Chapter 20 AVIATION WEATHER

Previous weather chapters indicated the importance of weather conditions to aviation activities. This chapter will take a closer look at what weather can do with aviation. While factors such as turbulence and thunderstorms will again be studied, this time they will be investigated more thoroughly.

Objectives

Describe weather conditions that reduce visibility for aircraft.
Identify the forms of turbulence hazardous to aircraft.
Classify the types of icing hazardous to aircraft.
Define CAVU, hydroplane, VFR, IFR, and AGL.
Explain the three stages in the development of a thunderstorm.
Describe the general characteristics of a tornado.
Explain the Fujita-Pearson Scale.
State the general characteristics of a hurricane.
Explain the Saffir-Simpson Scale.
Explain the developmental stages of hail.
Describe the hazards of severe weather to aviation.
Identify the beneficial effects of severe weather.
Define thunder, lightning, tropical depression, tropical storm, cyclone, and good and bad weather.
Describe the characteristics of Arctic weather.
State the classifications of tropic weather.
Identify the hazards of Arctic and tropic weather to aviation.
Define equatorial trough.

Weather Hazards

If the sky is clear of clouds, if the winds are calm, if the air is cool and if there is no haze, the weather is Ceiling and Visibility Unlimited (CAVU). It is time to fly! This is a rare condition of the atmosphere even in a local area. Much of the time when aviators fly, they encounter some type of weather condition that could be hazardous to their flight, especially if they fly long distances.

What are these weather hazards to aviation? Basically, they include any weather condition that produces an in-flight reduction of visibility, turbulence for the aircraft in flight, icing on the aircraft itself or within its power plant while in flight.

An airplane moving on the ground can also experience weather problems. Wet runways can cause an airplane's tires to hydroplane (slide on a film of water), making braking ineffective and causing skidding. Wet runways can affect both takeoffs and landings. Similar incidents or accidents have occurred when a runway was glazed with ice or covered in snow too deep for the aircraft's landing gear to work properly.

T38 -As in the Clouds

F-16 Landing on a Rain-slick Runway

Reduced Visibility

Visual Flight Rules (VFR). These are the general weather conditions the FAA considers a pilot can expect at the surface. VFR criteria mean a cloud ceiling greater than 3,000 feet and greater than 5 miles visibility. If any clouds are around, the noninstrument pilot must stay clear of them.

Instrument Flight Rules (IFR). Weather conditions at an airport during which a pilot must use instruments to assist takeoff and landing. IFR conditions mean the minimum cloud ceiling is greater than 500 feet and less than 1,000 feet, and visibility is greater than 1 mile and less than 3 miles.

Clouds, Rain, Snow, Fog and Obstructions. Visibility is reduced to zero if an airplane is flying within a cloud. Different types of fog pose a hazard to all aviation activities, and this includes up-to-date military and civilian aircraft—if you can't see the landing area or runway, it isn't safe to land. Rain, especially intense rain, can reduce visibility to the hazard level and snow greatly reduces visibility.

A B-1B taking off in foggy conditions.

The possibilities for landing accidents are increased when visibility is reduced. This same danger is also present in flight and is greatest for those pilots who are not trained to fly according to IFR and/or are not flying aircraft equipped for IFR flight.

For example: (1) pilots of different aircraft may not see each other until a midair crash is inevitable, (2) an improperly set altimeter could cause a plane to fly into a mountain because it is hidden by clouds, fog, rain, etc., and (3) across the land, there are very tall towers (up to 2,000 feet above ground level), which pose a hazard to flight. These towers are clearly marked on aeronautical charts; however, mix the presence of such a tower with greatly reduced visibility and the possibility of collision with the tower is increased.

In addition to clouds, rain, snow and fog, what else can cause reduced visibility? Haze and smoke, blowing dust, blowing sand, blowing snow and a condition that may occur where there is snowfall called "whiteout" can reduce visibility.

Haze and Smoke. Earlier study defined a temperature inversion as the condition where cooler air is overlain by warmer air. This condition can result from several causes, but the net result is a stable atmosphere. That is, the air doesn't mix through convection to disperse the particulates of dust, pollen, smoke and so forth. The wind is calm so the haze and smoke cannot move laterally out of the area. If this condition persists for several days, the visibility will become progressively poorer.

This atmospheric condition is especially common in the heavily populated and heavily industrialized areas of the country. It is noticeable in the early morning because radiation cooling the earth's surface during the nighttime has, in turn, cooled the air near the ground level and lowered the ceiling of the haze layer.

As is often the case, the sun will warm the cool, hazy air and cause it to expand upward. Visibility at surface level becomes better and is quite acceptable to the surface traveler but not to the aviator.

What seems to be ample visibility upon takeoff suddenly becomes what appears to be a complete obstruction to visibility at 1,000 feet

Industrial areas may produce haze and smoke.

above the surface. Visibility is satisfactory up and down, but the pilot may feel very apprehensive about what could come out of the murk ahead. The actual visual range at this altitude may very well be more than the FAA's acceptable 3 miles. Yet, visual perception while traveling well over 100 mph may interpret this much visual range as a wall just beyond the airplane's nose.

Particularly in the summertime, haze and smoke within a stable high-pressure cell may extend upward more than 10,000 feet during the heat of the day. Most small aircraft fly lower than this altitude. To them, the greatest surprise is the thundershower or thunderstorm that lies hidden within the area of haze and smoke. However, the weather service and FAA flight service personnel can warn of this type weather, if the aviator asks for such information by radio. When haze and smoke are present, the best preventive measure a pilot can take is to get a thorough weather briefing before flying.

Blowing Dust, Blowing Sand and Blowing Snow. Blowing dust of significant proportions is found in the relatively dry areas of the country. This condition develops when the air is unstable and there are strong winds. The horizontal wind picks up dust or soil particles while strong convective currents (vertical winds) carry it upward into the atmosphere. Working in combination, these winds can spread dust over hundreds of miles and upward to 15,000 feet. Visibility in these dust storms is reduced in all directions. The operation of an aircraft within a blowing-dust area is unthinkable. When in flight and approaching blowing dust, pilots have only one choice—to turn toward an airport that is clear and land.

Blowing sand is much more localized than dust. It occurs only in desert regions and only when the wind is strong enough to lift loose sand. Being much heavier than dust, the blowing sand is seldom lifted more than 50 feet above the surface. Still, this condition would prohibit an aircraft from taking off or landing.

Strong winds also are the cause of blowing snow. For this condition to exist, the snow must be lifted to a height of at least 6 feet. The frequency of blowing snow is much greater in the areas of the country where dry, or powdery, snow is more likely to fall. To the aviator, this blowing snow causes the same problems as fog, and it can reach 1,000 feet above the surface.

Aircraft taking off in snowy conditions.

Whiteout. This condition is more frequent in the arctic areas, but it can occur anywhere there is snow-covered ground. It is not a physical obstruction to visibility; it is an

optical phenomenon. Whiteout requires a snow-covered surface plus a low-level cloud deck of uniform thickness. With the sun at an angle of about 20 degrees above the horizon, its light rays are diffused as they penetrate the cloud layer. This causes them to strike the snow-covered surface from many angles; thus, shadows are not produced. These diffused light rays are reflected back and forth between the surface and the base of the cloud layer. The net effect is the loss of any reference to the horizon and of other references needed for depth perception. People, buildings, trees, and all other dark objects cast no shadows during a whiteout, so they all seem to float in space—not very conducive to the landing of an airplane.

Turbulence

Recall the atmospheric conditions that bring about turbulence, including the high-altitude types of clear air turbulence (CAT) which commercial jetliners sometimes encounter. The most important thing to remember about normal atmospheric turbulence is that you know it exists with cumulus, rotor and lenticular clouds, but CAT is where you find it (fly into it, in other words). The turbulence, or wake turbulence, created by aircraft is a form of CAT, but all aviators know that it exists if they see the airplane that creates it.

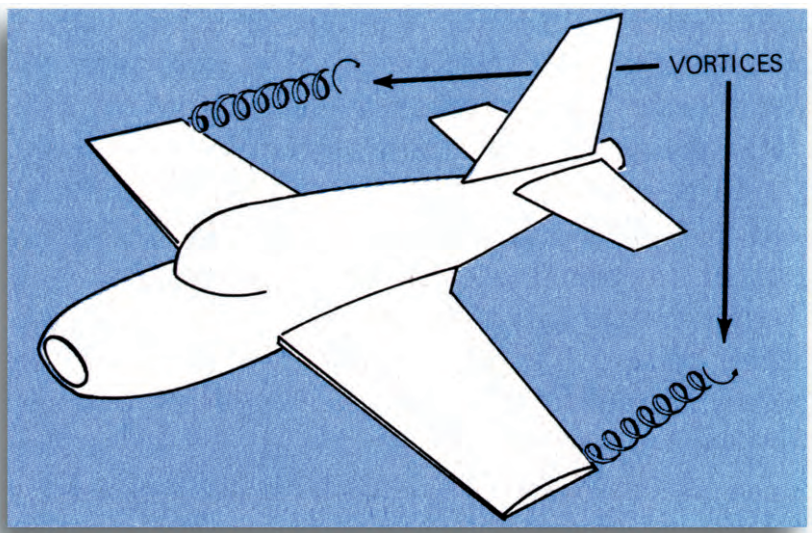
Wake turbulence has become more and more of a concern to light-aircraft pilots because it grows more severe as larger aircraft are built and flown. It results when air spills over and around the airframe and wingtips of an airplane.

There is some wake turbulence associated with all aircraft—even the lightest ones. It is not dangerous until the aircraft creating it are large enough and heavy enough to produce sizable and strong swirling air currents called wingtip vortices.

The vortices (from each wingtip) might be described as horizontal tornadoes. Their strength is greatest immediately behind the aircraft and varies with the size, speed and flight attitude of the aircraft. The vortices tend to settle between 500 to 800 feet below the parent aircraft's flight level and tend to remain there, spinning and waiting for an unsuspecting lighter-weight aircraft to come along.

The vortices will remain active well after the aircraft that spawned them has passed. How long they remain active depends on how stable the atmosphere is at their level.

Knowing that dangerous vortices are present behind the larger aircraft, the light-aircraft pilot best avoids them by staying clear of



Small airplanes produce wingtip vortices.

them. If at the same altitude, the pilot of the small aircraft should climb well above the other aircraft's flight path. If the small aircraft is 1,000 feet below the flight path of the larger plane, there should be no problem; yet, it wouldn't be a bad idea to descend still more just in case the difference in altitude has been misjudged. Now, if it isn't advisable to climb or descend, what should the light-aircraft pilot do? The answer is to turn in the opposite direction and fly parallel to the other aircraft's flight path until a separation of 15 to 20 miles is obtained.

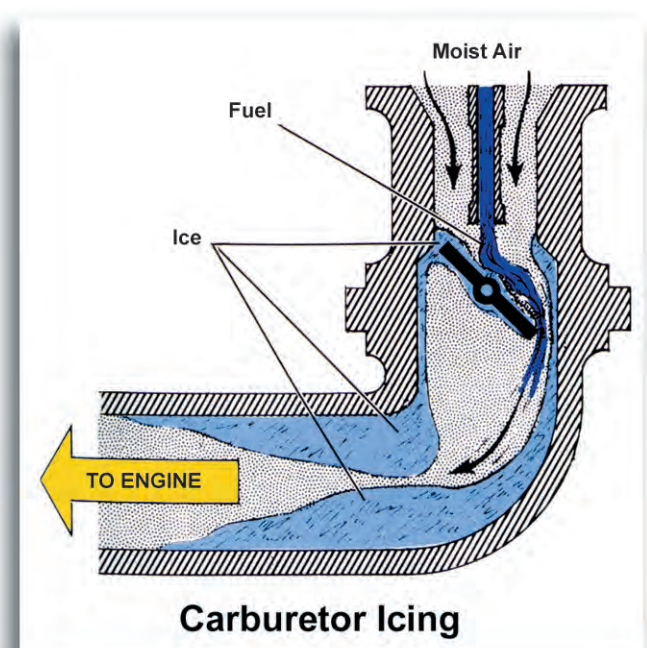
The greatest danger of wake turbulence is found at and near airports, and the first reason is obvious —this is where airplanes are concentrated. The second reason is that the large jets create the most severe wingtip vortices when they are taking off or landing. Their wings are at a greater angle of attack, which generates larger vortices that possess greater energy than vortices generated when in cruising flight.

Icing

Icing is a definite weather hazard to aircraft. Already mentioned was the fact that a runway covered with even a thin film of ice can cause loss of directional and braking control. In takeoff and in flight, the threat of ice hazard is increased.

Winter brings on icing conditions; however, ice is present, or potentially present, somewhere in the atmosphere at all times no matter what the season. What is critical is the altitude of the freezing level, which may be around 15,000 feet during summer and perhaps as low as 1,000 feet above ground level (AGL) on warm winter days.

Carburetor Ice. When the temperature and dew point are close, it is certain that water vapor is condensing within the carburetor of an aircraft reciprocating engine; and, if the engine is run at low speed, the condensation is turning into ice. This is why some engine manufacturers recommend that carburetor heat be applied when the throttle is retarded for prolonged descent and prior to landing. Ice forms because of lowered temperature within the carburetor as a result of fuel/air expansion within the carburetor system (as gas expands or as its pressure is reduced, its temperature lowers). The coldest point within the carburetor can be 40° F or more below that of the air through which the airplane is flying.



Carburetor Icing

Glaze and Rime Ice. Glaze and rime are names given to the ice that forms on an airplane's windshield, its propeller and other aerodynamic surfaces. Glaze ice is formed and builds quickly as an airplane flies through supercooled rain droplets. These droplets instantaneously turn to ice as they strike the airplane. This is what happens in a surface-level ice storm when power lines

and trees are broken from the weight of the ice that continues to accumulate.

This rapid increase of weight on an airplane in flight is a dangerous factor, but the greatest problem is the changing of the shape of the airfoil. The shapes of the wings and tail surfaces (airfoils) contribute to lift and the propeller's airfoil provides thrust. If ice distorts these shapes, lift and thrust will be adversely affected.

Rime ice has that frosty appearance seen on the walls of frozen-food lockers. It forms when the airplane is flying through supercooled clouds. It normally is no problem, but if it is allowed to accumulate, it will reduce lift and become a danger to flight.

Frost. Frost is another ice factor deserving mention. Frost would appear to be an inconsequential thing that develops on cold fall or spring mornings, and soon melts after the sun rises. However, frost disturbs the airflow enough to reduce the lift efficiency of aerodynamic surfaces.

This isn't to say that an airplane will not fly when there is frost on its wings, because it will. However, the danger becomes apparent at takeoff. The partial loss of lift caused by frost makes a much longer takeoff run necessary and reduces the rate of climb. On a relatively short runway, the result can be—and has been—a flight that ends just beyond the runway.

The larger, more complex aircraft are equipped to break or melt ice as it is formed—even on propellers. On the other hand, the great majority of aircraft flying today are not equipped to combat icing conditions, and aviators who fly them must be prepared to recognize atmospheric conditions that can cause icing. With the assistance of weather and flight service specialists during the flight-planning stage, all pilots should be able to avoid flight through areas where icing is likely.

Frost on a Parked Airplane

Severe Weather

The National Weather Service's severe weather classifications are based upon destructive effects with regard to man-made features. For example, a 40-knot (46-mph) wind has enough force to harm lightweight structures. Hail of 1/4-inch diameter can shred certain crops. Thus, the same weather is certainly a threat to aircraft. The violent "big three"—thunderstorms, tornadoes and hurricanes—pose the greatest in-flight hazards.

Dangerous Lightning

Thunderstorms

A thunderstorm may be defined as any storm accompanied by thunder and lightning. Lightning is the flash of light produced by electrical discharges in a thunderstorm area. Thunder is the sound sent out by rapidly expanding gases along the lightning's trail. It is attended by some form of precipitation and can cause trouble for aircraft in the form of turbulence, icing and poor visibility. The more severe thunderstorms produce hail and, in some cases, tornadoes. The thunderstorm is local in nature and is always produced by the growth of a cumulus cloud into a cumulonimbus cloud.

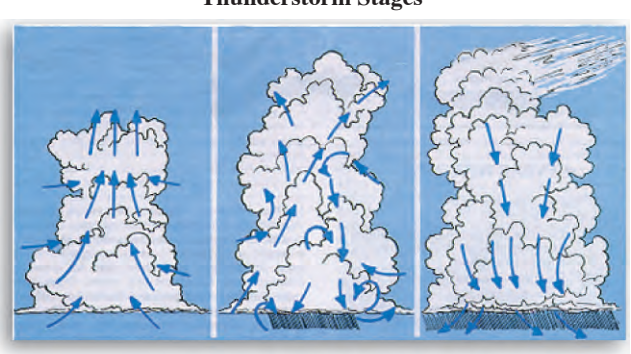
The severe elements of the thunderstorm are the result of the convection currents (vertical air movements) within the cloud. Individual thunderstorms are rarely larger than 10 miles in diameter, and they usually last no more than 1 1/2 hours.

Thunderstorms often form along weather fronts and appear to march across the land in lines of storms. This is the case when the local weather forecaster announces that a line of thundershowers is approaching and that thunderstorm warnings are in effect for the next few hours.

Thunderstorms are best studied by dividing them into three separate stages. They are cumulus (or building) stage, the mature stage and the dissipating stage.

The Cumulus Stage. Most cumulus clouds do not become thunderstorms, but all thunderstorms are born in cumulus clouds. The main feature of this first stage of the thunderstorm is the updraft: a large air current flowing upward from the ground through the chimney-like cloud. The updraft may reach speeds of over 3,000 feet per minute and altitudes of 40,000 feet or more. During this stage, water droplets grow to raindrop size as the cloud builds upward into a cumulonimbus cloud.

Thunderstorm Stages



Building Mature Dissipating

The Mature Stage. The mature stage of a thunderstorm is marked by the beginning of rain at the earth's surface. The raindrops (or ice particles) have become so large that the cloud's updraft can no longer support them, and they begin to fall. As they fall, the raindrops drag air behind them causing the characteristically strong downdrafts of mature thunderstorms. These down drafts spread

Lightning Cloud

out horizontally when they reach the surface, producing strong, gusty winds, sharp drops in temperature (because the air was chilled at high altitudes) and a sharp rise in pressure. As the downdrafts continue to build and spread, the updrafts weaken and the entire thunderstorm eventually becomes an area of downdrafts.

The Dissipating Stage. The downdrafts produce heating and drying causing the rainfall gradually to cease and the thunderstorm to dissipate or weaken. During this stage, the cloud develops the characteristic anvil shape at the top and may take on a stratiform (layered) appearance at the bottom. This stage is usually the longest of the three stages of a thunderstorm's life. Sometimes, the same conditions that cause thunderstorms can also bring on a much more destructive type of storm, the tornado.

Tornadoes

A tornado is a local storm that focuses nature's most destructive force on a small area. It consists of violently swirling winds with rapidly rising air at its center. The tornado is small and usually short of life, but because of its violence, it is probably the most feared storm of all.

Tornadoes occur with severe thunderstorms. Their circular whirlpools of air take the shape of a funnel or tube hanging from a cumulonimbus cloud. The rotating column of air in a tornado may range in diameter from 100 feet to half a mile.

If a tornado touches the ground, its path may be very erratic. (Technically, if the funnel does not reach the ground, the storm is not a tornado, but a funnel cloud.) It may touch the ground at some points along its path and completely miss other points. Its boundaries of complete destruction may be fairly well-defined. It may destroy houses on one side of the street and leave those on the other side untouched.

The very low pressure of tornadoes gives them great suction. They can lift objects as heavy as automobiles and rooftops of houses and carry them for considerable distances. They have been known to suck water from creeks and ponds.

Tornadoes occur most often in North America and in Australia. They have been observed in every state in the continuous United States, but most frequently in the central part of the nation. They occur most often in the spring and in the afternoon hours, approaching with a very loud roar like a railroad train or a flight of airplanes. Tornadoes are more numerous in the spring (March, April and May) and in the late fall (September through December).

It is very difficult to forecast tornadoes. The storm usually lasts only a short time and is primarily a local condition. The conditions identified as favorable to tornado production include an active cold front separating maritime tropical air from polar air.

In the same area, there is a strong high altitude jet of cold air from the west crossing a tongue of moist air from the Atlantic or the Gulf of Mexico. Doppler radar gives the ability to "see" inside storms and identify rotating air masses. This has greatly increased the warning time given for people to take shelter.

Dr. Fujita and Allen Pearson of the Severe Weather Forecast Center in Kansas City developed a tornado classification system. It has quickly become the standard method to describe tornadoes around the world.

Tornadoes

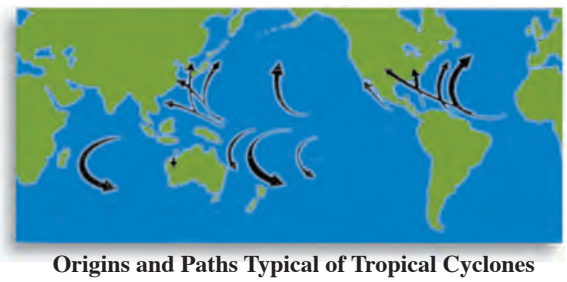
Fujita – Pearson Tornado Intensity Scale

Type	Wind Speed	Possible Damage
F0 (Light)	40-72 mph	Minor roof, tree and sign damage
F1 (Moderate)	72-112 mph	Roofs damaged, weak trailers flipped and torn apart, cars thrown from roads
F2 (Considerable)	113-157 mph	Strong buildings unroofed, weaker buildings destroyed, trailers disintegrated
F3 (Severe)	158-206 mph	Outside walls of strong buildings blown away, weaker buildings completely swept away
F4 (Devastating)	207-260 mph	All interior and exterior walls of strong buildings blown away, cars thrown 300 yards or more in the air
F5 (Unbelievable)	261-318 mph	All types of buildings completely blown away

Hurricanes

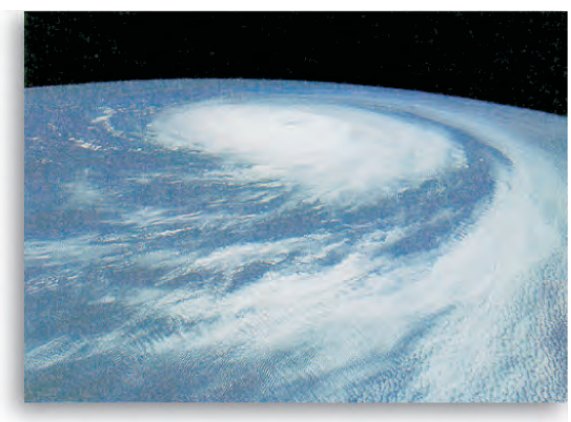
Second only to tornadoes in damaging effects, and even more dangerous to people and property, is the hurricane. This storm is a strong tropical cyclone with winds that often surpass 100 mph and have been clocked at more than 200 mph. Tropical cyclones occur around the world. They are known as "typhoons" in the western Pacific, "baguios" in the South China Sea, "cyclones" in the Indian Ocean and "willy-willies" in Australia.

A hurricane is a large, revolving storm with a calm center—called the eye—resulting from the speed of the whirling winds around the low-pressure core. It is an area of convective action, with the air moving upward in spirals around the eye. The calm center (eye) averages around 15 to 20 miles in diameter. The hurricane itself is usually several hundred miles across.



Origins and Paths Typical of Tropical Cyclones

Hurricanes that affect the United States originate over the warm tropical waters of the Atlantic and Pacific Oceans, the Gulf of Mexico and the Caribbean Sea. August, September and October are the peak months of the hurricane season.



Hurricane

Hurricanes receive their energy from the heat given off by the condensation of moisture in the warm air. Heat lowers the atmospheric pressure and wind begins to flow into the heated (low-pressure) area. The Coriolis Force deflects that wind, setting up the typical cyclonic movement of winds at less than 39 mph. At this point, the storm is called a tropical depression and many such storms never grow beyond that level.

The next step is the level of tropical storm. In this stage, winds range between 40 and 74 mph. When wind speeds reach or exceed 75 mph, the tropical cyclone is called a hurricane. In the early 1970s, Herbert Saffir and Dr. Robert Simpson (then director of the National Hurricane Center) developed a scale to express hurricane intensity. It is known as the Saffir-Simpson Scale. It rates potential damage that can be done by a hurricane based on barometric pressure, wind speeds and storm surge. The easiest correlation is by wind speed as shown in the table on page 434.

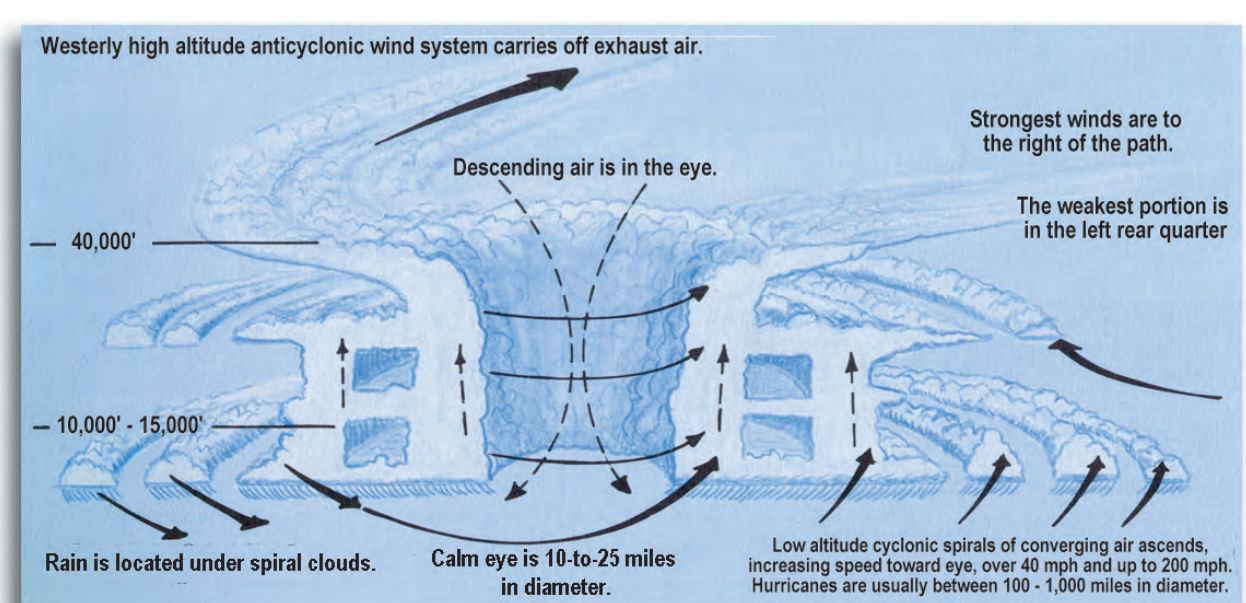
Heavy rainfall accompanies the hurricane with individual convective showers and thunderstorms lining up in a circular pattern around the eye of the hurricane. Heavy rainfall often continues after the hurricane moves inland, even after the wind circulation decreases. Flood damage is often a major problem associated with hurricanes. Cooler surface temperatures over the land or over nontropical seas help to bring on the weakening of the hurricane. Other factors are the loss of moisture, the inflow of air from the land and the increase in surface friction over the land.

The National Weather Service (NWS) keeps a constant watch for hurricane development, especially during the hurricane season. Using weather aircraft and satellites, the NWS can track the movement

Saffir-Simpson Hurricane Damage Potential Scale

Intensity Category	Wind Speed	Expected Damage
1 (Minimal)	74-95 mph	Limited to trees, shrubs, unanchored mobile homes
2 (Moderate)	96-110 mph	Small trees blown down; minor damage to windows, doors and roofs of buildings; major damage to mobile homes
3 (Extensive)	111-130 mph	Foliage torn from trees, some trees blown down; some damage to roofing, windows and doors; some structural damage to small buildings, mobile homes destroyed
4 (Extreme)	131-155 mph	Large trees blown down, extensive damage to roofs, windows and doors; mobile homes demolished
5 (Catastrophic)	156+ mph	Considerable damage to roofs, extensive shattering of windows, widespread structural damage to all kinds of buildings

and development of cyclonic areas in the tropics, and can issue warnings to endangered areas. The conditions that cause hurricanes last longer than those causing tornadoes; therefore, hurricane development is easier to predict. Although satellites have made the prediction of hurricane paths much



Cross-sectional Drawing of a Hurricane

more accurate, they still behave in unexpected ways and specific warnings cannot be 100 percent correct.

What do hurricanes mean to aviation, since only specially equipped meteorological research aircraft fly into them? They mean stay well clear, and this means hundreds of miles. It is not unusual for the cyclonic wind flow of the larger hurricanes to have a diameter of 500 miles, and they have been known to be much larger. A variety of weather will be associated with the system—everything except blizzards and dust storms. Hurricanes breed thunderstorms and, in many cases, tornadoes within the areas they affect. Knowing the perils of turbulence, thunderstorms and tornadoes to aviation, it is obvious why the hurricane is to be avoided.

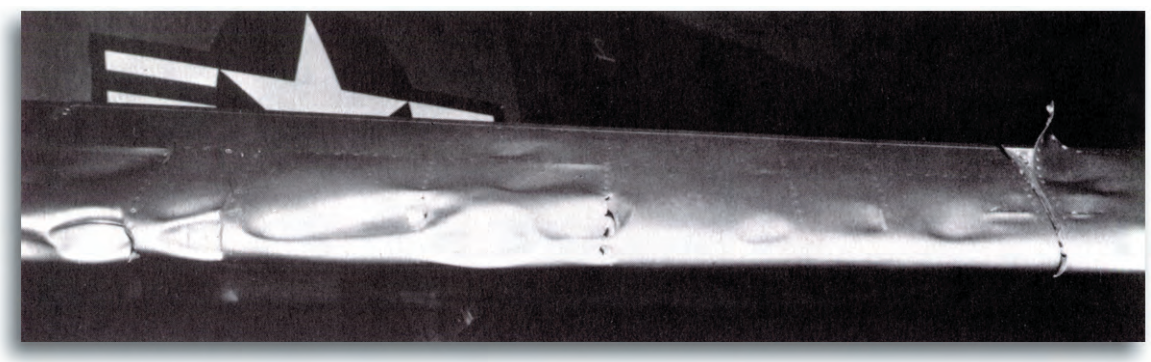
Hail

Previous study related how hail is formed within the thunderstorm prior to falling to the ground. However, its importance as a hazard to aviation deserves special emphasis.

Hail this size can do quite a bit of damage.

In the first place, hail may very well be within a building cumulus cloud before any type of precipitation falls to the surface. At this developing stage, the hail pellets may not be very large because strong air currents still are able to carry them about within the clouds. Even so, the combined velocity of an aircraft and hail give these small pellets a tremendous amount of energy.

Under these conditions, and especially if the pellets are hard because of exceptionally cold temperature at their level, the aircraft will experience some damage. The damage may be no more than many small dents in the aircraft's outer cover, but this is a very costly experience for the aircraft owner. Fender and body work on an airplane costs several times that of an automobile.



Hail Damage to an Aircraft Wing

Encounters with larger hail are even more damaging. Hail of the sizes, weights and velocities produced by thunderstorms in the western and mountainous areas could literally rip a small airplane apart if it were to fly into such an area. This reference is to hailstones approaching the diameter of a baseball, which, it is estimated, occurs in one out of about 5,000 thunderstorms. On the other hand, which of the 5,000 storms will contain hail of this size can't be predicted.

An example of what hail and intense rain can do to a jetliner occurred in 1977. In this instance, the storm area was producing thunderstorms with tops reaching 40,000 feet—a good indicator of high intensity. Radar showed heavy precipitation with indications of hail. The crew of a DC-9 elected to penetrate the storm area rather than avoid it and ran into one of the storm cells somewhere between 14,000 and 17,000 feet. Hail and rain pulled into the aircraft's engines caused the engines to stall and flame out. This also caused internal damage to the engines. The net result was the DC-9 making a crash landing and 63 of the 85 persons on board being killed.

Hail, therefore, is a definite hazard to flight, no matter how large the airplane. The only way to avoid it in flight is to stay well clear of the thunderstorms that produce hail.

Beneficial Effects

These severe or extreme forms of weather usually are referred to as bad weather because they may bring harmful effects to people and property. Of course, weather in itself is neither good nor bad. Any kind of weather may be considered good or bad depending on what is needed. Warm, sunshiny periods may be thought of as good weather, but can become bad if they last too long and cause shortages of moisture or even drought.

When the needed rain comes, suddenly the wet weather is good. However, if the rainy period lasts too long, it becomes bad weather again since floods may occur. What is needed is a balance of different types of weather.

In the same way, these forms of severe weather are neither good nor bad. Their effects on people and property are often devastating, but they are beneficial in the natural scheme of the earth's weather. They act to balance different forces at work in the atmosphere. They dissipate (break up) concentrations of energy in the forms of heat and atmospheric pressure that could, indeed, make the earth uninhabitable. It is true that these types of weather are often violent and, because of this, they are justly feared.

Arctic and Tropic Weather

People living in the temperate zones of the world are likely to consider arctic and tropical weather patterns as extreme. Natives of those regions, though, think of their weather as normal. Arctic weather and tropical weather are interesting to study and are important to weather in middle or temperate latitudes.

Aircraft in Arctic Weather

Arctic Weather

The Arctic is of passing interest to the student of weather, mostly because it causes the coldest air masses. While these air masses affect weather at lower latitudes, weather in the Arctic, unpleasant as it may seem, is not a major factor in most of our lives. It is included here because it may be a point of curiosity and because aviators fly there.

Mountains around the arctic Circle hold arctic air masses in the area. The Arctic Circle is a circle of latitude that marks off the earth's northern frigid zone. It is parallel to the equator and lies at approximately 66° north latitude. Because temperatures are so cold, the air has little moisture and little evaporation takes place. Precipitation (usually snow) in the Arctic is light, ranging from 3 to 7 inches per year in the coastal areas to 5 to 15 inches in the interior. This compares with some of the desert areas of the United States.

Cloudiness is at a minimum during the winter and at a maximum during the summer and fall. Strong winds occur frequently during the fall and winter. Winds stronger than 100 mph are not uncommon along the Greenland Coast during the winter.

Arctic winters are characterized by frequent windstorms and well-defined frontal passages. Visibility is a major problem at low levels in the Arctic due to fog haze, blowing and drifting snow, and peculiar light conditions including the dreaded whiteout.

Tropic Weather

The tropics feature weather quite differently from the Arctic, and not just in temperature. Fronts are rare in this area and there is much moisture in the air, especially in the oceanic and coastal regions. Continental tropical weather, however, can be quite different from oceanic and coastal tropical weather.

Oceanic Weather. Clouds cover about half the sky over the tropical oceans outside the equatorial trough. The equatorial trough is an area of low pressure and light winds near the Equator, varying from north to south of that line with the changing seasons. It is also the area in which the northeast and southeast trade winds converge (come together), and it is sometimes referred to as the intertropical convergence zone. Some amount of unsettled convective weather is found in this area at all times. When the wind convergence gets strong, thunderstorms develop that may produce wind gusts of up to 70 mph. Normal cloudiness includes a line of cumulonimbus clouds with sheets of cirrus clouds spread north and south of them.

In the oceanic zones outside the equatorial trough, the cumulus clouds yield showers in local areas, but outside the showers, visibility is good. Temperatures rarely vary from day to day or month to month, and humidity remains almost constant.

Continental Weather. Continental tropical weather and climate are quite different from oceanic tropical weather. It is subject to extreme variation because of the different features of the land: coastal mountain ranges, altitudes, wind flow patterns and rate of evaporation from surrounding ocean surfaces.

In Africa, various combinations of these factors produce tropical weather ranging from the hot, humid climate of the lower Congo River, to the arid Libyan Desert, to the snowcapped mountains of Kenya. Snow can also be found on the higher mountain peaks in the Hawaiian Islands.

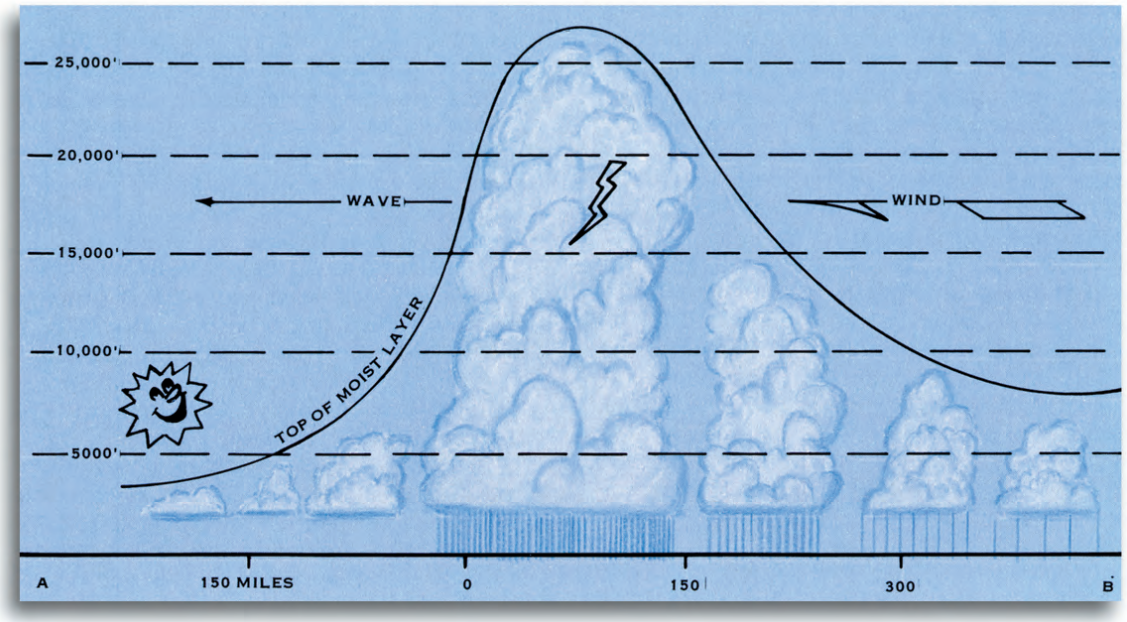
In the arid areas behind coastal mountains, daytime temperatures may exceed 100° F, but nighttime temperatures in the desert regions may go below freezing. "Dry" thunderstorms produce sudden, violent squall winds and may cause severe dust storms or sandstorms, and precipitation often evaporates before it reaches the ground.

Where no mountains or high terrain are present to obstruct the flow of maritime air onshore, the warm, moist air influences wide continental areas in the tropics. Cloudiness and precipitation are at a maximum over these jungle regions and tropical rain forests. Thick, early morning steam fog often forms in the jungles. There is also a good bit of cloudiness over these areas. Occasional heavy rains, with descending cold air currents, can drive nighttime temperatures down to about 60° F, some 30 degrees below normal daytime ranges.

Island and Coastal Weather. Weather conditions are similar along coastal areas and over the various mountainous islands of the tropics. During the day, as warm, moist air moves inland and is lifted over the terrain, large cumuliform clouds develop. While these clouds are common in coastal areas, the lifting of moist air on the windward side of mountainous islands also produces towering cumulus clouds. These clouds frequently may be seen from long distances, indicating the presence of islands.

These islands, especially when mountainous, also have an interesting effect on rainfall. The almost-constant trade winds result in a predominantly onshore wind on one side of an island, while the opposite side has an offshore wind most of the time. These two sides of an island are referred to as the windward and leeward sides, respectively.

Precipitation and cloudiness are considerably heavier on the windward side than on the leeward. An example is the island of Kauai, Hawaii, where Mount Waialeale receives the highest average annual rainfall of all rain measured in the world, 460 inches. Only 10 miles away, on the leeward side of Kauai, sugarcane plantations must be irrigated.



Weather Occurring with an Easterly Wave

One of the major factors influencing tropical weather is the easterly wave. This is a common tropical weather disturbance that normally occurs in the trade-wind belt. Easterly waves of the Northern Hemisphere have advance winds blowing somewhat more northerly than the usual trade-wind direction. As the wave line approaches, the atmospheric pressure falls.

The wind shifts to the east as the line passes. The typical wave is preceded by fair weather, but followed by much cloudiness, low cloud ceilings, rain, and, usually, thunderstorms.

Easterly waves are more numerous and stronger during summer and early fall. Their effects occasionally reach as far north as the Gulf Coast area of the United States. They frequently affect Hawaii and are commonly observed in the West Indies. A wave that is hardly noticeable on the weather chart may one day deepen rapidly and, by the next day, become the spawning ground of a tropical cyclone (hurricane).

Key Terms and Concepts

- Visual Flight Rules (VFR)
- Instrument Flight Rules (IFR)
- haze and smoke
- blowing sand, dust, and snow
- whiteout
- vortices
- icing
- freezing level
- glaze and rime ice
- frost
- thunderstorm
- tornado
- hurricane (typhoon and cyclone)
- hail
- arctic and tropical weather

? Test Your Knowledge ?

MATCHING

1. *Perfect flying conditions*
2. *Flying strictly by eyesight*
3. *Sliding on a film of water*
4. *Usually associated with low ceiling and visibility*
5. *Any level above the ground*

a. IFR
b. Hydroplane
c. CAVU
d. VFR
e. AGL

MATCHING

6. *Another name for a hurricane*
7. *First stage of a hurricane*
8. *Produced by electrical discharge*
9. *Pre-hurricane winds of 40-74 mph*
10. *Depends on what is needed*
11. *Produced by violent expansion of the air*

a. Tropical depression
b. Lightning
c. Good and bad weather
d. Tropical storm
e. Cyclone
f. Thunder

FILL IN THE BLANKS

12. _____ *is a condition that results in an optical phenomenon.*
13. *Visibility equals zero if you fly in a* _____.
14. _____ _____ *occurs most often in dry areas.*
15. *Intense rain and snow can reduce visibility to the* _____ *level.*
16. _____ _____ *is seldom lifted more than 50 feet above the surface, but is still threatening when taking off or landing.*
17. *A temperature inversion is most often the culprit for the hazards of* _____ *and* _____.
18. *To the pilot,* _____ _____ *causes the same problem as fog.*
19. _____ *are clearly marked on charts and have proper lighting, yet can pose a hazard.*
20. *Wake turbulence presents a hazard to light aircraft because the* _____ *of larger aircraft remain indefinitely and are invisible.*
21. *CAT is hazardous because pilots cannot* _____ *it.*
22. *Hail may form whenever a* _____ *is present and may be within a building* _____ *cloud before any precipitation falls to the ground.*
23. *Hail can damage aircraft as well as crops. An in-flight aircraft can receive damage to its* _____ *and* _____.
24. *Severe weather is beneficial in that it acts as a balance* _____ *breaking up* _____ *that could make the earth* _____.

MULTIPLE CHOICE

25. *The icing that forms when an aircraft is flying through supercooled clouds is called*
    a. *carburetor.*
    b. *glaze.*
    c. *frost.*
    d. *rime.*
26. *Icing which seems insignificant, but can affect takeoffs, is called*
    a. *carburetor.*
    b. *glaze.*
    c. *frost.*
    d. *rime.*
27. *Icing which results from supercooled rain droplets that turn to ice as they hit the aircraft is*
    a. *carburetor.*
    b. *glaze.*
    c. *frost.*
    d. *rime.*

28. *The aircraft engine could stop running in flight if water vapor condenses and turns into ice within the*
    a. *carburetor.*
    b. *glaze.*
    c. *frost.*
    d. *rime.*

TRUE OR FALSE

29. *There are three stages in hurricane development.*
30. *Hurricanes receive their energy from heat given off by the condensation of moisture in the warm air.*
31. *Typical hurricane movement is to the west or northwest.*
32. *The forward speed of a hurricane matches its wind speed.*