



Review of Aviation Accidents Involving Weather Turbulence in the United States 1992-2001

March 2004

NASDAC

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*National Aviation Safety Data Analysis Center
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Introduction

This report is an information summary of aviation accidents¹ involving weather turbulence that occurred in the United States of America between the years 1992 and 2001.

Please note: Accidents that occurred within U.S. territories (Virgin Islands, Puerto Rico, etc.) and other countries are not included in this study.

Data was extracted from the National Transportation Safety Board Aviation Accident/Incident Data System (NTSB). The NTSB Accident and Incident Database is the official repository of aviation accident data and causal factors. The National Transportation Safety Board, an independent Federal Agency not part of the Department of Transportation, maintains the data.

There are separate reports issued for each aircraft involved in an aviation accident. This publication will have 'event counts' and 'aircraft counts.' The data searches used for this report focused on final reports where the causes and/or factors of the event were identified. The search criteria also included weather turbulence conditions as defined by the NTSB Coding Manual:

Figure 1. Turbulence Weather Condition Codes and Descriptions

NTSB Subject Modifier Code	Description
2205	Downdraft
2217	Mountain Wave
2224	Turbulence
2225	Turbulence, Clear Air
2226	Turbulence, In Clouds
2227	Turbulence, Thunderstorms
2236	Updraft
2253	Turbulence, Terrain Induced
2256	Turbulence, Convection Induced

The data is current as of 25-February-2004.

¹ The NTSB defines an accident as an event associated with the operation of an aircraft that takes place between the time any person boards the aircraft with the intention of flight and all such persons have disembarked, and in which any person suffers death or serious injury, or in which the aircraft receives substantial damage.

An incident is an event, other than an accident, associated with the operation of an aircraft that affects or could affect the safety of operations.

Fatal injury is any event that results in death within 30 days of the event.

Serious injury is any injury that (1) Requires hospitalization for more than 48 hours, commencing within seven days from the date the injury was received; (2) Results in a fracture of any bone (except simple fractures of fingers, toes, or nose); (3) Causes severe hemorrhages, nerve, muscle, or tendon damage; (4) Involves any internal organ or; (5) Involves second or third degree burns affecting more than five percent of the body surface.

Substantial damage is damage or failure that adversely affects the structural strength, performance, or flight characteristics of the aircraft, and would normally require major repair or replacement of the affected component. Engine failure or damage limited to the engine if only one engine fails or is damaged, bent fairings or cowlings, dented skin, small puncture holes in the skin or fabric, ground damage to rotor or propeller blades, and damage to landing gear, wheels, tires, flaps, engine accessories, brakes, or wingtips are not considered "substantial damage" for the purpose of this part.

Weather and Turbulence

Accident Comparison – Ten-Year Review

From 1992 to 2001, a total of 20,607 aircraft were involved in 20,334 accidents that occurred in the United States. During this same time frame, 4,316 aircraft were involved in 4,306 accidents where weather was identified as the cause or factor. Of these 4,306 weather accidents, turbulence was the cause or factor in 506 accidents (508 aircraft). Figure 2 depicts the ten-year accident count, comparing total weather events (4,306) to turbulence events (506). For this time period, turbulence accounted for over eleven percent of the weather accidents.

Figure 2. Comparison of Weather Accidents to Weather Turbulence Accidents

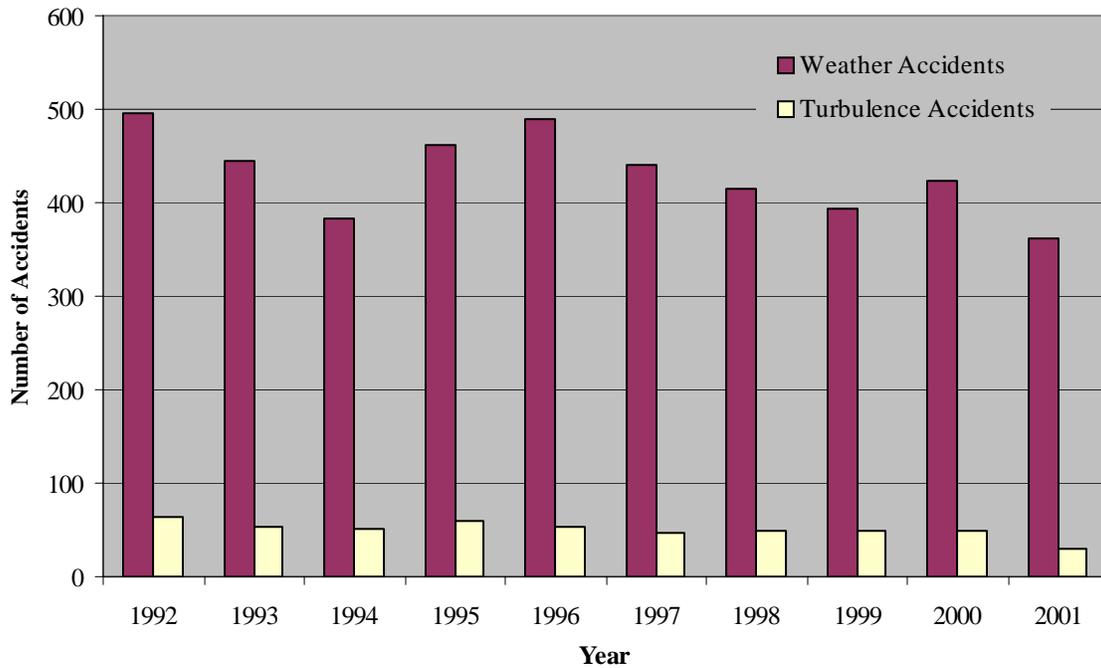


Figure 3. Percentage of Weather Turbulence Accidents to Weather Accidents

Year	Weather Accidents	Turbulence Accidents	Percentage of Turbulence Accidents To Weather Accidents
1992	496	64	12.90%
1993	444	54	12.16%
1994	382	52	13.61%
1995	462	59	12.77%
1996	489	53	10.84%
1997	441	46	10.43%
1998	414	50	12.08%
1999	393	50	12.72%
2000	423	48	11.35%
2001	362	30	8.29%
Total	4306	506	11.75%

Accident Comparison – Injury Review

From 1992 to 2001, in the United States, there were 3,792 fatalities (on board the aircraft) that resulted from 1,056 fatal accidents where weather was identified as the cause or factor. During this same time period, there were 250 fatalities (on board the aircraft) that resulted from 114 fatal accidents due to turbulent weather conditions. From 1992 to 2001, turbulence accounted for over ten percent of the fatal weather accidents and almost seven percent of the fatalities due to weather conditions.

Figure 4. Fatal Weather Accidents Compared to Fatal Weather Turbulence Accidents

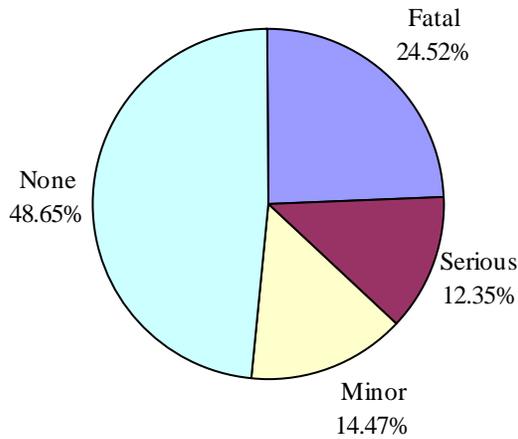
Year	Fatal Weather Accidents	Fatal Turbulence Accidents	Percentage of Fatal Turbulence Accidents to Fatal Weather Accidents
1992	150	12	8.00%
1993	119	14	11.76%
1994	101	14	13.86%
1995	121	13	10.74%
1996	121	16	13.22%
1997	101	13	12.87%
1998	102	14	13.73%
1999	72	8	11.11%
2000	101	6	5.94%
2001	68	4	5.88%
Total	1056	114	10.80%

Figure 5. Weather Fatalities Compared to Weather Turbulence Fatalities

Year	Weather Fatalities	Weather Turbulence Fatalities	Percentage of Weather Turbulence Fatalities to Weather Fatalities
1992	601	38	6.32%
1993	524	36	6.87%
1994	453	27	5.96%
1995	439	27	6.15%
1996	383	37	9.66%
1997	344	27	7.85%
1998	288	22	7.64%
1999	243	17	7.00%
2000	296	13	4.39%
2001	221	6	2.71%
Total	3792	250	6.59%

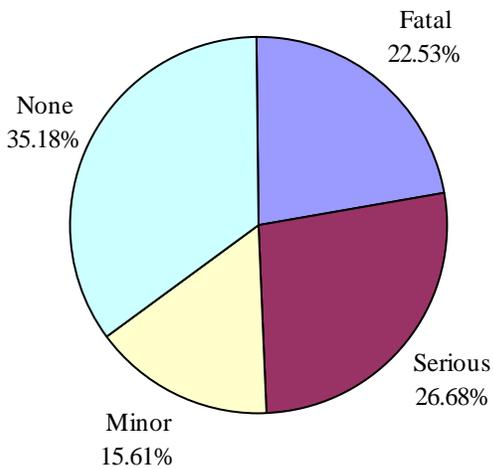
Figures 6 and 7 depict the distribution of injury severity for accidents due to weather conditions and turbulent weather conditions, respectively from 1992 through 2001 in the United States. The data indicates that weather turbulence resulted in serious injuries more often (as a percentage) than the total weather accidents (26.68 percent versus 12.35 percent).

Figure 6. Weather Accidents – Injury Severity



Injury Severity	Number of Accidents
Fatal	1056
Serious	532
Minor	623
None	2095
Total	4306

Figure 7. Weather Turbulence Accidents – Injury Severity



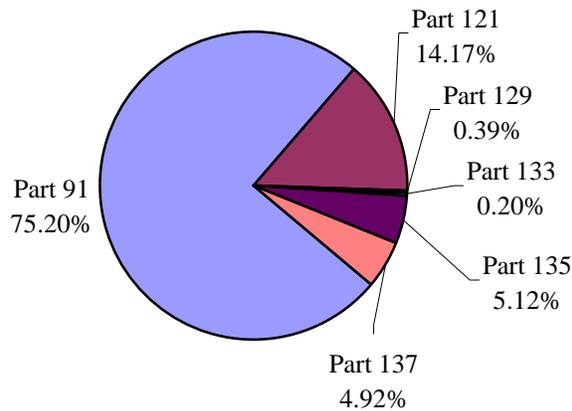
Injury Severity	Number of Accidents
Fatal	114
Serious	135
Minor	79
None	178
Total	506

Weather Turbulence Accidents – Operating Flight Rules Review

Accidents due to weather turbulence conditions from 1992 through 2001 in the United States occurred during flights operating under Title 14 Code of Federal Aviation Regulations (FAR) Parts:

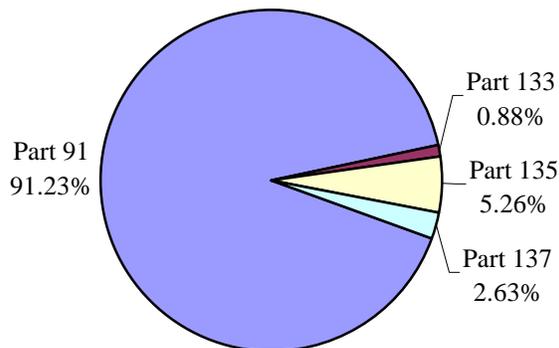
1. 91 – General aviation (recreation, training, etc.)
2. 121 – Scheduled airlines and cargo carriers that fly large transport-category aircraft
3. 129 – Foreign air carriers
4. 133 – Rotorcraft external-load operations
5. 135 – Scheduled or non-scheduled air taxi operators (nine or fewer passengers)
6. 137 – Agricultural aircraft operations

Figure 8. Weather Turbulence Accidents by Operation (Aircraft Count)



FAR Part	Number of Accidents	Percentage of Turbulence Accidents
Part 91	382	75.20%
Part 121	72	14.17%
Part 129	2	0.39%
Part 133	1	0.20%
Part 135	26	5.12%
Part 137	25	4.92%
Total	508	100%

Figure 9. Fatal Weather Turbulence Accidents by Operation (Aircraft Count)



FAR Part	Number of Fatal Accidents	Percentage of Fatal Turbulence Accidents
Part 91	104	91.23%
Part 121	0	0.00%
Part 129	0	0.00%
Part 133	1	0.88%
Part 135	6	5.26%
Part 137	3	2.63%
Total	114	100%

Part 91 – General Aviation Review

FAR Part 91, or general aviation, refers to all aviation other than commercial airline and military operations. Flights operating for recreation and training are generally carried out under this part. Although general aviation usually involves small aircraft, the definition depends on the nature of the operation rather than the size of the aircraft.

From 1992 to 2001, according to NTSB final reports, weather turbulence was identified as the cause or factor in 506 accidents (involving 508 aircraft). General aviation accounted for 381 accidents (involving 382 aircraft). This section will concentrate on the 381 general aviation weather turbulence accidents.

The number of Part 91 accidents due to weather turbulence has been decreasing since 1992. When comparing the number of events that occurred at year-end 1992 with those that occurred at year-end 2001, there has been a reduction of over 35 percent.

Figure 10. Part 91 Weather Turbulence Accidents by Year

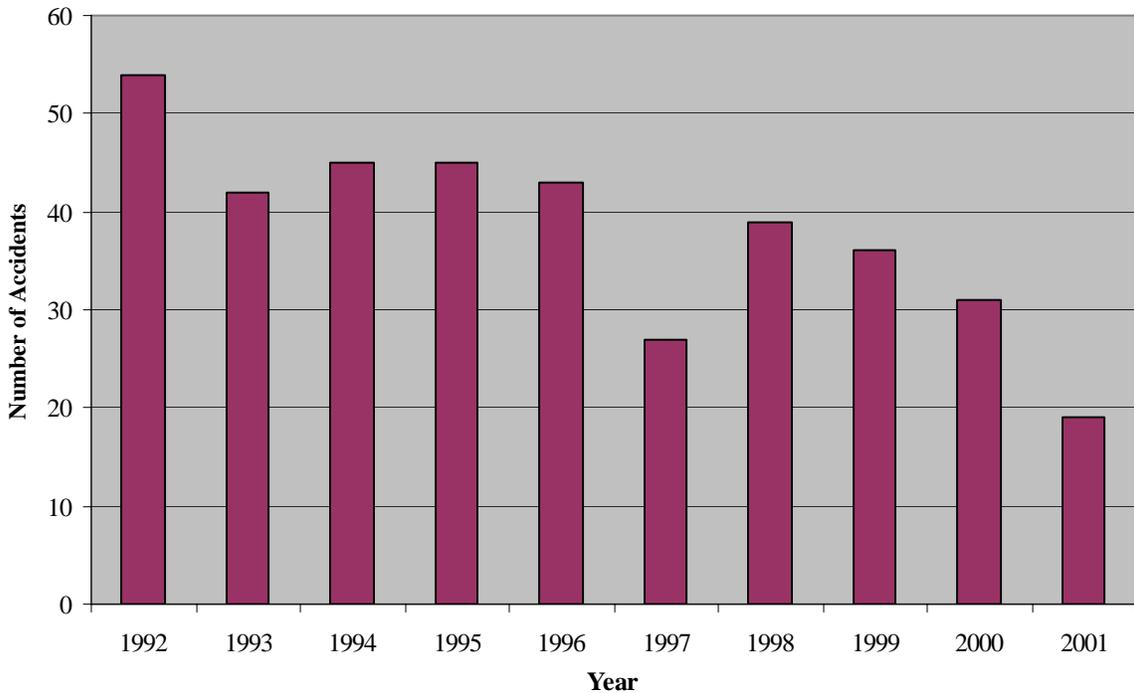


Figure 11. Part 91 Weather Turbulence Accidents – Year

Year	Number of Accidents	Percentage of Part 91 Weather Turbulence Accidents
1992	54	14.17%
1993	42	11.02%
1994	45	11.81%
1995	45	11.81%
1996	43	11.29%
1997	27	7.09%
1998	39	10.24%
1999	36	9.45%
2000	31	8.14%
2001	19	4.99%
Total	381	100%

There is a noticeable increase in weather turbulence events that occur in the summer months, peaking in July, between 1992 and 2001. This is because turbulence can occur in the lowest part of the troposphere during the daytime when heating of the sun causes convective mixing of the air.

Figure 12. Part 91 Weather Turbulence Accidents by Month

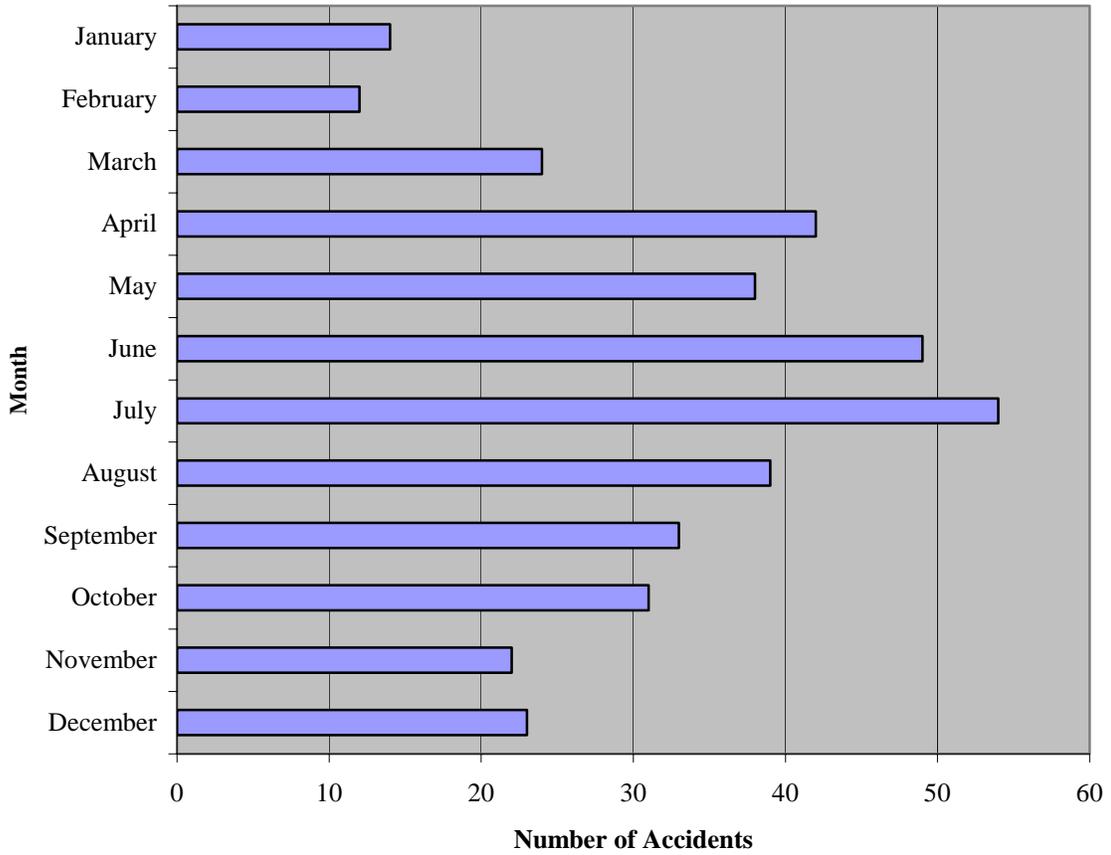
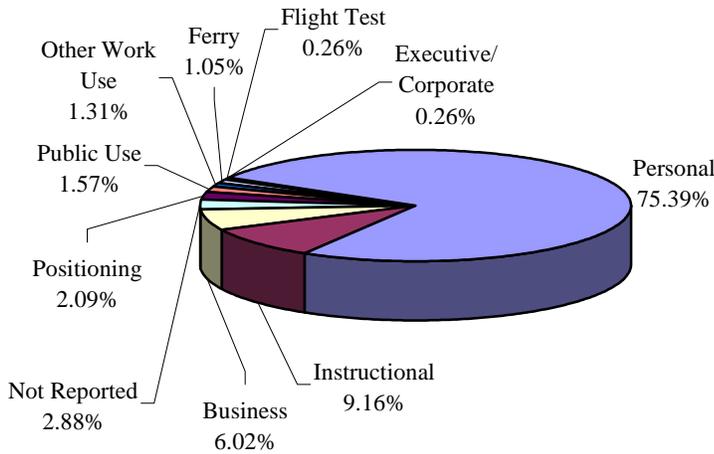


Figure 13. Part 91 Weather Turbulence Accidents - Month

Month	Number of Accidents	Percentage of Part 91 Weather Turbulence Accidents
January	14	3.67%
February	12	3.15%
March	24	6.30%
April	42	11.02%
May	38	9.97%
June	49	12.86%
July	54	14.17%
August	39	10.24%
September	33	8.66%
October	31	8.14%
November	22	5.77%
December	23	6.04%
Total	381	100%

General aviation operations can be classified further by the specific use of the aircraft for the individual flight. The majority of the weather turbulence events involving Part 91 operations involve personal use flights, followed distantly by instruction.

Figure 14. Part 91 Weather Turbulence Events - Aircraft Use (Aircraft Count)



Aircraft Use	Number of Aircraft
Personal	288
Instructional	35
Business	23
Not Reported	11
Positioning	8
Public Use	6
Other Work Use	5
Ferry	4
Executive/Corporate	1
Flight Test	1
Total	382

California and Alaska are the top two states for weather turbulence involving general aviation aircraft to occur, followed by Colorado and New Mexico. Please note that if a state does not appear in the following figure, it is due to zero weather turbulence events in that state from 1992 to 2001.

Figure 15. Part 91 Weather Turbulence Events – State (Event Count)

State	Number of Events
California	56
Alaska	47
Colorado	22
New Mexico	20
Wyoming	16
Washington	16
Florida	16
Idaho	14
Arizona	12
Texas	11
Utah	10
Oregon	10
Montana	9
Nevada	8
Alabama	7
Wisconsin	7
Pennsylvania	7
Oklahoma	7
Missouri	7
Iowa	6
Massachusetts	6
New York	6
Virginia	5

State	Number of Events
Michigan	5
Georgia	5
North Carolina	5
Hawaii	4
Vermont	3
Maryland	3
Louisiana	3
New Jersey	3
Indiana	3
Kansas	2
Arkansas	2
Ohio	2
Mississippi	2
Connecticut	2
Illinois	2
Tennessee	2
North Dakota	2
Nebraska	2
Minnesota	1
New Hampshire	1
Maine	1
Kentucky	1
Grand Total	381

When examining all of the Part 91 operations, the most common result of weather turbulence events from 1992 to 2001 is substantially damaged aircraft and no injuries sustained by the passengers and/or crew.

One example of a substantially damaged aircraft with no sustained injuries involved a pilot whom encountered strong winds aloft when he entered a mountain pass at 10,500 feet MSL in Colorado. He experienced a severe downdraft that caused an 800-foot altitude loss, putting the airplane below the ridgeline. The pilot attempted to turn away from the ridge, but was unable to clear the terrain. He flared the airplane to reduce the forward airspeed of the airplane before impacting deep snow.
NTSB Report Number: FTW94LA105

An example of a turbulence event that resulted in a fatal injury involved a pilot operating in California. The pilot advised air traffic control that she was experiencing moderate to severe turbulence and was unable to maintain altitude. She requested the nearest airport and was given a heading and distance to the field. After the pilot reported that the door popped open, radio and radar contact were lost. A witness reported that the aircraft was in level flight and then abruptly rolled to the right, pitched forward, and continued in a nose down attitude until it experienced an in-flight breakup. Weather forecasts were for moderate to severe turbulence, strong winds, scattered to broken clouds, and rain and icing conditions. The investigator cited clear air turbulence and windshear as factors to this fatal accident.
NTSB Report Number: LAX97FA070

Figure 16. Part 91 Weather Turbulence Events by Aircraft Damage and Injury Severity (Aircraft Count)

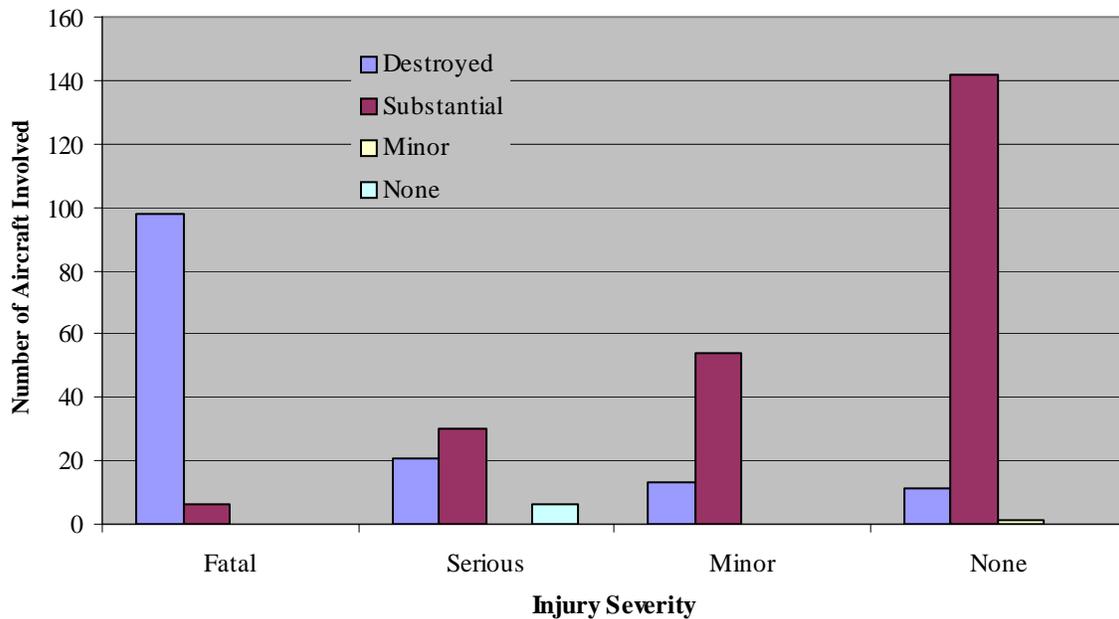
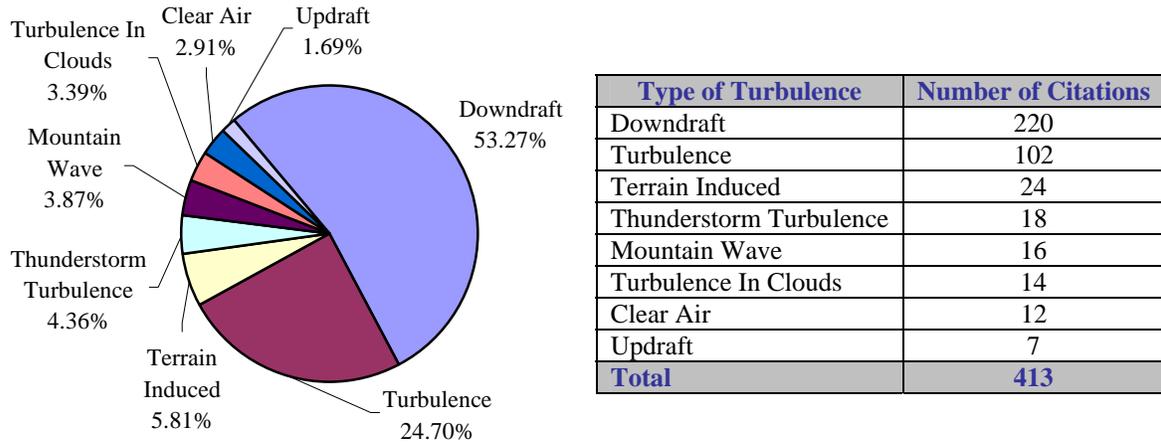


Figure 17. Part 91 Weather Turbulence Events – Aircraft Damage and Injury Severity (Aircraft Count)

	Fatal	Serious	Minor	None	Total
Destroyed	98	21	13	11	143
Substantial	6	30	54	142	232
Minor	0	0	0	1	1
None	0	6	0	0	6
Total	104	57	67	154	382

The following counts are based on the number of causes and factors identified by the accident investigator. It is possible that a single event has more than one turbulence cause or factor cited. For example, an individual aircraft may have encountered a downdraft and terrain induced turbulence in one event. For the 382 aircraft involved in turbulence events, there are 413 turbulence-related causes and/or factors cited. The specific type of turbulence involving Part 91 operations from 1992 through 2001 varied. However, the NTSB cited downdraft as the cause or factor most often in these accidents.

Figure 18. Part 91 Weather Turbulence Events – Type of Turbulence



While examining the breakout percentages of the types of turbulence for Part 91 events, it is interesting to note the structure of the breakout of injury severity. Although downdraft accounts for the majority of the turbulence events, almost fifty percent of these events result in those on board the aircraft sustaining no injuries, and only ten percent involving fatalities.

Figure 19. Part 91 Weather Turbulence Events by Types of Turbulence and Injury Severity

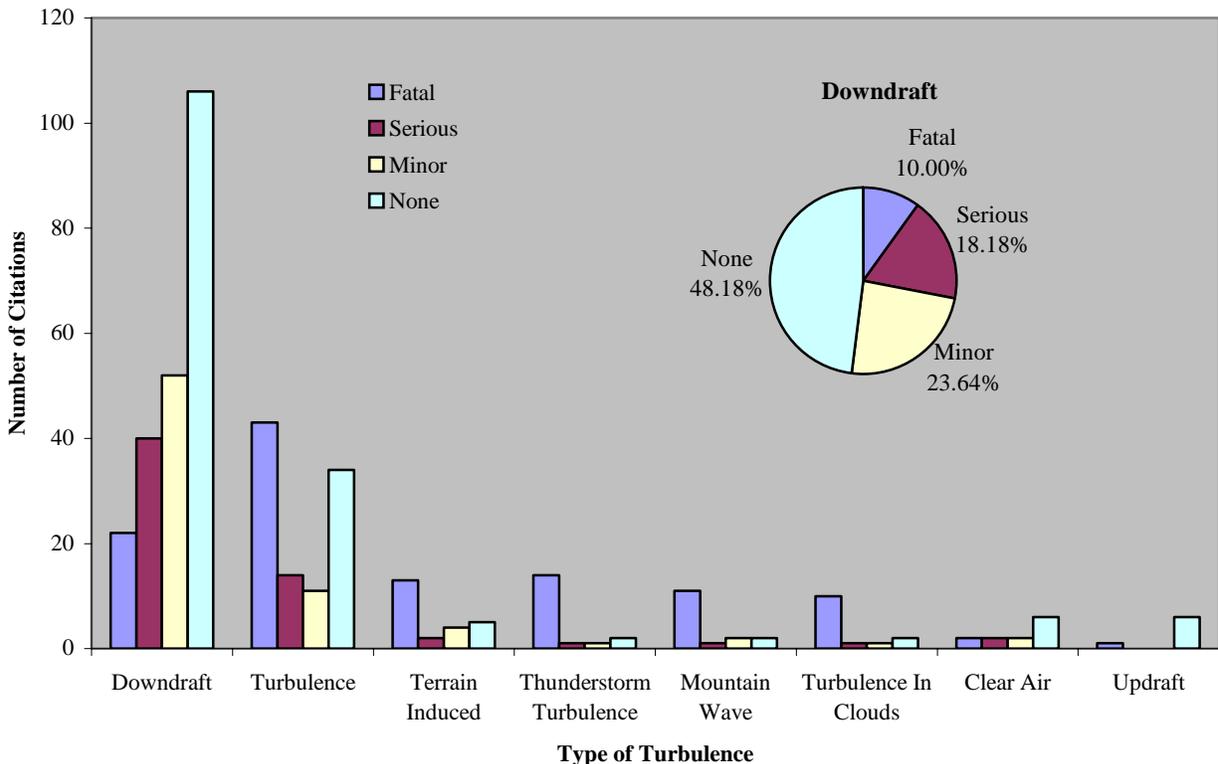
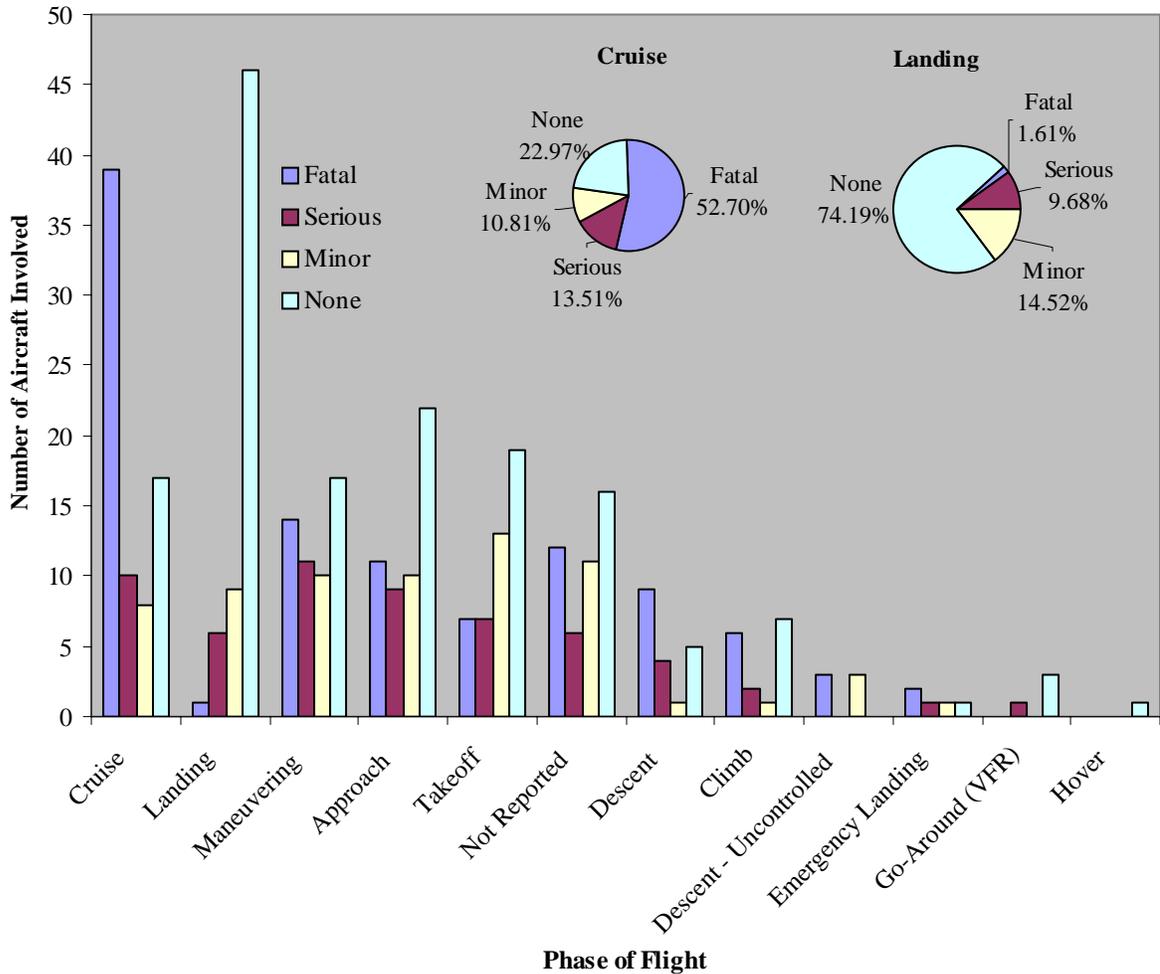


Figure 20. Part 91 Weather Turbulence Events by Types of Turbulence and Injury Severity

Type of Turbulence	Fatal	Serious	Minor	None	Total
Downdraft	22	40	52	106	220
Turbulence	43	14	11	34	102
Terrain Induced	13	2	4	5	24
Thunderstorm Turbulence	14	1	1	2	18
Mountain Wave	11	1	2	2	16
Turbulence In Clouds	10	1	1	2	14
Clear Air	2	2	2	6	12
Updraft	1	0	0	6	7
Total	116	61	73	163	413

The majority of the events involving general aviation operations occurred during the cruise phase of flight, followed by the landing phase. Most of the fatal events also occurred during the cruise phase of flight; however the landing phase resulted in no injuries almost 75 percent of the time.

Figure 21. Part 91 Weather Turbulence Events by Phase of Flight and Injury Severity (Aircraft Count)



**Figure 22. Part 91 Weather Turbulence Events –
Flight Phase and Injury Severity (Aircraft Count)**

	Fatal	Serious	Minor	None	Total
Cruise	39	10	8	17	74
Landing	1	6	9	46	62
Maneuvering	14	11	10	17	52
Approach	11	9	10	22	52
Takeoff	7	7	13	19	46
Unknown	12	6	11	16	45
Descent	9	4	1	5	19
Climb	6	2	1	7	16
Descent – Uncontrolled	3	0	3	0	6
Emergency Landing	2	1	1	1	5
Go Around (VFR)	0	1	0	3	4
Hover	0	0	0	1	1
Total	104	57	67	154	382

Part 121 – Air Carrier Review

FAR Part 121 refers to scheduled domestic airlines and cargo carriers that fly large transport-category aircraft.

From 1992 to 2001, according to NTSB final reports, weather turbulence was identified as the cause or factor in 506 accidents (involving 508 aircraft). Part 121 operations accounted for 72 of the 506 accidents. This section will concentrate on the 72 Part 121 weather turbulence accidents.

Please note that due to the threshold of the definition of an ‘accident’ according to the NTSB, several weather turbulence events involving Part 121 operations will not be included in this publication. For example, a scheduled flight on a large transport aircraft that encountered moderate turbulence in which a minor injury was the result will not be included in the counts represented in this study.

The number of Part 121 accidents due to weather turbulence has increased from 4 events in 1992 to 8 events in 2001.

Figure 23. Part 121 Weather Turbulence Accidents by Year

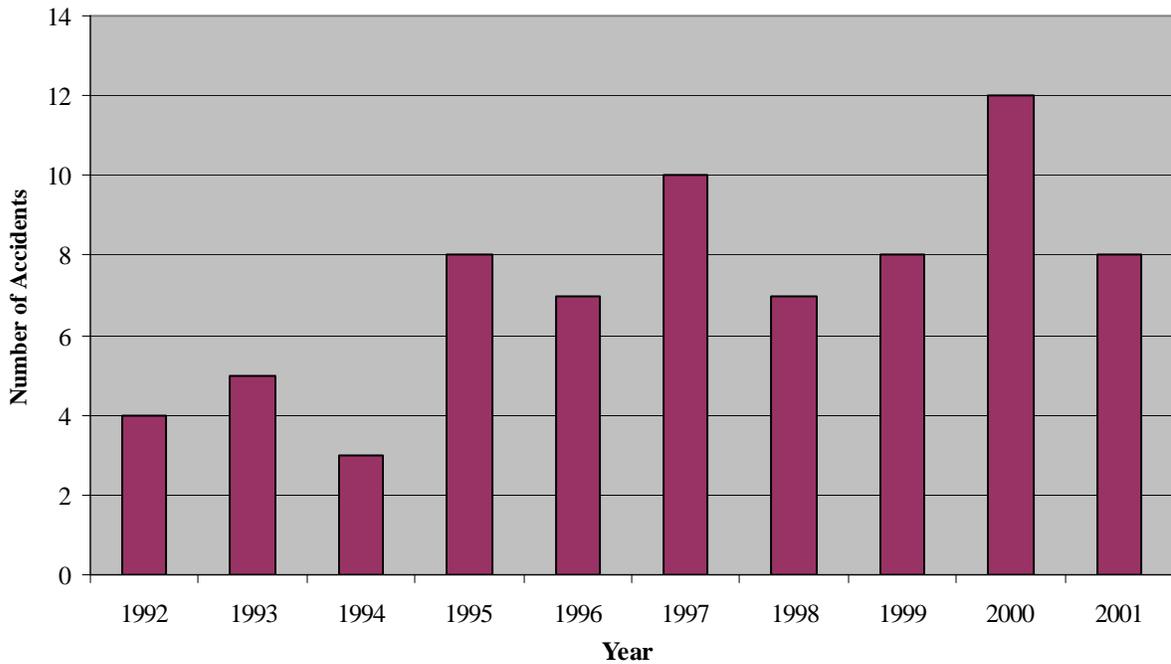


Figure 24. Part 121 Weather Turbulence Accidents - Year

Year	Number of Accidents	Percentage of Part 121 Weather Turbulence Accidents
1992	4	5.56%
1993	5	6.94%
1994	3	4.17%
1995	8	11.11%
1996	7	9.72%
1997	10	13.89%
1998	7	70.00%
1999	8	11.11%
2000	12	16.67%
2001	8	11.11%
Total	72	100%

71 of the 72 weather turbulence events involving Part 121 operations from 1992 through 2001 investigated by the NTSB have resulted in serious injuries to passengers and/or crew on board the aircraft. An example of such a flight follows:

The flight was being vectored between two thunderstorm cells in Instrument Meteorological Conditions (IMC). After entering an area of visual conditions, the flight crew noticed a cumulus nimbus buildup directly ahead of the flight path. The condition had not been displayed on their radar and the cell was too close to avoid. The captain immediately made an announcement for the flight attendants, who were in the process of serving the cabin, to be seated. The flight experienced about ten seconds of severe turbulence and lost approximately 900 feet in altitude. Three of the nine flight attendants and one passenger, who did not have the seat belt fastened, were seriously injured.

NTSB Report Number: CHI95LA188

The following event is an example of a Part 121 flight where the result was a substantially damaged aircraft, a seriously injured flight attendant, and a seriously injured passenger:

The flight crew received an incomplete flight release from dispatch prior to this flight. Neither a pertinent Convective SIGMET nor a tornado watch bulletin was included in the dispatch documents. During initial climb after takeoff, the flight crew noticed that they were approaching a line of thunderstorms. The captain initially planned to fly around this line, but noticed a ten-mile gap in the line that was depicted on the airplane's on-board weather radar display and decided to fly through it. Radar and weather data indicate that the airplane penetrated an extreme weather echo (VIP level 6) that likely contained a severe thunderstorm, hail, and severe to extreme turbulence. The flight attendants and passengers did not receive an adequate or timely briefing to remain seated and to prepare for the possibility of turbulence. The aft flight attendant and a passenger were seriously injured. Hail shattered the front windshield and damaged the pitot system, radome, wings, tail, and engines.

NTSB Report Number: DCA98MA045

The last example involves a substantially damaged cargo aircraft resulting in no injuries to those on board the aircraft:

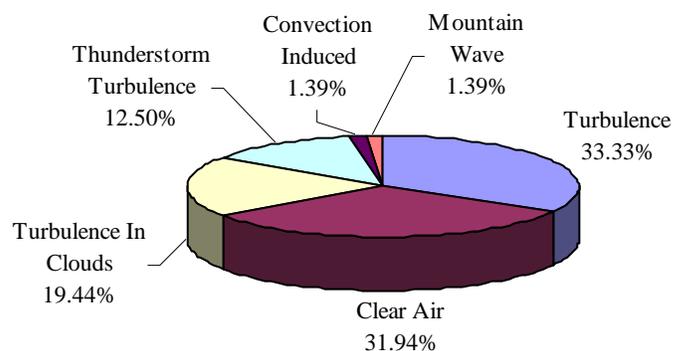
During the cruise phase of flight at flight level 310, the all cargo aircraft encountered severe clear air turbulence that caused major fluctuations in speed and oscillations in both pitch and roll. During these departures from controlled flight, the number one engine and 19 feet of the leading edge of the left wing separated from the aircraft. In addition, the number four-engine pylon cracked and experienced substantial structural damage.

NTSB Report Number: DEN93FA015

The following counts are based on the number of causes and factors identified by the accident investigator.

Figure 25. Part 121 Weather Turbulence Events by Type of Turbulence

Type of Turbulence	Number of Citations
Turbulence	24
Clear Air	23
Turbulence In Clouds	14
Thunderstorm Turbulence	9
Convection Induced	1
Mountain Wave	1
Total	72



Part 135 – Air Taxi and Commuter Review

FAR Part 135 refers to either scheduled (commuter operations) or nonscheduled (air taxi operations) flights. Scheduled Part 135 operations apply to smaller aircraft carrying nine or fewer passengers on regularly scheduled routes. Nonscheduled Part 135 operations apply to smaller aircraft carrying nine or fewer passengers with schedules that are arranged between the passengers and the operator. The nonscheduled operations also include cargo planes with payload capacities of 7,500 pounds or less.

From 1992 to 2001, according to NTSB final reports, weather turbulence was identified as the cause or factor in 506 accidents (508 aircraft). Part 135 operations accounted for 26 of the 471 accidents. This section will concentrate on the 26 Part 135 weather turbulence accidents.

Figure 26. Part 135 Weather Turbulence Accidents by Year

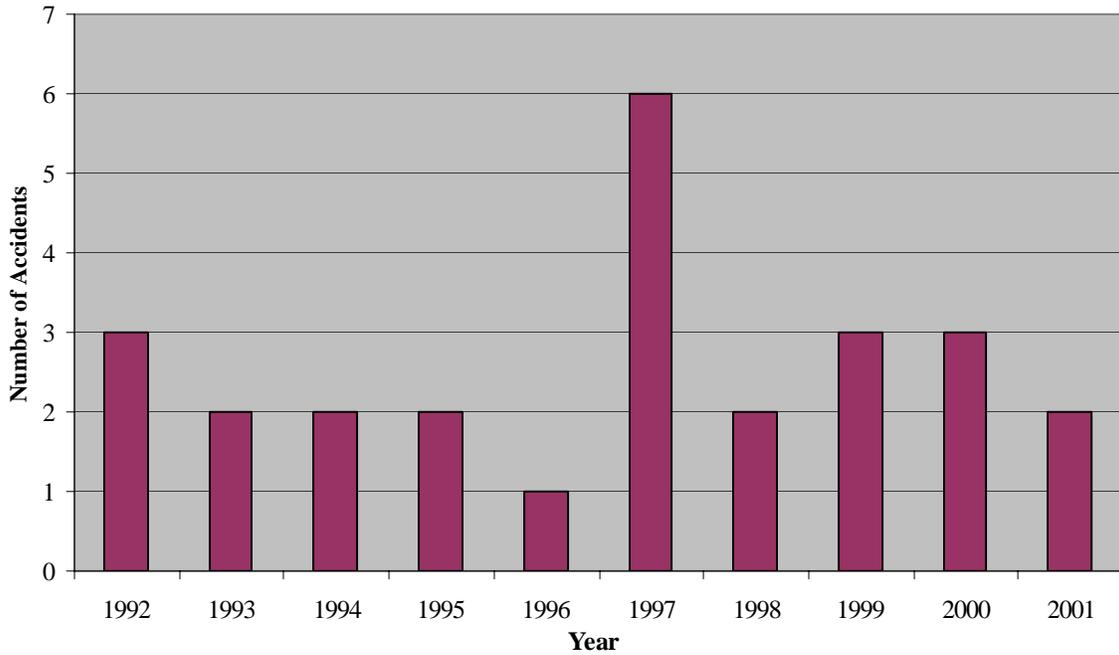


Figure 27. Part 135 Weather Turbulence Accidents – Year

Year	Number of Accidents	Percentage of Part 135 Weather Turbulence Accidents
1992	3	11.54%
1993	2	7.69%
1994	2	7.69%
1995	2	7.69%
1996	1	3.85%
1997	6	23.08%
1998	2	7.69%
1999	3	11.54%
2000	3	11.54%
2001	2	7.69%
Total	26	100%

The following counts are based on the number of causes and factors identified by the accident investigator. It is possible that a single event has more than one turbulence cause or factor cited. For the 26 aircraft involved in weather turbulence events, there are 29 turbulence-related causes and/or factors cited. Downdraft was the major weather turbulence factor involving Part 135 operations, accounting for more than 50 percent of the total.

Figure 28. Part 135 Weather Turbulence Accidents by Type of Turbulence

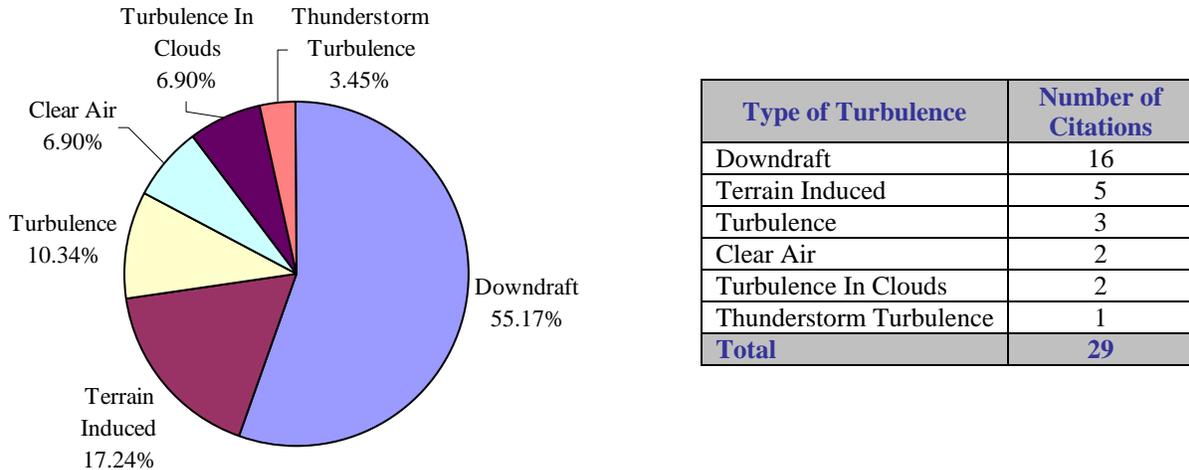


Figure 29. Part 135 Weather Turbulence Accidents - Type of Turbulence and Injury Severity

	Fatal	Serious	Minor	None	Total
Downdraft	2	1	4	9	16
Terrain Induced	2	1	1	1	5
Turbulence	0	0	1	2	3
Clear Air	1	1	0	0	2
Turbulence In Clouds	2	0	0	0	2
Thunderstorm Turbulence	1	0	0	0	1
Total	8	3	6	12	29

An example of a Part 135 weather turbulence event involved a local sightseeing helicopter flying in mountainous terrain. The pilot encountered clouds covering the mountain pass and elected to proceed toward an alternate destination. The clouds forced the pilot to climb the helicopter to 10,500 feet MSL. The pilot allowed the airspeed to decrease, executed a turn, and encountered a downdraft. The pilot was unable to maintain the altitude and the helicopter collided with the mountainous terrain. Two of the passengers were seriously injured.

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Part 137 – Agricultural Operations Review

FAR Part 137 refers to agricultural aircraft operations. Agricultural aircraft operation means the operation of an aircraft for the purpose of (1) dispensing any economic poison; (2) dispensing any other substance intended for plant nourishment, soil treatment, propagation of plant life, or pest control; or (3) engaging in dispensing activities directly affecting agricultural, horticultural, or forest preservation, but not including the dispensing of live insects.

From 1992 to 2001, according to NTSB final reports, weather turbulence was identified as the cause or factor in 506 accidents (involving 508 aircraft). Part 137 operations accounted for 24 of the 506 accidents and 25 of the 508 aircraft. This section will concentrate on the 24 Part 137 weather turbulence accidents.

Figure 30. Part 137 Weather Turbulence Accidents by Year

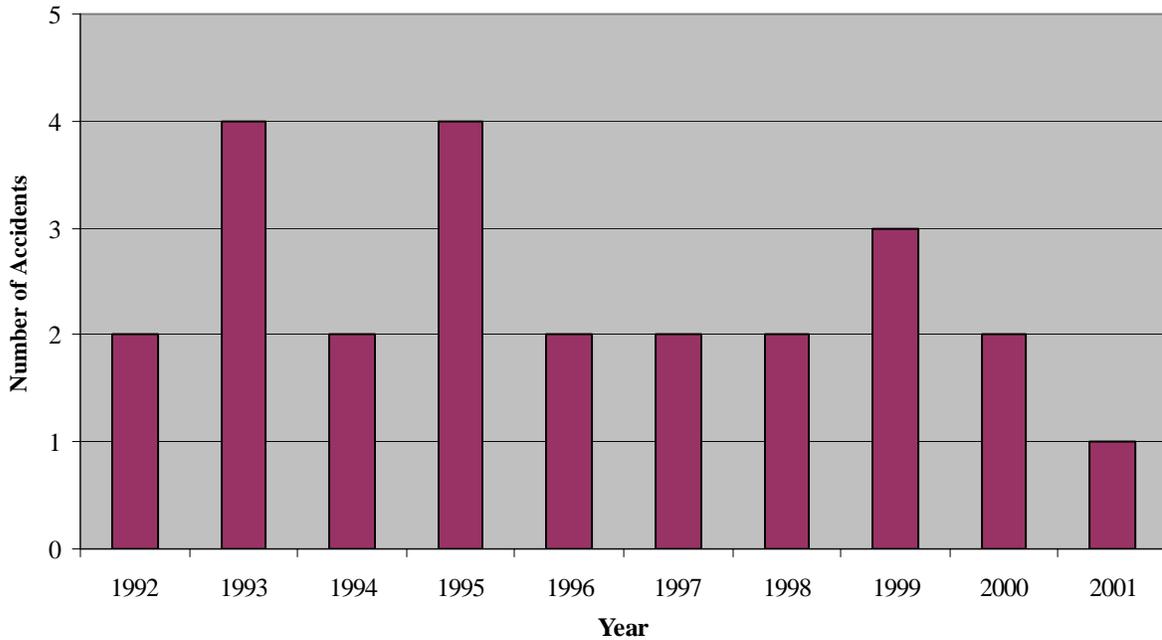
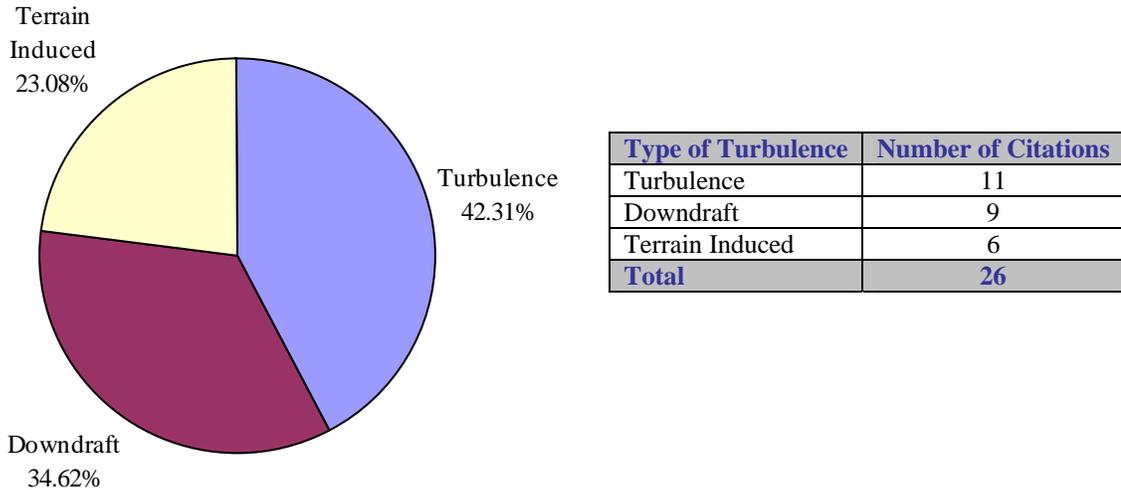


Figure 31. Part 137 Weather Turbulence Accidents – Year

Year	Number of Accidents	Percentage of Part 137 Weather Turbulence Accidents
1992	2	8.33%
1993	4	16.67%
1994	2	8.33%
1995	4	16.67%
1996	2	8.33%
1997	2	8.33%
1998	2	8.33%
1999	3	12.50%
2000	2	8.33%
2001	1	4.17%
Total	24	100%

The following counts are based on the number of causes and factors identified by the accident investigator. It is possible that a single event has more than one turbulence cause or factor cited. For the 24 accidents involved in weather turbulence, there are 26 turbulence-related causes and/or factors cited.

Figure 32. Part 137 Turbulence Weather Accidents by Type of Turbulence



The 24 accidents involving Part 137 resulted in three fatal accidents, two of which involved terrain induced turbulence. About 50 percent of these 24 accidents resulted in no injuries.

Figure 33. Part 137 Weather Turbulence Accidents - Type of Turbulence and Injury Severity

	Fatal	Serious	Minor	None	Total
Turbulence	1	1	0	9	11
Downdraft	0	0	7	2	9
Terrain Induced	2	2	0	2	6
Total	3	3	7	13	26

An illustration of a Part 137 operation encountering turbulence involves a pilot who was completing a swath run. Following the run, the aircraft crossed over a ridge and experienced a severe downdraft. The pilot stated that he was unable to stop the aircraft’s descent and collided with the terrain. The pilot walked away with minor injuries.

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