NATIONAL TRANSPORTATION SAFETY BOARD

Office of Aviation Safety
Washington, D.C. 20594

April 14, 2014

Group Chairman's Factual Report

METEOROLOGY

DCA14FA058

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A. ACCIDENT

Location:	Memphis, Tennessee
Date:	February 5, 2014
Time:	About 0022 central standard time (0622 UTC[1])
Airplane:	Trans State EMB145; registration N802HK

B. METEOROLOGY GROUP

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C. SUMMARY

On February 5, 2014, about 0022 central standard time, N802HK, an EMB145EP operated by Trans States Airlines LLC as a Title 14 CFR Part 121 scheduled domestic passenger flight to Memphis, Tennessee, landed hard on runway 36R. Instrument meteorological conditions prevailed at the time of the accident, and an instrument flight rules flight plan was filed. The airplane incurred substantial damage. There were no injuries to the 3 flight crew members or 50 passengers aboard. The flight originated in Houston, Texas, the previous day, about 2022.

D. DETAILS OF THE INVESTIGATION

The National Transportation Safety Board's (NTSB) Senior Meteorologist was not on scene for this investigation and conducted the meteorology phase of the investigation from the Washington D.C. office, collecting data from official National Weather Service (NWS) sources including the Weather Prediction Center and the National Climatic Data Center (NCDC). All times are central standard time (CST) based upon the 24 hour clock, local time +6 hours to UTC, and UTC=Z. Directions are referenced to true north and distances in nautical miles. Heights are above mean sea level (msl) unless otherwise noted. Visibility is in statute miles and fractions of statute miles. NWS airport and station identifiers use standard International Civil Aviation Organization (ICAO) 4-letter station identifiers versus International Air Transport Association (IATA) 3-letter identifiers which deletes the initial country code designator "K" for U.S. airports. Both codes are both used intermittently in this report.

The accident plots are centered on the Memphis International Airport (KMEM) located at latitude 35.04241° N and longitude 89.9766° W, and an elevation of 341 feet.

[1] UTC – is an abbreviation for Coordinated Universal Time.

The NTSB Form 6120.1 Pilot/Operator Aircraft Accident/Incident Report filed by the operator provided more details of the event. Trans States Airlines indicated that Flight 3395 departed Houston's George Bush Intercontinental Airport (KIAH) on the evening of February 04, 2014 to Memphis International Airport (KMEM) with a scheduled flight time of 57 minutes en route. The flight departed in night visual conditions, and flew uneventfully to Memphis. At Memphis, the flight encountered instrument meteorological conditions on approach. Flight 3395 was cleared for an ILS approach to Runway 36C, but elected a missed approach near the final approach fix due to problems receiving the localizer. Memphis Air Traffic Control vectored the flight to the ILS Runway 36R. The approach appeared normal. The autopilot was disconnected at approximately 300 feet agl. Approximately 20-40 feet above the ground, the crew reported the aircraft banked sharply to the right, and the right wing tip contacted the ground. The crew recovered the aircraft, landed, and taxied to the gate under their own power. At the gate, the crew noted damage to the right wing. The crew also noted that both wings and engine inlets were coated with ice. The crew reported that they had not received an ice detection activation message on the EICAS, and that the aircraft's ice protection system did not activate. A photograph of the iced up wing taken by the Captain and is included in this report.

E. FACTUAL INFORMATION

1.0 Synoptic Situation

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

1.1 Surface Analysis Chart

The regional NWS Surface Analysis Chart for 0000 CST (0600Z) on February 5, 2014 centered over Tennessee is included as figure 1 with the approximate accident site within the red circle. The chart depicted a low pressure system at 1009-hectopascals (hPa) over northern Alabama to the east-southeast of the accident site with a cold front extending south-southwestward across Alabama, extreme southern Mississippi, into Louisiana, and into the Gulf of Mexico. A warm front extended south-southeastward from the low in Alabama into Georgia and then become stationary. A second low pressure center at 1008-hPa was located over central Kentucky along a stationary front which extended central Tennessee into eastern Kentucky, with a trough of low pressure extending westward from the low pressure system into the boot heal of Missouri, northern Arkansas, and southern Missouri. The Memphis area was located in the cold air sector behind the cold front and immediately south of the trough of low pressure.

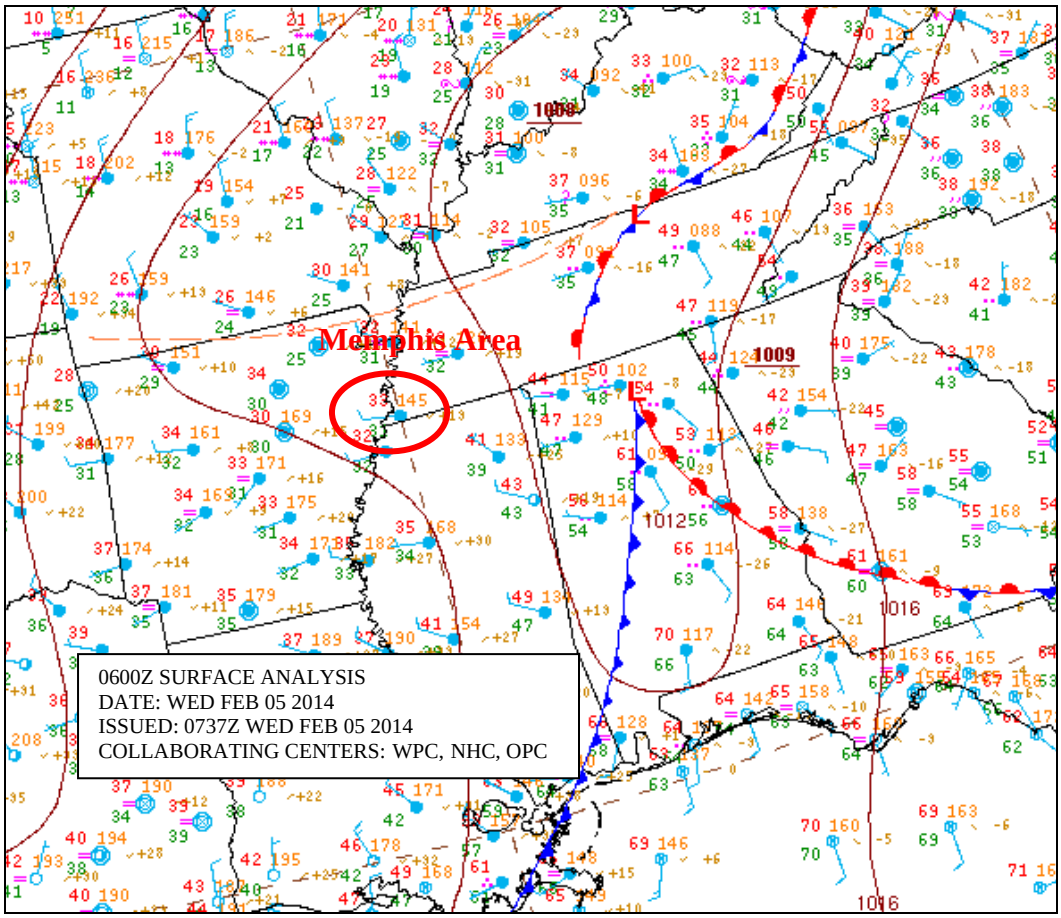

Figure 1 – NWS Surface Analysis Chart for 0000 CST on February 5, 2014

The station model for Memphis indicated a westerly wind at approximately 10 knots, overcast sky cover, temperature of 33° Fahrenheit (F), dew point of 30° F, and a sea level pressure of 1012.6-hPA. Several stations in the immediate vicinity reported visibility restricted in fog and/or mist. A large area of precipitation in rain was also indicated along the cold and warm front east and southeast of the Memphis area, and an extensive area of snow to the north over Missouri and Illinois.

1.2 Radar Mosaic

Figure 2 is the NWS radar mosaic for 0020 CST and depicted an area of snow showers over Missouri and Illinois north of the Memphis area and a line of rain showers and thunderstorms east of Nashville, Tennessee, which extended southward to the Gulf coast. No significant precipitation echoes were depicted along the route of flight from Houston to Memphis.

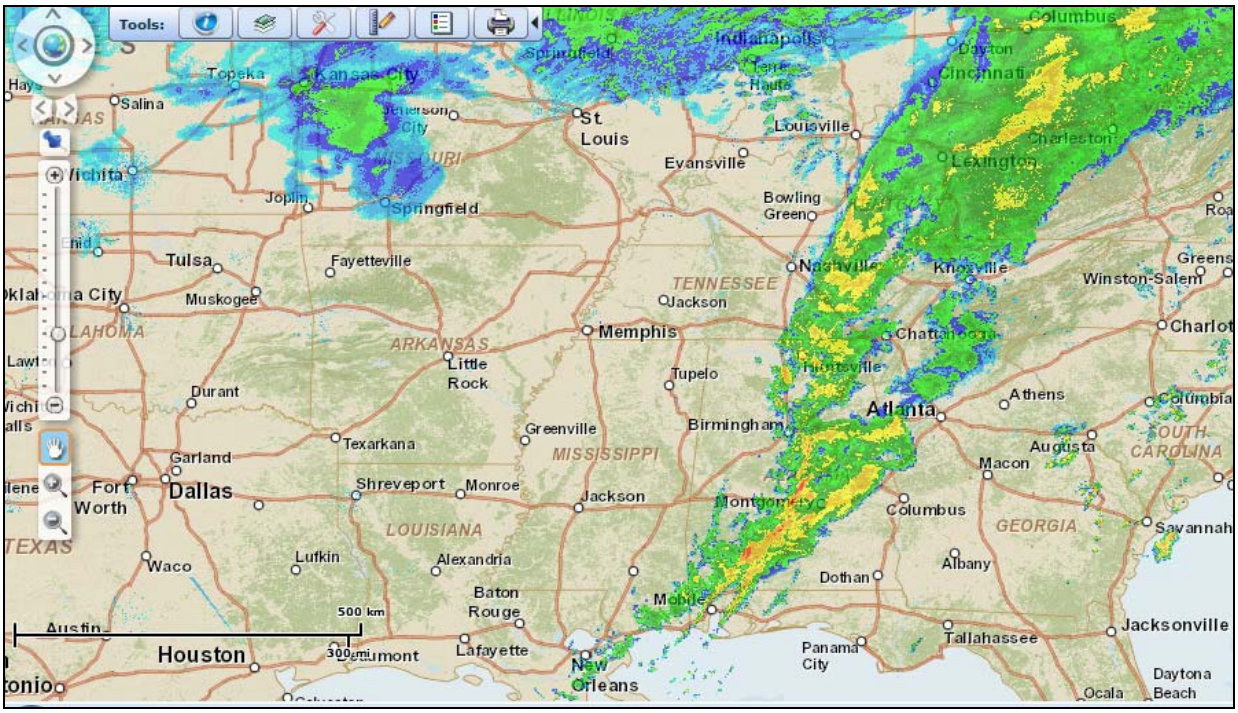

Figure 2 - NWS Radar Mosaic for 0020 CST

1.3 Weather Depiction Charts

The NWS Weather Depiction Charts for 2200 CST (0400Z) and 0100 CST (0700Z) are included as figures 3 and 4 respectively, and depict the coverage of low ceilings and visibilities across the region. The charts depict the general flight categories of instrument flight rule (IFR)[2], marginal visual flight rule (MVFR)[3], and visual flight rule (VFR) conditions[4] over the country surrounding the period. Both charts depicted an extensive area of IFR conditions extending from eastern Texas to the east coast and extending from the Gulf coast to the Great Lakes, with only a few breaks of MVFR conditions. The Memphis area reported IFR conditions on both charts with visibility 1/2 mile and ceiling overcast at 400 feet agl.

[2] Instrument Flight Rule (IFR) conditions – are defined as a ceiling or lowest layer of clouds reported as broken, overcast, or the vertical visibility into a surface based obscuration of less than 1,000 feet above ground level (agl) and/or visibility less than 3 statute miles.

[3] Marginal Visual Flight Rule (MVFR) conditions – is defined as a ceiling between 1,000 and 3,000 feet agl and/or visibility 3 to 5 miles inclusive.

[4] Visual Flight Rule (VFR) conditions – is defined as no ceiling or a ceiling greater than 3,000 feet, and visibility greater than 5 miles.

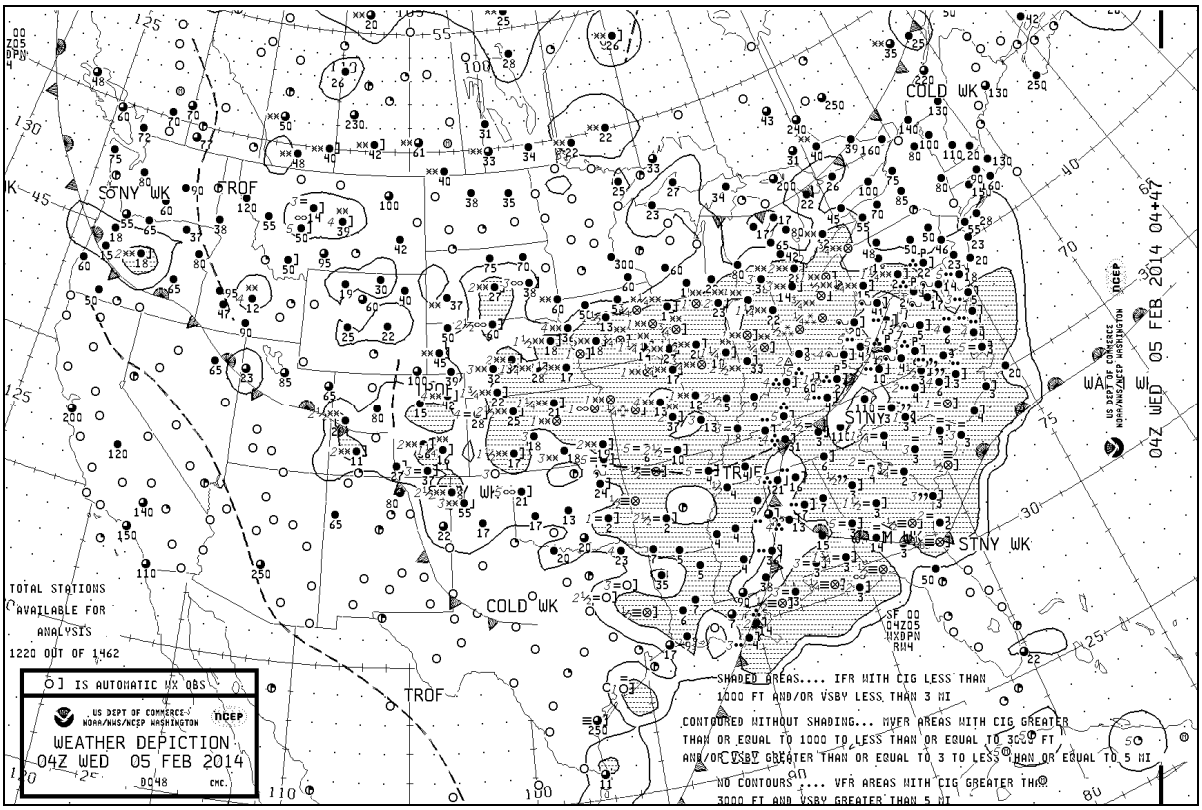

Figure 3 - NWS Weather Depiction Chart for 2200 CST

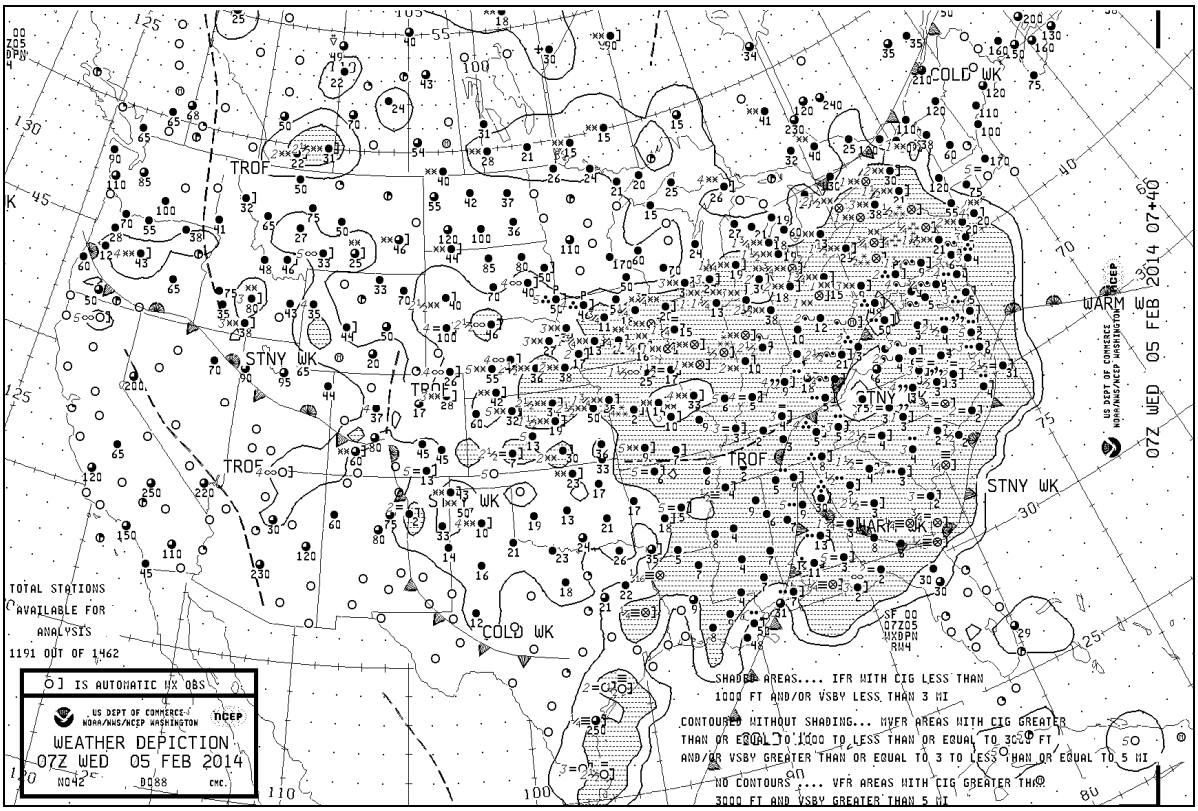

Figure 4 - NWS Weather Depiction Chart for 0100 CST

2.0 Surface Observations

The official NWS Meteorological Aerodrome Reports (METARs) and special reports (SPECIs) surrounding the period were documented for Memphis, Tennessee. The cloud heights are reported above ground level (agl).

2.1 Memphis International Airport (KMEM), Memphis, Tennessee

Memphis International Airport (KMEM), Memphis, Tennessee had a reported elevation of 341 feet, a magnetic variation of 1° East, and had a federally installed and maintained Automated Surface Observation System (ASOS). The following observations were the official observations issued prior to and after the accident:

Memphis International Airport weather observation at 2354 CST (0554Z), wind from 280° at 10 knots, tower visibility 1/2 mile, ceiling overcast at 400 feet, temperature 1° Celsius (C), dew point temperature -1° C, altimeter 29.95 inches of mercury (Hg). Remarks: automated observation system, surface visibility 8 miles, sea level pressure 1014.5-hPa, 3-hour precipitation 0.10 inches, temperature 0.6° C, dew point -0.6° C, 6-hour maximum temperature 1.7° C, 6-hour minimum temperature 0.6° C, 3-hour pressure tendency risen 1.3-hPa, maintenance indicator[5].

Memphis International Airport weather observation at 0054 CST (0654Z), wind from 290° at 12 knots gusting to 19 knots, tower visibility 1/2 mile in mist, ceiling overcast at 400 feet, temperature 1° C, dew point temperature -1° C, altimeter 29.99 inches of Hg. Remarks: automated observation system, surface visibility 6 miles, ceiling 300 feet variable 700 feet, sea level pressure 1015.6-hPa, temperature 0.6° C, dew point -1.1° C, maintenance indicator being reported.

The raw observations surrounding the period with the general flight categories were as follows:

LIFR[6] *METAR KMEM 050254Z 30006KT 1/2SM OVC004 01/00 A2992 RMK AO2 SFC VIS 8 SLP132 60010 T00060000 53022 $=*

LIFR METAR KMEM 050354Z 29008KT 1/2SM OVC004 01/M01 A2992 RMK AO2 SFC VIS 7 SLP132 T00061006 $=

LIFR METAR KMEM 050454Z 29007KT 1/2SM BR OVC004 01/M01 A2994 RMK AO2 SFC VIS 6 SLP140 T00061006 $=

LIFR METAR KMEM 050554Z 28010KT 1/2SM OVC004 01/M01 A2995 RMK AO2 SFC VIS 8 SLP145 60010 T00061006 10017 20006 400171011 53013 $=

[5] Maintenance indicator ($) – advises the user that the system is out of calibration, out of service, or needs requires servicing from a maintenance technician.

[6] NWS defines Low Instrument Flight Rules (LIFR) conditions as a ceiling below 500 feet agl and/or visibility less than 1 statute mile, and brackets IFR conditions as a ceiling between 500 to below 1,000 feet agl and/or visibility 1 to less than 3 miles.

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LIFR METAR KMEM 050654Z 29012G19KT 1/2SM BR OVC004 01/M01 A2999 RMK AO2 SFC VIS 6 CIG 003V007 SLP156 T00061011 $=

IFR SPECI KMEM 050701Z 28012KT 1/2SM BR OVC006 01/M01 A2999 RMK AO2 SFC VIS 6 CIG 004V009$

IFR/LIFR SPECI KMEM 050704Z 28011KT 6SM BR OVC006 01/M01 A2999 RMK AO2 CIG 004V009 $=

MVFR/IFR SPECI KMEM 050735Z 27008KT 6SM BR BKN010 OVC013 01/M01 A2999 RMK AO2 CIG 006V012 $=

MVFR/IFR METAR KMEM 050754Z 26008KT 6SM BR OVC010 01/M01 A3000 RMK AO2 CIG 008V013 SLP160 T00061011 $=

IFR SPECI KMEM 050817Z 27008KT 6SM BR OVC008 01/M01 A3001 RMK AO2 $=

IFR METAR KMEM 050854Z 27005KT 6SM BR OVC008 01/M01 A3002 RMK AO2 SLP166 T00061006 51021 $=

The high resolution 5-minute and 1-minute ASOS data was not available surrounding the period due to some archive issued associated with the NWS on February 5, 2014.

2.2 Olive Branch Airport (KOLV), Olive Branch, Mississippi

The next closest weather reporting location was from Olive Branch Airport (KOLV), Olive Branch, Mississippi, located approximately 10 miles east immediately south of the Tennessee border at an elevation of 402 feet. The airport had an Automated Weather Observation System (AWOS) without a precipitation discriminator, which could not determine the weather type or precipitation. At the approximate time of the accident the airport reported the following conditions:

Olive Branch Airport weather at 0015 CST (0615Z), automated, wind from 270° at 10 knots gusting to 15 knots, visibility 3 miles, ceiling overcast at 400 feet agl, temperature 0° C, altimeter 29.97 inches of Hg.

The general flight category and raw observations surrounding the period were as follows:

LIFR METAR KOLV 050255Z AUTO 28011KT 1 1/4SM OVC002 00/ A2991 RMK A01 P000=

LIFR METAR KOLV 050315Z AUTO 29007KT 4SM OVC002 00/ A2990=

LIFR METAR KOLV 050335Z AUTO 28007KT 4SM OVC002 00/ A2991=

LIFR METAR KOLV 050355Z AUTO 27005KT 6SM OVC003 00/ A2992 RMK A01 P000=

LIFR METAR KOLV 050415Z AUTO 28009KT 7SM OVC003 00/ A2992=

LIFR METAR KOLV 050435Z AUTO 28009KT 2 1/2SM OVC002 00/ A2994=

LIFR METAR KOLV 050455Z AUTO 28006KT 2 1/2SM OVC002 00/ A2994 RMK A01 P000=

LIFR METAR KOLV 050515Z AUTO 28009KT 3SM OVC002 00/ A2994=

LIFR METAR KOLV 050535Z AUTO 28010G15KT 7SM OVC003 00/ A2994=

LIFR METAR KOLV 050555Z AUTO 26007G15KT 6SM OVC004 00/ A2996 RMK A01 P000=

LIFR METAR KOLV 050615Z AUTO 27010G15KT 3SM OVC004 00/ A2997=

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LIFR METAR KOLV 050635Z AUTO 27006G18KT 6SM OVC003 00/ A2998=

LIFR METAR KOLV 050655Z AUTO 27009G17KT 5SM OVC004 00/ A2999 RMK A01 P000=

LIFR METAR KOLV 050715Z AUTO 29013G16KT 3SM OVC003 00/ A3000 RMK A01 P000=

LIFR METAR KOLV 050735Z AUTO 28010G14KT 5SM OVC003 00/ A3000=

IFR METAR KOLV 050755Z AUTO 26007KT 8SM OVC008 00/ A3000 RMK A01 P000=

IFR METAR KOLV 050815Z AUTO 27010G15KT 10SM OVC008 00/ A3001=

IFR METAR KOLV 050835Z AUTO 25007KT 10SM OVC008 00/00 A3002=

IFR METAR KOLV 050855Z AUTO 27006KT 9SM OVC008 00/00 A3002 RMK A01 P000=

2.3 Millington Regional Jetport Airport (KNQA), Millington, Tennessee

Millington Regional Jetport Airport (KNQA) was located approximately 19 miles north in Millington, Tennessee, at an elevation of 319 feet. The airport had an ASOS and was augmented by an observer; however, no remarks were added during the period. The following conditions were reported at the approximate time of the accident:

Millington Regional Jetport Airport (KNQA) weather at 2350 CST (0550Z), wind from 270° at 5 knots, visibility 3 miles in mist, ceiling overcast at 400 feet agl, temperature and dew point 1° C, altimeter 29.94 inches of Hg.

The general flight category and weather conditions surrounding the period were as follows:

LIFR METAR KNQA 050255Z 27003KT 9SM OVC004 01/01 A2992=

LIFR METAR KNQA 050350Z 28003KT 2SM BR OVC003 01/01 A2992=

LIFR METAR KNQA 050450Z 27005KT 2SM BR OVC003 01/01 A2994=

LIFR METAR KNQA 050550Z 27005KT 3SM BR OVC004 01/01 A2994=

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LIFR METAR KNQA 050650Z 27005KT 3SM BR OVC003 01/01 A2998=

IFR METAR KNQA 050815Z AUTO 27005KT 8SM OVC006 01/00 A3000 RMK=

IFR METAR KNQA 050835Z AUTO 26005KT 5SM OVC006 01/01 A3001 RMK=

IFR METAR KNQA 050855Z AUTO 26005KT 6SM BKN006 01/00 A3001 RMK=

IFR METAR KNQA 050915Z AUTO 25005KT 6SM OVC005 01/01 A3003 RMK=

IFR METAR KNQA 050935Z AUTO 25004KT 8SM OVC006 01/00 A3003 RMK=

IFR METAR KNQA 050955Z AUTO 25004KT 9SM OVC006 01/00 A3004 RMK=

3.0 Upper Air Data

The NOAA Forecast Systems Laboratory (FSL) North American Mesoscale (NAM) model sounding for 0000 CST (0600Z) on February 5, 2014 for Memphis is included as figure 5 plotted as a standard Skew-T log P diagram[7]. The model sounding depicted a shallow layer of below freezing temperatures capped by a temperature inversion immediately above the surface from 950 to 825-hPa or approximately from 2,000 to 5,000 feet, where temperatures remained above freezing. The sounding was saturated with a relative humidity greater than 80% from the surface to approximately 800-hPa or 6,000 feet, with drier air above.

[7] Skew T log P diagram – is a standard meteorological plot using temperature and the logarithmic of pressure as coordinates, used to display winds, temperature, dew point, and various indices used to define the vertical structure of the atmosphere.

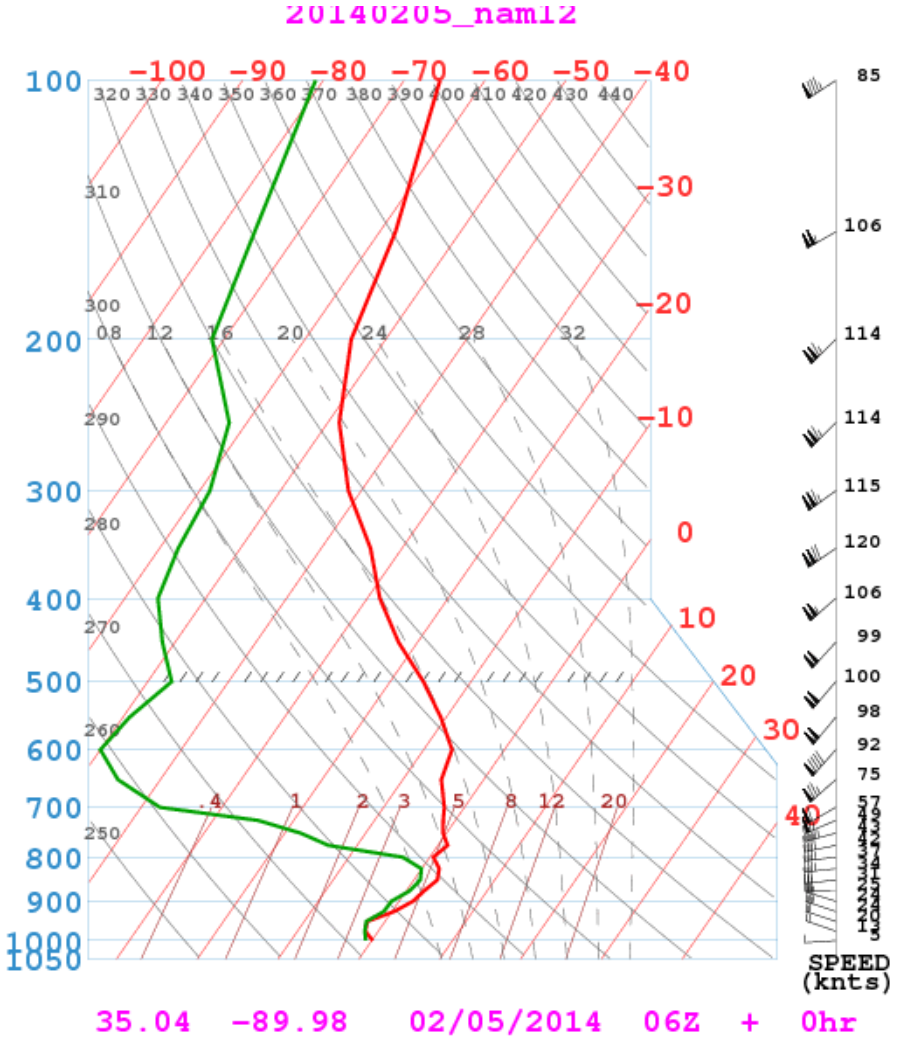


Figure 5 - North American Mesoscale Model Sounding for 0000 CST for Memphis

The wind profile depicted surface wind from the west at 6 knots with wind backing to the southwest above 10,000 feet. Wind speeds increased with height and were above 50 knots above 8,000 feet. The maximum wind depicted in the model was near 350-hPa or 32,000 feet at 120 knots.

Figure 6 is a table of the model output of pressure, height in meters, temperature, dew point, wind direction and wind speed in meters per second from the surface through approximately 23,000 feet.

PRESS HPA	HGT(MSL) M	TEMP C	DEW PT C	WND DIR DEG	WND SPD M/S
1004.	86.	0.5	-0.4	268.1	3.6
1000.	121.	0.1	-0.8	266.9	3.0
975.	324.	-1.6	-1.7	284.8	6.9
950.	530.	-2.2	-2.3	284.5	10.6
925.	743.	0.3	-1.0	284.3	12.4
900.	963.	1.7	-0.9	283.4	12.8
875.	1190.	2.2	0.4	270.4	13.2
850.	1425.	2.9	0.8	264.8	16.2
825.	1667.	2.2	-0.0	265.3	18.0
800.	1914.	0.5	-3.3	265.0	19.2
775.	2169.	1.2	-13.5	260.9	21.7
750.	2432.	-0.4	-18.0	258.3	22.2
725.	2702.	-1.5	-24.4	252.0	25.4
700.	2980.	-2.5	-37.7	246.2	29.8
650.	3564.	-5.2	-45.2	236.0	39.1
600.	4190.	-6.5	-50.0	228.9	47.6
550.	4864.	-10.7	-49.2	227.3	50.6
500.	5589.	-15.9	-47.0	228.0	52.0
450.	6372.	-22.3	-51.6	230.1	51.3
400.	7225.	-28.4	-55.9	236.0	55.1

Figure 6 - Model sounding output

4.0 Aircraft Soundings

A review of Aircraft Meteorological Data Reports (AMDAR) surrounding the period from the NOAA web site provided several descent sounding plots into Memphis immediately after the accident. Figures 7 and 8 are the AMDAR Skew-T log P diagrams for aircraft #11622 landing at 0027 CST and from aircraft #9813 landing at 0039 CST. Both sounding provided consistent information and were similar to the FSL mesoscale model sounding, and supported a layer from the surface to approximately 2,500 feet with below freezing conditions with the temperatures between 0° to -3.3° C and conductive to icing conditions.

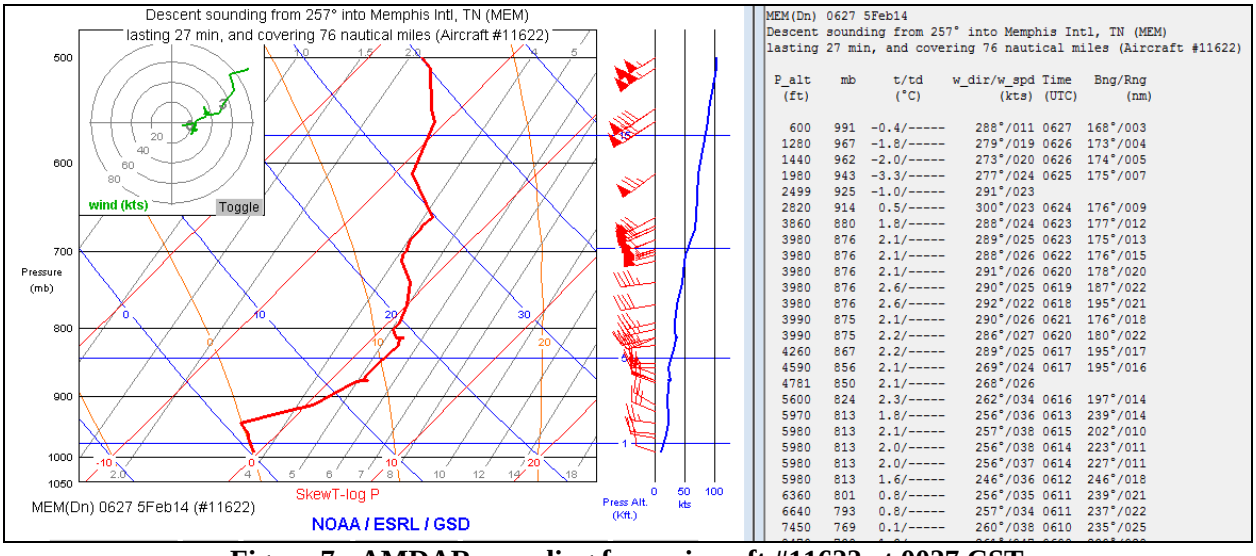
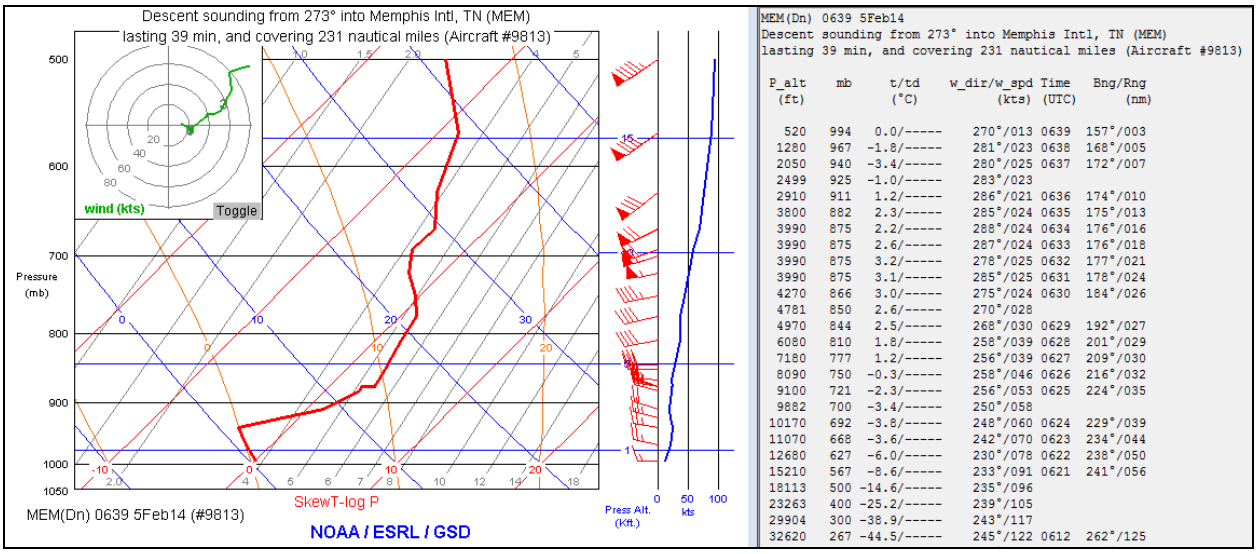


Figure 7 - AMDAR sounding from aircraft #11622 at 0027 CST



MEM(Dn) 0639 5Feb14
Descent sounding from 273° into Memphis Intl, TN (MEM)
lasting 39 min, and covering 231 nautical miles (Aircraft #9813)

P_alt (ft)	mb	t/td (°C)	w_dir/w_spd (kts)	Time (UTC)	Bng/Rng (nm)
520	994	0.0/-----	270°/013	0639	157°/003
1280	967	-1.8/-----	281°/023	0638	168°/005
2050	940	-3.4/-----	280°/025	0637	172°/007
2499	925	-1.0/-----	283°/023		
2910	911	1.2/-----	286°/021	0636	174°/010
3800	882	2.3/-----	285°/024	0635	175°/013
3990	875	2.2/-----	288°/024	0634	176°/016
3990	875	2.6/-----	287°/024	0633	176°/018
3990	875	3.2/-----	278°/025	0632	177°/021
3990	875	3.1/-----	285°/025	0631	178°/024
4270	866	3.0/-----	275°/024	0630	184°/026
4781	850	2.6/-----	270°/028		
4970	844	2.5/-----	268°/030	0629	192°/027
6080	810	1.8/-----	258°/039	0628	201°/029
7180	777	1.2/-----	256°/039	0627	209°/030
8090	750	-0.3/-----	258°/046	0626	216°/032
9100	721	-2.3/-----	256°/053	0625	224°/035
9882	700	-3.4/-----	250°/058		
10170	692	-3.8/-----	248°/060	0624	229°/039
11070	668	-3.6/-----	242°/070	0623	234°/044
12680	627	-6.0/-----	230°/078	0622	238°/050
15210	567	-8.6/-----	233°/091	0621	241°/056
18113	500	-14.6/-----	235°/096		
23263	400	-25.2/-----	239°/105		
29904	300	-38.9/-----	243°/117		
32620	267	-44.5/-----	245°/122	0612	262°/125

Figure 8 - AMDAR sounding from aircraft #9813 at 0039 CST

5.0 Satellite Data

The Geostationary Operational Environmental Satellite number 13 (GOES-13) data was obtained from an archive at the Space Science Engineering Center (SSEC) at the University of Wisconsin-Madison (UW) in Madison, Wisconsin, and processed using the Safety Board's Man-computer Interactive Data Access System (McIDAS) software. The infrared long wave imagery (band 4) at a wavelength of 10.7 microns (μm) provided standard satellite image with radiative cloud top temperatures with a resolution of 4 km.

Figure 9 is the GOES-13 infrared image at 0015 CST (0615Z) at 2X magnification with a standard MB temperature enhancement curve applied to highlight the higher and colder cloud tops associated with deep convection and high cirriform type clouds. The image depicted a band of low stratiform clouds over the Memphis area with a radiative cloud top temperature of 269° Kelvin or -4.0° C, which corresponded to cloud tops near 2,000 feet based on the sounding.

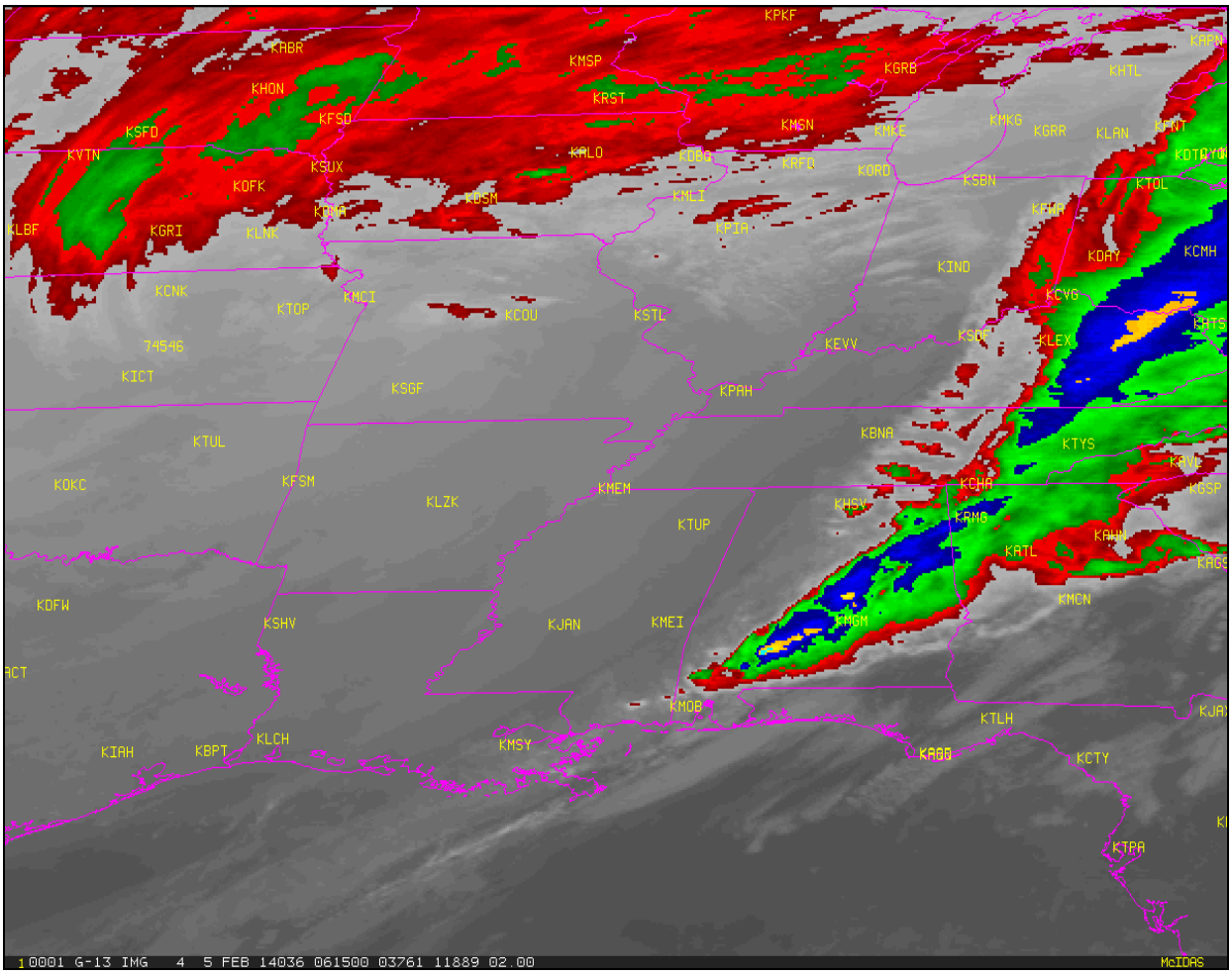


Figure 9 - GOES-13 infrared image at 0015 CST

6.0 Pilot Reports

The following pilot reports (PIREPs) were recorded over Tennessee surrounding the period:

DYR UA /OV DYR 045060/TM 0047/FL315/TP E145/TB OCNL MOD 340-315/RM ZME=

BNA UA /OV GHM/TM 0046/FL080/TP B737/TA M06/IC LGT RIME 160-080/RM ZME=

MEM UA /OV MEM 135050/TM 0230/FL280/TP MULTIPLE/TB MOD/RM ZME=

MEM UA /OV MEM180004 /TM 0458 /FLUNKN /TP DC10 /SK OVC004-TOP017=

BNA UA /OV BNA045025 /TM 0510 /FL220 /TP AT72 /TA M24 /IC LGT RIME=

There was one pilot report over Memphis at 2258 CST (0458Z) from a pilot operating a DC-10 heavy jet aircraft that reported the bases of the overcast clouds at 400 feet with tops at 1,700 feet. There were also several reports of light rime icing in the vicinity of Nashville surrounding the period, with no official reports of icing in the vicinity of Memphis.

7.0 Terminal Aerodrome Forecast

The NWS Memphis Forecast Office issued the following Terminal Aerodrome Forecasts (TAFs) during the 6 hour period prior to the accident. The last scheduled forecast issued at 2332 CST (0532Z) and current at the time of the accident expected LIFR conditions to prevail with a surface wind from 300° at 6 knots, visibility 6 miles, ceiling overcast at 400 feet agl. Light freezing drizzle was expected between 0300 and 0700 CST. The raw TAFs were as follows:

TAF KMEM 042325Z 0500/0524 32006KT 5SM -RA BR VCSH BKN005 OVC035
FM050300 32006KT 4SM BR VCSH BKN005 OVC020
TEMPO 0503/0506 -FZDZ
FM050600 30008KT P6SM BKN009 OVC020
FM051400 34014G20KT P6SM BKN018 OVC025
TEMPO 0518/0522 SCT018=

TAF AMD KMEM 050258Z 0503/0524 30006KT 6SM BR BKN004 OVC020
TEMPO 0505/0509 -DZ
FM050900 30008KT 5SM BR VCSH BKN006 OVC020
TEMPO 0509/0513 3SM -FZDZ BR BKN004
FM051400 34014G20KT P6SM BKN018 OVC025=

TAF KMEM 050301Z 0503/0524 30006KT 6SM BR BKN004 OVC020
TEMPO 0505/0509 3SM -DZ
FM050900 30008KT 5SM BR VCSH BKN006 OVC020
TEMPO 0509/0513 3SM -FZDZ BR BKN004
FM051400 34014G20KT P6SM BKN018 OVC025=

TAF KMEM 050532Z 0506/0606 30006KT 6SM BR OVC004
TEMPO 0509/0513 4SM -FZDZ BR
FM051400 32014G22KT P6SM FEW007 OVC015
FM051900 34014G22KT P6SM FEW015 OVC025
FM060100 01012G18KT P6SM OVC018=

Accident 0622Z

8.0 Area Forecast

The Area Forecast (FA) is a forecast of visual Flight Rules (VFR) clouds and weather conditions over an area as large as the size of several states. It must be used in conjunction with the AIRMET Sierra (IFR) bulletin for the same area in order to get a complete picture of the weather. The area forecast together with the AIRMET Sierra bulletin are used to determine forecast enroute weather and to interpolate conditions at airports which do not have a terminal forecast (TAF) issued. The NWS Aviation Weather Center (AWC) located in Kansas City, Missouri, issues the FA at regular intervals and issues specials reports as necessary usually in the form of an AIRMET. The Dallas-Fort Worth (KDFW) regional forecast that was current at the time of the accident was issued at 2045 CST on February 4, 2014 and valid through 0900 CST on February 5, 2014. The forecast was as follows:

FAUS44 KKCI 050245 *2014036 0242*
FA4W
-DFWC FA 050245
SYNOPSIS AND VFR CLDS/WX

SYNOPSIS VALID UNTIL 052100
CLDS/WX VALID UNTIL 051500...OTLK VALID 051500-052100
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...03Z LOW INVOF BNA WITH CDFNT ALG A BNA-MSL-HRV LN...
CONTG SWWD ACRS THE W CNTRL GLFMEX. WRMFNT ALG A BNA-MCN LN.
CDFNT ALG AN ABI-30N INK-LVS LN. 21Z RDG OF HIGH PRES OVR THE
PLAINS...BUILDING EWD. AMS MSTLY DRY AND STABLE.
.
SERN TX
EXTRM ERN...OVC010 TOPS 030. VIS 4SM BR. 09Z SCT010. OTLK...VFR.
RMNDR...SKC. OCNL SCT015-025. BECMG 0709 OCNL VIS 4SM BR. OTLK...VFR.
.
S CNTRL TX
CSTL SXNS...SCT040 SCT-BKN CI. BECMG 0609 BKN010 TOPS 030. VIS
3-5SM BR. OTLK...VFR.
INLAND...SKC. OCNL SCT CI. BECMG 0911 SCT035 BKN-SCT CI.
OTLK...VFR.
.
AR
N HLF...OVC025 TOPS 120. VIS 3-5SM BR. OCNL -SN NRN SXNS. OTLK...MVFR CIG.
S HLF...OVC020 TOPS 080. OCNL VIS 3-5SM BR. OTLK...MVFR CIG
THRUT...18Z VFR SRN SXNS.
.
TN
W TN...OVC025 TOPS 150. VIS 3-5SM BR. OCNL -RA/-FZDZ. BECMG 0608 OVC020 TOPS 060.
OTLK...MVFR CIG.
MIDDLE TN...OVC015 TOPS FL350. VIS 3SM RA BR. BECMG 0912 OVC015 TOPS 070. OTLK...IFR
CIG...17Z MVFR CIG.
E TN...SCT020 OVC035 TOPS 140. WDLY SCT -SHRA. BECMG 0508 OVC030 TOPS FL350. VIS 3SM IN
SCT -SHRA. ISOL EMBD -TSRA. CB TOPS FL400.
OTLK...MVFR CIG THRUT EXC TIL 18Z IFR CIG WRN SXNS.

9.0 In-Flight Weather Advisories

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

WAUS44 KKCI 050245 *2014036 0255*
WA4S
-DFWS WA 050245
AIRMET SIERRA FOR IFR AND MTN OBSCN VALID UNTIL 050900
.

AIRMET IFR...TX AND CSTL WTRS
FROM 20E IAH TO 60SSE IAH TO 50NNW BRO TO 30E LRD TO 50NW PSX TO 20E IAH
CIG BLW 010/VIS BLW 3SM BR/FG. CONDS DVLPG 03-06Z. CONDS CONTG
BYD 09Z ENDG 12-15Z.
.
AIRMET IFR...OK TX AR TN LA MS AL AND CSTL WTRS
FROM OSW TO RZC TO HMV TO GQO TO 50SW PZD TO 40W CEW TO 130ESE LEV TO 100ESE PSX
TO 40S LFK TO TTT TO ABI TO 20WSW LBB TO 20SSW AMA TO 50W LBL TO OSW
CIG BLW 010/VIS BLW 3SM PCPN/BR/FG. CONDS CONTG BYD 09Z THRU 15Z.
.
AIRMET MTN OBSCN...TN KY
FROM HNN TO HMV TO GQO TO LOZ TO HNN
MTNS OBSC BY CLDS/PCPN/BR. CONDS CONTG BYD 09Z THRU 15Z.
....

WAUS44 KKCI 050245 2014036 0234
WA4T
-DFWT WA 050245
AIRMET TANGO FOR TURB AND LLWS VALID UNTIL 050900
.
AIRMET TURB...AR TN MS AL MO IL IN KY
FROM FWA TO CVG TO HNN TO HMV TO GQO TO LGC TO 20WSW MEI TO
40WSW SQS TO LIT TO 20N FAM TO AXC TO FWA
MOD TURB BLW FL180. CONDS CONTG BYD 09Z THRU 15Z.
.
AIRMET TURB...OK TX AR KS MO
FROM GLD TO 50E BUM TO 20NNW ARG TO 40NW DYR TO 20NNW MEM TO 50S
FSM TO 40S ADM TO 40N ABI TO 20W TXO TO 30ESE TBE TO 50W LBL TO GLD
MOD TURB BTN FL180 AND FL330. CONDS CONTG BYD 09Z THRU 15Z.
.
LLWS POTENTIAL...TN MS AL IN KY
BOUNDED BY CVG-HNN-HMV-GQO-20SSE LGC-30WSW MEI-20E PXV-CVG
LLWS EXP. CONDS CONTG BYD 09Z ENDG 09-12Z.
.
OTLK VALID 0900-1500Z...TURB OK TX AR TN NE KS IA MO IL IN KY
BOUNDED BY BFF-30ESE OVR-30N AXC-FWA-CVG-HNN-30E BWG-20NNW MEM-
20SSE OKC-60NNE TCC-30ESE TBE-50W LBL-GLD-BFF
MOD TURB BTN FL180 AND FL330. CONDS CONTG THRU 15Z.
....

WAUS44 KKCI 050245 2014036 0247
WA4Z
-DFWZ WA 050245
AIRMET ZULU FOR ICE AND FRZLVL VALID UNTIL 050900
.
AIRMET ICE...OK TX AR
FROM OSW TO RZC TO 30NE ARG TO 50WSW ARG TO 30SSW FSM TO 20WSW MLC TO 40NE TCC
TO 30ESE TBE TO 50W LBL TO OSW
MOD ICE BTN FRZLVL AND FL180. FRZLVL SFC-100. CONDS CONTG BYD 09Z THRU 15Z.
.
FRZLVL...RANGING FROM SFC-145 ACRS AREA
MULT FRZLVL BLW 120 BOUNDED BY 50WSW ROD-CVG-HNN-40S IIU-
20NNE MEI-40WNW MCB-20NNE SAT-40E FST-INK-50SSW TXO-40SSW
ADM-20ESE FSM-40SW TTH-50WSW ROD
SFC ALG 20N INK-50E MAF-50ESE ABI-40WSW TXK-50ENE ELD-30SSE DYR-50ENE DYR

040 ALG 50NW MAF-40E MAF-60W ACT-30WSW ELD-30SW SQS-40ENE SQS-40WNW BNA
080 ALG 50SSE ELP-50WSW JCT-40W CWK-40S EIC-20ENE MHZ-50SE BWG
120 ALG 40SSE DLF-40WSW AEX-50ESE MCB-40NNE SJI-20SSE CEW-50E CEW-40W PZD
....

The NWS had an AIRMET current for IFR conditions and moderate turbulence below 12,000 feet over the Memphis area. No significant icing or low-level wind shear was expected over the route of flight or the Memphis area.

10.0 Center Weather Service Unit Products

The NWS Center Weather Service Unit (CWSU) located in the Memphis Center (KZME) normal hours of operation are from 0600 to 2200 local, and was closed at the time of the accident. Prior to their closure the Memphis CWSU issued a Center Weather Advisory (CWA) at 2045 CST for an area of LIFR condition and a Meteorological Impact Statement (MIS) at 2105 CST and indicated IFR to LIFR ceilings from 400 to 1,000 feet agl were expected to impact KMEM with a chance of light freezing drizzle after 0300 CST. These advisories were included in the flights weather document and were as follows:

ZME3 CWA 050245 COR
ZME CWA 302 VALID UNTIL 050445
FROM 25N RZC-75NW ARG-ARG-FSM-25N RZC
AREA OF LIFR CONDS..CIGS AOB 003 AND VIS AOB 2SM. EXP CONDS TO CONT BYD END OF PD. NO UPDATES AFT 0330Z.

FAUS20 KZME 050305 2014036 0305
ZME MIS 04 VALID 050305-051400
...FOR ATC PLANNING PURPOSES ONLY...
OVER ZME E OF A LINE FROM PXV-MCB
ONGOING WDSPRD RAIN WITH TOPS TO FL300 AND EMBD TS LINES WITH MAX TOPS TO FL380 WILL CONT MOVG EASTWARD AND EXIT ZME BY END OF PD. W OF MCB-PXV LINE..IFR AND LIFR CIGS RANGING FM 004-010. FZDZ DVLPG BY 09Z. SEE AIRMETS/SIGMETS/CWAS FOR ADNL INFO. NO UPDATES AFT 0330Z. REPLACES MIS 03.

11.0 Preflight Weather Briefing

The dispatch release and weather briefing paperwork issued to Trans States Airlines flight 1632 were generated at 2148 CST (0348Z) on February 4, 2014, and was planned for a cruising level at 31,000 feet and an estimated time enroute of 0:57. The flight was also planned for a destination alternate airport of Little Rock, Arkansas (KLIT). The full document is included as attachment 1.

The weather briefing portion of the document included 3 hours of observations for the departure, destination, and planned alternate airports, and the TAFs current at the time, and applicable Notices to Airmen. The document also included the Area Forecast for the enroute forecast, winds and temperature aloft forecast, pilot reports, and in-flight weather advisories

current during the period, which included the full series of AIRMETs, Convective SIGMET 4C for the central United States, and Center Weather Advisories issued by Memphis Center (ZME).

The applicable reports and forecast for KMEM were as follows:

KMEM 050254Z 30006KT 1/2SM OVC004 01/00 A2992 RMK AO2 SFC VIS 8 SLP132 60010 T00060000 53022
KMEM 050154Z COR 30006KT 1/2SM OVC004 01/00 A2989 RMK AO2 SFC VIS 8 RAE11B40E51 PRESRR SLP122 P0000 T00110000
KMEM 050154Z 30006KT 1/2SM OVC004 01/00 A2989 RMK AO2 SFC VIS 8 RAE11B40E51UPB38E40 PRESRR SLP122 P0000 T00110000
KMEM 050054Z 31005KT 1/2SM -RA BR BKN004 OVC039 01/01 A2984 RMK AO2 SFC VIS 3 SLP107 P0010 T00110006
SPECI KMEM 050029Z 30005KT 1/2SM R36L/2200VP6000FT RA BR OVC004 01/01 A2986 RMK AO2 SFC VIS 3 P0005

TAF COR KMEM 050301Z 0503/0524 30006KT 6SM BR BKN004 OVC020
TEMPO 0505/0509 3SM -DZ
FM050900 30008KT 5SM BR VCSH BKN006 OVC020
TEMPO 0509/0513 3SM -FZDZ BR BKN004
FM051400 34014G20KT P6SM BKN018 OVC025

No NWS advisories were current for any icing conditions over the route of flight.

12.0 Astronomical Data

The United States Naval Observatory website provided the following astronomical data for Memphis, Shelby County, Tennessee, for February 4, 2014:

Sun	
Beginning of civil twilight	0630 CST
Sunrise	0657 CST
Sunset	1732 CST
End of civil twilight	1758 CST
Accident	0022 CST on February 5, 2014

Moon	
Moonset	2311 CST
Moonrise	1027 CST on February 5, 2014

The phase of the Moon on February 4, 2014 was a waxing crescent with approximately 29% of the Moon's visible disk illuminated. At the time of the accident both the Sun and the Moon were more than 15° below the horizon and provided no illumination.

13.0 Current Icing Potential

The National Center for Environmental Research (NCAR) provided the following Current Icing Products (CIP) that were created at 2300, 0000, and 0100 CST surrounding the period of

the accident from 1,000 through 3,000 feet over the region. The Memphis International Airport is indicated by the circle on the models. The CIP products are computer-generated three-dimensional analyses of information related to the likelihood of encountering icing conditions. The CIP graphics are automatically produced with no human modifications and available to users from the NWS Aviation Weather Center. Information on the graphics is determined from observational data including WSR-88D radar, satellite, pilot weather reports, surface weather reports, lightning and computer model output. The CIP represents the latest analysis of potential icing regions.

Figures 10 through 12 are the icing probability, icing severity, and potential for supercooled large droplets (SLD) for 1000, 2000, and 3000 feet for 2300 CST (0500Z). The charts indicated a high of 40% probability of trace icing conditions at 1,000 feet, with a less than 10% probability of encountering SLD conditions below 3,000 feet.

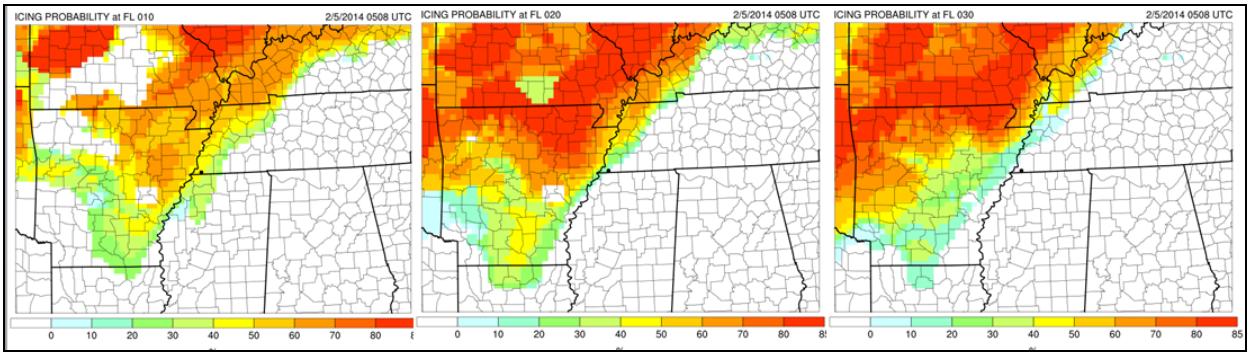


Figure 10 - Icing Probability for 2300 CST (0500Z) on February 4, 2014

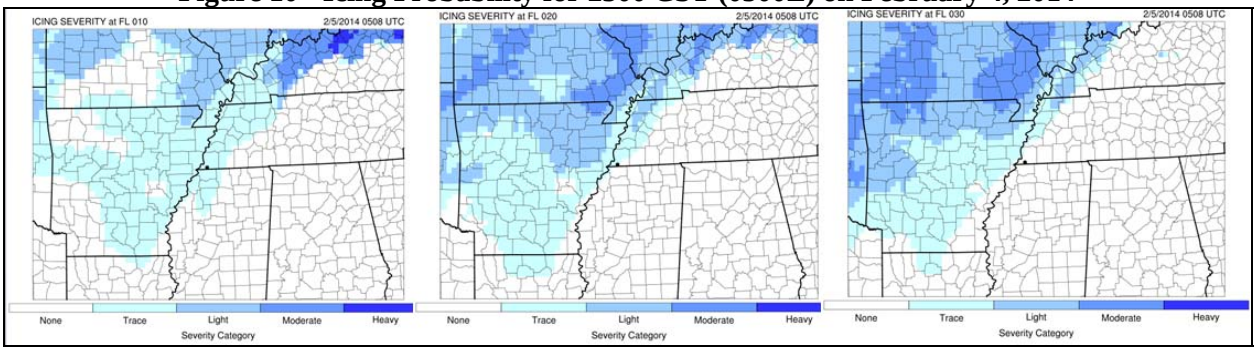


Figure 11 - Icing Severity at 2300 CST (0500Z)

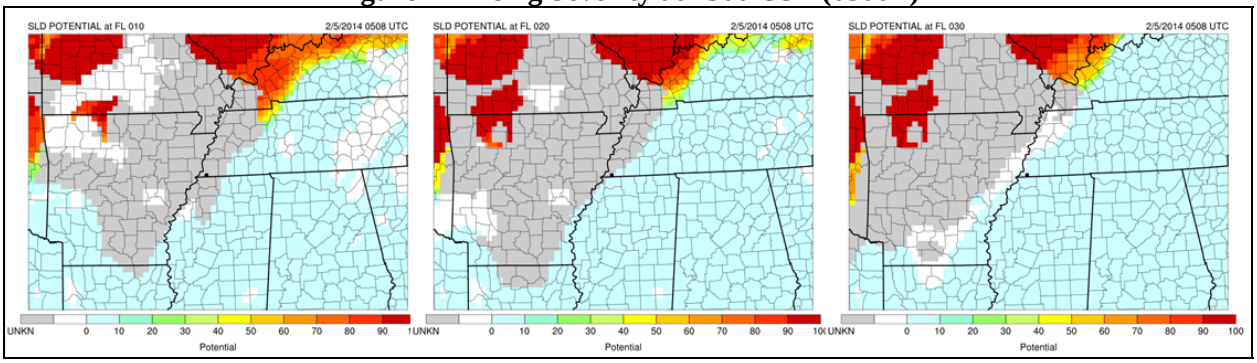


Figure 12 - Supercooled Large Droplet (SLD) Potential for 2300 CST (0500Z)

Figures 13 through 15 are the same series of charts for 0000 CST (0600Z). The charts indicated a 50 to 70% probability of a trace to light icing conditions below 2,000 feet.

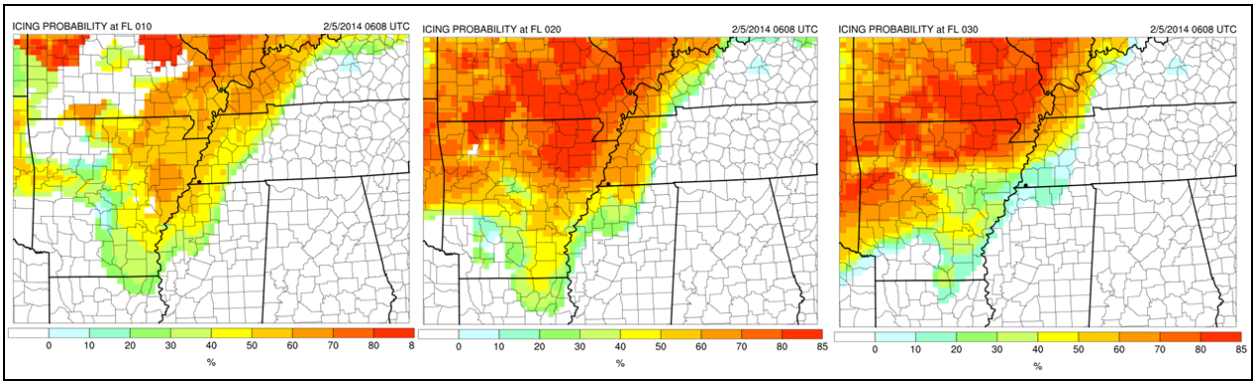


Figure 13 - Icing Probability for 0000 CST (0600Z) on February 5, 2014

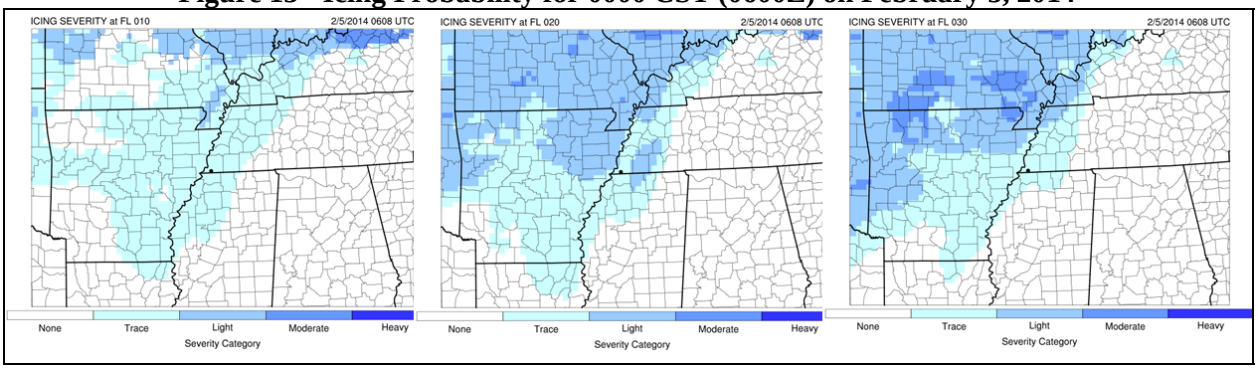


Figure 14 - Icing Severity for 0000 CST (0600Z)

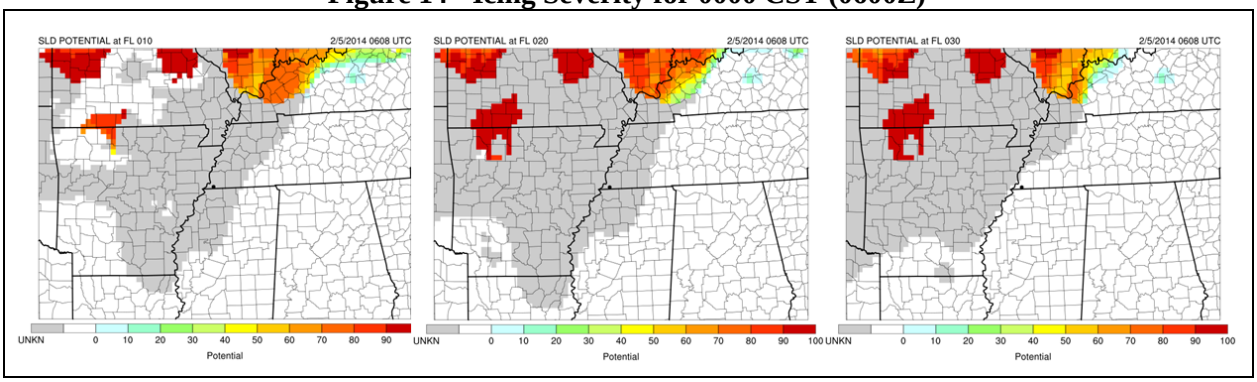


Figure 15 - SLD Potential for 0000 CST (0600Z)

Figures 16 through 18 are the CIP products for 0100 CST (0700Z). The charts indicated a 60 to 85% probability of light to moderate icing below 2,000 feet.

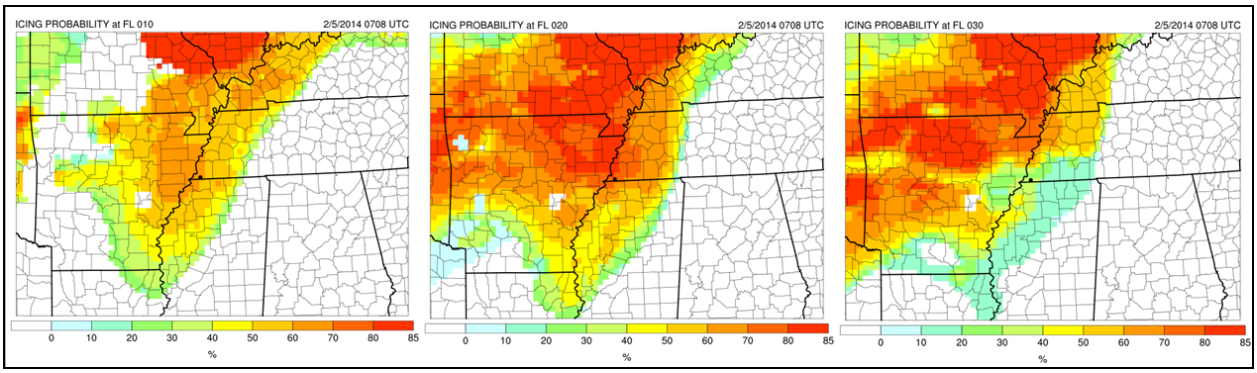


Figure 16 - Icing Potential for 0100 CST (0700Z)

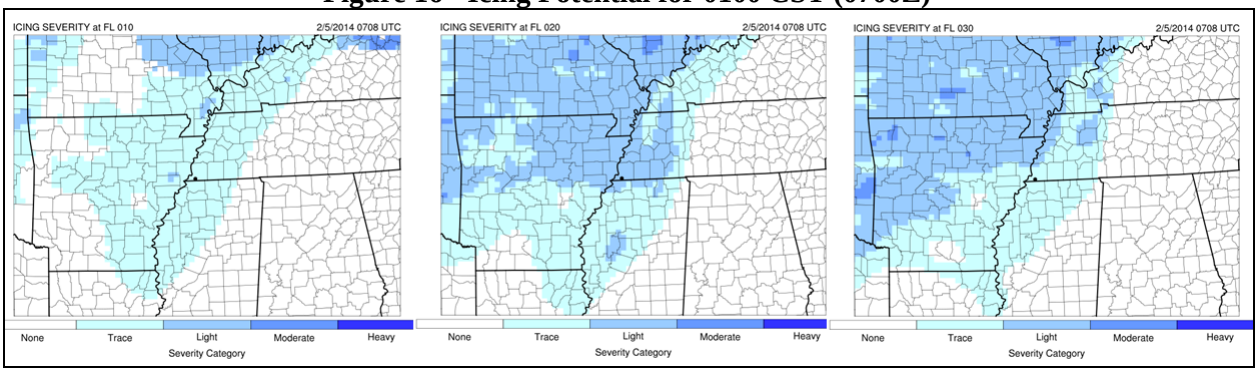


Figure 17 - Icing Severity for 0100 CST (0700Z)

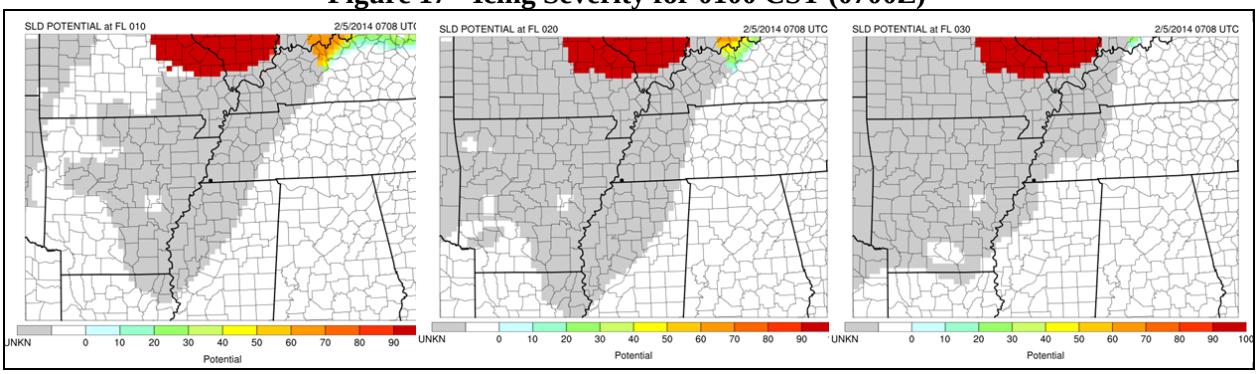


Figure 18 - SLD Potential for 0100 CST (0700Z)

The CIP guidance provides information on expected icing severity as five categories: none, trace, light, moderate, and heavy. The severity estimations are roughly based on the accretion rate of ice on an airplane, and the levels are determined by the time it would take for an airfoil to accrete 1/4 in on ice: trace, flight longer than an hour; light, icing encounter between 15 and 60 minutes; moderate, icing encounter between 5-15 minutes; and severe less than 5 minute encounter. The rates are, in turn, estimated from the amount of supercooled liquid water expected with a nominal drop diameter of 15 microns, and are further tuned by nearby pilot reports of encountered severity. These are relative values and the use of which should take into account the airframe and the level of icing protection provided by the aircraft. The ultimate safety factor is the vigilance demonstrated by the pilot in potential icing situations.

Different aircraft and different flight configurations (airspeed, angle of attack, etc.) will experience variations in accretion rate. These rates have been simulated for a range of aircraft

and are a "broad brush" approach to severity prediction. They are presented as guidance and supplementary information to the primary forecasts produced as AIRMETs by the NWS Aviation Weather Center.

14.0 Photograph of Icing Conditions Encountered

After the Trans States flight 3384 taxied to the gate the captain and first officer observed that all the leading edges of the airfoil and the engine inlets had a significant buildup of mixed icing and photographed the leading edge upon exiting the airplane (figure 19).

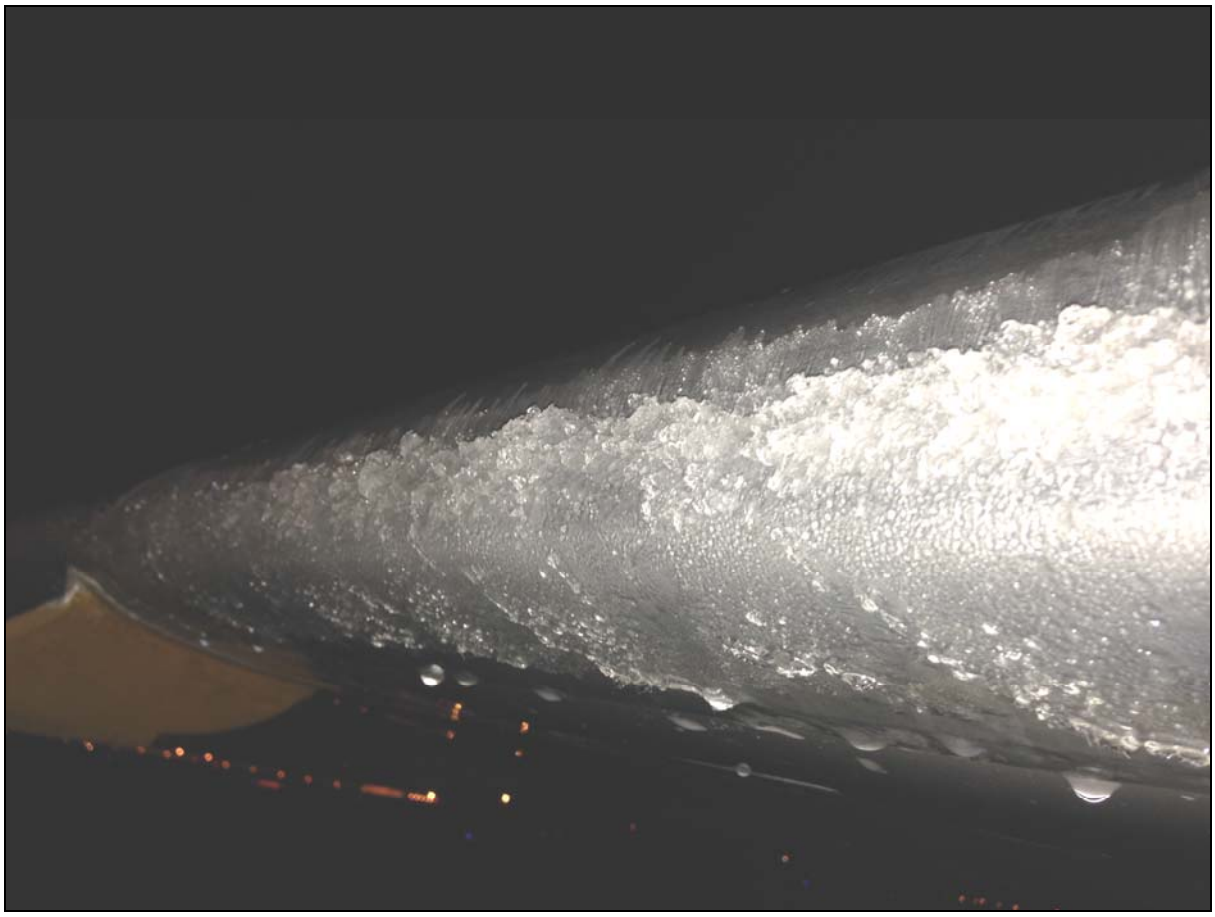


Figure 19 - Structural icing left on the wing after the airplane arrived at the gate

15.0 Icing Intensity Table

The FAA defines icing intensity classified as a trace, light, moderate, or severe. The following table is from 7110.10W - Flight Services, regarding pilot reports.

Icing Intensity	Airframe Ice Accumulation
Trace	Ice becomes perceptible. Rate of accumulation slightly greater than rate of sublimation. Deicing/anti-icing equipment is not utilized unless encountered for extended period of time over an hour.
Light	The rate of accumulation may create a problem if flight is prolonged in this environment over 1 hour. Occasional use of the deicing/anti-icing equipment removes/prevents accumulation. It does not present a problem if deicing/anti-icing equipment is used.
Moderate	The rate of accumulation is such that even short encounters become potentially hazardous, and use of the de-icing/anti-icing equipment or diversion is necessary.
Severe	The rate of accumulation of ice is such that de-icing/anti-icing equipment fails to reduce or control the hazard. Immediate diversion is necessary.

F. LIST OF ATTACHMENTS

Attachment 1: Dispatch Flight Release and Weather Document

Submitted by:

Donald Eick
NTSB Senior Meteorologist