NATIONAL TRANSPORTATION SAFETY BOARD

Office of Aviation Safety
Washington, D.C. 20594

March 23, 2017

Group Chairman's Report

METEOROLOGY

CEN15FA190

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A. ACCIDENT

Location: Bloomington, Illinois
Date: April 7, 2015
Time: About 0006 central daylight time (0506 UTC[1])
Airplane: Cessna 414; registration N789UP

B. METEOROLOGY GROUP

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C. SUMMARY

On April 7, 2015, about 0006 central daylight time, a Cessna model 414A twin-engine airplane, N789UP, was substantially damaged when it collided with terrain following a loss of control during an instrument approach to Central Illinois Regional Airport (BMI), Bloomington, Illinois. The airline transport pilot and six passengers were fatally injured. The airplane was owned by and registered to Make It Happen Aviation, LLC, and was operated by the pilot under the provisions of 14 *Code of Federal Regulations* Part 91 while on an instrument flight rules (IFR) flight plan. Night instrument meteorological conditions prevailed for the cross-country flight that departed Indianapolis International Airport (IND), Indianapolis, Indiana, at 2307 central daylight time.

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 NWS products are issued with time reference to UTC, or "Zulu" time. Local central daylight time (CDT) used in this report is based upon the 24 hour clock, with local time +5 hours to UTC, and UTC=Z. Directions are referenced to true north and distances in nautical miles. Heights are above mean sea level (msl) unless otherwise noted. Visibility is in statute miles and fractions of statute miles. NWS airport and station identifiers use standard International Civil Aviation Organization (ICAO) 4-letter station identifiers versus International Air Transport Association (IATA) 3-letter identifiers which deletes the initial country code designator "K" for U.S. airports. Both codes are both used intermittently in this report.

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

The accident site was located at latitude 40.495° N and longitude 88.867° W at an elevation of approximately 870 feet.

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 NWS Surface Analysis Chart for 0100 CDT (0600Z) on April 7, 2015 centered over the area is included in figure 1 depicting the conditions immediately after the accident. The Bloomington, Illinois area and accident site is located within the red circle overlaid. The chart depicted a stationary front extending across central Iowa, northern Illinois and Indiana, immediately north of the Bloomington area. A second stationary front was depicted extending over Kansas, into Missouri, and turning southeastward into Tennessee and Alabama. The station models on the chart in the vicinity of the accident site indicated northeasterly winds of 10 to 15 knots north of the stationary front across Illinois, and from the east-southeast at 5 knots or less south of the boundary. The station models also depicted an extensive area of overcast clouds over the region, and with most stations along and south of the front reporting light continuous rain, drizzle, and/or mist. The station model for Bloomington indicated wind from the east-southeast at approximately 5 knots, visibility restricted in mist, overcast cloud cover, temperature and dew point at 55° Fahrenheit (F), and a sea level pressure of 1015.2-hectopascals (hPa). The station models surrounding Bloomington indicated similar conditions with overcast clouds, light continuous rain and/or mist.

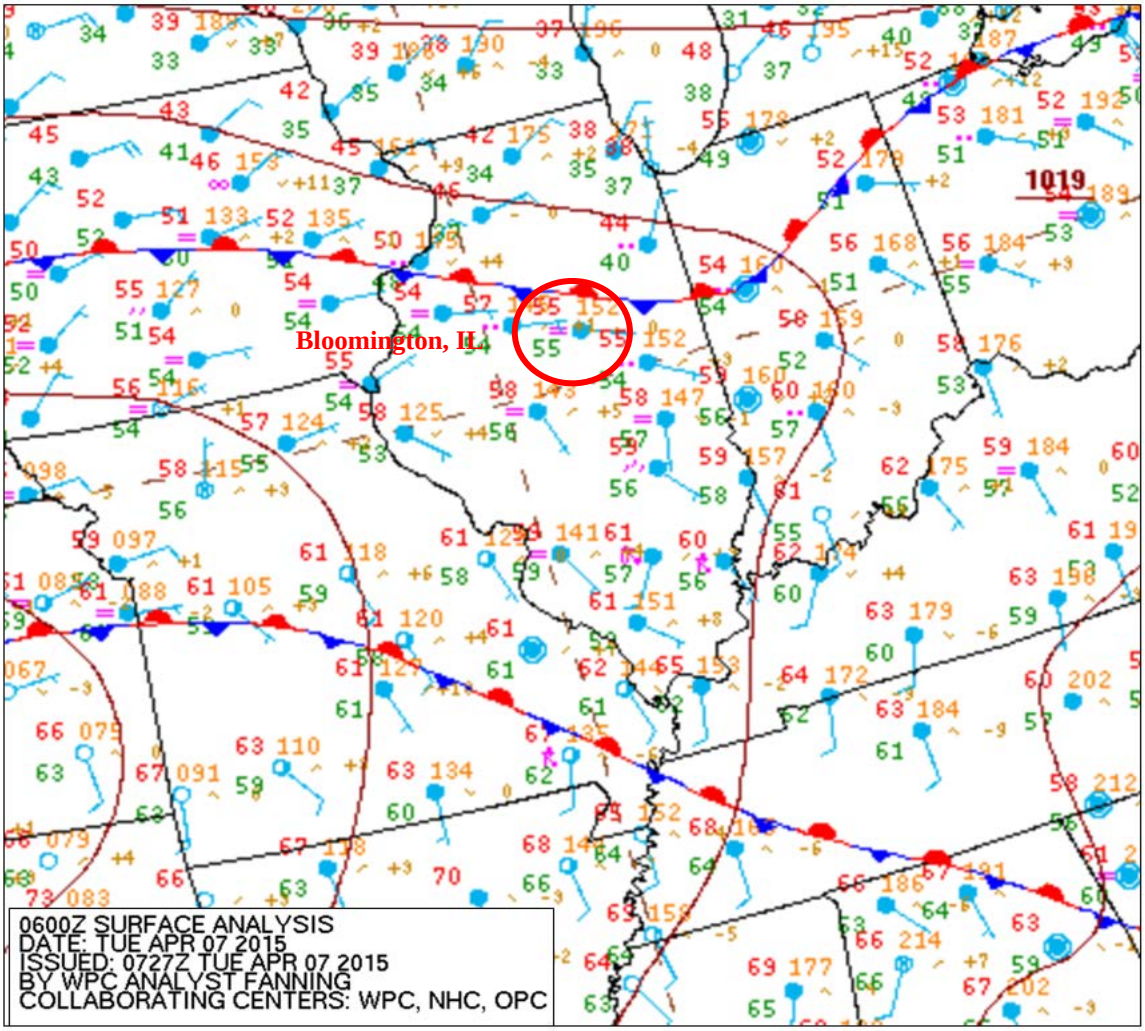

Figure 1 - NWS Surface Analysis Chart for 0100 CDT

1.2 Weather Depiction Chart

The eastern portion of the NWS Weather Depiction Chart for 0200 CDT (0700Z) is included as figure 2, with the approximate accident site enclosed in a red circle. The chart depicted two stationary fronts with an extensive area of instrument flight rule (IFR) conditions[2] by a shaded contour line between the fronts stretching from South Dakota and Nebraska east-southeastward into Iowa, Missouri, most of Illinois, western Indiana, western Kentucky, Tennessee, northern Alabama and Georgia. That area was surrounded by a larger area of marginal visual flight rule (MVFR) conditions[3] , depicted by an unshaded contour. Visual flight rule (VFR) conditions[4]

[2] IFR conditions – are defined as a ceiling or lowest layer of clouds reported as broken or 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] MVFR conditions – are defined as a ceiling between 1,000 to 3,000 feet inclusive, and/or visibility 3 to miles inclusive.

were depicted over extreme northern Illinois, north of the stationary front and over central and southwestern Missouri and to the northeast over Michigan. The station model for Bloomington indicated visibility 1 1/2 miles in mist, ceiling overcast at 200 feet agl.

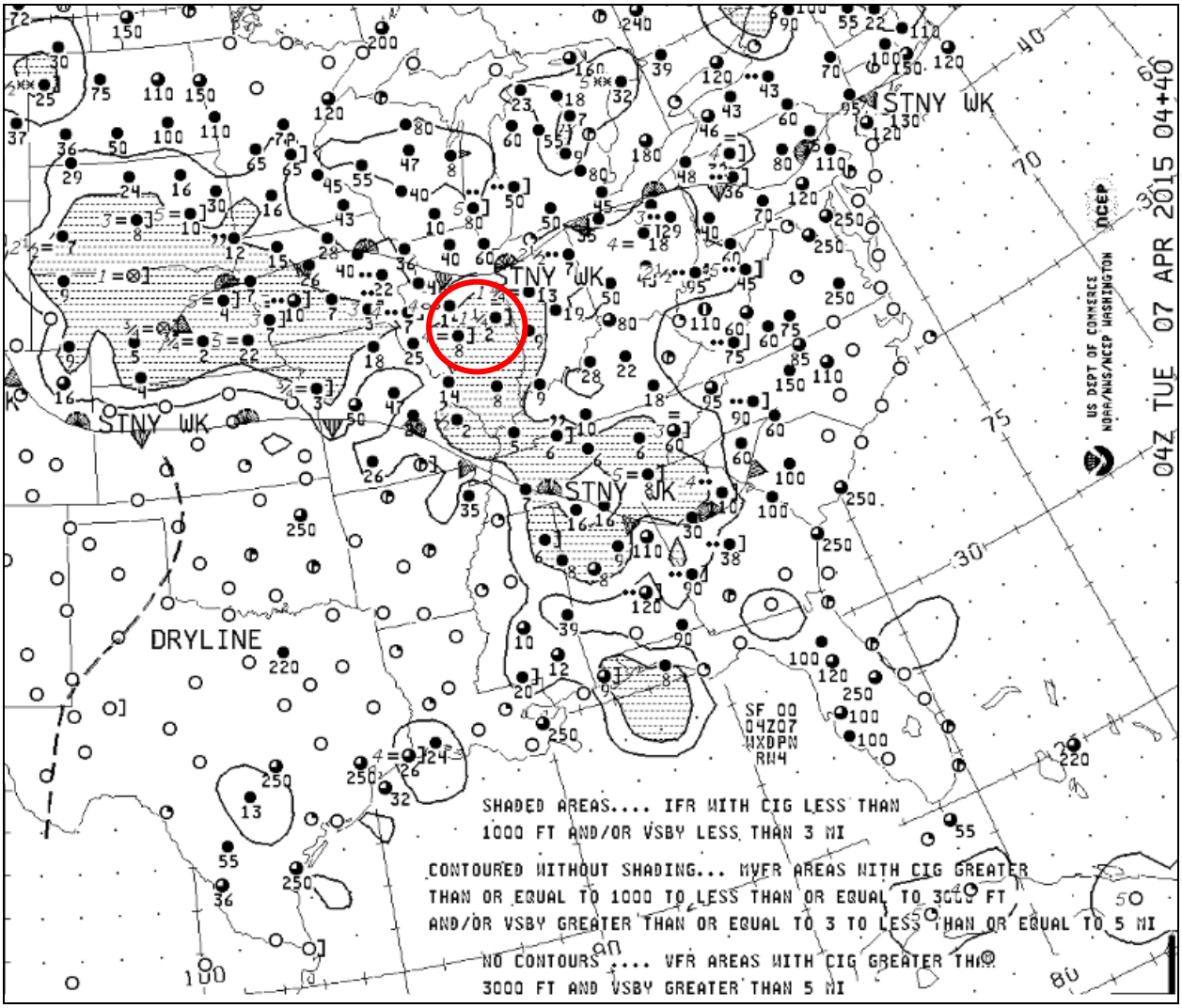

Figure 2 - NWS Weather Depiction Chart for 02300 CDT on April 6, 2015

1.3 Weather Radar Mosaic

The NOAA National Climatic Data Center (NCDC) National composite radar for 0000 CDT (0500Z) on April 7, 2015 was obtained and is included as figure 3, with the approximate accident site marked by the red star. The chart depicted no significant radar echoes greater than 30 dBZ over the Bloomington-Normal area. The closest convective echoes were located approximately 25 miles northeast through east of the accident site, and approximately 70 miles south. No significant echoes were identified over the route of flight.

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[4] VFR conditions – are defined as no ceiling or a ceiling greater than 3,000 feet agl and visibility greater than 5 miles.

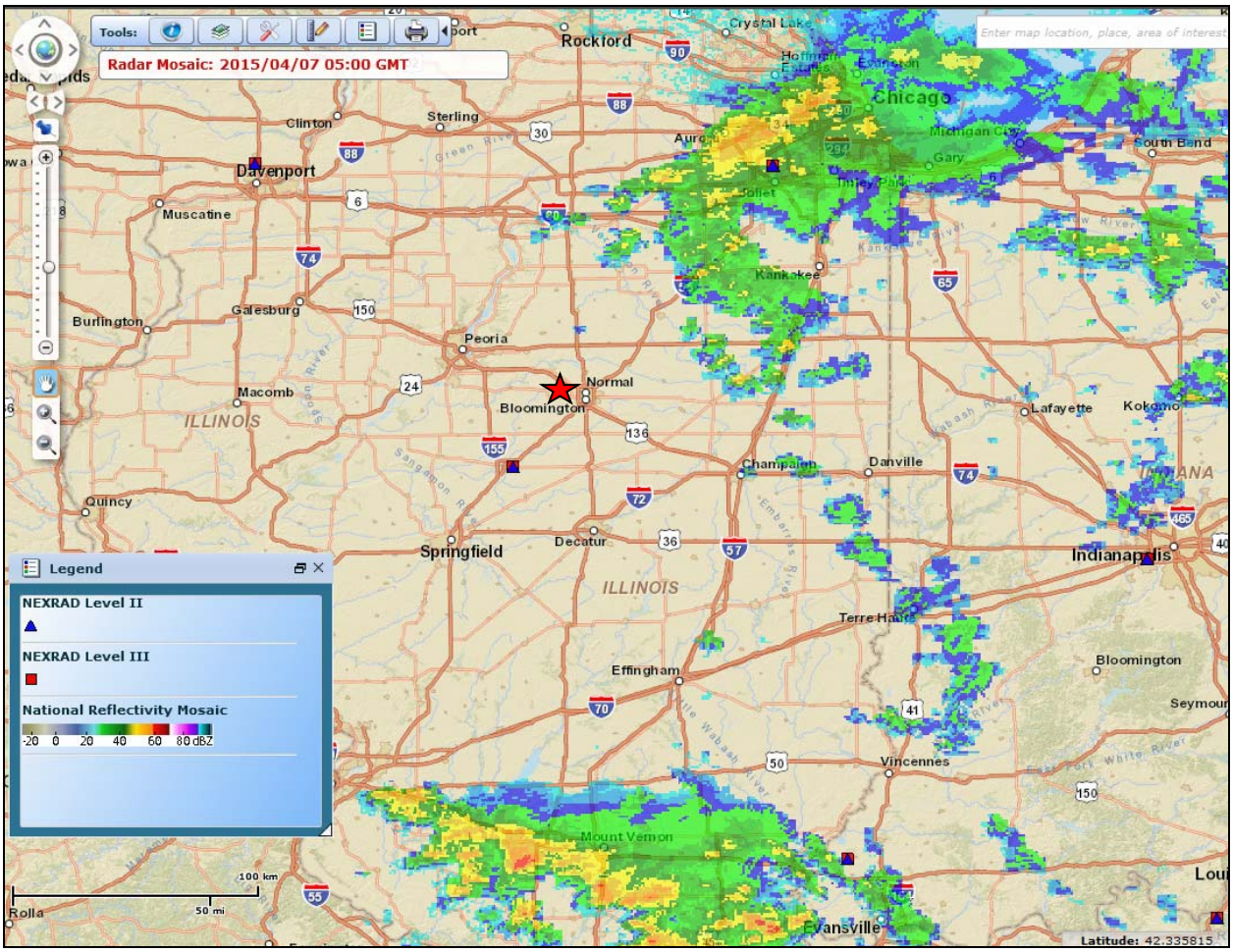

Figure 3 – NCDC regional radar mosaic for 0000 CDT

1.4 Upper Air Charts

The NWS 850- and 700-millibar (mb) Constant Pressure Charts for 1900 CDT on April 6, 2015 (0000Z April 7, 2015) depicting the flight conditions at approximately 5,000 and 10,000 feet are included as figure 4 and 5 respectively. The 850-mb chart depicted an upper level low pressure system over the Colorado and Wyoming border with a trough of low pressure extending eastward into northern Illinois. The Lincoln, Illinois, station model in the immediate vicinity of the accident site depicted a wind from the south-southwest at 15 knots, temperature of 10° C, and a temperature-dew point spread of 2° C, which indicated saturated conditions at that level. The 700-mb chart depicted west-southwest winds at 25 knots over the region with a temperature of 4° C, and the temperature-dew point depression of 8° C.

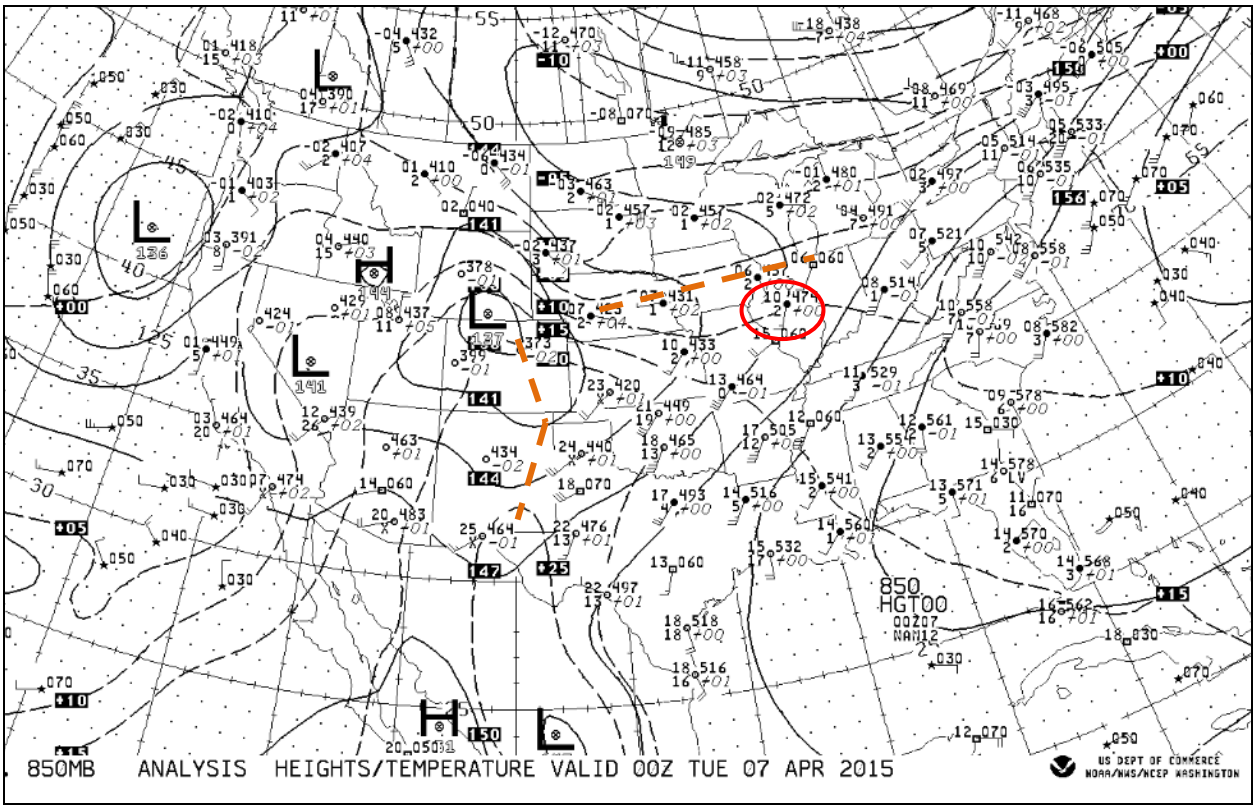

Figure 4 - NWS 850-mb Constant Pressure Chart for 1900 CDT

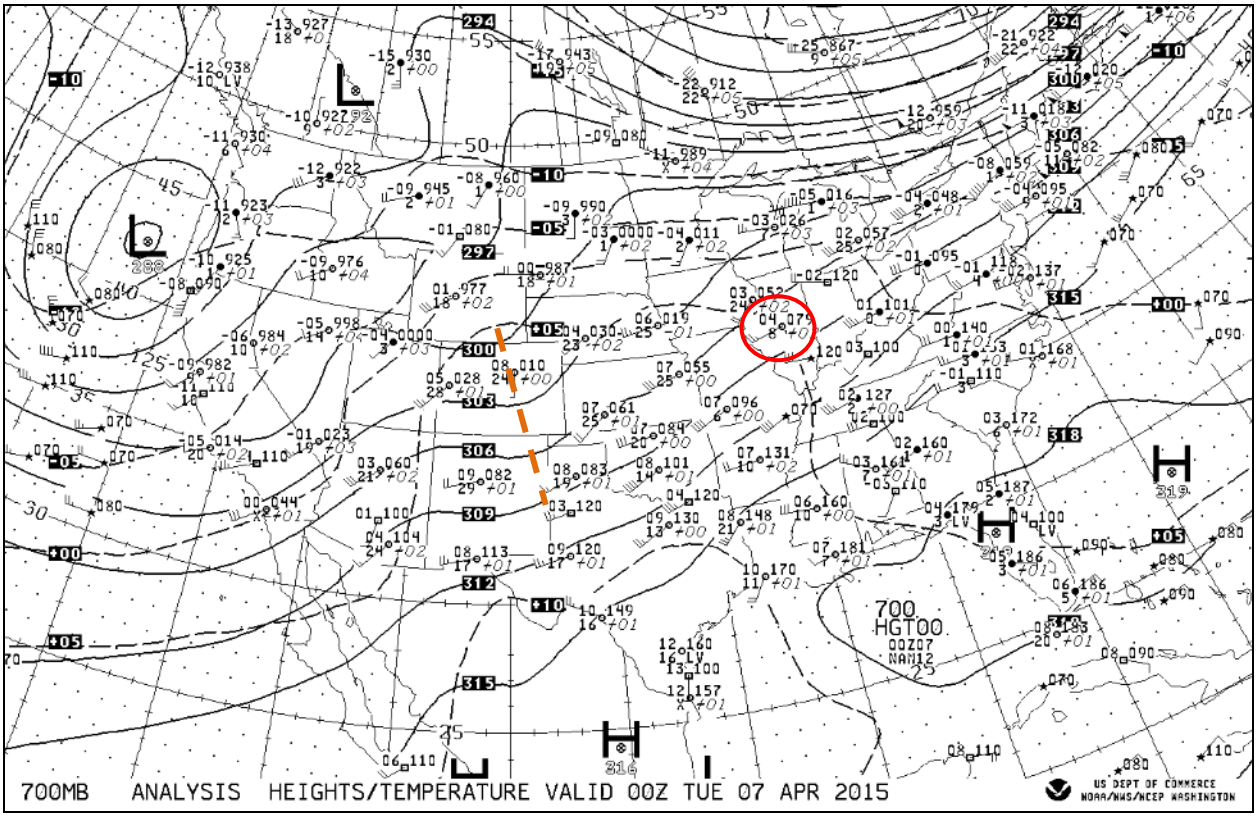

Figure 5 - NWS 700-mb Constant Pressure Chart for 1900 CDT

1.5 Low Level Significant Weather Prognostic Chart

The NWS 12 and 24 hour Low Level Significant Weather Prognostic Chart valid for the period is included as figure 6. The left portion of the chart was the 12 hour forecast and valid for 0100 CDT. The chart depicted a low pressure system along the stationary front stretching across northern Illinois with rain showers and thunderstorms over the route. The top left portion of the chart depicted an extensive area of IFR conditions expected over Indiana and Illinois, and extending into Iowa and Missouri. The freezing level was near 12,000 feet over Illinois and lowering to 10,000 feet over Indiana. The chart depicted no significant turbulence below 24,000 feet over the route of flight.

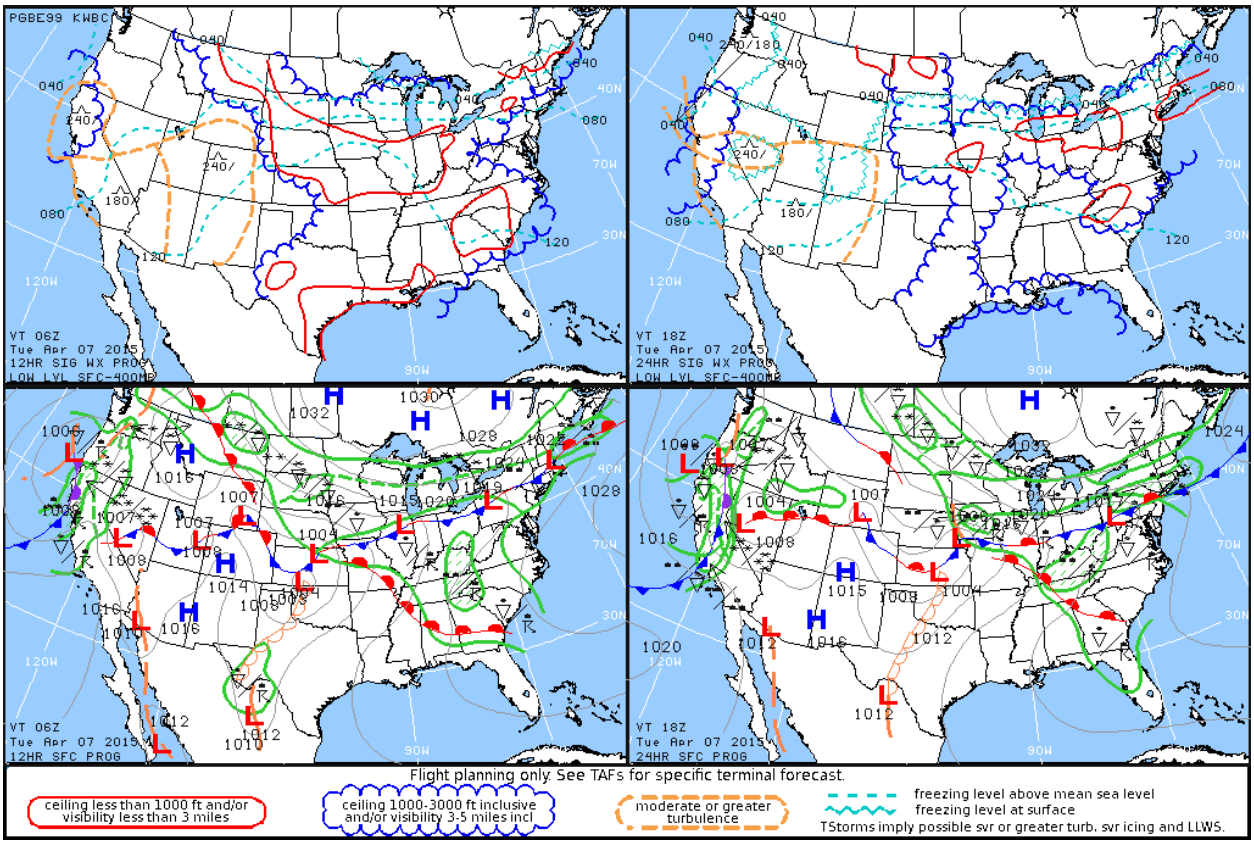

Figure 6 - NWS 12 and 24 hour Low Level Significant Weather Prognostic Chart

2.0 Bloomington Surface Observations

The official NWS Meteorological Aerodrome Reports (METARs) and special reports (SPECIs) surrounding the period were documented for Central Illinois Regional Airport at Bloomington-Normal, IL. The airport had an Automated Surface Observation System (ASOS) and lists an airport elevation of 871 feet and a magnetic variation of 0° East. The following weather conditions were reported surrounding the time of the accident, with cloud heights reported above ground level (agl).

Central Illinois Regional Airport weather at 2356 CDT, automated, wind from 060° at 4 knots, visibility 3/4 statute mile, runway 29 visual range 6,000 variable +6,000 feet, weather light rain and fog, ceiling overcast at 200 feet agl, temperature and dew point 13° Celsius (C), altimeter 29.99 inches of mercury. Remarks; automated observation system, temperature 12.7° C, dew point 12.7° C, lightning distant[5] east, hourly precipitation less than 0.01 inches or a trace, sea level pressure 1015.3-hectopascals (hPa)[6].

A special observation was issued at 0011 CDT, immediately after the accident reporting visibility 1/2 statute mile in light rain and fog, ceiling overcast at 200 feet, with runway visual range 4,000 variable 5,000 feet.

The raw observations surrounding the period from 2100 through 0230 CDT (0100Z to 0730Z) with the general flight categories[7] were as follows:

MVFR METAR KBMI 070156Z 17012G18KT 10SM BKN012 OVC018 14/12 A2997 RMK AO2 T01380116 BKN V OVC SLP148

MVFR METAR KBMI 070256Z 15004KT 10SM OVC012 14/12 A2998 RMK AO2 53017 T01380116 SLP152=

IFR SPECI KBMI 070348Z AUTO 14007KT 1 3/4SM -RA BR OVC010 13/12 A2999 RMK AO2 RAB39 P0000=

IFR METAR KBMI 070356Z AUTO 15006KT 1 3/4SM -RA BR SCT001 OVC010 13/12 A2999 RMK AO2 T01270122 RAB39 P0000 SLP154

IFR SPECI KBMI 070403Z AUTO 14006KT 2SM -RA BR SCT001 OVC008 13/13 A2999 RMK AO2 CIG 004V010 P0000

Departed KIND 0407Z

LIFR SPECI KBMI 070423Z AUTO 11005KT 1 3/4SM -RA BR OVC004 13/13 A2998 RMK AO2 CIG 001V007 P0000

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[5] Distant refers to more than 10 nautical miles from the airport center point.

[6] Hectopascal (hPa) is the new standard term for pressure and is interchangeable with the term millibars (mb).

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

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

* By definition, IFR is a ceiling less than 1,000 feet agl and/or visibility less than 3 miles while LIFR is a sub-category of IFR.
**By definition, VFR is a ceiling greater than or equal to 3,000 feet agl and visibility greater than 5 miles while MVFR is a sub-category of VFR.

LIFR SPECI KBMI 070437Z AUTO 11005KT 1SM R29/P6000FT -RA BR BKN002 OVC006 13/13 A2999 RMK AO2 P0000

LIFR METAR KBMI 070456Z AUTO 06004KT 3/4SM R29/6000VP6000FT -RA BR OVC002 13/13 A2999 RMK AO2 T01270127 LTG DSNT E P0000 SLP153

Accident 0506Z

LIFR SPECI KBMI 070511Z AUTO 07006KT 1/2SM R29/4000V5000FT -RA FG OVC002 13/13 A2998 RMK AO2 P0000

LIFR SPECI KBMI 070541Z AUTO 11004KT 3/4SM R29/3500V5500FT BR OVC002 13/13 A2999 RMK AO2 RAE25 P0000

LIFR SPECI KBMI 070548Z AUTO 10005KT 1/2SM R29/3000V4000FT FG OVC002 13/13 A2998 RMK AO2 RAE25 P0000

LIFR METAR KBMI 070556Z AUTO 11005KT 1/2SM R29/3500V4000FT FG OVC002 13/13 A2998 RMK AO2 50000 60000 T01270127 10161 20127 401770100 RAE25 P0000 SLP152

LIFR SPECI KBMI 070615Z AUTO 11007KT 3/4SM R29/5000VP6000FT BR OVC002 13/13 A2998 RMK AO2 P0001

LIFR SPECI KBMI 070625Z AUTO 11006KT 1SM R29/P6000FT BR OVC002 13/13 A2998 RMK AO2 P0001

LIFR METAR KBMI 070656Z AUTO 11006KT 1SM R29/P6000FT BR OVC002 13/13 A2998 RMK AO2 T01270127 P0001 SLP149

LIFR SPECI KBMI 070729Z AUTO 13004KT 3/4SM R29/5000VP6000FT BR OVC002 13/13 A2997 RMK AO2 RAB11E26 P0000

2.1 NWS METAR Displays

The NWS Aviation Weather Center (AWC) website display of hourly observations at 2300, 0000, and 0100 CDT over Illinois and Indiana are included as figures 7-9, with the Bloomington area within the red circle. The display also depicts the general flight categories by color coded station models with blue indicating MVFR, red IFR, pink LIFR, and unshaded VFR conditions. The images depict MVFR conditions prevailing in the departure area with IFR to LIFR conditions over the route and in the Bloomington (BMI) area surrounding the period.

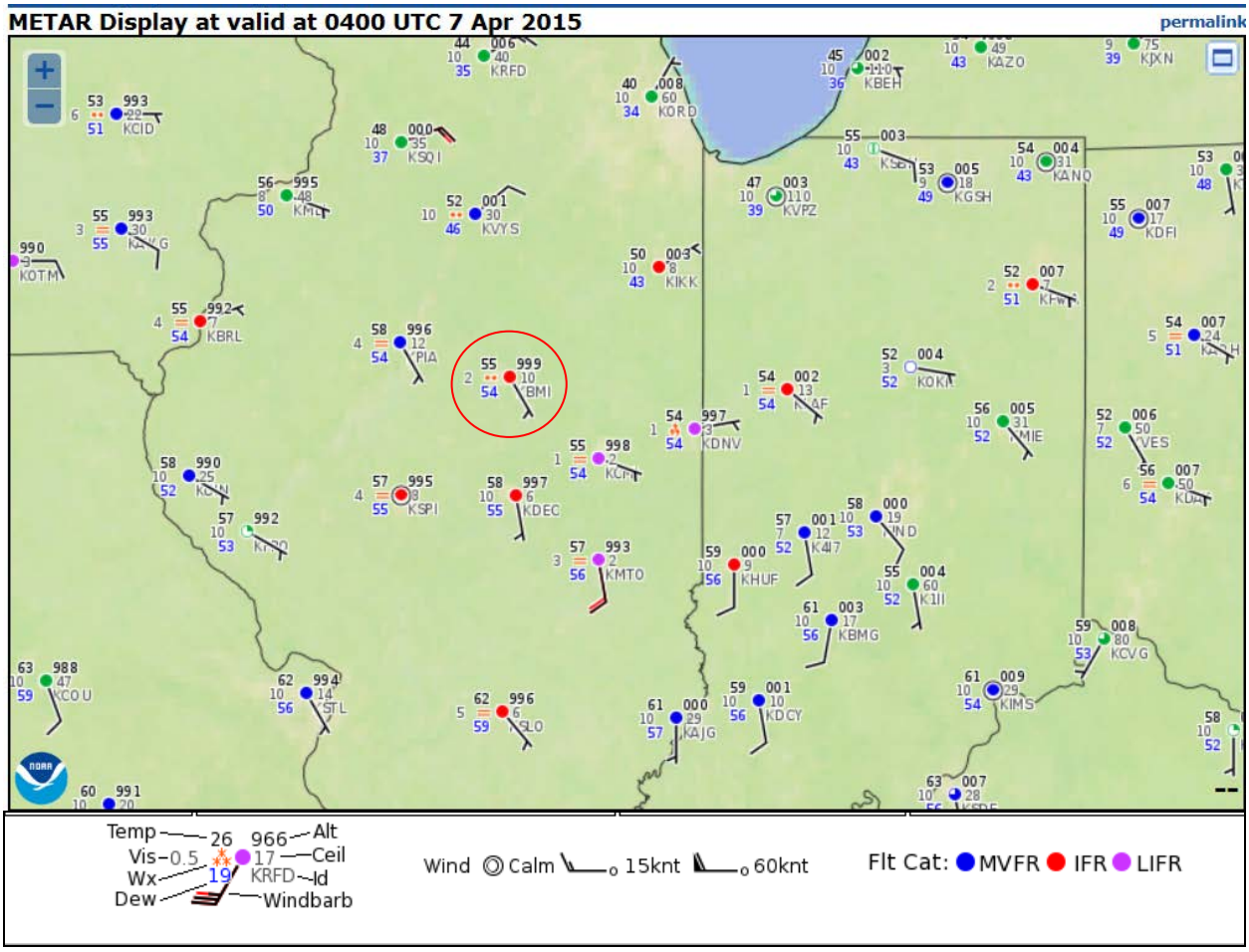

Figure 7 - NWS AWC Observations at 2300 CDT

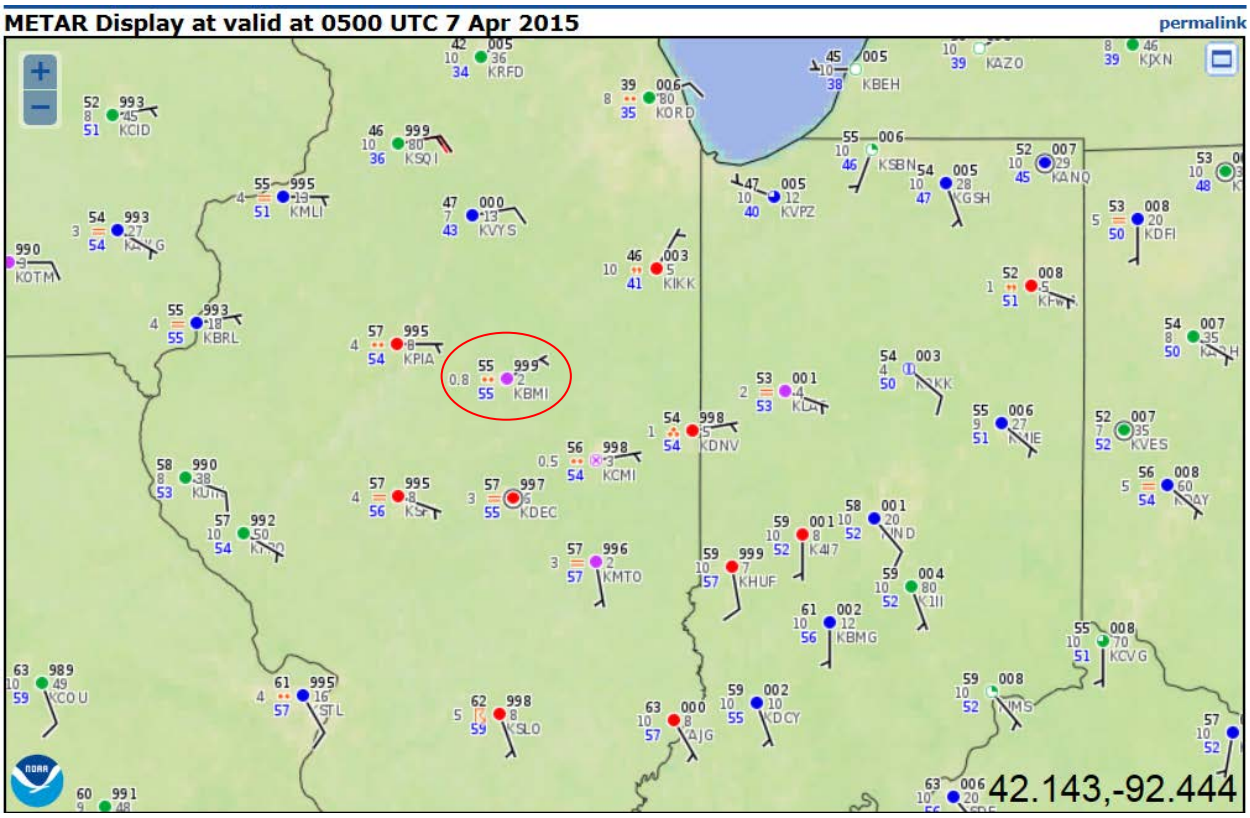

Figure 8 – NWS AWC Surface Observations at 0000 CDT

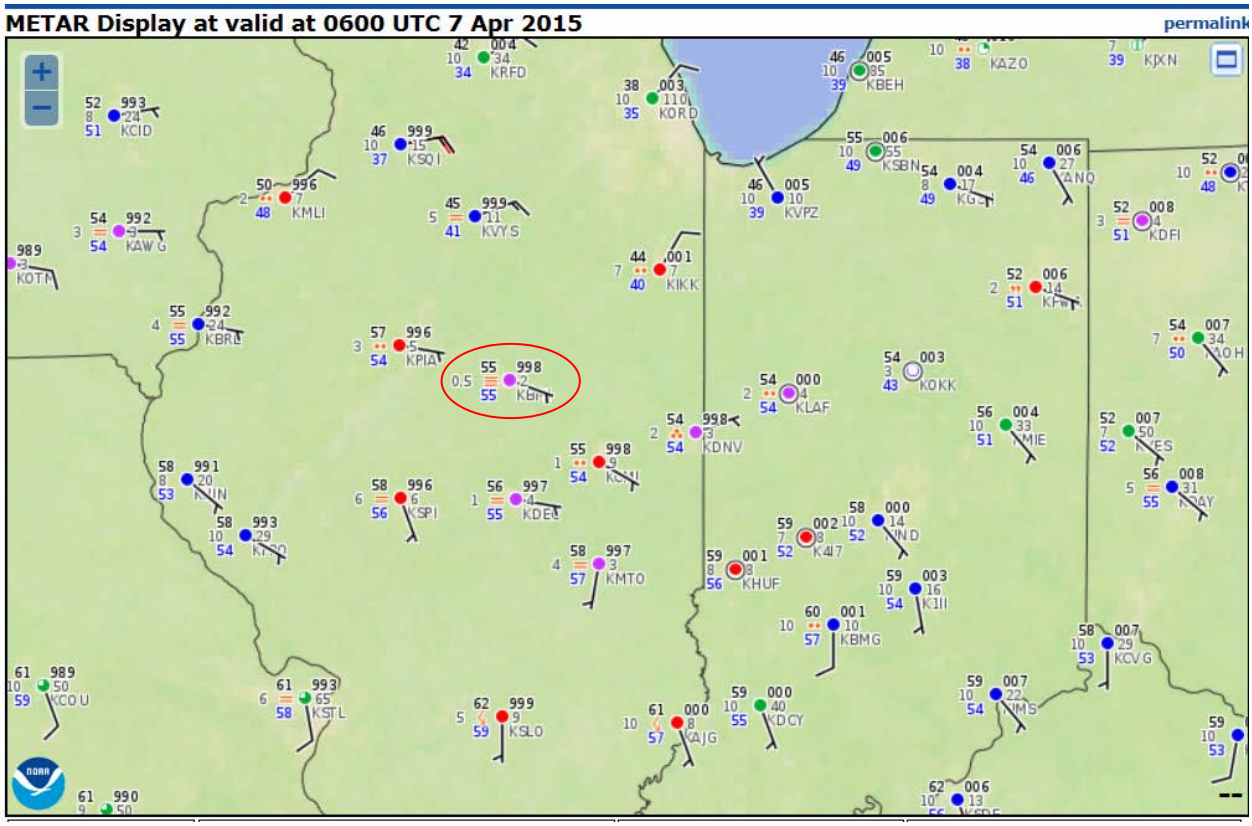

Figure 9 - NWS AWC Observations at 0100 CDT

2.2 High Resolution ASOS Data

The 5 minute ASOS data for KBMI was also obtained and documented surrounding the time of the accident from 2340 through 0025 CDT (0440Z-0525Z). Within a minute prior to the accident, the ASOS was reporting the following conditions:

Central Illinois Regional Airport weather at 0005 CDT, automated, wind from 060° at 6 knots, visibility 1/2 statue mile, runway 29 visual range 4,000 variable 6,000 feet, weather light rain and fog, ceiling overcast at 200 feet agl, temperature and dew point 13° C, altimeter 29.98 inches of mercury. Remarks; automated observation system, lightning distant east, hourly precipitation less than 0.01 inches.

The raw observations were as follows:

METAR KBMI 070440Z AUTO 11005KT 1SM R29/P6000FT –RA BR OVC002 13/13 A299 RMK A02 OVC V BKN

METAR KBMI 070445Z AUTO 10003KT 1SM R29/P6000FT –RA BR OVC002 13/13 A2999 RMK A02

METAR KBMI 070450Z AUTO 08004KT 3/4SM R29/P6000FT –RA BR OVC002 13/13 A2999 RMK A02 T01270127 P0000 SLP153

METAR KBMI 070455Z AUTO 06004KT 3/4SM R29/6000VP6000FT –RA BR OVC002 13/13 A2999 RMK A02 T01270127 LTG DSNT E P0000 SLP153

METAR KBMI 070500Z AUTO 07005KT 3/4SM R29/5000VP6000FT –RA BR OVC002 13/13 A2999 RMK A02 LTG DSNT E

METAR KBMI 070505Z AUTO 06006KT 1/2SM R29/4000V6000FT –RA BR OVC002 13/13 A2998 RMK A02 LTG DSNT E P0000

Accident 0506Z

SPECI KBMI 070510Z AUTO 07006KT 1/2SM R29/4000V5000FT –RA FG OVC002 13/13 A2998 RMK A02 P0000

METAR KBMI 070515Z AUTO 08006KT 1/2SM R29/4000V5000FT –RA FG OVC002 13/13 A2998 RMK A02

METAR KBMI 070520Z AUTO 09006KT 1/2SM R29/4000V5000FT –RA FG OVC002 13/13 A2998 RMK A02

METAR KBMI 070525Z AUTO 09006KT 1/2SM R29/4000V5000FT FG OVC002 13/13 A2998 RMK A02 RAE25

3.0 Upper Air Data

The closest upper air sounding or rawinsonde observation (RAOB) was from the NWS Lincoln (KILN), Illinois, site number 74560, located approximately 30 miles southwest of the accident site at an elevation of 584 feet. The 1900 CDT (0000Z on April 7, 2015) sounding was

plotted from the surface to 500-hPa or 18,000 feet on a standard Skew-T log P diagram[8] utilizing RAOB[9] software and is included as figure 10.

The Lincoln 1900 CDT sounding depicted a surface temperature of 16° C, and a dew point of 10.6° C. A defined frontal inversion (shown by green bar on sounding) was depicted immediately above the surface from approximately 1,900 to 3,200 feet agl, with a second inversion due to subsidence between 6,000 and 7,000 feet, where temperature increased with height. The lifted condensation level (LCL)[10] was located at 907-hPa or at 2,483 feet agl, and the convective condensation level (CCL)[11] was at 703-hPa or 6,417 feet agl. The sounding had a relative humidity greater than 80% between the LCL or 2,500 feet through 6,000 feet, and between 14,000 and 14,900 feet. The freezing level was identified at approximately 11,200 feet (blue line). The sounding was stable with a Lifted Index (LI)[12] of 2.0, and supported nimbostratus type clouds, with a precipitable water content of 0.95 inches.

The sounding wind profile indicated a surface wind the southeast or 150° at 11 knots, with a veering clockwise in the wind direction with height to the southwest and west with height, with a gradual increase in wind speeds with height. The mean 0 to 6 kilometer (km) or 18,000 feet wind was from 250° at 21 knots, and the level of maximum wind was from 265° at 82 knots at 42,000 feet.

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[8] 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.

[9] RAOB – (The complete Rawinsonde Observation program) is an interactive sounding analysis program developed by Environmental Research Services, Matamopras, Pennsylvania.

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

[11] Convective Condensation Level (CCL) - The height to which a parcel of air, if heated sufficiently from below, will rise adiabatically until condensation starts. This is typically used to identify the base of cumuliform clouds, which are normally produced from surface heating and thermal convection.

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

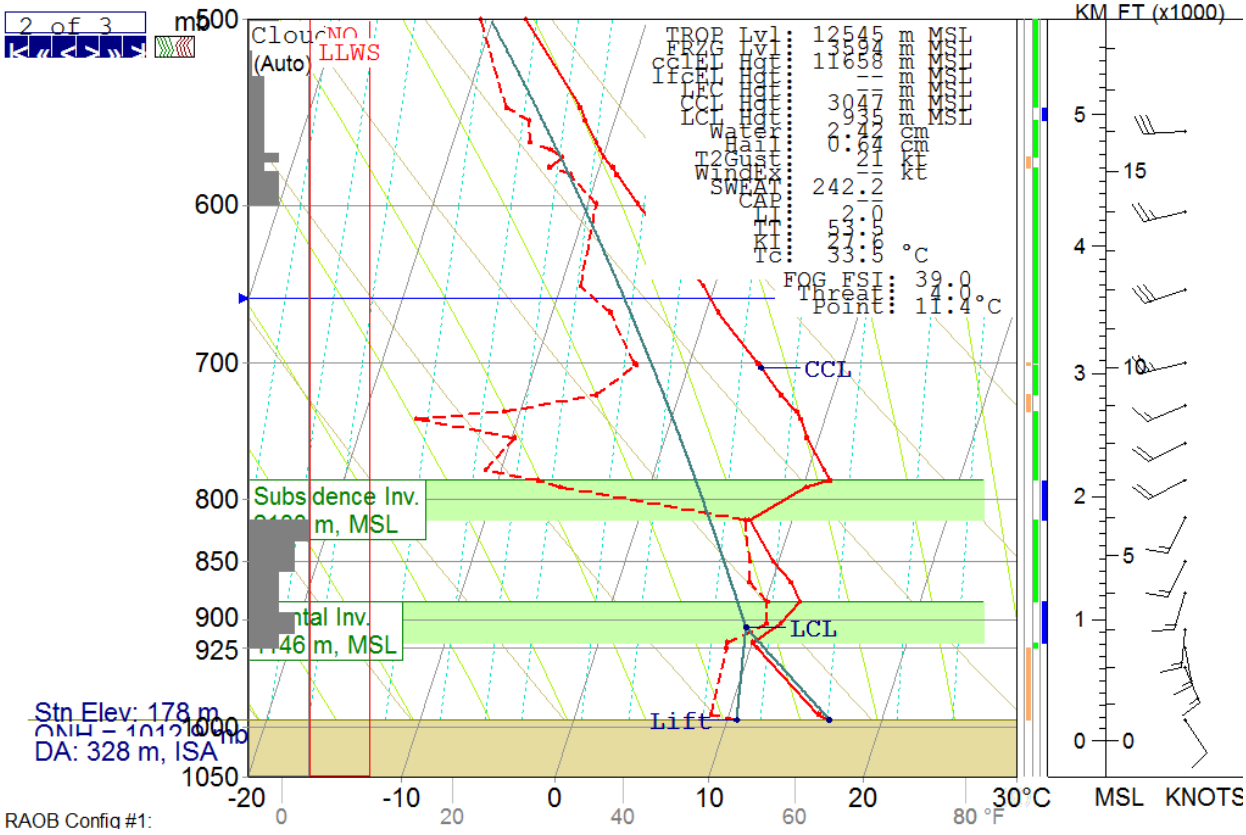

Figure 10 – Lincoln 1900 CDT sounding

Figure 11 is a listing of the 1900 CDT Lincoln sounding parameters and included the observed height, pressure, temperature, dew point temperature, relative humidity (RH), wind direction and speed, and derived clear air turbulence (CAT), low-level wind shear (LLWS), and icing potential. At the accident airplanes cruising altitude of 8,000 feet, the sounding indicated a wind from 240° at 19 knots, and a temperature of approximately 10° C. For the approach into Central Illinois Regional Airport (KBMI) the wind profile indicated a southerly wind of approximately 15 knots.

Height (ft-MSL)	Pres (mb)	T (C)	Td (C)	RH (%)	DD/FF (deg/kts)	CAT (AF)	LLWS	Icing - Type (S-F clouds)
584	992	16.6	10.6	68	150/11			
725	987	15.8	8.8	63				
2000	942				160/13			
2517	925	10.4	8.4	87	170/14			
2665	920	10.0	8.3	89				
3000	909				185/17			
3176	903	11.4	10.5	94				
3761	884	12.2	10.1	87				
4000	876				195/14			
4295	867	11.2	8.5	83				
4837	850	9.6	8.1	90	205/13			
5947	816	7.2	6.9	98	205/14			
6827	790	10.2	-5.8	32		L-M		
7001	785	11.6	-7.4	26	240/20			
7281	777	11.0	-11.0	20				
8000	757				240/19			
8136	753	9.2	-9.8	25				
8645	739	8.4	-16.6	15				
8829	734	8.0	-11.0	25				
9000	729				245/17			
9274	722	6.6	-5.4	42				
10067	701	4.6	-3.4	56		LGT		
10105	700	4.4	-3.6	56	255/23			
11427	666	0.8	-6.2	59				
12000	652				250/28			
12107	649	-0.7	-8.7	55				
14000	603				255/27			
14187	599	-6.7	-9.4	81				TRC Clear
14923	582	-8.7	-11.7	79				TRC Clear
15098	578	-9.1	-13.2	72				TRC Clear
15363	572	-9.9	-12.6	81				TRC Clear
15541	568	-10.3	-13.5	77				TRC Clear

Figure 11 - Lincoln sounding parameters

To better approximate the conditions at the time of the accident, the NOAA Air Resource Laboratory (ARL) North American Mesoscale (NAM) numerical model over the accident site at 0100 CDT (0600Z), and was obtained and plotted in figure 12 on a similar Skew-T log P diagram. The sounding indicated an estimated LCL at 976-hPa or 293 feet agl, and had a relative humidity greater than 80% from the surface through 2,600 feet. The frontal inversion was at the surface with the second inversion at approximately 6,000 feet, and indicated a stable atmosphere with a Lifted Index of 5.0.

The model sounding wind profile indicated a surface wind from 112° at 4 knots, with wind veering to the southwest and west with height. The mean o to 6 km wind was from 250° at 27 knots. Figure 13 is the model parameters of the sounding. The model sounding indicated a light low-level wind shear (LLWS) threat due to the frontal inversion and shift in wind direction and speed immediately above the surface.

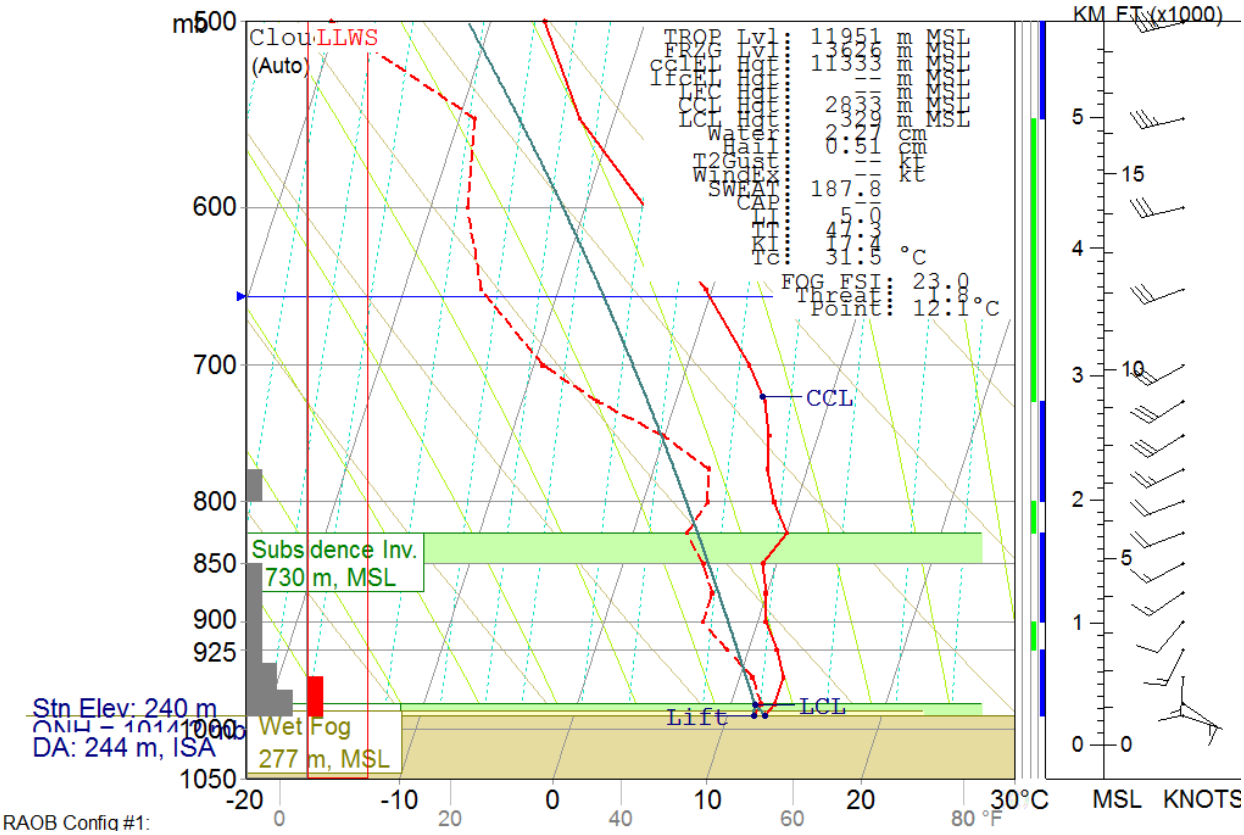

Figure 12 - North American Mesoscale (NAM) Model sounding for 0100 CDT

Height (ft-MSL)	Pres (mb)	T (C)	Td (C)	RH (%)	DD/FF (deg/kts)	CAT (AF)	LLWS	Icing - Type (S-F clouds)
787	986	12.4	11.7	95	112/4		LIGHT	
1097	975	12.8	11.9	94	128/10	L-M	LIGHT	
1815	950	12.8	10.8	88	184/13			
2550	925	11.8	8.6	81	204/15			
3302	900	10.5	6.4	76	218/12			
4072	875	9.9	6.4	79	234/13			
4863	850	9.1	5.2	77	240/15			
5677	825	10.0	3.5	64	247/18			
6515	800	8.5	4.2	74	247/22	LGT		
7376	775	7.4	3.6	77	241/25	LGT		
8262	750	6.8	-0.1	61	236/28			
9175	725	5.8	-5.1	45	235/30			
10114	700	4.0	-9.4	37	238/30	LGT		
12075	650	-0.4	-15.0	32	249/31			
14154	600	-6.0	-17.6	39	256/31			
16364	550	-12.2	-19.0	57	255/33			
18736	500	-16.5	-30.4	29	255/38	LGT		

Figure 13 - NAM sounding data

4.0 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. Both the infrared long wave and visible band imagery were obtained surrounding the time of the accident. The infrared long wave imagery (band 4) at a wavelength of 10.7 microns (μm) provided standard satellite image with radiative cloud top temperatures with a resolution of 4 km.

Figure 15 is the GOES-13 infrared image at 0000 CDT on April 7, 2015, at 4X magnification and with the frontal position at 0100 CDT overlaid and the flight track. The image depicted an area of convective clouds over southern and northeastern Illinois, with low stratus over central portion of the state and over Indiana. The radiative cloud top temperature over the accident site was 273° Kelvin or -0.15° C, which corresponded to cloud tops near 12,000 feet based on the sounding data.

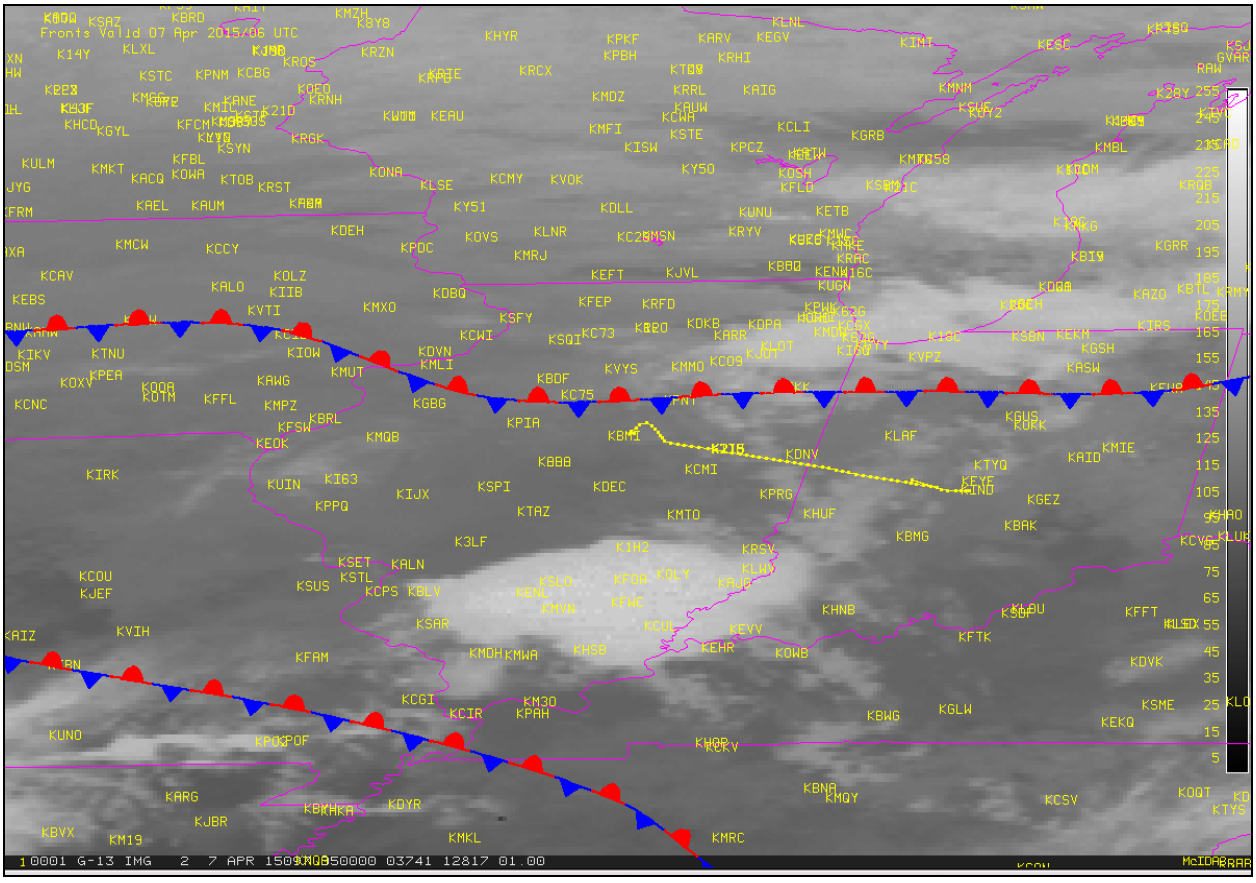

Figure 14 - GOES-13 infrared image at 0000 CDT

5.0 Weather Radar Information

The closest Weather Surveillance Radar-1988, Doppler (WSR-88D) to the accident site was from the NWS Lincoln (KILX), or central Illinois forecast office located approximately 30 miles southwest of the accident site. The level II archive data was obtained from the National Climatic Data Center (NCDC) utilizing the Hierarchical Data Storage System (HDSS) and displayed using the NWS NEXRAD Interactive Viewer and Data Exporter software.

The WSR-88D is a S-band 10 centimeter wavelength radar with a power output of 750,000 watts, with a 28-foot parabolic antenna concentrating the energy into a 0.95° beam width. The radar produces three basic types of products reflectivity, radial velocity, and spectral width.

5.1 Volume Scan Strategy

The WSR-88D is a computer controlled radar system, which automatically creates a complete series of specific scans in a specific sequence known as a volume scan. Individual elevation scans are immediately available on the WSR-88D's Principle Users Processor (PUP). Products that require data from multiple elevation scans are not available until the end of the six minute volume scan.

The WSR-88D operates in several different scanning modes, identified as Mode A and Mode B. Mode A is the precipitation scan and has three common scanning strategies. The most common is the non-severe convective mode where the radar makes 9 elevation scans from 0.50° to 19.5° every six minutes. This particular scanning strategy is documented as volume coverage pattern 21 (VCP-21). Mode B is the clear air mode, where the radar makes 5 elevation scans during a ten minute period. During the period surrounding the accident the KILX WSR-88D radar was operating in the precipitation mode VCP-121 where the radar makes 9 different elevation scans in approximately 6 minutes. This mode is typically used by the NWS during periods when rapidly evolving wide spread severe convection is expected, and allows for improved low-level vertical resolution of the storms. 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.

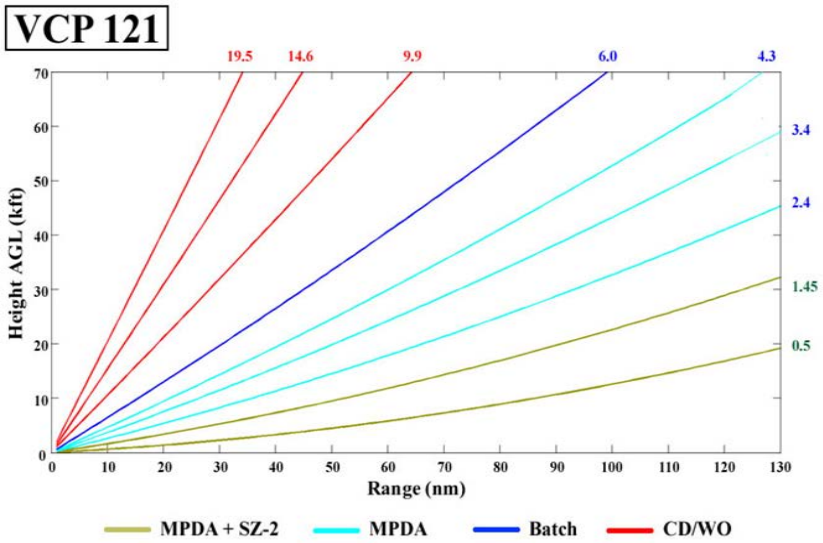

Figure 15- VCP-121 scanning mode

5.2 Beam Height Calculation

Assuming standard refraction[13] of the 0.95° radar beam of the KILX WSR-88D with an antenna height of 115 feet and a distance of 30 miles and an azimuth of 60° from the radar, the following table shows the approximate beam height and width information of the radar display over the site of the accident. The heights have been rounded to the nearest 10 feet.

ANTENNA ELEVATION	BEAM CENTER	BEAM BASE	BEAM TOP	BEAM WIDTH
0.5°	2,300 feet	790 feet	3,810 feet	3,020 feet

Based on the radar height calculations, the 0.5° elevation scan depicts the conditions encompassing the altitude between 790 and 3,810 feet over the accident site.

5.3 Reflectivity

Reflectivity is the measure of the efficiency of a target in intercepting and returning radio energy. With hydrometeors[14] 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

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

[14] 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 glaze ice.

in decibels (dBZ_{15}), and is a general measure of echo intensity. The chart below relates the NWS video integrator and processor (VIP) intensity levels versus the WSR-88D's display levels, precipitation mode reflectivity in decibels, and rainfall rates.

NWS VIP/DBZ CONVERSION TABLE

NWS VIP	WSR-88D LEVEL	PREC MODE DBZ	RAINFALL
0	0 1 2	< 5 5 to 9 10 to 14	
1 Very Light	3 4 5	15 to 19 20 to 24 25 to 29	.01 in/hr .02 in/hr .04 in/hr
2 Light to Moderate	6 7	30 to 34 35 to 39	.09 in/hr .21 in/hr
3 Strong	8	40 to 44	.48 in/hr
4 Very Strong	9	45 to 49	1.10 in/hr
5 Intense	10	50 to 54	2.49 in/hr
6 Extreme	11 12 13 14 15	55 to 59 60 to 64 65 to 69 70 to 74 > 75	>5.67 in/hr

Air traffic control (ATC) weather display systems also use radar weather processors with the ability to determine precipitation intensity, with controllers instructed to describe the intensity to pilots based on the following scale:

Precipitation Intensity	Reflectivity Level
Light	< 30 dBZ, NWS VIP level 1, not displayed
Moderate	30 to 40 dBZ, NWS VIP level 2
Heavy	>40 to 50 dBZ, NWS VIP level 3-4
Extreme	>50 dBZ, NWS VIP level 5-6

5.4 Base Reflectivity

The KILX WSR-88D 0.5 base reflectivity image at 0004 CDT is included as figure 16 with the flight track of N789UP overlaid. The image depicted echoes of -10 to 15 dBZ over the Central Illinois Regional Airport and the flight track from shortly before the flight began turned to the north-northwest being vectored for the approach and then southward on the final approach course. To the northeast of the flight track echoes in the range of 20 to 35 dBZ likely associated

[15] dBZ - 10 log Ze

with moderate rain showers were noted, with no defined echoes associated with thunderstorms were detected within 50 miles of the flight track. The echoes along the flight track indicated that the accident airplane was likely in instrument meteorological conditions (IMC) during the approach and at the time of the accident.

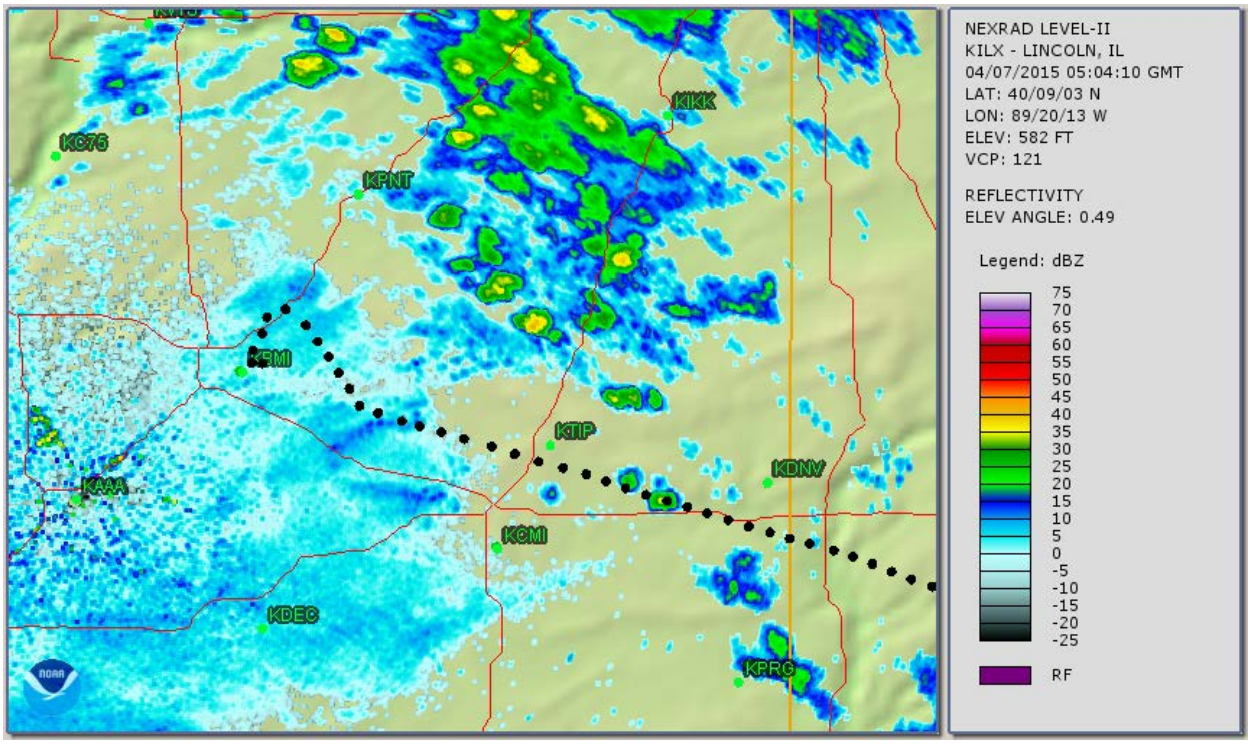

Figure 16 - NWS Lincoln WSR-88D 0.5° base reflectivity image at 0004 CDT

6.0 Pilot Reports

The only pilot reports (PIREPs) over Illinois surrounding the period reported multiple layers of clouds with varying tops. The reports were as follows:

CMI UA /OV CMI/TM 2209/FL036/TP E145/SK OVC036-TOP044/OVC065-TOP072/SKC/RM DURD AWC-WEBFAA.CMH

CMI UA /OV CMI270015 /TM 2310 /FL036 /TP LJ40 /SK OVC030-TOP036 /TA 10 /RM DURD IN AND OUT OF BASES

DNV UA /OV DNV/TM 2332/FL070/TP H25B/SK OVC070/SKC/TB LGT CHOP

CMI UA /OV CMI/TM 0201/FLUNKN/TP E145/SK OVC015-TOP030/OVCUNKN-TOP041/OVCUNKN-TOP060/SKC/RM DURC

7.0 Terminal Aerodrome Forecast

The NWS Terminal Aerodrome Forecast (TAF) for Central Illinois Regional Airport (KBMI) issued surrounding the period were as follows:

TAF KBMI 062326Z 0700/0724 16010KT P6SM OVC025
FM070600 14006KT P6SM VCSH OVC025
FM071000 08008KT 3SM -SHRA VCTS OVC012CB
FM071900 06012KT P6SM BKN020=

TAF AMD KBMI 070148Z 0702/0724 16010KT P6SM OVC012
FM070600 14006KT P6SM VCSH OVC010
FM071000 08008KT 3SM -SHRA VCTS OVC012CB
FM071900 06012KT P6SM BKN020=

TAF KBMI 070538Z 0706/0806 08006KT 1/2SM -DZ FG OVC002
FM071300 07005KT 1 1/2SM BR VCSH OVC002
FM071600 09010KT 5SM BR OVC010
FM080200 15010KT P6SM BKN012=

The initial forecast issued for Central Illinois Regional Airport at 1826 CDT (2326Z) expected MVFR conditions to prevail during the period with wind from 160° at 10 knots, visibility greater than 6 miles, and a ceiling overcast at 2,500 feet agl, with rain showers in the vicinity after 0100 CDT.

The forecast was amended at 2048 CDT (0148Z) by the NWS lowering the ceiling to over cast at 1,200 feet agl. This forecast was current immediately prior to the aircraft departed from Indianapolis, and most likely used in any preflight briefing for the return flight. The forecast expected MVFR conditions prevailing during the period with no mention of any IFR or LIFR conditions.

It was not until after the accident occurred, at the next scheduled update to the forecast at 0038 CDT (0538Z) or immediately after the accident that IFR or more specifically LIFR conditions were forecasted. The new forecast expected the prevailing wind from the east or from 080° at 6 knots, visibility 1/2 mile in light drizzle and fog, with a ceiling overcast at 200 feet agl.

8.0 Area Forecast Discussion

The NWS Lincoln Area Forecast Discussion (AFD) issued at 2352 CDT immediately after the flight departed Indianapolis and current for the period is included below and is intended to provide a well-reasoned discussion of the meteorological thinking which went into the preparation of the forecast products, or specifically for aviation the KBMI TAF. The discussion was as follows:

AVIATION...(For the 06Z TAFS through 06Z Tuesday night)
ISSUED AT 1152 PM CDT MON APR 6 2015

Warm front is sitting over the area tonight and making the wind forecast tricky for overnight and tomorrow. Conditions have dropped to IFR or LIFR at all sites and do not see any improvement until the front moves north tomorrow sometime. One area of showers is exiting the state, but another area is forecast by the short range models to develop west and move across the area. Since showers will likely be scattered, will just have VCSH in all TAFs for a period overnight through tomorrow morning. Not thinking there will be any thunder, so have left out for now.

Once the front moves north, cigs will improve and light pcpn will end. Question is how far north with the front lift. Thinking it will clear SPI and DEC and maybe CMI. PIA and BMI is very uncertain,but still think pcpn will end at those sites around noon. Conditions will remain about the same at PIA and BMI, and improve slightly at CMI. Winds will be light overnight as the front remains around the area. Then as front moves, winds will become south at SPI and DEC, southeast at CMI, and likely remain easterly at PIA and BMI.

9.0 Area Forecast

The NWS Area Forecast issued by the NWS Aviation Weather Center (AWC) at 2045 CDT (0145Z) for Illinois and Indiana were as follows:

FAUS43 KKCI 070145
FA3W
CHIC FA 070145
SYNOPSIS AND VFR CLDS/WX
SYNOPSIS VALID UNTIL 072000
CLDS/WX VALID UNTIL 071400...OTLK VALID 071400-072000
ND SD NE KS MN IA MO WI LM LS MI LH IL IN KY
.
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...NONE.
.
IL
NRN...OVC080 TOP 160. SCT -SHRA/ISOL TSRA. CB TOP FL380. 05Z
OVC020. VIS 3SM BR. SCT -SHRA. TIL 10Z ISOL TSRA. CB TOP FL360.
OTLK...IFR CIG SHRA BR 18Z MVFR CIG.
CNTRL...OVC015 TOP 060. WDLY SCT -SHRA/ISOL TSRA. CB TOP FL380.
09Z SCT -SHRA/WDLY SCT TSRA. OTLK...IFR CIG SHRA TSRA.
S...OVC015 TOP 060. VIS 3SM BR. 07Z SCT -SHRA/TSRA. CB TOP FL360.
OTLK...IFR CIG SHRA TSRA 18Z MVFR CIG SHRA TSRA.
.
IN
N...BKN030 TOP 060. VIS 3SM -DZ BR. 05Z OVC020. SCT -SHRA/ISOL
TSRA. CB TOP FL380. OTLK...IFR CIG SHRA TSRA 18Z MVFR CIG BR.
S...OVC025 TOP 080. 05Z OVC020. SCT -SHRA/TSRA. CB TOP FL380.
OTLK...IFR CIG SHRA TSRA.

The forecast for central Illinois expected an overcast layer of clouds from 1,500 feet with tops near 6,000 feet with widely scattered light rain showers and isolated thunderstorms.

10.0 In-Flight Weather Advisories

The NWS issues in-flight weather advisories designated as Severe Weather Forecast Alerts (AWW's), Convective SIGMET's (WST's), SIGMET's (WS's), Center Weather Advisories (CWA's), and AIRMET's (WA's). In-flight advisories serve to notify en route pilots of the possibility of encountering hazardous flying conditions, which may not have been forecast at the

time of the preflight briefing. Whether or not the condition described is potentially hazardous to a particular flight is for the pilot to evaluate on the basis of experience and the operational limits of the aircraft. During the period the NWS issued AIRMET Sierra for IFR conditions due to low ceilings and visibility for the route of flight and over the accident site. Figure 17 is a depiction of the AIRMETs issued over the period.

AIRMETs

WAUS43 KKCI 070245
WA3S
CHIS WA 070245
AIRMET SIERRA FOR IFR AND MTN OBSCN VALID UNTIL 070900
.
AIRMET IFR...IA MO LM MI LH IL IN KY AR TN LA MS AL AND CSTL WTRS
FROM 30NNE ASP TO 50SSE ECK TO FWA TO CVG TO 40E VXV TO GQO TO
50SW PZD TO 40W CEW TO 50SW CEW TO 20WSW LEV TO 20SSE ELD TO BUM
TO 40SE IOW TO 40SSE DBQ TO ORD TO 30NNE ASP
CIG BLW 010/VIS BLW 3SM PCPN/BR. CONDS CONTG BYD 09Z THRU 15Z.
.

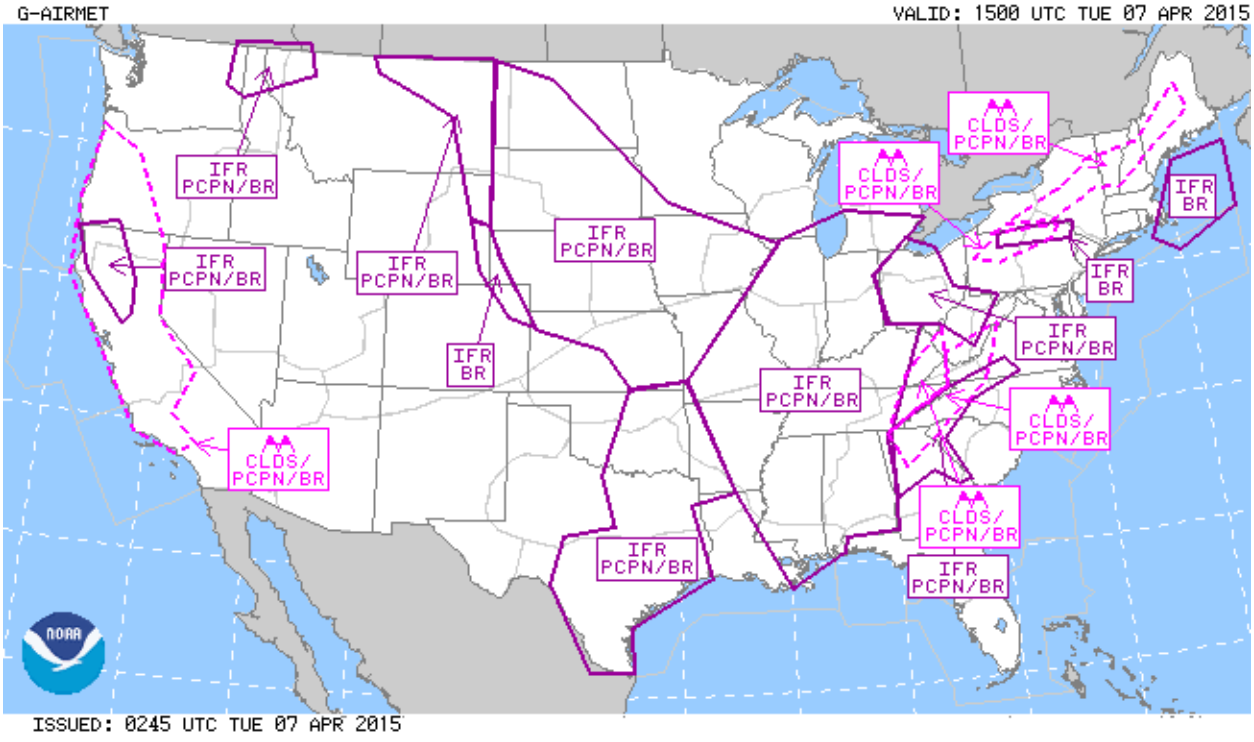

Figure 17 - AIRMET Sierra for IFR conditions

11.0 Winds and Temperature Aloft Forecast

The NWS Wind and Temperature Aloft Forecast (FD) current for the period provided the following information:

WINDS ALOFT FORECASTS
DATA BASED ON 070000Z

VALID 070600Z FOR USE 0200-0900Z. TEMPS NEG ABV 24000

FT	*3000*	*6000*	*9000*	*12000*	*18000*	*24000*	*30000*	*34000*	*39000*
IND	*2227*	*2332+08*	*2426+07*	*2528+00*	*2627-18*	*2846-28*	*285245*	*275654*	*276763*
CVG	*2221*	*2424+09*	*2421+05*	*2820-01*	*2824-18*	*2844-27*	*285344*	*276154*	*277462*
FWA	*2321*	*2534+08*	*2433+02*	*2527-03*	*2833-17*	*2843-30*	*286246*	*286955*	*277463*
LOU	*2334*	*2525+09*	*2620+08*	*2719+00*	*2827-18*	*2845-27*	*275444*	*275953*	*267561*
JOT	*1813*	*2113+07*	*2328+05*	*2434-01*	*2635-19*	*2744-30*	*275946*	*276755*	*277163*
SPI	*2322*	*2523+09*	*2430+07*	*2529+01*	*2634-16*	*2746-28*	*274945*	*275654*	*276463*

12.0 Preflight Weather Briefing

The pilot utilized a commercial weather vender FlightPlan.com to obtain his preflight weather briefing and logged several briefings at 1614, 1957, 2117, and 2228 CDT on April 6, 2015. The briefings included weather reports, forecast, and notice to airmen (NOTAM) for the departure, destination, alternate, and selected nearby airports and pilot reports. The last briefing obtained at 2228 CDT included the TAF for Bloomington issued at 2048 CDT which expected MVFR conditions, and contained nearby airports which were already reporting LIFR conditions with ceilings overcast in the 200 to 300 feet agl range. The briefing did not include the Area Forecast or any in-flight weather advisories. The pilot had filed an IFR flight plan, which included an alternate airport.

13.0 Astronomical Data

Sunset	1925 CDT
End of civil twilight	1953 CDT
Moonrise	2143 CDT
Beginning of civil twilight	0603 CDT
Sunrise	0631 CDT

Phase of the moon was a waning gibbous and was 21.5° above the horizon at an azimuth of 134°, and had 93% of the moon's visible disk illuminated.

Submitted by:

Donald Eick
NTSB Senior Meteorologist