NATIONAL TRANSPORTATION SAFETY BOARD

Office of Aviation Safety
Washington, D.C. 20594

August 28, 2017

Group Chairman's Factual Report

METEOROLOGY

CEN16FA286

Table Of Contents

A. ACCIDENT

Location: Sugar Land, Texas
Date: July 26, 2016
Time: 1510 central daylight time
2010 Coordinated Universal Time (UTC)
Aircraft: Embraer 505, registration: N362FX

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 was launched to Sugar Land, Texas, for the accident investigation. Meteorological data was gathered on scene as well as from official weather sources including the National Weather Service (NWS) and National Centers for Environmental Information (NCEI). All times in this report are central daylight time (CDT) based upon the 24 hour clock, local time is -5 hours from UTC, and UTC=Z. Directions are referenced to true north and distances in nautical miles. Heights are above mean sea level (msl) unless otherwise noted. Visibility is in statute miles and fractions of statute miles.

The accident site's approximate location was latitude 29.62° N, longitude 95.66° W, at an elevation of 75 feet.

D. FACTUAL INFORMATION

1.0 Synoptic Situation

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

1.1 Surface Analysis Chart

The NWS Surface Analysis Chart for 1600 CDT is provided as figure 1, with the approximate location of the accident site marked. The chart depicted a high pressure center with a pressure of 1013-hectopascals (hPa) located in southeastern Texas near the accident site. There was a surface trough[1] located in central Texas, stretching from College Station westward to Dryden. The station models around the accident site depicted air temperatures in the mid 70's to mid 80's degrees Fahrenheit (°F), with temperature-dew point spreads of 12° F or less, a southwest to southeast wind below 10 knots, cloudy skies, thunderstorms, and rain.

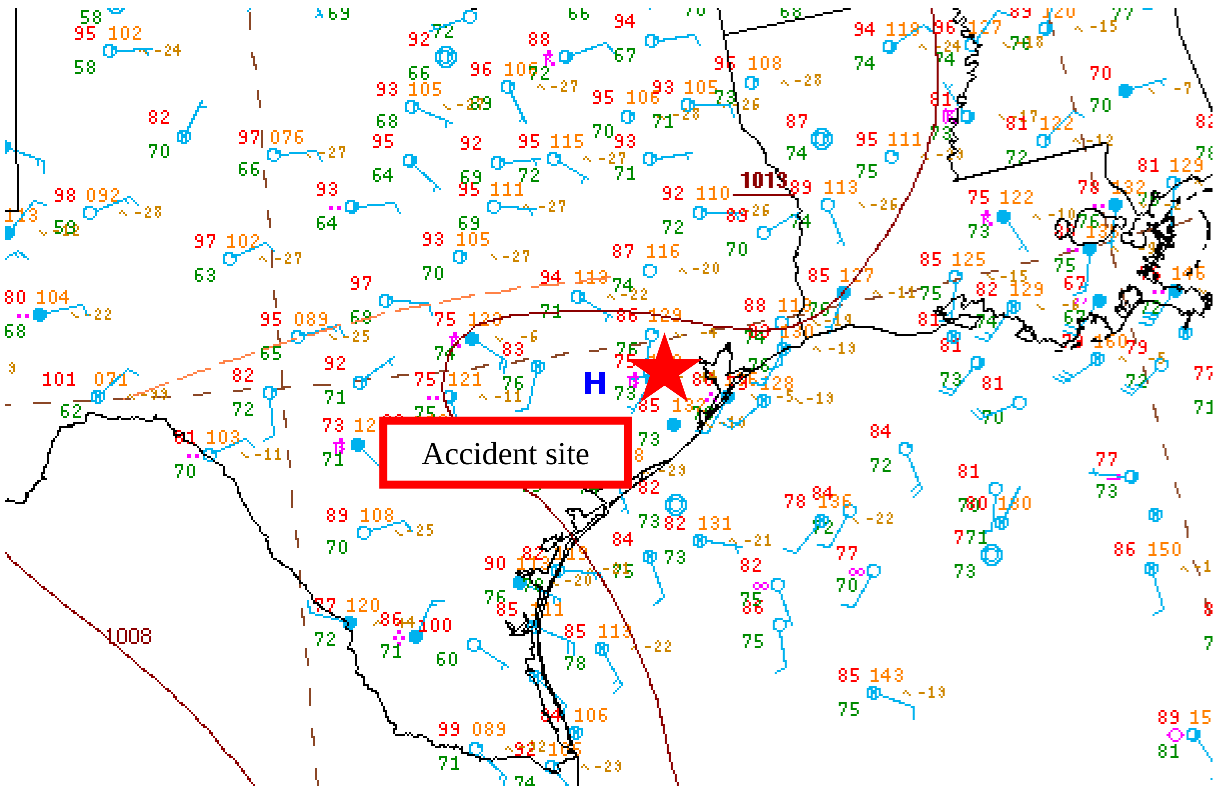

Figure 1 – NWS Surface Analysis Chart for 1600 CDT

1.2 Upper Air Charts

The NWS Storm Prediction Center (SPC) Constant Pressure Charts for 1900 CDT at 925-, 850-, 700-, 500-, and 300-hPa are presented in figures 2 through 6. The 850- and 700-hPa charts depicted a low- to mid-level trough directly above the accident site at 1900 CDT. The 22° Celsius (C) dew point temperature at 925-hPa at Corpus Christi, Texas (CRP), was near the record dew point temperature of 22.6° C for the date (figure 2). The wind direction from 925- through 300-hPa remained variable and wind magnitudes were below 10 knots.

[1] Trough – An elongated area of relatively low atmospheric pressure or heights.

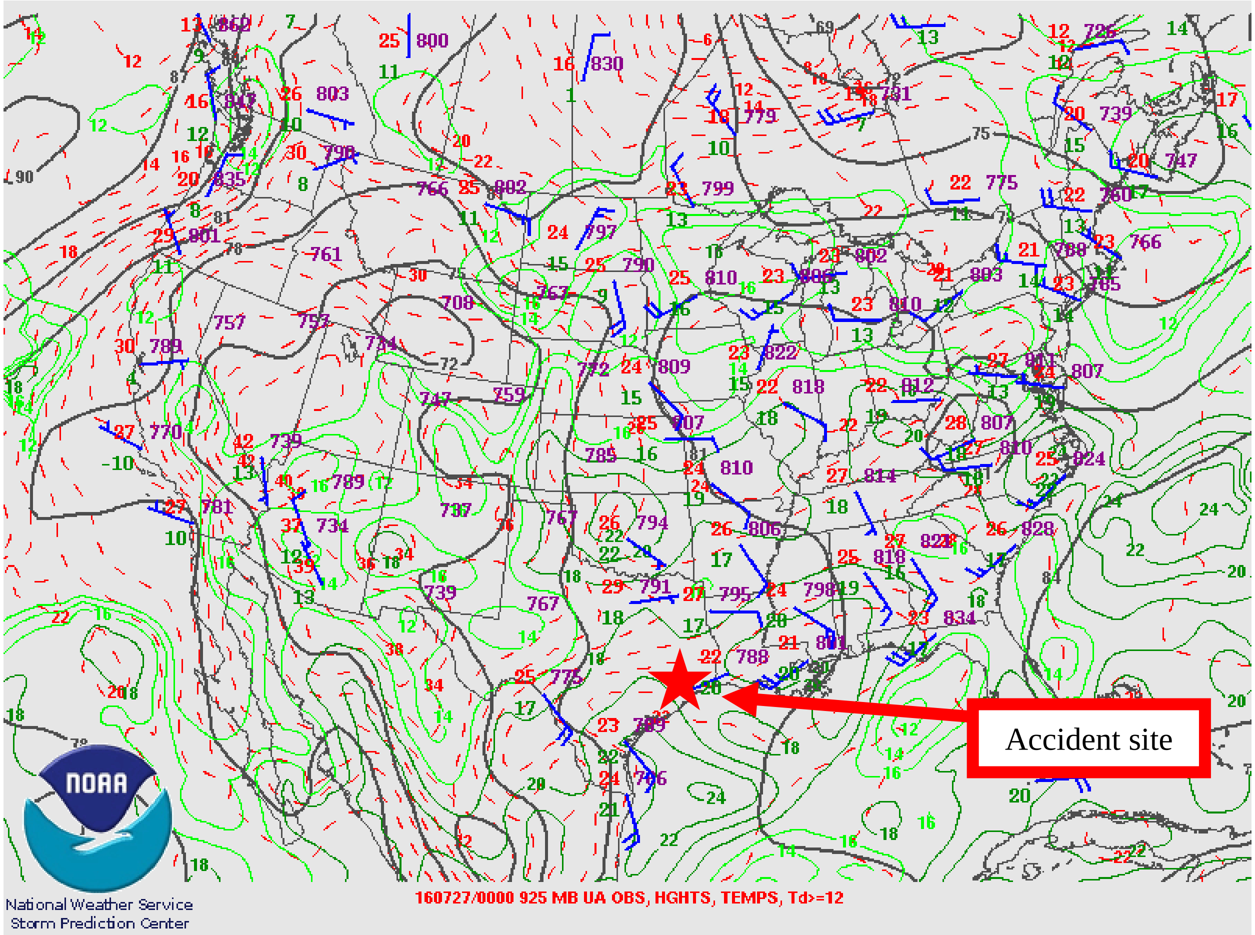

Figure 2 – 925-hPa Constant Pressure Chart for 1900 CDT

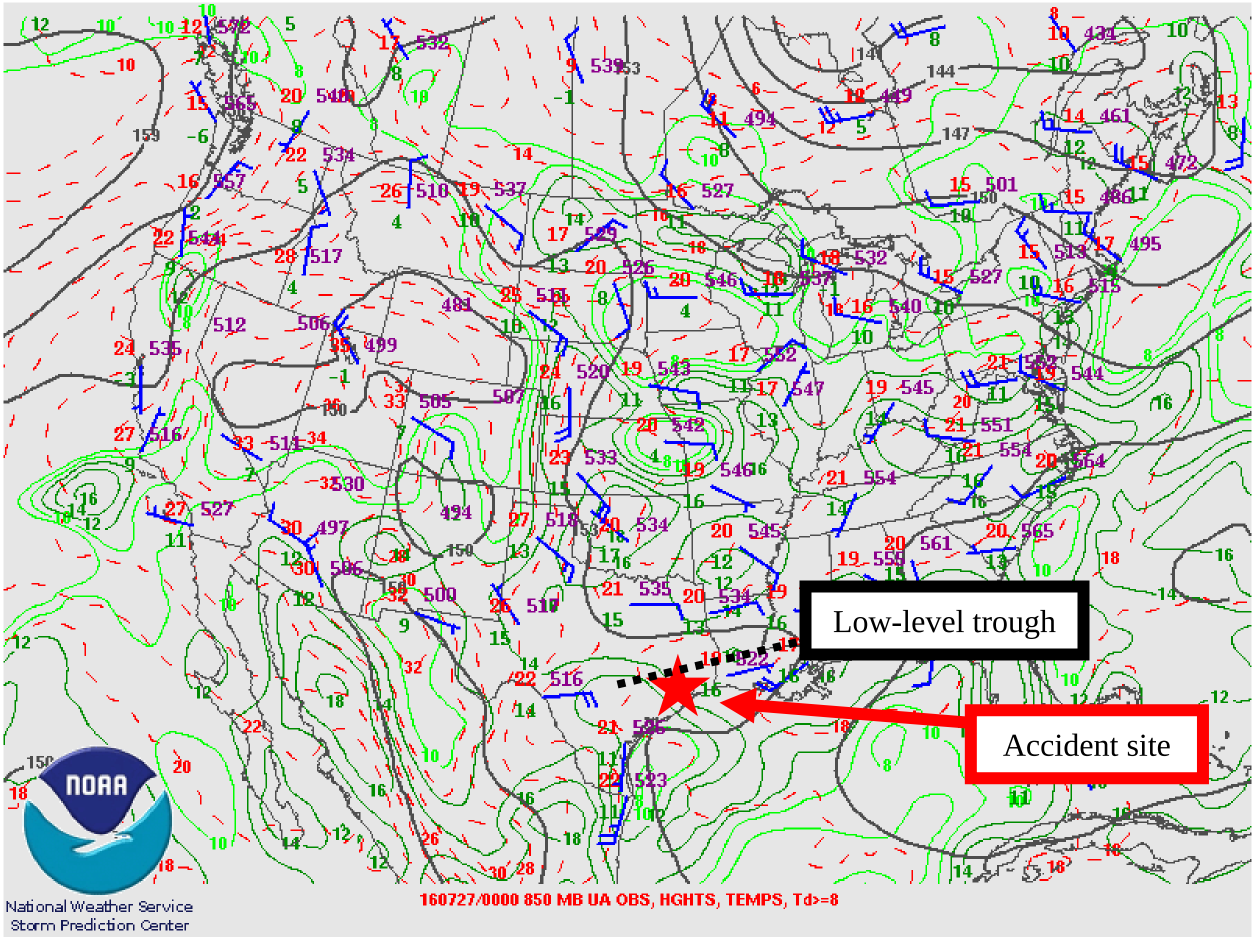

Figure 3 – 850-hPa Constant Pressure Chart for 1900 CDT

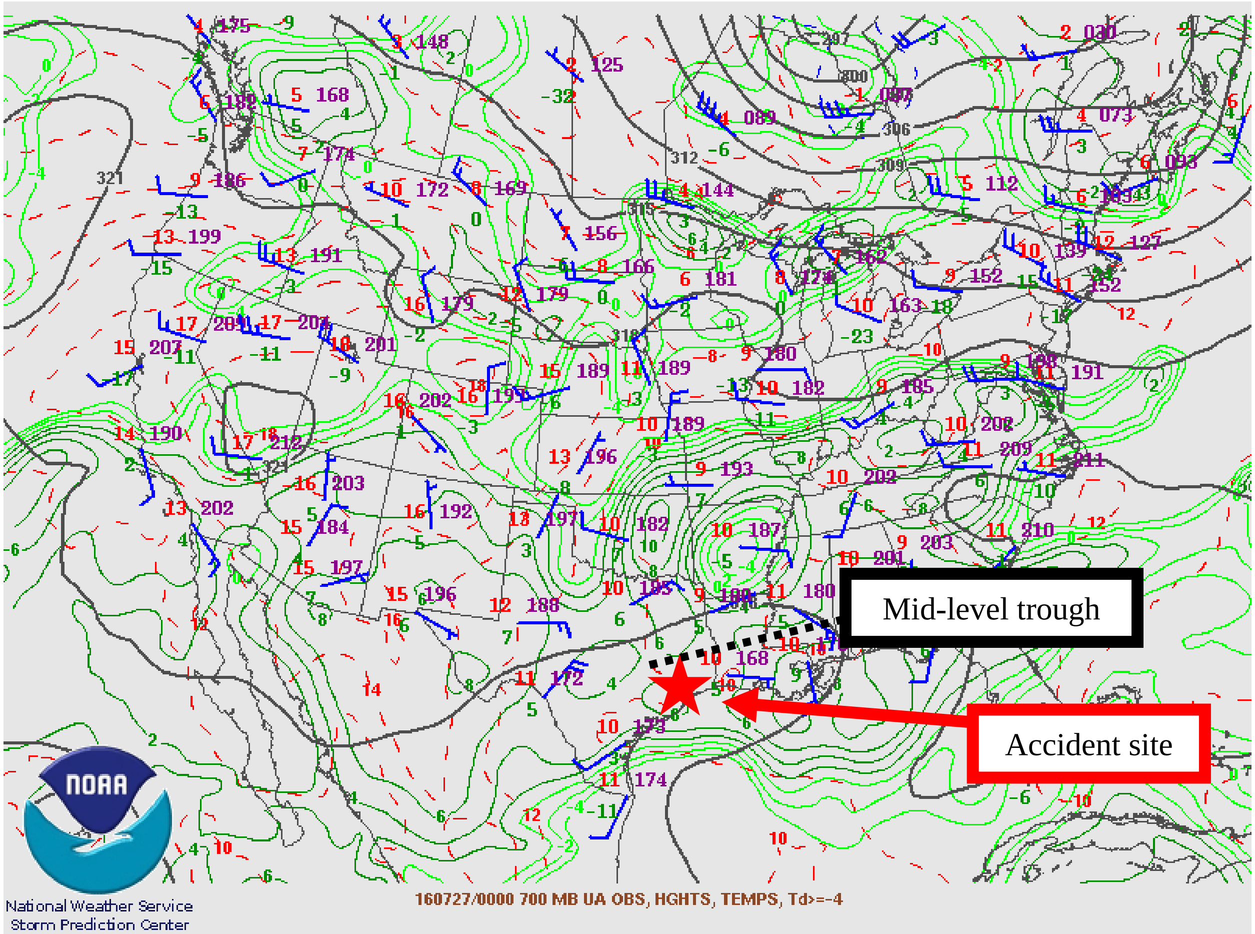

Figure 4 – 700-hPa Constant Pressure Chart for 1900 CDT

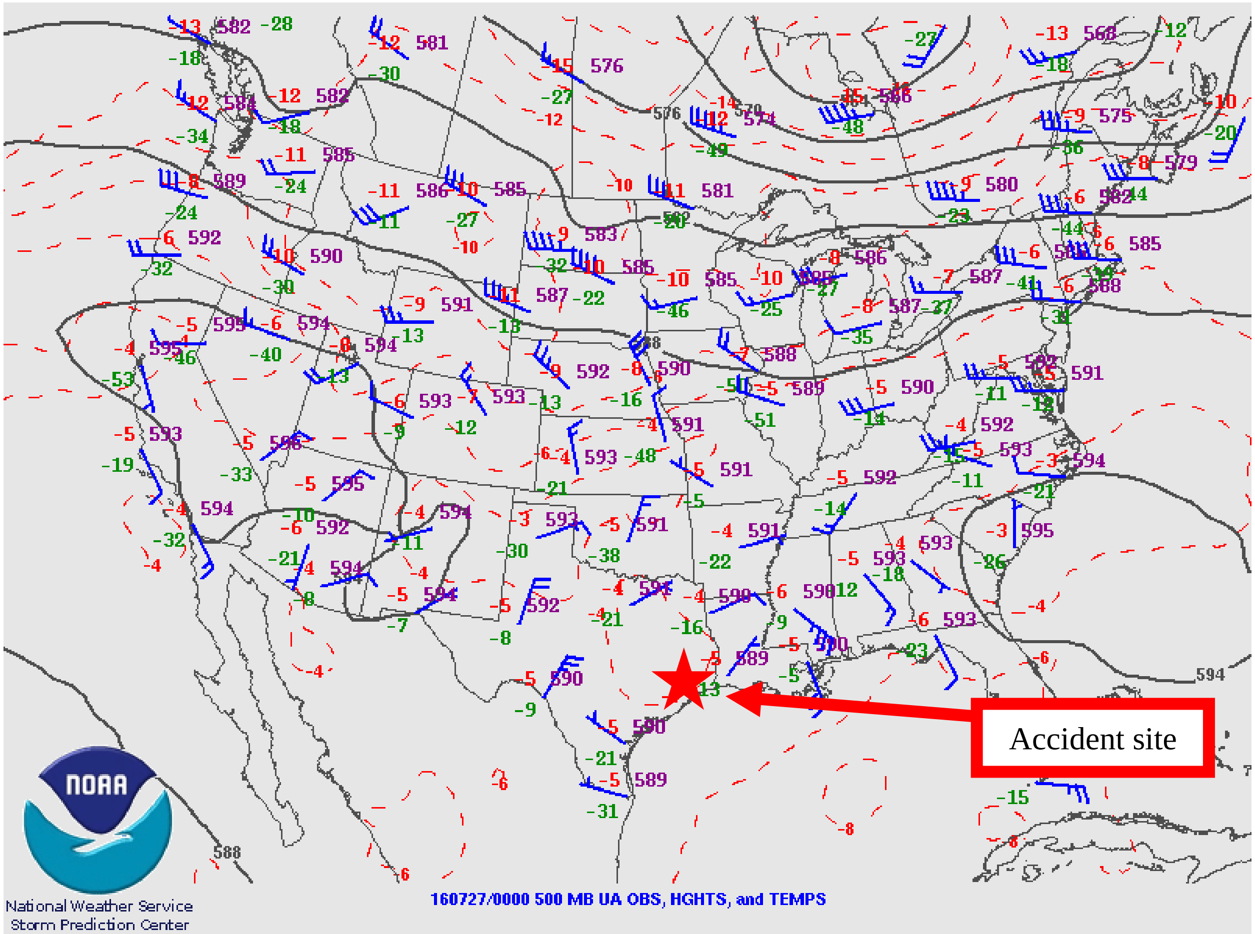

Figure 5 – 500-hPa Constant Pressure Chart for 1900 CDT

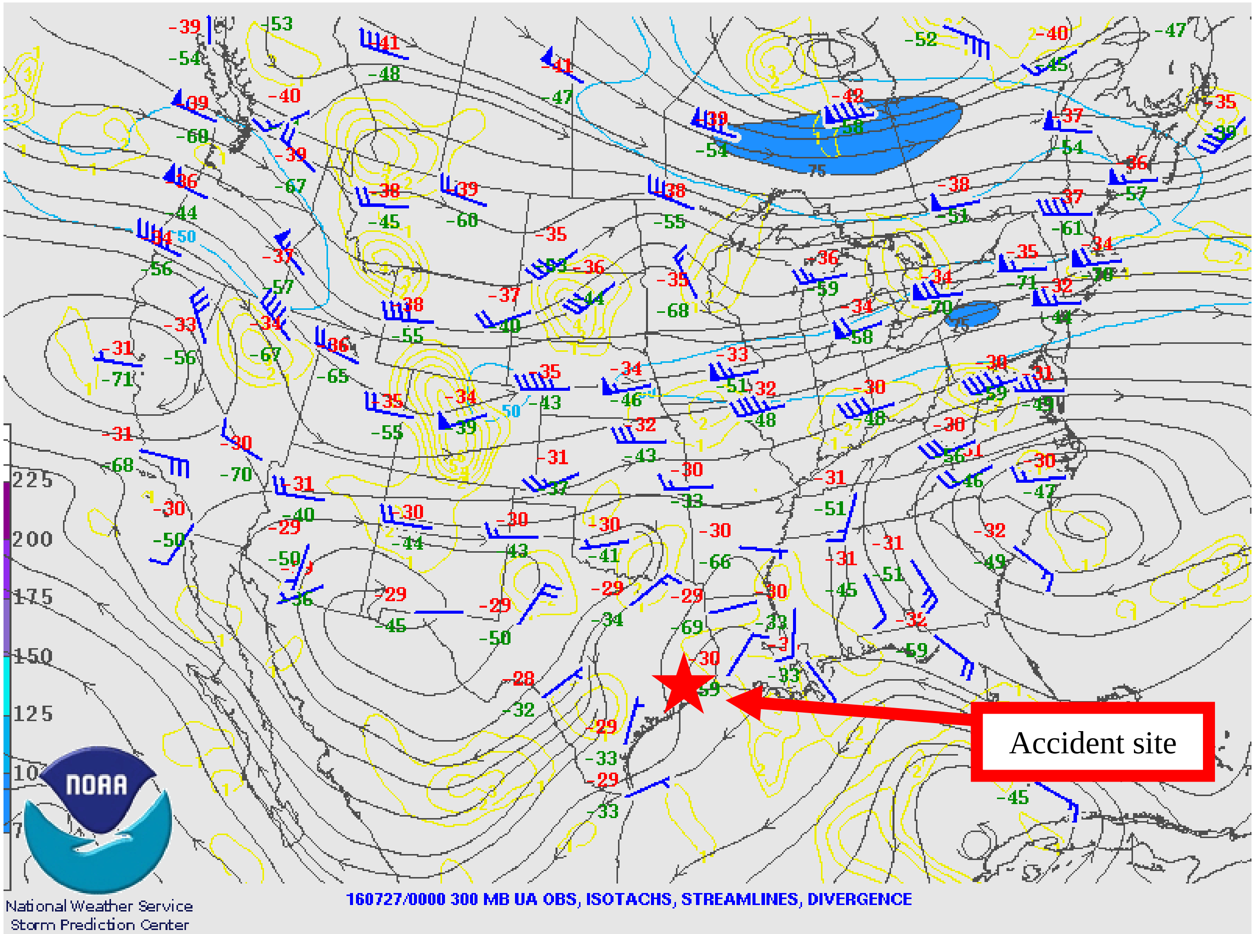

Figure 6 – 300-hPa Constant Pressure Chart for 1900 CDT

2.0 Storm Prediction Center Products

The SPC issued the following Day 1 Convective Outlook at 1450 CDT (figure 7) with areas of general (non-severe) thunderstorms forecast for the accident site during the accident day:

SPC AC 261950

DAY 1 CONVECTIVE OUTLOOK
NWS STORM PREDICTION CENTER NORMAN OK
0250 PM CDT TUE JUL 26 2016

VALID 262000Z - 271200Z

...THERE IS A SLGT RISK OF SVR TSTMS LATE THIS AFTERNOON AND EVENING ACROSS NORTHERN PORTIONS OF THE CENTRAL PLAINS...

...THERE IS A MRGL RISK OF SVR TSTMS ACROSS SURROUNDING AREAS OF THE PLAINS INTO THE UPPER GREAT LAKES REGION...

...THERE IS A MRGL RISK OF SVR TSTMS THIS AFTERNOON ACROSS PARTS OF THE MIDDLE OHIO VALLEY AND MID ATLANTIC COAST REGION...

...SUMMARY...
THUNDERSTORMS MAY PRODUCE SEVERE GUSTS AND LARGE HAIL THIS AFTERNOON AND EVENING OVER PARTS OF WESTERN AND CENTRAL NEBRASKA AND SOUTH DAKOTA.

...20Z OUTLOOK UPDATE...
SOME ADJUSTMENTS TO CATEGORICAL AND PROBABILISTIC LINES HAVE BEEN MADE...MAINLY TO BETTER ACCOUNT FOR ONGOING DESTABILIZATION AND CURRENT CONVECTIVE TRENDS.

IN THE EAST...LOW SEVERE WEATHER PROBABILITIES HAVE BEEN FOCUSED IN NARROW CORRIDOR NEAR THE NORTHERN PERIPHERY OF A WEAKENING SUBTROPICAL HIGH...AHEAD OF AN EASTWARD MIGRATING CONVECTIVELY GENERATED OR ENHANCED CYCLONIC VORTICITY CENTER NOW APPROACHING THE CENTRAL APPALACHIANS. WESTERLY MEAN FLOW AND SHEAR ACROSS THIS REGION ARE RATHER MODEST...BUT FORCING FOR ASCENT AND INSTABILITY MAY BE SUFFICIENT TO SUPPORT ONE OR TWO SMALL ORGANIZING CONVECTIVE CLUSTERS AND ASSOCIATED SURFACE COLD POOLS WITH SOME POTENTIAL FOR SUSTAINED STRONG SURFACE GUSTS.

ACROSS THE PLAINS...PRIMARY THUNDERSTORM DEVELOPMENT STILL SEEMS LIKELY TO BE FOCUSED NEAR A WEAK SURFACE FRONT AND LEE SURFACE TROUGHING TO THE EAST AND SOUTH OF THE BLACK HILLS REGION. BENEATH STEEP MID-LEVEL LAPSE RATES...MIXED-LAYER CAPE HAS BECOME LARGE IN THE PRESENCE OF SUFFICIENT VERTICAL SHEAR /LARGELY DUE TO VEERING OF WINDS WITH HEIGHT/ FOR ORGANIZED CONVECTIVE DEVELOPMENT...INCLUDING SUPERCELLS. THE MOST SUBSTANTIVE INCREASE IN STORM DEVELOPMENT MAY NOT OCCUR UNTIL AFTER 27/00Z...WITH INHIBITION STILL CONSIDERABLE ACROSS MUCH OF THE REGION. HOWEVER...STORM DEVELOPMENT DOES APPEAR UNDERWAY ACROSS THE BLACK HILLS.

..KERR.. 07/26/2016

.PREV DISCUSSION... /ISSUED 1130 AM CDT TUE JUL 26 2016/

...SYNOPSIS...
BASIC CONUS UPPER-AIR PATTERN THROUGH REMAINDER OF PERIOD WILL BE CHARACTERIZED BY...
1. STG ANTICYCLONE CENTERED OVER SRN GREAT BASIN REGION...MOVING LITTLE.
2. WRN EXTENSION OF BERMUDA HIGH OVER COASTAL CAROLINAS...FCST TO ERODE/SHIFT EWD OVER ATLC.
3. TROUGHING AND ASSOCIATED VORTICITY MAXIMA AND WEAK 500-MB LOWS IN SUBTROPICAL ELYS...INITIALLY EXTENDING FROM LOWER MS VALLEY SWWD ACROSS NWRN GULF AND LOWER TX COAST REGION. SRN PART IS EXPECTED TO PROCEED WWD OVER S TX...LOWER RIO GRANDE VALLEY AND NERN MEX...WHILE NRN LOBE SHIFTS NNWWD FROM MS TO SRN AR. THIS WILL CONTRIBUTE TO REGIONAL GEN-TSTM POTENTIAL THROUGHOUT PERIOD.
4. BELT OF NEARLY ZONAL FLOW OVER NRN CONUS AND SRN CANADA...WITH SEVERAL EMBEDDED/LOW-AMPLITUDE SHORTWAVES. OF THOSE...TWO MAIN PERTURBATIONS RELEVANT TO THIS OUTLOOK ARE EVIDENT IN MOISTURE-CHANNEL IMAGERY AND UPPER-AIR ANALYSES...
...A. OVER IA/IL/MO...AND FCST TO MOVE EWD TO OH BY 12Z...WITH GRADUAL WEAKENING.
...B. OVER ERN MT AND NRN WY...FCST TO MOVE EWD WITH SOME SWD EXPANSION POSSIBLE THIS EVENING AND TONIGHT BY MEANS OF CONVECTIVE

SUPPLEMENTATION OF VORTICITY.

AT SFC...15Z ANALYSIS SHOWED COLD FRONT OFFSHORE SRN NEW ENGLAND COAST AND WSWWD ACROSS SRN DELMARVA..BECOMING WAVY/QUASISTATIONARY WWD THROUGH WEAK LOWS OVER SRN INDIANA AND NERN OK...THEN DIFFUSE SWWD THROUGH OUTFLOW FROM CENTRAL OK CONVECTION OF LAST NIGHT. FRONTAL ZONE SHOULD REMAIN QUASISTATIONARY OVERLAND FROM MO EWD TODAY...MODULATED ON MESOBETA TO LOCAL SCALES BY CONVECTIVELY GENERATED BAROCLINICITY. WRN PORTION WILL BECOME DIFFUSE ACROSS SRN PLAINS AS LOW DEVELOPS ALONG OUTFLOW BOUNDARY AND QUASISTATIONARY FRONTAL ZONE OVER NWRN NEB/SWRN SD AREA. THAT FRONT WILL EXTEND NEWD ACROSS SD THEN ENEWD OVER CENTRAL MN..BECOMING COLD FRONT FARTHER E OVER NWRN ONT...MOVING OVER LS TO UPPER MI TONIGHT.

...N-CENTRAL PLAINS TO UPPER MI...
EPISODIC CLUSTERS OF TSTMS SHOULD DEVELOP THROUGH THIS EVENING NEAR AND SE OF FRONTAL ZONE...OUTFLOW BOUNDARY AND LEE TROUGH...AS WELL AS OVER BLACK HILLS. THIS WILL BE IN ADDITION TO ANY ONGOING... ISOLATED/MRGL HAIL POTENTIAL FROM TSTMS OVER NERN SD. DAMAGING GUSTS AND LARGE HAIL WILL BE PRIMARY CONCERNS. AXIS OF WIND THREAT IS SOMEWHAT DISPLACED E AND SE OF THAT FOR HAIL...GIVEN LIKELIHOOD OF EVOLUTION FROM MORE HAIL-SUPPORTING EARLY/DISCRETE MODES TO WIND-CONDUCIVE AGGREGATED CLUSTERS WITH TIME.

NARROW/S-N CORRIDOR OF FAVORABLE LOW-LEVEL MOISTURE WAS EVIDENT IN 925- AND 850-MB ANALYSES THIS MORNING...ATOP SFC DEW POINTS GENERALLY 60S F. THIS WILL SUPPORT 1500-3000 J/KG MLCAPE THIS AFTN BENEATH STEEP MIDLEVEL LAPSE RATES OF 8-9 DEG C/KM. 25-40 KT EFFECTIVE-SHEAR MAGNITUDES WILL SUPPORT MAINLY ORGANIZED MULTICELLS...THOUGH TRANSIENT SUPERCELL STRUCTURES ALSO ARE POSSIBLE. MOIST PLUME WILL SHIFT EWD SOMEWHAT FROM LATE AFTN THROUGH EVENING...BUT NOT AS FAST AS CONVECTIVE MOTION. SEVERAL HOURS OF TIME WINDOW FOR UPSCALE GROWTH OF AFTN CONVECTION INTO MCS WILL BE AVAILABLE ACROSS PORTIONS SD/NEB. THROUGH LATE-EVENING AND OVERNIGHT HOURS...TSTM COVERAGE AND OVERALL SVR THREAT ARE EXPECTED TO DIMINISH WITH TIME. ACTIVITY SHOULD ENCOUNTER PROGRESSIVELY LOWER-THETAE AIR WITH EWD EXTENT...RELATED TO COMBINATION OF DIABATIC SFC STABILIZATION AND RELATIVELY DRY TRAJECTORIES EMANATING FROM LOW-LEVEL ANTICYCLONE THAT FOLLOWED PASSAGE OF SRN FRONTAL ZONE.

ADDITIONAL TSTMS SHOULD DEVELOP ALONG PREFRONTAL SFC CONFLUENCE ZONES AND LAKE-BREEZE BOUNDARIES OVER PORTIONS MN/NRN WI/UPPER MI...PRIMARILY DURING AFTN AND INTO EARLY EVENING WHEN CAPE IS MAXIMIZED AND MLCINH IS MINIMIZED. ISOLATED DAMAGING GUSTS AND LARGE HAIL WILL BE POSSIBLE.

...TIDEWATER TO LOWER OH VALLEY...
IN ADDITION TO ONGOING CONVECTION OVER SRN INDIANA...WIDELY SCATTERED TO SCATTERED TSTMS ARE EXPECTED TO DEVELOP NEAR AND S OF FRONTAL ZONE THROUGH AFTN ACROSS MUCH OF THIS CORRIDOR. MAIN CONCERN WILL BE SPORADIC DAMAGING WINDS AND ISOLATED SVR GUSTS. THIS REGION WILL RESIDE ALONG SRN RIM OF WLYS ALOFT...AND JUST N OF WEAK RIDGING EXTENDING WWD FROM BERMUDA HIGH. SUBTLE FORCING FOR ASCENT PRECEDING WEAKENING MIDLEVEL SHORTWAVE TROUGH ALSO MAY SUPPORT CONVECTIVE POTENTIAL ACROSS WRN/NWRN PORTIONS OF OUTLOOK

AREA.

MORNING RAOBS AND SFC ANALYSIS SHOW RICH LOW-LEVEL MOISTURE SURMOUNTED BY MODEST MIDLEVEL LAPSE RATES...WITH PW GENERALLY 1.5-2 INCHES AND SFC DEW POINTS 70S F...EXCEPT 60S AT HIGHER ELEVATIONS IN APPALACHIANS. VIS IMAGERY SHOWS LITTLE SUBSTANTIAL CLOUD COVER AWAY FROM ONGOING CONVECTION. THIS WILL FOSTER SUSTAINED...STG SFC HEATING THAT WILL ERODE MLCINH AND SUPPORT TSTM DEVELOPMENT TODAY...OFFSETTING THOSE MODEST LAPSE RATES ALOFT ENOUGH TO YIELD MLCAPE 1000-2500 J/KG. LIGHT LOW-LEVEL WINDS WITH PREDOMINANT WLY COMPONENT WILL LIMIT VERTICAL SHEAR...WITH PULSE AND MULTICELLULAR MODES LIKELY. OUTFLOWS AND SEA BREEZES WILL BECOME INCREASINGLY IMPORTANT WITH TIME THIS AFTN INTO EARLY EVENING AS FOCI FOR SUBSEQUENT STAGES OF TSTM DEVELOPMENT...UNTIL COMBINATION OF EVENING NOCTURNAL COOLING AND INCREASING COVERAGE OF OUTFLOW AIR REDUCES TSTM INTENSITY/COVERAGE.

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

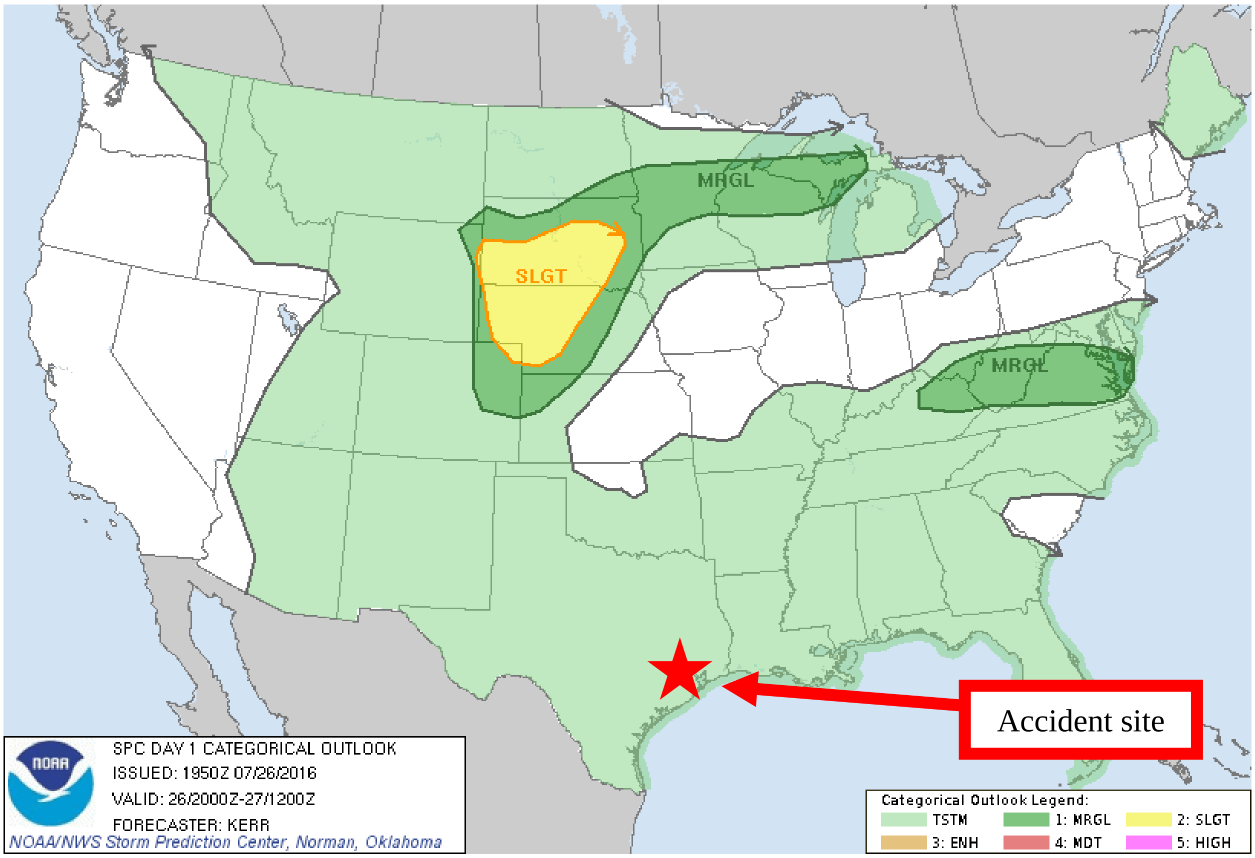

Figure 7 – Storm Prediction Center day 1 Convective Outlook valid at the time of the accident

3.0 Surface Observations

The area surrounding the accident site was documented using official Meteorological Aerodrome Reports (METARs) and Specials (SPECIs). The following observations were taken from standard code and are provided in plain language.

Sugar Land Regional Airport (KSGR/SGR)[2] was the accident airport and the closest official weather station to the accident site located 17 miles southwest of Houston, Texas. KSGR had an Automated Surface Observing System (ASOS[3]) whose reports were supplemented by Air Traffic Control. KSGR air traffic control tower was Limited Aviation Weather Reporting Station (LAWRS) certified. KSGR was at an elevation of 82 feet and had a 5° easterly magnetic variation.[4] The following observations were taken and disseminated during the times surrounding the accident[5]:

[1424 CDT] KSGR 261924Z 31007KT 1 1/2SM VCTS +RA BR FEW020 BKN028 OVC050 25/23 A2994 RMK AO2 LTG DSNT ALQDS TSE24 P0019 T02500228=

[1432 CDT] KSGR 261932Z 29007KT 1 3/4SM -TSRA BR FEW021 BKN034 OVC055 25/23 A2993 RMK AO2 LTG DSNT ALQDS TSE24B32 P0021 T02500228=

[1434 CDT] KSGR 261934Z 30007KT 3SM -TSRA BR FEW027 BKN034 OVC055 25/23 A2993 RMK AO2 LTG DSNT ALQDS TSE24B32 P0021 T02500228=

[1453 CDT] KSGR 261953Z 30007KT 10SM -TSRA SCT015 BKN035 OVC060 24/23 A2993 RMK AO2 LTG DSNT NW-E TSE24B32 SLP138 P0021 T02440228=

[1501 CDT] KSGR 262001Z 13004KT 3SM +TSRA BR BKN015 BKN025 OVC047 24/23 A2994 RMK AO2 LTG DSNT NE AND E AND W P0008 T02440228 $=

[1506 CDT] KSGR 262006Z 13008KT 3SM +TSRA BR FEW007 BKN013 OVC037 24/23 A2994 RMK AO2 LTG DSNT E AND W AND NW P0027 T02440228 $=

ACCIDENT TIME 1510 CDT

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[2] Both KSGR, the International Civil Aviation Organization (ICAO) identifier, and SGR, the International Air Transport Association (IATA) identifier are used throughout this report. The KSGR identifier typically refers to weather information in this report, while SGR refers to the airport or procedures for the airport in this report.

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

[4] Magnetic variation – The angle (at a particular location) between magnetic north and true north. 2000, latest measurement taken from http://www.airnav.com/airport/KSGR

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

[1517 CDT] ***KSGR 262017Z 18013G19KT 3SM +TSRA BR FEW008 BKN011 OVC018 24/23 A2994 RMK AO2 LTG DSNT E AND NW ACFT MISHAP P0097 T02440233 $=***

[1528 CDT] ***KSGR 262028Z 19009KT 3SM +TSRA BR FEW007 OVC011 24/23 A2993 RMK AO2 WSHFT 2008 LTG DSNT E AND SE AND NW ACFT MISHAP P0154 T02390233 $=***

[1553 CDT] KSGR 262053Z 22005KT 3SM +TSRA BR OVC025 24/23 A2993 RMK AO2 WSHFT 2008 LTG DSNT ALQDS SLP138 ACFT MISHAP P0239 60263 T02390228 51004=

[1558 CDT] KSGR 262058Z 22005KT 1SM +TSRA BR OVC031 24/23 A2993 RMK AO2 LTG DSNT ALQDS P0002 T02390228=

[1603 CDT] KSGR 262103Z 22005KT 1 1/4SM +RA BR BKN031 BKN048 OVC080 24/23 A2993 RMK AO2 TSE01 P0004 T02390228=

KSGR weather at 1501 CDT was reported as wind from 130° at 4 knots, 3 miles visibility, thunderstorm and heavy rain, mist, a broken ceiling at 1,500 above ground level (agl), broken skies at 2,500 feet agl, overcast skies at 4,700 feet agl, temperature of 24° C, dew point temperature of 23° C, and an altimeter setting of 29.94 inches of mercury. Remarks, automated station with precipitation discriminator, lightning distant[6] northeast and east and west, precipitation of 0.08 inches since 1453 CDT, temperature 24.4° C, dew point temperature 22.8° C, maintenance is needed on the system.

KSGR weather at 1506 CDT was reported as wind from 130° at 8 knots, 3 miles visibility, thunderstorm and heavy rain, mist, few clouds at 700 feet agl, a broken ceiling at 1,300 agl, overcast skies at 3,700 feet agl, temperature of 24° C, dew point temperature of 23° C, and an altimeter setting of 29.94 inches of mercury. Remarks, automated station with precipitation discriminator, lightning distant east and west and northwest, precipitation of 0.27 inches since 1453 CDT, temperature 24.4° C, dew point temperature 22.8° C, maintenance is needed on the system.

KSGR weather at 1517 CDT was reported as wind from 180° at 13 knots with gusts to 19 knots, 3 miles visibility, thunderstorm and heavy rain, mist, few clouds at 800 feet agl, a broken ceiling at 1,100 agl, overcast skies at 1,800 feet agl, temperature of 24° C, dew point temperature of 23° C, and an altimeter setting of 29.94 inches of mercury. Remarks, automated station with precipitation discriminator, lightning distant east and northwest, aircraft mishap, precipitation of 0.97 inches since 1453 CDT, temperature 24.4° C, dew point temperature 23.3° C, maintenance is needed on the system.

[6] Distant indicated that the lightning was beyond 10 miles but less than 30 miles from the center of the airport (or airport location point, ALP).

KSGR weather at 1528 CDT was reported as wind from 190° at 9 knots, 3 miles visibility, thunderstorm and heavy rain, mist, few clouds at 700 feet agl, an overcast ceiling at 1,100 agl, temperature of 24° C, dew point temperature of 23° C, and an altimeter setting of 29.93 inches of mercury. Remarks, automated station with precipitation discriminator, wind shift at 1508 CDT, lightning distant east and southeast and northwest, aircraft mishap, precipitation of 1.54 inches since 1453 CDT, temperature 23.9° C, dew point temperature 23.3° C, maintenance is needed on the system.

3.1 One Minute Wind Observations

The one-minute KSGR ASOS surface data was provided by the NWS for the time surrounding the accident. One-minute raw visibility extinction coefficient data was provided along with the one-minute raw wind data with two separate magnitudes and wind directions[7]. The visibility extinction coefficient is used to determine the visibility at the ASOS and the ASOS sensor samples visibility once every 30 seconds (table 1). For more information on the visibility and calculations therein please see attachment 1. The first wind data in table 1 is the two-minute average wind speed, which was updated every 5 seconds and reported once a minute. The second source of one-minute wind data is the five-second maximum wind average, which was updated every five seconds and reported once every minute (table 1). The one-minute observation of the present weather occurring, liquid equivalent accumulation, temperature, and dew point are provided in table 2. The following tables provide the meteorological data in local time (CST)[8] as well as UTC time.

[7] The wind directions are in reference to true north.
[8] The one-minute wind observations from an ASOS are not automatically reported in daylight time.

Time (CST)	Time (UTC)	visibility extinction coefficient	FLAG1 visibility daytime	Dir of 2min avg wind	Speed of 2 min avg wind (knots)	Dir of max 5 sec avg wind	Speed of max 5 sec avg wind (knots)
1350	1950	0.149	D	300	5	312	7
1351	1951	0.176	D	300	6	299	8
1352	1952	0.19	D	297	7	303	9
1353	1953	0.209	D	300	7	301	8
1354	1954	0.265	D	301	6	306	8
1355	1955	1.143	D	297	5	285	7
1356	1956	7.025	D	292	4	285	4
1357	1957	[7.887]	D	283	2	322	2
1358	1958	4.362	D	250	1	248	3
1359	1959	2.036	D	190	2	180	3
1400	2000	1.462	D	143	3	135	4
1401	2001	1.185	D	129	4	125	6
1402	2002	1.479	D	131	5	128	7
1403	2003	1.833	D	126	7	131	9
1404	2004	2.836	D	131	9	148	13
1405	2005	5.358	D	138	10	139	11
1406	2006	6.229	D	126	8	128	11
1407	2007	5.506	D	136	10	161	15
1408	2008	6.096	D	153	10	155	16
1409	**2009**	**8.016**	**D**	**154**	**11**	**159**	**16**
1410	**2010**	**8.379**	**D**	**152**	**11**	**152**	**12**
1411	**2011**	**8.124**	**D**	**154**	**10**	**151**	**12**
1412	2012	8.444	D	157	10	154	13
1413	2013	6.647	D	169	11	187	14
1414	2014	6.946	D	181	12	172	14
1415	2015	7.69	D	180	13	174	16

Table 1 – One-minute KSGR ASOS data for the time surrounding the accident

Time (CST)	Time (UTC)	present weather occurring	liquid equivalent accumulated	temperature (°F)	dew point temperature (°F)
1350	1950	NP	0	76	73
1351	1951	R-	0	76	73
1352	1952	R-	0	76	73
1353	1953	R-	0	76	73
1354	1954	R-	0	76	73
1355	1955	R-	0.02	76	73
1356	1956	R+	0.03	76	73
1357	1957	R+	0.01	76	73
1358	1958	R+	0.01	76	73
1359	1959	R+	0	76	73
1400	2000	R+	0.01	76	73
1401	2001	R+	0	76	73
1402	2002	R+	0.01	76	73
1403	2003	R+	0.01	77	74
1404	2004	R+	0.03	77	74
1405	2005	R+	0.07	76	73
1406	2006	R+	0.07	76	73
1407	2007	R+	0.06	76	73
1408	2008	R+	0.05	76	73
1409	**2009**	**R+**	**0.1**	**76**	**74**
1410	**2010**	**R+**	**0.07**	**76**	**74**
1411	**2011**	**R+**	**0.06**	**76**	**74**
1412	2012	R+	0.06	76	74
1413	2013	R+	0.05	76	74
1414	2014	R+	0.06	76	74
1415	2015	R+	0.07	76	74

Table 2 – Additional one-minute KSGR ASOS data for the time surrounding the accident

At 1509 CDT, KSGR reported the one-minute visibility of three-eighths of a mile, two-minute average wind from 154° at 11 knots, a five-second maximum average wind from 159° at 16 knots, heavy rain, one-minute precipitation accumulation of 0.10 inches, temperature of 76° F, and a dew point temperature of 74° F.

At 1510 CDT, KSGR reported the one-minute visibility of three-eighths of a mile, two-minute average wind from 152° at 11 knots, a five-second maximum average wind from 152° at 12 knots, heavy rain, one-minute precipitation accumulation of 0.07 inches, temperature of 76° F, and a dew point temperature of 74° F.

At 1511 CDT, KSGR reported the one-minute visibility of three-eighths of a mile, two-minute average wind from 154° at 10 knots, a five-second maximum average wind from 151° at 12 knots, heavy rain, one-minute precipitation accumulation of 0.06 inches, temperature of 76° F, and a dew point temperature of 74° F. For more one-minute observational data from KSGR please see attachment 2.

3.2 SGR ASOS Local Data

The ASOS equipment was located three-eighths of a mile south-southeast of the SGR air traffic control tower (figure 8). Figure 9 shows a view from the ASOS equipment looking north-northwestward toward the air traffic control tower. The ASOS equipment including the visibility sensor was operating during normal parameters around the time of the accident. A NWS technician from the Houston/Galveston, Texas office had serviced the SGR ASOS equipment on July 18, 2016, including cleaning off the visibility (figure 10) sensor lenses and other equipment.

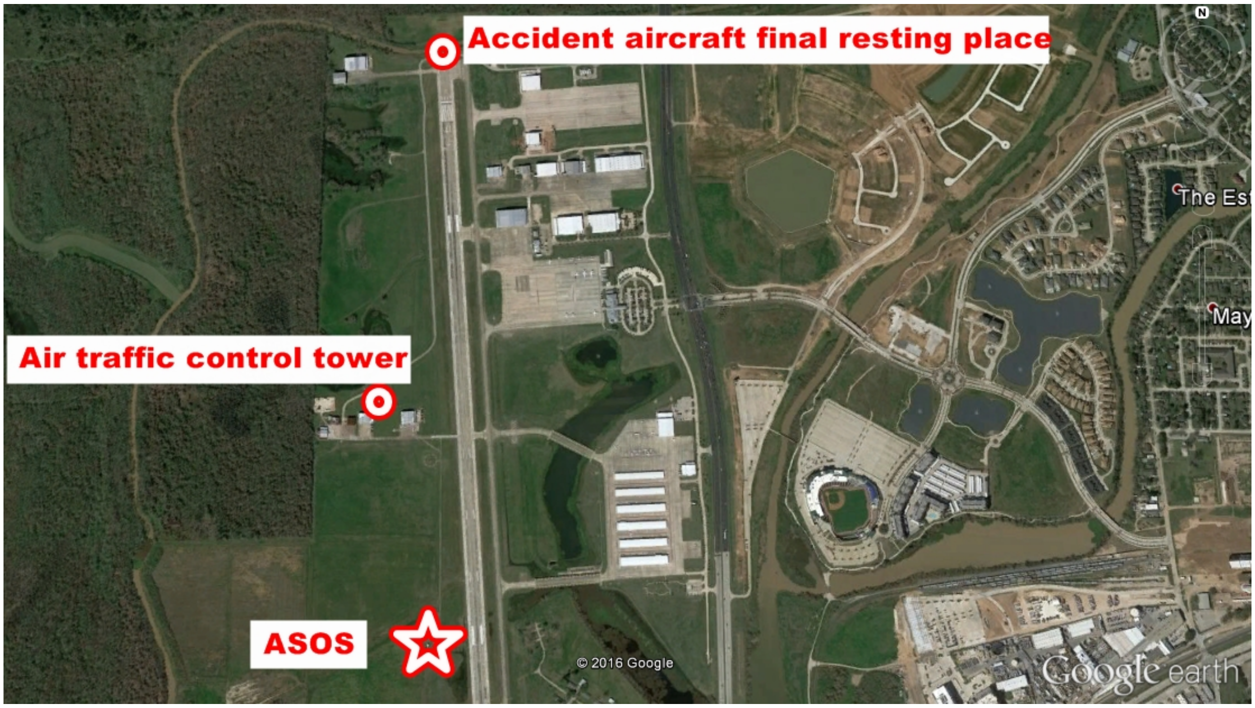

Figure 8 – SGR airport overview diagram

Figure 9 – SGR ASOS equipment and air traffic control tower

Figure 10 – SGR ASOS visibility equipment

4.0 Upper Air Data

A North American Mesoscale (NAM) model sounding was created for the accident site for 1600 CDT. The 1600 CDT NAM sounding was plotted on a standard Skew-T log P diagram[9] with the derived stability parameters included in figure 11 (with data from the surface to 150-hPa, or 45,000 feet msl.) This sounding was analyzed utilizing the RAOB[10] software package. The sounding depicted the lifted condensation level (LCL)[11] at 1,930 feet msl, a convective condensation level (CCL)[12] of 2,736 feet, and a level of free convection (LFC)[13] at 1,930 feet. The freezing level was located at 15,789 feet. The precipitable water value was 2.48 inches, and 2.48 inches was above both the daily max moving averages at Lake Charles, Louisiana (LCH), and CRP, the two closest upper air soundings to the accident site.[14]

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[9] 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.
[10] RAOB – (The complete Rawinsonde Observation program) is an interactive sounding analysis program developed by Environmental Research Services, Matamopras, Pennsylvania.
[11] LCL - The height at which a parcel of moist air becomes saturated when it is lifted dry adiabatically.
[12] 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.
[13] LFC – The level at which a parcel of saturated air becomes warmer than the surrounding air and begins to rise freely. This occurs most readily in a conditionally unstable atmosphere.
[14] http://www.spc.noaa.gov/exper/soundingclimo/

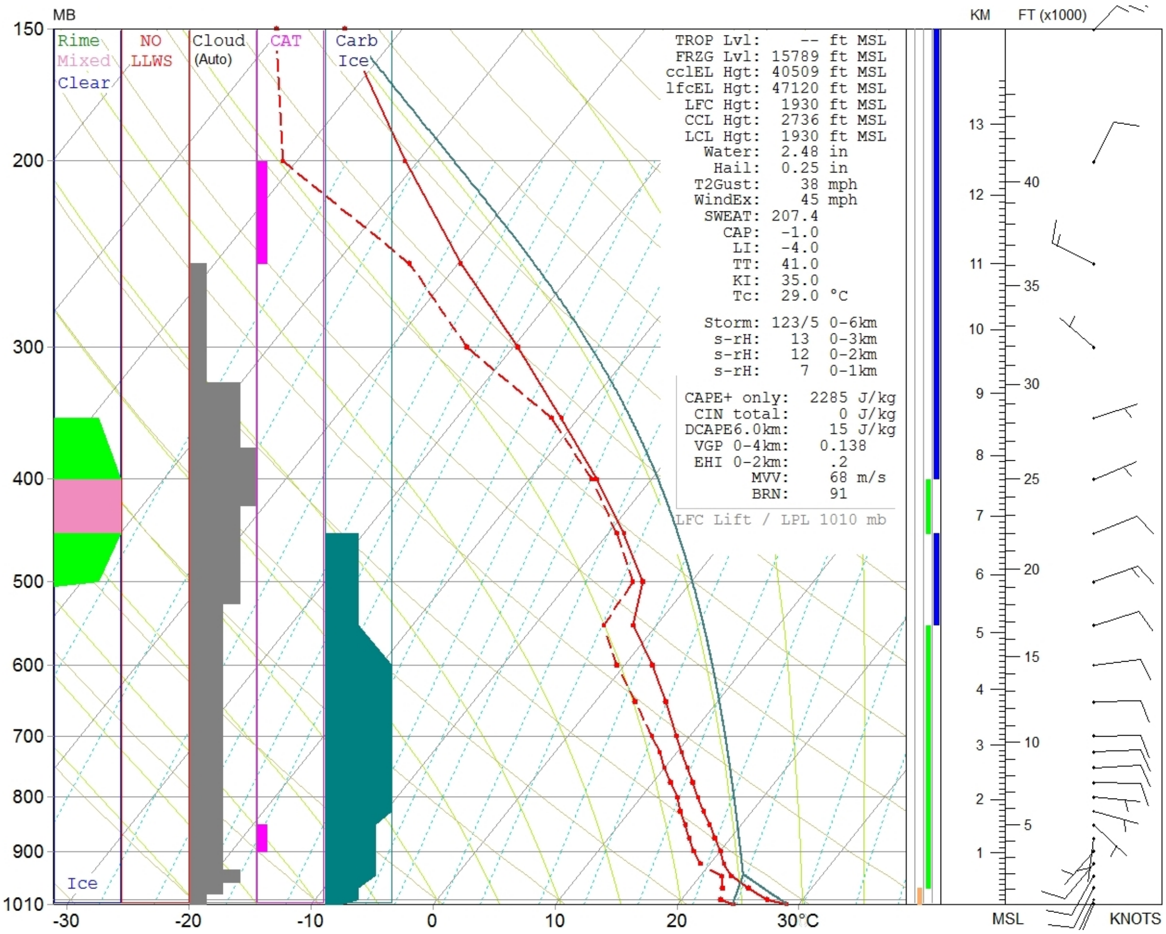

Figure 11 – 1600 CDT NAM sounding for the accident site

The 1600 CDT NAM sounding indicated a conditionally unstable environment with 2,285 J/kg of CAPE[15] lifting a parcel from the ground. The maximum vertical velocity (MVV)[16] possible within rain showers or thunderstorm updrafts was 68 meters per second (m/s) or 132 knots given the 1600 CDT NAM sounding environment. RAOB identified the possibility of clouds between the surface and 37,000 feet msl. No areas of icing were indicated by RAOB for below 15,000 feet msl. If rain showers or thunderstorms formed the 1600 CDT NAM sounding indicated the strongest wind speeds possible with a microburst, outflow boundary, or gust front would have been 38 mph (33 knots) as indicated by the T2Gust parameter or 45 mph (39 knots) as indicated by the WindEx parameter.

The sounding wind profile indicated a surface wind from 202° at 10 knots with the wind shifting to the east by 5,000 feet msl. The wind speed remained below 15 knots from the surface through 20,000 feet msl. RAOB did not indicate the possibility of low-level wind shear (LLWS) outside of rain shower or thunderstorm activity. Two layers of possible clear-air turbulence were indicated between the surface and 45,000 feet msl.

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

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

5.0 Satellite Data

Visible and infrared data from the Geostationary Operational Environmental Satellite number 13 (GOES-13) was obtained from an archive at the Space Science Engineering Center at the University of Wisconsin-Madison in Madison, Wisconsin, and processed using the NTSB's Man-computer Interactive Data Access System software. Visible and infrared imagery (GOES-13 bands 1 and 4) at wavelengths of 0.65 microns (µm) and 10.7 µm retrieved brightness temperatures for the scene. Satellite imagery surrounding the time of the accident, from 1100 CDT through 1800 CDT at approximately 15-minute intervals, were reviewed and the images most applicable to the time of the accident are documented here.

Figures 12 and 13 present the GOES-13 visible imagery from 1500 and 1515 CDT at 2X magnification with the accident site highlighted with a red square. Inspection of the visible imagery indicated a general east to west movement of the clouds over the accident site at the accident time with cumuliform clouds above the accident site (attachment 3). Figure 14 presents the GOES-13 infrared imagery from 1515 CDT at 6X magnification with the accident site highlighted with a red square. Inspection of the infrared imagery indicated abundant clouds over the accident site at the accident time. The cooler brightness temperatures and cloud tops (blue and green colors) were over the accident site at the accident time. Based on the brightness temperatures above the accident site and the vertical temperature profile provided by the 1600 CDT NAM sounding, the approximate cloud-top heights over the accident site were 42,000 feet at 1515 CDT. It should be noted these figures have not been corrected for any parallax error.

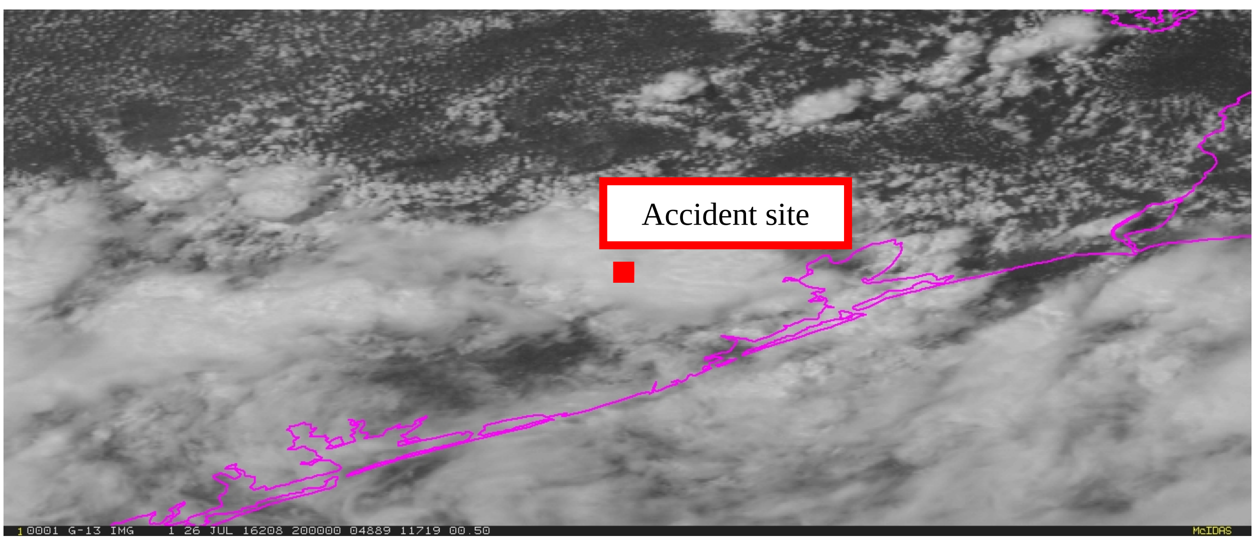


Figure 12 – GOES-13 visible image at 1500 CDT

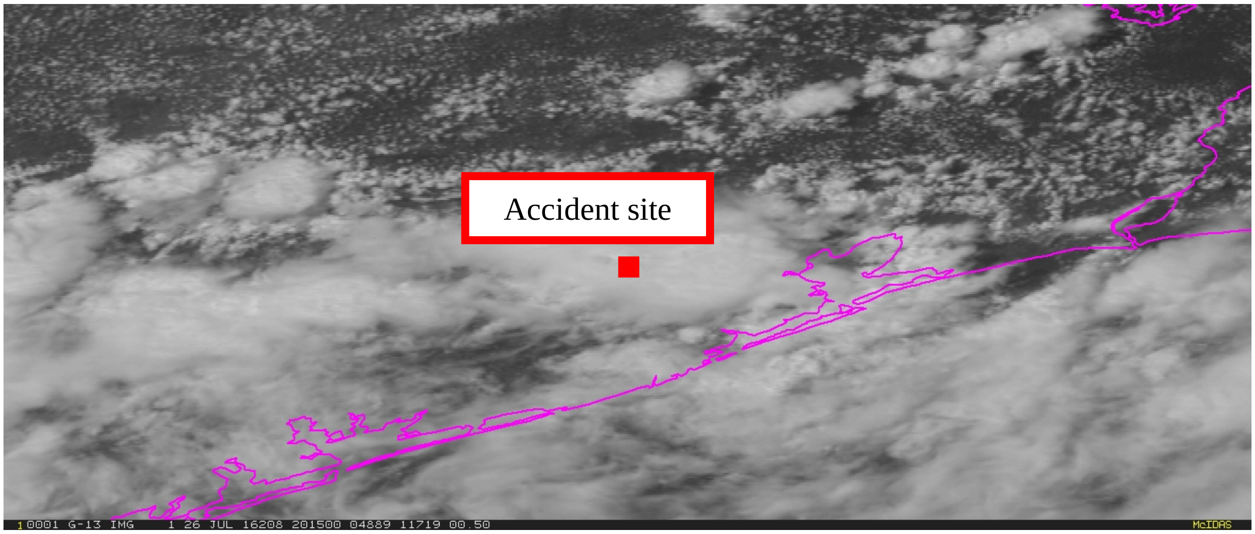


Figure 13 – GOES-13 visible image at 1515 CDT

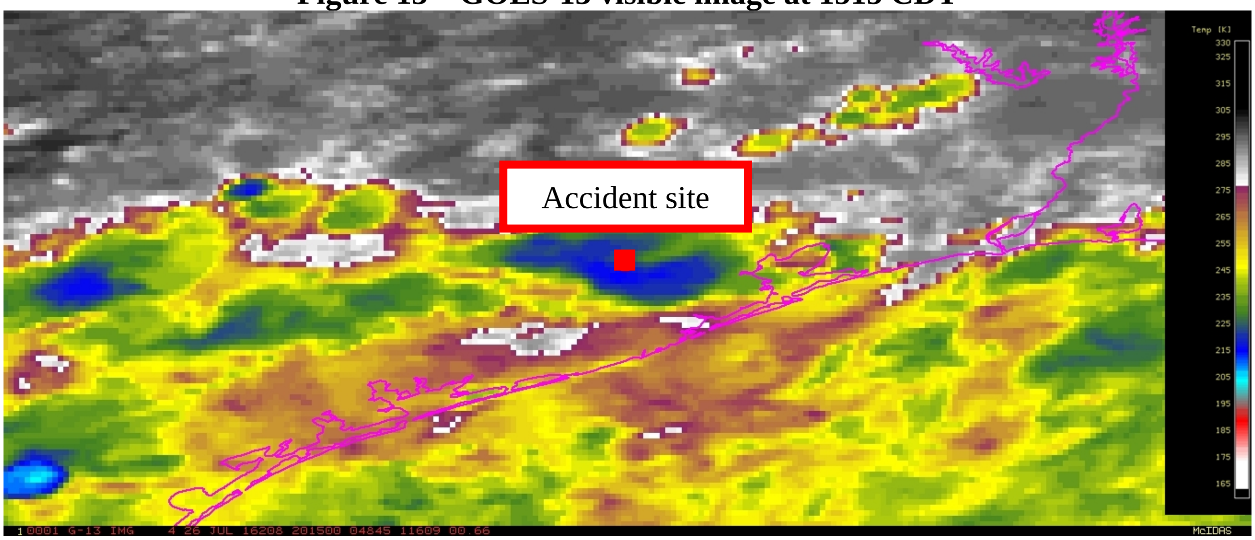


Figure 14 – GOES-13 infrared image at 1515 CDT

6.0 Radar Imagery Information

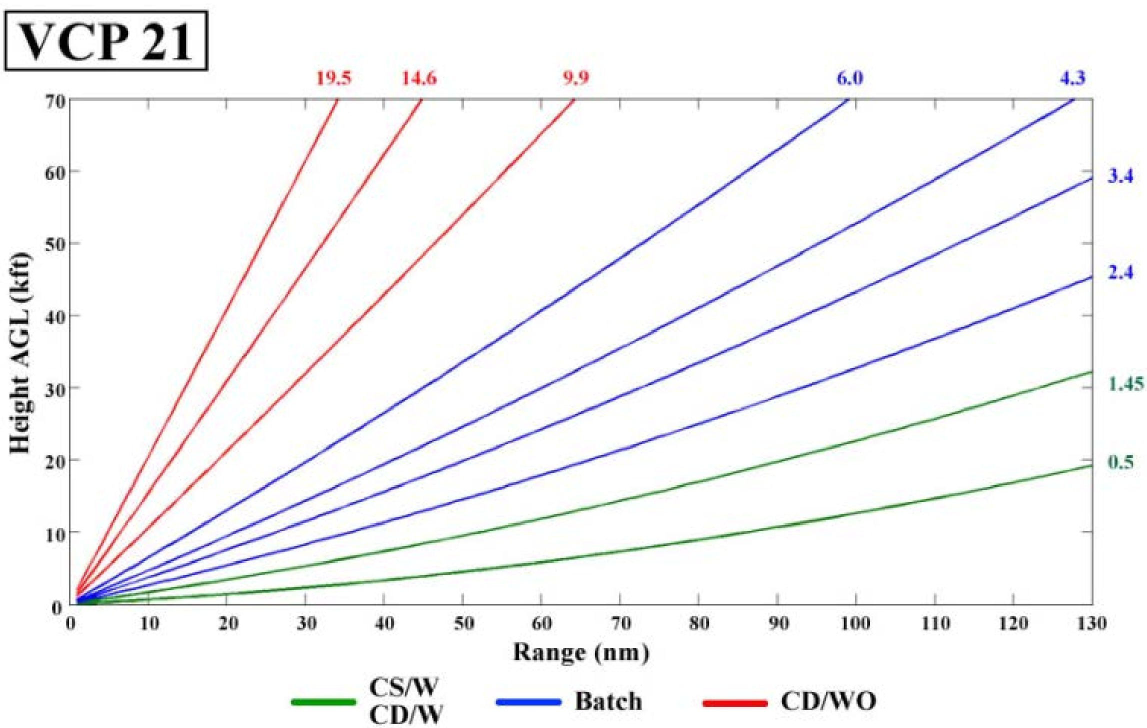
The closest NWS Weather Surveillance Radar-1988, Doppler (WSR-88D)[17] was Houston, Texas, (KHGX), located 31 miles east-southeast of the accident site. Level II and III archive radar data was obtained from the NCEI utilizing the NEXRAD Data Inventory Search and displayed using the NOAA's Weather and Climate Toolkit software.

[17] 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.

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 four and a half 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 six minutes. This particular scanning strategy is documented as volume coverage pattern 21 (VCP-21). Mode B is the clear-air mode, where the radar makes 5 elevation scans during a ten minute period. During the period surrounding the accident, the KHGX WSR-88D radar was operating in the precipitation mode (Mode A, VCP-21). The following chart provides an indication of the different elevation angles in this VCP, and the approximate height and width of the radar beam with distance from the radar site.



VCP-21 Precipitation Mode Scan Strategy

6.2 Beam Height Calculation

Assuming standard refraction[18] of the WSR-88D 0.95° wide radar beam, the following table shows the approximate beam height and width[19] information[20] of the radar display over the site of the accident. The heights have been rounded to the nearest 10 feet.

ANTENNA ELEVATION	BEAM CENTER	BEAM BASE	BEAM TOP	BEAM WIDTH
0.5°	2,360 feet	830 feet	3,890 feet	3,060 feet

Based on the radar height calculations, the 0.5° elevation scan depicted the conditions between 830 feet and 3,890 feet msl over the accident site at the accident time and these are the closest altitudes to the accident site. [21]

6.3 Reflectivity

Reflectivity is the measure of the efficiency of a target in intercepting and returning radio energy. With hydrometeors[22] it is a function of the drop size distribution, number of particles per unit volume, physical state (ice or water), shape, and aspect. Reflectivity is normally displayed in decibels (dBZ[23]), and is a general measure of echo intensity. FAA Advisory Circular AC 00-24C, "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:

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

[19] Beam width – A measure of the angular width of a radar beam.

[20] Beamwidth values are shown for legacy resolution products. Super resolution products would an effective beamwidth that would be approximately half these values.

[21] For more information see the ATC data contained in the docket for this accident.

[22] 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.

[23] 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.

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

6.4 Radar Summary

Figure 15 provides a radar summary image from 1515 CDT with reflectivity values over the southern United States, with the accident site located in an area of 40 to 50 dBZ values. These reflectivity values indicated moderate to heavy echoes near the accident site around the accident time.

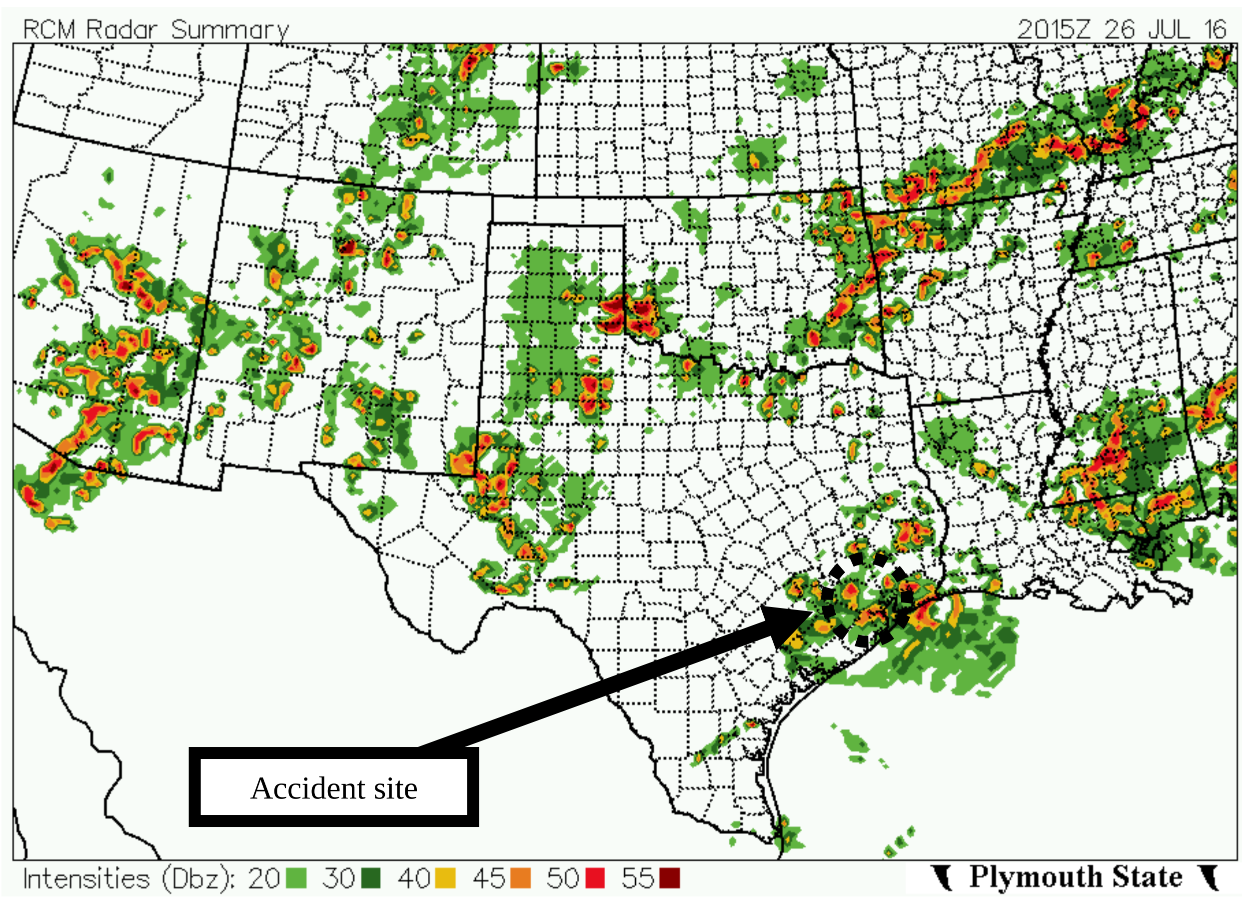


Figure 15 – Radar summary image for 1515 CDT with the accident site

6.5 Base Reflectivity and Lightning Data[24]

Figures 16, 17, and 18 present the KHGX WSR-88D base reflectivity images for the 0.5° elevation scan with a resolution of 0.5° X 250 meters at 1458, 1504, and 1510 CDT. An area of base reflectivity values up 55 dBZ was located above the last 3 minutes of the accident flight's track. There were three lightning flashes[25] that occurred within 0.90 miles of the accident flight during the last 5 minutes of the flight (figures 16 through 18 and attachment 4) [26]. Attachment 5 indicated that the thunderstorm activity and greater than 50 dBZ reflectivity values moved over SGR as early as 1458 CDT and the thunderstorm activity continued to slowly build northward past SGR through 1533 CDT. In addition to the lightning data, the KHGX 1-hour digital precipitation over SGR indicated that 2.00 to 2.40 inches of precipitation fell in the hour before 1550 CDT (attachment 6). The 1-hour digital precipitation from KHGX was very similar to the 2.39 inches of precipitation between 1453 and 1553 CDT observed by KSGR ASOS (section 3.0).

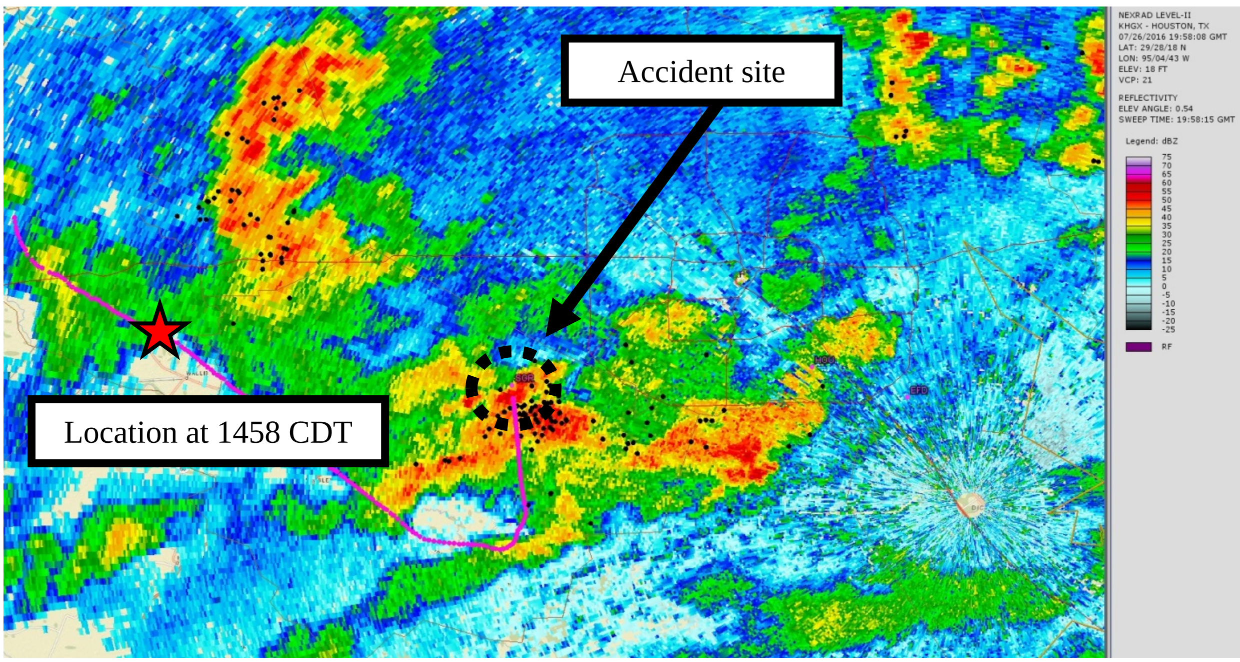


Figure 16 – KHGX WSR-88D base reflectivity for the 0.5° elevation scan initiated at 1458 CDT with ATC accident flight track from 1455 to 1510 CDT (pink line) and lightning strikes from 1455 to 1510 CDT (black dots)

[24] Lightning data was lightning flash data from Earth Networks Total Lightning Network
[25] Lightning Flash – This is one contiguous conducting channel and all the current strokes/pulses that flow through it. There are two types of flashes: ground flashes and cloud flashes.
[26] For more information see the ATC data contained in the docket for this accident.

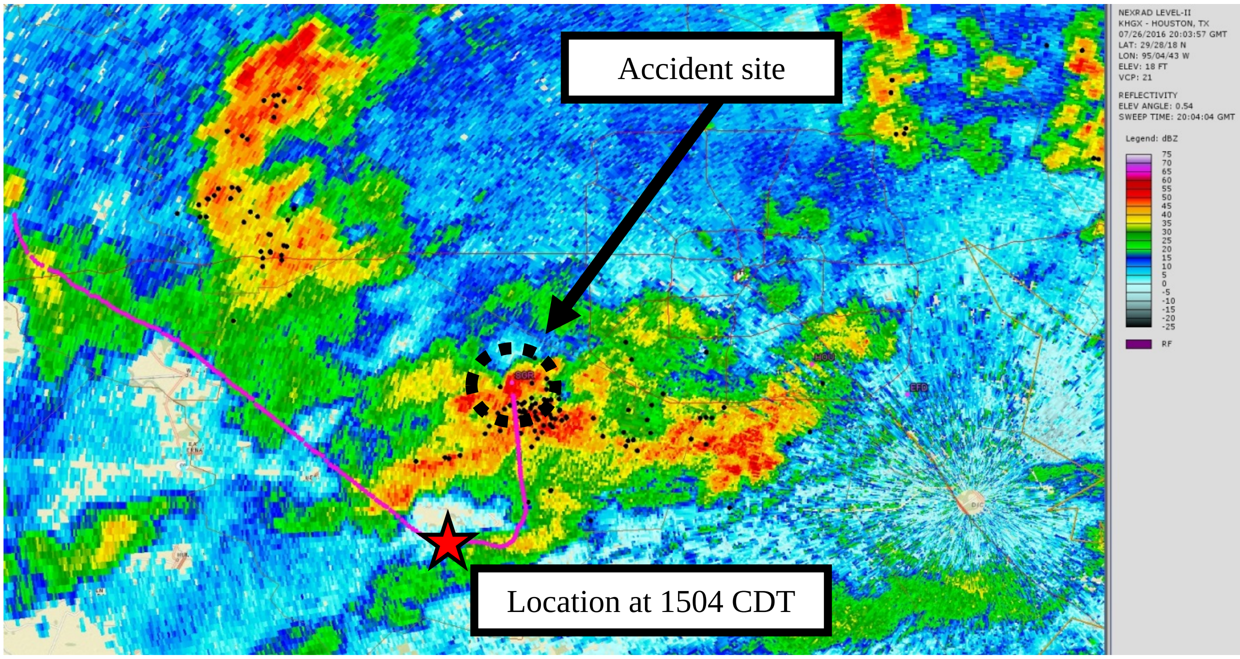


Figure 17 – KHGX WSR-88D base reflectivity for the 0.5° elevation scan initiated at 1504 CDT with ATC accident flight track from 1455 to 1510 CDT (pink line) and lightning strikes from 1455 to 1510 CDT (black dots)

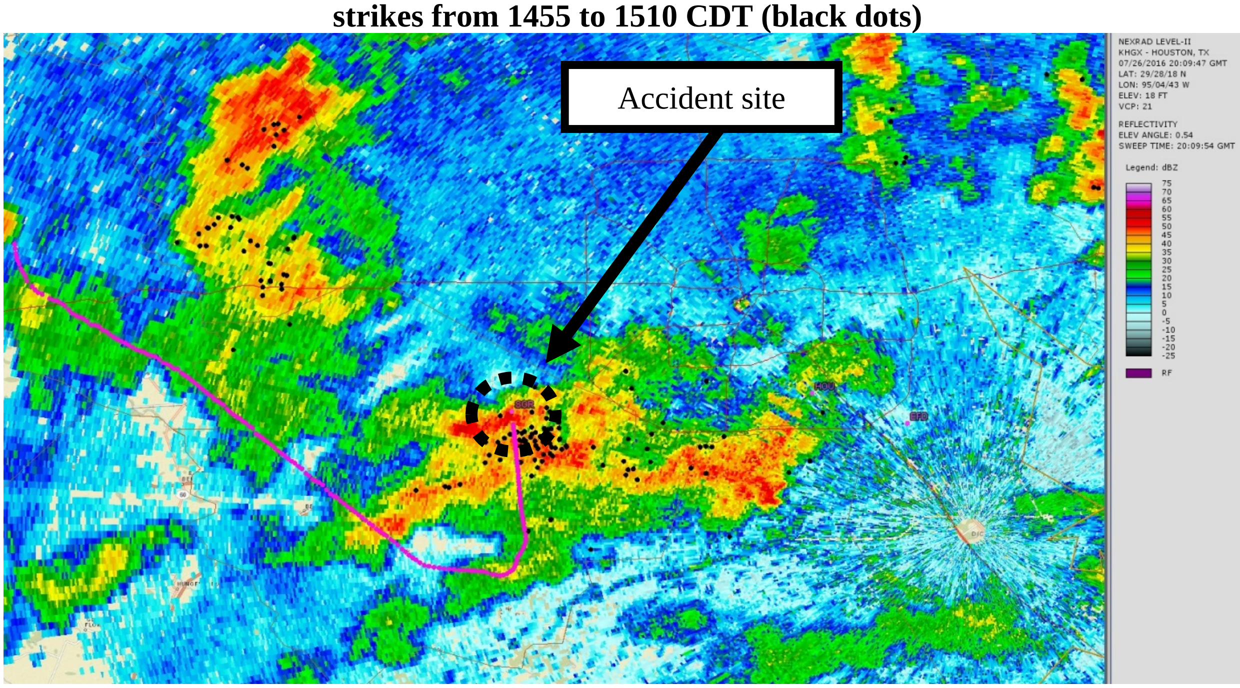


Figure 18 – KHGX WSR-88D base reflectivity for the 0.5° elevation scan initiated at 1510 CDT with ATC accident flight track from 1455 to 1510 CDT (pink line) and lightning strikes from 1455 to 1510 CDT (black dots)

6.6 Composite Reflectivity

Figures 19, 20, and 21 present the KHGX WSR-88D composite reflectivity images for 1458, 1504, and 1510 CDT with a resolution of 1 km X 1 km. An area of composite reflectivity values of 50 dBZ, or to VIP level 5 values (section 6.3), were located above the last 3 minutes of the accident flight's track. Reflectivity values of 35 to 50 dBZ surrounded SGR between 1458 CDT and 1510 CDT, with the largest concentration of 40 to 55 dBZ reflectivity values south of SGR and then eastward towards KHGX.

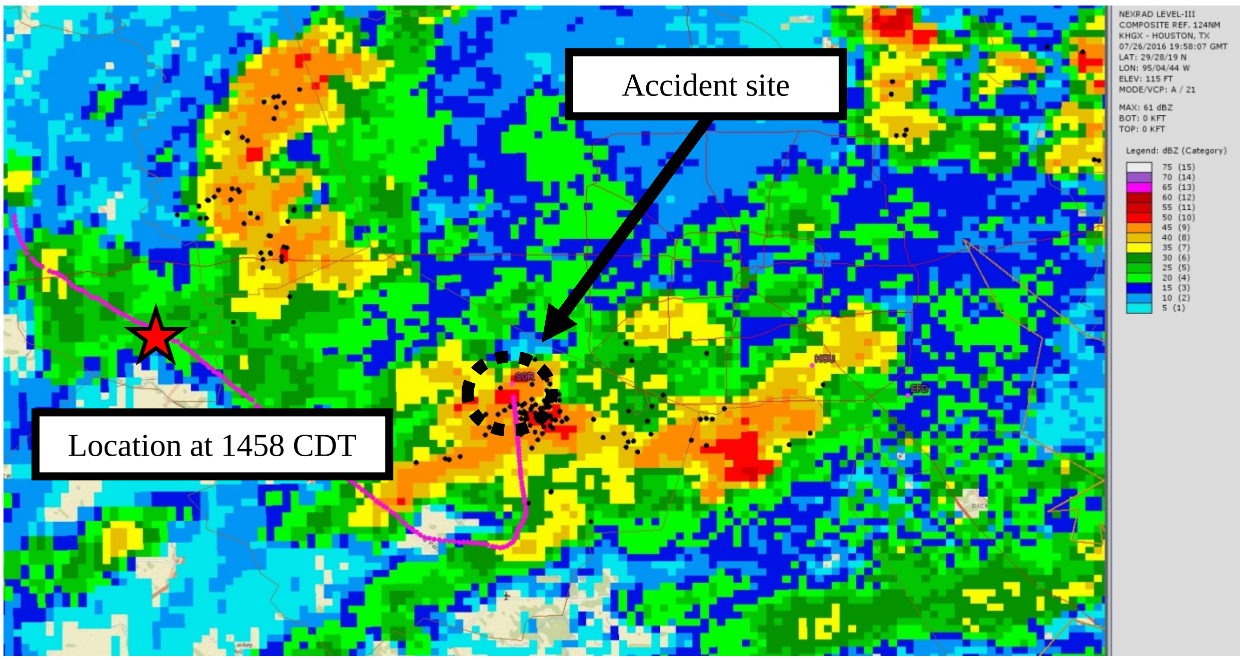


Figure 19 – KHGX WSR-88D composite reflectivity initiated at 1458 CDT with ATC accident flight track from 1455 to 1510 CDT (pink line) and lightning strikes from 1455 to 1510 CDT (black dots)

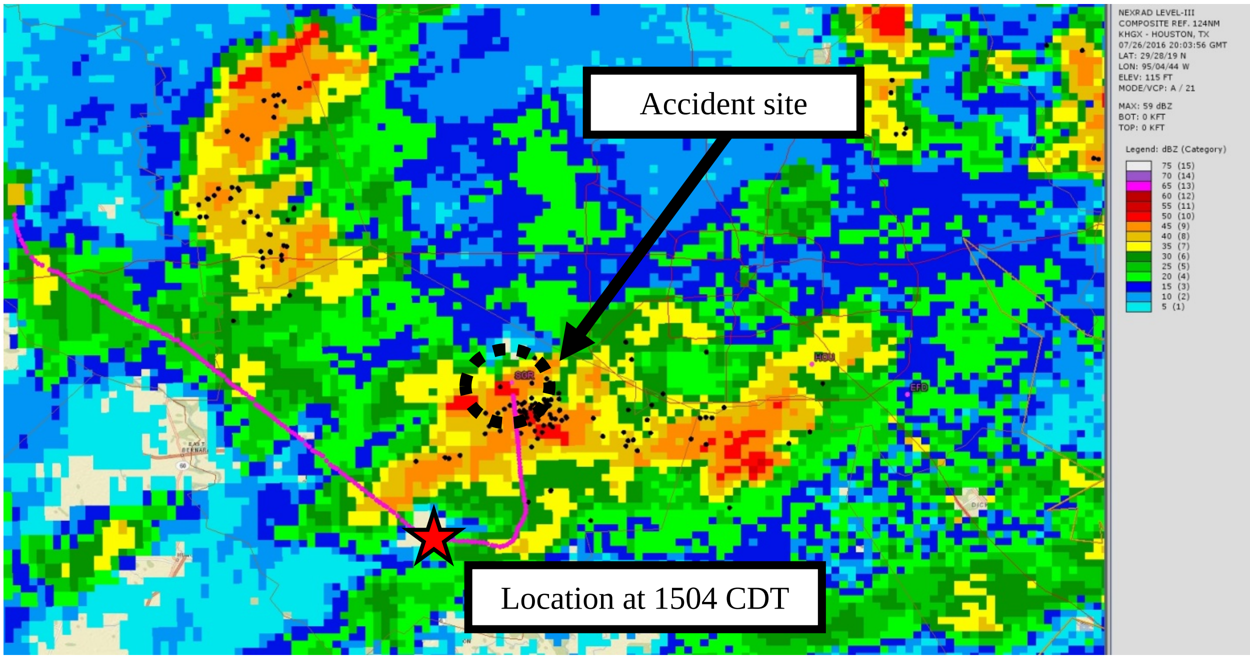


Figure 20 – KHGX WSR-88D composite reflectivity initiated at 1504 CDT with ATC accident flight track from 1455 to 1510 CDT (pink line) and lightning strikes from 1455 to 1510 CDT (black dots)

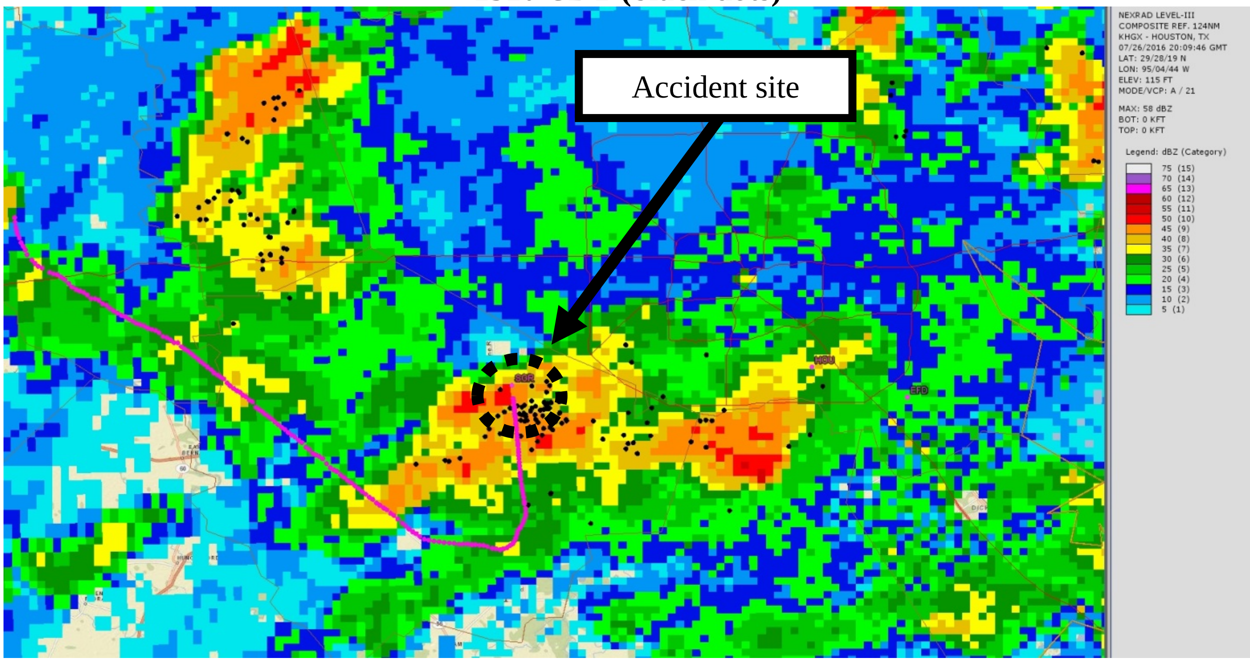


Figure 21 – KHGX WSR-88D composite reflectivity initiated at 1510 CDT with ATC accident flight track from 1455 to 1510 CDT (pink line) and lightning strikes from 1455 to 1510 CDT (black dots)

6.7 TDWR Data

The Terminal Doppler Weather Radar (TDWR) data for William P Hobby Airport (THOU) and George Bush Intercontinental Airport (TIAH) were retrieved for the accident time. Figure 22 presents the THOU TDWR base reflectivity image for the 0.2° elevation scan at 1510 CDT. THOU was located 23 miles east-southeast of the accident site at an elevation of 116 feet. The 0.2° THOU base reflectivity data captured reflectivity data between 320 feet and 1,660 feet msl over the accident site. The THOU 1510 CDT base reflectivity data indicated that there were 35 dBZ reflectivity values above the accident site at the accident time. Attachment 7 indicated that there were up to 45 dBZ reflectivity values above the accident flight's track between 1457 and 1520 CDT. The THOU composite reflectivity data from 1508 CDT (figure 23) indicated reflectivity values up to 50 dBZ above the last 3 minutes of the accident flight's track. Figure 24 presents the TIAH TDWR base reflectivity image for the 0.1° elevation scan at 1510 CDT. TIAH was located 27 miles north-northeast of the accident site at an elevation of 253 feet. The 0.1° TIAH base reflectivity data captured reflectivity data between 280 feet and 1,860 feet msl over the accident site. The TIAH 1510 CDT base reflectivity data indicated that there were 45 dBZ reflectivity values above the accident site at the accident time. Attachment 8 indicated that there were up to 57 dBZ reflectivity values above the accident flight's track between 1457 and 1520 CDT. The TIAH composite reflectivity data from 1509 CDT (figure 25) indicated reflectivity values up to 50 dBZ above the last 3 minutes of the accident flight's track.

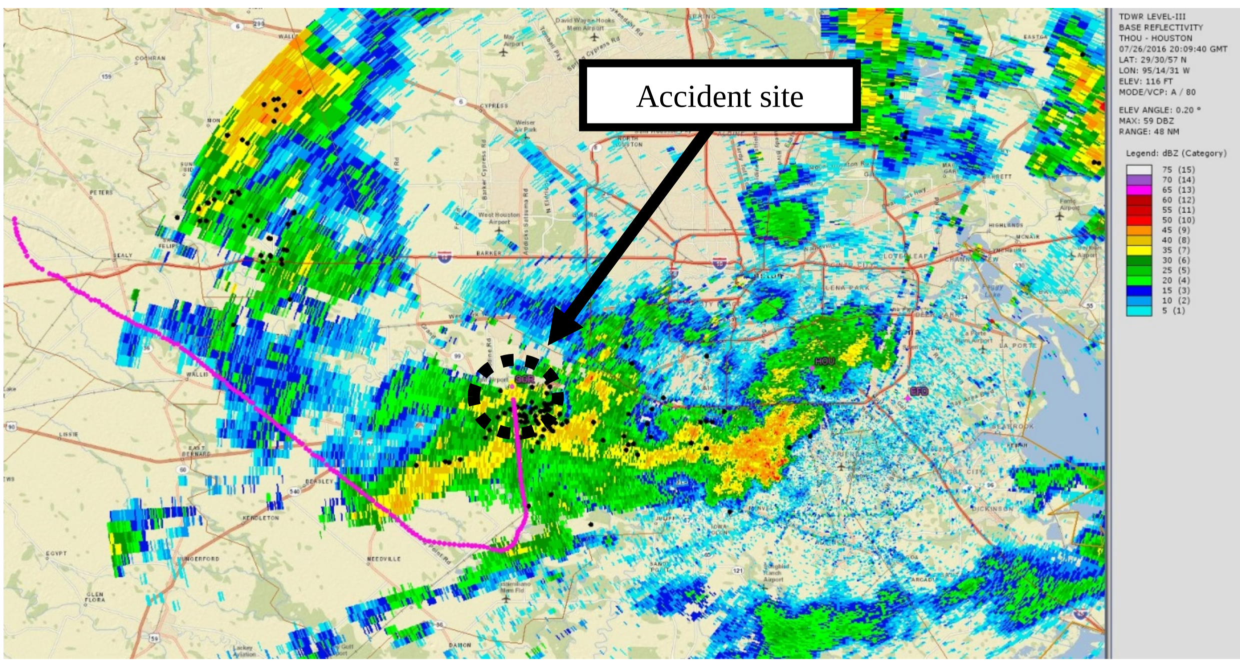


Figure 22 – THOU TDWR base reflectivity for the 0.2° elevation scan initiated at 1510 CDT with ATC accident flight track from 1455 to 1510 CDT (pink line) and lightning strikes from 1455 to 1510 CDT (black dots)

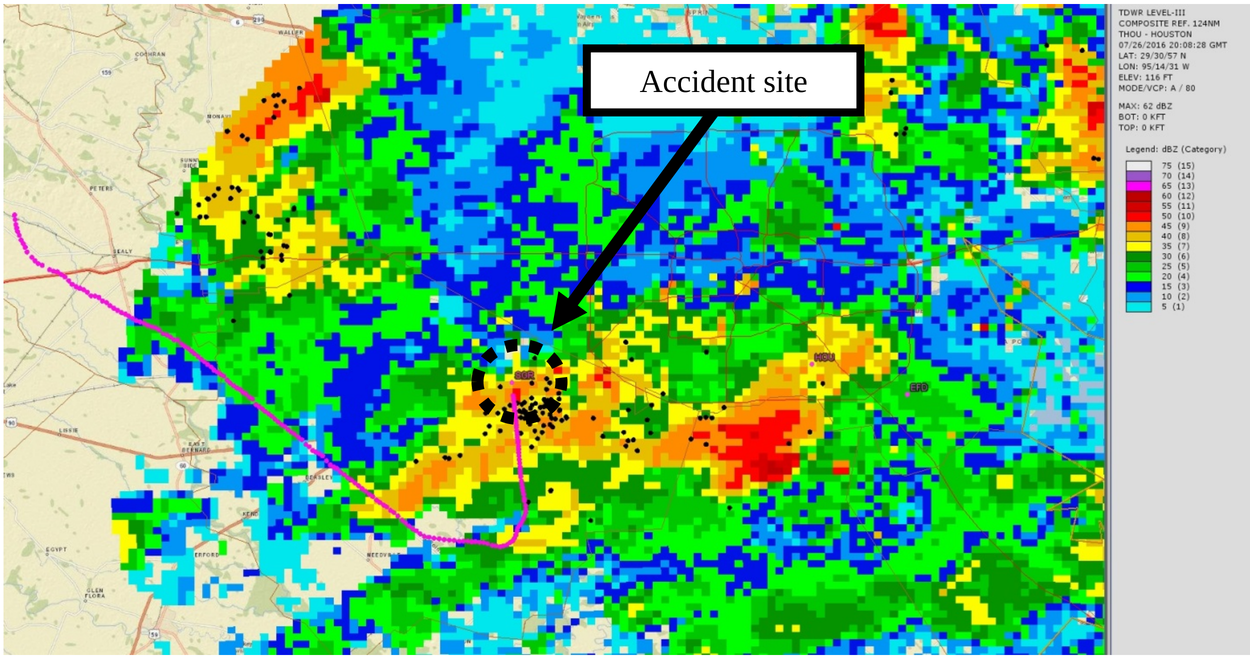


Figure 23 – THOU TDWR composite reflectivity initiated at 1508 CDT with ATC accident flight track from 1455 to 1510 CDT (pink line) and lightning strikes from 1455 to 1510 CDT (black dots)

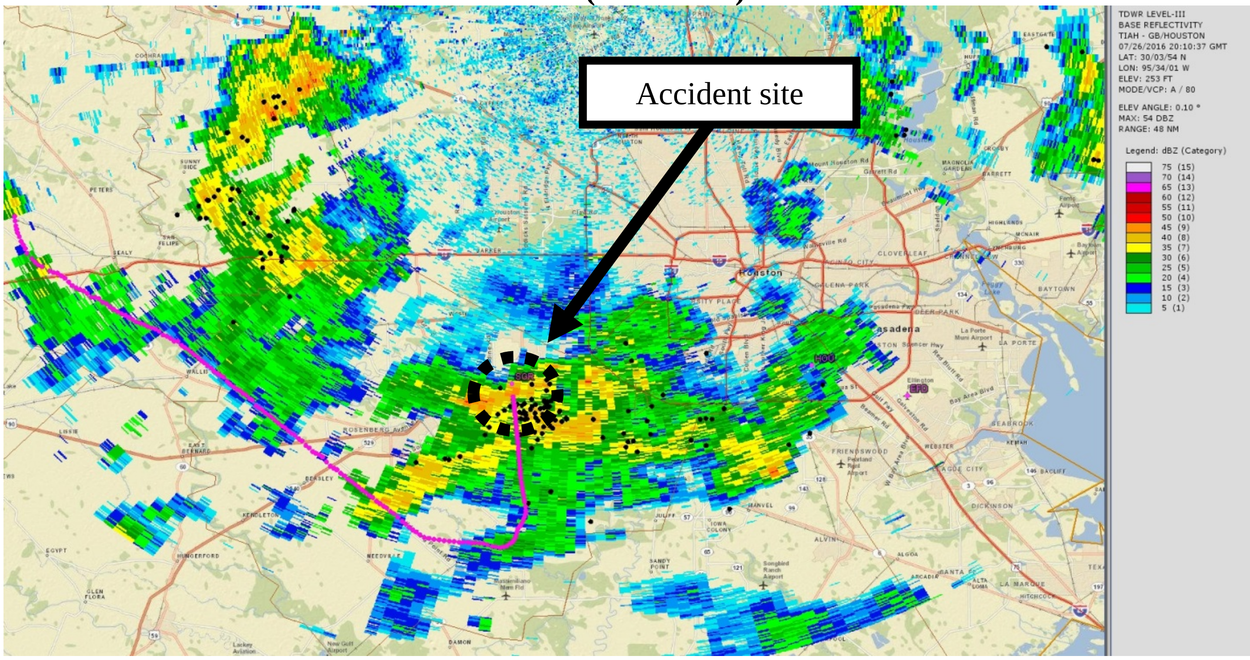


Figure 24 – TIAH TDWR base reflectivity for the 0.1° elevation scan initiated at 1510 CDT with ATC accident flight track from 1455 to 1510 CDT (pink line) and lightning strikes from 1455 to 1510 CDT (black dots)

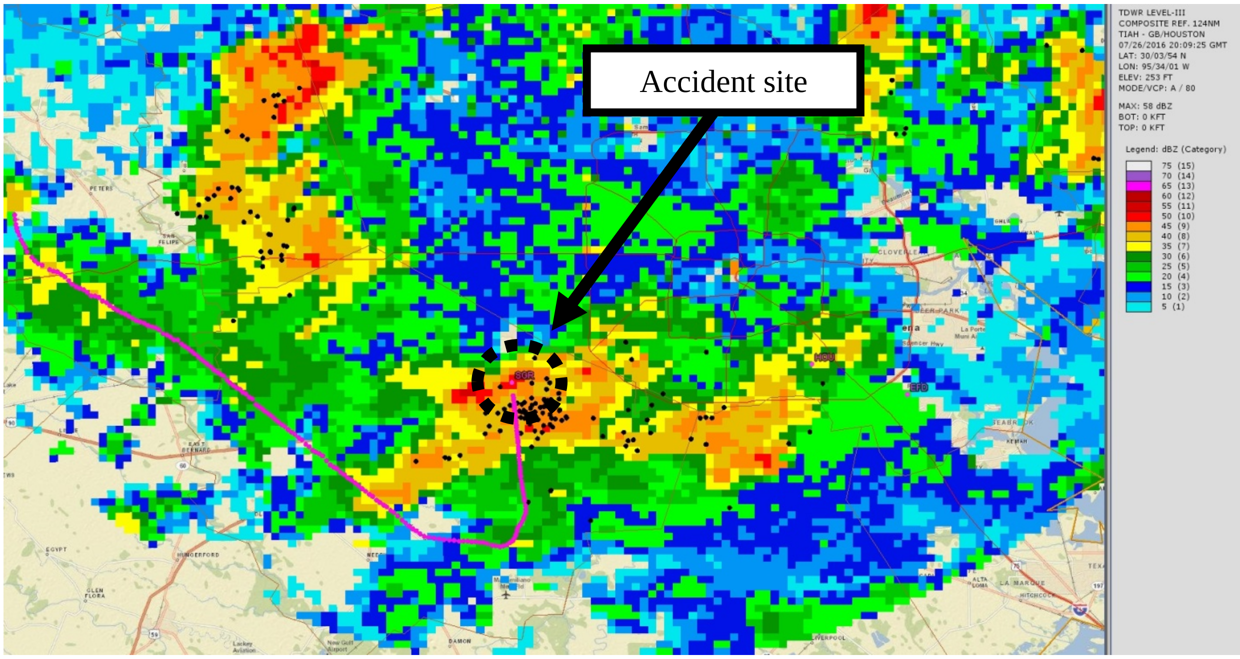


Figure 25 – TIAH TDWR composite reflectivity initiated at 1509 CDT with ATC accident flight track from 1455 to 1510 CDT (pink line) and lightning strikes from 1455 to 1510 CDT (black dots)

7.0 Pilot Reports

All pilot reports (PIREPs) were reviewed close to the accident site from around two hours prior to the accident time to around two hours after the accident time and the PIREPs displayed below are the PIREPs valid below 20,000 feet with altitude heights in feet msl:

KIAH UA /OV 3NM E IAH/TM 1810/FL022/TP B738/SK BKN022/WV VARIABLE 20-30 KNOTS

CRP UA /OV CRP315020/TM 1855/FL150/TP C421/WX HEAVY PRCP/TB OCL CHOP

IAH UA /OV IAH090020/TM 1906/FL020/TP E135/TB LGT-MOD

Routine pilot report (UA); 3 miles east of Houston, Texas; Time – 1310 CDT (1810Z); Altitude – 2,200 pressure feet msl; Type aircraft – Boeing 737-800; Sky – Broken ceiling at 2,200 feet msl; Wind – Variable 20 to 30 knots.

Routine pilot report (UA); 20 miles from Corpus Christi, Texas, on the 315° radial; Time – 1355 CDT (1855Z); Altitude – 15,000 pressure feet msl; Type aircraft – Cessna 421; Weather – Heavy precipitation; Turbulence – Occasional chop.

Routine pilot report (UA); 20 miles from Houston, Texas, on the 090° radial; Time – 1406 CDT (1906Z); Altitude – 2,000 pressure feet msl; Type aircraft – Embraer ERJ-135; Turbulence – Light to moderate.

While on scene at SGR and Houston Terminal Radar Approach Control (I90 TRACON) the NTSB meteorologist reviewed the ATC recordings and interactions before, during, and after the accident flight. The ATC recordings revealed that the I90 controller controlling the accident flight did solicit "ride reports" from flight crews during the accident time and passed the "ride report" information along to other aircraft in the accident controller's airspace. The "ride reports" or PIREPs and weather information gathered by the controller did not make it into the National Airspace (NAS) for distribution. Only one PIREP was documented as making it into the NAS from I90 TRACON on either July 25 or 26 (attachment 9). Although required by FAA 7110 order, the controllers at SGR did not solicit nor distribute any PIREPs for at least one hour before and one hour after the accident time.[27] SGR air traffic control tower had not sent any PIREPs into the NAS for distribution in the 15 days prior to the accident time.

8.0 SIGMET and CWSU Advisories

Significant Meteorological Information (SIGMET) advisories 92C and 02C were valid for the accident site at the accident time with SIGMET 92C being issued at 1355 CDT (valid through 1555 CDT) and SIGMET 02C being issued at 1455 CDT (valid through 1655 CDT). Figures 26 and 27 indicate the spatial extent of the SIGMETs valid for the accident site at the accident time:

WSUS32 KKCI 261955
SIGC
CONVECTIVE SIGMET 02C
VALID UNTIL 2155Z
TX AND CSTL WTRS
FROM 20S LFK-70ESE IAH-30S LRD-40WNW LRD-40W SAT-20S LFK
AREA EMBD TS MOV LTL. TOPS ABV FL450.

WSUS32 KKCI 261855
SIGC
CONVECTIVE SIGMET 92C
VALID UNTIL 2055Z
LA TX AND CSTL WTRS
FROM 20NW IAH-40SSE LCH-80S LCH-40WSW IAH-20NW IAH
AREA EMBD TS MOV FROM 11005KT. TOPS ABV FL450.

CONVECTIVE SIGMET 94C
VALID UNTIL 2055Z
TX
FROM 40W IAH-20E PSX-30S LRD-40WNW LRD-40W SAT-40W IAH
AREA TS MOV LTL. TOPS ABV FL450.

No Center Weather Service Unit (CWSU) Advisory (CWA) was valid for the accident site at the accident time.

No CWSU Meteorological Impact Statement (MIS) was valid for the accident site at the accident time.

[27] For more information see the ATC data contained in the ATC factual of this accident.

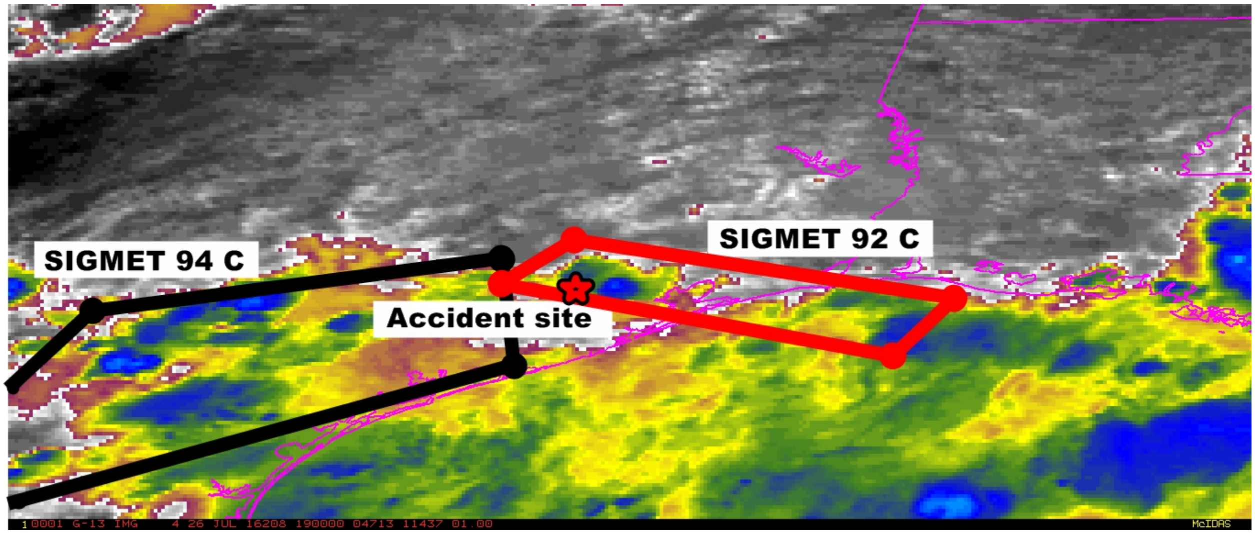


Figure 26 – SIGMETs valid at 1400 CDT

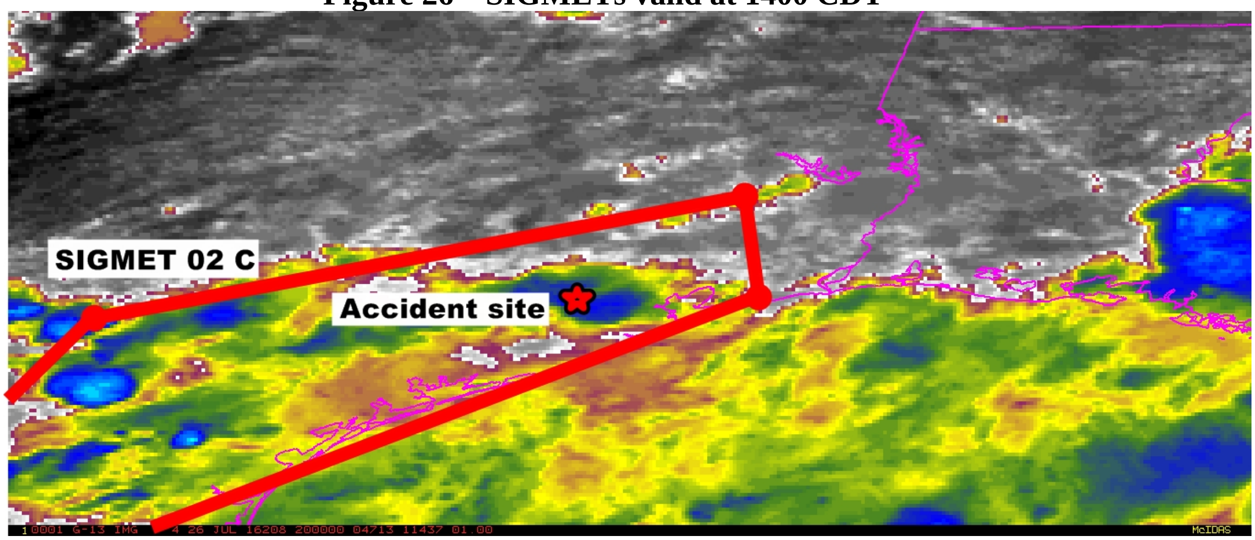


Figure 27 – SIGMET valid at 1500 CDT

9.0 AIRMETs

No Airmen’s Meteorological Information (AIRMET) advisories were valid for the accident site at the accident time.

10.0 Area Forecast

The Area Forecast issued at 1345 CDT, valid at the accident time, forecasted a scattered to broken ceiling at 4,500 feet msl with tops at 8,000 feet msl. Widely scattered thunderstorms with moderate rain were forecast with cumulonimbus cloud tops to FL450[28]. The Area Forecast valid before the accident flight took off was issued at 0445 CDT and forecast a broken ceiling at 4,000 feet msl with tops to FL240, and scattered light rain and thunderstorms with cumulonimbus cloud tops to FL450:

FAUS44 KKCI 261845
FA4W
_DFWC FA 261845
SYNOPSIS AND VFR CLDS/WX
SYNOPSIS VALID UNTIL 271300
CLDS/WX VALID UNTIL 270700...OTLK VALID 270700-271300
OK TX AR TN LA MS AL
.
SEE AIRMET SIERRA FOR IFR CONDS AND MTN OBSCN.
TS IMPLY SEV OR GTR TURB SEV ICE LLWS AND IFR CONDS.
NON MSL HGTS DENOTED BY AGL OR CIG.
.
SYNOPSIS...STNR FNT ACRS NRN AR-NRN OK. BROAD AREA LOW PRES
GLFMEX CSTLN CNTRD OVR SE LA. BY 13Z WK LOW PRES SW MS.
.
OK
W HLF PNHDL...SCT120. WDLY SCT TSRA. CB TOP FL450. 01Z SCT-BKN
CI. OTLK...VFR.
RMNDR PNHDL-NWRN...SCT CI. OTLK...VFR.
SW...SCT-BKN065 TOP 100. WDLY SCT TSRA. CB TOP FL450. 23Z SCT100.
OTLK...VFR.
ERN...SCT030 BKN045 TOP 120. SCT TSRA. CB TOP FL450. 01Z SCT045
SCT100. OTLK...VFR.
.
NWRN TX
W HLF...SCT-BKN120 TOP FL180. WDLY SCT TSRA. CB TOP FL450. 01Z
SCT-BKN CI. OTLK...VFR.
ELSW...SCT100-120. 00Z SKC. OTLK...VFR.
.
SWRN TX
MTNS...SCT-BKN140 TOP FL180. WDLY SCT TSRA. CB TOP FL450. 01Z
SCT-BKN CI. OTLK...VFR.
TRANSPECOS REGION...SCT-BKN075 TOP 140. WDLY SCT TSRA. CB TOP
FL450. 01Z SCT080. OTLK...VFR...10Z SERN PTNS MVFR CIG.
ELSW...SCT090. ISOL TSRA. CB TOP FL450. 00Z SKC. OTLK...VFR.
.
N CNTRL TX
NW...SCT-BKN065 TOP 100. ISOL TSRA. CB TOP FL450. 23Z SCT100.
OTLK...VFR.
NERN...SCT-BKN045 TOP 120. WDLY SCT TSRA. CB TOP FL450. 00Z
SCT045 SCT100. OTLK...VFR.

---

[28] Flight Level – A Flight Level (FL) is a standard nominal altitude of an aircraft, in hundreds of feet. 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.

S HLF...SCT045. ISOL TSRA. CB TOP FL450. 00Z SKC.
OTLK...VFR...10Z MVFR CIG.
.
NERN TX
SCT-BKN045 TOP 120. WDLY SCT TSRA. CB TOP FL450. 00Z SCT045
SCT100. OTLK...VFR...BECMG 0810 SERN PTNS IFR CIG BR.
.
SERN TX
SCT-BKN045 TOP 080. WDLY SCT TSRA. CB TOP FL450. 00Z SCT045.
OTLK...VFR...BECMG 0810 IFR CIG BR.
.
S CNTRL TX
HILL COUNTRY...BKN050 TOP 140. SCT TSRA. CB TOP FL450. 01Z
SCT080. OTLK...VFR...10Z IFR CIG.
RIO GRANDE VALLEY-LWR CSTL PLAINS...SCT025 SCT060. ISOL TSRA. CB
TOP FL450. 01Z SCT025. OTLK..VFR...10Z MVFR CIG.
ELSW...SCT025 BKN040 TOP 170. SCT TSRA. CB TOP FL450. 03Z SCT025
SCT100. OTLK...VFR...10Z IFR CIG BR.
.
AR
NW HLF...SCT030 BKN045 TOP 120. SCT TSRA. CB TOP FL450. 01Z
SCT045 SCT100. OTLK...VFR.
SE HLF...SCT050. ISOL TSRA. CB TOP FL450. 03Z SCT050 BKN120 TOP
FL270. WDLY SCT SHRA. OTLK...VFR...10Z MVFR CIG SHRA.
.
LA
W HLF...SCT-BKN045 TOP 080. WDLY SCT TSRA. CB TOP FL450. 00Z
SCT045. OTLK...VFR...BECMG 0810 IFR CIG BR.
NERN...SCT050. ISOL TSRA. CB TOP FL450. 00Z SCT050 BKN120 TOP
FL270. WDLY SCT -SHRA/ISOL TSRA. OTLK...MVFR CIG SHRA...10Z IFR
CIG SHRA.
SE...BKN025 BKN120 TOP FL270. SCT TSRA. CB TOP FL450. 02Z SCT025
BKN060. WDLY SCT -SHRA/ISOL TSRA. OTLK...VFR SHRA.
.
TN
SCT045. 20Z SCT-BKN045 TOP 120. WDLY SCT TSRA. CB TOP FL450. 02Z
SCT040 SCT120. OTLK...VFR.
.
MS
NRN 1/3...SCT050. ISOL TSRA. CB TOP FL450. 03Z SCT050 BKN120 TOP
FL270. WDLY SCT SHRA. OTLK...VFR...10Z MVFR CIG SHRA.
CNTRL 1/3...SCT045. 21Z SCT025 BKN120 TOP FL270. SCT TSRA. CB TOP
FL450. 03Z SCT025 BKN060. WDLY SCT -SHRA/ISOL TSRA. OTLK...MVFR
CIG SHRA...10Z IFR CIG SHRA.
S 1/3...BKN025 BKN120 TOP FL270. SCT TSRA. CB TOP FL450. 02Z
SCT025 BKN060. WDLY SCT -SHRA/ISOL TSRA. OTLK...VFR SHRA.
.
AL
S 1/3...BKN025 BKN120 TOP FL270. SCT TSRA. CB TOP FL450. 02Z
SCT025 BKN060. WDLY SCT -SHRA/ISOL TSRA. OTLK...VFR SHRA...10Z
MVFR CIG SHRA.
ELSW...SCT045. 23Z SCT030 SCT080. ISOL TSRA. CB TOP FL450. 03Z
WDLY SCT -SHRA. OTLK...VFR SHRA...10Z MVFR CIG SHRA.
....

FAUS44 KKCI 260945

FA4W
_DFWC FA 260945
SYNOPSIS AND VFR CLDS/WX
SYNOPSIS VALID UNTIL 270400
CLDS/WX VALID UNTIL 262200...OTLK VALID 262200-270400
OK TX AR TN LA MS AL
.
SEE AIRMET SIERRA FOR IFR CONDS AND MTN OBSCN.
TS IMPLY SEV OR GTR TURB SEV ICE LLWS AND IFR CONDS.
NON MSL HGTS DENOTED BY AGL OR CIG.
.
SYNOPSIS...HI PRES OVER ERN TN. LOW PRES OVER SERN MO WITH STNR
FRONT EXTDG SWWD ACROSS NW AR-NERN OK AND INTO SERN KS. LOW PRES
OVER FAR SRN TX. BY 04Z LOW PRES OVER NRN LA WITH SFC TROF EXTDG
SEWD FROM LOW CENTER INTO SRN MS-SRN AL. STNR FRONT REMAINS OVER
NRN AR-NERN OK. HI PRES OVER ERN TN.
.
OK
PNHDL...SCT-BKN CI. 15Z SCT060 BKN CI. OTLK...VFR...00Z TSRA.
W...BKN080 TOP 150. 18Z ISOL -TSRA. CB TOP FL450. OTLK...VFR
TSRA.
RMNDR N...BKN060 TOP FL240. ISOL -TSRA. CB TOP FL450. 16Z BKN100
TOP FL260. 18Z SCT -TSRA. CB TOP FL450. OTLK...VFR TSRA.
ELSW...SCT060 BKN100 TOP FL240. WDLY SCT -TSRA. CB TOP FL450. 16Z
SCT100 BKN CI. 18Z BKN050 LYRD FL250. SCT -TSRA. CB TOP FL450.
OTLK...VFR...TIL 00Z TSRA.
.
NWRN TX
PNHDL...SCT-BKN CI. 15Z SCT060 BKN CI. OTLK...VFR...01Z TSRA.
S PLAINS...SCT100 BKN CI. ISOL -TSRA. CB TOP FL450. 18Z BKN100
TOP 150. WDLY SCT -TSRA. CB TOP FL450. 21Z SCT -TSRA. CB TOP
FL450. OTLK...VFR TSRA.
.
SWRN TX
TRANSPECOS REGION...SCT050 BKN130 TOP FL180. 18Z SCT100. WDLY SCT
-TSRA. CB TOP FL450. OTLK...VFR TSRA.
ELSW...SCT100 SCT CI. 18Z SCT100. WDLY SCT -TSRA. CB TOP FL450.
OTLK...VFR TSRA.
.
N CNTRL TX
SCT100 BKN CI. 14Z SCT040. 19Z SCT060 BKN CI. ISOL -TSRA. CB TOP
FL450. OTLK...VFR...TIL 02Z TSRA.
.
NERN TX
SCT050 BKN130 TOP FL260. 12Z BKN050. VIS 4SM BR. 20Z SCT100. WDLY
SCT -TSRA. CB TOP FL450. OTLK...VFR...TIL 03Z TSRA.
.
SERN TX
BKN010 TOP FL250. VIS 4SM BR. WDLY SCT -TSRA. CB TOP FL450. **BECMG
1719 BKN040 TOP FL240. SCT -TSRA. CB TOP FL450**. OTLK...VFR...TIL
01Z TSRA.
.
S CNTRL TX
BKN010 TOP FL250. VIS 4SM BR. 16Z SCT040 BKN CI. WDLY SCT -TSRA.
CB TOP FL450. 19Z SCT -TSRA. CB TOP FL450. OTLK...VFR...TIL 01Z
TSRA.

.

11.0 Terminal Aerodrome Forecast

The accident site (KSGR) was the closest site with a NWS TAF. The TAF valid at the time of the accident was issued at 1459 CDT and was valid for a 22-hour period beginning at 1500 CDT. The TAF for KSGR was as follows:

TAF AMD KSGR 261959Z 2620/2718 **30007KT P6SM VCTS SCT015 BKN035CB OVC060**
TEMPO 2620/2623 VRB10G20KT 2SM +TSRA BKN030CB
FM270100 VRB04KT P6SM FEW035 BKN100
FM270600 VRB03KT P6SM BKN250
FM271300 VRB04KT P6SM VCSH BKN025
PROB30 2713/2716 SHRA
FM271600 VRB05KT P6SM VCTS BKN035CB
PROB30 2716/2718 TSRA=

The forecast expected a wind from 300° at 7 knots, greater than 6 miles visibility, vicinity[29] thunderstorms, scattered clouds at 1,500 feet agl, a broken ceiling of cumulonimbus clouds at 3,500 feet agl, and overcast skies at 6,000 feet agl. Temporary conditions between 1500 and 1800 CDT expected a variable wind of 10 knots with gusts to 20 knots, 2 miles visibility, thunderstorms and heavy rain, and a broken ceiling of cumulonimbus clouds at 3,000 feet agl.

The two KSGR TAFs valid before the 1459 CDT TAF were issued at 1220 CDT and 0846 CDT respectively. The 1220 CDT KSGR TAF was valid for a 24-hour period beginning at 1300 CDT, while the 0846 CDT KSGR TAF was valid for a 22-hour period beginning at 0900 CDT:

TAF KSGR 261720Z 2618/2718 **VRB04KT P6SM FEW060 SCT070 BKN250**
TEMPO 2619/2623 VRB10G20KT TSRA BKN030CB
FM270100 VRB04KT P6SM FEW035 BKN100
FM270600 VRB03KT P6SM BKN250
FM271300 VRB04KT P6SM VCSH BKN025
PROB30 2713/2716 SHRA
FM271600 VRB05KT P6SM VCTS BKN035CB
PROB30 2716/2718 TSRA=

TAF AMD KSGR 261346Z 2614/2712 **VRB04KT P6SM FEW060 SCT070 BKN250**
TEMPO 2619/2623 VRB10G20KT TSRA BKN030CB
FM270100 VRB04KT P6SM FEW035 BKN100
FM270600 VRB03KT P6SM BKN250=

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

The 1220 CDT KSGR TAF forecast expected a variable wind at 4 knots, greater than 6 miles visibility, few clouds at 6,000 feet agl, scattered clouds at 7,000 feet agl, and a broken ceiling at 25,000 feet agl. Temporary conditions between 1400 and 1800 CDT expected a variable wind of 10 knots with gusts to 20 knots, thunderstorms and moderate rain, and a broken ceiling of cumulonimbus clouds at 3,000 feet agl. The 0846 CDT KSGR TAF forecast expected a variable wind at 4 knots, greater than 6 miles visibility, few clouds at 6,000 feet agl, scattered clouds at 7,000 feet agl, and a broken ceiling at 25,000 feet agl. Temporary conditions between 1400 and 1800 CDT expected a variable wind of 10 knots with gusts to 20 knots, thunderstorms and moderate rain, and a broken ceiling of cumulonimbus clouds at 3,000 feet agl.

12.0 NWS Area Forecast Discussion

The NWS office in Houston/Galveston, Texas, issued an Area Forecast Discussion (AFD) at 1207 CDT (the latest AFD before the accident time). The aviation section of the AFD mentioned that rain showers were developing near the Houston metro area and that these rain showers and thunderstorms would likely continue expanding northward through the afternoon before dissipating by the early evening. The aviation section of the 1012 CDT AFD mentioned the "…first 6 hrs of each TAF challenging…" for the local Houston TAF sites. The forecaster mentioned "Will keep TAF overly pessimistic given the uncertainty on conditions":

FXUS64 KHGX 261707
AFDHGX
Area Forecast Discussion
National Weather Service Houston/Galveston TX
1207 PM CDT TUE JUL 26 2016
.AVIATION...
**Showers developing along a line from near 66R-HOU-Galveston Bay.
Left over boundary from last night still evident with these storms
and should remain a focus eventually storms will probably expand
away from the boundary and or lift north slowly with development
of seabreeze which may be hampered by cloud cover. Storms should
dissipate by early evening**...last hold outs will probably be near
CLL. Very moist atmosphere over the area will likely lead to the
redevelopment of low stratus and/or fog for the northern sites
after midnight. NAM convective feedback lights up by 12z and so am
skeptical of it's forecast for tomorrow morning but with what
should be weak PVA expect some sort of cluster of storms to
develop around Galveston Bay area and coast and expand westward
into the Metro hubs and coastal sites after 12-14z.
45
&&
.PREV DISCUSSION... /ISSUED /
UPDATE...
Morning rainfall has largely come to an end this morning, with
most rain now over the waters and a handful of showers over land.
This convection has put temperatures well behind their forecast
this morning, so needed to get that back on track. Given how well
we warmed yesterday despite a fair amount of convection, don't
want to give up on highs in the lower to middle 90s and for now
will just readjust the day's warming trend.
Morning convection has also worked over the atmosphere fairly well
per mesoanalysis. Unfortunately, his area also happens to be

where the forecast's highest precip chances were this afternoon.
Chose to slide the axis of highest chances north a bit towards
Conroe - this should put it back in a more unstable airmass, and
any remnant boundaries from this morning could provide a focus for
development of new convection.
25
PREV DISCUSSION... /ISSUED 656 AM CDT TUE JUL 26 2016/
AVIATION...
KCLL/KUTS/KCXO...main concern has been restricted visibility and
VLIFR CIGS as fog has formed from wet grounds due to yesterday's
rains and favorable radiational cooling. Atmosphere should recover
quickly this morning and could get TSRA to form later this morning
and through the afternoon. Not sure if fog and low CIGS will be
possible again tomorrow morning but will at least hint at
possibility for KCXO.
KIAH/KHOU/KSGR...overall 2 main concerns for Houston terminals.
First is convection that has impacted both KSGR/KHOU this morning
with limiting visibility and MVFR cigs due to heavy rainfall.
Convection seems to be forming on an outflow boundary from
yesterday and may be showing signs of moving farther north due to
outflow from ongoing convection. KIAH is on the edge of fog and
LIFR CIGS that are impacting KCXO. This has made first 6 hrs of
each TAF challenging since there is little guidance on when
visibility and CIGS will improve or when convection may develop.
Convection will be largely dependent upon outflow boundary
collisions and mesoscale interactions. Will keep TAF overly
pessimistic given the uncertainty on conditions. TAFs will be
amended as needed with conditions changing rapidly.
KLBX/KGLS...As has been the case with the Houston terminals,
convection will be the main issue today. Will keep mention of
VCTS/TSRA but timing will be difficult to pinpoint due to
mesoscale interactions. Again TAFs on the pessimistic side and
will likely need to amend as convection evolves.
Overpeck
PREV DISCUSSION... /ISSUED 427 AM CDT TUE JUL 26 2016/
DISCUSSION...
An upper level weakness in the ridge located over the north-
central and northwestern Gulf of Mexico will continue to drift
toward and over the Texas coast today. This weakness will probably
remain overhead through the upcoming weekend. A weak mid level
low was also located just south of the Southeastern Louisiana
coast. Drier air caught up in the circulation around the low over
Mississippi, Alabama, and the Tennessee Valley was endeavoring to
work its way into the far eastern portions of Texas. A better
plume of moisture was seen over the northern and northwestern
portion of the Gulf of Mexico, southern Louisiana, and the Texas
coastal plains -- the RAP analysis indicated PWs in this airmass
were between 2 and 2.3 inches.
The main challenge for today will be thunderstorm coverage and
temperatures. A model consensus has the best rain chances from the
I-10 corridor south to the coast. Went with likely POPS in these
locations and scattered chances elsewhere. With model PWs near
2.4 inches, also included the mention of locally heavy rainfall
this afternoon. Forecast soundings showed weak steering winds and
storm motion may be slow enough for isolated 1 to 2 inch amounts
in the stronger storms. The temperature forecast was quite a

challenge. Yesterday, Wharton received a little over 2 inches of rainfall but the temperature reached 100 degrees! A better cloud cover and better coverage of showers and thunderstorms should lead lower high temperatures today. However, the potential is there for highs to reach to near 94 over the inland areas.
Wednesday should see slightly less coverage of rain and thunderstorms, especially toward the coastal areas. The Nam12, Gfs, and Ecmwf all forecast the highest moisture moving inland and north throughout the day on Wednesday.
After Wednesday, a model consensus then has a general weakness in the upper level ridge overhead of Southeast Texas through the end of the week. However, the models slowly dry out the airmass as the lower-level ridge builds across the Gulf into the area. Kept a model consensus of mainly daytime isolated to scattered coverage through the weekend and into early next week. The lower pressure aloft should also lead to daytime highs only reaching into the mid 90s beginning on Thursday. This also means that heat indices will be on the rise again during the late week and weekend period.
40
MARINE...
Deep moisture remains over the coastal waters this morning and should continue over much of the area today. Numerous showers and thunderstorms will be possible starting out this morning over the upper Texas coast. Thunderstorm activity should spread inland during the day. Scattered shower and thunderstorm coverage will slowly decrease on Wednesday as moisture decreases some and the upper level trough moves west. Winds will pick up early Tuesday afternoon, as some thermally induced mixing with the low level jet brings 10-15 kt winds down to the surface and over the coastal waters. Moderate southerly winds should continue into the weekend. Seas of 1 to 3 feet will be the norm through the weekend. Tide levels one half to one foot above normal can be expected as well.
39
&&
.PRELIMINARY POINT TEMPS/POPS...
College Station (CLL) 94 76 95 76 96 / 50 20 50 20 40
Houston (IAH) 94 76 96 77 97 / 70 30 50 30 40
Galveston (GLS) 89 81 93 83 92 / 60 40 50 30 40
&&
.HGX WATCHES/WARNINGS/ADVISORIES...
TX...NONE.
GM...NONE.
&&
$$

FXUS64 KHGX 261512
AFDHGX
Area Forecast Discussion
National Weather Service Houston/Galveston TX
1012 AM CDT TUE JUL 26 2016
.UPDATE...
Morning rainfall has largely come to an end this morning, with most rain now over the waters and a handful of showers over land. This convection has put temperatures well behind their forecast this morning, so needed to get that back on track. Given how well we warmed yesterday despite a fair amount of convection, don't

want to give up on highs in the lower to middle 90s and for now
will just readjust the day's warming trend.
Morning convection has also worked over the atmosphere fairly well
per mesoanalysis. Unfortunately, his area also happens to be
where the forecast's highest precip chances were this afternoon.
Chose to slide the axis of highest chances north a bit towards
Conroe - this should put it back in a more unstable airmass, and
any remnant boundaries from this morning could provide a focus for
development of new convection.
25
&&
.PREV DISCUSSION... /ISSUED 656 AM CDT TUE JUL 26 2016/
AVIATION...
KCLL/KUTS/KCXO...main concern has been restricted visibility and
VLIFR CIGS as fog has formed from wet grounds due to yesterday's
rains and favorable radiational cooling. Atmosphere should recover
quickly this morning and could get TSRA to form later this morning
and through the afternoon. Not sure if fog and low CIGS will be
possible again tomorrow morning but will at least hint at
possibility for KCXO.
**KIAH/KHOU/KSGR...overall 2 main concerns for Houston terminals.
First is convection that has impacted both KSGR/KHOU this morning
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yesterday and may be showing signs of moving farther north due to
outflow from ongoing convection. KIAH is on the edge of fog and
LIFR CIGS that are impacting KCXO. This has made first 6 hrs of
each TAF challenging since there is little guidance on when
visibility and CIGS will improve or when convection may develop.
Convection will be largely dependent upon outflow boundary
collisions and mesoscale interactions. Will keep TAF overly
pessimistic given the uncertainty on conditions. TAFs will be
amended as needed with conditions changing rapidly.**
KLBX/KGLS...As has been the case with the Houston terminals,
convection will be the main issue today. Will keep mention of
VCTS/TSRA but timing will be difficult to pinpoint due to
mesoscale interactions. Again TAFs on the pessimistic side and
will likely need to amend as convection evolves.
Overpeck
PREV DISCUSSION... /ISSUED 427 AM CDT TUE JUL 26 2016/
DISCUSSION...
An upper level weakness in the ridge located over the north-
central and northwestern Gulf of Mexico will continue to drift
toward and over the Texas coast today. This weakness will probably
remain overhead through the upcoming weekend. A weak mid level
low was also located just south of the Southeastern Louisiana
coast. Drier air caught up in the circulation around the low over
Mississippi, Alabama, and the Tennessee Valley was endeavoring to
work its way into the far eastern portions of Texas. A better
plume of moisture was seen over the northern and northwestern
portion of the Gulf of Mexico, southern Louisiana, and the Texas
coastal plains -- the RAP analysis indicated PWs in this airmass
were between 2 and 2.3 inches.
The main challenge for today will be thunderstorm coverage and
temperatures. A model consensus has the best rain chances from the
I-10 corridor south to the coast. Went with likely POPS in these

locations and scattered chances elsewhere. With model PWs near 2.4 inches, also included the mention of locally heavy rainfall this afternoon. Forecast soundings showed weak steering winds and storm motion may be slow enough for isolated 1 to 2 inch amounts in the stronger storms. The temperature forecast was quite a challenge. Yesterday, Wharton received a little over 2 inches of rainfall but the temperature reached 100 degrees! A better cloud cover and better coverage of showers and thunderstorms should lead lower high temperatures today. However, the potential is there for highs to reach to near 94 over the inland areas.
Wednesday should see slightly less coverage of rain and thunderstorms, especially toward the coastal areas. The Nam12, Gfs, and Ecmwf all forecast the highest moisture moving inland and north throughout the day on Wednesday.
After Wednesday, a model consensus then has a general weakness in the upper level ridge overhead of Southeast Texas through the end of the week. However, the models slowly dry out the airmass as the lower-level ridge builds across the Gulf into the area. Kept a model consensus of mainly daytime isolated to scattered coverage through the weekend and into early next week. The lower pressure aloft should also lead to daytime highs only reaching into the mid 90s beginning on Thursday. This also means that heat indices will be on the rise again during the late week and weekend period.
40
MARINE...
Deep moisture remains over the coastal waters this morning and should continue over much of the area today. Numerous showers and thunderstorms will be possible starting out this morning over the upper Texas coast. Thunderstorm activity should spread inland during the day. Scattered shower and thunderstorm coverage will slowly decrease on Wednesday as moisture decreases some and the upper level trough moves west. Winds will pick up early Tuesday afternoon, as some thermally induced mixing with the low level jet brings 10-15 kt winds down to the surface and over the coastal waters. Moderate southerly winds should continue into the weekend. Seas of 1 to 3 feet will be the norm through the weekend. Tide levels one half to one foot above normal can be expected as well.
39
&&
.PRELIMINARY POINT TEMPS/POPS...

College Station (CLL)	94	76	95	76	96 /	50	20	50	20	40
Houston (IAH)	94	76	96	77	97 /	70	30	50	30	40
Galveston (GLS)	89	81	93	83	92 /	60	40	50	30	40

&&
.HGX WATCHES/WARNINGS/ADVISORIES...
TX...NONE.
GM...NONE.
&&
$$

13.0 NWS Hazardous Weather Outlook

The NWS office in Houston/Galveston, Texas, issued a Hazardous Weather Outlook (HWO) at 0515 CDT. The HWO mentioned scattered to numerous thunderstorms were expected across southeastern Texas during the accident day with the possibility of gusty winds, small hail, and locally heavy rainfall:

FLUS44 KHGX 261015
HWOHGX
HAZARDOUS WEATHER OUTLOOK
NATIONAL WEATHER SERVICE HOUSTON/GALVESTON TX
515 AM CDT TUE JUL 26 2016
TXZ163-164-176>179-195>200-210>214-226-227-235>238-271300-
AUSTIN-BRAZORIA-BRAZOS-BURLESON-CHAMBERS-COLORADO-FORT BEND-
GALVESTON-GRIMES-HARRIS-HOUSTON-JACKSON-LIBERTY-MADISON-MATAGORDA-
MONTGOMERY-POLK-SAN JACINTO-TRINITY-WALKER-WALLER-WASHINGTON-
WHARTON-
515 AM CDT TUE JUL 26 2016
THIS HAZARDOUS WEATHER OUTLOOK IS FOR PORTIONS OF SOUTHEAST TEXAS.
.DAY ONE...TODAY AND TONIGHT
SCATTERED TO NUMEROUS THUNDERSTORMS ARE EXPECTED ACROSS SOUTHEAST TEXAS TODAY THROUGH EARLY THIS EVENING. STRONG GUSTY WINDS AND SMALL HAIL WILL BE POSSIBLE IN THE STRONGEST STORMS. THERE IS ALSO THE POTENTIAL FOR LOCALLY HEAVY RAINFALL WITH ANY SLOW MOVING STRONG STORMS THAT DEVELOP. IN GENERAL...RAINFALL BETWEEN ONE-QUARTER TO ONE INCH IS EXPECTED. HOWEVER...ISOLATED TOTALS UP TO TWO INCHES ARE POSSIBLE.
.DAYS TWO THROUGH SEVEN...WEDNESDAY THROUGH MONDAY
SCATTERED TO NUMEROUS THUNDERSTORMS ARE AGAIN POSSIBLE ON WEDNESDAY. THERE IS THE POTENTIAL FOR ISOLATED STRONG STORMS GENERATING GUSTY WINDS AND RAINFALL OF 1 TO 2 INCHES.
.SPOTTER INFORMATION STATEMENT...
SPOTTER ACTIVATION MAY BE REQUIRED TODAY AND WEDNESDAY.
$$

14.0 NWS Flood Advisory

The NWS office in Houston/Galveston, Texas, issued a Flood Advisory at 1353 CDT valid through 1545 CDT for parts of Harris, Brazoria, and Fort Bend Counties, including SGR. The Flood Advisory warned of heavy rain in the area that was causing minor flooding, including street flooding across parts of the above mentioned counties:

WGUS84 KHGX 261853
FLSHGX
FLOOD ADVISORY
NATIONAL WEATHER SERVICE HOUSTON/GALVESTON TX
153 PM CDT TUE JUL 26 2016
TXC039-157-201-262045-
/O.NEW.KHGX.FA.Y.0151.160726T1853Z-160726T2045Z/
/00000.N.ER.000000T0000Z.000000T0000Z.000000T0000Z.OO/
HARRIS TX-BRAZORIA TX-FORT BEND TX-
153 PM CDT TUE JUL 26 2016
THE NATIONAL WEATHER SERVICE IN LEAGUE CITY HAS ISSUED A

* FLOOD ADVISORY FOR...
  HARRIS COUNTY IN SOUTHEASTERN TEXAS...
  NORTHERN BRAZORIA COUNTY IN SOUTHEASTERN TEXAS...
  NORTHEASTERN FORT BEND COUNTY IN SOUTHEASTERN TEXAS...
* UNTIL 345 PM CDT
* AT 152 PM CDT...DOPPLER RADAR INDICATED HEAVY RAIN DUE TO
  THUNDERSTORMS. THIS WILL CAUSE MINOR FLOODING IN THE ADVISORY AREA.
  UP TO TWO INCHES OF RAIN HAVE ALREADY FALLEN SOME OF THIS HAS
  FALLEN ON AREAS THAT HAD STREET FLOODING AND HEAVY RAINFALL EARLY
  THIS MORNING.
* SOME LOCATIONS THAT WILL EXPERIENCE FLOODING INCLUDE...
  PASADENA...NORTHWESTERN PEARLAND...**SUGAR LAND**...MISSOURI CITY...
  DEER PARK...STAFFORD...SOUTH HOUSTON...BELLAIRE...
  WEST UNIVERSITY PLACE...GALENA PARK...ASTRODOME AREA...FRESNO...
  TOWN WEST...PECAN GROVE...FIRST COLONY...GREATER EASTWOOD...
  GREATER HOBBY AREA...GREENWAY / UPPER KIRBY AREA...
  SOUTH BELT / ELLINGTON AND UNIVERSITY PLACE.
PRECAUTIONARY/PREPAREDNESS ACTIONS...
EXCESSIVE RUNOFF FROM HEAVY RAINFALL WILL CAUSE FLOODING OF SMALL
CREEKS AND STREAMS...URBAN AREAS...HIGHWAYS...STREETS AND
UNDERPASSES AS WELL AS OTHER DRAINAGE AREAS AND LOW LYING SPOTS.
A FLOOD ADVISORY MEANS RIVER OR STREAM FLOWS ARE ELEVATED...OR
PONDING OF WATER IN URBAN OR OTHER AREAS IS OCCURRING OR IS IMMINENT.
&&
LAT...LON 2975 9512 2963 9510 2949 9558 2961 9574
      2973 9568
$$

15.0 Winds and Temperature Aloft Forecast

The NWS winds and temperatures aloft forecasts valid for the closest point to the accident site are included below and were issued at 1501 and 0900 CDT respectively:

```
FBUS31 KWNO 262001
FD1US1
_DATA BASED ON 261800Z
VALID 270000Z   FOR USE 2000-0300Z. TEMPS NEG ABV 24000
FT  3000    6000    9000   12000   18000   24000  30000  34000  39000

HOU 2207 9900+16 1106+11 1007+07 0711-04 3608-14 321130 341140 021052

FBUS31 KWNO 261400
FD1US1
_DATA BASED ON 261200Z
VALID 261800Z   FOR USE 1400-2100Z. TEMPS NEG ABV 24000
FT  3000    6000    9000   12000   18000   24000  30000  34000  39000

HOU 2205 9900+16 9900+11 0806+06 0716-04 0708-15 990029 250940 061051
```

Houston, Texas, (HOU)[30] was the closest site to the accident site with a NWS winds and temperatures forecast. The 1501 CDT HOU forecast indicated a wind at 3,000 feet from 220° at 7 knots, a calm wind at 6,000 feet with a temperature of 16° C, a wind at 9,000 feet from 110° at 6 knots with a temperature of 11° C. The 0900 CDT HOU forecast indicated a wind at 3,000 feet from 220° at 5 knots, a calm wind at 6,000 feet with a temperature of 16° C, a calm wind at 9,000 feet with a temperature of 11° C.

16.0 ATC Information[31]

The NTSB ATC group and NTSB meteorologist visited the SGR air traffic control tower and interviewed the two air traffic control personnel working during the accident. The SGR ground controller was in charge of updating and sending out the KSGR METARs and SPECIs around the time of the accident. Figure 28 shows an exemplar image of the ASOS Operator Interface Device (OID) and National Information Display System (NIDS) that the ground controller was interfacing with on the day of the accident. The SGR ground controller described the weather developing very rapidly at SGR on the accident day. The SGR air traffic controllers working at the time of the accident were very familiar with the type of weather that developed in the Houston area. After 15 to 20 minutes on shift (the ground controller reported on shift at 1415 CDT), the ground controller stated that the precipitation was light to moderate. The ground controller stated that the weather was developing to the southeast (away from the airport) and wind went from south to northwest. The ground controller stated he was more concerned when thunderstorms developed towards the west as happened on the accident day. The ground controller stated that there was a "mean one" at least 5 miles in diameter to the southeast of the airport at the accident time. During the accident time the ground controller stated that he thought there was moderate rain on the windows and the rain was not interfering with operations. When the accident flight was approaching the airport the ground controller stated that there was no rain. The ground controller stated that the weather was changing rapidly on ASOS and that he could not keep up. The ground controller stated that not even a minute would go by and new ASOS information would show up on the ASOS OID[32] (figure 28). When the accident flight was on 3 mile final the ground controller stated that it started to rain on the field and that he was focusing on the winds as they had shifted back to the south. In addition, his other focus was on the opposite direction converging traffic around the accident time. The ground controller stated that the visibility remained 3 miles throughout the accident time with better visibility to the west, but the ground controller doesn't remember what the ASOS OID said for visibility during the accident sequence. The ground controller stated that there was nothing unusual about the wet runway. The ground controller normally reviewed the weather (ASOS and TAF information) before a shift on the Aeronautical Information System Replacement (AISR) displayed on the computer at the back of the SGR tower cab. The ground controller will sometimes edit the main line of the METAR or its remarks section based on his assessment as a LAWRS observer. The ground controller stated that the KSGR ASOS visibility sensor is really sensitive and the METAR weather phenomena he adjusts, for his LAWRS observations, is mainly the KSGR visibility. When a pilot requests weather information the ground controller will always

[30] The Houston (HOU) NAVAID point.
[31] For more information see the ATC data contained in the docket for this accident.
[32] An ASOS OID will update when the ASOS equipment has new METAR/SPECI information to provide into the NAS.

provide what he views[33] on the Standard Terminal Automation Replacement System (STARS) displayed weather as he trusts the STARS displayed weather information more than himself. The ground controller stated that he receives very limited PIREP information from pilots and doesn't solicit PIREPs as much as he should. The ground controller will likely only solicit PIREPs if the conditions in the FAA 7110 order are happening in real-time rather than weather forecast conditions that meet the FAA 7110 order criteria. The AISR system (figure 29) is a much easier way to get PIREP information into the NAS than having to go through flight service. During the accident timeframe, the ground controller stated that his first priority was to separate the converging traffic and weather augmentation fell lower on his priority list. The ground controller stated that he wished he could cut the Automatic Terminal Information Service (ATIS)[34] "…to straight weather mode…", when the weather is rapidly changing, as it takes too much of his time during rapidly changing weather conditions to cut a new ATIS recording with the new weather observation. The ground controller did not solicit any braking action PIREPs before, during, or after the accident time. The ground controller doesn't remember seeing any lightning around the accident time.

Figure 28 – Exemplar image of the KSGR ASOS OID and NIDS

[33] For example, the STARS information as in figure 31.
[34] ATIS messages can be made ("cut") in an automated voice or with a controller's voice.

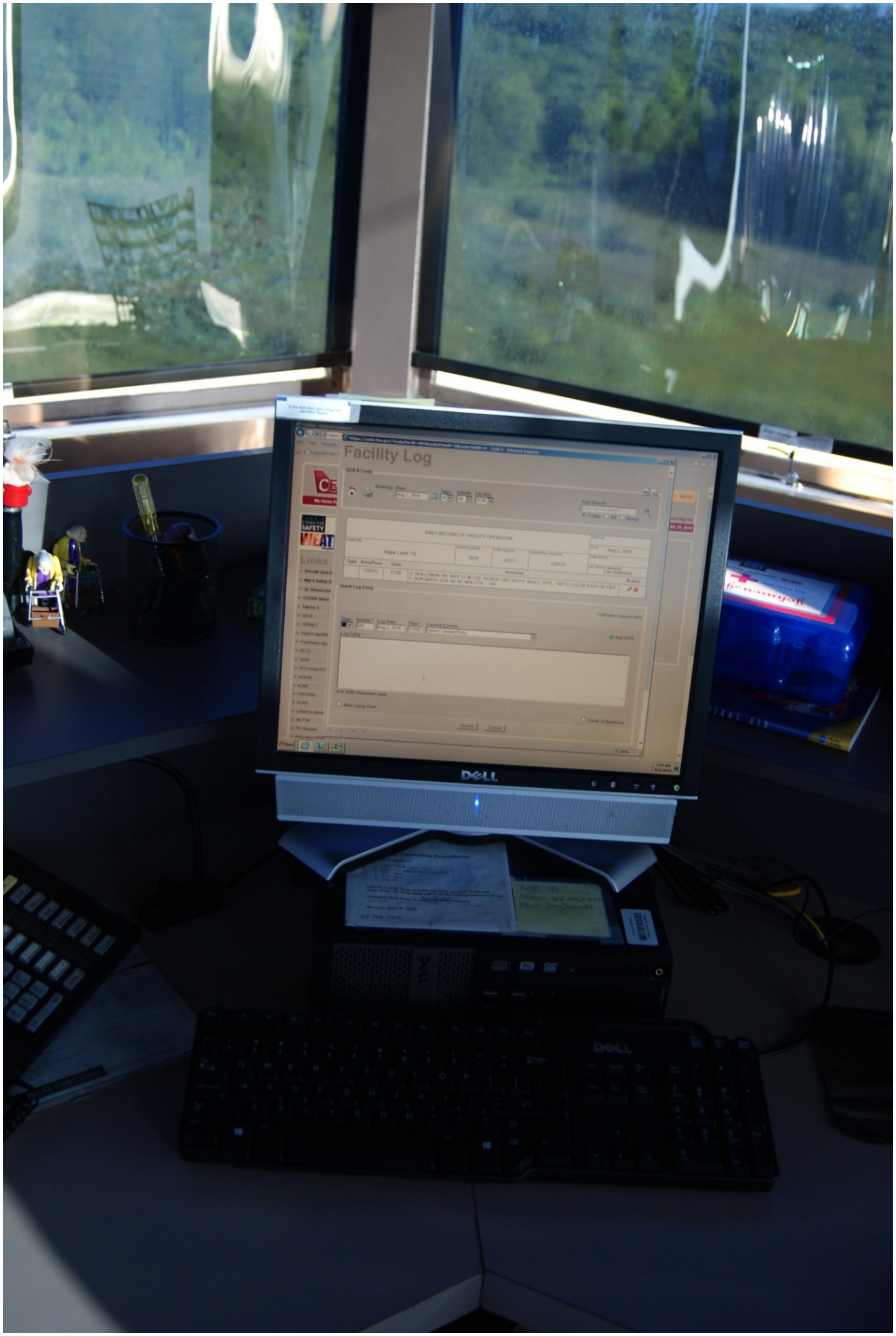

Figure 29– Exemplar image of the SGR AISR display

In addition to the surface observational data, STARS display of weather was obtained with the actual weather display viewed by the SGR air traffic controller's data from around the accident time. The SGR air controller did have settings for level 1 through level 6 precipitation active and available for view:[35]

1: 18<30 dbz
2: 30<41 dbz
3: 41<46 dbz
4: 46<50 dbz
5: 50<57 dbz
6: 57+ dbz

Figure 30 provides an exemplar view of what precipitation levels 1 through 6 look like on STARS display of precipitation. Figures 31 through 38 show the STARS display of precipitation used and seen by the accident controllers at 1458, 1500, 1502, 1504, 1506, 1508, 1509, and 1510 CDT. Between 1458 and 1510 CDT level 3 precipitation was indicated down runway 17/35 centerline (at SGR) with level 4 precipitation to the east and southeast of SGR. An animation of the STARS display of weather and precipitation over SGR from 1450 to 1514 CDT is provided in attachment 10. For comparison purposes, animations of the STARS weather and precipitation display from the individual Airport Surveillance Radar-9 (ASR-9) sites at William P Hobby Airport (attachment 11) and George Bush Intercontinental Airport (attachment 12) are provided with data from 1506 to 1510 CDT with the accident flight track marked. The STARS display of the weather available to the accident air traffic controllers was a composite combination of the ASR-9 information from attachment 11 and 12 (attachment 13). The STARS display of weather and precipitation levels at SGR did not match the WSR-88D weather radar display of level 5 precipitation over SGR at the accident time (sections 6.5 and 6.6). Attachments 13, 14, 15, and 16, provide more information on the exact details (locations and antenna coverage patterns, etc…) of the weather information that went into the STARS display of weather available to the accident air traffic controllers.

[35] The FAA provided the following dBZ levels for the ASR-9 radars (which provided info to STARS). For more information regarding STARS display please see attachment 2 of CEN16FA276.

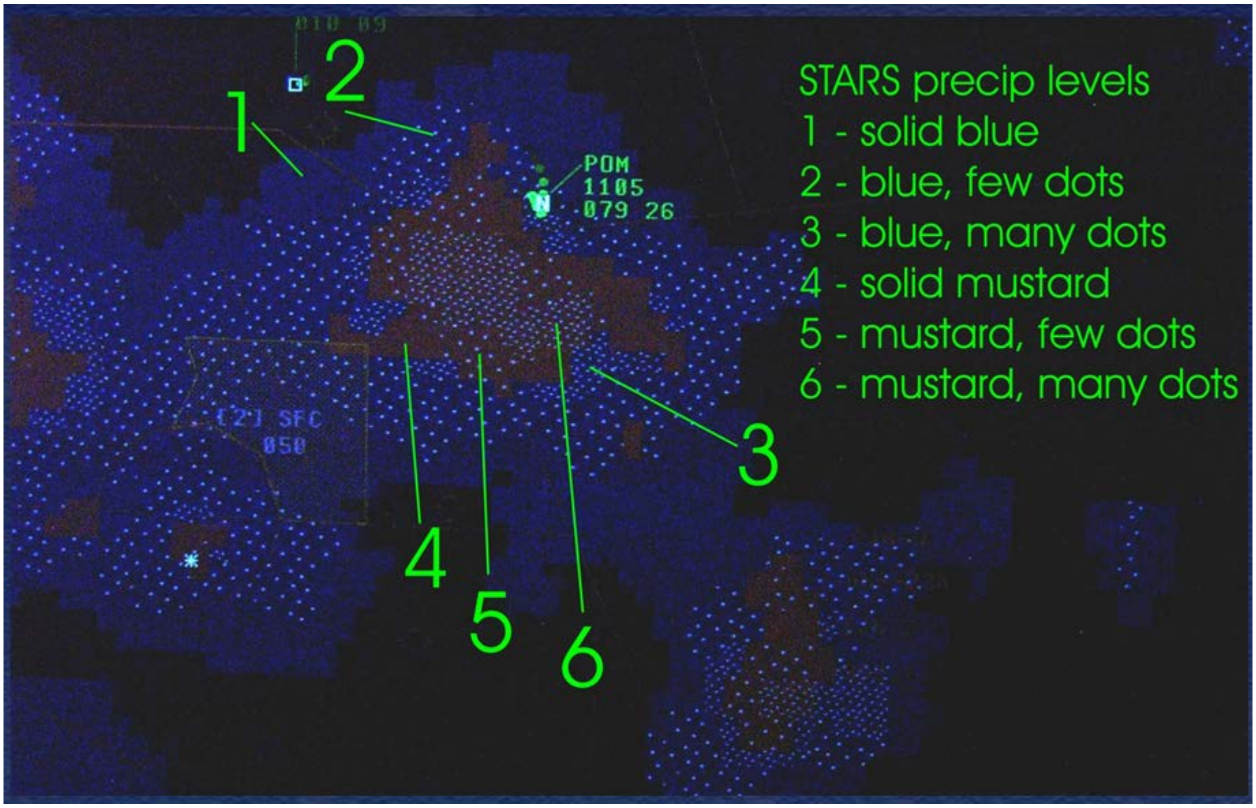

Figure 30 – Exemplar display of STARS precipitation levels 1 through 6

Figure 31 – STARS weather and precipitation level display used and seen by accident controller from 1458 CDT with SGR in the middle of the image

Figure 32 – STARS weather and precipitation level display used and seen by accident controller from 1500 CDT with SGR in the middle of the image

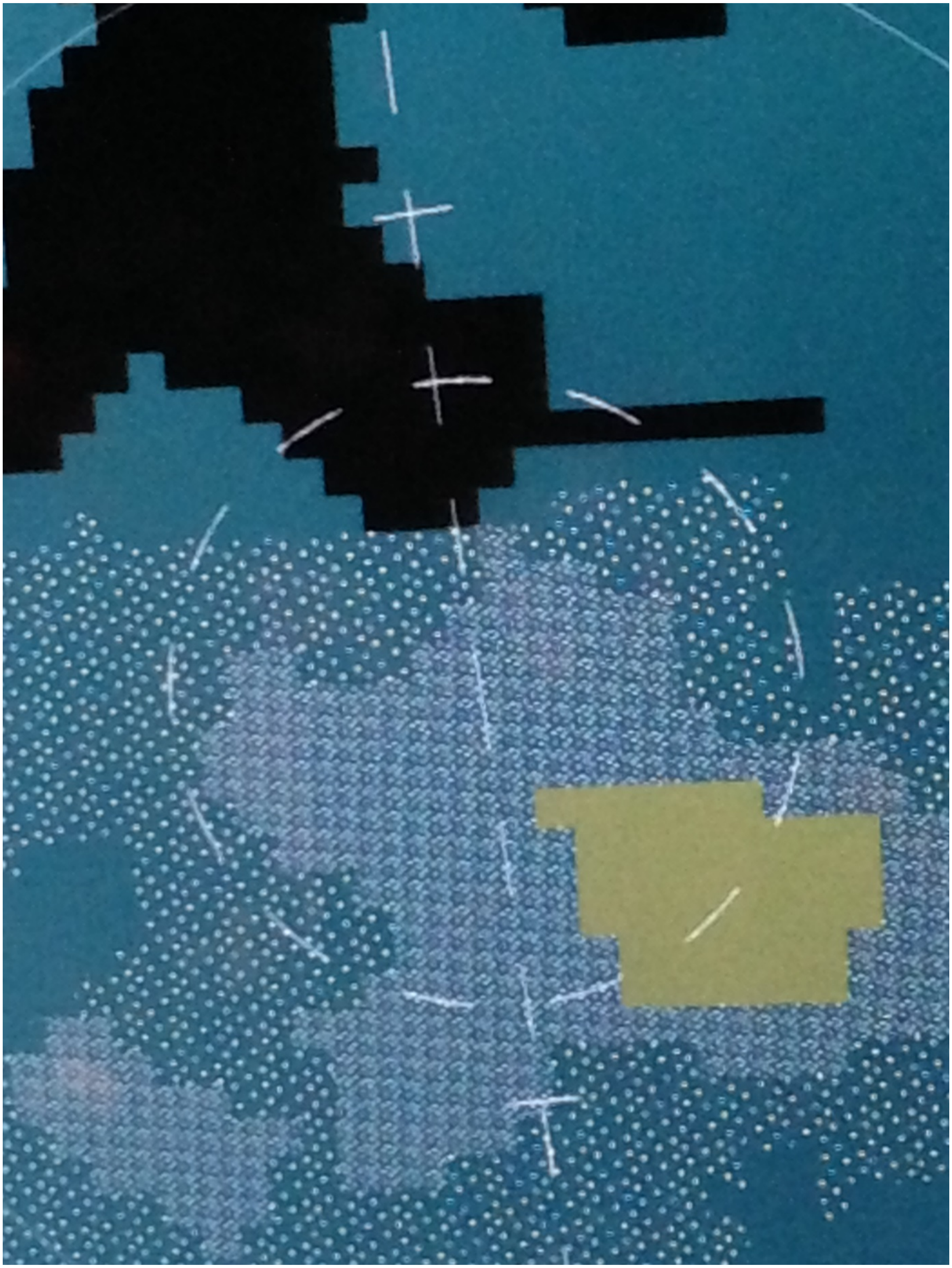

Figure 33 – STARS weather and precipitation level display used and seen by accident controller from 1502 CDT with SGR in the middle of the image

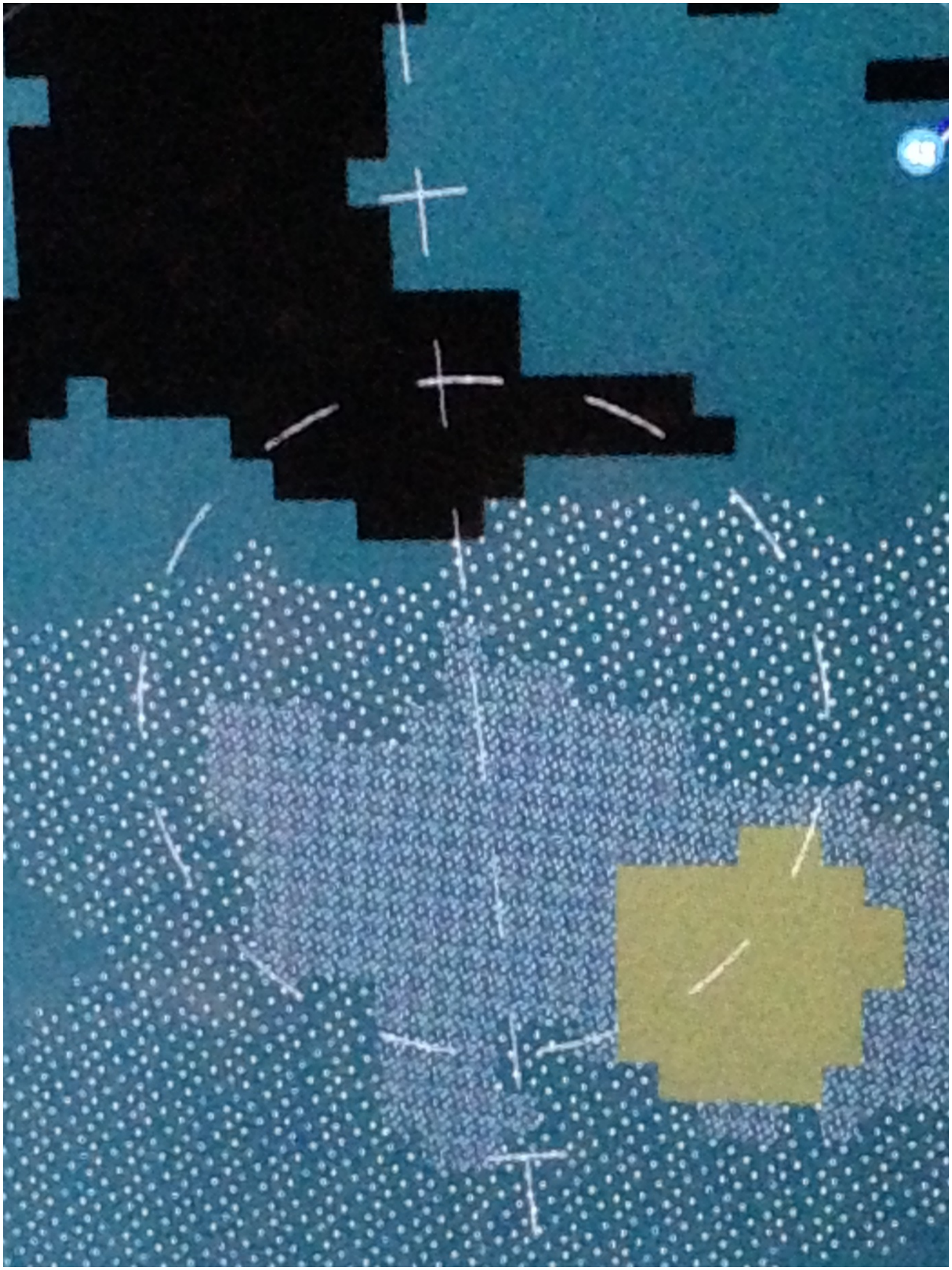

Figure 34 – STARS weather and precipitation level display used and seen by accident controller from 1504 CDT with SGR in the middle of the image

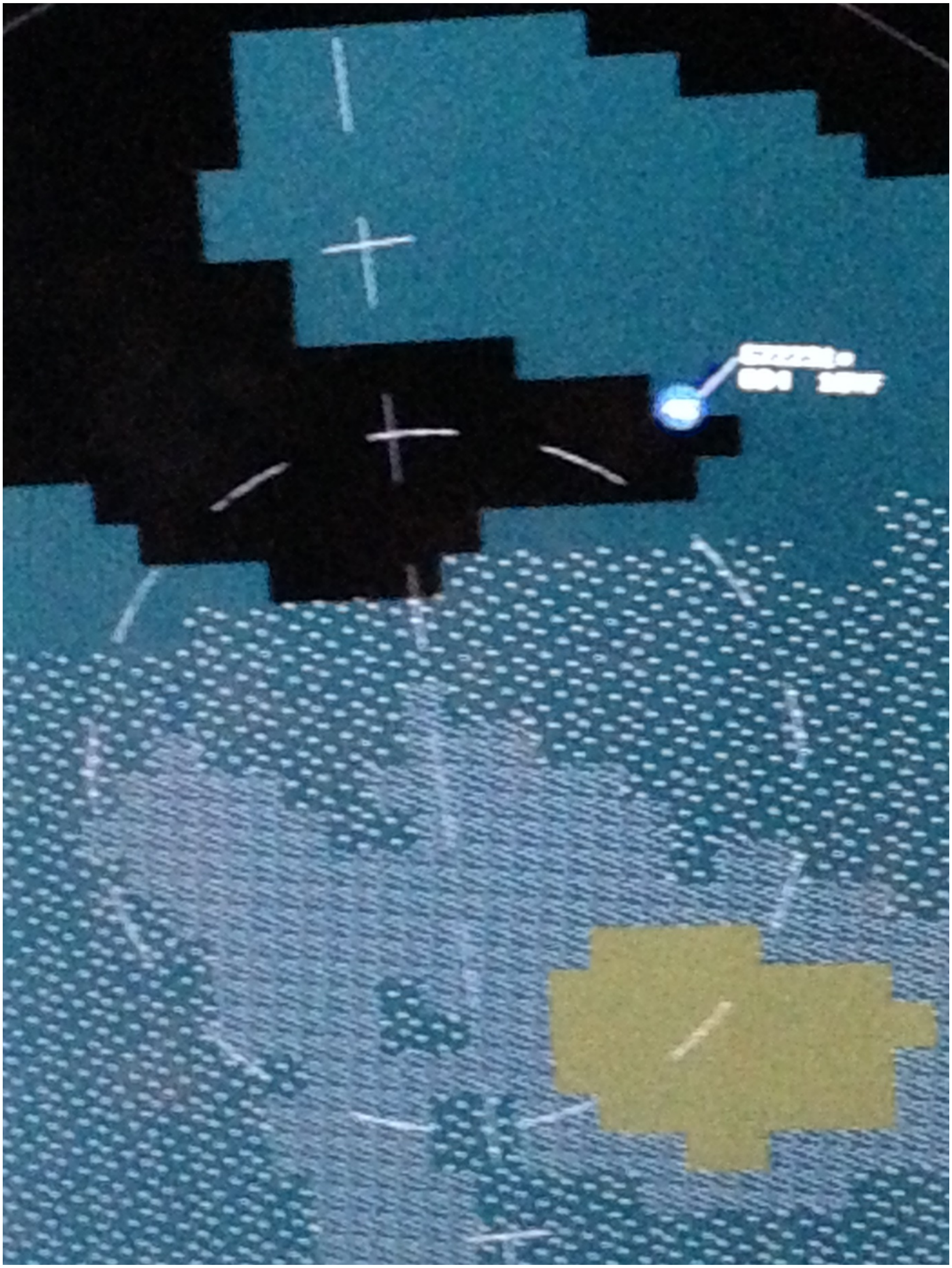

Figure 35 – STARS weather and precipitation level display used and seen by accident controller from 1506 CDT with SGR in the middle of the image

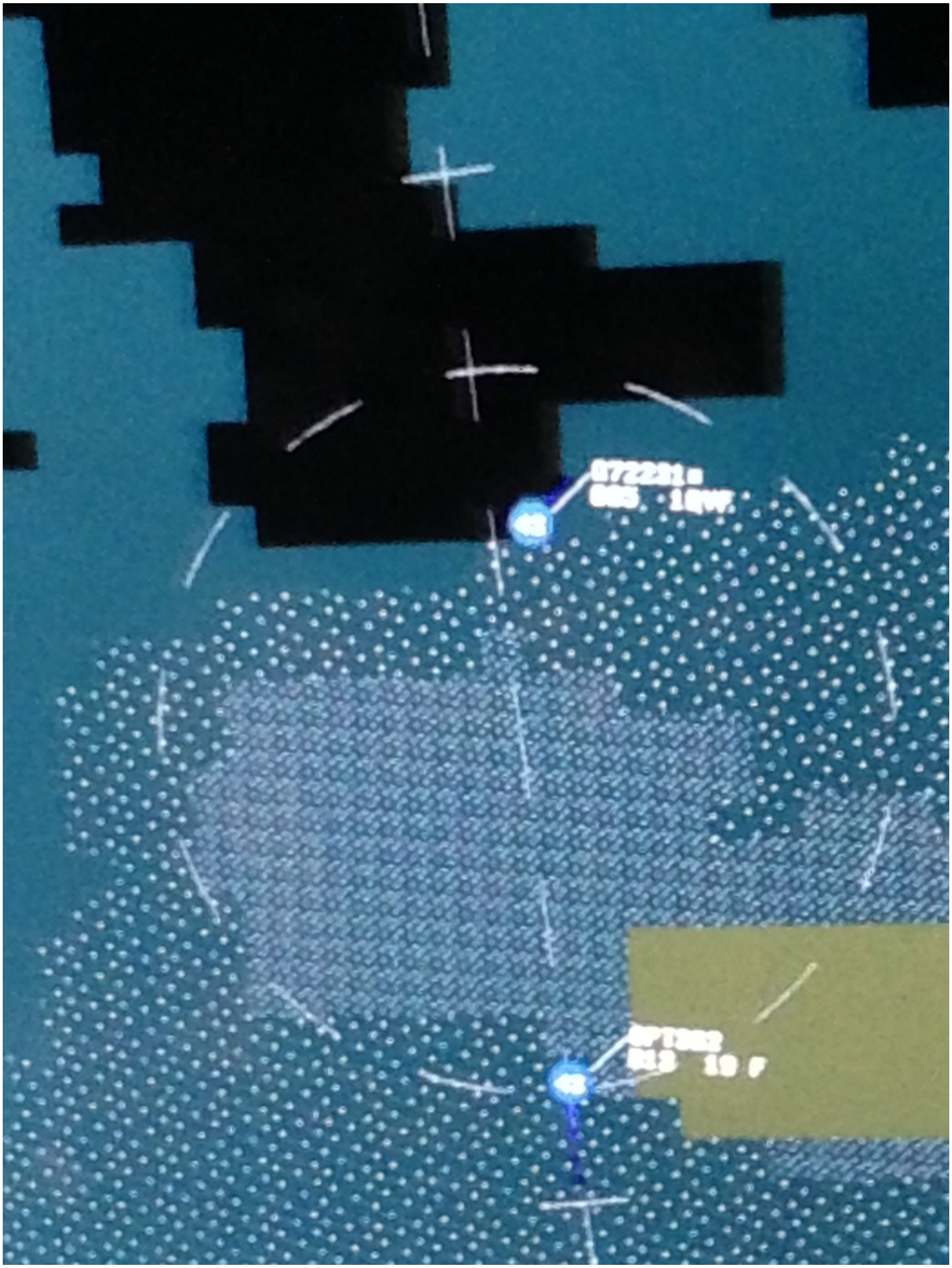

Figure 36 – STARS weather and precipitation level display used and seen by accident controller from 1508 CDT with SGR in the middle of the image

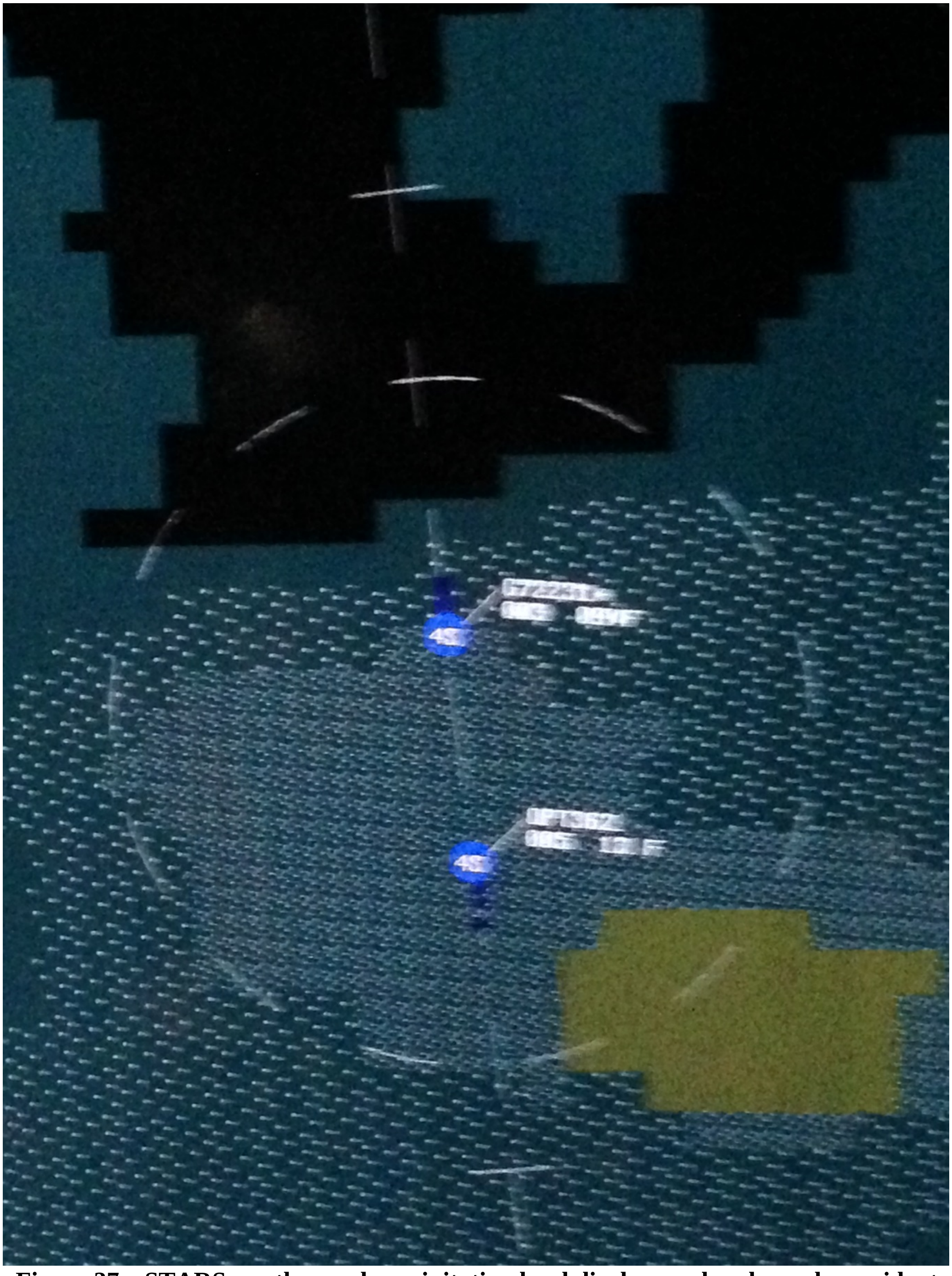

Figure 37 – STARS weather and precipitation level display used and seen by accident controller from 1509 CDT with SGR in the middle of the image

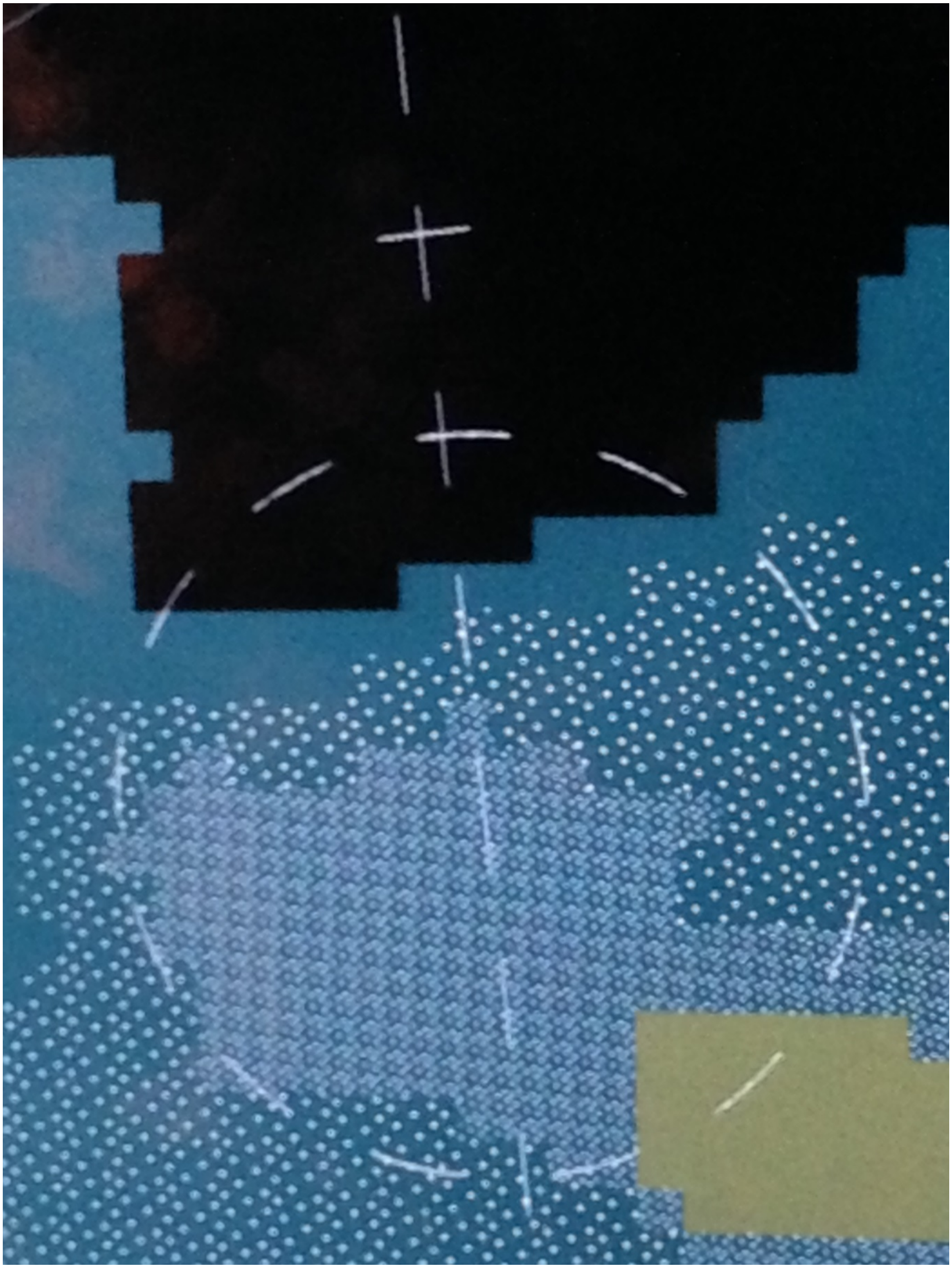

Figure 38 – STARS weather and precipitation level display used and seen by accident controller from 1510 CDT with SGR in the middle of the image

16.1 WARP Weather Imagery from ZHU

Weather information from the Houston Air Route Traffic Control Center (ZHU ARTCC) was requested from the FAA immediately after this accident. ZHU air traffic controllers' weather information is available via the Weather and Radar Processor (WARP)[36]. Composite reflectivity (section 6.6) is the weather radar data that goes into air traffic control's WARP for a view of weather targets on the scope at ARTCCs. The FAA did not provide the requested ZHU WARP information in a timely fashion and the data was then lost due to the FAA's retention policies.

17.0 PIC and Weather Briefing Information[37]

Several NTSB personnel and the NTSB meteorologist interviewed the pilot in command (PIC) of the accident flight. The PIC recalled the weather in the Houston area on the accident day as similar to the weather on the previous day when he had flown in and out of SGR. The PIC recalled receiving a wind report from SGR ATC as wind from 150° at 11 or 12 knots. During the accident flight, the PIC recalled breaking out of the cloud cover at 500 to 600 feet agl and seeing the runway. The PIC indicated that he had landed in heavier rain situations, and described the rain as a little heavier than light and that he had no forward visibility issues. The PIC didn't feel any wind gusts while landing. When reviewing the weather conditions before the accident flight the PIC did take a little extra fuel onboard. The PIC stated that there was lightning "here and there" around the Houston area during descent into SGR, but NEXRAD displayed on Multi-Function Display (MFD) and iPad display of weather showed no weather radar returns greater than the color yellow. The PIC kept current on the weather throughout the flight using the MFD and also reviewed weather on an iPad. Before hand off to SGR ATC, I90 TRACON gave the accident flight vectors around the weather, and I90 TRACON mentioned that all other flights being routed that way were not experiencing anything more than light chop.[38] The PIC doesn't recall receiving any PIREPs from SGR ATC or I90 TRACON. When the PIC checked the ATIS for SGR it went from message JULIET to message KILO, and on final the PIC received updated wind information from SGR ATC that was different than the ATIS messages JULIET and KILO. While flying into SGR, the PIC stated that the NEXRAD displayed on the iPad didn't show anything worse than green, and the MFD didn't show anything worse than yellow, so the PIC did not turn on the onboard weather radar in the nose cone of the accident aircraft. The PIC saw lightning displayed on the iPad and MFD and could see lightning flashes while landing at SGR. The PIC stated that he remembers only receiving sustained wind information from SGR ATC while on final, with no wind gust information. The PIC stated that SGR ATC did not issue any braking action PIREPs or other PIREPs to them.

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[36] WARP – Weather and radar processor - A device that provides real-time, accurate, predictive, and strategic weather information presented in an integrated manner in the National Airspace System (NAS). Details surface conditions as derived from METAR and other surface observations and is displayed on air traffic control radar displays.

[37] For more information see the Operational and Record of Conversation data contained in the docket for this accident.

[38] For more information see the ATC data contained in the docket for this accident.

The PIC received weather information prior to the accident flight via an APG service/application and then looked at FltPlan.com for weather information. The only archived and obtainable source of weather information provided to the accident pilot preflight was from Flight Options via Jeppesen Weather, which is found in attachment 17. The preflight weather information was provided to the accident pilot at 0651 CDT and contained the latest METAR information from KSGR, the KSGR TAF from 0637 CDT, and NOTAM information. In addition, the PIC had tablets available in flight and the accident aircraft was equipped with Wi-Fi. The PIC did obtain additional weather data (including NEXRAD, METARs) via the internet while in flight and additional weather data was also displayed on the accident aircraft's MFD throughout the flight. The accident pilot had many different sources of approved weather (attachment 18).

18.0 ASOS and LAWRS Documentation

Viewing the one-minute visibility data (table 1) there was a large discrepancy between the METARs and SPECIs sent into the NAS from the KSGR ASOS and the one-minute observations. The one-minute KSGR ASOS visibility data remains at or below 1 mile from 1456 to 1459 CDT and from 1504 CDT through 1547 CDT (attachments 1 and 2). However, from 1501 through 1553 CDT the visibility in the KSGR METARs and SPECIs was 3 miles. The visibility sensor became not operational at 1457 CDT because of the large drop in visibility during the minutes of 1454, 1455, and 1456 CDT: "*ST 2793 VISIBILITY SENSOR #1 NOT OPERATIONAL: VISIBILITY DROPPED FROM 7 MILES TO LESS THAN 2" (attachments 19, 20, and 21). This large drop in the one-minute visibility caused the visibility sensor to report visibility as missing. Due to the missing visibility on the ASOS OID, at 1457:56 CDT SGR air traffic control manually input 3 miles visibility (figure 39) in the ASOS OID (figure 28). As LAWRS certified observers SGR air traffic control can manually input or adjust weather observations. SGR air traffic controllers have visibility markers surrounding the tower available for reference in the NIDS (figures 40 and 41). In this case, the SGR controllers did not continually update the visibility after 1457:56 CDT during the rapidly changing weather conditions experienced at SGR (sections 3.0, 3.1, 3.2, and 16.0). Therefore the visibility remained 3 miles for every METAR and SPECI observation until after the next hourly observation of KSGR at 1553 CDT. As is documented when a large drop in visibility occurs in one-minute (attachments 1, 2, 19, and 21), the ASOS visibility sensor is designed to report missing, then after 9 one-minute visibility observations the ASOS visibility will again report visibility. However, if the visibility is manually edited (as was the case in this accident) the ASOS will wait till after the following hourly observation to adjust to the ASOS visibility sensor observation (see attachment 25).

In addition, due to SGR air traffic control priorities[39] around the accident time (section 16.0), there were also two KSGR SPECIs that were sent to the ASOS OID, but the two KSGR SPECIs were cancelled from being sent into the NAS by SGR ATC. One of the SPECIs was taken at 1509 CDT and the second SPECI that was not sent into the NAS was taken at 1513 CDT (figure 39).

[39] For more information see the ATC data contained in the ATC factual report.

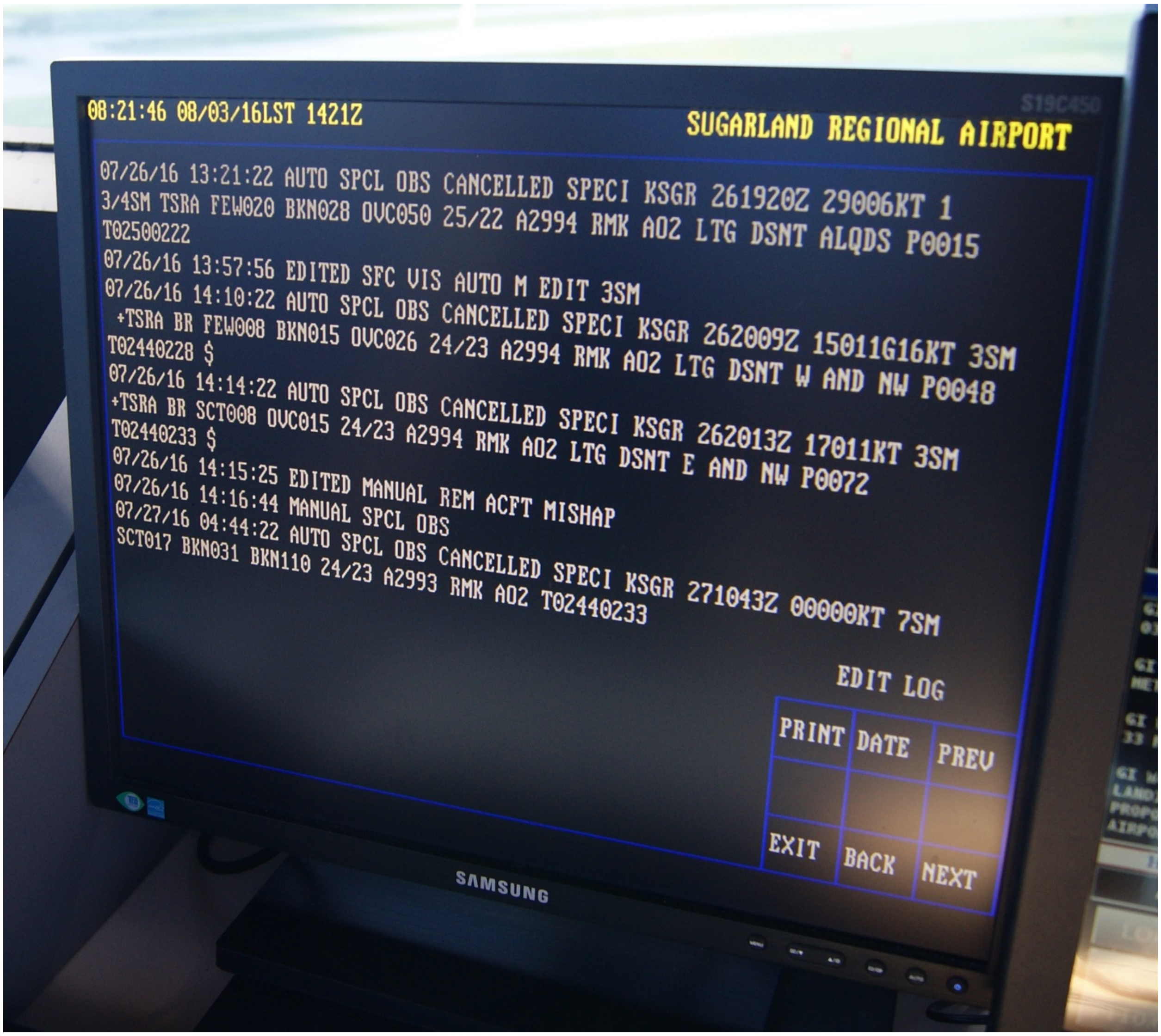

Figure 39 – KSGR edit log from the accident day

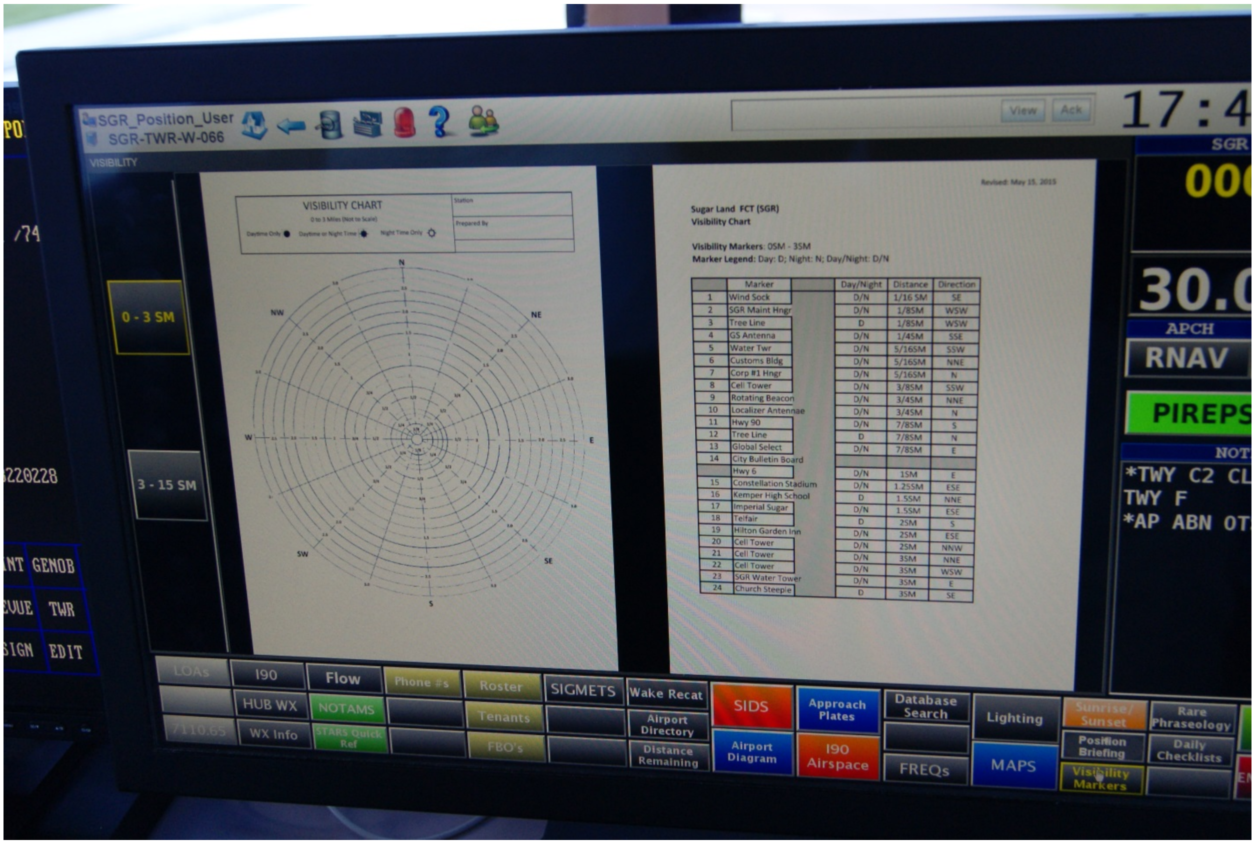

Figure 40 – KSGR 0 to 3 mile visibility markers for LAWRS observations

Figure 41 – KSGR 3 to 15 mile visibility markers for LAWRS observations

19.0 SGR Video Imagery

SGR camera imagery was obtained from 1403 to 1527 CDT (attachment 23, figures 43 to 55). The East Tarmac camera was located five-eighths of a mile north-northeast of the KSGR ASOS equipment (with the ASOS located near the tree line behind the concrete bridge over the pond, figure 43) and three-eighths of a mile east-northeast of the air traffic control tower (figure 42). Figure 43 showed the south-southwest facing SGR security camera imagery from 1450:16 CDT with visibility towards the south-southwest greater than five-eighths of a mile. Between 1500 and 1505 CDT the visibility towards the south-southwest dropped below five-eighths of a mile (figures 45 and 46), and the visibility (based on the SGR camera imagery) remained below five-eighths of a mile through the accident time (figures 47 through 49). The west-southwest facing camera (figures 50 through 55) indicated a similar drop in visibility (as the south-southwest facing camera) between 1459 and 1505 CDT (figures 52 and 53), with a further reduction in visibility by 1509 CDT (figure 54). The accident airplane can be seen at 1510:09 CDT (figure 55, red circle) with visibilities to the west-southwest at or below three-eighths of a mile.

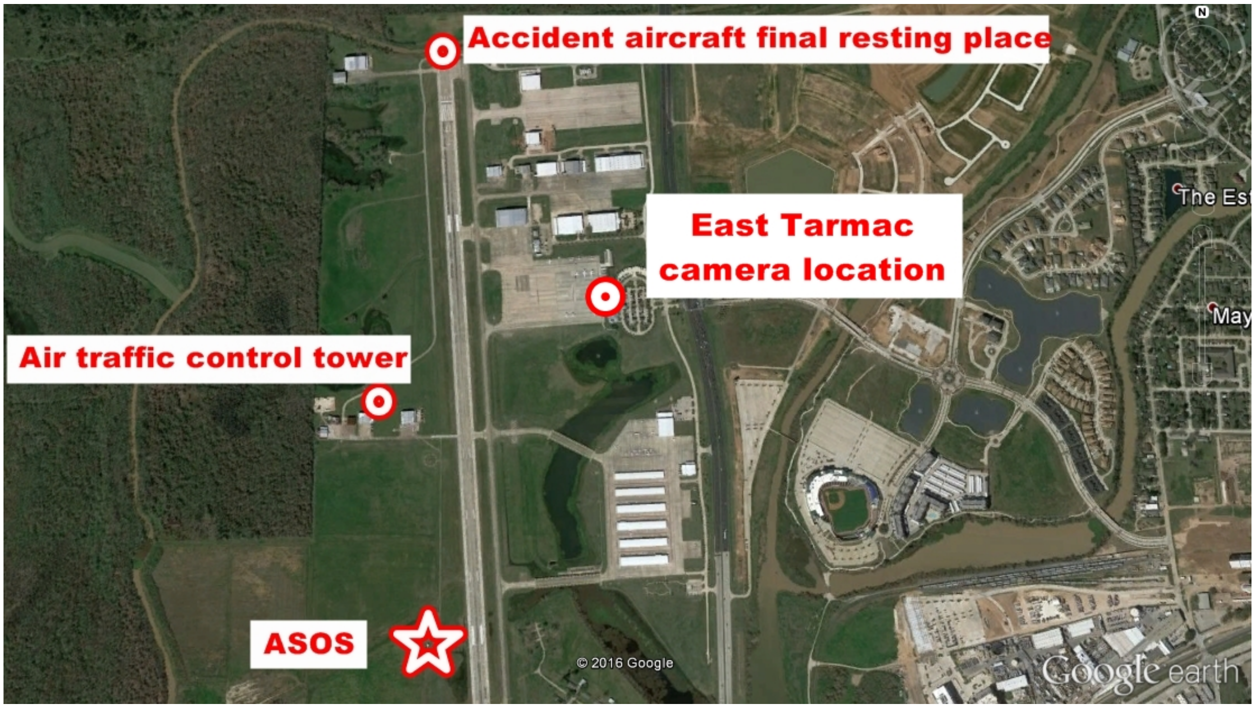

Figure 42 – SGR airport overview diagram with the location of KSGR, the air traffic control tower, the East Tarmac camera location, and accident aircraft final resting place

Figure 43 – SGR Security Camera image looking south-southwest towards the south end of the SGR runway at 1450:16 CDT

Figure 44 – SGR Security Camera image looking south-southwest towards the south end of the SGR runway at 1454:56 CDT

Figure 45 – SGR Security Camera image looking south-southwest towards the south end of the SGR runway at 1500:00 CDT

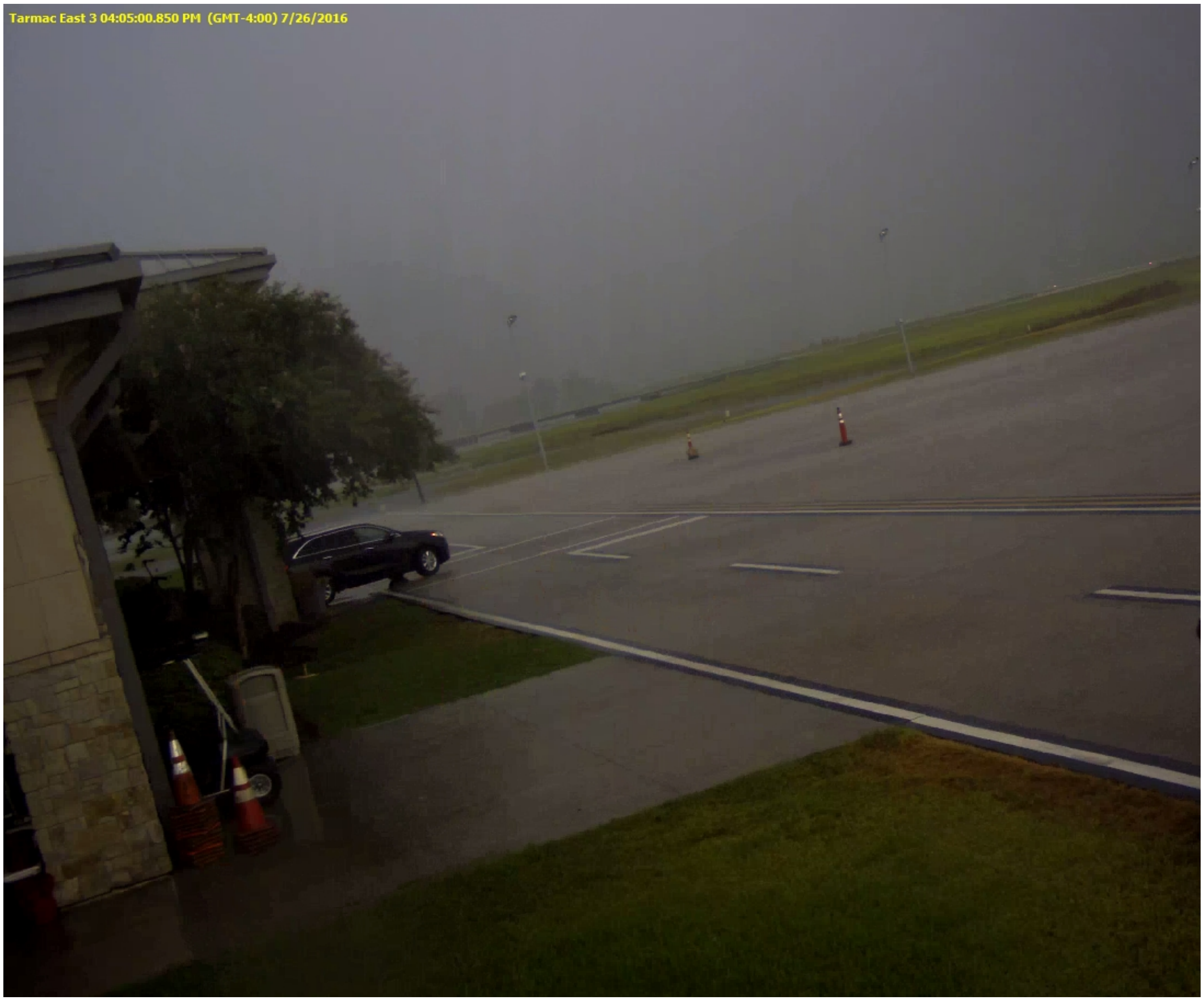

Figure 46 – SGR Security Camera image looking south-southwest towards the south end of the SGR runway at 1505:00 CDT

Figure 47 – SGR Security Camera image looking south-southwest towards the south end of the SGR runway at 1508:17 CDT

Figure 48 – SGR Security Camera image looking south-southwest towards the south end of the SGR runway at 1509:11 CDT

Figure 49 – SGR Security Camera image looking south-southwest towards the south end of the SGR runway at 1510:03 CDT

Figure 50 – SGR Security Camera image looking west-southwest towards the air traffic control tower at 1450:20 CDT

Figure 51 – SGR Security Camera image looking west-southwest towards the air traffic control tower at 1454:56 CDT

Figure 52 – SGR Security Camera image looking west-southwest towards the air traffic control tower at 1459:37 CDT

Figure 53 – SGR Security Camera image looking west-southwest towards the air traffic control tower at 1505:13 CDT

Figure 54 – SGR Security Camera image looking west-southwest towards the air traffic control tower at 1509:02 CDT

Figure 55 – SGR Security Camera image looking west-southwest towards the air traffic control tower at 1510:09 CDT

20.0 Houston Lightning Mapping Array Data

Lightning data near SGR was obtained from the Houston Lightning Mapping Array (HLMA) operated by Dr. Richard Orville from Texas A&M University.[40] The HLMA had a lightning detection sensor located at the SGR right next to the ASOS equipment (figure 8). Lightning flashes first occurred right next to the SGR sensor around 1451 CDT (figure 56) with an additional cluster of lightning flashes near SGR around 1455 CDT (figure 57). The majority of the lightning flashes at 1510 CDT (figure 58) were south of SGR, but along the flight path that the accident flight took into SGR (sections 6.5, 6.6, and 6.7). For more lightning data surrounding the accident time please see attachment 24.

[40] For more information on the HLMA please see: http://atmo.tamu.edu/ciams/lma/aboutlma/about.html

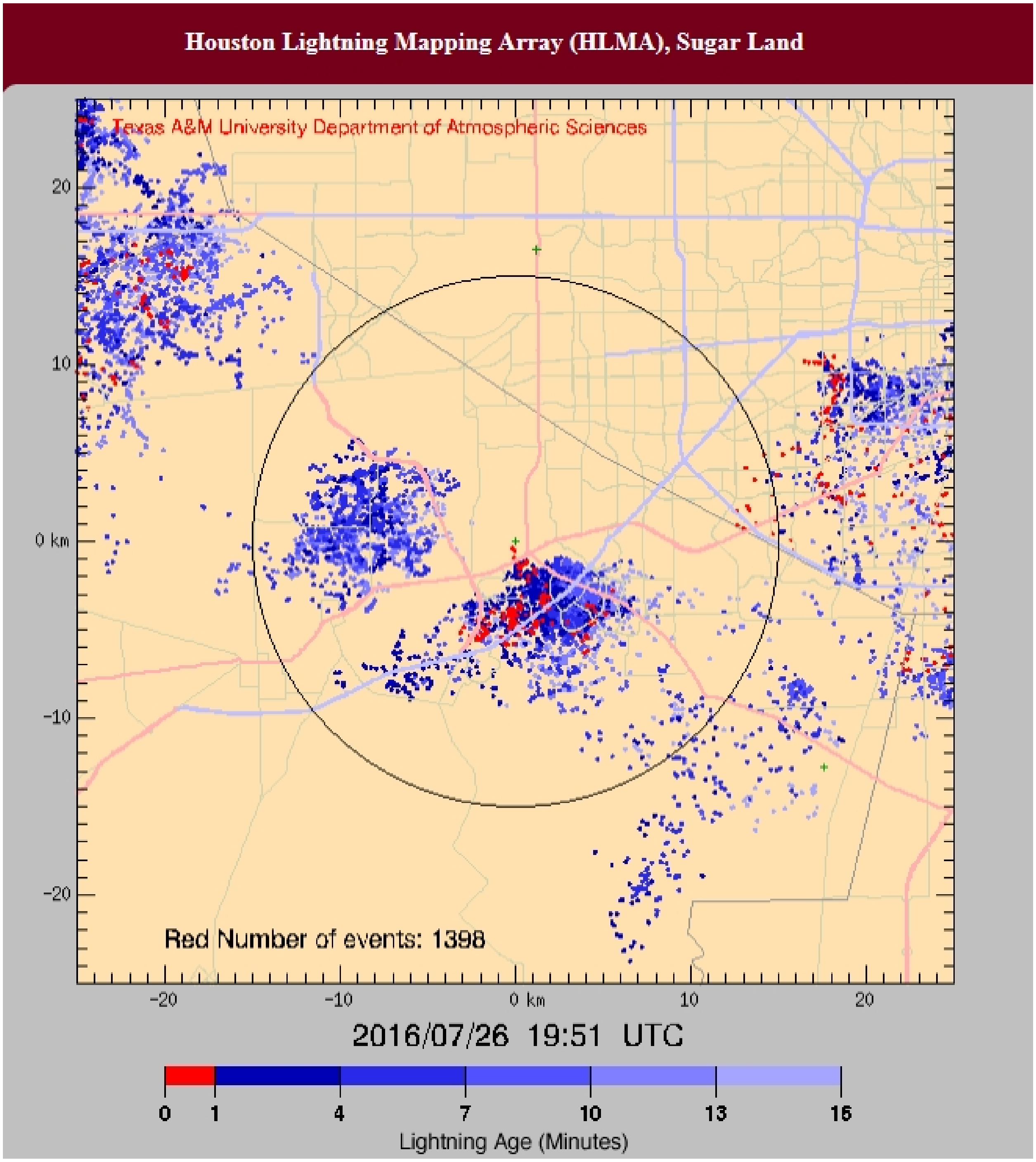

Figure 56 – HLMA data from Sugar Land from 1451 CDT

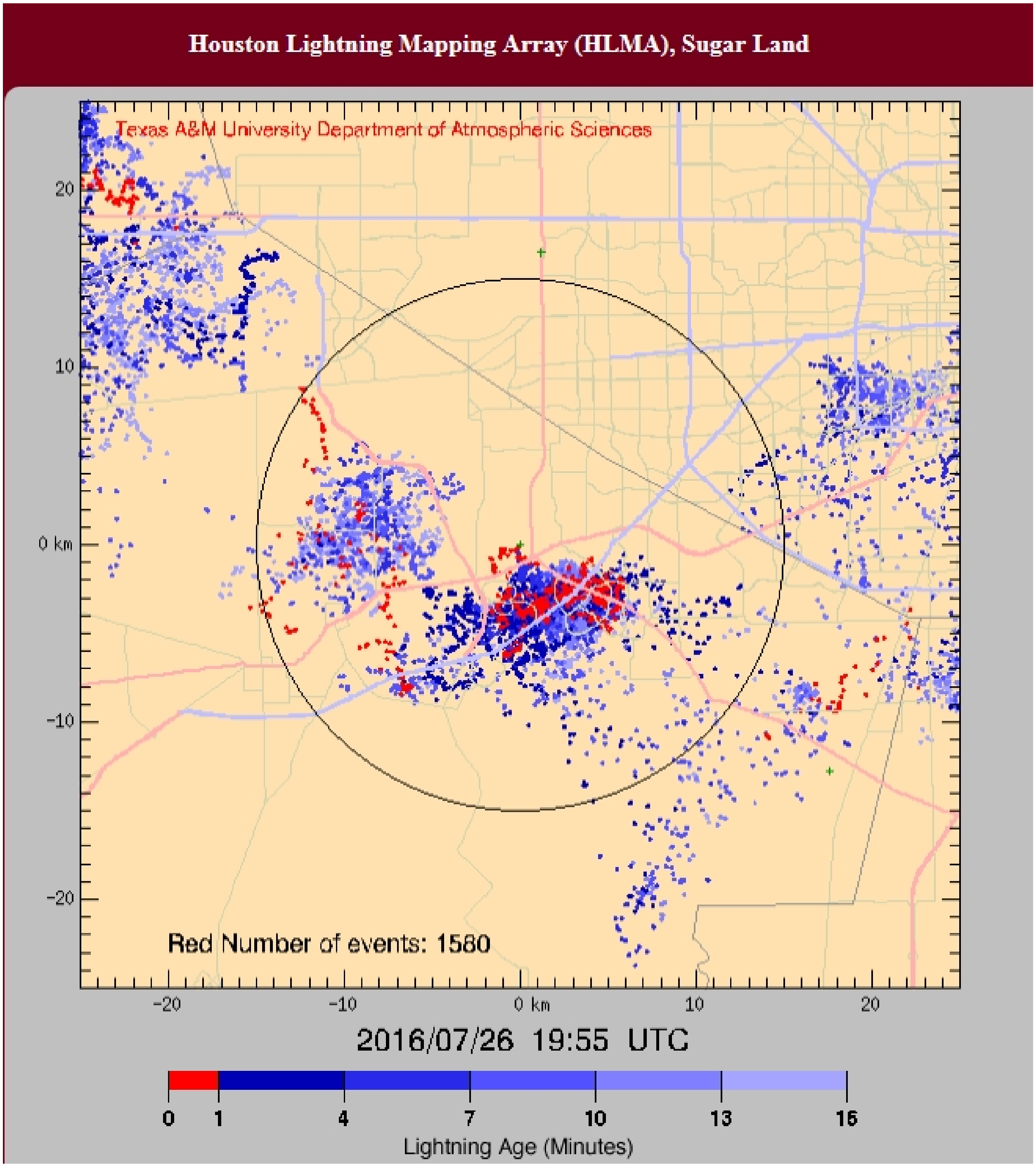

Figure 57 – HLMA data from Sugar Land from 1455 CDT

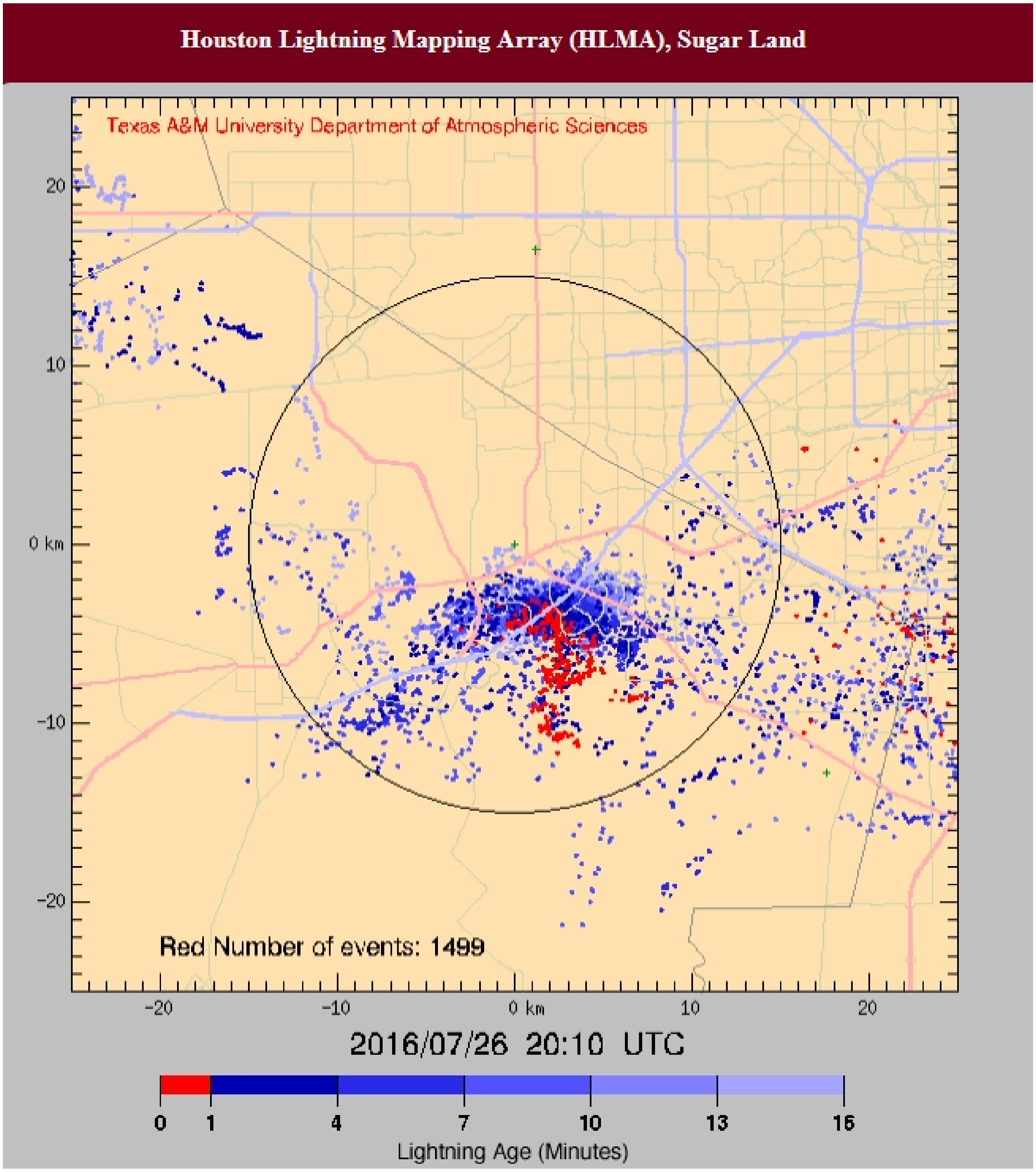

Figure 58 – HLMA data from Sugar Land from 1510 CDT

21.0 Astronomical Data

The astronomical data obtained from the United States Naval Observatory for the accident site on July 26, 2016, indicated the following:

SUN	
Begin civil twilight	0613 CDT
Sunrise	0639 CDT
Sun transit	1329 CDT
Sunset	2019 CDT
End civil twilight	2045 CDT

22.0 Thunderstorm Training Information

The Federal Aviation Administration's (FAA) Advisory Circular AC 00-24C titled "Thunderstorms" issued in February 2013 is a training guide on thunderstorm hazards used for flight training guidance. As a result of the hazardous nature of thunderstorms the FAA has published several common practices or "do's and don'ts" on thunderstorm flying, which are published in AC 00-24C and the Aeronautical Information Manual (AIM) under Chapter 7 Safety of Flight, section 7-1-29. The following avoidance rules are published:

DOS AND DON'TS OF THUNDERSTORM AVOIDANCE.

a. 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.

b. Dos Before Entering a Storm. If unable to avoid penetrating a thunderstorm, the following are some dos *before* entering the storm:

(1) Tighten the safety belt, put on the shoulder harness (if installed), and secure all loose objects.

(2) Plan and hold the course to take the aircraft through the storm in a minimum time.

(3) To avoid the most critical icing, establish a penetration altitude below the freezing level or above the level of -15ºC.

(4) Verify that pitot heat is on and turn on carburetor heat or jet engine anti-ice. Icing can be rapid at any altitude and cause almost instantaneous power failure and/or loss of airspeed indication.

(5) Establish power settings for turbulence penetration airspeed recommended in the aircraft manual.

(6) Turn up cockpit lights to highest intensity to lessen temporary blindness from lightning.

(7) If using automatic pilot, disengage Altitude Hold Mode and Speed Hold Mode. The automatic altitude and speed controls will increase maneuvers of the aircraft thus increasing structural stress.

(8) If using airborne radar, tilt the antenna up and down occasionally. This will permit the detection of other thunderstorm activity at altitudes other than the one being flown.

c. Dos and Don’ts for Thunderstorm Penetration. Following are some dos and don’ts during the thunderstorm penetration:

(1) Do keep your eyes on the flight instruments. Looking outside the cockpit can increase danger of temporary blindness from lightning.

(2) Don’t change power settings; maintain settings for the recommended turbulence penetration airspeed.

(3) Do maintain constant attitude. Allow the altitude and airspeed to fluctuate.

(4) Don’t turn back once in the thunderstorm. A straight course through the storm most likely will get the aircraft out of the hazards most quickly. In addition, turning maneuvers increase stress on the aircraft.

E. LIST OF ATTACHMENTS

Attachment 1 – National Climatic Data Center data documentation for ASOS surface 1-minute data

Attachment 2 – Additional 5- and 1-minute ASOS observations from KSGR

Attachment 3 – GOES-13 animation from 1400 to 1615 CDT

Attachment 4 – Lightning data from 1455 to 1510 CDT

Attachment 5 – Animation of KHGX WSR-88D base reflectivity images for the 0.5° elevation scan from 1429 to 1533 CDT

Attachment 6 – Animation of KHGX WSR-88D digital 1-hour precipitation images from 1429 to 1556 CDT

Attachment 7 – Animation of THOU TDWR base reflectivity images for the 0.2° elevation scan from 1457 to 1520 CDT

Attachment 8 – Animation of TIAH TDWR base reflectivity images for the 0.1° elevation scan from 1457 to 1520 CDT

Attachment 9 – I90 TRACON PIREP log sheet for July 25 and 26

Attachment 10 – Animation of STARS display of weather and precipitation used and seen by the accident controllers from 1450 to 1514 CDT

Attachment 11 – STARS weather and precipitation display from the ASR-9 site at William P Hobby Airport from 1506 to 1510 CDT

Attachment 12 – STARS weather and precipitation display from the ASR-9 site at George Bush Intercontinental Airport from 1506 to 1510 CDT

Attachment 13 – FAA reply to NTSB request 16-303

Attachment 14 – ASR-9 tilt indicator

Attachment 15 – ASR-9 antenna coverage patterns

Attachment 16 – FAA reply to NTSB request 16-303 part 2

Attachment 17 – Preflight weather information provided to the accident pilot

Attachment 18 – Approved sources of weather

Attachment 19 – KSGR system log

Attachment 20 – ASOS official documentation

Attachment 21 – ASOS visibility sensor documentation

Attachment 22 – KSGR raw ASOS information

Attachment 23 – SGR East Tarmac camera imagery

Attachment 24 – Texas A&M Houston Lightning Mapping Array Data

Attachment 25 – Correspondence with NWS about ASOS observations

Submitted by:

Paul Suffern
Senior Meteorologist

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