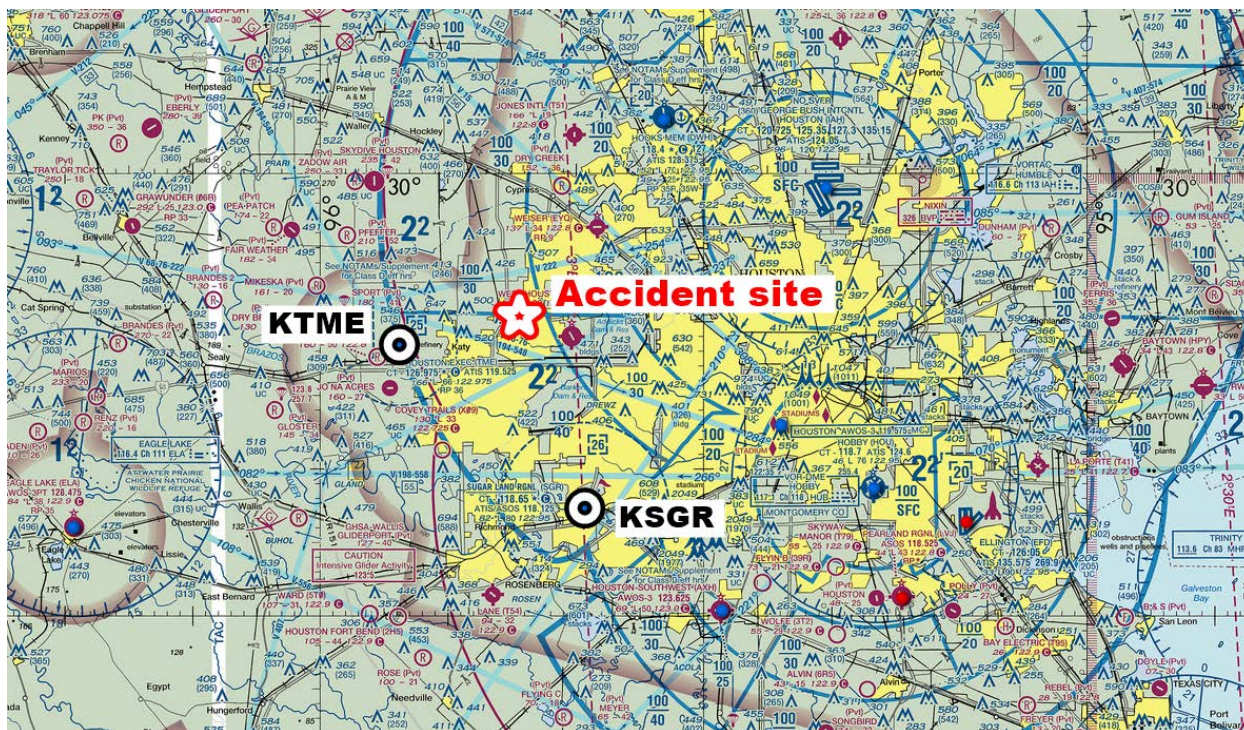


Figure 8 – Sectional map of the accident area with the location of the accident site and surface observation sites

Houston Executive Airport (KTME) had the closest official weather station to the accident site and was located 28 miles west of Houston, Texas. KTME had an Automated Weather Observing System (AWOS³) whose reports were not supplemented. KTME was located 9 miles west-southwest of the accident site, at an elevation of 166 ft, and had a 3° easterly magnetic variation⁴ (figure 8). The following observations were taken and disseminated during the times surrounding the accident:⁵

[1335 CST] METAR KTME 311935Z AUTO 12009KT 7SM OVC014 15/13 A3013 RMK AO2=

[1355 CST] METAR KTME 311955Z AUTO 12009KT 6SM BR OVC014 15/13 A3012 RMK AO2=

[1415 CST] METAR KTME 312015Z AUTO 10011KT 6SM BR BKN012 15/13 A3011 RMK AO2=

[1435 CST] METAR KTME 312035Z AUTO 12009KT 7SM BKN011 OVC048 15/13 A3012 RMK AO2=

[1455 CST] METAR KTME 312055Z AUTO 12010G18KT 7SM BKN010 BKN013 OVC018 15/13 A3011 RMK AO2=

[1515 CST] METAR KTME 312115Z AUTO 11010G15KT 6SM BR BKN010 OVC016 15/13 A3010 RMK AO2=

[1535 CST] METAR KTME 312135Z AUTO 09008KT 4SM -RA OVC010 15/14 A3009 RMK AO2=

[1555 CST] METAR KTME 312155Z AUTO 12008G13KT 4SM -RA OVC010 14/14 A3010 RMK AO2=

ACCIDENT TIME 1610 CST

[1615 CST] METAR KTME 312215Z AUTO 12008KT 2 1/2SM -RA OVC009 14/14 A3010 RMK AO2=

³ AWOS – Automated Weather Observing System is equipped with meteorological instruments to observe and report temperature, dewpoint, wind speed and direction, visibility, cloud coverage and ceiling up to twelve thousand feet, and altimeter setting.

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

⁵ The bold sections in this NWS product and the rest of the products in this report are intended to highlight the sections that directly reference the weather conditions that affected the accident location around the accident time. The local times in this section next to the METARs are provided for quick reference between UTC and local times around the accident time.

[1635 CST] METAR KTME 312235Z AUTO 12010KT 2 1/2SM -RA OVC008 14/14 A3009 RMK AO2=

[1655 CST] METAR KTME 312255Z AUTO 12011KT 4SM -DZ OVC006 14/14 A3009 RMK AO2=

[1715 CST] METAR KTME 312315Z AUTO 10010KT 5SM -RA OVC006 14/14 A3009 RMK AO2=

KTME weather at 1535 CST, automated, wind from 090° at 8 knots, 4 miles visibility, light rain, overcast ceiling at 1,000 ft above ground level (agl), temperature of 15 °Celsius (C), dew point temperature of 14 °C, and an altimeter setting of 30.09 inches of mercury. Remarks: automated station with a precipitation discriminator.

KTME weather at 1555 CST, automated, wind from 120° at 8 knots with gusts to 13 knots, 4 miles visibility, light rain, overcast ceiling at 1,000 ft agl, temperature of 14 °C, dew point temperature of 14 °C, and an altimeter setting of 30.10 inches of mercury. Remarks: automated station with a precipitation discriminator.

KTME weather at 1615 CST, automated, wind from 120° at 8 knots, 2 and a half miles visibility, light rain, overcast ceiling at 900 ft agl, temperature of 14 °C, dew point temperature of 14 °C, and an altimeter setting of 30.10 inches of mercury. Remarks: automated station with a precipitation discriminator.

KTME weather at 1635 CST, automated, wind from 120° at 10 knots, 2 and a half miles visibility, light rain, overcast ceiling at 800 ft agl, temperature of 14 °C, dew point temperature of 14 °C, and an altimeter setting of 30.09 inches of mercury. Remarks: automated station with a precipitation discriminator.

Sugar Land Regional Airport (KSGR) had the next closest official weather station to the accident site and was located 17 miles southwest of Houston, Texas. KSGR had an Automated Surface Observing System (ASOS⁶) whose reports were supplemented by air traffic control (ATC) when ATC was available between 0500 and 2300 CST. KSGR was located 14 miles south-southeast of the accident site at an elevation of 82 ft (figure 8). The following observations were taken and disseminated during the times surrounding the accident:

[1312 CST] SPECI KSGR 311912Z 10007KT 10SM OVC015 16/13 A3012 RMK AO2 T01610128=

[1337 CST] SPECI KSGR 311937Z 08010KT 8SM -RA OVC013 16/13 A3011 RMK AO2 RAB20 P0000 T01560128=

[1353 CST] METAR KSGR 311953Z 08008KT 6SM -RA BKN014 OVC019 16/13 A3011 RMK AO2 RAB20 SLP199 P0000 T01560128=

⁶ ASOS – Automated Surface Observing System is equipped with meteorological instruments to observe and report wind, visibility, ceiling, temperature, dewpoint, altimeter, and barometric pressure.

[1435 CST] SPECI KSGR 312006Z 07007KT 8SM -RA BKN016 OVC060 16/13 A3010
RMK AO2 LTG DSNT S P0000 T01560133=

[1424 CST] SPECI KSGR 312024Z 10006KT 8SM -RA FEW009 BKN013 OVC018 15/13
A3011 RMK AO2 P0001 T01500133=

[1446 CST] SPECI KSGR 312046Z 08010KT 7SM -RA BKN009 OVC017 15/13 A3010
RMK AO2 P0001 T01500133=

**[1453 CST] METAR KSGR 312053Z 09010KT 7SM -RA BKN009 OVC017 15/13 A3010
RMK AO2 CIG 007V011 SLP193 P0002 60002 T01500133 56024=**

**[1553 CST] METAR KSGR 312153Z 10013KT 7SM RA OVC006 15/13 A3006 RMK
AO2 PRESFR SLP181 P0003 T01500133=**

ACCIDENT TIME 1610 CST

**[1653 CST] METAR KSGR 312253Z 09008KT 4SM +RA BR OVC006 15/14 A3009
RMK AO2 SLP190 P0012 T01500139=**

**[1753 CST] METAR KSGR 312353Z 11011KT 10SM -RA OVC006 15/13 A3008 RMK
AO2 SLP186 P0009 60026 T01500133 10167 20144 56006=**

[1853 CST] METAR KSGR 010053Z 10008KT 8SM RA OVC005 15/13 A3007 RMK
AO2 SLP186 P0010 T01500133=

[1953 CST] METAR KSGR 010153Z 10007G16KT 10SM OVC005 15/13 A3007 RMK
AO2 RAE49 SLP185 P0005 T01500133=

KSGR weather at 1453 CST, wind from 090° at 10 knots, 7 miles visibility, light rain, broken ceiling at 900 ft agl, overcast skies at 1,700 ft agl, temperature of 15 °C, dew point temperature of 13 °C, and an altimeter setting of 30.10 inches of mercury. Remarks: automated station with a precipitation discriminator, ceiling varying between 700 ft agl and 1,100 ft agl, sea level pressure 1019.3 hPa, 0.02 inches of precipitation since 1353 CST, 6-hourly precipitation of 0.02 inches, temperature 15.0 °C, dew point temperature 13.3 °C, 3-hourly pressure decrease of 2.4 hPa.

KSGR weather at 1553 CST, wind from 100° at 13 knots, 7 miles visibility, moderate rain, overcast ceiling at 600 ft agl, temperature of 15 °C, dew point temperature of 13 °C, and an altimeter setting of 30.06 inches of mercury. Remarks: automated station with a precipitation discriminator, pressure falling rapidly, sea level pressure 1018.1 hPa, 0.03 inches of precipitation since 1453 CST, temperature 15.0 °C, dew point temperature 13.3 °C.

KSGR weather at 1653 CST, wind from 090° at 8 knots, 4 miles visibility, heavy rain and mist, overcast ceiling at 600 ft agl, temperature of 15 °C, dew point temperature of 14 °C, and an altimeter setting of 30.09 inches of mercury. Remarks: automated station with a precipitation discriminator, sea level pressure 1019.0 hPa, 0.12 inches of precipitation since 1553 CST, temperature 15.0 °C, dew point temperature 13.9 °C.

KSGR weather at 1753 CST, wind from 110° at 11 knots, 10 miles visibility, light rain, overcast ceiling at 600 ft agl, temperature of 15 °C, dew point temperature of 13 °C, and an altimeter setting of 30.08 inches of mercury. Remarks: automated station with a precipitation discriminator, sea level pressure 1018.6 hPa, 0.09 inches of precipitation since 1653 CST, 6-hourly precipitation of 0.26 inches, temperature 15.0 °C, dew point temperature 13.3 °C, 6-hourly maximum temperature 16.7 °C, 6-hourly minimum temperature of 14.4 °C, 3-hourly pressure decrease of 0.6 hPa.

Numerous observations from KTME and KSGR surrounding the accident time indicated IFR⁷ conditions, and included moderate to heavy rain and an east wind of 8 to 13 knots.

4.0 Upper Air Data

A High-Resolution Rapid Refresh (HRRR)⁸ model sounding was created for the accident site for 0000 CST on February 1, 2019, with station elevation of 40 ft.⁹ This was the closest HRRR sounding time available due to the government shutdown and the upper air sounding conditions were consistent between 0000 CST and the accident time. The 0000 CST HRRR sounding was plotted on a standard Skew-T Log P diagram¹⁰ with the derived stability parameters included in figure 9 with data from the surface to 600-hPa (or approximately 14,000 ft msl). This data was analyzed using the RAOB¹¹ software package. The sounding depicted the lifted condensation level (LCL)¹² at 215 ft agl (255 ft msl) and the convective condensation level (CCL)¹³ at 374 ft agl (414 ft msl). The sounding had a greater than 90% relative humidity from the surface through 6,500 ft msl. The freezing level was located at 10,266 ft msl. The precipitable water value was 1.30 inches.

⁷ Instrument Flight Rules (IFR) – Refers to the general weather conditions pilots can expect at the surface. IFR criteria means a ceiling below 1,000 ft agl and/or less than 3 miles visibility.

⁸ The HRRR is a NOAA real-time three-kilometer resolution, hourly-updated, cloud-resolving, convection-allowing atmospheric model, initialized by three-kilometer grids with three-kilometer radar assimilation. Radar data is assimilated in the HRRR every 15 minutes over a one hour period.

⁹ HRRR sounding was created using NOAA Air Resource Laboratory: <https://ready.arl.noaa.gov/READYamet.php>

¹⁰ 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.

¹¹ RAOB – (The complete Rawinsonde Observation program) is an interactive sounding analysis program developed by Environmental Research Services, Matamoras, Pennsylvania.

¹² LCL - The height at which a parcel of moist air becomes saturated when it is lifted dry adiabatically.

¹³ CCL – The level in the atmosphere to which an air parcel, if heated from below, will rise dry adiabatically, without becoming colder than its environment just before the parcel becomes saturated.

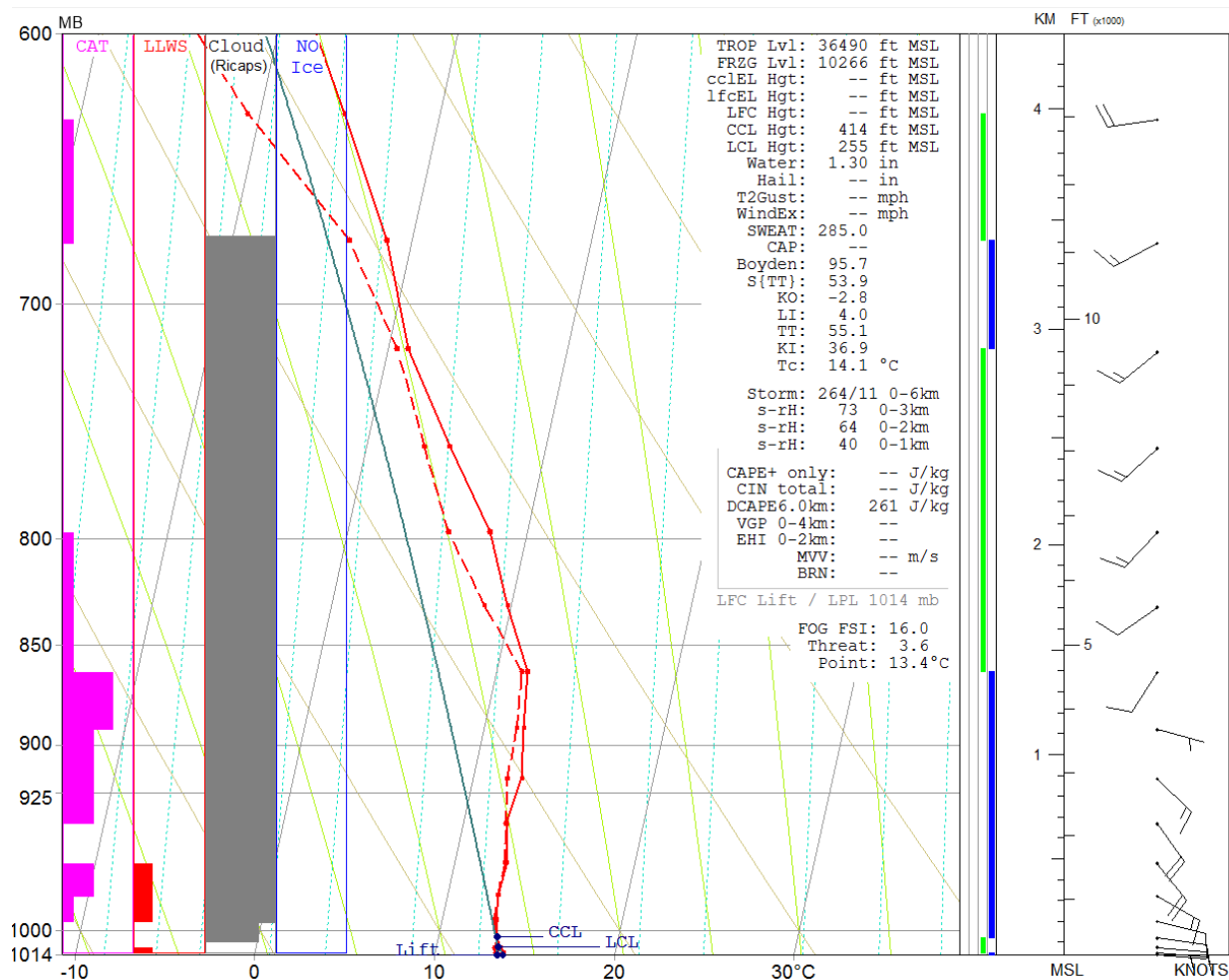


Figure 9 – 0000 CST February 1, 2019, HRRR sounding

The HRRR sounding indicated a stable environment from 200 ft through 4,600 ft msl. RAOB identified the possibility of clouds between 250 ft msl through 11,000 ft.

The HRRR sounding wind profile indicated a surface wind from 095° at 6 knots with the wind remaining easterly through 4,000 ft msl. The wind increased in speed to 21 knots by 1,500 ft msl. The wind veered¹⁴ to the southwest at 5,000 ft with a wind speed of 10 knots. The wind remained from the southwest between 5,000 and 12,000 ft msl and increased in speed to 20 knots again by 13,000 ft msl. RAOB indicated the possibility of light low-level wind shear (LLWS) between the surface and 1,500 ft msl. RAOB indicated a high probability of moderate or greater clear-air turbulence between the surface and 7,000 ft msl.

¹⁴ A change in wind direction with height in a clockwise sense in the Northern Hemisphere

5.0 Satellite Data

The Geostationary Operational Environmental Satellite number 16 (GOES-16) visible and infrared data were obtained from an archive at the Space Science Engineering Center at the University of Wisconsin-Madison in Madison, Wisconsin, and processed using the Man-computer Interactive Data Access System software. GOES-16 visible (band 2) and infrared (band 13) imagery at wavelengths of 0.64 microns (μm) and 10.3 μm , respectively, were retrieved for the period from 1400 CST through 1900 CST and reviewed. The closest images to the time of the accident are documented here.

Figure 10 presents the GOES-16 visible imagery at 1607 CST at 3X magnification with the accident site highlighted with a red square. The visible imagery indicated an extensive layer of cloud cover, which was cumuliform in nature, over the accident site, with the cloud cover moving from southwest to northeast (attachment 1).

Figure 11 presents the GOES-16 infrared imagery from 1607 CST at 4X magnification with the accident site highlighted with a red square. Inspection of the infrared imagery indicated cloud cover over the accident site. The lower brightness temperatures (blue and green colors; higher cloud tops) were located above and mostly to the southwest through southeast of the accident site (attachment 2) with the cloud cover moving from southwest to northeast. Based on the brightness temperatures above the accident site and the vertical temperature profile provided by the HRRR sounding, the approximate cloud-top heights over the accident site were 34,000 ft at 1607 CST (at temperatures of 220° Kelvin). It should be noted these figures have not been corrected for any parallax error.

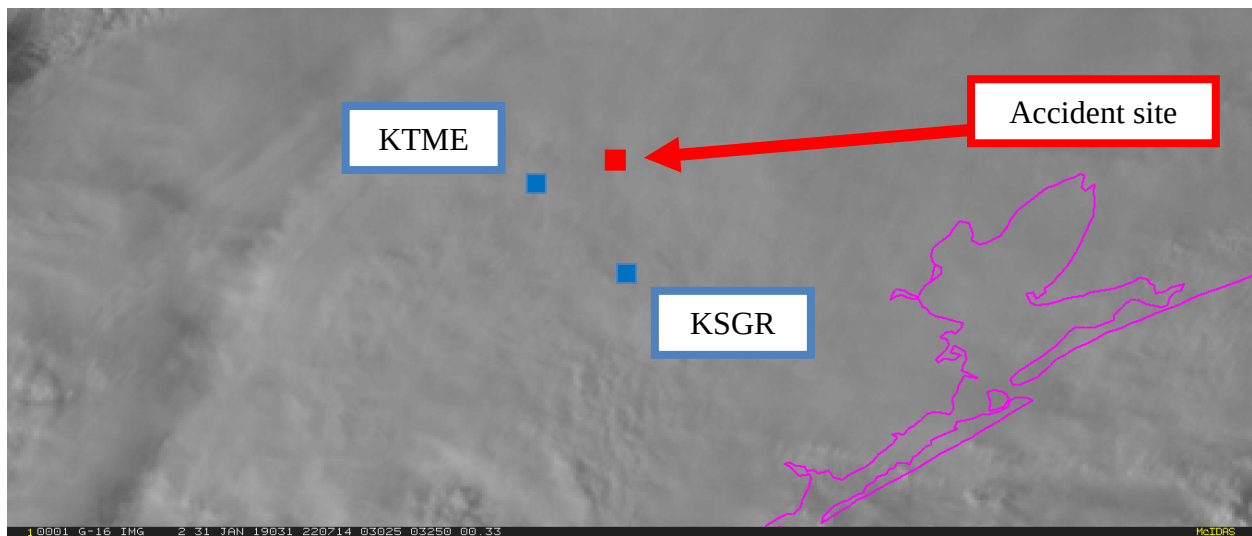


Figure 10 – GOES-16 visible image at 1607 CST

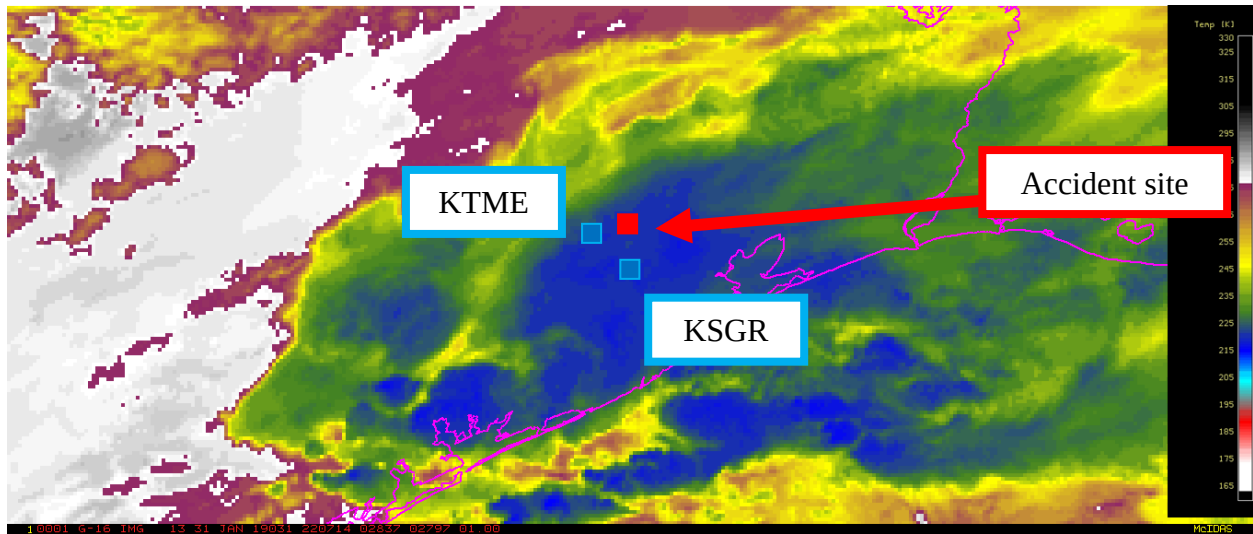


Figure 11 – GOES-16 infrared image at 1607 CST

6.0 Regional Radar Imagery Information

A regional view of the NWS national composite radar mosaic is included as figure 12 for 1610 CST with the approximate location of the accident site marked by a red circle. The image depicted 20 to 40 decibel (dBZ¹⁵) echoes above the accident site.

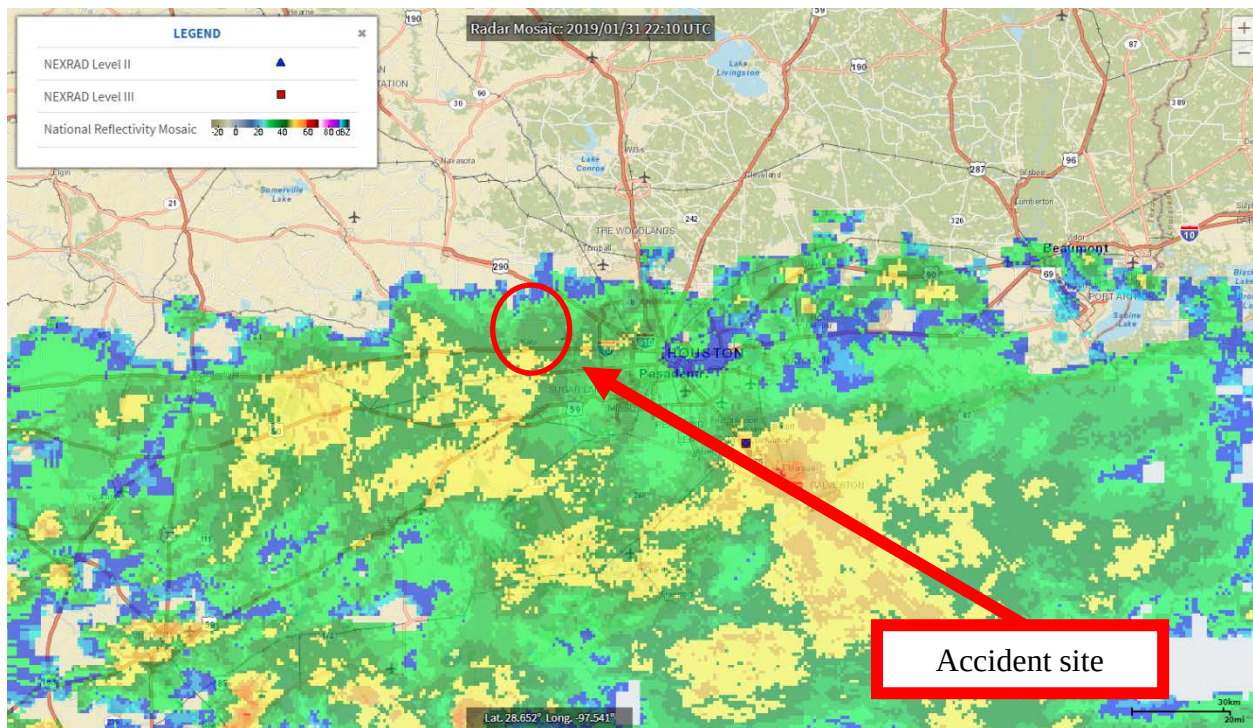


Figure 12 – Regional Composite Reflectivity image for 1610 CST

¹⁵ dBZ – A non-dimensional “unit” of radar reflectivity which represents a logarithmic power ratio (in decibels , or dB) with respect to radar reflectivity factor, Z.

7.0 Radar Imagery Information

The closest NWS Weather Surveillance Radar-1988, Doppler (WSR-88D)¹⁶ to the accident site was Houston, Texas, (KHGX). KHGX was located 41 miles southeast of the accident site. Level II and level III archive radar data was obtained from the NCEI utilizing the NEXRAD Data Inventory Search and displayed using the NOAA's Weather and Climate Toolkit software.

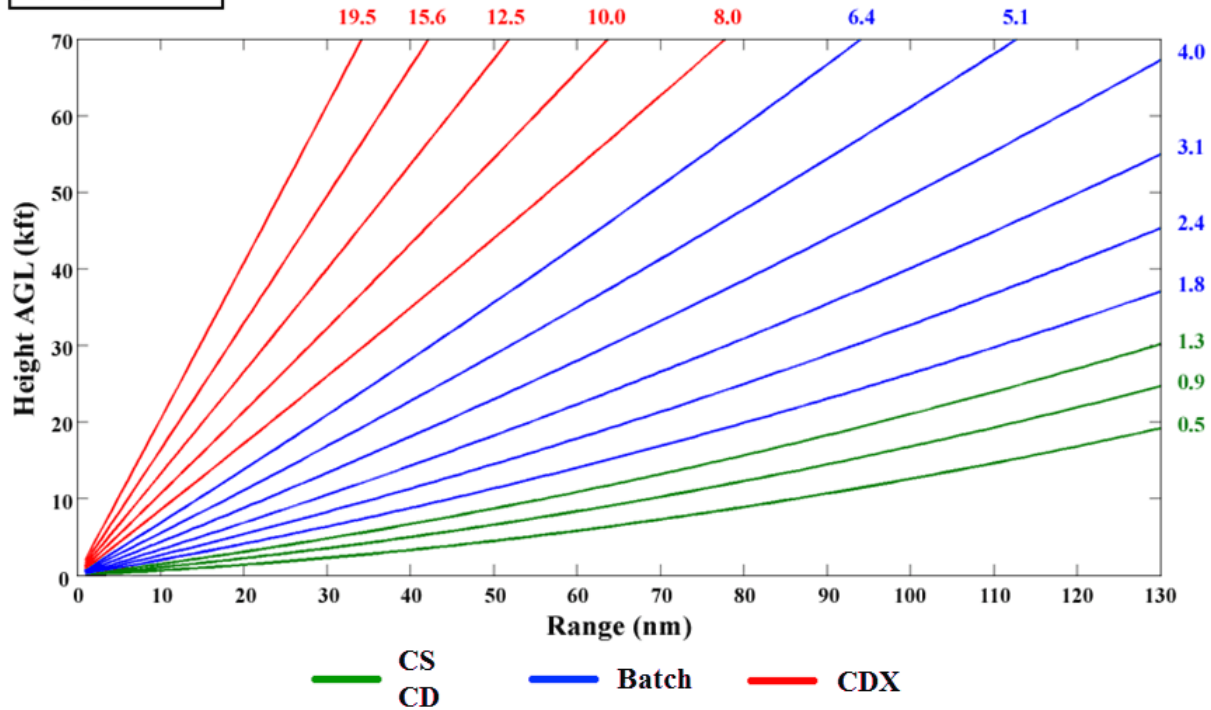
7.1 Volume Scan Strategy

The WSR-88D is a computer-controlled radar system, which automatically creates a complete series of specific scans in a specific sequence known as a volume scan. Individual elevation scans are immediately available. Products that require data from multiple elevation scans are not available until the end of the five to ten-minute volume scan.

The WSR-88D operates in several different scanning modes, identified as Mode A and Mode B. Mode A is the precipitation scan and has three common scanning strategies. The most common is where the radar makes 14 elevation scans from 0.5° to 19.5° every four and a half minutes. This particular scanning strategy is documented as volume coverage pattern 12 (VCP-12). Mode B is the clear-air mode, where the radar makes 5 elevation scans during a ten-minute period. During the period surrounding the accident, the KHGX WSR-88D radar was operating in the precipitation mode VCP-12. The following chart provides an indication of the different elevation angles in this VCP, and the approximate height and width of the radar beam with distance from the radar site.

¹⁶ The WSR-88D is an S-band 10-centimeter wavelength radar with a power output of 750,000 watts, and with a 28-foot parabolic antenna that concentrates the energy between a 0.87° and 0.96° beam width. The radar produces three basic types of products: base reflectivity, base radial velocity, and base spectral width.

VCP 12



VCP-12 Precipitation Mode Scan Strategy¹⁷

7.2 Beam Height Calculation

Assuming standard refraction¹⁸ of the WSR-88D radar beam with the antenna elevation at 115 ft, and considering a beamwidth¹⁹ of 0.95°, the following table shows the approximate heights for the radar beam center, top and base for antenna elevations over the accident site. These heights have been rounded to the nearest 10 ft.

ANTENNA ELEVATION	BEAM CENTER	BEAM BASE	BEAM TOP
KHGX 0.5°	3,510 ft	1,490 ft	5,530 ft

¹⁷ Contiguous Surveillance (CS)--The low Pulse Repetition Frequency (PRF) scan of the split cut. Gives a high R_{max} value to determine proper target location and intensity, but a low V_{max} value limits the velocities that can be measured. Contiguous Doppler (CD)--The high PRF scan of the split cut. Gives a low R_{max} value causing more range folded (multiple trip) echoes, but a high V_{max} value to get higher, more accurate velocity values.

Batch Mode – Uses alternating low and high PRFs on each radial for one full rotation at each elevation angle. The two resulting data sets (low PRF and high PRF) are combined to resolve range ambiguity. Used in the middle elevation angles.

W – With range unfolding (W)

WO – Without range unfolding (WO)

¹⁸ Standard Refraction in the atmosphere is when the temperature and humidity distributions are approximately average, and values set at the standard atmosphere.

¹⁹ Beamwidth - the angular separation between the half power points on the antenna radiation pattern, where the gain is one half the maximum value.

Based on the radar height calculations, the elevation scans listed in the above table depicted the conditions between 1,490 ft and 5,530 ft msl over the accident site and these scans “saw” the closest altitudes to the surface.

7.3 Reflectivity

Reflectivity is the measure of the efficiency of a target in intercepting and returning radio energy. With hydrometeors²⁰ it is a function of the drop size distribution, number of particles per unit volume, physical state (ice or water), shape, and aspect. Reflectivity is normally displayed in dBZ, and is a general measure of echo intensity. FAA Advisory Circular AC 00-24C²¹, “Thunderstorms,” dated February 19, 2013, also defines the echo intensity levels and weather radar echo intensity terminology associated with those levels. For dBZ values less than 30 the weather radar echo intensity terminology should be “light.” For dBZ values between 30 and 40, the terminology should be “moderate.” “Heavy” terminology is used for dBZ values greater than 40 dBZ but less than 50 dBZ, inclusive. Finally, any dBZ values above 50 dBZ shall be described as “extreme.” From the NWS, precipitation conditions at the surface can be inferred from VIP Levels described in the chart below:

- VIP 1 (Level 1, 18-30 dBZ) - Light precipitation
- VIP 2 (Level 2, 30-38 dBZ) - Light to moderate rain
- VIP 3 (Level 3, 38-44 dBZ) - Moderate to heavy rain
- VIP 4 (Level 4, 44-50 dBZ) - Heavy rain
- VIP 5 (Level 5, 50-57 dBZ) - Very heavy rain; hail possible
- VIP 6 (Level 6, >57 dBZ) - Very heavy rain and hail; large hail possible

7.4 Base Reflectivity and Lightning Data

Figures 13, 14, 15, 16, and 17 present the KHGX WSR-88D base reflectivity images for the 0.5° elevation scans initiated at 1550:10, 1555:09, 1600:06, 1605:03, and 1609:59 CST, respectively, with a resolution of 0.5° X 250 m. Reflectivity values between 20 and 35 dBZ²² were located above the accident site at the accident time and along the accident aircraft’s flight track²³ (pink line). The reflectivity bands were moving from west to east (attachment 3). The accident flight first encountered precipitation around the 1550 CST timeframe (figure 14, attachment 3).

²⁰ Hydrometeors are any product of condensation or sublimation of atmospheric water vapor, whether formed in the free atmosphere or at the earth’s surface; also, any water particles blown by the wind from the earth’s surface. Hydrometeors are classified as; (a) Liquid or solid water particles suspended in the air: cloud, water droplets, mist or fog. (b) Liquid precipitation: drizzle and rain. (c) Freezing precipitation: freezing drizzle and freezing rain. (d) Solid (frozen) precipitation: ice pellets, hail, snow, snow pellets, and ice crystals. (e) Falling particles that evaporate before reaching the ground: virga. (f) Liquid or solid water particles lifted by the wind from the earth’s surface: drifting snow, blowing snow, blowing spray. (g) Liquid or solid deposits on exposed objects: dew, frost, rime, and glazed ice.

²¹

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

²² Different color scale used between figure 12 and figures 13 through 17 given weather radar composite imagery (figure 12) and base reflectivity individual elevation scans (figures 13 through 17).

²³ For more information please see the ATC data in the docket for this accident.

There were no lightning strikes around the accident site at the accident time.²⁴

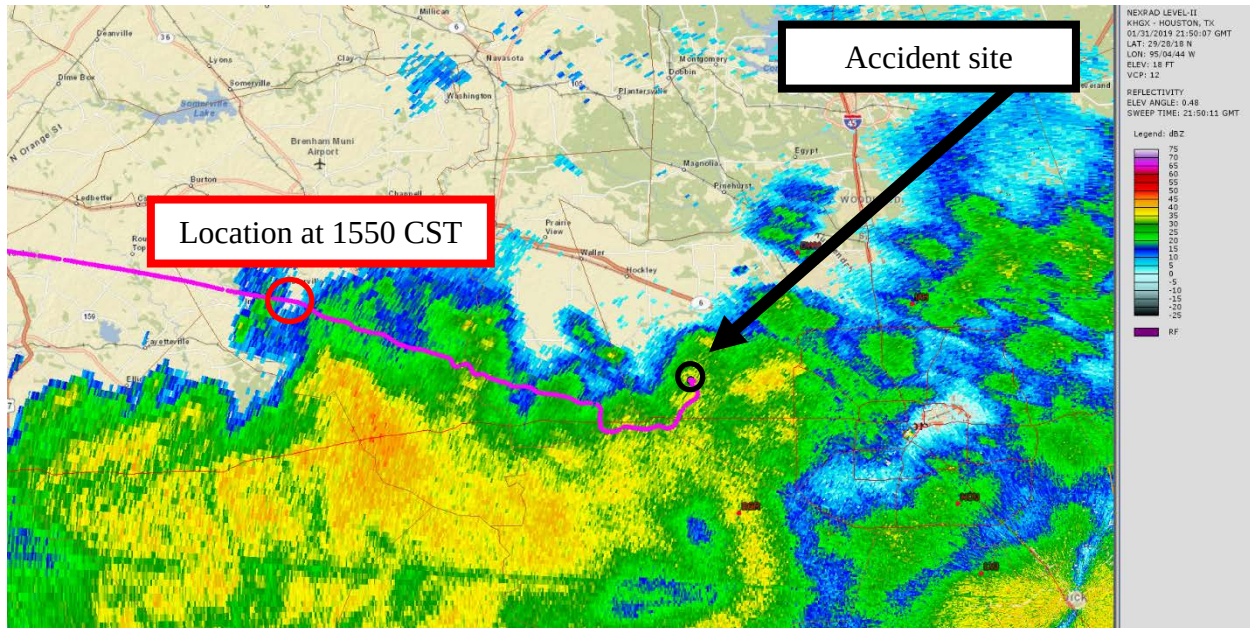


Figure 13 – KHXZ WSR-88D reflectivity for the 0.5° elevation scan initiated at 1550:10 CST with the accident site marked with black circle, and the accident flight track in pink

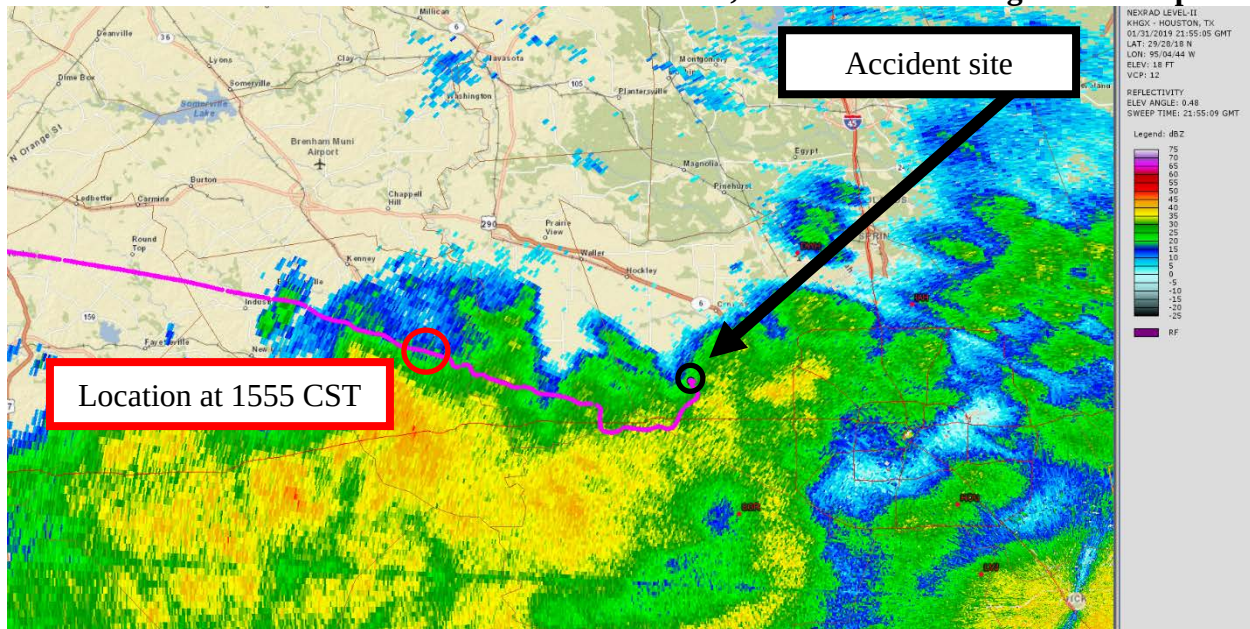


Figure 14 – KHXZ WSR-88D reflectivity for the 0.5° elevation scan initiated at 1555:09 CST with the accident site marked with black circle, and the accident flight track in pink

²⁴ A review of Earth Networks Total Lightning network was done.

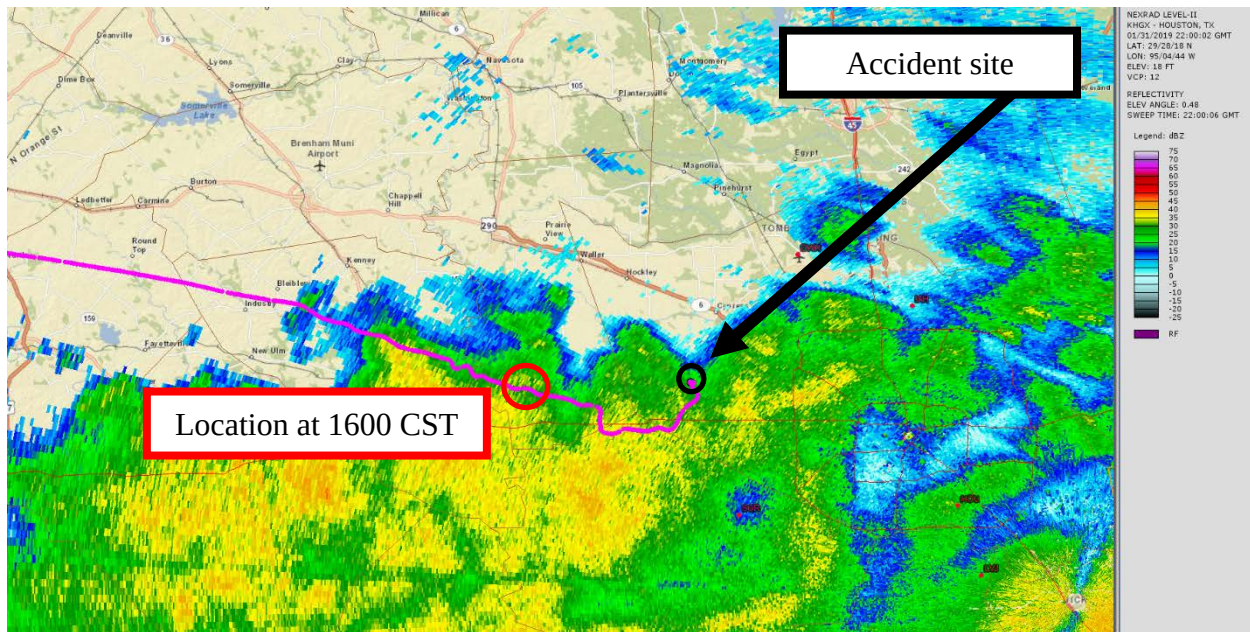


Figure 15 – KHGX WSR-88D reflectivity for the 0.5° elevation scan initiated at 1600:06 CST with the accident site marked with black circle, and the accident flight track in pink

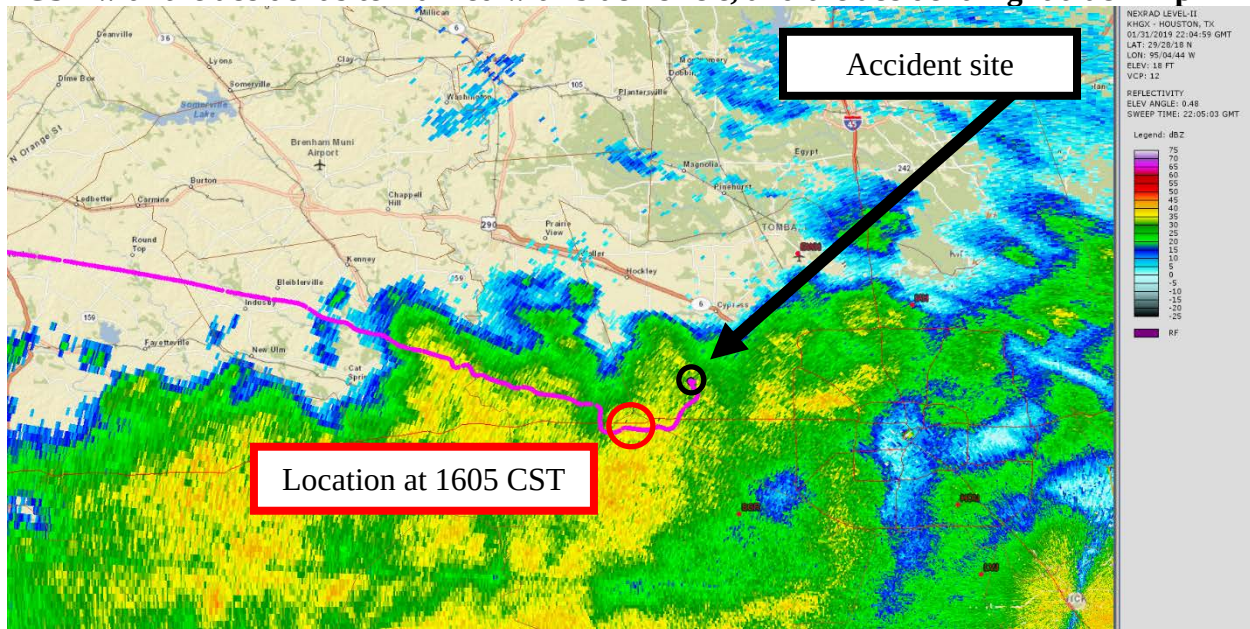


Figure 16 – KHGX WSR-88D reflectivity for the 0.5° elevation scan initiated at 1605:03 CST with the accident site marked with black circle, and the accident flight track in pink

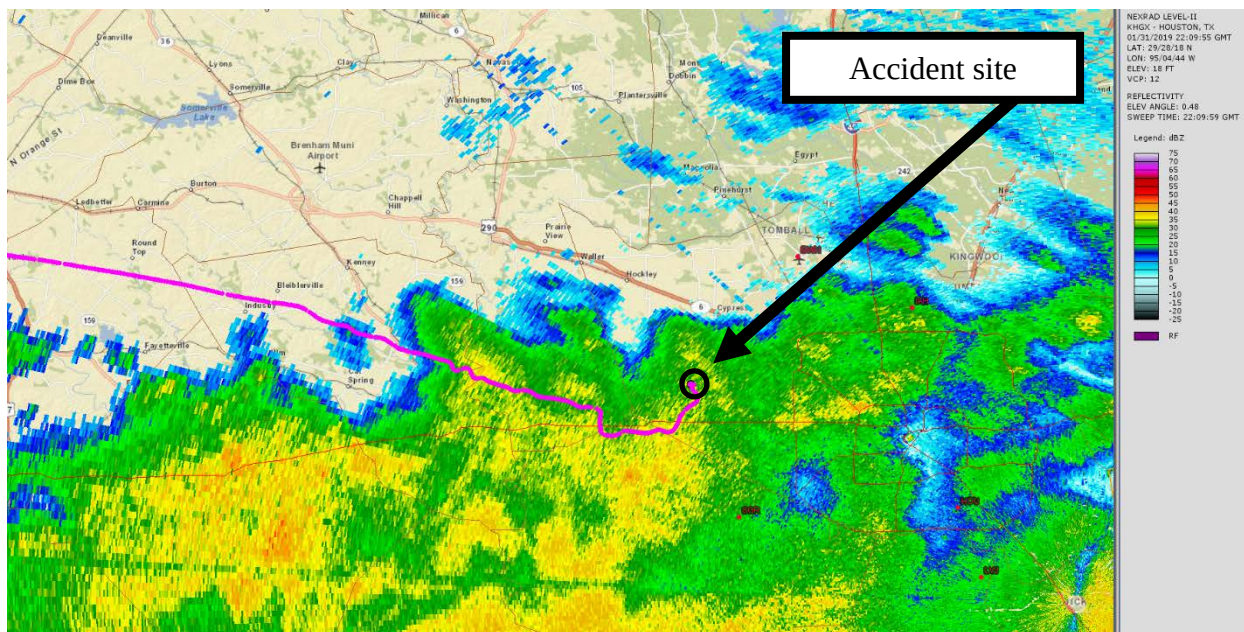


Figure 17 – KHXG WSR-88D reflectivity for the 0.5° elevation scan initiated at 1609:59 CST with the accident site marked with black circle, and the accident flight track in pink

8.0 Pilot Reports²⁵

All pilot reports (PIREPs) within 100 miles of the accident site from about one hour prior to the accident time to about one hour after the accident time for below FL200²⁶ are provided below:

CLL UA /OV KUTS360010/TM 2124/FL087/TP BE58/SK TOPS RPRTD/RM FM ZHU AWC-WEB/

IAH UA /OV IAH070004/TM 2127/FLDURD/TP E170/SK OVC008/TA 13

CLL UA /OV CLL180004/TM 2159/FL017/TP E145/SK BASES 015

HOU UA /OV HOU270030/TM 2203/FL100/TP B737/TB MODERATED TURBULENCE/IC LGT RIME

GLS UA /OV 1 1/2NM N GLS/TM 2210/FL006/TP S22T/SK BKN006/WX 2 1/2 -RA BR

IAH UA /OV IAH130004/TM 2212/FLDURGC/TP A320/SK OVC006

DWH UA /OV 1 SOUTH/TM 2218/FL009/TP B350/SK OVC008

VCT UA /OV PSX360020/TM 2229/FL160/TP C501/TA M05/IC MOD RIME/RM FM ZHU AWC-WEB/

IAH UA /OV IAH/TM 2230/FL007/TP E175/SK BKN007

CLL UA /OV CLL/TM 2235/FL014/TP C25A/RM BASE REPORTED AT 014 OVC

²⁵ Only pilot reports with the World Meteorological Organization headers UBTX** and UBLA** were considered.

²⁶ Flight Level – A Flight Level (FL) is a standard nominal altitude of an aircraft, in hundreds of ft. This altitude is calculated from the International standard pressure datum of 1013.25 hPa (29.92 inHg), the average sea-level pressure, and therefore is not necessarily the same as the aircraft's true altitude either above mean sea level or above ground level.

IAH UA /OV GLS/TM 2238/FL115/TP A700/IC LGT RHIME/RM OAT -2

IAH UA /OV IAH/TM 2240/FLDURGD/TP E145/SK OVC007

IAH UA /OV 1 WEST/TM 2241/FL007/TP CRJ/SK OVC

IAH UA /OV IAH/TM 2243/FL007/TP E170/SK OVC007

CLL UA /OV CLL/TM 2255/FL0122/TP BE20/SK OVC/WX 2

IAH UA /OV IAH140030/TM 2259/FL100/TP B737/TB MOD TURB

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

Routine pilot report (UA) Easterwood Field Airport, Texas (CLL); Over 10 miles from Huntsville Municipal Airport, Texas, (KUTS); Time – 1524 CST (2124Z); Altitude – 8,700 ft; Type aircraft – Beechcraft Baron; Sky – Tops reported; Remarks – From Houston Air Route Traffic Control Center (ZHU) Aviation Weather Center (AWC) web.

Routine pilot report (UA) George Bush Intercontinental/Houston Airport, Texas (IAH); Over 4 miles from IAH on the 070° radial; Time – 1527 CST (2127Z); Altitude – During descent; Type aircraft – Embraer ERJ-170; Sky – Overcast skies at 800 ft; Temperature – 13 °C.

Routine pilot report (UA) CLL; Over 4 miles from CLL on the 180° radial; Time – 1559 CST (2159Z); Altitude – 1,700 ft; Type aircraft – Embraer ERJ-145; Sky – Bases at 1,500 ft.

Routine pilot report (UA) William P Hobby Airport, Texas, (HOU); Over 30 miles from HOU on the 270° radial; Time – 1603 CST (2203Z); Altitude – 10,000 ft; Type aircraft – Boeing B737; Turbulence – Moderate turbulence; Icing – Light Rime.

Routine pilot report (UA) Scholes International Airport at Galveston, Texas, (GLS); Over 1 and a half miles north of GLS; Time – 1610 CST (2210Z); Altitude – 600 ft; Type aircraft – Cirrus SR-22; Sky – Broken clouds at 600 ft; Weather – 2 and half miles visibility, light rain, and mist.

Routine pilot report (UA) IAH; Over 4 miles from IAH on the 130° radial; Time – 1612 CST (2212Z); Altitude – During descent; Type aircraft – Airbus A320; Sky – Overcast skies at 600 ft.

Routine pilot report (UA) David Wayne Hooks Memorial Airport, Texas, (DWH); Over 1 mile south of DWH; Time – 1618 CST (2218Z); Altitude – 900 ft; Type aircraft – Beechcraft Super King Air; Sky – Overcast skies at 800 ft.

Routine pilot report (UA) Victoria Regional Airport, Texas (VCT); Over 20 miles from Palacios, Texas, (PSX); Time – 1629 CST (2229Z); Altitude – 16,000 ft; Type aircraft – Cessna 501 Citation; Temperature – -5 °C; Icing – Moderate rime; Remarks – From ZHU AWC web.

Routine pilot report (UA) IAH; Over IAH; Time – 1630 CST (2230Z); Altitude – 700 ft; Type aircraft – Embraer ERJ-175; Sky – Broken skies at 700 ft.

Routine pilot report (UA) CLL; Over CLL; Time – 1635 CST (2235Z); Altitude – 1,400 ft; Type aircraft – Cessna 525A; Remarks – Bases reported at 1,400 ft overcast skies.

Routine pilot report (UA) IAH; Over GLS; Time – 1638 CST (2238Z); Altitude – 11,500 ft; Type aircraft – Adam A700; Icing – Light rime; Remarks – Outside air temperature -2 °C.

Routine pilot report (UA) IAH; Over IAH; Time – 1640 CST (2240Z); Altitude – During descent; Type aircraft – Embraer ERJ-145; Sky – Overcast skies at 700 ft.

Routine pilot report (UA) IAH; Over 1 miles west of IAH; Time – 1641 CST (2241Z); Altitude – 700 ft; Type aircraft – Bombardier CRJ; Sky – Overcast skies.

Routine pilot report (UA) IAH; Over IAH; Time – 1643 CST (2243Z); Altitude – 700 ft; Type aircraft – Embraer ERJ-170; Sky – Overcast skies at 700 ft.

Routine pilot report (UA) CLL; Over CLL; Time – 1655 CST (2255Z); Altitude – 1,200 ft; Type aircraft – Beech 200 Super King Air; Sky – Overcast skies; Weather – 2 miles visibility.

Routine pilot report (UA) IAH; Over 30 miles from IAH on the 140° radial; Time – 1659 CST (2259Z); Altitude – 10,000 ft; Type aircraft – Boeing 737; Turbulence – Moderate turbulence.

9.0 SIGMET

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

10.0 CWSU Products

There were no Center Weather Service Unit (CWSU) Meteorological Impact Statements (MIS) valid for the accident site at the accident time. There were no CWSU Center Weather Advisories (CWA) valid for the accident site at the accident time (figure 18):

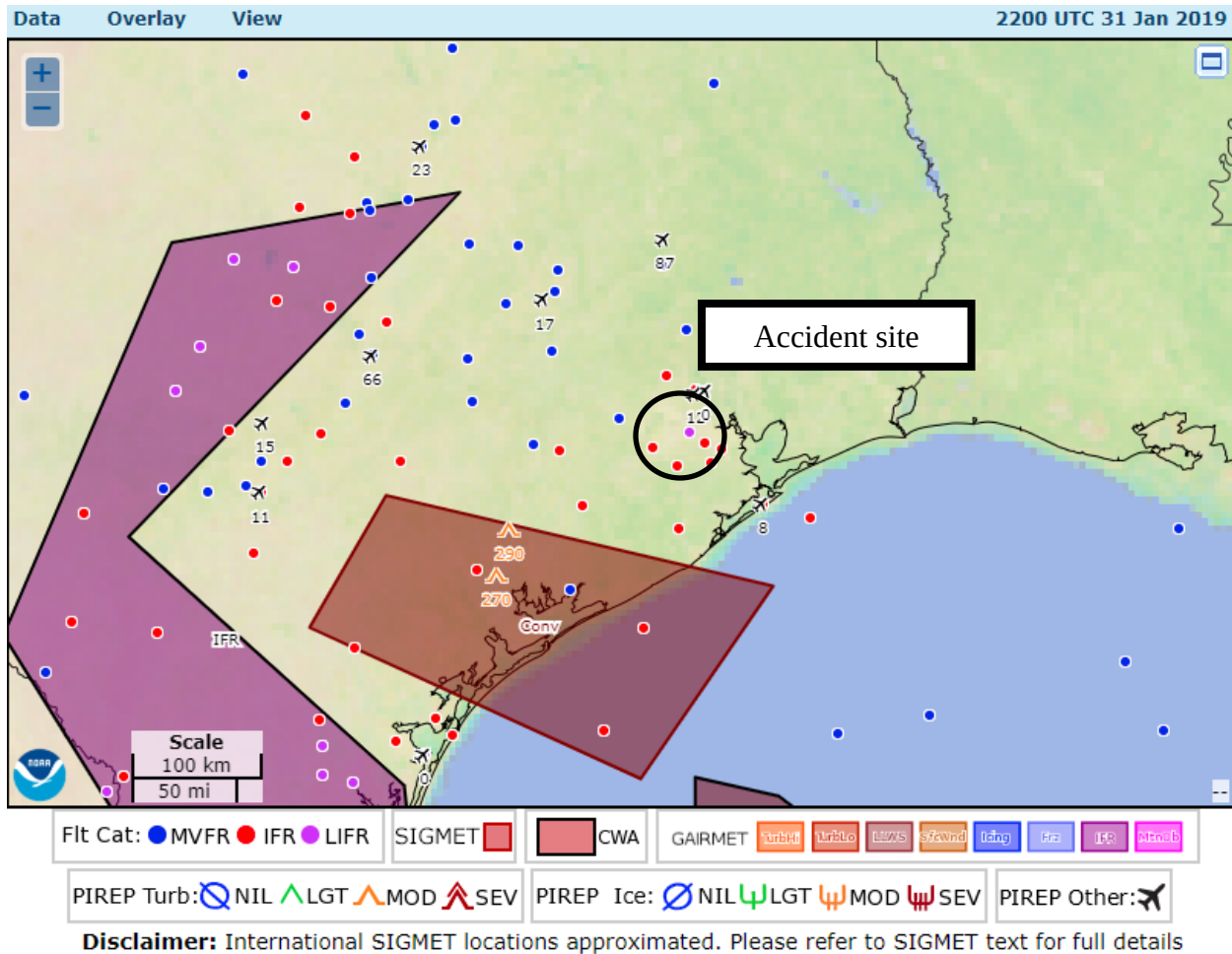


Figure 18 – SIGMETs and CWAs valid at 1600 CST

11.0 AIRMETs

Airmen's Meteorological Information (AIRMET) advisory Sierra was valid for the accident site at the accident time. AIRMET Zulu was valid but above 9,000 ft. AIRMET Sierra warned of IFR conditions with precipitation and mist:

WAUS44 KKCI 312045

WA4S

-DFWS WA 312045

AIRMET SIERRA UPDT 4 FOR IFR VALID UNTIL 010300

.

AIRMET IFR...OK TX LA AND CSTL WTRS

**FROM 50SSE ICT TO 40SW LFK TO 40SW LCH TO 120SSW LCH TO 80E BRO
TO 90W BRO TO DLF TO 60SSW SJT TO 60SE ABI TO 50SE SPS TO 50NW
END TO 50SSE ICT**

CIG BLW 010/VIS BLW 3SM PCPN/BR. CONDS CONTG BYD 03Z THRU 09Z.

.

OTLK VALID 0300-0900Z...IFR OK TX AR LA AND CSTL WTRS

BOUNDED BY OSW-RZC-30NW ARG-TXK-50SE GGG-40S AEX-20SE HRV-70SE

LEV-120SSW LCH-80E BRO-90W BRO-DLF-70SSE FST-20E FST-30NW SJT-
60SSW SPS-20E CDS-40N MMB-OSW
CIG BLW 010/VIS BLW 3SM PCPN/BR. CONDS CONTG THRU 09Z.
....

12.0 Graphical Forecasts for Aviation

The Graphical Forecasts for Aviation (GFA) products made available before the accident flight are shown in attachment 4. The GFA surface forecast products indicated VFR²⁷ surface visibilities at the accident site for 1500 and 1800 CST with G-AIRMET²⁸ Sierra forecast for the accident site by 1800 CST. There was a chance (between 30 and 60 percent) of rain shower activity forecast with a southeasterly surface wind of 5 to 10 knots. The GFA cloud forecast valid before departure (issued at 1002 CST) for 1500 CST indicated VFR ceilings around the Houston area and destination airport with ceiling conditions consistent with MVFR²⁹ conditions forecast by 1800 CST for the Houston area. The GFA cloud forecast issued at 1302 CST indicated similar forecast conditions for 1500 and 1800 CST as the 1002 CST GFA cloud forecast. For more information please see attachment 4.

The reason for the differences between the GFA surface forecast and the GFA cloud forecast is the two are computed automatically by two different weather models. In this case, the cloud forecast indicated a lower flight category condition than was forecast in the surface forecast product. The Rapid Refresh (RAP) weather model is used for the cloud forecast and the Localized Aviation MOS³⁰ Program (LAMP) weather model is used for the surface forecast charts, and both forecasts are issued with no human intervention. The only human-generated information reflected in the two GFA products are the AIRMETs and the GFA is “human-over-the-loop.”

13.0 Terminal Aerodrome Forecast

KSGR was the closest airport to the accident site with a NWS Terminal Aerodrome Forecast (TAF). The KSGR TAF valid at the time of the accident was issued at 1549 CST and was valid for a 20-hour period beginning at 1600 CST. The 1549 CST TAF for KSGR was as follows:

KSGR 312149Z 3122/0118 **09010KT P6SM -RA VCSH BKN009 OVC017**
FM010300 10011KT P6SM SCT007 OVC010
TEMPO 0111/0115 3SM BR BKN007
FM011700 10012KT P6SM SCT020 BKN035=

Between 1600 and 2100 CST, the forecast expected a wind from 090° at 10 knots, greater than 6 miles visibility, light rain, vicinity³¹ showers, a broken ceiling at 900 ft agl, and overcast skies at 1,700 ft agl.

²⁷ Visual Flight Rules – Refers to the general weather conditions pilots can expect at the surface. VFR criteria a ceiling greater than 3,000 feet agl and greater than 6 miles visibility.

²⁸ G-AIRMET, graphical AIRMETs. May differ in space from text AIRMET product.

²⁹ Marginal Visual Flight Rules – Refers to the general weather conditions pilots can expect at the surface. MVFR criteria, which is a sub-category of VFR conditions, are a ceiling 1,000 to 3,000 ft agl and/or 3 to 5 miles visibility.

³⁰ Model Output Statistics: https://www.weather.gov/mdl/mos_home

³¹ In the vicinity of the airport is defined as a weather phenomenon within 5-10 statute miles of the airfield.

The KSGR TAF that was issued before the accident flight departed was issued at 1120 CST and was valid for a 24-hour period beginning at 1200 CST. The 1120 CST TAF for KSGR was as follows:

TAF KSGR 311720Z 3118/0118 **10014KT P6SM VCSH BKN011 OVC040**
TEMPO 3120/3124 5SM SHRA BR BKN008
FM010300 10011KT P6SM SCT007 OVC010
TEMPO 0111/0115 3SM BR BKN007
FM011700 10012KT P6SM SCT020 BKN035=

Between 1200 and 2100 CST, the forecast expected a wind from 100° at 14 knots, greater than 6 miles visibility, vicinity showers, a broken ceiling at 1,100 ft agl, and overcast skies at 4,000 ft agl. Temporary conditions³² were forecast between 1400 and 1800 CST of 5 miles visibility, moderate rain showers, mist, and a broken ceiling at 800 ft agl.

14.0 NWS Area Forecast Discussion

The NWS office in Houston/Galveston, Texas, issued the following Area Forecast Discussion (AFD) at 1139 CST (closest AFD to the accident time). The aviation section of the AFD discussed general MVFR ceiling conditions with precipitation spreading northward across the Houston region through the afternoon into the evening hours:

FXUS64 KHGX 311739
AFDHGX

Area Forecast Discussion
National Weather Service Houston/Galveston TX
1139 AM CST Thu Jan 31 2019

.AVIATION...

A mixed bag of ceilings across the terminals at this hour. Would anticipate them to fall into the 1000-2000ft range in the next several hours as precip starts expanding across parts of the area from the sw. Best coverage looks like it'll be from the Houston airports southward, but cannot rule out sct activity further north. TAFs will, in general, advertise shra but there have been a few embedded tsra noted sw of Matagorda. Precip will taper off later this evening, but isolated activity (not mentioned in the TAFs) is possible through the night. 47

&&

.PREV DISCUSSION... /ISSUED 935 AM CST Thu Jan 31 2019/
Radar imagery is beginning to show some coverage of showers pushing west to east across the Gulf waters this morning, with lightning well offshore closer to the axis of the coastal trough. Also seeing returns inland area wide, but as of 9 AM, no observations have indicated rain so most of this moisture is evaporating before reaching the surface. Theses pockets of drier

³² Temporary conditions - temporary fluctuations to forecast conditions which are expected to last less than one hour in each instance and, in the aggregate, to cover less than half of the indicated period.

air visible in this morning's neighboring 12Z soundings in the low to mid levels should quickly erode by late this morning as onshore flow pumps Gulf moisture into the region. The lower levels of the atmosphere will quickly saturate, increasing from precipitable water values (PWs) near 0.80 inches this morning, to near 1.3 inches late this afternoon.

Much of the short term guidance such as the HRRR, ARW, and TT WRF are in good agreement with keeping the best coverage of precipitation associated with the coastal low over the Gulf waters, as we move into the late morning and afternoon hours. By this afternoon, showers and thunderstorms should also fill in over the coastal counties, and we can't rule out the chance for isolated thunder along and south of I-10. Still believe the best CAPE and instability should remain offshore throughout the day. Additionally, a short wave embedded in the upper level flow will also translate across SE TX today, helping to provide lift further inland. North of I-10, moisture values will also be on the rise, with PWs this morning starting near 0.80 inches and rising to 1.1-1.2 inches by this afternoon. Showers are mainly anticipated across this area, with the best instability elevated and surface to 3 km lapse rates only around 4 to 5 C/km. Showers and isolated thunderstorms will continue into the evening hours as the coastal trough and upper-level shortwave shifts east of the region by Friday morning.

Hathaway

&&

.PRELIMINARY POINT TEMPS/POPS...

College Station (CLL)	59	53	67	56	68	/	20	30	20	30	40
Houston (IAH)	60	54	67	57	68	/	30	30	20	30	40
Galveston (GLS)	59	57	62	58	63	/	60	70	30	30	40

&&

.HGX WATCHES/WARNINGS/ADVISORIES...

TX...NONE.

GM...Small Craft Advisory from 6 PM this evening to 6 AM CST Friday for the following zones: Coastal waters from Freeport to Matagorda Ship Channel TX out 20 NM...Coastal waters from High Island to Freeport TX out 20 NM.

SMALL CRAFT SHOULD EXERCISE CAUTION until 6 PM CST this evening for the following zones: Coastal waters from Freeport to Matagorda Ship Channel TX out 20 NM...Coastal waters from High Island to Freeport TX out 20 NM.

Small Craft Advisory until 6 AM CST Friday for the following zones: Waters from Freeport to Matagorda Ship Channel TX from 20 to 60 NM...Waters from High Island to Freeport TX from 20 to 60 NM.

&&

\$\$

15.0 Winds and Temperature Aloft Forecast

The NWS 1358 CST Winds and Temperature Aloft forecast valid for the closest point to the accident site is included below:

```
FBUS31 KWN0 311958
FD1US1
DATA BASED ON 311800Z
VALID 010000Z   FOR USE 2000-0300Z. TEMPS NEG ABV 24000

FT   3000    6000    9000    12000    18000    24000    30000    34000    39000
HOU 1422 2813+08 2527+02 2633-03 2540-16 2341-28 214445 224855 247158
```

The accident site was located closest to the HOU forecast point. The 1358 CST HOU forecast for use between 1400 CST and 2100 CST indicated a wind at 3,000 ft from 140° at 22 knots, a wind at 6,000 ft from 280° at 13 knots with a temperature of 8 °C, and a wind at 9,000 ft from 250° at 27 knots with a temperature of 2 °C.

16.0 Pilot Weather Briefing

The accident pilot received a weather briefing from Leidos at 1151 CST (attachment 5). The Leidos weather briefing contained all the standard weather forecast information including AIRMETs. The weather briefer mentioned that the central Texas portion of the flight was “VFR not recommended,” due to the AIRMETs. The weather briefer also mentioned moderate to heavy precipitation (including some thunderstorms) in east Texas, METARs, TAFs, the winds aloft forecast, and that the flight was “VFR not recommended” due to the KSGR TAF. The pilot was told there was no precipitation in the Houston area at the time of the briefing, but was advised to double check the precipitation when getting closer to Houston during the course of the flight. In addition, the accident pilot received a standard Leidos text weather package (attachment 6) and GFA imagery (attachment 7) at 1152 CST.

A search of archived ForeFlight information indicated that the accident pilot did not request weather information via ForeFlight. There is no record of the accident pilot receiving or retrieving any other weather information before or during the accident flight.

17.0 CWSU Weather Briefing for ATC

The ZHU CWSU provided a pre-duty weather briefing at 1104 CST for the ATC personnel at ZHU. This video weather briefing would have been available to all ATC personnel in the Houston area. The ATC personnel on duty at the time of the accident were required to view this pre-duty weather briefing prior to their first shift of the day. The CWSU pre-duty weather briefing contained all the standard weather forecast information valid at 1104 CST, including a weather radar and satellite summary for the ZHU region, 12 hour forecast information, winds aloft, flight category information with much of the area below 5,000 ft agl ceilings or below 5 miles visibility, PIREP information, and valid AIRMETs (attachment 8).

18.0 Astronomical Data

The astronomical data obtained from the United States Naval Observatory for the accident site on January 31, 2019, indicated the following:

SUN	
Begin civil twilight	0649 CST
Sunrise	0714 CST
Sun transit	1236 CST
Accident time	1610 CST³³
Sunset	1759 CST
End civil twilight	1824 CST

E. LIST OF ATTACHMENTS

Attachment 1 – GOES-16 Visible animation from 1507 to 1707 CST

Attachment 2 – GOES-16 Infrared animation from 1502 to 1702 CST

Attachment 3 – KHGX WSR-88D base reflectivity animation for the 0.5° elevation scans from 1530 to 1630 CST

Attachment 4 – GFA products valid for the accident flight

Attachment 5 – Leidos weather briefing audio from 1151 CST

Attachment 6 – Leidos text weather briefing package

Attachment 7 – Leidos GFA products provided along with the text weather briefing package

Attachment 8 – CWSU ZHU pre-duty weather briefing

Submitted by:

Paul Suffern
Senior Meteorologist

³³ Inserted accident time for reference and context.

THIS PAGE INTENTIONALLY BLANK