



NATIONAL TRANSPORTATION SAFETY BOARD

Office of Aviation Safety
Washington, D.C. 20594

January 6, 2020

Weather Study

METEOROLOGY

DCA19CA151

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A. ACCIDENT

Location: Jacksonville, Florida
Date: May 25, 2019
Time: about 1715 eastern daylight time
2115 Universal Coordinated Time (UTC)
Airplane: Southwest Airlines flight 2842, Boeing B737-800; Registration: N8697C

B. METEOROLOGIST

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National Transportation Safety Board

C. SUMMARY

On May 25, 2019, at about 1715 EDT, Southwest Airlines flight 2842, 737-800, N8697C, during descent into Jacksonville International Airport (KJAX), Jacksonville, Florida, the aircraft encountered moderate turbulence at about 12,000 feet. The “D” position Flight Attendant received a serious injury. There were 2 pilots, 4 flight attendants and 122 passengers on board. The flight was operating as a 14 *Code of Federal Regulation* (CFR) part 121 flight from Chicago Midway International Airport (KMDW), Chicago, Illinois, to KJAX.

D. DETAILS OF THE INVESTIGATION

The National Transportation Safety Board’s Senior Meteorologist was not on scene for this investigation and conducted the meteorology phase of the investigation from the Washington D.C. office, collecting data from official National Weather Service (NWS) sources including the Weather Prediction Center (WPC) and the National Center for Environmental Information (NCEI). All times are eastern daylight time (EDT) based upon the 24-hour clock, local time is -4 hours from UTC, and UTC=Z. NWS airport and station identifiers use the standard International Civil Aviation Organization 4-letter station identifiers versus the International Air Transport Association 3-letter identifiers, which deletes the initial country code designator “K” for U.S. airports. Directions are referenced to true north and distances in nautical miles. Heights are in feet (ft) above mean sea level (msl) unless otherwise noted. Visibility is in statute miles and fractions of statute miles.

The location of the turbulence encounter is based on the flight track position and flight data recorder (FDR) data provided by Southwest at latitude 30.94403° N and longitude 82.19659° W at an altitude of approximately 12,000 ft.

E. WEATHER INFORMATION

1.0 Synoptic Conditions

The synoptic or large-scale migratory weather systems influencing the area were documented using standard NWS charts issued by the National Center for Environmental Prediction (NCEP) located in College Park, Maryland. These are the base products used in describing weather features and in the creation of forecasts and warnings. Reference to these charts can be found in the joint NWS and Federal Aviation Administration (FAA) Advisory Circular “Aviation Weather Services”, AC 00-45H change 2.

1.1 Surface Analysis Chart

The southeast section of the NWS Surface Analysis Chart for 1700 EDT (2100Z) is included as figure 1 with the approximate turbulence location marked by a red star, and KJAX located within the red circle. The chart depicted a high pressure system of 1024-hectopascals (hPa) off the mid-Atlantic coast with a ridge extending southwest across northern and central Florida, with another high pressure system located in the Gulf of Mexico off the Mississippi and Alabama coasts at 1020-hPa. A generally weak pressure gradient was indicated over the southeast with no frontal boundaries over Georgia or Florida. The chart, however, did depict a trough of low pressure or an outflow boundary¹ over eastern Georgia into South Carolina, which was in the immediate vicinity of the accident site, with another outflow boundary over the Florida panhandle into western Florida along the coast. Both boundaries were found to be associated with sea-breeze fronts and not from any thunderstorm outflows.

¹ Outflow boundary, also known as a gust front, is a storm-scale or mesoscale boundary separating thunderstorm-cooled air (outflow) from the surrounding air; similar in effect to a cold front, with passage marked by a wind shift and usually a drop in temperature and a related pressure jump.

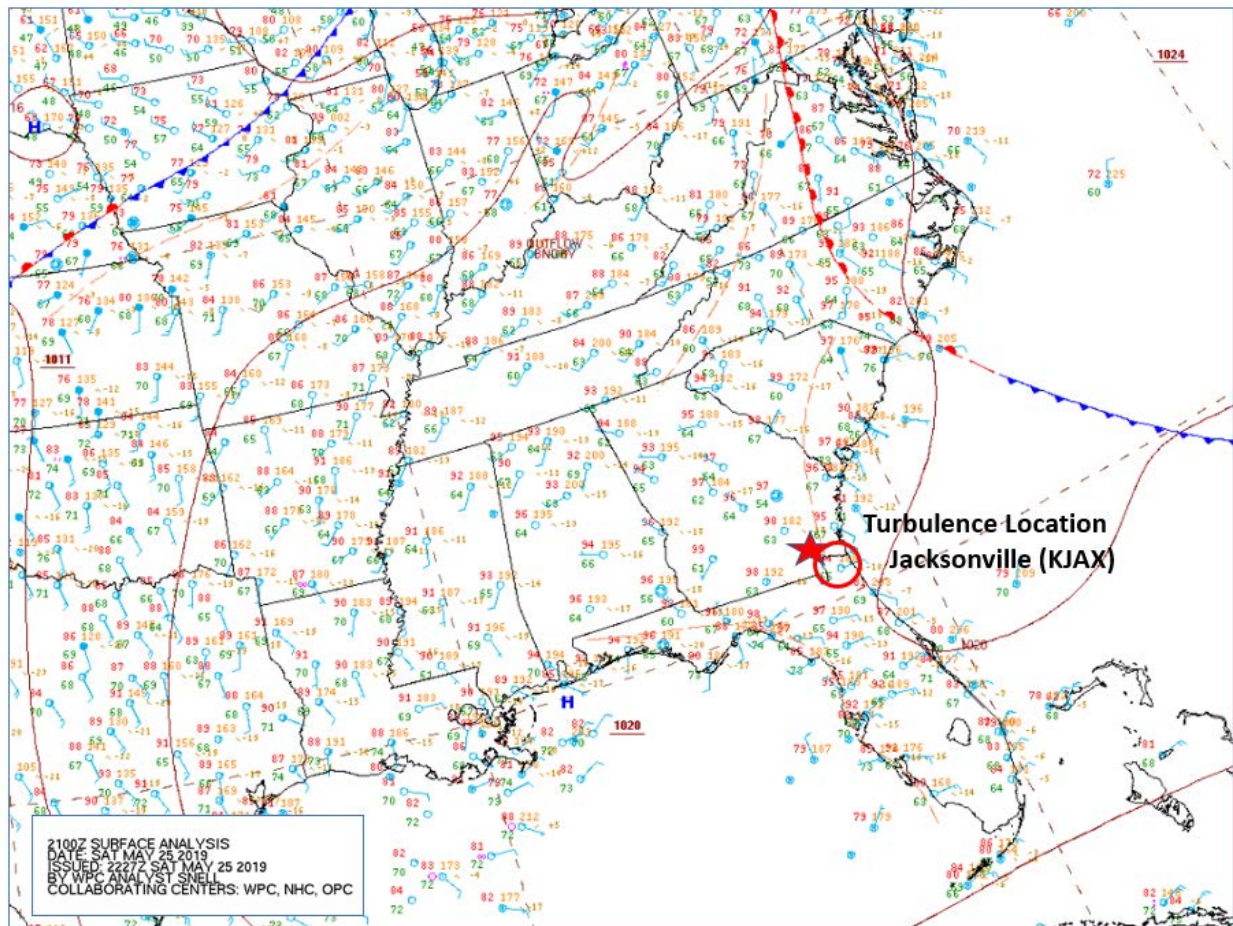


Figure 1 - NWS Surface Analysis Chart for 1700 EDT on May 25, 2019 with the approximate turbulence location noted by the red star and the Jacksonville area within the red circle.

The station model for Jacksonville indicated a wind from the east at 10 knots, scattered clouds, with a temperature of 94° Fahrenheit (F), with a dew point of 65° F. The station model for Waycross, Georgia, immediately north of the turbulence location indicated a calm wind, clear skies, with a temperature of 98° F, and a dew point of 63° F. No significant weather was reported in the vicinity of the turbulence location.

1.2 Streamline Analysis

A streamline analysis² of the observational wind data at 1700 EDT is included as figure 2, which was obtained from archive data from Plymouth State University. The image depicted easterly winds along the eastern seaboard with a convergence zone inland from South Carolina and North Carolina which coincided with the developing frontal zone to the north. The convergence zone continued into South Carolina, Georgia, and into northern Florida, with a potential low pressure circulation center developing near the Tallahassee area. The turbulence location was in the vicinity of the convergence boundary in Georgia.

² A streamline analysis is a depiction of the surface wind field. Streamlines are drawn parallel to the wind.

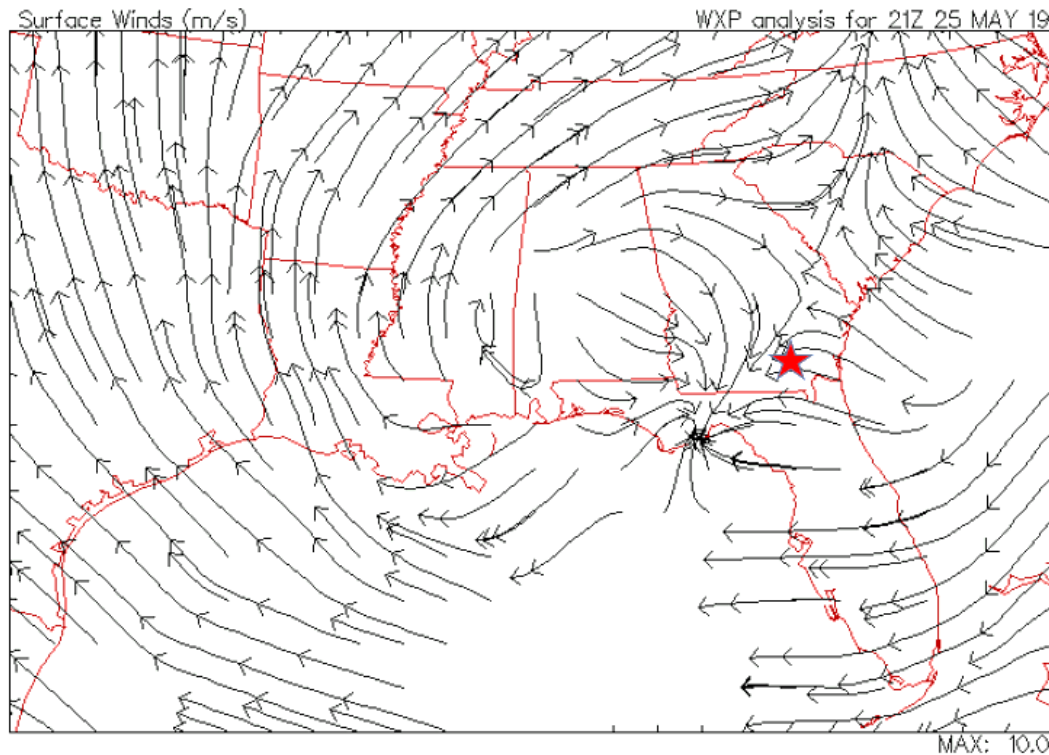


Figure 2 - Streamline analysis for 1700 EDT

The general convergence zone across southeast Georgia into northern Florida further support that the boundary on the surface analysis chart was not an outflow boundary associated with thunderstorms but was associated with warm moist air from the Atlantic interacting with drier air over inland areas (similar to a dry line front).

1.3 National Composite Radar Mosaic

Figure 3 is the southeast section of the NWS National Composite Radar Mosaic for 1720 EDT with the approximate turbulence location noted by the red star. The image depicted no significant meteorological echoes associated with precipitation over southern Georgia or northern Florida during the period. No large-scale organized thunderstorms were identified over the southeast during the period surrounding the turbulence event.

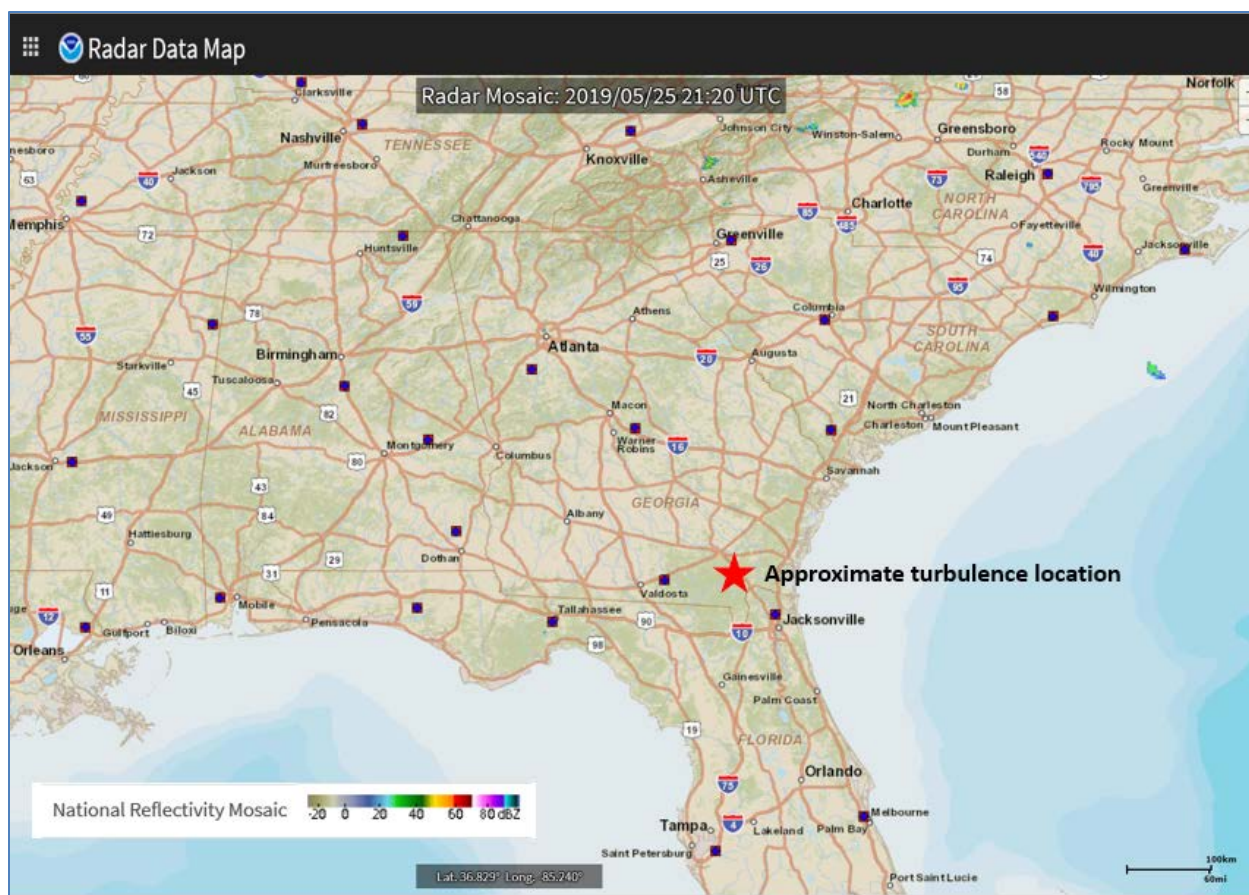


Figure 3 - NWS National Composite Radar Mosaic for 1720 EDT with the approximate turbulence location indicated by the red star

While no significant echoes were identified in the National Composite Radar Mosaic, based on the detection of a potential boundary in the vicinity of the turbulence location the closest NWS weather surveillance radar will be further documented in section 5.0 of this report.

1.4 Convective Outlook

The NWS Storm Prediction Center (SPC) afternoon Convective Outlook issued at 1548 EDT is included as figure 4. The chart depicted an area from the Texas and Oklahoma Panhandles into western and northern Oklahoma and southern Kansas where an enhanced risk of severe thunderstorms were expected, with a slight risk continuing into eastern Kansas, Missouri, and Illinois. Another slight risk area extended from eastern Indiana into Ohio, West Virginia, Pennsylvania, and western New York. No organized thunderstorms were expected over Georgia and Florida during the period.

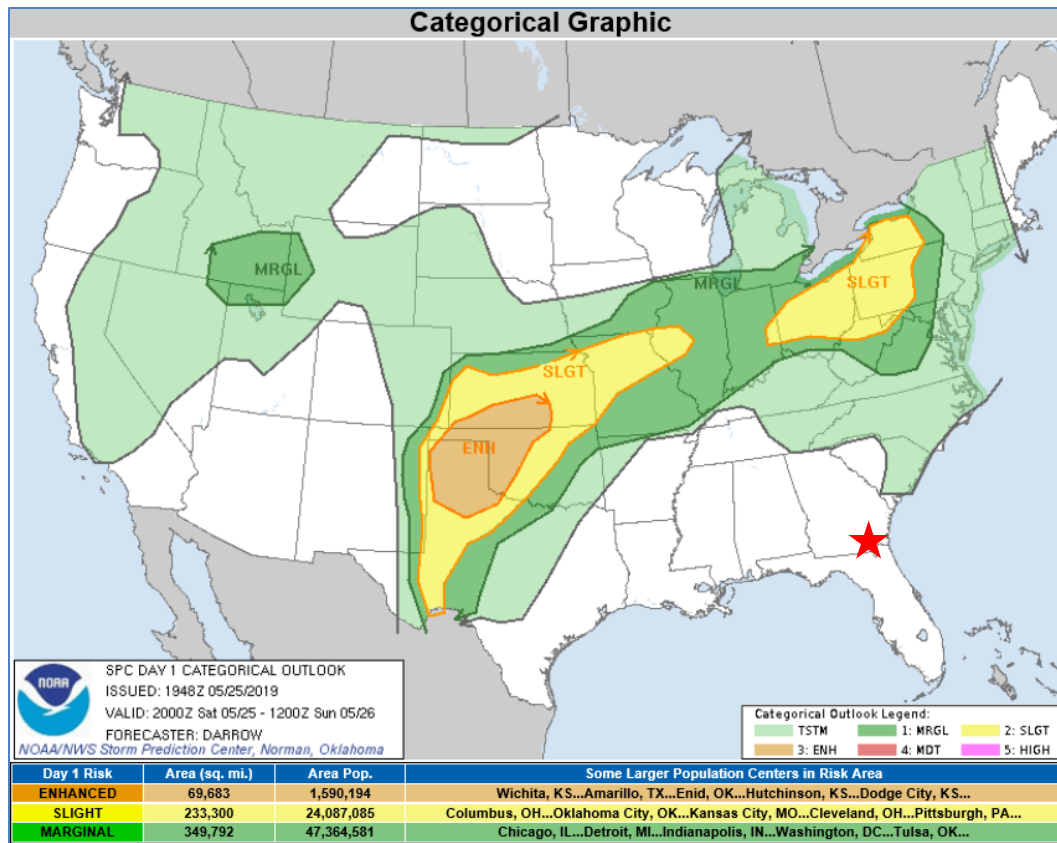


Figure 4 - NWS afternoon Convective Outlook issued at 1548 EDT

1.5 Constant Pressure Charts

The NWS Storm Prediction Centers (SPC) constant pressure charts that were produced from upper air data and from the North American Mesoscale (NAM) numerical model data were obtained from archive to document the upper level features over the region. The constant pressure charts for 700- and 500-hPa for 2000 EDT are included as figure 5 and 6, respectively, and represented the approximate conditions at 10,000 ft and 18,000 ft. The charts provided the height contours, isotherms³, and station observation of wind direction and speed, temperature, and temperature-dew point spread. The 700-hPa chart also provided a moisture analysis where temperature dew point spreads are 4° C or less (green lines).

The 700-hPa chart depicted a high pressure area over Georgia and Alabama with winds over KJAX from the east-northeast at 10 knots with a temperature of 11° C, and temperature-dew point spread of 10° C. The 500-hPa chart continued to depict the high pressure system over Georgia and the KJAX wind was from the east at 10 knots, where a temperature of -7° C was depicted. High pressure systems supported clear skies and general subsiding motion over the region, suppressing thunderstorm development.

³ Isotherm - A line connecting points of equal temperature.

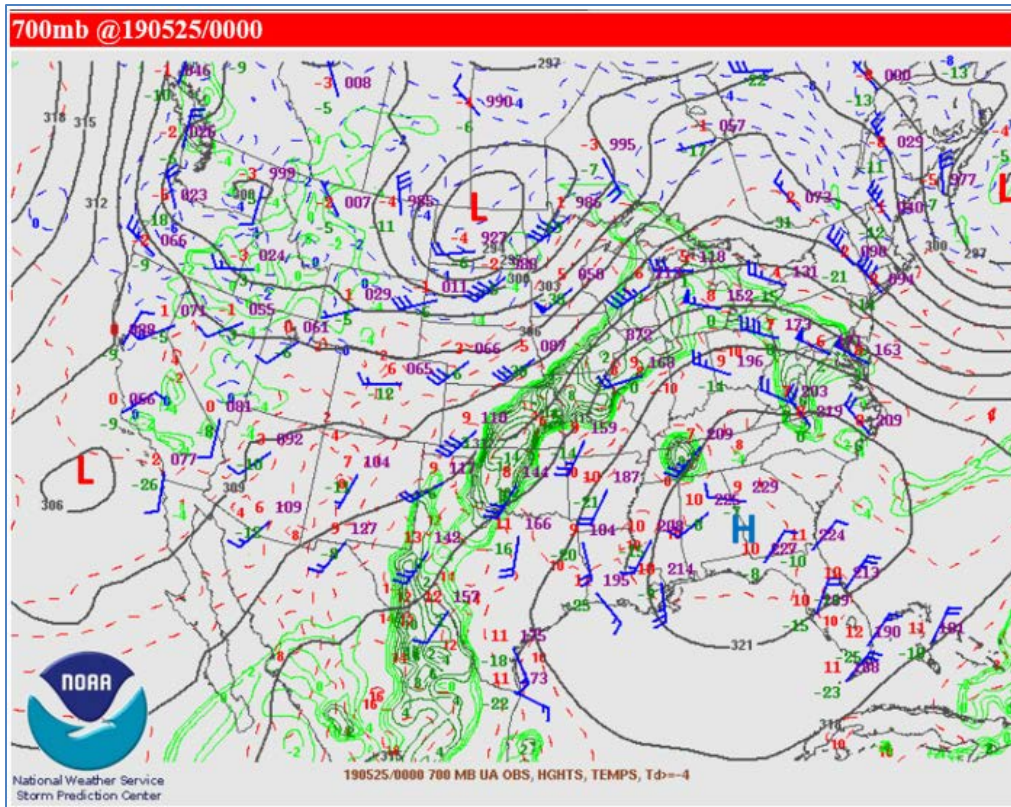


Figure 5 - 700-hPa constant pressure chart for 2000 EDT

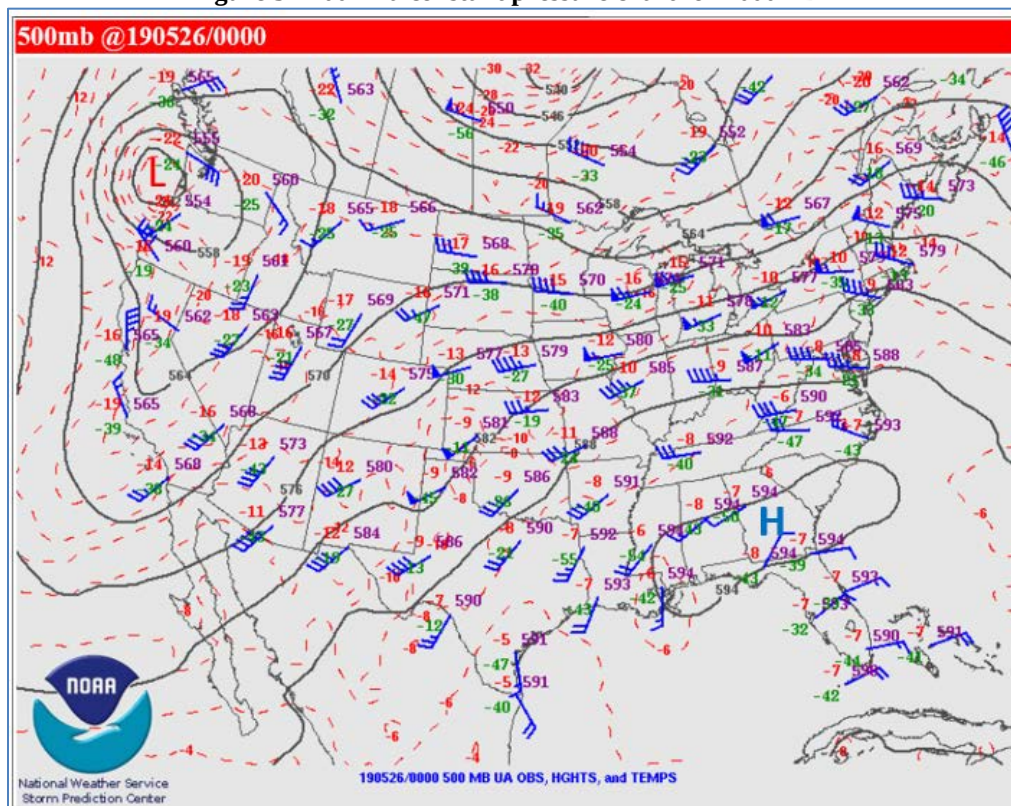


Figure 6 - 500-hPa constant pressure chart for 2000 EDT

1.6 High Level Significant Weather Prognostic Chart

The NWS 24-hour High Level Significant Weather Prognostic Chart for the United States issued at approximately 0400 EDT and valid for 2000 EDT is included as figure 7. The chart depicted the jet stream position and strength, areas of expected clear air turbulence (CAT) above 24,000 ft, areas of organized convection, upper level pressure systems and tropopause heights. The chart indicated that the route of flight between KMDW and KJAX was south of the jet stream and free of any expected convective activity. The tropopause was identified near 50,000 ft over the southeast with a high pressure system in the Gulf of Mexico raising the tropopause to 55,000 ft. No CAT was depicted along the route of flight.

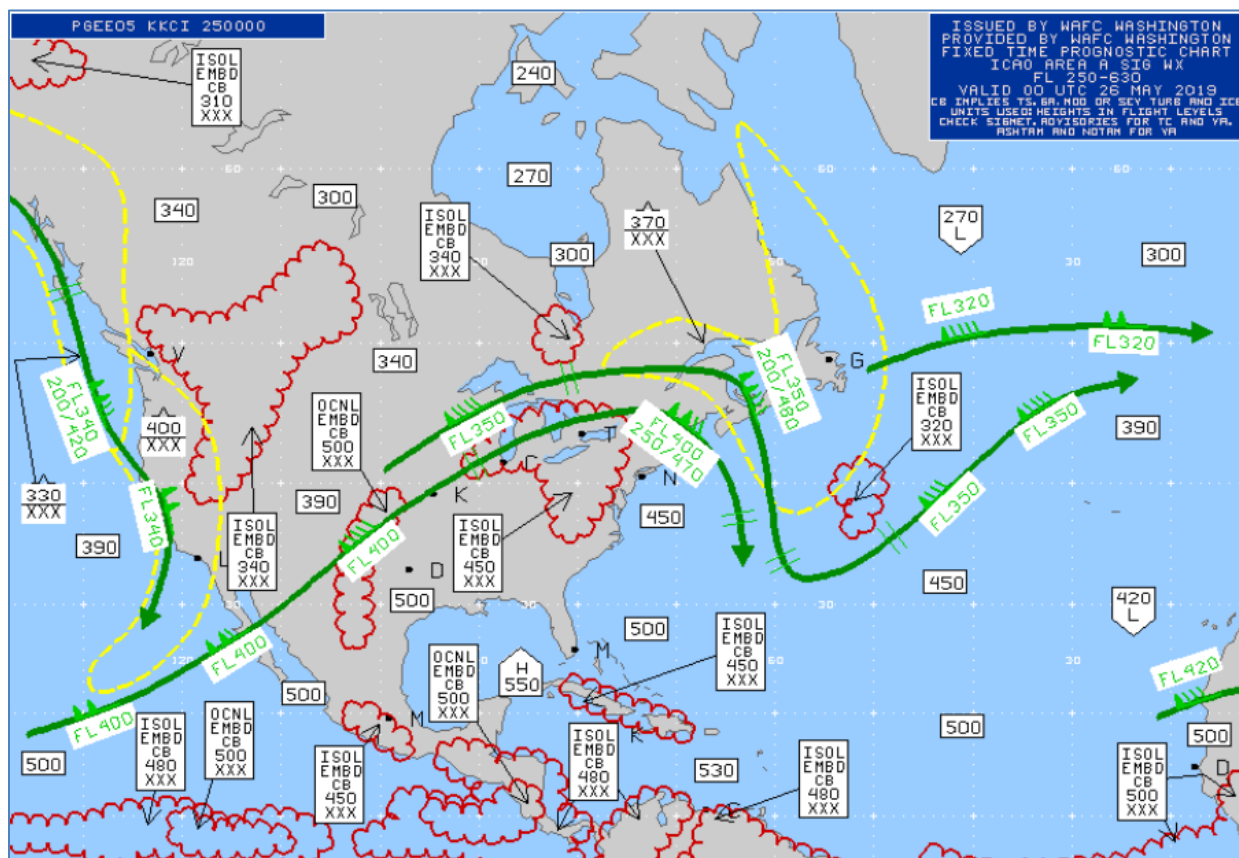


Figure 7 - NWS High Level Significant Weather Prognostic Chart valid for 2000 EDT

2.0 Observations

The official observations issued surrounding the accident site were documented using standard meteorological aerodrome reports (METARs) and specials (SPECI). Cloud heights are reported above ground level (agl) in the following section, and the magnetic variation was estimated at 6° west over the area based on the latest sectional chart.

2.1 Jacksonville, Florida

The planned destination was Jacksonville International Airport (KJAX), Jacksonville, Florida, located approximately 37 miles southeast of the accident location at an elevation of 29 ft. The

airport had an Automated Surface Observation System (ASOS) that was augmented by FAA tower personnel. The observation issued immediately prior to the turbulence event was as follows:

KJAX weather observation at 1656 EDT, wind from 090° at 10 knots, visibility 10 miles or more, a few clouds at 6,500 ft agl, temperature 34° Celsius (C), dew point temperature 18° C, altimeter 30.08 inches of mercury (Hg). Remarks: automated station with a precipitation discriminator, sea-level pressure 1018.8-hPa, temperature 34.4° C, dew point 18.3° C, 3-hour pressure tendency fallen 1.0-hPa.

The raw observations from approximately 1400 through 2000 EDT were as follows:

METAR KJAX 251756Z 08007KT 040V110 10SM FEW035 35/18 A3012 RMK AO2 SLP198 T03500183 10350 20222 58014=

METAR KJAX 251856Z 04003KT 10SM FEW040 35/17 A3010 RMK AO2 SLP194 T03500172=

METAR KJAX 251956Z 07009G15KT 10SM FEW065 35/18 A3009 RMK AO2 SLP189 T03500183=

METAR KJAX 252056Z 09010KT 10SM FEW065 34/18 A3008 RMK AO2 SLP188 T03440183 56010=

Accident 2115Z

METAR KJAX 252156Z 09011KT 10SM FEW065 34/18 A3009 RMK AO2 SLP189 T03390178=

METAR KJAX 252256Z 12010KT 10SM FEW060 32/18 A3009 RMK AO2 SLP190 T03220178=

METAR KJAX 252356Z 13007KT 10SM CLR 31/17 A3009 RMK AO2 SLP191 T03060172 10356 20306 52003=

A review of the observations indicated easterly winds around 10 knots during the period, with a few clouds (less than 1/8th sky coverage) between 3,500 and 6,500 ft agl associated with fair weather cumulus clouds, with the high temperatures of 35.0° C (95° F) being reported an hour prior to the turbulence event.

2.2 Waycross, Georgia

The closest weather reporting site to the accident site was from Waycross-Ware County Airport (KAYS), Waycross, Georgia, located 18 1/2 miles north of the accident site at an elevation of 141 ft. The airport had an Automated Weather Observation System (AWOS), whose observations were not augmented by any human observer and issued every 20-minutes. At the time of the turbulence encounter KAYS reported the following conditions.

KAYS weather observation at 1715 EDT, automated, wind calm, visibility 10 miles or more, sky clear below 12,000 ft, temperature 36° C, dew point 6° C, altimeter 30.08 inches of Hg. Remarks: automated station with a precipitation discriminator, temperature 35.8° C, dew point 5.6° C, thunderstorm sensor inoperative.

The raw observations issued for KAYS surrounding the period from 1600 through 1900 EDT were as follows:

METAR KAYS 251955Z AUTO 13006KT 10SM CLR 37/05 A3009 RMK AO2 T03670050 TSNO=
METAR KAYS 252015Z AUTO 00000KT 10SM CLR 37/05 A3009 RMK AO2 T03660050 TSNO=
METAR KAYS 252035Z AUTO 13005KT 10SM SCT085 37/06 A3008 RMK AO2 T03710057 TSNO=
METAR KAYS 252055Z AUTO 06006KT 10SM SCT085 37/06 A3008 RMK AO2 T03690057 TSNO=
Accident 2115Z

METAR KAYS 252115Z AUTO 00000KT 10SM CLR 36/06 A3008 RMK AO2 T03580056 TSNO=
METAR KAYS 252135Z AUTO 00000KT 10SM CLR 36/06 A3007 RMK AO2 T03590057 TSNO=
METAR KAYS 252155Z AUTO 00000KT 10SM CLR 36/06 A3007 RMK AO2 T03610056 TSNO=
METAR KAYS 252215Z AUTO 09004KT 10SM CLR 37/05 A3007 RMK AO2 T03660054 TSNO=
METAR KAYS 252235Z AUTO 15005KT 10SM CLR 37/06 A3007 RMK AO2 T03660056 TSNO=
METAR KAYS 252255Z AUTO 21004KT 10SM CLR 36/07 A3007 RMK AO2 T03630065 TSNO=

A review of the observations indicated light winds, visibility unrestricted, with clear skies conditions over the station, and temperatures in the upper 90's °F. The high temperature recorded at KAYS was reported approximately an hour after the accident at 36.6° C (98° F).

3.0 Sounding

A combination of balloon-launched rawinsonde and aircraft in-situ observations were documented to identify the upper air features in the vicinity of the turbulence encounter.

3.1 Jacksonville Rawinsonde Observation

The NWS Jacksonville (KJAX) upper air observation⁴, site number 72206, at 2000 CDT (0000Z May 26, 2019) was retrieved and plotted on a standard Skew T log P diagram⁵ using the complete Rawinsonde Observation RAOB program software⁶. Figure 8 is the KJAX sounding from the surface to approximately 21,000 ft. The sounding depicted a near surface temperature of 31.6° C (89° F), a dew point of 19.6° C (67° F), and a relative humidity of 49%. The lifted condensation level (LCL)⁷ was identified at 5,032 ft agl, the level of free convection (LFC)⁸ at

⁴ The NWS Jacksonville Weather Forecast Office is co-located at the Jacksonville International Airport and share the same station designator of KJAX.

⁵ Skew T log P diagram – is a standard meteorological plot or thermodynamic diagram using temperature and the logarithmic of pressure as coordinates, used to display winds, temperature, dew point, and various indices used to define the vertical structure of the atmosphere.

⁶ RAOB software – The complete RAWinsonde OBServation program is an interactive sounding analysis program developed by Environmental Research Services, Matamoras, Pennsylvania, for plotting and analyzing upper air data.

⁷ Lifting Condensation Level (LCL) - the level at which a lifted parcel becomes saturated. The LCL height corresponds to cloud base height for forced ascent.

⁸ Level of Free Convection (LFC) - the last level where a parcel becomes buoyant, or "warmer" than the environmental temperature at the same level. The LFC represents the bottom of the layer containing CAPE.

7,807 ft agl, and the convective condensation level (CCL)⁹ at 8,120 ft agl. The precipitable water content was 1.29 inches. The sounding did not depict any specific clouds layers, the relative humidity approached 65% between approximately 4,500 ft through 8,000 ft but was otherwise too dry to support cloud formation. The atmosphere was characterized as conditional unstable with a Lifted Index of -3, a Convective Available Potential Energy (CAPE) of 914 Joules/kilogram, and a K Index¹⁰ of 17.3 (which indicated a less than 20% probability of airmass type thunderstorm activity). A near isothermal or stable layer was indicated between approximately 8,000 ft to 10,000 ft where the temperature remained near constant. The freezing level was at approximately 15,900 ft, with no icing indicated.

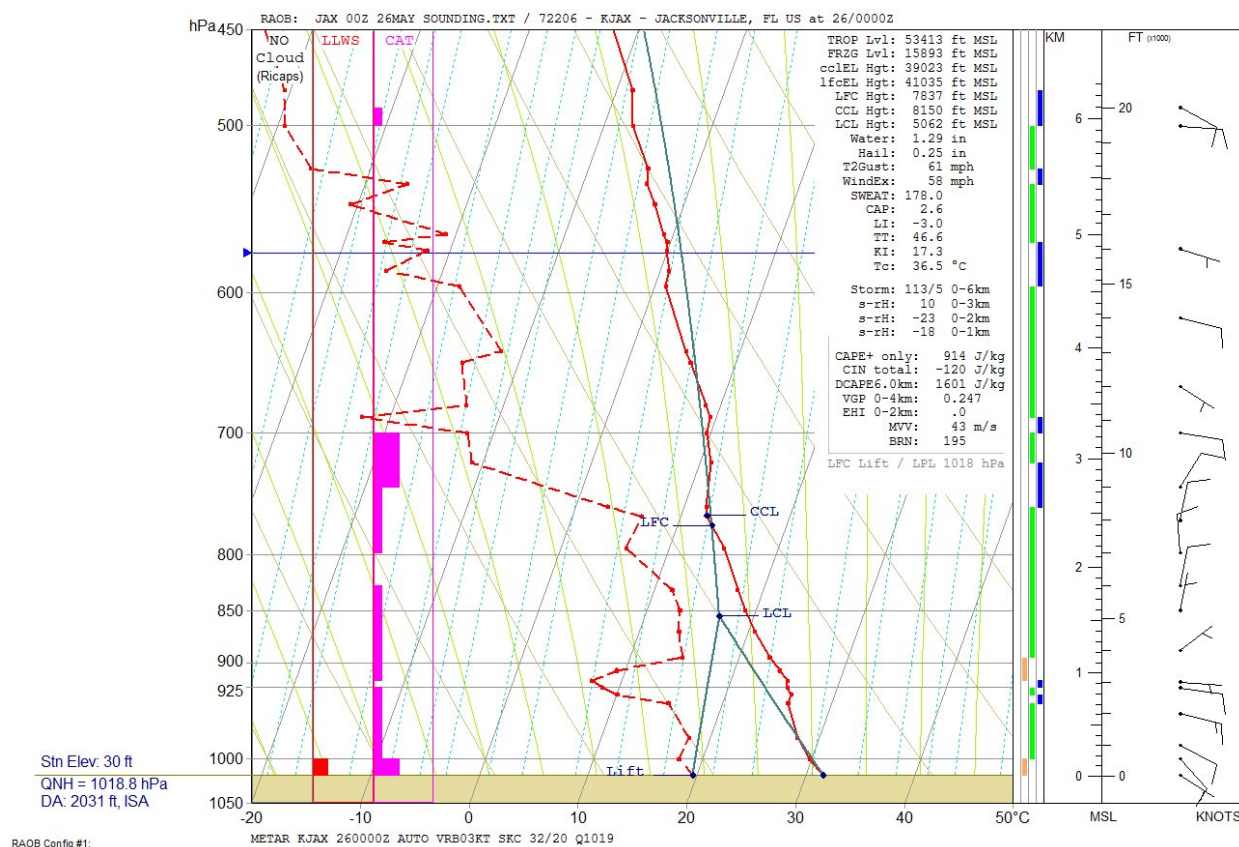


Figure 8 - KJAX 2000 EDT upper air sounding

The KJAX wind profile indicated a surface wind from 125° at 3 knots with winds backing to the east and then to the north at 5,000 ft before veering to the east again above 10,000 ft. The wind at 12,000 ft the level of the turbulence encounter was 125° at 7 knots. The mean 0 to 6 kilometer or 18,000 ft wind was from 083° at 6 knots. The level of maximum wind was identified at 50,000 ft from 010° at 33 knots, with the tropopause at approximately 53,400 ft.

⁹ The convective condensation level (CCL)- represents the height where an air parcel becomes saturated when heated from below and lifted adiabatically due to buoyancy.

¹⁰ Lifted Index (LI) - the difference between the lifted parcel temperature at 500 hPa and the 500 hPa temperature in the sounding. Negative values denote parcels that are warmer than the background 500 hPa temperatures, and are thus buoyant or "unstable".

Figure 9 is a table of the observed sounding parameters of height, pressure (Pres), temperature (T), dew point (Td), relative humidity (RH), wind direction and speed, and RAOB derived CAT, low-level wind shear (LLWS) and icing potential. Near 9,700 ft the RAOB turbulence algorithm indicated a potential for moderate turbulence due to a shallow layer of strong vertical wind shear of 7.2 knots per 1,000 ft. No strong wind shears were identified at 12,000 ft for any significant turbulence. The turbulence parameter does not consider turbulence in or near any convective type clouds.

Height (ft-MSL)	Pres (hPa)	T (C)	Td (C)	RH (%)	DD / FF (deg / kts)	CAT (FAA)	LLWS	Icing - Type (AFGWC method)
30	1018	31.6	19.6	49	125 / 3	MDT	LIGHT	
555	1000	29.8	17.8	49	140 / 9	LGT		
1000	985				120 / 11			
1236	977	28.0	18.0	55		LGT		
2000	952				105 / 13			
2327	941	26.0	15.0	51				
2605	932	26.0	10.0	37		LGT		
2823	925	25.4	8.4	34	100 / 8			
3042	918	25.2	7.2	32	95 / 7			
3357	908	24.2	9.2	39				
3771	895	22.8	14.8	61		LGT		
4000	888				50 / 4			
4579	870	20.6	13.6	64		LGT		
5238	850	19.0	13.0	68	10 / 6			
5875	831	17.6	11.6	68		LGT		
6000	827				10 / 10			
7000	798				355 / 9			
7149	794	15.0	6.0	55		LGT		
8000	770				10 / 12			
8107	767	12.4	6.4	67				
8396	759	12.0	3.0	54		LGT		
9000	742				30 / 11			
9729	723	11.0	-11.0	20		MDT		
10611	700	9.6	-12.4	20	100 / 9			
11081	688	9.4	-22.6	8				
11438	679	8.6	-13.4	20				
12000	665				125 / 7			
12698	648	5.8	-15.2	20				
13031	640	5.0	-12.0	28				
14000	617				105 / 10			
14923	596	1.0	-18.0	23				
15369	586	0.8	-25.2	12				
15959	573	-0.1	-22.1	17	110 / 7			
16189	568	-0.3	-26.3	12				
16421	563	-0.9	-20.9	20				
17269	545	-2.7	-30.7	10				
17846	533	-4.1	-26.1	16				
18286	524	-4.5	-35.5	7				

Figure 9 - KJAX sounding parameters and RAOB algorithm turbulence potential

3.2 Aircraft In-situ Reports

A search of the NOAA Forecast System Laboratory (FSL) archive site for Aircraft Meteorological Data Relay (AMDAR) reports provided data from several aircraft descending into KJAX surrounding the time of the turbulence event. These aircraft in-situ reports provided pressure altitude, pressure, temperature and wind information. The search indicated that no aircraft

reported eddy dissipation rate (EDR)¹¹ or water vapor in the vicinity of KJAX within 3 hours of the turbulence event. Figure 10 presents data from an aircraft identified as #10974, which arrived at KJAX at 1647 EDT. Figure 11 presents data from an aircraft identified as #11401, which arrived at KJAX at 1730 EDT. Both aircraft flew similar approaches into KJAX and were in the vicinity of the turbulence location during their descent phases. The inversions are annotated in green lines and the approximate turbulence encountered altitude noted by a red arrow.

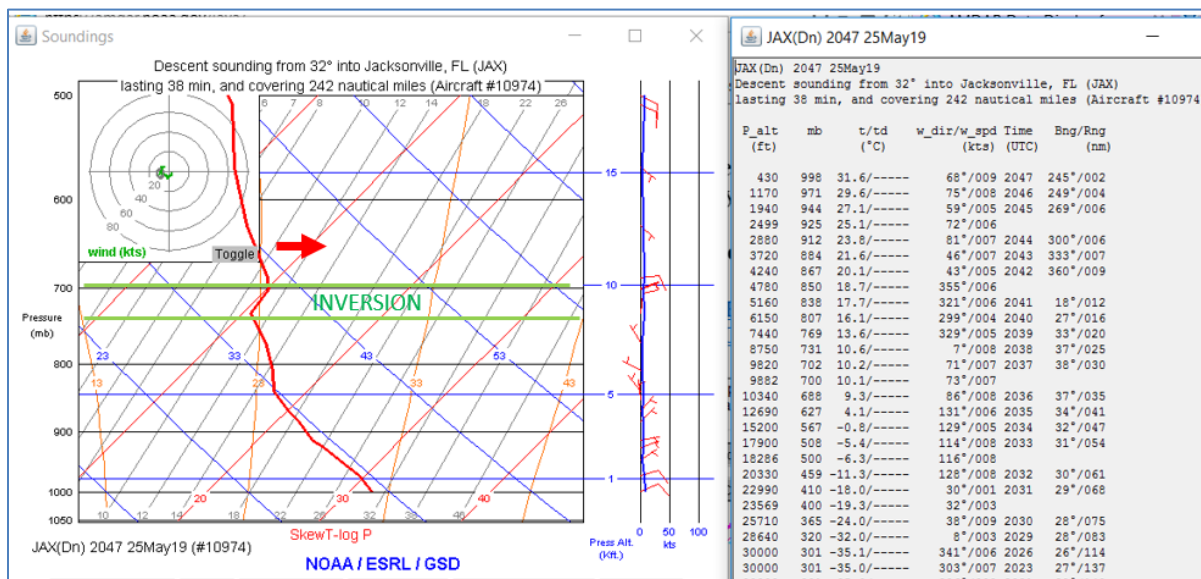


Figure 10 - Aircraft #10974 descent sounding into KJAX at 1647 EDT

Aircraft #11401's sounding plot indicated a more pronounced temperature inversion between 8,750 and 10,000 ft, where temperature increased with altitude or was isothermal (constant). The wind profile indicated easterly winds at less than 10 knots above 10,000 ft, with winds shifting to the west between the inversion at 10,000 ft to approximately 5,000 ft, and then shifting back to the east. At 12,690 ft aircraft #11401 reported a wind from 131° at 6 knots with a temperature of 4.1° C, and at 10,340 ft a wind from 086° at 8 knots with a temperature of 9.3° C, an approximately 45° directional shear.

¹¹ Eddy Dissipation Rate, or EDR, is an objective, aircraft-independent, universal measure of turbulence based on the rate at which energy dissipates in the atmosphere. In other words, it is a measure of the turbulent state of the atmosphere.

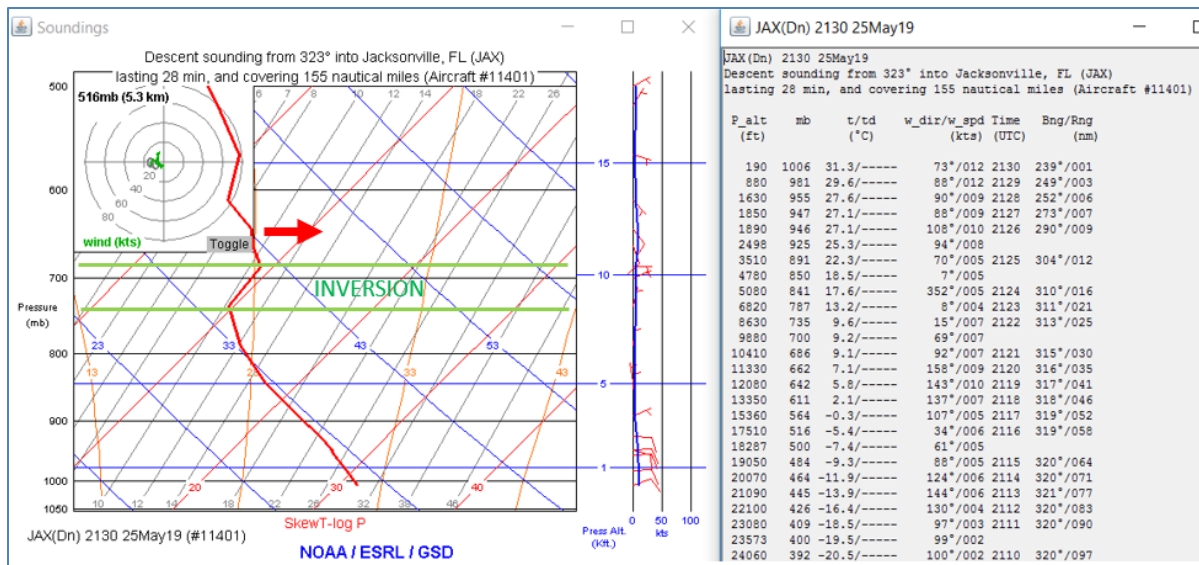


Figure 11 - Aircraft #11401 descent sounding into KJAX at 1730 EDT

Aircraft #11401's descent sounding also depicted an inversion between approximately 8,630 ft through 10,410 ft. The wind profile also indicated easterly winds above 15,000 ft which became more variable below that level. At 12,080 ft aircraft #11401 reported a wind from 143° at 10 knots with a temperature of 5.8° C and at 11,330 ft a wind from 158° at 9 knots with a temperature of 7.1° C.

4.0 Satellite Imagery

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

Figures 12 and 13 are the GOES-16 visible image at 2X magnification centered over Waycross, Georgia, at 1716 and 1731 EDT. The images depicted scattered fair weather cumulus clouds inland from the Atlantic coast and west of KJAX. The reported turbulence location was collocated with the location of one of the cumulus clouds.

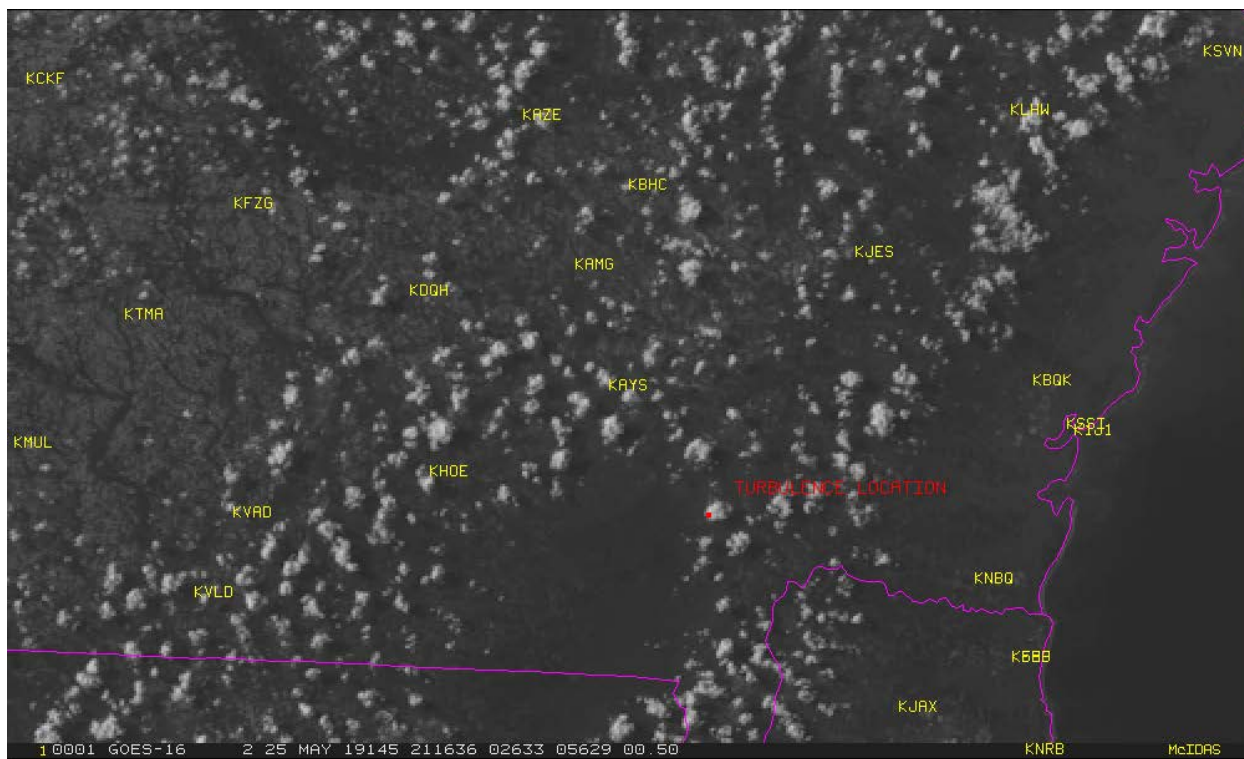


Figure 12 - GOES-16 visible image at 1716 EDT at 2X magnification

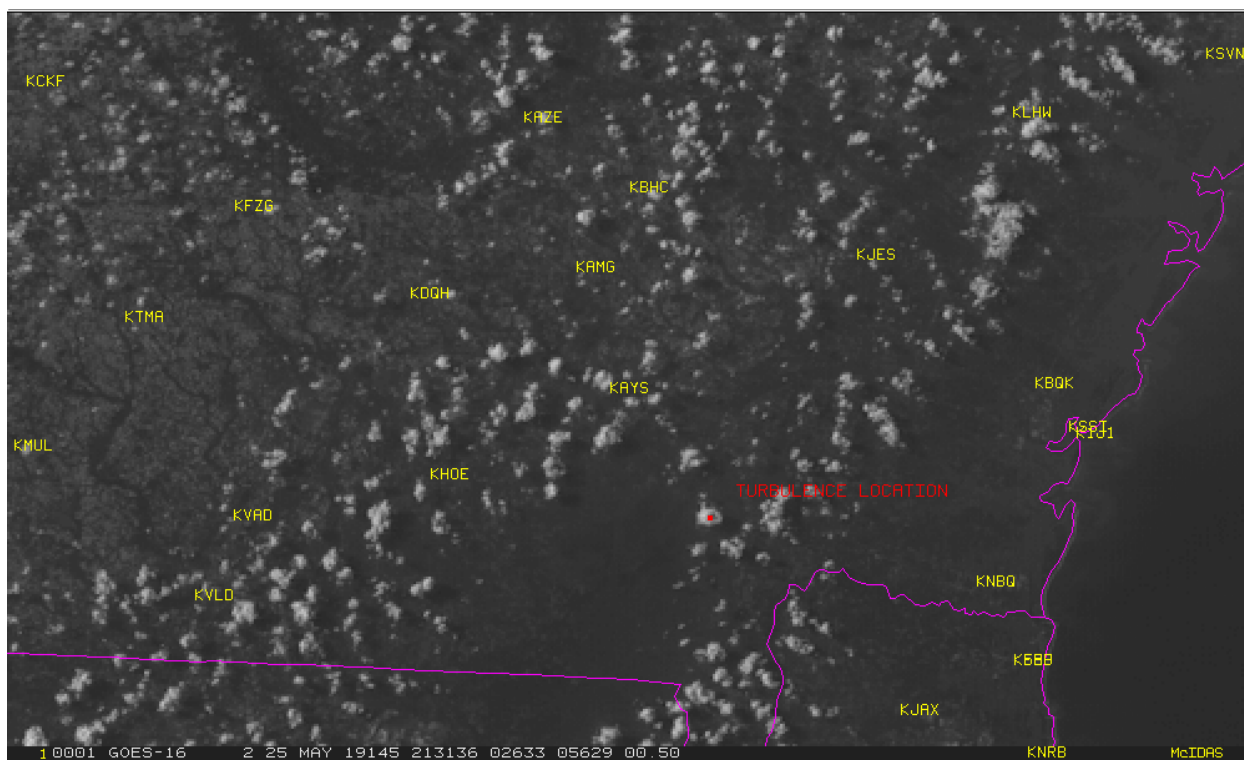


Figure 13 - GOES-16 visible image at 1731 EST at 2X magnification

5.0 Weather Surveillance Radar Imagery

The closest NWS Weather Surveillance Radar 1988 Doppler (WSR-88D) was located at KJAX approximately 37 miles southeast of the turbulence location. The level II archive data was obtained from the NCEI using the Hierarchical Data Storage System and displayed using the NWS NEXRAD Interactive Viewer and Data Exporter software.

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

5.1 Volume Scanning Strategies

During the period the KJAX WSR-88D was operating in the precipitation air mode volume scan pattern 215 (VCP-215), where the radar makes 15 different elevation scans in 6 minutes. Figure 14 is a depiction of the scanning mode VCP-215.

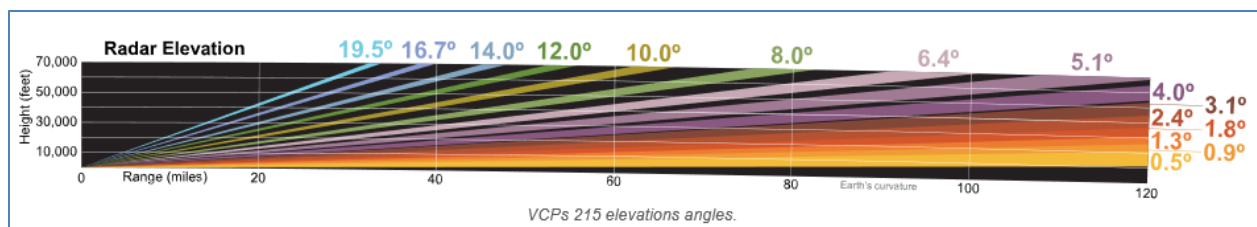


Figure 14 - VCP 215 elevation angles or scans

Based on the KJAX WSR-88D antenna height of 160 ft and a distance of 37 miles from the accident site, the 0.5° elevation beam was scanning the altitudes from 1,165 ft to 4,890 ft. The 2.4° elevation beam was scanning the 8,695 ft through 12,420 ft and captured the altitude where the turbulence was encountered.

5.1 Reflectivity

Reflectivity is the measure of the efficiency of a target in intercepting and returning radio energy. With hydrometeors, it is a function of the drop size distribution, number of particles per unit volume, physical state (ice or water), shape and aspect. Reflectivity is normally displayed in decibels (dBZ¹²) and is a general measure of echo intensity. Figure 15 relates the NWS former video integrator and processor (VIP) intensity levels (1-6) versus the WSR-88D's display levels (0-15), precipitation mode reflectivity in decibels (DBZ), and rainfall rates.

¹² dBZ - $10 \log Z_e$

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

Figure 15 - NWS VIP/DBZ intensity versus rainfall rates

The FAA has taken the previous NWS VIP levels 1 to 6 intensity levels and has redefined the intensity levels for pilots in Advisory Circular AC 00-24C - “Thunderstorm”. That AC further defined echoes less than 30 dBZ as “light” in intensity, “moderate” echoes at 30-40 dBZ, “heavy” echoes at >40-50 dBZ, and “extreme” intensity echoes above 50 dBZ. These are the new standard radio phraseology terms used by air traffic controllers to describe weather conditions to pilots, which are referenced in the Airmen’s Information Manual (AIM) section 7-1-14 (a) as shown in figure 16.

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

Figure 16 - Reflectivity dBZ ranges and radar intensity terminology

5.2 Base Reflectivity Imagery

Figure 17 is the KJAX WSR-88D 0.5° base reflectivity image for 1714 EDT, with echoes less than 0.0 dBZ filtered out. The image depicted a small area of very light intensity echoes of less than 25 dBZ west of KJAX near Lake City, Florida, otherwise only echoes near 5 to 15 dBZ were observed scattered over the area. Several very light intensity echoes were oriented in bands over the area, with a fine line of echoes near 5 to 15 dBZ associated with the sea-breeze front extending parallel to the coast across eastern Georgia and then kinking southward into northern Florida west of KJAX. Another thin line of echoes that ran north and south in the immediate vicinity of the

turbulence location, which coincided with the eastern boundary of the Okefenokee swamp. These boundaries supported convergence and general upward vertical motion and were located immediately under the flight path at the time of the turbulence encounter. The fine line, however, was not clearly identifiable at 12,000 ft as a line but only scattered echoes as seen in figure 18, which is the KJAX WSR-88D 2.42° base reflectivity image depicting the conditions at the altitude where the turbulence encounter occurred. The image depicted a small area of very light intensity echoes near 5 dBZ over the turbulence site.

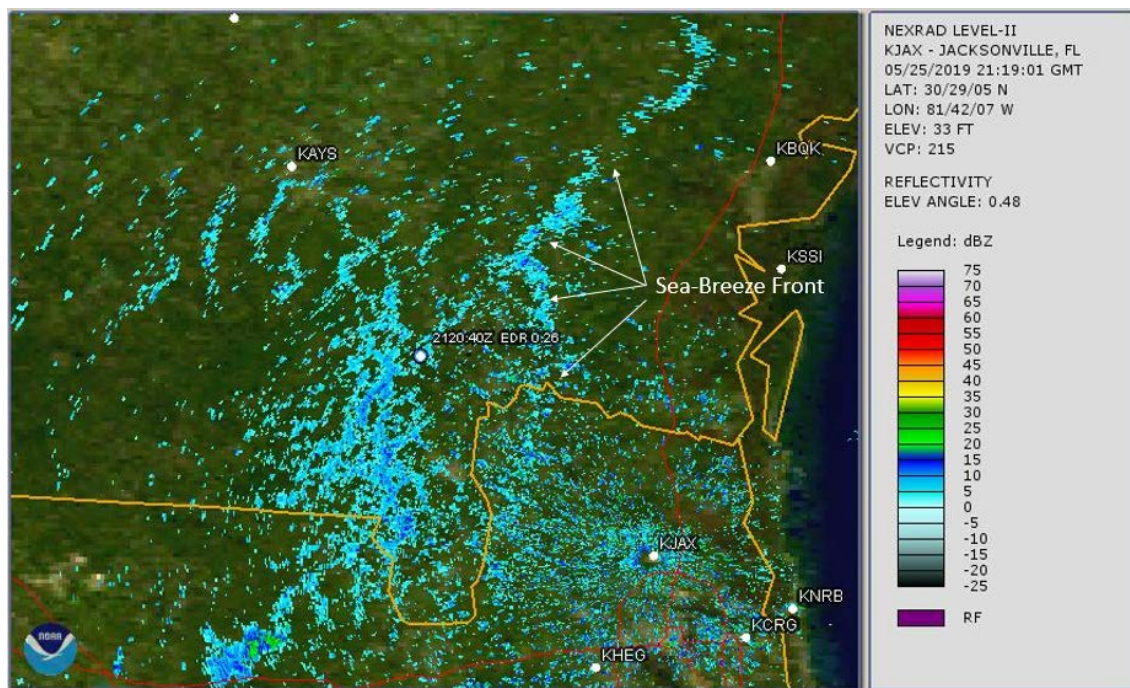


Figure 17 - KJAX WSR-88D 0.5° base reflectivity image for 1714 EDT

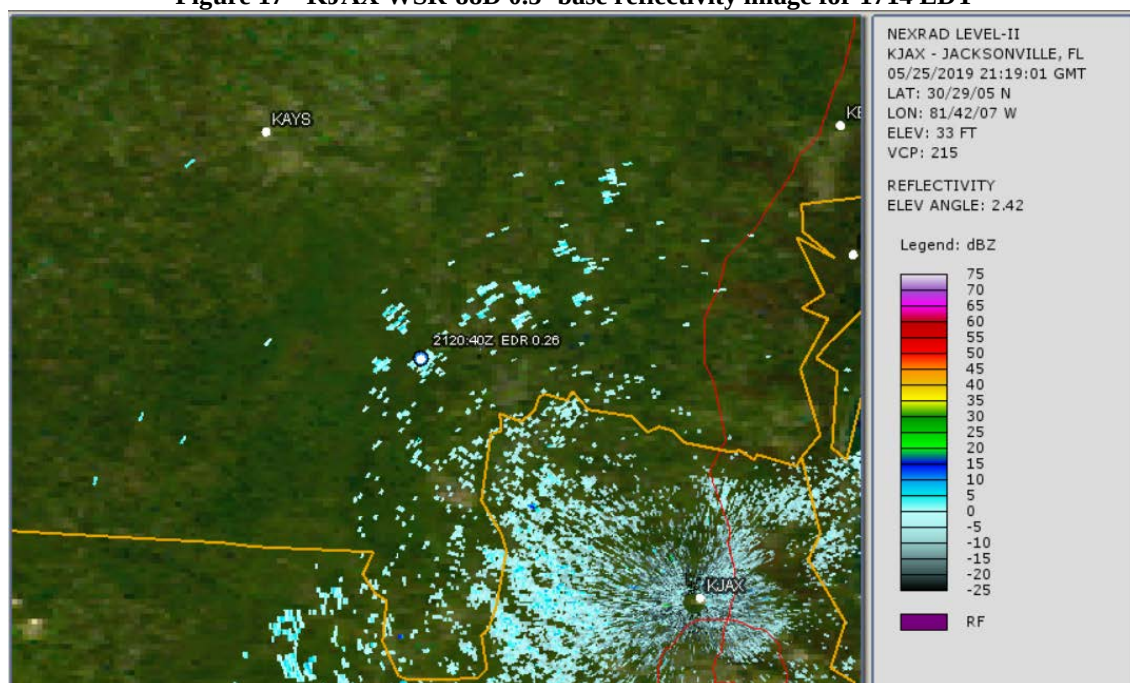


Figure 18 - KJAX WSR-88D 2.42° base reflectivity image for 1719 EDT depicting the echoes at altitude

6.0 Pilot Reports

A search of the NWS database only provided the following pilot report (PIREP) within 100 miles and within 2 hours either side of the accident. The report is believed to be from the accident airplane's encounter.

JAX UA /OV KJAX300030 /TM 2115 /FL120 /TP B738 /TB MOD /RM DURD INTO KJAX AWC-WEB

The report indicated an aircraft at a position of 300° and 30 miles from KJAX at 1715 EDT at 12,000 ft encountering moderate turbulence on descent into KJAX.

7.0 NWS Forecasts

7.1 Terminal Aerodrome Forecasts

The NWS Jacksonville (KJAX), Florida, Weather Forecast Office (WFO) was responsible for the issuance of the Terminal Aerodrome Forecast (TAF) for the airport and was located on the western boundary of the airport. A TAF is a concise statement of the expected meteorological conditions at an airport during a specified period usually 24 hours. TAFs are valid for a 5 mile radius around an airport's center point. The forecasts issued surrounding the period relevant to the preflight planning and the time of the accident were as follows. The TAF issued at 1320 EDT was current at the time of the accident and was as follows.

*TAF KJAX 251720Z 2518/2618 06008KT P6SM FEW060
FM252000 11010KT P6SM FEW060
FM260100 19004KT P6SM SKC=*

The forecast for KJAX from 1600 through 2100 EDT expected a wind from 110° at 10 knots, visibility 6 miles or more, with a few clouds at 6,000 ft agl.

7.2 Area Forecast Discussion

The NWS Area Forecast Discussions (AFD) are issued by each WFO to describe the short-term weather conditions within their region with an aviation section that includes the general conditions as it relates to the creation of the TAF. These are useful for additional aviation related issues that cannot be encoded into the TAF. The discussion also gives some reasoning behind the forecast. These are generated roughly every 6 hours and correspond to the release of the latest TAFs for that office. The area forecast discussion issued at 1544 EDT by KJAX was as follows, the long term and marine weather sections have been excluded.

*FXUS62 KJAX 251944
AFDJAX*

*Area Forecast Discussion
National Weather Service Jacksonville FL
344 PM EDT Sat May 25 2019*

...NEAR RECORD HEAT AND DRY WEATHER THIS MEMORIAL DAY WEEKEND...

...NEAR TERM (Through Sunday night)...

A strong deep layer ridge centered over south Ga will nudge south to across N Fl on Sunday. Potential for smoke from the Yellow Bluff Wildfire and other various wildfires to spread out again tonight and a Dense Smoke Advisory may be needed inland areas of Nassau and Duval and also along Baker and Columbia counties.

Strong subsidence and full sunshine on Sunday will allow for a continuation of the hot and dry conditions with near record high temps. Winds will be light except for afternoon seabreezes of around 10 mph along the coast and river. Afternoon high temps in the upper 90s to around 100 with heat indices 100-105 degrees inland. Coastal areas will be in the lower 90s with heat indices a shade under 100 degrees before the seabreeze develops and moves inland. Lows will be in the 60s inland and 70s coast.

.SHORT TERM /Monday-Tuesday night/...

The strong deep layer ridge over the area weakens some and shifts south especially by Tuesday as a low level trough drops south and washes out across the area. Despite the added convergence in the area (in addition to seabreezes) model soundings continue to indicate strong mid level cap and limited moisture persists although cannot rule out a brief shower from the added lift. Both forecast soundings and numerical guidance indicate a continuation of the hot and dry conditions with afternoon high temps near 100 with heat indices near 105 degrees inland and mid 90s with heat indices near 100 degrees coast.

.AVIATION...VFR through the period. East winds at 8-11 knots this afternoon with the East Coast Sea Breeze becoming SE-S at 5 knots or less after sunset.

.FIRE WEATHER...Elevated concern for wildfire outbreaks this holiday weekend due to increased outdoor activity including fireworks, camp fires, cigarettes and cookouts. An extended period of hot and dry weather through early June will continue elevated fire danger, despite not meeting locally defined "Red Flag" criteria. Temperatures will warm into the upper 90s to mid 100s inland each day with afternoon humidity ranging between 25-35%. Winds will be mainly local terrain influenced, with daily sea breezes, river breezes and lake breezes. Gusts 14-18 mph will be possible as the east coast sea breezes develops and presses inland each afternoon.

.CLIMATE...

Record Highs at climate sites for Memorial Day weekend & early next week:

	Sun 5/26	Mon 5/27	Tue 5/28
Jacksonville	99(1953)	98(1989)	99(1967)
Gainesville	100(1953)	100(1953)	99(1953)
Alma, GA	99(1962)	99(1967)	100(1967)
St. Simons Island	100(1953)	96(2006)	97(1964)

All-Time Record Max Temps for the Month of May...

JAX 100/05-13-1967
 GNV 101/05-31-1945
 AMG 100/05-28-1967
 SSI 100/05-26-1953

.PRELIMINARY POINT TEMPS/POPS...

AMG 70 99 74 99 / 0 10 10 10
 SSI 75 94 76 95 / 0 0 0 10
 JAX 69 97 71 99 / 0 0 0 10
 SGJ 71 91 72 95 / 0 0 0 10
 GNV 67 97 72 98 / 0 0 10 10
 OCF 68 96 71 98 / 0 0 0 10

.JAX WATCHES/WARNINGS/ADVISORIES...

FL...None.

GA...None.

AM...None.

7.3 Winds and Temperature Aloft Forecast

The NWS NCEP Winds and Temperature Aloft Forecast¹³ issued during the period was valid for 2000 EDT on May 25, 2019 and was for use between 1600 EDT through 2300 EDT. The winds and temperature data for KJAX was as follows:

WINDS ALOFT FORECASTS

DATA BASED ON 251800Z

VALID 260000Z FOR USE 2000-0300Z. TEMPS NEG ABV 24000

FT 3000 6000 9000 12000 18000 24000 30000 34000 39000

*JAX 1107 0308+18 0608+12 **1108+07** 0810-07 0812-19 081235 081044 020955*

The KJAX winds and temperature aloft forecast for 18,000 ft expected a wind from 080° at 10 knots with a temperature of -7° C, at 12,000 ft a wind from 110° at 8 knots with a temperature of 7° C, and at 9,000 ft a wind from 060° at 8 knots with a temperature of 12° C.

7.4 Graphic Turbulence Guidance

The Graphic Turbulence Guidance (GTG) product currently displayed for use on the NWS AWC website, version 3.0, was reviewed and did not depict any significant clear air turbulence over the area.

The National Center for Atmospheric Research (NCAR) was contacted and requested to run the newer GTG-N or Nowcast model which incorporates in situ EDR measurements, turbulence reports, radar reflectivity, NEXRAD Turbulence Detection Algorithm (NTDA), and the Rapid Refresh (RAP) model that is updated every 15-minutes, and specifically addresses convectively induced turbulence. This newer version 4.0 is being run in an experimental mode and was not available to the flight crew in this case. The results of that model data for 1700, 1715, and 1730 EDT for 12,000 ft is included as figure 19. No turbulence was indicated over the accident site until 1730 EDT, when area of EDR of 0.10 to 0.30 developed in the immediate vicinity of the turbulence encounter location. The full GTGN images from NCAR for 1700, 1715, and 1730 EDT, and the 2-hour GTGN forecast from 10,000 ft through 14,000 ft are included as attachment 1.

¹³ Bulletin FBUS31 KWNO documented for pilot reports.

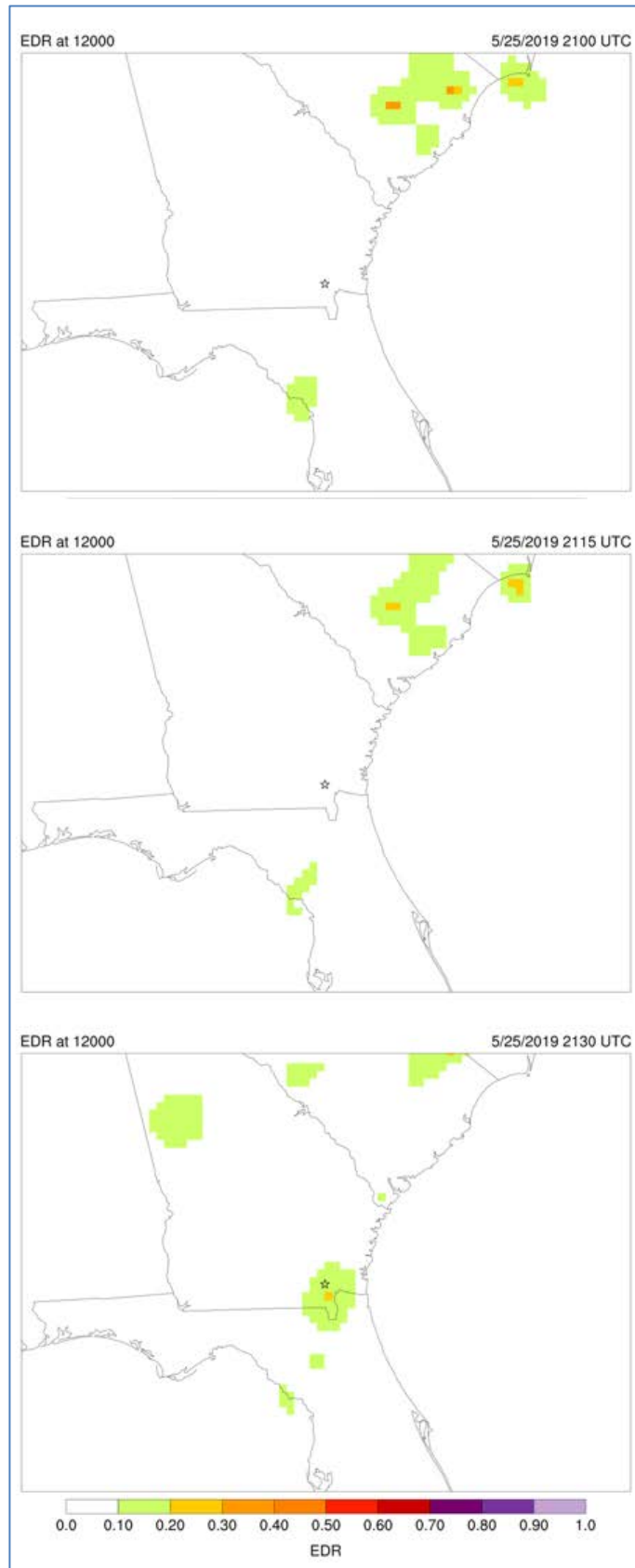


Figure 19 - NCAR GTG-N for 12,000 ft at 1700, 1715, and 1730 EDT

7.5 Inflight Weather Advisories

Inflight Aviation Weather Advisories are forecasts to advise en route aircraft of development of potentially hazardous weather. Inflight aviation weather advisories in the conterminous U.S. are issued by the NWS Aviation Weather Center (AWC), as well as from the Center Weather Service Units (CWSU) associated with FAA Air Route Traffic Control Centers (ARTCCs). There are four basic types of inflight aviation weather advisories: the Significant Meteorological Information (SIGMET), the Convective SIGMET, the AIRMET, and the Center Weather Advisory (CWA). Inflight 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 and/or flight dispatcher to evaluate on the basis of experience and the operational limits of the aircraft.

During the period surrounding the time of the accident the NWS had no SIGMETs, Convective SIGMETs, AIRMETs, or CWAs current for the area over Georgia and northern Florida. The NWS Jacksonville CWSU (KZJX) assigned to the FAA ARTCC had issued an advisory for an area of thunderstorms and heavy rain showers over portions of North Carolina and South Carolina between 1430 and 1530 EDT, and that advisory had expired by the time of the accident and did not extend over the turbulence location.

*FAUS22 KZJX 251834
ZJX2 CWA 251835
ZJX CWA 201 VALID UNTIL 252000
FROM 35ENE FLO-25SSW ILM-55SW ILM-10ESE FLO-35ENE FLO
AREA WDLY SCT TS WITH MOD-HVY PCPN MOV LTL. TOPS ABV FL450.*

The NWS AIRMET Tango issued at 1545 EDT indicated that no significant turbulence was expected outside of convective activity. The advisory was as follows:

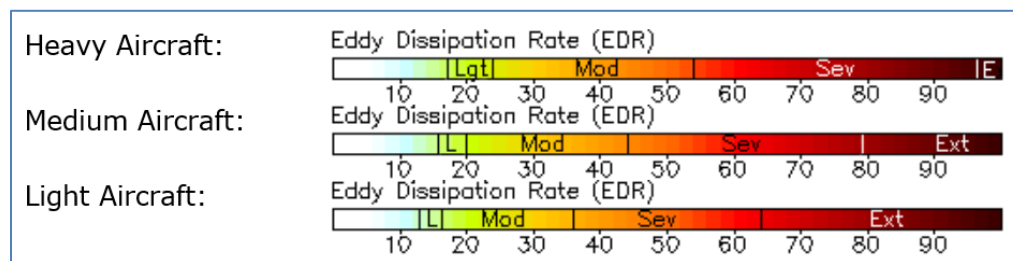
*WAUS42 KKKI 252045
WA2T
MIAT WA 252045
AIRMET TANGO UPDT 3 FOR TURB VALID UNTIL 260300
.
NO SGFNT TURB EXP OUTSIDE OF CNVTV ACT.*

8.0 Recorded Eddy Dissipation Rate

Southwest Airlines provided the following recorded EDR values on descent into KJAX from the accident airplanes.

Time (UTC)	Peak EDR	Altitude (MSL)	Location (Lat. Long.)	Wind (true-KT)	Temperature (°C)
2118:40Z	0.00	12,280 ft	31.029° -82.258°	149° 10kt	5°
2119:40Z	0.00	11,690 ft	30.955° -82.206°	149° 11kt	6°
2120:40Z	0.26	10,840 ft	30.881° -82.145°	123° 7kt	8°
2121:40Z	0.02	9,450 ft	30.814° -82.090°	020° 6kt	8°
2122:40Z	0.02	7,570 ft	30.749° -82.033°	012° 8kt	11°
2123:40Z	0.05	5,960 ft	30.693° -81.969°	028° 4kt	15°
2124:40Z	0.08	4,180 ft	30.637° -81.909°	094° 10kt	20°
2125:40Z	0.08	2,670 ft	30.574° -81.876°	094° 8kt	24°
2126:40Z	0.12	1,840 ft	30.523° -81.851°	078° 9kt	27°
2128:40Z	0.06	530 ft	30.486° -81.734°	092° 12kt	30°

The peak EDR was noted at 1720 EDT at 0.26, which for a medium weight category¹⁴ aircraft was consistent with moderate turbulence.



9.0 Preflight Weather Briefing

The weather document issued to the accident flight crew was generated at 1430 EDT (1830Z). The document served as the source for their weather briefing for the flight and included all the required observations, forecasts, and notices to airmen (NOTAMs). The briefing included the following details.

- Flight details – no alternate airport required
- Destination weather for KJAX
 - METARs for KJAX for 1756Z and 1656Z (2 hours)
 - ATIS for KJAX – information Mike 1756Z, visual approach for runway 8 in use
 - TAF for KJAX for 18Z
- Departure weather KMDW
- Field conditions & NOTAMs

¹⁴ Medium category: 15,500 to 300,000 lbs maximum takeoff weight

- PIREPs
- Enroute information
 - o Convective SIGMETs – area of wx over OH-IN-LE not applicable for route
 - o WSI SIGMETs – none
 - o WSI FPG Turbulence/Convection – none over the route
- WSI Radar Summary Chart – no echoes over the route
- WSI Significant Weather Chart – depicting areas of turbulence, thunderstorms, winds FL340
- WSI CONUS SIGMETs – none over the route

A copy of the weather document is included as attachment 2.

10.0 Flight Crew Statements

The accident flight crew were asked to provide statements of the encounter which are summarized below. For the full interview and statements of the flight crew see the Operations Report in the docket for further details.

The Captain of flight 2842 indicated as they were descending through 15,000 ft they noticed a scattered layer of clouds and signaled to the flight attendants to secure the cabin before the normal 10,000 ft level. No echoes were noted between their position and airport, so the airborne weather radar was turned off about 5 minutes prior to the event. Descending through approximately 12,000 ft they went through the cloud layer and encountered moderate turbulence. A few minutes later he was advised they had a flight attendant injured and requested medical assistance. They landed without incident about 10 minutes later.

The First Officer also indicated they had encountered unexpected and unreported moderate turbulence as they passed through a scattered cloud layer around 12,000 ft.

F. Attachments

Attachment 1 – NCAR Graphic Turbulence Guidance Nowcast (GTG-N) for period

Attachment 2 - Weather document issued to flight 2842.

Submitted by:

Don Eick
Senior Meteorologist