Obscured by Fog

When a cloud is not a cloud it becomes more of a hazard.

BY ED BROTAK

At 0841 local time on April 10, 2010, a Tupolev 154M passenger jet carrying the president of Poland, his wife and numerous government officials crashed about 1 km (0.6 mi) from the Smolensk Airport in Russia, killing all 96 people aboard. Short of the runway, the plane struck trees and broke apart. Preliminary reports say the flight crew had been warned of reduced visibility and was told to divert to another airport, and that they attempted the landing anyway. Regardless of whatever factor is eventually designated as the primary cause of the crash, fog clearly limited the airport's visibility.

Aviation accidents in which fog plays a major role often prove fatal. The worst aviation disaster of all time, the collision of two Boeing 747s in Tenerife, Canary Islands, involved fog. The captain of the departing aircraft and the traffic control tower could not see that the landing 747 was still on the runway, leading to the crash that killed 583 people.

To review the basics, fog is simply a cloud near or in contact with the earth's surface — usually flat ground. Low clouds that may obscure mountainous terrain generally are not defined as fog. For aviation interests, the point is moot since physically clouds and fog are the same thing — minute water droplets or ice crystals suspended in the air. With both fog and clouds, the water droplets or ice crystals are so small that gravity has a negligible effect, and thus they remain suspended. In fact, mountainous locations in the clouds simply report it as fog. For example, at the same time Seattle was reporting a visibility of 10 mi (16 km) and an overcast layer at 3,800 ft, nearby Stampede Pass, at an elevation of nearly 4,000 ft, was reporting ¼ mi (403 m) visibility and a vertical visibility, or ceiling, of 100 ft.

Fog occurs when a low layer of air becomes saturated and atmospheric water vapor begins to condense. There are two ways saturation and condensation occur in the atmosphere — moisture is added to the air, or the air is cooled. Cooling the air lessens its water-holding capacity. The dew point, a measure of moisture in the atmosphere, is the temperature at which saturation occurs. When the air temperature drops to the dew point, you have saturation, that is, 100 percent relative humidity. Condensation, the process of water vapor turning into liquid water, occurs instantaneously at this point, too.

At temperatures above freezing, fog is composed of tiny water droplets. "Freezing fog" occurs with temperatures below the freezing point but still consists of liquid fog droplets. This "supercooled water" also poses an icing problem for aircraft. At very cold temperatures — below 14 degrees F (minus 10 degrees

C) — ice fog is possible, with fog comprised of ice crystals.

Fog occurs from the Arctic to the tropics. Counterintuitively, even deserts are plagued by fog — cool water coastal deserts may go years without rain, but have fog nearly every day. Although many locations have seasons when fog is more prevalent, fog also can occur at any time of the year. Fog is most common in the morning hours, but it can occur at different times of the day, depending on location and conditions.

Meteorologists have classified six different types of fog based on the formation process. Ground fog — or radiation fog as it is officially called — is the most common type of fog. It can occur anywhere there is sufficient moisture in the air. It is most common in the early morning. After the sun sets, the earth's surface "radiates" heat out into space and cools. The layer of air just above the surface is cooled from below. If the temperature drops to the dew point, the air becomes saturated and condensation, or fog, will form. In fact, meteorologists often use the dew point to forecast fog. If the overnight low is forecast to drop to the dew point, fog is likely. In its lightest form, ground fog may only consist of wisps a few feet thick. In more extreme cases, the fog may have a vertical depth of several hundred to 1,000 ft. For pilots, a thin layer of ground fog may appear fairly transparent from above. But when viewing from the horizontal — for example,

when flying an approach — visibility can be drastically reduced since the pilots are looking through much more of the fog.

Ideal conditions for ground fog formation include clear skies and light to calm winds. The clear skies allow maximum radiational cooling. Light or no wind inhibits the mixing of different batches of air. In these situations, warmer air is above in an inversion condition. Mixing brings this warmer air down and slows the fog formation. However, the cool air is denser and tends to collect in lower elevations; valleys are prime locations for ground fog. When the sun rises, the ground and air warm and the fog begins rising. As the air mixes, it dries and the fog dissipates or "burns off."

Ideal conditions for ground fog formation include clear skies and light to calm winds.

A good example of radiation fog can be shown at Charleston, West Virginia, U.S., in the central Appalachian Mountains where dense fog is common in the fall. On Oct. 25, 2009, the high of 63 degrees F (17.2 degrees C) was reached at 1600 with a dew point of 36 degrees F (2 degrees C). There were clear skies, visibility of more than 10 mi, and calm winds. Temperatures fell quickly after sunset and reached 36 degrees F by 0300. Visibility was 8 mi (13 km), with wind still calm. By 0318, however, visibility had dropped to ¼ mi in dense fog. The temperature and dew point merged at 36 degrees F (2 degrees C). The fog persisted until 0800, when it burned off. Even during the foggy morning, occasionally light breezes increased visibilities to 6 mi (10 km), only to have them drop to 1/8 mi (201 m) a few minutes later. In Charleston, this cycle can persist for days in the fall. The fog usually lifts about the same time each morning.

In much of the mid-latitudes, ground fog is most common in the warmer months. Higher moisture content of the air and less wind are contributing factors. In some locations, a type of ground fog can develop in the winter. The worst situations involve valleys with extreme cold air flowing through. Sometimes the fog is so dense it reflects the heating rays of the sun, especially at higher latitudes. In these cases, the fog may persist for days. For example, at 2353 on Feb. 4, 1999, the Fairbanks Alaska airport reported 1/8 mi visibility in freezing fog. The temperature at the time was minus 42 degrees F (minus 41 degrees C), and these conditions persisted through the next day.

Frontal fog, obviously, is associated with fronts and primarily occurs in the cold season. Normally this type of fog occurs north of a warm front — south in the southern hemisphere — in the colder air. Occasionally, frontal fog occurs behind — to the north or west in the northern hemisphere — a cold front. Fronts have a vertical temperature structure that favors fog development, colder air under warmer air. The warmer air aloft is also moist. In frontal fog situations, there are often clouds above the fog deck and precipitation may be falling. This type of fog is usually widespread and consistent. It can occur day or night and persist for hours until the weather systems move. Snow on the ground often makes the fog worse, since it significantly cools the air while providing moisture from below.

Frontal fog can cause massive problems with aviation since its effects are so far reaching and last so long. On Jan. 23, 2010, a complex frontal system produced a warm, moist airflow which overrode colder air near the surface in the eastern half of the United States. Fog and low ceilings were reported from the southeast northward through the Ohio Valley and into the Midwest. Atlanta Hartsfield Airport reported visibilities of ¼ mi for nine hours. At the same time, the municipal airport in Mason City, Iowa, reported ½ mi (805 m) visibility in fog.

Another type of fog that often proves problematic to aviation is marine or sea fog. Marine fog forms over bodies of water when the water is colder than the air above it. This is a problem over some lakes in the summer and over ocean areas dominated by cold currents. In each case, the air is cooled from below by the cooler water. The cooling of the air in conjunction with the influx of moisture from below causes the fog to form.

Marine fog tends to be very thick and can be long lasting. It can alternately lift and descend, never really dissipating. When it lifts off the ground, it becomes a low stratus cloud deck. Although surface visibilities may improve, low ceilings are still an aviation concern. Any type of onshore wind brings this fog over land where it can cause great problems for coastal areas. If the wind shift is abrupt, visibility may drop quickly. If the wind shift is unexpected, pilots may be caught off guard.

In middle and higher latitudes, marine fog is primarily a summer occurrence. In tropical regions along cold-water coasts, marine fog is prevalent all year. The Tenerife accident occurred in a region known for marine fog. Although we normally associate marine fog with colder waters, it is the difference in the temperature of the air and water that is most important. Even warmer waters can initiate fog if the air above is warmer still. In the winter, a type of marine fog can occur with oceanic storms. For terminals near the coast, this can mean the dangerous combination of low visibility and strong winds. On Jan. 15, 2010, Astoria, Oregon, U.S., was in the warm sector of a strong winter storm. At one point, the airport reported ½ mi visibility in heavy rain and fog with southerly winds of 23 kt gusting to 41 kt.

Less of a problem for aviation is precipitation fog. Whenever rain or snow exists, some of it evaporates into the air and then recondenses as fog. This type of fog isn't very dense, and reductions in visibility due to the precipitation itself are more of a problem. Frontal fog and some marine fogs occur with precipitation, but this is a "true" fog not just formed by the precipitation. Visibilities in these cases can be reduced significantly.

Steam fog occurs when moisture evaporates from a surface and saturates the air above it. A simple example is when wet pavement, just after a rain when the sun comes back out, seems to have steam rising from it. Steam fog occurs over water when the water is warmer than the air above it. Usually steam fog does not cause great reductions in visibility. However, steam fog can produce icing when the air temperature is below freezing.

Upslope fog forms due to orographic lifting. When winds are blowing up a fairly gentle slope, condensation and fog can develop. This is fairly common in the Great Plains of the United States, when east winds occur in the winter. On Jan. 22, 2010, the interaction of a low-pressure area coming out of the Rocky Mountains and a high-pressure area near James Bay in Canada combined to produce a strong southeast air flow over the Central Plains. At North Platte, Nebraska, U.S., this combination resulted in ¼ mi visibility in fog with a vertical visibility of 100 ft. And the wind was blowing from 130 degrees at 16 kt, with gusts to 22 kt.

Fog combining with smoke produces some of the worst effects on visibility. Not only does the smoke reduce visibility on its own, but smoke particles act as condensation nuclei.

Fog combining with smoke produces some of the worst effects on visibility. Not only does the smoke reduce visibility on its own, but smoke particles act as condensation nuclei, accelerating the fog-making process. This often happens in the aftermath of a major wildfire. Even after the fire is controlled, smoldering remains can emit great amounts of smoke into the air. For example, in April, a major wildfire burned near North Myrtle Beach, South Carolina, U.S. Even though the fire was contained within 24 hours, for several days afterward the combination of fog and smoke in the morning brought air travel and other forms of transportation to a standstill. One morning, the visibility at the airport dropped from 5 mi (8 km) to ¼ mi in 12 minutes.

Another bad combination is dense fog and thunderstorms. This seems contradictory, involving extremes in stability and instability, but it can occur. The warmer marine fog develops with air masses than can support thunderstorm development. Also, colder, more stable air near the surface can be overridden by warmer, unstable air above in frontal situations. Thunderstorms can develop in this warmer air, but their effects such as lightning, gusty winds and turbulence, can be felt down to the ground.

For fog detection, the only other tool besides actual observations that can be useful is weather satellite visible imagery. Obviously, this is limited to daylight hours. Infrared imagery cannot distinguish low-lying fog from the ground surface since their temperatures are too close. On visible images, fog can be picked out from other clouds by its low-lying nature. Often fog follows topographic features, in valleys but below ridge tops. Fog does not show up on radar due to the very small size of the droplets involved.

Fog can form quickly when the air temperature reaches the dew point. At other times, the wind may blow a fog bank over an airport, quickly reducing visibility. But it seems that many of the fog-related accidents occur when the fog is readily apparent, and not a surprise.

Edward Brotak, Ph.D., retired in May 2007 after 25 years as a professor and program director in the Department of Atmospheric Sciences at the University of North Carolina Asheville.