



# National Transportation Safety Board

Washington, D.C. 20594

## Safety Recommendation

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**Date:** May 18, 2012

**In reply refer to:** A-12-18 through -20

The Honorable Michael P. Huerta  
Acting Administrator  
Federal Aviation Administration  
Washington, D.C. 20591

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The National Transportation Safety Board (NTSB) has recently investigated several accidents and incidents in which air carrier airplanes have encountered significant convective weather conditions in flight, resulting in turbulence-induced crew and passenger injuries, damage to airplanes from hail and lightning strikes, and associated flight diversions. Because thunderstorms are, by definition, always accompanied by lightning, the presence of lightning is a strong indicator of potentially severe weather conditions, and its identification serves to locate areas that should be avoided by all aircraft. Pilots and air traffic controllers currently attempt to protect aircraft from such encounters by using both airborne and ground-based weather radar systems that detect significant precipitation, which is frequently associated with convective weather. The NTSB believes that in addition to the precipitation data provided by weather radars, real-time information provided by modern “total lightning”<sup>1</sup> detection networks can further assist pilots and controllers in identifying specific areas where lightning exists, and, through observation of storm motion, may exist as aircraft proceed along their flightpaths.

Current ground-based lightning detection technology can retrieve information for both cloud-to-ground and intracloud lightning in real-time with high spatial accuracy. Scientific study has indicated that total lightning is well correlated with areas of convective turbulence<sup>2</sup> and suggests that intracloud lightning can be related to the vertical development of certain thunderstorms, as well as microbursts at the ground.<sup>3</sup> Because lightning detection networks operate independently of weather radar systems, their coverage areas complement each other and lightning information may indicate the presence of thunderstorms outside the range of ground-based weather radar systems. Therefore, lightning information may be critical for

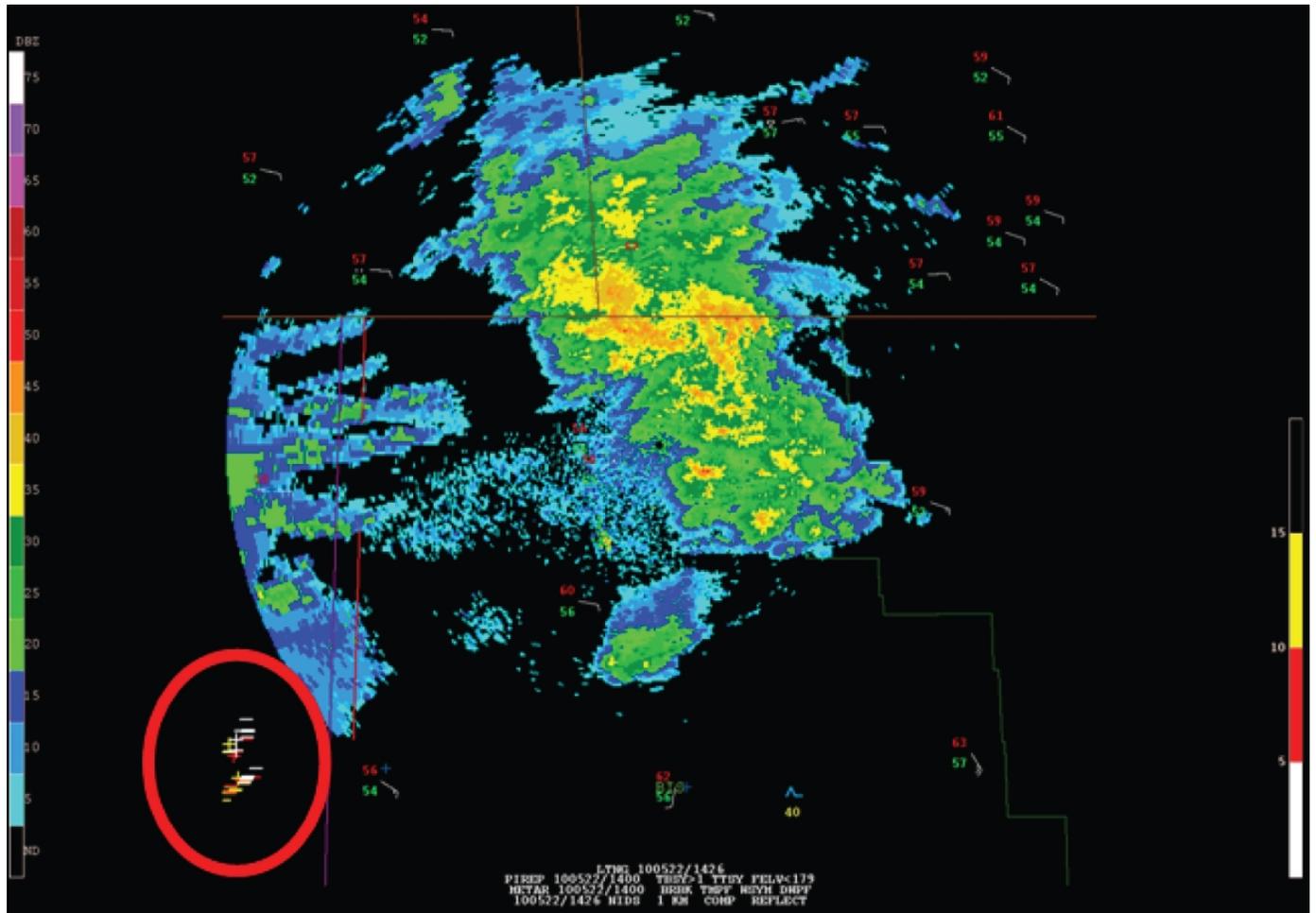
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<sup>1</sup> The term “total lightning” comprises both intracloud and cloud-to-ground lightning.

<sup>2</sup> W. Deierling and others “The Relationship of In-Cloud Convective Turbulence to Total Lightning,” presentation at 14th Conference on Mesoscale Processes/15th Conference on Aviation, Range, and Aerospace Meteorology, August 1-4, 2011, Los Angeles, California.

<sup>3</sup> E.R. Williams, M.E. Weber, and R.E. Orville, “The Relationship Between Lightning Type and Convective State of Thunderclouds,” *Journal of Geophysical Research*, vol. 94, no. D11 (1989), pp 13; 213-13; 220.

thunderstorm identification in regions of the National Airspace System where weather radar data are unavailable, such as parts of the Gulf of Mexico and portions of the western continental United States (see figure 1). In addition, lightning information is an important supplement to weather radar data because it can identify regions of airspace conducive to hazardous events even where precipitation returns from weather radar do not appear to be significant. For example, in 2002, a Chautauqua Airlines Embraer 145 regional jet descending through 13,000 feet near Windsor Locks, Connecticut, was struck by lightning,<sup>4</sup> resulting in two of its four elevator cables being severed. No thunderstorm-related precipitation had been detected by weather radar in the vicinity of the airplane.



**Figure 1.** Image depicting weather radar coverage from Minot, North Dakota, as well as lightning data (“+” and “-” symbols). The red circle highlights lightning data outside of weather radar coverage.<sup>5</sup>

<sup>4</sup> For more information, see NTSB case number NYC02IA076, which is available at <<http://www.ntsb.gov/aviationquery/index.aspx>>.

<sup>5</sup> Image taken from G.S. Harris, “Flying in the Void, PIREPS Vital to Flight Safety” *The Front*, November 2011, pp 7-10.

While the presence of lightning can indicate a high likelihood of other hazards to flight, such as hail, icing conditions, and turbulence, lightning itself poses direct safety hazards to airborne aircraft. Lightning strikes can cause engine failure, disrupt and damage aircraft electrical systems, lead to smoke and onboard fires, and cause temporary blindness to flight crews. The NTSB has investigated several events involving lightning strikes that led to the total loss of hydraulic systems or were responsible for structural damage that significantly affected aircraft controls.<sup>6</sup> Lightning has even resulted in the complete loss of an aircraft, such as occurred in the 1963 Boeing 707 accident near Elkton, Maryland, that claimed the lives of all 81 people on board. The Civil Aeronautics Board (predecessor to the NTSB) identified “lightning-induced ignition of (the) fuel/air mixture” as a causal factor in the accident.<sup>7</sup>

## Accidents and Incidents

### *American Eagle Flight 3224, Pioneer, Louisiana*

On June 28, 2010, about 1751 central daylight time, American Eagle flight 3224, an Embraer 145LR en route from Greensboro, North Carolina, to Dallas, Texas, encountered severe turbulence while in cruise flight approximately 38,000 feet over Pioneer, Louisiana. The captain declared an emergency and landed without incident at East Texas Regional Airport in Longview, Texas, about 1824. The captain and the first officer were not injured, and the sole flight attendant was seriously injured. Of the 42 passengers on board, 1 was seriously injured, and 3 sustained minor injuries.<sup>8</sup>

About 10 minutes before entering clouds visible ahead of the airplane, the captain turned on the seat belt sign and advised the passengers and the flight attendant of the possibility of turbulence. The flight conditions were smooth for about 10 minutes after the airplane entered the clouds. No precipitation returns appeared on the airplane’s weather radar display until about 20 seconds before the turbulence encounter, when a very small echo appeared about 5 miles ahead. Shortly after the crew noted the radar echo, the airplane encountered about 10 seconds of moderate rain and a strong updraft followed by a severe downdraft. The airplane climbed about 880 feet in altitude during the encounter. After the turbulence ended, the flight attendant called the flight crew to report that she and a passenger were injured. The captain immediately declared an emergency with Fort Worth Air Route Traffic Control Center (ARTCC), diverted the flight to Longview, Texas, and landed without further incident.

An NTSB review of recorded air traffic control (ATC) weather information along the airplane’s flightpath showed that an area of extreme intensity precipitation returns existed at the accident location and had been present for at least 15 minutes before the airplane encountered

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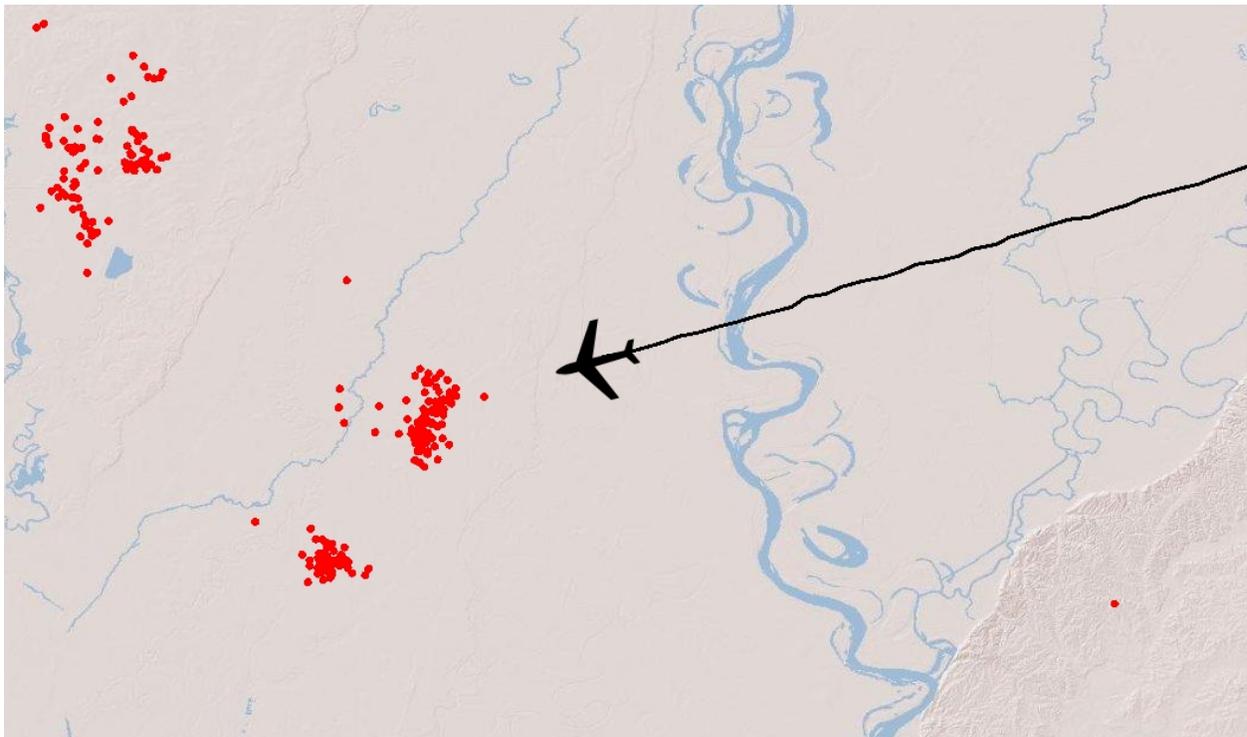
<sup>6</sup> For more information, see NTSB case numbers CHI93IA280, ATL83LA118, ANC05LA088, CEN10IA157, IAD01IA017, ANC11LA004, MIA98FA089, and LAX05LA080, which are available at <<http://www.nts.gov/aviationquery/index.aspx>>.

<sup>7</sup> For more information, see *Pan American World Airways, Inc., Boeing 707-121, N709PA, Near Elkton, Maryland, December 8, 1963*, Aircraft Accident Report File No. 1-0015 (Washington, DC: Civil Aeronautics Board, 1965), available at <[http://ntl1.specialcollection.net/scripts/ws.dll?websearch&site=dot\\_aircraftacc](http://ntl1.specialcollection.net/scripts/ws.dll?websearch&site=dot_aircraftacc)> (accessed March 14, 2012).

<sup>8</sup> For more information, see NTSB case number CEN10LA363, which is available at <<http://www.nts.gov/aviationquery/index.aspx>>.

severe turbulence. Review of ATC communications revealed that the air traffic controllers handling the flight did not advise the pilot of the precipitation ahead, as required by Federal Aviation Administration (FAA) Order 7110.65, *Air Traffic Control*.<sup>9</sup> When interviewed, the controllers handling flight 3224 stated that their displays did not show any precipitation at the accident location.<sup>10</sup>

An NTSB meteorologist also reviewed commercially available archived lightning data (from the Earth Networks Total Lightning Network [ENTLN]<sup>11</sup>) for the area and noted that substantial lightning activity had been recorded at the accident location. Figure 2 shows the airplane's position immediately before the accident, along with the locations of lightning strokes detected during the preceding 20 minutes. The lightning detected by the ENTLN was a strong indication of the presence of a thunderstorm immediately in front of the airplane. The captain stated in postaccident interviews that if he had been aware that there was a thunderstorm ahead, he would have asked ATC for a course change because American Eagle's policy instructed pilots to avoid thunderstorms by 20 miles.



**Figure 2.** American Eagle flight 3324 flightpath (black line) immediately before the accident 1751 central daylight time. Red dots indicate total lightning detected between 1731 and 1750.

<sup>9</sup> Paragraph 2-6-4, “Weather and Chaff Areas,” directs controllers to issue pertinent information on observed/reported weather areas. When requested by the pilot, controllers should also provide radar navigational guidance and/or approve deviations around weather areas.

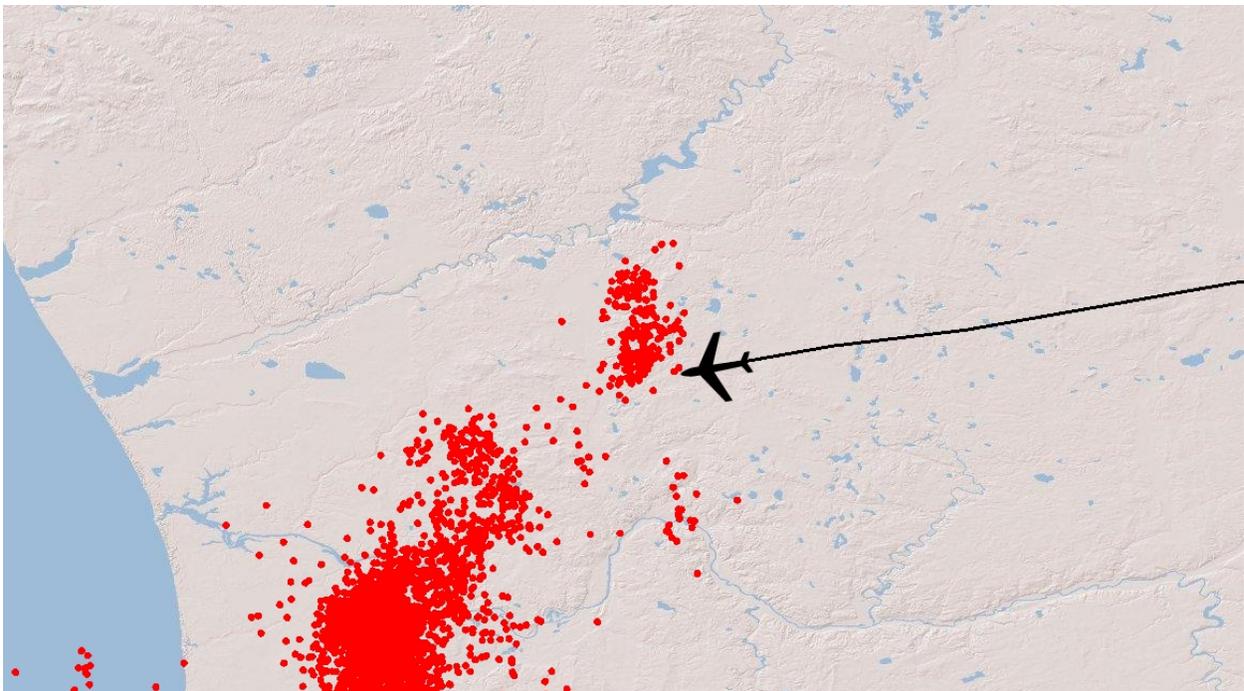
<sup>10</sup> Controllers at ARTCC facilities monitor aircraft using display system replacement radar displays that are supplied with precipitation information through a subsystem known as the weather and radar processor (WARP). WARP depicts precipitation information in three levels of intensity: moderate, heavy, and extreme.

<sup>11</sup> Total lightning information presented in this recommendation letter was obtained from the ENTLN; other sources of total lightning information are available in the United States.

*Pinnacle Airlines Flight 4018, Grand Rapids, Michigan*

On July 1, 2011, about 1230 central daylight time, Pinnacle Airlines flight 4018, a Bombardier CRJ-200, encountered hail at flight level 200 while en route from Detroit, Michigan, to Milwaukee, Wisconsin. The airplane incurred impact damage to the radome, wing leading edges, and engine inlets that was not discovered until inspection after the airplane landed in Milwaukee. Because the damage to the airplane did not meet the regulatory standard for an accident or incident, a formal NTSB investigation did not occur, but NTSB meteorology and ATC investigators reviewed the circumstances of the event.

Plots of the airplane's position along with lightning data (see figure 3) indicated that the airplane penetrated an area of dense lightning activity. Analysis of ground-based weather radar data indicated that a convective cell collocated with the lightning activity may have contained hail up to 2 inches in diameter. Figure 3 depicts the flightpath of flight 4018 immediately before the hail encounter and shows that lightning activity was present during the previous 20 minutes at the event location. Review of ATC communications indicated that the crew was not advised of any detected precipitation, and, according to information provided by Pinnacle, the flight crew did not recall seeing any precipitation on their airborne radar display.

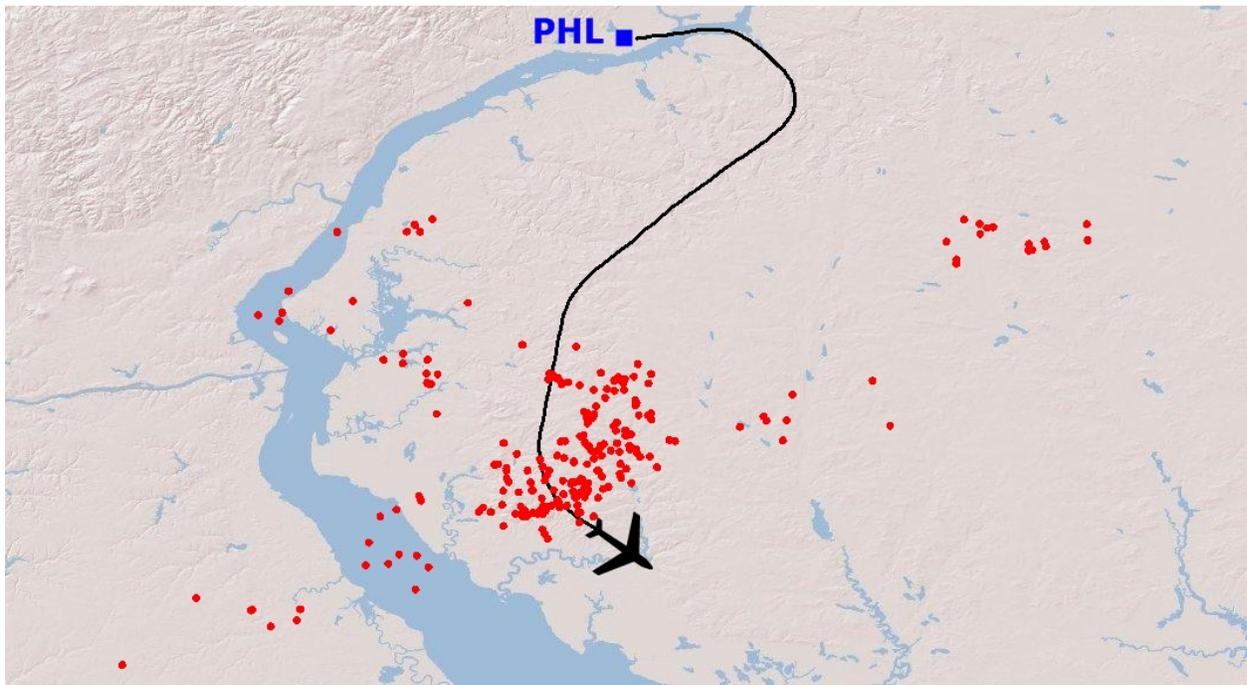


**Figure 3.** Pinnacle Airlines flight 4018 flightpath (black line) at 1226 central daylight time. Red dots indicate total lightning detected between 1206 and 1225 central daylight time.

*US Airways Flight 1209, on departure from Philadelphia, Pennsylvania*

On August 14, 2011, about 1015 eastern daylight time, US Airways flight 1209, a Boeing 757 en route from Philadelphia, Pennsylvania, to Philipsburg, St. Maarten, was struck by lightning at approximately 16,000 feet. The crew reported smoke in the cockpit, declared an

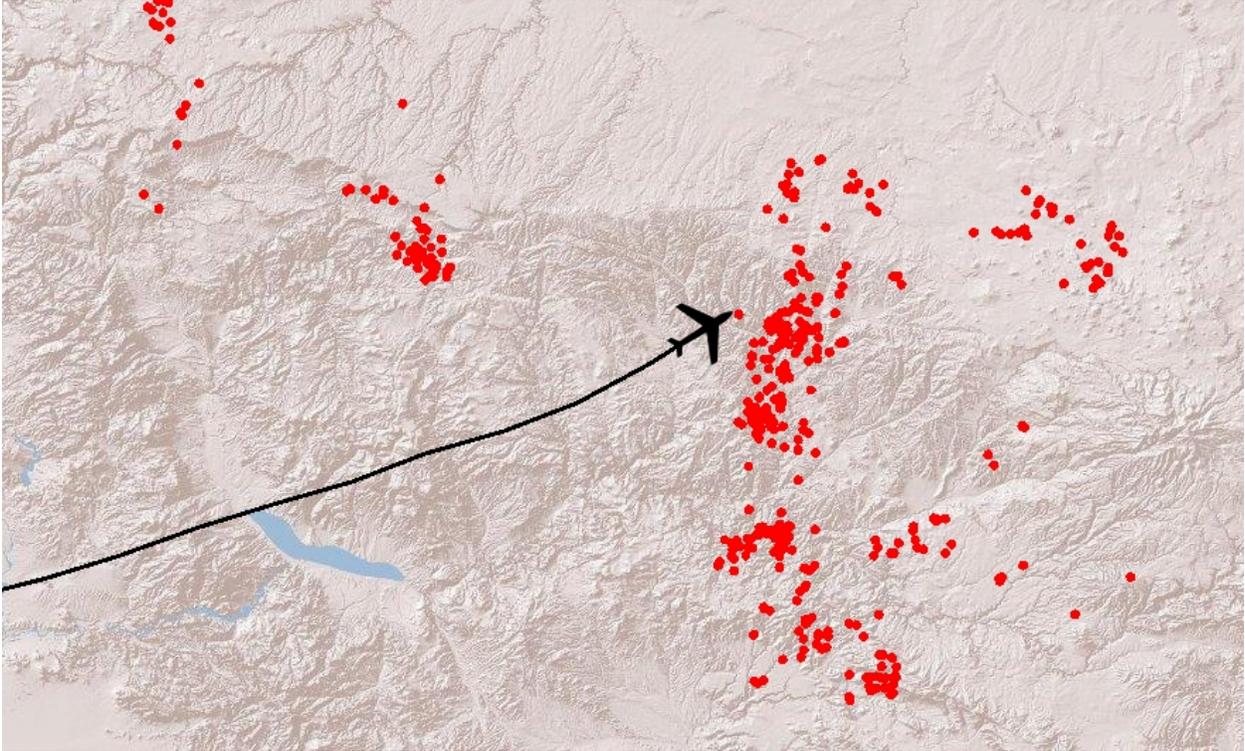
emergency, and diverted to Baltimore, Maryland, where the airplane landed without further incident. At the time of the incident, the flight was under control of the Washington ARTCC. When the pilot first contacted the center, the controller advised of moderate rain and turbulence along the airplane's route. About 3 minutes later, the pilot reported that the airplane had sustained a lightning strike and requested to return to Philadelphia "with priority," later changing the destination to Baltimore. The pilot added that the airspace the flight had just traversed contained "...moderate to possible severe..." turbulence, with multiple cloud-to-cloud lightning strokes. Figure 4 depicts the position of the airplane about the time that the pilot reported the lightning strike, along with the locations of lightning strokes detected in the area during the 15 minutes before the event.



**Figure 4.** US Airways flight 1209 flightpath (black line) about 1015 eastern daylight time. Red dots indicate total lightning detected between 1000 and 1015.

*American Airlines Flight 1894, Show Low, Arizona*

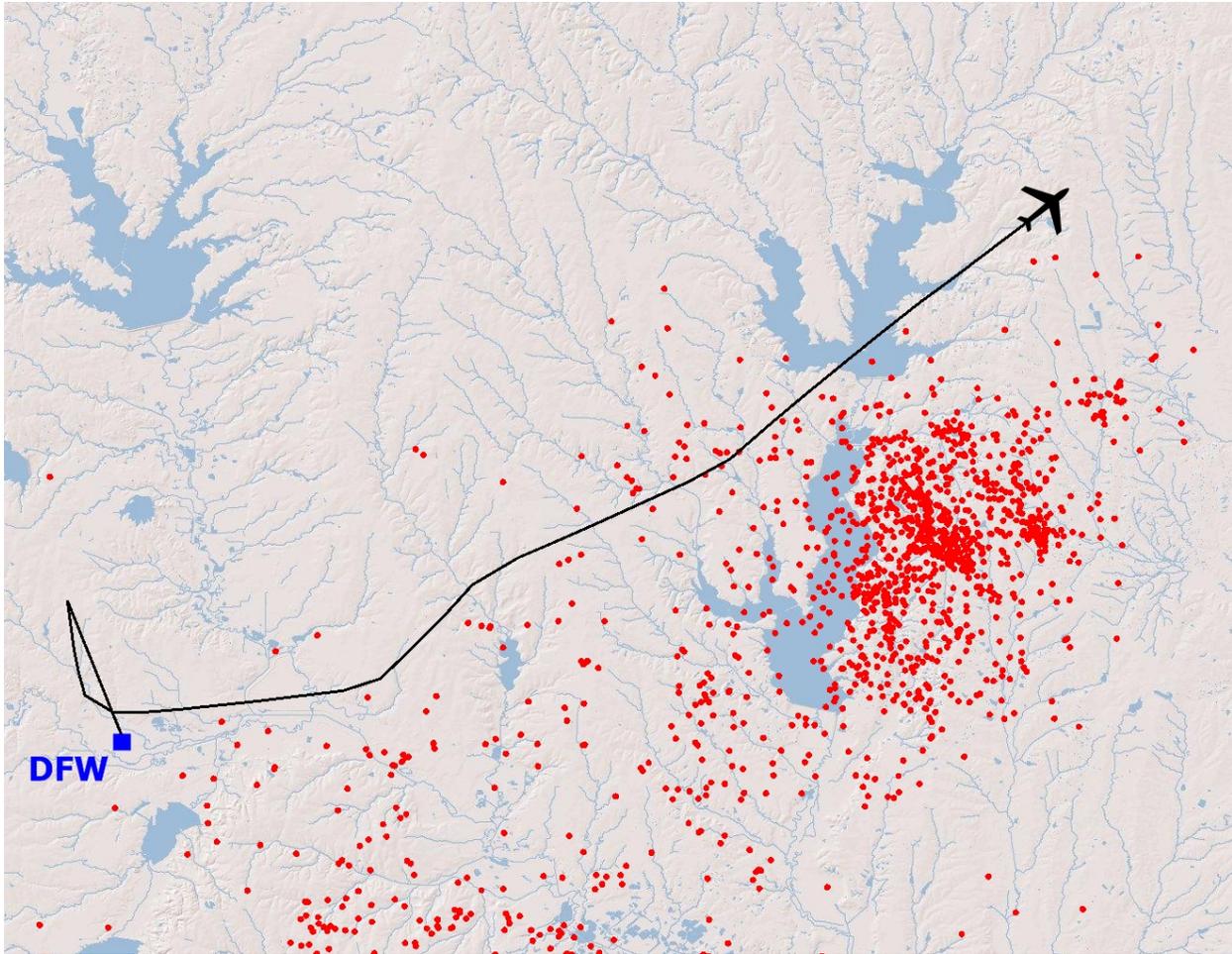
On August 18, 2011, about 1442 mountain daylight time, the flight crew of American Airlines flight 1894, a McDonnell-Douglas MD-83 en route from Phoenix, Arizona, to Dallas/Fort Worth, Texas, declared an emergency after encountering severe icing conditions at 33,000 feet near Show Low, Arizona. The crew diverted to Albuquerque, New Mexico, where the airplane landed without further incident. Severe icing events at these altitudes are rare and are normally associated with convective activity that can be readily detected by ground-based weather radar. Review of radar data recorded along the airplane's flightpath suggested the presence of convective activity in the area but only moderate precipitation returns at the location of the reported icing. However, as shown in figure 5, there was significant lightning detected in the area of the incident for at least 20 minutes before. If this information had been available to the crew, it would have alerted the pilots to potential hazards associated with convective activity well before they entered the area.



**Figure 5.** American Airlines flight 1894 flightpath (black line) at 1540 mountain daylight time. Red dots indicate total lightning detected between 1520 and 1539.

*American Eagle Flight 3376, Farmersville, Texas*

On January 24, 2012, about 1927 central standard time, the flight crew of American Eagle flight 3376, an Embraer 145 regional jet en route from Dallas/Fort Worth, Texas, to Madison, Wisconsin, declared an emergency after sustaining a lightning strike at about 17,500 feet near Farmersville, Texas. The crew immediately requested to divert to Little Rock, Arkansas, where the airplane landed without further incident. Review of weather radar data recorded along the airplane's flightpath showed convective activity in the immediate region; however, the aircraft had not penetrated any area of extreme precipitation returns. Although the aircraft successfully avoided the most dense area of lightning, significant lightning was detected along the aircraft's actual flightpath for at least 15 minutes before the emergency declaration (see figure 6). During postincident interviews, the controllers involved in the incident stated that the ability to depict lightning data on ATC displays would be useful in assisting pilots to avoid areas of hazardous weather.



**Figure 6.** American Eagle flight 3376 flightpath (black line) at 1927 central daylight time. Red dots indicate total lightning detected between 1912 and 1927.

### **Integration of Real-Time Lightning Detection Data**

As previously noted, FAA Order 7110.65, *Air Traffic Control*, requires controllers to provide pilots with information on observed or reported areas of precipitation and assistance in avoiding such areas if requested. Controllers and pilots try to avoid operations in or through areas that contain heavy-to-extreme levels of precipitation because such areas are more likely than others to indicate the presence of convective weather and the associated hazards to flight. However, the presence of extreme-intensity precipitation is not conclusive evidence that convective activity exists, and in numerous postaccident investigative interviews, ARTCC controllers have reported that aircraft appear to fly through radar-depicted areas of heavy-to-extreme intensity precipitation without ill effect. A possible explanation for this observation is the two-dimensional representation of weather conditions presented by ATC radar displays. Aircraft appeared to fly through areas of precipitation when they were actually operating at an altitude sufficient to pass safely over the top of the detected precipitation. In other circumstances, however, such as those described in this letter, aircraft have inadvertently entered hazardous weather that was either not sufficiently reflective to produce a strong radar return or had associated heavy-to-extreme intensity precipitation but was not recognized as hazardous by ATC or pilots. In either case, the availability of lightning detection data as an overlay on detected

precipitation would serve to identify, with a higher degree of accuracy, the location of thunderstorm activity. Access to such information would assist controllers in safely rerouting aircraft around the affected areas.

Although most of the incidents and accidents described in this letter involved aircraft receiving ATC services from an FAA ARTCC, thunderstorm hazards clearly are not limited to the ARTCC environment, and terminal radar approach control (TRACON) facilities should also have access to lightning detection data. As a system currently used at all ARTCCs to provide precipitation information, the weather and radar processor (WARP) system could be considered a potential mechanism for providing ARTCC controllers access to lightning data; however, as an ARTCC-only system, WARP does not directly interface with terminal radar data processing systems, such as the automated radar terminal system and standard terminal automation replacement system. Consequently, another mechanism may need to be considered. The NTSB believes that the addition of lightning data to the precipitation information currently available to ATC facilities would assist controllers in locating potentially hazardous conditions, adjusting traffic flows to avoid the affected areas, and helping pilots to avoid the hazards associated with flight near convective weather. Therefore, the NTSB recommends that the FAA study the technical feasibility of presenting, through the use of the WARP system or other means, real-time total lightning data on controller displays at both ARTCC and TRACON facilities, and, if feasible, incorporate real-time total lightning data on controller displays and in associated weather products for current and future display systems.

The NTSB notes that ARTCC facilities contain integrated National Weather Service (NWS) center weather service units (CWSU) staffed by trained meteorologists who are typically familiar with local weather conditions and area ATC operations. CWSUs were developed in response to the 1978 Southern Airways accident in New Hope, Georgia,<sup>12</sup> which resulted from the airplane's encounter with a severe thunderstorm. According to the NWS website, CWSU meteorologists provide face-to-face briefings with ATC that "...let the meteorologist convey a variety of weather information to air traffic controllers using science, past experiences and local knowledge."<sup>13</sup> As new weather display capabilities are made available to controllers, the knowledge and experience of CWSU meteorologists will be valuable in assisting controllers to better understand and maximize the usefulness of additional information, such as lightning data. Therefore, the NTSB recommends that, to the extent practicable, the FAA incorporate direct CWSU briefings on new weather-related ATC equipment and information services into controller training.

The NTSB also notes that the FAA currently offers flight information services–broadcast (FIS–B)<sup>14</sup> connectivity to pilots whose aircraft are equipped to support ground-to-air data link services. As with the recommended integration of lightning data into ATC radar displays, the NTSB believes that the addition of lightning information to the FIS-B data stream would improve safety by assisting pilots in identifying and avoiding areas of severe weather. Therefore,

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<sup>12</sup> For more information, see *Southern Airways Inc., DC-9-31, N1335U, New Hope, Georgia, April 4, 1977*, Aircraft Accident Report NTSB/AAR-78/03 (Washington, DC: NTSB, 1978).

<sup>13</sup> <<http://www.weather.gov/aviation/pages/CWSU/CWSU.php>> (accessed January 24, 2012)

<sup>14</sup> FIS–B enables equipped aircraft to receive digitally transmitted information, such as textual and graphical weather products, notices to airmen, and automatic terminal information service data.

the NTSB recommends that the FAA incorporate real-time total lightning data into the products supplied to pilots through the FIS-B data link.

Therefore, the National Transportation Safety Board makes the following recommendations to the Federal Aviation Administration:

Study the technical feasibility of presenting, through the use of the weather and radar processor system or other means, real-time total lightning data on controller displays at both air route traffic control centers and terminal radar approach control facilities, and, if feasible, incorporate real-time total lightning data on controller displays and in associated weather products for current and future display systems. (A-12-18)

To the extent practicable, incorporate direct center weather service unit briefings on new weather-related air traffic control equipment and information services into controller training. (A-12-19)

Incorporate real-time total lightning data into the products supplied to pilots through the flight information services – broadcast data link. (A-12-20)

In response to the recommendations in this letter, please refer to Safety Recommendations A-12-18 through -20. If you would like to submit your response electronically rather than in hard copy, you may send it to the following e-mail address: [correspondence@ntsb.gov](mailto:correspondence@ntsb.gov). If your response includes attachments that exceed 5 megabytes, please e-mail us asking for instructions on how to use our secure mailbox. To avoid confusion, please use only one method of submission (that is, do not submit both an electronic copy and a hard copy of the same response letter).

Chairman HERSMAN, Vice Chairman HART, and Members SUMWALT, ROSEKIND, and WEENER concurred in these recommendations.

*[Original Signed]*

By: Deborah A.P. Hersman  
Chairman