

WEATHER-RELATED AVIATION ACCIDENT STUDY

2003–2007

February 2, 2010



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EXECUTIVE SUMMARY

Federal Aviation Administration (FAA) Aviation Safety Information Analysis and Sharing (ASIAS) analysts performed a study of the National Transportation Safety Board (NTSB) Accident and Incident Database to identify aviation accidents in which weather was a cause or contributing factor. The data was analyzed to find relationships between the type of weather involved and the various factors, such as operating rules of Title 14, Code of Federal Regulations (14 CFR), and qualifications of flightcrew members.

Accident statistics and trends show from 2003 through 2007, there were 8,657 aviation accidents. Weather was a cause or contributing factor in 1,740 of these accidents. The study identified the following weather conditions as causes or contributing factors to weather-related accidents: wind, visibility/ceiling, high density altitude, turbulence, carburetor icing, updrafts/downdrafts, precipitation, icing, thunderstorms, windshear, thermal lift, temperature extremes, and lightning. The weather condition most often cited as a cause or contributing factor in accidents was wind, followed by visibility/ceiling and high density altitude, respectively. Additional analysis of the weather factors showed the phases of flight in which the accidents occurred.

ASIAS analysts further broke down the weather-related accidents into their respective operations category to determine which weather factors are the biggest threats to pilots and aircraft based on type of operation. The analysis showed that 14 CFR part 91 operations accounted for the highest percentage of weather-related accidents, followed by 14 CFR parts 135, 121, and 137 operations. Wind was the most common weather factor in part 91 and part 137 operations and the second leading factor in part 121 and 135 operations. Turbulence was identified as the most common weather hazard to part 121 operations, while visibility/ceiling contributed to the most weather-related accidents for part 135 operations.

1.0 INTRODUCTION

1.1 OVERVIEW

This report presents the results of an analysis of the National Transportation Safety Board (NTSB) Accident and Incident Database to identify aviation accidents where weather was a cause or contributing factor. The Federal Aviation Administration (FAA) Aviation Safety Information Analysis and Sharing (ASIAS) staff analyzed accident data to find relationships between the type of weather involved and various other factors involved in an accident, such as the type of operation and the qualifications of the flightcrew members.

1.2 METHODOLOGY AND PURPOSE

ASIAS staff extracted NTSB accident data from the ASIAS database system for all aviation accidents from 2003 through 2007 that were finalized as of February 8, 2009. Each data extraction focused on final accident reports where the NTSB indicated weather was a cause or a contributing factor in an accident. The search criteria included weather conditions as defined in the NTSB Aviation Coding Manual dated December 1998. (See appendix B for definitions of the weather conditions.) These accidents were then analyzed by operating rules, which revealed that the majority of accidents occurred from operating rules found in parts 91, 121, 135, and 137 of Title 14, Code of Federal Regulations (14 CFR). Analysts focused the study on these operating rules. The purpose of this report is to educate the aviation community on the relationship between weather and aviation accidents.

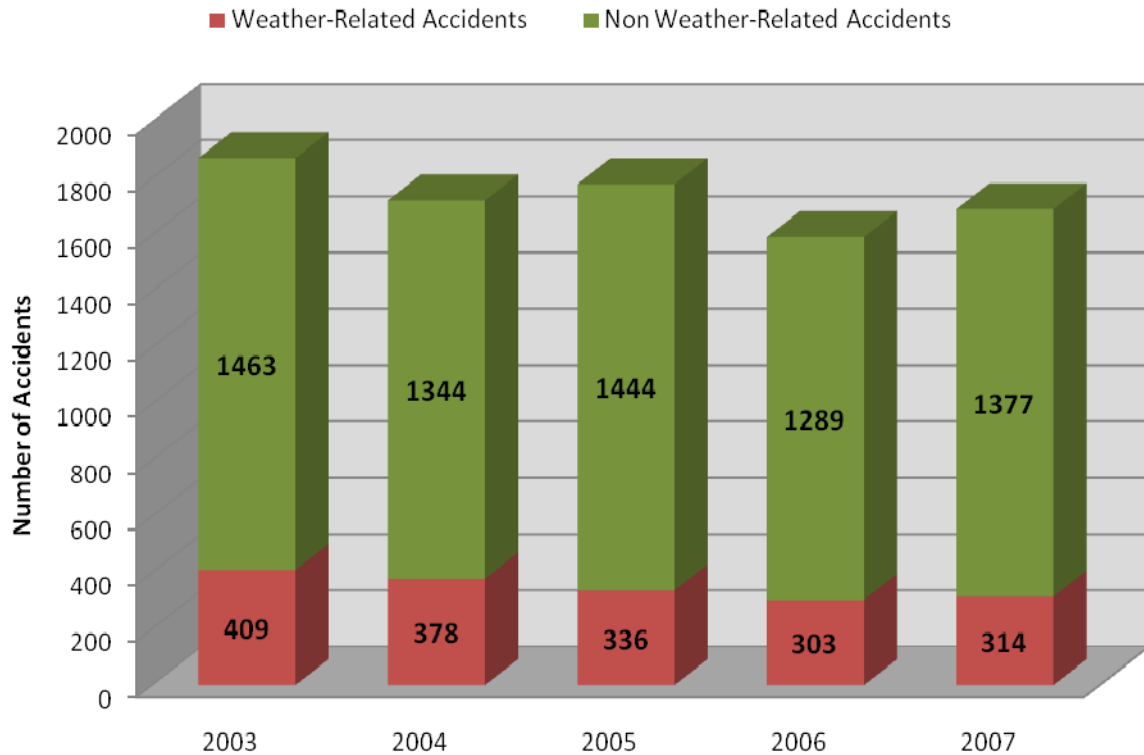
1.3 SCOPE OF THIS REPORT

This report includes three sections. Section 2.0 examines the overall trends in aviation accidents in which the NTSB identified weather as a cause or contributing factor in the accident. Section 3.0 examines the significance of specific weather and other factors with respect to aviation accidents. Section 4.0 examines trends and patterns in weather-related accidents in which aircraft operated under parts 91, 121, 135, and 137 were involved. This section also presents a summary of a representative accident involving operations under each part reviewed during the study that illustrates weather-related issues most frequently encountered during those operations. Appendix A contains a list of acronyms and appendix B contains definitions. Appendix C contains grouping charts for weather-related categories and for phase of flight. Appendix D includes additional tables containing raw data used to generate figures within this report.

2.0 OVERALL ACCIDENT STATISTICS AND TRENDS

From 2003 through 2007, there were 8,657 aviation accidents involving 8,754 aircraft¹. Weather was a cause or contributing factor in 1,740 accidents (20.1 percent), involving 1,741 aircraft (see figure 1). Figure 1 shows the breakdown of weather-related and non-weather-related accidents.

Figure 1. Weather-related Versus Non-weather-related Accidents 2003–2007



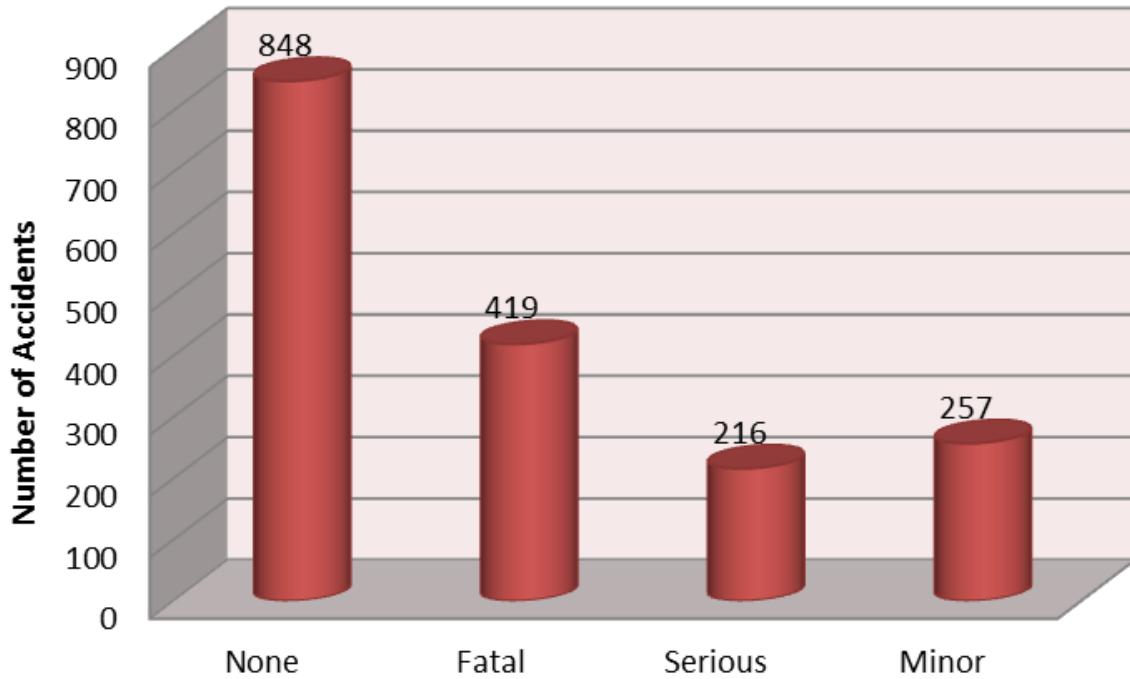
Source: NTSB Aviation Accident and Incident Database

According to the NTSB data, aviation accidents, including weather-related accidents, have shown an overall downward trend since 1994. There was a decrease of 21.8 percent to 18.6 percent (2003 through 2007).

¹ Multiple aircraft may be involved in a single accident.

For the purposes of injury level, each of the 1,740 accidents in this study is classified as none, fatal, serious, or minor (see Appendix B—Definitions) based on the highest level of injury in the accident (see figure 2). Of the accidents studied, 48.7 percent resulted in no injuries to passengers or crewmembers, while 24.1 percent resulted in at least one fatality.

Figure 2. Weather-related Accident Injury Levels 2003–2007



Source: NTSB Aviation Accident and Incident Database

3.0 WEATHER FACTORS IMPACTING ACCIDENTS

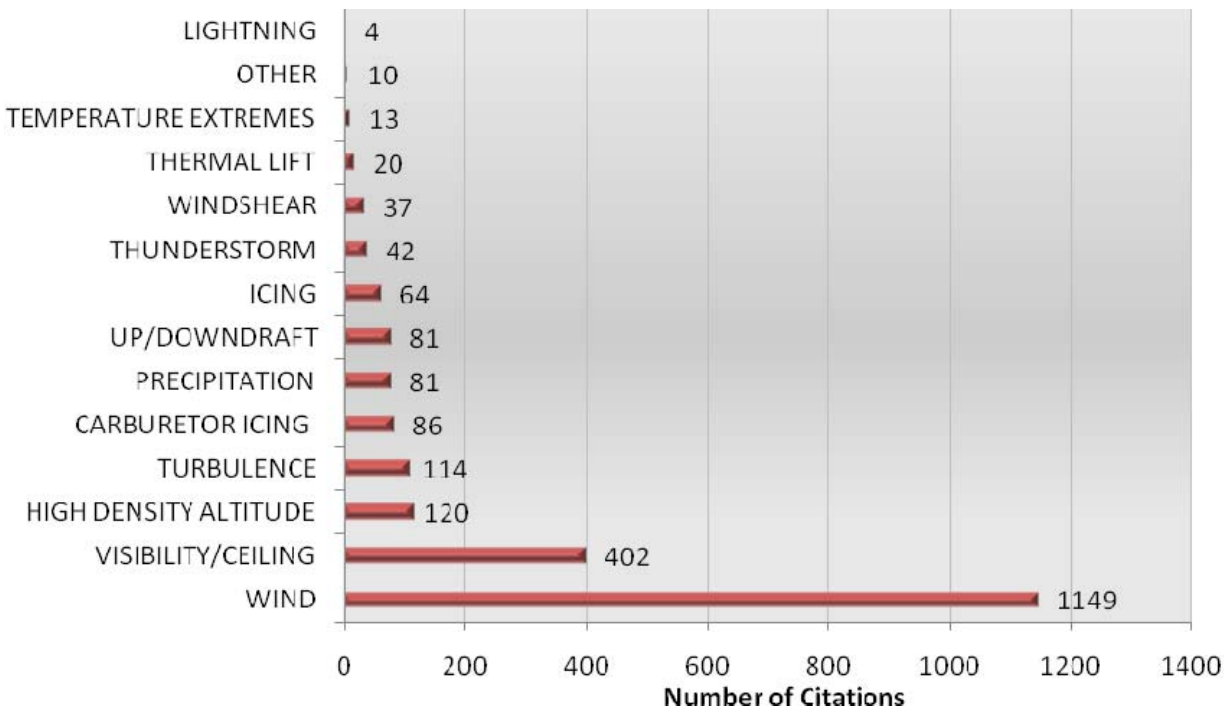
3.1 GENERAL DISCUSSION

For each accident investigation in which weather conditions were found to be a cause or contributing factor, in the final report, the NTSB cites a subject modifier designating the specific weather condition(s) encountered during the accident. A single accident may have multiple causes and/or contributing factors, resulting in multiple citations of subject modifiers for a single accident (not mutually exclusive). In this study of 1,740 accidents, there were 2,223 citations of weather-related subject modifiers.

For the purposes of this study, multiple subject modifiers were consolidated under a single weather factor category (see appendix C to this study). For example, the wind category includes reports in which the NTSB has specified crosswind, high wind, sudden windshift, tailwind, variable wind, or dust devil/whirlwind as a subject modifier. Figure 3 shows the breakdown of 2,223 citations, stemming from various weather conditions that the NTSB identified as a cause or contributing factor in 1,740 weather-related accidents.

The weather factors that caused or contributed to weather-related accidents are wind, visibility/ceiling, high density altitude, turbulence, carburetor icing, precipitation, updraft/downdraft, icing, thunderstorms, windshear, thermal lift, temperature extremes, other, and lightning (see figure 3).

Figure 3. Breakdown of Weather-related Accident Citations 2003–2007



Not mutually exclusive. Total number of weather citations = 2,223.

Source: NTSB Aviation Accident and Incident Database

The following sections discuss various weather factors or weather factor categories and their relationships with aviation accidents.

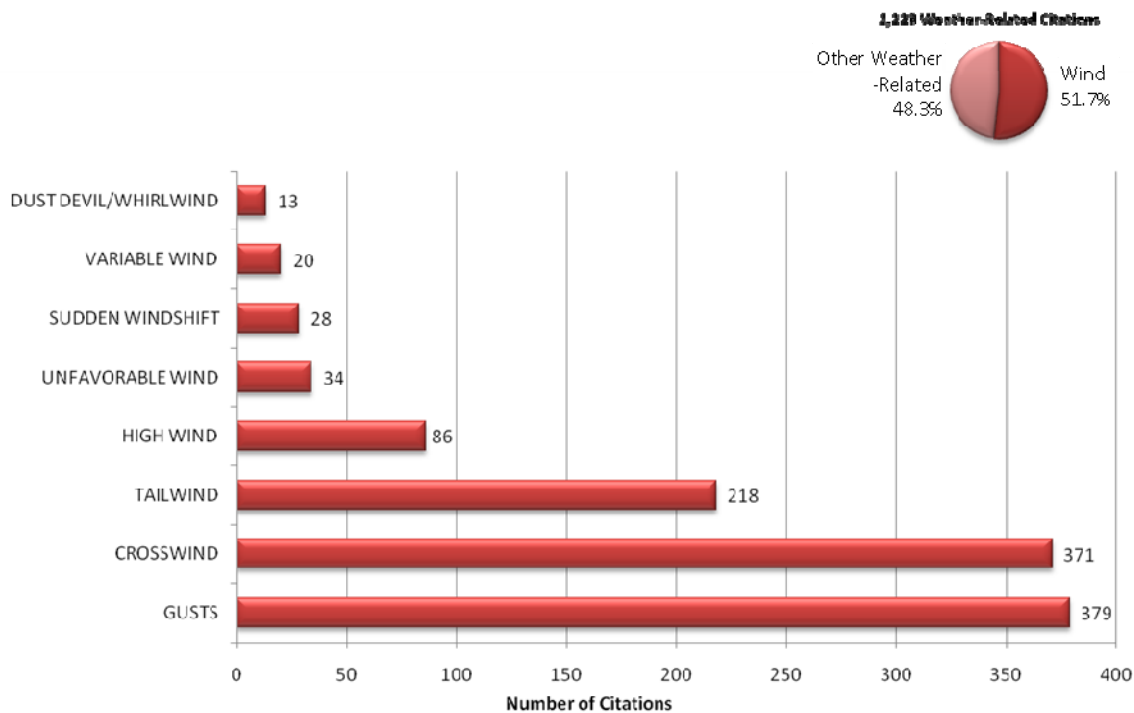
3.2 WIND

Wind is the horizontal movement of air currents across the Earth’s surface as a result of pressure differentials, temperature changes, and the Coriolis force (the force created by the rotation of the Earth²).

Wind was the overall leading cause or contributing factor of weather-related accidents from 2003 through 2007, with 1,149 citations accounting for more than half of the cause or contributing factor citations in the accidents studied (see figure 4). The largest number of wind citations occurred in part 91 operations. There were 1,047 wind citations in part 91, which is 53.4 percent of all part 91 weather-related citations. The majority of wind citations occurred during the takeoff or landing phase of flight (see figure 5).

The overall trend in wind citations has been downward. There was a steady decrease from 2003 to 2004 (by 50 citations), 2004 to 2005 (by 32 citations), and 2005 to 2006 (by 16 citations); however, from 2006 to 2007 there was an increase of 37 wind citations. The study period showed that even though there was an increase in wind citations in the year 2007, the overall outcome was a decrease by 21.1 percent from 2003 through 2007 (see figure 6).

Figure 4. Wind Citations 2003–2007

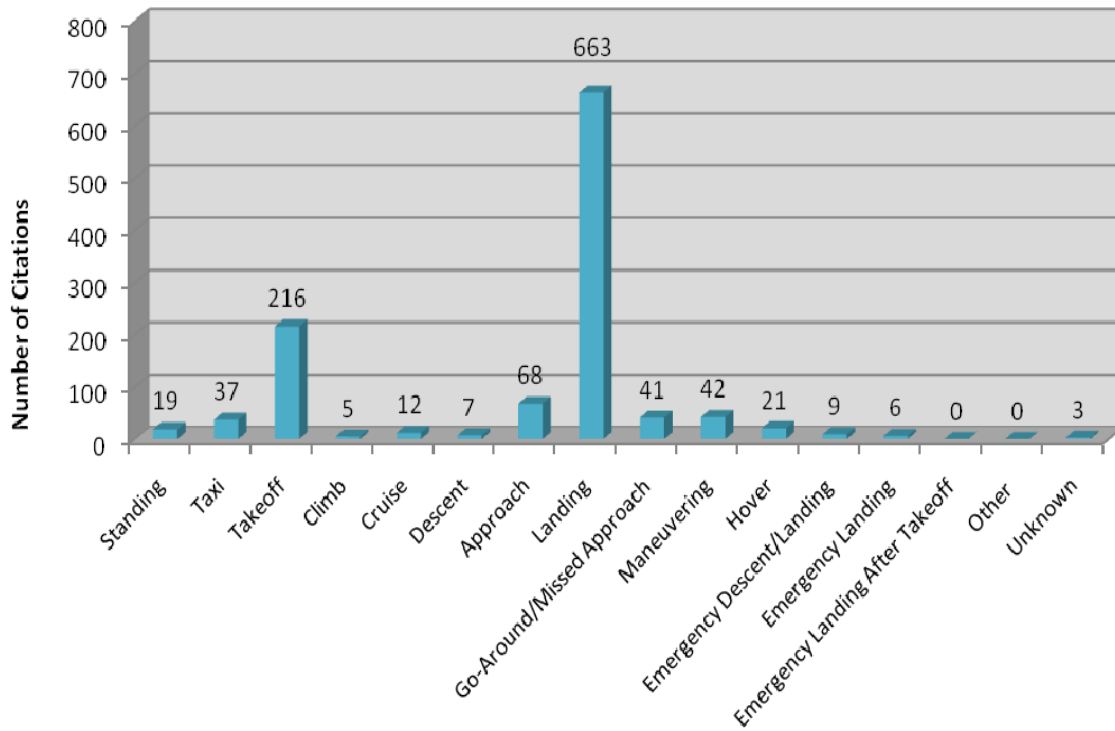


Not mutually exclusive. Total number of wind citations = 1,149.

Source: NTSB Aviation Accident and Incident Database

² Pilot’s Handbook of Aeronautical Knowledge, FAA–H–8083–25A. 2008. pages 11–4 and 11–7.

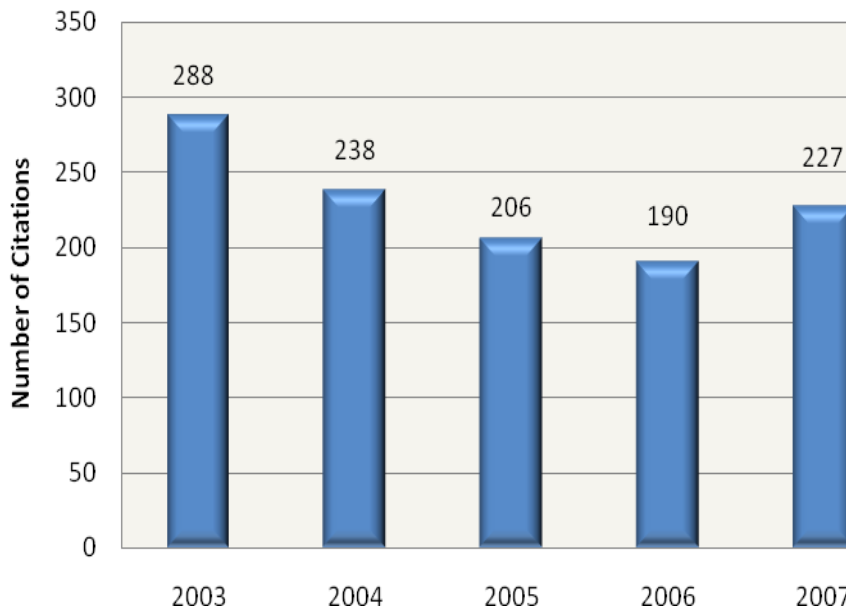
Figure 5. Wind Accidents by Phase of Flight 2003–2007



Not mutually exclusive. Total number of wind citations = 1,149.

Source: NTSB Aviation Accident and Incident Database

Figure 6. Wind Citations by Year 2003–2007



Source: NTSB Aviation Accident and Incident Database

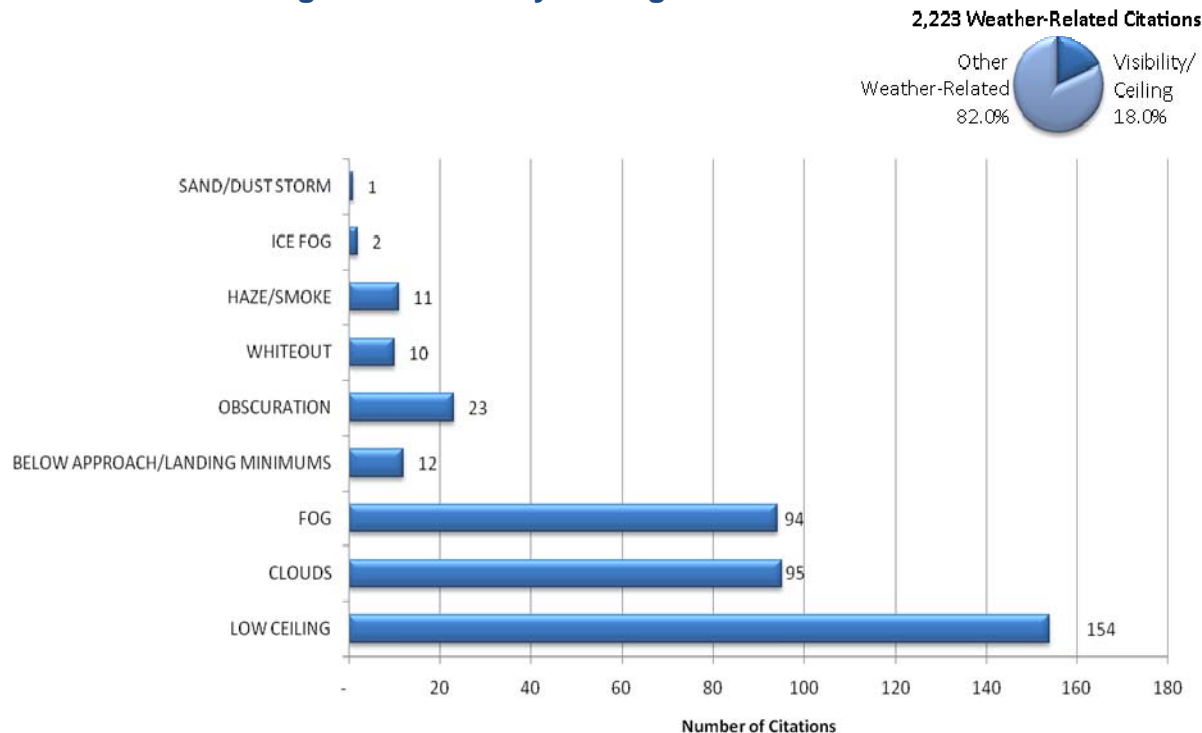
3.3 VISIBILITY/CEILING

Visibility refers to the greatest horizontal distance at which prominent objects can be viewed with the naked eye.³ Visibility is affected by factors such as precipitation, fog, and haze. For aviation purposes, a ceiling is defined as the lowest layer of clouds reported as being broken or overcast, or the vertical visibility into an obscuration like fog or haze.⁴

Visibility/ceiling was the second largest cause or contributing factor in weather-related accidents in the study, with 402 citations over the 5-year study period (see figure 7). It was the leading weather-related accident category in part 135 operations, with 46 citations. Visibility/ceiling ranked second on the list of causes or contributing factors in part 91 operations and accounted for 350 of 1,960 total weather-related citations (17.8 percent).

In addition, visibility/ceiling was the lowest ranking category for part 121 and part 137 operations, with only one citation each. The majority of visibility/ceiling citations occurred during the cruise phase of flight (140 citations), followed by the approach phase of flight (77 citations) (see figure 8). Accidents attributed to visibility/ceiling decreased by 54.5 percent over the 5-year study period, from 99 accidents in 2003 to 47 accidents in 2007 (see figure 9).

Figure 7. Visibility/Ceiling Citations 2003–2007



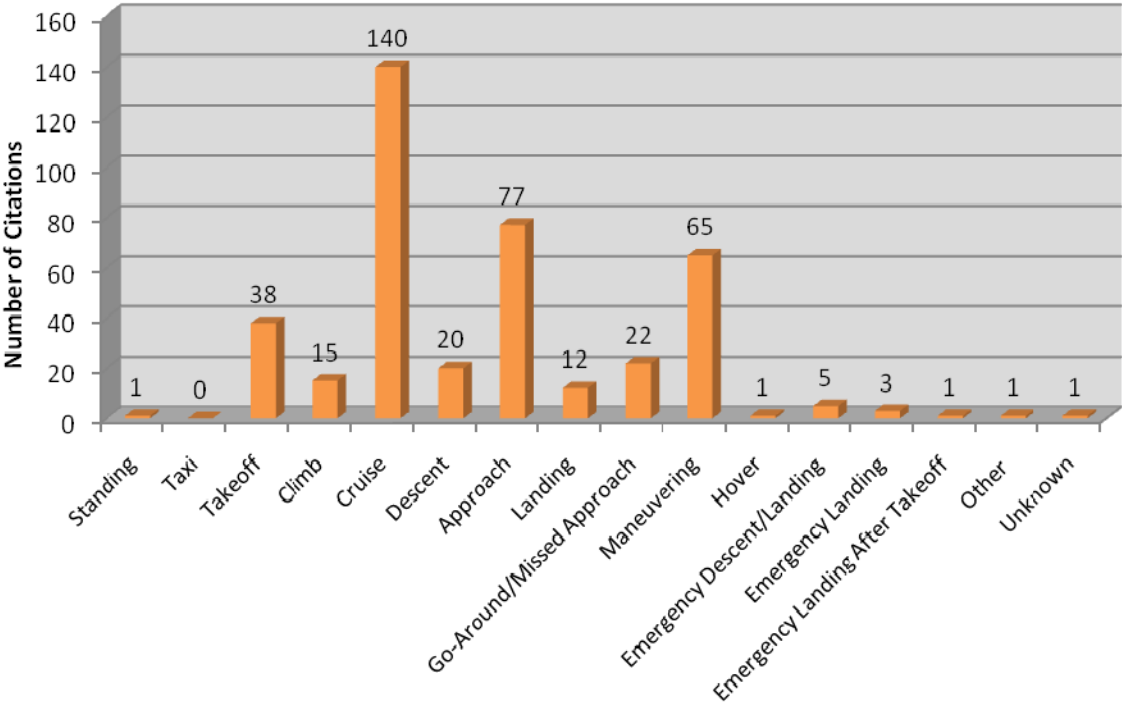
Not mutually exclusive. Total number of visibility/ceiling citations = 402.

Source: NTSB Aviation Accident and Incident Database

³ Pilot's Handbook of Aeronautical Knowledge, FAA-H-8083-25A. 2008. page 11–18.

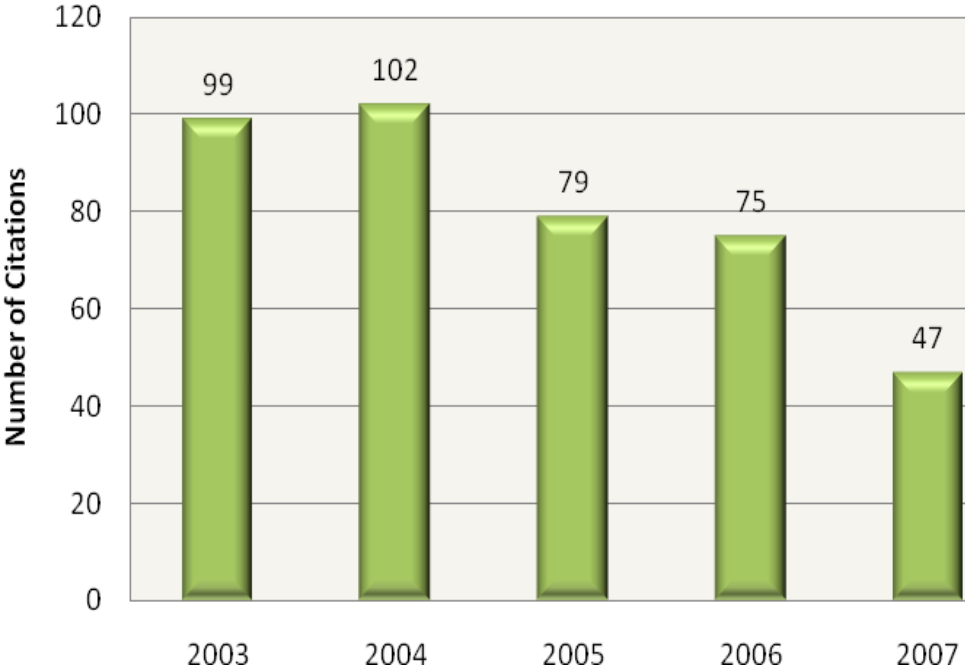
⁴ Pilot's Handbook of Aeronautical Knowledge, FAA-H-8083-25A. 2008. page 11–17.

Figure 8. Visibility/Ceiling Citations by Phase of Flight 2003–2007



Not mutually exclusive. Total number of visibility/ceiling citations = 402.
Source: NTSB Aviation Accident and Incident Database

Figure 9. Visibility/Ceiling Citations by Year 2003–2007



Source: NTSB Aviation Accident and Incident Database

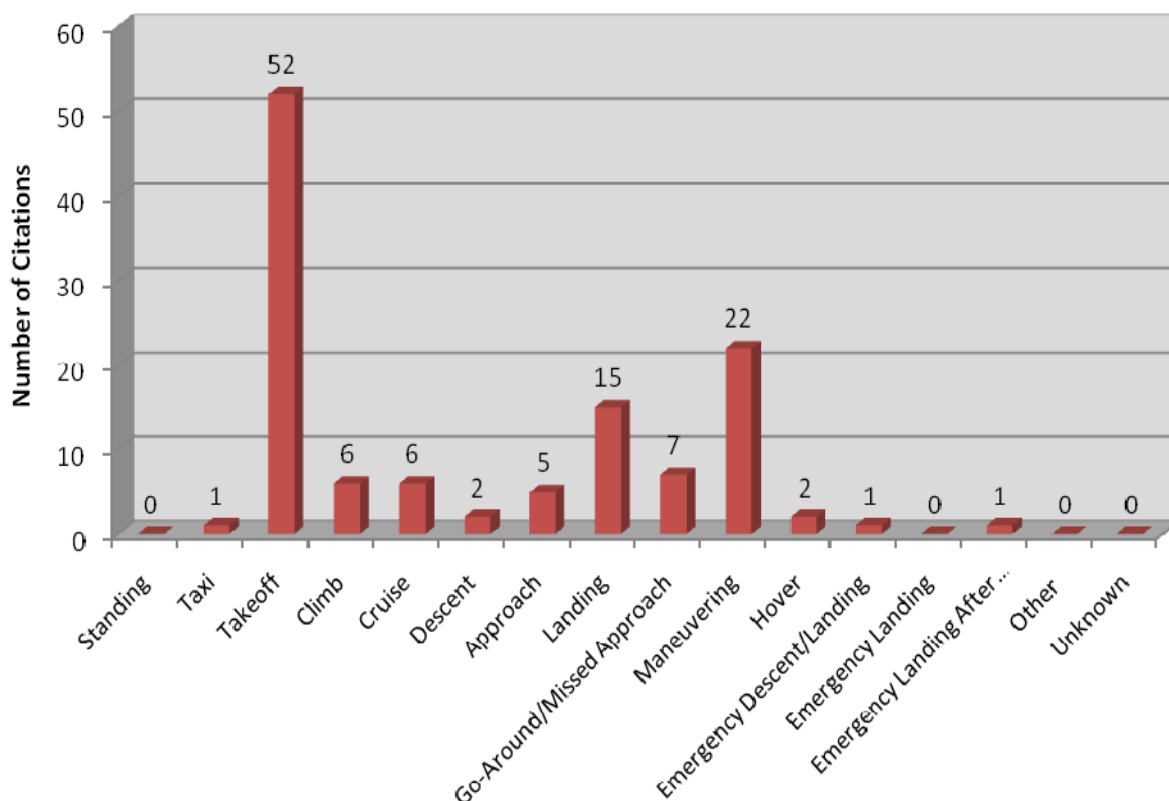
3.4 HIGH DENSITY ALTITUDE

Density altitude is the vertical distance above sea level in the standard atmosphere at which given density is to be found. It is calculated by correcting altitude for nonstandard pressure and temperature. Density altitude is a significant factor in aircraft performance; it is able to negatively affect engine and propeller efficiency and the production of lift.⁵

High density altitude was cited 120 times as a cause or contributing factor in weather-related accidents, making it the third highest weather factor. The largest number of high density altitude citations (108) was in part 91 operations, where it ranked third in the list of weather factors. High density altitude was also the second highest factor in part 137 operations, with nine citations.

High density altitude was cited only two times in part 135 operations and zero times in part 121 operations. Nearly half of all high density altitude citations (52) occurred on takeoff (see figure 10). In 2005, high density altitude accidents peaked. Since then, there has been an overall decrease of 42.4 percent in these accidents (see figure 11).

Figure 10. High Density Altitude Citations by Phase of Flight 2003–2007

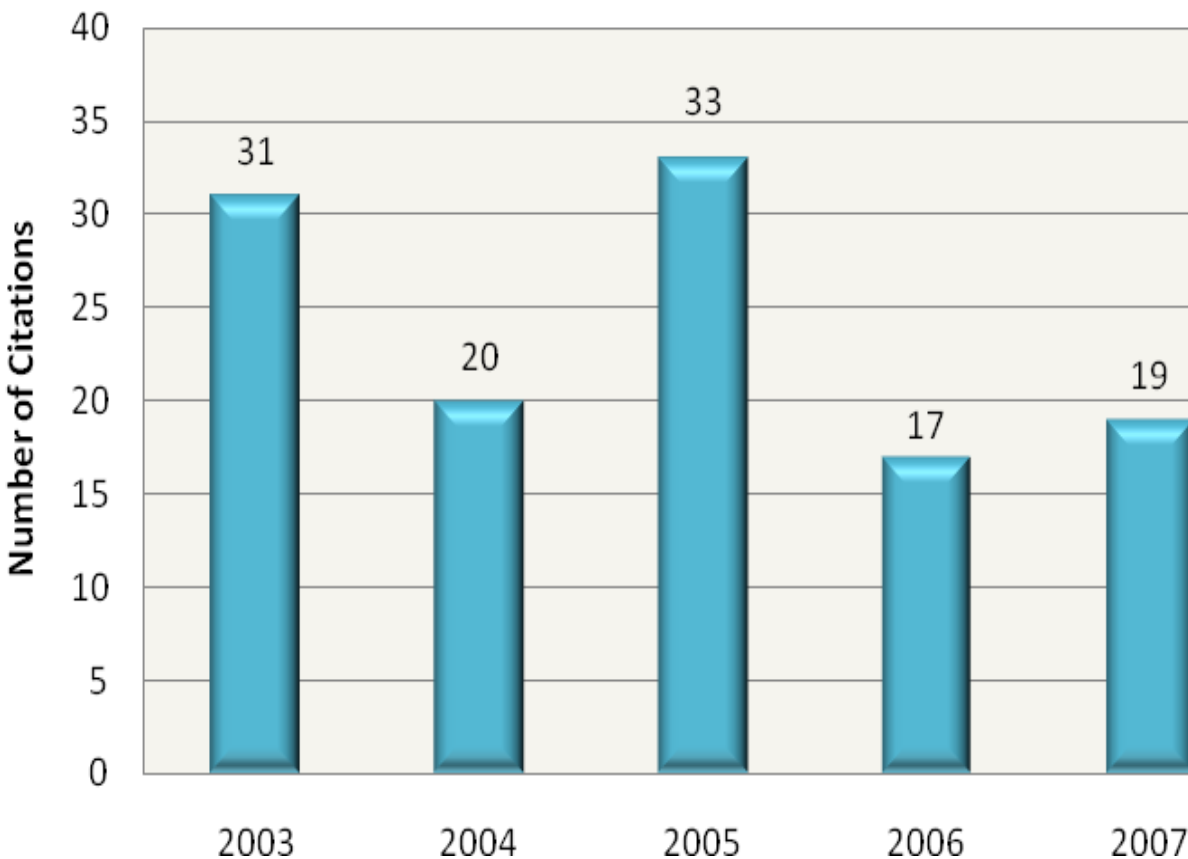


Not mutually exclusive. Total number of density altitude citations = 120.

Source: NTSB Aviation Accident and Incident Database

⁵ FAA Pilot's Handbook of Aeronautical Knowledge, FAA-H-8083-25A. 2008. page 3-3.

Figure 11. High Density Altitude Citations by Year 2003–2007



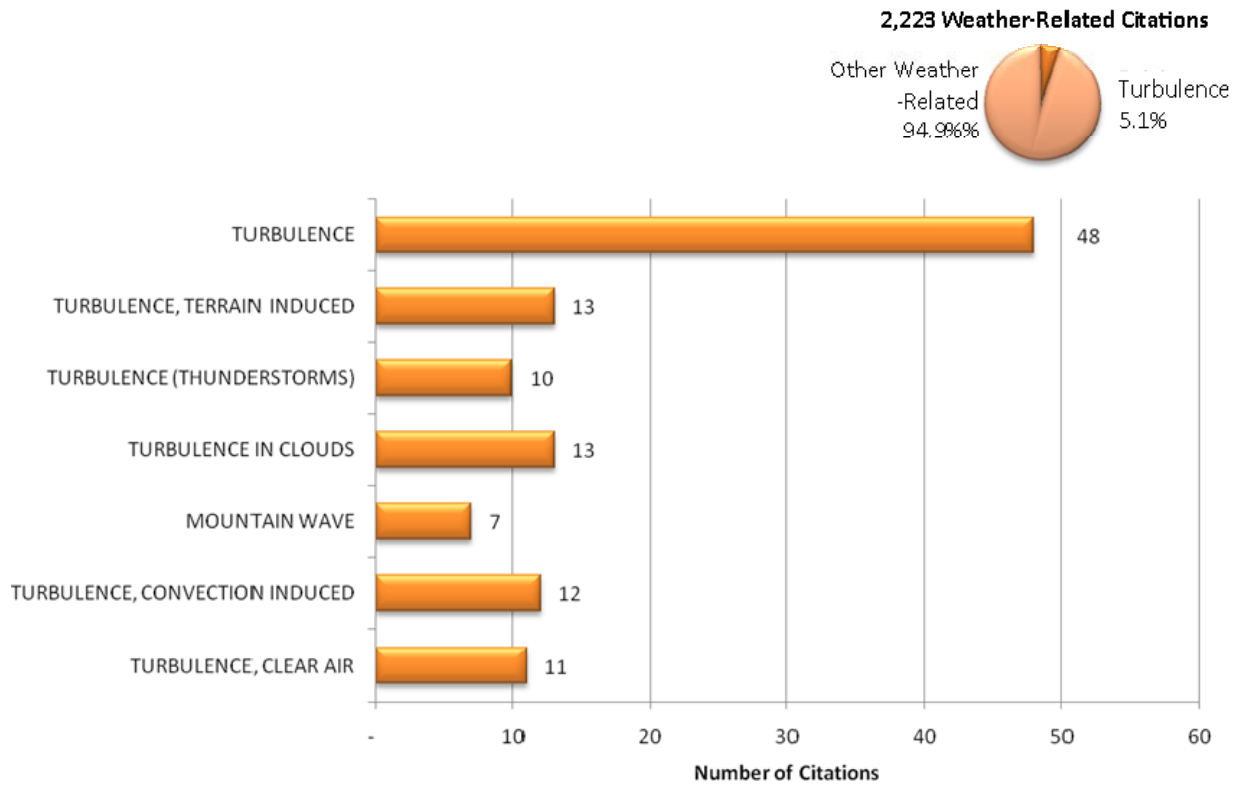
Source: NTSB Aviation Accident and Incident Database

3.5 TURBULENCE

Turbulence is the movement of unstable air and can be caused by many factors. Accidents citing turbulence as a cause or contributing factor ranked fourth in the study with 114 citations (see figure 12). The majority of the 114 citations were in part 121 operations, which had 42 turbulence citations; these accounted for 65.6 percent of all part 121 weather-related citations.

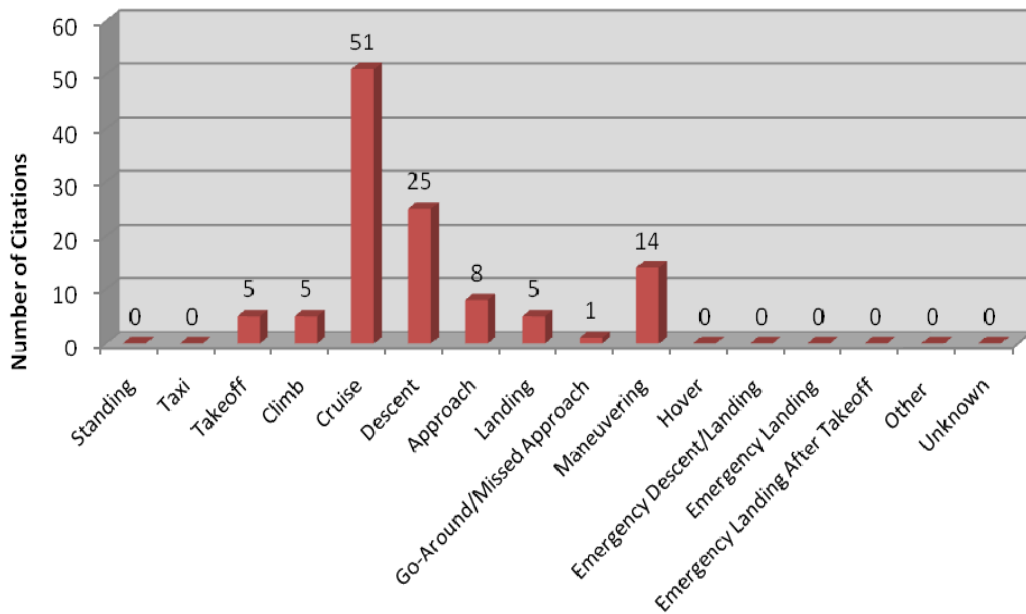
Part 91 operations had 62 turbulence citations, which is 3.2 percent of all part 91 weather-related citations in this study. The majority of turbulence citations (51) occurred during the cruise phase of flight (see figure 13). Turbulence citations showed a decrease of 55.9 percent from 2003 through 2006. From 2006 through 2007, there was an increase of 80 percent for turbulence citations (see figure 14).

Figure 12. Turbulence Citations 2003–2007



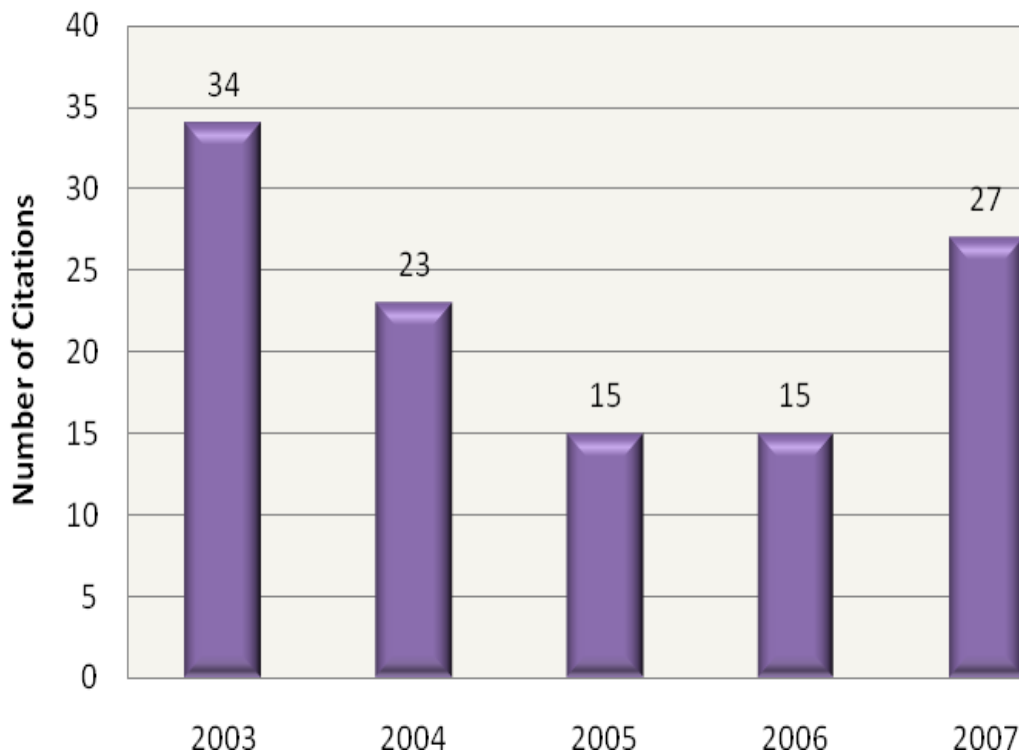
Not mutually exclusive. Total number of turbulence citations = 114.
Source: NTSB Aviation Accident and Incident Database

Figure 13. Turbulence Citations by Phase of Flight 2003–2007



Not mutually exclusive. Total number of turbulence citations = 114.
Source: NTSB Aviation Accident and Incident Database

Figure 14. Turbulence Citations by Year 2003–2007



Source: NTSB Aviation Accident and Incident Database

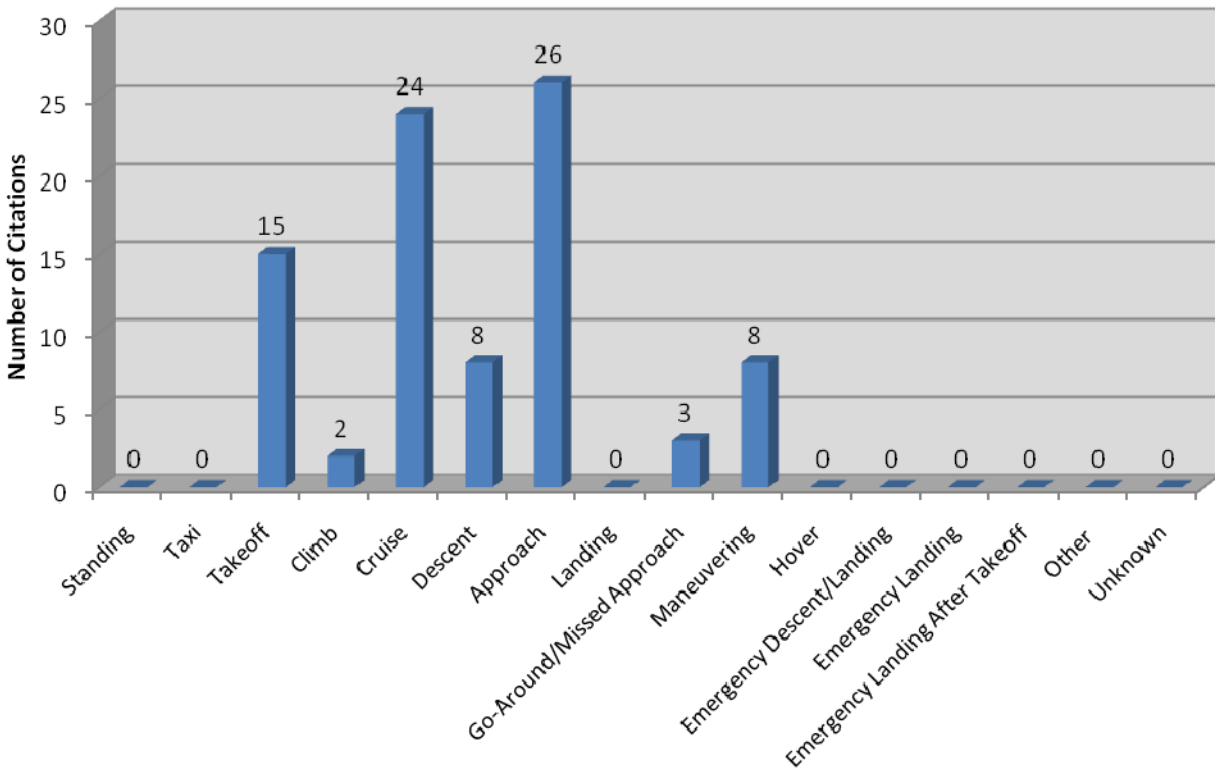
3.6 CARBURETOR ICING CONDITIONS

Carburetor icing is an engine condition that occurs in aircraft with float-type carburetors, which are the most common type used in carbureted reciprocating engines. Carburetor icing occurs when ice forms on the internal surfaces of the carburetor and can reduce engine power or cause engine failure. It is likely to occur when outside air temperatures are below 70 degrees Fahrenheit (21 degrees Celsius) and the relative humidity is above 80 percent. Engines with float-type carburetors are equipped with carburetor heat systems which, when activated, heat the air before it reaches the carburetor, therefore preventing the formation of carburetor ice.⁶

In part 91 operations, carburetor icing was cited as a cause or contributing factor in 86 (3.9 percent) of the 2,223 weather-related citations in the study. There were no carburetor icing accidents reported in part 121, 135, or 137 operations. There were 26 citations of carburetor icing during the approach phase of flight and 24 citations during the cruise phase of flight (see figure 15). The trend in carburetor icing accidents has remained relatively steady since 2003. For the duration of the study period, there was an average of 17.2 carburetor icing citations per year, with the highest number (20) of carburetor icing citations occurring in 2003 (see figure 16).

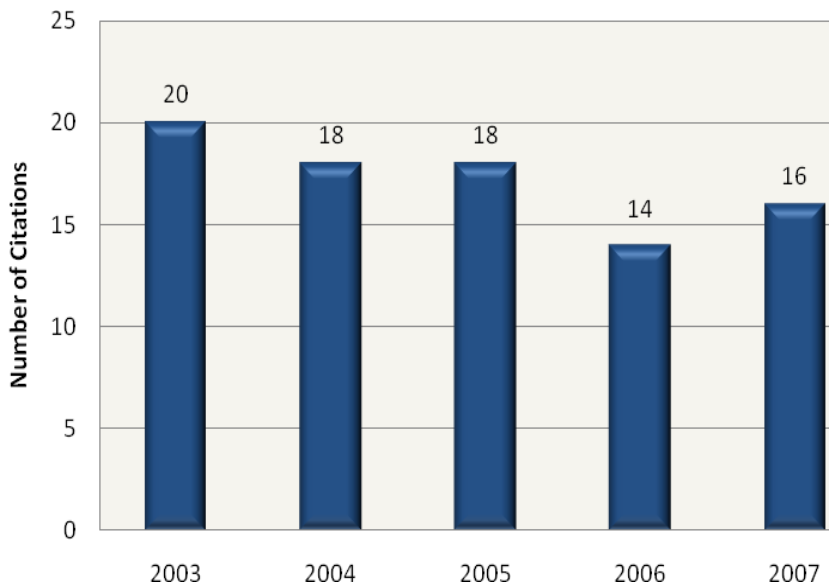
⁶ FAA Pilot's Handbook of Aeronautical Knowledge, FAA-H-8083-25A. 2008. pages 6–8 and 6–9.

Figure 15. Carburetor Icing Citations by Phase of Flight 2003–2007



Not mutually exclusive. Total number of carburetor icing citations = 86.
Source: NTSB Aviation Accident and Incident Database

Figure 16. Carburetor Icing Citations by Year 2003–2007



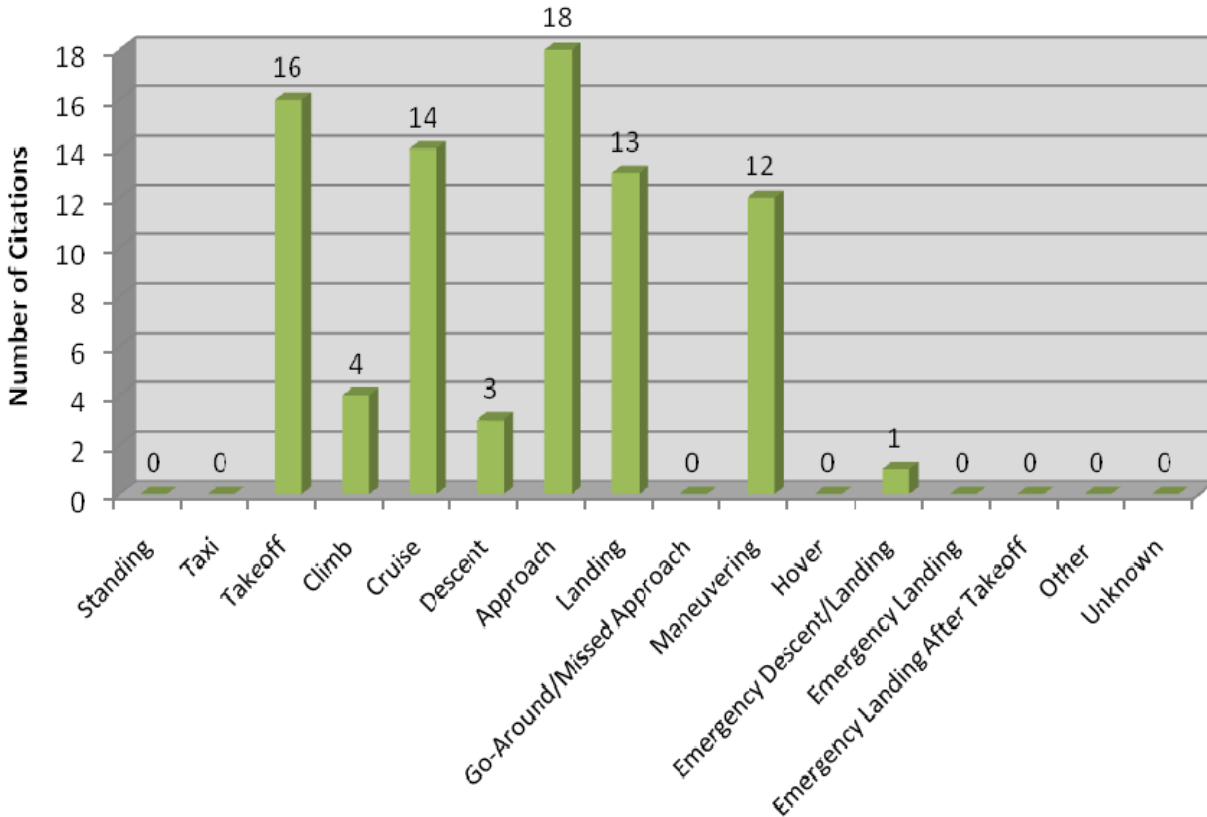
Source: NTSB Aviation Accident and Incident Database

3.7 UPDRAFT/DOWNDRAFT

Updraft/downdrafts (ascending/descending air) are vertical movements of air currents. Updrafts and downdrafts were cited 81 times (3.6 percent) in the study, which is equivalent to the number of precipitation citations. They were the fifth highest cause or contributing factor in part 91 weather-related accidents during the study period, with 74 of 1,960 citations (3.8 percent). There were four citations in part 135 operations and one citation in part 137 operations that were attributed to updrafts/downdrafts.

Updraft/downdraft citations were distributed relatively evenly among the takeoff, cruise, approach, landing, and maneuvering phases of flight (see figure 17). From 2003 through 2007, the number of accidents resulting from updraft/downdrafts has remained fairly steady with an average of 16.2 citations per year (see figure 18). In 2003, there were 19 citations, the most citations for updrafts/downdrafts in the study.

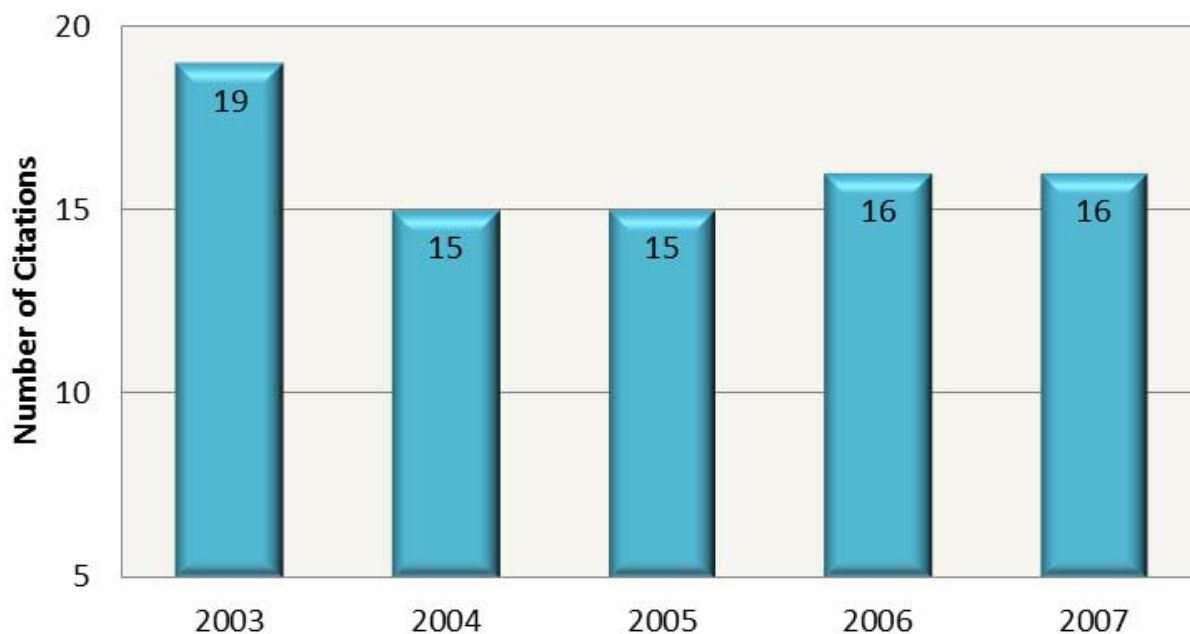
Figure 17. Updraft/Downdraft Citations by Phase of Flight 2003–2007



Not mutually exclusive. Total number of updraft/downdraft citations = 81.

Source: NTSB Aviation Accident and Incident Database

Figure 18. Updraft/Downdraft Citations by Year 2003–2007



Source: NTSB Aviation Accident and Incident Database

3.8 PRECIPITATION

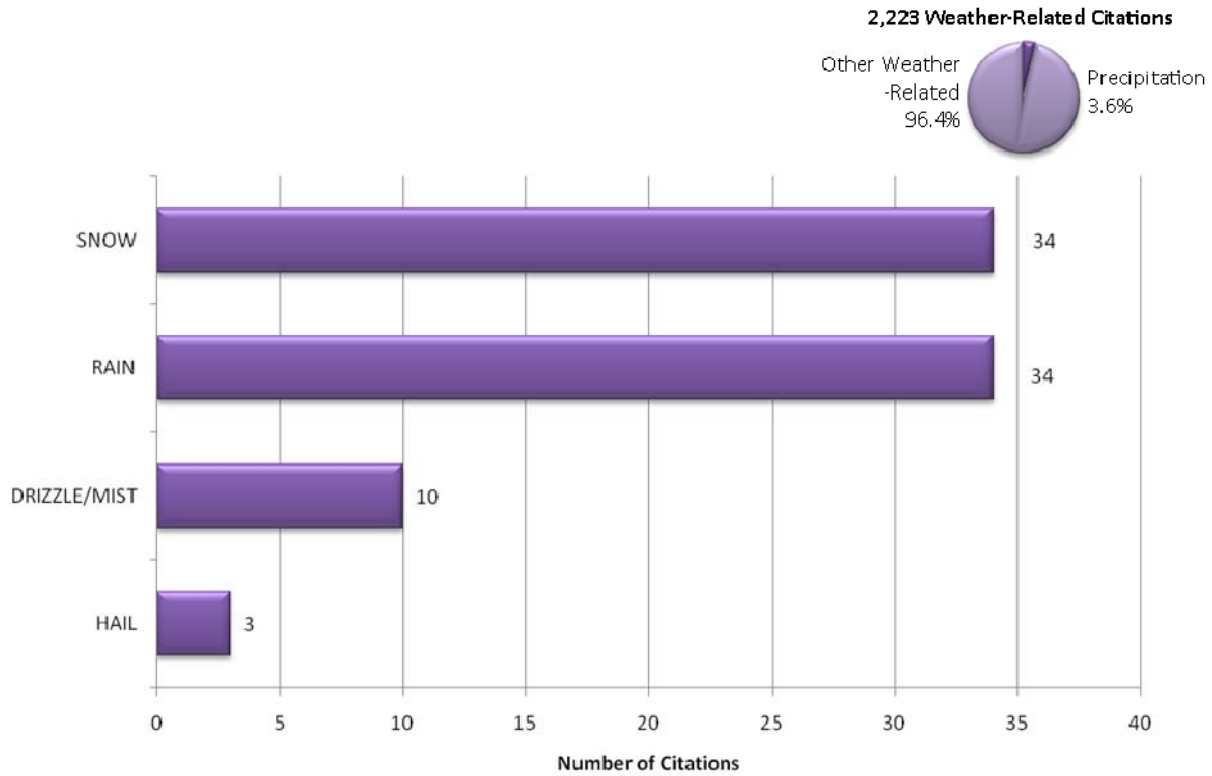
Precipitation is defined as any type of water particle that forms in the atmosphere and then falls to the ground. Forms of precipitation include drizzle, rain, snow, and hail. Precipitation can affect the safety of flight by reducing visibility, affecting aircraft performance, and producing icing conditions.⁷

Precipitation was cited as a cause or contributing factor in 81 of 2,223 total weather citations (3.6 percent) (see figure 19). Part 91 had 65 precipitation citations, accounting for 3.3 percent of all part 91 citations. Of 128 total part 135 weather-related citations, 10 of these citations were due to precipitation (7.8 percent).

Precipitation remained a relatively low-ranking factor in parts 91 and 137 during the study period, occurring in less than 5 percent of all weather-related accidents. The majority of precipitation citations occurred during the cruise phase of flight (27), followed by the approach phase of flight (18) (see figure 20). Precipitation citations showed a downward trend from 2003 to 2007, decreasing by 60.9 percent (see figure 21).

⁷ Pilot's Handbook of Aeronautical Knowledge, FAA-H-8083-25A. 2008. page 11–18.

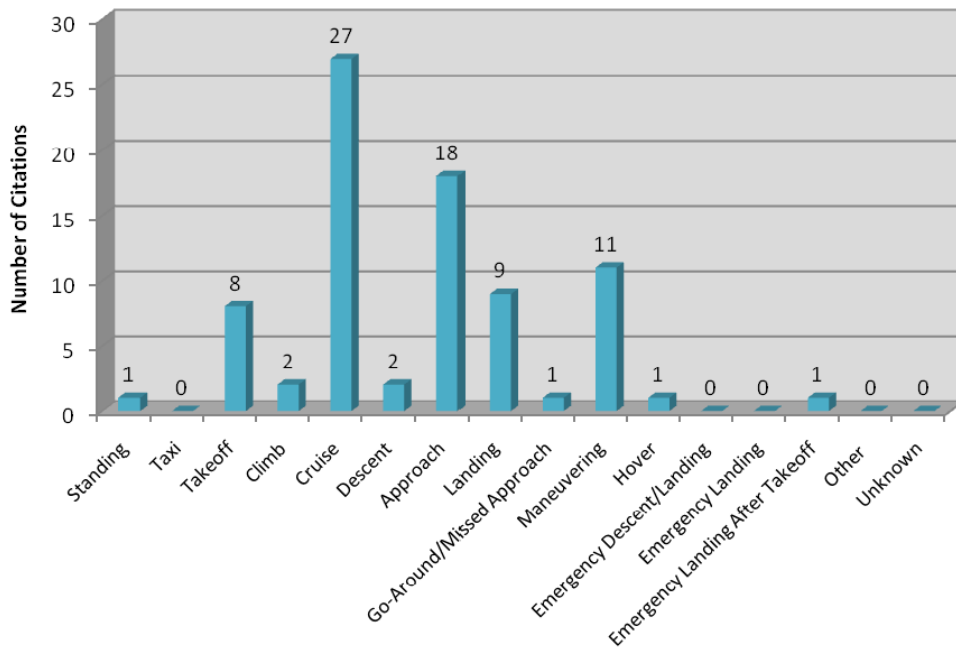
Figure 19. Precipitation Citations 2003–2007



Not mutually exclusive. Total number of precipitation citations = 81.

Source: NTSB Aviation Accident and Incident Database

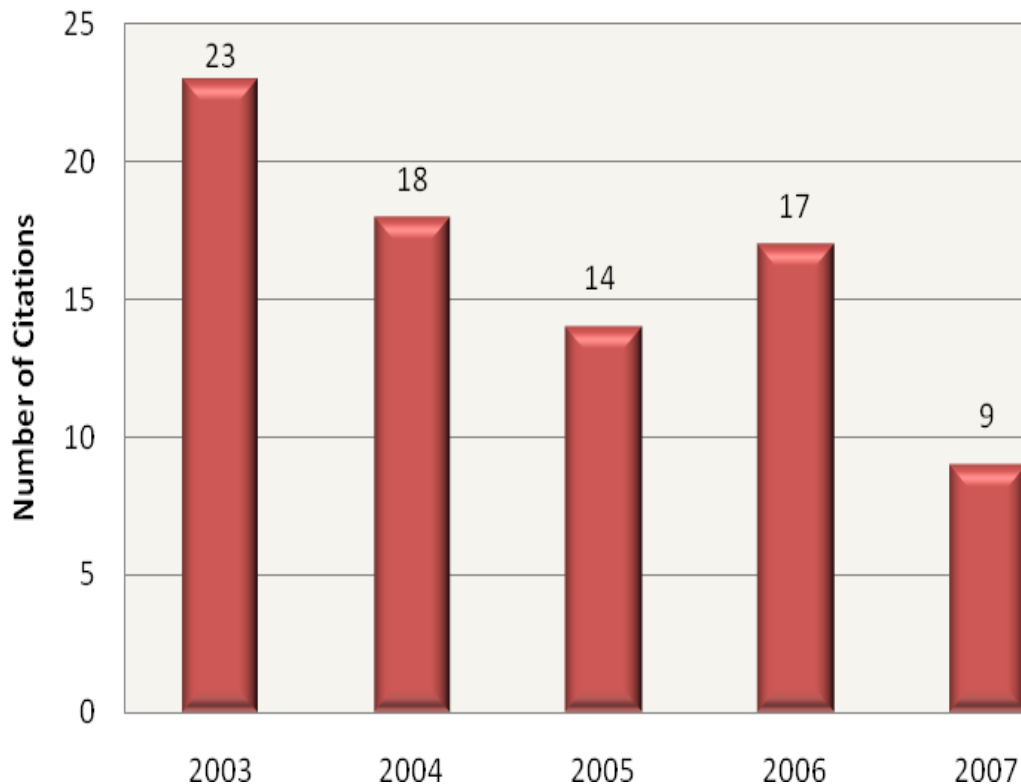
Figure 20. Precipitation Citations by Phase of Flight 2003–2007



Not mutually exclusive. Total number of precipitation citations = 81.

Source: NTSB Aviation Accident and Incident Database

Figure 21. Precipitation Citations by Year 2003–2007



Source: NTSB Aviation Accident and Incident Database

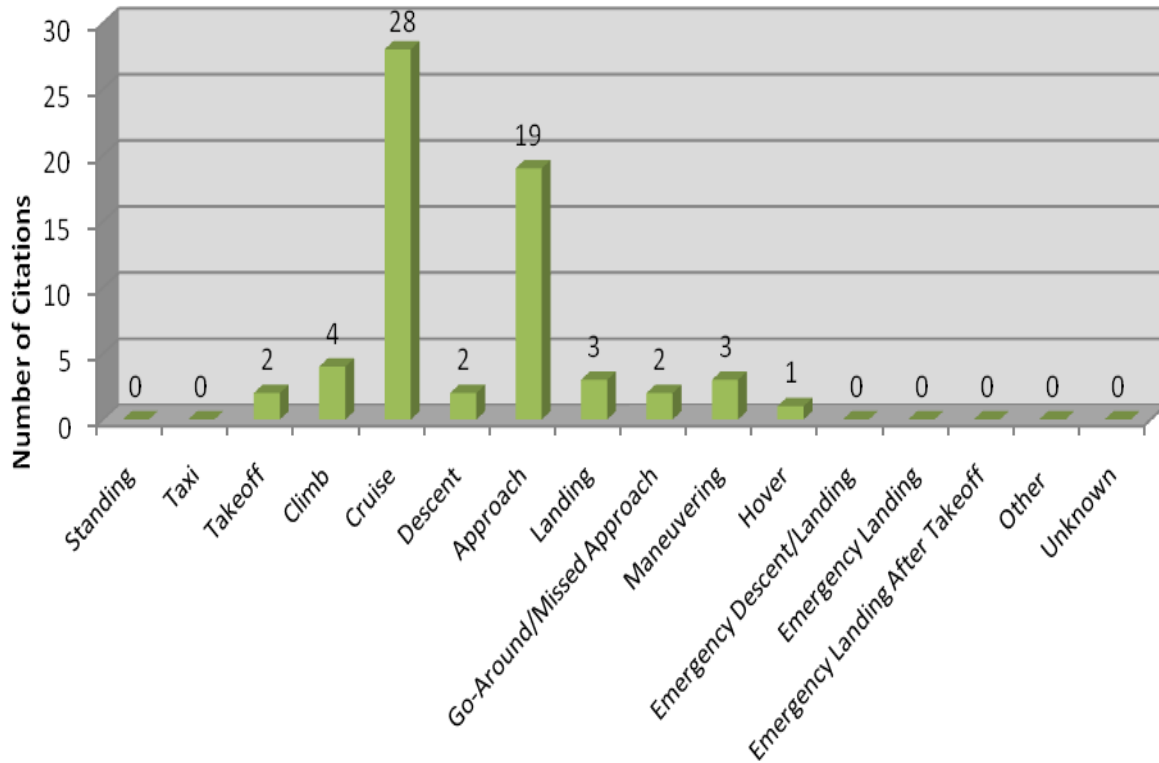
3.9 ICING

When the air temperature is 0 degrees Celsius or less and moisture is present, ice can form on an aircraft structure. The most significant hazard of structural icing is the disruption of airflow over aircraft surfaces. The disruption in airflow reduces lift and increases drag, causing the aircraft to stall at a lower angle of attack and higher speed than normal. Ice also can form in the engine intake, blocking the flow of air to the engine, which can cause engine failure. Many light aircraft are not certified for flight into known icing conditions. Larger aircraft are equipped with anti-icing systems, which prevent the formation of ice, or deicing systems, which remove ice from the aircraft.⁸

Icing was cited as a cause or contributing factor 64 times in weather-related accidents from 2003 through 2007. It also was not involved in any part 121 or part 137 operations. Part 135 had the highest percentage of icing citations (6), which accounted for 4.7 percent of all part 135 weather-related citations. Part 91 operations had 2.9 percent citations related to icing. The majority of icing citations occurred during the cruise phase of flight (28), followed by the approach phase of flight (19) (see figure 22). Icing citations showed a downward trend from 2003 through 2007, dropping by 26.7 percent (see figure 23).

⁸ AOPA Safety Advisor, Weather No. 1, Aircraft Icing. April 2008.

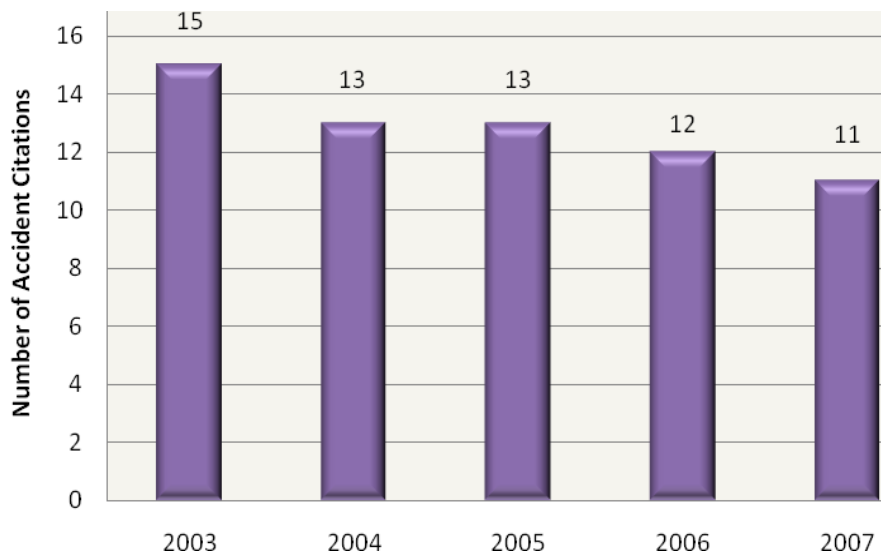
Figure 22. Icing Citations by Phase of Flight 2003–2007



Not mutually exclusive. Total number of icing citations = 64.

Source: NTSB Aviation Accident and Incident Database

Figure 23. Icing Citations by Year 2003–2007



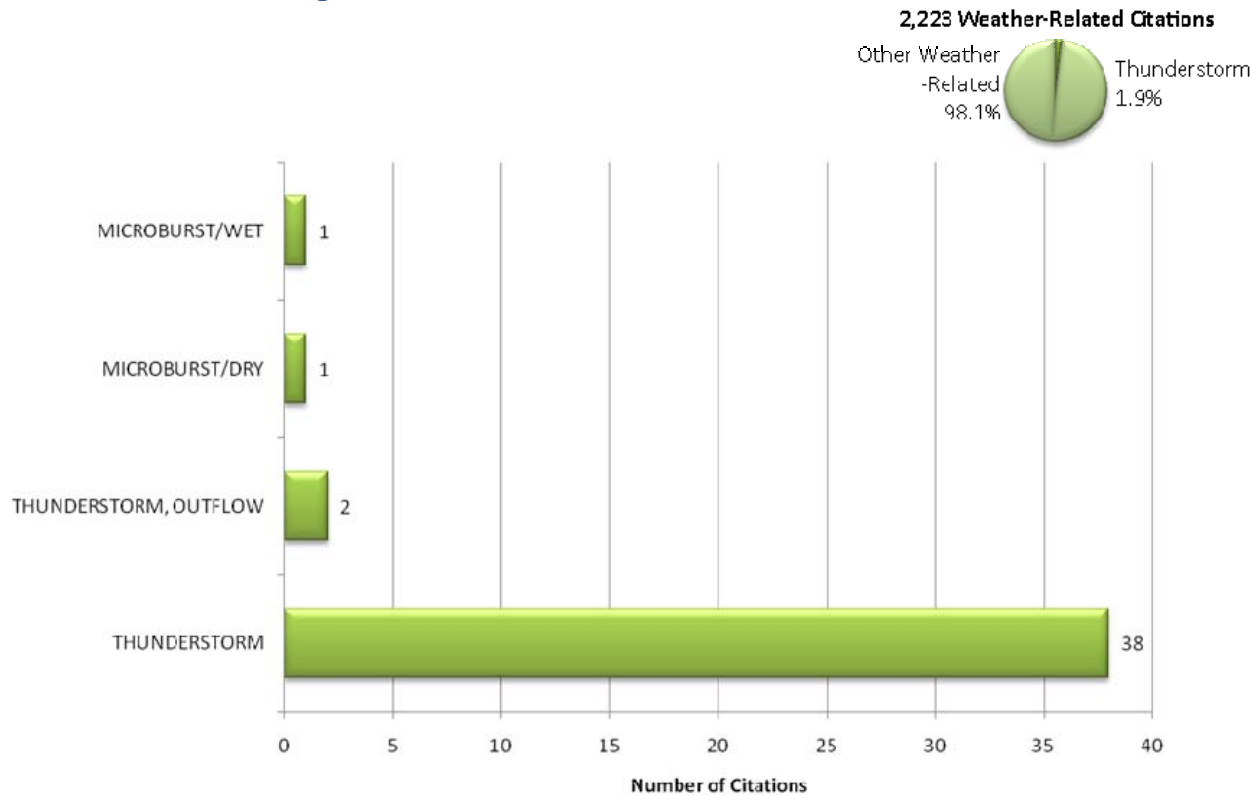
Source: NTSB Aviation Accident and Incident Database

3.10 THUNDERSTORMS

Thunderstorms occurring as the result of surface heating are known as air mass thunderstorms. Those occurring as the result of weather systems are known as steady-state thunderstorms. Hazards⁹ associated with thunderstorms include hail, tornadoes, windshear, microbursts, icing, and turbulence.

Thunderstorm citations are broken down into the following categories: thunderstorms; thunderstorm, outflow; microburst/dry; and microburst/wet (see figure 24). Approximately 1.9 percent (42 citations) of the 2,223 weather-related citations was attributed to thunderstorms. The highest percentage of thunderstorm citations occurred in part 135 operations, with six citations accounting for 4.7 percent of part 135 weather-related citations. Part 91 operations had the highest number of thunderstorm citations (33), which was 1.7 percent of all part 91 weather-related citations. Part 121 operations had two citations related to thunderstorms, while part 137 operations had one such citation. Almost half of the thunderstorm citations occurred during the cruise phase of flight (20) (see figure 25). The overall thunderstorm accident trend was relatively steady, with the exception of an increase in citations during 2004 (see figure 26).

Figure 24. Thunderstorm Citations 2003–2007

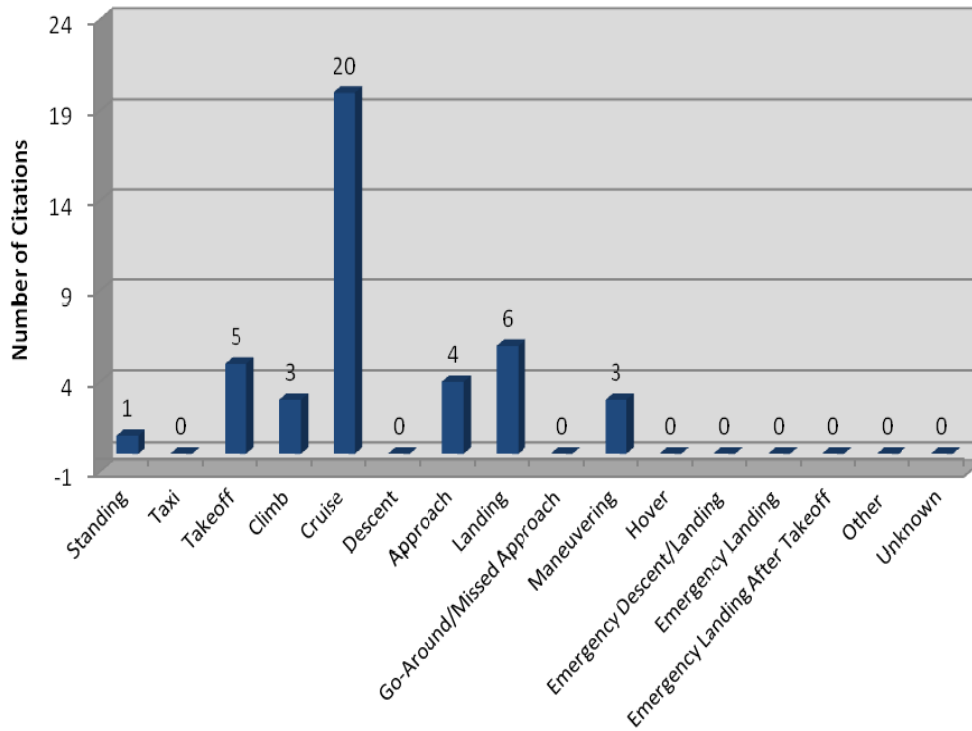


Not mutually exclusive. Total number of thunderstorm citations = 42.

Source: NTSB Aviation Accident and Incident Database

⁹ For the purposes of this study, many thunderstorm hazards are put into individual or separate categories.

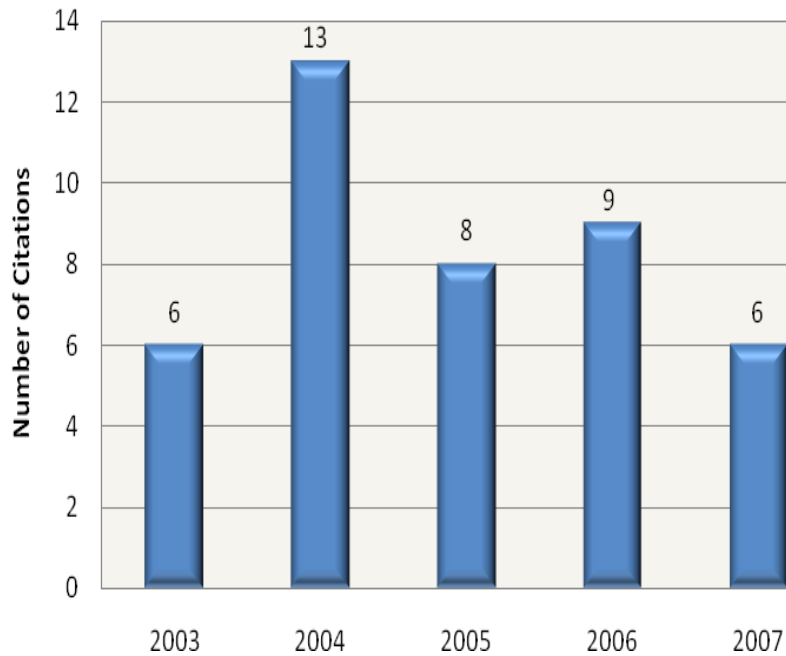
Figure 25. Thunderstorm Citations by Phase of Flight 2003–2007



Not mutually exclusive. Total number of thunderstorm citations = 42.

Source: NTSB Aviation Accident and Incident Database

Figure 26. Thunderstorm Citations by Year 2003–2007



Source: NTSB Aviation Accident and Incident Database

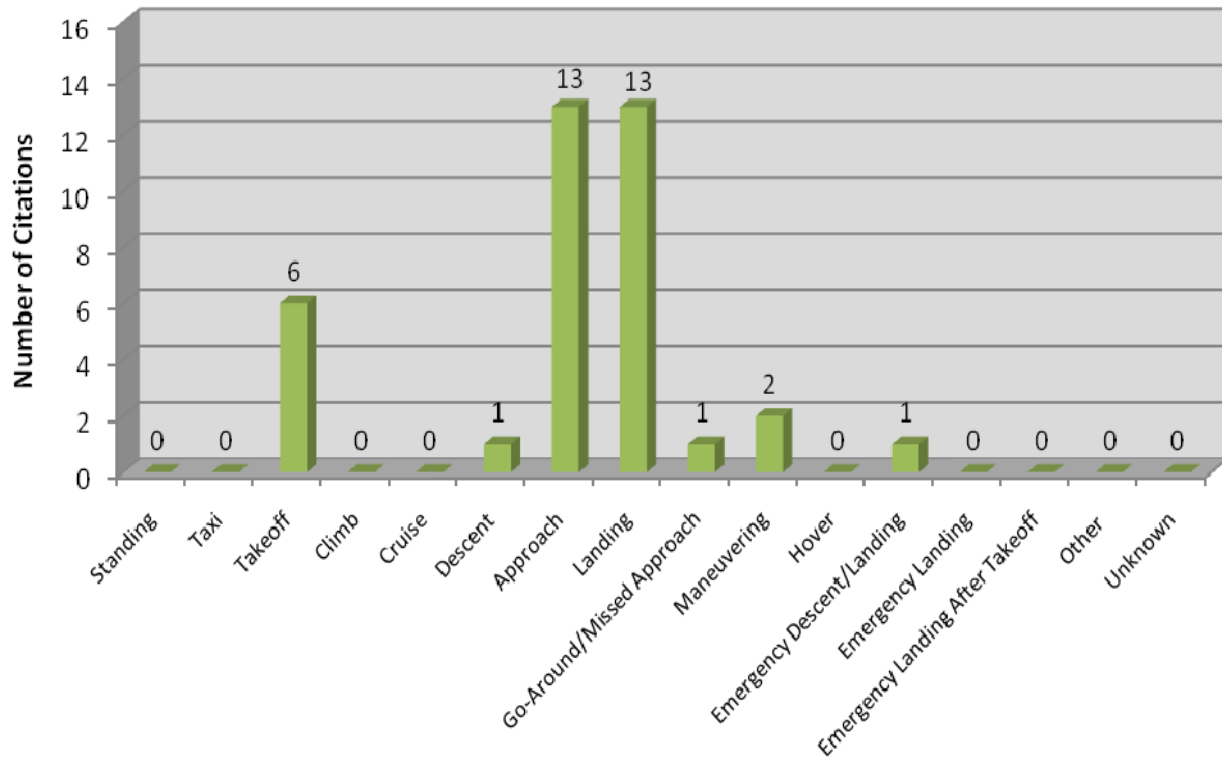
3.11 WINDSHEAR

Windshear is a sudden, drastic change in wind speed and/or direction that generally is associated with convective activity. An encounter with windshear can make it difficult or impossible to maintain control of an aircraft. Because windshear is so hazardous, some airports now have low-level windshear alert systems to warn pilots of the presence of windshear.¹⁰

Thirty-seven weather-related citations in the study (1.7 percent) were attributed to windshear. Only 35 windshear citations occurred in part 91 operations, accounting for 1.8 percent of 1,960 part 91 weather-related citations. The remaining two citations were in part 135 operations.

Most windshear citations occurred during the approach and landing phases of flight, with 13 citations each (see figure 27). The number of windshear citations remained relatively steady, with an average of 7.4 windshear citations from 2003 through 2007 (see figure 28). The number of windshear citations increased from 2003 to 2007 by three citations.

Figure 27. Windshear Citations by Phase of Flight 2003–2007

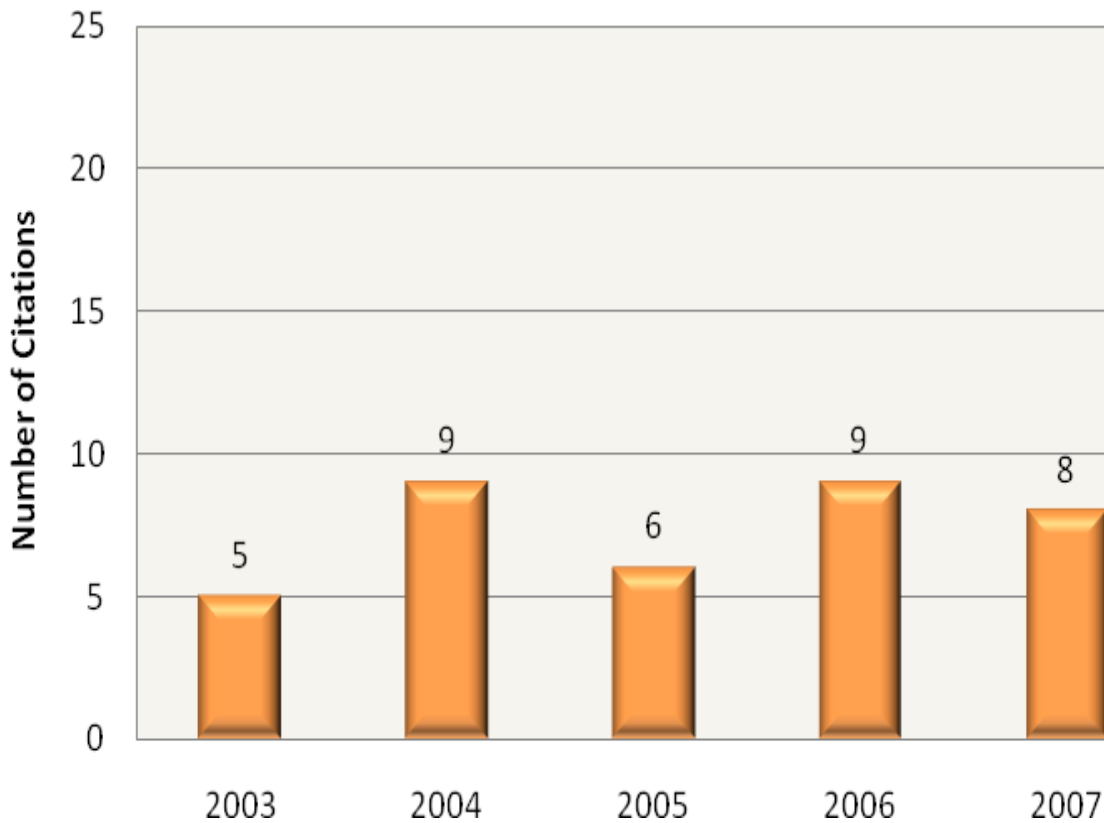


Not mutually exclusive. Total number of windshear citations = 37.

Source: NTSB Aviation Accident and Incident Database

¹⁰ Pilot's Handbook of Aeronautical Knowledge, FAA-H-8083-25A. 2008. page 11–11.

Figure 28. Windshear Citations by Year 2003–2007



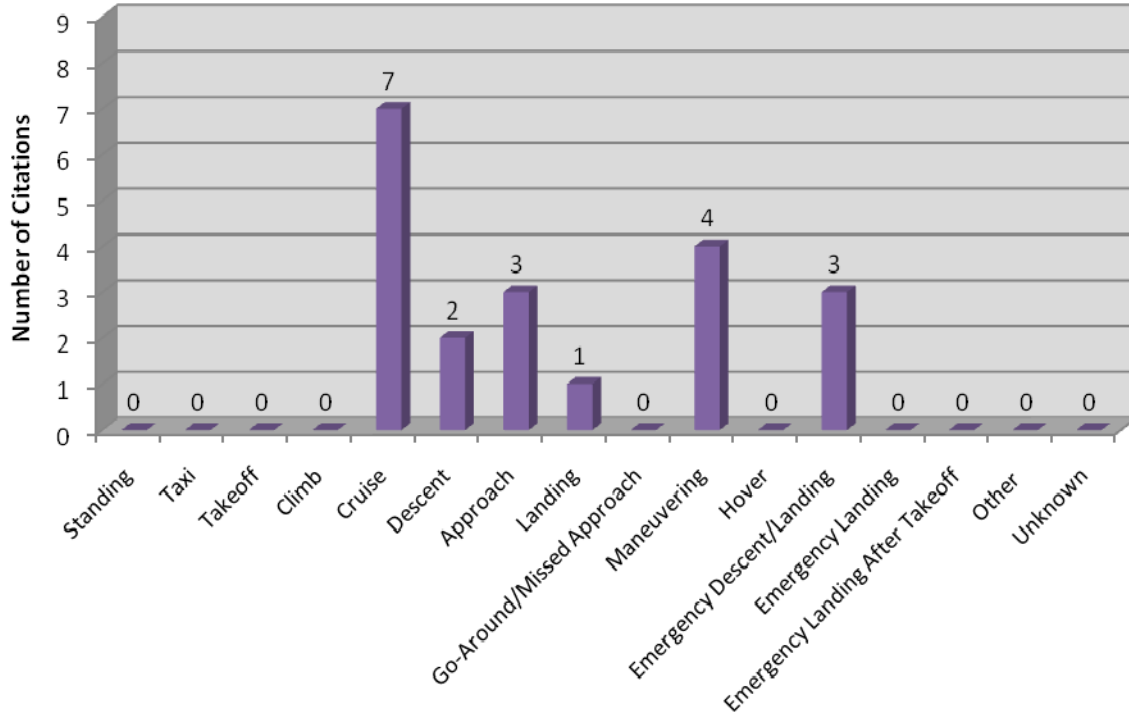
Source: NTSB Aviation Accident and Incident Database

3.12 THERMAL LIFT

Thermal lift is defined as a buoyant plume or bubble of rising air.¹¹ Thermal lift primarily affects gliders. Thermal lift accounted for 20 citations in the study (0.9 percent), with all citations occurring in part 91 operations. The majority of citations (7) as a result of thermal lift occurred in the cruise phase of flight (see figure 29). Accidents in the thermal lift category showed an increase from 2003 through 2006, followed by a decrease in 2007 (see figure 30).

¹¹ Glider Flying Handbook, FAA-H-8083-13. 2003. page G-5.

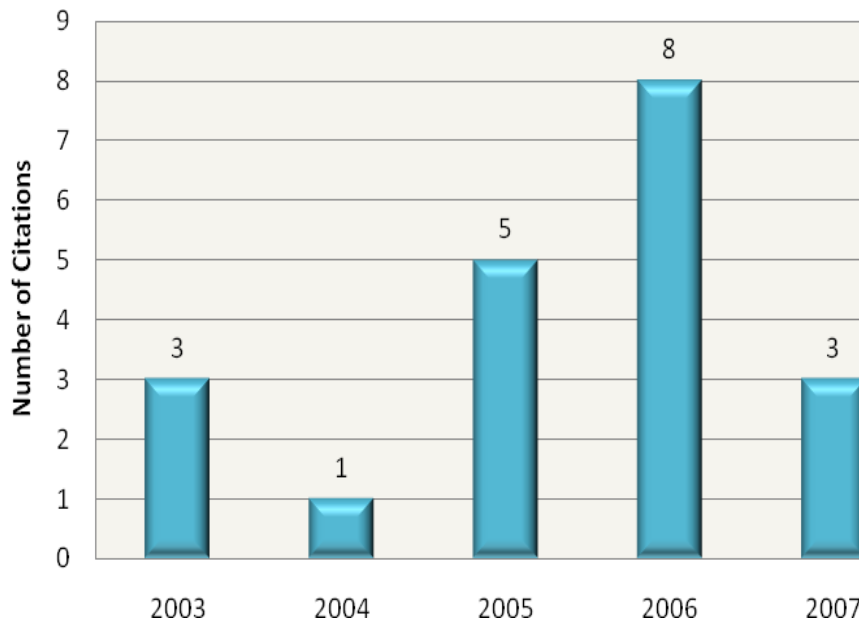
Figure 29. Thermal Lift Citations by Phase of Flight 2003–2007



Not mutually exclusive. Total number of thermal lift citations = 20.

Source: NTSB Aviation Accident and Incident Database

Figure 30. Thermal Lift Citations by Year 2003–2007



Source: NTSB Aviation Accident and Incident Database

3.13 TEMPERATURE EXTREMES

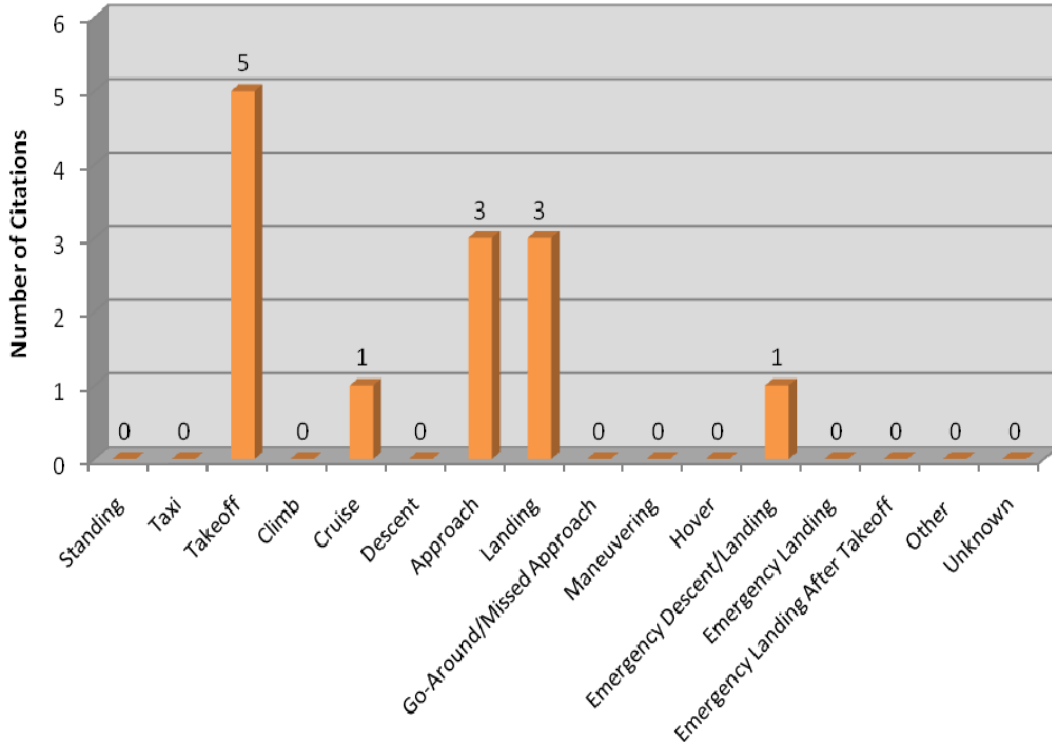
Extremely high or low temperatures can have an impact on aviation safety in a variety of ways, some of which are described here. Extreme high temperatures increase density altitude and can negatively impact aircraft performance. High temperatures can also cause a situation known as vapor lock. Vapor lock occurs when the engine heats the fuel lines and the contained fuel becomes a vapor¹². This tendency is increased if the fuel in the tank is warm, commonly as a result of high atmospheric temperatures. The fuel vapor can result in partial or complete interruption of fuel flow to the engine. Additionally, high temperatures can heat airport surfaces, such as tar, making them unsuitable for landing and taxiing. In extreme cold temperatures, if there is water contaminating a system, it can turn to ice and render the system inoperative. Cold-soaking is another condition that occurs in extremely cold conditions. Cold-soaking is when an aircraft is in prolonged cold temperatures, either in flight or on the ground, and the aircraft structure cools significantly. Cold-soaking can cause structural icing and a variety of mechanical difficulties. Lastly, research has shown that when engine power is reduced to idle, the engine cools rapidly, and vaporization of fuel is less complete, which can slow engine response times or cause a complete loss of engine power¹³. Sudden throttle movements can aggravate this situation, and the pilot should try to keep the engine warm during glides by frequently opening the throttle.

Temperature extremes were the second lowest ranking category of weather-related citations, with only 13 citations (0.6 percent). There were 12 citations that occurred during part 91 operations, with 1 citation that occurred during part 135 operations. The majority of temperature extreme citations (5) occurred during the takeoff phase of flight (see figure 31). Citations resulting from temperature extremes showed little change over the 5-year study period (see figure 32).

¹² Airplane Flying Handbook, p. G-16

¹³ NTSB report number NYC03LA041

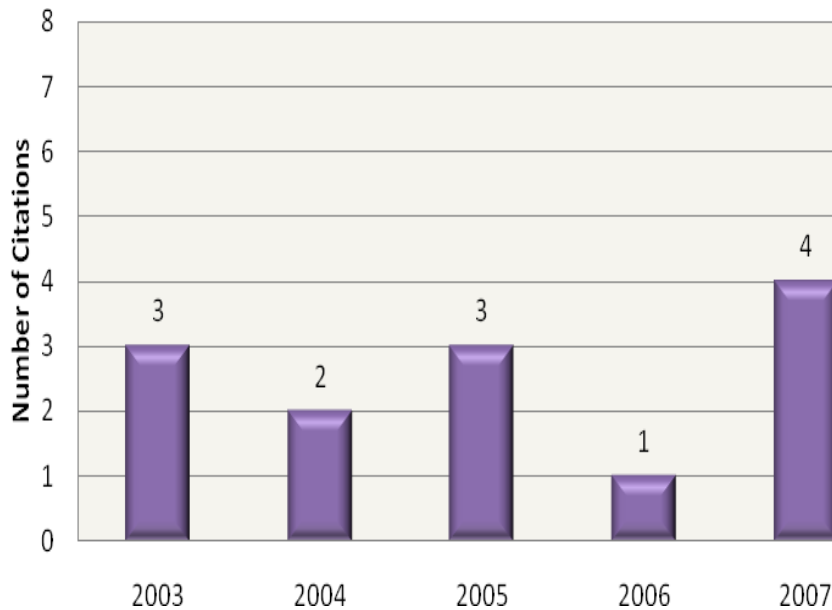
Figure 31. Temperature Extreme Citations by Phase of Flight 2003–2007



Not mutually exclusive. Total number of temperature extreme citations = 13.

Source: NTSB Aviation Accident and Incident Database

Figure 32. Temperature Extreme Citations by Year 2003–2007



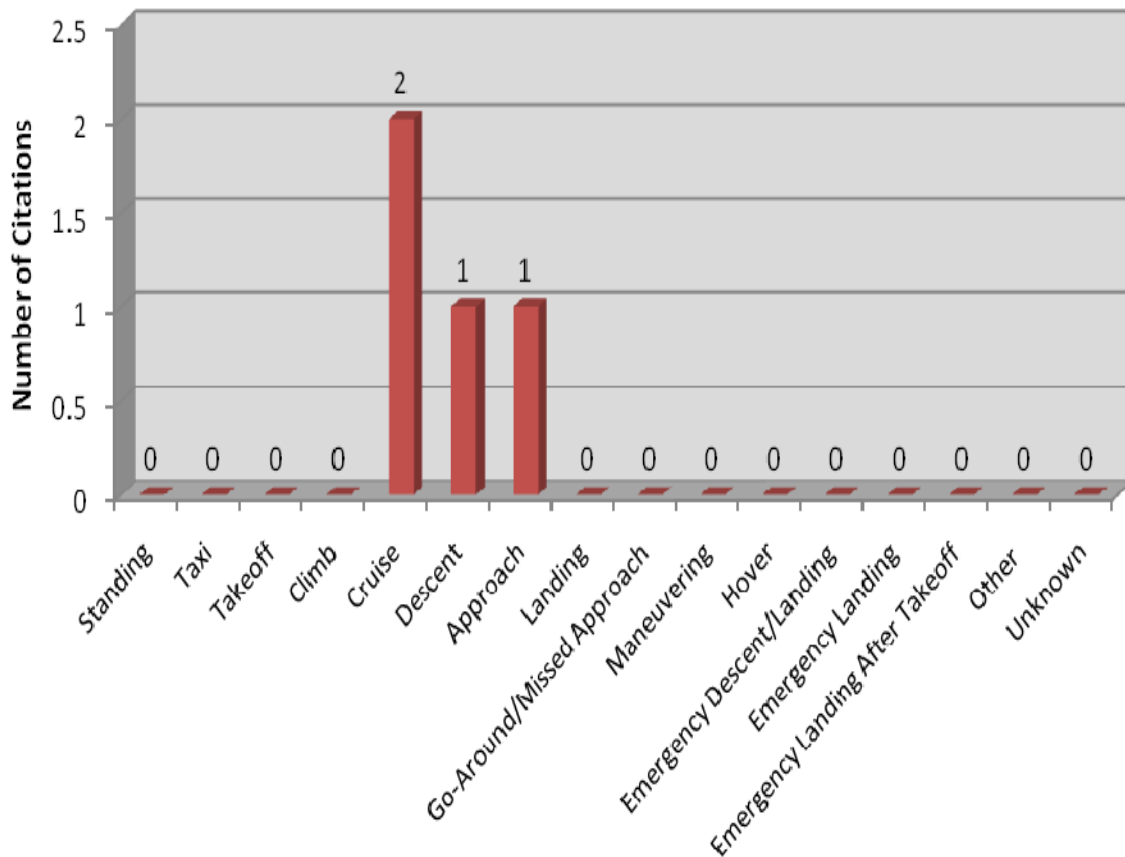
Source: NTSB Aviation Accident and Incident Database

3.14 LIGHTNING

Although aircraft structures are built to withstand lightning strikes, there are some hazards that are associated with lightning. Navigation and communication equipment, such as radios and magnetic compasses, can be damaged by lightning. Lightning also can temporarily blind a pilot.¹⁴

Lightning was the lowest ranking cause or contributing factor in the study, with only four citations (0.2 percent). One citation occurred during part 121 operations, while the other three citations occurred during part 91 operations. Two lightning citations occurred during the cruise phase of flight, while the descent and approach phases of flight each had one citation (see figure 33). The number of lightning citations has remained relatively steady from 2003 to 2005; however, there were no citations resulting from lightning in 2006 and 2007 (see figure 34).

Figure 33. Lightning Citations by Phase of Flight 2003–2007

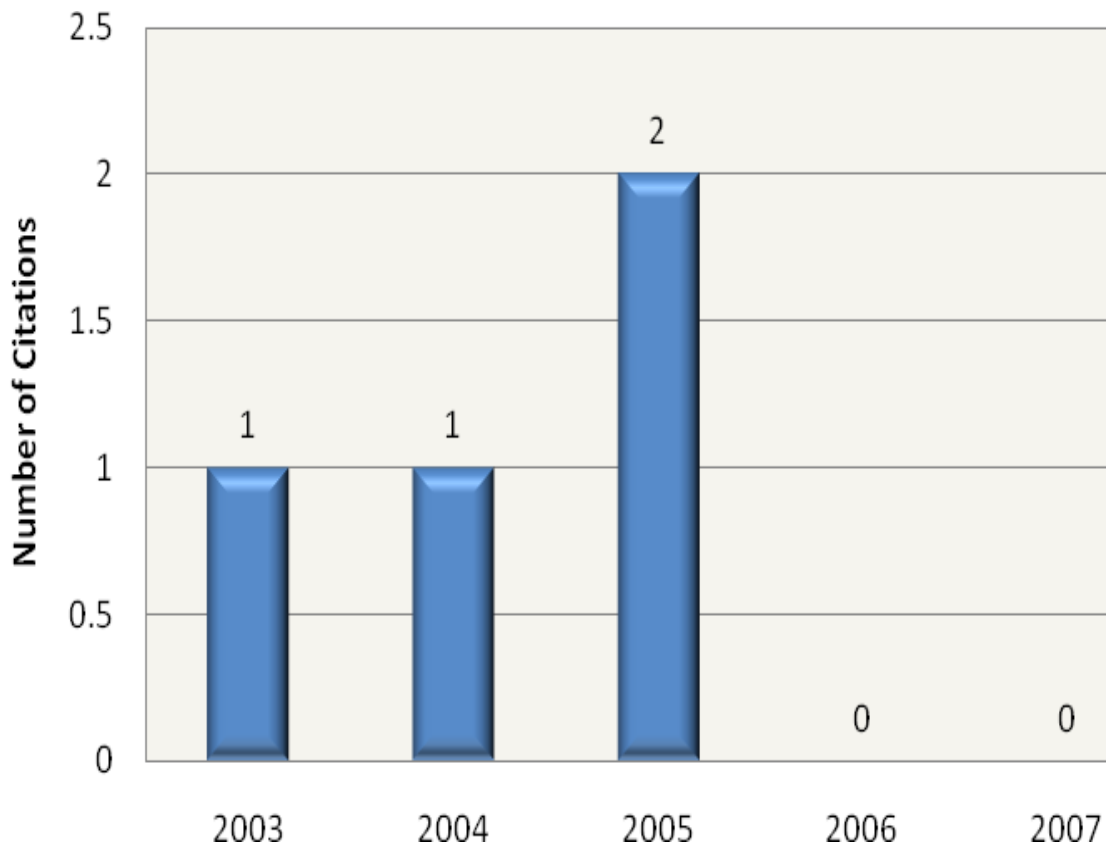


Not mutually exclusive. Total number of lightning citations = 4.

Source: NTSB Aviation Accident and Incident Database

¹⁴ Pilot's Handbook of Aeronautical Knowledge, FAA-H-8083-25A. 2008. page 11–25.

Figure 34. Lightning Citations by Year 2003–2007



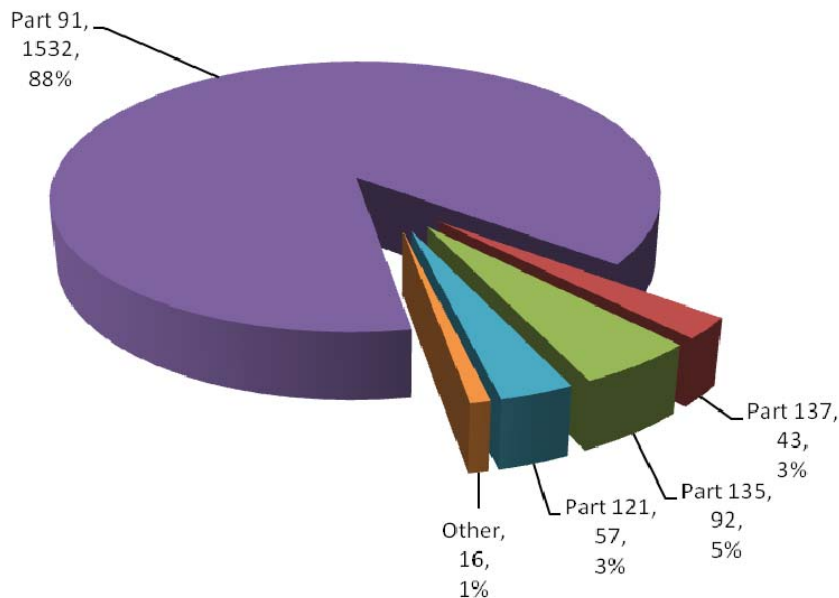
Source: NTSB Aviation Accident and Incident Database

4.0 ACCIDENT STATISTICS AND TRENDS BY OPERATING RULE

4.1 COMPARATIVE ANALYSIS—PARTS 91, 121, 135, AND 137

Analyzing weather-related accidents in a particular section of FAA operating rules can identify trends and hazards within various types of operations. The majority of all weather-related accidents occurred under the following operating rules: part 91 general aviation operations, part 121 air carrier operations, part 135 commuter and on-demand operations, and part 137 agricultural aircraft operations (see figure 35). As a result, section 4.0 focuses on the weather conditions and accident details of parts 91, 121, 135, and 137.

Figure 35. Number of Weather-related Accidents by Category of Operation 2003–2007



Other includes part 129; part 133; public use; non-U.S., noncommercial; non-U.S., commercial; and armed forces.

Source: NTSB Aviation Accident and Incident Database

The analysis of each operating rule section includes information on weather-related trends, the most common weather factor for each type of operation, injury severity, pilot qualifications, and a representative accident study. Part 91 had the highest number of weather-related accidents, accounting for 88 percent of all accidents in the study. Part 135 accounted for 5 percent of weather-related accidents, while parts 121 and 137 accounted for less than 4 percent each of accidents studied.

Part 91 operations accounted for 121.5 million hours flown for the study period, which resulted in the highest total hours flown of the four types of operations studied. Part 91 operations also had the highest rate of weather-related accidents per 100,000 hours flown. Part 135 operations followed part 91 with the second highest number of weather-related accidents, with a rate of 0.53 accidents per 100,000 hours flown. Part 121 had the second highest number of hours flown, but the lowest weather-related accident rate (see figure 36).

Figure 36. Hours Flown and Accident Rates 2003–2007

Operating Rule	Total Hours Flown 2003–2007 (in millions)	Accident Rate per 100,000 Hours Flown	Weather-related Accident Rate per 100,000 Hours Flown
Part 91	121.5	6.70	1.26
Part 121	94.0	.20	0.06
Part 135	17.2	1.87	0.53

Hours flown data was unavailable for part 137.

Source: Hours flown data from Bureau of Transportation Statistics

4.2 PART 91—GENERAL AVIATION OPERATIONS

4.2.1 Part 91 Trends

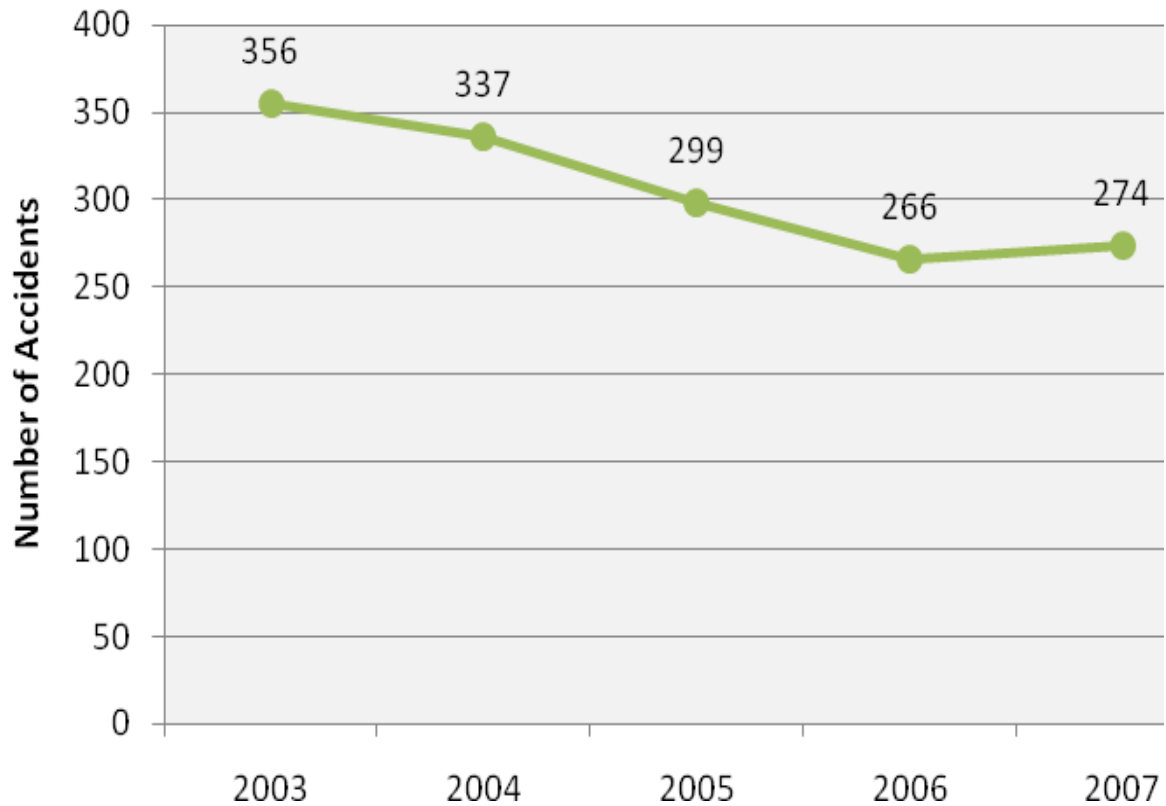
Part 91 applies to all civil aviation operations, not including operations under parts 121, 129, 133, 135, 136, and 137¹⁵. Part 91 operations encompass a variety of flight operations, which includes, but is not limited to, personal operations, business/corporate flying, aerial observation, skydiving, ferry flights, flight instruction, air race/show, and banner tow.

More weather-related accidents involved aircraft operating under part 91 than those operating under any other 14 CFR part. Overall, 88 percent (1,532) of all weather-related accidents from 2003 through 2007 involved part 91 operations. Weather was a cause or contributing factor in 20 percent¹⁶ of all part 91 accidents over the study period, resulting in weather being cited as a cause or contributing factor 1,960 times. However, weather-related accidents involving part 91 operations have decreased since 2003 (see figure 37). In 2007, a 23 percent reduction (356 to 274) in weather-related accidents occurred in part 91. The majority of the part 91 weather-related accidents (72.1 percent) were categorized as personal operations (1,105 out of 1,532).

¹⁵ Part 91 does not include moored balloons, kites, unmanned rockets, and unmanned free balloons, which are governed by 14 CFR part 101 and ultralight vehicles operated in accordance with 14 CFR part 103.

¹⁶ From 2003 to 2007, there were 7,649 part 91 accidents.

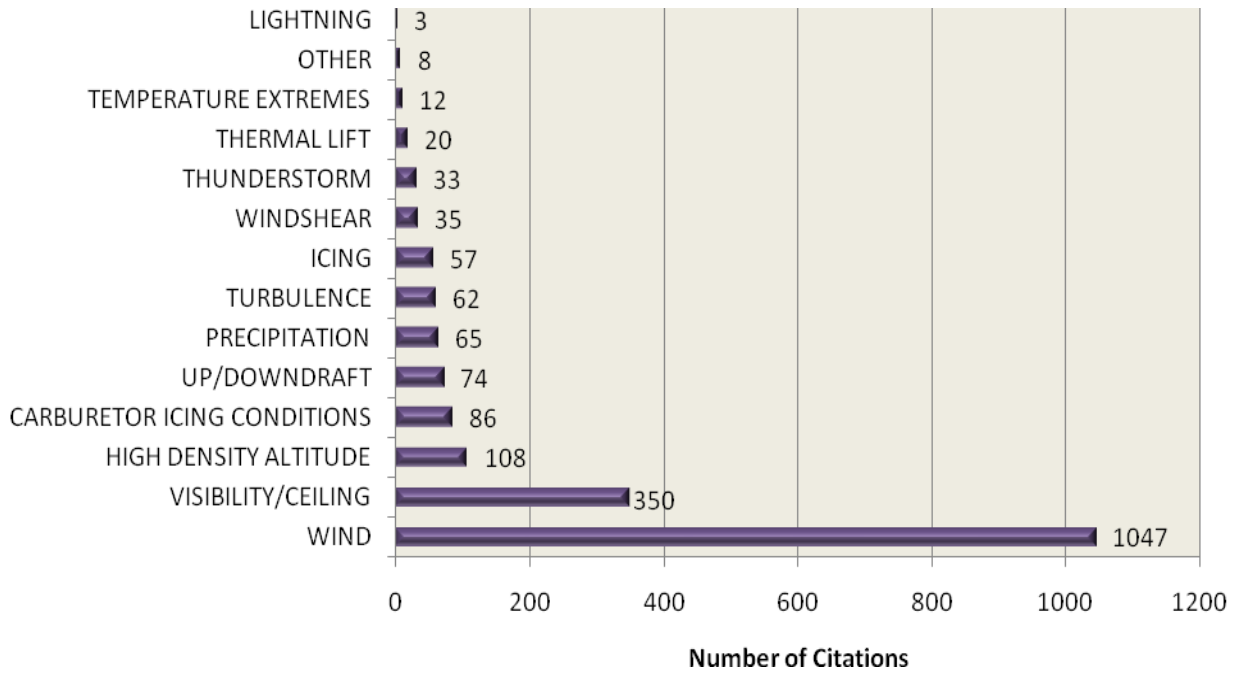
Figure 37. Part 91 Weather-related Accidents by Year 2003–2007



Source: NTSB Aviation Accident and Incident Database

The weather factors that contributed to part 91 accidents include wind, visibility/ceiling, high density altitude, carburetor icing, updraft/downdraft, precipitation, turbulence, icing, windshear, thunderstorm, thermal lift, temperature extremes, and lightning (see figure 38). The majority of weather-related accidents (82.6 percent) occurred during the day, while 9.8 percent occurred at night or during night/dark conditions (see figure 39).

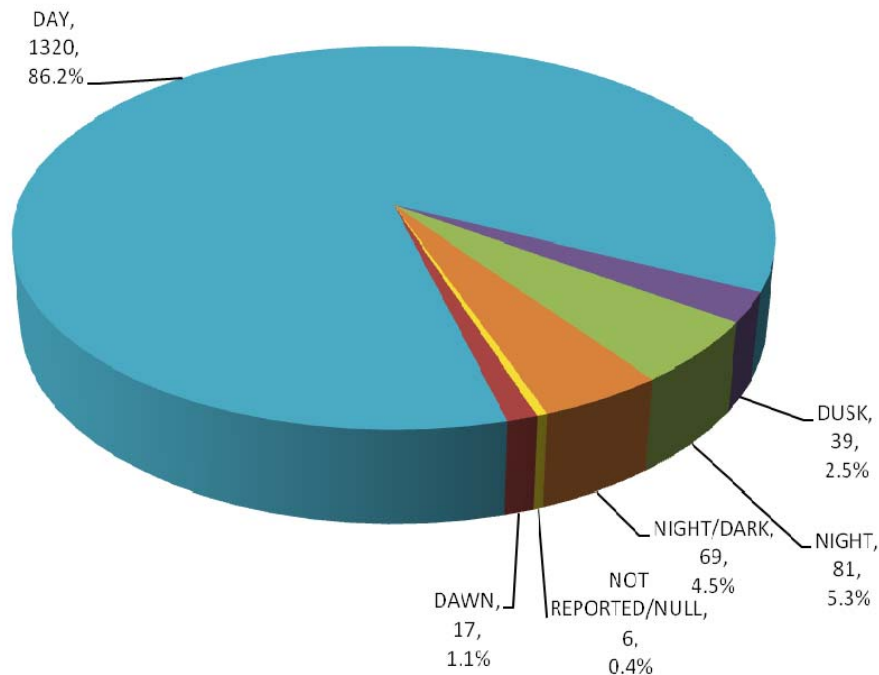
Figure 38. Part 91 Weather-related Citations by Weather Condition 2003–2007



Not mutually exclusive. Total number of part 91 weather citations = 1,960.

Source: NTSB Aviation Accident and Incident Database

Figure 39. Part 91 Weather-related Accidents by Light Condition 2003–2007



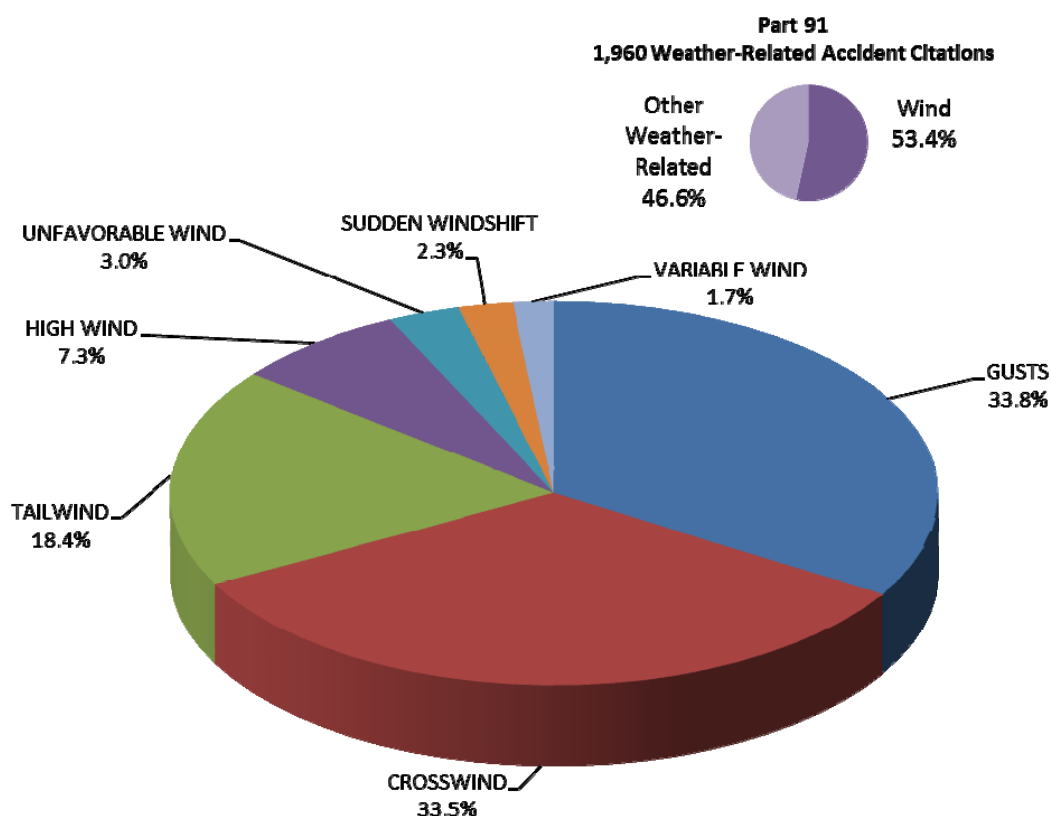
Total number of part 91 weather-related accidents = 1,532.

Source: NTSB Aviation Accident and Incident Database

4.2.2 Most Common Weather Factor for Part 91 Operation—Wind

Wind was the most common cause or contributing factor in part 91 weather-related accidents. Of the 1,960 part 91 weather-related citations, wind was cited as a cause or contributing factor 1,047 times during the study period (see figure 38 above). Wind also was the most common cause or contributing factor of part 91 operations, except for executive/corporate, air race/show, skydiving, and banner tow. The highest number of wind accident citations were for crosswind and gusts, followed by tailwind (see figure 40).

Figure 40. Breakdown of Part 91 Wind Citations 2003–2007



Not mutually exclusive. Total number of part 91 wind citations = 1,047.

Source: NTSB Aviation Accident and Incident Database

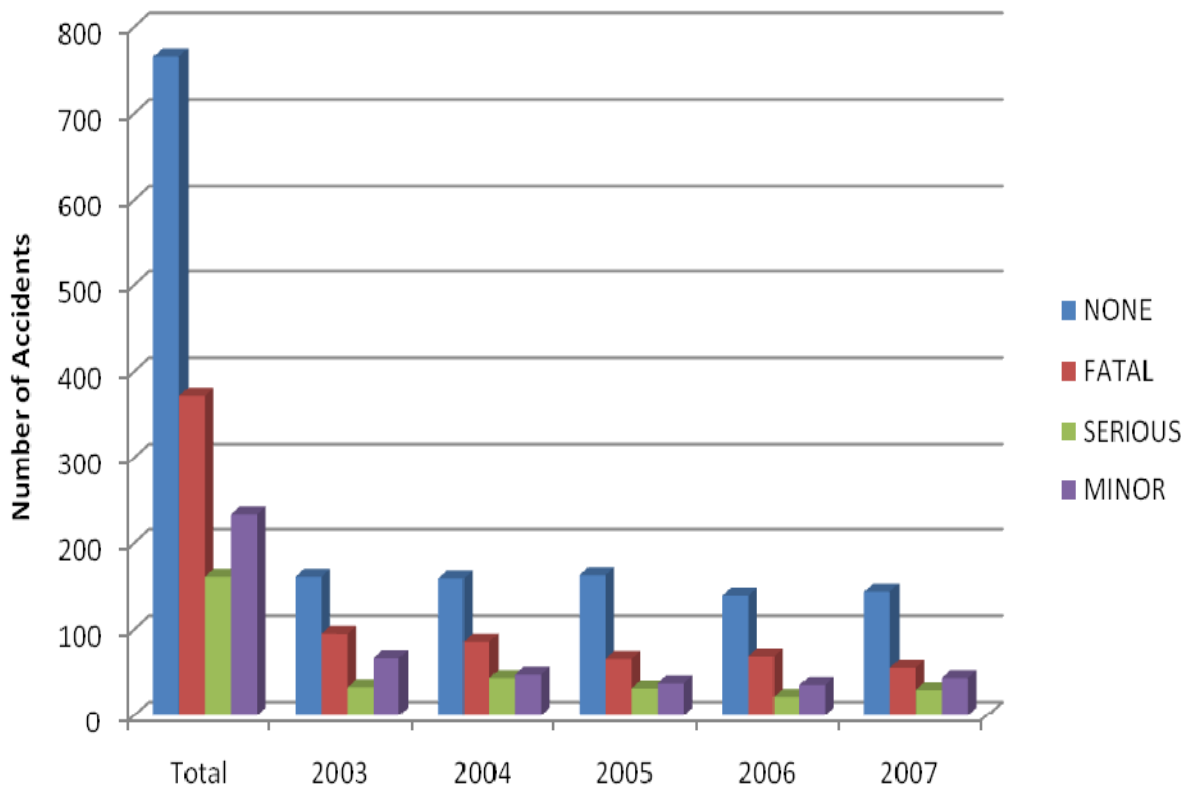
4.2.3 Injury Severity

From 2003 through 2007, 50 percent of the 1,532 part 91 weather-related accidents resulted in no injuries; however, there were 372¹⁷ part 91 weather-related accidents involving fatalities, 161 accidents with serious injuries, and 233 accidents with minor injuries. These accidents resulted in a total of 733 fatalities, 284 serious injuries, and 466 minor injuries. See appendix D to this study.

¹⁷ Injury accident counts represent the highest level of injury that occurred for each accident.

In 2007, there were 56 weather-related accidents that resulted in fatalities, a decrease of 41 percent from 2003, when there were 95 accidents involving fatalities (see figure 41). Minor injuries also decreased by 34.3 percent from 2003, while serious injuries remained relatively steady, averaging 32.2 percent per year.

Figure 41. Part 91 Weather-related Accidents by Injury Severity 2003–2007



Source: NTSB Aviation Accident and Incident Database

4.2.4 Pilot Qualifications

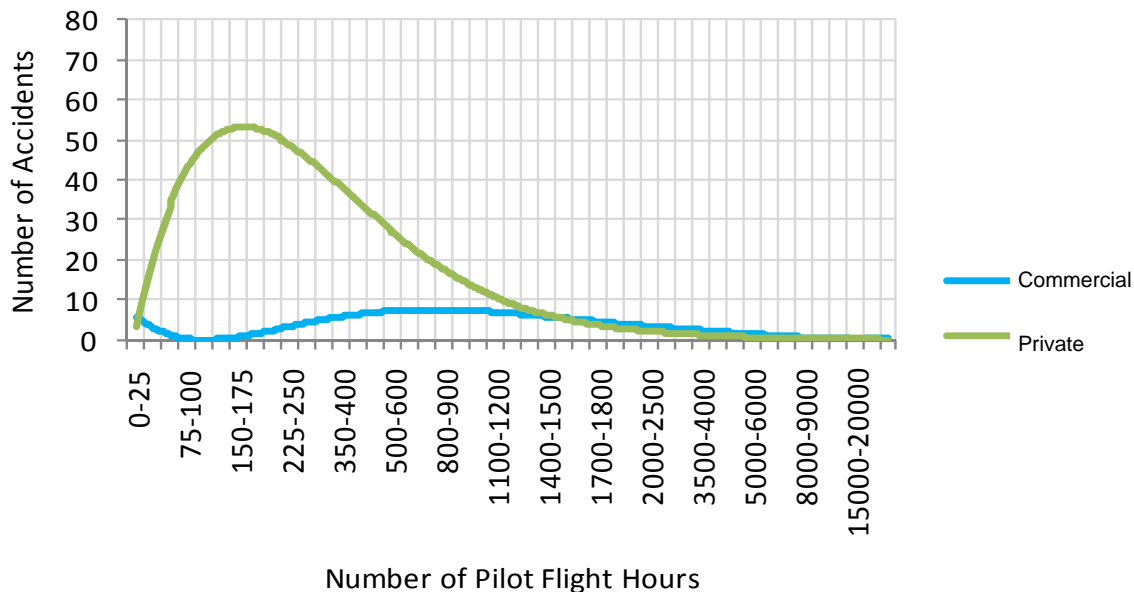
The qualifications and ratings held by the pilot or pilots involved may be a factor in an accident. Out of the 1,532 part 91 weather-related accidents, 179 of the pilots in command (PIC)¹⁸ involved held airline transport pilot (ATP) certificates, 460 held commercial pilot certificates, 773 held private pilot certificates, 5 held recreational pilot certificates, 90 held student pilot certificates, and 25 were not indicated.¹⁹

¹⁸ PIC information is based on NTSB data indicating that the pilot labeled as “pilot 1” is the PIC.

¹⁹ The accident data used to compile the pilot certification statistics in this report indicate the certificates and ratings held by the pilots involved in accidents, but does not necessarily indicate the certificate under which a pilot was operating at the time of an accident. For example, a pilot could hold a private pilot certificate with rotorcraft category rating, and a commercial pilot certificate with only an airplane rating. If the pilot were involved in an accident while flying a rotorcraft, the pilot would still be indicated as holding a commercial certificate, even though he or she was exercising privileges under the private pilot certificate at the time of the accident.

The experience of the pilot or pilots may also correlate to accident rates. Data analysis shows that private pilots who have accumulated a minimal number of flight hours without an instrument rating had the most number of weather-related accidents. The accident rate as a function of total flight time increases as the pilot accrues time, and subsequently declines. The probability of having a weather-related accident peaks for private pilots at approximately 175 to 225 hours of total flight time (see figure 42). Accident probability for commercial pilots peaks at approximately 700 to 1,200 hours total flight time.

Figure 42. Accident Rate as a Function of Pilot Flight Time 2003–2007



Source: NTSB Aviation Accident and Incident Database

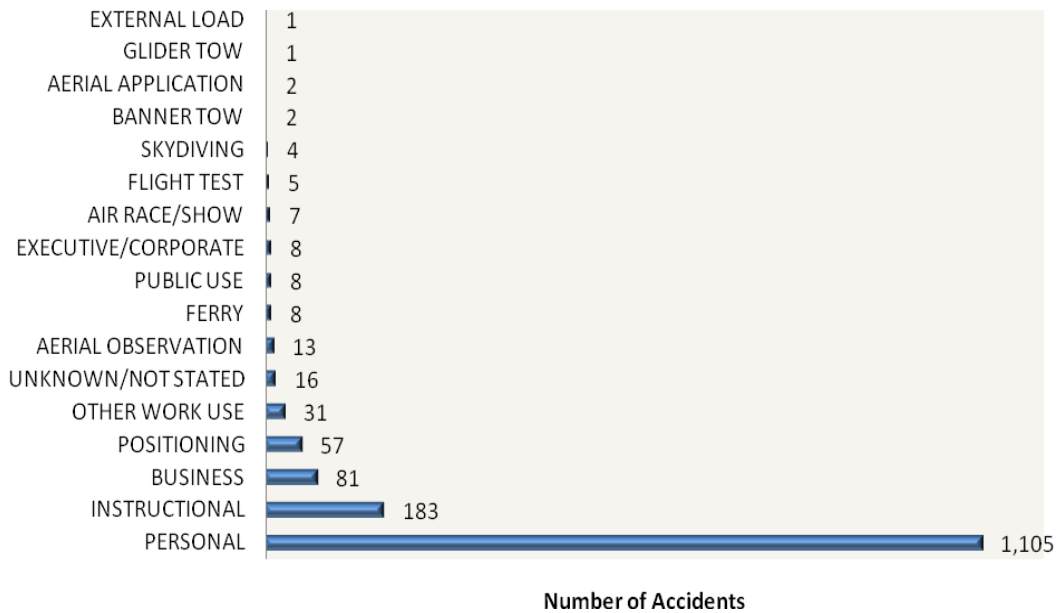
4.2.5 Part 91 Type of Operation

The majority of part 91 weather-related accidents (72.1 percent) occurred during personal operations, accounting for 1,105 accidents over the study period (see figure 43). Instructional flights (183) accounted for the second highest number of accidents (11.9 percent). Operations that accounted for less than one percent of part 91 accidents include aerial observation, ferry, public use, executive/corporate, air race/show, flight test, skydiving, banner tow, aerial application,²⁰ glider tow, and external load²¹.

²⁰ These reports are classified as part 91 as opposed to part 137.

²¹ These reports are classified as part 91 as opposed to part 133.

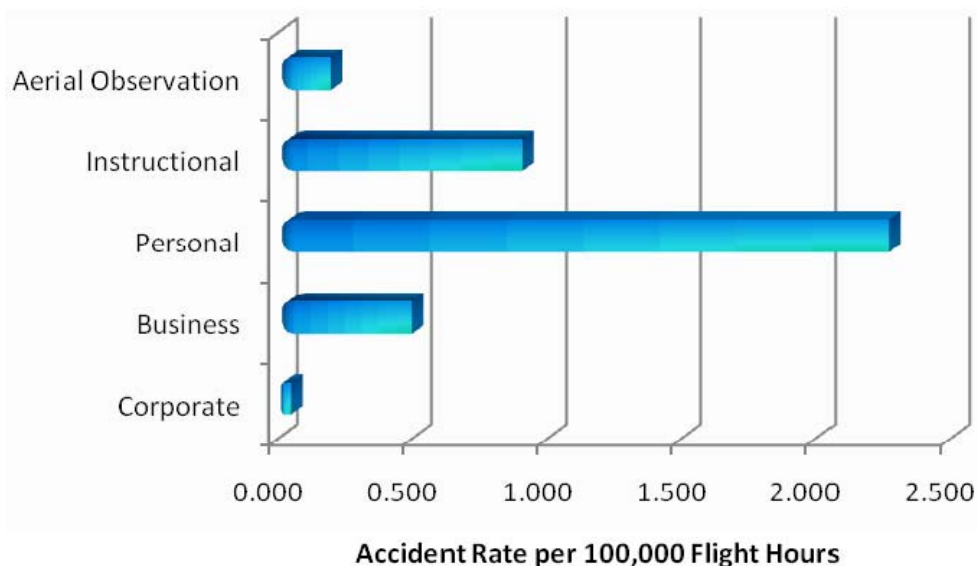
Figure 43. Part 91 Weather-related Accidents by Type of Operation 2003–2007



Source: NTSB Aviation Accident and Incident Database

ASIAS staff calculated the weather-related accident rate for aerial observation, instructional, personal, business, and corporate operations based on data available from the FAA Administrator’s Fact Book, which only provided the data for these specific part 91 operations. The rate of weather-related accidents for personal flights was 2.27 accidents per 100,000 flight hours (see figure 44). Aerial observation, instructional, business, and corporate all had weather-related accident rates less than 1 accident per 100,000 flight hours.

Figure 44. Part 91 Weather-related Accident Rate by Type of Operation 2003–2007



Source: FAA Administrator’s Fact Book November 2005, December 2006, and March 2009

4.2.6 Representative Accident Study (McMinnville Municipal Airport, McMinnville, Oregon); NTSB Accident Number SEA03LA036

Pilot Qualifications

The PIC held a private pilot certificate (without instrument rating) with 74 hours of total flight time, 5 flight hours in make and model, and 7 flight hours in the past 90 days at the time of the accident.

Accident Synopsis

The pilot, who was landing in gusty crosswinds, had already made one landing and was on the landing roll of his second when he encountered crosswinds that lifted the aircraft's left wing in the air. At the same time as the wing was being lifted, the aircraft started drifting toward the right side of the runway. As the pilot attempted to get the wing down using aileron deflection and tried to get the aircraft heading straight down the runway, it felt to him like the aircraft was going to cartwheel. He therefore decided to let the aircraft go off the side of the runway in the direction it was headed. After departing the runway, the aircraft encountered soft terrain, whereupon the nose gear dug in and the aircraft nosed over. According to the pilot, except for a minor nose wheel shimmy, there did not seem to be any problems with the aircraft's controls.

Probable Cause

The probable cause of the accident was the pilot's inadequate compensation for wind conditions and his failure to maintain directional control during the landing roll. Factors include gusty crosswinds and soft terrain in the area where the aircraft departed the side of the runway.

Findings

The NTSB found the following to be a cause or contributing factor in the accident study.

Occurrence # 1

LOSS OF CONTROL – ON GROUND/WATER

Phase of Operation: LANDING – ROLL

Event Seq #	Subject	Modifier	Personnel	Cause/Factor
1	Directional Control	Not Maintained	PIC	Cause
2	Compensation For Wind Conditions	Inadequate	PIC	Cause
3	Weather Condition	Crosswind		Factor
4	Weather Condition	Gusts		Factor

Occurrence # 2

ON GROUND/WATER ENCOUNTER WITH TERRAIN/WATER

Phase of Operation: LANDING – ROLL

Event Seq #	Subject	Modifier	Personnel	Cause/Factor
1	Terrain Condition	Soft		Factor

Commentary

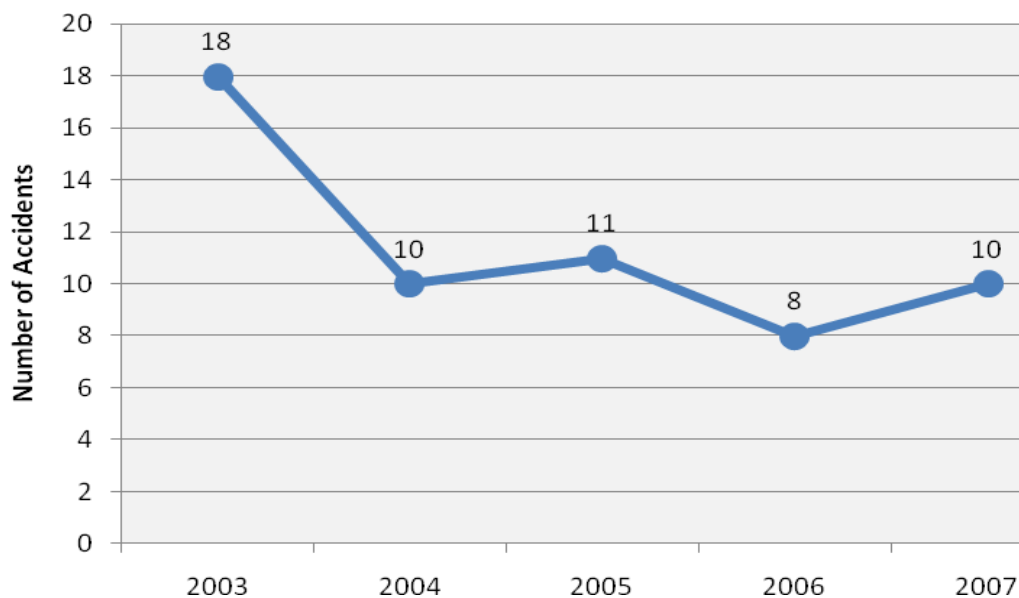
This accident represents one of the common accident scenarios involving wind in general aviation. Many of these wind-related accidents involved situations in which the pilots could not maintain control of the aircraft in windy conditions during either takeoff or landing.

4.3 PART 121—DOMESTIC, FLAG, AND SUPPLEMENTAL AIR CARRIER OPERATIONS

4.3.1 Part 121 Trends

Part 121 provides the operating rules for domestic, flag, and supplemental air carrier operations. There were 168 part 121 accidents from 2003 through 2007. Of those accidents, 57 (33.9 percent) were weather-related, resulting in 64 weather-related citations. Part 121 operations accounted for 3.3 percent of all weather-related accidents from 2003 through 2007. There were 18 part 121 weather-related accidents in 2003. The number of accidents decreased to 10 accidents in 2004 and remained relatively unchanged from 2005 to 2007 (see figure 45).

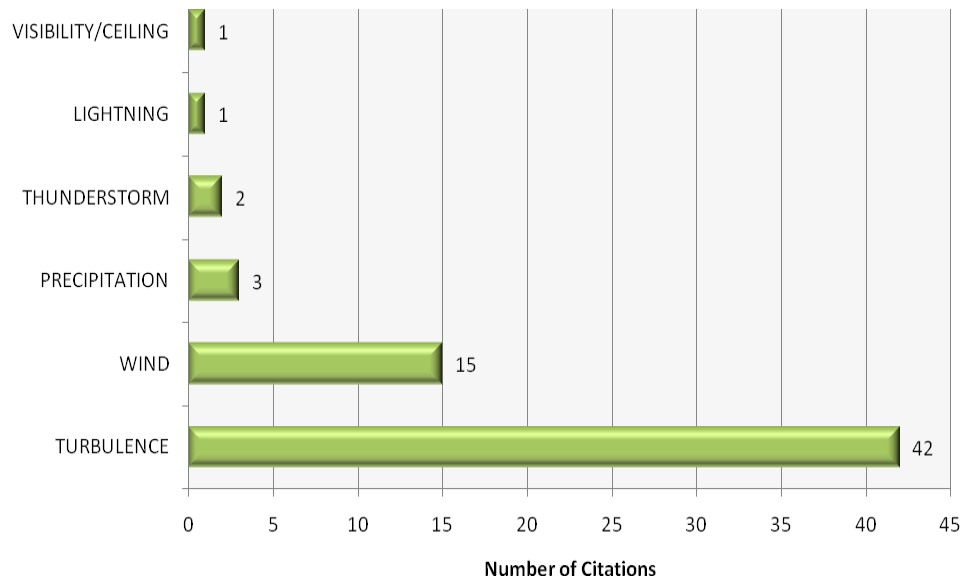
Figure 45. Part 121 Weather-related Accidents by Year 2003–2007



Source: NTSB Aviation Accident and Incident Database

The weather factors that contributed to part 121 accidents were turbulence, wind, precipitation, thunderstorms, lightning, and visibility/ceiling (see figure 46). During the timeframe of the study, 66.7 percent of all part 121 weather-related accidents occurred during the day, while 26.3 percent occurred at night or during night/dark conditions (see figure 47).

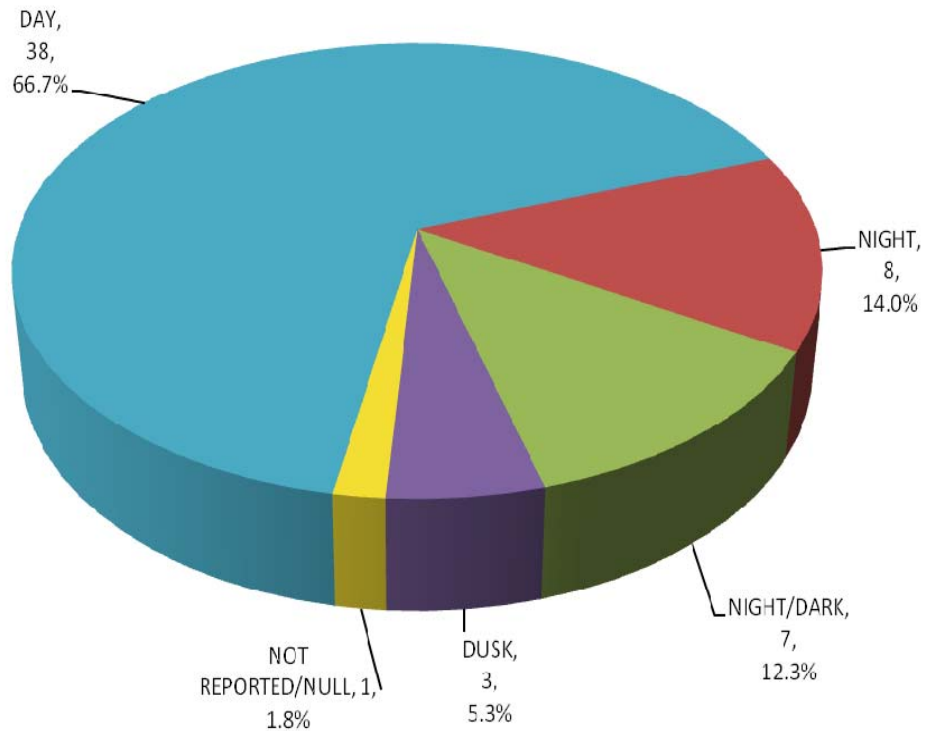
Figure 46. Part 121 Weather-related Citations by Weather Condition 2003–2007



Not mutually exclusive. Total number of part 121 weather citations = 64.

Source: NTSB Aviation Accident and Incident Database

Figure 47. Part 121 Weather-related Accidents by Light Condition 2003–2007



Not mutually exclusive. Total number of part 121 weather-related accidents = 57

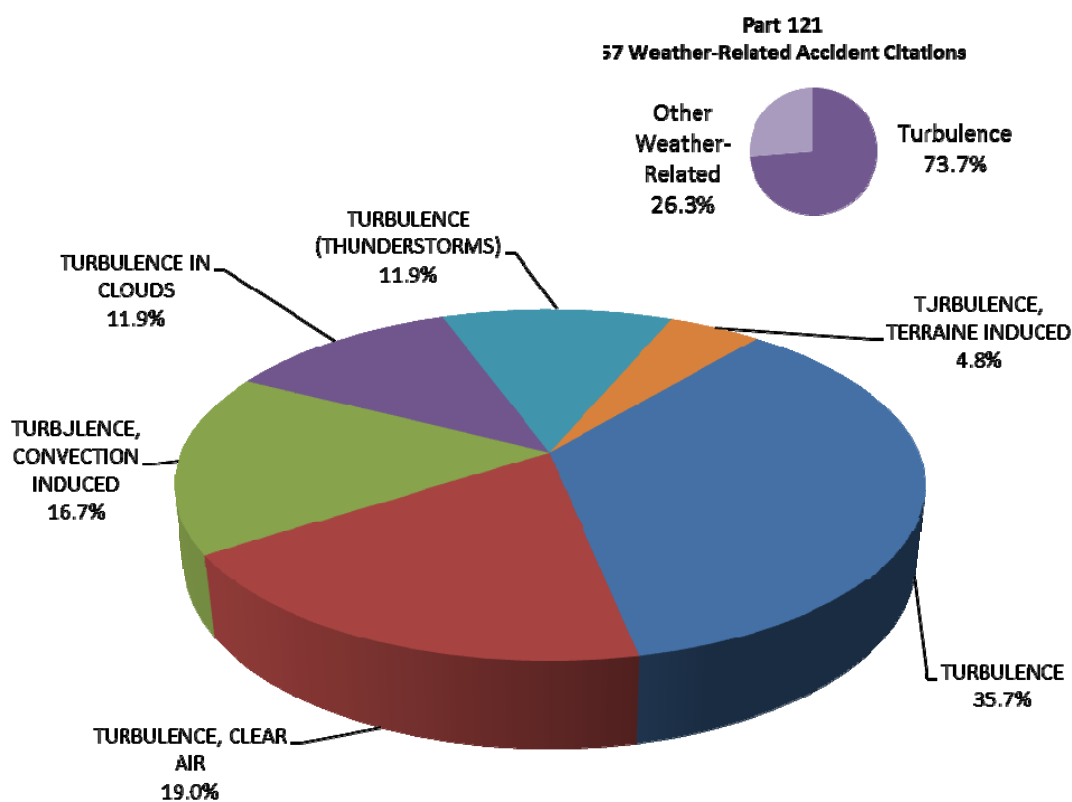
Source: NTSB Aviation Accident and Incident Database

4.3.2 Most Common Weather Factor for Part 121 Operations—Turbulence

Of the 57 part 121 weather-related accidents analyzed, turbulence was cited as a cause or contributing factor 42 times, yet turbulence accounted for only 5 percent of weather-related causes or contributing factors identified in accidents in the study. The following types of turbulence were included: clear air, convection-induced, thunderstorm-related, cloud-related, mountain wave, and terrain-induced turbulence (see figure 48). The NTSB defined all part 121 turbulence events as accidents because of the serious injury to flight attendants or passengers. None of the part 121 accidents resulted in damage to the aircraft.

Of the 42 turbulence citations representing 42 accidents, 39 resulted in injuries to at least 1 flight attendant, but only 6 accidents resulted in passenger injuries. ASIAs analysts conducted a case-by-case review of NTSB report narratives and found that the seatbelt sign was illuminated in 66.6 percent of the accidents, and in 38 percent, the flightcrew had told the flight attendants to take their seats. Of the six accidents involving passenger injuries, five occurred while the seatbelt sign was illuminated.

Figure 48. Breakdown of Part 121 Turbulence Citations 2003–2007



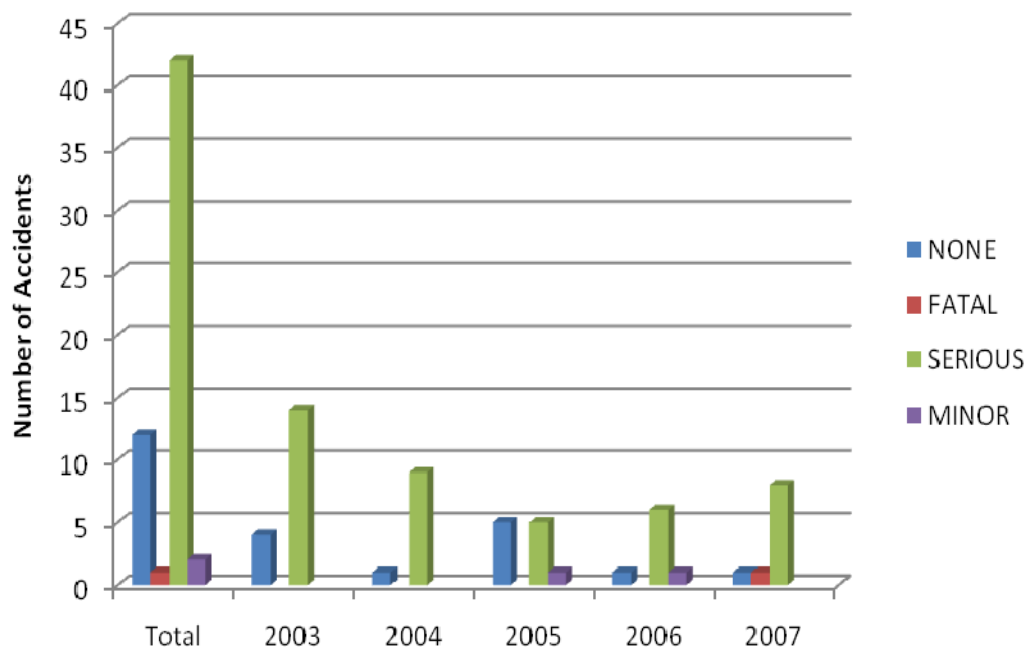
Not mutually exclusive. Total number of part 121 turbulence citations = 42.

Source: NTSB Aviation Accident and Incident Database

4.3.3 Injury Severity

There was only one fatal weather-related accident that occurred during the reporting period. From 2003 through 2007, there were 42 accidents with serious injuries and 2 accidents with minor injuries. These accidents resulted in 1 fatality, 45 serious injuries, and 23 minor injuries. In 2003, the highest recorded number of accidents with serious injuries was 14, but there were fewer than 10 accidents per year from 2004 to 2007 (see figure 49).

Figure 49. Part 121 Weather-related Accidents by Injury Severity 2003–2007



Source: NTSB Aviation Accident and Incident Database

4.3.4 Pilot Qualifications

The reports for all 57 weather-related accidents in part 121 that were studied included the qualifications of the pilots involved. In each accident, the PIC held an ATP certificate. In 55 accidents, second-in-command flightcrew member qualifications were reported, and 41 of those pilots held ATP certificates, while the remaining 14 pilots held commercial pilot certificates.

4.3.5 Representative Accident Study (Palestine, Texas); NTSB Accident Number FTW03LA121

Pilot Qualifications

The PIC held an ATP certificate and had accumulated 12,830 total flight hours, 4,050 flight hours in make and model, and 232 flight hours in the last 90 days.

Accident Synopsis

A Boeing 737 was deviating around weather in cruise flight at FL280 in visual meteorological conditions when the flight encountered severe turbulence. The flightcrew illuminated the “Fasten Seat Belt” sign for the entire flight. Before the turbulence encounter, the captain instructed the flight attendants to “leave the carts stowed” and to take their seats because of the probability of encountering turbulence.

Several minutes after the captain advised the flight attendants to be seated, the aircraft encountered severe turbulence with no preceding chop. The autopilot disconnected, and according to the flight data recorder, the maximum vertical acceleration parameter recorded was +2.16 g (minimum was 0.00 g). A flight attendant still trying to stow a beverage cart sustained a serious injury when the cart rolled into her right side and fractured her femur. Following the event, the flight diverted to another airport and landed without further incident.

Probable Cause

The probable cause of the accident was the airplane’s encounter with unforecasted clear air turbulence during cruise flight.

Findings

The NTSB found the following to be a cause or contributing factor in the accident study.

Occurrence # 1

IN FLIGHT ENCOUNTER WITH WEATHER

Phase of Operation: CRUISE

Event Seq #	Subject	Modifier	Personnel	Cause/Factor
1	Weather Condition	Turbulence, Clear Air		Cause

Commentary

Turbulence events represent a significant portion of part 121 weather-related accidents because part 121 operations are less susceptible to many of the weather conditions that prominently impact operations under other 14 CFR parts. Part 121 aircraft tend to operate at higher altitudes where severe clear air turbulence and thunderstorms with convective turbulence may be encountered.

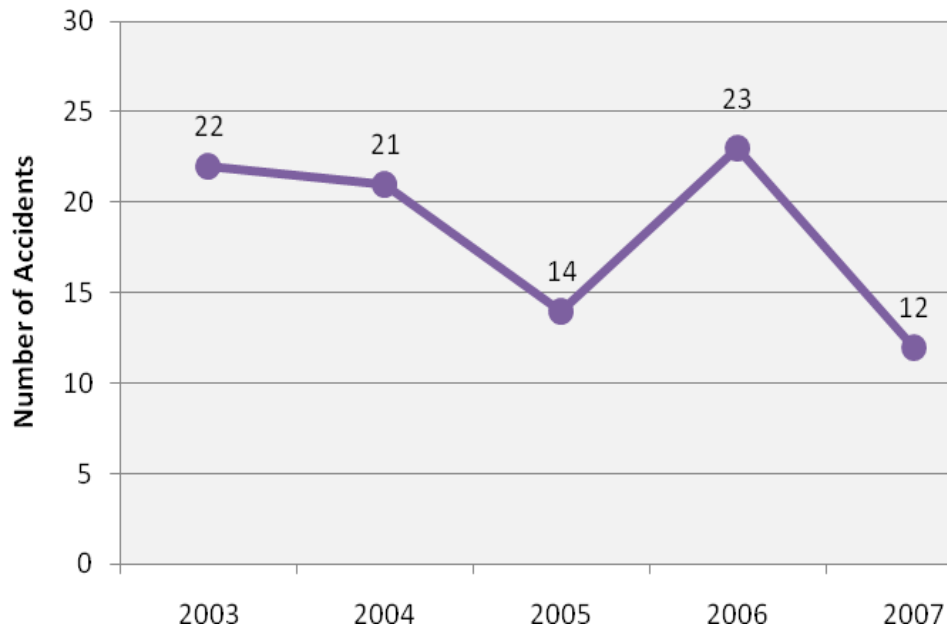
As stated previously, the NTSB classified most part 121 accidents involving turbulence as accidents not because the event resulted in damage to or total loss of the aircraft, but because the event resulted in serious injury to flight attendants. It should be noted that flight attendants often are not seated while performing their duties for a significant portion of most flights. In addition, flight attendants are not required crewmembers in other types of operations.

4.4 PART 135—COMMUTER AND ON-DEMAND AIR CARRIER OPERATIONS

4.4.1 Part 135 Trends

Part 135 provides the operating rules for commuter and on-demand air carrier operations. From 2003 through 2007, there were 321 accidents involving part 135 operations. Weather was cited as a cause or contributing factor in 92 of these accidents (28.7 percent), with 5.3 percent representing all weather-related accidents. In addition, these 92 accidents resulted in 128 citations of weather as a cause or contributing factor. There was an overall reduction of 45.5 percent in part 135 weather-related accidents from 2003 through 2007; however, there was a spike of 64.3 percent from 2005 to 2006 (see figure 50).

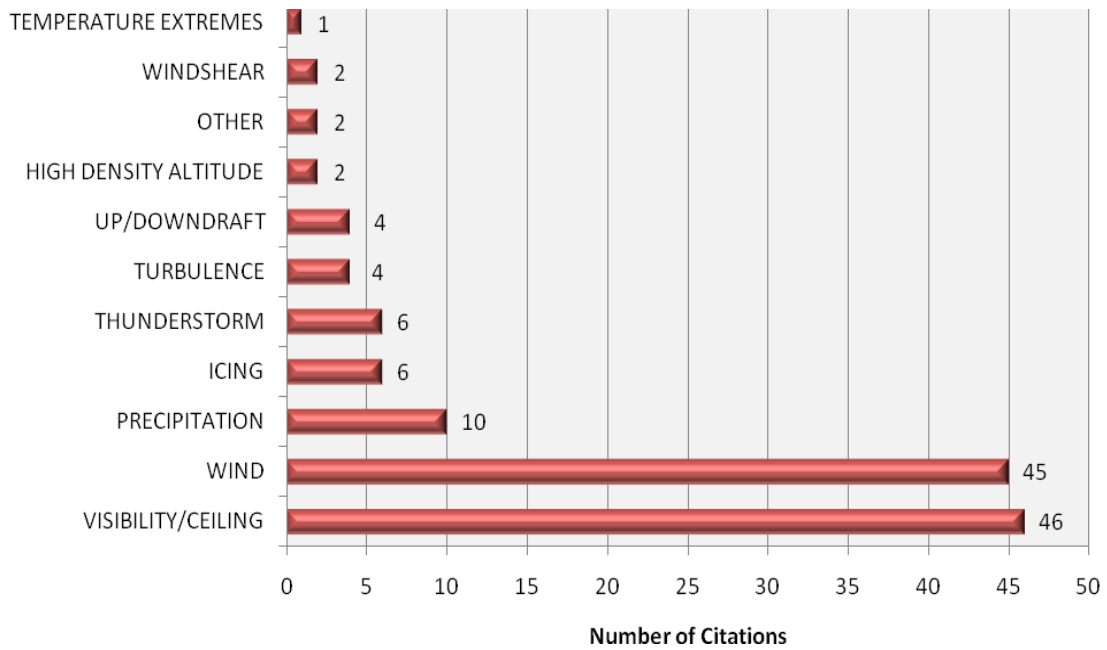
Figure 50. Part 135 Weather-related Accidents by Year 2003–2007



Source: NTSB Aviation Accident and Incident Database

The weather factors that contributed to part 135 accidents include visibility/ceiling, wind, precipitation, icing, thunderstorms, turbulence, updraft/downdraft, high density altitude, windshear, other, and temperature extremes (see figure 51). Most part 135 weather-related accidents occurred during the day (70.7 percent), while 21 percent occurred during night or night/dark conditions (see figure 52).

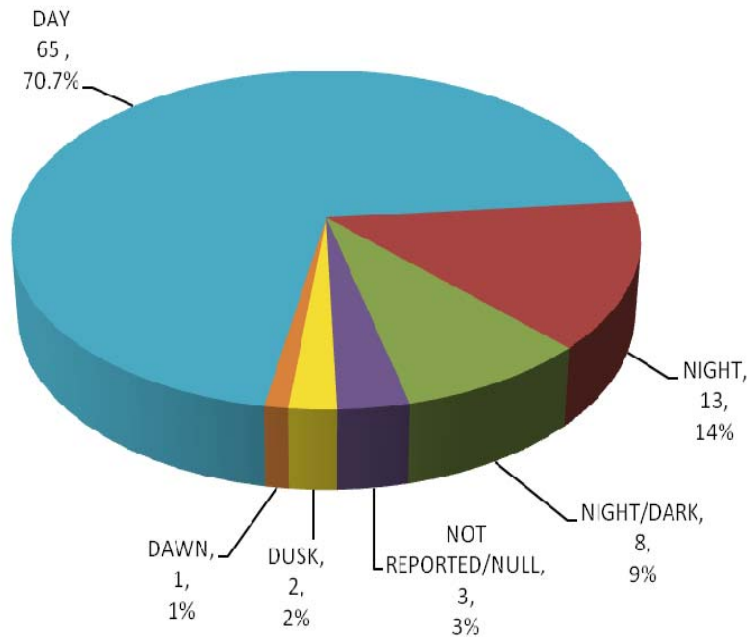
Figure 51. Part 135 Weather-related Citations by Weather Condition 2003–2007



Not mutually exclusive. Total number of part 135 weather citations = 128.

Source: NTSB Aviation Accident and Incident Database

Figure 52. Part 135 Weather-related Accidents by Light Condition 2003–2007



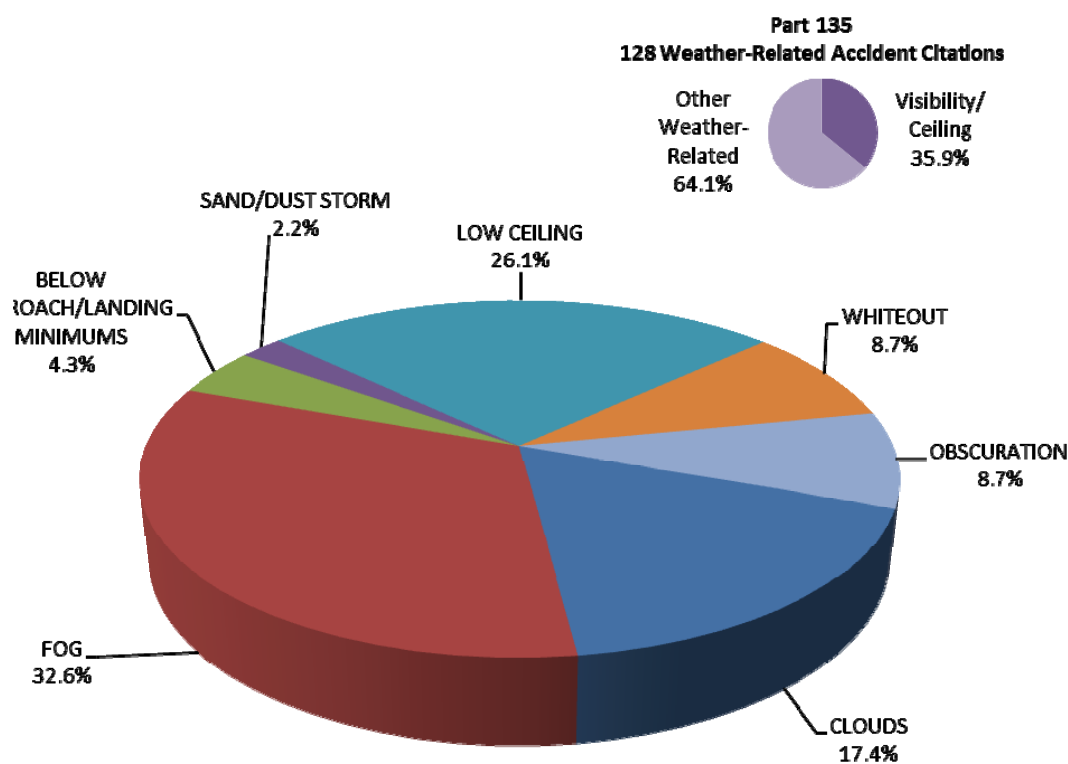
Not mutually exclusive. Total number of part 135 weather-related accidents = 92

Source: NTSB Aviation Accident and Incident Database

4.4.2 Most Common Weather Factor for Part 135 Operations—Visibility/Ceiling

The most common weather factor found in part 135 operations was visibility/ceiling accidents, closely followed by wind, which had one less citation. Visibility/ceiling was cited 46 times as a cause or contributing factor in part 135 accidents from 2003 through 2007 (see figure 53). A case-by-case review determined that most of these accidents were the result of inadvertent visual flight rules (VFR) flight into instrument meteorological conditions, the improper execution of instrument approach procedures, and flight into known adverse weather.

Figure 53. Breakdown of Part 135 Visibility/Ceiling Citations 2003–2007



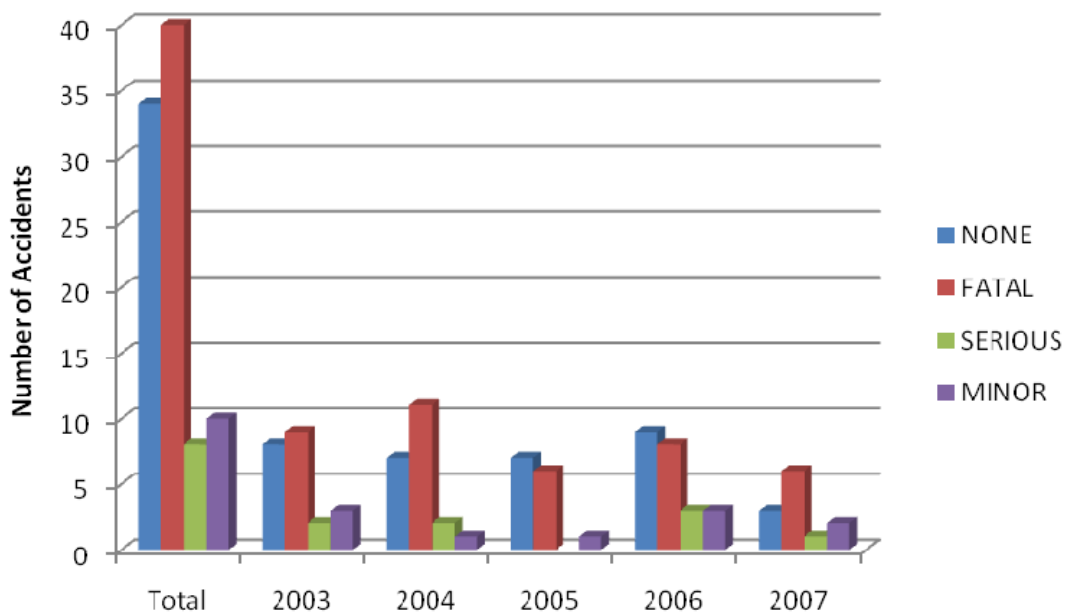
Not mutually exclusive. Total number of part 135 visibility/ceiling citations = 46

Source: NTSB Aviation Accident and Incident Database

4.4.3 Injury Severity

Of the 92 accidents from 2003 through 2007, 40 were fatal, 8 involved serious injuries, and 10 involved minor injuries. These accidents resulted in a total of 81 fatalities, 27 serious injuries, and 44 minor injuries. There was an average of 8 fatal accidents per year from 2003 through 2007; however, there was a significant increase in the number of fatal accidents in 2004, which saw 11 fatal weather-related accidents. In addition, there were 10 minor injuries from 2003 through 2007 (see figure 54).

Figure 54. Part 135 Weather-related Accidents by Injury Severity 2003–2007



Source: NTSB Aviation Accident and Incident Database

4.4.4 Pilot Qualifications

Out of the 92 part 135 weather-related accidents, 38 of the PICs involved held ATP certificates and 52 held commercial pilot certificates. For two accidents, the accident reports did not indicate the certificate(s) held by the PIC.

4.4.5 Representative Accident Study (New London, Connecticut); NTSB Accident Number NYC06FA137

Pilot Qualifications

The PIC of the LearJet 35 held an ATP certificate, flight instructor certificate, and type ratings in the Learjet, G-1159, and CA-212. The PIC had 18,750 hours of total flight time and 7,500 flight hours in make and model. The second in command also held ATP and flight instructor certificates and a Learjet 35 type rating. The second in command had 3,255 hours of total flight time.

Accident Synopsis

The flight was being operated on an instrument flight plan. The flightcrew obtained reported weather conditions via Automatic Terminal Information Services, which stated that there was 2 statute miles visibility and a broken ceiling at 100 feet above ground level (AGL). The flightcrew then initiated the instrument approach and subsequently confirmed that they had visual contact with the ground. The flightcrew continued to descend, when they realized that the aircraft was descending at a faster rate than the approach depicted. The aircraft eventually descended into the water. This accident resulted in two fatalities and three minor injuries.

Probable Cause

The probable cause of the accident was the flightcrew's failure to properly monitor the aircraft altitude resulted in the captain's inadvertent descent of the aircraft into water. Contributing to the accident were the foggy weather conditions and the captain's decision to descend below the decision height (DH) without sufficient visual cues.

Findings

The NTSB found the following to be a cause or contributing factor in the accident study.

Occurrence # 1

IN FLIGHT COLLISION WITH TERRAIN/WATER

Phase of Operation: APPROACH – FAF/OUTER MARKER TO THRESHOLD (IFR)

Event Seq #	Subject	Modifier	Personnel	Cause/Factor
1	Altitude	Not Maintained	Flightcrew	Finding
1	Diverted Attention		Flightcrew	Cause
2	Visual Illusion		PIC	Finding
3	Weather Condition	Fog		Factor
3	IFR Procedure	Not Followed	PIC	Factor
4	Terrain Condition	Water		Finding

Commentary

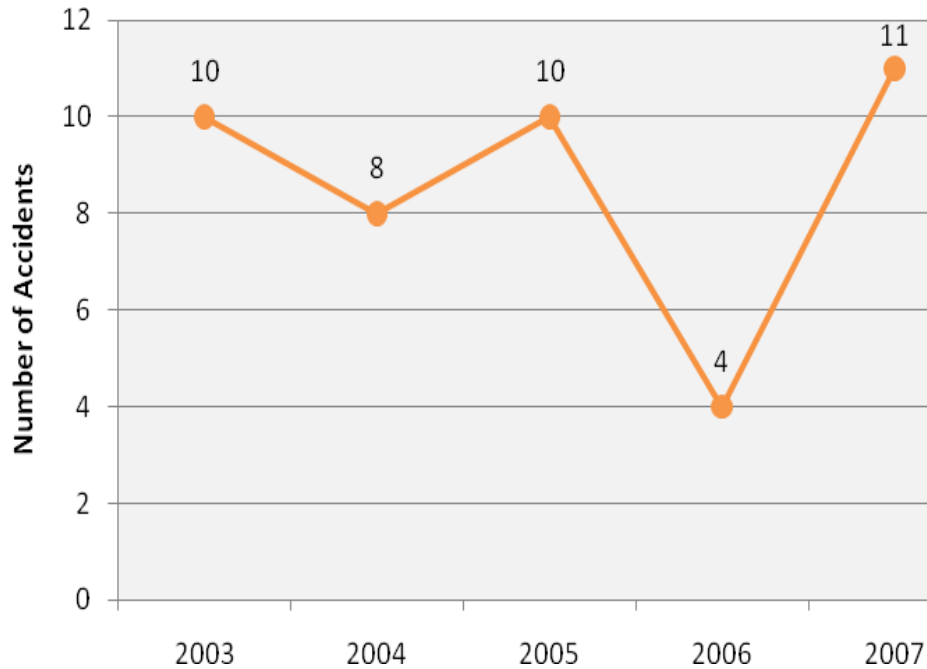
There were a significant number of accidents resulting from pilots not properly following instrument approach procedures. These accidents were the result of improperly descending below the minimum descent altitude or DH, not executing a missed approach when necessary, or improperly executing a missed approach.

4.5 PART 137—AGRICULTURAL AIRCRAFT OPERATIONS

4.5.1 Part 137 Trends

Part 137 provides the operating rules for aircraft that dispense substances for agricultural purposes, such as plant nourishment or pesticides. From 2003 through 2007, there were 387 accidents involving part 137 operations and, of those, 43 were weather-related accidents, which represents 2.5 percent of all weather-related accidents. Weather contributed to 11.1 percent of the part 137 accidents from 2003 through 2007. The least number of part 137 weather-related accidents occurred in 2006 (4 accidents), yet all other years studied had 8 or more accidents (see figure 55 below).

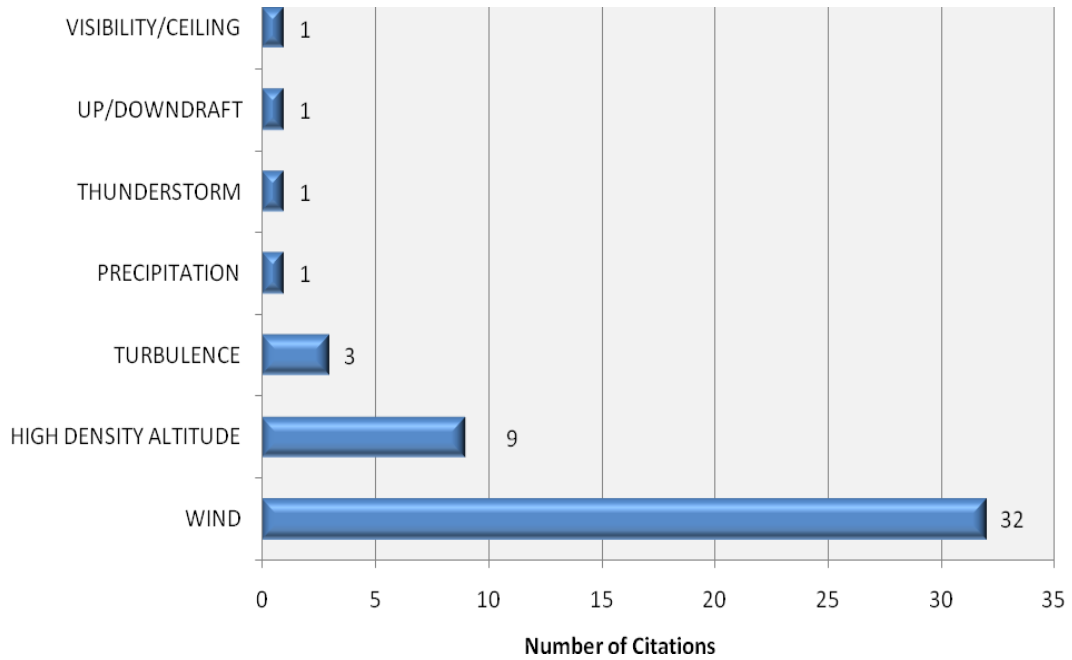
Figure 55. Part 137 Weather-related Accidents by Year 2003–2007



Source: NTSB Aviation Accident and Incident Database

Weather factors that contributed to part 137 accidents include wind, high density altitude, turbulence, precipitation, thunderstorms, updraft/downdraft, and visibility/ceiling (see figure 56). Nearly all part 137 accidents occurred during the day (97.7 percent). Only one accident occurred at dawn (2.3 percent) (see figure 57).

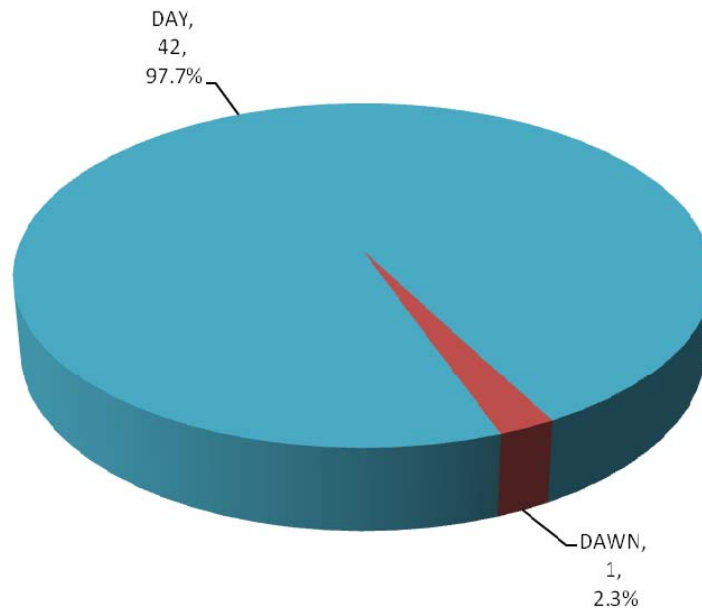
Figure 56. Part 137 Weather-related Citations by Weather Condition 2003–2007



Not mutually exclusive. Total number of part 135 weather citations = 48.

Source: NTSB Aviation Accident and Incident Database

Figure 57. Part 137 Weather-related Accidents by Light Condition 2003–2007



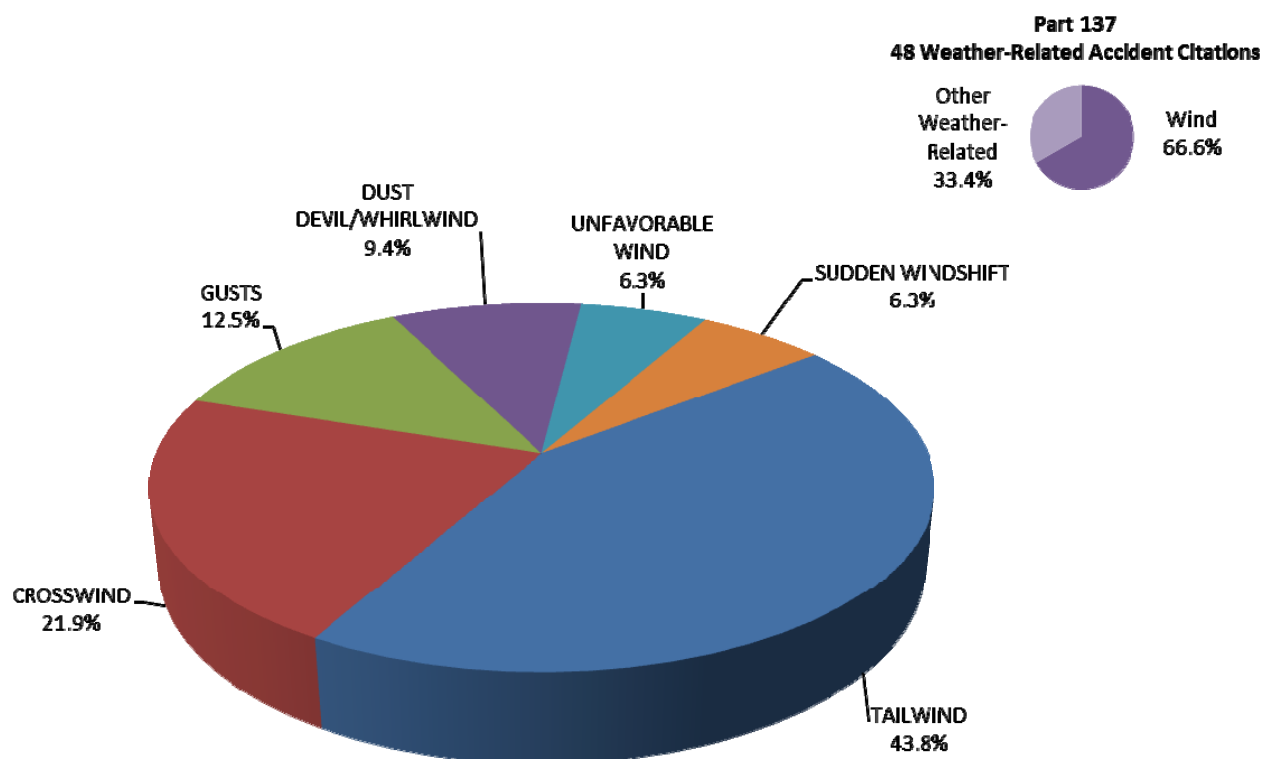
Not mutually exclusive. Total number of part 137 weather-related accidents = 43

Source: NTSB Aviation Accident and Incident Database

4.5.2 Most Common Weather Factor for Part 137 Operations—Wind

Wind was the most common factor in weather-related accidents for part 137 operations. In the NTSB reports, of the 43 weather-related accidents, wind was cited as a cause or contributing factor 32 times in accidents from 2003 through 2007, averaging 6.4 citations per year. In 2007, nine wind citations occurred, making it the most for the study period. Tailwinds accounted for 43.8 percent of the wind citations from 2003 through 2007, while crosswinds accounted for 21.9 percent (see figure 58).

Figure 58. Breakdown of Part 137 Wind Citations 2003–2007



Not mutually exclusive. Total number of part 137 wind citations = 32.

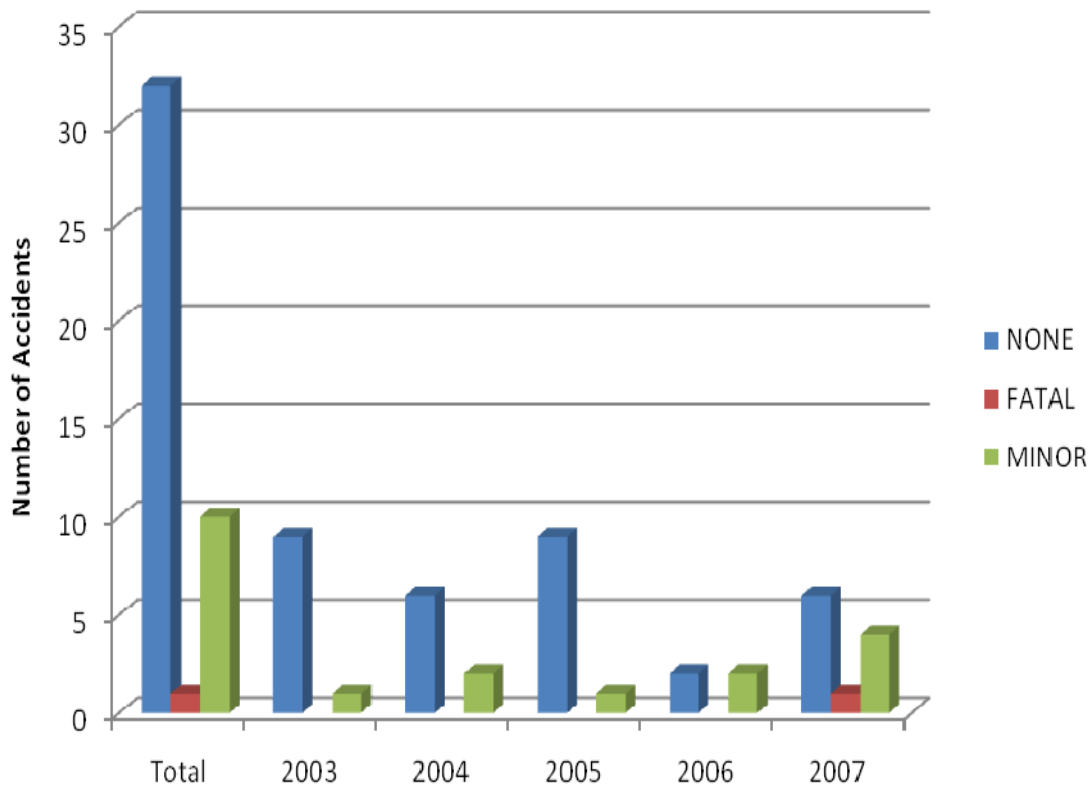
Source: NTSB Aviation Accident and Incident Database

4.5.3 Injury Severity

The majority of part 137 accidents had no injuries (see figure 59). There was one fatal part 137 weather-related accident from 2003 through 2007, 10 accidents with minor injuries, and no accidents with serious injuries. These accidents resulted in the same number of injuries (10).

Part 137 operations had the fewest number of weather-related injuries when compared with part 91, 121, and 135 operations.

Figure 59. Part 137 Weather-related Accidents by Injury Severity 2003–2007



Source: NTSB Aviation Accident and Incident Database

4.5.4 Pilot Qualifications

The reports, which contain all 43 weather-related accidents in part 137 that were studied, include the qualifications of the each PIC involved. In two of the accidents, the PICs involved held ATP certificates. In the remaining 41 accidents, the PICs held commercial pilot certificates.

4.5.5 Representative Accident Study (McGehee, Arkansas); NTSB Accident Number CHI03LA174

Pilot Qualifications

The PIC held a commercial pilot certificate, and had 1,482 total flight hours and 60 flight hours in make and model.

Accident Synopsis

On July 14, 2003, a Cessna CE-188 sustained substantial damage when it veered off the runway while landing. The PIC was operating under VFR without a flight plan. The PIC veered off the runway into a ditch because of a 5 knot or better quartering tailwind. There were no injuries resulting from this accident.

Probable Cause

The probable cause of the accident was the PIC's failure to maintain directional control of the airplane during landing. Contributing factors to the accident were the tailwind condition, the PIC's selection of the wrong runway on which to land, and the proximity of the ditch to the runway.

Findings

The NTSB found the following to be a cause or contributing factor in the accident study:

Occurrence # 1

LOSS OF CONTROL – ON GROUND/WATER

Phase of Operation: LANDING – ROLL

Event Seq #	Subject	Modifier	Personnel	Cause/Factor
1	Weather Condition	Tailwind		Factor
1	Wrong Runway	Selected	PIC	Factor
2	Directional Control	Not Maintained	PIC	Cause

Occurrence # 2

ON GROUND/WATER ENCOUNTER WITH TERRAIN/WATER

Phase of Operation: LANDING – ROLL

Event Seq #	Subject	Modifier	Personnel	Cause/Factor
1	Terrain Condition	Ditch		Factor

Commentary

The majority of part 137 wind-related accidents occurred when the pilot departed or landed with a tailwind or crosswind. In part 137 accidents studied, the pilot subsequently failed to either maintain directional control or sufficient terrain clearance. The majority of part 137 aircraft are tailwheel aircraft, which are more susceptible to weathervaning and ground looping than tricycle gear aircraft. Part 137 operations also tend to use relatively short, narrow runways, creating a narrower margin for error during takeoff and landing.

APPENDIX A—ACRONYMS

14 CFR	Title 14, Code of Federal Regulations
AGL	above ground level
ASIAS	Aviation Safety Information Analysis and Sharing
ATP	airline transport pilot
DH	decision height
FAA	Federal Aviation Administration
IMC	instrument meteorological conditions
NTSB	National Transportation Safety Board
PIC	pilot in command
UNICOM	Universal Communication
VFR	visual flight rules

APPENDIX B—DEFINITIONS

Aerial application

The operation of aircraft for the purposes of dispensing any substances required for agriculture, health, forestry, seeding, firefighting, and insect control purposes. (Reference: National Transportation Statistics, Appendix B—Glossary; Bureau of Transportation Statistics.)

Aerial observation

Any use of an aircraft for aerial mapping and photography, surveying, patrolling, fish spotting, search and rescue, hunting, sightseeing, or highway traffic advisory not included under 14 CFR part 135. (Reference: National Transportation Statistics, Appendix B—Glossary; Bureau of Transportation Statistics.)

Business operation

Use of an aircraft for business or business combined with pleasure, or for attending a convention, conference, or seminar. (Reference: National Transportation Statistics, Appendix B—Glossary; Bureau of Transportation Statistics.)

Clear air turbulence

Clear air turbulence is encountered outside of cloud formations at higher altitudes and is caused by the jetstream. (Reference: FAA Advisory Circular 00–06, Aviation Weather Turbulence Definitions.)

Commuter operation

Any scheduled operation conducted by any person operating one of the following types of aircraft with a frequency of operations of at least five round trips per week on at least one route between two or more points according to the published flight schedules:

- (1) Airplanes, other than turbojet powered airplanes, having a maximum passenger-seat configuration of 9 seats or less, excluding each crewmember seat, and a maximum payload capacity of 7,500 pounds or less; or
- (2) Rotorcraft.

(Reference: 14 CFR part 119.)

Convective turbulence

Convective turbulence is caused by the uneven heating of the Earth's surface, which causes air to both ascend and descend. (Reference: FAA Advisory Circular 00–06, Aviation Weather Turbulence Definitions.)

Crewmember

A person assigned to perform duty in an aircraft during flight time. (Reference: 14 CFR part 1.)

Domestic operation

Any scheduled operation conducted by any person operating any airplane described in paragraph (1) of this definition at locations described in paragraph (2) of this definition:

- (1) Airplanes:
 - (i) Turbojet-powered airplanes;
 - (ii) Airplanes having a passenger-seat configuration of more than 9 passenger seats, excluding each crewmember seat; or
 - (iii) Airplanes having a payload capacity of more than 7,500 pounds.
- (2) Locations:
 - (i) Between any points within the 48 contiguous States of the United States or the District of Columbia; or
 - (ii) Operations solely within the 48 contiguous States of the United States or the District of Columbia; or
 - (iii) Operations entirely within any State, territory, or possession of the United States; or
 - (iv) When specifically authorized by the Administrator, operations between any point within the 48 contiguous States of the United States or the District of Columbia and any specifically authorized point located outside the 48 contiguous States of the United States or the District of Columbia.

(Reference: 14 CFR part 119.)

Executive/Corporate operation

The use of aircraft owned or leased, and operated by a corporate or business firm for the transportation of personnel or cargo in furtherance of the corporation's or firm's business, and which are flown by pilots for compensation. (Reference: Bureau of Transportation Statistics Web site (www.bts.gov) dictionary.)

Fatal injury

Any injury that results in death within 30 days of the accident. (Reference: 49 CFR part 830.)

Flag operation

Any scheduled operation conducted by any person operating any airplane described in paragraph (1) of this definition at the locations described in paragraph (2) of this definition:

- (1) Airplanes:
 - (i) Turbojet-powered airplanes;

(ii) Airplanes having a passenger-seat configuration of more than 9 passenger seats, excluding each crewmember seat; or

(iii) Airplanes having a payload capacity of more than 7,500 pounds.

(2) Locations:

(i) Between any point within the State of Alaska or the State of Hawaii or any territory or possession of the United States and any point outside the State of Alaska or the State of Hawaii or any territory or possession of the United States, respectively; or

(ii) Between any point within the 48 contiguous States of the United States or the District of Columbia and any point outside the 48 contiguous States of the United States and the District of Columbia.

(iii) Between any point outside the United States and another point outside the United States.

(Reference: 14 CFR part 119.)

Flightcrew member

A pilot, flight engineer, or flight navigator assigned to duty in an aircraft during flight time.

(Reference: 14 CFR part 1.)

Ground loop

An involuntary, uncontrolled (abrupt) turn of an aircraft, while moving along the ground (that is, ground taxiing or moving on the takeoff or landing run). (Reference: National Transportation Safety Board Coding Manual.)

In-flight encounter with weather

Weather encountered that is not normal to the intended phase of operation. (Reference: National Transportation Safety Board Coding Manual.)

Instructional flying

Flying under the supervision of a flight instructor (excludes proficiency flying). (Reference: National Transportation Statistics, Appendix B—Glossary; Bureau of Transportation Statistics.)

Minor injury

Any injury that is not serious or fatal. (Reference: 49 CFR part 830.)

Mountain wave turbulence

Mountain wave turbulence is a disturbance in the airflow on the lee side of a mountain and is often accompanied by lenticular or rotor clouds. (Reference: FAA Advisory Circular 00-06, Aviation Weather Turbulence Definitions.)

Night

The time between the end of evening civil twilight and the beginning of morning civil twilight, as published in the American Air Almanac, converted to local time. (Reference: 14 CFR part 1.)

On-demand operation

Any operation for compensation or hire that is one of the following:

- (1) Passenger-carrying operations conducted as a public charter under 14 CFR part 380 or any operations in which the departure time, departure location, and arrival location are specifically negotiated with the customer or the customer's representative that are any of the following types of operations:
 - (i) Common carriage operations conducted with airplanes, including turbojet-powered airplanes, having a passenger-seat configuration of 30 seats or fewer, excluding each crewmember seat, and a payload capacity of 7,500 pounds or less, except that operations using a specific airplane that is also used in domestic or flag operations and that is so listed in the operations specifications as required by § 119.49(a)(4) for those operations are considered supplemental operations;
 - (ii) Noncommon or private carriage operations conducted with airplanes having a passenger-seat configuration of less than 20 seats, excluding each crewmember seat, and a payload capacity of less than 6,000 pounds; or
 - (iii) Any rotorcraft operation.
- (2) Scheduled passenger-carrying operations conducted with one of the following types of aircraft with a frequency of operations of less than five round trips per week on at least one route between two or more points according to the published flight schedules:
 - (i) Airplanes, other than turbojet powered airplanes, having a maximum passenger-seat configuration of 9 seats or less, excluding each crewmember seat, and a maximum payload capacity of 7,500 pounds or less; or
 - (ii) Rotorcraft.
- (3) All-cargo operations conducted with airplanes having a payload capacity of 7,500 pounds or less, or with rotorcraft.

(Reference: 14 CFR part 119.)

Personal flying

Flying by individuals in their own or rented aircraft for pleasure, or personal transportation not in furtherance of their occupation or company business. (Reference: Bureau of Transportation Statistics Web site (www.bts.gov) dictionary.)

Serious injury

Any injury that (1) requires hospitalization for more than 48 hours, commencing within 7 days from the date of injury was received; (2) results in a fracture of any bone (with the exception of simple fracture); (3) causes severe hemorrhages, or nerve, muscle, or tendon damage; (4) involves any internal damage; or (5) involves second or third degree burns, or any other burn affecting more than 5 percent of the body surface. (Reference: 49 CFR part 830.)

Supplemental operation

Any common carriage operation for compensation or hire conducted with any airplane described in paragraph (1) of this definition that is a type of operation described in paragraph (2) of this definition:

(1) Airplanes:

- (i) Airplanes having a passenger-seat configuration of more than 30 seats, excluding each crewmember seat;
- (ii) Airplanes having a payload capacity of more than 7,500 pounds; or
- (iii) Each propeller-powered airplane having a passenger-seat configuration of more than 9 seats and less than 31 seats, excluding each crewmember seat, that is also used in domestic or flag operations and that is so listed in the operations specifications as required by § 119.49(a)(4) for those operations; or
- (iv) Each turbojet powered airplane having a passenger seat configuration of 1 or more and less than 31 seats, excluding each crewmember seat, that is also used in domestic or flag operations and that is so listed in the operations specifications as required by § 119.49(a)(4) for those operations.

(2) Types of operation:

- (i) Operations for which the departure time, departure location, and arrival location are specifically negotiated with the customer or the customer's representative;
- (ii) All-cargo operations; or
- (iii) Passenger-carrying public charter operations conducted under 14 CFR part 380.

(Reference: 14 CFR part 119.)

Terrain-induced turbulence

Terrain-induced turbulence is a form of mechanical turbulence in which the normal air flow is disrupted by terrain. The wind speed and the unevenness of the terrain affect the degree of turbulence. (Reference: FAA Advisory Circular 00-06, Aviation Weather Turbulence Definitions.)

APPENDIX C—GROUPING CHARTS

Subject Modifier Groupings

CATEGORY	SUBJECT MODIFIER
CARBURETOR ICING CONDITIONS	
	CARBURETOR ICING CONDITIONS
HIGH DENSITY ALTITUDE	
	HIGH DENSITY ALTITUDE
ICING	
	ICING CONDITIONS
LIGHTNING	
	LIGHTNING
	LIGHTNING STRIKE
OTHER	
	OTHER
PRECIPITATION	
	DRIZZLE/MIST
	HAIL
	RAIN
	SNOW
TEMPERATURE EXTREMES	
	TEMPERATURE EXTREMES
	TEMPERATURE, HIGH
	TEMPERATURE, LOW
THERMAL LIFT	
	NO THERMAL LIFT
	THERMAL LIFT
THUNDERSTORM	
	THUNDERSTORM
	THUNDERSTORM, OUTFLOW
	MICROBURST/DRY
	MICROBURST/WET
TURBULENCE	
	TURBULENCE, CLEAR AIR
	TURBULENCE, CONVECTION INDUCED
	MOUNTAIN WAVE
	TURBULENCE IN CLOUDS
	TURBULENCE (THUNDERSTORMS)
	TURBULENCE, TERRAIN INDUCED
	TURBULENCE

CATEGORY	SUBJECT MODIFIER
UPDRAFT/DOWNDRAFT	
	UPDRAFT
	DOWNDRAFT
VISIBILITY/CEILING	
	CLOUDS
	FOG
	OBSCURATION
	HAZE/SMOKE
	WHITEOUT
	LOW CEILING
	SAND/DUST STORM
	BELOW APPROACH/LANDING MINIMUMS
	ICE FOG
WIND	
	CROSSWIND
	VARIABLE WIND
	DUST DEVIL/WHIRLWIND
	GUSTS
	HIGH WIND
	TAILWIND
	SUDDEN WINDSHIFT
	UNFAVORABLE WIND
WINDSHEAR	
	WINDSHEAR

Phase of Flight Groupings

CATEGORY	DETAILED PHASE OF FLIGHT
APPROACH	
	APPROACH
	APPROACH – CIRCLING (IRF)
	APPROACH – FAF/OUTER MARKER TO THRESHOLD (IFR)
	APPROACH – IAF TO FAF/OUTER MARKER (IFR)
	APPROACH – VFR PATTERN – BASE TO FINAL
	APPROACH – VFR PATTERN – BASE TURN
	APPROACH – VFR PATTERN – DOWNWIND
	APPROACH – VFR PATTERN – FINAL APPROACH
CLIMB	
	CLIMB
	CLIMB – TO CRUISE
CRUISE	
	CRUISE
	CRUISE – NORMAL
DESCENT	
	DESCENT
	DESCENT – EMERGENCY
	DESCENT – NORMAL
	DESCENT – UNCONTROLLED
EMERGENCY DESCENT/LANDING	
EMERGENCY LANDING	
EMERGENCY LANDING AFTER TAKEOFF	
GO-AROUND	
	GO-AROUND (VFR)
	MISSED APPROACH (IFR)
HOVER	
	HOVER
	HOVER– IN GROUND EFFECT
	HOVER– OUT OF GROUND EFFECT
LANDING	
	LANDING
	LANDING – ABORTED
	LANDING – FLARE/TOUCHDOWN
	LANDING – ROLL

CATEGORY	DETAILED PHASE OF FLIGHT
MANEUVERING	
	MANEUVERING
	MANEUVERING – AERIAL APPLICATION
	MANEUVERING – TURN TO LANDING AREA (EMERGENCY)
	MANEUVERING – TURN TO REVERSE DIRECTION
OTHER	
TAKEOFF	
	TAKEOFF
	TAKEOFF – ABORTED
	TAKEOFF – INITIAL CLIMB
	TAKEOFF – ROLL/RUN
TAXI	
	TAXI
	TAXI – AERIAL
	TAXI – TO TAKEOFF
	TAXI – FROM LANDING
UNKNOWN	

APPENDIX D—RAW DATA TABLES

The following raw data tables were used to create the charts and graphs presented in this study.

Total Weather Citations 2003–2007

Modifier Category	No. of Events
WIND	1,149
VISIBILITY/CEILING	402
HIGH DENSITY ALTITUDE	120
TURBULENCE	114
CARBURETOR ICING CONDITIONS	86
PRECIPITATION	81
UPDRAFT/DOWNDRAFT	81
ICING	64
THUNDERSTORM	42
WINDSHEAR	37
THERMAL LIFT	20
TEMPERATURE EXTREMES	13
OTHER	10
LIGHTNING	4
TOTAL	2,223

Part 91 Weather Citations 2003–2007

Modifier Category	Total	2003	2004	2005	2006	2007
WIND	1,047	266	219	181	176	205
VISIBILITY/CEILING	350	87	88	72	61	42
HIGH DENSITY ALTITUDE	108	29	17	30	16	16
CARBURETOR ICING CONDITIONS	86	20	18	18	14	16
UPDRAFT/DOWNDRAFT	74	16	15	15	14	14
PRECIPITATION	65	17	16	11	14	7
TURBULENCE	62	15	12	8	9	18
ICING	57	14	11	12	11	9
WINDSHEAR	35	5	9	6	7	8
THUNDERSTORM	33	4	10	7	8	4
THERMAL LIFT	20	3	1	5	8	3
TEMPERATURE EXTREMES	12	3	2	3	1	3
OTHER	8	2	2	1	0	3
LIGHTNING	3	1	1	1	0	0
TOTALS	1,960	482	421	370	339	348

Part 121 Weather Citations 2003–2007

Modifier Category	Total	2003	2004	2005	2006	2007
TURBULENCE	42	14	9	5	6	8
WIND	15	5	1	6	2	1
PRECIPITATION	3	1	0	1	0	1
THUNDERSTORM	2	1	0	0	0	1
LIGHTNING	1	0	0	1	0	0
VISIBILITY/CEILING	1	0	0	0	1	0
TOTALS	64	21	10	13	9	11

Part 135 Weather Citations 2003–2007

Modifier Category	Total	2003	2004	2005	2006	2007
VISIBILITY/CEILING	46	11	13	6	13	3
WIND	45	10	11	8	7	9
PRECIPITATION	10	5	1	1	3	0
ICING	6	1	2	1	1	1
THUNDERSTORM	6	1	3	1	1	0
TURBULENCE	4	1	1	2	0	0
UPDRAFT/DOWNDRAFT	4	2	0	0	1	1
HIGH DENSITY ALTITUDE	2	0	0	0	1	1
OTHER	2	0	0	1	1	0
WINDSHEAR	2	0	0	0	2	0
TEMPERATURE EXTREMES	1	0	0	0	0	1
TOTALS	128	31	31	20	30	16

Part 137 Weather Citations 2003–2007

Modifier Category	Total	2003	2004	2005	2006	2007
WIND	32	6	6	7	4	9
HIGH DENSITY ALTITUDE	9	2	3	3	0	1
TURBULENCE	3	2	1	0	0	0
PRECIPITATION	1	0	0	1	0	0
THUNDERSTORM	1	0	0	0	0	1
UPDRAFT/DOWNDRAFT	1	0	0	0	0	1
VISIBILITY/CEILING	1	1	0	0	0	0
TOTALS	48	11	10	11	4	12

**Part 91 Weather-related Accident Classification by Injury Severity
2003–2007**

Injury Level	Total	2003	2004	2005	2006	2007
NONE	766	161	159	163	139	144
FATAL	372	95	86	66	69	56
SERIOUS	161	33	44	32	22	30
MINOR	233	67	48	38	36	44

**Part 121 Weather-related Accident Classification by Injury Severity
2003–2007**

Injury Level	Total	2003	2004	2005	2006	2007
NONE	12	4	1	5	1	1
FATAL	1	0	0	0	0	1
SERIOUS	42	14	9	5	6	8
MINOR	2	0	0	1	1	0

**Part 135 Weather-related Accident Classification by Injury Severity
2003–2007**

Injury Level	Total	2003	2004	2005	2006	2007
NONE	34	8	7	7	9	3
FATAL	40	9	11	6	8	6
SERIOUS	8	2	2	0	3	1
MINOR	10	3	1	1	3	2

**Part 137 Weather-related Accident Classification by Injury Severity
2003–2007**

Injury Level	Total	2003	2004	2005	2006	2007
NONE	32	9	6	9	2	6
FATAL	1	0	0	0	0	1
SERIOUS	0	0	0	0	0	0
MINOR	10	1	2	1	2	4

**Weather-related Count of Injured Persons for
Parts 91, 121, 135, and 137**

Type of Operation	Fatal	Serious	Minor
Part 91	733	284	466
Part 121	1	45	23
Part 135	81	27	44
Part 137	1	0	10